Fluke 8010A Digital Multimeter Operating Instructions

Note that some of the lab benches have Fluke 8000A DMMs. These DMMs have the same functions as the model 8010A, but the buttons have been rearranged.

1-14. The LCD

1-15. The LDC is a 3 1/2 digit display. As shown in Figure 1-1, this display is made up of four digits. The three digits on the right can each register a count of 0 to 9. Together they register from 000 to 999. The digit on the left can register the minus sign and a 1 overflow from the three digits on the right. This is the 1/2 digit. Together the four digits can count from -1999 to +1999. For convenience of discussion, we will round the 1999 to 2000.

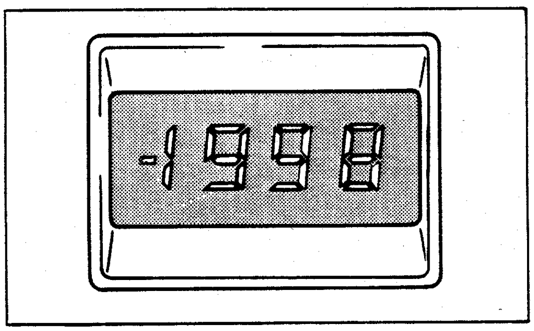


Figure 1-1. LCD

1-16. Power Switch

1-17. The POWER switch is the green switch in the lower right corner of the front panel. As the decal indicates, the pushbutton is a two position switch, ON and OFF. To change from one condition to the other, push the switch (never pull). If the button is out, or in the OFF position, push it. The control will lock in the ON position. Push the control again and the button will pop out to the OFF position.

1-18. AC/DC Select

1-19. The position of the pushbutton at the left end of the upper row of controls determines whether your instrument will be set up to read dc or ac signals. Operation of this control is exactly like the POWER control. As the decal shows, if the pushbutton is in, ac-coupled measurement is selected. If the pushbutton is out, dc measurement is selected. This control will only affect your instrument when either a voltage or current function is selected.

1-20. Voltage Measurements

1-21. The controls and terminals used for making voltage measurements are highlighted in Figure 1-2. Starting at the top, left is the AC/DC switch. Next is the V pushbutton. This pushbutton is interlocked with the other two white measurement function select switches, mA/A and kΩ/S. That is, if the V pushbutton is locked at the in position and either of the other two pushbuttons are pressed, the V pushbutton will pop to the out position. The pushbutton must be locked at the in position to determine measurement function. Push the V switch in.

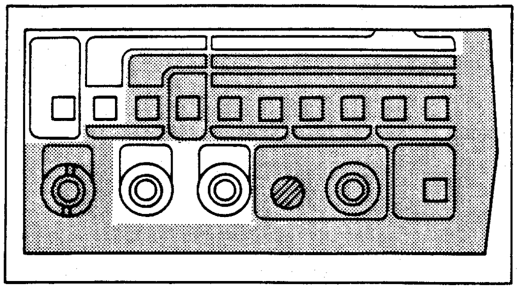


Figure 1-2. Voltage Measurement

1-22. The light green decal around the V control extends up and to the right. The five ranges of the voltage function are labeled in this green band over their respective range selection switches. These switches are all interlocked in the same manner as the three measurement function switches. Select the 2V range.

1-23. The two input terminals highlighted in the bottom row are banana jack connectors. The one on the left is labeled COMMON and has a black decal. This terminal is common to all measurement functions and the black test lead should always be connected here. A curved line with a note goes to the left and down from the COMMON input terminal. This note is a reminder to not measure signals where the COMMON lead will be more than 500V above ground potential. The other input terminal is labeled V/kΩ/S on a red decal. The red test lead is connected here for voltage, standard resistance, and conductance measurements. Between the two terminals is a hole and a thin connecting line with a subtended note. The note reminds the operator that signals exceeding 750V ac rms or 1000V dc should not be measured between the terminals. The hole is a key guide for the optional Touch and Hold Probe. Connect the test leads to the terminals.

