Instruction Manual

for

B+K PRECISION

Model 2520

20 MHz
DUAL-CHANNEL
DIGITAL STORAGE OSCILLOSCOPE

B+K PRECISION DYNASCAN CORPORATION

6460 West Cortland Street
Chicago, Illinois 60635

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FEATURES

DIGITAL FEATURES

1024 x 8-Bit Memory
Vertical resolution of 1 in 256 (approximately 30 steps/div) and horizontal resolution of 1 in 1024 (100 samples/div).

2 Msample/sec Sampling Rate
Allows capture of one time events with pulse widths of 5 µs or greater.

Equivalent Time Sampling
Allows repetitive waveforms of up to 20 MHz to be digitized and stored.

Capture Pretrigger Information
Allows selection of 0%, 25%, 75%, or 100% of the stored waveform to be pretrigger information.

Armed Store Mode
In the Armed/Store mode the oscilloscope begins storing information on trigger and continues through the entire sweep.

Roll Mode
In the Roll mode of operation, the trace moves across the display from right to left like a strip chart recorder. Ideal for capturing very slow events and pretrigger information.

DUAL TRACE FEATURES

Dual Trace

Model 2520 has two vertical input channels for displaying two waveforms simultaneously. Selectable single trace (either CH 1 or CH 2) or dual trace for both analog and digital operating modes. Alternate or chop sweep automatically selected by **TIME/DIV** control.

Sum and Difference Capability
Permits algebraic addition or subtraction of channel 1 and channel 2 waveforms in the analog operating mode, displayed as a single trace. Useful for differential voltage and distortion measurements.

CRT FEATURES

Rectangular CRT
Rectangular CRT with large 8 x 10 centimeter viewing area. Internal 8 x 10 division graticule eliminates parallax error.

Convenience
Trace rotation electrically adjustable from front panel. 10% and 90% markers for rise time measurements.

VERTICAL FEATURES

High Sensitivity
2 mV/div sensitivity for full bandwidth.

Calibrated Voltage Measurements
Accurate voltage measurements (±3%) on 12 calibrated ranges from 2 mV/div to 10 V/div. Vertical gain fully adjustable between calibrated ranges.

SWEEP FEATURES

Calibrated Time Measurements
Accurate (±3%) time measurements. In analog display mode, Model 2520 has 18 calibrated ranges from 0.2 s/div to 0.5 µs/div. Sweep time is fully adjustable between calibrated ranges. In digital display mode, 26 calibrated ranges are available from 0.5 µs/div to 50 sec/div.

X10 Sweep Magnification
Allows closer examination of waveforms, increases maximum sweep rate to 50 ns/div. Allows digitized waveforms to be expanded even after they have been stored.

TRIGGERING FEATURES

Auto Sweep
Selectable Auto sweep provides sweep without trigger input, automatically reverts to triggered sweep operation when adequate trigger is applied.

Triggered Sweep (Normal Triggering)
Sweep remains at rest unless adequate trigger signal is applied. Fully adjustable trigger level and (+) or (-) slope.

Three Trigger Sources
Three trigger source selections, including CH 1, CH 2, and Ext Trig.

Three Trigger Coupling Choices
Selectable AC, DC, or TV trigger coupling.

Video Sync
Frame or Line triggering selectable for observing composite video waveforms.

X-Y Operation
Channel 1 can be applied as horizontal deflection (X-axis) while channel 2 provides vertical deflection (Y-axis).

OTHER FEATURES

Z MOD Input
Intensity modulation capability permits time or frequency markers to be added. Trace decreases in intensity with positive signal, TTL compatible.

Built-In Probe Adjust Square Wave
A 1 V p-p, 1 kHz square wave generator permits probe compensation adjustment.

Supplied With Probes
Oscilloscope comes with two identical 10:1 probes (Model PR-47).

Plotter Output
Rear panel outputs allow a stored waveform to be fed to an analog plotter.

SPECIFICATIONS

CRT:

Type:
Rectangular with internal graticule.

Display Area:
8 X 10 div (1 div = 1 cm).

Accelerating Voltage:
2 kV.

VERTICAL AMPLIFIERS

Sensitivity:
2 mV/div to 10 V/div in 1-2-5 sequence with vernier control providing continuous adjustment between steps.

Accuracy:
±3%.

Input Resistance:
1 MΩ.

Input Capacitance:
28 pF.

Frequency Response:
DC: DC to 20 MHz (-3 dB).
AC: 2 Hz to 20 MHz (-3 dB).

Rise Time:
17.5 ns.

Analog Operating Modes:
X-Y: CH 1 is X Axis. CH 2 is Y Axis.
CH 1: CH 1, single trace.
CH 2: CH 2, single trace.
Dual: CH 1 and CH 2, dual trace. Alternate sweep operation (alternates between channel 1 and channel 2 signal) when sweep speeds of 0.2 ms/div or faster are selected. Chop sweep mode (both channels displayed simultaneously) when sweep speeds slower than 0.2 ms/div are selected.
Add: Algebraic sum of CH 1 + CH 2 single trace (CH 1 - CH 2 with CH 2 inverted).

Chop Frequency:
Approximately 500 kHz.

Polarity Reversal:
CH 2 only.

Maximum Input Voltage:
400 V (dc + ac peak) or 800 V ac p-p.

SWEEP SYSTEM

Analog Sweep Speed (Norm mode):
0.5 µs/div to 0.2 s/div in 1-2-5 sequence, 18 steps. Vernier control provides fully adjustable sweep time between steps.

Digitizing Sweep Speed (Store mode):
0.5 µs/div to 50 sec/div, 25 ranges in 1-2-5 sequence.

Accuracy:
±3% (to 0.2 µs/div).

Sweep Magnification:
10 X, ±3% (increases maximum sweep speed to 50 ns/div ±5%).

TRIGGERING

Modes:
Auto (free run) or Normal.

Source:
CH 1, CH 2, or External.

Coupling:
AC: 4 Hz to 20 MHz.
DC: DC to 20 MHz.
TV: Trigger signal is routed through a sync separator. Horizontal sync pulses are selected at sweep times of 0.05 ms/div and faster (TV Line). Vertical sync pulses are

selected at sweep times of 0.1 ms/div and slower (TV Frame).

Level:
$\pm 90^{\circ}$; permits selection of triggering at any point on the positive and negative slope of the displayed waveform.

Slopes:
+/-.

Trigger Sensitivity:

COUPLING	BANDWIDTH	INT	EXT
DC	DC - 2 MHz DC - 20 MHz	0.3 div 1.0 div	150 mV 600 mV
AC	10 Hz - 2 MHz 4 Hz - 20 MHz	0.3 div 1.0 div	150 mV 600 mV

DIGITAL FACILITIES

Storage Word Size:
1024 x 8 bits/channel (1 k/channel).

Vertical Resolution:
1 in 256, approximately 30 steps/div.

Horizontal Resolution:
1 in 1024, approximately 100 samples/div (0.05 ms/div range on Dual is 50 samples/div).

Expansion:
X10 expands waveform 10 times. Maximum sweep speed is increased to 0.05 µs/div in X10 mode.

Sample Rate:
2 M samples/sec maximum (0.05 ms/div), reduced in proportion to time base.

Equivalent Time Sampling Bandwidth:
20 MHz for repetitive waveforms.

Dot Joining:
Linear interpolation between samples.

Digital Display Modes:
Roll:
Stored data and display updated continually (50 sec/div to 0.05 ms/div sweep times).
Refreshed:
Stored data and display updated by triggered sweep (50 sec/div to 0.5 ms/div sweep times).
Equivalent Time Sampling:
Stored data and display updated from trigger point in Arm/Store mode.
Hold-All:
Freezes CH 1 and CH 2 data immediately.
Hold-CH 2:
Freezes CH 2 data immediately.
Pretrigger Storage:
Available in Roll mode only, switchable for 0%, 25%, 75%, and 100% of full store pre-trigger.

PLOT OUTPUT

Analog output of the stored display.

Y-Output:
Channel 1 or channel 2 selected by Plot 1 or Plot 2 pushbutton for the respective channel. Output via 4 mm socket (banana jack). Amplitude 100 mV/div nominal.

X-Output:
X ramp (sweep) via 4 mm socket (banana jack). Amplitude 100 mV/div nominal.

Output Sweep Rate:
Selected by TIME/DIV (main timebase) and ms/sec switch. Range of 50 sec/div to 50 ms/div in 1-2-5 sequence.

Output Impedance:
100 Ω.

Pen Lift Output:
High output or control pen lift. TTL open collector, maximum sink current is 8 mA.

OTHER SPECIFICATIONS

Calibrating Signal:
Approximately 1 kHz positive square wave. 1 V p-p ±2%.

Intensity Modulation (Z Mod):
Input Signal:
Intensity decreasing with more positive levels. TTL compatible.

Input Impedance:
Approximately 10 kΩ/10 pF.
Maximum Input Voltage:
100 V (dc + ac peak).

Trace Rotation:
Electrical, front panel adjustable.

Power Requirements:
100 V, 120 V, 220 V, or 240 V ±10%, 45 to 400 Hz, approximately 40 VA.

Dimensions:
140 x 305 x 460 mm (5.5 x 12.0 x 18.1").

Weight:
6 kg (13.2 lbs).

ACCESSORIES SUPPLIED
Two 10:1 Probes (PR-47).
Spare Fuse.
Schematic Diagram And Parts List.
AC Power Cord.

OPTIONAL ACCESSORIES
Front Panel Protective Cover (LC-130).
Protective Carrying Bag (LC-30).
Rack Mount Kit (RM-30).
10:1/Direct Probe (PR-37).

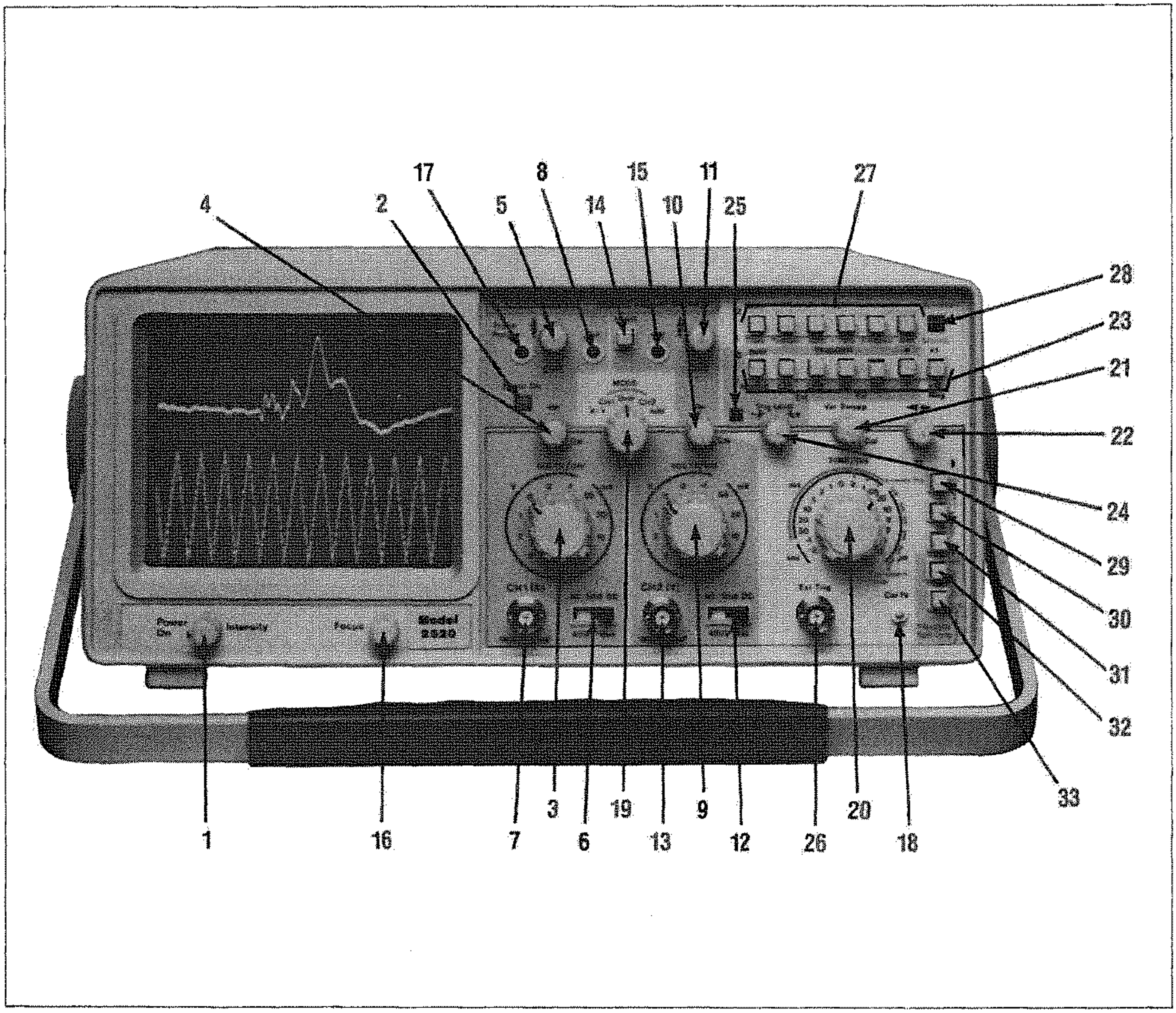

Fig. 1. Front Panel Controls And Indicators.

VERTICAL CONTROLS

CHANNEL 1 CONTROLS

1. **Power On/Intensity Control.** Turns power on and off and adjusts the brightness of the trace.

2. **Power On Indicator.** Lights when oscilloscope is turned on.

3. **VOLTS/DIV Control.** Vertical attenuator for channel 1. Provides step adjustment of vertical sensitivity. When channel 1 Variable control is set to Cal, vertical sensitivity is calibrated in 12 steps from 1 mV/div to 5 V/div in a 1-2-5 sequence. In X-Y operation, this control provides step adjustment of X-axis sensi-

tivity. Once a waveform has been digitized and stored, changing the **VOLTS/DIV** control setting will have no effect on the stored waveform.

4. **Variable Control.** Rotation provides vernier adjustment of channel 1 vertical gain. In the fully clockwise (**Cal**) position, the vertical attenuator is calibrated. In X-Y operation this control becomes the vernier X-axis gain control. Once a waveform has been digitized and stored, changing the **Variable** control setting will have no effect on the stored waveform.

5. **↕ CH1 Position Control.** Rotation adjusts vertical position of channel 1 trace. Once a waveform has been digitized and stored, changing the **↕ CH 1** control setting will have no effect on the stored waveform.

6. **AC-Gnd-DC Switch.** Three-position lever switch which operates as follows:
   - **AC:** Channel 1 input signal is capacitively coupled; dc component is blocked.
   - **Gnd:** Opens signal path and grounds input to vertical amplifier. This provides a zero-volt base line, the position of which can be used as a reference when performing dc measurements.
   - **DC:** Direct coupling of channel 1 input signal; both ac and dc component of signal produce vertical deflection.

7. **CH 1 Input Jack.** Vertical input for channel 1. X axis input for X-Y operation.

8. **Channel 1 Balance Control.** Screwdriver adjustment to balance the vertical position of the channel 1 trace at different attenuator levels (**VOLTS/DIV** control settings).

