# MS-1650B

## DIGITAL MEMORY OSCILLOSCOPE

# INSTRUCTION MANUAL

TRIO

# FEATURES

This instrument is a combination of an oscilloscope having a frequency band of DC-10 MHz and a digital memory having memory ability of 8 bits×1024 words and write speed up to 1 μs/word. Input signal can be stored in the memory so that memory signal is displayed on the CRT at any time.
The instrument is readily connected to a pen recorder. It memorizes and displays signals prior to triggering, instantaneous signals, transient waveforms and repetitive waveforms. This model is designed as a multitrace memory oscilloscope which combined with the memory unit MU-1651(-T) (option).

1. Instantaneous signals, transient waveforms, and repetitive waveforms can be stored in the memory for displaying on the CRT.
2. By connecting the MU-1651(-T) memory unit to MS-1650B, the later can be used for a maximum of 4 traces digital memory oscilloscope.
3. Semiconductor memory circuit having memory ability of 8 bits × 1024 words and write speed up to 1 μs/word.
4. The oscilloscope covers a wide DC-10 MHz band. The controls and switches of the oscilloscope are also used to store input signals in the memory and display memory signals.
5. −DELAY function is provided to store signals prior to triggering in the memory which is not possible with conventional oscilloscopes.
6. The automatic free-run function repeats write-in and read-out signals automatically.
   By pulling out the knob of DISPLAY TIME, the fixed read-out speed is applied up to 1 μs/word regardless of sweep time in read-out operation. Therefore read-out signals are easy to be seen.
7. Memory signals are readily displayed on the built-in CRT or recorded in a pen recorder.
8. A SMOOTHER switch has been built-in to make waveform more easily visible when monitoring memorized signals on the screen; sample intervals have become joined and smooth.
9. Real time waveform being displayed on the screen can be stored in the memory, thus providing simplified operation.
10. Both the real time waveform and memory signal can be displayed simultaneously, permitting you to compare one signal with the other.
11. Memorized date contents can be kept on hold for over a week after power has been cut off because a memory back-up capacitor has been built-in. Thus you can store data for as is while carring MS-1650B.
12. Signals synchronized with power frequency can be displayed or stored in the memory.
13. The oscilloscope can be used as a X-Y scope by simply setting the DISPLAY MODE switch to the X-Y position.
14. By connecting MU-1651(-T), feeding its output into HOR INPUT, X-Y operation of real time waveform and memory waveform can be executed.
15. Large sized, square CRT displays waveforms over the entire area of the screen.
16. Rigid construction with die casting front panel and compact design.
17. With the joiner CZ-84, MS-1650B and MU-1651 memory unit can be combined into one body, making it convenient to carry as a dual trace memory oscilloscope.

# CONTENTS

# SPECIFICATIONS

## Cathode Ray Tube

**Type**
E2713B31A

**Acceleration voltage**
Approx. 2 kV

**Display area**
8 div×10 div (1 div=9.5 mm)

## Vertical Axis

**Sensitivity**
10 mV/div — 20 V/div, ±5%

**Attenuator**
10 mV/div — 20 V/div, 1-2-5 sequence
11 ranges, fully adjustable

**Input impedance**
1 MΩ, ±5% 22 pF ±3 pF

**Frequency response**

| | | |
|---|---|---|
| Oscilloscope | DC: | DC-10 MHz (−3 dB) (10 mV/div — 20 V/div) |
| | AC: | 2 Hz-10 MHz (−3 dB) (10 mV/div — 20 V/div) |
| Digital memory | DC: | DC-250 kHz (−3 dB) |
| | AC: | 2 Hz-250 kHz (−3 dB) |

**Rise time**
35 ns (Oscilloscope operation)

**Maximum input voltage**
600 Vp-p or 300 V (DC+AC peak, at 1 kHz)

**Operating mode**
REAL: Oscilloscope operation or memory free-run
DUAL: Real time and memory waveforms, dual trace operation (CHOP mode of approx. 500 kHz)
MEMORY: Memory waveform readout
X-Y: X-Y scope operation

## A/D Converter

**Resolution**
8 bits

**Conversion system**
Successive comparison A/D converter

**Scale-over**
8 div vertical scale

## Sweep Circuit

**Sweep system**
Trigger sweep (NORM), auto sweep (AUTO)

**Sweep time**
1 μs/div — 1 s/div, ±5%
1-2-5 sequence
19 ranges, fully adjustable

**Magnifier**
5 MAG±10%

**Linearity**
Less than 3% (5 μs/div — 1 s/div)
Less than 5% (1 μs/div — 2 μs/div)

## Sync Circuit

**Sync input**
INT: Vertical input signal
LINE: Line frequency
EXT: EXT TRIG input signal

**Polarity**
Positive and negative

**Sync voltage**
INT: More than 1 div of amplitude on the CRT
LINE: Within the specified power supply voltage
EXT: More than 1 Vp-p

**Sync frequency**
INT: 20 Hz — 10 MHz
EXT: DC — 10 MHz

**External sync input voltage**
±15 V (DC+AC peak)

## Horizontal Axis

**Operating system**
DISPLAY MODE selector switch to X-Y position

**Sensitivity**
150 mV/div (±20%, HOR. GAIN MAX)

**Frequency response**
DC: DC—1 MHz (−3 dB) (HOR. GAIN MAX)

**Input impedance**
100 kΩ±20%, 35 pF or less

**Maximum input voltage**
50 V (DC+AC peak, HOR. GAIN MAX)

## Memory Unit

**Memory capacity**
1024 words (100 words/div)

**Write speed**
0.1 ms/div — 1 s/div, 13 ranges (equivalent to 1 μs/word — 10 ms/word)
EXT: Rising edge of EXT CLOCK input signal repetition rate frequency: Less than 500 kHz
High level pulse width: not less than 1 μs
Low level pulse width: not less than 500 ns
Rise time, not less than 500 ns

**Readout speed**
SCOPE: Same as write speed
Fixed read out (at 1 μs/word for DISPLAY TIME pulled position).
PEN: 10 ms/word, 20 ms/word 50 ms/word, 3 ranges (Switchable to 100 ms/word, 200 ms/word, 500 ms/word by changing jumper wire connection)
EXT: Rising edge of EXT CLOCK input signal repetition rate frequency: Less than 1 MHz
Input signal:
High level pulse width: not less than 500 ns
Low level pulse width: not less than 500 ns
Rise time, not less than 500 ns
Input voltage: TTL level
Maximum input voltage: 20 V (DC+AC peak)
Input resistance: Approx. 30 kΩ

**Delay**
— DELAY (0—9 div, DIG SW setting)

# SPECIFICATIONS

## Signal Output

**Display time**

The amount of time for which memory signals are displayed can be varied from approx. 1 to approx. 20 seconds.

**Memory out and Memory out for pen (Output of only PEN mode)**

**Display time**

Output wave: Memory wave
Output voltage: 1.6 Vp-p, full scale (at 8 div)
Output resistance: Approx. 430 Ω

**Read gate**

Output wave: Positive pulse (1 word) of final address
Output voltage: TTL level
Output resistance: Approx. 220 Ω

**Read gate for pen (Output of only PEN mode)**

Output voltage: TTL level (LOW active)
Output resistance: 220 Ω

**Sweep gate**

Output wave: Positive pulse synchronized with sweep signal
Output voltage: TTL level
Output resistance: Approx. 220 Ω

**CAL (Calibrating voltage)**

Output wave: 1 kHz, ±10%, square wave
Output voltage: 1 Vp-p ±5%

**Data out**

Data output:
8 bit binary parallel output, positive output (TTL level)
Timing pulse:
Positive, negative output (MOS) (TTL level)
Read gate out:
Positive output of the final-address one word
Output resistance: Approx. 220 Ω (TTL level)
Ext. clock:
TTL level clock input of 1 MHz or below
High level pulse width: Not less than 500 ns
Low level pulse width: Not less than 500 ns
Rise time: Not more than 500 ns
Input resistance: Approx. 30 kΩ

PIN CONFIGURATION

| 14-pin cable receptacle # | Data contents | 14-pin cable receptacle # | Data contents |
|---|---|---|---|
| Pin # 1 | Data LSB | Pin # 8 | MSB |
| Pin # 2 | BIT 2 | Pin # 9 | Timing pulse $\overline{\text{MOS}}$ |
| Pin # 3 | BIT 3 | Pin # 10 | Timing pulse MOS |
| Pin # 4 | BIT 4 | Pin # 11 | EXT. CLOCK |
| Pin # 5 | BIT 5 | Pin # 12 | GND |
| Pin # 6 | BIT 6 | Pin # 13 | GND |
| Pin # 7 | BIT 7 | Pin # 14 | READ GATE OUT |

## Signal Input

**Memory in**

Sensitivity: 1.6 Vp-p, full scale (200 mV/div)

## Memory signal input

(3 inputs for MU-1651)

**Frequency response:** DC— approx. 1 MHz (−3 dB), Smoother; off
DC— approx. 150 kHz (−3 dB), Smoother; on
**Input impedance:** Approx. 60 kΩ
**Maximum input voltage:** 20 Vp-p or 10 V (DC+AC peak)

## Intensity Modulation

**Input voltage**

TTL level (Intensity increasing with more positive levels)

**Input impedance**

Approx. 15 kΩ

**Input frequency**

DC — 1 MHz

**Maximum input voltage**

50 V (DC+AC peak)

## Power Requirement

**Voltage** 100/120/220/240 V, ±10%, 50/60 Hz
**Power consumption** Approx. 60 W

## Dimensions

**Width** 284 mm (328 mm)
**Height** 138 mm (153 mm)
**Depth** 400 mm (463 mm)
**( ) dimensions include protrusions from basic case outline dimensions**
**Weight** Approx. 9 kg

## Operating Temperature

Operating temperature for guaranteed specification: 0° ~ 40°C
Full operating temperature: 0° ~ 50°C

