Tektronix®

213 DMM OSCILLOSCOPE

WITH OPTIONS

OPERATORS

INSTRUCTION MANUAL

Tektronix®

COMMITTED TO EXCELLENCE

PLEASE CHECK FOR CHANGE INFORMATION AT THE REAR OF THIS MANUAL.

213
DMM
OSCILLOSCOPE

WITH OPTIONS

OPERATORS

INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

070-1480-00
Product Group 40

Serial Number ______________

First Printing DEC 1974
Revised DEC 1983

INSTRUMENT SERIAL NUMBERS

Each instrument has a serial number on a panel insert, tag, or stamped on the chassis. The first number or letter designates the country of manufacture. The last five digits of the serial number are assigned sequentially and are unique to each instrument. Those manufactured in the United states have six unique digits. The country of manufacture is identified as follows:

B000000	Tektronix, Inc., Beaverton, Oregon, USA
100000	Tektronix Guernsey, Ltd., Channel Islands
200000	Tektronix United Kingdom, Ltd., London
300000	Sony/Tektronix, Japan
700000	Tektronix Holland, NV, Heerenveen, The Netherlands

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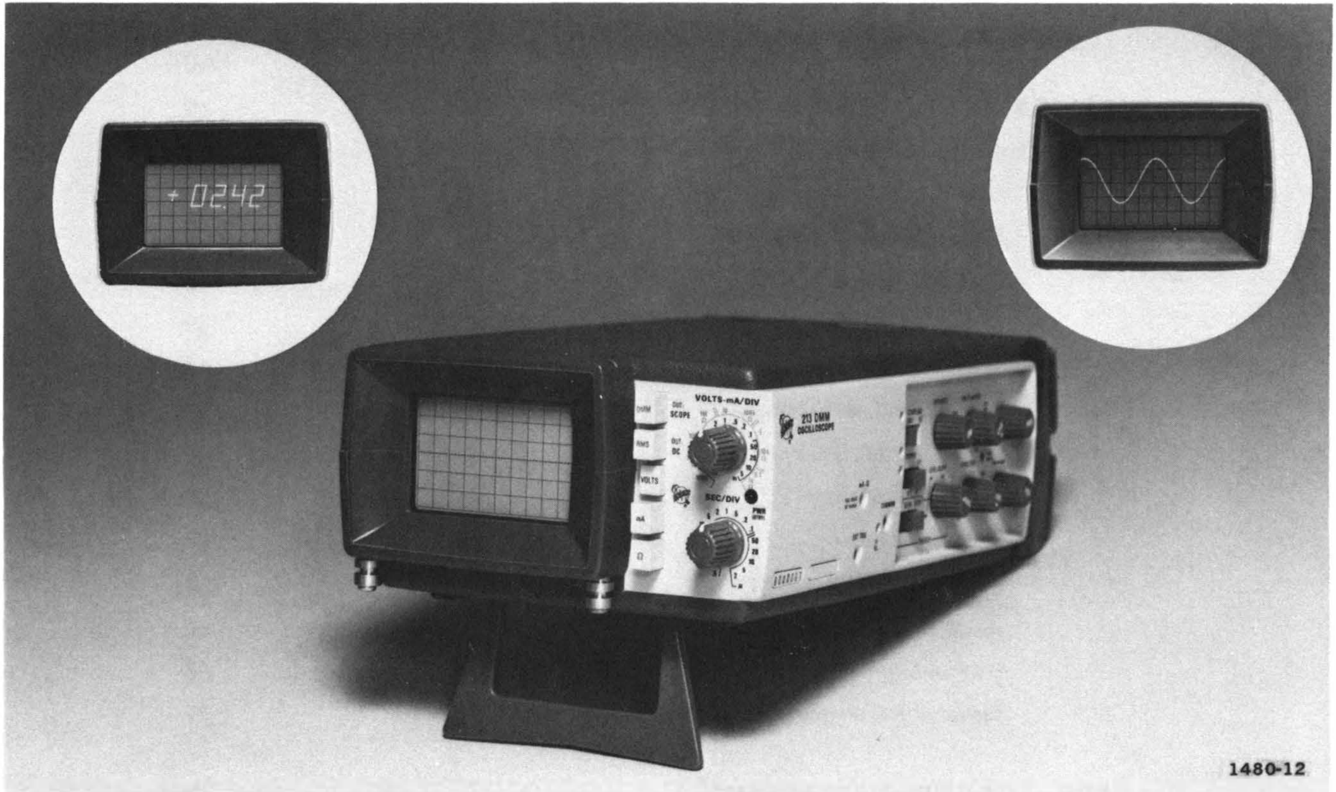

213 DMM Oscilloscope.

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BEFORE OPERATING

INTRODUCTION

This manual provides information necessary to effectively operate the 213 DMM Oscilloscope. Servicing instructions are contained in a separate 213 DMM Oscilloscope Service manual.

The 213 DMM Oscilloscope is a portable measurement instrument that is designed to be used as either a digital multimeter or an oscilloscope. Function selection is made with a front-panel push button switch. Voltage measurements are made with the integral high-impedance probe, while current and resistance measurements are made through a low-impedance banana jack input on the side panel. Operating power is provided by internal rechargeable batteries or from power line voltage. An integral battery charger recharges the batteries whenever the instrument is connected to the power line.

The digital multimeter measures ac or dc voltage and current, and resistance. It features true rms responding circuitry when making ac voltage or current measurements. Full scale measurement ranges are 0.1 to 1000 V; 0.1 to 1000 mA; and 1 kΩ to 10 MΩ with a 200% full scale overrange on all ranges except 1000 V. The crt readout is a 3½-digit display containing an automatic polarity indicator, and a decimal point which is positioned by the range selector switch. Overrange is indicated by an unblanked readout display consisting of scrambled character segments.

The oscilloscope function provides a single channel, dc to 1 MHz vertical deflection system with calibrated deflection factors of 5 mV to 100 V/division with a reduced bandwidth of dc to 400 kHz on the 5 mV and 10 mV/division ranges. Current deflection factors are 5 μA to 100 mA/division from dc to 400 kHz with a reduced bandwidth of dc to 200 kHz on the 5 μA and 10 μA/division ranges. The horizontal deflection system provides calibrated sweep rates from 0.5 s to 2 μs/division. A variable sweep magnifier provides uncalibrated sweep rates to at least 5 times faster than the selected rate. The trigger input is either internal or external and provides stable triggering over the full bandwidth of the vertical deflection system. The oscilloscope crt display is a 6 x 10 division graticule with each division approximately 0.2 inches (0.5 cm).

SAFETY INFORMATION

This instrument is designed with the input common reference floating above ground. Under this condtion,the probe common clip, COMMON input jack, mA-Ω input jack, EXT TRIG jack, and the power plug prongs may be at a dangerous potential. See Table 5, Common Isolation Protection in the Operators Specifications section.

When operated on batteries, the power line plug should be stored in the rear-panel insulated compartment. Potentials applied to the common connectors (probe common clip or COMMON jack) may cause small amounts of current to flow in the power line circuitry creating a possible shock hazard on the plug prongs.

The probe common clip and COMMON jack are electrically connected to each other; therefore, any potential applied to one is present on the other creating a possible shock hazard. Also, to prevent dissimilar voltages being applied to the probe common clip and COMMON jack which could cause equipment damage, only one should be connected to the circuit under test at any given time. The probe with its common clip, and the mA-Ω input jack with its COMMON jack should not be connected simultaneously to a circuit under test.

Personal and equipment safety precautions are used throughout this manual and are identified as follows:

Personal Safety	**WARNING**
Equipment Safety	**CAUTION**

PROBE CHARACTERISTICS ON 200-SERIES INSTRUMENTS

On the 200-series instrument probe(s), each probe body assembly is designed to meet the input resistance and attenuation factor for the specific instrument type. The assemblies are not interchangeable between all 200-series instruments; therefore, when more than one type of instrument is in use, it is possible for them to have the wrong assembly installed. Figure 1 shows how to identify the assembly.

To verify that the proper probe body assembly is installed on the probe, correlate the assembly with the Tektronix Part Number shown in Figure 1. Then compare that part number with the correct probe body assembly part number listed in the Mechanical Parts List section of the Service Manual.

