

Measuring Power Using the DL750

While a commercial power meter offers convenience and accuracy, and is the best approach to making power measurements, an oscilloscope with advanced mathematical calculation features offers an alternative method. Such an oscilloscope is the Yokogawa DL-750. While a commercial power meter is the very best way to measure power, there are instances where this equipment is unavailable, or that an accurate approximation of power consumption will suffice.

The following methodology is the same method used in the commercial power analyzers and with some caution; the DL750 can be used to calculate power with impressive accuracy. The results in the example below are comparable to those measured using a Yokogawa WT230.

The DL750 is a digital sampling oscilloscope, collecting many points of data. In the general sense these are voltage points which can represent any real world measurement, given the right sensor or probe. Used correctly, the DL750 becomes a powerful ally in custom RMS and power measurements. The method for calculating any root mean square or RMS value uses the following expression:



The RMS for a discrete collection of n values $\{x_1, x_2, x_3, \dots, x_n\}$ is:

$$X_{rms} = \sqrt{\left(\frac{1}{n}\right) \sum_1^n x_i^2}$$

Assuming that enough samples are collected, a plot of these points begins to approximate a continuous function $f(t)$, which we will examine over an interval $T_1 \leq t \leq T_2$. and the equation for RMS is now defined for a continuous waveform by:

$$F_{rms} = \sqrt{\left(\frac{1}{(T_2 - T_1)} \cdot \int_{T_1}^{T_2} [f(t)]^2 dt\right)}$$

The Yokogawa DL750 User Defined Math option makes evaluation of such an equation very easy. Calculations of power consumption always use RMS measurements, specifically, the following three expressions are applied to voltage and current measurements:

Instantaneous Power = $v(t) \cdot i(t)$

Apparent Power = $V_{rms} \cdot I_{rms}$, with units of Volt-Amps

Average Power = , sometimes called 'Real Power' with units of Watts and

Power Factor = (Average Power/Apparent Power), as defined by the IEEE, and is unit-less.

Application Note

An everyday example of power measurement is that of *line power measurement*. Often, it is necessary to measure Average Power, Apparent Power, and Power Factor. The following example illustrates the specific steps needed in order to measure and display current and voltage waveforms, calculate Real and *Apparent* power.

The following example, which calculates the power consumed by a linear power supply based on measured waveforms - the voltage and current waveforms are seen in in Figure 1. This is from a DL750 screenshot. Notice that the Time/Div is 10 ms, and displays exactly 6 cycles of the 60 Hertz waveform.