CHANNEL 2 CONTROLS

9. **VOLTS/DIV Control.** Vertical attenuator for channel 2. Provides step adjustment of vertical sensitivity. When channel 2 **Variable** control is set to **Cal**, vertical sensitivity is calibrated in 12 steps from 1 mV/div to 5 V/div in a 1-2-5 sequence. In X-Y operation, this control provides step adjustment of Y-axis sensitivity. Once a waveform has been digitized and stored, changing the **VOLTS/DIV** control setting will have no effect on the stored waveform.

10. **Variable Control.** Rotation provides vernier adjustment of channel 2 vertical sensitivity. In the fully clockwise (**Cal**) position, the attenuator is calibrated. In X-Y operation this control becomes the vernier Y-axis gain control. Once a waveform has been digitized and stored, changing the **Variable** control setting will have no effect on the stored waveform.

11. **↕ CH 2 Position Control.** Rotation adjusts vertical position of channel 2 trace. In X-Y operation, rotation adjusts vertical position of display. Once a waveform has been digitized and stored, changing the **↕ CH 2** position control setting will have no effect on the stored waveform.

12. **AC-Gnd-DC Switch.** Three-position lever switch which operates as follows:
    - **AC:** Channel 2 input signal is capacitively coupled; dc component is blocked.
    - **Gnd:** Opens signal path and grounds input to vertical amplifier. This provides a zero-volt base line, the position of which can be used as a reference when performing dc measurements.
    - **DC:** Direct coupling of channel 2 input signal; both ac and dc component of signal produce vertical deflection.

13. **CH 2 Input Jack.** Vertical input for channel 2. Y-axis input in X-Y operation.

14. **Channel 2 Invert Switch.** Selects inverted or normal polarity of channel 2 signal; inverted polarity when engaged, normal polarity when off.

15. **Channel 2 Balance Control.** Screwdriver adjustment to balance the vertical position of the channel 2 trace at different attenuator levels (**VOLTS/DIV** control settings).

MISCELLANEOUS CONTROLS

16. **Focus Control.** Adjusts sharpness of trace.

17. **Trace Rotate Control.** Adjusts the trace to a horizontal position.

18. **Cal 1 V Terminal.** This terminal provides a 1 kHz, 1-volt peak-to-peak square wave signal. This is useful for probe compensation adjustment and a general check of oscilloscope calibration accuracy.

19. **Vertical MODE Switch.**

    X-Y:
    Selects **X-Y** mode. Channel 1 becomes the X-axis and channel 2 becomes the Y-axis. The **TRIGGER** controls are disabled. The **X-Y** mode cannot be used when in the digitizing (**Store**) mode of operation.

    CH 1 Position:
    Only the input signal to channel 1 is displayed on the CRT.

    Dual Position:
    The input signal to CH 1 and CH 2 are alternately displayed (alternate sweep) when sweep speeds of 0.2 ms/div or faster are selected (because the sweep speed is so fast, when fast trigger signals are used the display of CH 1 and CH 2 will appear to be simultaneous). The CH 1 and CH 2 input signals are displayed simultaneously (chopped sweep) when sweep speeds slower than 0.2 ms/ div are selected (chop frequency is approx 500 kHz).

    CH 2 Position:
    Only the input signal to channel 2 is displayed on the CRT.

    ADD:
    The input from channel 1 and channel 2 are summed and displayed as a single signal. When the **CH 2 Invert** function is activated, the input from channel 2 is subtracted from channel 1 and the difference is displayed as a single signal. This function cannot be used in the digitizing (**Store**) mode of operation.

HORIZONTAL CONTROLS

SWEEP CONTROLS

20. **TIME/DIV Control.** Provides step selection of sweep rate. When the **Var Sweep** control is set to the **Cal** position, sweep rate is calibrated. For analog operation (**Norm** mode), this control has 18 steps from 0.5 µs/div to 0.2 s/div, in a 1-2-5 sequence. For digital operation (**Store** mode), this control has 16 steps from 0.5 µs/div to 50 ms/div, in a 1-2-5 sequence. When sweep times of 0.05 ms/ div to 0.2 ms/div (the three sweep **TIME/DIV** ranges with the adjacent red dots) are selected in the **Store** mode, the display is blanked anytime an adequate trigger is not present. When sweep times of 0.5 µs/div to 20 µs/div are selected in the **Store** mode, the Equivalent Time Sampling mode of operation is automatically selected. Once a waveform has been digitized and stored, changing the sweep **TIME/DIV** control setting will have no effect on the stored waveform.

21. **Var Sweep Control.** Rotation of control is vernier adjustment for sweep rate. In fully clockwise (**Cal**) position, sweep rate is calibrated. When in the digitizing (**Store**) mode, this control can only be used when in the Equivalent Time Sampling **TIME/DIV** ranges. Once a waveform has been digitized and stored, changing the **Var Sweep** control setting will have no effect on the stored waveform.

22. **◄► Position Control.** Horizontal position control for all display modes (**X-Y, CH 1, DUAL** etc.). Also controls hori-

zontal position in **Store** mode (even after a waveform has been stored, the horizontal position can be changed).

23. **TRIGGER Controls.**

Auto/Normal Switch. Selects automatic or normal triggering mode.

Auto Position. Generates sweep (free runs) in absence of trigger; automatically reverts to triggered sweep operation when adequate trigger signal is present.

Normal Position. Selects normal triggered sweep operation, which generates a sweep only when adequate trigger signal is present.

CH 1 And CH 2 Switches. When only the **CH 1** switch is engaged, channel 1 is selected as the trigger source and when only the **CH 2** switch is engaged, channel 2 is selected as the trigger source. When both the **CH 1** and the **CH 2** switches are engaged, the signal applied to the **Ext Trig** jack is selected as the trigger source.

AC And DC Switches. When only the **AC** switch is engaged, the trigger signal is capacitively coupled and the dc component is blocked. When only the **DC** switch is engaged, the trigger signal is direct coupled, and includes both the ac and dc components. When both the **AC** and **DC** switches are engaged, **TV** coupling is selected (trigger is routed through a sync separator); horizontal sync pulses (individual video lines may be viewed) are selected when sweep rates of 0.05 ms/div and faster are selected and vertical sync pulses (individual frames may be viewed) are selected when sweep rates of 0.1 ms/div and slower are selected.

+/- Switch. When this switch is disengaged (+ position), sweep is triggered on the trigger signal's positive going slope or, when switch is engaged (- position), sweep is triggered on the trigger signal's negative going slope.

X1/X10 Mag Switch. When switch is engaged (in the **X10** position), ten times sweep magnification is selected and the maximum sweep rate is increased to 50 ns/div. Switch also allows a stored waveform to be expanded by a factor of 10. When switch is disengaged (in the **X1** position), sweep speed is normal.

24. **Trig Level Control.** Trigger level adjustment, determines point on triggering waveform where sweep is triggered. Rotation in (-) direction selects more negative point of triggering, and rotation in (+) direction selects more positive point of triggering.

25. **Triggered Indicator.** Lights when sweep is triggered. Shows when trigger level is properly set.

26. **Ext Trig Jack.** External trigger input.

DIGITAL (STORE) MODE CONTROLS

27. **Digital Mode Controls:**

Norm/Store Switch. When switch is disengaged, the oscilloscope is in the **Norm** (conventional analog oscilloscope) mode of operation and the other five switches in this group are disabled. When this switch is engaged, the oscilloscope is in the **Store** (digitizing) mode of operation.

Roll/Refresh Switch. When this switch is disengaged, the oscilloscope is in the **Roll** mode of operation. In the **Roll** mode the trace moves across the CRT from right to left like a strip chart recorder (opposite of conventional oscilloscope operation) and the display is continually updated. When this switch is engaged, the oscilloscope is in the **Refresh** mode of operation. In the **Refresh** mode the trace moves across CRT from left to right and the display is updated each time an adequate trigger signal is supplied.

25% And 75% Pretrigger Switches. These two switches select the amount of a stored waveform that will be pretrigger information when using the **Roll** and **Armed/Stored** operating modes. When both the **25%** and **75%** switches are disengaged, 0% of the stored waveform is pretrigger information. When only the **25%** switch is engaged, 25% of the stored waveform is pretrigger information and when only the **75%** switch is engaged, 75% of the stored waveform is pretrigger information. When both the **25%** and **75%** switches are engaged, all 100% of the stored waveform will be pretrigger information.

Release Switch. Momentary action switch that releases the oscilloscope from **Armed/Stored** operating mode.

Arm Switch. Momentary action switch that arms the oscilloscope for storage of the waveform on the next adequate trigger signal.

28. **Armed/Stored Indicator. Armed/Stored** indicator will blink on and off when the oscilloscope is armed until an adequate trigger signal has been provided and the waveform is stored. Once the waveform is stored, the indicator will light continuously until either the **Release** or **Arm** switch is pressed.

29. **ms/sec Control.** When this switch is engaged and the oscilloscope is in the digitizing (**Store**) mode of operation, the ms/div ranges (0.05 ms/div through 50 ms/div) of the **TIME/DIV** control are changed to sec/div ranges (0.05 sec/div through 50 sec/div). When this switch is disengaged, the **TIME/DIV** control settings are as printed around the control.

30. **Plot 1 Control.** When the digitizing (**Store**) mode of operation is selected and the **Hold All** switch is engaged, pressing this button feeds the channel 1 trace to the rear panel **Y o/p** (output) jack at a rate determined by the **TIME/DIV** control setting. Oscilloscope makes one sweep of stored waveform then shuts off rear panel output jacks.

31. **Plot 2 Control.** When the digitizing (**Store**) mode of operation is selected and the **Hold All** switch is engaged, pressing this button feeds the channel 2 trace to the rear panel **Y o/p** (output) jack at a rate determined by the **TIME/DIV** control setting. Oscilloscope makes one sweep of stored waveform then shuts off rear panel output jacks.

32. **Hold All Control.** When in the digitizing (**Store**) mode of operation, engaging this switch freezes and stores the channel 1 and channel 2 traces immediately. The display and memory cannot be updated until this switch is released.

33. **Hold CH 2 Control.** When in the digitizing (**Store**) mode of operation, engaging this switch freezes and stores the channel 2 trace immediately. The channel 2 display and memory cannot be updated until this switch is released.

REAR PANEL CONTROLS

34. **Pen Lift Output Jack.** TTL open collector output to raise plotter pen. When plot information is being fed to the output jacks, the TTL signal is low. When plot information is not being fed to the output jacks, the TTL signal is high.

35. **Y o/p (output) Jack.** Banana jack supplies channel 1 or channel 2 digitized signal for use with an analog plotter when **Plot 1** or **Plot 2** buttons have been pressed.

36. ⊿ **X Output Jack.** Banana jack supplies sweep ramp output for use with a plotter when **Plot 1** or **Plot 2** buttons have been pressed.

37. ⊥ **Jack.** Oscilloscope chassis ground, and earth ground via 3-wire ac power cord.

38. **Z MOD Input Jack.** Input jack for intensity modulation of CRT electron beam. Positive-going signal decreases intensity.

39. **100 V/220 V Switch.** Operates in conjunction with **0 V/+20 V** switch to select line voltage.

40. **0 V/+20 V Switch.** Operates in conjunction with **100 V/220 V** switch to select line voltage as follows:
    100 V + 0 V = 100 V
    100 V + 20 V = 120 V
    220 V + 0 V = 220 V
    220 V + 20 V = 240 V

41. **Power Cord Receptacle.**

42. **Fuse Holder.** Contains line fuse.

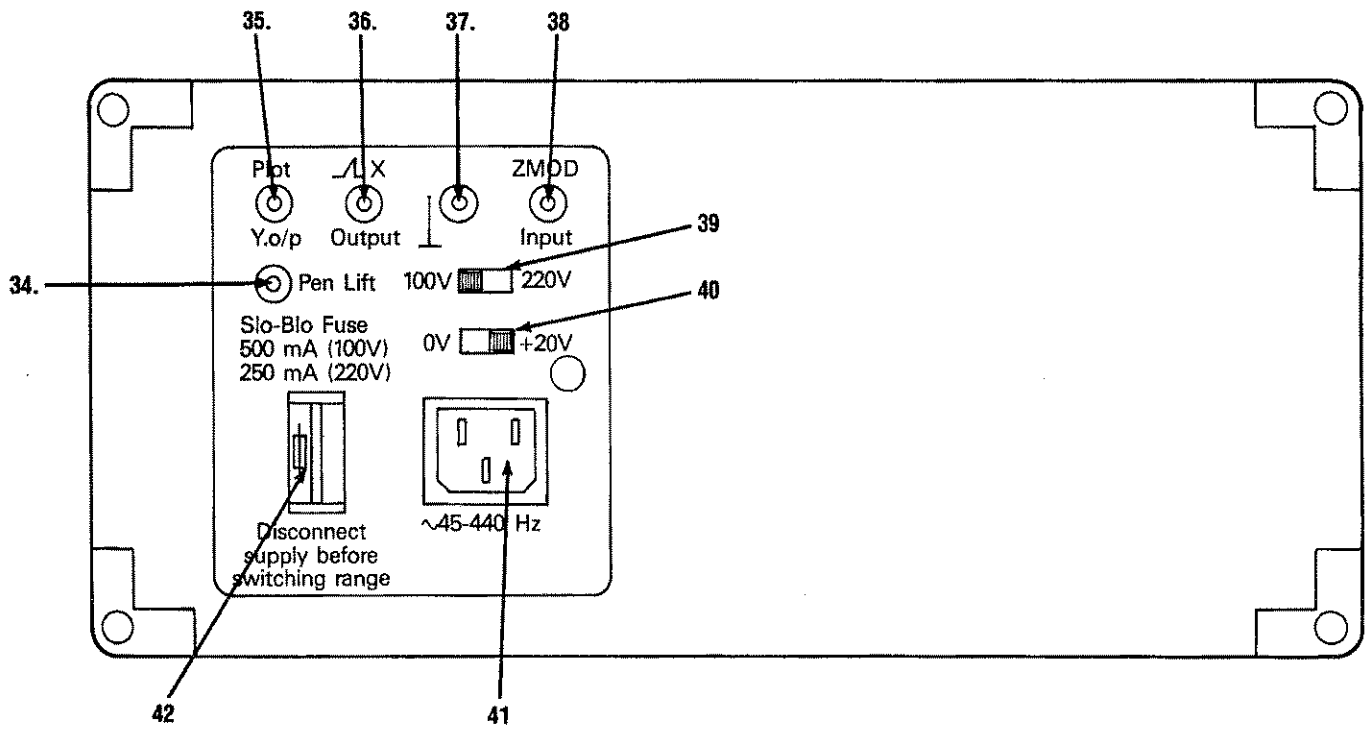

Fig. 2. Rear Panel Controls.

SAFETY PRECAUTIONS

WARNING

The following precautions must be observed to prevent electric shock.

1. When the oscilloscope is used to make measurements in equipment that contains high voltage, there is always a certain amount of danger from electrical shock. The person using the oscilloscope in such conditions should be a qualified electronics technician or otherwise trained and qualified to work in such circumstances. Observe the TEST INSTRUMENT SAFETY recommendations listed on the inside front cover of this manual.

2. Do not operate this oscilloscope with the case removed unless you are a qualified service technician. High voltage up to 2,000 volts is present when the unit is operating with the case removed.

3. The ground wire of the 3-wire ac power plug places the chassis and housing of the oscilloscope at earth ground. Use only a 3-wire outlet, and do not attempt to defeat the ground wire connection or float the oscilloscope; to do so may pose a great safety hazard.

