Measuring High Voltage Signals With WinDaq Software

DATAQ Instruments

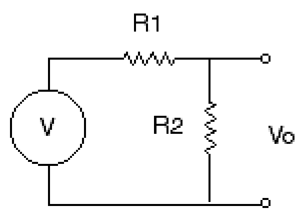
Voltage divider circuit and shunt resistor make high voltage data acquisition and analysis possible with WinDaq Software.

The WinDaq data acquisition system is being used in many environments to feed data from the real world into a computer for fast and accurate data recording, display, and analysis. This system is a proven, high-performance, versatile solution for many low voltage (+5 volts or lower) applications. But are you excluded from using this powerful tool if the application you wish to monitor generates a voltage signal beyond the +5 volt input measurement range of the data acquisition interface? Not if you are aware of a simple technique designers commonly use to reduce voltage signals called a voltage divider. By using a voltage divider circuit and the following guidelines, it is possible to measure a voltage signal greater than +5 volts with the WinDaq data acquisition system.

The Voltage Divider Principle

$$V_o = V\left(\frac{R2}{R1 + R2}\right)$$

By definition, the voltage divider principle states: In a series circuit, the ratio between any two voltage drops is the same as the ratio of the two resistances across which these voltage drops occur. This statement can be expressed as an algebraic equation by:



We can use the voltage divider principle to our advantage in measuring a signal greater than ±5 volts with the WinDaq data acquisition system. The following illustration depicts a simple voltage divider circuit, where V is the total applied voltage (or voltage signal to be divided) and Vo is the divided output voltage (or voltage signal to be connected to an WinDaq interface input). By selecting the proper ratio of resistors, the high voltage signal can be divided down to a level within the input measurement range of the data acquisition interface. However, one design constraint governs the value of R2. For interface module biasing purposes, the value selected for R2 must be less than 1 megohm.

A High Voltage Application

To illustrate the voltage divider concept, some data was acquired from an ordinary laser printer using the WinDaq data acquisition system and the Option 01 data acquisition interface module. The objective was to use the WinDaq data acquisition system to monitor the effective (rms) current drawn by the printer as it cycled through the printing process. To accomplish this, a shunt resistor of known value was connected to the laser printer as shown in Figure 1. The CODAS data acquisition system, since it is a voltage measuring device, would then be used to measure the voltage dropped across the shunt.

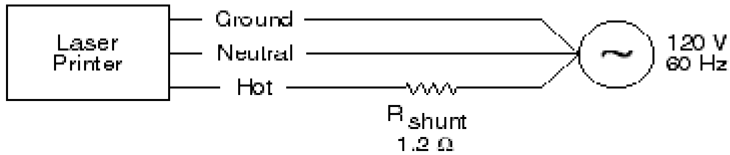


Figure 1. The circuit used to monitor rms current showing the location and value of the shunt resistor.

To measure shunt voltage, signal leads were positioned on both sides of the shunt resistor. This connection would enable us to measure 120 volts with respect to ground on one side of the shunt and 120 volts minus the voltage dropped across the shunt with respect to ground on the other side of the shunt. These voltages are obviously well beyond the input measurement range of the Option 01 interface, so a matched voltage divider was designed to divide each voltage signal down to a measurable level.

To aid in designing the matched divider, the expected voltage drop across the shunt resistor was calculated. Using Ohm's law and a current value of 6.6 amps obtained from the laser printer specifications, the voltage drop was calculated to be 7.92 volts. Knowing what the voltages would be on each side of the shunt, R2 was chosen to be 1 k ohm and R1 was calculated to be 99 k ohms to provide a precise "divide by" of 100 on each side of the shunt. The matched voltage divider was physically constructed using two ITT Pomona model 1837 isolation banana plugs. These plugs provided a perfect connection interface between the signal leads and the Option 01 interface. The divided voltages were then applied to the differentially configured Option 01 data acquisition interface. When in the differential operating mode, the Option 01 interface amplifier sees the difference in voltage between the positive (+) and negative (-) inputs, which is the voltage dropped across the shunt resistor. This voltage is ultimately displayed on the computer monitor as a waveform, courtesy of the WinDaq data acquisition system software. This waveform, which represents the voltage dropped across the shunt, is directly proportional to the current flowing through the shunt. Finally the displayed waveform was made meaningful by converting the waveform amplitude values (still in volts) to amperes using Ohm's law, the shunt resistance value, and a built-in WinDaq automatic scaling function. Figure 2 illustrates the entire circuit. With the waveform calibrated in amperes, a length of current waveform information representing normal printer operation was acquired and stored to disk.

