

SIEMENS

SIMATIC

S7-200 Programmable Controller

System Manual

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Preface, Contents	
Introducing the S7-200 Micro PLC	1
Installing an S7-200 Micro PLC	2
Installing and Using the STEP 7-Micro/WIN Software	3
Getting Started with a Sample Program	4
Additional Features of STEP 7-Micro/WIN	5
Basic Concepts for Programming an S7-200 CPU	6
CPU Memory: Data Types and Addressing Modes	7
Input/Output Control	8
Network Communications and the S7-200 CPU	9
Instruction Set	10
Appendix	
S7-200 Data Sheets	A
Power Calculation Table	B
Error Codes	C
Special Memory (SM) Bits	D
How STEP 7-Micro/WIN Works with Other STEP 7 Programming Products	E
Execution Times for STL Instructions	F
S7-200 Order Numbers	G
S7-200 Troubleshooting Guide	H
Index	

Safety Guidelines

This manual contains notices which you should observe to ensure your own personal safety, as well as to protect the product and connected equipment. These notices are highlighted in the manual by a warning triangle and are marked as follows according to the level of danger:



Danger

indicates that death, severe personal injury or substantial property damage will result if proper precautions are not taken.



Warning

indicates that death, severe personal injury or substantial property damage can result if proper precautions are not taken.



Caution

indicates that minor personal injury or property damage can result if proper precautions are not taken.

Qualified Personnel

The device/system may only be set up and operated in conjunction with this manual.

Only **qualified personnel** should be allowed to install and work on this equipment. Qualified persons are defined as persons who are authorized to commission, to ground, and to tag circuits, equipment, and systems in accordance with established safety practices and standards.

Correct Usage

Note the following:



Warning

This device and its components may only be used for the applications described in the catalog or the technical description, and only in connection with devices or components from other manufacturers which have been approved or recommended by Siemens.

This product can only function correctly and safely if it is transported, stored, set up, and installed correctly, and operated and maintained as recommended.

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Disclaimer of Liability

We have checked the contents of this manual for agreement with the hardware and software described. Since deviations cannot be precluded entirely, we cannot guarantee full agreement. However, the data in this manual are reviewed regularly and any necessary corrections included in subsequent editions. Suggestions for improvement are welcomed.

Technical data subject to change.
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Preface

Purpose

The S7-200 series is a line of micro-programmable logic controllers (Micro PLCs) that can control a variety of automation applications. Compact design, low cost, and a powerful instruction set make the S7-200 controllers a perfect solution for controlling small applications. The wide variety of CPU sizes and voltages, and the multiple programming options available, give you the flexibility you need to solve your automation problems.

This manual provides information about installing and programming the S7-200 Micro PLCs, including the following topics:

- Installing and wiring the S7-200 CPU and expansion I/O modules, and installing the STEP 7-Micro/WIN software
- Designing and entering a program
- Understanding the CPU operations, such as data types and addressing modes, the CPU scan cycle, password-protection, and network communication

This manual also includes descriptions and examples for the programming instructions, typical execution times for the instructions, and the data sheets for the S7-200 equipment.

Audience

This manual is designed for engineers, programmers, installers, and electricians who have a general knowledge of programmable logic controllers.

Scope of the Manual

The information contained in this manual pertains in particular to the following products:

- S7-200 CPU models: CPU 212 Release 1.01, CPU 214 Release 1.01, CPU 215 Release 1.02, and CPU 216 Release 1.02
- Version 2.1 of STEP 7-Micro/WIN programming software packages:
 - STEP 7-Micro/WIN 16 for the 16-bit Windows 3.1x
 - STEP 7-Micro/WIN 32 for the 32-bit Windows 95 and Windows NT

Agency Approvals

The SIMATIC S7-200 series meets the standards and regulations of the following agencies:

- European Community (CE) Low Voltage Directive 73/23/EEC
- European Community (CE) EMC Directive 89/336/EEC
- Underwriters Laboratories, Inc.: UL 508 Listed (Industrial Control Equipment)
- Canadian Standards Association: CSA C22.2 Number 142 Certified (Process Control Equipment)
- Factory Mutual Research: FM Class I, Division 2, Groups A, B, C, & D Hazardous Locations, T4A
- VDE 0160: Electronic equipment for use in electrical power installations

Refer to Appendix A for compliance information.

Related Information

Refer to the following documentation for more detailed information about selected topics:

- *ET 200 Distributed I/O System Manual*: describes how to install and use the ET 200 products for distributed I/O.
- Process Field Bus (PROFIBUS) standard (EN 50170): describes the standard protocol for the S7-200 DP communication capability.
- *TD 200 Operator Interface User Manual*: describes how to install and use the TD 200 with an S7-200 programmable logic controller.

How to Use This Manual

If you are a first-time (novice) user of S7-200 Micro PLCs, you should read the entire manual. If you are an experienced user, refer to the table of contents or index to find specific information.

The manual is organized according to the following topics:

- “Introducing the S7-200 Micro PLC” (Chapter 1) provides an overview of some of the features of the equipment.
- “Installing an S7-200 Micro PLC” (Chapter 2) provides procedures, dimensions, and basic guidelines for installing the S7-200 CPU modules and expansion I/O modules.
- “Installing and Using the STEP 7-Micro/WIN Software” (Chapter 3) describes how to install the programming software. It also provides a basic explanation about the features of the software.
- “Getting Started with a Sample Program” (Chapter 4) helps you enter a sample program, using the STEP 7-Micro/WIN software.
- “Additional Features of STEP 7-Micro/WIN” (Chapter 5) describes how to use the TD 200 Wizard and the S7-200 Instruction Wizard, and other new features of STEP 7-Micro/WIN.
- “Basic Concepts for Programming an S7-200 CPU” (Chapter 6), “CPU Memory: Data Types and Addressing Modes” (Chapter 7), and “Input/Output Control” (Chapter 8) provide information about how the S7-200 CPU processes data and executes your program.
- “Network Communications and the S7-200 CPU” (Chapter 9) provides information about how to connect the S7-200 CPU to different types of networks.
- “Instruction Set” (Chapter 10) provides explanations and examples of the programming instructions used by the S7-200 CPUs.

Additional information (such as the equipment data sheets, error code descriptions, execution times, and troubleshooting) are provided in the appendices.

Additional Assistance

For assistance in answering technical questions, for training on this product, or for ordering, contact your Siemens distributor or sales office.

For Internet information about Siemens products and services, technical support, or FAQs (frequently asked questions) and application tips, use this Internet address:

<http://www.ad.siemens.de>

Contents

1	Introducing the S7-200 Micro PLC	1-1
1.1	Comparing the Features of the S7-200 Micro PLCs	1-2
1.2	Major Components of the S7-200 Micro PLC	1-4
2	Installing an S7-200 Micro PLC	2-1
2.1	Panel Layout Considerations	2-2
2.2	Installing and Removing an S7-200 Micro PLC	2-5
2.3	Installing the Field Wiring	2-8
2.4	Using Suppression Circuits	2-13
2.5	Power Considerations	2-15
3	Installing and Using the STEP 7-Micro/WIN Software	3-1
3.1	Installing the STEP 7-Micro/WIN Software	3-2
3.2	Using STEP 7-Micro/WIN to Set Up the Communications Hardware	3-4
3.3	Establishing Communication with the S7-200 CPU	3-7
3.4	Configuring the Preferences for STEP 7-Micro/WIN	3-25
3.5	Creating and Saving a Project	3-26
3.6	Creating a Program	3-27
3.7	Creating a Data Block	3-32
3.8	Using the Status Chart	3-34
3.9	Using Symbolic Addressing	3-36
4	Getting Started with a Sample Program	4-1
4.1	Creating a Program for a Sample Application	4-2
4.2	Task: Create a Project	4-6
4.3	Task: Create a Symbol Table	4-8
4.4	Task: Enter the Program in Ladder Logic	4-10
4.5	Task: Create a Status Chart	4-14
4.6	Task: Download and Monitor the Sample Program	4-15
5	Additional Features of STEP 7-Micro/WIN	5-1
5.1	Using the TD 200 Wizard to Configure the TD 200 Operator Interface	5-2
5.2	Using the S7-200 Instruction Wizard	5-12
5.3	Using the Analog Input Filtering Instruction Wizard	5-14
5.4	Using Cross Reference	5-17
5.5	Using Element Usage	5-18

5.6	Using Find/Replace	5-19
5.7	Documenting Your Program	5-21
5.8	Printing Your Program	5-23
6	Basic Concepts for Programming an S7-200 CPU	6-1
6.1	Guidelines for Designing a Micro PLC System	6-2
6.2	Concepts of an S7-200 Program	6-4
6.3	Concepts of the S7-200 Programming Languages	6-5
6.4	Basic Elements for Constructing a Program	6-8
6.5	Understanding the Scan Cycle of the CPU	6-10
6.6	Selecting the Mode of Operation for the CPU	6-13
6.7	Creating a Password for the CPU	6-14
6.8	Debugging and Monitoring Your Program	6-16
6.9	Error Handling for the S7-200 CPU	6-19
7	CPU Memory: Data Types and Addressing Modes	7-1
7.1	Direct Addressing of the CPU Memory Areas	7-2
7.2	Indirect Addressing of the CPU Memory Areas	7-9
7.3	Memory Retention for the S7-200 CPU	7-11
7.4	Using Your Program to Store Data Permanently	7-16
7.5	Using a Memory Cartridge to Store Your Program	7-17
8	Input/Output Control	8-1
8.1	Local I/O and Expansion I/O	8-2
8.2	Using the Selectable Input Filter to Provide Noise Rejection	8-5
8.3	Using the Output Table to Configure the States of the Outputs	8-6
8.4	High-Speed I/O	8-7
8.5	Analog Adjustments	8-8
9	Network Communications and the S7-200 CPU	9-1
9.1	Communication Capabilities of the S7-200 CPU	9-2
9.2	Communication Network Components	9-6
9.3	Data Communications Using the PC/PPI Cable	9-9
9.4	Data Communications Using the MPI or CP Card	9-13
9.5	Distributed Peripheral (DP) Standard Communications	9-15
9.6	Network Performance	9-28
10	Instruction Set	10-1
10.1	Valid Ranges for the S7-200 CPUs	10-2
10.2	Contact Instructions	10-4
10.3	Comparison Contact Instructions	10-7
10.4	Output Instructions	10-10

10.5	Timer, Counter, High-Speed Counter, High-Speed Output, Clock, and Pulse Instructions	10-13
10.6	Math and PID Loop Control Instructions	10-50
10.7	Increment and Decrement Instructions	10-66
10.8	Move, Fill, and Table Instructions	10-68
10.9	Shift and Rotate Instructions	10-78
10.10	Program Control Instructions	10-84
10.11	Logic Stack Instructions	10-99
10.12	Logic Operations	10-102
10.13	Conversion Instructions	10-108
10.14	Interrupt and Communications Instructions	10-114
A	S7-200 Data Sheets	A-1
A.1	General Technical Specifications	A-3
A.2	CPU 212 DC Power Supply, DC Inputs, DC Outputs	A-6
A.3	CPU 212 AC Power Supply, DC Inputs, Relay Outputs	A-8
A.4	CPU 212 24 VAC Power Supply, DC Inputs, Relay Outputs	A-10
A.5	CPU 212 AC Power Supply, AC Inputs, AC Outputs	A-12
A.6	CPU 212 AC Power Supply, Sourcing DC Inputs, Relay Outputs	A-14
A.7	CPU 212 AC Power Supply, 24 VAC Inputs, AC Outputs	A-16
A.8	CPU 212 AC Power Supply, AC Inputs, Relay Outputs	A-18
A.9	CPU 214 DC Power Supply, DC Inputs, DC Outputs	A-20
A.10	CPU 214 AC Power Supply, DC Inputs, Relay Outputs	A-22
A.11	CPU 214 AC Power Supply, AC Inputs, AC Outputs	A-24
A.12	CPU 214 AC Power Supply, Sourcing DC Inputs, Relay Outputs	A-26
A.13	CPU 214 AC Power Supply, 24 VAC Inputs, AC Outputs	A-28
A.14	CPU 214 AC Power Supply, AC Inputs, Relay Outputs	A-30
A.15	CPU 215 DC Power Supply, DC Inputs, DC Outputs	A-32
A.16	CPU 215 AC Power Supply, DC Inputs, Relay Outputs	A-34
A.17	CPU 216 DC Power Supply, DC Inputs, DC Outputs	A-36
A.18	CPU 216 AC Power Supply, DC Inputs, Relay Outputs	A-38
A.19	Expansion Module EM221 Digital Input 8 x 24 VDC	A-40
A.20	Expansion Module EM221 Digital Input 8 x 120 VAC	A-41
A.21	Expansion Module EM221 Digital Sourcing Input 8 x 24 VDC	A-42
A.22	Expansion Module EM221 Digital Input 8 x 24 VAC	A-43
A.23	Expansion Module EM222 Digital Output 8 x 24 VDC	A-44
A.24	Expansion Module EM222 Digital Output 8 x Relay	A-45
A.25	Expansion Module EM222 Digital Output 8 x 120/230 VAC	A-46

A.26	Expansion Module EM223 Digital Combination 4 x 24 VDC Input/4 x 24 VDC Output	A-48
A.27	Expansion Module EM223 Digital Combination 8 x 24 VDC Input/8 x 24 VDC Output	A-50
A.28	Expansion Module EM223 Digital Combination 16 x 24 VDC Input/16 x 24 VDC Output	A-52
A.29	Expansion Module EM223 Digital Combination 4 x 24 VDC Input/4 x Relay Output	A-54
A.30	Expansion Module EM223 Digital Combination 4 x 120 VAC Input/4 x 120 VAC to 230 VAC Output	A-55
A.31	Expansion Module EM223 Digital Combination 8 x 24 VDC Input/8 x Relay Output	A-56
A.32	Expansion Module EM223 Digital Combination 16 x 24 VDC Input/16 x Relay Output	A-58
A.33	Expansion Module EM231 Analog Input AI 3 x 12 Bits	A-60
A.34	Expansion Module EM232 Analog Output AQ 2 x 12 Bits	A-66
A.35	Expansion Module EM235 Analog Combination AI 3/AQ 1 x 12 Bits	A-69
A.36	Memory Cartridge 8K x 8	A-78
A.37	Memory Cartridge 16K x 8	A-79
A.38	Battery Cartridge	A-80
A.39	I/O Expansion Cable	A-81
A.40	PC/PPI Cable	A-82
A.41	CPU 212 DC Input Simulator	A-84
A.42	CPU 214 DC Input Simulator	A-85
A.43	CPU 215/216 DC Input Simulator	A-86
B	Power Calculation Table	B-1
C	Error Codes	C-1
C.1	Fatal Error Codes and Messages	C-2
C.2	Run-Time Programming Problems	C-3
C.3	Compile Rule Violations	C-4
D	Special Memory (SM) Bits	D-1
E	Using STEP 7-Micro/WIN with STEP 7 and STEP 7-Micro/DOS	E-1
E.1	Using STEP 7-Micro/WIN with STEP 7	E-2
E.2	Importing Files from STEP 7-Micro/DOS	E-4
F	Execution Times for STL Instructions	F-1
G	S7-200 Order Numbers	G-1
H	S7-200 Troubleshooting Guide	H-1
	Index	Index-1

Introducing the S7-200 Micro PLC

The S7-200 series is a line of micro-programmable logic controllers (Micro PLCs) that can control a variety of automation applications. Figure 1-1 shows an S7-200 Micro PLC. The compact design, expandability, low cost, and powerful instruction set of the S7-200 Micro PLC make a perfect solution for controlling small applications. In addition, the wide variety of CPU sizes and voltages provides you with the flexibility you need to solve your automation problems.

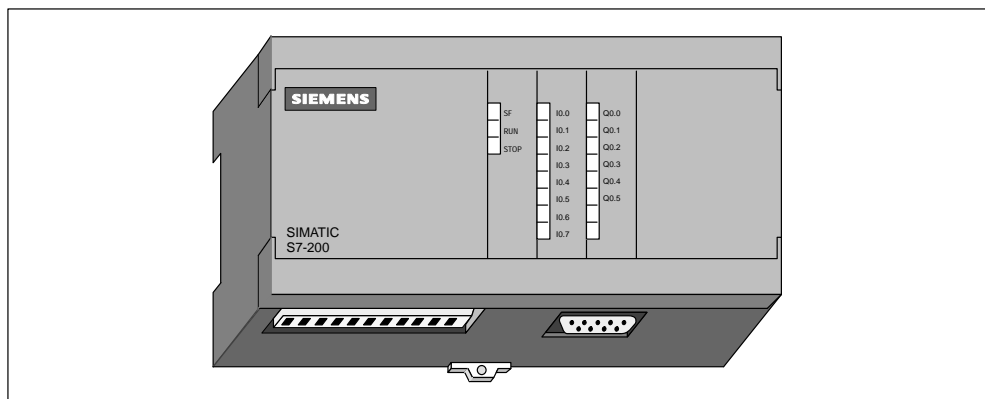


Figure 1-1 S7-200 Micro PLC

Chapter Overview

Section	Description	Page
1.1	Comparing the Features of the S7-200 Micro PLCs	1-2
1.2	Major Components of the S7-200 Micro PLC	1-4

1.1 Comparing the Features of the S7-200 Micro PLCs

Equipment Requirements

Figure 1-2 shows the basic S7-200 Micro PLC system, which includes an S7-200 CPU module, a personal computer, STEP 7-Micro/WIN programming software, and a communications cable.

In order to use a personal computer (PC), you must have one of the following sets of equipment:

- A PC/PPI cable
- A communications processor (CP) card and multipoint interface (MPI) cable
- A multipoint interface (MPI) card. A communications cable is provided with the MPI card.

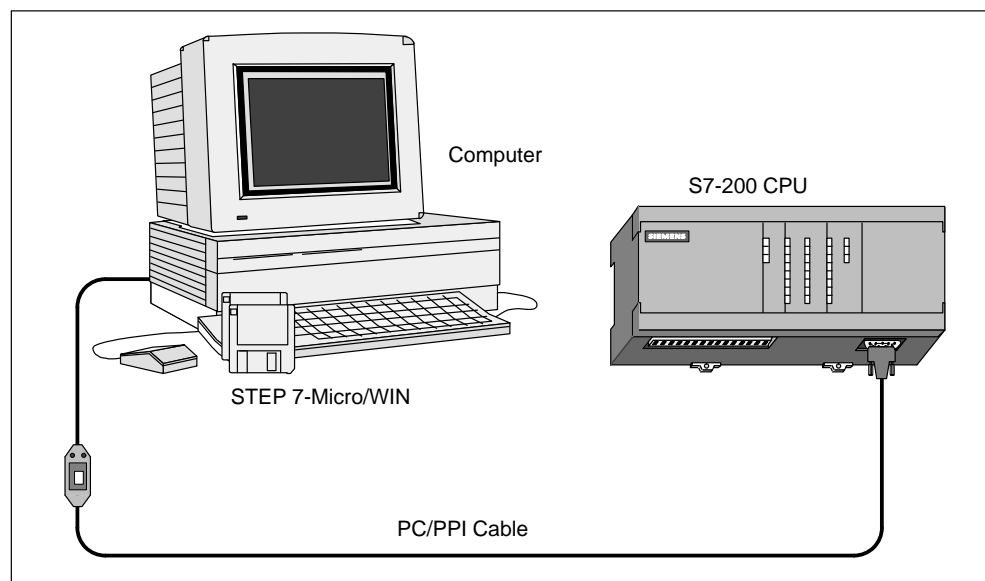


Figure 1-2 Components of an S7-200 Micro PLC System

Capabilities of the S7-200 CPUs

The S7-200 family includes a wide variety of CPUs. This variety provides a range of features to aid in designing a cost-effective automation solution. Table 1-1 provides a summary of the major features of each S7-200 CPU.

Table 1-1 Summary of the S7-200 CPUs

Feature	CPU 212	CPU 214	CPU 215	CPU 216
Physical Size of Unit	160 mm x 80 mm x 62 mm	197 mm x 80 mm x 62 mm	218 mm x 80 mm x 62 mm	218 mm x 80 mm x 62 mm
Memory				
Program (EEPROM)	512 words	2 Kwords	4 Kwords	4 Kwords
User data	512 words	2 Kwords	2.5 Kwords	2.5 Kwords
Internal memory bits	128	256	256	256
Memory cartridge	None	Yes (EEPROM)	Yes (EEPROM)	Yes (EEPROM)
Optional battery cartridge	None	200 days typical	200 days typical	200 days typical
Backup(super capacitor)	50 hours typical	190 hours typical	190 hours typical	190 hours typical
Inputs/Outputs (I/O)				
Local I/O	8 DI / 6 DQ	14 DI / 10 DQ	14 DI / 10 DQ	24 DI / 16 DQ
Expansion modules (max.)	2 modules	7 modules	7 modules	7 modules
Process-image I/O register	64 DI / 64 DQ	64 DI / 64 DQ	64 DI / 64 DQ	64 DI / 64 DQ
Analog I/O (expansion)	16 AI / 16 AQ	16 AI / 16 AQ	16 AI / 16 AQ	16 AI / 16 AQ
Selectable input filters	No	Yes	Yes	Yes
Instructions				
Boolean execution speed	1.2 μ s/instruction	0.8 μ s/instruction	0.8 μ s/instruction	0.8 μ s/instruction
Counters / timers	64/64	128/128	256/256	256/256
For / next loops	No	Yes	Yes	Yes
Integer math	Yes	Yes	Yes	Yes
Real math	No	Yes	Yes	Yes
PID	No	No	Yes	Yes
Additional Features				
High-speed counter	1 S/W	1 S/W, 2 H/W	1 S/W, 2 H/W	1 S/W, 2 H/W
Analog adjustments	1	2	2	2
Pulse outputs	None	2	2	2
Communication interrupt events	1 transmit/ 1 receive	1 transmit/1 receive	1 transmit/2 receive	2 transmit/4 receive
Timed interrupts	1	2	2	2
Hardware input interrupts	1	4	4	4
Real time clock	None	Yes	Yes	Yes
Communications				
Number of comm ports:	1 (RS-485)	1 (RS-485)	2 (RS-485)	2 (RS-485)
Protocols supported Port 0:	PPI, Freeport	PPI, Freeport	PPI, Freeport, MPI	PPI, Freeport, MPI
Port 1:	N/A	N/A	DP, MPI	PPI, Freeport, MPI
Peer-to-peer	Slave only	Yes	Yes	Yes

1.2 Major Components of the S7-200 Micro PLC

An S7-200 Micro PLC consists of an S7-200 CPU module alone or with a variety of optional expansion modules.

S7-200 CPU Module

The S7-200 CPU module combines a central processing unit (CPU), power supply, and discrete I/O points into a compact, stand-alone device.

- The CPU executes the program and stores the data for controlling the automation task or process.
- The power supply provides electrical power for the base unit and for any expansion module that is connected.
- The inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as sensors and switches), and the outputs control pumps, motors, or other devices in your process.
- The communications port allows you to connect the CPU to a programming device or to other devices. Some S7-200 CPUs have two communications ports.
- Status lights provide visual information about the CPU mode (RUN or STOP), the current state of the local I/O, and whether a system fault has been detected.

Figures 1-3, 1-4, and 1-5 show the different S7-200 CPU modules.

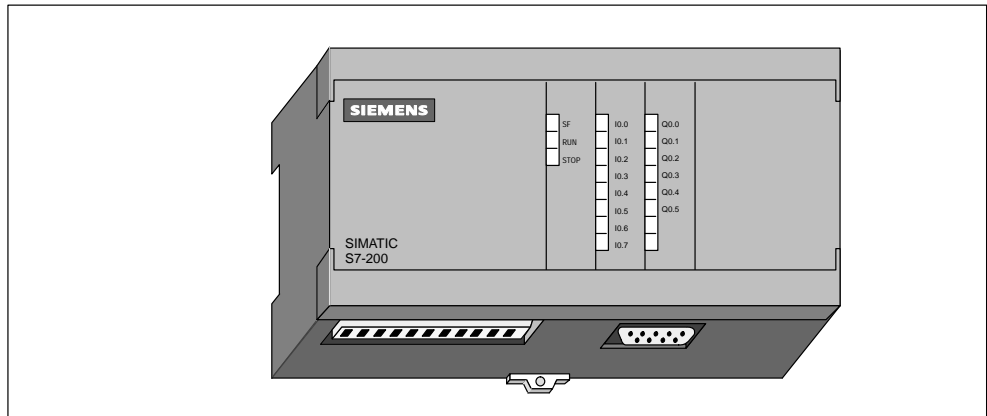


Figure 1-3 S7-212 CPU Module

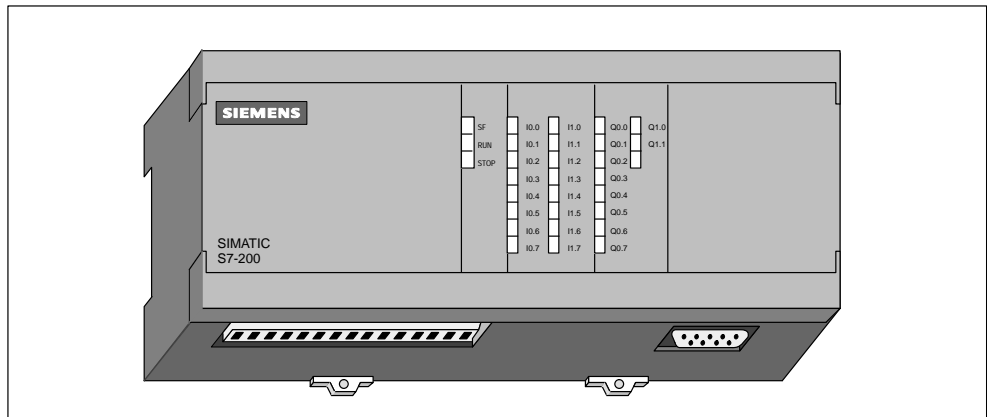


Figure 1-4 S7-214 CPU Module

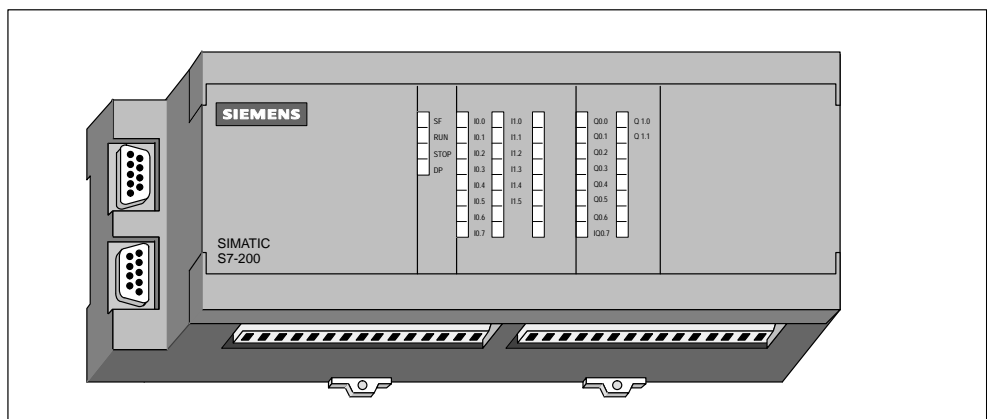


Figure 1-5 S7-215 and S7-216 CPU Module

Expansion Modules

The S7-200 CPU module provides a certain number of local I/O. Adding an expansion module provides additional input or output points. As shown in Figure 1-6, the expansion module comes with a bus connector for connecting to the base unit.

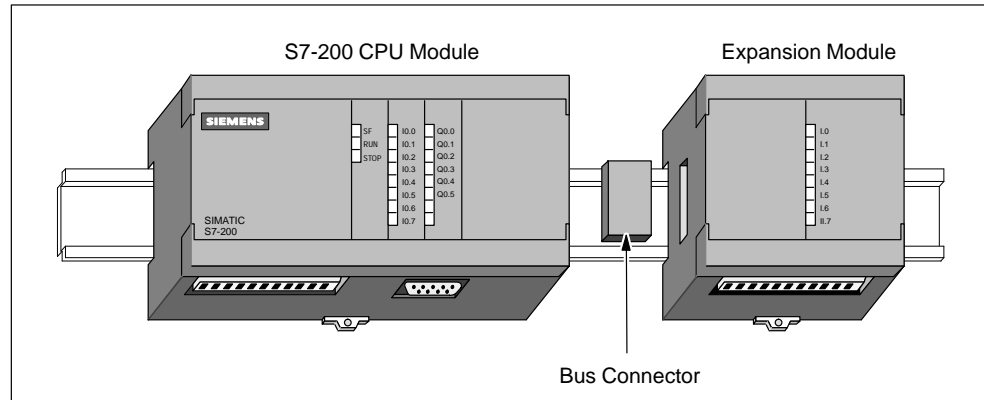


Figure 1-6 CPU Module with an Expansion Module

2

Installing an S7-200 Micro PLC

The installation of the S7-200 family is designed to be easy. You can use the mounting holes to attach the modules to a panel, or you can use the built-in clips to mount the modules onto a standard (DIN) rail. The small size of the S7-200 allows you to make efficient use of space.

This chapter provides guidelines for installing and wiring your S7-200 system.

Chapter Overview

Section	Description	Page
2.1	Panel Layout Considerations	2-2
2.2	Installing and Removing an S7-200 Micro PLC	2-5
2.3	Installing the Field Wiring	2-8
2.4	Using Suppression Circuits	2-13
2.5	Power Considerations	2-15

2.1 Panel Layout Considerations

Installation Configuration

You can install an S7-200 either on a panel or on a standard rail. You can mount the S7-200 either horizontally or vertically. An I/O expansion cable is also available to add flexibility to your mounting configuration. Figure 2-1 shows a typical configuration for these types of installations.

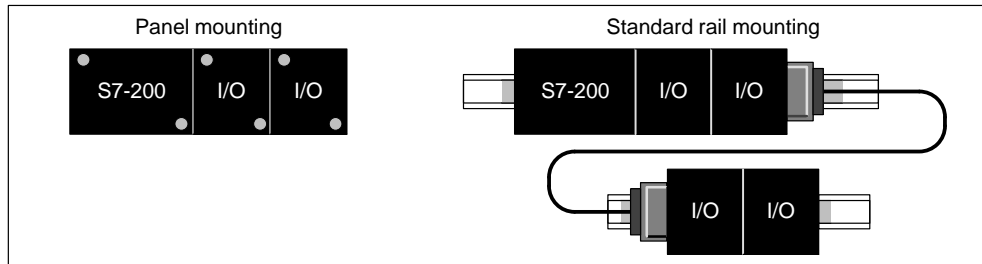


Figure 2-1 Mounting Configurations

Clearance Requirements for Installing an S7-200 PLC

Use the following guidelines as you plan your installation:

- The S7-200 CPU and expansion modules are designed for natural convection cooling. You must provide a clearance of at least 25 mm (1 in.), both above and below the units, for proper cooling. See Figure 2-2. Continuous operation of all electronic products at maximum ambient temperature and load reduces their life.
- For vertical mounting, the output loading may need to be derated because of thermal constraints. Refer to Appendix A for the data sheet for your particular CPU. If you are mounting the CPU and modules on a DIN Rail, the DIN rail stop is recommended.
- If you are installing an S7-200 horizontally or vertically on a panel, you must allow 75 mm (2.9 in.) for the minimum panel depth. See Figure 2-2.
- If you plan to install additional modules horizontally or vertically, allow a clearance of at least 25 mm (1 in.) on either side of the unit for installing and removing the module. This extra space is required to engage and disengage the bus expansion connector.
- Be sure to allow enough space in your mounting design to accommodate the I/O wiring and communication cable connections.

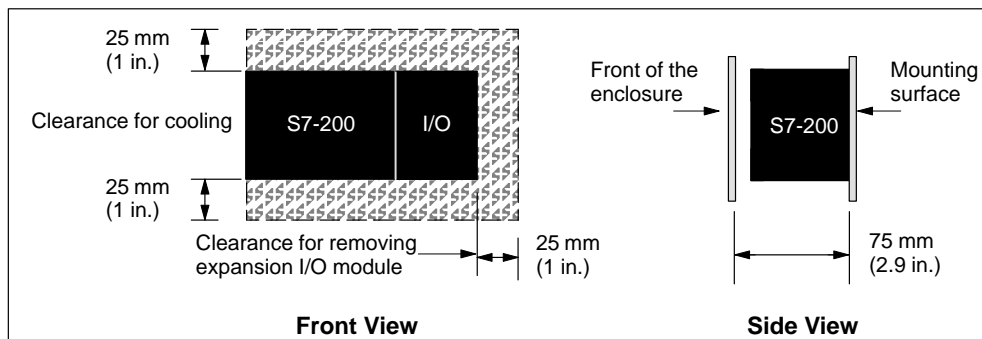


Figure 2-2 Horizontal and Vertical Clearance Requirements for Installing an S7-200 PLC

Standard Rail Requirements

The S7-200 CPU and expansion modules can be installed on a standard (DIN) rail (DIN EN 50 022). Figure 2-3 shows the dimensions for this rail.

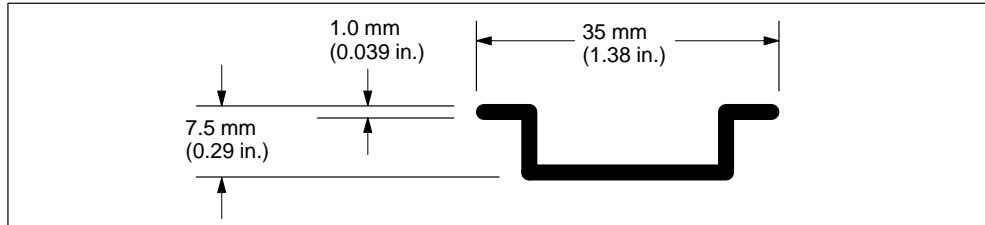


Figure 2-3 Standard Rail Dimensions

Panel-Mounting Dimensions

S7-200 CPUs and expansion modules include mounting holes to facilitate installation on panels. Figures 2-4 through 2-8 provide the mounting dimensions for the different S7-200 modules.

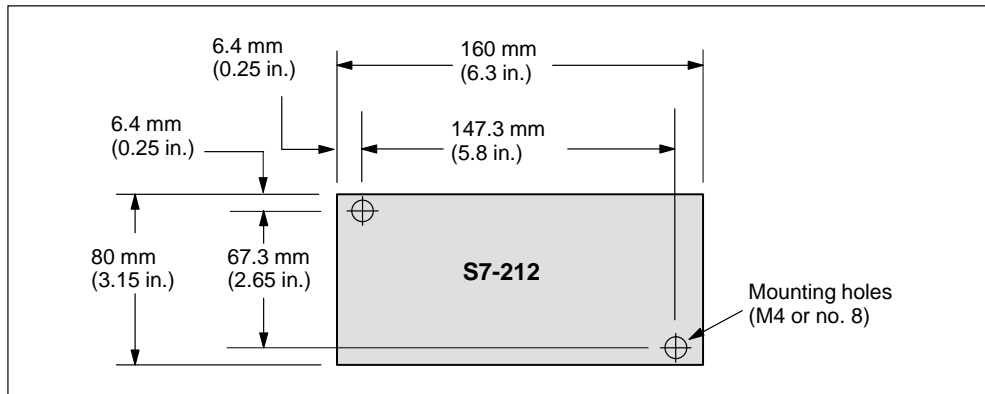


Figure 2-4 Mounting Dimensions for an S7-212 CPU Module

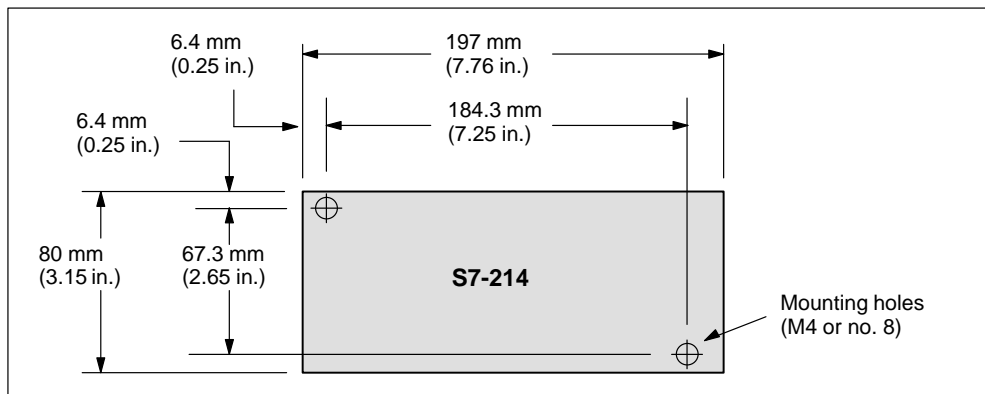


Figure 2-5 Mounting Dimensions for an S7-214 CPU Module

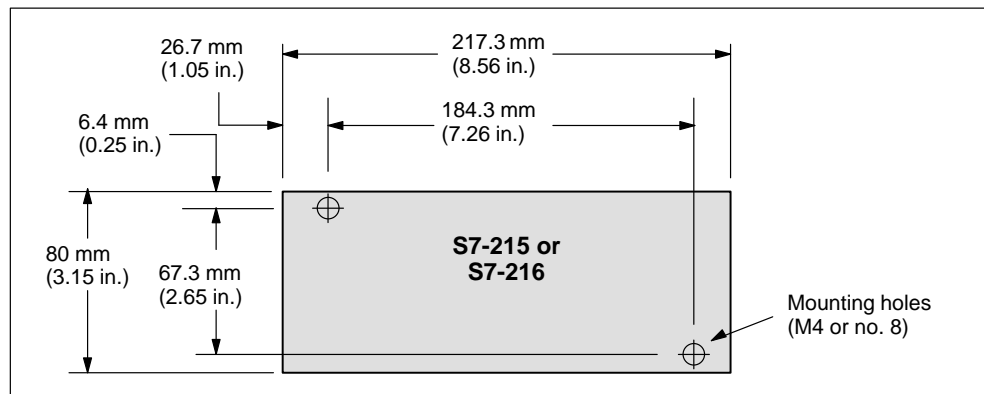


Figure 2-6 Mounting Dimensions for an S7-215 or S7-216 CPU Module

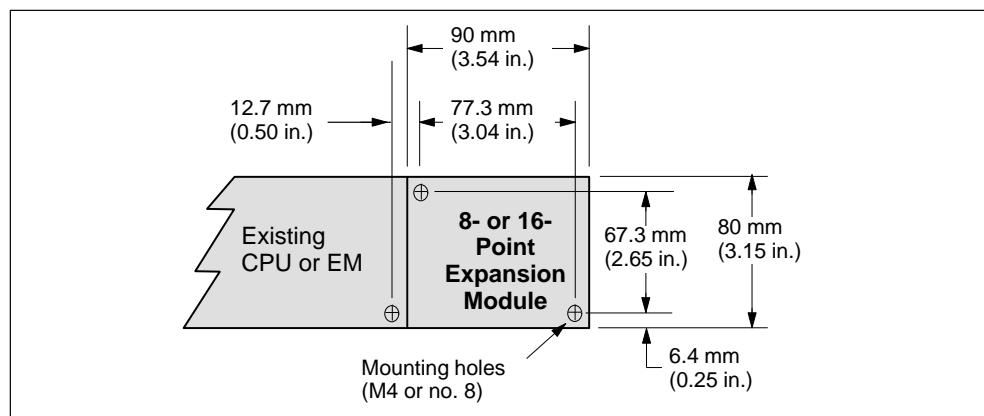


Figure 2-7 Mounting Dimensions for an 8- or 16-Point Expansion Module

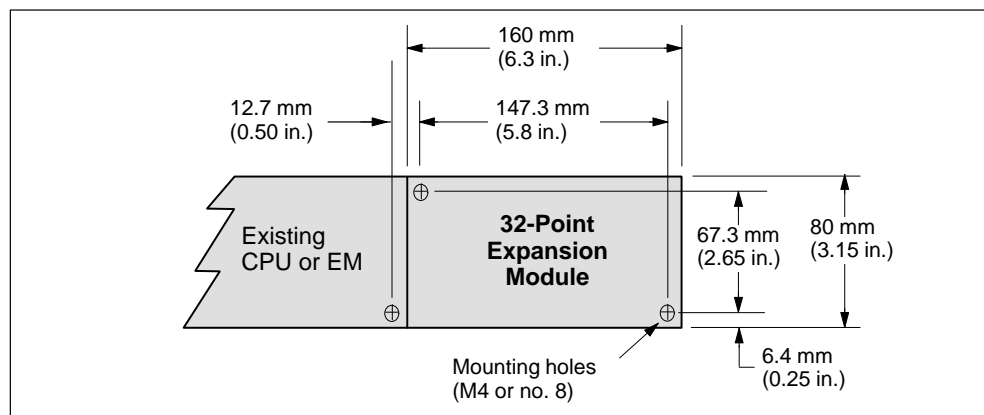


Figure 2-8 Mounting Dimensions for a 32-Point Expansion Module

2.2 Installing and Removing an S7-200 Micro PLC

Mounting an S7-200 Micro PLC on a Panel



Warning

Attempts to install or remove S7-200 modules or related equipment when they are powered up could cause electric shock.

Failure to disable all power to the S7-200 modules and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 modules is disabled before installation.

Use the following procedure for installing an S7-200:

1. Locate, drill, and tap the mounting holes for DIN M4 or American Standard number 8 screws. Refer to Section 2.1 for mounting dimensions and other considerations.
2. Secure the S7-200 modules onto the panel, using DIN M4 or American Standard number 8 screws.

If you are installing an expansion module, use the following steps:

1. Remove the bus expansion port cover from the existing module housing by inserting a screwdriver into the space between the bus expansion port cover and the housing, and gently prying. Ensure that the plastic connecting joints are completely removed. Use caution not to damage the module. Figure 2-9 shows proper screwdriver placement.
2. Insert the bus connector into the bus expansion port of the existing module and ensure that the connector snaps into place.
3. Ensure that the expansion module is correctly oriented with respect to the CPU module. If you are using an expansion cable, orient the cable up towards the front of the module.
4. Connect the expansion module to the bus connector by sliding the module onto the bus connector so that it snaps into place.

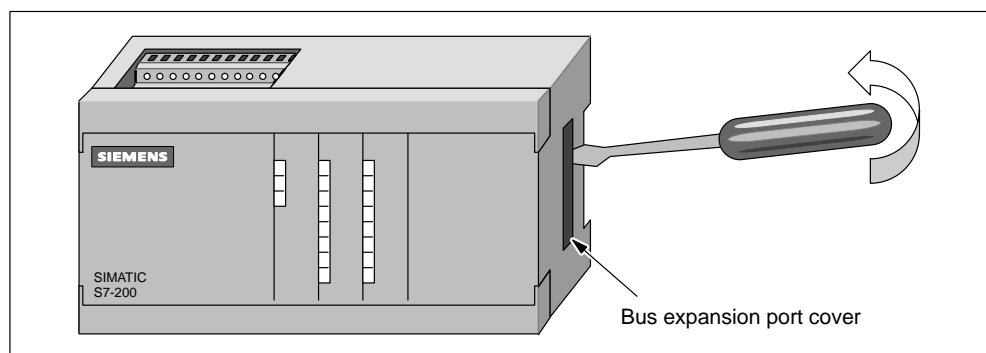


Figure 2-9 Removing the Bus Expansion Port Cover on an S7-200 CPU Module

Installing an S7-200 Micro PLC onto a Standard Rail



Warning

Attempts to install or remove S7-200 modules or related equipment when they are powered up could cause electric shock.

Failure to disable all power to the S7-200 modules and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 modules is disabled before installation.

To install the S7-200 CPU module, follow these steps:

1. Secure the rail every 75 mm (3.0 in.) to the mounting panel.
2. Snap open the clip (located on the bottom of the module) and hook the back of the module onto the rail.
3. Snap the clip closed, carefully checking to ensure that the clip has fastened the module securely onto the rail.

Note

Modules in an environment with high vibration potential or modules that have been installed in a vertical position may require DIN rail stops.

If you are installing an expansion module, use the following steps:

1. Remove the bus expansion port cover from the existing module housing by inserting a screwdriver into the space between the bus expansion port cover and the housing, and gently prying. Ensure that the plastic connecting joints are completely removed. Use caution not to damage the module. Figure 2-9 shows proper screwdriver placement.
2. Insert the bus connector into the bus expansion port of the existing module and ensure that the connector snaps into place.
3. Ensure that the expansion module is correctly oriented with respect to the CPU module. If you are using an expansion cable, orient the cable up towards the front of the module.
4. Snap open the clip and hook the back of the expansion module onto the rail. Slide the expansion module onto the bus connector until it snaps into place.
5. Snap the clip closed to secure the expansion module to the rail. Carefully check to ensure that the clip has fastened the module securely onto the rail.

Removing the S7-200 Modules



Warning

Attempts to install or remove S7-200 modules or related equipment when they are powered up could cause electric shock.

Failure to disable all power to the S7-200 modules and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 modules is disabled before you install or remove a CPU or expansion module.

To remove the S7-200 CPU module or expansion module, follow these steps:

1. Disconnect all the wiring and cabling that is attached to the module that you are removing. If this module is in the middle of a chain, the modules to the left or right must be moved at least 25 mm (1 in.) to allow the bus connector to be disconnected. See Figure 2-10.
2. Unscrew the mounting screws or snap open the clip, and slide the module at least 25 mm (1 in.) to disengage the bus connector. The bus connector must be disconnected on both sides of the module.
3. Remove the module from the panel or rail, and install a new module.



Warning

If you install an incorrect module, the program in the micro PLC could function unpredictably.

Failure to replace an expansion module and expansion cable with the same model or in the proper orientation may result in death or serious personal injury, and/or damage to equipment.

Replace an expansion module with the same model, and orient it correctly. If you are using an expansion cable, orient the cable up towards the front of the module.

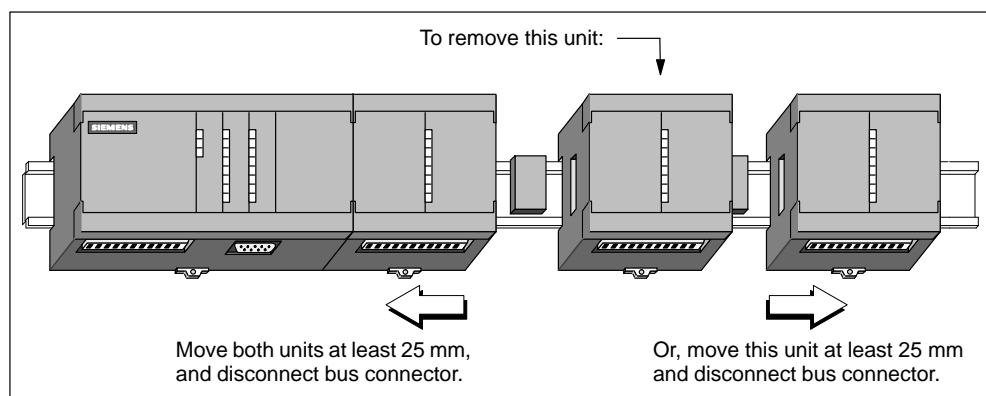


Figure 2-10 Removing the Expansion Module

2.3 Installing the Field Wiring



Warning

Attempts to install or remove S7-200 modules or related equipment when they are powered up could cause electric shock.

Failure to disable all power to the S7-200 modules and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 modules is disabled before installing field wiring.

General Guidelines

The following items are general guidelines for designing the installation and wiring of your S7-200 Micro PLC:

- Ensure that you follow all applicable electrical codes when wiring the S7-200 Micro PLC. Install and operate all equipment according to all applicable national and local standards. Contact your local authorities to determine which codes and standards apply to your specific case.
- Always use the proper wire size to carry the required current. The S7-200 modules accept wire sizes from 1.50 mm² to 0.50 mm² (14 AWG to 22 AWG).
- Ensure that you do not overtighten the connector screws. The maximum torque is 0.56 N-m (5 inches-pounds).
- Always use the shortest wire possible (maximum 500 m shielded, 300 m unshielded). Wiring should be run in pairs, with a neutral or common wire paired with a hot or signal-carrying wire.
- Separate AC wiring and high-energy, rapidly switched DC wiring from low-energy signal wiring.
- Properly identify and route the wiring to the S7-200 module, using strain relief for the wiring as required. For more information about identifying the terminals, see the data sheets in Appendix A.
- Install appropriate surge suppression devices for any wiring that is subject to lightning surges.
- External power should not be applied to an output load in parallel with a DC output point. This may cause reverse current through the output, unless a diode or other barrier is provided in the installation.



Warning

Control devices can fail in an unsafe condition, resulting in unexpected operation of controlled equipment.

Such unexpected action could result in death or serious personal injury, and/or equipment damage.

Consider using an emergency stop function, electromechanical overrides, or other redundant safeguards that are independent of the programmable controller.

Grounding and Circuit Reference Point Guidelines for Using Isolated Circuits

The following items are grounding and circuit guidelines for using isolated circuits:

- You should identify the reference point (0 voltage reference) for each circuit in the installation, and the points at which circuits with possible different references can connect together. Such connections can result in unwanted current flows that can cause logic errors or can damage circuits. A common cause of different reference potentials is grounds which are physically separated by long distances. When devices with widely separated grounds are connected with a communication or sensor cable, unexpected currents can flow through the circuit created by the cable and the ground. Even over short distances, load currents of heavy machinery can cause differences in ground potential or can directly induce unwanted currents by electromagnetic induction. Power supplies that are improperly referenced with respect to each other can cause damaging currents to flow between their associated circuits.
- S7-200 products include isolation boundaries at certain points to help prevent unwanted current flows in your installation. When you plan your installation, you should consider where these isolation boundaries are, and where they are not provided. You should also consider the isolation boundaries in associated power supplies and other equipment, and where all associated power supplies have their reference points.
- You should choose your ground reference points and use the isolation boundaries provided to interrupt unneeded circuit loops that could allow unwanted currents to flow. Remember to consider temporary connections which may introduce a new circuit reference, such as the connection of a programming device to the CPU.
- When locating grounds, you must also consider safety grounding requirements and the proper operation of protective interrupting devices.

The following descriptions are an introduction to general isolation characteristics of the S7-200 family, but some features may be different on specific products. Consult the data sheet in Appendix A for your product for specifications of which circuits include isolation boundaries and the ratings of the boundaries. Isolation boundaries rated less than 1,500 VAC are designed as functional isolation only, and should not be depended on as safety boundaries.

- CPU logic reference is the same as DC sensor supply M.
- CPU logic reference is the same as the input power supply M on a CPU with DC power supply.
- CPU communication ports have the same reference as CPU logic (except DP ports).
- Analog inputs and outputs are not isolated from CPU logic. Analog inputs are full differential to provide low voltage common mode rejection.
- CPU logic is isolated from ground to 100 VDC.
- DC digital inputs and outputs are isolated from CPU logic to 500 VAC.
- DC digital I/O groups are isolated from each other by 500 VAC.
- Relay outputs, AC outputs, and AC inputs are isolated from CPU logic to 1,500 VAC.
- AC and relay output groups are isolated from each other by 1,500 VAC.
- AC power supply line and neutral are isolated from ground, the CPU logic, and all I/O to 1500 VAC.

Using the Optional Field Wiring Connector

The optional field wiring fan-out connector (Figure 2-11) allows for field wiring connections to remain fixed when you remove and re-install the S7-200. Refer to Appendix G for the order number.

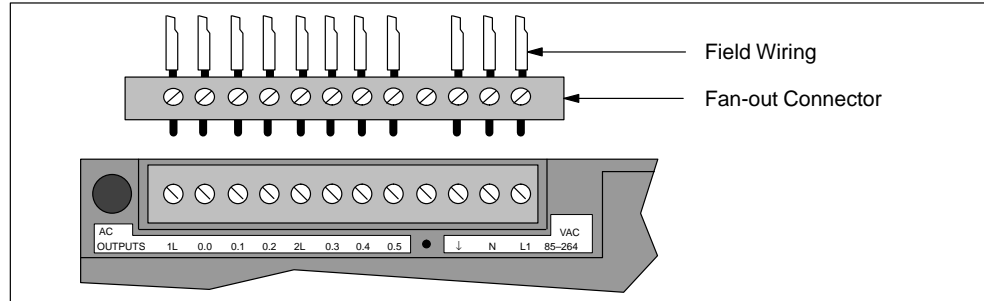


Figure 2-11 Optional Field Wiring Connector

Guidelines for AC Installation

The following items are general wiring guidelines for AC installations. Refer to Figure 2-12.

- Provide a single disconnect switch (1) that removes power from the CPU, all input circuits, and all output (load) circuits.
- Provide overcurrent devices (2) to protect the CPU power supply, the output points, and the input points. You can also fuse each output point individually for greater protection. External overcurrent protection for input points is not required when you use the 24 VDC sensor supply (3) from the Micro PLC. This sensor supply is short-circuit protected.
- Connect all S7-200 ground terminals to the closest available earth ground (4) to provide the highest level of noise immunity. It is recommended that all ground terminals be connected to a single electrical point. Use 14 AWG or 1.5 mm² wire for this connection.
- DC sensor supply from the base unit may be used for base unit inputs (5), expansion DC inputs (6), and expansion relay coils (7). This sensor supply is short-circuit protected.

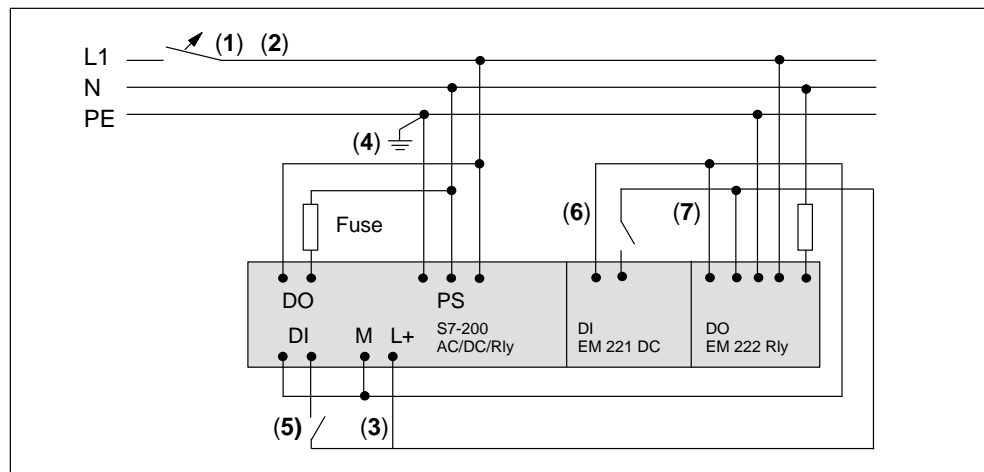


Figure 2-12 120/230 VAC Using a Single Overcurrent Switch to Protect the CPU and Load Wiring

Guidelines for North American Installation

The following items are general wiring guidelines for installations in North America where multiple AC voltages are present. Refer to Figure 2-14 as you read these guidelines.

- Provide a single disconnect switch (1) that removes power from the CPU, all input circuits, and all output (load) circuits.
- Provide overcurrent devices to protect the CPU power supply (2), the output points (3), and the input points (4). You may also fuse each output point individually for greater protection.
- Make AC power connections to the CPU power supply, AC output driven loads, and relay-driven loads either line-to-grounded neutral (5) or line-to-line (6).
- Connect all S7-200 ground terminals to the closest available earth ground (7) to provide the highest level of noise immunity. It is recommended that all ground terminals be connected to a single electrical point. Use 14 AWG or 1.5 mm² wire for this connection.



Caution

Line-to-line voltages in power systems with 230 VAC nominal line-neutral voltages will exceed the voltage rating of the S7-200 power supply, inputs, and outputs.

Exceeding the voltage may cause failure of the S7-200 and connected equipment.

Do not use line-to-line connections where the voltage rating of your S7-200 module is exceeded.

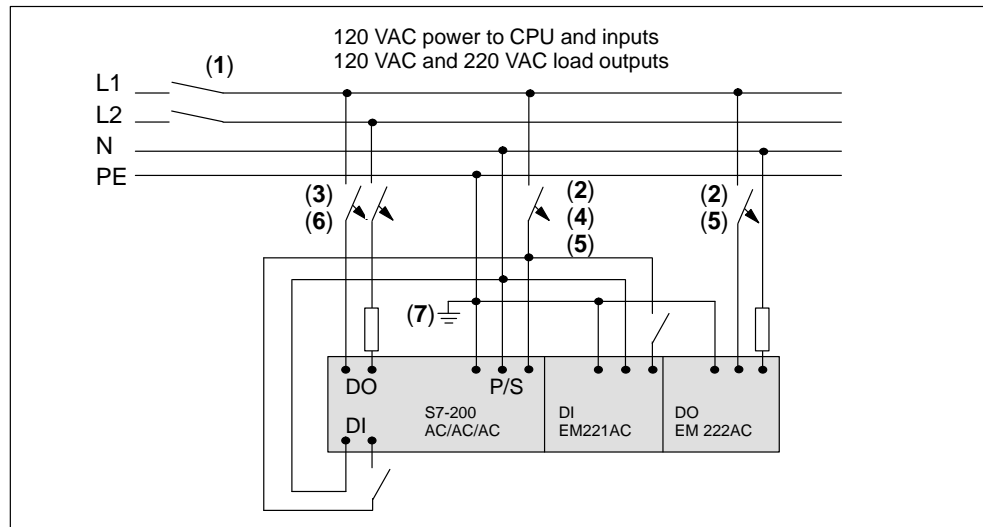


Figure 2-14 AC System Installation

2.4 Using Suppression Circuits

General Guidelines

Equip inductive loads with suppression circuits that limit voltage rise on loss of power. Use the following guidelines to design adequate suppression. The effectiveness of a given design depends on the application, and you must verify it for a particular use. Be sure all components are rated for use in the application.

Protecting DC Transistors

The S7-200 DC transistor outputs contain zener diodes that are adequate for many installations. Use external suppression diodes for either large or frequently switched inductive loads to prevent overpowering the internal diodes. Figures 2-15 and 2-16 show typical applications for DC transistor outputs.

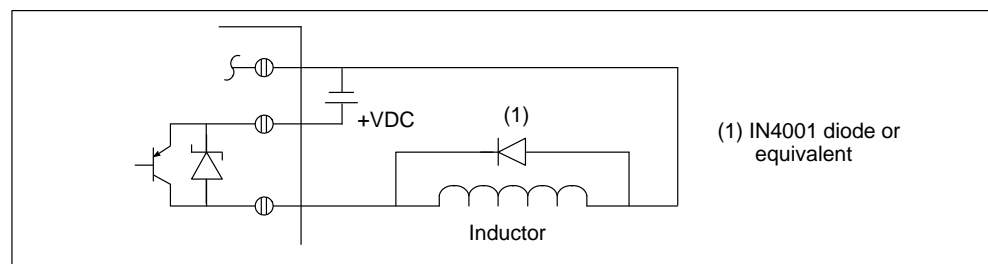


Figure 2-15 Diode Suppression

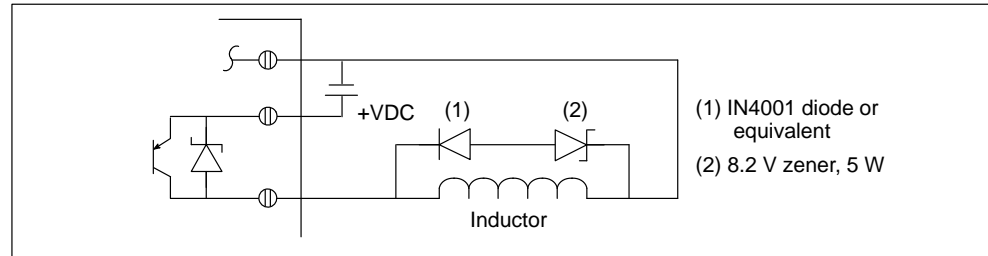


Figure 2-16 Zener Diode Suppression

Protecting Relays That Control DC Power

Resistor/capacitor networks, as shown in Figure 2-17, can be used for low voltage (30 V) DC relay applications. Connect the network across the load.

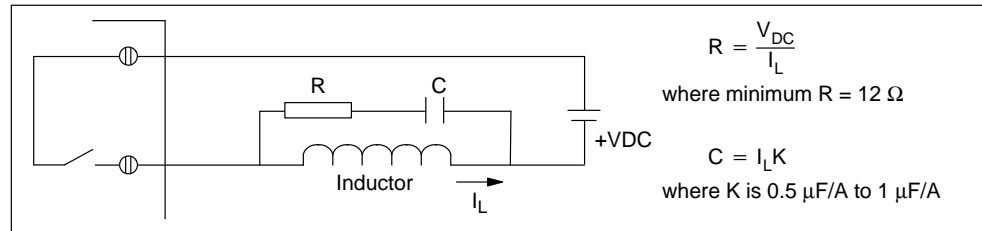


Figure 2-17 Resistor/Capacitor Network on Relay-Driven DC Load

You can also use diode suppression, as shown in Figures 2-15 and 2-16, for DC relay applications. A threshold voltage of up to 36 V is allowed if you use a reverse zener diode.

Protecting Relays and AC Outputs That Control AC

When you use a relay or AC output to switch 115 V/230 VAC loads, place resistor/capacitor networks across either the relay contacts or the AC outputs as shown in Figure 2-18. You can also use a metal oxide varistor (MOV) to limit peak voltage. Ensure that the working voltage of the MOV is at least 20% greater than the nominal line voltage.

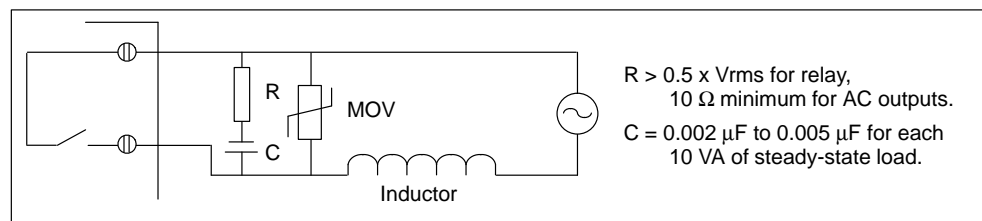


Figure 2-18 AC Load with Network across Relay or AC Outputs

The capacitor allows leakage current to flow around the open switch. Be sure that the leakage current, I (leakage) = $2 \times 3.14 \times f \times C \times V_{rms}$, is acceptable for the application.

For example: A NEMA size 2 contactor lists 183 VA coil inrush and 17 VA sealed coil load. At 115 VAC, the inrush current is $183 \text{ VA}/115 \text{ V} = 1.59 \text{ A}$, which is within the 2A switching capability of the relay contacts.

The resistor = $0.5 \times 115 = 57.5 \Omega$; choose 68 Ω as a standard value.

The capacitor = $(17 \text{ VA}/10) \times 0.005 = 0.0085 \mu F$; choose 0.01 μF as the value.

The leakage current = $2 \times 3.14 \times 60 \times 0.01 \times 10^{-6} \times 115 = 0.43 \text{ mA rms}$.

2.5 Power Considerations

The S7-200 base units have an internal power supply that provides power for the base unit, the expansion modules, and other 24 VDC user power requirements. Use the following information as a guide for determining how much power (or current) the base unit can provide for your configuration.

Power Requirements

Each S7-200 CPU module supplies both 5 VDC and 24 VDC power:

- Each CPU module has a 24 VDC sensor supply that can supply 24 VDC for local input points or for relay coils on the expansion modules. If the power requirement for 24 VDC exceeds the power budget of the CPU module, you can add an external 24 VDC power supply to provide 24 VDC to the expansion modules.
- The CPU module also provides 5 VDC power for the expansion modules when an expansion module is connected. If the 5 VDC power requirements for expansion modules exceeds the power budget of the CPU module, you must remove expansion modules until the requirement is within the power budget.



Warning

Connecting an external 24 VDC power supply in parallel with the S7-200 DC Sensor Supply can result in a conflict between the two supplies as each seeks to establish its own preferred output voltage level.

The result of this conflict can be shortened lifetime or immediate failure of one or both power supplies, with consequent unpredictable operation of the PLC system. Unpredictable operation could result in death or serious injury to personnel, and/or damage to equipment and property.

The S7-200 DC Sensor Supply and any external power supply should provide power to different points. A single connection of the commons is allowed.

The data sheets in Appendix A provide information about the power budgets of the CPU modules and the power requirements of the expansion modules.

Calculating a Sample Power Requirement

Table 2-1 shows a sample calculation of the power requirements for an S7-200 Micro PLC that includes the following modules:

- CPU 214 DC/DC/DC
- Three EM 221 Digital Input 8 x DC 24 V expansion modules
- Two EM 222 Digital Output 8 x Relay expansion modules

The CPU in this example provides sufficient 5 VDC current for the expansion modules; however, it requires an additional power supply to provide the 24 VDC power requirement. (The I/O requires 448 mA of 24 VDC power, but the CPU provides only 280 mA.) Appendix B provides a blank power calculation table.

Table 2-1 Power Budget Calculations for a Sample Configuration

CPU Power Budget	5 VDC	24 VDC
<i>CPU 214 DC/DC/DC</i>	<i>660 mA</i>	<i>280 mA</i>
minus		
System Requirements	5 VDC	24 VDC
<i>CPU 214 DC/DC/DC</i>	BASE UNIT	<i>14 input x 7 mA = 98 mA</i>
<i>Three EM 221 expansion modules</i>	<i>3 x 60 mA = 180 mA</i>	<i>3 x 60 mA = 180 mA</i>
<i>Two EM 222 expansion modules</i>	<i>2 x 80 mA = 160 mA</i>	<i>2 x 85 mA = 170 mA</i>
Total Requirement	<i>340 mA</i>	<i>448 mA</i>
equals		
Current Balance	5 VDC	24 VDC
Current Balance Total	<i>320 mA</i>	<i>[168 mA]</i>

Installing and Using the STEP 7-Micro/WIN Software

3

This manual describes Version 2.1 of STEP 7-Micro/WIN. Previous versions of the software may operate differently.

STEP 7-Micro/WIN is a Windows-based software application that supports both the 16-bit Windows 3.1 environment (STEP 7-Micro/WIN 16) and the 32-bit Windows 95 and Windows NT environments (STEP 7-Micro/WIN 32). In order to use STEP 7-Micro/WIN, the following equipment is recommended:

- Recommended: a personal computer (PC) with an 80586 or greater processor and 16 Mbytes of RAM, or a Siemens programming device (such as a PG 740); minimum computer requirement: 80486 processor with 8 Mbytes
- One of the following sets of equipment:
 - A PC/PPI cable connected to your communications port (PC COM1 or COM2)
 - A communications processor (CP) card and multipoint interface (MPI) cable
 - A multipoint interface (MPI) card (A communications cable comes with the MPI card.)
- VGA monitor, or any monitor supported by Microsoft Windows
- At least 50 Mbytes of free hard disk space
- Microsoft Windows 3.1, Windows for Workgroups 3.11, Windows 95, or Windows NT 4.0 or greater
- Optional but recommended: any mouse supported by Microsoft Windows

STEP 7-Micro/WIN provides extensive online help. Use the **Help** menu command or press F1 to obtain the most current information.

Chapter Overview

Section	Description	Page
3.1	Installing the STEP 7-Micro/WIN Software	3-2
3.2	Using STEP 7-Micro/WIN to Set Up the Communications Hardware	3-4
3.3	Establishing Communication with the S7-200 CPU	3-7
3.4	Configuring the Preferences for STEP 7-Micro/WIN	3-25
3.5	Creating and Saving a Project	3-26
3.6	Creating a Program	3-27
3.7	Creating a Data Block	3-32
3.8	Using the Status Chart	3-34
3.9	Using Symbolic Addressing	3-36

3.1 Installing the STEP 7-Micro/WIN Software

Pre-Installation Instructions

Before running the setup procedure, do the following:

- If a previous version of STEP 7-Micro/WIN is installed, back up all STEP 7-Micro/WIN projects to diskette.
- Make sure all applications are closed, including the Microsoft Office toolbar.

Installation may require that you restart your computer.

Installation Instructions for Windows 3.1

If you have Windows 3.1 (Windows for Workgroups 3.11) on your machine, use the following procedure to install the STEP 7-Micro/WIN 16 software:

1. Start by inserting Disk 1 in the disk drive of your computer (usually drive A or drive B).
2. From the Program Manager, select the menu command **File ► Run...**
3. In the Run dialog box, type **a:\setup** and click "OK" or press ENTER. This starts the setup procedure.
4. Follow the online setup procedure to complete the installation.

Installation Instructions for Windows 95 or Windows NT 4.0

If you have Windows 95 or Windows NT 4.0 on your machine, use the following procedure to install the STEP 7-Micro/WIN 32 software:

1. Start by inserting Disk 1 in the disk drive of your computer (usually drive A or drive B).
2. Click once on the "Start" button to open the Windows 95 menu.
3. Click on the **Run...** menu item.
4. In the Run dialog box, type **a:\setup** and click on "OK" or press ENTER. This starts the setup procedure.
5. Follow the online setup procedure to complete the installation.
6. At the end of the installation, the Install/Remove Modules dialog box appears automatically. See Figure 3-1. You can install the hardware for your machine to communicate now (see Section 3.2), or you can wait until later (see Section 3.3).

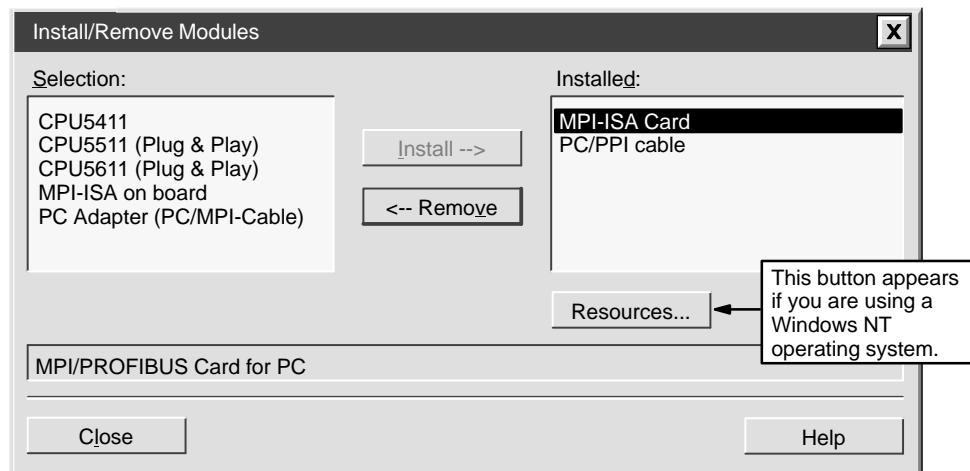


Figure 3-1 Install/Remove Modules Dialog Box

Troubleshooting the Installation

The following situations can cause the installation to fail:

- Not enough memory: at least 50 Mbytes of free space are required on your hard disk.
- Bad diskette: verify that the diskette is bad, then call your salesman or distributor.
- Operator error: start over and read the instructions carefully.
- Failure to close any open applications, including the Microsoft Office toolbar

Review the READMEx.TXT file included on your diskettes for the most recent information about STEP 7-Micro/WIN. (In the x position, the letter A = German, B = English, C = French, D = Spanish, E = Italian.)

3.2 Using STEP 7-Micro/WIN to Set Up the Communications Hardware

General Information for Installing or Removing the Communications Hardware

If you are using Windows 95 or Windows NT 4.0, the Install/Remove Modules dialog box appears automatically at the end of your software installation. See Figure 3-1. If you are using Windows 3.1, follow these steps:

1. Select the menu command **Setup ► Communications....** The Communications dialog box appears.
2. Click the "PG/PC Interface..." button. The Setting the PG/PC Interface dialog box appears.
3. Click the "Install..." button. The Install/Remove Modules dialog box appears. See Figure 3-1.

You will need to base your installation of communications hardware on the following criteria:

- The operating system that you are using (Windows 3.1, Windows 95, or Windows NT 4.0)
- The type of hardware you are using, for example:
 - PC with PC/PPI cable
 - PC or SIMATIC programming device with multipoint interface (MPI) or communications processor (CP) card
 - CPU 212, CPU 214, CPU 215, CPU 216
 - Modem
- The baud rate you are using

Table 3-1 shows the possible hardware configurations and baud rates that STEP 7-Micro/WIN supports, depending on the type of CPU that you are using. For more detailed information on communications setup, see Section 3.3.

Table 3-1 Hardware Configurations Supported by STEP 7-Micro/WIN

Type of CPU	STEP 7-Micro/WIN Version	Hardware Supported	Baud Rates Supported	Operating System	Type of Parameter Set
CPU 212, CPU 214, CPU 216 CPU 215 port 0	Micro/WIN 16	PC/PPI cable, MPI-ISA card	9.6 kbaud or 19.2 kbaud	Windows 3.1	PPI, PPI multi-master
	Micro/WIN 32	PC/PPI cable, MPI-ISA card, MPI-ISA card on board, CP 5411, CP 5511, CP 5611	9.6 kbaud or 19.2 kbaud	Windows 95 or Windows NT	PPI
CPU 215 port 1 (DP port)	Micro/WIN 16	Not supported	Not supported	Windows 3.1 Windows 95 or Windows NT	Not supported
	Micro/WIN 32	MPI-ISA card, MPI-ISA card on board, CP 5411, CP 5511, CP 5611	9.6 kbaud to 12 Mbaud	Windows 95 or Windows NT	MPI

Note

STEP 7-Micro/WIN 16 does not support the multi-master parameter set under the Windows 95 or Windows NT 4.0 operating system.

The following hardware configurations are possible:

- CPU 212, CPU 214, CPU 216, CPU 215 (port 0)
 - PC/PPI Cable (PPI), 9.6 kbaud or 19.2 kbaud
 - MPI Card (PPI), 9.6 kbaud or 19.2 kbaud
- CPU 215 (port 1, that is, the DP port)
 - MPI Card (MPI), 9.6 kbaud to 12 Mbaud

Note

STEP 7-Micro/WIN 16 does not support communications on port 1 of the CPU 215.

The selections for MPI Card are different for STEP 7-Micro/WIN 16 and STEP 7-Micro/WIN 32.

On the left side of the Install/Remove Modules dialog box is a list of hardware types that you have not installed yet (see Figure 3-1). On the right side is a list of currently installed hardware types. If you are using the Windows NT 4.0 operating system, there is a "Resources" button under the Installed list box.

To install the hardware, follow these steps:

1. From the Selection list box, select the hardware type that you have. A description of your selection is shown in the lower window.
2. Click the "Install -->" button.

To remove hardware, follow these steps:

1. Select the hardware from the Installed list box on the right.
2. Click the "<-- Remove" button.

When you are finished installing or removing hardware, click the "Close" button. This action returns you to the Setting the PG/PC Interface dialog box. The selections that you made appear now in the list box that contains the module parameter sets. See Figure 3-7.

For detailed information on the communications setup for your configuration, see Section 3.3.

Special Hardware Installation Information for Windows NT Users

Installing hardware modules under the Windows NT operating system is slightly different from installing hardware modules under Windows 95. Although the hardware modules are the same for either operating system, installation under Windows NT requires more knowledge of the hardware that you want to install. Windows 95 tries automatically to set up system resources for you; however, Windows NT does not. Windows NT provides you with default values only. These values may or may not match the hardware configuration. However, these parameters can be modified easily to match the required system settings.

When you have installed a piece of hardware, select it from the Installed list box and click the "Resources" button. The Resources dialog box appears. See Figure 3-2. The Resources dialog box allows you to modify the system settings for the actual piece of hardware that you installed. If this button is unavailable (gray), you do not need to do anything more.

At this point you may need to refer to your hardware manual to determine the setting for each of the parameters listed in the dialog box, depending on your hardware settings. You may need to try several different interrupts in order to establish communication correctly.

For detailed information on the communications setup for your configuration, see Section 3.3.

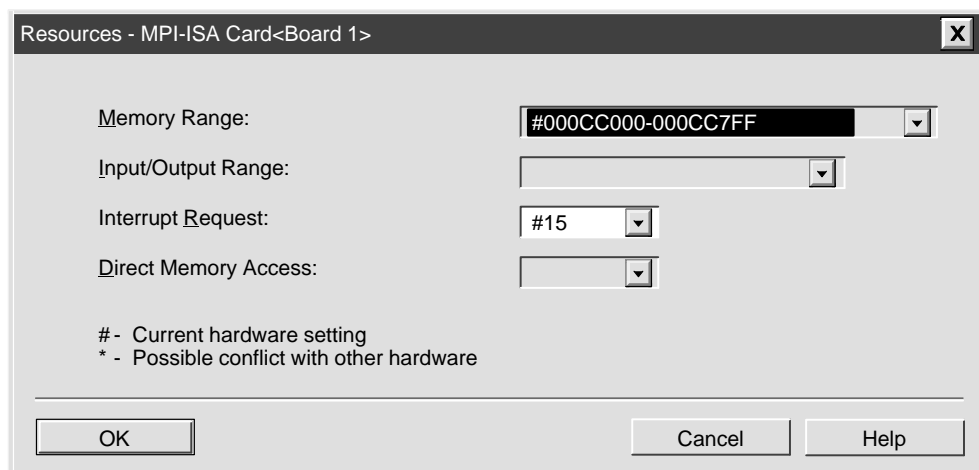


Figure 3-2 Resources Dialog Box for Windows NT

3.3 Establishing Communication with the S7-200 CPU

You can arrange the S7-200 CPUs in a variety of configurations to support network communications. You can install the STEP 7-Micro/WIN software on a personal computer (PC) that has a Windows 3.1x, Windows 95, or Windows NT operating system, or you can install it on a SIMATIC programming device (such as a PG 740). You can use the PC or the programming device as a master device in any of the following communications configurations:

- A single master device is connected to one or more slave devices. See Figure 3-3.
- A single master device is connected to one or more slave devices and one or more master devices. See Figure 3-4 and Figure 3-5.
- A CPU 215 functions as a remote I/O module owned by an S7-300 or S7-400 programmable logic controller or by another PROFIBUS master. See Figure 3-13.
- A single master device is connected to one or more slave devices. This master device is connected by means of 11-bit modems to either one S7-200 CPU functioning as a slave device or else to a network of S7-200 CPUs functioning as slave devices. See Figure 3-14.

Connecting Your Computer to the S7-200 CPU Using the PC/PPI Cable

Figure 3-3 shows a typical configuration for connecting your personal computer to your CPU with the PC/PPI cable. To establish proper communications between the components, follow these steps:

1. Set the DIP switches on the PC/PPI cable for the baud rate.
2. Connect the RS-232 end of the PC/PPI cable labeled PC to the communications port of your computer, either COM1 or COM2, and tighten the connecting screws.
3. Connect the other end (RS-485) of the PC/PPI cable to the communications port of the CPU, and tighten the connecting screws.

For the technical specifications of the PC/PPI cable, see Section A.40; for its order number, see Appendix G.

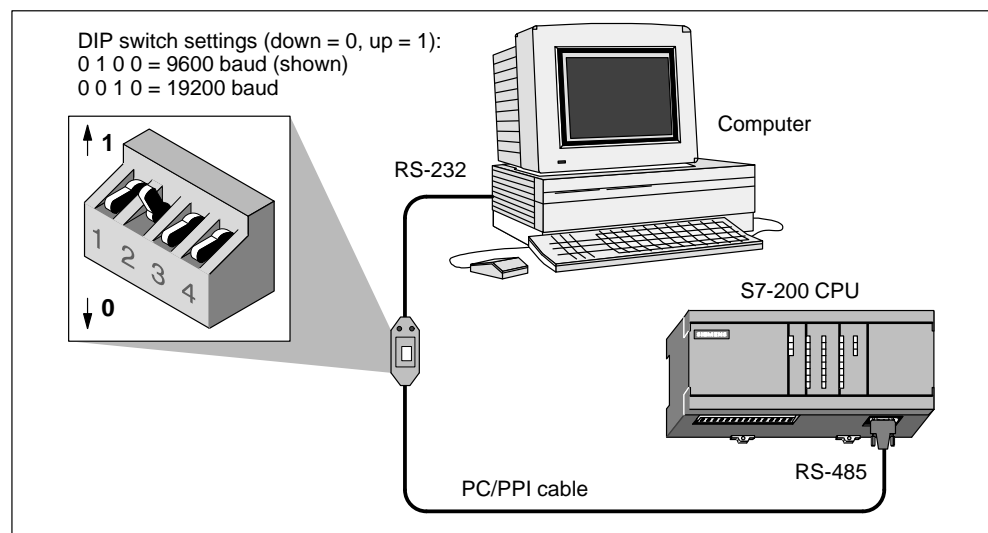


Figure 3-3 Communicating with a CPU in PPI Mode

Figure 3-4 shows a configuration with a personal computer connected to several S7-200 CPU modules. STEP 7-Micro/WIN is designed to communicate with one S7-200 CPU at a time; however, you can access any CPU on the network. The CPU modules in Figure 3-4 could be either slave or master devices. The TD 200 is a master device. For detailed information on network communications, see Chapter 9.

Note

Only STEP 7-Micro/WIN 16 with a Windows 3.1 operating system and STEP 7-Micro/WIN 32 support multiple masters through the PC/PPI cable; STEP 7-Micro/DOS does not.

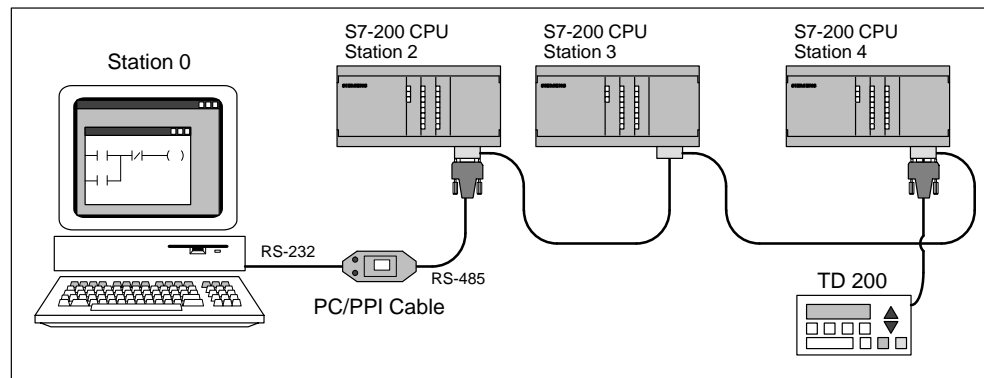


Figure 3-4 Using a PC/PPI Cable for Communicating with Several S7-200 CPU Modules

Connecting Your Computer to the S7-200 CPU Using the MPI or CP Card

You can use STEP 7-Micro/WIN with a multipoint interface (MPI) or communications processor (CP) card. Either card provides a single RS-485 port for connection to the network using an MPI cable. STEP 7-Micro/WIN 32 (the 32-bit version) supports the MPI parameter set for an MPI network; STEP 7-Micro/WIN 16 (the 16-bit version) does not. After establishing MPI communications, you can connect STEP 7-Micro/WIN on a network that contains other master devices. Each master must have a unique address. Figure 3-5 shows a sample network with master and slave devices. For detailed information on network communications, see Chapter 9. For information on the MPI card and the various CP cards that are available, see Section 9.4. Appendix G lists their order numbers.

Note

If you are using the PPI parameter set, STEP 7-Micro/WIN does not support two different applications running on the same MPI or CP card at the same time. Close the other application before connecting STEP 7-Micro/WIN to the network through the MPI or CP card.

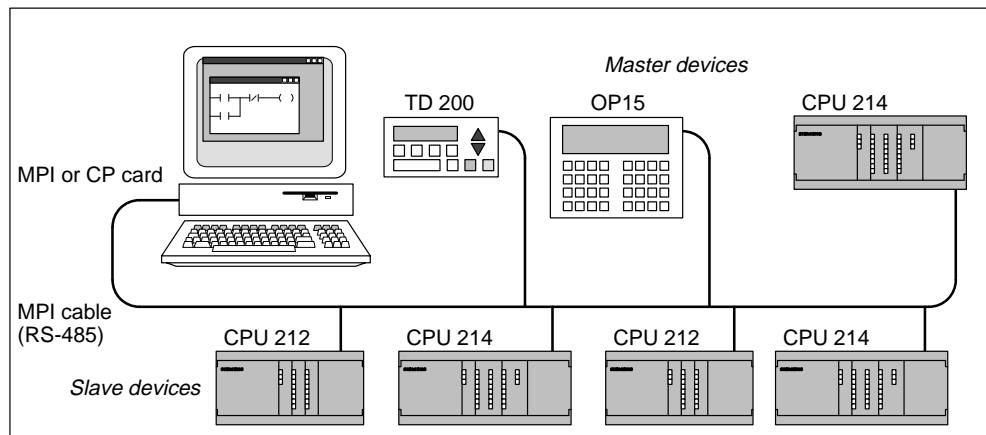


Figure 3-5 Example of an MPI or CP Card with Master and Slave Devices

From What Point Do I Set Up Communications?

Depending on the operating system that you are using, you can set up communications from any of the following points:

- Under Windows 3.1
 - Within STEP 7-Micro/WIN 16 only
- Under Windows 95 or Windows NT 4.0
 - During the final step of the installation (see Section 3.1)
 - From the Setting the PG/PC Interface icon, found in the Windows Control Panel
 - Within STEP 7-Micro/WIN 32

Setting Up Communications within STEP 7-Micro/WIN

Within STEP 7-Micro/WIN there is a Communications dialog box that you can use to configure your communications setup. See Figure 3-6. You can use one of the following ways to find this dialog box:

- Select the menu command **Setup ► Communications....**
- Create a new project and click the “Communications...” button in the CPU Type dialog box.
- If you have a project open, select the menu command **CPU ► Type...** and click the “Communications...” button in the CPU Type dialog box.

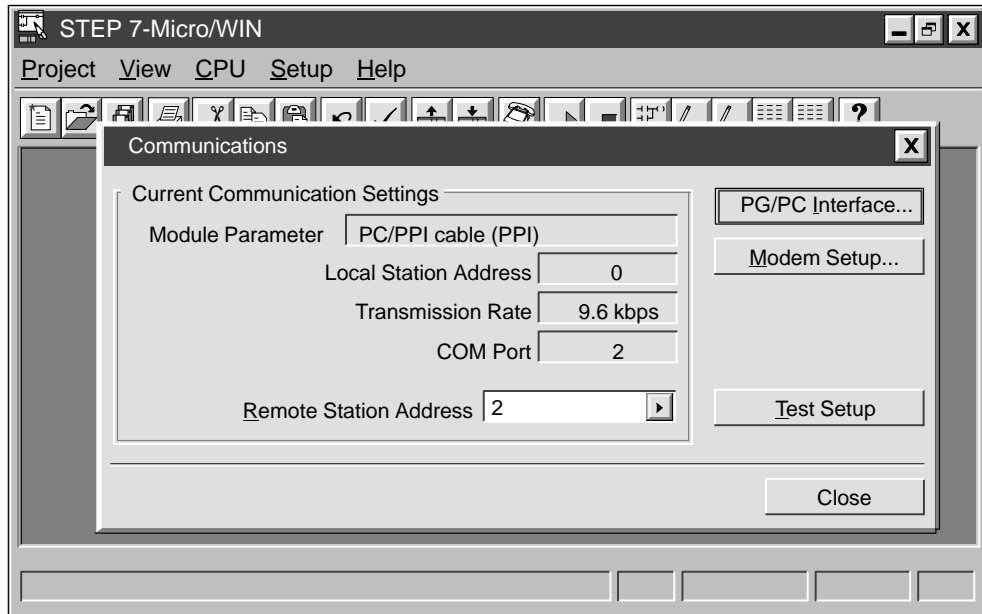


Figure 3-6 Setting Up the Communications between Programming Device or PC and the CPU

After you have called up the Communications dialog box, click the “PG/PC Interface...” button. The Setting the PG/PC Interface dialog box appears. See Figure 3-7.

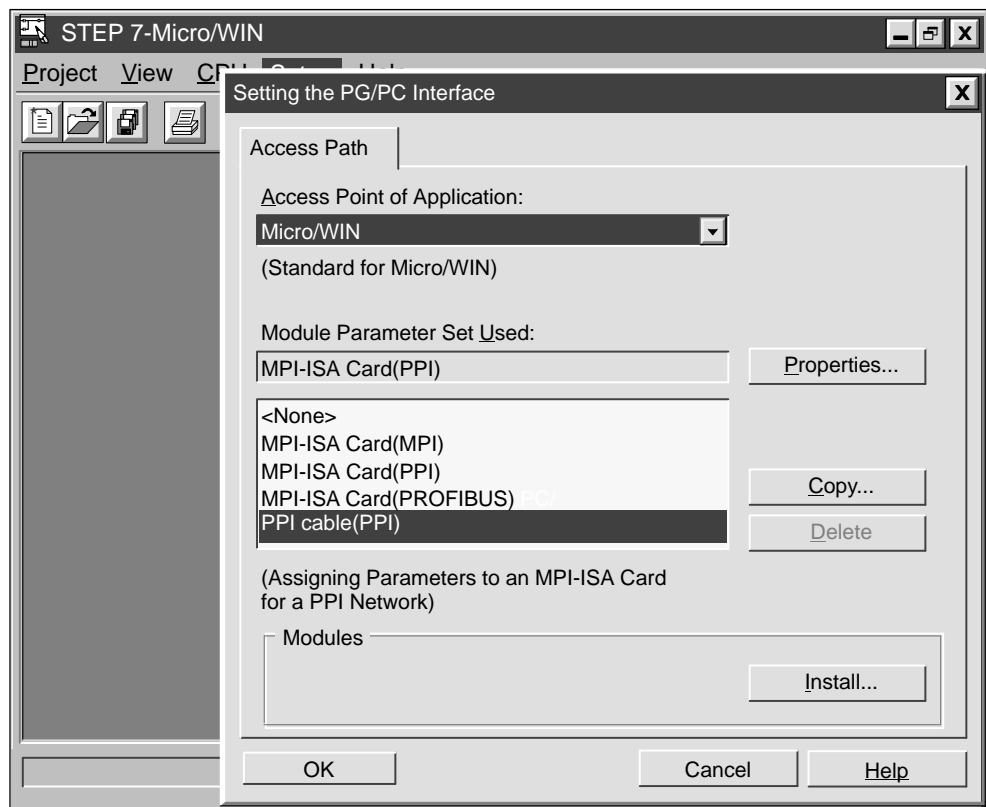


Figure 3-7 Setting the PG/PC Interface Dialog Box

Setting Up Communications from the Windows Control Panel

If you are using the Windows 95 or Windows NT 4.0 operating system, you can set up the communications configuration by means of the Control Panel. From the Control Panel, select the Setting the PG/PC Interface icon. See Figure 3-8.

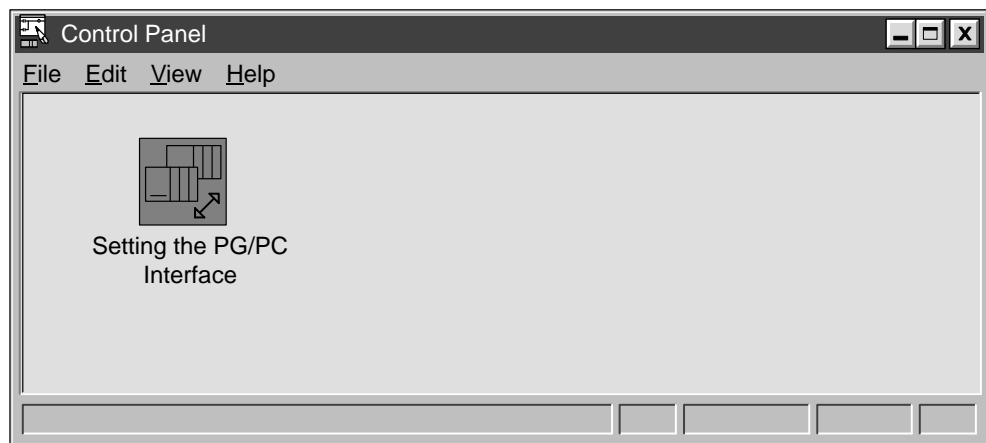


Figure 3-8 Control Panel with Setting the PG/PC Interface Icon

Setting Up Communications during Installation

Under the Windows 95 or Windows NT 4.0 operating system, at the end of the STEP 7-Micro/WIN installation, the Communications dialog box appears automatically. You can set up your configuration at that time, or later.

Selecting the Correct Module Parameter Set and Setting It Up

When you have reached the Setting the PG/PC Interface dialog box (see Figure 3-7), you must select "Micro/WIN" in the Access Point of Application list box in the Access Path tab. This dialog box is common to several different applications, such as STEP 7 and WinCC, so you must tell the program the application for which you are setting parameters.

When you have selected "Micro/WIN" and have installed your hardware, you need to set the actual properties for communicating with your hardware. The first step is to determine the protocol that you want to use on your network. See Table 3-1 or Chapter 9 to find out what your CPU supports and what you should use for your configuration. In most cases, you will use the PPI protocol for all of your CPU modules, except for the high-speed port (DP port) on the CPU 215. This port uses the MPI protocol.

When you have decided what protocol you want to use, you can choose the correct setup from the Module Parameter Set Used list box in the Setting the PG/PC Interface dialog box. This box lists each hardware type that you have installed, along with the protocol type in parentheses. For example, a simple setup might require you to use the PC/PPI cable to communicate with a CPU 214. In this case, you select "PC/PPI cable(PPI)." Another example is a setup that requires communicating with a CPU 215 through its high-speed port (DP port) by means of a plain MPI-ISA card that you have installed in your computer. In this case, you select "MPI-ISA Card(MPI)."

After you have selected the correct module parameter set, you must set up the individual parameters for the current configuration. Click the "Properties..." button in the Setting the PG/PC Interface dialog box. This action takes you to one of several possible dialog boxes, depending on the parameter set that you selected. The sections that follow describe each of these dialog boxes in detail.

In summary, to select a module parameter set, follow these steps:

1. In the Setting the PG/PC Interface dialog box (see Figure 3-7), select "Micro/WIN" in the Access Point of Application list box in the Access Path tab.
2. Ensure that your hardware is installed. See Section 3.2.
3. Determine the protocol that you want to use.
4. Select the correct setup from the Module Parameter Set Used list box in the PG/PC Interface dialog box.
5. Click the "Properties..." button in the Setting the PG/PC Interface dialog box.

From this point, you make selections according to the parameter set that you chose.

Setting Up the PC/PPI Cable (PPI) Parameters

This section explains how to set up the PPI parameters for the following operating systems and hardware:

- Windows 3.1: PC/PPI cable
- Windows 95 or Windows NT 4.0: PC/PPI cable

From the Setting the PG/PC Interface dialog box, if you are using the PC/PPI cable and you click the “Properties...” button, the properties sheet appears for PC/PPI cable (PPI). See Figure 3-9.

Follow these steps:

1. In the PPI Network tab, select a number in the Local Station Address box. This number indicates where you want STEP 7-Micro/WIN to reside on the programmable controller network.
2. Select a value in the Timeout box. This value represents the length of time that you want the communications drivers to spend to attempt to establish connections. The default value should be sufficient.
3. Determine whether you want STEP 7-Micro/WIN to participate on a network that has multiple masters. See Chapter 9 for more information. You can leave the check mark in the Multiple Master Network box, unless you are using a modem. In that case, the box cannot be checked because STEP 7-Micro/WIN does not support that functionality.
4. Set the transmission rate at which you want STEP 7-Micro/WIN to communicate over the network. See Chapter 9, Table 9-1, for valid baud rates for your CPU module.
5. Select the highest station address. This is the address where STEP 7-Micro/WIN stops looking for other masters on the network.

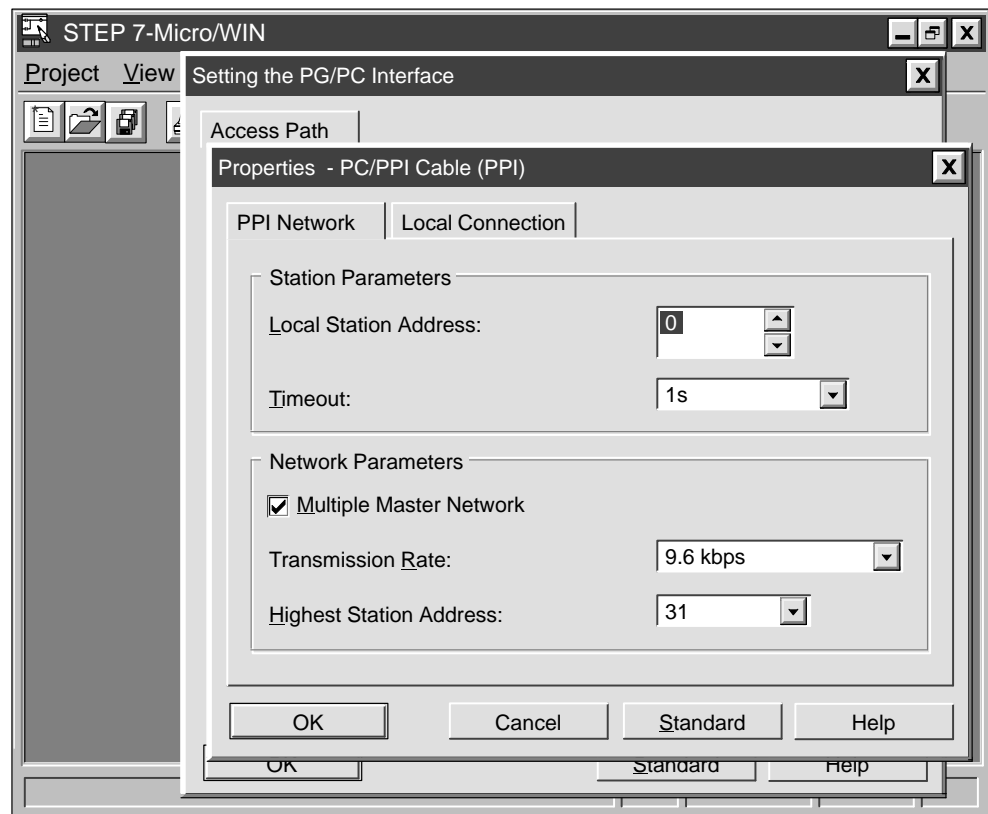


Figure 3-9 PC/PPI Cable (PPI) Properties Sheet, PPI Network Tab

6. Click the Local Connection tab. See Figure 3-10.
7. In the Local Connection tab, select the COM port to which your PC/PPI cable is connected. If you are using a modem, select the COM port to which the modem is connected and select the Use Modem check box.
8. Click the "OK" button to exit the Setting the PG/PC Interface dialog.

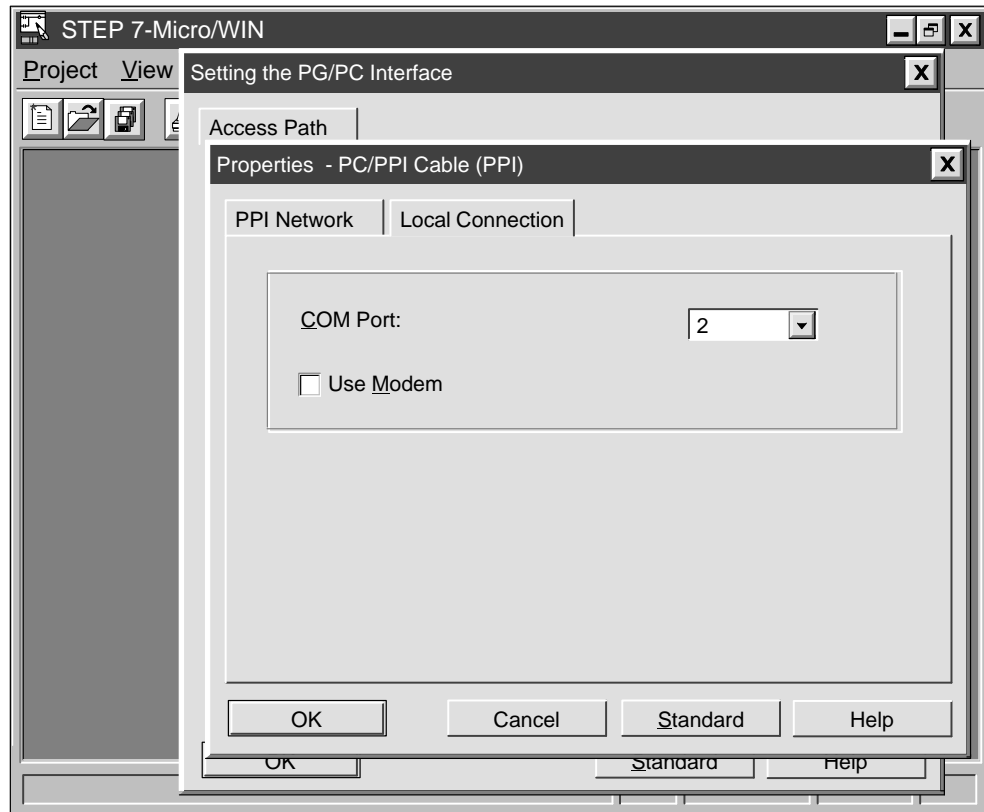


Figure 3-10 PC/PPI Cable (PPI) Properties Sheet, Local Connection Tab

Setting Up the MPI Card (PPI) Parameters

This section explains how to set up the PPI parameters for the following operating systems and hardware:

- Windows 3.1: MPI-ISA card (including those found in SIMATIC programming devices)
- Windows 95 or Windows NT 4.0:
 - MPI-ISA card
 - MPI-ISA card on board (MPI cards for SIMATIC programming devices)
 - CP 5411
 - CP 5511
 - CP 5611

From the Setting the PG/PC Interface dialog box, if you are using any of the MPI or CP cards listed above along with the PPI protocol, and you click the “Properties...” button, the properties sheet appears for XXX Card(PPI), where “XXX” stands for the type of card you installed, for example, MPI-ISA. See Figure 3-11.

Follow these steps:

1. In the PPI Network tab, select a number in the Local Station Address box. This number indicates where you want STEP 7-Micro/WIN to reside on the programmable controller network.
2. Select a value in the Timeout box. This value represents the length of time that you want the communications drivers to spend to attempt to establish connections. The default value should be sufficient.
3. Determine whether you want STEP 7-Micro/WIN to participate on a network that has multiple masters. See Chapter 9 for more information. You can leave the check mark in the Multiple Master Network box.
4. Set the transmission rate at which you want STEP 7-Micro/WIN to communicate over the network. See Chapter 9, Table 9-1, for valid baud rates for your CPU module.
5. Select the highest station address. This is the address where STEP 7-Micro/WIN stops looking for other masters on the network.
6. Click the “OK” button to exit the Setting the PG/PC Interface dialog box.

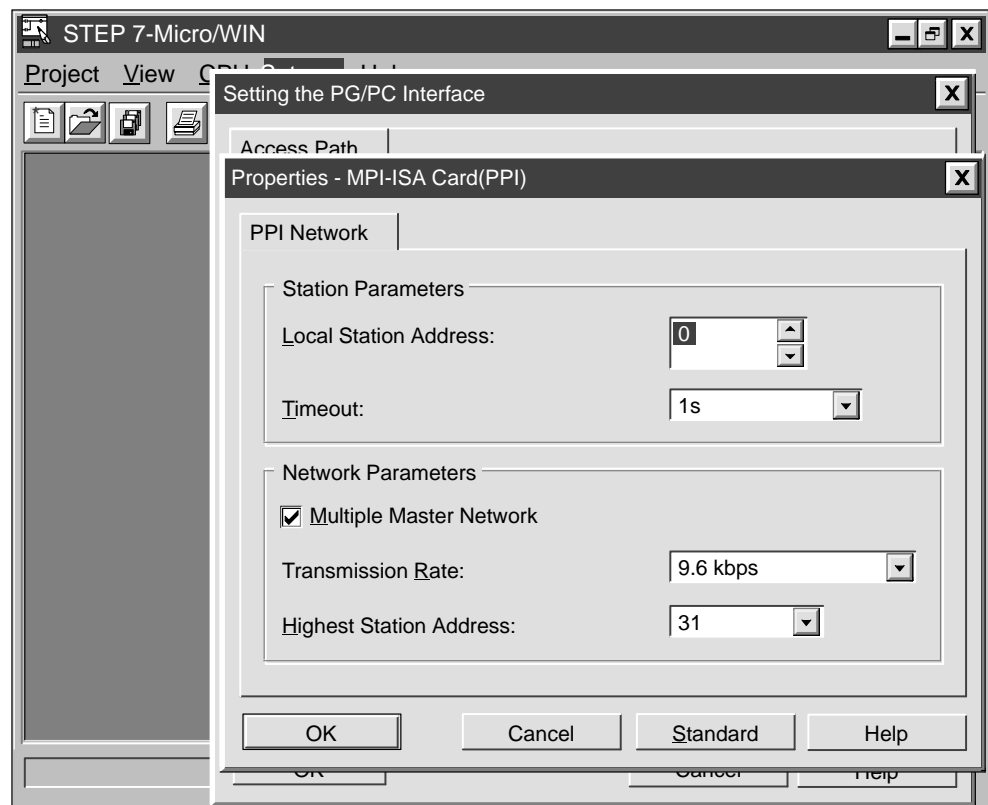


Figure 3-11 MPI-ISA Card (PPI) Properties Sheet

Setting Up the MPI Card (MPI) Parameters

This section explains how to set up the MPI parameters for the following operating systems and hardware:

- Windows 3.1: MPI-ISA card (including those found in SIMATIC programming devices)
- Windows 95 or Windows NT 4.0:
 - MPI-ISA card
 - MPI-ISA card on board (MPI cards for SIMATIC programming devices)
 - CP 5411
 - CP 5511
 - CP 5611

From the Setting the PG/PC Interface dialog box, if you are using any of the MPI or CP cards listed above along with the MPI protocol, and you click the “Properties...” button, the properties sheet appears for XXX Card(MPI), where “XXX” stands for the type of card you installed, for example, MPI-ISA. See Figure 3-12.

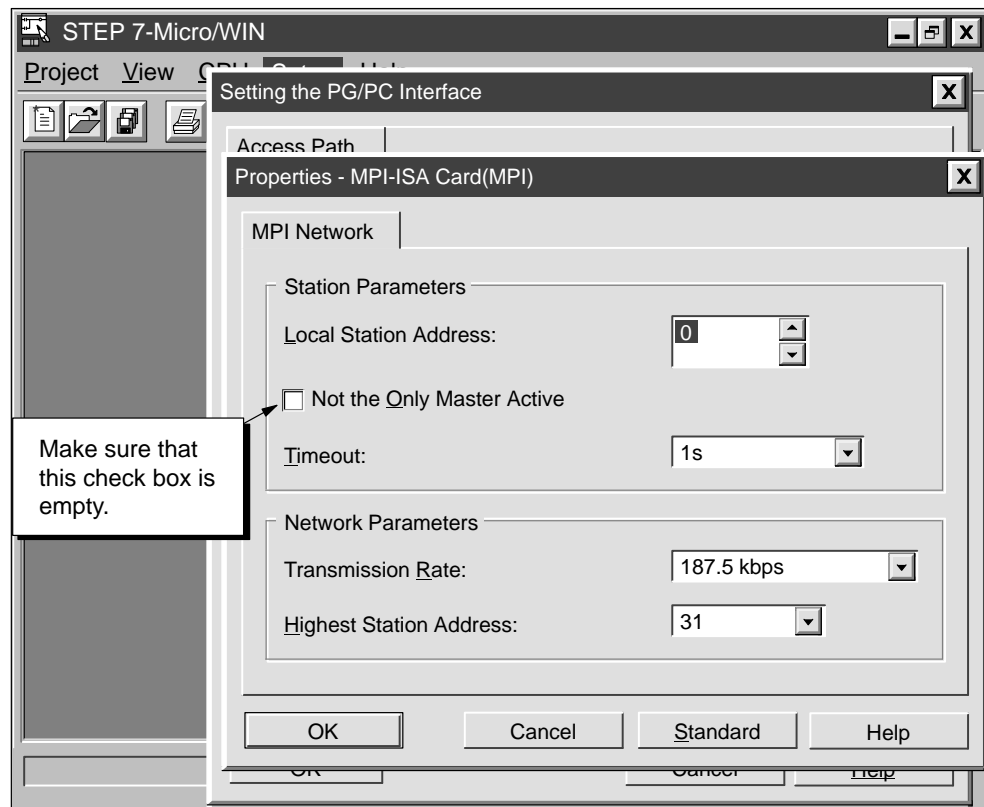


Figure 3-12 MPI-ISA Card (MPI) Properties Sheet

Follow these steps:

1. In the MPI Network tab, select a number in the Local Station Address box. This number indicates where you want STEP 7-Micro/WIN to reside on the programmable controller network.
2. Make sure that the Not the Only Master Active check box is cleared, regardless of the number of masters you have on your network. If the check box contains a check mark, click the box to clear it. Be sure to connect the communication cable between the programming device and the CPU before initiating communications. If you start communications before connecting the programming device to the existing CPU network including one or more master devices, then communications are disrupted while the network is being reinitialized.
3. Select a value in the Timeout box. This value represents the length of time that you want the communications drivers to spend to attempt to establish connections. The default value should be sufficient.
4. Set the transmission rate at which you want STEP 7-Micro/WIN to communicate over the network. Because you are probably using the DP port on a CPU 215, you can select any available transmission rate up to 12 Mbaud. See Chapter 9, Table 9-1, for valid baud rates for your CPU module.
5. Select the highest station address. This is the address where STEP 7-Micro/WIN stops looking for other masters on the network.
6. Click the "OK" button to exit the Setting the PG/PC Interface dialog box.

Troubleshooting the MPI Communications Setup for 16-Bit Applications

The MPI Card option activates the MPI drivers in the S7DPMPI.INI configuration file, which was placed in the Windows directory during the STEP 7-Micro/WIN installation.

If you get an interrupt error, you must set the MPI card to a free hardware interrupt request (IRQ) line. The default interrupt line is IRQ 5. The IRQ field is used to specify the interrupt number used by the MPI card. An interrupt error indicates that IRQ 5 is already in use. To specify a different IRQ line, follow these steps:

1. Select the menu command **Setup ► Communications....** The communications dialog box is displayed. Locate the hardware interrupt options and choose an alternate value.
2. Accept your changes by clicking "OK" or pressing ENTER. The software automatically modifies the S7DPMPI.INI file, and informs you if exiting the application is required.
3. Restart the STEP 7-Micro/WIN application and select the MPI option again.

Note

The following are the default addresses for the S7-200 CPU modules with more than one communication port:

- CPU 215 Port 0: 2
 Port 1: 126
 - CPU 216 Port 0: 2
 Port 1: 2
-

Troubleshooting the MPI Communications Setup for Windows NT 4.0

Setting up the MPI card correctly under Windows NT 4.0 is somewhat difficult. If you have problems with your setup (assuming that you have the MPI card installed in the communications setup screens), follow these steps:

1. Make sure you have a working MPI card. There are several ways to do this: you can test it on a Windows 95 machine or check it under STEP 7-Micro/WIN Version 2.0.
2. Check the DIP switches on the side of your MPI card to determine how much memory to reserve for the card. See Table 3-2.
3. Check to see what resources Windows NT has reserved for the card to make sure that the reserved resources match the switch configuration. Follow these steps:
 - a. Open the Setting the PG/PC Interface dialog box.
 - b. Click the "Install..." button.
 - c. Select the MPI Card from the Installed list.
 - d. Click the "Resources" button. This button is available only under Windows NT.
4. If the resource allocation is correct and your card still does not work, try changing the hardware interrupt request line to which the card is linked. There may be a conflict with another piece of hardware. You can use the Resources dialog box to make this change.
5. If you have gone through every interrupt and the card still does not work, you must change the DIP switch settings on the card to a different address. Repeat step 3. Repeat step 4.
6. If you have tried all of the steps above and your card still does not work, all of your resources are probably already taken by other pieces of hardware. You can try to remove or disable some of these other hardware pieces (for example, sound cards) to try to make some resources available. Then start again with step 2 above.
7. If all else fails, use a different communications driver.

The documentation that comes with the MPI card explains in more detail the hardware conflicts that may possibly occur.

Table 3-2 Amount of Memory Required for an MPI Card

SW1	SW2	SW3	Memory
ON	ON	ON	#000C8000-000C87FF
ON	ON	OFF	#000C9000-000C97FF
ON	OFF	ON	#000CC000-000CC7FF
ON	OFF	OFF	#000D0000-000D07FF
OFF	ON	ON	#000D1000-000D17FF
OFF	ON	OFF	#000DC000-000DC7FF
OFF	OFF	ON	#000E1000-000E17FF

Connecting a CPU 215 as a Remote I/O Module

You can connect the CPU 215 to a PROFIBUS network, where it can function as a remote I/O module owned by an S7-300 or S7-400 programmable logic controller or by another PROFIBUS master. See Figure 3-13.

The CPU 215 has a port marked as DP on the CPU. Use the DP port to connect your CPU 215 as a remote I/O module on a PROFIBUS network.

The only setting you must make on the CPU 215 to use it as a PROFIBUS slave is the station address of the DP port of the CPU. This address must match the address in the configuration of the master. The master device configures the CPU 215. For more information about distributed peripheral (DP) standard communications, see Section 9.5.

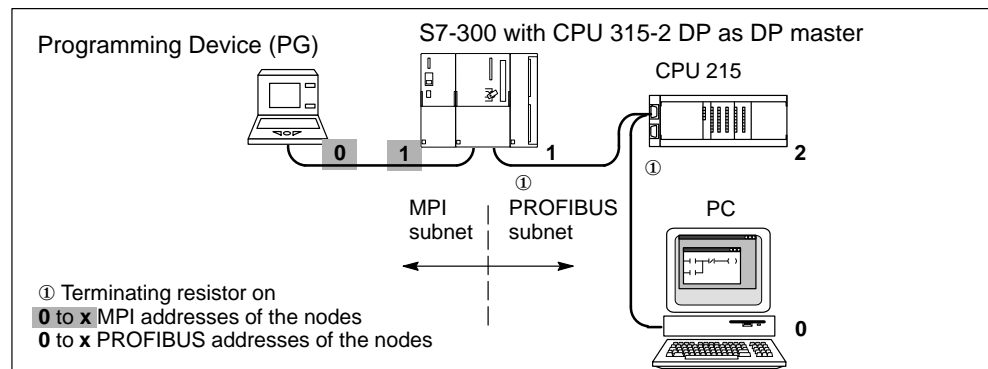


Figure 3-13 CPU 215 on a PROFIBUS Subnetwork, with MPI Subnetwork

Using Modems to Connect an S7-200 CPU to a STEP 7-Micro/WIN Master

Using STEP 7-Micro/WIN on a PC with a Windows 3.1x, Windows 95, or Windows NT operating system or on a SIMATIC programming device (such as a PG 740) as a single-master device, you can make connections to the following S7-200 devices by means of modems:

- A single S7-200 CPU as a slave device
- Multiple S7-200 CPUs as slaves on a network

Depending on whether you want to connect to only one S7-200 CPU or to a network of them, you need the following cables and adapter (see Figure 3-14):

- A cable with RS-232 capability at each end to connect the PC or SIMATIC programming device to a full-duplex 11-bit modem at one end of the telephone line
- A null modem adapter to connect the modem at the other end of the telephone line to a PC/PPI cable
- A PC/PPI cable to connect the null modem adapter to either of the following ports:
 - The communications port of the S7-200 CPU (see Figure 3-14)
 - A Siemens programming port connector on a PROFIBUS network (see Figure 9-3)

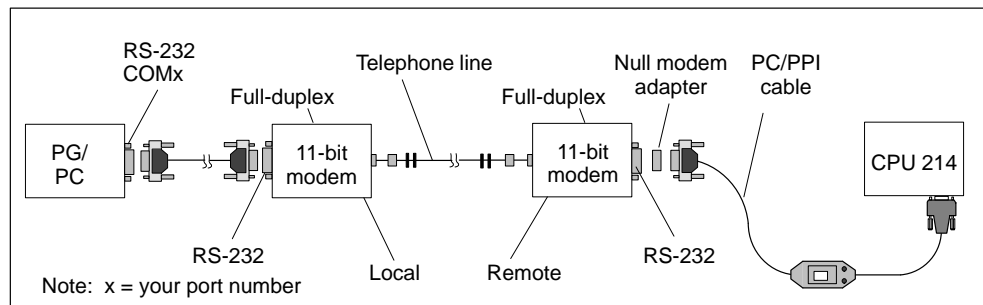


Figure 3-14 S7-200 Data Communications Using an 11-Bit Modem

Because these configurations allow only one master device, there is no token passing. These configurations support only the PPI protocol. In order to communicate through the PPI interface, the S7-200 programmable logic controller requires that the modem use an 11-bit data string. The S7-200 controller requires one start bit, eight data bits, one parity bit (even parity), one stop bit, asynchronous communication, and a transmission speed of 9600 baud for PPI. Many modems are not capable of supporting this data format. The modem requires the settings listed in Table 3-3.

Figure 3-15 shows the pin assignments for a null modem adapter. For more information on network communications using the PC/PPI cable, see Chapter 9.

Table 3-3 Modem Settings Required

Data Format in Bits	Transmission Speed between Modem and PC	Transmission Speed on the Line	Other Features
8 data	9600 baud	9600 baud	Ignore DTR signal
1 start			No hardware flow control
1 stop			
1 parity (even)			

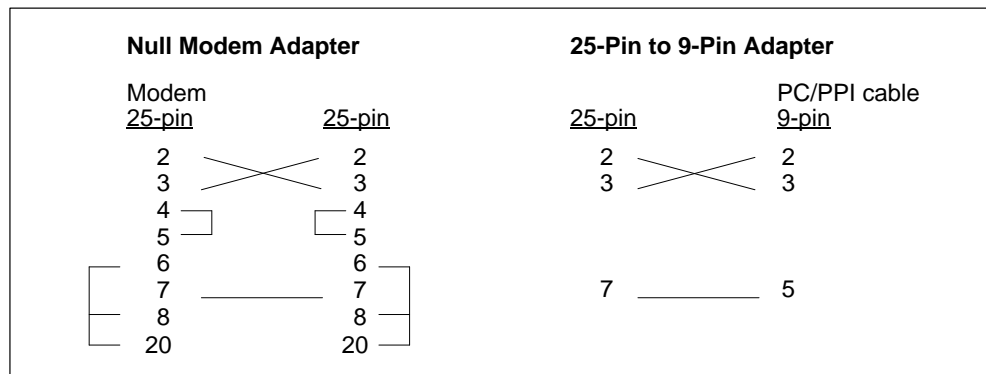


Figure 3-15 Pin Assignments for a Null Modem Adapter

Setting Up the Communications Parameters When Using Modems

To set up communications parameters between your programming device or PC and the CPU when using modems, you must use the module parameter set for the PC/PPI cable. Otherwise, the Configure Modems function is not enabled. Ensure that the Configure Modems function is enabled and then set up the configuration parameters by following these steps:

Note

The communications setup described here applies to the Multi Tech MultiModemZDX MT1932ZDX. If you are not using this type of modem, you must choose "User-Defined" as the Selected Modem in the Configure Modems dialog box. Your modem must be an 11-bit modem and must run at 9600 baud. Check the manual for your modem to determine the parameters to enter in the Configuration tabs of the Configure Modems dialog box.

1. Select the menu command **Setup ► Communications....**

In the Communications dialog box, if the Current Protocol area shows "PC/PPI cable(PPI)," click the "PG/PC Interface..." button and go on to step 3.

If the Current Protocol area does not show "PC/PPI cable(PPI)," click the "PG/PC Interface..." button and continue with step 2.

2. In the Access Path tab, in the Module Parameter Set Used list box, select PC/PPC cable(PPI). If this selection is not in the list box, you must install it. See Section 3.1.
3. Click the "Properties" button. The PC/PPI cable(PPI) properties sheet appears.
4. In the PC/PPI cable(PPI) properties sheet, click the Local Connection tab.
5. In the COM Port area, ensure that the Use Modem box contains a check mark. If the box is empty, select it to insert a check mark.
6. Click the "OK" button. The Access Path tab appears again.
7. Click the "OK" button. The Communications dialog box appears again.

8. Click the "Configure Modems..." button. The Configure Modems dialog box appears. (You can also access the "Configure Modems..." button by selecting the menu command **Setup ► Connect Modem....** The button appears in the Connect dialog box.)

The General Information tab of the Configure Modems dialog box provides the 11-bit data string requirements for the modems and lists the hardware components that you need. Figure 3-14 shows the same hardware components.

9. Click the Local Modem Configuration tab. See Figure 3-16.
10. In the Local Modem Configuration tab, in the Selected Modem list box, choose Multi Tech MultiModemZDX MT1932ZDX.

The only other fields that you can edit in this tab are Connect Phone Number and Timeout. The time-out is the length of time that the local modem attempts to set up a connection to the remote modem. If the time indicated in seconds in the Timeout field elapses before the connection is set up, the attempt to connect fails.

11. If you want to test the configuration of your local modem, click the "Test Modem" button while the modem is connected to your local machine (your programming device or PC).
12. Disconnect your local modem and connect your remote modem to your local machine (your programming device or PC).

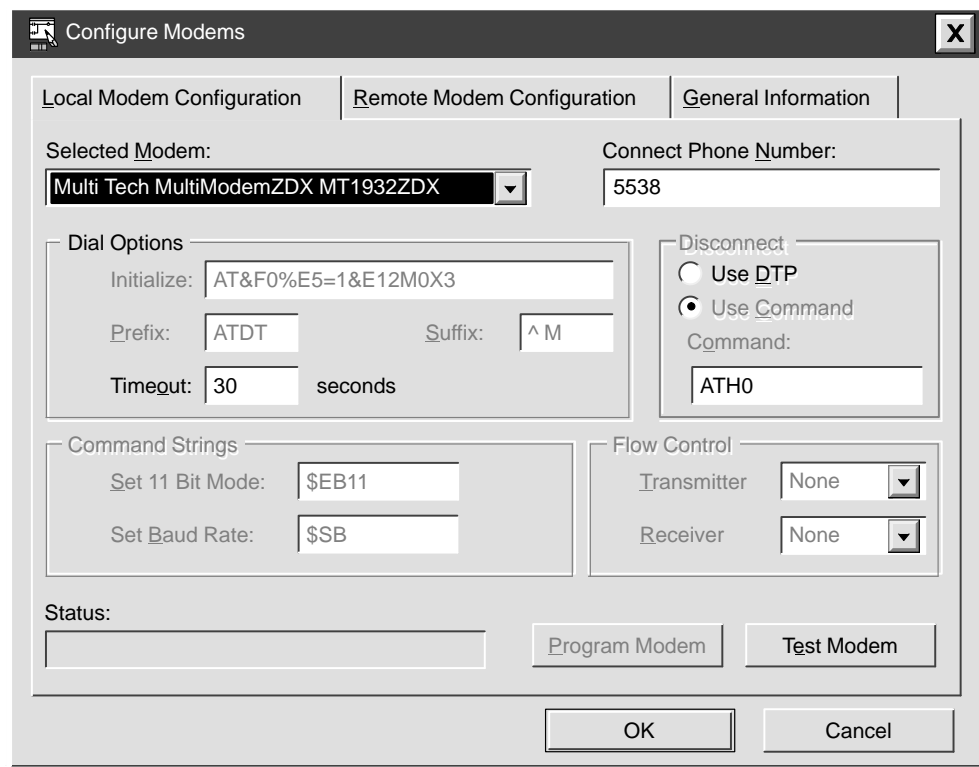


Figure 3-16 Local Modem Configuration Tab of the Configure Modems Dialog Box

13. Click the Remote Modem Configuration tab. See Figure 3-17.
14. In the Remote Modem Configuration tab, in the Selected Modem list box, choose Multi Tech MultiModemZDX MT1932ZDX.
15. Click the "Program Modem" button. This action transfers the parameters into a memory chip in the remote modem.
16. If you want to test your remote modem to see if it is programmed correctly, click the "Test Modem" button.
17. Click the "OK" button. The Communications dialog box appears again.

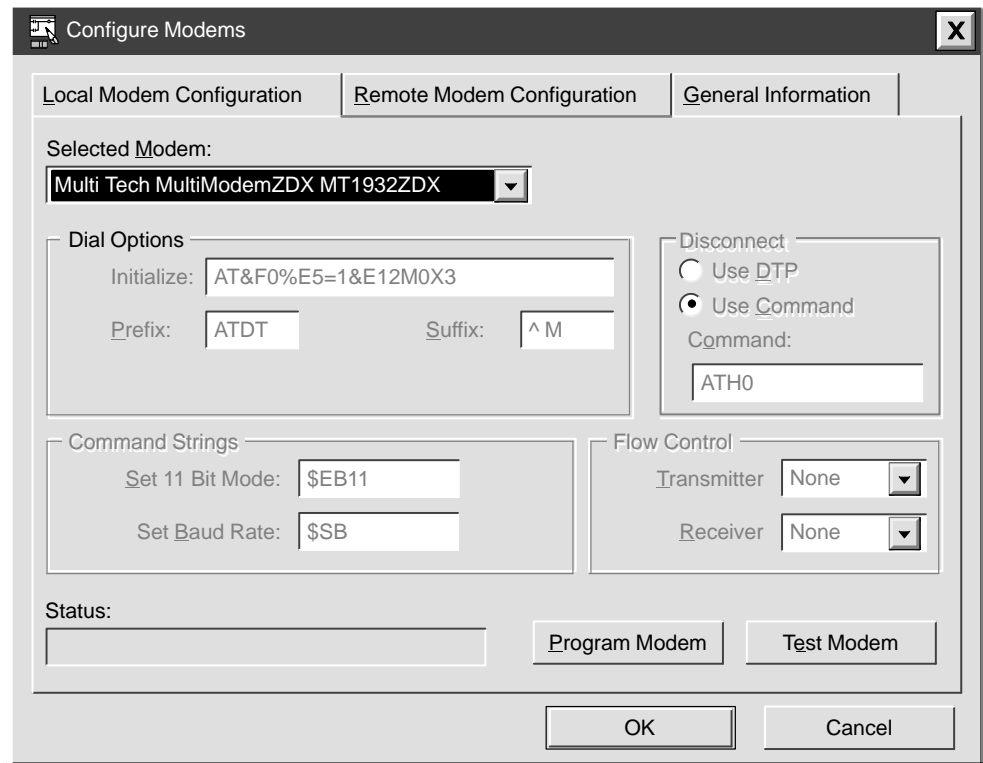


Figure 3-17 Remote Modem Configuration Tab of the Configure Modems Dialog Box

18. Disconnect your remote modem from your local machine (your programming device or PC).
19. Connect the remote modem to your S7-200 programmable controller.
20. Connect your local modem to your programming device or PC.
21. Ensure that your setup matches the one shown in the General Information tab of the Configure Modems dialog box. See also Figure 3-14.
22. When you have finished your setup, click the “OK” button to exit the Communications dialog box.
23. To connect your modem, select the menu command **Setup ► Connect Modem....** The Connect dialog box appears. See Figure 3-18.
24. If you did not already enter a phone number in the Connect Phone Number field of the Local Modem Configuration tab of the Configure Modems dialog box, or if you want to change the phone number that you entered there, enter the number in the Phone Number field.
25. Click the “Connect” button. Your modem setup is complete.



Figure 3-18 Connect Dialog Box

3.4 Configuring the Preferences for STEP 7-Micro/WIN

Before creating a new project, specify the preferences for your programming environment. To select your preferences, follow these steps:

1. Select the menu command **Setup ► Preferences...** as shown in Figure 3-19.
2. Select your programming preferences in the dialog box that appears.
3. Confirm your choices by pressing ENTER or clicking the “OK” button.

Note

To enable a change in the Language field shown below, you must exit STEP 7-Micro/WIN and restart the software.

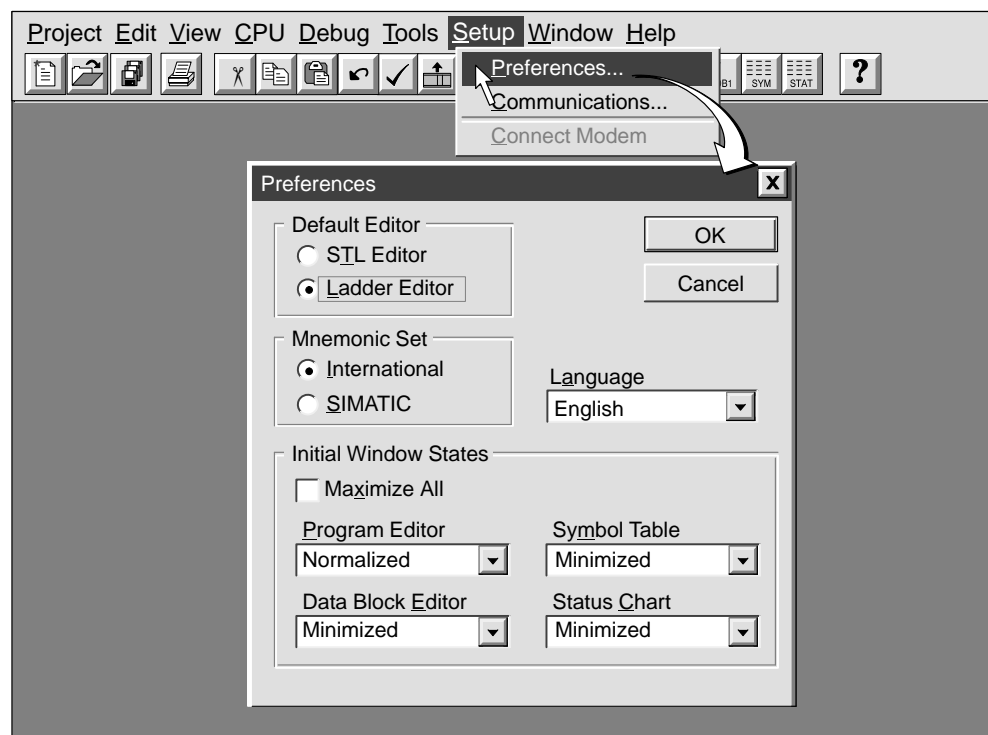


Figure 3-19 Selecting Your Programming Preferences

3.5 Creating and Saving a Project

Before you create a program, you must create or open a project. When you create a new project, STEP 7-Micro/WIN opens the following editors:

- Ladder Editor or Statement List Editor (depending on your selected preference)
- Data Block Editor
- Status Chart
- Symbol Table

Creating a New Project

The Project menu command allows you to create a new project, as shown in Figure 3-20. Select the menu command **Project ► New....** The CPU Type dialog box is displayed. If you select the CPU type from the drop-down list box, the software displays only those options which are available for your CPU; if you select "None," no CPU-specific restrictions are placed on your program. When you download the program, the CPU notifies you if you have used options that are not available. For example, if your program uses an instruction that is not supported by your CPU, the program is rejected.

Note

STEP 7-Micro/WIN does not check the range of parameters. For example, you can enter VB9999 as a parameter to a ladder instruction even though it is an invalid parameter.

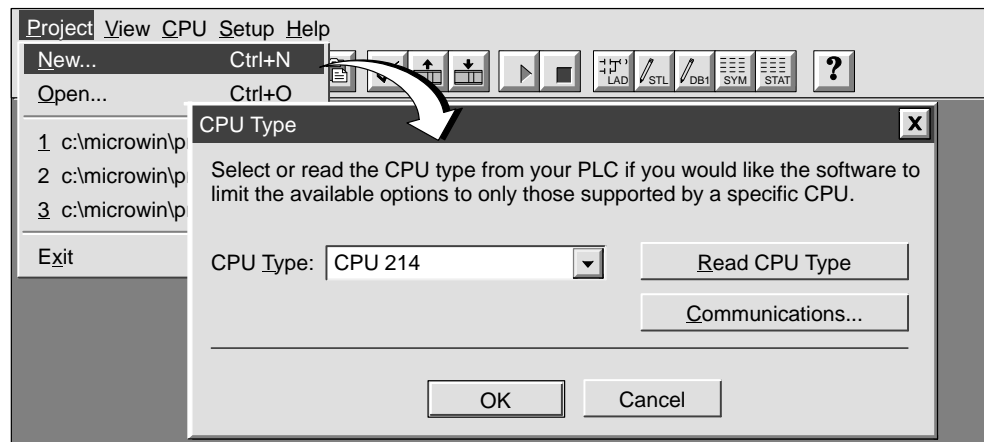



Figure 3-20 Creating a New Project

Saving a Project

You can save all of the components of your project by selecting the menu command **Project ► Save All** or by clicking the Save All button: 

You can save a copy of the active project to a different name or location by selecting the menu command **Project ► Save As....**

3.6 Creating a Program

STEP 7-Micro/WIN allows you to create the user program (OB1) with either the Ladder Editor or the Statement List Editor.

Entering Your Program in Ladder Logic

The Ladder Editor window allows you to write a program using graphical symbols (see Figure 3-21). The toolbar includes some of the more common ladder elements used to enter your program. The first (left) drop-down list box contains instruction categories. You can access these categories by clicking or pressing F2. After a category is selected, the second drop-down list contains the instructions specific to that category. To display a list of all instructions in alphabetical order, press F9 or select the All Instructions category. Or you can select the **View ► Instruction Toolbar** to display the Ladder Instruction Toolbar.

There are two comments associated with each network as described below.

- Single-line network title comments are always visible in the ladder display, and you can access these by clicking anywhere in the network title region.
- Multi-line network comments are accessed by double-clicking on the network number region. Multi-line network comments are only visible through a dialog box, but are printed on all printouts.

To start entering your program, follow these steps:

1. To enter a program title, select the menu command **Edit ► Program Title....** Type in your new program title, then click the "OK" button.
2. To enter ladder elements, select the type of element you want by clicking the corresponding icon button or selecting it from the instruction list.
3. Type the address or parameter in each text field and press ENTER.

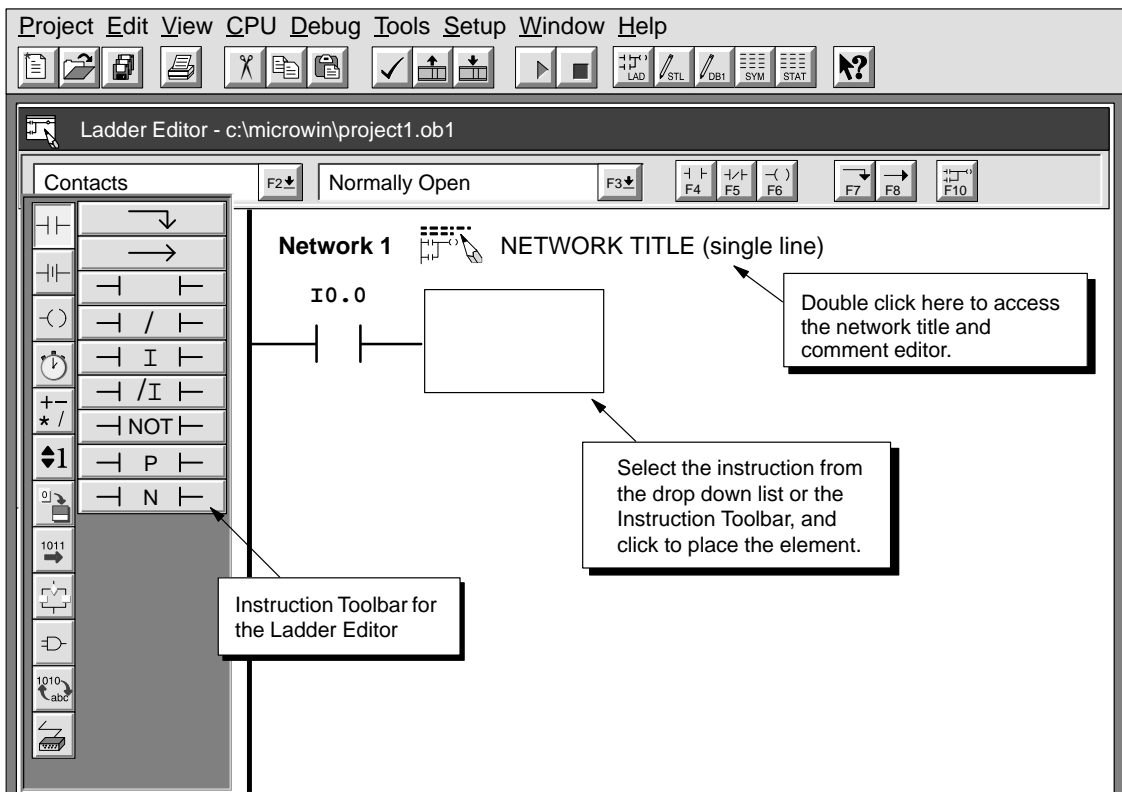


Figure 3-21 Ladder Editor Window

Entering Your Program in Statement List

The Statement List (STL) Editor is a free-form text editor which allows a certain degree of flexibility in the way you choose to enter program instructions. Figure 3-22 shows an example of a statement list program.

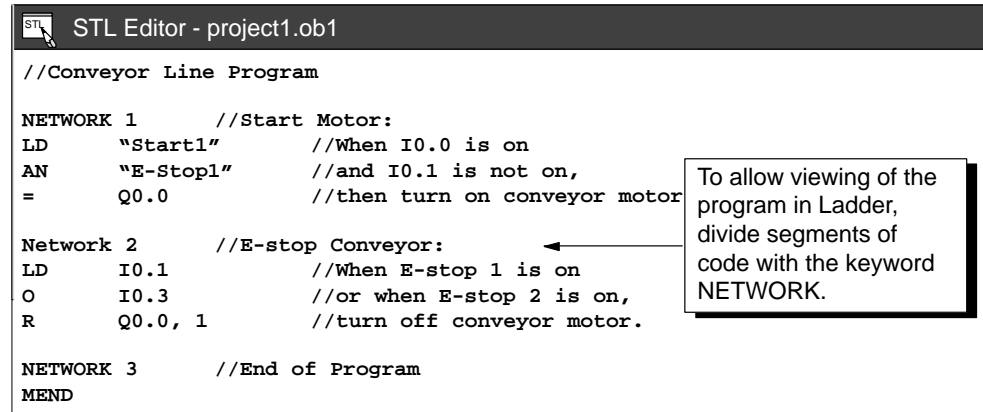



Figure 3-22 STL Editor Window with Sample Program

To enter an STL program, follow these guidelines:

- To be able to view an STL program in ladder, you must divide segments of code into separate networks by entering the keyword NETWORK. (Network numbers are generated automatically after you compile or upload the program.) The Network declarations must come at appropriate boundaries for ladder representation.
- Start each comment with a double slash (//). Each additional comment line must also begin with a double slash.
- End each line with a carriage return.
- Separate each instruction from its address or parameter with a space or tab.
- Do not use a space between the operand type and the address (for example, enter I0.0, not I 0.0).
- Separate each operand within an instruction with a comma, space, or tab.
- Use quotation marks when entering symbol names. For example, if your symbol table contains the symbol name Start1 for the address I0.0, enter the instruction as follows:

```
LD "Start1"
```

Compiling the Program

After completing a network or series of networks, you can check the syntax of your code by selecting the menu command **CPU ► Compile** or by clicking the Compile button. 

Downloading Your Program

After completing your program, you can download the project to the CPU. To download your program, select the menu command **Project ► Download...** or click the Download button in the main window. 

The Download dialog box that appears allows you to specify the project components that you want to download, as shown in Figure 3-23.

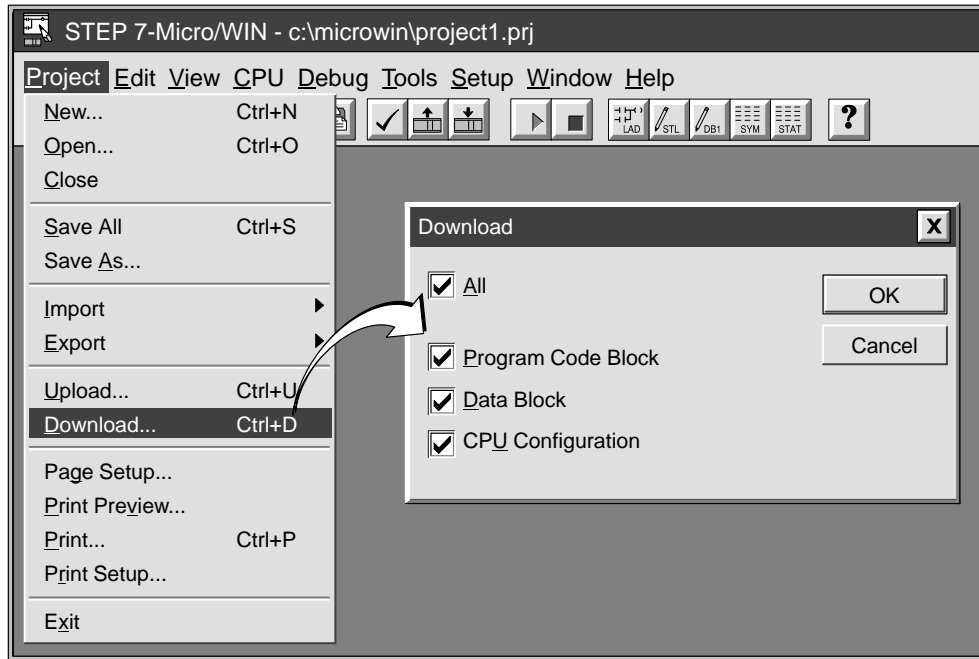


Figure 3-23 Downloading Project Components to the CPU

- Program Code Block (OB1) contains your program logic to be executed by the CPU.
- Data Block (DB1) contains the initialization values to be used by your program.
- CPU Configuration (CFG) contains the system setup information, which includes communication parameters, retentive ranges, input filter selections, password, and output table definitions.

Click the “OK” button or press ENTER to confirm your choices and to execute the download operation.

Viewing a Program in Ladder Logic or Statement List

You can view a program in either ladder or STL by selecting the menu command **View ▶ STL** or **View ▶ Ladder**, as shown in Figure 3-24.

When you change the view from STL to ladder and back again to STL, you may notice changes in the presentation of the STL program, such as:

- Instructions and addresses are changed from lower case to upper case.
- Spaces between instructions and addresses are replaced with tabs.

You can accomplish the same formatting of the STL instructions by selecting the menu command **CPU ▶ Compile** while the STL Editor is active.

Note

Certain combinations of statement list instructions cannot be converted successfully to ladder view. In that case, the message "Illegal Network" marks the section of code that cannot be represented in ladder.

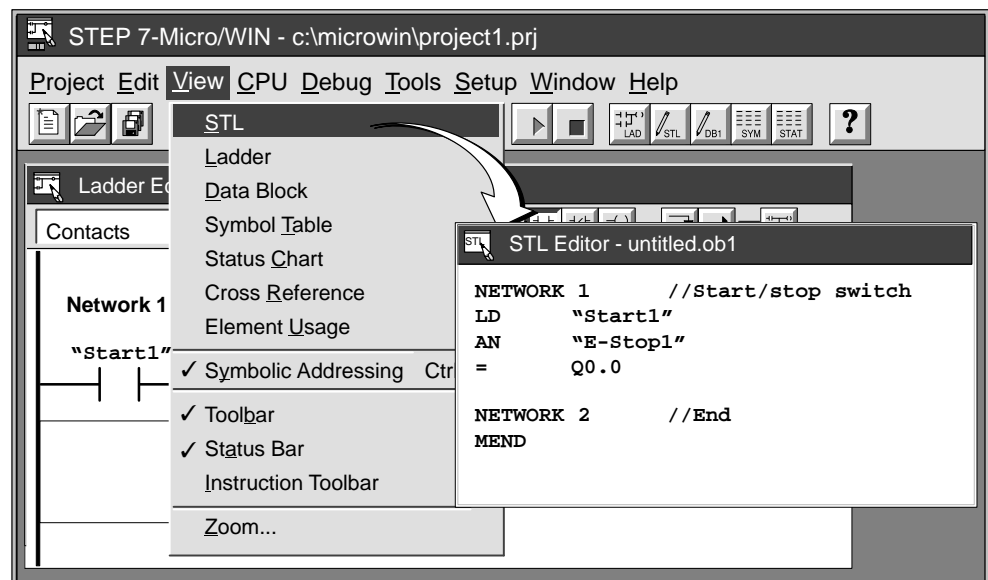


Figure 3-24 Changing the Program View from Ladder to Statement List

3.7 Creating a Data Block

You can use the Data Block Editor to pre-define or initialize variables to be used in your program. Usage of the data block is optional.

