

# Selection Guide to Clamp-On Current Probes

Current Measurements

## INTRODUCTION

Clamp-on current probes are designed to extend the current measuring capabilities of DMMs, power instruments, oscilloscopes, hand-held scopes, recorders or loggers, and other diverse instruments. The probe is "clamped" around the current carrying conductor to perform non contact current measurements and without interrupting the circuit under test. The Probe outputs current or voltage signal directly proportional to the measured current, thereby providing current measuring and displaying capabilities to instruments with low current or voltage inputs.

When making a measurement, the current carrying conductor is not broken and remains electrically isolated from the meter input terminals. As a result, the meter's low input terminal may be either floated or grounded. It is not necessary to interrupt the power supply when using a clamp-on current probe for taking measurements, so costly down time can be eliminated.

True RMS measurements within the probe frequency response are possible by using most AEMC current probes with a true RMS Multimeter. In most cases, RMS measurements are not limited by the probes, but by the instrument to which they are connected. Best results are provided by probes offering inherent high accuracy, good frequency response, and minimal phase shift.

AEMC offers the widest selection of current probes available to measure AC or DC current. Several AEMC probes are patented for their unique circuitry and design.

## AC CLAMP-ON CURRENT PROBES

### Theory of Operation

An AC clamp-on current probe may be viewed as a variance of a simple current transformer.

A transformer (Figure 1) is essentially two coils wound on a common iron core. A current  $I_1$  is applied through the coil

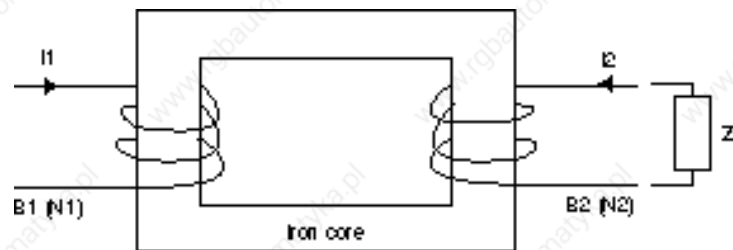


Figure 1

$C1$ , inducing through the common core a current  $I_2$  in the coil  $C2$ . The number of turns of each coil and the current are related by  $N_1 \times I_1 = N_2 \times I_2$ , where  $N_1$  and  $N_2$  are the number of turns in each coil. From this relationship:

$$I_2 = N_1 / N_2 \times I_1 \text{ or } I_1 = N_2 / N_1 \times I_2$$

This same principle is applied to a clamp-on current probe (Figure 2). The articulated magnetic core holds the coil  $B_2$  and clamps onto a conductor where the current  $I_1$  is flowing.  $B_1$  is simply the conductor where the user is measuring the current with the number of turns  $N_1$

equal to one. The current probe clamped around the conductor provides an output proportional to the number of turns in its coil  $B_2$ , such that:

$$I_2 \text{ (probe output)} = N_1 / N_2 \times I_1 \text{ where } N_1 = 1 \text{ or Probe output} = I_1 / N_2 \text{ (Number of turns in the probe coil)}$$

It is often difficult to measure  $I_1$  directly because of currents which are too high to be fed directly into a meter or simply because breaking into the circuit is not possible. To provide a manageable output level multiple turns are set into the probe coil bobbin.

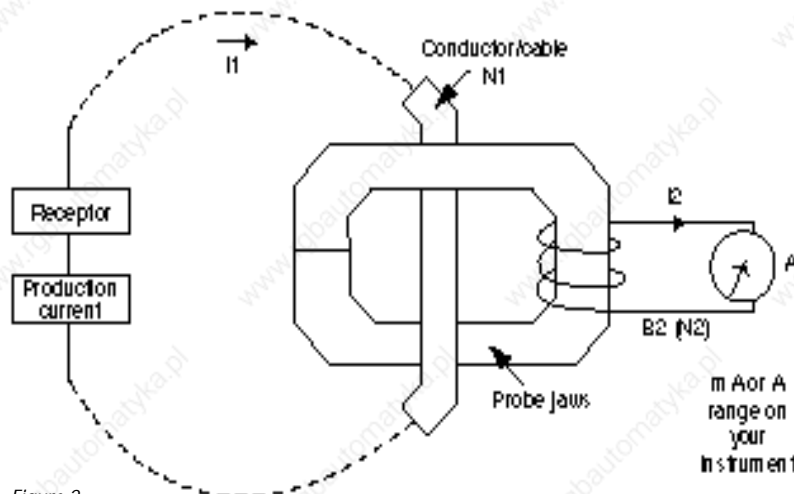


Figure 2

The number of turns in the clamp-on coil are generally simple multiples (e.g. 100, 500 or 1000). If  $N_2$  equals 1000, then the clamp has a ratio of  $N_1/N_2$  or  $1/1000$ , which is expressed as 1000:1. Another way to express this ratio is to say that the probe output is  $1\text{mA}/\text{A}$  - the probe output is 1mA (I<sub>2</sub>) for 1A (or 1A @ 1000A) flowing in the jaw window.