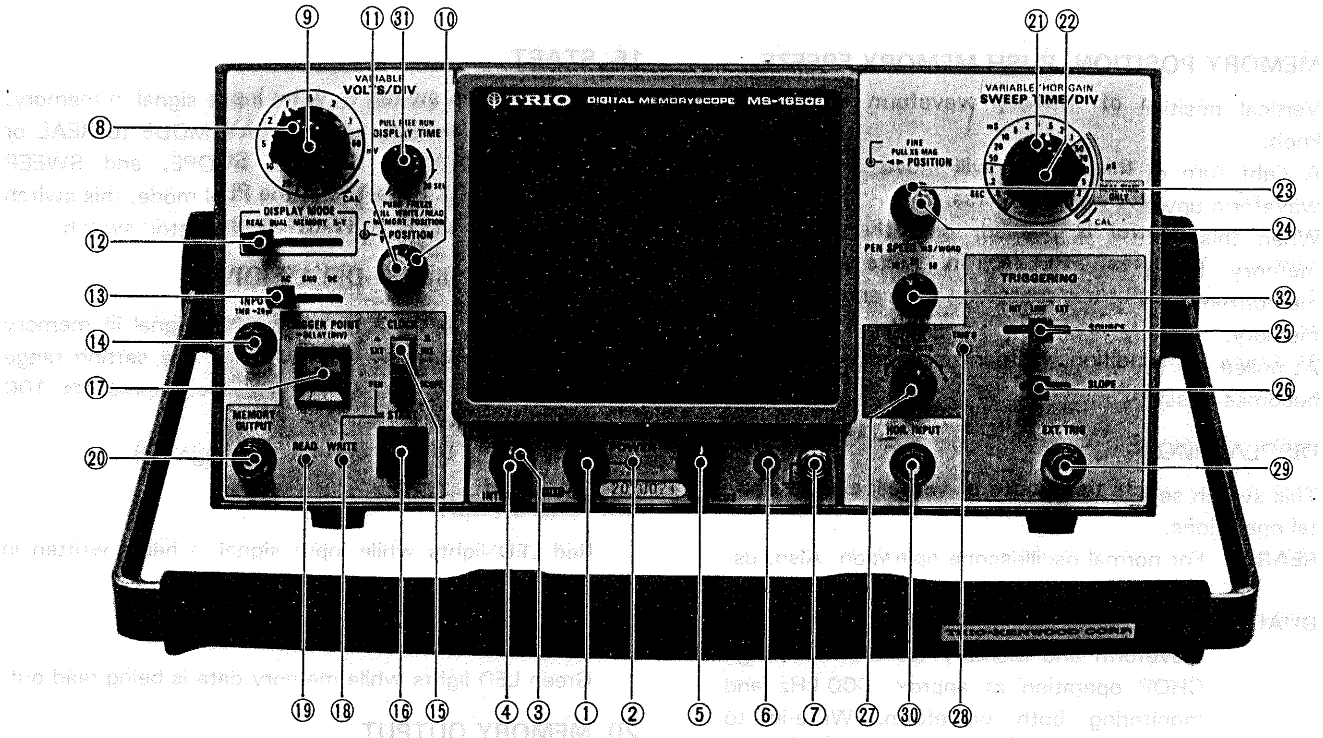
## Accessory

Probe (PC−22) .......... 1 piece
Attenuation .......... 1/10
Input impedance .......... 10 MΩ
Less than 18 pF
Replacement fuse .......... 1.5 A, 2 pieces
0.7 A, 2 pieces
Instruction manual .......... 1 copy
AC cord .......... 1 piece
Digital output plug .......... 1 piece

## Option

Joiner CZ-84

# CONTROLS ON PANELS




## CONTROLS ON FRONT PANEL

### 1. POWER/SCALE ILLUM

Power switch and scale illumination control. Fully counterclockwise rotation of this control turns off oscilloscope. Clockwise rotation turns on oscilloscope. Further clockwise rotation of this control increases the illumination level of the scale.

### 2. LED PILOT LAMP

Lights when oscilloscope is turned on.

### 3. INTENSITY

Intensity control. Adjusts the brightness of spot and waveforms for easy viewing. A left turn allows the waveforms to disappear.

### 4. TRACE ROTATION

This control is used to eliminate inclination of horizontal trace.

### 5. FOCUS

Spot focus control to obtain optimum waveform according to brightness.

### 6. CAL

Provides 1 kHz, 1 volt peak-to-peak square wave output signal. This is used for calibration of the vertical amplifier attenuators and to check the frequency compensation adjustment of the probes used with the oscilloscope.

### 7. GND TERMINAL

Earth terminal of the oscilloscope.

### 8. VOLTS/DIV

Vertical attenuator calibrated in voltage per division. In the extreme clockwise (CAL) position, the vertical attenuator is calibrated.

Select the position of the control according to the magnitude of input voltage to obtain the optimum waveform.

Vertical sensitivity is calibrated in 11 steps from 0.01 to 20 volts per div.

### 9. VARIABLE

Fine adjustment control of vertical sensitivity. The sensitivity within the 11 ranges of VOLTS/DIV (8) is continuously adjustable. The extreme clockwise (CAL) position is used to calibrate the vertical attenuator.

### 10. ♦ POSITION

The rotation of this control adjusts vertical position of real time waveform as desired. A right turn of this control will shift the real time waveform upward, and vice versa.

# CONTROLS ON PANELS

## 11. MEMORY POSITION, PUSH MEMORY FREEZE

Vertical position of memory waveform adjustment knob.
A right turn of this control will move the memory waveform upward, and vice versa.
When this control is pushed, only the main unit memory becomes FREEZE; in write condition, memorized waveform is preserved and cannot write in memory.
At pulled out condition, write-in to main unit memory becomes possible.

## 12. DISPLAY MODE

This switch selects the modes of vertical and horizontal operations.

**REAR:** For normal oscilloscope operation. Also, used to write a signal in memory.

**DUAL:** This mode for switching between real time waveform and memory waveform through CHOP operation at approx. 500 kHz and monitoring both waveform. Write-in to memory can only be accomplished through manual operation of START (16) switch.

**MEMORY:** For readout of memory waveform.

**X-Y:** For X-Y oscilloscope.

## 13. AC-GND-DC

Vertical input selector switch. AC position blocks DC component of input signal. GND position opens signal input path and grounds amplifier input. DC position directs input of AC and DC components to amplifier.
When the DISPLAY MODE is set to REAL or DUAL, a trace appears on the scope in GND position of AC-GND-DC switch regardless of the position of the PULL AUTO (27).

## 14. INPUT

Vertical input terminal.

## 15. CLOCK

**INT/EXT:** Clock selector switch. Write-in and read-out occures via the clock inputted at the EXT CLOCK (35) terminal. In this position, the waveform on the scope cannot be synchronized. INT position is used for write and readout. There are two functions, SCOPE and PEN (readout only)

**SCOPE/PEN:** Memory readout mode selector switch.
In SCOPE position, readout on the screen is effected repeatedly.
In pen position, readout to MEMORY OUT terminal is effective each time START is depressed. For write mode, use the SCOPE position.
The memory data from the initial address to final address are read out once by pressing this switch.

## 16. START

A pushbutton switch to write input signal in memory.
To use this switch, set DISPLAY MODE to REAL or DUAL, CLOCK to INT and SCOPE, and SWEEP TIME/DIV to 0.1 ms-1 s. In the PEN mode, this switch functions as the PEN START push button switch.

## 17. TRIGGER POINT −DELAY (DIV)

This switch is used to write input signal in memory before trigger signal is generated. The setting range covers from 0 div. to 9 div. 1 div. represents 100 words in memory.
(Refer to "−DELAY Setting" on page 10)

## 18. WRITE (LED)

Red LED lights while input signal is being written in memory.

## 19. READ (LED)

Green LED lights while memory data is being read out.

## 20. MEMORY OUTPUT

Memory data output terminal. Readout speed is varied according to 3 readout modes, SCOPE, PEN and EXT CLOCK.

## 21. SWEEP TIME/DIV

Horizontal sweep time selector. It selects sweep times of 1 $\mu s$ to 1 s in 19 steps. The 1 $\mu s$-50 $\mu s$ range is used for real time.

## 22. VARIABLE/HOR. GAIN

Used for fine adjustment of sweep time. Continuous adjustment between 19 ranges of SWEEP TIME/DIV (21) is possible. Sweep time is calibrated at the extreme clockwise position (CAL). When the DISPLAY MODE is set to X-Y, the signal from the HOR INPUT is attenuated by SWEEP/TIME DIV. control.

## 23. ◄► POSITION

Rotation adjusts the horizontal position of trace as desired. Clockwise rotation shifts the trace to the right and counterclockwise rotation, to the left

## 24. FINE PULL X5MAG

Horizontal position fine adjuster and sweep magnification selector switch. Pull the knob and the trace is magnified five times as large in the left and right directions. Brightness is slightly decreased.
Input signal stored in the memory is not magnified even in the X5MAG position.

# CONTROLS ON PANELS

## 25. SOURCE

Sync source voltage selector switch for three functions, INT (internal sync), LINE (50/60 Hz sync) and EXT (external sync).

INT: Sweep is triggered by vertical input signal.
LINE: Sweep is triggered by 50/60 Hz power frequency.
EXT: Sweep is triggered by voltage applied to EXT TRIG terminal and DC component.

## 26. SLOPE

Sync polarity selector switch. In the "+" position, sweep is triggered with rising slope of input waveform, and in the "−" position, with falling slope of input waveform.

## 27. LEVEL, PULL AUTO

Triggering level control adjusts sync phase to determine the starting point of sweep on the slope of trigger signal waveform. By pulling the knob toward you, auto sweep is effected; the sweep is set in free-run state and the trace is displayed on CRT even when no trigger signal is present. When trigger signal is present, sweep is started so the triggering level can be adjusted.

## 28. TRIG'D

Sync indication lamp lights when sync signal is triggered. Check this lamp lights when writing input singal to memory.
The lamp may light in the GND position of the AC-GND-DC (13). This is normal and is not an indication that the unit is defective.

## 29. EXT TRIG

Input terminal for external trigger signal. External trigger signal (1 Vp-p or higher) should be applied with SOURCE switch set to EXT.

