INSTRUCTION MANUAL

FOR

MODEL 5521 OSCILLOSCOPE

KIKUSUI ELECTRONICS CORP., JAPAN

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.

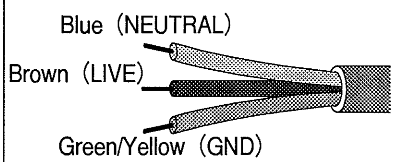
☐ AC power cable

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.

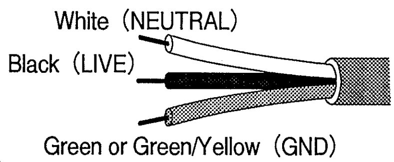
WARNING

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

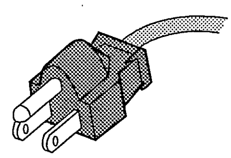
☐ Without a power plug



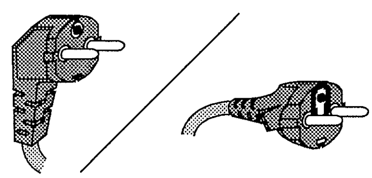
☐ Without a power plug



☐ 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 ______________________________

 Kikusui Part No. Z9-000-027 IB001681 KIKUSUI

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1. GENERAL

The Kikusui Model 5521 Oscilloscope is a portable dual-trace instrument with a 105-mm square screen, rear stage helical accelerated CRT. The 5521 employs a start sweep system.

The vertical system has two channels with a high sensitivity of 5 mV/cm and a wide frequency range of DC to 20 MHz. The sweep time covers a wide range of 0.2 μsec/cm to 0.5 sec/cm and, moreover, a sweep magnifier with a magnification factor of 5 is incorporated to increase the sweep speed to 0.04 μsec/cm maximum. The 5521 employs the start sweep system which ensures stable triggering for all sweep ranges.

Being fabricated with solid state circuits, the 5521 is compact, light-weight, and consumes less wattage. The oscilloscope is highly portable and is best suited for measurement in a limited room space.

COMPOSITION

A set of Kikusui Model 5521 Oscilloscope is composed of the following articles:

Oscilloscope (Main Unit) 1

Accessories

- Probes (955 BNC) 2
- BNC terminal adaptor 1
- Hex wrench (3 mm) 1
- Fuses 2
- Instruction manual 1
- Inspection data 1

2. SPECIFICATIONS

VERTICAL DEFLECTION SYSTEM

Item	Specification	Remarks
Sensitivity	5 mV/cm ~ 10 V/cm, 11 ranges	1 - 2 - 5 step
Sensitivity accuracy	Better than ±3% of nominal value indicated by panel switch, when VARIABLE control is set in CAL'd position.	Sensitivity is calibrated at 5 mV/cm range.
Continuous variation of sensitivity	Continuously variable to 2.5 times of the value indicated by panel switch. Example: Variable up to 2.5 V/cm (non-calibrated) when panel switch is set at 1 V/cm range position.	
Frequency bandwidth	DC coupling: DC to 20 MHz AC coupling: 3 Hz to 20 MHz	Within -3 dB
Rise time	17.5 nsec.	
Pulse wave characteristics	Overshoot: Within 3% Ringing: Within 2% Sag (200 kHz): Within 2% Sag (60 Hz): Within 2%	As measured with DC coupling, amplitude within 4 cm and waveform displayed in screen center.
Signal delay time	Approx. 120 nsec.	
Input impedance	1 MΩ ±2%, 38 pF ±2 pF	Parallel
Input terminal	BNC receptacle	
Maximum allowable input voltage	400 V maximum at 5 mV/cm range. 600 V maximum at other ranges than 5 mV/cm. (At frequencies below 1 kHz)	Voltage is as DC + AC peak. For ACp-p, voltage must not exceed

			400 Vp-p and 600 Vp-p, respectively.
Input coupling systems	AC and DC		
Trace shift caused by DC offset	Within 2 mm at 5 mV/cm range		
Vertical system operation modes	CH 1	CH 1 alone operates independently.	
	CH 2	CH 2 alone operates independently.	
	ALT	Traces of CH 1 and CH 2 are alternately swept.	Switching is made at sweep frequency.
	CHOP	Dual trace of CH 1 and CH 2 are displayed in chopped sweep mode.	
	ADD	CH 2 ± CH 1	
Chopping frequency	150 kHz ±20%		
Polarity	Polarity of CH 1 alone can be inverted.		
Linearity	When a signal with vertical amplitude of 4 cm in the screen center is moved to the upper and lower ends of the effective screen area, variation in amplitude is within ±2 mm.		At frequencies below 100 kHz. Includes the linearity of CRT itself.
Common mode rejection ratio	100 : 1 or higher at 50 kHz		When sensitivities of CH 1 and CH 2 are adjusted mutually identical.
Inter-channel interference	1000 : 1 or less at 100 kHz. 60 : 1 or less at 20 MHz. (For interference at 20 MHz, test is made at 5 mV/cm range and with vertical amplitude of 4 cm.)		Both CH 1 and CH 2 are set at 5 mV/cm range; operation in ALT mode; a signal for full scale ampli-

		tude is applied to one channel, and the input of the other channel is shorted with a 50-ohm resistor.

HORIZONTAL DEFLECTION SYSTEM

Item	Specification	Remarks
Sweep time	0.2 µsec/cm ~ 0.5 sec/cm, 20 ranges	1 - 2 - 5 step
Continuous variation of sweep time	Continuously variable up to 2.5 times of the value indicated by panel switch.	
Variable range	The maximum sweep time is approx. 12.5 sec/cm (uncalibrated).	
Sweep time accuracy	Within ±3% of value indicated by panel switch.	With VARIABLE control set in CAL'D position.
Linearity of sweep	Better than ±3%	
Sweep magnification	5 times	
Magnification accuracy	Add ±2% to sweep time accuracy, excluding 0.2 µsec/cm range for which ±5% must be added.	
Magnification linearity	Add ±2% to sweep linearity, excluding 0.2 µsec/cm range for which ±5% must be added.	Excluding 60 nsec both at start and end of sweep.
Magnification shift	Within 5 mm in CRT center.	

TRIGGER CIRCUIT

Item	Specification	Remarks
Trigger signal source	NORM: Triggered with signal being displayed on screen. CH 2 ONLY: Triggered with CH 2 signal only. EXT: Triggered with external signal.	
Coupling	AC, HF REF, and LF REJ	
Polarity	"+" and "-"	
Internal trigger sensitivity AC	50 Hz ~ 10 MHz 3 mm ~ 20 MHz 6 mm 5 Hz ~ 6 mm	Amplitude on CRT screen
HF REJ	50 Hz ~ 50 kHz 3 mm	
LF REJ	30 kHz ~ 8 MHz 3 mm ~ 20 MHz 6 mm	
External trigger sensitivity AC HF REJ LF REJ	50 Hz ~ 20 MHz ... 100 mVp-p 50 Hz ~ 50 kHz ... 100 mVp-p 30 kHz ~ 20 MHz .. 100 mVp-p	
Trigger level adjustment range	EXT trigger: 4 Vp-p, 1 kHz sine wave	
AUTO	Specified trigger sensitivity is satisfied with a signal higher than 50 Hz.	

External trigger input impedance	Approx. 100 kΩ, with parallel capacitance not larger than 30 pF	
Maximum allowable input voltage	400 V (DC + AC peak)	Below 1 kHz for AC
Input terminal	BNC receptacle	

EXTERNAL SWEEP AMPLIFIER

Item	Specification	Remarks
Deflection sensitivity	20 mV/cm or over. Continuously adjustable to approx. 1/100 with HOR GAIN control.	When set in 5X MAG state, sensitivity does~~n't~~ change.
Frequency bandwidth	DC ~ 500 kHz (When sensitivity is max.)	Within -3 dB
Waveform distortion	Non-distortion operation range is 10 cm (effective full horizontal range) with the spot placed in the center of the CRT screen.	
Input impedance	110 kΩ ±5%, with parallel capacitance not larger than 50 pF	
Maximum allowable input voltage	400 V (DC + AC peak)	Below 1 kHz for AC
Input terminal	BNC receptacle	

CALIBRATION VOLTAGE

Item	Specification	Remarks
Waveform	Square wave	
Polarity	Positive-going, reference level 0 V (zero volts)	
Output voltage	20 mVp-p, 5 Vp-p	Two outputs
Output voltage accuracy	Better than ±3%	
Frequency	1 kHz, ±20%	
Duty cycle	Within a range of 48% to 52%	
Rise time	Approx. 1 μsec.	
Output terminal	Panel jack	

CRT

Item	Specification	Remarks
Type	Rectangular screen	
Fluorescent material	P31	
Acceleration voltage	Approx. 3550 V	Total voltage
Effective screen area	6 cm (vertical) x 10 cm (horizontal)	

Luster distortion	Not higher than 3%	
Alignment of trace with graticule	Adjustable with a rotator.	
Unblanking system	Deflection unblanking system	
Graticule illumination	Continuously variable	

POWER REQUIREMENTS

Item	Specification	Remarks
Voltage	____V ±10%	The internal regulated power supply normally operates with these ranges.
Frequency	50 Hz ~ 60 Hz	
Wattage	Approx. 56 VA	

AMBIENT TEMPERATURE

Item	Specification	Remarks
Maximum operatable temperature range	0°C to +40°C	
Range to satisfy specifications	+15°C to +35°C	

DIMENSIONS AND WEIGHT

Item	Specification	Remarks
Dimensions	290 mm wide, 200 mm high, 440 mm deep	Maximum dimensions
	237 mm wide, 184 mm high, 382 mm deep	Housing only
Weight	Approx. 9.8 kg	Main unit only

ACCESSORIES

Item	Q'ty
955 BNC low-capacitance probes	2
BNC terminal adaptor	1
Power cord (approx. 2 meters)	1
1 A time-lag fuse	1
Wrench, hex rod, 3 mm	1
Instruction manual	1
Inspection data	1

3. OPERATION PROCEDURE

3.1 EXPLANATION OF PANELS

This chapter explains switches, controls, and terminals of the front and rear panels. Of a double-knob switch or control, the grey knob corresponds to black figures and the red knob to red figures.

