INSTRUCTION MANUAL

STORAGE OSCILLOSCOPE

MODEL 5516ST

KIKUSUI ELECTRONICS CORPORATION

# Power Requirements of this Product

Power requirements of this product have been changed and the relevant sections of the Operation Manual should be revised accordingly.
(Revision should be applied to items indicated by a check mark ☑.)

## ☐ Input voltage

The input voltage of this product is ________ VAC,
and the voltage range is ________ to ________ VAC. Use the product within this range only.

## ☐ Input fuse

The rating of this product's input fuse is ________A, ________VAC, and ________.

**WARNING**

- To avoid electrical shock, always disconnect the AC power cable or turn off the switch on the switchboard before attempting to check or replace the fuse.
- Use a fuse element having a shape, rating, and characteristics suitable for this product. The use of a fuse with a different rating or one that short circuits the fuse holder may result in fire, electric shock, or irreparable damage.

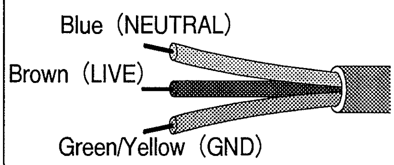
## ☐ AC power cable

The product is porvided with AC power cables described below. If the cable has no power plug, attach a power plug or crimp-style terminals to the cable in accordance with the wire colors specified in the drawing.

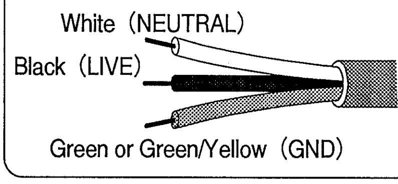
**WARNING**

- The attachment of a power plug or crimp-style terminals must be carried out by qualified personnel.

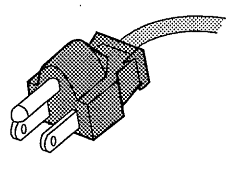
☐ Without a power plug



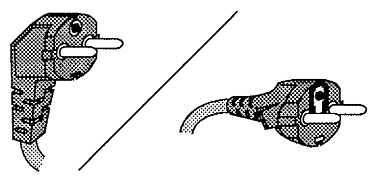

☐ Without a power plug




☐ Plugs for USA



☐ Plugs for Europe



☐ Provided by Kikusui agents

Kikusui agents can provide you with suitable AC power cable.
For further information, contact your Kikusui agent.

☐ Another Cable ____________________________

TABLE OF CONTENTS


PAGE

1. GENERAL .......... 1
   1.1 DESCRIPTION .......... 1

2. SPECIFICATION .......... 2

3. EXPLANATION OF PANEL SWITCHES AND CONTROLS .......... 12
   3.1 EXPLANATION OF FRONT PANEL .......... 12
   3.2 EXPLANATION OF REAR PANEL .......... 21
   3.3 PRECAUTIONS IN OPERATING THE OSCILLOSCOPE ...... 22
   3.4 AC LINE VOLTAGE MODIFICATION .......... 25

4. OPERATION METHOD .......... 26
   4.1 CALIBRATION VOLTAGE SIGNAL DISPLAY .......... 27
   4.2 DUAL-CHANNEL OPERATION AND ADD OPERATION ....... 28
   4.3 X-Y OPERATION .......... 30
   4.4 INTENSITY MODULATION .......... 31
   4.5 TRIGGER AND TIME BASE .......... 31
   4.6 TYPE OF TRIGGER SIGNAL SOURCES .......... 32
   4.7 AC AND DC-COUPLING .......... 33
   4.8 FLAT AND HF REJ .......... 34
   4.9 LEVEL KNOB AND PUSH +, PULL - .......... 34
   4.10 COMP AUTO OPERATION .......... 36
   4.11 AUTO OPERATION .......... 36
   4.12 NORM OPERATION .......... 36
   4.13 SINGLE-SWEEP OPERATION .......... 37
   4.14 SWEEP MAGNIFICATION (PULL 5 × MAG) .......... 37
   4.15 APPLICATION METHOD OF VERTICAL INPUT SIGNAL .... 39

5. MEASUREMENTS .......... 44
   5.1 VOLTAGE MEASUREMENTS .......... 44
   5.2 MEASUREMENT OF TIME .......... 46
   5.3 PULSE WIDTH MEASUREMENT .......... 46
   5.4 MEASUREMENT OF PULSE RISE TIME AND FALL TIME ... 47
   5.5 LISSAJOUS MEASUREMENT OF FREQUENCY .......... 48
   5.6 PHASE MEASUREMENT .......... 49

PAGE

6. OPERATION DESCRIPTION .............................. 52
6.1 GENERAL ........................................ 52
6.2 VERTICAL AMPLIFIER ............................. 53
6.3 TRIGGER CIRCUIT AND SWEEP GENERATOR CIRCUIT ... 58
6.4 HORIZONTAL AMPLIFIER ........................... 63
6.5 Z-AXIS AMPLIFIER ............................... 65
6.6 STORAGE CIRCUIT ................................ 65
6.7 HIGH VOLTAGE CIRCUIT ........................... 68
6.8 POWER SUPPLY ................................... 69
6.9 CALIBRATION VOLTAGE GENERATOR .................. 70

7. STORAGE TUBE ........................................ 71
7.1 STRUCTURE OF STORAGE TUBE ...................... 71
7.2 STORAGE PRINCIPLE .............................. 73
7.3 STORAGE OPERATION .............................. 74
7.4 GENERAL CHARACTERISTICS ........................ 77

8. CALIBRATION ......................................... 83
8.1 GENERAL ........................................ 83
8.2 CHECK AND CALIBRATION OF DC SUPPLY VOLTAGE .... 83
8.3 VERTICAL DEFLECTION SENSITIVITY ................ 86
8.4 INPUT CAPACITANCES AND PHASE COMPENSATIONS OF VOLTS/DIV RANGES ................................. 87
8.5 SWEEP TIME ..................................... 88
8.6 CALIBRATION OF PROBE ........................... 90
8.7 ADJUSTMENT OF ASTIGMATISM AND GEOMETRY ........ 91
8.8 ADJUSTMENT OF BACK ELECTRODE VOLTAGE .......... 92
8.9 TIMER .......................................... 94

* BLOCK DIAGRAM ........................................ 95

* CIRCUIT SCHEMATICS ................................... 96

* REPLACEABLE PARTS .................................... 112

* PARTS LOCATIONS ...................................... 140

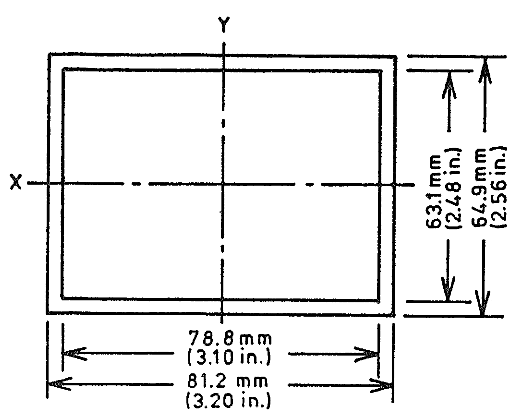
# 1. GENERAL

## 1.1 DESCRIPTION

Kikusui Model 5516ST Storage Oscilloscope is a high-sensitivity dual-channel oscilloscope with a 133-mm (5.24 in.) bi-stable storage tube. It provides a measuring sensitivity of 5 mV, and covers a frequency range of DC - 10 MHz. It features high reliability and ease of operation, and is used for applications from laboratories to production lines.

## 2. SPECIFICATION

CRT Section

| Item | Specification | Remarks |
|---|---|---|
| Cathode-ray tube | Bi-stable direct-viewing storage tube, 133 mm (5.24 in.) | Round screen |
| Fluorescent color | B1 | Blue-green |
| Effective display area | 8 × 10 DIV | 1 DIV ≅ 9.5 mm (0.37 in.) |
| Acceleration voltage | Approx. 2000 V | |
| Blanking | With G1 | |
| Writing speed | 40 μsec/DIV (5 μsec/DIV with enhance mode) | |
| Storage time | Approx. 60 minutes | |
| Erase time | Approx. 0.5 sec | |
| Pattern distortion | Within a range between outer frame of 81.2 × 64.9 $mm^2$ and inner frame of 78.8 × 63.1 $mm^2$.   | Including trace overlapped on frame line |

| Item | Specification | Remarks |
|---|---|---|
| Trace/graticule alignment | With electrical trace rotation coil | |
| Graticule illumination | Continuously variable | |

Storage Section

| Item | Specification | | Remarks |
|---|---|---|---|
| Operation mode | NORM | Normal oscilloscope operation | |
| | STORAGE | Storage oscilloscope operation | |
| | ENHANCE | Operation with enhanced writing speed | With ENHANCE LEVEL knob on front panel |
| | AUTO ERASE | Automatically erases the displayed trace after holding it for a preset period of time | The holding period is adjustable for approx. 1 - 30 sec with ERASE INTERVAL knob. |
| | ERASE | Displayed trace is erased. | |
| | HOLD | Displayed trace is held. | Trace displayed in the NORM mode is not held. |

Vertical Deflection Circuit

| Item | Specification | Remarks |
|---|---|---|
| Sensitivity | 5 mV/DIV - 10 V/DIV, 11 steps | 1-2-5 step system |
| Sensitivity accuracy | Better than ±3% of dial nominal value (with VARIABLE knob set in CAL'D position) | 1 kHz, at 4 or 5 DIV |
| Frequency response | "DC": DC - 10 MHz<br>"AC": 2 Hz - 10 MHz | Within -3 dB, with 50 kHz 8 DIV reference |
| Continuously variable sensitivity control | Adjustable for 2.5 times or over of dial nominal value | |
| Rise time | 35 nsec | Calculated value |
| Input impedance | 1 MΩ ±2%, 35 pF ±2 pF | Parallel |
| Input terminals | BNC receptacles | |
| Maximum allowable input voltage | 5 mV/DIV range: 400 V<br>Other ranges: 600 V | DC + AC peak (1 kHz or over for AC) |
| Input coupling | "AC" and "DC" | |
| Trace shift caused by offset | 0.2 DIV or less at 5 mV/DIV range | When switched from DC to GND, with input terminals open |
| Trace shift caused by range switching | Within 1 DIV when switched between 2 V/DIV and 5 V/DIV | With AC/DC/GND switch set in GND position |

| Item | Specification | | Remarks |
|---|---|---|---|
| Linearity | Vertical expansion or compression is within ±0.2 DIV when a 4-DIV trace in CRT screen center is moved to the top or bottom position on CRT screen. | | With frequency not higher than 100 kHz |
| Common-mode rejection ratio | 100:1 or over, at 50 kHz | | With CH1 and CH2 sensitivities set the same |
| Channel isolation between CH1 and CH2 | 1000:1 or better (at 100 kHz, with 8 DIV reference) | | In dual operation, both CH1 and CH2 set at 5 mV/DIV, a signal corresponding to full CRT screen amplitude is applied to one channel, the other channel terminated with 50 Ω. |
| Operation mode | CH1 | Channel 1 alone | |
| | CH2 | Channel 2 alone | |
| | DUAL (automatic switching) | ALT: Alternate sweep between CH1 and CH2 | |
| | | CHOP: Traces of CH1 and CH2 chopped with a frequency of approx. 100 kHz. | |
| | ADD | Channels 1 + 2 | |
| PUSH INV | Polarity of CH2 alone is inverted. | | |

Horizontal Deflection Circuit

| Item | Specification | Remarks |
|---|---|---|
| Sweep time | 0.5 μsec/DIV - 1 sec/DIV | 20 ranges,<br>1-2-5 step system |
| Sweep time accuracy | Better than ±3% | VARIABLE knob set in CAL'D position |
| Continuously variable adjustment of sweep time | Variable by 2.5 times or over of dial-indicated value | |
| Sweep magnification | 5 times | |
| Magnification accuracy | ±3% (1 sec/DIV - 0.5 μsec/DIV) | |
| Shift caused by sweep magnification | Within ±1 DIV at CRT screen center | |

Trigger Circuit

| Item | Specification | Remarks |
|---|---|---|
| Trigger source signal | NORM: CH1 and CH2 signals<br>CH1: CH1 signal alone<br>CH2: CH2 signal alone<br>EXT: External signal | |
| Coupling | DC, AC, and HF REJECT | |
| Polarity | + and - | |

| Item | Specification | Remarks |
|---|---|---|
| Internal trigger sensitivity<br>DC<br>AC<br>HF REJ | <br><br>DC - 10 MHz: 0.3 DIV<br>5 Hz - 10 MHz: 0.3 DIV<br>DC - 50 kHz: 0.3 DIV | |
| External trigger sensitivity<br>DC<br>AC<br>HF REJ | <br><br>DC - 10 MHz: 200 mVp-p<br>5 Hz - 10 MHz: 200 mVp-p<br>DC - 50 kHz: 200 mVp-p | |
| COMP AUTO | Completely triggers with a signal of 0.3 DIV or over of amplitude on CRT screen and of a repetition frequency of 50 Hz or over. | Trigger level can be used to select trigger point. Triggering is effected with a 0.3 DIV signal irrespective of setting of the knob. |
| AUTO | Satisfies the trigger sensitivity specification, for a signal of 50 Hz or over of repetition frequency. | When external trigger signal is disconnected, the sweep runs automatically (free run). |
| NORM | Satisfies the trigger sensitivity specification | When no trigger signal is applied, the trace is blanked out and remains in the READY state. |
| SINGLE | One-shot sweep; satisfies all trigger specification items mentioned in the above. | Remains in the READY state until a trigger pulse is applied. |

| Item | Specification | Remarks |
|---|---|---|
| External trigger input impedance | Approx. 100 kΩ, 60 pF or less | Parallel |
| Input terminals | BNC receptacles | |
| Maximum allowable input voltage | 100 V (DC + AC peak) | AC frequency 1 kHz or less |

External Sweep Amplifier (X-Y)

| Item | Specification | Remarks |
|---|---|---|
| Display system | XY system: CH1 for X<br>CH2 for Y | X: Horizontal axis<br>Y: Vertical axis |
| Sensitivity | X: 5 mV/DIV - 10 V/DIV<br>Y: 5 mV/DIV - 10 V/DIV | 11 steps, for both X and Y |
| Frequency response | X: DC - 1 MHz<br>Y: DC - 10 MHz | Within -3 dB<br>Within -3 dB |
| Input impedance | 1 MΩ ±2%, 35 pF ±2 pF, for both X and Y | Parallel |
| Maximum allowable input voltage | 5 mV/DIV range: 400 V<br>Other ranges: 600 V<br>(for both X and Y) | DC + AC peak, 1 kHz or less |
| Input terminals | BNC receptacles (for both X and Y) | X, Y letter indication on panel |

Calibration Voltage

| Item | Specification | Remarks |
|---|---|---|
| Waveform | Square wave | |
| Polarity | Positive polarity | |
| Output voltage | 200 mVp-p, 2 Vp-p | |
| Output voltage accuracy | Better than ±3% | |
| Frequency | 1 kHz ±25% | |
| Duty ratio | 45:55 or less | |
| Rise time | Approx. 150 nsec | |
| Output terminal | Clip terminals | |

Z-axis Amplifier

| Item | Specification | Remarks |
|---|---|---|
| Intensity modulation | Discernible intensity modulation with 3 Vp-p input signal. Positive input darkens the trace. | |
| Frequency response | DC - 1 MHz | |
| Input resistance | Approx. 10 kΩ | |
| Input terminals | Binding post terminals | |

Power Requirements

| Item | Specification | Remarks |
|---|---|---|
| AC line voltage | 100 V, 110 V, 117 V, 200 V, 220 V, 230 V, 240 V; ±10% | Can be changed with transformer taps, normally set at 100 V as shipped from the factory. |
| Frequency | 50 - 60 Hz | |
| Power consumption | Approx. 68 VA | |

Dimensions and Weight

| Item | Specification | Remarks |
|---|---|---|
| External dimensions | 315 W × 225 H × 465 D mm (12.40W × 8.86H × 18.31D in.) | Maximum dimensions |
| | 280 W × 184 H × 400 D mm (11.02W × 7.24H × 15.75D in.) | Chassis |
| Weight | Approx. 11 kg (24.2 lb.) | Net |

Accessories

| Item | Q'ty |
|---|---|
| Probe 960 BNC (1:1, 10:1) | 2 |
| Type 942A Adaptor | 1 |
| Shorting bar (short) | 1 |
| Hex bar wrench (3 mm (0.12 in.)) | 1 |
| Fuse (1 A, slow blow) | 1 |
| Instruction Manual | 1 |

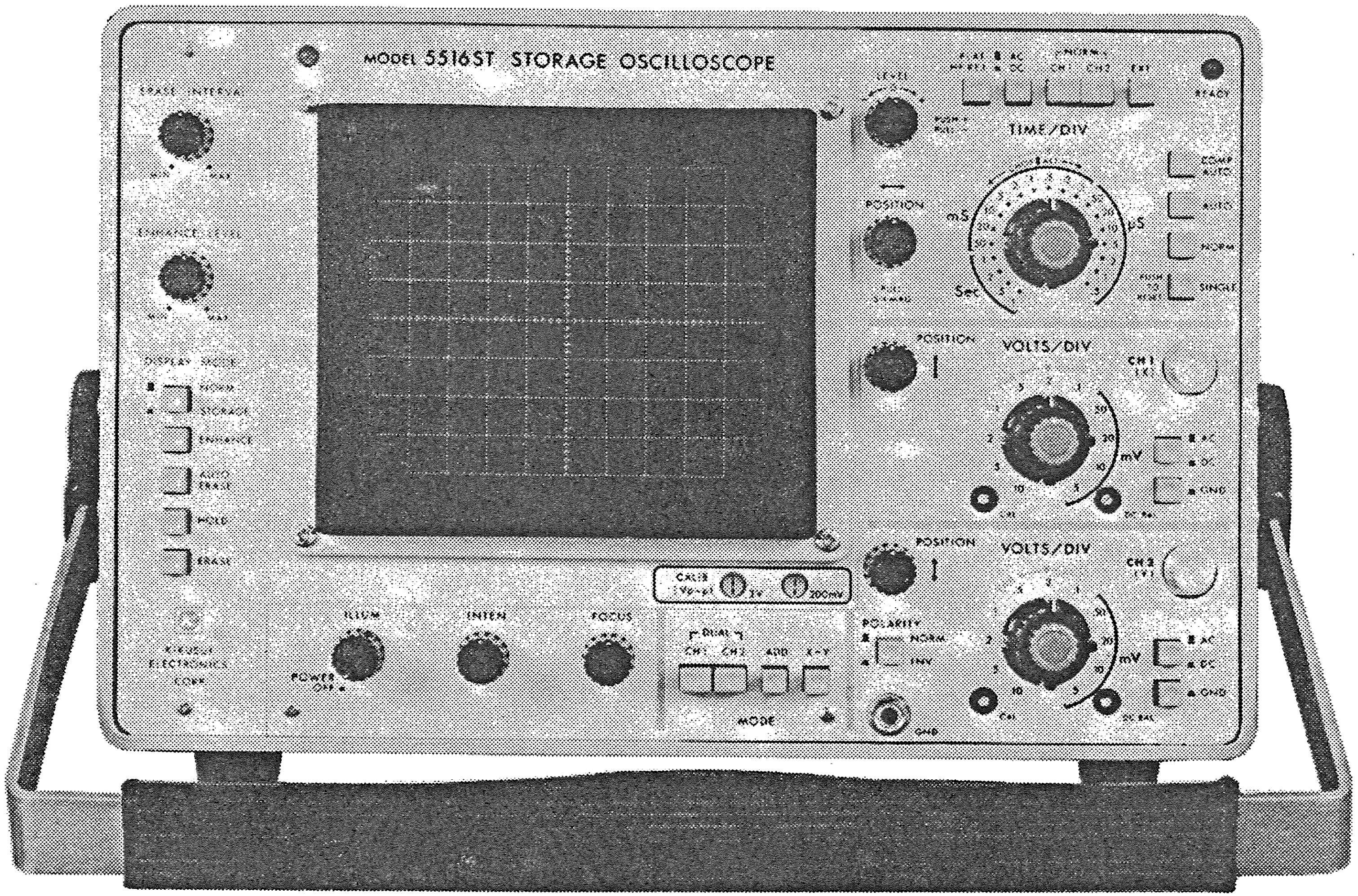

MODEL 5516ST STORAGE OSCILLOSCOPE
TIME/DIV
VOLTS/DIV
VOLTS/DIV
POSITION
POSITION
POSITION
DISPLAY MODE
NORM
STORAGE
ENHANCE
AUTO ERASE
HOLD
ERASE
ILLUM
INTEN
FOCUS
POWER
POLARITY
NORM
INV
MODE
DUAL
CH1
CH2
ADD
X-Y
CH1
CH2
AC
DC
GND
COMP AUTO
AUTO
NORM
SINGLE
READY

Figure 3-1

## 3. EXPLANATION OF PANEL SWITCHES AND CONTROLS

### 3.1 EXPLANATION OF FRONT PANEL

This section covers the switches, controls, and terminals of the instrument panels. Of the double-control knobs, the black knobs correspond to black letters and red knobs correspond to red letters.

| | |
|---|---|
| POWER OFF: | In common with the ILLUMINATION knob. The extreme counterclockwise position is POWER OFF. |
| ILLUM: | Graticule illumination control. Becomes brighter as this knob is turned clockwise. |
| INTEN: | Trace intensity control. Trace becomes brighter as this knob is turned clockeise. |
| FOCUS: | Focusing control of spot or trace on CRT screen. Should be so adjusted (in combination with internal ASTIG control as required) that spot or trace becomes sharpest. |
| CALIB (Vp-p): | Square-wave generator for sensitivity calibration or probe phase characteristics adjustment. Output voltages are 2 Vp-p and 200mV, and frequency is approximately 1 kHz. The output signal is delivered through the clip terminal on the front panel. |

Vertical Deflection Units:

The functions of controls and terminals of CH1 and CH2 are idential, and the same explanation is applicable to both channels.

| | |
|---|---|
| CH1, CH2:<br>(X) (Y) | Vertical input terminals (or X-Y input terminals). The input signals are connected to these terminals (also when the probe(s) is used). |

AC, DC

Input coupling mode selector pushbutton switch. Depressed state is for DC and popped up state is for AC. When in AC coupling, the DC component (if any) of the input signal is blocked and the AC component alone is displayed. When in DC coupling, the input signal including the DC component is displayed.

GND:

As you depress this GND pushbutton switch, the input circuit of vertical amplifier is disconnected from the BNC input terminal and is grounded. This state is convenient for checking the zero potential position on CRT screen.

VOLTS/DIV

Black knob is the vertical deflection sensitivity selector switch for 5 mV/DIV - 10 V/DIV in 11 ranges. It indicates the vertical sensitivity per 1 DIV on the CRT screen, with the VARIABLE knob set in the CAL'D position.

VAR ← ▼ CAL'D

Red knob is the continuously-variable sensitivity control, of which extreme clockwise position is the CAL'D position. As this knob is turned to the extreme counterclockwise position, the sensitivity is reduced by a factor of 1/2.5 approximately.

POSITION ↕

Vertical positioning of the trace. The trace moves upward as this knob is turned clockwise.

DC BAL:

Potentiometer for adjusting the shift of trace when the VOLTS/DIV switch is turned. (For this oscilloscope, the switch is turned between 2 V/DIV and 5 V/DIV for specification.)

CAL: Vertical sensitivity adjustment. Common for all ranges.

GND: Ground terminal electrically connected to the panel, chassis, and main unit. (Common for CH1 and CH2)

POLARITY: Pushbutton switch for inverting the phase of CH2 input signal. The depressed state is for phase inversion.