## 30. HOR INPUT

Input terminal for external horizontal signal. DISPLAY MODE switch should be set to X-Y.

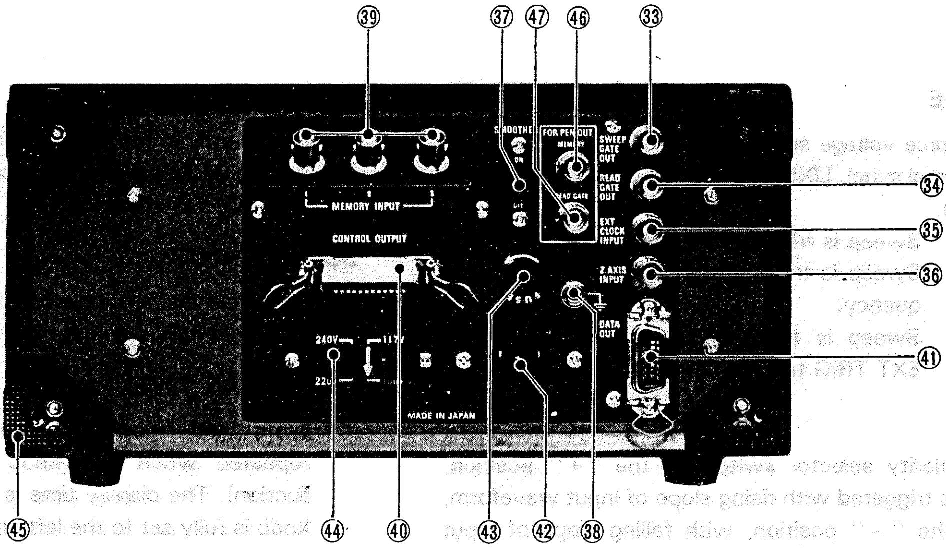
## 31. DISPLAY TIME

Store and read-out operation are automatically repeated when this knob is pulled out (free run fuction). The display time is about 1 second when the knob is fully set to the left and about 20 seconds when it is fully set to the right. This function is effective only when the DISPLAY mode is REAL.

## 32. PEN SPEED

Selects the memory read speed in the PEN mode from among three speeds: 10 to 50 ms/word. This switch functions regardless of the position of SWEEP TIME/DIV (21).

# CONTROLS ON PANELS




## CONTROLS ON REAR PANEL

### 33. SWEEP GATE OUT

Sweep gate signal (positive pulse) is available at this terminal.

### 34. READ GATE OUT

Positive pulse for one word of final memory address is available at this terminal.
The signal can be used as a stop signal when a pen recorder is used.

### 35. EXT CLOCK

Input terminal for external clock.
CLOCK switch (15) should be set to EXT.

### 36. Z-AXIS INPUT

Intensity modulation terminal. Intensity is modulated at TTL level.

### 37. SMOOTHER

When slided this switch to ON side, the sample waveform becomes joined and makes visible.

### 38. GND

Ground terminal. Oscilloscope chassis ground, and earth ground.

### 39. MEMORY INPUT

Three input terminals for memorized signals when connecting MU-1651 memory unit and using as a mutiple trace memory oscilloscope.

### 40. CONTROL OUTPUT

Control signal output terminal for memorized signal when connecting MU-1651 memory unit and using as a mutiple trace memory oscilloscope.

### 41. DATA OUT

Output terminal for memory data (8 bit BINARY) and timing signal.

### 42. POWER CONNECTOR

For connection of accessory power cord.

### 43. FUSE HOLDER

For 100/120 V operation, use a 1.5A fuse. For 220/240 V operation, be sure to use a 0.7A fuse.

### 44. POWER VOLTAGE SELECTOR

Set the selector to the position corresponding to the correct AC power voltage, 100/120/220/240 V.

### 45. CORD REEL

Wind the power cord in the reel when the oscilloscope needs to be transported or it is to be left unused.

### 46. MEMORY (FOR PEN OUT)

This output terminal is only effective for PEN mode. When START (16) is pressed, output of the same data as that of MEMORY OUTPUT (20) starts.

### 47. READ GATE (FOR PEN OUT)

This is valid only in PEN mode. This terminal outputs the same signal as that READ GATE (34). This output signal drops to the GND level to start pen operation, and rises to the H level to stop pen operation when reading is finished. The terminal is grounded in the SCOPE mode.

# OPERATION

## OSCILLOSCOPE OPERATION

Refer to the previous section "Controls on Panels". Before operating the oscilloscope, set the switches and controls as follows:

| Switches and Controls | Position |
|---|---|
| 1. POWER/SCALE ILLUM | OFF |
| 3. INTENSITY | Center (slightly right) |
| 5. FOCUS | Center |
| 8. VOLTS/DIV | 20 V |
| 9. VARIABLE | Full clockwise |
| 10. ⬍ POSITION | Center |
| 12. DISPLAY MODE | REAL |
| 13. AC-GND-DC | GND |
| 21. SWEEP TIME/DIV | 1 ms |
| 22. VARIABLE | Full clockwise |
| 23. ◁▷ POSITION | Center |
| 24. FINE PULL × 5 MAG | Center (PUSH) |
| 25. SOURCE | INT |
| 26. SLOPE | + |
| 27. LEVEL | Center (PULL) AUTO |
| 31. DISPLAY TIME | PUSH |

1. Connect the supplied power cord to the power connecter. The oscilloscope is factory adjusted to operate on AC 240V.
2. Turn the POWER switch (1) to ON and the POWER lamp (2) will light. Then horizontal trace will appear. If horizontal trace does not appear at the center of the screen, adjust the ⬍ POSITION (10).
3. Adjust the intensity by the INTENSITY (3). If the trace is unclear, adjust the FOCUS (5).
4. If the trace is inclined, adjust the TRACE ROTATION (4).
5. Set the AC-GND-DC (13) to AC or DC position and apply input signal to the INPUT (14). Turn the VOLTS/DIV (8) clockwise to obtain optimum waveform.
6. If the waveform is running and not triggered, turn the LEVEL (27). By pushing the LEVEL knob, the auto function is released. The waveform disappears when the knob is turned clockwise or counterclockwise and appears again at the approximate midposition of it. Turn the knob until optimum triggering level is obtained.
7. When the signal voltage is more than 0.01 V and waveform does not appear on the screen, the oscilloscope may be checked by feeding input from the CAL (6) terminal. Since the calibration voltage is 1 Vp-p, the waveform becomes 5 div at the 0.2 V position of the VOLTS/DIV.
8. In measuring DC component, set the AC-GND-DC (13) to DC. If it contains positive (+) potential, the waveform moves upward. If negative (−) potential is contained, the waveform moves downward. The zero potential can be checked at the GND position.

## DIGITAL MEMORY OPERATION

Set the switches and controls as follows before using the digital memory:
Other knobs and controls are the same in function as those of oscilloscope operation.

| Switches and Controls | Position |
|---|---|
| 11. MEMORY POSITION | Pull mechanical center |
| 12. DISPLAY MODE | REAL or DUAL |
| 15. CLOCK | INT/SCOPE |
| 17. TRIGGER POINT | 0 |
| 21. SWEEP TIME/DIV | 0.1 ms — 1 s |
| 27. LEVEL | NORMAL (PUSH) |
| 31. DISPLAY TIME | PUSH |
| 32. PEN SPEED | 10 ms, 20 ms, 50 ms/word |

**[A] Manual Operation**

1. Operate the oscilloscope and display a triggered signal on the screen.
2. Depress the WRITE START (16) and the WRITE (18) lamp will light.
3. When the WRITE lamp goes off, the READ (19) lamp begins to flicker.
4. Set the DISPLAY MODE (12) to DUAL or MEMORY, and memory waveform will be displayed. In the DUAL mode, the real time waveform overlaps with the memory waveform. By adjusting the ⬍ POSITION (10) or MEMORY POSITION (11), both waveforms can be observed.
5. When observing memory waveform, it is not necessary to adjust the VOLTS/DIV (8) and SWEEP TIME/DIV (21). The VOLTS/DIV does not change the amplitude of the memory waveform. The SWEEP TIME/DIV changes only the readout speed; the memory waveform remains unchanged on the screen.

**[B] Automatic write-in, read-out Operation**

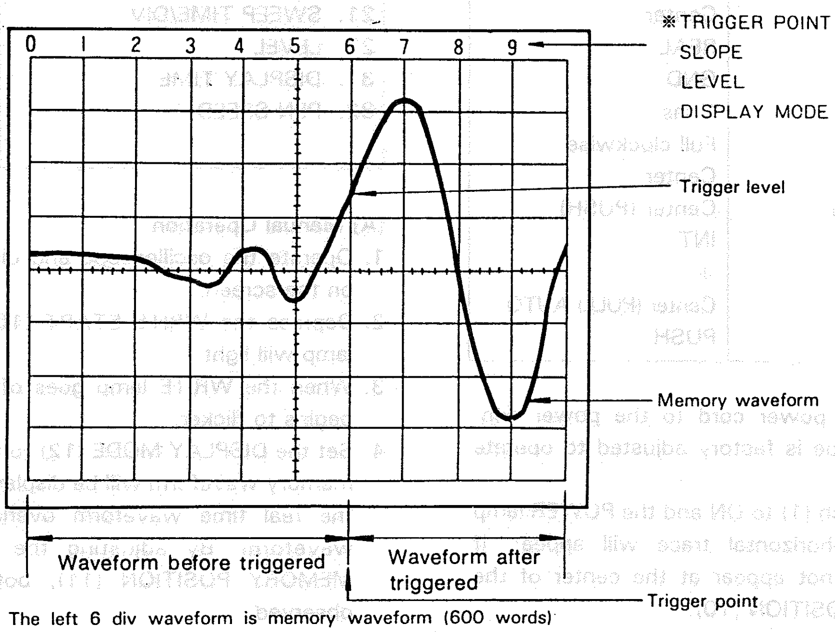
Pull out the DISPLAY TIME (31) forward you and set this control at about 9 o'clock position in FREE RUN state.
Refer to FREE RUN function on page 11.