4. Special precautions are required to measure or observe line voltage waveforms with any oscilloscope. Use the following procedure:

   a. Do not connect the ground clip of the probe to either side of the line. The clip is already at earth ground and touching it to the hot side of the line may "weld" or "disintegrate" the probe tip and cause possible injury, plus possible damage to the scope or probe.

   b. Insert the probe tip into one side of the line voltage receptacle, then the other. One side of the receptacle should be "hot" and produce the waveform. The other side of the receptacle is the ac return and no waveform should result.

EQUIPMENT PROTECTION PRECAUTIONS

CAUTION

The following precautions will help avoid damage to the oscilloscope.

1. Never allow a small spot of high brilliance to remain stationary on the screen for more than a few seconds. The screen may become permanently burned. A spot will occur when the scope is set up for **X-Y** operation and no signal is applied. Either reduce the intensity so the spot is barely visible, apply a signal, or switch back to normal sweep operation. It is also advisable to use low intensity with **Auto** triggering and no signal applied or when a stored waveform is displayed for long periods. A high intensity trace at the same position could cause a line to become permanantly burned onto the screen.

2. Do not rest objects on top of the oscilloscope or otherwise obstruct the ventilating holes in the case, as this will increase the internal temperature.

3. Excessive voltage applied to the input jacks may damage the oscilloscope. The maximum ratings of the inputs are as follows:

   CH 1 (X) and **CH 2 (Y):**
   800 V p-p; 400 V dc + ac peak.
   Ext Trig:
   250 V dc + ac peak.
   Z MOD Input:
   100 volts dc + ac peak.

   Never apply external voltage to oscilloscope output jacks.

4. Always connect a cable from the ground terminal of the oscilloscope to the chassis of the equipment under test. Without

this precaution, the entire current for the equipment under test may be drawn through the probe clip leads under certain circumstances. Such conditions could also pose a safety hazard, which the ground cable will prevent.

5. The probe ground clips are at oscilloscope ground and should be connected only to the common of the equipment under test. To measure with respect to any point other than the common, use CH 1 - CH 2 subtract operation (Add mode and **CH 2 Invert**), with the channel 1 probe to the point of measurement and the channel 2 probe to the point of reference. Use this method even if the reference point is a dc voltage with no signal.

OPERATING TIPS

The following recommendations will help obtain the best performance from the oscilloscope.

1. Always use the probe ground clips for best results, attached to a circuit ground point near the point of measurement. Do not rely solely on an external ground wire in lieu of the probe ground clips as undesired signals may be induced.

2. Avoid the following operating conditions:
   a. Direct sunlight.
   b. High temperature and humidity.
   c. Mechanical vibration.
   d. Electrical noise and strong magnetic fields, such as near large motors, power supplies, transformers, etc.

3. Occasionally check trace rotation, probe compensation, and calibration accuracy of the oscilloscope using the procedures found in the MAINTENANCE section of this manual.

4. Terminate the output of a signal generator in its characteristic impedance to minimize ringing, especially if the signal has fast edges such as square waves or pulses. For example, the typical 50 Ω output of a square wave generator should be terminated into an external 50 Ω terminating resistor and connected to the the oscilloscope with 50 Ω coaxial cable.

5. Probe compensation adjustment matches the probe to the input of the scope. For

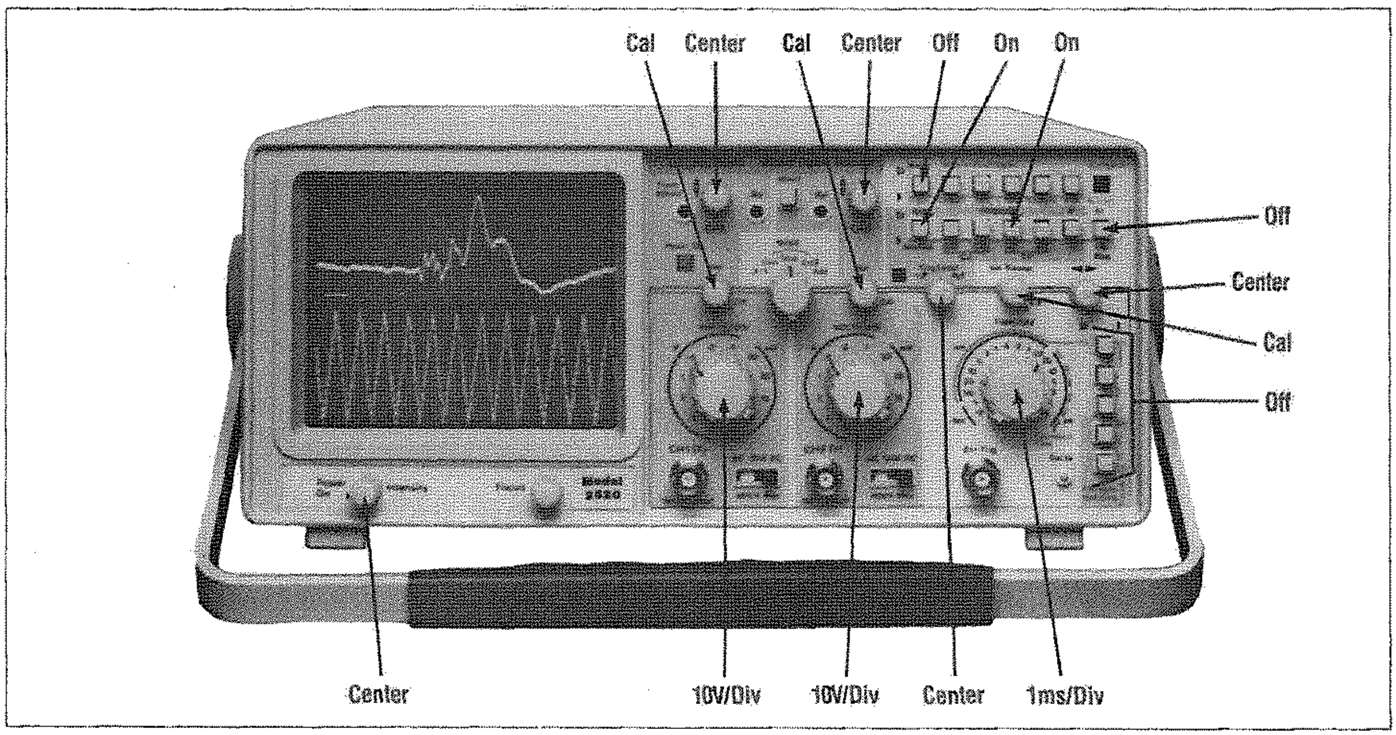

Fig. 3. Initial Control Settings.

best results, compensation should be adjusted initially, then the same probe always used with the same channel. Probe compensation should be readjusted when a probe from a different oscilloscope is used.

INITIAL STARTING PROCEDURE

Until you familiarize yourself with the use of all controls, the settings shown in Fig. 3 may be used as a reference point to obtain a trace on the CRT in preparation for waveform observation.

1. Turn the **Power** control clockwise; the unit will be turned on and the pilot light will be illuminated.
2. When power is turned on, the controls should be set as follows; the vertical mode is set to **CH 1**, the **Auto/Normal** switch is set to **Auto**, and the **Store/Norm** switch is set to **Norm**.
3. A trace should appear on the CRT. Adjust the trace brightness with the **Power/Intensity** control, and the trace sharpness with the **Focus** control.

SINGLE TRACE DISPLAY

Either channel 1 or channel 2 may be used for single-trace operation. The advantage of using channel 2 is that the waveform on the display can be inverted if desired with the **CH 2 Invert** switch.

1. Perform the steps of the "Initial Starting Procedure" with the vertical mode switch set to **CH 2**.
2. Connect the probe to the **CH 2** input jack.
3. Connect the probe ground clip to the chassis or common of the equipment under test. Connect the probe tip to the point of measurement.
4. If no waveforms appear, increase the sensitivity by turning the **CH 2 VOLTS/DIV** control clockwise to a position that gives 2 to 6 divisions vertical deflection.
5. The display on the CRT may be unsynchronized. Refer to the "Triggering" paragraphs in this section for procedures on setting triggering and sweep time controls to obtain a stable display showing the desired number of waveforms.

DUAL TRACE DISPLAY

In observing simultaneous waveforms on channel 1 and 2, the waveforms are usually related in frequency, or one of the waveforms is synchronized to the other, although the basic frequencies are different. If the two waveforms have no phase or frequency relationship (there is seldom reason to observe both waveforms simultaneously), they cannot be observed in the Analog Display (**Norm**) mode. However, with the Digital Display (**Store**) mode, two waveforms not related in frequency or period can be simultaneously viewed.

1. Connect probes to both the **CH 1** and **CH 2** input jacks.
2. Connect the ground clips of the probes to the chassis or common of the equipment under test. Connect the tips of the probes to the two points in the circuit where waveforms are to be measured.
3. When the **Add** mode is selected, the algebraic sum of channel 1 + channel 2 is displayed as a single trace. When the **CH 2 Invert** button is also engaged, the algebraic difference of channel 1 - channel 2 is displayed. (The **Add** mode cannot be used when in the **Store** mode of operation.)
4. To view both waveforms simultaneously, set the vertical mode switch to the **Dual** position.
5. When sweep times of 0.2 ms/div and faster are selected, the alternate sweep mode is selected. In the alternate sweep mode, one sweep displays the channel 1 signal and the next sweep displays the

channel 2 signal in an alternating sequence.

6. When sweep speeds of 0.5 ms/div and slower are selected, the chop sweep mode is selected. In the chop sweep mode, the sweep is chopped at an approximate 500 kHz rate and switched between channel 1 and channel 2.

7. Adjust the channel 1 and channel 2 position controls to place the channel 1 trace above the channel 2 trace.

8. Set the **CH 1** and **CH 2 VOLTS/DIV** controls to a position that gives 2 to 3 divisions of vertical deflection for each trace. If the display on the screen is unsynchronized, refer to the "Triggering" paragraphs in this section of the manual for procedures for setting triggering and sweep time controls to obtain a stable display showing the desired number of waveforms.

TRIGGERING

The Model 2520 Oscilloscope provides versatility in sync triggering for ability to obtain a stable, jitter-free display in single-trace or dual-trace operation. The proper settings depend upon the type of waveforms being observed and the type of measurement desired. An explanation of the various controls which affect synchronization is given to help you select the proper setting over a wide range of conditions.

Auto/Norm Switch

1. The **Normal** position provides normal triggered sweep operation. The sweep remains at rest until the selected trigger source signal crosses the threshold level set by the **Trig Level** control. The trigger causes one sweep to be generated, after which the sweep again remains at rest until triggered. In the **Normal** position, there will be no trace unless an adequate trigger signal is present. Typically, signals that produce even 1/2 division of vertical deflection are adequate for normal triggered sweep operation.

2. In the **Auto** position, automatic sweep operation is selected. In automatic sweep operation, the sweep generator free runs to generate a sweep without a trigger signal. However, it automatically switches to triggered sweep operation if an acceptable trigger source signal is present. The **Auto** position is handy when first setting up the scope to observe a waveform; it provides sweep for waveform observation until other controls can be properly set. Once the controls are set, operation is often switched back to the **Normal** triggering mode, since it is more sensitive. Use the triggered indicator to set the **Trig Level** in the **Auto** mode, then switch to the **Normal** mode. Automatic sweep must be used for dc measurements and signals of such low amplitude that they will not trigger the sweep.

NOTE

In the **X-Y** mode, the sweep generator and triggering circuits are disconnected and have no effect.

Also, the **Auto** sweep mode should not be selected when in the store mode of operation. If the **Auto** sweep mode is selected when in the **Store** mode, pretrigger information cannot be captured and the **Armed Store** function will not function properly.

CH 1 And CH 2 (Trigger Source) Switches

The **CH 1** and **CH 2** switches select the signal to be used as the sync trigger.

1. When only the **CH 1** switch is engaged, the channel 1 signal becomes the trigger source.

2. When only the **CH 2** switch is engaged, the channel 2 signal becomes the trigger source.

3. When both the **CH 1** and **CH 2** switches are engaged, the signal applied to the **Ext Trigger** jack becomes the trigger

source. This signal must have a timing relationship to the displayed waveform for a synchronized display.

Trig Level and Slope Controls
(Refer to Fig. 4)

A sweep trigger is developed when the trigger source signal crosses a preset threshold level. Rotation of the **Trig Level** control varies the threshold level. In the + direction, the triggering threshold shifts to a more positive value, and in the - direction, the triggering threshold shifts to a more negative value. When the control is centered, the threshold level is set at the approximate average of the signal used as the triggering source. Proper adjustment of this control usually synchronizes the display.

The **Trig Level** control adjusts the start of the sweep to almost any desired point on a waveform. On sine wave signals, the phase at which sweep begins is variable. Note that if the **Trig Level** control is rotated toward its extreme + or - setting, no sweep will be developed in the **Normal** trigger mode because the triggering threshold exceeds the peak amplitude of the sync signal.

When the slope (+/-) switch is set to the + position, the sweep is developed from the trigger source waveform as it crosses a threshold level in a positive-going direction. When the slope (+/-) switch is set to the - position, a sweep trigger is developed from the trigger source waveform as it crosses the threshold level in a negative-going direction.

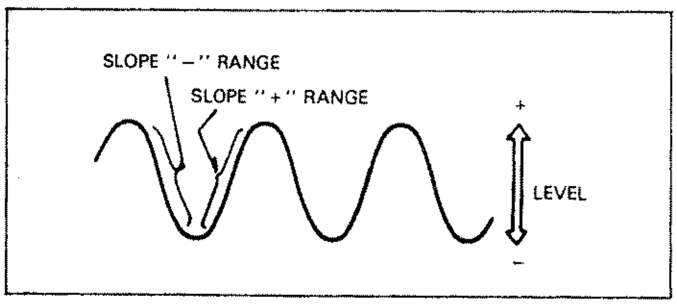

Fig. 4. Function of Slope and Level Controls.

Trigger Coupling Switches

The **AC** and **DC** coupling switches control the trigger coupling in the following manner:

1. For viewing most types of waveforms only the **AC** switch should be engaged. The trigger signal is capacitively coupled and may be used for all signals from 4 Hz to 20 MHz.

2. When you wish to include the triggering effects of dc components only the **DC** switch should be engaged.

3. For viewing composite video waveforms both the **AC** and **DC** switches should be engaged (**TV** coupling). A sync separator circuit separates sync pulses from video. Horizontal sync pulses are selected as trigger at sweep rates of 0.05 ms/div and faster (line) and vertical sync pulses are selected as trigger at sweep rates of 0.1 ms/div and slower (frame). Additional procedures for observing video waveforms are given later in this section of the manual.

Sweep TIME/DIV Control

Set the sweep **TIME/DIV** control to display the desired number of cycles of the waveform. If there are too many cycles displayed for good resolution, switch to a faster sweep time. If only a line is displayed, try a slower sweep time. When the sweep time is faster than the waveform being observed, only part of it will be displayed, which may appear as a straight line for a square wave or pulse waveform.

MAGNIFIED SWEEP OPERATION

Since merely shortening the sweep time to magnify a portion of an observed waveform can result in the desired portion disappearing off the screen, such magnified display should be performed using MAGNIFIED SWEEP.

Press the **X10** magnification switch to magnify the display ten times. Using the horizontal ◄► position control, adjust the desired portion of waveform to the center of the CRT. For this type of display the sweep time is the sweep **TIME/DIV** setting divided by 10.

