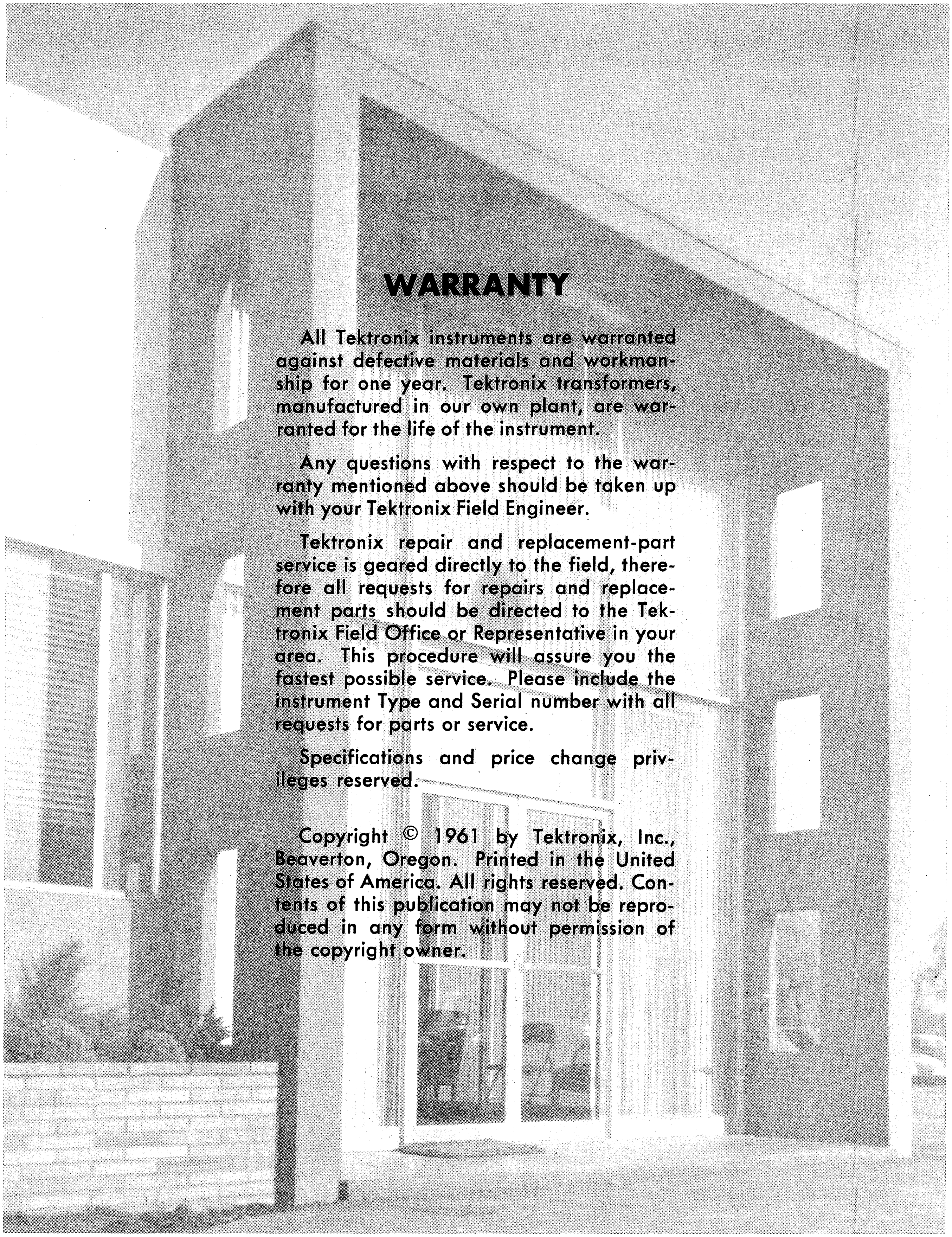
# INSTRUCTION
# MANUAL

# TYPE 945

## OSCILLOSCOPE

S. W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon ● Phone MI 4-0161 ● Cables: Tektronix

80-0001-00



# WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or Representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial number with all requests for parts or service.

Specifications and price change privileges reserved.

## TABLE OF CONTENTS


| Paragraph | | Page |
|---|---|---|
| | SECTION I. SPECIFICATIONS | |
| 1-1 | General Specifications | 1-1 |
| | Table 1-1. Electrical Specifications | 1-2 |
| | Table 1-2. Environmental Specifications | 1-6 |
| | Table 1-3. Mechanical Specifications | 1-7 |
| | SECTION II. OPERATING INSTRUCTIONS | |
| 2-1 | General Information | 2-1 |
| | Table 2-1. Functions of Controls, Indicators and Connectors | 2-1 |
| 2-5 | First Time Operation (oscilloscope) | 2-5 |
| 2-42 | Main Sweep Triggering | 2-10 |
| 2-121 | Measurement Methods | 2-22 |
| | SECTION III. TRIGGERING INSTRUCTIONS | |
| 3-1 | Main Sweep Operation | 3-1 |
| 3-2 | Selecting the Triggering Signal Source | 3-1 |
| 3-5 | Triggered (AUTOmatic mode) | 3-1 |
| 3-9 | Triggered (AC mode) | 3-1 |
| 3-12 | Triggered (DC mode) | 3-2 |
| 3-16 | Triggered (AC LF REJECT mode) | 3-2 |
| 3-19 | Dual-Trace Operation | 3-2 |
| 3-23 | Synchronized (HF SYNC mode) | 3-3 |
| 3-27 | Using the Variable Stability Control | 3-3 |
| 3-29 | Delaying Sweep Operation | 3-3 |
| 3-33 | Delaying Main-Sweep Operation | 3-19 |
| 3-36 | Delayed-and Triggered Main-Sweep Operation | 3-19 |
| 3-39 | Rate-Generator Feature | 3-20 |
| 3-41 | Single Sweeps (Manual Operation) | 3-21 |
| 3-44 | Single Sweeps (Triggered Operation) | 3-21 |
| 3-47 | External Sweep | 3-21 |
| 3-50 | Possible Causes of Improper Display | 3-22 |
| | SECTION IV. CIRCUIT DESCRIPTION | |
| 4-1 | Block Diagram | 4-1 |
| 4-38 | Vertical-Deflection System | 4-2 |
| 4-60 | Horizontal-Deflection System | 4-4 |
| 4-87 | Main Sweep Generator | 4-7 |
| 4-121 | Delaying-Sweep Circuits | 4-11 |
| 4-135 | Delay Pickoff | 4-12 |
| 4-143 | Delaying-Sweep Trigger | 4-13 |
| 4-156 | Delaying-Sweep Generator | 4-15 |
| 4-178 | Horizontal/Sweep Amplifier | 4-18 |

| | | |
|---|---|---|
| 4-195 | Low-Voltage Power Supply | 4-20 |
| 4-222 | Calibrator | 4-21 |
| 4-225 | High-Voltage Power Supply and CRT Circuitry | 4-22 |
| 4-232 | Cathode-Ray Tube Control Circuits | 4-22 |


SECTION V. MAINTENANCE


| | | |
|---|---|---|
| 5-1 | Removal and Replacement of Parts | 5-1 |
| 5-35 | Troubleshooting Procedure | 5-5 |
| | Table 5-1. General Color Code | 5-6 |
| 5-45 | Circuit Troubleshooting | 5-7 |
| 5-48 | Low-Voltage Power Supply | 5-9 |
| 5-62 | CRT Circuit and High-Voltage Power Supply | 5-13 |
| 5-76 | Vertical Amplifier | 5-14 |
| 5-108 | Calibrator | 5-19 |
| 5-115 | Horizontal/Sweep Amplifier | 5-20 |
| 5-123 | Main Sweep Trigger | 5-22 |
| 5-131 | Main Sweep Generator | 5-22 |
| 5-143 | Delay Pickoff | 5-24 |
| 5-149 | Delaying-Sweep Trigger and Generator | 5-24 |


SECTION VI. SPECIAL TOOLS AND EQUIPMENT


| | | |
|---|---|---|
| 6-1 | Special Tools and Equipment | 6-1 |


SECTION VII. CALIBRATION PROCEDURE


| | | |
|---|---|---|
| 7-1 | Introduction | 7-1 |
| 7-6 | Preliminary | 7-1 |
| 7-10 | Procedure | 7-4 |
| 7-11 | Low-Voltage Power Supplies | 7-4 |
| 7-18 | Amplitude Calibrator Adjustment | 7-4 |
| 7-22 | High-Voltage Power Supply Adjustment | 7-5 |
| 7-24 | CRT Adjustments | 7-6 |
| 7-46 | Fan Drive Symmetry | 7-6 |
| 7-48 | Vertical Amplifier Gain Preliminary | 7-9 |
| 7-56 | Triggering Adjustments | 7-10 |
| 7-75 | Sweep Circuit Adjustments | 7-12 |
| 7-131 | Delay Line and High Frequency Compensation | 7-18 |


SECTION VIII. INTRODUCTION TO PARTS LIST


| | | |
|---|---|---|
| 8-1 | General | 8-1 |
| 8-5 | Explanation of Mechanical and Accessories Parts List | 8-1 |
| 8-7 | Federal Supply Code Numbers for Manufactures | 8-2 |
| 8-9 | Abbreviations Used in Parts List | 8-4 |


SECTION IX. ELECTRICAL PARTS LIST

SECTION X. MECHANICAL PARTS LIST

## LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| Frontispiece | Type 945 with Type MC Preamplifier Plug-In | vi |
| 1-1 | Typical Dimensions of the Type 945 | 1-8 |
| 2-1 | Plug-In Insertion | 2-5 |
| 2-2 | Rotation of the Graticule | 2-6 |
| 2-3 | Compensation of the Probe | 2-8 |
| 2-4 | Front-panel Controls and Connectors | 2-9 |
| 2-5 | TRIGGER SLOPE Control Selection of Signal Source | 2-11 |
| 2-6 | Effects of + and - Settings of TRIGGER SLOPE Control | 2-12 |
| 2-7 | Effects of + and - TRIGGERING LEVEL Settings | 2-14 |
| 2-8 | Using the Gate or Sawtooth Output Waveforms to Synchronize or Trigger External Equipment | 2-16 |
| 2-9 | Calculating Delay Time | 2-16 |
| 2-10 | Comparison of the Two Delayed-Sweep Modes | 2-18 |
| 2-11 | DEL'G SWEEP and MAIN SWEEP DELAYED correlation | 2-19 |
| 2-12 | Single Sweep and Repetitive Sweep Comparison | 2-19 |
| 2-13 | Sweep Magnifier Operation | 2-20 |
| 2-14 | Crt Deflection Plates Access Location | 2-21 |
| 2-15 | AC Coupling Directly to Crt Deflection Plates | 2-21 |
| 2-16 | Peak-to-Peak AC Voltage Measurement | 2-23 |
| 2-17 | Instantaneous Voltage Measurement With Reference | 2-24 |
| 2-18 | Time Measurement | 2-25 |
| 2-19 | Frequency Measurement | 2-26 |
| 3-1 | Typical AC Measurement Settings | 3-4 |
| 3-2 | Typical DC Measurement Settings | 3-5 |
| 3-3 | Typical Frequency Measurement Settings | 3-6 |
| 3-4 | Typical Triggered (AUTOMATIC Mode) | 3-7 |
| 3-5 | Triggered (AC Mode) | 3-8 |
| 3-6 | Triggered (DC Mode) | 3-9 |
| 3-7 | Triggered (AC LF REJECT Mode) | 3-10 |
| 3-8 | Dual-Trace Operation | 3-11 |
| 3-9 | Synchronized (HF SYNC Mode) | 3-12 |
| 3-10 | Delaying Sweep Operation | 3-13 |
| 3-11 | Delayed and Triggered Operation | 3-14 |
| 3-12 | Delayed Main-Sweep Operation | 3-15 |
| 3-13 | Single Sweep (Manual Operation) | 3-16 |
| 3-14 | Single Sweep (Triggered Operation) | 3-17 |
| 3-15 | X-Y Measurements | 3-18 |
| 4-1 | Simplified Main Sweep Trigger Circuitry | 4-5 |
| 4-2 | Simplified Main Sweep Generator Circuitry | 4-8 |
| 4-3 | Block Diagram Shows Circuitry With MAIN SWEEP DELAYED | 4-11 |
| 4-4 | Simplified Delay Pickoff Diagram | 4-13 |
| 4-5 | Positive-Going Signal Path in Delaying Sweep Trigger | 4-14 |
| 4-6 | Negative-Going Signal Path in Delaying Sweep Trigger | 4-15 |
| 4-7 | Simplified Delaying Sweep Generator | 4-16 |
| 5-1 | Locations of CRT Rotation Handle and CRT Clamp | 5-1 |
| 5-2 | Power Transformer Terminal Locations | 5-2 |
| 5-3 | Fan Drive Test Locations | 5-2 |
| 5-4 | Soldering Iron Tip Shaped and Tinned | 5-3 |
| 5-5 | Correct Heat Application to Ceramic Strip | 5-4 |
| 5-6 | Slight Fillet of Solder Around Wire | 5-4 |
| 5-7 | Soldering to a Terminal | 5-4 |
| 5-8 | A Soldering Aid | 5-4 |
| 5-9 | Soldering to a Terminal Mounted in Plastic | 5-5 |

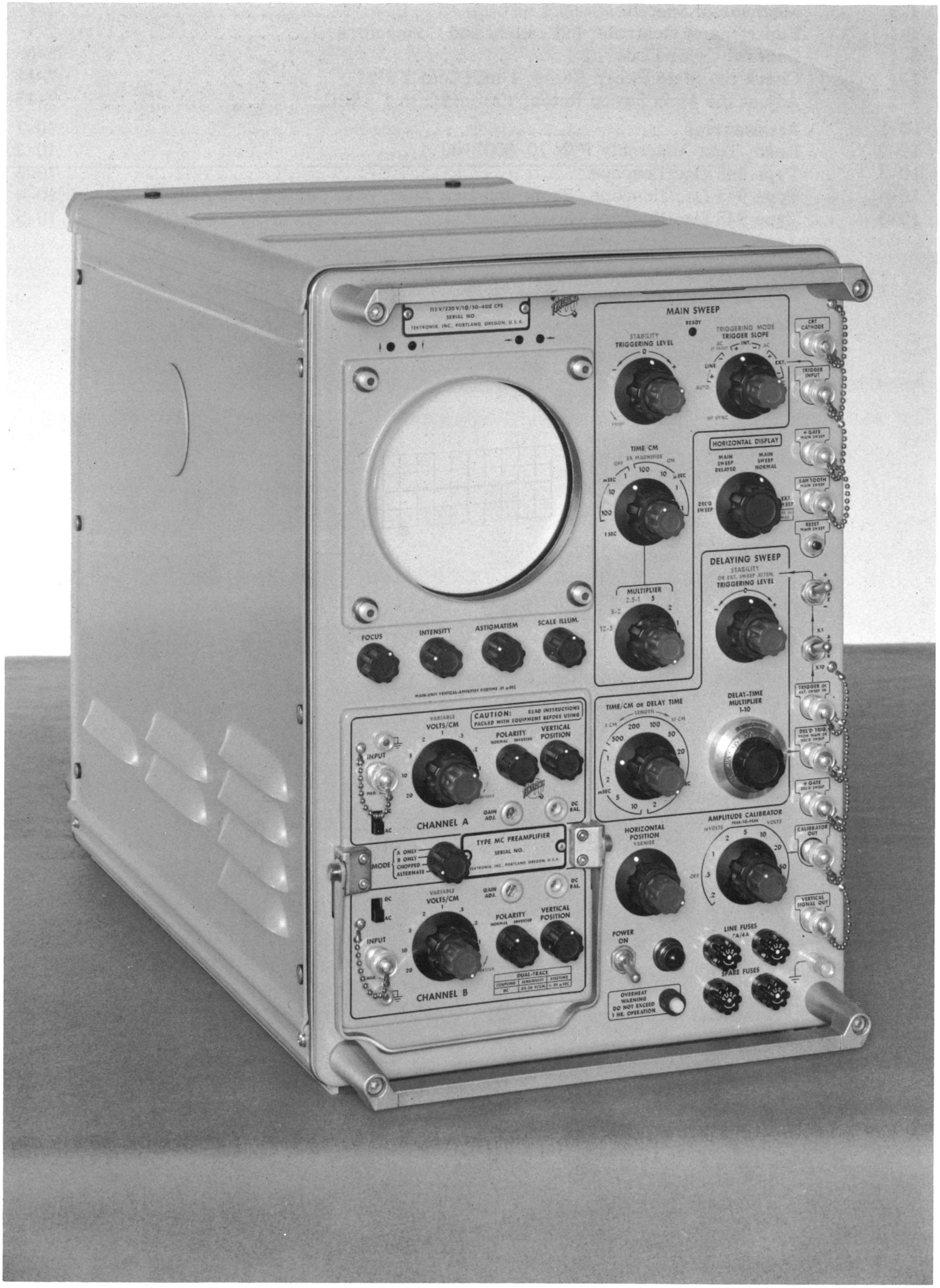
5-10 The Ceramic Strip Mounting. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-5
5-11 Self-Checking Mode Circuit Configuration. . . . . . . . . . . . . . . . . . . . . . 5-7
5-12 Self-Checking Mode Connections . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-8
5-13 Circuits Found on Top of Type 945 Oscilloscope . . . . . . . . . . . . . . . . 5-10
5-14 Circuits Found on Right Side of Type 945 Oscilloscope . . . . . . . . . . . . 5-10
5-15 Circuits Found on Type 945 Left Side. . . . . . . . . . . . . . . . . . . . . . . . 5-11
5-16 Circuits Found on Bottom of Type 945 Oscilloscope . . . . . . . . . . . . . . 5-11
5-17 Silicon Rectifier Location . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-12
5-18 Low-Voltage Power Supply Test Points . . . . . . . . . . . . . . . . . . . . . . 5-12
5-19 High-Voltage Check Point . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-13
5-20 Horizontal and Vertical Deflection Plate Neck Pins . . . . . . . . . . . . . . 5-14
5-21 Shorting Strap to Use in Checking Amplifier . . . . . . . . . . . . . . . . . . . 5-15
5-22 Location of Input to Delay Line . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-16
5-23 Grid and Plate Line Termination in Vertical Amplifier . . . . . . . . . . . . . 5-16
5-24 Waveform Distortion With Description, Cause, Display, and Cure for Typical Problems. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-18
5-25 Top View of Type 945 Showing Test Points . . . . . . . . . . . . . . . . . . . 5-21
5-26 Delaying Sweep Chassis Showing Test Points. . . . . . . . . . . . . . . . . . 5-21
5-27 Location of Delaying Sweep Timing Switch . . . . . . . . . . . . . . . . . . . 5-24
7-1 Internal Controls on Right Side . . . . . . . . . . . . . . . . . . . . . . . . . . . 7-2
7-2 Internal Controls on Left Side. . . . . . . . . . . . . . . . . . . . . . . . . . . . 7-2
7-3 Internal Controls on Top of Type 945 . . . . . . . . . . . . . . . . . . . . . . . 7-3
7-4 Bottom View of Type 945. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 7-3
7-5 Location of Low-Voltage Power Supply Test Points . . . . . . . . . . . . . . 7-4
7-6 Fan Drive Circuit Points . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 7-4
7-7 Regulated DC Heater Supply Circuit Location. . . . . . . . . . . . . . . . . . 7-5
7-8 High-Voltage Check Point Location . . . . . . . . . . . . . . . . . . . . . . . . 7-5
7-9 Time-Marker Connections to the Type 945 . . . . . . . . . . . . . . . . . . . 7-6
7-10 Adjustment of the Geometry Control . . . . . . . . . . . . . . . . . . . . . . . 7-7
7-11 Internal Controls Location on Top Front Deck. . . . . . . . . . . . . . . . . . 7-8
7-12 Location of Internal Controls on Top Central Deck. . . . . . . . . . . . . . . 7-8
7-13 Trigger Sens. Control Adjustment Waveforms. . . . . . . . . . . . . . . . . . 7-10
7-14 Adjustment of the Preset Adjust Control. . . . . . . . . . . . . . . . . . . . . 7-11
7-15 Location of C26F, C26H and C26J . . . . . . . . . . . . . . . . . . . . . . . . 7-13
7-16 Adjusting Swp Mag Regis. Control. . . . . . . . . . . . . . . . . . . . . . . . . 7-14
7-17 Adjustment of the Lockout Level Adj. Control . . . . . . . . . . . . . . . . . 7-14
7-18 Location of Delaying Sweep Internal Controls . . . . . . . . . . . . . . . . . 7-15
7-19 External Sweep Input Compensation Controls. . . . . . . . . . . . . . . . . . 7-15
7-20 Time Delay Horizontal Jitter Not to Exceed 5mm. . . . . . . . . . . . . . . . 7-17
7-21 Locations of C42D and C42F. . . . . . . . . . . . . . . . . . . . . . . . . . . . . 7-18
7-22 Waveforms Showing Effects of Defective Tubes in Vertical Amplifier . . . 7-19
7-23 Significant Portions of Waveform Used in Checking Vertical Amplifier . . 7-21
7-24 Waveform For Determining Risetime . . . . . . . . . . . . . . . . . . . . . . . 7-22
7-25 Effects of Specific Misadjustments . . . . . . . . . . . . . . . . . . . . . . . . 7-23
7-26 Approximate Settings of Trimmer Capacitors in the Delay Line . . . . . . . 7-24
7-27 Normal Adjustment Pattern of Trimmer Capacitors . . . . . . . . . . . . . . 7-24
7-28 Location of Internal Adjustments in the Vertical Amplifier. . . . . . . . . . 7-26

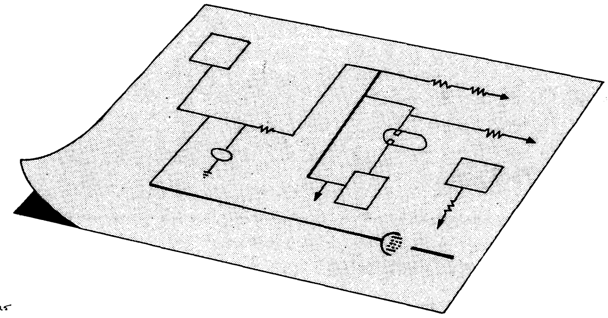
## LIST OF TABLES

Table Page

1-1 Electrical Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1-2
1-2 Environmental Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1-6

| | | |
|---|---|---|
| 1-3 | Mechanical Specifications | 1-7 |
| 2-1 | Functions of Controls, Indicators and Connectors | 2-1 |
| 5-1 | General Color Code | 5-6 |
| 7-1 | Check the Main Sweep Rates, 1 mSEC to 2 SEC | 7-12 |
| 7-2 | Adjust the Main Sweep Rates, 100 $\mu$SEC to 1 $\mu$SEC | 7-13 |
| 10-1 | Accessories | 10-1 |
| 10-2 | Lead, Test Assembly P/N 70-6001-00 | 10-2 |
| 10-3 | Type 945 Oscilloscope | 10-3 |
| 10-4 | Type 945 Oscilloscope (Front and Left Side, With Cabinet Cut Away) | 10-4 |
| 10-5 | Type 945 Oscilloscope (Rear) | 10-5 |


MAIN SWEEP
READY
STABILITY
TRIGGERING LEVEL
TRIGGERING MODE
TRIGGER SLOPE
TIME/CM
MULTIPLIER
HORIZONTAL DISPLAY
DELAYING SWEEP
TRIGGERING LEVEL
FOCUS
INTENSITY
ASTIGMATISM
SCALE ILLUM.
CAUTION:
VOLTS/CM
POLARITY
VERTICAL POSITION
INPUT
CHANNEL A
GAIN ADJ.
DC BAL.
TIME/CM OR DELAY TIME
DELAY-TIME MULTIPLIER 1-10
TYPE MC PREAMPLIFIER
SERIAL NO.
MODE
A ONLY
B ONLY
CHOPPED
ALTERNATE
HORIZONTAL POSITION
AMPLITUDE CALIBRATOR
VOLTS/CM
POLARITY
VERTICAL POSITION
INPUT
CHANNEL B
POWER ON
LINE FUSES
SPARE FUSES
OVERHEAT WARNING DO NOT EXCEED 1 HR. OPERATION
CRT CATHODE
TRIGGER INPUT
CALIBRATOR OUT
VERTICAL SIGNAL OUT



# SECTION 1

# SPECIFICATIONS

## 1-1. GENERAL SPECIFICATIONS

**1-2.** Description of the Tektronix Type 945. The Type 945 is a rugged precision oscilloscope with plug-in preamplifier, Delaying Sweep, amplitude calibrator, and a wide range of sweep rates. It was designed to meet military test equipment specifications, therefore it is capable of operating in a variety of severe environments.

**1-3.** The Type 945/MC design is based on the requirements of MIL-T-945A: Test Equipment, for General Use with Electronic Equipment, General Specification for,. Since this is a general specification, certain areas have required interpretation. The electrical-environmental specifications describe the capabilities of the Tektronix Type 945/MC and take preference over any conflict with MIL-T-945A. MIL-T-21200 and MIL-E-16400 are general specifications similar to MIL-T-945A. Portions of these specifications are applicable to the Type 945/MC. The parts, materials and processes of MIL-T-945A are followed in most cases. Where a deviation exists, the intent of the specifications has been met by performing to the required environment.

**1-4.** The Electrical Requirements embody the following environmental tests: Storage, Temperature, Altitude, Water drip, Primary power frequency, Humidity, Fungus, Vibration, Shock Radio interference and Salt spray. If no statement is made to modify a characteristic or tolerance for any of the above environments, it may be assumed that it will remain within stated accuracy.

**1-5.** Advantages of the Type 945 in addition to the electronic capabilities. The oscilloscope will survive extreme shipping and storage conditions. It will perform with good accuracy and reliability in severe environment. Additional reliability is obtained if it is used in a non-severe environment. Spare parts stocking problems are minimized by the use of standard military components.

**1-6.** Knowledge of capabilities. The user of the Type 945 should know and understand its capabilities both electronically and environmentally, in order to enjoy the maximum advantages of the instrument.

**1-7.** The Type 945/MC can be supplied with front and rear protective panels that contain all of the accessory items and instruction manual.

Standard Accessories:

2 - 10X attenuator Type P6003 probes with 42" cables, holders, tips and ground leads.

2 - Coax cable, RG58C/U, 50Ω, 24", BNC

2 - Binding Post Adaptors UG 1090/U, (special), BNC

1 - Green light filter

1 - Instruction manual

Additional accessories with Panel Covers:

1 - Coax cable, RG58C/U, 50Ω, 48", BNC

2 - Adaptors, Conn., UG 273/U, UHF, plug

2 - Adaptors, Conn., UG 274/U, BNC tee

2 - Adaptors, Conn., UG 914/U, st. BNC

2 - Adaptors, Conn., UG 255/U, BNC Jack

2 - Alignment tools

1 - Screwdriver

5 - Allen Key Wrench - one each: #4, #8, 3/32", 3/16", 1/4".

**TABLE 1-1**

**ELECTRICAL SPECIFICATIONS**

| Characteristics | Requirements |
|---|---|
| VERTICAL DEFLECTION | |
| | Type MC Dual Channel Plug-In Preamplifier |
| Modes | A only, B only, Chopped, and Alternate |
| Deflection Factor Range | 0.05 volts/cm to 50 volts/cm. .05 volts/cm to 20 volts/cm in nine calibrated steps. 1, 2, 5, 10 sequence |
| Variable Attenuator | 2.5 to 1 uncalibrated variable attenuator extends range to 50 volts/cm |
| Deflection Factor Absolute Accuracy | Adjustable to 0% error on front panel, at 0.05 volts/cm |
| Attenuator Accuracy | +or- 3% -20°C to +55°C, +or- 5% -40°C to -20°C, +or- 5% Vibration and Shock |
| Attenuator Compensation | Within +or- 1%. |
| Frequency Response | DC to 24 MC, $^{+3}_{-0}$ MC; +or- 3 MC, Humidity, Fungus, Vibration and Shock. High frequency response; no greater than 30% (3db) down from 50 kc.<br><br>Low frequency response; no greater than 2% down from 1 kc to DC. |
| Risetime | 15 nsec or less, at 0.05 volts/cm. |
| Transient Response | Rolloff, overshoot, ringing, no greater than +or-1% at 0.05 volts/cm; +or-2% Humidity, +or-3% Fungus, Vibration and Shock. |
| Linearity | +or- 2.5% from 2 cm to 4 cm. |
| Input Impedance | 1 Meg +or-5%, 20 pF +or-5% |
| Trace Drift | +or-1cm, -20°C to +55°C; +or-2cm, -40°C to +70°C (Temp. only) |
| Maximum Input Voltage | 600 volts (DC + peak AC) |
| Microphonics | 5 mm maximum during Vibration test only. |
| Channel Isolation | 80 db minimum, with 1 kc Amplitude Calibrator square wave, 80 volts; 20 volts/cm and 0.05 volts/cm. |

| | |
|---|---|
| | Type P6003 Probe, with 42 inch cable |
| Attenuator Ratio | 10:1, +or- 5% |
| Frequency Response | DC to 24 MC, $^{+3}_{-0}$ MC. +or- 3 MC Humidity, Fungus, Vibration and Shock. High frequency response; no greater than 30% (3 db) down from 50 kc. Low frequency response; no greater than 2% down from 1 kc to DC. |
| Risetime | 15 nsec or less |
| Input Impedance | 10 Meg +or-5%, 10 pF +or-5% |
| Maximum Input Voltage | 600 Volts (DC + peak AC) |
| | Amplitude Calibrator |
| Voltage Range | 0.2 millivolts to 100 volts pk-pk, in 1, 2, 5, 10 sequence. |
| Accuracy | +or- 2% -40°C to +55°C<br>+or- 4% +55°C to +71°C |
| Frequency | 1 kc +or- 40% square wave |
| HORIZONTAL DEFLECTION | |
| | Main Sweep |
| Time/cm Range | 0.02 µs/cm to 12 s/cm<br>0.1 µs/cm to 5 s/cm in 24 calibrated steps; 1, 2, 5, 10 sequence. Uncalibrated vernier extends range to 12 s/cm. |
| Accuracy | +or- 3% -20°C to +55°C<br>+or- 5% -40°C to +71°C<br>+or- 5% Vibration and Shock |
| Sweep Expansion | X5 +or- 3% -20°C to +55°C, +or- 5% -40°C to +71°C<br>Extends range to 0.02 µs/cm |
| Triggering | External<br>AC, AC LF REJECT, DC and AUTO. 0.5 v to 100 v<br>Internal<br>AC and AC LF REJECT 2 mm or less<br>DC and AUTO 4 mm or less<br>HF SYNC 30 MC or greater, (2 cm deflection and 2 mm maximum horizontal jitter). |
| Trigger Input Impedance | 1 Megohm +or-10%<br>30 pF +or-15% AC and AC LF REJECT |
| Single Sweep | Manual or electronic reset. Electronic reset is obtained by use of the delaying sweep with external trigger. |

| | |
|---|---|
| | Delaying Sweep |
| Time/cm Range | 2 μs/cm to 10 ms/cm in 12 calibrated steps; 1, 2, 5, 10 sequence. |
| Accuracy | +or- 3% -20°C to +55°C<br>+or- 5% -40°C to +71°C<br>+or- 5% Vibration and Shock |
| Triggering | 1 volt to 100 volts |
| Jitter | 1/20,000 at 1 ms/cm, (5 mm at 1000 expansion using Delay Time Multiplier and Main Sweep Display) |
| Sweep Length | Continuously variable from 4 cm +or- 0.5 cm to 10 cm -0 +1 cm. |
| | Variable Time Delay |
| Delay Time Range | 1 μsec to 100 msec<br>2 μsec to 10 msec in 12 calibrated steps; 1, 2, 5, 10 sequence.<br>Calibrated 10 turn vernier/multiplier extends range to 1 μsec and 100 msec |
| Accuracy | +or- 1% -20°C to +55°C<br>+or- 3% -40°C to +71°C<br>Incremental 0.2% -40°C to +71°C at 500 μsec |
| | Horizontal Amplifier |
| External Input | DC Coupled |
| Deflection Factor | Continuously variable from 0.2 volts/cm or less to 10 volts/cm or greater with 5X magnifier on. |
| Attenuator Accuracy | X10<br>+or- 3% -40°C to +55°C |
| Attenuator Compensation | Within +or- 3% in X1 and X10, at maximum variable gain. |
| Frequency Response | DC to 1 MC at maximum gain; high frequency no greater than 30% (3db) down from 1 kc; low frequency response no greater than 3% down from 1 kc to DC. |
| Input Impedance | 1 Meg +or-5%, 47 pF +or- 5% |
| OUTPUT SIGNALS | |
| | +Gate Main Sweep |
| Volts, pk-pk | 25 +or- 50% |

| | |
|---|---|
| | Sawtooth Main Sweep |
| Volts, pk-pk | 165 +or- 20% |
| | Delayed Trigger |
| Volts, pk-pk | 7 +or- 50% |
| | +Gate Delaying Sweep |
| Volts, pk-pk | 20 +or- 50% |
| | Vertical Signal Out |
| Volts, pk-pk | 2 +or- 50% per cm of vertical deflection. |
| Frequency Response | 20 cps to 4.5 MC. No greater than 30% down, 50 kc reference. |
| | Power Source |
| | 115/230v +or- 10%, 1 ϕ, 50 to 400 cps +or- 10%, 700 watts maximum |
| Regulation | At voltage limits 103.5 and 126.5 no greater than the following change from 115v line will be observed:<br>Deflection Factor +or- 1.5%, +or- 2% Humidity, Fungus, Vibration and Shock (Both channels at 0.05 volts/cm)<br>Amplitude calibrator, +or- 0.5% at 100 volts<br>Time Base +or- 0.75% Main and Delaying Sweep at 1 ms/cm |
| **GENERAL** | |
| Warm-up Time | 20 min. for rated accuracies |
| CRT | T945P2 |
| Accelerating Potential | 10KV |
| Useful Scan | 4 X 10 cm |
| Visual Writing Rate | Visible trace in darkened room with no brightened spot at start of sweep. Sweep at 0.02 $\mu$sec/cm, 10 cps trigger rate. |
| Geometry | No greater than 1 mm of tilt or bowing. |
| Focus | Horizontal; 1 mm markers distinguishable over 8 cm. Vertical; with 2 lines/mm raster, distinguishable lines can be observed over entire 4 cm of vertical deflection with nominal intensity. |
| Cathode Modulation | Intensity modulation can be obtained with 20 volts pk-pk or more. |

**TABLE 1-2**

**ENVIRONMENTAL SPECIFICATIONS**

| | |
|---|---|
| Storage | As a result of preconditioning test Para. 4.4.1 of MIL-T-945A +85°C, -65°C, 50,000 ft., there will be no visible damage or electrical malfunction. Adjustments may be performed if necessary to meet required accuracies. |
| Temperature | Following Para. 4.4.4 of MIL-T-945A, -40°C to +85°C, the instrument will perform to the limits indicated in the individual characteristic requirements.<br><br>Maximum continuous operating temperature is +55°C for all rated accuracies. Operation from +55°C to +71°C is limited to one hour. The amplitude calibrator, main sweep, delaying sweep and time delay have specific tolerances up to +71°C. Other characteristics will deteriorate an unspecified amount depending on the length of time and how high above +55°C the operation takes place.<br><br>Overheat warning light turns on at +59°C +or- 3°C. The thermal cut-off functions at +75°C +or- 3°C for complete shut-down.<br><br>Minimum operating temperature is -40°C. |
| Altitude | The instrument is capable of operating up to 20,000 ft. altitude with the maximum continuous operation temperature reduced to +50°C. Test is performed according to Para. 4.4.4 of MIL-T-945A with 20,000 ft. altitude, instead of 10,000 ft. |
| Water Drip | The enclosure test is performed to meet Para. 5.2.3 of MS-108D, as called out in Para. 4.4.8 of MIL-T-945A. A stream of water directed at an angle of 15° from vertical, from a nozzle 3' above specimen, 1 ft. head, all surfaces for a period of 5 minutes. The instrument will meet all electrical specifications as indicated in individual characteristic requirements. Minor water entry will be tolerated. |
| Primary Power Frequency | The instrument will meet electrical requirements at 50 to 400 cps +or- 10%. |
| Humidity | Para. 4.4.2 of MIL-T-945A refers to MS-170 10 day Humidity test. +18°C to +65°C, 90% to 98% R.H. The instrument will perform to the limits indicated in the individual characteristic requirements. |
| Fungi | The instrument is placed in a Fungus test chamber for 28 days as described in Para. 4.4.3 of MIL-T-945A. +30°C +or- 5°C, 90 to 100% humidity. After 48 hours drying at room conditions, all electrical specifications are met, modified as indicated in the individual requirements. |

| | |
|---|---|
| Vibration | Para. 4.4.5 of MIL-T-945A requires:<br>10 to 33 cps 0.06" pk-pk, 15 min. cycling<br>10 to 55 cps 0.03" pk-pk, 15 min. cycling, in each of three major axis.<br>Also, 3 min. at each of four most severe resonant points.<br><br>The Type 945/MC will meet these requirements. The instrument is energized with all circuits functioning. There will be no intermittent or erratic behavior of display. Visible breakage, loosening of parts, excessive wear or fatigue will not be permissible. All electrical specifications are met after the test, modified as indicated in the individual characteristic requirement. |
| Shock | The instrument will meet the 400 lb. hammer drop test of MIL-T-945A, Para. 4.4.6, a total of nine blows:<br>Back and side, 1, 2 and 3 feet; top, 2, 3, and 4 feet.<br>Specimen is energized. Minor damage is permissible. After the test, the instrument will meet all electrical specifications as modified in the individual requirements. |
| Radio Interference | The Type 945/MC meets limits for broadband radiated and conducted interference of MIL-I-16910A, MIL-I-26600, MIL-I-11748B from 14 kc to 1000 mc. It also meets susceptibility test of MIL-T-945A, Para. 3.43.1.2, 1 mv, 50 kc to 400 mc. |
| Salt Spray | Parts are finished so there will be no destructive corrosion after 100 hour salt spray test according to Fed. Std. 151, Para. 3.35, MIL-T-945A. |

**TABLE 1-3**

**MECHANICAL SPECIFICATIONS**

| | |
|---|---|
| Ventilation | Safe operating temperature is maintained by filtered, forced-air ventilation. A minimum of 2" of unobstructed clearance around the instrument is recommended for adequate ventilation. |
| Finish | Military gray enamel per MIL-E-15090, Class 2, Film E, on cabinet and front panel. Photo-etched lettering. |
| Dimensions | 18.1 in. high; 13.4 in. wide; 25.3 in. deep -- without panel covers<br>18.4 in. high; 13.8 in. wide; 26.4 in. deep -- with panel covers |
| Weight | Without Plug-in Preamplifier 78 lbs<br>Type MC Plug-in Preamplifier 5.5 lbs<br>Front and rear panel covers with accessories 14 lbs |
| Power Cable | Permanently attached three wire with a MIL-C-3432A plug. (2 or 3 prong). |
| Connectors | All input and output signal jacks are of the BNC type. |

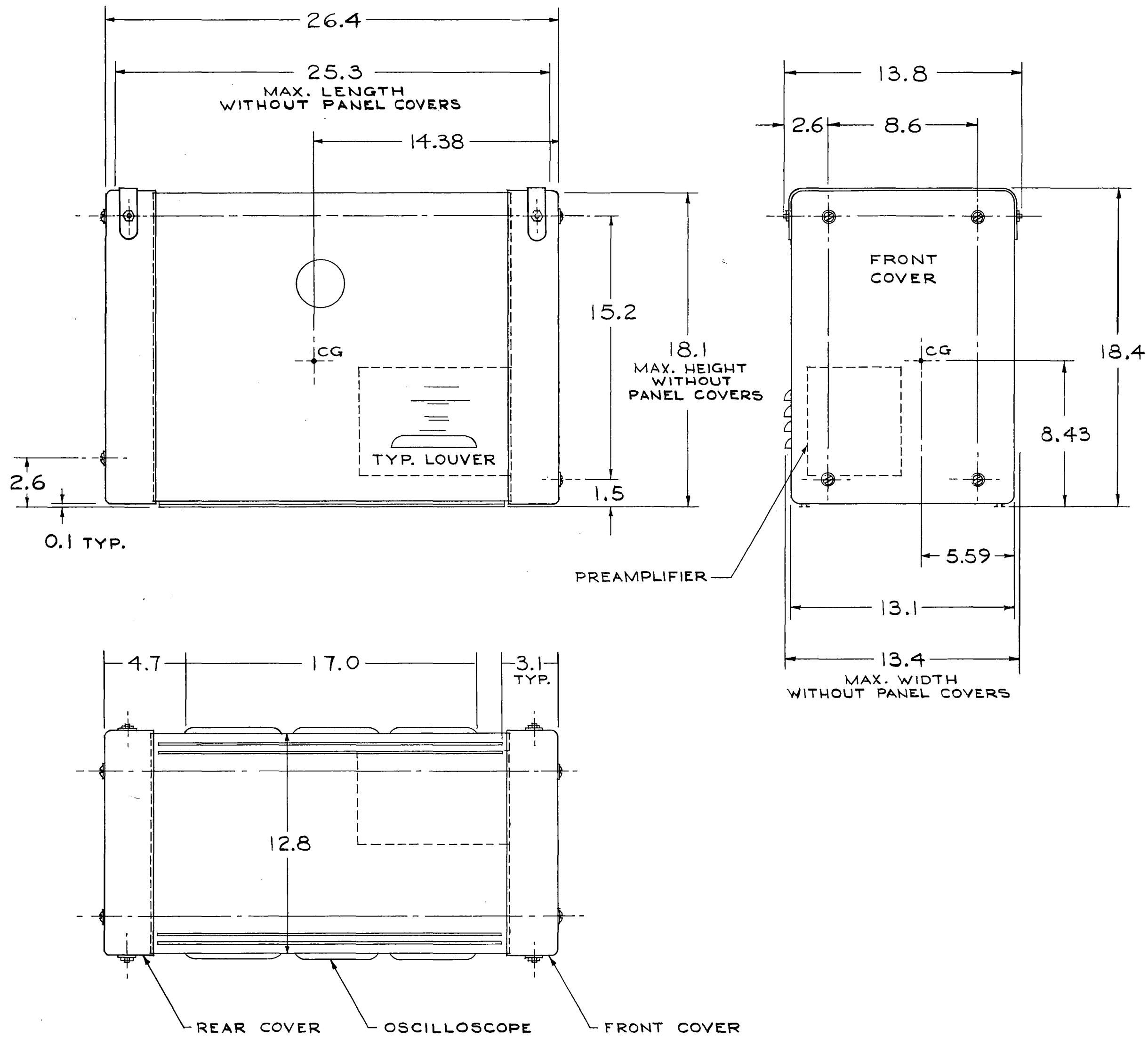
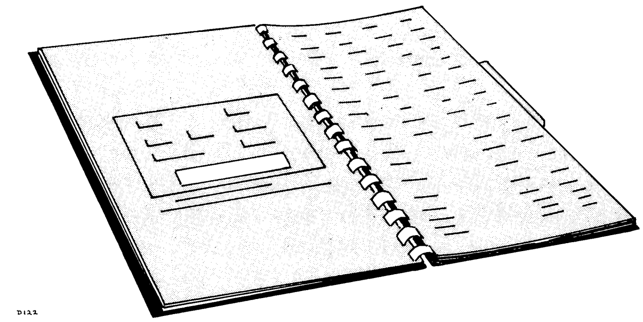



Fig. 1-1. Typical Dimensions of the Type 945.



# SECTION 2

# OPERATING INSTRUCTIONS

**2-1. GENERAL INFORMATION**

**2-2.** The Type 945 Oscilloscope and MC Plug-In Preamplifier Unit form a versatile combination adaptable to a number of uses. To make full use of the potentialities of the instrument, it is necessary that you understand the operation of each control. This section of the instruction manual provides you with basic information you will require.

**2-3. Plug-In Units**

**2-4.** While a special plug-in, the Type MC Unit, is provided for the Type 945 oscilloscope, it is possible to use other Tektronix plug-ins with the Type 945*. To use a Tektronix commercial type plug-in, remove the Type MC unit from the Type 945 plug-in compartment and insert the desired plug-in instead. Press the plug-in firmly into the compartment to insure that all the connectors have seated properly. Tighten the locking control (a grey knob at the bottom of the plug-in panel) to hold the unit securely in place. For information on the operation of commercial plug-ins see the instruction manual for the plug-in you wish to use.

*The Type 945 oscilloscope will accommodate Tektronix commercial type plug-in units with the following designations: Type 53 (followed by a letter designation, for example, Type 53A.) Type 53/54 (followed by a letter designation, for example, Type 53/54A.) Type (followed by a letter designation, for example, Type A.) Plug-ins with other designations will not operate in the Type 945.

**TABLE 2-1**

**FUNCTIONS OF CONTROLS, INDICATORS AND CONNECTORS**

| NAME OF CONTROL | FUNCTION |
|---|---|
| HORIZONTAL DISPLAY | Four position switch that sets up the four different types of sweep operation. This switch is the key to main circuit connections. The various circuit connections with each switch setting are shown in block diagram form in Schematic Diagrams 81-0001-01 through 81-0001-04. In the MAIN SWEEP NORMAL and the MAIN SWEEP DELAYED positions, the output of the Main Sweep is connected to the sweep-amplifier input. In the DELAYING SWEEP position, the output of the Delaying Sweep is connected to the sweep-amplifier input. In the MAIN SWEEP DELAYED and the DEL'G SWEEP positions, the Main Sweep is held inoperative--"locked out" --until after a delay time following triggering of the Delaying Sweep. (See DELAY-TIME MULTIPLIER, p. 2-3). In the EXT. SWEEP position, the TRIGGER OR EXT. SWEEP IN connector is connected to the sweep-amplifier input. Output from the Main Sweep can be obtained but the Delaying Sweep and the Delay Pickoff circuits are disabled. (When the HORIZONTAL DISPLAY switch is in the EXT. SWEEP position, the 5X MAGNIFIER switch should be turned ON.) |

| MAIN SWEEP | |
|---|---|
| TRIGGER SLOPE | Black TRIGGER SLOPE switch selects Main Sweep triggering signals. The triggering sources are: the displayed signal (+INT. or -INT.), a signal fed to the TRIGGER INPUT connector (+EXT. or -EXT.), and the power-line wave (+LINE or -LINE). In +INT., +EXT. and +LINE positions, triggering occurs during the voltage rise of the triggering waveform. In - slope positions, triggering occurs during the voltage fall portion. |
| TRIGGERING MODE | Five-position switch (red knob) selects one of four types of triggering (AUTO., AC, DC or AC LF REJECT), or synchronized operation (HF SYNC). See discussion of these operating modes on p. 2-13 to 2-16. |
| STABILITY | Red STABILITY control adjusts Main Sweep for triggered or free-running operation. With Main Sweep TRIGGERING MODE switch in AC, DC or AC LF REJECT, Main Sweep STABILITY can generally be used in PRESET. (For manual operation of Main-Sweep STABILITY control, see p. 3-3). This control is the synchronizing control when the TRIGGERING MODE switch is in HF SYNC. Main Sweep STABILITY is disabled when Main Sweep TRIGGERING MODE is in AUTO. |
| TRIGGERING LEVEL | Black TRIGGERING LEVEL control determines at what voltage on the input triggering signal the horizontal trace will start. This control is disabled when the Main-Sweep TRIGGERING MODE switch is in the AUTO. or HF SYNC positions. |
| TIME/CM | Eight-position switch (black knob) to control Main Sweep rate. |
| MULTIPLIER | Six-position switch (black knob). Three positions marked in black, indicate factors by which TIME/CM settings are to be multiplied to obtain Main Sweep rate. Three positions, marked in red, provide variable (uncalibrated) Main Sweep rate control by means of associated red knob. |
| 5X MAGNIFIER | When the red 5X MAGNIFIER knob is turned from the OFF position to the ON position, that part of the display which occupied the middle two divisions of the graticule is expanded to fill the graticule horizontally. Turn the 5X MAGNIFIER ON when you set the HORIZONTAL DISPLAY switch to EXT. SWEEP. |
| TRIGGER INPUT | Connector for accepting an external triggering signal for the Main-Sweep generator when the Main-Sweep TRIGGER SLOPE switch is in the +EXT. or the -EXT. position. |
| SAWTOOTH MAIN SWEEP | Connector supplying a positive-going sawtooth having a peak value of about +150 volts. The rising part of the sawtooth coincides with the left-to-right trace of the Main Sweep. The rate at which the sawtooth rises is controlled by the Main-Sweep TIME/CM switch and by the black and red MULTIPLIER controls. |

| | |
|---|---|
| +GATE MAIN SWEEP | Connector supplying a positive-going rectangular wave having a maximum value of about +20 volts. Its starting time and duration correspond to the starting time and duration of the positive-going part of the saw-tooth available at the SAWTOOTH MAIN SWEEP connector. |
| RESET | Push-button which produces manually-controlled single sweeps (p.3-21), or which arms the Main Sweep for triggered single sweeps (p.3-21). |
| DELAYING SWEEP | |
| SLOPE +, - (toggle sw.) | Two-position switch. In the +position, triggering of the Delaying Sweep occurs during the voltage rise of the triggering waveform. In the -positions, triggering of the Delaying Sweep occurs during the voltage fall of the triggering waveform. |
| STABILITY OR EXT. SWEEP ATTEN. | Red control adjusts the Delaying-Sweep generator for triggered or free-running operation. When the HORIZONTAL DISPLAY switch is in the EXT. SWEEP position, red control provides variable control of the horizontal deflection. |
| TRIGGERING LEVEL | Black control determines at what voltage on the Delaying-Sweep input triggering signal the Delaying Sweep will start. |
| TIME/CM OR DELAY TIME | Twelve-position switch to control Delaying Sweep rate. (See also DELAY-TIME MULTIPLIER, below). |
| DELAY-TIME MULTIPLIER 1-10 | Ten-turn control. When the HORIZONTAL DISPLAY switch is in the DEL'G SWEEP or the MAIN SWEEP DELAYED positions, the Main Sweep is held inoperative-" locked out" -until after a delay time following the triggering of the Delaying Sweep. This delay time is the product of the settings of the TIME/CM OR DELAY TIME control and of the DELAY-TIME MULTIPLIER control. (See also DEL'D TRIG. FROM MAIN OR DEL'G SWEEP, below.) |
| DEL'D TRIG. FROM MAIN OR DEL'G SWEEP | Connector supplying delayed positive-going triggering signals. When the HORIZONTAL DISPLAY switch is in the MAIN SWEEP NORMAL position, the output triggering signal occurs following the start of the Main Sweep, after a delay equal to the product of the settings of the Main-Sweep TIME/CM control, the MULTIPLIER control and the DELAY-TIME MULTIPLIER control. When the HORIZONTAL DISPLAY switch is in the MAIN SWEEP DELAYED or in the DEL'G SWEEP position, the output triggering signal occurs following the start of the Delaying Sweep, after a delay equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control. |
| LENGTH | Sweep-length control permits delaying sweep to be reverted immediately after delayed Main Sweep is triggered, to increase possible duty cycle. (Normally control will remain in fully clockwise position.) |
| +GATE DEL'G SWEEP | Connector supplying a positive-going rectangular wave having a maximum value of about +20 volts. Its positive portion coincides with the left-to-right trace of the Delaying Sweep. |

| | |
|---|---|
| TRIGGER OR EXT. SWEEP IN | Coaxial connector that accepts triggering signals for the Delaying Sweep when the HORIZONTAL DISPLAY switch is in any position except EXT. SWEEP. When the HORIZONTAL DISPLAY switch is in the EXT. SWEEP position, this connector accepts external horizontal-deflection waveforms (See ATTEN., below.) |
| ATTEN., X1, X10 (toggle sw.) | Two-position switch. When waveforms supplied to the TRIGGER OR EXT. SWEEP IN connector exceed about 10 volts, use the X10 position. Otherwise, use the X1 position. |
| | OTHER FRONT-PANEL CONTROLS, CONNECTORS AND INDICATORS |
| FOCUS | Control operated in conjunction with ASTIGMATISM to obtain a sharp, clearly defined trace or spot. |
| INTENSITY | Control used to adjust the brightness of the oscilloscope display. |
| ASTIGMATISM | Control operated in conjunction with FOCUS to obtain a sharp, clearly defined trace or spot. |
| SCALE ILLUM. | Control used to adjust intensity of graticule illumination. |
| HORIZONTAL POSITION | Black knob positions trace horizontally. |
| VERNIER | Red knob provides fine control of horizontal position of trace. |
| AMPLITUDE CALIBRATOR | Black knob selects any one of nine calibrated square-wave output amplitudes. Red knob (three-position switch) selects black-knob range in either VOLTS or mVOLTS; also turns Calibrator OFF. |
| CALIBRATOR OUT | Connector for supplying square-wave output voltage from Calibrator. |
| VERTICAL SIGNAL OUT | Connector supplies vertical waveform being displayed on oscilloscope. Approximately 2 volts peak-to-peak for each centimeter of vertical deflection. |
| CRT CATHODE | Connector for accepting intensity-modulation voltage. Capacitively coupled. When not in use, this connector should be grounded by attaching its cover. |
| Ground | Connector for grounding auxiliary equipment to chassis of oscilloscope. |
| POWER | Switch applies line voltage to power transformer. |
| Pilot Light | Red indicator lamp lights when power transformer is in operation. |
| OVERHEAT WARNING | White indicator lamp turns on at +59°C. +or-3°C. Operation of instrument between +55°C. and +71°C. is limited to one hour. |
| READY | Neon indicator lamp lights when Lockout Circuit has made MAIN SWEEP ready to receive a trigger. |
| Beam Position Indicators | Indicator lamps marked with arrows, show the direction in which the beam is off the screen if it is not visible. |

| | |
|---|---|
| LINE FUSES | Fuse Holders provide easy access to line fuses: 7-ampere fuses for 115-volt operation; 4-ampere fuses for 230-volt operation. |
| SPARE FUSES | Fuse Holders provide convenient storage for spare fuses. |

**2-5. FIRST TIME OPERATION (oscilloscope)**

**2-6. Preparation for Use**

**2-7.** When the plug-in unit has been selected, insert it into the plug-in compartment of the oscilloscope and press firmly to insure that the connectors make proper contact. Close the plug-in unit locking handle to hold the unit securely in place and turn the oscilloscope INTENSITY control fully counterclockwise. Connect the power cord to the power line.

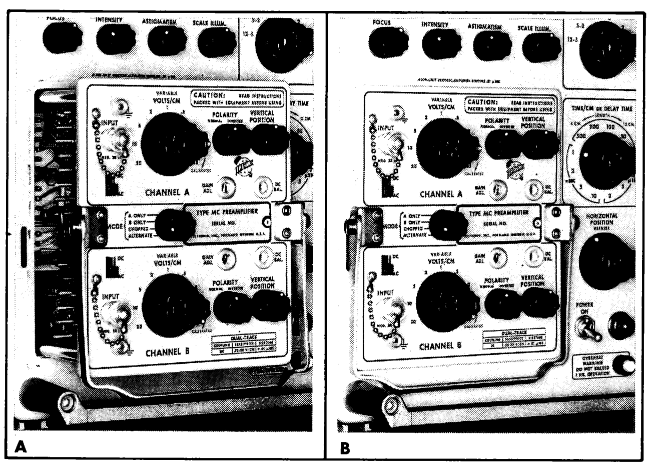



Fig. 2-1. (a) Type MC Plug-In Unit in Type 945 with the latch released. (b) Proper insertion of the Type MC Unit in the Type 945.

**CAUTION:** The cathode-ray tube in this instrument has an accelerating potential of 10,000 volts. The intensity of a sharply focused spot can be bright enough to burn the screen phosphor if the spot remains in one place. Be careful not to leave a fixed bright spot on the screen. Turn the INTENSITY down so that the spot is dim or extinguished if you leave the instrument unattended.

**2-8.** Set the front-panel controls as shown:

| | |
|---|---|
| FOCUS | mid-scale |
| INTENSITY | full-left |
| ASTIGMATISM | centered |
| SCALE ILLUM. | centered |
| MAIN SWEEP section | |
| STABILITY | full right |
| TRIGGERING LEVEL | full right |
| TRIGGERING MODE | +INT. |
| TRIGGER SLOPE | AC LF REJECT |
| TIME/CM | 10 μSEC |
| MULTIPLIER | 1 |
| 5X MAGNIFIER | OFF |
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| ATTEN | X1 |
| SLOPE | + |
| HORIZONTAL POSITION | centered |
| VERNIER | centered |
| AMPLITUDE CALIBRATOR | 50 mVOLTS |
| POWER | ON |

**2-9. Time Delay**

**2-10.** The time delay relay used in the Type 945 Oscilloscope delays operation of the instrument for 30-45 seconds after the POWER switch is turned ON to allow a brief tube-warmup period. The delay allows the tubes sufficient time to heat before the dc operating voltages are applied. The OVERHEAT WARNING light will glow until the time delay relay operates.

**2-11.** If the ac power is off for only an instant, the normal 30-45 second delay will occur before the instrument returns to full operation. This delay will occur regardless of whether the ac power is off because of a momentary power failure or is turned off with the POWER switch.

**2-12. Focus and Astigmatism Controls**

**2-13.** The FOCUS and ASTIGMATISM controls operate in conjunction with each other to allow you to obtain a sharp, clearly defined spot or trace. The proper setting of the ASTIGMATISM control is obtained by rotating the FOCUS control fully clockwise, setting the HORIZONTAL DISPLAY switch at EXT. SWEEP, and adjusting the INTENSITY control to obtain a dim spot on the screen. After positioning the spot to the center of the screen, the ASTIGMATISM control is adjusted for the most nearly circular spot possible. The FOCUS control is then adjusted to reduce the spot diameter as much as possible. (You must be certain that all input signals to the oscilloscope are disconnected when you adjust the FOCUS and ASTIGMATISM controls.)

**2-14. Intensity Control**

**2-15.** The INTENSITY control is used to adjust the brightness of the oscilloscope display. This permits you to compensate for changes in brightness resulting from changes in the sweep or triggering rate. The INTENSITY control is rotated clockwise to increase brightness and counterclockwise to decrease brightness. Care must be taken when using the INTENSITY control that the brightness is not turned up to the point where the face of the cathode-ray tube is permanently damaged. If the intensity of the beam is turned up too far, the phosphor on the face of the crt may be burned. The intensity of the beam should never be turned up to the point where a halo forms around the spot.

**2-16. Graticule Illumination Control**

**2-17.** The graticule used with the Type 945 Oscilloscope is accurately marked with 10 horizontal and 4 vertical 1-centimeter divisions with 2-millimeter markings on the centerlines. These graticule markings allow you to make time and voltage measurements from the oscilloscope screen.

**2-18.** The graticule is illuminated by two lamps located at the top end of the graticule. This illumination can be controlled so that the graticule markings appear either red or white, as desired. The graticule markings are changed from red to white or from white to red by removing the graticule cover and rotating the graticule through 180° about an axis through the center of the graticule (see Figure 2-2). As a general rule, white graticule markings are superior to red for photographic purposes.

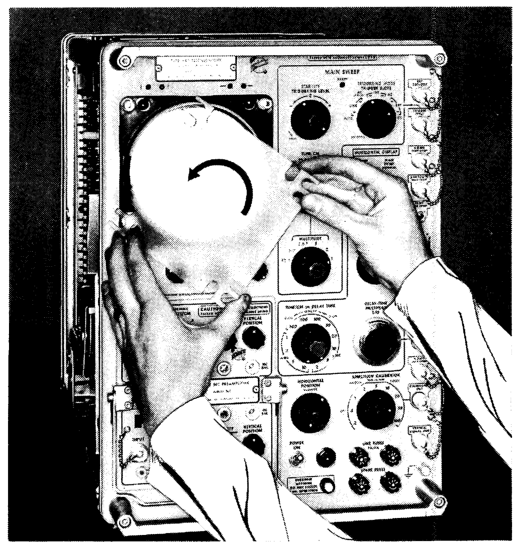


Fig. 2-2. Rotating the graticule to change the color of the graticule markings from red to white or from white to red.

**2-19.** Graticule illumination is adjusted by the SCALE ILLUM control located just under the oscilloscope screen. Rotating the control clockwise increases the brightness of the graticule markings and rotating the control counterclockwise decreases the brightness.

**2-20. Positioning Controls**

**2-21.** Four controls are used with the Type 945 Oscilloscope with Type MC Preamplifier Unit to allow you to position the traces to the desired point on the oscilloscope screen. Two of these controls are used to set the horizontal position of the traces and are located on the front panel of the instrument. The other controls are used to set the vertical position of the traces and are located on the front panel of the plug-in unit used with the oscilloscope.

**2-22.** The two HORIZONTAL POSITION controls cause the trace to move to the right when they are rotated in the clockwise direction and to the left when they are rotated counterclockwise. The combination of the two controls has a total positioning range of approximately 12 centimeters with the sweep magnifier OFF or approximately 60 centimeters with the sweep magnifier ON. The black HORIZONTAL POSITION control has approximately three times the range of the red VERNIER control. The fine range of adjustment of the VERNIER control makes this control particularly useful whenever fine horizontal positioning is required, as for example, when the sweep magnifier is used.

**2-23.** The Type MC vertical positioning controls have sufficient range to allow either trace to be positioned completely off the top or bottom of the screen or to any intermediate point. The trace moves up when the control is rotated clockwise and down when the control is rotated counterclockwise.

**2-24. Beam Position Indicators**

**2-25.** Four small indicator lights located just above the oscilloscope screen indicate the position of the spot or trace. When one of these lamps is lit, it indicates that the trace is off-centered in the direction of the arrow. These four lights allow you to position the spot to the center of the screen even though the intensity is so low that the trace is not visible. When the sweep is running, the spot moves from the left side of the screen to the right and may cause both horizontal lamps to light each time the sweep runs.

**2-26. Input Signal Connections**

**2-27.** The electrical waveform to be observed is applied to the plug-in unit input connector. The waveform is then connected through the vertical-deflection system of the plug-in unit and the oscilloscope to cause the spot to be deflected vertically and to trace out the waveform on the screen of the crt. The vertical size of the displayed waveform is adjusted with the plug-in unit VOLTS/CM switch. The VOLTS/CM switch is an accurately calibrated control which, when used with the graticule, allows you to make precise voltage measurements from the displayed waveforms.

**2-28.** Certain precautions must be taken when you are connecting the oscilloscope to the input signal source to insure that accurate information is obtained from the oscilloscope display. This is particularly true when you are observing low-level signals or waveforms containing high- or extremely low-frequency components. For applications where you are observing low-level signals, unshielded input leads are unsatisfactory due to their tendency to pick up stray signals which produce erroneous oscilloscope displays. Shielded cables should be used whenever possible, with the shield connected to the chassis of both the oscilloscope and the signal source. Regardless of the type of input lead used, leads should be kept as short as possible.

**2-29.** Distortion of the input waveform may result if very low-frequency input signals are ac coupled into the oscilloscope, if high-frequency waveforms are not properly terminated, or if the input waveform contains high-frequency components which exceed the bandpass of the oscilloscope and plug-in unit combination. You must be aware of the limitations of the instrument.

**2-30.** In analyzing the displayed waveform, you must consider the loading effect that the oscilloscope has on the input-signal source. In some cases this loading effect is negligible; however in other applications, loading caused by the oscilloscope may materially alter the results obtained. In such cases the amount of loading may be reduced through the use of a probe.

**2-31. Use of Probes**

**2-32.** Occasionally connecting the input of an oscilloscope to a signal source loads the source sufficiently to adversely affect both the operation of the source and the waveform displayed on the oscilloscope. In such cases an attenuator probe may be used to decrease both the capacitive and resistive loading caused by the oscilloscope.

**2-33.** In addition to providing isolation of the oscilloscope from the signal source, an attenuator probe also decreases the amplitude of the displayed waveform by the attenuation factor of the probe. Use of a probe allows you to observe the vertical-deflection signals which are beyond the normal limits of the oscilloscope and plug-in combination. Signal amplitudes, however, must be limited to the maximum allowable value for the probe used.