### −DELAY Setting

With conventional oscilloscopes, it is not possible to observe a trace before triggering signal is developed. This oscilloscope has "−DELAY" function to store a waveform in memory before triggering signal is developed, thus permitting a wide variety of applications. The numbers indicated by the setting TRIGGER POINT switch (17) correspond to the horizontal scale divisions so that trigger points can be easily checked on the scope.
The diagram below shows the −DELAY points indicated by the setting TRIGGER POINT switch (17).

When a trigger point indicated by the setting TRIGGER POINT switch (17) appears on the scale, the oscilloscope provides a negative delay of up to 9 div. When the −DELAY switch is "6" position, the memory waveform is as shown in Fig. 1.

**Note:**
When the −DELAY is set for one-shot signal observation, be sure to press the LEVEL (27) to NORMAL TRIGGER (PUSH) and then press write START (16)




The left 6 div waveform is memory waveform (600 words) before triggered. The right 4 div waveform is a memory waveform (400 words) after triggered.
The −DELAY setting switch is used in conjunction with the scale. When the − DELAY is set to 6, the trigger point is the 6th division from the left end of the scale.

Fig. 1

### Read-out to Pen Recorder

This oscilloscope permits any high speed traces to be stored in memory and converted into slow speed time base which a recorder is able to follow. Thus, it is possible to record a memory data in a recorder at a speed suitable to the recorder's response.
The standard readout speeds are 10ms/word, 20ms/word and 50ms/word but can be applied to 100ms/word, 200ms/word and 500ms/word by changing the connections of the jumper wire in control circuit board (Fig. 2).
To record a memory data in a pen recorder, perform the following procedures:

1. Operate the digital memory and write input signal in memory.
2. Set the DISPLAY MODE to DUAL or MEMORY. It may be set to REAL mode while the FREE RUN function is being used.
3. Connect the pen recorder to the MEMORY OUT FOR PEN.
4. Set the CLOCK to INT/PEN.
5. Depress the START, and the memory waveform is read out. The readout is completed at 1024 words and is set in the D/A conversion saturating point. To resume the readout, depress the START once again.

## OPERATION

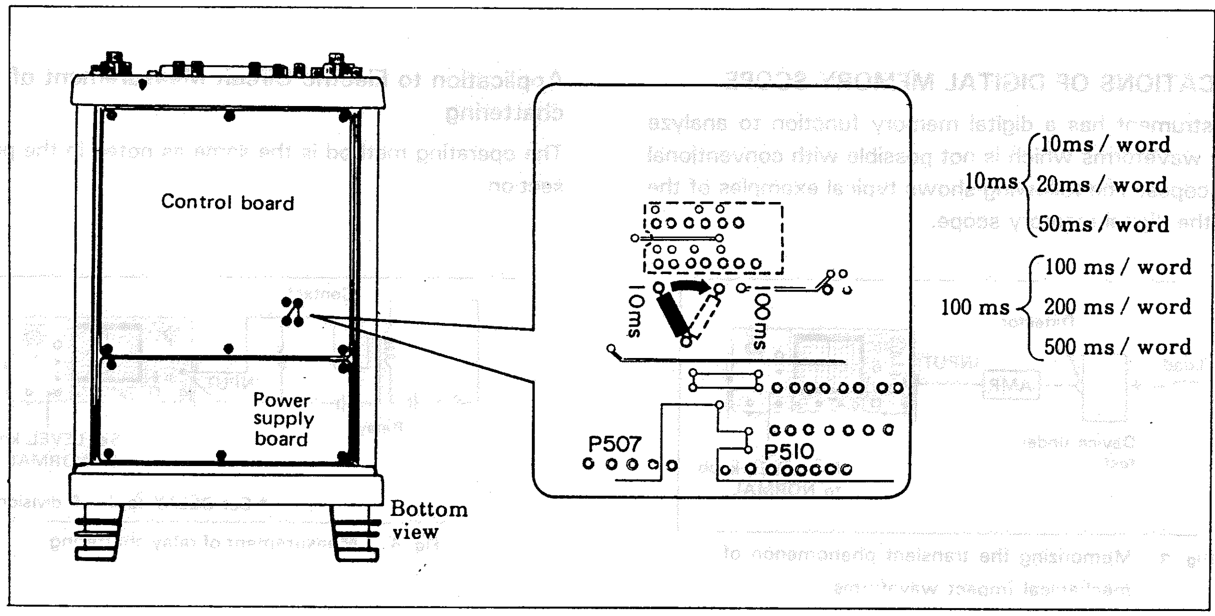



Fig. 2

### Measurement of Input Signal Voltage with Pen Recorder

To obtain input signal voltage V from the waveform recorded by the pen recorder, use the following equation:

$$V(v) = \frac{\text{Pen recorder input level (V/cm)} \times \text{Recorded amplitude (cm)}}{0.2\ \text{(V/div)}} \times \text{Write input level (V/div)}$$

### Measurement of Input Signal Time with Pen Recorder

To obtain write signal time T from the waveform recorded by the pen recorder, use the following equation:

$$T(\text{sec/cm}) = \frac{\text{Pen recorder feed speed (sec/cm)}}{\text{Readout speed (sec/div)}} \times \text{Write speed (sec/div)}$$

### FREE RUN function

This function is used to automatically repeat store and read operations. The period for which the input waveform data is stored in the memory can be varied from about 1 to 20 seconds with the DISPLAY TIME knob; this is convenient when it is necessary to observe consecutive phenomena without observer intervention.

By pulling the DISPLAY TIME knob (REAL position), the FREE RUN functions.

Depressing the DISPLAY TIME knob resets the free run function and sets the REAL mode.

Pressing and holding the write START button for one repetition of the store and read input waveform data cycle temporarily suspends the automatic free run function in the memory read state. Press and then pull the DISPLAY TIME knob, or set the DISPLAY MODE switch to the MEMORY (or DUAL) position, then to the REAL position to restart the automatic free run function.

**Note:**

The FREE RUN function will not always start by turning on the POWER switch with the DISPLAY TIME knob in the pull out position.

# APPLICATIONS

## APPLICATIONS OF DIGITAL MEMORY SCOPE

This instrument has a digital memory function to analyze various waveforms which is not possible with conventional oscilloscopes. The following shows typical examples of the use of the digital memory scope.

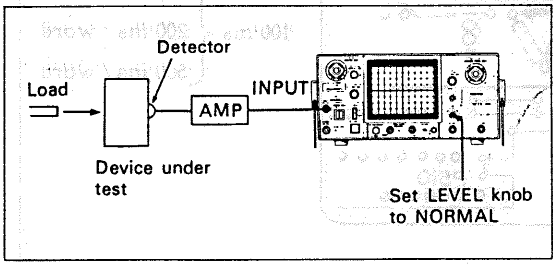



Fig. 3 . Memorizing the transient phenomenon of mechanical impact waveforms

### Setting of the Digital Memory Scope

1. Connect the detector to the device under test, then connect the output of the detector to the input of the scope through the amplifier so that the output level can be set to the input level of the scope.
2. Operation of the scope
   (1) Input Selector: Set to AC or DC position (set to either position according to the input signal being applied).
   (2) DISPLAY MODE: Set to REAL or DUAL position.
   Observe the signal from the device under test using the oscilloscope (REAL MODE) and set the input level, trigger point and sweep speed as shown below.

**LEVEL knob:** NORMAL — The input signal is swept once and stops.

**Vertical attenuator (VOLTS/DIV):** Any position.

**SWEEP TIME/DIV:** Any position between 0.1 s and 0.1 ms.

**CLOCK:** INT

**SCOPE PEN:** SCOPE

**TRIGGER POINT (−DELAY/DIV):** This digital switch is used to record a signal prior to triggering and should be set to 0 — 9 div.

3. After setting the above switches, turn the START switch to ON. The WRITE LED (red) will light to indicate that the input signal is in standby mode. The signal is now ready to be memorized.
4. Next, apply the signal from the device under test to the detector. Test the data. When the output level of the detector reaches the value set by the TRIG LEVEL, the signal from that point is stored in the memory.
5. To check the waveform being stored, set the DISPLAY MODE switch to DUAL or MEMORY position.

## Application to Electric Circuit Measurement of relay chattering

The operating method is the same as noted in the previous section.

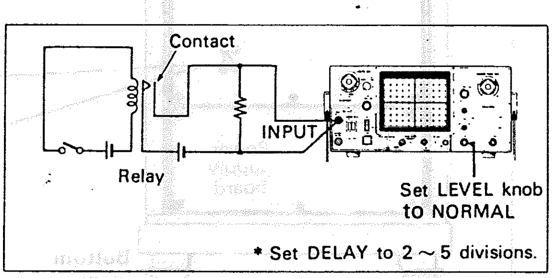



Fig. 4. Measurement of relay chattering

## Data recording with pen recorder

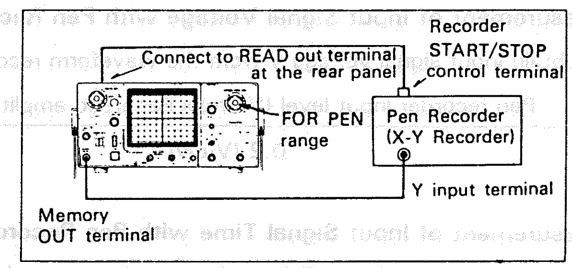



Fig. 5. Data recording with pen recorder

To record memory data with pen recorder (X-Y recorder), make connection as shown in Fig. 7 and operate the scope as follows:

1. Change the position of the CLOCK mode switch from SCOPE to PEN (Set the CLOCK to INT and the DISPLAY MODE to DUAL or MEMORY). It may be set to REAL while the FREE RUN function is on.
2. Set the PEN SPEED knob to either the 10, 20 or 50 ms position.
3. Depress the START (memory data is outputted word by word).

**Note**

If the pen recorder has an external START/STOP control terminal, the timing pulse output is obtained from the READ OUT FOR PEN terminal (BNC) at the rear panel. The START signal is outputted in GND level.