The Data Block Editor appears by default as a minimized window icon at the bottom of the main window (if selected in **Setup ► Preferences...**). To access the data block, double-click the icon, or click the Restore or Maximize button on the icon (in Windows 95).

Entering Data Block Values

The Data Block Editor is a free-form text editor that allows a certain degree of flexibility in the format that you choose to enter the data values.

Use the following guidelines when creating a data block:

- Use the first column of each line to specify the data size and starting address of each value to be stored in V memory.
- Separate the starting address from the data value(s) by a space or tab as shown below.

Figure 3-25 shows a sample data block with comments that describe each data element.

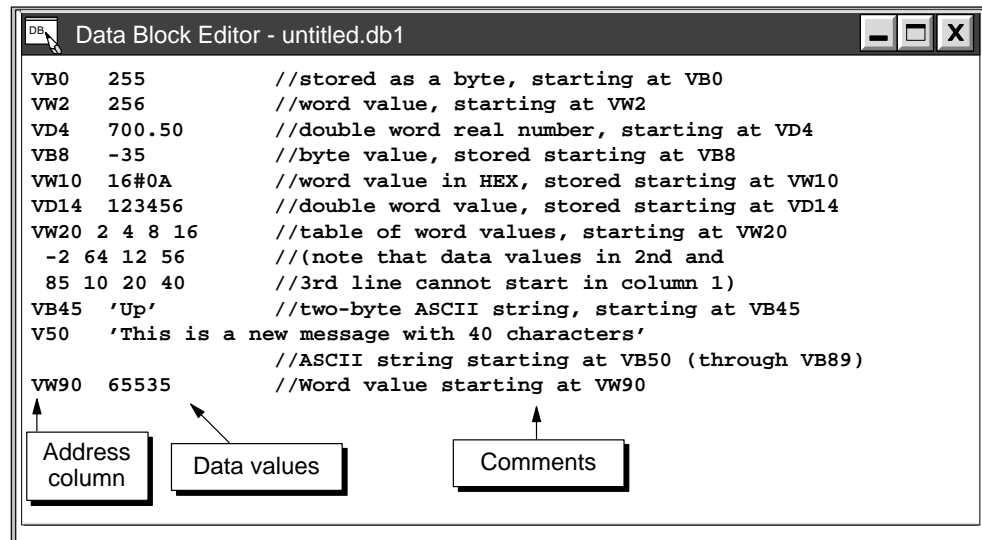


Figure 3-25 Example of a Data Block



Warning

STEP 7-Micro/WIN uses column 1 of every line in the Data Block Editor to determine the starting address for the values to be stored in the data block. If you enter a number in column 1, that number is interpreted as the starting address in V memory for any data that follow. If you intended the number in column 1 to be a data value and not an address, this could inadvertently cause data entered in the data block to be overwritten by the new data.

Referencing incorrect data could lead to unpredictable activity within the process when you download the data block to a CPU. Unpredictable operations could cause death or serious personal injury and/or damage to equipment.

To help ensure that data are stored in the correct locations in V memory, always specify a size and address, such as VB100. Also, always proofread carefully to ensure that no data value was inadvertently entered in column 1.

Table 3-4 gives examples of the notation to be used when entering values for a data block.

Table 3-4 Notation for Entering Values in a Data Block

Data Type	Example
Hexadecimal	16#AB
Integer (decimal)	10 <i>or</i> 20
Signed integer (decimal)	-10 <i>or</i> +50
Real (floating point): use a period (“.”) and not a comma (“,”)	10.57
Text (ASCII): string text, contained within apostrophes (Note: “\$” is a special character for designating that the following character is an apostrophe or a dollar sign within a string.)	'Siemens' 'That\$'s it' 'Only \$\$25'

Table 3-5 shows the valid designators for entering the data size and starting address.

Table 3-5 Valid Size Designators

Size of Data	Example	Description
Byte	VB10	Stores the values that follow as bytes of data, starting at the address specified.
Word	VW22	Stores the values that follow as words of data, starting at the address specified.
Double Word	VD100	Stores the values that follow as double words of data, starting at the address specified.
Auto-size	V10	Stores the data in the minimum size (byte, word, or double word) required for storing the values. The values entered on that line are stored starting at the specified V address.
Keep the previous size	(Address column is empty)	Stores data in byte, word, or double word, depending on the size specified in the preceding line.





3.8 Using the Status Chart

You can use the Status Chart to read, write, or force variables in your program.

The Status Chart editor appears by default as a minimized window icon at the bottom of the main window (if selected in **Setup ► Preferences...**). To access the Status Chart, double-click the icon, or click the Restore or Maximize button on the icon (in Windows 95).

Reading and Writing Variables with the Status Chart

Figure 3-26 shows an example of a Status Chart. To read or write variables using the Status Chart, follow these steps:

1. In the first cell in the Address column, enter the address or the symbol name of an element from your program that you want to read or write, and press ENTER. Repeat this step for all of the additional elements that you want in the chart.
2. If the element is a bit (I, Q, or M, for example), the format is set as bit in the Format column. If the element is a byte, word, or double word, select the cell in the Format column and double-click or press the SPACEBAR to cycle through the valid formats.
3. To view the current PLC value of the elements in your chart, click the Single Read button  or the Continuous Read button  on the Status Chart.
4. To stop the updating of status, click the Continuous Read button. 
5. To change a value, enter the new value in the "Change Value" column and click the Write button  to write the value to the CPU.

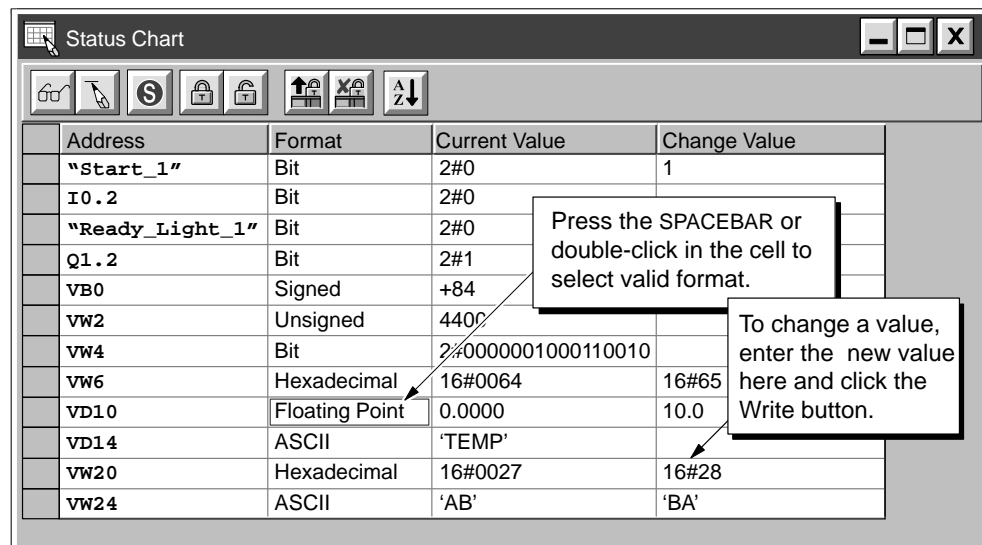







Figure 3-26 Example of a Status Chart

Forcing Variables Using the Status Chart

To force a variable in the Status Chart to a specific value, follow these steps:

1. For a cell in the Address column, enter the address or symbol name of the variable that you want to force.
2. If the element is a bit (I0.0, Q0.1), the format is always bit and cannot be changed. If the element is a byte, word, or double word, select the format that you wish to use by double-clicking or pressing the SPACEBAR to cycle through the valid formats.
3. To force the variable to its current value, first read the current values in the PLC by selecting the menu command **Debug ► Single Read** or clicking the Single Read button .

Click or scroll to the cell that contains the current value you wish to force. Press the Force button  while positioned on a current value to force the variable to that value.

4. To force a new value for a variable, enter the desired value in the "Change Value" column and press the Force button. 
5. To view all currently forced variables, click the Read Force button. 
6. To unforce all currently forced variables in the CPU, click the Unforce All button. 

Editing Addresses

To edit an address cell, use the arrow keys or mouse to select the cell you want to edit.

- If you begin typing, the field clears and the new characters are entered.
- If you double-click the mouse or press F2, the field becomes highlighted and you can use the arrow keys to move the editing cursor to the place that you want to edit.

3.9 Using Symbolic Addressing

The Symbol Table allows you to give symbolic names to inputs, outputs, and internal memory locations. See Figure 3-27. You can use the symbols that you have assigned to these addresses in the Ladder Editor, STL Editor, and Status Chart of STEP 7-Micro/WIN. The Data Block Editor does not support the use of symbolic names.

Guidelines for Entering Symbolic Addresses

The first column of the Symbol Table is used to select a row. The other columns are for the symbol name, address, and comment. For each row, you assign a symbolic name to the absolute address of a discrete input, output, memory location, special memory bit, or other element. A comment for each assigned symbol is optional. Follow these guidelines when creating a Symbol Table:

- You can enter symbol names and absolute addresses in any order.
- You can use up to 23 characters in the Symbol Name field.
- You can define up to 1,000 symbols.
- The Symbol Table is case-sensitive: for example, "Pump1" is considered a different symbol from "pump1".
- All leading and trailing spaces are removed from the symbol name by the Symbol Table Editor. All adjacent internal spaces are converted to a single underscore. For example, "Motor starter 2" changes to "Motor_starter_2".
- If you have duplicate symbol names and/or addresses, they are marked with blue italics by the Symbol Table Editor. These duplicate names are not compiled, and they are not recognized outside the symbol table. Overlapping addresses are not flagged as duplicates; for example, VBO and VW0 overlap in memory but are not flagged as duplicates.

Starting the Symbol Table Editor

The Symbol Table Editor appears by default as a minimized window icon at the bottom of the main window. To access the Symbol Table, double-click the icon, or click the Restore or Maximize button on the icon (in Windows 95).

Symbol Name	Address	Comment
Start1	I0.0	assembly line 1
E-Stop1	I0.1	for assembly line 1
ReadyLight1	Q1.0	ready light (green)
MotorStarter1	Q1.1	Assembly Line 1 motor
Mixer1_Timer	T0	
Mixer2_Timer	T37	
Line1_Counter	C1	
<i>Relay_1</i>	M0.0	
<i>Relay_1</i>	M0.1	

Figure 3-27 Example of a Symbol Table

Editing Functions within the Symbol Table

The Symbol Table provides the following editing functions:

- **Edit ► Cut / Copy / Paste** within a cell or from one cell to another.
- **Edit ► Cut / Copy / Paste** one or several adjacent rows.
- **Edit ► Insert Row** above the row containing the cursor. You can also use the INSERT or INS key for this function.
- **Edit ► Delete Row** for one or several highlighted adjacent rows. You can also use the DELETE or DEL key for this function.
- To edit any cell containing data, use the arrow keys or mouse to select the cell that you want to edit. If you begin typing, the field clears and the new characters are entered. If you double-click the mouse or press F2, the field becomes highlighted, and you can use the arrow keys to move the editing cursor to the place you want to edit.

Sorting Table Entries

After entering symbol names and their associated absolute addresses, you can sort the Symbol Table alphabetically by symbol names or numerically by addresses in the following ways:

- Select the menu command **View ► Sort Symbol Name** to sort the symbol names in alphabetical order.
- Select the menu command **View ► Sort Symbol Address** to sort the absolute addresses by memory types.

4

Getting Started with a Sample Program

The examples and descriptions in this manual support Version 2.1 of STEP 7-Micro/WIN programming software. Previous versions of the programming software may operate differently.

This chapter describes how to use the STEP 7-Micro/WIN software to perform the following tasks:

- Entering a sample program for a mixing tank with two supply pumps
- Creating a Symbol Table, Status Chart, and Data Block
- Monitoring the sample program

STEP 7-Micro/WIN provides extensive online help. Use the **Help** menu command or press F1 to obtain the most current information.

Chapter Overview

Section	Description	Page
4.1	Creating a Program for a Sample Application	4-2
4.2	Task: Create a Project	4-6
4.3	Task: Create a Symbol Table	4-8
4.4	Task: Enter the Program in Ladder Logic	4-10
4.5	Task: Create a Status Chart	4-14
4.6	Task: Download and Monitor the Sample Program	4-15

4.1 Creating a Program for a Sample Application

System Requirements for the Sample Program

After you create and download the sample program provided in this chapter, you can run this program on an S7-200 CPU. Figure 4-1 shows the components that are required to run and monitor the sample program:

- PC/PPI programming cable, or MPI card installed in your computer and RS-485 cable to connect to the S7-200 CPU
- S7-200 CPU
- Input simulator
- Power cord and power supply
- STEP 7-Micro/WIN 32 Version 2.1 for the 32-bit Windows 95 and Windows NT, or STEP 7-Micro/WIN 16 Version 2.1 for the 16-bit Windows 3.1x

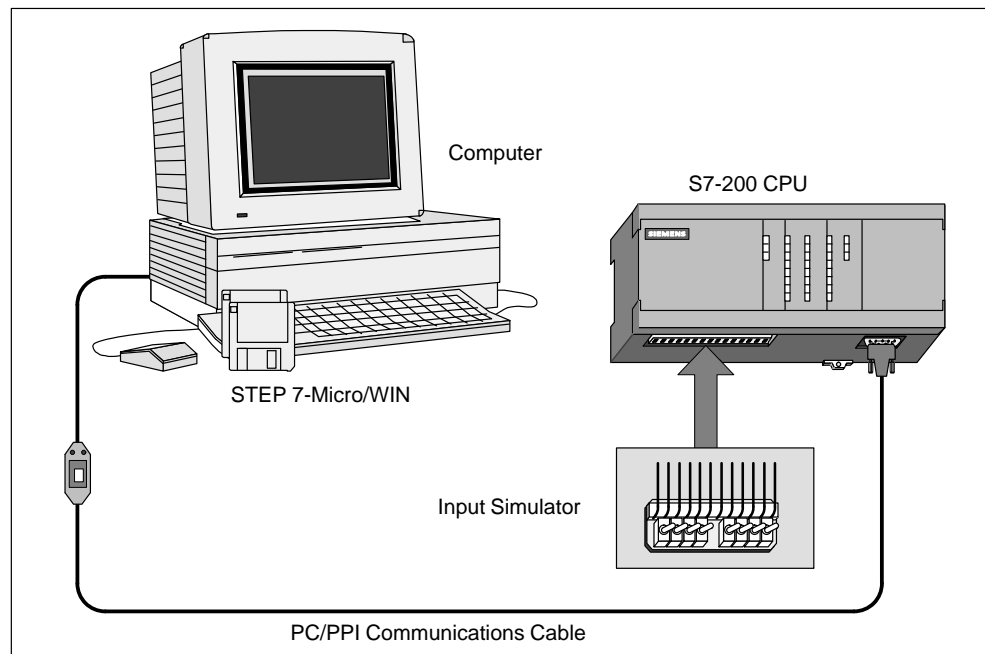


Figure 4-1 Requirements to Run the Sample Program

Tasks for a Sample Mixing Tank Application

Figure 4-2 shows the diagram for a mixing tank. This mixing tank can be used for different applications, such as for making different colors of paint. In this application, two pipelines enter the top of the tank; these supply two different ingredients. A single pipeline at the bottom of the tank transports the finished mixture. The sample program controls the filling operation, monitors the tank level, and controls a mixing and heating cycle. The following tasks describe the process:

- Step 1: Fill the tank with Ingredient 1.
- Step 2: Fill the tank with Ingredient 2.
- Step 3: Monitor the tank level for closure of the high-level switch.
- Step 4: Maintain the pump status if the start switch opens.
- Step 5: Start the mix-and-heat cycle.
- Step 6: Turn on the mixer motor and steam valve.
- Step 7: Drain the mixing tank.
- Step 8: Count each cycle.

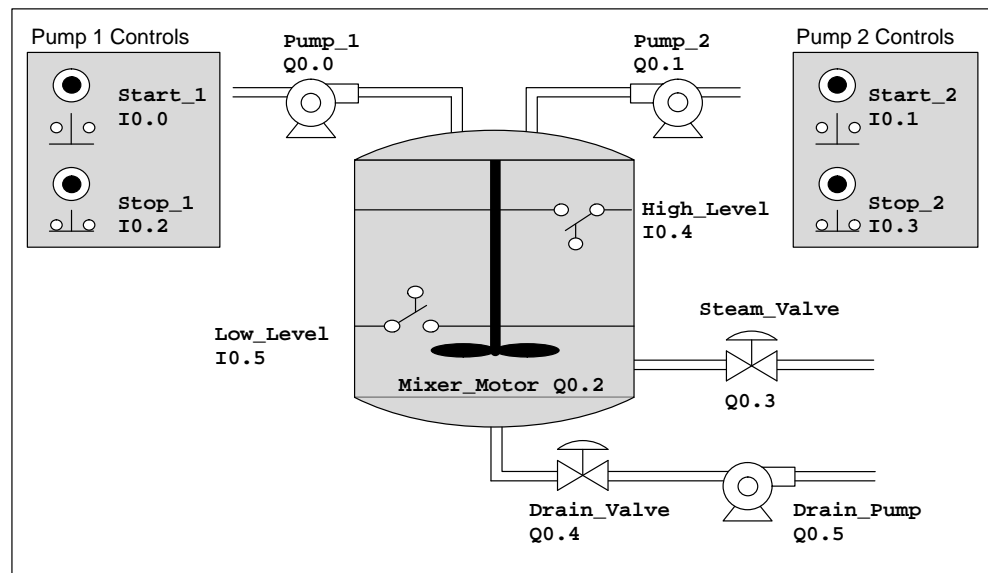


Figure 4-2 Program Example: Mixing Tank

Sample Program in Statement List (STL) and Ladder Logic

You can enter the sample program in either statement list (STL) or ladder representation. Table 4-1 provides the STL version of the sample program, and Figure 4-3 shows the same sample program in ladder. Sections 4.2 to 4.4 guide you through the tasks required to enter this program in ladder.

Table 4-1 Sample Program in Statement List

STL	Description
NETWORK 1	//Fill the tank with Ingredient 1.
LD "Start_1"	
O "Pump_1"	
A "Stop_1"	
AN "High_Level"	
= "Pump_1"	
NETWORK 2	//Fill the tank with Ingredient 2.
LD "Start_2"	
O "Pump_2"	
A "Stop_2"	
AN "High_Level"	
= "Pump_2"	
NETWORK 3	//Set memory bit if high level is reached.
LD "High_Level"	
S "Hi_Lev_Reached", 1	
NETWORK 4	//Start timer if high level is reached.
LD "Hi_Lev_Reached"	
TON "Mix_Timer", +100	
NETWORK 5	//Turn on the mixer motor.
LDN "Mix_Timer"	
A "Hi_Lev_Reached"	
= "Mixer_Motor"	
= "Steam_Valve"	
NETWORK 6	//Drain the mixing tank.
LD "Mix_Timer"	
AN "Low_Level"	
= "Drain_Valve"	
= "Drain_Pump"	
NETWORK 7	//Count each cycle.
LD "Low_Level"	
A "Mix_Timer"	
LD "Reset"	
CTU "Cycle_Counter", +12	
NETWORK 8	//Reset memory bit if low level or time-out.
LD "Low_Level"	
A "Mix_Timer"	
R "Hi_Lev_Reached", 1	
NETWORK 9	//End the main program.
MEND	

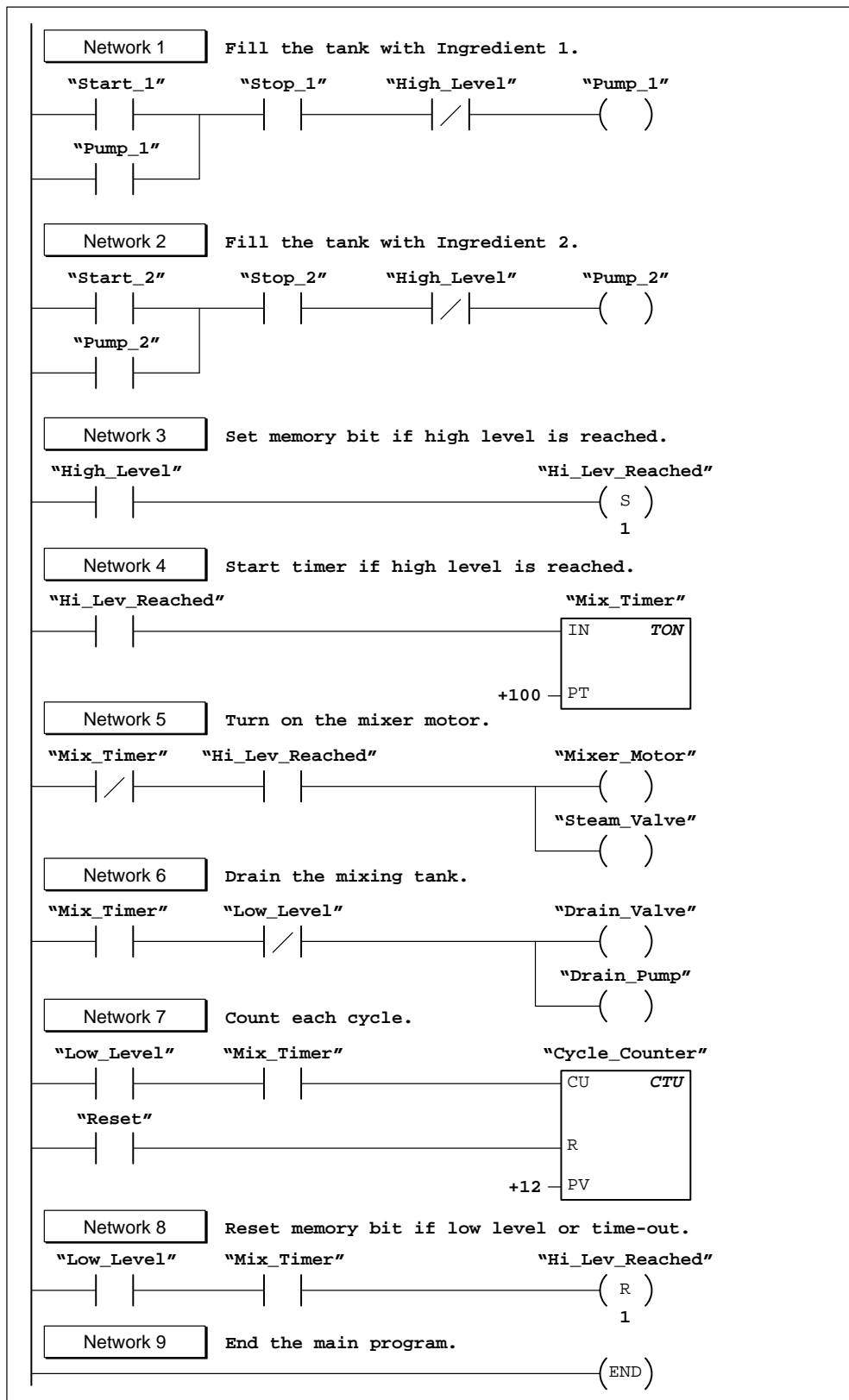


Figure 4-3 Sample Program in Ladder Logic

4.2 Task: Create a Project

Creating a New Project

When you create or open a project, STEP 7-Micro/WIN starts the Ladder or STL Editor (OB1), and depending on your selected preference, the Data Block Editor (DB1), the Status Chart, and the Symbol Table.

To create a new project, select the menu command **Project ► New...**, as shown in Figure 4-4, or click the New Project toolbar button. 

The CPU Type dialog box is displayed. Select your CPU type from the drop-down list box.

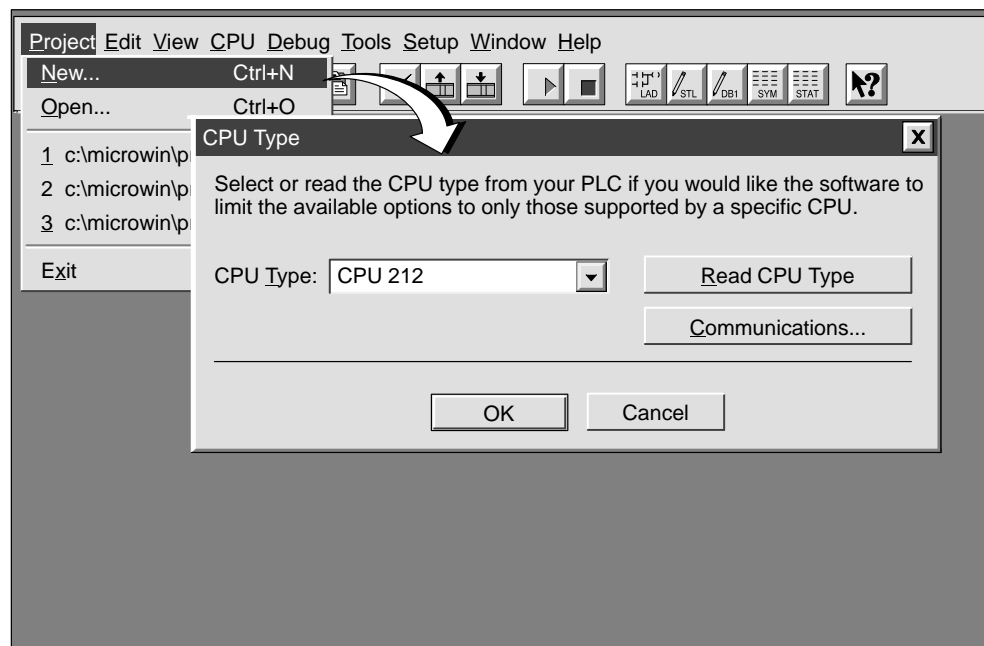


Figure 4-4 Creating a New Project and Selecting the CPU Type

Naming the Sample Project

You can name your project at any time; for this example, refer to Figure 4-5 and follow these steps to name the project:

1. Select the menu command **Project ► Save As...**
2. In the File Name field, type the following: `project1.prj`
3. Click the “Save” button.

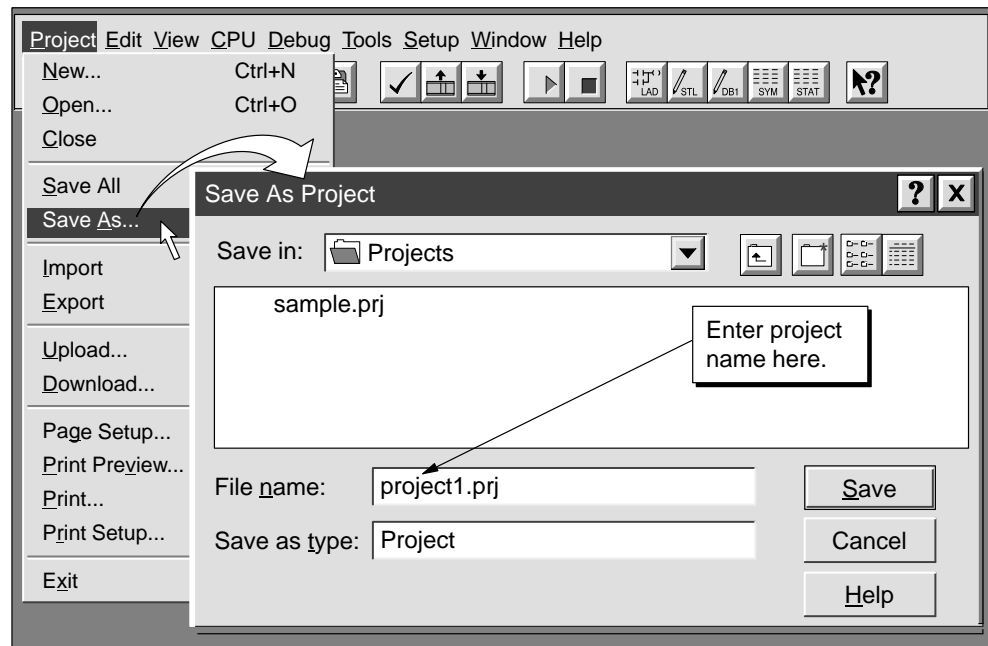


Figure 4-5 Naming the Sample Project

4.3 Task: Create a Symbol Table

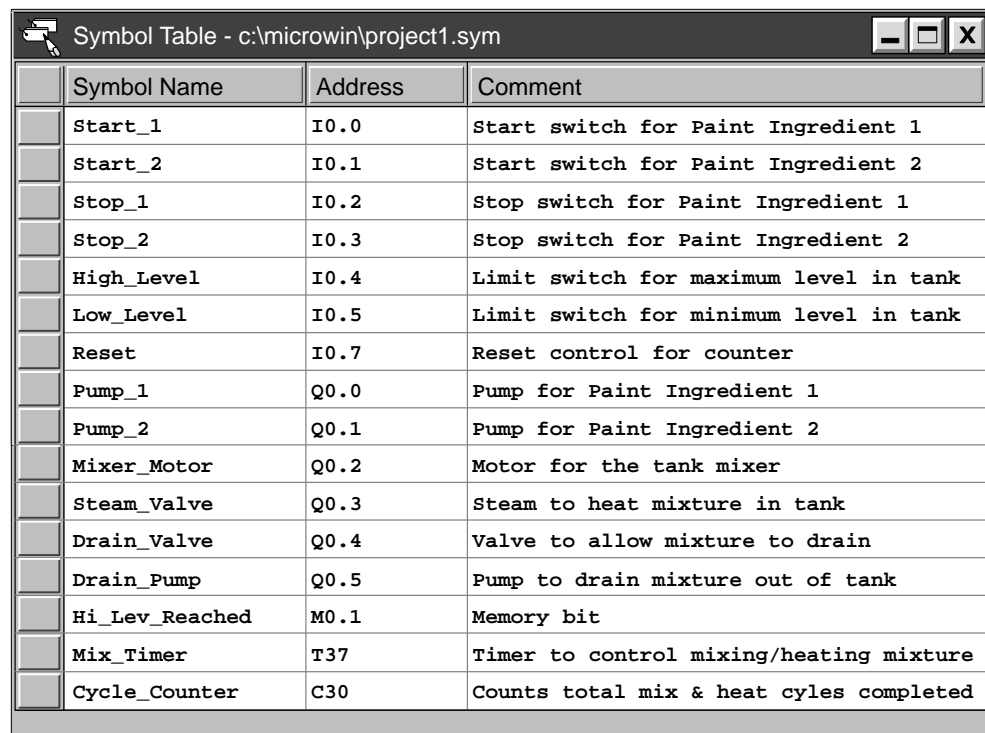
Opening the Symbol Table Editor

To define the set of symbol names used to represent absolute addresses in the sample program, open the Symbol Table editor. Double-click the icon, or click the Restore or Maximize button on the icon (in Windows 95). You can also select the menu command **View ► Symbol Table**.

Entering the Symbol Names

Figure 4-6 shows the list of symbol names and the corresponding addresses for the sample program. To enter the symbol names, follow these steps:

1. Select the first cell in the Symbol Name column, and type the following: `start_1`
2. Press ENTER to move the focus to the first cell in the Address column. Type the address `I0.0` and press ENTER. The focus moves to the cell in the Comment column. (Comments are optional, but they are a useful way to document the elements in your program.)
3. Press ENTER to start the next symbol row, and repeat these steps for each of the remaining symbol names and addresses.
4. Use the menu command **Project ► Save All** to save your Symbol Table.



Symbol Name	Address	Comment
Start_1	I0.0	Start switch for Paint Ingredient 1
Start_2	I0.1	Start switch for Paint Ingredient 2
Stop_1	I0.2	Stop switch for Paint Ingredient 1
Stop_2	I0.3	Stop switch for Paint Ingredient 2
High_Level	I0.4	Limit switch for maximum level in tank
Low_Level	I0.5	Limit switch for minimum level in tank
Reset	I0.7	Reset control for counter
Pump_1	Q0.0	Pump for Paint Ingredient 1
Pump_2	Q0.1	Pump for Paint Ingredient 2
Mixer_Motor	Q0.2	Motor for the tank mixer
Steam_Valve	Q0.3	Steam to heat mixture in tank
Drain_Valve	Q0.4	Valve to allow mixture to drain
Drain_Pump	Q0.5	Pump to drain mixture out of tank
Hi_Lev_Reached	M0.1	Memory bit
Mix_Timer	T37	Timer to control mixing/heating mixture
Cycle_Counter	C30	Counts total mix & heat cycles completed

Figure 4-6 Symbol Table for the Sample Program

Programming with Symbolic Addresses

Before you start entering your program, make sure the ladder view is set for symbolic addressing. Use the menu command **View ► Symbolic Addressing** and look for a check mark next to the menu item, which indicates that symbolic addressing is enabled.

Note

Symbol names are case-sensitive. The name you enter must match exactly the uppercase and lowercase characters entered in the symbol table. If there is any mismatch, the cursor stays on the element and the message "Invalid parameter" appears in the status bar at the bottom of the main window.

4.4 Task: Enter the Program in Ladder Logic

Opening the Ladder Editor

To access the Ladder Editor, double-click the icon at the bottom of the main window. Figure 4-7 shows some of the basic tools in the Ladder Editor.

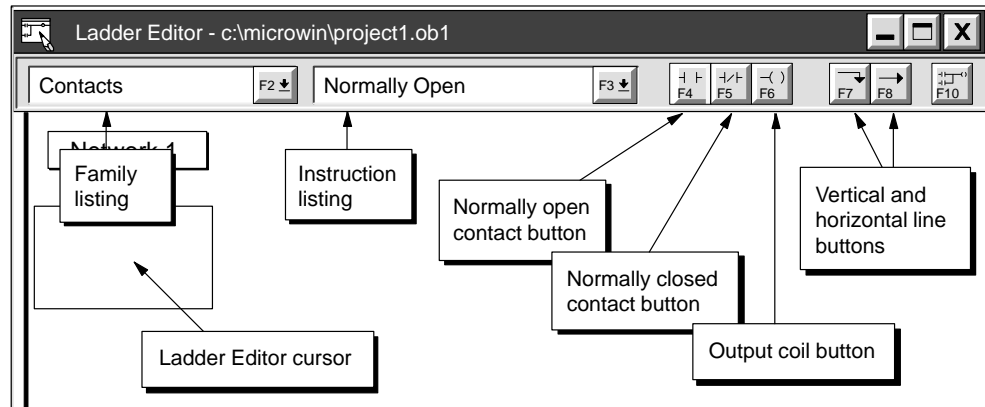


Figure 4-7 Some of the Basic Ladder Editor Tools

Instruction Toolbar in the Ladder Editor

You can also select **View ► Instruction Toolbar** to display the Ladder Instruction Toolbar. See Figure 4-8.

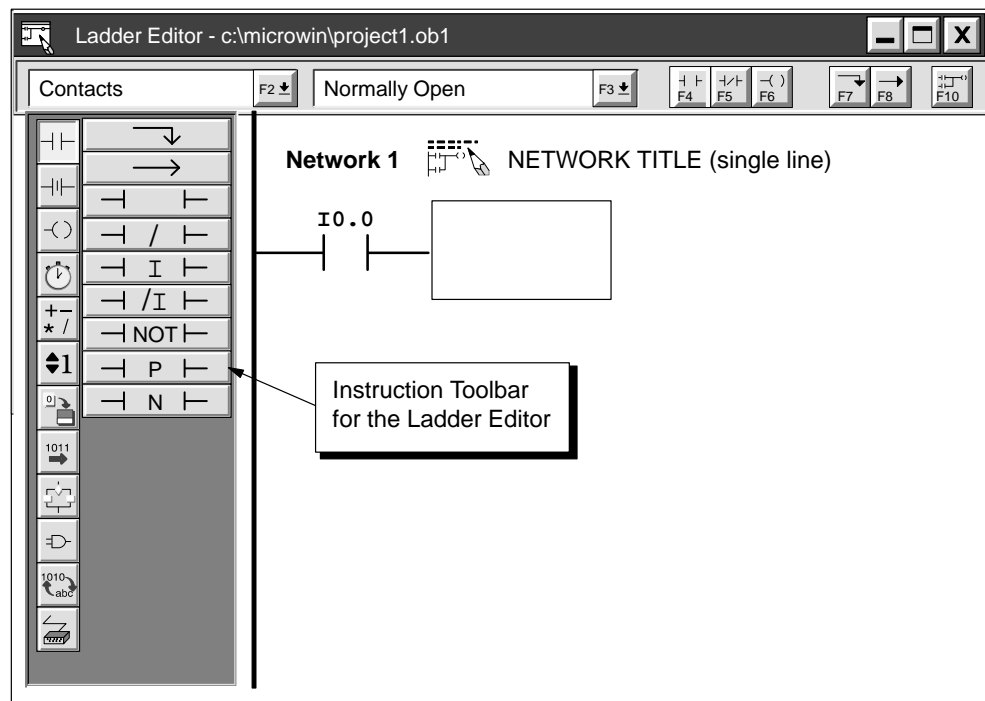


Figure 4-8 Some of the Basic Ladder Editor Tools

Entering the First Network Element

Follow these steps to enter the first network of the sample program:

1. Double click on or near the numbered network label to access the Title field in the Comment Editor. Type the comment shown in Figure 4-9, and click "OK."
2. Press the down arrow key. The ladder cursor moves down to the first column position on the left.
3. Select the normally open by selecting "Contacts" from the family listing and then selecting "Normally Open" from the instruction listing.
4. Press ENTER, and a normally open contact appears with the name "Start_1" highlighted above it.

(Every time you enter a contact, the software displays the default address of I0.0, which in this example is defined as Start_1 in the Symbol Table.)

5. "Start_1" is the first element required for Network 1. Press ENTER to confirm the first element and its symbol name. The ladder cursor moves to the second column position.

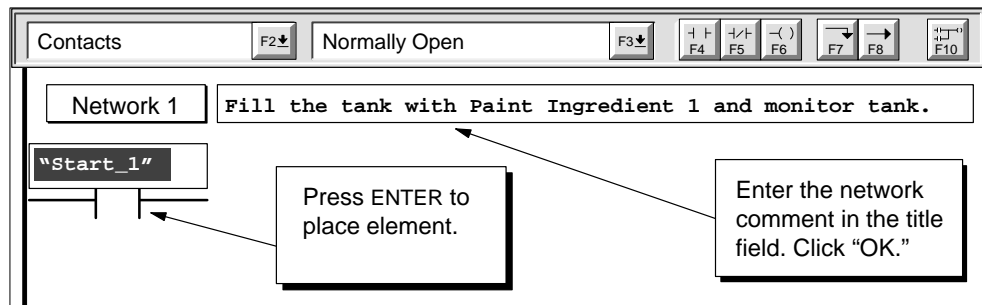


Figure 4-9 Entering the Network Comment and the First Ladder Element

Follow these steps to enter the remaining contacts of the first network:

1. Press ENTER to enter the second element. A normally open contact appears with the default symbol name "Start_1" highlighted above it.
2. Type `stop_1` and press ENTER. The cursor moves to the next column.
3. Click the normally closed contact button ("F5"). A closed contact appears with the default symbol name "Start_1" highlighted above it.
4. Type `High_Level` and press ENTER.

The ladder network should look like the one shown in Figure 4-10.

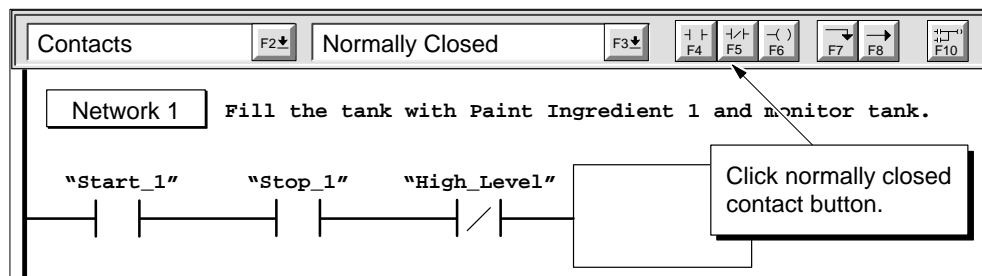


Figure 4-10 Entering the Next Ladder Element

The ladder cursor is now positioned to the right of the normally closed "High_Level" input. Refer to Figure 4-11 and follow these steps to complete the first network:

1. Click the coil button ("F6") and move the mouse cursor inside the ladder cursor and click. A coil appears with the name "Pump_1" highlighted above it. (Each coil that you enter is given the default address of Q0.0, which in this case has been defined as Pump_1 in the symbol table.)
2. Press ENTER to confirm the coil and its symbol name.
3. Use the mouse or press the left arrow key to move the cursor back to the first element of the current network.
4. Click the vertical line button ("F7") to draw a vertical line between the first and second contacts.
5. Click the normally open contact button ("F4") on the toolbar, and press ENTER. A contact with the name "Start_1" appears.
6. Type **Pump_1** and press ENTER.

The first network is now complete.

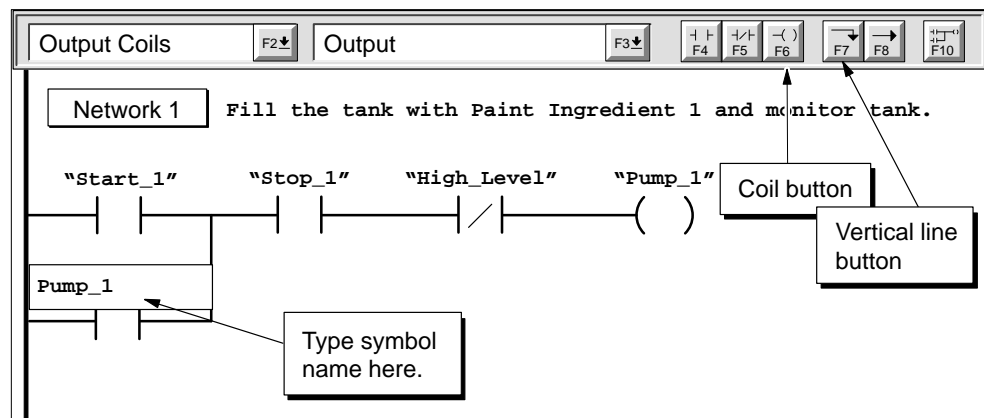


Figure 4-11 Completing the First Network

Entering the Second Network

Follow these steps to enter the second network of the sample program:

1. Use the mouse or press the down arrow key to move the cursor to Network 2.
2. In the network comment field, type the comment shown in Figure 4-12. (Since the comment for Network 2 is nearly identical to the one for Network 1, you can also select and copy the text from Network 1 and paste it into the comment field for Network 2, then change the paint ingredient number to 2.)
3. Repeat the steps you used to enter the elements of Network 1, using the symbol names shown in Figure 4-12.
4. After you finish Network 2, move the cursor down to Network 3.

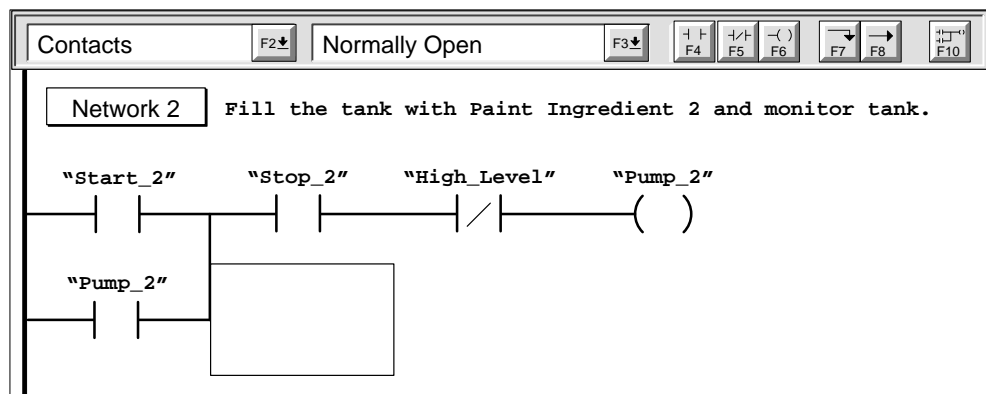



Figure 4-12 Entering the Second Network

Entering the Remaining Networks


From this point on, you can follow the same general procedures that you have used up to now to enter the remaining networks. Refer to Figure 4-3 for the remaining networks.

Compiling the Program

After completing the sample program, check the syntax by selecting the menu command **CPU ► Compile** or by clicking the Compile button. 

If you have entered all the networks correctly as shown in the sample program, you get a "Compile Successful" message that also includes information on the number of networks and the amount of memory used by the program. Otherwise, the Compile message indicates which networks contain errors.

Saving the Sample Program

You can save your project by selecting the menu command **Project ► Save All** or by clicking the Save All button.  This action saves all the components of your sample project.

4.5 Task: Create a Status Chart

Building Your Status Chart


To monitor the status of selected elements in the sample program, you create a Status Chart that contains the elements that you want to monitor while running the program. To access the Status Chart editor, double-click the icon at the bottom of the main window. Then enter the elements for the sample program by following these steps:

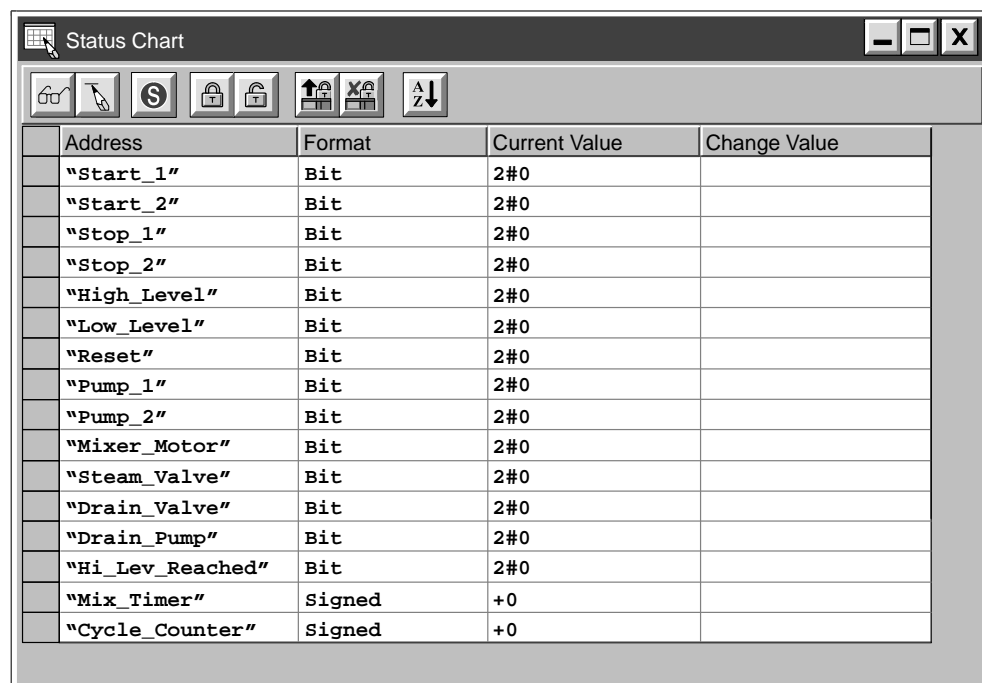
1. Select the first cell in the Address column, and type the following: `start_1`
2. Press ENTER to confirm your entry. This element type can only be displayed in bit format (either 1 or 0), so you cannot change the format type.
3. Select the next row, and repeat these steps for each of the remaining elements, as shown in Figure 4-13.

When an Address cell is in focus and the row below is empty, pressing ENTER automatically increments the address for each additional row. Refer to the online Help for more information about using the Status Chart.

You can use the menu command **Edit ► Insert Row** (or the INSERT or INS key) to insert a blank row above the row containing the cursor.

4. The timer T37 and the counter C30 can each be displayed in other formats. With the focus in the Format column cell, press the SPACEBAR to cycle through the formats that are valid for these element types. For this example, select Signed for the timer and counter.

Save your Status Chart by selecting the menu command **Project ► Save All** or by clicking the Save All button. 



Address	Format	Current Value	Change Value
"start_1"	Bit	2#0	
"start_2"	Bit	2#0	
"stop_1"	Bit	2#0	
"stop_2"	Bit	2#0	
"High_Level"	Bit	2#0	
"Low_Level"	Bit	2#0	
"Reset"	Bit	2#0	
"Pump_1"	Bit	2#0	
"Pump_2"	Bit	2#0	
"Mixer_Motor"	Bit	2#0	
"Steam_Valve"	Bit	2#0	
"Drain_Valve"	Bit	2#0	
"Drain_Pump"	Bit	2#0	
"Hi_Lev_Reached"	Bit	2#0	
"Mix_Timer"	Signed	+0	
"Cycle_Counter"	Signed	+0	



Figure 4-13 Status Chart for the Sample Program

4.6 Task: Download and Monitor the Sample Program

Next you must download your program to the CPU and place the CPU in RUN mode. You can then use the Debug features to monitor or debug the operation of your program.

Downloading the Project to the CPU

Before you can download the program to the CPU, the CPU must be in STOP mode. Follow these steps to select STOP mode and to download the program:

1. Set the CPU mode switch (which is located under the access cover of the CPU module) to TERM or STOP.
2. Select the menu command **CPU ► Stop** or click the Stop button  in the main window.
3. Answer "Yes" to confirm the action.
4. Select the menu command **Project ► Download...** or click the Download button in the main window: .
5. The Download dialog box allows you to specify the project components you want to download. Press ENTER or click "OK."

An information message tells you whether or not the download operation was successful.


Note

STEP 7-Micro/WIN does not verify that your program uses memory or I/O addresses that are valid for the specific CPU. If you attempt to download a program that uses addresses beyond the range of the CPU or program instructions that are not supported by the CPU, the CPU rejects the attempt to download the program and displays an error message.

You must ensure that all memory locations, I/O addresses, and instructions used by your program are valid for the CPU you are using.

Changing the CPU to RUN Mode

If the download was successful, you can now place the CPU in RUN mode.

1. Select the menu command **CPU ► Run** or click the Run button  in the main window.
2. Answer "Yes" to confirm the action.

Monitoring Ladder Status

Ladder status shows the current state of events in your program. Reopen the Ladder Editor window, if necessary, and select the menu command **Debug ► Ladder Status On**.

If you have an input simulator connected to the input terminals on your CPU, you can turn on switches to see power flow and logic execution. For example, if you turn on switches **I0.0** and **I0.2**, and the switch for **I0.4** ("High_Level") is off, the power flow for Network 1 is complete. The network looks like the one shown in Figure 4-14.

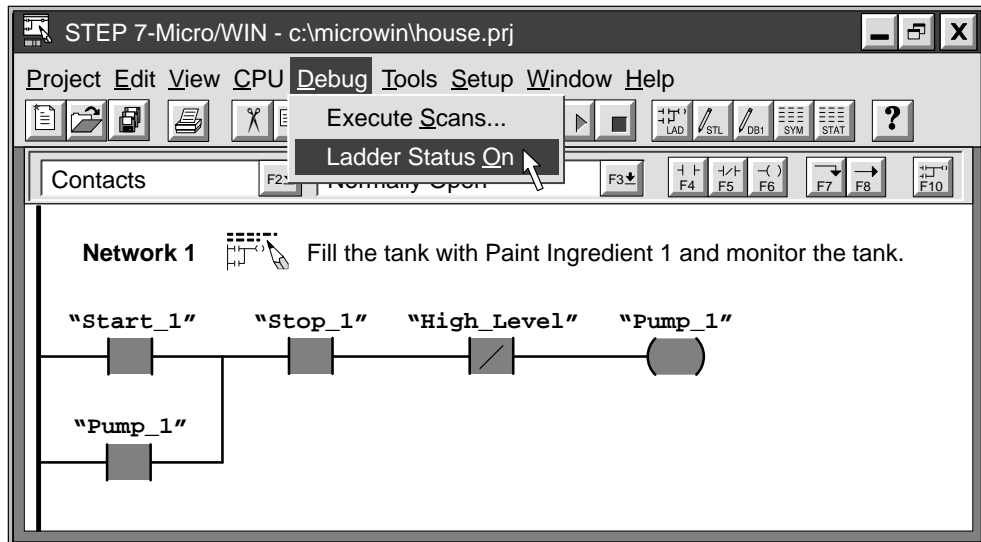


Figure 4-14 Monitoring Status of the First Network

If your STEP 7-Micro/WIN program does not match the CPU program, you are notified by the warning screen shown in Figure 4-15. You are then asked to either compare the program to the CPU, continue this operation, or cancel the operation.

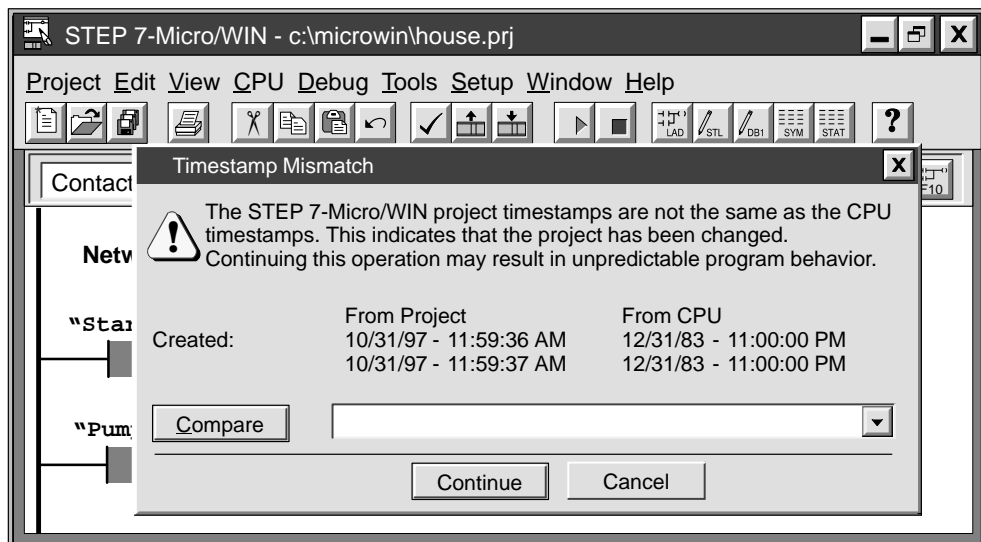





Figure 4-15 Timestamp Mismatch Warning Screen

Viewing the Current Status of Program Elements

You can use the Status Chart to monitor or modify the current values of any I/O points or memory locations. Reopen the Chart window, if necessary, and select the menu command **Debug ► Chart Status On**, as shown in Figure 4-16. As you switch inputs on or off with the CPU in RUN mode, the Status Chart shows the current status of each element.

- To view the current PLC value of the elements in your program, click the Single Read button  or the Continuous Read button  in the Status Chart window.
- To stop the reading of status, click the Continuous Read button  in the Status Chart window.

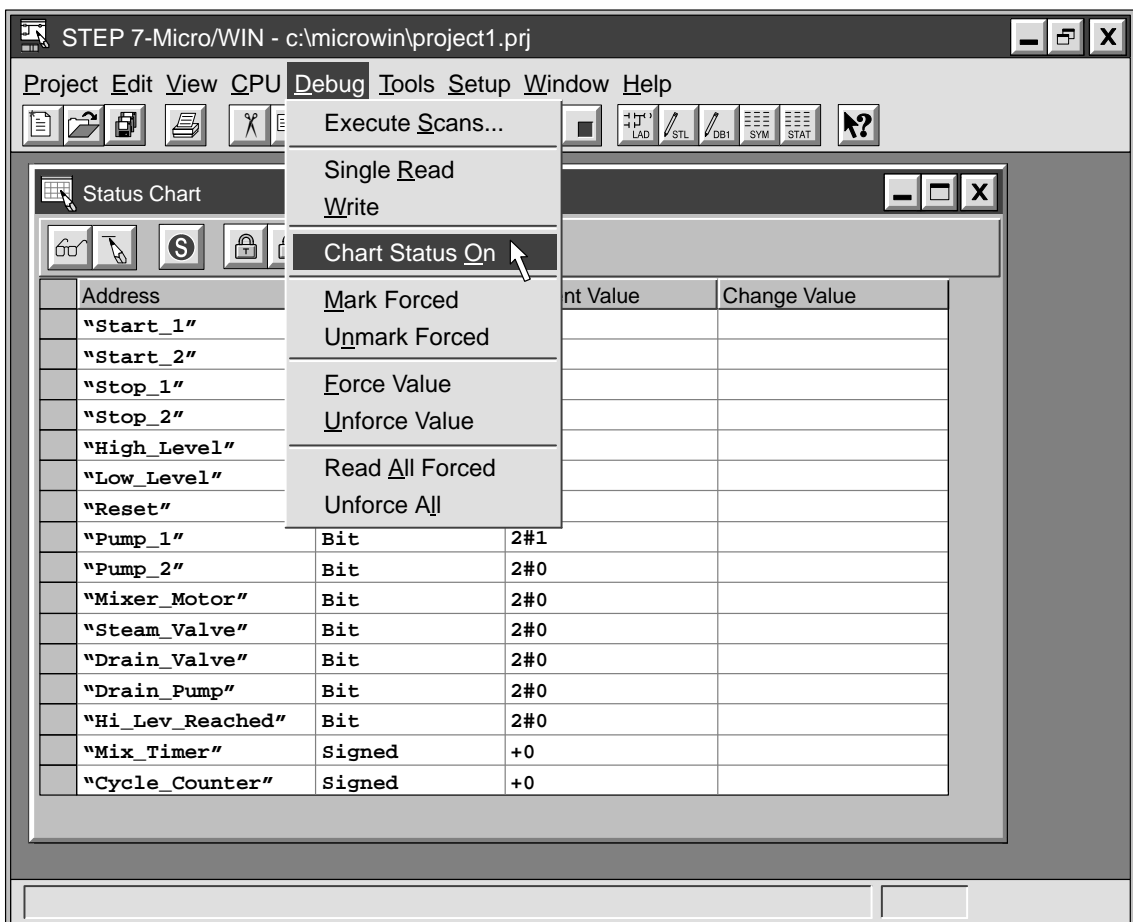


Figure 4-16 Monitoring the Status Chart of the Sample Program

Additional Features of STEP 7-Micro/WIN

5

This chapter describes how to use the TD 200 Wizard to configure the TD 200 Operator Interface. It also tells how to use the S7-200 Instruction Wizard to configure complex operations, and describes other new features of version 2.1 of STEP 7-Micro/WIN.

Chapter Overview

Section	Description	Page
5.1	Using the TD 200 Wizard to Configure the TD 200 Operator Interface	5-2
5.2	Using the S7-200 Instruction Wizard	5-12
5.3	Using the Analog Input Filtering Instruction Wizard	5-14
5.4	Using Cross Reference	5-17
5.5	Using Element Usage	5-18
5.6	Using Find/Replace	5-19
5.7	Documenting Your Program	5-21
5.8	Printing Your Program	5-23

5.1 Using the TD 200 Wizard to Configure the TD 200 Operator Interface

The TD 200 Operator Interface is a text display device that displays messages enabled by the S7-200 CPU. See Figure 5-1. You do not have to configure or program the TD 200. The only operating parameters stored in the TD 200 are the addresses of the TD 200, the address of the CPU, the baud rate, and the location of the parameter block. The configuration of the TD 200 is stored in a TD 200 parameter block located in the V memory (data memory) of the CPU. The operating parameters of the TD 200, such as language, update rate, messages, and message-enabled bits, are stored in a program in the CPU.

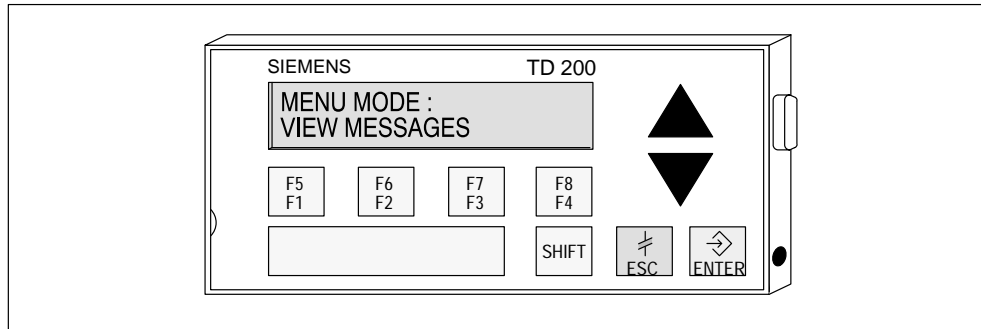


Figure 5-1 SIMATIC TD 200 Operator Interface

Defining the TD 200 Parameter Block

The parameter block consists of 10 or 12 bytes of memory which define the modes of operation and point to the location in CPU memory where the actual messages are stored, as shown in Figure 5-2. When you power up the TD 200, it looks for a parameter block identifier in the CPU at the offset configured in the TD 200, either the ASCII characters "TD" or an offset to the parameter block location, and it reads the data contained in the block.

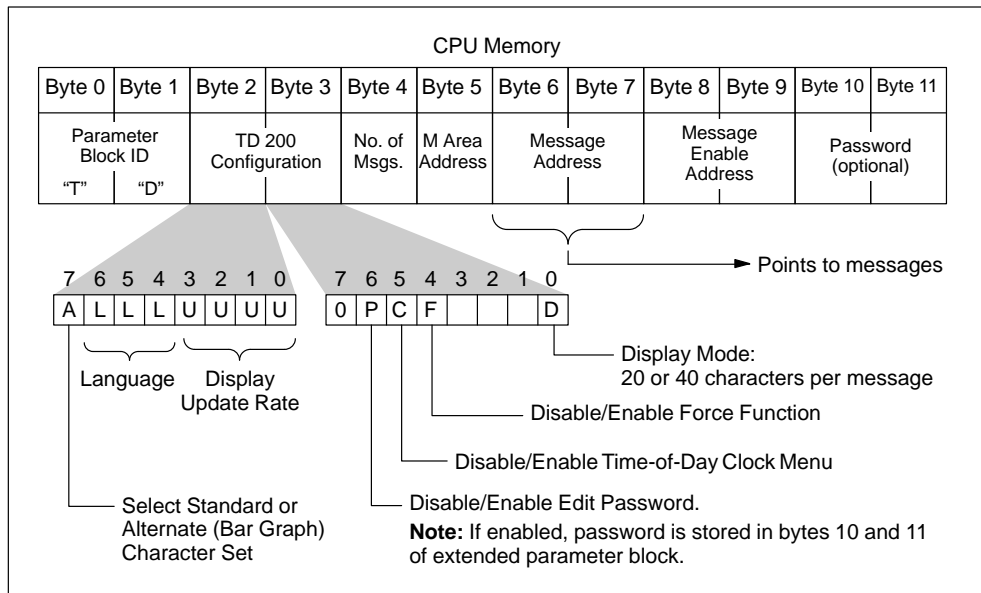


Figure 5-2 TD 200 Parameter Block

Using the TD 200 Wizard Configuration Tool

STEP 7-Micro/WIN provides a “wizard” that makes it easy to configure the parameter block and the messages in the data memory area of the S7-200 CPU. The TD 200 Configuration Wizard automatically writes the parameter block and the message text to the Data Block Editor after you finish choosing the options and creating the messages. This data block can then be downloaded to the CPU. For complete information on the TD 200, refer to the *SIMATIC TD 200 Operator Interface User Manual*.

To create the parameter block and messages for the TD 200, follow these steps:

1. Select the menu command **Tools ► TD 200 Wizard...** as shown in Figure 5-3.
2. Click on “Next>” or select an existing parameter block from the drop-down list, and follow the step-by-step instructions to create or edit a TD 200 parameter block in V memory.

At any time in the procedure, you can click on the “<Prev” button to go back to a previous dialog box if you need to change or review any of the parameters you have defined.

3. At the end of the procedure, click on “Finish” to validate and save the parameter block. You can view the configured parameter block by opening the data block editor.

When you download all blocks to the S7-200 CPU, the data block containing the TD 200 parameter block is stored in the CPU memory, where it can be read by the TD 200.

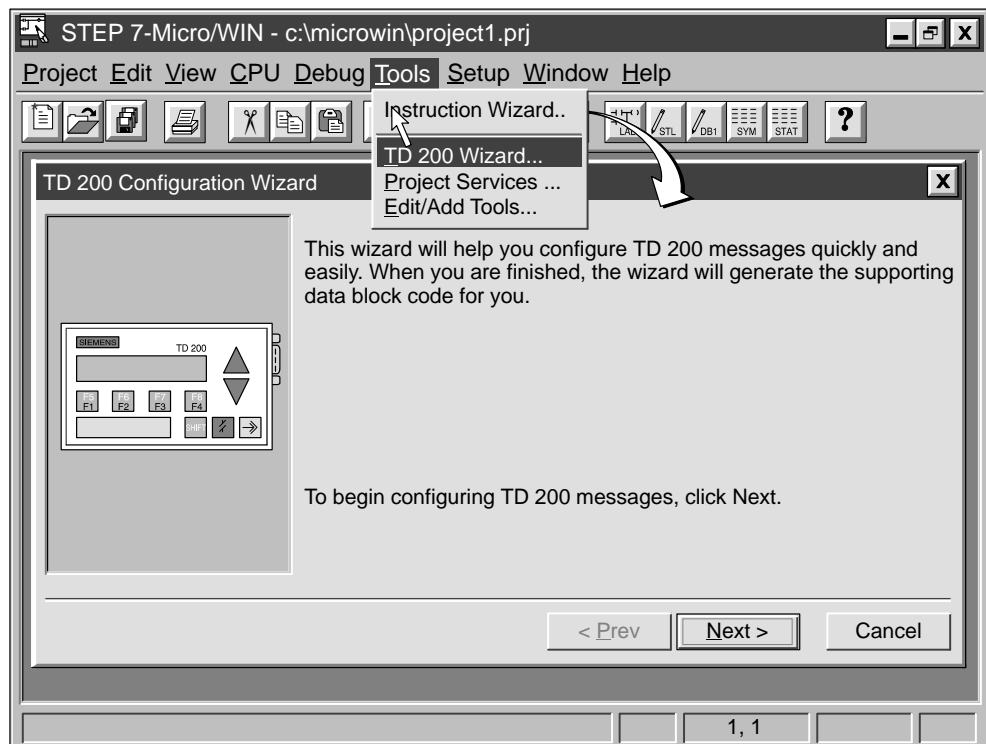


Figure 5-3 Accessing the TD 200 Configuration Wizard

Selecting Language and Bar Graph Character Set

The first dialog box in the TD 200 Wizard allows you to select the menu language and character set. Use the drop-down list box shown in Figure 5-4 to select the language in which the TD 200 menus display. Use the option buttons to select the standard character set or the alternative character set that allows you to display bar graph charts on the TD 200. The TD 200 Wizard sets the corresponding bits in byte 2 of the parameter block.

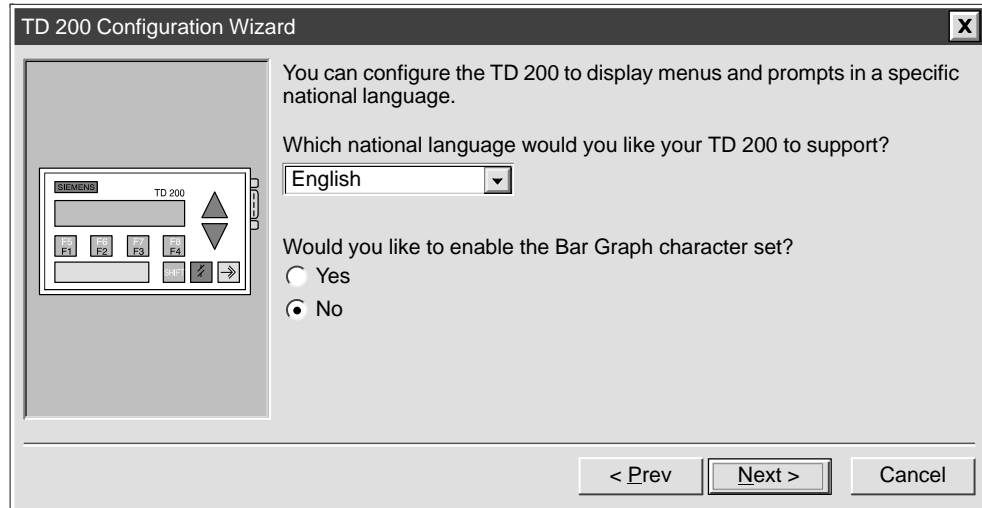


Figure 5-4 TD 200 Language and Character Set

Enabling the Time of Day Menu, Force Function, and Password Protection

Use the option buttons to select the modes shown in Figure 5-5. If you select password protection, a field appears for you to assign a password. Refer to the *SIMATIC TD 200 Operator Interface User Manual* for more information on these options. The TD 200 Wizard sets the corresponding bits in byte 3 of the parameter block.

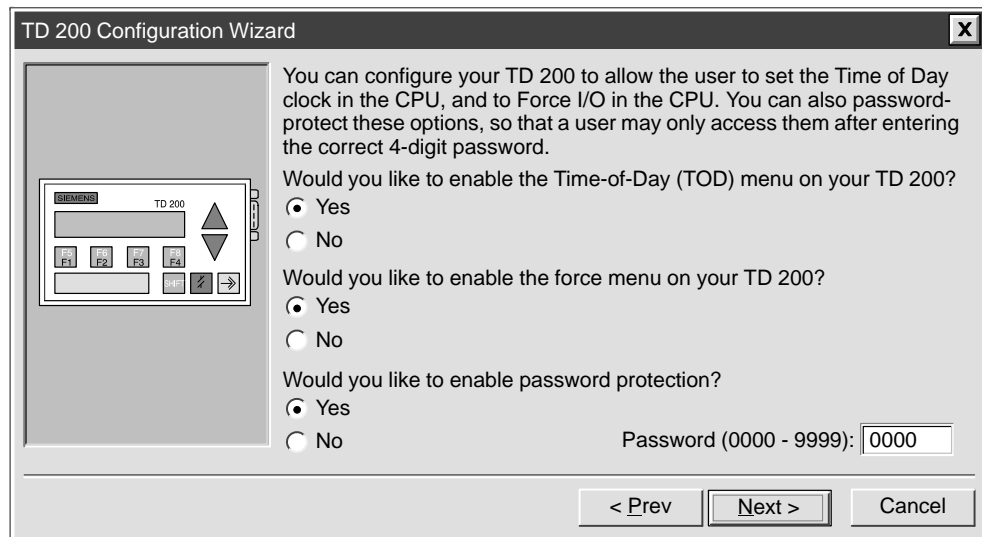


Figure 5-5 TD 200 Time-of-Day Clock, Force I/O, and Password Protection

Specifying Function Key Memory Bits and the Display Update Rate

You must specify a byte address in M memory to reserve eight bits that correspond to the function keys on the TD 200. Valid address values are 0 to 15 in the CPU 212 and 0 to 31 in the CPU 214, CPU 215, and CPU 216. The TD 200 Wizard writes the value to byte 5 of the parameter block. Use the drop-down list box to select the display update rate, as described in Figure 5-6. The TD 200 Wizard sets the corresponding bits in byte 2 of the parameter block.

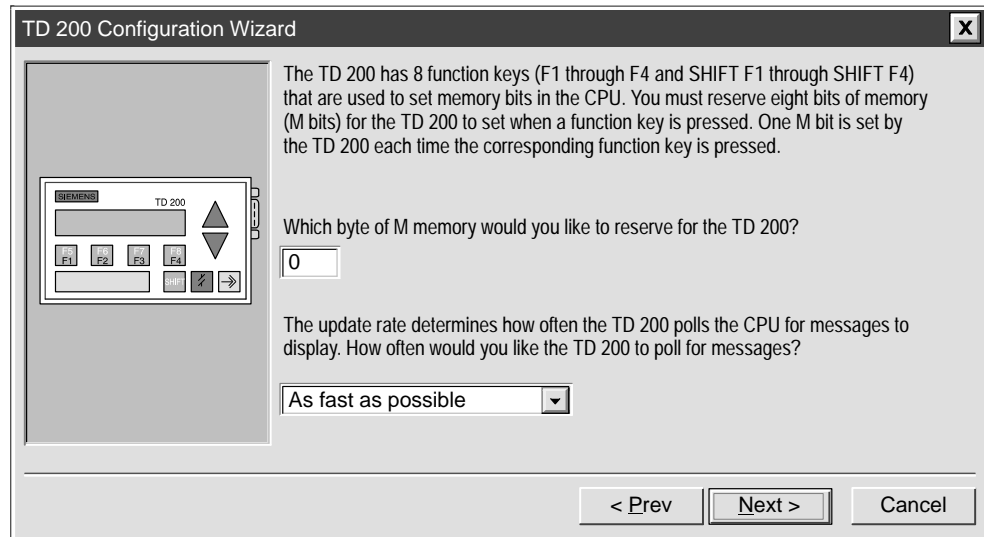


Figure 5-6 TD 200 Function Key Memory Bits and Update Rate



Warning

The TD 200 sets an M bit each time a function key is pressed. If you do not intend to use function keys, and so do not assign an M byte address for function keys, the TD 200 defaults to byte M0 for the function keys. If your program uses bits in M0, and a user presses any function key, the TD 200 sets the corresponding bit in M0, overwriting the value assigned to that bit by your program.

Inadvertent changes to M bits could cause your program to behave unexpectedly. Unpredictable controller operation could cause death or serious injury to personnel, and/or damage to equipment.

Always reserve an M area address, even when your program does not utilize function keys.

Selecting Message Size and Number of Messages

Use the option buttons to select the message size (bit 0 of byte 3 in the parameter block). Enter a number from 1 to 80 in the text field to specify the number of messages you want to create. The corresponding value is written to byte 4 in the parameter block. See Figure 5-7.



Figure 5-7 TD 200 Message Size and Number of Messages

Specifying the Parameter Block Address, Message Enable Flags, and Message Location

In the dialog box shown in Figure 5-8, you specify addresses for the parameter block itself, the message enable flags, and the messages.

- The TD 200 always looks for a parameter block identifier at the offset configured in the CPU. Use the first text field to specify the location of the parameter block if you want it to reside at a different location than the default address. The value (TD) is written to bytes 0 and 1 of the parameter block.
- Then specify an address in V memory for the message-enable bits to reside. This value is written to bytes 8 and 9 of the parameter block.
- Finally, specify an address in V memory where the messages are to start in consecutive bytes. (The value of 32 is only a default.) The address you specify is written to bytes 6 and 7 of the parameter block. The number of bytes required is shown in the dialog according to how many messages you specified in the previous dialog. Remember that each 20-character message uses 20 consecutive bytes of V memory, and each 40-character message uses 40 consecutive bytes.



Figure 5-8 TD 200 Block Address, Enable Flags, and Message Location

Creating TD 200 Messages

The dialog box shown in Figure 5-9 allows you to create each of the 20- or 40-character messages you specified in Figure 5-8. The messages are stored in V memory, beginning at the address that you specified in Figure 5-8, as shown in Figure 5-9.

Type in your message, one character per text box. If you have specified more than one message, click on the “Next Message >” button to enter text for each subsequent message.

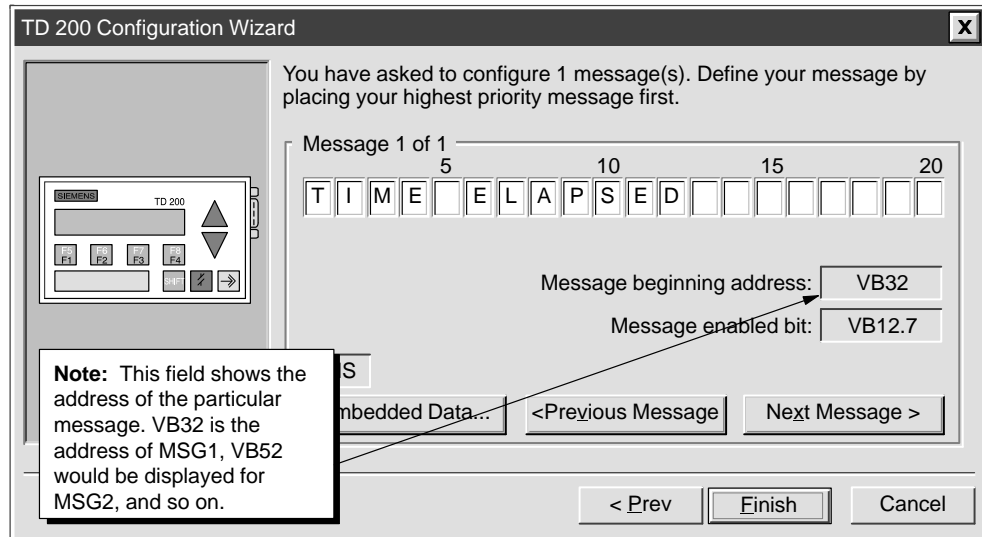


Figure 5-9 TD 200 Message Configuration Dialog

Embedding Data Values in a Text Message

You can place a data value within the message that displays on the TD 200. For example, you can create a message that displays an elapsed time value as it is read by the CPU. In order to display a data value, you must reserve space in the message.

To insert a place holder for a variable data value, place the cursor at the starting digit position and click on the “Embedded Data...” button in the lower part of the dialog box. A dialog box appears in which you define the format of the data value and other options, such as whether or not the message requires acknowledgement, whether the data value can be edited, and whether or not editing requires a password.

Typing International and Special Characters

When you enter certain international and special characters in the TD 200 Configuration Wizard, they may not appear correctly on the TD 200 display. If the characters do not display correctly, use the ALT key and number combinations shown in Table 5-1 to enter the characters in the TD 200 Wizard.

Table 5-1 ALT Key Combinations for International and Special Characters

Character	ALT Key Combination	Character	ALT Key Combination
ü	ALT+0129	ñ	ALT+0164
ä	ALT+0132	Ω	ALT+0234
æ	ALT+0145	Σ	ALT+0228
Æ	ALT+0146	Π	ALT+0227
á	ALT+0134	¥	ALT+0157
ö	ALT+0148	←	ALT+0195 (left arrow ←)
Å	ALT+0143	→	ALT+0180 (right arrow →)
°	ALT+0248		ALT+0200 (single bar)
α	ALT+0224		ALT+0201 (double bar)
β	ALT+0225		ALT+0202 (triple bar)
ε	ALT+0238		ALT+0203 (four bars)
μ	ALT+0230		ALT+0204 (five bars)
σ	ALT+0229	↑	ALT+0194 (up arrow)
ç	ALT+0155		

Formatting the Embedded Data Value

Figure 5-10 shows the dialog box where you define the parameters of the value to be displayed. The format and options you specify are written to a format word (two bytes) that precedes each embedded value. Select the size, display format, number of decimal places, and other options for the embedded data variable.

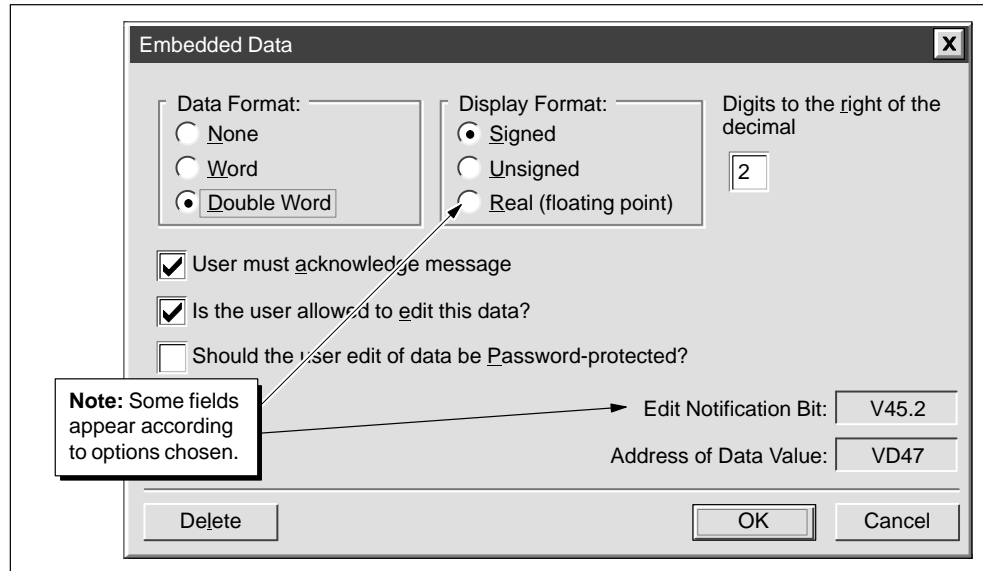


Figure 5-10 TD 200 Message Embedded Data Dialog

Figure 5-11 shows the message dialog box after you have selected the parameters for an embedded data value. The grayed fields are the place holders for the data value. If you specified that a user must acknowledge each message, then the acknowledgement notification bit is displayed in the message dialog.

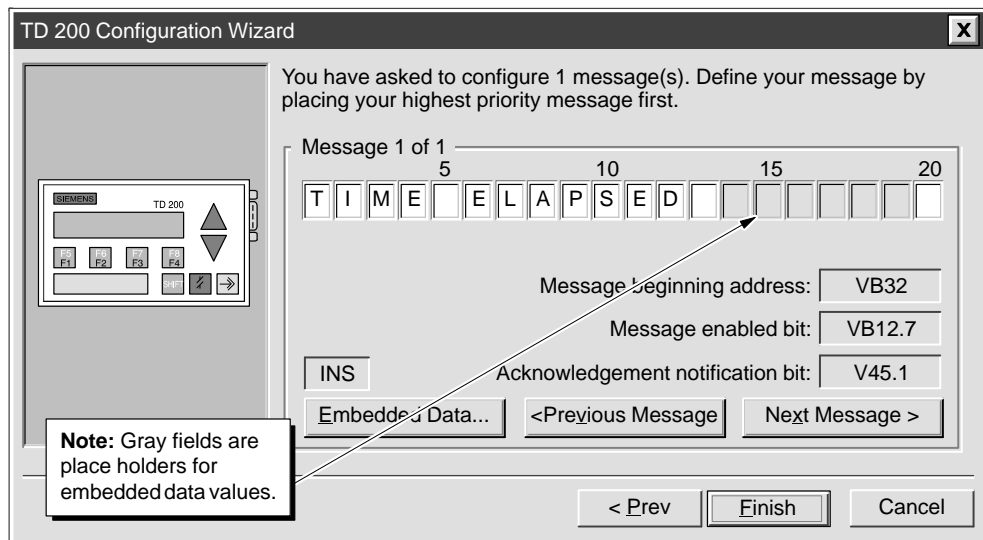
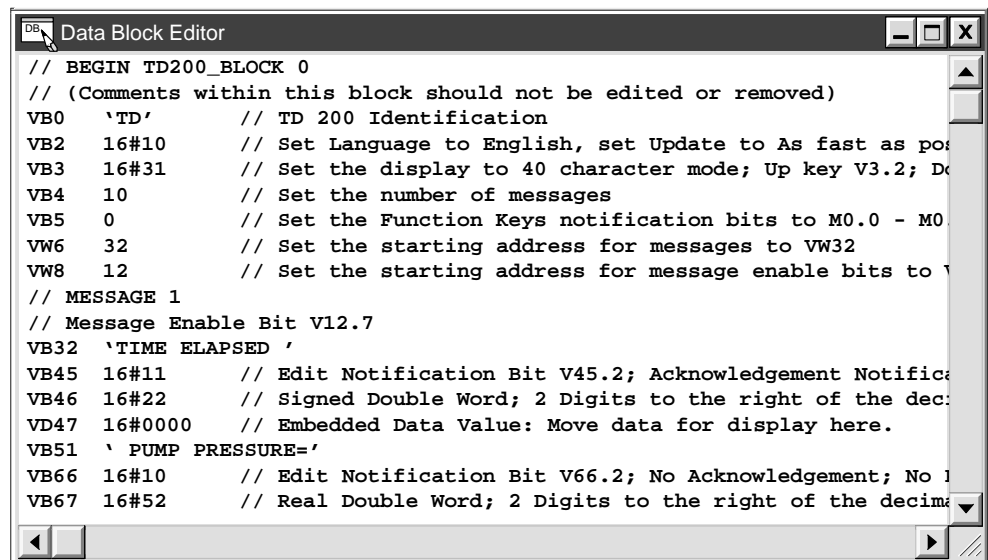


Figure 5-11 TD 200 Embedded Data Value Place Holder in Message

Finishing the TD 200 Parameter Block

Click on the “Next Message >” button to enter text for each subsequent message. After entering all of your TD 200 messages, click on “Finish” to save your configured parameter block and messages to the data block.

You can view the TD 200 parameter block as formatted by the TD 200 Wizard by opening the data block editor. Figure 5-12 shows a sample parameter block for a 40-character message as it appears in the data block editor.



```

// BEGIN TD200_BLOCK 0
// (Comments within this block should not be edited or removed)
VB0  `TD'          // TD 200 Identification
VB2  16#10         // Set Language to English, set Update to As fast as possible
VB3  16#31         // Set the display to 40 character mode; Up key V3.2; Down key V3.3
VB4  10            // Set the number of messages
VB5  0             // Set the Function Keys notification bits to M0.0 - M0.7
VW6  32            // Set the starting address for messages to VW32
VW8  12            // Set the starting address for message enable bits to VW12
// MESSAGE 1
// Message Enable Bit V12.7
VB32 `TIME ELAPSED '
VB45 16#11         // Edit Notification Bit V45.2; Acknowledgement Notification Bit V45.3
VB46 16#22         // Signed Double Word; 2 Digits to the right of the decimal point
VD47 16#0000       // Embedded Data Value: Move data for display here.
VB51 ` PUMP PRESSURE='
VB66 16#10         // Edit Notification Bit V66.2; No Acknowledgement; No Notification Bit V66.3
VB67 16#52         // Real Double Word; 2 Digits to the right of the decimal point

```

Figure 5-12 Data Block Editor Showing a Sample TD 200 Parameter Block

5.2 Using the S7-200 Instruction Wizard

STEP 7-Micro/WIN provides the S7-200 Instruction Wizard, which lets you configure the following complex operations quickly and easily.

- Configure the operation of a PID instruction
- Configure the operation of a Network Read or Network Write instruction
- Configure a sampling and averaging algorithm (Analog Input Filtering)
- Configure the operations of a High-Speed Counter

In Section 5.3, an example of the Analog Input Filtering Wizard is shown.

Selecting the S7-200 Instruction Wizard

To select the S7-200 Instruction Wizard, follow these steps:

1. Select the menu command **Tools ► Instruction Wizard...** as shown in Figure 5-13.
2. Click on the instruction formula that you want to configure.
3. Click on "Next>". If you have not compiled your program since the last edit, you must do so. Since a program compile may take some time (if your program is lengthy), you are asked if you want to proceed. The message "Compile Needed. Your program must be compiled in order to proceed. Compile Now?" appears. Click on "OK" to compile, or on "Cancel" to cancel out of the wizard without compiling.
4. Once you choose an instruction formula and your program has compiled, the specific formula screens appear.

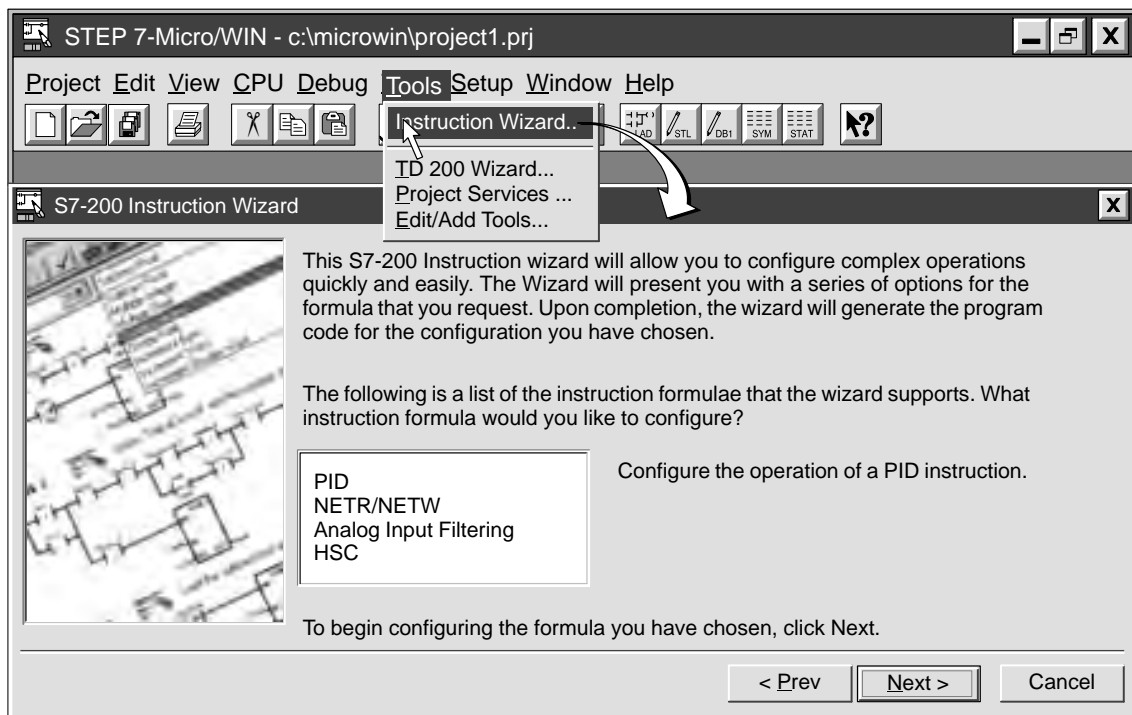


Figure 5-13 Using the S7-200 Instruction Wizard

After you have answered all the queries for the chosen formula, you are shown the final screen of the S7-200 Wizard, as shown in Figure 5-14. This screen explains the program segments to be generated for the configuration you have chosen. It also allows you to specify where the code should be placed within the main program.

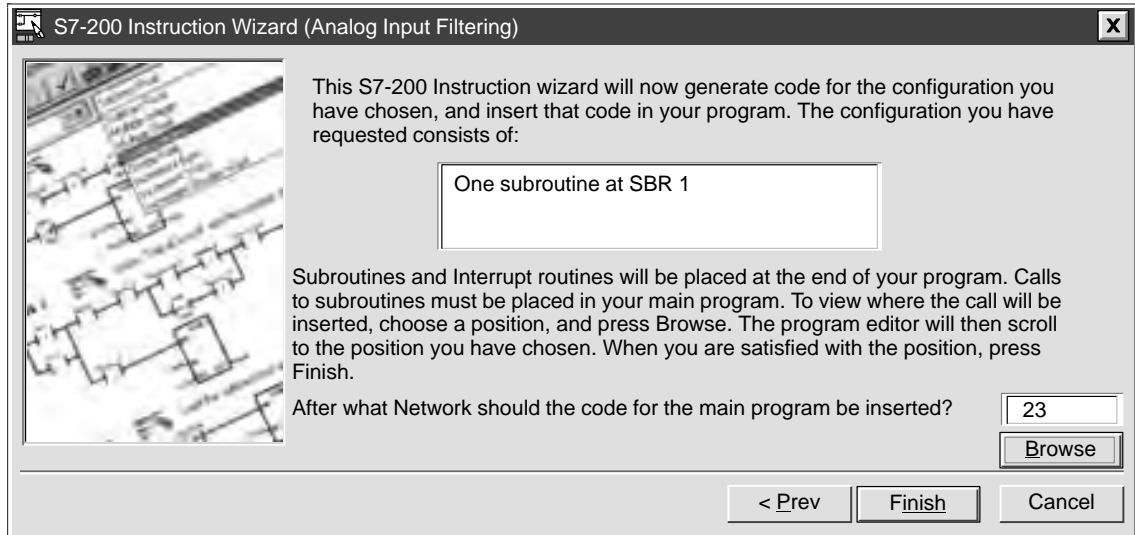


Figure 5-14 Program Segments Generated by the S7-200 Instruction Wizard

5.3 Using the Analog Input Filtering Instruction Wizard

You can use the Analog Input Filtering Wizard to add an averaging routine to your program. The S7-200 analog module is a high-speed module. It can follow rapid changes in the analog input signal (including internal and external noise). Reading-to-reading variations caused by noise for a constant or slowly changing analog input signal can be minimized by averaging a number of readings. As the number of readings used in computing the average value increases, a correspondingly slower response time to changes in the input signal can be observed. An average value computed from a large number of samples can stabilize the reading while slowing down its response to changes in the input signal.

Basic Filtering

To accomplish basic filtering, you need to answer three questions:

1. Which analog input do you wish to filter? (AIW0, AIW2, AIW4,...)
2. To what address should the filtered value be written? (VWx, AQWx, ...)
3. In what address do you want the scratchpad area for calculations to be placed? The filtering code requires 12 bytes of data storage for calculations. (VBx, ...)

Additional Filtering Options

You can configure several options for more information about the analog input you are monitoring,

- Configurable Sample Size
- Error Conditions

Specifying Input and Output

Specify which AIW is to be the input and where the output is to be written, as shown in Figure 5-15. You can enter either an address or a symbol name for the output.

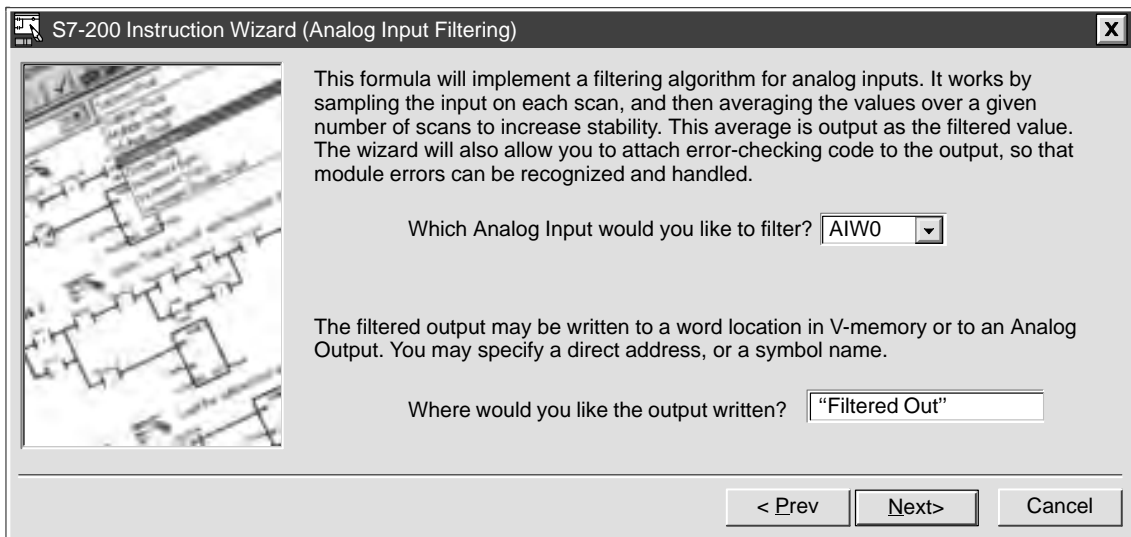


Figure 5-15 Specifying Input and Output in the Analog Input Filtering Wizard

Choosing the Address for the 12-Byte Scratchpad

Choose the area to begin the 12-byte scratchpad, as shown in Figure 5-16. You must also choose the subroutine number for code generation and the sample size.

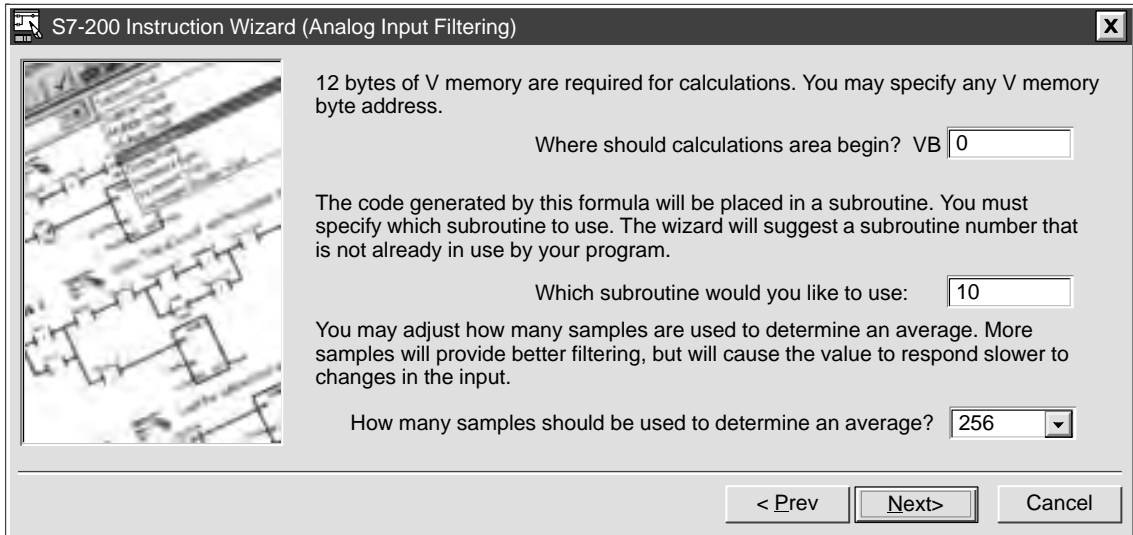


Figure 5-16 Choosing the Address for the 12-Byte Scratchpad

Module Error Checking

You can select the option of adding module error-checking code to your configuration. You must specify the position of the analog module you are using in order to generate the code that checks the correct SM locations. You must also specify a bit to contain the module error status. In the event of a module error, this bit is set. If you choose to output a specific value in the event of a module error, you must enter the value to output. See Figure 5-17.

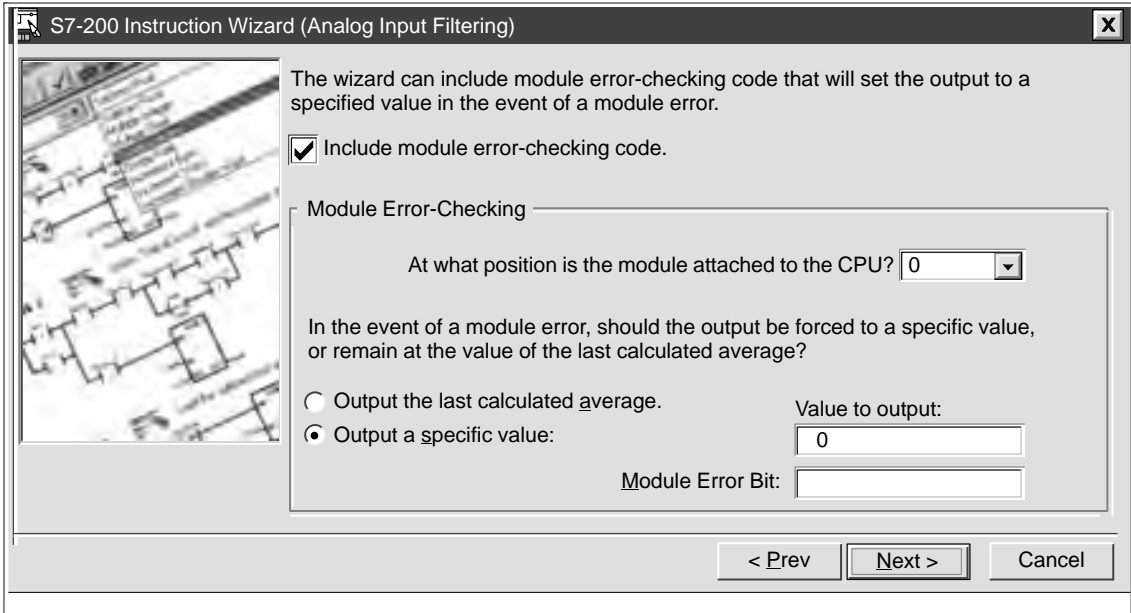


Figure 5-17 Analog Input Filtering - Outputting a Specific Value in the Event of a Module Error

Alternatively, you can choose to output the last calculated average value in the event of a module error. See Figure 5-18.

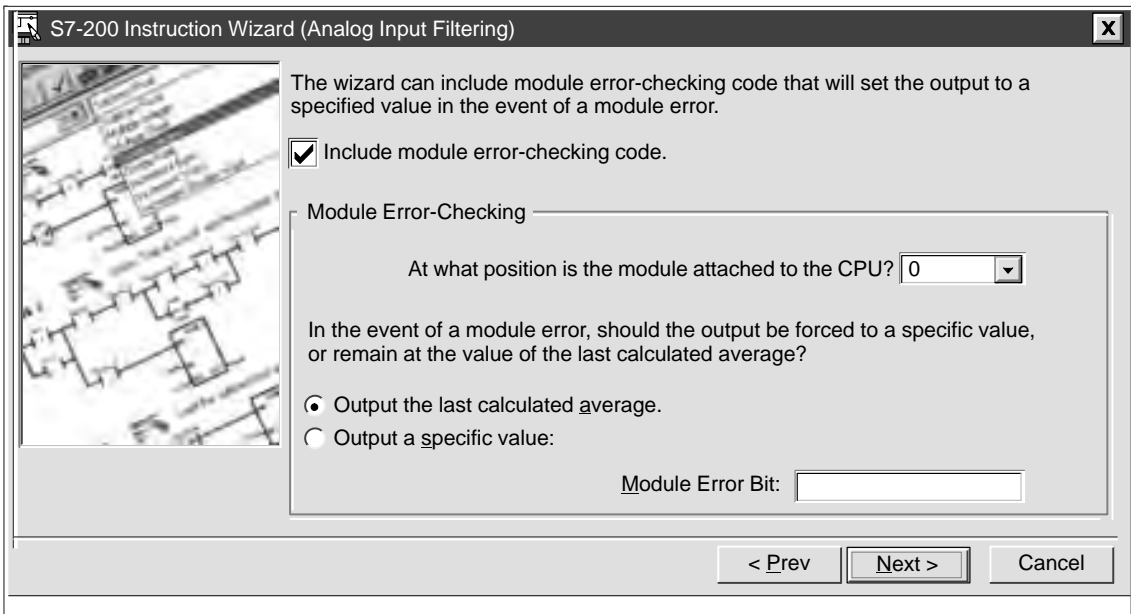


Figure 5-18 Analog Input Filtering - Outputting the Last Calculated Average in the Event of a Module Error

5.4 Using Cross Reference

Use Cross Reference to generate a list of addresses used in your program. Cross Reference lets you monitor the addresses as you write your program. When you select Cross Reference, your program is compiled and the Cross Reference table is generated.

The Cross Reference table shows the element name, the network number, and the instruction. See Figure 5-19. Indirect addresses in the Cross Reference table are shown with the symbols (*) or (&).

To generate a Cross Reference table, follow these steps:

1. Select **View ► Cross Reference**.
2. Your program is compiled and the Cross Reference table is generated.
3. You can leave the Cross Reference table up while you are entering your program. If you change the program and then click into the Cross Reference table, you must update the table by selecting the Refresh option that appears at the top of the Cross Reference screen.
4. To view an element in your program, double-click on that element in the Cross Reference table, and that element is highlighted in the Program Editor.

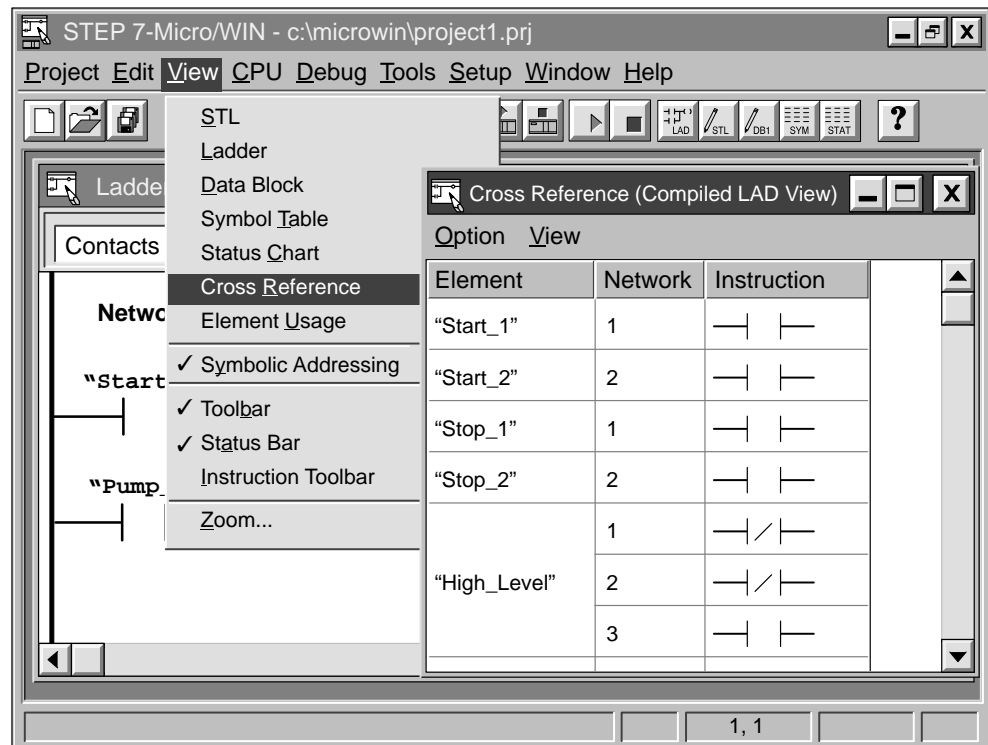


Figure 5-19 Viewing the Cross Reference List

5.5 Using Element Usage

You can use Element Usage to show the addresses and ranges that you have assigned in your program. Element Usage shows this information in a more compact form than the Cross Reference table. The range shown begins with the first used address, and ends with the last used address. Unused addresses are shown as blank rows. See Figure 5-20.

There are two ways to view Element Usage:

- Bit Format shows I, Q, M, and S
- Byte Format shows V usage, AIW, AQW, MB, SMB, T, C, and HSC

Some considerations:

- Within the Byte view, the double word address shows up as four consecutive D's. If there are not four consecutive D's you may have used this address twice, or it may be a deliberate programming effort. (A word shows up as two consecutive W's; a byte is one B; and a bit is one b.)
- Elements marked in usage with dashes (--) indicate ranged references. A ranged reference results from addresses that are used by an instruction without being explicitly stated. For example, the NET READ (NETR) instruction uses an 8-byte table in V memory; however the first byte is the only explicit reference.

To generate a Element Usage table, select **View ► Element Usage**. Your program is compiled and the Element Usage table appears. See Figure 5-20. You can leave the Element Usage table up while you are entering your program. If you change the program, then click into the Element Usage table, you must update the table by selecting the Refresh option that appears at the top of the Element Usage screen.

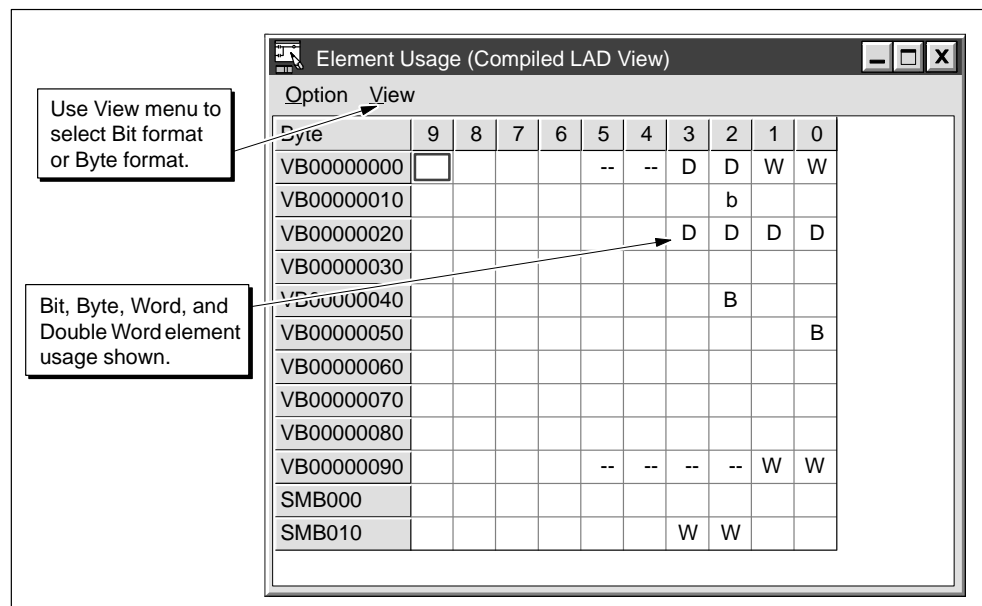


Figure 5-20 Viewing the Element Usage Table

5.6 Using Find/Replace

You can use Find to search for a specific parameter and Replace to replace that parameter with another one. See Figure 5-21.

Using Find to Search for a Parameter

To use Find to search for a specific parameter, follow these steps:

1. Select **Edit ► Find.....** Figure 5-21 shows the Find dialog box.
2. Select the parameters that you want to find.
3. Select the Direction in which you want your program to be searched.
4. Press the “Find Next” button to begin the search.

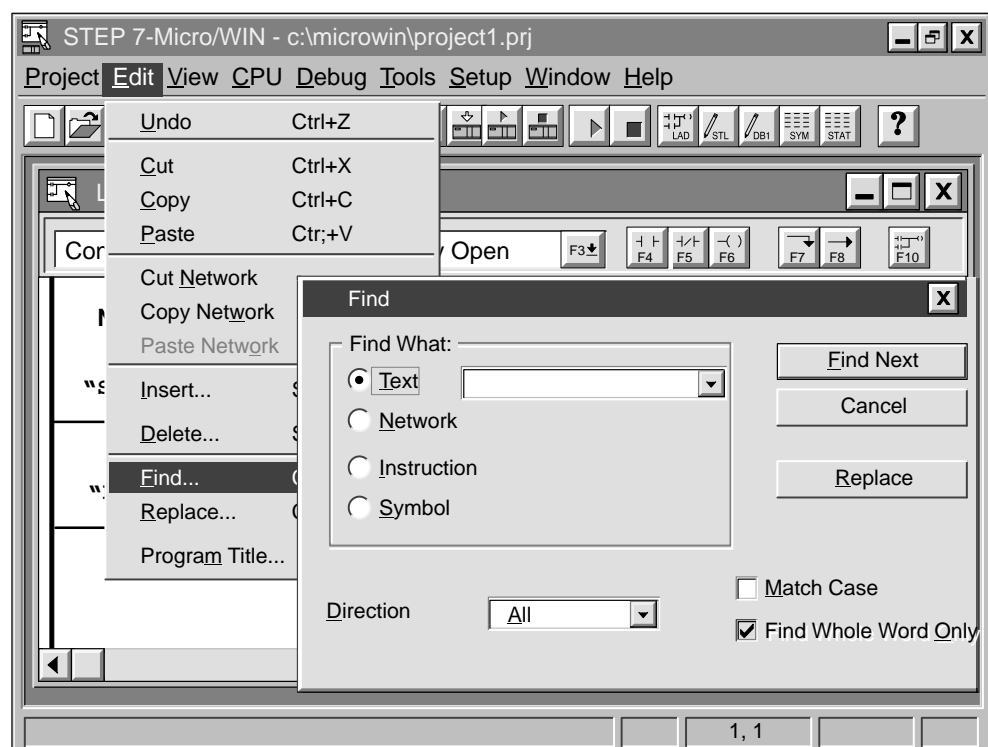


Figure 5-21 Find Dialog Box

Replacing a Parameter

To replace a specific parameter, follow these steps:

1. Select **Edit ► Replace..** Figure 5-22 shows the Replace dialog box.
2. You must define the network to replace.
3. Press the “Replace” button to replace an occurrence. When you press the “Replace” button, the first occurrence is found. You must press the “Replace” button again to replace that occurrence, and to find the next occurrence.
4. The “Replace All” button ignores any set ranges, and replaces all occurrences.

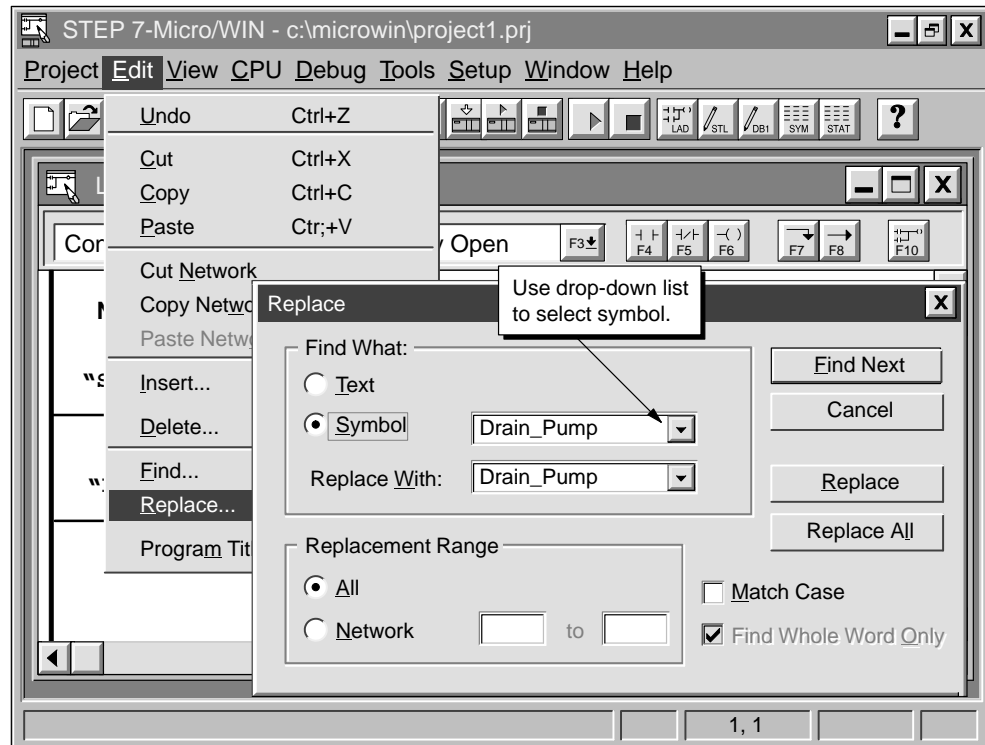


Figure 5-22 Replace Dialog Box

5.7 Documenting Your Program

You can document your ladder program using program titles, network titles, and network comments. You can document your STL program with descriptive comments.

Guidelines for Documenting LAD Programs

The ladder program title is used to provide a brief description of your project. To edit the program title, select **Edit ► Program Title....** Enter your new program title, then click the “OK” button.

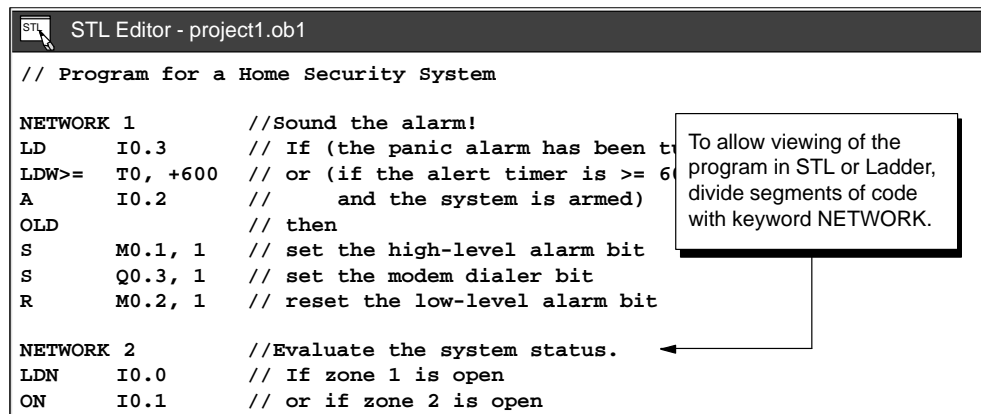
The ladder network title allows you to summarize the function of that network. The single-line network title is always visible in the ladder display. To edit the network title, double-click on the “Network Title” field in your program. Enter your summary in the “Title” field of the LAD Network Title/Comment Editor. Click the “OK” button.

Ladder network comments allow you to describe the function of the network more completely. To enter network comments, double-click on the “Network Title” field in your program. Enter your comments in the “Comment” field, then click the “OK” button. Network comments are not visible on the program screen, but you can view them by double-clicking on a “Network Title” field.

To print your ladder network comments, select **Project ► Print....** Click on the “Page Setup...” button, then select the “Print Network Comments” option, and click the “OK” button.

Guidelines for Documenting STL Programs

Any text on a line in an STL program that is preceded by a double slash (//) is considered to be an STL comment. You can use comments at the beginning of the program to describe its overall purpose. You can also use comments on a line by themselves, or on the same line as an instruction, to document the details of your program. See Figure 5-23.



```

STL Editor - project1.ob1
// Program for a Home Security System

NETWORK 1          //Sound the alarm!
LD      I0.3        // If (the panic alarm has been t
LDW>=   T0, +600    // or (if the alert timer is >= 6
A       I0.2        // and the system is armed)
OLD     // then
S       M0.1, 1     // set the high-level alarm bit
S       Q0.3, 1     // set the modem dialer bit
R       M0.2, 1     // reset the low-level alarm bit

NETWORK 2          //Evaluate the system status.
LDN     I0.0        // If zone 1 is open
ON      I0.1        // or if zone 2 is open

```

Figure 5-23 Documenting Your STL Program

Viewing an STL Program in Ladder

If you plan to view your STL program in ladder, you should follow these conventions when writing your STL program. See Figure 5-23.

- You must divide the segments of STL code into separate networks by entering the keyword, "Network". The network declarations must come at appropriate boundaries for ladder representation. Network numbers are generated automatically after you compile or upload your program.
- The STL comment lines that come before the first "Network" keyword become the ladder program title.
- An STL comment placed on a network line after the "Network" keyword becomes a ladder network title.
- STL comments that appear between the "Network" line and the first instruction of that network become ladder network comments. An example is:

```
NETWORK                // NETWORK TITLE
//NETWORK COMMENT LINE 1
//NETWORK COMMENT LINE 2
LD I0.0
```

5.8 Printing Your Program

You can use the Print function to print your entire program or portions of the program.

- Select **Project ► Print...** to print your program. Select what you want to print, then click the “OK” button. See Figure 5-24.
- Use Page Setup to select additional printing options: margins, absolute/symbolic addresses, network comments, and headers/footers.
- Use Setup to select your printer and paper options.

To print your program, follow these steps:

1. Select **Project ► Print...** The Print dialog box shown in Figure 5-24 appears.
2. Select the options to print from the “Print What:” field.
3. Select the network range to print from the “LAD Network Range” field.
4. If you need to change your printer setup, you can select either Page Setup or Setup.
5. Click “OK”.

Note

If you choose to print the Cross Reference table and/or the Element Usage table, you may be required to compile your program. The time it takes for a program compile depends upon the size of your program.

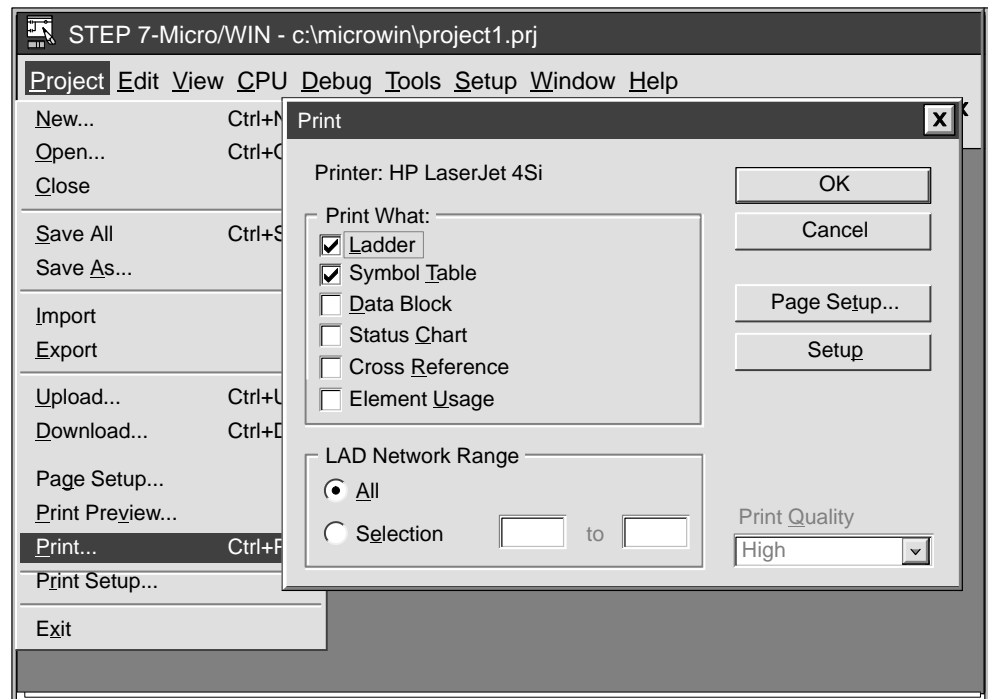


Figure 5-24 Print Dialog Box

Basic Concepts for Programming an S7-200 CPU

6

Before you start to program your application using the S7-200 CPU, you should become familiar with some of the basic operational features of the CPU.

Chapter Overview

Section	Description	Page
6.1	Guidelines for Designing a Micro PLC System	6-2
6.2	Concepts of an S7-200 Program	6-4
6.3	Concepts of the S7-200 Programming Languages	6-5
6.4	Basic Elements for Constructing a Program	6-8
6.5	Understanding the Scan Cycle of the CPU	6-10
6.6	Selecting the Mode of Operation for the CPU	6-13
6.7	Creating a Password for the CPU	6-14
6.8	Debugging and Monitoring Your Program	6-16
6.9	Error Handling for the S7-200 CPU	6-19

6.1 Guidelines for Designing a Micro PLC System

There are many methods for designing a Micro PLC system. This section provides some general guidelines that can apply to many design projects. Of course, you must follow the directives of your own company's procedures and of the accepted practices of your own training and location. Figure 6-1 shows some of the basic steps in the design process.

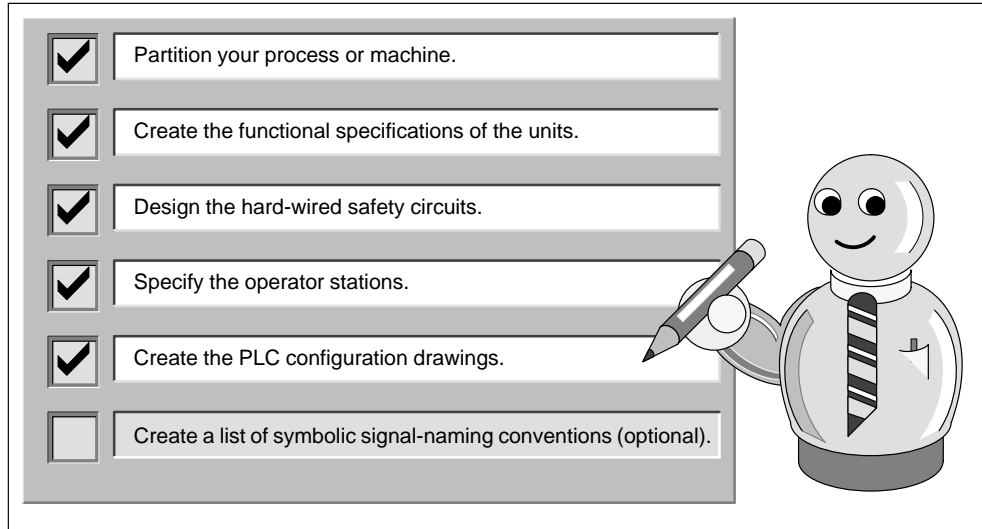


Figure 6-1 Basic Steps for Planning a PLC System

Partitioning Your Process or Machine

Divide your process or machine into sections that have a level of independence from each other. These partitions determine the boundaries between controllers and influence the functional description specifications and the assignment of resources.

Creating the Functional Specifications

Write the descriptions of operation for each section of the process or machine. Include the following topics:

- Input/output (I/O) points
- Functional description of the operation
- Permissives (states that must be achieved before allowing action) for each actuator (solenoids, motors, drives, etc.)
- Description of the operator interface
- Interfaces with other sections of the process or machine

Designing the Safety Circuits

Identify equipment requiring hard-wired logic for safety. Control devices can fail in an unsafe manner, producing unexpected startup or change in the operation of machinery. Where unexpected or incorrect operation of the machinery could result in physical injury to people or significant property damage, consideration should be given to the use of electro-mechanical overrides which operate independently of the CPU to prevent unsafe operations.

The following tasks should be included in the design of safety circuits:

- Identify improper or unexpected operation of actuators that could be hazardous.
- Identify the conditions that would assure the operation is not hazardous, and determine how to detect these conditions independently of the CPU.
- Identify how the CPU and I/O affect the process when power is applied and removed, and when errors are detected. This information should only be used for designing for the normal and expected abnormal operation, and should not be relied on for safety purposes.
- Design manual or electro-mechanical safety overrides that block the hazardous operation independent of the CPU.
- Provide appropriate status information from the independent circuits to the CPU so that the program and any operator interfaces have necessary information.
- Identify any other safety-related requirements for safe operation of the process.

Specifying the Operator Stations

Based on the requirements of the functional specifications, create drawings of the operator station. Include the following items:

- Overview showing the location of each operator station in relation to the process or machine
- Mechanical layout of the devices (display, switches, lights, etc.) for the operator station
- Electrical drawings with the associated I/O of the CPU or expansion module

Creating the PLC Configuration Drawings

Based on the requirements of the functional specification, create configuration drawings of the control equipment. Include the following items:

- Overview showing the location of each CPU module in relation to the process or machine
- Mechanical layout of the CPU module and expansion I/O modules (including cabinets and other equipment)
- Electrical drawings for each CPU module and expansion I/O module (including the device model numbers, communication addresses, and I/O addresses)

Creating a List of Symbolic Names

If you choose to use symbolic names for addressing, create a list of symbolic names for the absolute addresses. Include not only the physical I/O signals, but also the other elements to be used in your program.

6.2 Concepts of an S7-200 Program

Relating the Program to Inputs and Outputs

The basic operation of the S7-200 CPU is very simple:

- The CPU reads the status of the inputs.
- The program that is stored in the CPU uses these inputs to evaluate the control logic. As the program runs, the CPU updates the data.
- The CPU writes the data to the outputs.

Figure 6-2 shows a simple diagram of how an electrical relay diagram relates to the S7-200 CPU. In this example, the state of the operator panel switch for opening the drain is added to the states of other inputs. The calculations of these states then determine the state for the output that goes to the solenoid that closes the drain.

The CPU continuously cycles through the program, reading and writing data.

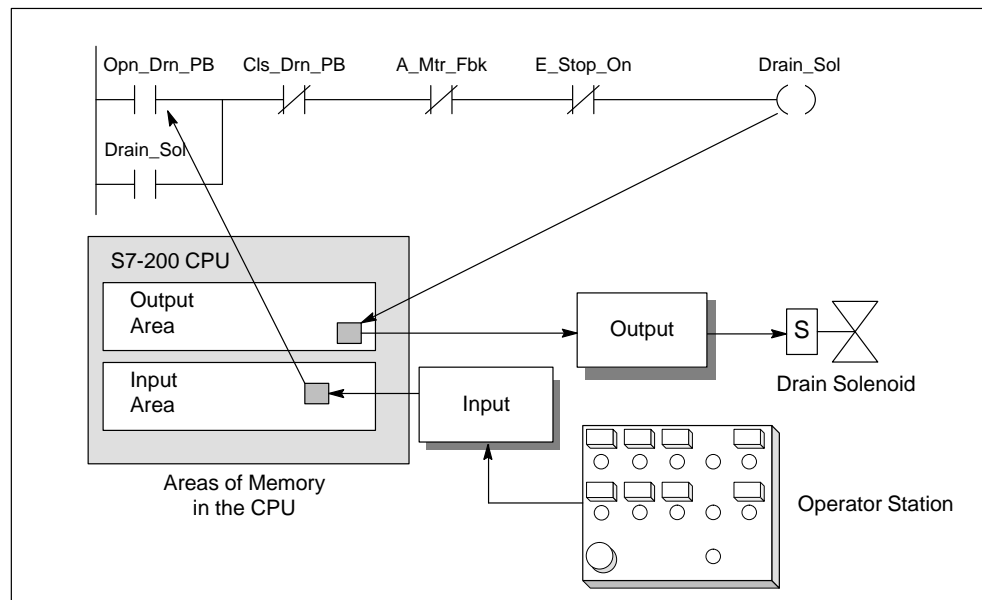


Figure 6-2 Relating the Program to Inputs and Outputs

Accessing Data in the Memory Areas

The CPU stores the status of the inputs and outputs in specific areas of memory. Figure 6-2 shows a simplified flow of information: input → memory area → program → memory area → output. Each memory area is assigned an identifier (such as “I” for input and “Q” for output) that is used for accessing the data stored in that area of memory.

STEP 7-Micro/WIN provides “absolute” addresses for all memory areas. You access a specific location by entering an address (such as I0.0 for the first input point).

STEP 7-Micro/WIN also allows you to define symbolic names for absolute addresses. An absolute address for a memory area includes not only the area identifier (such as “V”), but also the size (up to 4 bytes or 32 bits) of data to be accessed: B (byte), W (word, or two bytes), or D (double word, or 4 bytes). The absolute address also includes a numeric value: either the number of bytes from the beginning of the memory area (offset) or the device number. (This value depends on the area identifier. See Section 7.1.)

6.3 Concepts of the S7-200 Programming Languages

The S7-200 CPU (and STEP 7-Micro/WIN) supports the following programming languages:

- Statement list (STL) is a set of mnemonic instructions that represent functions of the CPU.
- Ladder logic (LAD) is a graphical language that resembles the electrical relay diagrams for the equipment.

STEP 7-Micro/WIN also provides two representations for displaying the addresses and the programming instructions in the program: international and SIMATIC. Both the international and SIMATIC representations refer to the same S7-200 instruction set. There is a direct correspondence between the international and the SIMATIC representation; both representations have the same functionality.

Understanding the Basic Elements of Ladder Logic

When you write a program in ladder, you create and arrange the graphical components to form a network of logic. As shown in Figure 6-3, the following types of elements are available for creating your program:

- Contacts: each of these elements represents a switch through which power can flow when a switch is closed.
- Coils: each of these elements represents a relay that is energized by power flowing to that relay.
- Boxes: each of these elements represents a function that is executed when power flows to the box.
- Networks: each of these elements forms a complete circuit. Power flows from the left power rail through the closed contacts to energize the coils or boxes.

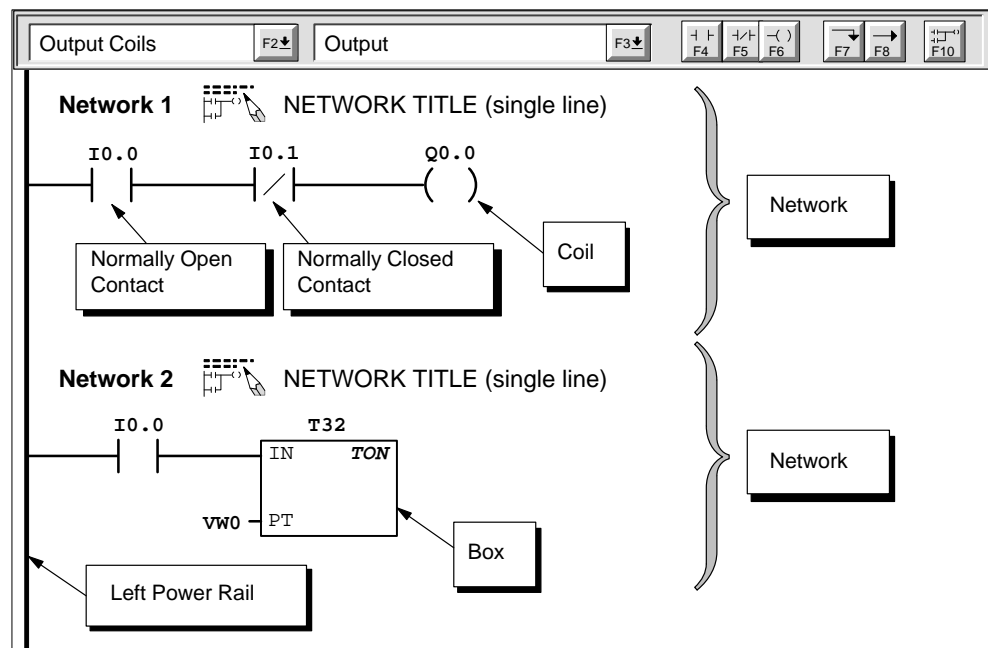


Figure 6-3 Basic Elements of Ladder Logic

Understanding the Statement List Instructions

Statement list (STL) is a programming language in which each statement in your program includes an instruction that uses a mnemonic abbreviation to represent a function of the CPU. You combine these instructions into a program to produce the control logic for your application.

Figure 6-4 shows the basic elements of a statement list program.

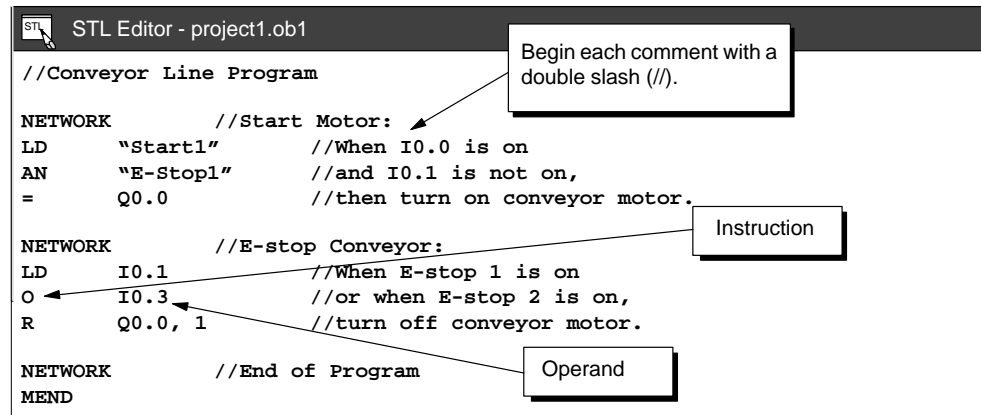


Figure 6-4 STL Editor Window with Sample Program

The STL instructions use a logic stack in the CPU for solving your control logic. As shown in Figure 6-5, this logic stack is nine bits deep by one bit wide. Most of the STL instructions work either with the first bit or with the first and the second bits of the logic stack. New values can be "pushed" (or added) onto the stack; when the top two bits of the stack are combined, the stack is "popped" (reduced by one bit).

While most STL instructions only read the values in the logic stack, many STL instructions also modify the values stored in the logic stack. Figure 6-5 shows examples of how three instructions use the logic stack.

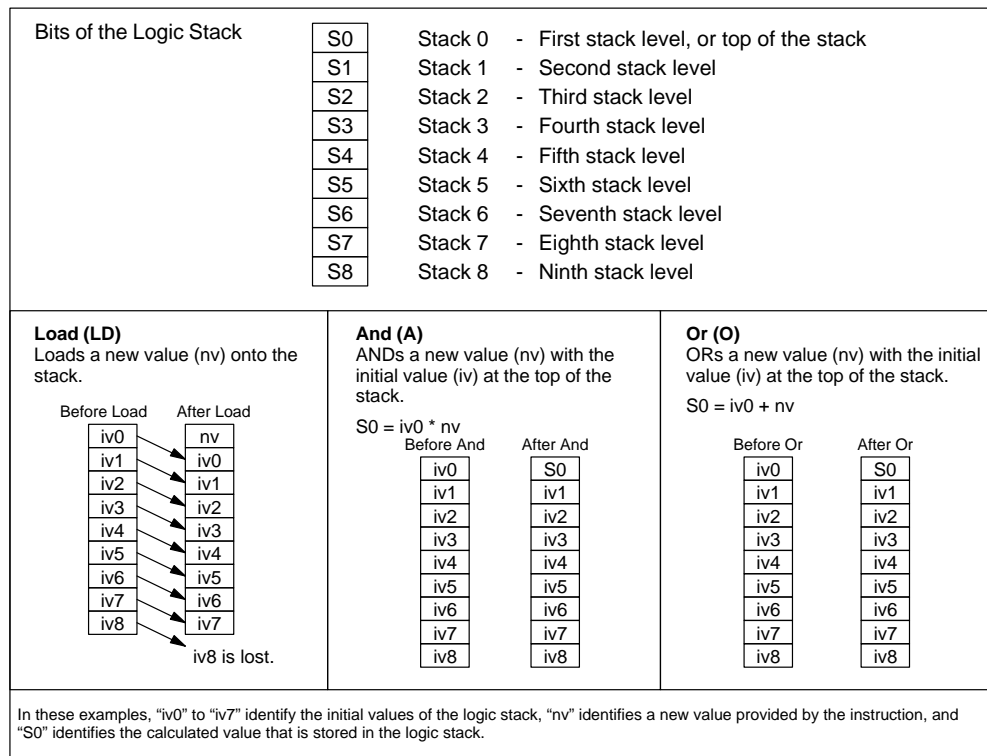


Figure 6-5 Logic Stack of the S7-200 CPU

6.4 Basic Elements for Constructing a Program

The S7-200 CPU continuously executes your program to control a task or process. You create this program with STEP 7-Micro/WIN and download it to the CPU. From the main program, you can call different subroutines or interrupt routines.

Organizing the Program

Programs for an S7-200 CPU are constructed from three basic elements: the main program, subroutines (optional), and interrupt routines (optional). As shown in Figure 6-6, an S7-200 program is structured into the following organizational elements:

- **Main program:** The main body of the program is where you place the instructions that control your application. The instructions in the main program are executed sequentially, once per scan of the CPU. To terminate the main program, use an Unconditional End coil in ladder or a Main Program End instruction (MEND) in STL. See (1) in Figure 6-6.
- **Subroutines:** These optional elements of your program are executed only when called from the main program. Place the subroutines after the end of the main program (following the Unconditional End coil in ladder logic or the MEND instruction in STL). Use a Return (RET) instruction to terminate each subroutine. See (2) in Figure 6-6.
- **Interrupt routines:** These optional elements of your program are executed on each occurrence of the interrupt event. Place the interrupt routines after the end of the main program (following the Unconditional End coil in ladder logic or the MEND instruction in STL). Use a Return From Interrupt (RETI) instruction to terminate each interrupt routine. See (3) in Figure 6-6.

Subroutines and interrupt routines follow the Unconditional End coil or MEND instruction of the main program; there is no other requirement for locating the subroutines and interrupt routines within your program. You can mix subroutines and interrupt routines following the main program; however, in order to provide a program structure that is easy to read and understand, consider grouping all of the subroutines together after the main program, and then group all of the interrupt routines together after the subroutines.

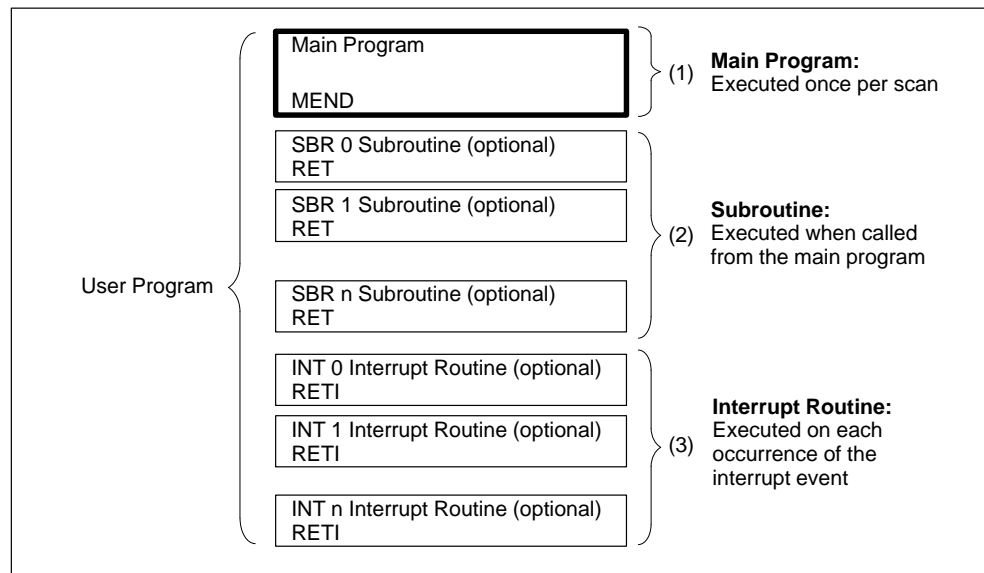


Figure 6-6 Program Structure for an S7-200 CPU

Example Program Using Subroutines and Interrupts

Figure 6-7 shows a sample program for a timed interrupt, which can be used for applications such as reading the value of an analog input. In this example, the sample rate of the analog input is set to 100 ms.

Ladder Logic	Statement List
Main Program	
<p>Network 1</p> <p>Network 2</p>	<pre> Network 1 LD SM0.1 //When first scan bit //comes on CALL 0 //Call subroutine 0. Network 2 MEND </pre>
Subroutines	
<p>Network 3</p> <p>Network 4</p> <p>Network 5</p>	<pre> Network 3 SBR 0 //Begin subroutine 0 Network 4 LD SM0.0 //Always on memory bit, MOVW 100, SMB34 //set timed int. 0. //interval to 100 ms ENI //Global Interrupt Enable ATCH 0, 10 //Attach timed int. 0 to //int. routine 0. Network 5 RET //Terminate subroutine. </pre>
Interrupt Routines	
<p>Network 6</p> <p>Network 7</p> <p>Network 8</p>	<pre> Network 6 INT 0 //Begin Int. routine 0. Network 7 MOVW AIW4, VW100 //Sample Analog Input 4 Network 8 RETI //Terminate interrupt //routine </pre>

Figure 6-7 Sample Program for Using a Subroutine and an Interrupt Routine

6.5 Understanding the Scan Cycle of the CPU

The S7-200 CPU is designed to execute a series of tasks, including your program, repetitively. This cyclical execution of tasks is called the scan cycle. During the scan cycle shown in Figure 6-8, the CPU performs most or all of the following tasks:

- Reading the inputs
- Executing the program
- Processing any communication requests
- Executing the CPU self-test diagnostics
- Writing to the outputs

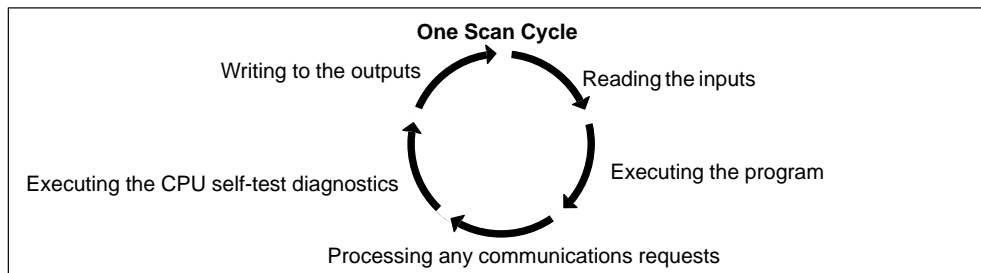


Figure 6-8 Scan Cycle of the S7-200 CPU

The series of tasks executed during the scan cycle is dependent upon the operating mode of the CPU. The S7-200 CPU has two modes of operation, STOP mode and RUN mode. With respect to the scan cycle, the main difference between STOP and RUN mode is that in RUN mode your program is executed, and in STOP mode your program is not executed.

Reading the Digital Inputs

Each scan cycle begins by reading the current value of the digital inputs and then writing these values to the process-image input register.

The CPU reserves the process-image input register in increments of eight bits (one byte). If the CPU or expansion module does not provide a physical input point for each bit of the reserved byte, you cannot reallocate these bits to subsequent modules in the I/O chain or use them in your program. The CPU resets these unused inputs to zero in the image register at the beginning of every scan. However, if your CPU module can accommodate several expansion modules and you are not using this I/O capacity (have not installed the expansion modules), you can use the unused expansion input bits as additional memory bits.