**2-34.** Before using a probe you must check (and adjust if necessary) the compensation of the probe to prevent distortion of the applied waveform. To adjust the probe compensation place the HORIZONTAL DISPLAY switch at MAIN SWEEP NORMAL, the Main Sweep TRIGGERING MODE switch at AUTO., and the Main Sweep TRIGGER SLOPE switch at + INT. Turn up the intensity until the trace is visible and connect the probe tip to the CALIBRATOR OUT connector. Set the AMPLITUDE CALIBRATOR switch for 2 centimeters of displayed signal. Set the Main Sweep TIME/CM switch to display approximately 3 or 4 cycles of the Calibrator waveform and adjust the probe compensation control to obtain flat tops on the displayed Calibrator square-waves (see Figure 2-3). Since the Type P6003 probe is used with the Type 945, it is necessary to first unlock the Locking Sleeve by turning it counterclockwise. The probe is then compensated by rotating the probe body while watching the oscilloscope display for the desired waveform. When compensation is completed, carefully turn the Locking Sleeve clockwise to lock it without disturbing the adjustment of the probe.

**2-35.** Check the FIRST TIME OPERATION of the preamplifier plug-in unit (such as the Type MC).

### 2-36. Horizontal Sweep

**2-37.** The usual oscilloscope display is a graphical presentation of instantaneous voltage versus time. Voltage information is presented by vertical deflection of the trace and time information is presented by horizontal deflection. To obtain a useful display, it is necessary for the spot formed by the electron beam to

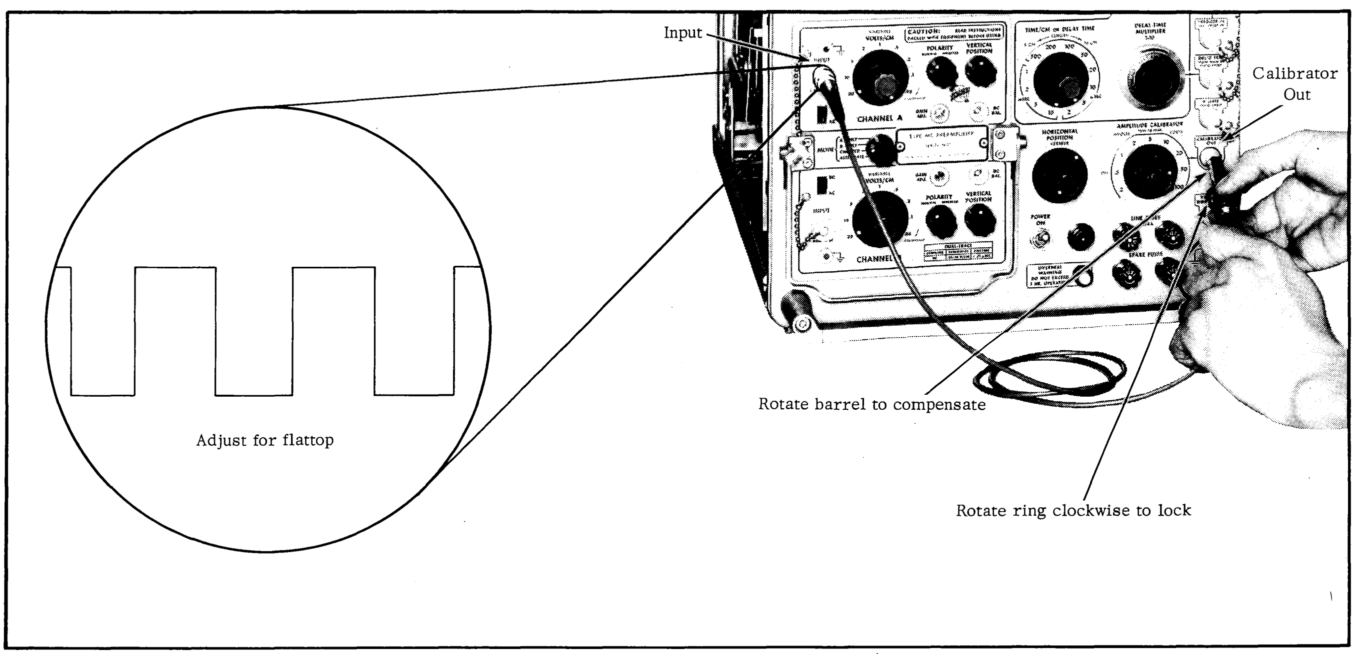



Fig. 2-3. When compensating the probe it is adjusted to obtain an undistorted presentation of the calibrator square-waves.

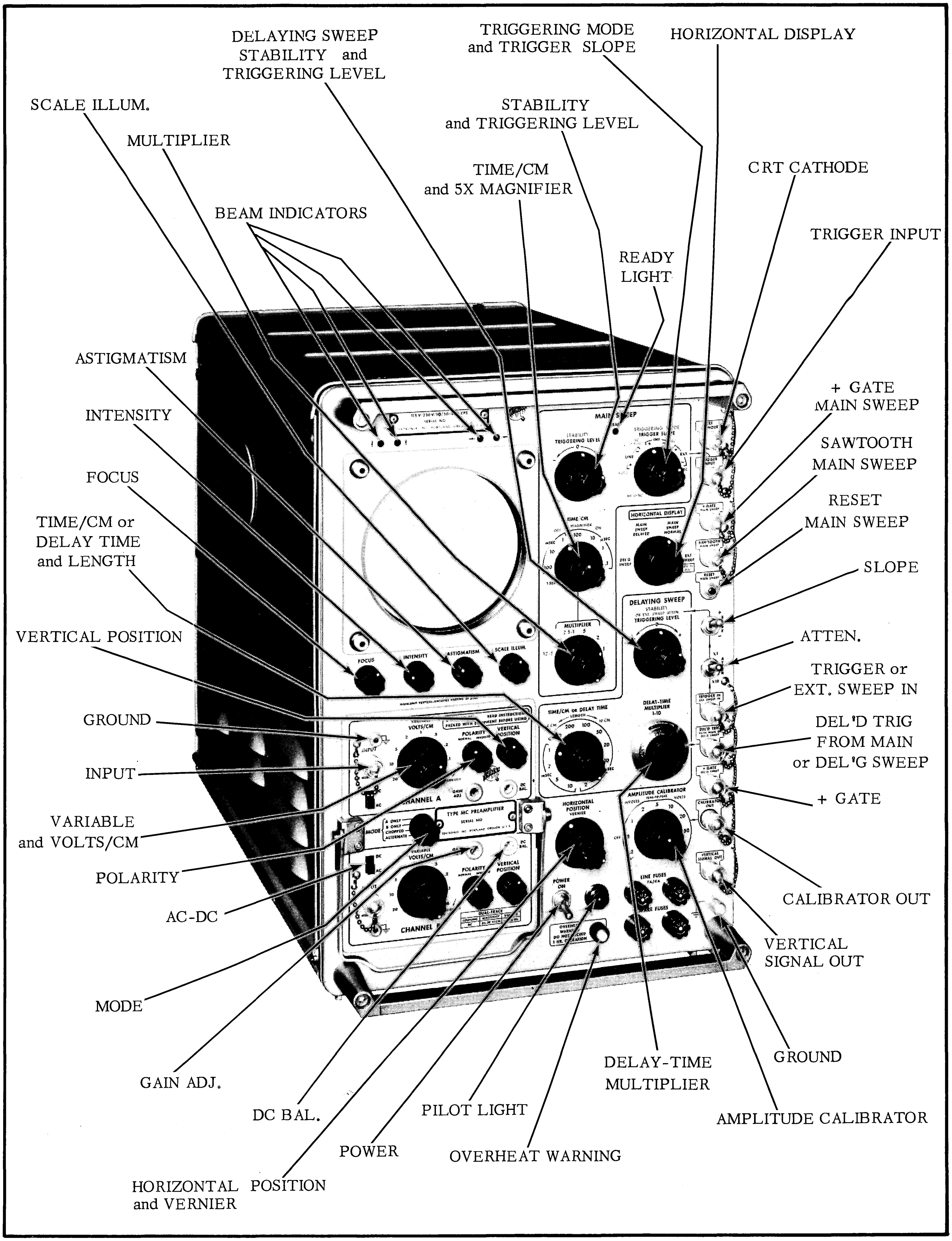



Fig. 2-4. Front-panel controls and connectors of the Type 945 Oscilloscope.

be deflected horizontally at a known rate so that any horizontal distance on the screen represents a definite known period of time. The trace formed by the deflection of the spot across the screen is known as the horizontal sweep. Since the horizontal deflection of the spot bears a definite relationship to time and provides the means for making time measurements from the screen, the horizontal sweep is also known as the time base.

**2-38.** The Type 945 Oscilloscope features two independent time-base units: MAIN SWEEP and DELAYING SWEEP. Either of the two time bases may be displayed on the oscilloscope screen at any time. Controls affecting MAIN SWEEP and DELAYING SWEEP operation are in the correspondingly labeled blocks on the oscilloscope front panel. The HORIZONTAL DISPLAY switch determines which time base is used and the type of display to be presented. This switch is the key to the operation of the sweep as emphasized by the block diagrams in the schematic section. The functional block diagrams show the circuitry changes with each position of the HORIZONTAL DISPLAY switch. The Main Sweep is selected when the HORIZONTAL DISPLAY switch is in the MAIN SWEEP NORMAL position and the Delaying Sweep time base is selected when the switch is in the DEL'G SWEEP position.

**2-39.** The rate at which the spot is deflected across the screen is accurately controlled by the setting of the appropriate TIME/CM controls. The settings of the TIME/CM controls determine the sweep speed and the horizontal size of the displayed waveform. The controls are set to display the portion of the waveform you wish to observe.

**2-40.** The Main Sweep has 24 accurately calibrated sweep speeds ranging from .1 microseconds to 5 seconds per centimeter. The MULTIPLIER and TIME/CM controls permit you to vary the sweep speed between .1 microseconds and approximately 12 seconds per centimeter. The 3 variable ranges of the MULTIPLIER switch are not accurately calibrated.

**2-41.** The Delaying Sweep has sweep speeds ranging from 2 microseconds to 10 milliseconds per centimeter in 12 steps. There is no MULTIPLIER control for the Delaying Sweep. The red LENGTH control adjusts the sweep length between approximately 4 and 10 centimeters.

## 2-42. MAIN SWEEP TRIGGERING

**2-43.** The oscilloscope display is formed by the repetitive sweep of the spot across the oscilloscope screen. If the sweeps are allowed to occur at random or at a rate unrelated to the rate of occurrence of the input waveform, the displayed waveform will be traced out at a different point on the screen each time the sweep runs. This will either cause the waveform to drift across the screen or to be indistinguishable.

**2-44.** In most cases it is desirable for a repetitive waveform to appear stationary on the oscilloscope screen so that the characteristics of the waveform can be examined in detail. As a necessary condition for this type of display, the start of the sweep must bear a definite, fixed-time relationship to the appearance of the input waveform. This means that the sweep must be synchronized with the input waveform. In the Type 945 Oscilloscope that is accomplished by starting (triggering) the sweep with the displayed waveform or with another waveform bearing a definite time relationship to the displayed waveform.

**2-45.** The following paragraphs outline the means for selecting the triggering source, triggering slope, triggering mode and triggering level with specific information regarding the operation of the controls affecting triggering. More specific information on the selection of the triggering signal source is given in Section III. These pages give the more exact settings for each mode of operation of the Type 945 Oscilloscope.

### 2-46. Selecting the Triggering Source

**2-47.** In preparing the Type 945 Oscilloscope for triggered operation of the Main Sweep, it is

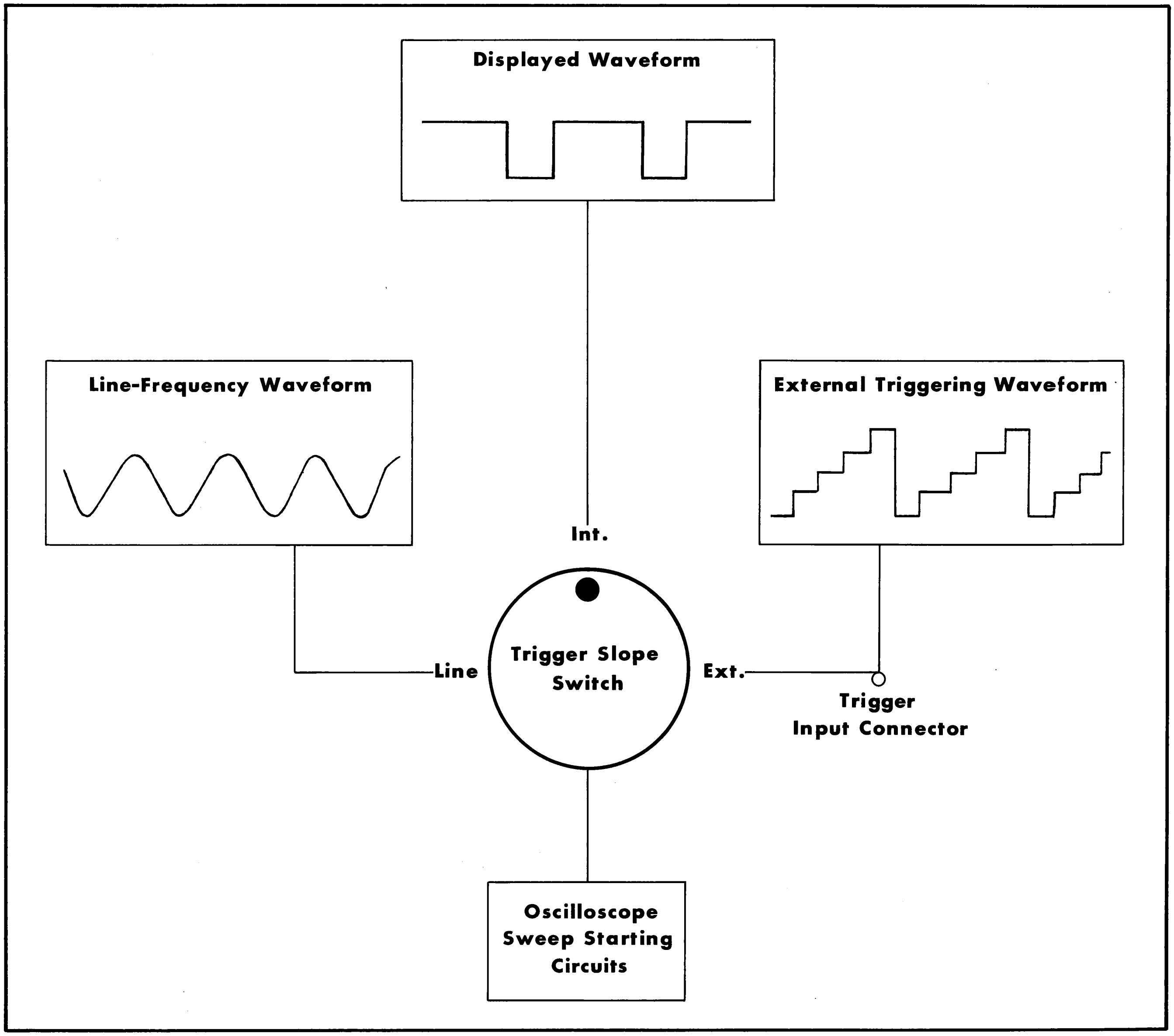



Fig. 2-5. The triggering signal is selected from three possible sources with the TRIGGER SLOPE control.

first necessary to select the triggering signal source which will provide the best display for the particular application. The sweep can be triggered by the displayed waveform, a line-frequency waveform, or by an externally derived waveform. This selection is made by the setting of the TRIGGER SLOPE control. Each type of triggering has certain advantages for some applications.

**2-48.** Triggering from the displayed waveform is the method most commonly used. The displayed waveform is selected when the TRIGGER SLOPE control is in either the + INT. or -INT. position. Internal triggering is convenient since no external triggering connections are required. Satisfactory results are obtained in most applications.

**2-49.** When you are observing a waveform which is related to the line frequency, you may wish to trigger the sweep from a line-frequency waveform. This can be done by placing the TRIGGER SLOPE switch in either the + LINE or the -LINE position. This type of triggering is particularly useful in observing waveforms which bear a definite relationship to the line frequency. The shape and amplitude of the triggering waveform remains constant to provide extremely stable triggering.

**2-50.** To trigger the sweep from some external waveform, connect the triggering waveform to the appropriate TRIGGER INPUT connector and place the TRIGGER SLOPE switch in either the +EXT. or -EXT. position. External triggering provides definite advantages over other methods of triggering in certain cases. With external triggering, the triggering signal usually remains constant in amplitude and shape. It is thereby possible to observe the shaping and amplification of a signal in an external circuit without resetting the oscilloscope triggering controls for each observation.

**2-51.** Also, time and phase relationships between the waveforms at different points in the circuit can be seen. If for example, the external triggering signal is derived from the waveform at the input to a circuit, the time relationship and phase of the waveforms at each point in the circuit are compared to the input signal by the display presented on the oscilloscope screen. When you are using external triggering and a stable triggering signal, it is possible to observe and accurately measure jitter of the displayed waveform. This is not possible when the sweep is triggered internally.

## 2-52. Selecting the Triggering Slope

**2-53.** The horizontal sweep can be triggered on either the rising (+slope) or falling (-slope) portion of the triggering waveform as determined by the position of the TRIGGER SLOPE switch.

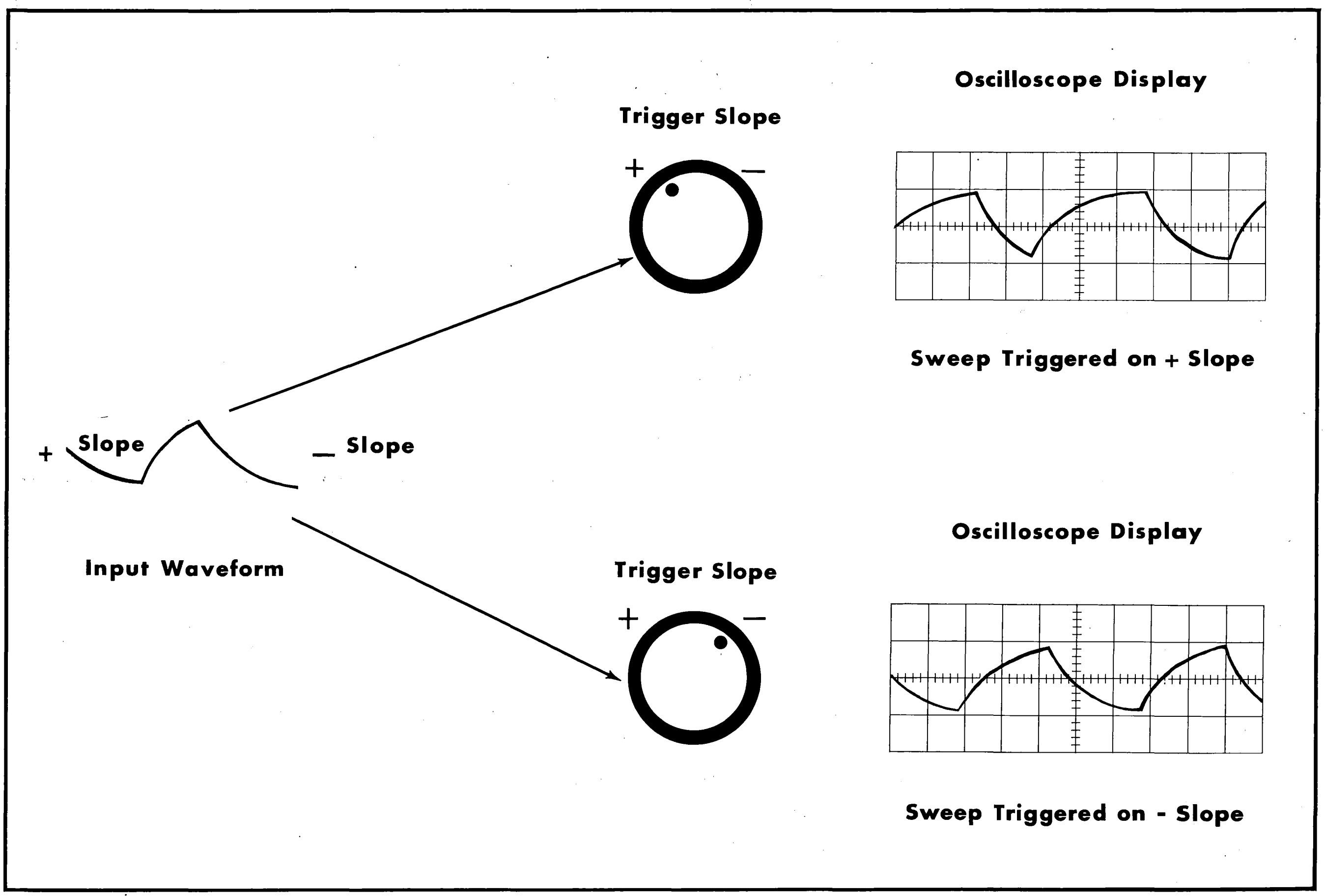



Fig. 2-6. Effects on the oscilloscope display produced by+ and - settings of the TRIGGER SLOPE control.

When the switch is in one of the + positions, the sweep is triggered on the rising portion of the triggering waveform; when the TRIGGER SLOPE switch is in one of the - positions, the sweep is triggered on the falling portion of the waveform (see Fig. 2-6).

**2-54.** In many applications the triggering slope is not important since triggering on either slope will provide a display which is suitable to the application. However, in many other cases, such as pulse measurements, the triggering slope is very important. If, while using a fast sweep, you may wish to observe the rise of a pulse at a fast sweep speed, it may be necessary to trigger the sweep on the falling portion of the waveform by placing the TRIGGER SLOPE switch in one of the - positions. In either case, selection of the wrong triggering slope may make it impossible for you to observe the portion of the waveform you wish to check.

### 2-55. Selecting the Triggering Mode

**2-56.** After selecting the triggering source and triggering slope, it is next necessary to select the triggering mode which will allow you to obtain the desired display. There are five triggering modes for the Type 945 Oscilloscope.

**2-57.** Each of the triggering modes is designed to provide stable triggering from a certain type of waveform. For most applications, however, several of the triggering modes will work equally well. For applications of this type, the triggering mode used is purely a matter of choice. The primary thing to consider in choosing the triggering mode is whether or not it allows you to obtain the display you want.

**2-58.** To determine the best mode of operation for a particular application, it is usually best to try each triggering mode in the application. The Automatic mode should be tried first since this triggering mode provides stable triggering in most applications without the necessity of setting the STABILITY or TRIGGERING LEVEL controls. If the Automatic mode does not provide the desired display, it will then be necessary for you to try one or more of the other triggering modes.

### 2-59. Automatic Triggering Mode

**2-60.** The automatic mode is most frequently used because of its ease of operation. This mode is useful in obtaining stable triggering from waveforms with frequencies of from approximately 60 cycles to 2 megacycles. The principal advantage of this type of operation is that it is not necessary to adjust either the STABILITY or TRIGGERING LEVEL controls to obtain a stable display. This permits you to observe a large number of waveforms with different shapes and amplitudes without adjusting any of the triggering controls. In the absence of a triggering signal, the sweep continues to run to provide a convenient reference trace on the oscilloscope screen.

**2-61.** The automatic triggering mode is selected by placing the TRIGGERING MODE switch in the AUTO. position. The triggering source and slope is then selected and the input signal is applied to the oscilloscope. No other control adjustments are required. Since the TRIGGERING LEVEL control has no effect on the display when automatic triggering is used, it is impossible to select the point on the triggering waveform where the sweep is triggered. Each sweep is instead triggered at the average voltage point of the waveform.

### 2-62. DC Triggering Mode

**2-63.** The DC triggering mode is selected by placing the TRIGGERING MODE switch in the DC position. This mode permits excellent triggering on all types of waveforms in the frequency range from dc to approximately 5 mc. The DC mode also permits the selection of the point on the triggering waveform where the sweep is triggered through the use of the TRIGGERING LEVEL control.

**2-64.** To use the DC triggering mode you must set the STABILITY and TRIGGERING LEVEL controls after first selecting the triggering signal source and slope. The method used to set the STABILITY and TRIGGERING LEVEL controls is the same for the DC mode, AC mode, and AC Low Frequency Reject mode. The STABILITY control must be set properly before

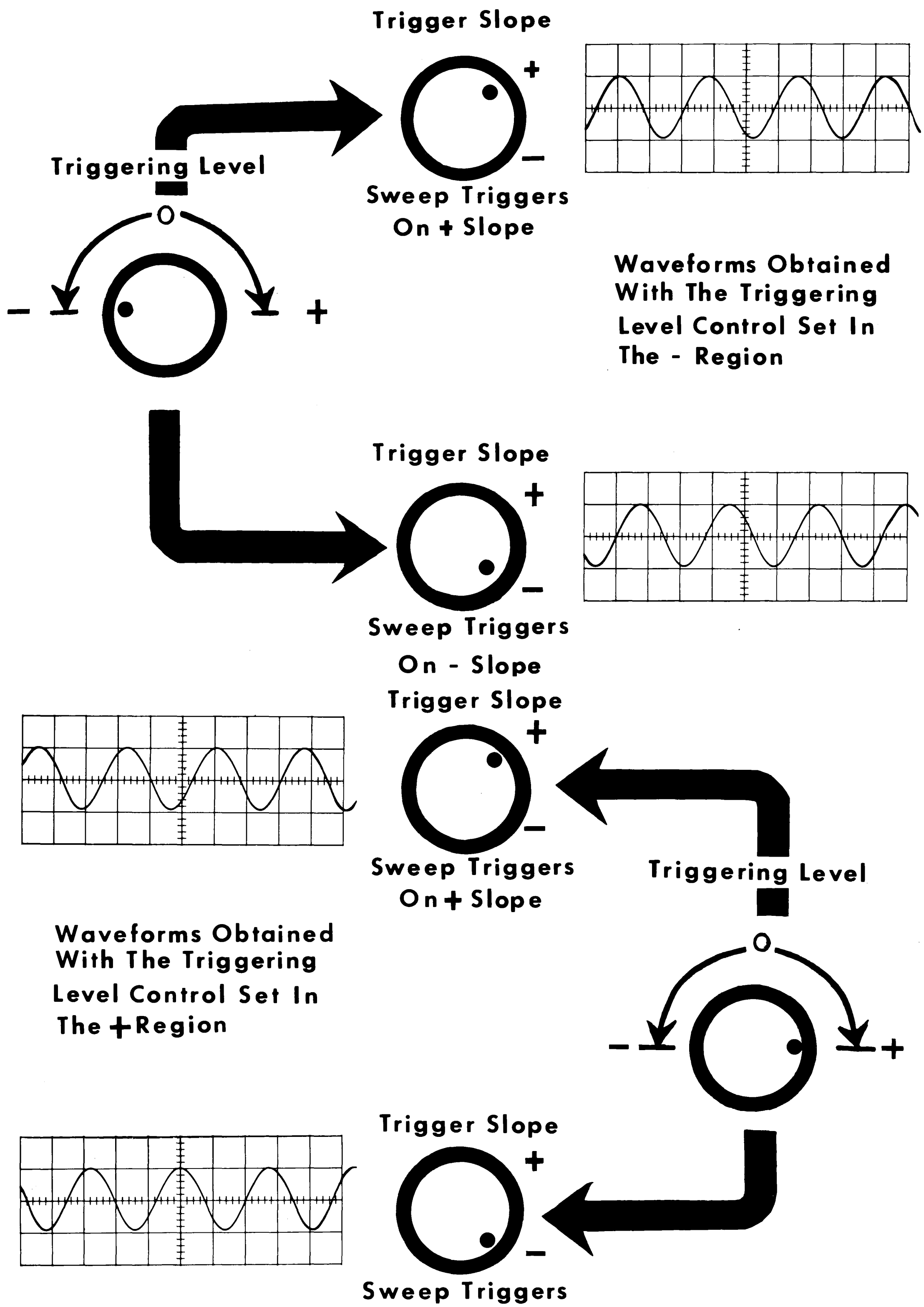



Fig. 2-7. Effects on the oscilloscope display produced by + and - settings of the TRIGGERING LEVEL control. When the TRIGGERING LEVEL control is set in the + region, the sweep is triggered on the upper portion of the input waveform; when it is set in the - region, the sweep is triggered on the lower portion of the input waveform. The TRIGGER SLOPE control determines whether the sweep is triggered on the rising portion or the falling portion of the input waveform.

the TRIGGERING LEVEL control can be adjusted.

**2-65.** The STABILITY control has a PRESET position at the fully counterclockwise setting of the control. This position permits proper triggering in most applications without necessitating additional adjustment of the STABILITY control. If it becomes impossible or difficult for you to obtain proper triggering with the STABILITY control at PRESET, you must then adjust the control. This is done with the TRIGGERING LEVEL control fully clockwise. The proper setting for the STABILITY control is obtained by rotating the knob clockwise from the PRESET position until a trace appears on the screen, then turning it slowly counterclockwise until the trace just disappears again. A triggered display may then be obtained with the TRIGGERING LEVEL control.

**2-66.** The TRIGGERING LEVEL control determines the point on the triggering waveform where triggering of the sweep occurs. This control is set to provide the display you want while at the same time causing stable triggering. Rotating the control clockwise causes the sweep to trigger at more positive points on the waveform, while rotating the control counterclockwise causes the sweep to trigger at more negative points. If the displayed waveform is vertically centered under the graticule, setting the TRIGGERING LEVEL control at 0 will cause the sweep to start at approximately the mid-voltage point of the waveform. In the DC mode, rotating the VERTICAL POSITION control will change the point on the triggering waveform where the sweep is started.

**2-67.** The + and - markings for the TRIGGERING LEVEL control should not be confused with similar markings for the TRIGGER SLOPE control. The markings on the TRIGGER SLOPE control indicate only whether triggering occurs on the rising or falling portion of the triggering waveform. The markings for the TRIGGERING LEVEL control indicate whether triggering occurs on the upper portion or lower portion of the waveform.

## 2-68. AC Triggering Mode

**2-69.** Selection of the AC triggering mode is made by placing the TRIGGERING MODE switch in the AC position. This mode provides useful triggering in the frequency range of approximately 15 cycles to 5 mc. These frequency limits vary slightly depending upon the shape and amplitude of the triggering waveform. In the AC mode, triggering is unaffected by the dc components of the triggering signal or by the vertical positioning of the trace. The triggering level can be selected to provide the desired display using the STABILITY and TRIGGERING LEVEL controls. These two controls are set as described for the DC triggering mode.

## 2-70. AC Low Frequency Reject Triggering Mode

**2-71.** The AC Low Frequency Reject triggering mode is used when the TRIGGERING MODE switch is in the AC L F REJECT position. This mode is similar to the AC mode except that low-frequency waveforms are rejected by the triggering circuit. This triggering mode works well with high-frequency waveforms, but it may be difficult to obtain stable triggering with frequencies below approximately 1000 cycles.

**2-72.** Occasionally you may be required to obtain stable triggering from a fairly high-frequency waveform that is mixed with a great deal of low-frequency noise or line-frequency pickup. In such cases the additional noise and pickup can make it very difficult to obtain a stable display. If this occurs, you can select the AC Low Frequency Reject mode, thereby eliminating the effects of the low frequency noise and pickup. The low frequencies are blocked from the triggering circuit while the high-frequency triggering waveform is passed to produce the stable triggering that you require. In all other respects the AC Low Frequency Reject triggering mode is identical to the AC mode.

## 2-73. High Frequency Synchronization Mode

**2-74.** The High Frequency Synchronization mode permits stable displays of waveforms with frequencies higher than approximately 5 mc.

Stability of the display is adjusted with the STABILITY control. The TRIGGERING LEVEL control is not used. To use the High Frequency Synchronization mode, place the TRIGGERING MODE switch in the HF SYNC position. Rotate the STABILITY control clockwise until a trace appears. Continue to adjust the STABILITY control until a stable display is obtained.

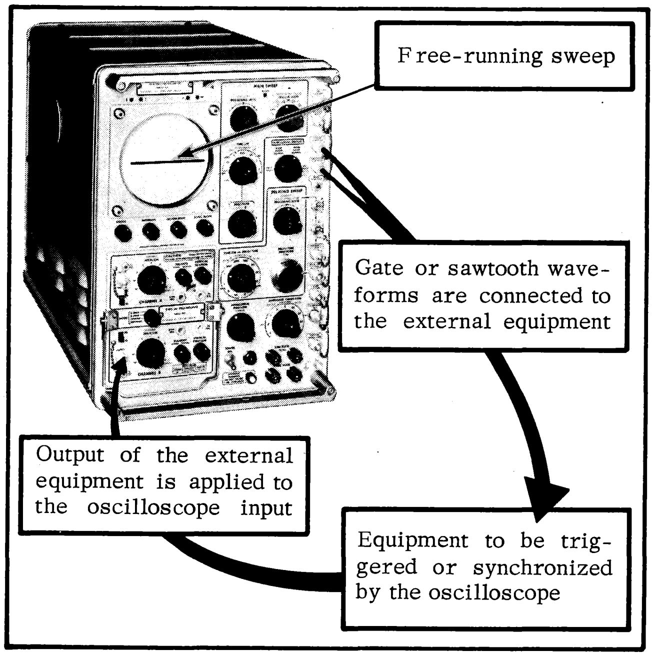



Fig. 2-8. Using the Gate or Sawtooth output waveforms to synchronize or trigger external equipment.

**2-75.** Although the synchronization signal source is selected with the TRIGGER SLOPE control, the slope cannot be selected. Also you cannot use the PRESET position of the STABILITY control in this mode.

**2-76. Free-Running Sweep Operation**

**2-77.** In the usual oscilloscope application, the sweep is triggered or synchronized by the input waveform. However, in some applications it may be more desirable to reverse the process and initiate the input waveform through use of a periodically recurrent waveform from the oscilloscope. In this type of application the sweep is caused to free-run and an output from either the +GATE or SAWTOOTH connectors is used to trigger or synchronize the input waveform (see Fig. 2-8).

**2-78.** The sweep can be made to free-run with any setting of the TRIGGERING MODE switch by rotating the STABILITY control fully clockwise. In all positions of the TRIGGERING MODE switch except AUTO., the number of sweeps per second is determined by the setting of the TIME/CM controls. In the AUTO. position, the sweep repetition rate remains at approximately 50 sweeps per second regardless of the setting of the TIME/CM control.

**2-79.** In addition to providing the means for controlling an applied waveform, a free-running sweep also provides a convenient reference trace on the oscilloscope screen without requiring an input signal. This trace can then be used to position the sweep or to establish a voltage reference line.

**2-80. Delayed Sweep**

**2-81.** With the Type 945 Oscilloscope the start of the horizontal sweep can be delayed for a period of from 3 microseconds to 100 msec after application of the triggering waveform. This is done through simultaneous use of both sweeps. In this application the Delaying Sweep is used to provide the accurate time delay while the Main Sweep presents a normal horizontal sweep at the end of the delay period. The duration of the sweep delay is controlled by the Delaying Sweep TIME/CM OR DELAY TIME switch and the DELAY-TIME MULTIPLIER control.

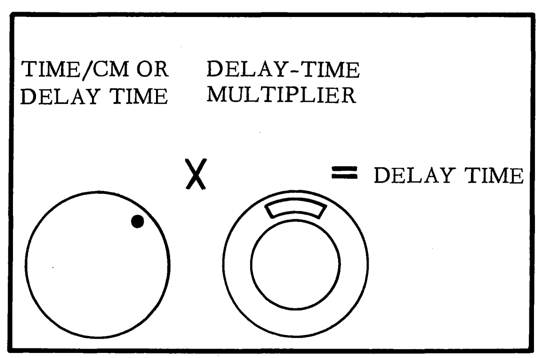



Fig. 2-9. Calculating delay time.

**2-82.** The delayed sweep feature of the Type 945 Oscilloscope can be used in a number of special applications to increase the versatility of the instrument. Such applications include high magnification of a selected portion of an undelayed sweep, accurate time measurements, and accurate measurements of waveform jitter. Also, it is possible to pick off and display any desired line of a television scan or to check pulse-time modulation. In addition, the delayed sweep feature is readily adaptable to a great number of other applications.

**2-83.** The delayed sweep is selected when the HORIZONTAL DISPLAY switch is in the MAIN SWEEP DELAYED position. The amount of delay occurring from the application of the triggering waveform until the sweep runs is indicated directly by the settings of the TIME/CM OR DELAY TIME switch and the DELAY TIME MULTIPLIER control. The settings of the two controls are multiplied together to obtain the actual delay time. For example, if the TIME/CM OR DELAY TIME switch is set at 1 MILLISEC and the vernier dial of the DELAY TIME MULTIPLIER control indicates 6.75, the delay time is 6.75 milliseconds. When the Main Sweep STABILITY control is in the fully clockwise position, the horizontal sweep starts immediately at the completion of the delay period at a rate determined by the settings of the Main Sweep TIME/CM controls.

**2-84.** There are actually two modes of delayed sweep operation available in the Type 945 Oscilloscope. In one mode the delayed sweep is started immediately after the completion of the delay time. This is the mode described previously and is obtained with the Main Sweep STABILITY control fully clockwise. This mode permits you to select continuously variable delay times and is the mode of operation used to make accurate time and waveform jitter measurements as well as most other measurements.

**2-85.** The second delayed-sweep mode is different from the first in that the sweep does not start at the completion of the delay time until a triggering waveform is applied to the MAIN SWEEP. The delay time in this mode is not continuously variable and is dependent not only on the settings of the delay-time controls, but on the occurrence of the MAIN SWEEP triggering waveform as well. The primary purpose of this mode is to eliminate jitter from the displayed waveform. Since the sweep is triggered by the input waveform, jitter is eliminated from the display even though it is inherent in the input waveform.

**2-86.** The second delayed-sweep mode is also obtained with the HORIZONTAL DISPLAY switch in the MAIN SWEEP DELAYED position. In this mode, however, the MAIN SWEEP triggering controls are set to provide normal triggering. The STABILITY control is not placed in the fully clockwise position.

**2-87.** When the HORIZONTAL DISPLAY switch is placed in the DEL'G SWEEP position, you can obtain a normal sweep presentation using this sweep. With all other controls set for delayed sweep operation, the Main Sweep TIME/CM switch set for a faster sweep rate than the DELAYING SWEEP control, and the Main Sweep STABILITY control fully clockwise, a portion of the displayed waveform will be brightened. The start of this brightened portion indicates the start of the delayed sweep and the length of the brightened portion indicates the delayed sweep duration. The start of the brightened portion can be positioned left or right with the DELAY-TIME MULTIPLIER control. The length of the brightened portion can be adjusted with the Main Sweep TIME/CM control. Using these two controls, it is possible to include any portion of the displayed waveform in the brightened area.

**2-88.** To expand a portion of the display obtained with the HORIZONTAL DISPLAY switch in the DEL'G SWEEP position, adjust the DELAY-TIME MULTIPLIER and Main Sweep TIME/CM controls to include the portion you wish to expand in the brightened area. Using AC LF REJECT, AC, or DC triggering of the Main Sweep leave the Main Sweep STABILITY control full right. Then place the HORIZONTAL DISPLAY switch in the MAIN SWEEP DELAYED position. This expands the brightened portion to the full width of the screen. The amount of magnification is the ratio of the Delaying Sweep TIME/CM OR DELAY TIME control setting to the Main Sweep TIME/CM control setting. For example, if the Delaying Sweep

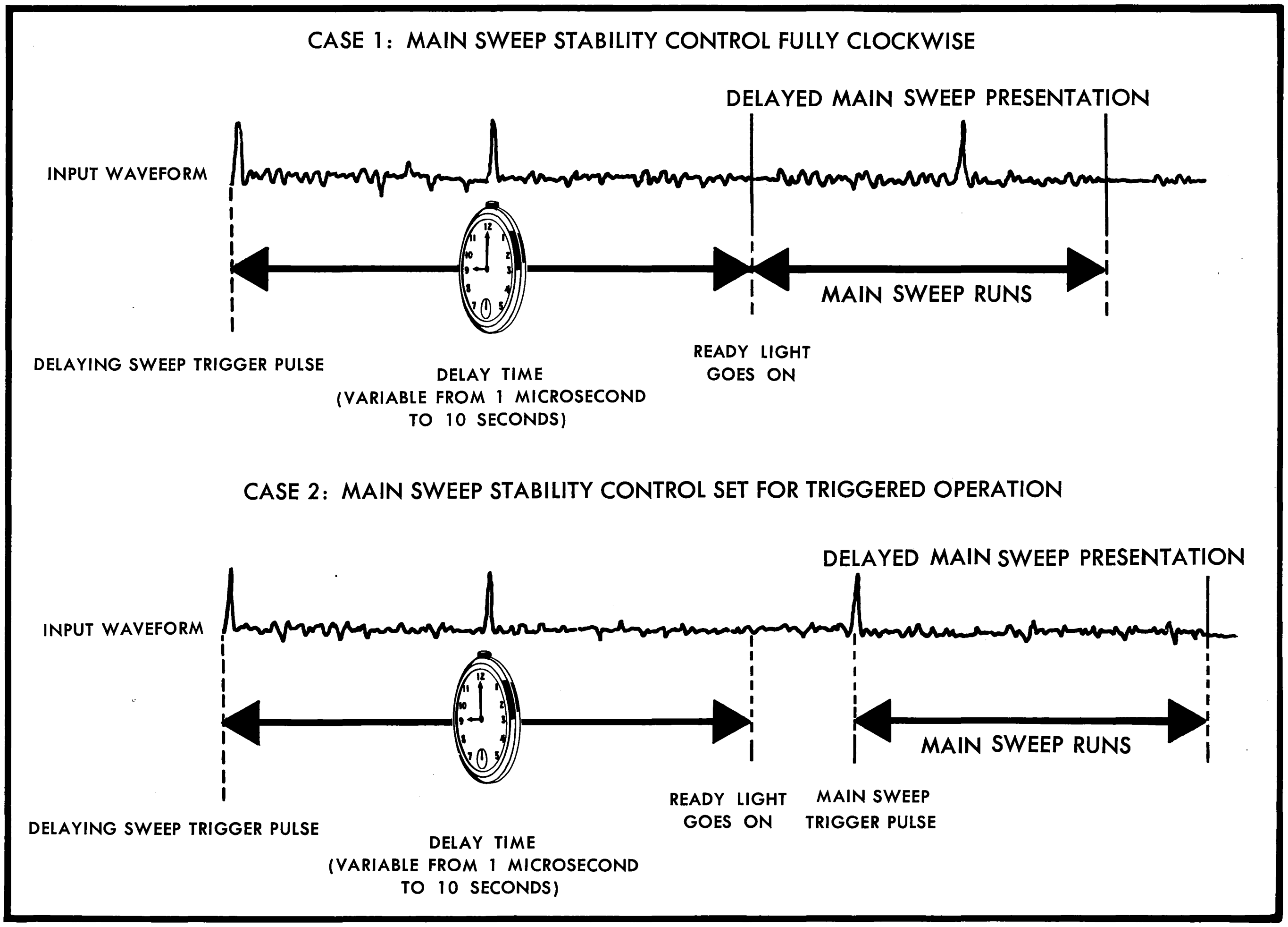



Fig. 2-10. Comparison of the two delayed-sweep modes. In each case the waveform shown represents the input to the oscilloscope. The waveform shown in the delayed-sweep presentation represents the portion of the input waveform that is actually displayed on the oscilloscope screen. Note that in Case 2 an additional triggering pulse is required before the delayed sweep will occur.

TIME/CM OR DELAY TIME switch is set at 1 MILLISEC and the Main Sweep TIME/CM switch is set at 1 $\mu$SEC, the brightened portion of the sweep is magnified horizontally 1,000 times. Using this method, practical sweep magnifications up to approximately 10,000 times are attainable.

**2-89.** At times when you are using the delayed sweep with high magnification the intensity of the trace will be so low that it is difficult to see. In many of these cases the intensity cannot be improved significantly with the INTENSITY control. However, the intensity can often be increased by using the Delaying Sweep LENGTH control to increase the duty cycle. To set the Sweep LENGTH control, place the HORIZONTAL DISPLAY switch in the DEL'G SWEEP position. Adjust the Sweep LENGTH control until the sweep runs to a point just past the brightened portion of the trace. Then return the HORIZONTAL DISPLAY switch to the Main Sweep DELAYED position.

**2-90. Delayed Trigger**

**2-91.** A delayed triggering pulse can be obtained from the DEL'D TRIG. connector of the oscilloscope. When using the Main Sweep for control, the triggering pulse occurs any time from .1 microseconds to 50 seconds after the start of a sweep. When the oscilloscope is set for delayed sweep operation, the delayed trigger pulse occurs at the start of the delayed Main Sweep.

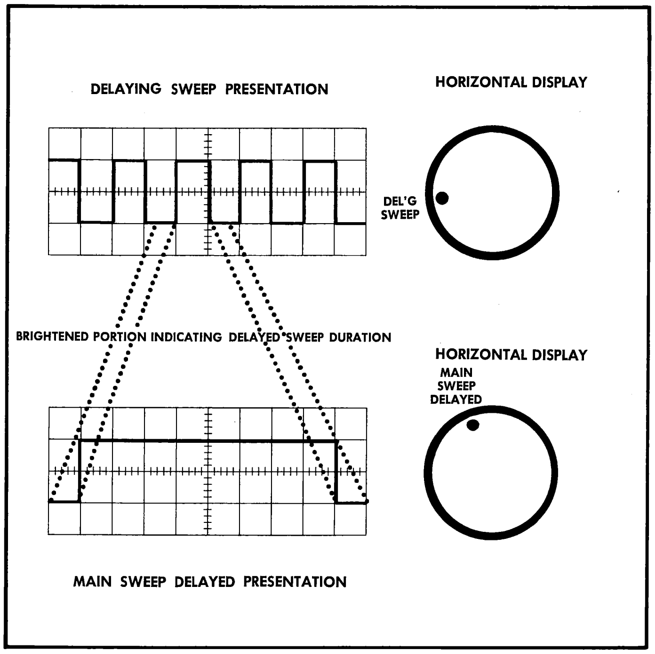



Fig. 2-11. Correlation of the DEL'G SWEEP and MAIN SWEEP DELAYED positions of the HORIZONTAL DISPLAY switch.

This delayed triggering pulse can be used to initiate some action after a known time interval, and when used with the Delaying Sweep, permits you to observe the resulting action.

**2-92.** In the DEL'G SWEEP, MAIN SWEEP DELAYED and EXT. SWEEP positions of the HORIZONTAL DISPLAY switch, the delayed trigger output is controlled by the Delaying Sweep. In the other position of the HORIZONTAL DISPLAY switch, the delayed trigger output is controlled by the Main Sweep.

**2-93.** To obtain a delayed trigger you must first adjust the appropriate time-base unit for triggered operation or for free-running operation, depending upon the application. The delay is then set with the appropriate TIME/CM control and the DELAY-TIME MULTIPLIER.

**2-94. Single-Sweep Operation**

**2-95.** The usual oscilloscope display formed by a repetitive sweep is entirely satisfactory for most applications. However, in applications where the displayed waveform is not repetitive or varies in amplitude, shape, or time interval, a repetitive sweep produces a jumbled display. When observing a waveform of this type, it is usually advantageous to use a single-sweep presentation.

**2-96.** The single sweep feature is selected by placing the HORIZONTAL DISPLAY switch

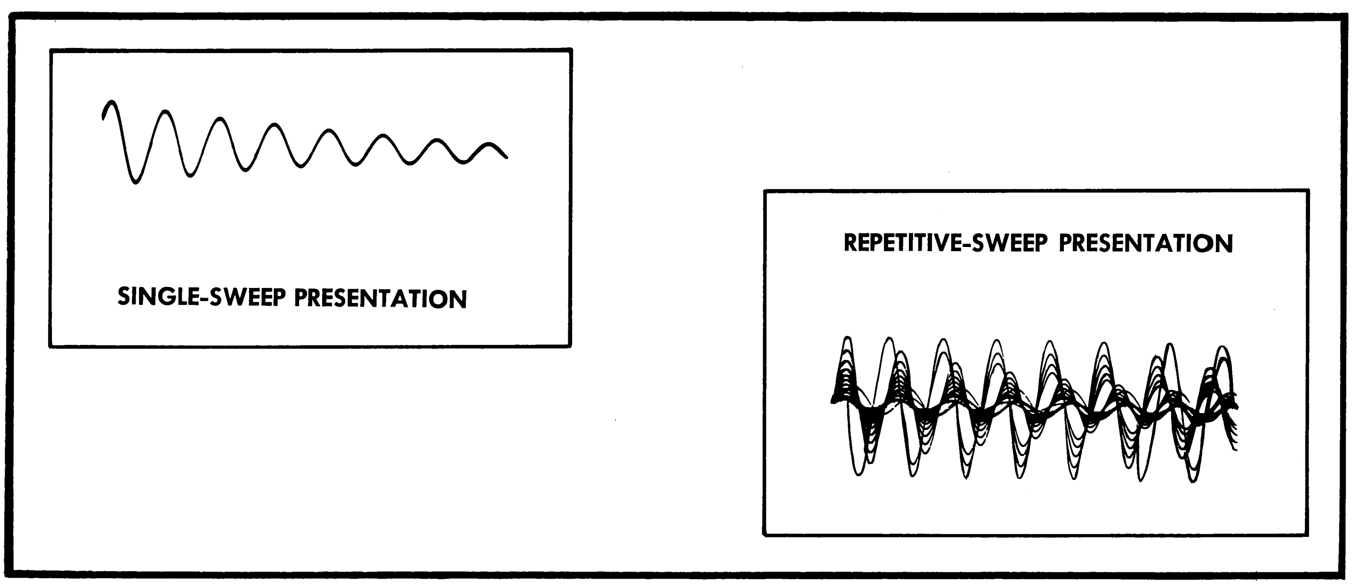



Fig. 2-12. Comparison of single sweep and repetitive sweep presentation of a damped sine wave. In the repetitive sweep presentation, it is difficult to determine what is being presented. However, in the single sweep presentation the damped sine wave can be clearly seen.

in the MAIN SWEEP DELAYED position and the Delaying Sweep STABILITY control MUST be FULLY counterclockwise to the stop position. The RESET button controls the start of the single sweep.

**2-97.** When the STABILITY control is set fully clockwise or the TRIGGERING MODE switch is in the AUTO. position, a single sweep runs immediately each time the RESET button is depressed. However, if the Main Sweep is set for triggered operation with the TRIGGERING MODE switch in other than the AUTO. or HF SYNC positions, the single sweep does not occur when the RESET button is depressed unless a triggering signal is applied to the Main Sweep. Instead the READY lamp lights to indicate that the sweep is ready to be triggered. When a triggering signal occurs, the single sweep runs and the READY light goes out. Each time the RESET button is depressed the procedure is repeated.

### 2-98. External Horizontal Input

**2-99.** For special applications you can deflect the trace horizontally with some externally derived waveform. This allows you to use the oscilloscope to plot one function versus another.

**2-100.** To use an external horizontal input, connect the externally derived waveform to the EXT. SWEEP IN connector, place the HORIZONTAL DISPLAY switch in the EXT. SWEEP position, and 5X MAGNIFIER ON. The horizontal deflection factor may be varied by a factor of 10 with the ATTEN. switch. + or - polarity may be selected with the SLOPE switch.

### 2-101. Sweep Magnifier

**2-102.** The sweep magnifier allows you to expand any two-centimeter portion of the displayed waveform to the full ten-centimeter width of the graticule. This is done by first using the HORIZONTAL POSITION control to move the portion of the display you wish to expand to the center of the graticule, then placing the 5X MAGNIFIER switch in the ON position. Any portion of the original unmagnified display can then be observed by rotating the HORIZONTAL POSITION controls. The sweep magnifier can be used with either time base unit.

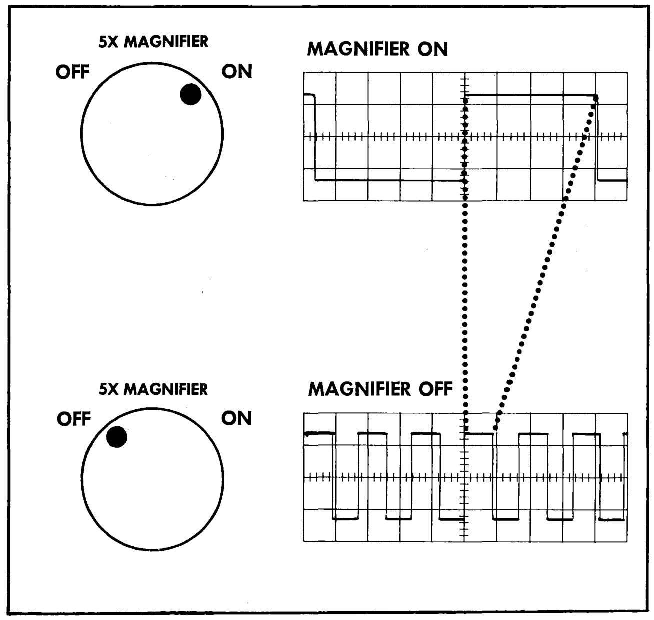



Fig. 2-13. Operation of the sweep magnifier.

**2-103.** In magnified sweep operation, the sweep speed indicated by the position of the TIME/CM control is divided by 5 to obtain the actual time required for the spot to move one centimeter. For example, if the TIME/CM control is set at 5 mSEC, the actual time per centimeter is 5 milliseconds divided by 5, or 1 millisecond per centimeter. The actual time per centimeter must be used for all measurements of time.

### 2-104. Amplitude Calibrator

**2-105.** The amplitude calibrator provides a convenient source of square waves of known amplitude at a frequency of approximately 1 kc. The square waves are used primarily to adjust probes and to verify the calibration of the vertical-deflection system of the oscilloscope and plug-in unit.

**2-106.** Calibrator square-waves are adjustable from .2 millivolts, peak-to-peak, to 100 volts, peak-to-peak. The three-position center switch selects mVOLTS, VOLTS, or OFF. The outer switch selects the value of the mVOLTS or VOLTS. The amplitude is controlled by the setting of the AMPLITUDE CALIBRATOR switch and is accurate within 2% of the AMPLITUDE CALIBRATOR switch setting when the output is connected to a high impedance load.

**2-107. Intensity Modulation**

**2-108.** The crt display of the Type 945 can be intensity modulated by an external signal to display additional information. This is done by connecting the modulating signal to the CRT CATHODE connector on the front panel of the instrument.

**2-109.** The connector cover used on the CRT CATHODE connector automatically grounds the connector when it is in place. Be sure to replace the cover when you do not wish to use intensity modulation.

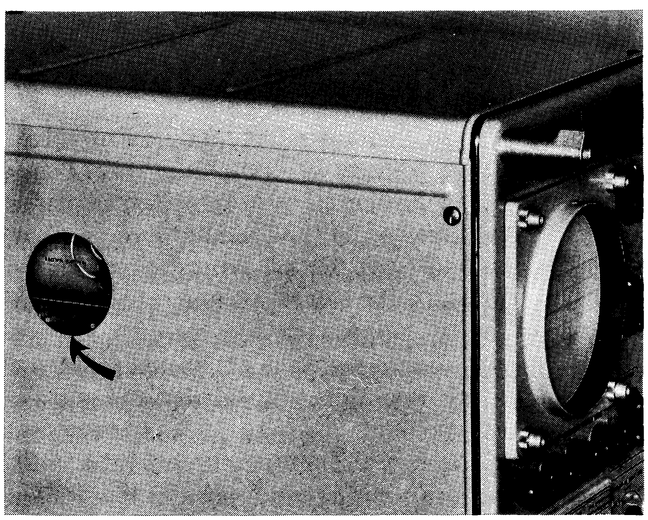


Fig. 2-14. Location of the access opening for the crt deflection plates.

**2-110.** When you wish to make very accurate time measurements from the crt display, you can intensity modulate the beam with time markers and make your measurements directly from the time markers presented on the screen. A positive signal of approximately 25 volts is required to cut off the beam from normal intensity.

**2-111. Direct Connection to CRT Deflection Plates**

**2-112.** The vertical deflection plate pins are located on the side of the crt neck. The horizontal deflection plate pins are located on the top. In some applications, it is advantageous to connect a signal directly to either one, or both sets of these deflection plate pins--bypassing the internal oscilloscope amplifiers. Maintain the average dc voltage on the deflection plates between +275 and +300 volts. If the voltage is not within this range, the crt displayed becomes defocused.

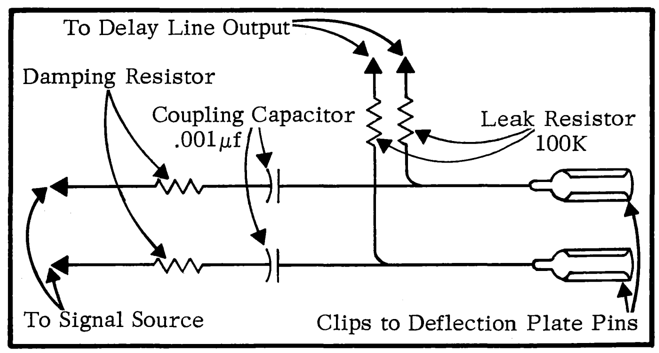



Fig. 2-15. Connecting directly to the crt deflection plates by AC coupling.

**2-113.** For dc coupling, it is necessary to supply positioning voltages from the signal source. These voltages should fall within the +275 and +300 volt range. When dc coupling the signal to the deflection plates, you should tape the ends of the wires you have removed from the crt pins. This prevents shorting to the chassis and damage to the amplifier. The external signal source is then connected to the crt pins. No leak resistors are used.

**2-114.** In many applications, it is advantageous to use ac coupling. This is necessary for those signals which cannot be made to have the right dc voltage. For this type of application, the wires you have removed from the crt pins are connected through 100K leak resistors to the new crt leads. See Figure 2-15. Dc positioning voltage is supplied from the oscilloscope through these wires, using the normal positioning controls.

**2-115.** Direct connection to the crt deflection plates is usually used to utilize the ultimate rise-time capability of the crt. The connecting network between the external coax and the crt pins must be short. The coax should be hung from the oscilloscope chassis so that no pressure is applied to the crt pins.

**2-116.** Referring to Fig. 2-15, connect one damping resistor to the coax center conductor. Connect the other damping resistor to the coax outer conductor. The size of the damping resistor will depend upon the coaxial line impedance, the lead lengths, and the coupling capacitor type. The best value is found by passing a fast-rise signal through the coax and adjusting the resistance until the display is just short of overshoot. A good starting value is 68 Ω for a 52-Ω coaxial cable. No damping resistors are needed for cables with impedances above approximately 200 Ω.

**2-117.** In order to realize the desired amount of deflection sensitivity in the Type 945P2 Cathode Ray Tube, the deflection plates have been placed as close as possible to the path of the electron beam. As a result, a small amount of current will flow in the deflection plate circuits. This current flow varies non-linearly with the beam position, increasing rapidly in that plate toward which the beam is positioned. In the Type 945 oscilloscope, the effects of these currents are negligible. However, when using ac coupling for an external signal, these currents can cause objectionable voltage drops if large leak resistors are used. For resistance values greater than 110K you may experience some difficulty from deflection plate current. Some defocusing or distortion may be evident. These effects are most noticeable when the display is positioned close to the limits of the crt graticule.

**2-118.** The low frequency response required will determine the size of the coupling capacitor needed. The formula for the size of the coupling capacitor is $C = 1/2\pi RF$, where R is the leak resistor, and F is the desired low-frequency cutoff. For example, to find the coupling capacitor needed when the low frequency cutoff is 1600 cps and the leak resistor is 100 K, take the reciprocal of $2\pi RF$. The coupling capacitor is .001 $\mu$f.

**2-119.** The coupling capacitor should be spaced about 1/4" to 3/8" from the damping resistors, and should be of the ceramic disc type, or equivalent, to preserve the fast-rise capability of the Type 945-P2 crt.

**2-120.** To simplify making the direct connection to the crt vertical deflection plates, you can order a plastic plate and mounting bracket from Tektronix Inc. The mounting bracket is designed to clamp around the neck of the crt shield, adjacent to the deflection plate connections. When mounted correctly, the plate will be accessible through the crt deflection plate access hole in the left side panel. The bracket and plate may be ordered with or without the necessary parts for vertical positioning voltages. Specify Tektronix part number 013-008 (Environmental N/A) for the blank unit without parts, or Tektronix part number 013-007 (Environmental N/A) for the wired unit. Holes can be drilled in the plastic plate for mounting coaxial cable and other connectors.

## 2-121. MEASUREMENT METHODS

### 2-122. Voltage Measurements

**2-123.** The Type 945 Oscilloscope can be used to measure the voltage of the input waveform by using the calibrated vertical-deflection factors of the instrument and associated plug-in unit. The method used for all voltage measurements is basically the same although the actual techniques vary somewhat depending on the type of voltage measurements required. Essentially there are two types of voltage measurements: ac-component voltage measurements and instantaneous voltage measurements with respect to some reference potential. Many waveforms contain both ac and dc voltage components. It is often necessary to measure one or both of these components.

**2-124.** When making voltage measurements, you should display the waveform over as large a vertical portion of the screen as practical for maximum resolution. Also, it is important that you do not include the width of the trace in your measurements. You should consistently make all measurements from one side of the trace. If the bottom side of the trace

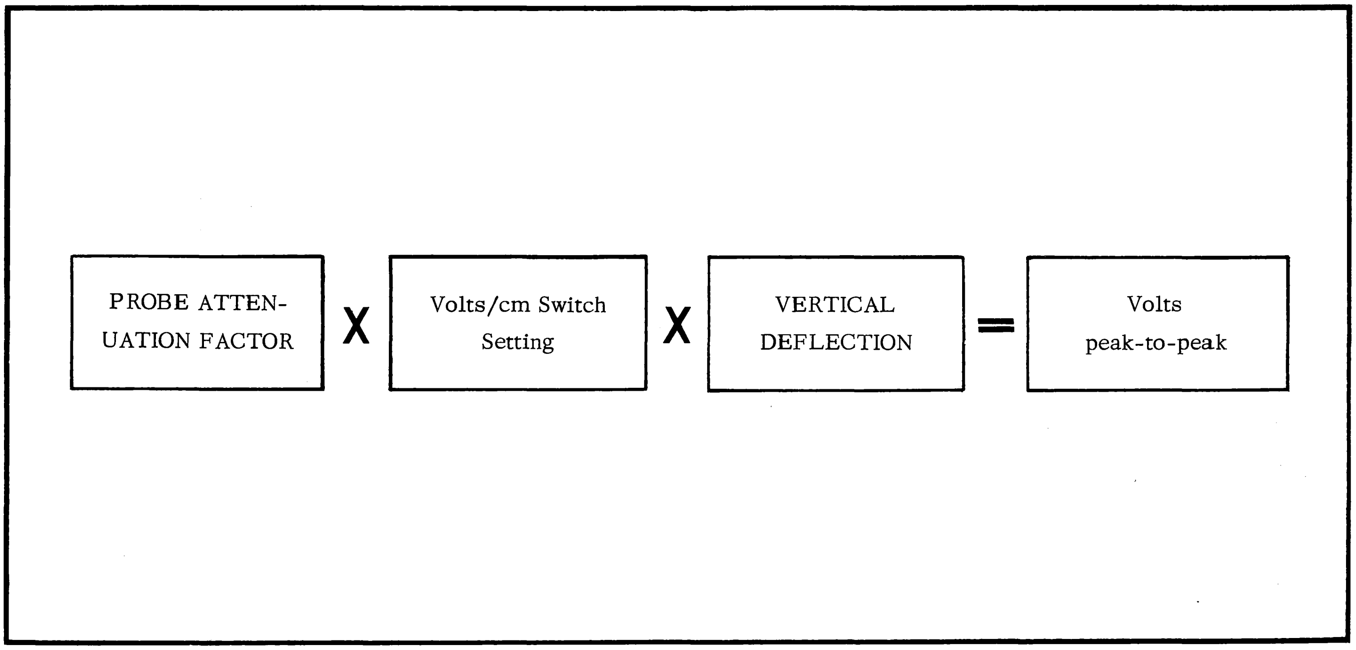



Fig. 2-16. Measuring the peak-to-peak ac component voltage of an applied waveform.

is used for one reading, it should be used for all succeeding readings. The VARIABLE VOLTS/CM control must be in the CALIBRATED position.