Reviewing the Acquired Waveform

The acquired waveform revealed a couple of"surprises" during playback. The first was the general shape of the waveform. A clean sine wave that increased in amplitude as the current demand grew larger (e.g., the internal printer heater cycled on, or a page of text was printed) was expected. However, the resulting waveform did not meet this expectation. A very abnormal shape, vaguely sinusoidal, characterized the steady state waveform (Figure 3). The second revelation occurred when the internal heater cycled on. A sinusoidal waveform that would increase in amplitude (to indicate a larger current demand) then decrease back to steady state conditions after the heater duty cycle ended was expected. For reasons unknown, the resulting waveform did not meet this expectation. Figure 3 shows the very erratic shape of the waveform, where one waveform period or cycle is almost impossible to determine with the heater activated.

Deriving A Cycle-By-Cycle rms Level

Technically, the objective of measuring a voltage signal greater than +5 volts with the WinDaq data acquisition system was achieved. But with the waveform acquired to disk, an excellent opportunity to apply the powerful playback software and advanced CODAS analytical tools existed. These software tools would provide further analysis and interpretation of the waveform data. The shabby appearance of the waveform with its sporadic cycle prompted us to run a discrete Fourier transfer (DFT) on an arbitrarily selected number of waveform data points in order to verify that the fundamental frequency of the waveform was 60 Hz. The DFT procedure was performed by playback software and the resulting fundamental was found to be exactly 60 Hz.

If the acquired waveform had been a clean sine wave, the rms value could have been easily determined by multiplying its peak value by 0.707. But because of the irregular, noisy shape of the acquired waveform, this could not be done. The following general, textbook rms equation was substituted instead:

$$i_{rms} = \left(\frac{\int_0^T i(t)^2 \, dt}{T} \right)^{0.5}$$

where i(t) is the acquired current waveform with respect to time and T is the cycle time of i(t). From this formula, the rms current was derived by applying two Advanced CODAS utilities (the waveform arithmetic operation utility and the waveform integrator utility) in three passes.

The first step in deriving the rms current was to square the original acquired waveform. This was accomplished by simply passing the original waveform through the arithmetic operations utility. Next, the squared waveform was integrated with respect to time using the waveform integrator utility. The integrator utility was configured for a reset condition based on time, once every 16.667 milliseconds (the reciprocal of our validated 60 Hz frequency). The integral hold feature was also enabled to hold the previously integrated value on the display until the next value is calculated and displayed. This feature, when enabled, masks the reset transitions of the integrated waveform resulting in an uncluttered, step-like waveform. For complete information on the waveform integral utility, refer to DATAQ Instruments' Application Note number AN-9, A Closer Look at Waveform Integration with Advanced CODAS. A final pass through the arithmetic operations utility divided the integrated waveform by the cycle time and calculated the square root of that quotient all in one step. Figure 3 illustrates the final, derived rms waveform.

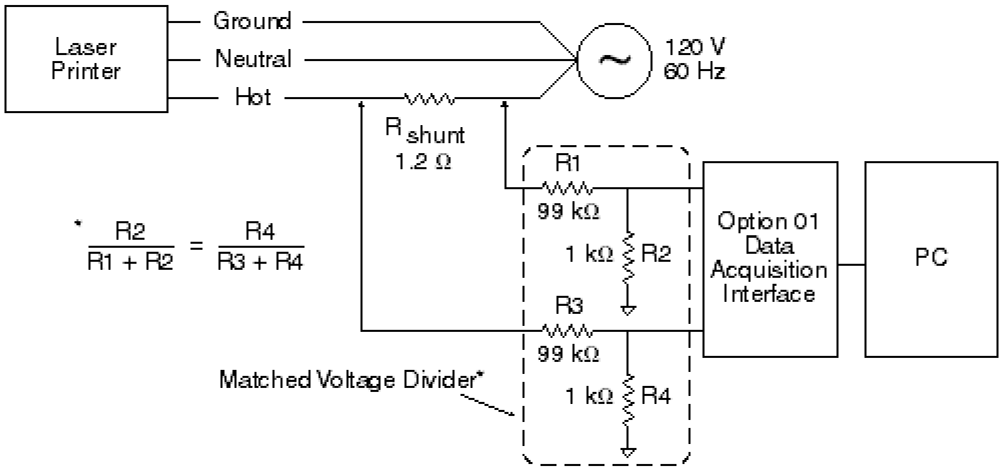


Figure 2. The circuit used to monitor rms current showing the configuration of the matched voltage divider.

