4. APPLICATIONS

4.1 INTRODUCTION

This section describes some measurement techniques and considerations to help you use the DP 100 more effectively. It also tells you about the sources of error that are part of the measurement process so that you know how to correct for them.

4.2 PERFORMING BASIC MEASUREMENTS

The following information explains how to perform basic measurements using the front panel pushbuttons. Table 4-1 tells you which terminals to use for each type of measurement. After selecting a measurement function and connecting the test leads, the display annunciators will indicate the measurement function and units of measure. This information assumes that you are familiar with basic DP 100 operation. If not, review Section 2, PREPARING FOR OPERATION, and Section 3, FRONT PANEL OPERATION.

WARNING

DO NOT exceed the maximum inputs specified on the DP 100 front panel. Doing so could be hazardous to you and could damage the DP 100. It will also void the DP 100 warranty.

Table 4-1. Use of Input Terminals

Measurement	Terminals To Use	
Resistance, Voltage, or Frequency	HI / LO	V, Ω, F, T
Current	A / LO	V, Ω, F, T
Four-Terminal Resistance or Temperature	HI / LO HI / LO	V, Ω, F, T SENSE

4.2.1 Measuring Resistance, Voltage, or Frequency

To measure resistance, voltage, or frequency:

(1) Select the appropriate measurement function using the FUNCTION ▲ or ▼ pushbuttons.

(2) Connect the test leads to the appropriate input terminals (see Table 4-1) and the meter's AUTO range mode will select the appropriate range.

(3) To select a fixed range, use the RANGE ▲ or ▼ pushbuttons.

For more information, see Section 4.3, MEASURING DC VOLTAGE, Section 4.6, MEASURING RESISTANCE, and Section 4.8, MEASURING FREQUENCY.

Analogic can supply you with 1X probes for all measurements and 10X probes for frequency measurements only (see Appendix B, ACCESSORIES).

4.2.2 Measuring Current

To measure current:

(1) Select the current measurement function using the FUNCTION ▲ or ▼ pushbuttons.

(2) Connect the test leads to the current input terminal (A) and the LO V,Ω,F,T terminal. The meter's AUTO range mode will select the appropriate current range.

(3) To select a fixed range, use the RANGE ▲ or ▼ pushbuttons.

For more information, see Section 4.4, MEASURING DC CURRENT, and Section 4.5, MEASURING AC VOLTAGE AND CURRENT.

Analogic can supply you with ac/dc clamp-on current probes and 20 A current shunts (see Appendix B, ACCESSORIES).

4.2.3 Measuring Four-Terminal Resistance or Temperature

To measure four-terminal resistance or temperature:

(1) Select the appropriate measurement function using the FUNCTION ▲ or ▼ pushbuttons.

(2) Connect the test leads to the appropriate input terminals. If measuring resistance, the meter's AUTO range mode will select the appropriate range. To select a fixed resistance range, use the RANGE ▲ or ▼ pushbuttons.

(3) If measuring temperature, select °C or °F using the RANGE ▲ or ▼ pushbuttons.

For more information, see Section 4.6.2, Four-Terminal Resistance and Section 4.7, MEASURING TEMPERATURE.

Analogic can supply you with air temperature probes, surface temperature probes, and general purpose/immersion temperature probes (see Appendix B, ACCESSORIES).

4.3 MEASURING DC VOLTAGE

Making precise measurements requires understanding sources of error in the measuring circuit and the measurement environment.

4.3.1 Sources of Measurement Errors

When measuring voltages at or below the 2-volt range, the input looks directly into the high input impedance of the input amplifier (>10 GΩ) (see Figure 4-1). When the input is above 2 Volts, it looks into a 10 MΩ 100:1 input divider. The measurement error due to loading of the circuit by the multimeter can be calculated as

$$\%\ \text{Error} = \frac{R_s}{R_s + R_i} \times 100$$

where R_s is equal to the source impedance of the circuit being measured and R_i is equal to the input impedance of the multimeter.

For example, a circuit with a source impedance of 10 kΩ will introduce a measurement error of 0.1% on the 20-volt range and an error of only 0.0001% on the 2 Volt range.