Of the above items except the GND terminal and POLARITY switch, the functions are identical for both CH1 and CH2.

MODE: Four pushbuttons for selecting operation modes of CH1 and CH2 vertical amplifiers as mentioned in the following.

CH1: CH1 alone operates, making the oscilloscope a single channel instrument.

CH2: CH2 alone operates, making the oscilloscope a single channel instrument.

DUAL
CH1 CH2 : When both CH1 and CH2 buttons are depressed, CH1 and CH2 vertical amplifiers are automatically switched in the CHOP or ALT mode and the oscilloscope operates as a dual channel instrument. The CHOP mode is for 0.5 sec/DIV to 1 msec/DIV and the ALT mode is for 0.5 msec/DIV to 0.2 μsec/DIV.

ADD: CH1 and CH2 opetate at the same time and the sum (CH1 + CH2) or difference (CH1 - CH2) of the two channels is displayed on the screen. For (CH1 - CH2), depress the POLARITY button of CH2.

X-Y: Displays an X-Y pattern with X-axis for CH1 and Y-axis for CH2. Frequency response of X-axis is DC - 1 MHz (-3 dB).

## Horizontal Deflection Section

POSITION: For horizontal positioning of spot or trace. The spot moves leftward as this knob is turned clockwise, and vice versa.

PULL
5 x MAG: This switch is in common with the POSITION knob. As you pull out this knob, the sweep amplitude is magnified by 5 times with the screen center as the center of magnification, except the case of XY-scope in which case the magnification function remains idle.

TIME/DIV: Black knob selects a sweep range among 20 ranges covering from 0.5 sec/DIV to 0.2 usec/DIV. The dial values are sweep speeds per 1 DIV, with the VARIABLE knob set in the CAL'D position.

VAR ← ▼ CAL'D: Red knob is for continuously-variable adjustment of sweep speed. Its extreme clockwise position is the CAL'D position. When at the extreme counterclockwise position, the sweep speed is reduced by a factor of 1/2.5 approximately.

LEVEL
0
\- +

For adjusting the trigger level of the trigger signal waveform. The trigger level becomes higher in the positive direction as this knob is turned clockwise, and vice versa.

PUSH +
PULL -

Pushbutton switch for selecting a triggering slope on the trigger signal waveform. The "PUSH +" state is for triggering with a positive-going slope and the "PULL -" state is for triggering with a negative-going slope.

COMP AUTO:

This button is for operating the COMPLETE AUTO TRIGGER circuit. When this button is depressed, the trigger level is automatically adjusted and triggering is effected as long as the triggering input signal is 0.3 DIV or over as displayed on the CRT screen or the input signal applied to the EXTERNAL TRIGGER INPUT terminal (BNC receptacle on the rear panel) is 200 mV or over. Even when in this mode, the trigger level can be set at any point within the peak-to-peak range of the input signal so that the required section of the signal waveform is displayed on the CRT screen.

AUTO:

When this button is depressed, the horizontal sweep runs in the FREE RUN mode. When no input signal is applied, a sweep trace is displayed on the screen. It can be triggered with an input signal of 50 Hz or over and 3 mm or over of amplitude on the screen. (The sweep is synchronized if the trigger level is within the measured input signal range, or the sweep runs in the free mode if the level is not within the input signal range.)

| | |
|---|---|
| NORM: | When no measured signal is applied, the time base is in a stand-by state and no sweep runs. When a measured input signal is applied, the sweep runs being synchronized with the signal, provided that the trigger level is within the peak-to-peak range of the signal. |
| SINGLE: | Pushbutton switch for one-shot sweep operation. As you press this button, all of the other three buttons (COMP AUTO, AUTO, and NORM buttons) are reset to the popped-up state and this SINGLE button itself also is reset to the popped-up state. |
| PUSH TO RESET: | The SINGLE sweep button is used in common for this function. By pressing this button, the single-sweep operation can be reset after it has completed its one cycle of operation. |
| READY: | This LED lamp indicates that the time base is in the READY state for the SINGLE sweep operation. |
| FLAT ⊓<br>HF REJ ⊓ : | Pushbutton switch for selecting a coupling state of trigger input signal. When in the FLAT state, the trigger signal of CH1, CH2, NORM or EXT is directly applied to the trigger circuit. When in the HF REJ (high frequency reject) state, the trigger signal is applied through low pass filter of approximately 50 kHz so that noise or other high-frequency components higher than this frequency are cut off. |

AC ⊓ / DC ⊓ : Pushbutton switch for selecting a coupling state of trigger input circuit. When in the AC state, the trigger input circuit is AC-coupled and the DC component, if any, of the trigger signal is cut off and the AC component alone is applied to the trigger circuit. When in the DC state, the trigger input circuit is DC-coupled and the input signal including the DC component is applied to the trigger circuit.

NORM (CH1, CH2) EXT : Pushbuttons for selecting a signal source among four types as follows:

CH1: The signal applied to vertical CH1 is used as the trigger signal, irrespective of vertical MODE switch setting (whether it is set for CH2, DUAL, or ADD).

CH2: The signal applied to vertical CH2 is used as the trigger signal, irrespective of vertical mode switch setting (whether it is set for CH1, DUAL, or ADD).

NORM (CH1, CH2) : When CH1 and CH2 are depressed at the same time, triggering is in the NORM mode and the displayed signal waveforms are triggered with respective signals. (Alternate trigger)

EXT: The signal applied to the EXT TRIGGER IN terminal is used as the trigger signal.

Storage Section

NORM / STORAGE: When in the NORM state, the instrument operates as a regular oscilloscope. When in the STORAGE state (depressed state), it operates as a storage oscilloscope. When switched from the NORM mode to the STORAGE mode, the image existing on the CRT screen is erased.

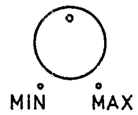
ENHANCE: When this button is depressed, the writing speed becomes faster. The level of this effect is adjustable with the ENHANCE LEVEL knob.

AUTO ERASE: If this button is kept depressed, the displayed pattern is automatically erased when the desired period has elapsed. The period is adjustable with the ERASE INTERVAL knob. The instrument repeats the STORAGE and ERASE operations.

ERASE: As you push this button, the image displayed on the CRT screen is erased. This ERASE function has the highest priority over all other functions except the HOLD function.

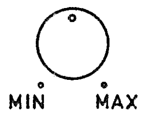
HOLD: At the moment this button is pressed, the pattern existing on the CRT screen is held. This function has the highest priority, and the pattern is kept in the held state until this button is pressed again or the operation is changed to the NORM mode or the POWER is turned off. Thus, this button is used when the pattern is required to be held for any required period of time up to an hour. Note that the CRT life may be badly reduced if a stored pattern is displayed for a period of time exceeding one hour.

ERASE INTERVAL:




Adjusts the automatic erase period. This control is effective only when the AUTO ERASE button is kept depressed. The adjusting range is approx. 1 sec (minimum) to approx. 30 sec (maximum).

ENHANCE LEVEL:




Adjusts the level of the enhance function. This control is effective only when the ENHANCE button is kept depressed. The enhance level is increased as this knob is turned clockwise. When this knob is turned to the extreme clockwise position, overall CRT screen becomes bright. This knob should be turned to a position of compromise between writing speed and quality of display. The writing speed without ENHANCE is approximately 40 μsec/DIV, that with ENHANCE can be increased to approximately 5 μsec/DIV with fairly good display.

## 3.2 EXPLANATION OF REAR PANEL

The items on the rear panel are the EXT TRIG IN terminal (BNC receptacle), TRACE ROTATION control (variable resistor), Z-AXIS IN terminals (binding posts), fuse holder, and power cord.

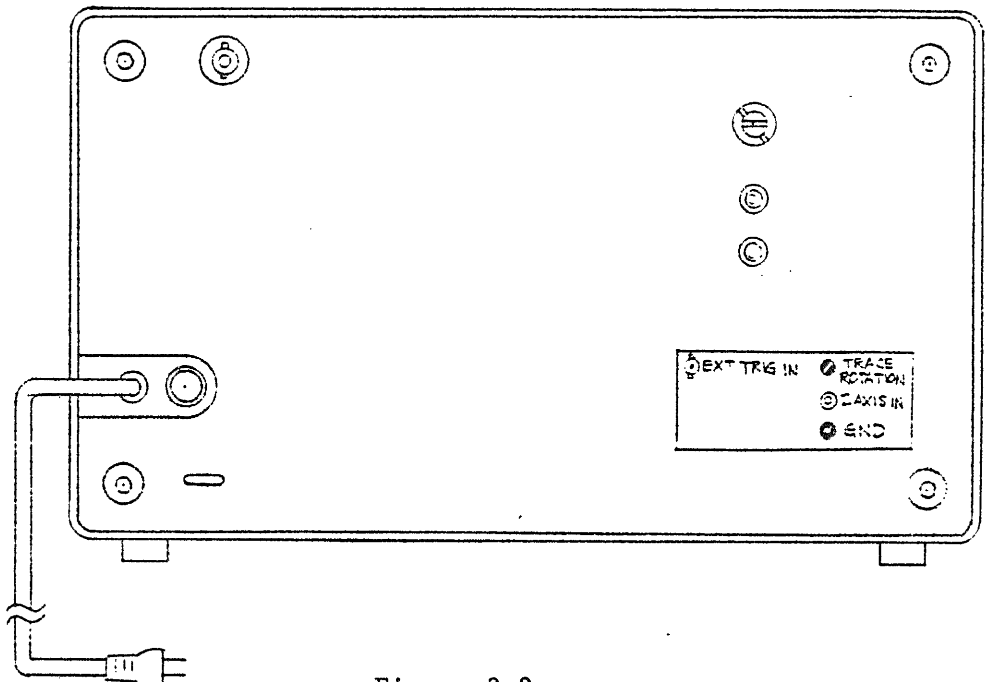



Figure 3-2

EXT TRIG IN: BNC receptacle for external trigger input signal.

Z-AXIS IN
GND : Binding post terminals for external intensity-modulation input signal. Red terminal is for hot and black terminal for ground. When not in use, these terminals should be connected together with the shorting bar (supplied).

TRACE ROTATION: Variable resistor adjustment of trace to align with the horizontal graticule.

FUSE: 1-Ampere slow-blow fuse in AC power input circuit. The fuse can be removed by turning the fuse holder cap counterclockwise.

AC LINE: AC power cord to be connected to an AC line outlet of the specified voltage.

## 3.3 PRECAUTIONS IN OPERATING THE OSCILLOSCOPE

AC line voltage:

The oscilloscope normally is shipped being set for the nominal 100 V AC line power, as a general rule. With this setting the oscilloscope normally operates on an AC line power of 100 V ±10%. Note that the oscilloscope may not operate normally or may be damaged if the voltage is not within this range.

Environments:

Ambient temperature and humidity: The ambient temperature specification of this oscilloscope is 0°C to 40°C (32°F to 104°F). Note that mal-functioning and life shortening may result if the oscilloscope is used or stored in high-temperature high-humidity atmosphere for a long period.

Electromagnetic or electrostatic field: The measuring accuracy may be degraded if the oscilloscope is placed in a strong electromagnetic or electrostatic field.

Protection of CRT screen:

Note that the CRT screen may be damaged if the trace intensity is abnormally high or a stationary spot is left for a long period.

Maximum allowable voltages of input terminals:

The maximum allowable input voltages of the input terminals and probe are as shown in the following table. Note that the input circuit may be damaged if an input voltage higher than the specified value is applied.

| | |
|---|---|
| CH1 and CH2 terminals<br>when VOLTS/DIV is in 5 mV range position<br>when VOLTS/DIV is in other range position | <br>400 V (DC + AC peak)<br>600 V (DC + AC peak) |
| Probe (960 BNC) | 600 V (DC + AC peak) |
| EXT TRIG IN terminal | 100 V (DC + AC peak) |
| Z-AXIS IN terminal | 100 V (DC + AC peak) |

Repetition frequency: Not higher than 1 kHz

Precautions in storage operation:

(1) If you turn on the power switch of the oscilloscope while set in the STORAGE state, the CRT may be stored over the entire screen. In such a case, push the ERASE button once or twice. If you leave the images stored on the screen, the life of the CRT is adversely affected. When you have switched the display mode from the NORM to the STORAGE, the images are erased as the ERASE function is automatically effected. However, if any image is left over, press the ERASE button once or twice.

(2) The maximum storage time is approximately 60 minutes. Note that the storage function or writing speed is degraded if stored images are left over for a long period exceeding about an hour. To make the best use of the service life of the storage tube, store the images for the required minimum periods of time. Pay attention also to the following states which also adversely affect the life expectancy of the CRT tube.

2-1. A high-intensity stationary spot is left displayed on the screen.

2-2. A high-intensity horizontal sweep trace is left displayed on the screen.

2-3. A sweep trace of 1 msec/DIV or lower speed is left displayed on the screen.

(3) Be careful not to forget to erase the displayed image after holding the displayed image by depressing the HOLD button. When in the hold state, the image is dead stationary and, if you forget to erase the image, the CRT screen is very adversely affected.

## 3.4 AC LINE VOLTAGE MODIFICATION

The oscilloscope can be modified for other AC line voltages than 100 V, as shown in the following table, by changing transformer taps. The rating of the AC power cord which accompanies the oscilloscope is 125 V, 7A. When modifying the instrument for a voltage higher than 125 V, replace the cord with that of a higher voltage rating. The fuse rating should be as indicated in the table.

| Voltage | Fuse (A) | Note |
|---|---|---|
| 90 - 110<br>100 - 120<br>105 - 129 | 1 | Use a slow-blow fuse. |
| 180 - 220<br>200 - 240<br>210 - 258 | 0.5 | |

## 4. OPERATION METHOD

Before turning ON the oscilloscope power, set the switches and controls on the front panel as follows:

| | | |
|---|---|---|
| INTEN, POWER OFF | | Extreme counterclockwise |
| FOCUS | | Mid-position |
| NORM, STORAGE | | NORM |
| MODE | | Press CH1 button |
| TRIGGER | LEVEL | Mid-position |
| | FLAT - HF REJ | FLAT |
| | AC - DC | AC |
| | CH1 - CH2 - NORM - EXT | CH1 |
| | COMP AUTO - AUTO - NORM | AUTO |
| | - SINGLE | |
| TIME/DIV | | 0.2 mS |
| POSITION (horizontal) | | Mid-position |
| CH1 | POSITION (vertical) | Mid-position |
| | VOLTS/DIV | 0.2 V (red knob in CAL'D position) |
| | AC - DC | DC |
| | GND | Press GND button |

Connect the power cord to a power line outlet (100 V AC) and turn clockwise the INTEN knob from its POWER OFF position. The oscilloscope power is turned ON, and the LED at upper left of the panel lights. Wait in this state about 10 seconds and, then turn the INTEN knob clockwise so that a trace of an appropriate brightness is displayed on the screen.

FOCUS adjustment:

Move the trace to the center of the screen by adjusting the CH1 and horizontal POSITION knobs. So adjust the FOCUS knob that the displayed trace becomes focused.

## 4.1 CALIBRATION VOLTAGE SIGNAL DISPLAY

Display on the screen the CALIB signal of the oscilloscope by setting to CH1 input terminal the BNC terminal adaptor (supplied) and connecting the square wave calibration voltage signal using as short wires as possible. (Set the CALIB output signal at 200 mV.) Set the switches and controls on the front panel as follows.

| | |
|---|---|
| AC - DC (CH1) pushbutton switch: | DC |
| GND (CH1) pushbutton switch: | Not depressed |
| VOLTS/DIV (CH1) knob: | 50 mV |
| VARIABLE (CH1) knob: | CAL'D |
| TIME/DIV knob: | 0.2 mS |
| VARIABLE knob: | CAL'D |
| Other switches and controls: | As set when the power is turned ON |

When the switches and controls are set as above, a square wave with an amplitude of 4 DIV will be displayed on the screen.

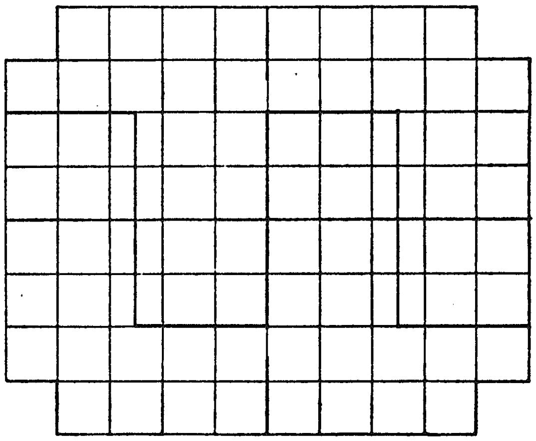



Figure 4-1

As you turn the VOLTS/DIV knob counterclockwise range by range, the vertical amplitude will be reduced in response. As you turn counterclockwise the VARIABLE knob, the amplitude will be reduced continuously. With these operations, you can know the effects of the VOLTS/DIV and VARIABLE knobs on the displayed waveform amplitude.

## 4.2 DUAL-CHANNEL OPERATION AND ADD OPERATION

Dual-channel operation:

Set the MODE pushbutton switch in the DUAL mode. (Press the CH1 and CH2 pushbutton switches at the same time.) Apply the calibration signal (200 mV) also to CH2. (In the above operation, the signal was applied to CH1 only and no signal was applied to CH2.) In this case, leave the TRIGGER selector switch in the CH1 position so that the signal of CH2 also is triggered by the signal of CH1. If the signal applied to CH2 is in a synchronizing relationship with respect to that applied to CH1, the displayed waveforms of both CH1 and CH2 are stationary.

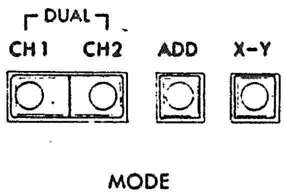
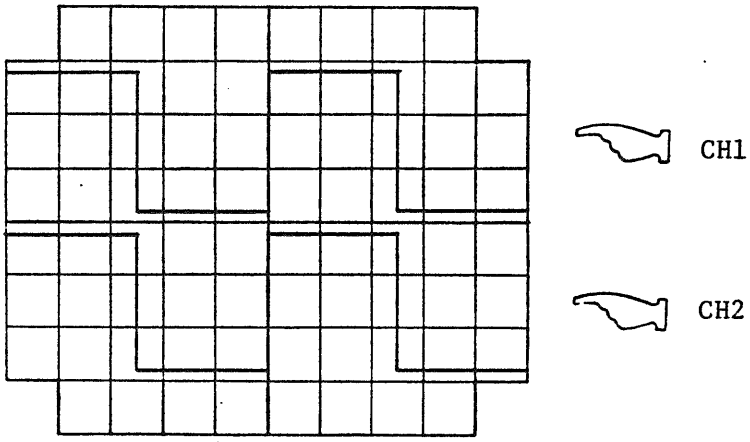



Figure 4-2




For dual-channel operation, this oscilloscope has no CHOP or ALT switch but has a DUAL pushbutton switch only. Switching between CHOP and ALT modes is done by the TIME/DIV knob -- CHOP mode for 1 S - 1 mS/DIV ranges and ALT mode for 0.5 mS - 0.5 μS/DIV ranges.

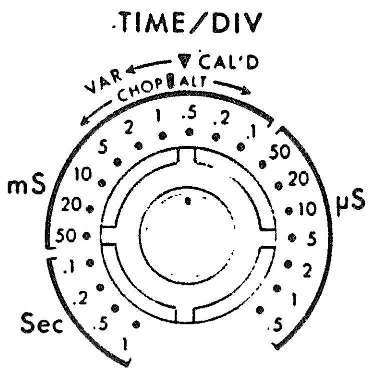



Figure 4-3

ADD operation:

Set the MODE pushbutton in the ADD mode. The displayed waveform is the sum (or difference) of the two signals applied to CH1 and CH2.

CH1 ± CH2 = Add waveform

Next, set the CH2 polarity pushbutton switch in the INV mode. In this case the difference of CH1 - CH2 is displayed on the screen. (INV state: Polarity of CH2 signal inverted by 180°)

## 4.3 X-Y OPERATION

Set the MODE pushbutton switch in the X-Y state. With this single action, the oscilloscope operates as an X-Y scope with CH1 as X-axis and CH2 as Y-axis.

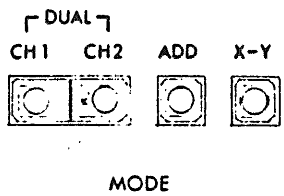



Figure 4-4

While the electrical performance of the Y-axis remains the same with that of CH2 operated in the single-channel CH2 mode, frequency response of the X-axis becomes DC - 1 MHz, -3 dB. (The VARIABLE knob and CH1 POSITION knob remain idle.)

The X-axis position is adjustable with the horizontal POSITION knob. When in the X-Y mode, the operation is more pronounced than when in the sweep mode. The other electrical performances remain the same as when CH1 is operated in the single-channel CH1 mode.

Next, apply the CALIB signal to both X and Y axes and adjust the VOLTS/DIV switches so that two spots are displayed on a diagonal line on the screen. A Lissajous figure with frequency ratio 1:1 and phase angle $\cong$ 0 will be displayed.

When in the X-Y operation, the 5 × MAG switch (which is linked to the horizontal POSITION knob) remains idle.

4.4 INTENSITY MODULATION

The INTEN MOD signal input terminals are located at the rear of the oscilloscope. For intensity modulation, remove the short bar from the terminals and connect an external intensity modulation signal between red terminal and black (GND) terminal. When intensity modulation is not used, keep the short bar connected between the two terminals.

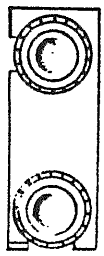


Figure 4-5

4.5 TIRGGER AND TIME BASE

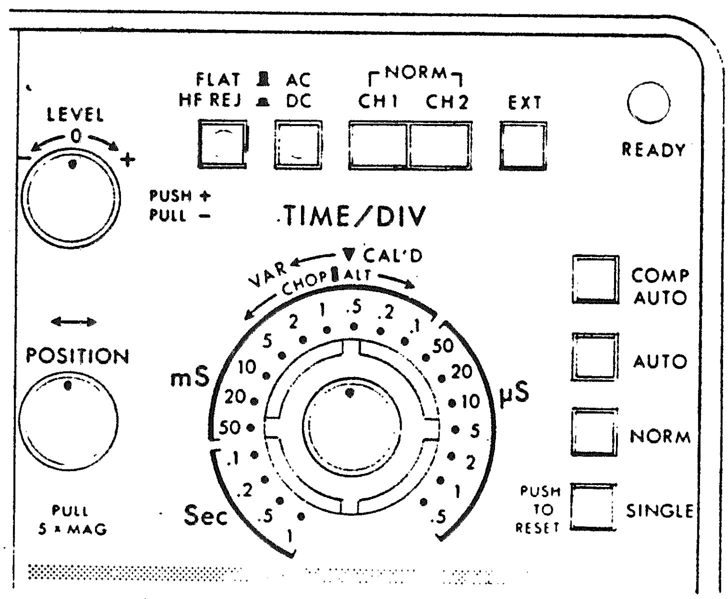



Figure 4-6

The CALIB voltage signal is a square wave of approximately 1 kHz. When the TIME/DIV knob is set in the 0.2 mS/DIV position, one cycle of the square wave is displayed with a horizontal magnitude of approximately 5 DIV.