INTEN: Control for trace brightness. The trace becomes brighter as this control is turned clockwise.

FOCUS: For focussing of the spot or trace displayed on the CRT screen (hereafter referred to simply as screen). This control may be used in combination with the ASTIG control (semi-fixed resistor) located on the rear panel.

ILLUM: Control for graticule illumination. The illumination increases as this control is turned clockwise.

POWER ON: Main power switch. As this switch is thrown to the upper position, the power of the oscilloscope is turned on and the power pilot lamp lights.

CALIB: To obtain square wave reference signal for sensitivity calibration. The signal is a positive-going pulse wave (square wave) with a frequency of approx. 1 kHz and two voltages of 20 mVp-p and 5 Vp-p. The output is available at the panel jack terminal.

VERTICAL DEFLECTION SYSTEM (CH 1)

Explanation is made for CH 1 only, because CH 2 is identical with CH 1 and the same explanation is immediately applicable to CH 2 also.

INPUT: Vertical input terminal with a BNC receptacle. An input signal is connected to this terminal directly or through a probe.

AC-DC-GND: Selector switch of input coupling mode.

- AC: AC-coupling. The DC component is blocked and the AC component alone is measured.
- DC: DC-coupling. Both AC and DC components are measured.
- GND: The input signal is isolated and the input terminal of vertical amplifier is grounded. Used to check instantaneously the ground potential as displayed on the screen.

VOLTS/CM: (grey knob) Selects the vertical deflection sensitivity in 11 steps for total range of 5 mV/cm to 10 V/cm. Scale values represent input voltage for 1 cm deflection on the screen with the VARIABLE knob set in the CAL'D position (extremely clockwise position).

VAR: (red knob) Continuously variable vertical deflection sensitivity attenuator, up to approx. 1/2.5 at the fully counter-clockwise position, to cover the span between any two adjoining ranges of VOLTS/CM switch.

POSITION: Vertical positioning of the trace or spot. Clockwise knob rotation is for upward trace movement, and vice versa.

DC BAL: Semi-fixed resistor for DC balance adjustment. Unless DC balance is correctly obtained, the displayed trace will be vertically shifted when the VARIABLE control is turned. Once DC balance is correctly adjusted, the adjusted state is scarcely altered although it may be slightly affected by ambient temperature variation.

GAIN CAL: Semi-fixed resistor for vertical deflection sensitivity calibration. This control should be so adjusted that the trace is deflected by 1 cm on the screen when an input voltage indicated by the VOLTS/CM switch is applied. The switch is correctly adjusted at the factory before shipment.

GND: Terminal for grounding of panels and chassis.

CH 1 INV: Demi-switch for switching of CH 1 signal polarity. The pushed state is for normal polarity and the pulled state for reverse polarity.

(CH 2): The functions of switches, controls, and terminals of CH 2 are identical with those of CH 1, excluding the CH 1 INV switch.

MODE: Selects modes of CH 1 and CH 2 as below.

CH 1: The oscilloscope operates as a single-trace instrument with CH 1 alone.

CH 2: The oscilloscope operates as a single-trace instrument with CH 2 alone.

ALT: The oscilloscope operates as a dual-trace instrument, with CH 1 and CH 2 alternately swept (switched at the end of each sweep of the other channel). When sweep speed is below a certain limit (2 msec/cm or below), two phenomena cannot be simultaneously displayed. This mode is suitable for observation of phenomena of high repetition frequencies.

CHOP: CH 1 and CH 2 are chopped at a frequency of 150 kHz to display two traces on the screen. Since the two traces are electronically switched, waveforms cannot be well observed at high sweep speeds (10 μsec/cm and higher). This mode is suitable for observation of low frequency phenomena.

ADD: Algebraic sum or difference of CH 1 and CH 2 is displayed on the screen. Switching between sum and difference can be made with the CH 1 INV switch.

HORIZONTAL DEFLECTION SYSTEM

POSITION: (grey knob) For horizontal positioning of the trace or spot.

PULL 5X MAG: Common knob with the POSITION control knob. When this knob is pulled, the trace is magnified by 5 times in the horizontal direction.

EXT HOR IN: BNC receptacle terminal for external sweep input of horizontal axis.

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

TIME/CM: (grey knob) Selects the sweep time. Scale values represent the time for 1 cm of horizontal sweep, with the VARIABLE knob set in the CAL'D position (extremely clockwise position).

VAR: (red knob) For continuous variation of sweep time. The TIME/CM switch indication is calibrated for the state this knob is turned to the CAL'D position.

EXT: When the TIME/CM switch is turned to the extremely counterclockwise position, the horizontal circuit stops producing a sweep time signal and starts operating as a horizontal amplifier to amplify the external signal applied through the EXT HOR IN terminal.

VAR: The VAR control in the above state is used to vary continuously the sensitivity of the horizontal amplifier. The sensitivity is highest (1/100)when the control is turned to the fully clockwise position.

TRIGGER SYSTEM

LEVEL: Determines the trigger start point on the trigger signal waveform.

PUSH AUTO: When this switch is in the pushed state, the time axis generator operates in the auto sweep mode. The trace is displayed on the screen without any input signal being applied. When the input signal is 50 Hz or higher, the sweep is triggered with it.

When this switch is in the pulled state, the time axis operates in the triggered sweep mode. When no input signal is being applied, the sweep circuit is in the stand-by state and no sweep is displayed on the screen. At the instant the input signal is applied, the sweep starts.

SLOPE ±: Selects the triggering slope of the trigger signal waveform. The "+" position is for triggering with a positive-going slope and the "-" position is for triggering with a negative-going slope.

COUPLE: Selects coupling mode of trigger signal as below.

AC: The DC component of trigger signal is blocked and the AC component alone is passed to the trigger circuit. Triggering can hardly be made with a signal lower than 50 Hz.

HF REJ: This mode is suitable for triggering with a waveform which includes high-frequency noise and for observation of two signals in the CHOP mode. Triggering can hardly be made with a signal higher than approx. 50 kHz.

LF REJ: The low frequency component is blocked. This mode is suitable for triggering with the high frequency component alone. Triggering can hardly be made with a signal lower than approx. 30 kHz.

SOURCE: Selects the trigger signal as below.

NORM: The signal being displayed on the screen is used as the trigger signal.

CH 2 ONLY: The signal being applied to CH 2 alone is used as the trigger signal.

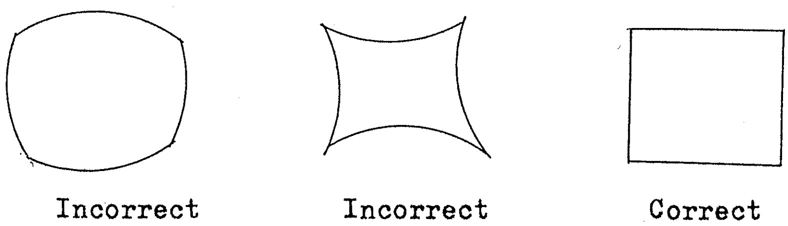
EXT: The external signal being applied through the EXT TRIG IN terminal is used as the trigger signal.

3.2 EXPLANATION OF REAR PANEL

The astigmatism, geometry, preset rotator, and rotation controls (semi-fixed resistors), and power fuse and power connector are mounted on the rear panel. These articles are indicated with respective identification plates.

ASTIG: This control (semi-fixed resistor), in conjunction with the FOCUS control of the front panel, is used to obtain sharp focus of the spot or trace displayed on the screen.

GEOMETRY: This control (semi-fixed resistor) is used to eliminate distortions of lusters displayed on the rectangular area on the screen.



PRESET ROTATOR: This control (semi-fixed resistor) is used to align the horizontal base line with the graticule scale. This control should be adjusted with the ROTATION control set in the mid-position of its adjusting range.

ROTATION: This control (semi-fixed resistor) is used to align the horizontal base line with the graticule scale. Actually, this control is primarily used for alignment. If alignment with this control alone is unsuccessful, the PRESET ROTATOR also will be used.

FUSE: A fuse holder which houses a 1-ampere time-lag fuse. The cap can be removed by turning it counterclockwise, to replace the fuse.

3.3 PRECAUTIONS

(a) Line Voltage

The oscilloscope normally operates with a line voltage of ____V ±10%. If a line voltage exceeding this range is applied, the oscilloscope may be damaged. If the line voltage is not within this range, adjust it to within this range employing an appropriate device.

(b) Ambient Temperature

The oscilloscope satisfactorily operates in an ambient temperature of 0°C to +40°C. To satisfy the specified performance accuracy, the ambient temperature must be +15°C to +35°C.

(c) Allowable Voltages of Input Terminals

The allowable maximum input voltages of the input terminals and probe are as shown below. Note that the input circuit may be damaged if a voltage higher than the specified maximum is applied.

Input terminals of CH 1 and CH 2:	400 V (DC + AC peak) when VOLTS/CM switch is set in 5 mV/cm position. 600 V (DC + AC peak) when VOLTS/CM switch is set in other position than 5 mV/cm.
Accessory probe (955 BNC):	600 V (DC + AC peak)
EXT HOR IN terminal:	400 V (DC + AC peak)
EXT TRIG IN terminal:	400 V (DC + AC peak)

Repetition frequency: Not higher than 1 kHz

(d) Spot Intensity

Do not make the spot intensity too high or leave the spot stationary for a long period lest the CRT fluorescent screen should be burned.