Another source of error in high impedance circuits is due to the input bias current of the input amplifier. The input amplifier has a very low input bias current (I_b), typically only a few picoamperes. With a source impedance of 1 MΩ and a bias current of three picoamperes, the error at the input will be only three microvolts. Note that if the input terminals are open-circuited on the three low ranges, the meter reads a fictitious voltage caused by the integration of I_b.

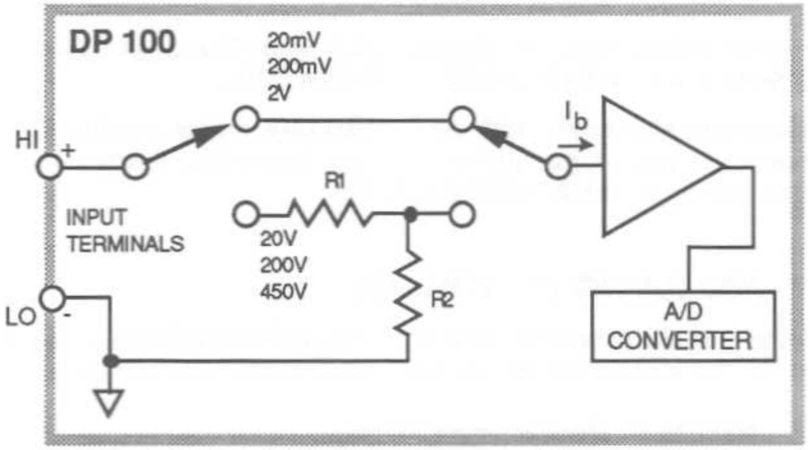


Figure 4-1. DP 100 DC Voltage Input Circuit

When using the 20-mV dc range, keep in mind that the 100-nanovolt resolution of this range represents the measurement of an extremely small voltage. High impedance measurements at this resolution are very sensitive to noise and thermocouple effects.

For best results, we recommend using shielded input connections for these types of measurements. Keep the leads as short as possible and maintain all connections, if possible, at the same temperature. In addition, when operating the instrument on the 20-mV dc range via the RS-232 interface, we recommend that you do not read data from the DP 100 more often than once every three seconds.

4.3.2 Common Mode Rejection

The DP 100 measures the potential difference (volts) between two points, neither of which is ground. In order to make this measurement, the DP 100's front end is isolated from the external environment "ground." The average of the HI and LO input terminal voltages with respect to earth ground is referred to as the common-mode voltage.

The ability of the instrument to measure the difference between HI and LO and ignore the common-mode voltage to earth is known as common-mode rejection (CMR). Two examples of typical measurements requiring CMR are bridge measurements and voltage measurements across a component which is not referenced to earth ground.

The source impedance of the common-mode voltage, together with the impedances of the HI and LO terminals to earth ground, creates an impedance divider for the common-mode voltage. Because of the impedance differences between the HI and LO terminals to earth ground, a different part of the common-mode voltage appears from HI to ground than from LO to ground. Thus, the common-mode voltage appears as a normal-mode signal (a signal from HI to LO).

For dc common-mode signals, the HI and LO impedances to ground are leakage paths on the circuit board. As these impedances are very high, the ratio of the common-mode signal to normal-mode signal is better than 140 dB. For ac signals, the impedances are capacitive. Although a larger part of the common-mode signal becomes normal-mode, this normal-mode signal is further rejected as described below.

The ac voltage mode CMR is lower than the dc voltage mode CMR because, in the ac voltage mode, any ac normal-mode signal is measured as input signal.

4.3.3 Normal Mode Rejection

The voltage which appears between the HI and LO terminals is the normal mode signal. It is not unusual for line frequency noise or other interference to appear as a normal-mode signal. The DP 100 can reject this line frequency noise when measuring dc voltages. This ability is known as normal-mode rejection (NMR).

NMR is a characteristic of analog-to-digital converters which integrate the input signal over integer multiples of the power line frequency. The DP 100 integrates the input for an interval of 100 milliseconds. This time period integrates over an integral number of line cycles of both 50 Hz and 60 Hz.