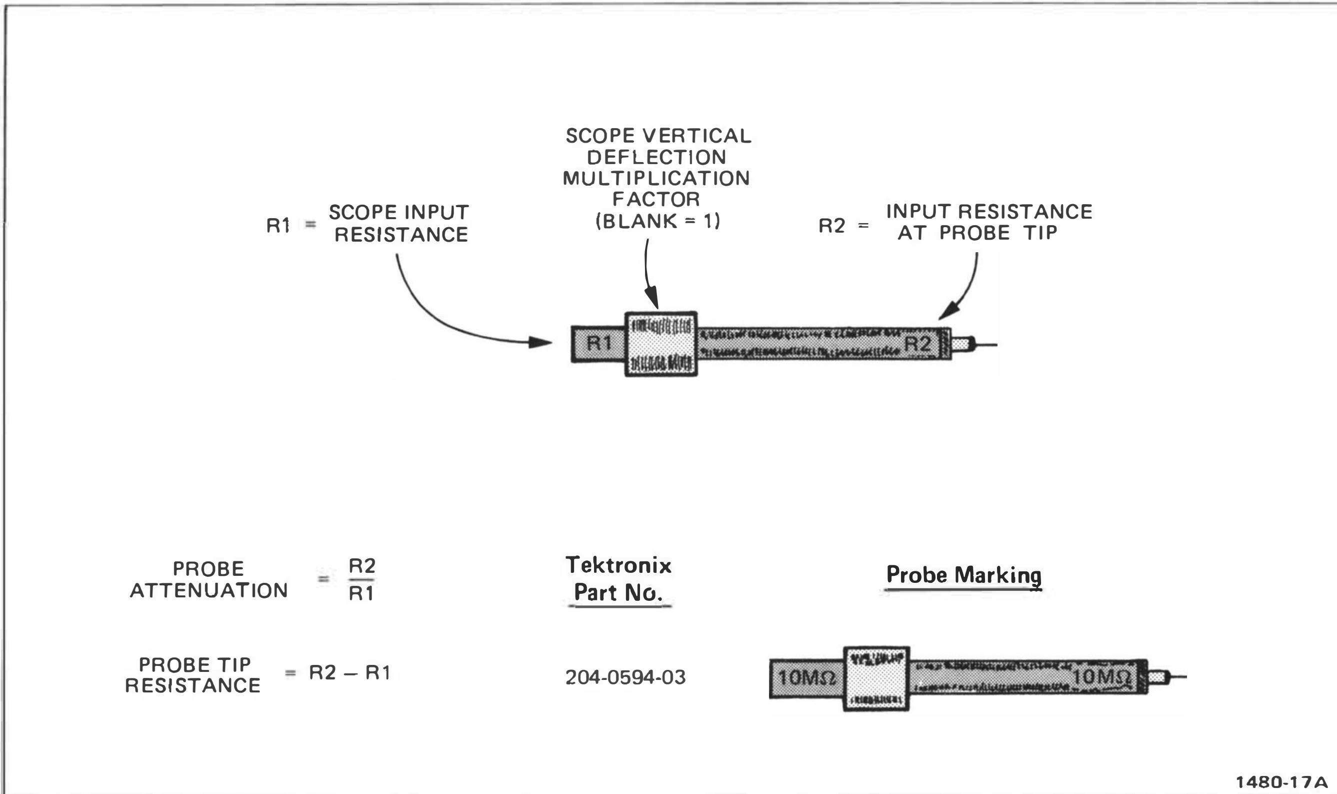

Fig. 1. Probe Body Assembly identification.

STANDARD ACCESSORIES INCLUDED

1	Carrying Case	016-0512-00
1	Operators Manual	070-1480-00
1	Service Manual	070-1481-00
1	View Hood, Folding	016-0199-01
1	Neck Strap	346-0104-00
2	Power Line Fuses	159-0080-00
2	Test Leads, Alligator Clip to Banana Jack, (1 red/1 black)	012-0014-00 (black)
		012-0015-00 (red)
1	Power Line Plug Adapter (Option 1 only)	161-0077-01

OPTIONS

Option 1

This option allows the instrument to charge the batteries or operate from a power line source of 180 to 250 V ac (48 to 62 Hz) or dc. Refer to the 213 DMM Oscilloscope Service Manual for further information.

CONTROLS, CONNECTORS AND INDICATORS

FRONT PANEL

(1) **VOLTS**—Selects voltage mode for either digital multimeter or oscilloscope function.

(2) **RMS (OUT:DC)**—DMM only. Selects true rms circuitry (button in) or ac rejection filter (button out). Button must be in out position when measuring resistance or the reading accuracy will be degraded.

(3) **DMM (OUT:SCOPE)**—Selects digital multimeter function (button in) or oscilloscope function (button out).

(4) **VOLTS-mA/DIV**—Inner ring (black scale) indicates the calibrated voltage or current vertical deflection factor selected for oscilloscope display when the VOLTS-mA/DIV VAR control is in the CAL detent. Outer ring (blue scale) indicates the full scale range selected for the digital multimeter.

(5) **PWR (BTRY)**—Lights when instrument is on and sufficient battery charge is available. Light extinguishes when battery requires recharging.

(6) Ω—Selects resistance mode for digital multimeter. RMS button must be in the out position when measuring resistance or the reading accuracy will be degraded.

(7) **mA**—Selects current mode for either digital multimeter or oscilloscope function.

(8) **SEC/DIV**—Selects the calibrated sweep rate for the oscilloscope when the HORIZ MGF VAR control is in the CAL detent.

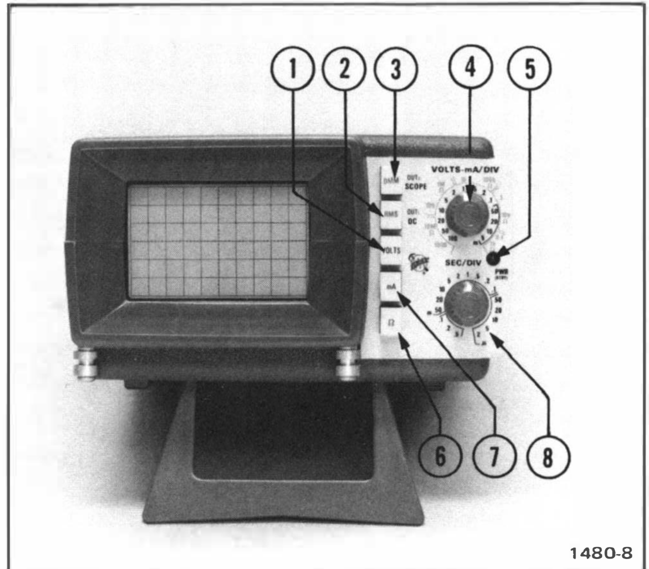

Fig. 2. Front panel.

SIDE PANEL

(9) **DC BAL**—Screwdriver adjustment to adjust for minimum trace shift, or change in DMM zero reading, when switching vertical deflection factors or DMM range.

(10) **POWER**—Turns instrument on and off. When the instrument is connected to the power line, charging power is provided to the batteries in either position of the switch.

(11) **INPUT COUPLING**—Selects method for coupling of input signal from voltage probe into input amplifier.

AC: Signal is capacitively coupled and the dc component is blocked.

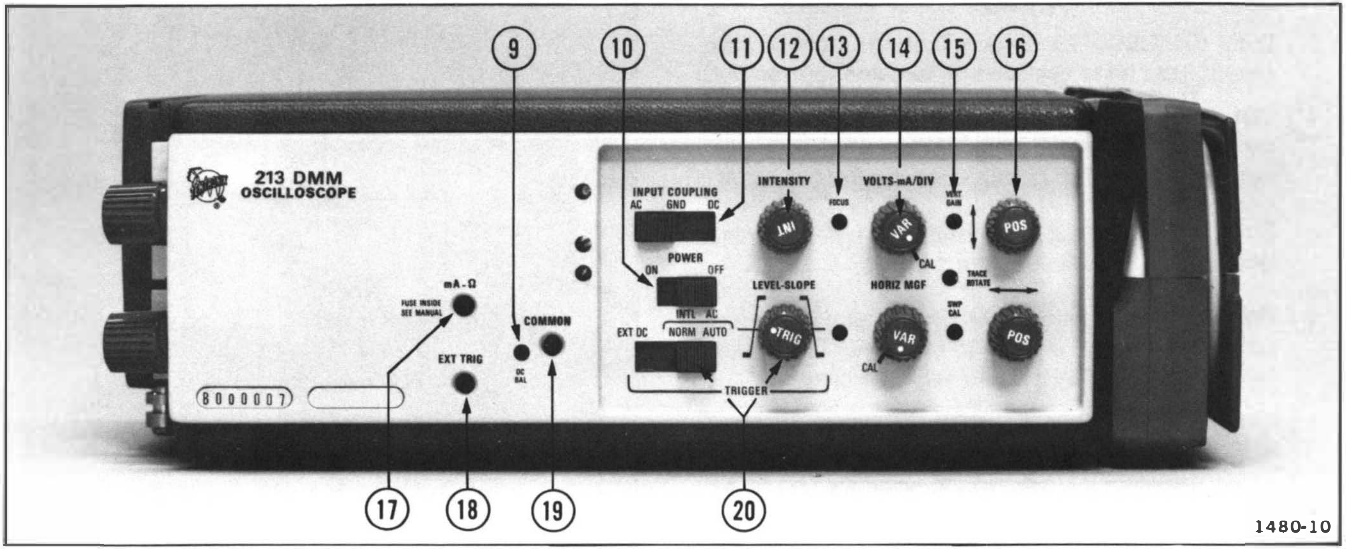

Fig. 3. Side panel.