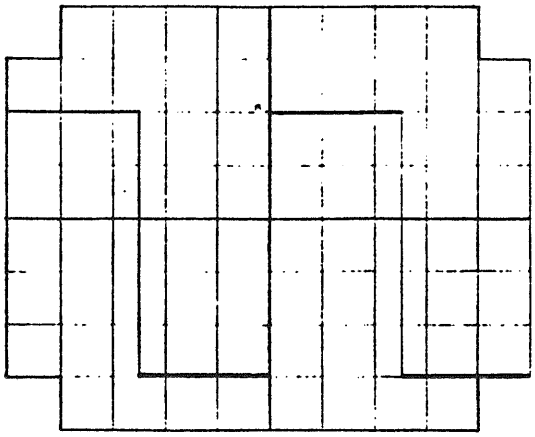


Figure 4-7

As you turn the TIME/DIV knob clockwise, the sweep time becomes faster. The VARIABLE knob is for continuously-variable adjustment of sweep time.

## 4.6 TYPE OF TRIGGER SIGNAL SOURCES

To display a stationary pattern on the screen, a signal which is synchronized to the input signal must be applied to the trigger circuit for triggering the sweep circuit. The four types of trigger signal sources are the NORM (signals displayed on the screen), CH1 (signal of CH1), CH2 (signal of CH2), and EXT (external signal applied through the EXT TRIG IN terminal).

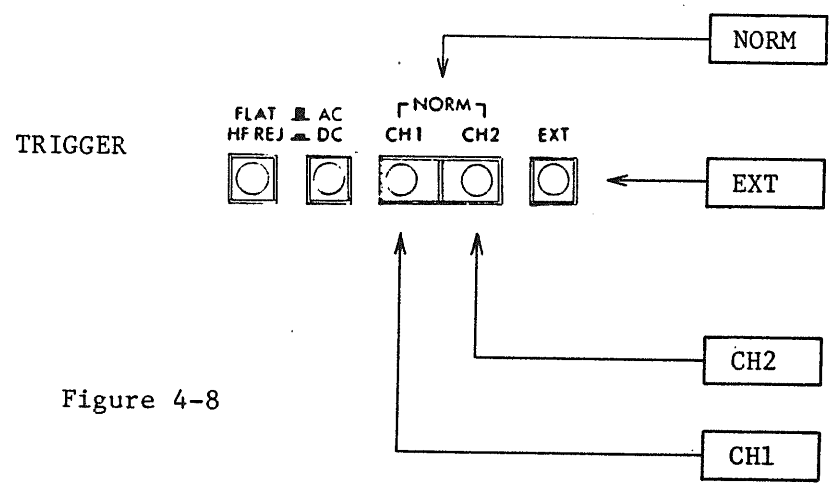



Figure 4-8

4.6.1 INTERNAL TRIGGER (NORM CH1, CH2)

When in the internal trigger mode, the input signal is picked up at a point in the vertical amplifier and the signal is amplified to a sufficient level for triggering and applied to the trigger circuit.

When in the NORM mode, the signals (CH1 and CH2) displayed on the screen are used as trigger signals. When in the CH1 mode, the input signal of CH1 alone is used as trigger signal, when in the CH2 mode, the input signal of CH2 alone is used as trigger signal.

4.7 AC AND DC-COUPLING

This oscilloscope is capable of DC-coupling of trigger input. The DC-coupling is especially advantageous when the input trigger signal is 5 Hz - DC and when used in the single sweep mode. The AC-coupling is used for a trigger input signal of 5 Hz - 10 MHz or when the trigger signal has a DC component.

4.8 FLAT AND HF REJ

When in the HF REJ, a low pass filter of 50 kHz is connected before the trigger input circuit in order to eliminate the noize and high frequency components which are superimposed on the trigger signal.

Triggering may be improved by setting in the HF REJ state when the oscilloscope is in the dual-channel mode and the TIME/DIV knob is in the CHOP range.

When 50 kHz or higher frequency is superimposed

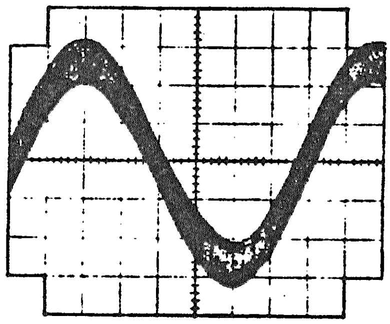


Figure 4-9

When in the FLAT mode, stable triggering can be done for a range of DC - 10 MHz.

4.9 LEVEL KNOB AND PUSH +, PULL -

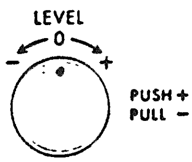
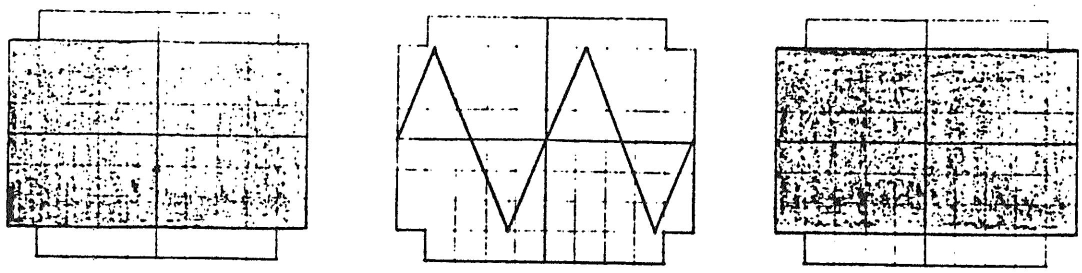



Figure 4-10

Apply a sinusoidal or triangular signal of approximately 1 kHz to the CH1 input terminal. (So adjust the input signal level or the input attenuator of the oscilloscope that the signal is displayed with an amplitude of 6 DIV or over.)
Set the switches and controls as follow:

| | |
|---|---|
| FLAT HF REJ: | FLAT |
| AC - DC: | AC |
| CH1, CH2, NORM, EXT: | CH1 |
| TIME/DIV: | 0.2 mS/DIV |
| COMP AUTO, AUTO, NORM, SINGLE: | AUTO |

Turning the LEVEL knob from the counterclockwise position to the clockwise position, observe that the displayed image changes from the free-run state to a synchronized state, the starting point of the waveform moves from upward to downward and again the displayed waveform free-runs.



(a) Free-run (b) Synchronized waveform (c) Free-run

Figure 4-11

As you turn the LEVEL knob clockwise from the position where the displayed waveform has become stationary, the waveform will move from right to left on the screen and the starting point of the waveform also will be moved from a lower position to an upper position. (trigger level shift)

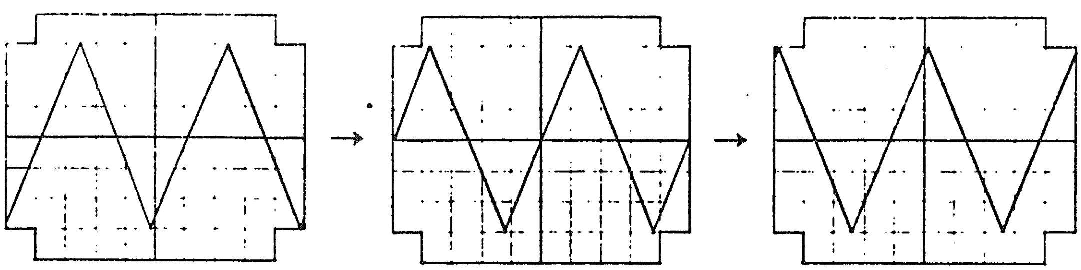


Figure 4-12

Next, pull out the LEVEL knob. The slope of the starting point of the waveform will be inverted, indicating that triggering is effected with the negative polarity.

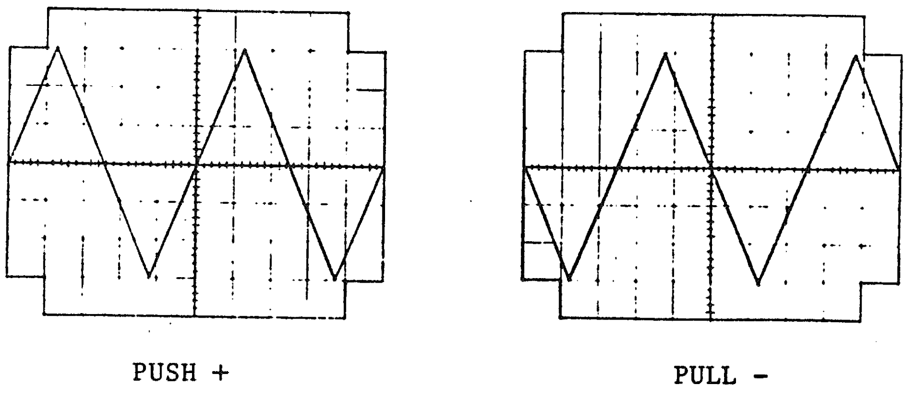



Figure 4-13

## 4.10 COMP AUTO OPERATION

Change the mode from the AUTO pushbutton switch to the COMP AUTO pushbutton switch. At the same time, so adjust the input attenuator of the oscilloscope that the displayed signal waveform amplitude becomes approximately 0.3 DIV. The displayed waveform will remain stationary and its amplitude will be reduced. (This can be observed more clearly by setting the TIME/DIV knob in the 1 mS/DIV position.) A synchronized stationary waveform is displayed even when the amplitude is increased to 8 DIV or over.

## 4.11 AUTO OPERATION

When set in the AUTO mode, the sweep circuit operates without requiring any trigger input signal and a bright trace is displayed even at a fast sweep range, enabling to check easily the zero level.

## 4.12 NORM OPERATION

When set in the NORM mode, the sweep circuit is in the standby state and no trace is displayed on the screen if no input signal is applied to the oscilloscope, if the external signal applied to the EXT TRIG IN terminal is less than 200 mVp-p, or if the setting of the LEVEL knob is exceeding the triggering point.

## 4.13 SINGLE-SWEEP OPERATION

For the single-sweep operation, proceed as follows:

(a) Apply a repetitive signal to CH1 or CH2, set the trigger circuit in the NORM mode, and so adjust the trigger LEVEL knob that the signal waveform is displayed on the screen.

(b) Change the trigger mode from NORM to SINGLE.

(c) Disconnect the input signal.

(d) Press the SINGLE switch again. (PUSH TO RESET operation)

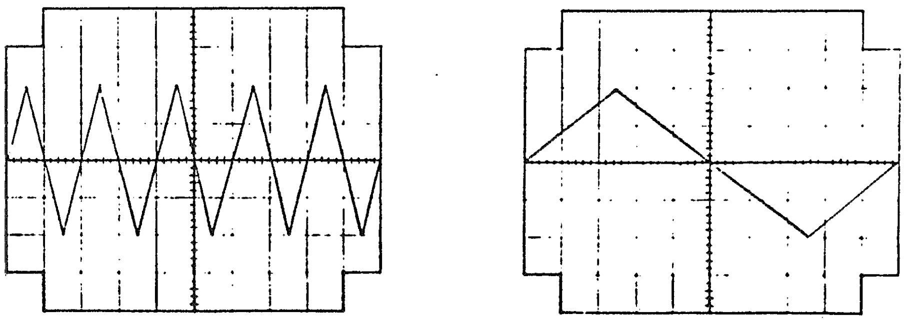
(e) As you release the switch, it is reset to the original state and the LED lamp at upper right on the front panel lights to indicate that the sweep circuit is in the standby state.

(f) Apply the signal to be observed. The sweep circuit will be triggered with this signal and the sweep circuit will operate only once and the LED lamp will go off. The sweep circuit does not operate again unless the SINGLE pushbutton switch is pressed again.

## 4.14 SWEEP MAGNIFICATION (PULL 5 × MAG)

When you want an enlarged waveform of a certain part of the input signal, you may use a fast sweep time. However, if you use a fast sweep when the part to be observed is away from the start of the sweep, the required part may run off the screen. In such a case, this sweep magnification feature is used.

As you pull out the horizontal POSITION knob to the 5 × MAG state, the displayed waveform is magnified horizontally by 5 times with the center of screen as center of magnification.



(a) Before magnification (b) After magnification

Figure 4-14

The sweep time when in the magnification can be calculated as follows:

TIME/DIV (DIAL VALUE) ÷ 5 = SWEEP TIME/DIV

Thus the maximum sweep speed of this oscilloscope become 100 nS/DIV as 0.5 μS/DIV is magnified by five times with sweep magnification.

The trace intensity is reduced when operated in the sweep magnification mode. Therefore, this mode should not be used except the following cases:

(1) When a part which is away from the start point of the displayed waveform is required to be magnified.

(2) When a sweep speed faster than 0.5 μS/DIV is required.

## 4.15 APPLICATION METHOD OF VERTICAL INPUT SIGNAL

### 4.15.1 USING A COAXIAL CABLE

When the signal source impedance is 50 or 75 ohms, a coaxial cable of matched impedance may be used so that a signal which has high frequency components can be transmitted with less attenuation. For impedance matching, terminate the cable at the oscilloscope side using a purely-resistive resistor of 50 or 75 ohms.

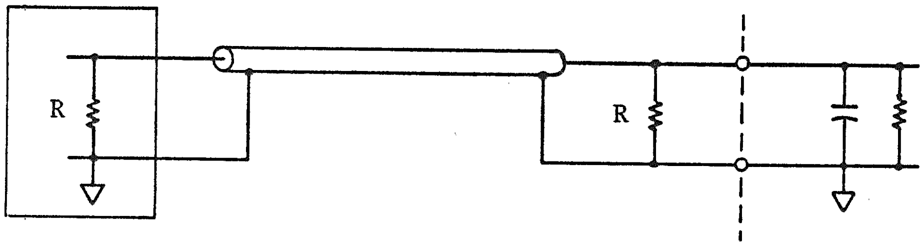
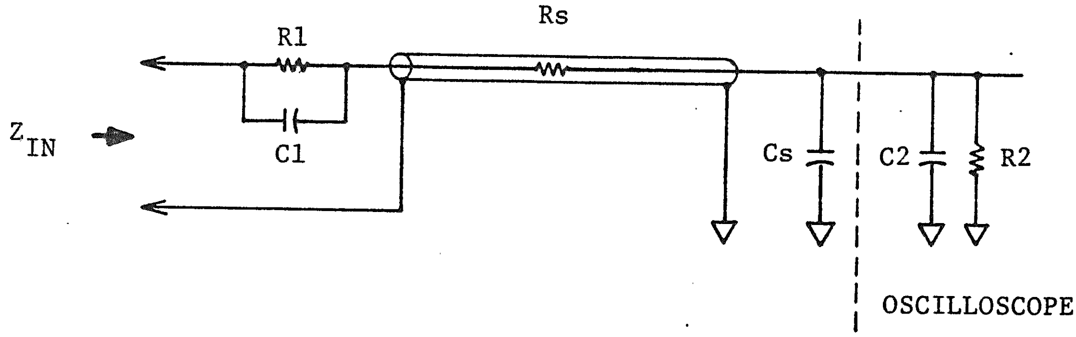



Figure 4-15

### 4.15.2 USING THE PROBE

The signal to be observed can be fed most effectively by using the 10:1 attenuation probe which is supplied as an accessory item. The cable from the probe to the oscilloscope and the probe itself are shielded to prevent external noise.




$$Z_{IN} = \frac{R1 + R2}{\omega C\ (R1 + R2) + 1}$$

$$C = \frac{C1 \times (C2 + Cs)}{C1 + C2 + Cs}$$

Rs: Series resistance of cable

Cs: Stray capacitance + cable capacitance

Figure 4-16

Attenuation resistor R1 and its parallel capacitor C1 make up a wide band attenuator. The use of this probe is especially advantageous when the measured signal source impedance is high or when the signal has high frequency components. The use of the probe reduces the loading effect on the measured signal source. The attenuation ratio is 10:1 as calculated below:

$$\frac{R2}{R1 + R2} = \frac{1\ M\Omega}{9\ M\Omega + 1\ M\Omega} = \frac{1}{10}$$

The purpose of attenuation is not to lower the signal voltage level but is to reduce the loading effect on the measured signal source.

### 4.15.3 NOTES WHEN USING THE PROBE

(1) Make sure that the measured signal is not higher than the specified maximum allowable input voltage.

(2) When measuring a wide frequency signal at a high sensitivity, be sure to use the groud wire supplied. Also use the ground wires supplied when measuring in the dual-channel mode.

(3) Make sure that the phase of the probe is accurately adjusted. Be sure to use the probe supplied as an accessory of the oscilloscope.

(4) Be careful not to apply abnormally large mechanical shocks or vibration to the probe. Do not pull or sharply bend the probe cable.

(5) The probe main unit and its tip are not highly heat resistant. Do not apply a soldering iron close to the probe.

### 4.15.4 OPERATION IN AC-COUPLING

To observe an AC signal superimposed on a DC component the AC-coupling is used in general. When the frequency is lower than 1 kHz, however, pay attention to that the phase may lead or lag and the amplitude may be decreased. When a square wave of 1 kHz is applied, for example, sag may be caused and the waveform may be distorted as illustrated.


Figure 4-17

The waveform of (1) shows typical sag which is caused when the low frequency component is in a leading phase and the amplitude is attenuated. The waveform of (2) shows typical sag which is caused when the low frequency component is in a lag phase and the amplitude is attenuated. The use of DC-coupling is ideal.

The input impedance of the oscilloscope is 1 MΩ, with the 0.1 μF AC-coupling capacitor connected in series. When a low frequency square wave or stepwise signal is applied, sag as shown in waveform (1) is caused.

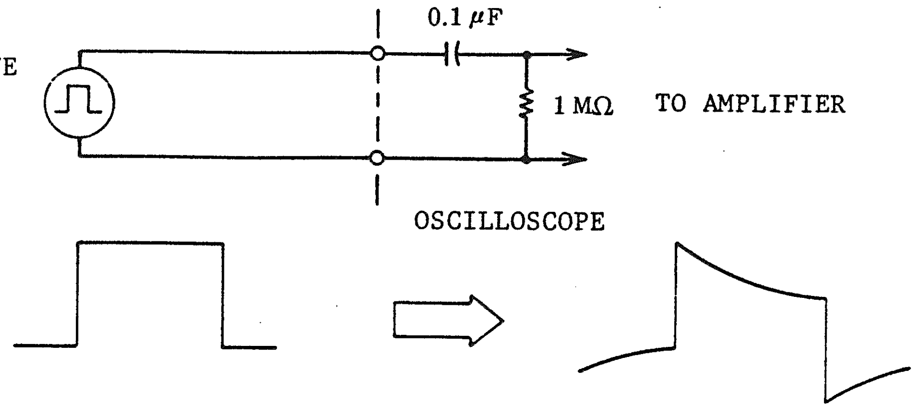



Figure 4-18

The percent of sag can be calculated as follows:

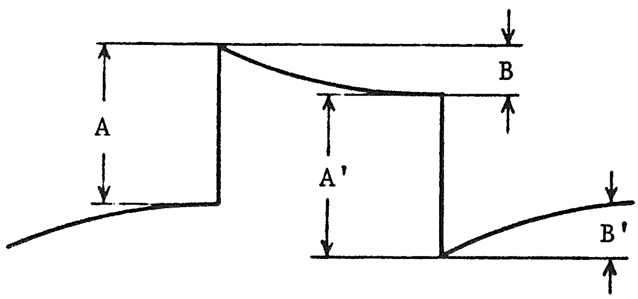



Figure 4-19

A: Basic amplitude

B: Sag

$$\text{Sag (\%)} = \frac{B}{A} \left(\text{or } \frac{B'}{A'}\right) \times 100$$

Percent of sag of this oscilloscope is shown in the following:

| Repetition frequency | Sag (%) |
|---|---|
| 10 Hz | 26 |
| 50 Hz | 4 |
| 100 Hz | 2 |
| 500 Hz | 0.6 |

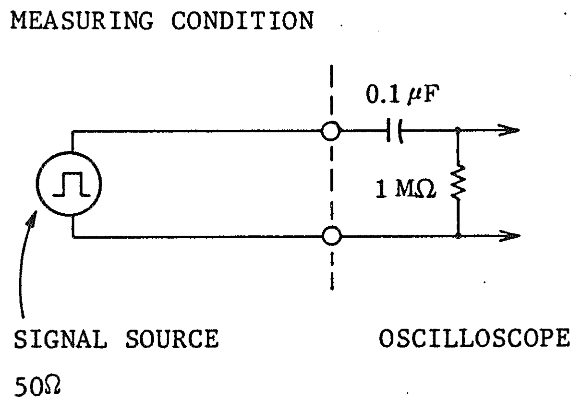



Figure 4-20

Percent of sag when the 10:1 probe is used is shown in the following:

| Repetition frequency | Sag (%) |
|---|---|
| 10 Hz | 2.6 |
| 50 Hz | 0.4 |
| 100 Hz | 0.2 |
| 500 Hz | 0.06 |

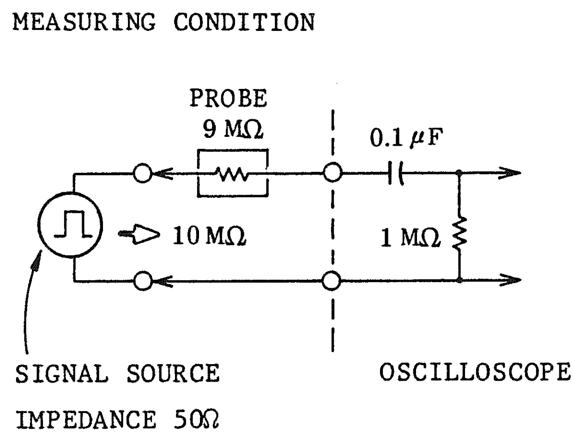



Figure 4-21

As can be seen in the above table, sag is reduced to about 1/10 when the 10:1 probe is used than when the signal is directly fed to the oscilloscope. When the probe is used, however, the input signal voltage is reduced to 1/10. The use of the probe is advantageous when the signal can not be DC-coupled and yet a waveform with less sag is required.

# 5. MEASUREMENTS

## 5.1 VOLTAGE MEASUREMENTS

### 5.1.1 DC VOLTAGE MEASUREMENT

(1) Set the trigger switch in the AUTO mode and the TIME/DIV switch at 1 mS/DIV and display a trace line.

(2) Set the GND pushbutton switch of the vertical input circuit in the GND state. This trace position is used as the reference position (0 V position) for voltage measurement. Move the trace to a convenient position with the POSITION knob.

(3) Set the AC-DC pushbutton switch in the DC state, apply the voltage to be measured to the vertical input terminal, and determine the vertical deflection of the trace on the screen.

(4) If the trace is deflected off the screen upward, turn counter-clockwise the VOLTS/DIV switch to select a lower sensitivity range so that the trace is deflected to an easily measurable position.

(5) If the trace is deflected upward, the porality of the measured signal is positive; if it is deflected downward, the polarity is negative.

(6) Voltage measurement with or without probe

- o When the signal is applied directly to the input terminal:

  Voltage V = VOLTS/DIV indication × Deflection (DIV)

- o When the signal applied using the 10:1 probe:

  Voltage V = VOLTS/DIV indication × Deflection (DIV) × 10

### 5.1.2 AC VOLTAGE MEASUREMENT

If the AC-DC switch is set in the DC state when measuring an AC voltage superimposed on a DC voltage and if the DC component is large as compared to the DC voltage, the AC voltage may be deflected off the screen. It may be possible to bring the AC voltage component onto the screen by adjusting the vertical POSITION control. It also is possible to bring the AC voltage component onto the screen by turning the VOLTS/DIV switch to a lower range position.

In general, however, the AC voltage is measured by setting the AC-DC pushbutton switch in the AC state to cut off the DC component and displaying the AC voltage component alone with an appropriate amplitude.