To obtain the amplitude cycle of input signal from the waveform recorded by the pen recorder, refer to the section "Operation".

# APPLICATIONS

## Readout from external CLOCK

When the scope is operated with external CLOCK, it functions only as a readout scope and does not function as a write-in scope. The readout function is useful when observing a magnified waveform (magnified to HOR×5 MAG). In this case, the SWEEP TIME/DIV is disabled so the waveform display remains the same, except that the sweep speed is varied. It is also used to read out the MEMORY OUT signal to an external device at a speed other than the scope's readout speed (INT CLOCK), or to transfer the data word by word by connecting digital output, to the external device (see Fig. 6).

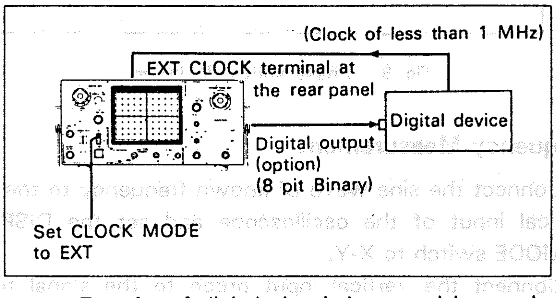



Fig. 6. Transfer of digital signal data word by word to another digital device using external clock

## APPLICATIONS OF OSCILLOSCOPE OPERATING

### Phase Measurement

Phase measurements may be made with an oscilloscope. Typical applications are in circuits designed to produce a specific phase shift, and measurement of phase shift distortion in audio amplifiers or other audio networks. Distortions due to non-linear amplification is also displayed in the oscilloscope waveform.

A sine wave input is applied to the audio circuit being tested. The same sine wave input is applied to the vertical input of the oscilloscope, and the output of the tested circuit is applied to the horizontal input of the oscilloscope. The amount of phase difference between the two signals can be calculated from the resulting Lissajous' waveform. To make phase measurements, use the following procedures (refer to Fig. 7).

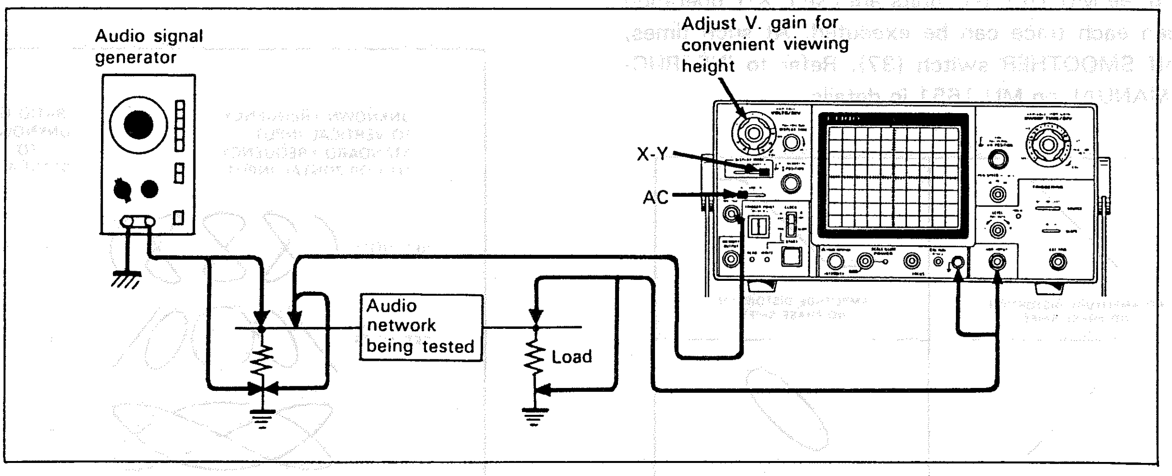



Fig. 7 Typical phase measurement

# APPLICATIONS

1. Using an audio signal generator with a pure sinusoidal signal, apply a sine wave test signal to the audio network being tested.
2. Set the signal generator output for the normal operating level of the circuit being tested. Observe the circuit's output on the oscilloscope and if the test circuit is overdriven, the sine wave display is clipped and the signal level must be reduced.
3. Connect the HOR. INPUT to the output of the test circuit.
4. Set the DISPLAY MODE to X-Y.
5. Connect the probe to the input of the test circuit.
6. Adjust the vertical and horizontal gain controls for a suitable viewing size.
7. Some typical results are shown in Fig. 8. If the two signals are in phase, the oscilloscope trace is a straight line. If the vertical and horizontal gain are properly adjusted, this line is at 45° angle. A 90° phase shift produces a circular oscilloscope pattern. Phase shift of less (or more) than 90° produces an elliptical Lissajous' pattern. The amount of phase shift can be calculated by the method shown in Fig. 9.
   When, in particular, the MU-1651 memory unit is connected and its MEMORY OUT is applied to HOR INPUT, the phase of two memorized waveforms can be calculated.
   When three MU-1651(-T) units are used, X-Y operation between each trace can be executed. At such times, turn off SMOOTHER switch (37). Refer to INSTRUCTION MANUAL on MU-1651 in details.

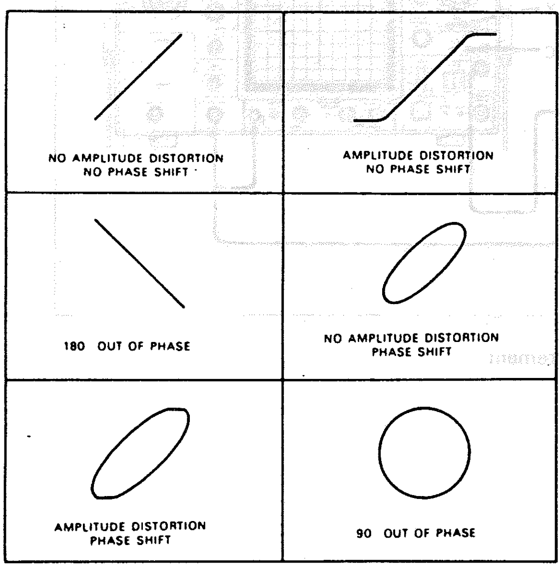



Fig. 8. Typicl phase measurement oscilloscope displays

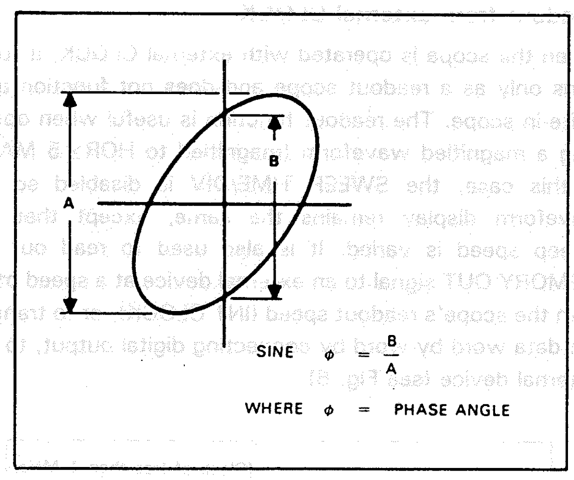



Fig. 9. Phase shift calculation

## Frequency Measurement

1. Connect the sine wave of known frequency to the vertical input of the oscilloscope and set the DISPLAY MODE switch to X-Y.
2. Connect the vertical input probe to the signal to be measured.
3. Adjust the vertical input and horizontal input for proper sizes.
4. The resulting Lissajous' pattern shows the ratio between the two frequencies (see Fig. 10).

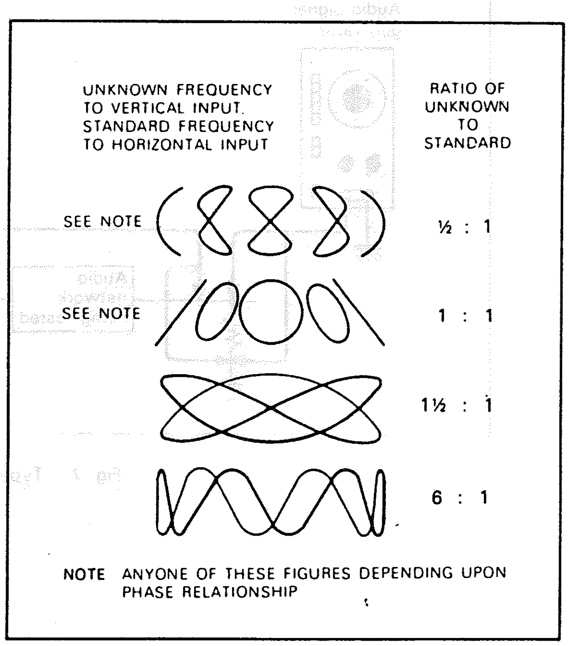



Fig. 10. Lissajous' waveforms used for frequency measurement

# APPLICATIONS

## Amplifier Square Wave Test

### Introduction

A square wave generator and the oscilloscope can be used to observe various types of distortion present in electric circuits. A square wave of a given frequency contains a large number of odd harmonics of that frequency. If a 500 Hz square wave is injected into a circuit, frequency components of 1.5 kHz, 2.5 kHz and 3.5 kHz are also provided. Since vacuum tubes and transistors are non-linear, it is difficult to amplify and reproduce a square wave which is identical to the input signal. Inter electrode capacitances, junction capacitances, stray capacitances as well as narrow band devices and transformer response are the factors which prevent faithful response of a square wave signal. A welldesigned amplifier can minimize the distortion caused by these limitations. Poorly designed or defective amplifiers can introduce distortion to the point where their performance is unsatisfactory. As stated before, a square wave contains a large number of odd harmonics. By injecting a 500 Hz sine wave into an amplifier, we can evaluate amplifier response at 500 Hz only, but by injecting a square wave of the same frequency we can understand how the amplifier would response to input signals from 500 Hz up to the 15th or 21st harmonic.

The need for square wave evaluation becomes apparent if we realize that some audio amplifiers will be required during normal use to pass simultaneously a large number of different frequencies. With a square wave, we can evaluate the quality of input and output characteristics of a signal containing a large number of frequency components such as complex waveforms of musical instruments or voices.