There are numerous other ratios possible: 500:5, 2000:2, 3000:1, 3000:5, etc. for different applications.

The most common application is the use of a current probe with a digital multimeter. Take as an example a current probe with a ratio of 1000:1 (Model SD601A) with an output of  $1\text{mA}/\text{A}$ . This ratio means that any current flowing through the probe jaws will result in a current flowing at the output:

Conductor	Probe Output (1000 times less or 1mA/A)
1000 A	1000 mA (1 A)
750 A	750 mA
250 A	250 mA
10 A	10 mA

The probe output is connected to a DMM set on the AC current range to handle the probe output. Then, to determine the current in the conductor, multiply the reading of the DMM by the ratio (e.g., 150 mA read on the 200 mA DMM range represents  $150\text{ mA} \times 1000 = 150\text{ A}$  in the conductor measured).

Current probes may be used with other instruments with current ranges, provided that these instruments have the required input impedance (see Figure 3).

Current probes may also have AC or DC voltage outputs to accommodate current measurements with instruments (loggers, scopes, etc.) with voltage ranges only (Figures 4 and 5). This is simply done by conditioning the current probe output inside the probe to provide voltage (e.g., Model MD301 or MN103). In these cases, the probe mV output is proportional to the measured current (e.g.,  $1\text{ mV AC}/\text{A AC}$ ).

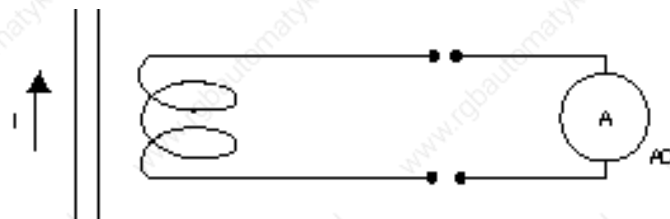


Figure 3

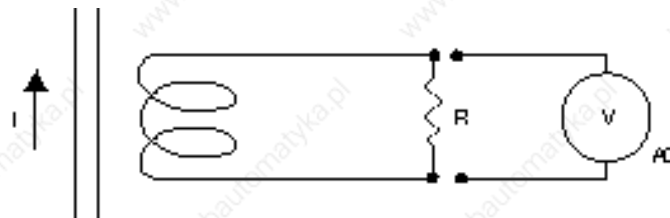


Figure 4

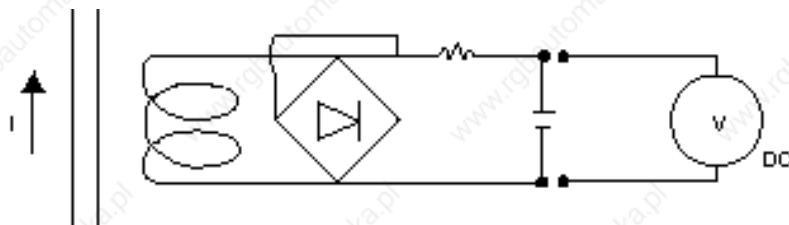


Figure 5

**AC/DC CLAMP-ON CURRENT PROBES**

Theory of Operation (Hall effect)

Differing from traditional AC transformers, AC/DC current sensing is often achieved by measuring the strength of a magnetic field created by a current-carrying conductor in a semi-

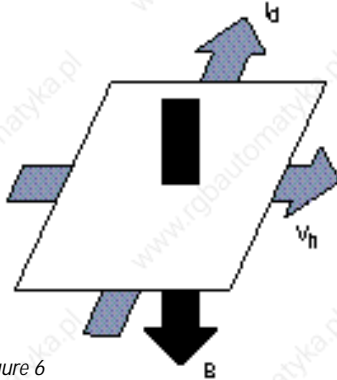


Figure 6

conductor chip using the Hall effect principle.