3.4 OPERATING PROCEDURE

Before turning on the power switch, set the controls of the front panel as below.

INTEN:		Fully clockwise position
FOCUS:		Mid-position
MODE:		CH 1
TRIGGERING	PUSH AUTO:	Pushed state
	SLOPE:	+
	COUPLE:	AC
	SOURCE:	NORM

Connect the power cord to an AC power outlet (100 V), and turn on the power switch. A bright trace should appear on the screen in approximately 15 seconds. Turn clockwise the INTEN knob to obtain adequate trace brightness.

Focus Adjustment:

Move the trace to the screen center by adjusting the vertical and horizontal POSITION controls. Obtain the sharpest image by adjusting the FOCUS and ASTIG controls. The ASTIG control (semi-fixed resistor) is mounted on the rear panel and is correctly adjusted at the factory before shipment.

Signal Application and Displaying:

Apply the calibration voltage of the oscilloscope to the VERT CH 1 input terminal using the BNC terminal adaptor (supplied as an accessory) and wires as short as possible, and display the calibration voltage (square wave) on the screen. A square wave with a vertical amplitude of 4 cm should be observed on the screen when the controls are set as below.

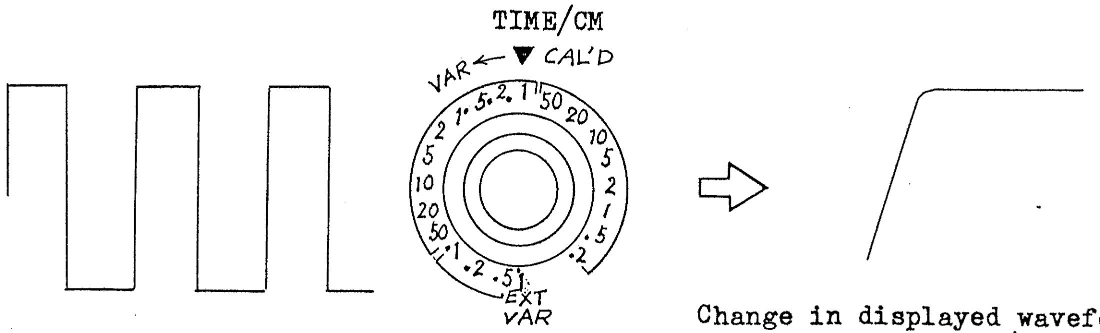
AC-DC-GND (CH 1):	DC
VOLTS/CM (CH 1):	5 mV
VARIABLE (CH 1):	CAL'D
CALIB:	20 mVp-p terminal
TIME/CM:	0.5 mS
VARIABLE:	Mid-position
TRIGGERING LEVEL:	Mid-position

As the VOLTS/CM switch is turned counterclockwise step by step, the vertical amplitude will decrease stepwise. As the VARIABLE control is turned counterclockwise, the amplitude will continuously decrease. These will show you the relationship of the VOLTS/CM switch and VARIABLE control with respect to the input signal level and the displayed waveform amplitude.

Time Axis and Triggering:

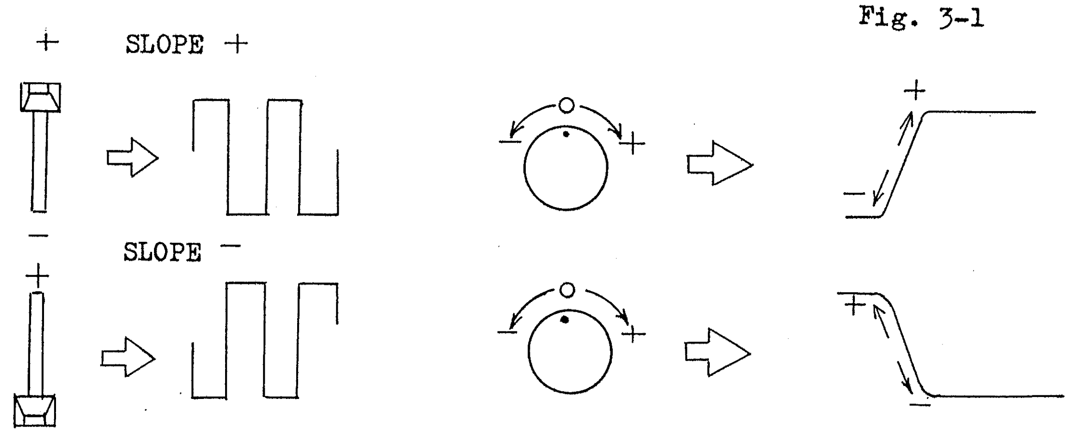
Since the repetition frequency of the calibration signal is approximately 1 kHz, one repetition cycle of signal is displayed with a horizontal length of approximately 2 cm when the TIME/CM switch is set in the 0.5 mS position. As the TIME/CM switch is turned clockwise, the sweep time (sweep speed) increases. The sweep time is continuously variable with the VARIABLE control. Thus, a certain expanded section of the calibration signal can be observed. As the

TIME/CM switch is turned clockwise further, the rise edge of a pulse cycle will be expanded and displayed as shown in Fig. 3. Change the SLOPE switch to the "+" and "-" position and turn the LEVEL control, and check that the triggering point varies as shown in Fig. 3-2. This will show you that the sweep start point on the rising or falling edge of the square wave is adjustable as desired by turning the LEVEL control.



Change in displayed waveform in response to TIME/CM switch turning.

Fig. 3-1



Change in displayed waveform in response to SLOPE switch change

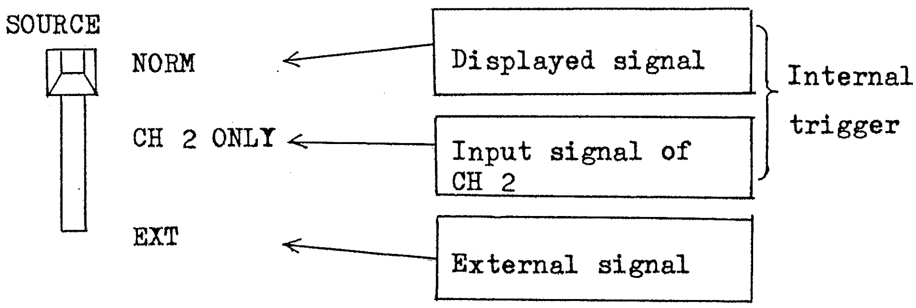
Change in triggering point on waveform in response to LEVEL control turning

Fig. 3-2

<u>Types of Trigger Signal Sources</u>:

To observe a stationary waveform on the screen, the input signal (observed signal) or an external signal which has a certain periodical correlation with respect to the input signal must be applied to the trigger circuit of the time axis circuit. The former method is referred to as internal trigger and the latter as external trigger. For internal triggering, the TRIGGERING SOURCE switch is set in the NORM position (for triggering with the input signal to be observed on the screen) or in the CH 2 ONLY position (for triggering with the input signal of the CH 2 input terminal) so that either input signal is applied within the oscilloscope to the trigger circuit. For external triggering, the TRIGGERING SOURCE switch is set in the EXT position and the input signal itself or another signal which has a periodical correlation with the input signal is applied externally to the trigger circuit.

Selection of trigger signal source
with SOURCE switch



Internal Trigger (NORM and CH 2 ONLY)

For internal trigger mode of operation, the input signal is applied from a certain point of the vertical amplifier to the trigger circuit internally within the oscilloscope. When the SOURCE switch is set in the NORM position, the signal being displayed on the screen is used as the trigger signal; when the switch is set in the CH 2 ONLY position, the CH 2 input signal is used as the trigger signal. Since even a low level input signal is internally amplified to an appropriate level for triggering, the operating procedure is very simple.

External Trigger (EXT)

With the external trigger mode of operation, the triggering circuit can be operated independent from the vertical amplifier circuit. With the internal trigger, the voltage applied to the trigger circuit may vary as the VOLTS/CM switch or the vertical POSITION control is turned and, therefore, the TRIGGER LEVEL control is required to be adjusted accordingly. With the external trigger, on the other hand, triggering is unaffected by setting of switches and controls of the vertical amplifier circuit and remains stable so far as the external trigger signal itself is not varied. However, it should be noted that the external trigger signal must not be higher than 4 Vp-p because adjustment of the triggering point with the LEVEL control becomes ineffective if the external trigger voltage is higher than this level.

Functions of LEVEL Control:

As described in Paragraph 3.4, such a state that triggering is obtained simply by adjusting the LEVEL control is obtained. As the LEVEL control is gradually turned, triggering is effected and the displayed waveform becomes stationary when the LEVEL control is turned to its mid-position. Next, turn counterclockwise the VOLTS/CM switch of CH 1 so that the amplitude of the displayed waveform is made 5 mm. Depending upon setting of the LEVEL control, triggering may become ineffective and the sweep may run in the AUTO mode. In such a case, correct triggering can be restored by slightly turning the LEVEL control clockwise or counterclockwise.

The above explanation is for the pushed state of the LEVEL control. Under this state of setting, the time axis generator circuit automatically oscillates and the trace is swept in the AUTO mode when the value selected by the LEVEL control has exceeded the triggering point or when no trigger signal is applied. However, the sweep driven under the AUTO mode cannot successfully display an input signal which is below 50 Hz. For such signal, proceed as below.

