MS-1650

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 proir to triggering, instantaneous signals, transient waveforms and repetitive waveforms.

1. Instantaneous signals, transient waveforms, and repetitive waveforms can be stored in the memory for displaying on the CRT.
2. Semiconductor memory circuit having memory ability of 8 bits × 1024 words and write speed up to 1 μs/word.
3. 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.
4. −DELAY function is provided to store signals prior to triggering in the memory which is not possible with conventional oscilloscopes.
5. Memory signals are readily displayed on the built-in CRT or recorded in a pen recorder.
6. Real time waveform being displayed on the CRT can be stored in the memory, thus providing simplified operation.
7. Both the real time waveform and memory signal can be displayed simultaneously, permitting you to compare one signal with the other.
8. By using alkaline battery (option), the memory data can be retained for many hours even when the power cord is disconnected. Battery charge terminal is also provided.
9. Signals synchronized with power frequency can be displayed or stored in the memory.
10. The oscilloscope can be used as a X-Y scope by simply setting the DISPLAY MODE switch to the X-Y position.
11. Large sized, square CRT displays waveforms over the entire area of the screen.
12. Rigid construction with die casing front panel and compact design.

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SPECIFICATIONS

Cathode Ray Tube

Type
E2713B31

Acceleration voltage
Approx. 2 kV

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

Vertical Axis

Sensitivity
10 mV/div — 20V/div, ±5%

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

Input impedance
1 MΩ, ±5%
22pF, ±4pF

Frequency response

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

Rising time:
35 ns (Oscilloscope operation)

Overshoot
3% or less (at 100 kHz square wave)

Maximum input voltage
600 Vp-p or 300V (DC + AC peak)

Operating mode

REAL:	Oscilloscope operation
DUAL:	Real time and memory waveforms, dual trace operation (500 kHz CHOP)
MEMORY:	Memory waveform readout
X-Y:	X-Y scope operation

A/D Converter

Resolution
8 bits

Convertion system
Successive comparision A/D converter

Scale-over
8 div vertical scale

Sweep Circuit

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

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

Magnifier
5 MAG ±10%

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

Sync Circuit

Sync input

INT:	Vertical input
LINE:	Line input
EXT:	EXT TRIG input

Polarity
Positive and negative

Sync voltage

INT:	More than 1 div of amplitude on CRT
LINE:	More than 1 div of amplitude on CRT.
EXT:	More than 1 Vp-p

Sync frequency

INT:	20 Hz — 10 MHz
EXT:	DC — 10 MHz

External sync input voltage
20V (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
50V (DC + AC peak)

Memory Unit

Memory capacity
1024 words (100 words/div)

Write speed
0.1 ms/div — 1s/div, 13 ranges (equivalent to 1μs/word — 10 ms/word)

Readout speed
SCOPE: Same as write speed

PEN: 100ms/word, 200ms/word, 500ms/word, 3 ranges (Switchable to 10ms/word, 20ms/word, 50ms/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 more than 500 ns
Low level: Pulse width more than 500 ns
Rising time, Within 500 ns
Input voltage
TTL level
Maximum input voltage
20V (DC + AC peak)
Input impedance
Approx. 30 kΩ

Delay

— DELAY (0-9 div, DIG SW setting)

Signal Output

MEMORY OUT

Output wave: Memory wave
Output voltage: 1.6 Vp-p, full scale (at 8 div)
Output impedance: Approx. 470Ω

READ GATE

Output wave: Positive pulse (1 word) of final address
Output voltage: TTL level
Output impedance: Approx. 1 kΩ

SWEEP GATE

Output wave: Positive pulse synchronized with sweep signal
Output voltage: TTL level
Output impedance: Approx. 1 kΩ

CAL (Calibrating voltage)

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

Intensity Modulation

Input voltage

TTL level (Possitive voltage increases brightness)

Input impedance

Approx. 15 kΩ

Input frequency

DC — 1 MHz

Maximum input voltage

50V (DC + AC peak)

Power Requirement

Voltage

100/120/220/240V, ±10%

Power consumption

Approx. 50W

Dimensions

Width

284 mm (328 mm)

Height

138 mm (153 mm)

Depth

400 mm (463 mm)

Figures in ( )show maximum size

Weight

Approx. 9 kg

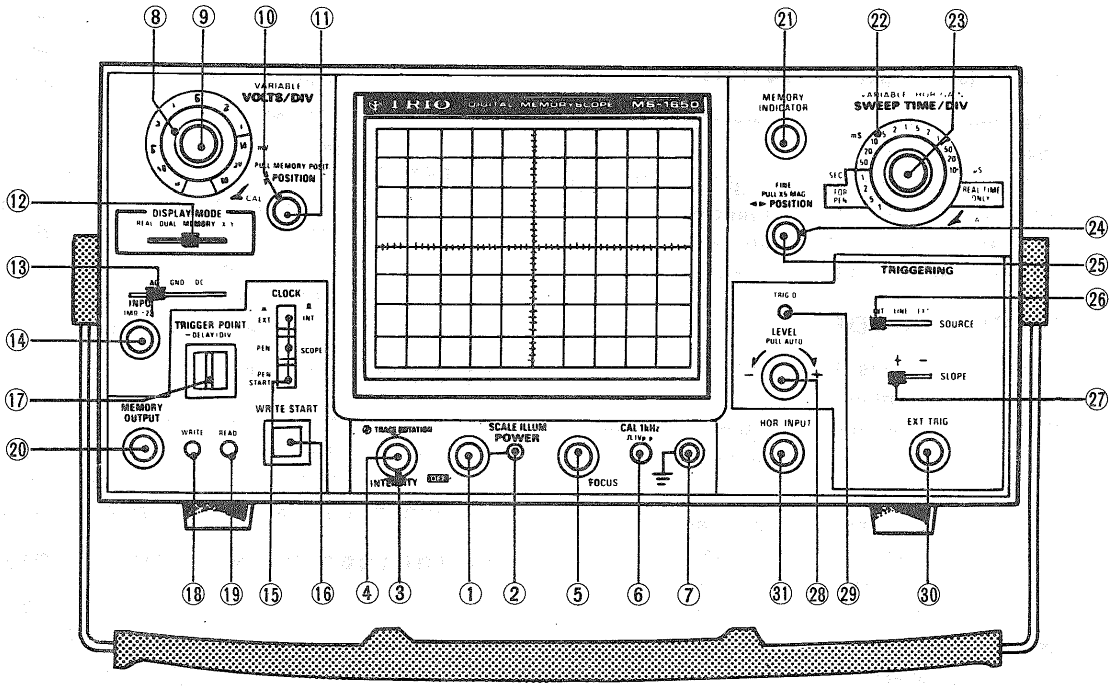
Accessory

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

Option

Backup battery	Alkaline battery (UM3 × 3)
DATA OUT	8 bit Binary output terminal

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

4. TRACE ROTATION

This 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 input 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

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

10. ▲▼ POSITION

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

11. PULL MEMORY POSITION

CAL switch and memory waveform vertical position adjuster.
Pull the knob and turn to right or left. The trace will shift by 1 div. Depress the knob and the trace is set in CAL mode to indicate the vertical position read in the memory.

12. DISPLAY MODE

This switch selects the modes of vertical and horizontal operations.

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

DUAL: Real time waveform and memory waveform can be observed by 500 kHz CHOP operation. Memory write and readout functions.

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 (28).

14. INPUT

Vertical input terminal.

15. CLOCK

INT/EXT: Clock selector switch. EXT position is used for readout only. Clock signal is inputted to EXT CLOCK (34) terminal. In this position, the waveform on the scope cannot be synchronized. INT position is used for write and readout. There are two funcitons, SCOPE and PEN (readout only).

SCOPE/PEN: Memory readout mode selector switch. In SCOPE position, readout to the scope is effected repeatedly.

In PEN position, readout to MEMORY OUT termianl is effective each time PEN START is depressed. For write mode, use the SCOPE position.

PEN START: To use this switch, set the SCOPE/PEN switch to PEN and the SWEEP TIME/DIV to FOR PEN. The memory data from the initial address to the final address are read out once by pressing this switch.

16. WRITE 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 0.1ms-1s.

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.
For —DELAY operation, push LEVEL (28) switch.

18. WRITE (LED)

Lights while input signal is being written in memory.

19. READ (LED)

Lights while memory data is being read out.