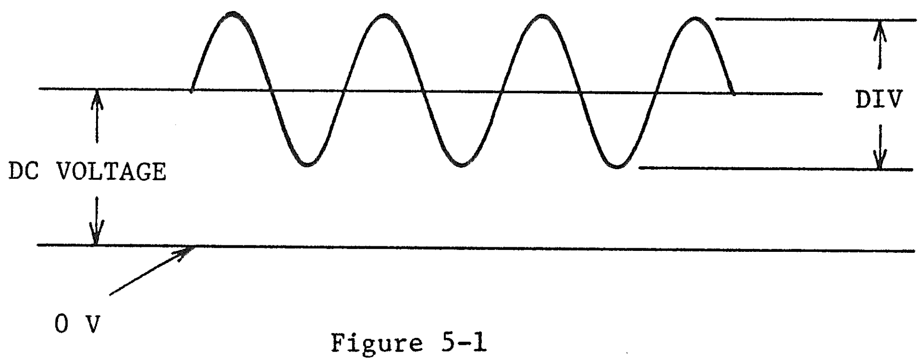



Figure 5-1

From the deflection amplitude (DIV determined on the screen), the voltage is calculated as follows:

Voltage Vp-p = VOLTS/DIV indication × Deflection (DIV)

When the 10:1 probe is used, the voltage is calculated as follows:

Voltage Vp-p = VOLTS/DIV indication × Deflection (DIV) × 10

## 5.2 MEASUREMENT OF TIME

Measurement of time interval:

The time interval (T) between two points on the waveform can be measured by setting the TIME/DIV VARIABLE knob in the CAL'D position and determining the horizontal distance between the two points on the screen.

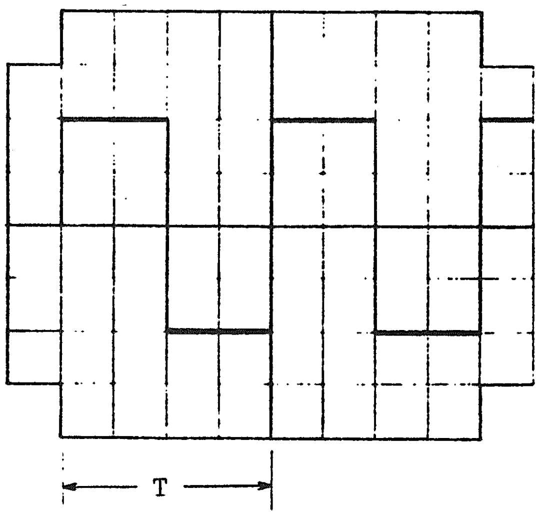



Figure 5-2

Time T (sec) = TIME/DIV (sec) × Distance (DIV) × Magnification factor ................................. (A)

The magnification factor is 1 when the sweep is not magnified or it is 1/5 = 0.2 when the sweep is magnified.

## 5.3 PULSE WIDTH MEASUREMENT

Display the pulse signal in the center of the screen with a horizontal magnitude of 2 - 4 DIV for ease of measurement.

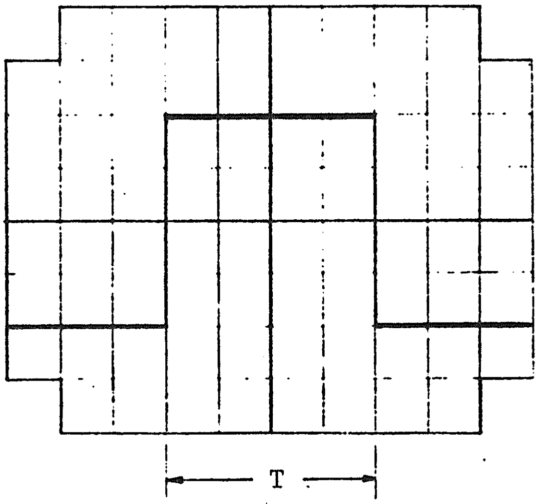



Figure 5-3

Set the TIME/DIV VARIABLE knob in the CAL'D position. When the pulse width is narrow, pull out the 5 × MAG switch as required. Determine the distance T and calculate the width using equation (A).

## 5.4 MEASUREMENT OF PULSE RISE TIME AND FALL TIME

Determine distance T in the same manner as is done for pulse width measurement and calculate the time using equation (A). When the rise time of the oscilloscope itself (35 nS) is negligible as compared to the measured pulse rise or fall time, the value can be immediately known. When it is not negligible, correct the value using the following equation:

$$Tn = \sqrt{T^2 - T_O^2 - T_G^2}$$

Tn: True value

T: Measured value

$T_O$: Rise time of oscilloscope, 35 nS (theoretical value)

$T_G$: Rise time of signal of pulse generator



4 7

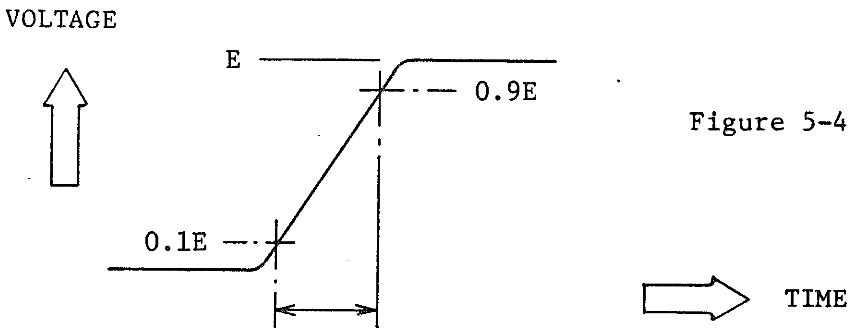



Figure 5-4

## 5.5 LISSAJOUS MEASUREMENT OF FREQUENCY

When the signal frequency is not higher than 10 kHz and is of a simple waveform such as sine wave, the signal frequency can be measured by operating the oscilloscope as an X-Y scope and displaying a Lissajous figure on the screen. For the X-Y operation, refer to Section 4.3.

MEASURING SETUP

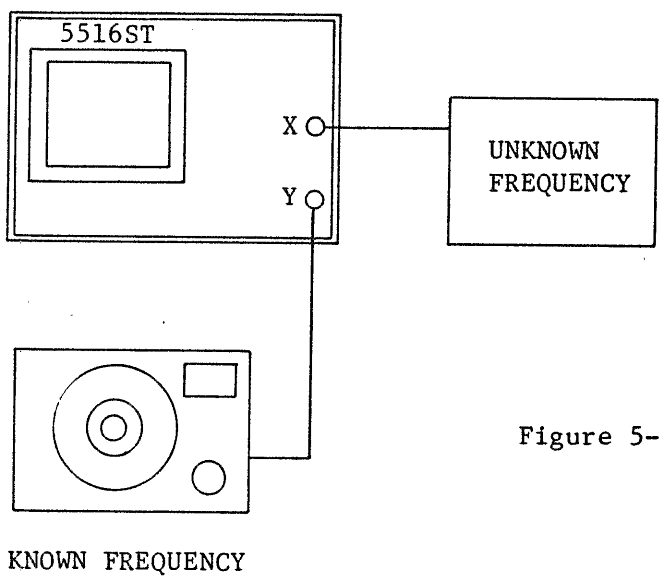



Figure 5-5

Make roughly equal the horizontal and vertical amplitudes of the displayed figure by adjusting the VOLT/DIV switches or VARIABLE controls of both channels.

Gradually change the known frequency until a 1:1 Lissajous figure as illustrated is displayed.

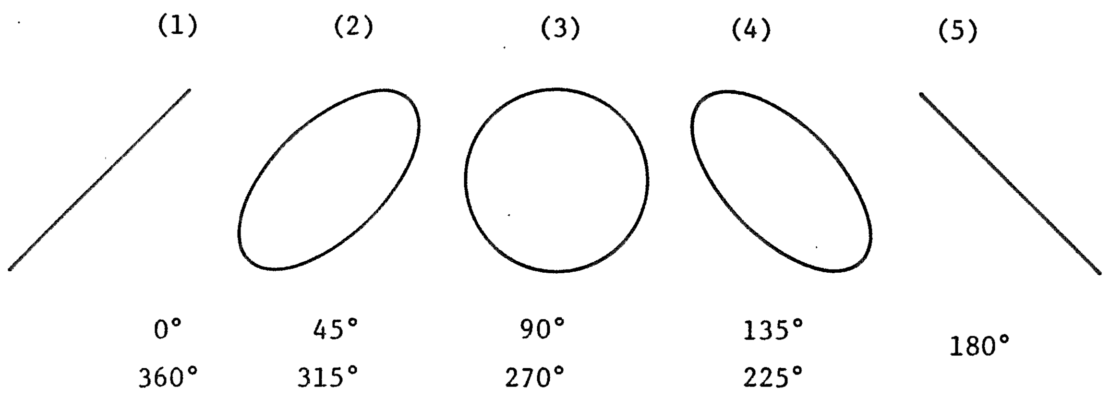



Figure 5-6

When the frequency ratio is 1:1, the displayed Lissajous figure is either a circle, an ellipse, or a line. When the frequency ratio has become close to 1:1, the displayed figure will vary in the sequence of (1) → (5) → (1), repeatedly. As the known frequency becomes closer to the unknown frequency, the change becomes slower. When the two frequencies have become the same, the displayed figure remains stationary in a pattern of one of (1) - (5). Now the unknown frequency is the same as the known frequency.

## 5.6 PHASE MEASUREMENT

(1) Phase measurement with Lissajous figure:

In the same method as that for frequency measurement, operate the oscilloscope in the X-Y mode and display a Lissajous figure.

Operate the X-axis and Y-axis amplifiers at as large sensitivity as possible. Determine distances A and B on the screen and calculate the phase difference using the following the equation:

$$\text{Phase difference } \theta = \sin^{-1} \frac{A}{B}$$

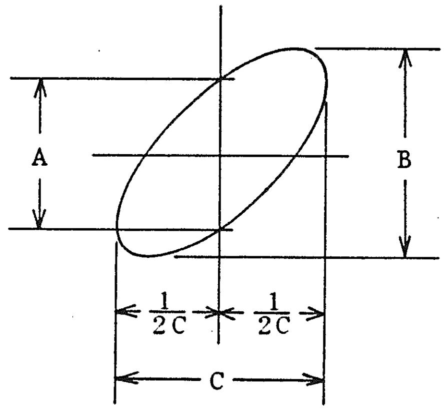



Figure 5-7

Phase measurement in the Lissajous figure method has disadvantages as follows:

(1) With the conventional oscilloscope, the frequency response of the X-axis is narrow and a large phase difference is caused by the oscilloscope itself.

(2) Phase difference measuring accuracy is comparatively poor.

Due to the above reasons, the dual-channel method explained next is recommended when more accurate phase difference measurement is required.

(2) Phase difference measurement in dual-channel method:

Set the vertical-axis MODE switch in the DUAL state and press the TRIGGER CH1 button. Apply the reference signal to CH1 and the measured signal to CH2 so that the waveforms are displayed as illustrated.

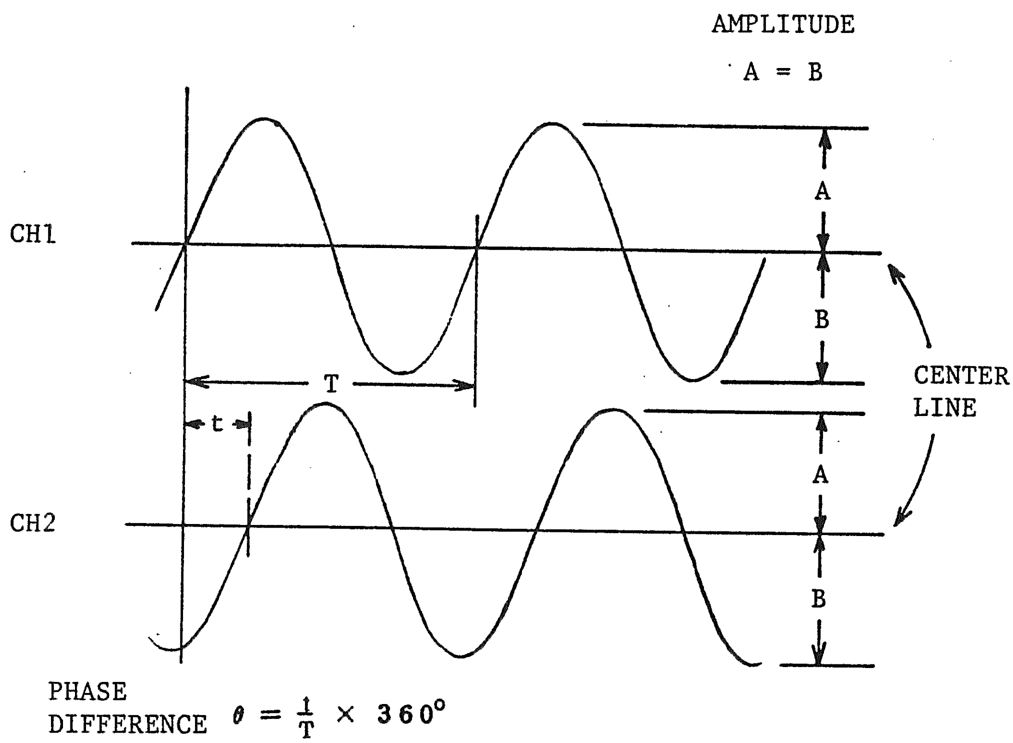



Figure 5-8

Display waveforms as large as possible by increasing the signals applied to CH1 and CH2 or increasing the sensitivities of both channels.

Center both signals around a graticule (A=B). If probes are to be used, use probles for both channels and adjust accurately the phase characteristics of both channels using the CALIB signal.

The phase difference measurement in the dual-channel method has the advantages that even a small phase difference can be measured and the leading or lagging state can be known at a glance.

# 6. OPERATION DESCRIPTION

## 6.1 GENERAL

The OSCILLOSCOPE is a visual instrument (SCOPE) for observation of electrical signal change. Its circuits operate so that its input signal is displayed in an easily observable form on a cathode-ray tube screen. A block diagram of the oscilloscope is shown in Figure 6-1.

The signal applied to the vertical input axis is amplified by the vertical amplifier and the amplified signal is applied to the Y-axis deflection plates of the CRT. The electron beam emitted from the CRT cathode is vertically deflected by this signal.

Additionally, the vertical signal is branched off and amplified by the trigger amplifier to produce a trigger pulse signal which is synchronized with the vertical signal. The trigger pulse signal is applied to the sweep generator circuit which produces a sawtooth signal. The sawtooth signal is amplified by the horizontal amplifier and applied to the X-axis deflection plates of the CRT in order to deflect the electron beam in the X-axis direction. Thus, a stationary waveform being synchronized with the input signal is displayed on the CRT screen.

The Z-axis amplifier controls the brightness of the trace. Its output is applied to the CRT so that the unrequired portion of the signal is blanked out.

The storage circuit store the displayed waveform on the CRT screen. It generates an erase signal when the sweep operation is over.

The power supply circuit and high voltage supply circuit provide the required voltages to the functional circuits and CRT. The calibration voltage generator circuit provides a quality square wave signal for calibration of the probe.

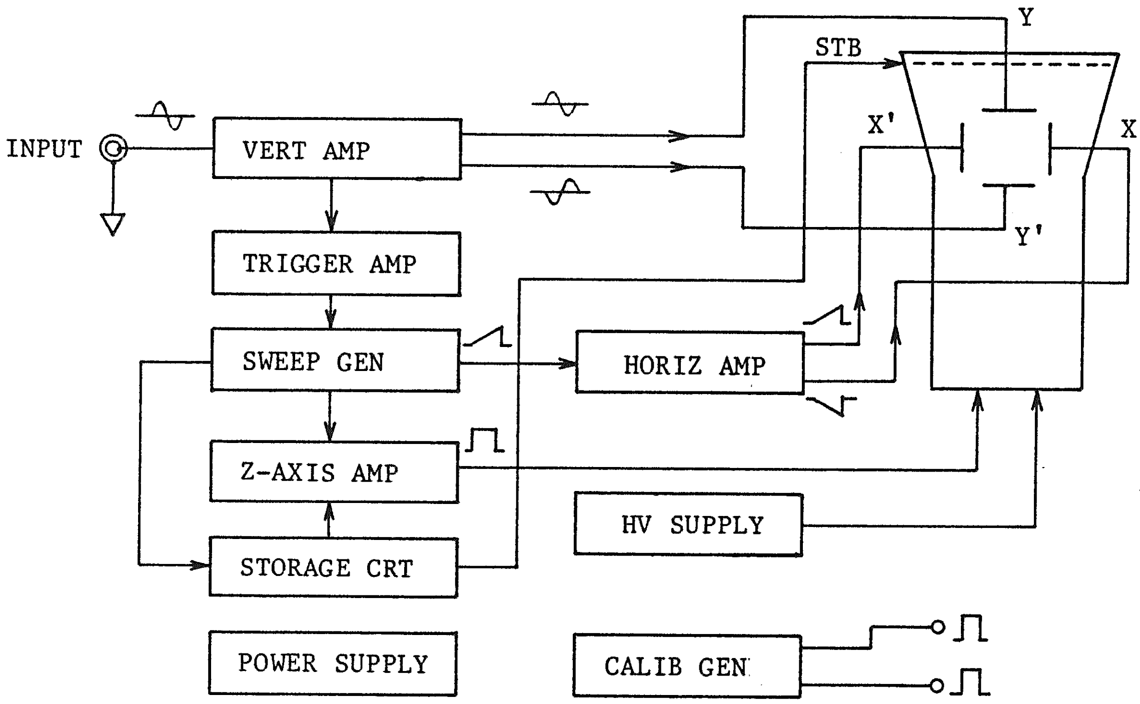



Figure 6-1. A block diagram of the oscilloscope

## 6.2 VERTICAL AMPLIFIER

The vertical amplifier deflects the beam in the Y-axis direction on the CRT screen. It has an input circuit, an attenuator, a preamplifier, a CH1/CH2 selector circuit, and an output stage amplifier the output of which is applied to the Y-axis deflection plates of the CRT. All circuits from the preamplifier to the Y-axis deflection plates are of a differential circuit type.

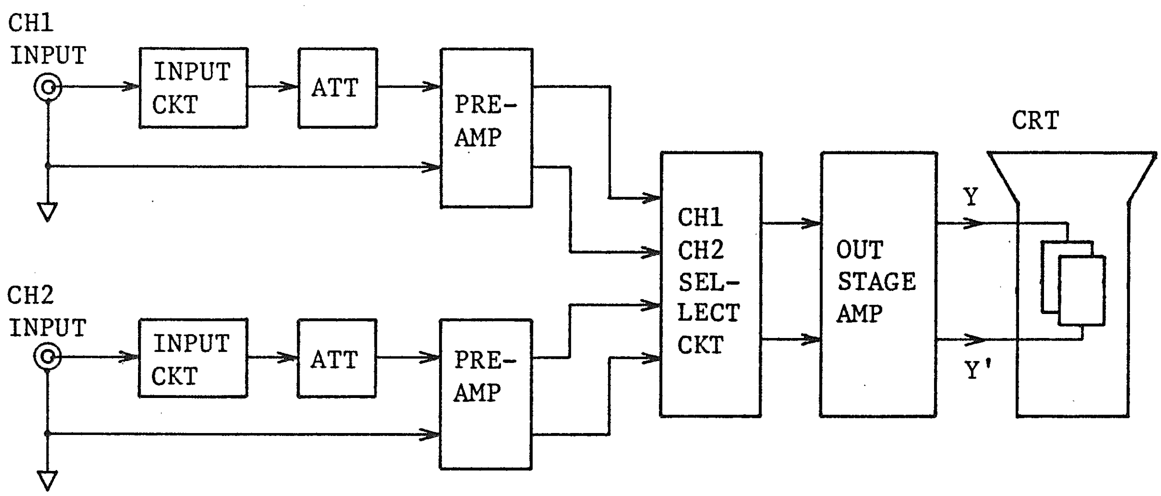



Figure 6-2. A block diagram of the vertical amplifier

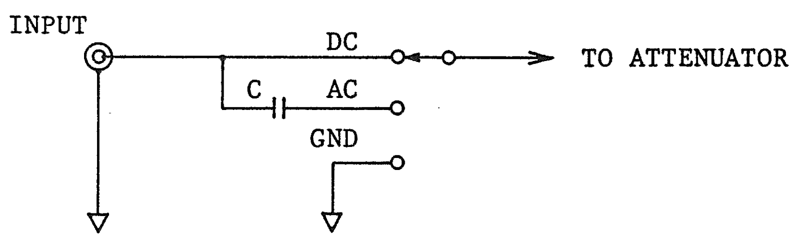



Figure 6-3. The input circuit

The input circuit selects the input mode for DC, AC, or GND. The DC coupling mode is for measurement of a DC signal, the AC coupling is for observation of an AC signal superimposed on a DC component, and the GND position is for confirming the zero level position on the CRT screen.

The function of the attenuator circuit is to reduce the input signal with selectable ratios. With combinations of the 1/2, 1/4, 1/10 and 1/100 attenuation circuits, a total attenuation range of 1/2 to 1/2000 can be covered. The attenuator circuit is designed so that the impedance as viewed from the input side remains constant even when conbinations are changed.

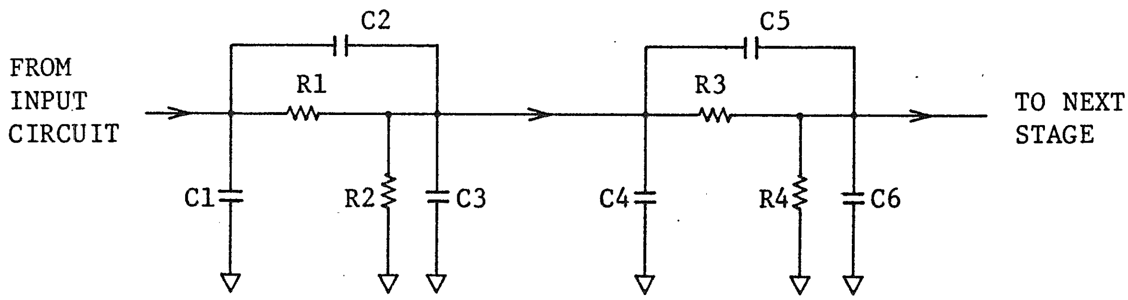



Figure 6-4. An example of combination of attenuator circuits

The preamplifier consists of an input protection circuit, an impedance converter circuit, a differential converter circuit, a trigger signal amplifier circuit, and a polarity switching circuit (for CH2 only).

The input protection circuit has a diode to clamp the input signal when its voltage is abnormally large, in order to protect the subsequent circuits.

The impedance converter circuit provides a large input impedance and a small output impedance in order to prevent loading on the attenuator circuit to ensure reliable attenuation ratios and to provide the signal with a sufficiently low output impedance for the next stage. This circuit employs dual FETs which operate as a source follower with a constant current circuit. An emitter follower is used in addition. The FETs employed are two premium-quality chips of equal characteristics sealed in one package attaining excellent thermal balance. The transistors of the emitter follower also are premium-quality matched-characteristic ones and are positioned closely on the printed circuit board to ensure thermal balance.

