Technical Information

Digital Multimeters

Digital multimeters convert analog signals to digital information. In general, DMMs have a minimum of five typical functions. They are DC voltage, AC voltage, DC current, AC current, and resistance. While specifications vary, most DMMs can be described with block diagrams similar to Figure 1 .

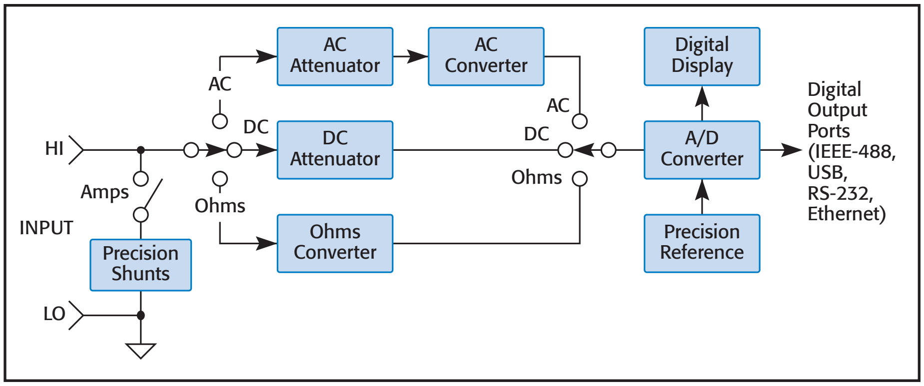

Figure 1: DMM Block Diagram

Analog to Digital Conversion

The A/D converts the analog input signal to a digital output and is primarily responsible for key instrument characteristics of reading speed, linearity, resolution, normal mode rejection, and precision. The digital output is shown or obtained in several ways. One way is visually, via the front panel with a display of digits and other information. Another way is electronically, with results sent via a port (GPIB, RS-232, USB, or Ethernet) to a computer for further processing.

Resolution

Resolution is defined as the smallest detectable change on any range referenced to full scale. For example, if an instrument displays a maximum of 19,999 on any range, and the smallest detectable change in the input signal is ±1 least significant digit (LSD), then the resolution is 1/19999 or 0.005%.

Resolution is commonly expressed as a whole number plus a fraction, e.g., 5½ digits. The whole number represents the number of digits that can display the numbers from 0 to 9. The fraction indicates that the most significant digit has one or more non-zero states, that is, it can display 0, 1, or 2.

Sensitivity

Sensitivity is similar to resolution in that it deals with the smallest change of the input signal the instrument can detect. However, sensitivity is not referenced to full scale, so it is expressed in absolute terms and applies to the lowest range on any function. The sensitivity of a 7½-digit DMM is 10nV if its lowest measurement range is 200mV.

Accuracy

Accuracy is specified as a two-term specification: ±(% of reading + % of range) or as (ppm of reading + ppm of range). The closer to zero on the range that the percent of range term of the specification is, the greater the weight it has in the accuracy calculation. The closer to full scale on the range the percent of reading term of the specification is, the greater the weight it has in the accuracy calculation. The best accuracy is obtained near full scale.

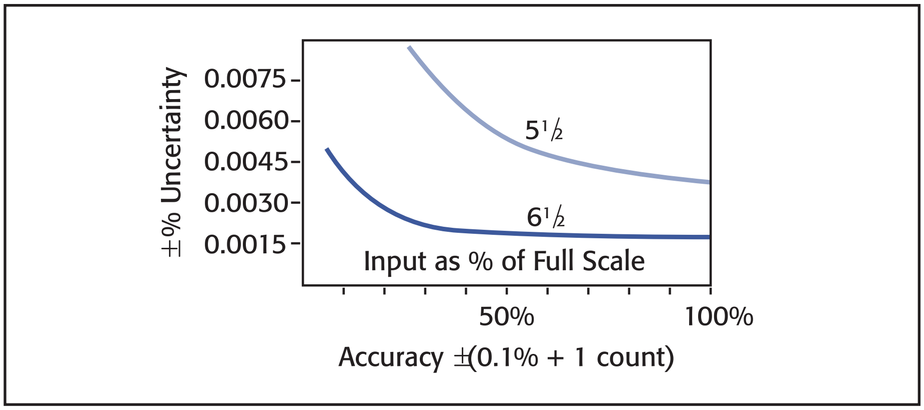

Figure 2: Expected Reading Uncertainty: 5½- vs. 6½-Digit DMMs

Accuracy is also generally stated under several conditions, including ±1°C, ±5°C operating temperature, and 24-hour, 90-day, and one-year calibration intervals. The expected accuracy can be improved by controlling temperature variations in the environment and by electing more frequent calibration intervals. Figure 2 illustrates the effect on accuracy at various levels of input signal within the measurement range. Accuracy for both meters is specified at ±(0.1% + 1 count).

Loading and Input Impedance

Loading is the disturbance to the circuit being measured caused by the finite input impedance of the DMM. Input impedance is the equivalent resistance and capacitance of the input terminals of the DMM.

Loading error (**Figure 3**) is the difference between the voltage measured by the meter (V_M) and the voltage of an ideal source (V_S).

Voltage burden error (**Figure 4**) is the difference between the expected current through the load (R_L) and the measured current (I_M) caused by the finite voltage drop of the measuring instrument.

Two-Wire vs. Four-Wire Ohms

Two-terminal DMMs source test current through the measuring test leads, terminating at the HI-LO inputs of the DMM. This two-wire ohms system works fine for most resistance measurement applications. However, the I-R drop in the test leads (R_L) can cause inaccuracies that become apparent in lower resistance measure ments (**Figure 5**).

Four-wire ohms or Kelvin measurements bypass the voltage drop across R_L by bringing two high impedance voltage sense leads out to the unknown R_X. There is very little current in the sense circuit because of the high input impedance, so there's effectively no I-R drop in the leads, and the voltage seen by the sense