20. MEMORY OUT

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

21. MEMORY INDICATOR

Backup power check indicator (option). If it stays in the blue zone when the MEMORY BATT switch (36) at the rear panel is set to ON (power off), it means that the data is stored in memory.
When the power is ON, the indicator glows with blue regardless of the position of the MEMORY BATT switch.

22. SWEEP TIME/DIV

Horizontal sweep time selector. It selects sweep times of $1\mu s$ to 1s in 19 steps. The $1\mu s$-$50\mu s$ range is used for real time. The 0.1s-0.5s range (FOR PEN) is used to select the readout speed in PEN mode, where 0.1s, 0.2s and 0.5s represent 100ms/word, 200ms/word and 500ms/word, respectively.

23. VARIABLE HOR. GAIN

Used for fine adjustment of sweep time. Continuous adjustment between 19 ranges of SWEEP TIME/DIV (22) 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/TIM DIV. control.

24. ◀▶ POSITION

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

25. 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 left and right directions. Brightness is slightley decreased.
Input signal stored in the memory is not magnified even in the X5MAG position.

26. 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.

27. 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.

28. 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 flyback line 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.

29. TRIG'D

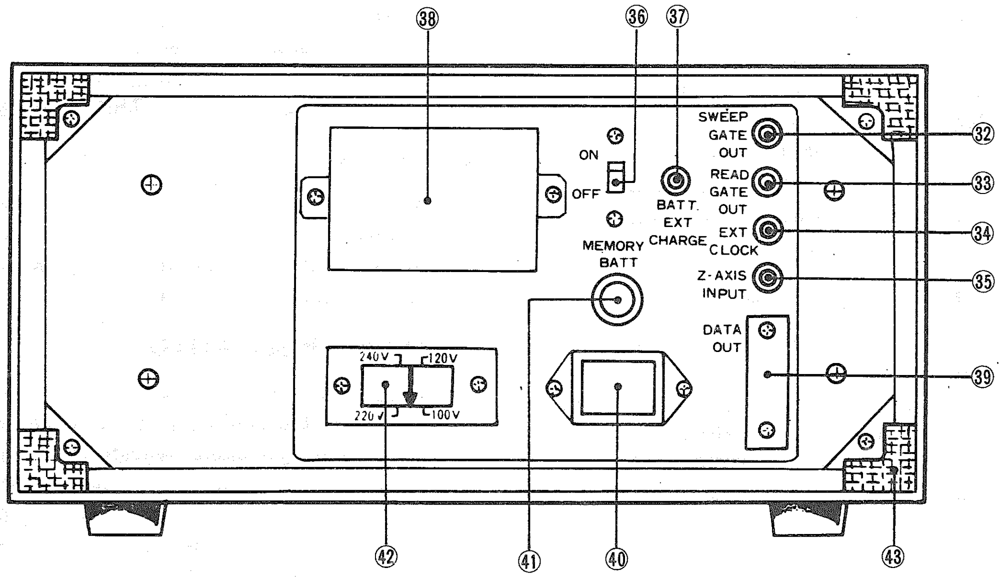
Sync indicating lamp lights when sync signal is triggered. Check this lamp lights when writing input singal to memory.
The lamp may light in the GND position of the AC-GND-DC. This is normal and is not an indication that the unit is defective.

30. 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.

31. HOR INPUT

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



CONTROLS ON REAR PANEL

32. SWEEP GATE OUT

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

33. 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.

34. EXT CLOCK

Input terminal for external clock used for readout only.

CLOCK switch (15) should be set to EXT.

35. Z-AXIS INPUT

Intensity modulation terminal. Intensity is modulated at TTL level.

36. MEMORY BATT

Memory backup battery selector switch (ON-OFF). Turn ON the switch to hold the memory data at power OFF. When backup battery is not used, this switch should be set to OFF.

37. BATT. EXT

Backup battery charging terminal.

A pin in the center is minus. The battery is fully charged in about 4.5 hours at DC 7V or in about 6 hours at DC 6V. Use a power source of more than 200 mA, to charge the battery. By using battery fully charged, memory waveform is stored for 500 hours. For quick charging, set the POWER switch to OFF.

38. BATTERY CASE

Backup battery case for loading optional alkaline battery (UM3 × 3). The battery is charged at power ON.

39. DATA OUT

This is a place to mount the memory data output terminal.

Output terminal for memory data (option).

40. POWER CONNECTOR

For connection of accessory power cord.

41. FUSE HOLDER

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

42. POWER VOLTAGE SELECTOR

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

43. CORD REEL

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

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	20V
9. VARIABLE	Full clockwise
10. ⇕ POSITION	Center
12. DISPLAY MODE	REAL
13. AC-GND-DC	GND
22. SWEEP TIME/DIV	1ms
23. VARIABLE	Full clockwise
24. ◂▸ POSITION	Center
25. FINE PULL × 5 MAG	Center (PUSH)
26. SOURCE	INT
27. SLOPE	+
28. LEVEL	Center (PULL) AUTO

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. When 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 (28). By pushing the LEVEL knob, the auto function is released. The waveform disappears when the knob is turned clockwise or counter-clockwise 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 0.01V 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 0.2V 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.

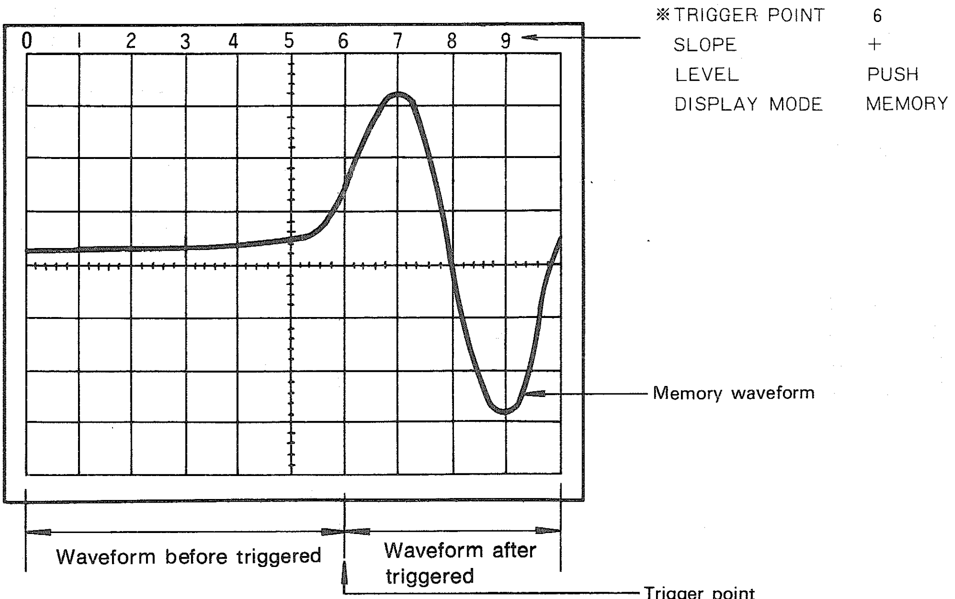
Switches and Controls	Position
11. MEMORY POSITION	CAL (PUSH)
12. DISPLAY MODE	REAL or DUAL
15. CLOCK	INT/SCOPE
17. TRIGGER POINT	0
22. SWEEP TIME/DIV	0.1ms — 1s
28. LEVEL	NORMAL (PUSH)

1. Operate the oscilloscope and display a triggered signal.
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 (22). The VOLTS/DIV does not change the sensitivity of the memory waveform. The SWEEP TIME/DIV changes only the readout speed; the memory waveform remains unchanged on the screen.

—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 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 switch (17).
When a trigger point indicated by the setting 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 below.
When the —DELAY is set for one-shot signal observation, be sure to press the LEVEL (28) to NOMAL TRIGGER and then press the WRITE START (16).



The left 6 div waveform is a memory waveform (600 words) before triggered. The right 4 div waveform is a memory wave (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

Readout 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 100ms/word, 200ms/word and 500ms/word, but can be changed to 10ms/word, 20ms/word and 50ms/word by changing the connections of the jumper wire in control circuit board.
To record a memory data in a pen recorder, use the following procedures:

1. Operate the digital memory and write input signal in memory.
2. Set the DISPLAY MODE to MEMORY.
3. Set the CLOCK to INT/PEN.
4. Set the SWEEP TIME/DIV to the desired range of FOR PEN.
5. Connect the pen recorder to the MEMORY OUT terminal.
6. Depress the PEN 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 PEN START once again.