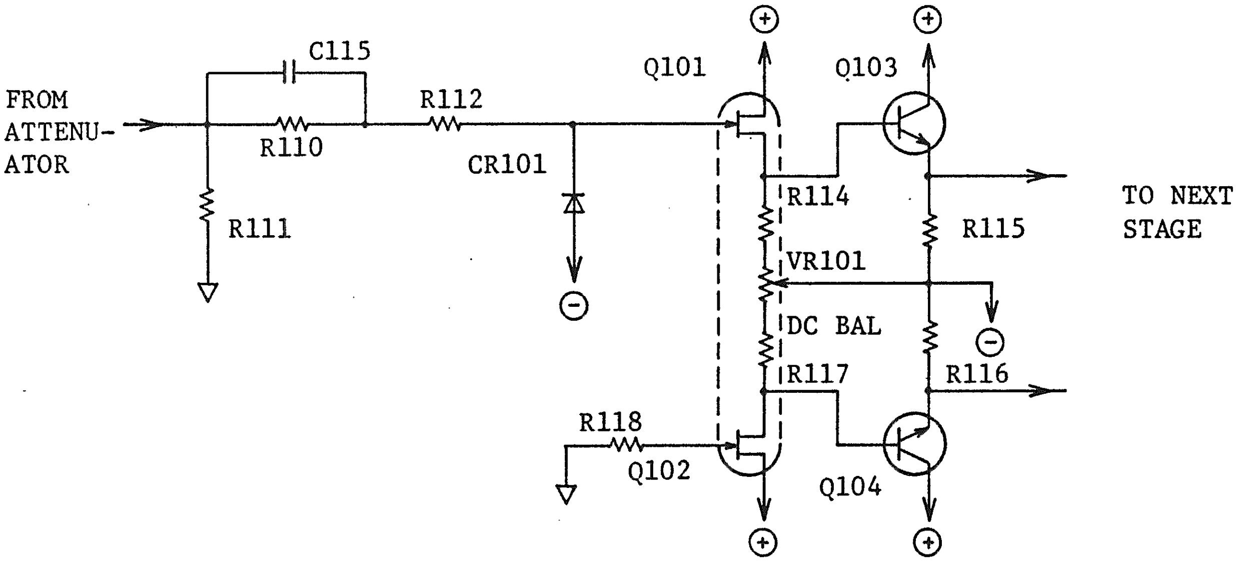



Figure 6-5. The input protector and impedance converter

For the converter circuit, a differential cascade amplifier is used. For differential coupling, a constant-current circuit is used to improve the commom-mode characteristics.

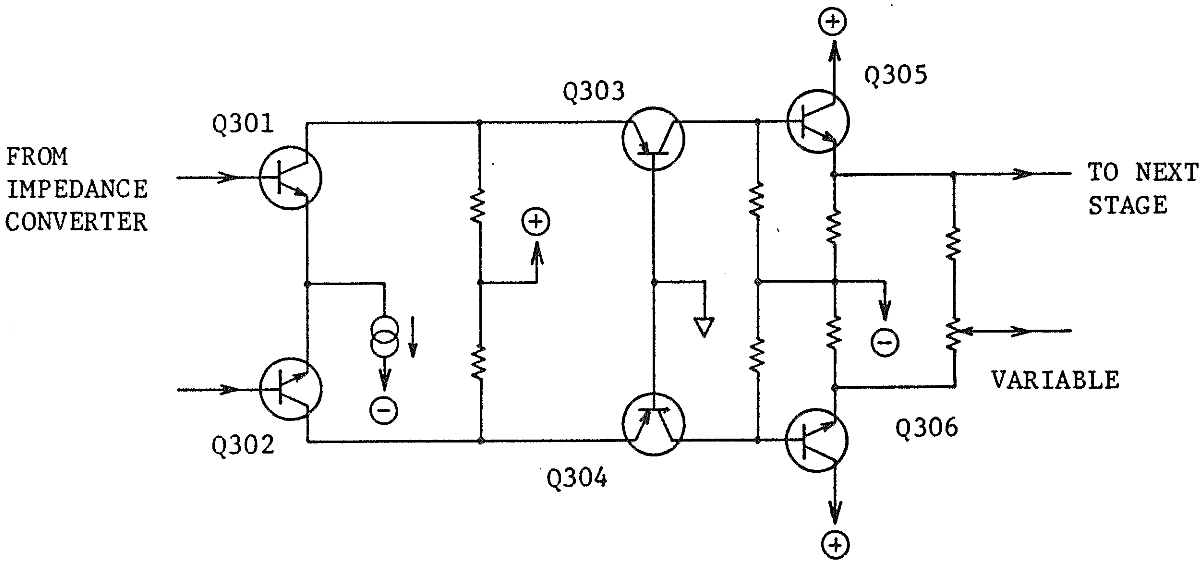



Figure 6-6. The preamplifier (front stages)

The positioning circuit also employs a differential cascade amplifier of the same type as that shown in Figure 6-6 and the differential balance is varied on purpose to move the trace position. The polarity switching circuit provides an inverted output by changing the connections between cascade circuits to the opposite polarity.

As explained above, the input signal applied to the oscilloscope is attenuated to an appropriate level by the attenuator, converted into a differential signal, fed through the required functional circuits, amplified by the output circuit, and fed to the CH1/CH2 selector circuit.

The selector circuit selects channel 1 or channel 2 depending on the front panel switch setting.

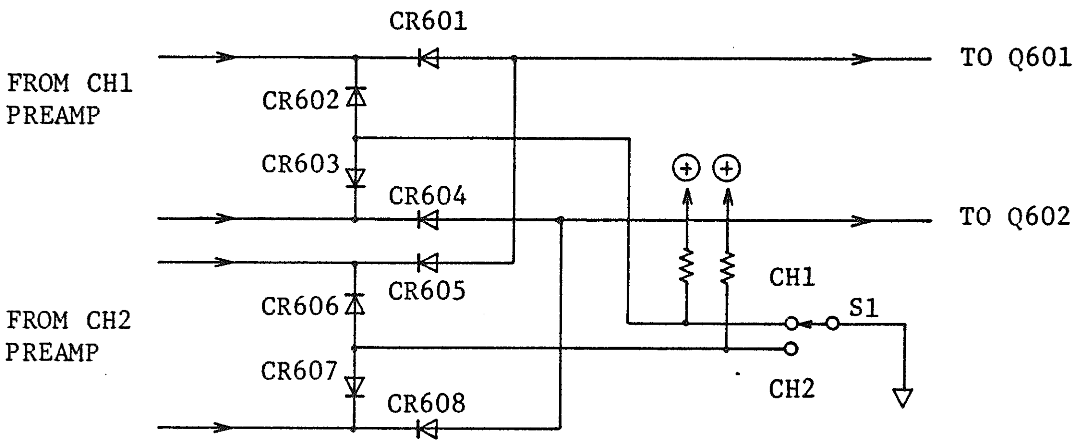



Figure 6-7. The CH1/CH2 selector circuit

Assume that S1 has been connected to the CH1 side. In this case, diodes CR602 and CR603 are OFF and CR606 and CR607 are ON, and the signal switching diodes (CR601 and CR604) of CH1 are on and those (CR605 and CR608) of CH2 are off. Therefore, the CH1 signal alone is fed.

When switch S1 is connected to the CH2 side, the operations are in the reverse of the above and the signal of the CH1 preamplifier is fed to Q601 and Q602.

Switch S1 actually is an electronic switching circuit (a NAND gate circuit made up of U502-1 and U502-2) and is capable of rapid switching for the CHOP operation.

The CH1/CH2 selector circuit is connected between input and output stages of the cascade amplifier and operated in a low-impedance current mode in order to minimize effects to other circuits. The output stage of the cascade amplifier converts the current signal into a voltage signal and this voltage signal is fed to the emitter follower which drives with sufficiently low impedance the power amplifier.

The power amplifier is a differential cascade amplifier and employs high-$f_T$ drive transistors and high-voltage high-frequency transistors in combination. It provides sufficient power for deflecting the electron beam, ensuring excellent frequency response and phase characteristics .

## 6.3 TRIGGER CIRCUIT AND SWEEP GENERATOR CIRCUIT

The trigger circuit selects the CH1, CH2 or NORM internal trigger signal, or the external trigger signal, and it produces a trigger pulse signal which is synchronized with the input signal so that a staionary waveform can be displayed on the CRT screen.

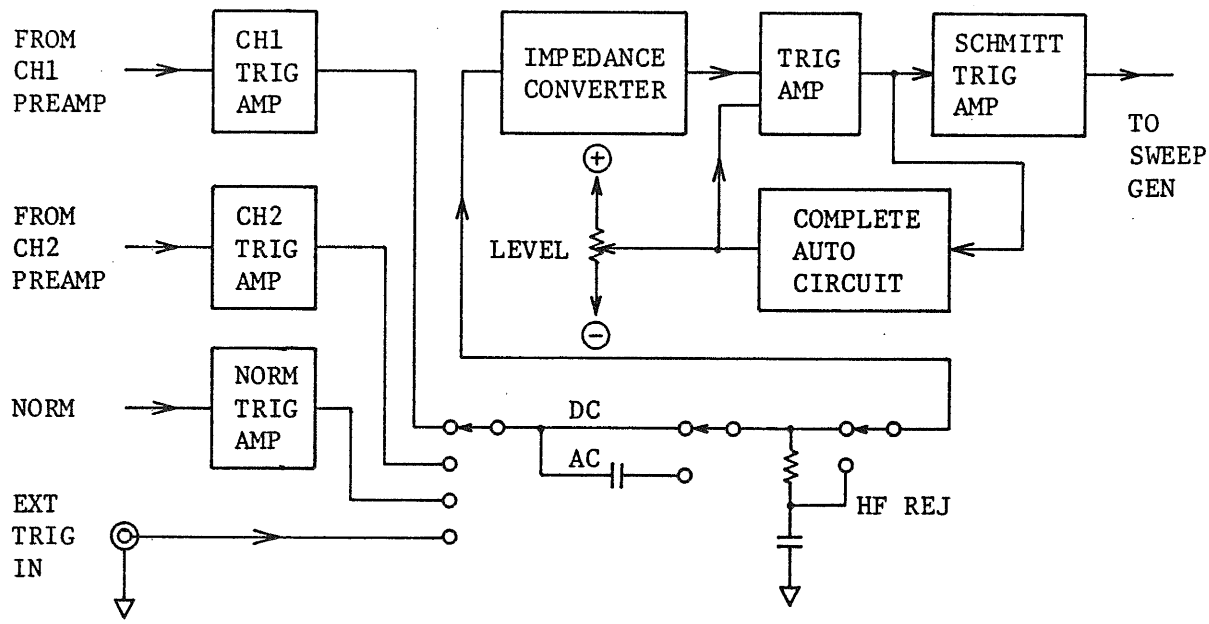



Figure 6-8. A block diagram of the trigger circuit

The input signals amplified by the CH1 and CH2 amplifiers and selected by the CH1/CH2 selector circuit, to gether with the amplified NORM signal, are amplified further by the CH1, CH2 and NORM trigger amplifiers. The resultant signals, together with the external trigger signal, are fed to the trigger source selector circuit. The selected trigger source signal is fed through the AC/DC trigger coupling circuit and NORM/HF REJ circuit to the impedance converter circuit.

The impedance converter circuit employs a source follower comprised of a dual-FET constant-current circuit to provide low output impedance. The trigger signal is amplified further by the trigger amplifier. At the same time, an offset signal is applied to the amplifier to control the trigger level.

The COMPLETE AUTO circuit receives the trigger amplifier output and provides an automatic offset signal to the trigger amplifier in order to maintain the trigger level always within the peak to peak range of the trigger signal waveform.

The output signal of the trigger amplifier is fed to the Schmitt trigger circuit which produces a trigger pulse signal of a sharp rising or falling edge. The Schmitt trigger circuit is comprised of an R-S flip-flop. Switching of trigger slope is done by using its inverted output.

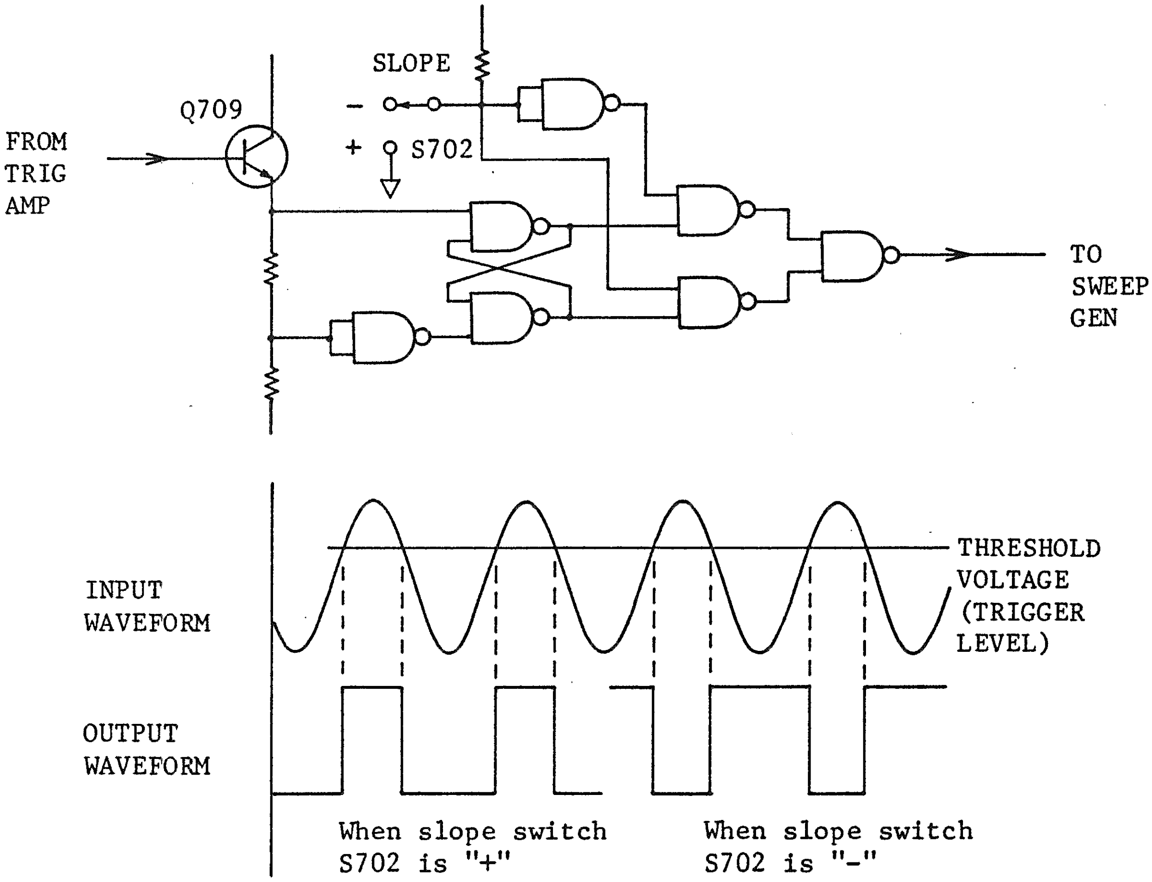



Figure 6-9. The trigger pulse generator circuit and timing chart

The trigger pulse signal generated as above is applied to the sweep signal generator circuit of the next stage, which with its Miller integration circuit generates a sawtooth signal.

Most oscilloscopes employ a Miller integration circuit for their sweep circuit and incorporate a gate circuit to control generating timing of the sawtooth wave. By synchronizing the timing of sawtooth signal generation with the trigger pulse signal, the displayed waveform can be maintained stationary.

If no trigger pulse is applied, the oscilloscope operates in the FREE RUN mode. This mode is such that when one sweep is over the next sweep starts. With this mode the displayed waveform cannot remain stationary.

When in the NORM mode, the sawtooth signal is generated in synchronization with the trigger pulse. Unless the trigger pulse is applied, no sweep occurs and no waveform is displayed.

A block diagram of the sweep generator circuit is shown in Figure 6-10.

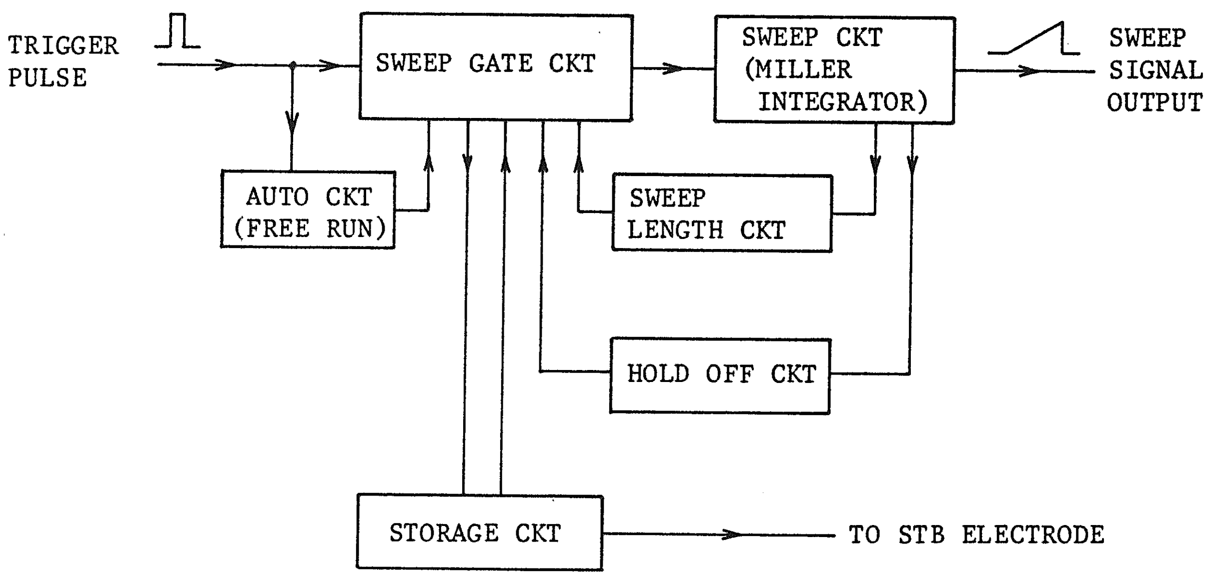



Figure 6-10. A block diagram of the sweep generator

The trigger pulse signal which is applied to the sweep gate circuit is applied also to the AUTO circuit in order that, when the TRIGGER MODE switch on the front panel is set in the AUTO (or COMP MODE) mode, the sweep circuit is driven by a trigger signal if it is applied and operates in the automatic trigger mode if no trigger signal is applied.

When the TRIGGER MODE switch is set in the NORM or SINGLE mode, the AUTO circuit is disconnected. The sweep circuit is driven by a trigger signal applied or it does not operates if no trigger pulse is applied.

When the output signal of the Schmitt trigger circuit is applied to the sweep gate circuit, it produces a sweep start command signal. In compliance to this command signal, the sweep circuit starts its integration operation and its output voltage increases at a certain rate. When the output voltage has reached a certain value, the sweep length circuit operates and produces a pulse. As this pulse is applied, the sweep gate circuit generates a sweep stop command signal so that the charge of the Miller integrator capacitor is rapidly discharged and the output voltage of the sweep circuit returns to zero. The sweep circuit remains in this state for a period as dictaded by the holdoff circuit (the period differs by the range of the sweep time selector switch). When the next trigger pulse is applied, the sweep circuit repeats the above operation. (See Figure 6-11.)

The STORAGE circuit has functions of storing the displayed waveform in synchronization with the sweep signal and of stopping the sweep operation during the waveform storage period or the erase period.

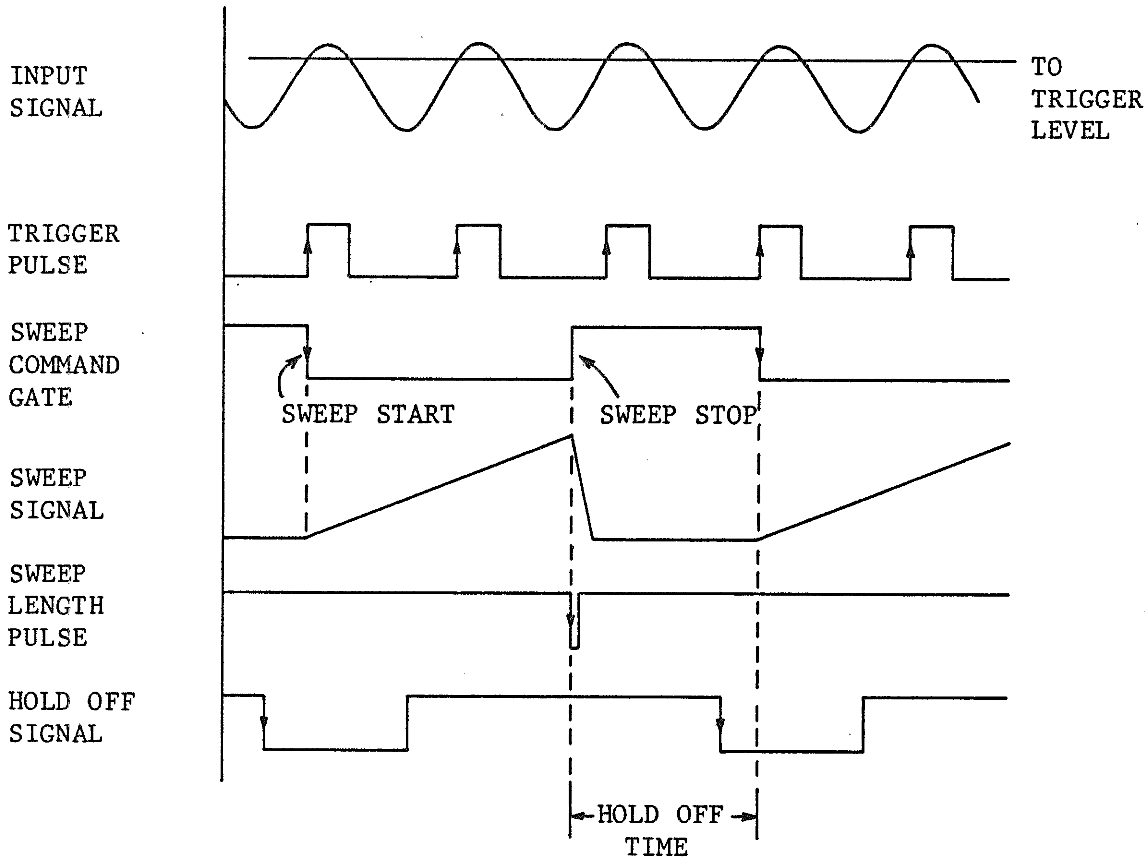



Figure 6-11. A timing chart of the sweep circuit

The sweep signal produced as above is applied, together with the X signal when in the XY operation, to the horizontal signal selector circuit which selects either one of these signals as dictated by switch setting on the front panel. The selected signal is fed to the horizontal amplifier.

## 6.4 HORIZONTAL AMPLIFIER

The horizontal amplifier amplifies the signal for deflecting the beam spot in the X-axis direction on the CRT screen. It is comprised of a horizontal signal selector circuit and an output amplifier (with ×5 MAG circuit).