X-Y OPERATION

X-Y operation permits the oscilloscope to perform many measurements not possible with conventional sweep operation. The CRT display becomes an electronic graph of two instantaneous voltages. The display may be a direct comparison of the two voltages such as vectorscope display of video color bar patterns. However, the **X-Y** mode can be used to graph almost any dynamic characteristic if a transducer is used to change the characteristic (frequency, temperature, velocity, etc.) into a voltage. One common application is frequency response measurements, where the Y axis corresponds to signal amplitude and the X axis corresponds to frequency.

1. Set the vertical mode switch to the **X-Y** position. In this mode, channel 1 becomes the X axis input and channel 2 becomes the Y axis input.

2. The X and Y positions are now adjusted using the ⬍ CH 2 position and ◂▸ position controls respectively.

3. Adjust the amount of horizontal (X axis) deflection with the **CH 1 VOLTS/DIV** and **Variable** controls.

4. Adjust the amount of vertical (Y axis) deflection with the **CH 2 VOLTS/DIV** and **Variable** controls.

VIDEO SIGNAL OBSERVATION

Engaging both the **AC** and **DC** switches permits selection of vertical or horizontal sync pulses for sweep triggering when viewing composite video waveforms.

The **TV** line mode is automatically selected at sweep rates of 0.05 ms/div and faster. Horizontal sync pulses are selected as triggers to permit viewing of horizontal lines of video. A sweep time of about 10 µs/div is appropriate for displaying lines of video. The **Var Sweep** control can be set to display the exact number of waveforms desired.

The **TV** frame mode is automatically selected at sweep rates of 0.1 ms/div and slower. Vertical sync pulses are selected as triggers to permit viewing of vertical fields and frames of video. A sweep time of 2 ms/div is appropriate for viewing fields of video and 5 ms/div for complete frames (two interlaced fields) of video.

At most points of measurement, a composite video signal is of the (-) polarity, that is, the sync pulses are negative and the video is positive. In this case, use (-) slope. If the waveform is taken at a circuit point where the video waveform is inverted, the sync pulses are positive and the video is negative. In this case, use (+) slope.

DIGITAL (STORE MODE) OPERATION

Digitizing Waveforms

1. Set up the oscilloscope to view a waveform in the analog operating (**Norm**) mode. Adjust the trigger, **VOLTS/DIV**, sweep **TIME/DIV**, and vertical position controls as desired.

   NOTE
   Do not use the **0.2 sec** or **0.1 sec** Sweep **TIME/DIV** control settings or the **X-Y** or **Add** vertical modes. These control settings cannot be used when digitizing a waveform.

2. The group of switches in the lower right corner (**Hold All, Hold CH 2,** etc.) and at the upper right corner (**Norm/Store, Roll/Refresh,** etc) must all be disengaged. If the red **Armed/Stored** indicator is on or flashing, press the **Release** button.

3. Select **Normal** triggering (**Auto/Norm** switch engaged) and the **Store** (**Norm/Store** switch engaged) and **Refresh** (**Roll/Refresh** switch engaged) operating modes. If a sweep time between 50 ms/div and 0.05 ms/div is selected, the waveform will be digitized and displayed on the CRT. If a sweep speed higher than 0.05 ms/div is selected or if the waveform is a onetime event, the waveform must be stored in order to be viewed (see the **Storing Waveforms** paragraph below).

   NOTE
   When sweep speeds of 0.05 ms/div, 0.1 ms/div, or 0.2 ms/div

are selected, the display will be blanked whenever an adequate trigger is not present.

4. For very slow waveforms, sweep speeds slower than 50 ms/div can be selected by engaging the **ms/sec** switch. All the sweep speeds between 0.05 ms/div and 50 ms/div become sec/div ranges when the **ms/sec** switch is engaged (i.e., the 20 ms/div position becomes 20 sec/div).

Storing Waveforms

1. Set up the oscilloscope according to the **Digitizing Waveforms** instructions.

2. Press the **Arm** switch (the **Armed/Stored** indicator will flash until the waveform is stored). Once the waveform is stored, the **Armed/Stored** indicator will light continuously. After the **Arm** switch is pressed, the oscilloscope begins storing the waveform as soon as the next adequate trigger signal occurs. When relatively fast sweep speeds are being used the waveform will appear to be stored almost instantly. However, on the slowest sweep speed (50 sec/div), the waveform will not be stored until almost 8-1/2 minutes (50 sec/div x 10 divisions) after the first adequate trigger after the **Armed** switch is pressed.

3. To refresh the display, press the **Arm** button again. This will store the current wavefrom in the memory and update the display. To go back to continuously refreshing the display (**Refresh** operation), press the **Release** switch.

NOTE

When sweep speeds higher than 0.05 ms/div are selected, it is only possible to store a waveform for viewing. In order to continuously update the display, sweep speeds slower than 20 µs/div must be selected before the **Release** switch is pressed.

Long Term Waveform Storage

Once a waveform is digitized it can be stored in long term memory by pressing the **Hold All** or **Hold CH 2** switches. The **Hold CH 2** switch immediately stores the channel 2 waveform. The **Hold All** switch immediately freezes the display and stores both the channel 1 and channel 2 waveforms. Once a waveform(s) is stored by engaging the **Hold All** or **Hold CH 2** switch, the waveform(s) will be stored until the switch (**Hold All** or **Hold CH 2**) is disengaged or the power is turned off.

Roll Operation

In the **Roll** operating mode, the waveform rolls across the CRT from the right side of the screen to the left (as opposed to standard oscilloscopes which have the trace moving from left to right) in the same manner as most strip chart recorders. This is convenient to users that are familiar with the use of strip chart recorders rather than oscilloscopes. This is also ideal for viewing very slow events and allows the capture of pretrigger information (see the **Capturing Pretrigger Information** instructions later in this section of the instruction manual).

1. Set up the oscilloscope to view a waveform in the analog operating (**Norm**) mode. Adjust the trigger, **VOLTS/DIV**, sweep **TIME/DIV**, and vertical position controls as desired.

2. Select **Normal** (**Auto/Normal** switch engaged) triggering and set the **Norm/Store** switch to **Store** and the **Roll/Refresh** switch to **Roll**. As the sweep speed is decreased, the waveform will move across the screen more slowly and the Roll feature will become more apparent. If the **ms/sec** switch is engaged, the sweep speed will become 1000 times the control setting. For example, if the 50 ms/div sweep speed is selected and the **ms/sec** switch is engaged, the waveform will take 500 seconds (8-1/3 minutes) to move across the CRT (50 seconds for each of the 10 divisions).

Capturing Pretrigger Information

NOTE

Pretrigger information cannot be captured when sweep speeds faster than 0.05 ms/div are selected.

1. Set the sweep **TIME/DIV**, **VOLTS/DIV**, ▲▼ **CH 1** position, ▲▼ **CH 2** position, **Trig Level**, trigger slope, trigger coupling, and trigger source controls so that the waveform that you wish to capture will trigger the sweep and be positioned on the display in an appropriate place.

   NOTE

   It is important that the trigger controls be properly set. The pretrigger information can only be captured if the trigger signal is adequate for triggering the sweep.

2. Select the **Store** and **Roll** modes of operation.

3. Select the desired percentage of pretrigger information. This oscilloscope allows you to select either 0%, 25%, 75%, or 100% of the memory and display as pretrigger information. When both the **25%** and **75%** switches are disengaged, 0% of the memory and display will be pretrigger information. When only the **25%** switch is engaged, 25% of the memory and display will be devoted to pretrigger information and when only the **75%** switch is engaged, 75% of the memory and display will be devoted to pretrigger information. When both the **25%** and **75%** switches are engaged, 100% of the memory and display will be devoted to pretrigger information.

4. Pressing the **Arm** switch will cause the **Armed/Stored** indicator to flash and the oscilloscope will store the event when trigger occurs. Whatever percentage of pretrigger information is selected will be stored in the memory (with the remaining percentage being devoted to trigger and posttrigger information) and displayed on the CRT. Each time the **Arm** switch is pressed, the scope will be rearmed and will store the waveform and pretrigger information on the next trigger.

Comparing Waveforms

1. To store or digitize and compare two waveforms perform the following steps:

   a. Set up the oscilloscope to view the two desired waveforms with dual trace display in the analog operating (**Norm**) mode. Adjust the trigger, **VOLTS/DIV**, sweep **TIME/DIV**, and vertical position controls as desired.

   b. Select **Normal** trigger, set the **Norm/Store** switch to **Store**, and the **Roll/Refresh** switch to Refresh.

   c. Store both waveforms by pressing the **Arm** or **Hold All** switch. The two digitized waveforms can now be compared.

2. To store one waveform and compare it to an analog waveform, perform the following steps:

   a. Set up the oscilloscope to view a waveform in the analog operating (**Norm**) mode. Adjust the trigger, **VOLTS/DIV**, sweep **TIME/DIV**, and vertical position controls as desired.

   b. Set the **Auto/Normal** switch to **Normal**, the **Norm/Store** switch to **Store**, and the **Roll/Refresh** switch to **Refresh**. Press the **Hold All** or **Arm** switch to store the waveform.

   c. The oscillscope can now be switched between **Store** and **Norm** to alternate between the digitized waveform and the analog version of that same waveform.

Using Plotter Output

The Model 2520 Oscilloscope provides facilities for driving an analog plotter. The following instructions explain how to store and output a waveform. Since plotters vary greatly, only general instructions have been given, consult the manual for the plotter to be used for more specific operating instructions.

1. Set up the oscilloscope to view a waveform in the analog operating (**Norm**) mode. Adjust the trigger, **VOLTS/DIV**, sweep **TIME/DIV**, and vertical position controls as desired.

2. Set the **Auto/Normal** switch to **Normal,** the **Store/Norm** switch to **Store,** and the **Roll/Refresh** switch to **Roll.** Press the **Hold All** switch to store the waveform(s).

3. Connect a plotter to the **Pen Lift, Y o/p,** and ⎍ **X Output** jacks at the rear panel of the oscilloscope. After the waveform(s) has been stored, the **TIME/DIV** control and **ms/sec** switch can be set for a "sweep speed" that is correct for the plotter that is being used.

4. To plot the channel 1 waveform press the **Plot 1** switch or to plot the channel 2 waveform press the **Plot 2** switch.

5. The oscilloscope will provide one sweep of the stored waveform and then shut the rear panel output jacks off.

DC VOLTAGE MEASUREMENTS
(Refer to Fig. 5)

The following technique may be used to measure the instantaneous dc level at any portion of a waveform, or to measure a dc voltage where no waveform is present.

1. Connect the signal to be measured to the input jack and set the vertical mode switch to the channel to be used. Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The **Var** and **Var Sweep** controls must be set to **Cal.**

2. Set the **Auto/Normal** switch to **Auto** and the **AC-Gnd-DC** switch to **Gnd,** which establishes a trace at the zero volt reference. Using the ▲▼ position control, adjust the trace to the desired reference level position, making sure not to disturb this setting once made.

3. Set the **AC-Gnd-DC** switch to **DC** to observe the waveform, including its dc component. If an inappropriate reference level position was selected in step 2 or an inappropriate **VOLTS/DIV** setting was made, the waveform may not be visible at this point (deflected completely off the screen). This is especially true when the dc component is large with respect to the waveform amplitude. If so, reset the **VOLTS/DIV** control and repeat steps 2 and 3 until the waveform and the zero reference are both on the screen.

4. Use the ◄► position control to bring the portion of the waveform to be measured to the center vertical graduation line of the graticule scale.

5. Measure the vertical distance from the zero reference level to the point to be measured (at least 3 divisions desirable for best accuracy). The reference level can be rechecked by momentarily returning the **AC-Gnd-DC** switch to **Gnd.**

6. Multiply the distance measured above by the **VOLTS/DIV** setting and the probe attenuation ratio as well. Voltages above the reference level are positive and voltages below the reference level are negative.

The measurement is summarized by the following equation:

DC level = Vert div x **VOLTS/DIV** x Probe

For the example shown in Fig. 5, the point being measured is 3.8 divisions from the reference level (ground potential). If the **VOLTS/DIV** control is set to **0.2 V** and a 10:1 probe is used, the dc voltage level is calculated as follows:

$$\text{DC level} = 3.8\ (\text{div}) \times 0.2\ (\text{V/div}) \times 10$$
$$= 7.6\ \text{V}$$

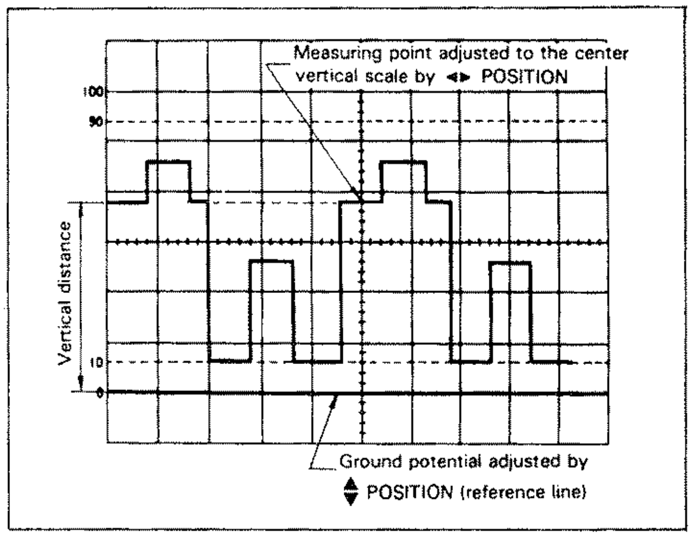

Fig. 5. DC Voltage Measurement.

MEASUREMENTS OF VOLTAGE BETWEEN TWO POINTS ON A WAVEFORM
(Refer to Fig. 6)

This procedure may be used to measure peak-to-peak voltages, or for measuring the voltage difference between any two points on a waveform.

1. Connect the signal to be measured to the input connector, set the vertical mode switch to the channel to be used, and set the **AC-Gnd-DC** switch to **AC.** Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The **Var** controls must be set to **Cal.**

2. Using the ▲▼ position control, adjust the waveform position such that one of the two points falls on a major horizontal graduation line.

3. Using the ◄► position control, adjust the second point to coincide with the center vertical graduation line.

4. Measure the vertical distance between the two points (at least 3 divisions desirable for best accuracy). Multiply the number of divisions by the setting of the **VOLTS/DIV** control. If a probe is used, further multiply this by the probe attenuation ratio.

The measurement is summarized by the following equation:

Voltage = Vert div x **VOLTS/DIV** x probe

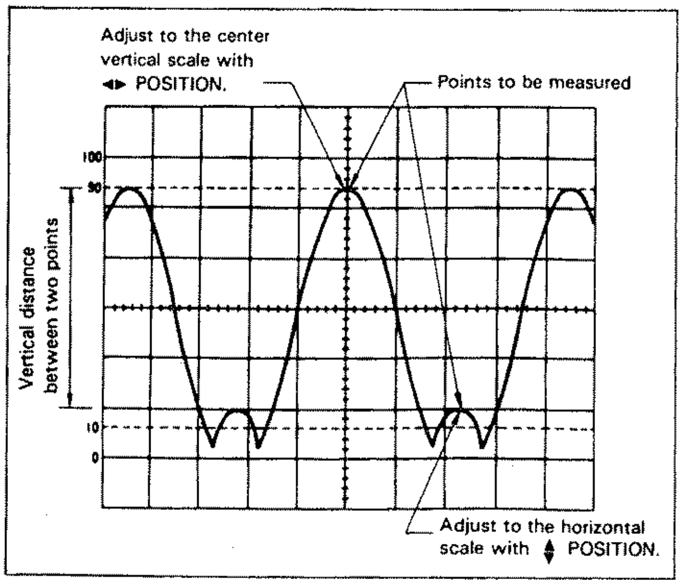

Fig. 6. Voltage Measurement.