In the dc voltage mode, the DP 100 can reject normal-mode line frequency noise by more than 60 dB, provided that the noise amplitude is less than 10% of full scale and the combined ac noise and dc signal does not exceed full scale. When the input signal has substantial normal-mode noise, it may be necessary to manually select a higher range to get a satisfactory reading.

4.4 MEASURING DC CURRENT

The DP 100 current measuring circuit converts current to voltage using a 0.1 Ω shunt resistor (see Figure 4-2).

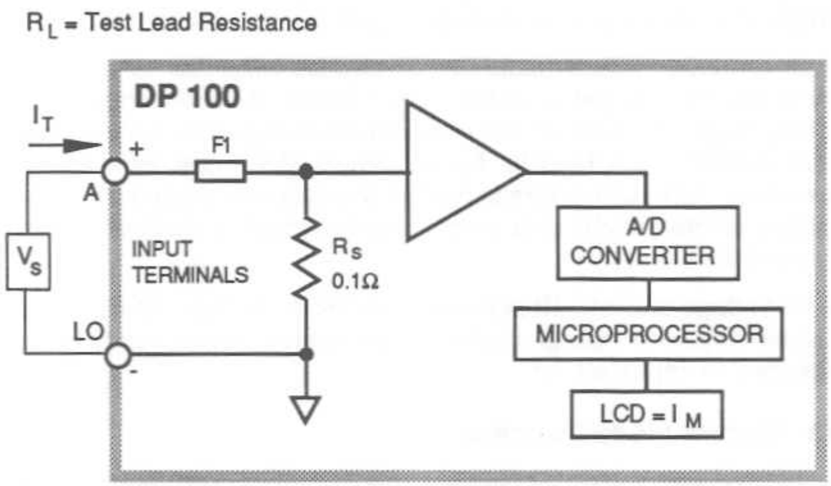


Figure 4-2. DP 100 DC Current Input Circuit

The voltage developed across this resistor is called the burden voltage. When the current source is soft or less than an ideal current source, the resistance of the test leads (R_L), the current input fuse (F1), the interconnections within the instrument, and the shunt resistor (R_S) changes the current that flows in the circuit. This results in a measurement error which is equal to the ratio of the voltage drop across this additional resistance to the open circuit voltage of the current source (V_S):

$$\%\ \text{Error} = \frac{I_M(2R_L + 0.2\ \Omega)}{V_S} \times 100$$

where I_M is the measured current as indicated by the multimeter, and R_L is the resistance of one test lead.

The 0.2Ω added to $2R_L$ is the sum of the 0.1Ω shunt resistor and 0.1Ω for the resistance of the fuse and the internal wiring. This error can also be expressed as

$$\%\ \text{Error} = \frac{I_T - I_M}{I_T} \times 100$$

where I_T is the true current. Using this expression, the true current can be calculated by the following equation.

$$I_T = \frac{I_M}{1 - (\%\ \text{Error} / 100)} = \frac{V_S I_M}{V_S - I_M(2R_L + 0.1\ \Omega)}$$

As an example, if V_S was measured as 18 V, R_L was measured as 0.1 Ω , and the measured current was 960 mA, then the actual current would be calculated as shown.

$$I_T = \frac{18\ \text{V X } 960\ \text{mA}}{18\ \text{V} - (960\ \text{mA X } 0.4\ \Omega)} = 981\ \text{mA}$$

If this correction is not done, the error would be

$$\%\ \text{Error} = \frac{981 - 960}{981} \times 100 = 2.14\ \%.$$

4.5 MEASURING AC VOLTAGE AND CURRENT

When the multimeter is in the ac voltage function, the switch is in the up position, and the ac component of the input signal looks into the 1 MΩ input impedance (see Figure 4-3).