GND: Connects the input amplifier to common to provide a zero reference voltage without physically disconnecting the probe from the circuit under test. Connects the input signal to the ac coupling capacitor through a 10 MΩ resistor which provides precharging.

DC: All components of the input signal are passed to the input amplifier.

(12) **INTENSITY**—Controls brightness of crt display.

(13) **FOCUS**—Screwdriver adjustment to provide optimum display definition.

(14) **VOLTS-mA/DIV VAR**—Provides continuously variable uncalibrated deflection factors to at least 2.5 times the calibrated settings of the VOLTS-mA/DIV control. The calibrated detent is at the fully clockwise position.

(15) **VERT GAIN**—Screwdriver adjustment to set the calibration of the VOLTS-mA/DIV control when the VOLTS-mA/DIV VAR control is in the calibrated detent.

(16) **POS (Vertical Arrow Line)**—Controls the vertical position of the oscilloscope display.

(17) **mA-Ω**—Banana jack input for current and resistance measurements. In the Ω mode, this jack is negative with respect to the COMMON jack.

(18) **EXT TRIG**—Banana jack high impedance input for external trigger voltage.

(19) **COMMON**—Banana jack common return path for current and resistance measurements, or as an alternate reference point or common return when using the voltage probe. It is electrically connected to the probe common clip.

(20) **TRIGGER**—This section contains the trigger mode and level-slope controls.

EXT DC: Selects dc coupled external trigger.

INTL AC NORM: Selects internal ac coupled trigger signal. There is no trace when the vertical input signal is not sufficient to cause triggering.

INTL AC AUTO: Same as INTL AC NORM except the sweep free runs and provides a bright reference trace when the vertical input signal is not sufficient to cause triggering.

LEVEL-SLOPE: Selects the amplitude point and slope of the trigger signal on which the sweep is triggered. When the control indicator dot is to the left of center, the sweep is triggered on the positive-going slope of the trigger signal as shown by the positive-going waveform. When to the right of center, the sweep is triggered on the negative-going slope of the trigger signal as shown by the negative-going waveform.

(21) **HORIZ MGF VAR**—Provides continuously variable uncalibrated sweep magnification to at least 5 times the sweep rate indicated by the SEC/DIV control. The calibrated detent is at the fully counterclockwise position.

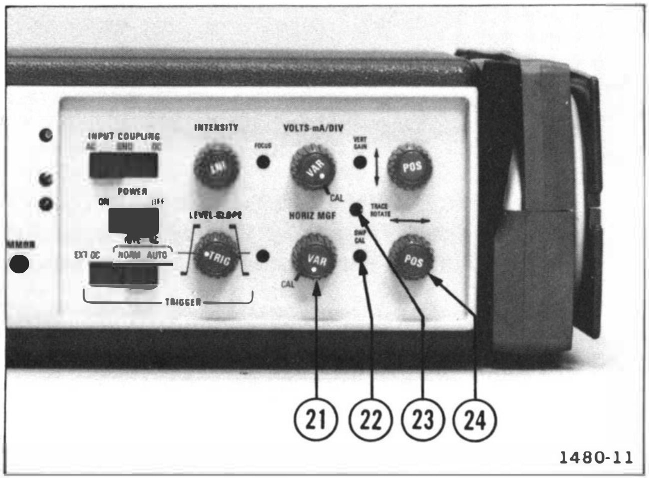

Fig. 4. Partial side panel.

(22) **SWP CAL**—Screwdriver adjustment to set the calibrated sweep timing of the SEC/DIV control when the HORIZ MGF VAR control is in the calibrated detent.

(23) **TRACE ROTATE**—Screwdriver adjustment to align trace with the horizontal graticule line.

(24) **POS (Horizontal Arrow Line)**—Controls the horizontal position of the oscilloscope display.

REAR PANEL

(25) **Integral Voltage Probe**—Used by both the DMM and oscilloscope for all voltage measurements. The alligator clip is the common connection.

(26) **Insulated Compartment**—Used to store the power line plug when battery operated.

(27) **Power Cord**—Used when instrument is to be operated on power line voltage or the batteries are being charged. When battery operated, the power line plug should be stored in the rear panel insulated compartment. To store the power cord, wrap the cord in the direction of the arrow located on top of the vinyl cord wrap cover. On the last wrap, store the plug in the insulated compartment.

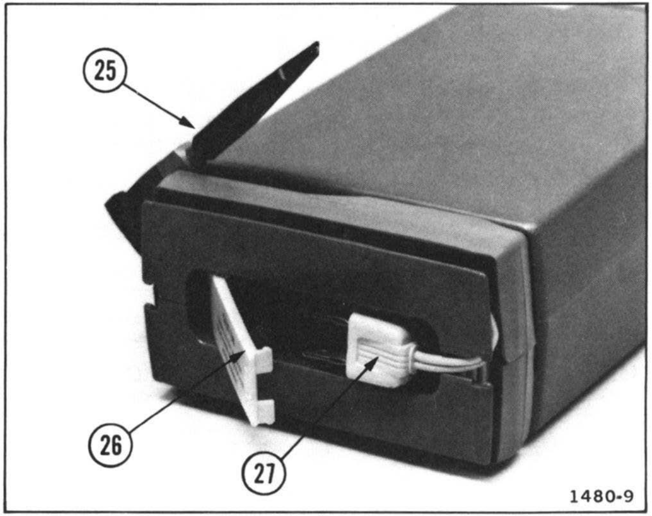

Fig. 5. Rear panel.

PROBE STORAGE

To store the probe, lay the common clip lead parallel to the probe lead, and attach the common clip to the probe lead with the small plastic clip provided on the common clip. Then, snugly wrap the leads in the direction of the arrow on the vinyl cord wrap cover (see Fig. 6). When the common clip is in position to be wrapped into the bottom side of the storage slot, gently press the common clip down into the slot (see Fig. 6) and continue to wrap the leads. As the wrap is completed, carefully guide the probe into its place in the top slot of the vinyl cover (see Fig. 5) and gently press the probe down into the slot.

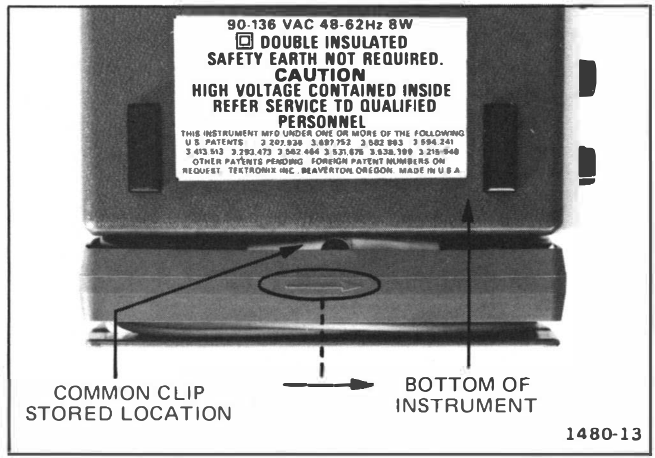

Fig. 6. Probe storage.

OPERATING POWER INFORMATION

INTERNAL BATTERY OPERATION

This instrument features battery operation from two internal rechargeable nickel-cadmium cells. The operating time of the internal batteries depends upon display intensity, battery charge and discharge temperature, and the function (DMM or Oscilloscope) being used. When the batteries are charged and operated at +20 to +30°C (+68 to +86°F), the typical operating time of fully charged batteries at maximum display intensity in the DMM mode of operation is 3.5 hours.

A light-emitting diode (LED), labeled PWR (BTRY), indicates that the instrument is on and the battery charge is sufficient for operation. When the battery charge is low, the LED extinguishes. Within 4 to 10 minutes after the LED extinguishes, an automatic battery deep discharge protection circuit will turn the instrument off. This prevents excessive discharge which would result in battery damage.