For the example shown in Fig. 6, the two points are separated by 4.4 divisions vertically. If the **VOLTS/DIV** setting is **20 mV** and a 10:1 probe is used, the voltage is calculated as follows:

Voltage = 4.4 (div) x 20 (mV/div) x 10

= 880 mV

ELIMINATION OF AN UNDESIRED SIGNAL COMPONENT

(Refer to Fig. 7)

The **Add** mode can be conveniently used to cancel out the effect of an undesired signal component which is superimposed on the signal you wish to observe (for example, undesired 60 Hz hum superimposed on an rf signal).

1. Apply the signal containing an undesired component to the **CH 1 (X)** input jack and the undesired signal itself alone to the **CH 2 (Y)** input jack.

2. Select a trigger source of channel 2. Adjust the controls to display two signals, such as shown in Fig. 7. Verify that the channel 2 trace represents the unwanted signal in reverse polarity. The polarity may be reversed by pressing **CH 2 Invert.**

3. Now select the **Add** mode and select channel 1 as the trigger source. Adjust the **CH 2 VOLTS/DIV** and **Var** controls so that the undesired signal component is cancelled as much as possible. The remaining signal should be the signal you wish to observe alone, and free of the unwanted signal.

TIME MEASUREMENTS

(Refer to Fig. 8)

This is the procedure for making time (period) measurements between two points on a waveform. The two points may be the beginning and ending of one complete cycle if desired.

1. Connect the signal to be measured to the input connector and set the vertical mode to the channel to be used. Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to obtain a normal display of the

waveform to be measured. Be sure the **Var Sweep** control is set to **Cal.**

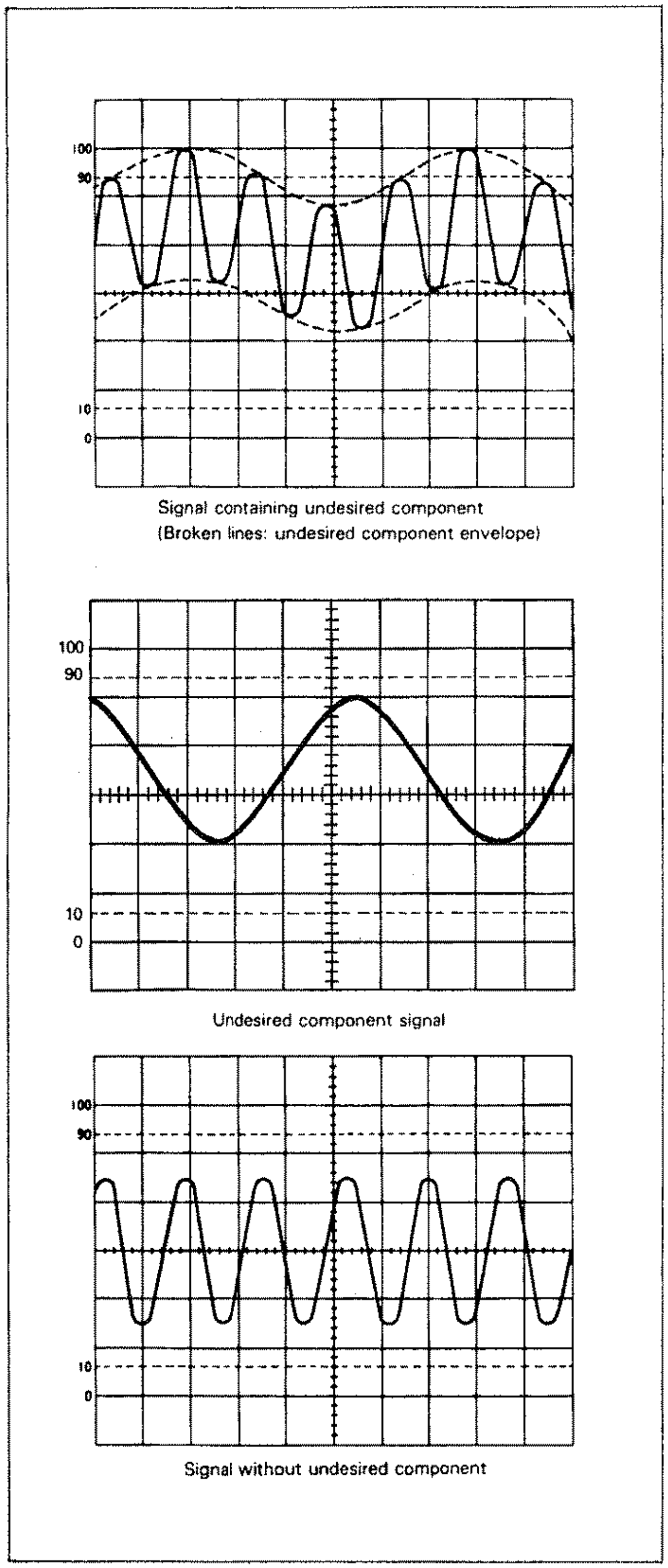

Fig. 7. Eliminating An Undesired Signal Component.

2. Using the ▲▼ position control, set one of the points to be used as a reference to coincide with the horizontal center line. Use the ◄► position control to set this point at the intersection of any vertical graduation line.

3. Measure the horizontal distance between the two points (at least 4 divisions desirable for best accuracy). Multiply this by the setting of the sweep **TIME/DIV** control to obtain the time between the two points. If **X10 Mag** is used, multiply this further by 1/10.

The measurement is summarized by the following equation:

Time = Hor div x sweep **TIME/DIV**

(x 1/10 if **X10 Mag** is used)

For the example shown in Fig. 8, the horizontal distance between the two points is 5.4 divisions. If the sweep **TIME/DIV** is **0.2 ms** and **X10 Mag** is not used, the time period is calculated as follows:

Time = 5.4 (div) x 0.2 (ms/div)

= 1.08 ms

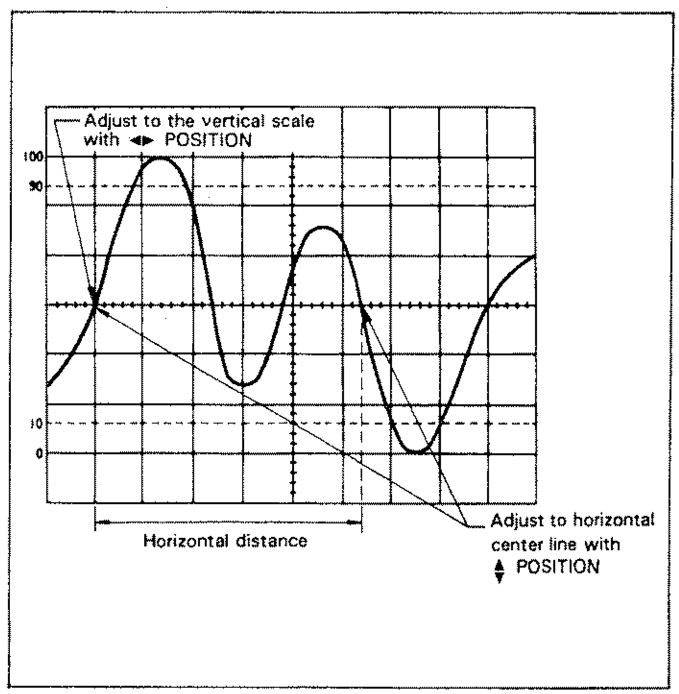

Fig. 8. Time Measurement.

FREQUENCY MEASUREMENTS

Method No. 1
(Refer to Fig. 9)

Frequency measurements are made by measuring the time period of one cycle of waveform and calculating the frequency, which equals the reciprocal of the time period.

1. Set up the oscilloscope to display one cycle of waveform (see Fig. 9).

2. Measure the time period of one cycle and calculate the frequency as follows:

$$\text{Freq} = \frac{1}{\text{Period}}$$

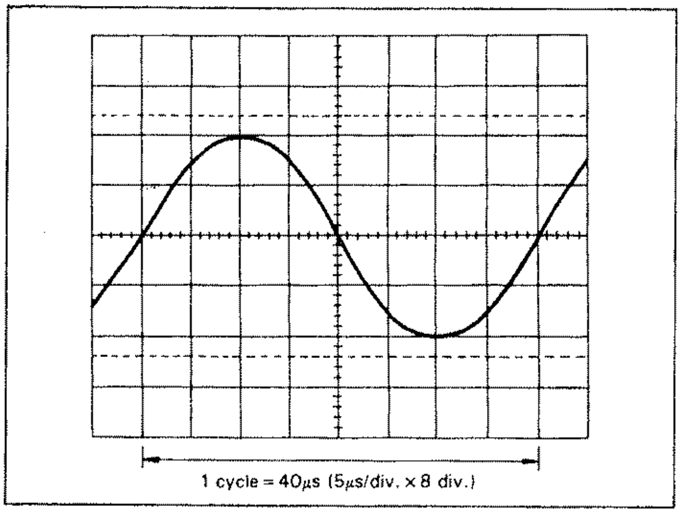

Fig. 9. Frequency Measurement.

In the example shown in Fig. 9, a period of 40 μs is observed. Substituting this value into the above equation, the frequency is calculated as follows:

$$\text{Freq} = \frac{1}{40 \times 10^{-6}}$$

$$= 2.5 \times 10^{4}$$

$$= 25 \text{ kHz}$$

Method No. 2
(Refer to Fig. 10)

While the previously described method relies upon direct period measurement of one cycle, the frequency may also be measured by counting the number of cycles present in a given time period.

1. Set up the oscilloscope to display several cycles of the waveform. The **Var Sweep** control must be set to **Cal.**

2. Count the number of cycles of waveform between a chosen set of vertical graduation lines (see Fig. 10).

3. Multiply the number of horizontal divisions by the sweep **TIME/DIV** setting to calculate the time span. Multiply the reciprocal of this value by the number of cycles present in the time span. If **X10 Mag** is used, multiply this further by 10. Note that errors will occur for displays having only a few cycles.

The measurement is summarized by the following equation:

$$\text{Freq} = \frac{\text{No of cycles (x 10 for X10 Mag)}}{\text{Hor div x sweep TIME/DIV}}$$

For the example shown in Fig. 10, there are 10 cycles within 7 divisions. If the sweep **TIME/DIV** is **5 μs** and **X10 Mag** is not used, the frequency is calculated as follows:

$$\text{Freq} = \frac{10 \text{ (cycles)}}{7 \text{ (div)} \times 5 \text{ (μs)}} = 285.7 \text{ kHz}$$

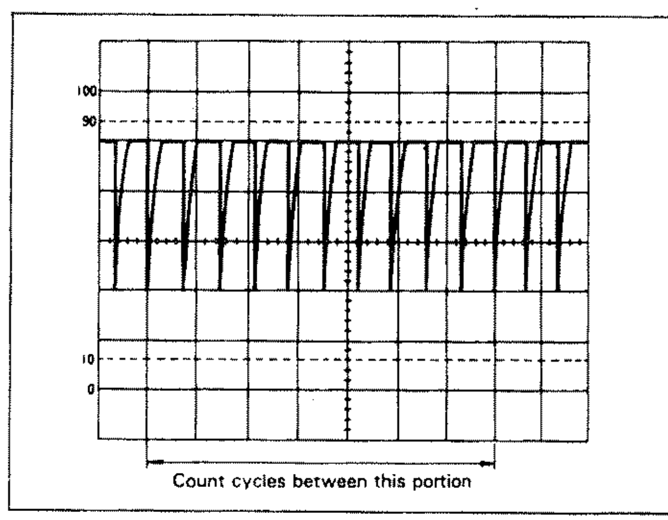

Fig. 10. Alternate Method of Frequency Measurement.

PULSE WIDTH MEASUREMENTS
(Refer to Fig. 11)

1. Apply the pulse signal to the input and set the vertical mode switch to the channel to be used.

2. Use the **VOLTS/DIV** and **Var** controls to adjust the display so the waveform is easily observed. Use the ▲▼ position control to position the pulse over the center horizontal graduation line. Use the ◄► position control to align the leading edge of the pulse with one of the vertical graduation lines.

3. Measure the distance between the leading edge and trailing edge of the pulse (along the center horizontal graduation line). Be sure that the **Var Sweep** control is set to **Cal.** Multiply the number of horizontal divisions by the sweep **TIME/DIV**, and if **X10 Mag** is used, further multiply this value by 1/10.

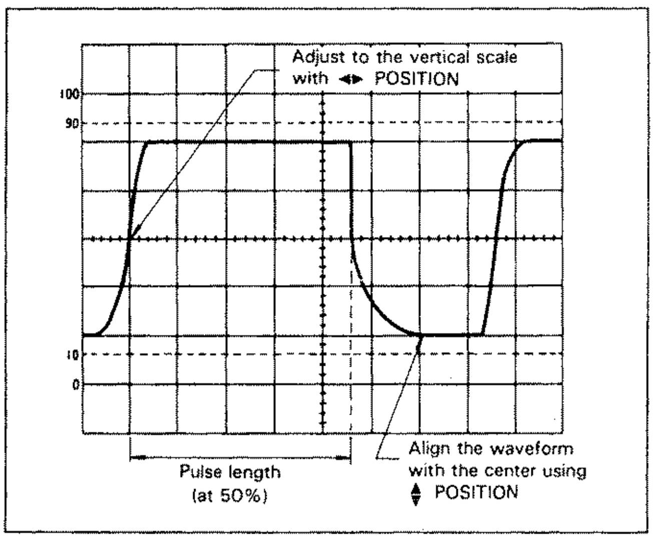

Fig. 11. Pulse Width Measurement.

The measurement is summarized by the following equation:

Pulse Width = Hor div x sweep **TIME/DIV**

(x 1/10 if **X10 Mag** is used)

For the example shown in Fig. 11, the pulse width at the center of the pulse is 4.6 divisions. If the sweep **TIME/DIV** is **0.2 ms** and **X10 Mag** is used, the pulse width is calculated as follows:

Pulse Width =

4.6 (div) x 0.2 (ms/div) x 1/10

= .092 ms or 92 μs

PULSE RISE TIME AND FALL TIME MEASUREMENTS

Method No. 1:
(Refer to Fig. 12)

For rise time and fall time measurements, the 10% and 90% amplitude points are used as starting and ending reference points.

1. Apply a signal to the input and set the vertical mode switch to the channel to be used. Use the **VOLTS/DIV** and **Var** controls to adjust the waveform peak to peak height to six divisions.

2. Using the ▲▼ position control, adjust the display so that the waveform is centered vertically on the display. Set the sweep **TIME/DIV** control to as fast a setting as possible while still being able to observe both the 10% and 90% points. Set the **Var Sweep** to the **Cal** position.

3. Use the ◄► position control to adjust the 10% point to coincide with a vertical graduation line and measure the horizontal distance in divisions between the 10% and 90% points on the waveform. Multiply this by the sweep **TIME/DIV** setting and also by 1/10 if the **X 10 Mag** mode was used.

NOTE
Be sure that the correct 10% and 90% lines are used. For such measurements the 10% and 90% points are marked on the CRT screen.