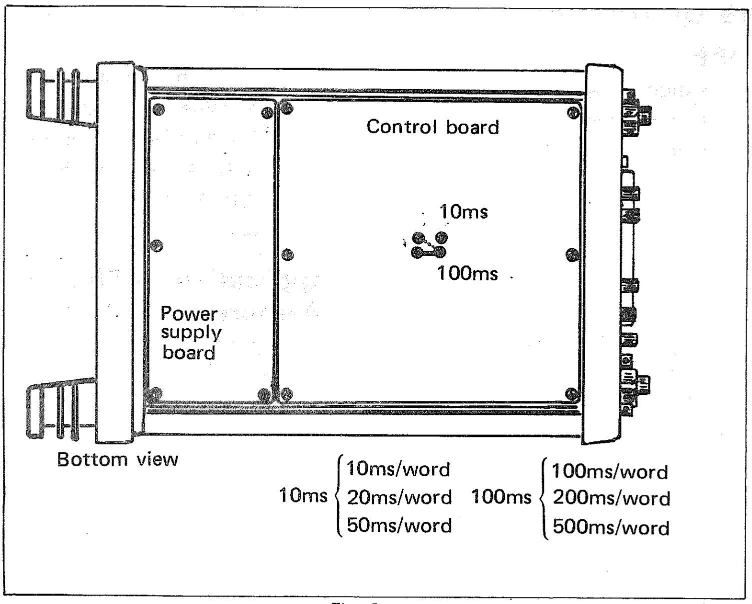


Fig. 2

Measurement of Input Signal Voltage with Pen Recorder

To obtain input signal voltage 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:

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

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.

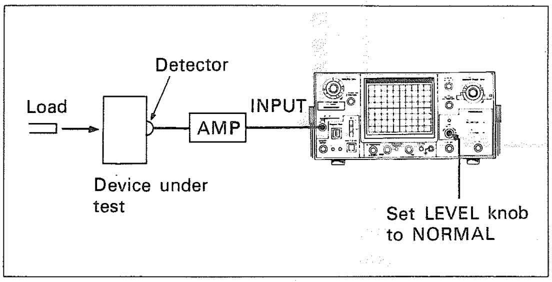


Fig. 3 . Memorizing the transient phenomenon of mechanical impact waveforms

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 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 orDC 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 singal is swept once and stops.

   Vertical attenuator (VOLTS/DIV): Any position

   SWEEP TIME/DIV: Any position between 0.1s 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 WRITE 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. Next, 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 Electiric Circuit Measurement of relay chattering

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

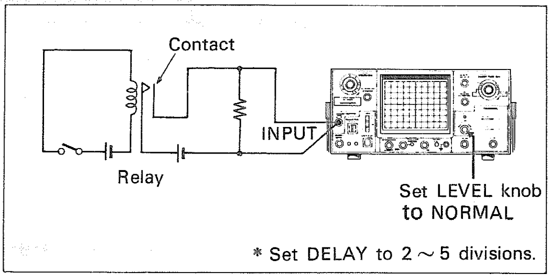


Fig. 4. Measurement of relay chattering

Data recording with pen recorder

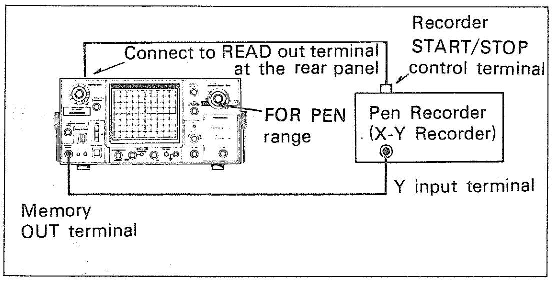


Fig. 5. Data recording with pen recorder

To record memory data with pen recorder (X-Y recorder), make the above connection 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).
2. Set the SWEEP TIME knob to any position (depending on specification of pen recorder) of the FOR PEN range (0.1, 0.2, 0,5s).
3. Depress the PEN 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 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".

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 is disabled so the waveform cycle 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 outputs (option) to the external device (see Fig. 6).

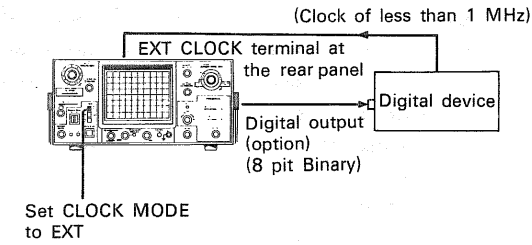


Fig. 6. Transfer of digital signal data word by word to another digital device using external clock

APPLICATIONS OF OSCILLOSCOPE OPERATION

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).

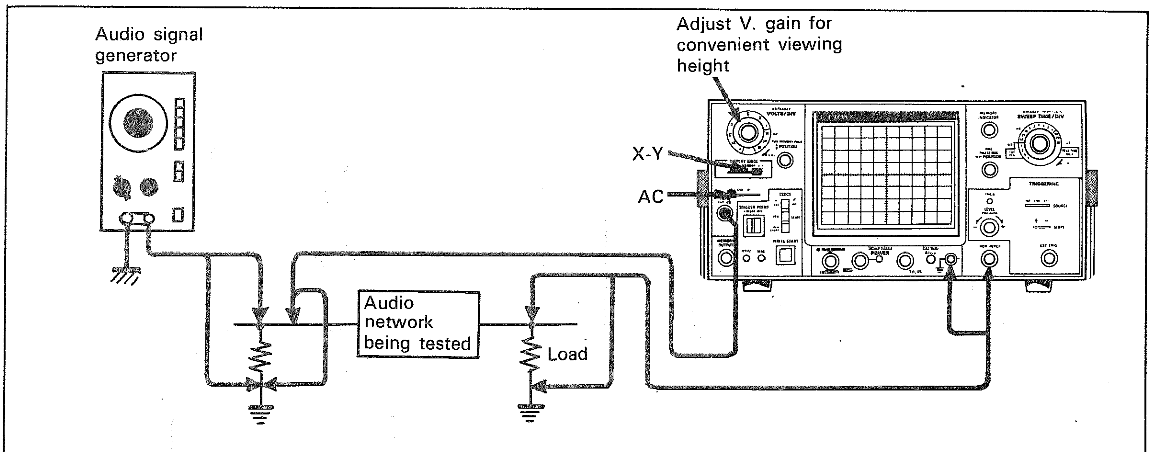


Fig. 7. Typical phase measurement

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 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.

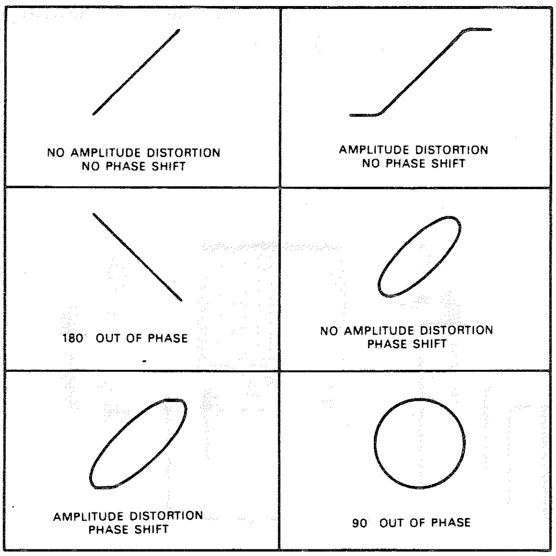


Fig. 8. Typicl phase measurement oscilloscope displays

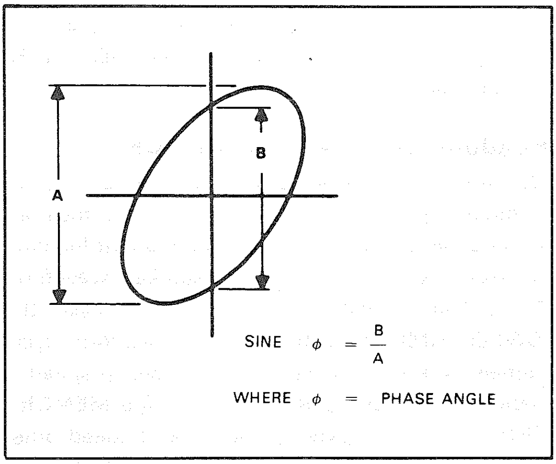


Fig. 9. Phase shift calculation

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).