Pull out the LEVEL control to change from the AUTO mode to the trigger mode. As is the case with the AUTO mode, triggering can be effected by turning the level control. If the TRIGGERING COUPLE switch is set in the AC position, triggering can be successfully made with such a low frequency as 5 Hz. However, the sweep operation will stop and the trace will disappear from the screen when no trigger signal is applied or when the point selected by the LEVEL control has exceeded the trigger point.

Sweep Magnification:

The input signal can be displayed in an enlarged waveform by using a fast sweep time (sweep speed). When a fast sweep time is used, however, the section required to be observed may move out of the screen if the section is at a delayed point from the start of the sweep. In such a case, the PULL 5X MAG switch may be pulled out so that the displayed waveform is expanded by a factor of 5 to both rightward and leftward with the screen center as the reference point of expansion. Thus, the horizontal POSITION control knob has two functions of horizontal positioning and sweep magnification by a factor of 5.

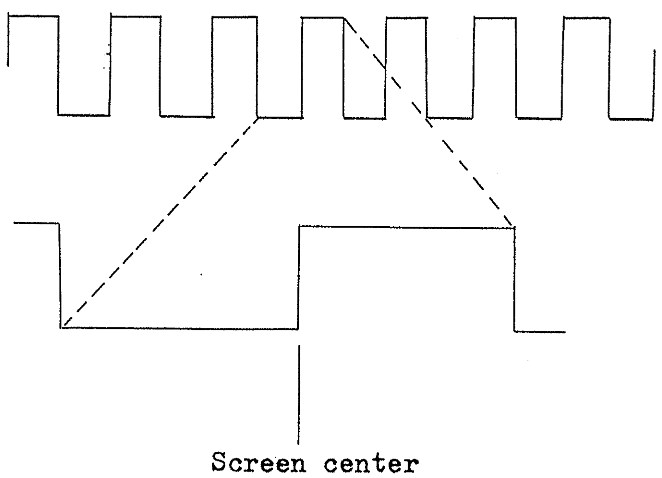


Fig. 3-4

When the PULL 5X MAG switch is pulled, the sweep time is reduced by a factor of 1/5 or the sweep speed is increased by a factor of 5. Therefore, the maximum sweep time (0.2 μsec/cm) of the oscilloscope is reduced by a factor of 1/5 or the maximum sweep speed is increased by a factor of 5 as below when the sweep magnification operation is employed.

0.2 μsec/cm x 1/5 = 0.04 μsec/cm

However, when the input signal is measured in the magnified sweep mode, the trace intensity will be reduced and there is a chance of forgetting to multiply by a factor of 1/5 the value indicated by the TIME/CM switch. Sweep magnification is not recommendable excluding the following cases:

(1) A portion of the waveform delayed from the start point is required to be observed.

(2) A sweep speed faster than 0.2 μsec/cm is required.

DUAL-TRACE OPERATION (ALT), AND "ADD OR SUBTRACTION" OPERATIONS

Dual-Trace Operation:

Turn the MODE selector switch to the ALT position. A horizontal sweep line should be displayed on the screen because the calibration signal is applied to CH 1 and no signal is applied to CH 2 as described in the operating procedure up to the preceding paragraph. The triggering operation is being made in the NORM mode or the signal to be displayed on the screen is used as the trigger signal. As the MODE switch is turned to the NORM position, the trigger signal ceases to be a continuously repetitive 1-kHz square wave and becomes a repetitive signal which returns to zero for each cycle.

Now, apply the calibration voltage simultaneously to CH 1 and CH 2. Two square waveforms should be displayed on the screen. Move the CH 1 waveform to the upper half of the screen and the CH 2 waveform to the lower half by turning the POSITION controls. Since the trigger is in the NORM mode, the signal to be displayed is used as the trigger signal. Thus, the trigger signal will be as shown in Fig. 3-5 and the triggering operation will be unstable.

Displayed waveform

Triggering waveform when TRIGGER SOURCE switch is set in NORM position.

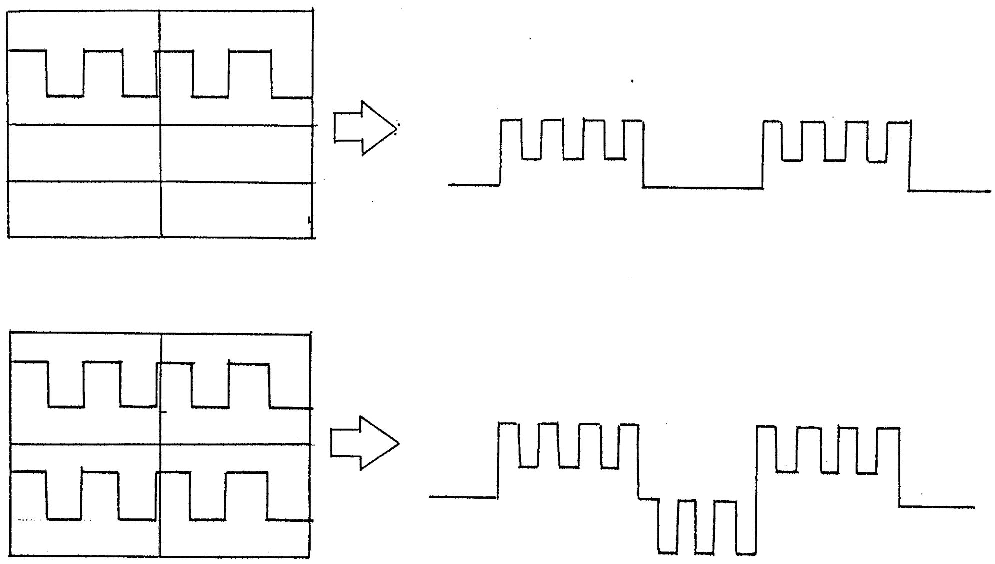


Fig. 3-5

By turning the TRIGGERING SOURCE switch to the CH 2 ONLY position under the above state, a stable triggering can be obtained as it is not affected by the state of the signal to be displayed on the screen. For the dual-trace operation, therefore, the TRIGGERING SOURCE switch is, as a general rule, set in the CH 2 ONLY position so that the signal of CH 2 alone is used as the trigger signal.

Next, turn counterclockwise the TIME/CM switch to reduce the sweep speed. With the ALT mode of operation in which CH 1 and CH 2 are alternately swept, the two waveforms cannot be simultaneously displayed on the screen.

To observe two low frequency signals simultaneously on the screen in the dual trace mode, turn the mode switch to the CHOP position. In the CHOP mode, however, on the contrary to the ALT mode, traces will be displayed as dotted lines at high sweep speeds. The TRIGGERING SOURCE switch for the CHOP mode of operation should be set in the CH 2 ONLY position as is the case for the ALT mode. If triggering is unstable, turn the COUPLE switch to the HF REJ position.

As described in the above, the ALT mode for observation of high frequencies and the CHOP mode for observation of low frequencies in the dual-trace display operation will be used and, thus, signals for overall ranges of TIME/CM switch can be displayed in the dual-trace mode.

Add or Subtract Operation:

To measure the sum or difference of the two input signals of CH 1 and CH 2, set the MODE switch in the ADD position. Selection between addition and subtraction can be made by pressing the PUSH INV button. When the PUSH INV switch is indicated with the red mark, the polarity of the CH 1 signal is inverted by 180° and the amplitude of the signal displayed on the screen represents the difference between the two input signals, or (- CH 1) + CH 2. When the PUSH INV switch is pressed once more, the amplitude of the displayed signal represents the sum of the two input signals, or CH 1 + CH 2.

X-Y Scope Operation:

To operate the oscilloscope as an X-Y scope, set the TIME/CM switch in the EXT position and the MODE switch in the CH 1 position. Apply the calibration voltage to the CH 1 input terminal and EXT HOR IN terminal. Adjust the displayed waveform to an appropriate amplitude with the VARIABLE control of TIME/CM and the VOLTS/CM switch of CH 1. When this is done, two spots will be displayed at diagonal positions. These spots represent a Lissajous' figure of frequency ratio 1:1 and phase difference zero degrees.

4. MEASUREMENTS

4.1 CONNECTION OF INPUT SIGNAL

The input impedance of the input terminal of the oscilloscope is 1 MΩ with 38 pF in parallel and that of the accessory probe (955 BNC) is 10 MΩ with 14 pF or less in parallel. The signal may be applied to the input terminal of the oscilloscope in various methods, including the use of ordinary jacketed wires, shielded cable, probe, or coaxial cable. A suitable method should be used taking the following conditions into consideration.

(a) Output impedance of input signal source.

(b) Voltage and frequency of input signal.

(c) External induction noise.

(d) Distance between input signal source and oscilloscope.

Connection methods will be classified by types of input signals as shown in Table 4-1.

Table 4-1

Type of input signal \ Connection method			Jacketed wire	Shielded cable	Probe	Coaxial cable	Others
Low freq.	Low imp.	Near	o	o	o	o	
		Far		o		o	
	High imp.	Near		o	o		
		Far		o			
High freq.	Low imp.	Near			o	o	
		Far				o	
	High imp.	Near			o		
		Far					

Input with Jacketed Wires:

Connect the BNC terminal adaptor (supplied as an accessory) to the vertical input terminal of the oscilloscope, and connect the jacketed wires to the adaptor. This method is advantageous in that the procedure is simple and the signal is less attenuated. It is disadvantageous in that, when the wires are long and the output impedance of the signal source is high, external induction noise is apt to be introduced and signal observation is disturbed. Also, the stray capacity with respect to ground is large and the measured surface is subjected to larger affect as compared with the case the accessory probe of 10:1 attenuation is used.