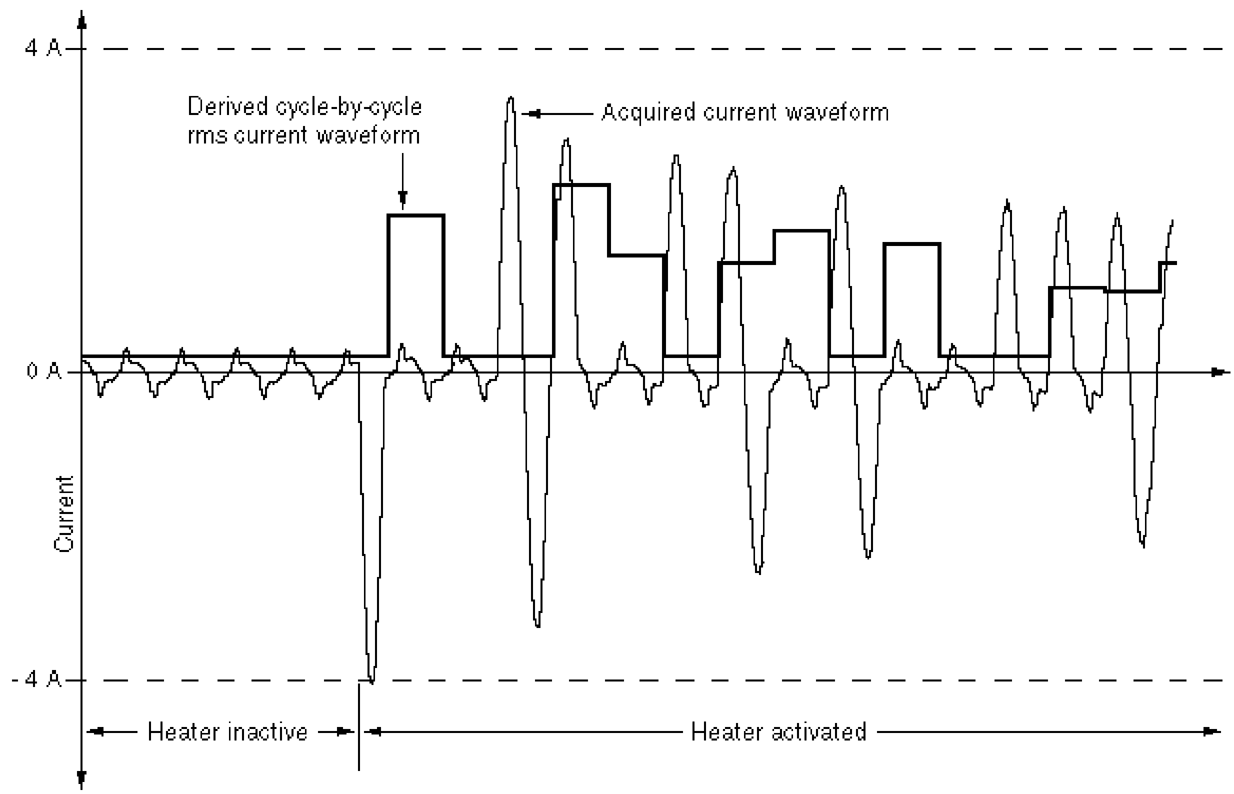


Figure 3. The original acquired current waveform and the derived cycle-by-cycle rms current waveform. Because the integral hold feature holds the last integrated value until the next value is calculated, the derived waveform is delayed from the acquired waveform by one cycle. Note the irregular shape of the original acquired waveform at steady state and after the heater activates. Note also that the waveforms are shown with an applied compression factor of 4 to condense the heater activity for presentation purposes.