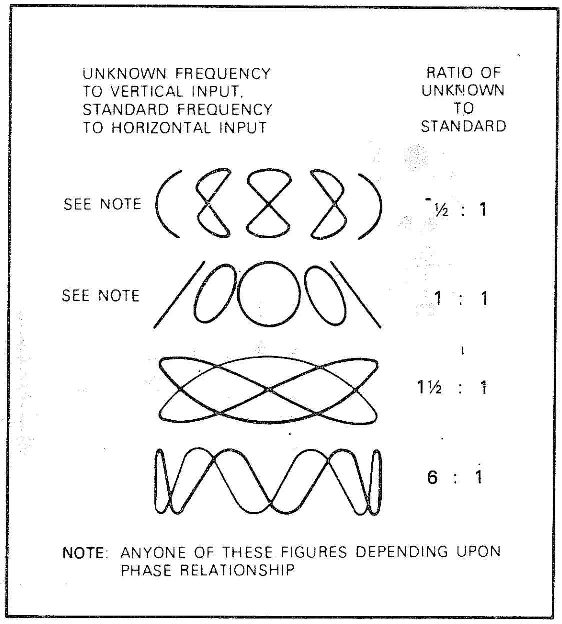


Fig. 10. Lissajous' waveforms used for frequency measurement

Amplifier Square Wave Test

Introduction

A square wave generator and the oscilloscope can be used to display 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 determine 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 comples 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 be known 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.

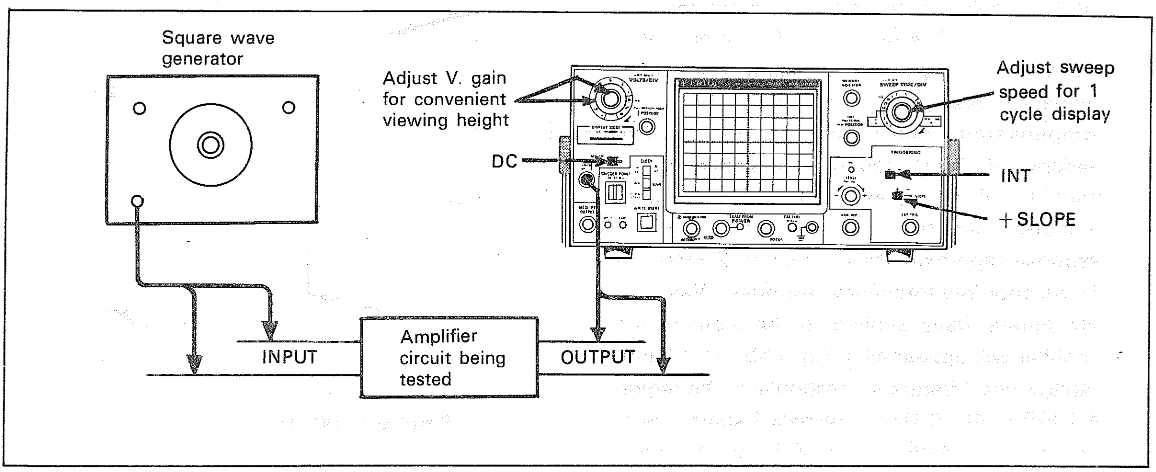


Fig. 11. Equipment set-up for square wave testing of amplifiers

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 otherwise 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 over-compensated 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

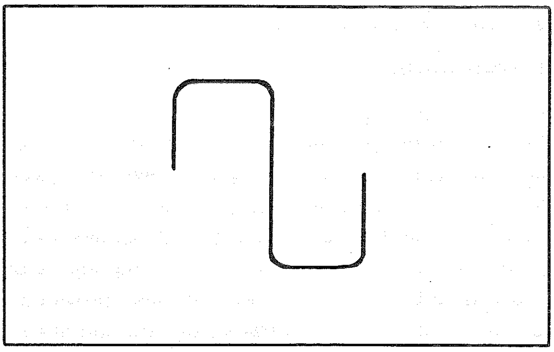


Fig. 12. Square wave response with high frequency loss

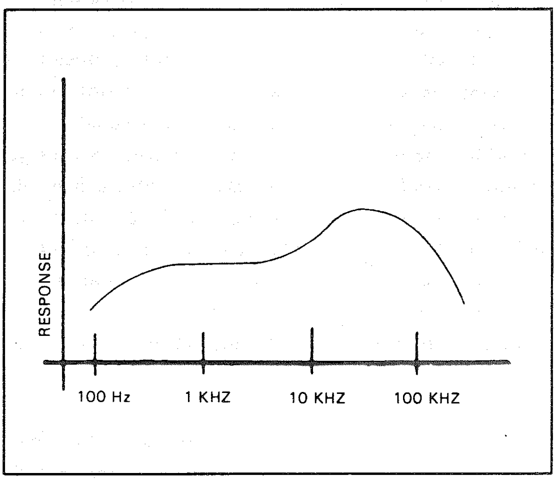


Fig. 13. Response curve of amplifier with poor low and high ends

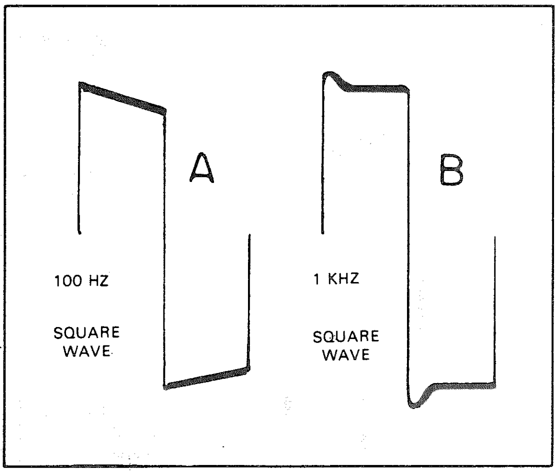


Fig. 14. Resultant 100 Hz and 1 kHz square waves from amplifier in Fig. 13.

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.
Now, the region between 100 Hz and 4000 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 usually caused by a reactive element, causing, in turn, a phase shift of the components, producitng 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 ocmponents which have been reduced in amplitude and shifted in phase. It will be noted that these examples of low-frequency distortion are characterized by change in shape of the flat portion of the square wave.

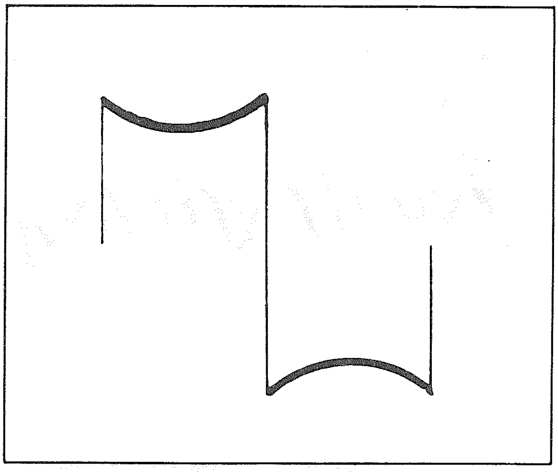


Fig. 15. Reduction of square wave fundamental frequency component in turned circuit

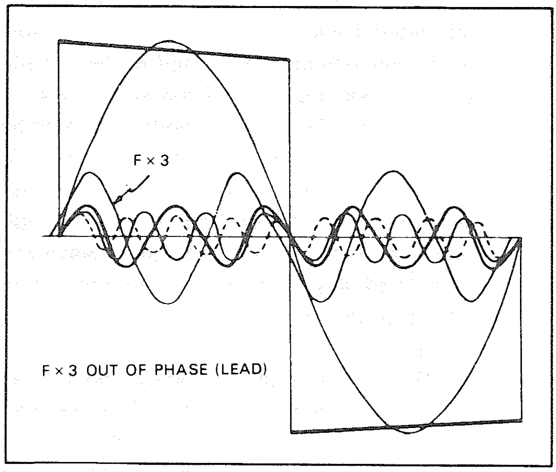


Fig. 16. Square wave tilt resulting from 3rd harmonic phase shift

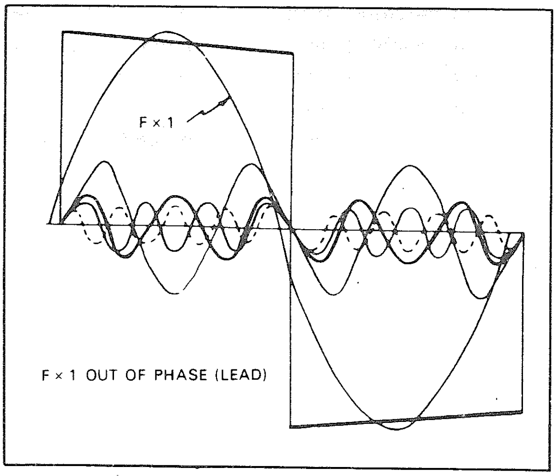


Fig. 17. Tilt resulting from phase shift of fundamental frequency in a leading direction