The CPU does not automatically update analog inputs as part of the scan cycle and does not maintain an analog input image register. You must access the analog inputs directly from your program.

Executing the Program

During the execution phase of the scan cycle, the CPU executes your program, starting with the first instruction and proceeding to the end instruction. The immediate I/O instructions give you immediate access to inputs and outputs during the execution of either the program or an interrupt routine.

If you use interrupts in your program, the interrupt routines that are associated with the interrupt events are stored as part of the program. (See Section 6.4.) The interrupt routines are not executed as part of the normal scan cycle, but are executed when the interrupt event occurs (which may be at any point in the scan cycle).

Processing the Communication Requests

During the message-processing phase of the scan cycle, the CPU processes any messages that were received from the communications port.

Executing the CPU Self-Diagnostic Test

During this phase of the scan cycle, the CPU checks its firmware and your program memory (RUN mode only). It also checks the status of any I/O modules.

Writing to the Digital Outputs

At the end of every scan cycle, the CPU writes the values stored in the process-image output register to the digital outputs.

The CPU reserves the process-image output register in increments of eight bits (one byte). If the CPU or expansion module does not provide a physical output point for each bit of the reserved byte, you cannot reallocate these bits to subsequent modules in the I/O chain. However, you can use the unused bits of the process-image output register like the internal memory (M) bits.

The CPU does not automatically update analog outputs as part of the scan cycle and does not maintain an analog output image register. You must access the analog outputs directly from your program.

When the CPU operating mode is changed from RUN to STOP, the digital outputs are set to the values defined in the Output Table, or are left in their current state (see Section 8.3). Analog outputs remain at the value last written.

Interrupting the Scan Cycle

If you use interrupts, the routines associated with each interrupt event are stored as part of the program. The interrupt routines are not executed as part of the normal scan cycle, but are executed when the interrupt event occurs (which may be at any point in the scan cycle). Interrupts are serviced by the CPU on a first-come-first-served basis within their respective priority assignments.

Process-Image Input and Output Registers

It is usually advantageous to use the process-image register rather than to directly access inputs or outputs during the execution of your program. There are three reasons for using the image registers:

- The sampling of all inputs at the top of the scan synchronizes and freezes the values of the inputs for the program execution phase of the scan cycle. The outputs are updated from the image register after the execution of the program is complete. This provides a stabilizing effect on the system.
- Your program can access the image register much quicker than it can access I/O points, allowing faster execution of the program.
- I/O points are bit entities and must be accessed as bits, but you can access the image register as bits, bytes, words, or double words. Thus, the image registers provide additional flexibility.

An additional benefit is that the image registers are large enough to handle the maximum number of input and output points. Since a real system consists of both inputs and outputs, there is always some number of image register locations not used. You can use the unused locations as extra internal memory bits. See Section 8.1.

Immediate I/O

Immediate I/O instructions allow direct access to the actual input or output point, even though the image registers are normally used as either the source or the destination for I/O accesses. The corresponding process-image input register location is not modified when you use an immediate instruction to access an input point. The corresponding process-image output register location is updated simultaneously when you use an immediate instruction to access an output point.

6.6 Selecting the Mode of Operation for the CPU

The S7-200 CPU has two modes of operation:

- **STOP:** The CPU is not executing the program. You can download a program or configure the CPU when the CPU is in STOP mode.
- **RUN:** The CPU is running the program. When the CPU is in RUN mode, you cannot download a program or configure the CPU.

The status LED on the front of the CPU indicates the current mode of operation. You must place the CPU in the STOP mode to load the program into program memory.

Changing the Operating Mode with the Mode Switch

You can use the mode switch (located under the access door of the CPU module) to select the operating mode for the CPU manually:

- Setting the mode switch to STOP mode stops the execution of the program.
- Setting the mode switch to RUN mode starts the execution of the program.
- Setting the mode switch to TERM (terminal) mode does not change the CPU operating mode, but it does allow the programming software (STEP 7-Micro/WIN) to change the CPU operating mode.

If a power cycle occurs when the mode switch is set to either STOP or TERM, the CPU goes automatically to STOP mode when power is restored. If a power cycle occurs when the mode switch is set to RUN, the CPU goes to RUN mode when power is restored.

Changing the Operating Mode with STEP 7-Micro/WIN

As shown in Figure 6-9, you can use STEP 7-Micro/WIN to change the operating mode of the CPU. To enable the software to change the operating mode, you must set the mode switch on the CPU to either TERM or RUN.

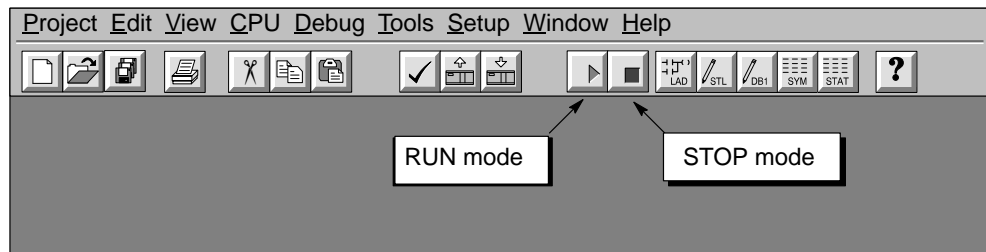


Figure 6-9 Using STEP 7-Micro/WIN to Change the Operating Mode of the CPU

Changing the Operating Mode from the Program

You can insert the STOP instruction in your program to change the CPU to STOP mode. This allows you to halt the execution of your program based on the program logic. For more information about the STOP instruction, see Chapter 10.

6.7 Creating a Password for the CPU

All models of the S7-200 CPU provide password protection for restricting access to specific CPU functions. A password authorizes access to the CPU functions and memory: without a password, the CPU provides unrestricted access. When password protected, the CPU prohibits all restricted operations according to the configuration provided when the password was installed.

Restricting Access to the CPU

As shown in Table 6-1, S7-200 CPUs provide three levels of restricting access to CPU functions. Each level allows certain functions to be accessible without a password. For all three levels of access, entering the correct password provides access to all of the CPU functions. The default condition for S7-200 CPUs is level 1 (no restriction).

Entering the password over a network does not compromise the password protection for the CPU. Having one user authorized to access restricted CPU functions does not authorize other users to access those functions. Only one user is allowed unrestricted access to the CPU at a time.

Note

After you enter the password, the authorization level for that password remains effective for up to one minute after the programming device has been disconnected from the CPU.

Table 6-1 Restricting Access to the S7-200 CPU

Task	Level 1	Level 2	Level 3
Read and write user data	Not restricted	Not restricted	Not restricted
Start, stop and restart the CPU			
Read and write the time-of-day clock			
Read the forced data in the CPU			
Upload the user program, data, and the configuration		Password required	Password required
Download to the CPU			
Delete the user program, data, and the configuration ¹			
Force data or single/multiple scan			
Copy to the memory cartridge			

¹ The “Delete” protection can be overridden by the Clear password, “clearplc”.

Configuring the CPU Password

You use STEP 7-Micro/WIN to create the password for the CPU. Select the menu command **CPU ► Configure** and click the Password tab. See Figure 6-10. Enter the appropriate level of access for the CPU, then enter and verify the password for the CPU.

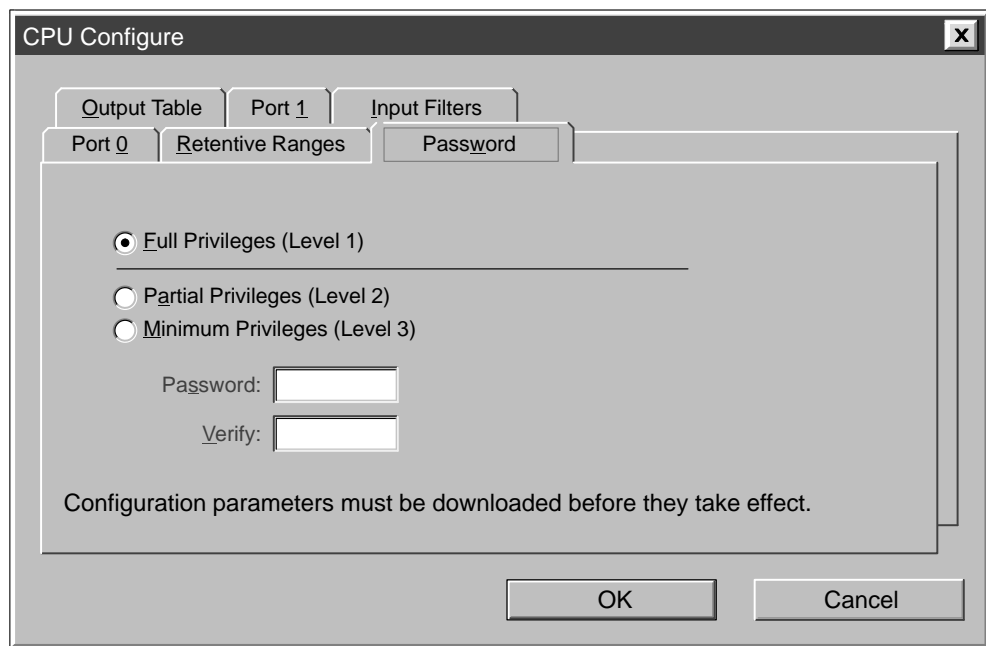


Figure 6-10 Configuring a Password for the CPU

What to Do If You Forget the Password

If you forget the password, you must clear the CPU memory and reload your program. Clearing the CPU memory puts the CPU in STOP mode and resets the CPU to the factory-set defaults, except for the node address and the time-of-day clock.

To clear your program in the CPU, select the **CPU ► Clear...** menu command to display the Clear dialog box. Select the "All" option and confirm your action by clicking the "OK" button. This displays a password-authorization dialog box. Entering the Clear password (clearplc) allows you to continue the Clear All operation.

The Clear All operation does not remove the program from a memory cartridge. Since the memory cartridge stores the password along with the program, you must also reprogram the memory cartridge to remove the lost password.



Warning

Clearing the CPU memory causes the outputs to turn off (or in the case of an analog output, to be frozen at a specific value).

If the S7-200 CPU module is connected to equipment when you clear the CPU memory, changes in the state of the outputs can be transmitted to the equipment. If you had configured the "safe state" for the outputs to be different from the factory settings, changes in the outputs could cause unanticipated activity in the equipment, which could also cause death or serious injury to personnel, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that your process is in a safe state before clearing the CPU memory.

6.8 Debugging and Monitoring Your Program

STEP 7-Micro/WIN provides a variety of tools for debugging and monitoring your program.

Using Single/Multiple Scans to Monitor Your Program

You can specify that the CPU execute your program for a limited number of scans (from 1 scan to 65,535 scans). By selecting the number of scans for the CPU to run, you can monitor the program as it changes the process variables. Use the menu command **Debug ► Execute Scans** to specify the number of scans to be executed. Figure 6-11 shows the dialog box for entering the number of scans for the CPU to execute.

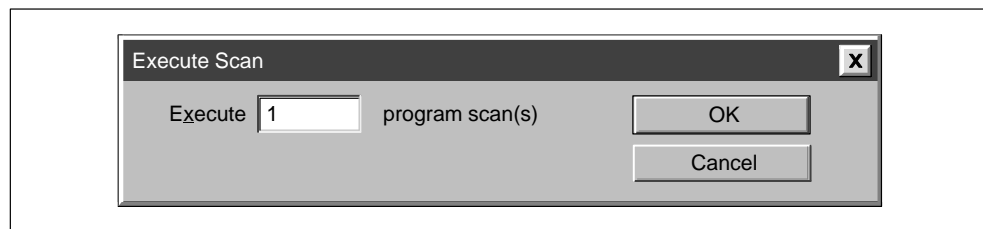


Figure 6-11 Executing Your Program for a Specific Number of Scans

Using a Status Chart to Monitor and Modify Your Program

As shown in Figure 6-12, you can use a Status Chart to read, write, force, and monitor variables while the program is running. For more information about building a chart, see Section 3.8.

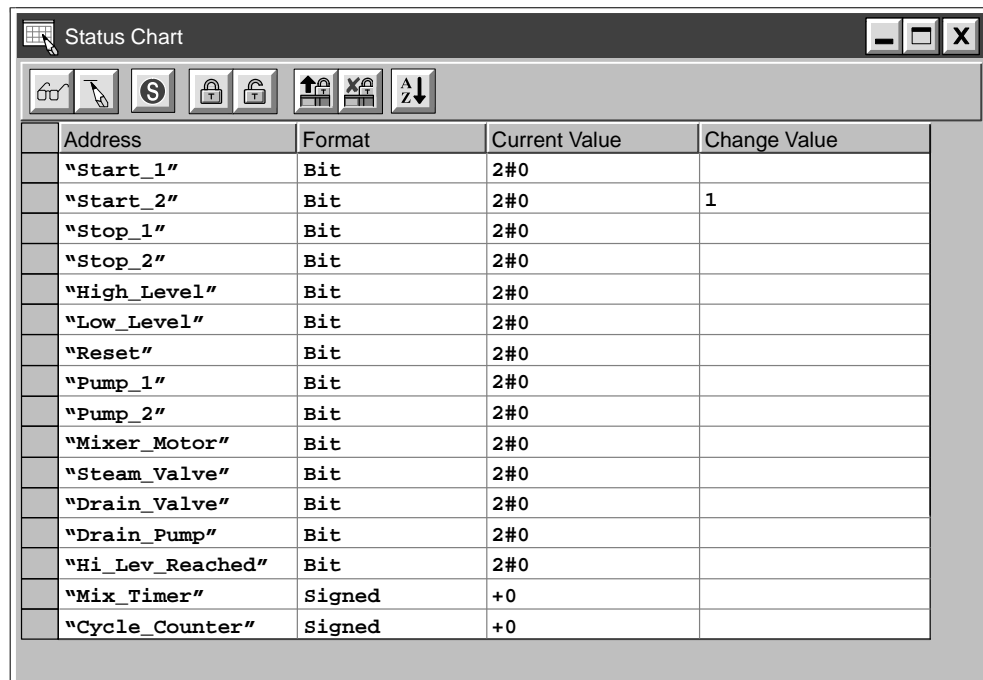


Figure 6-12 Monitoring and Modifying Variables with a Status Chart

Displaying the Status of the Program in Ladder Logic

As shown in Figure 6-13, the program editor of STEP 7-Micro/WIN allows you to monitor the status of the online program. (The program must be displaying ladder logic.) This allows you to monitor the status of the instructions in the program as they are executed by the CPU.

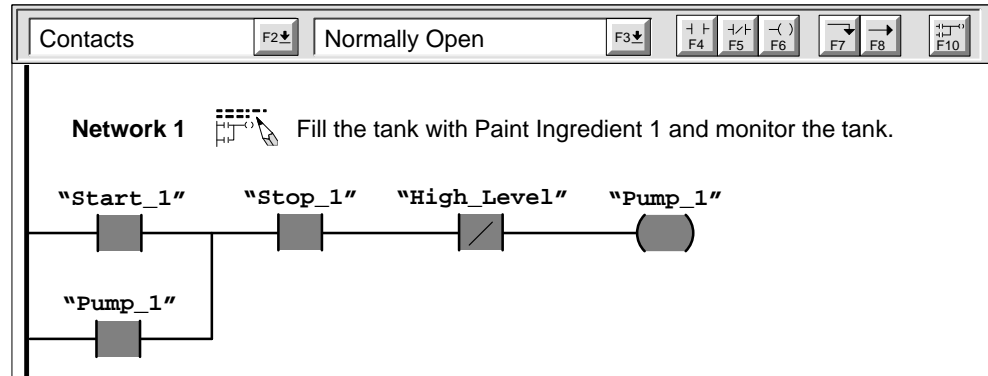


Figure 6-13 Displaying the Status of a Program in Ladder Logic

Using a Status Chart to Force Specific Values

The S7-200 CPU allows you to force any or all of the I/O points (I and Q bits) and variables to specific values. In addition, you can also force up to 16 internal memory values (V or M) or analog I/O values (AI or AQ). V memory or M memory values can be forced in bytes, words, or double words. Analog values are forced as words only, on even-byte boundaries (such as AIW6 or AQW14). All forced values are stored in the permanent EEPROM memory of the CPU.

Because the forced data might be changed during the scan cycle (either by the program, by the I/O update cycle, or by the communications-processing cycle), the CPU reapplies the forced values at various times in the scan cycle. Figure 6-14 shows the scan cycle, highlighting when the CPU updates the forced variables.

The Force function overrides an immediate-read or immediate-write instruction. The Force function also overrides an output that was configured to go to a specified value on transition to STOP mode: if the CPU goes to STOP mode, the output reflects the forced value and not the configured value.

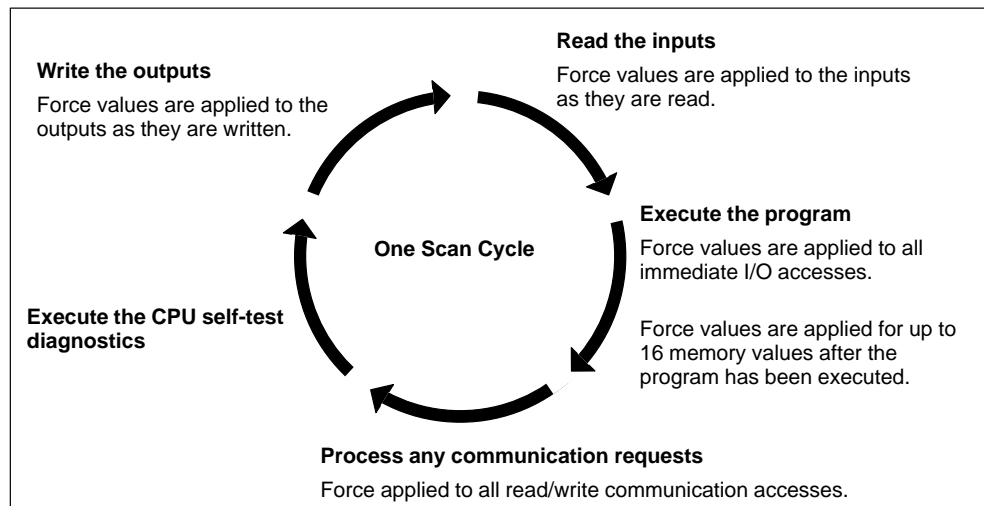


Figure 6-14 Scan Cycle of the S7-200 CPU

Figure 6-15 shows an example of the Status Chart. For more information on how to use the Status Chart, see Section 3.8.

Address	Format	Current Value	Change Value
"Start_1"	Bit	2#0	
"Start_2"	Bit	2#0	1
"Stop_1"	Bit	2#0	
"Stop_2"	Bit	2#0	
"High_Level"	Bit	2#0	
"Low_Level"	Bit	2#0	
"Reset"	Bit	2#0	
"Pump_1"	Bit	2#0	
"Pump_2"	Bit	2#0	
"Mixer_Motor"	Bit	2#0	
"Steam_Valve"	Bit	2#0	
"Drain_Valve"	Bit	2#0	
"Drain_Pump"	Bit	2#0	
"Hi_Lev_Reached"	Bit	2#0	
"Mix_Timer"	Signed	+0	
"Cycle_Counter"	Signed	+0	

Figure 6-15 Forcing Variables with the Status Chart

6.9 Error Handling for the S7-200 CPU

The S7-200 CPU classifies errors as either fatal errors or non-fatal errors. You can use STEP 7-Micro/WIN to view the error codes that were generated by the error. Figure 6-16 shows the dialog box that displays the error code and the description of the error. Refer to Appendix C for a complete listing of the error codes.

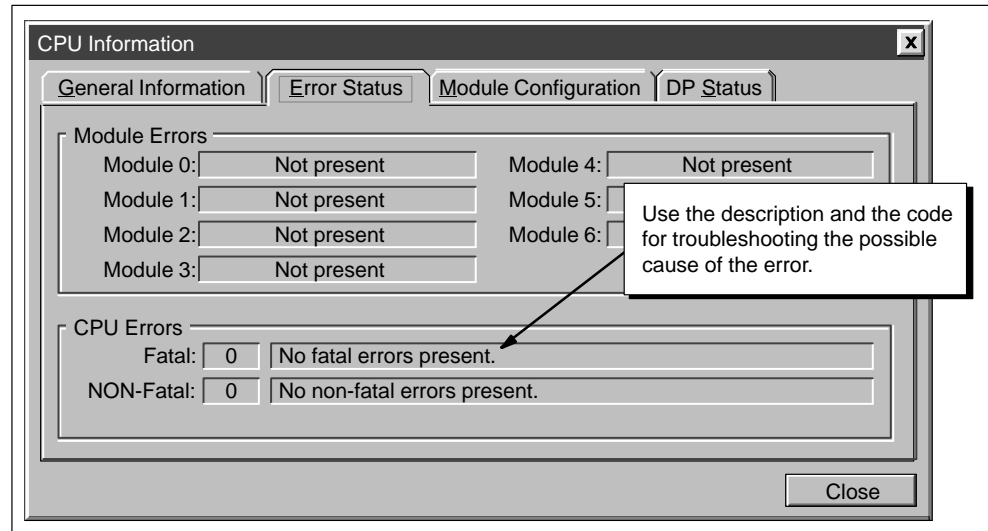


Figure 6-16 CPU Information Dialog: Error Status Tab

Responding to Fatal Errors

Fatal errors cause the CPU to stop the execution of your program. Depending upon the severity of the fatal error, it can render the CPU incapable of performing any or all functions. The objective for handling fatal errors is to bring the CPU to a safe state from which the CPU can respond to interrogations about the existing error conditions. When a fatal error is detected by the CPU, the CPU changes to the STOP mode, turns on the System Fault LED and the STOP LED, and turns off the outputs. The CPU remains in this condition until the fatal error condition is corrected.

Once you have made the changes to correct the fatal error condition, you must restart the CPU. You can restart the CPU either by turning the power off and then on, or by changing the mode switch from RUN or TERM to STOP. Restarting the CPU clears the fatal error condition and performs power-up diagnostic testing to verify that the fatal error has been corrected. If another fatal error condition is found, the CPU again sets the fault LED indicating that an error still exists. Otherwise, the CPU begins normal operation.

There are several possible error conditions that can render the CPU incapable of communication. In these cases, you cannot view the error code from the CPU. These types of errors indicate hardware failures that require the CPU module to be repaired; these conditions cannot be fixed by changes to the program or clearing the CPU memory.

Responding to Non-Fatal Errors

Non-fatal errors can degrade some aspect of the CPU performance, but they do not render the CPU incapable of executing your program or from updating the I/O. As shown in Figure 6-16, you can use STEP 7-Micro/WIN to view the error codes that were generated by the non-fatal error. There are three basic categories of non-fatal errors:

- Run-time errors. All non-fatal errors detected in RUN mode are reflected in special memory (SM) bits. Your program can monitor and evaluate these bits. Refer to Appendix D for more information about the SM bits used for reporting non-fatal run-time errors.

At startup, the CPU reads the I/O configuration and stores this information in the system data memory and in the SM memory. During normal operation, the I/O status is periodically updated and stored in the SM memory. If the CPU detects a difference in the I/O configuration, the CPU sets the configuration-changed bit in the module-error byte; the I/O module is not updated until this bit is reset. For the CPU to reset this bit, the module I/O must again match the I/O configuration stored in the system data memory.

- Program-compile errors. The CPU compiles the program as it downloads. If the CPU detects that the program violates a compilation rule, the download is aborted and an error code is generated. (A program that was already downloaded to the CPU would still exist in the EEPROM and would not be lost.) After you correct your program, you can download it again.
- Run-time programming errors. You (or your program) can create error conditions while the program is being executed. For example, an indirect-address pointer that was valid when the program compiled may be modified during the execution of the program to point to an out-of-range address. This is considered a run-time programming error. Use the dialog box shown in Figure 6-16 to determine what type of error occurred.

The CPU does not change to STOP mode when it detects a non-fatal error. It only logs the event in SM memory and continues with the execution of your program. However, you can design your program to force the CPU to STOP mode when a non-fatal error is detected. Figure 6-17 shows a network of a program that is monitoring an SM bit. This instruction changes the CPU to STOP mode whenever an I/O error is detected.

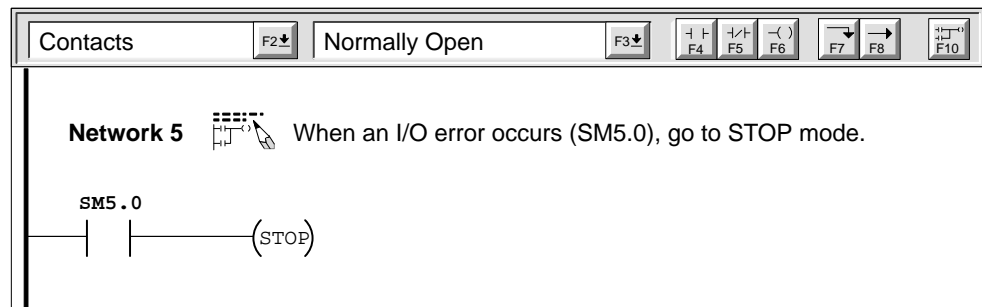


Figure 6-17 Designing Your Program to Detect Non-Fatal Error Conditions

CPU Memory: Data Types and Addressing Modes

7

The S7-200 CPU provides specialized areas of memory to make the processing of the control data faster and more efficient.

Chapter Overview

Section	Description	Page
7.1	Direct Addressing of the CPU Memory Areas	7-2
7.2	Indirect Addressing of the CPU Memory Areas	7-9
7.3	Memory Retention for the S7-200 CPU	7-11
7.4	Using Your Program to Store Data Permanently	7-16
7.5	Using a Memory Cartridge to Store Your Program	7-17

7.1 Direct Addressing of the CPU Memory Areas

The S7-200 CPU stores information in different memory locations that have unique addresses. You can explicitly identify the memory address that you want to access. This allows your program to have direct access to the information.

Using the Memory Address to Access Data

To access a bit in a memory area, you specify the address, which includes the memory area identifier, the byte address, and the bit number. Figure 7-1 shows an example of accessing a bit (which is also called "byte.bit" addressing). In this example, the memory area and byte address (I=input, and 3=byte 3) are followed by a period (".") to separate the bit address (bit 4).

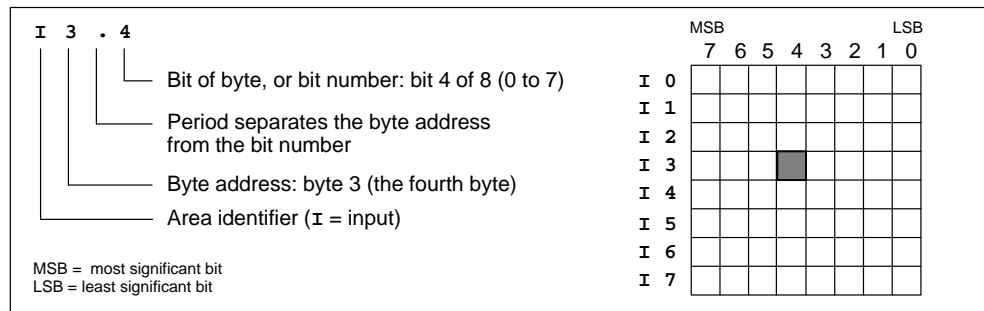


Figure 7-1 Accessing a Bit of Data in the CPU Memory (Byte.bit Addressing)

By using the byte address format, you can access data in many CPU memory areas (V, I, Q, M, and SM) as bytes, words, or double words. To access a byte, word, or double word of data in the CPU memory, you must specify the address in a way similar to specifying the address for a bit. This includes an area identifier, data size designation, and the starting byte address of the byte, word, or double-word value, as shown in Figure 7-2. Data in other CPU memory areas (such as T, C, HC, and the accumulators) are accessed by using an address format that includes an area identifier and a device number.

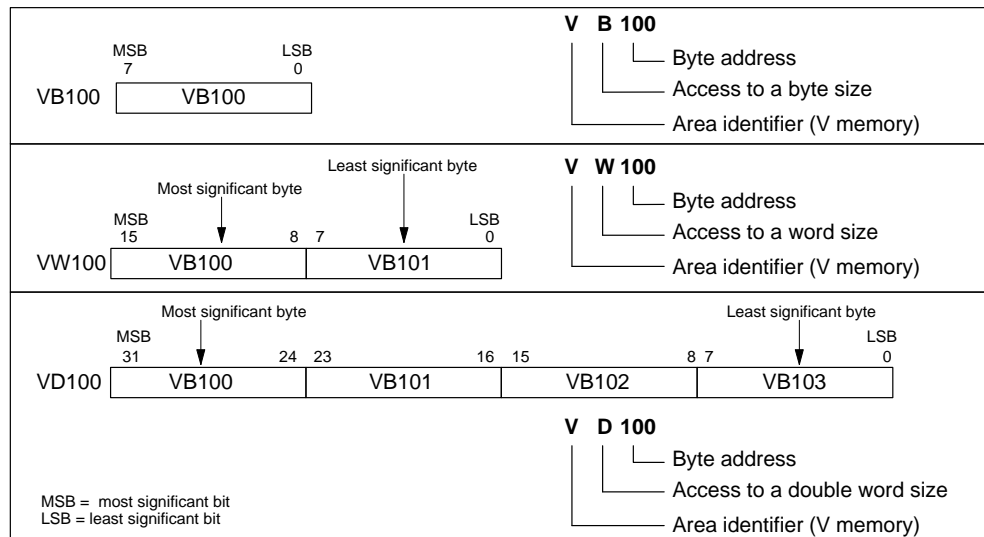


Figure 7-2 Comparing Byte, Word, and Double-Word Access to the Same Address

Representation of Numbers

Table 7-1 shows the range of integer values that can be represented by the different sizes of data.

Real (or floating-point) numbers are represented as 32-bit, single-precision numbers, whose format is described in the ANSI/IEEE 754-1985 standard. Real number values are accessed in double-word lengths.

Table 7-1 Data Size Designations and Associated Integer Ranges

Data Size	Unsigned Integer Range		Signed Integer Range	
	Decimal	Hexadecimal	Decimal	Hexadecimal
B (Byte): 8-bit value	0 to 255	0 to FF	-128 to 127	80 to 7F
W (Word): 16-bit value	0 to 65,535	0 to FFFF	-32,768 to 32,767	8000 to 7FFF
D (Double word, Dword): 32-bit value	0 to 4,294,967,295	0 to FFFF FFFF	-2,147,483,648 to 2,147,483,647	8000 0000 to 7FFF FFFF

Addressing the Process-Image Input Register (I)

As described in Section 6.5, the CPU samples the physical input points at the beginning of each scan cycle and writes these values to the process-image input register. You can access the process-image input register in bits, bytes, words, or double words.

Format: Bit *I[byte address].[bit address]* I0.1
 Byte, Word, Double Word *I[size][starting byte address]* IB4

Addressing the Process-Image Output Register (Q)

At the end of the scan cycle, the CPU copies the values stored in the process-image output register to the physical output points. You can access the process-image output register in bits, bytes, words, or double words.

Format: Bit *Q[byte address].[bit address]* Q1.1
 Byte, Word, Double Word *Q[size][starting byte address]* QB5

Addressing the Variable (V) Memory Area

You can use V memory to store intermediate results of operations being performed by the control logic in your program. You can also use V memory to store other data pertaining to your process or task. You can access the V memory area in bits, bytes, words, or double words.

Format: Bit *V[byte address].[bit address]* V10.2
 Byte, Word, Double Word *V[size][starting byte address]* VW100

Addressing the Bit Memory (M) Area

You can use the internal memory bits (M memory) as control relays to store the intermediate status of an operation or other control information. While the name "bit memory area" implies that this information is stored in bit-length units, you can access the bit memory area not only in bits, but also in bytes, words, or double words.

Format: Bit *M[byte address].[bit address]* M26.7
 Byte, Word, Double Word *M[size][starting byte address]* MD20

Addressing the Sequence Control Relay (S) Memory Area

Sequence Control Relay bits (S) are used to organize machine operations or steps into equivalent program segments. SCRs allow logical segmentation of the control program. You can access the S bits as bits, bytes, words, or double words.

Format: Bit *S[byte address].[bit address]* S3.1
 Byte, Word, Double Word *S[size][starting byte address]* SB4

Addressing the Special Memory (SM) Bits

The SM bits provide a means for communicating information between the CPU and your program. You can use these bits to select and control some of the special functions of the S7-200 CPU, such as:

- A bit that turns on for the first scan
- Bits that toggle at fixed rates
- Bits that show the status of math or operational instructions

For more information about the SM bits, see Appendix D. While the SM area is based on bits, you can access the data in this area as bits, bytes, words, or double words.

Format: Bit *SM[byte address].[bit address]* SM0.1
 Byte, Word, Double Word *SM[size][starting byte address]* SMB86

Addressing the Timer (T) Memory Area

In the S7-200 CPU, timers are devices that count increments of time. The S7-200 timers have resolutions (time-base increments) of 1 ms, 10 ms, or 100 ms. There are two variables that are associated with a timer:

- Current value: this 16-bit signed integer stores the amount of time counted by the timer.
- Timer bit: this bit turns on (is set to 1) when the current value of the timer is greater than or equal to the preset value. (The preset value is entered as part of the timer instruction.)

You access both of these variables by using the timer address (T + timer number). Access to either the timer bit or the current value is dependent on the instruction used: instructions with bit operands access the timer bit, while instructions with word operands access the current value. As shown in Figure 7-3, the Normally Open Contact instruction accesses the timer bit, while the Move Word (MOV_W) instruction accesses the current value of the timer. For more information about the S7-200 instruction set, refer to Chapter 10.

Format: *T[timer number]* T24

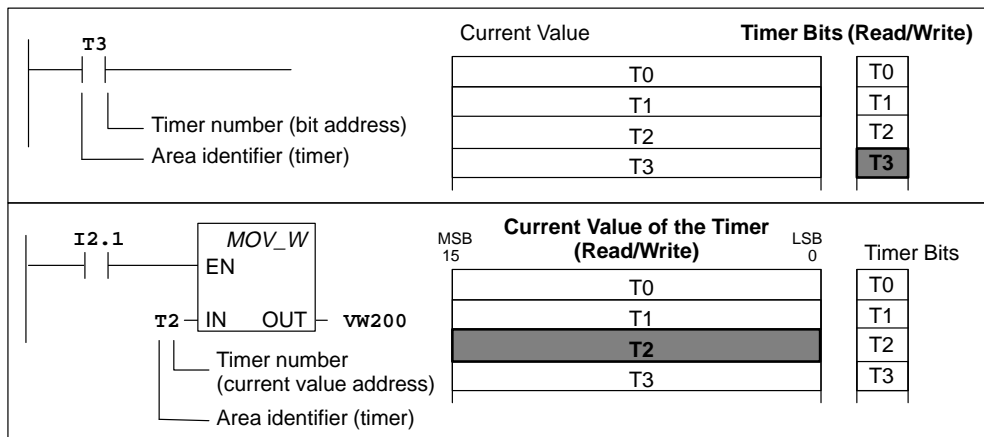


Figure 7-3 Accessing the Timer Data

Addressing the Counter (C) Memory Area

In the S7-200 CPU, counters are devices that count each low-to-high transition event on the counter input(s). The CPU provides two types of counters: one type counts up only, and the other counts both up and down. There are two variables that are associated with a counter:

- Current value: this 16-bit signed integer stores the accumulated count.
- Counter bit: this bit turns on (is set to 1) when the current value of the counter is greater than or equal to the preset value. (The preset value is entered as part of the counter instruction.)

You access both of these variables by using the counter address (C + counter number). Access to either the counter bit or the current value is dependent on the instruction used: instructions with bit operands access the counter bit, while instructions with word operands access the current value. As shown in Figure 7-4, the Normally Open Contact instruction accesses the counter bit, while the Move Word (MOV_W) instruction accesses the current value of the counter. For more information about the S7-200 instruction set, refer to Chapter 10.

Format: *C[counter number]* C20

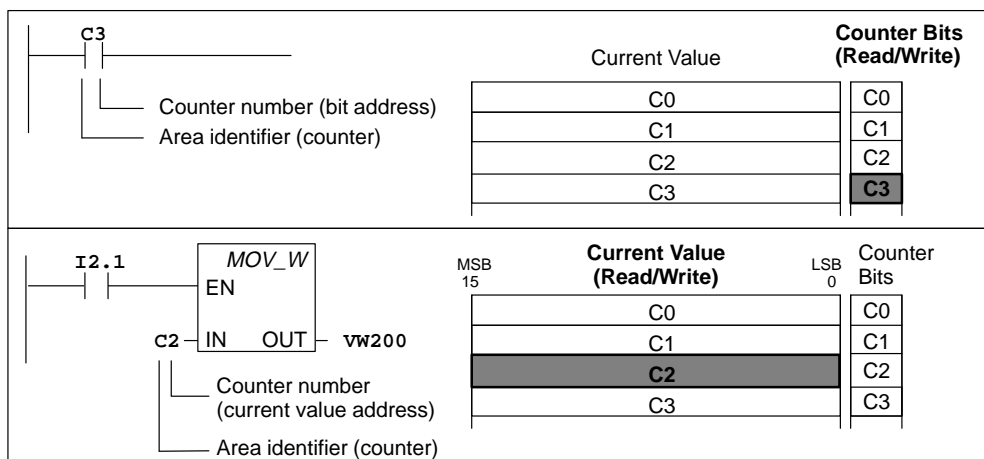


Figure 7-4 Accessing the Counter Data

Addressing the Analog Inputs (AI)

The S7-200 converts a real-world, analog value (such as temperature or voltage) into a word-length (16-bit) digital value. You access these values by the area identifier (AI), size of the data (W), and the starting byte address. Since analog inputs are words and always start on even-number bytes (such as 0, 2, or 4), you access them with even-number byte addresses (such as AIW0, AIW2, or AIW4), as shown in Figure 7-5. Analog input values are read-only values.

Format: *AIW[starting byte address]* *AIW4*

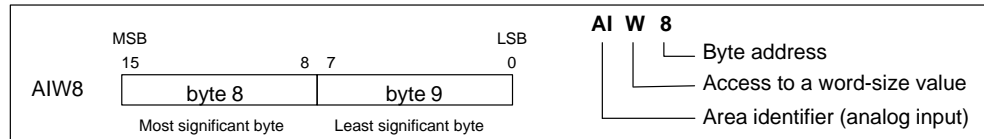


Figure 7-5 Accessing an Analog Input

Addressing the Analog Outputs (AQ)

The S7-200 converts a word-length (16-bit) digital value into a current or voltage, proportional to the digital value (such as for a current or voltage). You write these values by the area identifier (AQ), size of the data (W), and the starting byte address. Since analog outputs are words and always start on even-number bytes (such as 0, 2, or 4), you write them with even-number byte addresses (such as AQW0, AQW2, or AQW4), as shown in Figure 7-6. Your program cannot read the values of the analog outputs.

Format: *AQW[starting byte address]* *AQW4*

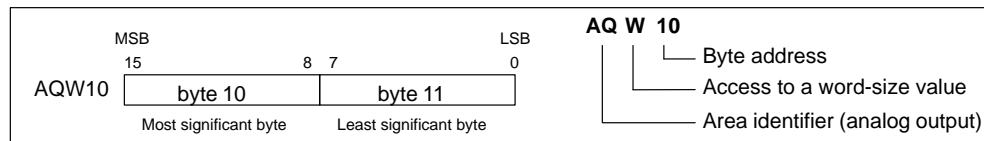


Figure 7-6 Accessing an Analog Output

Addressing the Accumulators (AC)

Accumulators are read/write devices that can be used like memory. For example, you can use accumulators to pass parameters to and from subroutines and to store intermediate values used in a calculation. The CPU provides four 32-bit accumulators (AC0, AC1, AC2, and AC3). You can access the data in the accumulators as bytes, words, or double words. As shown in Figure 7-7, to access the accumulator as bytes or words you use the least significant 8 or 16 bits of the value that is stored in the accumulator. To access the accumulator as a double word, you use all 32 bits. The size of the data being accessed is determined by the instruction that is used to access the accumulator.

Format: *AC[accumulator number]* *AC0*

Note

See Section 10.14 for information about using the accumulators with interrupt routines.

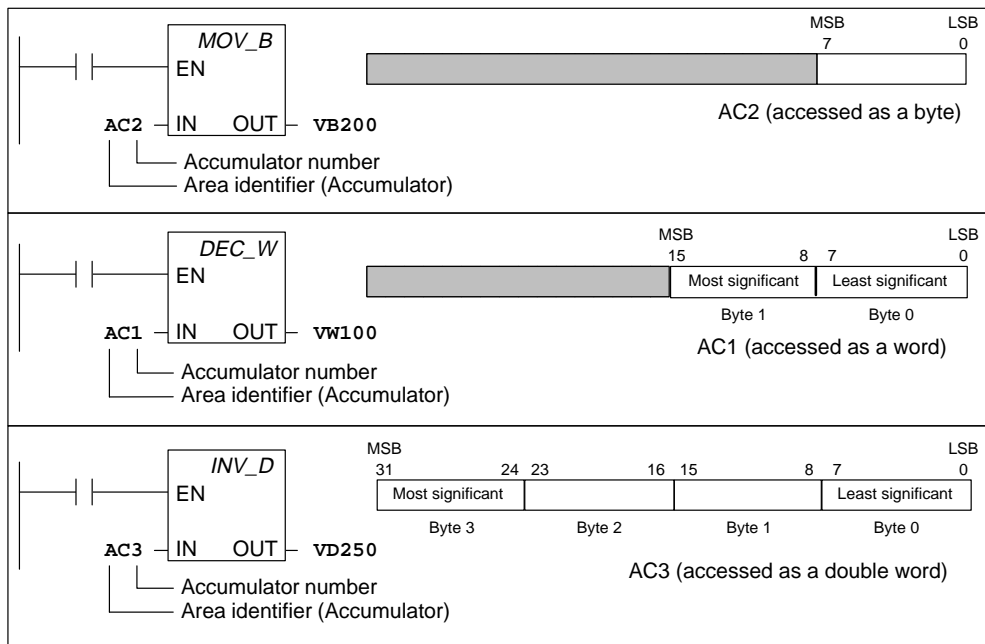


Figure 7-7 Addressing the Accumulators

Addressing the High-Speed Counters (HC)

High-speed counters are designed to count events faster than the CPU can scan the events. High-speed counters have a signed, 32-bit integer counting value (or current value). To access the count value for the high-speed counter, you specify the address of the high-speed counter, using the memory type (HC) and the counter number (such as HC0). The current value of the high-speed counter is a read-only value and, as shown in Figure 7-8, can be addressed only as a double word (32 bits).

Format: **HC[high-speed counter number] HC1**

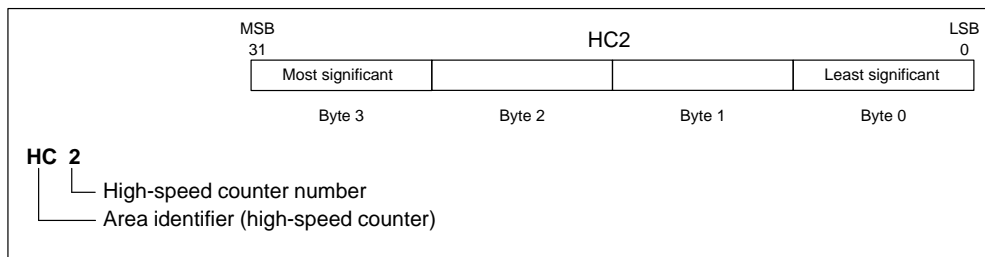


Figure 7-8 Accessing the High-Speed Counter Current Values

Using Constant Values

You can use a constant value in many of the S7-200 instructions. Constants can be bytes, words, or double words. The CPU stores all constants as binary numbers, which can then be represented in decimal, hexadecimal, or ASCII formats.

Decimal Format: [decimal value]
Hexadecimal Format: 16#[hexadecimal value]
ASCII Format: '[ASCII text]'

The S7-200 CPU does not support “data typing” or data checking (such as specifying that the constant is stored as an integer, a signed integer, or a double integer). For example, an Add instruction can use the value in VW100 as a signed integer value, while an Exclusive Or instruction can use the same value in VW100 as an unsigned binary value.

The following examples show constants for decimal, hexadecimal, and ASCII format:

- Decimal constant: 20047
- Hexadecimal constant: 16#4E4F
- ASCII constant: ·Text goes between single quotes·

7.2 Indirect Addressing of the CPU Memory Areas

Indirect addressing uses a pointer to access the data in memory. The S7-200 CPU allows you to use pointers to address the following memory areas indirectly: I, Q, V, M, S, T (current value only), and C (current value only). You cannot address individual bit or analog values indirectly.

Creating a Pointer

To address a location in memory indirectly, you must first create a pointer to that location. Pointers are double word memory locations that contain the address of another memory location. You can only use V memory locations or accumulator registers (AC1, AC2, AC3) as pointers. To create a pointer, you must use the Move Double Word (MOVD) instruction to move the address of the indirectly addressed memory location to the pointer location. The input operand of the instruction must be preceded with an ampersand (&) to signify that the address of a memory location, instead of its contents, is to be moved into the location identified in the output operand of the instruction (the pointer).

Example:

```

MOVD      &VB100, VD204
MOVD      &MB4, AC2
MOVD      &C4, VD6

```

Note

If you want to access a word or double word value in the I, Q, V, M, or S memory areas indirectly, you must specify the address of the value's initial byte as the input operand of the MOVD instruction used to create the pointer. For example, VB100 is the address of the initial byte of VW100, and MB4 is the address of the initial byte of MD4. If a symbol name was assigned to the word or double word value, then you cannot use that symbol name in the MOVD instruction used to create the pointer since the address of the value's initial byte must be specified in the instruction's input operand. You must assign a different symbol name to the address of the initial byte of the word or double word memory location for use in pointer creation under these circumstances.

Example: 'Pump_Speed' assigned as the symbol name for VW100
 'Pump_Speed_IB' assigned as the symbol name for VB100
 (which is the initial byte of the word value stored in VW100)

```

MOVD &"Pump_Speed", AC1    illegal (&VW100 is not allowed)
MOVD &"Pump_Speed_IB", AC1 correct (&VB100 is OK)

```

Using a Pointer to Access Data

Entering an asterisk (*) in front of an operand for an instruction specifies that the operand is a pointer. Using the example shown in Figure 7-9, *AC1 specifies that AC1 is a pointer to the word-length value being referenced by the Move Word (MOVW) instruction. In this example, the values stored in both V200 and V201 are moved to accumulator AC0.

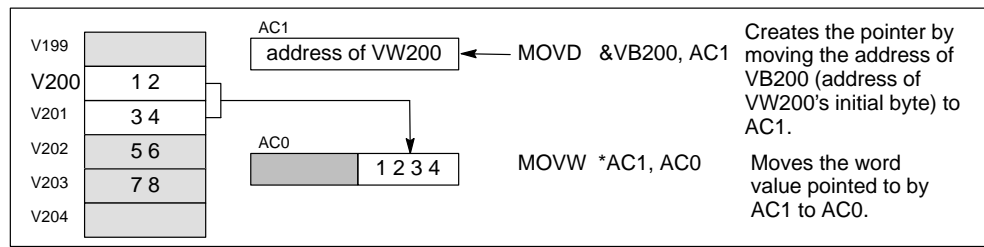


Figure 7-9 Using a Pointer for Indirect Addressing

Modifying Pointers

You can change the value of a pointer. Since pointers are 32-bit values, use double-word instructions to modify pointer values. Simple mathematical operations, such as adding or incrementing, can be used to modify pointer values. Remember to adjust for the size of the data that you are accessing:

- When accessing bytes, increment the pointer value by one.
- When accessing a word or a current value for a timer or counter, add or increment the pointer value by two.
- When accessing a double word, add or increment the pointer value by four.

Figure 7-10 shows an example of how you can create an indirect address pointer, how data is accessed indirectly, and how you can increment the pointer.

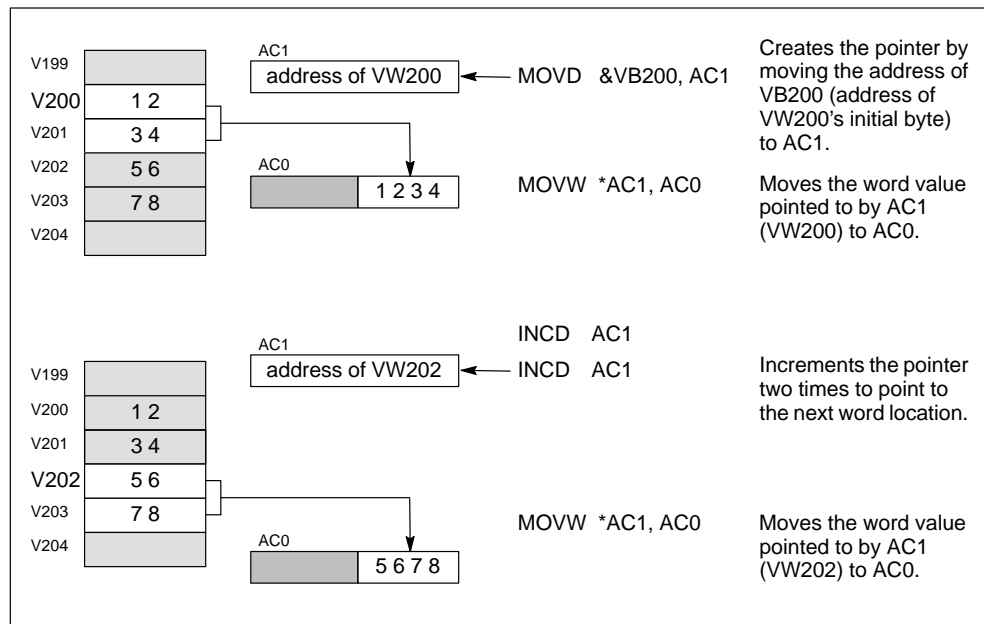


Figure 7-10 Modifying a Pointer When Accessing a Word Value

7.3 Memory Retention for the S7-200 CPU

The S7-200 CPU provides several methods to ensure that your program, the program data, and the configuration data for your CPU are properly retained:

- The CPU provides an EEPROM to store permanently all of your program, selected data areas, and the configuration data for your CPU. See Figure 7-11.
- The CPU provides a super capacitor that maintains the integrity of the RAM after power has been removed from the CPU. Depending on the CPU module, the super capacitor can maintain the RAM for several days.
- Some CPU modules support an optional battery cartridge that extends the amount of time that the RAM can be maintained after power has been removed from the CPU. The battery cartridge provides power only after the super capacitor has been drained.

This section discusses the permanent storage and retention of the data in RAM under a variety of circumstances.

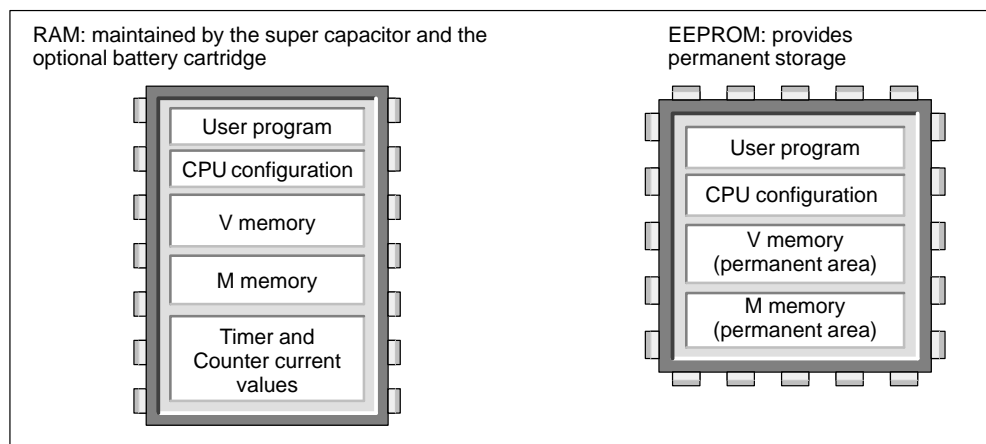


Figure 7-11 Storage Areas of an S7-200 CPU

Downloading and Uploading Your Program

Your program consists of three elements: the user program, the data block (optional), and the CPU configuration (optional). As shown in Figure 7-12, downloading the program stores these elements in the RAM area of the CPU memory. The CPU also automatically copies the user program, data block (DB1), and the CPU configuration to the EEPROM for permanent storage.

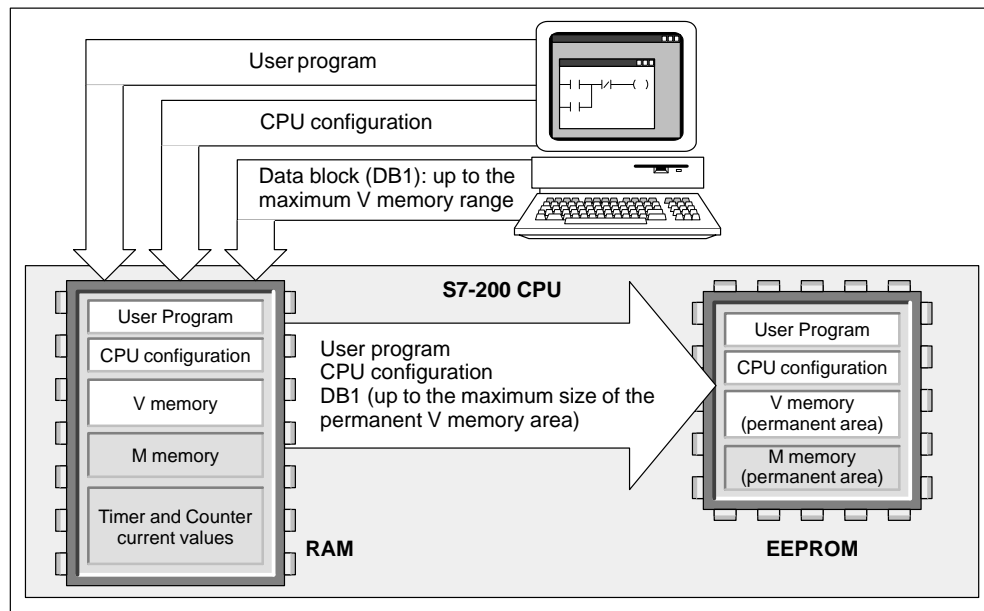


Figure 7-12 Downloading the Elements of the Program

When you upload a program from the CPU, as shown in Figure 7-13, the user program and the CPU configuration are uploaded from the RAM to your computer. When you upload the data block, the permanent area of the data block (stored in the EEPROM) is merged with the remainder of the data block (if any) that is stored in RAM. The complete data block is then transferred to your computer. The size of the permanent V memory area depends on your CPU. See Section 10.1.

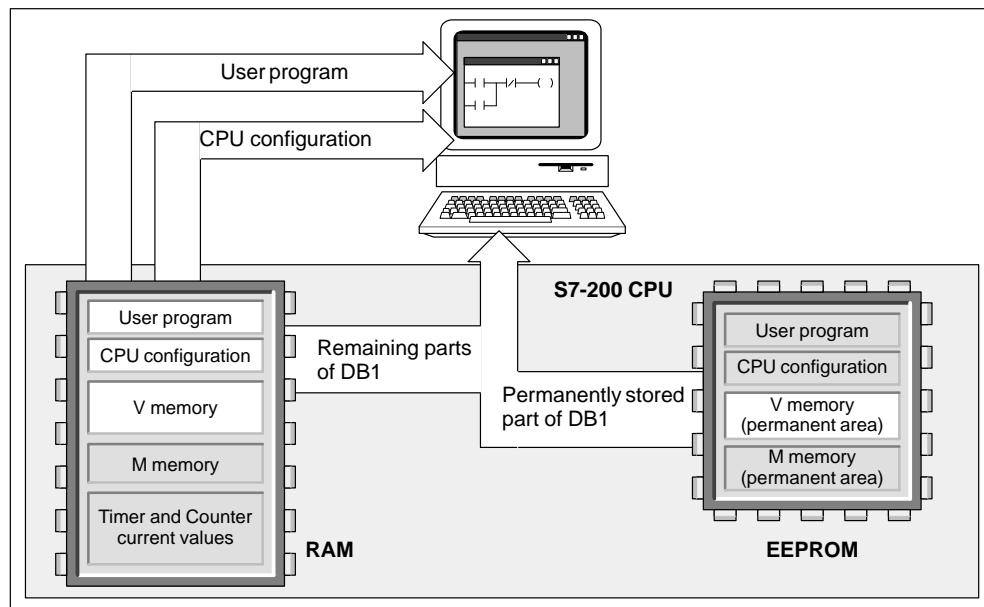


Figure 7-13 Uploading the Elements of the Program

Automatically Saving the Data from the Bit Memory (M) Area When the CPU Loses Power

The first 14 bytes of M memory (MB0 to MB13), if configured to be retentive, are permanently saved to the EEPROM when the CPU module loses power. As shown in Figure 7-14, the CPU moves these retentive areas of M memory to the EEPROM.

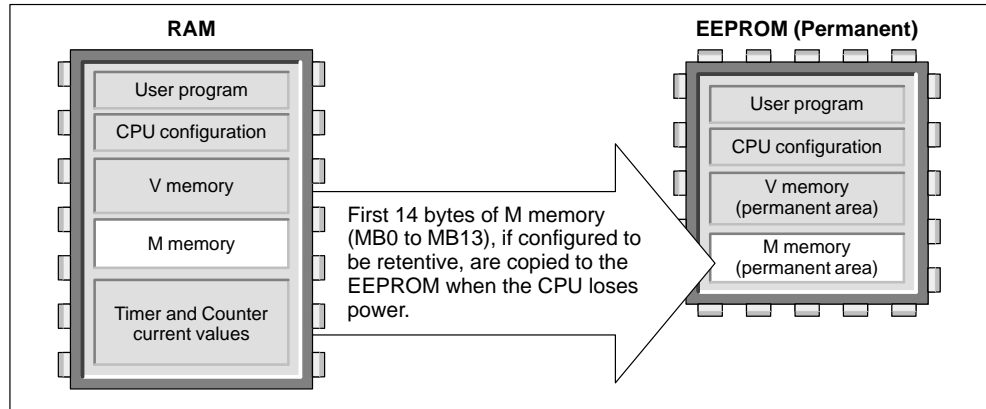


Figure 7-14 Saving Parts of Bit Memory (M) to EEPROM on Power Off

Retaining Memory on Power On

At power-up, the CPU restores the user program and the CPU configuration from the EEPROM memory. See Figure 7-15.

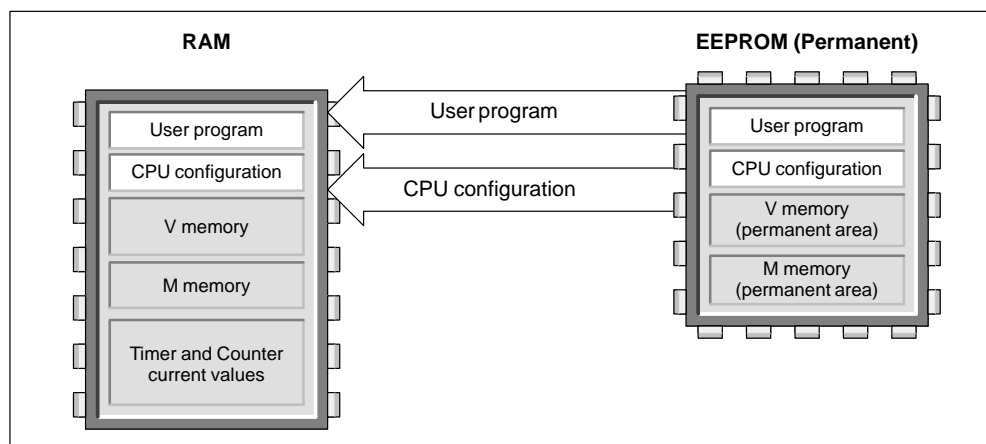


Figure 7-15 Restoring the User Program and CPU Configuration on Power On

At power on, the CPU checks the RAM to verify that the super capacitor successfully maintained the data stored in RAM memory. If the RAM was successfully maintained, the retentive areas of RAM are left unchanged. As shown in Figure 7-16, the non-retentive areas of V memory are restored from the corresponding permanent area of V memory in the EEPROM.

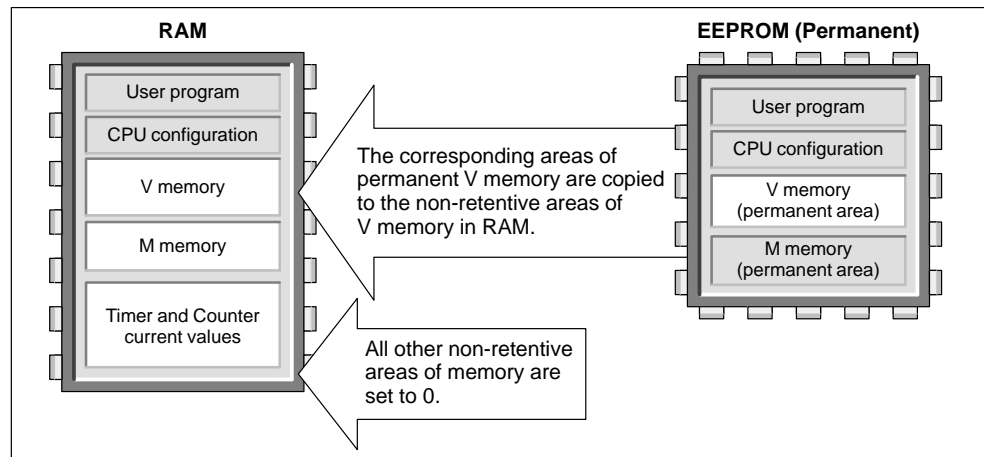


Figure 7-16 Restoring Program Data on Power On (Data Was Successfully Maintained in RAM)

If the contents of the RAM were not maintained (such as after an extended power failure), the CPU clears the RAM (including both the retentive and non-retentive ranges) and sets the Retentive Data Lost memory bit (SM0.2) for the first scan following power on. As shown in Figure 7-17, the data stored in the permanent EEPROM are then copied to the RAM.

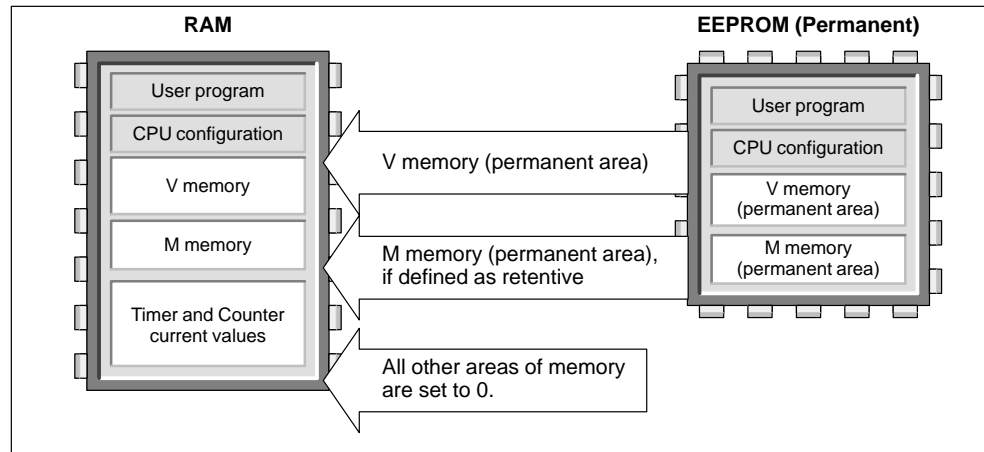


Figure 7-17 Restoring Program Data on Power On (Data Not Maintained in RAM)

Defining Retentive Ranges of Memory

As shown in Figure 7-18, you can define up to six retentive ranges to select the areas of memory you want to retain through power cycles. You can define ranges of addresses in the following memory areas to be retentive: V, M, C, and T. For timers, only the retentive timers (TONR) can be retained.

Note

Only the current values for timers and counters can be retained: the timer and counter bits are not retentive.

To define the retentive ranges for the memory areas, select the **CPU ► Configure** menu command and click the Retentive Ranges tab. The dialog box for defining specific ranges to be retentive is shown in Figure 7-18. To obtain the default retentive ranges for your CPU, press the **Defaults** button.

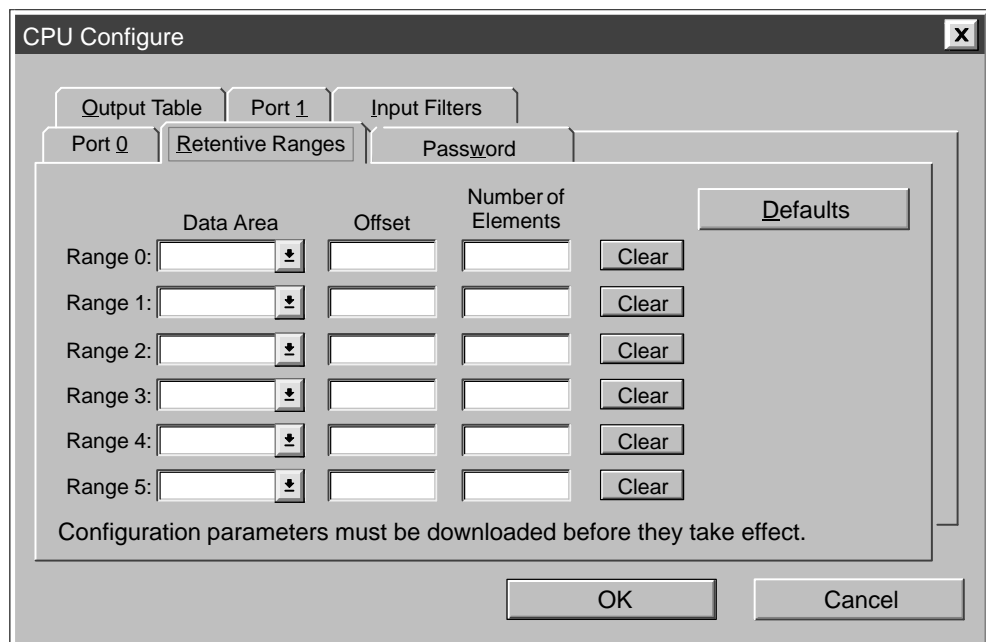


Figure 7-18 Configuring the Retentive Ranges for the CPU Memory

7.4 Using Your Program to Store Data Permanently

You can save a value (byte, word, or double word) stored in V memory to EEPROM. This feature can be used to store a value in any location of the permanent V memory area.

A save-to-EEPROM operation typically affects the scan time by 15 ms to 20 ms. The value written by the save operation overwrites any previous value stored in the permanent V memory area of the EEPROM.

Note

The save-to-EEPROM operation does not update the data in the memory cartridge.

Copying V Memory to the EEPROM

Special Memory Byte 31 (SMB31) and Special Memory Word 32 (SMW32) command the CPU to copy a value in V memory to the permanent V memory area of the EEPROM. Figure 7-19 shows the format of SMB31 and SMW32. Use the following steps to program the CPU to save or write a specific value in V memory:

1. Load the V memory address of the value to be saved in SMW32.
2. Load the size of the data in SM31.0 and SM31.1. (See Figure 7-19.)
3. Set SM31.7 to 1.

At the end of every scan, the CPU checks SM31.7; if the SM31.7 equals 1, the specified value is saved to the EEPROM. The operation is complete when the CPU resets SM31.7 to 0. Do not change the value in V memory until the save operation is complete.

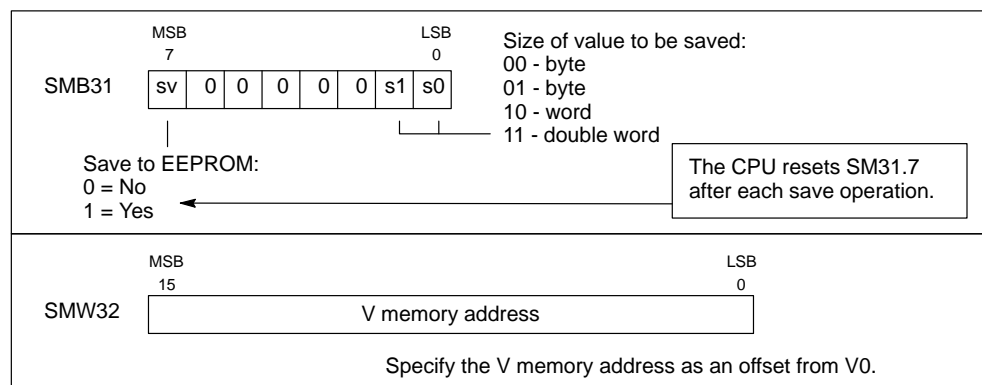


Figure 7-19 Format of SMB31 and SMW32

Limiting the Number of Programmed Saves to EEPROM

Since the number of save operations to the EEPROM is limited (100,000 minimum, and 1,000,000 typical), ensure that only necessary values are saved. Otherwise, the EEPROM can be worn out and the CPU can fail. Typically, you perform save operations at the occurrence of specific events that occur rather infrequently.

For example, if the scan time of the S7-200 is 50 ms and a value was saved once per scan, the EEPROM would last a minimum of 5,000 seconds, which is less than an hour and a half. On the other hand, if a value were saved once an hour, the EEPROM would last a minimum of 11 years.

7.5 Using a Memory Cartridge to Store Your Program

Some CPUs support an optional memory cartridge that provides a portable EEPROM storage for your program. You can use the memory cartridge like a diskette. The CPU stores the following elements on the memory cartridge:

- User program
- Data stored in the permanent V memory area of the EEPROM
- CPU configuration

For information about the memory cartridge that is appropriate for your CPU, see Appendix A.

Copying to the Memory Cartridge

You can copy your program to the memory cartridge from the RAM only when the CPU is powered on and the memory cartridge is installed.



Caution

Electrostatic discharge can damage the memory cartridge or the receptacle on the CPU.

Make contact with a grounded conductive pad and/or wear a grounded wrist strap when you handle the cartridge. Store the cartridge in a conductive container.

You can install or remove the memory cartridge while the CPU is powered on. To install the memory cartridge, remove the protective tape from the memory cartridge receptacle, and insert the memory cartridge into the receptacle located under an access cover of the CPU module. (The memory cartridge is keyed for proper installation.) After the memory cartridge is installed, use the following procedure to copy the program.

1. If the program has not already been downloaded to the CPU, download the program.
2. Use the menu command **CPU ► Program Memory Cartridge** to copy the program to the memory cartridge. Figure 7-20 shows the elements of the CPU memory that are stored on the memory cartridge.
3. Remove the memory cartridge (optional).

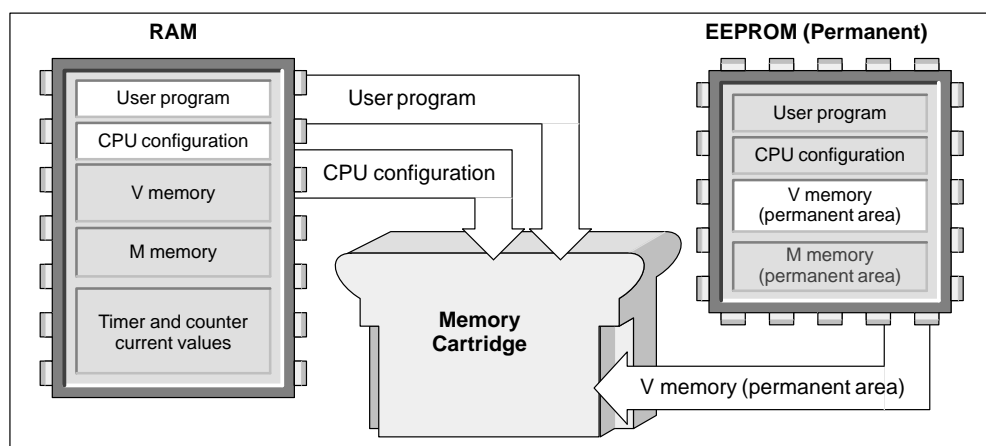


Figure 7-20 Copying the CPU Memory to the Memory Cartridge

Restoring the Program and Memory with a Memory Cartridge

To transfer the program from a memory cartridge to the CPU, you must cycle the power to the CPU with the memory cartridge installed. As shown in Figure 7-21, the CPU performs the following tasks after a power cycle (when a memory cartridge is installed):

- The RAM is cleared.
- The contents of the memory cartridge are copied to the RAM.
- The user program, the CPU configuration, and the V memory area (up to the maximum size of the permanent V memory area) are copied to the permanent EEPROM.

Note

Powering on a CPU with a blank memory cartridge, or a memory cartridge that was programmed in a different model number CPU, causes an error. Remove the memory cartridge and power on again. The memory cartridge can then be inserted and programmed.

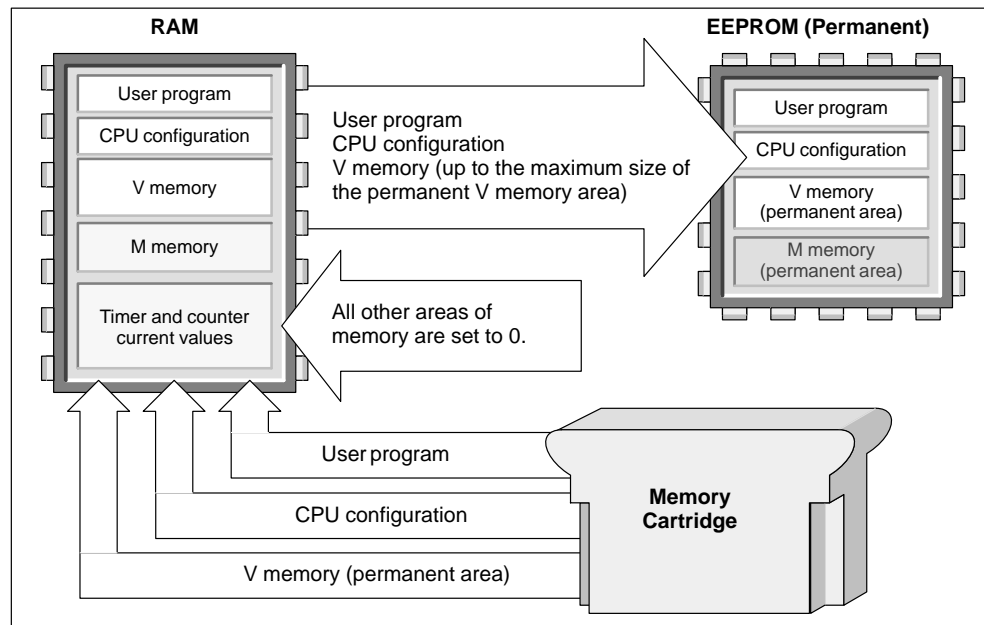


Figure 7-21 Restoring Memory on Power On (with Memory Cartridge Installed)

Input/Output Control

The inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as sensors and switches), and the outputs control pumps, motors, or other devices in your process. You can have local I/O (provided by the CPU module) or expansion I/O (provided by an expansion I/O module). The S7-200 CPU modules also provide high-speed I/O.

Chapter Overview

Section	Description	Page
8.1	Local I/O and Expansion I/O	8-2
8.2	Using the Selectable Input Filter to Provide Noise Rejection	8-5
8.3	Using the Output Table to Configure the States of the Outputs	8-6
8.4	High-Speed I/O	8-7
8.5	Analog Adjustments	8-8

8.1 Local I/O and Expansion I/O

The inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as sensors and switches), and the outputs control pumps, motors, or other devices in your process. You can have local I/O (provided by the CPU) or expansion I/O (provided by an expansion I/O module):

- The S7-200 CPU module provides a certain number of digital local I/O points. For more information about the amount of local I/O provided by your CPU module, refer to the data sheets in Appendix A.
- The S7-200 CPU modules support the addition of both digital and analog expansion I/O. For more information about the capabilities of the different expansion I/O modules, refer to the data sheets in Appendix A.

Addressing the Local and Expansion I/O

The local I/O provided by the CPU module provides a fixed set of I/O addresses. You can add I/O points to the CPU by connecting expansion I/O modules to the right side of the CPU, forming an I/O chain. The addresses of the points of the module are determined by the type of I/O and the position of the module in the chain, with respect to the preceding input or output module of the same type. For example, an output module does not affect the addresses of the points on an input module, and vice versa. Likewise, analog modules do not affect the addressing of digital modules, and vice versa.

Discrete or digital expansion modules always reserve process-image register space in increments of eight bits (one byte). If a module does not provide a physical point for each bit of each reserved byte, these unused bits cannot be assigned to subsequent modules in the I/O chain. For output modules, the unused bits in the reserved bytes can be used like internal memory bits (M bits). For input modules, the unused bits in reserved bytes are set to zero with each input update cycle, and therefore cannot be used as internal memory bits.

Analog expansion modules are always allocated in increments of two points. If a module does not provide physical I/O for each of these points, these I/O points are lost and are not available for assignment to subsequent modules in the I/O chain. Since there is no image memory provided for analog I/O, there is no way to use these unused analog I/O points. All analog I/O accesses are made immediately at the time of instruction execution.

Examples of Local and Expansion I/O

Figures 8-1, 8-2, and 8-3 provide examples that show how different hardware configurations affect the I/O numbering. Notice that some of the configurations contain gaps in the addressing that cannot be used by your program, while other I/O addresses can be used in the same manner as the internal memory (M) bits.

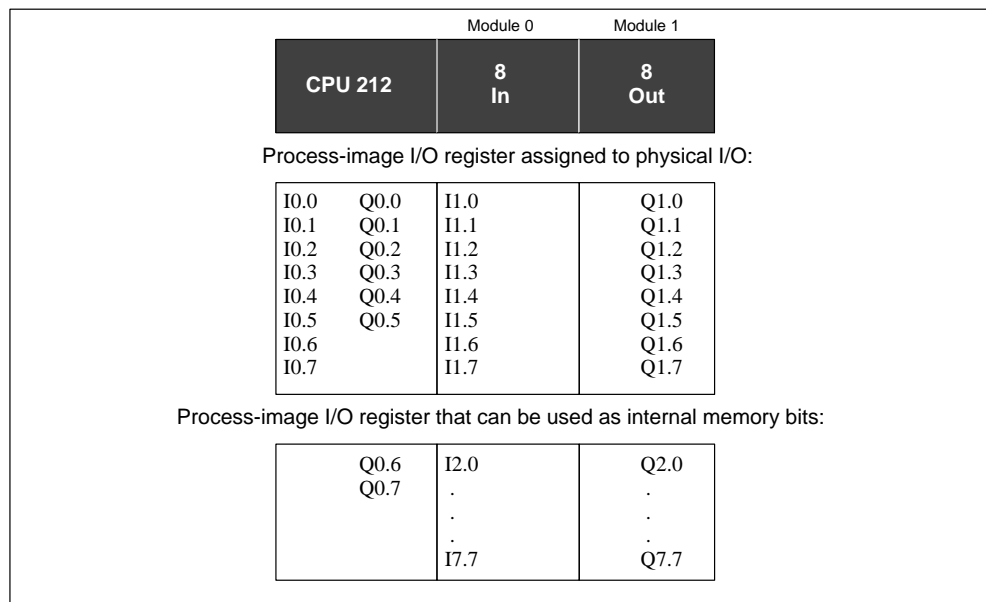


Figure 8-1 I/O Numbering Examples for a CPU 212

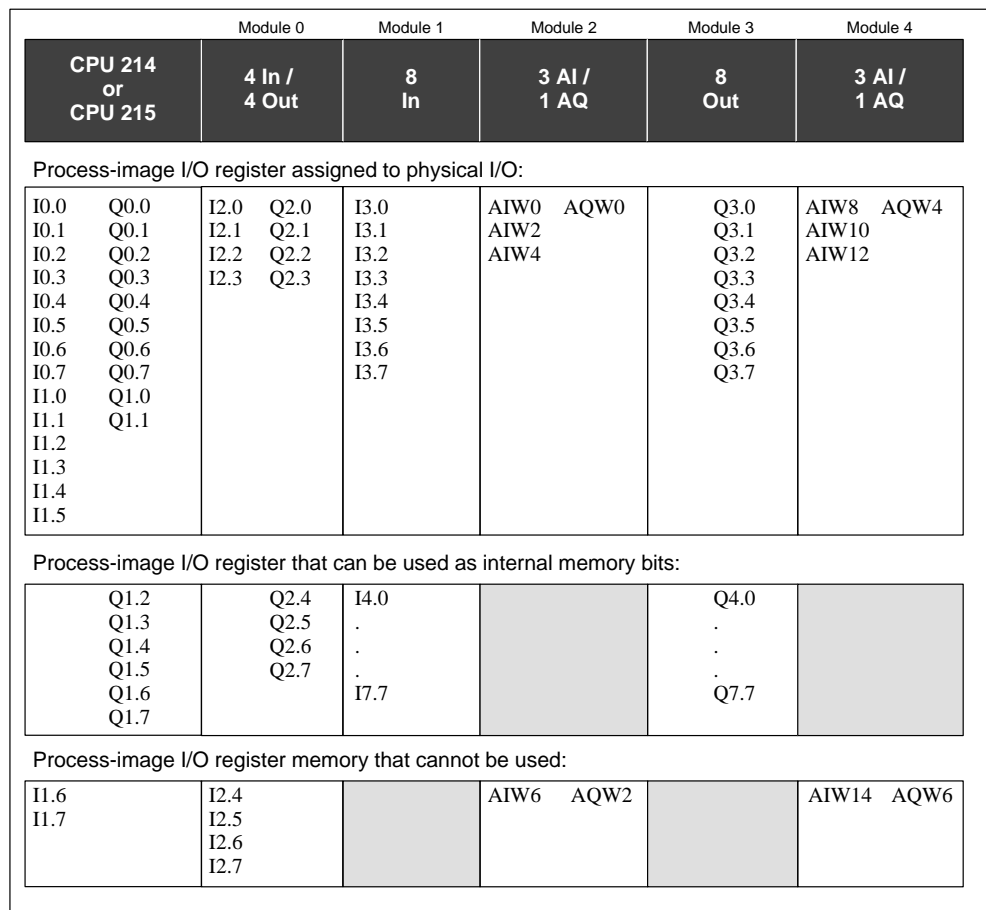


Figure 8-2 I/O Numbering Examples for a CPU 214 or CPU 215

Module 0		Module 1		Module 2	
CPU 216		8 In / 8 Out	16 In / 16 Out	16 In / 16 Out	
Process-image I/O register assigned to physical I/O:					
I0.0	Q0.0	I3.0	Q2.0	I4.0	Q3.0
I0.1	Q0.1	I3.1	Q2.1	I4.1	Q3.1
I0.2	Q0.2	I3.2	Q2.2	I4.2	Q3.2
I0.3	Q0.3	I3.3	Q2.3	I4.3	Q3.3
I0.4	Q0.4	I3.4	Q2.4	I4.4	Q3.4
I0.5	Q0.5	I3.5	Q2.5	I4.5	Q3.5
I0.6	Q0.6	I3.6	Q2.6	I4.6	Q3.6
I0.7	Q0.7	I3.7	Q2.7	I4.7	Q3.7
I1.0	Q1.0			I5.0	Q4.0
I1.1	Q1.1			I5.1	Q4.1
I1.2	Q1.2			I5.2	Q4.2
I1.3	Q1.3			I5.3	Q4.3
I1.4	Q1.4			I5.4	Q4.4
I1.5	Q1.5			I5.5	Q4.5
I1.6	Q1.6			I5.6	Q4.6
I1.7	Q1.7			I5.7	Q4.7
I2.0					I6.0
I2.1					I6.1
I2.2					I6.2
I2.3					I6.3
I2.4					I6.4
I2.5					I6.5
I2.6					I6.6
I2.7					I6.7
					I7.0
					I7.1
					I7.2
					I7.3
					I7.4
					I7.5
					I7.6
					I7.7
					Q5.0
					Q5.1
					Q5.2
					Q5.3
					Q5.4
					Q5.5
					Q5.6
					Q5.7
					Q6.0
					Q6.1
					Q6.2
					Q6.3
					Q6.4
					Q6.5
					Q6.6
					Q6.7

Figure 8-3 I/O Numbering Examples for a CPU 216

8.2 Using the Selectable Input Filter to Provide Noise Rejection

Some S7-200 CPUs allow you to select an input filter that defines a delay time (selectable from 0.2 ms to 8.7 ms) for some or all of the local digital input points. (See Appendix A for information about your particular CPU.) As shown in Figure 8-4, this delay time is added to the standard response time for groups of four input points. This delay helps to filter noise on the input wiring that could cause inadvertent changes to the states of the inputs.

The input filter is part of the CPU configuration data that is downloaded and stored in the CPU memory.

Use the menu command **CPU ► Configure...** and click on the Input Filters tab to configure the delay times for the input filter.

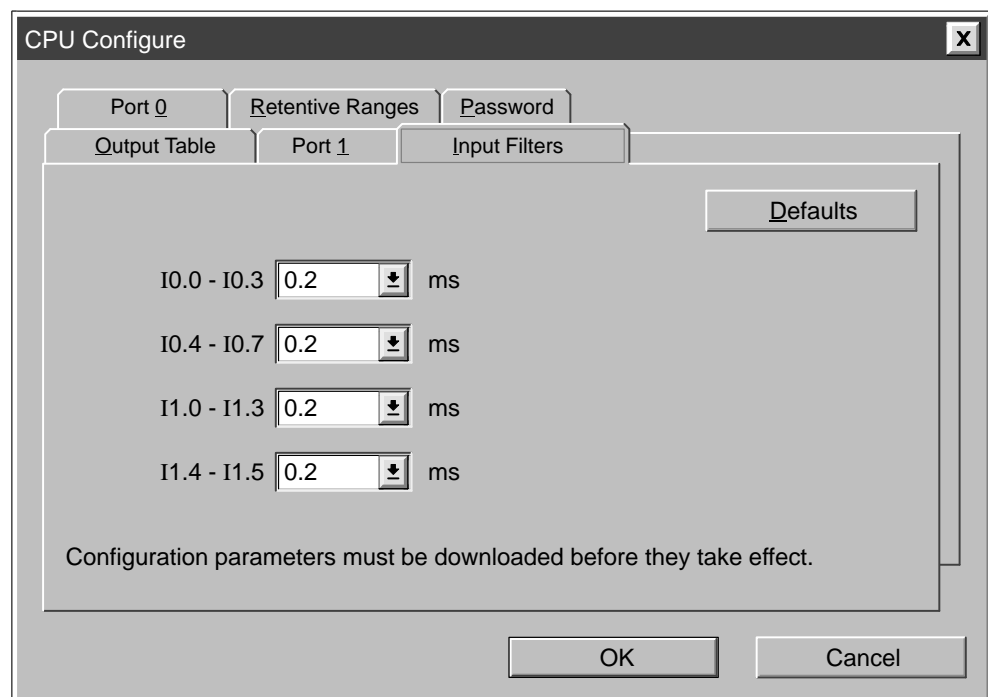


Figure 8-4 Configuring the Input Filters for Rejecting Noise

8.3 Using the Output Table to Configure the States of the Outputs

The S7-200 CPU provides the capability either to set the state of the digital output points to known values upon a transition to the STOP mode, or to leave the outputs in the state they were in prior to the transition to the STOP mode.

The output table is part of the CPU configuration data that is downloaded and stored in the CPU memory.

The configuration of output values applies only to the digital outputs. Analog output values are effectively frozen upon a transition to the STOP mode. This occurs because your program is responsible for updating the analog outputs as required. The CPU does not update the analog inputs or outputs as a system function. No internal memory image is maintained for these points by the CPU.

Select the menu command **CPU ► Configure...** and click on the Output Table tab to access the output table configuration dialog. See Figure 8-5. You have two options for configuring the outputs:

- If you want to freeze the outputs in their last state, choose the Freeze Outputs box and click on "OK."
- If you want to copy the table values to the outputs, then enter the output table values. Click the checkbox for each output bit you want to set to On (1) after a run-to-stop transition, and click on "OK" to save your selections.

The default setting of the CPU is the mode of copying the output table values to the outputs. The default values of the table are all zeroes.

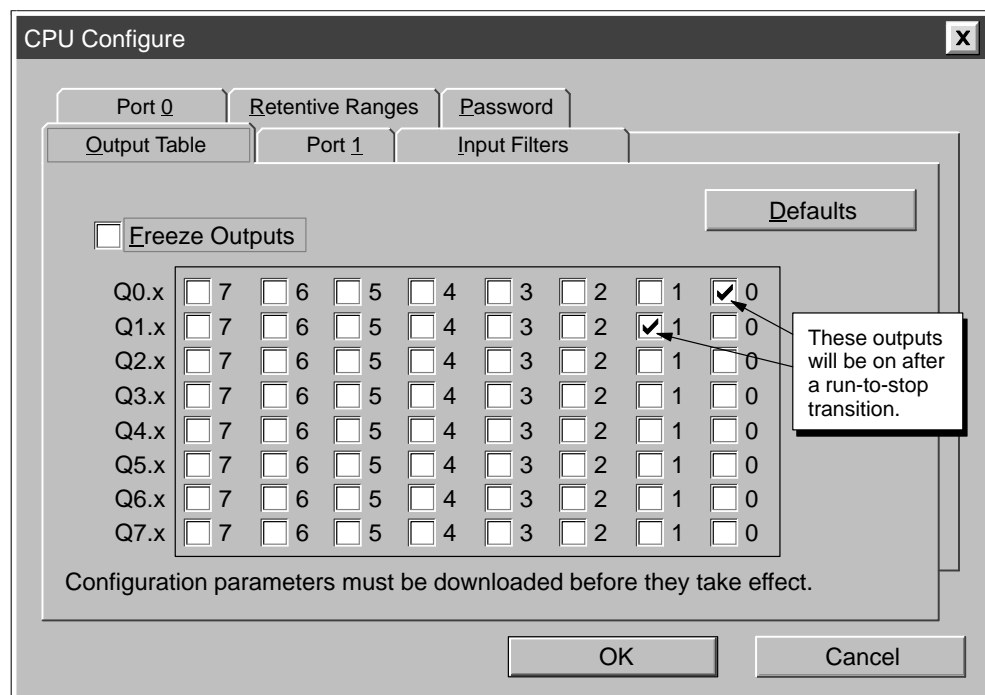


Figure 8-5 Configuring the State of the Outputs

8.4 High-Speed I/O

Your S7-200 CPU module provides high-speed I/O for controlling high-speed events. For more information about the high-speed I/O provided by each CPU module, refer to the data sheets in Appendix A.

High-Speed Counters

High-speed counters count high-speed events that cannot be controlled at the scan rates of the S7-200 CPU modules. Your S7-200 CPU module provides one software high-speed counter and up to two hardware high-speed counters (depending on your CPU):

- HSC0 is an up/down software counter that accepts a single clock input. The counting direction (up or down) is controlled by your program, using the direction control bit. The maximum counting frequency of HSC0 is 2 KHz.
- HSC1 and HSC2 are versatile hardware counters that can be configured for one of twelve different modes of operation. The counter modes are listed in Table 10-5. The maximum counting frequency of HSC1 and HSC2 is dependent on your CPU. See Appendix A.

Each counter has dedicated inputs for clocks, direction control, reset, and start, where these functions are supported. In quadrature modes, an option is provided to select one or four times the maximum counting rates. HSC1 and HSC2 are completely independent of each other and do not affect other high-speed functions. Both counters run at maximum rates without interfering with one another.

For more information about using the high-speed counters, see Section 10.5.

High-Speed Pulse Output

The S7-200 CPU supports high-speed pulse outputs. In these modules, Q0.0 and Q0.1 can either generate high-speed pulse train outputs (PTO) or perform pulse width modulation (PWM) control.

- The pulse train function provides a square wave (50% duty cycle) output for a specified number of pulses and a specified cycle time. The number of pulses can be specified from 1 to 4,294,967,295 pulses. The cycle time can be specified in either microsecond or millisecond increments either from 250 μ s to 65,535 μ s or from 2 ms to 65,535 ms. Specifying any odd number of microseconds or milliseconds (such as 75 ms) causes some duty cycle distortion.
- The pulse width modulation function provides a fixed cycle time with a variable duty cycle output. The cycle time and the pulse width can be specified in either microsecond or millisecond increments. The cycle time has a range either from 250 μ s to 65,535 μ s or from 2 ms to 65,535 ms. The pulse width time has a range either from 0 μ s to 65,535 μ s or from 0 ms to 65,535 ms. When the pulse width is equal to the cycle time, the duty cycle is 100 percent and the output is turned on continuously. When the pulse width is zero, the duty cycle is 0 percent and the output is turned off.

For more information about the high-speed outputs, see Section 10.5.

8.5 Analog Adjustments

Your S7-200 CPU module provides one or two analog adjustments (potentiometers located under the access cover of the module). You can adjust these potentiometers to increase or decrease values that are stored in bytes of Special Memory (SMB28 and SMB29). These read-only values can be used by the program for a variety of functions, such as updating the current value for a timer or a counter, entering or changing the preset values, or setting limits.

SMB28 holds the digital value that represents the position of analog adjustment 0. SMB29 holds the digital value that represents the position of analog adjustment 1. The analog adjustment has a nominal range of 0 to 255 and a guaranteed range of 10 to 200.

You use a small screwdriver to make the adjustments: turn the potentiometer clockwise (to the right) to increase the value, and counterclockwise (to the left) to decrease the value. Figure 8-6 shows an example program using the analog adjustment.

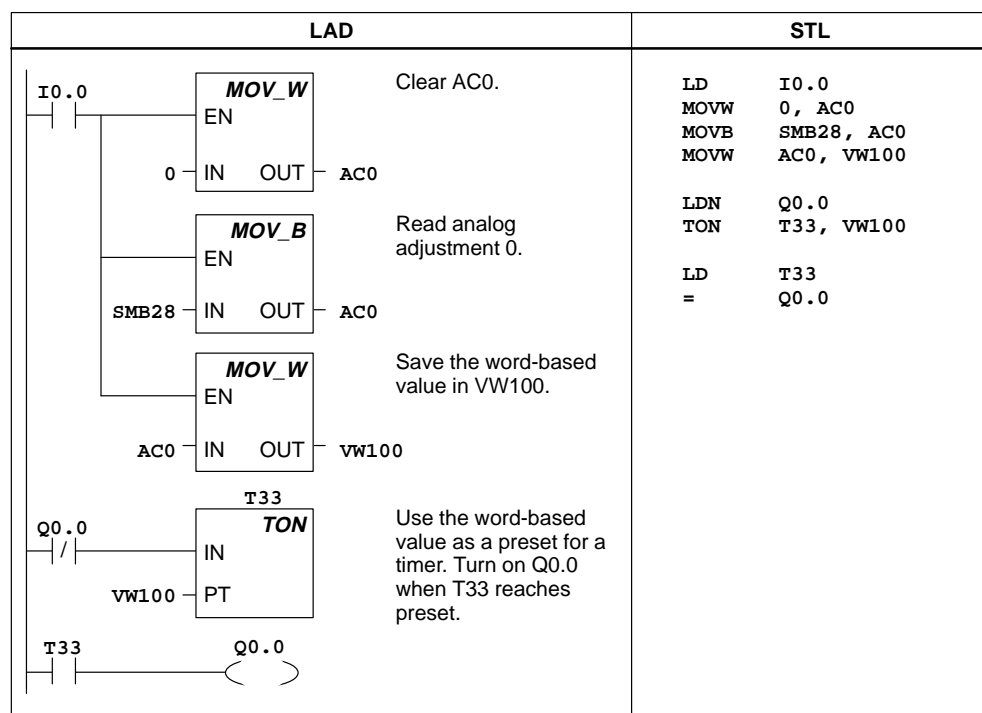


Figure 8-6 Example of Analog Adjustment

Network Communications and the S7-200 CPU

9

The S7-200 CPUs support a variety of data communication methods, including the following:

- Communication from point to point (PPI)
- Communication over a multiple-master network
- Communication over a network of distributed peripherals (remote I/O)

Chapter Overview

Section	Description	Page
9.1	Communication Capabilities of the S7-200 CPU	9-2
9.2	Communication Network Components	9-6
9.3	Data Communications Using the PC/PPI Cable	9-9
9.4	Data Communications Using the MPI or CP Card	9-13
9.5	Distributed Peripheral (DP) Standard Communications	9-15
9.6	Network Performance	9-28

9.1 Communication Capabilities of the S7-200 CPU

Network Communication Protocols

The S7-200 CPUs support a variety of communication capabilities. Depending on the S7-200 CPU that you use, your network can support one or more of the following communication protocols:

- Point-to-Point Interface (PPI)
- Multipoint Interface (MPI)
- PROFIBUS-DP

See Table 9-1 for details.

Table 9-1 Communication Capabilities for S7-200 CPUs

CPU	Port	PPI Slave	PPI Master	PROFIBUS-DP Slave	MPI Slave	Freeport	Baud Rate
212	0	Yes	No	No	No	Yes	9.6 kbaud, 19.2 kbaud
214	0	Yes	Yes	No	No	Yes	9.6 kbaud, 19.2 kbaud
215	0	Yes	Yes	No	Yes	Yes	9.6 kbaud, 19.2 kbaud
	DP	No	No	Yes	Yes	No	9.6 kbaud, 19.2 kbaud, 93.75 kbaud, 187.5 kbaud, 500 kbaud, 1 Mbaud, 1.5 Mbaud, 3 Mbaud, 6 Mbaud, 12 Mbaud
216	0	Yes	Yes	No	Yes	Yes	9.6 kbaud, 19.2 kbaud
	1	Yes	Yes	No	Yes	Yes	9.6 kbaud, 19.2 kbaud

These protocols are based upon the Open System Interconnection (OSI) seven-layer model of communications architecture. The PPI, MPI, and PROFIBUS-DP protocols are implemented on a token ring network which conforms to the Process Field Bus (PROFIBUS) standard as defined in the European Standard EN 50170.

These protocols are asynchronous, character-based protocols with one start bit, eight data bits, even parity, and one stop bit. Communication frames depend upon special start and stop characters, source and destination station addresses, frame length, and a checksum for data integrity. The three protocols can run on a network simultaneously without interfering with each other as long as the baud rate is the same for each of them.

The PROFIBUS network uses the RS-485 standard on twisted pair cables. This allows up to 32 devices to be connected together on a network segment. Network segments can be up to 1,200 m (3,936 ft.) in length, depending on the baud rate. Network segments can be connected with repeaters to allow more devices on a network and greater cable lengths. Networks can be up to 9,600 m (31,488 ft.) using repeaters, depending on the baud rate. See Section 9.2.

The protocols define two types of network devices: masters and slaves. Master devices can initiate a request to another device on the network. Slave devices can only respond to requests from master devices. Slaves never initiate a request on their own.

The protocols support 127 addresses (0 through 126) on a network. There can be up to 32 master devices on a network. All devices on a network must have different addresses in order to be able to communicate. SIMATIC programming devices and PCs running STEP 7-Micro/WIN have the default address of 0. Operator panels such as the TD 200, OP3, and the OP7 default to address 1. The programmable controllers have the default address of 2. The DP port on the CPU 215 has the default address of 126.

PPI Protocol

PPI is a master/slave protocol. In this protocol the master devices (other CPUs, SIMATIC programming devices, or TD 200s) send requests to the slave devices and the slave devices respond. Slave devices do not initiate messages, but wait until a master sends them a request or polls them for a response. All S7-200 CPUs act as slave devices on the network.

Some S7-200 CPUs can act as master devices while they are in RUN mode, if you enable PPI master mode in the user program. (See the description of SMB30 in Appendix D.) Once PPI master mode has been enabled, you can read from or write to other CPUs by using the Network Read (NETR) and Network Write (NETW) instructions. See Chapter 10 for a description of these instructions. While acting as a PPI master, the S7-200 CPU still responds as a slave to requests from other masters.

PPI has no limit on how many masters can communicate to any one slave CPU, but there can be no more than 32 masters on a network.

MPI Protocol

MPI may be either a Master/Master protocol or a Master/Slave protocol. Exactly how the protocol operates is based on the type of device. If the destination device is an S7-300 CPU, then a master/master connection is established because all S7-300 CPUs are network masters. If the destination device is an S7-200 CPU, then a master/slave connection is established because the S7-200 CPUs are slave devices.

MPI always establishes a connection between the two devices communicating with each other. A connection is like a private link between the two devices. Another master cannot interfere with a connection established between two devices. A master can establish a connection to use for a short period of time, or the connection can remain open indefinitely.

Because the connections are private links between devices and require resources in the CPU, each CPU can only support a finite number of connections. Table 9-2 lists the number and type of MPI connections supported by each S7-200 CPU. Each CPU reserves some of its connections for SIMATIC programming devices and operator panels. The reserved connection for a SIMATIC programming device or PC running STEP 7-Micro/WIN ensures that the user is always able to attach at least one SIMATIC programming device to the CPU and gain access to the CPU. Some CPUs also reserve a connection for an operator panel. These reserved connections cannot be used by other types of master devices (such as CPUs).

Table 9-2 Number and Type of MPI Logical Connections for S7-200 CPUs

CPU	Port	Total Number of Connections	Number and Type of Reserved Logical Connections
215	0	Four	Two: One for programming device One for operator panel
	DP	Six	Two: One for programming device One for operator panel
216	0	Four	Two: One for programming device One for operator panel
	1	Four	Two: One for programming device One for operator panel

The S7-300 and S7-400 CPUs can communicate with the S7-200 CPUs by establishing a connection on the non-reserved connections of the S7-200 CPU. The S7-300s and S7-400s can read and write data to the S7-200s using the XGET and XPUT instructions (refer to your S7-300 or S7-400 programming manuals).

Note

The MPI protocol cannot be used to communicate with S7-200 CPUs in which the PPI master function has been enabled. The MPI protocol classifies these devices as masters and attempts to communicate with them by means of a master/master protocol which the S7-200 CPUs do not support.

PROFIBUS-DP Protocol

The PROFIBUS-DP protocol is designed for high-speed communications with distributed I/O devices (remote I/O). There are many PROFIBUS devices available from a variety of manufacturers. These devices range from simple input or output modules to motor controllers and programmable controllers.

PROFIBUS-DP networks usually have one master and several slave I/O devices. The master device is configured to know what types of I/O slaves are connected and at what addresses. The master initializes the network and verifies that the slave devices on the network match the configuration. The master writes output data to the slaves and reads input data from them continuously. When a DP master configures a slave device successfully, it then owns that slave device. If there is a second master device on the network, it has very limited access to the slaves owned by the first master.

The CPU 215 has one port which functions as a PROFIBUS-DP port. See Figure 9-1. See Section 9.5 for complete information on the CPU 215 DP function.

User-Defined Protocols (Freeport)

Freeport communications is a mode of operation through which the user program can control the communication port of the S7-200 CPU. Using Freeport mode, you can implement user-defined communication protocols to interface to many types of intelligent devices.

The user program controls the operation of the communication port through the use of the receive interrupts, transmit interrupts, the transmit instruction (XMT) and the receive instruction (RCV). The communication protocol is controlled entirely by the user program while in Freeport mode. Freeport mode is enabled by means of SMB30 (port 0) and SMB130 (port 1) and is only active when the CPU is in RUN mode. When the CPU returns to STOP mode, Freeport communications are halted and the communication port reverts to normal PPI protocol operation. See Section 10.14 for information about using the Freeport mode.

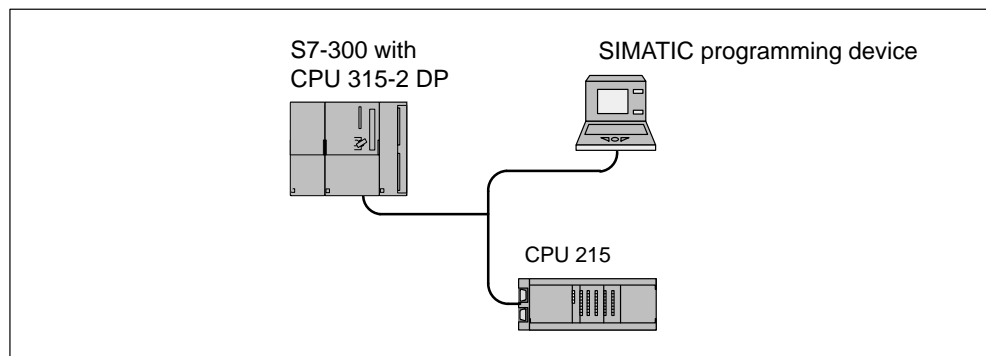


Figure 9-1 CPU 215 Connected to an S7-300 CPU and a Programming Device by Means of the DP Port

9.2 Communication Network Components

The communication port on each S7-200 enables you to connect it to a network bus. The information below describes this port, the connectors for the network bus, the network cable, and repeaters used to extend the network.

Communication Port

The communication ports on the S7-200 CPUs are RS-485 compatible on a nine-pin subminiature D connector in accordance with the PROFIBUS standard as defined in the European Standard EN 50170. Figure 9-2 shows the connector that provides the physical connection for the communication port, and Table 9-3 describes the signals.

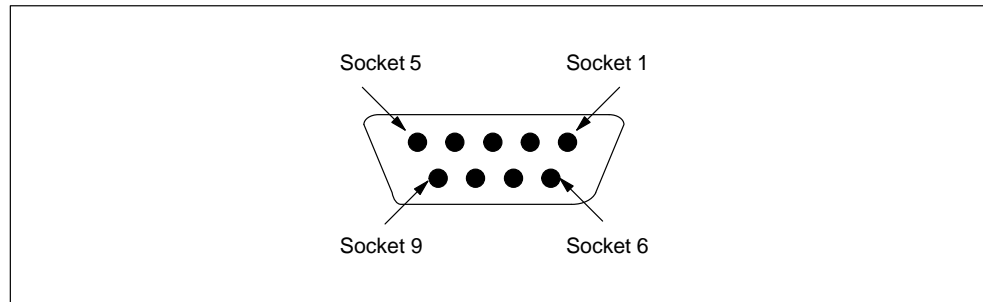


Figure 9-2 Pin Assignment for the S7-200 CPU Communication Port

Table 9-3 S7-200 Communication Port Pin Assignments

Socket	PROFIBUS Designation	Port 0 and Port 1	DP Port
1	Shield	Logic common	Logic common
2	24 V Return	Logic common	Logic common
3	RS-485 Signal B	RS-485 Signal B	RS-485 Signal B
4	Request-to-Send	No connection	Request-to-send ¹
5	5 V Return	Logic common	Isolated +5 V Return ²
6	+5 V	+5 V, 100 Ω series limit	Isolated +5 V, 90 mA
7	+24 V	+24 V	+24 V
8	RS-485 Signal A	RS-485 Signal A	RS-485 Signal A
9	Not applicable	No connection	No connection
Connector shell	Shield	Logic common (CPU 212/214) Chassis ground (CPU 215/216)	Chassis ground

¹ V_{OH} = 3.5 V, 1.6 mA, V_{OL} = 0.6 V, 1.6 mA, Signal = V_{OH} when the CPU is sending.

² Signals A, B, and Request-to-Send on DP port are isolated from CPU logic and referenced to this isolated 5 V return.

Network Connectors

Siemens offers two types of networking connectors that you can use to connect multiple devices to a network easily. Both connectors have two sets of terminal screws to allow you to attach the incoming and outgoing network cables. Both connectors also have switches to bias and terminate the network selectively. One connector type provides only a connection to the CPU. The other adds a programming port. See Figure 9-3. See Appendix G for ordering information.

The connector with the programming port connection allows a SIMATIC programming device or operator panel to be added to the network without disturbing any existing network connections. The programming port connector passes all signals from the CPU through to the programming port. This connector is useful for connecting devices (such as a TD 200 or an OP3) which draw power from the CPU. The power pins on the communication port connector of the CPU are passed through to the programming port.



Caution

Interconnecting equipment with different reference potentials can cause unwanted currents to flow through the interconnecting cable.

These unwanted currents can cause communication errors or can damage equipment.

Be sure all equipment that you are about to connect with a communication cable either shares a common circuit reference or is isolated to prevent unwanted current flows. See "Grounding and Circuit Reference Point for Using Isolated Circuits" in Section 2.3.

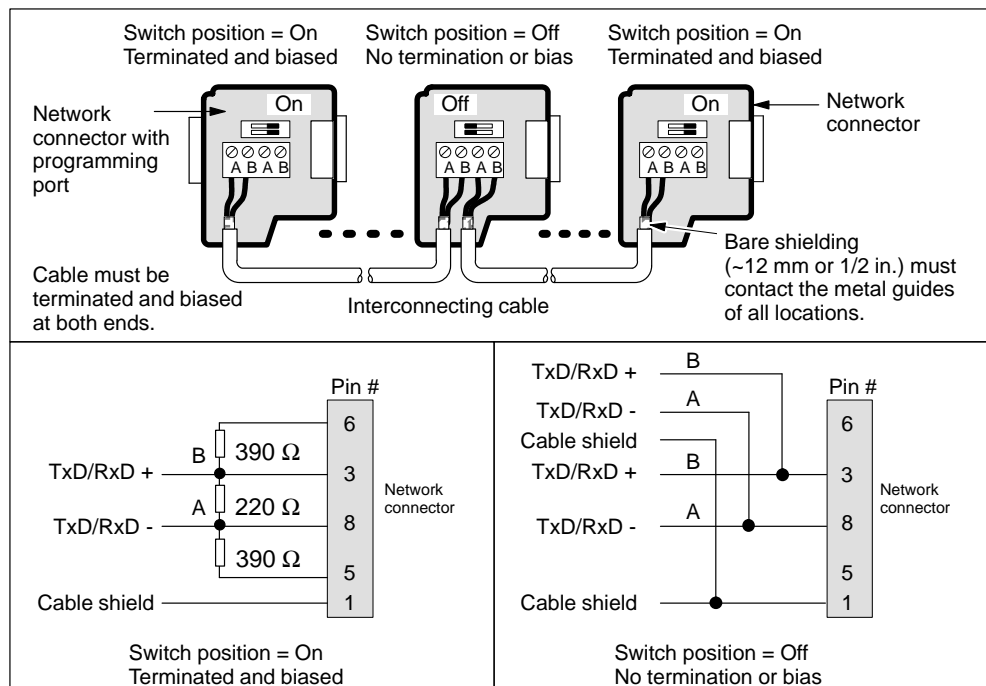


Figure 9-3 Bias and Termination of Interconnecting Cable

Cable for a PROFIBUS Network

Table 9-4 lists the general specifications for a PROFIBUS network cable. See Appendix G for the Siemens order number for PROFIBUS cable meeting these requirements.

Table 9-4 General Specifications for a PROFIBUS Network Cable

General Features	Specification
Type	Shielded, twisted pair
Conductor cross section	24 AWG (0.22 mm ²) or larger
Cable capacitance	< 60 pF/m
Nominal impedance	100 Ω to 120 Ω

The maximum length of a PROFIBUS network segment depends on the baud rate and the type of cable used. Table 9-5 lists the maximum segment lengths for cable matching the specifications listed in Table 9-4.

Table 9-5 Maximum Cable Length of a Segment in a PROFIBUS Network

Transmission Rate	Maximum Cable Length of a Segment
9.6 kbaud to 93.75 kbaud	1,200 m (3,936 ft.)
187.5 kbaud	1,000 m (3,280 ft.)
500 kbaud	400 m (1,312 ft.)
1.5 Mbaud	200 m (656 ft.)
3 Mbaud to 12 Mbaud	100 m (328 ft.)

Network Repeaters

Siemens provides network repeaters to connect PROFIBUS network segments. See Figure 9-4. The use of repeaters extends the overall network length and/or allows adding devices to a network. PROFIBUS allows a maximum of 32 devices on a network segment of up to 1,200 m (3,936 ft.) at 9600 baud. Each repeater allows you to add another 32 devices to the network and extend the network another 1,200 m (3,936 ft.) at 9600 baud. Up to 9 repeaters may be used in a network. Each repeater provides bias and termination for the network segment. See Appendix G for ordering information.

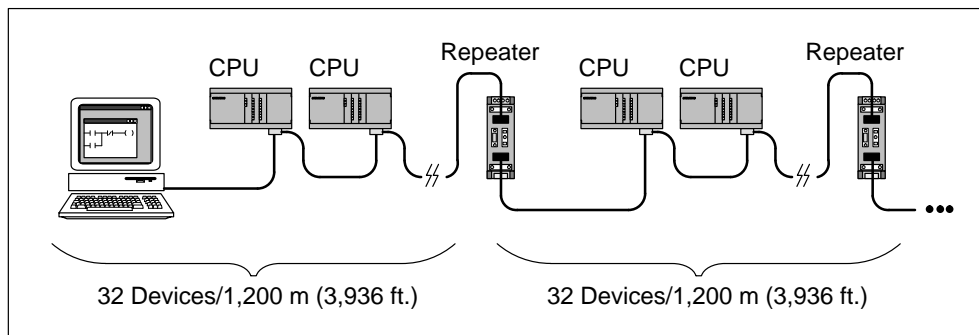


Figure 9-4 Network with Repeaters

9.3 Data Communications Using the PC/PPI Cable

PC/PPI Cable

The communication ports of a personal computer are generally ports that are compatible with the RS-232 standard. The S7-200 CPU communication ports use RS-485 to allow multiple devices to be attached to the same network. The PC/PPI cable allows you to connect the RS-232 port of a personal computer to the RS-485 port of an S7-200 CPU. See Figure 9-5. The PC/PPI cable can also be used to connect the communication port of an S7-200 CPU to other RS-232 compatible devices.

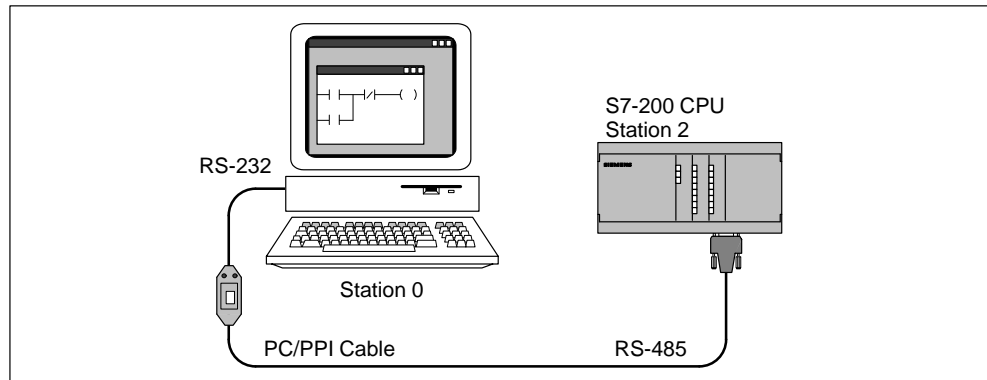


Figure 9-5 Using a PC/PPI Cable for Communicating with an S7-200 CPU

Using STEP 7-Micro/WIN with a PC/PPI Cable

STEP 7-Micro/WIN can use the PC/PPI cable to communicate with one or more S7-200 CPUs. See Figure 9-6. When using STEP 7-Micro/WIN, be sure that the baud rate selection on the PC/PPI cable is set to the correct baud rate for your network. STEP 7-Micro/WIN supports only 9600 baud and 19,200 baud.

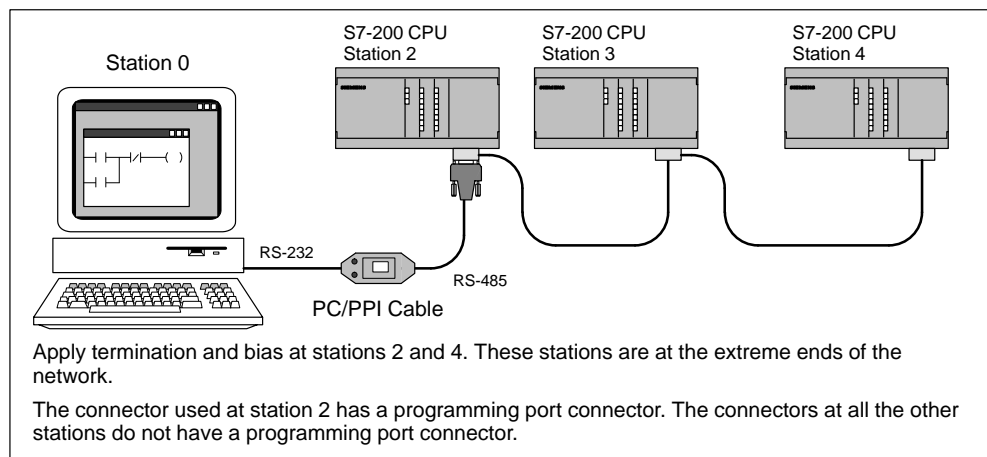


Figure 9-6 Using a PC/PPI Cable for Communicating with One CPU at a Time on a Network

STEP 7-Micro/WIN defaults to multiple-master PPI protocol when communicating to S7-200 CPUs. This protocol allows STEP 7-Micro/WIN to coexist with other master devices (TD 200s and operator panels) on a network. This mode is enabled by checking the “Multiple Master Network” check box on the PC/PPI Cable Properties dialog in the PG/PC Interface. See Section 3.3.

STEP 7-Micro/WIN also supports a single-master PPI protocol. When using the single-master protocol, STEP 7-Micro/WIN assumes that it is the only master on the network and does not cooperate to share the network with other masters. Single-master protocol should be used when transmitting over modems or over very noisy networks. The single-master mode is selected by clearing the “Multiple Master Network” check box on the PC/PPI Cable Properties dialog box in the PG/PC Interface. See Section 3.3.

For the technical specifications of the PC/PPI cable, see Appendix A.40; for its order number, see Appendix G.

Using the PC/PPI Cable with Other Devices and Freepoint

You can use the PC/PPI cable and the Freepoint communication functions to connect the S7-200 CPUs to many devices that are compatible with the RS-232 standard.

The PC/PPI cable supports baud rates between 600 baud and 38,400 baud. Use the DIP switches on the housing of the PC/PPI cable to configure the cable for the correct baud rate. Table 9-6 shows the baud rates and switch positions.

Table 9-6 Baud Rate Switch Selections on the PC/PPI Cable

Baud Rate	Switch (1 = Up)
38400	0000
19200	0010
9600	0100
4800	0110
2400	1000
1200	1010
600	1100

The RS-232 port of the PC/PPI cable is classified as Data Communications Equipment (DCE). The only signals present on this port are transmit data, receive data, and ground. Table 9-7 shows the pin numbers and functions for the RS-232 port of the PC/PPI cable. The PC/PPI cable does not use or supply any of the RS-232 control signals such as Request to Send (RTS) and Clear to Send (CTS).

Table 9-7 PC/PPI Cable: Pin Definitions for RS-232 Port

Pin Number	Function
2	Receive data (from DCE)
3	Transmit data (from DTE to DCE)
5	Ground

The PC/PPI cable is in the transmit mode when data is transmitted from the RS-232 port to the RS-485 port. The cable is in receive mode when it is idle or is transmitting data from the RS-485 port to the RS-232 port. The cable changes from receive to transmit mode immediately when it detects characters on the RS-232 transmit line. The cable switches back to receive mode when the RS-232 transmit line is in the idle state for a period of time defined as the turnaround time of the cable. This time depends on the baud rate selection made on the DIP switches of the cable. See Table 9-8.

If you are using the PC/PPI cable in a system where Freeport communication is also used, the turnaround time must be comprehended by the user program in the S7-200 CPU for the following situations:

- The S7-200 CPU responds to messages transmitted by the RS-232 device.
 After receiving a request message from the RS-232 device, the transmission of a response message by the S7-200 CPU must be delayed for a period of time greater than or equal to the turnaround time of the cable.
- The RS-232 device responds to messages transmitted from the S7-200 CPU.
 After receiving a response message from the RS-232 device, the transmission of the next request message by the S7-200 CPU must be delayed for a period of time greater than or equal to the turnaround time of the cable.

In both situations, the delay allows the PC/PPI cable sufficient time to switch from transmit mode to receive mode so that data can be transmitted from the RS-485 port to the RS-232 port.

Table 9-8 PC/PPI Cable Turnaround Time (Transmit to Receive Mode)

Baud Rate	Turnaround Time (in Milliseconds)
38400	1
19200	1
9600	2
4800	4
2400	7
1200	14
600	28

Using a Modem with a PC/PPI Cable

You can use the PC/PPI cable to connect the RS-232 communication port of a modem to an S7-200 CPU. Modems normally use the RS-232 control signals (such as RTS, CTS, and DTR) to allow a PC to control the modem. The PC/PPI cable does not use any of these signals, so when you use a modem with a PC/PPI cable, the modem must be configured to operate without these signals. As a minimum, you must configure the modem to ignore RTS and DTR. Consult the operator manual supplied with the modem to determine the commands required to configure the modem.

When connecting a modem to a PC/PPI cable, you must use a null modem adapter between the modem and the RS-232 port of the PC/PPI cable. Modems are classified as Data Communications Equipment (DCE). The RS-232 port of the PC/PPI cable is also classified as DCE. When you connect two devices of the same class (both DCE), the transmit data and receive data pins must be swapped. A null modem adapter swaps the transmit and receive lines. See Figure 9-7 for a typical setup and the pin assignment for a null modem adapter.

When using STEP 7-Micro/WIN with a modem, you must use a full-duplex modem which supports 11 bit characters. See Section 3.3 for more information about using STEP 7-Micro/WIN with a modem. When using a modem with a user-defined Freeport protocol, you can use any modem which supports the character size of the protocol.

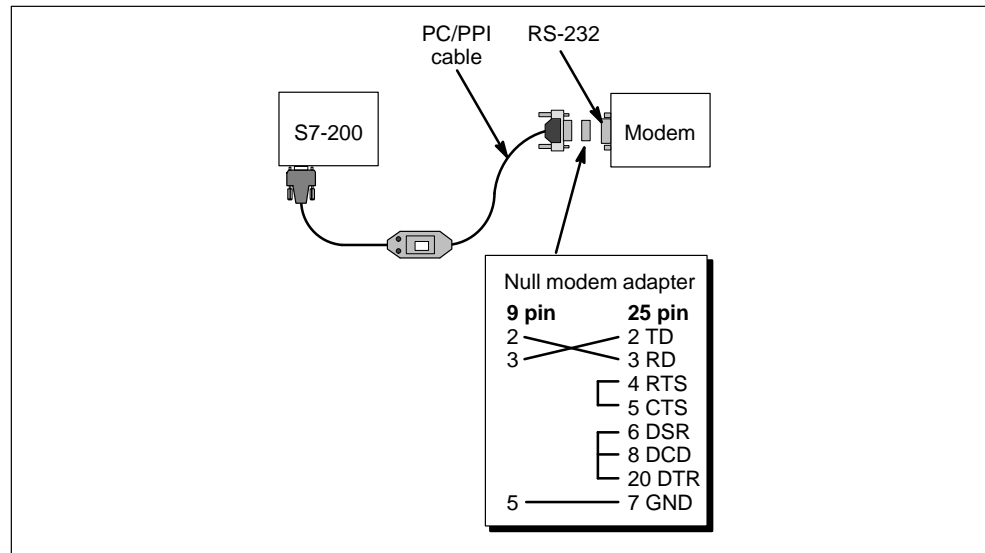


Figure 9-7 Modem with Null Modem Adapter

9.4 Data Communications Using the MPI or CP Card

Siemens offers several network interface cards that you can put into a personal computer or SIMATIC programming device. These cards allow the PC or SIMATIC programming device to act as a network master. These cards contain dedicated hardware to assist the PC or programming device in managing a multiple-master network, and can support different protocols at several baud rates. See Table 9-9.

Table 9-9 Cards for Connecting to a Multiple-Master Network

Name	Type	Operating Systems Supported	Comments
MPI	Short AT ISA or built into programming device	MS-DOS Windows 3.1x	Supports PPI protocol, 9600 baud and 19,200 baud
		Windows 95 Windows NT	Supports PPI, ¹ MPI, and PROFIBUS-DP protocols, 9600 baud to 1.5 Mbaud for PCs and programming devices
CP 5411	Short AT ISA	Windows 95 Windows NT	Supports PPI, ¹ MPI, and PROFIBUS-DP protocols, 9600 baud to 12 Mbaud for PCs and programming devices
CP 5511	PCMCIA, type II Plug and Play hardware	Windows 95 Windows NT	Supports PPI, ¹ MPI, and PROFIBUS-DP protocols, 9600 baud to 12 Mbaud for notebook PCs
CP 5611	Short PCI Plug and Play hardware	Windows 95 Windows NT	Supports PPI, ¹ MPI, and PROFIBUS-DP protocols, 9600 baud to 12 Mbaud for PCs

¹ At 9600 baud or 19,200 baud only

The specific card and protocol are set up using the PG/PC Interface from within STEP 7-Micro/WIN or from the Windows Control Panel. See Section 3.3.

When using Windows 95 or Windows NT, you can select any protocol (PPI, MPI, or PROFIBUS) to be used with any of the network cards. As a general rule, you should select PPI protocol at 9600 baud or 19200 baud when communicating to S7-200 CPUs. The only exception is the CPU 215. When communicating to this CPU by means of the DP port, you must select MPI protocol. The CPU 215 DP port supports baud rates from 9600 baud to 12 Mbaud. This port determines the baud rate of the master (CP or MPI card) automatically and synchronizes itself to use that baud rate.

Each card provides a single RS-485 port for connection to the PROFIBUS network. The CP 5511 PCMCIA card has an adapter that provides the 9-pin D port. You connect one end of an MPI cable to the RS-485 port of the card and connect the other end to a programming port connector on your network. See Figure 9-8. For more information on the communications processor cards, see the *SIMATIC Components for Totally Integrated Automation Catalog ST 70*.

Configurations Using a PC with an MPI or CP Card: Multiple-Master Network

Many configurations are possible when you use a multipoint interface card or communications processor card. You can have a station running the STEP 7-Micro/WIN programming software (PC with MPI or CP card, or a SIMATIC programming device) connected to a network that includes several master devices. (This is also true of the PC/PPI cable if you have enabled multiple masters.) These master devices include operator panels and text displays (TD 200 units). Figure 9-8 shows a configuration with two TD 200 units added to the network.

In this configuration, the communication possibilities are listed below:

- STEP 7-Micro/WIN (on station 0) can be monitoring the status on programming station 2, while the TD 200 units (stations 5 and 1) communicate with the CPU 214 modules (stations 3 and 4, respectively).
- Both CPU 214 modules can be enabled to send messages by using network instructions (NETR and NETW).
- Station 3 can read data from and write data to station 2 (CPU 212) and station 4 (CPU 214).
- Station 4 can read data from and write data to station 2 (CPU 212) and station 3 (CPU 214).

It is possible to connect many master and slave stations to the same network. However, the performance of the network can be adversely affected as more stations are added.

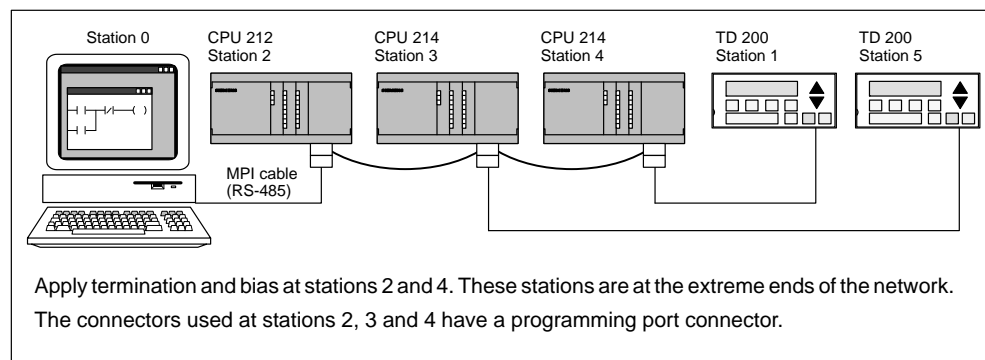


Figure 9-8 Using an MPI or CP Card to Communicate with S7-200 CPUs

9.5 Distributed Peripheral (DP) Standard Communications

The PROFIBUS-DP Standard

PROFIBUS-DP (or DP Standard) is a remote I/O communication protocol defined by the European Standard EN 50170. Devices that adhere to this standard are compatible even though they are manufactured by different companies. "DP" stands for "distributed peripherals," that is, remote I/O. "PROFIBUS" stands for "Process Field Bus."

The CPU 215 has implemented the DP Standard protocol as defined for slave devices in the following communication protocol standards:

- EN 50 170 (PROFIBUS) describes the bus access and transfer protocol and specifies the properties of the data transfer medium.
- EN 50 170 (DP Standard) describes the high-speed cyclic exchange of data between DP masters and DP slaves. This standard defines the procedures for configuration and parameter assignment, explains how cyclic data exchange with distributed I/O functions, and lists the diagnostic options which are supported.

A DP master is configured to know the addresses, slave device types, and any parameter assignment information that the slaves require. The master is also told where to place data that is read from the slaves (inputs) and where to get the data to write to the slaves (outputs). The DP master establishes the network and then initializes its DP slave devices. The master writes the parameter assignment information and I/O configuration to the slave. The master then reads the diagnostics from the slave to verify that the DP slave accepted the parameters and the I/O configuration. The master then begins to exchange I/O data with the slave. Each transaction with the slave writes outputs and reads inputs. The data exchange mode continues indefinitely. The slave devices can notify the master if there is an exception condition and the master then reads the diagnostic information from the slave.

Once a DP master has written the parameters and I/O configuration to a DP slave, and the slave has accepted the parameters and configuration from the master, the master now owns that slave. The slave only accepts write requests from the master that owns it. Other masters on the network can read the slave's inputs and outputs, but they cannot write anything to the slave.

Using the CPU 215 as a DP Slave

The CPU 215 can be connected to a PROFIBUS-DP network, where it functions as a DP slave device. Port 1 of the CPU 215 (labeled DP on the unit) is the DP port. This port operates at any baud rate between 9600 baud and 12 Mbaud. As a DP slave device, the CPU 215 accepts several different I/O configurations from the master to transfer different amounts of data to and from the master. This feature allows you to tailor the amount of data transferred to meet the requirements of the application. Unlike many DP devices, the CPU 215 does not transfer only I/O data. The CPU 215 uses a block of variable memory to transfer to and from the master. This allows you to exchange any type of data with the master. Inputs, counter values, timer values, or other calculated values can be transferred to the master by first moving the data to the variable memory in the CPU 215. Likewise, data from the master is stored in variable memory in the CPU 215 and can be moved to other data areas.

The DP port of the CPU 215 can be attached to a DP master on the network and still communicate as an MPI slave with other master devices such as SIMATIC programming devices or S7-300/S7-400 CPUs on the same network.

Figure 9-9 shows a PROFIBUS network with a CPU 215. In this situation, the CPU 315-2 is the DP master and has been configured by a SIMATIC programming device with STEP 7 programming software. The CPU 215 is a DP slave owned by the CPU 315-2. The ET 200 I/O module is also a slave owned by the CPU 315-2. The S7-400 CPU is attached to the PROFIBUS network and is reading data from the CPU 215 by means of XGET instructions in the S7-400 CPU user program.

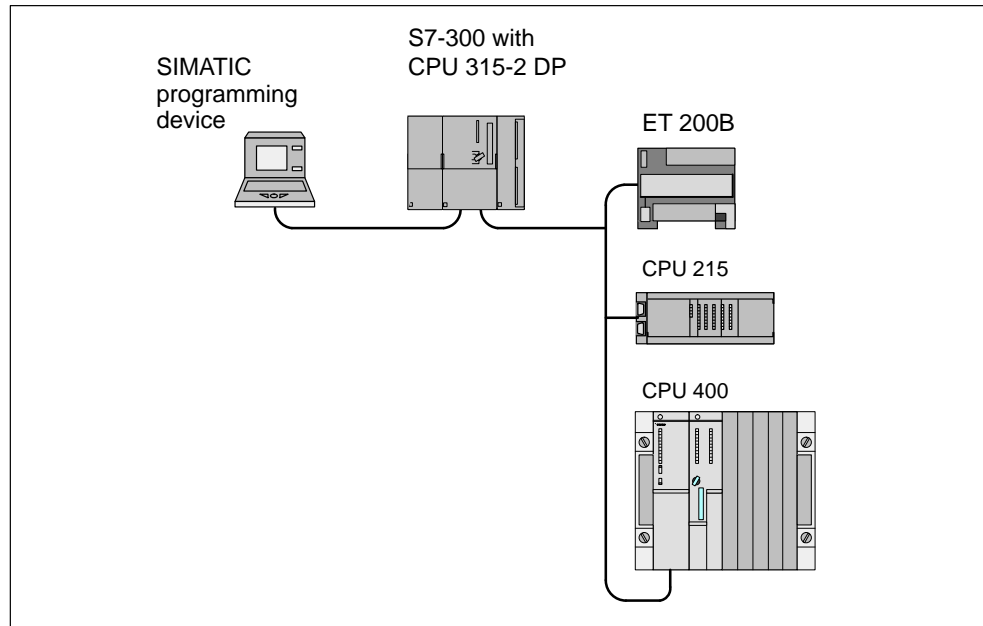


Figure 9-9 CPU 215 on a PROFIBUS Network

Configuration

The only setting you must make on the CPU 215 to use it as a DP slave is the station address of the DP port of the CPU. This address must match the address in the configuration of the master. You can use STEP 7-Micro/WIN to modify the CPU configuration for the DP port address and then download the new configuration to the CPU 215.

The address of the CPU 215 DP port can also be set with a DP configuration device attached to the DP port. Setting the DP port address with one of these devices is only possible if the DP port address shown in the STEP 7-Micro/WIN CPU configuration is the default address of 126. The DP port address set by STEP 7-Micro/WIN overrides an address that is set by means of a DP configuration device.

Note

To restore the default DP port address once the port address has been changed with a DP configuration device, you must perform the following steps:

1. Using STEP 7-Micro/WIN, modify the DP port address in the CPU configuration to an unused value (not 126).
 2. Download the CPU configuration to the CPU 215.
 3. Again using STEP 7-Micro/WIN, modify the DP port address in the CPU configuration to the default address (126).
 4. Download the CPU configuration to the CPU 215.
-

The master device exchanges data with each of its slaves by sending information from its output area to the slave's output buffer (called a "Receive mailbox"). The slave responds to the message from the master by returning an input buffer (called a "Send mailbox") which the master stores in an input area. See Figure 9-10.

The CPU 215 can be configured by the DP master to accept output data from the master and return input data to the master. The output and input data buffers reside in the variable memory (V memory) of the CPU 215. When you configure the DP master, you define the byte location in V memory where the output data buffer should start as part of the parameter assignment information for the CPU 215. You also define the I/O configuration as the amount of output data to be written to the CPU 215 and amount of input data to be returned from the CPU 215. The CPU 215 determines the size of the input and output buffers from the I/O configuration. The DP master writes the parameter assignment and I/O configuration information to the CPU 215.

Figure 9-10 shows a memory model of the V memory in a CPU 215 and the I/O address areas of a DP master CPU. In this example, the DP master has defined an I/O configuration of 16 output bytes and 16 input bytes, and a V memory offset of 5000. The output buffer and input buffer lengths in the CPU 215, determined from the I/O configuration, are both 16 bytes long. The output data buffer starts at V5000 and the input buffer immediately follows the output buffer and begins at V5016. The output data (from the master) is placed in V memory at V5000. The input data (to the master) is taken from the V memory at V5016.

Note

If you are working with a data unit (consistent data) of three bytes or data units (consistent data) greater than four bytes, you must use SFC14 to read the inputs of the DP slave and SFC15 to address the outputs of the DP slave. For more information, see the *System Software for S7-300 and S7-400 System and Standard Functions Reference Manual*.

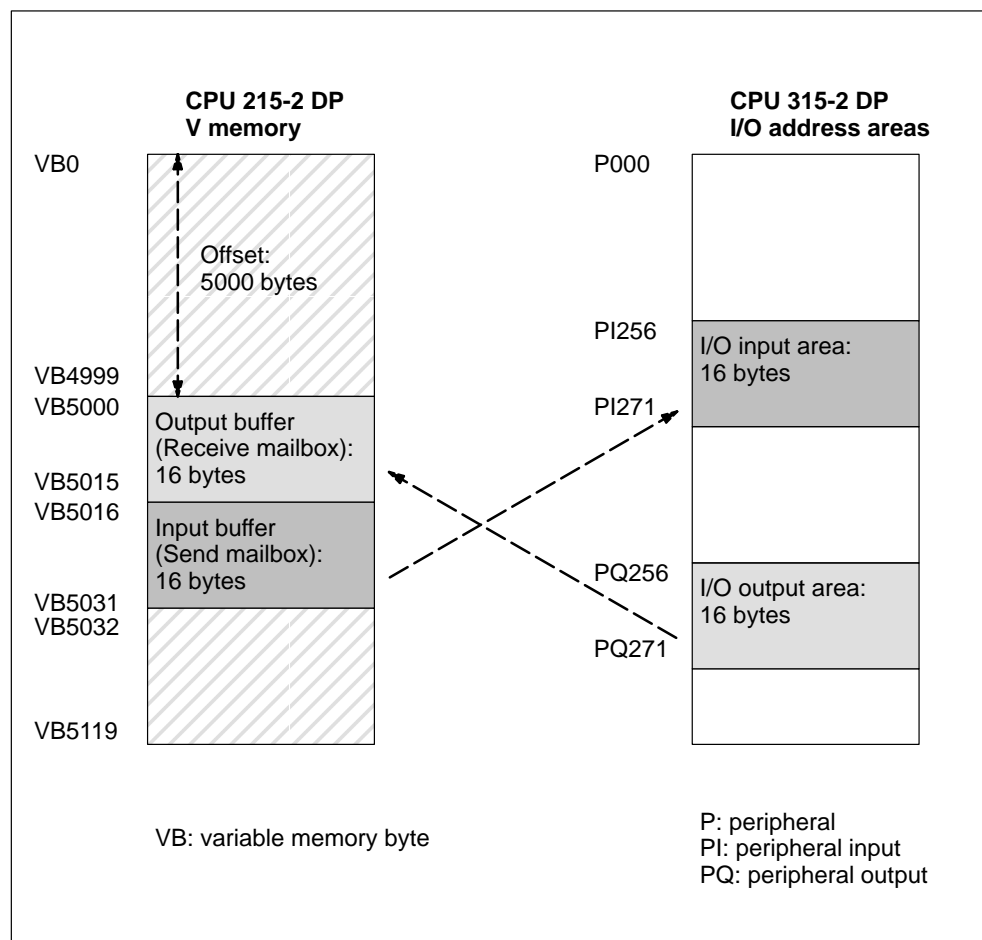


Figure 9-10 Example: CPU 215 V Memory and I/O Address Area of a PROFIBUS-DP Master

Table 9-10 lists the configurations that are supported by the CPU 215.

Table 9-10 I/O Configurations Supported by the CPU 215

Configuration	Input Buffer Size (Data to the Master)	Output Buffer Size (Data from the Master)	Data Consistency
1	1 word	1 word	Word consistency
2 (default)	2 words	2 words	
3	4 words	4 words	
4	8 words	8 words	
5	16 words	16 words	
6	32 words	32 words	
7	8 words	2 words	
8	16 words	4 words	
9	32 words	8 words	
10	2 words	8 words	
11	4 words	16 words	
12	8 words	32 words	
13	2 bytes	2 bytes	Byte consistency
14	8 bytes	8 bytes	
15	32 bytes	32 bytes	
16	64 bytes	64 bytes	
17	4 bytes	4 bytes	Buffer consistency
18	8 bytes	8 bytes	
19	12 bytes	12 bytes	
20	16 bytes	16 bytes	

The location of the input and output buffers may be configured to be anywhere in the V memory of the CPU 215. The default address for the input and output buffers is VB0. The location of the input and output buffers is part of the parameter assignment information that the master writes to the CPU 215. The master must be configured to recognize its slaves and to write the required parameters and I/O configuration to each of its slaves.

Use the following tools to configure the DP master:

- For SIMATIC S5 masters, use COM ET 200 (COM PROFIBUS) Windows software
- For SIMATIC S7 masters, use STEP 7 programming software
- For SIMATIC 505 masters, use COM ET 200 (COM PROFIBUS) and TISOFT2

For detailed information about using these configuration and programming software packages, refer to the manuals for these devices. For detailed information about the PROFIBUS network and its components, refer to the *ET 200 Distributed I/O System Manual*. (See Appendix G for the order number of this manual.)

Data Consistency

PROFIBUS supports three types of data consistency:

- Byte consistency ensures that bytes are transferred as whole units.
- Word consistency ensures that word transfers cannot be interrupted by other processes in the CPU. This means that the two bytes composing the word are always moved together and cannot be split.
- Buffer consistency ensures that the entire buffer of data is transferred as a single unit, uninterrupted by any other process in the CPU.

Word and buffer consistency force the CPU to halt any other processes, such as user interrupts, while manipulating or moving the DP I/O data within the CPU. Word consistency should be used if the data values being transferred are integers. Buffer consistency should be used if the data values are double words or floating point values. Buffer consistency should also be used when a group of values all relate to one calculation or item.

You set the data consistency as part of the I/O configuration in the master. The data consistency selection is written to the DP slave as part of the initialization of the slave. Both the DP master and the DP slave use the data consistency selection to be sure that data values (bytes, words, or buffers) are transferred uninterrupted within master and slave.

Figure 9-11 shows the different types of consistency.

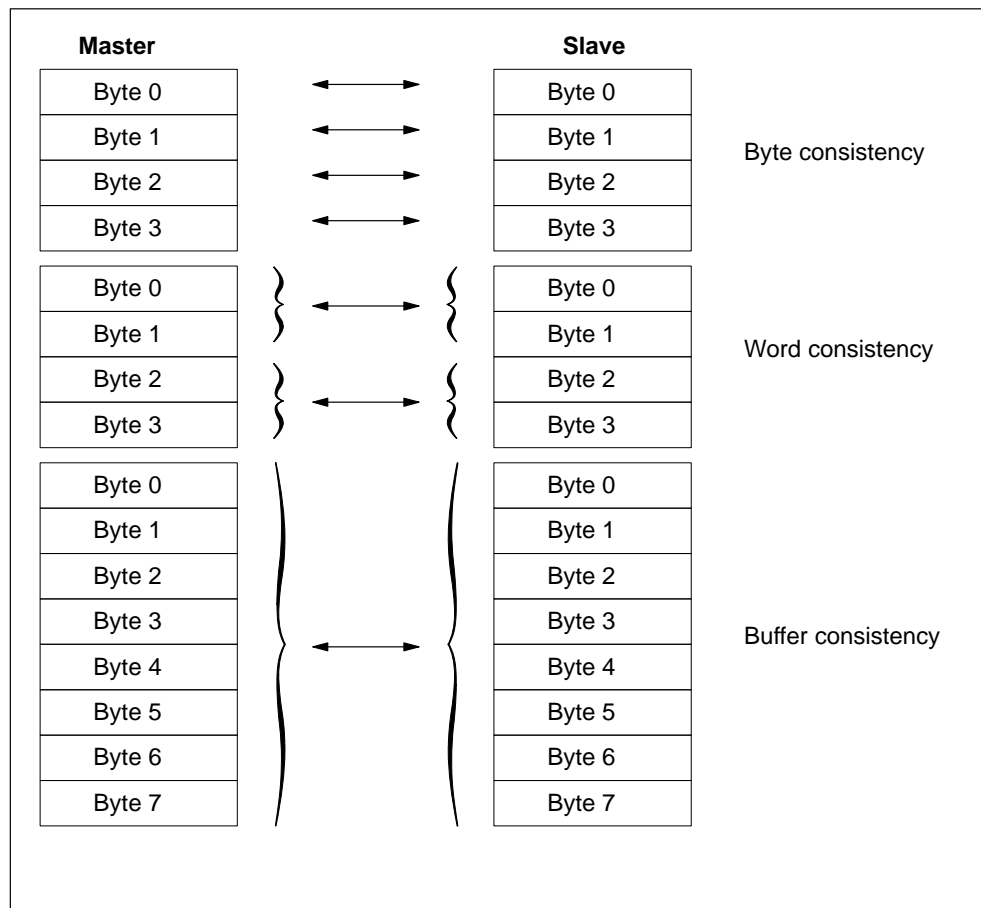


Figure 9-11 Byte, Word, and Buffer Data Consistency

User Program Considerations

Once the CPU 215 has been successfully configured by a DP master, the CPU 215 and the DP master enter data exchange mode. In data exchange mode, the master writes output data to the CPU 215 and the CPU 215 responds with input data. The output data from the master is placed into V memory (the output buffer) starting at the address that the DP master supplied during initialization. The input data to the master is taken from the V memory locations (the input buffer) immediately following the output data.

