# Three-Phase Power Measurements

**TECHNICAL BRIEF**

## Using a Four-Channel Scope to Measure Three-Phase Power

*January 24, 2013*


## Summary

*The two-wattmeter method for measuring power in three-phase circuits can be implemented using a four-channel oscilloscope.*


## Introduction

The power dissipated in a three-wire, three-phase load can be determined using a Teledyne LeCroy four-channel oscilloscope by measuring two phase currents and two line voltages. For example, looking at the schematic in figure 1, the total power dissipated in a three-phase motor can be determined by measuring Vac, Vbc, Ia and Ib.

$$P_T\ (t) = V_{ac}(t)\ i_a(t) + V_{bc}(t)\ i_b(t)$$

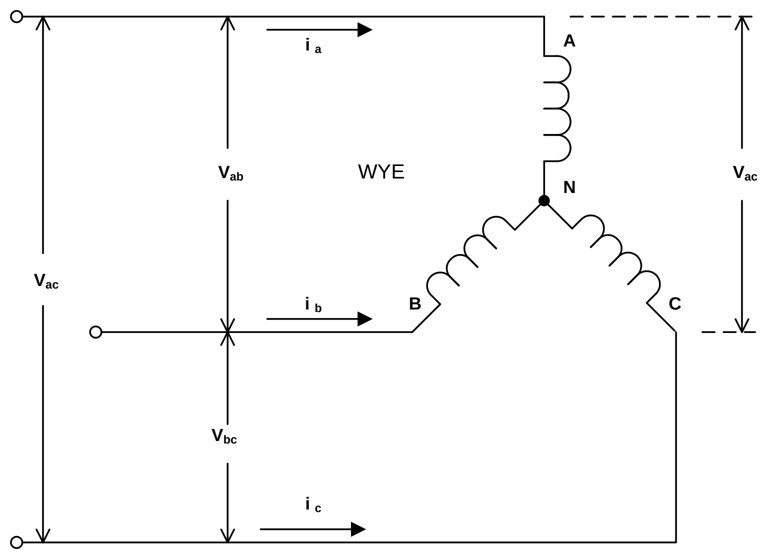


***Figure 1: The power dissipation of a three-wire, three-phase load (motor) can be measured using two current and two voltage waveforms***

This can be verified using the following mathematical derivation:

$$P_T = \mathbf{V_{an}(t)\ i_a(t)} + \mathbf{V_{cn}(t)\ i_c(t)} + \mathbf{V_{bn}(t)\ i_b(t)}$$

but, using Kirchoff's current law: $i_a+i_b+i_c = 0$ or $+i_c = -\ i_a - i_b$

$$P_T(t) = \mathbf{V_{an}(t)\ i_a(t)} - \mathbf{V_{cn}(t)\ i_a(t)} - \mathbf{V_{cn}(t)\ i_b(t)} + \mathbf{V_b n(t)\ \ i_b(t)}$$

$$P_T\ (t) = \mathbf{V_{ac}(t)\ i_a(t)} + \mathbf{V_{bc}(t)\ i_b(t)}$$

The line voltages, $V_{ac}(t)$ and $V_{bc}(t)$ are measured using differential probes. The phase currents, $i_a$ and $i_b$, are measured using current probes. This requires an oscilloscope with four input channels.

Each product term for the total instantaneous power is computed using waveform math. The average power can be determined by using the measurement parameter, mean, to take the average value of each product term. The sum of the mean parameters, computed using parameter math, is the total, average power dissipated by the three-phase motor. Note that this works only for a three-wire connection. The neutral or center tap (CT) can be connected as long as no current flows through that connection.

Figure 2 shows a power measurement for a three-phase motor. The motor was in a Delta configuration. The top-left trace, F1, is the phase current, $\mathbf{i_a(t)}$. The next trace down (left center), Trace F4, is the line-to-line voltage, $\mathbf{v_{ac}(t)}$. Trace F2 (upper right) is the phase current, $\mathbf{i_b(t)}$. Trace F4 (right center) is the line voltage, $\mathbf{v_{bc}(t)}$.

The product terms are calculated in math traces F7 and F8. These traces represent the instantaneous line power. Note that the measurement parameter, mean, computes the average value of the source waveform. In this example the average power of traces F7, and F8 is being read using the parameter in P1 and P2, which appear below the waveform display. The total power, the sum of the mean power in P1 and P2 computed using parameter math in parameter P3, was measured as 851.4 Watts.

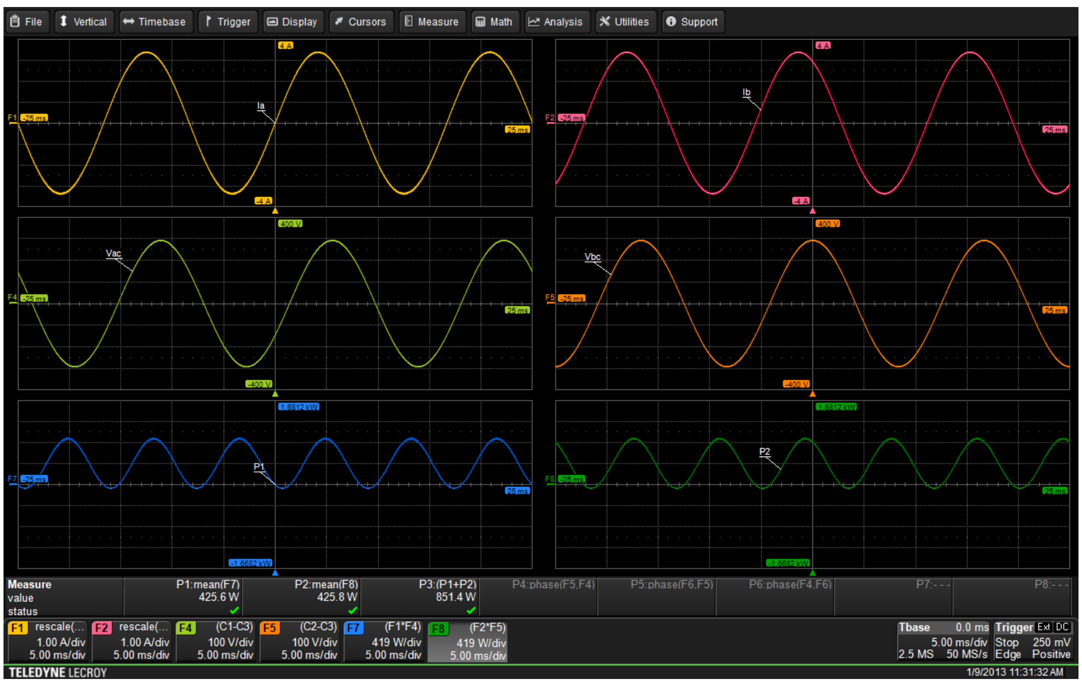


***Figure 2: Computing the total power drawn by a three-phase motor using two line-to-line voltages and two phase currents***

The measurement was confirmed by measuring the individual phase voltages and currents, as described in the second equation presented on page 1:

$$P_T = \mathbf{V_{an}(t)\, i_a(t)} + \mathbf{V_{cn}(t)\, i_c(t)} + \mathbf{V_{bn}(t)\, i_b(t)}$$

These measurements were made individually with the motor running under identical conditions. The total power using this technique was measured 851 Watts.