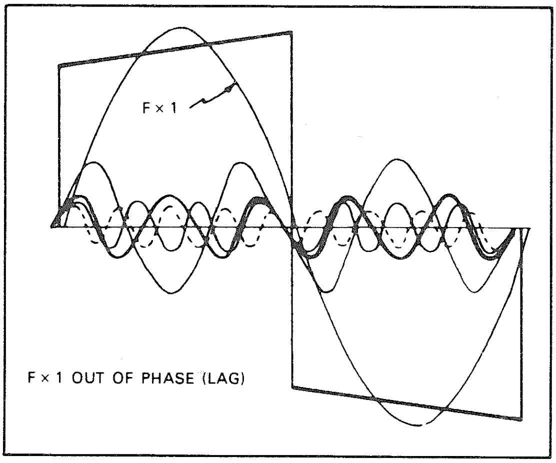


Fig. 18 Tilt resulting from a phase shift of fundamental frequency in a lagging direction

Fig. 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 abnormal 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 frequncy 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 ecplanations and serves as handy reference.

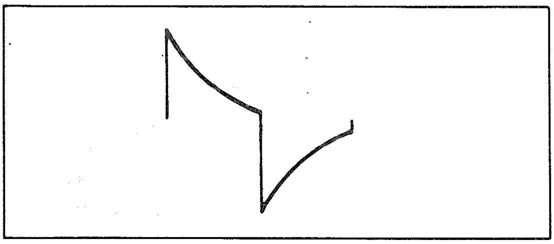


Fig. 19. Low frequency component loss and phase shift

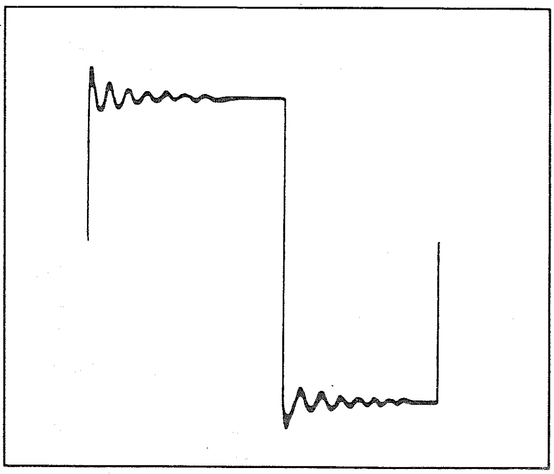


Fig. 20. Effect of high-frequency boost and poor damping

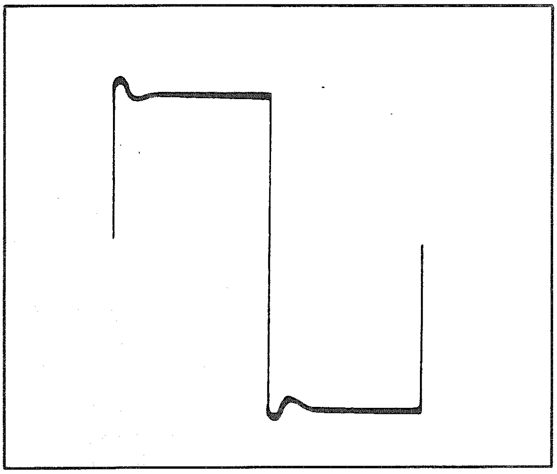
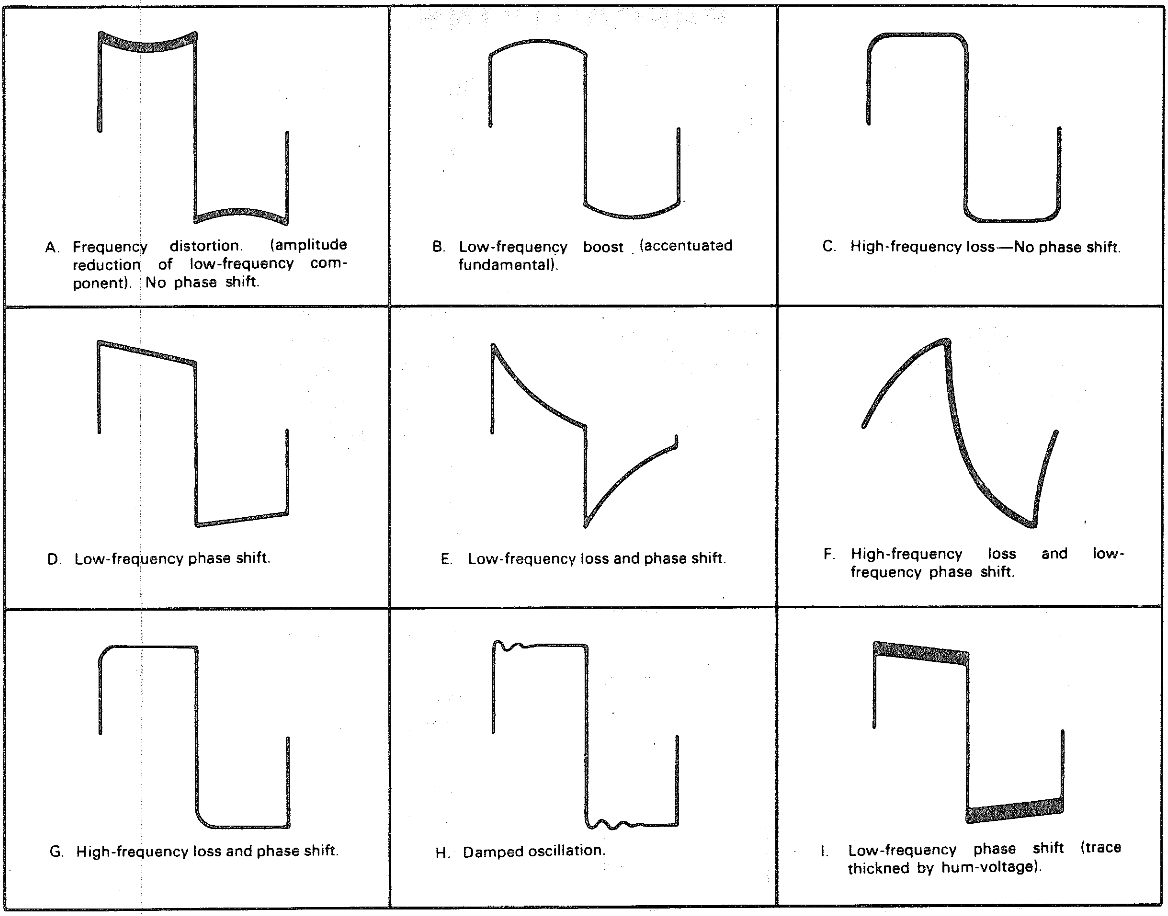


Fig. 21. Effect of high-frequency boost and good damping



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.

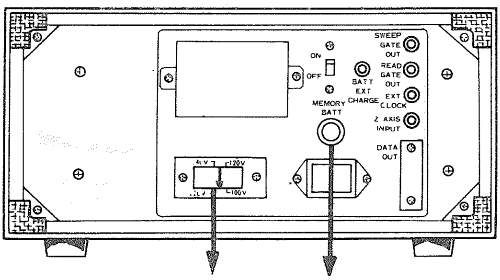
H. Damped oscillation.

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

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

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. The unit is factory adjusted to operate on AC100V.
   When the unit is to be operated from 120V, 220V or 240V, 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 220 or 240V, replace the fuse with one of 0.7A rating.
   For operation on 120V, plug the voltage selector to 117V position.
5. Fuse is fitted in the fuse holder at the rear panel.
   For operation on 100 or 120V, insert a fuse of 1.5A rating.