The starting address of the data buffers in V memory and the size of the buffers must be known at the time the user program for the CPU 215 is created. The output data from the master must be moved by the user program in the CPU 215 from the output buffer to the data areas where it is to be used. Likewise, the input data to the master must be moved from the various data areas to the input buffer for transfer to the master.

Output data from the DP master are placed into V memory immediately after the user program portion of the scan has been executed. Input data (to the master) are copied from V memory to an internal holding area for transfer to the master at this same time. Output data from the master are only written into V memory when there is new data available from the master. Input data to the master are transmitted to the master on the next data exchange with the master.

SMB110 through SMB115 provide status information about the CPU 215 DP slave. These SM locations show default values if DP communication has not been established with a master. After a master has written parameters and I/O configuration to the CPU 215, these SM locations show the configuration set by the DP master. You should check SMB110 to be sure that the CPU 215 is currently in data exchange mode with the master before using the information in SMB111 through SMB115. See Table 9-11.

Note

You cannot configure the CPU 215 I/O buffer sizes or buffer location by writing to memory locations SMB112 through SMB115. Only the DP master can configure the CPU 215 for DP operation.

Table 9-11 DP Status Information

SM Byte	Description								
SMB110	<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;"> $\overset{\text{MSB}}{7}$ <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="width: 15px;">0</td> <td style="width: 15px;">0</td> <td style="width: 15px;">0</td> <td style="width: 15px;">0</td> <td style="width: 15px;">0</td> <td style="width: 15px;">0</td> <td style="width: 15px;">s</td> <td style="width: 15px;">s</td> </tr> </table> </div> <div> $\overset{\text{LSB}}{0}$ Port 1: DP standard protocol status byte </div> </div> <p>ss: DP standard status byte 00 = DP communications have not been initiated since power on 01 = Configuration/parameter assignment error detected 10 = Currently in data exchange mode 11 = Dropped out of data exchange mode</p> <p>SM111 to SM115 are updated each time the CPU accepts configuration-parameter assignment information. These locations are updated even if a configuration-parameter assignment error is detected. These locations are cleared every time the CPU is turned on.</p>	0	0	0	0	0	0	s	s
0	0	0	0	0	0	s	s		
SMB111	This byte defines the address of the slave's master (0 to 126).								
SMB112 SMB113	These bytes define the V memory address of the output buffer (offset from VB0). SM112 is the most significant byte, and SM113 is the least significant byte.								
SMB114	This byte defines the number of bytes for the output data.								
SMB115	This byte defines the number of bytes for the input data.								

DP LED Status Indicator

The CPU 215 has a status LED on the front panel to indicate the operational state of the DP port:

- After the CPU is turned on, the DP LED remains off as long as DP communication is not attempted.
- Once DP communication has been successfully initiated (the CPU 215 has entered data exchange mode with the master), the DP LED turns green and remains on until data exchange mode is exited.
- If communication is lost, which forces the CPU 215 to exit data exchange mode, the DP LED turns red. This condition persists until the CPU 215 is powered off or data exchange is resumed.
- If there is an error in the I/O configuration or parameter information that the DP master is writing to the CPU 215, the DP LED flashes red.

Table 9-12 summarizes the status indications signified by the DP LED.

Table 9-12 DP LED Status Indicator

LED State	Status Indication Description
Off	No DP standard communication attempted since last power on
Flashing red	Error in parameter assignment or configuration, CPU not in data exchange mode
Green	Currently in data exchange mode
Red	Dropped out of data exchange mode

Device Database File: GSD

Different PROFIBUS devices have different performance characteristics. These characteristics differ with respect to functionality (for example, the number of I/O signals and diagnostic messages) or bus parameters such as transmission speed and time monitoring. These parameters vary for each device type and vendor and are usually documented in a technical manual. To help you achieve a simple configuration of PROFIBUS, the performance characteristics of a particular device are specified in an electronic data sheet called a device database file, or GSD file. Configuration tools based on GSD files allow simple integration of devices from different vendors in a single network.

The device database file provides a comprehensive description of the characteristics of a device in a precisely defined format. These GSD files are prepared by the vendor for each type of device and made available to the PROFIBUS user. The GSD file allows the configuration system to read in the characteristics of a PROFIBUS device and use this information when configuring the network.

The latest versions of the COM ET 200 (now called COM PROFIBUS) or STEP 7 software include configuration files for the CPU 215. If your version of software does not include a configuration file for the CPU 215, you can use a modem to access the PROFIBUS Bulletin Board Service (BBS) and copy the GSD file for the CPU 215. When accessing the bulletin board, respond to the prompts from the BBS to access the CPU 215 database, and copy the file. This is a self-extracting file that provides the files required for PROFIBUS. Use the following telephone numbers to access the BBS:

- In North and South America: (423) 461-2751
File name to copy: S7215.EXE
- In Europe: (49) (911) 73 79 72
File name to copy: W32150AX.200

You can also use the Internet to get the latest GSD file (device database file). The address is: www.profibus.com

If you are using a non-Siemens master device, refer to the documentation provided by the manufacturer on how to configure the master device by using the GSD file.

Listing of the CPU 215 GSD File

Table 9-13 provides a listing of the current GSD file (the device database file) for the CPU 215.

Table 9-13 Sample Device Database File for Non-SIMATIC Master Devices

```

;=====
; GSD-Data for the S7-215 DP slave with SPC3
; MLFB : 6ES7 215-2.D00-0XB0
; Date : 05-Oct-1996/release 14-March-97/09/29/97 (45,45)
; Version: 1.2 GSD
; Model-Name, Freeze_Mode_supp, Sync_mode_supp, 45,45k
; File : SIE_2150
;=====
#Profibus_DP
; Unit-Definition-List:
GSD_Revision=1
Vendor_Name="Siemens"
Model_Name="CPU 215-2 DP"
Revision="REV 1.00"
Ident_Number=0x2150
Protocol_Ident=0
Station_Type=0
Hardware_Release="A1.0"
Software_Release="Z1.0"
9.6_supp=1
19.2_supp=1
45.45_supp=1
93.75_supp=1
187.5_supp=1
500_supp=1
1.5M_supp=1
3M_supp=1
6M_supp=1
12M_supp=1
MaxTsdr_9.6=60
MaxTsdr_19.2=60
MaxTsdr_45.45=250
MaxTsdr_93.75=60
MaxTsdr_187.5=60
MaxTsdr_500=100
MaxTsdr_1.5M=150
MaxTsdr_3M=250
MaxTsdr_6M=450
MaxTsdr_12M=800
Redundancy = 0
Repeater_Ctrl_Sig = 2
24V_Pins = 2
Implementation_Type="SPC3"
Bitmap_Device="S7_2150"
;
; Slave-Specification:
OrderNumber="6ES7 215-2.D00-0XB0"
Periphery="SIMATIC S5"
;
Freeze_Mode_supp=1
Sync_Mode_supp=1
Set_Slave_Add_supp=1
Min_Slave_Intervall=1

```

Table 9-13 Sample Device Database File for Non-SIMATIC Master Devices, continued

```

Max_Diag_Data_Len=6
Slave_Family=3@Tdf@SIMATIC
;
; UserPrmData-Definition
ExtUserPrmData=1 "I/O Offset in the V-memory"
Unsigned16 0 0-5119
EndExtUserPrmData
; UserPrmData: Length and Preset:
User_Prm_Data_Len=3
User_Prm_Data= 0,0,0
Ext_User_Prm_Data_Ref(1)=1
;
Modular_Station=1
Max_Module=1
Max_Input_Len=64
Max_Output_Len=64
Max_Data_Len=128
;
; Module-Definitions:
;
Module="2 Bytes Out/ 2 Bytes In      -- 0x31
EndModule
Module="8 Bytes Out/ 8 Bytes In      -- 0x37
EndModule
Module="32 Bytes Out/ 32 Bytes In    -- 0xC0,0x1F,0x1F
EndModule
Module="64 Bytes Out/ 64 Bytes In    -- 0xC0,0x3F,0x3F
EndModule

Module="1 Word Out/ 1 Word In        -- 0x70
EndModule
Module="2 Word Out/ 2 Word In        -- 0x71
EndModule
Module="4 Word Out/ 4 Word In        -- 0x73
EndModule
Module="8 Word Out/ 8 Word In        -- 0x77
EndModule
Module="16 Word Out/ 16 Word In      -- 0x7F
EndModule
Module="32 Word Out/ 32 Word In      -- 0xC0,0x5F,0x5F
EndModule

Module="2 Word Out/ 8 Word In        -- 0xC0,0x41,0x47
EndModule
Module="4 Word Out/ 16 Word In       -- 0xC0,0x43,0x4F
EndModule
Module="8 Word Out/ 32 Word In       -- 0xC0,0x47,0x5F
EndModule
Module="8 Word Out/ 2 Word In        -- 0xC0,0x47,0x41
EndModule
Module="16 Word Out/ 4 Word In       -- 0xC0,0x4F,0x43
EndModule
Module="32 Word Out/ 8 Word In       -- 0xC0,0x5F,0x47
EndModule
Module="4 Byte buffer I/O           -- 0xB3
EndModule
Module="8 Byte buffer I/O           -- 0xB7
EndModule
Module="12 Byte buffer I/O          -- 0xBB
EndModule
Module="16 Byte buffer I/O          -- 0xBF
EndModule

```

Sample Program for DP Communication to a CPU 215 Slave

Table 9-14 provides a listing for a sample program in statement list for a CPU 215 that uses the DP port information in SM memory. Figure 9-12 shows the same program in ladder logic. This program determines the location of the DP buffers from SMW112 and the sizes of the buffers from SMB114 and SMB115. This information is used in the program to copy the data in the DP output buffer to the process-image output register of the CPU 215. Similarly, the data in the process-image input register of the CPU 215 are copied into the DP input buffer.

Table 9-14 Sample Statement List Program for DP Communication to a CPU 215 Slave

```

Program Listing
//The DP configuration data in the SM memory area indicate how the
//master has configured the DP slave. The program uses the following data:
//  SMB110    DP status
//  SMB111    Master address
//  SMB112    V memory offset of outputs (word value)
//  SMB114    Number of output bytes
//  SMB115    Number of input bytes
//  VD1000    Output data pointer
//  VD1004    Input data pointer

NETWORK
LD      SM0.0                //On every scan:
MOVD    &VB0, VD1000        //create an output pointer,
MOVW    SMW112, VW1002      //add in the output offset,
MOVD    &VB0, VD1004        //create an input pointer,
MOVW    SMW112, VW1006      //add in output offset,
MOVW    +0, AC0             //clear the accumulator,
MOVB    SMB114, AC0         //load the number of output bytes.
+I      AC0, VW1006         //Offset pointer

NETWORK
LDB>=   SMB114, 9           //If the number of output bytes > 8,
MOVB    8, VB1008          //output count = 8
NOT      VB1008             //Else
MOVB    SMB114, VB1008     //output count = number of output bytes.

NETWORK
LDB>=   SMB115, 9           //If the number of input bytes > 8,
MOVB    8, VB1009          //input count = 8
NOT      VB1009            //Else
MOVB    SMB115, VB1009     //input count = number of input bytes.

NETWORK
LD      SM0.0                //On every scan:
BMB     *VD1000, QB0, VB1008 //copy the DP outputs to the outputs,
BMB     IB0, *VD1004, VB1009 //copy the inputs to the DP inputs.

NETWORK
MEND

```

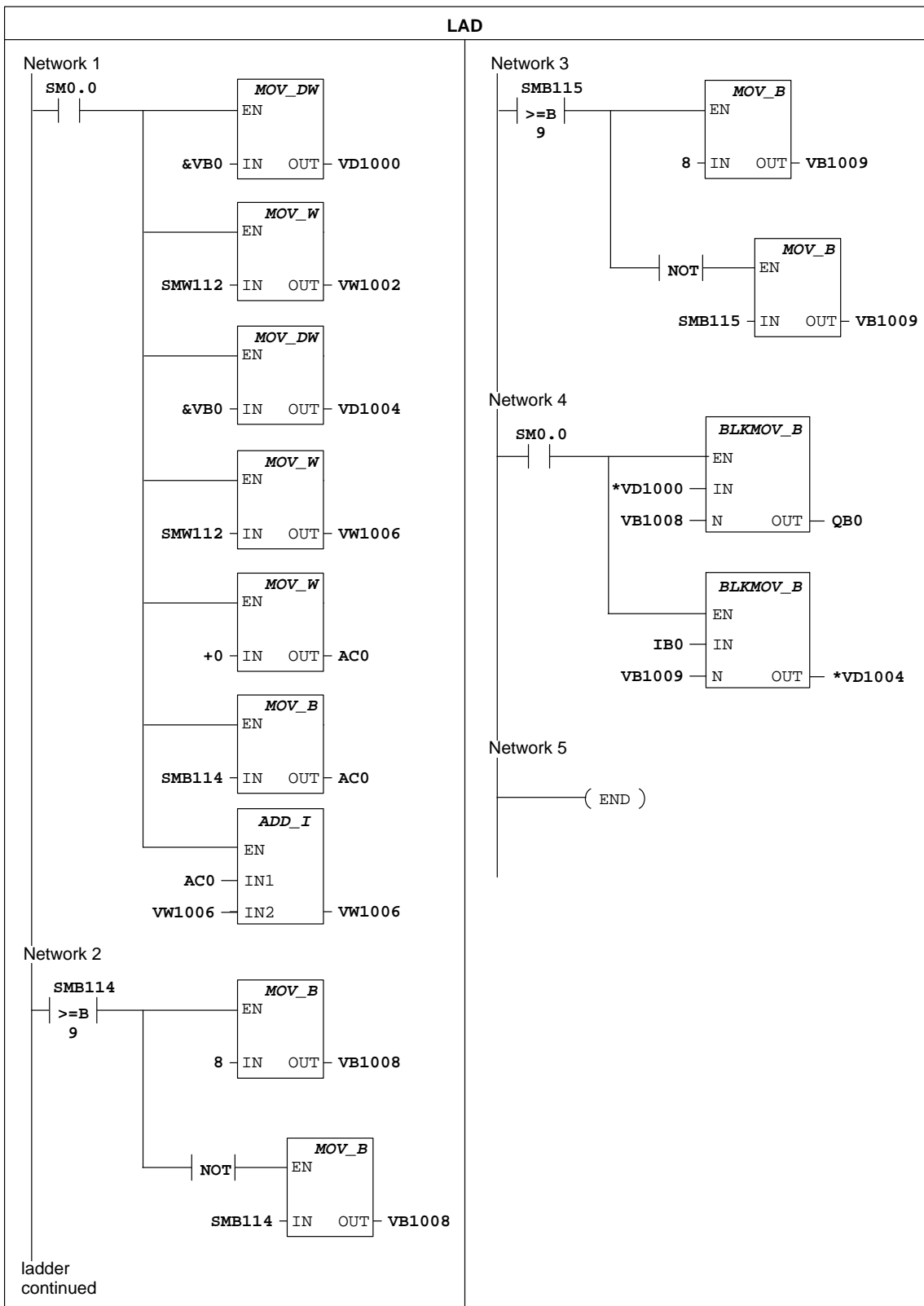


Figure 9-12 Sample Ladder Logic Program for DP Communication to a CPU 215 Slave

9.6 Network Performance

Limitations

Network performance is a function of many complex variables, but two basic factors dominate the performance of any network: baud rate and the number of stations connected to the network.

Example of a Token-Passing Network

In a token-passing network, the station that holds the token is the only station that has the right to initiate communication. Therefore, an important performance figure for a token-passing network is the token rotation time. This is the time required for the token to be circulated to each of the masters (token holders) in the logical ring. In order to illustrate the operation of a multiple-master network, consider the example shown in Figure 9-13.

The network in Figure 9-13 has four S7-200 CPU modules, and each has its own TD 200. Two CPU 214 modules gather data from all the other CPU modules.

Note

The example provided here is based on a network such as the one shown in Figure 9-13. The configuration includes TD 200 units. The CPU 214 modules are using the NETR and NETW instructions. The formulas for token hold time and token rotation time shown in Figure 9-14 are also based on such a configuration.

COM PROFIBUS provides an analyzer to determine network performance.

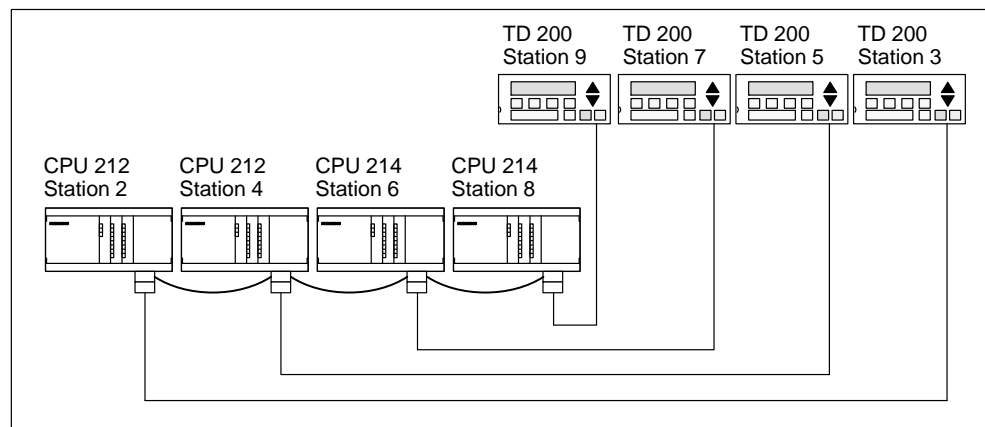


Figure 9-13 Example of a Token-Passing Network

In this configuration, the TD 200 (station 3) communicates with the CPU 212 (station 2), TD 200 (station 5) communicates with CPU 212 (station 4), and so on. Also, CPU 214 (station 6) is sending messages to stations 2, 4, and 8, and CPU 214 (station 8) is sending messages to stations 2, 4, and 6. In this network, there are six master stations (the four TD 200 units and the two CPU 214 modules) and two slave stations (the two CPU 212 modules).

Sending Messages

In order for a master to send a message, it must hold the token. For example: When station 3 has the token, it initiates a request message to station 2 and then it passes the token to station 5. Station 5 then initiates a request message to station 4 and then passes the token to station 6. Station 6 then initiates a message to station 2, 4, or 8, and passes the token to station 7. This process of initiating a message and passing the token continues around the logical ring from station 3 to station 5, station 6, station 7, station 8, station 9, and finally back to station 3. The token must rotate completely around the logical ring in order for a master to be able to send a request for information. For a logical ring of six stations, sending one request message per token hold to read or write one double-word value (four bytes of data), the token rotation time is approximately 900 ms at 9600 baud. Increasing the number of bytes of data accessed per message or increasing the number of stations increases the token rotation time.

Token Rotation Time

The token rotation time is determined by how long each station holds the token. You can determine the token rotation time for your S7-200 multiple-master network by adding the times that each master holds the token. If the PPI master mode has been enabled (under the PPI protocol on your network), you can send messages to other CPUs by using the Network Read (NETR) and Network Write (NETW) instructions with CPU 214, CPU 215, or CPU 216. (See the description of these instructions in Chapter 10.) If you send messages using these instructions, you can use the formula shown in Figure 9-14 to calculate the approximate token rotation time when the following assumptions are true:

- Each station sends one request per token hold.
- The request is either a read or write request for consecutive data locations.
- There is no conflict for use of the one communication buffer in the CPU.
- No CPU has a scan time longer than about 10 ms.

Token hold time (T_{hold}) = (128 overhead + n data char) * 11 bits/char * 1/baud rate

Token rotation time (T_{rot}) = T_{hold} of master 1 + T_{hold} of master 2 + . . . + T_{hold} of master m

where n is the number of data characters (bytes)
and m is the number of masters

Solving for the token rotation time using the example shown above, where each of the six masters has the same token hold time, yields:

T (token hold time) = (128 + 4 char) * 11 bits/char * 1/9600 bit times/s
= 151.25 ms/master

T (token rotation time) = 151.25 ms/master * 6 masters
= 907.5 ms

(One "bit time" equals the duration of one signaling period.)

Figure 9-14 Formulas for Token Hold Time and Token Rotation Time, Using NETR and NETW

Token Rotation Comparison

Table 9-15 and Table 9-16 show comparisons of the token rotation time versus the number of stations and amount of data at 19.2 kbaud, and 9.6 kbaud, respectively. The times are figured for a case where you use the Network Read (NETR) and Network Write (NETW) instructions with CPU 214, CPU 215, or CPU 216.

Table 9-15 Token Rotation Time versus Number of Stations and Amount of Data at 19.2 kbaud

Bytes Transferred per Station at 19.2 kbaud	Number of Stations, with Time in Seconds								
	2 stations	3 stations	4 stations	5 stations	6 stations	7 stations	8 stations	9 stations	10 stations
1	0.15	0.22	0.30	0.37	0.44	0.52	0.59	0.67	0.74
2	0.15	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.74
3	0.15	0.23	0.30	0.38	0.45	0.53	0.60	0.68	0.75
4	0.15	0.23	0.30	0.38	0.45	0.53	0.61	0.68	0.76
5	0.15	0.23	0.30	0.38	0.46	0.53	0.61	0.69	0.76
6	0.15	0.23	0.31	0.38	0.46	0.54	0.61	0.69	0.77
7	0.15	0.23	0.31	0.39	0.46	0.54	0.62	0.70	0.77
8	0.16	0.23	0.31	0.39	0.47	0.55	0.62	0.70	0.78
9	0.16	0.24	0.31	0.39	0.47	0.55	0.63	0.71	0.78
10	0.16	0.24	0.32	0.40	0.47	0.55	0.63	0.71	0.79
11	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80
12	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80
13	0.16	0.24	0.32	0.40	0.48	0.57	0.65	0.73	0.81
14	0.16	0.24	0.33	0.41	0.49	0.57	0.65	0.73	0.81
15	0.16	0.25	0.33	0.41	0.49	0.57	0.66	0.74	0.82
16	0.17	0.25	0.33	0.41	0.50	0.58	0.66	0.74	0.83

Table 9-16 Token Rotation Time versus Number of Stations and Amount of Data at 9.6 kbaud

Bytes Transferred per Station at 9.6 kbaud	Number of Stations, with Time in Seconds								
	2 stations	3 stations	4 stations	5 stations	6 stations	7 stations	8 stations	9 stations	10 stations
1	0.30	0.44	0.59	0.74	0.89	1.03	1.18	1.33	1.48
2	0.30	0.45	0.60	0.74	0.89	1.04	1.19	1.34	1.49
3	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1.35	1.50
4	0.30	0.45	0.61	0.76	0.91	1.06	1.21	1.36	1.51
5	0.30	0.46	0.61	0.76	0.91	1.07	1.22	1.37	1.52
6	0.31	0.46	0.61	0.77	0.92	1.07	1.23	1.38	1.54
7	0.31	0.46	0.62	0.77	0.93	1.08	1.24	1.39	1.55
8	0.31	0.47	0.62	0.78	0.94	1.09	1.25	1.40	1.56
9	0.31	0.47	0.63	0.78	0.94	1.10	1.26	1.41	1.57
10	0.32	0.47	0.63	0.79	0.95	1.11	1.27	1.42	1.58
11	0.32	0.48	0.64	0.80	0.96	1.11	1.27	1.43	1.59
12	0.32	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60
13	0.32	0.48	0.65	0.81	0.97	1.13	1.29	1.45	1.62
14	0.33	0.49	0.65	0.81	0.98	1.14	1.30	1.46	1.63
15	0.33	0.49	0.66	0.82	0.98	1.15	1.31	1.47	1.64
16	0.33	0.50	0.66	0.83	0.99	1.16	1.32	1.49	1.65

Optimizing Network Performance

The two factors which have the greatest effect on network performance are the baud rate and the number of masters. Operating the network at the highest baud rate supported by all devices has the greatest effect on the network. Minimizing the number of masters on a network also increases the performance of the network. Each master on the network increases the overhead requirements of the network. Fewer masters lessen the overhead.

The following factors also affect the performance of the network:

- Selection of master and slave addresses
- Gap update factor
- Highest station address

The addresses of the master devices should be set so that all of the masters are at sequential addresses with no gaps between addresses. Whenever there is an address gap between masters, the masters continually check the addresses in the gap to see if there is another master wanting to come online. This checking requires time and increases the overhead of the network. If there is no address gap between masters, no checking is done and so the overhead is minimized.

Slave addresses may be set to any value without affecting network performance as long as the slaves are not between masters. Slaves between masters increase the network overhead in the same way as having address gaps between masters.

The S7-200 CPUs can be configured to check address gaps only on a periodic basis. This checking is accomplished by setting the gap update factor (GUF) in the CPU configuration for a CPU port with STEP 7-Micro/WIN. The GUF tells the CPU how often to check the address gap for other masters. A GUF of one tells the CPU to check the address gap every time it holds the token. A GUF of two tells the CPU to check the address gap once every two times it holds the token. Setting a higher GUF reduces the network overhead if there are address gaps between masters. If there are no address gaps between masters, the GUF has no effect on performance. Setting a large number for the GUF causes long delays in bringing masters online since addresses are checked less frequently. The GUF is only used when a CPU is operating as a PPI master.

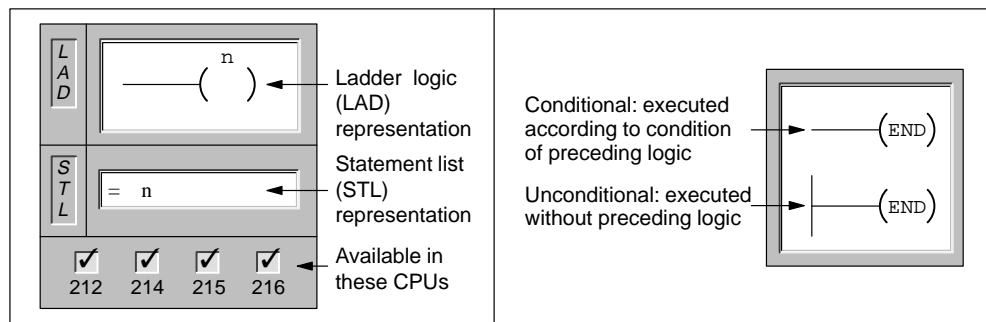
The highest station address (HSA) defines the highest address at which a master should look for another master. Setting an HSA limits the address gap which must be checked by the last master (highest address) in the network. Limiting the size of the address gap minimizes the time required to find and bring online another master. The highest station address has no effect on slave addresses. Masters can still communicate with slaves which have addresses greater than the HSA. The HSA is only used when a CPU is operating as a PPI master. The HSA can be set in the CPU configuration for a CPU port with STEP 7-Micro/WIN.

As a general rule, you should set the highest station address on all masters to the same value. This address should be greater than or equal to the highest master address. The S7-200 CPUs default to a value of 126 for the highest station address.

10

Instruction Set

The following conventions are used in this chapter to illustrate the equivalent ladder logic and statement list instructions and the CPUs in which the instructions are available:



Chapter Overview

Section	Description	Page
10.1	Valid Ranges for the S7-200 CPUs	10-2
10.2	Contact Instructions	10-4
10.3	Comparison Contact Instructions	10-7
10.4	Output Instructions	10-10
10.5	Timer, Counter, High-Speed Counter, High-Speed Output, Clock, and Pulse Instructions	10-13
10.6	Math and PID Loop Control Instructions	10-50
10.7	Increment and Decrement Instructions	10-66
10.8	Move, Fill, and Table Instructions	10-68
10.9	Shift and Rotate Instructions	10-78
10.10	Program Control Instructions	10-84
10.11	Logic Stack Instructions	10-99
10.12	Logic Operations	10-102
10.13	Conversion Instructions	10-108
10.14	Interrupt and Communications Instructions	10-114

10.1 Valid Ranges for the S7-200 CPUs

Table 10-1 Summary of S7-200 CPU Memory Ranges and Features

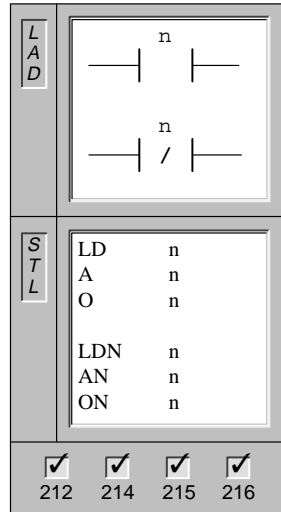
Description	CPU 212	CPU 214	CPU 215	CPU 216
User program size	512 words	2 Kwords	4 Kwords	4 Kwords
User data size	512 words	2 Kwords	2.5 Kwords	2.5 Kwords
Process-image input register	I0.0 to I7.7	I0.0 to I7.7	I0.0 to I7.7	I0.0 to I7.7
Process-image output register	Q0.0 to Q7.7	Q0.0 to Q7.7	Q0.0 to Q7.7	Q0.0 to Q7.7
Analog inputs (read only)	AIW0 to AIW30	AIW0 to AIW30	AIW0 to AIW30	AIW0 to AIW30
Analog outputs (write only)	AQW0 to AQW30	AQW0 to AQW30	AQW0 to AQW30	AQW0 to AQW30
Variable memory (V) Permanent area (max.)	V0.0 to V1023.7 V0.0 to V199.7	V0.0 to V4095.7 V0.0 to V1023.7	V0.0 to V5119.7 V0.0 to V5119.7	V0.0 to V5119.7 V0.0 to V5119.7
Bit memory (M) Permanent area (max.)	M0.0 to M15.7 MB0 to MB13	M0.0 to M31.7 MB0 to MB13	M0.0 to M31.7 MB0 to MB13	M0.0 to M31.7 MB0 to MB13
Special Memory (SM) Read only	SM0.0 to SM45.7 SM0.0 to SM29.7	SM0.0 to SM85.7 SM0.0 to SM29.7	SM0.0 to SM194.7 SM0.0 to SM29.7	SM0.0 to SM194.7 SM0.0 to SM29.7
Timers	64 (T0 to T63)	128 (T0 to T127)	256 (T0 to T255)	256 (T0 to T255)
Retentive on-delay 1 ms	T0	T0, T64	T0, T64	T0, T64
Retentive on-delay 10 ms	T1 to T4	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68
Retentive on-delay 100 ms	T5 to T31	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95
On-delay 1 ms	T32	T32, T96	T32, T96	T32, T96
On-delay 10 ms	T33 to T36	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100
On-delay 100 ms	T37 to T63	T37 to T63, T101 to T127	T37 to T63, T101 to T255	T37 to T63, T101 to T255
Counters	C0 to C63	C0 to C127	C0 to C255	C0 to C255
High speed counter	HC0	HC0 to HC2	HC0 to HC2	HC0 to HC2
Sequential control relays	S0.0 to S7.7	S0.0 to S15.7	S0.0 to S31.7	S0.0 to S31.7
Accumulator registers	AC0 to AC3	AC0 to AC3	AC0 to AC3	AC0 to AC3
Jumps/Labels	0 to 63	0 to 255	0 to 255	0 to 255
Call/Subroutine	0 to 15	0 to 63	0 to 63	0 to 63
Interrupt routines	0 to 31	0 to 127	0 to 127	0 to 127
Interrupt events	0, 1, 8 to 10, 12	0 to 20	0 to 23	0 to 26
PID loops	Not supported	Not supported	0 to 7	0 to 7
Ports	0	0	0	0 and 1

Table 10-2 S7-200 CPU Operand Ranges

Access Method	CPU 212	CPU 214	CPU 215	CPU 216
Bit access (byte.bit)	V 0.0 to 1023.7	V 0.0 to 4095.7	V 0.0 to 5119.7	V 0.0 to 5119.7
	I 0.0 to 7.7	I 0.0 to 7.7	I 0.0 to 7.7	I 0.0 to 7.7
	Q 0.0 to 7.7	Q 0.0 to 7.7	Q 0.0 to 7.7	Q 0.0 to 7.7
	M 0.0 to 15.7	M 0.0 to 31.7	M 0.0 to 31.7	M 0.0 to 31.7
	SM 0.0 to 45.7	SM 0.0 to 85.7	SM 0.0 to 194.7	SM 0.0 to 194.7
	T 0 to 63	T 0 to 127	T 0 to 255	T 0 to 255
	C 0 to 63	C 0 to 127	C 0 to 255	C 0 to 255
	S 0.0 to 7.7	S 0.0 to 15.7	S 0.0 to 31.7	S 0.0 to 31.7
Byte access	VB 0 to 1023	VB 0 to 4095	VB 0 to 5119	VB 0 to 5119
	IB 0 to 7	IB 0 to 7	IB 0 to 7	IB 0 to 7
	QB 0 to 7	QB 0 to 7	QB 0 to 7	QB 0 to 7
	MB 0 to 15	MB 0 to 31	MB 0 to 31	MB 0 to 31
	SMB 0 to 45	SMB 0 to 85	SMB 0 to 194	SMB 0 to 194
	AC 0 to 3	AC 0 to 3	AC 0 to 3	AC 0 to 3
	SB 0 to 7	SB 0 to 15	SB 0 to 31	SB 0 to 31
Constant	Constant	Constant	Constant	
Word access	VW 0 to 1022	VW 0 to 4094	VW 0 to 5118	VW 0 to 5118
	T 0 to 63	T 0 to 127	T 0 to 255	T 0 to 255
	C 0 to 63	C 0 to 127	C 0 to 255	C 0 to 255
	IW 0 to 6	IW 0 to 6	IW 0 to 6	IW 0 to 6
	QW 0 to 6	QW 0 to 6	QW 0 to 6	QW 0 to 6
	MW 0 to 14	MW 0 to 30	MW 0 to 30	MW 0 to 30
	SMW 0 to 44	SMW 0 to 84	SMW 0 to 193	SMW 0 to 193
	AC 0 to 3	AC 0 to 3	AC 0 to 3	AC 0 to 3
	AIW 0 to 30	AIW 0 to 30	AIW 0 to 30	AIW 0 to 30
	AQW 0 to 30	AQW 0 to 30	AQW 0 to 30	AQW 0 to 30
	SW 0 to 6	SW 0 to 14	SW 0 to 30	SW 0 to 30
Constant	Constant	Constant	Constant	
Double word access	VD 0 to 1020	VD 0 to 4092	VD 0 to 5116	VD 0 to 5116
	ID 0 to 4	ID 0 to 4	ID 0 to 4	ID 0 to 4
	QD 0 to 4	QD 0 to 4	QD 0 to 4	QD 0 to 4
	MD 0 to 12	MD 0 to 28	MD 0 to 28	MD 0 to 28
	SMD 0 to 42	SMD 0 to 82	SMD 0 to 191	SMD 0 to 191
	AC 0 to 3	AC 0 to 3	AC 0 to 3	AC 0 to 3
	HC 0	HC 0 to 2	HC 0 to 2	HC 0 to 2
	SD 0 to 4	SD 0 to 12	SD 0 to 28	SD 0 to 28
Constant	Constant	Constant	Constant	

10.2 Contact Instructions

Standard Contacts



The **Normally Open** contact is closed (on) when the bit value of address n is equal to 1.

In STL, the normally open contact is represented by the **Load, And, and Or** instructions. These instructions Load, AND, or OR the bit value of address n to the top of the stack.

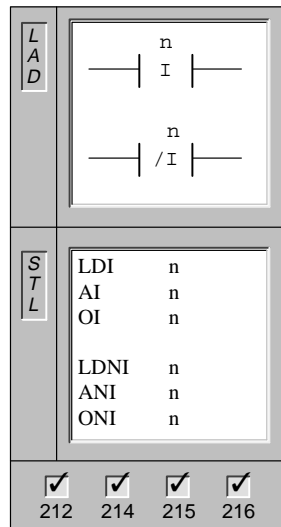
The **Normally Closed** contact is closed (on) when the bit value of address n is equal to 0.

In STL, the normally closed contact is represented by the **Load Not, And Not, and Or Not** instructions. These instructions Load, AND, or OR the logical Not of the bit value of address n to the top of the stack.

Operands: n: I, Q, M, SM, T, C, V, S

These instructions obtain the referenced value from the process-image register when it is updated at the beginning of each CPU scan.

Immediate Contacts



The **Normally Open Immediate** contact is closed (on) when the bit value of the referenced physical input point n is equal to 1.

In STL, the Normally Open Immediate contact is represented by the **Load Immediate, And Immediate, and Or Immediate** instructions. These instructions Load, AND, or OR the bit value of the referenced physical input point n to the top of the stack immediately.

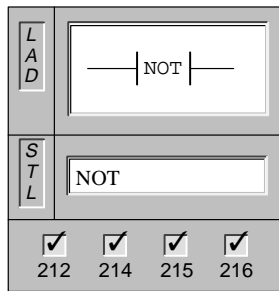
The **Normally Closed Immediate** contact is closed (on) when the bit value of the referenced physical input point n is equal to 0.

In STL, the Normally Closed Immediate contact is represented by the **Load Not Immediate, And Not Immediate, and Or Not Immediate** instructions. These instructions Load, AND, or OR the logical Not of the value of the referenced physical input point n to the top of the stack immediately.

Operands: n: I

The immediate instruction obtains the referenced value from the physical input point when the instruction is executed, but the process-image register is not updated.

Not

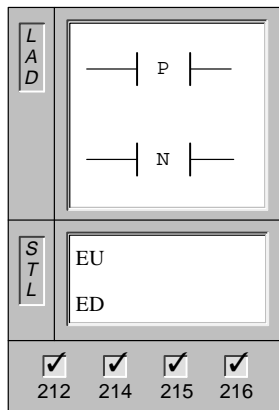


The **Not** contact changes the state of power flow. When power flow reaches the Not contact, it stops. When power flow does not reach the Not contact, it supplies power flow.

In STL, the **Not** instruction changes the value on the top of the stack from 0 to 1, or from 1 to 0.

Operands: none

Positive, Negative Transition



The **Positive Transition** contact allows power to flow for one scan for each off-to-on transition.

In STL, the Positive Transition contact is represented by the **Edge Up** instruction. Upon detection of a 0-to-1 transition in the value on the top of the stack, the top of the stack value is set to 1; otherwise, it is set to 0.

The **Negative Transition** contact allows power to flow for one scan, for each on-to-off transition.

In STL, the Negative Transition contact is represented by the **Edge Down** instruction. Upon detection of a 1-to-0 transition in the value on the top of the stack, the top of the stack value is set to 1; otherwise, it is set to 0.

Operands: none

Contact Examples

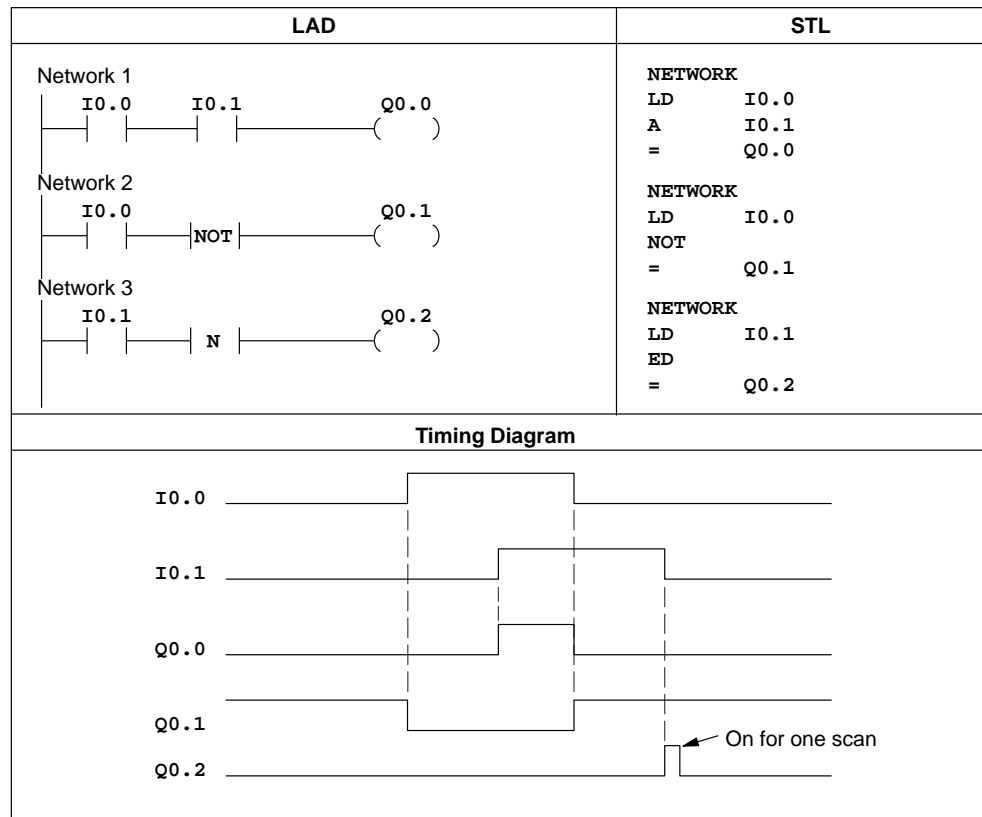
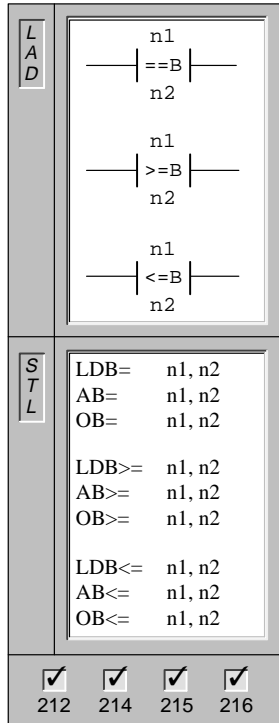


Figure 10-1 Examples of Boolean Contact Instructions for LAD and STL

10.3 Comparison Contact Instructions

Compare Byte



The **Compare Byte** instruction is used to compare two values: n1 to n2. A comparison of n1 = n2, n1 >= n2, or n1 <= n2 can be made.

Operands: n1, n2: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

In LAD, the contact is on when the comparison is true.

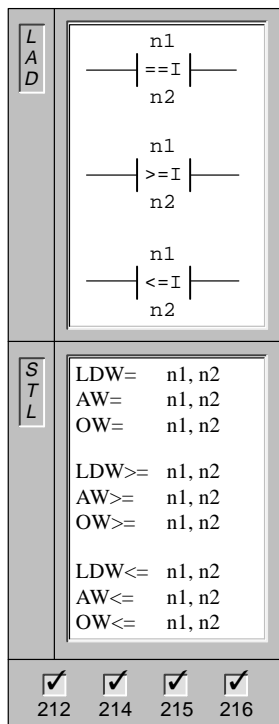
In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Byte comparisons are unsigned.

Note: You can create a <>, <, or > comparison by using the Not instruction with the =, >=, or <= Compare instruction. The following sequence is equivalent to a <> comparison of VB100 to 50:

```
LDB= VB100, 50
NOT
```

Compare Word Integer



The **Compare Word Integer** instruction is used to compare two values: n1 to n2. A comparison of n1 = n2, n1 >= n2, or n1 <= n2 can be made.

Operands: n1, n2: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

In LAD, the contact is on when the comparison is true.

In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Word comparisons are signed (16#7FFF > 16#8000).

Note: You can create a <>, <, or > comparison by using the Not instruction with the =, >=, or <= Compare instruction. The following sequence is equivalent to a <> comparison of VW100 to 50:

```
LDW= VW100, 50
NOT
```

Compare Double Word Integer

L A D			
S T L	LDD= n1, n2		
	AD= n1, n2		
	OD= n1, n2		
	LDD>= n1, n2		
	AD>= n1, n2		
	OD>= n1, n2		
	LDD<= n1, n2		
	AD<= n1, n2		
	OD<= n1, n2		
<input checked="" type="checkbox"/> 212	<input checked="" type="checkbox"/> 214	<input checked="" type="checkbox"/> 215	<input checked="" type="checkbox"/> 216

The **Compare Double Word** instruction is used to compare two values: n1 to n2. A comparison of n1 = n2, n1 >= n2, or n1 <= n2 can be made.

Operands: n1, n2: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD

In LAD, the contact is on when the comparison is true.

In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Double word comparisons are signed (16#7FFFFFFF > 16#80000000).

Note: You can create a <>, <, or > comparison by using the Not instruction with the =, >=, or <= Compare instruction. The following sequence is equivalent to a <> comparison of VD100 to 50:

```
LDD= VD100, 50
NOT
```

Compare Real

L A D			
S T L	LDR= n1, n2		
	AR= n1, n2		
	OR= n1, n2		
	LDR>= n1, n2		
	AR>= n1, n2		
	OR>= n1, n2		
	LDR<= n1, n2		
	AR<= n1, n2		
	OR<= n1, n2		
<input type="checkbox"/> 212	<input checked="" type="checkbox"/> 214	<input checked="" type="checkbox"/> 215	<input checked="" type="checkbox"/> 216

The **Compare Real** instruction is used to compare two values: n1 to n2. A comparison of n1 = n2, n1 >= n2, or n1 <= n2 can be made.

Operands: n1, n2: VD, ID, QD, MD, SMD, AC, Constant, *VD, *AC, SD

In LAD, the contact is on when the comparison is true.

In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Real comparisons are signed.

Note: You can create a <>, <, or > comparison by using the Not instruction with the =, >=, or <= Compare instruction. The following sequence is equivalent to a <> comparison of VD100 to 50:

```
LDR= VD100, 50.0
NOT
```

Comparison Contact Examples

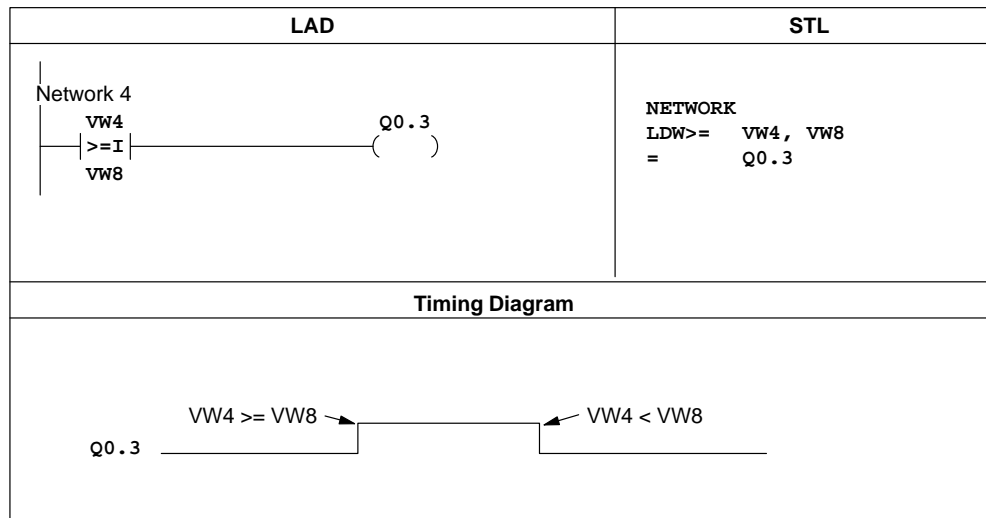
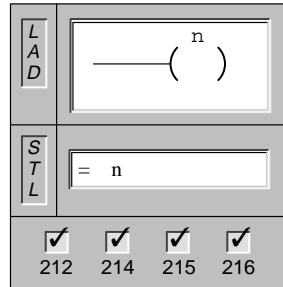


Figure 10-2 Examples of Comparison Contact Instructions for LAD and STL

10.4 Output Instructions

Output

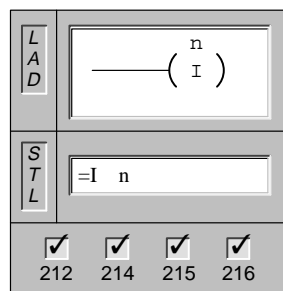


When the **Output** instruction is executed, the specified parameter (n) is turned on.

In STL, the output instruction copies the top of the stack to the specified parameter (n).

Operands: n: I, Q, M, SM, T, C, V, S

Output Immediate



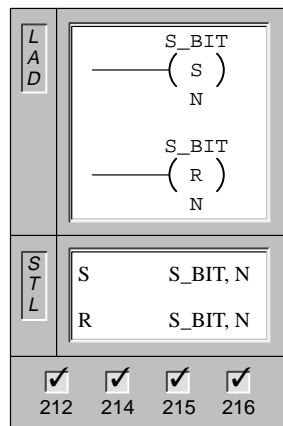
When the **Output Immediate** instruction is executed, the specified physical output point (n) is turned on immediately.

In STL, the output immediate instruction copies the top of the stack to the specified physical output point (n) immediately.

Operands: n: Q

The "I" indicates an immediate reference; the new value is written to both the physical output and the corresponding process-image register location when the instruction is executed. This differs from the non-immediate references, which write the new value to the process-image register only.

Set, Reset

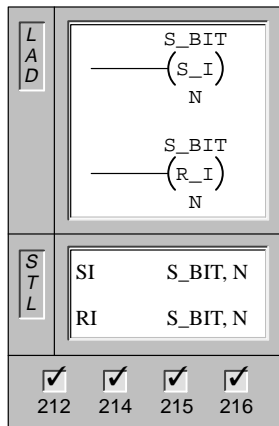


When the **Set** and **Reset** instructions are executed, the specified number of points (N) starting at the S_BIT are set (turned on) or reset (turned off).

Operands: S_BIT: I, Q, M, SM, T, C, V, S
N: IB, QB, MB, SMB, VB, AC, Constant, *VD, *AC, SB

The range of points that can be set or reset is 1 to 255. When using the Reset instruction, if the S_BIT is specified to be either a T or C bit, then either the timer or counter bit is reset and the timer/counter current value is cleared.

Set, Reset Immediate



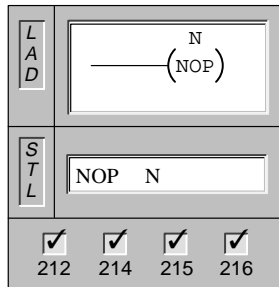
When the **Set Immediate** and **Reset Immediate** instructions are executed, the specified number of physical output points (N) starting at the S_BIT are immediately set (turned on) or immediately reset (turned off).

Operands: S_BIT: Q
 N: IB, QB, MB, SMB, VB, AC, Constant,
 *VD, *AC, SB

The range of points that can be set or reset is 1 to 64.

The "I" indicates an immediate reference; the new value is written to both the physical output point and the corresponding process-image register location when the instruction is executed. This differs from the non-immediate references, which write the new value to the process-image register only.

No Operation



The **No Operation** instruction has no effect on the user program execution. The operand N is a number from 0 to 255.

Operands: N: 0 to 255

If you use the NOP instruction, you must place it inside the main program, a subroutine, or an interrupt routine.

Output Examples

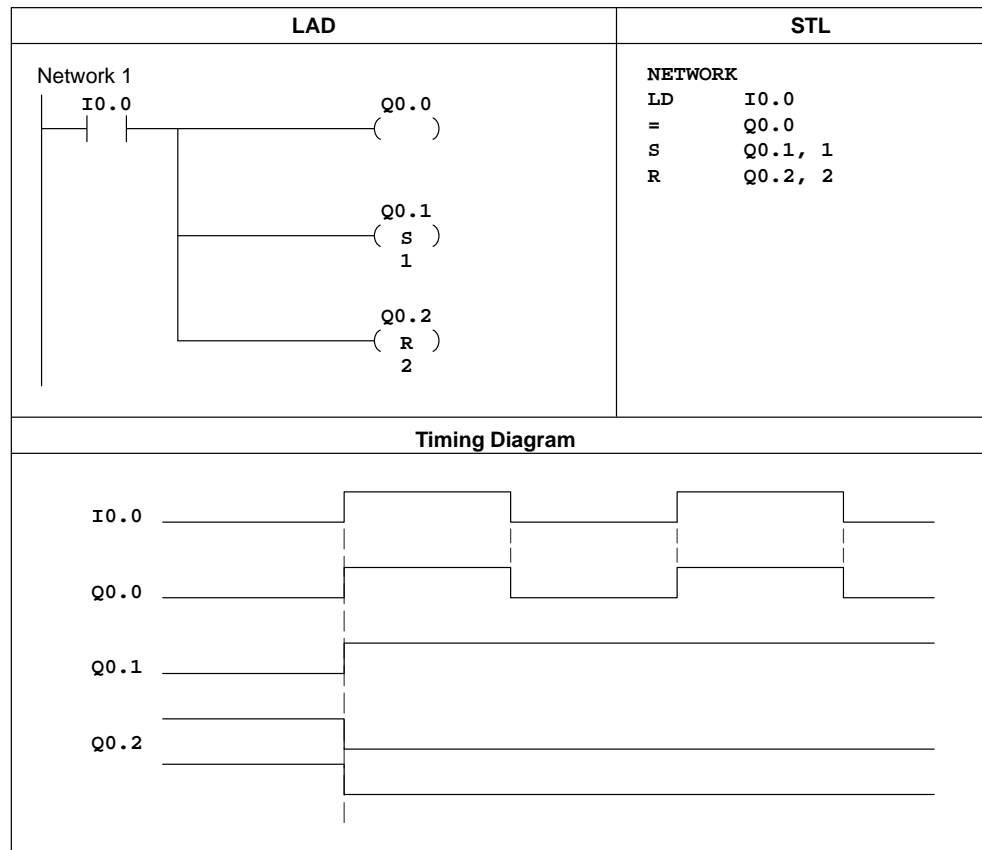
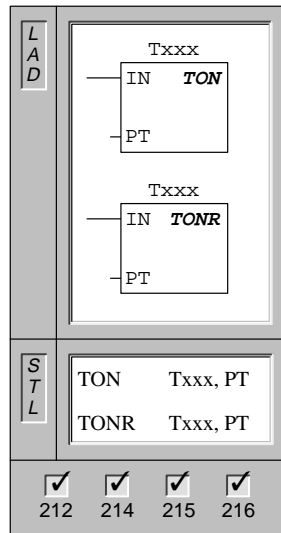


Figure 10-3 Examples of Output Instructions for LAD and STL

10.5 Timer, Counter, High-Speed Counter, High-Speed Output, Clock, and Pulse Instructions

On-Delay Timer, Retentive On-Delay Timer



The **On-Delay Timer** and **Retentive On-Delay Timer** instructions time up to the maximum value when enabled. When the current value (Txxx) is \geq to the Preset Time (PT), the timer bit turns on.

The On-Delay timer is reset when disabled, while the Retentive On-Delay timer stops timing when disabled. Both timers stop timing when they reach the maximum value.

Operands:	Txxx:	<u>TON</u>	<u>TONR</u>
	1 ms	T32, T96	T0, T64
	10 ms	T33 to T36 T97 to T100	T1 to T4 T65 to T68
	100 ms	T37 to T63 T101 to T255	T5 to T31 T69 to T95
	PT:	VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW	

TON and TONR timers are available in three resolutions. The resolution is determined by the timer number and is shown in Table 10-3. Each count of the current value is a multiple of the time base. For example, a count of 50 on a 10-millisecond (ms) timer represents 500 ms.

Table 10-3 Timer Numbers and Resolutions

Timer	Resolution	Maximum Value	CPU 212	CPU 214	CPU 215/216
TON	1 ms	32.767 seconds (s)	T32	T32, T96	T32, T96
	10 ms	327.67 s	T33 to T36	T33 to T36, T97 to T100	T33 to T36, T97 to T100
	100 ms	3276.7 s	T37 to T63	T37 to T63, T101 to T127	T37 to T63, T101 to T255
TONR	1 ms	32.767 s	T0	T0, T64	T0, T64
	10 ms	327.67 s	T1 to T4	T1 to T4, T65 to T68	T1 to T4, T65 to T68
	100 ms	3276.7 s	T5 to T31	T5 to T31, T69 to T95	T5 to T31, T69 to T95

Understanding the S7-200 Timer Instructions

You can use timers to implement time-based counting functions. The S7-200 provides two different timer instructions: the On-Delay Timer (TON), and the Retentive On-Delay Timer (TONR). The two types of timers (TON and TONR) differ in the ways that they react to the state of the enabling input. Both TON and TONR timers time up while the enabling input is on: the timers do not time up while the enabling input is off, but when the enabling input is off, a TON timer is reset automatically and a TONR timer is not reset and holds its last value. Therefore, the TON timer is best used when you are timing a single interval. The TONR timer is appropriate when you need to accumulate a number of timed intervals.

S7-200 timers have the following characteristics:

- Timers are controlled with a single enabling input, and have a current value that maintains the elapsed time since the timer was enabled. The timers also have a preset time value (PT) that is compared to the current value each time the current value is updated and when the timer instruction is executed.
- A timer bit is set or reset based upon the result of the comparison of current value to the preset time value.
- When the current value is greater than or equal to the preset time value, the timer bit (T-bit), is turned on.

Note

Some timer current values can be made retentive. The timer bits are not retentive, and are set only as a result of the comparison between the current value and the preset value.

When you reset a timer, its current value is set to zero and its T-bit is turned off. You can reset any timer by using the Reset instruction, but using a Reset instruction is the only method for resetting a TONR timer. Writing a zero to a timer's current value does not reset its timer bit. In the same way, writing a zero to the timer's T-bit does not reset its current value.

Several 1-ms timers can also be used to generate an interrupt event. See Section 10.14 for information about timed interrupts.

Updating Timers with 1-ms Resolution

The S7-200 CPU provides timers that are updated once per millisecond (1-ms timers) by the system routine that maintains the system time base. These timers provide precise control of an operation.

Since the current value of an active 1-ms timer is updated in a system routine, the update is automatic. Once a 1-ms timer has been enabled, the execution of the timer's controlling TON/TONR instruction is required only to control the enabled/disabled state of the timer.

Since the current value and T-bit of a 1-ms timer are updated by a system routine (independent from the programmable logic controller scan and the user program), the current value and T-bits of these timers can be updated anywhere in the scan and are updated more than once per scan if the scan time exceeds one millisecond. Therefore, these values are not guaranteed to remain constant throughout a given execution of the main user program.

Resetting an enabled 1-ms timer turns the timer off, resets the timer's current value to zero, and clears the timer T-bit.

Note

The system routine that maintains the 1-ms system time base is independent of the enabling and disabling of timers. A 1-ms timer is enabled at a point somewhere within the current 1-ms interval. Therefore, the timed interval for a given 1-ms timer can be up to 1 ms short. You should program the preset time value to a value that is 1 greater than the minimum desired timed interval. For example, to guarantee a timed interval of at least 56 ms using a 1-ms timer, you should set the preset time value to 57.

Updating Timers with 10-ms Resolution

The S7-200 CPU provides timers that count the number of 10-ms intervals that have elapsed since the active 10-ms timer was enabled. These timers are updated at the beginning of each scan by adding the accumulated number of 10-ms intervals (since the beginning of the previous scan) to the current value for the timer.

Since the current value of an active 10-ms timer is updated at the beginning of the scan, the update is automatic. Once a 10-ms timer is enabled, execution of the timer's controlling TON/TONR instruction is required only to control the enabled or disabled state of the timer. Unlike the 1-ms timers, a 10-ms timer's current value is updated only once per scan and remains constant throughout a given execution of the main user program.

A reset of an enabled 10-ms timer turns it off, resets its current value to zero, and clears its T-bit.

Note

The process of accumulating 10-ms intervals is performed independently of the enabling and disabling of timers, so the enabling of 10-ms timers will fall within a given 10-ms interval. This means that a timed interval for a given 10-ms timer can be up to 10 ms short. You should program the preset time value to a value 1 greater than the minimum desired timed interval. For example, to guarantee a timed interval of at least 140 ms using a 10-ms timer, you should set the preset time value to 15.

Updating Timers with 100-ms Resolution

Most of the timers provided by the S7-200 use a 100-ms resolution. These timers count the number of 100-ms intervals that have elapsed since the 100-ms timer was last updated. These timers are updated by adding the accumulated number of 100-ms intervals (since the beginning of the previous scan) to the timer's current value when the timer instruction is executed.

The update of 100-ms timers is not automatic, since the current value of a 100-ms timer is updated only if the timer instruction is executed. Consequently, if a 100-ms timer is enabled but the timer instruction is not executed each scan, the current value for that timer is not updated and it loses time. Likewise, if the same 100-ms timer instruction is executed multiple times in a single scan, the number of 100-ms intervals are added to the timer's current value multiple times, and it gains time. Therefore, 100-ms timers should only be used where the timer instruction is executed exactly once per scan. A reset of a 100-ms timer sets its current value to zero and clears its T-bit.

Note

The process of accumulating 100-ms intervals is performed independently of the enabling and disabling of timers, so a given 100-ms timer will be enabled at a point somewhere within the current 100-ms interval. This means that a timed interval for a given 100-ms timer can be up to 100 ms short. You should program the preset time value to a value 1 greater than the minimum desired timed interval. For example, to guarantee a timed interval of at least 2100 ms using a 100-ms timer, the preset time value should be set to 22.

Updating the Timer Current Value

The effect of the various ways in which current time values are updated depends upon how the timers are used. For example, consider the timer operation shown in Figure 10-4.

- In the case where the 1-ms timer is used, Q0.0 is turned on for one scan whenever the timer's current value is updated after the normally closed contact T32 is executed and before the normally open contact T33 is executed.
- In the case where the 10-ms timer is used, Q0.0 is never turned on, because the timer bit T33 is turned on from the top of the scan to the point where the timer box is executed. Once the timer box has been executed, the timer's current value and its T-bit is set to zero. When the normally open contact T33 is executed, T33 is off and Q0.0 is turned off.
- In the case where the 100-ms timer is used, Q0.0 is always turned on for one scan whenever the timer's current value reaches the preset value.

By using the normally closed contact Q0.0 instead of the timer bit as the enabling input to the timer box, the output Q0.0 is guaranteed to be turned on for one scan each time the timer reaches the preset value (see Figure 10-4). Figure 10-5 and Figure 10-6 show examples of the Timer instructions for ladder logic and statement list.

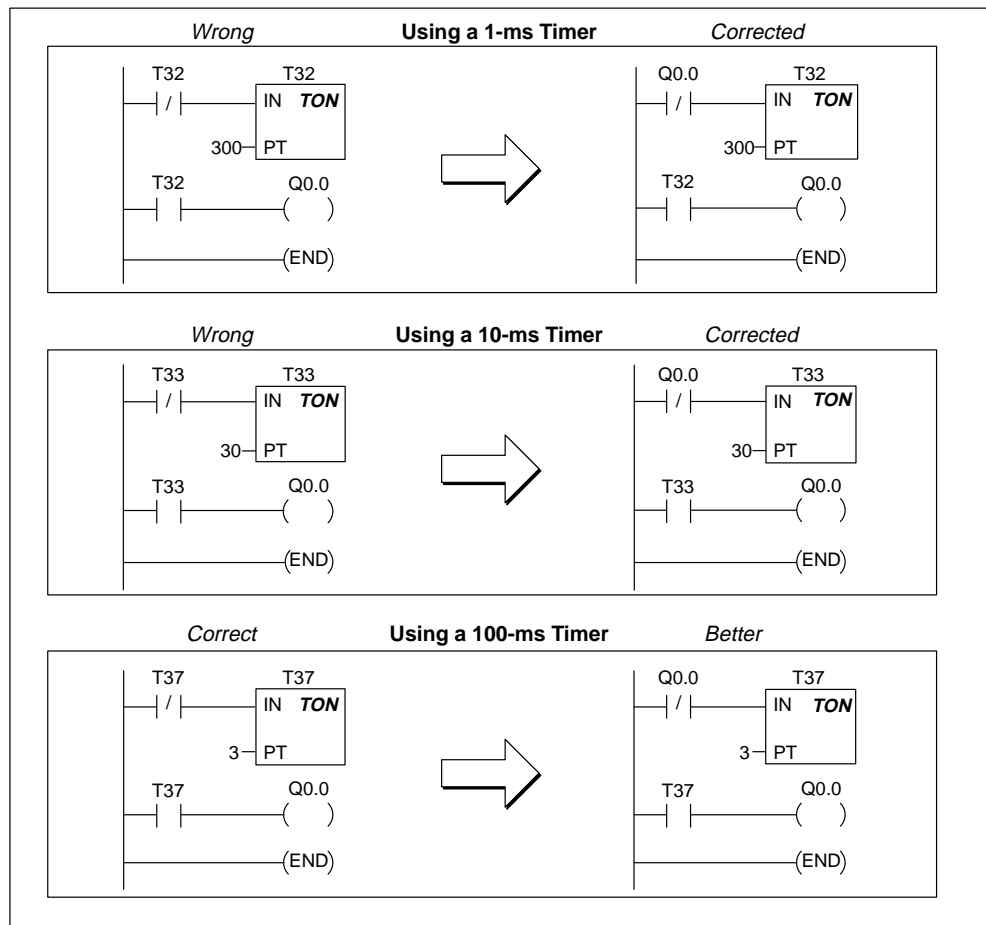


Figure 10-4 Example of Automatically Retriggered One Shot Timer

On-Delay Timer Example

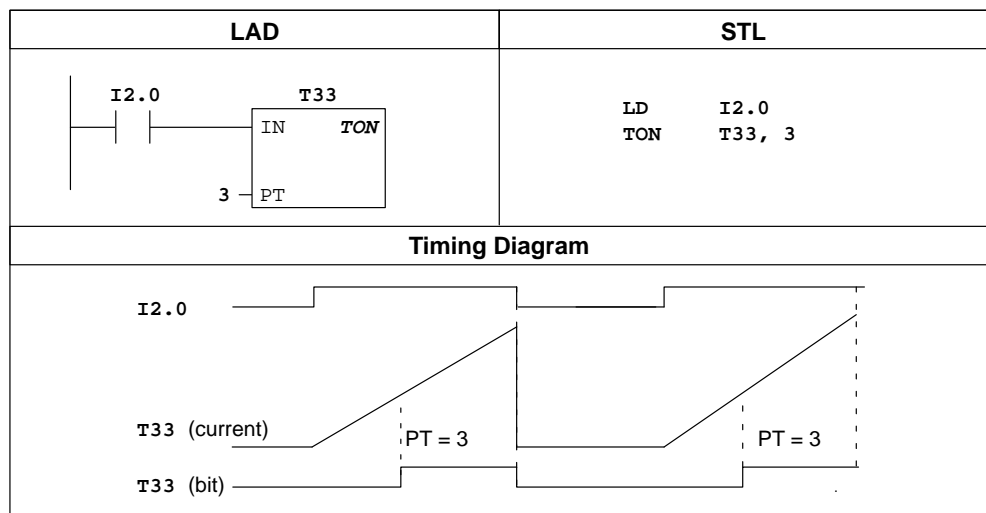


Figure 10-5 Example of On-Delay Timer Instruction for LAD and STL

Retentive On-Delay Timer Example

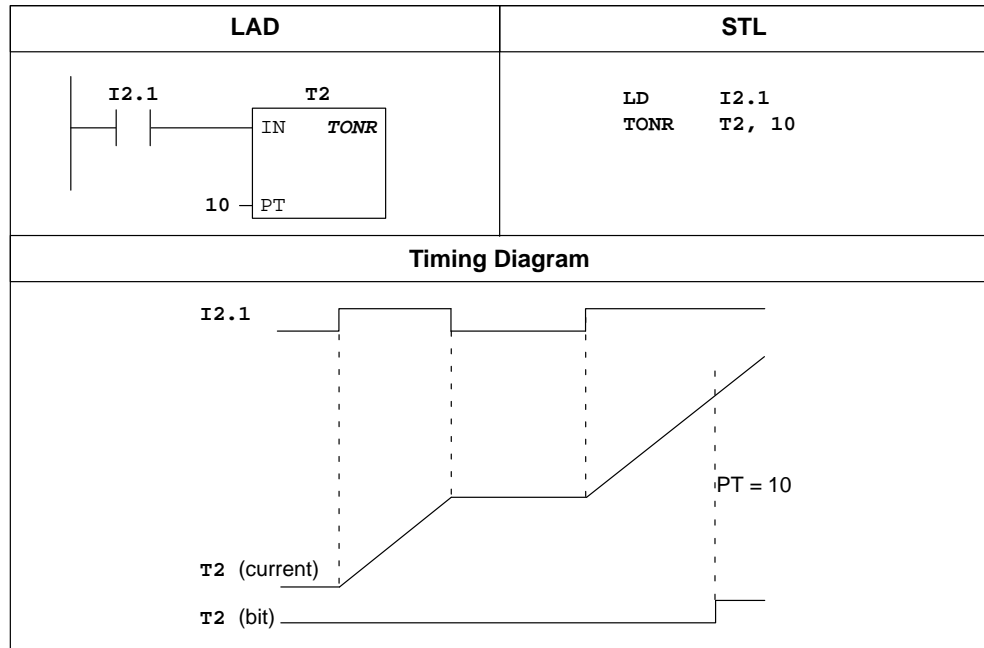
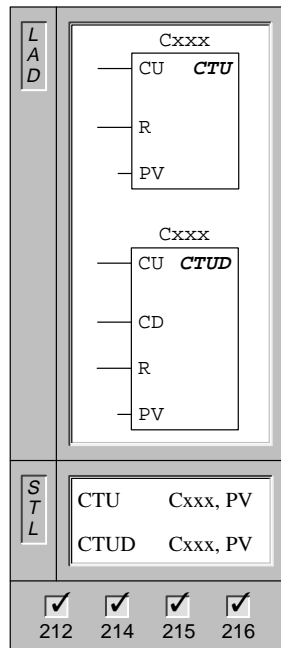


Figure 10-6 Example of Retentive On-Delay Timer Instruction for LAD and STL

Count Up Counter, Count Up/Down Counter



The **Count Up** instruction counts up to the maximum value on the rising edges of the Count Up (CU) input. When the current value (Cxxx) greater than or equal to the Preset Value (PV), the counter bit (Cxxx) turns on. The counter is reset when the Reset (R) input turns on.

In STL, the Reset input is the top of the stack value, while the Count Up input is the value loaded in the second stack location.

The **Count Up/Down** instruction counts up on rising edges of the Count Up (CU) input. It counts down on the rising edges of the Count Down (CD) input. When the current value (Cxxx) is greater than or equal to the Preset Value (PV), the counter bit (Cxxx) turns on. The counter is reset when the Reset (R) input turns on.

In STL, the Reset input is the top of the stack value, the Count Down input is the value loaded in the second stack location, and the Count Up input is the value loaded in the third stack location.

Operands: Cxxx: 0 to 255
 PV: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

Understanding the S7-200 Counter Instructions

The Up Counter (CTU) counts up from the current value of that counter each time the count-up input makes the transition from off to on. The counter is reset when the reset input turns on, or when the Reset instruction is executed. The counter stops upon reaching the maximum value (32,767).

The Up/Down Counter (CTUD) counts up each time the count-up input makes the transition from off to on, and counts down each time the count-down input makes the transition from off to on. The counter is reset when the reset input turns on, or when the Reset instruction is executed. Upon reaching maximum value (32,767), the next rising edge at the count-up input causes the current count to wrap around to the minimum value (-32,768). Likewise on reaching the minimum value (-32,768), the next rising edge at the count-down input causes the current count to wrap around to the maximum value (32,767).

When you reset a counter using the Reset instruction, both the counter bit and the counter current value are reset.

The Up and Up/Down counters have a current value that maintains the current count. They also have a preset value (PV) that is compared to the current value whenever the counter instruction is executed. When the current value is greater than or equal to the preset value, the counter bit (C-bit) turns on. Otherwise, the C-bit turns off.

Use the counter number to reference both the current value and the C-bit of that counter.

Note

Since there is one current value for each counter, do not assign the same number to more than one counter. (Up Counters and Up/Down Counters access the same current value.)

Counter Example

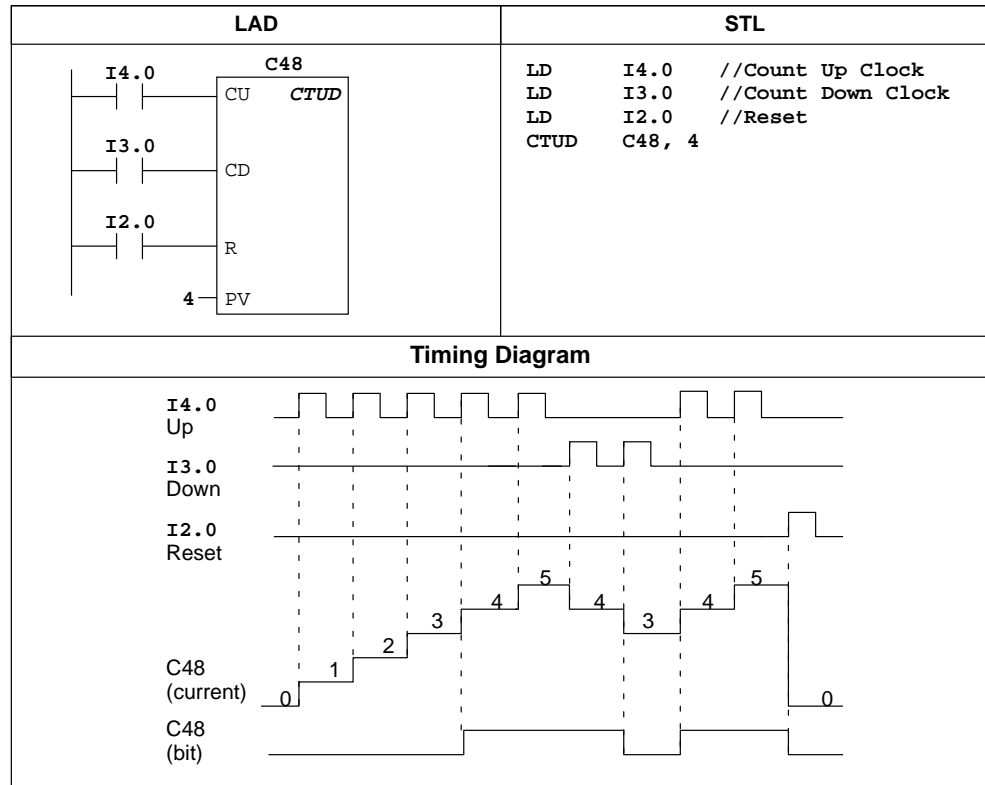
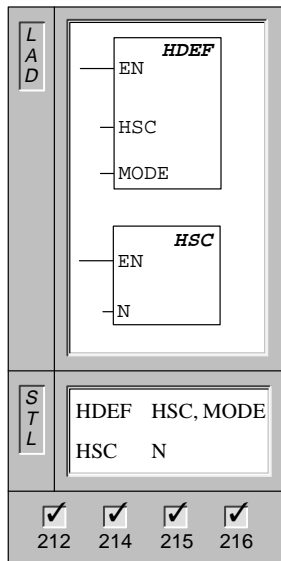


Figure 10-7 Example of Counter Instruction for LAD and STL

High-Speed Counter Definition, High-Speed Counter



The **High-Speed Counter Definition** instruction assigns a MODE to the referenced high-speed counter (HSC). See Table 10-5.

The **High-Speed Counter** instruction, when executed, configures and controls the operational mode of the high-speed counter, based on the state of the HSC special memory bits. The parameter N specifies the high-speed counter number.

Only one HDEF box may be used per counter.

Operands: HSC: 0 to 2
 MODE: 0 (HSC0)
 0 to 11 (HSC1 or 2)
 N: 0 to 2

Understanding the High-Speed Counter Instructions

High-speed counters count high-speed events that cannot be controlled at CPU scan rates.

- HSC0 is an up/down software counter that accepts a single clock input. The counting direction (up or down) is controlled by your program, using the direction control bit. The maximum counting frequency of HSC0 is 2 KHz.
- HSC1 and HSC2 are versatile hardware counters that can be configured for one of twelve different modes of operation. The counter modes are listed in Table 10-5. The maximum counting frequency of HSC1 and HSC2 is dependent on your CPU. See Appendix A.

Each counter has dedicated inputs for clocks, direction control, reset, and start where these functions are supported. For the two-phase counters, both clocks may run at their maximum rates. In quadrature modes, an option is provided to select one time (1x) or four times (4x) the maximum counting rates. HSC1 and HSC2 are completely independent of each other and do not affect other high-speed functions. Both counters run at maximum rates without interfering with one another.

Figure 10-16 shows an example of the initialization of HSC1.

Using the High-Speed Counter

Typically, a high-speed counter is used as the drive for a drum timer, where a shaft rotating at a constant speed is fitted with an incremental shaft encoder. The shaft encoder provides a specified number of counts per revolution and a reset pulse that occurs once per revolution. The clock(s) and the reset pulse from the shaft encoder provide the inputs to the high-speed counter. The high-speed counter is loaded with the first of several presets, and the desired outputs are activated for the time period where the current count is less than the current preset. The counter is set up to provide an interrupt when the current count is equal to preset and also when reset occurs.

As each current-count-value-equals-preset-value interrupt event occurs, a new preset is loaded and the next state for the outputs is set. When the reset interrupt event occurs, the first preset and the first output states are set, and the cycle is repeated.

Since the interrupts occur at a much lower rate than the counting rates of the high-speed counters, precise control of high-speed operations can be implemented with relatively minor impact to the overall scan cycle of the programmable logic controller. The method of interrupt attachment allows each load of a new preset to be performed in a separate interrupt routine for easy state control, making the program very straight forward and easy to follow. Of course, all interrupt events can be processed in a single interrupt routine. For more information, see the section on Interrupt Instructions.

Understanding the Detailed Timing for the High-Speed Counters

The following timing diagrams (Figure 10-8, Figure 10-9, Figure 10-10, and Figure 10-11) show how each counter functions according to category. The operation of the reset and start inputs is shown in a separate timing diagram and applies to all categories that use reset and start inputs. In the diagrams for the reset and start inputs, both reset and start are shown with the active state programmed to a high level.

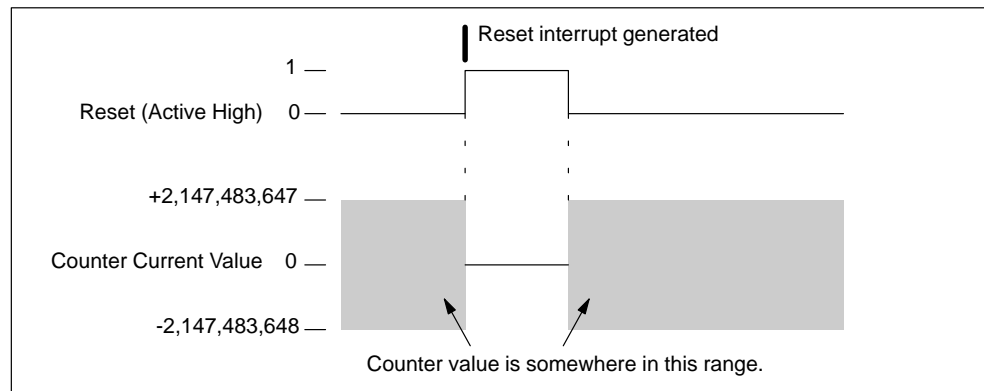


Figure 10-8 Operation Example with Reset and without Start

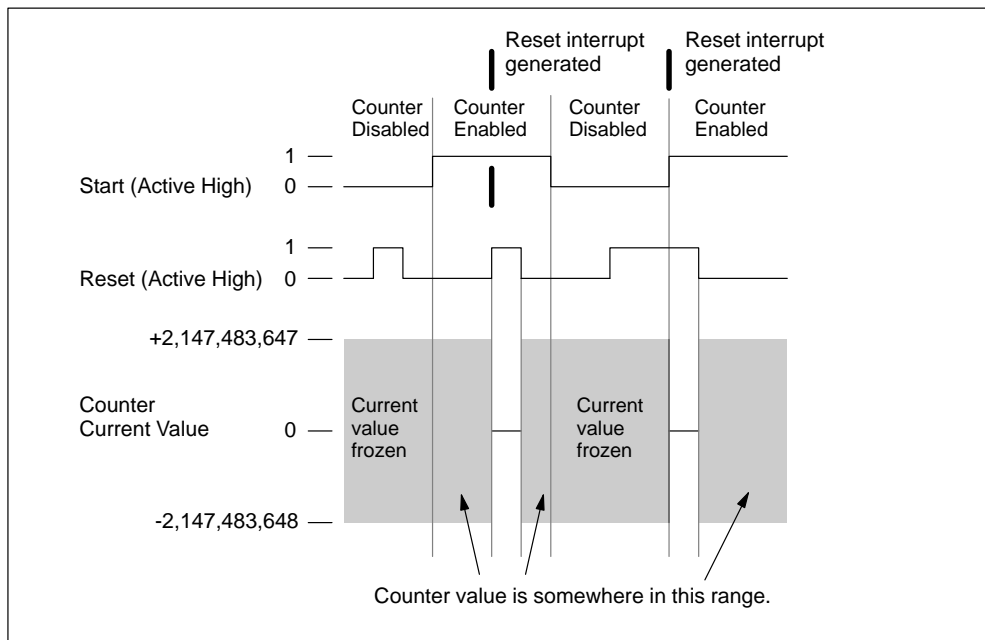


Figure 10-9 Operation Example with Reset and Start

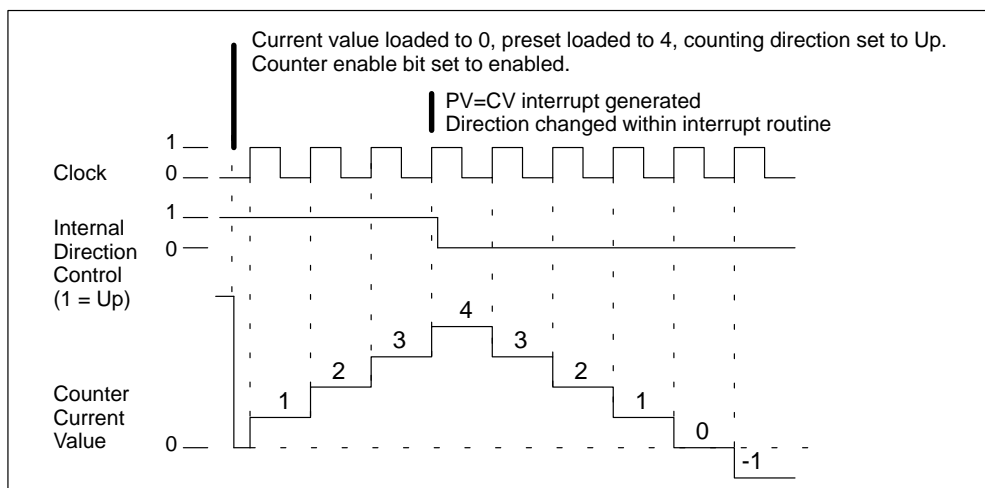


Figure 10-10 Operation Example of HSC0 Mode 0 and HSC1, or HSC2 Modes 0, 1, or 2

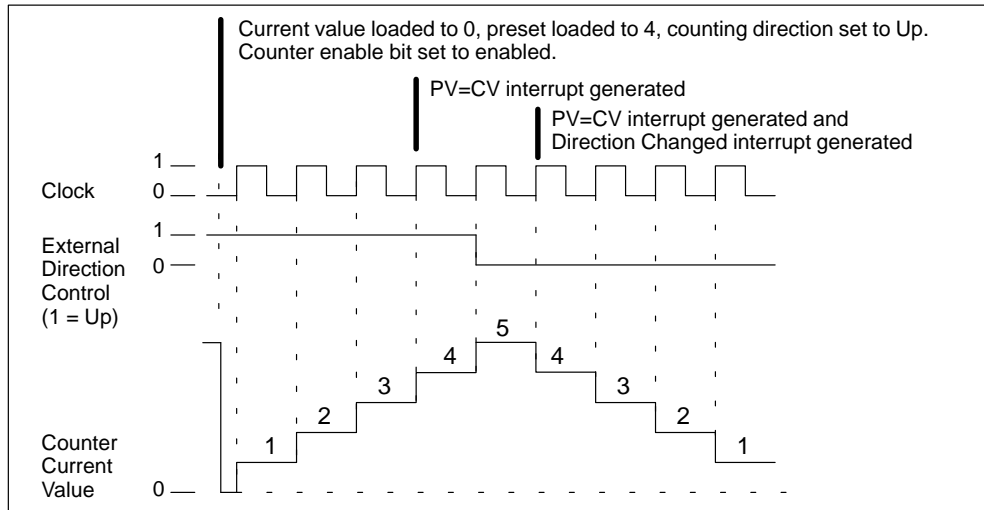


Figure 10-11 Operation Example of HSC1 or HSC2 Modes 3, 4, or 5

When you use counting modes 6, 7, or 8 in HSC1 or HSC2, and a rising edge on both the up clock and down clock inputs occurs within 0.3 microseconds of each other, the high-speed counter may see these events as happening simultaneously to each other. If this happens, the current value is unchanged and no change in counting direction is indicated. As long as the separation between rising edges of the up and down clock inputs is greater than this time period, the high-speed counter captures each event separately. In either case, no error is generated and the counter maintains the correct count value. See Figure 10-12, Figure 10-13, and Figure 10-14.

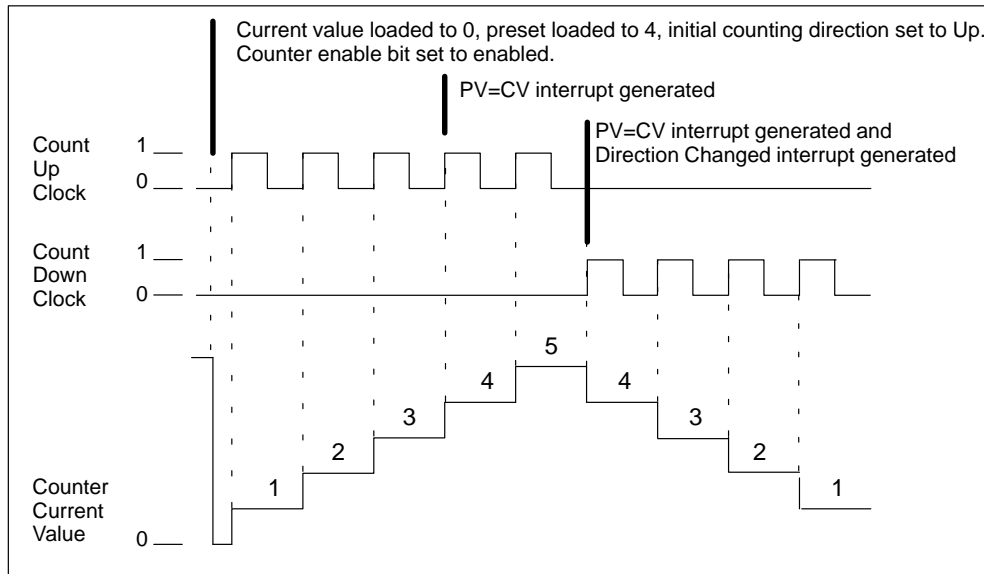


Figure 10-12 Operation Example of HSC1 or HSC2 Modes 6, 7, or 8

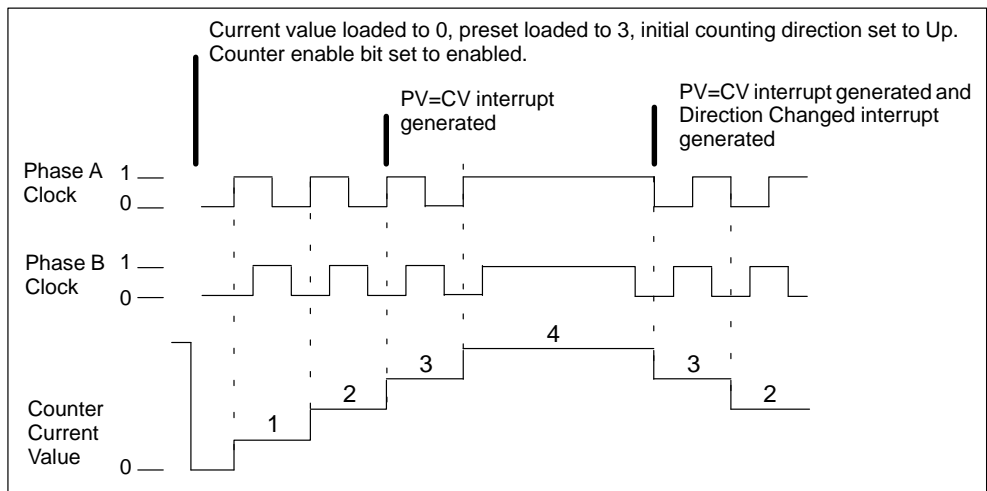


Figure 10-13 Operation Example of HSC1 or HSC2 Modes 9, 10, or 11 (Quadrature 1x Mode)

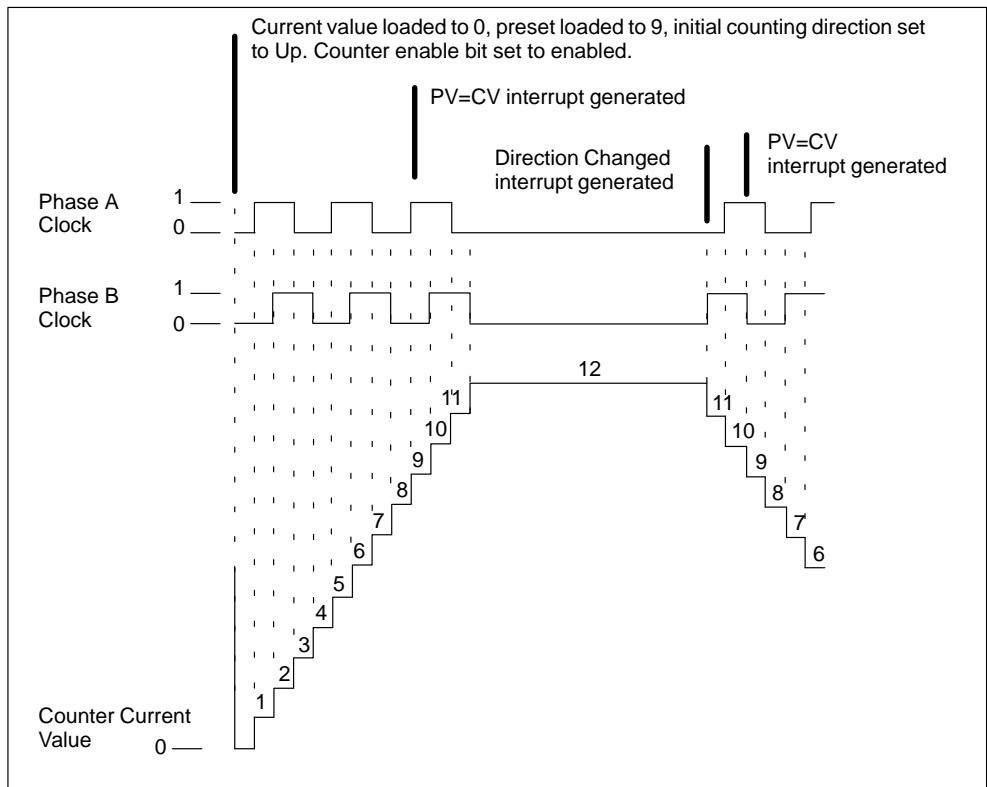


Figure 10-14 Operation Example of HSC1 or HSC2 Modes 9, 10, or 11 (Quadrature 4x Mode)

Connecting the Input Wiring for the High-Speed Counters

Table 10-4 shows the inputs used for the clock, direction control, reset, and start functions associated with the high-speed counters. These input functions are described in Table 10-5.

Table 10-4 Dedicated Inputs for High-Speed Counters

High-Speed Counter	Inputs Used
HSC0	I0.0
HSC1	I0.6, I0.7, I1.0, I1.1
HSC2	I1.2, I1.3, I1.4, I1.5

Addressing the High-Speed Counters (HC)

To access the count value for the high-speed counter, you specify the address of the high-speed counter, using the memory type (HC) and the counter number (such as HC0). The current value of the high-speed counter is a read-only value and can be addressed only as a double word (32 bits), as shown in Figure 10-15.

Format: `HC[high-speed counter number] HC1`

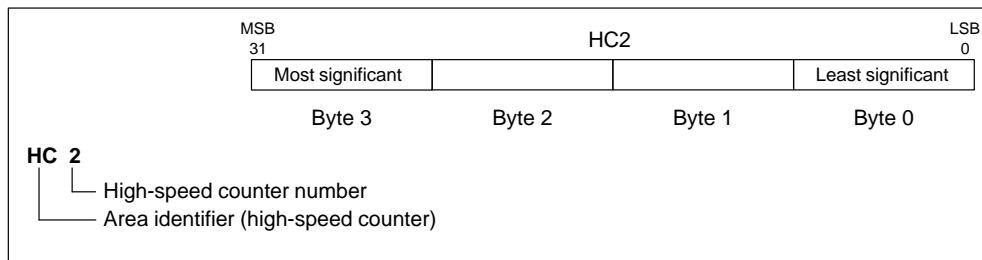


Figure 10-15 Accessing the High-Speed Counter Current Values

Table 10-5 HSC Modes of Operation

HSC0					
Mode	Description	I0.0			
0	Single phase up/down counter with internal direction control SM37.3 = 0, count down SM37.3 = 1, count up	Clock			
HSC1					
Mode	Description	I0.6	I0.7	I1.0	I1.1
0	Single phase up/down counter with internal direction control SM47.3 = 0, count down SM47.3 = 1, count up	Clock			
1				Reset	
2					Start
3	Single phase up/down counter with external direction control I0.7 = 0, count down I0.7 = 1, count up	Clock	Dir.		
4				Reset	
5					Start
6	Two-phase counter with count up and count down clock inputs	Clock (Up)	Clock (Dn)		
7				Reset	
8					Start
9	A/B phase quadrature counter, phase A leads B by 90 degrees for clockwise rotation, phase B leads A by 90 degrees for counterclockwise rotation	Clock Phase A	Clock Phase B		
10				Reset	
11					Start
HSC2					
Mode	Description	I1.2	I1.3	I1.4	I1.5
0	Single phase up/down counter with internal direction control SM57.3 = 0, count down SM57.3 = 1, count up	Clock			
1				Reset	
2					Start
3	Single phase up/down counter with external direction control I1.3 = 0, count down I1.3 = 1, count up	Clock	Dir.		
4				Reset	
5					Start
6	Two phase counter with count up and count down clock inputs	Clock (Up)	Clock (Dn)		
7				Reset	
8					Start
9	A/B phase quadrature counter, phase A leads B by 90 degrees for clockwise rotation, phase B leads A by 90 degrees for counterclockwise rotation	Clock Phase A	Clock Phase B		
10				Reset	
11					Start

Understanding the Different High-Speed Counters (HSC0, HSC1, HSC2)

All counters (HSC0, HSC1, and HSC2) function the same way for the same counter mode of operation. There are four basic types of counter modes for HSC1 and HSC2 as shown in Table 10-5. You can use each type: without reset or start inputs, with reset and without start, or with both start and reset inputs.

When you activate the reset input, it clears the current value and holds it cleared until you de-activate reset. When you activate the start input, it allows the counter to count. While start is de-activated, the current value of the counter is held constant and clocking events are ignored. If reset is activated while start is inactive, the reset is ignored and the current value is not changed, while the start input remains inactive. If the start input becomes active while reset remains active, the current value is cleared.

You must select the counter mode before a high-speed counter can be used. You can do this with the HDEF instruction (High-Speed Counter Definition). HDEF provides the association between a High-speed Counter (HSC0, HSC1, or HSC2) and a counter mode. You can only use one HDEF instruction for each high-speed counter. Define a high-speed counter by using the first scan memory bit, SM0.1 (this bit is turned on for the first scan and is then turned off), to call a subroutine that contains the HDEF instruction.

Selecting the Active State and 1x/4x Mode

HSC1 and HSC2 have three control bits used to configure the active state of the reset and start inputs and to select 1x or 4x counting modes (quadrature counters only). These bits are located in the control byte for the respective counter and are only used when the HDEF instruction is executed. These bits are defined in Table 10-6.

You must set these control bits to the desired state before the HDEF instruction is executed. Otherwise, the counter takes on the default configuration for the counter mode selected. The default setting of reset input and the start input are active high, and the quadrature counting rate is 4x (or four times the input clock frequency) for HSC1 and HSC2. Once the HDEF instruction has been executed, you cannot change the counter setup unless you first go to the STOP mode.

Table 10-6 Active Level Control for Reset and Start; 1x/4x Select Bits for HSC1 and HSC2

HSC1	HSC2	Description (used only when HDEF is executed)
SM47.0	SM57.0	Active level control bit for Reset: 0 = Reset is active high; 1 = Reset is active low
SM47.1	SM57.1	Active level control bit for Start: 0 = Start is active high; 1 = Start is active low
SM47.2	SM57.2	Counting rate selection for Quadrature counters: 0 = 4X counting rate; 1 = 1X counting rate

Control Byte

Once you have defined the counter and the counter mode, you can program the dynamic parameters of the counter. Each high-speed counter has a control byte that allows the counter to be enabled or disabled; the direction to be controlled (modes 0, 1, and 2 only), or the initial counting direction for all other modes; the current value to be loaded; and the preset value to be loaded. Examination of the control byte and associated current and preset values is invoked by the execution of the HSC instruction. Table 10-7 describes each of these control bits.

Table 10-7 Control Bits for HSC0, HSC1, and HSC2

HSC0	HSC1	HSC2	Description
SM37.0	SM47.0	SM57.0	Not used after HDEF has been executed (Never used by HSC0)
SM37.1	SM47.1	SM57.1	Not used after HDEF has been executed (Never used by HSC0)
SM37.2	SM47.2	SM57.2	Not used after HDEF has been executed (Never used by HSC0)
SM37.3	SM47.3	SM57.3	Counting direction control bit: 0 = count down; 1 = count up
SM37.4	SM47.4	SM57.4	Write the counting direction to the HSC: 0 = no update; 1 = update direction
SM37.5	SM47.5	SM57.5	Write the new preset value to the HSC: 0 = no update; 1 = update preset
SM37.6	SM47.6	SM57.6	Write the new current value to the HSC: 0 = no update; 1 = update current value
SM37.7	SM47.7	SM57.7	Enable the HSC: 0 = disable the HSC; 1 = enable the HSC

Setting Current Values and Preset Values

Each high-speed counter has a 32-bit current value and a 32-bit preset value. Both the current and the preset values are signed integer values. To load a new current or preset value into the high-speed counter, you must set up the control byte and the special memory bytes that hold the current and/or preset values. You must then execute the HSC instruction to cause the new values to be transferred to the high-speed counter. Table 10-8 describes the special memory bytes used to hold the new current and preset values.

In addition to the control bytes and the new preset and current holding bytes, the current value of each high-speed counter can be read using the data type HC (High-Speed Counter Current) followed by the number (0, 1, or 2) of the counter. Thus, the current value is directly accessible for read operations, but can only be written with the HSC instruction described above.

Table 10-8 Current and Preset Values of HSC0, HSC1, and HSC2

Current Value of HSC0, HSC1, and HSC2			
HSC0	HSC1	HSC2	Description
SM38	SM48	SM58	Most significant byte of the new 32-bit current value
SM39	SM49	SM59	The next-to-most significant byte of the new 32-bit current value
SM40	SM50	SM60	The next-to-least significant byte of the new 32-bit current value
SM41	SM51	SM61	The least significant byte of the new 32-bit current value
Preset Value of HSC0, HSC1, and HSC2			
HSC0	HSC1	HSC2	Description
SM42	SM52	SM62	Most significant byte of the new 32-bit preset value
SM43	SM53	SM63	The next-to-most significant byte of the new 32-bit preset value
SM44	SM54	SM64	The next-to-least significant byte of the new 32-bit preset value
SM45	SM55	SM65	The least significant byte of the new 32-bit preset value

Status Byte

A status byte is provided for each high-speed counter that provides status memory bits that indicate the current counting direction, if the current value equals preset value, and if the current value is greater than preset. Table 10-9 defines each of these status bits for each high-speed counter.

Table 10-9 Status Bits for HSC0, HSC1, and HSC2

HSC0	HSC1	HSC2	Description
SM36.0	SM46.0	SM56.0	Not used
SM36.1	SM46.1	SM56.1	Not used
SM36.2	SM46.2	SM56.2	Not used
SM36.3	SM46.3	SM56.3	Not used
SM36.4	SM46.4	SM56.4	Not used
SM36.5	SM46.5	SM56.5	Current counting direction status bit: 0 = counting down; 1 = counting up
SM36.6	SM46.6	SM56.6	Current value equals preset value status bit: 0 = not equal; 1 = equal
SM36.7	SM46.7	SM56.7	Current value greater than preset value status bit: 0 = less than or equal; 1 = greater than

Note

Status bits for HSC0, HSC1, and HSC2 are valid only while the high-speed counter interrupt routine is being executed. The purpose of monitoring the state of the high-speed counter is to enable interrupts for the events that are of consequence to the operation being performed.

HSC Interrupts

HSC0 supports one interrupting condition: interrupt on current value equal to preset value. HSC1 and HSC2 provide three interrupting conditions: interrupt on current value equal to preset value, interrupt on external reset activated, and interrupt on a counting direction change. Each of these interrupt conditions may be enabled or disabled separately. For a complete discussion on the use of interrupts, see the Interrupt Instructions.

To help you understand the operation of high-speed counters, the following descriptions of the initialization and operation sequences are provided. HSC1 is used as the model counter throughout these sequence descriptions. The initialization descriptions make the assumption that the S7-200 has just been placed in the RUN mode, and for that reason, the first scan memory bit is true. If this is not the case, remember that the HDEF instruction can be executed only one time for each high-speed counter after entering RUN mode. Executing HDEF for a high-speed counter a second time generates a run-time error and does not change the counter setup from the way it was set up on the first execution of HDEF for that counter.

Initialization Modes 0, 1, or 2

The following steps describe how to initialize HSC1 for Single Phase Up/Down Counter with Internal Direction (Modes 0, 1, or 2):

1. Use the first scan memory bit to call a subroutine in which the initialization operation is performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SM47 according to the desired control operation. For example:

SM47 = 16#F8 produces the following results:
Enables the counter
Writes a new current value
Writes a new preset value
Sets the direction to count up
Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE input set to 0 for no external reset or start to 1 for external reset and no start, or to 2 for both external reset and start.
4. Load SM48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SM52 (double word size value) with the desired preset value.
6. In order to capture the event of current value equal to preset, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See the section on Interrupt Instructions in this chapter for complete details on interrupt processing.
7. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
8. Execute the global interrupt enable instruction (ENI) to enable HSC1 interrupts.
9. Execute the HSC instruction to cause the S7-200 to program HSC1.
10. Exit the subroutine.

Initialization Modes 3, 4, or 5

The following steps describe how to initialize HSC1 for Single Phase Up/Down Counter with External Direction (Modes 3, 4, or 5):

1. Use the first scan memory bit to call a subroutine in which the initialization operation is performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SM47 according to the desired control operation. For example:
SM47 = 16#F8 produces the following results:
 - Enables the counter
 - Writes a new current value
 - Writes a new preset value
 - Sets the initial direction of the HSC to count up
 - Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE input set to 3 for no external reset or start, 4 for external reset and no start, or 5 for both external reset and start.
4. Load SM48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SM52 (double word size value) with the desired preset value.
6. In order to capture the event of current value equal to preset, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Interrupt Instructions for complete details on interrupt processing.
7. In order to capture direction changes, program an interrupt by attaching the direction changed interrupt event (event 14) to an interrupt routine.
8. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
9. Execute the global interrupt enable instruction (ENI) to enable HSC1 interrupts.
10. Execute the HSC instruction to cause the S7-200 to program HSC1.
11. Exit the subroutine.

Initialization Modes 6, 7, or 8

The following steps describe how to initialize HSC1 for Two Phase Up/Down Counter with Up/Down Clocks (Modes 6, 7, or 8):

1. Use the first scan memory bit to call a subroutine in which the initialization operations are performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SM47 according to the desired control operation. For example:
SM47 = 16#F8 produces the following results:
 - Enables the counter
 - Writes a new current value
 - Writes a new preset value
 - Sets the initial direction of the HSC to count up
 - Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE set to 6 for no external reset or start, 7 for external reset and no start, or 8 for both external reset and start.
4. Load SM48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SM52 (double word size value) with the desired preset value.
6. In order to capture the event of current value equal to preset, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Interrupt Instructions for complete details on interrupt processing.
7. In order to capture direction changes, program an interrupt by attaching the direction changed interrupt event (event 14) to an interrupt routine.
8. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
9. Execute the global interrupt enable instruction (ENI) to enable HSC1 interrupts.
10. Execute the HSC instruction to cause the S7-200 to program HSC1.
11. Exit the subroutine.

Initialization Modes 9, 10, or 11

The following steps describe how to initialize HSC1 for A/B Phase Quadrature Counter (Modes 9, 10, or 11):

1. Use the first scan memory bit to call a subroutine in which the initialization operations are performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SM47 according to the desired control operation.

For example (1x counting mode):

SM47 = 16#FC produces the following results:
Enables the counter
Writes a new current value
Writes a new preset value
Sets the initial direction of the HSC to count up
Sets the start and reset inputs to be active high

For example (4x counting mode):

SM47 = 16#F8 produces the following results:
Enables the counter
Writes a new current value
Writes a new preset value
Sets the initial direction of the HSC to count up
Sets the start and reset inputs to be active high

3. Execute the HDEF instruction with the HSC input set to 1 and the MODE input set to 9 for no external reset or start, 10 for external reset and no start, or 11 for both external reset and start.
4. Load SM48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SM52 (double word size value) with the desired preset value.
6. In order to capture the event of current value equal to preset, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Interrupt Instructions for complete details on interrupt processing.
7. In order to capture direction changes, program an interrupt by attaching the direction changed interrupt event (event 14) to an interrupt routine.
8. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
9. Execute the global interrupt enable instruction (ENI) to enable HSC1 interrupts.
10. Execute the HSC instruction to cause the S7-200 to program HSC1.
11. Exit the subroutine.

Change Direction Modes 0, 1, or 2

The following steps describe how to configure HSC1 for Change Direction for Single Phase Counter with Internal Direction (Modes 0, 1, or 2):

1. Load SM47 to write the desired direction:
 - SM47 = 16#90 Enables the counter
 Sets the direction of the HSC to count down
 - SM47 = 16#98 Enables the counter
 Sets the direction of the HSC to count up
2. Execute the HSC instruction to cause the S7-200 to program HSC1.

Load a New Current Value (Any Mode)

The following steps describe how to change the counter current value of HSC1 (any mode):

Changing the current value forces the counter to be disabled while the change is made. While the counter is disabled, it does not count or generate interrupts.

1. Load SM47 to write the desired current value:
 - SM47 = 16#C0 Enables the counter
 Writes the new current value
2. Load SM48 (double word size) with the desired current value (load with 0 to clear it).
3. Execute the HSC instruction to cause the S7-200 to program HSC1.

Load a New Preset Value (Any Mode)

The following steps describe how to change the preset value of HSC1 (any mode):

1. Load SM47 to write the desired preset value:
 - SM47 = 16#A0 Enables the counter
 Writes the new preset value
2. Load SM52 (double word size value) with the desired preset value.
3. Execute the HSC instruction to cause the S7-200 to program HSC1.

Disable a High-Speed Counter (Any Mode)

The following steps describe how to disable the HSC1 high-speed counter (any mode):

1. Load SM47 to disable the counter:
 - SM47 = 16#00 Disables the counter
2. Execute the HSC instruction to disable the counter.

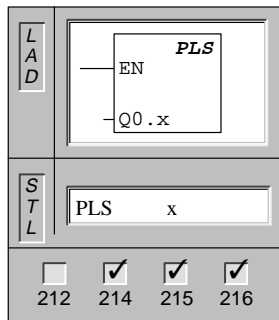
Although the above sequences show how to change direction, current value, and preset value individually, you may change all or any combination of them in the same sequence by setting the value of SM47 appropriately and then executing the HSC instruction.

High-Speed Counter Example

LAD		STL
Network 1		<p>On the first scan, call subroutine 0.</p>
Network 2		<p>End of main program.</p>
Network 3		<p>Start of subroutine 0.</p>
Network 4		<p>Enable the counter. Write a new current value. Write a new preset value. Set initial direction to count up. Set start and reset inputs to be active high. Set 4x mode. HSC1 configured for quadrature mode with reset and start inputs. Clear the current value of HSC1. Set HSC1 preset value to 50. HSC 1 current value = preset value (EVENT 13) attached to interrupt routine 0. Global interrupt enable. Program HSC1.</p>
Network 5		<p>Terminate subroutine.</p>
Network 6		<p>Start of interrupt 0.</p>
Network 7		<p>Clear the current value of HSC1. Write a new current value and enable the counter. Program HSC1.</p>
Network 8		<p>Terminate interrupt routine.</p>
Network 1		<p>Network 1 LD SM0.1 CALL 0</p>
Network 2		<p>Network 2 MEND</p>
Network 3		<p>Network 3 SBR 0</p>
Network 4		<p>Network 4 LD SM0.0 MOVB 16#F8, SMB47 HDEF 1, 11 MOVD 0, SMD48 MOVD 50, SMD52 ATCH 0, 13 ENI HSC 1</p>
Network 5		<p>Network 5 RET</p>
Network 6		<p>Network 6 INT 0</p>
Network 7		<p>Network 7 LD SM 0.0 MOVD 0, SMD48 MOVB 16#C0, SMB47 HSC 1</p>
Network 8		<p>Network 8 RETI</p>

Figure 10-16 Example of Initialization of HSC1

Pulse



The **Pulse** instruction examines the special memory bits for the pulse output (0.x). The pulse operation defined by the special memory bits is then invoked.

Operands: x: 0 to 1

Understanding the S7-200 High-Speed Output Instructions

Some CPUs allow Q0.0 and Q0.1 either to generate high-speed pulse train outputs (PTO) or to perform pulse width modulation (PWM) control. The pulse train function provides a square wave (50% duty cycle) output for a specified number of pulses and a specified cycle time. The number of pulses can be specified from 1 to 4,294,967,295 pulses. The cycle time can be specified in either microsecond or millisecond increments either from 250 microseconds to 65,535 microseconds or from 2 milliseconds to 65,535 milliseconds. Specifying any odd number of microseconds or milliseconds causes some duty cycle distortion.

The PWM function provides a fixed cycle time with a variable duty cycle output. The cycle time and the pulse width can be specified in either microsecond or millisecond increments. The cycle time has a range either from 250 microseconds to 65,535 microseconds or from 2 milliseconds to 65,535 milliseconds. The pulse width time has a range either from 0 to 65,535 microseconds or from 0 to 65,535 milliseconds. When the pulse width is equal to the cycle time, the duty cycle is 100 percent and the output is turned on continuously. When the pulse width is zero, the duty cycle is 0 percent and the output is turned off.

If a cycle time of less than two time units is specified, the cycle time defaults to two time units.

Note

In the PTO and PWM functions, the switching times of the outputs from off to on and from on to off are not the same. This difference in the switching times manifests itself as duty cycle distortion. Refer to Appendix A for switching time specifications. The PTO/PWM outputs must have a minimum load of at least 10 percent of rated load to provide crisp transitions from off to on and from on to off.

Changing the Pulse Width

PWM is a continuous function. Changing the pulse width causes the PWM function to be disabled momentarily while the update is made. This is done asynchronously to the PWM cycle, and could cause undesirable jitter in the controlled device. If synchronous updates to the pulse width are required, the pulse output is fed back to one of the interrupt input points (I0.0 to I0.4). By enabling the rising edge interrupt of that input when the pulse width needs to be changed, you can synchronize the PWM cycle. See Figure 10-19 for an example.

The pulse width is actually changed in the interrupt routine and the interrupt event is detached or disabled in the interrupt routine. This prevents interrupts from occurring except when the pulse width is to be changed.

Invoking the PTO/PWM Operation

Each PTO/PWM generator has a control byte (8 bits); a cycle time value and a pulse width value which are unsigned, 16-bit values; and a pulse count value which is an unsigned, 32-bit value. These values are all stored in designated areas of special memory bit memory. Once these special memory bit memory locations have been set up to give the desired operation, the operation is invoked by executing the Pulse instruction (PLS). This instruction causes the S7-200 to read the special memory bit locations and program the PTO/PWM generator accordingly.

PTO Pipeline

In addition to the control information, there are two status bits used with the PTO function that either indicate that the specified number of pulses were generated, or that a pipeline overflow condition has occurred.

The PTO function allows two pulse output specifications to be either chained together or to be piped one after the other. By doing this, continuity between subsequent output pulse trains can be supported. You load the pipeline by setting up the first PTO specification and then executing the PLS instruction. Immediately after executing the PLS instruction, you can set up the second specification, and execute another PLS instruction.

If a third specification is made before the first PTO function is completed (before the number of output pulses of the first specification are generated), the PTO pipeline overflow bit (SM66.6 or SM76.6) is set to one. This bit is set to zero on entry into RUN mode. It must be set to zero by the program after an overflow is detected, if subsequent overflows are to be detected.

The SM locations for pulse outputs 0 and 1 are shown in Table 10-10.

Note

Default values for all control bits, cycle time, pulse width, and pulse count values are zero.

Table 10-10 PTO/PWM Locations for Piping Two Pulse Outputs

Q0.0	Q0.1	Status Bit for Pulse Outputs	
SM66.6	SM76.6	PTO pipeline overflow	0 = no overflow; 1 = overflow
SM66.7	SM76.7	PTO idle	0 = in progress; 1 = PTO idle
Q0.0	Q0.1	Control Bits for PTO/PWM Outputs	
SM67.0	SM77.0	PTO/PWM update cycle time value	0 = no update; 1 = update cycle time
SM67.1	SM77.1	PWM update pulse width time value	0 = no update; 1 = update pulse width
SM67.2	SM77.2	PTO update pulse count value	0 = no update; 1 = update pulse count
SM67.3	SM77.3	PTO/PWM time base select	0 = 1 μ s/tick; 1 = 1ms/tick
SM67.4	SM77.4	Not used	
SM67.5	SM77.5	Not used	
SM67.6	SM77.6	PTO/PWM mode select	0 = selects PTO; 1 = selects PWM
SM67.7	SM77.7	PTO/PWM enable	0 = disables PTO/PWM; 1 = enables PTO/PWM
Q0.0	Q0.1	Cycle Time Values for PTO/PWM Outputs (Range: 2 to 65,535)	
SM68	SM78	Most significant byte of the PTO/PWM cycle time value	
SM69	SM79	Least significant byte of the PTO/PWM cycle time value	
Q0.0	Q0.1	Pulse Width Values for PWM Outputs (Range: 0 to 65,535)	
SM70	SM80	Most significant byte of the PWM pulse width value	
SM71	SM81	Least significant byte of the PWM pulse width value	
Q0.0	Q0.1	Pulse Count Values for Pulse Outputs (Range: 1 to 4,294,967,295)	
SM72	SM82	Most significant byte of the PTO pulse count value	
SM73	SM83	Next-to-most significant byte of the PTO pulse count value	
SM74	SM84	Next-to-least significant byte of the PTO pulse count value	
SM75	SM85	Least significant byte of the PTO pulse count value	

You can use Table 10-11 as a quick reference to determine the value to place in the PTO/PWM control register to invoke the desired operation. Use SMB67 for PTO/PWM 0, and SMB77 for PTO/PWM 1. If you are going to load the new pulse count (SMD72 or SMD82), pulse width (SMW70 or SMW80), or cycle time (SMW68 or SMW78), you should load these values as well as the control register before you execute the PLS instruction.

Table 10-11 PTO/PWM Hexadecimal Reference Table

Control Register (Hex Value)	Result of executing the PLS instruction					
	Enable	Select Mode	Time Base	Pulse Count	Pulse Width	Cycle Time
16#81	Yes	PTO	1 μ s/tick			Load
16#84	Yes	PTO	1 μ s/tick	Load		
16#85	Yes	PTO	1 μ s/tick	Load		Load
16#89	Yes	PTO	1 ms/tick			Load
16#8C	Yes	PTO	1 ms/tick	Load		
16#8D	Yes	PTO	1 ms/tick	Load		Load
16#C1	Yes	PWM	1 μ s/tick			Load
16#C2	Yes	PWM	1 μ s/tick		Load	
16#C3	Yes	PWM	1 μ s/tick		Load	Load
16#C9	Yes	PWM	1 ms/tick			Load
16#CA	Yes	PWM	1 ms/tick		Load	
16#CB	Yes	PWM	1 ms/tick		Load	Load

PTO/PWM Initialization and Operation Sequences

Descriptions of the initialization and operation sequences follow. They can help you better understand the operation of PTO and PWM functions. The output Q0.0 is used throughout these sequence descriptions. The initialization descriptions assume that the S7-200 has just been placed in RUN mode, and for that reason the first scan memory bit is true. If this is not the case, or if the PTO/PWM function must be re-initialized, you can call the initialization routine using a condition other than the first scan memory bit.

PWM Initialization

To initialize the PWM for Q0.0, follow these steps:

1. Use the first scan memory bit to set the output to 1, and call the subroutine that you need in order to perform the initialization operations. When you use the subroutine call, subsequent scans do not make the call to the subroutine. This reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SM67 with a value of 16#C3 for PWM using microsecond increments (or 16#CB for PWM using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PWM operation, select either microsecond or millisecond increments, and set the update pulse width and cycle time values.
3. Load SM68 (word size value) with the desired cycle time.
4. Load SM70 (word size value) with the desired pulse width.
5. Execute the PLS instruction so that the S7-200 programs the PTO/PWM generator.
6. Load SM67 with a value of 16#C2 for microsecond increments (or 16#CA for millisecond increments). This resets the update cycle time value in the control byte and allows the pulse width to change. A new pulse width value is loaded, and the PLS instruction is executed without modifying the control byte.
7. Exit the subroutine.

Optional steps for synchronous updates. If synchronous updates are required, follow these steps:

1. Execute the global interrupt enable instruction (ENI).
2. Using the condition you will use to update pulse width, enable (ATCH) a rising edge event to an interrupt routine. The condition you use to attach the event should be active for only one scan.
3. Add an interrupt routine that updates the pulse width, and then disables the edge interrupt.

Note

The optional steps for synchronous updates require that the PWM output is fed back to one of the interrupt inputs.

Changing the Pulse Width for PWM Outputs

To change the pulse width for PWM outputs in a subroutine, follow these steps:

1. Call a subroutine to load SM70 (word size value) with the desired pulse width.
2. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator.
3. Exit the subroutine.

PTO Initialization

To initialize the PTO, follow these steps:

1. Use the first scan memory bit to reset the output to 0, and call the subroutine that you need to perform the initialization operations. When you call a subroutine, subsequent scans do not make the call to the subroutine. This reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SM67 with a value of 16#85 for PTO using microsecond increments (or 16#8D for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update pulse count and cycle time values.
3. Load SM68 (word size value) with the desired cycle time.
4. Load SM72 (double word size value) with the desired pulse count.
5. This is an optional step. If you want to perform a related function as soon as the pulse train output is complete, you can program an interrupt by attaching the pulse train complete event (Interrupt Category 19) to an interrupt subroutine, and execute the global interrupt enable instruction. Refer to Section 10.14 Interrupt Instructions for complete details on interrupt processing.
6. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator.
7. Exit the subroutine.

Changing the PTO Cycle Time

To change the PTO Cycle Time in an interrupt routine or subroutine, follow these steps:

1. Load SM67 with a value of 16#81 for PTO using microsecond increments (or 16#89 for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update cycle time value.
2. Load SM68 (word size value) with the desired cycle time.
3. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator.
4. Exit the interrupt routine or the subroutine. (Subroutines cannot be called from interrupt routines.)

Changing the PTO Count

To change the PTO Count in an interrupt routine or a subroutine, follow these steps:

1. Load SM67 with a value of 16#84 for PTO using microsecond increments (or 16#8C for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update pulse count value.
2. Load SM72 (double word size value) with the desired pulse count.
3. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator.
4. Exit the interrupt routine or the subroutine. (Subroutines cannot be called from interrupt routines.)

Changing the PTO Cycle Time and the Pulse Count

To change the PTO Cycle Time and Pulse Count in an interrupt routine or a subroutine, follow these steps:

1. Load SM67 with a value of 16#85 for PTO using microsecond increments (or 16#8D for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update cycle time and pulse count values.
2. Load SM68 (word size value) with the desired cycle time.
3. Load SM72 (double word size value) with the desired pulse count.
4. Execute the PLS instruction so that the S7-200 programs the PTO/PWM generator.
5. Exit the interrupt routine or the subroutine. (Subroutines cannot be called from interrupt routines.)

Active PTO/PWM

When a PTO or a PWM function is active on Q0.0 or Q0.1, the normal use of Q0.0 or Q0.1, respectively, is inhibited. Neither the values stored in the process-image register nor any forced values for these points are transferred to the output as long as either the PTO or PWM function is active. A PTO is active when enabled and not complete. Immediate output instructions, writing to these points while PTO or PWM outputs are active, do not cause disruptions to either the PTO or PWM wave form.

Note

If a PTO function is disabled before completion, then the current pulse train is terminated, and the output Q0.0 or Q0.1 reverts to normal image register control. Reenabling the PTO function causes the pulse train to restart from the beginning using the last pulse output specification loaded.

Effects on Outputs

The PTO/PWM function and the process-image register share the use of the outputs Q0.0 and Q0.1. The initial and final states of the PTO and PWM waveforms are affected by the value of the corresponding process-image register bit. When a pulse train is output on either Q0.0 or Q0.1, the process-image register determines the initial and final states of the output, and causes the pulse output to start from either a high or a low level.

Since both the PTO and PWM functions are disabled momentarily between PTO pipelined changes and PWM pulse width changes, a small discontinuity in the output waveforms can exist at the change points. To minimize any adverse effects of this discontinuity, always use the PTO function with the process-image register bit set to a 0, and use the PWM function with the process-image register bit set to a 1. The resulting waveforms of both the PTO and PWM functions are shown in Figure 10-17. Notice that in the case of the PTO function at the change point, the last half-cycle is shortened to a pulse width of about 120 μ s. In the case of the PWM function using the optional sequence for synchronous update, the first high time pulse after the change is increased by about 120 μ s.

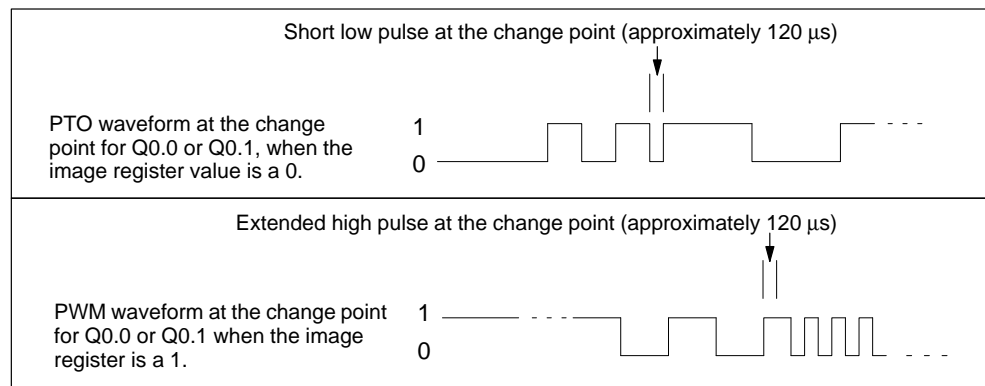


Figure 10-17 Sample Pulse Train Shapes for Q0.0 or Q0.1

Example of Pulse Train Output

LAD		STL
<p>Network 1</p>	<p>On the first scan, reset image register bit low, and call subroutine 0.</p>	<p>Network 1 LD SM0.1 R Q0.0, 1 CALL 0</p>
<p>Network 2</p>	<p>End of main ladder.</p>	<p>Network 2 MEND</p>
<p>Network 3</p>	<p>Start of subroutine 0.</p>	<p>Network 3 SBR 0</p>
<p>Network 4</p>	<p>Set up PTO 0 control byte: - select PTO operation - select ms increments - set the pulse count and cycle time values - enable the PTO function</p> <p>Set cycle time to 500 ms.</p> <p>Set pulse count to 4 pulses.</p> <p>Define interrupt routine 3 to be the interrupt for processing PTO 0 interrupts.</p> <p>Global interrupt enable.</p> <p>Invoke PTO 0 operation. PLS 0 => Q0.0</p>	<p>Network 4 LD SM0.0 MOVB 16#8D, SMB67 MOVW 500, SMW68 MOVD 4, SMD72 ATCH 3, 19 ENI 0</p>
<p>Network 5</p>	<p>Terminate subroutine.</p>	<p>Network 5 RET</p>

Figure 10-18 Example of a Pulse Train Output

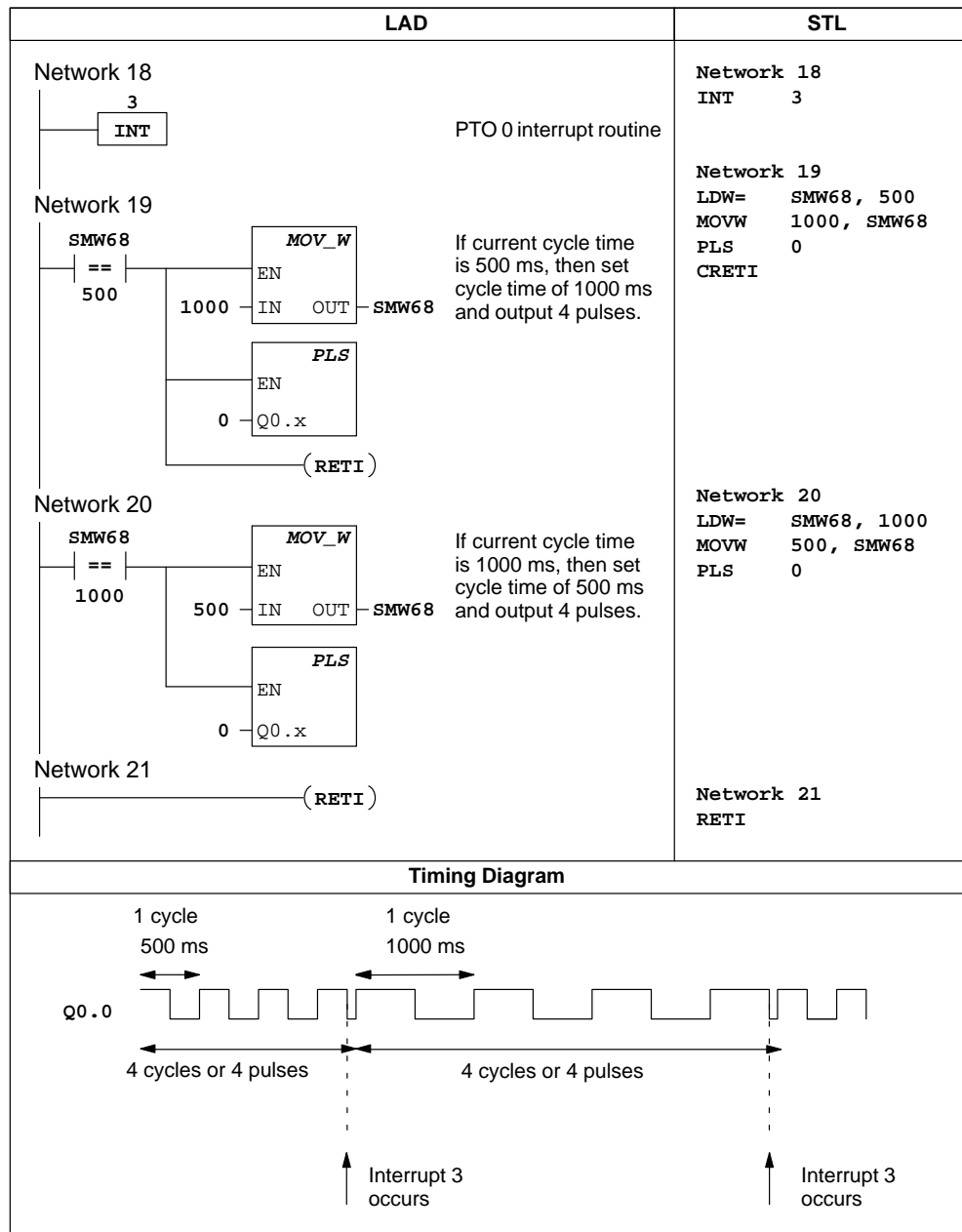


Figure 10-18 Example of a Pulse Train Output (continued)

Example of Pulse Width Modulation

Figure 10-19 shows an example of the Pulse Width Modulation. Changing the pulse width causes the PWM function to be disabled momentarily while the update is made. This is done asynchronously to the PWM cycle, and could cause undesirable jitter in the controlled device. If synchronous updates to the pulse width are required, the pulse output is fed back to the interrupt input point (I0.0). When the pulse width needs to be changed, the input interrupt is enabled, and on the next rising edge of I0.0, the pulse width will be changed synchronously to the PWM cycle.

The pulse width is actually changed in the interrupt routine and the interrupt event is detached or disabled in the interrupt routine. This prevents interrupts from occurring except when the pulse width is to be changed.

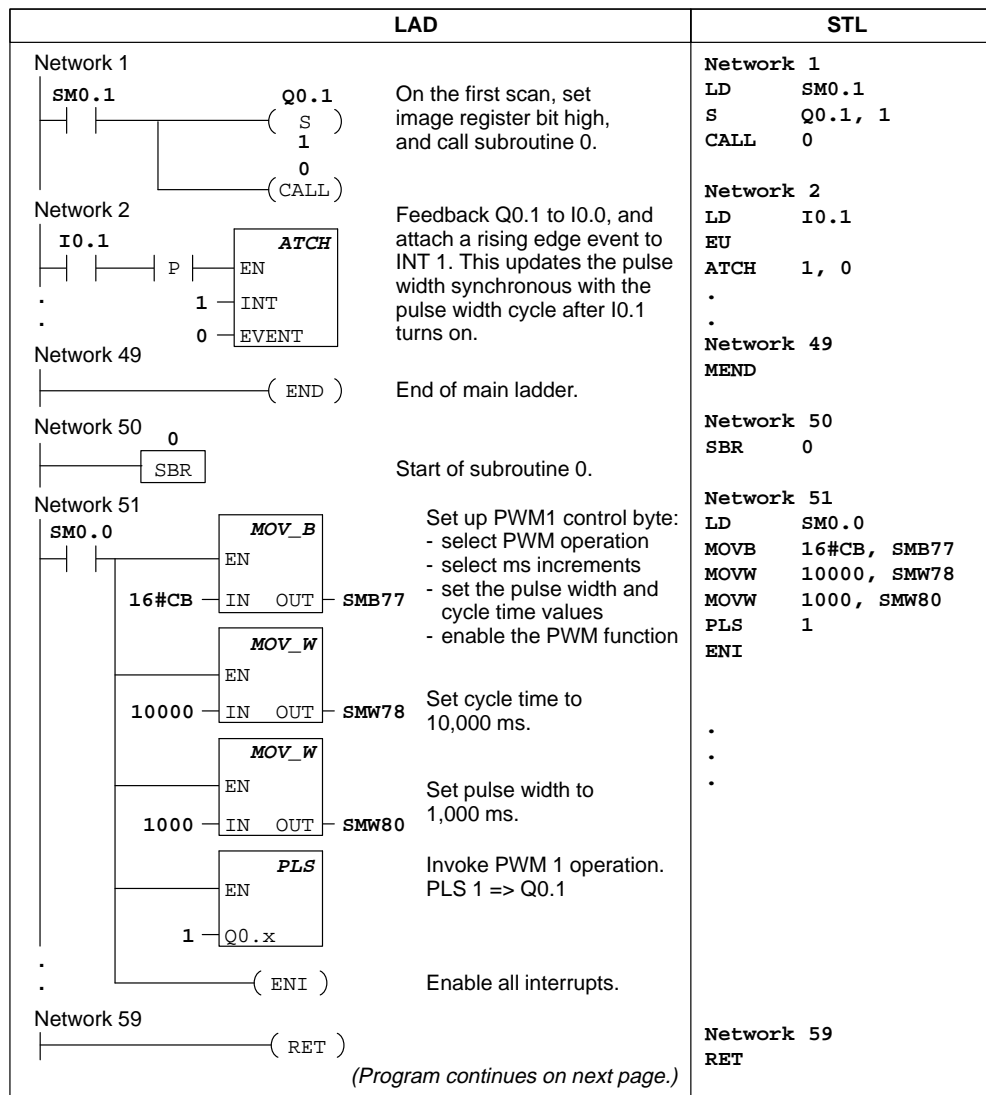


Figure 10-19 Example of High-Speed Output Using Pulse Width Modulation

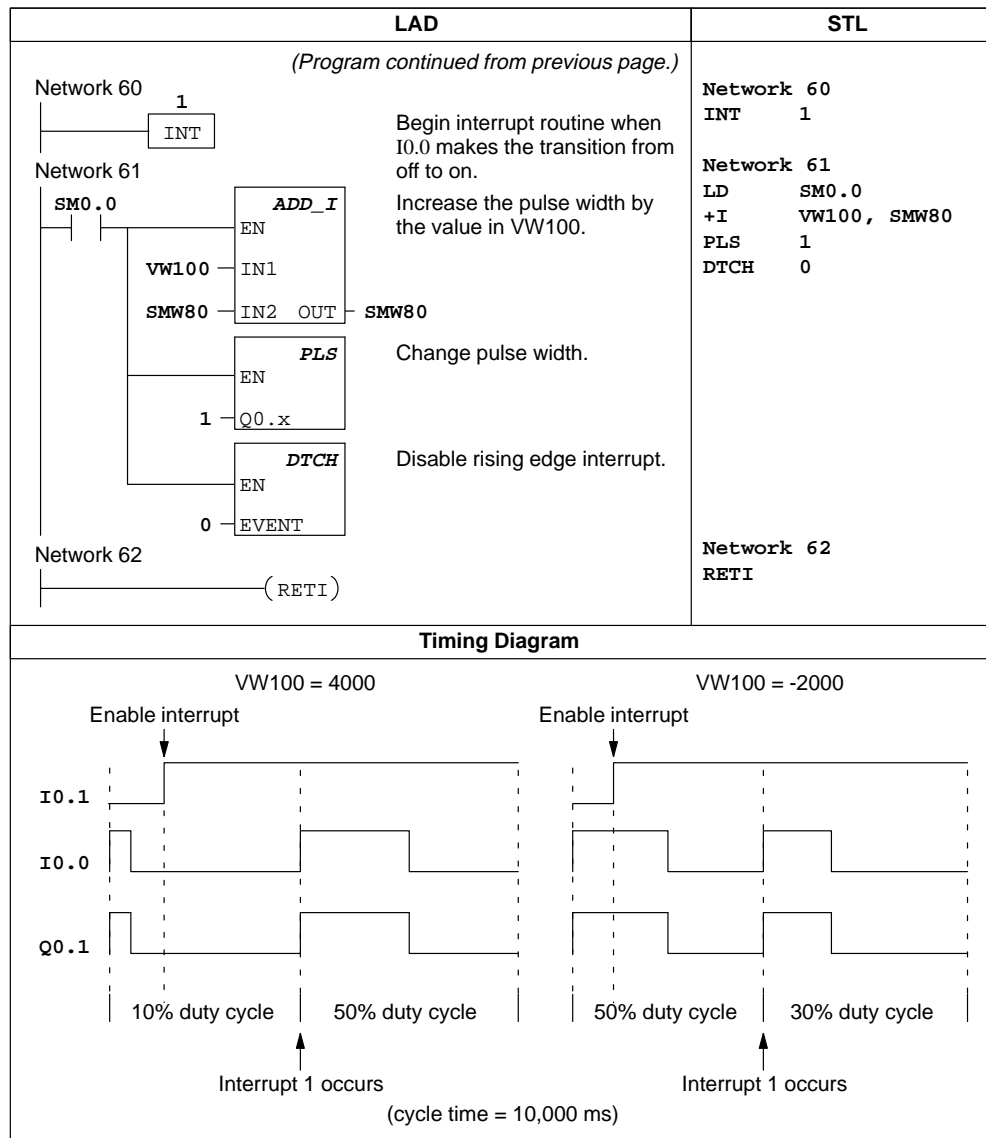
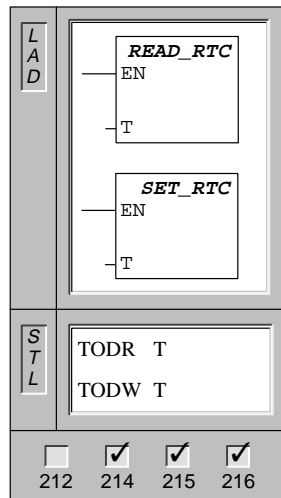


Figure 10-19 Example of High-Speed Output Using Pulse Width Modulation (continued)

Read Real-Time Clock, Set Real-Time Clock



The **Read Real-Time Clock** instruction reads the current time and date from the clock and loads it in an 8-byte buffer (starting at address T).

The **Set Real-Time Clock** instruction writes the current time and date loaded in an 8-byte buffer (starting at address T) to the clock.

In STL, the Read_RTC and Set_RTC instructions are represented as Time of Day Read (TODR) and Time of Day Write (TODW).

Operands: T: VB, IB, QB, MB, SMB, *VD, *AC, SB

The time-of-day clock initializes the following date and time after extended power outages or memory has been lost:

Date: 01-Jan-90
 Time: 00:00:00
 Day of Week: Sunday

The time-of-day clock in the S7-200 uses only the least significant two digits for the year, so for the year 2000, the year will be represented as 00 (it will go from 99 to 00).

You must code all date and time values in BCD format (for example, 16#97 for the year 1997). Use the following data formats:

Year/Month	yymm	yy - 0 to 99	mm - 1 to 12
Day/Hour	ddhh	dd - 1 to 31	hh - 0 to 23
Minute/Second	mmss	mm - 0 to 59	ss - 0 to 59
Day of week	000d	d - 0 to 7	1 = Sunday 0 = disables day of week (remains 0)

Note

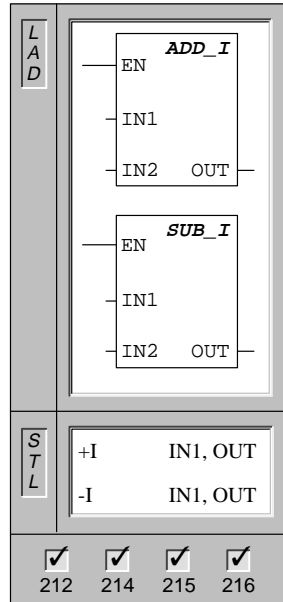
The S7-200 CPU does not perform a check to verify that the day of week is correct based upon the date. Invalid dates, such as February 30, may be accepted. You should ensure that the date you enter is correct.

Do not use the TODR/TODW instruction in both the main program and in an interrupt routine. A TODR/TODW instruction in an interrupt routine which attempts to execute while another TODR/TODW instruction is in process will not be executed. SM4.3 is set indicating that two simultaneous accesses to the clock were attempted.

The S7-200 PLC does not use the year information in any way and will not be affected by the century rollover (year 2000). However, user programs that use arithmetic or compares with the year's value must take into account the two-digit representation and the change in century.

10.6 Math and PID Loop Control Instructions

Add, Subtract Integer



The **Add** and **Subtract Integer** instructions add or subtract two 16-bit integers and produce a 16-bit result (OUT).

Operands: IN1, IN2: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

OUT: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

In LAD: $IN1 + IN2 = OUT$
 $IN1 - IN2 = OUT$

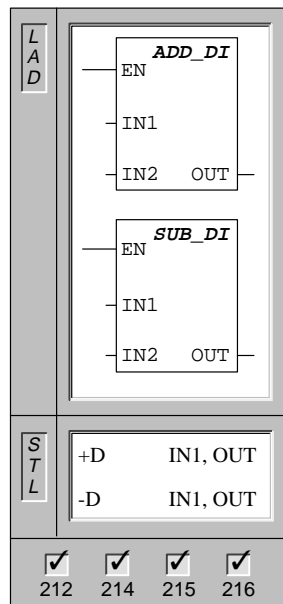
In STL: $IN1 + OUT = OUT$
 $OUT - IN1 = OUT$

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Add, Subtract Double Integer



The **Add** and **Subtract Double Integer** instructions add or subtract two 32-bit integers, and produce a 32-bit result (OUT).

Operands: IN1, IN2: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD

OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

In LAD: $IN1 + IN2 = OUT$
 $IN1 - IN2 = OUT$

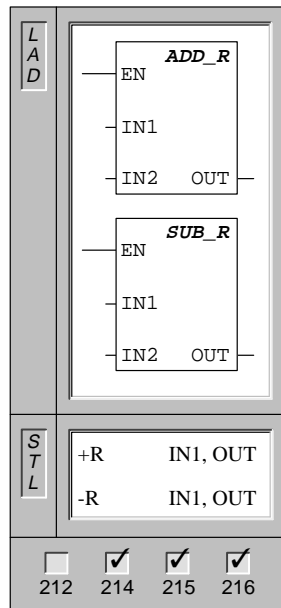
In STL: $IN1 + OUT = OUT$
 $OUT - IN1 = OUT$

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Add, Subtract Real



The **Add** and **Subtract Real** instructions add or subtract two 32-bit real numbers and produce a 32-bit real number result (OUT).

Operands: IN1, IN2: VD, ID, QD, MD, SMD, AC, Constant
 *VD, *AC, SD
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

In LAD: IN1 + IN2 = OUT
 IN1 - IN2 = OUT

In STL: IN1 + OUT = OUT
 OUT - IN1 = OUT

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

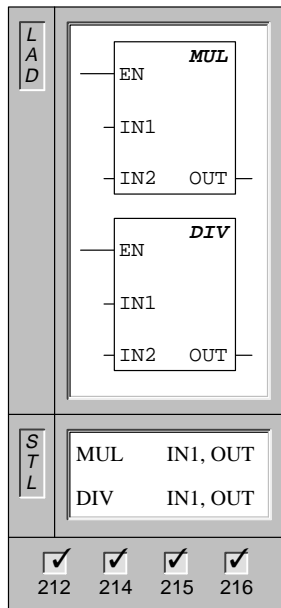
These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow/illegal value); SM1.2 (negative)

Note

Real or floating-point numbers are represented in the format described in the ANSI/IEEE 754-1985 standard (single-precision). Refer to the standard for more information.

Multiply, Divide Integer



The **Multiply** instruction multiplies two 16-bit integers and produces a 32-bit product (OUT).

In STL, the least-significant word (16 bits) of the 32-bit OUT is used as one of the factors.

The **Divide** instruction divides two 16-bit integers and produces a 32-bit result (OUT). The 32-bit result (OUT) is comprised of a 16-bit quotient (least significant) and a 16-bit remainder (most significant).

In STL, the least-significant word (16 bits) of the 32-bit OUT is used as the dividend.

Operands: IN1, IN2: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

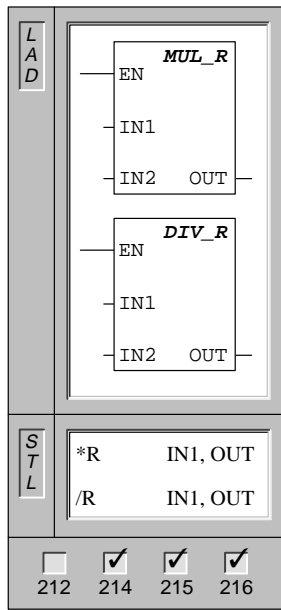
In LAD: $IN1 * IN2 = OUT$
 $IN1 / IN2 = OUT$
 In STL: $IN1 * OUT = OUT$
 $OUT / IN1 = OUT$

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative); SM1.3 (divide-by-zero)

Multiply, Divide Real



The **Multiply Real** instruction multiplies two 32-bit real numbers, and produces a 32-bit real number result (OUT).

The **Divide Real** instruction divides two 32-bit real numbers, and produces a 32-bit real number quotient.