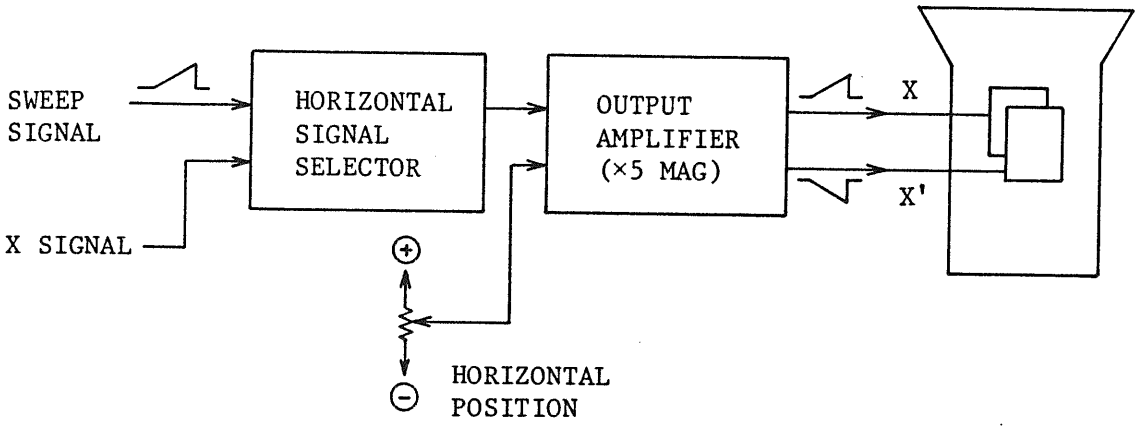



Figure 6-12. A block diagram of the horizontal amplifier

Either the sweep signal or the X signal is selected by the horizontal signal selector circuit (relay circuit). The selected signal is applied to the output amplifier. The output amplifier is a differential cascade amplifier with emitter followers for its input stage, and the signal to be measured is applied to one input circuit and the horizontal position signal to the other input circuit. This amplifier has a 5-time sweep magnification function, accomplished by changing the impedance of the differential coupling circuit of the cascade-connected input stage.

The differential horizontal signal obtained as above is applied to the horizontal deflection plates of the cathode-ray tube to deflect horizontally the beam spot on the CRT screen.

Due to the above functions, if a sweep signal which is synchronized with the input signal is being generated, the input signal is displayed as a stationary waveform on the CRT screen. If the oscilloscope is operating in the XY mode, a Lissajous figure is displayed.

## 6.5 Z-AXIS AMPLIFIER

The function of the Z-axis amplifier is to vary the intensity of the beam spot for trace brightness adjustment as controlled with the INTEN knob on the front panel, for intensity modulation of the displayed trace with an external signal applied to the Z AXIS IN terminal, for blanking the return sweep traces, and for erasing the switching noise of the vertical axis signal when in the chopping mode.

The sweep gate signal or the CHOP blanking signal when in the dual-channel CHOP mode as selected with switches on the front panel is automatically applied to the input of the Z-axis amplifier. When an external signal is applied to the Z AXIS IN terminal, the CRT trace intensity can be directly driven with the signal regardless of panel switch setting.

The Z-axis amplifier amplifies its input signal to a sufficiently high level to drive the CRT. It is of cascade connection, active load type and a negative feedback circuit is incorporated in order to suppress the effect of line voltage variation.

The output signal of the Z-axis amplifier is shifted into a high voltage by the high voltage circuit explained in a subsequent subsection and, then, it is applied to the grid (G1) of the CRT.

## 6.6 STORAGE CIRCUIT

The function of the storage circuit is to keep the displayed trace on the CRT screen for a controllable period of time. This storage function is accomplished by means of a readout gun and back electrodes. A block diagram of the storage circuit is shown in Figure 6-13.

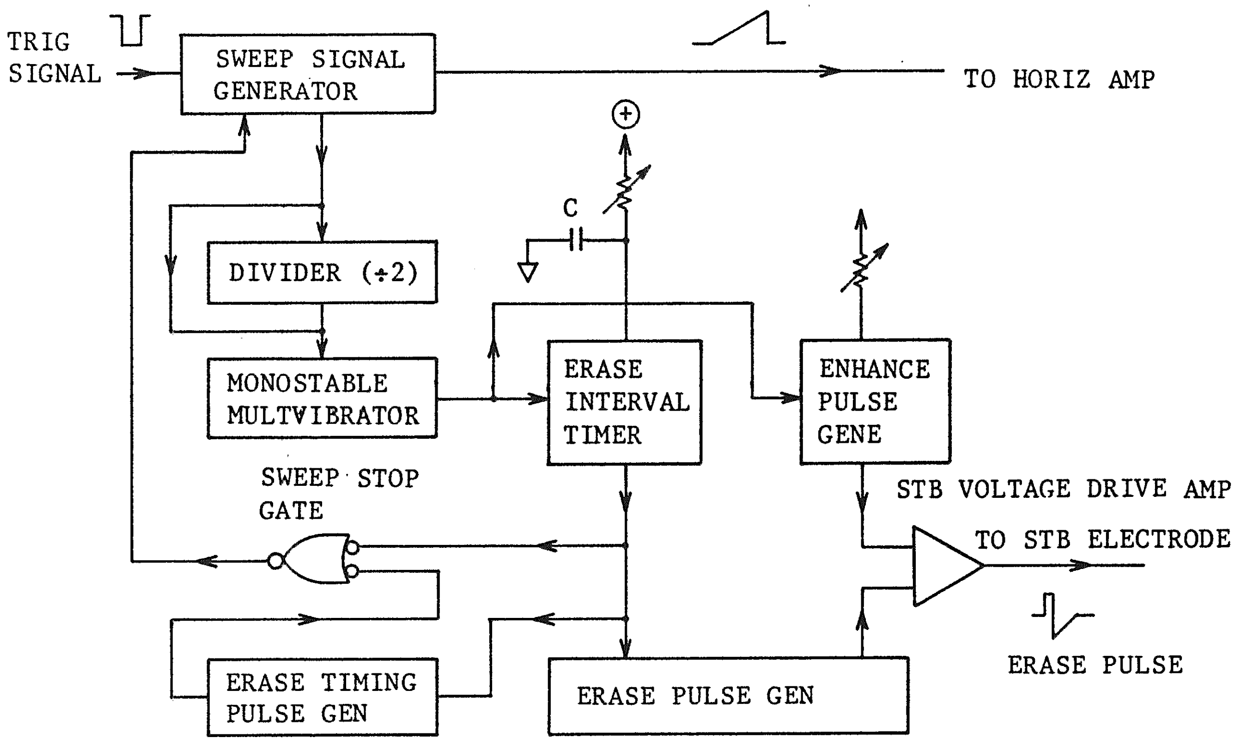



Figure 6-13. A block diagram of the storage circuit

To understand the operation of the storage circuit, knowledge of the BHD type storage tube is necessary. For this tube, refer to its explanation given elsewhere. ( See page 71.)

Assume that the voltages applied to the storage CRT are for the storage state. As the trigger signal is applied to the sweep signal generator circuit, a sweep starts and the storage operation begins on the CRT screen. At the instant the sweep has ended, the monostable multivibrator is driven by the sweep stop signal which is produced in the sweep signal generator circuit. (When this is done, the divider circuit is brought into effect provided that the dual-trace ALT sweep mode (excluding the SINGLE mode) is selected. If in other mode, the sweep stop command signal is fed bypassing the divider circuit.) The monostable multivibrator converts the sweep stop command signal into a pulse signal which has an appropriate pulse width for handling by the erase interval timer. As the pulse signal is applied to the erase interval timer and it starts operating, its output is applied via the sweep stop gate to the sweep signal generator circuit, thereby inhibiting the sweep operation during the period the timer is operating. Thus the displayed waveform is maintained during the period the timer is in operation.

At the instant the timer period has elapsed, an erase pulse is generated. The erase pulse is amplified by the STB voltage drive amplifier and applied to the STB electrodes of the CRT to erase the stored trace. Since a period of approximately 0.5 second is required for erasure, a pulse signal of approximate 0.5 second is generated by the erase timing pulse generator and this signal is applied via the sweep stop gate to the sweep signal generator circuit in order to inhibit the sweep operation regardless of application of the trigger pulse.

When the oscilloscope is in the storage state, a waveform can be recorded (stored), held and erased as explained above. These functions can be selected as required. For example, when the oscilloscope is in the storage state but not in the auto erase state, the timer does not operate and the storage action alone is repeated each time the trace is swept.

The enhancement function is as follows: This function is effective when the sweep speed is very high and the storing rate on the screen is insufficient. Actually, it is effective for a range or two faster than the maximum storing speed range in the regular mode. In such a range or two, the trace is in such state that it can be stored if a slightly higher energy is applied. When in this state, the storing effect can be pulled up to the display level by applying an additional energy by means of an enhancement pulse. At the instant the sweep is over, the enhancement pulse generator circuit produces an enhancement pulse. This pulse is amplified by the STB voltage drive amplifier and applied to the STB electrode. Due to this additional pulse, energy distribution on the screen is temporarily pulled up to a level suffient for storing. At the end of the pulse, energy distribution returns to the original level. (For further details, refer to the section for the recording speed enhancement method of the storage CRT.)

When the sweep speed is faster by far, no storing can be occured even if the enhancement pulse is applied.

The degree of enhancement is adjustable by adjusting the enhancement pulse signal.

## 6.7 HIGH VOLTAGE CIRCUIT

The high voltage circuit produces a high negative voltage of approximately 2 kV to accelerate the electron beam. It is a DC-DC converter with a blocking oscillator. A high-insulation high-voltage transformer is used for isolation between low voltage circuit and high voltage circuit. The high output voltage of the transformer is double-voltage rectified to produce a high-voltage DC output. Part of the output voltage is fed back through a high-voltage feedback resistor to the blocking oscillator in order to obtain a stable acceleration voltage.

## 6.8 POWER SUPPLY

The power supply circuit provides DC voltages required by the various circuits of the oscilloscope. Supply voltages are regulated as required. To attain good insulation between the line power and the internal circuits, this oscilloscope employs a specially designed transformer. A block diagram of the power supply is shown in Figure 6-14.

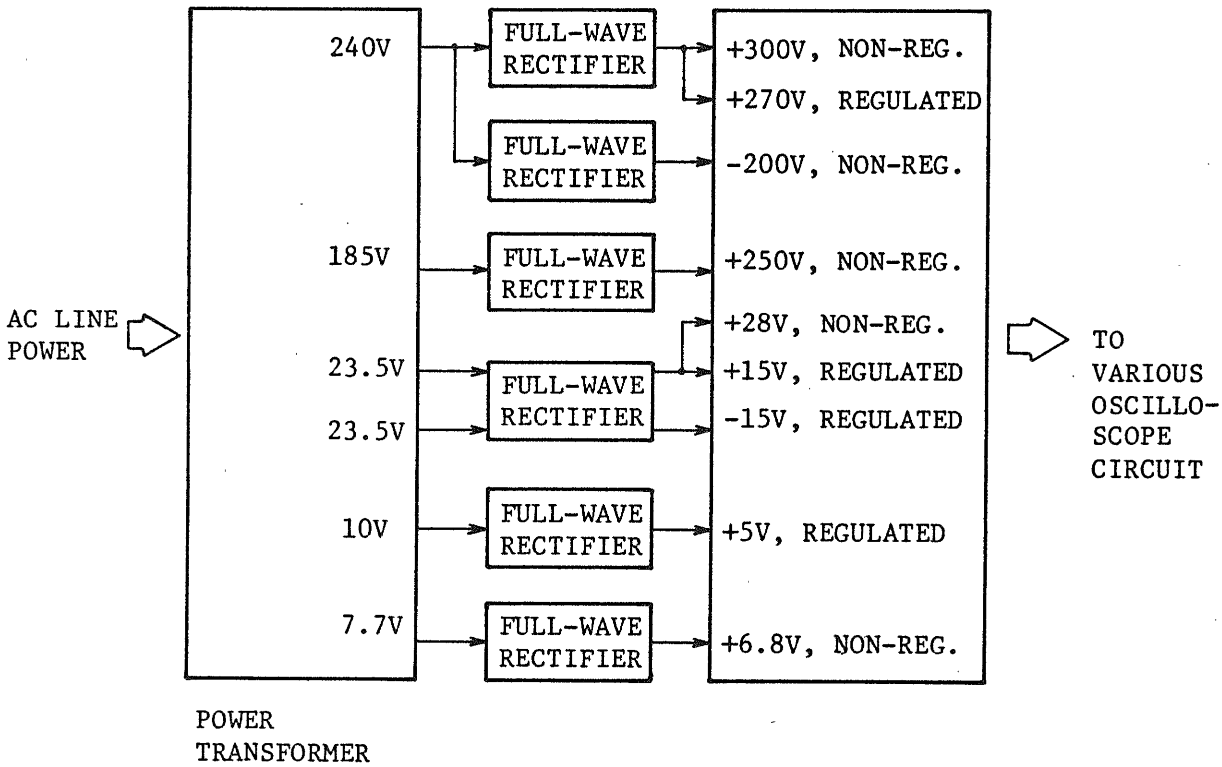



Figure 6-14. A block diagram of the power supply

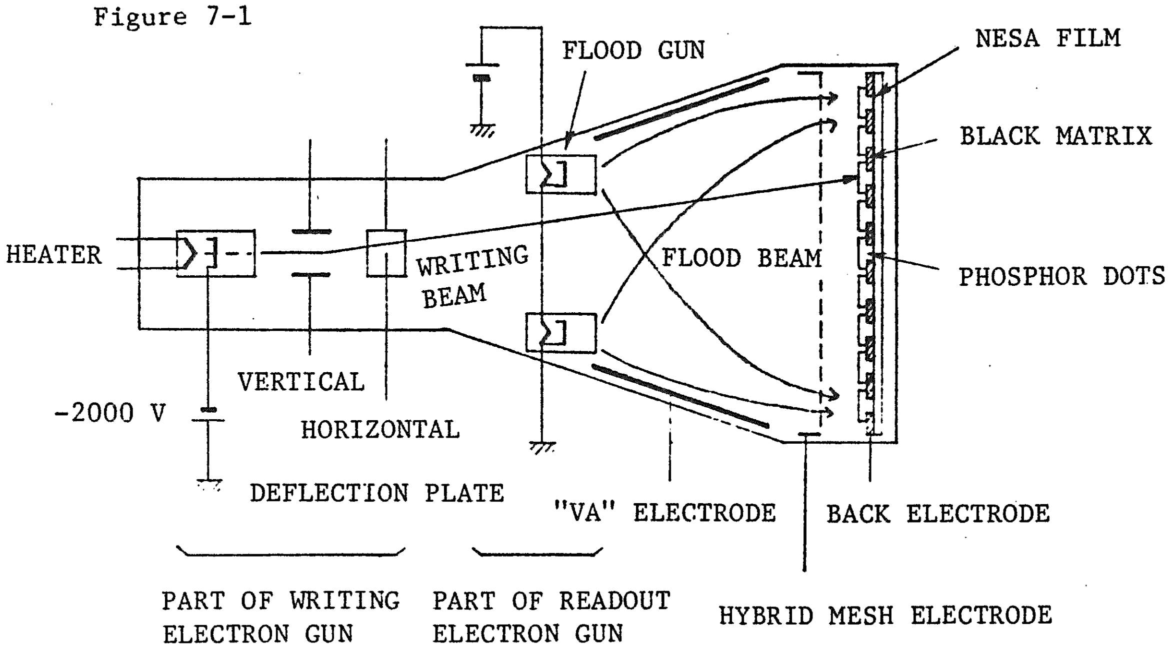
## 6.9 CALIBRATION VOLTAGE GENERATOR

The calibration voltage generator produces a quality square wave signal, with less sag and overshoot, to calibrate the phase characteristics of the probe, etc. The generator employs a TTL multivibrator. The output voltage is divided with resistors to produce a 2 Vp-p signal and a 200 mVp-p signal. The output signal is delivered to the terminal which has a hole for easy connection of the probe.

# 7. STORAGE TUBE

## 7.1 STRUCTURE OF STORAGE TUBE

Figure 7-1




(a) The writing electron gun:

The function of this gun is the same with that of the regular CRT. It produces an electron beam which hits the storage target screen which is composed on Nesa film, black matrix and phosphor dots.

(b) The readout electron gun:

This electron gun (flood gun) is characteristic to the storage tube. It rains out a flood of electrons (flood beam) to overall surface of the storage target so that the stored waveform is maintained in the displayed state.

(c) VA electrode:

Provides a weak electron lens for producing a flood beam which is applied to overall storage surface in the perpendicular direction.

(d) Hybrid mesh:

Has functions of capturing secondary electrons emitted from the storage target surface and repelling positive ions produced in the electron gun side, in order to protect the storage plane.

(e) Storage target:

The storage target is composed of transparent conductive film (Nesa film), black matrix and phosphor dots (insulators). It stores the charged pattern and, when the readout beam is applied, displays the stored pattern. When the oscilloscope is operated as a regular oscilloscope, the storage target operates as a regular fluorescent screen.

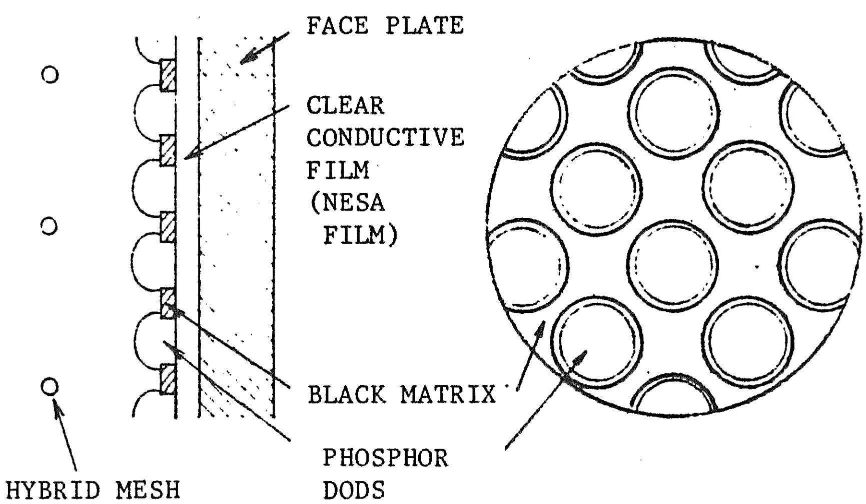



Figure 7-2

7.2 STORAGE PRINCIPLE

When an insulator in an electric field is bombarded with primary electrons, secondary electrons are emitted from the insulator. The rate of emission of secondary electrons depends on the energy of the primary electrons (the strength of the electric field or the acceleration voltage). The storage function is attained making use of the fact that the secondary-electron emission ratio becomes larger than 1 as shown in figure 7-3.

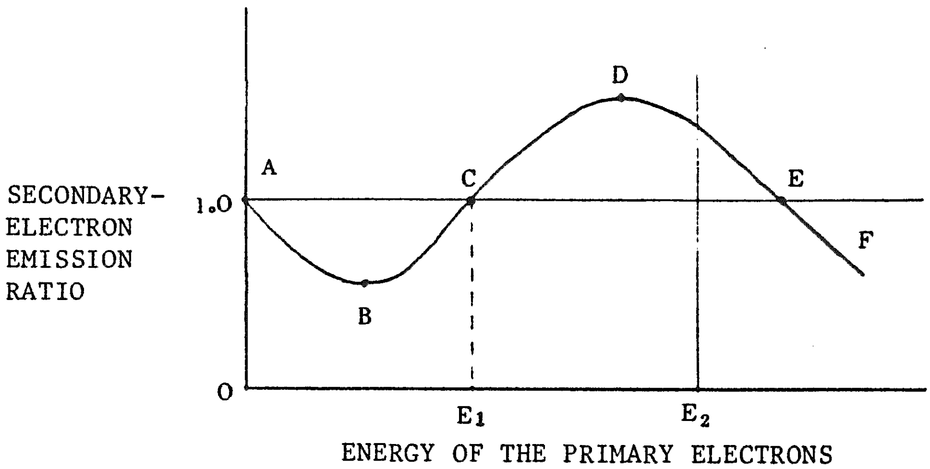



Figure 7-3

As shown in Figure 7-3, as the energy of primary electrons is increased the secondary-electron emission ratio at first is reduced but, as the potential is increased further, the ratio starts increasing and the ratio becomes larger than 1. As the potential is increased still more, the ratio starts decreasing and finally falls below 1. The storage tube of this oscilloscope employs a phosphor material for the insulator. With this material, $E_1$ is 20 - 70 V and $E_2$ is approximately 180 V. The characteristics of an actual storage tube are shown in the illustration.

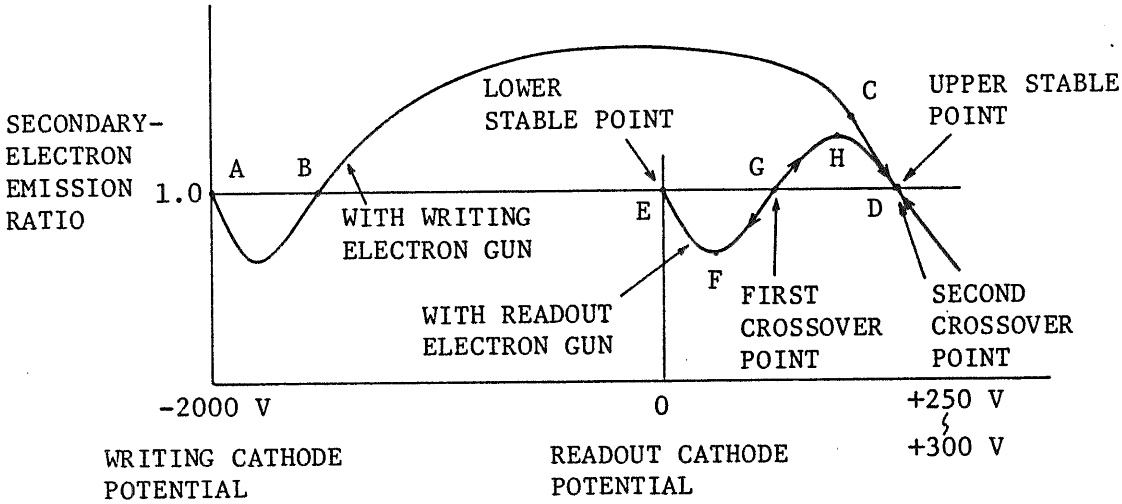



Figure 7-4

In the illustration, point D is the upper stable point and point E is the lower stable point. As the tube has two stable points, this type of tube is called bi-stable storage tube.

Point G moves upward or downward depending on slight change in potential. This point is called unstable point (1st crossover point). (Point D is called also as 2nd crossover point.)

In practice, $E_{STB}$ (back electrode voltage) is varied (0 - 300 V) so that the surface voltage of the phosphor dots are varied along points E - F - G - H - D on the curve.

## 7.3 STORAGE OPERATION

The storage operation of the tube in the due order of actual actions are as follows:

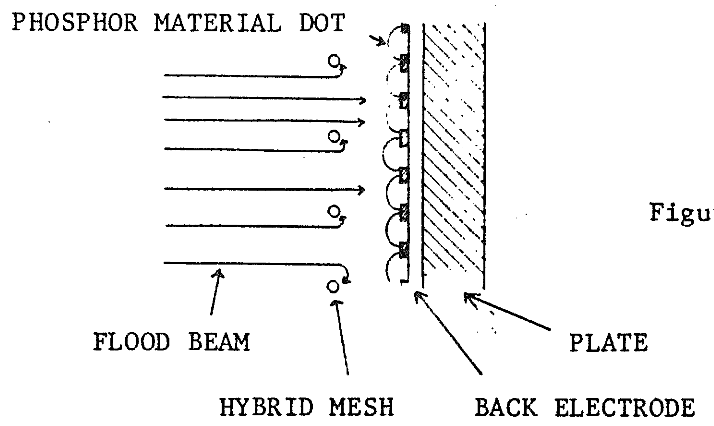



Figure 7-5

(A) Preparation for writing (ready state)

When in this state, $E_{STB}$ which may vary for each tube is applied to the back electrode. To the hybrid mesh electrode, the highest voltage (approximately 300 V) among the internal electrodes of the tube is applied.

As the voltage is applied to the back electrode, the potential of the phosphor dot surface is raised to the same voltage. However, due to the flood beam, it is lowered to the readout gun cathode voltage (0 V).

The above is the state ready for writing. There is a potential difference $E_{STB}$ between back electrode and phosphor dot surface. This differential potential is maintained by the high insulation of the phosphor itself.