1-25. Current Measurements

1-26. The controls and terminals used for making current measurements are highlighted in Figure 1-3. The AC/DC switch and the mA switch determine the measurement function. On the 8010A, the current switch is labeled mA/A because the same switch selects the high current measurement range also.

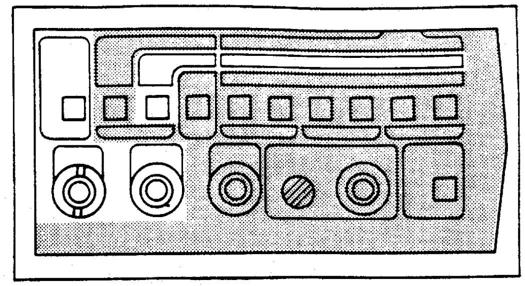


Figure 1-3. mA Measurement

1-27. The pink decal around the mA control extends up and to the right. The ranges of current measurement are labeled in this pink band above their respective range selection switches.

1-28. The two input terminals are the COMMON terminal and the mA terminal. There is a line between them with a note to remind the operator that current measurements over 2A should not be read between these terminals. The mA terminal is also the end of a protective fuse holder. The collar is slotted to facilitate fuse replacement. There is a curved arrow with a 2A fuse note to the left of the mA terminal to indicate how to remove the 2A fuse. For additional information on fuse replacement, refer to Section 2.

1-29. 10A Current Measurement - 8010A Only

1-30. The controls and terminals used for the 10A current measurement function are highlighted in Figure 1-4. The AC/DC and mA switches and the last range switch on the right select the 10A current measurement function. The COMMON and 10A terminals are used for signal input. The 10A input terminal is labeled to remind the operator that the maximum current measured between these two terminals is 10A and that the function is not fuse protected.

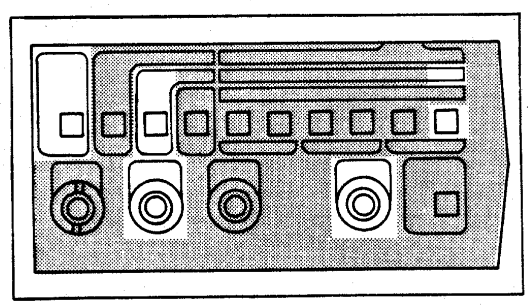


Figure 1-4. 10A Current Measurement - 8010A Only

1-31. Resistance Measurements

1-32. The controls and terminals used for making resistance measurements are highlighted in Figure 1-5. The measurement function is selected by the kΩ/S switch. The tan decal extends up and to the right with the six ranges of resistance in the standard resistance function labeled in this tan band over their respective range switches. The COMMON and V/kΩ/S terminals are used for signal input.

1-33. Let's use the following procedure to exercise the resistance function and see how the range switches affect the position of the decimal point on the display.

1. Select the resistance function, 2000 kΩ range.
2. The LCD should display an overrange indication, a 1 with the three right hand digits blank.
3. Connect the test leads to the input terminals, black lead to COMMON and red lead to V/kΩ/S.
4. Make a firm connection between the sampling ends of the test leads. The LCD should count down to a reading of 000.
5. Maintaining a firm contact between the sampling ends of the test leads, sequentially select the ranges starting with the 200Ω range switch. The decimal point for each should be as follows:

200Ω	00.0*	200 kΩ	00.0
2 kΩ	.000	2000 kΩ	000
20 kΩ	0.00	20 mΩ	0.00

* Display may display .1 or .2Ω of lead resistance.

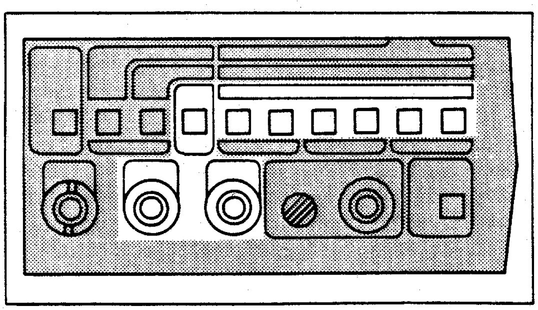


Figure 1-5. Resistance Measurement

1-37. Conductance Measurements

1-38. The controls and terminals for making conductance measurements are highlighted in Figure 1-7. With the exception of the selection of range, the controls and connections are exactly the same as for resistance measurements. There are three ranges of conductance. Each range is selected by simultaneously pushing in two range switches.-The pairs of range switches required are indicated by the three grey decals below the range switches.