**2-125. AC Component Voltage Measurements**

**2-126.** To measure the ac component of a waveform, the plug-in unit input selector switch should usually be set to one of the AC positions. In these positions only the ac components of the input waveform are displayed on the oscilloscope screen. However, when the ac component of the input waveform is of very low frequency it is necessary for you to make voltage measurements with the input selector switch in one of the DC positions to prevent errors.

**2-127.** To make a peak-to-peak voltage measurement on the ac component of a waveform, perform the following steps (see Figure 2-16):

a. With the aid of the graticule, measure the vertical distance in centimeters from the positive peak to the negative peak.

b. Multiply the vertical distance measured by the setting of the plug-in unit VOLTS/CM control to obtain the indicated voltage.

c. Multiply the indicated voltage by the attenuation factor of the probe used to obtain the actual peak-to-peak voltage.

**2-128.** As an example of the method, assume that using a 10X probe and a deflection factor of 1 volt per centimeter, you measure a vertical distance between peaks of 4 centimeters. In this case then, 4 centimeters multiplied by 1 volt per centimeter gives you an indicated voltage of 4 volts peak-to-peak. The indicated voltage multiplied by the probe's attenuation factor of 10 then gives you the true peak-to-peak amplitude of 40 volts.

**2-129.** When sinusoidal waveforms are measured, the peak-to-peak voltage obtained can be converted to peak, rms, or average voltage through use of standard conversion factors.

**2-130. Instantaneous Voltage Measurements**

**2-131.** The method used to measure instantaneous voltages is virtually identical to the method described previously for the measurement of the ac components of a waveform. However for instantaneous voltage measurements the plug-in unit input selector switch must be placed in one of the DC positions. Also since instantaneous voltages are measured with respect to some potential (usually ground) a reference line must be established on the oscilloscope screen which corresponds to that potential. If, for example, voltage measurements are to be made with respect to +100 volts, the reference line would correspond to +100 volts. In the following procedure the method is given for establishing this reference line as ground since measurements with respect to ground are by far the most common type. The same general method may be used to measure voltage with respect to any other potential, however, so long as that potential is used to establish the reference line.

**2-132.** To obtain an instantaneous voltage measurement with respect to ground, perform the following steps (see Figure 2-17):

a. To establish the voltage reference line, touch the probe tip to an oscilloscope ground terminal (or if the reference line is to represent a voltage other than ground, to a source of that voltage) and adjust the oscilloscope controls to obtain a free-running sweep. Vertically position the trace to a convenient point on the oscilloscope screen. This point will depend on the polarity and amplitude of the input signal, but should always be chosen so that the trace lies along one of the major divisions of the graticule. The graticule division corresponding to the position of the trace is the voltage reference line and all voltage measurements must be made with respect to this line. (Do not adjust the vertical positioning control after the reference line has been established.)

b. Remove the probe tip from ground and connect it to the signal source. Adjust the triggering controls for a stable display.

c. Using the graticule, measure the vertical distance in centimeters from the desired point on the waveform to the voltage reference line.

d. Multiply the setting of the VOLTS/CM control by the distance measured to obtain the indicated voltage.

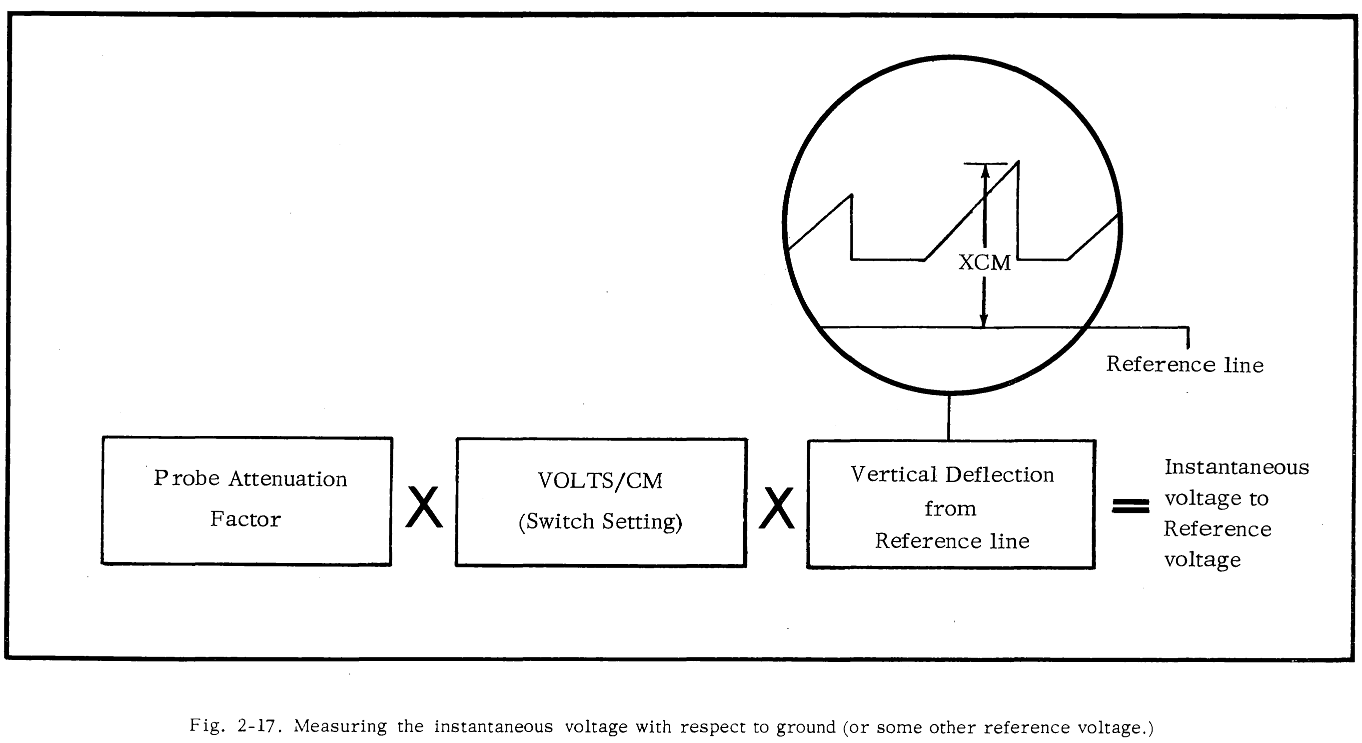



Fig. 2-17. Measuring the instantaneous voltage with respect to ground (or some other reference voltage.)

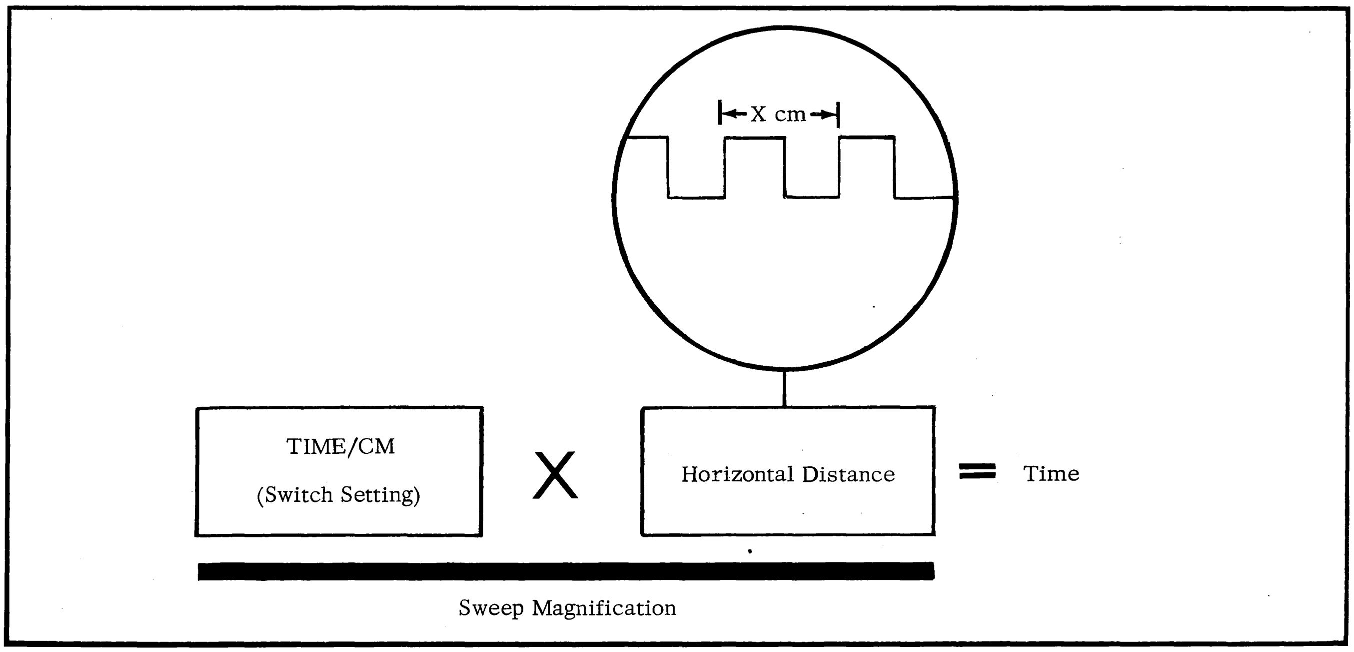



Fig. 2-18. Measuring the time interval between events displayed on the oscilloscope screen.

e. Multiply the indicated voltage by the attenuation factor of the probe you are using to obtain the actual voltage with respect to ground (or other reference voltage).

**2-133.** As an example of this method, assume that you are using a 10X probe and deflection factor of .2 volts per centimeter. After setting the voltage reference line at the second from the bottom division of the graticule, you measure a distance of 3 centimeters to the point you wish to check. In this case, then, 3 centimeters multiplied by .2 volts per centimeter gives you an indicated .6 volts. Since the voltage point is above the voltage reference line the polarity is indicated to be positive. The indicated voltage multiplied by the probe's attenuation factor of 10 then gives you the actual voltage of positive 6 volts.

**2-134. Time Measurements**

**2-135.** The calibrated sweeps of the Type 945 Oscilloscope cause any horizontal distance on the screen to represent a definite known interval of time. Using this feature you can accurately measure the time lapse between two events displayed on the oscilloscope screen. One method which produces sufficient accuracy for most applications is as follows (see Figure 2-18):

a. Using the graticule, measure the horizontal distance between the two displayed events whose time interval you wish to find.

b. Multiply the distance measured by the setting of the appropriate TIME/CM control to obtain the apparent time interval. (The VARIABLE TIME/CM control must be in the CALIBRATED position).

c. If the MAGNIFIER is ON, divide the apparent time interval by 5 to obtain the actual time interval.

**2-136.** For example, assume that the TIME/CM switch setting is 1 mSEC, the magnifier is on, and that you measure a horizontal distance of 5 centimeters between events. In this example then, 5 centimeters multiplied by 1 millisecond per centimeter gives you an apparent time interval of 5 milliseconds. The apparent time divided by 5 then gives you the actual time interval of 1 millisecond.

**2-137.** Another method for measuring time intervals involves the use of the delayed sweep

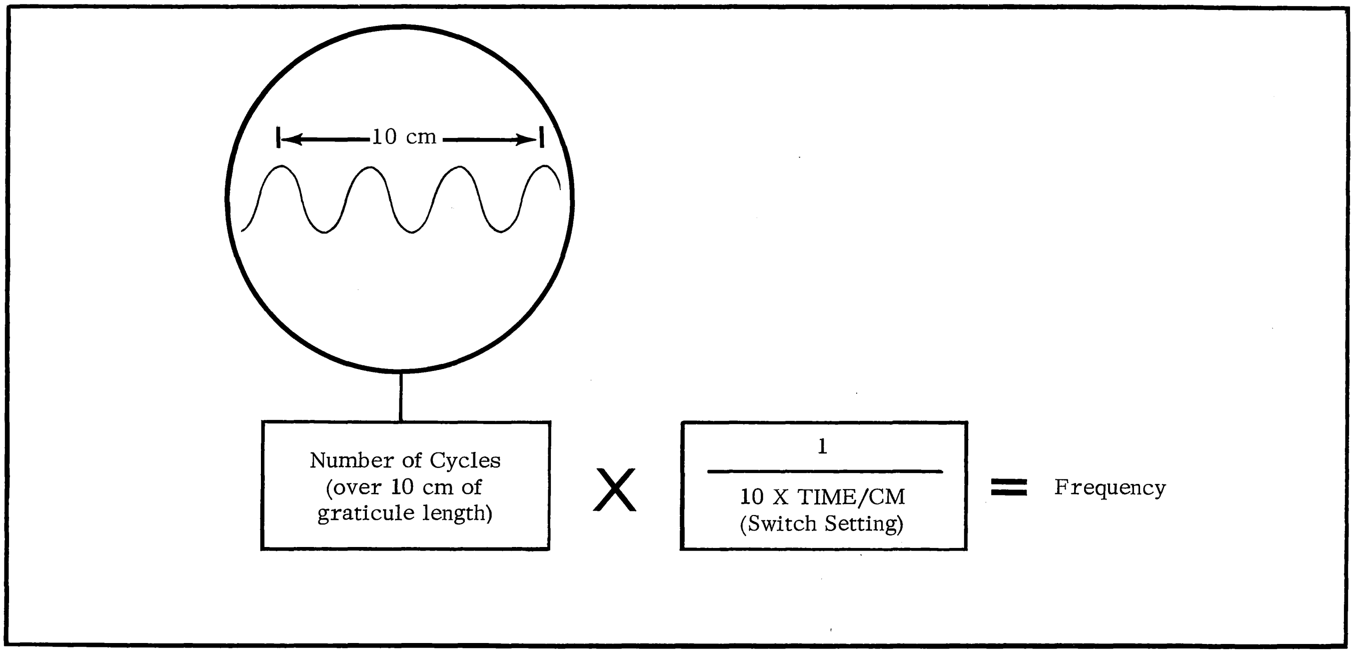



Fig. 2-19. Measuring the frequency of a repetitive input signal.

feature of the Type 945 Oscilloscope. Time measurements of better than 1% accuracy can be obtained by this method. In this method the HORIZONTAL DISPLAY switch is placed in the DEL'G SWEEP position to brighten a portion of the trace. The brightened portion of the trace and the DELAY TIME MULTIPLIER control are then used to make the time measurements. This method provides a very high degree of accuracy when care is taken in making the measurements. The method is summarized as follows:

a. Place the HORIZONTAL DISPLAY switch in the DEL'G SWEEP position and adjust the Delaying Sweep triggering controls for a stable display of the input waveform. Adjust the Main Sweep for free-running operation.

b. Turn the intensity down until the brightened portion of the trace is easily distinguishable. Adjust the Main Sweep TIME/CM controls to reduce the brightened area to a small spot or to cover as small a portion of the trace as possible.

c. Using the DELAY TIME MULTIPLIER control, position the start of the brightened portion to the beginning of the interval you wish to measure. Record the setting of the DELAY TIME MULTIPLIER control.

d. Using the DELAY TIME MULTIPLIER control, position the start of the brightened portion of the trace to the end of the interval you wish to measure. Again record the setting of the DELAY TIME MULTIPLIER control.

e. Subtract the first DELAY TIME MULTIPLIER control setting from the second and multiply the result by the setting of the Delaying Sweep TIME/CM control. The figure obtained is the time interval between the two events. The figure obtained is correct regardless of whether the magnifier is on or off. Even greater accuracy may be obtained by the improved resolution with the HORIZONTAL DISPLAY switch in the MAIN SWEEP DELAYED position.

#### 2-138. Frequency Measurements

**2-139.** Using one of two main methods described in the previous section, you can measure the period (time required for one cycle) of a recurrent waveform. The frequency of the waveform can then easily be calculated since frequency is the reciprocal of the period. For example, if the period of a recurrent waveform is accurately measured and found to be 0.2 microseconds, the frequency is the reciprocal of 0.2 microseconds, or 5 MC.

**2-140.** At any given oscilloscope sweep speed, the number of cycles of the input waveform that is displayed on 10 centimeters of the screen is dependent on the frequency of the input waveform. Frequencies can usually be measured faster by the following method than by the one given in the last paragraph.

**2-141.** If you divide the cycles per unit of length by the time required for the input waveform to sweep this unit of length, you get the frequency. The total number of cycles are found for 10 cm for greater accuracy. Since the TIME/CM switch gives time for 1 cm, multiply this setting by 10 to have the time required for 10 cm. (See Fig. 2-19.)

**2-142.** To obtain the frequency of a repetitive input signal, perform the following steps:

a. Adjust the TIME/CM control to display several cycles of the input waveform. Insure that the VARIABLE TIME/CM control is in the CALIBRATED position.

b. Count the number of cycles of the waveform shown on the 10 centimeters of the graticule.

c. Divide this number by 10 times the TIME/CM switch setting. This gives you the frequency of the input waveform.

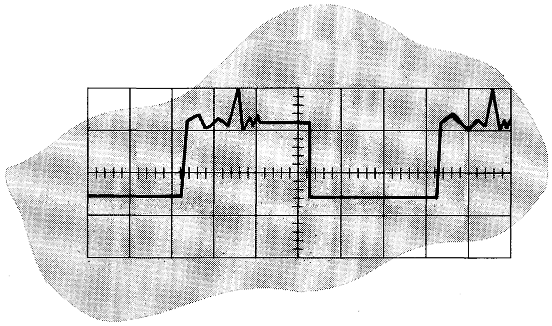
**2-143.** For example, assume that when you are using a sweep speed of 50 milliseconds per centimeter, you count 7.2 cycles in 10 centimeters. The frequency is 7.2 cycles divided by 50 milliseconds times 10, or 500 milliseconds. 500 milliseconds are 500 x .001 seconds, or .5 seconds. 7.2 cycles per 1/2 second gives you 14.4 cycles per second.

**2-144. Low Voltage Power Supply Connections and Fuse Rating**

**2-145.** The low voltage power transformer operates on either 115 volts or 130 volts, 50 to 400 cycles/sec ac. Unless otherwise tagged, the instrument is wired for 115-volt operation. Provision is made, however, for easy conversion to 130-volt operation by changing connections on the split input windings. Terminals #13 and #20 (Fig. 5-2) are connected to one input winding, and terminals #14 and #19 to the other input winding. The leads from the power line are always attached to terminals #13 and #19. For 115-volt operation (parallel connected) terminal #13 is joined to #14 with a bus wire, and terminal #19 is joined to #20 in the same manner. To convert to 230-volt operation (series connected) remove these two bus wires and join terminals #14 and #20 with a single bus wire.

**2-146.** Correct line fuse size is: 7 amperes for 115-volt operation; 4 amperes for 230-volt operation.

## NOTES



# SECTION 3

# TRIGGERING INSTRUCTIONS

### 3-1. MAIN SWEEP OPERATION

### 3-2. Selecting the Triggering Signal Source

a. To trigger the sweep from the waveform being observed set the black TRIGGER SLOPE knob to +INT. or to -INT.

b. To trigger the sweep from the power-line wave, as in the case where you are observing a waveform which has a time relationship to the power-line wave, set the TRIGGER SLOPE knob to +LINE or to -LINE.

c. To trigger the sweep from some externally derived waveform which has a time relationship to the observed waveform, connect the source of triggering waveform to the TRIGGER INPUT connector. Set the TRIGGER SLOPE knob to +EXT. or to -EXT.

**3-3.** If you want the start of the display, at the left-hand end of the graticule, to occur at a time when the triggering signal is rising (has a positive slope), use the +INT., the +LINE or the +EXT. position of the TRIGGER SLOPE knob, as described above. If you want the start of the display to occur when the triggering signal is falling (has a negative slope), use the -INT., the -LINE or the -EXT. position of the TRIGGER SLOPE knob.

**3-4.** If a display fails to appear after completing the detailed instructions given for each mode, refer to the final paragraph in this section, 3-50, POSSIBLE CAUSES OF IMPROPER DISPLAY.

### 3-5. Triggered (AUTOmatic mode)

**3-6.** Useful for periodic signals 60 cycles to 2 megacycles. This is an especially useful triggering mode because it does not require the adjustment of the STABILITY and TRIGGERING LEVEL controls. It also provides a desirable horizontal reference trace during intervals when no triggering signals are being received.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGER SLOPE | *+INT. or -INT. |
| TRIGGERING MODE | AUTO |
| TRIGGERING LEVEL | not used in this mode |

**3-7.** Set TIME/CM and MULTIPLIER controls for a sweep rate suited to the waveform being observed.

**3-8.** This mode is particularly useful when you are testing equipment by moving the input connection from one point in the circuit to another. Because they are not used in this mode, it is not necessary to place the STABILITY and TRIGGERING LEVEL controls in the positions shown in the photograph.

### 3-9. Triggered (AC mode)

**3-10.** Useful for transient or periodic signals 20 cycles to 5 megacycles.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGER SLOPE | *+INT. or -INT. |
| TRIGGERING MODE | AC |
| TRIGGERING LEVEL | full right or full left |
| STABILITY | **PRESET |

*See Paragraphs 3-1 through 3-3 for instructions on selecting the triggering signal source.

**Turn the STABILITY control to the left until the PRESET switch is actuated.

a. Set TIME/CM and MULTIPLIER controls for a sweep rate suited to the waveform being displayed.

b. Turn the TRIGGERING LEVEL control toward the center of its range for a stable display of input signal.

**3-11.** In this mode, the TRIGGERING LEVEL control determines the height on the waveform at which the display will start. If you experience difficulty in getting a stable display, you may want to manually adjust the STABILITY control (see Paragraphs 3-27 and 3-28).

**3-12. Triggered (DC mode)**

**3-13.** Useful for transient or periodic signals DC to 5 megacycles.

**3-14.** This mode is especially useful for signals that change slowly.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGER SLOPE | *+ INT. or -INT. |
| TRIGGERING MODE | DC |
| TRIGGERING LEVEL | full right or full left |
| STABILITY | **PRESET |

a. Set TIME/CM and MULTIPLIER controls for a sweep rate suited to the waveform being observed.

b. Turn the TRIGGERING LEVEL control toward the center of its range for a stable display of input signals. The final setting of the control will depend upon the setting of the VERTICAL POSITION control. If the display is positioned to the top or bottom of the graticule, the TRIGGERING LEVEL control will be set to one side or the other of the midrange position.

**3-15.** In this mode, the TRIGGERING LEVEL control determines the height on the graticule at which the display will start. When the control is set at 0 (mid-range), the display will start at the center horizontal graticule line.

**3-16. Triggered (AC LF REJECT mode)**

**3-17.** For transient or periodic signals, 10 kc to 5 MC. For most cases, the AC mode (paragraph 3-9) is preferable to AC LF REJECT. AC is principally for use with Type MC Dual-Trace Plug-In Unit (Paragraphs 3-19). Aside from this use, AC LF REJECT may reduce jitter due to hum in the triggering signal.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGERING SLOPE | *+ INT. or -INT. |
| TRIGGERING MODE | AC LF REJECT |
| TRIGGERING LEVEL | full right or full left |
| STABILITY | **PRESET |

a. Set TIME/CM and MULTIPLIER controls for a sweep rate suited to the waveform being observed.

b. Turn the TRIGGERING LEVEL control toward the center of its range for a stable display of input signal.

**3-18.** This mode is particularly useful for displaying signals when low-frequency interference is present in the triggering signal. For example, interference from 60- or 120-cycle hum can be reduced by using this mode.

**3-19. Dual-Trace Operation**

**3-20.** Alternate Sweeps using Type MC Plug-In Preamplifier.

**3-21.** Here, waveforms fed to CHANNEL A INPUT and to CHANNEL B INPUT are displayed alternately.

*See Paragraphs 3-1 through 3-3 for instructions on selecting the triggering signal source.

**Turn the STABILITY control to the left until the PRESET switch is actuated.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGER SLOPE | *+ INT. or -INT. |
| TRIGGERING MODE | AC LF REJECT** |
| TRIGGERING LEVEL | full right or full left |
| STABILITY | ***PRESET |
| MODE (on Type MC) | ALTERNATE |

*See Paragraphs 3-1 through 3-3 for instructions on selecting the triggering signal source.

**It may be preferable to use AC if one (or both) of the signals displayed is of low frequency.

***Turn the STABILITY control to the left until the PRESET switch is actuated.

a. Set TIME/CM and MULTIPLIER controls for a sweep rate suited to the waveform being displayed.

b. Turn the TRIGGERING LEVEL control toward the center of its range for a stable display of input signal.

**3-22.** Place the MODE switch on the plug-in unit in the CHOPPED position to view low-frequency signals, or in the ALTERNATE position to view high-frequency signals. The inset picture shows the MODE switch in the ALTERNATE position.

**3-23. Synchronized (HF SYNC mode)**

**3-24.** Useful for periodic signals 5 to 25 Megacycles.

**3-25.** In contrast to triggered operation, synchronized operation gives you a recurrent horizontal sweep which can be synchronized, by means of the STABILITY control, with waveforms in the range from 5 megacycles to 25 Megacycles.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGER SLOPE | *+ INT. or -INT. |
| TRIGGERING MODE | HF SYNC |
| TRIGGERING LEVEL | not used in this MODE |
| STABILITY | full right |

*The sweep can be synchronized with an external signal by placing the switch in the + EXT. or -EXT. position.

a. Set TIME/CM and MULTIPLIER controls for a sweep rate suited to the waveform being displayed.

b. Turn the STABILITY control left until you get a stable display of the input signal.

**3-26.** In this mode, the final setting of the STABILITY control depends upon the nature of the synchronizing signal. It may vary from one extreme of the range of the control to the other.

**3-27. Using the Variable Stability Control**

**3-28.** For a few particularly difficult triggering applications, you may wish to use a setting of the STABILITY control other than the one available in the PRESET position. You can do this if you are using triggered operation in any of these modes: DC, AC, or AC LF REJECT.

a. Start with the STABILITY and TRIGGERING LEVEL controls turned full right. Use other control settings as given in the preceding instructions for the desired triggering mode.

b. Turn the STABILITY control left until the trace disappears, then two or three degrees further left.

c. Turn the TRIGGERING LEVEL control slowly toward 0 for a stable display of the input signals.

**3-29. DELAYING SWEEP OPERATION**

**3-30.** If you wish, you can use the Delaying Sweep, rather than the Main Sweep, in displaying an input signal.

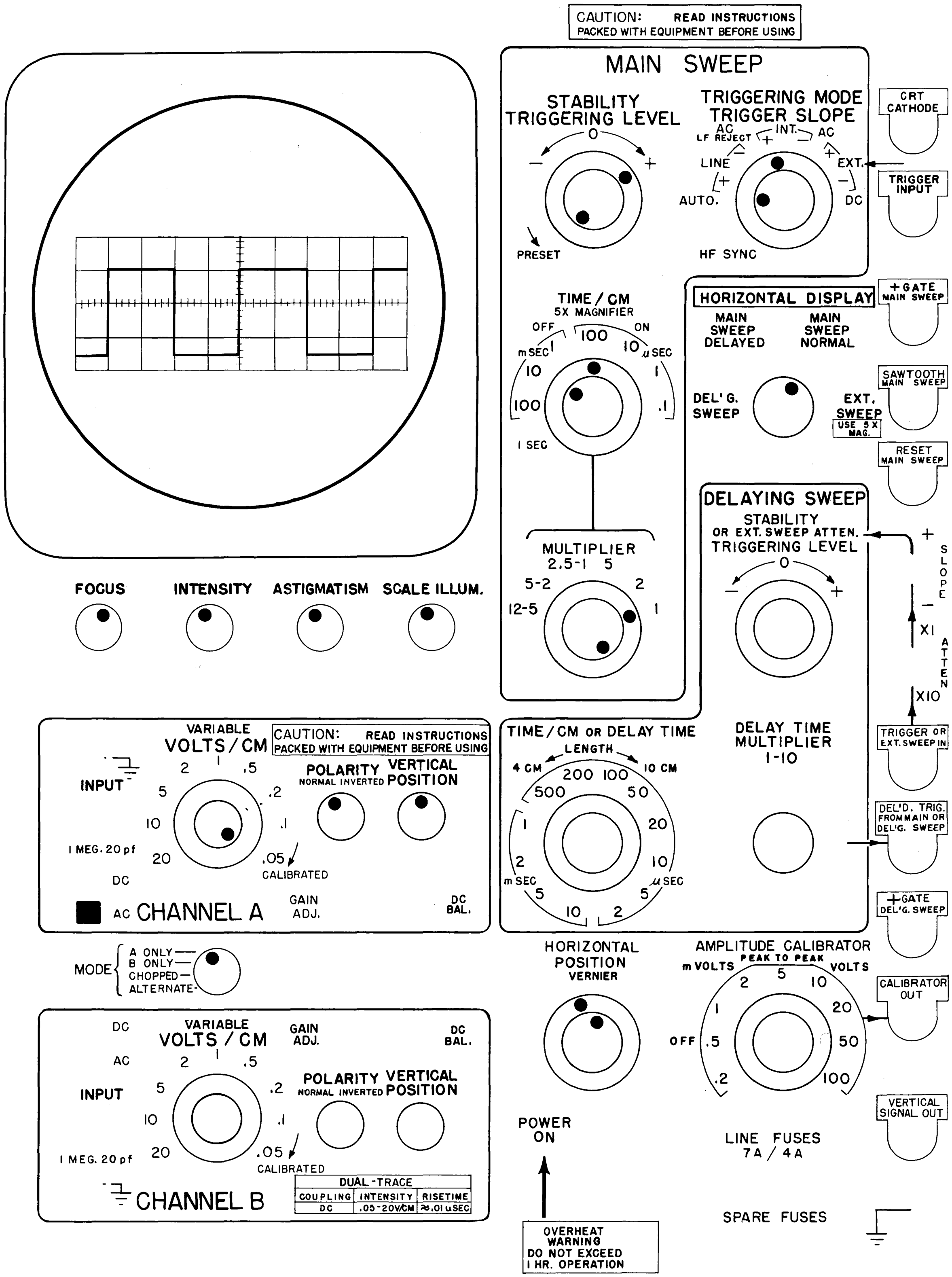



Fig. 3-1. Typical AC Measurement settings.

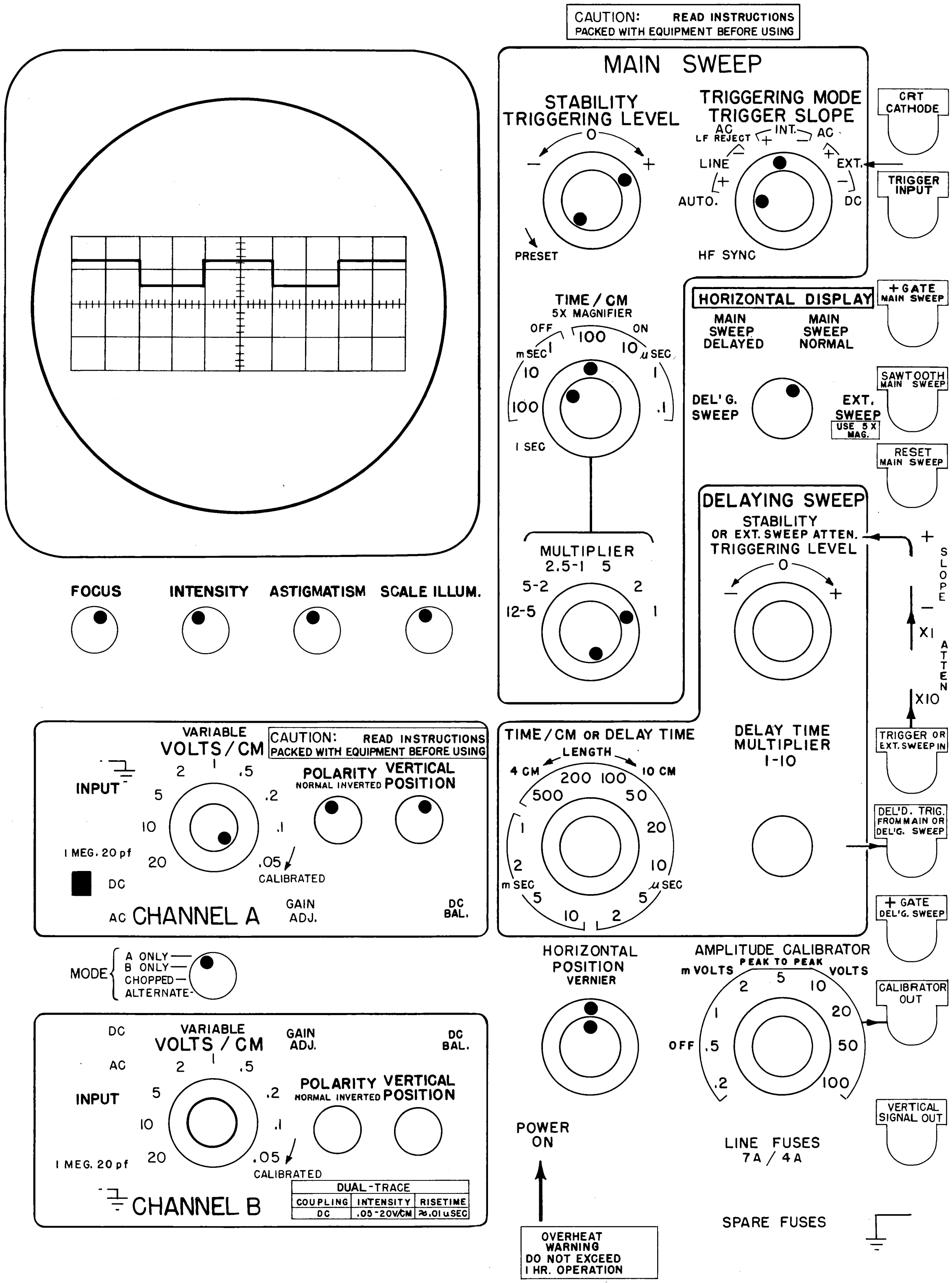



Fig. 3-2. Typical DC Measurement settings.

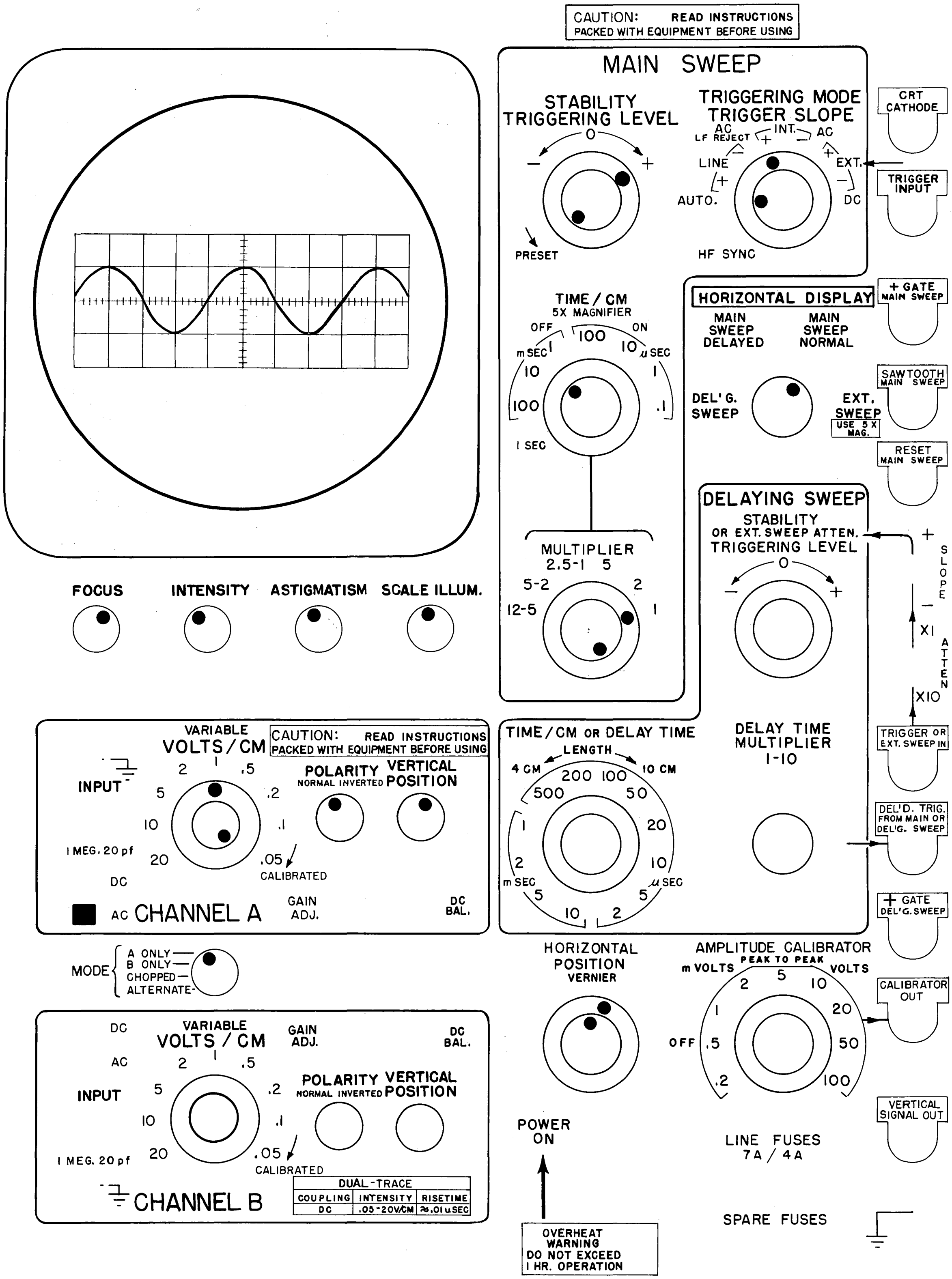



Fig. 3-3. Typical Frequency Measurement settings.

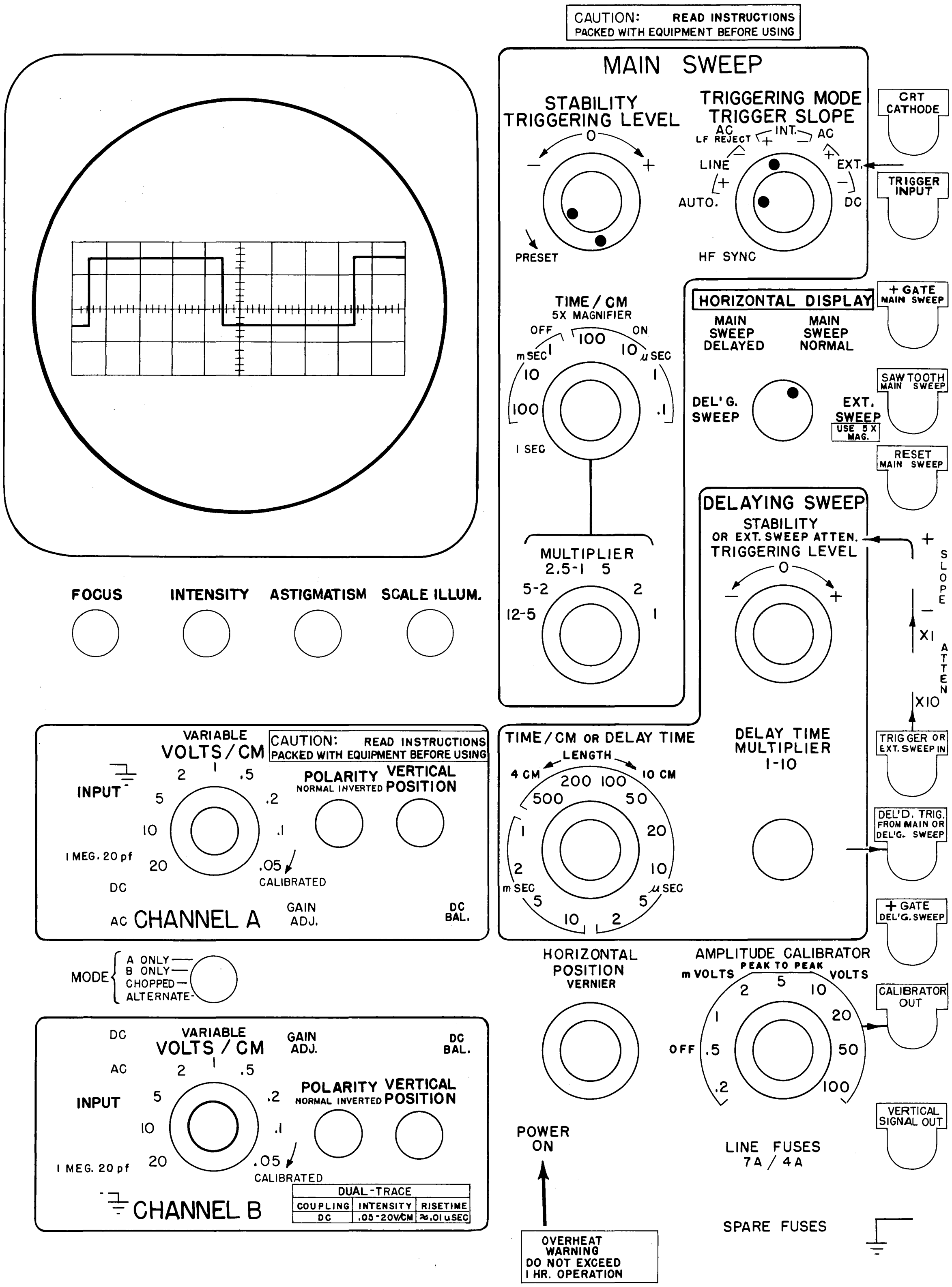



Fig. 3-4. Typical setting for Triggered (AUTOMATIC Mode).

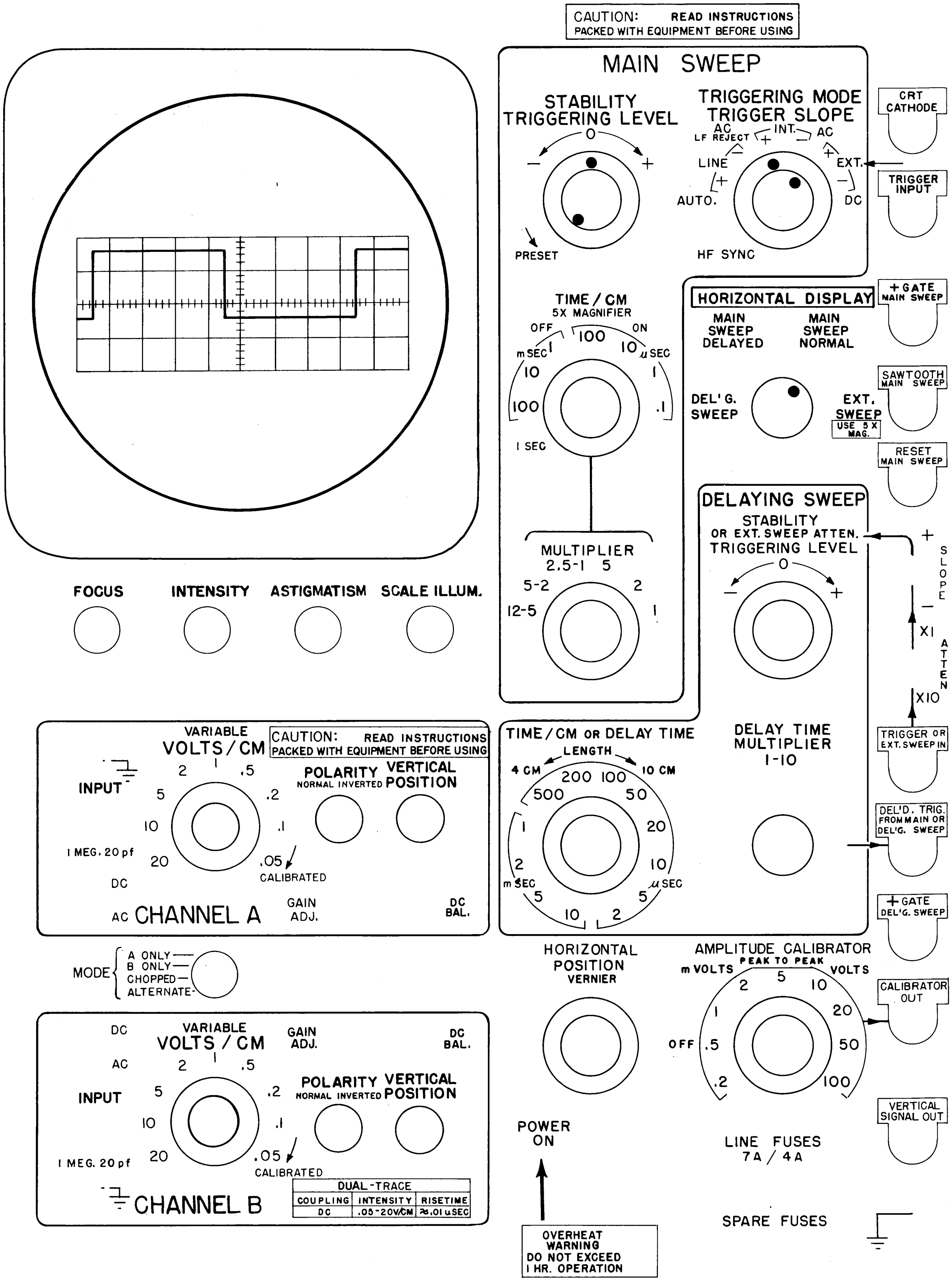



Fig. 3-5. Triggered (AC Mode).

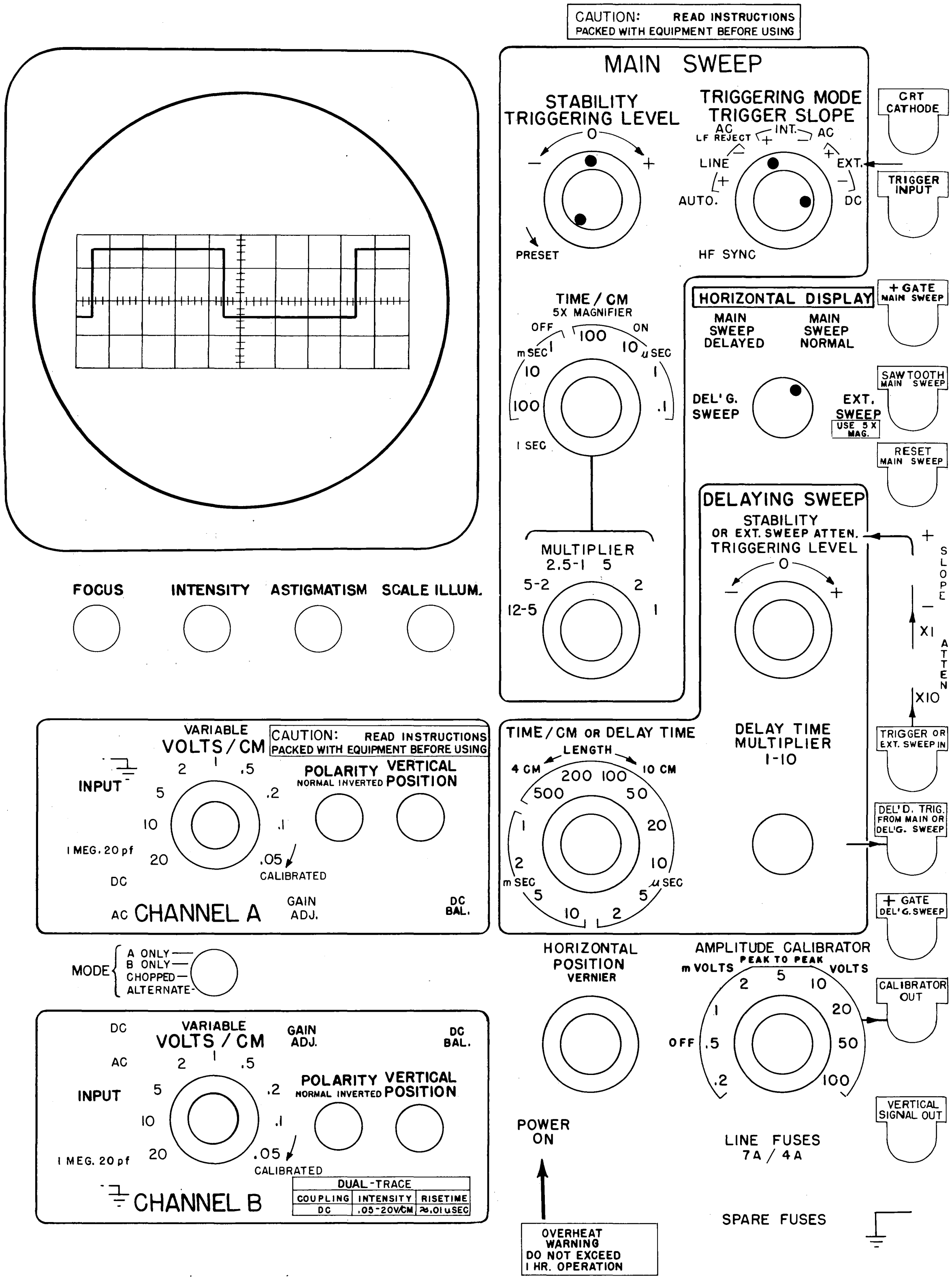



Fig. 3-6. Triggered (DC Mode).

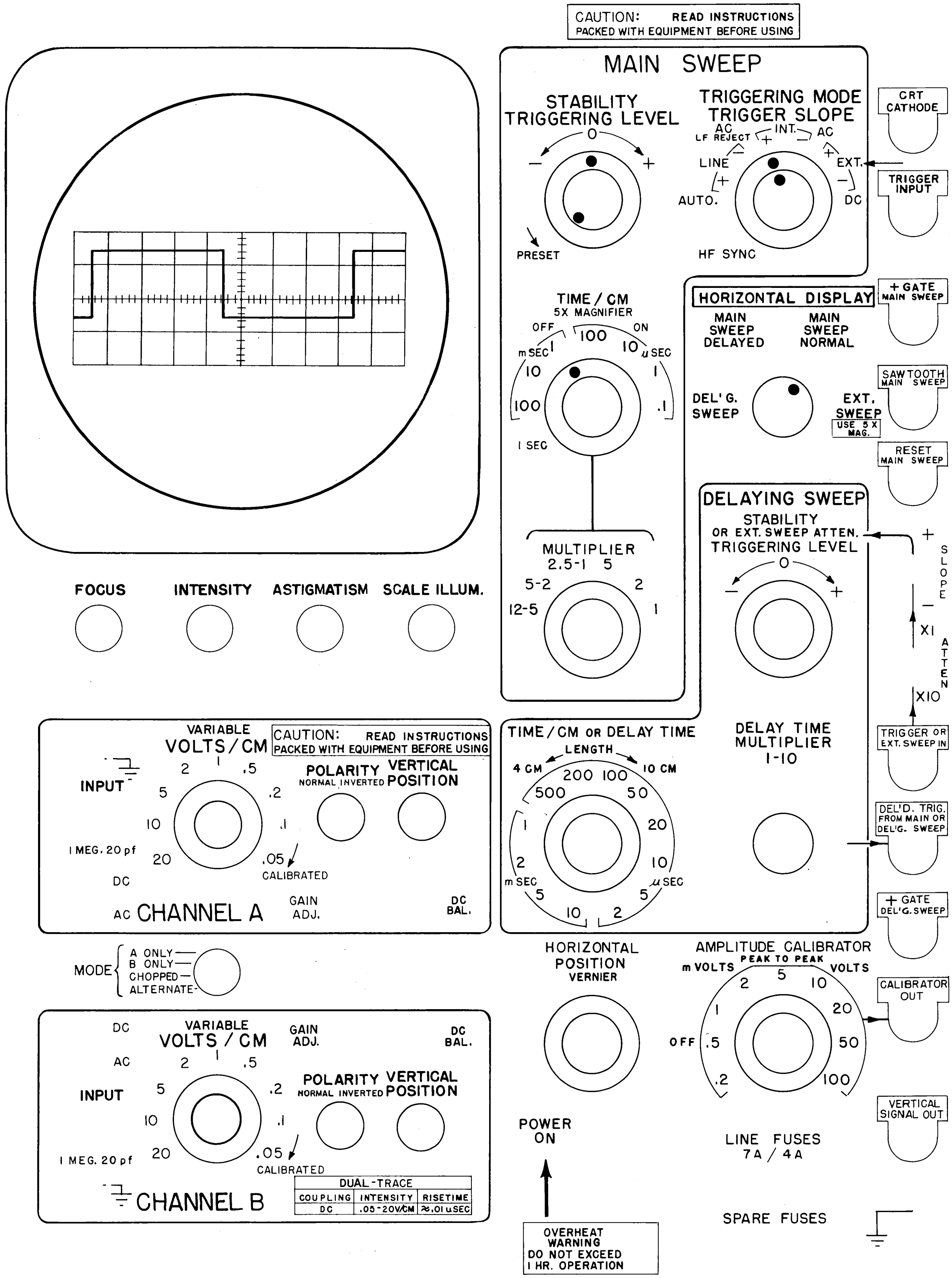



Fig. 3-7. Triggered (AC LF REJECT Mode).

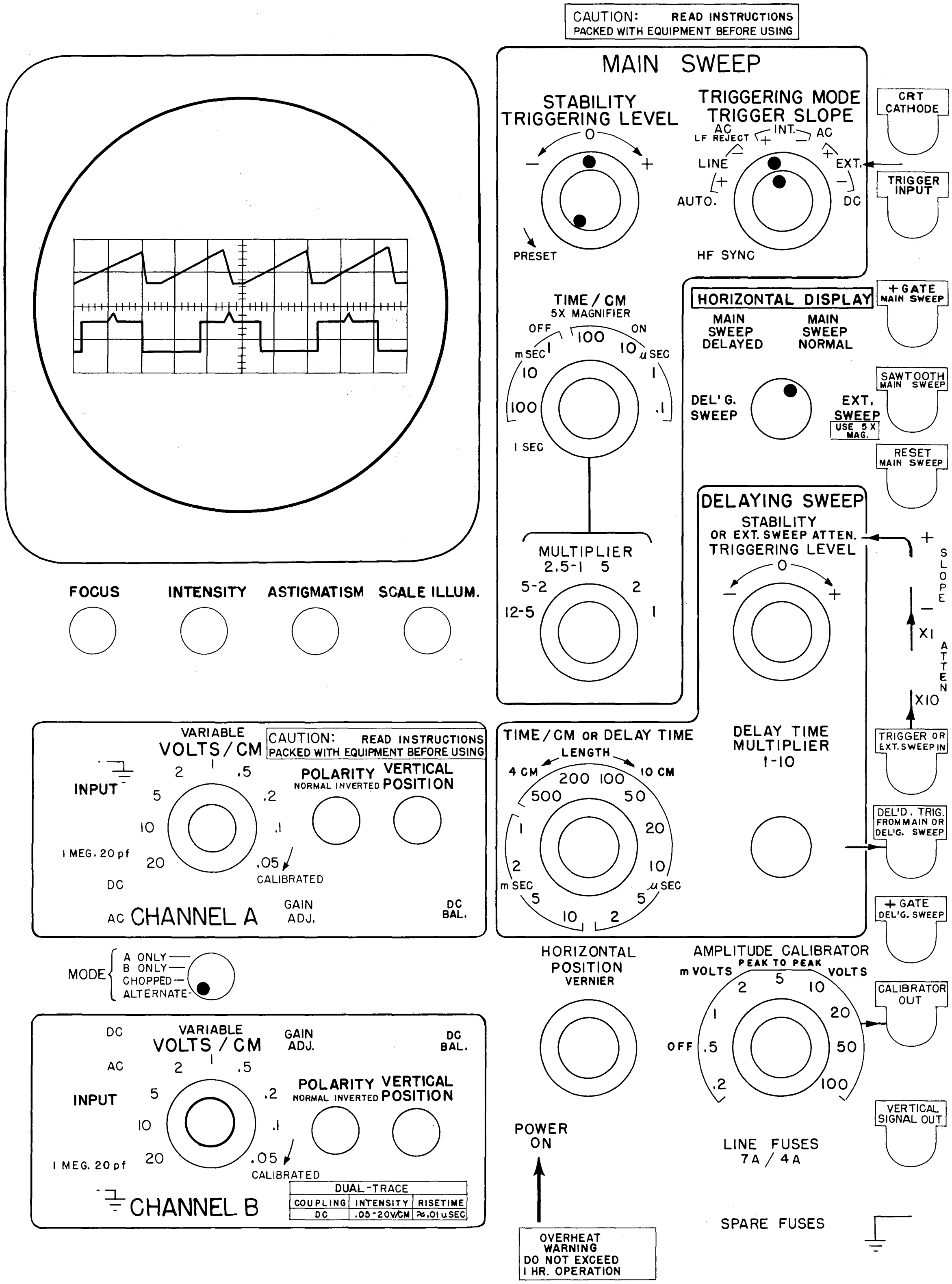



Fig. 3-8. Dual-Trace Operation.

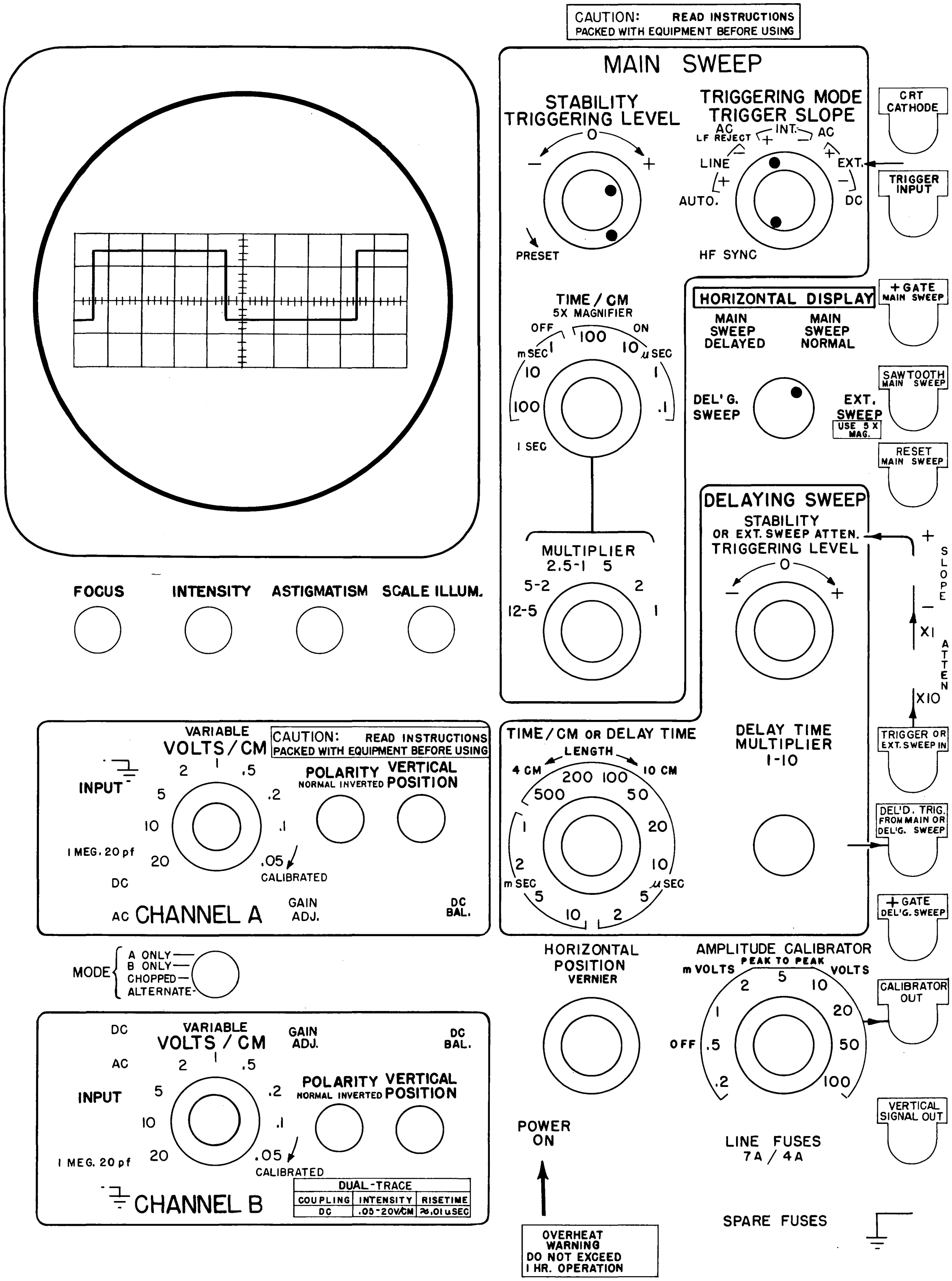



Fig. 3-9. Synchronized (HF SYNC Mode).

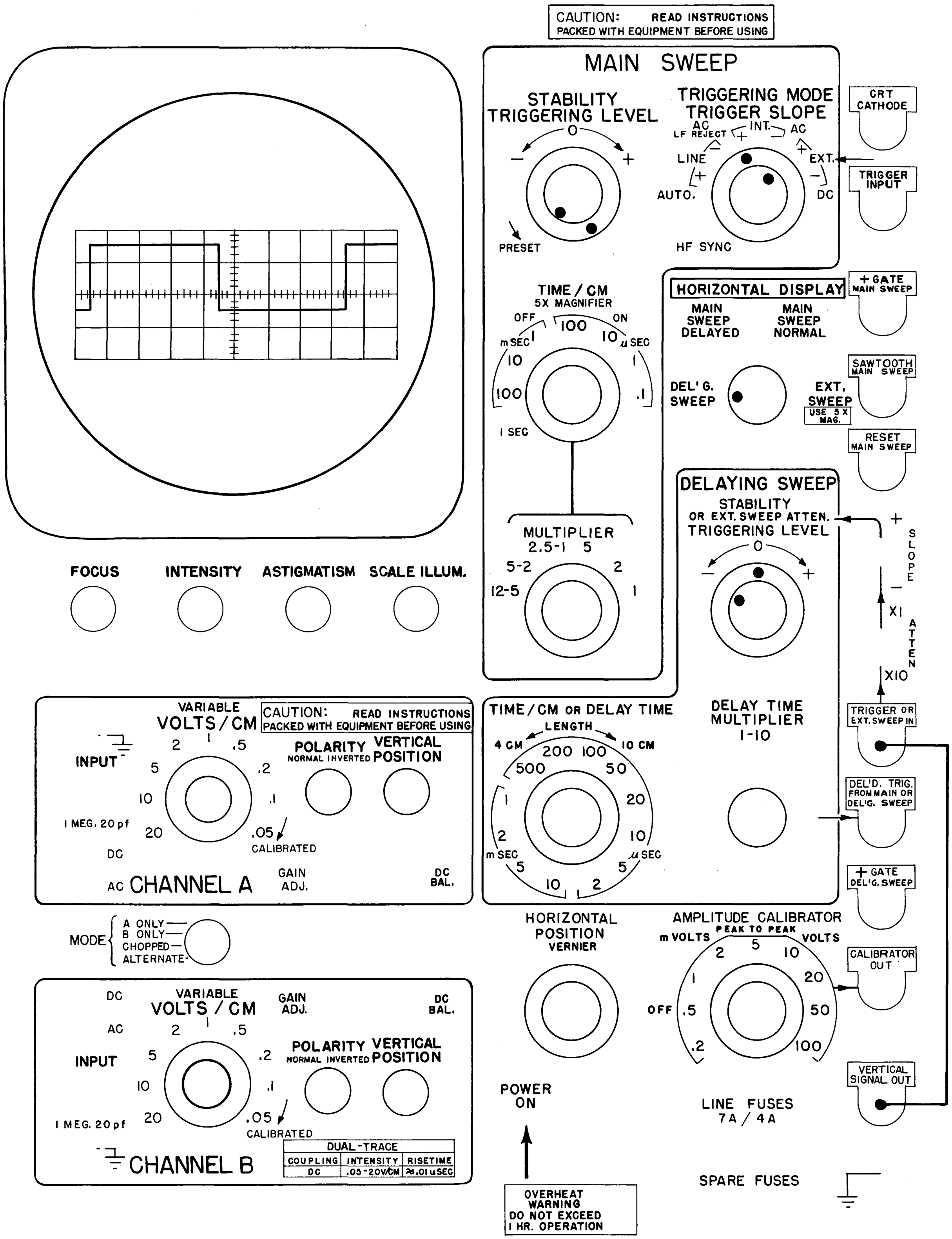



Fig. 3-10. Delaying Sweep Operation.