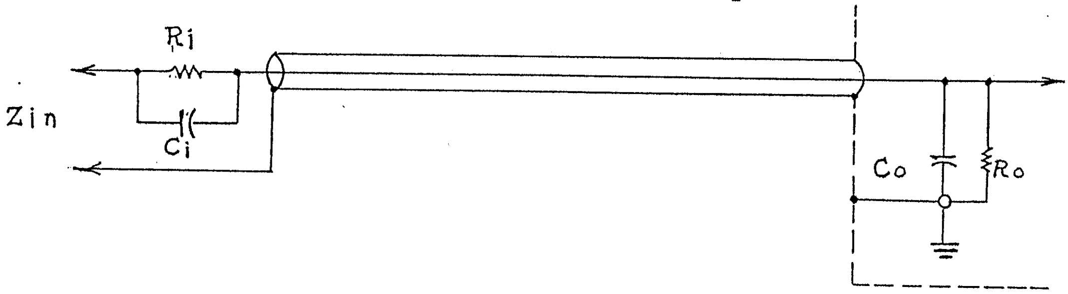
Input with Shielded Cable:

External induction noise can be eliminated by using a shielded cable. However, the shielded cable has as large distribution capacity as 50 - 100 pF/meter and is not suitable when the output impedance of the signal source is large or when the signal frequency is high.

Input with Probe:

The accessory probe of 10:1 attenuation has a shielded lead wire and provides a wide-band attenuator with attenuation resistor Ri and parallel capacitor Ci as shown in Fig. 4-1. The use of the probe is advantageous when the output impedance of the input signal source is large or the signal frequency is high.

Input impedance when the probe is used



Oscilloscope

$$Z_{in} = \frac{R}{2\pi fCR + 1} \qquad R = Ri + Ro \qquad C = \frac{C_i \times C_o}{C_i + C_o}$$

$$Cp = \frac{Co \times Ro}{Rp} \qquad (C_o \text{ includes cable capacitance.})$$

Input with Coaxial Cable:

When the output impedance of the input signal source is 50 or 75 ohms, a coaxial cable of the matching impedance may be used so that signals up to a high frequency can be transmitted with less attenuation. For impedance matching, the input side of the oscilloscope should be terminated with a 50 or 75 ohm resistor as shown in Fig. 4-2.

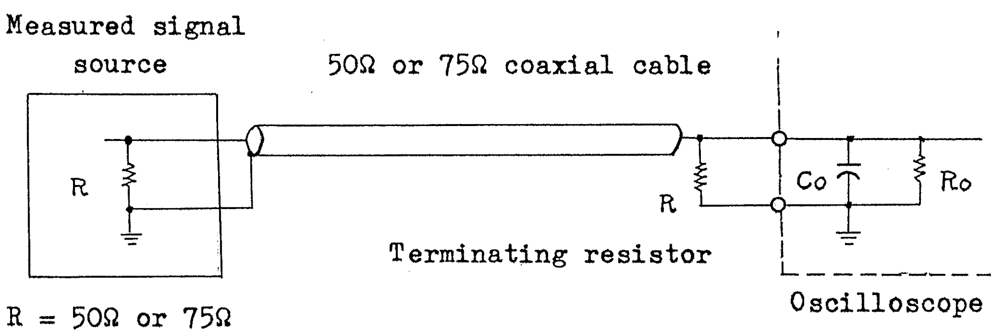


Fig. 4-2

4.2 VOLTAGE MEASUREMENT

DC Voltage Measurement:

Set the time axis switch in the PUSH AUTO state, and set the TIME/CM switch at approximately 1 msec/cm and display the trace on the screen. Next, set the AC-DC-GND switch in the GND position. When this is done, the trace moves to the position corresponding to zero volts of the input signal. Move the trace to a position convenient for measurement, by turning the POSITION control. Then, turn the AC-DC-GND switch to the DC state, apply the voltage of the measured point to the vertical input terminal, and read the resultant vertical displacement of the trace on the graticule.

If the trace is deflected out of the screen when the measured signal is applied to the input terminal, turn counterclockwise the VOLTS/CM switch to a position where the vertical displacement of the trace is convenient for measurement.

If the trace is deflected upward, the polarity of the measured signal is positive; if it is deflected downward, the polarity is negative. The above measurement must be made with the VARIABLE control of VOLTS/CM turned to the CAL'D position (extremely clockwise position).

The voltage of the measured signal can be known from the reading (cm) on the graticule and equations (4-1) and (4-2) below.

When 10:1 probe is used:

Voltage (V) = (Value indicated by VOLTS/CM)
x (Deflection amplitude, cm) x 10 .... (4-1)

When signal is directly applied to input terminal:

Voltage (V) = (Value indicated by VOLTS/CM)
x (Deflection amplitude, cm) .... (4-2)

<u>AC Voltage Measurement</u>:

If the AC-DC-GND switch is set in the DC state for observation of a signal which has an AC component superimposed on a DC component as shown in Fig. 4-3, the AC component may run out of the screen and cannot be measured provided that the DC component is quite large as compared with the AC component. The AC component may possibly be brought back into the screen area by turning the vertical POSITION control. However, measurement under such state should be avoided because it will involve large errors. The AC component also may possibly be brought back into the screen area by turning the VOLTS/CM switch to a position for a reduced amplitude. This state also will make measurement inaccurate because the AC component is reduced to a very small amplitude as displayed on the screen.

For accurate measurement of an AC voltage superimposed on a DC voltage, the AC-DC-GND switch should be set in the AC state. When this is done, the DC voltage of the signal is blocked and the AC voltage alone is amplified and displayed with a sufficiently large amplitude for accurate measurement. The VARIABLE control should be set in the CAL'D position for quantitative measurement of the signal.

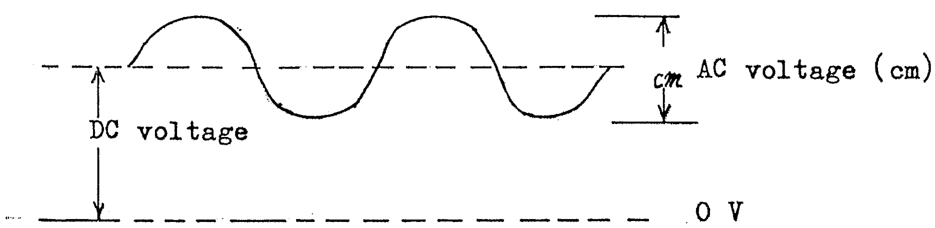


Fig. 4-3

The voltage of the measured signal can be known from the read amplitude (cm) and equations (4-1) and (4-2). (When the AC coupling is employed, the amplitude attenuates by -3 dB at approximately 3 kHz.) The voltage obtained by calculating with equation (4-1) or (4-2) is peak-to-peak value. The voltage can be converted into the rms value by using equation (4-3).

$$\text{Voltage (V rms)} = \frac{\text{Voltage (V p-p)}}{2\sqrt{2}} \quad \text{..............} \quad (4\text{-}3)$$

4.3 TIME MEASUREMENT

Time Interval Measurement:

The time interval (period) between two points on a waveform can be directly read on the graticule referring to the value indicated by the TIME/CM switch provided that the VARIABLE control is set in the CAL'D position. For this measurement, operate the trigger circuit in the PUSH AUTO mode and turn the TIME/CM switch to a position where the two measured points are placed in an appropriate distance for measurement on the screen as shown in Fig. 4-4. The time interval can be calculated using equation 4-4.

$$\text{Time } T \text{ (sec)} = \text{TIME/CM (sec)} \times \text{Distance on graticule (cm)} \times \text{Reciprocal of magnification factor} \quad \ldots\ldots (4\text{-}4)$$

The reciprocal of the magnification factor is unit (1) when the sweep magnification operation is not employed and it is 1/5 or 0.2 when the sweep magnification operation is employed.

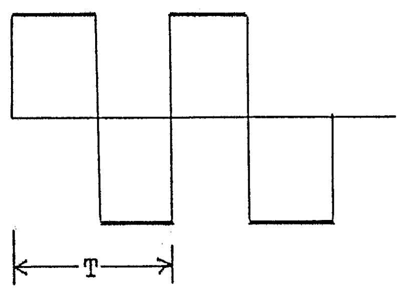


Fig. 4-4

Pulsewidth Measurement:

Display the measured pulse signal with a vertical amplitude of 2 cm or 4 cm symmetrically from the vertical center of the graticule. Turn the VARIABLE control of TIME/CM to the CAL'D position. Turn the TIME/CM switch to a position where the pulse signal is displayed with an appropriate horizontal amplitude for measurement. Determine on the graticule the distance (T) between the two mid-position of the rise and fall edges of the pulse as shown in Fig. 4-5. The pulsewidth now can be calculated by using equation (4-4). When the pulsewidth is the narrow, make use of the 5X MAG sweep magnification operation.