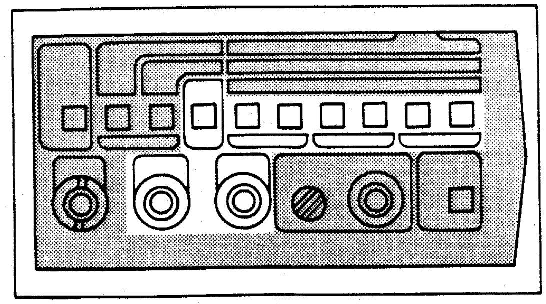


Figure 1-7. Conductance measurement

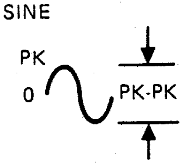
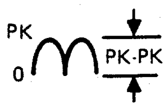
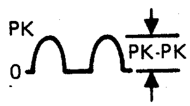
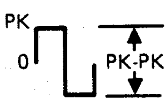
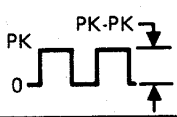
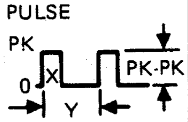
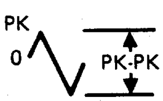
2-17. Making Voltage Measurements

2-18. In Section 1, we discussed the operation of the controls and terminals used to make voltage measurements. To use your instrument effectively, there are other factors of which you should be aware. Some of these factors will not normally affect your instrument and will be covered later as AC Measurement Considerations.

2-19. Your instrument has five ac voltage and five dc voltage ranges: 200 mV, 2V, 20V, 200V and either 750V ac or 1000V dc. All of these ranges present an input impedance of 10 MΩ. On the ac ranges, this input impedance is shunted by less than 100 pF. When you make the voltage measurements, be sure you do not exceed the overload limits listed in Table 2-1.

2-20. CONVERTING VOLTAGE MEASUREMENTS

2-21. Your instrument is one of the new family of Fluke meters that actually measure the true rms value of an ac signal. This is a feature that allows accurate measurement of standard waveforms like distorted or mixed frequency sine waves, square waves, sawtooths, noise, pulse trains (with a duty cycle of at least .1), etc. In the past, the methods of ac measurement used have introduced large errors in the readings. Unfortunately, we've all grown used to these erroneous voltage readings and depend upon them to indicate whether or not a piece of equipment is working correctly. The data contained in Figure 2-1 should help you to convert between different measurement methods for the waveforms shown.

AC-COUPLED INPUT WAVEFORM	PEAK VOLTAGES		METERED VOLTAGES			DC AND AC TOTAL RMS
			AC COMPONENT ONLY		DC COMPONENT ONLY	
	PK-PK	0-PK	RMS CAL*	8010A 8012A		TRUE RMS = $\sqrt{ac^2 + dc^2}$
SINE 	2.828	1.414	1.000	1.000	0.000	1.000
RECTIFIED SINE (FULL WAVE) 	1.414	1.414	0.421	0.435	0.900	1.000
RECTIFIED SINE (HALF WAVE) 	2.000	2.000	0.764	0.771	0.636	1.000
SQUARE 	2.000	1.000	1.110	1.000	0.000	1.000
RECTIFIED SQUARE 	1.414	1.414	0.785	0.707	0.707	1.000
RECTANGULAR PULSE  D = X/Y K = $D - D^2$	2.000	2.000	2.22K	2K	2D	$2\sqrt{D}$
TRIANGLE SAWTOOTH 	3.464	1.732	0.960	1.000	0.000	1.000

* RMS CAL IS THE DISPLAYED VALUE FOR AVERAGE RESPONDING METERS THAT ARE CALIBRATED TO DISPLAY RMS FOR SINE WAVES

Figure 2-1. Voltage Conversion

2-22. CIRCUIT LOADING ERROR

2-23. Connecting any voltmeter to a circuit changes the operating voltage of the circuit (loads the circuit down). As long as the circuit resistance (source impedance) is small compared to the input impedance of the meter, the error is not significant. For example, when measuring voltage with your meter, as long as the source impedance is 10 kΩ or less, the error will be $\leq 0.1\%$. If circuit loading does present a problem, the percentage of error can be calculated using the appropriate formula in Figure 2-2.