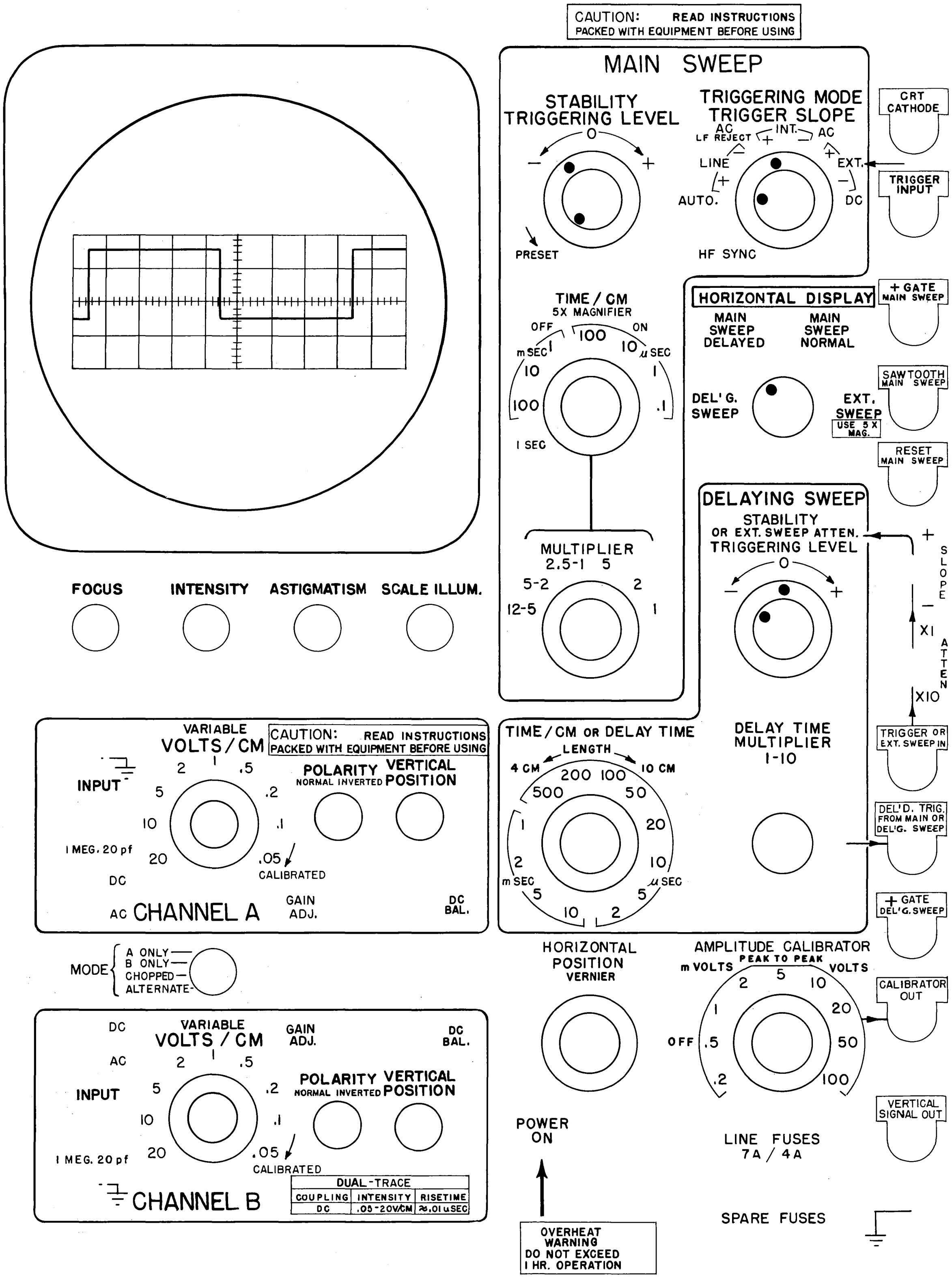



Fig. 3-11. Delayed and Triggered Operation.

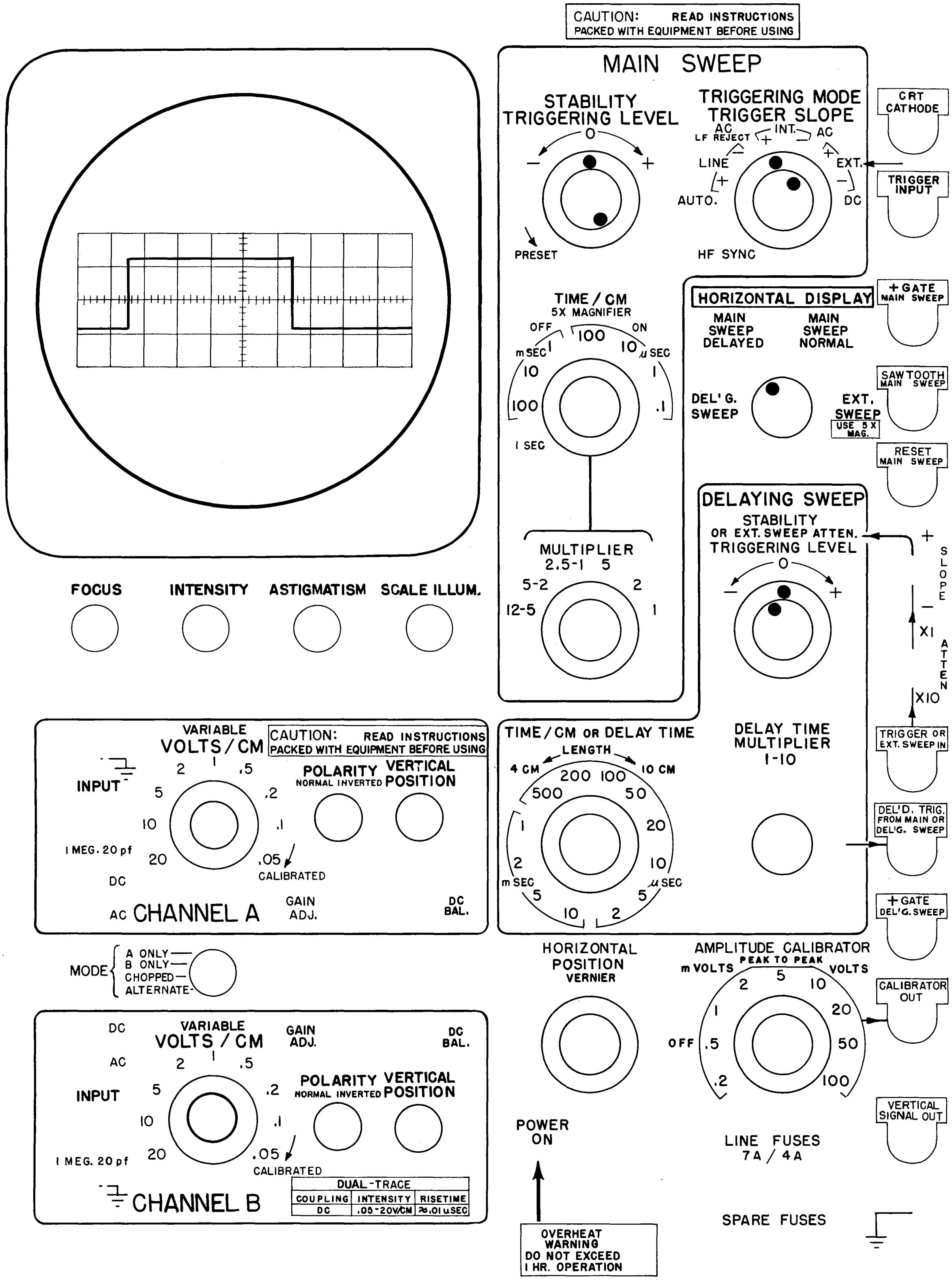



Fig. 3-12. Delayed Main-Sweep Operation.

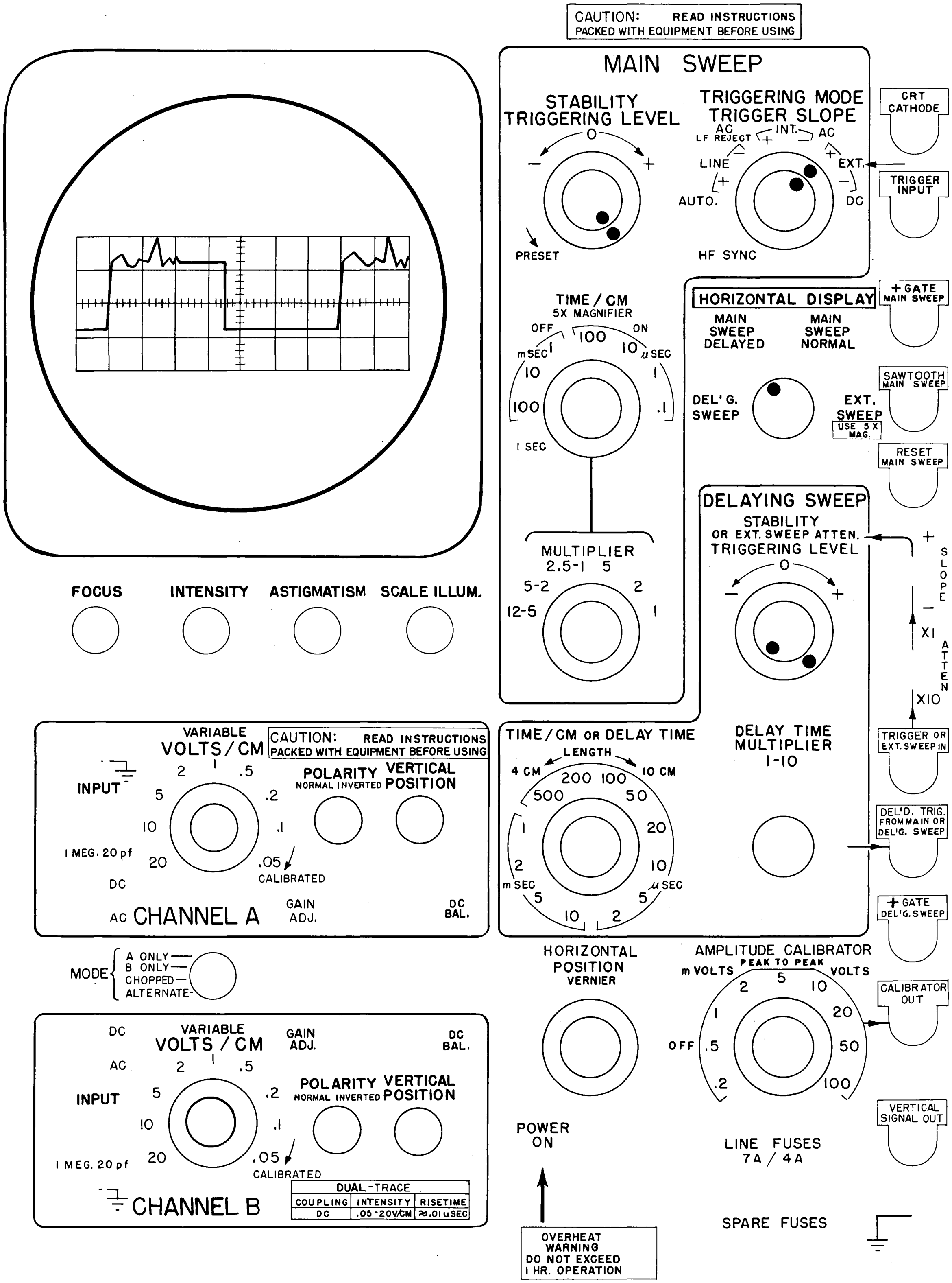



Fig. 3-13. Single Sweep (Manual Operation).

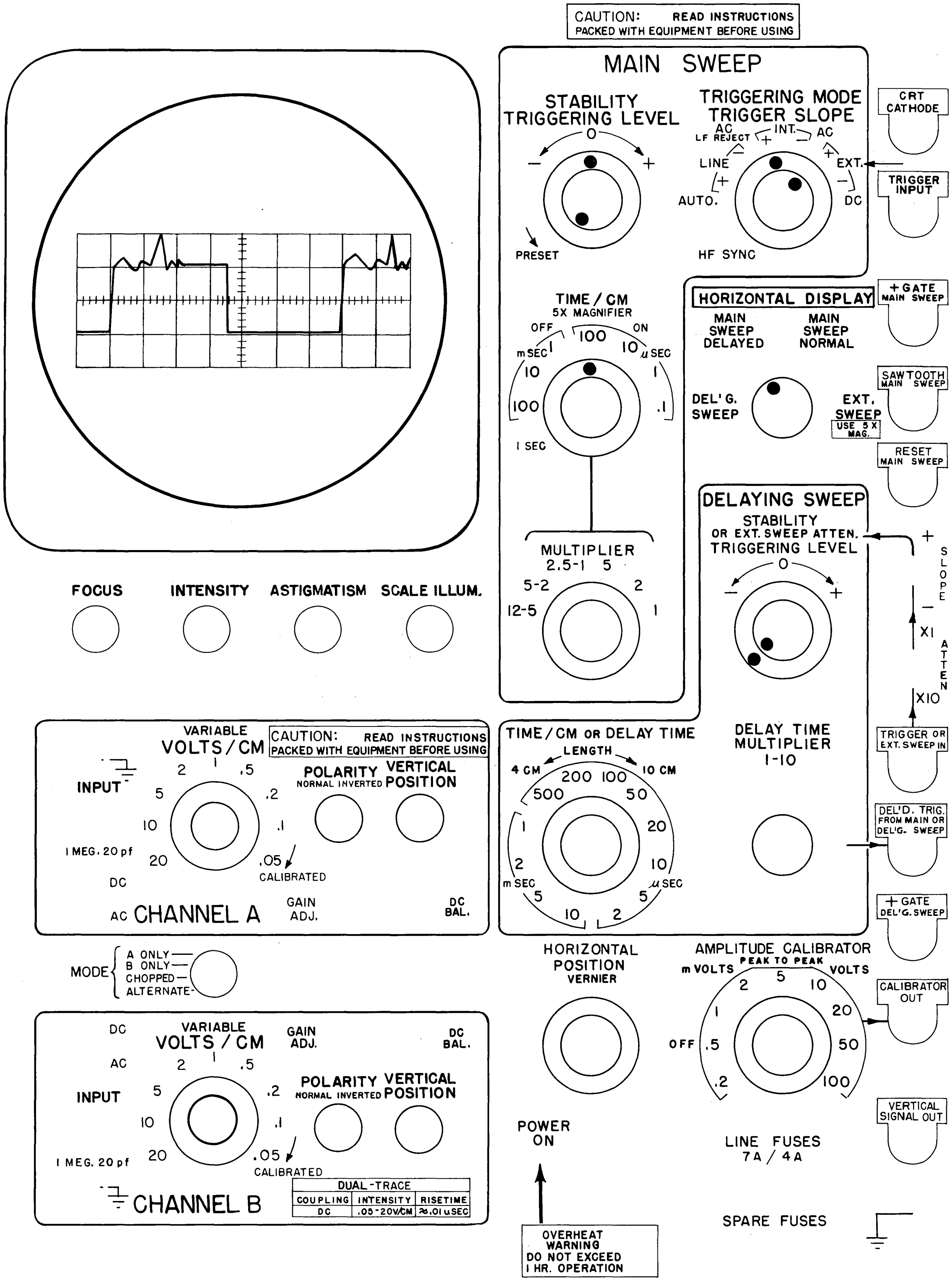



Fig. 3-14. Single Sweep (Triggered Operation).

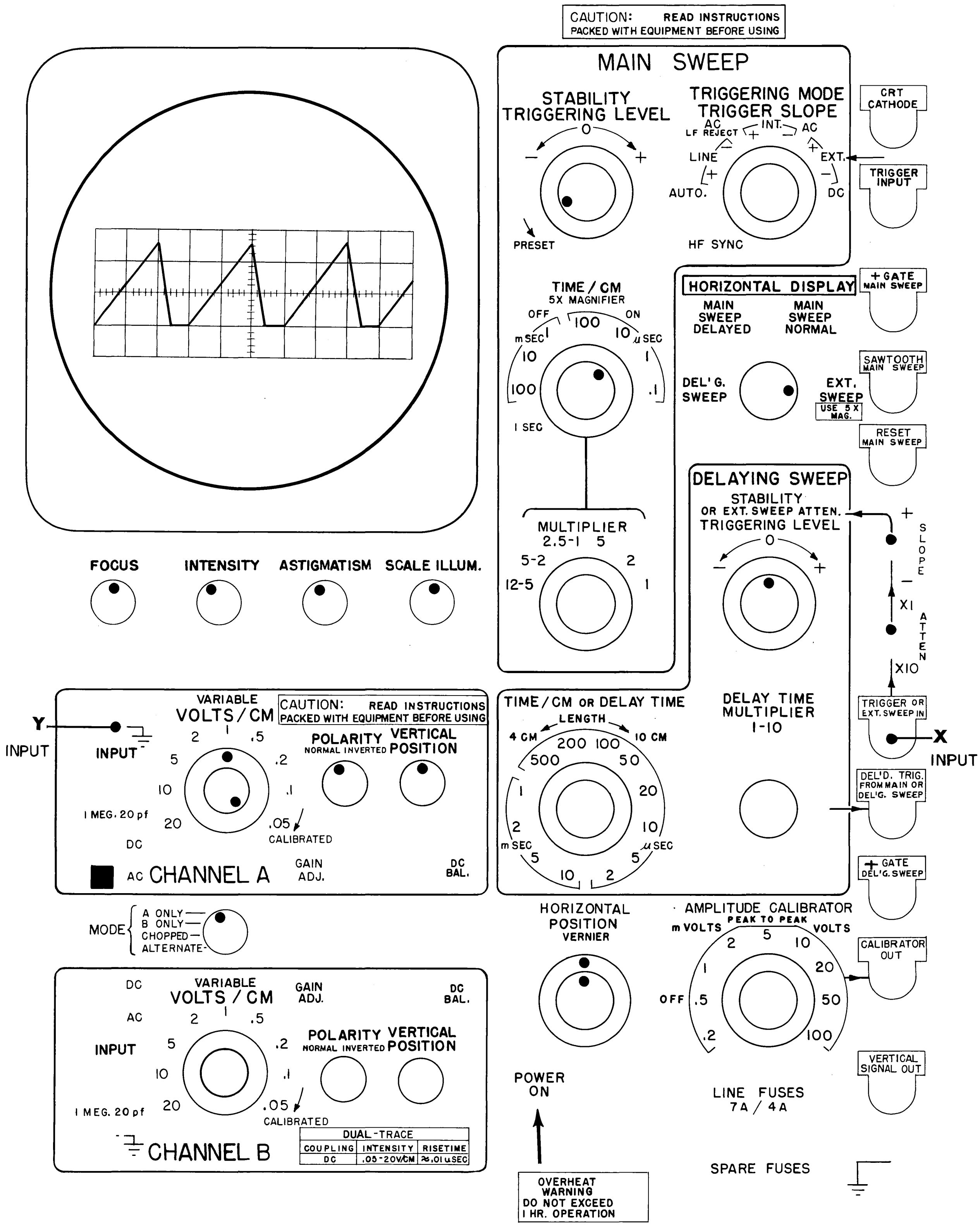



Fig. 3-15. X-Y Measurements.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | DEL'G SWEEP* |
| Main Sweep STABILITY | full left** |
| Del. Sweep STABILITY | full right |
| Del. Sweep TRIG. LEVEL | full right or left |
| Del. Sweep LENGTH | full right |
| SLOPE toggle switch | + or - |
| ATTEN. | X1 |

*With operation described in this section, no delaying operation is applied to the sweep.

**Not so far left as to operate the PRESET switch.

a. Connect VERTICAL SIGNAL OUT or an external triggering signal to TRIGGER OR EXT. SWEEP IN.

b. Advance INTENSITY setting somewhat beyond setting used with Main Sweep.

c. Set TIME/CM OR DELAY TIME control to reasonable setting for desired signal.

d. Turn Delaying-Sweep STABILITY left until trace disappears, then two or three degrees farther left.

e. Turn Delaying-Sweep TRIGGERING LEVEL toward 0 for stable display of input signal.

**3-31.** To trigger the Delaying Sweep, it is necessary to connect the source of the triggering signal to the TRIGGERING OR EXT. SWEEP IN connector. In some instances the source of the triggering signal is the VERTICAL SIG. OUT connector.

**3-32.** Operating the oscilloscope in the manner described on these pages is useful as a quick check on the operation of the Main Sweep.

### 3-33. Delayed Main-Sweep Operation

**3-34.** Useful for transient or periodic signals. Main Sweep is used in displaying the input signal. Display begins after a predetermined delay time following receipt of Delaying-Sweep triggering signal.

a. Obtain a display using the Delaying Sweep, as described in paragraphs 3-29 through 3-31.

b. Set the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control for the desired delay time (equal to the product of these controls).

c. Set the Main-Sweep TIME/CM and MULTIPLIER controls for the desired Main-Sweep rate (in general, a rate faster than that for which you set the TIME/CM OR DELAY TIME control).

d. Set the Main-Sweep TRIGGERING MODE control to AC, and turn the Main-Sweep STABILITY control full right. The brightened portion of the trace is that part which will be displayed on the Main Sweep in Step e.

e. Set the HORIZONTAL DISPLAY switch to MAIN SWEEP DELAYED. The portion of the display which appeared brightened in Step d will now be displayed across the entire graticule length.

**3-35.** This mode of operation is particularly useful for displaying a pulse train where several pulses of the same amplitude are preceded by a synchronizing pulse of greater amplitude. The Delaying Sweep can be triggered by the synchronizing pulse and subsequent pulses viewed with the Delayed Main Sweep. This permits examination of each pulse at a faster sweep rate than would be otherwise possible.

### 3-36. Delayed-and-Triggered Main-Sweep Operation

**3-37.** Useful for transient or periodic signals. Main Sweep is used in displaying the input signal. Display cannot begin until after a predetermined delay time following receipt of Delaying-Sweep triggering signal. After this delay, the display begins upon receipt of the first succeeding Main-Sweep triggering signal.

a. Turn the HORIZONTAL DISPLAY switch to MAIN SWEEP. With the TRIGGER SLOPE control in +INT. or -INT. and the TRIGGERING MODE switch at AC, adjust the TRIGGERING LEVEL control to obtain a stable display.

b. Turn the HORIZONTAL DISPLAY switch to DEL'G SWEEP and adjust the Delaying sweep controls for a stable display. (Para. 3-29 to 3-31).

c. Set the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control for the desired delay time (equal to the product of the reading of these controls).

d. Set the Main-Sweep TIME/CM and MULTIPLIER controls for the desired Main-Sweep rate (in general, a rate faster than that for which you set the TIME/CM OR DELAY TIME control).

e. Turn the HORIZONTAL DISPLAY switch to MAIN SWEEP DELAYED. Each Delaying-Sweep triggering signal will now permit the Main Sweep to be triggered once, after the predetermined delay time following the Delaying-Sweep triggering signal.

**3-38.** With this mode of operation, it is frequently possible to markedly decrease the jitter in a display resulting from a low-frequency interfering signal. To do this, connect the source of the jitter-producing signal to the TRIGGER OR EXT. SWEEP IN connector and adjust the oscilloscope controls as described above.

### 3-39. RATE-GENERATOR FEATURE

**3-40.** While you are using the Main Sweep to display a waveform from some source, you can at the same time use the Delaying Sweep to perform these two simultaneous functions: (1) to actuate or trigger the source of the waveform being displayed, and (2) to trigger the Main Sweep so that the display will be stable.

a. Turn the Delaying-Sweep STABILITY control full right. Set the Delaying-Sweep repetition rate to the desired value. In general, when the Delaying-Sweep LENGTH control is turned full right, this repetition rate will be somewhat less than one-tenth the setting of the TIME/CM OR DELAY TIME control. You can make a precise determination of the repetition rate as follows:

(1) Connect the probe cable to the INPUT connector, and connect the probe tip to the +GATE DEL'G SWEEP connector.

(2) Set the HORIZONTAL DISPLAY switch to MAIN SWEEP NORMAL. Set the Main Sweep controls to display the +GATE DEL'G SWEEP waveform, using the AUTO. or AC mode (p. 3-1).

(3) The repetition rate of the +GATE DEL'G SWEEP waveform is equal to the reciprocal of the product of the setting of the Main Sweep TIME/CM and MULTIPLIER controls and the horizontal distance in centimeters on the graticule occupied by one cycle of the waveform. The Delaying-Sweep LENGTH control provides a fine control of the repetition rate.

b. Connect the +GATE DEL'G SWEEP output signal to the Main-Sweep TRIGGER INPUT connector. Also connect the +GATE DEL'G SWEEP connector so that the leading edge of its output will trigger or actuate the source of the waveform being observed. (NOTE: Alternatively, you can use the output from the DEL'D TRIGGER FROM MAIN OR DEL'G SWEEP connector to actuate the source of the waveform to be observed. In this case, the source of the waveform to be observed will be actuated after the Main Sweep is triggered. The delay time involved will be equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control.)

c. Feed the waveform to be observed into the INPUT connector.

d. Set the Main-Sweep TRIGGER SLOPE control to +EXT. Set the Main-Sweep TRIGGERING MODE, STABILITY and TRIGGERING LEVEL controls for triggering in the AC or in the AUTO. mode (paragraph 3-5 or paragraph 3-9).

## 3-41. SINGLE SWEEPS

(Manual operation)

**3-42.** Useful in photographing recurrent phenomena when succeeding waves are similar but not necessarily identical--for example, in certain biological work. Also useful in displaying result of an action initiated by +GATE MAIN SWEEP output.

| Control | Position |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP DELAYED* |
| Main Sweep STABILITY | full right |
| Del. Sweep STABILITY | full left |

*With operation as described on this page, no delaying operation is applied to the sweep.

a. Set TIME/CM and MULTIPLIER controls to reasonable setting for desired signal.

b. When photographic equipment has been prepared to receive picture, push RESET button once and close the camera shutter.

**3-43.** In this mode of operation, the oscilloscope can be used as a pulse generator to initiate some action and as a recorder to photographically record the results of the action. A positive-going pulse is present at the +GATE MAIN SWEEP connector simultaneous with the start of the left-to-right travel of the crt beam. The pulse can be used to initiate the action, which, in turn, is displayed through the vertical-deflection system of the oscilloscope.

## 3-44. SINGLE SWEEPS

(Triggered operation)

**3-45.** Permits photography of a single transient, without interference in the photograph from succeeding signals.

a. Set HORIZONTAL DISPLAY switch to MAIN SWEEP NORMAL, Delaying-Sweep STABILITY full left. Get a stable display of CALIBRATOR signal whose amplitude is about that expected of the desired signal. Use either AC (paragraph 3-9) or DC (paragraph 3-12). If EXT. triggering is to be used, see also 3-48.

b. Turn HORIZONTAL DISPLAY switch to MAIN SWEEP DELAYED*. Trace should disappear and READY lamp should extinguish.

c. Remove CALIBRATOR lead and connect source of expected signal to plug-in INPUT. Operate RESET pushbutton. READY lamp should now light.

d. The next trigger signal received will cause a single trace to be displayed. The READY light will now go out. To repeat the operation, operate the RESET push-button again, causing the READY lamp to light.

*With operation as described on this page, no delaying operation is applied to the sweep.

**3-46.** This mode of operation is useful where it is desired to photograph the display resulting from a single action occuring at an unpredictable time. For example, the instrument could be prepared as part of an experiment to observe the effect of a lightning stroke.

## 3-47. EXTERNAL SWEEP

**3-48.** Here, horizontal deflection of the beam is effected from an externally derived signal (fed to the TRIGGER OR EXT. SWEEP IN connector), and vertical deflection is effected from a second externally derived signal (fed to the INPUT connector of the plug-in preamplifier). This operation can be useful when these two signals are related with respect to time.

a. Turn 5X MAGNIFIER ON. Turn Main-Sweep STABILITY full left (but not so far left as to operate the PRESET switch on the control).

b. Connect external source of horizontal-sweep voltage to the TRIGGER OR EXT. SWEEP IN connector. This sweep voltage should not have a large dc component, because of resulting horizontal-positioning problems.

c. Set HORIZONTAL DISPLAY to EXT. SWEEP. Set ATTEN. toggle switch to X10 if the horizontal-sweep source delivers more than about 10 volts. Set ATTEN. toggle switch to X1 if this voltage is less than about 10 volts.

d. Adjust STABILITY OR EXT. SWEEP ATTEN. for a horizontal sweep of the desired length. When sinusoidal sweep signals above 1 MC are used, it is necessary to limit the maximum horizontal sweep in order to prevent distortion.

**3-49.** When using an externally derived signal to deflect the crt beam, set the TRIGGERING MODE switch to some position other than AUTOMATIC and turn the STABILITY control as far to the left as possible without actuating the internal PRESET switch. (This disables the oscilloscope sweep generator and prevents possible objectionable brightening of parts of the display resulting from unblanking pulses being fed to the crt.)

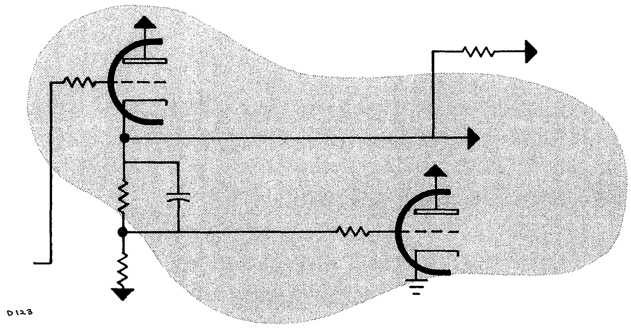
**3-50. POSSIBLE CAUSES OF IMPROPER DISPLAY**

a. The INTENSITY control is not turned sufficiently to the right. (Caution: Do not allow the spot to be excessively bright or allow it to remain long in one position, as the screen might be damaged in a few seconds.)

b. The TIME/CM and MULTIPLIER settings are too fast or too slow to present the display correctly.

c. The VOLTS/CM control on the plug-in unit is not set properly for the waveform under observation. If the sensitivity setting is too high, the trace may be deflected off the screen at the top or bottom. If the setting is too low, the deflection may be insufficient to show the display.

d. The beam may be positioned off the screen. Observe indication of beam-position indicator lamps, and adjust VERTICAL POSITION or HORIZONTAL POSITION control accordingly.





# SECTION 4

# CIRCUIT DESCRIPTION

## 4-1. BLOCK DIAGRAM

### 4-2. General

**4-3.** The Block Diagram shows the interconnections between the major functional sections of the oscilloscope. Functions of the switches are shown instead of their actual connections.

### 4-4. Plug-In Preamplifier

**4-5.** In the top part of the Block Diagram is shown the vertical-deflection system. The block labeled Preamplifier Plug-In represents a Tektronix Unit such as the Type MC Unit, which accepts the vertical input signal. Connections for power in and signal out are made through a multiple-contact mating plug and socket.

### 4-6. Vertical Amplifier

**4-7.** The Vertical Amplifier amplifies the signal and drives the delay line which terminates in the vertical deflection plates. The trigger pickoff circuits obtain a sample of the vertical signal for triggering the sweep.

### 4-8. Delay Line

**4-9.** The balanced, 50-section delay line adds 0.2 microsecond of delay to the signal so the sweep circuits will have time to get the cathode-ray spot unblanked and sweeping before the signal reaches the vertical deflection plates.

### 4-10. Trigger Pickoff

**4-11.** The Trigger Pickoff amplifies the vertical signal and delivers it to the VERTICAL SIGNAL OUT connector, and to the Main Sweep trigger circuit.

### 4-12. Main Sweep Trigger

**4-13.** The trigger circuit converts the vertical signal into negative pulses for triggering the sweep-gating multivibrator. Either the rising or the falling portion on the signal may be used to produce a trigger, depending on the setting of the Slope switch, and the level is determined by the Triggering Level control.

### 4-14. Sweep-Gating Multivibrator

**4-15.** The sweep-gating multivibrator turns on the sweep generator through the disconnect diodes, and generates the crt unblanking pulse when it is switched from its quiescent state. The sharp negative-going trigger signal from the trigger circuit trips the multivibrator, which thereafter stays in its second state until the sweep generator reverts to its quiescent state.

### 4-16. Main Sweep Generator

**4-17.** The sweep generator is a Miller integrator that produces a positive-going sawtooth about 150 volts peak-to-peak. The sweep generator turns itself off when it reaches a level prescribed by the setting of the sweep length control, by transmitting a signal through the trigger-holdoff circuits to the sweep gating multivibrator.

### 4-18. Holdoff Circuit

**4-19.** The trigger-holdoff circuit transmits the sweep turn-off signal to the multivibrator and briefly holds off subsequent trigger signals from starting the sweep again until all parts of the circuit have reached their quiescent states.

### 4-20. Lockout Multivibrator

**4-21.** With Stability set properly, the Lockout Multivibrator permits the sweep-gating multivibrator to turn on the sweep generator for one sweep when a trigger pulse arrives. Subsequent pulses are locked out--have no effect on the circuits--until the circuit is reset.

**4-22. Trigger Amplifier (Delaying Sweep)**

**4-23.** The Delaying Sweep trigger circuit operates only on externally applied pulses, usually from the VERTICAL SIGNAL OUT connector, and supplies negative pulses to the sweep-gating multivibrator of the Delaying Sweep generator. Controls in this circuit also provide for application of an external sweep when HORIZONTAL DISPLAY switch is in EXT. SWEEP IN position.

**4-24. Sweep-Gating Multivibrator (Delaying Sweep)**

**4-25.** The multivibrator turns on the sweep generator through the disconnect diodes, and also generates an unblanking pulse which is fed to the unblanking mixer in the main sweep generator.

**4-26. Sweep Generator (Delaying Sweep)**

**4-27.** The sweep generator is a Miller integrator similar in operation to that described for the Main Sweep generator.

**4-28. Holdoff Circuit (Delaying Sweep)**

**4-29.** The Delaying Sweep holdoff circuit is similar in operation to that in the main sweep.

**4-30. Horizontal/Sweep Amplifier**

**4-31.** The sweep amplifier converts the sawtooth output of the sweep generators into push-pull output at low impedance to drive the horizontal deflection plates of the crt. The amplifier gain can be increased by a factor of five for sweep magnification.

**4-32. Delay Pickoff**

**4-33.** The output from either sweep generator is applied to a comparator circuit in the delay pickoff. With the Delay Time Multiplier control the point at which the main sweep will operate can be selected.

**4-34. Unblanking Mixer**

**4-35.** This circuit transmits unblanking pulses from one or both sweep-gating multivibrators through a floating high-negative-voltage supply to the control grid of the crt.

**4-36. High-Voltage Supply**

**4-37.** A single oscillator furnishes approximately 50 kc excitation for the high-voltage rectifiers. Separate supplies for the grid and cathode isolate the accelerating voltage from the unblanking pulses applied to the grid of the crt.

**4-38. VERTICAL DEFLECTION SYSTEM**

**4-39. General**

**4-40.** The dc-coupled, push-pull, main Vertical Amplifier provides the necessary gain to drive the Delay Line and the vertical deflection plates of the crt. The main units of the Vertical Amplifier are the Input Amplifier stage V32 and V33, the cathode follower stages V34 and V36, and the 6-section Distributed Amplifier output stage. Other circuits of importance are the Trigger Pickoff Amplifier V35 and V37, the Trigger Pickoff C.F. V39B, the Vert. Sig. Out C.F. V39A, and the Indicator Amplifiers and Lamps, V38A and DS9, and V38B and DS10, respectively.

**4-41. Input Circuit**

**4-42.** The signal input from the plug-in unit is coupled through terminals 1 and 3 of the interconnecting plug to the grids of the Input Amplifier stage. R236, VA Gain Adj. varies the cathode degeneration, and thus sets the gain of the stage to agree with the Preamplifier's front-panel calibration when the VARIABLE knob is in the CALIBRATED position.

**4-43.** The Input Amplifier is coupled to the Distributed Amplifier by the cathode followers V34 and V36. The cathode followers isolate the Distributed Amplifier from the Input Amplifier, and provide the necessary low-impedance drive for the Distributed Amplifier's grid line.

**4-44.** High-frequency compensation for the Input Amplifier is provided by the variable peaking coils T1 and T2. Variable inductors L3 and L4 provide additional peaking at the very high frequencies.

### 4-45. Output Stage

**4-46.** The output stage is a 6-section Distributed Amplifier. The tapped inductors in the transmission line, between each grid and between each plate, isolate each section from the capacitance of the adjacent sections.

**4-47.** The input signal for each tube is obtained from the grid line, which is driven by the cathode followers V34 and V36. The amplified signal at each plate, fed to the plate line, becomes an integral part of the wave traveling down the line toward the deflection plates.

**4-48.** The vertical signal is delayed 0.2 microsecond between the input to the grid line and the vertical deflection plates. This delay insures that the very "front" of fast vertical signals can be observed. About 0.015 microsecond of the total delay time occurs in the Distributed Amplifier; the remaining 0.185 microsecond occurs in the Delay Line.

**4-49.** The tapped inductors between each section of the Distributed Amplifier provide about 0.003 microsecond of delay. By making the delay time in the grid and plate lines equal, the signal arriving at each plate, through the electron stream of the tube, will be synchronous with the signal moving down the plate line from the preceding sections.

### 4-50. DC Shift Compensation

**4-51.** DC shift in the amplifier--a condition whereby the dc and very low-frequency transconductance is less than at mid-frequencies--is compensated for in two ways. R257 and C67, in plate line T3, and R271 and C71 in plate line T6, form a low-frequency boost network; the time constant of this network is such that the termination resistance of the line is increased in the range from very low frequencies to dc. A longer time constant, for extremely low-frequency and dc compensation, is provided by R228, R227 and C67 in one plate line, and by R243, R242 and C71 in the other, which provide a small amount of positive feedback from the plate lines to the plate circuits of the Input Amplifier. A variable resistor R244, the DC Shift Comp. control, is connected between the two networks to adjust for the proper amount of compensation.

### 4-52. Beam-Positioning Indicators

**4-53.** The beam-position indicators DS9 and DS10, located on the front panel above the crt, indicate the relative vertical position of the trace with respect to the center of the graticule. When the beam is centered vertically, the potential across either neon is insufficient to light it. As the beam is positioned up or down the screen, however, the current through the Indicator Amplifiers, and hence the voltage across the neons, will change. The voltage across one neon will increase, causing it to light, and the voltage across the other will decrease, causing it to remain extinguished. The neon that lights will indicate the direction in which the beam has been moved.

### 4-54. Trigger Pickoff

**4-55.** When internal triggering of the Time Base Generator is desired (black TRIGGER SLOPE knob is either the + or -INT. position), a "sample" of the vertical signal is used to develop the triggering pulse. This "sample" is obtained from the trigger pickoff circuit consisting of the Trigger Pickoff Amplifier V35 and V37, and Trigger Pickoff C.F. V39B.

**4-56.** This "sample" of the vertical signal is also ac-coupled, through V39A and C80, to a front-panel connector labeled VERTICAL SIGNAL OUT.

### 4-57. Delay Line

**4-58.** The output signal from the Vertical Amplifier is coupled through the balanced Delay Line to the vertical deflection plates of the crt. The function of the Delay Line is to retard the arrival of the waveform at the deflection plates until the crt has been unblanked and the horizontal sweep started. This delay, as mentioned previously, insures that the very "front" of fast vertical signals can be observed. The line is adjusted, by means of the variable capacitors connected across the line, for optimum transient response.

**4-59.** The entire Delay Line, which includes the plate line in the Distributed Amplifier, is reverse-terminated in its characteristic impedance. The Termination Network, shown on the Vertical Amplifier diagram, is designed to dissipate both the dc and signal energy in the line by presenting a constant resistance over the frequency range of the amplifier. The terminating resistors are specially made, wirewound, noninductive, distributed resistors. The 600 ohms total resistance in each is "tapered", or distributed, in steps. The largest segment of the terminating resistance appears nearest the line; the smallest segment appears at the opposite end. Each step of the resistance is then tuned, by means of the variable capacitors, so that the network will present an optimum load to the line.

## 4-60. HORIZONTAL-DEFLECTION SYSTEM

### 4-61. Time-Base Trigger

### 4-62. Trigger Slope

**4-63.** The function of the Main Sweep Trigger circuitry is to develop a negative-going triggering pulse to trigger the Main Sweep Generator in the proper time sequence. The signal from which the negative-going triggering pulse is produced may emanate from one of three sources, as determined by the setting of the TRIGGER SLOPE switch. When the switch is in the + or -EXT. position, an external signal is employed in the development of the triggering pulse. When the switch is in the + or -INT. position, the vertical signal itself is used to develop the triggering pulse. In the + or -LINE position of the switch, a voltage at the power line frequency is used to develop the triggering pulse.

**4-64.** In addition to selecting the source of the triggering voltage, the TRIGGER SLOPE switch also arranges the input circuit of the Trigger-Input Amplifier so that a negative-going pulse is always produced at the plate of V2B regardless of whether the switch is in the + or - position of the EXT., INT. or LINE setting.

### 4-65. Trigger-Input Amplifier

**4-66.** The Trigger-Input Amplifier V1 is a polarity-inverting, cathode-coupled amplifier. The output is always taken from the plate of V1A, but the grid of either stage may be connected to the input signal source. When the TRIGGER SLOPE switch is in the - position (EXT., INT. or LINE range), the grid of V1B is connected to the input source. The grid of V1A is connected to a dc bias source, adjustable by means of the TRIGGERING LEVEL control. This bias voltage establishes the quiescent voltage at the plate of V1A. When the TRIGGER SLOPE switch is in the + position (for any of the three ranges), the grid of V1A is connected to the signal input and the grid of V1B is connected to the bias source.

**4-67.** The voltage at the grid of V1B and the voltage at the plate of V1A are in phase with each other. Therefore, when the switch is in any of the - positions (the signal applied to the grid of V1B, the voltage at the plate of V1A is in phase with the input signal voltage. By this arrangement V1B acts as a cathode follower, having a gain of approximately unity, and the signal voltage developed across the cathode resistor becomes the signal input to V1A.

**4-68.** When the switch is moved to any of the + positions, the grid of V1A is connected to the input signal source. With this configuration, the signal at the plate of V1A will be 180 degrees out of phase with the input signal. Thus, depending on the setting of the switch (+ or -), the plate-signal swing of V1A may be in phase, or 180 degrees out of phase, with the input signal.

### 4-69. Trigger Multivibrator

**4-70.** A Schmitt Trigger circuit V2 is used as the Trigger Multivibrator. In the quiescent state, i.e., ready to receive a signal, V2A is conducting and its plate is down. This holds the grid of V2B below cutoff, since the two circuits are dc-coupled. With V2B cutoff its plate voltage is up; hence no output is being developed.

**4-71.** A negative-going signal is required at the grid of V2A to drive the multivibrator into its other state in which a triggering pulse can be produced. However, the signal coupled to the grid of V2A is a component of the vertical input signal, and therefore contains both negative- and positive-going voltages.

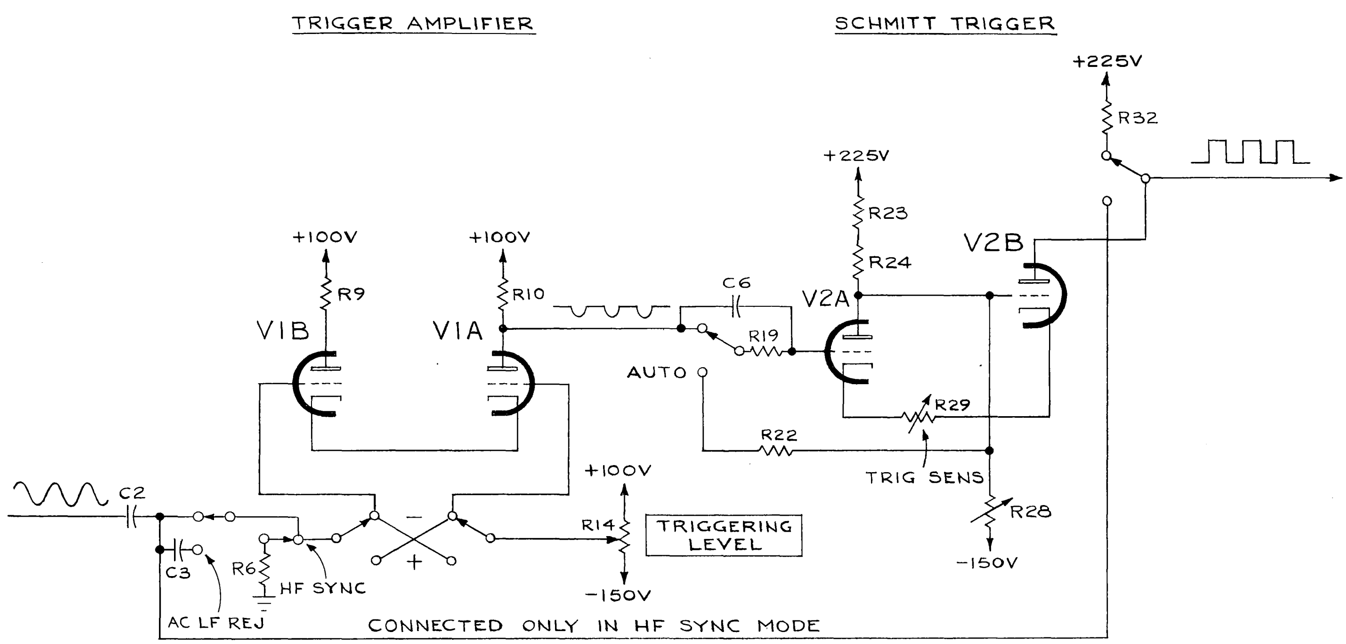



Fig. 4-1. Type 945 Simplified Main Sweep Trigger Circuitry.

**4-72.** The negative-going portion will drive the grid of V2A in the negative direction, and the cathodes of both tubes will follow the grid down. At the same time the plate voltage of V2A starts rising, which causes the grid voltage of V2B to rise. With the grid of V2B going up and its cathode going down, V2B starts conducting. The cathodes will now follow the grid of V2B; hence the cathode voltages start going up. With the grid of V2A down and its cathode up, this tube cuts off. As V2B conducts its plate voltage drops, creating a negative step at the output. This transition occurs very rapidly, regardless of how slowly the grid signal of V2A falls.

**4-73.** When the signal at the grid of V2A starts in the positive direction, just the opposite will occur. That is, V2A will start conducting again, V2B will be cutoff, and the circuit will revert to its original state with the plate voltage of V2B up. This completes the negative step-voltage output from the Schmitt Trigger circuit.

**4-74.** The operation of the Schmitt Trigger circuit is exactly the same for + or - positions of the TRIGGER SLOPE knob. However, since there is a reversal in signal polarity--between these two settings--at the output of the Trigger-Input Amplifier, triggering will occur at different points with respect to the signal being observed. For example, when the switch is in the + position, triggering will occur during the positive slope of the waveform being observed. That is, the start of the trace will occur when the waveform is going in the positive direction. Conversely, when the switch is in the - position the trace will start when the waveform is going in the negative direction.

**4-75. Trigger Sensitivity**

**4-76.** The hysteresis of the Trigger Multivibrator is determined by the setting of the Trigger Sensitivity control R29. Increasing the resistance of R29 reduces the loop gain and decreases the hysteresis. The lower the hysteresis the greater the sensitivity of the circuit. Increasing the resistance of R29 therefore increases the trigger sensitivity.

**4-77.** The Trigger Level Centering control R28 is adjusted to set the dc quiescent condition of the Multivibrator about the same as that of the Trigger Amplifier.

**4-78. Triggering Mode**

**4-79.** The TRIGGERING MODE switch selects the type or mode of triggering. In the DC position the triggering signal is dc-coupled to the Trigger Input stage, which in turn is dc-coupled to the Trigger Multivibrator circuit.

**4-80.** In the AC and AC LF REJECT modes, capacitor C2 removes the dc component of the triggering signal; the Trigger Input stage is still dc-coupled to the Multivibrator, however. The AC LF REJECT mode contains a high-pass filter C3-R6 to remove any low-frequency components from the triggering signal and allow fast recovery of the trigger circuits in the presence of dc level changes.

**4-81.** In the AUTO. mode the Schmitt circuit is converted from a bistable multivibrator to a recurrent configuration. This is accomplished by coupling the grid circuit of V2B to the grid circuit of V2A via R22. In addition, the dc coupling between the Trigger Input stage and the Multivibrator is removed in this mode of triggering.

**4-82.** The addition of R22 to the circuit causes the Multivibrator to free-run in the absence of a triggering signal. For example, assume the grid of V2A is just being driven into cutoff. The voltage at its plate starts to rise, carrying with it the voltage at the grid of V2B. Since the two grids are dc coupled through R22 and R19, this action will pull the grid of V2A back up. The time constant of the r-c network R22, R19 and C6 is such that it takes about .01 second for the grid voltage of V2A to rise exponentially from its starting point below cutoff to a value where plate current can flow.

**4-83.** As V2A starts to conduct its plate voltage drops, which in turn lowers the grid voltage of V2B. The voltage at the grid of V2A then starts dropping exponentially toward cutoff. When this tube cuts off, the circuit has completed one cycle of its approximately 50-cycle repetition rate.

**4-84.** The hysteresis of the circuit (the range of voltage at the grid of V2A between V2A cutoff and V2B cutoff) is about 6 volts when triggering in the AUTO. mode. This is increased from about 0.25 volt, for the DC, AC and AC LF REJECT modes, by the addition of R22 and R23 to the circuit. Since the grid of V2A is never more than 6 volts from cutoff, a triggering signal with a peak-to-peak amplitude of 6 volts can drive the grid to cutoff at any time and produce a trigger output. Smaller signals can also produce a trigger output, but only if they occur at a time when the sum of the signal voltage and the triode grid voltage is sufficient to drive the grid of V2A to cutoff. However, the duty cycle of operation is somewhat reduced when smaller triggering signals are being received.

**4-85.** With the circuit configuration just described, the horizontal sweep can be triggered with repetitive signals, over a wide range of frequencies, without readjustment. When not receiving triggers, the sweep continues at approximately a 50-cycle rate. Thus, in the absence of any vertical signal, the sweep generates a base line which indicates that the oscilloscope is adjusted to display any signal that might be connected to the vertical deflection system.

**4-86.** When the TRIGGERING MODE switch is in the HF SYNC position, the Trigger circuits are bypassed and the input "triggering" signal is applied directly to the Main Sweep Generator. This signal now acts as a synchronizing voltage, superimposed on the hold-off waveform (to be discussed in the section that follows). This synchronizes the Main Sweep at a sub-multiple of the triggering-signal frequency. This mode is useful for input signals in the range from 5 MC to 30 MC.

## 4-87. MAIN SWEEP GENERATOR

**4-88.** The Trigger circuit produces a negative-going waveform which is coupled to the Main Sweep Generator. This waveform is differentiated in the grid circuit of V8B to produce a sharp negative-going triggering pulse to trigger the Main Sweep Generator in the proper time sequence. Positive-going pulses are also produced in the differentiation process, but they are not used in the operation of the Main Sweep Generator.

**4-89.** The Main Sweep Generator consists of three main circuits: a Sweep-Gating Multivibrator, a Miller Runup Circuit, and a Hold-Off Circuit. The Sweep-Gating Multivibrator consists of V8B, V9 and the cathode follower V8A. The essential components in the Miller Runup circuit are the Miller Tube V12, the Sweep Gen. C.F. V13, the Disconnect Diodes V11, the Timing Capacitor C26 and the Timing Resistor R82. The Hold-Off Circuit consists of the Hold-Off C.F.'s V6A-V5B, the Hold-Off Capacitor C21 and the Hold-Off Resistors R100 and R78.

### 4-90. Sweep Gating Multivibrator

**4-91.** The Sweep-Gating Multivibrator operates as a bistable circuit. In the quiescent state V8B is conducting and its plate is down. This cuts off V9 through V8A and the divider R55-R56, and the common cathode resistor R76. With V9 cutoff, its plate is clamped about 3 volts below ground by the conduction of diodes V11 (A and B) through R59 and R74. Conduction of the lower diode V11A through the Timing Resistor R82 then clamps the grid of the Miller tube at about -3.5 volts. Synchronizing pulses for multi-trace plug-in units are supplied by V6B. When the negative multivibrator, V9, generates its positive plate step, it also generates a sharp differentiated positive trigger voltage at its screen. This occurs because L1 (which is actually wound around a damping resistor) connects the screen to +100 volts. The positive screen trigger pulse is coupled to the grid of V6B through C22. Grid bias of about -9 volts is set by divider R79, R80, between ground and -150 volts. Plate voltage and cathode circuits are completed in the plug-in unit.

### 4-92. Miller Runup Circuit

**4-93.** The quiescent state of the Miller circuit is determined by a dc network between plate and grid. This network consists of the neon glow tube DS2, the Sweep Gen. CF V13 and the Disconnect Diodes V11. The purpose of this network is to establish a voltage at the plate of the Miller tube of such a value that the tube will operate within the linear region of its transfer characteristic curve. This quiescent plate voltage is about +43 volts.

### 4-94. Sweep Generation

**4-95.** If the STABILITY and TRIGGERING LEVEL controls are now adjusted for triggered operation, a negative trigger will drive the grid of V8B below cutoff and force the Sweep-Gating Multivibrator into its other state in which V9 is the conducting tube. As V9 conducts its plate drops, cutting off the Disconnect Diodes V11. Any spiking that may occur during this transition is attenuated by the C23-R75 network.

**4-96.** With V11 cutoff the grid of the Miller tube and the cathode of the Sweep Gen C.F. are free to seek their own voltages. The grid of the Miller tube then starts to drop, since it is connected to the -150-volt bus through the Timing Resistor R82. The plate of the Miller tube starts to rise, carrying with it the grid and cathode of V13. This raises the voltage at the top of the Timing Capacitor C26, which in turn pulls up the grid of the Miller tube and prevents it from dropping. The gain of the Miller tube, as a Class A amplifier, is so high that the voltage coupled back through C26 keeps the grid constant within a fraction of a volt.

**4-97.** The Timing Capacitor then starts charging with current from the -150-volt bus. This charging current flows through the Timing

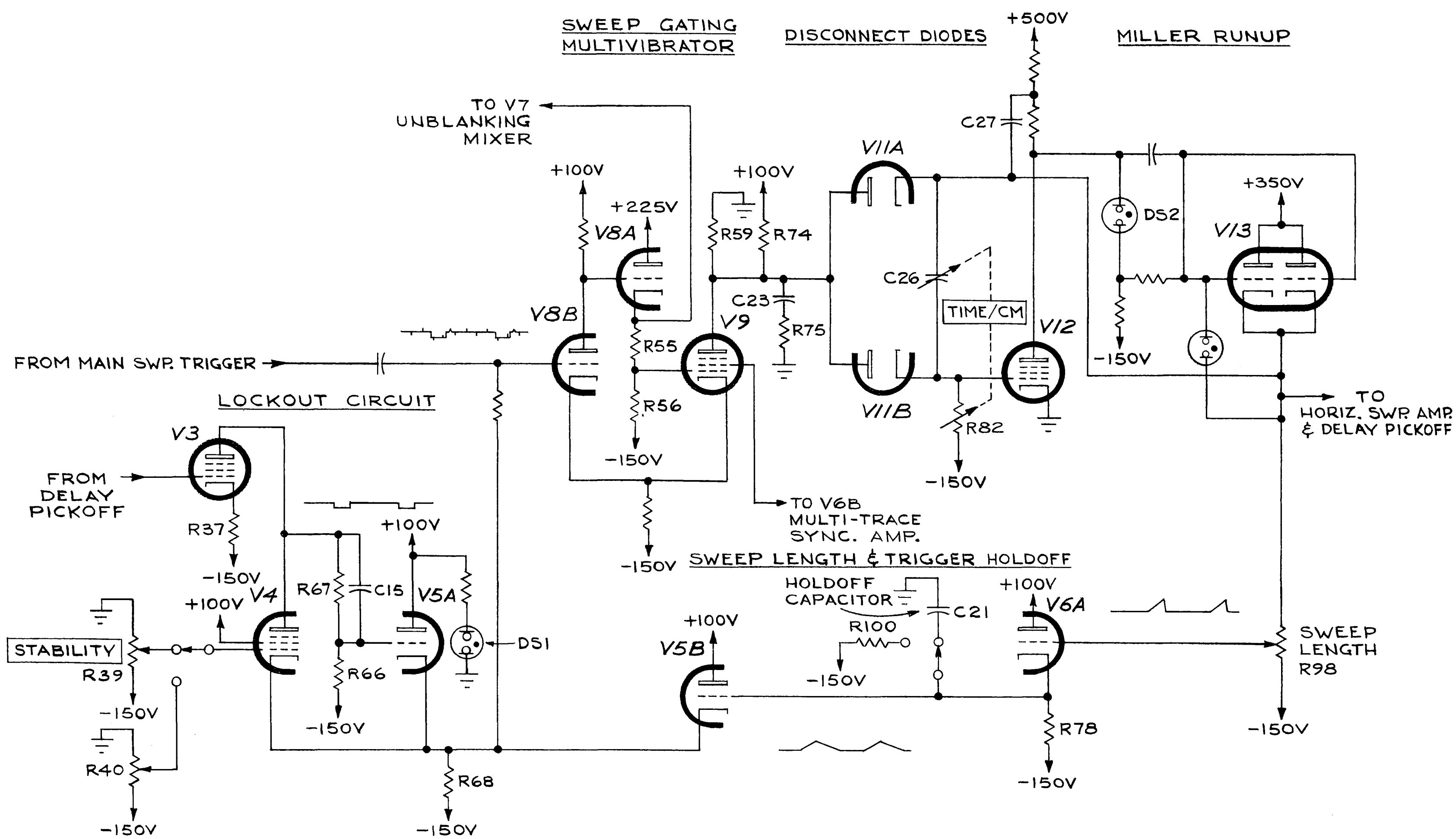



Fig. 4-2. Type 945 Simplified Main Sweep Generator Circuitry.

Resistor R82. Since the voltage at the grid of the Miller tube remains essentially constant the voltage drop across the Timing Resistor remains essentially constant. This provides a constant source of current for charging C26. By this action C26 charges linearly, and the voltage at the cathode of V13 rises linearly. Any departure from a linear rise in voltage at this point will produce a change in the voltage at the grid of the Miller tube in a direction to correct for the error.

#### 4-98. Timing Switch

**4-99.** The linear rise in voltage at the cathode of V13 is used as the sweep time-base. Timing Capacitor C26 and Timing Resistor R82 are selected by the TIME/CM switch. R82 determines the current that charges C26. By means of the TIME/CM switch both the size of the capacitor being charged and the charging current can be selected to cover a wide range of sawtooth slopes (sweep rates). For high-speed sweeps, bootstrap capacitor C27 helps supply current to charge the stray capacitance at the plate of the Miller tube; this permits the plate voltage to rise at the required rate.

**4-100.** If uncalibrated sweep rates are desired, the VARIABLE TIME/CM (red knob) control may be turned away from the CALIBRATED position. (See Timing Switch diagram.) This control, varies the sweep rate over a 2.5 to 1 range.

#### 4-101. Sweep Length

**4-102.** As explained previously, the sweep rate (the rate at which the spot moves across the face of the crt) is determined by the timing circuit C26 and R82. The length of the sweep (the distance the spot moves across the face of the crt), however, is determined by the setting of the Sweep Length control R98. As the sweep voltage rises linearly at the cathode of V13 there will be a linear rise in voltage at the arm of the Sweep Length control R98. This will increase the voltage at the grid and cathode of V6A and at the grid and cathode of V5B. As the voltage at the cathode of V6A rises, the voltage at the grid of V5B will rise. When the voltage at this point is sufficient to bring V8B out of cutoff, the multivibrator circuit will rapidly revert to its original state with V8B conducting and V9 cutoff. The voltage at the plate of V9 rises, carrying with it the voltage at the diode plate V11A. The diode then conducts and provides a discharge path for C26 through R59 and R74 and through the resistance in the cathode circuit of V13. The plate voltage of the Miller Tube now falls linearly, under feedback conditions essentially the same as when it generated the sweep portion of the waveform except for a reversal of direction. The resistance through which C26 discharges is much less than that of the Timing Resistor (through which it charges). The capacitor current for this period will therefore be much larger than during the sweep portion, and the plate of the Miller Tube will return rapidly to its quiescent voltage. This produces the retrace portion of the sweep sawtooth during which time the crt beam returns rapidly to its starting point.

#### 4-103. Hold -Off

**4-104.** The Hold-off Circuit prevents the Main Sweep Generator from being triggered during the retrace interval. That is, the hold-off allows a finite time for the Main Sweep circuits to regain a state of equilibrium after the completion of a sweep.

**4-105.** During the trace portion of the sweep sawtooth the Hold-Off Capacitor C21 charges through V6A, as a result of the rise in voltage at the cathode of V6A. At the same time the grid of V8B is being pulled up, through V5B, until V8B comes out of cutoff and starts conducting. As mentioned previously, this is the action that initiates the retrace. At the start of the retrace interval C21 starts discharging through the Hold-Off Resistor R78. The time constant of this circuit is long enough, however, so that during the retrace interval (and for a short period of time after the completion of the retrace) C21 holds the grid of V8B high enough so that it cannot be triggered. However, when C21 discharges to the point that V5B is cut off, it loses control over the grid of V8B and this grid returns to the level established by the STABILITY control. The hold-off time required is determined by the size of the

Timing Capacitor. For this reason the TIME/CM switch changes the time constant of the Hold-Off Circuit simultaneously with the change of Timing Capacitors. (In the .1, 1 and 10 μSEC position of the TIME/CM switch R78 is shunted by either R100A or R100B, shown on the Timing Switch diagram.)

**4-106. Stability**

**4-107.** The operational mode of the Main Sweep Generator is determined by the setting of the STABILITY control R39. By means of this control the sweep can be turned off, adjusted for triggered operation, or adjusted for free-running operation. The STABILITY control, through cathode follower V4, regulates the grid level of V8B. (V5A is inoperative for MAIN SWEEP NORMAL operation).

**4-108.** For triggered operation, the STABILITY control is adjusted so that the grid of V8B is just high enough to prevent the Sweep-Gating Multivibrator from free-running. Adjusted in this manner a sweep can only be produced when an incoming negative trigger pulse drives the grid of V8B below cutoff.

**4-109.** Moving the arm of the STABILITY control toward ground (ccw rotation), but not so far as to actuate the PRESET switch, will raise the grid level of V8B and prevent the Sweep-Gating Multivibrator from being triggered. This action turns off the sweep. Moving the arm toward -150 volts drops the grid of V8B to the point where the discharge of the Hold-Off Capacitor C21 can switch the multi. Adjusted in this manner, the Sweep-Gating Multivibrator will free-run and produce a recurrent sweep.

**4-110.** When the STABILITY control is turned full ccw to the PRESET position, R39 is switched out of the circuit and R40 is switched in. This control, screwdriver adjustment labeled PRESET ADJUST, provides a fixed dc voltage for the grid of V8A. When properly adjusted, PRESET operation can be used for most triggering applications. Where triggering may be difficult, however, the manual STABILITY control R39 should be used.

**4-111. Lockout Multivibrator**

**4-112.** The Lockout Multivibrator is set up in the sweep circuitry when the HORIZONTAL DISPLAY switch is the MAIN SWEEP DELAYED or DEL'G SWEEP position and the Delaying Sweep STABILITY control is turned fully counterclockwise.

**4-113.** To operate the lockout circuitry the Main Sweep STABILITY control is set up as it would be for normal operation. The desired triggering signal source is connected to the Main Sweep triggering circuits.

**4-114.** With the controls set as detailed above, V4 and V5A form a bistable multivibrator. At the completion of one sweep and before the RESET button is pushed, V5A is conducting. The conduction occurring in V5A determines the cathode level common to V4 and V5A. This level is high enough to prevent V8B from triggering on pulses fed to its grid by the Main Sweep trigger circuitry.