(B) Writing

As the writing beam is applied to the storage target in the ready state, the protruding phosphor dots are excited and become luminous and, at the same time, emit secondary electrons. The secondary electrons and the writing beam electrons are absorbed by the back electrode and hybrid mesh electrode. As the high-energy writing beam is applied, the rate of emission of secondary electrons becomes larger than the writing beam. Therefore, the surface potential of phosphor dots shifts toward the back electrode voltage ($E_{STB}$) from 0 V.

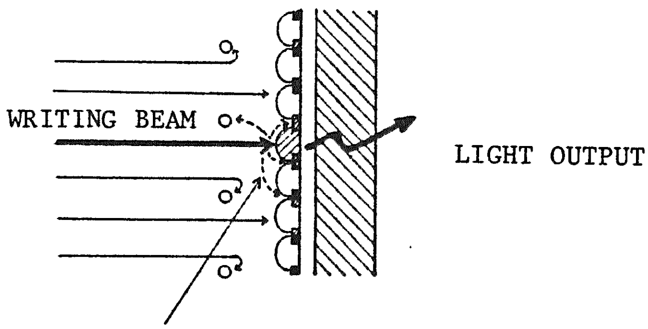
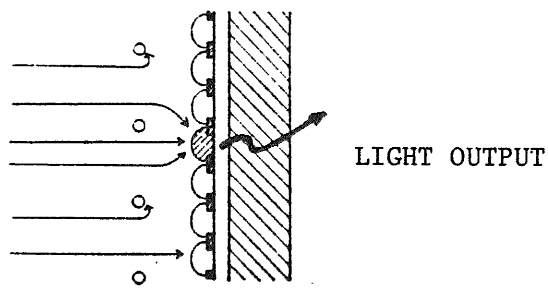



Figure 7-6

(C) Readout (storage)

Once the state of (B) has been established, even if the beam is turned off, the phosphor dots to which the writing beam has been applied remain luminous as their surface voltage remains 180 V so far as the readout beam is applied.




$E_{STB}$= 180 V

Figure 7-7

(D) Erasure

The displayed image can be erased by making the back electrode potential zero volts so that the storage phosphor surface potential also becomes zero volts. For erasure, and erase pulse voltage as illustrated is applied to the back electrode.

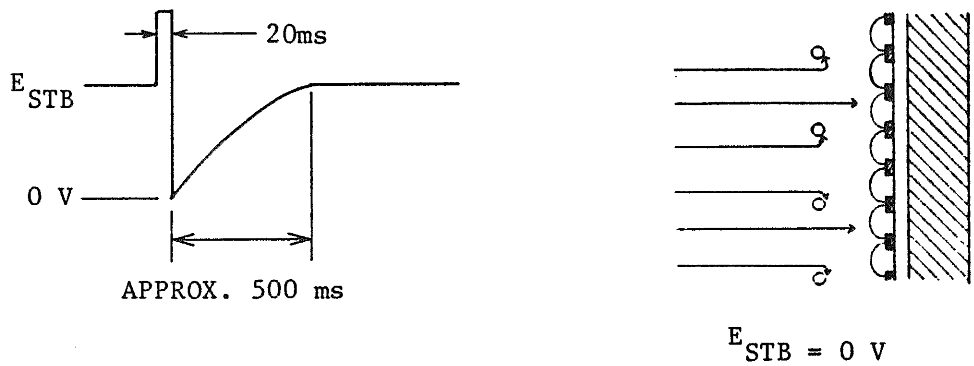



Figure 7-8

## 7.4 GENERAL CHARACTERISTICS

### 7.4.1 HYSTERESIS CHARACTERISTICS

Voltage $E_{STB}$ which is applied to the back electrode is a cardinally important voltage of the storage tube. The relationship between $E_{STB}$ and storage screen intensity is as illustrated.

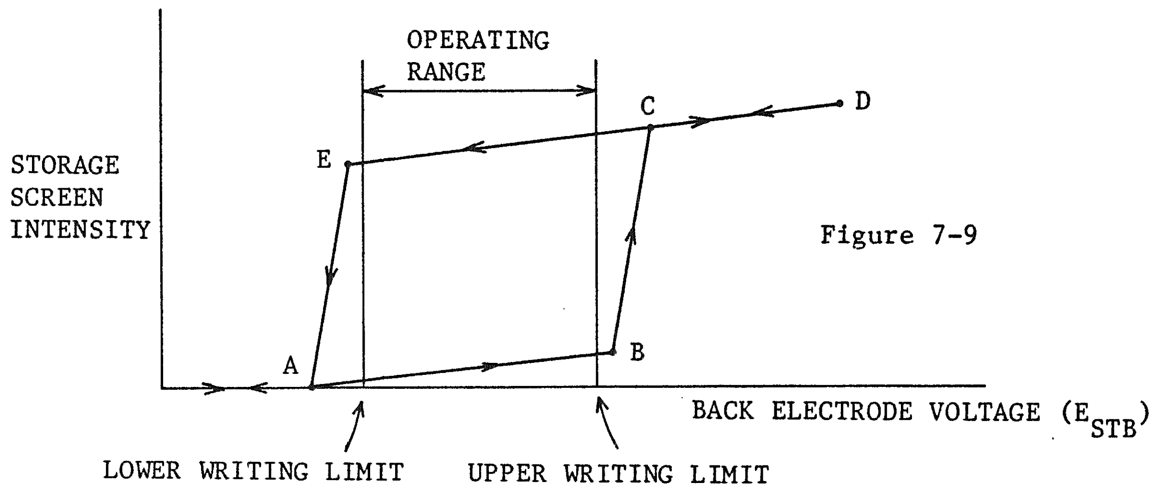



Figure 7-9

Refering to the illustration, a positive potential is applied to the back electrode so that the back electrode voltage ($E_{STB}$) is moved from point 0 to point A. Between 0 and A, no change is caused to the storage tube. (The erase state is maintained and no dots are luminous on the screen.) As the potential is raised in the positive direction, overall screen becomes slightly luminous (only dimly lighted, rather than luminous). This range corresponds to range A - B in the illustration. When a voltage higher than point B is applied, overall screen becomes quite luminous. This is the state of point C. If the voltage is raised still further, brightness of the screen is increased slightly more. Point D denotes the state when a voltage of approximately 300 V is applied.

Now, assume that the voltage is gradually lowered from point D. When point C has been passed, the curve does not return to point B but moves toward point E. Down to point E, the screen becomes darker in proportion to the voltage. When point E has been passed, the screen becomes darker at a high rate and the curve returns to point A.

As mentioned in the illustration, the point a little before point B and that a little before point E are the upper writing limit point and lower writing limit point, respectively. The back electrode voltage is set within this range. The voltage should be set close to the upper writing limit point so that the best resolution is obtained.

### 7.4.2 LIFE TIME AND BACK ELECTRODE VOLTAGE

The back electrode voltage varies as the use time of the oscilloscope increases, as shown with a curve in the illustration.

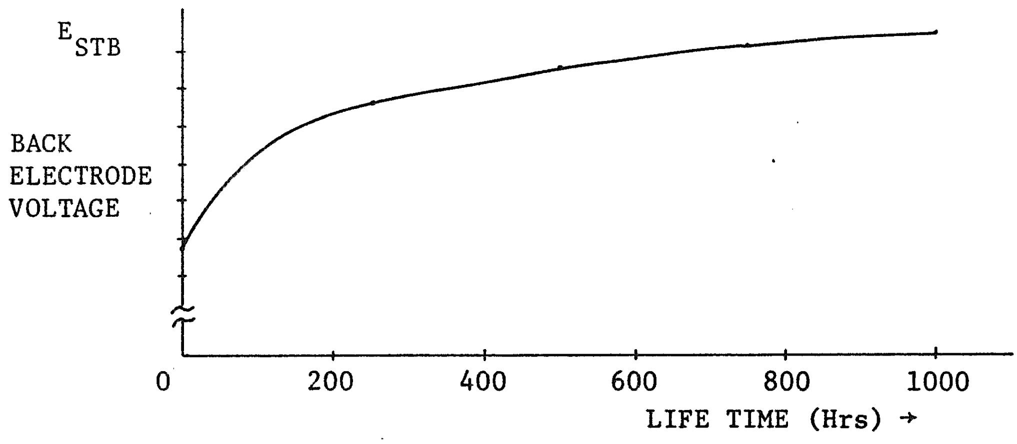



Figure 7-10

From this viewpoint also, it is recommendable to set the back electrode voltage as close to the upper writing limit point as possible.

7.4.3 LIFE TIME AND STORAGE INTENSITY

The storage intensity decreases as the used time of the oscilloscope increases, as a typical curve is shown in the illustration.

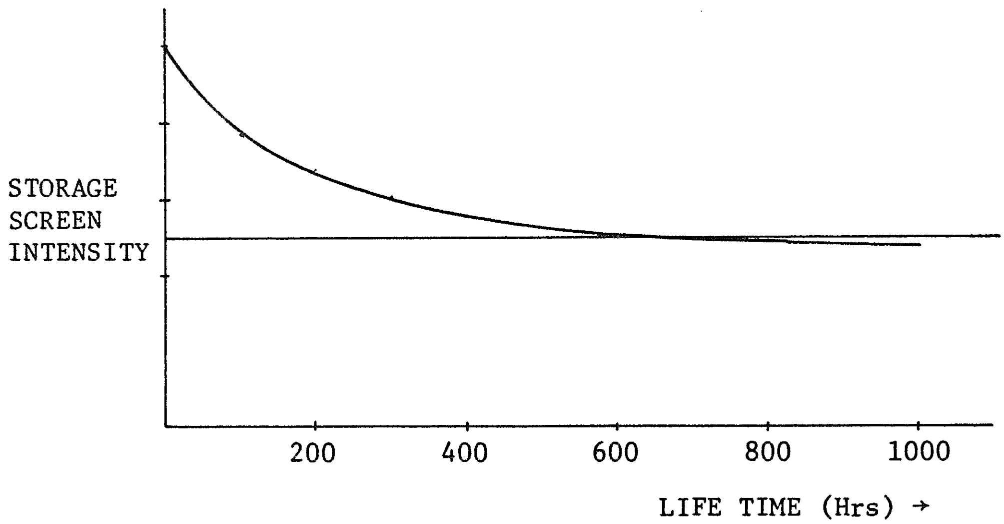



Figure 7-11

### 7.4.4 MAXIMUM WRITING SPEED

Set the CRT in the storage state, apply a one-shot signal as illustrated and check the writing operation. Checking whether the trace at sections intersecting with the X-X' line are stored or not, vary the signal frequency to find the maximum storage limit frequency. The writing speed (Ws) in this case is calculated as follows:

$$Ws = \pi F A \quad [m/sec]$$

where, F: Limit frequency (Hz)
A: Amplitude of sinusoidal wave displayed (m)

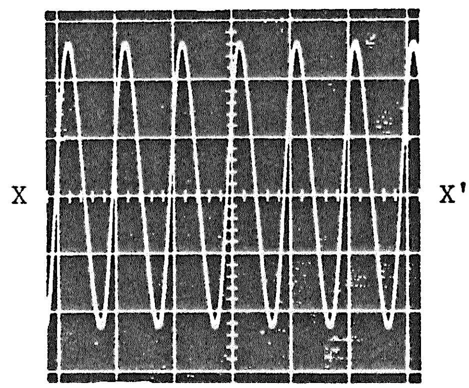



Figure 7-12

### 7.4.5 WRITING SPEED ENHANCEMENT

At a beam speed higher than the writing limit, no image can be stored. This is because, whatever the beam intensity is increased, writing beam runs away before the potential of the storage target surface which is at the lower stable point reaches the 1st cross-over point. However, on the storage target surface, storage of certain degree is done on the storage target surface in proportion to the density of the writing beam.

Making use of the fact, the writing speed can be enhanced. This is done by shifting temporarily the back electrode potential when the operating range of the phosphor dots of the storage target to which the writing beam is applied is at immediately before 1st crossover point.

The surface voltage of the phosphor dots is shifted at the same time, passes through the 1st crossover point, and settles at the upper stable point so that storage is done. Thus a writing speed higher than the regular maximum writing speed can be attained.

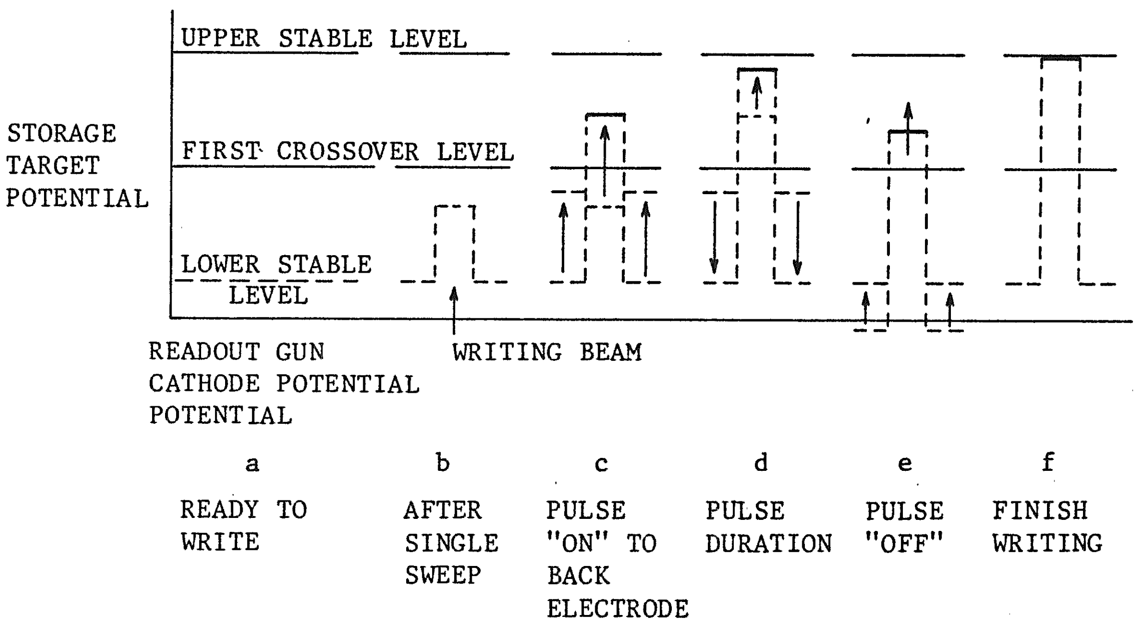



Figure 7-13

a) When in the ready state for writing, the average potential of the storage target surface is slightly higher than the readout gun cathode potential due to partial leak.

b) When in the normal mode of operation, if a single-shot signal whose speed is higher than the writing limit is applied, the surface potential of the storage target surface rises but it does not reach the 1st crossover potential.

c) The storage surface is capacitance-coupled to the back electrode. When an appropriate positive pulse is applied to the back electrode immediately after the above, the potential rise of (b) passes over the 1st crossover voltage.

d) In the pulse duration, the sections of the storage surface which are above and below the 1st crossover point are shifted to the upper and lower stable points, respectively, due to the effect of the readout beam.

e) When the pulse has become off, overall surface becomes negative due to capacitance-coupling. However, the signal input section is at a potential higher than the 1st crossover potential.

f) Due to the effect of the readout beam, the surface assumes writing state.

## 8. CALIBRATION

### 8.1 GENERAL

The oscilloscope should be calibrated on overall items at regular intervals. Abbreviated calibration, stressing on a particular item such as sweep time accuracy or vertical sensitivity accuracy pertient for a particular measurement, may be appropriate. However, when the oscilloscope has been used for approximately 6 months or when a component has been replaced for repair, overall items should be calibrated. Overall calibration is required also when a regulated DC power supply voltage, which affects all circuits, has been adjusted.

A simplified calibration procedure is explained in the following.

### 8.2 CHECK AND CALIBRATION OF DC SUPPLY VOLTAGES

When calibrating the oscilloscope, the DC supply voltages should be checked first of all. For voltage check, use a reliably calibrated digital voltmeter. Voltages and adjustments for the DC supplies are shown in the following table.

| DC supply | Type | Voltage range | Adjustment | Note |
|---|---|---|---|---|
| +5 V | Regulated | +4.75 V to +5.25 V | No adjustment | |
| +15 V | Regulated | +14.9 V to +15.1 V | VR1403 | ⊘ |
| -15 V | Regulated | -14.6 V to -15.4 V | No adjustment | |
| +205 V | Non-regulated | ±20% | - | |
| +300 V | Non-regulated | ±20% | - | |
| +270 V | Regulated | +260 V to +280 V | No adjustment | |
| -1850 V | Regulated | -1845 V to -1855 V | VR1301 | ⊘ |

For voltage check, measure the voltage between each check point and the ground. Each voltage should be checked with an AC line voltage to match the input power selected.

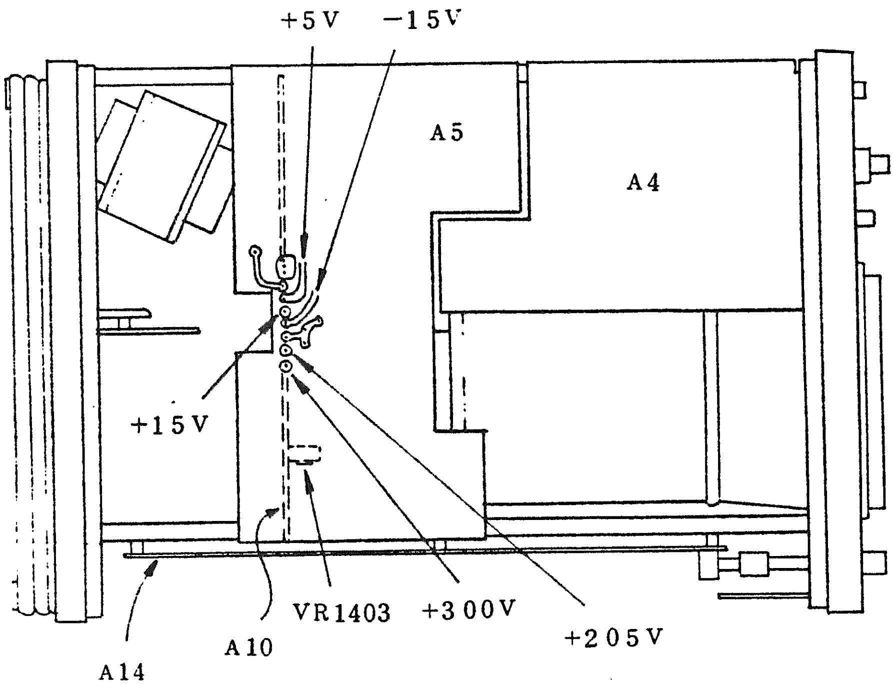



Figure 8-1

The -1850 V supply is for the CRT acceleration voltage. Note that the trace intensity, and vertical and horizontal deflection sensitivities are largely affected if this voltage is varied. Check this voltage between CRT Socket Pin No. 1 and ground.

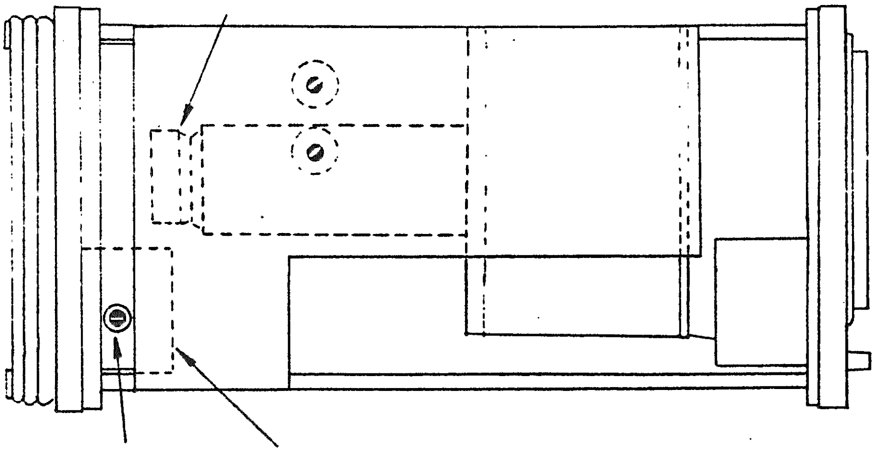



Figure 8-2

Notes: Check and adjust the DC power supply voltages in the following sequence:

1. +5 V supply check
2. +15 V supply adjustment
3. -15 V supply check
4. +205 V check
5. +300 V check
6. +270 V check
7. -1850 V adjustment

For adjusting the -1850 V supply, use a high-input-impedance precision digital voltmeter.

## 8.3 VERTICAL DEFLECTION SENSITIVITY

Apply to the vertical input terminal a signal of 20 mVp-p and 1 kHz, using a square wave generator of an accuracy of 0.5% or better. So adjust the CAL control (VR305 for CH1 or VR405 for CH2) on the front panel that, with the VOLTS/DIV switch set in the 5 mV position, the signal displayed on the screen becomes 4 DIV accurately. For each position of the VOLTS/DIV switch, apply a signal with an amplitude of 4 times of the VOLTS/DIV indicated value, and check the displayed signal amplitude. The normal indication for all ranges is that the displayed value is within ±3% of the indicated value.

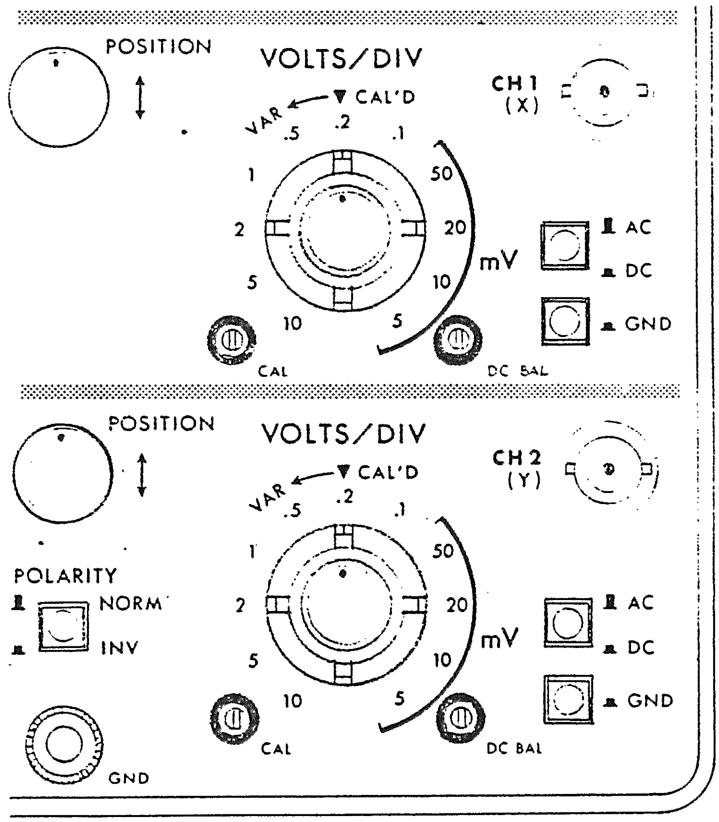



Figure 8-3

## 8.4 INPUT CAPACITANCES AND PHASE COMPENSATIONS OF VOLTS/DIV RANGES

Unless the phase characteristics at each position of the VOLTS/DIV switch are correctly adjusted, the frequency response may be degraded and the displayed waveforms may be distorted. The phase characteristics can be adjusted by varying the input capacitors and high-frequency compensation capacitors. For this adjustment, a capacitance meter for measurement of the input capacitance (35 pF) and a square wave generator which can provide a quality signal of approximately 1 kHz are required. For input capacitance measurement, bridge-type meters are inadequate. Use a low-capacitance C meter. For the 1 kHz square wave signal, the CALIB signal (for probe calibration) of this instrument can be used. When using a square wave generator, use an instrument which provides waveforms with less sags or overshoots and with a rise time of faster than 1 μsec. The trimmer capacitors for this adjustment are shown in the following table.

| VOLTS/DIV switch position | CH1 Trimmer capacitors | | CH2 Trimmer capacitors | |
|---|---|---|---|---|
| | Input capacitor | High frequency compensation capacitor | Input capacitor | High frequency compensation capacitor |
| 5 mV | C114 | - | C214 | - |
| 10 mV | C109 | C108 | C209 | C208 |
| 20 mV | C112 | C111 | C212 | C211 |
| 50 mV | C102 | C103 | C202 | C203 |
| 0.1 V | - | - | - | - |
| 0.2 V | - | - | - | - |
| 0.5 V | C106 | C105 | C206 | C205 |
| 1 V | - | - | - | - |
| 2 V | - | - | - | - |
| 5 V | - | - | - | - |
| 10 V | - | - | - | - |

The "-" mark signifies "no adjustment."