BATTERY CHARGING

To charge the batteries, connect the instrument to the power line and allow at least 16 hours for the batteries to reach full charge. To obtain the longest operating life for the batteries, the instrument should be turned on at least once a month and the batteries discharged, and then recharged for 24 hours. This procedure balances the charge on the batteries and reduces the possibility of either cell becoming reverse charged.

The 213 can be operated while the batteries are being charged.

NOTE

If the instrument does not operate with ac power applied, and the PWR (BTRY) indicator does not light, the power line fuse may be blown. See Power Line Fuse Replacement for instructions.

The energy capacity of nickel-cadmium cells varies with the temperature at which they are charged and operated. Table 1 shows the percentage of full charge capacity at various charging and operating temperatures.

TABLE 1

Battery Charge Capacity

Charging Temperature	Operating Temperature		
	−15°C	+20°C to +30°C	+55°C
0°C	40%	60%	50%
+20°C to +30°C	65%	100%	85%
+40°C	40%	65%	55%

Nickel-cadmium cells will self-discharge when the instrument is not used or is stored for extended periods of time. The rate of self-discharge is dependent upon temperature and humidity. When the instrument is to be stored for extended periods of time, particularly at high temperature or high humidity, the batteries should be charged for at least 16 hours every two weeks, or leave the 213 connected to the power line.

POWER LINE OPERATION

This instrument can be operated from a power line voltage of 90 to 136 V, 48 to 62 Hz (180 to 250 V, 48 to 62 Hz or 180 to 250 V dc for Option 1).

OPERATING TEMPERATURE

The 213 can be battery operated in ambient air temperatures between −15 and +55°C (+5 and +131°F). It should be connected to the power line only in ambient air temperatures between 0 and +40°C (+32 and +104°F).

POWER LINE FUSE REPLACEMENT

To replace the power line fuse requires removal of the top and bottom cabinet halves (removal of top half necessitates removal of the bottom half for reassembly of the power cord and probe leads). Proceed as follows:

WARNING

Potentially dangerous voltages exist inside this instrument when it is operating. Disconnect the instrument from the power line and turn it off (disconnecting the instrument from the power line does not turn it off) before removing the cabinet halves.

1. Unwind the probe lead and then the power cord. Turn the instrument on its top and remove the four screws holding the cabinet together (see Fig. 7). Two of the screws are located inside the probe storage slot.

CAUTION

The instrument is not secured to either cabinet half except by a tight fit around the crt face plate; therefore, if the instrument remains attached to either cabinet half as it is lifted off, it can drop free and be damaged.

2. Remove the bottom cabinet half and note the position of the power cord and probe lead inside the rear of the cabinet.

3. Lift the instrument out of the top cabinet half.

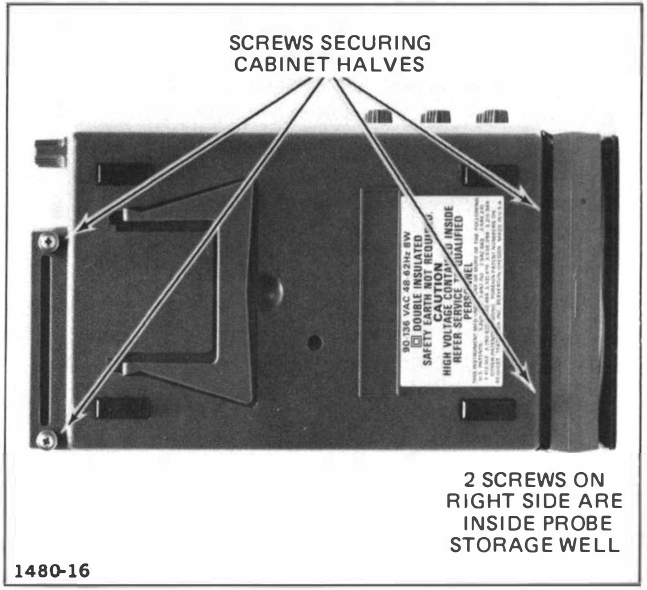

Fig. 7. Location of screws securing cabinet halves.

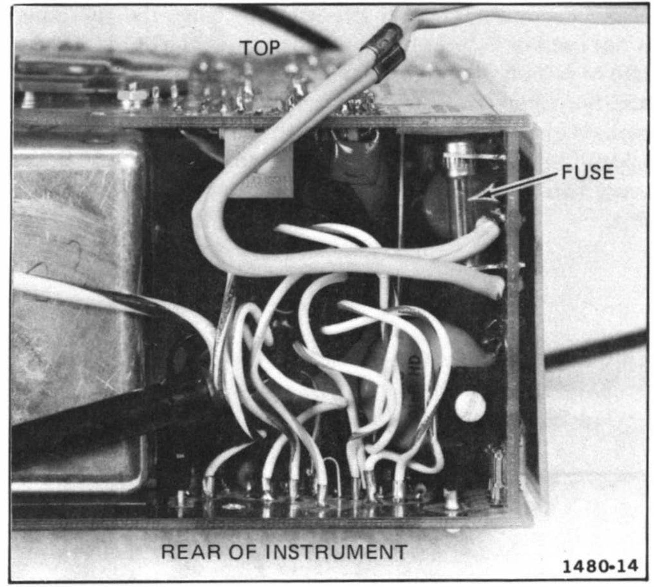

Fig. 8. Power line fuse location.

4. Replace the power line fuse (see Fig. 8) and reassemble the cabinet halves in the reverse order of disassembly. Be sure the power line cord and probe lead are properly placed at the inside rear of the cabinet and in their respective cabinet exit slots before installing the bottom half. One method of installing the insulated compartment door is to lightly tighten the rear screws, then insert the door hinge in its respective holes and tighten the screws.

CURRENT (mA) INPUT FUSE REPLACEMENT

Replace the mA input protective fuse as follows:

1. Remove the bottom cabinet half as described in steps 1 and 2 of the Power Line Fuse Replacement instructions.

2. Unplug the mA protective fuse from its socket (see Fig. 9). Replace fuse and reassemble the bottom cabinet half in the reverse order of removal.

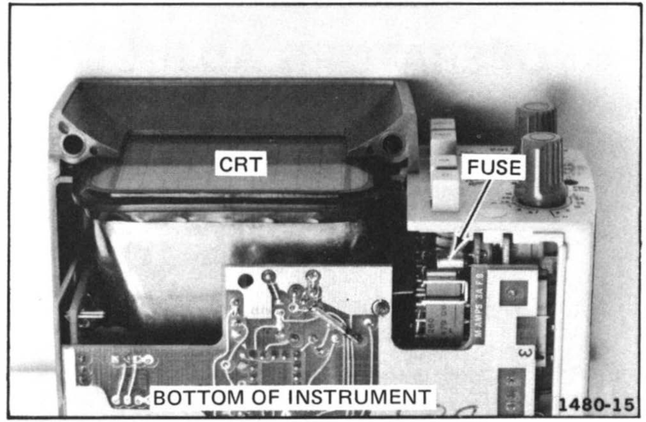

Fig. 9. mA input fuse location.

OPERATORS ADJUSTMENTS AND BASIC DISPLAYS

This section provides instructions for making initial operators adjustments and obtaining basic displays. Since these procedures involve most of the controls and connectors, they can be used for basic familiarization on the operation of the instrument. Before starting the check-out, either charge the batteries for at least 16 hours or connect the instrument to the power line.

WARNING

When battery operated, store the power line plug in the rear-panel insulated compartment. Potentials applied to the common connectors may cause small amounts of current to flow in the power line circuitry creating a possible shock hazard on the power plug prongs.

WARNING

The probe common clip and the COMMON jack are electrically connected to each other, and potentials applied to one are present on the other creating a possible shock hazard.

CAUTION

The probe common clip and COMMON jack are electrically connected to each other. Dissimilar voltages applied to the common clip and COMMON jack can cause equipment damage.

OPERATORS ADJUSTMENTS

The equipment required to make the initial operators adjustments is a screwdriver with a maximum blade size of 3/32 inch. To obtain the basic displays, a dc source, an ac source, and one or two resistors are required. Suggested items for the basic displays are a battery, an audio signal generator, a 3 kΩ resistor, and a 100 kΩ resistor.

1. Set the controls as follows:

POWER	ON
INPUT COUPLING	GND
TRIGGER	AUTO
LEVEL-SLOPE	Midrange of either slope (do not set at control midrange)
VOLTS-mA/DIV VAR	CAL detent
HORIZ MGF VAR	CAL detent
POS (both)	Midrange of control
DMM (OUT:SCOPE)	Button out
RMS (OUT:DC)	Button out
VOLTS	Button in
VOLTS-mA/DIV	1 (blue scale)
SEC/DIV	.5 m
INTENSITY	Minimum for a visible trace

2. Set the SEC/DIV control to .5 and adjust the FOCUS control (screwdriver adjustment on the side panel) for the best spot definition (the dot will be slowly sweeping across the screen from left to right).