**4-115.** Operation of the RESET control (shown on the Delay Pickoff diagram) applies a negative pulse to V5A, cutting it off. As V5A cuts off V4 begins to conduct. V4 now controls the common cathode level. This lowers the common cathode level, and hence the grid of V8B, into the range at which the next trigger pulse to arrive will cause the Sweep-Gating Multivibrator to operate. At the end of the sweep cycle in the Sweep Generator, V5B, the Holdoff Cathode-Follower, raises the common cathode level up again momentarily, switching V5A on, and returning the Lockout Multivibrator to its first stable state.

**4-116. Ready Light**

**4-117.** The READY light, DS1, shows when V4 is conducting. When V4 conducts it pulls down the grid of V5A, raising the plate high enough to light the neon glow lamp.

**4-118.** When the READY light is glowing, a single negative-going pulse at the grid of V8B will trigger a single sweep and the circuit will then be disarmed for subsequent triggering pulses.

**4-119. Unblanking**

**4-120.** The control-grid voltage for the CRT is produced by a winding and rectifier, V67, similar to the crt cathode supply, but insulated from it. The positive end of the control-grid supply is connected to the cathode of unblanking mixer V7, and the negative end at -1450 volts is connected to the crt control grid through potentiometer R407, labeled INTENSITY on the front panel. When the unblanking pulse is produced at the cathode of the unblanking mixer, it drives the whole grid-voltage supply with it, winding, filter, potentiometer, so that the same pulse appears at the cathode-ray tube grid 1550 volts below. Since this is a dc connection, the unblanking pulse may have any duration with no change in grid voltage. C208 transmits the leading edge of the unblanking pulse to reduce unblanking time for fast sweeps, and R404, R408, and R409, provide the right time constant to prevent overshoot.

**4-121. DELAYING-SWEEP CIRCUITS**

**4-122. Horizontal-Display Switch**

**4-123.** The HORIZONTAL DISPLAY switch selects the source of signal to the sweep amplifier and unblanking circuits, and connects the delayed trigger to the main-sweep circuits. The functional block diagrams show the effects of the various HORIZONTAL DISPLAY switch settings. Each switch setting has a corresponding block diagram, #81-0001-01 through #81-0001-04.

**4-124.** In the MAIN SWEEP NORMAL position, this switch connects the main-sweep generator to the sweep amplifier, grounds the grid of the delaying-sweep unblanking mixer and supplies main-sweep sawtooth to the delay pickoff.

**4-125.** In the DEL'G SWEEP position the switch connects the delaying-sweep generator to the sweep amplifier and to the delay-pickoff comparator circuit, and connects the delaying-sweep gate to the unblanking mixer. Both the main- and the delaying-sweep unblanking signals unblank the cathode-ray tube.

**4-126.** In the MAIN SWEEP DELAYED position of the switch, the Main Sweep generator is connected to the horizontal/sweep amplifier, the delaying sweep generator is connected to the delay pickoff, and the delaying sweep unblanking mixer grid is grounded.

**4-127.** In the EXT. SWEEP position the switch rearranges the delaying-sweep trigger shaper into a cathode follower and connects its output to the sweep-amplifier input. It also biases

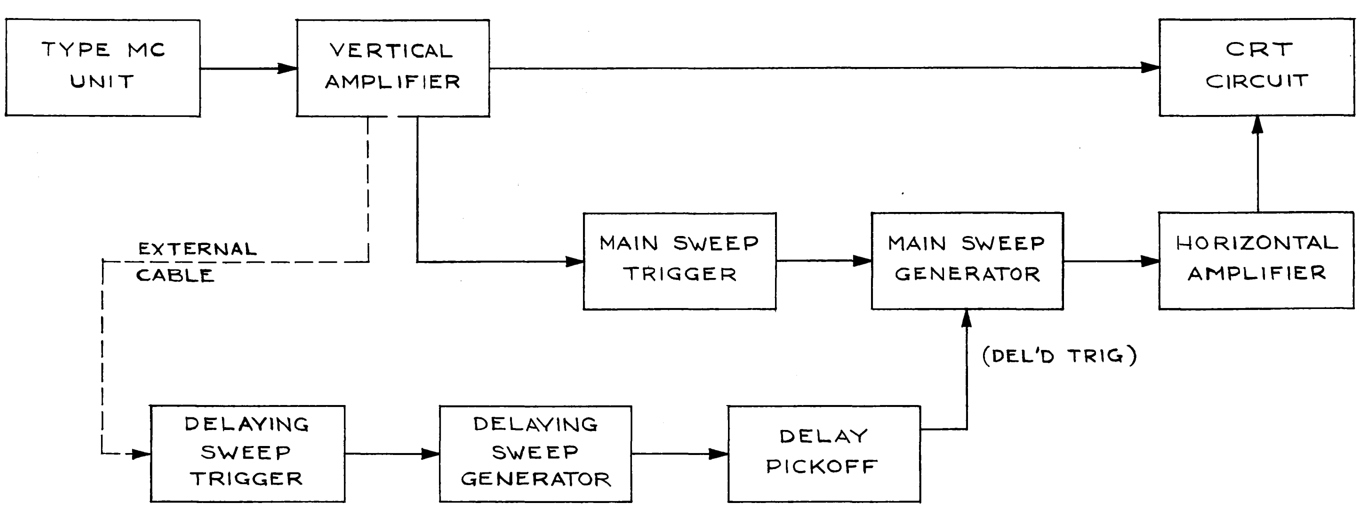



Fig. 4-3. Type 945 Block Diagram showing the circuitry with the HORIZONTAL DISPLAY switch in the Main Sweep Delayed position.

off the delay-trigger circuit and the delaying-sweep multivibrator, and supplies a positive dc bias to the unblanking circuit to hold the cathode-ray tube unblanked.

### 4-128. Delayed-Trigger Amplifier

**4-129.** The delayed trigger from the delay-pickoff circuit described in a later paragraph, is amplified in V3, and applied to the grid of delayed-trigger cathode follower V5A through compensated voltage-divider C15, R67, R66. The cathode voltage of V5A is determined by current through R68 which is returned to -150 volts.

**4-130.** Current through R68 can be contributed by cathode current through any of three cathode followers, V4, the stability tube; V5B, the holdoff tube; or V5A, the delayed-trigger tube, depending on the position of the HORIZONTAL DISPLAY switch, the setting of the STABILITY control, and the stage of the trigger-and-sweep sequence.

**4-131.** With the MAIN SWEEP NORMAL position the plate of V5A is disconnected and screen current furnishes the cathode current of V4. With the switch in the MAIN SWEEP DELAYED and the DEL'G SWEEP positions plate voltage is connected to V5A. The plate of V4 is connected to the grid of V5A through compensated voltage divider C15, R66, R67, in such a way that V4 and V5A becomes a bistable multivibrator.

**4-132.** In the quiescent state V5A conducts and holds the common-cathode voltage so high V4 is cut off. A positive pulse at the grid of V3 will therefore become a negative pulse at its plate. This negative pulse drives the grid of V5A down below cutoff, and the multivibrator assumes the second stable state in which V4 conducts and V5A is cut off. The cathode level in this state can be set by means of the bias voltage determined by the setting of the STABILITY control.

**4-133.** By setting the cathode level past the threshold of triggering for the sweep-gating multivibrator, a sweep will not be triggered, but the grid will be placed close enough to triggering that a negative trigger pulse from the main-sweep trigger circuit will trigger a sweep.

**4-134.** Two methods of delayed triggering are thus available. The first method in which the delayed trigger actually triggers the sweep is the ordinary system. The second method permits the sweep to be triggered actually from the delayed pulse you want to observe. The delayed trigger opens up the normal trigger channel that has been closed up to that time so as to hold off undesired triggers.

## 4-135. DELAY PICKOFF

**4-136.** The delay pickoff circuit is a sawtooth comparator circuit arranged to produce a positive output voltage at the time of pickoff. Before the pickoff time, V24 is cut off. Its cathode is tied to the cathode of V25 which is conducting and therefore determining the common-cathode voltage.

**4-137.** The common-cathode voltage is adjustable by means of R169, a 10-turn helical resistor, labeled DELAY-TIME MULTIPLIER on the front panel. V26A is a constant-current tube supplying cathode current to the comparators from the -150-volt supply. This arrangement permits the cathode of V25 to follow its grid over a wide range with very little variation of cathode current.

**4-138.** Plate current through R165 therefore also remains very nearly constant while V25 is conducting, no matter at what voltage the grid is set by the DELAY-TIME MULTIPLIER control, R169. This is important because the plate voltage of V25 is required to hold the grid voltage of the Delay Trigger Multivibrator, V27A, near the triggering level.

**4-139.** The positive-going delaying-sweep sawtooth raises the grid of non-conducting V24 toward its cathode voltage. When the grid rises past the cathode voltage set by the DELAY-TIME MULTIPLIER control, V24 conducts and V25 cuts off.

### 4-140. Delayed-Trigger Shaper

**4-141.** When V25 cuts off, because of conduction in V24, its plate rises carrying the grid of Delay Trig. Multivibrator V27A positive past its transition point. The Delay Trig. Multivibrator stage is regenerative so as to produce a fast transition, and the resulting positive step at the plate of V27B is differentiated through C47 and used to arm or to trigger the main-sweep circuits. The sharp differentiated pulse is transmitted to the succeeding circuits through cathode follower V26B.

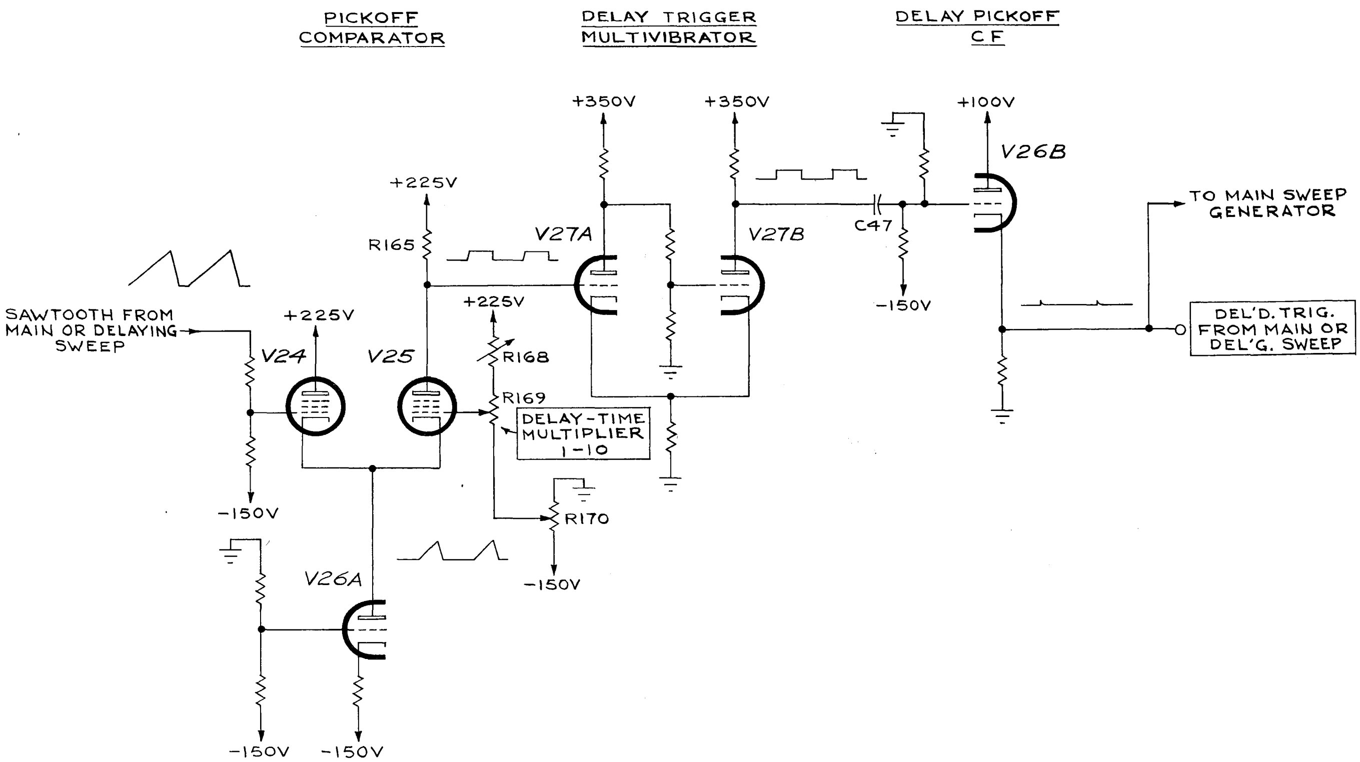



Fig. 4-4. Type 945 Simplified Delay Pickoff Diagram.

**4-142.** Two internal screwdriver controls accessible from the right side permit you to adjust the delay time more accurately if necessary so you can read centimeters of delay within a fraction of one per cent directly from the micrometer dial of the 10-turn DELAY-TIME MULTIPLIER control. R168 adjusts the total dc voltage across R169 so that each of the ten turns of this resistor positions the point of delay pickoff one centimeter of horizontal beam displacement. R170 sets the dc level of the delay sawtooth accurately so that the zero setting of the DELAY-TIME MULTIPLIER control corresponds to the start of the delaying sawtooth.

## 4-143. DELAYING-SWEEP TRIGGER

**4-144.** The Delaying-Sweep Trigger can perform either of two functions: it develops a trigger pulse to initiate a cycle of action in the Delaying-Sweep generator, or acts as a preamplifier for the Horizontal/Sweep Amplifier when external sweep or X-Y use of the oscilloscope is desired.

**4-145.** The input signal for the Delaying-Sweep Trigger circuitry is from a front panel connector. Either X1 or X10 attenuation of the input signal may be selected with the ATTEN. switch. X10 attenuation is developed by a fixed attenuator. Input capacitance and response are varied by two capacitors adjusted during the calibration of the instrument.

**4-146.** V14A and V14B are cathode-followers for the push-pull input stage of the Delaying-Sweep Trigger. The grid of one half of V14 is connected to a dc source adjusted by the Delaying Sweep TRIGGERING LEVEL control. The grid of the other half of V14 is connected to the signal after it has passed through the attenuator.

resistor, is connected between the cathodes of V15A and V15B. Resistor R115 is ganged with R124. It is controlled by the same knob which controls the STABILITY of the Delaying Sweep.

**4-150.** V16A and V16B form a Schmitt Trigger circuit in all positions of the HORIZONTAL DISPLAY switch except EXT. SWP. In this position the connection between the two cathodes

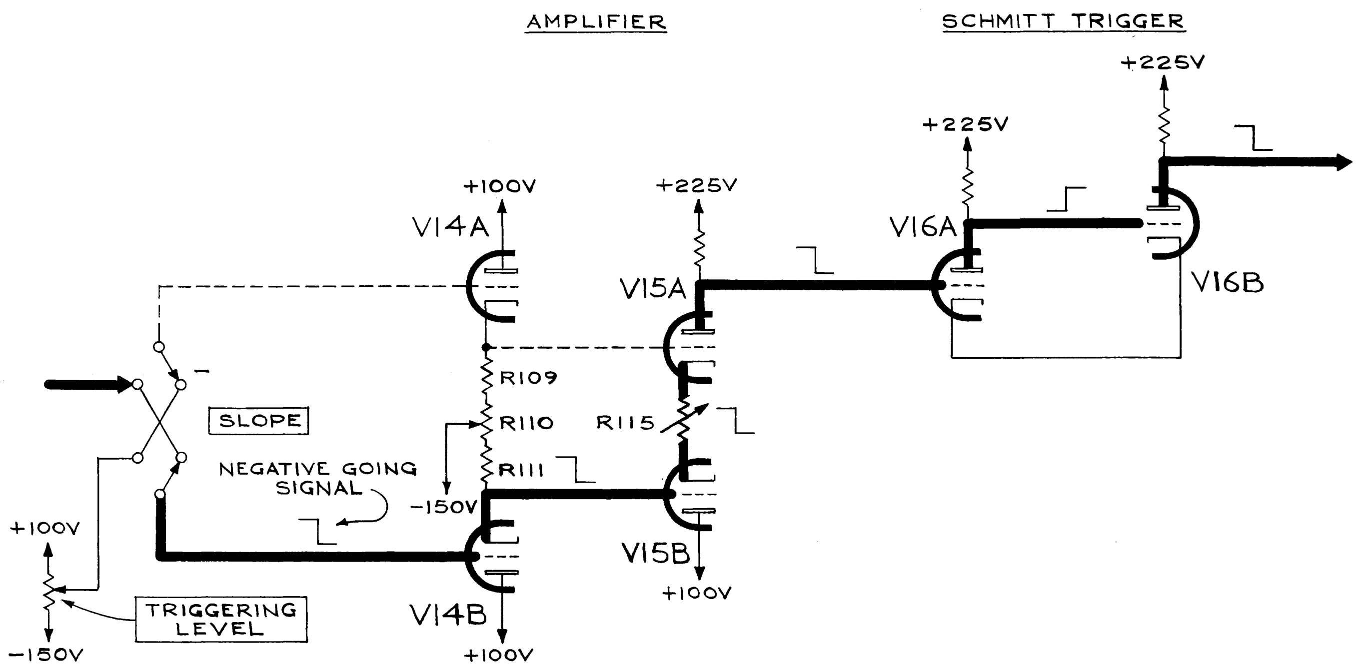



Fig. 4-5. Type 945 Delaying Sweep Trigger Circuitry showing the path of the positive-going signal.

**4-147.** The grid to which the input signal is connected is selected by the SLOPE switch. For triggering from positive-going signals the grid of V14A is connected to the triggering signal. For triggering from negative-going signals the grid of V14B is connected to the triggering signal.

**4-148.** The cathodes of V14A and V14B are coupled through the resistor series R109, R110, and R111. Resistor R110 is adjusted during calibration to remove dc shift as the input attenuator is switched in and out.

**4-149.** The output of V14 is dc coupled to the grids of V15A and V15B. R115, a variable

is removed and V16A acts as a cathode follower to drive the Sweep Amplifier.

**4-151.** When V16A and V16B are connected as a Schmitt Trigger V16A conducts during the quiescent state of the multivibrator. With V16A conducting its plate is down. This holds the grid of V16B below cutoff, since the two circuits are dc coupled. With V16B cut off its plate is up; hence no output is developed.

**4-152.** A negative-going signal is required at the grid of V16A to drive the multivibrator into its other state in which a triggering signal is developed. However, the signal coupled to the grid of V16A contains both negative-going and positive-going components.

**4-153.** The negative-going components will drive the grid of V16A down, and the cathodes of both tubes will follow the grid of V16A down. At the same time, the plate of V16A starts rising, which causes the grid voltage of V16B to rise. With the grid of V16B going up and its cathode going down V16B starts to conduct. The cathodes will now follow the grid of V16B; hence the cathode voltage starts rising. With the grid of V16A down and its cathode up this tube cuts off. As V16B conducts its plate voltage drops, creating a negative step at the output. This transition occurs very rapidly, regardless of how slowly the grid of V16A falls.

is the same for either + or - settings of the SLOPE switch. Since there is a reversal of signal polarity between these two settings triggering will occur at different points with respect to the signal being observed. With the SLOPE switch in the + position triggering will occur during the positive-going portion of the triggering waveform. With the SLOPE switch in the - position triggering will occur during the negative-going portion of the triggering waveform.

## 4-156. DELAYING-SWEEP GENERATOR

**4-157.** The Delaying Sweep Trigger circuit produces a negative-going waveform which is coupled to the Delaying Sweep Generator. This waveform is differentiated in the grid circuit

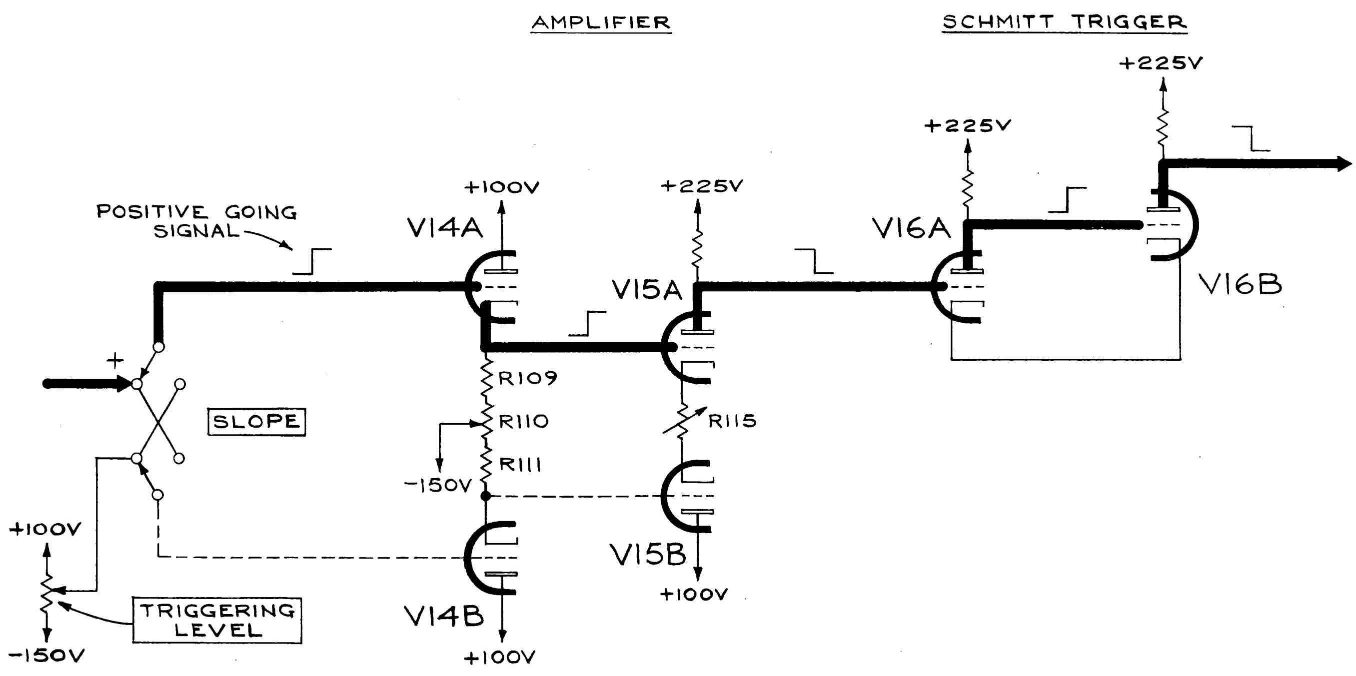



Fig. 4-6. Type 945 Delaying Sweep Trigger Circuitry showing the path of the negative-going signal.

**4-154.** When the signal at the grid of V16A becomes positive-going the action outlined above reverses itself. V16A starts to conduct, V16B is cut off, and the circuit reverts to its original condition with the plate voltage of V16B up. This completes the negative-step-voltage output from the Schmitt Trigger.

**4-155.** The operation of the Schmitt Trigger

of V17A to produce a sharp negative-going triggering pulse to trigger the Delaying Sweep Generator in the proper time sequence. Positive-going pulses are also produced in the differentiation process, but they are not used in the operation of the Delaying Sweep Generator.

**4-158.** The Delaying Sweep Generator consists of three main circuits: a Sweep-Gating Multi-

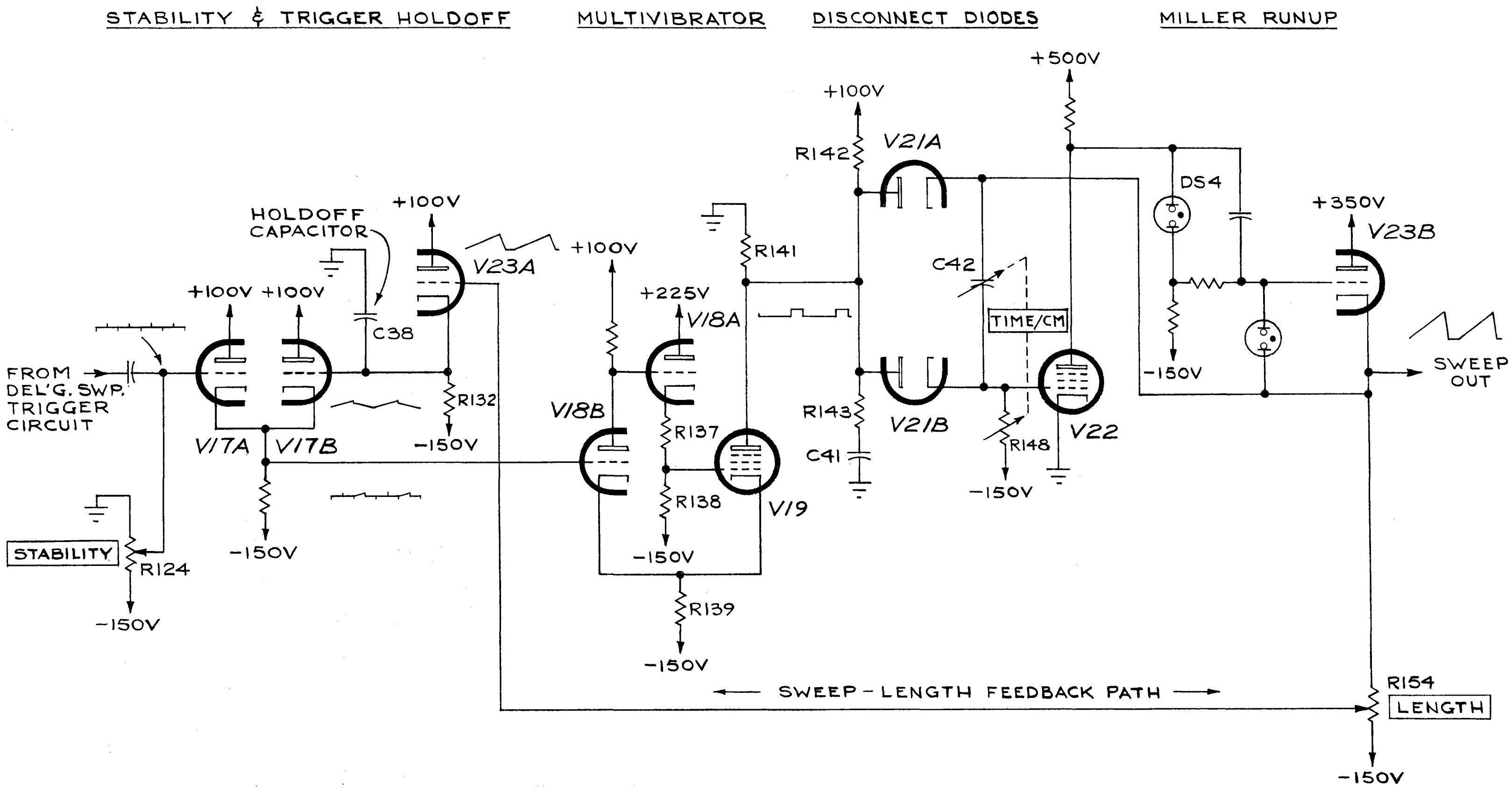



Fig. 4-7. Simplified Delaying Sweep Generator Circuitry of the Type 945.

vibrator, a Miller Runup Circuit, and a Hold-Off Circuit. The Sweep-Gating Multivibrator consists of V18B, V19 and the cathode follower V18A. The essential components in the Miller Runup circuit are the Miller Tube V22, the Sweep Gen C.F. V23B, the Disconnect Diodes V21, the Timing Capacitor C42 and the Timing Resistor R148. The Hold-Off Circuit consists of the Hold-Off C.F's V23A, V17B, the Hold-Off Capacitor C38 and the Hold-Off Resistor R132.

**4-159. Sweep Gating Multivibrator**

**4-160.** The Sweep-Gating Multivibrator operates as a bistable circuit. In the quiescent state V18B is conducting and its plate is down. This cuts off V19 through V18A and the divider R137-R138, and the common cathode resistor R139. With V19 cutoff, its plate is clamped about 3 volts below ground by the conduction of diodes V21 (A and B) through R141 and R142. Conduction of the lower diode V21B through the Timing Resistor R148 then clamps the grid of the Miller tube at about -3.5 volts.

**4-161. Miller Runup Circuit**

**4-162.** The quiescent state of the Miller circuit is determined by a dc network between plate and grid. This network consists of the neon glow tube DS4, the Sweep Gen CF V23B and of the Disconnect Diodes V21. The purpose of this network is to establish a voltage at the plate of the Miller tube of such a value that the tube will operate within the linear region of its transfer characteristic curve. The quiescent plate voltage is about +43 volts.

**4-163. Sweep Generation**

**4-164.** If the STABILITY and TRIGGERING LEVEL controls are now adjusted for triggered operation, a negative trigger will drive the grid of V18B below cutoff and force the Sweep-Gating Multivibrator into its other state in which V19 is the conducting tube. As V19 conducts its plate drops, cutting off the Disconnect Diodes V21. Any spiking that may occur during this transition is attenuated by the R143-C41 network.

**4-165.** With V21 cutoff the grid of the Miller tube and the cathode of the Sweep Gen. C.F. are free to seek their own voltages. The grid of the Miller tube then starts to drop, since it is connected to the -150-volt bus through the Timing Resistor R148. The plate of the Miller tube starts to rise, carrying with it the grid and cathode of V23B. This raises the voltage at the top of the Timing Capacitor C42, which in turn pulls up the grid of the Miller tube and prevents it from dropping. The gain of the Miller tube, as a Class A amplifier, is so high that the voltage coupled back through C42 keeps the grid constant within a fraction of a volt.

**4-166.** The Timing Capacitor then starts charging with current from the -150-volt bus. This charging current flows through the Timing Resistor R148. Since the voltage at the grid of the Miller tube remains essentially constant the voltage drop across the Timing Resistor remains essentially constant. This provides a constant source of current for charging C42. By this action C42 charges linearly, and the voltage at the cathode of V23B rises linearly. Any departure from a linear rise in voltage at this point will produce a change in the voltage at the grid of the Miller tube in a direction to correct for the error.

**4-167. Timing Switch**

**4-168.** The linear rise in voltage at the cathode of V23B is used as the sweep time-base. Timing Capacitor C42 and Timing Resistor R148 are selected by the TIME/CM switch. R148 determines the current that charges C42. By means of the TIME/CM switch both the size of the capacitor being charged and the charging current can be selected to cover a wide range of sawtooth slopes (sweep rates).

**4-169. Sweep Length**

**4-170.** As explained previously, the sweep rate (the rate at which the spot moves across the face of the crt) is determined by the timing circuit C42 and R148. The length of the sweep (the distance the spot moves across the face of the crt), however, is determined by the setting of the LENGTH control R154. As the sweep voltage rises linearly at the cathode of V23B there will be a linear rise in voltage at the arm of the LENGTH control R154. This will increase the voltage at the grid and cathode of V23A and at the grid and cathode of V17B. As the voltage at the cathode of V17B rises, the voltage at the grid of V18B will rise. When the voltage at this point is sufficient to bring V18B out of cutoff, the multivibrator circuit will rapidly revert to its original state with V18B conducting and V19 cutoff. The voltage at the plate of V19 rises, carrying with it the voltage at the diode plates V21. The diodes then conduct and provide a discharge path for C42 through R141 and R142 and through the resistance in the cathode circuit of V23B. The plate voltage of the Miller Tube now falls linearily, under feedback conditions essentially the same as when it generated the sweep portion of the waveform except for a reversal of direction. The resistance through which C42 discharges is much less than that of the Timing Resistor (through which it charges). The capacitor current for this period will therefore be much larger than during the sweep portion, and the plate of the Miller Tube will return rapidly to its quiescent voltage. This produces the retrace portion of the sweep sawtooth during which time the crt beam returns rapidly to its starting point.

#### 4-171. Hold-Off

**4-172.** The Hold-off Circuit prevents the Delaying Sweep Generator from being triggered during the retrace interval. That is, the hold-off allows a finite time for the sweep circuits to regain a state of equilibrium after the completion of a sweep.

**4-173.** During the trace portion of the sweep sawtooth the Hold-Off Capacitor C38 charges through V23A, as a result of the rise in voltage at the cathode of V23B. At the same time the grid of V18B is being pulled up, through V17B, until V18B comes out of cutoff and starts conducting. As mentioned previously, this is the action that initiates the retrace. At the start of the retrace interval C38 starts discharging through the Hold-Off Resistor R132. The time constant of this circuit is long enough, however, so that during the retrace interval (and for a short period of time after the completion of the retrace) C38 holds the grid of V18B high enough so that it cannot be triggered. However, when C38 discharges to the point where V17B is cut off, it loses control over the grid of V18B and this grid returns to the level established by the STABILITY control. The hold-off time required is determined by the size of the Timing Capacitor. For this reason the TIME/CM switch changes the time constant of the Hold-Off Circuit simultaneously with the change of Timing Capacitors.

#### 4-174. Stability

**4-175.** The operational mode of the Delaying Sweep Generator is determined by the setting of the STABILITY control R124. By means of this control the sweep can be turned off, adjusted for triggered operation, or adjusted for free-running operation. The STABILITY control, through cathode follower V17A, regulates the grid level of V18B.

**4-176.** For triggered operation, the STABILITY control is adjusted so that the grid of V18B is just high enough to prevent the Sweep-Gating Multivibrator from free-running. Adjusted in this manner a sweep can only be produced when an incoming negative trigger pulse drives the grid of V18B below cutoff.

**4-177.** Moving the arm of the STABILITY control toward ground (ccw rotation), will raise the grid level of V18B and prevent the Sweep-Gating Multivibrator from being triggered. This action turns off the sweep. Moving the arm toward -150 volts drops the grid of V18B to the point that the discharge of the Hold-Off Capacitor C38 can switch the multi. Adjusted in this manner, the Sweep-Gating Multivibrator will free-run and produce a recurrent sweep.

### 4-178. HORIZONTAL/SWEEP AMPLIFIER

#### 4-179. Amplifier

**4-180.** Input to the amplifier is selected by one of the positions of the HORIZONTAL DISPLAY switch, S4. A cathode follower, V28B, feeds the selected signal to a second cathode follower, V28A, which in turn feeds a common-cathode, grounded-grid phase inverter, V30A and V29A. Gain of the phase-inverter stage can be adjusted by adjusting R204 and R208, labeled Sweep Cal and Mag. Gain on the chassis which determine the degree of coupling between the two cathodes. Output from the phase-inverter stage is applied to the horizontal-deflection plates of the cathode-ray tube through cathode followers, V30B and V29B.

**4-181. 5 X Magnifier**

**4-182.** A negative voltage feedback network, made up of R195 and the parallel resistance of R196 and R199, accurately determines the gain of the sweep amplifier. This negative feedback can be disconnected by means of S11, labeled 5X MAGNIFIER, ON and OFF, in red on the front panel. When the feedback is removed, the gain of the amplifier is increased by a factor of five for the magnified sweep. R204 and R208 between cathodes of the phase-inverter stage V30A and V29A are also switched by the 5X MAGNIFIER switch, to permit the gains to be individually adjusted so as to keep the ratio of gains exactly five times for the two positions while permitting the spot speeds to be accommodated to the graticule. An internal screwdriver adjustment, R198, labeled Swp./Mag. Regis. adjusts the bias of the driver cathode follower V28A so that it is the same for both switch positions. This permits the magnified and normal sweep traces to be kept in accurate register, so that the center portion of the normal sweep will be centered when magnified.

**4-183. HF Current Booster**

**4-184.** Cathode current for cathode follower V30B which drives the negative-going, left-hand plate of the crt, is determined by the plate current of pentode V31. The pentode is used because its large plate current remains nearly constant over a large range of plate voltage, so that the cathode-follower current is kept nearly constant even though its cathode voltage drops through a range of about 150 volts. For the fastest sweeps, the maximum permissible continuous current through these tubes is too small to discharge the capacitance of the crt deflection plate and its associated wiring at the required rate. To increase the current through these tubes to the required value, a positive, flat-topped pulse is applied to the grid of the pentode during the period of the sweep. The positive pulse is derived by differentiating the positive-going sawtooth, through an rc network. Its amplitude is thus proportional to sweep speed. For the fastest sweep, the tube current is several times normal, but at the reduced duty cycle of the sweep, is well within the average dissipation limit of the tubes.

**4-185. Beam-Position Indicators**

**4-186.** Two neon glow lamps, DS7 and DS8, connected across the deflection plates, indicate which direction the spot is off the screen if it cannot be seen. If either plate assumes a voltage much higher than the average voltage, the glow lamp connected to that plate will glow.

**4-187. Positioning**

**4-188.** The HORIZONTAL POSITION potentiometer, R188, and the VERNIER control, R194, adjust the dc level at the grid of V28B. This change in dc level changes the dc level on the signal path through the amplifier, thus changing the dc voltage applied to the crt horizontal deflection plates and affecting horizontal positioning. The VERNIER control moves the spot about one-fifth as far as the HORIZONTAL POSITION control does.

**4-189. External Sweep Amplifier**

**4-190.** When the HORIZONTAL DISPLAY switch, S4, is in the EXT. SWEEP position, the EXT. SWEEP connector connects to an auxiliary amplifier which uses the tubes and circuits of delaying-sweep phase inverters.

**4-191.** External-sweep signals are applied either to the grid of V14A or V14B, depending on the setting of SLOPE switch, S8. For in-phase amplification the SLOPE switch should be switched to -, and the signal will be connected to V14B.

**4-192.** The signal applied to V14B grid is cathode coupled to V15B, which with V15A, is a cathode-coupled, grounded-grid amplifier. Gain of this amplifier can be adjusted by varying R115 which determines the amount of cathode coupling. The two cathodes must be at the same dc voltage, or variation of R115 will change the dc level. R110 labeled Ext. Swp. DC Bal. on the chassis can be adjusted so that the cathodes of V15A and V15B are at the same voltage.

**4-193.** Plate output from V15A is connected to the sweep amplifier through cathode follower V16A in the EXT. SWEEP position of the HORIZONTAL DISPLAY switch.

**4-194.** Adjustment of the Delaying Sweep STABILITY OR EXT. SWEEP ATTEN. control will position the trace horizontally. Note that the external sweep signal must not have a dc component of its own or the dc balance of the circuit will be upset.

## 4-195. LOW-VOLTAGE POWER SUPPLY

**4-196.** Plate and filament power for the tubes in the Type 945 is furnished by a single power transformer T11. The primary has two equal windings which may be connected in parallel for 115-volt operation, or in series for 230-volt operation. The power supply will maintain regulation over line voltage ranges of 103.5 to 126.5 volts, or 207 to 253 volts, rms, 50-400 cycles. Bridge rectifiers are employed for the full wave power supplies. The supplies furnish regulated output voltages of -150, +100, +225, +350, +500 volts and 12.6 volts.

### 4-197. -150-Volt Supply

**4-198.** Reference voltage for the -150-volt supply is furnished by a gas diode voltage-reference tube V63. This tube, which has a constant voltage drop, establishes a fixed potential of about -87 volts at the grid of V64A, one-half of a difference amplifier. The grid voltage for the other half of the difference amplifier, V64B, is obtained from a divider consisting of R386, R391 and R397. The -150 Adj. control R391 determines the percentage of total voltage that appears at the grid of V64B and thus determines the total voltage across the divider. This control is adjusted so that the output voltage is exactly -150-volts.

**4-199.** If line-voltage or load fluctuations tend to change the output voltage, an error signal exists between the two grids of the difference amplifier. The error signal is amplified in V64B and V62 and applied to the grid of the series tube V60B. Capacitors C196 and C198 improve the ac gain of the feedback loop to increase the response of the regulator circuit to sudden changes in output voltage.

**4-200.** A small amount of unregulated bus ripple is coupled to the screen of V62 through R381. The phase of the amplified ripple voltage at the plate of V62 is such as to cancel most of the ripple on the -150-volt bus.

### 4-201. +100-Volt Supply

**4-202.** The +100-volt supply is regulated by comparing to ground (the cathode of V61) the voltage of a point near ground potential obtained from the divider R375-R376 connected between the +100-volt bus and the regulated -150-volt supply. Any error voltage that exists is amplified and inverted in polarity by V61 and coupled through the cathode follower V60A to the output to prevent the output voltage from changing. Capacitor C194 improves the ac gain of this circuit.

**4-203.** A small sample of the unregulated bus ripple appears at the screen of V61 through R372. This produces a ripple component at the grid of the cathode follower V60A that is opposite in polarity to the ripple at the plate; this tends to cancel the ripple at the cathode and hence on the +100-volt bus. This same circuit also improves the regulation in the presence of line-voltage variations.

### 4-204. +225-Volt Supply

**4-205.** Rectified voltage from terminals 16 and 15 of the power transformer is added to the rectified voltage from terminals 21, 22, and 27 to furnish power for the +225-volt regulator. This supply is regulated by comparing to ground (the grid of V59A) the voltage of a point near ground obtained from the divider R363-R366 connected between the +225-volt bus and the regulated -150-volt supply. Any error voltage that exists between the grids of the difference amplifier (V59) is amplified in both V59 and V58, and coupled through the cathode follower V54B to the +225-volt bus. The change in voltage at the cathode of V54B, due to the regulator action, will be opposite in polarity to the original error signal and will thus tend to keep the output constant.

**4-206.** This supply also furnishes an unregulated output of about +325 volts for the oscillator in the crt high-voltage supply. It is unnecessary to regulate this voltage as the crt supply has its own regulator circuits.

**4-207.** The unregulated D voltage for the fan drive circuit is an unregulated output from this supply also. The voltage in this circuit is -90 volts during the 30-second warmup period, and is +175 volts thereafter. The fan drive circuitry is in the auxiliary circuit diagram section.

**4-208. +350-Volt Supply**

**4-209.** Rectified voltage from terminals 16 and 15 of T11 is added to the rectified voltage from 21 and 27 to furnish power for the +350-volt regulator. This supply is regulated by comparing to ground the voltage of a point near ground obtained from the divider R352-R353 connected between the +350-volt bus and the regulated -150-volt supply. The operation of the regulator circuit is the same as that described for the +100-volt supply.

**4-210. +500-Volt Supply**

**4-211.** Rectified voltage from terminals 26 and 32 of T11 is added to the regulated side of the +350-volt supply to furnish power for the +500-volt regulator. This supply is regulated by comparing to the regulated +350-volts the voltage of a point near +350 v obtained from the divider R338-R339 connected between the +500-volt bus and the regulated -150-volt supply. The regulator action of this circuit is the same as that described for the +100-volt supply.

**4-212. Time-Delay**

**4-213.** A time-delay relay K2 delays the application of dc voltages to the amplifier tubes in the instrument for about 45 seconds. This delay is to allow the tube heaters time to bring the cathodes up to emission temperature before operating potentials are applied.

**4-214. Fan Drive**

**4-215.** This is a DC to AC converter to provide power for an induction fan motor. The motor is free of primary power frequency change effect (50-400 cycles).

**4-216.** A transistor multivibrator (Q3-Q4) switches two power transistors, Q1, Q2 alternately on and off at approximately 100 cps rate. This provides a square-wave source to drive the bifilar wound, capacitor run, induction fan motor.

**4-217. Regulated DC Heater Supply**

**4-218.** To improve the stability of the Vertical Amplifier, the supply voltage for the heaters is regulated. The voltage appearing across terminals 18 and 23 (center tapped at 24) is rectified by a full-wave rectifier and delivered across the regulating circuit.

**4-219.** Reference voltage for the supply is provided by a divider consisting of R447, R449, and R450. The reference voltage may be adjusted by R450 to correct the output voltage. A Zener diode, CR25, protects the base to collector junction of Q10 from an over-voltage condition.

**4-220.** CR22 clamps Q9 so it can't become appreciably more positive than the emitter line. Q9 and Q10 amplify the ripple and the output of Q10, in the proper phase and amplitude to correct for variations in line voltage.

**4-221.** The output of Q9 controls the series regulators, Q5, Q6, Q7 and Q8. Output for the supply is developed across the vertical amplifier heaters. The 12.6-volt dc supply is elevated to +100 volts.

**4-222. CALIBRATOR**

**4-223.** The calibrator is a symmetrical multivibrator with V52A and V53 connected so as to turn cathode follower V52B on and off as it oscillates. During the negative pulse at multivibrator V53, the grid of the cathode follower is driven well below cutoff, so the cathode is at ground voltage. During the positive pulse at the multivibrator the plate is cut off and rests slightly below +100 volts. The voltage of the plate during cutoff is determined by the setting of R314, part of a divider between +100 volts and ground. R314 is a screwdriver adjustment labeled Cal. Adj. Cathodes of the multivibrator are returned to -150 volts. The multivibrator frequency is about one kilocycle.

**4-224.** Cathode follower V52B has a tapped calibrated voltage divider for its cathode resistor. When the Cal. Adj. control is properly set, the cathode-follower cathode is at +100 volts when V53 is cut off. Taps on the divider divide the 100 volts down to 50, 20, 10, 5, 2, 1, .5 and .2 volts. A second divider with a division ratio of 1000 to 1, can be switched in if desired to divide these voltages into millivolts. C222 from the cathode to ground corrects a slight overshoot. No internal connection from the calibrator to the vertical-deflection circuits is provided.

### 4-225. HIGH-VOLTAGE POWER SUPPLY AND CRT CIRCUITRY

#### 4-226. High-Voltage Supply

**4-227.** Accelerating voltages for the cathode-ray tube are obtained by rectifying a 50-kc high ac voltage produced by a vacuum-tube oscillator. V65 is the oscillator tube connected as a Hartley oscillator with the primary of transformer T12 as the tapped inductor, and C204 as the capacitor.

**4-228.** A voltage-tripler rectifier, consisting of V68, V69, V70, C211, C212, and C210, supplies about 8650 volts positive for the post-deflection accelerating anode of the cathode-ray tube.

#### 4-229. High-Voltage Regulator

**4-230.** The crt cathode voltage is set to -1350 volts by R412 (HV Adj). A sample of the crt cathode voltage is tapped off by R411, R412, R413, R414, R415, R416, and applied to the grid of the comparator tube, V66A. The cathode of V66A is connected to -150 volts, and the grid is compared to that voltage. The difference voltage is amplified in the comparator tube and amplified again in shunt-regulator tube V66B, whose plate voltage determines the screen voltage of oscillator V65.

**4-231.** If, for example, the high voltage should become too high, it would make the grid of the comparator tube more negative with respect to its cathode. When the grid drops, the plate rises, thereby raising the grid of V66B. When its grid rises its plate drops, thereby dropping the screen voltage of the oscillator tube, and reducing the amplitude of oscillation. The reduction of primary voltage of T12 reduces the high voltage, thereby correcting the original departure. C205 at V66A grid reduces noise and hum.

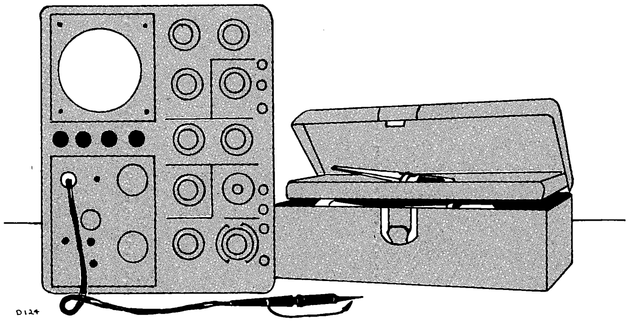
### 4-232. CATHODE-RAY TUBE CONTROL CIRCUITS

#### 4-233. CRT Geometry Adjust

**4-234.** The second-anode voltage required for best linearity at the extremes of deflection may vary somewhat between tubes. R420, a screwdriver control, labeled Geom. Adj. on the chassis, permits this voltage to be adjusted.

**4-235.** The INTENSITY control R407 varies the voltage at the grid of the crt to control the beam current. The FOCUS control R415 varies the voltage at the focusing ring to focus the trace. The ASTIGMATISM control R421 varies the voltage at the astigmatism anode to focus the spot in both dimensions simultaneously.

**4-236.** The CRT CATHODE connector is connected to the crt cathode through C216 for intensity modulation of the beam. Normally there is a grounding BNC connector installed at this point. This BNC connector is removed and a signal applied to the CRT CATHODE connector for intensity modulation.





# SECTION 5
# MAINTENANCE

## 5-1. REMOVAL AND REPLACEMENT OF PARTS

**5-2.** The procedure required for replacement of most parts in the Type 945 is obvious. Detailed instructions are therefore not required. Other parts, however, can best be removed if a definite procedure is followed. Instructions for the removal of some of these parts are contained in the following paragraphs. Because of the nature of the instrument, replacement of certain parts will require that you recalibrate portions of the oscilloscope in order to insure the proper operation of this instrument. Refer to Section 7 for recalibration procedures.

### 5-3. Removal of Panels

**5-4.** The panels of the Type 945 Oscilloscope are held in place by one-quarter-turn fasteners. To remove the panels, use a screwdriver. Rotate the fasteners approximately one-fourth turn counterclockwise; then pull the panels outward. To remove the bottom panel, lay the instrument on its back or front handles. Rotate the fasteners approximately one-quarter turn counterclockwise, and pull off the panel. Panels are replaced by reversing the order of their removal.

### 5-5. Replacement of the Cathode-Ray Tube

**5-6.** To remove the cathode-ray tube, first disconnect the tube socket and all leads connected to the neck of the tube. Loosen the tube clamp at the base of the crt. Remove the graticule cover. Pull the crt straight out through the front panel. When the new crt is in place, the leads may be properly connected to the neck of the tube by following the color code information provided on the tube shield. After replacing a crt, you must recalibrate the oscilloscope.

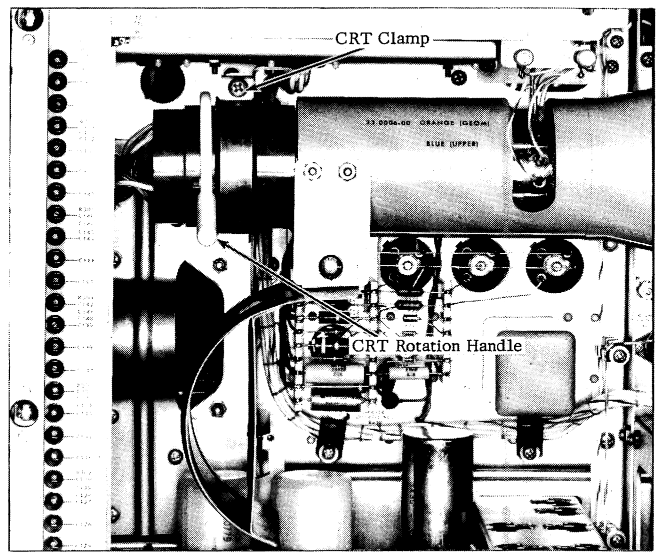



Fig. 5-1. Locations of crt rotation handle and crt clamp.

### 5-7. Replacement of Switches

**5-8.** Methods for removal of defective switches are, for the most part, obvious. Only a normal amount of care is required. Single wafers are normally not replaced on the switches used in the Type 945. If one wafer is defective, the entire switch should be replaced.

### 5-9. Tube Replacement

**5-10.** Care should be taken in preventive and corrective maintenance that tubes are not replaced unless they actually cause a circuit malfunction. Many times, during routine maintenance, it will be necessary to remove tubes from their sockets. It is important that these tubes be returned to the same sockets, unless actually defective. Replacement or switching of tubes will often necessitate recalibration of the instrument.

**5-11.** If tubes require replacement, they should be replaced by previously checked high quality tubes of the same equivalent military type. After replacing any vacuum tube, all related circuitry must be checked for calibration. Tubes for the Vertical Amplifier must also be checked for balance in the system. See Paragraphs 7-156 through 7-173.

**5-12.** When replacing a pair of matched 12BY7's (both tubes should have the same code numbers) at the Input Amplifier stage in the Vertical Amplifier section, it is suggested that a number of checked tubes be tried. Tektronix specially selects some aged tubes to meet certain bias requirements at a constant current. Since the whole oscilloscope DC balance may be widely affected, the best possible tube should be selected. If either 12BY7 is found defective, both must be replaced with new checked-and-aged tubes. The procedure for selecting and balancing the input amplifier tubes is described in Paragraphs 7-144, 7-149, 7-150 and 7-173 of this Manual. If these tubes (12BY7s) are replaced the high-frequency adjustments must be checked, and adjusted if necessary. See Paragraphs 7-178 through 7-198.

### 5-13. HV Power Supply Replacement

**5-14.** When the HV Power Supply is found to need replacement after troubleshooting, the whole unit is replaced. This encapsulated supply has some screws attaching it to the metal chassis that need to be removed after unsoldering the leads on the ceramic strips. These leads are color-coded to permit easy identification. Remember that a complete recalibration is necessary when this supply is replaced.

### 5-15. Power Transformer Replacement

**5-16.** When a complete examination shows that the power transformer needs replacement, be certain that the exact replacement is used. Figure 5-2 shows the power transformer connections for the Type 945 Oscilloscope. A complete recalibration is required after power transformer replacement.

### 5-17. Fan Motor and Fan Blades

**5-18.** Wipe fan blades when you clean the air filter, about every three or four months.

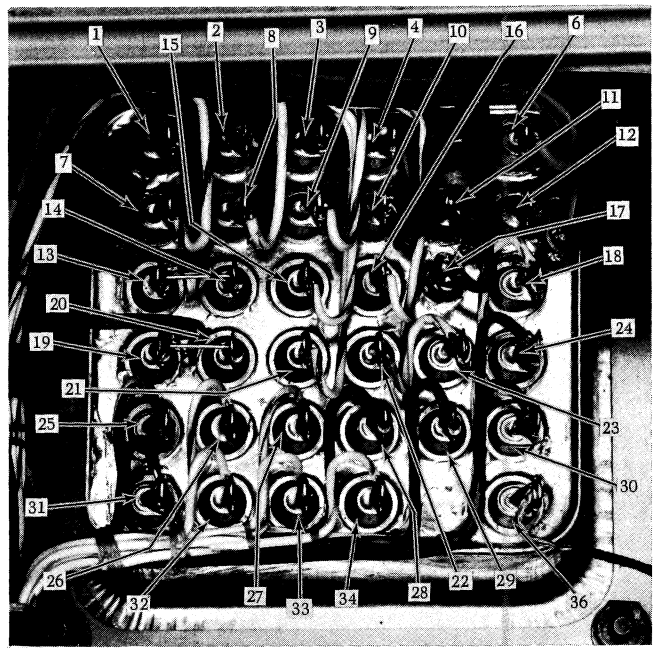



Fig. 5-2. Power transformer terminal locations.

**5-19.** The fan bearings are sealed and do not require oiling. If the fan motor seems unduly noisy, check the fan drive symmetry as in Paragraph 7-47. Within the range of 95 to 105 cycles, adjust the Freq. Adj., R437, until the noise level is lowest. If the fan motor still seems unduly noisy, check the bearings and replace if play is excessive.

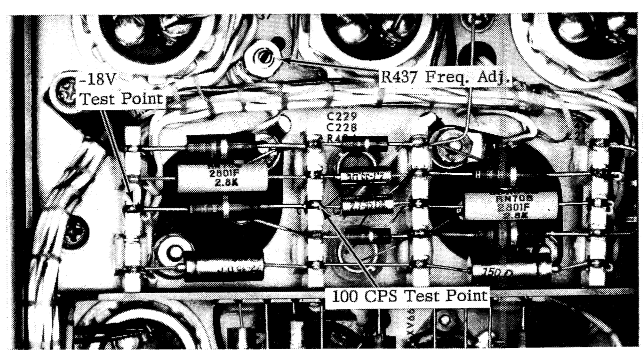



Fig. 5-3. Fan drive circuit showing -18v test point, 100 cps test point and Freq. Adj. locations.

### 5-20. Air Filter

**5-21.** Care must be taken to assure free ventilation of the Type 945 Oscilloscope inasmuch as some of the components are operated at dissipation levels such that excessive interior temperatures will result without adequate air circulation. To assure free passage of air the instrument must be placed so that the air intake is not blocked, and the filter must be kept clean. Moreover, the side panels and bottom cover must be in place for proper air circulation; do not remove the covers except during maintenance.

**5-22.** A washable "E-Z KLEEN" filter is used at the air intake port of the instrument. Under normal operating conditions the filter should be inspected and cleaned if necessary every three to four months. More frequent inspection is required when the operating conditions are more severe.

**5-23.** The following cleaning instructions are issued by the filter manufacturer:

(1) If grease or dirt load is light, remove filter from installation and rap gently on hard surface to remove loose dirt. Flush remaining dirt or grease with a stream of hot water or steam; flush from clean side.

(2) If load is too heavy for treatment described in (1), prepare mild soap or detergent solution in pan or sink deep enough to cover filter when laid flat. Agitate filter up and down in solution until grease or dirt is loosened and floated off.

(3) Rinse filter and let dry.

(4) Dip or spray filter with fresh Filter Coat or Handi-Coater. These products are available from the local representative of the Research Products Corporation, and from most air-conditioner suppliers.

## 5-24. Soldering and Ceramic Strips

**5-25.** Many of the components in your Tektronix instrument are mounted on ceramic terminal strips. The notches in these strips are lined with a silver alloy. Repeated use of excessive heat, or use of ordinary tin-lead solder will break down the silver-to-ceramic bond. Occasional use of tin-lead solder will not break the bond if excessive heat is not applied.

**5-26.** If you are responsible for the maintenance of a large number of Tektronix instruments, or if you contemplate frequent parts changes, we recommend that you keep on hand a stock of solder containing about 3% silver or Mil. Part #01-0003-00. This type of solder is used frequently in printed circuitry and should be readily available from radio-supply houses. If you prefer, you can order the solder directly from Tektronix in one-pound rolls. Order by Tektronix Military Part Number 01-0003-00.

**5-27.** Because of the shape of the terminals on the ceramic strips it is advisable to use a wedge-shaped tip on your soldering iron when you are installing or removing parts from the strips. Figure 5-4 will show you the correct shape for the tip of the soldering iron. Be sure and file smooth all surfaces of the iron which will be tinned. This prevents solder from building up on rough spots where it will quickly oxidize.

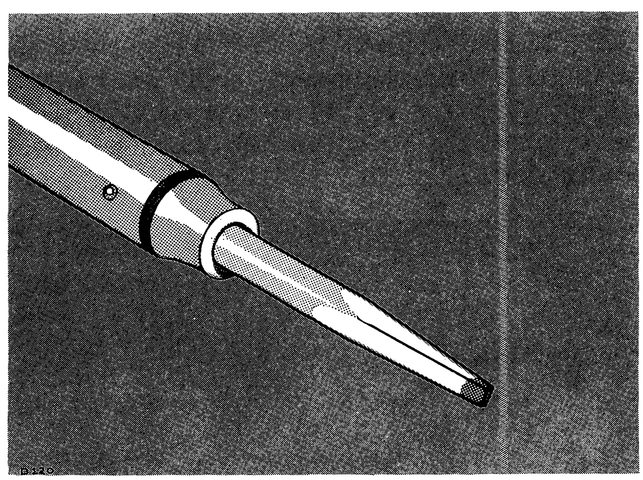


Fig. 5-4. Soldering iron tip properly shaped and tinned.

**5-28.** When removing or replacing components mounted on the ceramic strips you will find that satisfactory results are obtained if you proceed in the manner outlined below.

1. Use a soldering iron of about 75-watt rating.

2. Prepare the tip of the iron as shown in Fig. 5-4.

3. Tin only the first 1/16 to 1/8 inch of the tip. For soldering to ceramic terminal strips, tin the iron with solder containing about 3% silver.

4. Apply one corner of the tip to the notch where you wish to solder (see Fig. 5-5).

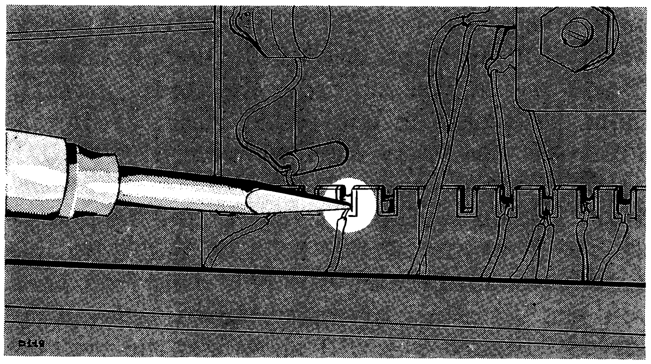


Fig. 5-5. Correct method of applying heat in soldering to a ceramic strip.

5. Apply only enough heat to make the solder flow freely.

6. Do not attempt to fill the notch on the strip with solder; instead, apply only enough solder to cover the wires adequately, and to form a slight fillet on the wire as shown in Fig. 5-6.

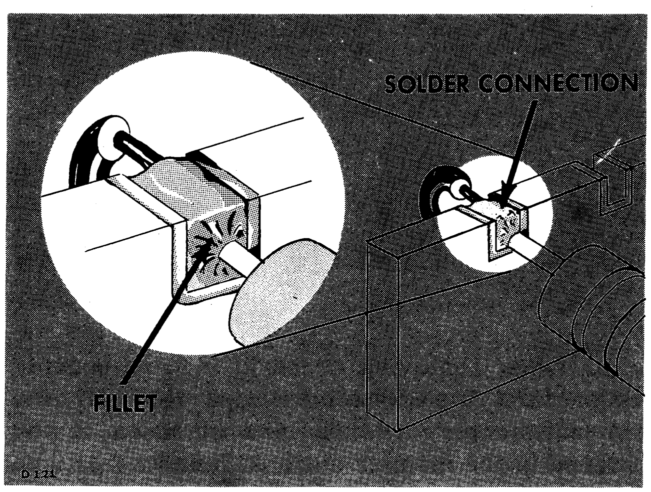



Fig. 5-6. A slight fillet of solder is formed around the wire when heat is applied correctly.

**5-29.** In soldering to metal terminals (for example, pins on a tube socket) a slightly different technique should be employed. Prepare the iron as outlined above, but tin with ordinary tin-lead solder. Apply the iron to the part

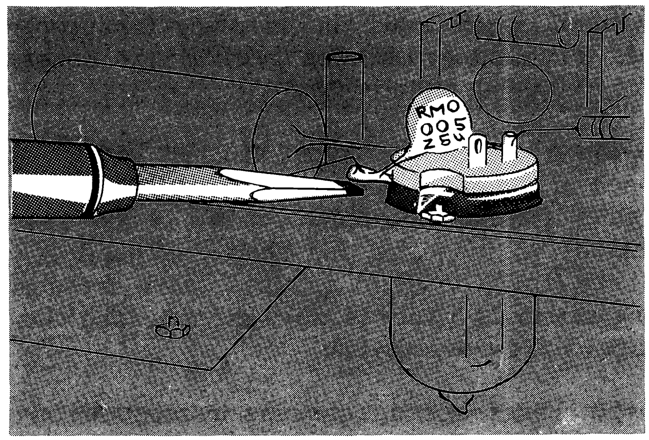


Fig. 5-7. Soldering to a terminal. Note the slight fillet of solder--exaggerated for clarity--formed around the wire.

to be soldered as shown in Fig. 5-7. Use only enough heat to allow the solder to flow freely along the wire so that a slight fillet will be formed as shown in Fig. 5-6.

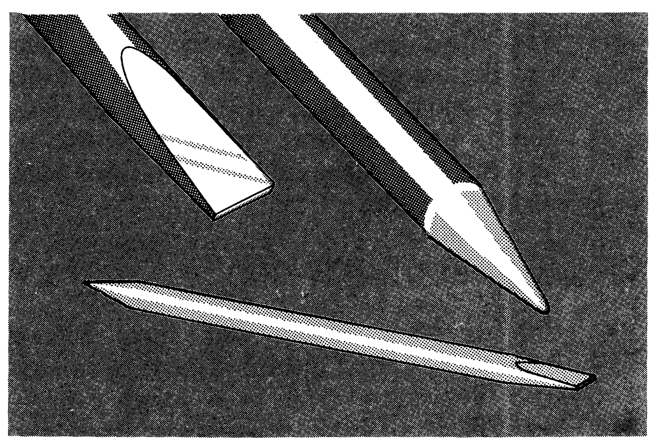


Fig. 5-8. A soldering aid constructed from a 1/4 inch wooden dowel.

## 5-30. General Soldering Considerations

**5-31.** When replacing wires in terminal slots clip the ends neatly as close to the solder joint as possible. In clipping the ends of wires take care the end removed does not remain in the instrument.