2-24. COMBINED AC AND DC SIGNAL MEASUREMENT

2-25. The waveform shown in Figure 2-3 is a simple example of an ac signal riding on a dc level. To measure waveforms such as these, first measure the rms value of the ac component using the AC function of your meter. Measure the dc component using the DC function of your instrument. The relationship between the total rms value of the waveform and the ac component and the dc component is:

$$\text{RMS Total} = \sqrt{(\text{ac component rms})^2 + (\text{dc component})^2}$$

1. DC VOLTAGE MEASUREMENTS

$$\text{Loading Error in \%} = 100 \times Rs \div (Rs + 10^7)$$

Where: Rs = Source resistance in ohms of circuit being measured.

2. AC VOLTAGE MEASUREMENTS

First, determine input impedance, as follows:

$$Zin = \frac{10^7}{\sqrt{1 + (2\pi F \cdot Rin \cdot C)^2}}$$

Where: Zin = effective input impedance
Rin = 10^7 ohms
Cin = 100×10^{-12} Farads
F = frequency in Hz

Then, determine source loading error as follows:

$$\text{Loading Error in \%} = 100 \times \frac{Zs}{Rs + Zin}$$

Where: Zs = source impedance
Zin = input impedance (calculated)
Rs = source resistance

Figure 2-2. Circuit Loading Error Calculations

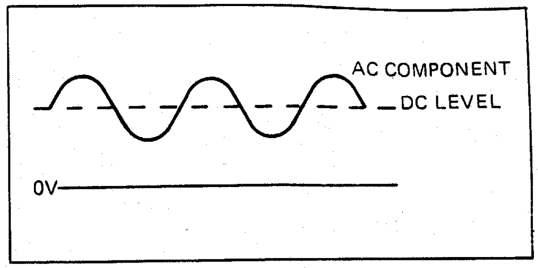


Figure 2-3. RMS Values

2-26. OFFSET

2-27. If you short the input of your meter while the AC voltage function is selected, you may have a reading of one or two digits on the display. This minute offset is caused by the action of amplifier noise and offset of the true rms converter. This offset will not significantly affect any readings until you try to measure signals almost at the floor of the meter. For example:

GIVEN: A dc offset over twice the normal maximum or offset = 5 digits.

Input signal = 10 mV

$$\text{Total RMS} = \sqrt{(10)^2 + (.5)^2} = \sqrt{100.25} = 10.01 \text{ mV}$$

but the meter will read this as:

Total RMS = 10 mV

or using a realistic offset for your instrument,

GIVEN: offset = 2 digits.

Input signal = 1 mV

$$\text{Total RMS} = \sqrt{1^2 + .2^2} = \sqrt{1 + .04} = \sqrt{1.04} = 1.02 \text{ mV}$$

The meter will read this as 1.0 mV.

2-28. NOISE ERRORS

2-29. Many noise errors in dc voltage measurements are due to the line power frequency coupling into the circuit. Design features of your instrument have a noise rejection of approximately 60 dB (cut the noise to 1/1000 of its original level) when operated in the line-frequency environment it is designed for. The decal on the bottom of your instrument will be marked for the line-frequency that your instrument will reject (50 Hz or 60 Hz). Instruments are available with a switch selectable line-frequency circuit. If you have this type of instrument and wish to change the selected line-frequency rejection, remove the outer cover as described under Fuse Replacement and place S3 in the appropriate position. The component location diagrams of the Main PCB in section 5 and 8 show the location of S3.