3. Set the SEC/DIV control to .5 m and adjust the vertical POS control so the trace coincides with the center horizontal graticule line. If the trace is not parallel with this line, adjust the TRACE ROTATE control (screwdriver adjustment on the side panel) for coincidence.

4. Depress the DMM pushbutton. Alternately switch the VOLTS-mA/DIV control between the 0.1 volt and 1 volt ranges (blue scale) and check for the same count (approximately zero) and polarity sign in both positions. If they are not the same, adjust DC BAL (screwdriver adjustment on the side panel) for the same count and polarity sign.

DIGITAL MULTIMETER DISPLAYS

Voltage Measurement Display

1. Perform the Operators Adjustments steps.

2. Set the INPUT COUPLING switch to DC, select a VOLTS-mA/DIV range (blue scale) compatible with the amplitude of the dc voltage source to be measured, and connect the dc voltage source between the probe tip and the probe common clip. The display represents the value of the dc voltage source.

3. Reverse the probe tip and common clip connections and note that the numerical reading remains approximately the same but the opposite polarity sign is displayed. Disconnect the dc source.

4. Depress the RMS pushbutton, set the INPUT COUPLING switch to AC, select a VOLTS-mA/DIV range (blue scale) compatible with the amplitude of the ac voltage source to be measured, and connect the ac voltage source between the probe tip and probe common clip. The display represents the value of the ac voltage source. Set the RMS pushbutton to the out position and note that the average dc value of the ac signal is zero verifying that the ac filter is operational. Disconnect the ac signal.

Current Measurement Display

5. Depress the mA pushbutton, set the RMS pushbutton to the out position, and select a VOLTS-mA/DIV range (blue scale) compatible with the amplitude of the current generated by the dc voltage source and a series current limiting resistor. Connect the dc voltage source in series with the current limiting resistor, and connect this combination between the mA-Ω jack and the COMMON jack with test leads. The display represents the value of the dc current. Disconnect the dc source and resistor.

6. Depress the RMS pushbutton and select a VOLTS-mA/DIV range (blue scale) compatible with the amplitude of the current generated by the ac voltage source and a series current limiting resistor. Connect the ac voltage source in series with the current limiting resistor, and connect this combination between the mA-Ω jack and the COMMON jack with test leads. The display represents the value of the ac current. Disconnect the ac source and resistor.

Resistance Measurement Display

7. Depress the Ω pushbutton and set the RMS pushbutton to the out position. Select a VOLTS-mA/DIV range compatible with the value of the resistor to be measured and connect the resistor between the mA-Ω jack and COMMON jack with test leads. The display represents the value of the resistor.

Overrange Display

8. Disconnect the resistor and the display shows an overrange condition.

OSCILLOSCOPE DISPLAYS

Normal Sweep Display

1. Perform the Operators Adjustments steps.

2. Set the DMM pushbutton to the out position and INPUT COUPLING switch to AC. Select a VOLTS-mA/DIV range (black scale) compatible with the amplitude of the ac voltage source to be applied and connect the ac voltage source between the probe tip and probe common clip. Select a SEC/DIV range for the desired display and adjust the LEVEL-SLOPE control for a stable display.

3. Rotate the VOLTS-mA/DIV VAR control counterclockwise out of its calibrated detent and observe the reduction in the vertical size of the display. Return the control to the CAL detent.

4. Set TRIGGER switch to NORM and rotate the LEVEL-SLOPE control to obtain a stable display at some position on both slopes of the control. Reset the TRIGGER switch to AUTO.

Magnified Sweep Display

5. Adjust the horizontal POS control to move the display to be magnified to the center portion of the crt. Turn the HORIZ MGF VAR control clockwise out of its calibrated detent and adjust the display for the desired amount of magnification. Return the control to its CAL detent. Disconnect the ac source.

APPLICATIONS AND MEASUREMENTS

Once the operator becomes familiar with the instrument and makes the initial operator's adjustments, this section will aid in making measurements. Basically, this instrument is used the same as if it were an individual multimeter or general purpose oscilloscope with the added convenience of being able to change modes with the push of a switch.

The procedures for making the basic voltage, current, and resistance measurements with the digital multimeter are the same as those in the Operators Adjustments and Basic Displays section and will not be duplicated here.

PRELIMINARY INFORMATION

Common Connections

Reliable signal measurements cannot be made unless the instrument and unit under test are connected together by a common reference. The common clip on the probe provides the best common connection when using the probe, while the COMMON jack is used with a mA-Ω input jack. Also, the COMMON jack may be used as an alternate common connection for the probe.

WARNING

The probe common clip and the COMMON jack are electrically connected to each other. Potentials applied to one are present on the other which creates a possible shock hazard.

CAUTION

The probe common clip and COMMON jack are electrically connected to each other. Dissimilar voltages applied simultaneously to the common clip and COMMON jack can cause equipment damage.

Measurement Precautions

When making measurements with the probe or mA-Ω lead, the unused lead and its corresponding common connection should be disconnected to prevent a signal on that lead from interferring with the signal being measured.

When making resistance measurements, check that the RMS pushbutton is in the out position or the reading will be in error. Also, if the circuit being measured is voltage sensitive, the mA-Ω lead will be at a negative potential with respect to the common connection. The potential across the unknown resistance is −1 V per 1000 counts on the 10 kΩ through 10 MΩ ranges, and −0.1 V per 1000 counts on the 1 kΩ range.

When making voltage measurements, the mA-Ω input jack is connected to common; therefore, any voltage applied to the mA-Ω input jack may blow the internal protection fuse. See Current (mA) Input Fuse Replacement for instructions.

RMS Considerations

When making rms voltage measurements, the composition of the signal and the type of input coupling must be considered. For current measurements, the input is always dc coupled. The input voltage signal may be ac only (average value is zero) or a composite of ac and dc, in which case, the type of input coupling selected will affect the reading.

If the input voltage signal is ac only (average value is zero), either the AC or DC position of the INPUT COUPLING switch may be used.

If the input voltage signal is ac and dc (average value is not zero), two different rms values are possible. With the INPUT COUPLING switch in the AC position, the dc (or average value) is blocked and the reading is the rms value of the ac portion of the signal. In the DC position of the INPUT COUPLING switch, the reading is the rms value of the combined ac and dc signal.

Unknown Voltage and Current Measurements With DMM

When making unknown voltage and current measurements with the digital multimeter, always set the VOLTS-mA/DIV control on the highest range before attaching the probe or mA-Ω test lead. Then decrease the range until overrange occurs (scrambled character segments or 8's) and then increase the range one step.

PROCEDURES

Peak-to-Peak AC Voltage

The oscilloscope is used to measure peak-to-peak ac voltages or the voltage between any two points on a waveform.

If the amplitude measurement is critical or the trace is thick as a result of noise, hum, etc. on the signal, measure from the peak of the signal to the valley. This method subtracts the trace thickness from the measurement.

Make sure the VOLTS-mA/DIV VAR control is in the calibrated detent. Vertically position the display so the lower portion coincides with a graticule line and the upper portion is in the viewing area. Horizontally position the display so one of the upper peaks lies near the center vertical line (see Fig. 10).

Measure the divisions of vertical deflection from peak to peak and multiply the vertical deflection by the VOLTS-mA/DIV control setting.

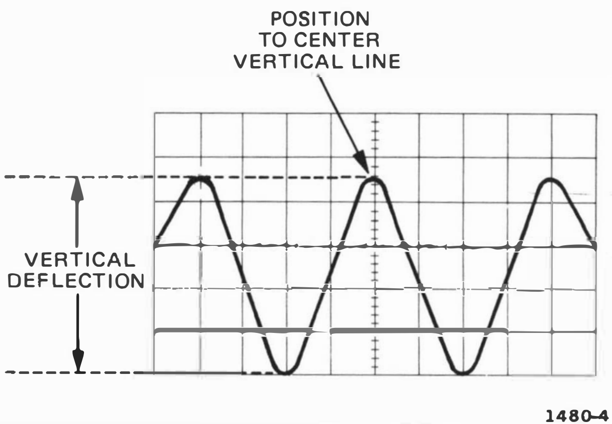

Fig. 10. Peak to peak voltage of a waveform.

EXAMPLE: The peak-to-peak vertical deflection measured is 4.6 divisions (see Fig. 10) with the VOLTS-mA/DIV control set at .5.