Voltage selector
(plug to change voltage)

Fuse

100V,120V−1.5A
220V,240V−0.7A

Fig. 23

6. Do not apply input voltage exceeding their maximum ratings.
   The input voltage applied to the vertical amplifier should not exceed 600 Vp-p or 300V (DC + AC peak), EXT CLOCK is up to 20V and the input to EXT TRIG is up to 20V (DC + AC peak).
   Do not connect external voltage to any output terminals.
7. Do not increase the intensity more than necessary.
8. When the unit is to be left unused with the bright spot on the scope, turn down the INTENSITY control and FOCUS control.
9. To prevent electrical shocks, be sure to connect the GND (on the front panel) to an appropiate earth point.
10. This instrument should be operated on alkaline battery (nickel cadmium battery) for operating backup battery.
    Do not use manganese battery.
11. After connecting a backup battery (option), if the memory data fails to be retained under POWER OFF condition, be sure to set the MEMORY BATT switch to OFF; otherwise, the battery will be discharged. The battery is trickle charged when POWER is ON even when the MEMORY BATT switch is OFF.
    When backup battery (option) is not loaded, do not apply voltage to the BATT EXT CHARGE terminal.
12. Installation
    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 top of the unit or cover the ventilation holes of the case, as it will increase the temperature in the case.

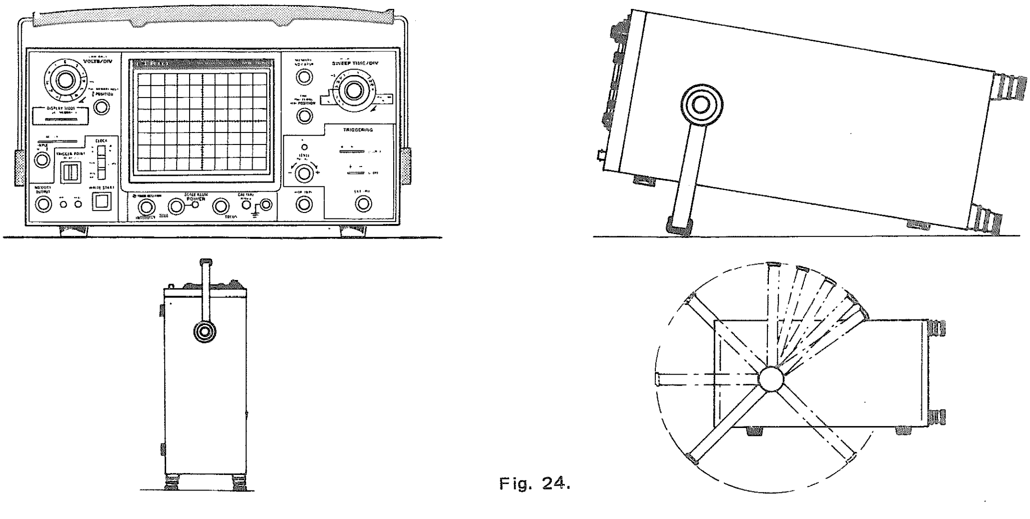


Fig. 24.

MAINTENANCE AND ADJUSTMENT

MAINTENANCE

Removal of case

1. Lift the handle to 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.

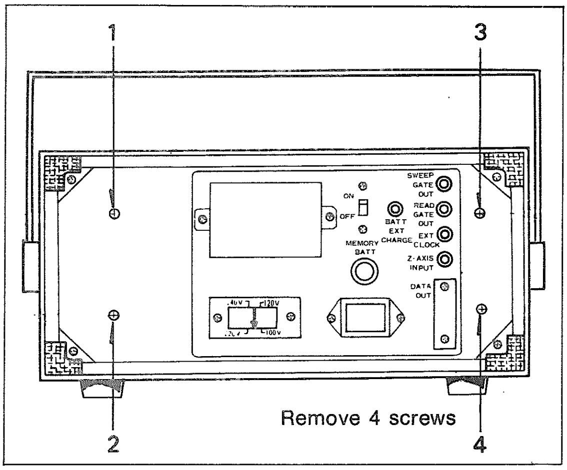


Fig. 25. Removal of case

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 adjustments 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 2000V) 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 before making adjustments.

Vertical Deflection Circuit

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 VR201 so that the trace is stationary at all ranges when the VOLTS/DIV is turned.
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 VR203 until it is centered.
   (2) Repeat the above steps so that the trace stays still when the VARIABLE is turned.

ASTIG Adjustment

Adjust the VR105 until the waveform trace is even in thickness. This adjustment shoud be made in conjunction with the FOCUS control. Since the ASTIG is stabilized, no readjustment is required.

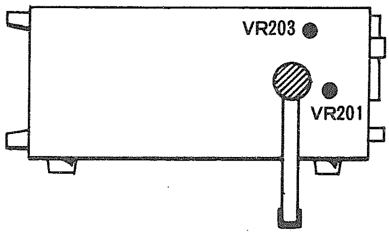


Fig. 26 DC BAL adjustment

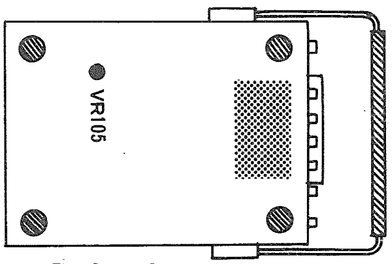
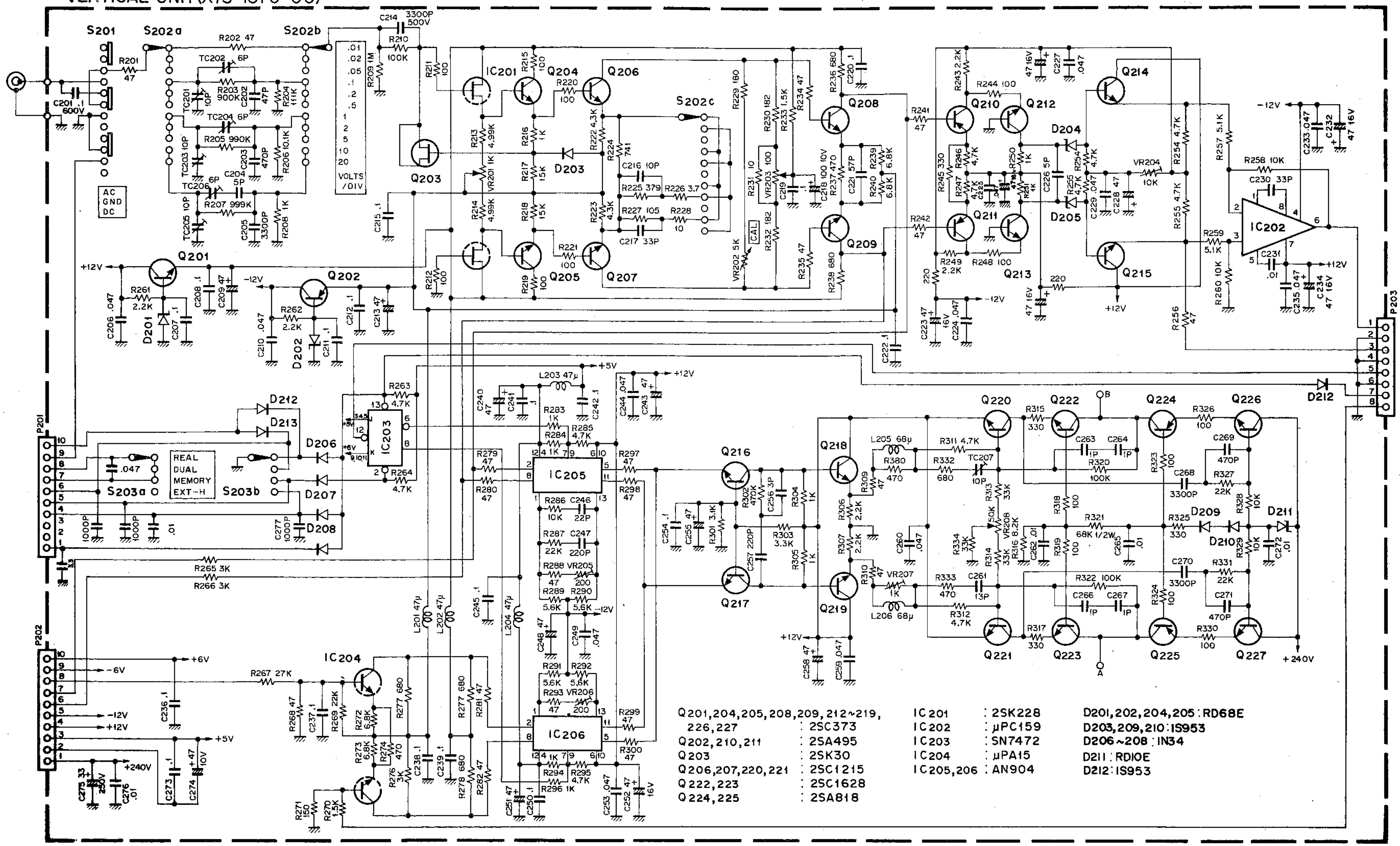