2-30. Making Current Measurements

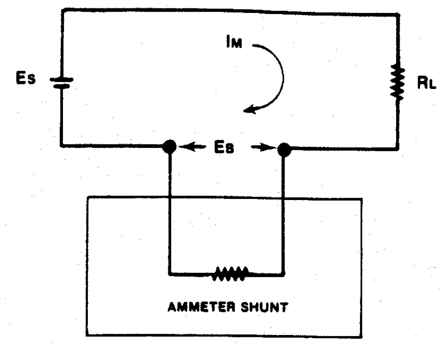
2-31. Both the 8010A and 8012A have five ac and five dc current ranges: 200 μA, 2 mA, 20 mA, 200 mA, and 2000 mA. In addition, the 8010A has a 10A current measurement function. In both instrument, the five lower ranges are diode protected up to 2 amps and fuse protected above 2 amps. If either or both of the protective fuses blow, refer to the Fuse Replacement information presented earlier in this section. The 10A function on the 8010A is unfused, but will safely carry currents up to 12A or to the limits of the test leads.

2-32. When a meter is place in series with a circuit to measure current, you may have to consider an error caused by the voltage drop across the meter (in this case, across the protective fuses and current shunts). This voltage drop is called burden voltage. The full scale burden voltages for your instrument are: 0.3V for the four lowest ranges, 0.9V for the 2000 mA range, and 0.5V for the 10A range on the 8010A. These voltage drops can affect the accuracy of a current measurement if the current source is unregulated and the resistance of the shunt and fuse represents a signficant part (1/1000 or more) of the source resistance. If burden voltage does present a problem, the percentage error can be calculated using the formulae in Figure 2-4. This error can be minimized by selecting the highest current range that provides the necessary resolution.

2-33. Making Resistance Measurements

2-34. Both the 8010A and the 8012A have six direct reading resistance ranges: 200Ω, 2 kΩ, 20 kΩ, 200 kΩ, 2000 kΩ and 20 MΩ. In addition, the 8012A offers a 2Ω and a 20Ω range on the LO RANGE Ω function.

2-35. Your instrument uses the two wire measurement techniques, so the readings will be in error by the amount of the resistance of your test leads. A pair of standard test leads has a combined lead resistance on the order of 0.2Ω to 0.3Ω. This low resistance only effects readings on your meter in the ranges below 2 kΩ. The LO RANGE Ω function of the 8012A has a ZERO adjustment to compensate for lead resistance. After selecting the 2Ω range, make a firm contact between the sampling ends of the test leads and adjust the ZERO control until the LCD displays zero. The 200Ω range has no compensation for lead resistance. Short the sampling ends of the test leads



E_S = Source voltage
R_L = Load resistance + Source resistance
I_M = Measured current (display reading in amps)
E_B = Burden voltage (calculated), i.e.
Display reading expressed as a % of full scale (100 x $\frac{\text{READING}}{\text{FULL SCALE}}$) times full scale burden voltage for selected range. See table.

RANGE	F.S. BURDEN VOLTAGE
2 mA to 200 mA	0.3V
2000 mA	0.9V
10A	0.5V

Current error due to Burden Voltage

$$\text{IN \%} = 100 \times \frac{E_B}{E_S - E_B}$$

$$\text{IN AMPS} = \frac{E_B \times I_M}{E_S - E_B}$$

Example: $E_S = 14V$, $R_L = 9\Omega$, $I_M = 1.497A$,

$$E_B = 100 \times \frac{1497}{2000} \times 0.9 \text{ (from Table)} =$$

74.9% of 0.9 = 0.674V

$$\text{Error in \%} = 100 \frac{.674}{14-.674} = 100 \frac{.674}{13.326} = 5.06\%$$

Increase displayed current by 5.06% to obtain true current.

$$\text{Error in amps} = \frac{.674 \times 1.497}{14-.674} = \frac{.991}{13.326} = 0.074A$$

Increase displayed current by 0.074A to obtain true current

Figure 2-4. Calculating Burden Voltage Error

together and read the lead resistance. When making resistance measurements, subtract the measured lead resistance and you will have an accurate resistance value.