Using the formula:

$$\text{Volts Peak-to-Peak} = \text{vertical deflection (divisions)} \times \text{VOLTS-mA/DIV setting}$$

Substituting: $4.6 \times .5 = 2.3\ \text{V}$

Instantaneous DC Voltages

Make sure the VOLTS-mA/DIV VAR control is in the calibrated detent. Alternately switch the INPUT COUPLING switch between GND and DC to establish the polarity of the signal. If the waveform deflection is above the reference graticule line, the voltage is positive; below the line is negative. If the voltage to be measured is positive, set the INPUT COUPLING switch to GND and position the trace to the bottom graticule line. Do not move the vertical POS control after this reference line is established.

Set the INPUT COUPLING switch to DC. Measure the divisions of deflection between A and B (see Fig. 11). Multiply the vertical deflection by the VOLTS-mA/DIV control setting.

EXAMPLE: The vertical distance measured in 5 divisions (see Fig. 11), the waveform is above the reference line, and the VOLTS-mA/DIV control is set to .5.

Using the formula:

$$\text{Instantaneous Voltage} = \text{vertical distance (divisions)} \times \text{polarity} \times \text{VOLTS-mA/DIV setting}$$

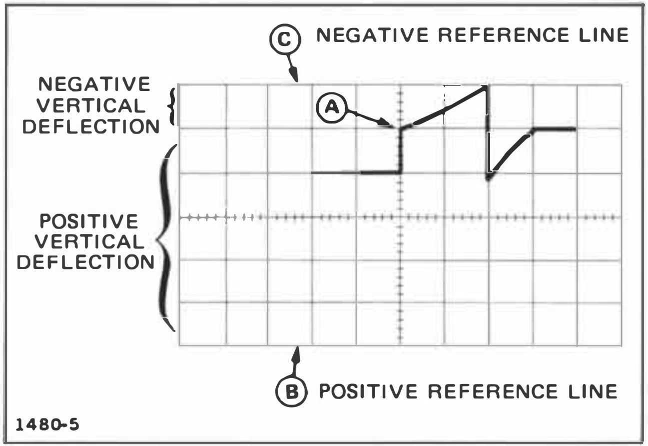

Fig. 11. Dc voltage with respect to a reference line.

Substituting:

$$5 \times +1 \times .5 = +2.5\ V$$

If a negative voltage is to be measured, position the trace to the top graticule line and measure between A and C (see Fig. 11).

The ground reference line can be checked at any time by setting the INPUT COUPLING switch to the GND position.

To measure a voltage level with respect to another voltage level, connect the common lead to the reference voltage and make an instantaneous voltage measurement. See Elevated Reference Voltage procedure.

Composite Voltage

In practice, most voltages measured are composites of ac and dc, and may be either sinusoidal or non-sinusoidal. It is these voltages for which this instrument is best suited.

The waveform shown in Fig. 12 has its ac zero reference at a dc level and could be representative of a dc power supply output with an ac ripple. It can be measured by combining instantaneous dc, peak-to-peak ac, and rms measurement procedures.

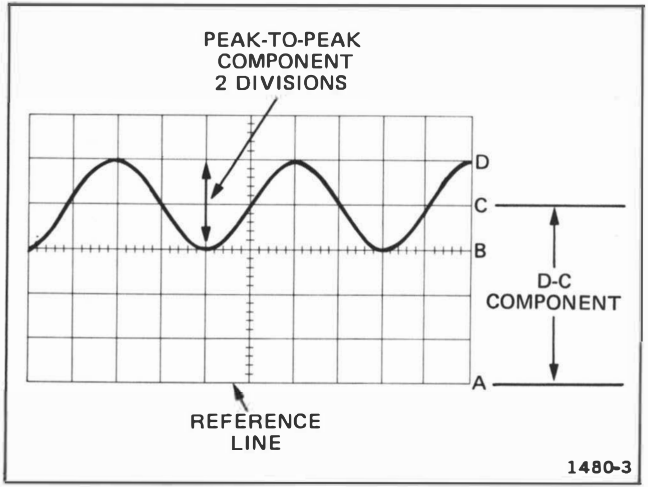

Fig. 12. Composite waveform.

Use the Instantaneous DC Voltage procedure to determine the dc component (deflection A to C) of the waveform and the Peak-to-Peak AC Voltages procedure to determine the peak-to-peak component (deflection B to D) of the waveform.

EXAMPLE: In the oscilloscope mode of operation the VOLTS-mA/DIV control is set to .5, the dc vertical deflection is 4 divisions, and the peak-to-peak vertical deflection is 2 divisions.

Using the formulas:

$$\text{Instantaneous DC Voltage} = \text{vertical deflection (divisions)} \times \text{polarity} \times \text{VOLTS-mA/DIV setting}$$

$$\text{Peak-to-Peak Voltage} = \text{vertical deflection (divisions)} \times \text{VOLTS-mA/DIV setting}$$

Substituting:

4 x +1 x .5 = 2.0 V (instantaneous dc)

2 x .5 = 1.0 V (p-p ac)

The rms component of the waveform has two values; the ac rms value of the ripple and the combined ac and dc rms value of the entire waveform. To obtain the ac rms value, set the instrument to measure rms voltage in the DMM mode of operation and select ac coupling. The reading displayed is the ac rms value of the ripple. To obtain the composite ac and dc rms value, select dc coupling. The reading displayed is the rms value of the combined ac and dc value of the entire waveform.

EXAMPLE: In the DMM mode of operation, if the ripple is a true sinewave, the readings should be approximately 0.35 volt for the ac rms value of the ripple and approximately 2.03 volts for the rms value of the entire waveform.

Another measurement value is the average dc of the combined ac and dc portion of the waveform. This is obtained in the DMM mode of operation with ac coupling and the RMS pushbutton in the out position. This value for the sample waveform is approximately 2 volts.

Time Duration

Make sure the HORIZ MGF VAR control is set to the calibrated detent. Set the SEC/DIV control for at least a single event and position the display to place the time measurements points (see Fig. 13). Measure the horizontal distance between the time measurement points and multiply the distance measured by the setting of the SEC/DIV control.

EXAMPLE: The distance between the time measurement points is 4 divisions and the SEC/DIV control is set to 2 m.

Using the formula:

$$\text{Time Duration} = \begin{array}{c}\text{horizontal}\\ \text{distance}\\ \text{(divisions)}\end{array} \times \begin{array}{c}\text{SEC/DIV}\\ \text{setting}\end{array}$$

Substituting: 4 x 2 m = 8 ms

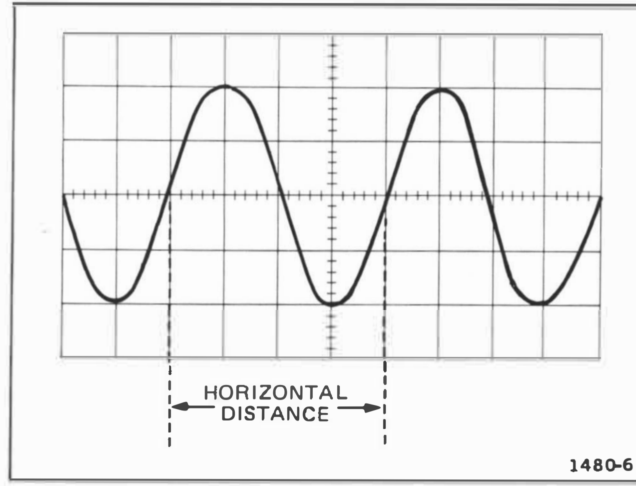

Fig. 13. Time duration between points on a waveform.

Periodic Signal Frequency

The time-duration measurement can be used to determine the frequency of a periodic signal. Measure the time-duration of one event as described in Time-Duration Measurements and compute the reciprocal of the measurement to determine the frequency.

EXAMPLE: The time duration of the signal in Fig. 13 was 8 ms. Its frequency is:

$$\text{Frequency} = \frac{1}{\text{time duration}}$$

Substituting:

$$\frac{1}{8\text{ ms}} = 125\text{ Hz}$$

Amplitude Comparison

ARBITRARY VERTICAL DEFLECTION FACTOR. The desired signal amplitude to be measured may not be an exact number of divisions of deflection. If the measurement is repetitious (e.g., on an assembly-line test), it is possible to obtain more accurate, easily read measurements if the VOLTS-mA/DIV control and the VOLTS-mA/DIV VAR control are adjusted to set the desired signal amplitude to an exact number of divisions.

To establish an arbitrary vertical conversion factor, connect a known amplitude reference signal and adjust the VOLTS-mA/DIV and VOLTS-mA/DIV VAR controls for the desired vertical deflection. Be careful not to move the VOLTS-mA/DIV VAR control after this setting.