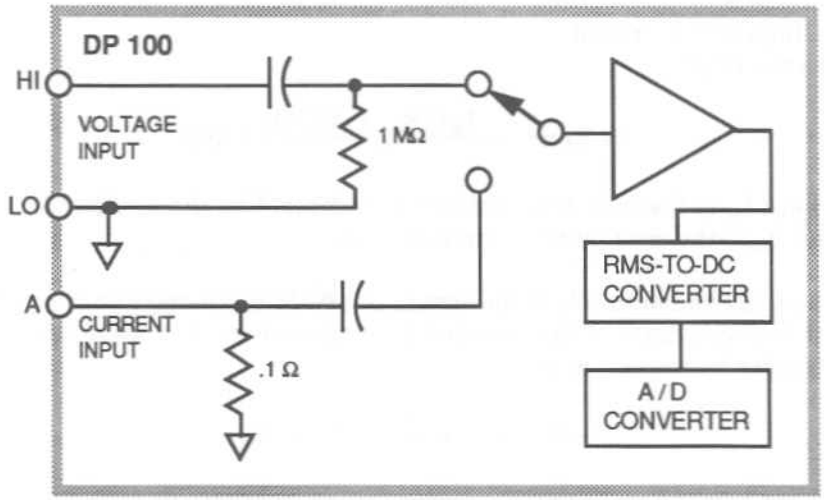


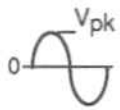
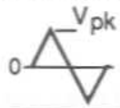
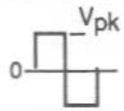
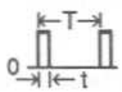
Figure 4-3. DP 100 AC Input Circuit

In the ac current mode, the switch is in the down position, and the current is converted to a voltage through the 0.1Ω current shunt. The signal is then scaled to the input range of the RMS-TO-DC CONVERTER.

The DP 100 uses a true RMS-TO-DC CONVERTER. With this type of converter the dc output voltage has the equivalent heating power of the ac input waveform. The true rms converter provides an accurate measurement of many different ac waveforms. An average-responding converter provides an accurate measurement only for pure sine waves.

A characteristic of an ac waveform is its crest factor. The crest factor of a waveform is defined as the ratio of the peak signal amplitude to its rms value. Table 4-2 compares the response of the true rms converter to the average-responding converter for some typical waveforms. Note that the true rms converter has significantly better accuracy for non-sinusoidal waveforms.

Table 4-2. Input Waveform Response

Waveform	RMS	Sine Calibrated Average Responding	Crest Factor	Error Due to Average Responding Technique vs True RMS
Sine wave 	.707 Vpk	.707 Vpk	$\sqrt{2}$	0
Triangular or Sawtooth 	.58 Vpk	.56 Vpk	$\sqrt{3}$	–3.4%
Squarewave 	Vpk	1.11 Vpk	1	+11%
Pulse Train 	$Vpk\sqrt{t/T}$ t/T rms .25 .5Vpk .0625 .25 Vpk .0156 .125 Vpk	1.11 Vpk(t/T) .278 Vpk .07 Vpk .017 Vpk	$\frac{1}{\sqrt{t/T}}$ 2 4 8	 –44% –72% –86%

The DP 100 specifications provide the accuracy for sine wave inputs. For non-sinusoidal waveforms, an additional error term is added. See Figure 4-4. Note that a sine wave (crest factor 1.414) experiences no crest factor error, while any other signal of crest factor 1.414 experiences an error, in addition to the specifications, of up to 0.2%.

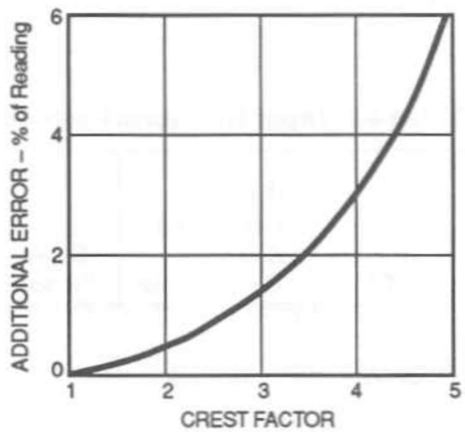


Figure 4-4. Additional Error Due to Non-Sinusoidal ac Waveform

4.6 MEASURING RESISTANCE

The DP100's resistance measuring circuit (see Figure 4-5) consists of a precise, stable current source (I_S) and the normal dc-voltage measuring channel. Resistance is determined by dividing the measured voltage across the unknown by the value of the current source (Ohm's Law).