2-36. The three resistance ranges with a diode symbol beside the range value have a high enough open circuit voltage to turn on a silicon junction. These ranges (2 kΩ, 200 kΩ, and 20 MΩ) can be used to check silicon diodes and transistors. The 2 kΩ range is preferred. It is marked with the largest diode symbol. On the other ranges, the voltage is too small to turn on silicon junctions. Use these ranges to make in circuit resistance measurements.

2-37. The range and resolution of the LO RANGE Ω function of the 8012A allows the measurement of such things as ballast resistors, transformer windings, heating elements, coils, relay contact resistance, fuses, etc. Readings can be made down to a few milliohms.

2-38. Making Conductance Measurements

2-39. There are three conductance ranges on your meter; 2 mS, 20 μS, and 200 nS. You can think of this function either as a new type of measurement or as another way to measure high resistances. As a high resistance meter, your Fluke offers many advantages over previous methods, including the ability to make these high resistance readings at voltages within the operating range of IC's and MOS devices. As a conductance meter, your instrument can measure directly inverse function components. For example, the resistance of a photo-diode decreases as the available light increases. When using conductance, both parameters change together allowing easier, less error prone applications. The display is in conductance units, Siemens. If resistance readings are desired, refer to the conductance-to-resistance conversion information in Figure 2-5.

2-40. The 200 nS range can be used for making resistance measurements from 5 MΩ to 10,000 MΩ. Since conductance is the inverse of resistance, as the resistance measured increases, accuracy and measurement decrease so resolution noise problems decrease. Using a standard high-resistance meter in this range requires careful shielding to prevent noise pick-up. With your meter, standard test leads are all you need. Except for high voltage stress testing, this range of conductance replaces the megger and can be used to check high value resistors and low leakage components like diodes or capacitors. For more information, refer to the Applications material presented later in this section.

2-41. The 20 μS range can be used for making resistance measurements from 50 kΩ to 100 MΩ. This range of conductance is the one best suited for measuring inverse resistance components such as phototransistors. For more information, refer to the Applications material presented later in this section.

2-42. The 2 mS range can be used for making resistance measurements from 500Ω to 1 MΩ. It can be used either for resistance measurements or for such things as direct-reading dc current gain (Beta) measurements on transistors. Beta measurement require a special test fixture presented in the Applications material later in this section.

2-43. The three conductance ranges span resistance measurements of 500Ω to 10,000 MΩ. When using Ohm's law to determine current or power, it is sometimes necessary to divide by the resistance of the circuit or component. You may find it more convenient to measure conductance and multiply.

2-44. AC Measurement Considerations

2-45. When making precise measurements of ac signals, there are special parameters that must be considered such as the type of ac converter the meter uses (average, rms, etc.), crest factor, bandpass, noise, etc.

2-46. TRUE RMS

2-47. In order to compare dissimilar waveforms or calculate Ohm's law statements, or power relationships, you must know the effective value of a signal. If it is a dc signal, the effective value equals the dc level. If the signal is ac, however, we have to borrow the root mean square technique from the world of statistics in order to find the effective value of the signal. In electronics, this effective value is called the root mean square or rms value of the signal. Classically, the rms value of a current or voltage is defined as being numerically equal to the dc current or voltage that produces the same heating effect in a given resistance that the ac current or voltage produces.

2-48. In the past, average responding converters were the type of converter most widely used. Theoretically, the rms value of a sine wave is $1/\sqrt{2}$ of peak value and the average value is 2/pi of the peak value. Since the meters converted to the average value, the rms value was $1/\sqrt{2} \div 2/pi = pi/2\sqrt{2} = 1.11$ of the average value when measuring a sine wave. Most meters used an average responding converter and multiplied by 1.11 to present true rms measurements of sine waves. As the signal being measured deviated from a pure sine wave the errors in measurement rose sharply. Signals such as square waves, mixed frequencies, white noise, modulated signals, etc. could not be accurately measured. Rough correction factors could be calculated for ideal waveforms if the signal being measured was distortion free, noise-free, and a standard waveform. The true rms converter in your meter provides direct, accurate measurement of these and other signals.