Operands: IN1, IN2: VD, ID, QD, MD, SMD, AC, Constant, *VD, *AC, SD

OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

In LAD: IN1 * IN2 = OUT
IN1 / IN2 = OUT

In STL: IN1 * OUT = OUT
OUT / IN1 = OUT

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

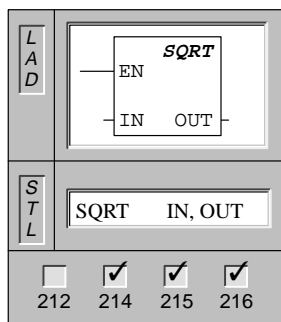
SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative); SM1.3 (divide-by-zero)

If SM1.1 or SM1.3 are set, then the other math status bits are left unchanged and the original input operands are not altered.

Note

Real or floating-point numbers are represented in the format described in the ANSI/IEEE 754-1985 standard (single-precision). Refer to the standard for more information.

Square Root



The **Square Root of Real Numbers** instruction takes the square root of a 32-bit real number (IN) and produces a 32-bit real number result (OUT) as shown in the equation:

$$\sqrt{IN} = OUT$$

Operands: IN: VD, ID, QD, MD, SMD, AC, Constant, *VD, *AC, SD

OUT: VD, ID, QD, MD, SMD AC, *VD, *AC, SD

This instruction affects the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Math Examples

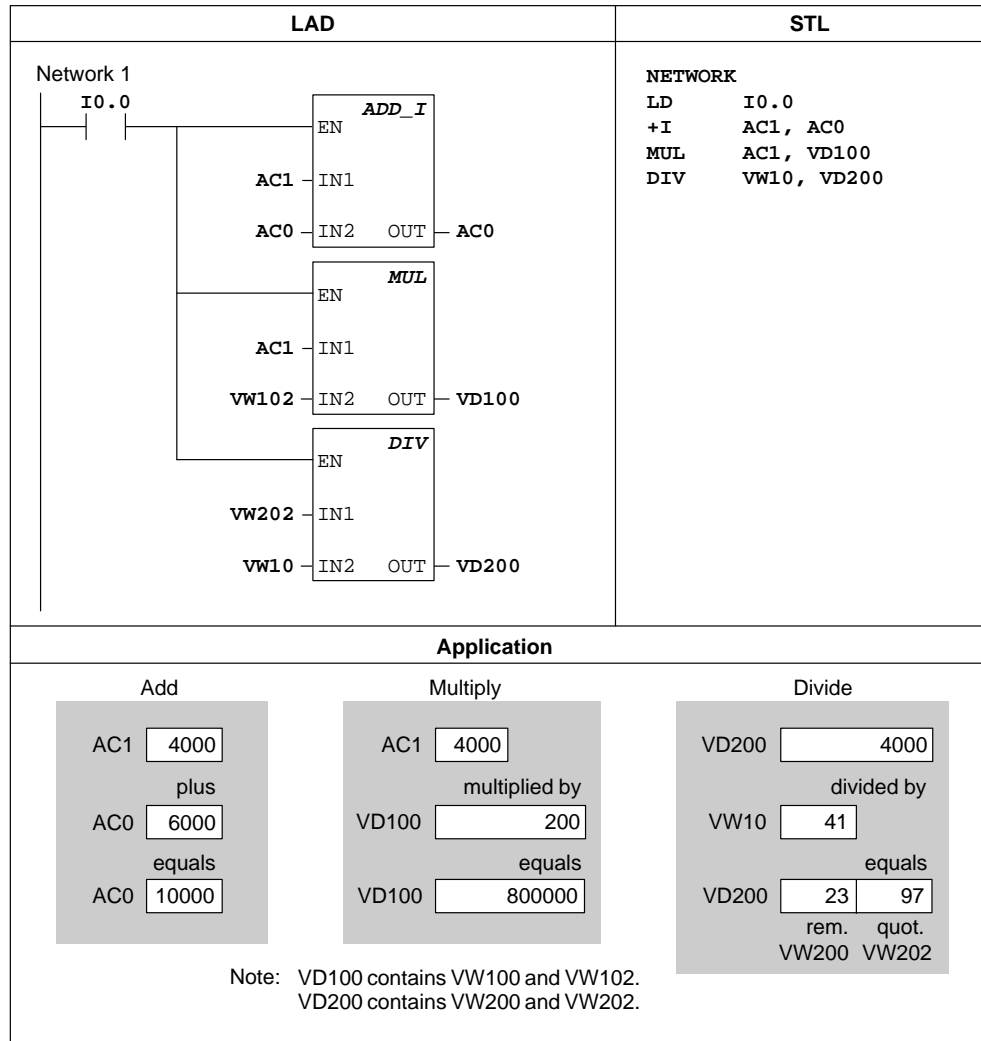
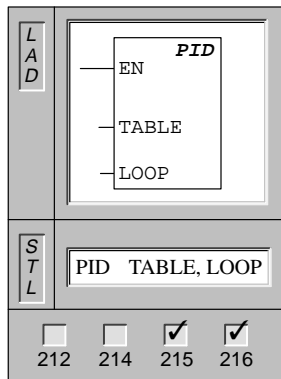


Figure 10-20 Examples of Math Instructions for LAD and STL

PID Loop Control



The **PID Loop** instruction executes a PID loop calculation on the referenced LOOP based on the input and configuration information in TABLE.

Operands: Table: VB
 Loop: 0 to 7

This instruction affects the following Special Memory bits:
 SM1.1 (overflow)

The PID loop instruction (Proportional, Integral, Derivative Loop) is provided to perform the PID calculation. The top of the logic stack (TOS) must be ON (power flow) to enable the PID calculation. The instruction has two operands: a TABLE address which is the starting address of the loop table and a LOOP number which is a constant from 0 to 7. Only eight PID instructions can be used in a program. If two or more PID instructions are used with the same loop number (even if they have different table addresses), the PID calculations will interfere with one another and the output will be unpredictable.

The loop table stores nine parameters used for controlling and monitoring the loop operation and includes the current and previous value of the process variable, the setpoint, output, gain, sample time, integral time (reset), derivative time (rate), and the integral sum (bias).

To perform the PID calculation at the desired sample rate, the PID instruction must be executed either from within a timed interrupt routine or from within the main program at a rate controlled by a timer. The sample time must be supplied as an input to the PID instruction via the loop table.

PID Algorithm

In steady state operation a PID controller regulates the value of the output so as to drive the error (e) to zero. A measure of the error is given by the difference between the setpoint (SP) (the desired operating point) and the process variable (PV) (the actual operating point). The principle of PID control is based upon the following equation that expresses the output, M(t), as a function of a proportional term, an integral term, and a differential term:

$M(t)$	=	$K_C * e$	+	$K_C \int_0^t e \, dt$	+	$M_{initial}$	+	$K_C * de/dt$
output	=	proportional term	+	integral term	+		+	differential term

where:

- M(t) is the loop output as a function of time
- K_C is the loop gain
- e is the loop error (the difference between setpoint and process variable)
- M_{initial} is the initial value of the loop output

In order to implement this control function in a digital computer, the continuous function must be quantized into periodic samples of the error value with subsequent calculation of the output. The corresponding equation that is the basis for the digital computer solution is:

M_n	=	$K_C * e_n$	+	$K_I * \sum_1^n$	+	$M_{initial}$	+	$K_D * (e_n - e_{n-1})$
output	=	proportional term	+	integral term	+		+	differential term

where:

- M_n is the calculated value of the loop output at sample time n
- K_C is the loop gain
- e_n is the value of the loop error at sample time n
- e_{n-1} is the previous value of the loop error (at sample time n - 1)
- K_I is the proportional constant of the integral term
- $M_{initial}$ is the initial value of the loop output
- K_D is the proportional constant of the differential term

From this equation, the integral term is shown to be a function of all the error terms from the first sample to the current sample. The differential term is a function of the current sample and the previous sample, while the proportional term is only a function of the current sample. In a digital computer it is not practical to store all samples of the error term, nor is it necessary.

Since the digital computer must calculate the output value each time the error is sampled beginning with the first sample, it is only necessary to store the previous value of the error and the previous value of the integral term. As a result of the repetitive nature of the digital computer solution, a simplification in the equation that must be solved at any sample time can be made. The simplified equation is:

M_n	=	$K_C * e_n$	+	$K_I * e_n + MX$	+	$K_D * (e_n - e_{n-1})$
output	=	proportional term	+	integral term	+	differential term

where:

- M_n is the calculated value of the loop output at sample time n
- K_C is the loop gain
- e_n is the value of the loop error at sample time n
- e_{n-1} is the previous value of the loop error (at sample time n - 1)
- K_I is the proportional constant of the integral term
- MX is the previous value of the integral term (at sample time n - 1)
- K_D is the proportional constant of the differential term

The CPU uses a modified form of the above simplified equation when calculating the loop output value. This modified equation is:

M_n	=	MP_n	+	MI_n	+	MD_n
output	=	proportional term	+	integral term	+	differential term

where:

- M_n is the calculated value of the loop output at sample time n
- MP_n is the value of the proportional term of the loop output at sample time n
- MI_n is the value of the integral term of the loop output at sample time n
- MD_n is the value of the differential term of the loop output at sample time n

Proportional Term

The proportional term MP is the product of the gain (K_C), which controls the sensitivity of the output calculation, and the error (e), which is the difference between the setpoint (SP) and the process variable (PV) at a given sample time. The equation for the proportional term as solved by the CPU is:

$$MP_n = K_C * (SP_n - PV_n)$$

where:

MP_n	is the value of the proportional term of the loop output at sample time n
K_C	is the loop gain
SP_n	is the value of the setpoint at sample time n
PV_n	is the value of the process variable at sample time n

Integral Term

The integral term MI is proportional to the sum of the error over time. The equation for the integral term as solved by the CPU is:

$$MI_n = K_C * T_S / T_I * (SP_n - PV_n) + MX$$

where:

MI_n	is the value of the integral term of the loop output at sample time n
K_C	is the loop gain
T_S	is the loop sample time
T_I	is the integration period of the loop (also called the integral time or reset)
SP_n	is the value of the setpoint at sample time n
PV_n	is the value of the process variable at sample time n
MX	is the value of the integral term at sample time n - 1 (also called the integral sum or the bias)

The integral sum or bias (MX) is the running sum of all previous values of the integral term. After each calculation of MI_n , the bias is updated with the value of MI_n which may be adjusted or clamped (see the section "Variables and Ranges" for details). The initial value of the bias is typically set to the output value ($M_{initial}$) just prior to the first loop output calculation. Several constants are also part of the integral term, the gain (K_C), the sample time (T_S), which is the cycle time at which the PID loop recalculates the output value, and the integral time or reset (T_I), which is a time used to control the influence of the integral term in the output calculation.

Differential Term

The differential term MD is proportional to the change in the error. The equation for the differential term:

$$MD_n = K_C * T_D / T_S * ((SP_n - PV_n) - (SP_{n-1} - PV_{n-1}))$$

To avoid step changes or bumps in the output due to derivative action on setpoint changes, this equation is modified to assume that the setpoint is a constant ($SP_n = SP_{n-1}$). This results in the calculation of the change in the process variable instead of the change in the error as shown:

$$MD_n = K_C * T_D / T_S * (SP_n - PV_n - SP_n + PV_{n-1})$$

or just:

$$MD_n = K_C * T_D / T_S * (PV_{n-1} - PV_n)$$

where:

MD_n	is the value of the differential term of the loop output at sample time n
K_C	is the loop gain
T_S	is the loop sample time
T_D	is the differentiation period of the loop (also called the derivative time or rate)
SP_n	is the value of the setpoint at sample time n
SP_{n-1}	is the value of the setpoint at sample time n - 1
PV_n	is the value of the process variable at sample time n
PV_{n-1}	is the value of the process variable at sample time n - 1

The process variable rather than the error must be saved for use in the next calculation of the differential term. At the time of the first sample, the value of PV_{n-1} is initialized to be equal to PV_n .

Selection of Loop Control

In many control systems it may be necessary to employ only one or two methods of loop control. For example only proportional control or proportional and integral control may be required. The selection of the type of loop control desired is made by setting the value of the constant parameters.

If you do not want integral action (no "I" in the PID calculation), then a value of infinity should be specified for the integral time (reset). Even with no integral action, the value of the integral term may not be zero, due to the initial value of the integral sum MX.

If you do not want derivative action (no "D" in the PID calculation), then a value of 0.0 should be specified for the derivative time (rate).

If you do not want proportional action (no "P" in the PID calculation) and you want I or ID control, then a value of 0.0 should be specified for the gain. Since the loop gain is a factor in the equations for calculating the integral and differential terms, setting a value of 0.0 for the loop gain will result in a value of 1.0 being used for the loop gain in the calculation of the integral and differential terms.

Converting and Normalizing the Loop Inputs

A loop has two input variables, the setpoint and the process variable. The setpoint is generally a fixed value such as the speed setting on the cruise control in your automobile. The process variable is a value that is related to loop output and therefore measures the effect that the loop output has on the controlled system. In the example of the cruise control, the process variable would be a tachometer input that measures the rotational speed of the tires.

Both the setpoint and the process variable are real world values whose magnitude, range, and engineering units may be different. Before these real world values can be operated upon by the PID instruction, the values must be converted to normalized, floating-point representations.

The first step is to convert the real world value from a 16-bit integer value to a floating-point or real number value. The following instruction sequence is provided to show how to convert from an integer value to a real number.

```
XORD  AC0, AC0           // Clear the accumulator.
MOVW  AIW0, AC0         // Save the analog value in the accumulator.
LDW>= AC0, 0           // If the analog value is positive,
JMP   0                 // then convert to a real number.
NOT   0                 // Else,
ORD   16#FFFF0000, AC0 // sign extend the value in AC0.
LBL   0
DTR   AC0, AC0         // Convert the 32-bit integer to a real number.
```

The next step is to convert the real number value representation of the real world value to a normalized value between 0.0 and 1.0. The following equation is used to normalize either the setpoint or process variable value:

$$R_{\text{Norm}} = (R_{\text{Raw}} / \text{Span}) + \text{Offset}$$

where:

R_{Norm}	is the normalized, real number value representation of the real world value
R_{Raw}	is the un-normalized or raw, real number value representation of the real world value
Offset	is 0.0 for unipolar values is 0.5 for bipolar values
Span	is the maximum possible value minus the minimum possible value = 32,000 for unipolar values (typical) = 64,000 for bipolar values (typical)

The following instruction sequence shows how to normalize the bipolar value in AC0 (whose span is 64,000) as a continuation of the previous instruction sequence:

```
/R   64000.0, AC0       // Normalize the value in the accumulator
+R   0.5, AC0          // Offset the value to the range from 0.0 to 1.0
MOVR AC0, VD100        // Store the normalized value in the loop TABLE
```

Converting the Loop Output to a Scaled Integer Value

The loop output is the control variable, such as the throttle setting in the example of the cruise control on the automobile. The loop output is a normalized, real number value between 0.0 and 1.0. Before the loop output can be used to drive an analog output, the loop output must be converted to a 16-bit, scaled integer value. This process is the reverse of converting the PV and SP to a normalized value. The first step is to convert the loop output to a scaled, real number value using the formula given below:

$$R_{Scal} = (M_n - Offset) * Span$$

where:

R_{Scal} is the scaled, real number value of the loop output
 M_n is the normalized, real number value of the loop output
 Offset is 0.0 for unipolar values
 is 0.5 for bipolar values
 Span is the maximum possible value minus the minimum possible value
 = 32,000 for unipolar values (typical)
 = 64,000 for bipolar values (typical)

The following instruction sequence shows how to scale the loop output:

```

MOVR  VD108, AC0           // Move the loop output to the accumulator
-R    0.5, AC0             // Include this statement only if the value is bipolar.
*R    64000.0, AC0        // Scale the value in the accumulator.
  
```

Next, the scaled, real number value representing the loop output must be converted to a 16-bit integer. The following instruction sequence shows how to do this conversion:

```

TRUNC AC0, AC0           // Convert the real number value to a 32-bit integer.
MOVW  AC0, AQW0         // Write the 16-bit integer value to the analog output.
  
```

Forward- or Reverse-Acting Loops

The loop is forward-acting if the gain is positive and reverse-acting if the gain is negative. (For I or ID control, where the gain value is 0.0, specifying positive values for integral and derivative time will result in a forward-acting loop, and specifying negative values will result in a reverse-acting loop.)

Variables and Ranges

The process variable and setpoint are inputs to the PID calculation. Therefore the loop table fields for these variables are read but not altered by the PID instruction.

The output value is generated by the PID calculation, so the output value field in the loop table is updated at the completion of each PID calculation. The output value is clamped between 0.0 and 1.0. The output value field can be used as an input by the user to specify an initial output value when making the transition from manual control to PID instruction (auto) control of the output (see discussion in the Modes section below).

If integral control is being used, then the bias value is updated by the PID calculation and the updated value is used as an input in the next PID calculation. When the calculated output value goes out of range (output would be less than 0.0 or greater than 1.0), the bias is adjusted according to the following formulas:

$$MX = 1.0 - (MP_n + MD_n) \quad \text{when the calculated output, } M_n > 1.0$$

or

$$MX = - (MP_n + MD_n) \quad \text{when the calculated output, } M_n < 0.0$$

where:

MX	is the value of the adjusted bias
MP _n	is the value of the proportional term of the loop output at sample time n
MD _n	is the value of the differential term of the loop output at sample time n
M _n	is the value of the loop output at sample time n

By adjusting the bias as described, an improvement in system responsiveness is achieved once the calculated output comes back into the proper range. The calculated bias is also clamped between 0.0 and 1.0 and then is written to the bias field of the loop table at the completion of each PID calculation. The value stored in the loop table is used in the next PID calculation.

The bias value in the loop table can be modified by the user prior to execution of the PID instruction in order to address bias value problems in certain application situations. Care must be taken when manually adjusting the bias, and any bias value written into the loop table must be a real number between 0.0 and 1.0.

A comparison value of the process variable is maintained in the loop table for use in the derivative action part of the PID calculation. You should not modify this value.

Modes

There is no built-in mode control for S7-200 PID loops. The PID calculation is performed only when power flows to the PID box. Therefore, "automatic" or "auto" mode exists when the PID calculation is performed cyclically. "Manual" mode exists when the PID calculation is not performed.

The PID instruction has a power-flow history bit, similar to a counter instruction. The instruction uses this history bit to detect a 0-to-1 power flow transition, which when detected will cause the instruction to perform a series of actions to provide a bumpless change from manual control to auto control. In order for change to auto mode control to be bumpless, the value of the output as set by the manual control must be supplied as an input to the PID instruction (written to the loop table entry for M_n) before switching to auto control. The PID instruction performs the following actions to values in the loop table to ensure a bumpless change from manual to auto control when a 0-to-1 power flow transition is detected:

- Sets setpoint (SP_n) = process variable (PV_n)
- Sets old process variable (PV_{n-1}) = process variable (PV_n)
- Sets bias (MX) = output value (M_n)

The default state of the PID history bits is "set" and that state is established at CPU startup and on every STOP-to-RUN mode transition of the controller. If power flows to the PID box the first time that it is executed after entering RUN mode, then no power flow transition is detected and the bumpless mode change actions will not be performed.

Alarming and Special Operations

The PID instruction is a simple but powerful instruction that performs the PID calculation. If other processing is required such as alarming or special calculations on loop variables, these must be implemented using the basic instructions supported by the CPU.

Error Conditions

When it is time to compile, the CPU will generate a compile error (range error) and the compilation will fail if the loop table start address or PID loop number operands specified in the instruction are out of range.

Certain loop table input values are not range checked by the PID instruction. You must take care to ensure that the process variable and setpoint (as well as the bias and previous process variable if used as inputs) are real numbers between 0.0 and 1.0.

If any error is encountered while performing the mathematical operations of the PID calculation, then SM1.1 (overflow or illegal value) will be set and execution of the PID instruction will be terminated. (Update of the output values in the loop table may be incomplete, so you should disregard these values and correct the input value causing the mathematical error before the next execution of the loop's PID instruction.)

Loop Table

The loop table is 36 bytes long and has the format shown in Table 10-12:

Table 10-12 Format of the Loop Table

Offset	Field	Format	Type	Description
0	Process variable (PV _n)	Double word - real	in	Contains the process variable, which must be scaled between 0.0 and 1.0.
4	Setpoint (SP _n)	Double word - real	in	Contains the setpoint, which must be scaled between 0.0 and 1.0.
8	Output (M _n)	Double word - real	in/out	Contains the calculated output, scaled between 0.0 and 1.0.
12	Gain (K _C)	Double word - real	in	Contains the gain, which is a proportional constant. Can be a positive or negative number.
16	Sample time (T _S)	Double word - real	in	Contains the sample time, in seconds. Must be a positive number.
20	Integral time or reset (T _I)	Double word - real	in	Contains the integral time or reset, in minutes. Must be a positive number.
24	Derivative time or rate (T _D)	Double word - real	in	Contains the derivative time or rate, in minutes. Must be a positive number.
28	Bias (MX)	Double word - real	in/out	Contains the bias or integral sum value between 0.0 and 1.0.
32	Previous process variable (PV _{n-1})	Double word - real	in/out	Contains the previous value of the process variable stored from the last execution of the PID instruction.

PID Program Example

In this example, a water tank is used to maintain a constant water pressure. Water is continuously being taken from the water tank at a varying rate. A variable speed pump is used to add water to the tank at a rate that will maintain adequate water pressure and also keep the tank from being emptied.

The setpoint for this system is a water level setting that is equivalent to the tank being 75% full. The process variable is supplied by a float gauge that provides an equivalent reading of how full the tank is and which can vary from 0% or empty to 100% or completely full. The output is a value of pump speed that allows the pump to run from 0% to 100% of maximum speed.

The setpoint is predetermined and will be entered directly into the loop table. The process variable will be supplied as a unipolar, analog value from the float gauge. The loop output will be written to a unipolar, analog output which is used to control the pump speed. The span of both the analog input and analog output is 32,000.

Only proportional and integral control will be employed in this example. The loop gain and time constants have been determined from engineering calculations and may be adjusted as required to achieve optimum control. The calculated values of the time constants are:

K_C is 0.25

T_S is 0.1 seconds

T_I is 30 minutes

The pump speed will be controlled manually until the water tank is 75% full, then the valve will be opened to allow water to be drained from the tank. At the same time, the pump will be switched from manual to auto control mode. A digital input will be used to switch the control from manual to auto. This input is described below:

I0.0 is Manual/Auto control; 0 is manual, 1 is auto

While in manual control mode, the pump speed will be written by the operator to VD108 as a real number value from 0.0 to 1.0.

Figure 10-21 shows the control program for this application.

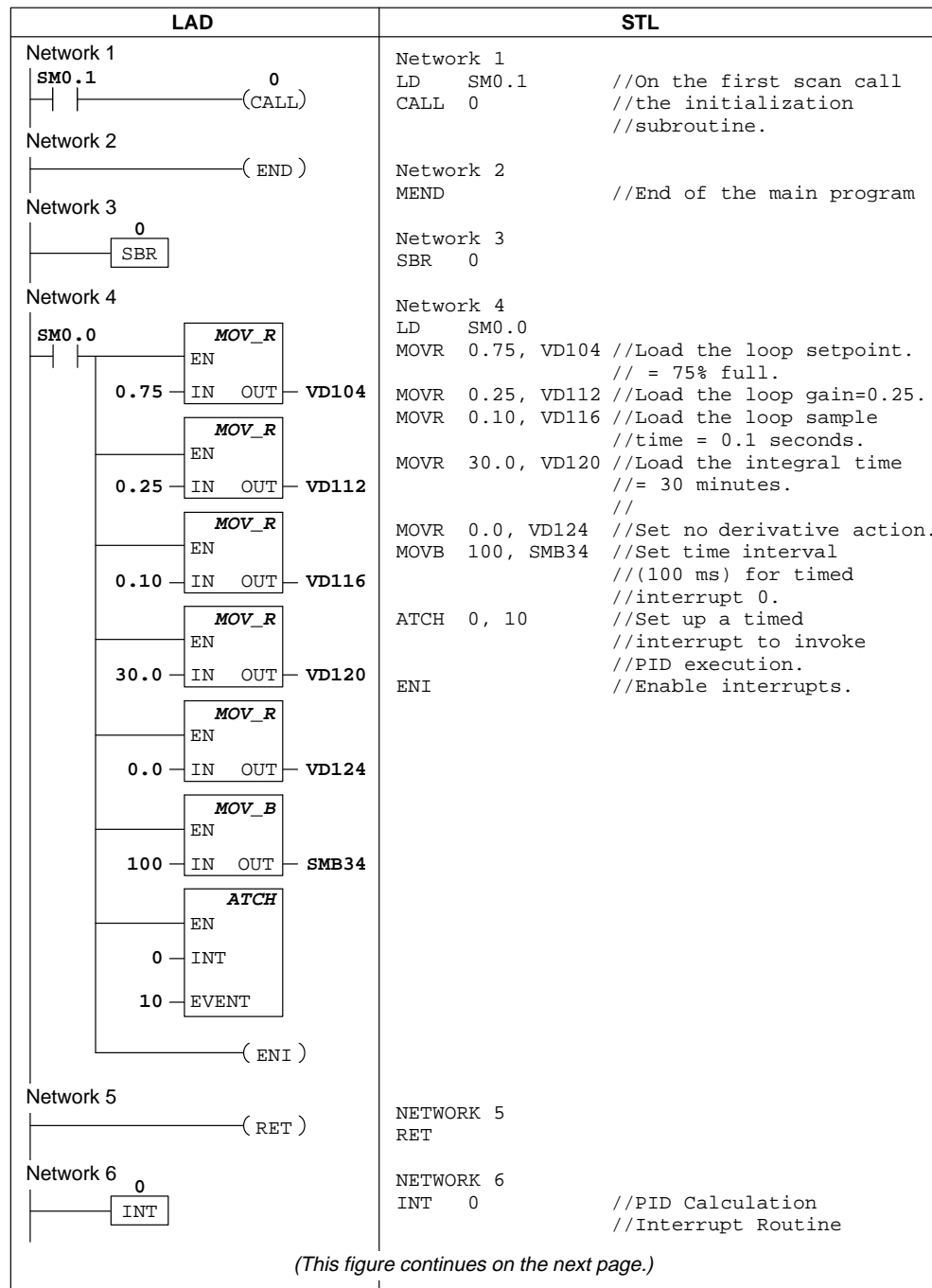


Figure 10-21 Example of PID Loop Control

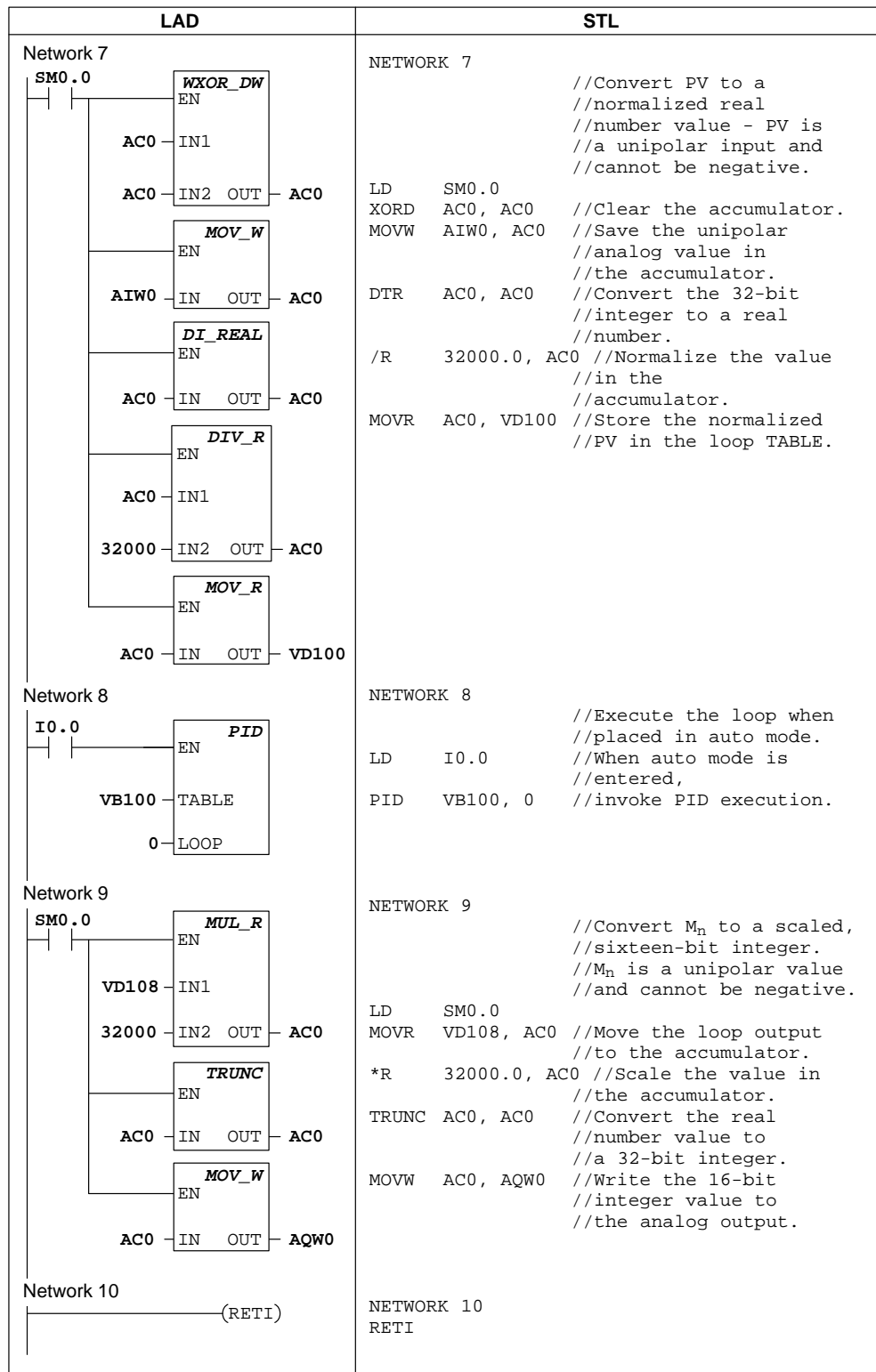
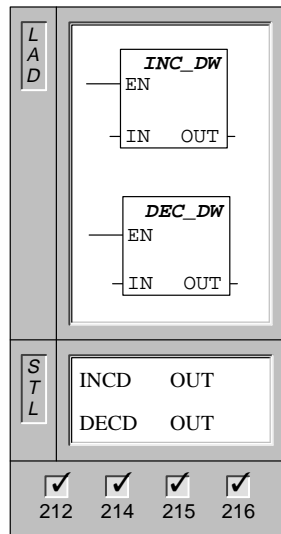


Figure 10-21 Example of PID Loop Control (continued)

Increment Double Word, Decrement Double Word



The **Increment Double Word** and **Decrement Double Word** instructions add or subtract 1 to or from the input double word.

Operands: IN: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

In LAD: IN + 1 = OUT
 IN - 1 = OUT

In STL: OUT + 1 = OUT
 OUT - 1 = OUT

Increment and decrement double word operations are signed (16#7FFFFFFF > 16#80000000).

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Increment, Decrement Example

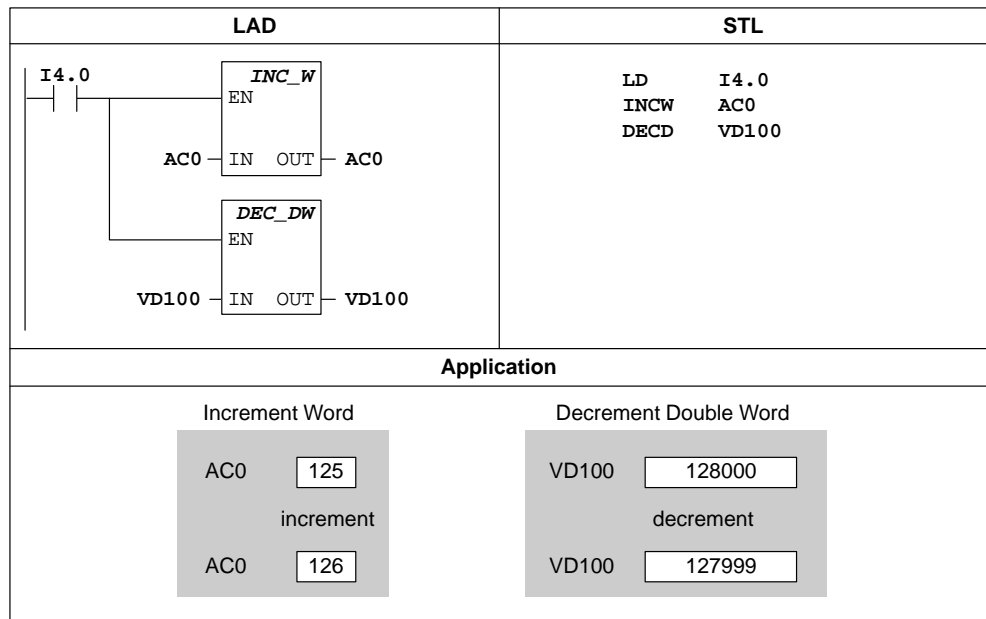
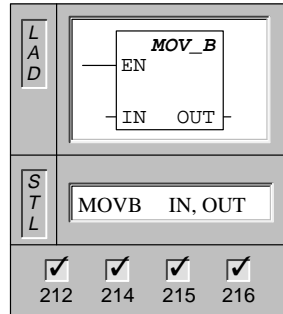


Figure 10-22 Example of Increment/Decrement Instructions for LAD and STL

10.8 Move, Fill, and Table Instructions

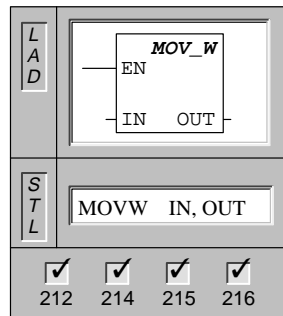
Move Byte



The **Move Byte** instruction moves the input byte (IN) to the output byte (OUT). The input byte is not altered by the move.

Operands: IN: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VB, IB, QB, MB, SMB, AC, *VD, *AC, SB

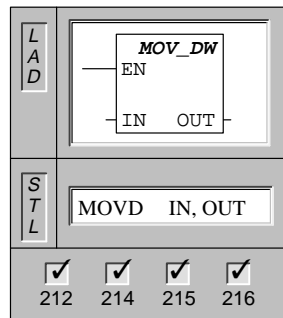
Move Word



The **Move Word** instruction moves the input word (IN) to the output word (OUT). The input word is not altered by the move.

Operands: IN: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW
 OUT: VW, T, C, IW, QW, MW, SMW, AC, AQW, *VD, *AC, SW

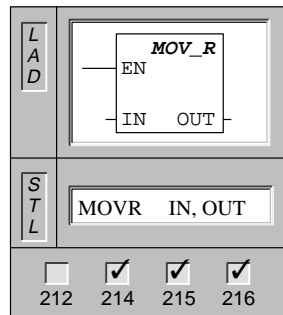
Move Double Word



The **Move Double Word** instruction moves the input double word (IN) to the output double word (OUT). The input double word is not altered by the move.

Operands: IN: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, &VB, &IB, &QB, &MB, &T, &C, &SB, SD
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

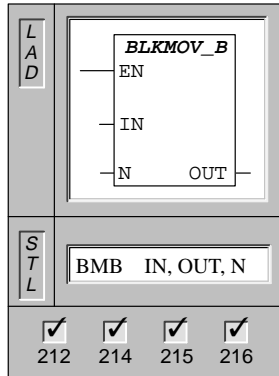
Move Real



The **Move Real** instruction moves a 32-bit, real input double word (IN) to the output double word (OUT). The input double word is not altered by the move.

Operands: IN: VD, ID, QD, MD, SMD, AC, Constant, *VD, *AC, SD
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

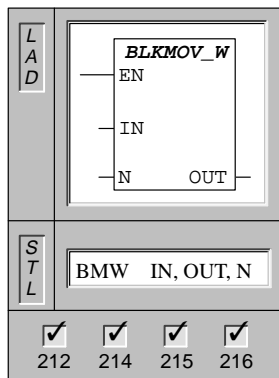
Block Move Byte



The **Block Move Byte** instruction moves the number of bytes specified (N), from the input array starting at IN, to the output array starting at OUT. N has a range of 1 to 255.

Operands: IN, OUT: VB, IB, QB, MB, SMB, *VD, *AC, SB
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

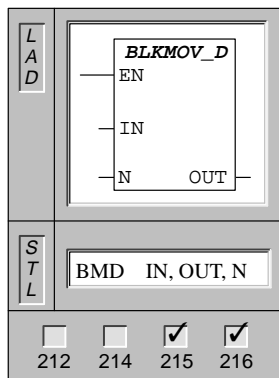
Block Move Word



The **Block Move Word** instruction moves the number of words specified (N), from the input array starting at IN, to the output array starting at OUT. N has a range of 1 to 255.

Operands: IN: VW, T, C, IW, QW, MW, SMW, AIW, *VD, *AC, SW
 OUT: VW, T, C, IW, QW, MW, SMW, AQW, *VD, *AC, SW
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

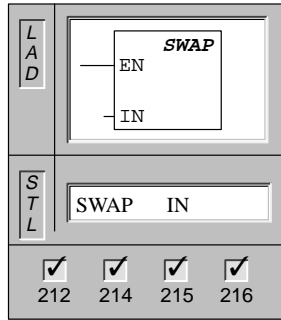
Block Move Double Word



The **Block Move Double Word** instruction moves the number of double words specified (N), from the input array starting at IN, to the output array starting at OUT. N has a range of 1 to 255.

Operands: IN, OUT: VD, ID, QD, MD, SMD, *VD, *AC, SD
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

Swap Bytes



The **Swap Bytes** instruction exchanges the most significant byte with the least significant byte of the word (IN).

Operands: IN: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

Move and Swap Examples

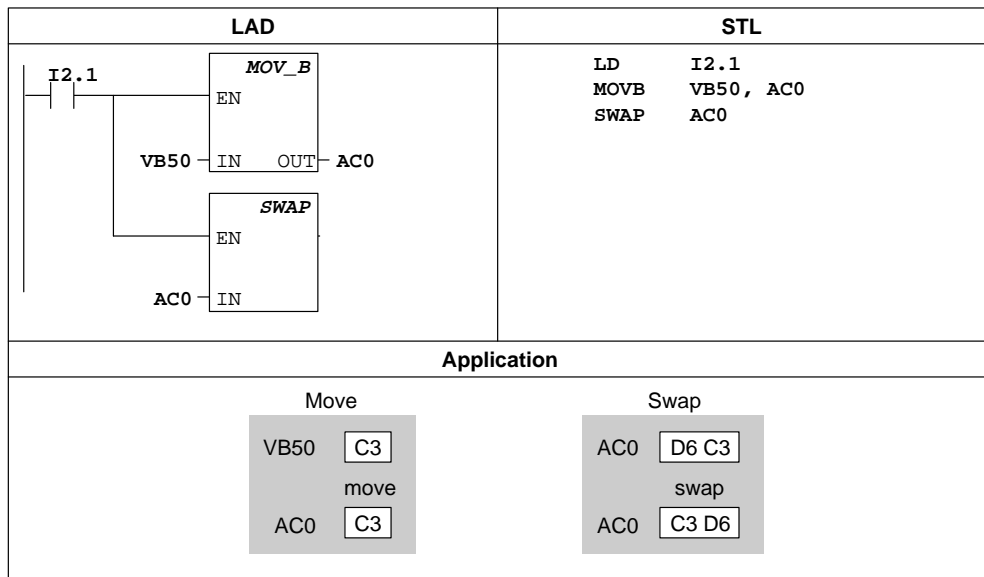


Figure 10-23 Example of Move and Swap Instructions for LAD and STL

Block Move Example

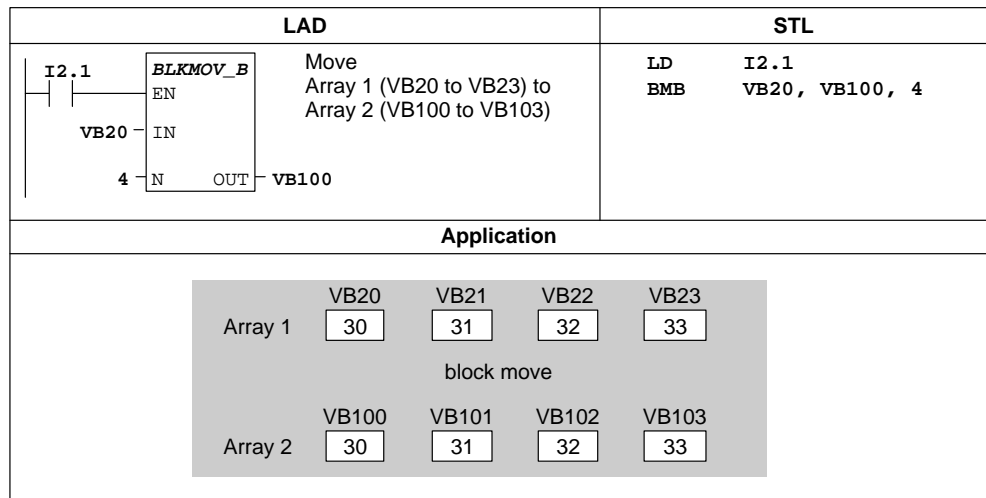
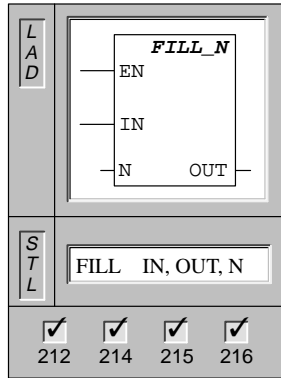


Figure 10-24 Example of Block Move Instructions for LAD and STL

Memory Fill



The **Memory Fill** instruction fills the memory starting at the output word (OUT), with the word input pattern (IN) for the number of words specified by N. N has a range of 1 to 255.

Operands: IN: VW, T, C, IW, QW, MW, SMW, AIW, Constant, *VD, *AC, SW
 OUT: VW, T, C, IW, QW, MW, SMW, AQW, *VD, *AC, SW
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

Fill Example

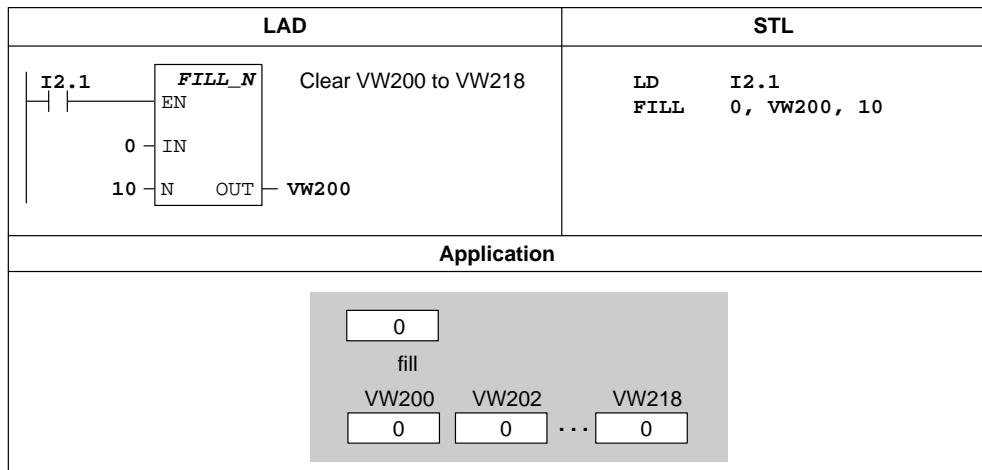
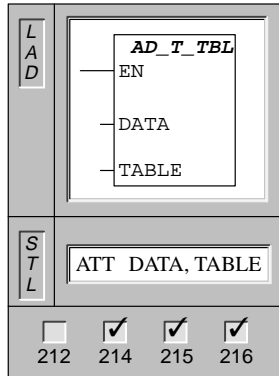


Figure 10-25 Example of Fill Instructions for LAD and STL

Add to Table



The **Add To Table** instruction adds word values (DATA) to the table (TABLE).

Operands: DATA: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW
 TABLE: VW, T, C, IW, QW, MW, SMW, *VD, *AC, SW

The first value of the table is the maximum table length (TL). The second value is the entry count (EC), which specifies the number of entries in the table. (See Figure 10-26.) New data are added to the table after the last entry. Each time new data are added to the table, the entry count is incremented. A table may have up to 100 entries, excluding both parameters specifying the maximum number of entries and the actual number of entries.

This instruction affects the following Special Memory bits:
 SM1.4 is set to 1 if you try to overfill the table.

Add to Table Example

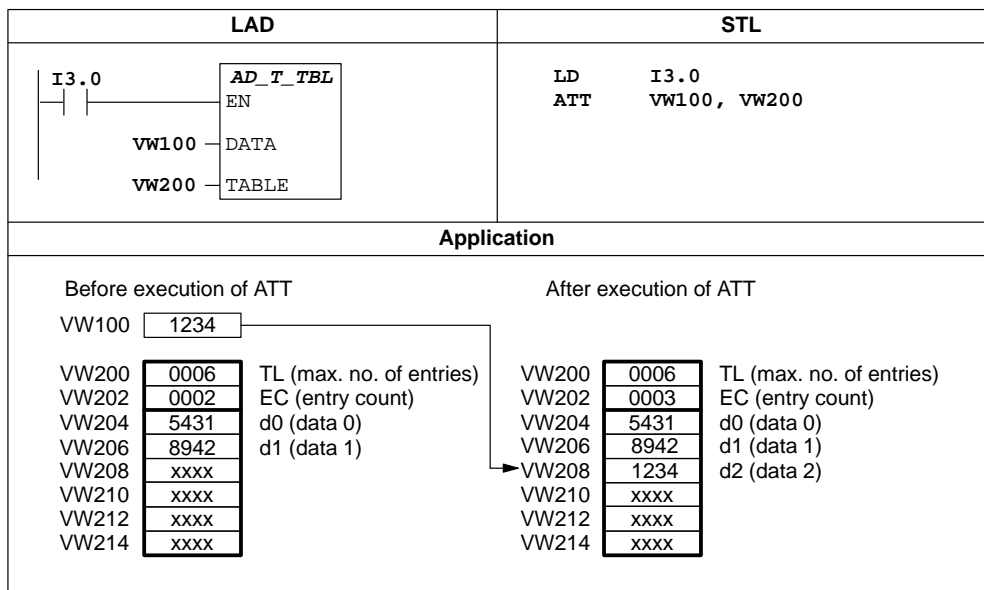
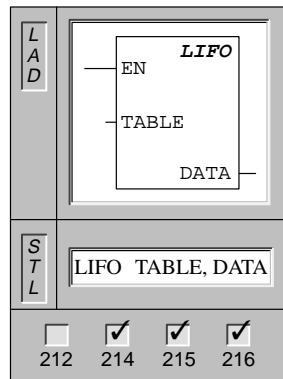


Figure 10-26 Example of Add To Table Instruction

Last-In-First-Out



The **Last-In-First-Out** instruction removes the last entry in the table (TABLE), and outputs the value to a specified location (DATA). The entry count in the table is decremented for each instruction execution.

Operands: TABLE: VW, T, C, IW, QW, MW, SMW, *VD, *AC, SW
 DATA: VW, T, C, IW, QW, MW, SMW, AC, AQW, *VD, *AC, SW

This instruction affects the following Special Memory bits:

SM1.5 is set to 1 if you try to remove an entry from an empty table.

Last-In-First-Out Example

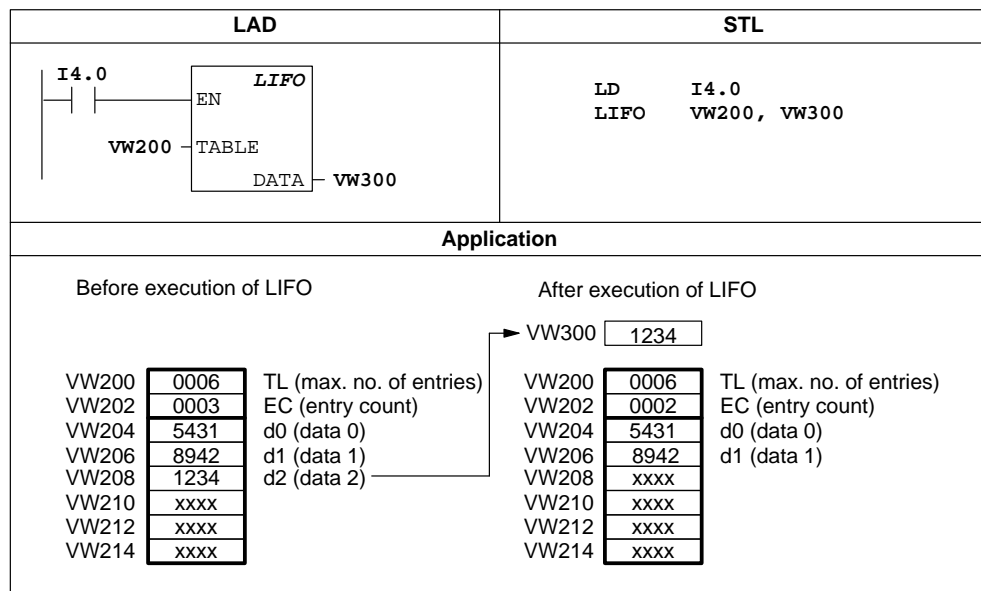
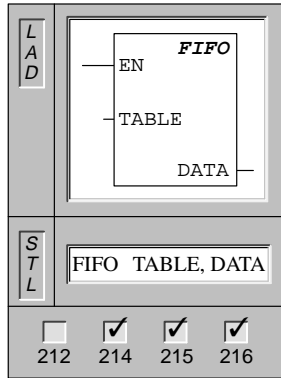


Figure 10-27 Example of Last-In-First-Out Instruction

First-In-First-Out



The **First-In-First-Out** instruction removes the first entry in the table (TABLE), and outputs the value to a specified location (DATA). All other entries of the table are shifted up one location. The entry count in the table is decremented for each instruction execution.

Operands: TABLE: VW, T, C, IW, QW, MW, SMW, *VD, *AC, SW
 DATA: VW, T, C, IW, QW, MW, SMW, AC, AQW, *VD, *AC, SW

This instruction affects the following Special Memory bits:

SM1.5 is set to 1 if you try to remove an entry from an empty table.

First-In-First-Out Example

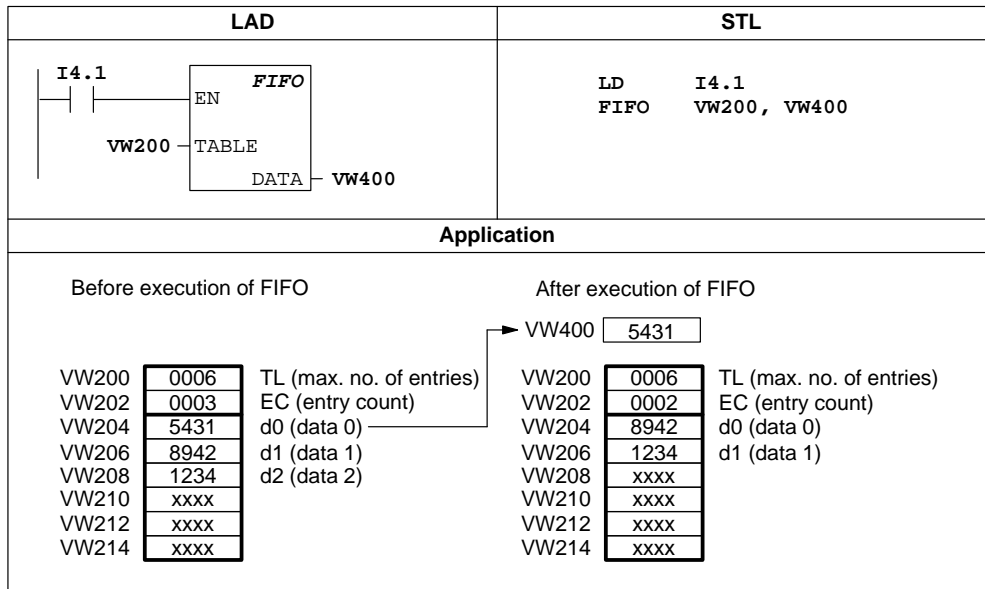
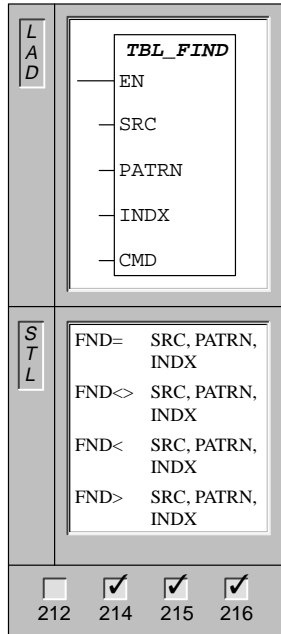


Figure 10-28 Example of First-In-First-Out Instruction

Table Find



The **Table Find** instruction searches the table (SRC), starting with the table entry specified by INDX, for the data value (PATRN) that matches the search criteria of =, <>, <, or >.

In LAD, the command parameter (CMD) is given a numeric value of 1 to 4 that corresponds to =, <>, <, and >, respectively.

- Operands:
- SRC: VW, T, C, IW, QW, MW, SMW, *VD, *AC, SW
 - PATRN: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW
 - INDX: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW
 - CMD: 1 (=) 2 (<>) 3 (<) 4 (>)

If a match is found, the INDX points to the matching entry in the table. To find the next matching entry, the INDX must be incremented before invoking the Table Find instruction again. If a match is not found, the INDX has a value equal to the entry count.

The data entries (area to be searched) are numbered from 0 to a maximum value of 99. A table may have up to 100 entries, excluding both the parameters specifying the allowed number of entries and the actual number of entries.

Note

When you use the Find instructions with tables generated with ATT, LIFO, and FIFO instructions, the entry count and the data entries correspond directly. The maximum-number-of-entries word required for ATT, LIFO, and FIFO is not required by the Find instructions. Consequently, the SRC operand of a Find instruction is one word address (two bytes) higher than the TABLE operand of a corresponding ATT, LIFO, or FIFO instruction, as shown in Figure 10-29.

Table format for ATT, LIFO, and FIFO			Table format for TBL_FIND		
VW200	0006	TL (max. no. of entries)	VW202	0006	EC (entry count)
VW202	0006	EC (entry count)	VW204	xxxx	d0 (data 0)
VW204	xxxx	d0 (data 0)	VW206	xxxx	d1 (data 1)
VW206	xxxx	d1 (data 1)	VW208	xxxx	d2 (data 2)
VW208	xxxx	d2 (data 2)	VW210	xxxx	d3 (data 3)
VW210	xxxx	d3 (data 3)	VW212	xxxx	d4 (data 4)
VW212	xxxx	d4 (data 4)	VW214	xxxx	d5 (data 5)
VW214	xxxx	d5 (data 5)			

Figure 10-29 Difference in Table Format between Find Instructions and ATT, LIFO, and FIFO

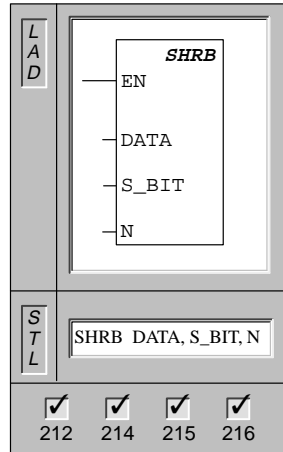
Table Find Example

LAD	STL																					
<p style="margin-left: 40px;">When I2.1 is on, search the table for a value equal to 3130 HEX.</p>	<pre>LD I2.1 FND= VW202, 16#3130, AC1</pre>																					
Application																						
<p>This is the table you are searching. If the table was created using ATT, LIFO, and FIFO instructions, VW200 contains the maximum number of allowed entries and is not required by the Find instructions.</p> <table style="margin-left: auto; margin-right: auto; border-collapse: collapse;"> <tr> <td style="padding: 2px;">VW202</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">0006</td> <td style="padding: 2px;">EC (entry count)</td> </tr> <tr> <td style="padding: 2px;">VW204</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">3133</td> <td style="padding: 2px;">d0 (data 0)</td> </tr> <tr> <td style="padding: 2px;">VW206</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">4142</td> <td style="padding: 2px;">d1 (data 1)</td> </tr> <tr> <td style="padding: 2px;">VW208</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">3130</td> <td style="padding: 2px;">d2 (data 2)</td> </tr> <tr> <td style="padding: 2px;">VW210</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">3030</td> <td style="padding: 2px;">d3 (data 3)</td> </tr> <tr> <td style="padding: 2px;">VW212</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">3130</td> <td style="padding: 2px;">d4 (data 4)</td> </tr> <tr> <td style="padding: 2px;">VW214</td> <td style="border: 1px solid black; padding: 2px; text-align: center;">4541</td> <td style="padding: 2px;">d5 (data 5)</td> </tr> </table> <p>AC1 <input style="width: 50px;" type="text" value="0"/> AC1 must be set to 0 to search from the top of table.</p> <p style="text-align: center;">Execute table search</p> <p>AC1 <input style="width: 50px;" type="text" value="2"/> AC1 contains the data entry number corresponding to the first match found in the table (d2).</p> <p>AC1 <input style="width: 50px;" type="text" value="3"/> Increment the INDX by one, before searching the remaining entries of the table.</p> <p style="text-align: center;">Execute table search</p> <p>AC1 <input style="width: 50px;" type="text" value="4"/> AC1 contains the data entry number corresponding to the second match found in the table (d4).</p> <p>AC1 <input style="width: 50px;" type="text" value="5"/> Increment the INDX by one, before searching the remaining entries of the table.</p> <p style="text-align: center;">Execute table search</p> <p>AC1 <input style="width: 50px;" type="text" value="6"/> AC1 contains a value equal to the entry count. The entire table has been searched without finding another match.</p> <p>AC1 <input style="width: 50px;" type="text" value="0"/> Before the table can be searched again, the INDX value must be reset to 0.</p>		VW202	0006	EC (entry count)	VW204	3133	d0 (data 0)	VW206	4142	d1 (data 1)	VW208	3130	d2 (data 2)	VW210	3030	d3 (data 3)	VW212	3130	d4 (data 4)	VW214	4541	d5 (data 5)
VW202	0006	EC (entry count)																				
VW204	3133	d0 (data 0)																				
VW206	4142	d1 (data 1)																				
VW208	3130	d2 (data 2)																				
VW210	3030	d3 (data 3)																				
VW212	3130	d4 (data 4)																				
VW214	4541	d5 (data 5)																				

Figure 10-30 Example of Find Instructions for LAD and STL

10.9 Shift and Rotate Instructions

Shift Register Bit



The **Shift Register Bit** instruction shifts the value of DATA into the Shift Register. S_BIT specifies the least significant bit of the Shift Register. N specifies the length of the Shift Register and the direction of the shift (Shift Plus = N, Shift Minus = -N).

Operands: DATA, S_BIT: I, Q, M, SM, T, C, V, S
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

Understanding the Shift Register Bit Instruction

The Shift Register Bit instruction provides an easy method for the sequencing and controlling of product flow or data. Use the Shift Register Bit instruction to shift the entire register one bit, once per scan. The Shift Register Bit instruction is defined by both the least significant bit (S_BIT) and the number of bits specified by the length (N). Figure 10-32 shows an example of the Shift Register Bit instruction.

The address of the most significant bit of the Shift Register (MSB.b) can be computed by the following equation:

$$\text{MSB.b} = [(\text{Byte of S_BIT}) + ((\text{N}] - 1 + (\text{bit of S_BIT})) / 8] . [\text{remainder of the division by 8}]$$

You must subtract 1 bit because S_BIT is one of the bits of the Shift Register.

For example, if S_BIT is V33.4, and N is 14, then the MSB.b is V35.1, or:

$$\begin{aligned} \text{MSB.b} &= \text{V33} + ((14] - 1 + 4) / 8 \\ &= \text{V33} + 17 / 8 \\ &= \text{V33} + 2 \text{ with a remainder of } 1 \\ &= \text{V35.1} \end{aligned}$$

On a Shift Minus, indicated by a negative value of length (N), the input data shifts into the most significant bit of the Shift Register, and shifts out of the least significant bit (S_BIT).

On a Shift Plus, indicated by a positive value of length (N), the input data (DATA) shifts into the least significant bit of the Shift Register, specified by the S_BIT, and out of the most significant bit of the Shift Register.

The data shifted out is then placed in the overflow memory bit (SM1.1). The maximum length of the shift register is 64 bits, positive or negative. Figure 10-31 shows bit shifting for negative and positive values of N.

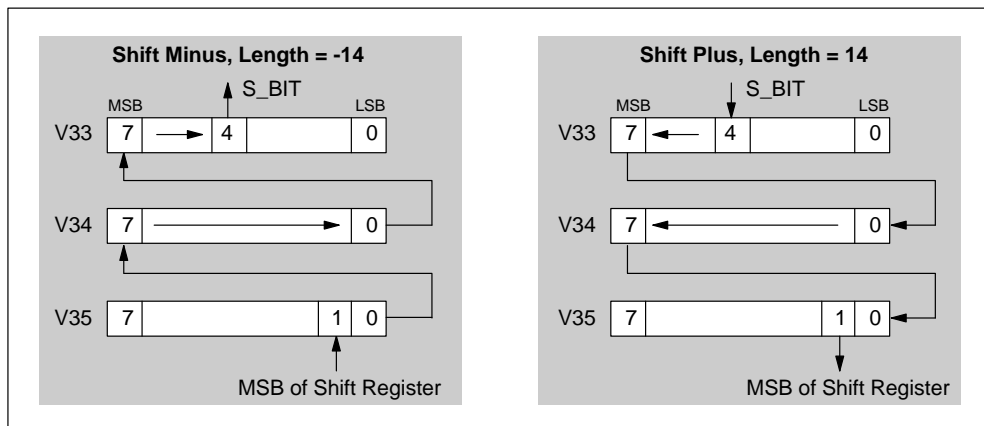


Figure 10-31 Shift Register Entry and Exit for Plus and Minus Shifts

Shift Register Bit Example

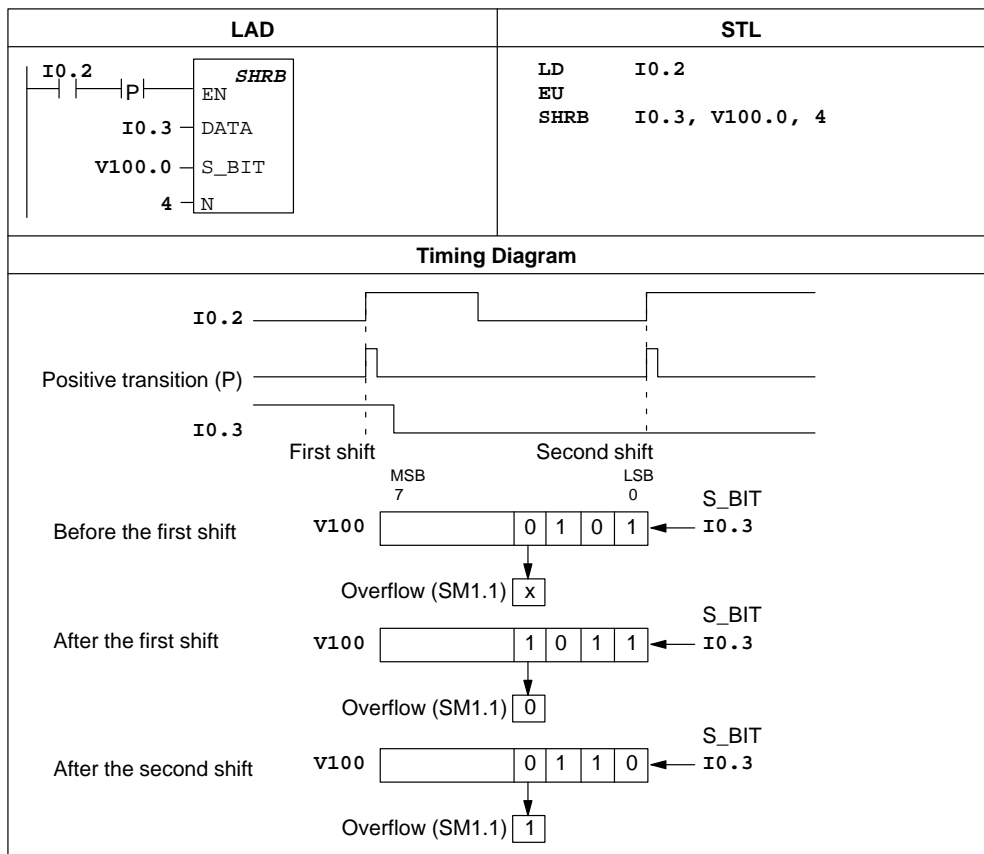
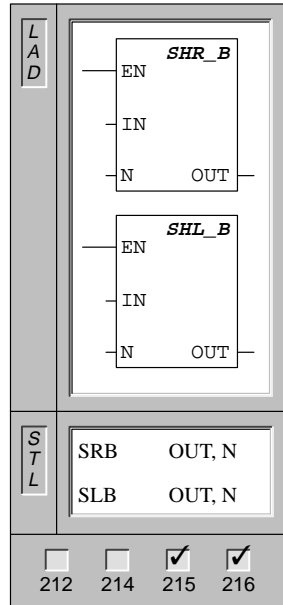


Figure 10-32 Example of Bit Shift Register Instruction for LAD and STL

Shift Right Byte, Shift Left Byte



The **Shift Right Byte** and **Shift Left Byte** instructions shift the input byte value right or left by the shift count (N), and load the result in the output byte (OUT).

Operands: IN: VB, IB, QB, MB, SMB, SB, AC, *VD, *AC
 N: VB, IB, QB, MB, SMB, SB, AC, Constant, *VD, *AC
 OUT: VB, IB, QB, MB, SMB, SB, AC, *VD, *AC

The shift instructions fill with zeros as each bit is shifted out.

If the shift count (N) is greater than or equal to 8, the value is shifted a maximum of 8 times. If the shift count is greater than 0, the overflow memory bit takes on the value of the last bit shifted out.

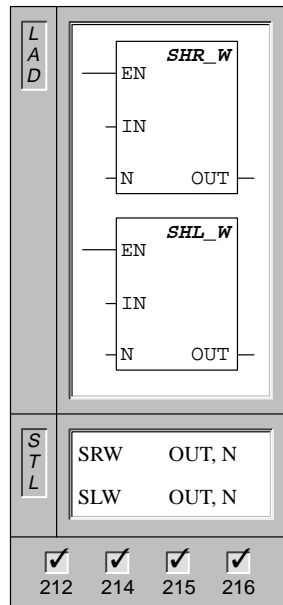
Shift right and shift left byte operations are unsigned.

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow)

Shift Right Word, Shift Left Word



The **Shift Right Word** and **Shift Left Word** instructions shift the input word value right or left by the shift count (N), and load the result in the output word (OUT).

Operands: IN: VW, T, C, IW, MW, SMW, AC, QW, AIW, Constant, *VD, *AC, SW
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

The shift instructions fill with zeros as each bit is shifted out.

If the shift count (N) is greater than or equal to 16, the value is shifted a maximum of 16 times. If the shift count is greater than zero, the overflow memory bit takes on the value of the last bit shifted out.

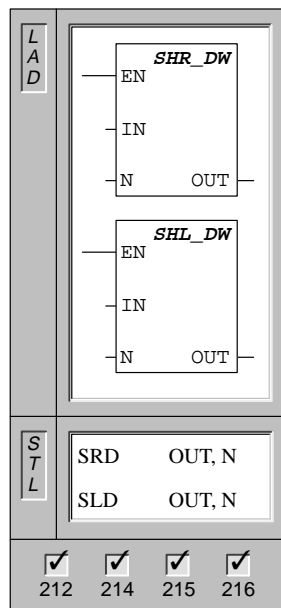
Shift right and shift left word operations are unsigned.

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow)

Shift Right Double Word, Shift Left Double Word



The **Shift Right Double Word** and **Shift Left Double Word** instructions shift the input double word value right or left by the shift count (N), and load the result in the output double word (OUT).

Operands: IN: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

The shift instructions fill with zeros as each bit is shifted out.

If the shift count (N) is greater than or equal to 32, the value is shifted a maximum of 32 times. If the shift count is greater than 0, the overflow memory bit takes on the value of the last bit shifted out.

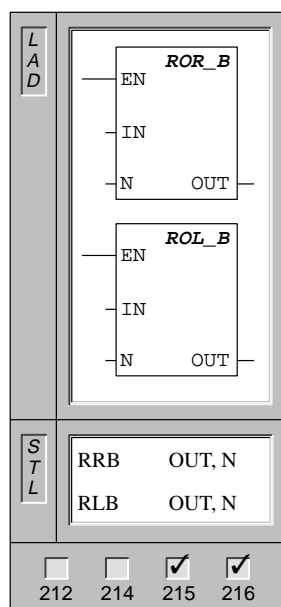
Shift right and shift left double word operations are unsigned.

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow)

Rotate Right Byte, Rotate Left Byte



The **Rotate Right Byte** and **Rotate Left Byte** instructions rotate the input byte value right or left by the shift count (N), and load the result in the output byte (OUT).

Operands: IN: VB, IB, QB, MB, SMB, SB, AC, *VD, *AC, SB
 N: VB, IB, QB, MB, SMB, SB, AC, Constant, *VD, *AC, SB
 OUT: VB, IB, QB, MB, SMB, SB, AC, *VD, *AC, SB

If the shift count (N) is greater than or equal to 8, a modulo-8 operation is performed on the shift count (N) before the rotate is executed. This results in a shift count of 0 to 7. If the shift count is 0, a rotate is not performed. If the rotate is performed, the value of the last bit rotated is copied to the overflow bit.

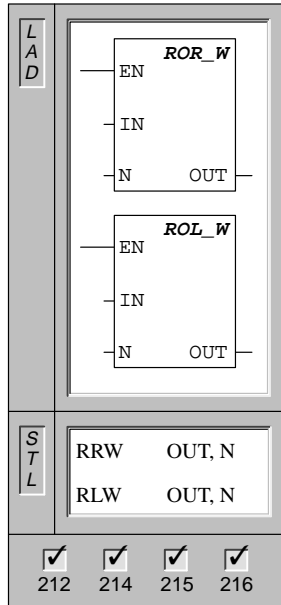
Rotate right and rotate left byte operations are unsigned.

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow)

Rotate Right Word, Rotate Left Word



The **Rotate Right Word** and **Rotate Left Word** instructions rotate the input word value right or left by the shift count (N), and load the result in the output word (OUT).

Operands: IN: VW, T, C, IW, MW, SMW, AC, QW, AIW, Constant, *VD, *AC, SW
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

If the shift count (N) is greater than or equal to 16, a modulo-16 operation is performed on the shift count (N) before the rotation is executed. This results in a shift count of 0 to 15. If the shift count is 0, a rotation is not performed. If the rotation is performed, the value of the last bit rotated is copied to the overflow bit.

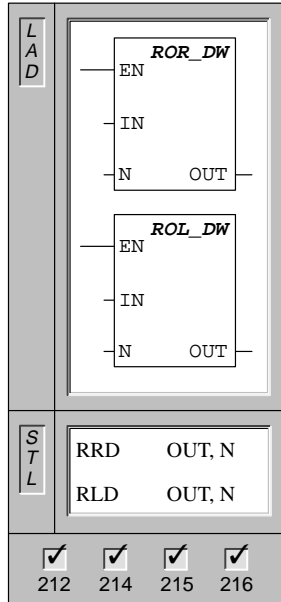
Rotate Right and Rotate Left Word operations are unsigned.

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow)

Rotate Right Double Word, Rotate Left Double Word



The **Rotate Right Double Word** and **Rotate Left Double Word** instructions rotate the input double word value right or left by the shift count (N), and load the result in the output double word (OUT).

Operands: IN: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD
 N: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

If the shift count (N) is greater than or equal to 32, a modulo-32 operation is performed on the shift count (N) before the rotation is executed. This results in a shift count of 0 to 31. If the shift count is 0, a rotation is not performed. If the rotation is performed, the value of the last bit rotated is copied to the overflow bit.

Rotate Right and Rotate Left Double-Word operations are unsigned.

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero); SM1.1 (overflow)

Shift and Rotate Examples

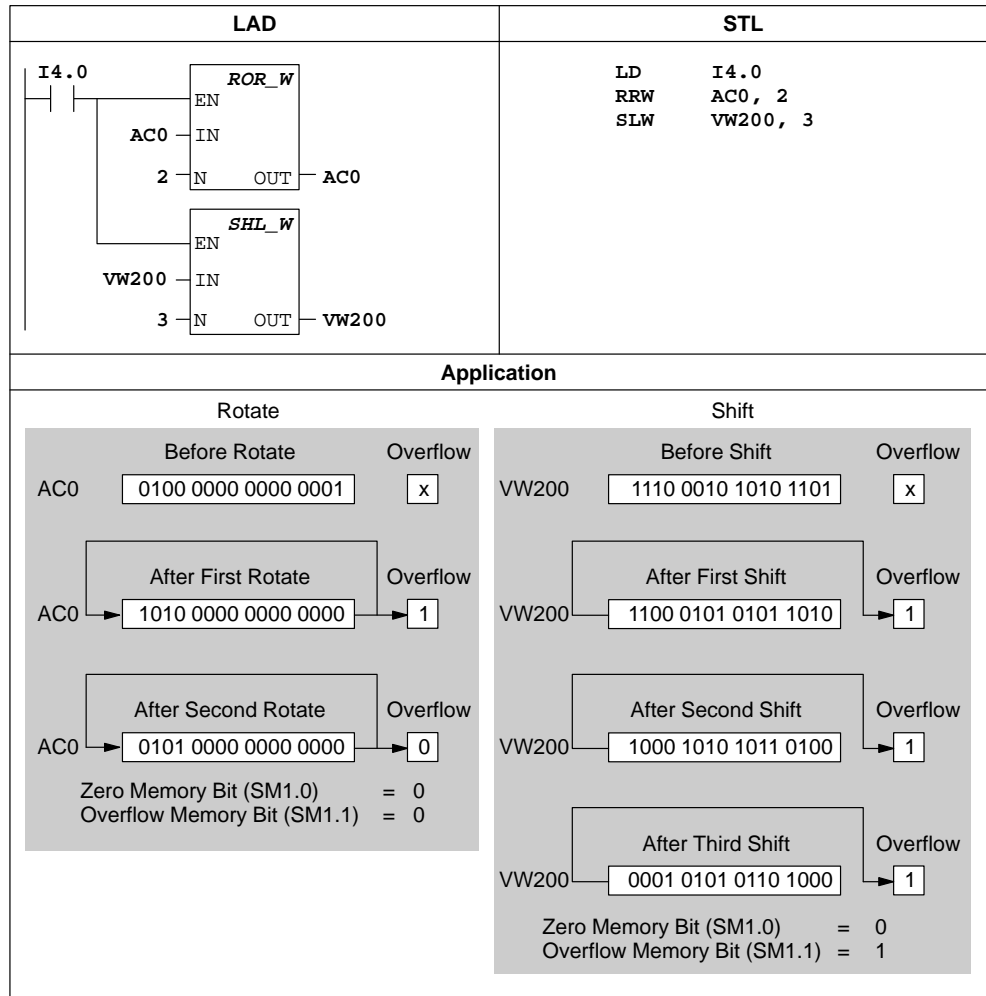
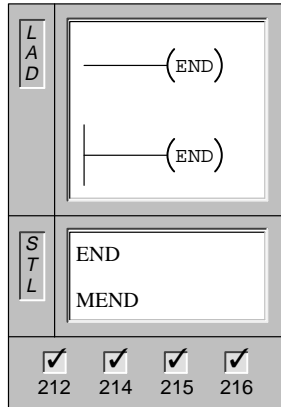


Figure 10-33 Example of Shift and Rotate Instructions for LAD and STL

10.10 Program Control Instructions

End



The **Conditional END** instruction terminates the main user program based upon the condition of the preceding logic.

The **Unconditional END** coil must be used to terminate the main user program.

In STL, the unconditional END operation is represented by the **MEND** instruction.

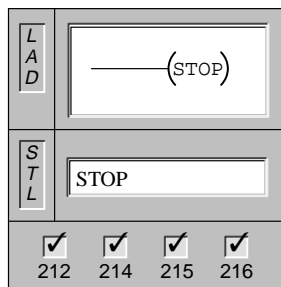
Operands: None

All user programs must terminate the main program with an unconditional END instruction. The conditional END instruction is used to terminate execution before encountering the unconditional END instruction.

Note

You can use the Conditional END and Unconditional END instructions in the main program, but you cannot use them in either subroutines or interrupt routines.

Stop

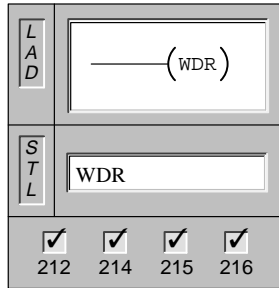


The **STOP** instruction terminates the execution of your program immediately by causing a transition of the CPU from RUN to STOP mode.

Operands: None

If the STOP instruction is executed in an interrupt routine, the interrupt routine is terminated immediately, and all pending interrupts are ignored. The rest of the program is scanned and the transition from RUN to STOP mode is made at the end of the current scan.

Watchdog Reset



The **Watchdog Reset** instruction allows the CPU system watchdog timer to be retriggered. This extends the time that the scan is allowed to take without getting a watchdog error.

Operands: None

Considerations for Using the WDR Instruction to Reset the Watchdog Timer

You should use the Watchdog Reset instruction carefully. If you use looping instructions either to prevent scan completion, or to delay excessively the completion of the scan, the following processes are inhibited until the scan cycle is terminated:

- Communication (except Freeport Mode)
- I/O updating (except Immediate I/O)
- Force updating
- SM bit updating (SM0, SM5 to SM29 are not updated)
- Run-time diagnostics
- 10-ms and 100-ms timers will not properly accumulate time for scans exceeding 25 seconds
- STOP instruction, when used in an interrupt routine

Note

If you expect your scan time to exceed 300 ms, or if you expect a burst of interrupt activity that may prevent returning to the main scan for more than 300 ms, you should use the WDR instruction to re-trigger the watchdog timer.

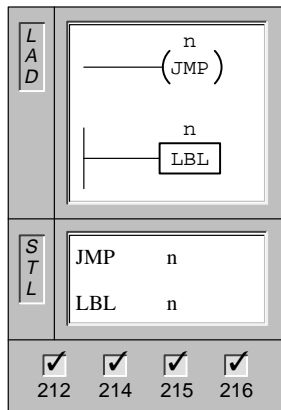
Changing the switch to the STOP position will cause the CPU to assume the STOP mode within 1.4 seconds.

Stop, End, and WDR Example

LAD		STL
<p>Network 1</p> <p>When an I/O error is detected, force the transition to STOP mode.</p>	<p>Network</p> <p>LD SM5.0</p> <p>STOP</p> <p>.</p> <p>.</p> <p>.</p>	
<p>Network 15</p> <p>When M5.6 is on, retrigger the Watchdog Reset (WDR) to allow the scan time to be extended.</p>	<p>Network</p> <p>LD M5.6</p> <p>WDR</p> <p>.</p> <p>.</p> <p>.</p>	
<p>Network 78</p> <p>Terminate the main program.</p>	<p>Network</p> <p>MEND</p>	

Figure 10-34 Example of Stop, End, and WDR Instructions for LAD and STL

Jump to Label, and Label



The **Jump to Label** instruction performs a branch to the specified label (n) within the program. When a jump is taken, the top of stack value is always a logical 1.

The **Label** instruction marks the location of the jump destination (n).

Operands: n: 0 to 255

Both the Jump and corresponding Label must be in the main program, a subroutine, or an interrupt routine. You cannot jump from the main program to a label in either a subroutine or an interrupt routine. Likewise, you cannot jump from a subroutine or interrupt routine to a label outside that subroutine or interrupt routine.

Figure 10-35 shows an example of the Jump to Label and Label instructions.

Jump to Label Example

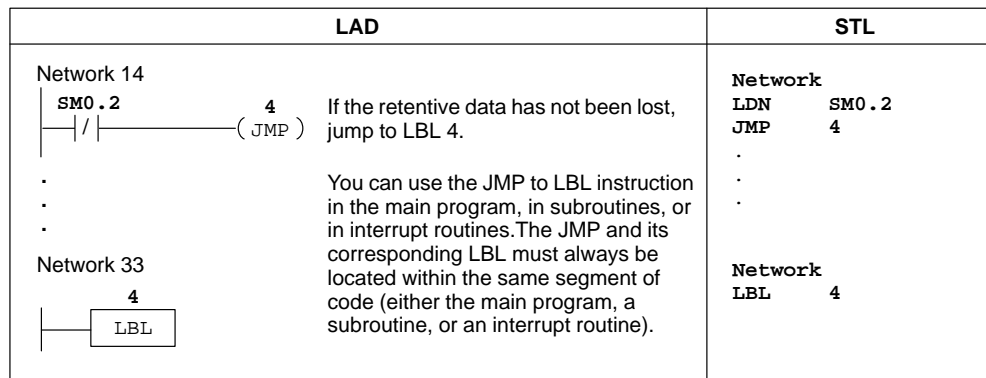
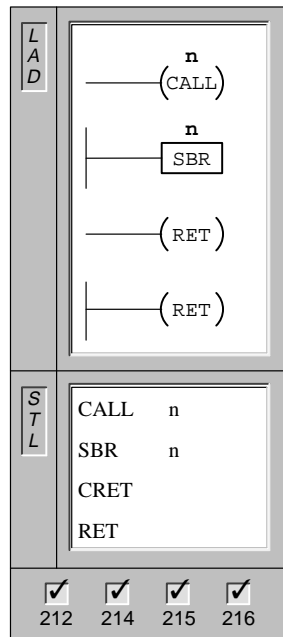


Figure 10-35 Example of Jump to Label and Label Instructions for LAD and STL

Call, Subroutine, and Return from Subroutine



The **Call** instruction transfers control to the subroutine (n).

The **Subroutine** instruction marks the beginning of the subroutine (n).

The **Conditional Return from Subroutine** instruction is used to terminate a subroutine based upon the preceding logic.

The **Unconditional Return from Subroutine** instruction must be used to terminate each subroutine.

Operands: n: 0 to 63

Once the subroutine completes its execution, control returns to the instruction that follows the CALL.

You can nest subroutines (place a subroutine call within a subroutine), to a depth of eight. Recursion (a subroutine that calls itself) is not prohibited, but you should use caution when using recursion with subroutines.

When a subroutine is called, the entire logic stack is saved, the top of stack is set to one, all other stack locations are set to zero, and control is transferred to the called subroutine. When this subroutine is completed, the stack is restored with the values saved at the point of call, and control is returned to the calling routine.

Also when a subroutine is called, the top of stack value is always a logical 1. Therefore, you can connect outputs or boxes directly to the left power rail for the network following the SBR instruction. In STL, the Load instruction can be omitted following the SBR instruction.

Accumulators are passed freely among the main program and subroutines. No save or restore operation is performed on accumulators due to subroutine use.

Figure 10-36 shows an example of the Call, Subroutine, and Return from Subroutine instructions.

Restrictions

Restrictions for using subroutines follow:

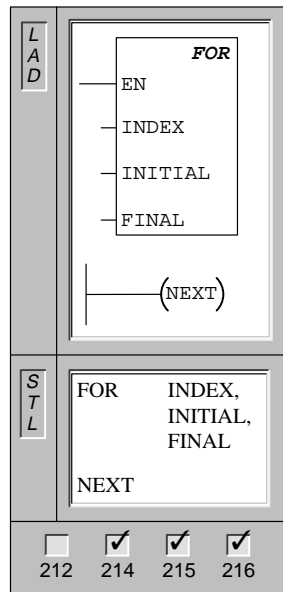
- Put all subroutines after the end of the main ladder program.
- You cannot use the LSCR, SCRE, SCRT, and END instructions in a subroutine.
- You must terminate each interrupt routine by an unconditional return from subroutine instruction (RET).

Call to Subroutine Example

LAD		STL
Network 1		Network LD SM0.1 CALL 10 . .
Network 39		Network MEND . .
Network 50		Network SBR 10 . .
Network 65		Network LD M14.3 CRET . .
Network 68		Network RET

Figure 10-36 Example of Subroutine Instructions for LAD and STL

For, Next



The **FOR** instruction executes the instructions between the FOR and the NEXT. You must specify the current loop count (INDEX), the starting value (INITIAL), and the ending value (FINAL).

The **NEXT** instruction marks the end of the FOR loop, and sets the top of the stack to 1.

Operands: INDEX: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

INITIAL: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

FINAL: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

For example, given an INITIAL value of 1 and a FINAL value of 10, the instructions between the FOR and the NEXT are executed 10 times with the INDEX value being incremented 1, 2, 3, ...10.

If the starting value is greater than the final value, the loop is not executed. After each execution of the instructions between the FOR and the NEXT instruction, the INDEX value is incremented and the result is compared to the final value. If the INDEX is greater than the final value, the loop is terminated.

Use the FOR/NEXT instructions to delineate a loop that is repeated for the specified count. Each FOR instruction requires a NEXT instruction. You can nest FOR/NEXT loops (place a FOR/NEXT loop within a FOR/NEXT loop) to a depth of eight.

Figure 10-37 shows an example of the FOR/NEXT instructions.

For/Next Example

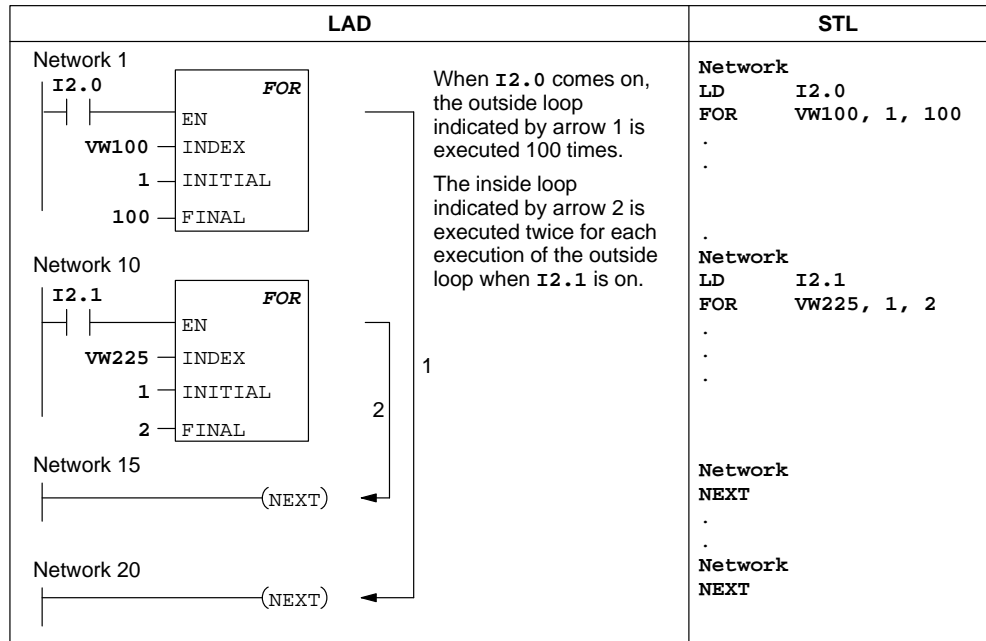
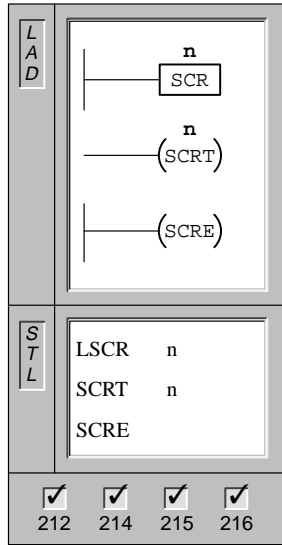


Figure 10-37 Example of For/Next Instructions for LAD and STL

Sequence Control Relay Instructions



The **Load Sequence Control Relay** instruction marks the beginning of an SCR segment. When $n = 1$, power flow is enabled to the SCR segment. The SCR segment must be terminated with an SCRE instruction.

The **Sequence Control Relay Transition** instruction identifies the SCR bit to be enabled (the next S bit to be set). When power flows to the coil, the referenced S bit is turned on and the S bit of the LSCR instruction (that enabled this SCR segment) is turned off.

The **Sequence Control Relay End** instruction marks the end of an SCR segment.

Operands: n: S

Understanding SCR Instructions

In ladder logic and statement list, Sequence Control Relays (SCRs) are used to organize machine operations or steps into equivalent program segments. SCRs allow logical segmentation of the control program.

The LSCR instruction loads the SCR and logic stacks with the value of the S-bit referenced by the instruction. The SCR segment is energized or de-energized by the resulting value of the SCR stack. The top of the logic stack is loaded to the value of the referenced S-bit so that boxes or output coils can be tied directly to the left power rail without an intervening contact. Figure 10-38 shows the S stack and the logic stack and the effect of executing the LSCR instruction.

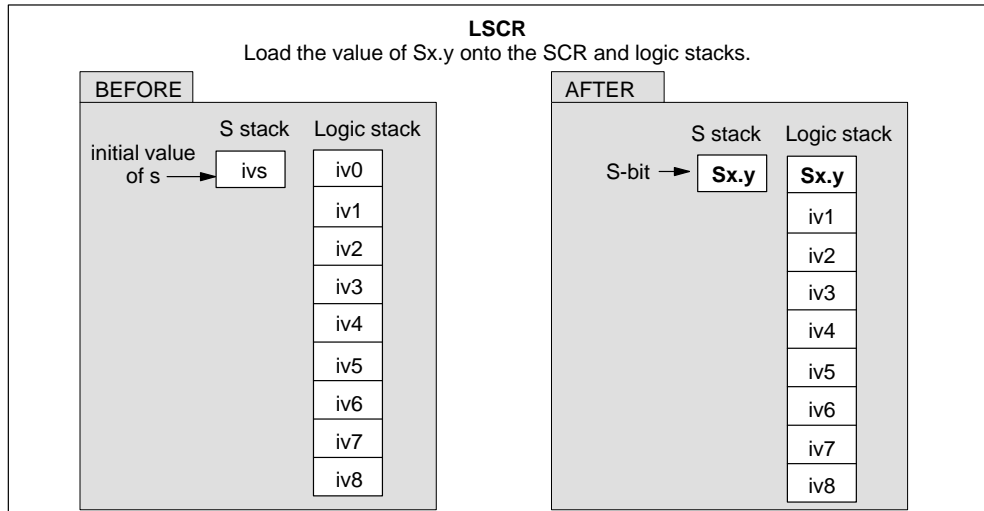


Figure 10-38 Effect of LSCR on the Logic Stack

The following is true of Segmentation instructions:

- All logic between the LSCR and the SCRE instructions make up the SCR segment and are dependent upon the value of the S stack for its execution. Logic between the SCRE and the next LSCR instruction have no dependency upon the value of the S stack.
- The SCRT instruction sets an S bit to enable the next SCR and also resets the S bit that was loaded to enable this section of the SCR segment.

Restrictions

Restrictions for using SCRs follow:

- You can use SCRs in the main program, but you cannot use them in subroutines and interrupt routines.
- You cannot use the JMP and LBL instructions in an SCR segment. This means that jumps into, within, or out of an SCR segment are not allowed. You can use jump and label instructions to jump around SCR segments.
- You cannot use the FOR, NEXT, and END instructions in an SCR segment.

SCR Example

Figure 10-39 shows an example of the operation of SCRs.

- In this example, the first scan bit SM0.1 is used to set S0.1, which will be the active State 1 on the first scan.
- After a 2-second delay, T37 causes a transition to State 2. This transition deactivates the State 1 SCR (S0.1) segment and activates the State 2 SCR (S0.2) segment.

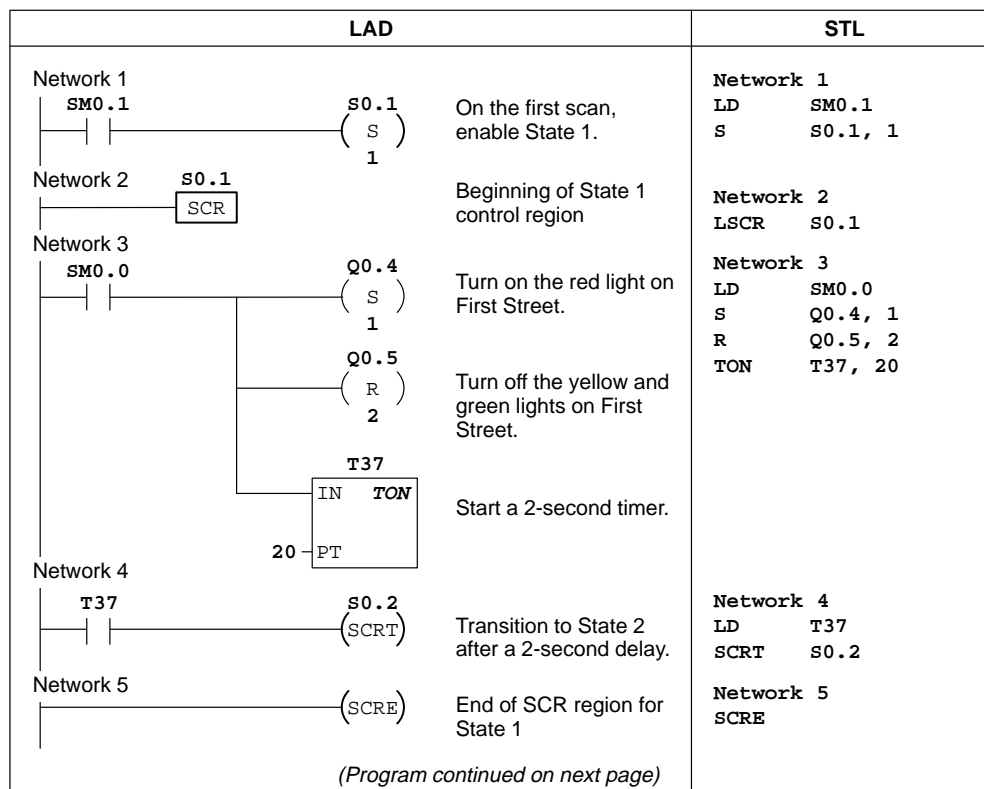


Figure 10-39 Example of Sequence Control Relays (SCRs)

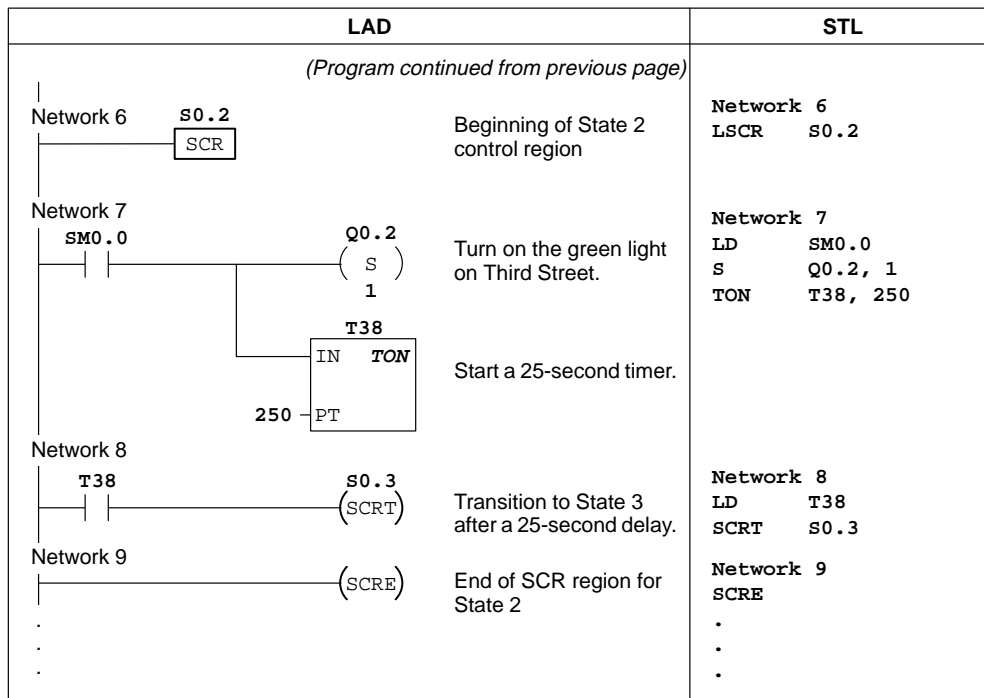


Figure 10-39 Example of Sequence Control Relays (SCRs), continued

Divergence Control

In many applications, a single stream of sequential states must be split into two or more different streams. When a stream of control diverges into multiple streams, all outgoing streams must be activated simultaneously. This is shown in Figure 10-40.

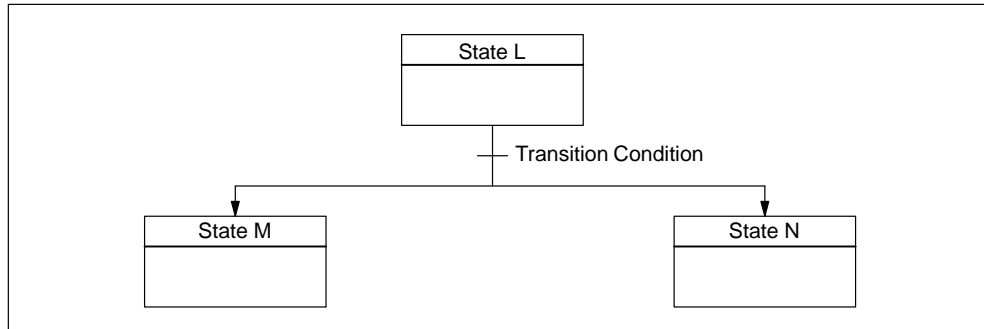


Figure 10-40 Divergence of Control Stream

The divergence of control streams can be implemented in an SCR program by using multiple SCRT instructions enabled by the same transition condition, as shown in Figure 10-41.

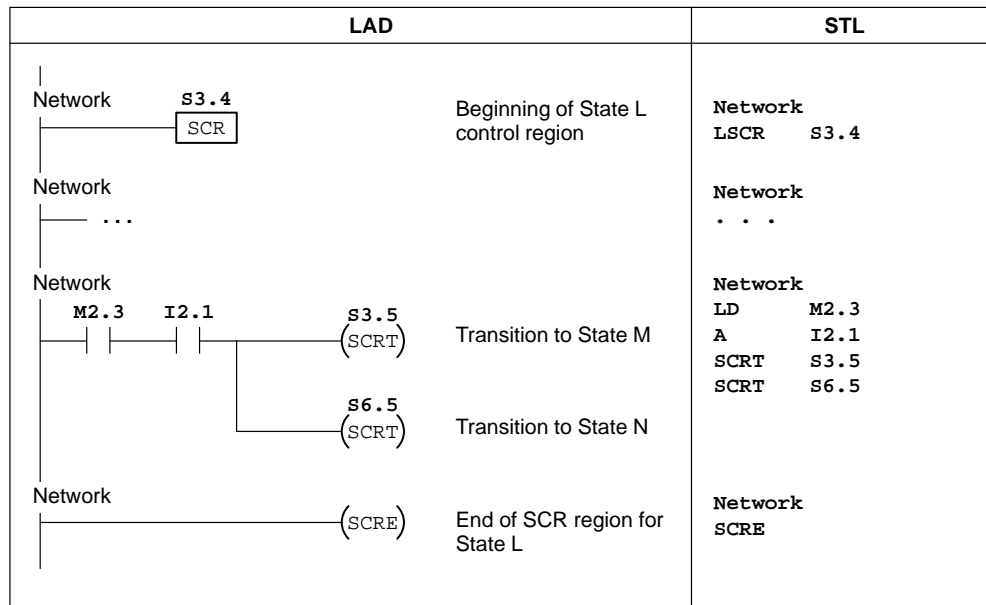


Figure 10-41 Example of Divergence of Control Streams

Convergence Control

A similar situation arises when two or more streams of sequential states must be merged into a single stream. When multiple streams merge into a single stream, they are said to converge. When streams converge, all incoming streams must be complete before the next state is executed. Figure 10-42 depicts the convergence of two control streams.

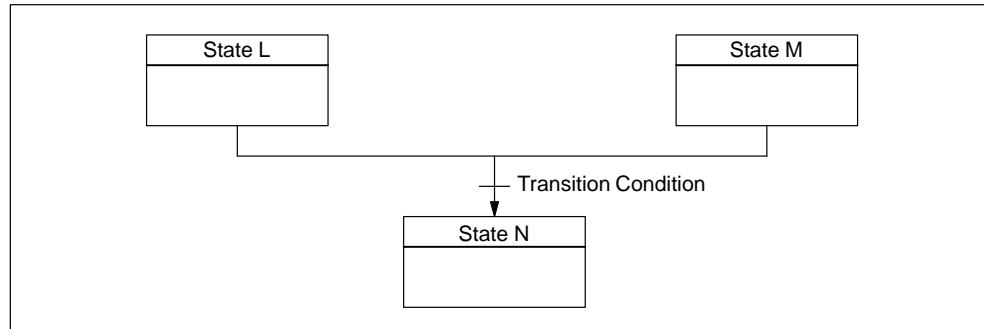


Figure 10-42 Convergence of Control Streams

The convergence of control streams can be implemented in an SCR program by making the transition from state L to state L' and by making the transition from state M to state M'. When both SCR bits representing L' and M' are true, state N can be enabled as shown below.

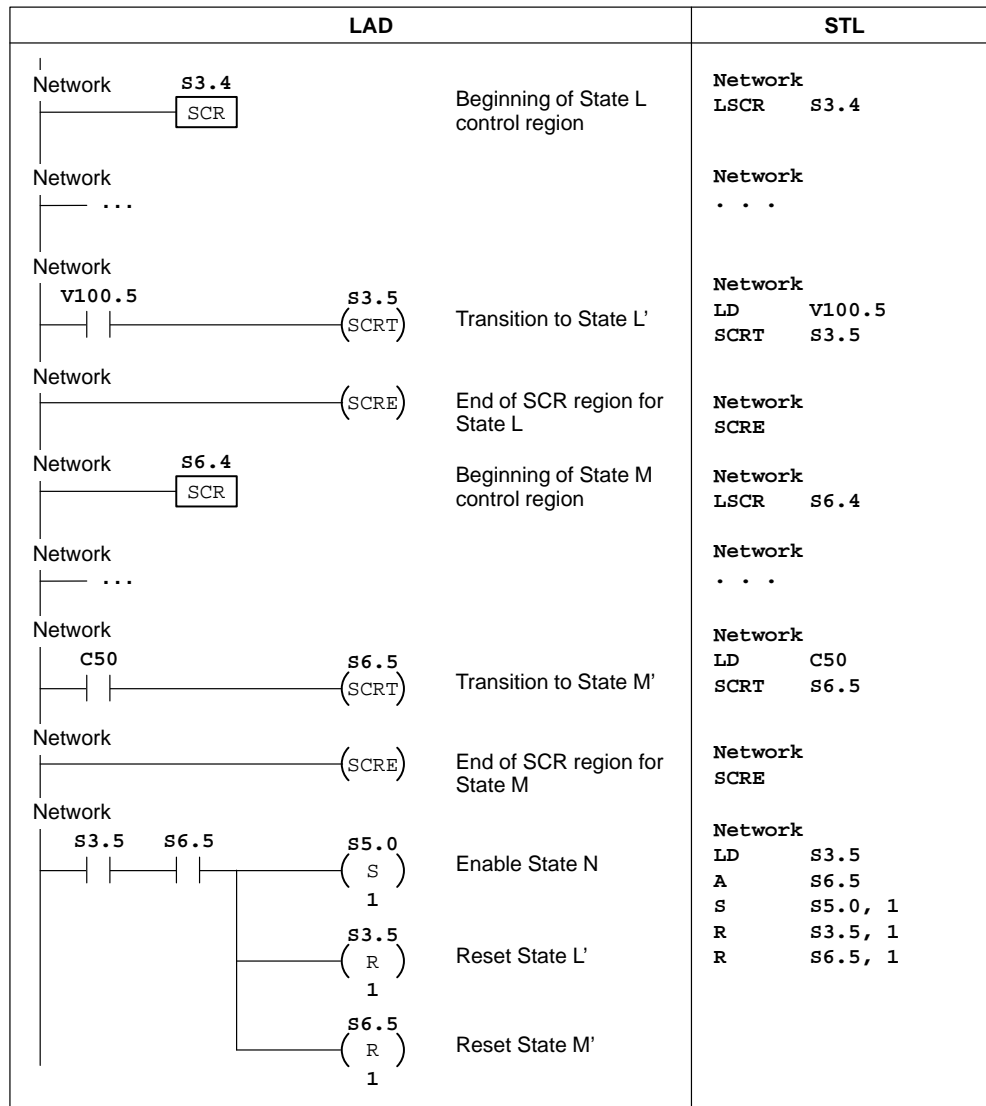


Figure 10-43 Example of Convergence of Control Streams

In other situations, a control stream may be directed into one of several possible control streams, depending upon which transition condition comes true first. Such a situation is depicted in Figure 10-44.

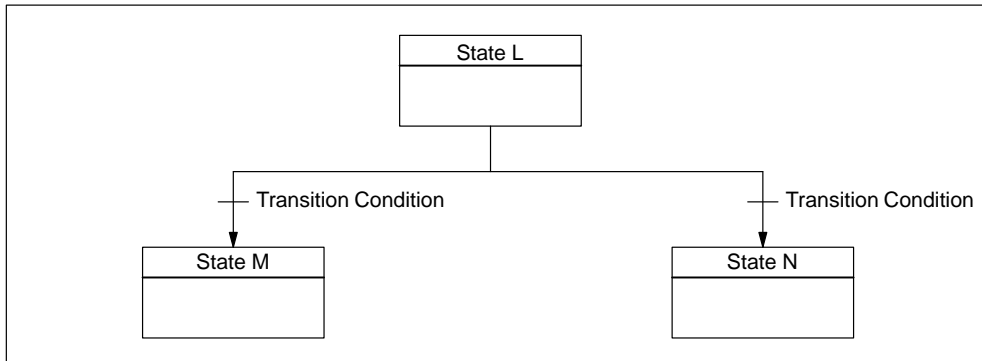


Figure 10-44 Divergence of Control Stream, Depending on Transition Condition

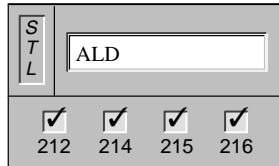
An equivalent SCR program is shown in Figure 10-45.

LAD		STL
Network	S3.4 SCR	Beginning of State L control region
Network	...	
Network	M2.3 ———— S3.5 (SCRT)	Transition to State M
Network	I3.3 ———— S6.5 (SCRT)	Transition to State N
Network	————— (SCRE)	End of SCR region for State L
		Network LSCR S3.4
		Network ...
		Network LD M2.3 SCRT S3.5
		Network LD I3.3 SCRT S6.5
		Network SCRE

Figure 10-45 Example of Conditional Transitions

10.11 Logic Stack Instructions

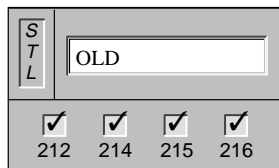
And Load



The **And Load** instruction combines the values in the first and second levels of the stack using a logical And operation. The result is loaded in the top of stack. After the ALD is executed, the stack depth is decreased by one.

Operands: none

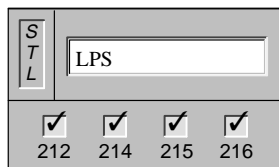
Or Load



The **Or Load** instruction combines the values in the first and second levels of the stack, using a logical Or operation. The result is loaded in the top of stack. After the OLD is executed, the stack depth is decreased by one.

Operands: none

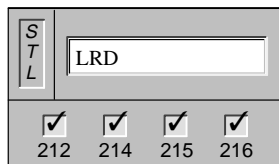
Logic Push



The **Logic Push** instruction duplicates the top value on the stack and pushes this value onto the stack. The bottom of the stack is pushed off and lost.

Operands: none

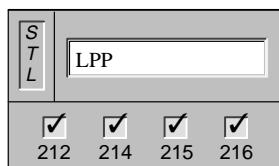
Logic Read



The **Logic Read** instruction copies the second stack value to the top of stack. The stack is not pushed or popped, but the old top of stack value is destroyed by the copy.

Operands: none

Logic Pop



The **Logic Pop** instruction pops one value off of the stack. The second stack value becomes the new top of stack value.

Operands: none

Logic Stack Operations

Figure 10-46 illustrates the operation of the And Load and Or Load instructions.

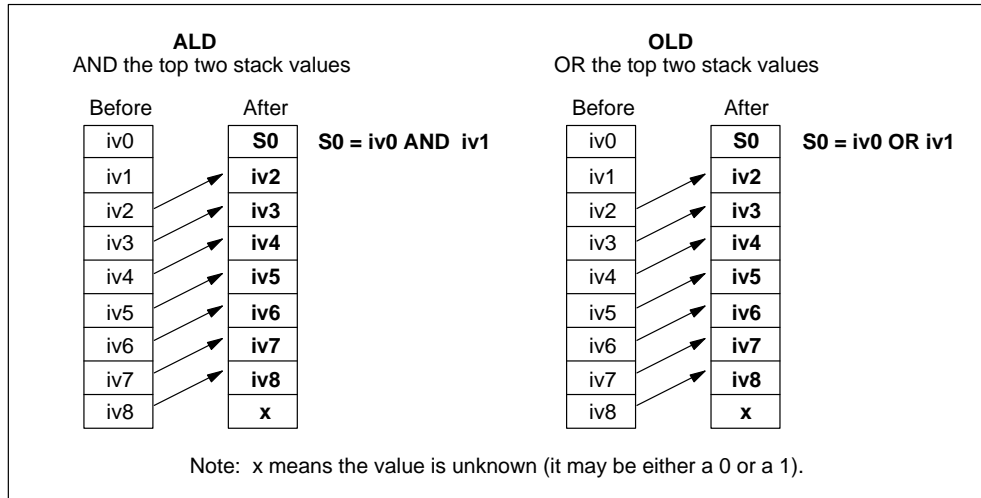


Figure 10-46 And Load and Or Load Instructions

Figure 10-47 illustrates the operation of the Logic Push, Logic Read, and Logic Pop instructions.

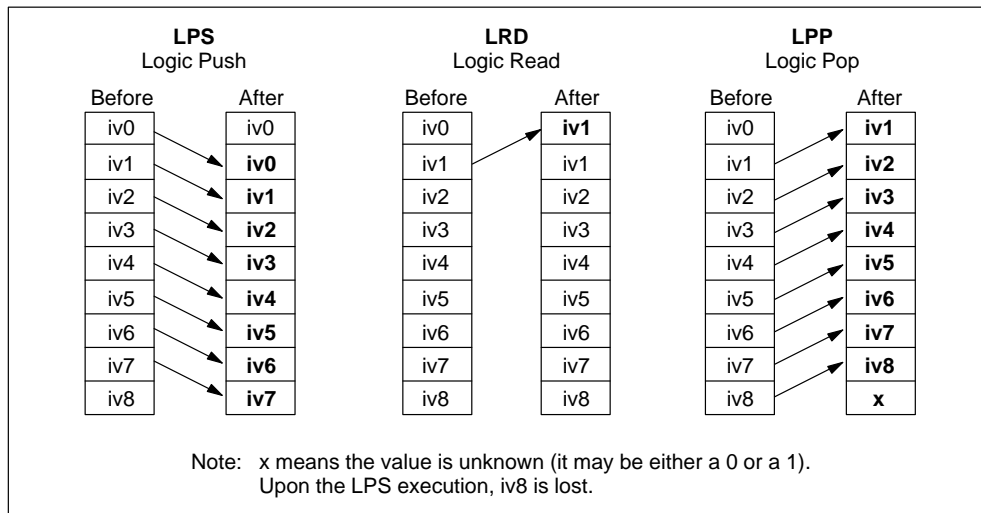


Figure 10-47 Logic Push, Logic Read, and Logic Pop Instructions

Logic Stack Example

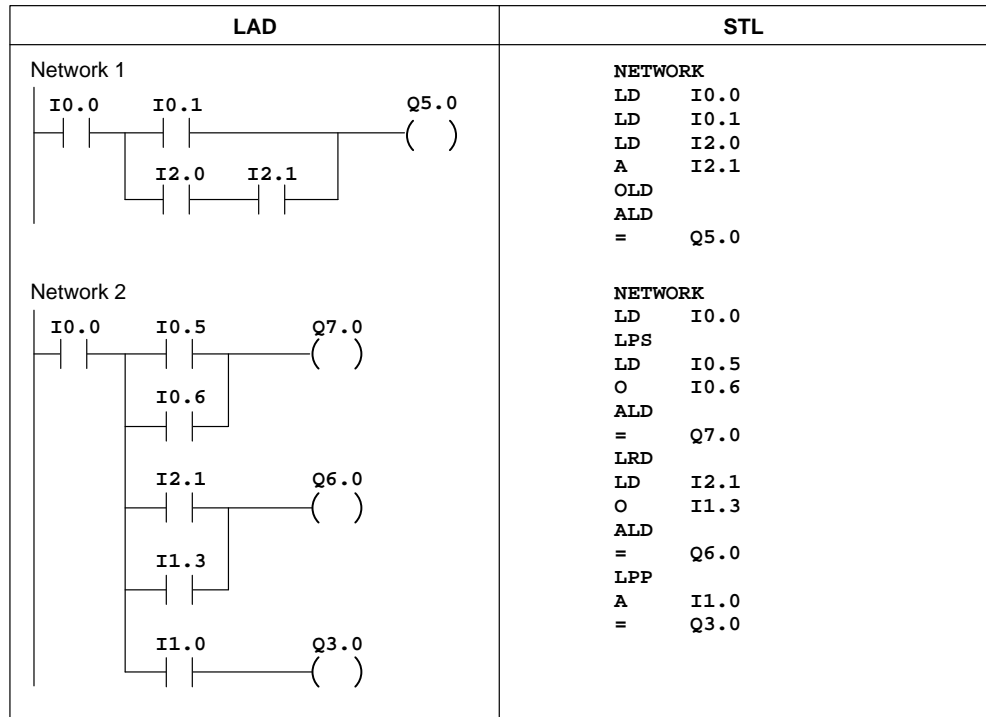
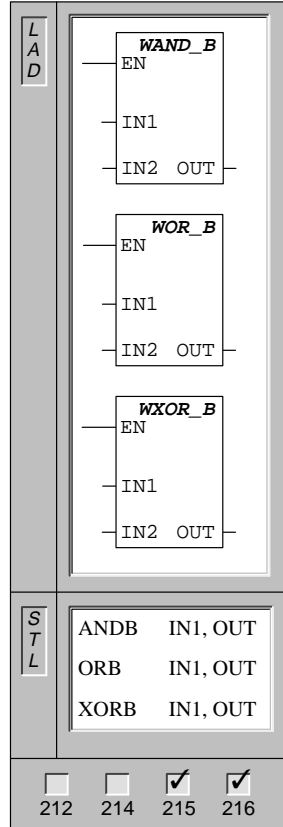


Figure 10-48 Example of Logic Stack Instructions for LAD and STL

10.12 Logic Operations

And Byte, Or Byte, Exclusive Or Byte



The **And Byte** instruction ANDs the corresponding bits of two input bytes and loads the result (OUT) in a byte.

The **Or Byte** instruction ORs the corresponding bits of two input bytes and loads the result (OUT) in a byte.

The **Exclusive Or Byte** instruction XORs the corresponding bits of two input bytes and loads the result (OUT) in a byte.

Operands: IN1, IN2: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

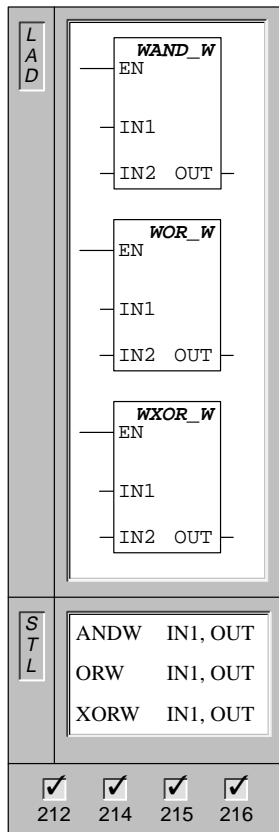
OUT: VB, IB, QB, MB, SMB, AC, *VD, *AC, SB

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero)

And Word, Or Word, Exclusive Or Word



The **And Word** instruction ANDs the corresponding bits of two input words and loads the result (OUT) in a word.

The **Or Word** instruction ORs the corresponding bits of two input words and loads the result (OUT) in a word.

The **Exclusive Or Word** instruction XORs the corresponding bits of two input words and loads the result (OUT) in a word.

Operands: IN1, IN2: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

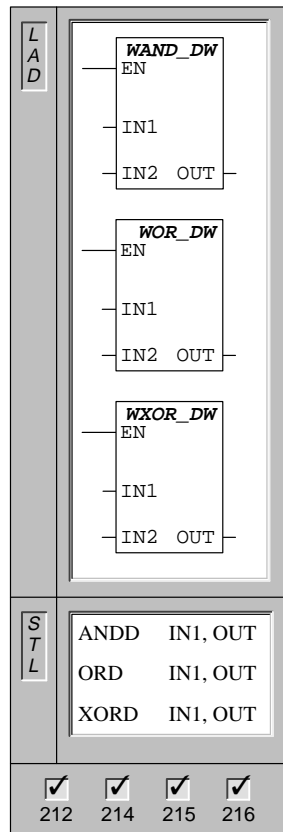
OUT: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero)

And Double Word, Or Double Word, Exclusive Or Double Word



The **And Double Word** instruction ANDs the corresponding bits of two input double words and loads the result (OUT) in a double word.

The **Or Double Word** instruction ORs the corresponding bits of two input double words and loads the result (OUT) in a double word.

The **Exclusive Or Double Word** instruction XORs the corresponding bits of two input double words and loads the result (OUT) in a double word.

Operands: IN1, IN2: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD

OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

Note: When programming in LAD, if you specify IN1 to be the same as OUT, you can reduce the amount of memory required.

These instructions affect the following Special Memory bits:

SM1.0 (zero)

And, Or, and Exclusive Or Instructions Example

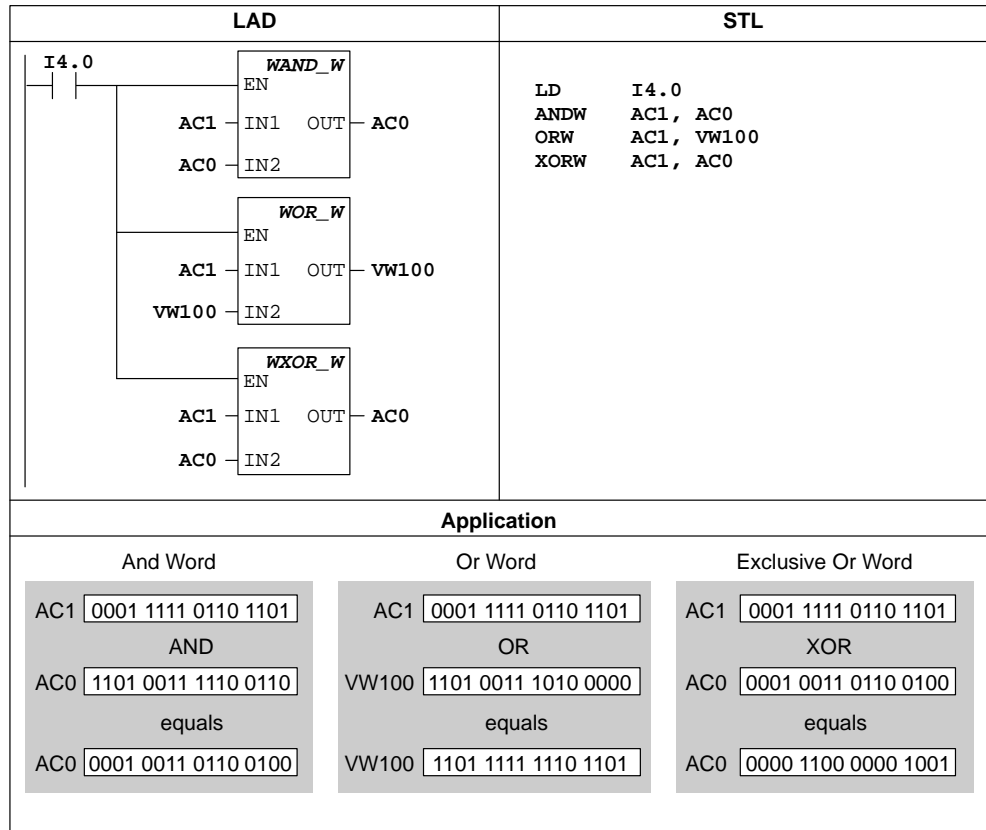
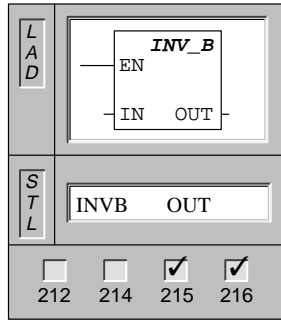


Figure 10-49 Example of the Logic Operation Instructions

Invert Byte



The **Invert Byte** instruction forms the ones complement of the input byte value, and loads the result in a byte value (OUT).

Operands: IN: VB, IB, QB, MB, SMB, AC,
 *VD, *AC, SB

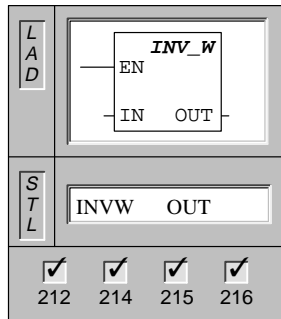
 OUT: VB, IB, QB, MB, SMB, AC,
 *VD, *AC, SB

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

This instruction affects the following Special Memory bits:

SM1.0 (zero)

Invert Word



The **Invert Word** instruction forms the ones complement of the input word value, and loads the result in a word value (OUT).

Operands: IN: VW, T, C, IW, QW, MW, SMW, AC,
 AIW, Constant, *VD, *AC, SW

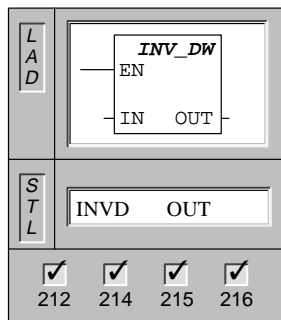
 OUT: VW, T, C, IW, QW, MW, SMW, AC,
 *VD, *AC, SW

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

This instruction affects the following Special Memory bits:

SM1.0 (zero)

Invert Double Word



The **Invert Double Word** instruction forms the ones complement of the input double word value, and loads the result in a double word value (OUT).

Operands: IN: VD, ID, QD, MD, SMD, AC, HC,
 Constant, *VD, *AC, SD

 OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC,
 SD

Note: When programming in LAD, if you specify IN to be the same as OUT, you can reduce the amount of memory required.

This instruction affects the following Special Memory bits:

SM1.0 (zero)

Invert Example

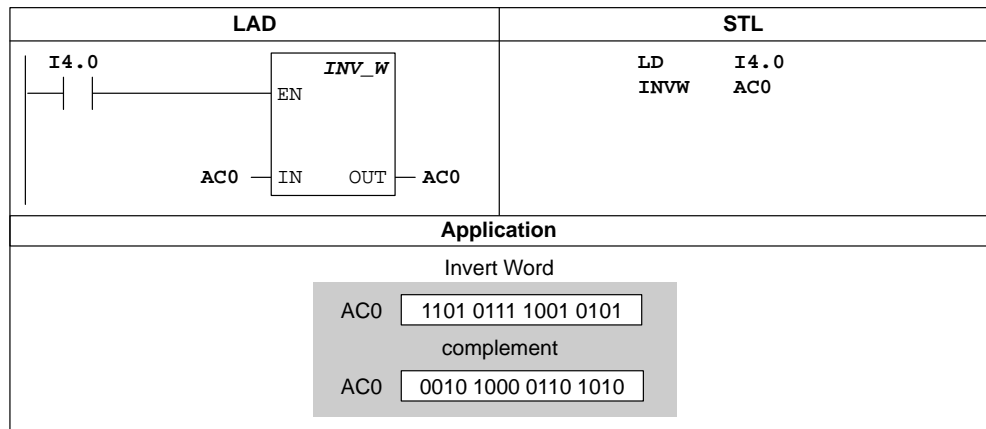
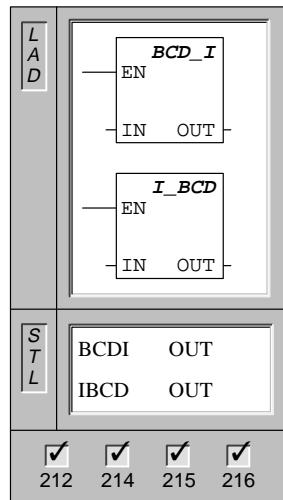


Figure 10-50 Example of Invert Instruction for LAD and STL

10.13 Conversion Instructions

BCD to Integer, Integer to BCD Conversion



The **BCD to Integer** instruction converts the input Binary-Coded Decimal value and loads the result in OUT.

The **Integer to BCD** instruction converts the input integer value to a Binary-Coded Decimal value and loads the result in OUT.

Operands: IN: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW

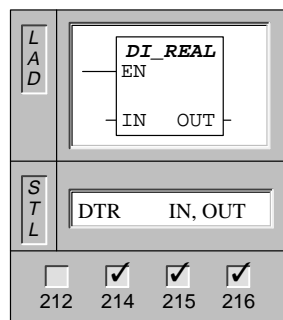
OUT: VW, T, C, IW, QW, MW, SMW, AC, *VD, *AC, SW

Note: When programming in ladder logic, if you specify IN to be the same as OUT, you can reduce the amount of memory used.

These instructions affect the following Special Memory bits:

SM1.6 (invalid BCD)

Double Word Integer to Real

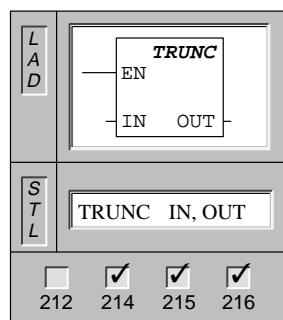


The **Double Word Integer to Real** instruction converts a 32-bit, signed integer (IN) into a 32-bit real number (OUT).

Operands: IN: VD, ID, QD, MD, SMD, AC, HC, Constant, *VD, *AC, SD

OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

Truncate



The **Truncate** instruction converts a 32-bit, real number (IN) into a 32-bit signed integer (OUT). Only the whole number portion of the real number is converted (round-to-zero).

Operands: IN: VD, ID, QD, MD, SMD, AC, Constant, *VD, *AC, SD

OUT: VD, ID, QD, MD, SMD, AC, *VD, *AC, SD

This instruction affects the following Special Memory bits:

SM1.1 (overflow)

Convert and Truncate Example

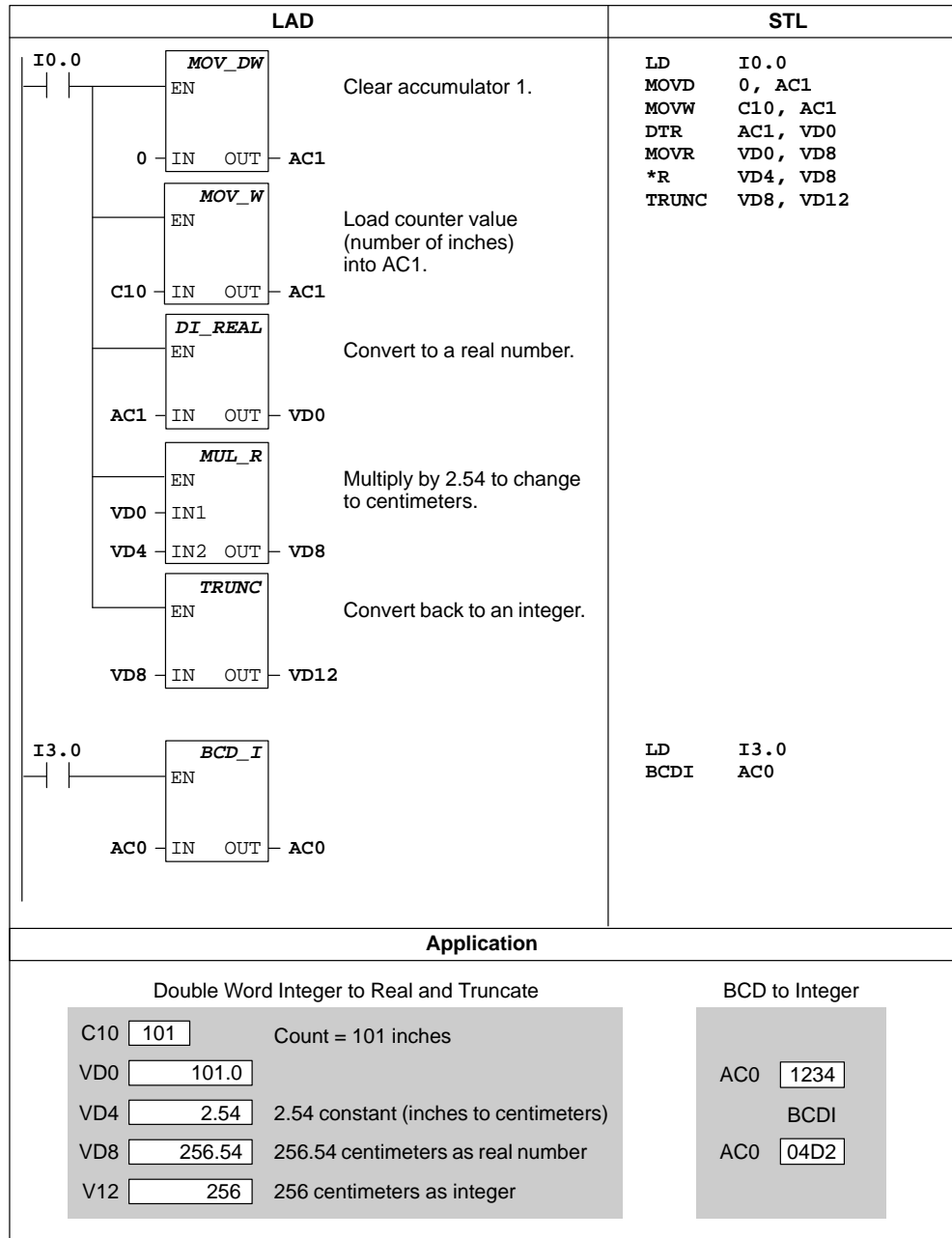
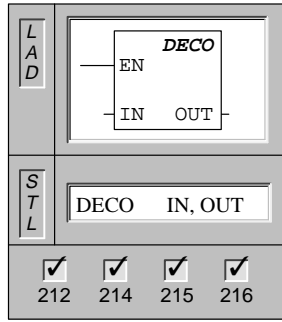


Figure 10-51 Example of Real Number Conversion Instruction

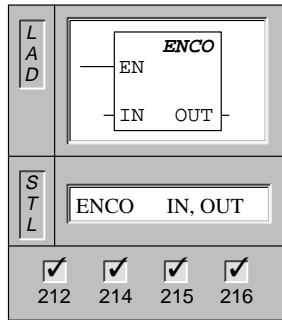
Decode



The **Decode** instruction sets the bit in the output word (OUT) that corresponds to the bit number (Bit #), represented by the least significant “nibble” (4 bits) of the input byte (IN). All other bits of the output word are set to 0.

Operands: IN: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VW, T, C, IW, QW, MW, SMW, AC, AQW, *VD, *AC, SW

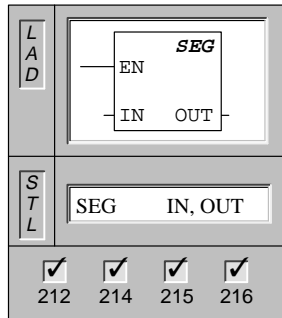
Encode



The **Encode** instruction writes the bit number (bit #) of the least significant bit set of the input word (IN) into the least significant “nibble” (4 bits) of the output byte (OUT).

Operands: IN: VW, T, C, IW, QW, MW, SMW, AC, AIW, Constant, *VD, *AC, SW
 OUT: VB, IB, QB, MB, SMB, AC, *VD, *AC, SB

Segment



The **Segment** instruction generates a bit pattern (OUT) that illuminates the segments of a seven-segment display. The illuminated segments represent the character in the least significant digit of the input byte (IN).

Operands: IN: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB
 OUT: VB, IB, QB, MB, SMB, AC, *VD, *AC, SB

Figure 10-52 shows the seven segment display coding used by the Segment instruction.

(IN) LSD	Segment Display	(OUT) - g f e d c b a	(IN) LSD	Segment Display	(OUT) - g f e d c b a
0		0 0 1 1 1 1 1 1	8		0 1 1 1 1 1 1 1
1		0 0 0 0 0 1 1 0	9		0 1 1 0 0 1 1 1
2		0 1 0 1 1 0 1 1	A		0 1 1 1 0 1 1 1
3		0 1 0 0 1 1 1 1	B		0 1 1 1 1 1 0 0
4		0 1 1 0 0 1 1 0	C		0 0 1 1 1 0 0 1
5		0 1 1 0 1 1 0 1	D		0 1 0 1 1 1 1 0
6		0 1 1 1 1 1 0 1	E		0 1 1 1 1 0 0 1
7		0 0 0 0 0 1 1 1	F		0 1 1 1 0 0 0 1

Figure 10-52 Seven Segment Display Coding

Decode, Encode Examples

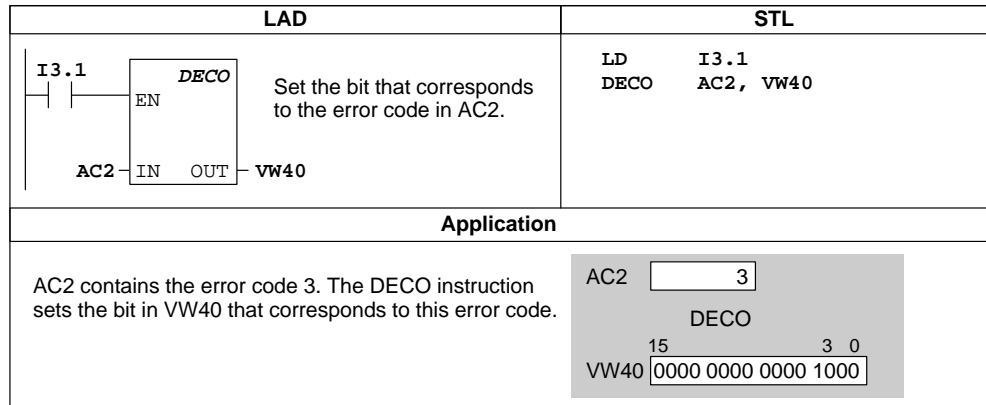


Figure 10-53 Example of Setting an Error Bit Using Decode

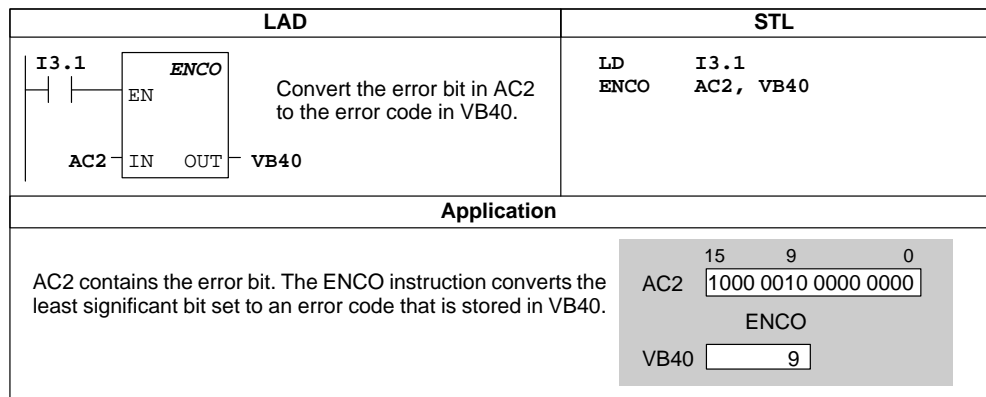


Figure 10-54 Example of Converting the Error Bit into an Error Code Using Encode

Segment Example

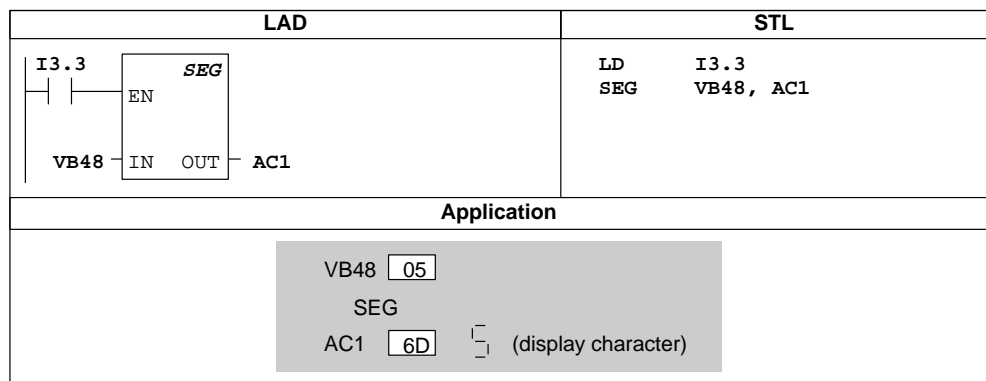
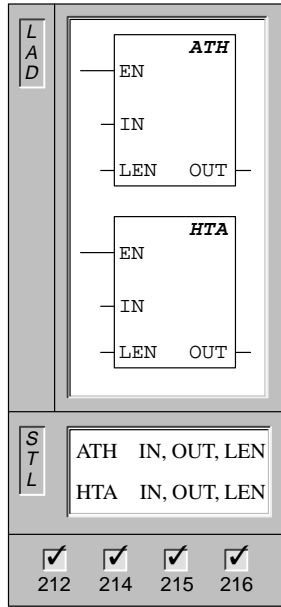


Figure 10-55 Example of Segment Instruction

ASCII to HEX, HEX to ASCII



The **ASCII to HEX** instruction converts the ASCII string of length (LEN), starting with the character (IN), to hexadecimal digits starting at a specified location (OUT). The maximum length of the ASCII string is 255 characters.

The **HEX to ASCII** instruction converts the hexadecimal digits, starting with the input byte (IN), to an ASCII string starting at a specified location (OUT). The number of hexadecimal digits to be converted is specified by length (LEN). The maximum number of the hexadecimal digits that can be converted is 255.

Operands: IN, OUT: VB, IB, QB, MB, SMB, *VD, *AC, SB
 LEN: VB, IB, QB, MB, SMB, AC, Constant, *VD, *AC, SB

Legal ASCII characters are the hexadecimal values 30 to 39, and 41 to 46.

These instructions affect the following Special Memory bits:
 SM1.7 (illegal ASCII)

ASCII to HEX Example

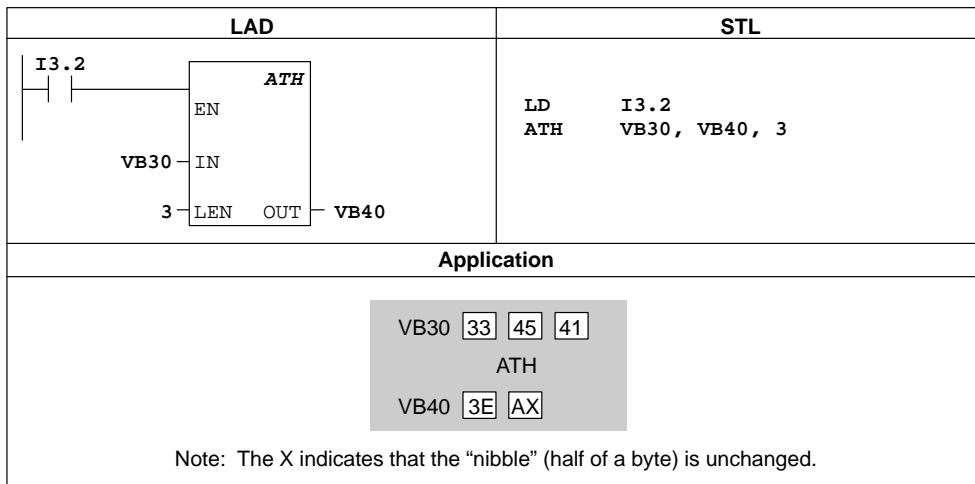
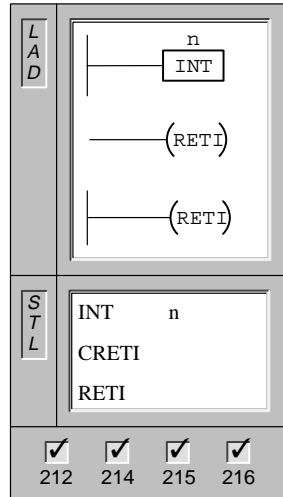


Figure 10-56 Example of ASCII to HEX Instruction

10.14 Interrupt and Communications Instructions

Interrupt Routine, Return from Interrupt Routine



The **Interrupt Routine** instruction marks the beginning of the interrupt routine (n).

The **Conditional Return from Interrupt** instruction may be used to return from an interrupt, based upon the condition of the preceding logic.

The **Unconditional Return from Interrupt** coil must be used to terminate each interrupt routine.

Operands: n: 0 to 127

Interrupt Routines

You can identify each interrupt routine by an interrupt routine label that marks the entry point into the routine. The routine consists of all your instructions between the interrupt label and the unconditional return from interrupt instruction. The interrupt routine is executed in response to an associated internal or external event. You can exit the routine (thereby returning control to the main program) by executing the unconditional return from interrupt instruction (RETI), or by executing a conditional return from an interrupt instruction. The unconditional return instruction is always required.

Interrupt Use Guidelines

Interrupt processing provides quick reaction to special internal or external events. You should optimize interrupt routines to perform a specific task, and then return control to the main routine. By keeping the interrupt routines short and to the point, execution is quick and other processes are not deferred for long periods of time. If this is not done, unexpected conditions can cause abnormal operation of equipment controlled by the main program. For interrupts, the axiom, "the shorter, the better," is definitely true.

Restrictions

Restrictions for using the interrupt routine follow:

- Put all interrupt routines after the end of the main ladder program.
- You cannot use the DISI, ENI, CALL, HDEF, FOR/NEXT, LSCR, SCRE, SCRT, and END instructions in an interrupt routine.
- You must terminate each interrupt routine by an unconditional return from interrupt instruction (RETI).

System Support for Interrupt

Because contact, coil, and accumulator logic may be affected by interrupts, the system saves and reloads the logic stack, accumulator registers, and the special memory bits (SM) that indicate the status of accumulator and instruction operations. This avoids disruption to the main user-program caused by branching to and from an interrupt routine.

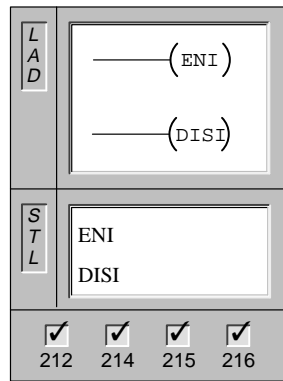
Sharing Data Between the Main Program and Interrupt Routines

You can share data between the main program and one or more interrupt routines. For example, a part of your main program may provide data to be used by an interrupt routine, or vice versa. If your program is sharing data, you must also consider the effect of the asynchronous nature of interrupt events, which can occur at any point during the execution of your main program. Problems with the consistency of shared data can result due to the actions of interrupt routines when the execution of instructions in your main program is interrupted by interrupt events.

There are a number of programming techniques you can use to ensure that data is correctly shared between your main program and interrupt routines. These techniques either restrict the way access is made to shared memory locations, or prevent interruption of instruction sequences using shared memory locations.