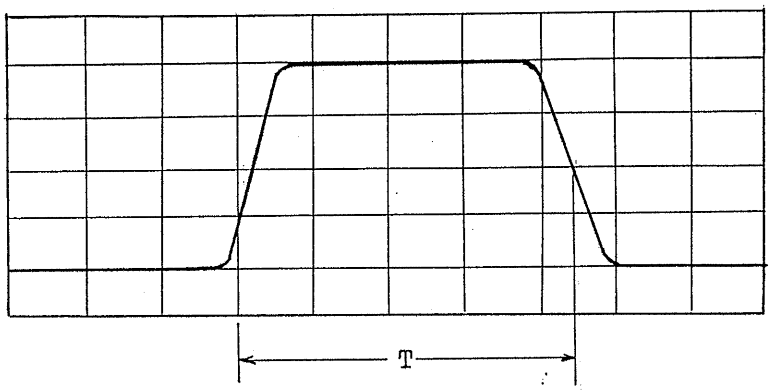


Fig. 4-5

<u>Measurement of Pulse Rise or Fall Time</u>:

Operate the oscilloscope in the same manner as for pulsewidth measurement. Determine the value of T and calculated the rise or fall time employing equation (4-4). When the rise or fall time of the pulse is sufficiently small as compared with the rise time of the oscilloscope itself (17.5 nsec), the value can be directly read. When the rise or fall time is quite fast, the value must be compensated for by using equation (4-5).

$$T_u = \sqrt{T^2 - T_o^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4\text{-}5)$$

T_o: Rise time of oscilloscope (17.5 nsec)

T^2: Measured value

T_u: True value

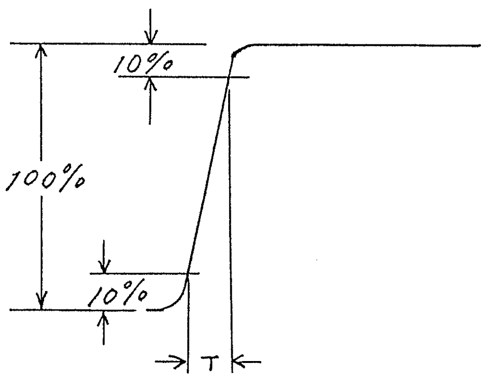


Fig. 4-6

Frequency Measurement:

There are three method of frequency measurement. First, the period per one cycle is calculated using equation (4-4) and the frequency is calculated using equation (4-6).

$$\text{Frequency f (Hz)} = \frac{1}{\text{Period T (sec)}} \quad \cdots\cdots\cdots\cdots\cdots \quad (4\text{-}6)$$

Second, the period for a few tens cycles (10 - 20 cycles) is determined. The number (N) of periods which fall within the 10-cm horizontal span of the graticule is determined, and the frequency is calculated using equation (4-7). This method is advantageous over the first method because it reduces measuring errors provided a sufficiently large number is employed as for N.

$$\text{Frequency f (Hz)} = \frac{N}{\text{Indication of TIME/CM (sec)} \times 10} \quad \cdots \quad (4\text{-}7)$$

Third, the frequency can be measured by means of Lissajous' figure. While the frequency in the first and second methods is measured by determining the period, the frequency in this third method is determined by operating the oscilloscope as an X-Y scope when the measured signal is below 10 kHz. As the oscilloscope is operated as an X-Y scope, the TIME/CM switch must be set in the EXT position. Then, apply the measured signal to the CH 1 input terminal and the reference signal to the EXT HOR

IN terminal. Adjust both vertical and horizontal amplitudes to 4 cm by adjusting the VOLTS/CM switch and the VARIABLE control of TIME/CM (HOR GAIN control). Vary the frequency of the reference signal until a Lissajous' figure of 1:1 frequency ratio is displayed on the screen.

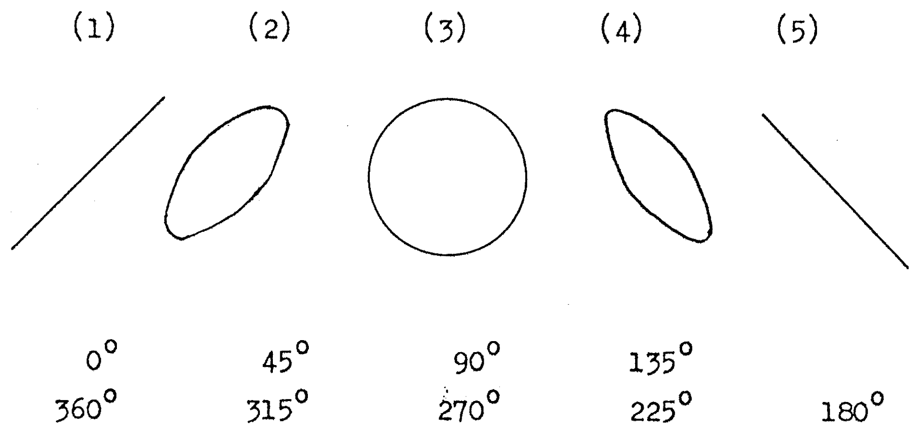


Fig. 4-7

At the frequency ratio of 1:1, the Lissajous' figure is either circular, elliptical, or linear. As the frequency ratio approaches 1:1, the Lissajous' figure continuously and repeatedly varies in the sequence of from (1) to (5) to back to (1). As the frequency ratio becomes very close to 1:1, the repetitive variation becomes very slow and, ultimately, as the ratio becomes exactly 1:1, the figure becomes stationary. At this state the frequency of the measured signal is the same with that of the reference signal. The frequency of the measured signal not in the 1:1 ratio but in other integer or fraction ratios with respect to the reference signal also can be determined since such ratios are represented by specific patterns of Lissajous' figure. However, measurement in the 1:1 ratio using a reference signal generator which covers a wide frequency range is most recommendable since this method is simple and less subjected to errors.

Phase Measurement:

To measure the phase difference between two signals of the same frequency, operate the oscilloscope as an X-Y scope and display a Lissajous' figure in the same manner as is made for frequency measurement. The phase difference can be calculated employing equation (4-8) and referring to Fig. 4-8 for the values of A and B.

$$\sin\theta = \frac{A}{B} \qquad \text{(4-8)}$$

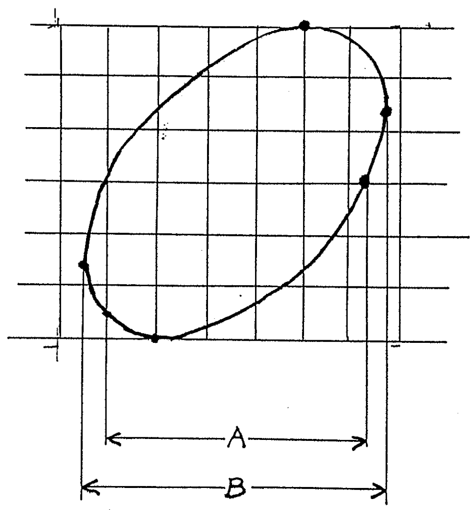


Fig. 4-8

5. CALIBRATION

5.1 GENERAL

The oscilloscope should be calibrated after it has been used for a certain period of time. Calibration will be made either totally or partially. Judgement on whether overall calibration or partial calibration is required can be easily made if the oscilloscope has been routinely checked of its vertical deflection sensitivity, sweep time accuracy, and other performance characteristics. Calibration will be required after the oscilloscope is repaired. Calibration of a certain item (the low voltage supply or high voltage supply, for example) will necessitate calibration of other items also.

Low Voltage Power Supply:

The low voltage power supply should be calibrated first of all calibration items. An accurate calibration using a digital voltmeter is recommended. The low voltage power supply provides stabilized voltages and non-stabilized voltages as shown in Table 5-1. The voltage check points are shown in Fig. 5-1. Measure the voltage between each check point and ground, and ensure that the actual voltages of the nominal -15 V and +15 V supplies are within respective tolerances shown in Table 5-1. Check the -15 V supply first and the +15 V supply next. Location of the voltage controls (semi-fixed resistors) is shown in Fig. 5-2.

Table 5-1

Supply voltage	Type	Tolerance	Remarks
-15 V	Regulated	14.9 - 15.1 V	Semi-fixed
+15 V	Regulated	14.9 - 15.1 V	Semi-fixed
+25 V	Non-regulated	-	-
-80 V	Non-regulated	-	-
+130 V	Non-regulated	-	-
+180 V	Non-regulated	-	-