2-49. CREST FACTOR

2-50. Crest factor range is one of the parameters used to describe the dynamic range of a voltmeter's amplifiers. The crest factor of a waveform is the ratio of the peak to the rms voltage with the dc component removed. In waveforms where the positive and negative half cycles have different peak voltages, the higher voltage is used in computing crest factor. Crest factors start at 1.0 for a square wave (peak voltage equals rms voltage).

2-51. Your instrument has a crest factor range of 1.0 to 3.0. If an input signal has a crest factor of 3.0 or less, voltage measurements will not be in error due to crest factor limitations. If crest factor of a waveform is not known and you wish to know if it falls within the crest factor range of your meter, measure the signal with both your meter and an ac coupled oscilloscope. If the rms reading on your meter is 1/3 of the peak voltage on the waveform or less, then the crest factor is less than 3.0.

2-52. The waveforms in Figure 2-6 show signals with increasing values of crest factor. As you can see from the series of waveforms, a signal with a crest factor above 3.0 is unusual.

WAVEFORM	CREST FACTOR
SQUARE WAVE	1.0
SINE WAVE	1.414
TRIANGLE SAWTOOTH	1.732
MIXED FREQUENCIES	1.414 to 2.0
SCR OUTPUT OF 100% – 10%	1.414 to 3.0
WHITE NOISE	3.0 to 4.0
PULSE TRAIN (t_0, T, $t_0 = 1/10\ T$)	3.0
PULSE TRAIN D<.012	>9.0

Figure 2-6. Crest Factor

2-53. Rectangular waves, as usual, have their own special formula. It is:

$$\text{Crest Factor} = \sqrt{1/D - 1}$$

Where D = duty cycle or the ratio of pulse width to cycle length. Using this formula backwards, we find that your meter can accurately measure pulse trains with a duty cycle above 10% without being limited by crest factor.

$$\text{Crest Factor} = 3.0 = \sqrt{1/D - 1}$$
$$9.0 = 1/D - 1$$
$$10.0 = 1/D$$
$$D = 1/10 = 10\%$$

2-54. BANDWIDTH

2-55. Bandwidth defines the range of frequencies where attenuation by the voltmeter's amplifiers and filters is no more than 3 dB down (half power levels). Your instrument has a bandwidth of up to 200 kHz on the 200 mV and 20V ranges and at least twice that on the 2V and 200V ranges. For brevity, let's call the bandwidth of your meter 200 kHz for these discussions.

2-56. SLEW RATE

2-57. Slew rate is also called the rate limit or the voltage velocity limit. It defines the maximum rate of change of the amplifiers for a large input signal.

2-58. RISE AND FALL TIME EFFECT ON ACCURACY

2-59. The rise and fall times of a waveform are the length of time it takes a waveform to change between the points that are 10% and 90% of the peak value. When discussing these periods, we'll only mention rise time. Errors due to rise or fall time can be caused either by bandwidth or slew rate. Slew rate should not affect your measurement with either the 8010A or the 8012A.

2-60. A good rule-of-thumb for converting the effects of bandpass into a rise time limit is to divide 0.35 by the high frequency value at the 3 dB point. For your instrument this will be 0.35/ 200k = 1.75 μsec. The following example will help you to calculate errors due to this limitation when measuring rectangular pulses. These calculations will be rough because ideal waveforms are used in the analysis.

2-61. Ideally, the rectangualr pulses would have zero rise and fall times and would be the right angled waveform shown in Figure 2-7, Part A. In practice, every waveform has a rise and fall time and looks more like the waveform in Figure 2-7, Part B. When calculating the error caused by the bandpass of your instrument, we will assume worst case conditions, where the rise and fall times equal the effect caused by bandpass - 1.75 μsec. To do this, we will calculate the values for the theoretical signal with zero rise and fall times then calculate the values for a signal with the same period but with total slope periods equal to 1.75 μsec. A comparison of the results will show the measurement error due to the bandpass.