- For an STL program that is sharing a single variable: If the shared data is a single byte, word, or double-word variable and your program is written in STL, then correct shared access can be ensured by storing the intermediate values from operations on shared data only in non-shared memory locations or accumulators.
- For a LAD program that is sharing a single variable: If the shared data is a single byte, word, or double-word variable and your program is written in ladder logic, then correct shared access can be ensured by establishing the convention that access to shared memory locations be made using only Move instructions (MOV_B, MOV_W, MOV_DW, MOV_R). While many LAD instructions are composed of interruptible sequences of STL instructions, these Move instructions are composed of a single STL instruction whose execution cannot be affected by interrupt events.
- For an STL or LAD program that is sharing multiple variables: If the shared data is composed of a number of related bytes, words, or double-words, then the interrupt disable/enable instructions (DISI and ENI) can be used to control interrupt routine execution. At the point in your main program where operations on shared memory locations are to begin, disable the interrupts. Once all actions affecting the shared locations are complete, re-enable the interrupts. During the time that interrupts are disabled, interrupt routines cannot be executed and therefore cannot access shared memory locations; however, this approach can result in delayed response to interrupt events.

Enable Interrupt, Disable Interrupt



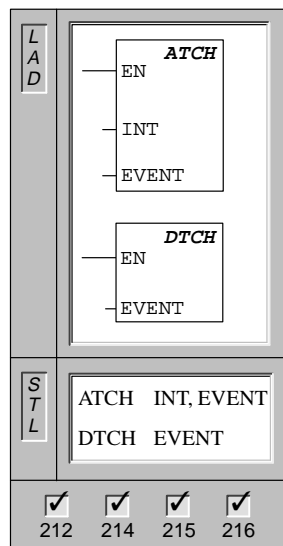
The **Enable Interrupt** instruction globally enables processing of all attached interrupt events.

The **Disable Interrupt** instruction globally disables processing of all interrupt events.

Operands: None

When you make the transition to the RUN mode, you disable the interrupts. Once in RUN mode, you can enable all interrupts by executing the global Enable Interrupt instruction. The global Disable Interrupt instruction allows interrupts to be queued, but does not allow the interrupt routines to be invoked.

Attach Interrupt, Detach Interrupt



The **Attach Interrupt** instruction associates an interrupt event (EVENT) with an interrupt routine number (INT), and enables the interrupt event.

The **Detach Interrupt** instruction disassociates an interrupt event (EVENT) from all interrupt routines, and disables the interrupt event.

Operands: INT : 0 to 127
EVENT: 0 to 26

Understanding Attach and Detach Interrupt Instructions

Before an interrupt routine can be invoked, an association must be established between the interrupt event and the program segment that you want to execute when the event occurs. Use the Attach Interrupt instruction (ATCH) to associate an interrupt event (specified by the interrupt event number) and the program segment (specified by an interrupt routine number). You can attach multiple interrupt events to one interrupt routine, but one event cannot be concurrently attached to multiple interrupt routines. When an event occurs with interrupts enabled, only the last interrupt routine attached to this event is executed.

When you attach an interrupt event to an interrupt routine, that interrupt is automatically enabled. If you disable all interrupts using the global disable interrupt instruction, each occurrence of the interrupt event is queued until interrupts are re-enabled, using the global enable interrupt instruction.

You can disable individual interrupt events by breaking the association between the interrupt event and the interrupt routine with the Detach Interrupt instruction (DTCH). The Detach instruction returns the interrupt to an inactive or ignored state.

Table 10-13 lists the different types of interrupt events.

Table 10-13 Descriptions of Interrupt Events

Event Number	Interrupt Description	212	214	215	216
0	Rising edge, I0.0*	Y	Y	Y	Y
1	Falling edge, I0.0*	Y	Y	Y	Y
2	Rising edge, I0.1		Y	Y	Y
3	Falling edge, I0.1		Y	Y	Y
4	Rising edge, I0.2		Y	Y	Y
5	Falling edge, I0.2		Y	Y	Y
6	Rising edge, I0.3		Y	Y	Y
7	Falling edge, I0.3		Y	Y	Y
8	Port 0: Receive character	Y	Y	Y	Y
9	Port 0: Transmit complete	Y	Y	Y	Y
10	Timed interrupt 0, SMB34	Y	Y	Y	Y
11	Timed interrupt 1, SMB35		Y	Y	Y
12	HSC0 CV=PV (current value = preset value)*	Y	Y	Y	Y
13	HSC1 CV=PV (current value = preset value)		Y	Y	Y
14	HSC1 direction input changed		Y	Y	Y
15	HSC1 external reset		Y	Y	Y
16	HSC2 CV=PV (current value = preset value)		Y	Y	Y
17	HSC2 direction input changed		Y	Y	Y
18	HSC2 external reset		Y	Y	Y
19	PLS0 pulse count complete interrupt		Y	Y	Y
20	PLS1 pulse count complete interrupt		Y	Y	Y
21	Timer T32 CT=PT interrupt			Y	Y
22	Timer T96 CT=PT interrupt			Y	Y
23	Port 0: Receive message complete			Y	Y
24	Port 1: Receive message complete				Y
25	Port 1: Receive character				Y
26	Port 1: Transmit complete				Y
* If event 12 (HSC0, PV = CV) is attached to an interrupt, then neither event 0 nor 1 can be attached to interrupts. Likewise, if either event 0 or 1 is attached to an interrupt, then event 12 cannot be attached to an interrupt.					

Communication Port Interrupts

The serial communications port of the programmable logic controller can be controlled by the ladder logic or statement list program. This mode of operating the communications port is called Freeport mode. In Freeport mode, your program defines the baud rate, bits per character, parity, and protocol. The receive and transmit interrupts are available to facilitate your program-controlled communications. Refer to the transmit/receive instructions for more information.

I/O Interrupts

I/O interrupts include rising/falling edge interrupts, high-speed counter interrupts, and pulse train output interrupts. The CPU can generate an interrupt on rising and/or falling edges of an input. See Table 10-14 for the inputs available for the interrupts. The rising edge and the falling edge events can be captured for each of these input points. These rising/falling edge events can be used to signify an error condition that must receive immediate attention when the event happens.

Table 10-14 Rising/Falling Edge Interrupts Supported

I/O Interrupts	CPU 212	CPU 214	CPU 215	CPU 216
I/O Points	I0.0	I0.0 to I0.3	I0.0 to I0.3	I0.0 to I0.3

The high-speed counter interrupts allow you to respond to conditions such as the current value reaching the preset value, a change in counting direction that might correspond to a reversal in the direction in which a shaft is turning, or an external reset of the counter. Each of these high-speed counter events allows action to be taken in real time in response to high-speed events that cannot be controlled at programmable logic controller scan speeds.

The pulse train output interrupts provide immediate notification of completion of outputting the prescribed number of pulses. A typical use of pulse train outputs is stepper motor control.

You can enable each of the above interrupts by attaching an interrupt routine to the related I/O event.

Time-Based Interrupts

Time-based interrupts include timed interrupts and the Timer T32/T96 interrupts. The CPU can support one or more timed interrupts (see Table 10-15). You can specify actions to be taken on a cyclic basis using a timed interrupt. The cycle time is set in 1-ms increments from 5 ms to 255 ms. You must write the cycle time in SMB34 for timed interrupt 0, and in SMB35 for timed interrupt 1.

Table 10-15 Timed Interrupts Supported

Timed Interrupts	CPU 212	CPU 214	CPU 215	CPU 216
Number of timed interrupts supported	1	2	2	2

The timed interrupt event transfers control to the appropriate interrupt routine each time the timer expires. Typically, you use timed interrupts to control the sampling of analog inputs at regular intervals.

A timed interrupt is enabled and timing begins when you attach an interrupt routine to a timed interrupt event. During the attachment, the system captures the cycle time value, so subsequent changes do not affect the cycle time. To change the cycle time, you must modify the cycle time value, and then re-attach the interrupt routine to the timed interrupt event. When the re-attachment occurs, the timed interrupt function clears any accumulated time from the previous attachment, and begins timing with the new value.

Once enabled, the timed interrupt runs continuously, executing the attached interrupt routine on each expiration of the specified time interval. If you exit the RUN mode or detach the timed interrupt, the timed interrupt is disabled. If the global disable interrupt instruction is executed, timed interrupts continue to occur. Each occurrence of the timed interrupt is queued (until either interrupts are enabled, or the queue is full). See Figure 10-58 for an example of using a timed interrupt.

The timer T32/T96 interrupts allow timely response to the completion of a specified time interval. These interrupts are only supported for the 1-ms resolution on-delay timers (TON) T32 and T96. The T32 and T96 timers otherwise behave normally. Once the interrupt is enabled, the attached interrupt routine is executed when the active timer's current value becomes equal to the preset time value during the normal 1-ms timer update performed in the CPU (refer to section 10.5). You enable these interrupts by attaching an interrupt routine to the T32/T96 interrupt events.

Understanding the Interrupt Priority and Queuing

Interrupts are prioritized according to the fixed priority scheme shown below:

- Communication (highest priority)
- I/O interrupts
- Time-based interrupts (lowest priority)

Interrupts are serviced by the CPU on a first-come-first-served basis within their respective priority assignments. Only one user-interrupt routine is ever being executed at any point in time. Once the execution of an interrupt routine begins, the routine is executed to completion. It cannot be pre-empted by another interrupt routine, even by a higher priority routine. Interrupts that occur while another interrupt is being processed are queued for later processing.

The three interrupt queues and the maximum number of interrupts they can store are shown in Table 10-16.

Table 10-16 Interrupt Queues and Maximum Number of Entries per Queue

Queue	CPU 212	CPU 214	CPU 215	CPU 216
Communications queue	4	4	4	8
I/O Interrupt queue	4	16	16	16
Timed Interrupt queue	2	4	8	8

Potentially, more interrupts can occur than the queue can hold. Therefore, queue overflow memory bits (identifying the type of interrupt events that have been lost) are maintained by the system. The interrupt queue overflow bits are shown in Table 10-17. You should use these bits only in an interrupt routine because they are reset when the queue is emptied, and control is returned to the main program.

Table 10-17 Special Memory Bit Definitions for Interrupt Queue Overflow Bits

Description (0 = no overflow, 1 = overflow)	SM Bit
Communication interrupt queue overflow	SM4.0
I/O interrupt queue overflow	SM4.1
Timed interrupt queue overflow	SM4.2

Table 10-18 shows the interrupt event, priority, and assigned event number.

Table 10-18 Descriptions of Interrupt Events

Event Number	Interrupt Description	Priority Group	Priority in Group	
8	Port 0: Receive character	Communications (highest)	0	
9	Port 0: Transmit complete		0*	
23	Port 0: Receive message complete		0*	
24	Port 1: Receive message complete		1	
25	Port 1: Receive character		1*	
26	Port 1: Transmit complete		1*	
0	Rising edge, I0.0**	I/O (middle)	0	
2	Rising edge, I0.1		1	
4	Rising edge, I0.2		2	
6	Rising edge, I0.3		3	
1	Falling edge, I0.0**		4	
3	Falling edge, I0.1		5	
5	Falling edge, I0.2		6	
7	Falling edge, I0.3		7	
12	HSC0 CV=PV (current value = preset value)**		0	
13	HSC1 CV=PV (current value = preset value)		8	
14	HSC1 direction input changed		9	
15	HSC1 external reset		10	
16	HSC2 CV=PV (current value = preset value)		11	
17	HSC2 direction input changed		12	
18	HSC2 external reset		13	
19	PLS0 pulse count complete interrupt		14	
20	PLS1 pulse count complete interrupt		15	
10	Timed interrupt 0		Timed (lowest)	0
11	Timed interrupt 1			1
21	Timer T32 CT=PT interrupt			2
22	Timer T96 CT=PT interrupt	3		
<p>* Since communication is inherently half-duplex, both transmit and receive are the same priority. ** If event 12 (HSC0, PV = CV) is attached to an interrupt, then neither event 0 nor 1 can be attached to interrupts. Likewise, if either event 0 or 1 is attached to an interrupt, then event 12 cannot be attached to an interrupt.</p>				

Interrupt Examples

Figure 10-57 shows an example of the Interrupt Routine instructions.

LAD	STL
<p>Network 1</p> <p>On the first scan: Define interrupt routine 4 to be a rising edge interrupt routine for I0.0.</p> <p>Globally enable interrupts.</p>	<p>Network 1</p> <pre>LD SM0.1 ATCH 4, 0 ENI</pre>
<p>Network 2</p> <p>If an I/O error is detected, disable the rising edge interrupt for I0.0. (This rung is optional.)</p>	<p>Network 2</p> <pre>LD SM5.0 DTCH 0</pre>
<p>Network 3</p> <p>Disable all interrupts when M5.0 is on.</p> <p>⋮</p>	<p>Network 3</p> <pre>LD M5.0 DISI</pre> <p>⋮</p>
<p>Network 50</p> <p>End of main ladder.</p> <p>⋮</p>	<p>Network 50</p> <pre>MEND</pre> <p>⋮</p>
<p>Network 60</p> <p>I/O rising edge interrupt subroutine.</p> <p>⋮</p>	<p>Network 60</p> <pre>INT 4</pre> <p>⋮</p>
<p>Network 65</p> <p>Conditional return based on I/O error</p>	<p>Network 65</p> <pre>LD SM5.0 CRETI</pre>
<p>Network 66</p> <p>End of I0.0 rising edge interrupt routine.</p>	<p>Network 66</p> <pre>RETI</pre>

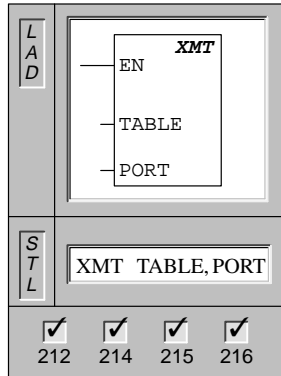
Figure 10-57 Example of Interrupt Instructions

Figure 10-58 shows how to set up a timed interrupt to read the value of an analog input.

LAD	STL
Main Program	
<p>Network 1</p> <p>Network 2</p>	<p>Network 1</p> <pre>LD SM0.1 CALL 0</pre> <p>Network 2</p> <pre>MEND</pre>
Subroutines	
<p>Network 3</p> <p>Network 4</p> <p>Network 5</p>	<p>Network 3</p> <pre>SBR 0</pre> <p>Network 4</p> <pre>LD SM0.0 MOVB 100, SMB34 ENI ATCH 0, 10</pre> <p>Network 5</p> <pre>RET</pre>
Interrupt Routines	
<p>Network 6</p> <p>Network 7</p> <p>Network 8</p>	<p>Network 6</p> <pre>INT 0</pre> <p>Network 7</p> <pre>MOVW AIW4, VW100</pre> <p>Network 8</p> <pre>RETI</pre>

Figure 10-58 Example of How to Set Up a Timed Interrupt to Read the Value of an Analog Input

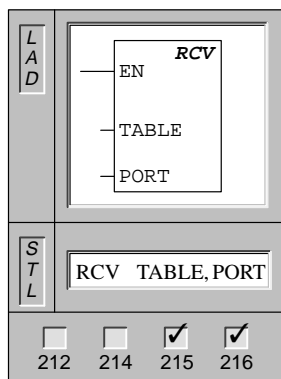
Transmit, Receive



The **Transmit** instruction invokes the transmission of the data buffer (TABLE). The first entry in the data buffer specifies the number of bytes to be transmitted. PORT specifies the communication port to be used for transmission.

Operands: TABLE: VB, IB, QB, MB, SMB, *VD, *AC, SB
 PORT: 0 to 1

The XMT instruction is used in Freeport mode to transmit data by means of the communication port(s).



The **Receive** instruction invokes setup changes that initiate or terminate the Receive Message service. You must specify a start and an end condition for the Receive box to operate. Messages received through the specified port (PORT) are stored in the data buffer (TABLE). The first entry in the data buffer specifies the number of bytes received.

Operands: TABLE: VB, IB, QB, MB, SMB, *VD, *AC, SB
 PORT: 0 to 1

The RCV instruction is used in Freeport mode to receive data by means of the communication port(s).

Understanding Freeport Mode

You can select the Freeport mode to control the serial communication port of the CPU by means of the user program. When you select Freeport mode, the ladder logic program controls the operation of the communication port through the use of the receive interrupts, the transmit interrupts, the transmit instruction (XMT), and the receive instruction (RCV). The communication protocol is entirely controlled by the ladder program while in Freeport mode. SMB30 (for port 0) and SMB130 (for port 1 if your CPU has two ports) are used to select the baud rate and parity.

The Freeport mode is disabled and normal communication is re-established (for example, programming device access) when the CPU is in the STOP mode.

In the simplest case, you can send a message to a printer or a display using only the Transmit (XMT) instruction. Other examples include a connection to a bar code reader, a weighing scale, and a welder. In each case, you must write your program to support the protocol that is used by the device with which the CPU communicates while in Freeport mode.

Freeport communication is possible only when the CPU is in the RUN mode. Enable the Freeport mode by setting a value of 01 in the protocol select field of SMB30 (Port 0) or SMB130 (Port 1). While in Freeport mode, communication with the programming device is not possible.

Note

Entering Freeport mode can be controlled using special memory bit SM0.7, which reflects the current position of the mode switch. When SM0.7 is equal to 0, the switch is in TERM position; when SM0.7 = 1, the switch is in RUN position. If you enable Freeport mode only when the switch is in RUN position, you can use the programming device to monitor or control the CPU operation by changing the switch to any other position.

Freeport Initialization

SMB30 and SMB130 configure the communication ports, 0 and 1, respectively, for Freeport operation and provide selection of baud rate, parity, and number of data bits. The Freeport control byte(s) description is shown in Table 10-19.

Table 10-19 Special Memory Bytes SMB30 and SMB130

Port 0	Port 1	Description								
Format of SMB30	Format of SMB130	<div style="display: flex; justify-content: space-between; align-items: center;"> MSB 7 LSB 0 </div> <div style="display: flex; justify-content: center; align-items: center; margin-top: 5px;"> <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="padding: 2px 5px;">p</td> <td style="padding: 2px 5px;">p</td> <td style="padding: 2px 5px;">d</td> <td style="padding: 2px 5px;">b</td> <td style="padding: 2px 5px;">b</td> <td style="padding: 2px 5px;">b</td> <td style="padding: 2px 5px;">m</td> <td style="padding: 2px 5px;">m</td> </tr> </table> Freeport mode control byte </div>	p	p	d	b	b	b	m	m
p	p	d	b	b	b	m	m			
SM30.6 and SM30.7	SM130.6 and SM130.7	pp Parity select 00 = no parity 01 = even parity 10 = no parity 11 = odd parity								
SM30.5	SM130.5	d Data bits per character 0 = 8 bits per character 1 = 7 bits per character								
SM30.2 to SM30.4	SM130.2 to SM130.4	bbb Freeport Baud rate 000 = 38,400 baud (for CPU 212: = 19,200 baud) 001 = 19,200 baud 010 = 9,600 baud 011 = 4,800 baud 100 = 2,400 baud 101 = 1,200 baud 110 = 600 baud 111 = 300 baud								
SM30.0 and SM30.1	SM130.0 and SM130.1	mm Protocol selection 00 = Point-to-Point Interface protocol (PPI/slave mode) 01 = Freeport protocol 10 = PPI/master mode 11 = Reserved (defaults to PPI/slave mode)								
Note: For Port 0 operation, one stop bit is generated for all configurations except for the 7 bits per character, no parity case, where two stop bits are generated. For Port 1 operation, one stop bit is generated for all configurations.										

Using the XMT Instruction to Transmit Data

You can use the XMT instruction to facilitate transmission. The XMT instruction lets you send a buffer of one or more characters, up to a maximum of 255. An interrupt is generated (interrupt event 9 for port 0 and interrupt event 26 for port 1) after the last character of the buffer is sent, if an interrupt routine is attached to the transmit complete event. You can make transmissions without using interrupts (for example, sending a message to a printer) by monitoring SM4.5 or SM4.6 to signal when transmission is complete.

Using the RCV Instruction to Receive Data

You can use the RCV instruction to facilitate receiving messages. The RCV instruction lets you receive a buffer of one or more characters, up to a maximum of 255. An interrupt is generated (interrupt event 23 for port 0 and interrupt event 24 for port 1) after the last character of the buffer is received, if an interrupt routine is attached to the receive message complete event. You can receive messages without using interrupts by monitoring SM86.

SMB86 (or SMB186) will be non-zero when the RCV box is inactive. It will be zero when a receive is in progress.

The RCV instruction allows you to select the message start and message end conditions. See Table 10-20 (SM86 through SM94 for port 0, and SM186 through SM194 for port 1) for descriptions of the start and end message conditions.

Note

The Receive Message function is automatically terminated by an overrun or a parity error. You must define a start condition (x or z), and an end condition (y, t, or maximum character count) for the Receive Message function to operate.

Table 10-20 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194

Port 0	Port 1	Description								
SMB86	SMB186	<div style="display: flex; justify-content: space-between; align-items: center;"> MSB 7 LSB 0 </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="padding: 2px 5px;">n</td> <td style="padding: 2px 5px;">r</td> <td style="padding: 2px 5px;">e</td> <td style="padding: 2px 5px;">0</td> <td style="padding: 2px 5px;">0</td> <td style="padding: 2px 5px;">t</td> <td style="padding: 2px 5px;">c</td> <td style="padding: 2px 5px;">p</td> </tr> </table> <div style="margin-left: 10px;">Receive message status byte</div> </div> <p>n: 1 = Receive message terminated by user disable command r: 1 = Receive message terminated: error in input parameters or missing start or end condition e: 1 = End character received t: 1 = Receive message terminated: timer expired c: 1 = Receive message terminated: maximum character count achieved p 1 = Receive message terminated because of a parity error</p>	n	r	e	0	0	t	c	p
n	r	e	0	0	t	c	p			
SMB87	SMB187	<div style="display: flex; justify-content: space-between; align-items: center;"> MSB 7 LSB 0 </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="padding: 2px 5px;">n</td> <td style="padding: 2px 5px;">x</td> <td style="padding: 2px 5px;">y</td> <td style="padding: 2px 5px;">z</td> <td style="padding: 2px 5px;">m</td> <td style="padding: 2px 5px;">t</td> <td style="padding: 2px 5px;">0</td> <td style="padding: 2px 5px;">0</td> </tr> </table> <div style="margin-left: 10px;">Receive message control byte</div> </div> <p>n: 0 = Receive Message function is disabled. 1 = Receive Message function is enabled . The enable/disable receive message bit is checked each time the RCV instruction is executed.</p> <p>x: 0 = Ignore SMB88 or SMB188. 1 = Use the value of SMB88 or SMB188 to detect start of message.</p> <p>y: 0 = Ignore SMB89 or SMB189. 1 = Use the value of SMB89 or SMB189 to detect end of message.</p> <p>z: 0 = Ignore SMW90 or SMB190. 1 = Use the value of SMW90 to detect an idle line condition.</p> <p>m: 0 = Timer is an inter-character timer. 1 = Timer is a message timer.</p> <p>t: 0 = Ignore SMW92 or SMW192. 1 = Terminate receive if the time period in SMW92 or SMW192 is exceeded.</p> <p>These bits define the criteria for identifying the message (including both the start-of-message and end-of-message criteria). To determine the start of a message, the enabled start of message criteria are logically ANDed, and must occur in sequence (idle line followed by a start character). To determine the end of a message, the enabled end of message criteria are logically ORed.</p> <p>Equations for start and stop criteria: Start of Message = z * x End of Message = y + t + maximum character count reached</p> <p>Note: The Receive Message function is automatically terminated by an overrun or a parity error. You must define a start condition (x or z), and an end condition (y, t, or maximum character count) for the receive message function to operate.</p>	n	x	y	z	m	t	0	0
n	x	y	z	m	t	0	0			
SMB88	SMB188	Start of message character								
SMB89	SMB189	End of message character								
SMB90 SMB91	SMB190 SMB191	Idle line time period given in milliseconds. The first character received after idle line time has expired is the start of a new message. SM90 (or SM190) is the most significant byte and SM91 (or SM191) is the least significant byte.								

Table 10-20 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194

Port 0	Port 1	Description
SMB92 SMB93	SMB192 SMB193	Inter-character/message timer time-out value given in milliseconds. If the time period is exceeded, the receive message is terminated. SM92 (or SM192) is the most significant byte, and SM93 (or SM193) is the least significant byte.
SMB94	SMB194	Maximum number of characters to be received (1 to 255 bytes). Note: This range must be set to the expected maximum buffer size, even if the character count message termination is not used.

Using Character Interrupt Control to Receive Data

To allow complete flexibility in protocol support, you can also receive data using character interrupt control. Each character received generates an interrupt. The received character is placed in SMB2, and the parity status (if enabled) is placed in SM3.0 just prior to execution of the interrupt routine attached to the receive character event.

- SMB2 is the Freeport receive character buffer. Each character received while in Freeport mode is placed in this location for easy access from the user program.
- SMB3 is used for Freeport mode and contains a parity error bit that is turned on when a parity error is detected on a received character. All other bits of the byte are reserved. Use this bit either to discard the message or to generate a negative acknowledge to the message.

Note

SMB2 and SMB3 are shared between Port 0 and Port 1. When the reception of a character on Port 0 results in the execution of the interrupt routine attached to that event (interrupt event 8), SMB2 contains the character received on Port 0, and SMB3 contains the parity status of that character. When the reception of a character on Port 1 results in the execution of the interrupt routine attached to that event (interrupt event 25), SMB2 contains the character received on Port 1 and SMB3 contains the parity status of that character.

Receive and Transmit Example

This sample program shows the use of Receive and Transmit. This program will receive a string of characters until a line feed character is received. The message is then transmitted back to the sender.

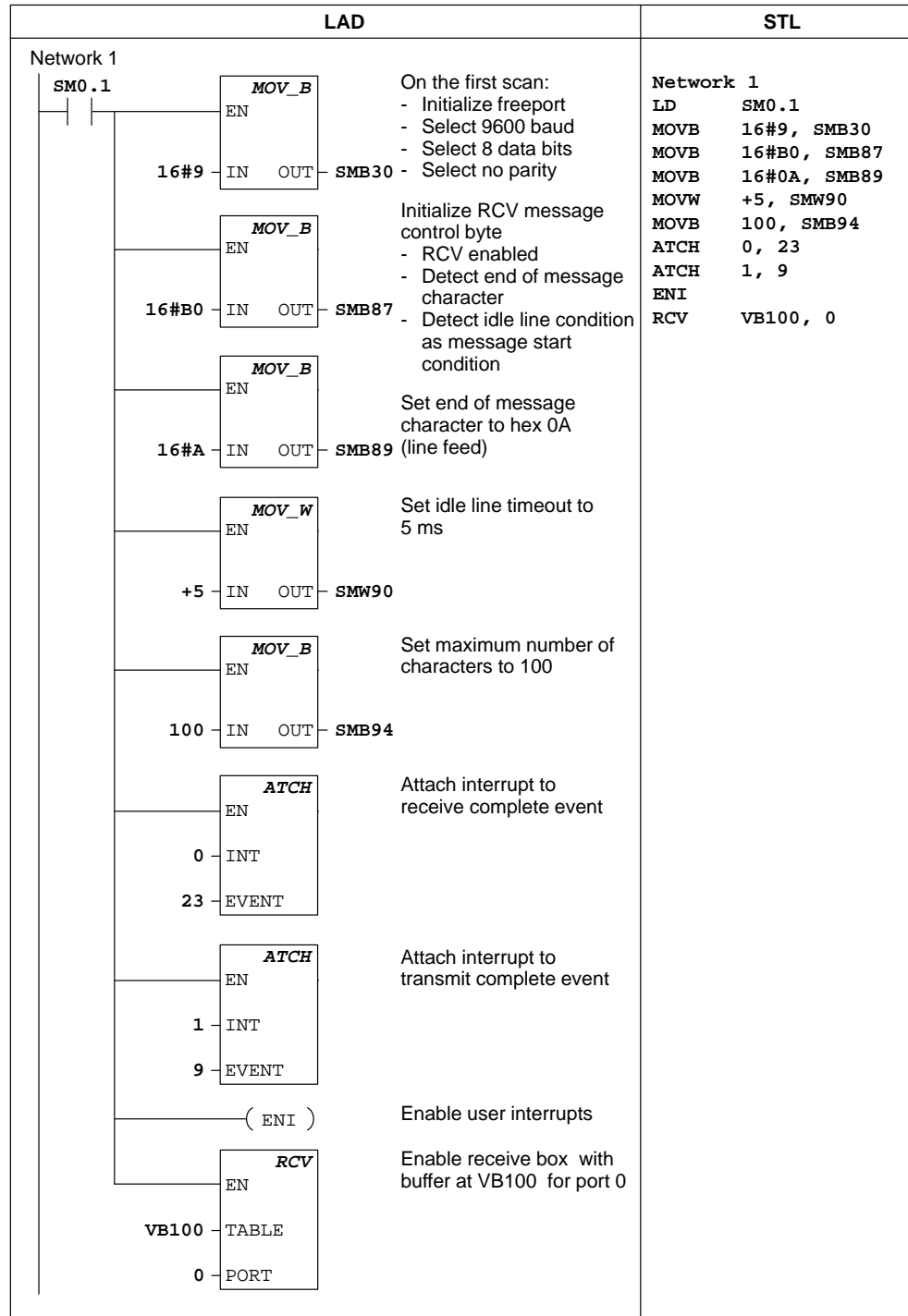


Figure 10-59 Example of Transmit Instruction

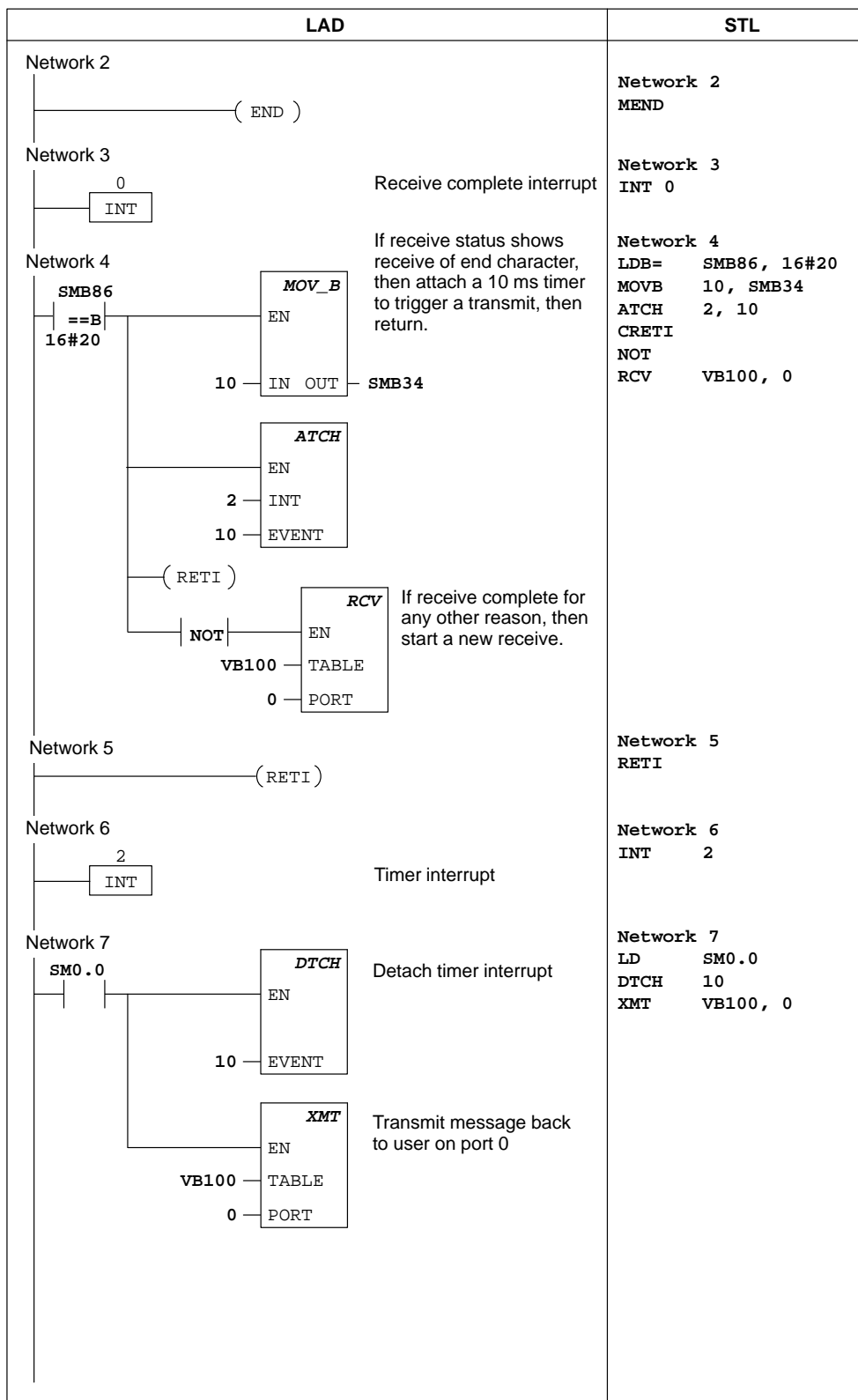


Figure 10-60 Example of Transmit Instruction (continued)

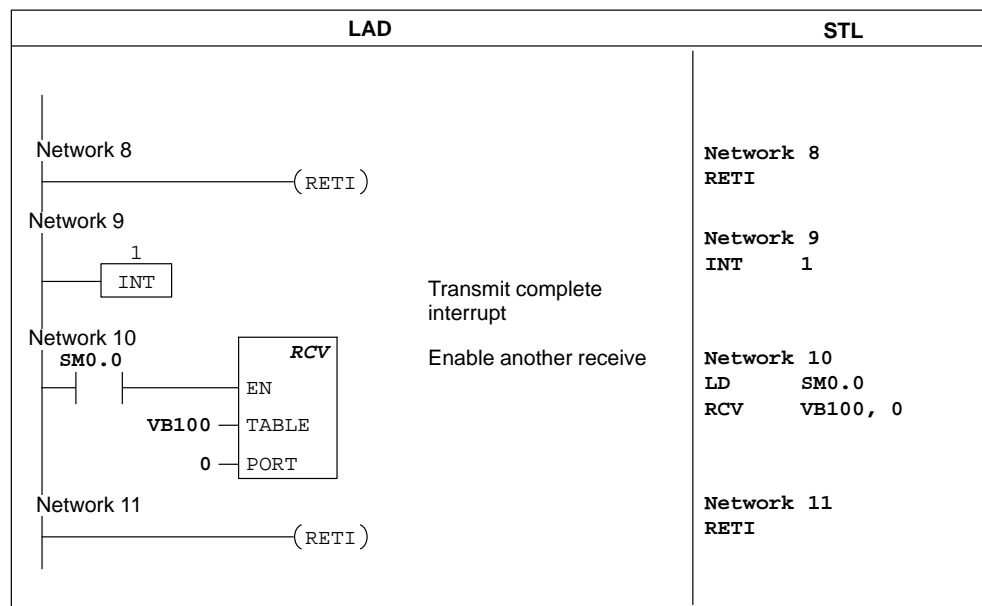
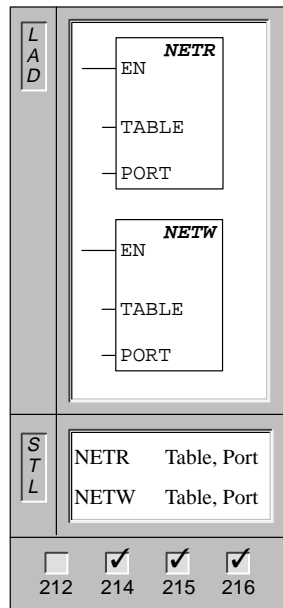


Figure 10-60 Example of Transmit Instruction (continued)

Network Read, Network Write



The **Network Read** instruction initiates a communication operation to gather data from a remote device through the specified port (PORT), as defined by the table (TABLE).

The **Network Write** instruction initiates a communication operation to write data to a remote device through the specified port (PORT), as defined by the table (TABLE).

Operands: Table: VB, MB, *VD, *AC
 Port: 0 to 1

The NETR instruction can read up to 16 bytes of information from a remote station, and the NETW instruction can write up to 16 bytes of information to a remote station. A maximum of eight NETR and NETW instructions may be activated at any one time. For example, you can have four NETRs and four NETWs, or two NETRs and six NETWs in a given S7-200 programmable logic controller.

Figure 10-60 defines the table that is referenced by the TABLE parameter in the NETR and NETW instructions.

		D Done (function has been completed):		0 = not done	1 = done
		A Active (function has been queued):		0 = not active	1 = active
		E Error (function returned an error):		0 = no error	1 = error

Byte Offset	7					0
0	D	A	E	0	Error code	
1	Remote station address					
2	Pointer to the data					
3	area in the					
4	remote station					
5	(I, Q, M, S, or V)					
6	Data length					
7	Data byte 0					
8	Data byte 1					
	⋮					
22	Data byte 15					

Error Code	Definition
0	No error
1	Time-out error; remote station not responding
2	Receive error; parity, framing or checksum error in the response
3	Offline error; collisions caused by duplicate station addresses or failed hardware
4	Queue overflow error; more than eight NETR/NETW boxes have been activated
5	Protocol violation; attempt execute NETR/NETW without enabling PPI+ in SMB30
6	Illegal parameter; the NETR/NETW table contains an illegal or invalid value
7	No resource; remote station is busy (upload or download sequence in process)
8	Layer 7 error; application protocol violation
9	Message error; wrong data address or incorrect data length
A-F	Not used; (reserved for future use)

Figure 10-60 Definition of TABLE for NETR and NETW

Example of Network Read and Network Write

Figure 10-61 shows an example to illustrate the utility of the NETR and NETW instructions. For this example, consider a production line where tubs of butter are being filled and sent to one of four boxing machines (case packers). The case packer packs eight tubs of butter into a single cardboard box. A diverter machine controls the flow of butter tubs to each of the case packers. Four CPU 212 modules are used to control the case packers and a CPU 214 module equipped with a TD 200 operator interface is used to control the diverter. Figure 10-61 shows the network setup.

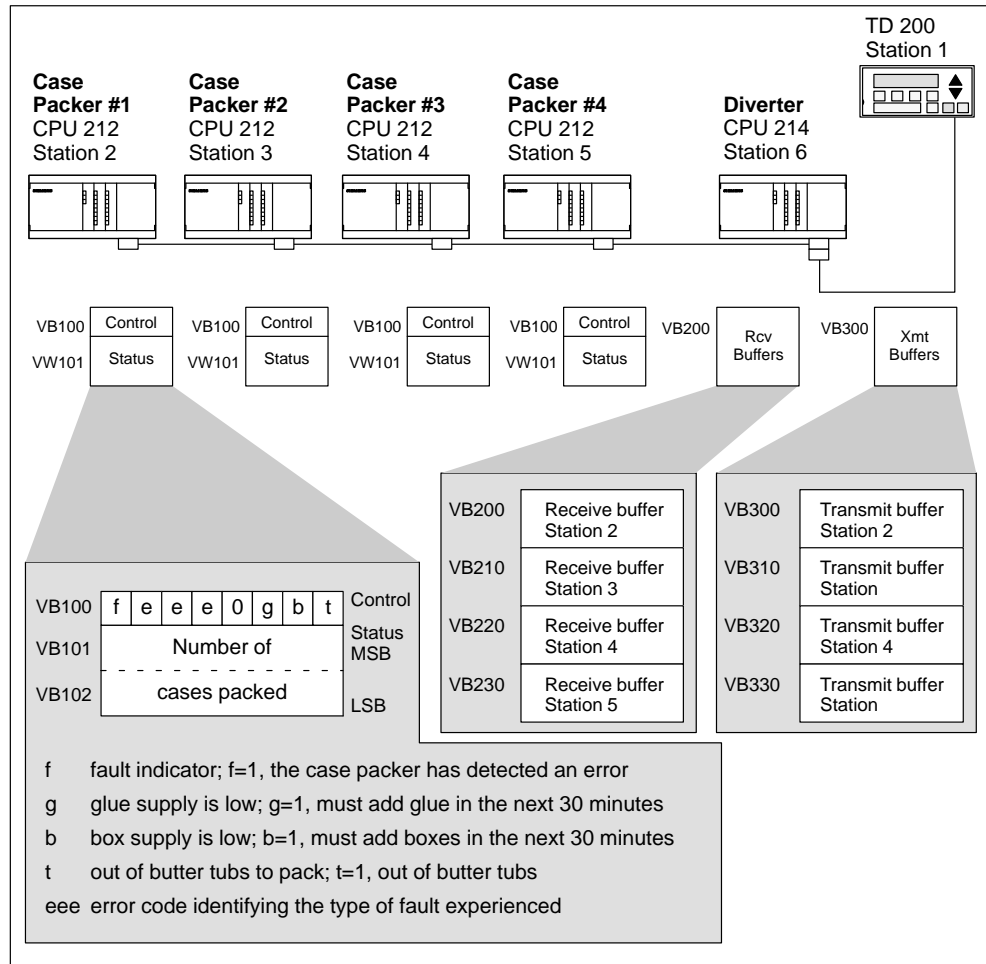


Figure 10-61 Example of NETR and NETW Instructions

The receive and transmit buffers for accessing the data in station 2 (located at VB200 and VB300, respectively) are shown in detail in Figure 10-62.

The CPU 214 uses a NETR instruction to read the control and status information on a continuous basis from each of the case packers. Each time a case packer has packed 100 cases, the diverter notes this and sends a message to clear the status word using a NETW instruction.

The program required to read the control byte, the number of cases packed and to reset the number of cases packed for a single case packer (case packer #1) is shown in Figure 10-63.

Diverter's Receive Buffer for reading from Case Packer #1					Diverter's Transmit Buffer for clearing the count of Case Packer #1						
	7			0		7			0		
VB200	D	A	E	0	Error code	VB300	D	A	E	0	ErrorCode
VB201	Remote station address					VB301	Remote station address				
VB202	Pointer to the					VB302	Pointer to the				
VB203	data area					VB303	data area				
VB204	in the					VB304	in the				
VB205	Remote station = (&VB100)					VB305	Remote station = (&VB101)				
VB206	Data length = 3 bytes					VB306	Data length = 2 bytes				
VB207	Control					VB307	0				
VB208	Status (MSB)					VB308	0				
VB209	Status (LSB)										

Figure 10-62 Sample TABLE Data for NETR and NETW Example

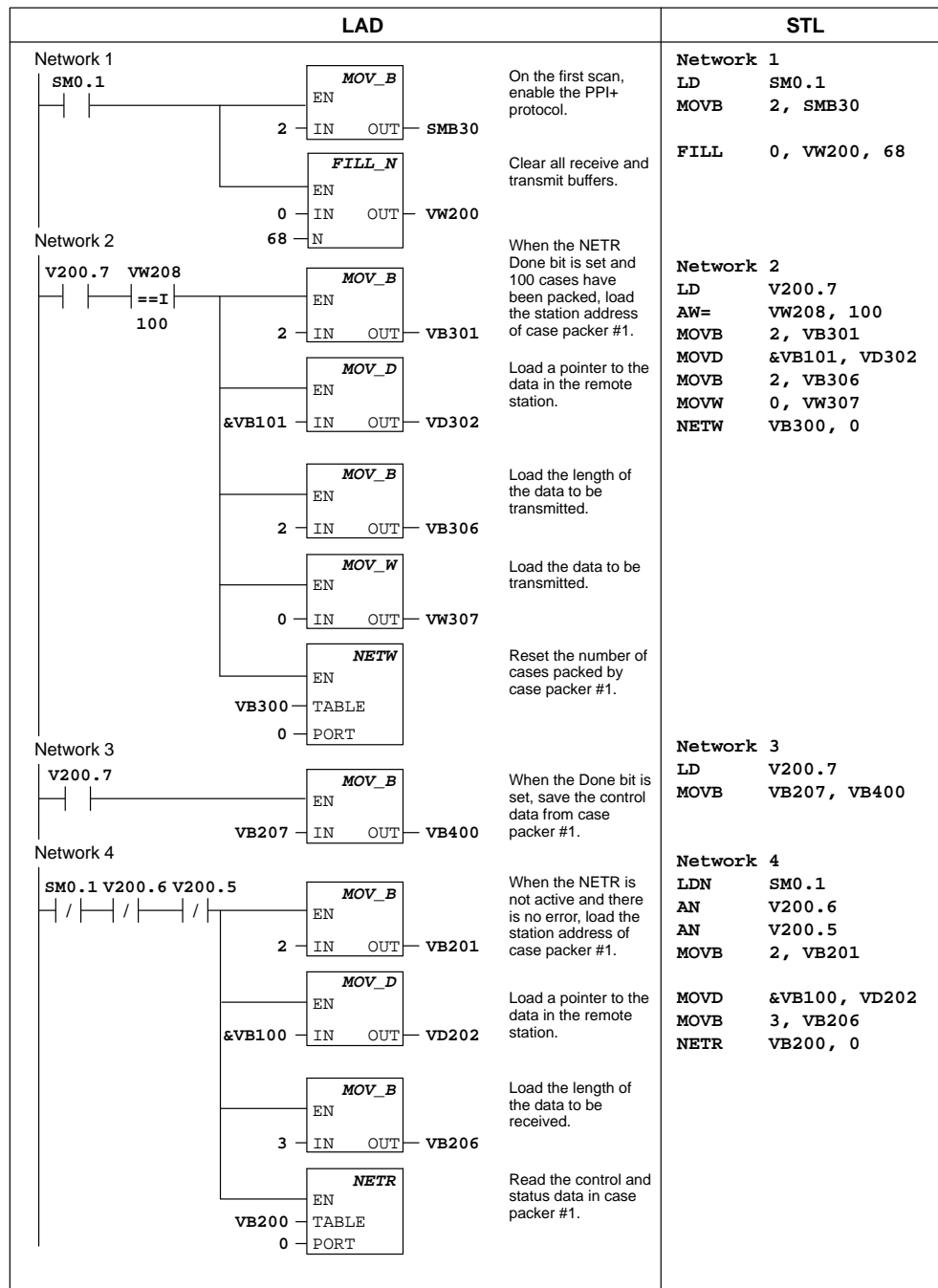


Figure 10-63 Example of NETR and NETW Instructions

S7-200 Data Sheets

A

Chapter Overview

Section	Description	Page
A.1	General Technical Specifications	A-3
A.2	CPU 212 DC Power Supply, DC Inputs, DC Outputs	A-6
A.3	CPU 212 AC Power Supply, DC Inputs, Relay Outputs	A-8
A.4	CPU 212 24 VAC Power Supply, 24 DC Inputs, Relay Outputs	A-10
A.5	CPU 212 AC Power Supply, AC Inputs, AC Outputs	A-12
A.6	CPU 212 AC Power Supply, Sourcing DC Inputs, Relay Outputs	A-14
A.7	CPU 212 AC Power Supply, 24 VAC Inputs, AC Outputs	A-16
A.8	CPU 212 AC Power Supply, AC Inputs, Relay Outputs	A-18
A.9	CPU 214 DC Power Supply, DC Inputs, DC Outputs	A-20
A.10	CPU 214 AC Power Supply, DC Inputs, Relay Outputs	A-22
A.11	CPU 214 AC Power Supply, AC Inputs, AC Outputs	A-24
A.12	CPU 214 AC Power Supply, Sourcing DC Inputs, Relay Outputs	A-26
A.13	CPU 214 AC Power Supply, 24 VAC Inputs, AC Outputs	A-28
A.14	CPU 214 AC Power Supply, AC Inputs, Relay Outputs	A-30
A.15	CPU 215 DC Power Supply, DC Inputs, DC Outputs	A-32
A.16	CPU 215 AC Power Supply, DC Inputs, Relay Outputs	A-34
A.17	CPU 216 DC Power Supply, DC Inputs, DC Outputs	A-36
A.18	CPU 216 AC Power Supply, DC Inputs, Relay Outputs	A-38
A.19	EM221 Digital Input 8 x 24 VDC	A-40
A.20	EM221 Digital Input 8 x 120 VAC	A-41
A.21	EM221 Digital Sourcing Input 8 x 24 VDC	A-42
A.22	EM221 Digital Input 8 x 24 VAC	A-43
A.23	EM222 Digital Output 8 x 24 VDC	A-44
A.24	EM222 Digital Output 8 x Relay	A-45
A.25	EM222 Digital Output 8 x 120/230 VAC	A-46
A.26	EM223 Digital Combination 4 x 24 VDC Input / 4 x 24 VDC Output	A-48
A.27	EM223 Digital Combination 8 x 24 VDC Input / 8 x 24 VDC Output	A-50
A.28	EM223 Digital Combination 16 x 24 VDC Input / 16 x 24 VDC Output	A-52
A.29	EM223 Digital Combination 4 x 24 VDC Input / 4 x Relay Output	A-54

Section	Description	Page
A.30	EM223 Digital Combination 4 x 120 VAC Input / 4 x 120 to 230 VAC Output	A-55
A.31	EM223 Digital Combination 8 x 24 VDC Input / 8 x Relay Output	A-56
A.32	EM223 Digital Combination 16 x 24 VDC Input / 16 x Relay Output	A-58
A.33	EM231 Analog Input AI 3 x 12 Bits	A-60
A.34	EM232 Analog Output AQ 2 x 12 Bits	A-66
A.35	EM235 Analog Combination AI 3 / AQ 1 x 12 Bits	A-69
A.36	Memory Cartridge 8K x 8	A-78
A.37	Memory Cartridge 16K x 8	A-79
A.38	Battery Cartridge	A-80
A.39	I/O Expansion Cable	A-81
A.40	PC/PPI Cable	A-82
A.41	CPU 212 DC Input Simulator	A-84
A.42	CPU 214 DC Input Simulator	A-85
A.43	CPU 215/216 DC Input Simulator	A-86

A.1 General Technical Specifications

National and International Standards

The national and international standards listed below were used to determine appropriate performance specifications and testing for the S7-200 family of products. Table A-1 defines the specific adherence to these standards.

- Underwriters Laboratories, Inc.: UL 508 Listed (Industrial Control Equipment)
- Canadian Standards Association: CSA C22.2 Number 142 Certified (Process Control Equipment)
- Factory Mutual Research: FM Class I, Division 2, Groups A, B, C, & D Hazardous Locations, T4A
- VDE 0160: Electronic equipment for use in electrical power installations
- European Community (CE) Low Voltage Directive 73/23/EEC
EN 61131-2: Programmable controllers - Equipment requirements
- European Community (CE) EMC Directive 89/336/EEC

Electromagnetic emission standards:

EN 50081-1: residential, commercial, and light industry

EN 50081-2: industrial environment

Electromagnetic immunity standards:

EN 50082-2: industrial environment

Technical Specifications

The S7-200 CPUs and all S7-200 expansion modules conform to the technical specifications listed in Table A-1.

Table A-1 Technical Specifications for the S7-200 Family

Environmental Conditions — Transport and Storage	
IEC 68-2-2, Test Bb, Dry heat and IEC 68-2-1, Test Ab, Cold	-40° C to +70° C
IEC 68-2-30, Test Db, Damp heat	25° C to 55° C, 95% humidity
IEC 68-2-31, Toppling	100 mm, 4 drops, unpacked
IEC 68-2-32, Free fall	1 m, 5 times, packed for shipment
Environmental Conditions — Operating	
Functional range	0° C to 55° C, 95% maximum non-condensing humidity
IEC 68-2-14, Test Nb	5° C to 55° C, 3° C/minute
IEC 68-2-27 Mechanical shock	15 G, 11 ms pulse, 6 shocks in each of 3 axis
IEC 68-2-6 Sinusoidal vibration	0.35 mm peak-to-peak 10 to 57 Hz; 2 G panel mount, 1G DIN rail mount, 57 Hz to 150 Hz; 10 sweeps each axis, 1 octave/minute
EN 60529, IP20 Mechanical protection	Protects against finger contact with high voltage as tested by standard probes. External protection is required for dust, dirt, water, and foreign objects of less than 12.5 mm in diameter.
Electromagnetic Compatibility — Immunity¹ per EN50082-2¹	
EN 61000-4-2 (IEC 801-2) Electrostatic discharge	8 kV air discharge to all surfaces and communication port
EN 50140 (IEC 801-3) Radiated electromagnetic field EN50204	26 MHz to 1 GHz 10 V/m, 80% modulation with 1 kHz signal 900 MHz ± 5 MHz, 10 V/m, 50% duty cycle, 200 Hz repetition frequency
EN 61000-4-4 (IEC 801-4) Fast transient bursts	2 kV, 5 kHz with coupling network to AC and DC system power 2 kV, 5 kHz with coupling clamp to digital I/O and communications
EN 61000-4-5 (IEC 801-5) Surge immunity	2 kV asymmetrical, 1 kV symmetrical 5 positive/5 negative pulses 0°, +90°, -90° phase angle (24 VDC circuits require external surge protection)
VDE 0160 Non-periodic overvoltage	at 85 VAC line, 90° phase angle, apply 390 V peak, 1.3 ms pulse at 180 VAC line, 90° phase angle, apply 750 V peak, 1.3 ms pulse

Table A-1 Technical Specifications for the S7-200 Family, continued

Electromagnetic Compatibility — Conducted and Radiated Emissions² per EN50081 -1 and -2²	
EN 55011, Class A, Group 1, conducted ¹ 0.15 MHz to 0.5 MHz 0.5 MHz to 5 MHz 5 MHz to 30 MHz	< 79 dB (μV) Quasi-peak; < 66 dB (μV) Average < 73 dB (μV) Quasi-peak; < 60 dB (μV) Average < 73 dB (μV) Quasi-peak; < 60 dB (μV) Average
EN 55011, Class A, Group 1, radiated ¹ 30 MHz to 230 kHz 230 MHz to 1 GHz	30 dB (μV/m) Quasi-peak; measured at 30 m 37 dB (μV/m) Quasi-peak; measured at 30 m
EN 55011, Class B, Group 1, conducted ³ 0.15 to 0.5 MHz 0.5 MHz to 5 MHz 5 MHz to 30 MHz	< 66 dB (μV) Quasi-peak decreasing with log frequency to 56 dB (μV); < 56 dB (μV) Average decreasing with log frequency to 46 dB (μV) < 56 dB (μV) Quasi-peak; < 46 dB (μV) Average < 60 dB (μV) Quasi-peak; < 50 dB (μV) Average
EN 55011, Class B, Group 1, radiated ³ 30 MHz to 230 kHz 230 MHz to 1 GHz	30 dB (μV/m) Quasi-peak; measured at 10 m 37 dB (μV/m) Quasi-peak; measured at 10 m
High Potential Isolation Test	
24 V/5 V nominal circuits 115/230 V circuits to ground 115/230 V circuits to 115/230 V circuits 230 V circuits to 24 V/5 V circuits 115 V circuits to 24 V/5 V circuits	500 VAC (optical isolation boundaries) 1,500 VAC 1,500 VAC 1,500 VAC 1,500 VAC

- 1 Unit must be mounted on a grounded metallic frame with the S7-200 ground connection made directly to the mounting metal. Cables are routed along metallic supports.
- 2 Applicable for all devices bearing the CE (European Community) mark.
- 3 Unit must be mounted in a grounded metal enclosure. AC input power line must be equipped with a Schaffner FN 680-2.5/06 filter or equivalent, 25. cm max. wire length from filters to the S7-200. The 24 VDC supply and sensor supply wiring must be shielded.

Relay Electrical Service Life

Figure A-1 shows typical performance data supplied by relay vendors. Actual performance may vary depending upon your specific application.

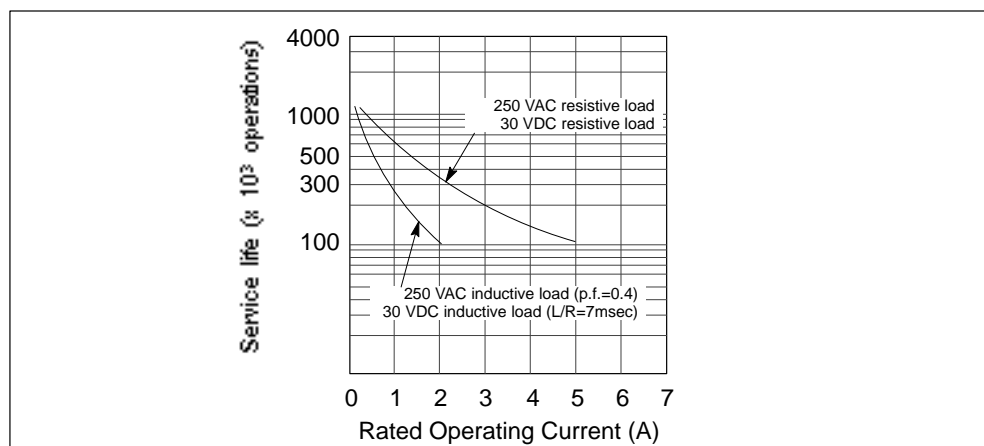


Figure A-1 Electrical Service Life

A.2 CPU 212 DC Power Supply, DC Inputs, DC Outputs

Order Number: 6ES7 212-1AA01-0XB0

General Features		Output Points (continued)	
Physical size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Switching delay	25 μ s ON, 120 μ s OFF
Weight	0.3 kg (0.7 lbs.)	Surge current	4 A, 100 ms
Power dissipation	5 W at 1.75 A load	Voltage drop	1.8 V maximum at maximum current
User program size/storage	512 words/EEPROM	Optical isolation	500 VAC, 1 min
User data size/storage	512 words/RAM	Short circuit protection	None
Data retention	50 hr typical (8 hr minimum at 40° C)	Input Points	
Local I/O ¹	8 inputs/6 outputs	Input type (IEC 1131-2)	Type 1 sinking
Maximum number of expansion modules	2	ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Digital I/O supported	64 inputs/64 outputs	ON state nominal	24 VDC, 7 mA
Analog I/O supported	16 inputs/16 outputs	OFF state maximum	5 VDC, 1 mA
Boolean execution speed	1.2 μ s/instruction	Response time I0.0 to I0.7	0.3 ms maximum
Internal memory bits	128	Optical isolation	500 VAC, 1 min
Timers	64 timers	Power Supply	
Counters	64 counters	Voltage range	20.4 to 28.8 VDC
High-speed counters	1 software (2 KHz max.)	Input current	60 mA typical, CPU only 500 mA maximum load
Analog adjustments	1	UL/CSA rating	50 VA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Holdup time	10 ms minimum from 24 VDC
Output Points		Inrush current	10 A peak at 28.8 VDC
Output type	Sourcing transistor	Fusing (non-replaceable)	1 A, 125 V, slow blow
Voltage range	20.4 VDC to 28.8 VDC	5 VDC current	260 mA for CPU 340 mA for expansion I/O
Maximum load current	0 to 40° C 55° C ² Per single point 0.75 A 0.50 A Per 2 adjacent points 1.00 A 0.75 A All points total 2.25 A 1.75 A	Isolated	No
Inductive load clamping	(per common)	DC Sensor Supply	
Single pulse	2A L/R = 10 ms 1A L/R = 100 ms	Voltage range	16.4 to 28.8 VDC
Repetitive	1 W energy dissipation (1/2 Li ² x switch rate < 1 W)	Ripple/noise (<10MHz)	Same as supplied voltage
Leakage current	100 μ A	24 VDC available current	180 mA
		Short-circuit current limit	< 600 mA
		Isolated	No

¹ The CPU reserves 8 process-image input and 8 process-image output image register points for local I/O.

² Linear derate 40 to 55° C Vertical mount derate 10° C.

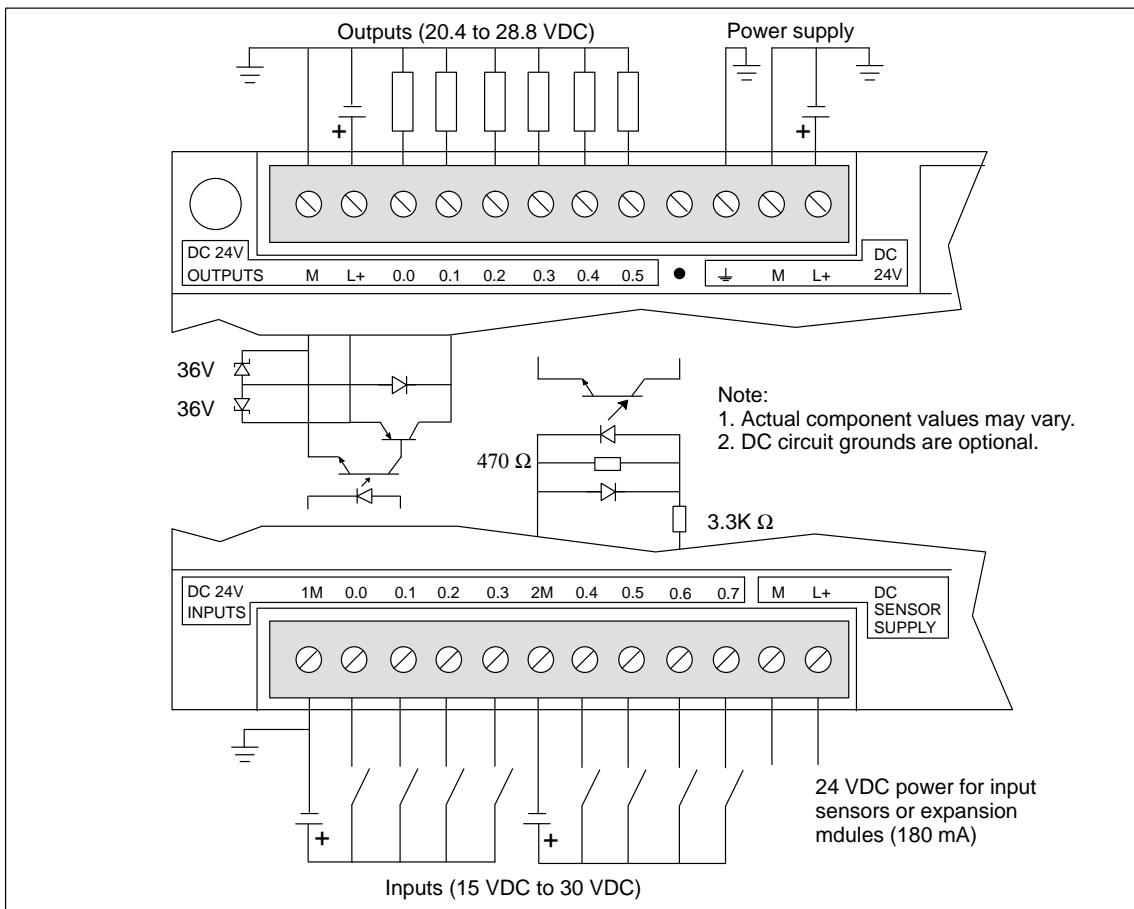


Figure A-2 Connector Terminal Identification for CPU 212 DC/DC/DC

A.3 CPU 212 AC Power Supply, DC Inputs, Relay Outputs

Order Number: 6ES7 212-1BA01-0XB0

General Features		Input Points	
Physical size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Input type (IEC 1131-2)	Type 1 sinking
Weight	0.4 kg (0.9 lbs.)	ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	6 W	ON state nominal	24 VDC, 7 mA
User program size/storage	512 words/EEPROM	OFF state maximum	5 VDC, 1 mA
User data size/storage	512 words/RAM	Response time	
Data retention	50 hr typical (8 hr minimum at 40° C)	I0.0 to I0.7	0.3 ms maximum
Local I/O ¹	8 inputs/6 outputs	Optical isolation	500 VAC, 1 min
Maximum number of expansion modules	2	Power Supply	
Digital I/O supported	64 inputs/64 outputs	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
Analog I/O supported	16 inputs/16 outputs	Input current	4 VA typical, CPU only 50 VA maximum load
Boolean execution speed	1.2 µs/instruction	Holdup time	20 ms minimum from 110 VAC
Internal memory bits	128	Inrush current	20 A peak at 264 VAC
Timers	64 timers	Fusing (non-replaceable)	2 A, 250 V, slow blow
Counters	64 counters	5 VDC current	260 mA for CPU 340 mA for expansion I/O
High-speed counters	1 software (2 KHz max.)	Isolated	Yes. Transformer, 1500 VAC, 1 min
Analog adjustments	1	DC Sensor Supply	
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Voltage range	20.4 to 28.8 VDC
Output Points		Ripple/noise (<10MHz)	1 V peak-to-peak maximum
Output type	Relay, dry contact	24 VDC available current	180 mA
Voltage range	5 to 30 VDC/250 VAC	Short circuit current limit	< 600 mA
Maximum load current	2 A/point, 6 A/common	Isolated	No
Overcurrent surge	7 A with contacts closed		
Isolation resistance	100 MΩ minimum (new)		
Switching delay	10 ms maximum		
Lifetime	10,000,000 mechanical 100,000 with rated load		
Contact resistance	200 mΩ maximum (new)		
Isolation			
coil to contact	1500 VAC, 1 min		
contact to contact (between open contacts)	750 VAC, 1 min		
Short circuit protection	None		

¹ The CPU reserves 8 process-image input and 8 process-image output image register points for local I/O.

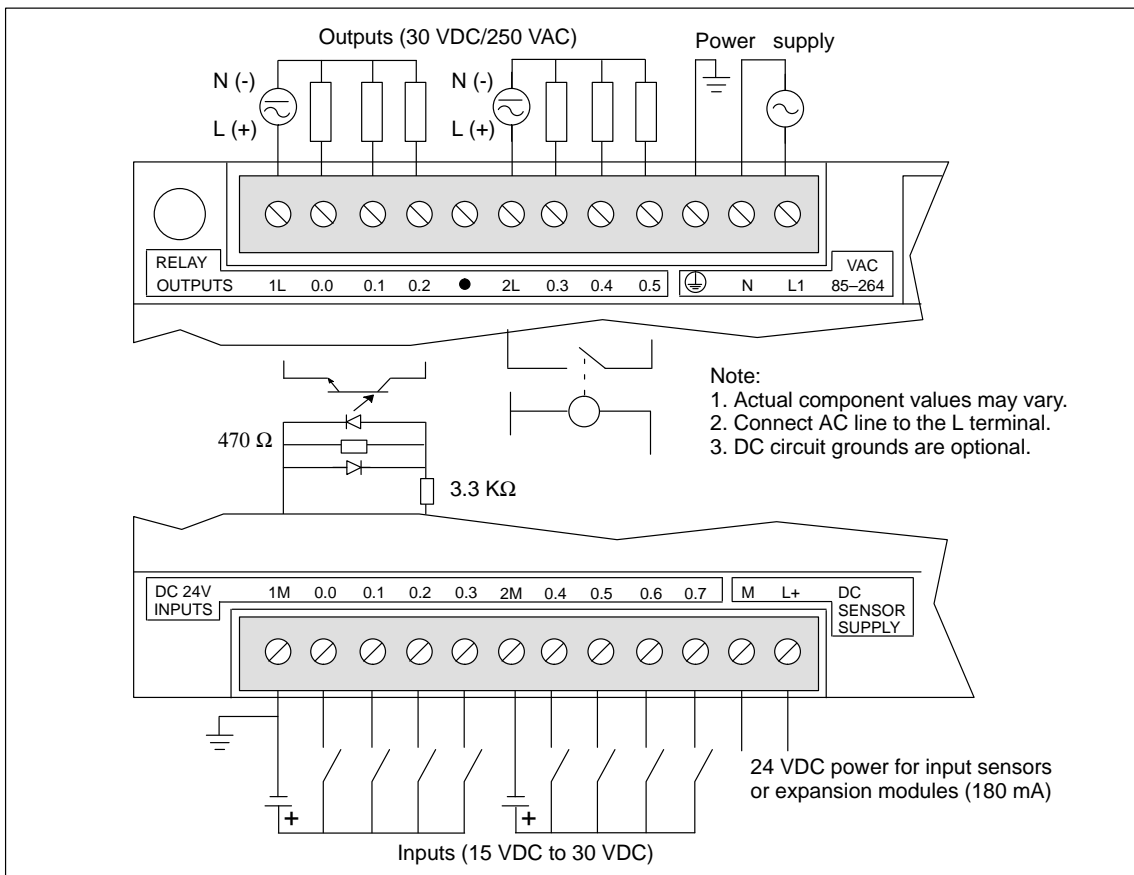


Figure A-3 Connector Terminal Identification for CPU 212 AC/DC/Relay

A.4 CPU 212 24 VAC Power Supply, DC Inputs, Relay Outputs

Order Number: 6ES7 212-1FA01-0XB0

General Features		Input Points	
Physical size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Input type (IEC 1131-2)	Type 1 sinking
Weight	0.4 kg (0.9 lbs.)	ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	6 W	ON state nominal	24 VDC, 7 mA
User program size/storage	512 words/EEPROM	OFF state maximum	5 VDC, 1 mA
User data size/storage	512 words/RAM	Response time	
Data retention	50 hr typical (8 hr minimum at 40° C)	I0.0 to I0.7	0.3 ms maximum
Local I/O ¹	8 inputs/6 outputs	Optical isolation	500 VAC, 1 min
Maximum number of expansion modules	2	Power Supply	
Digital I/O supported	64 inputs/64 outputs	Voltage/frequency range	20 to 29 VAC at 47 to 63 Hz
Analog I/O supported	16 inputs/16 outputs	Input current	4 VA typical, CPU only 50 VA maximum load
Boolean execution speed	1.2 µs/instruction	Holdup time	20 ms minimum from 24 VAC
Internal memory bits	128	Inrush current	20 A peak at 29 VAC
Timers	64 timers	Fusing (non-replaceable)	2 A, 250 V, slow blow
Counters	64 counters	5 VDC current	260 mA for CPU 340 mA for expansion I/O
High-speed counters	1 software (2 KHz max.)	Isolated	Yes. Transformer, 500 VAC, 1 min
Analog adjustments	1	DC Sensor Supply	
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Voltage range	20.4 to 28.8 VDC
Output Points		Ripple/noise (<10MHz)	1 V peak-to-peak maximum
Output type	Relay, dry contact	24 VDC available current	180 mA
Voltage range	5 to 30 VDC/250 VAC	Short circuit current limit	< 600 mA
Maximum load current	2 A /point, 6 A /common	Isolated	No
Overcurrent surge	7 A with contacts closed		
Isolation resistance	100 MΩ minimum (new)		
Switching delay	10 ms maximum		
Lifetime	10,000,000 mechanical 100,000 with rated load		
Contact resistance	200 mΩ maximum (new)		
Isolation			
coil to contact	1500 VAC, 1 min		
contact to contact (between open contacts)	750 VAC, 1 min		
Short circuit protection	None		

¹ The CPU reserves 8 process-image input and 8 process-image output image register points for local I/O.

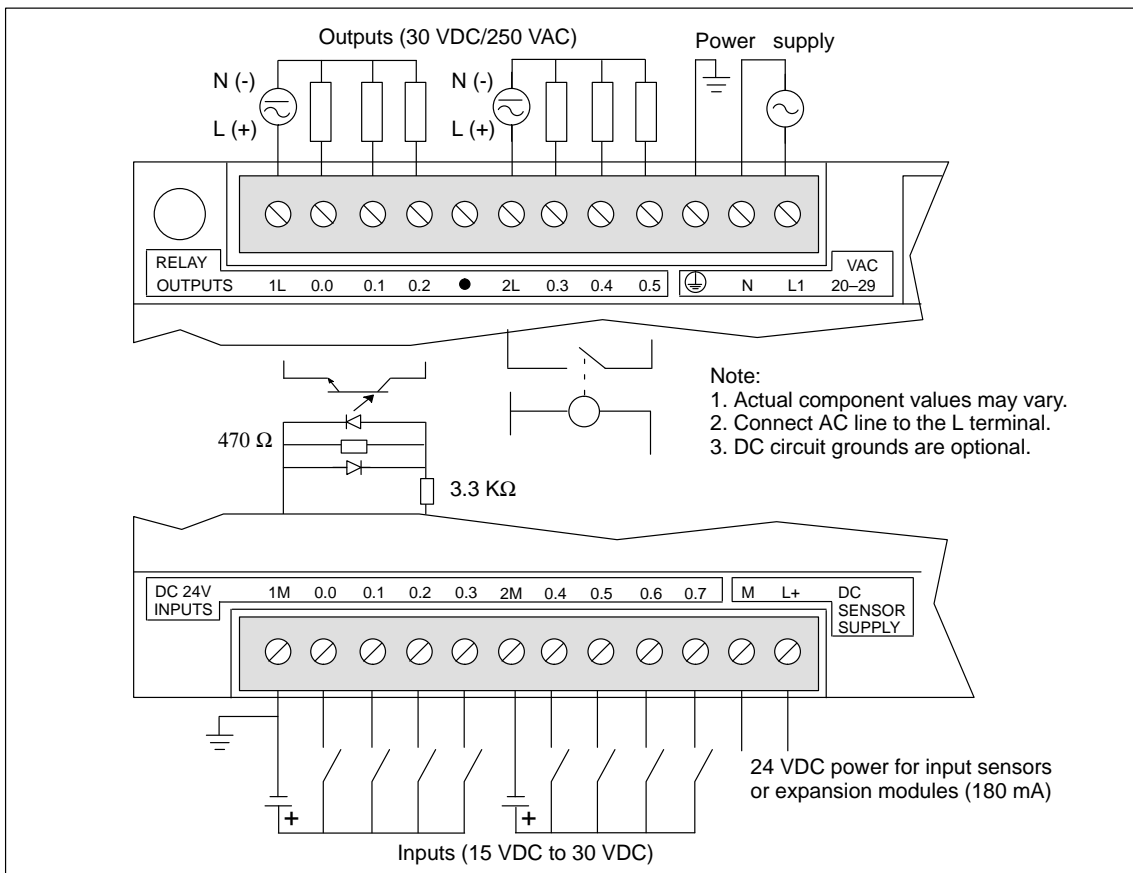


Figure A-4 Connector Terminal Identification for CPU 212 24 VAC/DC/Relay

A.5 CPU 212 AC Power Supply, AC Inputs, AC Outputs

Order Number: 6ES7 212-1CA01-0XB0

General Features		Output Points (continued)	
Physical size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Switching delay	1/2 cycle
Weight	0.4 kg (0.9 lbs.)	Surge current	30 A peak, 1 cycle / 10 A peak, 5 cycle
Power dissipation	7 W at 2.5 A load	Voltage drop	1.5 V maximum at maximum current
User program size/storage	512 words/EEPROM	Optical isolation	1500 VAC, 1 min
User data size/storage	512 words/RAM	Short circuit protection	None
Data retention	50 hr typical (8 hr minimum at 40° C)	Input Points	
Local I/O ¹	8 inputs/6 outputs	Input type (IEC 1131-2)	Type 1 sinking
Maximum number of expansion modules	2	ON state range	79 to 135 VAC, 47 to 63 Hz, 4 mA minimum
Digital I/O supported	64 inputs/64 outputs	ON state nominal	120 VAC, 60 Hz, 7 mA
Analog I/O supported	16 inputs/16 outputs	OFF state maximum	20 VAC, 1 mA
Boolean execution speed	1.2 µs/instruction	Response time	10 ms typical, 15 ms max.
Internal memory bits	128	Optical isolation	1500 VAC, 1 min
Timers	64 timers	Power Supply	
Counters	64 counters	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
High-speed counters	1 software (50 Hz max.)	Input current	4 VA typical, CPU only 50 VA maximum load
Analog adjustments	1	Holdup time	20 ms minimum from 110 VAC
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Inrush current	20 A peak at 264 VAC
Output Points		Fusing (non-replaceable)	2 A, 250 V, slow blow
Output type	Triac, zero-crossing	5 VDC current	320 mA for CPU 280 mA for expansion I/O
Voltage/frequency range	20 to 264 VAC, 47 to 63 Hz	Isolated	Yes. Transformer, 1500 VAC, 1 min
Load circuit power factor	0.3 to 1.0	DC Sensor Supply	
Inductive load clamping	MOV 275 V working voltage	Voltage range	20.4 to 28.8 VDC
Maximum load current	0 to 40° C 55° C ²	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
per single point	1.20 A 1.00 A	24 VDC available current	180 mA
per 2 adjacent points	1.50 A 1.25 A	Short circuit current limit	< 600 mA
all points total*	3.50 A 2.50 A	Isolated	No
Minimum load current	30 mA		
Leakage current	1.5 mA, 120 VAC/2.0 mA, 240 VAC		

¹ The CPU reserves 8 process-image input and 8 process-image output register points for local I/O.

² Linear derate 40 to 55° C. Vertical mount derate 10° C.

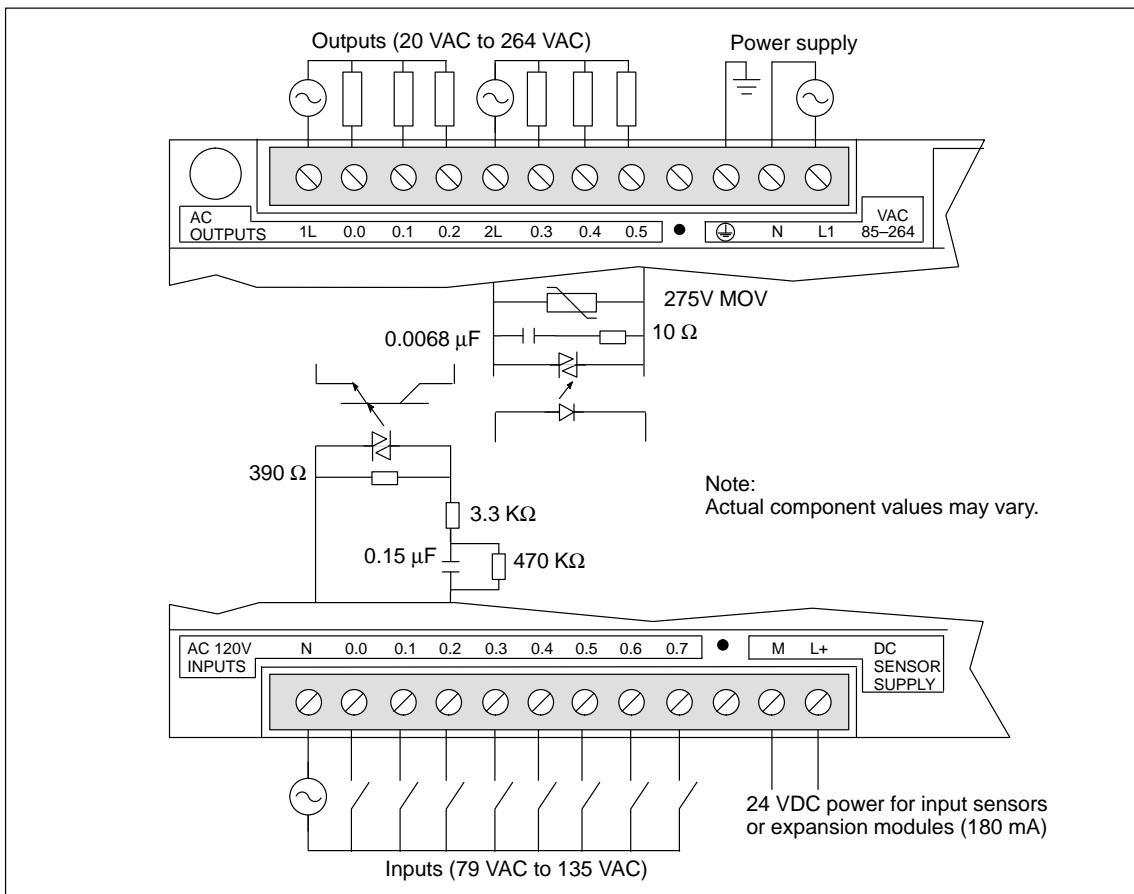


Figure A-5 Connector Terminal Identification for CPU 212 AC/AC/AC

A.6 CPU 212 AC Power Supply, Sourcing DC Inputs, Relay Outputs

Order Number: 6ES7 212-1BA10-0XB0

General Features		Input Points	
Physical size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Type	Sourcing
Weight	0.4 kg (0.9 lbs.)	Input voltage range	15 to 30 VDC, 35 VDC for 500 ms
Power dissipation	6 W	ON state	4 mA minimum
User program size/storage	512 words/EEPROM	OFF state	1 mA maximum
User data size/storage	512 words/RAM	Response time	0.3 ms maximum
Data retention	50 hr typical (8 hr minimum at 40° C)	10.0 to I0.7	
Local I/O ¹	8 inputs/6 outputs	Optical isolation	500 VAC, 1 min
Maximum number of expansion modules	2		
Digital I/O supported	64 inputs/64 outputs	Power Supply	
Analog I/O supported	16 inputs/16 outputs	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
Boolean execution speed	1.2 µs/instruction	Input current	4 VA typical, CPU only 50 VA maximum load
Internal memory bits	128	Holdup time	20 ms minimum from 110 VAC
Timers	64 timers	Inrush current	20 A peak at 264 VAC
Counters	64 counters	Fusing (non-replaceable)	2 A, 250 V, slow blow
High-speed counters	1 software (2 KHz max.)	5 VDC available current	260 mA for CPU 340 mA for expansion I/O
Analog adjustments	1	Isolated	Yes. Transformer, 1500 VAC, 1 min
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant		
Output Points		DC Sensor Supply	
Output type	Relay, dry contact	Voltage range	20.4 to 28.8 VDC
Voltage range	5 to 30 VDC/250 VAC	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
Maximum load current	2 A /point, 6 A/common	24 VDC available current	180 mA
Overcurrent surge	7 A with contacts closed	short circuit current limit	< 600 mA
Isolation resistance	100 MΩ minimum (new)	Isolated	No
Switching delay	10 ms maximum		
Lifetime	10,000,000 mechanical 100,000 with rated load		
Contact resistance	200 mΩ maximum (new)		
Isolation			
coil to contact	1500 VAC, 1 min		
contact to contact (between open contacts)	750 VAC, 1 min		
Short circuit protection	None		

¹ The CPU reserves 8 process-image input and 8 process-image output register points for local I/O.

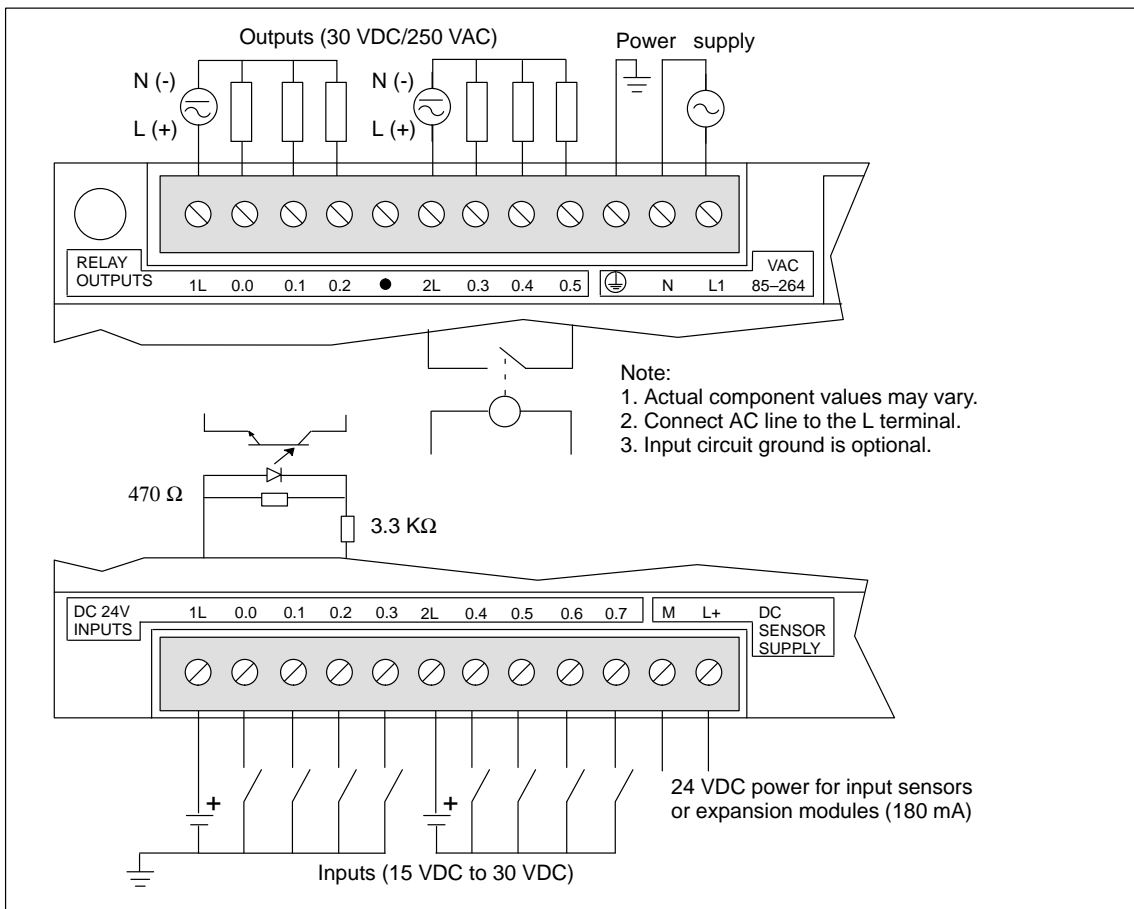


Figure A-6 Connector Terminal Identification for CPU 212 AC/Sourcing DC/Relay

A.7 CPU 212 AC Power Supply, 24 VAC Inputs, AC Outputs

Order Number: 6ES7 212-1DA01-0XB0

General Features		Output Points (continued)	
Physical size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Switching delay	1/2 cycle
Weight	0.4 kg (0.9 lbs.)	Surge current	30 A peak, 1 cycle / 10 A peak, 5 cycle
Power dissipation	7 W at 2.5 A load	Voltage drop	1.5 V maximum at maximum current
User program size/storage	512 words/EEPROM	Optical isolation	1500 VAC, 1 min
User sata size/storage	512 words/RAM	Short circuit protection	None
Data retention	50 hr typical (8 hr minimum at 40° C)	Input Points	
Local I/O ¹	8 inputs/6 outputs	Input type (IEC 1131-2)	Type 1 sinking
Maximum number of expansion modules	2	ON state range	15 to 30 VAC, 47 to 63 Hz, 4 mA minimum
Digital I/O supported	64 inputs/64 outputs	ON state nominal	24 VAC, 60 Hz, 7 mA
Analog I/O supported	16 inputs/16 outputs	OFF state maximum	5 VAC, 1 mA
Boolean execution speed	1.2 µs/instruction	Response time	10 ms typical, 15 ms max.
Internal memory bits	128	Optical isolation	1500 VAC, 1 min
Timers	64 timers	Power Supply	
Counters	64 counters	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
High-speed counters	1 software (50 Hz max.)	Input current	4 VA typical, CPU only 50 VA maximum load
Analog adjustments	1	Holdup time	20 ms minimum from 110 VAC
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Inrush current	20 A peak at 264 VAC
Output Points		Fusing (non-replaceable)	2 A, 250 V, slow blow
Output type	Triac, zero-crossing	5 VDC current	320 mA for CPU 280 mA for expansion I/O
Voltage/frequency range	20 to 264 VAC, 47 to 63 Hz	Isolated	Yes. Transformer, 1500 VAC, 1 min
Load circuit power factor	0.3 to 1.0	DC Sensor Supply	
Inductive load clamping	MOV 275 V working voltage	Voltage range	20.4 to 28.8 VDC
Maximum load current	0 to 40° C 55° C ²	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
per single point	1.20 A 1.00 A	24 VDC available current	180 mA
per 2 adjacent points	1.50 A 1.25 A	Short circuit current limit	< 600 mA
all points total	3.50 A 2.50 A	Isolated	No
Minimum load current	30 mA		
Leakage current	1.5 mA, 120 VAC/2.0 mA, 240 VAC		

¹ The CPU reserves 8 process-image input and 8 process-image output register points for local I/O.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

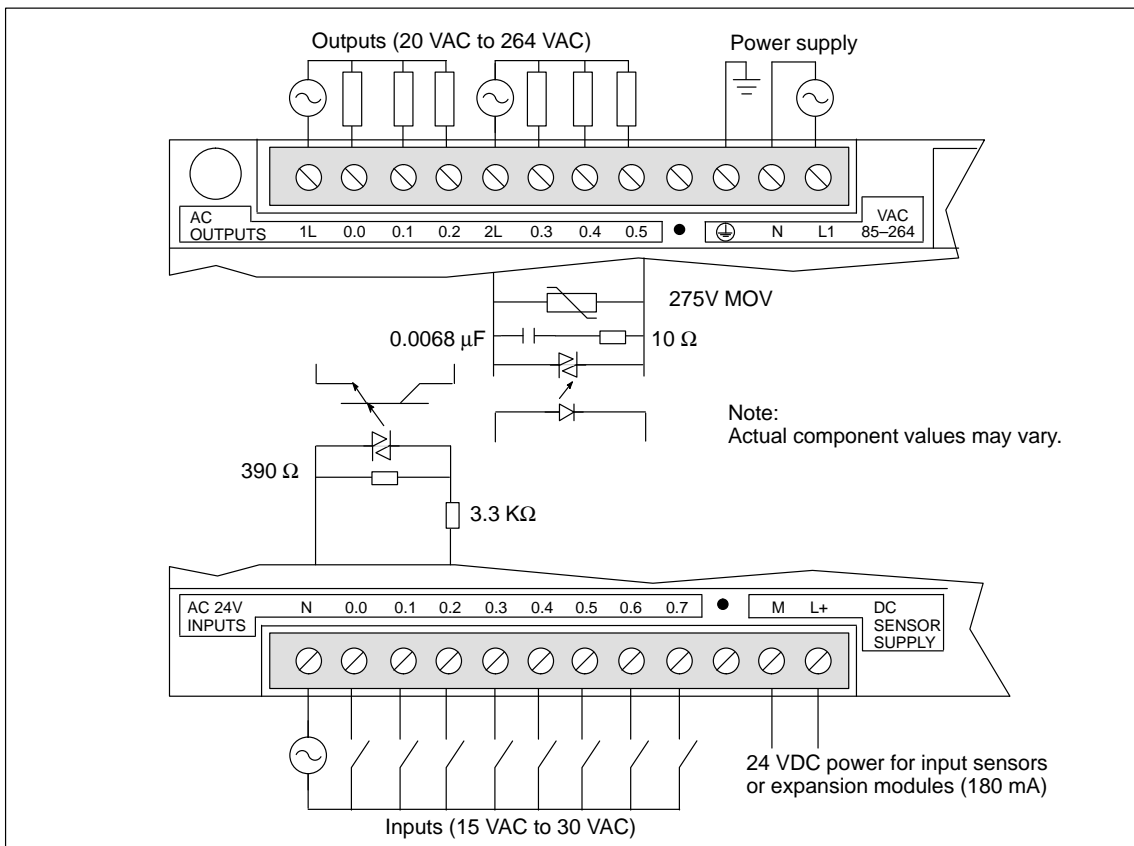


Figure A-7 Connector Terminal Identification for CPU 212 AC/AC/AC

A.8 CPU 212 AC Power Supply, AC Inputs, Relay Outputs

Order Number: 6ES7 212-1GA01-0XB0

General Features		Input Points	
Physical Size (L x W x D)	160 x 80 x 62 mm (6.3 x 3.15 x 2.44 in.)	Input Type (IEC 1131-2)	Type 1 Sinking
Weight	0.4 kg (0.9 lbs.)	ON State Range	79 to 135 VAC, 47 to 63 Hz. 4 mA minimum
Power Dissipation	6 W	ON State Nominal	120 VAC, 60 Hz, 7mA
User program size/storage	512 Words / EEPROM	OFF State Maximum	20 VAC, 1 mA
User data size/storage	512 Words / RAM	Response Time	10 ms typical, 15 ms max.
Data retention	50 hr typical (8 hr minimum at 40° C)	Optical Isolation	1500 VAC, 1 minute
Local I/O ¹	8 Inputs / 6 Outputs	Power Supply	
Maximum Number of Expansion Modules	2	Voltage/frequency Range	85 to 264 VAC at 47 to 63 Hz
Digital I/O Supported	64 Inputs / 64 Outputs	Input Current	4 VA typical, CPU only 50 VA maximum load
Analog I/O Supported	16 Inputs / 16 Outputs	Hold Up Time	20 ms minimum from 110 VAC
Boolean Execution Speed	1.2 µs/instruction	Inrush Current	20 A peak at 264 VAC
Internal Memory Bits	128	Fusing (non-replaceable)	2 A, 250 V, Slow Blow
Timers	64 Timers	5 VDC Current	260 mA for CPU 340 mA for expansion I/O
Counters	64 Counters	Isolated	Yes. Transformer, 1500 VAC, 1 minute
High-speed counters	1 Software (2 KHz max.)	DC Sensor Supply	
Analog Adjustments	1	Voltage Range	20.4 to 28.8 VDC
Standards Compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Ripple/noise (<10Mhz)	1 V peak-to-peak maximum
Output Points		24 VDC Available Current	180 mA
Output Type	Relay, dry contact	Short Circuit Current Limit	< 600 mA
Voltage Range	5 to 30 VDC / 250 VAC	Isolated	No
Maximum Load Current	2 A/point		
Overcurrent Surge	7 A with contacts closed		
Isolation Resistance	100 MΩ minimum (new)		
Switching Delay	10 ms maximum		
Lifetime	10,000,000 Mechanical 100,000 with Rated Load		
Contact Resistance	200 mΩ maximum (new)		
Isolation			
Coil to Contact	1500 VAC, 1 minute		
Contact to Contact	1000 VAC, 1 minute		
Short Circuit Protection	None		

¹ The CPU reserves 8 input and 8 output image register points for local I/O.

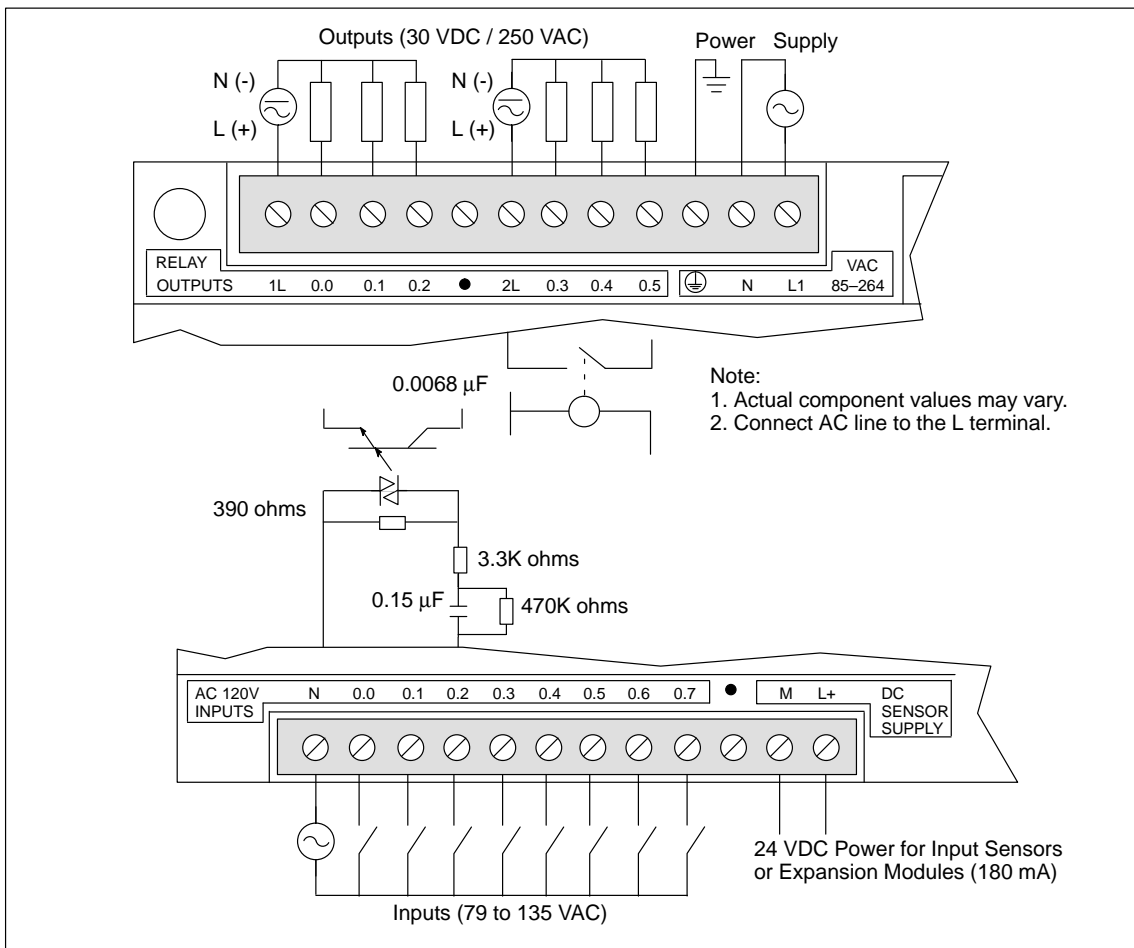


Figure A-8 Connector Terminal Identification for CPU 212 AC/AC/Relay

A.9 CPU 214 DC Power Supply, DC Inputs, DC Outputs

Order Number: 6ES7 214-1AC01-0XB0

General Features		Optical isolation	
Physical size (L x W x D)	197 x 80 x 62 mm (7.76 x 3.15 x 2.44 in.)		500 VAC, 1 min
Weight	0.4 kg (0.9 lbs.)	Output Points	
Power dissipation	8 W at 3 A load	Output type	Sourcing Transistor
User program size/storage	2 Kwords/EEPROM	Voltage range	20.4 to 28.8 VDC
User data size/storage	2 Kwords/RAM	Maximum load current	<u>0 to 40° C</u> <u>55° C</u> ²
Data and TOD retention		per single point	0.75 A 0.50 A
Supercap	190 hr typ. (120 hr minimum at 40° C)	per 2 adjacent points	1.00 A 0.75 A
Optional battery	200 days continuous usage	all points total	4.00 A 3.00 A
Local I/O ¹	14 inputs/10 outputs	Inductive load clamping	(per common)
Max. I/O expansion modules	7	Single pulse	2A L/R = 10 ms 1A L/R = 100 ms
Digital I/O supported	64 inputs/64 outputs	Repetitive	1 W energy dissipation (1/2 Li ² x switch rate < 1 W)
Analog I/O supported	16 inputs/16 outputs	Leakage current	100 µA
Boolean execution speed	0.8 µs/instruction	Switching delay	25 µs ON, 120 µs OFF
Internal memory bits	256	Surge current	4 A, 100 ms
Timers	128 timers	Voltage drop	1.8 V maximum at maximum current
Counters	128 counters	Optical isolation	500 VAC, 1 min
High-speed counters	1 software (2 KHz max.) 2 hardware (7 KHz max. ea.)	Short circuit protection	None
TOD clock tolerance	6 minutes per month	Power Supply	
Pulse outputs	2 (4 KHz max. each)	Voltage range	20.4 to 28.8 VDC
Analog adjustments	2	Input current	85 mA typical, CPU only 900 mA, maximum load
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	UL/CSA rating	50VA
		Holdup time	10 ms min. from 24 VDC
		Inrush current	10 A peak at 28.8 VDC
		Fusing (non-replaceable)	1 A, 125 V, slow blow
		5 VDC current	340 mA for CPU 660 mA for expansion I/O
		Isolated	No
Input Points		DC Sensor Supply	
Input type (IEC 1131-2)	Type 1 sinking	Voltage range	16.4 to 28.8 VDC
ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge	Ripple/noise (<10MHz)	Same as supplied voltage
ON state nominal	24 VDC, 7 mA	24 VDC available current	280 mA
OFF state maximum	5 VDC, 1 mA	Short circuit current limit	< 600 mA
Maximum response time		Isolated	No
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default		
I0.6 to I1.5 as used by HSC1 and HSC2	30 µs typical / 70 µs max.		

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

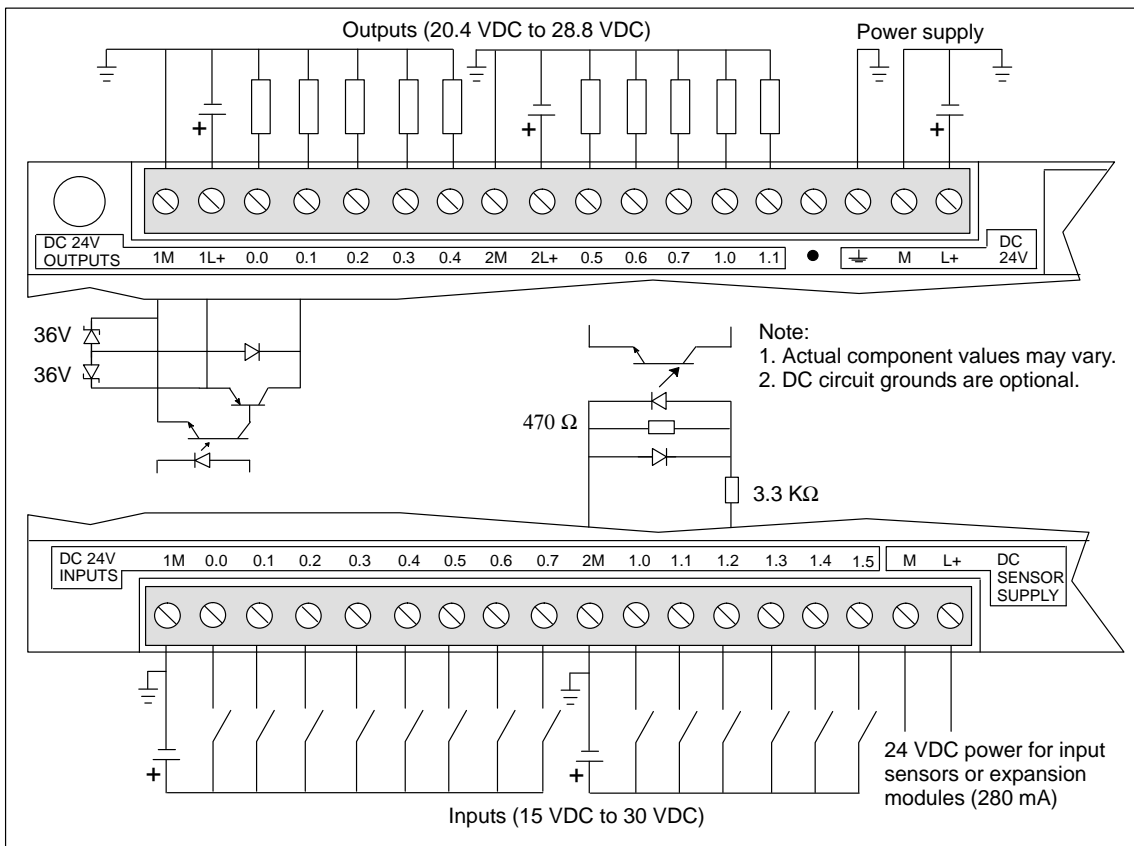


Figure A-9 Connector Terminal Identification for CPU 214 DC/DC/DC

A.10 CPU 214 AC Power Supply, DC Inputs, Relay Outputs

Order Number: 6ES7 214-1BC01-0XB0

General Features		Output Points	
Physical size (L x W x D)	197 x 80 x 62 mm (7.76 x 3.15 x 2.44 in.)	Output type	Relay, dry contact
Weight	0.5 kg (1.0 lbs.)	Voltage range	5 to 30 VDC/250 VAC
Power dissipation	9 W	Maximum load current	2 A/point, 8 A/common
User program size/Storage	2 Kwords/EEPROM	Overcurrent surge	7 A with contacts closed
User data size/storage	2 Kwords/RAM	Isolation resistance	100 M Ω minimum (new)
Data and TOD retention		Switching delay	10 ms maximum
Supercap	190 hr typ. (120 hr minimum at 40° C)	Lifetime	10,000,000 mechanical 100,000 with rated load
Optional battery	200 days continuous usage	Contact resistance	200 m Ω maximum (new)
Local I/O ¹	14 inputs/10 outputs	Isolation	
Max. I/O expansion modules	7	coil to contact	1500 VAC, 1 min
Digital I/O supported	64 inputs/64 outputs	contact to contact	750 VAC, 1 min
Analog I/O supported	16 inputs/16 outputs	(between open contacts)	
Boolean execution speed	0.8 μ s/instruction	Short circuit protection	none
Internal memory bits	256	Power Supply	
Timers	128 timers	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
Counters	128 counters	Input current	4.5 VA typical, CPU only 50 VA max. load
High-speed counters	1 software (2 KHz max.) 2 hardware (7 KHz max. ea.)	Holdup time	20 ms min. from 110 VAC
TOD clock tolerance	6 minutes per month	Inrush current	20 A peak at 264 VAC
Pulse outputs	Not recommended	Fusing (non-replaceable)	2 A, 250 V, slow blow
Analog adjustments	2	5 VDC current	340 mA for CPU 660 mA for expansion I/O
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Isolated	Yes. Transformer, 1500 VAC, 1 min
Input Points		DC Sensor Supply	
Input type (IEC 1131-2)	Type 1 sinking	Voltage range	20.4 to 28.8 VDC
ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
ON state nominal	24 VDC, 7 mA	24 VDC available current	280 mA
OFF state maximum	5 VDC, 1 mA	Short circuit current limit	< 600 mA
Maximum response time		Isolated	No
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default		
I0.6 to I1.5 as used by HSC1 and HSC2	30 μ s typical / 70 μ s max.		
Optical isolation	500 VAC, 1 min		

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

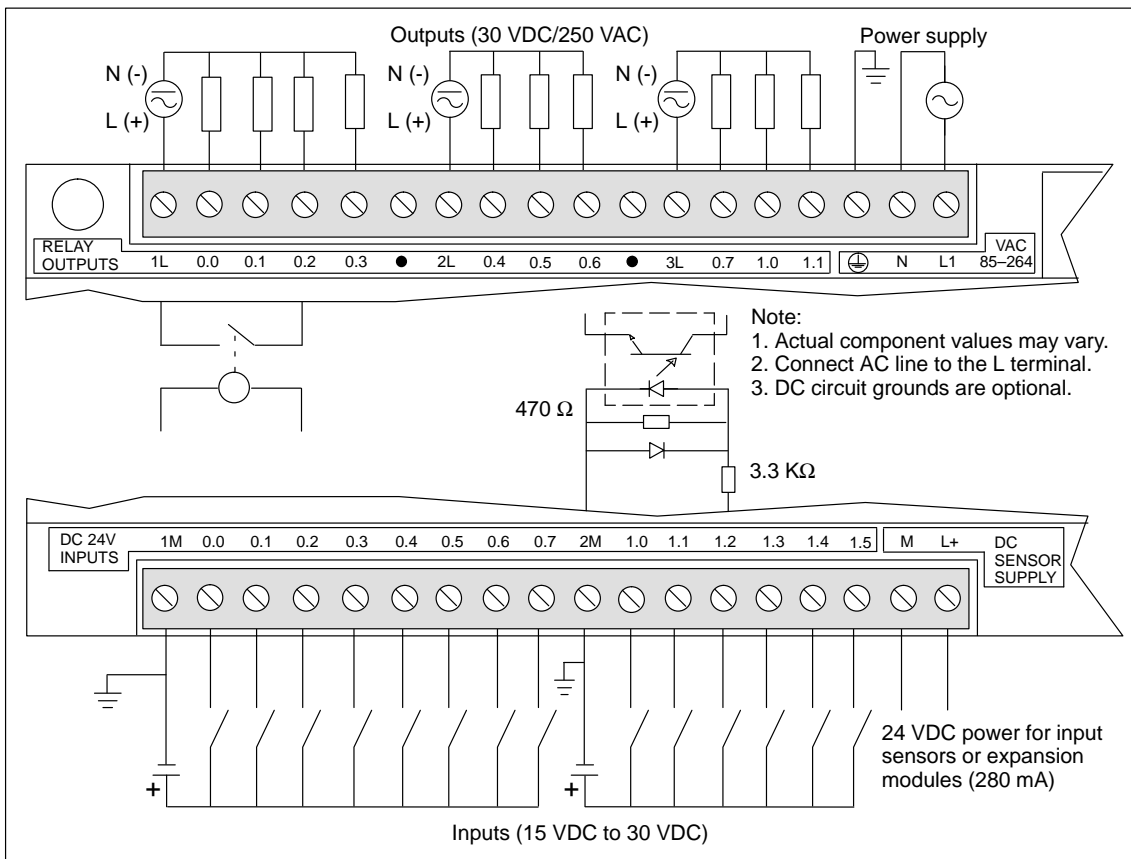


Figure A-10 Connector Terminal Identification for CPU 214 AC/DC/Relay

A.11 CPU 214 AC Power Supply, AC Inputs, AC Outputs

Order Number: 6ES7 214-1CC01-0XB0

General Features		Output Points	
Physical size (L x W x D)	197 x 80 x 62 mm (7.76 x 3.15 x 2.44 in.)	Output type	Triac, zero-crossing
Weight	0.5 kg (1.0 lbs.)	Voltage/frequency range	20 to 264 VAC, 47 to 63 Hz
Power dissipation	11 W at 4.25 A load	Load circuit power factor	0.3 to 1.0
User program size/storage	2 Kwords/EEPROM	Inductive load clamping	MOV 275 V working voltage
User data size/storage	2 Kwords/RAM	Maximum Load Current	<u>0 to 40° C</u> <u>55° C</u> ²
Data and TOD retention		per single point	1.20 A 1.00 A
Supercap	190 hr typ. (120 hr minimum at 40° C)	per 2 adjacent points	1.50 A 1.25 A
Optional battery	200 days continuous usage	all points total	6.00 A 4.25 A
Local I/O ¹	14 inputs/10 outputs	Minimum load current	30 mA
Max. I/O expansion modules	7	Leakage current	1.5 mA, 120 VAC/2.0 mA, 240 VAC
Digital I/O supported	64 inputs/64 outputs	Switching delay	1/2 cycle
Analog I/O supported	16 inputs/16 outputs	Surge current	30 A peak, 1 cycle / 10 A peak, 5 cycle
Boolean execution speed	0.8 µs/instruction	Voltage drop	1.5 V maximum at maximum current
Internal memory bits	256	Optical isolation	1500 VAC, 1 min
Timers	128 timers	Short circuit protection	None
Counters	128 counters	Power Supply	
High-speed counters	1 software (50 Hz) 2 hardware (50 Hz each)	Voltage / Frequency Range	85 to 264 VAC at 47 to 63 Hz
TOD Clock tolerance	6 minutes per month	Input Current	4.5 VA typical, CPU only 50 VA maximum load
Pulse outputs	2 (100 Hz each)	Hold Up Time	20 ms min. from 110 VAC
Analog adjustments	2	Inrush Current	20 A peak at 264 VAC
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Fusing (non-replaceable)	2 A, 250 V, slow blow
Input Points		5 VDC Current	440 mA for CPU 560 mA for expansion I/O
Input type (IEC 1131-2)	Type 1 sinking	Isolated	Yes. Transformer, 1500 VAC, 1 min
ON state range	79 to 135 VAC, 47 to 63 Hz, 4 mA minimum	DC Sensor Supply	
ON state nominal	120 VAC, 60 Hz, 7 mA	Voltage Range	20.4 to 28.8 VDC
OFF state maximum	20 VAC, 1 mA	Ripple/noise (<10MHz)	<1 V peak-to-peak maximum
Maximum response time	0.2 ms to 8.7 ms selectable plus 15.0 ms for fixed filter 15.2 ms default	24 VDC Available Current	280 mA
Optical isolation	1500 VAC, 1 min	Short Circuit Current Limit	< 600 mA
		Isolated	No

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

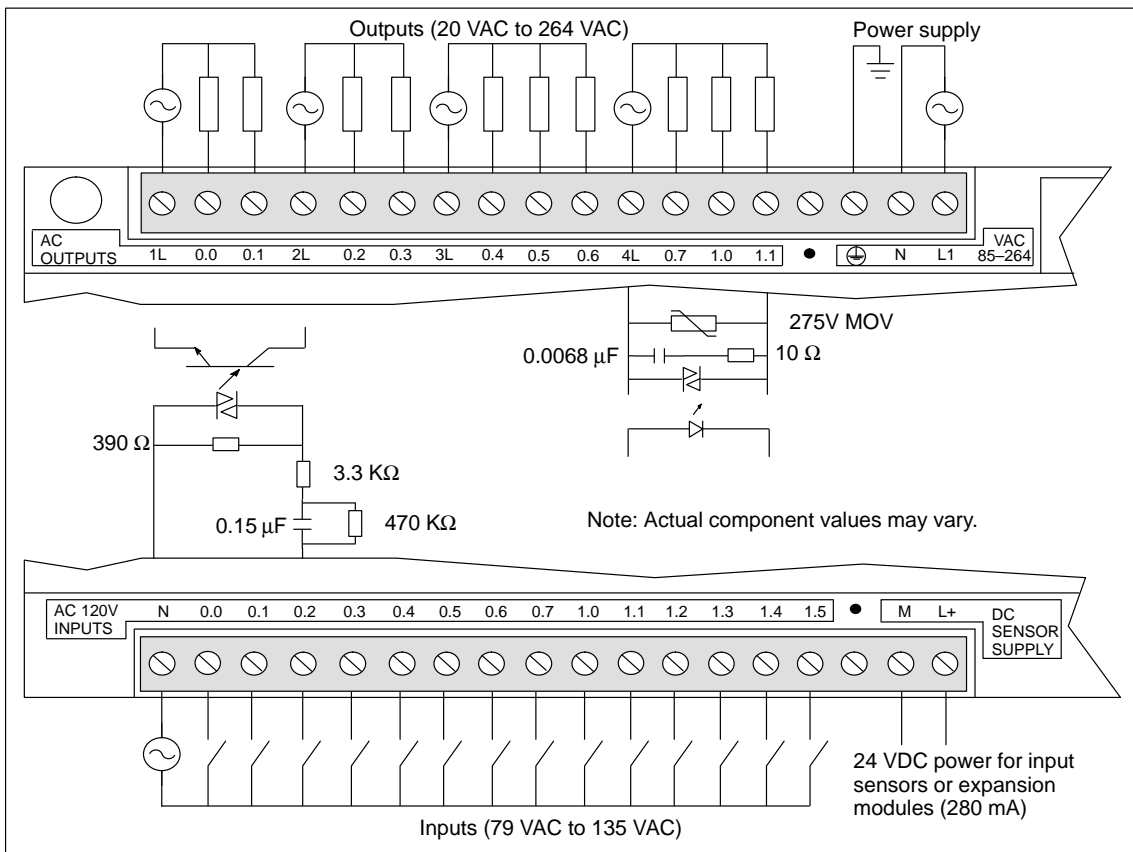


Figure A-11 Connector Terminal Identification for CPU 214 AC/AC/AC

A.12 CPU 214 AC Power Supply, Sourcing DC Inputs, Relay Outputs

Order Number: 6ES7 214-1BC10-0XB0

General Features		Output Points	
Physical size (L x W x D)	197 x 80 x 62 mm (7.76 x 3.15 x 2.44 in.)	Output type	Relay, dry contact
Weight	0.5 kg (1.0 lbs.)	Voltage range	5 to 30 VDC/250 VAC
Power dissipation	9 W	Maximum load current	2 A /point, 8 A/common
User program size/storage	2 Kwords/EEPROM	Overcurrent surge	7 A with contacts closed
User data size/storage	2 Kwords/RAM	Isolation resistance	100 M Ω minimum (new)
Data and TOD retention		Switching delay	10 ms maximum
Supercap	190 hr typ. (120 hr minimum at 40° C)	Lifetime	10,000,000 mechanical 100,000 with rated load
Optional battery	200 days continuous usage	Contact resistance	200 m Ω maximum (new)
Local I/O ¹	14 inputs/10 outputs	Isolation	
Max. I/O expansion modules	7	Coil to contact	1500 VAC, 1 min
Digital I/O supported	64 inputs/64 outputs	Contact to contact	750 VAC, 1 min (Between open contacts)
Analog I/O supported	16 inputs/16 outputs	Short circuit protection	None
Boolean execution speed	0.8 μ s/instruction	Power Supply	
Internal memory bits	256	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
Timers	128 timers	Input current	4.5 VA typical, CPU only 50 VA max. load
Counters	128 counters	Holdup time	20 ms min. from 110 VAC
High-speed counters	1 software (2 KHz max.) 2 hardware (7 KHz max. ea.)	Inrush current	20 A peak at 264 VAC
TOD clock tolerance	6 minutes per month	Fusing (non-replaceable)	2 A, 250 V, slow blow
Pulse outputs	Not recommended	5 VDC current	340 mA for CPU 660 mA for expansion I/O
Analog adjustments	2	Isolated	Yes. Transformer, 1500 VAC, 1 min
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	DC Sensor Supply	
Input Points		Voltage range	20.4 to 28.8 VDC
Type	Sourcing	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
Input voltage range	15 to 30 VDC, 35 VDC for 500 ms	24 VDC available current	280 mA
ON state	4 mA minimum	Short circuit current limit	< 600 mA
OFF state	1 mA maximum	Isolated	No
Maximum response time			
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default		
I0.6 to I1.5 as used by HSC1 and HSC2	30 μ s typical/70 μ s max.		
Optical isolation	500 VAC, 1 min		

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

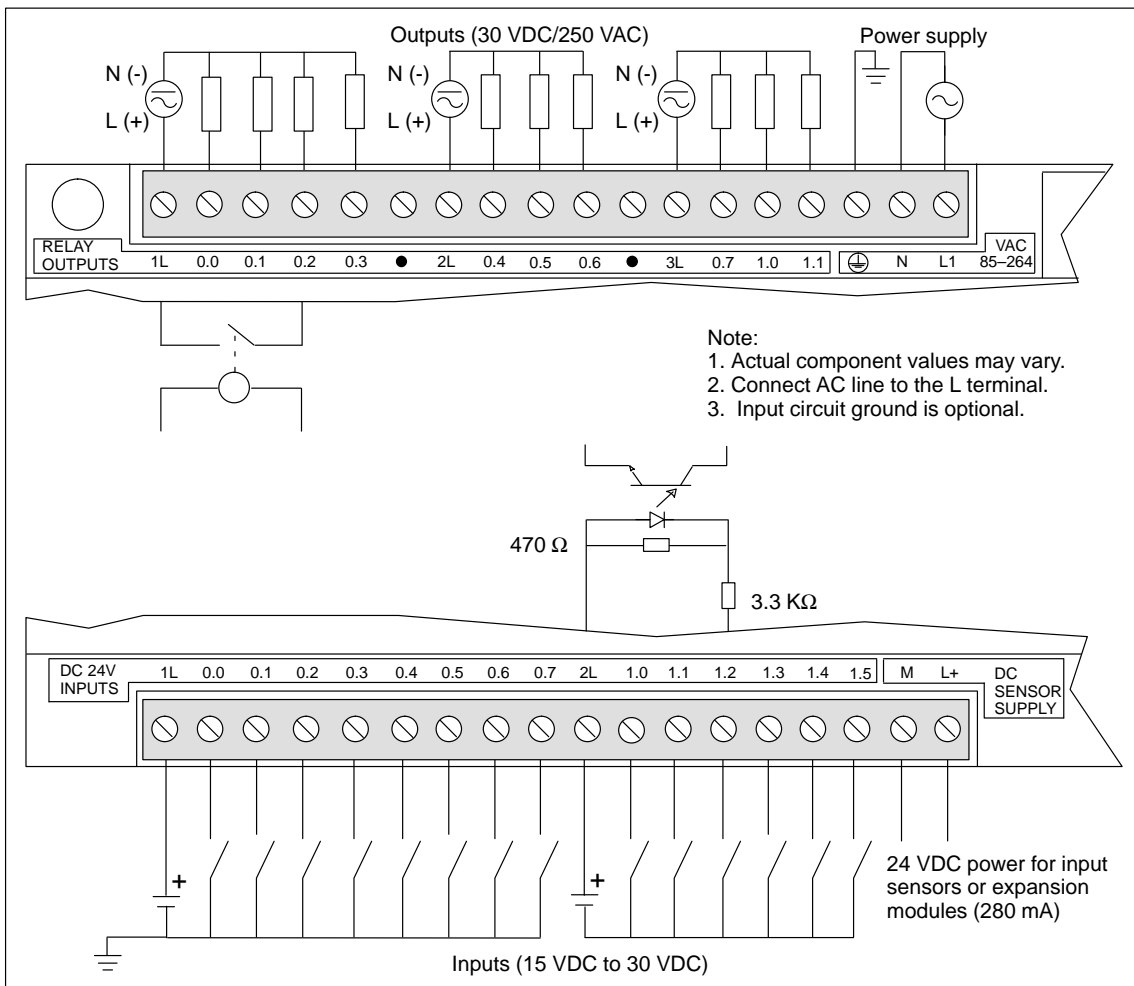


Figure A-12 Connector Terminal Identification for CPU 214 AC/Sourcing DC/Relay

A.13 CPU 214 AC Power Supply, 24 VAC Inputs, AC Outputs

Order Number: **6ES7 214-1DC01-0XB0**

General Features		Output Points	
Physical size (L x W x D)	197 x 80 x 62 mm (7.76 x 3.15 x 2.44 in.)	Output type	Triac, zero-crossing
Weight	0.5 kg (1.0 lbs.)	Voltage/frequency range	20 to 264 VAC, 47 to 63 Hz
Power dissipation	11 W at 4.25 A load	Load circuit power factor	0.3 to 1.0
User program size/storage	2 Kwords/EEPROM	Inductive load clamping	MOV 275 V working voltage
User data size/storage	2 Kwords/RAM	Maximum load current	<u>0 to 40° C</u> <u>55° C</u> ²
Data and TOD retention		per single point	1.20 A 1.00 A
Supercap	190 hr typ. (120 hr minimum at 40° C)	per 2 adjacent points	1.50 A 1.25 A
Optional battery	200 days continuous usage	all points total	6.00 A 4.25 A
Local I/O ¹	14 inputs/10 outputs	Minimum load current	30 mA
Max. I/O expansion modules	7	Leakage current	1.5 mA, 120 VAC/2.0 mA, 240 VAC
Digital I/O supported	64 inputs/64 outputs	Switching delay	1/2 cycle
Analog I/O supported	16 inputs/16 outputs	Surge current	30 A peak, 1 cycle / 10 A peak, 5 cycle
Boolean execution speed	0.8 µs/instruction	Voltage drop	1.5 V maximum at maximum current
Internal memory bits	256	Optical isolation	1500 VAC, 1 min
Timers	128 timers	Short circuit protection	None
Counters	128 counters	Power Supply	
High-speed counters	1 software (50 Hz) 2 hardware (50 Hz each)	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
TOD clock tolerance	6 minutes per month	Input current	4.5 VA typical, CPU only 50 VA maximum load
Pulse outputs	2 (100 Hz each)	Holdup time	20 ms min. from 110 VAC
Analog adjustments	2	Inrush current	20 A peak at 264 VAC
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Fusing (non-replaceable)	2 A, 250 V, slow blow
Input Points		5 VDC available current	440 mA for CPU 560 mA for expansion I/O
Input type (IEC 1131-2)	Type 1 sinking	Isolated	Yes. Transformer, 1500 VAC, 1 min
ON state range	15 to 30 VAC, 47 to 63 Hz, 4 mA minimum	DC Sensor Supply	
ON state nominal	24 VAC, 60 Hz, 7 mA	Voltage range	20.4 to 28.8 VDC
OFF state maximum	5 VAC, 1 mA	Ripple/noise (<10MHz)	<1 V peak-to-peak maximum
Maximum response time	0.2 ms to 8.7 ms selectable plus 15.0 ms for fixed filter 15.2 ms default	24 VDC available current	280 mA
Optical isolation	1500 VAC, 1 min	Short circuit current limit	< 600 mA
		Isolated	No

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

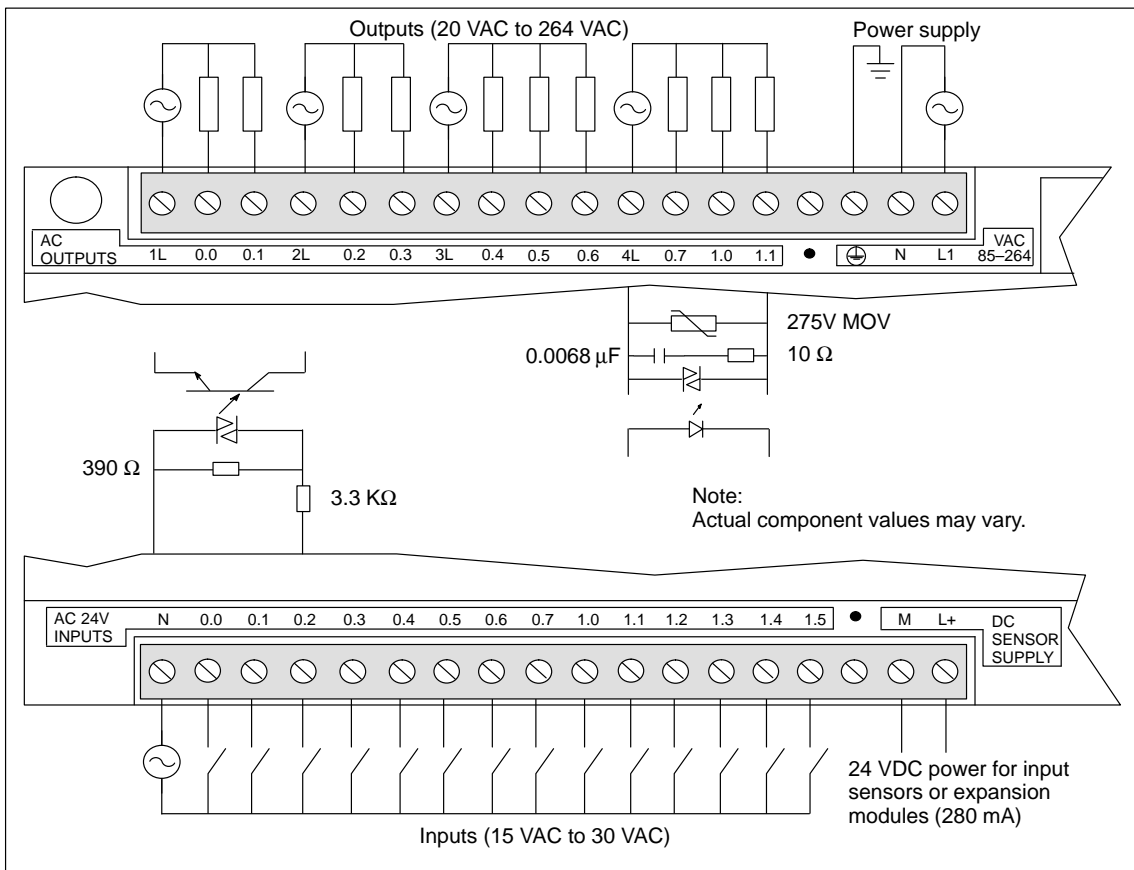


Figure A-13 Connector Terminal Identification for CPU 214 AC/AC/AC

A.14 CPU 214 AC Power Supply, AC Inputs, Relay Outputs

Model Number: 6ES7 214-1GC01-0XB0

General Features		Output Points	
Physical Size (L x W x D)	197 x 80 x 62 mm (7.75 x 3.15 x 2.44 in.)	Output Type	Relay, dry contact
Weight	0.5 kg (1.0 lbs.)	Voltage Range	5 to 30 VDC / 250 VAC
Power Dissipation	9 W	Maximum Load Current	2 A/point
User program size/storage	2K Words / EEPROM	Overcurrent Surge	7 A with contacts closed
User data size/storage	2K Words / RAM	Isolation Resistance	100 MΩ minimum (new)
Data and TOD Retention Supercap	190 hr typ. (120 hr minimum at 40° C)	Switching Delay	10 ms maximum
Optional Battery	200 days continuous usage	Lifetime	10,000,000 Mechanical 100,000 with Rated Load
Local I/O ¹	14 Inputs / 10 Outputs	Contact Resistance	200 mΩ maximum (new)
Max. I/O Expansion Modules	7	Isolation	
Digital I/O Supported	64 Inputs / 64 Outputs	Coil to Contact	1500 VAC, 1 minute
Analog I/O Supported	16 Inputs / 16 Outputs	Contact to Contact	1000 VAC, 1 minute
Boolean Execution Speed	0.8 μs/instruction	Short Circuit Protection	None
Internal Memory Bits	256	Power Supply	
Timers	128 Timers	Voltage / Frequency Range	85 to 264 VAC at 47 to 63 Hz
Counters	128 Counters	Input Current	4.5 VA typical, CPU only 50 VA max. load
High-speed counters	1 Software (2 KHz max.) 2 Hardware (7 KHz max. ea.)	Hold Up Time	20 ms min. from 110VAC
TOD Clock Tolerance	6 minutes per month	Inrush Current	20 A peak at 264 VAC
Pulse Outputs	Not recommended	Fusing (non-replaceable)	2 A, 250 V, Slow Blow
Analog Adjustments	2	5 VDC Current	340 mA for CPU 660 mA for expansion I/O
Standards Compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Isolated	Yes. Transformer, 1500 VAC, 1 minute
Input Points		DC Sensor Supply	
Input Type (IEC 1131-2)	Type 1 Sinking	Voltage Range	20.4 to 28.8 VDC
ON State Range	79 to 135 VAC, 47 to 63 Hz 4 mA minimum	Ripple/noise (<10Mhz)	1 V peak-to-peak maximum
ON State Nominal	120 VAC, 60 Hz. 7mA	24 VDC Available Current	280 mA
OFF State Maximum	20 VAC, 1 mA	Short Circuit Current Limit	< 600 mA
Maximum Response Time	0.2 ms to 8.7 ms selectable plus 15.0 ms for fixed filter 15.2 ms default	Isolated	No
Optical Isolation	1500 VAC, 1 minute		

¹ The CPU reserves 16 input and 16 output image register points for local I/O.

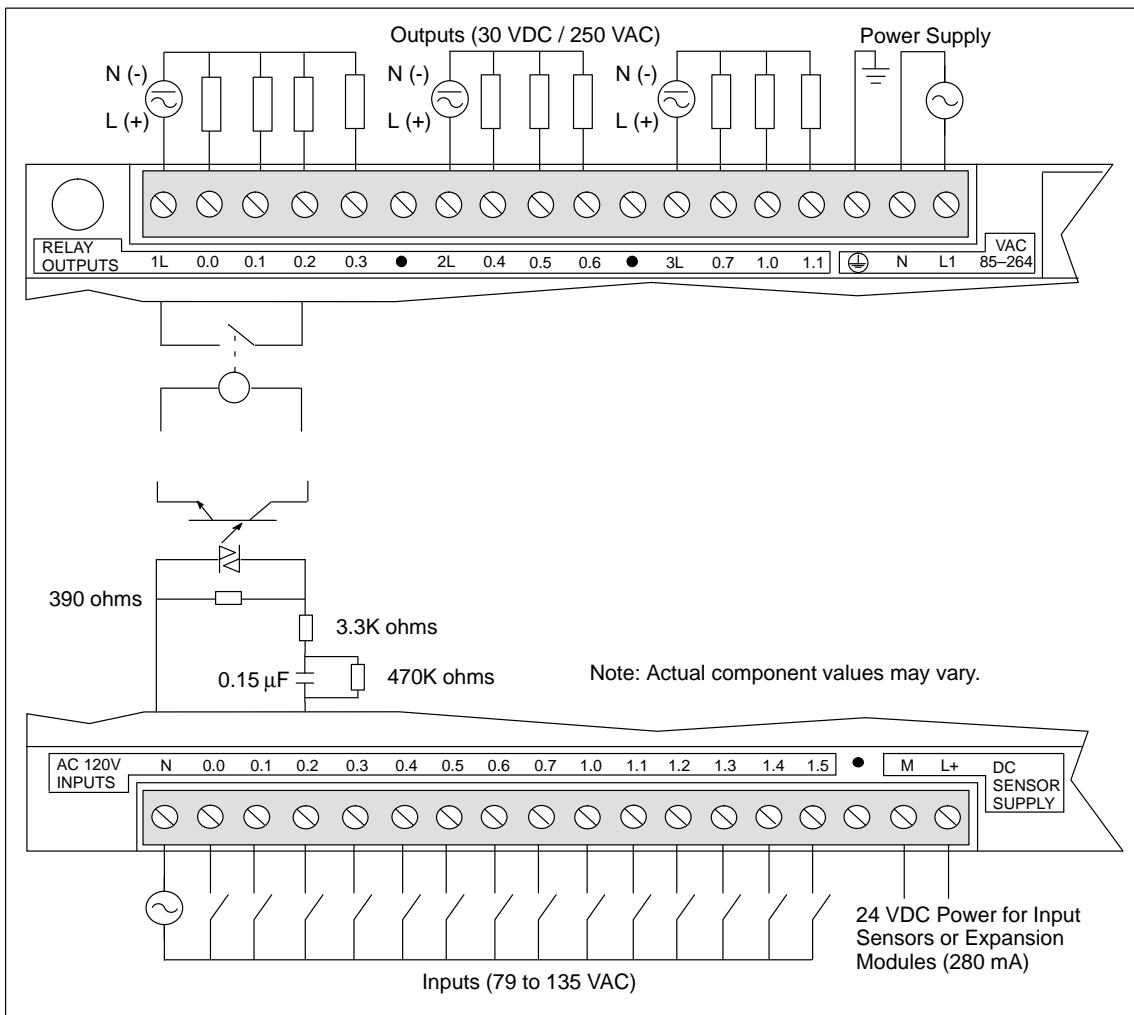


Figure A-14 Connector Terminal Identification for CPU 214 AC/AC/Relay

A.15 CPU 215 DC Power Supply, DC Inputs, DC Outputs

Order Number: 6ES7 215-2AD00-0XB0

General Features		Output Points	
Physical size (L x W x D)	217.3 x 80 x 62 mm (8.56 x 3.15 x 2.44 in.)	Output type	Sourcing MOSFET
Weight	0.5 kg (1.1 lbs.)	Voltage range	20.4 to 28.8 VDC
Power dissipation	8 W	Maximum load current	0 to 55° C
User program size/storage	4 Kwords/EEPROM	Q0.0 to Q0.7	0.5A/Point
User sata size/storage	2.5 Kwords/RAM	Q1.0, Q1.1	1.0A/Point
Data and TOD retention		Outputs may be connected parallel for higher current	
Supercap	190 hr typ. (120 hr minimum at 40° C)	Leakage current	
Optional battery	200 days continuous usage	Q0.0 to Q0.7	200 µA
Local I/O ¹	14 inputs/10 outputs	Q1.0, Q1.1	400 µA
Max. I/O expansion modules	7	Switching delay	
Digital I/O supported	64 inputs/64 outputs	Q0.0, 0.1	100 µs, ON/OFF
Analog I/O supported	16 inputs/16 outputs	All others	150 µs ON, 400 µs OFF
Boolean execution speed	0.8 µs/instruction	On resistance	400 mΩ max.
Internal memory bits	256	Short circuit protection	
Timers	256 timers	Q0.0 to Q0.7	0.7 to 1.5 A/channel
Counters	256 counters	Q1.0, Q1.1	1.5 to 3A/channel
High-speed counters	1 software (2 KHz max.) 2 hardware (20 KHz max. ea.)	Optical isolation	500 VAC, 1 min
TOD clock tolerance	6 minutes per month	Power Supply	
Pulse outputs	2 (4 KHz max. each)	Voltage range	20.4 to 28.8 VDC
Analog adjustments	2	Input current	120 mA typical, CPU only 1.3 A maximum load
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	UL/CSA rating	50VA
Input Points		Holdup time	10 ms min. from 24 VDC
Input type	Sink/Source IEC Type 1 in sink mode	Inrush current	10 A peak at 28.8 VDC
ON state range	15 to 30 VDC, 4 mA min. 35 VDC, 500 ms surge	Fusing (non-replaceable)	2 A, slow blow
ON state nominal	24 VDC, 7 mA	5 VDC current	1000 mA for expansion I/O
OFF state maximum	5 VDC, 1 mA	Isolated	No
Maximum response time		DC Sensor Supply	
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default	Voltage range	16.4 VDC to 28.8 VDC
I0.6 to I1.5 as used by HSC1 and HSC2	6 µs ON, 30 µs OFF	Ripple/noise (<10MHz)	Same as supplied Voltage
Optical isolation	500 VAC, 1 min	24 VDC available current	400 mA
		Short circuit current limit	< 600 mA
		Isolated	No
		5-V DP Communication Supply	
		5 VDC current:	90 mA, available at DP Port, pins 6-5, for DP Repeater
		Isolation	Transformer, 500 VAC, 1 min

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

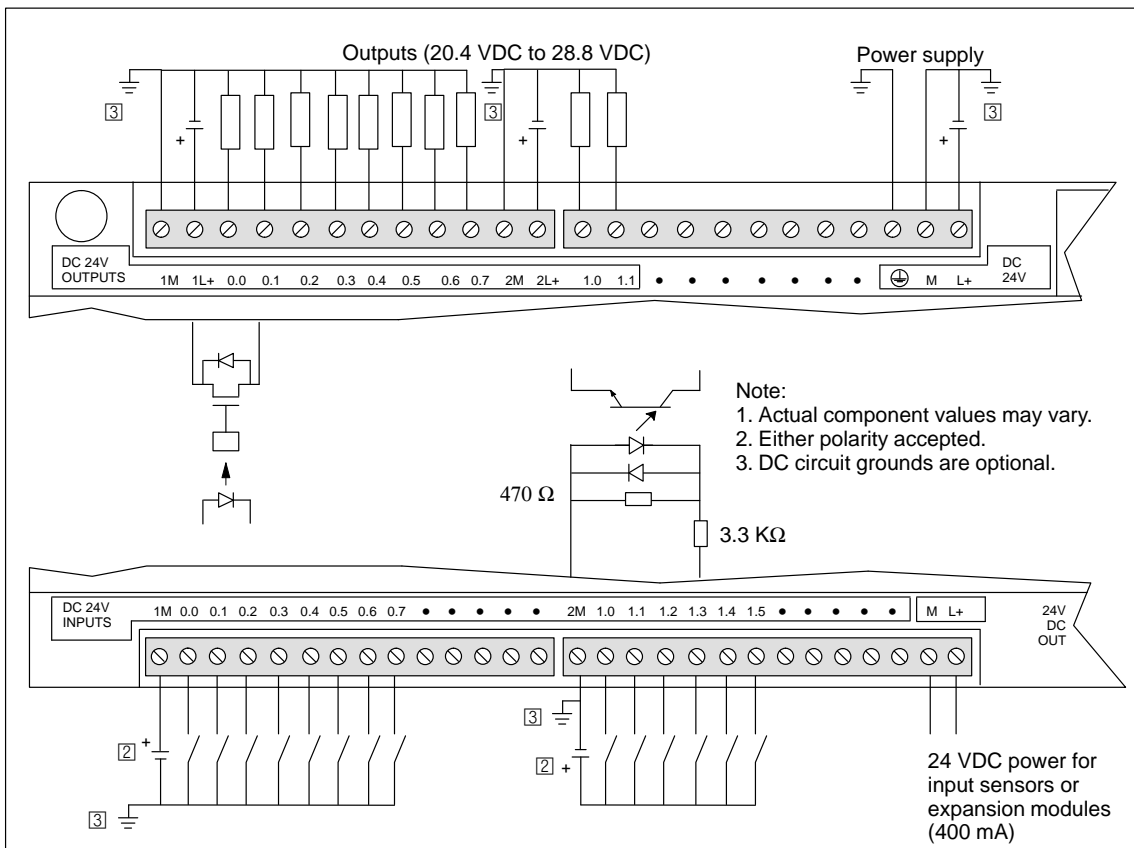


Figure A-15 Connector Terminal Identification for CPU 215 DC/DC/DC

A.16 CPU 215 AC Power Supply, DC Inputs, Relay Outputs

Order Number: 6ES7 215-2BD00-0XB0

General Features		Output Points	
Physical size (L x W x D)	217.3 x 80 x 62 mm (8.56 x 3.15 x 2.44 in.)	Output type	Relay, dry contact
Weight	0.6 kg (1.3 lbs.)	Voltage range	5 VDC to 30 VDC/250 VAC
Power dissipation	9 W	Maximum load current	2 A/point, 6 A/common
User program size/storage	4 Kwords/EEPROM	Overcurrent surge	7 A with contacts closed
User data size/storage	2.5 Kwords/RAM	Isolation resistance	100 M Ω minimum (new)
Data and TOD retention		Switching delay	10 ms maximum
Supercap	190 hr typ (120 hr min. at 40°C)	Lifetime	10,000,000 mechanical 100,000 with rated load
Optional battery	200 days continuous usage	Contact resistance	200 m Ω maximum (new)
Local I/O ¹	14 input/10 outputs	Isolation	
Max. I/O expansion modules	7	Coil to contact	1500 VAC, 1 min
Digital I/O supported	64 input/64 outputs	Contact to contact	750 VAC, 1 min
Analog I/O supported	16 inputs/16 outputs	(Between open contacts)	
Boolean execution speed	0.8 μ s/instruction	Short circuit protection	None
Internal memory bits	256	Power Supply	
Timers	256 Timers	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
Counters	256 Counters	Input current	6 VA typical, CPU only 50 VA max. load
High-speed counters	1 software (2 KHz max.) 2 hardware (20 KHz max. ea.)	Holdup time	20 ms min. from 110 VAC
TOD clock tolerance	6 minutes per month	Inrush current	20 A peak at 264 VAC
Pulse outputs	Not recommended	Fusing (non-replaceable)	2 A, 250 V, Slow Blow
Analog adjustments	2	5 VDC current	1000 mA for expansion I/O
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Isolated	Yes. Transformer, 1500 VAC, 1 min
Input Points		DC Sensor Supply	
Input type	Sink/Source IEC 1131 Type 1 in sink mode	Voltage range	19.2 to 28.8 VDC
ON state range	15 to 30 VDC, 4 mA minimum 35 VDC, 500 ms surge	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
ON state nominal	24 VDC, 7 mA	24 VDC available current	400 mA
OFF state maximum	5 VDC, 1 mA	Short circuit current limit	< 600 mA
Maximum response time		Isolated	No
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default	5-V DP Communication Supply	
I0.6 to I1.5 as used by HSC1 and HSC2	6 μ s ON, 30 μ s OFF	5 VDC current:	90 mA, available at DP Port, pins 6-5, for DP Repeater
		Isolation	Transformer, 500 VAC, 1 min

¹ The CPU reserves 16 process-image input and 16 process-image output register points for local I/O.