When a thin semiconductor (Figure 6) is placed at right angles to a magnetic field (B), and a current ( $I_d$ ) is applied to it, a voltage ( $V_h$ ) is developed across the semiconductor. This voltage is known as the Hall voltage, named after the US scientist Edwin Hall who first reported the phenomenon.

When the Hall device drive current ( $I_d$ ) is held constant, the magnetic field (B) is directly proportional to the current in a conductor. Thus, the Hall output voltage ( $V_h$ ) is representative of that current. Such an arrangement has two important benefits for universal current measurement.

First, since the Hall voltage is not dependent on a reversing magnetic field, but only on its strength, the device can be used for DC measurement. Second, when the magnetic field strength varies due to varying current flow in the conductor, response to change is instantaneous. Thus, complex AC wave forms may be detected and measured with high accuracy and low phase shift.

The basic construction of a probe jaw assembly is shown in Figure 7, (Note:

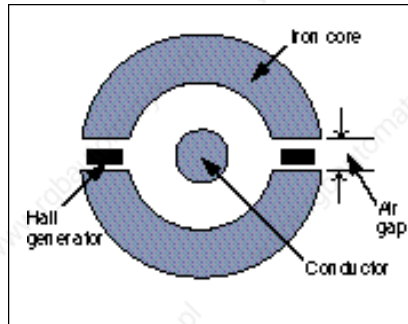


Figure 7

one or two Hall generators are used depending on the type of current probe).

The many AEMC AC/DC Current Probes were developed based on the above principle, together with patented electronic circuitry incorporating signal conditioning for linear output and a temperature compensation network. These have a wide dynamic range and frequency response with highly accurate linear output, for application in all areas of current measurement up to 1500 A. Direct currents can be measured without the need of expensive, power consuming shunts, and alternating currents up to several kHz can be measured with fidelity to respond to the requirements of complex signals and RMS measurements.

The probe outputs are in mV (mV DC when measuring DC, and mV AC when measuring AC) and may be connected to most instruments with a voltage input, such as DMMs, loggers, oscilloscopes, hand held scopes, recorders, etc.

AEMC also offers different technologies for DC measurements such as in the K100 and K110 designed to measure very low DC currents and using saturated magnetic technology.

AC/DC probes also offer the opportunity to display or measure True RMS in AC or AC+DC.

**AC OR DC CURRENT MEASUREMENT**

- Connect the probe to the instrument.
- Select the function and range.
- Clamp the probe around a single conductor.
- Read the conductor's current value.

Example (Figure 8):

**AC:** Probe Model: MD302

Ratio: 1000:1

Output: 1 mA AC/ A AC.

DMM: Set to 200 mA AC range

DMM Reading: 125 mA AC

Current in Conductor: 125 mA x 1000 = 125 A AC

**DC:** Probe Model: MR521

1mV DC/ A DC (Hall sensor)

DMM: Set to 200 mV DC range

DMM Reading: 160 mV DC

Current in Conductor: 160 A DC

**AC:** Probe Model: MR411

Output: 1 mV AC/ A AC (Hall sensor)

DMM: Set to 200 mV AC range

DMM Reading: 120 mV AC

Current in Conductor: 120 A AC

**DC:** Micro probe K100

Output: 1 mV mA

DMM: Set to 200 mV DC range

DMM Reading: 7.4 mV DC

Current in Conductor: 7.4 mA DC

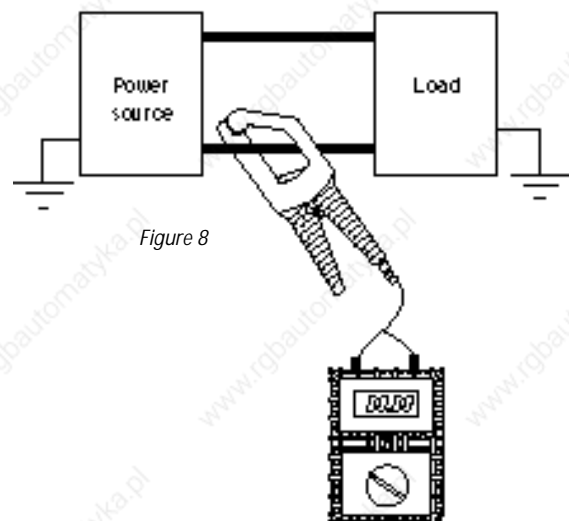


Figure 8

### LOW CURRENT, PROCESS LOOPS, LEAKAGE AND DIFFERENTIAL MEASUREMENTS

Numerous probes are offered for low current measurements. For example, the Models K100 and K110 have a 50 mA DC sensitivity and the Model k110 may be used on 4-20 mA process loops. The selection guide has a special section on low current probes.