2-62. Let's look at the waveform in Figure 2-7, Part B. When using your meter to measure the ac component of the signal, the display will indicate the rms value of the ac signal riding on the dc level. (This dc level is the average value of the waveform when considered from the baseline.) The total rms value of the waveform can be calculated using the relationship:

$$\text{E total rms} = \sqrt{\text{E ac rms}^2 + \text{E dc}^2}$$

There are long established formula for computing the dc level and total rms values. Using Figure 2-7, Part B, for a reference, these formulae are:

$$\text{E total rms} = A\sqrt{\frac{3to + 2tl}{3T}}$$

$$\text{E dc} = A\left(\frac{(to + tl)}{T}\right)$$

Since we can calculate two values, to find what your meter measures, use the formula:

$$\text{Eac rms} = \sqrt{(\text{E total rms})^2 - (\text{Edc})^2}$$

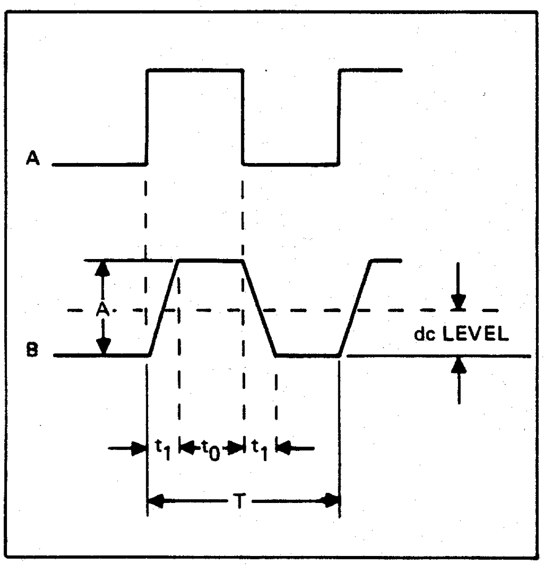


Figure 2-7. Components of a Rectangular Waveform

2-63. For our example let's use a 10 kHz pulse train with 50 μsec pulses at a peak value of 1V. Ideally, the pulses would have a zero rise time as shown in Figure 2-8, A.

$$\text{E total rms} = 1\sqrt{\frac{3(50) + 2(0)}{3(100)}} = \sqrt{\frac{150 + 0}{300}} = \sqrt{\frac{1}{2}}$$

$$\text{E total rms} = 0.707$$

$$\text{E dc} = 1\left(\frac{50 + 0}{100}\right) = \frac{50}{100} = 0.5$$

$$\text{So, the E ac rms} = \sqrt{(0.707)^2 - (0.5)^2} = \sqrt{0.50 - 0.25}$$

$$\text{E ac rms} = \sqrt{0.25} = 0.5$$

When the maximum distortion in rise time of 1.75 μsec is assumed, the signal becomes the isoceles trapezoid waveform shown in Figure 2-8, Part B. In this case,

$$\text{E total rms} = 1\sqrt{\frac{3(48.25) + 2(1.75)}{3(100)}} = \sqrt{\frac{144.75 + 3.50}{300}}$$

$$\text{E total rms} = \sqrt{\frac{148.25}{300}} = \sqrt{0.494} = 0.703$$

$$\text{E dc} = 1\left(\frac{(48.25) + 1.75}{100}\right) = \frac{50}{100} = 0.50$$

$$\text{So, E ac rms} = \sqrt{(0.703)^2 - (0.50)^2} = \sqrt{0.494 - .25}$$

$$\text{E ac rms} = \sqrt{0.244} = 0.494$$

Note that the E dc stayed the same.

So, the errors are:

In E total rms: - 0.6%
In E ac rms: - 1.2%

2-64. OPERATION

2-65. Operation of your instrument is easy:

1. Set the POWER switch to ON.

2. Set the function and range switches to the correct position for the measurement being made. (Refer to Section 1.)

3. Connect the test leads to the appropriate terminals. (Refer to Section 1.)