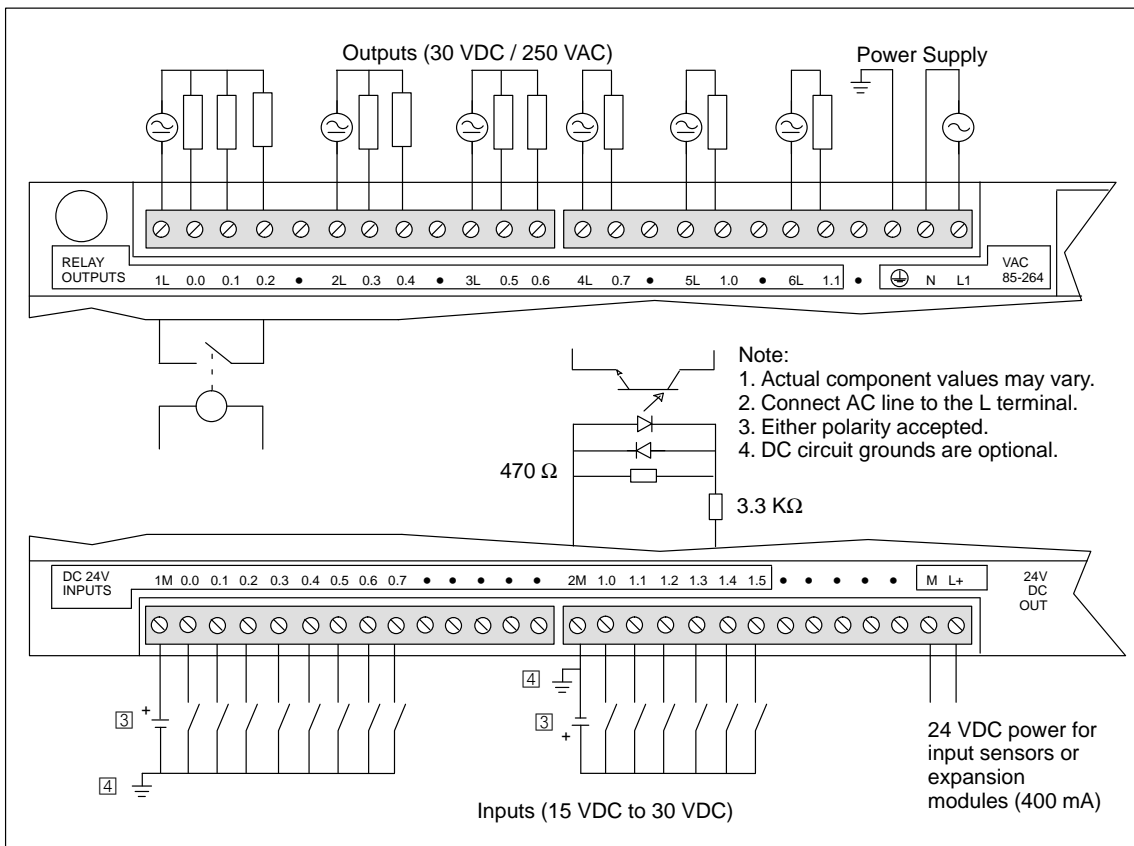


Figure A-16 Connector Terminal Identification for CPU 215 AC/DC/Relay

A.17 CPU 216 DC Power Supply, DC Inputs, DC Outputs

Order Number: 6ES7 216-2AD00-0XB0

General Features		Output Points	
Physical size (L x W x D)	217.3 x 80 x 62 mm (8.56 x 3.15 x 2.44 in.)	Output type	Sourcing MOSFET
Weight	0.5 kg (1.1 lbs.)	Voltage range	20.4 VDC to 28.8 VDC
Power dissipation	8 W	Maximum load current	0 to 55° C
User program size/storage	4 Kwords/EEPROM	Outputs may be connected parallel for higher current	0.5A/Point
User data size/storage	2.5 Kwords/RAM	Leakage current	200 µA
Data and TOD retention Supercap	190 hr typ. (120 hr minimum at 40° C)	Switching delay	
Optional battery	200 days continuous usage	Q0.0, 0.1	100 µs, ON/OFF
Local I/O ¹	24 inputs/16 outputs	All others	150 µs ON, 400 µs OFF
Max. I/O expansion modules	7	On resistance	400 mΩ max.
Digital I/O supported	64 inputs/64 outputs	Short circuit protection	0.7 to 1.5 A/channel
Analog I/O supported	16 inputs/16 outputs	Optical isolation	500 VAC, 1 min
Boolean execution speed	0.8 µs/instruction	Power Supply	
Internal memory bits	256	Voltage range	20.4 VDC to 28.8 VDC
Timers	256 timers	Input current	100 mA typical, CPU only 1.2A maximum load
Counters	256 counters	UL/CSA Rating	50VA
High-speed counters	1 software (2 KHz max.) 2 hardware (20 KHz max. ea.)	Holdup time	10 ms min. from 24 VDC
TOD clock tolerance	6 minutes per month	Inrush current	10 A peak at 28.8 VDC
Pulse outputs	2 (4 KHz max. each)	Fusing (non-replaceable)	2 A, slow blow
Analog adjustments	2	5 VDC current	1000 mA for expansion I/O
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Isolated	No
Input Points		DC Sensor Supply	
Input type	Sink/Source IEC 1131 Type 1 in sink mode	Voltage range	16.4 VDC to 28.8 VDC
ON state range	15 to 30 VDC, 4 mA min. 35 VDC, 500 ms surge	Ripple/noise (<10MHz)	Same as supplied voltage
ON state nominal	24 VDC, 7 mA	24 VDC available current	400 mA
OFF state maximum	5 VDC, 1 mA	Short circuit current limit	< 600 mA
Maximum response time		Isolated	No
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default		
I0.6 to I1.5 as used by HSC1 and HSC2	6 µs ON, 30 µs OFF		
I1.6 to I2.7	4 ms max		
Optical isolation	500 VAC, 1 min		

¹ The CPU reserves 24 process-image input and 16 process-image output register points for local I/O.

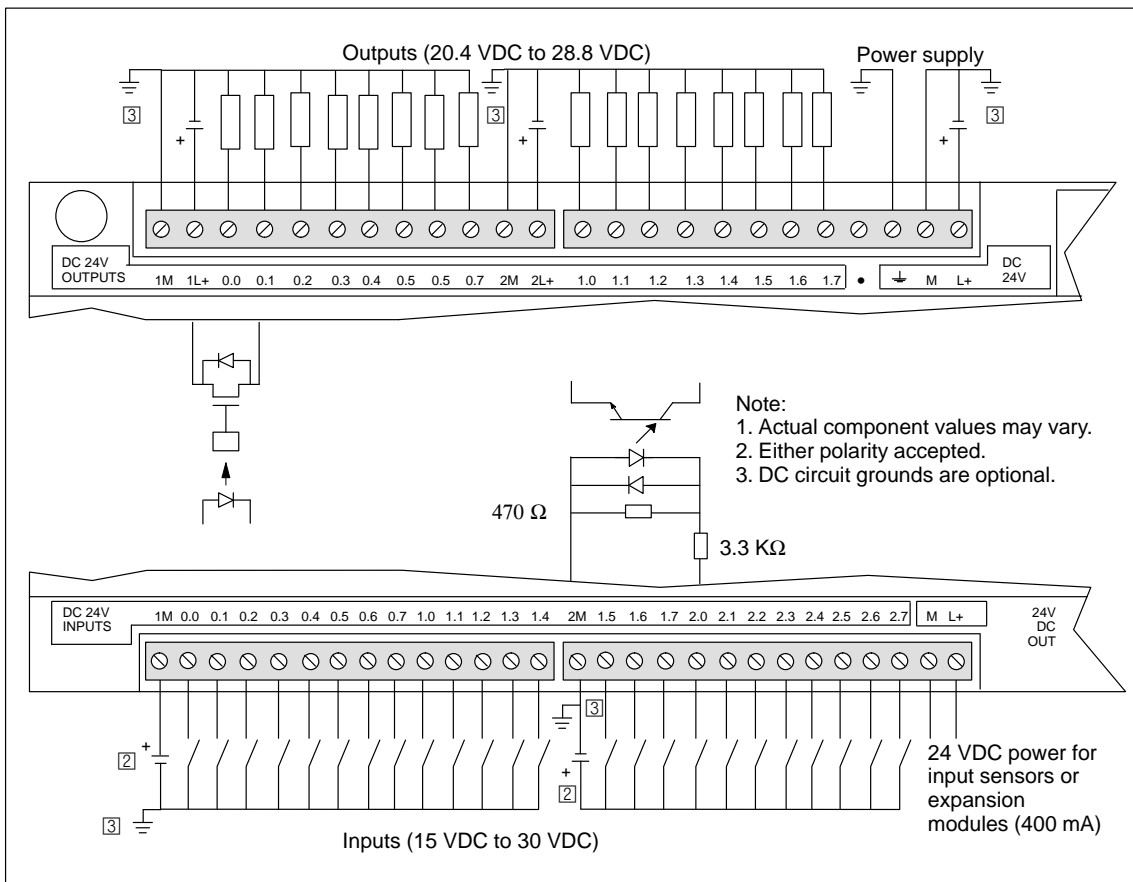


Figure A-17 Connector Terminal Identification for CPU 216 DC/DC/DC

A.18 CPU 216 AC Power Supply, DC Inputs, Relay Outputs

Order Number: 6ES7 216-2BD00-0XB0

General Features		Output Points	
Physical size (L x W x D)	217.3 x 80 x 62 mm (8.56 x 3.15 x 2.44 in.)	Output type	Relay, dry contact
Weight	0.6 kg (1.3 lbs.)	Voltage range	5 to 30 VDC/250 VAC
Power dissipation	9 W	Maximum load current	2 A/point, 10 A/common
User program size/storage	4 Kwords/EEPROM	Overcurrent surge	7 A with contacts closed
User data size/storage	2.5 Kwords/RAM	Isolation resistance	100 M Ω minimum (new)
Data and TOD retention		Switching delay	10 ms maximum
Supercap	190 hr typ. (120 hr min. at 40°C)	Lifetime	10,000,000 mechanical 100,000 with rated load
Optional battery	200 days continuous usage	Contact resistance	200 m Ω maximum (new)
Local I/O ¹	24 inputs/16 outputs	Isolation	
Max. I/O expansion modules	7	Coil to contact	1500 VAC, 1 min
Digital I/O supported	64 inputs/64 outputs	Contact to contact (Between open contacts)	750 VAC, 1 min
Analog I/O supported	16 inputs/16 outputs	Short circuit protection	None
Boolean execution speed	0.8 μ s/instruction	Power Supply	
Internal memory bits	256	Voltage/frequency range	85 to 264 VAC at 47 to 63 Hz
Timers	256 timers	Input current	6 VA typical, CPU only 50 VA max. load
Counters	256 counters	Holdup time	20 ms min. from 110 VAC
High-speed counters	1 software (2 KHz max.) 2 hardware (20 KHz max. ea.)	Inrush current	20 A peak at 264 VAC
TOD clock tolerance	6 minutes per month	Fusing (non-replaceable)	2 A, 250 V, Slow Blow
Pulse outputs	Not recommended	5 VDC current	1000 mA for expansion I/O
Analog adjustments	2	Isolated	Yes. Transformer, 1500 VAC, 1 min
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	DC Sensor Supply	
Input Points		Voltage range	19.2 VDC to 28.8 VDC
Input type	Sink/Source IEC Type 1131 in sink mode	Ripple/noise (<10MHz)	1 V peak-to-peak maximum
ON state range	15 to 30 VDC, 4 mA minimum 35 VDC, 500 ms surge	24 VDC available current	400 mA
ON state nominal	24 VDC, 7 mA	Short circuit current limit	< 600 mA
OFF state maximum	5 VDC, 1 mA	Isolated	No
Maximum response time			
I0.0 to I1.5	0.2 ms to 8.7 ms selectable 0.2 ms default		
I0.6 to I1.5 as used by HSC1 and HSC2	6 μ s ON, 30 μ s OFF		
I1.6 to I2.7	4 ms maximum		
Optical isolation	500 VAC, 1 min		

¹ The CPU reserves 24 process-image input and 16 process-image output register points for local I/O.

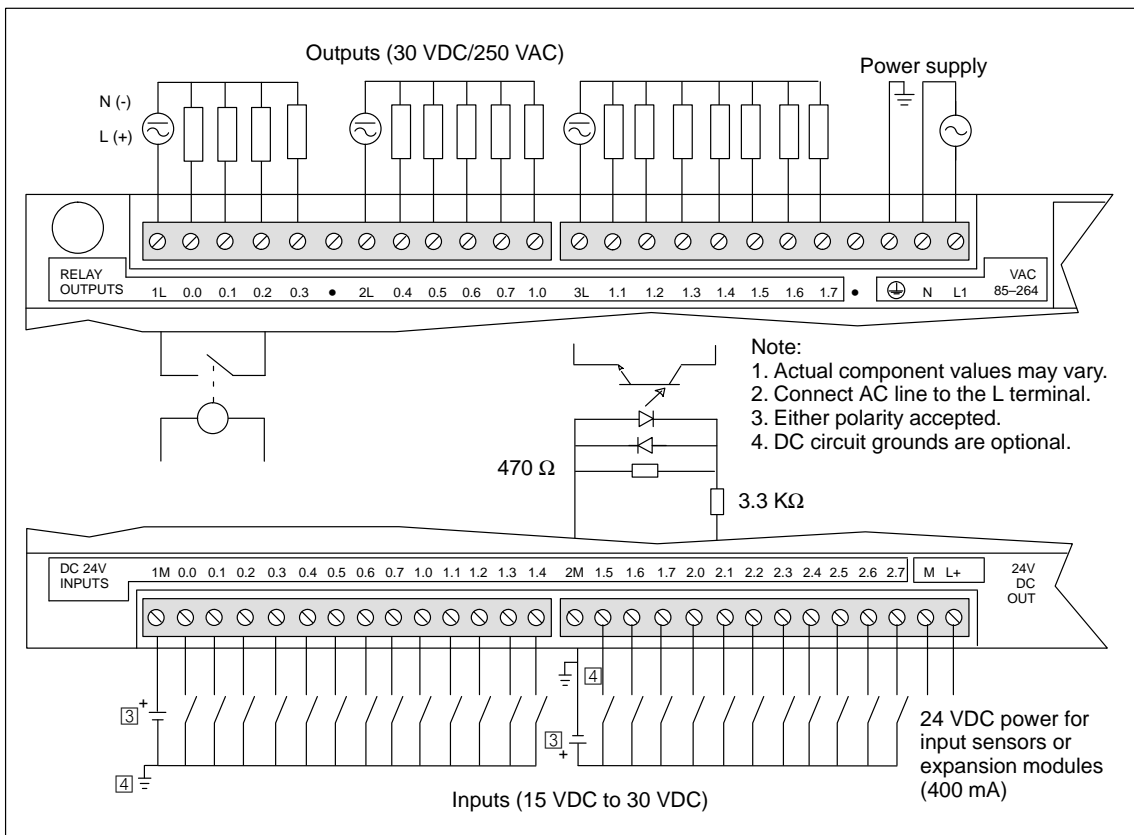


Figure A-18 Connector Terminal Identification for CPU 216 AC/DC/Relay

A.19 Expansion Module EM221 Digital Input 8 x 24 VDC

Order Number: 6ES7 221-1BF00-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Input type	Type 1 Sinking per IEC 1131-2
Weight	0.2 kg (0.4 lbs.)	ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	2 W	ON state nominal	24 VDC, 7 mA
Points ¹	8 digital inputs	OFF state maximum	5 VDC, 1 mA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Response time	3.5 ms typical/4.5 ms max.
		Optical isolation	500 VAC, 1 min
		Current Requirements	
		5 VDC logic current	60 mA from base unit
		24 VDC sensor current	60 mA from base unit or external power supply

¹ The CPU reserves 8 process-image input register points for this module.

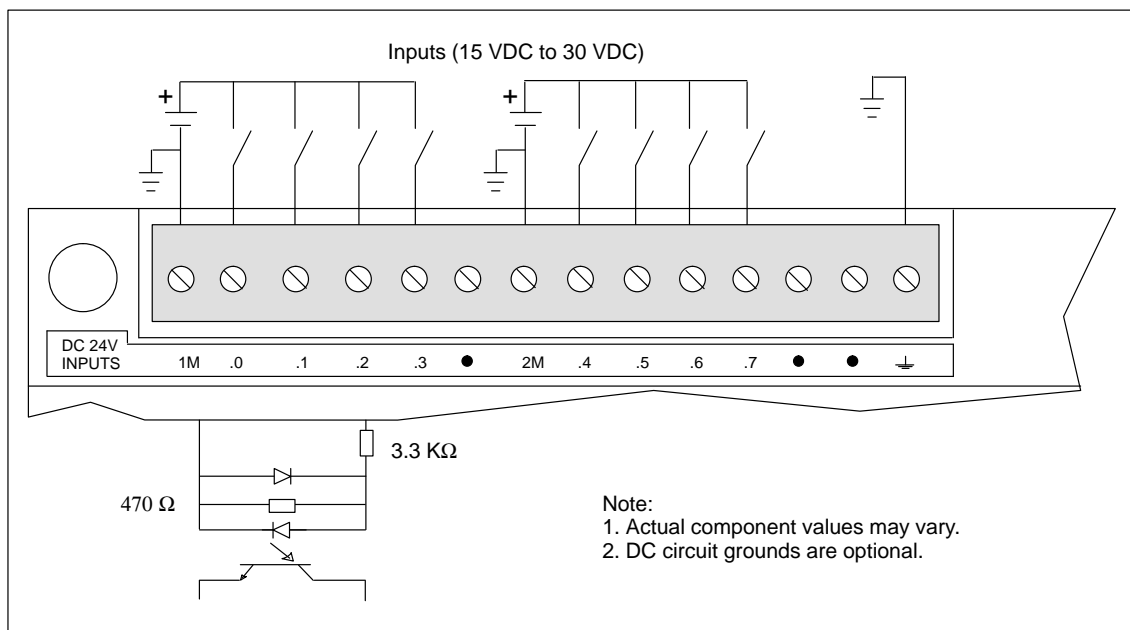


Figure A-19 Connector Terminal Identification for EM221 Digital Input 8 x 24 VDC

A.20 Expansion Module EM221 Digital Input 8 x 120 VAC

Order Number: 6ES7 221-1EF00-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Input type	Type 1 sinking per IEC 1131-2
Weight	0.2 kg (0.4 lbs.)	ON state range	79 to 135 VAC, 47 to 63 Hz, 4 mA minimum
Power dissipation	2 W	ON state nominal	120 VAC, 60 Hz, 7 mA
Points ¹	8 digital inputs	OFF state maximum	20 VAC, 1 mA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Response time	15 ms maximum
		Optical isolation	1500 VAC, 1 min
		Current Requirements	
		5 VDC logic current	70 mA from base unit

¹ The CPU reserves 8 process-image input register points for this module.

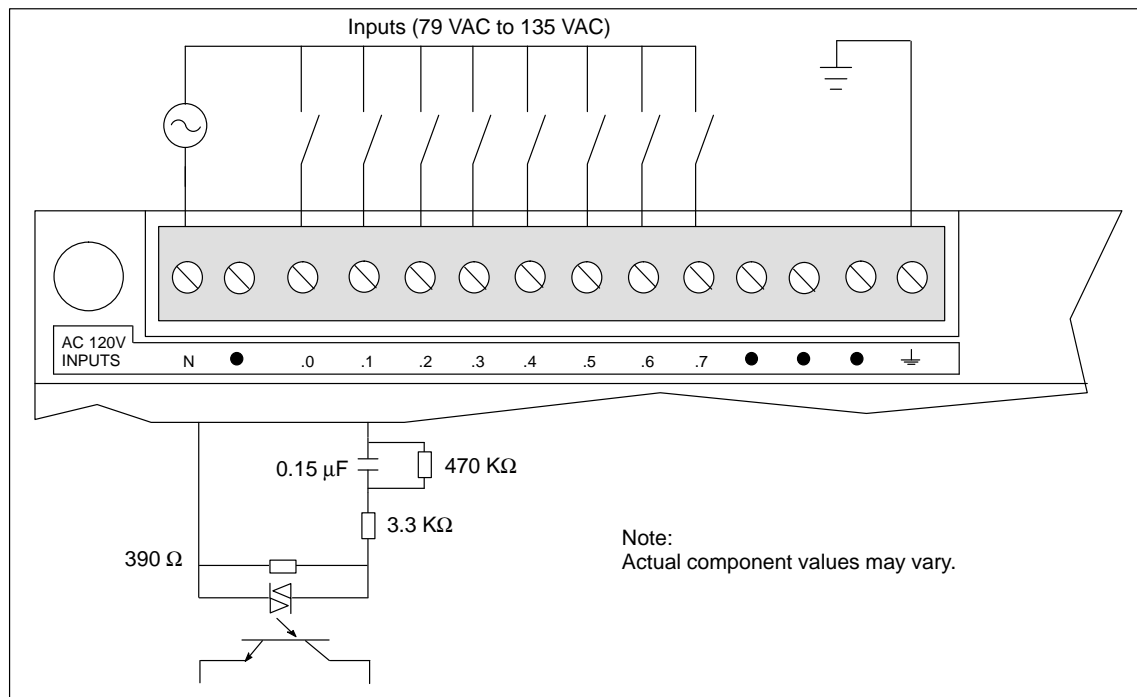


Figure A-20 Connector Terminal Identification for EM221 Digital Input 8 x 120 VAC

A.21 Expansion Module EM221 Digital Sourcing Input 8 x 24 VDC

Order Number: 6ES7 221-1BF10-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Type	Sourcing
Weight	0.2 kg (0.4 lbs.)	Input voltage range	15 VDC to 30 VDC, 35 VDC for 500 ms.
Power dissipation	2 W	ON state	4 mA minimum
Points ¹	8 digital inputs	OFF state	1 mA maximum
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Response time	3.5 ms typical/4.5 ms max.
		Optical isolation	500 VAC, 1 min
		Current Requirements	
		5 VDC logic current	60 mA from base unit
		24 VDC sensor current	60 mA from base unit or external power supply

¹ The CPU reserves 8 process-image input register points for this module.

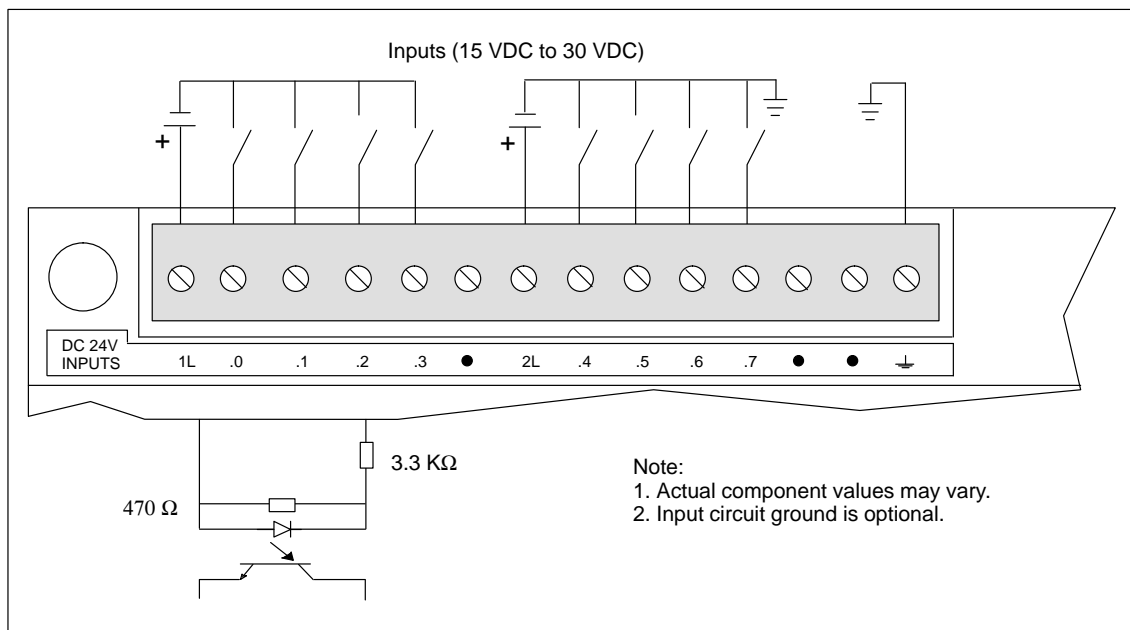


Figure A-21 Connector Terminal Identification for EM221 Digital Sourcing Input 8 x 24 VDC

A.22 Expansion Module EM221 Digital Input 8 x 24 VAC

Order Number: 6ES7 221-1JF00-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Input type	Type 1 sinking per IEC 1131-2
Weight	0.2 kg (0.4 lbs.)	ON state range	15 to 30 VAC, 47 to 63 Hz, 4 mA minimum
Power dissipation	2 W	ON state nominal	24 VAC, 60 Hz, 7 mA
Points ¹	8 digital inputs	OFF state maximum	5 VAC, 1 mA
Standards compliance (pending)	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Response time	15 ms maximum
		Optical isolation	1500 VAC, 1 min
		Current Requirements	
		5 VDC logic current	70 mA from base unit

¹ The CPU reserves 8 process-image input register points for this module.

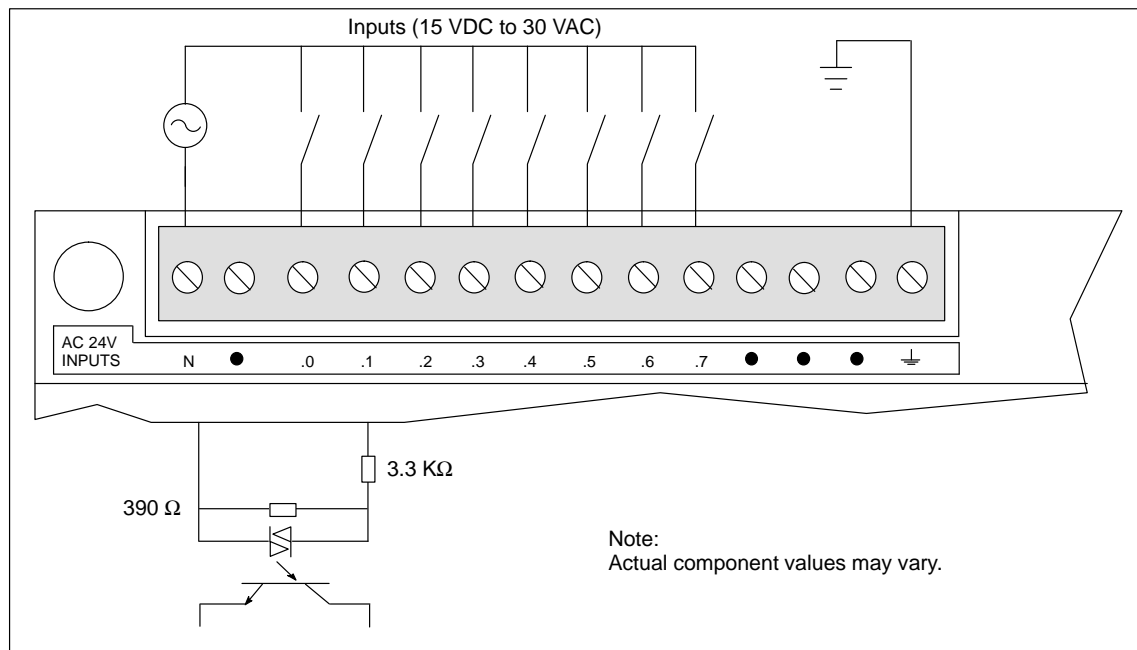


Figure A-22 Connector Terminal Identification for EM221 Digital Input 8 x 24 VAC

A.23 Expansion Module EM222 Digital Output 8 x 24 VDC

Order Number: 6ES7 222-1BF00-0XA0

General Features		Output Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Inductive load clamping	(per common)
Weight	0.2 kg (0.4 lbs.)	Single Pulse	2A L/R = 10 ms 1A L/R = 100 ms
Power dissipation	4 W at 3 A load	Repetitive	1 W energy dissipation (1/2 Li ² x switch rate < 1 W)
Points ¹	8 digital outputs	Leakage current	100 µA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Switching delay	50 µs ON, 200 µs OFF
Output Points		Surge current	4 A, 100 ms
Output type	Sourcing transistor	Voltage drop	1.8 V maximum at maximum current
Voltage range	20.4 VDC to 28.8 VDC	Optical isolation	500 VAC, 1 min
Maximum load current	0 to 40° C 55° C ²	Short circuit protection	None
per single point	0.75 A 0.50 A	Current Requirements	
per 2 adjacent points	1.00 A 0.75 A	5 VDC logic current	80 mA from base unit
all points total	4.00 A 3.00 A	Output point current	Supplied by user at module common

¹ The CPU reserves 8 process-image output register points for this module.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

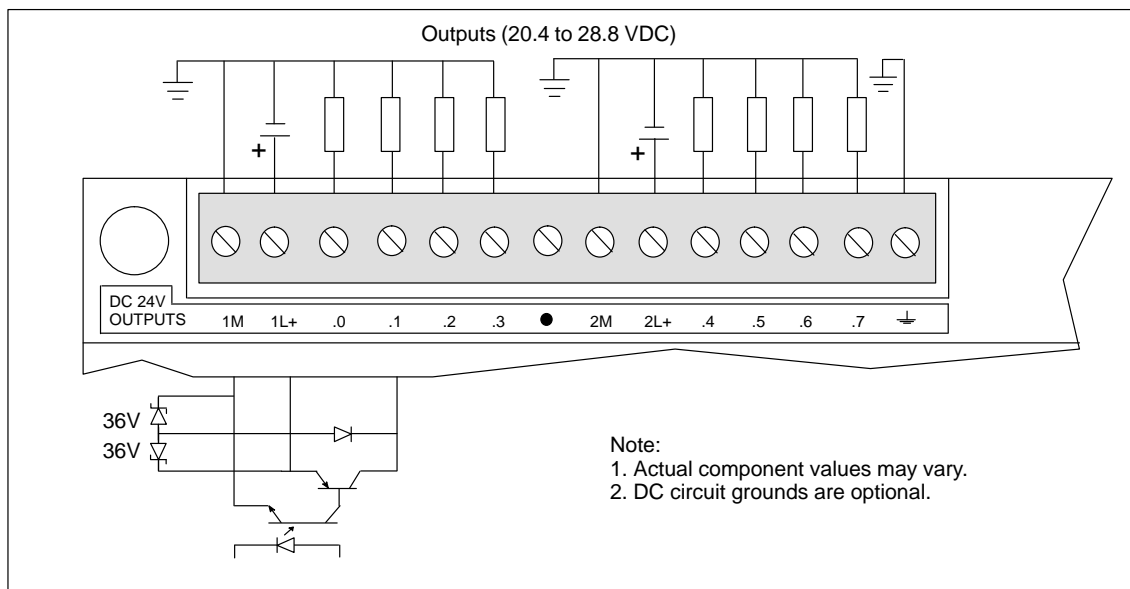


Figure A-23 Connector Terminal Identification for EM222 Digital Output 8 x 24 VDC

A.24 Expansion Module EM222 Digital Output 8 x Relay

Order Number: 6ES7 222-1HF00-0XA0

General Features		Output Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Switching delay	10 ms maximum
Weight	0.2 kg (0.4 lbs.)	Lifetime	10,000,000 mechanical 100,000 with rated load
Power dissipation	3 W	Contact resistance	200 mΩ maximum (new)
Points ¹	8 digital relay outputs	Isolation	
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Coil to contact	1500 VAC, 1 min
		Contact to contact (between open contacts)	750 VAC, 1 min
		Short circuit protection	None
Output Points		Current Requirements	
Output type	Relay, dry contact	5 VDC logic current	80 mA from base unit
Voltage range	5 to 30 VDC/250 VAC	24 VDC coil current	85 mA from base unit or external power supply
Maximum load current	2 A/point, 8 A/common	Output point current	Supplied by user at module common
Overcurrent surge	7 A with contacts closed		
Isolation resistance	100 MΩ minimum (new)		

¹ The CPU reserves 8 process-image output register points for this module.

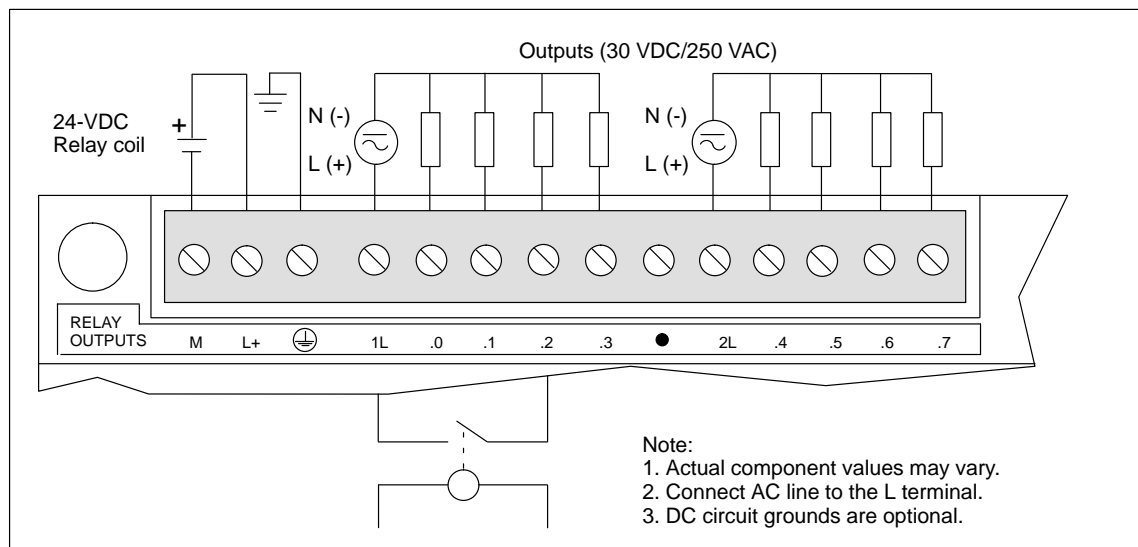


Figure A-24 Connector Terminal Identification for EM222 Digital Output 8 x Relay

A.25 Expansion Module EM222 Digital Output 8 x 120/230 VAC

Order Number: 6ES7 222-1EF00-0XA0

General Features		Output Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Minimum load current	30 mA
Weight	0.2 kg (0.4 lbs.)	Leakage current	1.5 mA, 120 VAC/2.0 mA, 240 VAC
Power dissipation	5 W at 3.5 A load	Switching delay	1/2 cycle
Points ¹	8 digital outputs	Surge current	30 A peak 1 cycle, 10 A peak 5 cycle
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Voltage drop	1.5 V maximum at maximum current
Output Points		Optical isolation	1500 VAC, 1 min
Output type	Triac, zero-cross turn on	Short circuit protection	None
Voltage/frequency range	20 to 264 VAC, 47 to 63 Hz	Current Requirements	
Load circuit power factor	0.3 to 1.0	5 VDC logic current	120 mA from base unit
Maximum load current	<u>0 to 40° C</u> <u>55° C</u> ²	Output point current	Supplied by user at module common
per single point	1.20 A 1.00 A		
per 2 adjacent points	1.50 A 1.25 A		
all points total	4.75 A 3.50 A		

¹ The CPU reserves 8 process-image output register points for this module.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

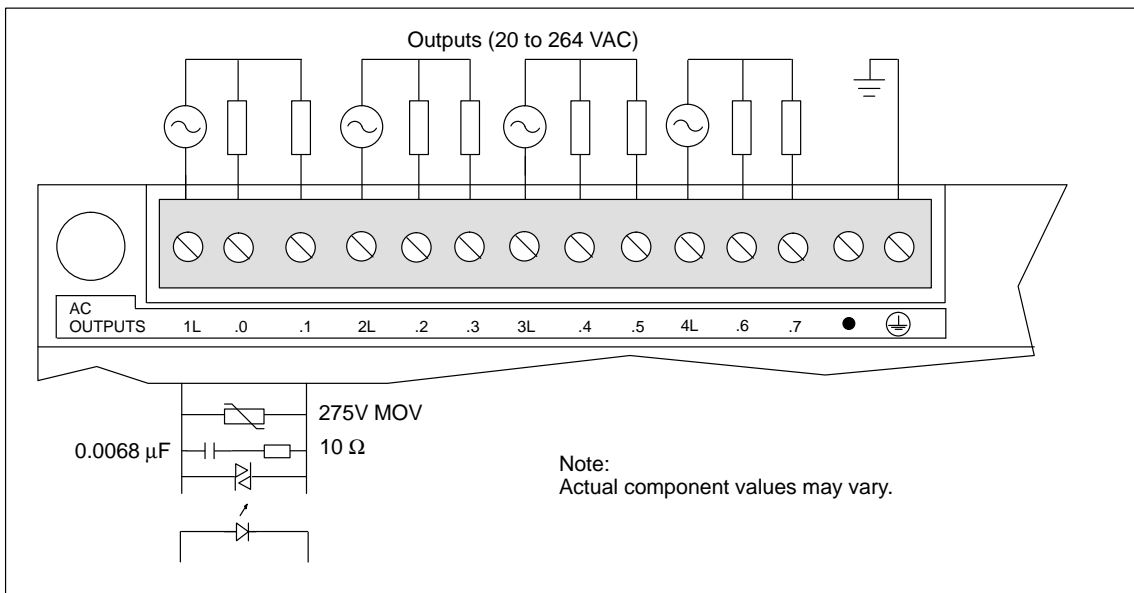


Figure A-25 Connector Terminal Identification for EM222 Digital Output 8 x 120/230 VAC

A.26 Expansion Module EM223 Digital Combination

4 x 24 VDC Input/4 x 24 VDC Output

Order Number: 6ES7 223-1BF00-0XA0

General Features		Output Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Leakage current	1 μ A maximum
Weight	0.2 kg (0.4 lbs.)	Switching delay	25 μ s ON, 120 μ s OFF max.
Power dissipation	3.5 W at 3 A load	Surge current	7 A, 100 ms
Points ¹	4 digital inputs 4 digital outputs	Optical isolation	500 VAC, 1 min
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Short circuit protection	None
Output Points		Input Points	
Output type	Sourcing transistor (P-Channel MOSFET)	Input type	Type 1 Sinking per IEC 1131-2
Voltage range	20.4 to 28.8 VDC	ON state range	15-30 VDC, 4 mA minimum 35 VDC, 500 ms surge
ON state resistance	400 m Ω maximum	ON state nominal	24 VDC, 7 mA
Maximum load current	0 to 40 $^{\circ}$ C 55 $^{\circ}$ C*	OFF state maximum	5 VDC, 1 mA
per single point	2.50 A 2.00 A	Response time	3.5 ms typical/4.5 ms maximum
all points total	4.00 A 3.00 A	Optical isolation	500 VAC, 1 min
*Linear derate 40 to 55 $^{\circ}$ C Vertical mount derate 10 $^{\circ}$ C (Two points can be connected in parallel to serve a high current load.)		Current Requirements	
Inductive load clamping	(per common)	5 VDC logic current	80 mA from base unit
Single Pulse	2A L/R = 10 ms 1A L/R = 100 ms	24 VDC sensor current	30 mA from base unit or external power supply
Repetitive	1 W energy dissipation (1/2 Li ² x switch rate < 1 W)	Output point current	Supplied by user at module common

¹ The CPU reserves 8 process-image input and 8 process-image output register points for this module.

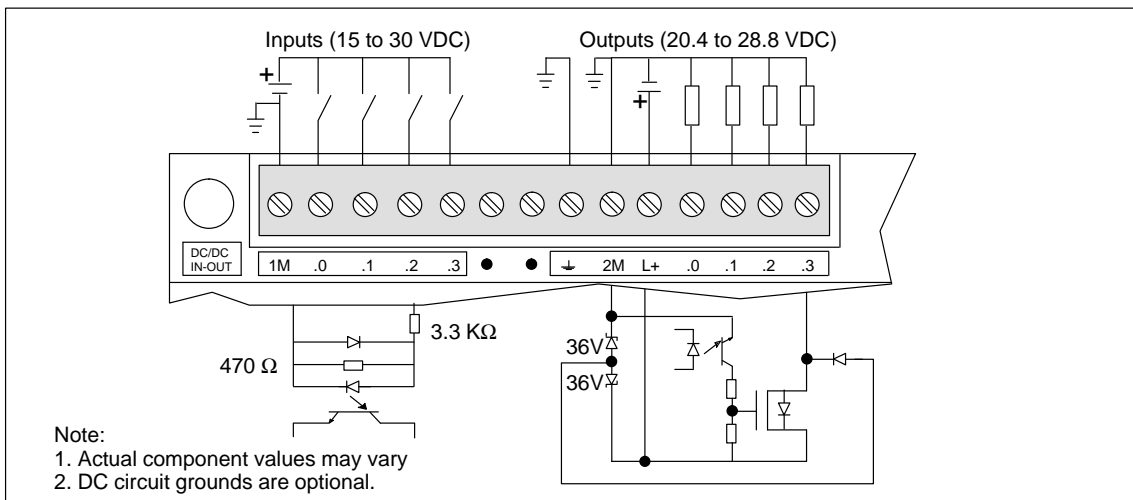


Figure A-26 Connector Terminal Identification for EM223 Digital Combination 4 x 24 VDC Input/4 x 24 VDC Output

A.27 Expansion Module EM223 Digital Combination 8 x 24 VDC Input/8 x 24 VDC Output

Order Number: 6ES7 223-1BH00-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Input Type	Sink/Source IEC 1131 Type 1 in sink mode
Weight	0.2 kg (0.44 lbs.)	ON State Range	15 to 30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	3.0 W	ON State Nominal	24 VDC, 7 mA
Points ¹	8 digital inputs 8 digital outputs	OFF State Maximum	5 VDC, 1 mA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Response Time	4.0 ms maximum
		Optical Isolation	500 VAC, 1 min
Output Points		Current Requirements	
Output type	Sourcing MOSFET	5 VDC logic current	120 mA from base unit
Voltage range	20.4 VDC to 28.8 VDC	24 VDC sensor current	60 mA from base unit or external power supply
Maximum load current	0 to 55° C	Output point current	Supplied by user at module common
Outputs may be connected parallel for higher current	0.5 A/Point		
Leakage current	200 µA		
Switching delay	150 µs ON, 400 µs OFF		
On resistance	400 mΩ maximum		
Short circuit protection	0.7 to 1.5 A/channel		
Optical isolation	500 VAC, 1 min		

¹ The CPU reserves 8 process-image input and 8 process-image output register points for this module.

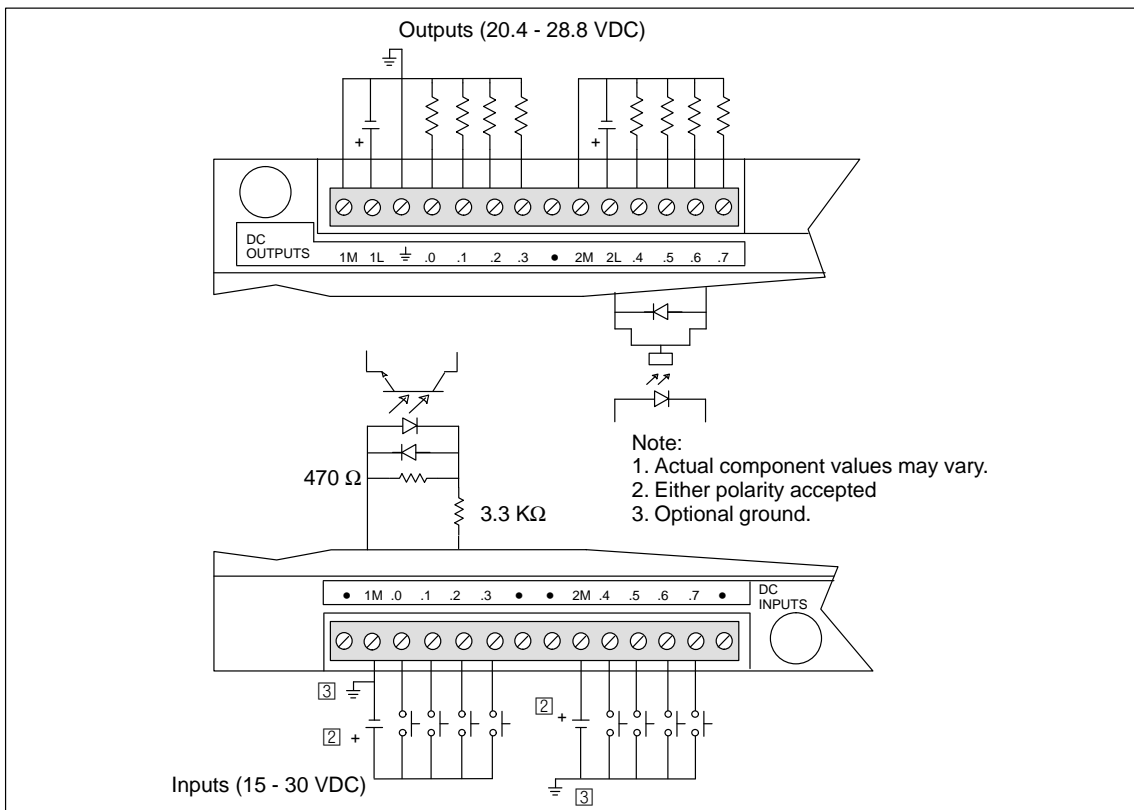


Figure A-27 Connector Terminal Identification for EM223 Digital Combination 8 x 24 VDC Inputs/8 x 24 VDC Outputs

A.28 Expansion Module EM223 Digital Combination 16 x 24 VDC Input/16 x 24 VDC Output

Order Number: 6ES7 223-1BL00-0XA0

General Features		Input Points	
Physical size (L x W x D)	160 x 80 x 62 mm (6.30 x 3.15 x 2.44 in.)	Input type	Sink/Source IEC 1131 Type 1 in sink mode
Weight	0.4 kg (0.9 lbs.)	ON state range	15 to 30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	5.5 W	ON state nominal	24 VDC, 7 mA
Points ¹	16 Digital inputs 16 Digital outputs	OFF state maximum	5 VDC, 1 mA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Response time	4.0 ms maximum
		Optical isolation	500 VAC, 1 minute
Output Points		Current Requirements	
Output type	Sourcing MOSFET	5 VDC logic current	210 mA from base unit
Voltage range	20.4 VDC to 28.8 VDC	24 VDC sensor current	120 mA from base unit or external power supply
Maximum load current	0 to 55° C	Output point current	Supplied by user at module common
Outputs may be connected parallel for higher current	0.5 A/Point		
Leakage current	200 µA		
Switching delay	150 µs ON, 400 µs OFF		
On resistance	400 mΩ maximum		
Short circuit protection	0.7 to 1.5 A/channel		
Optical isolation	500 VAC, 1 minute		

¹ The CPU reserves 16 process-image input and 16 process-image output register points for this module.

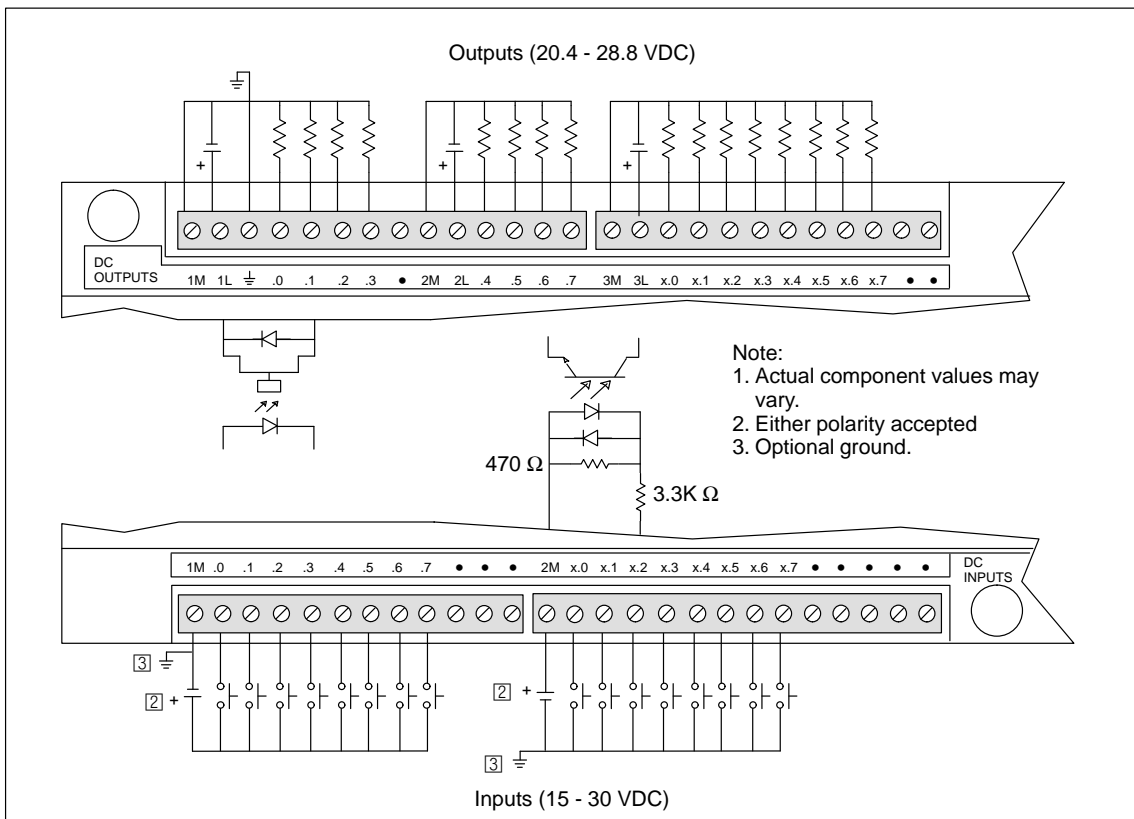


Figure A-28 Connector Terminal Identification for EM223 Digital Combination 16 x 24 VDC Inputs/16 x 24 VDC Outputs

A.29 Expansion Module EM223 Digital Combination 4 x 24 VDC Input/4 x Relay Output

Order Number: **6ES7 223-1HF00-0XA0**

General Features		Output Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Contact resistance	200 mΩ maximum (new)
Weight	0.2 kg (0.4 lbs.)	Short circuit protection	None
Power dissipation	2 W	Input Points	
Points ¹	4 digital inputs 4 digital relay outputs	Input type	Type 1 Sinking per IEC 1131-2
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	ON state range	15 to 30 VDC, 4 mA min. 35 VDC, 500 ms surge
Output Points		ON state nominal	24 VDC, 7 mA
Output type	Relay, dry contact	OFF state maximum	5 VDC, 1 mA
Voltage range	5 to 30 VDC/250 VAC	Response time	3.5 ms typical / 4.5 ms maximum
Maximum load current	2 A/Point	Optical isolation	500 VAC, 1 min
Isolation resistance	100 MΩ maximum (new)	Current Requirements	
Switching delay	10 ms maximum	5 VDC Logic current	80 mA from base unit
Lifetime	10,000,000 mechanical 100,000 with rated load	24 VDC Sensor current	30 mA from base unit or external power supply
Isolation		24 VDC Coil current	35 mA from base unit or external power supply
Coil to contact	1500 VAC, 1 min	Output point current	Supplied by user at module common
Contact to contact (between open contacts)	750 VAC, 1 min		

¹ The CPU reserves 8 process-image input and 8 process-image output register points for this module.

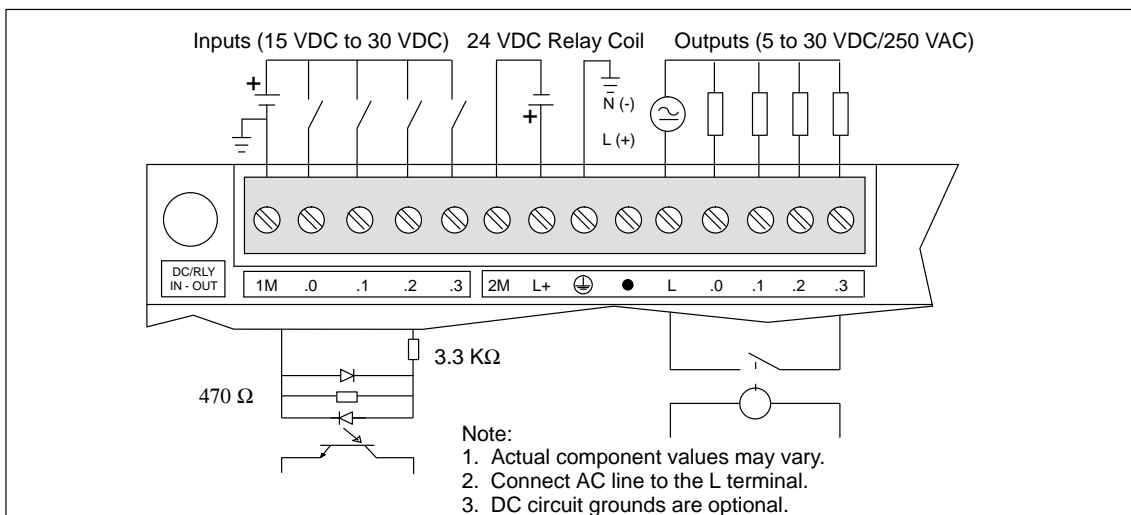


Figure A-29 Connector Terminal Identification for EM223 Digital Combination 4 x 24 VDC Input/4 x Relay Output

A.30 Expansion Module EM223 Digital Combination 4 x 120 VAC Input/4 x 120 VAC to 230 VAC Output

Order Number: 6ES7 223-1EF00-0XA0

General Features		Output Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Surge current	50 A peak, 1 cycle 15 A peak, 5 cycle
Weight	0.2 kg (0.4 lbs.)	Voltage drop	1.8 V maximum at maximum current
Power dissipation	5.5 W at 3 A load	Optical isolation	1500 VAC, 1 min
Points ¹	4 digital inputs 4 digital outputs	Short circuit protection	None
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 CE compliant	Input Points	
Output Points		Input type	Type 1 Sinking per IEC 1131-2
Output type	Triac, zero-cross turn on	ON state range	79 to 135 VAC, 47 to 63 Hz 4 mA minimum
Voltage/frequency range	70 to 264 VAC, 47 to 63 Hz	ON state nominal	120 VAC, 60 Hz, 7 mA
Load circuit power factor	0.3 to 1.0	OFF state maximum	20 VAC, 1 mA
Maximum load current	<u>0 to 40° C</u> 55° C ² per single point 2.40 A 2.00 A all points total 4.00 A 3.00 A	Response time	15 ms maximum
Minimum load current	10 mA	Optical isolation	1500 VAC, 1 min
Leakage current	2.5 mA, 120 V 4.0 mA, 230 V	Current Requirements	
Switching delay	1/2 cycle	5 VDC logic current	100 mA from base unit
		Output point current	Supplied by user at module common

¹ The CPU reserves 8 process-image input and 8 output process-image register points for this module.

² Linear derate 40 to 55° C. Vertical mount derate 10° C

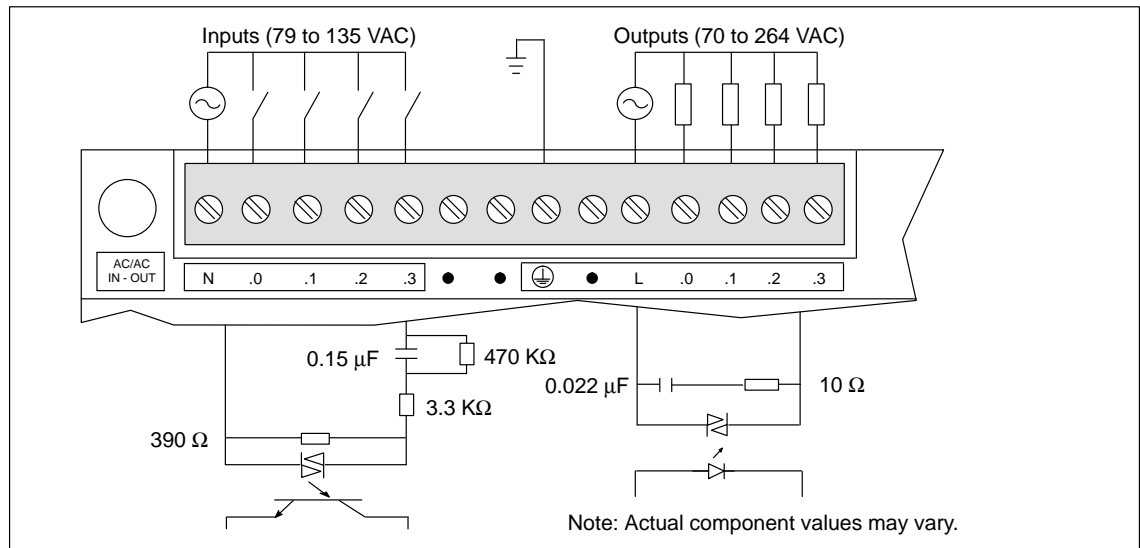


Figure A-30 Connector Terminal Identification for EM223 Digital 4 x 120 VAC Input/
4 x 120 VAC to 230 VAC Output

A.31 Expansion Module EM223 Digital Combination 8 x 24 VDC Input/8 x Relay Output

Order Number: 6ES7 223-1PH00-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Input Type	Sink/Source IEC 1131 Type 1 in sink mode
Weight	0.3 kg (0.7 lbs.)	ON State Range	15 to 30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	2.5 W	ON State Nominal	24 VDC, 7 mA
Points ¹	8 digital inputs 8 digital outputs	OFF State Maximum	5 VDC, 1 mA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Response Time	4.0 ms maximum
		Optical Isolation	500 VAC, 1 min
Output Points		Current Requirements	
Output type	Relay, dry contact	5 VDC logic current	100 mA from base unit
Voltage range	5 to 30 VDC/250 VAC	24 VDC sensor current	90 mA from base unit or external power supply
Maximum load current	2 A /point, 8 A/common	Output point current	Supplied by user at module common
Isolation resistance	100 MΩ maximum (new)		
Switching delay	10 ms maximum		
Lifetime	10,000,000 mechanical 100,000 with rated load		
Contact resistance	200 mΩ maximum (new)		
Isolation			
Coil to contact	1500 VAC, 1 min		
Contact to contact (Between open contacts)	750 VAC, 1 min		
Short circuit protection	None		

¹ The CPU reserves 8 process-image input and 8 process-image output register points for this module.

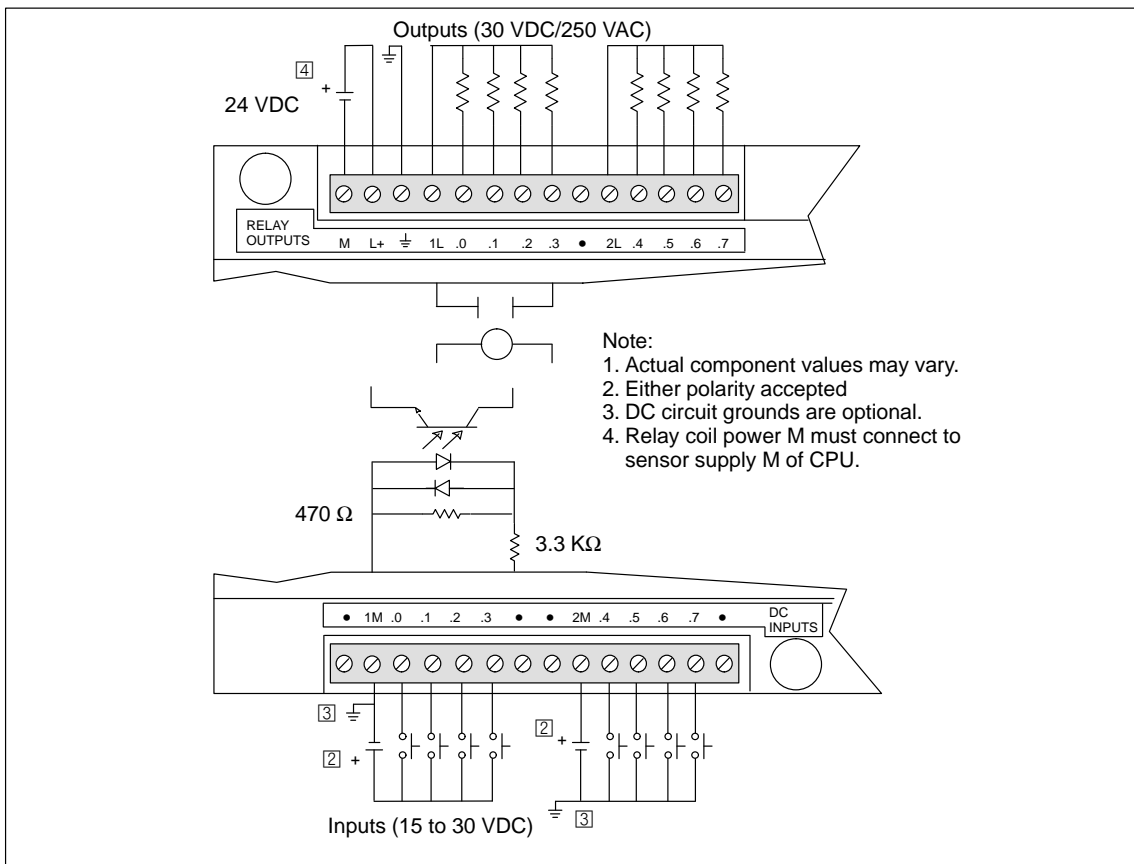


Figure A-31 Connector Terminal Identification for EM223 Digital 8 x 24 VDC Input/8 x Relay Output

A.32 Expansion Module EM223 Digital Combination 16 x 24 VDC Input/16 x Relay Output

Order Number: 6ES7 223-1PL00-0XA0

General Features		Input Points	
Physical size (L x W x D)	160 x 80 x 62 mm (6.30 x 3.15 x 2.44 in.)	Input type	Sink/Source IEC 1131 Type 1 in sink mode
Weight	0.45 kg (1.0 lbs.)	ON state range	15 to 30 VDC, 4 mA minimum 35 VDC, 500 ms surge
Power dissipation	7 W	ON state nominal	24 VDC, 7 mA
Points ¹	16 Digital inputs 16 Digital relay outputs	OFF state maximum	5 VDC, 1 mA
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Response time	3.5 ms typical/4.5 ms maximum
Output Points		Optical isolation	500 VAC, 1 minute
Output type	Relay, dry contact	Current Requirements	
Voltage range	5 to 30 VDC/250 VAC	5 VDC logic current	160 mA from base unit
Maximum load current	2 A/point, 8 A/common	24 VDC sensor current	120 mA from base unit or external power supply
Isolation resistance	100 MΩ maximum (new)	24 VDC coil current ²	130 mA from base unit or external power supply
Switching delay	10 ms maximum	Output point current	Supplied by user at module common
Lifetime	10,000,000 Mechanical 100,000 with rated load		
Contact resistance	200 mΩ maximum (new)		
Isolation			
Coil to contact	1500 VAC, 1 min		
Contact to contact (between open contacts)	750 VAC, 1 min		
Short circuit protection	None		

¹ The CPU reserves 16 process-image input and 16 process-image output register points for this module.

² Coil power must connect to common sensor supply M on the CPU.

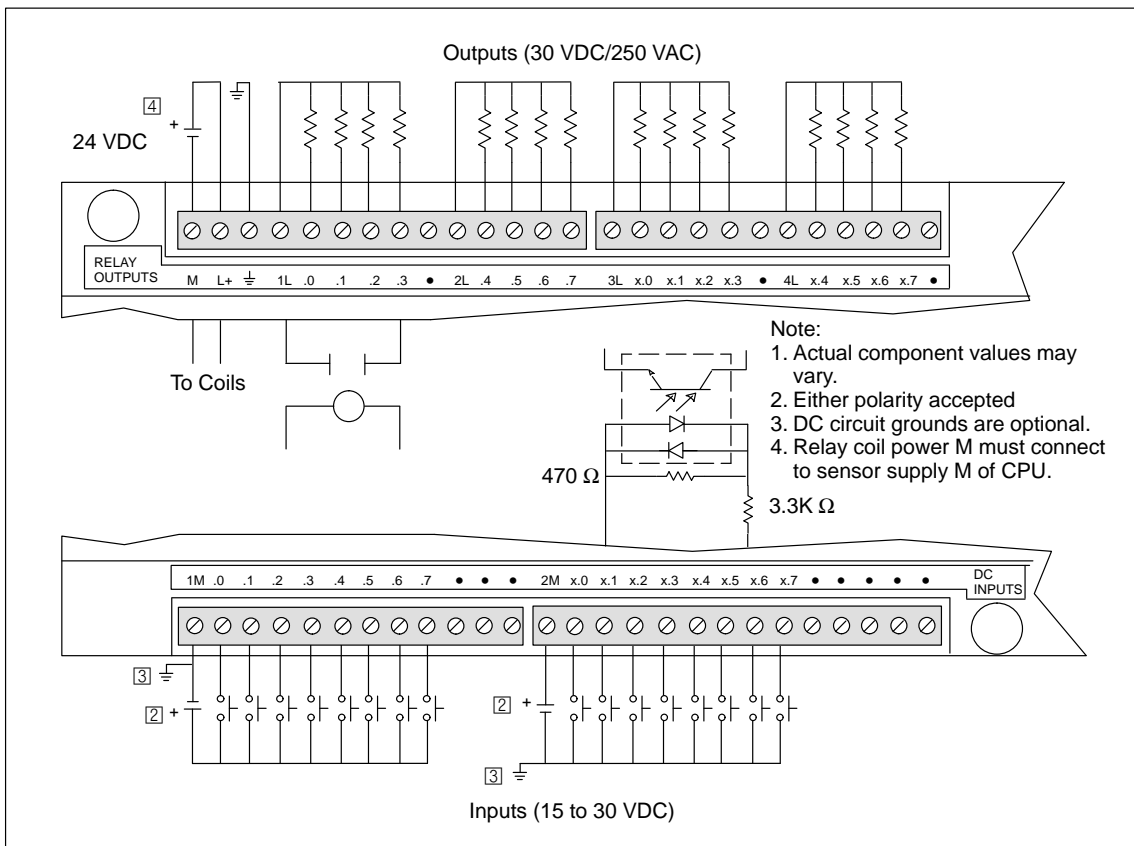


Figure A-32 Connector Terminal Identification for EM223 Digital Combination 16 x 24 VDC Input/16 x Relay Output

A.33 Expansion Module EM231 Analog Input AI 3 x 12 Bits

Order Number: 6ES7 231-0HC00-0XA0

General Features		Input Points (continued)	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in)	Analog-to-digital conversion time	< 250 μ s
Weight	0.2 kg (0.4 lbs.)	Analog step response	1.5 ms to 95%
Power dissipation	2 W	Common mode rejection	40 dB, DC to 60 Hz
Points ¹	3 Analog inputs	Common mode voltage	Signal voltage plus common mode voltage, less than or equal to 12 V
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Data word format ²	Unipolar, full-scale range 0 to 32000
Input Points		Current Requirements	
Input type	Differential	5 VDC logic current	70 mA from base unit
Input impedance	$\geq 10 \text{ M}\Omega$	External power supply	60 mA from base unit or external power supply (24 VDC nominal, Class 2 or DC sensor supply)
Input filter attenuation	-3 db @ 3.1 kHz		
Maximum input voltage	30 V		
Maximum input current	32 mA		
Resolution	12 bit A/D converter		
Isolation	Non-isolated		
		Indicator LED, EXTF	
		Power Supply Fault	Low voltage, on external 24 VDC

¹ The CPU reserves 4 analog input points for this module.

² Data Word increments in 8 count steps, left justified values. See Figure A-35.

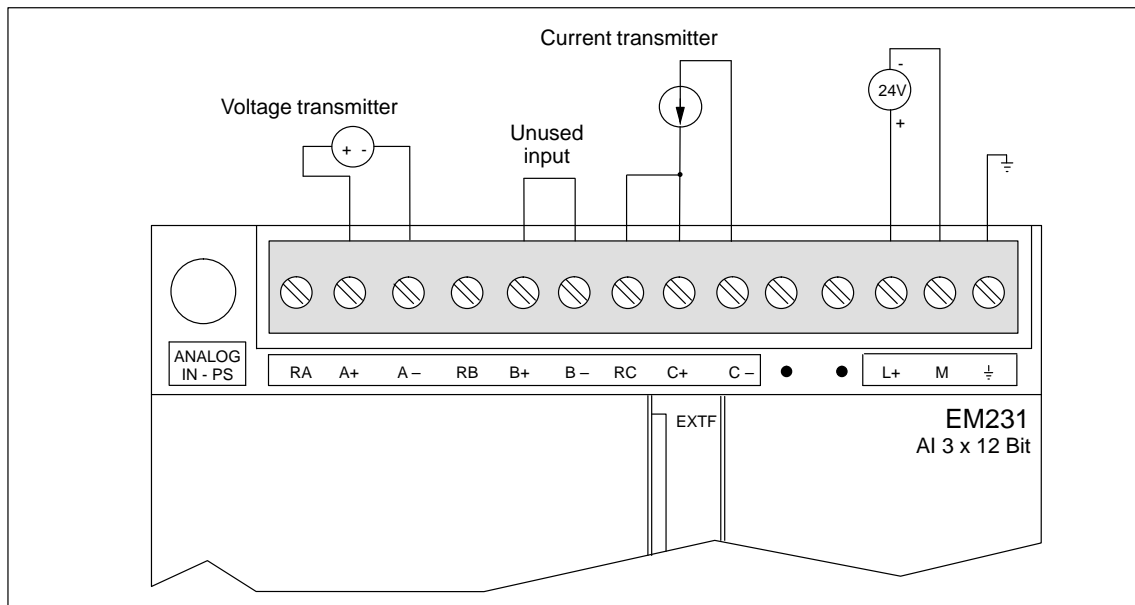


Figure A-33 Connector Terminal Identification for Expansion Module EM231 Analog Input AI 3 x 12 Bits

Calibration and Configuration Location

The calibration potentiometer and configuration DIP switches are accessed through the ventilation slots of the module, as shown in Figure A-34.

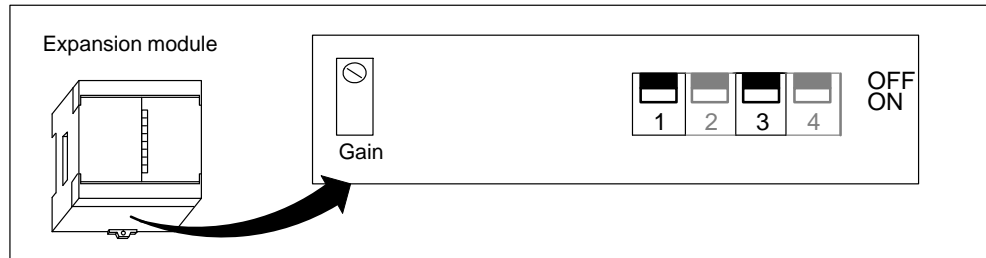


Figure A-34 Calibration Potentiometer and Configuration DIP Switches

Configuration

Table A-2 shows how to configure the module using the configuration DIP switches. Switches 1 and 3 select the analog input range. All inputs are set to the same analog input range.

Table A-2 Configuration Switch Table for EM231 Analog Input

Configuration Switch		Full-Scale Input	Resolution
1	3		
ON	OFF	0 to 5 V	1.25 mV
ON	OFF	0 to 20 mA ¹	5 μ A
OFF	ON	0 to 10 V	2.5 mV

¹ 0 to 20 mA measurements were made using the internal 250- Ω current-sense resistor.

Input Calibration

The module calibration is used to correct the gain error at full scale. Offset error is not compensated. The calibration affects all three input channels, and there may be a difference in the readings between channels after calibration.

To calibrate the module accurately, you must use a program designed to average the values read from the module. Use the Analog Input Filtering wizard provided in STEP 7-Micro/WIN to create this program (see Section 5.3). Use 64 or more samples to calculate the average value.

To calibrate the input, use the following steps.

1. Turn off the power to the module. Select the desired input range.
2. Turn on the power to the CPU and module. Allow the module to stabilize for 15 minutes.
3. Using a transmitter, a voltage source, or a current source, apply a zero value signal to one of the input terminals.
4. Read the value reported to the CPU by the appropriate input channel. The reading with a zero value input indicates the magnitude of the offset error. This error cannot be corrected by calibration.
5. Connect a full-scale value signal to one of the input terminals. Read the value reported to the CPU.
6. Adjust the GAIN potentiometer until the reading is 32,000, or the desired digital data value.

Data Word Format

Figure A-35 shows where the 12-bit data value is placed within the analog input word of the CPU.

A variance in repeatability of only $\pm 0.45\%$ of full scale can give a variance of ± 144 counts in the value read from the analog input.

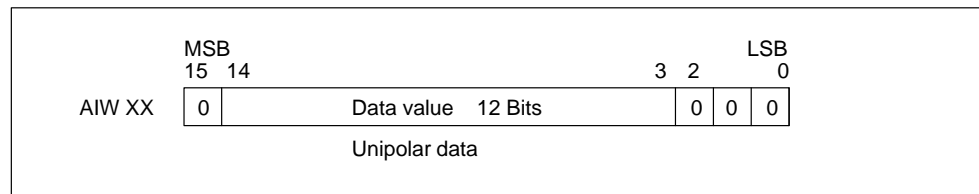


Figure A-35 Data Word Format

Note

The 12 bits of the analog-to-digital converter (ADC) readings are left-justified in the data word format. The MSB is the sign bit: zero indicates a positive data word value. The three trailing zeros cause the data word to change by a count of eight for each one count change in the ADC value.

Input Block Diagram

Figure A-36 shows the EM231 input block diagram.

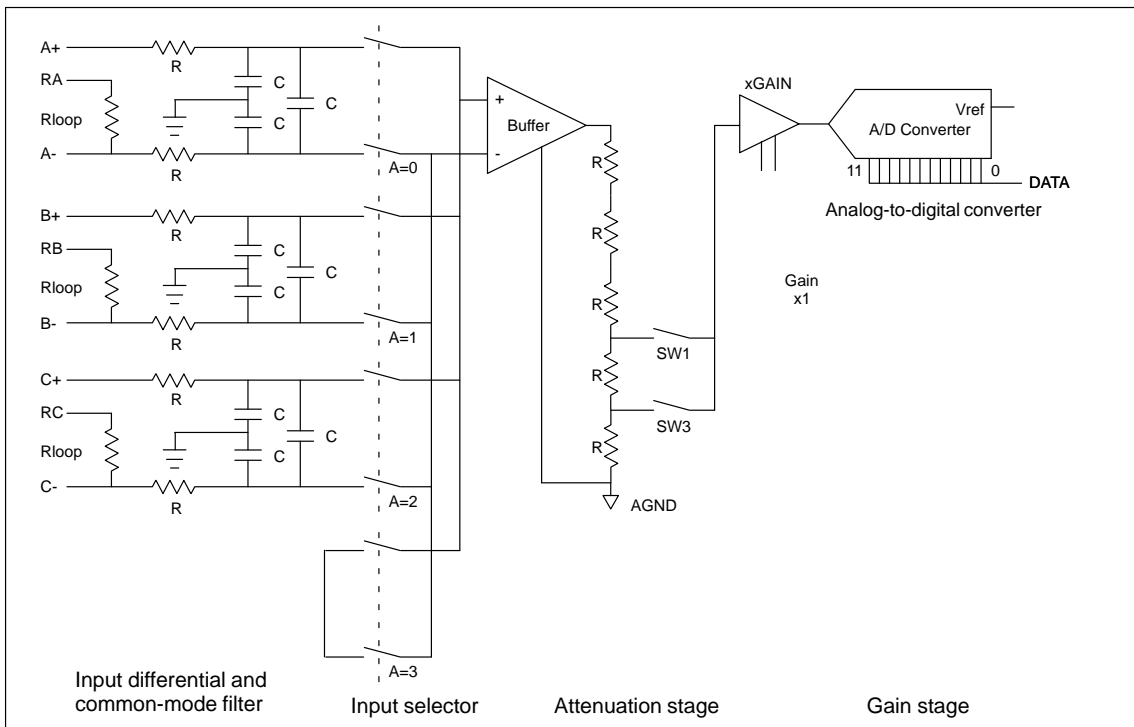


Figure A-36 EM231 Input Block Diagram

Installation Guidelines for EM231

Use the following guidelines to ensure accuracy and repeatability:

- Ensure that the 24-VDC Sensor Supply is free of noise and is stable.
- Calibrate the module.
- Use the shortest possible sensor wires.
- Use shielded twisted pair wiring for sensor wires.
- Terminate the shield at the sensor location only.
- Short the inputs for any unused channels, as shown in Figure A-33.
- Avoid bending the wires into sharp angles.
- Use wireways for wire routing.
- Ensure that input signals are floating or referenced to the external 24V common of the analog module.

Understanding and Using the Analog Input Module: Accuracy and Repeatability

The EM231 analog input module is a low-cost, high-speed 12 bit analog input module. The module is capable of converting an analog input to its corresponding digital value in 171 μ sec for the CPU 212 and 139 μ sec for all other S7-200 CPUs. Conversion of the analog signal input is performed each time the analog point is accessed by your program. These times must be added to the basic execution time of the instruction used to access the analog input.

The EM231 provides an unprocessed digital value (no linearization or filtering) that corresponds to the analog voltage or current presented at the module's input terminals. Since the module is a high-speed module, it can follow rapid changes in the analog input signal (including internal and external noise). Reading-to-reading variations caused by noise for a constant or slowly changing analog input signal can be minimized by averaging a number of readings. As the number of readings used in computing the average value increases, a correspondingly slower response time to changes in the input signal can be observed.

You can use the STEP 7-Micro/WIN Analog Input Filtering wizard (see Section 5.3). to add an averaging routine to your program. Remember that an average value computed from a large number of samples stabilizes the reading while slowing down its response to changes in the input signal. For slowly changing analog input signals, a sample size of 64 or greater is recommended for the averaging routine.

The specifications for repeatability describe the reading-to-reading variations of the module for an input signal that is not changing. The repeatability specification defines the limits within which 99% of the readings will fall. The mean accuracy specification describes the average value of the error (the difference between the average value of individual readings and the exact value of the actual analog input signal). The repeatability is described in the Figure A-37 by the bell curve. This figure shows the 99% repeatability limits, the mean or average value of the individual readings, and the mean accuracy in a graphical form. Table A-3 gives the repeatability specifications and the mean accuracy as they relate to each of the configurable ranges.

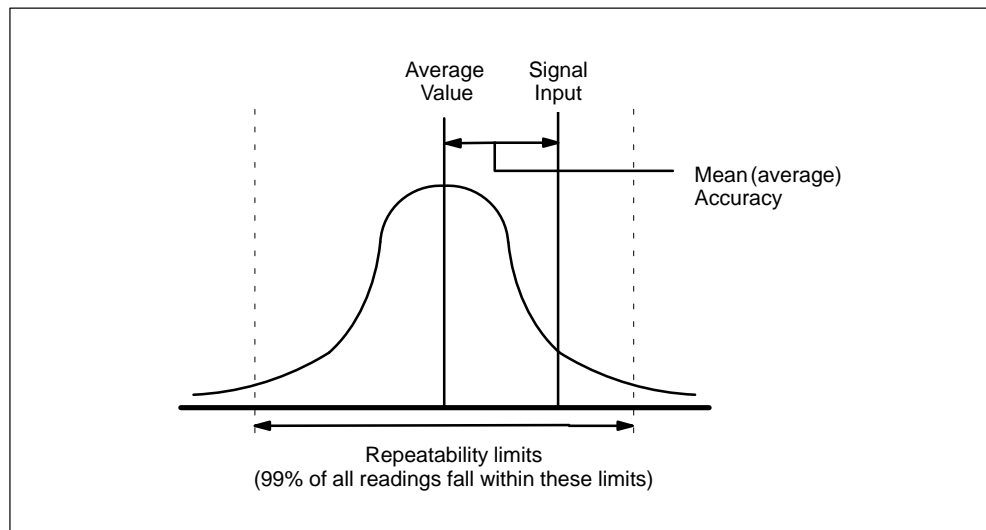


Figure A-37 Accuracy Definitions

Table A-3 Specifications for DC and AC Powered S7-200 CPUs

Full Scale Input Range	Repeatability ¹		Mean (average) Accuracy ^{1, 2, 3, 4}	
	% of Full Scale	Counts	% of Full Scale	Counts
Specifications for DC Powered S7-200 CPUs				
0 to 5 V	± 0.075%	± 24	± 0.1%	± 32
0 to 20 mA				
0 to 10 V				
Specifications for AC Powered S7-200 CPUs				
0 to 5 V	± 0.15%	± 48	± 0.1%	± 64
0 to 20 mA				
0 to 10 V				

¹ Measurements made after the selected input range has been calibrated.

² The offset error in the signal near zero analog input is not corrected, and is not included in the accuracy specifications.

³ There is a channel-to-channel carryover conversion error, due to the finite settling time of the analog multiplexer. The maximum carryover error is 0.1% of the difference between channels.

⁴ Mean accuracy includes effects of non-linearity and drift from 0 to 55 degrees C.

A.34 Expansion Module EM232 Analog Output AQ 2 x 12 Bits

Order Number: **6ES7 232-0HB00-0XA0**

General Features	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)
Weight	0.2 kg (0.4 lbs.)
Power dissipation	2 W
Points ¹	2 analog outputs
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant
Output Points	
Signal range	
Voltage output	± 10 V
Current output	0 to 20 mA
Resolution, full-range	
Voltage	12 bits
Current	11 bits
Resolution, full-scale	
Voltage, bipolar	1 in 2000 counts, 0.5% of full-scale per count
Current, unipolar	1 in 2000 counts, 0.5% of full-scale per count
Data word format	
Full-range	
Voltage, bipolar	-32768 to + 32752
Current, unipolar	0 to +32752
Full-scale	
Bipolar	-32000 to +32000
Unipolar	0 to + 32000
Accuracy	
Worst case, 0 to 55° C	
Voltage output	± 2% of full-scale
Current output	± 2% of full-scale
Typical, 25° C	
Voltage output	± 0.5% of full-scale
Current output	± 0.5% of full-scale
Settling time	
Voltage output	100 µs
Current output	2 ms
Maximum drive	
@ 24 V user supply	
Voltage output	5000Ω minimum
Current output	500Ω maximum
Current Requirements	
5 VDC logic current	70 mA from Base Unit
External power supply	60 mA, plus output current of 40 mA from Base Unit or External Supply (24 VDC nominal, Class 2 or DC Sensor Supply)
Indicator LED, EXTF	
Power supply fault	Low voltage, out-of-range

¹ The CPU reserves 2 analog output points for this module.

Figure A-38 shows the Connector Terminal Identification for EM232 Analog Output AQ 2 x 12 Bits.

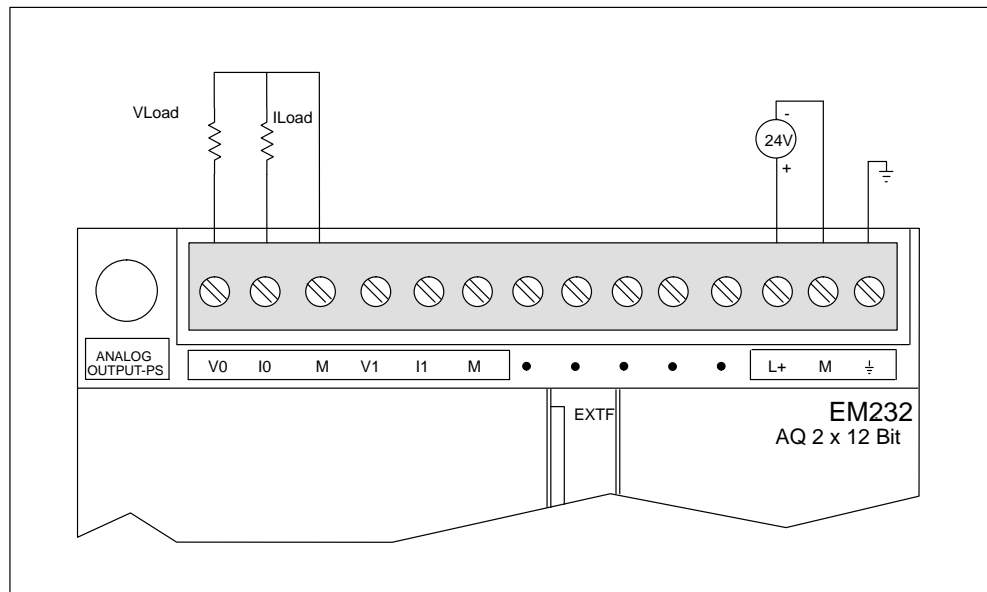


Figure A-38 Connector Terminal Identification for Expansion Module EM232 Analog Output AQ 2 x 12 Bits

Output Data Word Format

Figure A-39 shows where the 12-bit data value is placed within the analog output word of the CPU.

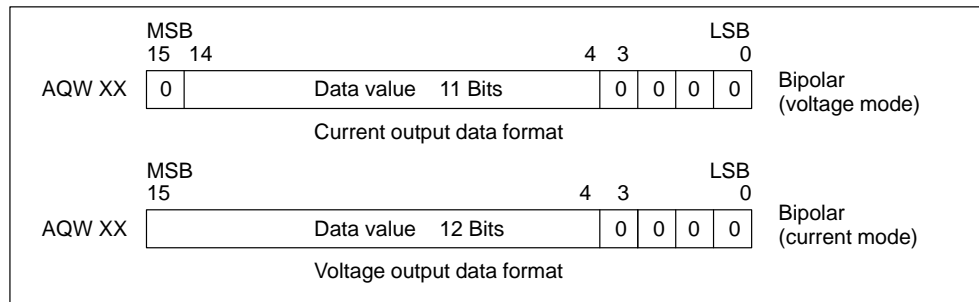


Figure A-39 Output Data Word Format

Note

The 12 bits of the digital-to-analog converter (DAC) readings are left-justified in the output data word format. The MSB is the sign bit: zero indicates a positive data word value. The four trailing zeros are truncated before being loaded into the DAC registers. These bits have no effect on the output signal value.

Output Block Diagram

Figure A-40 shows the EM232 output block diagram.

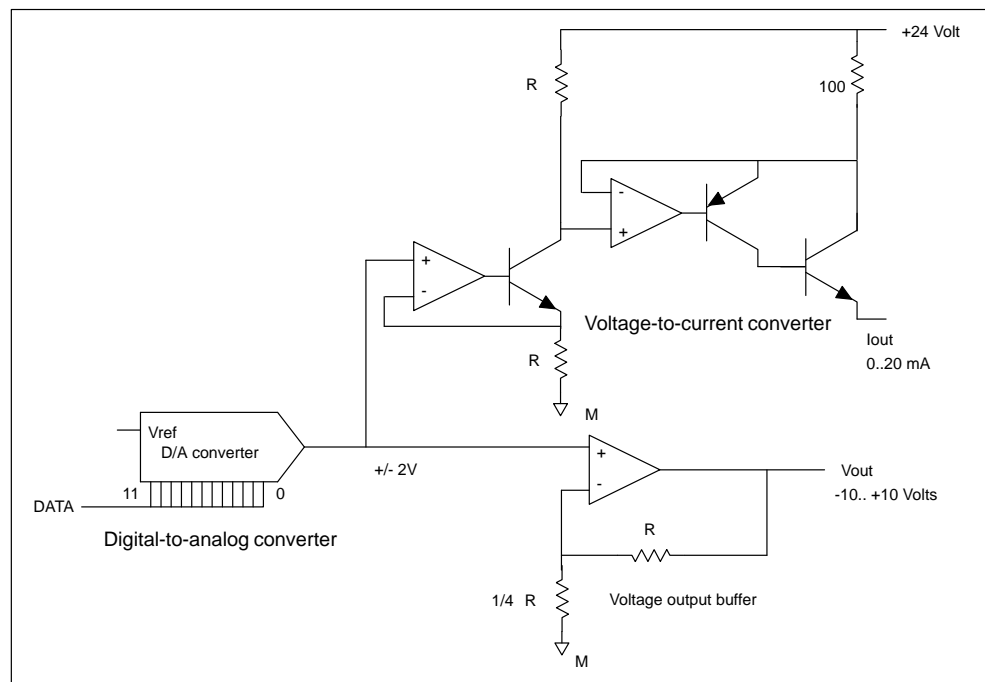


Figure A-40 EM232 Output Block Diagram

Installation Guidelines for EM232

Use the following guidelines to ensure accuracy:

- Ensure that the 24-VDC Sensor Supply is free of noise and is stable.
- Use the shortest possible sensor wires.
- Use shielded twisted pair wiring for sensor wires.
- Terminate the shield at the sensor location only.
- Avoid bending the wires into sharp angles.
- Use wireways for wire routing.
- Avoid placing signal wires parallel to high-energy wires. If the two wires must meet, cross them at right angles.

Definitions of the Analog Specifications

- Accuracy: deviation from the expected value on a given point.
- Resolution: the effect of an LSB change reflected on the output.

A.35 Expansion Module EM235 Analog Combination AI 3/AQ 1 x 12 Bits

Order Number: 6ES7 235-0KD00-0XA0

General Features		Input Points	
Physical size (L x W x D)	90 x 80 x 62 mm (3.54 x 3.15 x 2.44 in.)	Input type	Differential
Weight	0.2 kg (0.4 lbs.)	Input impedance	$\geq 10 \text{ M}\Omega$
Power dissipation	2 W	Input filter attenuation	-3db @ 3.1 kHz
Points ¹	3 analog inputs 1 analog output	Maximum input voltage	30 V
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant	Maximum input current	32 mA
Output Points		Resolution	12 bit A/D converter
Signal range		Isolation	Non-isolated
Voltage output	$\pm 10 \text{ V}$	Analog-to-digital conversion time	$< 250 \text{ }\mu\text{sec}$
Current output	0 to 20 mA	Analog step response	1.5 ms to 95%
Resolution, full-range		Common mode voltage	Signal voltage plus common mode voltage, less than or equal to 12 V
Voltage	12 bits	Common mode rejection	40 dB, DC to 60 Hz
Current	11 bits	Data word format ²	
Data word format ²		Bipolar range ³	-32000 to +32000
Bipolar range ³	-32000 to +32000	Unipolar range ²	0 to + 32000
Unipolar range ²	0 to + 32000	Current Requirements	
Accuracy		5 VDC logic current	70 mA from Base Unit
Worst case, 0 to 60° c		External power supply	60 mA, plus output current of 20 mA, from Base Unit or External Supply (24 VDC nominal, Class 2 or DC Sensor Supply)
Voltage output	$\pm 2\%$ of full-scale	Indicator LED, EXTF	
Current output	$\pm 2\%$ of full-scale	Power supply fault	Low voltage, on external 24 VDC
Typical, 25° c			
Voltage output	$\pm 0.5\%$ of full-scale		
Current output	$\pm 0.5\%$ of full-scale		
Settling time			
Voltage output	100 μs		
Current output	2 ms		
Maximum drive @ 24 V user supply			
Voltage output	5000 Ω minimum		
Current output	500 Ω maximum		

¹ The CPU reserves 4 analog input points and 2 analog output points for this module.

² Data word increments in 16 count steps, left justified ADC values. See Figure A-43 and Figure A-45.

³ Data word increments in 8 count steps, left justified ADC values. See Figure A-43.

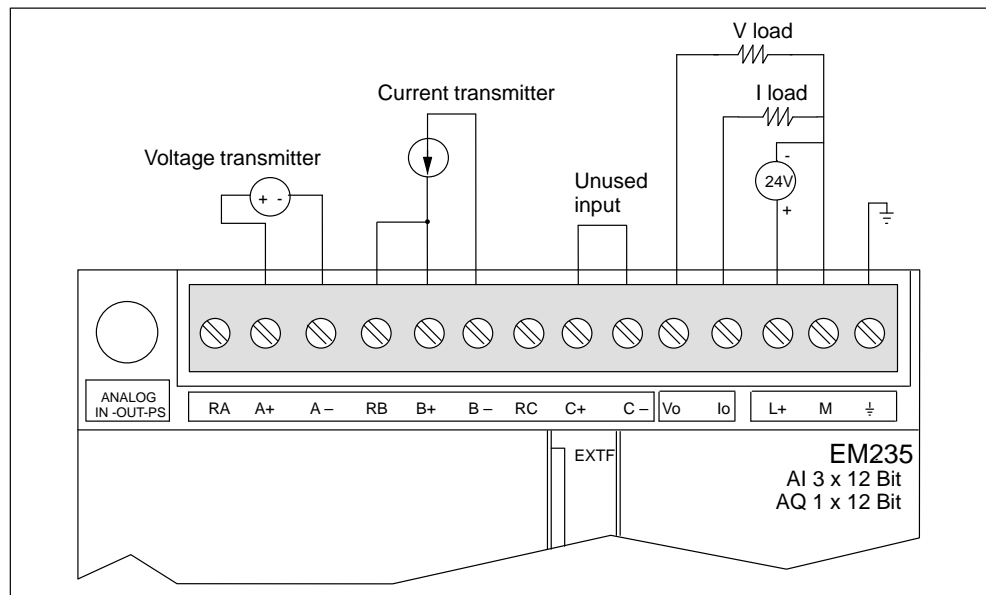


Figure A-41 Connector Terminal Identification for Expansion Module EM235 Analog Combination AI 3/AQ 1 x 12 Bits

Calibration and Configuration Location

The calibration potentiometers and configuration DIP switches are accessed through the ventilation slots of the module, as shown in Figure A-42.

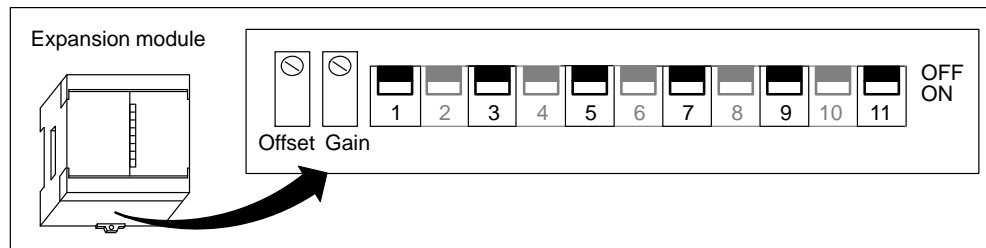


Figure A-42 Calibration Potentiometers and Configuration DIP Switches

Configuration

Table A-4 shows how to configure the module using the configuration DIP switches. Switches 1, 3, 5, 7, 9, and 11 select the analog input range and data format. All inputs are set to the same input range and format.

Table A-4 Configuration Switch Table for EM235 Analog Combination

Configuration Switch						Full-Scale Input	Resolution
1 ¹	3	5	7	9	11		
ON	ON	OFF	ON	OFF	OFF	0 to 50 mV	12.5 μ V
ON	ON	OFF	OFF	ON	OFF	0 to 100 mV	25 μ V
ON	OFF	ON	ON	OFF	OFF	0 to 500 mV	125 μ V
ON	OFF	ON	OFF	ON	OFF	0 to 1 V	250 μ V
ON	OFF	OFF	ON	OFF	OFF	0 to 5 V	1.25 mV
ON	OFF	OFF	ON	OFF	OFF	0 to 20 mA ²	5 μ A
ON	OFF	OFF	OFF	ON	OFF	0 to 10 V	2.5 mV
OFF	ON	OFF	ON	OFF	OFF	\pm 25 mV	12.5 μ V
OFF	ON	OFF	OFF	ON	OFF	\pm 50 mV	25 μ V
OFF	ON	OFF	OFF	OFF	ON	\pm 100 mV	50 μ V
OFF	OFF	ON	ON	OFF	OFF	\pm 250 mV	125 μ V
OFF	OFF	ON	OFF	ON	OFF	\pm 500 mV	250 μ V
OFF	OFF	ON	OFF	OFF	ON	\pm 1 V	500 μ V
OFF	OFF	OFF	ON	OFF	OFF	\pm 2.5 V	1.25 mV
OFF	OFF	OFF	OFF	ON	OFF	\pm 5 V	2.5 mV
OFF	OFF	OFF	OFF	OFF	ON	\pm 10 V	5 mV

¹ Switch 1 selects the input polarity: ON for unipolar and OFF for bipolar. CPU power cycle required when switching between unipolar and bipolar data formats. Switches 3, 5, 7, 9 and 11 select voltage range.

² 0 to 20 mA measurements were made using the internal 250 current-sense resistor.

Input Calibration

The calibration affects all three input channels, and there may be a difference in the readings between the channels after calibration.

To calibrate the module accurately, you must use a program designed to average the values read from the module. Use the Analog Input Filtering wizard provided in STEP 7-Micro/WIN to create this program (see Section 5.3). Use 64 or more samples in calculating the average value.

To calibrate the input, use the following steps.

1. Turn off the power to the module. Select the desired input range.
2. Turn on the power to the CPU and module. Allow the module to stabilize for 15 minutes.
3. Using a transmitter, a voltage source, or a current source, apply a zero value signal to one of the input terminals.
4. Read the value reported to the CPU by the appropriate input channel.
5. Adjust the OFFSET potentiometer until the reading is zero, or the desired digital data value.
6. Connect a full-scale value signal to one of the input terminals. Read the value reported to the CPU.
7. Adjust the GAIN potentiometer until the reading is 32000, or the desired digital data value.
8. Repeat OFFSET and GAIN calibration as required.

Input Data Word Format

Figure A-43 shows where the 12-bit data value is placed within the analog input word of the CPU.

A variance in repeatability of only $\pm 0.50\%$ of full scale can give a variance of ± 160 counts in the value read from the analog input.

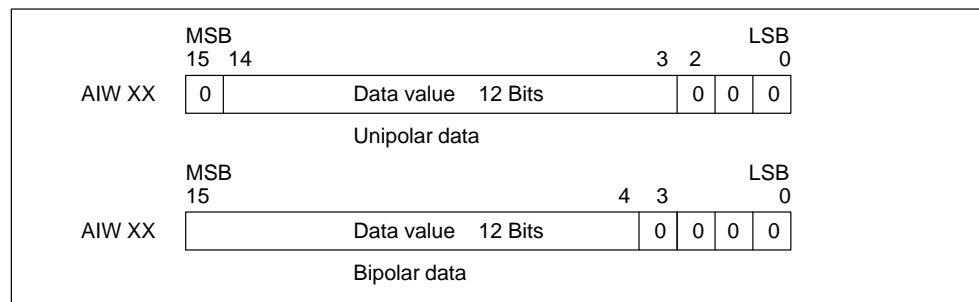


Figure A-43 Input Data Word Format

Note

The 12 bits of the analog-to-digital converter (ADC) readings are left-justified in the data word format. The MSB is the sign bit: zero indicates a positive data word value. In the unipolar format, the three trailing zeros cause the data word to change by a count of eight for each one-count change in the ADC value. In the bipolar format, the four trailing zeros cause the data word to change by a count of sixteen for each one count change in the ADC value.

Input Block Diagram

Figure A-44 shows the EM235 input block diagram.

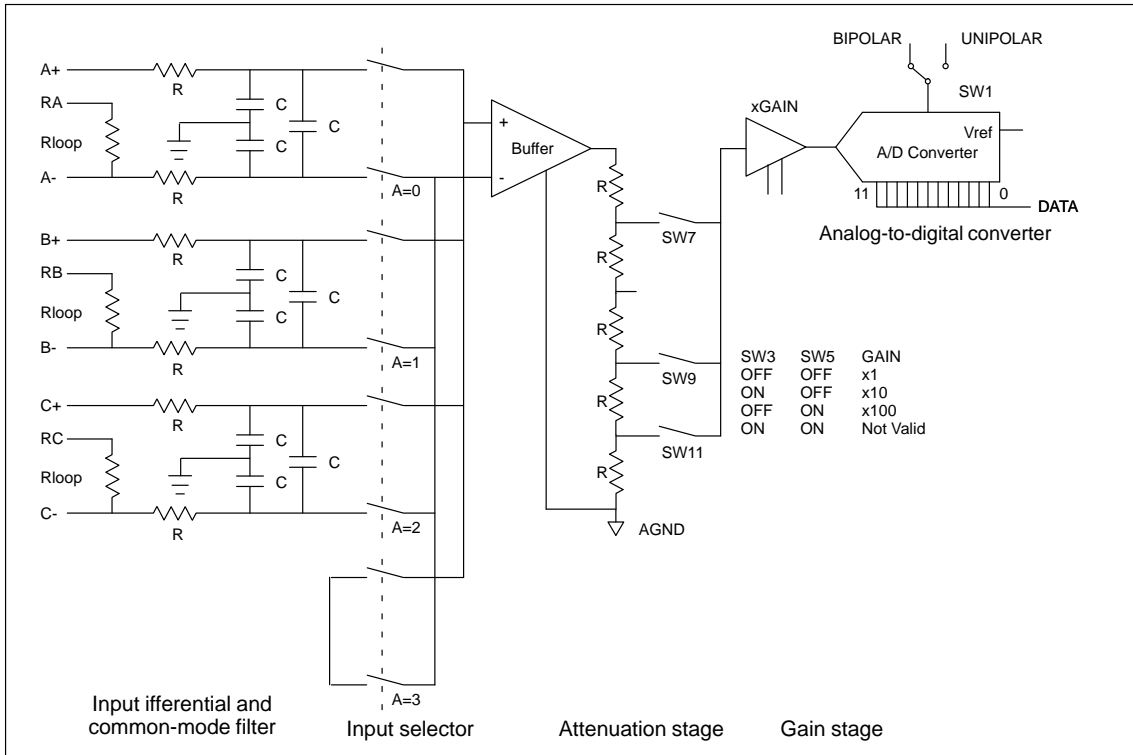


Figure A-44 EM235 Input Block Diagram

Output Data Word Format

Figure A-45 shows where the 12-bit data value is placed within the analog output word of the CPU. Figure A-46 shows the EM235 output block diagram.

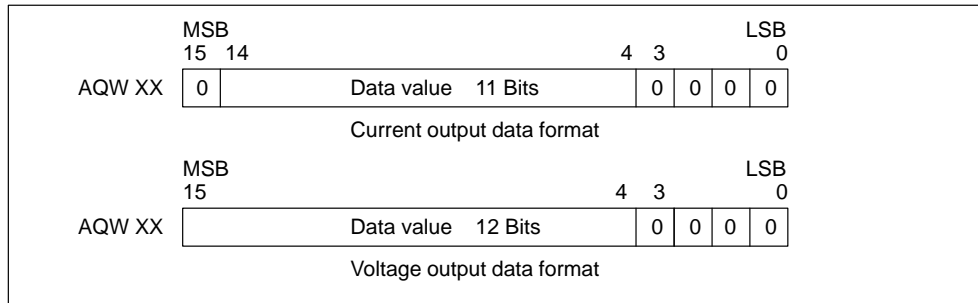


Figure A-45 Output Data Word Format

Note

The 12 bits of the digital-to-analog converter (DAC) readings are left-justified in the output data word format. The MSB is the sign bit: zero indicates a positive data word value. The four trailing zeros are truncated before being loaded into the DAC registers. These bits have no effect on the output signal value.

Output Block Diagram

Figure A-46 shows the EM235 output block diagram.

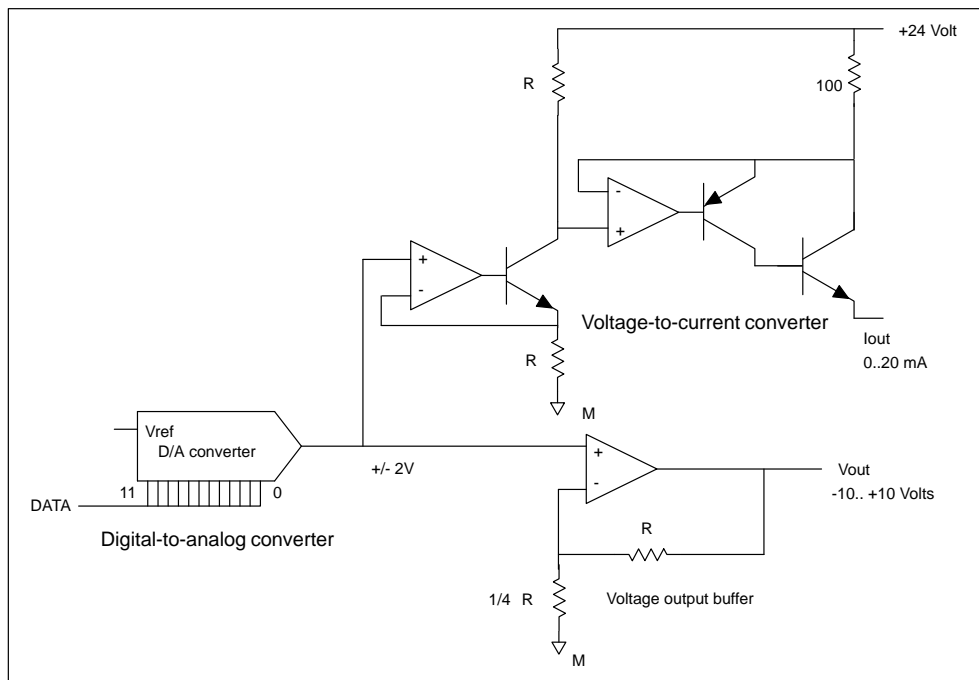


Figure A-46 EM235 Output Block Diagram

Installation Guidelines for EM235

Use the following guidelines to ensure good accuracy and repeatability:

- Ensure that the 24-VDC Sensor Supply is free of noise and is stable.
- Calibrate the module.
- Use the shortest possible sensor wires.
- Use shielded twisted pair wiring for sensor wires.
- Terminate the shield at the Sensor location only.
- Short the inputs for any unused channels, as shown in Figure A-41.
- Avoid bending the wires into sharp angles.
- Use wireways for wire routing.
- Avoid placing signal wires parallel to high-energy wires. If the two wires must meet, cross them at right angles.
- Ensure that the input signals are floating, or referenced to the external 24V common of the analog module.

Note

This expansion module is not recommended for use with thermocouples.

Understanding and Using the Analog Inputs: Accuracy and Repeatability

The EM235 combination input/output module is a low-cost, high-speed 12 bit analog input module. The module is capable of converting an analog input to its corresponding digital value in 171 μsec for the CPU 212, and 139 μsec for all other S7-200 CPUs. Conversion of the analog signal input is performed each time the analog point is accessed by the user program. These times must be added to the basic execution time of the instruction used to access the analog input.

The EM235 provides an unprocessed digital value (no linearization or filtering) that corresponds to the analog voltage or current presented at the modules input terminals. Since the module is a high-speed module, it can follow rapid changes in the analog input signal (including internal and external noise). Reading-to-reading variations caused by noise for a constant or slowly changing analog input signal can be minimized by averaging a number of readings. As the number of readings used in computing the average value increases, a correspondingly slower response time to changes in the input signal will be observed.

You may use the STEP 7-Micro/WIN Analog Input Filtering wizard to add an averaging routine to your program. Remember that an average value computed from a large number of samples will stabilize the reading while slowing down its response to changes in the input signal. For slowly changing analog input signals, a sample size of 64 or greater is recommended for the averaging routine.

The specifications for repeatability describe the reading-to-reading variations of the module for an input signal that is not changing. The repeatability specification defines the limits within which 99% of the readings will fall. The mean accuracy specification describes the average value of the error (the difference between the average value of individual readings and the exact value of the actual analog input signal). The repeatability is described in Figure A-47 by the bell curve. This figure shows the 99% repeatability limits, the mean or average value of the individual readings and the mean accuracy in a graphical form. Table A-5 gives the repeatability specifications and the mean accuracy as they relate to each of the configurable ranges.

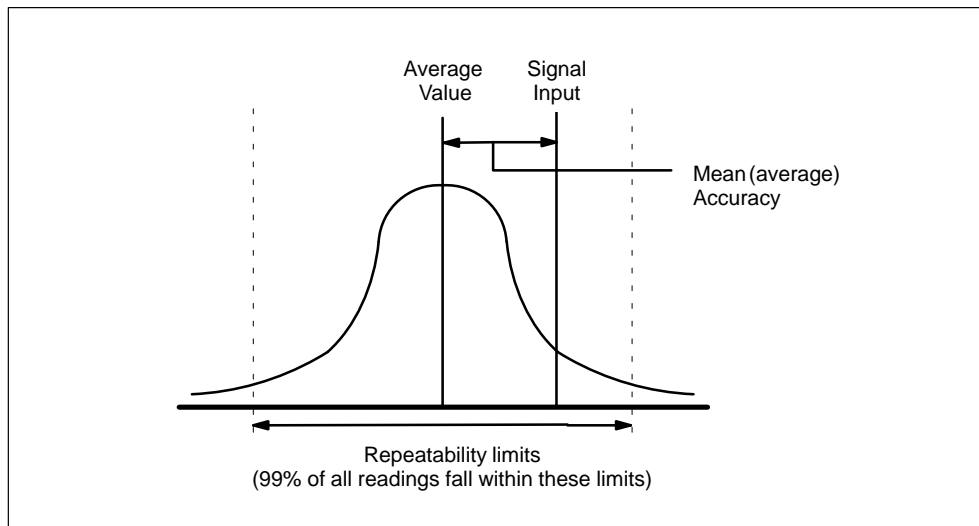


Figure A-47 Accuracy Definitions

Table A-5 Specifications for DC and AC Powered S7-200 CPUs

Full Scale Input Range	Repeatability ¹		Mean (average) Accuracy ^{1, 2, 3, 4}	
	% of Full Scale	Counts	% of Full Scale	Counts
Specifications for DC Powered S7-200 CPUs				
0 to 50 mV	± 0.075%	± 24	± 0.25%	± 80
0 to 100 mV			± 0.2%	± 64
0 to 500 mV			± 0.05%	± 16
0 to 1 V				
0 to 5 V				
0 to 20 mA				
0 to 10 V				
± 25 mV	± 0.075%	± 48	± 0.25%	± 160
± 50 mV			± 0.2%	± 128
± 100 mV			± 0.1%	± 64
± 250 mV			± 0.05%	± 32
± 500 mV				
± 1 V				
± 2.5 V				
± 5 V				
± 10 V				
Specifications for AC Powered S7-200 CPUs				
0 to 50 mV	± 0.15%	± 48	± 0.25%	± 80
0 to 100 mV			± 0.2%	± 64
0 to 500 mV			± 0.05%	± 16
0 to 1 V				
0 to 5 V				
0 to 20 mA				
0 to 10 V				
± 25 mV	± 0.15%	± 96	± 0.25%	± 160
± 50 mV			± 0.2%	± 128
± 100 mV			± 0.1%	± 64
± 250 mV			± 0.05%	± 32
± 500 mV				
± 1 V				
± 2.5 V				
± 5 V				
± 10 V				

¹ Measurements made after the selected input range has been calibrated.

² The offset error in the signal near zero analog input is not corrected, and is not included in the accuracy specifications.

³ There is a channel-to-channel carryover conversion error, due to the finite settling time of the analog multiplexer. The maximum carryover error is 0.1% of the difference between channels.

⁴ Mean accuracy includes effects of non-linearity and drift from 0 to 55 degrees C.

A.36 Memory Cartridge 8K x 8

Order Number: 6ES7 291-8GC00-0XA0

General Features	
Physical size (L x W x D)	28 x 10 x 16 mm (1.1 x 0.4 x 0.6 in.)
Weight	3.6 g (0.01 lbs.)
Power dissipation	0.5 mW
Memory type	EEPROM
User storage	4096 bytes program + 1024 bytes user data + internal system data
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant

Note

The 8K memory cartridge is produced in 4-pin and 5-pin versions. These versions are entirely compatible.

This memory cartridge can be used in any S7-200 CPU model, but the 8K memory cartridge will not store the maximum size program that is found in the CPU 215 or the CPU 216. To avoid problems with program size, it is recommended that you use the 8K memory cartridge only with the CPU 214 or the PDS 210.

Memory cartridges can only be used to transport programs between CPUs of the same CPU type. (For example, a memory cartridge programmed by a CPU 214 can be used only on another CPU 214.)

Memory Cartridge Dimensions

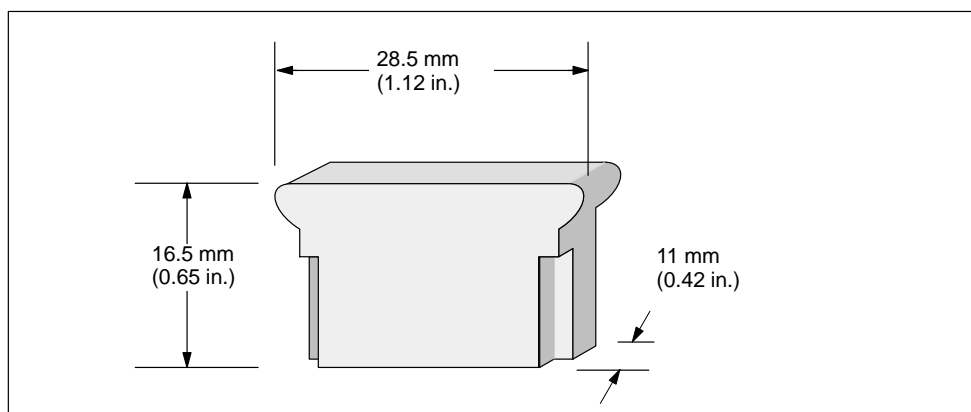


Figure A-48 Memory Cartridge Dimensions - 8K x 8

A.37 Memory Cartridge 16K x 8

Order Number: 6ES7 291-8GD00-0XA0

General Features	
Physical size (L x W x D)	28 x 10 x 16 mm (1.1 x 0.4 x 0.6 in.)
Weight	3.6 g (0.01 lbs.)
Power dissipation	0.5 mW
Memory type	EEPROM
User storage	8192 bytes program + 5120 bytes user data + internal system data
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant

Note

The 16K memory cartridge can be used in the PDS 210, the CPU 214, CPU 215, or the CPU 216.

Memory cartridges can only be used to transport programs between CPUs of the same CPU type. (For example, a memory cartridge programmed by a CPU 214 can only be used on another CPU 214).

Memory Cartridge Dimensions

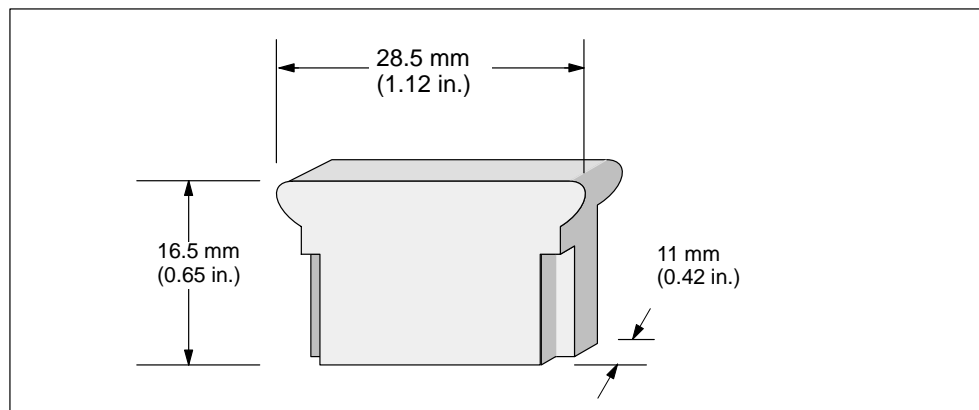


Figure A-49 Memory Cartridge Dimensions - 16K x 8

A.38 Battery Cartridge

Order Number: 6ES7 291-8BA00-0XA0

General Features	
Physical size (L x W x D)	28 x 10 x 16 mm (1.1 x 0.4 x 0.6 in.)
Weight	3.6 g (0.01 lbs.)
Battery	
Size (dia. x ht.)	9.9 x 2.5 mm (0.39 x 0.10 in.)
Type	Lithium (< 0.6 grams)
Shelf life	10 years
Typical life	200 days continuous usage*
Replacement	3V 30 mA/hr.(Renata CR 1025) 1 year interval recommended
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant CE compliant
*The battery is operational only after the super capacitor in the CPU has discharged. Power outages that are shorter than the super capacitor's data retention time will not subtract from the useful battery life.	

Battery Cartridge Dimensions

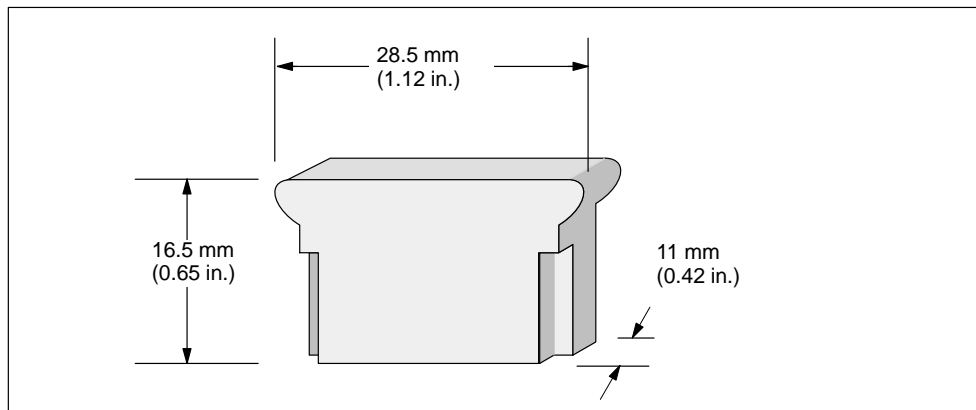


Figure A-50 Battery Cartridge Dimensions

A.39 I/O Expansion Cable

Order Number: 6ES7 290-6BC50-0XA0

General Features	
Cable length	0.8 m (32 in.)
Weight	0.2 kg (0.5 lbs.)
Connector type	Edge card

Typical Installation of the I/O Expansion Cable

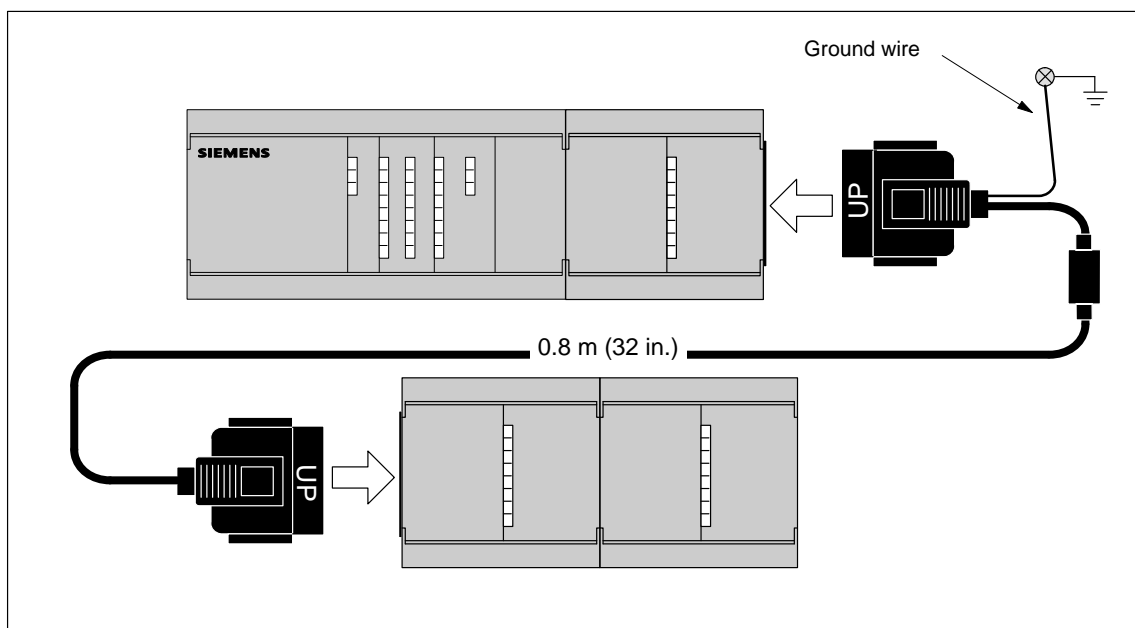


Figure A-51 Typical Installation of an I/O Expansion Cable



Caution

Incorrectly installing the I/O expansion cable can damage the equipment.

If you connect the I/O expansion cable incorrectly, the electrical current flowing through the cable can damage the expansion module.

Always orient the expansion cable so that the word "UP" on the connector of the cable faces the front of the module, as shown in Figure A-51.

A.40 PC/PPI Cable

Order Number: 6ES7 901-3BF00-0XA0

General Features															
Cable length	5 m (197 in.)														
Weight	0.3 kg (0.7 lbs.)														
Power dissipation	0.5 W														
Connector type	9 pin Sub D (socket)														
PC	9 pin Sub D (pins)														
PLC															
Cable type	RS-232 to RS-485 non-isolated														
Cable receive/transmit turn-around time	2 character times														
Baud rate supported (selected by DIP switch)	<table border="0"> <thead> <tr> <th></th> <th><u>Switch</u></th> </tr> </thead> <tbody> <tr> <td>38.4 k</td> <td>0000</td> </tr> <tr> <td>19.2 k</td> <td>0010</td> </tr> <tr> <td>9.6 k</td> <td>0100</td> </tr> <tr> <td>2.4 k</td> <td>1000</td> </tr> <tr> <td>1.2 k</td> <td>1010</td> </tr> <tr> <td>600</td> <td>1100</td> </tr> </tbody> </table>		<u>Switch</u>	38.4 k	0000	19.2 k	0010	9.6 k	0100	2.4 k	1000	1.2 k	1010	600	1100
	<u>Switch</u>														
38.4 k	0000														
19.2 k	0010														
9.6 k	0100														
2.4 k	1000														
1.2 k	1010														
600	1100														
Standards compliance	UL 508 CSA C22.2 142 FM Class I, Division 2 VDE 0160 compliant; CE compliant														

Table A-6 Cable Pin Assignment

RS-232 Pin	Function Computer End	RS-485 Pin	Function CPU S7-200 End
2	Received data (PC listens)	8	Signal A
3	Transmitted data (PC sends)	3	Signal B
5	Signal common	7	+24 V
		2	+24 V Return (PLC logic common)
		1	Shield (PLC logic common)

**Caution**

Interconnecting equipment with different reference potentials can cause unwanted currents to flow through the interconnecting cable.

These unwanted currents can cause communication errors or can damage equipment.

Be sure all equipment that you are about to connect with a communication cable either shares a common circuit reference or is isolated to prevent unwanted current flows. See “Grounding and Circuit Referencing Guidelines for Using Isolated Circuits” in Section 2.3.

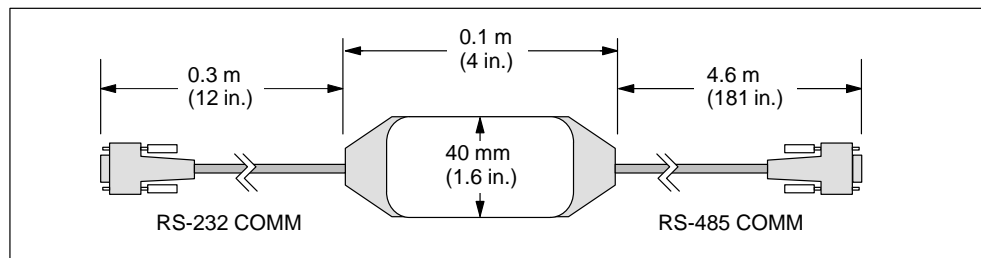
PC/PPI Cable Dimensions

Figure A-52 PC/PPI Cable Dimensions

A.41 CPU 212 DC Input Simulator

Order Number: 6ES7 274-1XF00-0XA0

General Features	
Physical size (L x W x D)	61 x 36 x 22 mm (2.4 x 1.4 x 0.85 in.)
Weight	0.02 Kg (0.04 lb.)
Points	8

User Installation

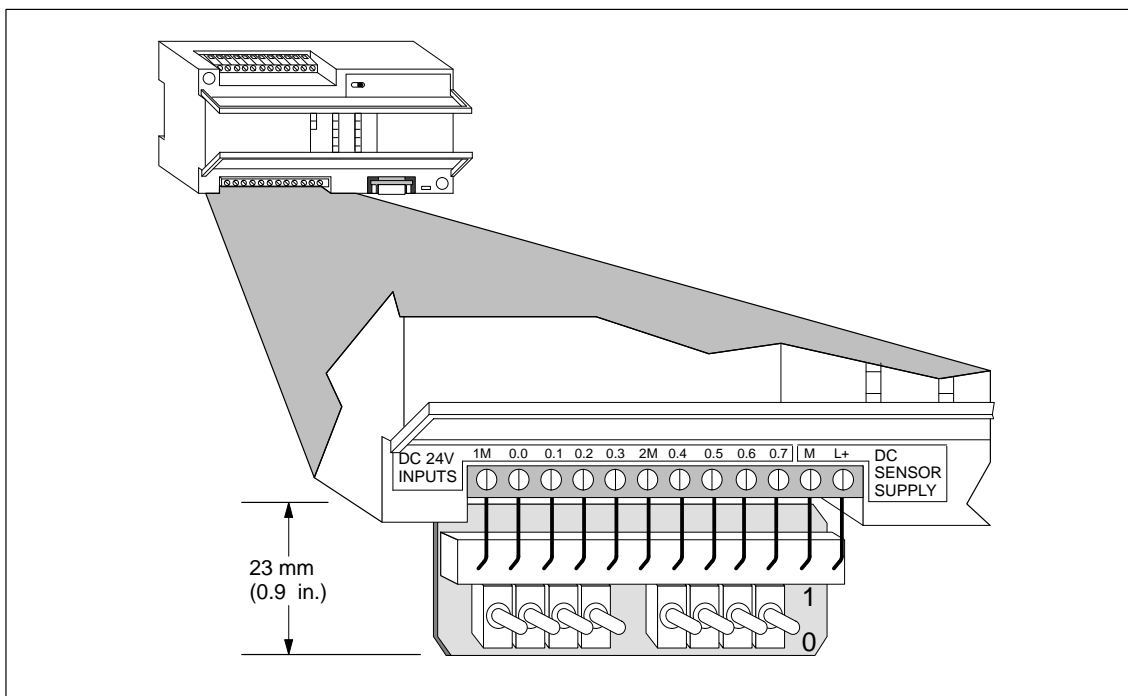


Figure A-53 Installation of the CPU 212 DC Input Simulator

A.42 CPU 214 DC Input Simulator

Order Number: 6ES7 274-1XH00-0XA0

General Features	
Physical size (L x W x D)	91 x 36 x 22 mm (3.6 x 1.4 x 0.85 in.)
Weight	0.03 Kg (0.06 lb.)
Points	14

User Installation

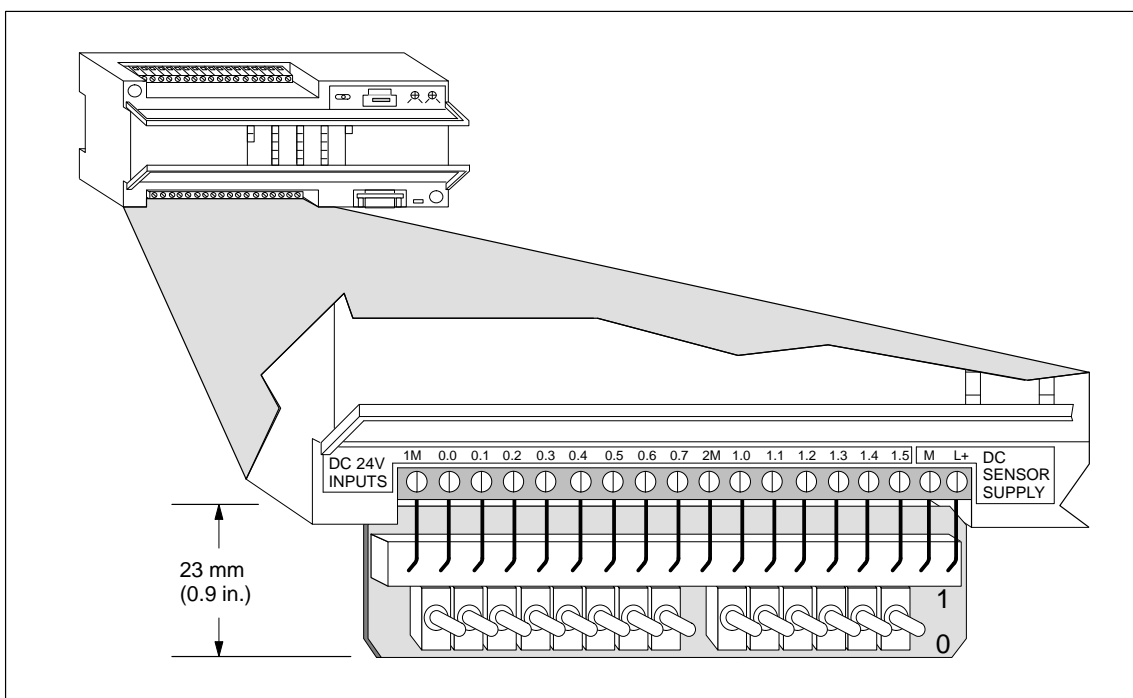


Figure A-54 Installation of the CPU 214 DC Input Simulator

A.43 CPU 215/216 DC Input Simulator

Order Number: 6ES7 274-1XK00-0XA0

General Features	
Physical size (L x W x D)	147 x 36 x 25 mm (3.6 x 1.4 x 0.85 in.)
Weight	0.04 Kg (0.08 lb.)
Points	24

User Installation

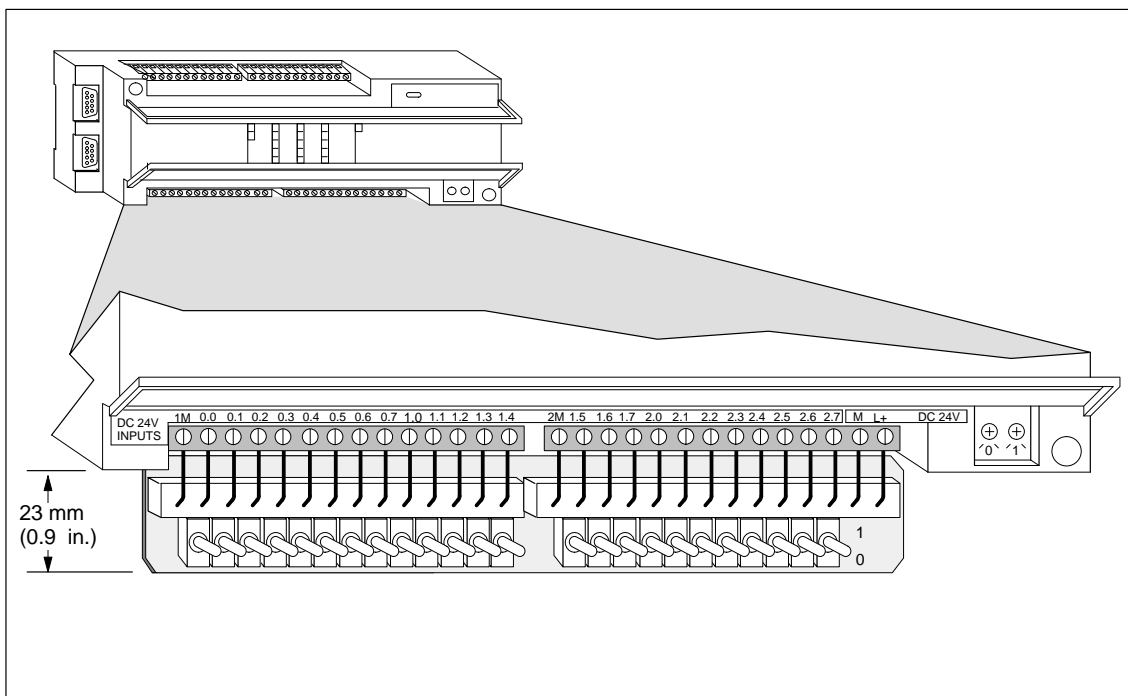


Figure A-55 Installation of the CPU 215/216 DC Input Simulator

B

Power Calculation Table

Each S7-200 CPU module (base unit) supplies 5 VDC and 24 VDC power for the expansion modules.

- The 5 VDC is automatically supplied to the expansion modules through the bus expansion port.
- Each CPU module provides a 24-VDC Sensor Supply for input points or expansion module relay coils. You must manually connect the 24-VDC supply to the input points or relay coils.

Use this table to determine how much power (or current) the CPU module can provide for your configuration. Refer to Appendix A for power budgets of the CPU module and the power requirements of the expansion modules. Section 2.5 provides an example for calculating a power budget.

Power Budget	5 VDC	24 VDC

Minus

System Requirements	5 VDC	24 VDC
	Base Unit	
Total Requirements		

Equals

Current Balance	5 VDC	24 VDC
Current Balance Total		

Error Codes

C

The information about error codes is provided to help you identify problems with your S7-200 CPU module.

Chapter Overview

Section	Description	Page
C.1	Fatal Error Codes and Messages	C-2
C.2	Run-Time Programming Problems	C-3
C.3	Compile Rule Violations	C-4

C.1 Fatal Error Codes and Messages

Fatal errors cause the CPU to stop the execution of your program. Depending on the severity of the error, a fatal error can render the CPU incapable of performing any or all functions. The objective for handling fatal errors is to bring the CPU to a safe state from which the CPU can respond to interrogations about the existing error conditions.

The CPU performs the following tasks when a fatal error is detected:

- Changes to STOP mode
- Turns on both the System Fault LED and the Stop LED
- Turns off the outputs

The CPU remains in this condition until the fatal error is corrected. Table C-1 provides a list with descriptions for the fatal error codes that can be read from the CPU.

Table C-1 Fatal Error Codes and Messages Read from the CPU

Error Code	Description
0000	No fatal errors present
0001	User program checksum error
0002	Compiled ladder program checksum error
0003	Scan watchdog time-out error
0004	Internal EEPROM failed
0005	Internal EEPROM checksum error on user program
0006	Internal EEPROM checksum error on configuration parameters
0007	Internal EEPROM checksum error on force data
0008	Internal EEPROM checksum error on default output table values
0009	Internal EEPROM checksum error on user data, DB1
000A	Memory cartridge failed
000B	Memory cartridge checksum error on user program.
000C	Memory cartridge checksum error on configuration parameters
000D	Memory cartridge checksum error on force data
000E	Memory cartridge checksum error on default output table values
000F	Memory cartridge checksum error on user data, DB1
0010	Internal software error
0011	Compare contact indirect addressing error
0012	Compare contact illegal value error
0013	Memory cartridge is blank, or the program is not understood by this CPU

C.2 Run-Time Programming Problems

Your program can create non-fatal error conditions (such as addressing errors) during the normal execution of the program. In this case, the CPU generates a non-fatal run-time error code. Table C-2 lists the descriptions of the non-fatal error codes.

Table C-2 Run-Time Programming Problems

Error Code	Run-Time Programming Problem (Non-Fatal)
0000	No error
0001	HSC box enabled before executing HDEF box
0002	Conflicting assignment of input interrupt to a point already assigned to a HSC
0003	Conflicting assignment of inputs to a HSC already assigned to input interrupt
0004	Attempted execution of ENI, DISI, or HDEF instructions in an interrupt routine
0005	Attempted execution of a second HSC with the same number before completing the first (HSC in an interrupt routine conflicts with HSC in main program)
0006	Indirect addressing error
0007	TODW (Time-of-Day Write) data error
0008	Maximum user subroutine nesting level exceeded
0009	Execution of a XMT or RCV instruction while a different XMT or RCV instruction is in progress
000A	Attempt to redefine a HSC by executing another HDEF instruction for the same HSC
0091	Range error (with address information): check the operand ranges
0092	Error in count field of an instruction (with count information): verify the maximum count size
0094	Range error writing to non-volatile memory with address information

C.3 Compile Rule Violations

When you download a program, the CPU compiles the program. If the CPU detects that the program violates a compile rule (such as an illegal instruction), the CPU aborts the download and generates a non-fatal, compile-rule error code. Table C-3 lists the descriptions of the error codes that are generated by violations of the compile rules.

Table C-3 Compile Rule Violations

Error Code	Compile Errors (Non-Fatal)
0080	Program too big to compile; you must reduce the program size.
0081	Stack underflow; you must split network into multiple networks.
0082	Illegal instruction; check instruction mnemonics.
0083	Missing MEND or instruction not allowed in main program: add MEND instruction, or remove incorrect instruction.
0084	Reserved
0085	Missing FOR; add FOR instruction or delete NEXT instruction.
0086	Missing NEXT; add NEXT instruction or delete FOR instruction.
0087	Missing label (LBL, INT, SBR); add the appropriate label.
0088	Missing RET or instruction not allowed in a subroutine: add RET to the end of the subroutine or remove incorrect instruction.
0089	Missing RETI or instruction not allowed in an interrupt routine: add RETI to the end of the interrupt routine or remove incorrect instruction.
008A	Reserved
008B	Reserved
008C	Duplicate label (LBL, INT, SBR); rename one of the labels.
008D	Illegal label (LBL, INT, SBR); ensure the number of labels allowed was not exceeded.
0090	Illegal parameter; verify the allowed parameters for the instruction.
0091	Range error (with address information); check the operand ranges.
0092	Error in the count field of an instruction (with count information); verify the maximum count size.
0093	FOR/NEXT nesting level exceeded.
0095	Missing LSCR instruction (load SCR)
0096	Missing SCRE instruction (SCR end) or disallowed instruction before the SCRE instruction

D

Special Memory (SM) Bits

Special memory bits provide a variety of status and control functions, and also serve as a means of communicating information between the CPU and your program. Special memory bits can be used as bits, bytes, words, or double words.

SMB0: Status Bits

As described in Table D-1, SMB0 contains eight status bits that are updated by the S7-200 CPU at the end of each scan cycle.

Table D-1 Special Memory Byte SMB0 (SM0.0 to SM0.7)

SM Bits	Description
SM0.0	This bit is always on.
SM0.1	This bit is on for the first scan. One use is to call an initialization subroutine.
SM0.2	This bit is turned on for one scan if retentive data was lost. This bit can be used as either an error memory bit or as a mechanism to invoke a special startup sequence.
SM0.3	This bit is turned on for one scan when RUN mode is entered from a power-up condition. This bit can be used to provide machine warm-up time before starting an operation.
SM0.4	This bit provides a clock pulse that is on for 30 seconds and off for 30 seconds, for a cycle time of 1 minute. It provides an easy-to-use delay, or a 1-minute clock pulse.
SM0.5	This bit provides a clock pulse that is on for 0.5 seconds and then off for 0.5 seconds, for a cycle time of 1 second. It provides an easy-to-use delay or a 1-second clock pulse.
SM0.6	This bit is a scan clock which is on for one scan and then off for the next scan. This bit can be used as a scan counter input.
SM0.7	This bit reflects the position of the Mode switch (off is TERM position, and on is RUN position). If you use this bit to enable Freeport mode when the switch is in the RUN position, normal communication with the programming device can be enabled by switching to the TERM position.

SMB1: Status Bits

As described in Table D-2, SMB1 contains various potential error indicators. These bits are set and reset by instructions at execution time.

Table D-2 Special Memory Byte SMB1 (SM1.0 to SM1.7)

SM Bits	Description
SM1.0	This bit is turned on by the execution of certain instructions when the result of the operation is zero.
SM1.1	This bit is turned on by the execution of certain instructions either when an overflow results or when an illegal numeric value is detected.
SM1.2	This bit is turned on when a negative result is produced by a math operation.
SM1.3	This bit is turned on when division by zero is attempted.
SM1.4	This bit is turned on when the Add to Table instruction attempts to overfill the table.
SM1.5	This bit is turned on when either LIFO or FIFO instructions attempt to read from an empty table.
SM1.6	This bit is turned on when an attempt to convert a non-BCD value to binary is made.
SM1.7	This bit is turned on when an ASCII value cannot be converted to a valid hexadecimal value.

SMB2: Freeport Receive Character

SMB2 is the Freeport receive character buffer. As described in Table D-3, each character received while in Freeport mode is placed in this location for easy access from the ladder logic program.

Table D-3 Special Memory Byte SMB2

SM Byte	Description
SMB2	This byte contains each character that is received from Port 0 or Port 1 during Freeport communication.

SMB3: Freeport Parity Error

SMB3 is used for Freeport mode and contains a parity error bit that is set when a parity error is detected on a received character. As shown in Table D-4, SM3.0 turns on when a parity error is detected. Use this bit to discard the message.

Table D-4 Special Memory Byte SMB3 (SM3.0 to SM3.7)

SM Bits	Description
SM3.0	Parity error from Port 0 or Port 1 (0 = no error; 1 = error was detected)
SM3.1 to SM3.7	Reserved

SMB4: Queue Overflow

As described in Table D-5, SMB4 contains the interrupt queue overflow bits, a status indicator showing whether interrupts are enabled or disabled, and a transmitter-idle memory bit. The queue overflow bits indicate either that interrupts are happening at a rate greater than can be processed, or that interrupts were disabled with the global interrupt disable instruction.

Table D-5 Special Memory Byte SMB4 (SM4.0 to SM4.7)

SM Bits	Description
SM4.0 ¹	This bit is turned on when the communication interrupt queue has overflowed.
SM4.1 ¹	This bit is turned on when the input interrupt queue has overflowed.
SM4.2 ¹	This bit is turned on when the timed interrupt queue has overflowed.
SM4.3	This bit is turned on when a run-time programming problem is detected.
SM4.4	This bit reflects the global interrupt enable state. It is turned on when interrupts are enabled.
SM4.5	This bit is turned on when the transmitter is idle (Port 0).
SM4.6	This bit is turned on when the transmitter is idle (Port 1).
SM4.7	Reserved.

¹ Use status bits 4.0, 4.1, and 4.2 only in an interrupt routine. These status bits are reset when the queue is emptied, and control is returned to the main program.

SMB5: I/O Status

As described in Table D-6, SMB5 contains status bits about error conditions that were detected in the I/O system. These bits provide an overview of the I/O errors detected.

Table D-6 Special Memory Byte SMB5 (SM5.0 to SM5.7)

SM Bits	Description
SM5.0	This bit is turned on if any I/O errors are present.
SM5.1	This bit is turned on if too many digital I/O points have been connected to the I/O bus.
SM5.2	This bit is turned on if too many analog I/O points have been connected to the I/O bus.
SM5.3 to SM5.7	Reserved.

SMB6: CPU ID Register

As described in Table D-7, SMB6 is the CPU identification register. SM6.4 to SM6.7 identify the type of CPU. SM6.0 to SM6.3 are reserved for future use.

Table D-7 Special Memory Byte SMB6

SM Bits	Description								
Format	<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: center;"> <small>MSB</small> 7 <table border="1" style="border-collapse: collapse;"> <tr> <td style="width: 15px; height: 15px; text-align: center;">x</td> <td style="width: 15px; height: 15px; text-align: center;">x</td> <td style="width: 15px; height: 15px; text-align: center;">x</td> <td style="width: 15px; height: 15px; text-align: center;">x</td> <td style="width: 15px; height: 15px; text-align: center;">r</td> <td style="width: 15px; height: 15px; text-align: center;">r</td> <td style="width: 15px; height: 15px; text-align: center;">r</td> <td style="width: 15px; height: 15px; text-align: center;">r</td> </tr> </table> </div> <div style="text-align: center;"> <small>LSB</small> 0 </div> <div style="margin-left: 20px;">CPU ID register</div> </div>	x	x	x	x	r	r	r	r
x	x	x	x	r	r	r	r		
SM6.4 to SM6.7	xxxx = 0000 = CPU 212 0010 = CPU 214 1000 = CPU 215 1001 = CPU 216								
SM6.0 to SM6.3	Reserved								

SMB7: Reserved

SMB7 is reserved for future use.

SMB8 to SMB21: I/O Module ID and Error Registers

SMB8 through SMB21 are organized in byte pairs for expansion modules 0 to 6. As described in Table D-8, the even-numbered byte of each pair is the module-identification register. These bytes identify the module type, the I/O type, and the number of inputs and outputs. The odd-numbered byte of each pair is the module error register. These bytes provide an indication of any errors detected in the I/O for that module.

Table D-8 Special Memory Bytes SMB8 to SMB21

SM Byte	Description																
Format	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Even-Number Byte: Module ID Register</p> <div style="text-align: center;"> <small>MSB</small> 7 <table border="1" style="border-collapse: collapse;"> <tr> <td style="width: 15px; height: 15px; text-align: center;">M</td> <td style="width: 15px; height: 15px; text-align: center;">t</td> <td style="width: 15px; height: 15px; text-align: center;">t</td> <td style="width: 15px; height: 15px; text-align: center;">A</td> <td style="width: 15px; height: 15px; text-align: center;">i</td> <td style="width: 15px; height: 15px; text-align: center;">i</td> <td style="width: 15px; height: 15px; text-align: center;">Q</td> <td style="width: 15px; height: 15px; text-align: center;">Q</td> </tr> </table> </div> <p>M: Module present 0 = Present 1 = Not present</p> <p>tt: 00 I/O module 01 Reserved 10 Reserved 11 Reserved</p> <p>A I/O type 0 = Discrete 1 = Analog</p> <p>ii 00 No inputs QQ 00 No outputs 01 2 AI or 8 DI 01 2 AQ or 8 DQ 10 4 AI or 16 DI 10 4 AQ or 16 DQ 11 8 AI or 32 DI 11 8 AQ or 32 DQ</p> </div> <div style="width: 45%;"> <p>Odd-Number Byte: Module Error Register</p> <div style="text-align: center;"> <small>MSB</small> 7 <table border="1" style="border-collapse: collapse;"> <tr> <td style="width: 15px; height: 15px; text-align: center;">C</td> <td style="width: 15px; height: 15px; text-align: center;">0</td> <td style="width: 15px; height: 15px; text-align: center;">0</td> <td style="width: 15px; height: 15px; text-align: center;">0</td> <td style="width: 15px; height: 15px; text-align: center;">R</td> <td style="width: 15px; height: 15px; text-align: center;">P</td> <td style="width: 15px; height: 15px; text-align: center;">r</td> <td style="width: 15px; height: 15px; text-align: center;">r</td> </tr> </table> </div> <p>C: Configuration error R: Out-of-range error P: No user power rr: Reserved</p> </div> </div>	M	t	t	A	i	i	Q	Q	C	0	0	0	R	P	r	r
M	t	t	A	i	i	Q	Q										
C	0	0	0	R	P	r	r										
SMB8	Module 0 ID register																
SMB9	Module 0 error register																
SMB10	Module 1 ID register																
SMB11	Module 1 error register																

Table D-8 Special Memory Bytes SMB8 to SMB21, continued

SM Byte	Description
SMB12	Module 2 ID register
SMB13	Module 2 error register
SMB14	Module 3 ID register
SMB15	Module 3 error register
SMB16	Module 4 ID register
SMB17	Module 4 error register
SMB18	Module 5 ID register
SMB19	Module 5 error register
SMB20	Module 6 ID register
SMB21	Module 6 error register

SMW22 to SMW26: Scan Times

As described in Table D-9, SMW22, SMW24, and SMW26 provide scan time information: minimum scan time, maximum scan time, and last scan time in milliseconds.