For two-terminal resistance measurements, the output of the current source and the input to the voltage measurement channel are connected in parallel at the HI and LO terminals.

For four-terminal resistance measurements, the two circuits are not connected together within the instrument. Instead, the current source is connected to the HI and LO terminals, and the voltage measurement channel is connected to the HI and LO SENSE terminals. Note that the 20-Megohm range is only available in the two-terminal mode. Errors due to lead resistance are negligible on this range.

The value of the current source and the full-scale voltage generated across the load resistor are functions of the selected resistance range. Table 4-3 lists these parameters for the various ranges.

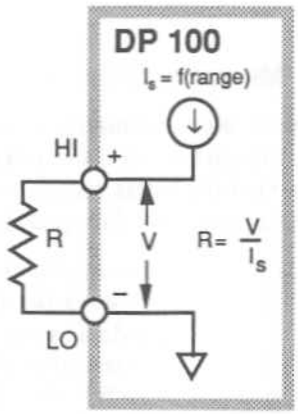


Figure 4-5. DP 100 Resistance Measuring Circuit

Table 4-3. Resistance Range Parameters

Range	Excitation Current	Full-Scale Voltage
200 Ω	1 mA	200mV
2 kΩ	1 mA	2V
20 kΩ	10 µA	200mV
200 kΩ	10 µA	2V
2 MΩ	1 µA	2V
20 MΩ	0.1 µA	2V

Note that the *open circuit voltage* across the HI and LO input terminals can be as high as *10 Vdc*. Use caution when testing components that might be damaged or degraded by the application of this voltage.

High resistance measurements are affected by leakage current paths that occur both within the instrument and in the test environment. For example, a leakage resistance of 10 Gigohms introduces a 0.1% error into a 10-Megohm measurement. Leakage effects are aggravated by high humidity. The accuracy of high resistance measurements is reduced at a relative humidity in excess of about 70%.

4.6.1 Two-Terminal Measurements

Two-terminal resistance measurements (see Figure 4-6) are made by simply connecting the unknown resistance to the HI and LO input terminals. The two-terminal mode is most useful for measuring large resistances and for qualitative measurements.

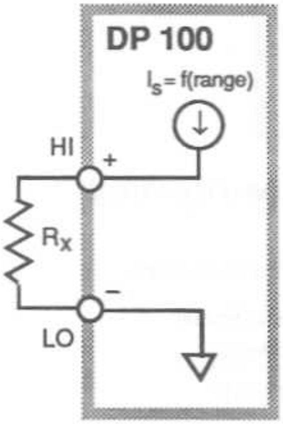


Figure 4-6. DP 100 Two-Terminal Resistance Measuring Circuit

The measured resistance value includes the resistance of the test leads as well as about 0.1 Ω of interconnecting resistance within the DP 100. This means that, for example, if the test leads have a resistance of 0.5 Ω, lead resistance introduces an error of about 0.6% into a 100 Ω measurement. Therefore, the four-terminal connection (see Section 4.6.2) should be used for all critical low-resistance measurements.

The two-terminal resistance mode is suitable for qualitative tests of semiconductor junctions and electrolytic capacitors.

4.6.2 Four-Terminal Measurements

The four-terminal resistance function (see Figure 4-7) is most useful for making precise measurements of small resistances. It eliminates the error due test lead resistance by separating the excitation connections from the measurement connections.

The unknown is connected to *two* pair of test leads, one for the HI and LO INPUT terminals (excitation) and one for the HI and LO SENSE terminals (measurement). If the unknown resistance is R_X and the resistance of each test lead is R_L, the conventional measurement technique yields a reading of R_X+2R_L. This is because the source current creates a voltage of $I_S(R_X+2R_L)$ at the input to the voltage measurement channel. With the four-terminal connection, the input to the voltage measurement channel is only I_SR_X, which yields the proper resistance measurement. There is no voltage drop across the resistance of the sense leads because the current through these leads is negligible due to the meter's high input impedance.