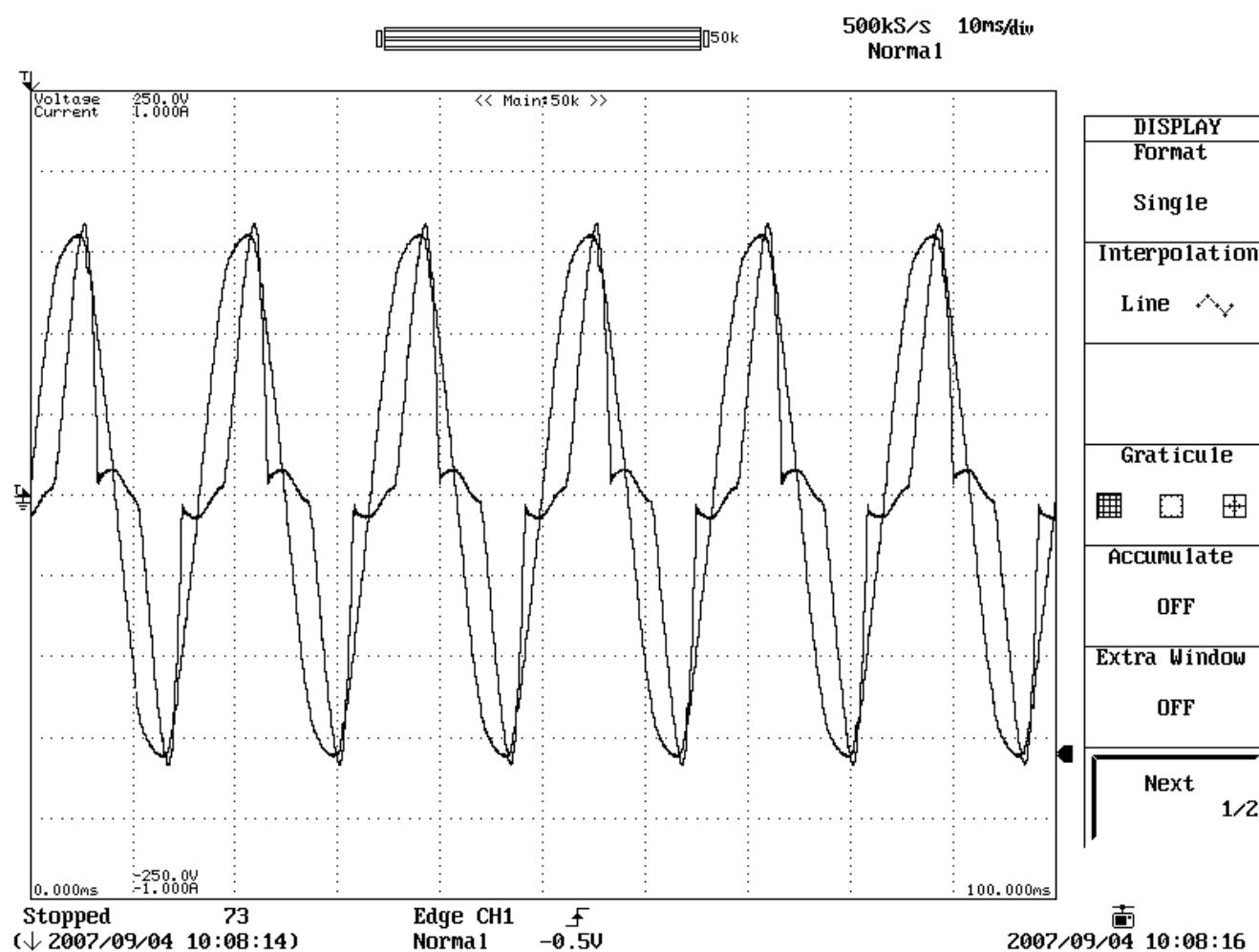


Figure 1 Voltage and Current illustrating distorted current waveform

Application Note

In Figure 2, the same waveforms are visible with the Time/Div later adjusted to 100ms/div in order to display exactly 60 cycles of a 60 Hertz waveform. This was chosen as a matter of convenience – and the calculations defined below are carried-out upon these 60 cycles. However, any convenient number of cycles may be chosen and the results multiplied

appropriately to achieve a result that calculates power over one second total time (since, Power = Joules/Sec). The sampling rate should be adjusted as appropriate, and in this example, it is 50 kS/s, which is sufficient for these types of waveforms. Any signal with a fast rise time, for example, will require a higher sample rate.