**5-32.** Occasionally you will wish to hold a bare wire in place as it is being soldered. A handy device for this purpose is a short length of wooden dowel, with one end shaped as shown in Fig. 5-8. In soldering to terminal pins mounted in plastic rods it is necessary to use some form of "heat sink" to avoid melting the plastic. A pair of long-nosed pliers (see Fig. 5-9) makes a convenient tool for this purpose.

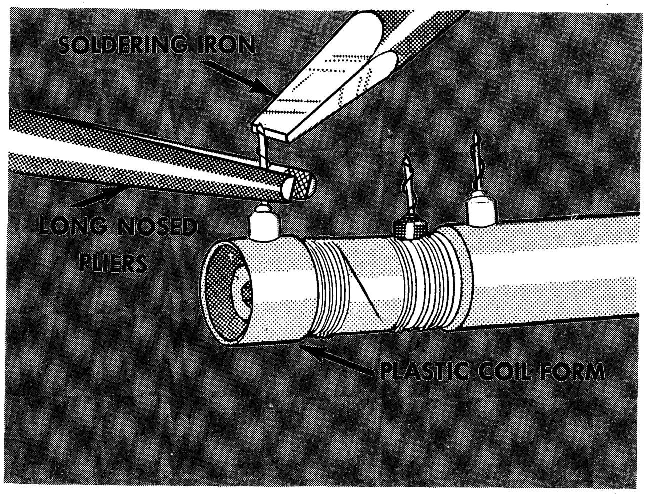



Fig. 5-9. Soldering to a terminal mounted in plastic. Note the use of the long-nosed pliers between the iron and the coil form to absorb the heat.

### 5-33. Mounting Ceramic Strips

**5-34.** To replace a ceramic strip, first remove the original fittings from the chassis. Assemble the mounting posts on the ceramic strip. Insert the nylon collars into the mounting holes in the chassis. Carefully force the mounting posts into the nylon collars. Snip off any portion of the mounting posts protruding below the nylon collars on the reverse side of the chassis.

**NOTE**

> Considerable force may be necessary to push the mounting rods into the nylon collars. Be sure that you apply this force to that area of the ceramic strip above the mounting rods.

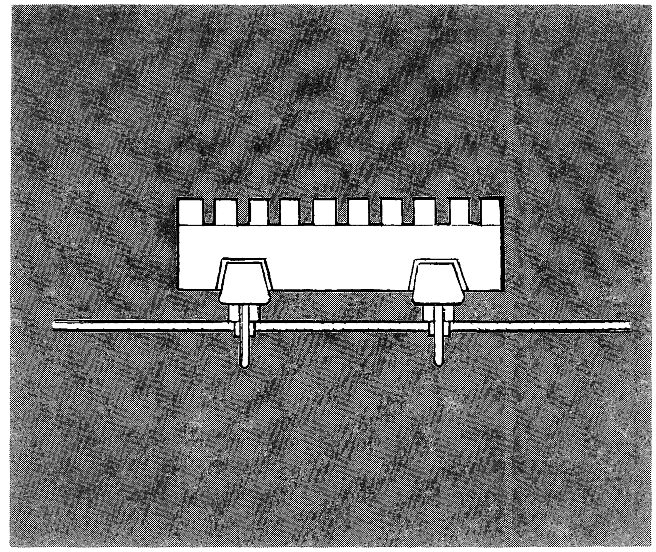


Fig. 5-10. The ceramic strip mounting.

### 5-35. TROUBLESHOOTING PROCEDURE

**5-36.** This section of the manual contains information for troubleshooting your oscilloscope. Before attempting to troubleshoot the instrument, however, make sure that any apparent trouble is actually due to a malfunction within the instrument and not to improper control settings or to a faulty plug-in unit. Instructions for the operation of the oscilloscope and general information concerning plug-in operation, are contained in the Operating Instructions section of this manual. Operating instructions for a specific plug-in unit will be found in the manual for that unit.

**5-37.** To determine whether or not the vertical deflection system of the oscilloscope is at fault, the plug-in unit may be replaced with another known to be in good operating condition. If the trouble is still apparent, it is almost a certainty that the oscilloscope is at fault. However, should the trouble appear to have been corrected by replacing the plug-in unit, the trouble most likely lies within the original plug-in unit and not the oscilloscope.

**5-38.** Tube failure is the most prevalent cause of circuit failure. For this reason, the first step in troubleshooting any circuit in the instrument is to check for defective tubes, preferably

**TABLE 5-1**
**GENERAL COLOR CODE**

| | |
|---|---|
| RED BACKGROUND - (B+) | OTHER STRIPES TO IDENTIFY |
| 2-0 +100V Regulated<br>2-N +225V Regulated<br>2-4 +350V Regulated<br>2-5 +500V Regulated<br>2-98 +100V Unregulated A or Switched +100V<br>2-90 +100V Unregulated B<br>2-9 +225V Unregulated<br>2-8 +75V Regulated<br>2-0+ Stripe Decoupled +100V<br>2-Stripe Decoupled +225V<br>2-4+ Stripe Decoupled +350V<br>2-9+ Stripe The number 9 in this place indicates unregulated. The stripe usually refers to power supply color code. | BLUE BACKGROUND - PLATES EXCEPT B+<br>Stripe to identify<br><br>GREEN BACKGROUND - CONTROL GRIDS<br>Stripe to identify<br><br>ORANGE BACKGROUND - SCREEN GRIDS<br>Stripe to identify |
| PURPLE BACKGROUND - (B-)<br>7-4 -1350V<br>7-5 -150V Regulated<br>7-53 Decoupled -150V | YELLOW BACKGROUND - CATHODES<br>Stripe to identify<br><br>BLACK BACKGROUND - GROUNDS<br>Stripe to identify |
| BROWN BACKGROUND - HEATERS<br>1-99 Elevated to -1350V Return<br>1-4 Elevated to +350V<br>1-44 Elevated to +350V Return<br>1-2 Elevated to +225V<br>1-22 Elevated to +225V Return<br>1-0 Elevated to +100V<br>1-00 Elevated to +100V Return<br>1-25 Regulated Heaters - Elevated to +100V Return | GREY BACKGROUND - AC POWER LINES<br>Stripe to identify<br><br>WHITE BACKGROUND - MISCELLANEOUS<br>Stripe to identify |

by direct substitution. Do not depend on tube testers to adequately indicate the suitability of a tube for certain positions within the instrument. The criterion for usability of a tube is whether or not it works satisfactorily in the instrument. Be sure to return each good tube to its original socket; if this procedure is followed, less recalibration of the instrument will be required upon completion of the servicing.

**5-39.** When replacing any tube in the instrument, check first to see that components through which the tube draws current have not been damaged. Shorted tubes will sometimes overload and damage plate-load and cathode resistors. These damaged components can generally be located by a visual inspection of the wiring. If no damaged components are apparent, and if tube replacement does not

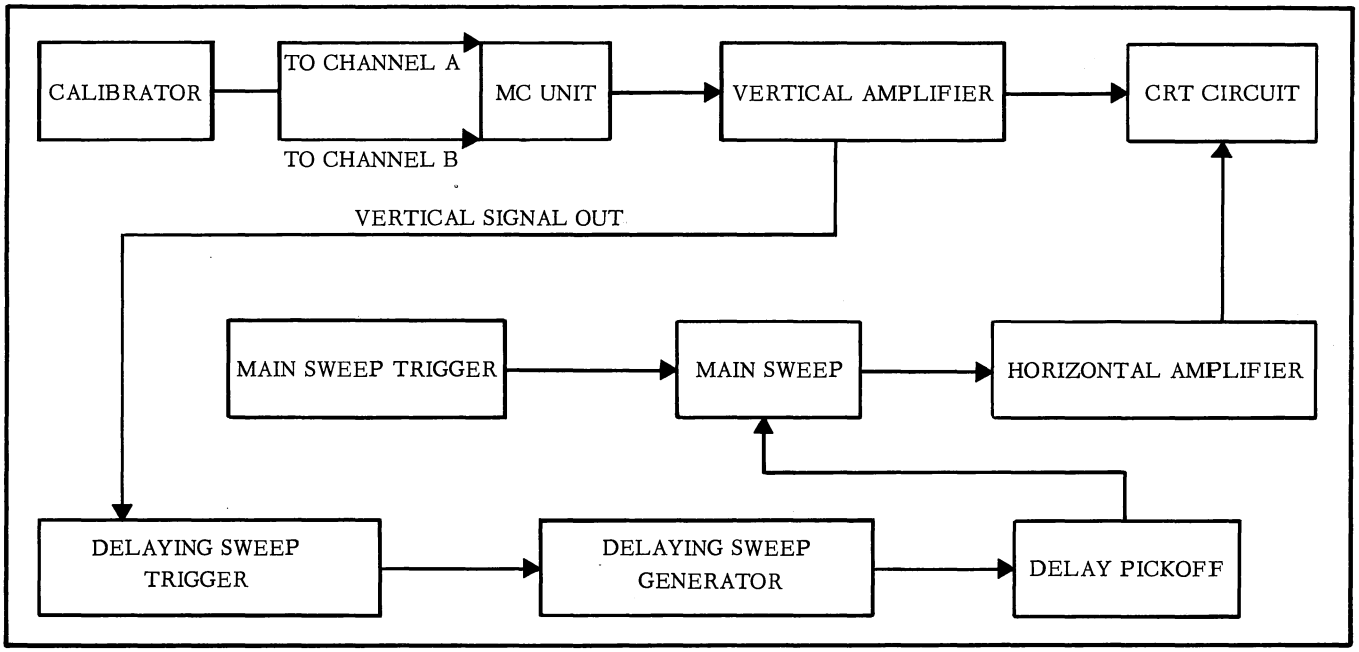



Fig. 5-11. Circuit configuration of the Type 945/MC combination when in the self-checking mode.

restore operation, it will be necessary to make measurements or other checks within the circuit to locate the trouble.

**5-40.** The component number of each resistor, inductor, capacitor, vacuum tube, control, and switch is shown on the circuit diagrams.

### 5-41. The Self-Checking Mode

**5-42.** The crt display can often be used to isolate troubles to one particular circuit. If there is no vertical deflection, for example, when the intensity and horizontal deflection appear normal, it is apparent that a fault exists in the plug-in or Vertical Amplifier, and these circuits should be investigated first.

**5-43.** Fig. 5-12 shows the front-panel controls settings necessary to place the Type 945 and Type MC Unit in the self-checking mode. Variations of these control settings to isolate specific circuits are given in the following instructions.

**5-44.** Once you have isolated the trouble to a specific circuit by means of the front-panel checks, detailed analysis of each major circuit is covered by the information in the Circuit Troubleshooting section.

## 5-45. CIRCUIT TROUBLESHOOTING

**5-46.** Although the Type 945 is a complex instrument it consists of ten major circuits, in addition to the Calibrator circuit. These are the:

1. Low-Voltage Power Supply
2. CRT Circuit and High Voltage Power Supply
3. Plug-In Preamplifier (MC or other suitable type)
4. Vertical Amplifier and Delay Line
5. Main-Sweep Trigger Circuit
6. Main-Sweep Generator
7. Delaying-Sweep Trigger
8. Delaying Sweep Generator
9. Delay Pickoff
10. Horizontal/Sweep Amplifier

**5-47.** The first circuit to check, for practically any type of trouble, is the Low-Voltage Power Supply. Because of the circuit configuration employed in the Type 945, an improper power supply voltage may affect one circuit more than another. For example, if the gain of

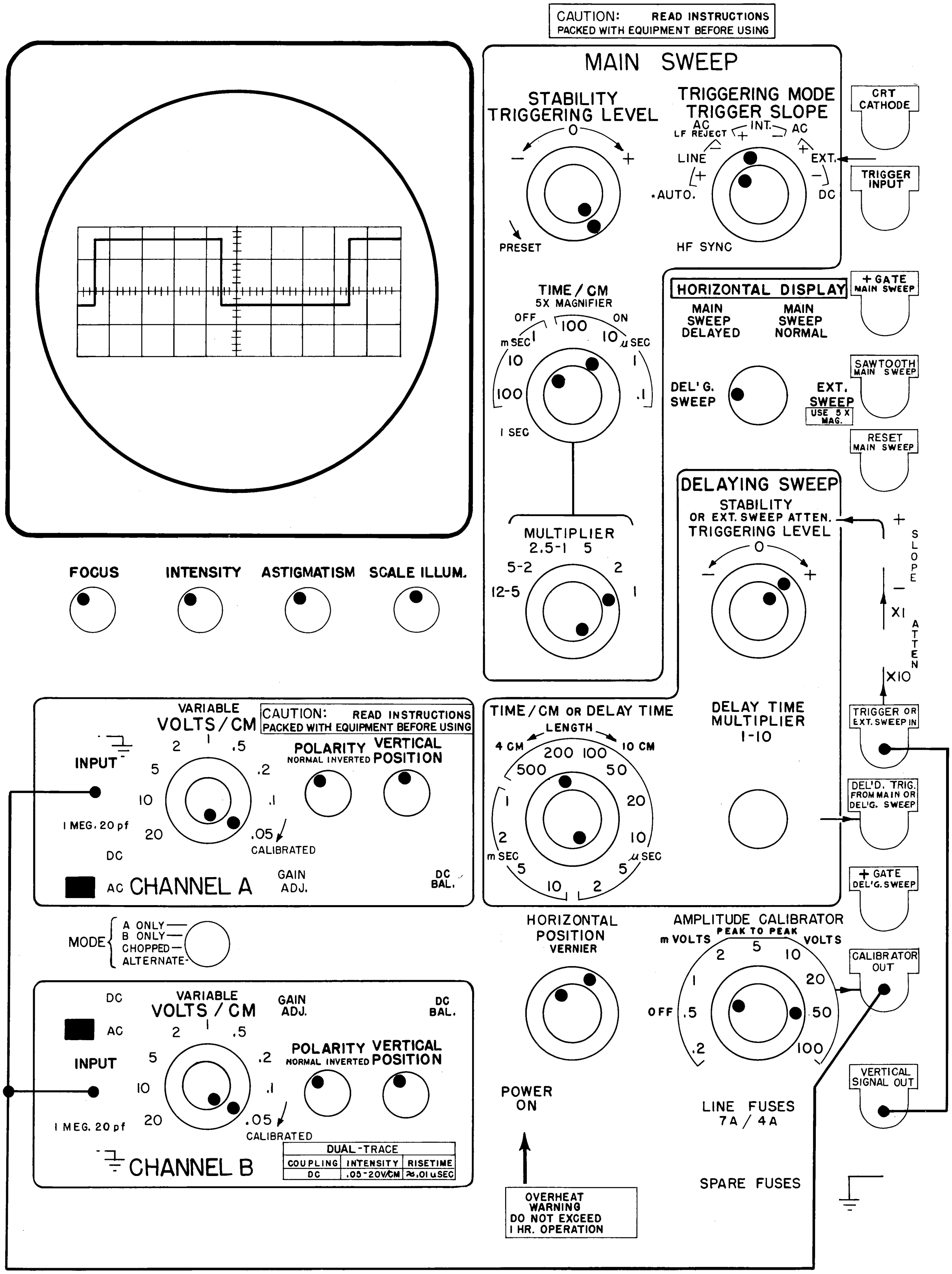



Fig. 5-12. Self-checking mode connections.

the Vertical Amplifier appears to decrease slightly while the operation of the remaining circuits is normal, the cause could be an improper supply voltage rather than a malfunction in the Vertical Amplifier itself. In cases of this type, valuable time can be saved by checking the power supply first.

**5-48. TROUBLESHOOTING THE LOW-VOLTAGE POWER SUPPLY**

**5-49.** Proper operation of every circuit in the Type 945 including the plug-in preamplifier depends on proper operation of the Low-Voltage Power Supply. The regulated dc voltages must remain within their specified tolerances for the instrument and plug-in unit to retain their calibration.

**CAUTION**

Exercise care in checking the power supply. Because of their high current capabilities and low impedance, the Low-Voltage supplies can produce more harmful shocks than the high-voltage supply in the CRT circuit.

**5-50.** If both the overheat warning light and pilot lamp come on when the power is turned on, the primary circuit of the power transformer is operating normally.

**5-51. Dead Power Circuit**

**5-52.** If the pilot lamp does not come on when the power is turned on, check the source of power and the power cord connections. Check the fuses on the front panel of the instrument. If the fuses are blown replace them with one of the proper value and turn the instrument on again. If the new fuses blow immediately, check the power transformer for shorted primary or secondary windings. Also check for a shorted rectifier. If the new fuses do not blow until the time-delay relay has activated (a "click" can be heard), check for a shorted condition in the regulator circuits and the loading on the supply.

**5-53.** If the fuses are good, check for an open primary winding in the power transformer. If your instrument is wired for 230-volt operation, check for an open Thermal Cutout Switch; the resistance of this switch is about .1 Ω. The Thermal Cutout Switch is located on the vertical chassis (bulkhead) toward the left rear of the instrument.

**5-54.** If any of the supplies fail to regulate the first thing to check is the line voltage. The supplies are designed to regulate between 103.5 and 126.5 volts with the design center at 115 volts, or between 207 and 253 volts with the design center at 230 volts, rms, 50-400 cycle single phase ac.

**5-55.** If the line voltage is the correct value, the next step is to turn the power off, remove the plug-in unit and measure the resistance between each regulated bus and ground. The following resistance values are approximate minimum readings; the actual resistance between each bus and ground will generally be higher than the values indicated here. These readings are taken with the HORIZONTAL DISPLAY switch set at MAIN SWEEP NORMAL. The meter common lead is grounded to the oscilloscope chassis.

| REGULATED BUS | APPROX. MINIMUM RESIST. TO GROUND |
|---|---|
| -150 v | 2.8 K |
| +100 v | 5 K |
| +225 v | 6.3 K |
| +350 v | 22 K* |
| +500 v | 20 K |

*You have to reverse meter leads because a diode will give you constant erroneous readings if you don't.

**5-56.** If the resistance values between the regulated buses and ground check out, check the tubes in the power supply (if this has not already been done). Then make sure that the line voltage is set near the design center for your instrument (115 or 230 v) and check the rms voltage across the secondary winding for each supply with a volt-ohmmeter of known accuracy. The nominal value of each secondary

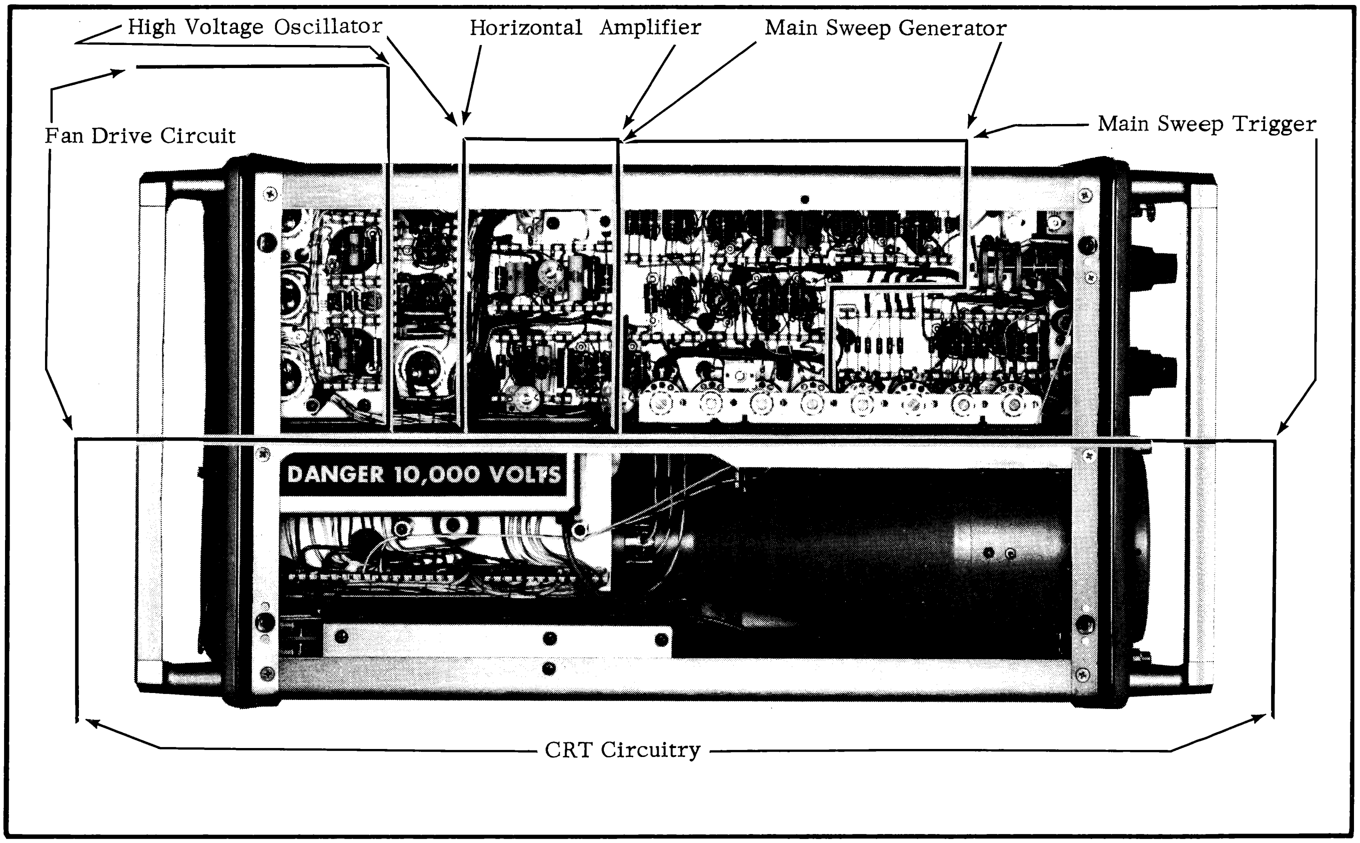



Fig. 5-13. Physical locations of the circuits found on the top of the Type 945 Oscilloscope.

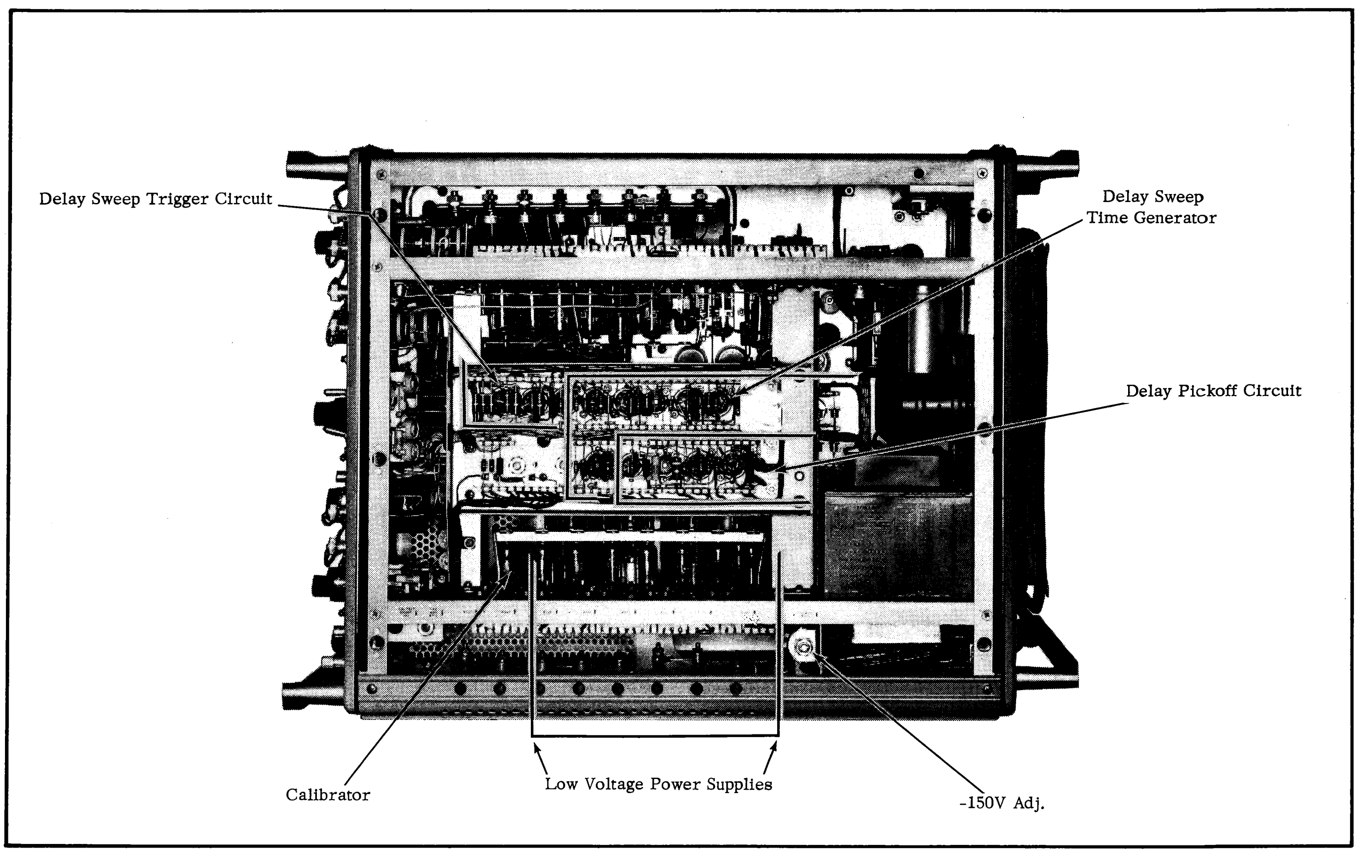



Fig. 5-14. Physical location of circuits found on the right side of the Type 945 Oscilloscope.

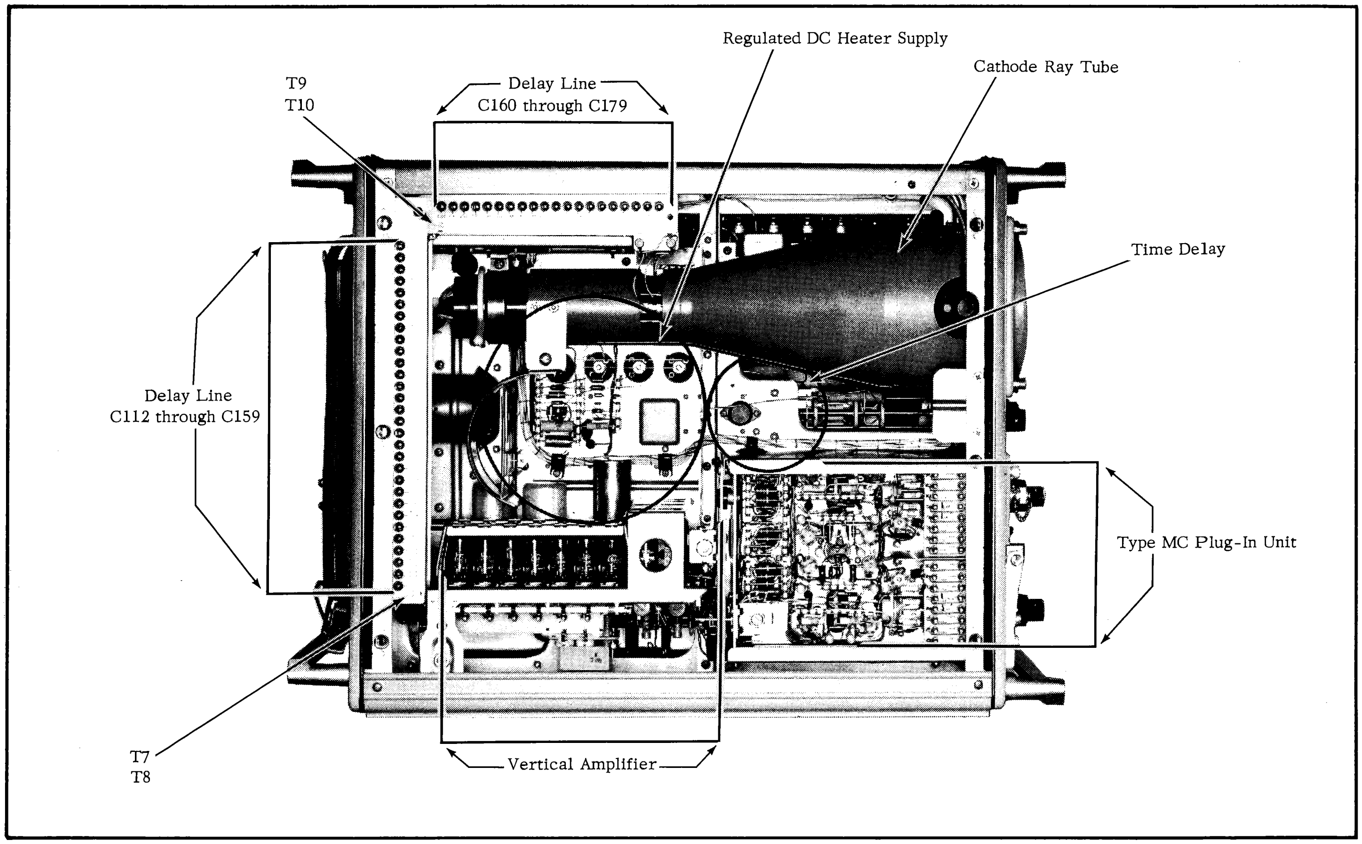



Fig. 5-15. Circuits located on the left side of the Type 945 Oscilloscope.

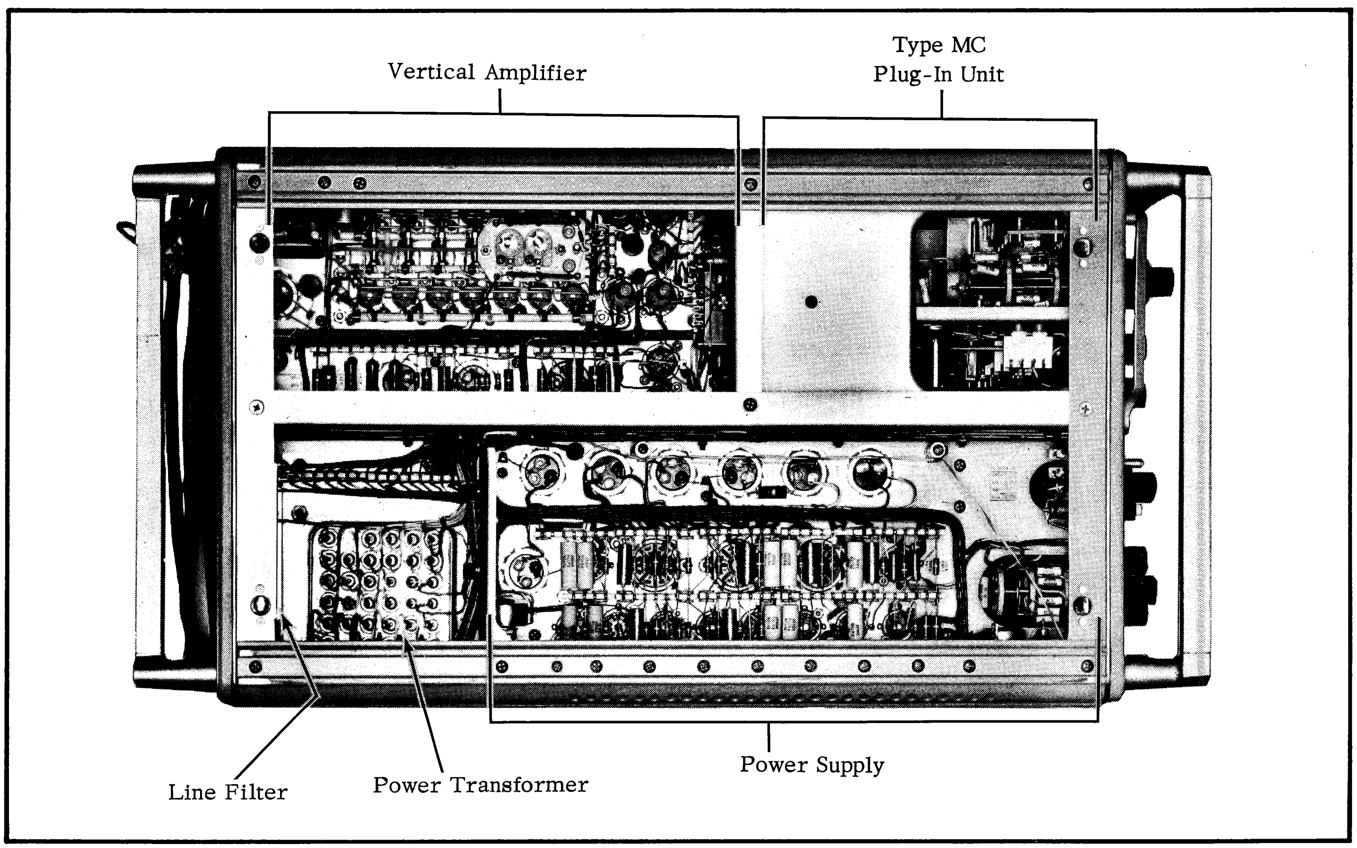



Fig. 5-16. Circuits located on the bottom of Type 945 Oscilloscope.

voltage, when the line is set to the design center, is indicated on the circuit diagram. Allow for meter calibration accuracy and wave shape. If the secondary voltages are all correct, check the operation of the bridge rectifiers. This can be done by measuring the rectified voltage at the input to each regulator. These values are also indicated on the circuit diagram. Then check for off-value resistors, especially in the dividers, and for open or leaky capacitors.

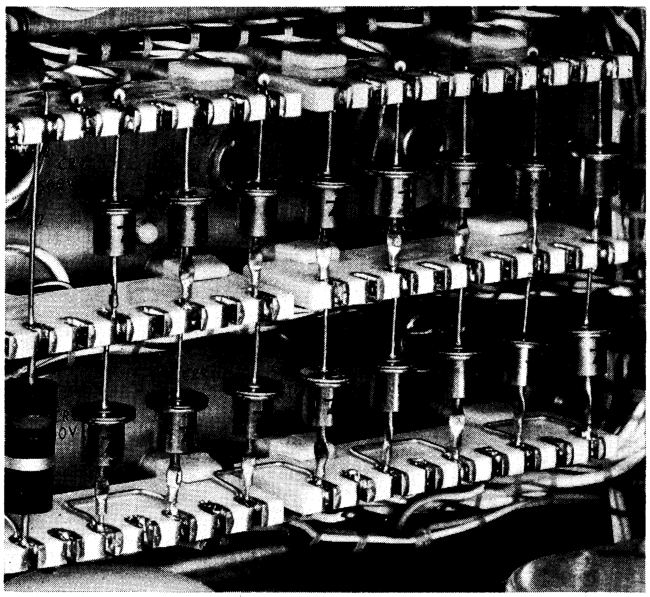


Fig. 5-17. Location of silicon rectifiers on the right side of the central bulkhead behind the Delaying Sweep hinged chassis.

**5-57.** The material that follows may be used as a quick index for troubleshooting the regulator circuits.

**5-58.** If the output voltage is high with excessive ripple check:

a. For high line voltage.

b. For open voltage-regulator tube V63.

c. The amplifier tubes V62, V64, V61, V58, V59, V57 and V55.

d. For insufficient loading.

**5-59.** If the output voltage is high with normal ripple, check:

a. For proper resistance values in the dividers (R397, R391, and R386, R375 and R376, R366 and R363, R352 and R353, and R338 and R339).

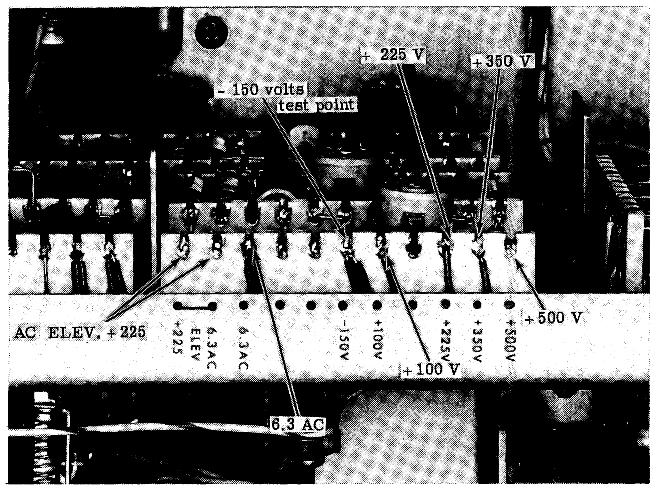



Fig. 5-18. Location of Low-Voltage Power Supply test points.

**5-60.** If the output is low with excessive ripple, check:

a. For low line voltage.

b. For shorted voltage-regulator tube V63.

c. The series tubes V60B, V60A, V54B, V56 and V54A.

d. For excessive loading.

e. Open or leaky filter capacitors.

f. Defective rectifiers.

**5-61.** If the output is low with normal ripple, check:

a. The resistance values in the dividers.

b. The capacitors across the dividers.

**IMPORTANT:** If any components in the -150-volt supply are changed, or if the setting of the -150 ADJ. control is changed, it will be necessary to recalibrate the instrument. NOTE-- Proper operation of all DC supplies, except the 12.6v Vertical Amplifier Heater Supply, is contingent upon proper operation of the -150v supply.

## 5-62. TROUBLESHOOTING THE CRT CIRCUIT AND HIGH-VOLTAGE POWER SUPPLY

**5-63.** The intensity, focus, geometry and calibration of the crt display depend on proper operation of the three high-voltage supplies in the CRT Circuit.

### 5-64. No Intensity

**5-65.** If the low-voltage power supply is operating normally, but no spot or trace is visible on the crt, the trouble could be a defective crt, a defect in the crt cathode circuit including the -1350-volt supply, an unbalanced dc condition in either or both of the deflection amplifiers, unblanking, high-voltage oscillator or others. In the one case the dc unbalance is producing improper positioning voltages and the beam is being deflected off the screen.

**5-66.** To determine which circuit is at fault, turn the INTENSITY control full right (cw). If a flare is observed on the crt screen (it may be necessary to darken the room), one of the deflection amplifiers is probably at fault; the procedure for troubleshooting these circuits follows a bit later in this section. If no flare is observed with the INTENSITY control turned full right, the trouble will either be due to a defective crt, to an inoperative high-voltage supply unit, unblanking, or high-voltage oscillator. The cathode supply can be checked by measuring the voltage at the HV Adj. Test Point on the ceramic strip as shown in Figure 5-19. The voltage at this point should be -1350 volts, when checked with an accurate meter, although it will vary with the setting of the HV Adj. control R412. If a voltage reading in the vicinity of -1350 volts is obtained, turn the instrument off and measure the resistance of R422, the 27K resistor connected to the test point. If this resistor is not open, a defective crt or unblanking problem is indicated.

**5-67.** If the voltage at the HV Adj. Test Point is zero or abnormally low, replace the Oscillator tube V65 and the DC Comparator and Shunt Regulator tube V66. If this does not restore operation the Oscillator circuit should be checked.

**5-68.** An accurate check on the Oscillator may be made by measuring the bias at the grid of

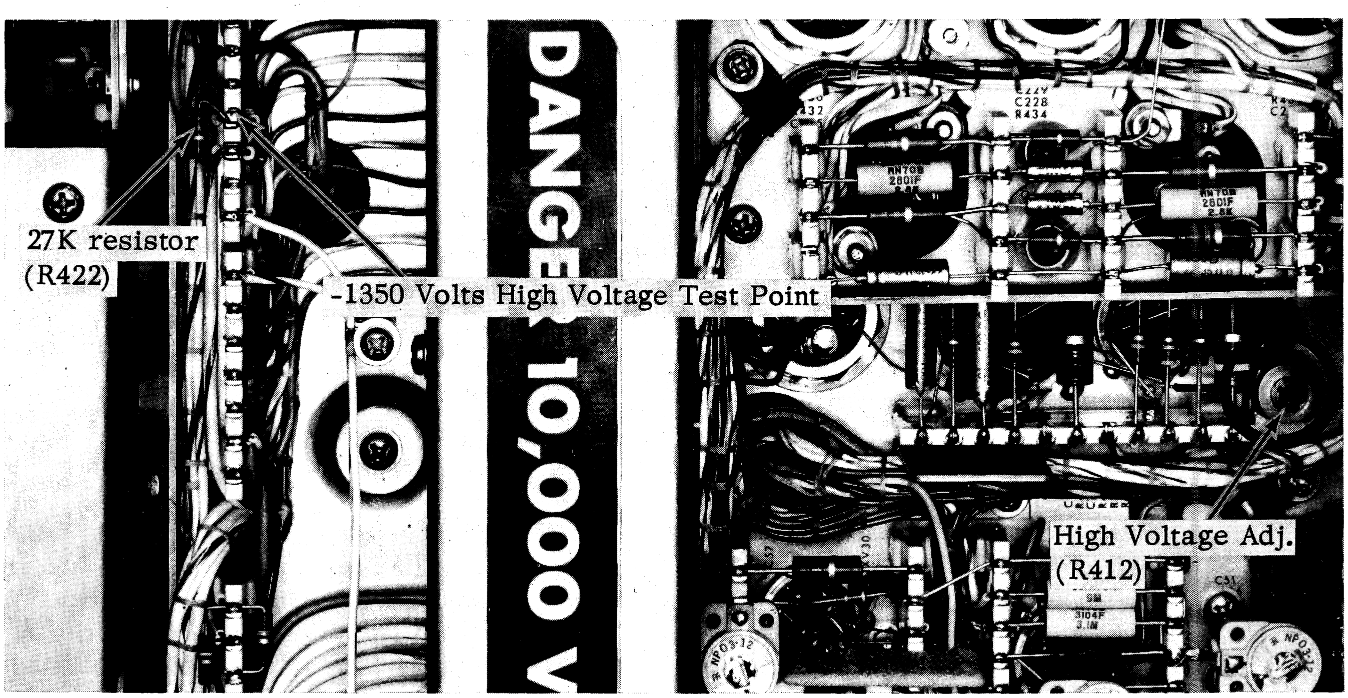



Fig. 5-19. The High-Voltage check point is found in the left rear section of the Type 945 top deck.

V65. This can be measured at the junction of the 100K resistor R400 and the .01 $\mu$F capacitor, C203. The voltage at this point should measure about -65 volts.

**5-69.** If the Oscillator circuit is operating properly, but the voltage at the HV Adj. Test Point does not measure in the vicinity of -1350 volts, the High-Voltage Power Supply package is most likely defective. Substitute a completely new unit, if further checking proves the original unit defective.

### 5-70. Abnormal Intensity

**5-71.** If a trace is visible on the crt, the relative intensity of the trace may be used to identify trouble in either the negative bias supply or the positive anode supply.

**5-72.** If the trace is excessively brilliant, and if the brilliance does not change as the INTENSITY control is adjusted, check the negative bias supply including the lead to pin 3 on the crt socket. Check for a defective INTENSITY control. If trouble is not found in any of the associated components, a defective crt is indicated.

**5-73.** If the intensity of the trace is extremely low, check for an inoperative positive supply. Also check the anode connection to the crt.

> **CAUTION:** Anode voltage will be approximately 8,650 VOLTS with reference to chassis with equipment turned on.

**5-74.** If the accelerating potentials appear to be too high, as evidenced by decreased deflection sensitivity, check the DC Comparator and Shunt Regulator tube circuitry.

**5-75.** If a badly distorted trace or spot is visible on the crt, check the Geom. Adj. control R420 and its connection to the neck pin on the crt, and the ASTIGMATISM control R421 and its connection to the crt base socket. If the FOCUS control has no effect on the trace, check this control (R415) and its connection to the crt base socket.

**IMPORTANT:** If any components in the Oscillator, DC Comparator or in the -1350-volt Cathode Supply circuit are changed, or if the setting of the HV Adj. control is changed, it will be necessary to recalibrate the instrument.

## 5-76. TROUBLESHOOTING THE VERTICAL AMPLIFIER

### 5-77. No Spot or Trace Visible on CRT

**5-78.** If all power supply voltages are normal, and the crt is known to be good, failure to obtain a spot or trace on the screen will be due to improper positioning voltages. This condition is caused by a dc unbalance in either or both of the deflection amplifier circuits.

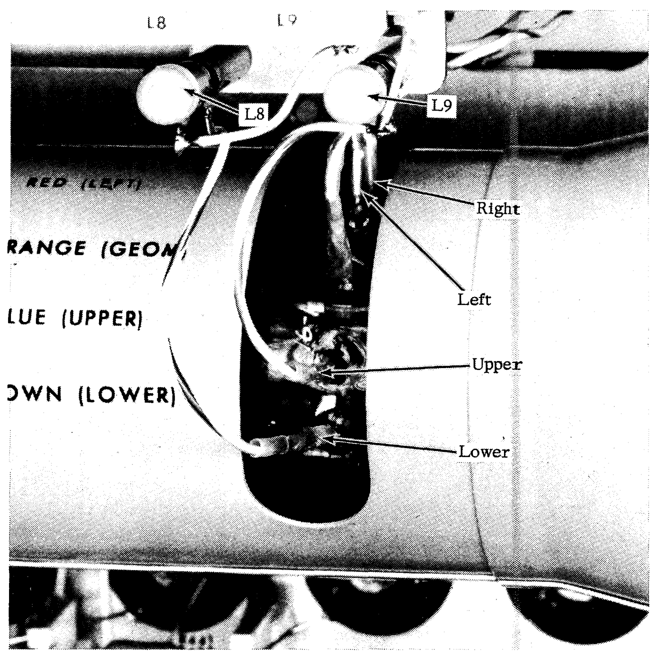



Fig. 5-20. Pin locations for horizontal and vertical deflection plates at the crt neck pins.

**5-79.** To determine which circuit is at fault, adjust the Time-Base controls for a free-running sweep at 1 millisec/cm (STABILITY control fully clockwise) and set the INTENSITY control to midscale. Using a "resistive shorting strap" (Fig. 5-21), short the vertical deflection plates together at the terminals of coils L8 and L9. These are the terminals connected to

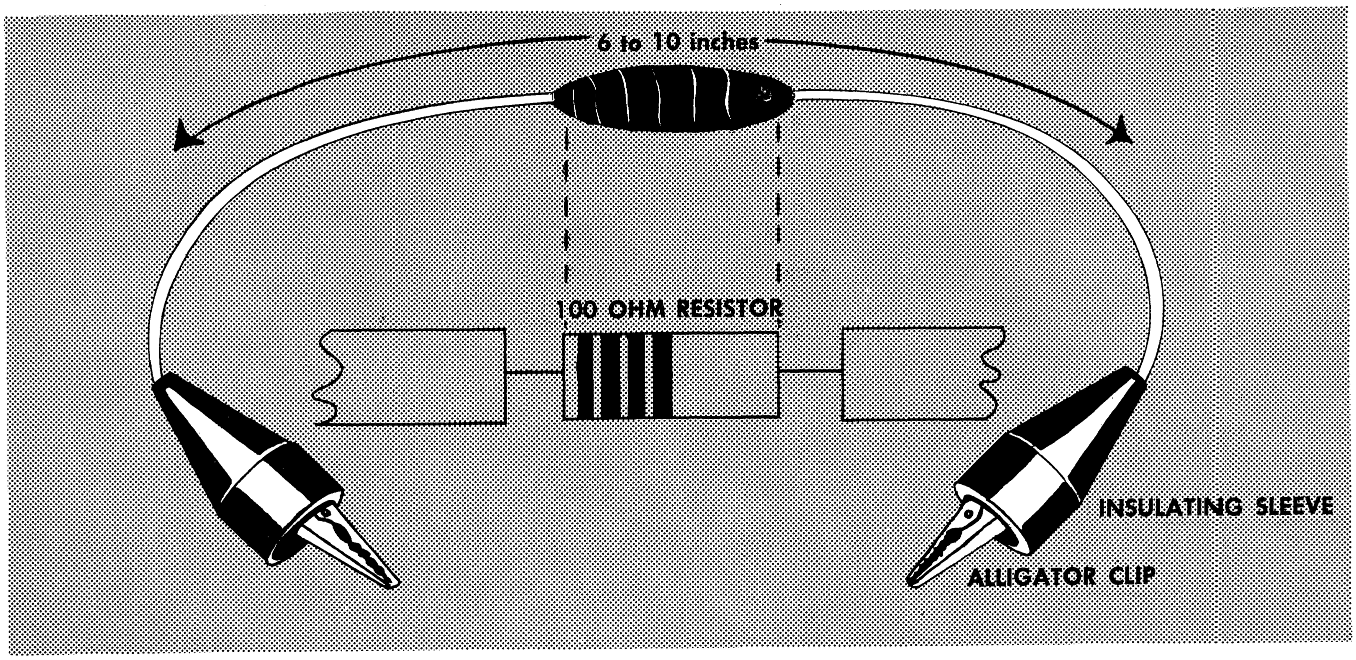



Fig. 5-21. Shorting strap useful in locating an unbalanced stage in a vertical or horizontal amplifier. Insulating tape covers the 100-ohm resistor.

the crt pins marked BLUE (UPPER) and BROWN (LOWER). Be careful not to short these terminals to the chassis or to the metal crt shield. If the dc unbalance is being produced in the vertical deflection circuit the trace will appear at or near the center of the crt when the vertical deflection plates are shorted together.

**5-80.** The most probable cause of this trouble is tube failure. Remember that tube replacement or interchanging will require recalibration of the vertical. To check for defective tubes in the vertical amplifier, start at the distributed amplifier and work back towards the input.

**5-81.** Short together the two grid lines, T4 and T5, of the distributed amplifier. This may be done by connecting pin 1 of tube V35 to pin 1 of V37 with the resistive shorting strap. If the trace does not now appear on the crt, omit Paragraphs 5-82 through 5-84. Remove the shorting strap.

**5-82.** If the trace appeared with the DA grids shorted together, the trouble is in an earlier stage of the vertical amplifier. Check the input driver tubes by shorting together the input grids with the resistive shorting strap (pin 2 of V34 and pin 2 of V36). Now if the trace does not appear, the driver stage is producing the trouble. Check the Calibration section of this manual (Para. 7-171) for selection and balance in replacing V34 and V36. Remove the shorting strap.

**5-83.** Either the input amplifier stage or the plug-in preamplifier is producing the difficulty if the trace appeared with the input driver grids shorted together. Now, with the resistive shorting strap, connect together pins 1 and 3 of the plug-in interconnecting socket. If the trace appears, the trouble is in the preamplifier. Refer to the Maintenance section of the Instruction Manual for the Type MC Unit.

**5-84.** If the trace did not appear with the shorting strap between pins 1 and 3 of the plug-in socket, the input amplifier stage, V32 and V33 is defective. See the Calibration section of this Manual (Paragraph 7-173) for selection and balance of these tubes when replacing. The high-frequency adjustments must be checked if tubes are replaced or interchanged.

**5-85.** If shorting the grid lines of the DA in Para. 5-81 did not make a trace appear

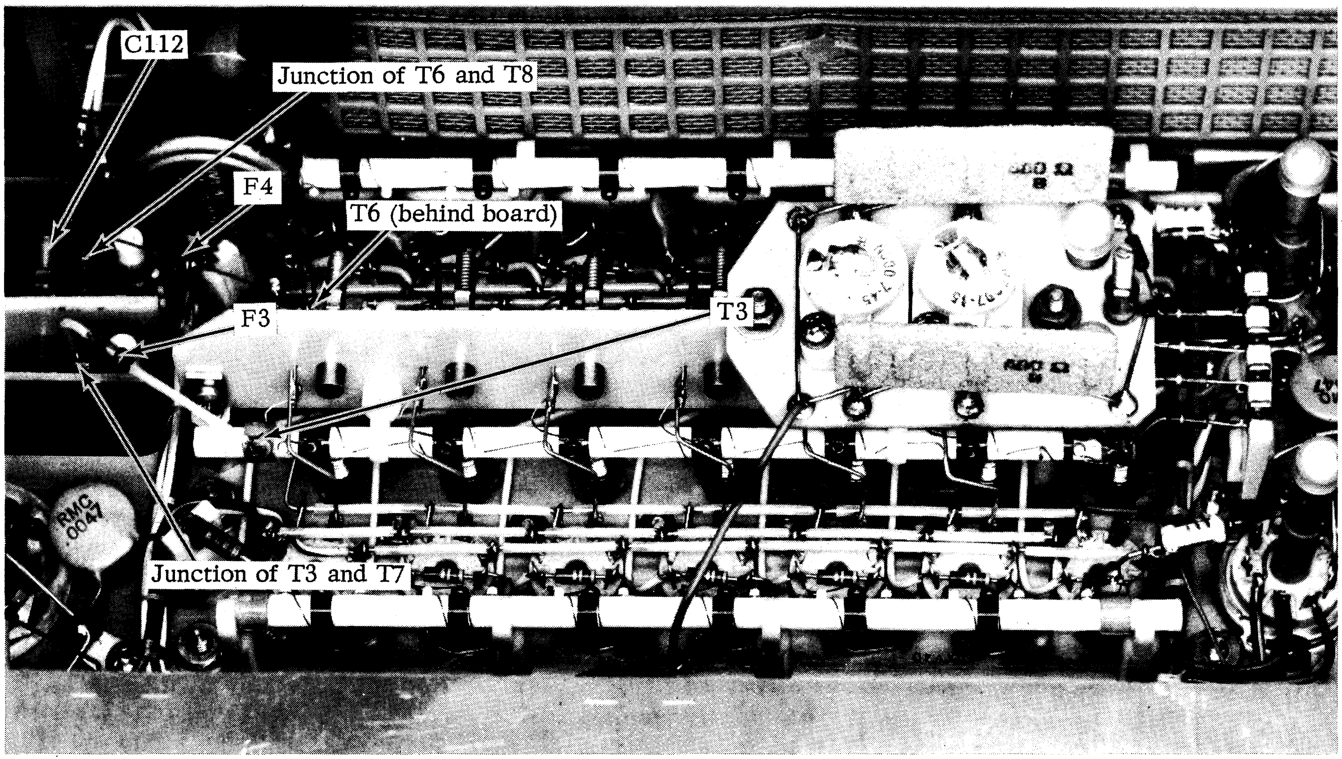



Fig. 5-22. Location of distributed amplifier output and the input to the delay line.

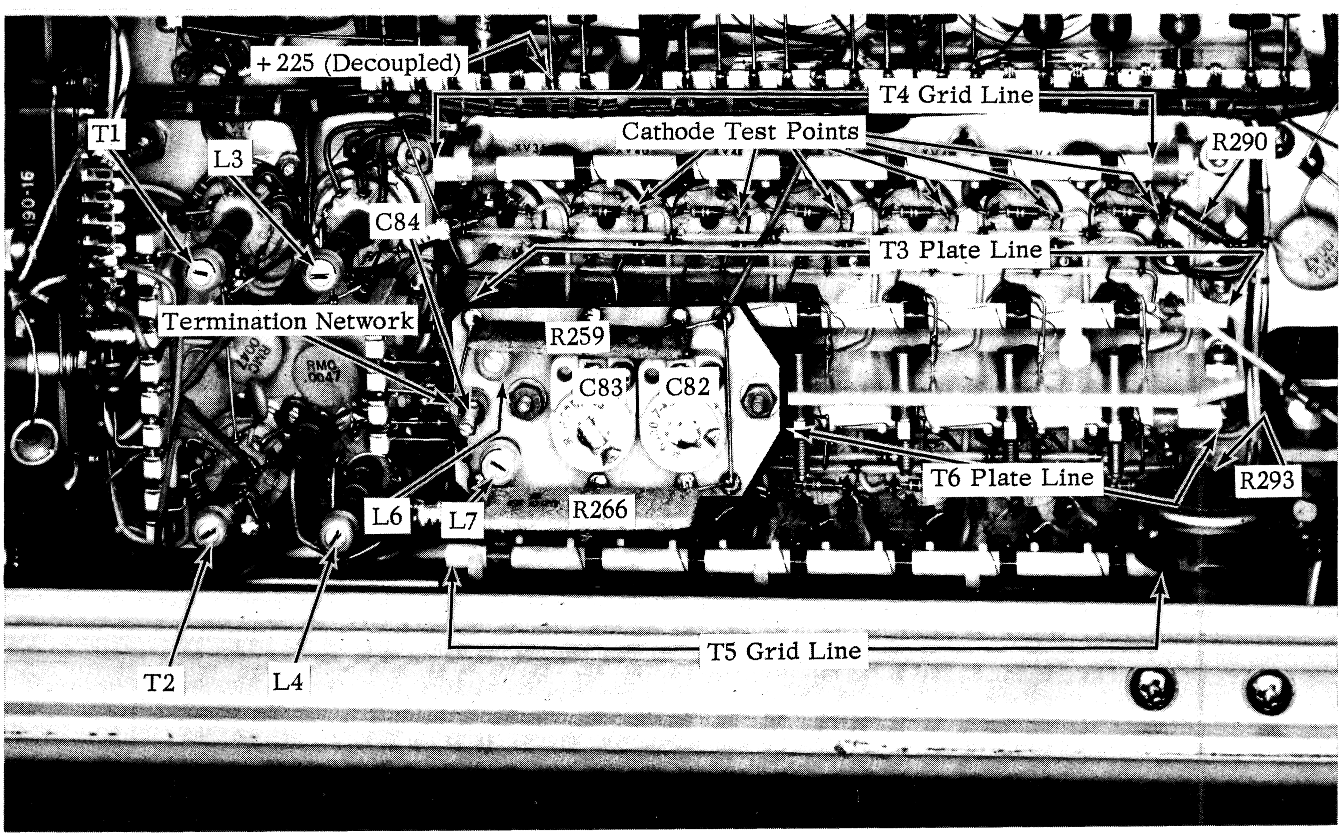



Fig. 5-23. Grid and plate line termination in the vertical amplifier.

on the crt, the difficulty is either in the tubes of the distributed amplifier or in other electronic components of the vertical amplifier. Since each DA tube produces only about 1/10th the output of the section, failure of only one tube is not likely to position the trace completely off the screen. Visually inspect the tubes (V40 through V51) for cold filaments or other unusual appearances. Do not reject a tube for a blue glow on the inside surface of the glass. A blue fluorescence is often produced by stray electrons striking the surface of the glass. However, a reddish-purple glow in the center of the tube indicates a gassy condition--the tube is defective and should be discarded.

**5-86.** Check the distributed amplifier circuit for normal voltages and for proper bias and balance. See the Vertical Amplifier Schematic Diagram, Para. 7-159 through 7-161, and Para. 7-165 through 7-169. The checks in the paragraphs mentioned call for balancing the input to the oscilloscope by centering the trace. During the checks now being made, the input balance will have to be provided in some other manner, because there is no trace on the crt. This dc balance may be provided by connecting a resistive shorting strap between pins 1 and 3 of the plug-in interconnecting socket. If any tubes are changed as a result of these checks, the high-frequency compensation and delay line must be recalibrated.

**5-87.** Recheck for bad lead connections, shorted or broken peaking coils, defective resistors and capacitors, if previous checks did not indicate defective tubes. Check R290 and R293 at the grid-line termination, and check R259 and R266 at the plate-line termination. The location of these components is shown in Figure 5-23.

### 5-88. Insufficient or No Vertical Deflection

**5-89.** Insufficient deflection indicates a change in the gain characteristics of the Vertical Amplifier. If only a slight change in deflection is apparent, the circuit can normally be recalibrated for gain. In this event, refer to the Calibration Procedure in this Manual (Para. 7-52).

**5-90.** If the vertical deflection is only about 1/2 its proper amount and there is severe compression toward the top and the bottom of the graticule, check for an open delay line or fuse. Measure the dc voltage level, to ground, at both ends of each delay line section. These readings should all be essentially the same. Attaching the voltmeter to one side of an open delay line will charge the capacitance of the line and the trace will be temporarily displaced off the screen. The voltage reading will be zero in this case. The long wire coil of each of the four delay-line sections is continously wound. If there is a break in the wire, the complete coil (T7, T8, T9 or T10) will have to be replaced. This includes unsoldering the coil from all connections, removing it, and connecting the new coil.

**5-91.** Each delay line input from the distributed amplifier has a 1/10 ampere fuse to protect the delay-line and the plate-line windings. The recommended method of checking continuity of one of these fuses is by measuring the dc voltage level at each end of the fuse. If the dc level is the same at both ends, there is continuity. However, if continuity is checked with an ohmmeter, be sure to use a high resistance scale on the meter. The current produced on the low scales of some ohmmeters is sufficient to blow these fuses.

**5-92.** Occasionally, improper vertical deflection results from component failure in the delay line. Visual inspection will often detect poor connections and defective components. If component trouble in the delay line cannot be found visually, it is sometimes possible to check along the delay line with a test scope to find the trouble. If the difficulty is not isolated by the previous means, it may be necessary to disconnect the long coils of the delay line (T7, T8, T9 and T10) to check them. It may even be necessary to replace the coils.

**5-93.** If there is a large increase or decrease in gain or if there is no deflection at all, first check for defective tubes, as in Paragraphs 7-144 through 7-175 of the Calibration Procedure. Check also those components which can affect the gain of the circuit but not the dc balance. Such components include the common cathode resistors, the Gain Adj. control, common screen resistors and common plate-load resistors.

### 5-94. Waveform Distortion

**5-95.** Any waveform distortion produced by the distributed amplifier will generally be of a high-frequency nature. There will usually be no low-frequency distortion since the deflection circuit is dc-coupled from input to output. Low-frequency distortion could be produced if the tubes carried a grid-current, however.

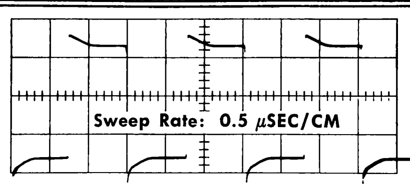
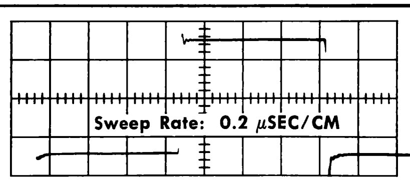
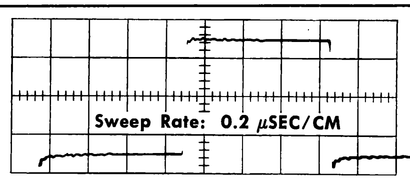
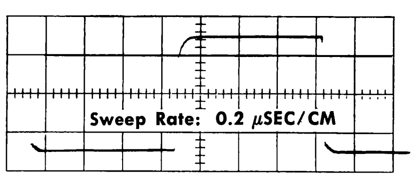
**5-96.** A distortion-free square wave having a risetime of 7 nanoseconds (millimicroseconds) or less, should be used to observe the high-frequency characteristics of the oscilloscope/plug-in combination. Refer to Paragraphs 7-135 through 7-141 in the Calibration Procedure for the method of presentation, and the characteristic distortions of the waveform.

**5-97.** Any distortion that may be produced by the vertical deflection circuit will occur in the rise, the first corner and the first 1/2 miscrosecond following the leading edge of a square wave display. This time corresponds to twice the delay time of the circuit, because the delay line is reverse terminated.

**5-98.** The vertical deflection circuit in the Type 945/Type MC combination may be divided into three general sections:

(1). The Type MC Plug-In Preamplifier.
(2). The Main-Unit Vertical Amplifier.
(3). The Delay Line.

Each section affects the waveform in a different region or in a different manner. Analysis of the distortion will give a clue to the part of the circuit at fault. See Figure 7-23 for the regions affected by the adjustments.

| Description and Cause | Display | Cure |
|---|---|---|
| Severe case of "cathode interface", a vacuum tube defect. |   | Replace defective tubes with a new balanced set. |
| Overshoot and ringing caused by shorted peaking coils, overcompensation of high-frequency controls. |   | Check high-frequency coils for damage; check peaking coil and trimmer capacitor adjustments. |
| Irregularities in first 0.4 µsec of pulse top, caused by impedance mis-matches in the delay line. |   | Recalibrate the delay line and high-frequency compensation, only after all other sources of distortion have been eliminated. |
| Rolloff, or undershoot, brought about by shorted distributed amplifier tubes, open peaking coils, undercompensation of high-frequency controls. |   | Check DA suppressor voltages; check for damaged coils; recalibrate high-frequency controls. |

DR-PM152

Fig. 5-24. Waveform distortions with description, cause, display, and cure for typical problems.