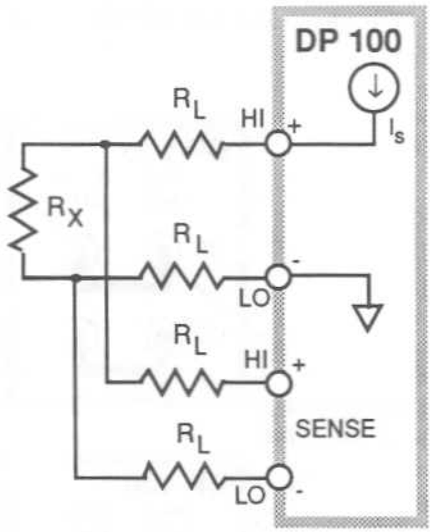


Figure 4-7. DP 100 Four-Terminal Resistance Measuring Circuit

In the four-terminal mode, the DP 100 compensates for lead resistances up to 1% of the full scale range without degrading its specifications. In fact, much larger lead resistances can be accommodated without introducing major errors into the measurement.

4.7 MEASURING TEMPERATURE

The DP 100 measures temperature with the same input circuitry it uses to measure 4-terminal resistance. The DP 100 measures the resistance of an RTD sensor and converts the result for display as a temperature. The RANGE pushbuttons are used to select °C or °F.

A 2-, 3-, or 4-lead RTD may be connected to the DP 100. Figure 4-8 shows how to connect each of these devices to the multimeter. Note that in each case, the DP 100 treats the sensor as a 4-lead device.

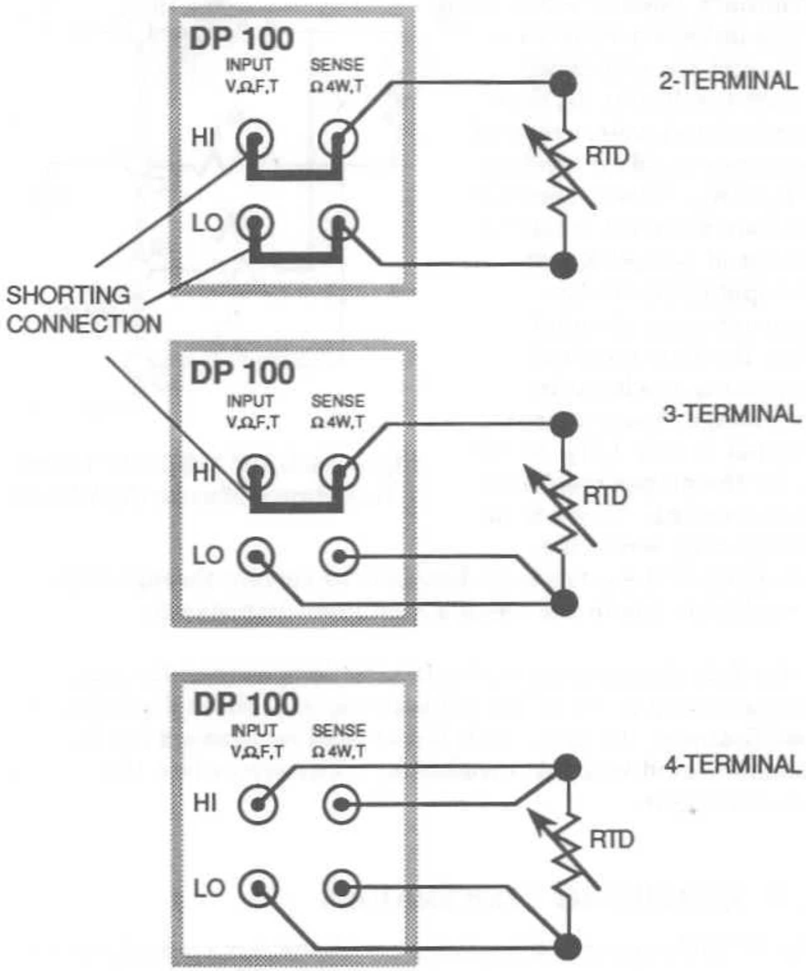


Figure 4-8. RTD-to-DP 100 Connections (2-, 3-, and 4-Terminal)

The DP 100 is calibrated for a PT 100 type RTD sensor. This type of device has a resistance of 100 Ω at 0°C and a temperature coefficient of resistance equal to 0.00385 Ω/Ω/°C (DIN 43760). Thus at 1°C, the sensor resistance is 100.385 Ω.