The square wave output of the signal generator must be extremely flat. The oscilloscope vertical input should be set to DC as it will introduce the least distortion, especially at low frequencies. Because of the harmonic content of the square wave, distortion will occur before the upper end of the amplifier bandpass.

It should be noted that the actual response check of an amplifier should be made using a sine wave signal. This is especially important in an limited bandpass amplifier such as a voice amplifier.

The square wave signal provides a quick check of amplifier performance and will give an estimate of overall amplifier quality. The square wave also will reveal some deficiencies not readily apparent when using a sine wave signal. Whether a sine wave or square wave is used for testing the amplifier, it is important that the manufacturer's specifications on the amplifier are based on in order to make a better judgement of its performance.

### Testing Procedure (refer to Fig. 11):

1. Connect the output of the square wave generator to the input of the amplifier being tested.
2. Connect the vertical input probe of the oscilloscope to the output of the amplifier.
3. If the DC component of the amplifier output is low, set the AC-GND-DC switch to DC position to allow both the AC and DC components to be viewed. However, the AC position may be used to observe the AC component only, though this will reduce the audio frequency content of less than 5 Hz.
4. Adjust the vertical gain controls for a convenient viewing height.
5. Adjust the sweep time controls for one cycle of square wave display on the screen.
6. For a close-up view of a portion of the square wave, use the X5 magnification.

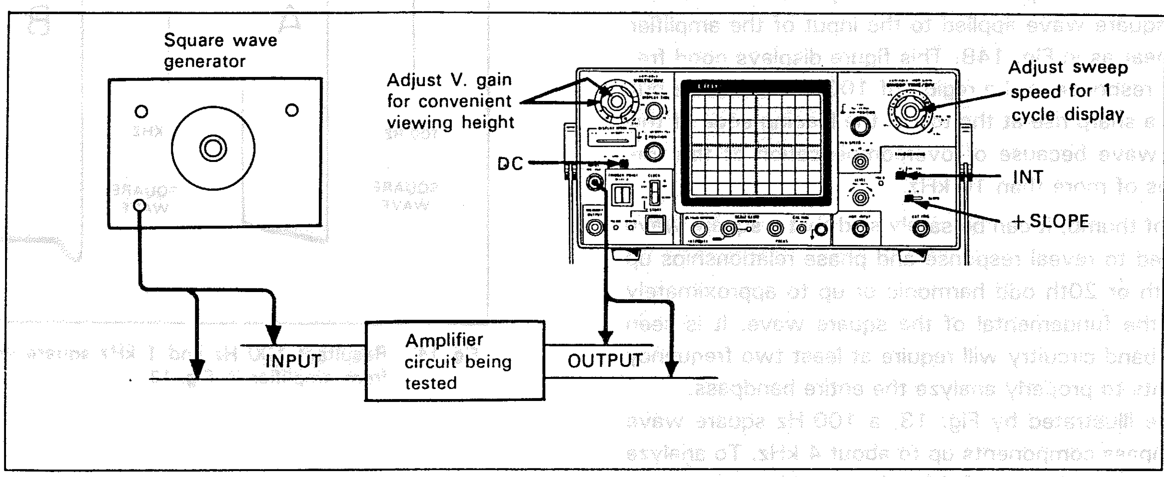



Fig. 11. Equipment set-up for square wave testing of amplifiers

# APPLICATIONS

**Analysing the Waveforms:**

The short rise time which occurs at the beginning of the half-cycle is created by the in-phase sum of the medium and high frequency sine wave components. The same holds true for the drop time. The reduction in high frequency components should produce a rounding of the square corners at all four points of one square wave cycle (see Fig. 12).

Distortion can be classified into the following three categories:

1. The first is frequency distortion and refers to the change in the amplitude of a complex waveform. In other words, the introduction in an amplifier circuit of resonant networks or selective filters created by combination of reactive components will create peaks or dips in an otherwose flat frequency response curve.
2. The second is non-linear distortion and refers to a change in waveshape produced by application of the waveshape to non-linear elements such as vacuum tubes, an iron core transformer or a clipper network.
3. The third is delay or phase distortion, which is distortion produced by a shift in phase between some components of a complex waveform.

   In actual practice, a change in amplitude of a square wave component is usually caused by a frequency selective network which includes capacity, inductance or both. The presence of the C or L introduces a difference in phase angle between components, creating phase distortion or delay distortion. Therefore, in square wave testing of practical circuitry, we will usually find that the distorted square wave includes a combination of amplitude and phase distortions.

   In a typical wide band amplifier, a square wave check reveals many distortion characteristics of the circuit. The response of an amplifier is indicated in Fig. 13, revealing poor low-frequency response along with the overcompensated high-frequency boost. The response of 100 Hz square wave applied to the amplifier will appear as in Fig. 14A. The figure indicates satisfactory medium frequency response (approximately 1 kHz to 2 kHz) but shows poor low frequency response. Next, a 1 kHz square wave applied to the input of the amplifier will appear as in Fig. 14B. This figure displays good frequency response in the region of 1000 to 4000 Hz but reveals a sharp rise at the top of the leading edge of the square wave because of overcompensation at the frequencies of more than 10 kHz.

As a rule of thumb, it can be safely said that a square wave can be used to reveal response and phase relationships up to the 15th or 20th odd harmonic or up to approximately 40 times the fundamental of the square wave. It is seen that wide-band circuitry will require at least two frequency check points to properly analyze the entire bandpass.

In the case illustrated by Fig. 13, a 100 Hz square wave will encompass components up to about 4 kHz. To analyze above 4 kHz and beyond 10,000 Hz, a 1 kHz square wave should be used.

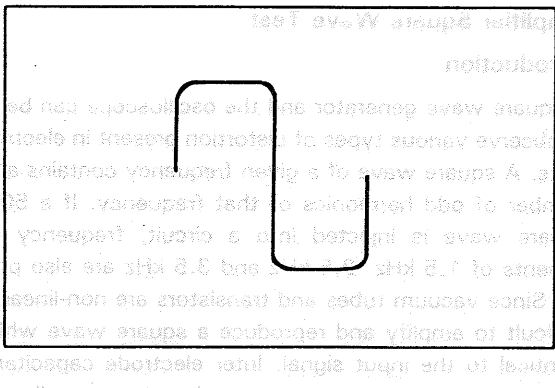


Fig. 12. Square wave response with high frequency loss

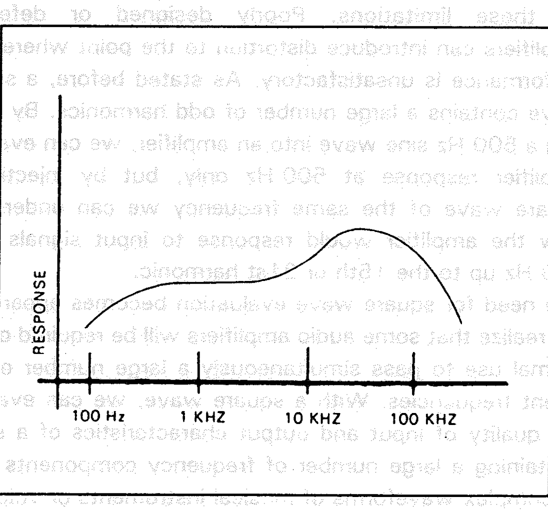



Fig. 13. Response curve of amplifier with poor low and high ends

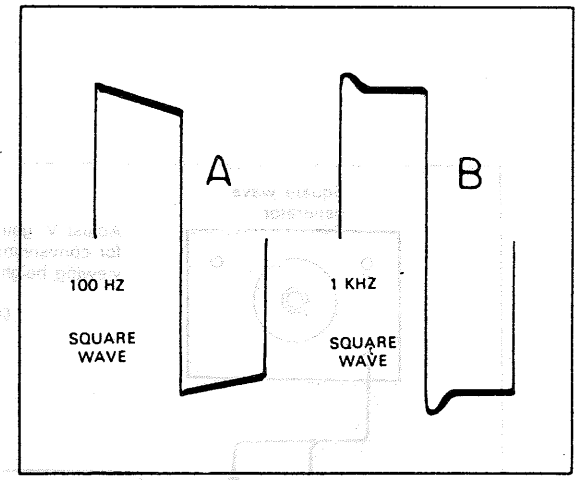



Fig. 14. Resultant 100 Hz and 1 kHz square waves from amplifier in Fig. 13.

# APPLICATIONS

Now, the region between 100 Hz and 400 Hz in Fig. 13 shows a rise from poor low-frequency (1000 Hz to 1 kHz) response to a flattening out from beyond 1000 and 4000 Hz. Therefore, we can expect that the higher frequency components in the 100 Hz square wave will be relatively normal in amplitude and phase but that the low-frequency components "B" in this same square wave will be modified by the poor low-frequency response of this amplifier (see Fig. 14A).

If the amplifier were such as to only depress the low frequency components in the square wave, a curve similar to Fig. 15 would be obtained. However, reduction in amplitude of the components is ususally caused by a reactive element, causing, in turn, a phase shift of the components, producting the tilt as shown in Fig. 14A.

Fig. 16 reveals a graphical development of a similarly tilted square wave. The tilt is seen to be caused by the strong influence of the phase-shifted 3rd harmonic. It also becomes evident that very slight shifts in phase are quickly shown up by tilt in the square wave. Fig. 17 indicates the tilt in square wave produced by a 10° phase shift of a low-frequency element in a leading direction. Fig. 18 indicates a 10° phase shift in a low-frequency component in a lagging direction. The tilts are opposite in the two cases because of the difference in polarity of the phase angle in the two cases as can be checked through algebraic addition of components.

Fig. 19 indicates low-frequency components which have been reduced in amplitude and shifted in phase. It will be noted that these examples of low-frequency distoriton are characterized by change in shape of the flat portion of the square wave.