Examples (Figure 9):

**4-20 mA loop: Probe Model K110**  
**Output: 10mV/ mA**  
**DMM: Set to 200 mV DC range**  
**DMM reading: 135 mV DC**  
**Loop Current: 13.5 mA DC**

When the current to be measured is too low for the probe or better accuracy is required, it is possible to insert the conductor multiple times through the probe jaws. The value of the current is the ratio of the reading to the number of turns.

**Probe Model: SD601A**  
**Ratio: 1000:1**  
**DMM: Set to 200 mA AC range**  
**Turns in Probe Jaw: 10**  
**DMM Reading: 60 mA AC**  
**Current in Conductor:**  
 $60 \text{ mA} \times 1000 / 10 = 6000 \text{ mA} = 6 \text{ A}$

When the probe is clamped around two conductors with different polarities, the resulting reading will be the difference between the two currents. If the currents are the same, the reading will be zero (Figure 10). When a reading other than zero is obtained, the reading is the amount of leakage current on the load (see Model 2610 on page xx). To measure low currents or leakage, you need a clamp-on which will measure low values, such as the Model 2610. Leakage current on grounds also may be measured directly with the Model MN103 (Figure 11).

Example:

**Differential: Probe Model: 2610**  
**Ratio: 1 mV AC/ mA AC**  
**Meter Reading: 30 mV AC**  
**Leakage: 30 mA AC**

**Leakage: Probe Model: MN103**  
**Ratio: 1 mV AC/ mA AC**  
**DMM: Set to 200 mV AC range**  
**DMM Reading: 10 mV AC**  
**Leakage Current: 10 mA AC**

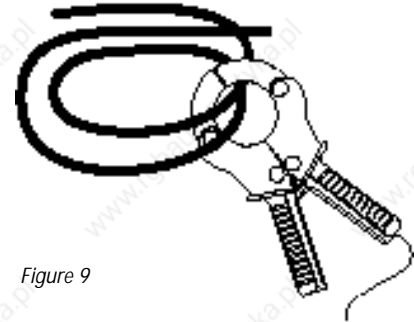


Figure 9

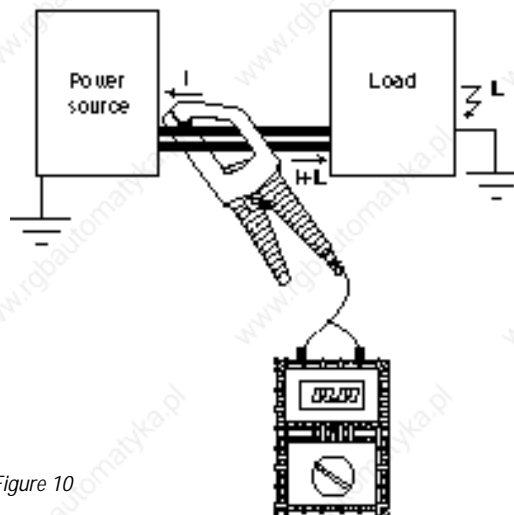


Figure 10

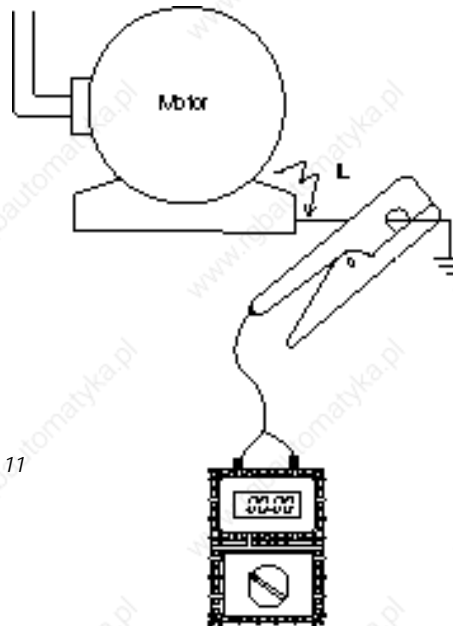


Figure 11

# Selecting the Correct Clamp-On Current Probes

Current Measurements

## SELECTING A CURRENT PROBE

A selection chart for all of the AEMC® Instruments current probes can be found at the front of this catalog. We recommend you use the chart as a reference, then consult the more detailed catalog pages.