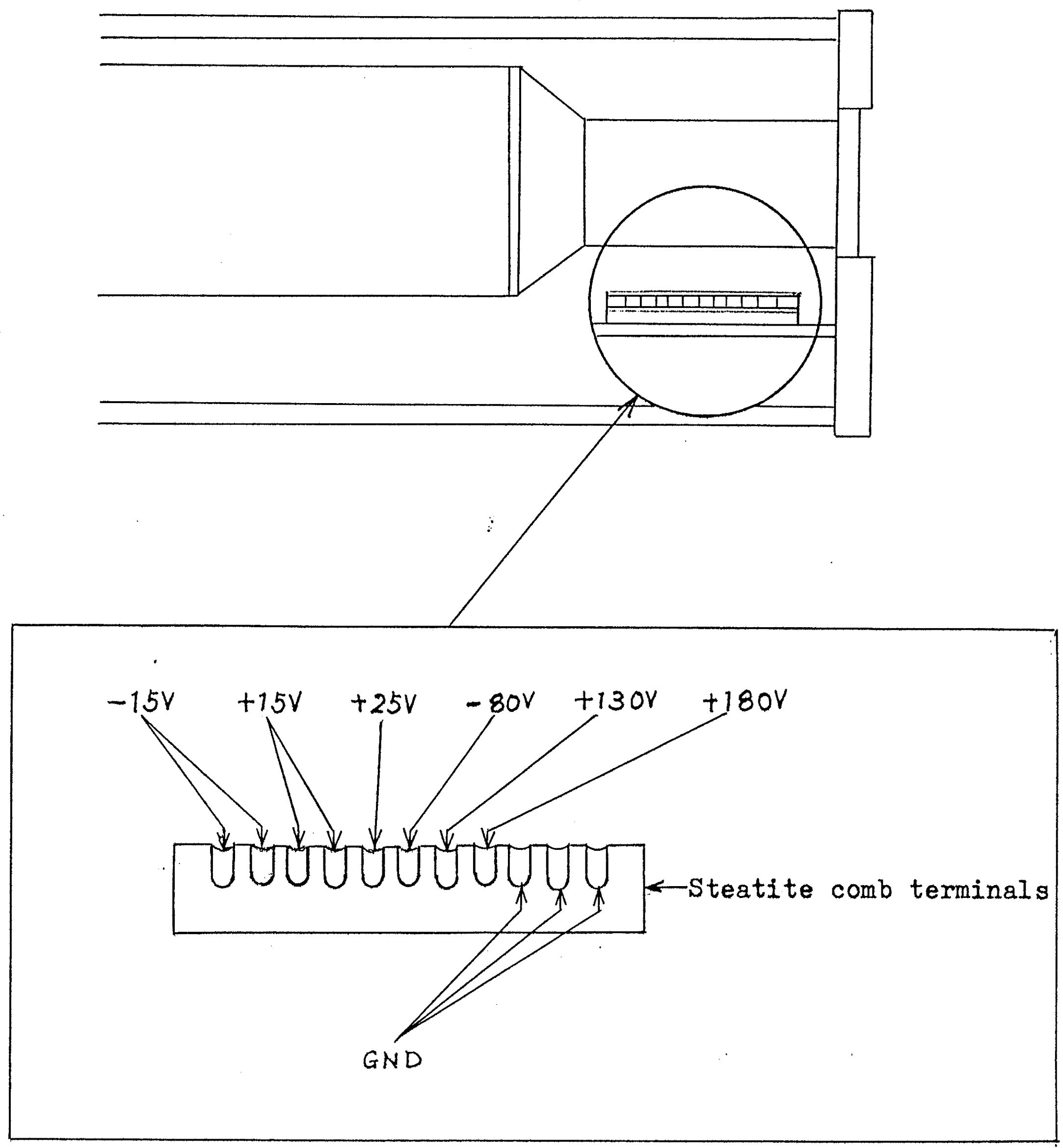


Fig. 5-1

The terminal voltages must be measured under the condition that the AC line voltage is ____V ±5%.

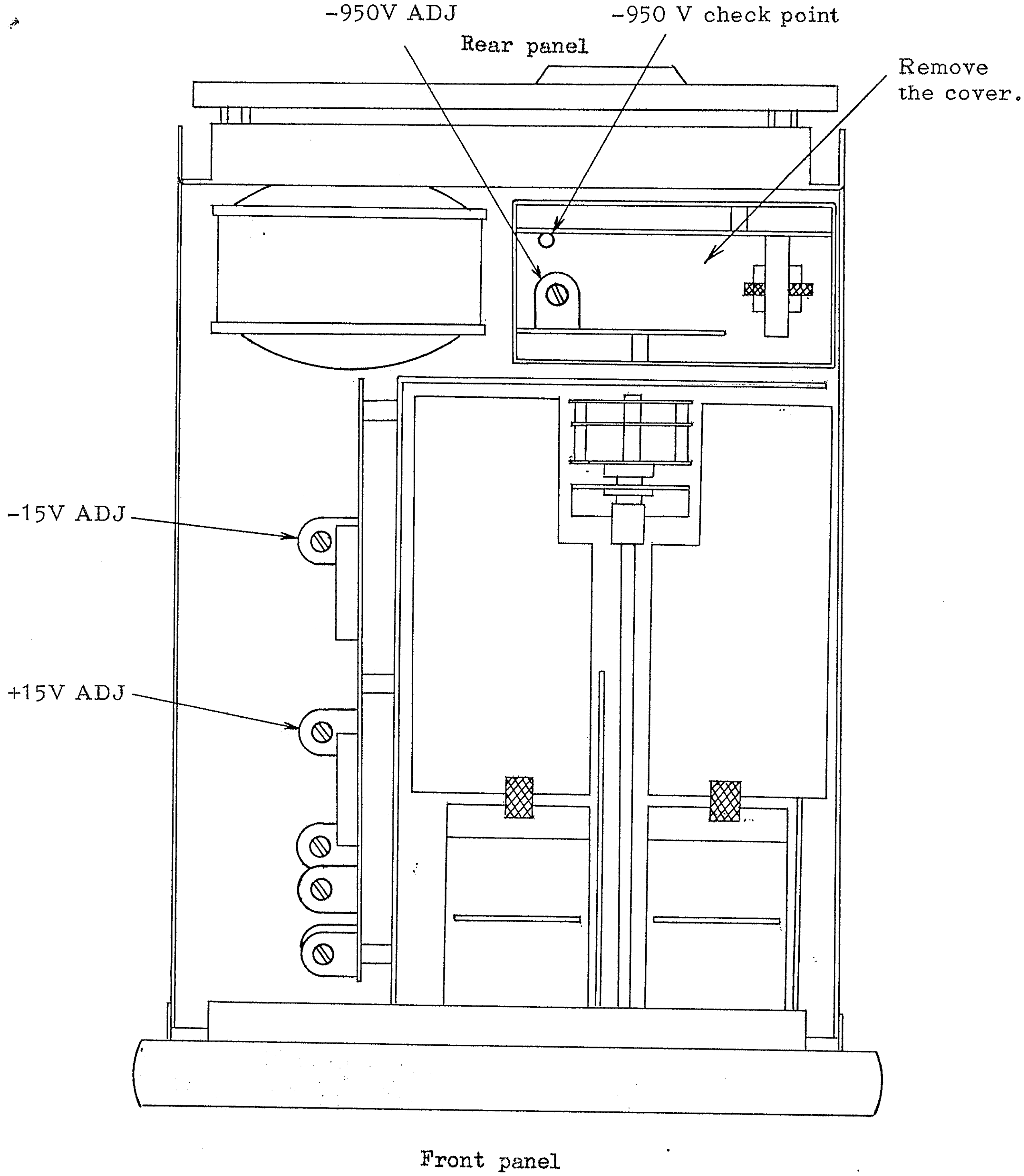

-950V ADJ
-950 V check point
Rear panel
Remove the cover.
-15V ADJ
+15V ADJ
Front panel

Fig. 5-2

High Voltage Power Supply:

If the high voltage supply varies, the vertical and horizontal deflection sensitivities vary. If the voltage variation is abnormally large, there is a mal-functioning component in the power supply circuit. In such a case, the focus and brightness of the trace displayed on the screen will be affected at first. The high voltages supply are shown in Table 2 and their check points and controls are shown in Fig. 5-2.

Table 5-2

Power supply	Voltage
Voltage supply of CRT cathode	-950 V
Voltage supply of CRT anode	Approx. +2.5 kV

The high voltages supply have been accurately adjusted using a precision electrostatic voltmeter at the factory prior to shipment. To measure the high voltages supply with an ordinary voltmeter, pay attention to the internal resistance of the voltmeter because large errors will be introduced unless the internal resistance is sufficiently high. This is especially true for anode voltage measurement.

Trace Rotator:

Parallelism between horizontal trace and CRT graticule may be disturbed by the effect of terrestrial magnetism. The horizontal trace can be rotated to conform with the graticule by turning the ROTATOR control (semi-fixed resistor) located on the rear panel. If adjustment with the ROTATOR alone is insufficient, use the PRESET ROTATOR control also.

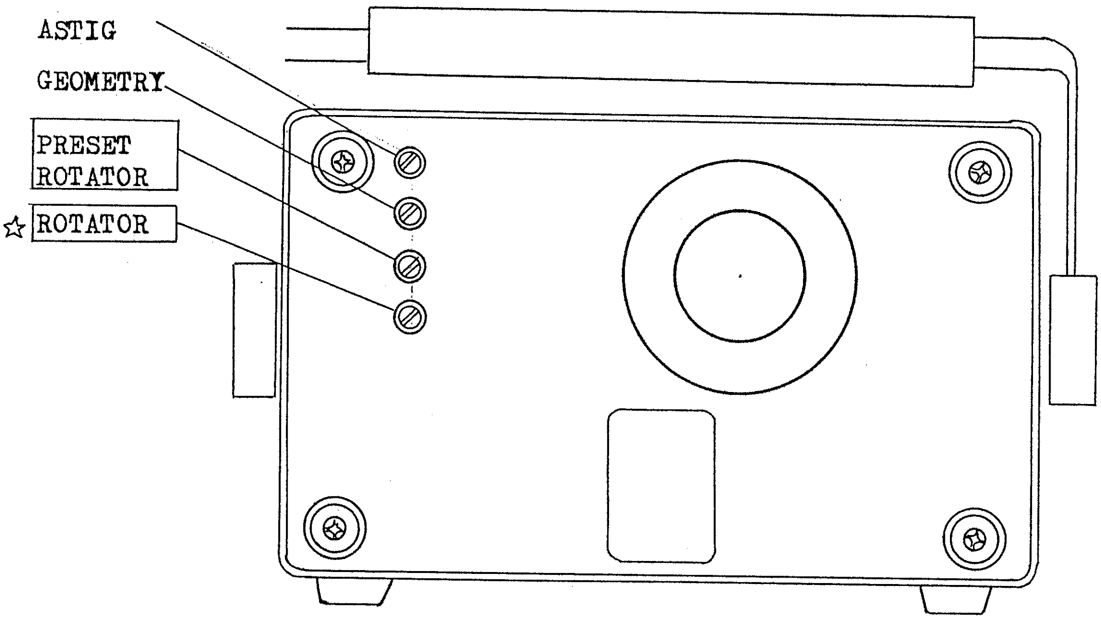


Fig. 5-3

Vertical Deflection Sensitivity:

Apply to the vertical input terminal a signal of 1 kHz, 20 mVp-p using a square wave generator having an output voltage accuracy of better than 0.5%. Adjust the GAIN CAL control (semi-fixed resistor mounted on the panel) so that the deflection amplitude is made accurately 4 cm with the VOLTS/CM switch set in the 5 mV position. Perform this calibration for both CH 1 and CH 2, by adjusting respective CAL controls.