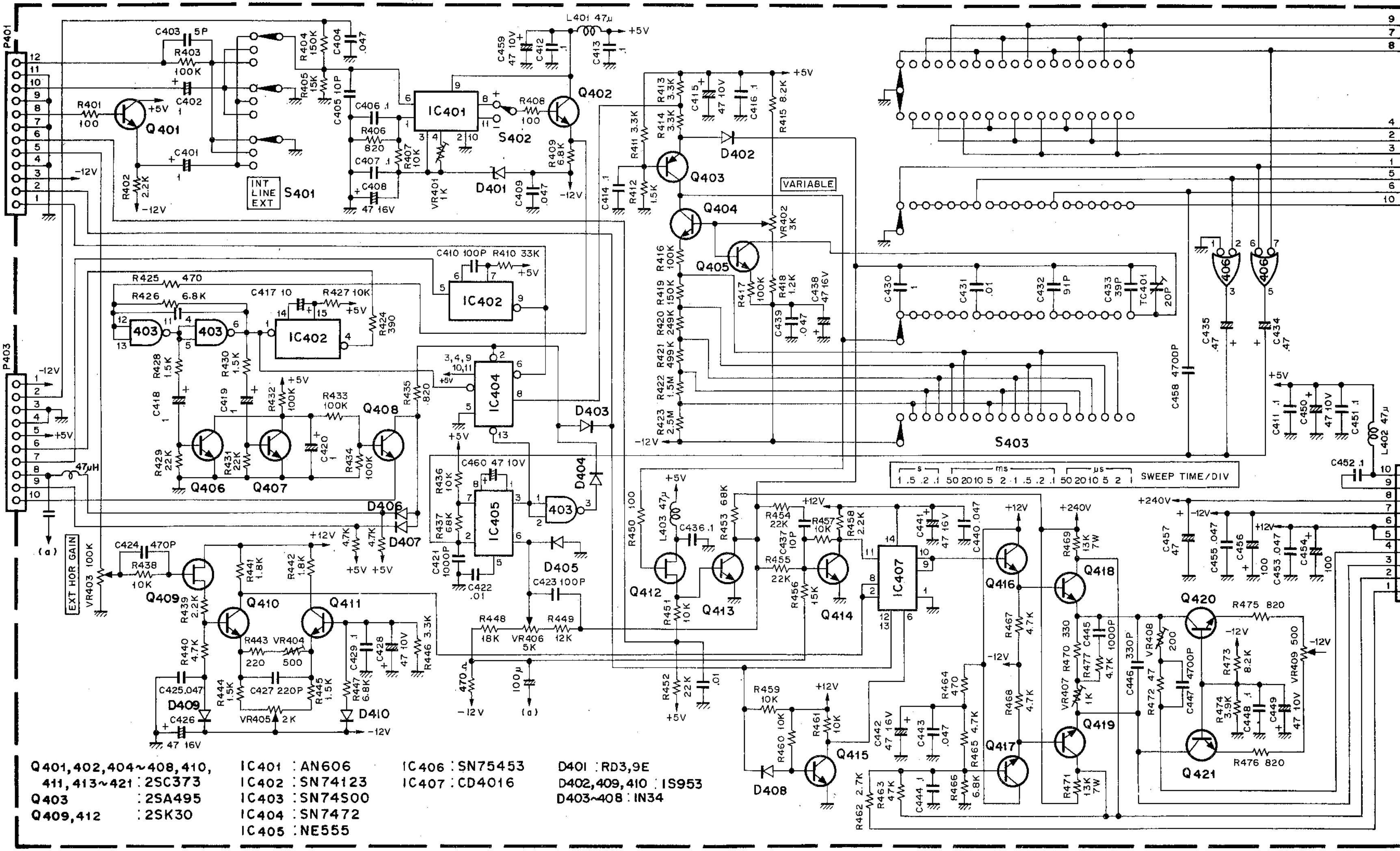
Fig. 27. ASTIG adjustment

MEMO

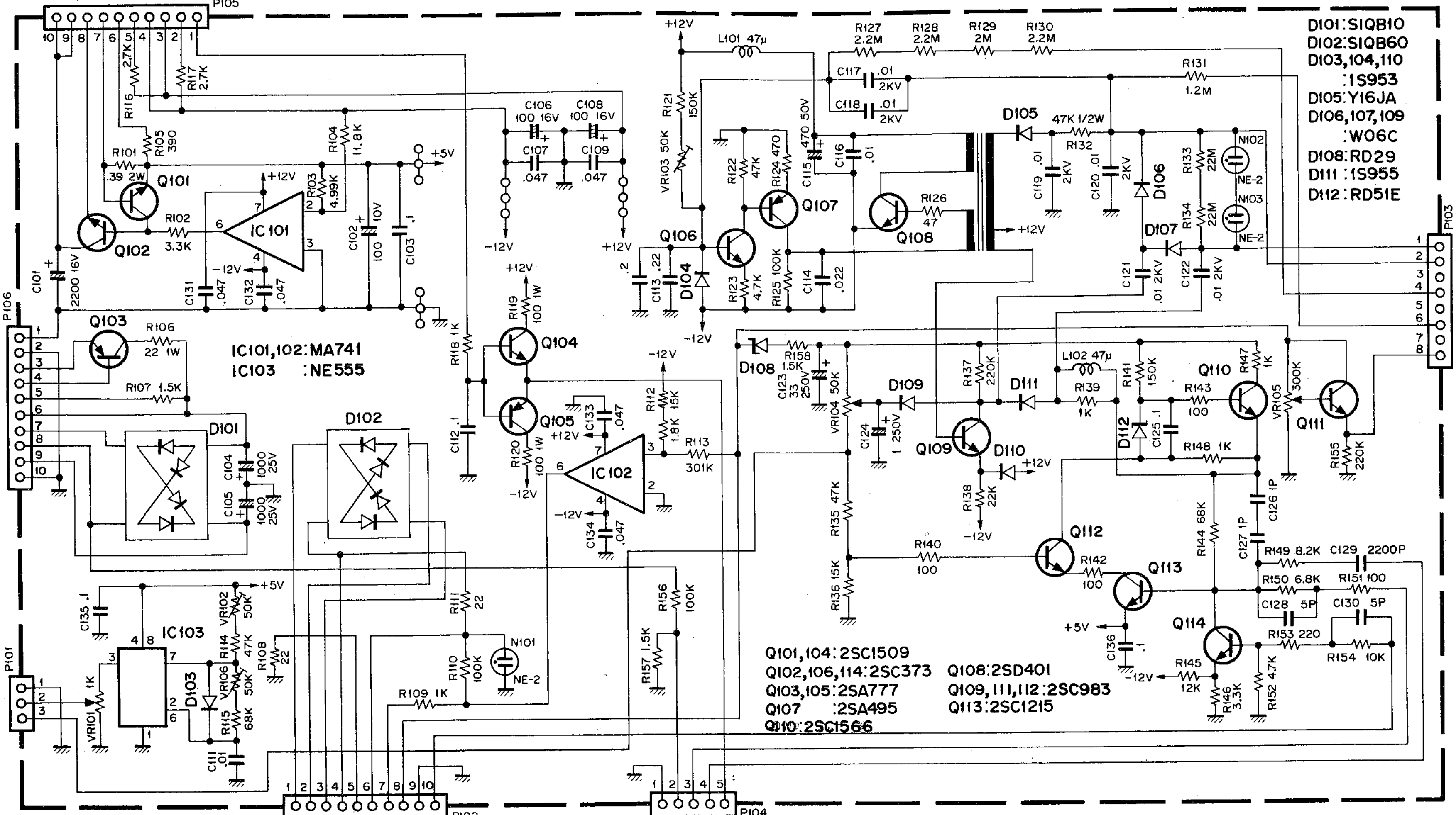
VERTICAL UNIT(X73-1370-00)