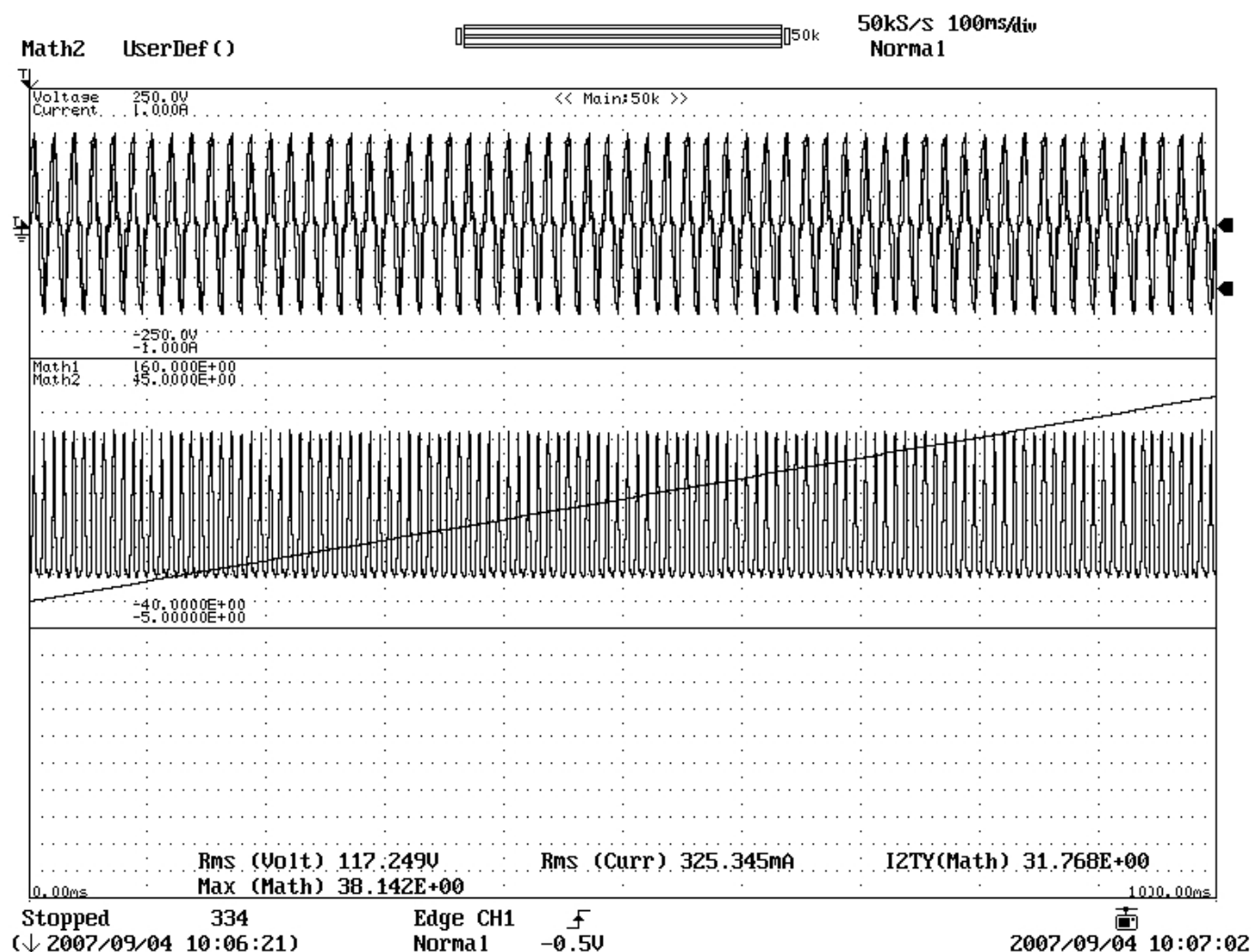


Figure 2 Voltage, Current, Instantaneous Power, and Integral Waveforms

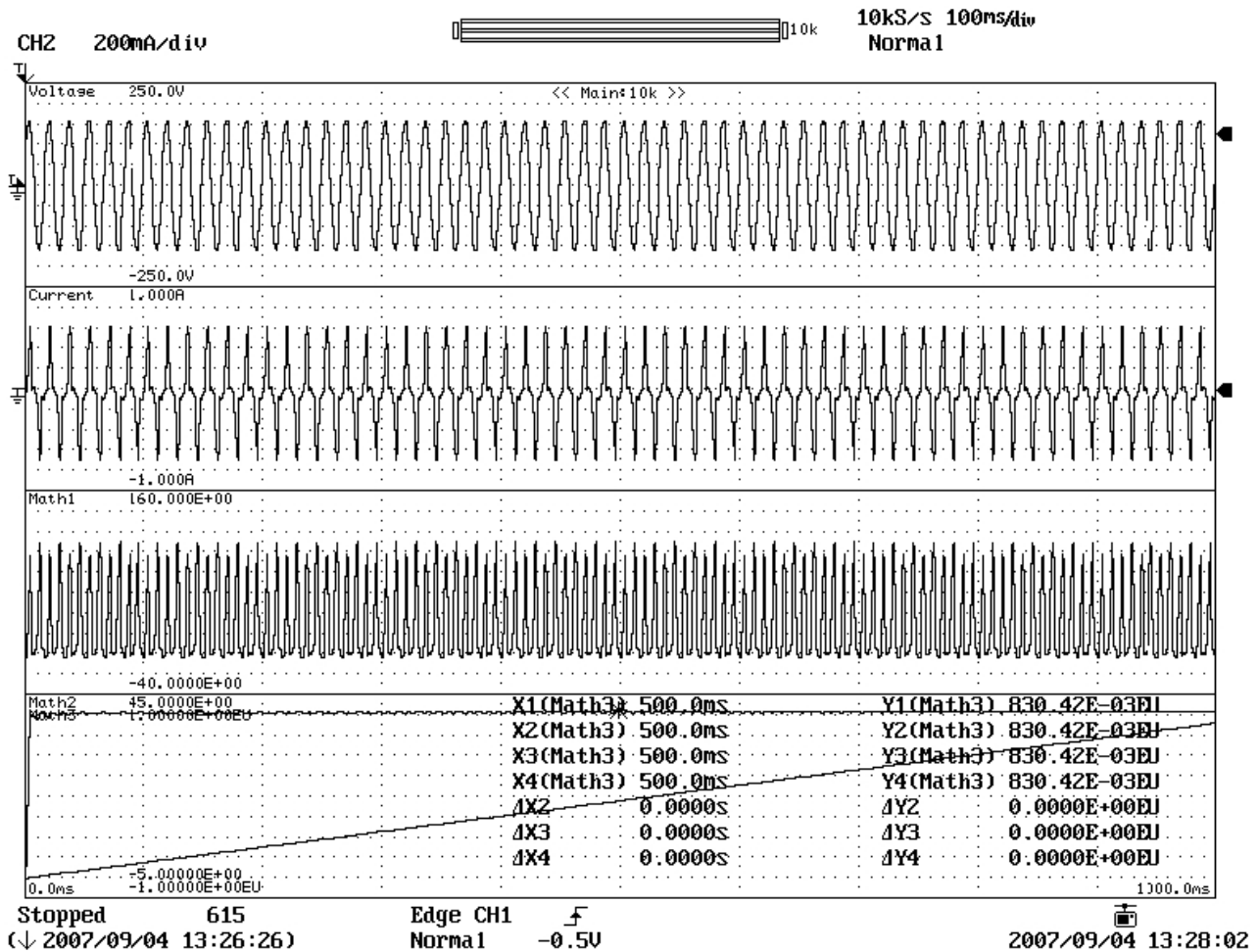


Figure 3 Power Factor

The DL750 User-Defined Math was set-up using the following Equations:

Math1=C1*C2, representing Voltage*Current, or *instantaneous power*, and can be seen as the 120 Hz. Waveform in the center of the D750 display in Figure 2.

Math2=SQRT(INTG(C1*C1)*SQRT(INTG(C2*C2))), which is the mathematical product of Vrms and Irms, and can be seen as the diagonal line in the center of the DL750 display in Figure 2.

In this calculation, T1=0 sec., and T2=1 sec. This is simply the Frms equation illustrated above into the DL750 User-Defined Math.

Math3=INTG(M1)/(SQRT(INTG(C1*C1)*SQRT(INTG(C2*C2))), is the ratio of Real Power to pparent Power, and this is the IEEE defintion of Power Factor, and thus calculates Power Factor. Place a MARKER from the CURSOR menu on this to read the value at a valid point (POSITION=0)

In the MEASURE menu, we take the following parametric measurements:

RMS(CH1) which is an RMS measurement of the Voltage waveform, and the result can be observed at the very bottom of the DL750 screen in Figure 2 as 'Rms (Volt)'.

RMS(CH2) which is an RMS measurement of the Current waveform, and the result can be observed at the very bottom of the DL750 screen in Figure 2 as 'Rms (Curr)'.

Int2TY(Math1) sums the Real power. This integral simply sums the *real power*, while subtracting out the *reactive power* from the *instantaneous power* equation. The result is REAL Power and can be observed at the very bottom of the DL750 screen in Figure 2 as 'I2TY (Math)'.

Max (Math2) is used to determine the arithmetic sum of the integral of *instantaneous power* over one second and thus the Apparent Power Volt-Amps. Each point in the equation (graphed as a diagonal line) is the sum of the Volt-Amps. The sum after one second is indicated by the very last point (to the far right of the DL750 screen in the middle of Figure 2.) Displayed as Max (Math)' in Figure 2.

In the CURSOR menu, we take the following parametric measurements:

Marker on Math3 at the midpoint.

Results:

The results of these measurements and calculations using the DL750, in this example, were found to be:

Apparent Power = 37.92 Volt-Amps

Average Power = 31.54 Watts

Power Factor = 0.83

These results agreed quite closely (within 2%) with a commercial power meter, the Yokogawa WT230:

Apparent Power = 38.51 VA

Average Power = 32.02

Power Factor = 0.83

Some tips, for good results when making power measurements:

- Zero current probes regularly and de-magnetize them before each use. This can be a frequent source of errors, contributing a false DC current to the current measurement. Particularly, Power Factor is sensitive to any error
- Use a sample rate that is appropriate for your waveform. Any wave form with high-frequency components (fast rise times) will need more samples.
- Use Auto-Scaling within the MATH menu and make sure that the waveforms do not "clip", introducing erroneous measurements.

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