Table D-9 Special Memory Words SMW22 to SMW26

SM Word	Description
SMW22	This word provides the scan time of the last scan.
SMW24	This word provides the minimum scan time recorded since entering the RUN mode.
SMW26	This word provides the maximum scan time recorded since entering the RUN mode.

SMB28 and SMB29: Analog Adjustment

As described in Table D-10, SMB28 holds the digital value that represents the position of analog adjustment 0. SMB29 holds the digital value that represents the position of analog adjustment 1.

Table D-10 Special Memory Bytes SMB28 and SMB29

SM Byte	Description
SMB28	This byte stores the value entered with analog adjustment 0. This value is updated once per scan in STOP/RUN.
SMB29	This byte stores the value entered with analog adjustment 1. This value is updated once per scan in STOP/RUN.

SMB30 and SMB130: Freeport Control Registers

SMB30 controls the Freeport communication for port 0; SMB130 controls the Freeport communication for port 1. You can read and write to SMB30 and SMB130. As described in Table D-11, these bytes configure the respective communication port for Freeport operation and provide selection of either Freeport or system protocol support.

Table D-11 Special Memory Byte SMB30

Port 0	Port 1	Description
Format of SMB30	Format of SMB130	<div style="display: flex; justify-content: space-between; align-items: center;"> MSB 7 LSB 0 </div> <div style="display: flex; justify-content: center; align-items: center; margin-top: 5px;"> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">p</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">p</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">d</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">b</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">b</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">b</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">m</div> <div style="border: 1px solid black; padding: 2px; margin: 0 2px;">m</div> </div> <div style="margin-left: 100px;">Freeport mode control byte</div>
SM30.6 and SM30.7	SM130.6 and SM130.7	pp Parity select 00 = no parity 01 = even parity 10 = no parity 11 = odd parity
SM30.5	SM130.5	d Data bits per character 0 = 8 bits per character 1 = 7 bits per character
SM30.2 to SM30.4	SM130.2 to SM130.4	bbb Freeport Baud rate 000 = 38,400 baud (for CPU 212: = 19,200 baud) 001 = 19,200 baud 010 = 9,600 baud 011 = 4,800 baud 100 = 2,400 baud 101 = 1,200 baud 110 = 600 baud 111 = 300 baud
SM30.0 and SM30.1	SM130.0 and SM130.1	mm Protocol selection 00 = Point-to-Point Interface protocol (PPI/slave mode) 01 = Freeport protocol 10 = PPI/master mode 11 = Reserved (defaults to PPI/slave mode)

SMB31 and SMW32: Permanent Memory (EEPROM) Write Control

You can save a value stored in V memory to permanent memory (EEPROM) under the control of your program. To do this, load the address of the location to be saved in SMW32. Then, load SMB31 with the command to save the value. Once you have loaded the command to save the value, you do not change the value in V memory until the CPU resets SM31.7, indicating that the save operation is complete.

At the end of each scan, the CPU checks to see if a command to save a value to permanent memory was issued. If the command was issued, the specified value is saved to permanent memory.

As described in Table D-12, SMB31 defines the size of the data to be saved to permanent memory and also provides the command that initiates the execution of a save operation. SMW32 stores the starting address in V memory for the data to be saved to permanent memory.

Table D-12 Special Memory Byte SMB31 and Special Memory Word SMW32

SM Byte	Description
Format	<p>SMB31: Software command</p> <p style="text-align: center;">MSB LSB</p> <p style="text-align: center;">7 0</p> <p style="text-align: center;">c 0 0 0 0 0 s s</p> <p>SMW32: V memory address</p> <p style="text-align: center;">MSB LSB</p> <p style="text-align: center;">15 0</p> <p style="text-align: center;">V memory address</p>
SM31.0 and SM31.1	<p>ss: Size of the value to be saved</p> <p>00 = byte</p> <p>01 = byte</p> <p>10 = word</p> <p>11 = double word</p>
SM30.7	<p>c: Save to permanent memory (EEPROM)</p> <p>0 = No request for a save operation to be performed</p> <p>1 = User program requests that the CPU save data to permanent memory.</p> <p>The CPU resets this bit after each save operation.</p>
SMW32	<p>The V memory address for the data to be saved is stored in SMW32. This value is entered as an offset from V0. When a save operation is executed, the value in this V memory address is saved to the corresponding V memory location in the permanent memory (EEPROM).</p>

SMB34 and SMB35: Time Interval Registers for Timed Interrupts

As described in Table D-13, SMB34 specifies the time interval for timed interrupt 0, and SMB35 specifies the time interval for timed interrupt 1. You can specify the time interval (in 1-ms increments) from 5 ms to 255 ms. The time-interval value is captured by the CPU at the time the corresponding timed interrupt event is attached to an interrupt routine. To change the time interval, you must reattach the timed interrupt event to the same or to a different interrupt routine. You can terminate the timed interrupt event by detaching the event.

Table D-13 Special Memory Bytes SMB34 and SMB35

SM Byte	Description
SMB34	This byte specifies the time interval (in 1-ms increments from 5 ms to 255 ms) for timed interrupt 0.
SMB35	This byte specifies the time interval (in 1-ms increments from 5 ms to 255 ms) for timed interrupt 1.

SMB36 to SMB65: HSC Register

As described in Table D-14, SMB36 through SM65 are used to monitor and control the operation of the high-speed counters.

Table D-14 Special Memory Bytes SMB36 to SMB65

SM Byte	Description
SM36.0 to SM36.4	Reserved
SM36.5	HSC0 current counting direction status bit: 1 = counting up
SM36.6	HSC0 current value equals preset value status bit: 1 = equal
SM36.7	HSC0 current value is greater than preset value status bit: 1 = greater than
SM37.0 to SM37.2	Reserved
SM37.3	HSC0 direction control bit: 1 = count up
SM37.4	HSC0 update direction: 1 = update direction
SM37.5	HSC0 update preset value: 1 = write new preset value to HSC0 preset
SM37.6	HSC0 update current value: 1 = write new current value to HSC0 current
SM37.7	HSC0 enable bit: 1 = enable
SMB38 SMB39 SMB40 SMB41	HSC0 new current value SMB38 is most significant byte, and SMB41 is least significant byte.
SMB42 SMB43 SMB44 SMB45	HSC0 new preset value SMB42 is most significant byte, and SMB45 is least significant byte.
SM46.0 to SM46.4	Reserved
SM46.5	HSC1 current counting direction status bit: 1 = counting up
SM46.6	HSC1 current value equals preset value status bit: 1 = equal
SM46.7	HSC1 current value is greater than preset value status bit: 1 = greater than
SM47.0	HSC1 active level control bit for reset: 0 = active high, 1 = active low
SM47.1	HSC1 active level control bit for start: 0 = active high, 1 = active low
SM47.2	HSC1 quadrature counter rate selection: 0 = 4x rate, 1 = 1x rate
SM47.3	HSC1 direction control bit: 1 = count up
SM47.4	HSC1 update direction: 1 = update direction
SM47.5	HSC1 update preset value: 1 = write new preset value to HSC1 preset
SM47.6	HSC1 update current value: 1 = write new current value to HSC1 current
SM47.7	HSC1 enable bit: 1 = enable
SMB48 SMB49 SMB50 SMB51	HSC1 new current value SMB48 is most significant byte, and SMB51 is least significant byte.

Table D-14 Special Memory Bytes SMB36 to SMB65, continued

SM Byte	Description
SMB52 to SMB55	HSC1 new preset value SMB52 is most significant byte, and SMB55 is least significant byte.
SM56.0 to SM56.4	Reserved
SM56.5	HSC2 current counting direction status bit: 1 = counting up
SM56.6	HSC2 current value equals preset value status bit: 1 = equal
SM56.7	HSC2 current value is greater than preset value status bit: 1 = greater than
SM57.0	HSC2 active level control bit for reset: 0 = active high, 1 = active low
SM57.1	HSC2 active level control bit for start: 0 = active high, 1 = active low
SM57.2	HSC2 quadrature counter rate selection: 0 = 4x rate, 1 = 1x rate
SM57.3	HSC2 direction control bit: 1 = count up
SM57.4	HSC2 update direction: 1 = update direction
SM57.5	HSC2 update preset value: 1 = write new preset value to HSC2 preset
SM57.6	HSC2 update current value: 1 = write new current value to HSC2 current
SM57.7	HSC2 enable bit: 1 = enable
SMB58 SMB59 SMB60 SMB61	HSC2 new current value SMB58 is most significant byte, and SMB61 is least significant byte.
SMB62 SMB63 SMB64 SMB65	HSC2 new preset value SMB62 is most significant byte, and SMB65 is least significant byte.

SMB66 to SMB85: PTO/PWM Registers

As described in Table D-15, SMB66 through SMB85 are used to monitor and control the pulse output and pulse width modulation functions. See the information on high-speed output instructions in Chapter 10 for a complete description of these bits.

Table D-15 Special Memory Bytes SMB66 to SMB85

SM Byte	Description
SM66.0 to SM66.5	Reserved
SM66.6	PTO0 pipeline overflow: 0 = no overflow, 1 = overflow
SM66.7	PTO0 idle bit: 0 = PTO in progress, 1 = PTO idle
SM67.0	PTO0/PWM0 update cycle time value: 1 = write new cycle time
SM67.1	PWM0 update pulse width value: 1 = write new pulse width
SM67.2	PTO0 update pulse count value: 1 = write new pulse count
SM67.3	PTO0/PWM0 time base: 0 = 1 μ s/tick, 1 = 1 ms/tick

Table D-15 Special Memory Bytes SMB66 to SMB85, continued

SM Byte	Description
SM67.4 and SM67.5	Reserved
SM67.6	PTO0/PWM0 mode select: 0 = PTO, 1 = PWM
SM67.7	PTO0/PWM0 enable bit: 1 = enable
SMB68 SMB69	PTO0/PWM0 cycle time value SMB68 is most significant byte, and SMB69 is least significant byte.
SMB70 SMB71	PWM0 pulse width value SMB70 is most significant byte, and SMB71 is least significant byte.
SMB72 SMB73 SMB74 SMB75	PTO0 pulse count value SMB72 is most significant byte, and SMB75 is least significant byte.
SM76.0 to SM76.5	Reserved
SM76.6	PTO1 pipeline overflow: 0 = no overflow, 1 = overflow
SM76.7	PTO1 idle bit: 0 = PTO in progress, 1 = PTO idle
SM77.0	PTO1/PWM1 update cycle time value: 1 = write new cycle time
SM77.1	PWM1 update pulse width value: 1 = write new pulse width
SM77.2	PTO1 update pulse count value: 1 = write new pulse count
SM77.3	PTO1/PWM1 time base: 0 = 1 μ s/tick, 1 = 1 ms/tick
SM77.4 and SM77.5	Reserved
SM77.6	PTO1/PWM1 mode select: 0 = PTO, 1 = PWM
SM77.7	PTO1/PWM1 enable bit: 1 = enable
SMB78 SMB79	PTO1/PWM1 cycle time value SMB78 is most significant byte, and SMB79 is least significant byte.
SMB80 SMB81	PWM1 pulse width value SMB80 is most significant byte, and SMB81 is least significant byte.
SMB82 SMB83 SMB84 SMB85	PTO1 pulse count value SMB82 is most significant byte, and SMB85 is least significant byte.

SMB86 to SMB94, and SMB186 to SMB194: Receive Message Control

As described in Table D-16, SMB86 through SMB94 and SMB186 through SMB194 are used to control and read the status of the Receive Message instruction.

Table D-16 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194

Port 0	Port 1	Description
SMB86	SMB186	<div style="display: flex; justify-content: space-between; align-items: center;"> MSB 7 LSB 0 </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <div style="border: 1px solid black; padding: 2px; display: flex; gap: 5px;"> nre00tcp </div> <div style="margin-left: 20px;">Receive Message status byte</div> </div> <p>n: 1 = Receive message terminated by user disable command r: 1 = Receive message terminated: error in input parameters or missing start or end condition e: 1 = End character received t: 1 = Receive message terminated: timer expired c: 1 = Receive message terminated: maximum character count achieved p: 1 = Receive message terminated because of a parity error</p>
SMB87	SMB187	<div style="display: flex; justify-content: space-between; align-items: center;"> MSB 7 LSB 0 </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <div style="border: 1px solid black; padding: 2px; display: flex; gap: 5px;"> nxyzmt00 </div> <div style="margin-left: 20px;">Receive Message control byte</div> </div> <p>n: 0 = Receive Message function is disabled. 1 = Receive Message function is enabled. The enable/disable receive message bit is checked each time the RCV instruction is executed. x: 0 = Ignore SMB88 or SMB188. 1 = Use the value of SMB88 or SMB188 to detect start of message. y: 0 = Ignore SMB89 or SMB189. 1 = Use the value of SMB89 or SMB189 to detect end of message. z: 0 = Ignore SMW90 or SMB190. 1 = Use the value of SMW90 to detect an idle line condition. m: 0 = Timer is an inter-character timer. 1 = Timer is a message timer. t: 0 = Ignore SMW92 or SMW192. 1 = Terminate receive if the time period in SMW92 or SMW192 is exceeded.</p> <p>These bits define the criteria for identifying the message (including both the start-of-message and end-of-message criteria). To determine the start of a message, the enabled start-of-message criteria are logically ANDed, and must occur in sequence (idle line followed by a start character). To determine the end of a message, the enabled end-of-message criteria are logically ORed.</p> <p>Equations for start and stop criteria: Start of Message = z * x End of Message = y + t + maximum character count reached</p> <p>Note: The Receive Message function is automatically terminated by an overrun or a parity error. You must define a start condition (x or z), and an end condition (y, t, or maximum character count) for the receive message function to operate.</p>
SMB88	SMB188	Start of message character
SMB89	SMB189	End of message character
SMB90 SMB91	SMB190 SMB191	Idle line time period given in milliseconds. The first character received after idle line time has expired is the start of a new message. SM90 (or SM190) is the most significant byte and SM91 (or SM191) is the least significant byte.

SMB92 SMB93	SMB192 SMB193	Inter-character/message timer time-out value (in milliseconds). If the time period is exceeded, the receive message is terminated. SM92 (or SM192) is the most significant byte, and SM93 (or SM193) is the least significant byte.
SMB94	SMB194	Maximum number of characters to be received (1 to 255 bytes). Note: This range must be set to the expected maximum buffer size, even if the character count message termination is not used.

SMB110 to SMB115: DP Standard Protocol Status

As described in Table D-17, SMB110 through SMB115 are used to monitor the status of the DP standard portocol.

Note

These locations are for status only. Do not write to them. The locations show values set by the DP master device during the configuration process.

Table D-17 Special Memory Bytes SMB110 to SMB115

SM Byte	Description								
SMB110	<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;"> <p>MSB 7</p> <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="width: 20px;">0</td> <td style="width: 20px;">0</td> <td style="width: 20px;">0</td> <td style="width: 20px;">0</td> <td style="width: 20px;">0</td> <td style="width: 20px;">0</td> <td style="width: 20px;">s</td> <td style="width: 20px;">s</td> </tr> </table> </div> <div> <p>LSB 0</p> </div> <div style="margin-left: 20px;"> <p>Port 1: DP standard protocol status byte</p> <p>ss: DP standard status byte 00 = DP communications have not been initiated since power on 01 = Configuration/parameter assignment error detected 10 = Currently in data exchange mode 11 = Dropped out of data exchange mode</p> <p>SM111 to SM115 are updated each time the CPU accepts configuration-parameter assignment information. These locations are updated even if a configuration-parameter assignment error is detected. These locations are cleared every time the CPU is turned on.</p> </div> </div>	0	0	0	0	0	0	s	s
0	0	0	0	0	0	s	s		
SMB111	This byte defines the address of the slave's master (0 to 126).								
SMB112 SMB113	These bytes define the V memory address of the output buffer (offset from VB0). SM112 is the most significant byte, and SM113 is the least significant byte.								
SMB114	This byte defines the number of bytes for the output data.								
SMB115	This byte defines the number of bytes for the input data.								

Using STEP 7-Micro/WIN with STEP 7 and STEP 7-Micro/DOS

E

STEP 7-Micro/WIN 32 works as an integrated product in conjunction with STEP 7. From within the STEP 7 software, you can use STEP 7-Micro/WIN in the same manner as any of the other STEP 7 applications (such as the symbol editor or the program editor). For more information about the STEP 7 programming software, refer to either online help or the *SIMATIC STEP 7 User Manual*.

You can also import program files which were created with STEP 7-Micro/DOS. These files can be edited and downloaded by STEP 7-Micro/WIN. For more information about STEP 7-Micro/DOS, refer to either the online help or the *SIMATIC STEP 7-Micro/DOS User Manual*.

Chapter Overview

Section	Description	Page
E.1	Using STEP 7-Micro/WIN with STEP 7	E-2
E.2	Importing Files from STEP 7-Micro/DOS	E-4

E.1 Using STEP 7-Micro/WIN with STEP 7

You can use STEP 7-Micro/WIN within the STEP 7 software to access your S7-200 program:

- Off-line: You can insert a SIMATIC 200 Station into a STEP 7 project.
- Online: You can access the S7-200 CPU in the online “life-list” of the active stations on the network.

Running the STEP 7-Micro/WIN programming software from within the STEP 7 software can cause slight differences in the appearance from when STEP 7-Micro/WIN is running as a stand-alone application:

- Browsers: If STEP 7-Micro/WIN is running within the STEP 7 software, you use the STEP 7 browsers to navigate to the S7-200 station objects in the STEP 7 hierarchy. You can only navigate to the S7-200 objects within the STEP 7 hierarchy; you cannot open any objects (projects, programs, data blocks, or status charts) which are stored under the STEP 7-Micro/WIN project hierarchy.
- Language and mnemonics: If STEP 7-Micro/WIN is running within the STEP 7 software, you use the language and mnemonics settings for STEP 7.

Creating an S7-200 CPU within a STEP 7 Project

To create an S7-200 CPU with the STEP 7 programming software, you insert a SIMATIC 200 Station into a STEP 7 project. STEP 7 creates the 200 station. Unlike the S7-300 and S7-400 stations, there are no other objects (such as CPUs or networks) associated with the S7-200 station. A single S7-200 station represents an entire STEP 7-Micro/WIN project, which includes the program, data block, symbols table, and status chart.

You can use the STEP 7 programming software to copy, move, delete, or rename the S7-200 project.

Note

You can insert an S7-200 CPU (“SIMATIC 200 Station”) only in the root of the STEP 7 project; you cannot insert a SIMATIC 200 Station under any other object type. There is no interaction between the SIMATIC 200 station and any of the other STEP 7 objects.

To create an S7-200 station, follow these steps:

1. Use the menu command **File ► New** to create a new project in the project window of the SIMATIC Manager.
2. Use the menu command **Insert ► Station ► SIMATIC 200 Station** to create an S7-200 object.
3. To edit the S7-200 station, double-click on the S7-200 object to open the station. STEP 7 starts the STEP 7-Micro/WIN programming software.

Note

You can have only one window running the STEP 7-Micro/WIN programming software at any time. If you already have another S7-200 project open, you must close the first project before you can open the second S7-200 project.

Using STEP 7 to Edit an Online S7-200 CPU

The SIMATIC Manager provides an online life-list of S7 nodes or stations on the network. This life-list includes any S7-200 nodes (stations) which have been connected to the network. When you select the S7-200 node from the life-list, STEP 7 starts the STEP 7-Micro/WIN programming software. STEP 7-Micro/WIN opens an empty (untitled) project and uploads the user program, the data block, and the CPU configuration from the S7-200 CPU.

Note

You can have different networks which can be accessed only through STEP 7 or only through STEP 7-Micro/WIN. When STEP 7-Micro/WIN is running within the STEP 7 software, the life-list of the network shows only those stations which are accessible through STEP 7.

Opening a STEP 7 Project from STEP 7-Micro/WIN

You can access the user program for an S7-200 station stored in STEP 7 projects even when STEP 7-Micro/WIN is not running within the STEP 7 software. To edit the user program, follow these steps:

1. From the STEP 7-Micro/WIN programming software, use the menu command **Project ► New** to create a new project.
2. Use the menu command **Project ► Import ► STEP 7 Project**, as shown in Figure E-1.
3. From the STEP 7 project browser, select the S7-200 station from the STEP 7 project and click the "Open" button.

The user program and other elements (data block, status chart, and symbol table) open under the STEP 7-Micro/WIN project. See Figure E-1.

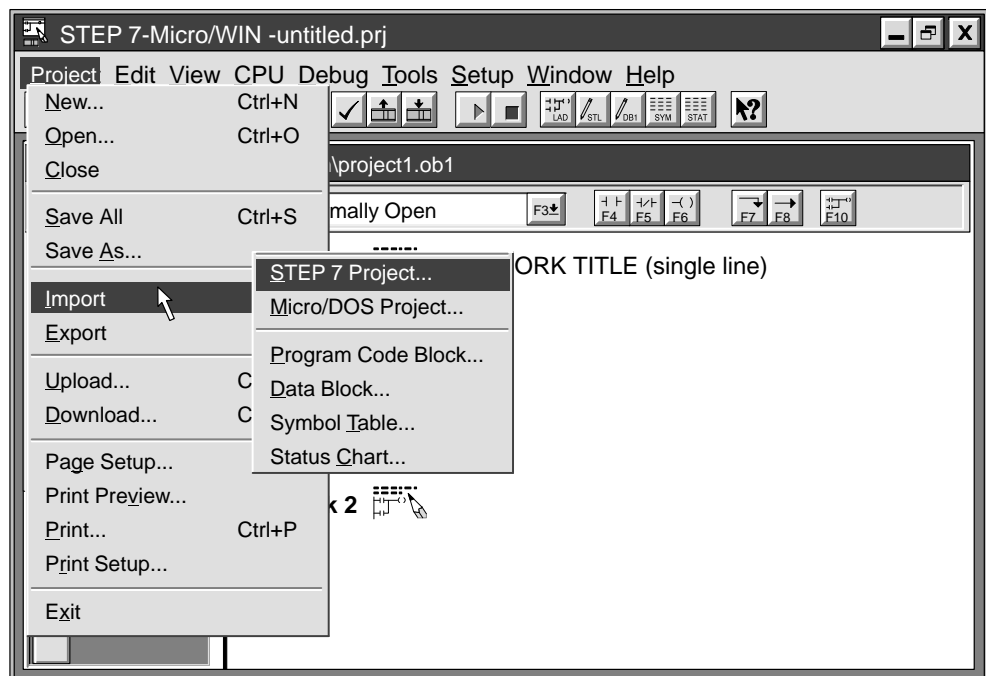


Figure E-1 Opening a STEP 7 Project from STEP 7-Micro/WIN

E.2 Importing Files from STEP 7-Micro/DOS

STEP 7-Micro/WIN allows you to import programs created in the STEP 7-Micro/DOS programming software into STEP 7-Micro/WIN projects.

Importing a STEP 7-Micro/DOS Program

To import a STEP 7-Micro/DOS program into a STEP 7-Micro/WIN project, follow these steps:

1. Select the menu command **Project ► New** to create an untitled project.
2. Select the menu command **Project ► Import ► Micro/DOS Project...**, as shown in Figure E-2.

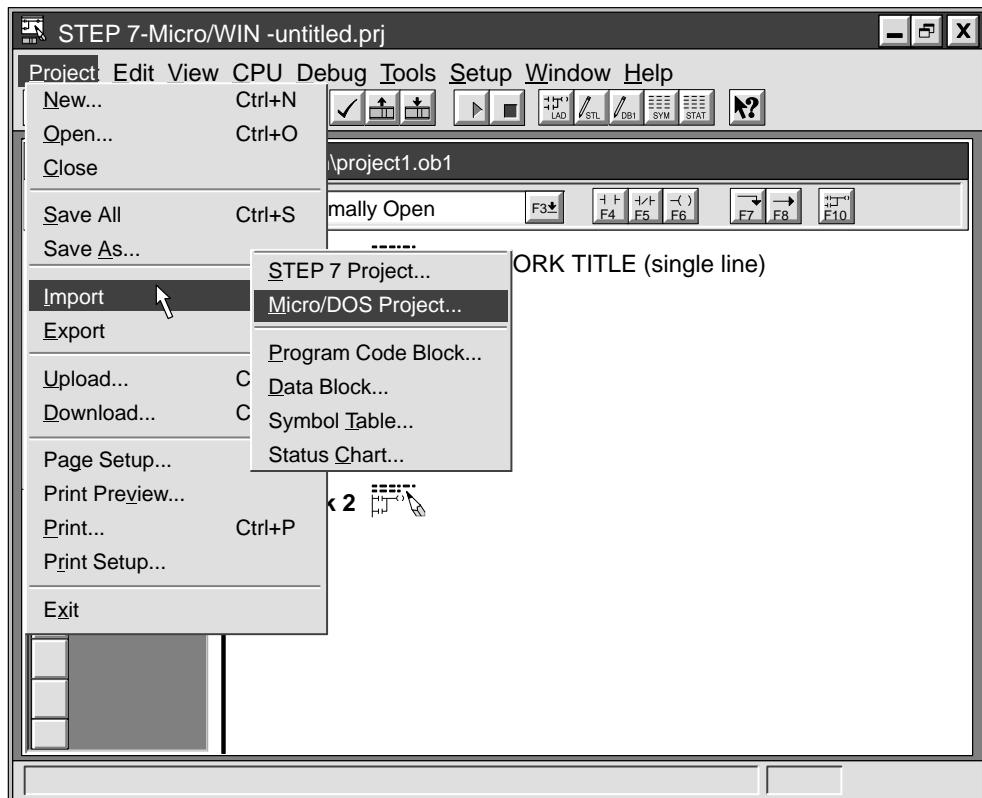


Figure E-2 Importing a STEP 7-Micro/DOS File

3. Respond to the message (which announces that importing the Micro/DOS program will overwrite the entire program) by clicking the "Yes" button to continue. (The new project contains an empty program.) Clicking the "No" button cancels the operation.
4. Using the Import Micro/DOS Program dialog box (shown in Figure E-3), select the directory that contains the STEP 7-Micro/DOS program you want to import.

5. Double-click on the STEP 7-Micro/DOS file (or enter the file name), as shown in Figure E-3.
6. Click the "Open" button. The imported program and associated files open as an untitled project.

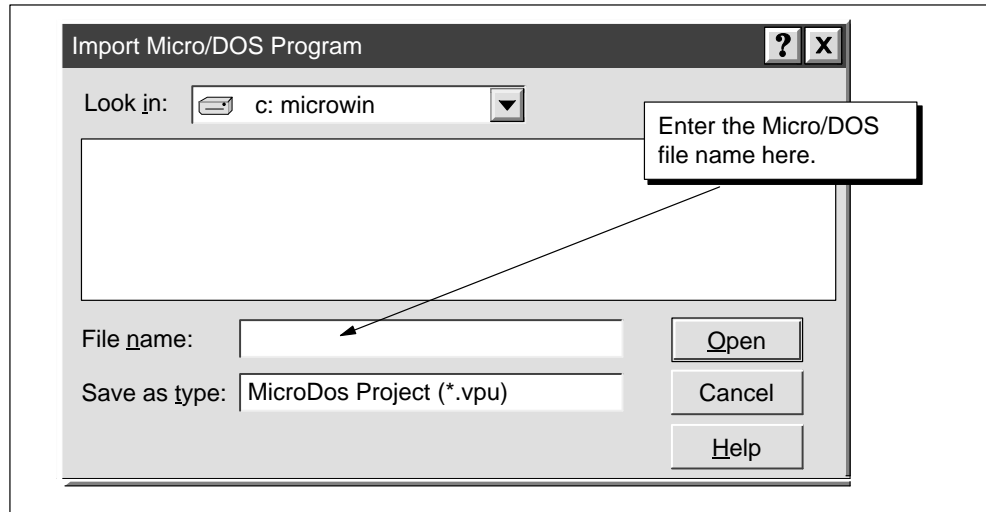


Figure E-3 Selecting the STEP 7-Micro/DOS Program

Import Guidelines and Limitations

When you import a STEP 7-Micro/DOS .vpu program file, a copy of the following Micro/DOS files are converted to the STEP 7-Micro/WIN format after you save them:

- Program files
- V memory and data
- Synonyms and descriptors
- Status chart that has the same name as the project

The following actions occur when you import a Micro/DOS program into a STEP 7-Micro/WIN project:

- Constants that were defined in V memory are maintained.
- Micro/DOS synonyms are converted to STEP 7-Micro/WIN symbols, but truncated, if necessary, to fit the 23-character limit. The synonym descriptors, which can be up to 144 characters, are truncated to the 79-character limit for symbol comments in STEP 7-Micro/WIN.
- Micro/DOS network comments (up to 16 lines of 60 characters) are preserved in the STL and LAD editors.
- A Micro/DOS status chart that has the same name as the Micro/DOS program is converted to a STEP 7-Micro/WIN status chart. For example, if you have a program named TEST.VPU that has status charts TEST.CH2 and TEST2.CH2, the status chart named TEST is imported, but not the status chart named TEST2.
- The network address, password, privilege level, output table, and retentive ranges are set based upon the Micro/DOS files. You can find these parameters with the menu command **CPU ► Configure...**

Saving the Converted Program

To add the imported program to the same directory as your other current STEP 7-Micro/WIN projects, follow these steps:

1. Select the menu command **Project ► Save As...** and use the directory browser to select your current STEP 7-Micro/WIN directory.
2. In the File Name box, type the name you want to assign to the imported program files, using the .prj extension.
3. Click the "OK" button.

Note

Once saved or modified, the program imported into STEP 7-Micro/WIN cannot be exported back into the STEP 7-Micro/DOS format. The original Micro/DOS files, however, are not changed. You can still use the original files within STEP 7-Micro/DOS.

F

Execution Times for STL Instructions

Effect of Power Flow on Execution Times

The calculation of the basic execution time for an STL instruction (Table F-4) shows the time required for executing the logic, or function, of the instruction when power flow is present (where the top-of-stack value is ON or 1). For some instructions, the execution of that function is conditional upon the presence of power flow: the CPU performs the function only when power flow is present to the instruction (when the top-of-stack value is ON or 1). If power flow is not present to the instruction (the top-of-stack value is OFF or 0), use a “no power-flow” execution time to calculate the execution time of your program. Table F-1 provides the execution time of an STL instruction with no power flow (when the top-of-stack value is OFF or 0) for each S7-200 CPU module.

Table F-1 Execution Time for Instructions with No Power Flow

Instruction with No Power Flow	CPU 212	CPU 214/215/216
All STL instructions	10 μ s	6 μ s

Effect of Indirect Addressing on Execution Times

The calculation of the basic execution time for an STL instruction (Table F-4) shows the time required for executing the instruction, using direct addressing of the operands or constants. If your program uses indirect addressing, increase the execution time for each indirectly addressed operand by the figure shown in Table F-2.

Table F-2 Additional Time to Add for Indirect Addressing

Instruction for Indirect Addressing	CPU 212	CPU 214/215/216
All instructions except R, RI, S, and SI	76 μ s	47 μ s
R, RI, S, and SI	185.3 μ s	120.2 μ s

Effect of Analog I/O on Execution Times

Accessing the analog inputs and outputs affects the execution time of an instruction. Table F-3 provides a factor to be added to the basic execution time for each instruction that accesses an analog value.

Table F-3 Impact of Analog Inputs and Analog Outputs on Execution Times

	Model	CPU 212	CPU 214/215/216
Analog Inputs	EM231, EM235	171 μ s	139 μ s
Analog Outputs	EM232, EM235	99 μ s	66 μ s

Basic Execution Times for STL Instructions

Table F-4 lists the basic execution times of the STL instructions for each of the S7-200 CPU modules.

Table F-4 Execution Times for the STL Instructions (in μ s)

Instruction	Description	CPU 212 (in μ s)	CPU 214 (in μ s)	CPU 215 (in μ s)	CPU 216 (in μ s)
=	Basic execution time: I, Q	1.2	0.8	0.8	0.8
	M	4.8	3.2	3.2	3.2
	SM, T, C, V, S	6.0	4.0	4.0	4.0
+D	Basic execution time	143	95	95	95
-D	Basic execution time	144	96	96	96
+I	Basic execution time	110	73	73	73
-I	Basic execution time	111	74	74	74
=I	Basic execution time	63	42	42	42
+R	Basic execution time	-	220	220	220
	Maximum execution time	-	350	350	350
-R	Basic execution time	-	225	225	225
	Maximum execution time	-	355	355	355
*R	Basic execution time	-	255	255	255
	Maximum execution time	-	320	320	320
/R	Basic execution time	-	810	810	810
	Maximum execution time	-	870	870	870
A	Basic execution time: I, Q	1.2	0.8	0.8	0.8
	M	3.0	2.0	2.0	2.0
	SM, T, C, V, S	4.8	3.2	3.2	3.2
AB < =	Execution time when comparison is true	65	43	43	43
	Execution time when comparison is false	68	45	45	45
AB =	Execution time when comparison is true	65	43	43	43
	Execution time when comparison is false	68	45	45	45
AB > =	Execution time when comparison is true	65	43	43	43
	Execution time when comparison is false	68	45	45	45
AD < =	Execution time when comparison is true	137	91	91	91
	Execution time when comparison is false	140	93	93	93
AD =	Execution time when comparison is true	137	91	91	91
	Execution time when comparison is false	140	93	93	93
AD > =	Execution time when comparison is true	137	91	91	91
	Execution time when comparison is false	140	93	93	93
AI	Basic execution time	54	36	36	36
ALD	Basic execution time	1.2	0.8	0.8	0.8
AN	Basic execution time: I, Q	1.2	0.8	0.8	0.8
	M	3.0	2.0	2.0	2.0
	SM, T, C, V, S	4.8	3.2	3.2	3.2
ANDB	Basic execution time	-	-	49	49
ANDD	Basic execution time	137	91	91	91

Table F-4 Execution Times for the STL Instructions (in μs), continued

Instruction	Description	CPU 212 (in μs)	CPU 214 (in μs)	CPU 215 (in μs)	CPU 216 (in μs)
ANDW	Basic execution time	110	73	73	73
ANI	Basic execution time	54	36	36	36
AR=	Basic execution time	-	98	98	98
AR<=	Basic execution time	-	98	98	98
AR>=	Basic execution time	-	98	98	98
ATCH	Basic execution time	48	32	32	32
ATH	Total = Basic time + (Length) * (Length multiplier) Basic execution time Length multiplier (LM)	729 62	486 41	486 41	486 41
ATT	Basic execution time	-	268	268	268
AW < =	Execution time when comparison is true Execution time when comparison is false	110 113	73 75	73 75	73 75
AW=	Execution time when comparison is true Execution time when comparison is false	110 113	73 75	73 75	73 75
AW > =	Execution time when comparison is true Execution time when comparison is false	110 113	73 75	73 75	73 75
BCDI	Basic execution time	249	166	166	166
BMB	Total = Basic time + (Length) * (LM) Basic execution time Length multiplier (LM)	633 32	422 21	422 21	422 21
BMD	Total = Basic time + (Length) * (LM) Basic execution time Length multiplier (LM)	- -	- -	446 43	446 43
BMW	Total = Basic time + (Length) * (LM) Basic execution time Length multiplier (LM)	636 51	424 34	424 34	424 34
CALL	Basic execution time	35	23	23	23
CRET	Basic execution time	26	17	17	17
CRETI	Basic execution time	75	50	50	50
CTU	Basic execution time	78	52	52	52
CTUD	Basic execution time	105	70	70	70
DECB	Basic execution time	-	-	37	37
DECD	Basic execution time	98	65	65	65
DECO	Basic execution time	84	56	56	56
DECW	Basic execution time	83	55	55	55
DISI	Basic execution time	36	24	24	24
DIV	Basic execution time	410	273	273	273
DTCH	Basic execution time	39	26	26	26

Table F-4 Execution Times for the STL Instructions (in μs), continued

Instruction	Description	CPU 212 (in μs)	CPU 214 (in μs)	CPU 215 (in μs)	CPU 216 (in μs)
DTR	Basic execution time Maximum execution time	- -	108 135	108 135	108 135
ED	Basic execution time	32	21	21	21
ENCO	Minimum execution time Maximum execution time	75 93	50 62	50 62	50 62
END	Basic execution time	1.8	1.2	1.2	1.2
ENI	Basic execution time	36	24	24	24
EU	Basic execution time	32	21	21	21
FIFO	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- - -	234 29	234 29	234 29
FILL	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	578 18	385 12	385 12	385 12
FND <	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- - -	424 28	424 28	424 28
FND <>	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- - -	423 29	423 29	423 29
FND =	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- - -	431 25	431 25	431 25
FND >	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- - -	428 28	428 28	428 28
FOR	Total = Basic time + (LM) * (Number of repetitions) Basic execution time Loop multiplier (LM)	- - -	135 129	135 129	135 129
HDEF	Basic execution time	80	53	53	53
HSC	Basic execution time	101	67	67	67
HTA	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	714 35	476 23	476 23	476 23
IBCD	Basic execution time	186	124	124	124
INCB	Basic execution time	-	-	34	34
INCD	Basic execution time	96	64	64	64
INCW	Basic execution time	81	54	54	54
INT	Typical execution time with 1 interrupt	180	120	120	120
INVB	Basic execution time	-	-	40	40
INVD	Basic execution time	99	66	66	66
INVW	Basic execution time	84	56	56	56

Table F-4 Execution Times for the STL Instructions (in μs), continued

Instruction	Description	CPU 212 (in μs)	CPU 214 (in μs)	CPU 215 (in μs)	CPU 216 (in μs)
JMP	Basic execution time	1.2	0.8	0.8	0.8
LBL	Basic execution time	0	0	0	0
LD	Basic execution time: I, Q M SM, T, C, V, S	1.2 3.0 4.8	0.8 2.0 3.2	0.8 2.0 3.2	0.8 2.0 3.2
LDB <=	Execution time when comparison is true Execution time when comparison is false	63 66	42 44	42 44	42 44
LDB =	Execution time when comparison is true Execution time when comparison is false	63 66	42 44	42 44	42 44
LDB >=	Execution time when comparison is true Execution time when comparison is false	63 66	42 44	42 44	42 44
LDD <=	Execution time when comparison is true Execution time when comparison is false	135 138	90 92	90 92	90 92
LDD =	Execution time when comparison is true Execution time when comparison is false	135 138	90 92	90 92	90 92
LDD > =	Execution time when comparison is true Execution time when comparison is false	135 138	90 92	90 92	90 92
LDI	Basic execution time	50	33	33	33
LDN	Basic execution time: I, Q M SM, T, C, V, S	1.8 3.6 5.4	1.2 2.4 3.6	1.2 2.4 3.6	1.2 2.4 3.6
LDNI	Basic execution time	50	33	33	33
LDR=	Basic execution time	-	98	98	98
LDR<=	Basic execution time	-	98	98	98
LDR>=	Basic execution time	-	98	98	98
LDW <=	Execution time when comparison is true Execution time when comparison is false	108 111	72 74	72 74	72 74
LDW =	Execution time when comparison is true Execution time when comparison is false	108 111	72 74	72 74	72 74
LDW >=	Execution time when comparison is true Execution time when comparison is false	108 111	72 74	72 74	72 74
LIFO	Basic execution time	-	261	261	261
LPP	Basic execution time	0.6	0.4	0.4	0.4
LPS	Basic execution time	1.2	0.8	0.8	0.8
LRD	Basic execution time	0.6	0.4	0.4	0.4
LSCR	Basic execution time	18	12	12	12
MEND	Basic execution time	1.2	0.8	0.8	0.8
MOVB	Basic execution time	45	30	30	30
MOVD	Basic execution time	81	54	54	54
MOVR	Basic execution time	81	54	54	54

Table F-4 Execution Times for the STL Instructions (in μs), continued

Instruction	Description	CPU 212 (in μs)	CPU 214 (in μs)	CPU 215 (in μs)	CPU 216 (in μs)
MOVW	Basic execution time	66	44	44	44
MUL	Basic execution time	210	140	140	140
NEXT	Basic execution time	-	0	0	0
NETR	Basic execution time	-	478	478	478
NETW	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	-	460 16.8	460 16.8	460 16.8
NOP	Basic execution time	0	0	0	0
NOT	Basic execution time	1.2	0.8	0.8	0.8
O	Basic execution time: I, Q M SM, T, C, V, S	1.2 3.0 4.8	0.8 2.0 3.2	0.8 2.0 3.2	0.8 2.0 3.2
OB < =	Execution time when comparison is true Execution time when comparison is false	65 68	43 45	43 45	43 45
OB =	Execution time when comparison is true Execution time when comparison is false	65 68	43 45	43 45	43 45
OB > =	Execution time when comparison is true Execution time when comparison is false	65 68	43 45	43 45	43 45
OD < =	Execution time when comparison is true Execution time when comparison is false	138 140	92 93	92 93	92 93
OD =	Execution time when comparison is true Execution time when comparison is false	138 140	92 93	92 93	92 93
OD > =	Execution time when comparison is true Execution time when comparison is false	138 140	92 93	92 93	92 93
OI	Basic execution time	54	36	36	36
OLD	Basic execution time	1.2	0.8	0.8	0.8
ON	Basic execution time: I, Q M SM, T, C, V, S	1.2 3.0 4.8	0.8 2.0 3.2	0.8 2.0 3.2	0.8 2.0 3.2
ONI	Basic execution time	54	36	36	36
OR=	Basic execution time	-	98	98	98
OR<=	Basic execution time	-	98	98	98
OR >=	Basic execution time	-	98	98	98
ORB	Basic execution time	-	-	49	49
ORD	Basic execution time	137	91	91	91
ORW	Basic execution time	110	73	73	73
OW < =	Execution time when comparison is true Execution time when comparison is false	108 111	72 74	72 74	72 74
OW =	Execution time when comparison is true Execution time when comparison is false	108 111	72 74	72 74	72 74

Table F-4 Execution Times for the STL Instructions (in μ s), continued

Instruction	Description	CPU 212 (in μ s)	CPU 214 (in μ s)	CPU 215 (in μ s)	CPU 216 (in μ s)
OW > =	Execution time when comparison is true	108	72	72	72
	Execution time when comparison is false	111	74	74	74
PID	Basic execution time	-	-	2000	2000
	Adder to recalculate ($K_c * T_s/T_i$) and ($K_c * T_d/T_s$) prior to the PID calculation. Recalculation occurs if the value of K_c , T_s , T_i , or T_d has changed from the previous execution of this instruction, or on a transition to auto control.	-	-	2600	2600
PLS	Basic execution time	-	153	153	153
R	Total = Operand time + (LM) * (Length)				
	Counter execution time	33.9	23	23	23
	Timer execution time	32.9	21	22	22
	Other operand execution time	39.9	27	27	27
	Counter length multiplier (LM)	28.8	19.2	19.2	19.2
	Timer length multiplier (LM)	49.7	33.1	33.1	33.1
	Other operand length multiplier (LM)	5.6	3.7	3.7	3.7
	If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	109.8	73.2	73.2	73.2
RCV	Basic execution time	-	-	126	126
RET	Basic execution time	27	18	18	18
RETI	Basic execution time	75	50	50	50
RI	Total = Basic time + (LM) * (Length)				
	Basic execution time	31.5	21	21	21
	Length multiplier (LM)	60	40	40	40
	If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	110	73	73	73
RLB	Total = Basic time + (LM) * (Length)				
	Basic execution time	-	-	62	62
	Length multiplier (LM)	-	-	1.2	1.2
RLD	Total = Basic time + (LM) * (Length)				
	Basic execution time	129	86	86	86
	Length multiplier (LM)	10.7	7.1	7.1	7.1
RLW	Total = Basic time + (LM) * (Length)				
	Basic execution time	116	77	77	77
	Length multiplier (LM)	6.9	4.6	4.6	4.6
RRB	Total = Basic time + (LM) * (Length)				
	Basic execution time	-	-	62	62
	Length multiplier (LM)	-	-	1.2	1.2
RRD	Total = Basic time + (LM) * (Length)				
	Basic execution time	135	90	90	90
	Length multiplier (LM)	10.4	6.9	6.9	6.9

Table F-4 Execution Times for the STL Instructions (in μ s), continued

Instruction	Description	CPU 212 (in μ s)	CPU 214 (in μ s)	CPU 215 (in μ s)	CPU 216 (in μ s)
RRW	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	117 6.6	78 4.4	78 4.4	78 4.4
S	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM) If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	38 5.6 110	25 3.7 74	25 3.7 74	25 3.7 74
SBR	Basic execution time	0	0	0	0
SCRE	Basic execution time	0	0	0	0
SCRT	Basic execution time	31	21	21	21
SEG	Basic execution time	47	31	31	31
SHRB	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	449 2.3	299 1.5	299 1.5	299 1.5
SI	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM) If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	32 58 110	21 38 73	21 38 73	21 38 73
SLB	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- -	- -	64 1.6	64 1.6
SLD	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	131 8.9	87 5.9	87 5.9	87 5.9
SLW	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	119 5.1	79 3.4	79 3.4	79 3.4
SQRT	Basic execution time Maximum execution time	-	1830 2110	1830 2110	1830 2110
SRB	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	- -	- -	64 1.6	64 1.6
SRD	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	137 8.6	91 5.7	91 5.7	91 5.7
SRW	Total = Basic time + (LM) * (Length) Basic execution time Length multiplier (LM)	120 5.0	80 3.3	80 3.3	80 3.3
STOP	Basic execution time	13	9	9	9
SWAP	Basic execution time	65	43	43	43

Table F-4 Execution Times for the STL Instructions (in μs), continued

Instruction	Description	CPU 212 (in μs)	CPU 214 (in μs)	CPU 215 (in μs)	CPU 216 (in μs)
TODR	Basic execution time	-	282	282	282
TODW	Basic execution time	-	489	489	489
TON	Basic execution time	48	32	32	32
TONR	Basic execution time	74	49	49	49
TRUNC	Basic execution time	-	258	258	258
	Maximum execution time		420	420	420
WDR	Basic execution time	21	14	14	14
XMT	Basic execution time	272	181	181	181
XORB	Basic execution time	-	-	49	49
XORD	Basic execution time	137	91	91	91
XORW	Basic execution time	110	73	73	73



S7-200 Order Numbers

CPUs	Order Number
CPU 212 DC Power Supply, DC Inputs, DC Outputs	6ES7 212-1AA01-0XB0
CPU 212 AC Power Supply, DC Inputs, Relay Outputs	6ES7 212-1BA01-0XB0
CPU 212 AC Power Supply, AC Inputs, AC Outputs	6ES7 212-1CA01-0XB0
CPU 212 AC Power Supply, Sourcing DC Inputs, Relay Outputs	6ES7 212-1BA10-0XB0
CPU 212 AC Power Supply, 24 VAC Inputs, AC Outputs	6ES7 212-1DA01-0XB0
CPU 212 24 VAC Power Supply, DC Inputs, Relay Outputs	6ES7 212-1FA01-0XB0
CPU 212 AC Power Supply, AC Inputs, Relay Outputs	6ES7 212-1GA01-0XB0
CPU 214 DC Power Supply, DC Inputs, DC Outputs	6ES7 214-1AC01-0XB0
CPU 214 AC Power Supply, DC Inputs, Relay Outputs	6ES7 214-1BC01-0XB0
CPU 214 AC Power Supply, AC Inputs, AC Outputs	6ES7 214-1CC01-0XB0
CPU 214 AC Power Supply, Sourcing DC Inputs, Relay Outputs	6ES7 214-1BC10-0XB0
CPU 214 AC Power Supply, 24 VAC Inputs, AC Outputs	6ES7 214-1DC01-0XB0
CPU 214 AC Power Supply, AC Inputs, Relay Outputs	6ES7 214-1GC01-0XB0
CPU 215 DC Power Supply, DC Inputs, DC Outputs	6ES7 215-2AD00-0XB0
CPU 215 AC Power Supply, DC Inputs, Relay Outputs	6ES7 215-2BD00-0XB0
CPU 216 DC Power Supply, DC Inputs, DC Outputs	6ES7 216-2AD00-0XB0
CPU 216 AC Power Supply, DC Inputs, Relay Outputs	6ES7 216-2BD00-0XB0

Expansion Modules	Order Number
EM221 Digital Input 8 x 24 VDC	6ES7 221-1BF00-0XA0
EM221 Digital Input 8 x 120 VAC	6ES7 221-1EF00-0XA0
EM221 Digital Sourcing Input 8 x 24 VDC	6ES7 221-1BF10-0XA0
EM221 Digital Input 8 x 24 VAC	6ES7 221-1JF00-0XA0
EM222 Digital Output 8 x 24 VDC	6ES7 222-1BF00-0XA0
EM222 Digital Output 8 x Relay	6ES7 222-1HF00-0XA0
EM222 Digital Output 8 x 120/230 VAC	6ES7 222-1EF00-0XA0
EM223 Digital Combination 4 x 24 VDC Input / 4 x 24 VDC Output	6ES7 223-1BF00-0XA0
EM223 Digital Combination 4 x 24 VDC Input / 4 x Relay Output	6ES7 223-1HF00-0XA0
EM223 Digital Combination 4 x 120 VAC Input / 4 x 120-230 VAC Output	6ES7 223-1EF00-0XA0
EM223 Digital Combination 8 x 24 VDC Input / 8 x Relay Output	6ES7 223-1PH00-0XA0
EM223 Digital Combination 8 x 24 VDC Input / 8 x 24 VDC Output	6ES7 223-1BH00-0XA0

Expansion Modules	Order Number
EM223 Digital Combination 16 x 24 VDC Input / 16 x Relay Output	6ES7 223-1PL00-0XA0
EM 223 Digital Combination 16 x 24 VDC Input / 16 x 24 VDC Output	6ES7 223-1BL00-0XA0
EM231 Analog Input AI 3 x 12 Bits	6ES7 231-0HC00-0XA0
EM232 Analog Output AQ 2 x 12 Bits	6ES7 232-0HB00-0XA0
EM235 Analog Combination AI 3/AQ 1 x 12 Bits	6ES7 235-0KD00-0XA0
CP 242-2 AS-Interface Master Module for S7-200	6GK7 242-2AX00-0XA0

Cables, Network Connectors, and Repeaters	Order Number
I/O Expansion Cable	6ES7 290-6BC50-0XA0
MPI Cable	6ES7 901-0BF00-0AA0
PC/PPI Cable	6ES7 901-3BF00-0XA0
PROFIBUS Network Cable	6XV1 830-0AH10
Network Bus Connector with Programming Port Connector, Vertical Cable Outlet	6ES7 972-0BB10-0XA0
Network Bus Connector (No Programming Port Connector), Vertical Cable Outlet	6ES7 972-0BA10-0XA0
RS 485 Bus Connector with Axial Cable Outlet	6GK1 500-0EA00
RS 485 Bus Connector with 30° Cable Outlet	6ES7 972-0BA30-0XA0
RS 485 IP 20 Repeater	6ES7 972-0AA00-0XA0

Communications Cards	Order Number
MPI Card: Short AT ISA	6ES7 793-2AA01-0AA0
CP 5411: Short AT ISA	6GK1 541-1AA00
CP 5511: PCMCIA, Type II, Plug and Play Hardware	6GK1 551-1AA00
CP 5611: Short PCI, Plug and Play Hardware	6GK1 561-1AA00

Operator Interfaces	Order Number
TD 200 Operator Interface	6ES7 272-0AA00-0YA0
OP3 Operator Interface	6AV3 503-1DB10
OP7 Operator Interface	6AV3 607-IJC20-0AX0
OP17 Operator Interface	6AV3 617-IJC20-0AX0

General		Order Number
Memory Cartridge 8K x 8		6ES7 291-8GC00-0XA0
Memory Cartridge 16K x 8		6ES7 291-8GD00-0XA0
Battery Cartridge		6ES7 291-8BA00-0XA0
DIN Rail Stops		6ES5 728-8MA11
12-Position Fan Out Connector (CPU 212/215/216)	10-pack	6ES7 290-2AA00-0XA0
14-Position Fan Out Connector (CPU 215/216 and Expansion I/O)	10-pack	6ES7 290-2CA00-0XA0
18-Position Fan Out Connector (CPU 214)	10-pack	6ES7 290-2BA00-0XA0
CPU 212 DC Input Simulator		6ES7 274-1XF00-0XA0
CPU 214 DC Input Simulator		6ES7 274-1XH00-0XA0
CPU 215/216 DC Input Simulator		6ES7 274-1XK00-0XA0

Programming Software		Order Number
STEP 7-Micro/WIN 16 (V2.1) Individual License		6ES7 810-2AA01-0YX0
STEP 7-Micro/WIN 16 (V2.1) Copy License		6ES7 810-2AA01-0YX1
STEP 7-Micro/WIN 16 (V2.1) Update		6ES7 810-2AA01-0YX3
STEP 7-Micro/WIN 32 (V2.1) Individual License		6ES7 810-2AA11-0YX0
STEP 7-Micro/WIN 32 (V2.1) Copy License		6ES7 810-2AA11-0YX1
STEP 7-Micro/WIN 32 (V2.1) Update		6ES7 810-2AA11-0YX3
STEP 7-Micro/DOS Individual License		6ES7 810-2DA00-0YX0

Manuals		Order Number
ET 200 Distributed I/O System Manual		6ES5 998-3ES22
PG 702 Programming Device Manual		6ES7 702-0AA00-8BA0
TD 200 Operator Interface User Manual		6ES7 272 0AA00-8BA0
CP242-2 AS-Interface Master Module Handbook		6GK7 242-2AX00-8BA0
STEP 7-Micro/DOS User Manual		6ES7 810-2DA10-8BA0

S7-200 Troubleshooting Guide



Table H-1 S7-200 Troubleshooting Guide

Problem	Possible Causes	Solution
Outputs stop working.	The device being controlled has caused an electrical surge that damaged the output.	When connecting to an inductive load (such as a motor or relay), a proper suppression circuit should be used. Refer to Section 2.4.
CPU SF (System Fault) light comes on.	<p>The following list describes the most common causes:</p> <ul style="list-style-type: none"> • User programming error <ul style="list-style-type: none"> – 0003 Watchdog error – 0011 Indirect addressing – 0012 Illegal compare • Electrical noise <ul style="list-style-type: none"> – 0001 through 0009 • Component damage <ul style="list-style-type: none"> – 0001 through 0010 	<p>Read the fatal error code number and refer to Section C.1:</p> <ul style="list-style-type: none"> • For a programming error, check the usage of the FOR, NEXT, JMP, LBL, and CMP instructions. • For electrical noise: <ul style="list-style-type: none"> – Refer to the wiring guidelines in Section 2.3. It is very important that the control panel is connected to a good ground and that high voltage wiring is not run in parallel with low voltage wiring. – Connect the M terminal on the 24 VDC Sensor Power Supply to ground.
Analog input values vary from one sample to the next even though the input signal is constant.	<p>This can be caused by a number of reasons:</p> <ul style="list-style-type: none"> • Electrical noise from the power supply • Electrical noise on the input signal • Improper grounding • The value returned is formatted differently than expected • The module is a high-speed module that does not provide any 50/60 Hz filtering 	<ul style="list-style-type: none"> • The value returned by the module is an unfiltered number. A simple filter routine can be added to the user program. Refer to the Analog Input Filter Wizard in Chapter 5. • Check the actual repeatability of the value from the module versus the specification in Appendix A. The S7-200 modules return an unfiltered left-justified value. This means that each step variation of 1 count will increase the value by a step of 8 from the S7-200 module. • To determine the source of the electrical noise, try shorting an unused analog input point. If the value read from the shorted point varies the same as the sensor input, then the noise is coming from the power lines. Otherwise, the noise is coming from the sensor or sensor wiring. <ul style="list-style-type: none"> – For noise on the sensor wiring, see the installation guidelines for EM231 (Section A.33) or EM235 (Section A.35). – For noise from the power supply, refer to the wiring guidelines in Section 2.3, or try connecting the M terminals on the analog module and the CPU Sensor Supply to ground.

Table H-1 S7-200 Troubleshooting Guide, continued

Problem	Possible Causes	Solution
Power supply damaged.	Over-voltage on the power lines coming to the unit.	Connect a line analyzer to the system to check the magnitude and duration of the over-voltage spikes. Based on this information, add the proper type arrestor device to your system. Refer to the wiring guidelines in Section 2.3 for information about installing the field wiring.
Electrical noise problems	<ul style="list-style-type: none"> • Improper grounding • Routing on wiring within the control cabinet. 	Refer to the wiring guidelines in Section 2.3. It is very important that the control panel is connected to a good ground and that high voltage wiring is not run in parallel with low voltage wiring. Connect the M terminal on the 24 VDC Sensor Power Supply to ground.
Intermittent values from expansion I/O modules	Excess vibration	Refer to Section A.1 for the sinusoidal vibration limits.
	Improper mounting of the standard (DIN) rail	If the system is counted on a standard (DIN) rail, refer to Section 2.2.
	The plastic connecting joints were not completely removed when the bus expansion cover was snapped out.	Refer to Section 2.2 for information about installing expansion modules.
	Defective bus connector	Replace the I/O bus connector.
Communication network is damaged when connecting to an external device. (Either the port on the computer, the port on the PLC, or the PC/PPI cable is damaged.)	The RS-485 port on the S7-200 CPU and the PC/PPI cable are not isolated (unless otherwise noted on the product data sheet). The communication cable can provide a path for unwanted currents if all non-isolated devices (such as PLCs, computers or other devices) that are connected to the network do not share the same circuit common reference. The unwanted currents can cause communication errors or damage to the circuits.	<ul style="list-style-type: none"> • Refer to the wiring guidelines in Section 2.3, and to the network guidelines in Chapter 9. • Purchase an isolated RS485-to-RS232 adapter (not supplied by Siemens) to use in place of the PC/PPI cable. • Purchase an isolated RS485-to-RS485 repeater when connecting machines that do not have a common electrical reference.
STEP 7-Micro/WIN Communication problems		Refer to Chapter 9 for information about network communications.
Error Handling		Refer to Appendix C for information about error codes.

Index

A

AC installation, guidelines, 2-10

AC outputs, 2-14

Access restriction. *See* Password

Accessing

 direct addressing, 7-2

 memory areas

 & and *, 7-9

 indirect addressing, 7-9–7-11

 modifying a pointer, 7-10

 operand ranges, 10-3

Accumulators, addressing, 7-6

Adapter, null modem, 3-19–3-20, 9-12

Add Double Integer instruction, 10-50

Add Integer instruction, 10-50

Add Real instruction, 10-51

Add to Table instruction, 10-73

Address, Status/Force Chart, 3-35

Addresses

 absolute, 6-4

 monitoring, 5-17, 5-18

 MPI communications, 3-17

 symbolic, 6-4

Addressing

 accumulators, 7-6

 analog inputs, 7-6

 analog outputs, 7-6

 bit memory area, 7-3

 byte:bit addressing, 7-2

 counter memory area, 7-5

 Element Usage Table, 5-18

 expansion I/O, 8-2

 high-speed counter memory area, 7-7

 indirect (pointers), 7-9–7-11

 & and *, 7-9

 modifying a pointer, 7-10

 local I/O, 8-2

 memory areas, 7-2

 network devices, 9-2

 process-image input register, 7-3

 process-image output register, 7-3

 range, viewing, 5-18

 sequence control relay memory area, 7-4

 special memory bits, 7-4

 timer, 7-4

 using symbolic, 3-36

 variable memory, 7-3

Agency approvals, A-3

Algorithm for PID loop control, 10-55–10-59

ALT key combinations, 5-9

Analog adjustment, 8-8

 SMB28, SMB29, D-5

Analog expansion module, addressing, 8-2

Analog I/O, effect on execution times, F-1

Analog Input Filtering Wizard, 5-14–5-16

Analog inputs

 accessing, 6-10

 addressing, 7-6

 read value interrupt routine, 10-123

Analog outputs

 accessing, 6-11

 addressing, 7-6

And Byte instruction, 10-102

And Double Word instruction, 10-104

And Load instruction, 10-99–10-101

And Word instruction, 10-103

ASCII to HEX instruction, 10-112

Attach Interrupt instruction, 10-116

B

- Bar graph character set, TD 200, 5-4
- Battery cartridge, 7-11
 - dimensions, A-80
 - order number, G-3
 - specifications, A-80
- Baud rates
 - communication ports, 9-2
 - CPUs, 9-2
 - PC/PPI cable, A-82
 - switch selections on the PC/PPI cable, 3-7, 9-10
- BCD to Integer instruction, 10-108
- Bias
 - adjustment, PID loop control, 10-61
 - PID algorithm, 10-57
- Biasing, network, 9-7
- Bit access, 7-2
 - CPU 212/214/215/216, 10-3
- Bit memory, 7-2
 - addressing, 7-3
- Bits, special memory, D-1–D-13
- Block Move Byte instruction, 10-69
- Block Move Double Word instruction, 10-69
- Block Move Word instruction, 10-69
- Boolean contact instructions, example, 10-6
- Buffer consistency, 9-20
- Bus connector, 2-5–2-7
 - removing expansion modules, 2-7
- Bus expansion port, removing breakaway cover, 2-5–2-7
- Byte, and integer range, 7-3
- Byte access, 7-2
 - CPU 212/214/215/216, 10-3
 - using pointer, 7-10
- Byte address format, 7-2
- Byte consistency, 9-20
- Byte memory, 7-2

C

- Cables
 - I/O expansion cable, specifications, A-81
 - installing the expansion cable, 2-5–2-7
 - MPI, 3-8
 - order number, G-2
 - PC/PPI, 9-9–9-11
 - baud rates, A-82
 - pin assignment, A-82
 - setting parameters, 3-12
 - specifications, A-82
 - PROFIBUS network, 9-8
 - removing modules, 2-7
- Calculating power requirements, 2-15
- Calibration
 - EM231, A-61
 - EM235, A-70, A-72
- Call instruction, 10-88
- CE certification, A-3
- Changing a pointer, 7-10
- Character interrupt control, 10-129
- Characters, TD 200 Wizard, 5-9
- Clearance requirements, 2-2
- Clock
 - enabling, 5-4
 - status bits, D-1
- Clock instructions, 10-13
- Clock, Real-Time, 10-49
- Communication instructions, 10-124–10-136
 - Network Read, 10-133
 - Network Write, 10-133
 - Receive, 10-124
 - Transmit, 10-124
- Communication port
 - interrupts, 10-118
 - pin assignment, 9-6

- Communications
 - baud rates, 9-2
 - capabilities, 9-2
 - checking setup, 3-9
 - configuration of CPU 215 as DP slave, 9-17-9-19
 - configurations, 9-2
 - connecting computer for, 3-7
 - DP (distributed peripheral) standard, 9-15-9-26
 - using the CPU 215 as slave, 3-19, 9-15
 - Freeport mode, 10-124, D-6
 - hardware
 - installing with Windows NT, 3-6
 - installing/removing, 3-4-3-6
 - master/slave devices, 9-9
 - modem, 3-19-3-24
 - MPI, 3-8, 9-3
 - network components, 9-6
 - PPI, 3-7, 9-3
 - processing requests, 6-11
 - PROFIBUS-DP protocol, 9-4
 - protocols supported, 9-2
 - remote I/O, 3-19, 9-15
 - sample program for CPU 215 as DP slave, 9-26
 - selecting a module parameter set, 3-12-3-13
 - setting up during installation, 3-12
 - setting up from the Windows Control Panel, 3-11
 - setting up parameters, 3-9
 - setup, 3-7-3-24
 - troubleshooting, 3-17
 - using a CP card, 3-8, 9-13-9-14
 - using the MPI card, 3-8, 9-13-9-14
 - using the PC/PPI cable, 9-9-9-11
- Communications processor (CP), order number, G-2
- Compare Byte instruction, 10-7
- Compare contact instructions
 - Compare Double Word Integer, 10-8
 - Compare Word Integer, 10-7
- Compare Double Word Integer instruction, 10-8
- Compare Real instruction, 10-8
- Compare Word instruction, 10-7
- Comparison, S7-200 CPUs, 1-3
- Comparison contact, example, 10-9
- Comparison contact instructions
 - Compare Byte, 10-7
 - Compare Real, 10-8
 - example, 10-9
- Compiling
 - errors
 - rule violations, C-4
 - system response, 6-20
 - STEP 7-Micro/WIN program, 3-29
- Configuration
 - calculating power requirements, B-1
 - communications hardware, 3-4
 - creating drawings, 6-3
 - DP master, 9-19
 - EM231, A-61
 - EM235, A-71
 - messages (TD 200), 5-3, 5-6-5-10
 - of CPU 215 as DP slave, 9-17-9-19
 - of PC with CP card and programming device, 9-14
 - of PC with MPI card and programming device, 9-14
 - output states, 8-6
 - parameter block, 5-3
 - PROFIBUS device database (GSD) file, 9-23-9-25
 - programming preferences, 3-25
 - retentive ranges of memory, 7-15
- Connections, MPI logical, 9-3, 9-4

- Connector terminal identification
 - CPU 212 24VAC/DC/Relay, A-11
 - CPU 212 AC/AC/AC, A-13, A-17
 - CPU 212 AC/DC/Relay, A-9
 - CPU 212 AC/Sourcing DC/Relay, A-15
 - CPU 212 DC/DC/DC, A-7
 - CPU 214 AC/AC/AC, A-25, A-29
 - CPU 214 AC/DC/Relay, A-23
 - CPU 214 AC/Sourcing DC/Relay, A-27
 - CPU 214 DC/DC/DC, A-21
 - CPU 215 AC/DC/Relay, A-35
 - CPU 215 DC/DC/DC, A-33
 - CPU 216 AC/DC/Relay, A-39
 - CPU 216 DC/DC/DC, A-37
 - EM221 Digital Input 8 x 120 VAC, A-41
 - EM221 Digital Input 8 x 24 VAC, A-43
 - EM221 Digital Input 8 x 24VDC, A-40
 - EM221 Digital Sourcing Input 8 x 24 VDC, A-42
 - EM222 Digital Output 8 x 120/230 VAC, A-47
 - EM222 Digital Output 8 x 24 VDC, A-44
 - EM222 Digital Output 8 x Relay, A-45
 - EM223 Digital Combination 16 x 24 VDC/16 x Relay, A-59
 - EM223 Digital Combination 4 x 120VAC/4 x 120 to 230 VAC, A-55
 - EM223 Digital Combination 4 x 24 VDC/4 x 24 VDC, A-49
 - EM223 Digital Combination 4 x 24 VDC/4 x Relay, A-54
 - EM223 Digital Combination 4 x 24 VDC/8 x Relay, A-57
 - EM231 Analog Input AI 3 x 12 Bits, A-60
 - EM235 Analog Combination AI 3/AQ 1 x 12 Bits, A-70
- Connectors
 - bus expansion port, 2-5–2-7
 - removing cover, 2-7
 - network, 9-7
 - order number, G-2
- Considerations
 - hardware installation, 2-2–2-4
 - high-vibration environment, 2-6
 - using DIN rail stops, 2-6
 - using Watchdog Reset instruction, 10-85
 - vertical installations, 2-6
- Consistency, data, 9-20
- Constants, 7-8
- Contact instructions, 10-4–10-6
 - example, 10-6
 - immediate contacts, 10-4
 - Negative Transition, 10-5
 - Not, 10-5
 - Positive Transition, 10-5
 - standard contacts, 10-4
- Control bits, High-Speed Counter, 10-28
- Conversion instructions, 10-108–10-113
 - ASCII to HEX, 10-112
 - BCD to Integer, 10-108
 - Decode, 10-110
 - Double Word Integer to Real, 10-108
 - Encode, 10-110
 - HEX to ASCII, 10-112
 - Integer to BCD, 10-108
 - Segment, 10-110
 - Truncate, 10-108
- Converting
 - integer to real number, 10-59
 - loop inputs, 10-59
 - real number to normalized value, 10-59
 - saving a converted program, E-6
 - STEP7-Micro/DOS files, E-4
- Correct orientation of the module, 2-5–2-8
- Count Up Counter instruction, 10-19
- Count Up/Down Counter instruction, 10-19
- Counter instructions, 10-13–10-49
 - Count Up, 10-19
 - Count Up/Down, 10-19
 - example, 10-20
 - operation, 10-19
- Counters
 - addressing memory area, 7-5
 - CPU 212/214/215/216, 10-2
 - types, 7-5
 - variables, 7-5
- CP (communications processor) card, 9-13
 - configuration with PC, 9-14
 - connection procedure, 3-8
- CP 5411, 9-13
 - order number, G-2
 - setting up the MPI Card (MPI) parameters, 3-16–3-17
 - setting up the MPI Card (PPI) parameters, 3-14

- CP 5511, 9-13
 - order number, G-2
 - setting up the MPI Card (MPI) parameters, 3-16–3-17
 - setting up the MPI Card (PPI) parameters, 3-14
- CP 5611, 9-13
 - order number, G-2
 - setting up the MPI Card (MPI) parameters, 3-16–3-17
 - setting up the MPI Card (PPI) parameters, 3-14
- CPU
 - basic operation, 6-4
 - clearing memory, 6-15
 - communication capabilities, 9-2
 - downloading STEP 7-Micro/WIN program, 3-30
 - error handling, 6-19
 - fatal errors, C-2
 - general technical specifications, A-4
 - ID register (SMB6), D-4
 - logic stack, 6-6
 - memory areas, 7-2
 - modem connection, 3-19–3-24
 - operand ranges, 10-3
 - order numbers, G-1
 - password, 6-14
 - scan cycle, 6-10
 - selecting mode, 6-13
- CPU 212
 - backup, 1-3
 - baud rates supported, 9-2
 - comm ports, 1-3
 - communication, 9-2
 - expansion modules, 1-3
 - features, 10-2
 - hardware supported for network communications, 3-4
 - I/O, 1-3
 - I/O numbering example, 8-3
 - input filters, 1-3
 - instructions, execution times, F-1–F-10
 - instructions supported, 1-3
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - And Double Word, 10-104
 - And Immediate/And Not Immediate, 10-4
 - And Load, 10-99
 - And Word, 10-103
 - And/And Not, 10-4
 - ASCII to HEX, 10-112
 - Attach Interrupt/Detach Interrupt, 10-116
 - BCD to Integer, 10-108
 - Block Move Byte, 10-69
 - Block Move Word, 10-69
 - Call, 10-88
 - Compare Byte, 10-7
 - Compare Double Word Integer, 10-8
 - Compare Word Integer, 10-7
 - Conditional End/Unconditional End, 10-84
 - Conditional/Unconditional Return from Interrupt, 10-114
 - Conditional/Unconditional Return from Subroutine, 10-88
 - Count Up, 10-19
 - Count Up/Down, 10-19
 - Decode, 10-110
 - Decrement Double Word, 10-67
 - Decrement Word, 10-66
 - Divide Integer, 10-52
 - Edge Up/Edge Down, 10-5
 - Enable Interrupt/Disable Interrupt, 10-116
 - Encode, 10-110
 - END/MEND, 10-84
 - Exclusive Or Double Word, 10-104
 - Exclusive Or Word, 10-103
 - HEX to ASCII, 10-112
 - High-Speed Counter Definition, 10-21
 - immediate contacts, 10-4
 - Increment Double Word, 10-67
 - Increment Word, 10-66
 - Integer to BCD, 10-108
 - Interrupt Routine, 10-114
 - Invert Double Word, 10-106
 - Invert Word, 10-106
 - Jump to Label/Label, 10-87
 - Load Immediate/Load Not Immediate, 10-4
 - Load Sequence Control Relay, 10-92
 - Load/Load Not, 10-4
 - Logic Pop, 10-99
 - Logic Push, 10-99
 - Logic Read, 10-99
 - Memory Fill, 10-72
 - Move Byte, 10-68
 - Move Double Word, 10-68
 - Move Word, 10-68
 - Multiply Integer, 10-52
 - No Operation, 10-11
 - Not, 10-5

- On-Delay Timer, 10-13
- Or Double Word, 10-104
- Or Immediate/Or Not Immediate, 10-4
- Or Load, 10-99
- Or Word, 10-103
- Or/Or Not, 10-4
- Output, 10-10
- Output Immediate, 10-10
- Positive Transition/Negative Transition, 10-5
- Retentive On-Delay Timer, 10-13
- Rotate Right Double Word/Rotate Left Double Word, 10-82
- Rotate Right Word/Rotate Left Word, 10-82
- Segment, 10-110
- Sequence Control Relay End, 10-92
- Sequence Control Relay Transition, 10-92
- Set Immediate/Reset Immediate, 10-11
- Set/Reset, 10-10
- Shift Register Bit, 10-78
- Shift Right Double Word/Shift Left Double Word, 10-81
- Shift Right Word/Shift Left Word, 10-80
- standard contacts, 10-4
- STOP, 10-84
- Subroutine, 10-88
- Subtract Double Integer, 10-50
- Subtract Integer, 10-50
- Swap Bytes, 10-70
- transition, 10-5
- Transmit, 10-124
- Watchdog Reset, 10-85
- interrupt events, 10-117
- interrupts, maximum, 10-120
- interrupts supported, 1-3, 10-118
- memory, 1-3
 - ranges, 10-2
- module, 1-5
- operand ranges, 10-3
- order number, G-1
- protocols supported, 1-3
- specifications, A-6–A-15
 - input simulator, A-84
- summary, 1-3
- CPU 212 DC input simulator, installation, A-84
- CPU 214
 - backup, 1-3
 - baud rates supported, 9-2
 - comm ports, 1-3
 - communication, 9-2
 - expansion modules, 1-3
 - features, 10-2
 - hardware supported for network communications, 3-4
 - I/O, 1-3
 - I/O numbering example, 8-3
 - input filters, 1-3
 - instructions, execution times, F-1–F-10
 - instructions supported, 1-3
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - Add Real, 10-51
 - Add To Table, 10-73
 - And Double Word, 10-104
 - And Immediate/And Not Immediate, 10-4
 - And Load, 10-99
 - And Word, 10-103
 - And/And Not, 10-4
 - ASCII to HEX, 10-112
 - Attach Interrupt/Detach Interrupt, 10-116
 - BCD to Integer, 10-108
 - Block Move Byte, 10-69
 - Block Move Word, 10-69
 - Call, 10-88
 - Compare Byte, 10-7
 - Compare Double Word Integer, 10-8
 - Compare Real, 10-8
 - Compare Word Integer, 10-7
 - Conditional End/Unconditional End, 10-84
 - Conditional/Unconditional Return from Interrupt, 10-114
 - Conditional/Unconditional Return from Subroutine, 10-88
 - Count Up, 10-19
 - Count Up/Down, 10-19
 - Decode, 10-110
 - Decrement Double Word, 10-67
 - Decrement Word, 10-66
 - Divide Integer, 10-52
 - Divide Real, 10-53
 - Double Word Integer to Real, 10-108
 - Edge Up/Edge Down, 10-5
 - Enable Interrupt/Disable Interrupt, 10-116

- Encode, 10-110
- END/MEND, 10-84
- Exclusive Or Double Word, 10-104
- Exclusive Or Word, 10-103
- First-In-First-Out, 10-75
- For/Next, 10-90
- HEX to ASCII, 10-112
- High-Speed Counter Definition, 10-21
- immediate contacts, 10-4
- Increment Double Word, 10-67
- Increment Word, 10-66
- Integer to BCD, 10-108
- Interrupt Routine, 10-114
- Invert Double Word, 10-106
- Invert Word, 10-106
- Jump to Label/Label, 10-87
- Last-In-First-Out, 10-74
- Load Immediate/Load Not Immediate, 10-4
- Load Sequence Control Relay, 10-92
- Load/Load Not, 10-4
- Logic Pop, 10-99
- Logic Push, 10-99
- Logic Read, 10-99
- Memory Fill, 10-72
- Move Byte, 10-68
- Move Double Word, 10-68
- Move Real, 10-68
- Move Word, 10-68
- Multiply Integer, 10-52
- Multiply Real, 10-53
- Network Read/Network Write, 10-133
- Next, 10-90
- No Operation, 10-11
- Not, 10-5
- On-Delay Timer, 10-13
- Or Double Word, 10-104
- Or Immediate/Or Not Immediate, 10-4
- Or Load, 10-99
- Or Word, 10-103
- Or/Or Not, 10-4
- Output, 10-10
- Output Immediate, 10-10
- Positive Transition/Negative Transition, 10-5
- Pulse, 10-37
- Read Real-Time Clock, 10-49
- Retentive On-Delay Timer, 10-13
- Rotate Right Double Word/Rotate Left Double Word, 10-82
- Rotate Right Word/Rotate Left Word, 10-82
- Segment, 10-110
- Sequence Control Relay End, 10-92
- Sequence Control Relay Transition, 10-92
- Set Immediate/Reset Immediate, 10-11
- Set Real-Time Clock, 10-49
- Set/Reset, 10-10
- Shift Register Bit, 10-78
- Shift Right Double Word/Shift Left Double Word, 10-81
- Shift Right Word/Shift Left Word, 10-80
- Square Root, 10-53
- standard contacts, 10-4
- STOP, 10-84
- Subroutine, 10-88
- Subtract Double Integer, 10-50
- Subtract Integer, 10-50
- Subtract Real, 10-51
- Swap Bytes, 10-70
- Table Find, 10-76
- transition, 10-5
- Transmit, 10-124
- Truncate, 10-108
- Watchdog Reset, 10-85
- interrupt events, 10-117
- interrupts, maximum, 10-120
- interrupts supported, 1-3, 10-118
- memory, 1-3
 - ranges, 10-2
- module, 1-5
- operand ranges, 10-3
- order number, G-1
- protocols supported, 1-3
- specifications, A-20–A-29
 - input simulator, A-85
- summary, 1-3
- CPU 214 DC input simulator, installation, A-85
- CPU 215
 - as DP slave, 3-19, 9-15
 - as remote I/O module, 3-19
 - backup, 1-3
 - baud rates supported, 9-2
 - comm ports, 1-3
 - communication, 9-2
 - configuration guidelines, 9-19
 - configuring as DP slave, 9-17–9-19
 - data buffer size, 9-19
 - data consistency, 9-20
 - data exchange mode with DP master, 9-21
 - DP LED status, 9-22
 - DP port, 3-19
 - expansion modules, 1-3

- features, 10-2
- hardware supported for network communications, 3-4
- I/O, 1-3
- I/O configurations supported, 9-19
- I/O numbering example, 8-3
- input buffer, 9-18, 9-21
- input filters, 1-3
- instructions, execution times, F-1–F-10
- instructions supported, 1-3
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - Add Real, 10-51
 - Add To Table, 10-73
 - And Byte, 10-102
 - And Double Word, 10-104
 - And Immediate/And Not Immediate, 10-4
 - And Load, 10-99
 - And Word, 10-103
 - And/And Not, 10-4
 - ASCII to HEX, 10-112
 - Attach Interrupt/Detach Interrupt, 10-116
 - BCD to Integer, 10-108
 - Block Move Byte, 10-69
 - Block Move Double Word, 10-69
 - Block Move Word, 10-69
 - Call, 10-88
 - Compare Byte, 10-7
 - Compare Double Word Integer, 10-8
 - Compare Real, 10-8
 - Compare Word Integer, 10-7
 - Conditional End/Unconditional End, 10-84
 - Conditional/Unconditional Return from Interrupt, 10-114
 - Conditional/Unconditional Return from Subroutine, 10-88
 - Count Up, 10-19
 - Count Up/Down, 10-19
 - Decode, 10-110
 - Decrement Byte, 10-66
 - Decrement Double Word, 10-67
 - Decrement Word, 10-66
 - Divide Integer, 10-52
 - Divide Real, 10-53
 - Double Word Integer to Real, 10-108
 - Edge Up/Edge Down, 10-5
 - Enable Interrupt/Disable Interrupt, 10-116
 - Encode, 10-110
 - END/MEND, 10-84
 - Exclusive Or Byte, 10-102
 - Exclusive Or Double Word, 10-104
 - Exclusive Or Word, 10-103
 - First-In-First-Out, 10-75
 - For/Next, 10-90
 - HEX to ASCII, 10-112
 - High-Speed Counter, 10-21
 - immediate contacts, 10-4
 - Increment Byte, 10-66
 - Increment Double Word, 10-67
 - Increment Word, 10-66
 - Integer to BCD, 10-108
 - Interrupt Routine, 10-114
 - Invert Byte, 10-106
 - Invert Double Word, 10-106
 - Invert Word, 10-106
 - Jump to Label/Label, 10-87
 - Last-In-First-Out, 10-74
 - Load Immediate/Load Not Immediate, 10-4
 - Load Sequence Control Relay, 10-92
 - Load/Load Not, 10-4
 - Logic Pop, 10-99
 - Logic Push, 10-99
 - Logic Read, 10-99
 - Memory Fill, 10-72
 - Move Byte, 10-68
 - Move Double Word, 10-68
 - Move Real, 10-68
 - Move Word, 10-68
 - Multiply Integer, 10-52
 - Multiply Real, 10-53
 - Network Read/Network Write, 10-133
 - Next, 10-90
 - No Operation, 10-11
 - Not, 10-5
 - On-Delay Timer, 10-13
 - Or Byte, 10-102
 - Or Double Word, 10-104
 - Or Immediate/Or Not Immediate, 10-4
 - Or Load, 10-99
 - Or Word, 10-103
 - Or/Or Not, 10-4
 - Output, 10-10
 - Output Immediate, 10-10
 - PID Loop, 10-55
 - Positive Transition/Negative Transition, 10-5
 - Pulse, 10-37
 - Read Real-Time Clock, 10-49
 - Receive, 10-124
 - Retentive On-Delay Timer, 10-13

- Rotate Right Byte/Rotate Left Byte, 10-81
- Rotate Right Double Word/Rotate Left Double Word, 10-82
- Rotate Right Word/Rotate Left Word, 10-82
- Segment, 10-110
- Sequence Control Relay End, 10-92
- Sequence Control Relay Transition, 10-92
- Set Immediate/Reset Immediate, 10-11
- Set Real-Time Clock, 10-49
- Set/Reset, 10-10
- Shift Register Bit, 10-78
- Shift Right Byte/Shift Left Byte, 10-80
- Shift Right Double Word/Shift Left Double Word, 10-81
- Shift Right Word/Shift Left Word, 10-80
- Square Root, 10-53
- standard contacts, 10-4
- STOP, 10-84
- Subroutine, 10-88
- Subtract Double Integer, 10-50
- Subtract Integer, 10-50
- Subtract Real, 10-51
- Swap Bytes, 10-70
- Table Find, 10-76
- transition, 10-5
- Transmit, 10-124
- Truncate, 10-108
- Watchdog Reset, 10-85
- interrupt events, 10-117
- interrupts, maximum, 10-120
- interrupts supported, 1-3, 10-118
- memory, 1-3
 - ranges, 10-2
- module, 1-5
- operand ranges, 10-3
- order number, G-1
- output buffer, 9-18, 9-21
- protocols supported, 1-3
- sample program for DP slave, 9-26
- specifications, A-32–A-35
 - input simulator, A-86
- status information as DP slave, 9-21
- summary, 1-3
- CPU 215/216 DC input simulator, installation, A-86
- CPU 216
 - backup, 1-3
 - baud rates supported, 9-2
 - comm ports, 1-3
 - communication, 9-2
 - expansion modules, 1-3
 - features, 10-2
 - hardware supported for network communications, 3-4
 - I/O, 1-3
 - I/O numbering example, 8-4
 - input filters, 1-3
 - instructions, execution times, F-1–F-10
 - instructions supported, 1-3
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - Add Real, 10-51
 - Add To Table, 10-73
 - And Byte, 10-102
 - And Double Word, 10-104
 - And Immediate/And Not Immediate, 10-4
 - And Load, 10-99
 - And Word, 10-103
 - And/And Not, 10-4
 - ASCII to HEX, 10-112
 - Attach Interrupt/Detach Interrupt, 10-116
 - BCD to Integer, 10-108
 - Block Move Byte, 10-69
 - Block Move Double Word, 10-69
 - Block Move Word, 10-69
 - Call, 10-88
 - Compare Byte, 10-7
 - Compare Double Word Integer, 10-8
 - Compare Real, 10-8
 - Compare Word Integer, 10-7
 - Conditional End/Unconditional End, 10-84
 - Conditional/Unconditional Return from Interrupt, 10-114
 - Conditional/Unconditional Return from Subroutine, 10-88
 - Count Up, 10-19
 - Count Up/Down, 10-19
 - Decode, 10-110
 - Decrement Byte, 10-66
 - Decrement Double Word, 10-67
 - Decrement Word, 10-66
 - Divide Integer, 10-52
 - Divide Real, 10-53

- Double Word Integer to Real, 10-108
- Edge Up/Edge Down, 10-5
- Enable Interrupt/Disable Interrupt, 10-116
- Encode, 10-110
- END/MEND, 10-84
- Exclusive Or Byte, 10-102
- Exclusive Or Double Word, 10-104
- Exclusive Or Word, 10-103
- First-In-First-Out, 10-75
- For/Next, 10-90
- HEX to ASCII, 10-112
- High-Speed Counter Definition, 10-21
- immediate contacts, 10-4
- Increment Byte, 10-66
- Increment Double Word, 10-67
- Increment Word, 10-66
- Integer to BCD, 10-108
- Interrupt Routine, 10-114
- Invert Byte, 10-106
- Invert Double Word, 10-106
- Invert Word, 10-106
- Jump to Label/Label, 10-87
- Last-In-First-Out, 10-74
- Load Immediate/Load Not Immediate, 10-4
- Load Sequence Control Relay, 10-92
- Load/Load Not, 10-4
- Logic Pop, 10-99
- Logic Push, 10-99
- Logic Read, 10-99
- Memory Fill, 10-72
- Move Byte, 10-68
- Move Double Word, 10-68
- Move Real, 10-68
- Move Word, 10-68
- Multiply Integer, 10-52
- Multiply Real, 10-53
- Network Read/Network Write, 10-133
- Next, 10-90
- No Operation, 10-11
- Not, 10-5
- On-Delay Timer, 10-13
- Or Byte, 10-102
- Or Double Word, 10-104
- Or Immediate/Or Not Immediate, 10-4
- Or Load, 10-99
- Or Word, 10-103
- Or/Or Not, 10-4
- Output, 10-10
- Output Immediate, 10-10
- PID Loop, 10-55
- Positive Transition/Negative Transition, 10-5
- Pulse, 10-37
- Read Real-Time Clock, 10-49
- Receive, 10-124
- Retentive On-Delay Timer, 10-13
- Rotate Right Byte/Rotate Left Byte, 10-81
- Rotate Right Double Word/Rotate Left Double Word, 10-82
- Rotate Right Word/Rotate Left Word, 10-82
- Segment, 10-110
- Sequence Control Relay End, 10-92
- Sequence Control Relay Transition, 10-92
- Set Immediate/Reset Immediate, 10-11
- Set Real-Time Clock, 10-49
- Set/Reset, 10-10
- Shift Register Bit, 10-78
- Shift Right Byte/Shift Left Byte, 10-80
- Shift Right Double Word/Shift Left Double Word, 10-81
- Shift Right Word/Shift Left Word, 10-80
- Square Root, 10-53
- standard contacts, 10-4
- STOP, 10-84
- Subroutine, 10-88
- Subtract Double Integer, 10-50
- Subtract Integer, 10-50
- Subtract Real, 10-51
- Swap Bytes, 10-70
- Table Find, 10-76
- transition, 10-5
- Transmit, 10-124
- Truncate, 10-108
- Watchdog Reset, 10-85
- interrupt events, 10-117
- interrupts, maximum, 10-120
- interrupts supported, 1-3, 10-118
- memory, 1-3
 - ranges, 10-2
- module, 1-5
- operand ranges, 10-3
- order number, G-1
- protocols supported, 1-3
- specifications, A-36–A-39
 - input simulator, A-86
- summary, 1-3

- CPU modules
 - clearance requirements, 2-2
 - dimensions
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
 - installation procedure
 - correct orientation of module, 2-5–2-8
 - expansion cable, 2-5–2-7
 - panel, 2-5
 - rail, 2-6
 - power requirements, 2-15
 - procedure, removing, 2-7
 - removal procedure, 2-7
 - screw sizes for installation, 2-3–2-5
 - Creating, STEP 7-Micro/WIN project, 3-26
 - Creating a program, example: set up timed interrupt, 6-9
 - Cross-Reference Table, 5-17
 - printing, 5-23
 - Current time values, updating, 10-16
 - Cycle time, Pulse train output (PTO) function, 10-42
- D**
- Data block
 - creating in STEP 7-Micro/WIN, 3-32
 - data type, 3-33
 - examples, 3-32
 - valid size designators, 3-33
 - Data Block Editor, 3-32
 - Data checking, 7-8
 - Data consistency, CPU 215, 9-20
 - Data exchange mode, DP master and CPU 215, 9-21
 - Data sheets. *See* Specifications
 - Data typing, 7-8
 - Data word format
 - EM231, A-62
 - EM235, A-72, A-74
 - Date, setting, 10-49
 - DC input simulator, installation, A-84, A-85, A-86
 - DC installation, guidelines, 2-11
 - DC relay, 2-14
 - DC transistor, protecting, 2-13
 - Debugging, program, 6-16–6-18
 - Decode instruction, 10-110
 - Decrement Byte instruction, 10-66
 - Decrement Double Word instruction, 10-67
 - Decrement instructions, 10-50–10-65
 - Decrement Byte, 10-66
 - Decrement Double Word, 10-67
 - Decrement Word, 10-66
 - example, 10-67
 - Subtract Double Integer, 10-50
 - Subtract Integer, 10-50
 - Subtract Real, 10-51
 - Decrement Word instruction, 10-66
 - Defining messages (TD 200), 5-8
 - Designing a Micro PLC system, 6-2
 - Detach Interrupt instruction, 10-116
 - Device database (GSD) file, 9-23–9-25
 - locating, 9-23
 - using for non-SIMATIC master devices, 9-24
 - Devices, using non-SIMATIC master, 9-24
 - Differential term, PID algorithm, 10-58
 - Digital expansion module, addressing, 8-2
 - Digital inputs, reading, 6-10
 - Digital outputs, writing to, 6-11
 - Dimensions
 - battery cartridge, A-80
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - memory cartridge, A-78
 - PC/PPI cable, A-83
 - screw sizes for installation, 2-3–2-5
 - DIN rail
 - clearance requirements, 2-2–2-4
 - dimensions, 2-3
 - high-vibration installations, 2-6
 - installation procedure, 2-6
 - order number, G-3
 - removal procedure, 2-7
 - using DIN rail stops, 2-6
 - vertical installations, 2-6
 - Diode suppression, 2-13
 - DIP switch settings, PC/PPI cable, 3-7
 - DIP switches
 - EM 231 configuration, A-61
 - EM235 configuration, A-70, A-71
 - Direct addressing, 7-2
 - Disable Interrupt instruction, 10-116
 - Display update rate, selecting, 5-5
 - Distributed peripheral (DP) standard communications, 9-15–9-26
 - Divide Integer instruction, 10-52

- Divide Real instruction, 10-53
 - Double word, and integer range, 7-3
 - Double word access, CPU 212/214/215/216, 10-3
 - Double Word Integer to Real instruction, 10-108
 - Downloading
 - error message, 4-15
 - mode requirements, 6-13
 - program, 3-30, 7-11
 - requirements for, 4-15
 - sample program, 4-15
 - DP (distributed peripheral) communications, 9-15–9-26
 - See also* Remote I/O
 - sample program, 9-26
 - using the CPU 215 as slave, 3-19, 9-15
 - DP LED status indicator, CPU 215 as DP slave, 9-22
 - DP master
 - configuration tools, 9-19
 - data exchange mode with CPU 215, 9-21
 - DP port, CPU 215, 3-19
 - DP Standard, monitoring status, D-12
 - DP status information, CPU 215 as DP slave, 9-21
- E**
- EEPROM, 7-11, 7-13
 - copying V memory, 7-16
 - error codes, C-2
 - saving from V memory, D-6
 - Electromagnetic compatibility, S7-200, A-5
 - Element Usage Table, 5-18
 - printing, 5-23
 - EM221, specifications, A-40–A-43
 - EM222, specifications, A-44–A-46
 - EM223, specifications, A-48–A-54
 - EM231
 - calibration, A-61
 - configuration, analog input range, A-61
 - data word format, A-62
 - DIP switches, A-61
 - location, A-61
 - input block diagram, A-63
 - installation guidelines, A-64
 - specifications, A-60–A-64
 - EM235
 - calibration, A-70
 - configuration, analog input range, A-71
 - data word format, A-72, A-74
 - DIP switches
 - location, A-70
 - setting, A-71
 - input block diagram, A-73
 - installation guidelines, A-75
 - output block diagram, A-74
 - specifications, A-69–A-75
 - Embedded data values (text messages), 5-8
 - formatting, 5-10
 - Enable Interrupt instruction, 10-116
 - Encode instruction, 10-110
 - End instruction, 10-84
 - Environmental specifications, A-4
 - Equipment requirements
 - S7-200, 1-2
 - STEP 7-Micro/WIN, 3-1
 - Error handling
 - fatal errors, 6-19
 - non-fatal errors, 6-20
 - responding to errors, 6-19
 - restarting the CPU after a fatal error, 6-19

- Errors
 - compile rule violations, C-4
 - fatal, C-2
 - Network Read/Network Write, 10-133
 - non-fatal, C-3, C-4
 - PID loop, 10-62
 - run-time programming, C-3
 - SMB1, execution errors, D-2
- ET 200, manual, G-3
- European Community (EC) certification, A-3
- Examples
 - Add to Table, 10-73
 - analog adjustment, 8-8
 - And, Or, Exclusive Or, 10-105–10-107
 - ASCII to HEX, 10-113
 - block move, 10-71–10-73
 - calculating power requirements, 2-15
 - call to subroutine, 10-89–10-91
 - comparison contact instructions, 10-9
 - contact instructions, 10-6
 - Convert and Truncate, 10-109
 - counter, 10-20
 - data block, 3-32
 - Decode/Encode, 10-111
 - decrement, 10-67
 - First-In-First-Out, 10-75
 - For/Next, 10-91–10-93
 - GSD file, 9-24
 - High-Speed Counter, 10-36
 - high-speed counter
 - operation of HSC0 Mode 0 and HSC1 or HSC2 Modes 0, 1, or 2, 10-23
 - operation of HSC1 or HSC2 Modes 3, 4, or 5, 10-24
 - operation of HSC1 or HSC2, Modes 6, 7 or 8, 10-24
 - operation of HSC1 or HSC2, Modes 9, 10, or 11, 10-25
 - operation with Reset and Start, 10-23
 - operation with Reset and without Start, 10-22
 - I/O numbering, 8-2, 8-3
 - increment, 10-67
 - initialization of HSC1, 10-21
 - Interrupt Routine instructions, 10-122
 - Invert, 10-107–10-109
 - Jump to Label, 10-87–10-89
 - Last-In-First-Out, 10-74
 - logic stack, 10-101–10-103
 - loop control (PID), 10-63–10-65
 - math, 10-54
 - memory fill, 10-72–10-74
 - move and swap, 10-70–10-72
 - MPI card with master/slave, 3-9
 - Network Read/Network Write, 10-134–10-136
 - on-delay timer, 10-17
 - output instructions, 10-12
 - parameter block, 5-11
 - program for DP communications, 9-26
 - Pulse Train Output, 10-45
 - Pulse width modulation, 10-47
 - Real number conversion instruction, 10-109
 - retentive on-delay timer, 10-18
 - sample program, 4-2
 - Segment, 10-111
 - Sequence Control Relay, 10-93–10-98
 - conditional transitions, 10-98
 - convergence control, 10-96–10-99
 - divergence control, 10-94
 - set up timed interrupt, 6-9
 - shift and rotate, 10-83–10-85
 - shift register bit, 10-79–10-81
 - Status/Force Chart, 3-34
 - Stop, End, and Watchdog Reset, 10-86–10-88
 - Symbol Table, 3-36
 - Table Find, 10-77
 - TD 200s added to network, 9-14
 - token passing network, 9-28
 - transmit instructions, 10-130
 - Truncate, 10-109
- Exclusive Or Byte instruction, 10-102
- Exclusive Or Double Word instruction, 10-104
- Exclusive Or Word instruction, 10-103
- Execution times
 - effect of analog I/O, F-1
 - effect of indirect addressing, F-1
 - effect of power flow, F-1
 - statement list instructions, F-1–F-11
- Expansion cable
 - See also* I/O expansion cable
 - installation procedure, 2-5–2-7
- Expansion module. *See* EM231, etc.

- Expansion modules, 1-4
 - addressing I/O points, 8-2
 - clearance requirements, 2-2
 - dimensions
 - 8-, 16-, and 32-point I/O modules, 2-4
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - screw sizes for installation, 2-3–2-5
 - expansion cable, installing, 2-5–2-7
 - ID and error register (SMB8 to SMB21), D-4
 - installation procedure
 - correct orientation of module, 2-5–2-8
 - expansion cable, 2-5–2-7
 - panel, 2-5
 - rail, 2-6
 - removing the bus expansion port connector, 2-5–2-7
 - order numbers, G-1
 - power requirements, 2-15
 - removal procedure, 2-7
 - screw sizes for installation, 2-3–2-5
- F**
- Fatal errors, C-2
 - and CPU operation, 6-19
- Field wiring
 - installation procedure, 2-8
 - optional connector, 2-10
 - wire sizes, 2-8
- Fill instructions, 10-68–10-77
 - example, 10-72–10-74
 - Memory Fill, 10-72
- Filtering analog input, 5-14–5-16
- Find instructions, 10-73–10-77
 - Add to Table, 10-73
 - First-In-First-Out, 10-75
 - Last-In-First-Out, 10-74
 - Table Find, 10-76
- Find/Replace tool, 5-19
- First-In-First-Out instruction, 10-75
- Floating-point values, loop control, 10-59
- Floating-point values, representing, 7-3
- For instruction, 10-90
- Force function, 6-17
 - enabling, 5-4
- Forcing variables, Status/Force Chart, 3-35
- Formatting, data values in text, 5-10
- Freeport mode
 - and operation modes, 10-124
 - character interrupt control, 10-129
 - definition, 10-118
 - enabling, 10-125
 - initializing, 10-126
 - operation, 10-124
 - SMB2, freeport receive character, D-2
 - SMB3, freeport parity error, D-2
 - SMB30, SMB130 freeport control registers, 10-126, D-6
- Freeport mode of communication
 - user-defined protocol, 9-5
 - using the PC/PPI cable, 9-10–9-11
- Freeze outputs, 8-6
- Function keys, enabling, 5-5
- G**
- Gap update factor (GUF), 9-31
- Grounding and circuit, wiring guidelines, 2-9
- GSD file
 - See also* Device database file
 - locating, 9-23
 - using for non-SIMATIC master devices, 9-24
- GUF. *See* Gap update factor
- Guidelines
 - AC installation, 2-10
 - DC installation, 2-11
 - designing a PLC system, 6-2–6-4
 - entering symbolic addresses, 3-36
 - grounding and circuit, 2-9
 - high-vibration environment, 2-6
 - installing EM235, A-75
 - modifying a pointer for indirect addressing, 7-10
 - North American installation, 2-12
 - suppression circuits, 2-13
 - AC output, 2-14
 - DC relay, 2-14
 - using DIN rail stops, 2-6
 - vertical installations, 2-6
 - wiring, 2-8
 - isolation, 2-9
- H**
- Help. *See* Online help
- HEX PTO/PWM Reference Table, 10-40

- HEX to ASCII instruction, 10-112
 - High potential isolation test, A-5
 - High-Speed Counter, SMB36 - SMB 65 HSC register, D-8
 - High-Speed Counter Definition instruction, 10-21
 - counter mode, 10-28
 - High-Speed Output
 - changing pulse width, 8-7, 10-38
 - operation, 10-37
 - PTO/PWM operation, 10-38–10-44
 - SMB66-SMB85 special memory bytes, D-9
 - High-Speed Output instructions, 10-37–10-49
 - See also* PTO/PWM functions
 - Pulse, 10-37
 - High-vibration environment, using DIN rail stops, 2-6
 - Highest station address (HSA), 9-31
 - High-Speed Counter, 8-7, 10-21–10-40
 - changing direction, 10-35
 - control byte, 10-28
 - disabling, 10-35
 - examples, 10-22–10-25, 10-36
 - HSC interrupts, 10-30
 - initialization modes, 10-31–10-34
 - input wiring, 10-26
 - loading new current/preset value, 10-35
 - modes of operation, 10-27
 - operation, 10-22
 - selecting active state, 10-28
 - setting current and preset values, 10-29
 - status byte, 10-30
 - timing diagrams, 10-22–10-25
 - High-Speed Counter (HSC) box, 10-21
 - High-Speed Counter Definition (HDEF) box, 10-21
 - High-Speed Counter instructions, 10-13, 10-21–10-49
 - High-Speed Counter Definition, 10-21
 - High-Speed Counter, 10-21
 - High-Speed Counter memory area, addressing
 - HC memory area, 7-7
 - High-speed I/O, 8-7
 - High-Speed Pulse Output, 8-7
 - HSA. *See* Highest station address
 - HSC register, D-8
- I**
- I/O address, of a PROFIBUS-DP master, 9-18
 - I/O configurations supported by the CPU 215, 9-19
 - I/O expansion cable
 - installation, A-81
 - specifications, A-81
 - I/O status, SMB5, D-3
 - Immediate contact instructions, 10-4
 - Immediate I/O, 6-12
 - Importing
 - guidelines and limitations, E-5
 - STEP 7-Micro/DOS files, E-4
 - Increment Byte instruction, 10-66
 - Increment Double Word instruction, 10-67
 - Increment instructions, 10-50–10-65
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - Add Real, 10-51
 - example, 10-67
 - Increment Byte, 10-66
 - Increment Double Word, 10-67
 - Increment Word, 10-66
 - Increment Word instruction, 10-66
 - Incrementing a pointer, 7-10
 - Indirect addressing, 7-9–7-11
 - & and *, 7-9
 - effect on execution times, F-1
 - modifying a pointer, 7-10
 - Initialization
 - freepoint mode, 10-126
 - High-Speed Counters, 10-31–10-34
 - PTO/PWM functions, 10-40
 - Pulse train output (PTO) function, 10-42
 - PWM function, 10-41
 - Input block diagram, EM231, A-63, A-73
 - Input buffer, CPU 215, 9-18, 9-21
 - Input calibration
 - EM231, A-62
 - EM235, A-72
 - Input data word format, EM235, A-72
 - Input filter, noise rejection, 8-5

- Input image register, 6-12
- Input simulator
 - CPU 212, A-84
 - CPU 214, A-85
 - CPU 215/216, A-86
 - order number, G-3
- Inputs, basic operation, 6-4
- Install/Remove dialog box, 3-3
- Installation
 - clearance requirements, 2-2
 - communications hardware, 3-4–3-6
 - special instructions for Windows NT users, 3-6
 - configurations, 2-2
 - CPU 212 DC input simulator, A-84
 - CPU 214 DC input simulator, A-85
 - CPU 215/216 DC input simulator, A-86
 - dimensions
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
 - standard rail, 2-3
 - EM231, A-64
 - EM235, A-75
 - high-vibration environment, using DIN rail stops, 2-6
 - I/O expansion cable, A-81
 - memory cartridge, 7-17
 - procedure
 - correct orientation of module, 2-5–2-8
 - expansion module, 2-5–2-7
 - panel, 2-5
 - rail, 2-6
 - removal procedure, 2-7
 - screw sizes for installation, 2-3–2-5
 - STEP 7-Micro/WIN
 - Windows 3.1, 3-2
 - Windows 95, 3-2
 - Windows NT, 3-2
 - vertical positioning, using DIN rail stops, 2-6
- Instruction Wizard, S7-200
 - accessing/using, 5-12–5-14
 - analog input filtering, 5-14–5-16
- Instructions
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - Add Real, 10-51
 - Add to Table, 10-73
 - And Byte, 10-102
 - And Double word, 10-104
 - And Load, 10-99–10-101
 - And Word, 10-103
 - ASCII to HEX, 10-112
 - Attach Interrupt, 10-116
 - BCD to Integer, 10-108
 - Block Move Byte, 10-69
 - Block Move Double Word, 10-69
 - Block Move Word, 10-69
 - Call, 10-88
 - clock, 10-13
 - Communication, 10-124–10-136
 - Compare Byte, 10-7
 - Compare Double Word Integer, 10-8
 - Compare Real, 10-8
 - Compare Word Integer, 10-7
 - Contacts, 10-4–10-6
 - Conversion, 10-108–10-113
 - Count Up, 10-19
 - Count Up/Down, 10-19
 - Counter, 10-13–10-49
 - counter, 10-19
 - Decode, 10-110
 - Decrement, 10-50–10-65
 - Decrement Byte, 10-66
 - Decrement Double Word, 10-67
 - Decrement Word, 10-66
 - Detach Interrupt, 10-116
 - Disable Interrupt, 10-116
 - Divide Integer, 10-52
 - Divide Real, 10-53
 - Double Word Integer to Real, 10-108
 - Enable Interrupt, 10-116
 - Encode, 10-110
 - End, 10-84
 - Exclusive Or Byte, 10-102
 - Exclusive Or Double Word, 10-104
 - Exclusive Or Word, 10-103
 - execution times, F-1–F-9
 - Fill, 10-68–10-77
 - Find, 10-73–10-77
 - Find/Replace, 5-19
 - First-In-First-Out, 10-75

- For, 10-90
- HEX to ASCII, 10-112
- High-Speed Counter, 10-13, 10-21–10-49
- High-Speed Counter Definition, 10-21
- High-Speed Counter, 8-7
- High-Speed Counter (HSC) box, 10-21
- High-Speed Counter Definition (HDEF) box, 10-21
- High-Speed Output, 8-7, 10-37–10-49
- immediate contacts, 10-4
- Increment, 10-50–10-65
- Increment Byte, 10-66
- Increment Double Word, 10-67
- Increment Word, 10-66
- incrementing a pointer, 7-10
- Integer to BCD, 10-108
- Interrupt, 10-114–10-136
- Interrupt Routine, 10-114
- Invert Byte, 10-106
- Invert Double Word, 10-106
- Invert Word, 10-106
- Jump to Label, 10-87
- Last-In-First-Out, 10-74
- Logic Operations, 10-102–10-107
- Logic Pop, 10-99–10-101
- Logic Push, 10-99–10-101
- Logic Read, 10-99–10-101
- Logic stack, 10-99–10-101
- Loop Control (PID), 10-55–10-65
- Math, 10-50–10-65
- Memory Fill, 10-72
- modifying a pointer, 7-10
- Move, 10-68–10-77
- Move Byte, 10-68
- Move Double Word, 10-68
- Move Real, 10-68
- Move Word, 10-68
- Multiply Integer, 10-52
- Multiply Real, 10-53
- Negative Transition, 10-5
- Network Read, 10-133
- Network Write, 10-133
- Next, 10-90
- No Operation, 10-11
- Not, 10-5
- On-Delay Timer, 10-13
- On-Delay Timer Retentive, 10-13
- Or Byte, 10-102
- Or Double Word, 10-104
- Or Load, 10-99–10-101
- Or Word, 10-103
- Output (coil), 10-10
- Output immediate, 10-10
- Outputs, 10-10–10-12
- PID, 10-55–10-65
- Positive Transition, 10-5
- Program Control, 10-84–10-98
- Pulse, 10-37
- Pulse (PLS), 8-7, 10-37
- Pulse (PLS) box, 8-7, 10-37
- Read Real-Time Clock, 10-49
- Real-Time Clock, 10-49
- Receive, 10-124
- Reset, 10-10
- Reset Immediate, 10-11
- Return from Interrupt Routine, 10-114
- Return from Subroutine, 10-88
- Rotate, 10-68–10-77
- Rotate Left Byte, 10-81
- Rotate Left Double Word, 10-82
- Rotate Left Word, 10-82
- Rotate Right Byte, 10-81
- Rotate Right Double Word, 10-82
- Rotate Right Word, 10-82
- Segment, 10-110
- Sequence Control Relay, 10-92
- Set, 10-10
- Set Immediate, 10-11
- Set Real-Time Clock, 10-49
- Shift, 10-68–10-77
- Shift Left Byte, 10-80
- Shift Left Double Word, 10-81
- Shift Left Word, 10-80
- Shift Register Bit, 10-78
- Shift Register Bit (SHRB), 10-78
- Shift Register Bit (SHRB) box, 10-78
- Shift Right Byte, 10-80
- Shift Right Double Word, 10-81
- Shift Right Word, 10-80
- Square Root, 10-53
- standard contacts, 10-4
- Stop, 10-84
- Subroutine, 10-88
- Subtract Double Integer, 10-50
- Subtract Integer, 10-50
- Subtract Real, 10-51
- Swap Bytes, 10-70
- Table, 10-73–10-77
- Table Find, 10-76
- Timer, 10-13–10-49
- Transmit, 10-124
- Truncate, 10-108
- Watchdog Reset, 10-85–10-87
- Integer, converting to real number, 10-59

- Integer to BCD instruction, 10-108
- Integral term, PID algorithm, 10-57
- International characters, TD 200 Wizard, 5-9
- Interrupt instructions, 10-114–10-136
 - Attach Interrupt, 10-116
 - Detach Interrupt, 10-116
 - Disable Interrupt, 10-116
 - Enable Interrupt, 10-116
 - example, 10-122
 - Interrupt Routine, 10-114
 - operation, 10-116
 - Return from Interrupt Routine, 10-114
- Interrupt Routine instruction, 10-114
- Interrupt routines, guidelines, 6-8
- Interrupts
 - and scan cycle, 6-11
 - bit definitions for queue overflow, 10-120
 - CPU 212/214/215/216, 10-2
 - data shared with main program, 10-115
 - enabling and disabling, 10-116
 - event types and numbers
 - CPU 212/214/215/216, 10-117
 - priority, 10-121
 - High-Speed Counters, 10-30
 - I/O, 10-118
 - priority, 10-120
 - queues, 10-120
 - restrictions for using, 10-114
 - rising/falling edge, 10-118
 - routines, 10-114
 - setting up, 10-116
 - system support, 10-114
 - timed, 10-119, D-7
 - set up to read analog input, 10-123
- Invert Byte instruction, 10-106
- Invert Double Word instruction, 10-106
- Invert Word instruction, 10-106
- Isolated DC wiring guidelines, 2-11

- J**
- Jump to Label instruction, 10-87

- L**
- Label instruction, 10-87

- Ladder logic
 - basic elements, 6-5
 - changing to statement list, 3-31
 - editor, 3-27
 - entering program, 5-21
 - printing program, 5-23
 - program, entering in STEP 7-Micro/WIN, 3-27
 - program status, 6-17
 - sample program, 4-5, 4-10
 - viewing STEP 7-Micro/WIN program, 3-31
- Language, operator interface, 5-4
- Last-In-First-Out instruction, 10-74
- Local I/O, addressing, 8-2
- Logic Operations instructions, 10-102–10-107
 - And Byte, 10-102
 - And Double Word, 10-104
 - And Word, 10-103
 - example
 - And, Or, Exclusive Or, 10-105–10-107
 - Invert, 10-107–10-109
 - Exclusive Or Byte, 10-102
 - Exclusive Or Double Word, 10-104
 - Exclusive Or Word, 10-103
 - Invert Byte, 10-106
 - Invert Double Word, 10-106
 - Invert Word, 10-106
 - Or Byte, 10-102
 - Or Double Word, 10-104
 - Or Word, 10-103
- Logic Pop instruction, 10-99–10-101
- Logic Push instruction, 10-99–10-101
- Logic Read instruction, 10-99–10-101
- Logic stack
 - operation, 6-6
 - Sequence Control Relays (SCRs), 10-92
- Logic Stack instructions, 10-99–10-101
 - And Load, 10-99–10-101
 - example, 10-101–10-103
 - Logic Pop, 10-99–10-101
 - Logic Push, 10-99–10-101
 - Logic Read, 10-99–10-101
 - operation, 10-100
 - Or Load, 10-99–10-101
- Logical connections, MPI, 9-3, 9-4

- Loop control
 - adjusting bias, 10-61
 - converting inputs, 10-59
 - converting outputs, 10-60
 - error conditions, 10-62
 - forward/reverse, 10-60
 - loop table, 10-62
 - modes, 10-61
 - program example, 10-63–10-65
 - ranges/variables, 10-60
 - selecting type, 10-58
- Loop Control (PID) instructions, 10-55–10-65
 - example, 10-63–10-65
- Loop table, 10-62

- M**
- Manuals, order number, G-3
- Master devices
 - GSD file, 9-24
 - in communications, 9-9
 - modem, 3-19
 - MPI protocol, 9-3, 9-13
 - PPI protocol, 9-3
 - PROFIBUS-DP protocol, 9-4
 - using non-SIMATIC, 9-24
- Math instructions, 10-50–10-65
 - Add Double Integer, 10-50
 - Add Integer, 10-50
 - Add Real, 10-51
 - Divide Integer, 10-52
 - Divide Real, 10-53
 - example, 10-54
 - Multiply Integer, 10-52
 - Multiply Real, 10-53
 - Square Root, 10-53
 - Subtract Double Integer, 10-50
 - Subtract Integer, 10-50
 - Subtract Real, 10-51
- Memory
 - clearing, 6-15
 - Element Usage Table, 5-18
- Memory areas, 6-4
 - accessing data, 6-4, 7-2
 - bit memory, 7-2
 - byte memory, 7-2
 - CPU, 7-2
 - operand ranges, 10-3
- Memory cartridge
 - copying to, 7-17
 - dimensions, A-78
 - error codes, C-2
 - installing, 7-17
 - order number, G-3
 - removing, 7-17
 - restoring the program, 7-18
 - specifications, A-78
 - using, 7-17
- Memory Fill instruction, 10-72
- Memory ranges, CPU 212/214/215/216, 10-2
- Memory retention, 7-11–7-16
 - battery cartridge (optional), 7-11
 - EEPROM, 7-11, 7-13, 7-16
 - power-on, 7-13–7-17
 - ranges, 7-15
 - super capacitor, 7-11
- Message enable flags (TD 200), 5-7
- Messages
 - defining, 5-8
 - embedding values, 5-8
 - enable flags, TD 200, 5-7
 - formatting embedded data value, 5-10
 - location, 5-7
 - size/number, 5-6
 - token-passing network, 9-29
- Mode control, PID loops, 10-61
- Mode switch, operation, 6-13
- Modem
 - cable requirements, 3-19
 - network communications, 3-19–3-24
 - null modem adapter, 9-12
 - PC/PG to CPU connection, 3-19–3-20
 - using with the PC/PPI cable, 9-12
- Modes. *See* Operation modes
- Modes of operation, High-Speed Counters, 10-27
- Modifying a pointer (indirect addressing), 7-10
- Monitoring
 - addresses, 5-17
 - addresses/range, 5-18
 - program, 6-16–6-18
 - program status, 6-17
 - sample program, 4-16

- Moudule parameter set
 - MPI Card (MPI), 3-16–3-17
 - MPI Card (PPI), 3-14
 - PC/PPI Cable (PPI), 3-12–3-13
 - selecting, 3-12–3-13
 - Mounting
 - clearance requirements, 2-2
 - dimensions
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
 - standard rail, 2-3
 - high-vibration environment, using DIN rail stops, 2-6
 - procedure
 - correct orientation of module, 2-5–2-8
 - expansion module, 2-5–2-7
 - panel, 2-5
 - rail, 2-6
 - removal procedure, 2-7
 - screw sizes for installation, 2-3–2-5
 - vertical positioning, using DIN rail stops, 2-6
 - Move Byte instruction, 10-68
 - Move Double Word instruction, 10-68
 - Move instructions, 10-68–10-77
 - Block Move Byte, 10-69
 - Block Move Double Word, 10-69
 - Block Move Word, 10-69
 - example of block move, 10-71–10-73
 - example of move and swap, 10-70–10-72
 - Move Byte, 10-68
 - Move Double Word, 10-68
 - Move Real, 10-68
 - Move Word, 10-68
 - Swap Bytes, 10-70
 - Move Real instruction, 10-68
 - Move Word instruction, 10-68
 - MPI (multipoint interface), protocol, 9-3
 - baud rate, 9-13
 - MPI (Multipoint Interface) card, order number, G-2
 - MPI cable, 3-8
 - MPI card, 3-8, 9-13
 - configuration with PC, 9-14
 - connection procedure, 3-8
 - MPI parameters, 3-16
 - PPI parameters, 3-14
 - setting up the MPI Card (MPI) parameters, 3-16–3-17
 - setting up the MPI Card (PPI) parameters, 3-14
 - MPI communications, 3-8, 9-3
 - CP cards, 9-13
 - default addresses, 3-17
 - troubleshooting, 3-17
 - MPI logical connections, 9-3, 9-4
 - Multi Master Network check box, 3-13
 - Multiple Master network
 - CP cards, 9-13
 - MPI card, 9-13
 - Multiple master network, 9-13
 - Multiply Integer instruction, 10-52
 - Multiply Real instruction, 10-53
- N**
- Negative Transition instruction, 10-5

Network

- biasing, 9-7
- cable connections, 9-9
- cable specifications, 9-8
- communication port, 9-6
- communications setup, 3-7–3-24
- components, 9-6
- connectors, 9-7
- device address, 9-2
- find/replace, 5-19
- gap update factor (GUF), 9-31
- highest station address (HSA), 9-31
- installing communications hardware, 3-4–3-6
- limitations, 9-28
- master devices, 9-2
- multiple master, 9-13
- optimizing performance, 9-31
- performance, 9-28
- repeaters, 9-8
- segments, 9-2
- selecting the parameter set, 3-12
- sending messages, 9-29
- slave devices, 9-2
- terminating, 9-7
- token rotation time, 9-29–9-32
- using non-SIMATIC master devices, 9-24
- Network Read instruction, 10-133
 - errors, 10-133
 - example, 10-134–10-136
- Network Write instruction, 10-133
 - errors, 10-133
 - example, 10-134–10-136
- Next instruction, 10-90
- No Operation instruction, 10-11
- Noise rejection, input filter, 8-5
- Non-fatal errors
 - and CPU operation, 6-20
 - system response, 6-20
- North American installation, guidelines, 2-12
- Not instruction, 10-5
- Not the Only Master Active check box, 3-17
- Null modem adapter, 3-19–3-20, 9-12
- Numbers
 - representation of, 7-3
 - using constant values, 7-8

O

- OB1 (user program), 3-27
- On-Delay Timer instruction, 10-13
- On-Delay Timer Retentive instruction, 10-13
- Online help, STEP 7-Micro/WIN, 3-1
- Operand ranges, CPU 212/214/215/216, 10-3
- Operation modes
 - and force function, 6-17
 - and Freeport communication, 10-124
 - changing, 6-13
 - changing CPU to RUN in sample program, 4-15
 - status bits, D-1
- Operator interface, TD 200, 5-2
- Operator stations, specifying, 6-3
- Or Byte instruction, 10-102
- Or Double Word instruction, 10-104
- Or Load instruction, 10-99–10-101
- Or Word instruction, 10-103
- Order numbers, G-1
- Orientation of the module, 2-5–2-8
- Output (coil) instruction, 10-10
- Output block diagram, EM235, A-74
- Output buffer, CPU 215, 9-18, 9-21
- Output data word format, EM235, A-74
- Output image register, 6-12
- Output immediate instruction, 10-10
- Output instructions, 10-10–10-12
 - example, 10-12
 - No Operation, 10-11
 - Output (coil), 10-10
 - Output immediate, 10-10
 - Reset, 10-10
 - Reset Immediate, 10-11
 - Set, 10-10
 - Set immediate, 10-11
- Output table, configure output states, 8-6
- Outputs
 - basic operation, 6-4
 - freezing, 8-6
 - high-speed pulse, 8-7

P

Panel

- dimensions
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
- expansion modules, 2-4
- installation procedure, 2-5
 - expansion cable, 2-5–2-7
- removal procedure, 2-7

- Parameter, find/replace, 5-19
- Parameter block (TD 200), 5-2
 - address, 5-7
 - configuring, 5-3
 - sample, 5-11
 - saving/viewing, 5-11
- Parameter set, module
 - MPI Card (MPI), 3-16–3-17
 - MPI Card (PPI), 3-14
 - PC/PPI Cable (PPI), 3-12–3-13
 - selecting, 3-12–3-13
- Password
 - clearing, 6-15
 - configuring, 6-14
 - CPU, 6-14
 - enabling password protection (TD 200), 5-4
 - lost, 6-15
 - privilege level, 6-14
 - restricting access, 6-14
- PC/PPI cable, 9-9–9-11
 - baud rate switch selections, 9-10
 - connection procedure, 3-7
 - dimensions, A-83
 - DIP switch settings, 3-7
 - pin definitions for RS-232 port, 9-10
 - setting up parameters, 3-12
 - specifications, A-82
 - using with a modem, 3-19–3-20, 9-12
 - using with the Freeport communication mode, 9-10–9-11
- PC/PPI network, 9-9
- Peer-to-peer communications, 1-3
- Permanent program storage, 7-16
- PG/PC Interface dialog box, 3-10
- Physical size
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
- PID algorithm, 10-55–10-59
- PID instructions, 10-55–10-65
 - example, 10-63–10-65
- PID Loop instruction
 - history bits, 10-61
 - modes, 10-61
- PID loop table, 10-62
- PID loops
 - adjusting bias, 10-61
 - converting inputs, 10-59
 - converting outputs, 10-60
 - CPU 212/214/215/216, 10-2
 - error conditions, 10-62
 - forward/reverse, 10-60
 - loop table, 10-62
 - modes, 10-61
 - program example, 10-63–10-65
 - ranges, variables, 10-60
 - selecting loop control type, 10-58
- Pin assignment
 - communication port, 9-6
 - PC/PPI, A-82
- Pointers, 7-9–7-11
 - & and *, 7-9
 - modifying a pointer, 7-10
- Positive Transition instruction, 10-5
- Potentiometer location
 - EM231, A-61
 - EM235, A-70
- Potentiometers, and SMB28, SMB29, 8-8
- Power flow, effect on execution times, F-1
- Power requirements
 - calculating, 2-15
 - calculation table, B-1
 - CPU, 2-15
 - expansion module, 2-15
- Power-on, memory retention, 7-13–7-17
- PPI (point-to-point interface)
 - cable connections, 9-9
 - communications, 3-7
 - network connection, 9-9
 - protocol, 9-3
- PPI communications, 9-3
- Preferences, setting, 3-25
- Printing, STL or LAD program, 5-23
- Process variable, converting, 10-59
- Process-image input register
 - addressing, 7-3
 - operation, 6-10
- Process-image output register, 6-11
 - addressing, 7-3
 - and PTO/PWM function, 10-44

- PROFIBUS
 - data consistency, 9-20
 - device database (GSD) file, 9-23–9-25
 - network cable specifications, 9-8
 - network repeaters, 9-8
- PROFIBUS standard, pin assignment, 9-6
- PROFIBUS-DP, 9-17
 - See also* DP (distributed peripheral) standard protocol, 9-4
- PROFIBUS-DP master, I/O address area, 9-18
- PROFIBUS-DP standard, 9-15
- PROFIBUS-DP communications, 9-4
- Program
 - analog inputs, 6-10
 - basic elements, 6-8
 - compiling in STEP 7-Micro/WIN, 3-29
 - creating in STEP 7-Micro/WIN, 3-27–3-31
 - debugging, 6-16–6-18
 - downloading, 7-11
 - downloading in STEP 7-Micro/WIN, 3-30
 - entering, 5-21
 - entering comments, 5-21
 - executing, 6-11
 - importing a STEP 7-Micro/DOS, E-4
 - importing guidelines and limitations, E-5
 - inputs/outputs, 6-4
 - monitoring, 6-16–6-18
 - monitoring status, 6-17
 - printing, 5-23
 - restoring from memory cartridge, 7-18
 - sample program, 4-2–4-19
 - saving permanently, 7-16
 - STEP 7-Micro/WIN preferences, 3-25
 - storage, 7-11–7-14, 7-17
 - structure, 6-8
 - uploading, 7-11
 - using Status/Force Chart, 6-16
 - using subroutines, 10-88
 - viewing a STEP 7-Micro/WIN, 3-31
- Program Control instructions, 10-84–10-98
 - Call, 10-88
 - example, 10-89–10-91
 - End, 10-84
 - example, 10-86–10-88
 - For, 10-90
 - For/Next, example, 10-91–10-93
 - Jump to Label, 10-87
 - example, 10-87–10-89
 - Next, 10-90
 - Return from Subroutine, 10-88
 - Sequence Control Relay, 10-92
 - Stop, 10-84
 - example, 10-86–10-88
 - Subroutine, 10-88
 - Watchdog Reset, 10-85–10-87
 - example, 10-86–10-88
- Programming concepts, 6-4
- Programming language, concepts, 6-5
- Programming software, order numbers, G-3
- Project
 - components, 3-30
 - creating, 4-6
 - creating in STEP 7-Micro/WIN, 3-26
 - download to CPU, 3-30
 - sample program, 4-6
 - saving in STEP 7-Micro/WIN, 3-26
- Proportional term, PID algorithm, 10-57
- Protocols. *See* Communications, protocols;
Module parameter set

- PTO/PWM functions, 10-38–10-44
 - and process image register, 10-44
 - control bits, 10-39
 - control byte, 10-38
 - control register, 10-40
 - SMB66-SMB85, D-9
 - cycle time, 10-39
 - effects on outputs, 10-43
 - hexadecimal reference table, 10-40
 - initialization, 10-40
 - PTO pipeline, 10-38
 - pulse width/pulse count, 10-39
 - status bit, 10-39
 - PTO/PWM HEX Reference Table, 10-40
 - Pulse (PLS), 8-7, 10-37
 - Pulse (PLS) box, 8-7, 10-37
 - Pulse instruction, 10-37
 - Pulse outputs, 8-7
 - Pulse train output (PTO) function, 8-7, 10-37
 - changing cycle time, 10-42
 - changing cycle time and pulse count, 10-43
 - changing pulse count, 10-42
 - example, 10-45
 - initializing, 10-42
 - Pulse width modulation (PWM) function, 8-7, 10-37
 - changing pulse width, 10-38, 10-41
 - example, 10-47
 - initializing, 10-41
- R**
- Rail
 - clearance requirements, 2-2–2-4
 - dimensions, 2-3
 - high-vibration installations, 2-6
 - installation procedure, 2-6
 - removal procedure, 2-7
 - using DIN rail stops, 2-6
 - vertical installations, 2-6
 - Read Real-Time Clock instruction, 10-49
 - Real-Time Clock instructions, 10-49
 - Read Real-Time Clock, 10-49
 - Set Real-Time Clock, 10-49
 - Receive instruction, 10-124, 10-127
 - SMB86-SMB94, SMB186-SMB194, D-10
 - Relays, resistor/capacitor networks, 2-14
 - Remote I/O, communications, 3-19, 9-15
 - Remote I/O module, CPU 215, 3-19
 - Removal
 - bus connector port cover, 2-5–2-7
 - clearance requirements, 2-2
 - correct orientation of module, 2-7
 - CPU, 2-7
 - dimensions
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
 - expansion module, 2-7
 - memory cartridge, 7-17
 - screw sizes for installation, 2-3–2-5
 - Repeater, order number, G-2
 - Repeaters, PROFIBUS network, 9-8
 - Replace tool, 5-19
 - Reset Immediate instruction, 10-11
 - Reset instruction, 10-10
 - Resistor/capacitor networks, relay applications, 2-14
 - Resources dialog box for Windows NT, 3-6
 - Restarting the CPU, after a fatal error, 6-19
 - Retaining memory, 7-11–7-16
 - Retentive On-Delay Timer instruction, 10-13
 - Retentive ranges of memory, defining, 7-15
 - Return from Interrupt Routine instruction, 10-114
 - Return from Subroutine instruction, 10-88
 - Rotate instructions, 10-68–10-77
 - example of shift and rotate, 10-83–10-85
 - Rotate Left Byte, 10-81
 - Rotate Left Double Word, 10-82
 - Rotate Left Word, 10-82
 - Rotate Right Byte, 10-81
 - Rotate Right Double Word, 10-82
 - Rotate Right Word, 10-82
 - Rotate Left Byte instruction, 10-81
 - Rotate Left Double Word instruction, 10-82
 - Rotate Left Word instruction, 10-82
 - Rotate Right Byte instruction, 10-81
 - Rotate Right Double Word instruction, 10-82
 - Rotate Right Word instruction, 10-82
 - RUN mode, 6-13

- Run-time errors, C-3
 - system response, 6-20
- S**
- S7-200
 - clearance requirements, 2-2
 - components, 1-4
 - CPU modules, removal procedure, 2-7
 - CPU summary, 1-3
 - dimensions
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
 - electromagnetic compatibility, A-5
 - environmental conditions, A-4
 - expansion modules, 1-4
 - removal procedure, 2-7
 - installation procedure
 - correct orientation of module, 2-5–2-8
 - expansion cable, 2-5–2-7
 - panel, 2-5
 - rail, 2-6
 - Instruction Wizard, 5-12–5-16
 - analog input filtering, 5-14–5-16
 - removal procedure, 2-7
 - screw sizes for installation, 2-3–2-5
 - system components, 1-2
 - technical specifications, A-4
- Safety circuits, designing, 6-3
- Sample program
 - changing modes, 4-15
 - compiling, 4-13
 - creating a project, 4-6
 - creating a Status Chart, 4-14
 - creating symbol table, 4-8
 - downloading, 4-15
 - how to enter ladder logic, 4-10–4-14
 - ladder logic, 4-5
 - monitoring, 4-16
 - saving, 4-13
 - statement list, 4-4
 - system requirements, 4-2
 - tasks, 4-3
- Sampling analog input, 5-14–5-16
- Saving
 - program permanently, 7-16
 - STEP 7-Micro/WIN project, 3-26
 - value to EEPROM, D-6
- Scaling loop outputs, 10-60
- Scan cycle
 - and force function, 6-18
 - and Status/Force Chart, 6-17
 - interrupting, 6-11
 - status bits, D-1
 - tasks, 6-10
- Scan time, SMW22 to SMW26), D-5
- Screw sizes (for installation), 2-3–2-5
- Segment instruction (Conversion instructions), 10-110
- Segmentation instructions (SCR instructions), 10-93
- Segments, network, 9-2
- Sequence Control Relay instructions, 10-92
 - examples, 10-93–10-97
- Sequence control relays
 - addressing memory area, 7-4
 - CPU 212/214/215/216, 10-2
- Set Immediate instruction, 10-11
- Set instruction, 10-10
- Set Real-Time Clock instruction, 10-49
- Setpoint, converting, 10-59
- Setting the PG/PC interface dialog box, 3-10
- Setting up
 - communications, 3-7–3-24
 - communications during installation, 3-12
 - communications from the Windows Control Panel, 3-11
 - communications parameters, 3-9
- Shift instructions, 10-68–10-77
 - example of shift and rotate, 10-83–10-85
 - example of shift register bit, 10-79–10-81
- Shift Left Byte, 10-80
- Shift Left Double Word, 10-81
- Shift Left Word, 10-80
- Shift Register Bit, 10-78
- Shift Right Byte, 10-80
- Shift Right Double Word, 10-81
- Shift Right Word, 10-80
- Shift Left Byte instruction, 10-80
- Shift Left Double Word instruction, 10-81
- Shift Left Word instruction, 10-80
- Shift register, 10-78

- Shift Register Bit (SHRB), 10-78
- Shift Register Bit (SHRB) box, 10-78
- Shift Register Bit instruction, 10-78
- Shift Right Byte instruction, 10-80
- Shift Right Double Word instruction, 10-81
- Shift Right Word instruction, 10-80
- Simulator. *See* Input simulator
- Single-phase wiring guidelines, 2-10
- Size of the modules
 - CPU 212, 2-3
 - CPU 214, 2-3
 - CPU 215, 2-4
 - CPU 216, 2-4
 - expansion I/O modules, 2-4
 - screw sizes for installation, 2-3–2-5
- Slave devices
 - communications, 9-9
 - CPU 215 as DP slave, 3-19, 9-15
- SM0.2 retentive data lost memory bit, 7-14
- SMB0 status bits, D-1
- SMB1 status bits, D-2
- SMB110-SMB115 standard protocol status, D-12
- SMB186-SMB194 receive message control, D-10
- SMB2 freeport receive character, D-2
 - character interrupt control, 10-129
- SMB28, SMB29 analog adjustment, 8-8, D-5
- SMB3 freeport parity error, D-2
 - character interrupt control, 10-129
- SMB30, SMB130 freeport control registers, 10-126, D-6
- SMB34/SMB35 time-interval registers, D-7
- SMB36-SMB65 HSC register, D-8
- SMB4 queue overflow, D-3
- SMB5 I/O status, D-3
- SMB6 CPU ID register, D-4
- SMB66-SMB85 PTO/PWM registers, D-9
- SMB7 reserved, D-4
- SMB8-SMB21 I/O module ID and error registers, D-4
- SMB86-SMB94 receive message control, D-10
- SMW22-SMW26 scan times, D-5
- Special memory bits, D-1–D-13
 - addressing, 7-4
 - SMB0 status bits, D-1
 - SMB1 status bits, D-2
 - SMB110-SMB115 DP standard protocol status, D-12
 - SMB186-SMB194 receive message control, D-10
 - SMB2 freeport receive character, D-2
 - SMB28, SMB29 analog adjustment, D-5
 - SMB3 freeport parity error, D-2
 - SMB30, SMB130 freeport control registers, 10-126, D-6
 - SMB31 permanent memory (EEPROM)
 - write control, D-6
 - SMB34/SMB35 time interval registers, D-7
 - SMB36-SMB65 HSC register, D-8
 - SMB4 queue overflow, D-3
 - SMB5 I/O status, D-3
 - SMB6 CPU ID register, D-4
 - SMB66-SMB85 PTO/PWM registers, D-9
 - SMB7 reserved, D-4
 - SMB8-SMB21 I/O module ID and error registers, D-4
 - SMB86-SMB94 receive message control, D-10
 - SMW22-SMW26 scan times, D-5
 - SMW32 permanent memory (EEPROM)
 - write control, D-6

- Specifications
 - battery cartridge, A-80
 - CPU 212, A-6–A-15
 - CPU 214, A-20–A-29
 - CPU 215, A-32–A-35
 - CPU 216, A-36–A-39
 - creating functional, 6-2
 - EM221, A-40–A-43
 - EM222, A-44–A-46
 - EM223, A-48–A-54
 - EM231, A-60–A-64
 - EM235, A-69–A-75
 - I/O expansion cable, A-81
 - Input simulator
 - CPU 212, A-84
 - CPU 214, A-85
 - CPU 215/216, A-86
 - memory cartridge, A-78
 - PC/PPI cable, A-82
 - S7-200 family, A-4
- Square Root instruction, 10-53
- Standard contact instructions, 10-4
- Standard rail
 - clearance requirements, 2-2–2-4
 - dimensions, 2-3
 - high-vibration installations, 2-6
 - installation procedure, 2-6
 - removal procedure, 2-7
 - using DIN rail stops, 2-6
 - vertical installations, 2-6
- Standards, national and international, A-3
- Statement list, 6-5
 - allow viewing in ladder logic, 3-29
 - basic elements, 6-6
 - changing to ladder logic, 3-31
 - editor, 3-29
 - entering program, 5-21
 - execution times, F-1–F-11
 - program
 - entering in STEP 7-Micro/WIN, 3-29
 - printing, 5-23
 - sample program, 4-4
 - viewing STEP 7-Micro/WIN program, 3-31
- Status bits (SMB0), D-1
- Status byte, High-Speed Counter, 10-30
- Status Chart
 - building for sample program, 4-14
 - sample program, 4-14
- Status information, CPU 215 as DP slave, 9-21
- Status LED, CPU 215 as DP slave, 9-22
- Status/Force Chart
 - and scan cycle, 6-17
 - editing addresses, 3-35
 - forcing variables, 3-35
 - modifying program, 6-16
 - monitor/modify values, 4-17
 - reading and writing variables, 3-34
 - STEP 7-Micro/WIN, 3-34
- STEP 7-Micro/DOS
 - converting files, E-4
 - importing files, E-4
- STEP 7-Micro/WIN
 - compiling a program, 3-29
 - converting STEP 7-Micro/DOS files to, E-4
 - copy license order number, G-3
 - creating a data block, 3-32
 - creating a program, 3-27–3-31
 - creating a project, 3-26
 - Data Block Editor, 3-32
 - downloading a program, 3-30
 - equipment requirements, 3-1
 - hardware for network communications, 3-4
 - installing, 3-2
 - installing communications hardware, 3-4–3-6
 - modem communications, 3-19–3-24
 - online help, 3-1
 - order number, G-3
 - programming preferences, 3-25
 - saving a project, 3-26
 - setting up communications within, 3-10
 - Status/Force Chart, 3-34
 - troubleshooting installation, 3-2
 - update order number, G-3
 - viewing a program, 3-31
- Stop instruction, 10-84
- STOP mode, 6-13
- Subroutine
 - example, 6-9
 - guidelines, 6-8
- Subroutine instruction, 10-88
- Subtract Double Integer instruction, 10-50
- Subtract Integer instruction, 10-50
- Subtract Real instruction, 10-51
- Summary of S7-200 CPU
 - features, 1-3
 - memory ranges, 10-2
 - operand ranges, 10-3
- Super capacitor, 7-11

- Suppression circuits, guidelines
 - AC output, 2-14
 - DC relay, 2-14
 - DC transistor, 2-13
 - Swap Bytes instruction, 10-70
 - Symbol, find/replace, 5-19
 - Symbol Table
 - creating, 4-8
 - edit functions, 3-37
 - sample program, 4-8
 - sort by name/address, 3-37
 - STEP 7-Micro/WIN, 3-36
 - Symbolic Addressing, 3-36
 - Symbolic names, creating, 6-3
 - Synchronous updates, PWM function, 10-41
 - System design, Micro PLC, 6-2
- T**
- Table Find instruction, 10-76
 - Table instructions, 10-73–10-77
 - Add to Table, 10-73
 - First-In-First-Out, 10-75
 - Last-In-First-Out, 10-74
 - Table Find, 10-76
 - TD 200, 5-2–5-9
 - bar graph character set, 5-4
 - configuring parameter block, 5-3
 - creating messages, 5-8
 - display update rate, 5-5
 - force function, 5-4
 - function keys, 5-5
 - menu language, 5-4
 - messages, 5-6–5-10
 - parameter block, 5-2
 - password protection, 5-4
 - Wizard configuration tool, 5-3
 - TERM mode, 6-13
 - Terminating, network, 9-7
 - Three-phase wiring guidelines, 2-12
 - Time-based interrupts, 10-119
 - Time-of-Day (TOD) menu, enabling, 5-4
 - Time, setting, 10-49
 - Timed interrupt
 - example, 6-9, 10-123
 - SMB34, SMB35, D-7
 - Timer instructions, 10-13–10-49
 - example of on-delay timer, 10-17
 - example of retentive on-delay timer, 10-18
 - On-Delay Timer, 10-13
 - On-Delay Timer Retentive, 10-13
 - Timer T32/T96, interrupts, 10-119
 - Timers
 - addressing memory area, 7-4
 - CPU 212/214/215/216, 10-2
 - number, 10-13
 - operation, 10-13
 - resolution, 10-13
 - updating, 10-14–10-18
 - Token rotation comparison, 9-30
 - Token rotation time, 9-29–9-32
 - Token-passing network, example, 9-28
 - Transmit instruction, 10-124, 10-127
 - example, 10-130
 - Troubleshooting
 - compile errors, C-4
 - error handling, 6-19
 - fatal errors, C-2
 - MPI communications, 3-17
 - network read/network write errors, 10-133
 - non-fatal errors, 6-20
 - password lost, 6-15
 - PID loop, 10-62
 - run-time programming errors, C-3
 - STEP 7-Micro/WIN installation, 3-2
 - Truncate instruction, 10-108
- U**
- Updating, timers, 10-14
 - Uploading, program, 7-11
 - User program (OB1), 3-27
 - User-defined protocol, Freepoint mode of communication, 9-5
 - Using pointers, 7-9
 - & and *, 7-9
 - modifying a pointer, 7-10
 - Using subroutines, 10-88
- V**
- V memory, copying using EEPROM, 7-16
 - Valid ranges for CPUs, 10-2
 - Values
 - data block, 3-33
 - in text messages, 5-8
 - Variable memory area, addressing, 7-3
 - Variables, forcing, 3-35, 6-17
 - Vertical positioning, using DIN rail stops, 2-6
 - Vibration potential on installation, using DIN rail stops, 2-6

Viewing, program, 3-31

W

Watchdog Reset instruction, 10-85–10-87

Watchdog Timer instruction, considerations,
10-85

Windows 3.1

installing STEP 7-Micro/WIN, 3-2

troubleshooting the MPI communications
setup, 3-17

Windows 95, installing STEP 7-Micro/WIN, 3-2

Windows NT

installing hardware, 3-6

installing STEP 7-Micro/WIN, 3-2

troubleshooting the MPI communications
setup, 3-18

Wiring

guidelines, 2-8–2-13

AC installation, 2-10

DC installation, 2-11

North American installation, 2-12

inputs, High-Speed Counters, 10-26

optional field wiring connector, 2-10

removing modules, 2-7

suppression circuits, 2-13–2-14

Wiring diagram

CPU 212 24VAC/DC/Relay, A-11

CPU 212 AC/AC/AC, A-13, A-17

CPU 212 AC/DC/Relay, A-9

CPU 212 AC/Sourcing DC/Relay, A-15

CPU 212 DC/DC/DC, A-7

CPU 214 AC/AC/AC, A-25, A-29

CPU 214 AC/DC/Relay, A-23

CPU 214 AC/Sourcing DC/Relay, A-27

CPU 214 DC/DC/DC, A-21

CPU 215 AC/DC/Relay, A-35

CPU 215 DC/DC/DC, A-33

CPU 216 AC/DC/Relay, A-39

CPU 216 DC/DC/DC, A-37

EM221 Digital Input 8 x 120 VAC, A-41

EM221 Digital Input 8 x 24 VAC, A-43

EM221 Digital Input 8 x 24VDC, A-40

EM221 Digital Sourcing Input 8 x 24 VDC,
A-42

EM222 Digital Output 8 x 120/230 VAC,
A-47

EM222 Digital Output 8 x 24 VDC, A-44

EM222 Digital Output 8 x Relay, A-45

EM223 Digital Combination 16 x 24

VDC/16 x Relay, A-59

EM223 Digital Combination 4 x 120 VAC/4

x 120 to 230 VAC, A-55

EM223 Digital Combination 4 x 24 VDC/4

x 24 VDC, A-49

EM223 Digital Combination 4 x 24 VDC/4

x Relay, A-54

EM223 Digital Combination 4 x 24 VDC/8

x Relay, A-57

EM231 Analog Input AI 3 x 12 Bits, A-60

EM235 Analog Combination AI 3/AQ 1 x
12 Bits, A-70

Wizard, TD 200, 5-3

international and special characters, 5-9

Word, and integer range, 7-3

Word access, 7-2

CPU 212/214/215/216, 10-3

using pointer, 7-10

Word consistency, 9-20

Write control, D-6

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