The measurement is summarized by the following equation:

Rise Time = Hor div x sweep **TIME/DIV**

(x 1/10 if **X10 Mag** is used)

For the example shown in Fig. 12, the horizontal distance is 4.0 divisions. The sweep **TIME/DIV** setting is 2 µs. The rise time is calculated as follows:

Rise Time = 4.0 (div) x 2 (µs/div) = 8 µs

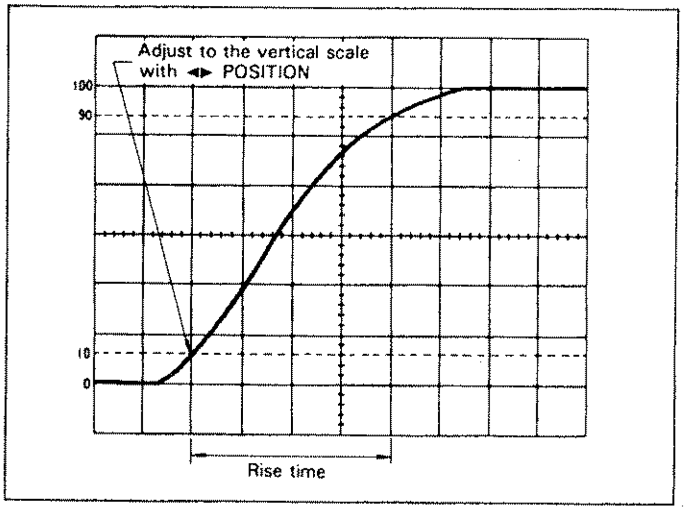

Fig. 12. Rise Time and Fall Time Measurement.

Method No. 2:
(Refer to Fig. 13)

The following step can be substituted for step 3 in method No. 1:

> Use the ◄► position control to set the 10% point to coincide with the center vertical graduation line and measure the horizontal distance to the point of the intersection of the waveform with center horizontal line. Let this distance be D_1. Next adjust the waveform position so that the 90% point coincides with the vertical centerline and measure the distance from that line to the intersection of the waveform with the horizontal centerline. Let this distance be D_2. The total horizontal distance is D_1 plus D_2.

The following equation summarizes the measurement:

Rise Time = $(D_1 + D_2)$ x sweep **TIME/DIV**

(x 1/10 if **X10 Mag** is used)

For the example shown in Fig. 13, D_1 is 1.8 divisions and D_2 is 2.2 divisions. If the sweep **TIME/DIV** setting is **2 µs**, the rise time is calculated as follows:

Rise Time = (1.8 + 2.2) x 2 (µs/div) = 8 µs

NOTE
See APPENDIX I for important rise time and fall time considerations.

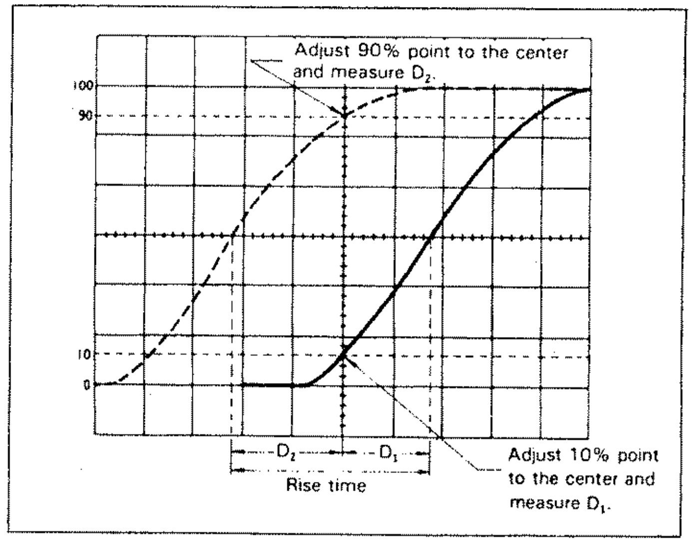

Fig. 13. Rise Time and Fall Time Measurement.

TIME DIFFERENCE MEASUREMENTS
(Refer to Fig. 14)

This procedure is useful in measurement of time difference between signals that are synchronized to one another but skewed in time.

1. Apply the two signals to the **CH 1 (X)** and **CH 2 (Y)** input jacks.

2. Select the faster of the two signals as the trigger source and use the **VOLTS/DIV** and sweep **TIME/DIV** controls to obtain an easily observed display.

3. Use the ▲▼ position controls to superimpose both waveforms to intersect the center horizontal graduation line as shown in Fig. 14. Use the ◄► position control to set the reference signal coincident with one of the vertical graduation lines.

4. Measure the horizontal distance between the two signals and multiply this distance

(in divisions) by the sweep **TIME/DIV** setting. If **X10 Mag** is used, multiply this again by 1/10.

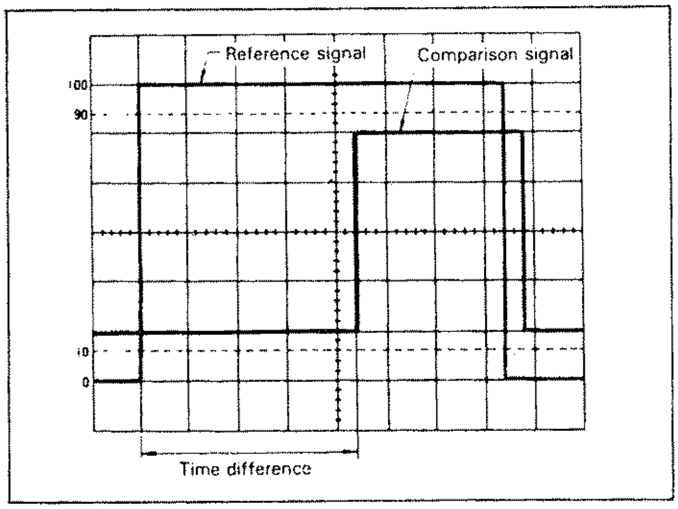

Fig. 14. Time Difference Measurement.

The measurement is summarized by the following equation:

Time = Hor div x sweep **TIME/DIV**

(x 1/10 if **X10 Mag** is used)

For the example shown in Fig. 14, the horizontal distance measured is 4.4 divisions. If the sweep **TIME/DIV** is **0.2 ms** and **X10 Mag** is not used, the time difference is calculated as follows:

Time = 4.4 (div) x 0.2 (ms/div)

= 0.88 ms or 880 μs

PHASE DIFFERENCE MEASUREMENTS

Method No. 1
(Refer to Fig. 15)

This procedure is useful in measuring the phase difference of signals of the same frequency.

1. Apply the two signals to the **CH 1 (X)** and **CH 2 (Y)** input jacks.

2. Select the signal which is leading in phase as the trigger source and use the **VOLTS/DIV** controls to adjust the two waveforms so they are equal in amplitude.

3. Use the ▲▼ position controls to position the waveforms in the vertical center of the screen. Use the sweep **TIME/DIV** and **Var** controls to adjust the display so one cycle of the reference signal occupies 8 divisions horizontally (see Fig. 15). The **Trig Level** and ◄► position controls are also useful in achieving this display. The display should be as shown in Fig. 15, where one division now represents 45° in phase.

4. Measure the horizontal distance between corresponding points on the two waveforms. Multiply the distance (in divisions) by 45° per division to obtain the phase difference.

The measurement is summarized by the following equation:

Phase difference = Hor div x 45°/div

For the example shown in Fig. 15, the horizontal distance is 1.7 divisions. Thus, the phase difference is calculated as follows:

Phase difference = 1.7 x 45°/div = 76.5°

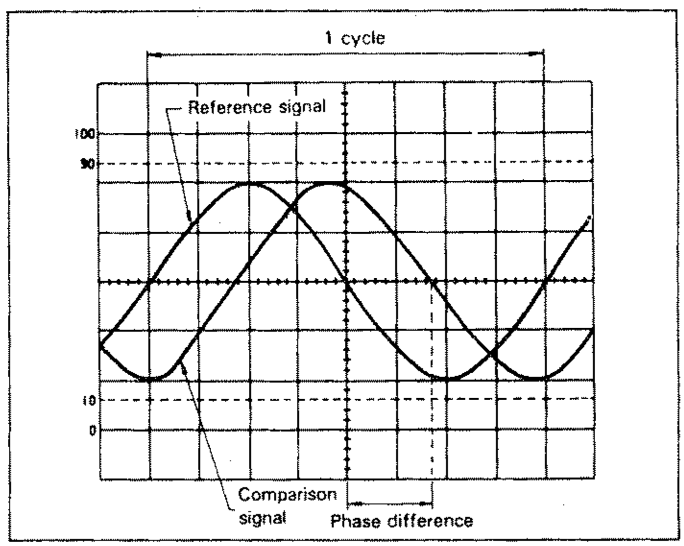

Fig. 15. Phase Difference Measurement.

Method No. 2
(Refer to Fig. 16)

The above procedure allows 45° per division, which may not give the desired accuracy for small phase differences.

If greater accuracy is required, the sweep **TIME/DIV** setting may be changed to expand the display as shown in Fig. 16, but the **Var Sweep** setting must not be touched. If necessary, the **Trig Level** may be readjusted. For this type of operation, the relationship of one division to 45° no longer holds. Instead the following equation must be used:

$$\text{Phase diff} = \text{Hor div} \times 45^\circ/\text{div} \times \frac{A}{B}$$

Where:
A = New sweep **TIME/DIV** setting.
B = Original sweep **TIME/DIV** setting.

A simpler method of obtaining more accuracy quickly is to simply use **X10 Mag** for a scale factor of 4.5°/division.

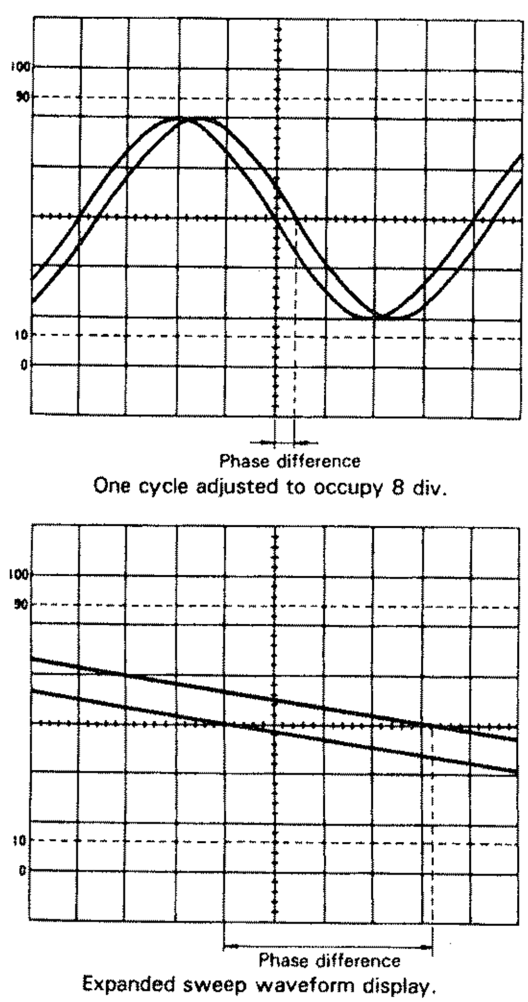

Fig. 16. Measuring Small Phase Difference.

RELATIVE MEASUREMENTS

If the amplitude and period of some reference signal are known, an unknown signal may be measured for amplitude and period without the **Var** and **Var Sweep** controls set to **Cal.** The measurement is made in units relative to the reference signal.

Relative Voltage Measurements
(refer to Fig. 17)

1. Apply the reference signal to the input jack and adjust the display for a normal waveform display. Adjust the **VOLTS/DIV** and **Var** controls so that the amplitude of the reference signal occupies a fixed number of divisions. After adjusting, be sure not to disturb the setting of the **Var** control.

2. Calculate the vertical calibration coefficient as follows:

$$\text{vertical coefficient} = \frac{C}{D \times E}$$

Where:
C = Amplitude of reference signal (in volts).
D = Amplitude of reference signal (in divisions).
E = **VOLTS/DIV** setting.

3. Remove the reference signal and apply the unknown signal to the input jack, using only the **VOLTS/DIV** control to adjust the amplitude for easy observation (do not disturb the **Var** setting).

4. Measure the amplitude of the displayed waveform, in divisions. Multiply the number of divisions by the **VOLTS/DIV** setting and the vertical coefficient from above to find the value of the unknown voltage.

The measurement is summarized by the following equation:

$$\text{Unknown Voltage} = \text{Vert div} \times \textbf{VOLTS/DIV} \times \text{vert coefficient}$$

For the example shown in Fig. 17, the **Var** control is adjusted so the amplitude of the reference signal is 4 divisions. If the reference signal is 2.0 volts p-p, and the **VOLTS/DIV** setting is **1 V**, the vertical coefficient is 0.5; which was calculated as follows:

$$\text{vertical coefficient} = \frac{2\ (V)}{4\ (div) \times 1\ (V/div)} = 0.5$$

For the example shown in Fig. 17, the amplitude of the unknown signal is 3 divisions, and the previously calculated vertical coefficient is 0.5. If the **VOLTS/DIV** setting is **5 V**, the unknown signal is 7.5 V p-p; which was calculated as follows:

$$\text{Unknown Voltage} = 3\ (div) \times 5\ (V/div) \times 0.5\ (\text{vert coef}) = 7.5\ V$$

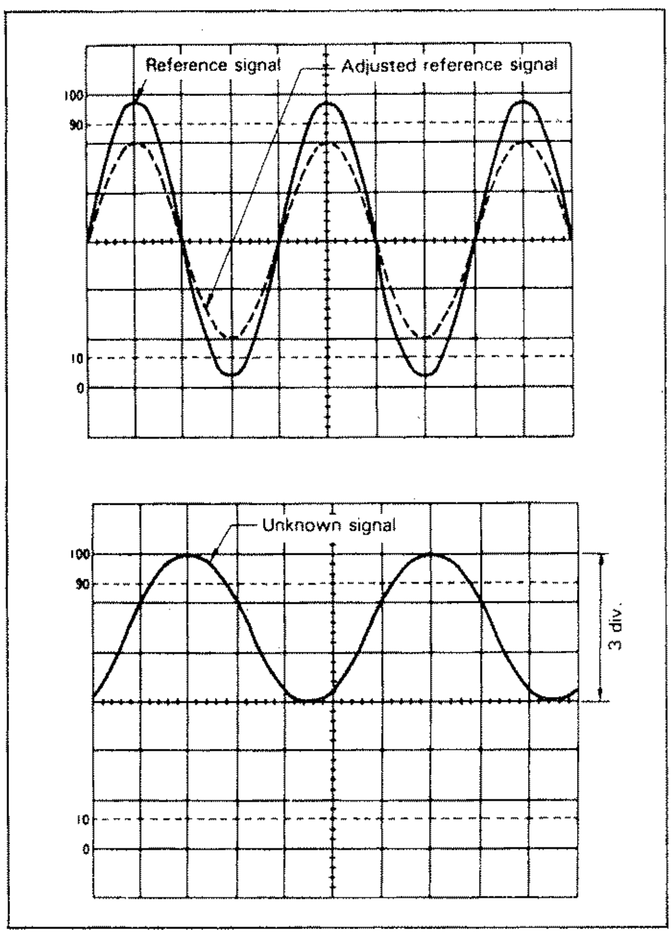

Fig. 17. Voltage Measurement, Relative Method.

NOTE

It is preferable that the reference voltage be the peak-to-peak value, as in the previous example. The measurement holds true for all waveforms if a p-p reference is used. It is also possible to use an rms value for the reference voltage. The unknown voltage value will also be in rms, but the measurement holds true only if both the reference and unknown signals are undistorted sine waves.