Determine the vertical conversion factor using this formula:

$$\text{Vertical Conversion Factor} = \frac{\text{reference signal amplitude (volts)}}{\text{vertical deflection (divisions)} \times \text{VOLTS-mA/DIV setting}}$$

EXAMPLE: The reference signal amplitude measured is 30 volts with the VOLTS-mA/DIV control set to 5 and the VOLTS-mA/DIV VAR control adjusted to provide a vertical deflection of 4 divisions.

Substituting:

$$\frac{30\text{ V}}{4 \times 5} = 1.5$$

To measure the unknown signal, set the VOLTS-mA/DIV control to provide sufficient vertical deflection to make an accurate measurement. Do not readjust the VOLTS-mA/DIV VAR control. Measure the vertical deflection in divisions and calculate the amplitude of the unknown signal using the following formula:

$$\text{Signal Amplitude} = \text{VOLTS-mA/DIV setting} \times \text{vertical conversion factor} \times \text{vertical deflection (divisions)}$$

EXAMPLE: The VOLTS-mA/DIV control is set to 1 and the vertical deflection of the signal is 5 divisions.

Substituting: $1 \times 1.5 \times 5 = 7.5$ V

ARBITRARY HORIZONTAL DEFLECTION FACTOR. The desired signal time to be measured may not be an exact number of divisions. If the measurement is repetitious (e.g. on an assembly-line test), it is possible to obtain more accurate, easily-read measurements if the SEC/DIV control and the HORIZ MGF VAR control are adjusted to set the desired signal timing to an exact number of divisions.

To establish an arbitrary horizontal deflection factor, connect a known time-duration reference signal and adjust the SEC/DIV and HORIZ MGF VAR controls for the desired horizontal deflection. Be careful not to move the HORIZ MGF VAR control after this setting.

Determine the horizontal conversion factor using the formula:

$$\text{Horizontal Conversion Factor} = \frac{\text{reference signal time-duration}}{\text{horizontal deflection (divisions)} \times \text{SEC/DIV setting}}$$

EXAMPLE: The reference signal time-duration is 2.19 ms (455 Hz) with the SEC/DIV control set to .2 m, and the HORIZ MGF VAR control adjusted to provide a horizontal deflection of 8 divisions.

Substituting: $$\frac{2.19\text{ ms}}{8 \times .2\text{ m}} = 1.37$$

To measure the unknown signal, set the SEC/DIV control to provide sufficient horizontal deflection to make an accurate measurement. Do not readjust the HORIZ MGF VAR control. Measure the horizontal deflection in divisions and calculate the time-duration of the unknown signal using the following formula:

$$\text{Time-Duration} = \text{SEC/DIV setting} \times \text{horizontal conversion factor} \times \text{horizontal deflection (divisions)}$$

EXAMPLE: The SEC/DIV control is set to 50 μ and the horizontal deflection is 7 divisions.

Substituting: $50\,\mu \times 1.37 \times 7 = 479.5\,\mu s$

Frequency can be obtained by computing the reciprocal of the time-duration.

Risetime

Risetime measurements use the same methods as time-duration measurements, except the measurements are made between the 10% and 90% points of the waveform. Falltime is measured between the 90% and 10% points on the trailing edge of the waveform.

Use a sweep speed setting that displays several cycles or events (if possible) and be sure the HORIZ MGF VAR control is in the calibrated detent. Set the VOLTS-mA/DIV and VOLTS-mA/DIV VAR controls (or signal amplitude) for exactly a 5 division display. Set vertical positioning so the display bottom crosses the midpoint of the bottom graticule division and the display top crosses the midpoint of the top graticule division (see Fig. 14).

Set the SEC/DIV control for a single-event display and horizontally position the display to the 10% point of the waveform intersects the second vertical graticule line (see Fig. 14).

Measure the horizontal distance between the 10% and 90% points and multiply the distance measured by the SEC/DIV control setting.

EXAMPLE: The horizontal distance between the 10% and 90% points is 4 divisions and the SEC/DIV control is set to 2 μ.

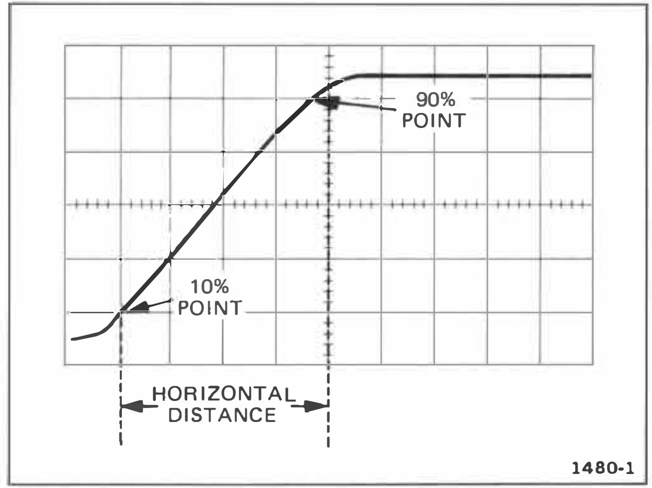

Fig. 14. Risetime.

Using the time duration formula to find risetime:

$$\text{Time Duration (risetime)} = \text{horizontal distance (divisions)} \times \text{SEC/DIV setting}$$

Substituting: $4 \times 2\,\mu = 8\,\mu s$

Elevated Reference Voltage

Elevated reference is a method of making a voltage measurement with respect to some reference voltage level rather than to a zero reference. These measurements are made by connecting the probe common clip or the COMMON jack directly to the reference voltage, and then making unknown voltage measurements by the procedures given earlier in this section.

WARNING

Before making elevated reference measurements, refer to the Common Isolation specifications at the rear of this manual, and the Common Connections paragraph at the beginning of this section.

OPERATORS SPECIFICATIONS

Refer to the service manual for complete specifications. Specifications given are for a warm-up time of 10 minutes and an operating temperature range of −15°C to +55°C unless otherwise stated.

When operating on power line voltage, add 10°C to the ambient temperature before computing DMM Temperature Coefficient (Temp Coef) accuracy factor. This compensates for internal heating caused by battery charger operation.

TABLE 2

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement
DC AND RMS VOLTS	
Range	0.1 V to 1000 V
Resolution	100 μV on 0. 1V range
Input Resistance	10 MΩ within 1%
Input Capacitance	
0. 1V to 10 V	Approximately 150 pF
100 V to 1000 V	Approximately 100 pF
Input Leakage Current	200 pA max at 30°C or less with 2 mV or less change from open to shorted probe
Max Safe Input Voltage	Ac component 1 MHz or less
0. 1V to 10 V	
Dc Coupled	500 V (dc + peak ac)
Ac Coupled	800 V (dc + peak ac). 500 V peak ac component max
100 V and 1000 V	800 V (dc + peak ac)

TABLE 2 (continued)

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement
DC VOLTS	
Accuracy (+20°C to +30°C) (Batteries Only)	Refer to the opening paragraphs under Operators Specifications for power line operation
0.1 V	Within 0.1% of reading ± 3 counts. Temp Coef is (within 0.015% of reading + 0.04% of full scale) per °C.
1 V	Within 0.1% of reading ± 1 count. Temp Coef is (within 0.01% of reading + 0.01% of full scale) per °C.
10 V and 100 V	Within 0.15% of reading ±1 count. Temp Coef is (within 0.015% of reading + 0.01% of full scale) per °C
1000 V	Within 0.2% of reading ± 1 count. Temp Coef is (within 0.02% of reading + 0.01% of full scale) per °C
Settling Time	1.5 seconds for reading within 0.1%
Normal Mode Rejection Ratio	–60 dB at 60 Hz, –3 dB at 1 Hz

TABLE 2 (continued

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement		
RMS VOLTS			
Accuracy (20°C to +30°C) (Batteries only – refer to opening paragraphs under Operators Specifications for power line operation). Crest factor < 2, reading at least 10% of full scale.	Temp Coef is (within 0.05% of reading +0.1% of full scale) per °C Within % of reading shown ± 5 counts at frequency shown:		
	Dc	40 Hz to 4 kHz	4 kHz to 40 kHz
0.1 V	2.5%	1.5%	3.5%
1 V	2%	1%	1%
10 V	2%	1%	1%
100 V	2%	1%	1%
1000 V	2%	1%	2%
Settling Time	2 seconds for reading within 1%		
Max Crest Factor[1]	Approximately 5		

[1] **Supplemental information only.**

TABLE 2 (continued)

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement
DC AND RMS CURRENT	
Range	0.1 mA to 1000 mA
Resolution	100 nA on 0.1 mA range
Input Shunt Resistance (Approximate)	
0.1 mA	1000 Ω
1 mA	100 Ω
10 mA	10.2 Ω
100 mA	1.2 Ω
1000 mA	0.3 Ω
Max Safe Input Current	2A rms on any scale or 3A peak