**5-99.** The Type MC and the input stage of the main-unit vertical amplifier will affect only the leading corner and the first .05 $\mu$SEC (50 nsec) following the leading edge of the step function. Figure 7-25 (e) shows rolloff at the leading corner of the pulse. This characteristic is the result of insufficient high-frequency compensation. A small amount of rolloff can usually be compensated by adjusting the peaking coils according to the instructions in the Calibration Procedure, Paragraphs 7-190 through 7-193.

**5-100.** If rolloff is quite pronounced, the tubes of the distributed amplifier should be checked. If a tube cannot deliver current instantaneously on demand, the high-frequency part of the signal will not be produced. Tube checking and selecting procedures are given in Paragraphs 7-144 through 7-175. (Remember that replacing or interchanging tubes will require rechecking the high-frequency controls for proper calibration).

**5-101.** Partially shorted peaking coils will result in rolloff with ringing. Be especially careful when soldering near the peaking circuits. Hot solder dropped on a coil may burn through the insulation and short the turns.

**5-102.** Ringing at the leading corner is produced by an over-compensated delay line or by damaged peaking coils. Overshoot at the front corner, without ringing, may also be produced by over-compensation. In the second case, the degree of compensation is not sufficient to produce ringing. Improper adjustment of the termination network may also cause overshoot or rolloff. These types of distortions can usually be eliminated by calibration of the high-frequency controls. If calibration does not eliminate the rolloff and ringing, check again for damaged coils and replace if necessary. Be sure to note replacement and adjustment instructions in the Calibration Procedure, Paragraphs 7-181 and 7-190 through 7-193.

**5-103.** Overshoot at the leading edge of a fast-rising pulse may also be the result of cathode interface in some of the vertical amplifier tubes. The check for cathode interface in described in the Calibration Procedure, Paragraphs 7-149 through 7-152.

**5-104.** The distributed amplifier will affect the step function both at the leading corner and in the 350-400 nsec region (see Figure 7-23, 5).

**5-105.** The delay line will affect the pulse for the first 350 nanoseconds following the front corner. If the line is de-tuned this section of the display will be uneven. The leading corner may also have some rolloff or spiking as a result of this de-tuned condition. Recalibration of the high-frequency controls will usually eliminate these irregularities. See the Calibration Procedure.

**5-106.** If there is a defective component in one of the delay-line sections its location will often be evident in the square-wave display, appearing as a dip or a bump. In this case, if recalibration cannot correct the situation, the component must be located and replaced. To find the portion of the delay line with the defective component, inspect the line after trying to tune out the display distortion. The adjustments in the immediate vicinity of the trouble will not follow the usual pattern. See Figures 7-26 and 7-27.

**5-107.** Another method of finding the part of the delay line producing distortion of the pulse is by touching the slugs of the trimmer capacitors with a small metal tool having an insulated shaft. Do not short to ground. The "dip" produced in the display shows the precise place on the waveform affected by the capacitor that was touched.

## 5-108. TROUBLESHOOTING THE CALIBRATOR

### 5-109. Asymmetrical Output

**5-110.** If the output square wave is not symmetrical (the positive portion has a duration different from that of the negative portion) the two tubes in the Multivibrator circuit are not being held cutoff for equal periods. This will normally be caused by a defective tube. If tube replacement does not correct the waveform, the circuit components must be checked. The triode in the Multivibrator is held cutoff for an interval determined by the discharge of C180, and the pentode is held cutoff for an interval determined by the discharge of C181. A change in the value of either capacitor, or in the value of the resistor through which they discharge, could produce an asymmetrical waveform.

**5-111.** In addition, the time needed for these capacitors to discharge a given amount is affected by the potential toward which they discharge; this would be the voltage at the plate of the triode in the case of C181, and the voltage at the screen of the pentode in the case of C180. Since these voltages are affected by the value of R308 and R313, these resistors should be checked. The resistors in the plate circuit of the pentode should also be checked, since they will affect the plate-to-screen ratio of the pentode.

### 5-112. Incorrect Output Voltage

**5-113.** The amplitude of the output square wave is determined almost entirely by the resistance values in the divider in the cathode-follower stage. A quick check of the resistance values can be made by turning off the Calibrator and measuring the voltage at the Cal. Test Pt; if this point does not measure exactly +100 volts the output voltages will not be correct when the Calibrator is turned on.

**5-114.** The CAL. ADJ. control R314 will vary the voltage at the test point over about a 10-volt range. If this voltage cannot be set to exactly +100 volts, and if the tubes have been replaced, then one or more of the precision resistors in the divider may have changed in value.

## 5-115. TROUBLESHOOTING THE HORIZONTAL SWEEP AMPLIFIER

### 5-116. No Spot or Trace Visible on the CRT

**5-117.** To determine that the Sweep Amplifier is in a state of dc unbalance, short the horizontal deflection plates together at the trimmer capacitors C57 and C62 with the shorting strap shown in Fig. 5-21. The horizontal deflection plates are marked RED (LEFT) and GREEN (RIGHT). The INTENSITY control should be set to midscale. If a spot appears when the horizontal deflection plates are shorted together (it may be necessary to adjust the Vertical control), the trouble lies in the Sweep Amplifier.

**CAUTION:** Do not permit the spot to remain on the crt at this setting of the INTENSITY control. Either reduce the intensity until the spot is just visible, or remove the short from the horizontal deflection plates.

**5-118.** The procedure for troubleshooting the Sweep Amplifier, to locate the defective stage, is similar to that explained for troubleshooting the Vertical Amplifier for unbalance. The shorting strap can be moved from the deflection plates back, until a point is reached where the spot does not appear. When the stage at fault is determined, check for defective tubes and components associated with that stage.

### 5-119. Insufficient or No Horizontal Deflection

**5-120.** If the gain of the Sweep Amplifier decreases, the trace will not extend from the left to the right side of the graticule. In addition, the timing will no longer correspond to the calibrated value indicated by the TIME/CM switch. (This is to distinguish the condition of insufficient sweep produced by a malfunction in the Sweep Amplifier from that produced by a malfunction in the Hold-Off circuit in the Sweep Generator, e.g., an improper adjustment of the SWP. LENGTH control. In the latter case the trace will start at the left side of the graticule, for the normal setting of the HORIZONTAL POSITION control, and the timing will not be affected.)

**5-121.** If the change in gain is slight, as indicated by improper timing and a slightly decreased sweep, the amplifier can usually be recalibrated. Since the gain of the Sweep Amplifier regulates the timing of the sweep, care must be taken to insure that the gain adjustments are accurately made. Be sure to refer to the Calibration Procedure if it is

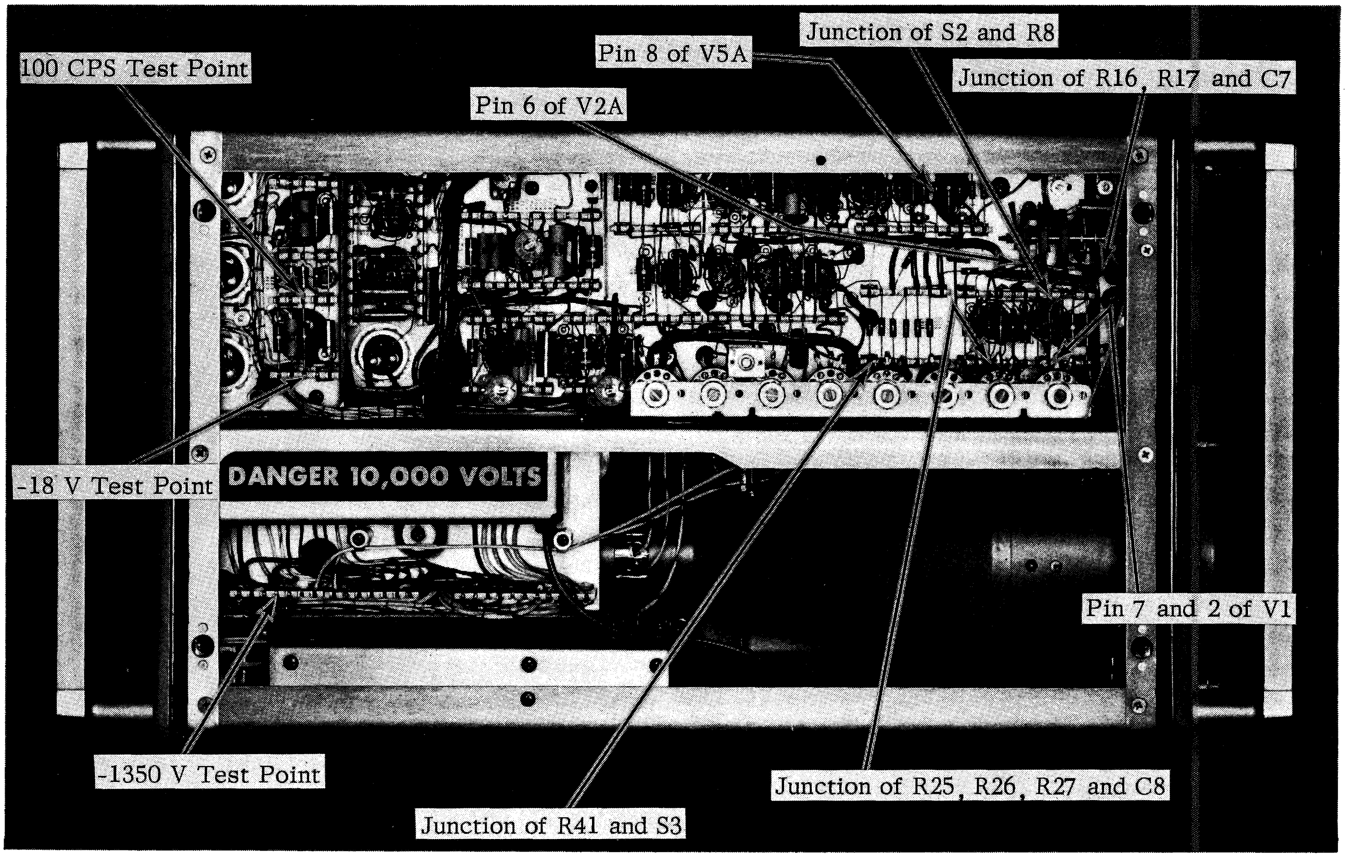



Fig. 5-25. Top view of the Type 945 showing test points.

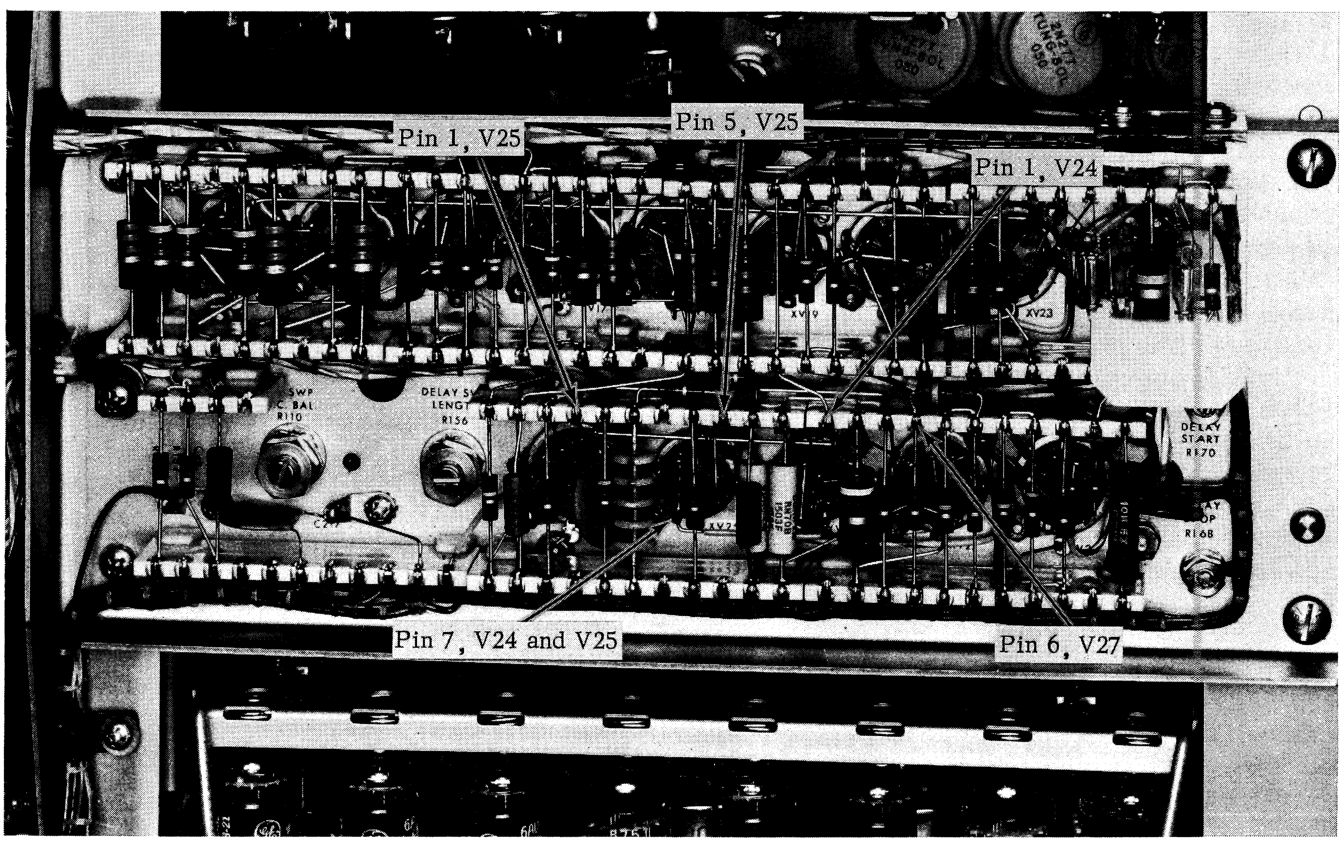



Fig. 5-26. Delaying Sweep chassis showing test points.

necessary to adjust the gain of the Sweep Amplifier.

**5-122.** If the decrease in gain of the Sweep Amplifier is more pronounced, or if there is no sweep at all (in which case only a spot will be visible on the horizontal axis), check for defective components which can affect the gain but not the dc balance. In addition to the tubes, such components would be the common cathode resistors and controls.

### 5-123. TROUBLESHOOTING THE MAIN SWEEP TRIGGER

#### 5-124. Unstable Triggering

**5-125.** If the sweep generator is not being properly triggered a stable display of a waveform will not be possible. If the sweep can be turned off and on with the STABILITY control (for any setting of the TRIGGERING MODE switch except AUTOMATIC) the sweep generator is apparently capable of being triggered; this indicates the trigger circuitry is not functioning properly. The first step is to replace the Trigger Pickoff tubes V35 and V37 in the Vertical Amplifier. The operation of this stage can also be checked by observing the signal available at the VERTICAL SIGNAL OUT binding post with another oscilloscope. (A signal, such as the calibrator, must be fed to the Vertical INPUT.) if no signal is available at this connector the Trigger Pickoff stage is defective, a proper signal at this connector indicates the stage is functioning correctly.

**5-126.** If the Trigger Pickoff stage is operating correctly, trouble exists in the Main Sweep Trigger circuit. To check the quiescent stage of the circuit, set the TRIGGERING MODE switch to AC, the TRIGGER SLOPE switch to -INT., and the TRIGGERING LEVEL control to 0. Next, connect a cable from the junction of R16, R17 and C7 (on the Trigger Switch), to ground. This fixed the voltage at the grid of V1A at ground potential. Then measure the voltage at the plate of V1A; this should be about +85 volts. If this voltage does not measure very close to +85 volts, replace the Trigger Input tube V1. If necessary, check for off-value resistors, broken leads and poor switch contacts.

**5-127.** The next step is to connect the voltmeter between the plate of V1A and the grid of V2B (the junction of R27, R25, C8 and R26 is more convenient than the grid of V2B). The voltage between the plate of V1A and the grid of V2B (or the divider side of R26) should not exceed about 2.75 volts. It is the function of the Trigger Level Centering control R28 to set the voltage at the grid of V2B approximately equal to the voltage at the grid of V2A. With the grids of the V2 at about the same voltage the center of the hysteresis of the Trigger Multivibrator circuit will be at the proper level. It is difficult to measure the voltage directly between the two grids of V2 due to the loading of the voltmeter; for this reason we suggest the voltage be measured between the plate of V1A and the grid circuit of V2B. A voltage of 2.5 to 2.75 volts between these points will indicate proper quiescent operation.

**5-128.** If the voltage at the grid of V2B cannot be adjusted to within 2.5 to 2.75 volts of the voltage at the plate of V1A, trouble in the Trigger Multivibrator is indicated. Replace V2; then, if necessary, check for off-value resistors, broken leads and defective switch contacts and connections.

**5-129.** Conversely, if the voltages are found to be correct, the adjustment of the Trigger Sensitivity control R29 can be checked. Refer to the Calibration Procedure for the proper method of checking the adjustment of this control.

**5-130.** When triggering in the DC mode from the signal being observed (TRIGGER SLOPE at + or -INT.), the Int Trig. DC Level Adj R2 and its associated components are connected to the input grid of V1. This control is adjusted so that the input grid (pin 7 at -INT; pin 2 at +INT.) is at ground potential when the trace is centered vertically on the crt. If the voltage at the input grid cannot be adjusted to zero, when the triggering-switch controls are in the indicated positions, this control and its associated components should be checked.

### 5-131. TROUBLESHOOTING THE MAIN SWEEP GENERATOR

**5-132. No Horizontal Sweep**

**5-133.** If the Main Sweep Generator is not producing a sawtooth sweep voltage when the STABILITY control is adjusted for a free-running sweep, some defect in the generator is preventing operation of the Miller run-up circuit. Depending on the on-off characteristics of the diodes V11, the Miller circuit may be clamped at either the high end or the low end of the sawtooth. The manner in which it is clamped may be determined by measuring the voltage at the SAWTOOTH Main Sweep binding post. If the Miller circuit is clamped at the high end of the sawtooth the voltage at the front-panel binding post will measure about +200 volts; if clamped at the low end, the voltage at this point will measure anywhere between ground and -20 to -30 volts, depending on the cause.

**5-134.** If the Miller circuit is clamped at the high end of the sawtooth, a check of the voltage at the grid of the Miller tube will offer a clue to the cause of the trouble. The static voltage at the Miller grid is determined by conduction through the Timing Resistor R82 (from -150-volt bus), the lower diode V11A, and the divider R59-R74. It will be impossible to measure the exact voltage at the Miller grid because of the loading of the meter. However, if a 20,000-Ω/v meter, or a vacuum-tube voltmeter is used, the voltage reading obtained will be sufficient to indicate the source of the trouble. For example, if a voltage reading more negative than about -15 volts is obtained, there is probably no conduction through the Timing Resistor. This would indicate an open divider R59-R74, assuming the diode V11 to be good.

**5-135.** If the Miller circuit is clamped at the low end of the sawtooth, as indicated by a voltage reading of zero or a few volts negative, a check of the voltage at the plate of the Miller tube will offer a clue to the cause. If this voltage is quite high (about +350 volts), check the neon lamp DS2 and the Sweep Gen. CF tube V13. If the voltage at the plate of the Miller tube is zero or slightly negative, check for an open plate-load resistor R83, R84 or R85.

**5-136.** However, if the voltage at the plate of the Miller tube is near quiescent level (about +45 volts) the trouble will generally lie ahead of the Miller tube. The result of the trouble is that the On-Off Diodes V11 cannot be gated off; they are conducting heavily and clamping the grid of the Miller tube near ground. Check the output of the Sweep-Gating Multivibrator with a test scope. If all of the tubes have been checked, then check for open plate and cathode resistors in the Sweep-Gating Multivibrator circuit, the Hold-Off circuit and the Sweep Gen. circuit. Also check that the STABILITY control can vary the voltage at the grid of V8B.

**5-137. Improper Triggering**

**5-138.** If the sweep cannot be triggered properly, the gating pulse from the Multivibrator is not turning the diodes V11 off and on properly. The start of the gating pulse, which turns the diodes off and starts the sweep, is initiated by the triggering pulse at the grid of V8B. The end of the gating pulse, which turns the diodes on and initiates the retrace, is controlled by the hold-off waveform at the grid of V8B. The Sweep-Gating Multivibrator can be eliminated as the cause of the trouble if the sweep can be turned off and on with the STABILITY control. The main component to check, in addition to the tubes, is the differentiating capacitor C16.

**5-139. Nonlinear Sweep**

**5-140.** A nonlinear sweep voltage will be generated if the current charging the Timing Capacitor C26 does not remain constant. If the nonlinearity occurs at all sweep rates a defective Miller tube will be the probable cause. If the nonlinearity occurs only at certain sweep rates a leaky Timing Capacitor will be the probable cause but the Miller tube should not be overlooked. A defective bootstrap capacitor C27 can cause the sweep to be nonlinear at the faster sweep rates.

**5-141. Insufficient Horizontal Deflection**

**5-142.** If the horizontal trace starts at the left side of the graticule, but does not extend to the right side, the Hold-Off circuit is causing V8B to conduct too soon after the triggering pulse had forced it into cutoff. If the trace cannot be expanded the full length of the graticule with the Swp. Length Adj. R98, check the resistance values in the cathode circuit of V13.

## 5-143. TROUBLESHOOTING THE DELAY PICKOFF

### 5-144. No Delayed Trigger

**5-145.** Set the HORIZONTAL DISPLAY switch to MAIN SWEEP NORMAL and turn the Main Sweep STABILITY clockwise to free-run the Main Sweep. With a test scope check the front panel connector DEL'D TRIG FROM MAIN OR DEL'G SWEEP, J6, for a sharp positive pulse about 7 volts in amplitude. If the pulse is not present, move the test scope probe to the grid circuit of the Pickoff Comparator tube at pin 1 of V24. A sawtooth waveform about 150 volts in amplitude should be observed if circuits preceding the Delay Pickoff are functioning normally.

**5-146.** Move the test scope probe to the cathodes at pins 7 of V24 and V25. A sawtooth waveform about 120v in amplitude should be observed. If not, try substituting new tubes for V24 and V26. If the trouble still exists, carefully check voltages and circuitry associated with the Pickoff Comparator and the constant current tube V26A.

**5-147.** Place the test scope probe on the plate, pin 5 of V25. The observed waveform should consist of flat-topped pulses about 45 volts in amplitude. If the waveform is not observed, try changing V25. Check the plate and grid circuits. Observe the effect on grid voltage (pin 1, V25) when the DELAY-TIME MULTIPLIER 1-10 is varied. The voltage divider circuit, including the DELAY-TIME MULTIPLIER, Delay Start, and Delay Stop networks, sets the accuracy of the range through which the grid of V25 matches the grid of V24. The calibration of the Delay Start and Delay Stop should be checked as in paragraphs 7-121 through 7-125.

**5-148.** Move the test scope probe to the plate, pin 6 of V27B. A flat-topped multivibrator waveform about 20 volts in amplitude should be observed. If not, try changing V27 and check the multivibrator circuit. In particular, check C46, a capacitor that helps speed V27B into cutoff for fast multivibrator switching. If there is still no output from the Delay Pickoff CF, try changing V26 and check the circuits associated with V26B including the coupling capacitor C47.

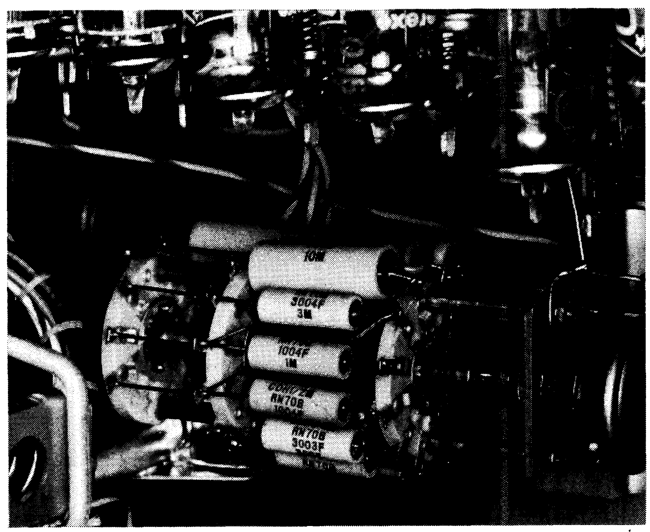
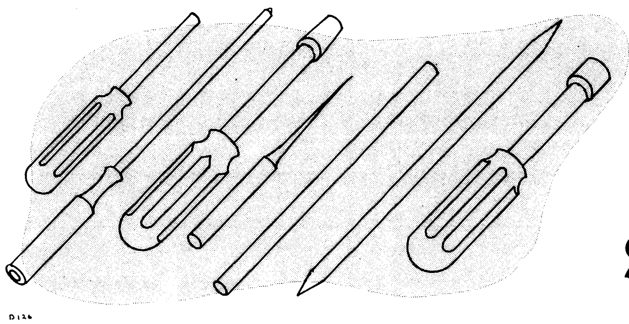


Fig. 5-27. Delaying Sweep timing switch location near the right front portion of the center bulkhead.

## 5-149. TROUBLESHOOTING THE DELAYING-SWEEP TRIGGER AND GENERATOR

**5-150.** The Delaying-Sweep Trigger circuitry and the Delaying-Sweep Generator circuitry may be checked as was the Main Sweep circuitry. The components of the circuit may be found on the schematics. The test points that are comparable to the Main Sweep test points are shown in Fig. 5-27. The Delaying Sweep timing switch location is shown in Fig. 5-28. The problems may be isolated by using the same techniques used in the Main Sweep Troubleshooting portion.



# SECTION 6

# SPECIAL TOOLS AND EQUIPMENT

## 6-1. Special Tools and Equipment

**6-2.** Some system of referring to fundamental standards is necessary when calibrating any measuring device. In most cases oscilloscopes are calibrated to primary standard instruments which are in turn referred to fundamental standards.

**6-3.** The following equipment is necessary for a complete calibration of the Type 945 and MC combination:

**6-4.** Constant Voltage Variable Frequency Sine-Wave Generator, Tektronix Type 190( )* or equivalent. For use in checking high-frequency characteristics of the Type 945 Oscilloscope. ( ) denotes any model of the instrument.

**6-5.** Time-Mark Generator, Tektronix Type 180A* or equivalent, having markers at 1 μsec, 10 μsec, 50 μsec, 100 μsec, 1 msec, 5 msec, 10 msec, 100 msec, 1 sec and 5 sec. This generator should have sine-wave output of 10 MC and 50 MC, with all markers and outputs having an accuracy of at least .03%.

**6-6.** Variable auto-transformer (e.g. Powerstat or Variac) having a rating of at least 7 amperes.

**6-7.** A test oscilloscope and associated probe, providing triggered sweeps and a bandpass of at least DC to 5 MC, 5 to 50 mv/div Max Sensitivity.

**6-8.** Fast-Rise Mercury Pulser, Tektronix Type P Plug-In Test Unit.*

**6-9.** A DC voltmeter, such as the Triplett 630, having a sensitivity of at least 5000 Ω/volt and calibrated for an accuracy of at least 1% at 100, 150, 225, 350 and 500 volts, and for an accuracy of at least 3% at 1350 volts. Portable multimeters should be regularly checked against an accurate standard and corrected readings noted, where necessary, at the above listed voltages. BE SURE YOUR METER IS ACCURATE.

**6-10.** An accurate rms-reading ac voltmeter, having a range of 0-150 volts. (0-250 volts for 234 volt operation)

**6-11.** Gain Adjust Adaptor* (Tek Part No. 013-005), Tektronix Type EP53A, permits an external calibrating signal to bypass the plug-in preamplifier when calibrating the sensitivity of the main amplifier.

**6-12.** 47 pF Input Capacitance Standardizer* with BNC connectors (Part No. 70-6004-00) or the Tektronix Type 130 L-C Meter or an accurate capacitance bridge.

**6-13.** 20 pF Input Capacitance Standardizer* with BNC connectors (Part No. 70-6003-00).

**6-14.** The Tektronix Type B52R Terminating Resistor* (Tek Part No. 011-001).

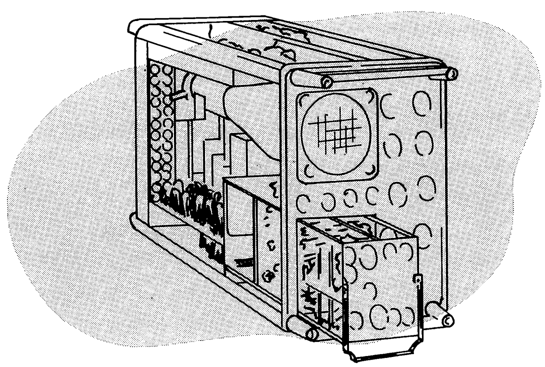
**6-15.** UHF/BNC Adaptor converts the BNC connector on the Type 945 to the UHF connectors used on many Tektronix instruments.

**6-16.** Low-Capacitance Calibrating Tools supplied in the Type 945 panel cover are: an insulated screwdriver and insulated alignment tools (Part No. 02-0002-00 and 02-0004-00).

---

*Environmental N/A

## NOTES



# SECTION 7

# CALIBRATION PROCEDURE

## 7-1. INTRODUCTION

**7-2.** The Type 945 Oscilloscope is a stable instrument that should not require frequent calibration. However, it will be necessary to calibrate certain circuits of the instrument when tubes or components are changed. Periodic check of overall scope calibration is suggested about every six months of intermittent operation from the standpoint of preventive maintenance.

**7-3.** In the instructions that follow, the steps are arranged in the proper sequence for full calibration. Each numbered step contains the information necessary to make one adjustment or check. Detailed instructions concerning the actual operation of the instrument are not given, since they are given in the Operating Instructions. If a complete calibration is not necessary, you may perform individual steps. These individual steps are performed ONLY if the steps do not affect other adjustments.

**7-4.** You must be fully aware of the interaction of adjustments. Generally speaking, the interaction of controls will be apparent in the schematic diagrams. If you are in doubt, check the calibration of the entire section on which you are working.

**7-5.** If you make ANY adjustments in the power supplies or replace the CRT, a complete check of the entire instrument is necessary. In particular, the sweep rates and vertical deflection factors must be checked.

Figures 7-1, 7-2, 7-3, and 7-4 show the location of the internal controls.

## 7-6. PRELIMINARY

**7-7.** Remove the top, side and bottom panels from the instrument to be calibrated.

**NOTE:** Front-panel controls are designated by entirely capitalizing the words. Internal controls have only the first letters capitalized.

**7-8.** Set the front-panel controls as follows:

| | |
|---|---|
| INTENSITY | full left |
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| AMPLITUDE CALIBRATOR | OFF |
| TRIGGERING MODE | AC |
| TRIGGERING SLOPE | + INT. |
| STABILITY (MAIN AND DELAYING SWEEP) | full left, but not PRESET |
| TIME/CM (MAIN AND DELAYING SWEEP) | 1 mSEC |
| 5X MAGNIFIER | OFF |
| MULTIPLIER | 1 |
| variable MULTIPLIER | full right |
| MODE (MC unit) | A ONLY |
| AC/DC (CHANNEL A and CHANNEL B) | DC |
| POLARITY (CHANNEL A and CHANNEL B) | NORMAL |
| VOLTS/CM (CHANNEL A and CHANNEL B) | .05 |
| VARIABLE | CALIBRATED (full right) |

**NOTE**

Settings for all controls not listed above are not pertinent to this part of the procedure and the controls may be left in any position.

**7-9.** Connect the instrument and the ac meter to the autotransformer output and turn on all equipment. Adjust the autotransformer to the design-center voltage for which your instru-

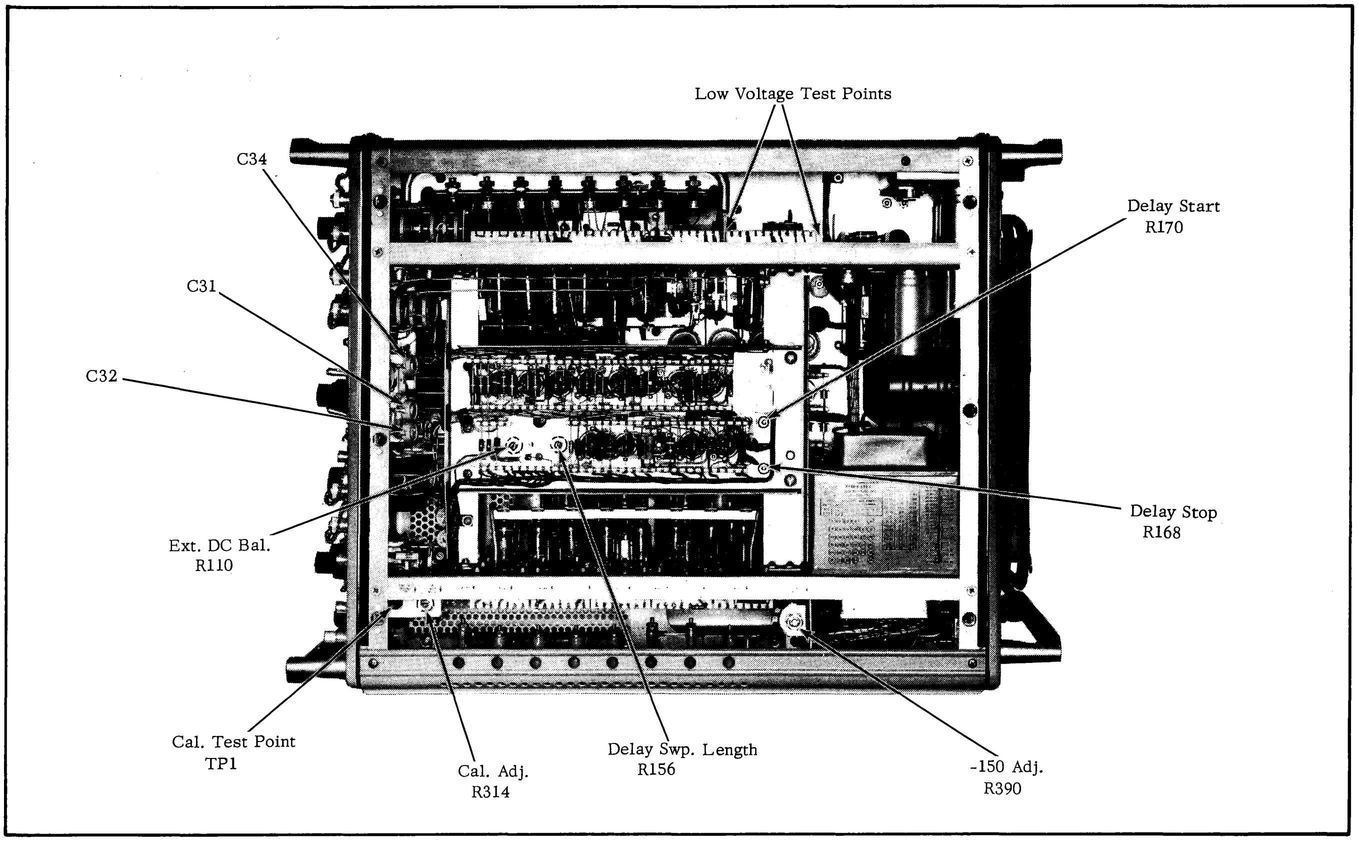



Fig. 7-1. Right side view showing location of internal controls.

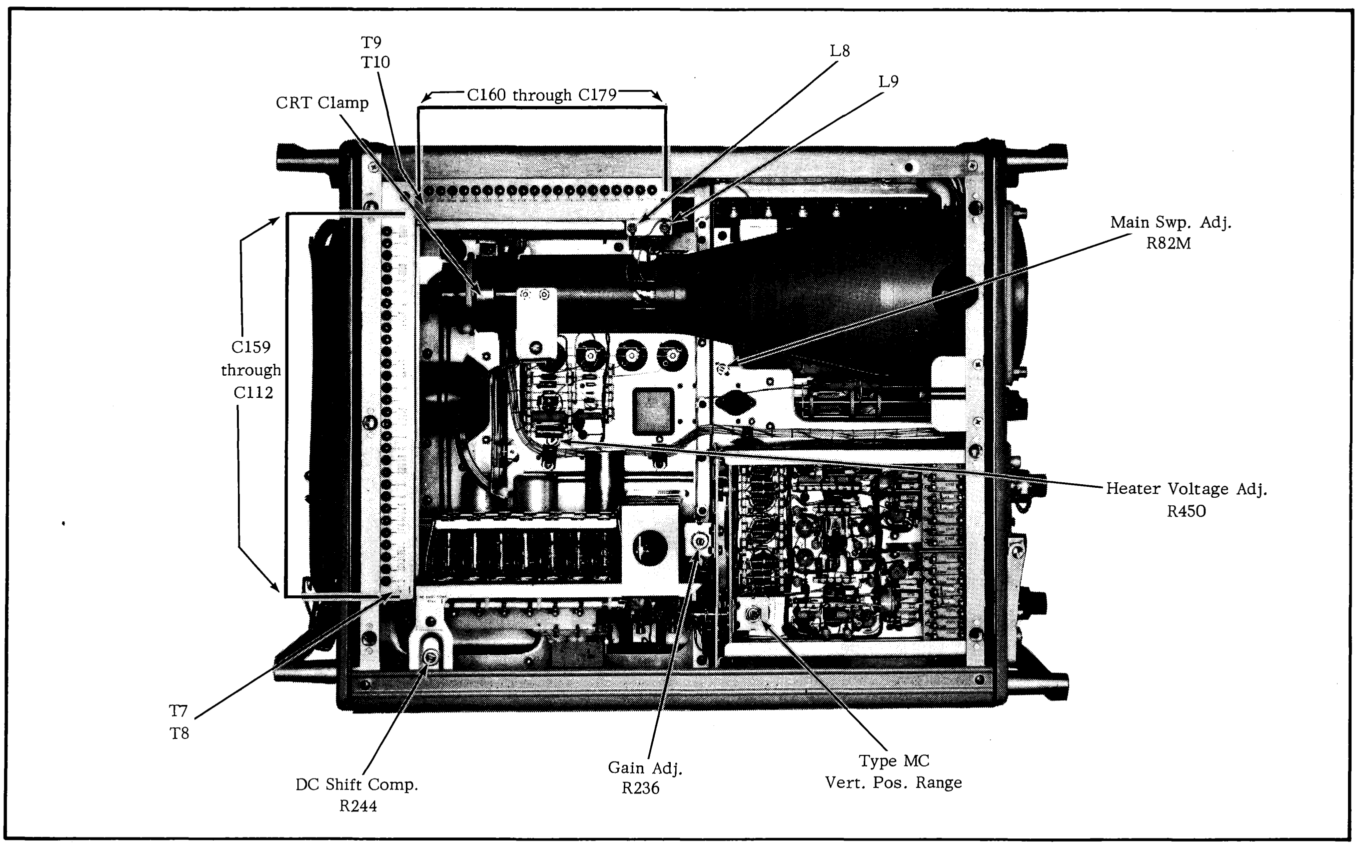



Fig. 7-2. Left side view of Type 945 showing controls used during adjustment in recalibration.

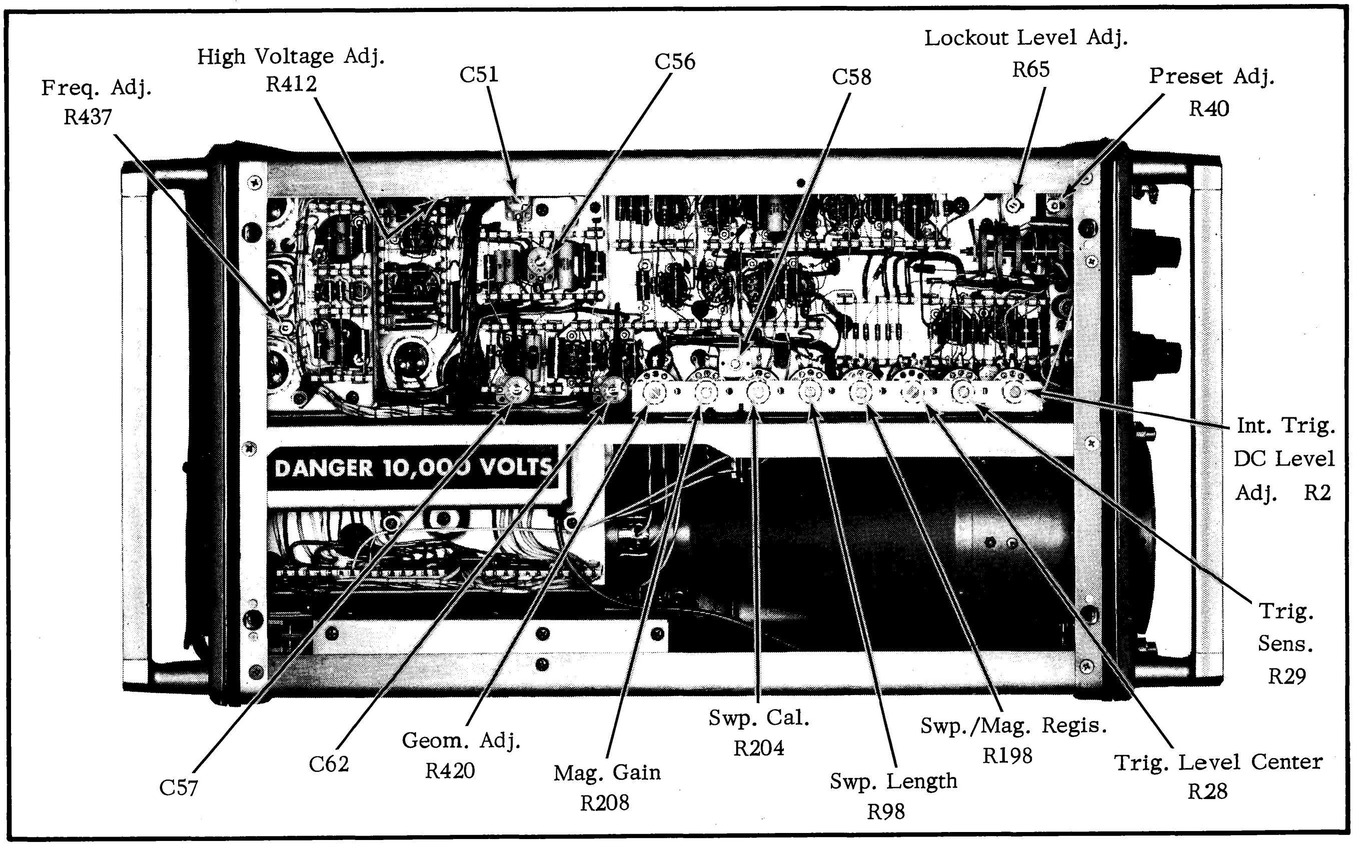



Fig. 7-3. Top view of Type 945 locating internal controls.

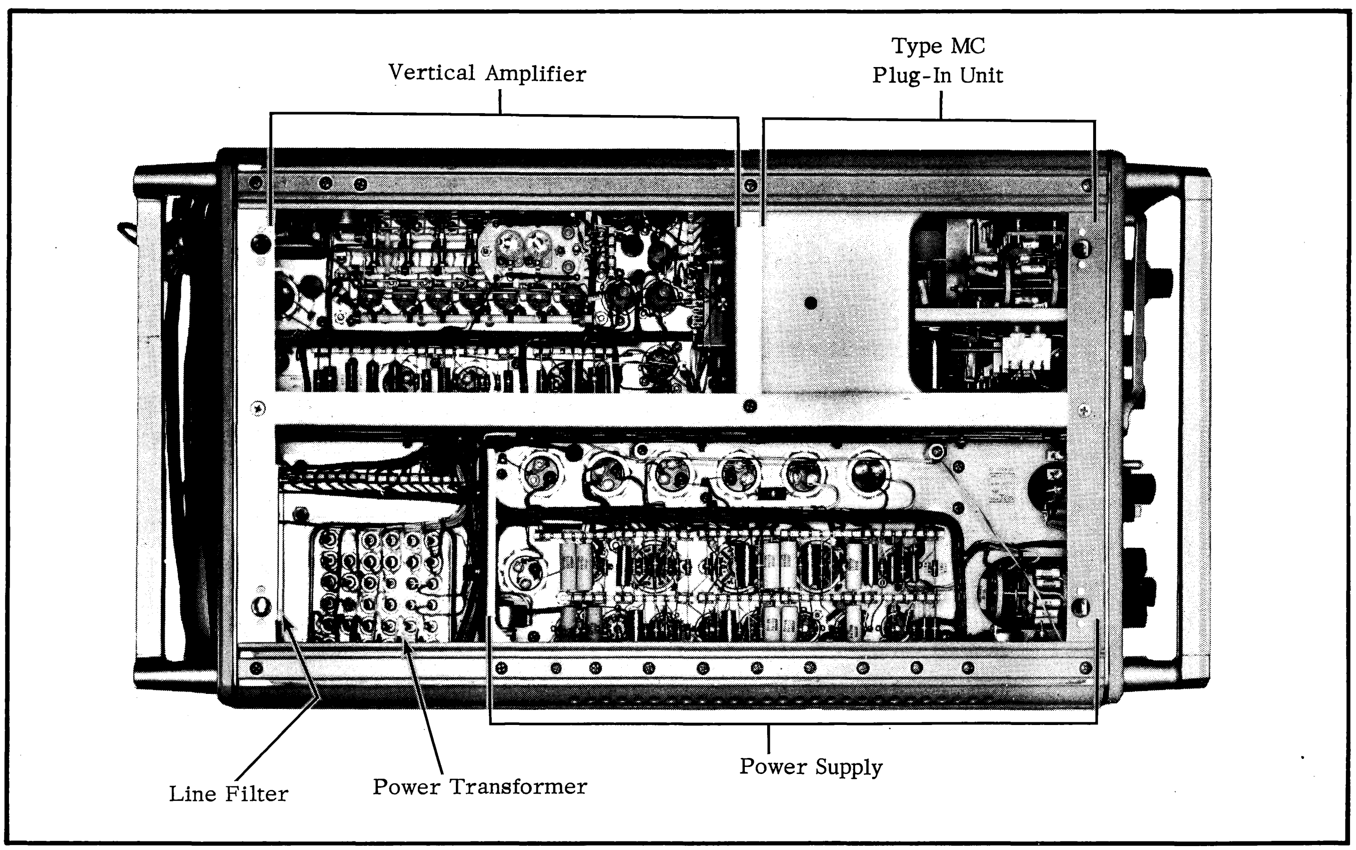



Fig. 7-4. Bottom view of Type 945.

ment is wired (115V or 230V) and allow at least 20 minutes warmup before making any adjustments.

## 7-10. PROCEDURE

## 7-11. LOW-VOLTAGE POWER SUPPLIES

**7-12.** Measure the output voltage of the -150v, 12.6v, +100v, +225v, +350v, and +500v supplies at the test points indicated in Figure 7-5 and Figure 7-7 with the dc meter. The meter must be accurate within 1% in the range up to 500 volts and 3% at 1350 volts (see Equipment Required). The major voltage test points are found on the ceramic strip at the farthest right section on top indicated in the Right Side View (See Figure 7-1). Don't adjust the -150v supply unless one or more of the supplies is really out of tolerance. Remember that the calibration of the entire instrument is affected by changes in the power supply voltages. All the positive voltage measurements depend upon the -150 volt supply measurement accuracy, so this adjustment must be done first, if necessary.

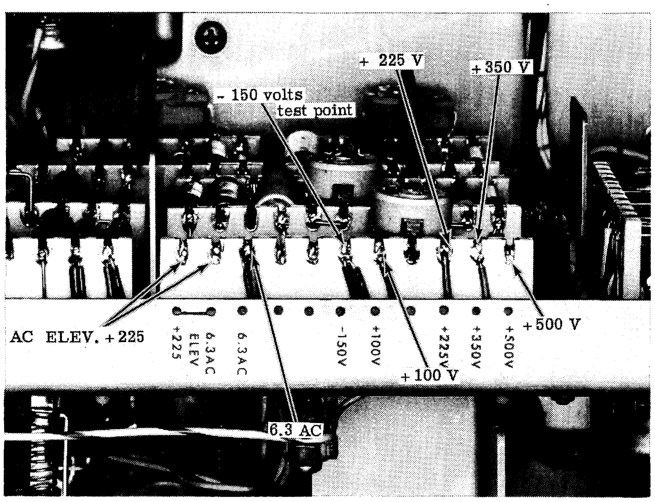



Fig. 7-5. Location of Low-Voltage Power Supply test points.

**7-13.** The -150V Adj., R390, is located on the lower right side of the Type 945 as shown in Figure 7-1. If the -150v test point shows an error over 1% in the -150v supply, adjust R390 until this voltage is accurate. Then recheck the positive supply voltages to see that they are within 2% of the values represented.

**7-14.** Some of the less common voltages and the test points are found in other portions of the oscilloscope chassis. The -18v Test Point is located on the fan drive circuit that is on a small separate chassis at the right rear side of the top deck (see Figure 7-6).

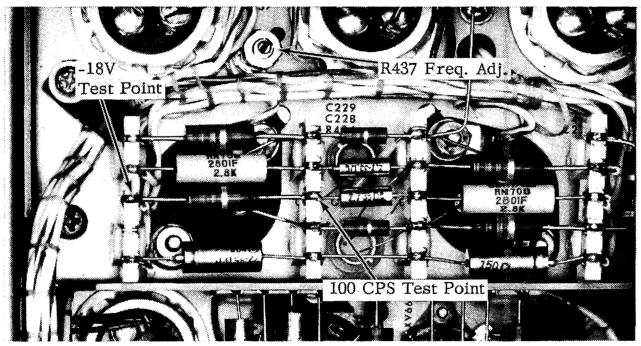



Fig. 7-6. Fan Drive circuit showing -18 v test point, 100 cps test point and Freq. Adj. locations.

**7-15.** The vertical amplifier regulated DC heater supply is found on the left side of the oscilloscope. (See Figure 7-7). The output should be adjusted to +12.6v, measured across R440. This adjustment is done with the Heater Voltage Adjust, R450, shown in Figure 7-7.

**7-16.** Check the supplies for proper regulation by varying the autotransformer from 103.5v to 115v and to 126.5v. A sharp increase in ripple voltage is the indication of the limit of regulation. Return the autotransformer to 115 volts.

**7-17.** Ripple present on any of the regulated supplies is measured at the voltage check points with the test scope. This ripple will be under 10 mv., with the AMPLITUDE CALIBRATOR in OFF position, and neither sweep operating.

## 7-18-AMPLITUDE CALIBRATOR ADJUSTMENT

**7-19.** When the AMPLITUDE CALIBRATOR switch is turned to OFF the calibrator cathode follower, V52B, remains conducting at the current required to develop 100 volts across the voltage divider. To check the calibrator, connect the ACCURATE voltmeter between the Cal. Test Point, TP1, and ground, (see Right Side View, Figure 7-1).

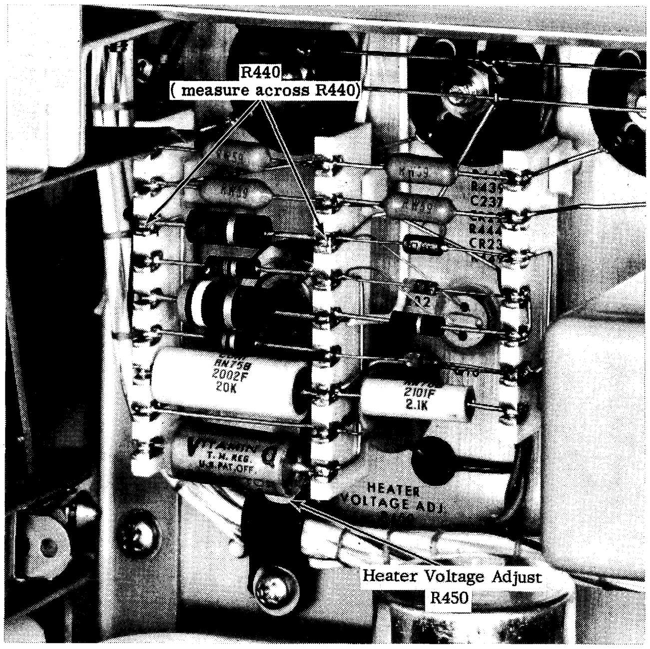



Fig. 7-7. Regulated DC Heater Supply circuit location on the left side of the Type 945.

**7-20.** If necessary, adjust the Cal. Adj. (R314) control for a reading of exactly 100 volts. This adjustment will insure calibrator accuracy of +or- 3%, peak-to-peak.

**7-21.** To assure suitable symmetry of the calibrator waveform, the reading of the voltage when the AMPLITUDE CALIBRATOR is ON must range between 45 v and 55 v. This range must be kept at all output voltage settings. Readings outside this range are generally caused by unbalanced multivibrator tubes (V52 and V53).

**7-22. HIGH-VOLTAGE POWER SUPPLY ADJUSTMENT**

This adjustment determines the total accelerating potential on the crt, and thus affects the deflection sensitivity.

**7-23.** Connect the voltmeter between ground and the high-voltage check point (see Figure 7-8). Set the High Voltage Adj., R412, (see Figure 7-3) for a meter reading of exactly -1350 volts. If your meter has a full scale reading of 1200 volts, you can connect the positive meter lead to the -150v supply, at any convenient point, and set the High Voltage Adj. for a meter reading of -1200v.

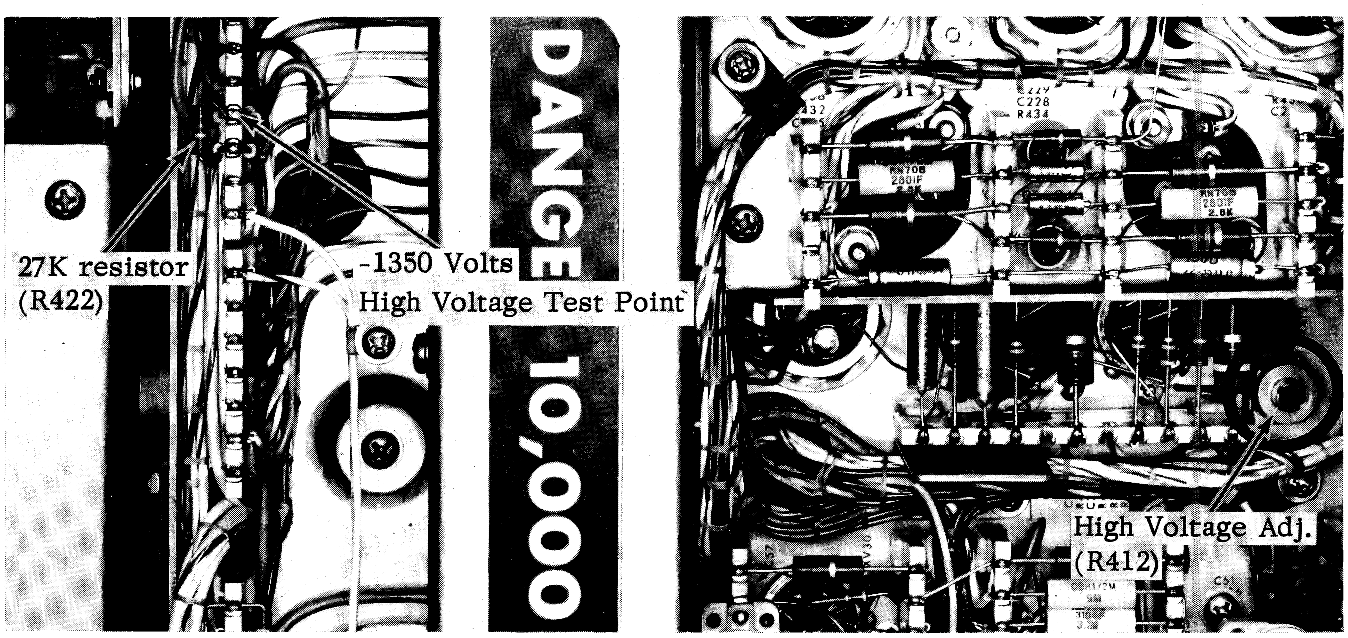



Fig. 7-8. The High-Voltage check point is found in the left rear section of the Type 945 top deck.

## 7-24. CRT ADJUSTMENTS

### 7-25. CRT Alignment

If the crt has been replaced, or if due to considerable handling, the trace does not align with the graticule, you should make this adjustment before proceeding with the calibration.

**NOTE**: The earth's magnetic field or stray magnetic fields can cause trace misalignment.

**7-26.** With the crt clamp loose (see Left Side View, Figure 7-2), and no vertical signal applied, free run MAIN SWEEP by turning the STABILITY control full right. Position the trace directly behind the center graticule line. If the trace and the graticule line do not coincide over the width of the graticule, rotate the crt until they are properly aligned.

**7-27.** After aligning, push the crt forward until it rests snugly against the graticule. Tighten the crt clamp. Recheck the alignment of the trace after tightening the clamp to be sure the crt didn't rotate when the clamp was being fastened.

### 7-28. Graticule Alignment

To check the alignment of the graticule, obtain a free-running trace on the oscilloscope, as explained in the last step. Next move the trace, with the VERTICAL POSITION control, to the top of the graticule until the trace disappears. Then move the trace to the bottom of the graticule until the trace disappears. If the graticule lines are not centered in the usable viewing area, the graticule is improperly aligned in the vertical plane. The graticule may be repositioned by means of a nylon adjusting cam, located in the lower left corner of the graticule.

**7-29.** To make this adjustment, remove the graticule cover and loosen the set screw that holds the positioning cam. By inserting a pointed tool (such as a scriber or center punch) into the small hole, the cam may be rotated until the graticule lines are centered in the usable viewing area. Then tighten the set screw that holds the nylon cam, and replace the graticule cover.

### 7-30. CRT Geometry

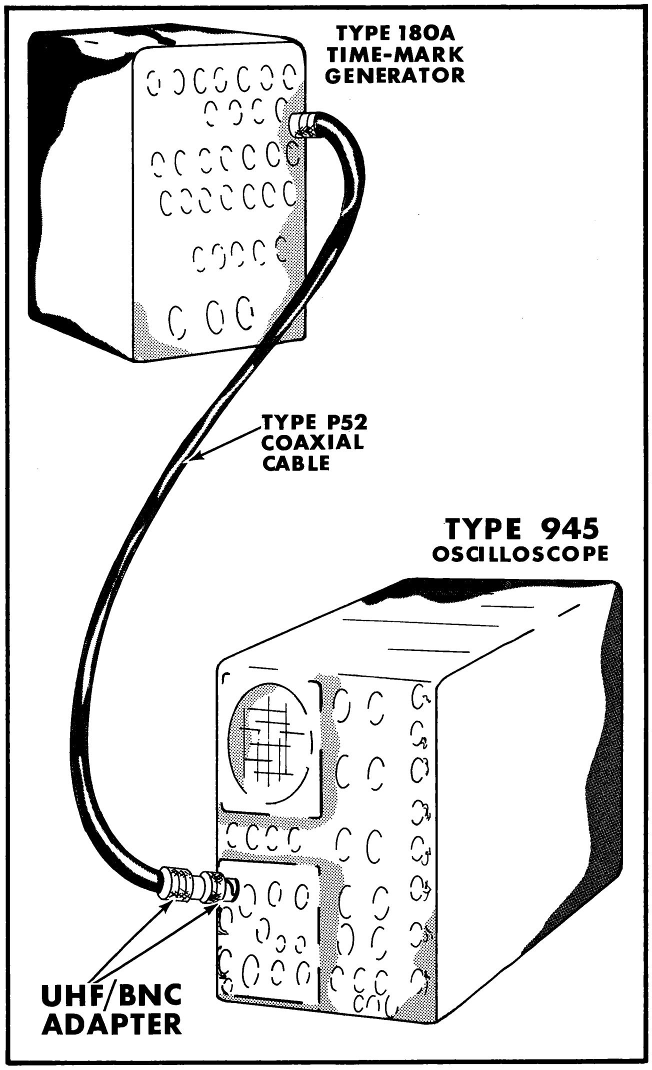



Fig. 7-9. Proper connections for time marker additions to the Type 945 and plug-in unit.

**7-31.** The geometry of the crt display is adjusted by means of the Geom. Adj. control, R420, seen in Figure 7-12. To get the best linearity, vertical lines are displayed on the crt and the Geometry control is adjusted for minimum bowing or curvature of the lines. Nonlinearity is most noticeable at the edges of the graticule.

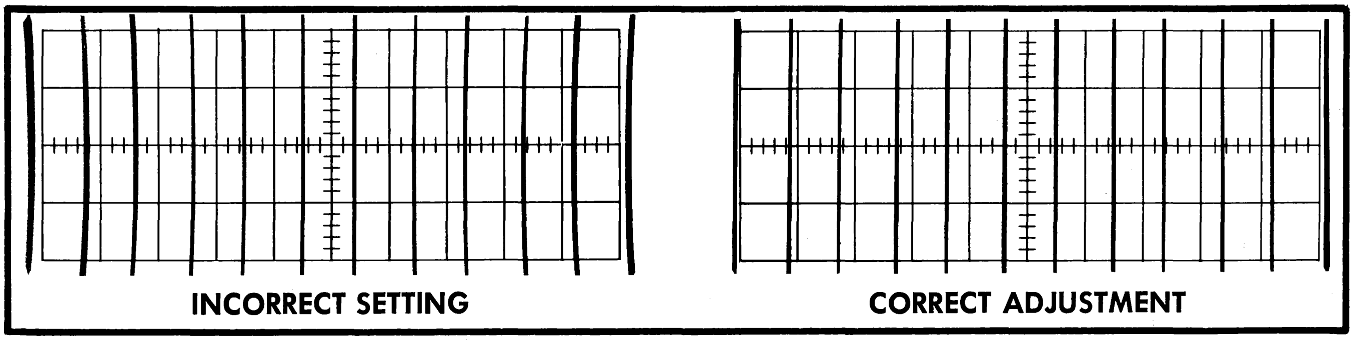



Fig. 7-10. Adjustment of the Geometry control.

**7-32.** Set front panel controls as follows (using MAIN SWEEP and CHANNEL A):

| | |
|---|---|
| MODE (plug-in) | A ONLY |
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TRIGGERING MODE | AC |
| TRIGGER SLOPE | + INT. |
| AC/DC | AC |
| TIME/CM | 1 mSEC |
| VARIABLE | CALIBRATED (full right) |
| VOLTS/CM (plug-in) | .2 |

**7-33.** Connect 100 MICROSECOND and 1 MILLISECOND markers from the Type 180 or Type 180A to the CHANNEL A INPUT connector using a UHF to BNC adapter if necessary. See Figure 7-9 for equipment setup. Position the base line of the timing comb below the bottom of the crt face so it is not visible. Adjust the Geom. Adj. control, R420, for straight vertical lines running parallel to the left and right edges of the graticule as shown in Figure 7-10. The lines must not deviate from straight vertical lines by more than 1 mm.

### 7-34. CRT Focus

### 7-35. Horizontal Focus

**7-36.** With the same setup as in the preceding adjustment, the 1 mm markers must be distinguishable over the center 8 cm. With the display clearly focused at the center of the graticule, there must be no overlapping of the markers within the center 8 major divisions of the graticule.

### 7-37. Vertical Focus

Remove the time-marker signal from the CHANNEL A INPUT. Delaying Sweep is free run at 10 µSEC/CM and STABILITY full right. HORIZONTAL DISPLAY is set in DEL'G SWEEP position, and the Main Sweep is freerun with STABILITY full right and the TIME/CM switch at 1 mSEC. Obtain a raster of 2 horizontal lines/mm by connecting the SAWTOOTH MAIN SWEEP to the CHANNEL A INPUT. Adjust the number of horizontal lines to 2/mm with vertical sensitivity. Optical magnification may help to adjust properly. Normal intensity is used.

### 7-38. Dual-Trace Check

**7-39.** Make the following control changes:

| | |
|---|---|
| MODE (MC plug-in unit) | CHOPPED |
| MAIN SWEEP TIME/CM | 1 µSEC |
| MULTIPLIER | 2 |

Stabilize the display with the TRIGGERING LEVEL and STABILITY controls. Check for two traces on the crt. Some adjustment of the vertical positioning controls may be necessary.