Relative Period Measurements
(refer to Fig. 18)

1. Apply the reference signal to the input jack and adjust for an easily observed waveform display. Using the sweep **TIME/DIV** and **Var Sweep** controls, adjust one cycle of the reference signal to occupy a fixed number of horizontal divisions. After this is done, be sure not to disturb the **Var Sweep** control setting

2. Calculate the sweep (horizontal) calibration coefficient using the following equation:

$$\text{Sweep coefficient} = \frac{F}{G \times H}$$

Where:
F = Period of reference signal (seconds).
G = Horizontal width of reference signal (divisions).
H = sweep **TIME/DIV** setting.

3. Remove the reference signal and apply the unknown signal to the input jack, using only the sweep **TIME/DIV** control to adjust the width of the display (do not disturb the **Var Sweep** setting).

4. Measure the width of one cycle of the displayed waveform, in divisions. Multiply the number of divisions by the sweep **TIME/DIV** setting and the sweep coefficient from above to find the period of the unknown waveform.

The measurement is summarized by the following equation:

Unknown Period = Horizontal divisions x sweep **TIME/DIV** x sweep coefficient

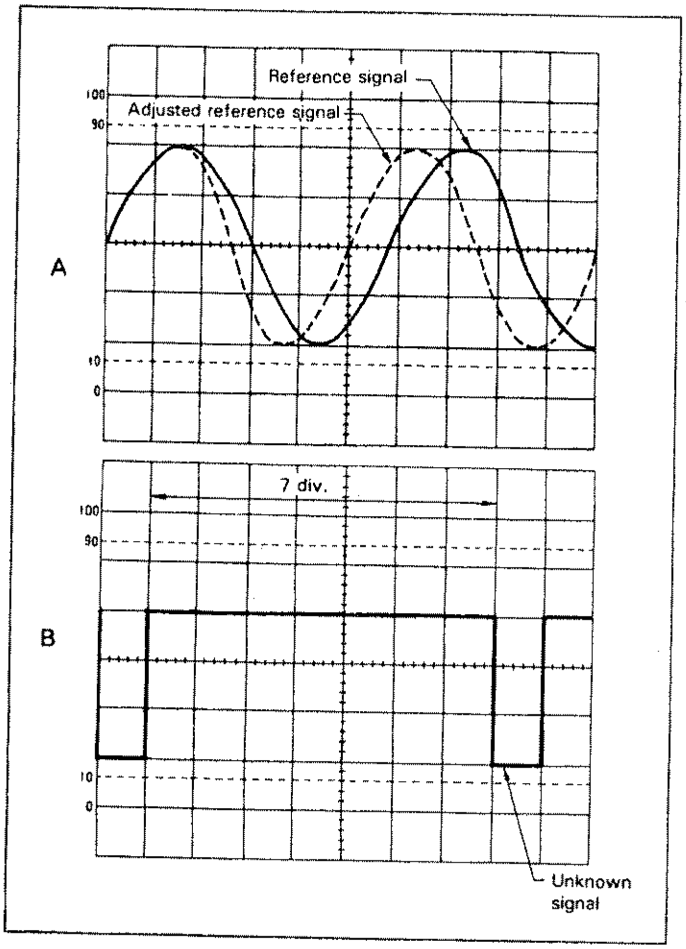

Fig. 18. Period Measurement, Relative Method.

For the example in Fig. 18A, the **Var Sweep** control is adjusted so the reference signal occupies 5 horizontal divisions. If the reference signal is 1.75 kHz, and the sweep **TIME/DIV** control is **0.1 ms**, the sweep coefficient is caluculated as follows:

$$\text{sweep coefficient} = \frac{1.75\ \text{kHz}^{-1}}{5\ (\text{div})\ \times\ 0.1\ (\text{ms/div})}$$

$$= 1.143$$

For the example in Fig. 18B, the width of the unknown signal is 7 divisions, and the previously calculated sweep coefficient is 1.143. If the sweep **TIME/DIV** setting is **0.2 ms**, the period is calculated as follows:

$$\text{Unknown Period} =$$

$$7\ (\text{div})\ \times\ 0.2\ (\text{ms/div})\ \times\ 1.143\ (\text{sweep coef})$$

$$= 1.6\ \text{ms}$$

X-Y MODE APPLICATIONS

Phase Measurements
(refer to Fig. 19.)

A dual-trace method of phase measurement was previously described. A second method of phase measurement requires calculations based on the Lissajous patterns obtained using X-Y operation. Distortion due to non-linear amplification can also be displayed.

A sine wave is applied to the audio circuit being tested. The same sine wave is applied to the vertical input of the oscilloscope, and the output of the tested circuit is applied to the horizontal input of the oscilloscope. The amount of phase difference between the two signals can be calculated from the resulting waveform.

1. Using an audio generator with a pure sinusoidal signal, apply a sine wave test signal at the desired test frequency to the audio network being tested.

2. Set the signal generator output for the normal operating level of the circuit being tested. If desired, the circuit's output may first be observed on the oscilloscope with normal sweep operation. If the test circuit is overdriven, the sine wave display on the oscilloscope is clipped and the signal level must be reduced.

3. Connect channel 1 to the input and channel 2 to the output of the test circuit. Set channel 1 and 2 gain controls for exactly the same amplitude waveform on the display in normal sweep operation.

4. Select X-Y operation by setting the vertical mode switch to the **X-Y** position.

5. If necessary, repeat step 3, readjusting the channel 1 and 2 gain controls for a suitable viewing size. Some typical results are shown in Fig. 19.

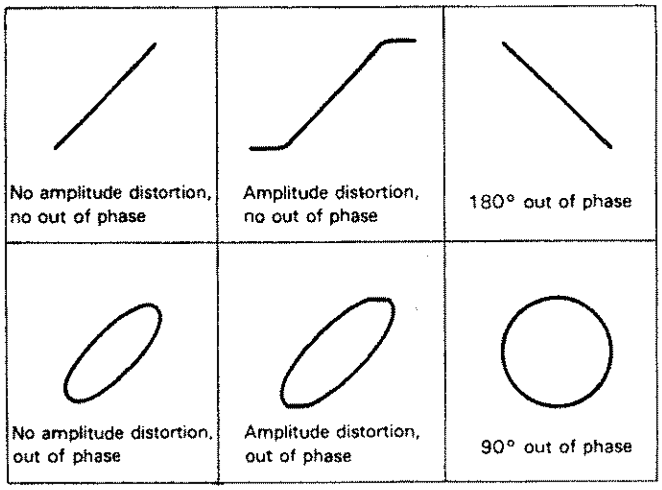

Fig. 19. Typical X-Y Phase Measurement Displays.

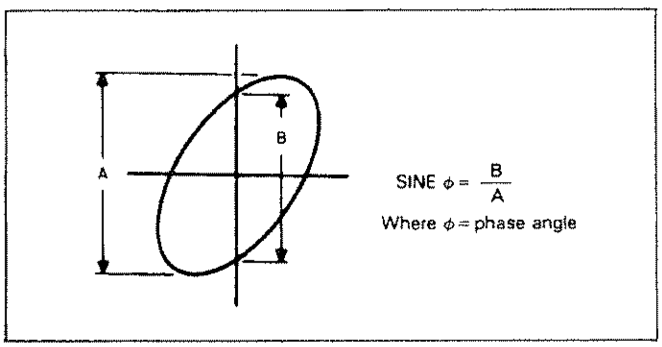

Fig. 20. Phase Measurement, X-Y Operation.

If the two signals are in phase, the oscilloscope trace is a straight diagonal line. If the vertical and horizontal gain are properly adjusted, this line is at a 45° angle. A 90° phase shift produces a circular oscilloscope pattern. Phase shift of less (or more) than 90° produces an elliptical oscilloscope pattern. The amount of phase shift can be calculated from the oscilloscope trace as shown in Fig. 20.

Frequency Response Measurements
(refer to Fig. 21)

A sweep generator and the X-Y mode of this oscilloscope may be used to measure the audio or rf frequency response of an active or passive device up to 20 MHz, such as an amplifier, band pass filter, coupling network, etc.

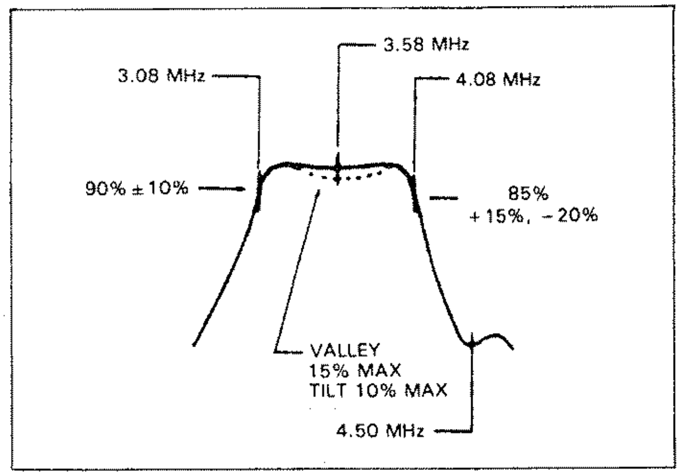

Fig. 21. Frequency Response Measurement.

1. Connect audio or rf output of the sweep generator to the input of the circuit under test and the output of the test circuit to channel 2 (vertical axis) of the oscilloscope. A demodulator probe will give a "text book" frequency response display as shown in Fig. 21, but a standard probe can be used which will result in an envelope display.

2. Connect the sweep ramp voltage of the sweep generator to the channel 1 input (horizontal axis) of the oscilloscope.

3. Set the vertical mode switch to **X-Y** and adjust the channel 1 and 2 controls for a suitable viewing size.

VIEWING ONE TIME EVENTS

1. Connect a probe to the point in the circuit where the glitch or other one time event is present.

2. Set the **Auto/Normal** switch to **Normal,** the **Store/Norm** switch to **Store,** and the **Roll/Refresh** switch to **Roll.** Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to appropriate settings. Set the vertical mode switch to the channel to be used and set the trigger controls so that the event will trigger the sweep.

3. If pretrigger information is desired, select the desired amount of pretrigger information using the **25%** and **75%** switches.

4. Press the **Arm** switch (the **Armed/Stored** indicator should flash until a sufficient trigger is applied) and wait for the glitch or other one time event to trigger the oscilloscope. Upon completion of the sweep (after triggering) the oscilloscope will automatically store the event (and any pretrigger information if selected).

VIEWING VERY SLOW SIGNALS

Slow signals are difficult to observe on an analog oscilloscope. Below 20 Hz the display flickers or becomes a dot moving across the screen. The digital storage mode permits easy viewing of slow waveforms (down to 8-1/2 minutes per occurance).

1. Connect a probe to the point in the circuit where the signal that you wish to observe is present.

2. Set the **Auto/Normal** switch to **Normal**, the **Store/Norm** switch to **Store**, the **AC-Gnd-DC** switch to **DC**, and the **Roll/Refresh** switch to **Refresh**. Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to appropriate settings. Set the vertical mode and the trigger source switches (**CH 1** and **CH 2**) to the channel to be used, select **DC** trigger coupling, and set the trigger controls so that the signal will trigger the sweep.

3. The waveform should now be displayed on the screen and should refresh the display each time a new sweep is triggered. It can be stored at any time by pressing the **Hold All** switch.

CAPTURING TELEPHONE DIAL PULSES

The relatively slow speed of pulse dial telephones combined with the fact that the dialing pulses are non-repetitive, make it almost impossible to view the pulses with a conventional oscilloscope. The extremely slow sweep speeds of this Digital Storage Oscilloscope allow the capture and analysis of dialing pulses from a pulse dial telephone.

1. With the telephone connected to a telephone line or telephone line simulator, connect the telephone (at the telephone line) to the input of the oscilloscope.

   NOTE
   Remember that dialing on an actual telephone line will be accepted by the telephone exchange and dialing a complete number will result in a connection being made.

2. Set the **Auto/Normal** switch to **Normal**, the **Store/Norm** switch to **Store**, the **Roll/Refresh** switch to **Roll**, the **+/-** (trigger slope) switch to **-**, the **ms/sec** switch to **sec**, the **VOLTS/DIV** control to **10 V**, the **TIME/DIV** control to **1 ms**, and the **AC-Gnd-DC** switch to **Gnd**.

3. Use the ▲▼ position control to move the trace up to the second horizontal graduation line from the top. Set the **AC-Gnd-DC** switch to **DC** and observe the voltage on the oscilloscope. An on hook telephone should have about -48 volts dropped across it. When the telephone is taken off hook, the voltage should be approximately -12 volts. As the telephone is dialed, there should be negative going pulses that drop all the way down to the telephone line voltage (the voltage dropped across the on hook telephone). The pulses will roll across the screen from right to left.

   NOTE
   With some telephone exchanges, the voltage may actually go to -70 volts.

4. At any time the pulses can be stored by pressing the **Hold All** switch. The groups of pulses can then be more closely examined by pressing the **X10 Mag** switch. The number of pulses should directly correspond with the number dialed (**i.e.**, when "2" is dialed there should be two pulses, when "6" is dialed there should be

six pulses, and when "0" is dialed there should be ten pulses).

5. If you wish to examine the pulses more closely, select a faster sweep **TIME/DIV** setting that will allow pulse rate, make time, break time, and interdigit time to be measured.

EVALUATING SWITCHING DEVICES

Spikes generated by switches, relays, and circuit breakers, often cause malfunctions to occur in electrical or electronic equipment. This oscilloscope can be used to capture such spikes. It can be triggered from either a "make" or a "break" in the circuit path and it can also capture the transient charactersitic that occured prior to the trigger. In addition, its ability to store and display two waveforms simultaneously, allows pole synchronization tests to be made.

1. Connect a probe to the relay contact, switch, or circuit breaker.

2. Set the **Auto/Normal** switch to **Normal** and the **Store/Norm** switch to **Store.** Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to appropriate settings. Set the vertical mode switch to the channel to be used and set the trigger controls so that the desired event will trigger the sweep.

3. If you wish to capture pretrigger information, set the **Roll/Refresh** switch to **Roll** and select the desired amount using the **25%** and **75%** switches and press the **Arm** switch before the event occurs. The event will then be stored when the triggered sweep is completed.

4. If you do not wish to capture pretrigger information but still wish to store the spike, select the **Refresh** mode and press the **Arm** switch before the event occurs. The event will then be stored when the triggered sweep is completed.

5. To obtain a hard copy of the display, connect a plotter to the plotter outputs on the rear panel, press the **Hold All** switch, select the appropriate sweep time for the plotter being used, and press either the **Plot 1** or **Plot 2** switch. Only one trace can be potted at a time so recording both waveforms will require first plotting one channel then the other.

TESTING BATTERY BACK-UP SYSTEMS

Using the Digital Storage Oscilloscope it is possible to measure the time between ac power is cut off and when the battery back-up takes over.

1. Connect a probe to any point that is powered by both the ac line voltage and the battery back-up system.

2. Set the **Auto/Normal** switch to **Normal,** the **Store/Norm** switch to **Store,** and the **Roll/Refresh** switch to **Roll.** Set the **VOLTS/DIV,** ▲▼ position control, and sweep **TIME/DIV** controls to appropriate settings. Set the vertical mode switch to the channel to be used and set the trigger controls so that the when the ac power is cut off, the sweep will be triggered.

3. Press the **Arm** switch before the power is cutoff. The event will then be stored when the triggered sweep is completed.

4. Use the ◄► position control to adjust the point where the ac power was cut off to coincide with a major vertical graduation line and measure the horizontal distance in divisions between the point where power was cut off and the point where the battery back-up took over. Multiply this by the sweep **TIME/DIV** setting and also by 1/10 if the **X10 Mag** mode was used.