Fig. 14B shows a high-frequency overshoot produced by rising amplifier response at the high frequencies. It should again be noted that this overshoot makes itself evident at the top of the leading edge of the square wave. The sharp rise of the leading edge is created by the summation of a large number of harmonic components. If an obnormal rise in amplifier response occurs at high frequencies, the high frequency components in the square wave will be amplified larger than the other components creating a higher algebraic sum along the leading edge.

Fig. 20 indicates high-frequency boost in an amplifier accompanied by a lightly damped "shock" transient. In this case, the sudden transition in the square wave potential from a sharply rising, relatively high frequency voltage, to a level value of low-frequency voltage, supplies the energy for oscillation in the resonant network. If this network in the amplifier is reasonably heavily damped, then a single cycle transient oscillation may be produced as indicated in Fig. 21.

Fig. 22 summarizes the preceding explanations and serves as handy reference.

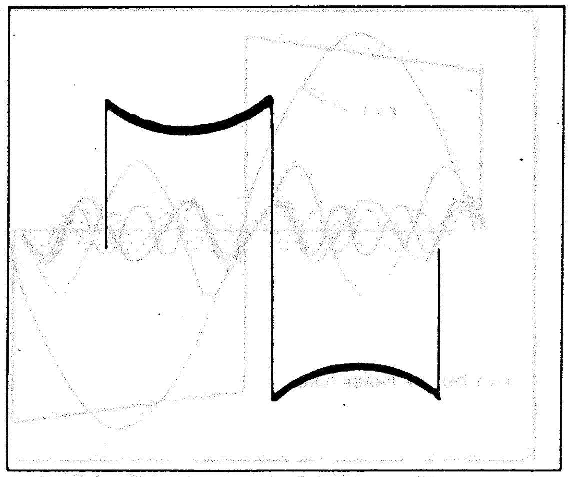


Fig. 15. Reduction of square wave fundamental frequency component in turned circuit

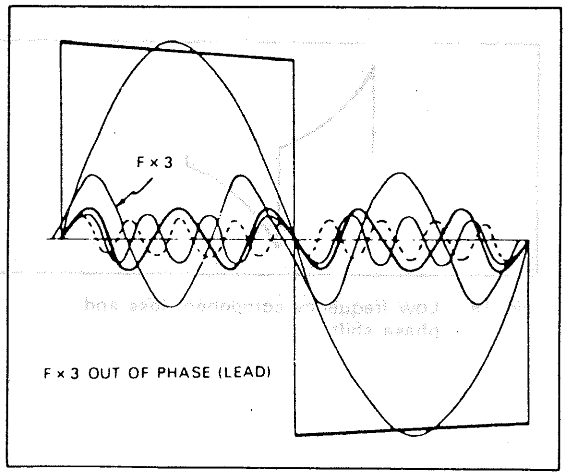



Fig. 16. Square wave tilt resulting from 3rd harmonic phase shift

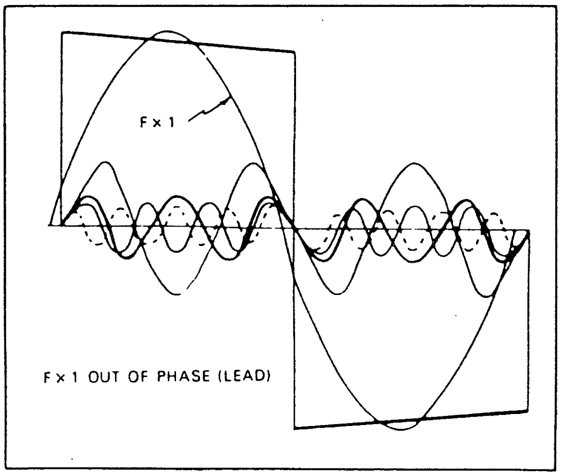



Fig. 17. Tilt resulting from phase shift of fundamental frequency in a leading direction

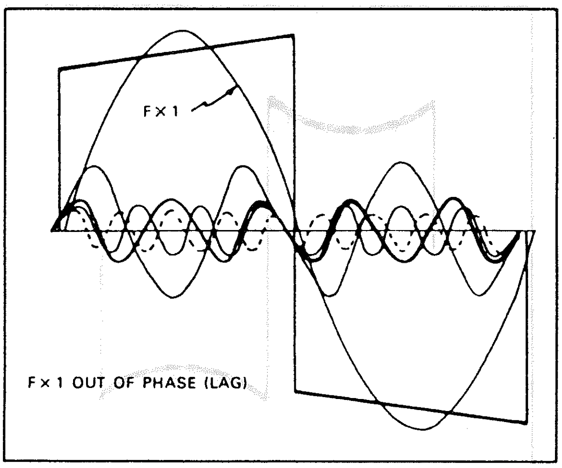



Fig. 18 Tilt resulting from a phase shift of fundamental frequency in a lagging direction

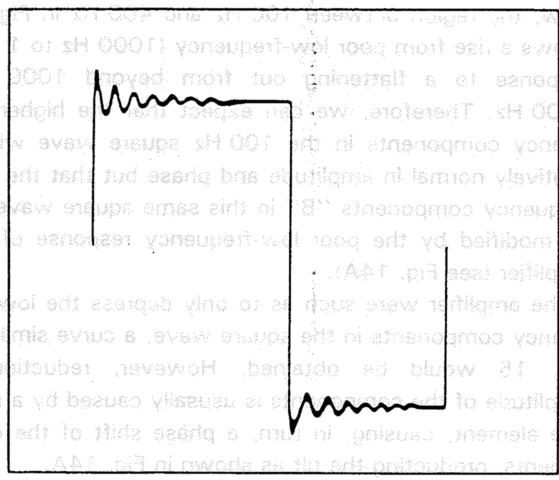


Fig. 20. Effect of high-frequency boost and poor damping

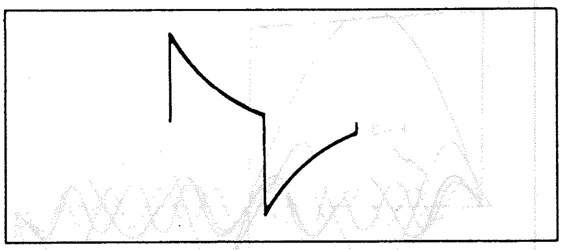


Fig. 19. Low frequency component loss and phase shift

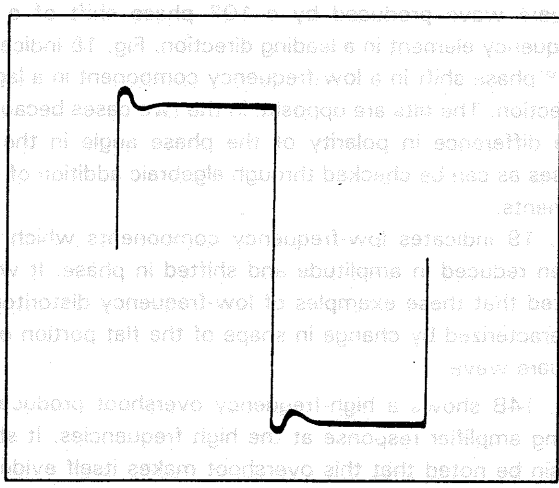
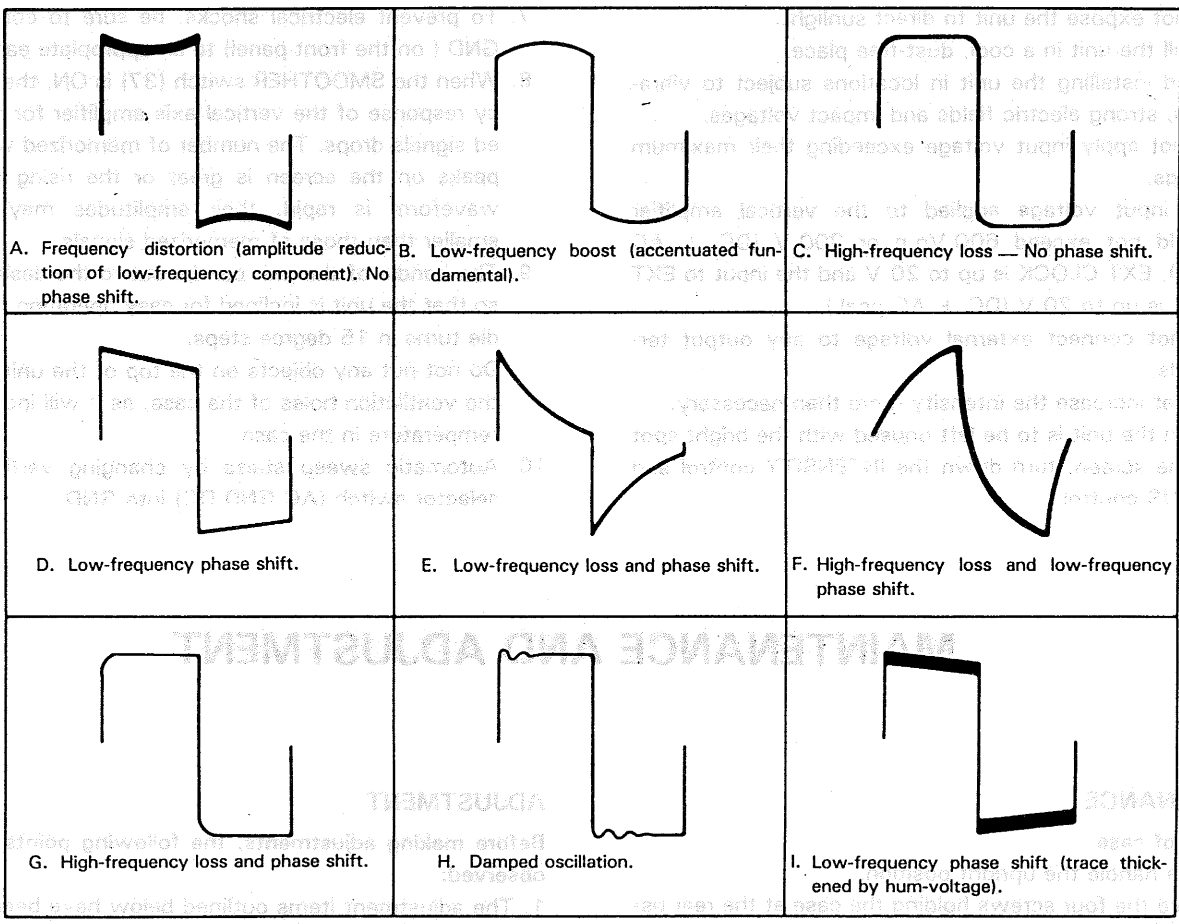


Fig. 21. Effect of high-frequency boost and good damping

# APPLICATIONS



A. Frequency distortion (amplitude reduction of low-frequency component). No phase shift.

B. Low-frequency boost (accentuated fundamental).

C. High-frequency loss — No phase shift.

D. Low-frequency phase shift.

E. Low-frequency loss and phase shift.

F. High-frequency loss and low-frequency phase shift.

G. High-frequency loss and phase shift.

H. Damped oscillation.

I. Low-frequency phase shift (trace thickened by hum-voltage).

Fig. 22. Summary of waveform analysis for square wave testing amplifiers

## PRECAUTIONS

When input signal contains the element of one half or less of the sampling frequency (at 10 m sec/div, 10 kHz by 0.1 m sec, or 1/100 of 10 m sec), even though this is in the critical range in use, a phenomena (Aliasing) will occur by which as if some element other than input signal, which in fact does not exist, is indicated in the frequency range of one half or less of the sampling frequency.