To achieve the DP 100's specified conversion accuracy, it is necessary to use a 4-lead RTD sensor. As explained above in the discussion of 4-terminal resistance measurements, the 4-terminal connection eliminates errors due to lead and contact resistances inherent in the 2-terminal method. A 3-lead RTD will halve the error contributed by a 2-lead device. Analogic offers 4-lead RTD sensors suitable for general purpose/immersion, air, and surface temperature measurement applications.

In the 4-terminal resistance mode, the DP 100 compensates for a lead resistance up to 1% of the full scale range without any degradation in its specifications. Using a 4-lead RTD, it is possible to make accurate measurements with considerably more lead resistance. For example, with 130 Ω of lead resistance (roughly equivalent to 3250 feet of 26-gauge wire), additional errors in temperature of only about 0.1°C can be expected.

4.8 MEASURING FREQUENCY

The DP 100 frequency counter is highly sensitive and has a very broad bandwidth. This means that good measurement techniques are required for successful results. Consider the following ideas:

- Use an oscilloscope probe. This limits circuit loading and assures that high frequency signals reach the multimeter. Analogic offers 1X and 10X probes, and BNC-to-Banana plug adapters to connect the probes to the DP 100. If the signal amplitude permits, 10X probes are preferred for high-frequency measurements due to their higher input impedance and lower input capacitance. (Note that the 30-picofarad input capacitance of the DP 100 presents an impedance of only 213 Ω to a 25 MHz signal.) 1X probes are good general purpose voltage measuring probes, but they should be restricted to low-frequency measurements.

- If you are not using a scope probe, twist the test leads or keep them adjacent to one another while taking measurements.
- Keep away from known sources of noise.
- If possible, look at square waves rather than smoothed signals.
- Although the frequency input circuit has some hysteresis to reject noise, you should filter the input when looking at noisy, low frequency signals. An RC low-pass filter with a corner frequency above that which you are measuring can be built onto a four terminal isolation banana plug. See Figure 4-9.

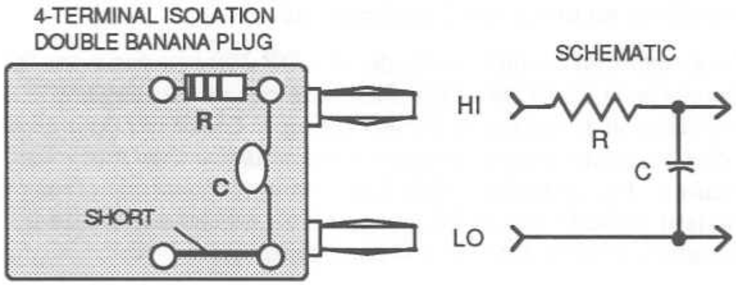


Figure 4-9. RC Low-Pass Filter

4.9 FILTERING

The DP 100 FILTER auxiliary function enables you to average a number of readings and display the result as a single measurement. This feature is useful when noise reduction is required in order to take more accurate measurements.

The filter may be set to average 2, 4, 8, or 16 readings. For each filter setting, the specified number of readings is accumulated into a buffer, averaged, and then displayed. The display remains constant while the buffer is cleared and a new set of values is accumulated. With the filter on, the display update rate is

$$\text{Display Update Rate} = \frac{1}{3}\ \text{second/reading} \times (\#\ \text{readings})$$

For example, with a filter value of 4 readings, the display update rate will be 1.33 seconds.

Choosing the optimal filter value is a trade off between noise rejection and the display update rate. Filtering will reduce noise by the square root of the number of samples averaged. A filter setting of four will reduce the noise amplitude by a a factor of two. Measurements of slow moving signals in noisy environments can benefit from large filter values.