Locations of the trimmer capacitors are shown in the following:

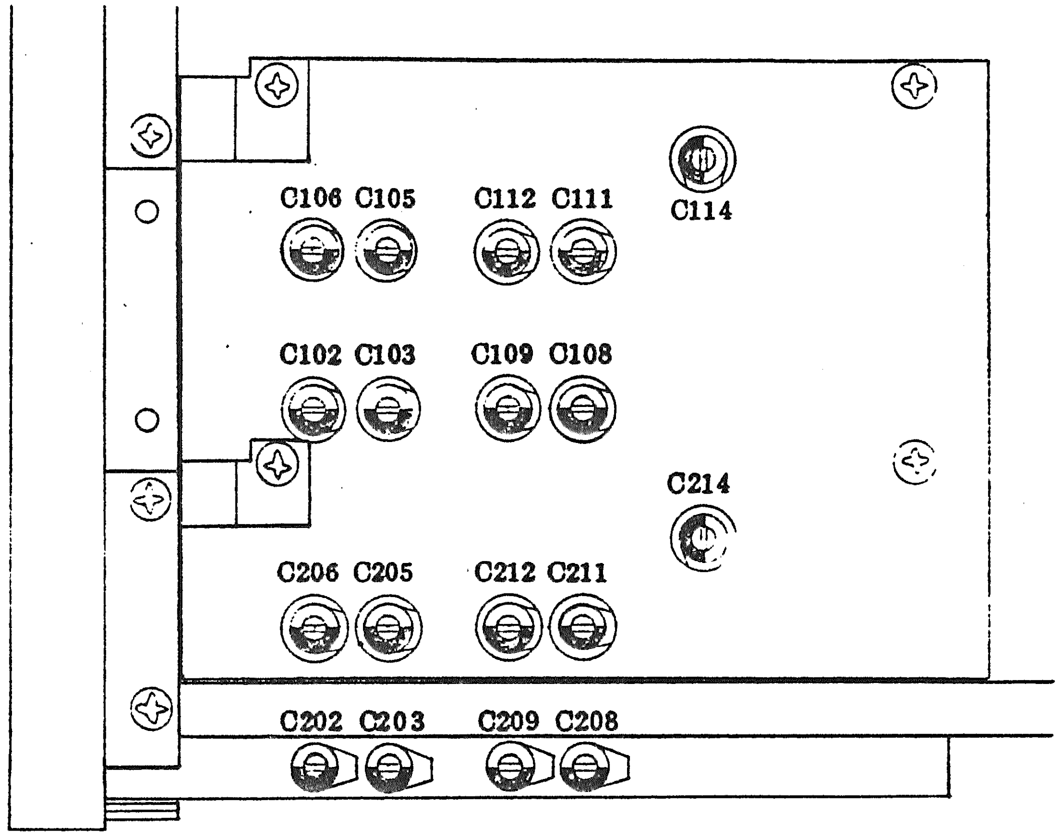



Figure 8-4

## 8.5 SWEEP TIME

Set the TRIGGER MODE switch and TIME/DIV switch as follows and apply to the vertical input terminal an accurate time marker signal of 1 msec or a 1 kHz signal (preferably a square wave).

| | |
|---|---|
| TRIGGER MODE: | AUTO |
| TIME/DIV: | 1 mS |

The sweep time accuracy specification is satisfied if the measured value is within ±3% of the panel indication. The 1 msec/DIV range is used as the reference for other ranges and, therefore this range should be calibrated especially accurately. So adjust the SWEEP CAL ±1 (VR1101) variable resistor that the accuracy becomes better than ±1%. Also, pull up the POSITION knob to the PULL 5 × MAG state and so adjust the MAG ADJ (VR1103) semi-fixed resistor that the accuracy becomes better than ±1%. Locations of the variable resistors are shown in the following illustration.

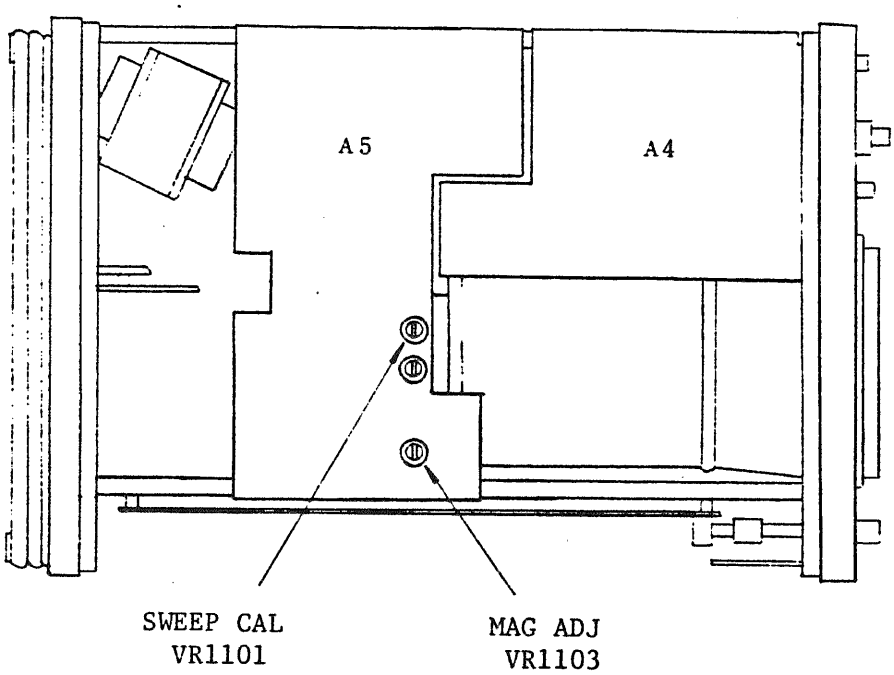



Figure 8-5

## 8.6 CALIBRATION OF PROBE

To calibrate the probe, use the 1 kHz signal of the calibration voltage terminal (200 mVp-p or 2 Vp-p).

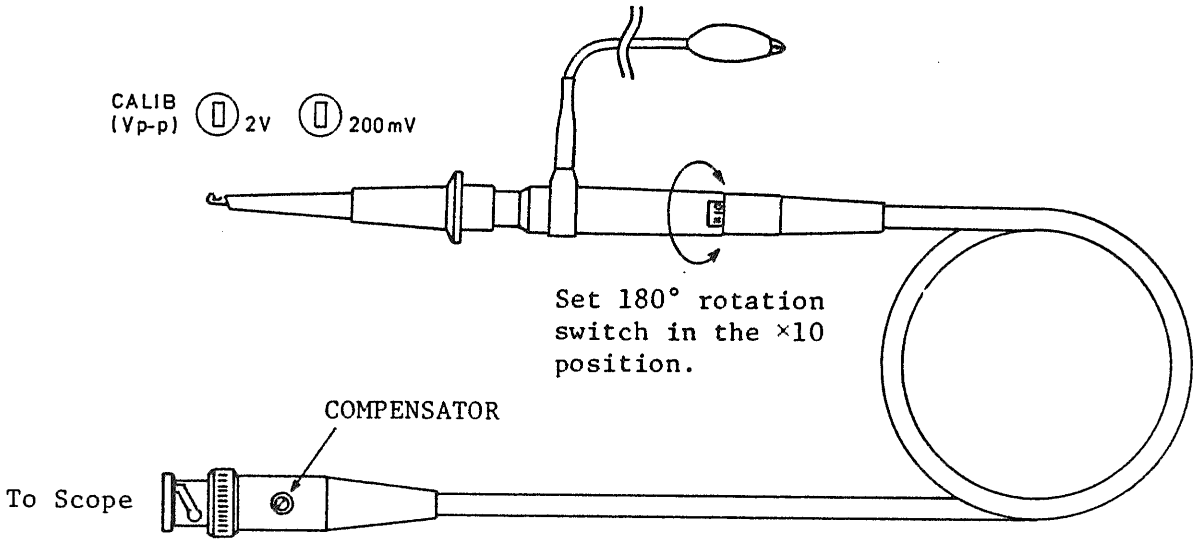



Figure 8-6

Connect the probe to the CH1 or CH2 input terminal and set the range at 50 mV. Touch the 2 Vp-p calibration voltage terminal with the probe tip, and a square wave signal with an amplitude of 4 DIV will be displayed on the screen. So adjust the compensator of the probe with a small screwdriver that a correct waveform is obtained.

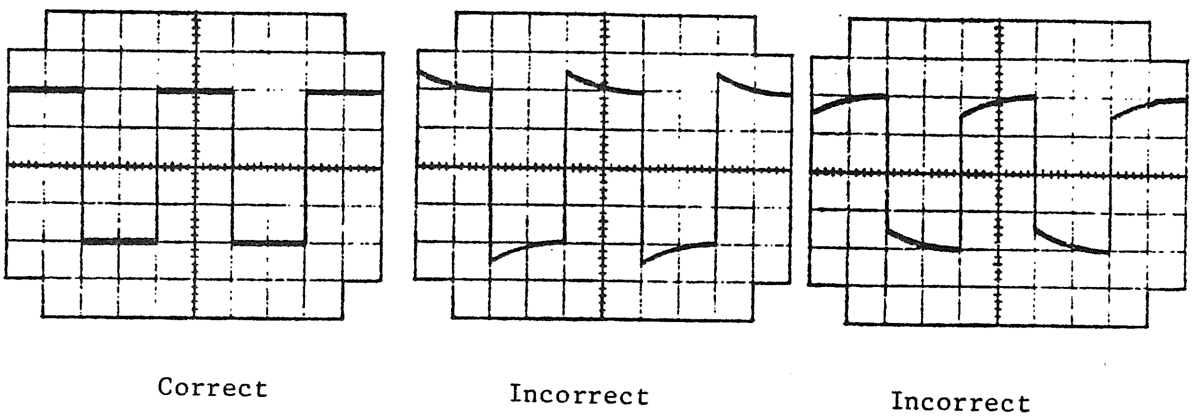



Figure 8-7

## 8.7 ADJUSTMENT OF ASTIGMATISM AND GEOMETRY

ASTIG: So adjust this control, together with the FOCUS control, that the displayed trace or spot becomes sharpest.

GEOMETRY: This control is for correction of barrel and pincushion distortion.

Locations of the controls are shown in the following illustration.

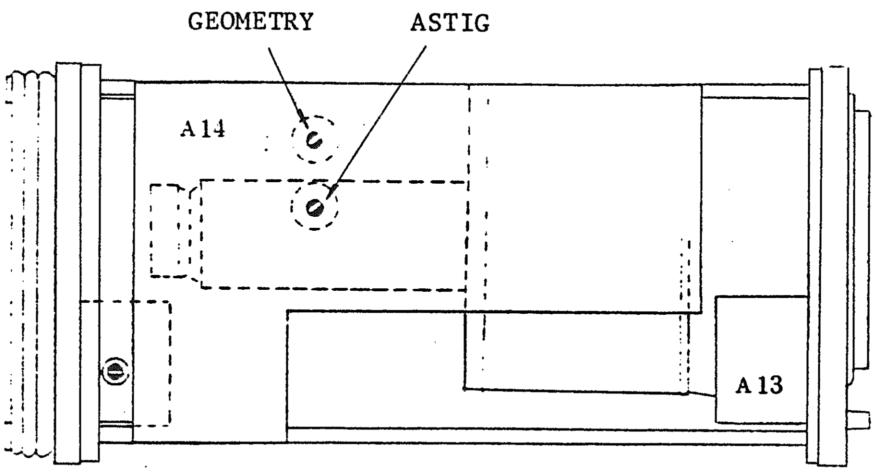



Figure 8-8

## 8.8 ADJUSTMENT OF BACK ELECTRODE VOLTAGE

This adjustment should be done measuring the hysteresis characteristics of Section 6.4.1. First, set the oscilloscope in the storage state and measure the voltage of PIN No. 14 output terminal (to which a yellow wire is connected) of A-14 printed board using a DC voltmeter or a digital voltmeter. (Note: Measurement can be conveniently done by operating the oscilloscope in the AUTO ERASE mode for 2 - 3 seconds interval.) Adjust the writing beam density (intensity) at an optimal value for 1 mS/DIV sweep.

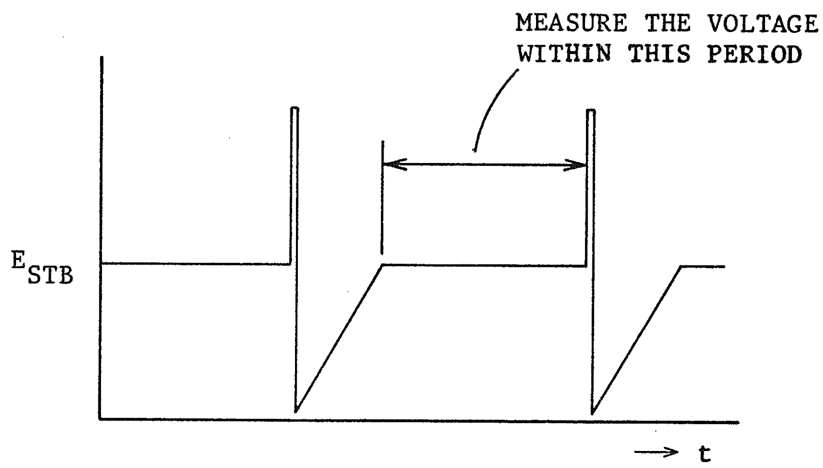



Figure 8-9

Waveform of back electrode voltage when in AUTO ERASE operation

Observing the waveform displayed on the screen, adjust the back electrode voltage setting potentiometer (VR 1605) of A-14 board. As you raise the back electrode voltage ($E_{STB}$), overall screen becomes bright as if traces had been written on entire screen. The voltage immediately before this bright screen is the upper writing limit voltage.

As you lower the back electrode voltage from the value at which the overall screen has become bright, the screen will become dark starting by the center of the screen. The voltage immediately before this darkening point is the lower-limit writing voltage. Determine an optimal back electrode voltage measuring both upper and lower writing limit voltages.

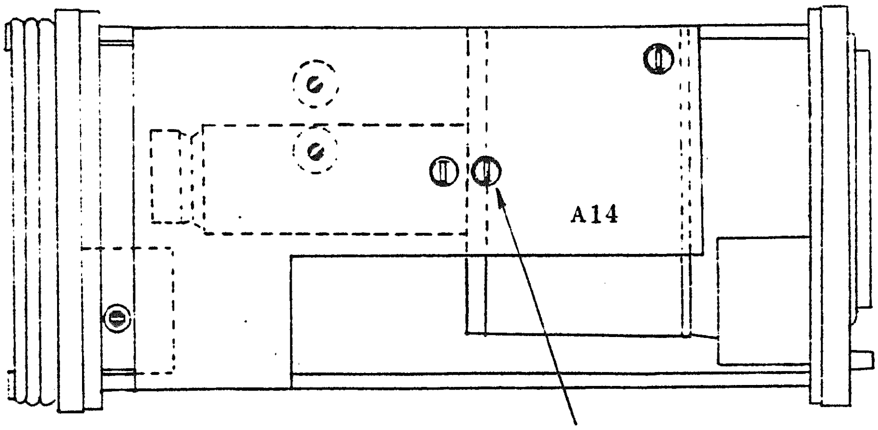



Figure 8-10

An optimal voltage for the back electrode should be selected taking into consideration the contrast between the written section (traces) and the unrecorded section (background) and the life (total used time) of the oscilloscope as explained in Section 6.4.2. Writing can be done so far as the back electrode voltage is between the upper and lower writing limit voltages. From the viewpoint of contrast, a voltage closer to the lower limit writing voltage is advantageous. It is advantageous to set the back electrode voltage at a value close to the upper limit writing voltage for a period of several tens to several hundreds hours and set it in the mid-point or a slightly higher point when the used period has reached several hundreds or thousand hours or over. Only when the contrast is of the prime importance, set the back electrode voltage at a value close to the lower limit writing voltage and adjust the voltage frequently (at every several tens hours).

## 8.9 TIMER

The instrument includes a timer for counting the total time of the use of the oscilloscope in the storage mode. It does not count the time used as a regular oscilloscope. The count up time is 2000 hours. The location of the timer is shown in the following illustration.

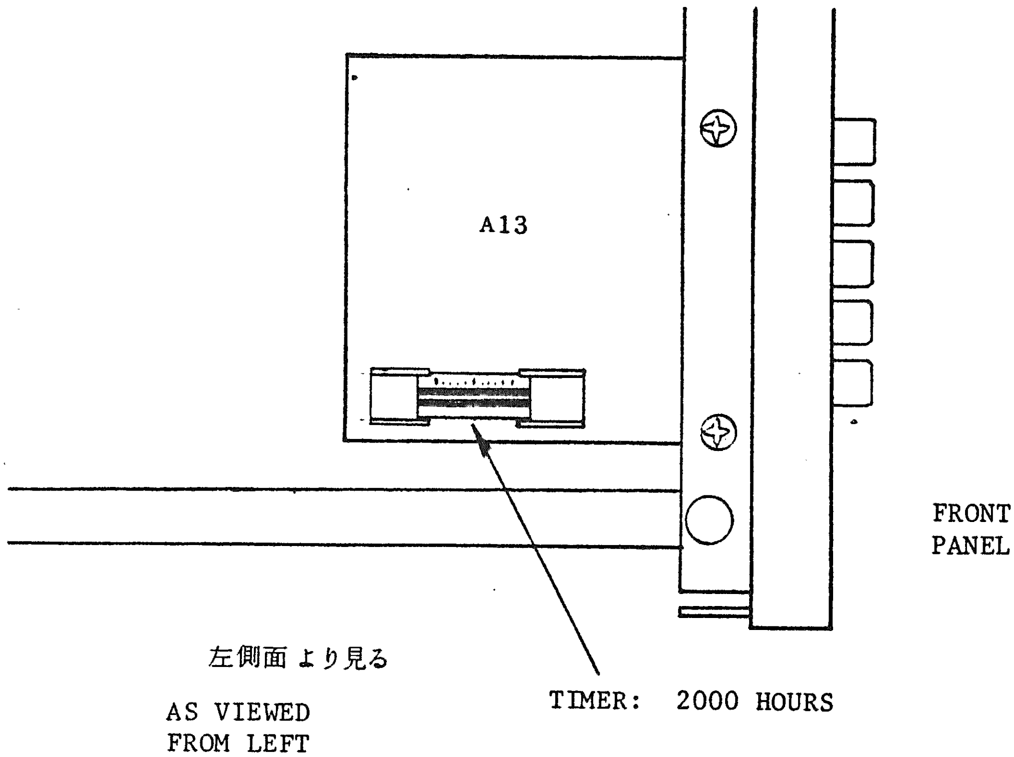
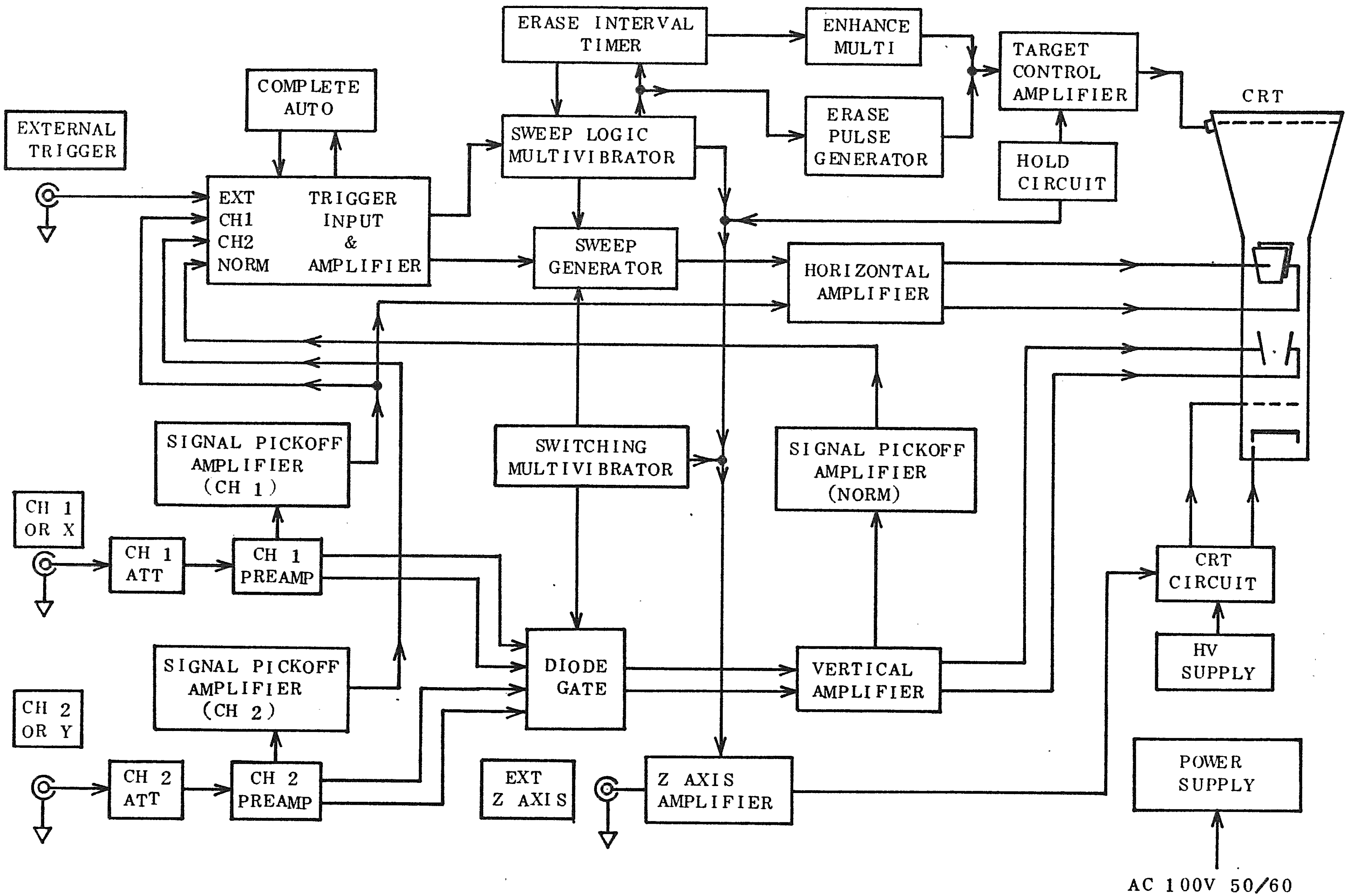



Figure 8-11




BLOCK BLOCK DIAGRAM