Next, for each of the VOLTS/CM switch positions, apply an input voltage of twice of the value indicated by the switch and measure the deflection amplitude. The measured value must be within ±3% of the value indicated by the VOLTS/CM switch for all its positions.

Phase Compensation of VOLTS/CM Switch:

If phase shift is being caused in the VOLTS/CM switch (in the input attenuator circuit), the frequency response of the input circuit will be degraded and the displayed waveform will be distorted. The phase characteristics of the input attenuator circuit is adjustable by means of the input capacitor and compensation capacitor. For this adjustment, a capacitance meter which can measure the input capacitance (38 pF) and a pulse generator which can provide a quality square wave signal of 1 kHz are required. The input capacitance cannot be reliably measured with a conventional bridge-type capacitance meter. Kikusui Model 231A LC Meter is most suitable for this measurement. As for the quality 1 kHz square wave signal, the CALIB signal (which is provided for calibration of the accessory probe) may be used most advantageously. If other signal is to be used, the signal must be free of sag and overshoot and the rise time must be faster than 0.1 µsec. Location of the controls for this adjustment is shown in Table 5-3.

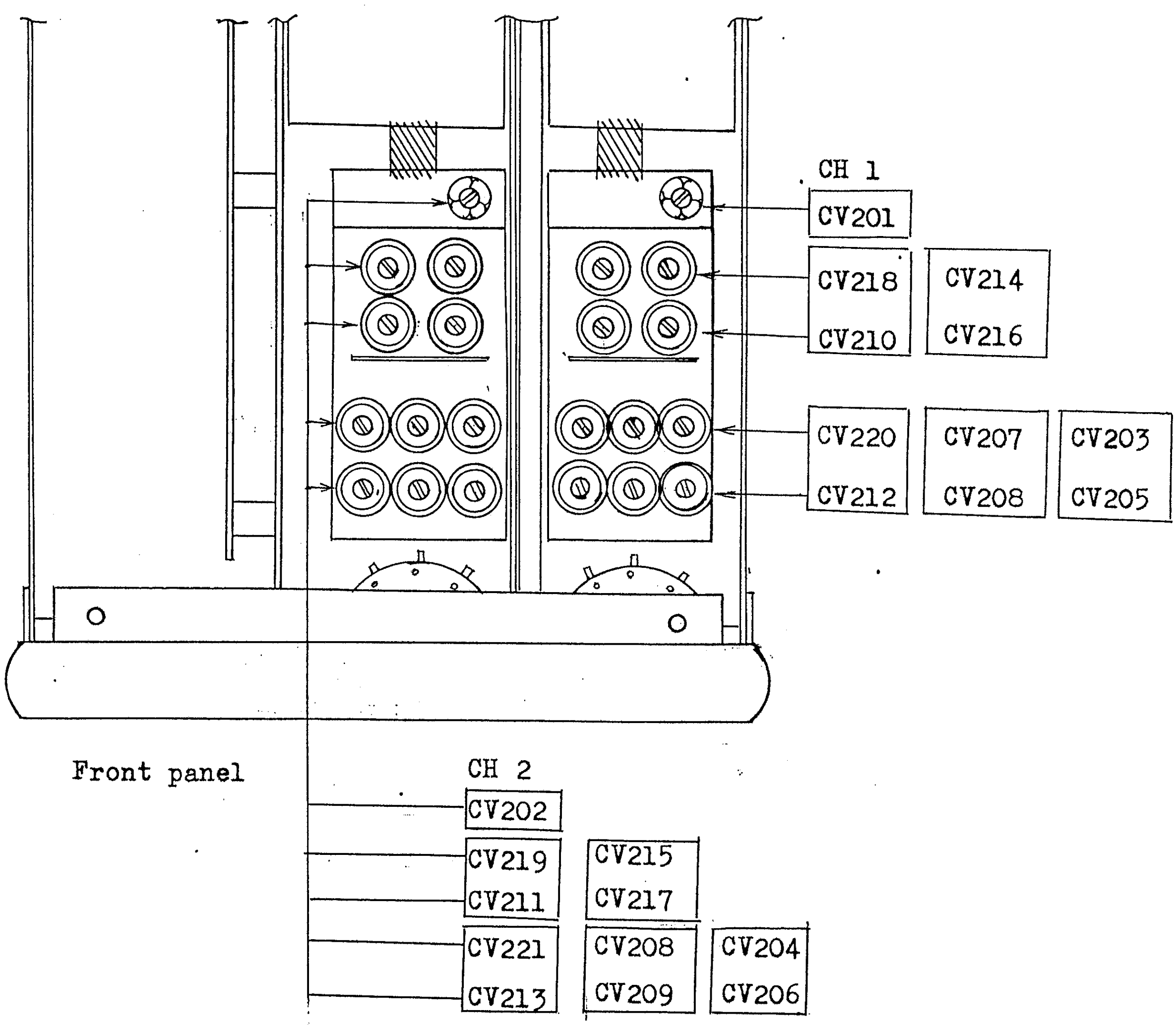
Table 5-3

CH 1

VOLTS/CM switch position	Calibration control (variable capacitor)	
	Input capacitor	HF compensation
5 mV	CV201	-
10 mV	CV216	CV214
20 mV	CV210	CV218
50 mV	CV205	CV203
0.1 V	-	-
0.2 V	-	-
0.5 V	CV208	CV207
1 V	-	-
2 V	-	-
5 V	CV212	CV220
10 V	-	-

CH 2

VOLTS/CM switch position	Calibration control (variable capacitor)	
	Input capacitor	HF compensation
5 mV	CV202	-
10 mV	CV217	CV215
20 mV	CV211	CV219
50 mV	CV206	CV204
0.1 V	-	-
0.2 V	-	-
0.5 V	CV209	CV208
1 V	-	-
2 V	-	-
5 V	CV213	CV221
10 V	-	-

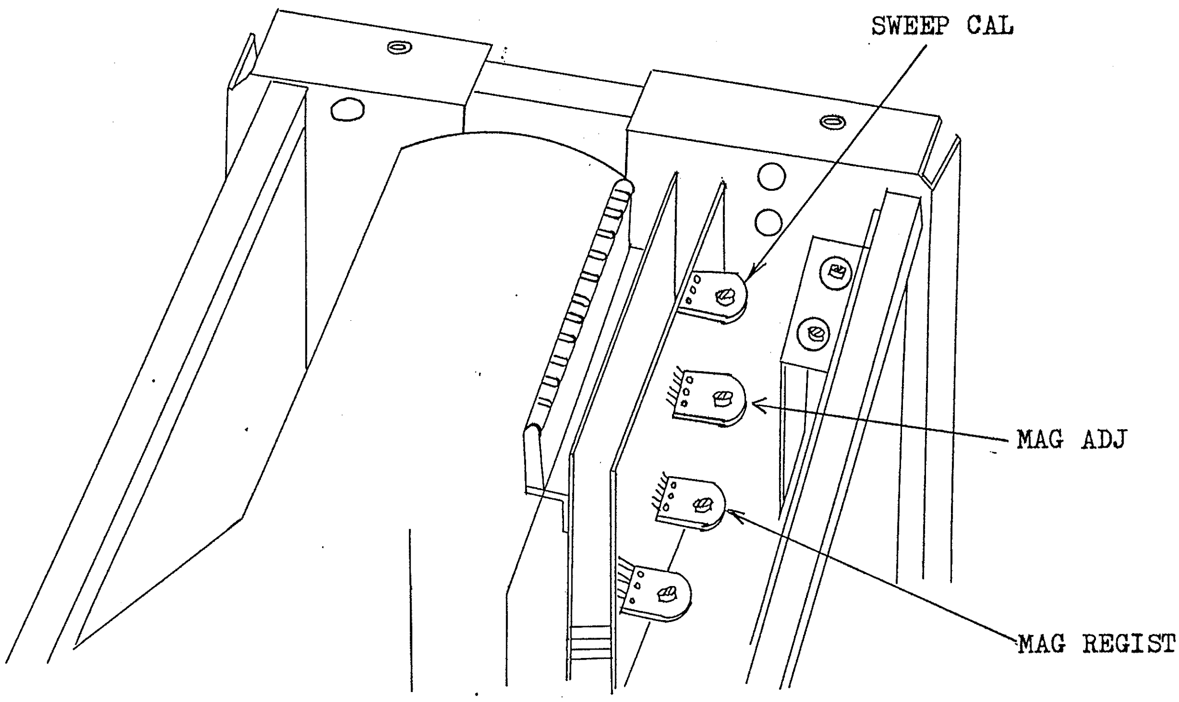


Sweep Time:

For sweep time calibration, proceed as follows: Set the switches as mentioned below. Apply to the vertical input terminal a signal which has time intervals of accurately 1 msec. This calibration work requires a time marker generator or a pulse generator which has a sufficiently wide frequency range to cover all ranges (0.5 sec - 0.2 μsec) of the TIME/CM switch.

TRIGGERING:	PUSH, AUTO
TIME/CM:	1 ms

The sweep time accuracy specification is ±3% of the indicated value. However, calibration for the 1 msec sweep time must be made as accurately as possible because this range is used as the reference for all other ranges of sweep time. It should be calibrated to an accuracy of ±1% by means of the SWEEP CAL control (semi-fixed resistor) shown in Fig. 5-5. Next, magnify the sweep by a factor of 5 (pull out the HOR POSITION knob), and adjust the 5X MAG ADJ control (semi-fixed resistor) so that the sweep is magnified by 5 times with an accuracy of ±1%.



MAG REGIST:

Adjust the MAG REGIST control so that the sweep is magnified with the screen center as the reference point of magnification.