Answering the following questions will help you to select the appropriate probe for your applications.

1. Determine if you are measuring AC or DC (DC current probes are categorized as AC/ DC because they measure both).
2. What is the the maximum current you will measure, and what is the minimum current you will measure? Check that the accuracy at low levels is appropriate, or select a low current measurement probe. Most probes perform with greater accuracy at the upper end of their range. Several probes are designed to measure very low DC or AC.
3. What size conductor will you clamp onto? This parameter determines the probe jaw size needed.
4. What type of probe output do you need or can you work with (mA, mV, AC, DC, etc.)? Check the maximum receiver impedance to ensure that the probe will perform to specifications.

Other factors you may want to consider:

What is the working voltage of the conductor to be measured? AEMC probes must not be used above 600 volts (see specifications)!

What type of termination do you need: jacks, leads or BNC?

Will the probe be used for harmonics or power measurements? Look at the frequency specifications and phase shift specifications.

Lastly, if you cannot find information you need or would like assistance, call our applications engineers at (800) 343-1391 or Fax us at (617) 423-2952. We have designed many more probes than those shown in this catalog, and we manufacture in Dover, New Hampshire, USA. For your convenience, at the end of the catalogue is a "Fax Request" form. Fill it out and fax it to us for a prompt response.

# Glossary

## Current Measurements

### GLOSSARY OF TERMS

**Accuracy** — measurement accuracy of a probe expressed as a percent of reading and a constant.

*Example:* AC probe accuracy is  $1\% \pm 0.1$  A; if the meter reading is 100 A, the correct measurement is  $100\text{ A} \pm 1.1\text{ A}$ , or 98.9 A to 101.1 A. **Note:** The accuracy of your meter should be added to the probe accuracy for overall accuracy.

**Bandwidth** — range of frequencies within which performance, with respect to some characteristic, falls within specific limits.

**Common mode voltage** — voltage that, at a given location, appears equally and in phase from each signal conductor to ground.

**Crest factor** — ratio of crest (peak, maximum) value to root-mean-square (rms) value.

**Current range** — range of measurable currents. Measurements below the minimum are often possible, but with increased error.

**Dielectric test (withstand voltage)** — dielectric test voltage between magnetic core and output for one minute. This is not the working voltage — probe may not be used in circuits at this rating!

**Duty cycle** — the ratio for a given time interval, of the on-load duration to the total time.

**Fall time** — the time interval between the instants at which the magnitude of the pulse at the output terminals reaches specified upper and lower limits respectively when a semiconductor device is being switched from its conducting to its non-conducting state. **Note.** — The upper and lower limits are usually 90% and 10% respectively of the initial amplitude of the output pulse.

**Frequency range** — range of frequency of measurable currents.

**Hall effect** — the production in a conductor or in a semiconductor of an electric field strength proportional to the vector product of the current density and the magnetic flux density.

**Hall effect probe** — a Hall effect specifically designed for the measurement of magnetic flux density.

**Harmonic** — a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.

**Input impedance** — the impedance of the input circuit looking into the device, measured between the input terminals of the device under operating conditions.

**Load impedance** — input impedance of meter connected to the current probe. Refer to your meter specifications.

**Noise** — unwanted electrical signals that produce undesirable effects in the circuits of the control systems in which they occur.

**Open secondary voltage** — voltage at output when a probe is clamped on a conductor and the meter (load) is not connected to the probe. **DANGER - Note:** Do not clamp a current probe without a load connected to it. High voltage may be present!

**Output signal** — current probe output signal proportional to measured current.

**Overload** — loading in excess of normal rating of the current probe.

**Phase shift** — phase angle shift between current measured and the probe output.

**Rise time** — time required for the output of a system (other than first-order) to make the change from a small specified percentage (often 5 or 10) of the steady-state increment to a large specified per-

centage (often 90 or 95), either before overshoot or in the absence of overshoot.

**Transformation ratio** — ratio between the current measured and the current output of the probe (refer to page 2 for details). Typical ratios are 1000:1, 2000:2, 3000:5, etc. This means that for a ratio of 1000:1 and a current of 500 A measured, the probe output will be  $500\text{ A} \times 1/1000$ , or 500 mA.

**Working voltage** — maximum voltage rating of the conductor being measured.