The measurement is summarized by the following equation:

Take-over Time =

Hor div x sweep **TIME/DIV**

(x 1/10 if **X10 Mag** is used)

For the example shown in Fig. 22, the horizontal distance is 4.0 divisions. The sweep **TIME/DIV** setting is **2 ms.** The take-over time is calculated as follows:

Take-over Time =

4.0 (div) x 2 (ms/div) x 1/10

= 0.8 ms

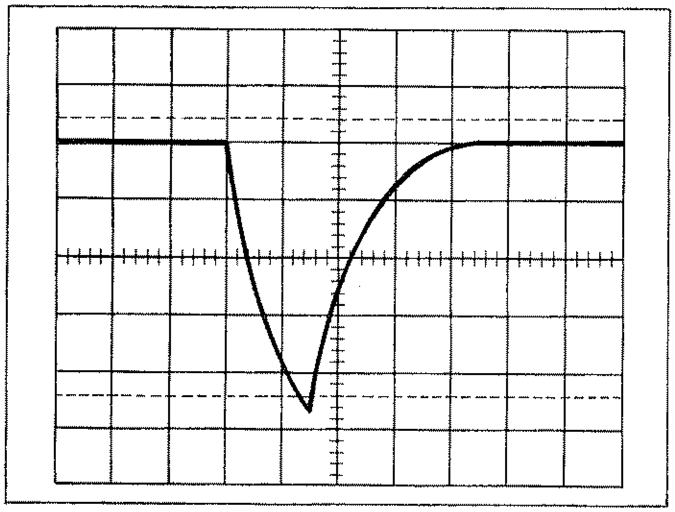

Fig. 22. Battery Back-Up Take-Over Time Measurement

RECORDING LIGHTNING INDUCED SURGES ON POWER LINES

Like switching spikes, lightning surges can cause serious malfunctions to occur to electrical and electronic equipment. This oscilloscope can be set up to record such an event even if the user is not present.

1. Connect a probe to the power line.

   NOTE
   Make sure that the probe is of sufficient rating to withstand the voltage produced by a surge. Also make sure that the voltage present on the oscilloscope side of the probe will not exceed the maximum input rating for the oscilloscope (400 V dc + ac peak).

2. Set the **Auto/Normal** switch to **Normal** and the **Store/Norm** switch to **Store.** Set the **VOLTS/DIV** and sweep **TIME/DIV** controls to appropriate settings. Set the vertical mode switch to the channel to be used and set the trigger controls so that the desired event will trigger the sweep.

3. If you wish to capture pretrigger information, set the **Roll/Refresh** switch to **Roll** and select the desired amount using the **25%** and **75%** switches and press the **Arm** switch. The event will automatically be stored when the triggered sweep is completed.

4. If you do not wish to capture pretrigger information, set the **Roll/Refresh** switch to **Refresh** and press the **Arm** switch. The event will then be stored when the triggered sweep is completed.

   NOTE
   The oscilloscope can now be left unattended. When the surge occurs, the oscilloscope will automatically store the waveform and hold it for later use (if the trigger controls have been set properly).

5. To obtain a hard copy of the display, connect a plotter to the plotter outputs on the rear panel, press the **Hold All** switch, select the appropriate sweep time for the plotter being used, and press either **Plot** switch that correspondes to the channel used.

WARNING

The following instructions are for use by qualified service personnel only. To avoid electrical shock, do not perform any servicing other than contained in the operating instructions unless you are qualified to do so.

High voltage up to 2,000 volts is present when covers are removed and the unit is operating. Remember that high voltage may be retained indefinitely on high voltage capacitors. Also remember that ac line voltage is present on line voltage input circuits any time the instrument is plugged into an ac outlet, even if turned off. Unplug the oscilloscope and discharge high voltage capacitors before performing service procedures.

FUSE REPLACEMENT

If the fuse blows, the pilot light will go out and the oscilloscope will not operate. The fuse should not normally open unless a problem has developed in the unit. Try to determine and correct the cause of the blown fuse, then replace only with the correct value fuse. For 100 or 120 V operation a 0.5 A slow blow fuse is used and for 200 or 240 V operation a 0.25 A slow blow fuse is used. The fuse is located on the rear panel (see Fig. 2).

LINE VOLTAGE SELECTION

The Model 2520 can operate on a 100, 120, 220, or 240 V power line. To select the desired line voltage:

1. Set the **100 V/220 V** switch to the **100 V** position for 100 or 120 V operation or to the **220 V** position for 220 or 240 V operation.

2. Set the **0 V/+20 V** switch to the **0 V** position for 100 or 220 V operation or to the **+20 V** position for 120 or 240 V operation. Be sure to install the correct value fuse (0.5 A for 100/120 V operation or 0.25 A for 200/240 V operation).

PERIODIC ADJUSTMENTS

Screwdriver adjustments only need to be checked and adjusted periodically. Probe compensation, trace rotation, and balance adjustments are included in this category. Procedures are given below.

Probe Compensation

1. Connect probes to channel 1 and channel 2 input jacks. Repeat procedure for each probe.

2. Touch tip of probe to **Cal 1 V** terminal.

3. Adjust oscilloscope controls to display 3 or 4 cycles of **Cal 1 V** square wave at 5 or 6 divisions amplitude.

4. Adjust compensation trimmer on probe for optimum square wave (minimum overshoot, rounding off, and tilt). Refer to Fig. 23.

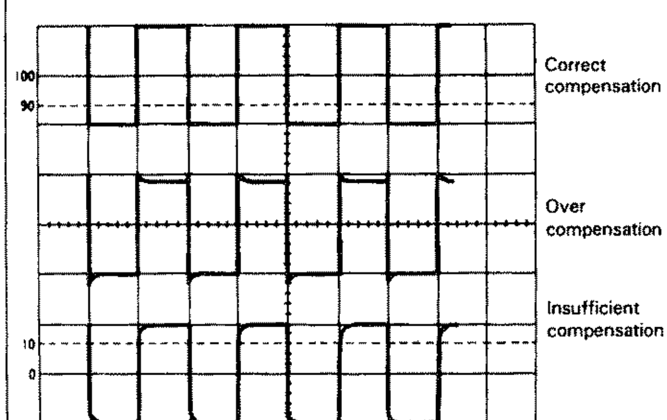

Fig. 23. Probe Compensation Adjustment.

Trace Rotation Adjustment

1. Set oscilloscope controls for a single trace display in CH 1 mode with the channel 1 **AC-Gnd-DC** switch set to **Gnd.**

2. Use the channel 1 ▲▼ position control to position the trace over the center horizontal line on the graticule scale. The trace should be exactly parallel with the horizontal line.

3. Use the **Trace Rotate** adjustment on the front panel to eliminate any trace tilt.

Balance Adjustments

1. Set oscilloscope controls for a single trace display in CH 1 mode with the channel 1 **AC-Gnd-DC** switch set to **Gnd.**

2. Use the ▲▼ **CH 1** position control to adjust the trace over a major horizontal graduation line.

3. Adjust the **CH 1 Bal** control so that switching between 0.1 V/div and 0.2 V/div sensitivity causes no vertical movement of the trace.

4. Repeat the procedure for channel 2.

CALIBRATION CHECK

A general check of calibration accuracy may be made by displaying the output of the **Cal 1 V** terminal on the screen. This terminal provides a square wave of 1.0 V p-p (within ± 2%). This signal should produce a displayed waveform amplitude of five divisions at 20 mV/div sensitivity for both channel 1 and 2 (with supplied fixed 10:1 probes). With direct probes, there should be five divisions amplitude at 0.2 V/div sensitivity. The **Var** controls must be set to **Cal** during this check.

*The **Cal 1 V** signal may be used only as a general check of calibration accuracy, not as a signal source for performing recalibration adjustments; a signal source of ± 0.3% or better accuracy is required for calibration adjustments.*

INSTRUMENT REPAIR SERVICE

Because of the specialized skills and test equipment required for instrument repair and calibration, many customers prefer to rely upon **B & K-Precision** for this service. We maintain a network of **B & K-Precision** authorized service agencies for this purpose. To use this service, even if the oscilloscope is no longer under warranty, follow the instructions given in the WARRANTY SERVICE INSTRUCTION portion of this manual. There is a nominal charge for instruments out of warranty.

APPENDIX I

IMPORTANT CONSIDERATIONS FOR RISE TIME AND FALL TIME MEASUREMENTS

Error In Observed Measurement

The observed rise time (or fall time) as seen on the CRT is actually the cascaded rise time of the pulse being measured and the oscilloscope's own risetime. The two rise times are combined in square law addition as follows:

$$T_{observed} = \sqrt{(T_{pulse})^2 + (T_{scope})^2}$$

The effect of the oscilloscope's rise time is almost negligible when its rise time is at least 3 times as fast as that of the pulse being measured. Thus, slower rise times may be measured directly from the CRT. However, for faster rise time pulses, an error is introduced that increases progressively as the pulse rise time approaches that of the oscilloscope. Accurate measurements can still be obtained by calculation as described below.

Direct Measurements

The Model 2520 oscilloscope has a rated rise time of 17.5 ns. Thus, pulse rise times of about 52.5 ns or greater can be measured directly. Most fast rise times are measured at the fastest sweep speed and using the **X10 Mag.** For Model 2520, this sweep rate is 50 ns/div. A rise time of less than about one division at this sweep speed should be calculated.

Calculated Measurements

For observed rise times of less than 52.5 ns, the pulse rise time should be calculated to eliminate the error introduced by the cascaded oscilloscope rise time. Calculate pulse rise time as follows:

$$T_{pulse} = \sqrt{(T_{observed})^2 - (T_{scope})^2}$$

Limits Of Measurement

Measurements of pulse rise times that are faster than the scope's rated rise time are not recommended because a very small reading error introduces significant error into the calculation. This limit is reached when the "observed" rise time is about 1.3 times greater than the scope's rated rise time, about 23 ns minimum for Model 2520.

Probe Considerations

For fast rise time measurements which approach the limits of measurement, direct connection via 50 Ω coaxial cable and 50 Ω termination is recommended where possible. When a probe is used, its rise time is also cascaded in square law addition. Thus the probe rating should be considerably faster than the oscilloscope if it is to be disregarded in the measurement.

UNIQUE CHARACTERISTICS OF DIGITAL STORAGE OSCILLOSCOPES

Digital Storage Oscilloscopes (DSO's) use a digital sampling technique to convert analog input signals to a series of digital words that can be stored in memory. Since digital sampling has disadvantages as well as advantages, it is important to be aware of these unique characteristics of DSO's.

ALIASING

This DSO uses Real Time Sampling when sweep **TIME/DIV** settings of 50 sec/div to 0.05 ms/div are selected. Real Time Sampling simply means that samples of the input signals are taken at equal spaces (e.g., every 0.5 ms when the 50 ms/div range is selected). With Real Time Sampling, a phenomena called "Aliasing" can occur when the input signal is not sampled often enough. This causes the digitized signal to appear to be of a lower frequency than that of the input signal. Unless you have an idea what the input signal is supposed to look like, you will usually be unaware that Aliasing is occuring.

Aliasing Example

To see what actually occurs when a Digital Storage Oscilloscope is Aliasing, perform the following example.

1. Apply a 10 kHz signal to the input jack and set the sweep **TIME/DIV** control to 0.05 ms/div. You should see about 5 cycles of the waveform on the display. Since the DSO samples the input waveform 100 times per division, each cycle is sampled 200 times.

2. Now change the sweep **TIME/DIV** control to 2 ms/div. The display should look crowded. Because the DSO takes 100 samples per division, the sample points are 20 µs apart. Since the input signal is at a frequency of 10 kHz, it is being sampled 5 times per cycle. The resulting display is too crowded to be useful, however, it is not incorrect (it is very similar to what you would see on a conventional oscilloscope).

3. Change the sweep **TIME/DIV** setting to 10 ms/div. Vary the frequency a slight amount (until the display is readable) to obtain as few cycles as possible on the CRT. If you were to calculate the frequency of the signal from the display, you would come up with a much lower frequency than that of the actual frequency of the signal at the input jack. If 3 cycles are displayed, the calculated frequency would be approximately 30 Hz. This is obviously incorrect. This occurs because the DSO is taking one sample every 0.1 ms and a 10 kHz signal has one cycle every 0.1 ms. What is actually happening is that the frequency is off (not perfectly 10 kHz) by just enough to cause the DSO to take one sample at a slightly different place on each cycle of the waveform.

Avoiding Aliasing

Aliasing is not limited to the above example. This phenomena can occur anytime that at least two samples per cycle are not taken (whenever the sweep **TIME/DIV** setting is much too slow for the waveform being applied to the input). Whenever the frequency of the signal is unknown, always begin with the fastest sweep speed (0.5 µs/div) or by viewing the waveform in the analog (**Norm**) mode of operation first.

NOTE

Viewing of one time events or glitches is not possible when sweep **TIME/DIV** settings higher than 0.05 ms/div are selected. Viewing of one time events poses no problem with Aliasing because Aliasing can only occur with repetitive waveforms. However, when viewing glitches, sweep **TIME/DIV** settings higher than 0.05 ms/div cannot be used (see the **Equivalent Time Sampling** paragraph later in this section) but Aliasing is possible (of course when aliasing does occur, a glitch will not be visible). Therefore it is very important to know the frequency of the signal which is being checked for glitches. If the base waveform has a frequency higher than about 200 kHz, you should not attempt to observe waveform irregularities with this oscilloscope.

EQUIVALENT TIME SAMPLING

This oscilloscope uses a sampling method called Equivalent Time Sampling when sweep speeds higher than 0.05 ms/div are selected. This mehtod permits viewing of repetitive waveforms to 20 MHz, although the maximum digital sampling rate is 2 Msamples/sec. When the Equivalent Time Sampling mode is activated, one sample is taken during each cycle. Of course if one sample is taken during each cycle at the trigger point (the same point on each cycle), only a flat trace would be produced. Therefore it is necessary to take each sample further (in time) from the trigger point than the last sample. This incremental delay is determined by the sweep **TIME/DIV** control setting. Because 1024 (1 k) samples are needed to fill the display and the memory, the oscilloscope must sample 1024 cycles of the waveform.

Therefore, only repetitive waveforms should be observed in this mode. Irregularities that are present on an otherwise repetitive waveform are not likely to show up when the Equivalent Time Sampling method is used because with only one sample being taken during each cycle, it is very likely that glitches and other irregularities will be skipped over. Even if a sample does happen to fall on a glitch, the irregularity will appear to be on every cycle of the displayed waveform. This is because essentially all the samples (one from each cycle of the waveform) are used to reconstruct one cycle of the waveform and then that one cycle is just repeated over and over again until the oscilloscope's display can be filled.

WARRANTY SERVICE INSTRUCTIONS
(For U.S.A. and its Overseas Territories)

1. Refer to the MAINTENANCE section of your **B & K-Precision** instruction manual for adjustments that may be applicable.

2. If the above-mentioned does not correct the problem you are experiencing with your unit, pack it securely (preferably in the original carton or double-packed). Enclose a letter describing the problem and include your name and address. Deliver to, or ship PREPAID (UPS preferred in U.S.A.) to the nearest **B & K-Precision** authorized service agency (see list enclosed with unit).

If your list of authorized **B & K-Precision** service agencies has been misplaced, contact your distributor for the name of your nearest service agency, or write to:

B & K-Precision, Dynascan Corporation
Factory Service Operations
6460 West Cortland Street
Chicago, Illinois 60635
Tel (312) 889-8870
Telex: 25-3475

Also use this address for technical inquiries and replacement parts orders.