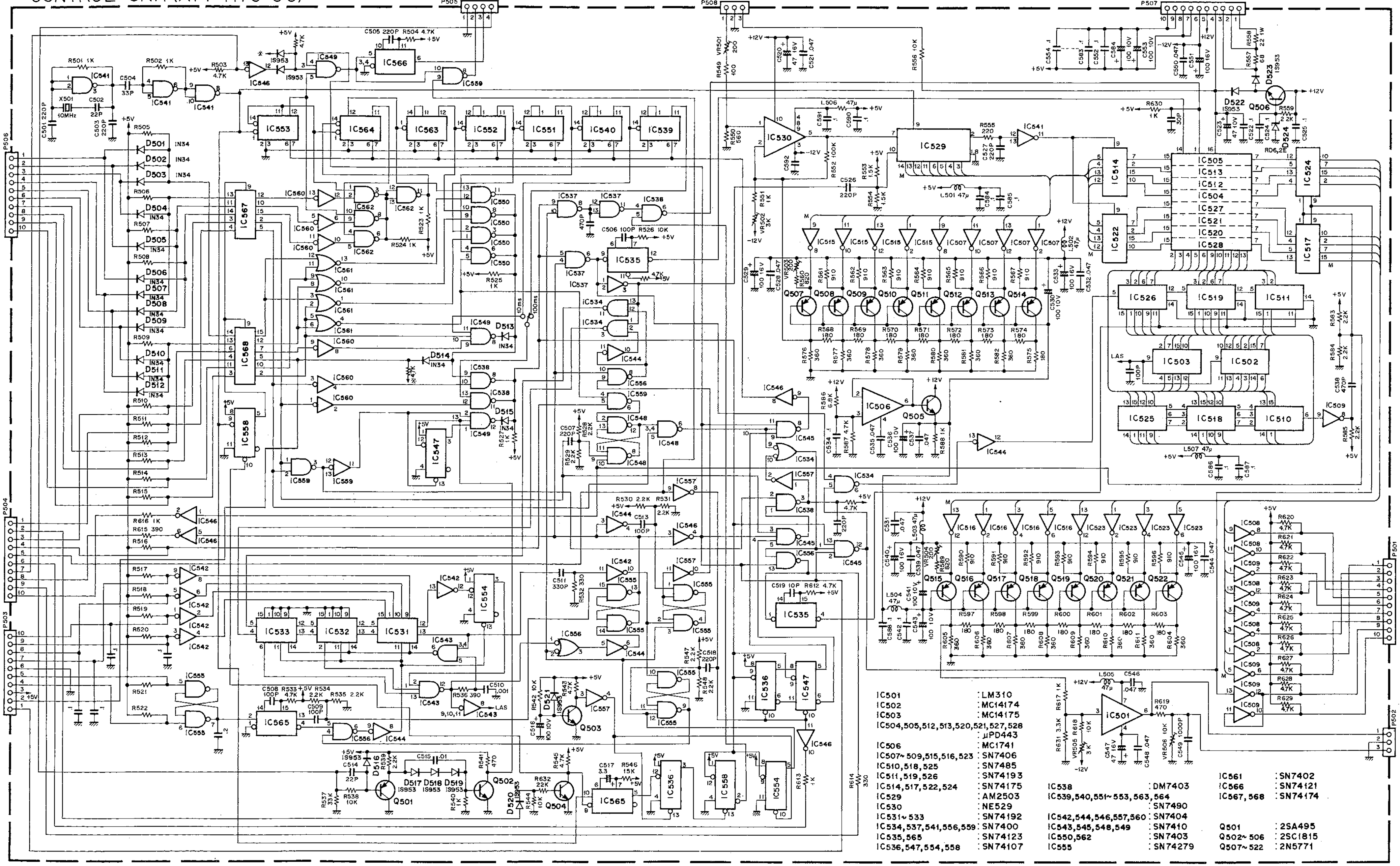
HORIZONTAL SWEEP UNIT (X74-1240-00)



POWER SUPPY UNIT(X68-1330-00)

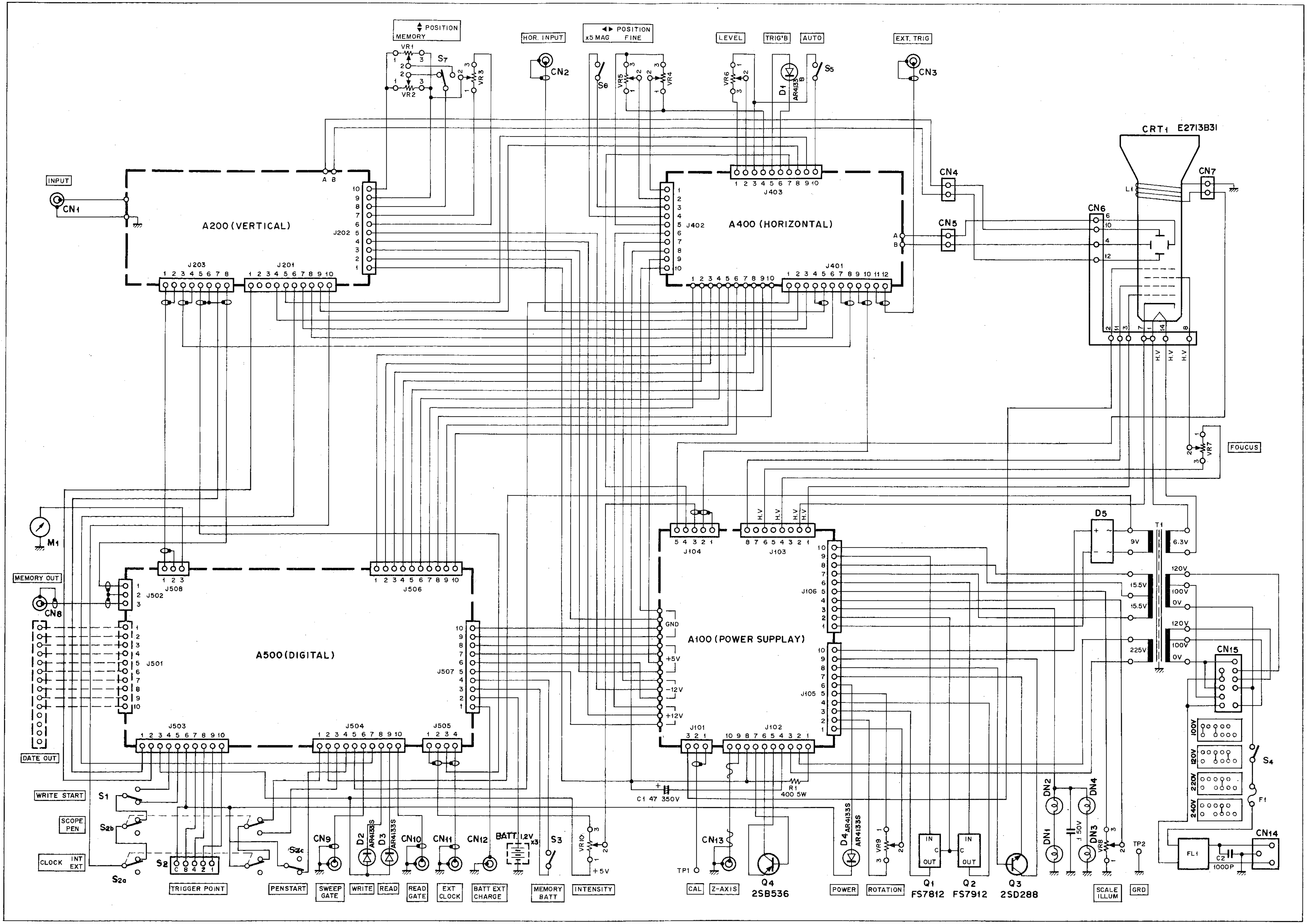


CONTROL UNIT(X77-1170-00)



Part	Type
IC501	LM310
IC502	MC14174
IC503	MC14175
IC504,505,512,513,520,521,527,528	μPD443
IC506	MC1741
IC507~509,515,516,523	SN7406
IC510,518,525	SN7485
IC511,519,526	SN74193
IC514,517,522,524	SN74175
IC529	AM2503
IC530	NE529
IC531~533	SN74192
IC534,537,541,556,559	SN7400
IC535,565	SN74123
IC536,547,554,558	SN74107
IC538	DM7403
IC539,540,551~553,563,564	SN7490
IC542,544,546,557,560	SN7404
IC543,545,548,549	SN7410
IC550,562	SN7403
IC555	SN74279
IC561	SN7402
IC566	SN74121
IC567,568	SN74174
Q501	2SA495
Q502~506	2SC1815
Q507~522	2N5771

TOTAL SCHEMATIC



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