Fluke Education Partnership Program

# Why true-rms?

## Non-linear loads need a true-rms current clamp for accurate readings

Application Note


**Figure 1.** One current—two readings. Which do you trust? The branch circuit above feeds a non-linear load with distorted current. The true-rms clamp on the right reads correctly but the average responding clamp reads low by 32 percent.

## Introduction

Troubleshooting the electrical service feeding adjustable speed motor loads can be difficult if you don't have the right tools. New solid state motor drives and heating controls often conduct non-sinusoidal (distorted) current. In other words, the current occurs in short pulses rather than the smooth sine wave drawn by a standard induction motor. The current wave shape can have a drastic effect on a current clamp reading.

Basically, there are two types of current clamps commonly available: "average responding" and "true-rms." The average responding units are widely used and are usually lower cost. They give correct readings for linear loads such as standard induction motors, resistance heaters, and incandescent lights. But when loads are non-linear, containing semiconductors, the average responding meters typically read low. Worst case non-linear loads include small adjustable speed drives (5 hp or less) connected line to line across two phases of a 480 V, three-phase system, solid state heater controls connected single phase to 240 V, or computers connected to 120 V. When troubleshooting a branch circuit that suffers from circuit breaker tripping (or fuse blowing), the cause of the trouble can usually be separated into one of three categories:

1. Too much current.
2. Too much heat in the electrical enclosure.
3. Faulty circuit breaker (or fuse).

Your first instinct will probably be to measure the current with a current clamp while the load is on. If the current is within the circuit rating, you may be tempted to replace the circuit breaker.

**Figure 2.** A computer load.

**Non-linear loads that cause measurement errors.**

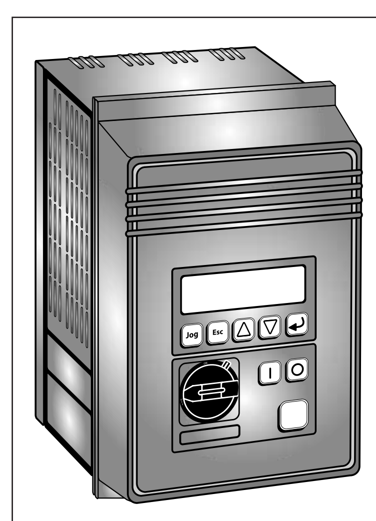


**Figure 3.** An adjustable speed motor load.

# What is true-rms?

"RMS" stands for root-mean-square. It comes from a mathematical formula that calculates the "effective" value (or heating value) of any ac wave shape. In electrical terms, the ac rms value is equivalent to the dc heating value of a particular waveform—voltage or current. For example, if a resistive heating element in an electric furnace is rated at 15 kW of heat at 240 V ac rms, then we would get the same amount of heat if we applied 240 V of dc instead of ac.

Electrical power system components such as fuses, bus bars, conductors, and thermal elements of circuit breakers are rated in rms current because their main limitation has to do with heat dissipation. If we want to check an electrical circuit for overloading, we need to measure the rms current and compare the measured value to the rated value for the component in question.

If a current clamp is labeled and specified to respond to the true-rms value of current, it means that the clamp's internal circuit calculates the heating value according to the rms formula. This method will give the correct heating value regardless of the current wave shape.

Certain low-cost current clamps which don't have true-rms circuitry use a short cut method to find the rms value. These meters are specified to be "average responding-rms indicating." These meters capture the rectified average of an ac waveform and scale the number by 1.1 to calculate the rms value. In other words, the value they display is not a true value, but rather is a calculated value based on an assumption about the wave shape. The average responding method works for pure sine waves but can lead to large reading errors up to 40 percent, when a waveform is distorted by non-linear loads such as adjustable speed drives or computers. The table below gives some examples of the way the two different types of meters respond to different wave shapes.

Current clamps come in two physical styles. The most common type is the integral clamp which has the jaws, readout, and measuring circuit built into a stand alone unit. Examples include Fluke Models 335, 336, and 337. Look for the words true-rms on the front panel.

The second style consists of a current transformer (CT)-type accessory which works with a digital multimeter. Examples include Fluke Models i200s, 80i-400, and 80i-600A. The jaws of the clamp enclose the conductor being measured which acts as a transformer primary of one turn. The secondary coil has 1,000 turns which divides the measured current by 1,000; i.e., the measured current is converted from amps to milliamps. When the clamp's output leads are plugged into the DMM's ac milliamp jacks, the display decimal reads correctly for amps in the jaws.

Before you do that, make two other observations: First, analyze the load. If the load contains power semiconductors, rectifiers, SCRs, etc., be suspicious of the current clamp reading. Second, look at the front panel of your current clamp—does it say true-rms? If you can't find the words true-rms on the front panel, then you probably have an average responding current clamp. *(See Figure 4.)*

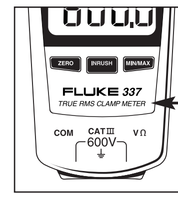


Figure 4. The true-rms clamp is labeled on the front panel.

If you are trying to measure current drawn by a non-linear load containing semiconductors, without a true-rms meter, you are likely to make the wrong conclusion; that the problem is a faulty circuit breaker. Replacing the breaker won't help. You'll get a call-back with some unpleasant words from your customer. To avoid this, read the sidebar about true-rms, find your local Fluke distributor and get yourself a true-rms current clamp or meter that will give correct readings regardless of the type of load or current wave shape. If your reputation depends on accurate current readings then it won't take you long to decide that a true-rms multimeter or current clamp is the only reasonable choice.

| **Multimeter type** | **Response to sine wave** | **Response to square wave** | **Response to single phase diode rectifier** | **Response to 3 ∅ diode rectifier** |
|---|---|---|---|---|
| Average responding | Correct | 10 % high | 40 % low | 5-30 % low |
| True-rms | Correct | Correct | Correct | Correct |

**Figure 5.** A comparison of average responding and true-rms units

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