# PRECAUTIONS

1. Do not expose the unit to direct sunlight.
2. Install the unit in a cool, dust-free place.
3. Avoid installing the unit in locations subject to vibrations, strong electric fields and impact voltages.
4. Do not apply input voltage exceeding their maximum ratings.
   The input voltage applied to the vertical amplifier should not exceed 600 Vp-p or 300 V (DC + AC peak), EXT CLOCK is up to 20 V and the input to EXT TRIG is up to 20 V (DC + AC peak).
   Do not connect external voltage to any output terminals.
5. Do not increase the intensity more than necessary.
6. When the unit is to be left unused with the bright spot on the screen, turn down the INTENSITY control and FOCUS control.
7. To prevent electrical shocks, be sure to connect the GND ( on the front panel) to an appropiate earth point.
8. When the SMOOTHER switch (37) is ON, the frequency response of the vertical axis amplifier for memorized signals drops. The number of memorized waveform peaks on the screen is great or the rising speed of waveform is rapid, their amplitudes may become smaller than those of memorized signals.
9. The handle of the unit can be set to the desired angle so that the unit is inclined for easy operation. The handle turns in 15 degree steps.
   Do not put any objects on the top of the unit or cover the ventilation holes of the case, as it will increase the temperature in the case.
10. Automatic sweep starts by changing vertical input selector switch (AC-GND-DC) into GND.

# MAINTENANCE AND ADJUSTMENT

## MAINTENANCE

### Removal of case

1. Lift the handle the upright position.
2. Remove the four screws holding the case at the rear using a Philips type screwdriver.
3. Push the rear panel and the unit can be removed from the case.

### Caution

High voltage of up to 2000V is present at the CRT socket, power supply circuit board and FOCUS control. To prevent electrical shock, be sure to turn off the power when removing the case. Special care should be used not to touch the high voltage circuits after the case has been removed.

### Voltage Conversion

(1) The unit is factory adjusted to operate on 240 V AC. When the unit is to be operated from 100 V, 120 V or 220 V, be sure to change the connection of the voltage selector plug at the rear panel observing the arrow mark provided on the plug. For operation on 100 or 120 V, replace the fuse with one of 1.5 A rating.
For operation on 120 V, plug the voltage selector to 117 V position.

(2) Fuse is fitted in the fuse holder at the rear panel.

## ADJUSTMENT

**Before making adjustments, the following points must be observed:**

1. The adjustment items outlined below have been factory aligned prior to shipment. If readjustments become necessary, make certain that the power supply voltage is properly calibrated (except for adjustment of probe).
2. **Adjustments can be made by the semi-fixed resistors and trimmers. Use a well insulated flat blade screwdriver.**
3. High voltage (about 2000 V) is present on the POWER SUPPLY circuit. Be sure to turn off the power before removing the circuit boards.
4. To insure optimum results, warm up the unit for more than about 30 minutes before making adjustments.

### DC BAL Adjustment

1. DC BAL (1) adjustment
   If the trace moves up or down at particular ranges when the vertical attenuator (VOLTS/DIV) is turned, perform the following adjustment.
   (1) Set the DISPLAY MODE to REAL and the input selector switch (AC-GND-DC) to GND, then set the trace in the center of the scale.
   (2) Turn the vertical attenuator VARIABLE fully counterclockwise and adjust the STEP BAL VR so that the trace is stationary at all ranges when the VOLTS/DIV is turned.

# MAINTENANCE AND ADJUSTMENT

2. DC BAL (2) adjustment
   If the trace moves up or down at particular ranges when the vertical attenuator VARIABLE is turned, perform the following adjustment.
   (1) With the VARIABLE turned fully counterclockwise, set the trace in the center of the scale. Next, turn the VARIABLE fully clockwise. If, at this time, the trace moves up or down, adjust the VAR BAL VR until it is centered.
   (2) Repeat the above steps so that the trace stays still when the VARIABLE is turned.

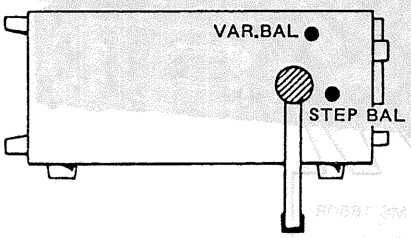



Fig. 23 DC BAL adjutment

**Vertical Attenuator Adjustment (VOLTS/DIV)**

(1) Using a square wave generator, apply 1kHz 0.5-100Vp-p signal to the vertical input terminal.
(2) Set the VOLTS/DIV to 0.1V and adjust the trimmer TC202 until high quality of square wave is obtained.
(3) Similarly, adjust the TC204 for the 1V range and the TC206 for the 10V range.

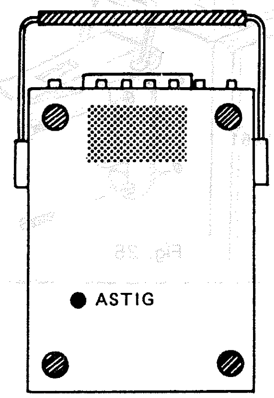



Fig. 24

# OPTION

## COMBINATION MS-1650B TO MU-1651 WITH JOINER (CZ-84)

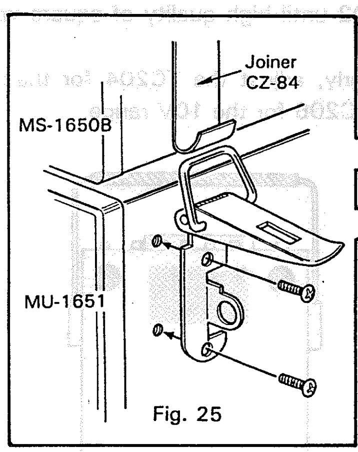
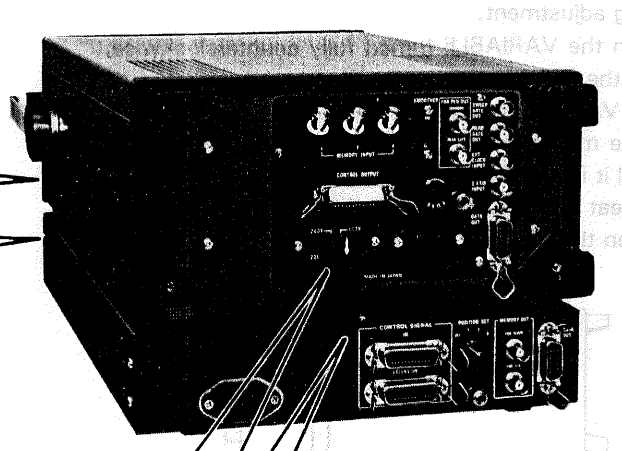



Fig. 25



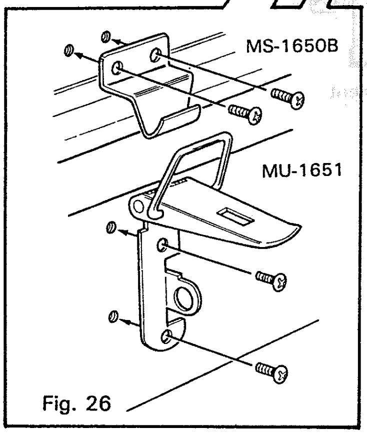



Fig. 26

## INSTALLATION OF ACCESSORY BAG (MC-78)

1. The unit can be installed accessory bag (MC-78, option). Detach the hock and separate the accessory bag and retainer plate.
2. When viewed from the front, align the four case right side holes with those of retainer plate and fix the retainer plate with 4 nylon rivets and 4 washers.
   At this time, confirm that the retainer plate is installed grommet and insert the plunger.
3. Cannot remove the case while installing the accessory bag. When removing the case, be sure to remove the accessory bag.

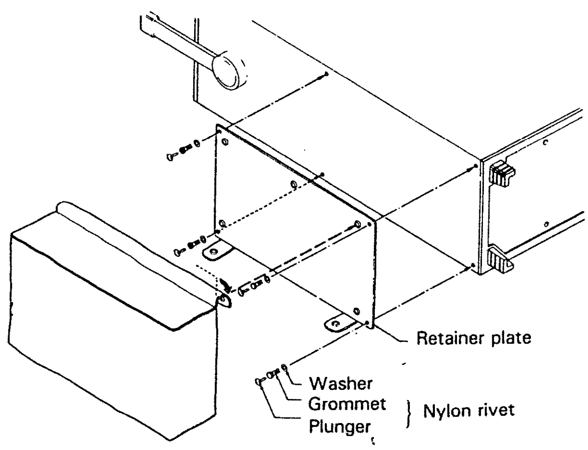



Fig. 27

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