TABLE 2 (continued)

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement
DC CURRENT	
Accuracy (+20°C to +30°C) (Batteries only—refer to opening paragraphs under Operators Specifications for power line operation)	Temp Coef is (within 0.02% of reading +0.04% of full scale) per °C
0.1 mA Range	Within 0.5% of reading ± 3 counts
1 mA to 1000 mA	Within 0.25% of reading ± 3 counts
Settling Time	1.5 seconds for reading within 0.1%

TABLE 2 (continued)

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement		
RMS CURRENT			
Accuracy (+20°C to +30°C)	Temp Coef is (within 0.05% of reading +0.1% of full scale) per °C		
(Batteries only—refer to opening paragraph of Operators Specifications for power line operation)			
(Crest factor < 2, rdng at least 10% of full scale)	Within % of reading shown ± 5 counts at frequency shown		
	Dc	40 Hz to 4 kHz	4 kHz to 40 kHz
0.1 mA	2.5%	1.5%	4.5%
1 mA to 1000 mA	2.5%	1.5%	3.5%
Max Crest Factor[1]	Approximately 5		
Settling Time	2 seconds for reading within 1%		

[1] Supplemental information only.

TABLE 2 (continued)

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement
RESISTANCE	
Range	1 kΩ to 10 MΩ
Resolution	1 Ω on 1 kΩ range
Accuracy (20°C to 30°C) (Batteries only)	Refer to opening paragraphs under Operators Specifications for power line operation
1 kΩ	Within 0.5% of reading ± 3 counts. Temp Coef is (within 0.03% of reading + 0.04% of full scale) per °C
10 kΩ to 1 MΩ	Within 0.5% of reading ± 1 count. Temp Coef is (within 0.02% of reading + 0.02% of full scale) per °C
10 MΩ	Within 1% of reading ± 1 count. Temp Coef is (within 0.05% of reading + 0.02% of full scale) per °C
Accidental Voltage Input Protection	125 V maximum on all ranges
Settling Time	2 seconds for reading within 2 counts
Reference Current[1]	Approximately 100 μA, 100 μA, 10 μA, 1 μA, and 100 nA for ranges 1 kΩthrough 10 MΩ respectively

[1] Supplemental information only.

TABLE 2 (continued)

Digital Multimeter Electrical Specifications

Characteristic	Performance Requirement
READOUT DISPLAY	
Number of Digits	3½ digits plus decimal and polarity sign
Sampling Rate[1]	Approximately 7 readings per second
Overrange Capability	At least 200% of full scale
Indication	Readout displays scrambled character segments or 8's
Input Amplifier Overload[1]	Indicates when input signal peak > 4 X selected range
A-D Converter Overload[1]	Indicates when readout display exceeds 2500 within 400 counts
RMS Converter Overload[1]	Indicates when crest factor exceeds approximately 5

[1] **Supplemental information only.**

TABLE 3

Oscilloscope Electrical Specifications

Characteristic	Performance Requirement
VERTICAL DEFLECTION SYSTEM	
DEFLECTION FACTOR	
Calibrated Range	5 mV to 100 V/div 5 μA to 100 mA/div
Accuracy	Within 3%
FREQUENCY RESPONSE	
5 μA to 10 μA/div	Dc to at least 200 kHz at −3 dB
20 μA to 100 mA/div 5 mV to 10 mV/div	Dc to at least 400 kHz at −3 dB
20 mV to 100 V/div	Dc to at least 1 MHz at −3 dB
Lower −3 dB point ac coupled (voltage only)	1 Hz or less

TABLE 3 (cont.)
Oscilloscope Electrical Specifications

Characteristic	Performance Requirement
VERTICAL DEFLECTION SYSTEM (cont.)	
STEP RESPONSE[1]	
Risetime	
5 mV and 10 mV/div	875 ns or less
20 mV to 100 V/div	350 ns or less
Aberrations	+5% to −2%. Total not to exceed 5% p-p
INPUT RESISTANCE (VOLTAGE)	10 MΩ within 1%
INPUT SHUNT RESISTANCE (CURRENT)	
5 μA to 10 μA/div	1000 Ω
20 μA to 100 μA/div	100 Ω
200 μA to 1 mA/div	10.2 Ω
2 mA to 10 mA/div	1.2 Ω
20 mA to 100 mA/div	0.3 Ω

[1] Supplemental information only.

TABLE 3 (cont.)

Oscilloscope Electrical Specifications

Characteristic	Performance Requirement
VERTICAL DEFLECTION SYSTEM (cont.)	
INPUT CAPACITANCE (VOLTAGE)	
5 mV to 1 V/div	Approximately 150 pF
2 V to 100 V/div	Approximately 100 pF
MAX SAFE INPUT VOLTAGE	Ac component 1 MHz or less
5 mV to 1 V/div	
Dc Coupled	500 V (dc + peak ac)
Ac Coupled	800 V (dc + peak ac) 500 V peak ac component maximum
2 V to 100 V/div	800 V (dc + peak ac)
MAX SAFE INPUT CURRENT	2 A rms on any range or 3A peak

TABLE 3 (cont.)
Oscilloscope Electrical Specifications

Characteristic	Performance Requirement
TRIGGERING	
TRIGGER SENSITIVITY	
Intl Ac Norm	0.5 div, 7 Hz to 1 MHz
Intl Ac Auto	Same as Intl Ac Norm except sweep free runs when input signal is not sufficient to cause triggering
Ext Dc	1 V, dc to 1 MHz
TRIGGER JITTER	0.5 μs or less at 1 MHz
INPUT IMPEDANCE	1 MΩ within 10% shunted by approximately 20 pF
MAX SAFE INPUT VOLTAGE[1]	200 V (dc + peak ac)
MAX USABLE INPUT VOLTAGE[1]	±8 V peak at 1 MHz or less

[1] Supplemental information only.

TABLE 3 (cont.)

Oscilloscope Electrical Specifications

Characteristic	Performance Requirement
HORIZONTAL DEFLECTION SYSTEM	
SWEEP RATE	
Calibrated Range	500 ms to 2 μs/div
Accuracy Over Center 8 Divisions	Within 5%

TABLE 4

Power Requirements

Characteristic	Performance Requirement
BATTERY OPERATION	
Type Batteries	Two rechargeable nickel-cadmium cells, D size
Typical Operating Time	3.5 hours
Typical Charge Time	16 hours
POWER LINE OPERATION	
Standard Voltage	90 to 136 Vac, 48 to 62 Hz
Option 1 Voltage	180 V to 250 V, dc or 48 to 62 Hz ac
Max Power Consumption	Less than 8 W

TABLE 5
Common Isolation Protection

Characteristic	Performance Requirement
BATTERY OPERATED	
(Common Input to Case)	Common input floating voltage not greater than 500 V rms or 700 V (dc + peak ac).
POWER LINE OPERATED	
(Common Input to Power Line)	Common input rms floating voltage plus the power line voltage not greater than 250 V rms.
	Common input composite (dc + peak ac) floating voltage plus 1.4 times the power line voltage not greater than 350 V rms.

TABLE 6
Environmental

Characteristic	Performance Requirement
TEMPERATURE	
Operating on Batteries	-15°C to $+55^{\circ}$C
Charging or Operating from Power Line	0°C to $+40^{\circ}$C
Storage	-40°C to $+60^{\circ}$C
ALTITUDE	
Operating	To 25,000 feet
Storage	To 40,000 feet
HUMIDITY	
Operating and Storage	80% or less relative humidity at $+40^{\circ}$C or less

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

MANUAL CHANGE INFORMATION

Tektronix®
COMMITTED TO EXCELLENCE

Date: 12-22-87

Change Reference: M65652

Product: 213 OPERATORS

Product Group 40

Manual Part No.: 070-1480-00

Replace the table on Page 31 with the following:

Characteristics	Performance Requirements		
RMS VOLTS			
Accuracy (20°C to +30°C) (Batteries only - refer to opening paragraphs under Operators Specifications for power line operation). Crest factor <2, reading at least 10% of full scale.	Temp Coef is (within 0.05% of reading + 0.1% of full scale) per °C. Within % of reading shown ± 5 counts at frequency shown:		
	DC	40 Hz to 1 kHz	1 kHz to 40 kHz
0.1V	2.5%	1.5%	3.5%
1V	2%	1%	1%
10V	2%	1%	5%
100V	2%	1%	1%
1000V	2%	1%	5%
Settling Time	2 seconds for reading within 1%.		
Max Crest Factor[1]	Approximately 5.		