### 7-40. Visual Writing Rate

**7-41.** Make the following control changes:

| | |
|---|---|
| MODE (MC plug-in unit) | A ONLY |
| MAIN SWEEP TIME/CM | .1 µSEC |

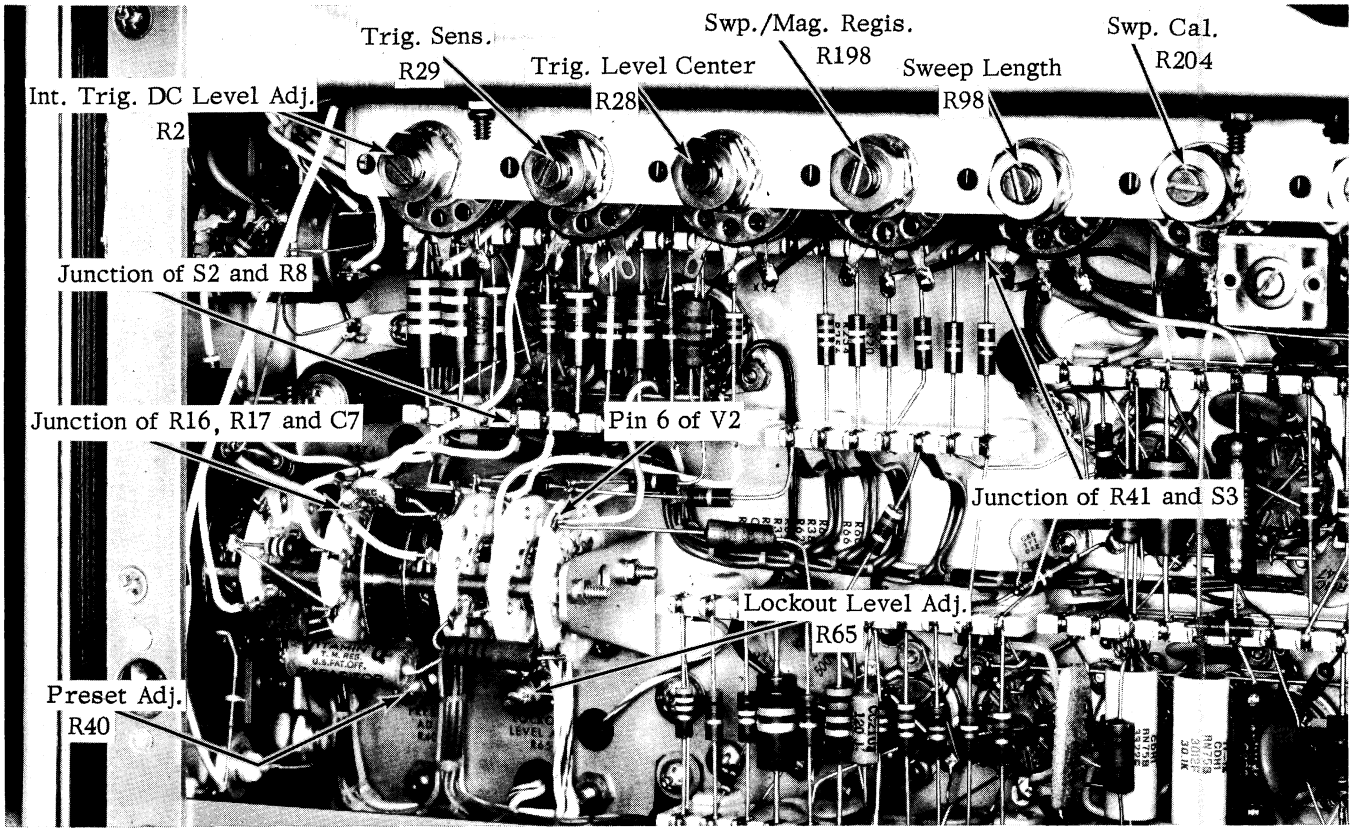



Fig. 7-11. Internal controls location on top front deck.

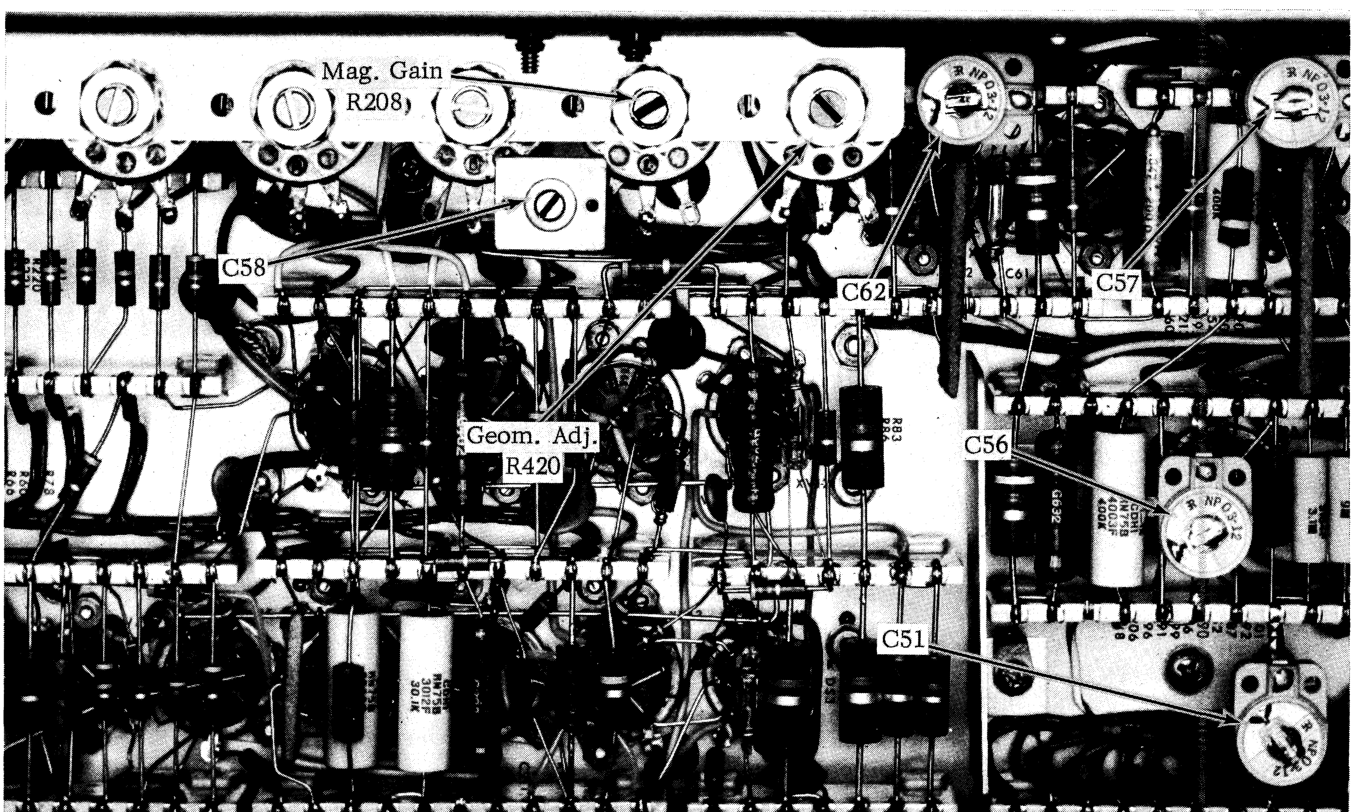



Fig. 7-12. Internal controls location on top central deck.

| | |
|---|---|
| MULTIPLIER | 5 |
| HORIZONTAL | MAIN SWEEP |
| DISPLAY | NORMAL |
| TRIGGER SLOPE | + EXT. |

**7-42.** Apply a 10 cps trigger pulse from the Type 180 or Type 180A to the TRIGGER INPUT connector (MAIN SWEEP). Adjust Main Sweep STABILITY and TRIGGERING LEVEL controls for triggered sweep. A visible trace should be found in a darkened room. It must be possible to adjust INTENSITY, FOCUS, and ASTIGMATISM for a sharp trace with no bright spot at the start of the sweep.

**7-43. Cathode Modulation Check**

**7-44.** From CALIBRATOR OUT connector insert a 20v signal into the CRT CATHODE connector. The trace should be modulated with normal intensity. The INTENSITY control should be about midscale.

**7-45.** Remove the coax cable and turn the AMPLITUDE CALIBRATOR OFF. Replace grounding Type BNC cover on the CRT CATHODE connector.

**7-46. FAN DRIVE SYMMETRY**

**7-47.** Using the test scope with the controls set for AC, + INT., 10 mSEC, and a standardized probe from the test scope input, check the frequency of the fan drive on the Type 945. The probe tip is touched to the spot marked 100 cps Test Point on Figure 7-6. Approximately 10 cycles should be observed on the 10 cm graticule with the 10 mSEC TIME/CM setting. To keep the +or- 5% accuracy, not more than 10.5 cycles per 10 cm or less than 9.5 cycles per 10 cm must be seen. If the frequency is outside of specifications, reset Freq. Adj., R437, (see Fig. 7-6) until the 100 cycles per second frequency is displayed on the test scope.

**7-48. VERTICAL AMPLIFIER GAIN PRELIMINARY**

**7-49.** Set front-panel controls as follows:

Type 945

| | |
|---|---|
| STABILITY | fully clockwise |
| HORIZONTAL | MAIN SWEEP |
| DISPLAY | NORMAL |
| TRIGGERING MODE | AUTO. |
| TRIGGER SLOPE | + INT. |
| TIME/CM | 1 mSEC |
| CALIBRATOR | .2 VOLTS |

Type MC

| | |
|---|---|
| AC/DC | DC |
| VOLTS/CM | .05 |
| VARIABLE | CALIBRATED (full right) |

**7-50.** Before proceeding with the calibration of the Vertical Amplifier the dc balance of the plug-in unit should be checked. Rotate the VARIABLE control; if any vertical displacement of the trace is apparent adjust the DC BAL control on the plug-in until the trace remains stationary as the VARIABLE control is rotated. Be sure to return the VARIABLE control to the CALIBRATED position after completing the adjustment.

**7-51. Vertical Amplifier Gain**

**7-52.** Install the Gain Adjust Adaptor between the plug-in preamplifier and the interconnecting socket, J7. Apply 0.2 volts of signal from the Calibrator to the connector on the Gain Adjust Adaptor and adjust STABILITY and TRIGGERING LEVEL controls for stable display. Adjust the Gain Adj. control, R236 seen in Fig. 7-2, for exactly 2 centimeters of vertical deflection.

> **NOTE:** This is the Gain Adj. control for the main Vertical Amplifier and not the one for the plug-in unit.

**7-53. DC Shift Comp. Adjustment**

**7-54.** Remove the Gain Adjust Adaptor and re-insert the Type MC Preamplifier. Free run the sweep with the STABILITY control turned fully clockwise. Position the trace to the top of the graticule. Use dc-coupling to apply a dc signal from an ohmmeter with the scale set for R x 1. After application of the negative voltage from the ohmmeter, adjust the sensitivity of the plug-in for full screen deflection of four centimeters.

**7-55.** The trace should be watched for 5 to 10 seconds after the removal of the signal from the INPUT connector to see that the trace does not drift more than one-half millimeter from the top of the graticule. If the trace drifts over this maximum amount the DC Shift Comp. control, R244 seen in Figure 7-2, should be adjusted carefully for as close to zero drift as possible.

## 7-56. TRIGGERING ADJUSTMENTS

### 7-57. Triggering Level Control Adjustments

**7-58.** Change the following controls:

| | |
|---|---|
| MULTIPLIER | 1 |
| TRIGGERING MODE | DC |
| TRIGGERING LEVEL (MAIN SWEEP) | 0 |
| STABILITY (MAIN SWEEP) | full left, but not PRESET position. |

**7-59.** Connect the dc voltmeter from the junction of R16, R17, and C7 shown in Figure 7-11 to ground. Set the voltmeter at the lowest voltage range and adjust the MAIN SWEEP TRIGGERING LEVEL control for a meter reading of exactly zero volts. If the TRIGGERING LEVEL knob does not read exactly zero at the zero position, loosen the set screw and reposition the knob.

### 7-60. Triggering Level Centering and Trigger Sensitivity (Main Sweep)

The Trigger Level Centering control sets the level of the trigger shaper stage so that no readjustment of the TRIGGERING LEVEL control is required as the TRIGGER SLOPE switch is changed from + or - slope. The Trigger Sensitivity control adjusts the sensitivity of the trigger shaper stage. If the sweep triggers erratically or on the wrong slope it may indicate this needs adjustment.

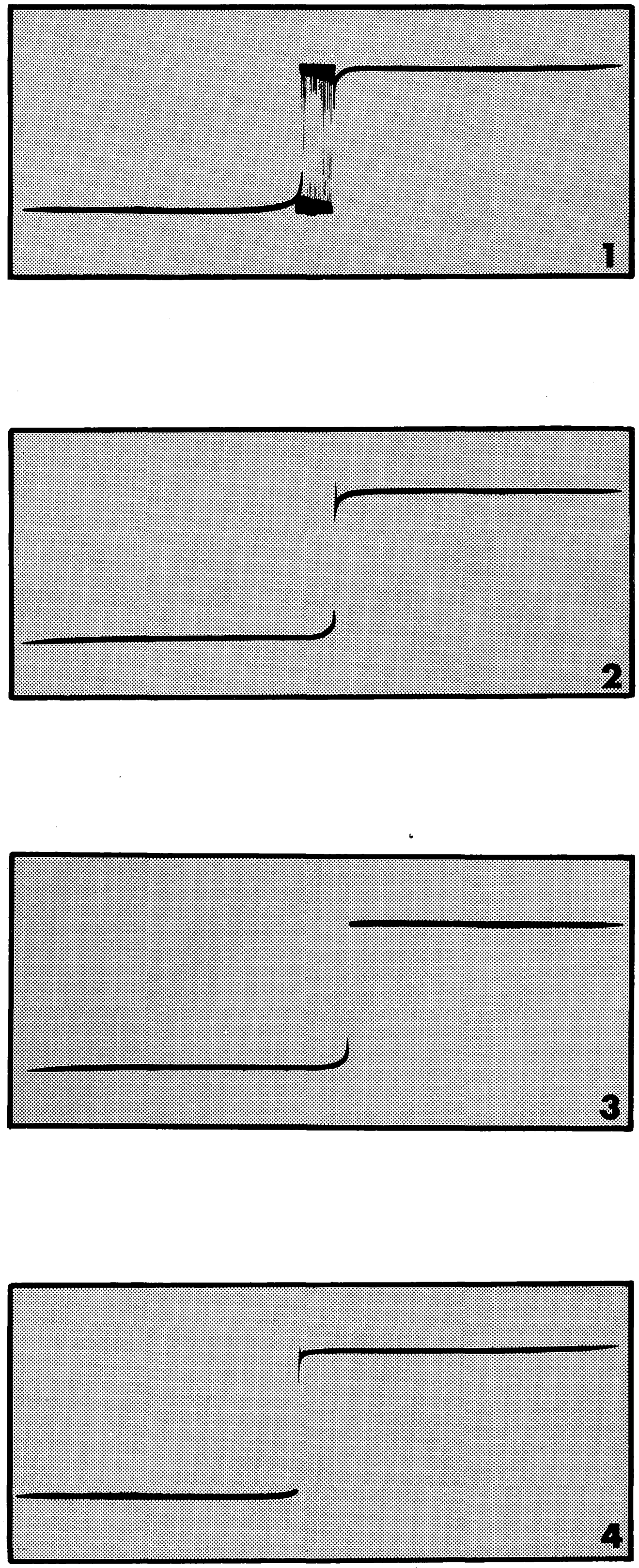



Fig. 7-13. Waveforms 1, 2, and 3 show changes in the waveform as the Trigger Sens. control is rotated clockwise. Waveform 4 is the display obtained when the control is adjusted correctly.

**7-61.** Set front panel controls as follows:

| | |
|---|---|
| AMPLITUDE CALIBRATOR | .2 VOLTS |
| TRIGGERING MODE | AC |
| STABILITY (MAIN SWEEP) | counterclockwise (not to PRESET) |
| TRIGGER SLOPE (MAIN SWEEP) | -EXT |
| TIME/CM (MAIN SWEEP) | 100 μSEC |
| MULTIPLIER | 5 |

**7-62.** Use clip lead to ground junction of R17, R16, and C7 that is shown in Figure 7-11. Do not remove until instructed to do so.

**7-63.** Set Trig. Sens., R29, (see Figure 7-11) to approximately the center of its range. Connect the CALIBRATOR OUT to Main Sweep TRIGGER INPUT. Use 10X probe with test scope set at 0.5 VOLTS/CM at 0.5 mSEC (or 100 μSEC with MULTIPLIER set at 5). Connect the probe tip to pin 6 of V2 (See Figure 7-11). Carefully adjust the Trig. Level Centering control, R28, (see Figure 7-11) to obtain a stable square-wave display on the test scope.

**7-64.** Rotate the Trig. Sens. control fully counterclockwise. Slowly rotate the Trig. Sens. control clockwise just to the point where the square wave reappears and becomes jitter-free. Do not turn the Trig. Sens. control any further to the right than is necessary to provide stable triggering. (See Figure 7-13.)

**7-65.** Switch TRIGGER SLOPE control from - to +EXT. and observe the test scope for stable triggering. It may be necessary to very slightly readjust Trig. Level Centering and/or Trig. Sens. controls to obtain stable triggering in both - and + slope positions. Remove the CALIBRATOR signal from the TRIGGER INPUT.

**7-66. Internal Trigger DC Level Adjustment**

**7-67.** This control sets the triggering level in the DC position of the TRIGGERING MODE switch. It is set so the sweep will trigger near 0 on the TRIGGERING LEVEL control when the trace is centered vertically.

**7-68.** Turn the STABILITY control fully clockwise to free run the sweep, the TRIGGER SLOPE switch to -INT and the TRIGGERING MODE switch to DC. Position the trace vertically to the exact center of the graticule and connect the dc meter between ground and the junction of R8 and S2 (see Figure 7-11). Set the meter to the lowest voltage range and adjust the Int. Trig. DC Level Adj., R2, shown in Figure 7-11 for exactly zero voltage. Remove grounding clip lead.

**7-69. Preset Adjust**

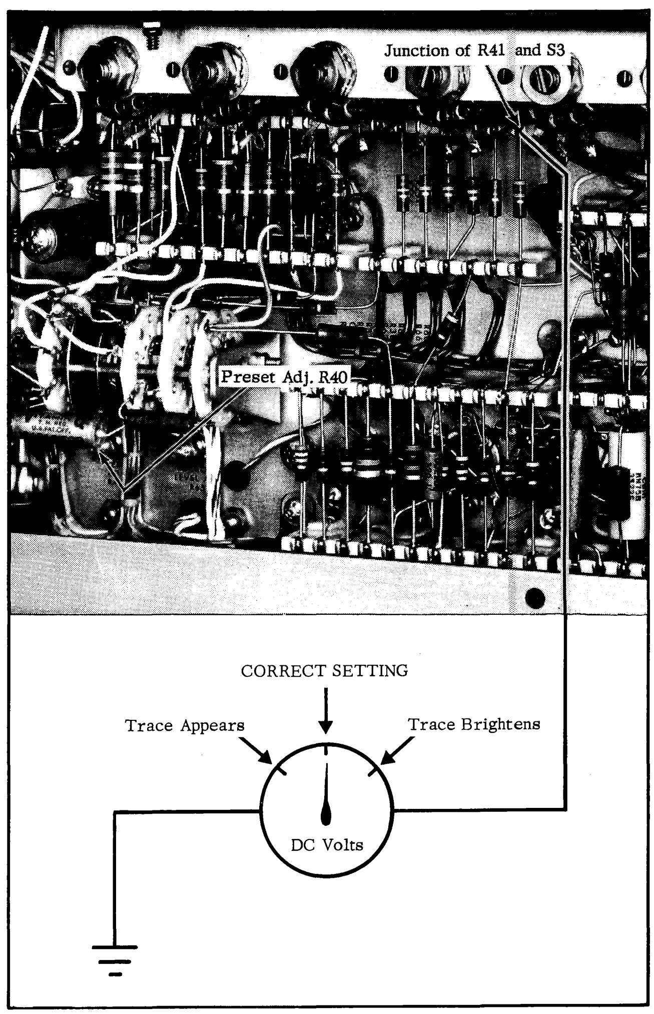



Fig. 7-14. Adjustment of the Preset Adjust control.

**7-70.** Set the TIME/CM switch at 100 μSEC, the TRIGGERING MODE switch at AUTO., and the TRIGGER SLOPE switch to +LINE.

> This adjustment MUST be made with a slow sweep speed such as the 100 μSEC setting.

**7-71.** Connect the dc voltmeter between the junction of R41 and S3, that is pictured in Figure 7-11, and ground. Rotate the Preset Adjust, R40, (see Figure 7-11), potentiometer counterclockwise to the full left position. Then, slowly rotate the control clockwise until a trace first appears and note the meter reading at this point. Continue to rotate the control until the trace brightens and again note the meter reading. Back the control in a counter-clockwise direction until the meter reads half-way between the two voltage readings noted. See Figure 7-14.

**7-72. HF SYNC Check**

**7-73.** Set the front panel controls as follows:

| | |
|---|---|
| TRIGGERING MODE | HF SYNC |
| TRIGGER SLOPE | +INT. |
| 5X MAGNIFIER | ON |
| MULTIPLIER | 1 |
| TIME/CM | .1 μSEC. |
| VOLTS/CM (CHANNEL A) | 2 VOLTS |

**7-74.** Apply a 30 mc signal from a constant amplitude signal generator, such as the Tektronix Type 190( ), to the vertical INPUT connector of CHANNEL A. Set the Type 190( ) attenuator to 10 VOLTS, peak-to-peak. A stable display should be obtainable with 2 cm vertical deflection by adjusting the Main Sweep STABILITY control. Strike the front panel at the top with the palm of the hand. Sync may be lost for a moment, but it should return immediately without changing the STABILITY setting. Remove the signal from the 190( ) to the vertical INPUT.

**7-75. SWEEP CIRCUIT ADJUSTMENTS**

**7-76. Swp. Cal. Adjustment**

**7-77.** The Swp. Cal. control adjusts the gain of the sweep amplifier to calibrate the low- and medium-speed sweeps.

**7-78.** Set the front panel controls as follows:

| | |
|---|---|
| TRIGGER SLOPE (MAIN SWEEP) | +INT |
| STABILITY (MAIN SWEEP) | counterclockwise (not to PRESET) |
| HORIZONTAL DISPLAY | DEL'G SWEEP |
| 5X MAGNIFIER | OFF |
| TIME/CM (MAIN SWEEP and DEL'G SWEEP) | 1 mSEC |

**7-79.** Connect the Time-Mark Generator, such as the Tektronix Type 180A or Type 181, to the CHANNEL A INPUT. Connect the VERTICAL SIGNAL OUT to the TRIGGER OR EXT SWEEP IN. Display 1-millisecond time markers, with second marker coincident with the 1 cm graticule line. Adjust the Swp. Cal. control, R204, that is shown in Figure 7-11 so the markers correspond to the graticule marks.

**7-80. Adjust Main Sweep Adj.**

**7-81.** Switch HORIZONTAL DISPLAY to MAIN SWEEP NORMAL. Adjust R82M (see Figure 7-2) to again align the 1-millisecond time markers with the graticule marks.

**7-82. Check the Main Sweep Rates, 1 mSec to 5 Sec** Set the front panel controls:

**TABLE 7-1**

| TIME/CM | MULTIPLIER | MARKERS | OBSERVE |
|---|---|---|---|
| 1 SEC | 1 | 1 SEC | 1 marker/cm |
| 1 SEC | 2 | 1 SEC | 2 markers/cm |
| 1 SEC | 5 | 5 SEC | 1 marker/cm |
| 100 mSEC | 1 | 100 mSEC | 1 marker/cm |
| 10 mSEC | 1 | 10 mSEC | 1 marker/cm |
| 1 mSEC | 1 | 1 mSEC | 1 marker/cm |
| 1 mSEC | 2 | 1 mSEC | 2 markers/cm |
| 1 mSEC | 5 | 5 mSEC | 1 marker/cm |

**7-83. Adjust C51**

**7-84.** Set MAIN SWEEP TIME/CM to 100 μSEC. Apply 10 MICROSECOND markers from the Type 180A to vertical INPUT (CHANNEL A) and adjust the triggering for a stable display. Turn the 5X MAGNIFIER to ON. Position the trace so the first marker is aligned with the center graticule line.

**7-85.** Switch the TIME/CM to 10 μSEC and check for horizontal shift of the first marker. If shift occurs, adjust C51, (see Figure 7-12) until the first markers at each sweep speed occur at the same point.

**7-86. Adjust Main Sweep Rates, 100μSEC CM, to 1μSEC CM**

**7-87.** Turn the 5X MAGNIFIER to OFF, MAIN SWEEP TIME/CM to 10 μSEC, MULTIPLIER to 1, and proceed with the following adjustments: See Figures 7-12 and 7-15.

**TABLE 7-2**

| TIME/CM | TYPE 180A | ADJUSTMENTS | OBSERVE |
|---|---|---|---|
| 10 μSEC | 10 MICROSECOND | C26F | 1 marker/cm |
| 1 μSEC | 1 MICROSECOND | C26H | 1 marker/cm |
| .1 μSEC MULT. at 5 | 1 MICROSECOND | C26J | 1 marker/2 cm |
| .1 μSEC | 10 MC | *C58 for linearity and C56 for time. | 1 cycle/cm |
| .1 μSEC 5X MAG. ON | 50MC** | C57 and C62 | 1 cycle/cm** |

*C58 only affects the first part of the display. There is considerable reaction between C56 and both C26J and C26H. The adjustments of C56 and C26J should be repeated back and forth several times to get optimum linearity with correct timing, after which C26H should be readjusted if necessary. Timing adjustments should be made between the first and ninth centimeter markings on the graticule.

**C57 and C62 should be set as nearly at the same capacity as possible. It may be necessary to slightly readjust C57 to get the best possible linearity. NOTE: Check linearity over entire sweep length, starting with the third cycle of display. Take the third cycle from the beginning of the waveform and place it under the first graticule line and then the ninth line. Next, take the cycle at the end and follow the same procedure. The Capacitors, C57 and C62 may have to be readjusted for best linearity.

**7-88. Adjust 5X Magnifier Gain**

**7-89.** Set controls as follows:

| | |
|---|---|
| HORIZONTAL DISPLAY | DEL'G SWEEP |
| TRIGGERING MODE | + INT. |
| TRIGGERING SLOPE | AC |
| 5X MAGNIFIER | ON |
| VOLTS/CM (CHANNEL A) | 2 VOLTS |
| TIME/CM (DEL'G SWEEP) | 1 mSEC |

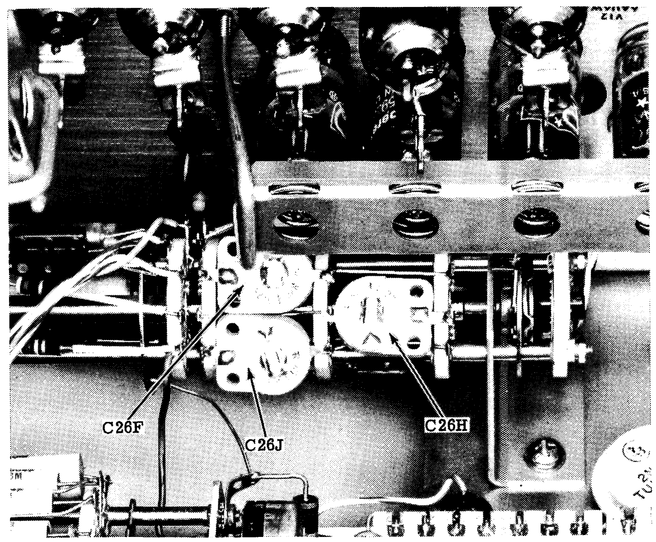



Fig. 7-15. Location of C26F, C26H and C26J.

**7-90.** Connect 1 MILLISECOND and 100 MICROSECOND markers from the 180A Time-Mark Generator to the CHANNEL A vertical INPUT connector. Adjust the delaying sweep trigger for a stable display. If necessary, adjust Mag. Gain, R208, seen in Fig. 7-12, to display 1 large marker every 5 cm, and 2 small markers every cm. Rotate the HORIZONTAL POSITION control knob to check the linearity over the whole sweep length.

**7-91. Adjust Sweep Magnifier Registration**

**7-92.** With the 5X MAGNIFIER ON, position the display so the first time-marker is directly behind the center graticule line. See Figure 7-16. Turn the MAGNIFIER OFF and adjust the Swp. Mag. Regis., R198, (see Figure 7-11) so the first time-marker falls directly behind the center graticule line. Readjust until inter-

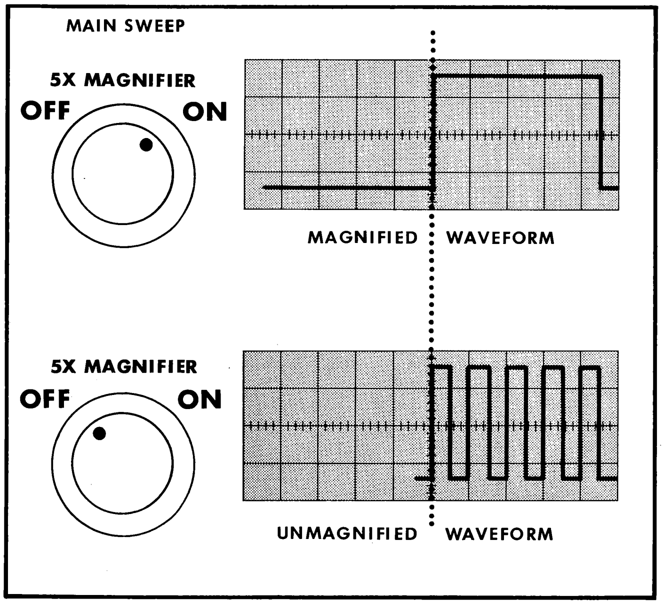



Fig. 7-16. When the adjustment of the Swp. Mag. Regis. control is adjusted properly, the portion of the displayed waveform at the exact center of the graticule remains stationary as the 5X MAGNIFIER is turned off and on.

action stops. Remove the time mark signal from the vertical INPUT.

**7-93. Adjust External DC Balance**

**7-94.** Connect a cable from the SAWTOOTH MAIN SWEEP connector to the CHANNEL A vertical INPUT. Switch the HORIZONTAL DISPLAY to EXT. SWEEP, and turn the 5X MAGNIFIER ON. Turn the MAIN SWEEP STABILITY control full right. Turn the HORIZONTAL POSITION control to the left to position a vertical trace to the left vertical graticule line. Now, adjust the Ext. Swp. DC Bal. control, R110 seen in Figure 7-18, for no horizontal shift of the trace while turning the EXT. SWEEP ATTEN. control.

**7-95. Set Lockout Level Adjust**

**7-96.** Make the following control settings:

| | |
|---|---|
| HORIZONTAL DISPLAY DELAYED | MAIN SWEEP |
| STABILITY (DEL'G SWEEP) | fully clockwise |
| TRIGGERING LEVEL (DEL'G SWEEP) | fully clockwise |
| SWEEP LENGTH (DEL'G SWEEP) | fully clockwise |
| DELAY-TIME MULTIPLIER | less than 9.50 |
| TIME/CM (both sweeps) | 100 $\mu$SEC |
| TRIGGERING LEVEL (MAIN SWEEP) | fully clockwise |
| STABILITY (MAIN SWEEP) | counterclockwise |

**7-97.** Slowly adjust the MAIN SWEEP STABILITY control until the trace first appears. Connect the test oscilloscope through a ten times (10X) probe to pin 3 of V5A using dc coupling, and observe the waveform as seen

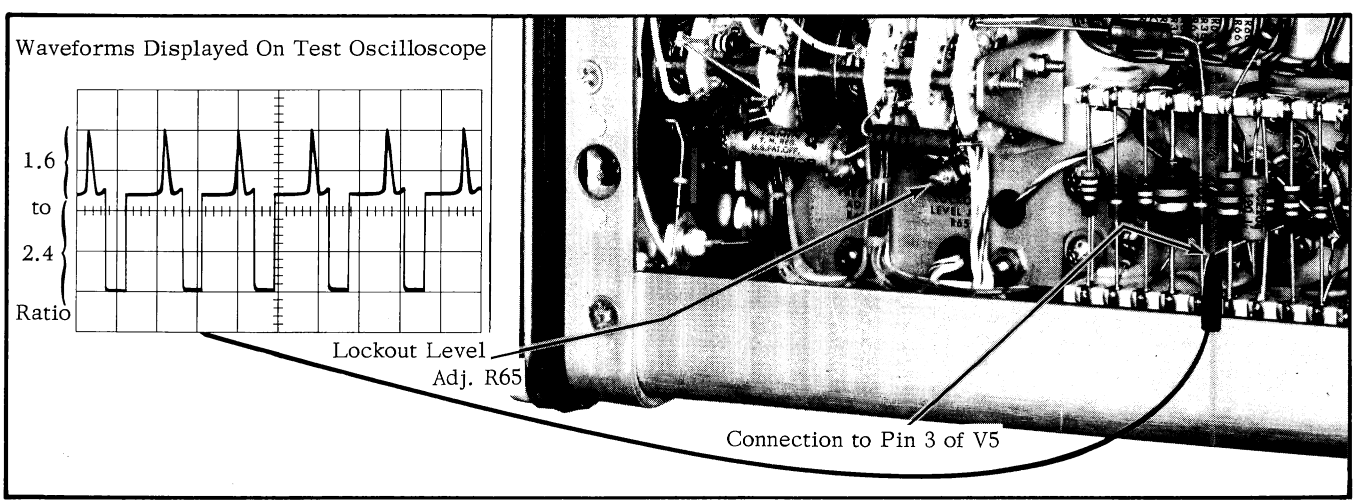



Fig. 7-17. Adjustment of the Lockout Level Adj. control.

in Figure 7-17. The displayed waveform should be made up in part by a square-wave and in part by a sawtooth waveform (see Figure 7-17). Adjust the test scope controls until there is a 4-centimeter vertical deflection of the waveform. Adjust the square-wave portion of the waveform to 2.4 centimeters with the Lockout Level Adj. control, R65, seen in Figure 7-17. During adjustments, the MAIN SWEEP STABILITY control should be checked frequently to be sure it is set where the sweep just runs.

**7-98. Single Sweep Check**

**7-99.** Set controls as follows:

| | |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| AC/DC (Type MC Preamp.) | AC |
| TRIGGERING MODE | AC |
| TRIGGER SLOPE | + INT. |
| AMPLITUDE CALIBRATOR | 1 VOLT |
| VOLTS/CM | 10 VOLTS |
| STABILITY (DEL'G SWEEP) | full counterclockwise |

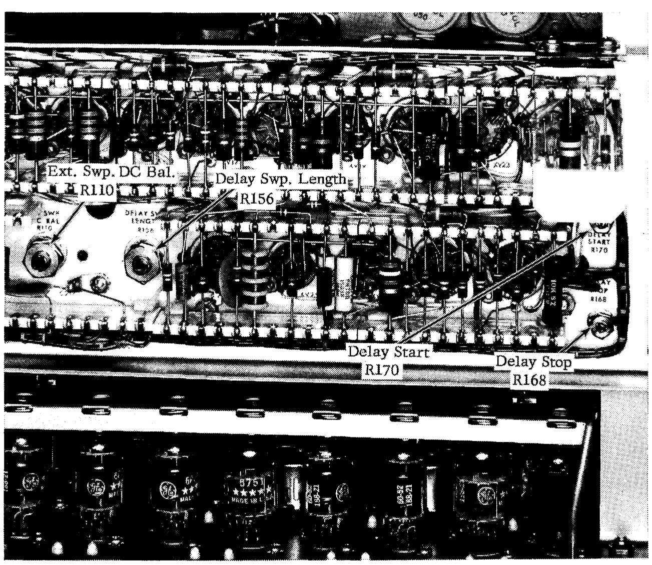



Fig. 7-18. Location of internal controls on the Delaying Sweep chassis on the scope right side.

**7-100.** Trigger the Type 945 Oscilloscope with the MAIN SWEEP STABILITY and TRIGGERING LEVEL controls. Switch the HORIZONTAL DISPLAY to MAIN SWEEP DELAYED. The display should disappear.

**7-101.** A single sweep of the display should now be produced each time the RESET button is pressed. Remove the signal from the INPUT and press the RESET button. The READY light should come on and remain on until the signal is reapplied to the INPUT

**7-102.** With the READY light out, turn the MAIN SWEEP STABILITY control slowly counterclockwise and watch the neon to make sure it remains extinguished. If it ignites, readjust the Lockout Level Adjust in the Paragraphs 7-96 and 7-97.

**7-103.** Turn AMPLITUDE CALIBRATOR OFF. Remove the cable from the CALIBRATOR.

**7-104. Check External Sweep Input Deflection Factor**

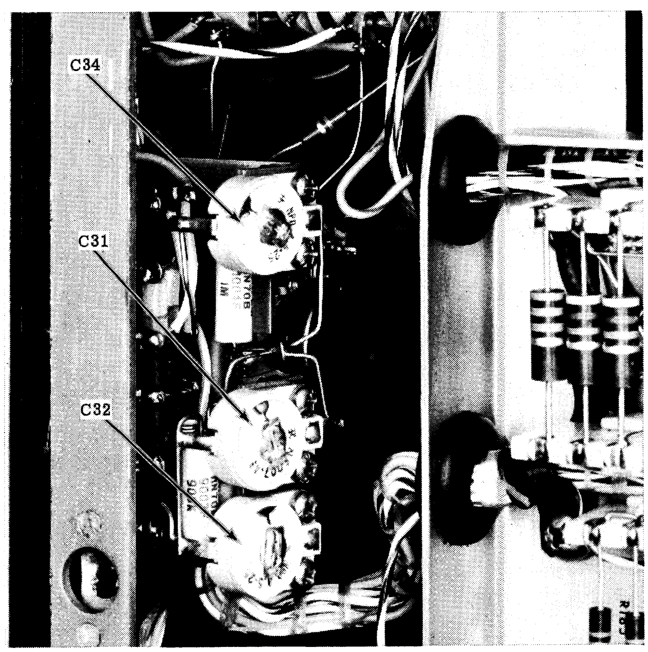



Fig. 7-19. External Sweep input compensation controls, --C34, C31 and C32.

**7-105.** With the conditions the same as shown in the following setup, connect a cable from CALIBRATOR OUT to TRIGGER OR EXT. SWEEP IN and to TRIGGER INPUT (MAIN

SWEEP). Connect a cable from SAWTOOTH MAIN SWEEP to CHANNEL A INPUT.

| | |
|---|---|
| AMPLITUDE CALIBRATOR | .2 VOLTS |
| VOLTS/CM (CHANNEL A) | 5 VOLTS |
| HORIZONTAL DISPLAY | EXT. SWEEP |
| TIME/CM (MAIN SWEEP) | 1 mSEC |
| 5X MAGNIFIER | ON |
| MULTIPLIER | 1 |
| ATTEN. | X1 |
| EXT. SWEEP ATTEN. | fully clockwise |
| TRIGGERING MODE | AC |
| TRIGGER SLOPE | +EXT. |

**7-106.** Obtain a stable waveform, using the Main Sweep TRIGGERING LEVEL and the STABILITY controls.

**7-107.** Increase the AMPLITUDE CALIBRATOR signal to 2.0 volts, set the ATTEN. at X10 and check the attenuator accuracy (+or- 2%). Return the X1 attenuation and rotate EXT. SWEEP ATTEN. fully counterclockwise. There should be approximately 8X attenuation.

**7-108. Adjust External Sweep Input Compensation**

**7-109.** Change front panel controls as follows:

| | |
|---|---|
| EXT. SWEEP ATTEN. | fully clockwise |
| AMPLITUDE CALIBRATOR | 5 VOLTS |

**7-110.** Connect CALIBRATOR OUT jack to TRIGGER OR EXT. SWEEP IN through a 47 $\mu\mu$f Input Capacitance Standardizer with BNC connector (Part No. 70-6004-00). Adjust C34 for best square wave. Now switch ATTEN. to X10, and increase AMPLITUDE CALIBRATOR to 50 VOLTS. Adjust C31 and C32 for best square wave. (See Fig. 7-19.) Remove connections.

**7-111. Swp. Length Adjustment**

**7-112.** Free run the sweep by turning the STABILITY control fully clockwise. Set the Swp. Length control, R98, (see Figure 7-11) for a sweep length of 10.5 centimeters.

**7-113. Check Delaying Sweep Rates, 1 mSEC to 10 mSEC**

**7-114.** Set controls as follows:

| | |
|---|---|
| HORIZONTAL DISPLAY | DEL'G SWEEP |
| TIME/CM (DEL'G SWEEP) | 1 mSEC |
| TRIGGERING MODE | AC |
| TRIGGER SLOPE | +INT. |
| 5X MAGNIFIER | OFF |
| VOLTS/CM (CHANNEL A) | 2 VOLTS |

**7-115.** Connect 1 MILLISECOND markers from the Type 180A to the vertical INPUT (CHANNEL A) and connect a cable from VERTICAL SIGNAL OUT to TRIGGER OR EXT. SWEEP IN. Adjust the DELAYING SWEEP triggering for a stable display

DELAYING SWEEP

| TIME/CM | MARKERS | OBSERVE |
|---|---|---|
| 1 mSEC | 1 mSEC | 1 marker/cm |
| 2 mSEC | 1 mSEC | 2 markers/cm |
| 5 mSEC | 5 mSEC | 1 marker/cm |
| 10 mSEC | 10 mSEC | 1 marker/cm |

**7-116. Check Time Delay Jitter**

**7-117.** Set the DELAYING SWEEP TIME/CM switch to 1 mSEC, the MAIN SWEEP TIME/CM switch to 1 $\mu$SEC and insert 1 MILLISECOND markers. The HORIZONTAL DISPLAY switch should be in the DEL'G SWEEP position and the triggering in AC, +INT. with the MAIN

SWEEP STABILITY control fully clockwise to free run the sweep. Trigger the sweep with the DELAYING SWEEP controls. Set the DELAY-TIME MULTIPLIER dial near 1.00, with the second time-marker in the brightened portion of the trace. With triggering set in this manner, switch the HORIZONTAL DISPLAY to MAIN SWEEP DELAYED and observe the horizontal jitter. The jitter should not exceed 5 mm (see Figure 7-20). Recheck the jitter at the 10th time-marker as follows.

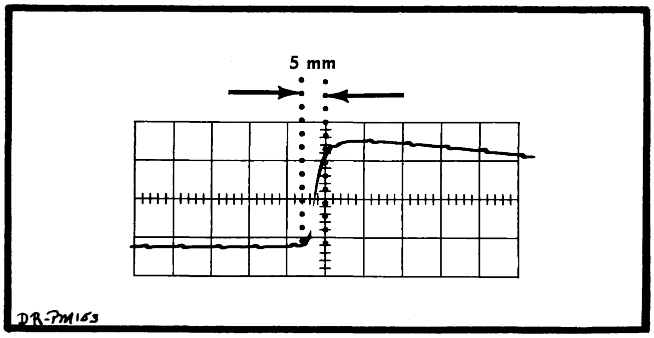



Fig. 7-20. Time delay horizontal jitter should not exceed 5 mm.

**7-118.** With the HORIZONTAL DISPLAY switch in the DEL'G SWEEP position, reset the DELAY-TIME MULTIPLIER dial near 9.00 with the 10th time-marker in the brightened portion of the trace. Switch the HORIZONTAL DISPLAY to MAIN SWEEP DELAYED and observe the horizontal jitter. This should not be more than 5 mm. If jitter exceeds 5 mm in either or both of the above cases, replacement of either V24, V25, or both, may be necessary to correct the condition.

**7-119. Set Delaying Sweep Length**

**7-120.** Place the HORIZONTAL DISPLAY switch at DEL'G SWEEP, the DELAYING SWEEP TIME/CM to .5 mSEC. Rotate the LENGTH control and check that the sweep length changes between 4 cm (+or- .5 cm) and 10 cm (-0 and +1 cm). If the control does not have the range necessary, adjust Delay Swp. Length, R156 in Figure 7-18, until the range is within limits.

**7-121. Set Delay Start and Delay Stop Adjustment**

**7-122.** Set the HORIZONTAL DISPLAY switch to DEL'G SWEEP, the DEL'G SWEEP TIME/CM switch to 500 μSEC. Connect a cable from the VERTICAL SIGNAL OUT to DELAYING SWEEP TRIGGER INPUT connector, and set the Delaying Sweep SLOPE to +. Set the TRIGGERING MODE switch to AC. Connect 500 μSEC markers from the Time-Mark Generator to CHANNEL A INPUT. Obtain a stable display with the triggering controls.

**7-123.** Set the controls as follows:

| | |
|---|---|
| HORIZONTAL DISPLAY | MAIN SWEEP DELAYED |
| TIME/CM (MAIN SWEEP) | 10 μSEC |
| STABILITY (MAIN SWEEP) | fully clockwise |
| TRIGGER SLOPE | +EXT. |
| DELAY-TIME MULTIPLIER | 1.00 |

**7-124.** Adjust the Delay Start, R170 in Figure 7-18, so the leading edge of the second marker occurs at the start of the sweep. You can check which marker is on the sweep by switching back to DEL'G SWEEP and observing which marker is brightened.

**7-125.** Turn the DELAY-TIME MULTIPLIER dial to 9.00 and adjust the Delay Stop, R168 in Figure 7-18, until the leading edge of the 10th marker occurs at the start of the sweep. Due to interaction between the Delay Start and Delay Stop these two adjustments may need to be repeated several times.

**7-126. Adjust Delaying Sweep Rates (50μSEC and 5μSEC)**

**7-127.** Set the controls as follows:

| | |
|---|---|
| HORIZONTAL DISPLAY | DEL'G SWEEP |
| TIME/CM (DELAYING SWEEP) | 50 μSEC |
| TIME/CM (MAIN SWEEP) | 1 μSEC |

**7-128.** Display 50 MICROSECOND markers. Set the DELAY-TIME MULTIPLIER dial (about 1.00) so the leading edge of the second marker occurs at the start of the sweep and note the dial reading.

**7-129.** Set the dial so it reads 8.00 plus the original reading and adjust C42D (see Figure 7-21) so the leading edge of the tenth marker occurs at the start of the sweep. If a change is made there may be some change in the original reading and the step should be repeated until interaction stops.

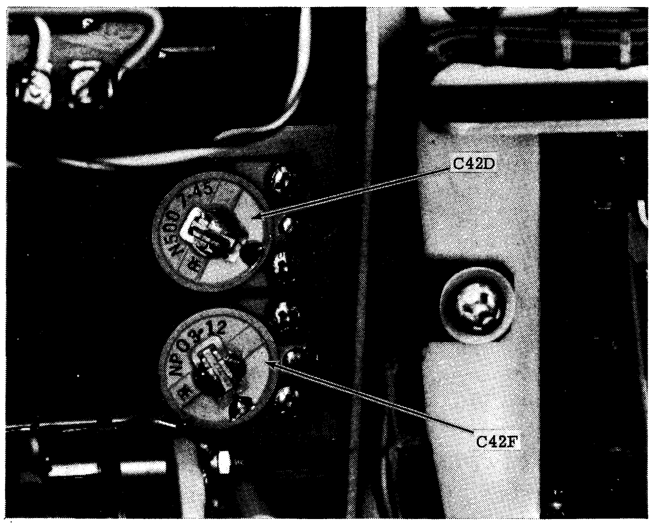



Fig. 7-21. Locations of C42D and C42F for adjusting Delaying Sweep rates, 50 μSEC and 5 μSEC.

**7-130.** Repeat the procedure just given with the DELAYING SWEEP TIME/CM switch at 5 μSEC and the markers changed to 5 MICROSECOND. The adjustment should be made with C42F, see Figure 7-21.

### 7-131. DELAY LINE AND HIGH FREQUENCY COMPENSATION

**7-132.** Delay Line adjustments are probably the most difficult adjustments to make. This is due to interaction between the large number of controls. In general, it is not necessary to completely readjust the delay line. Rather it is a case of occasionally touching up the line for best results.

**7-133.** There are 50 variable capacitors, and two variable inductors associated with the delay line. There are six variable inductors and nine variable capacitors in the vertical amplifier. These delay line and vertical amplifier variable inductors and capacitors interact considerably.

**NOTE**

Before attempting to adjust the delay line, be sure that it requires adjustment. The following steps provide a check of the adjustments of the delay line and vertical amplifier high-frequency compensation.

**7-134.** To check the adjustment of the high-frequency controls of the vertical amplifier and delay line, apply a fast-rising square wave to the vertical INPUT connector of the Type MC Preamplifier, and observe the resulting trace on the crt. The input signal should have a risetime of no more than 7 nanoseconds (millimicroseconds). A Tektronix Type 107 Square-Wave Generator is recommended for this check.

#### 7-135. Displaying the Test Signal

**7-136.** Using a BNC/UHF Adaptor (type UG 255/U), attach a Tektronix Type B52R Terminating Resistor to the CHANNEL A INPUT connector of the Type MC Unit. With a 50Ω coaxial cable, apply an input signal from a Type 107 Square-Wave Generator to the terminating resistor on the CHANNEL A connector. Use either a 50Ω coax with BNC connectors and two BNC/UHF Adaptors (type UG 273/U), or use a Type P52 coax with UHF connectors.

**7-137.** Set front-panel controls as follows:

| | |
|---|---|
| (Type 945) | |
| HORIZONTAL DISPLAY | MAIN SWEEP NORMAL |
| TIME/CM (MAIN SWEEP) | .1 μSEC |
| MULTIPLIER | 2 |
| 5X MAGNIFIER | OFF |
| TRIGGER SLOPE | + INT. |
| TRIGGERING MODE | AC |
| (Type MC) | |
| MODE | A ONLY |
| POLARITY | NORMAL |
| AC/DC Switch | DC |
| VOLTS/CM | .05 |
| VARIABLE | CALIBRATED |

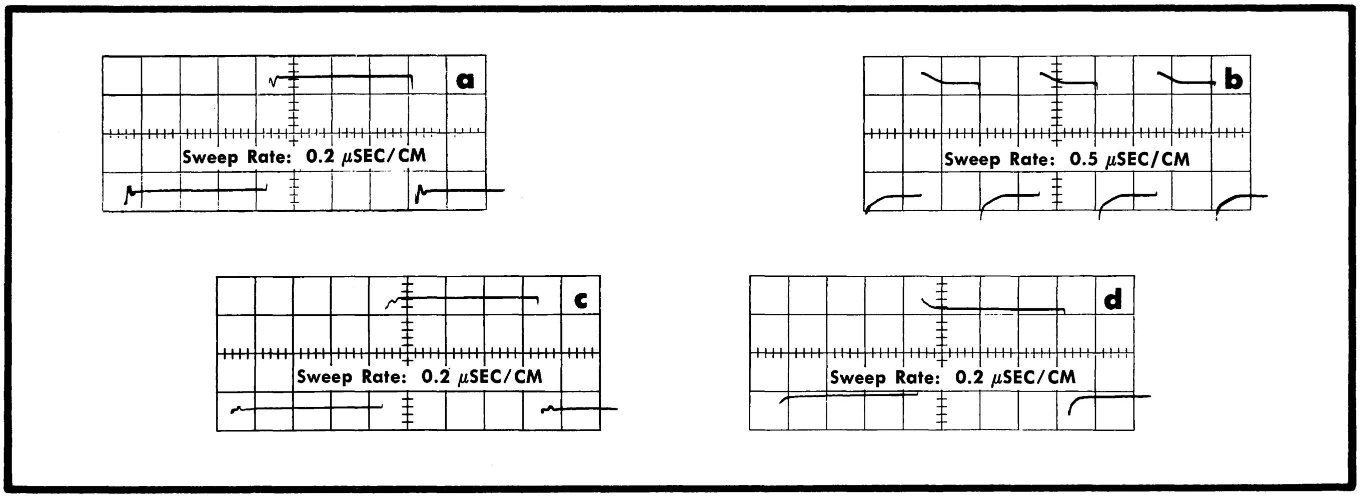



Fig. 7-22. Waveforms showing effects of defective tubes in Vertical Amplifier. (a) "notch" effect from Driver Stage tubes, (b) slope caused by "cathode interface" in Input Amplifier or Distributed Amplifier, (c) rolloff effect from a shorted Distributed Amplifier tube, (d) slope and decreased amplitude from a "cold" Distributed Amplifier tube.

**7-138.** Turn ON the instruments. After a warm-up period adjust the STABILITY and TRIGGERING LEVEL controls for a stable display with the triggering point about 1/2 cm to the left of the rising portion of the waveform. Adjust the AMPLITUDE control of the Type 107 to obtain approximately 3 cm of vertical deflection. Position the leading edge of the waveform near the center of the graticule.

**7-139. Check for Trouble in the Vertical Amplifier**

**7-140.** Carefully examine the waveform presentation for irregularities in the shape of the square wave. See Figure 7-23 for significant regions to check on the step function. If there are no irregularities, overshoot or ringing exceeding 1 tracewidth in the top of the pulse, the adjustments of the trimmer capacitors in the delay line and distributed amplifier are adequate. Also check the risetime as follows.

**7-141.** With the MAIN SWEEP TIME/CM switch at .1 μSEC, the MULTIPLIER at 1 and the MAGNIFIER ON, determine the risetime of the displayed signal. Referring to Figure 7-24, adjust signal amplitude to obtain exactly 2.5 cm of vertical deflection centered on the graticule. The top and the bottom of the waveform should appear 1.25 cm above and below the graticule center, respectively. "Standardized" risetime measurement (10% to 90% amplitude) is made in the center of the graticule, being measured horizontally between the two points where the trace crosses the 2nd and 4th horizontal graticule lines. This measurement must not be longer than 15 nanoseconds for the Type 945/Type MC combination (0.75 cm horizontal deflection at this sweep rate, 0.02 μSEC/CM). If the risetime does not exceed this limit the peaking coil adjustments are satisfactory.

**NOTE**

If the preceding two checks indicated satisfactory adjustment of the delay line and vertical amplifier high-frequency compensation, do not change any adjustments or switch any tubes. If any changes are made, the vertical system including the delay line will have to be completely re-checked, and adjusted where necessary. If the waveshape indicates there is no trouble in the vertical high-frequency adjustments, omit Paragraphs 7-142 through 7-155).

**7-142.** If the risetime of the system was longer than 15 nanoseconds, remove the Type MC Unit and replace it with a Type P Test Unit

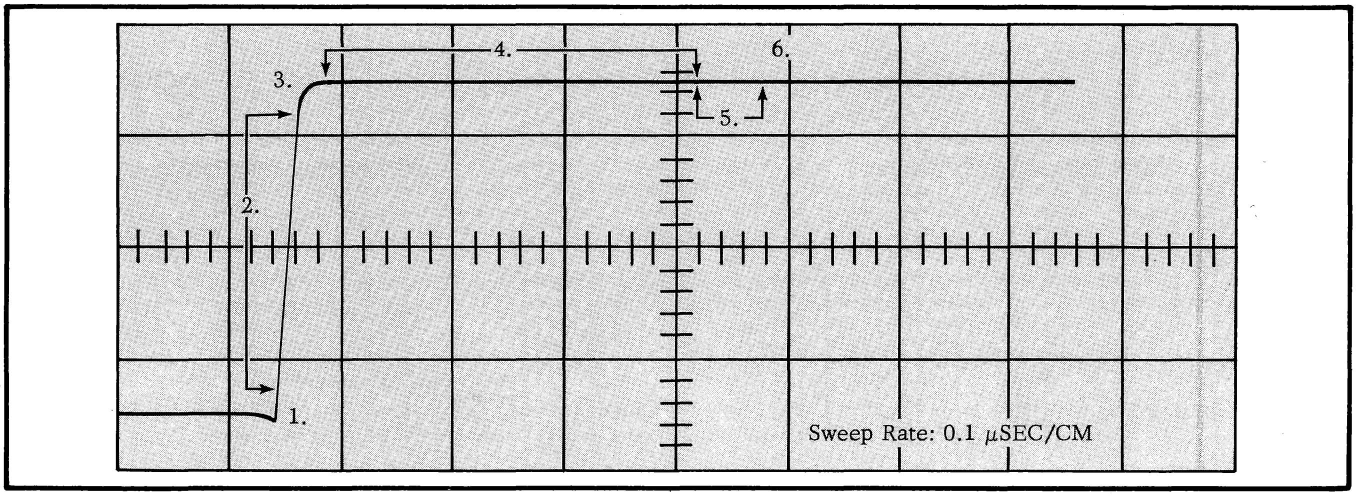



Fig. 7-23. Significant portions of waveform used in checking Vertical Amplifier. (1) "preshoot". About 5% is normal, (2) risetime, 10% to 90%. Related to front corner adjustment, (3) "front corner" and first 50 nsec. Should appear square, with overshoot and ringing no more than one tracewidth. Affected by peaking coils in the Main Unit Vertical Amplifier and in the plug-in Preamplifier, (4) first 350 nsec region. Normally affected only by Delay Line adjustments, (5) 350-400 nsec region. Affected by plate-line capacitors in Distributed Amplifier, (6) termination region. Primarily affected by adjustment of termination network.

to determine whether the difficulty is in the oscilloscope or in the plug-in unit. With the MAIN SWEEP TIME/CM switch at .1 μSEC, the MULTIPLIER at 1 and the MAGNIFIER ON as before, adjust for a display as in Para. 7-141 and measure the risetime again. If it is now no longer than 10 nanoseconds, the trouble which was found previously is probably in the Type MC Unit.

**7-143.** If difficulties were indicated in steps 7-139 through 7-142, continue checking and adjusting the vertical amplifier as described in the following paragraphs, where applicable. In general the high-frequency compensation checks and adjustments should be made of the complete system with the Type MC Unit installed. In checking the system the Type P Test Unit is used only to distinguish between trouble in the oscilloscope and trouble in the preamplifier. The Type P Unit will also be used later if adjustment of risetime is needed.

### 7-144. Check for Defective Tubes in the Vertical Amplifier

**7-145.** Unless otherwise specified, the connections and control settings for the following checks will be as listed in Paragraphs 7-136 and 7-137. A square-wave signal is applied from a Type 107 Square-Wave Generator.

**7-146.** Before changing any high-frequency adjustments of the delay line and distributed amplifier, check the vacuum tubes in the vertical amplifier. Most troubles in the vertical circuitry are caused by vacuum tube failure. When changing tubes do not mix brands in any pair or in the distributed amplifier.

**7-147.** Referring to figure 7-7, decrease the heater voltage to 11.5 volts with the Heater Adjust Control, R450. Measure the heater voltage across R440. Increase the voltage on the heaters to 13.7 volts while watching the crt display for overshoot or irregularities which change amplitude with a change in heater voltage.

**7-148.** A "notch" or dip immediately following the leading edge of the pulse (Figure 7-22 a) usually indicates a defective input driver tube. Replace one or both of tubes V34 and V36 and repeat the check.

**7-149.** Increase the sweep rate to .5 μSEC/CM and vary the heater voltage as before. Check for a change in slope in the first cm following the leading edge, or for a slope with a change in amplitude of the remainder of the pulse. See Figure 7-22 b. A slope in the first portion of the pulse indicates "cathode interface" is present in either the input amplifier or the distributed amplifier tubes of the oscilloscope, or the input amplifier tubes in the preamplifier.

**7-150.** To eliminate cathode interface from the vertical amplifier, first check to see if it is in the Type MC Unit. Remove the Type MC from the oscilloscope and install the Type P Test Plug-In. Set the MAIN SWEEP TIME/CM switch at .1 μSEC, the MULTIPLIER at 5 and the MAGNIFIER OFF. Adjust the AMPLITUDE control on the Type P to obtain approximately 3 cm of vertical deflection. Repeat the check for slope, as in Para. 7-149.. If slope is no longer evident in the waveform, the interface was probably in the input amplifier of the Type MC Unit.

**7-151.** If cathode interface was not eliminated by use of the Type P Unit, check the input amplifier tubes. Remove the Type P Plug-In and insert the Type MC in the oscilloscope again, connected as before (Para. 7-145). Replace both input amplifier tubes, V32 and V33. Matching of these tubes is critical--replace only with new aged-and-matched tubes, available from Tektronix. Recheck for the slope effect from cathode interface, as in Para. 7-149.

**NOTE**

Return the heater voltage to normal, exactly 12.6 volts, as described in Para. 7-15.

**7-152.** If the preceding checks did not eliminate slope in the waveform, the cathode interface is in the tubes of the distributed amplifier, V40 through V51. Since this condition develops at approximately the same rate in all 12 of these tubes, it is advisable to replace them all at the same time.

**7-153.** The tubes of the distributed amplifier are arranged in pairs which balance each other and must be closely matched in order to avoid distortion of high-frequency signals. Operating pairs are positioned side-by-side on the chassis. For example, V40 and V46 are a pair, V41 and V47 are a pair, etc. See Paragraphs 7-165 through 7-169 for selecting tubes for balance.

**7-154.** After changing distributed amplifier tubes, if the trace is not positionable over the entire graticule, replace the tubes one at a time until the trace is fully positionable.

**7-155.** If rolloff was found in the initial check for defective vacuum tubes (Fig. 7-22 c), it may have been caused by a single defective distributed amplifier tube. Remove the signal cable and the B52R Terminating Resistor from the INPUT connector to eliminate any input signal. Turn the MAIN SWEEP STABILITY control fully clockwise to free run the sweep, and center the trace vertically. With a DC voltmeter, check the voltage at each suppressor grid (V40 through V51) for +175 volts. Replace any tube which does not have at least +165 volts on the suppressor, if measuring with a 20,000Ω/volt voltmeter. With a 5,000Ω/volt meter, minimum voltage is +150 volts.

### 7-156. Balance of the Vertical Amplifier

**7-157.** Replacement of any tubes will require re-checking the balance of the vertical amplifier. Balance should also be checked in the periodic calibration.

**7-158.** A typical "resistive shorting strap" mentioned in the following paragraphs is shown in Figure 5-21. The "resistive shorting bar" also mentioned may be made by attaching an insulating handle to a 27Ω or a 47Ω 1/2-watt resistor.

### 7-159. Checking Distributed Amplifier Bias

**7-160.** Turn the STABILITY control fully clockwise and set the sweep rate at 1 mSEC/CM or faster. Center the free-running trace on the graticule. Short together the two D A grid lines, T4 and T5 shown in Figure 5-23. This may be done by connecting a resistive shorting strap between pin 1 of V35 and pin 1 of V37.

With a DC voltmeter, measure the grid bias of each pair of tubes, V40 through V51, between the shorting strap and either cathode (pin 2). Replace one or both tubes of any pair not having bias between 1 and 2 volts.

**7-161.** Bias, and the balance which is dependent on bias, changes during the first few hours of operation of new distributed amplifier tubes. Aged and checked tubes are available from Tektronix for this purpose, and are necessary for very critical work. It is suggested that new unaged tubes be operated for about 10 hours in the instrument before making final bias measurements and final balance adjustments.

**7-162.** Remove the shorting strap before proceeding.

**7-163. Checking Overall Vertical Balance**

**7-164.** Center a free-running trace on the graticule. Determine the electrical center of the crt by shorting the vertical deflection plates together (not to ground) with a small screwdriver placed between the terminals of coils L8 and L9. (See Figure 5-20 for position of coils). Note the position of the trace, then remove the short and re-position the trace to the electrical center just determined. Overall balance of the vertical is now determined by shorting together terminals 1 and 3 of the plug-in interconnecting socket with a resistive shorting bar. The trace should not shift more than 1 cm from electrical center. If the overall unbalance exceeds this limit, check the balance of the distributed amplifier as follows.

**7-165. Checking Distributed Amplifier Balance**

**7-166.** Position a free-running trace at the electrical center of the crt (Para. 7-164). Short together the two common grid lines of the D A (see Para. 7-160) and note the trace shift from electrical center. This shift must not exceed 2 mm. Remove the shorting strap.

**7-167.** If the trace shifted more than 2 mm in the previous check, determine the balance of each pair of tubes. This is done by individually biasing each pair to cutoff, by raising the voltage on the common cathode to +225 volts, and noting the shift in the trace. Voltage may be applied with a voltmeter lead. The +225-volt source and the common cathode leads are shown in Figures 5-22 and 5-23. The trace shift caused by any pair should not exceed 2 mm. It is usually convenient to work from one end of the distributed amplifier and record the amount and direction of trace deflection caused by each pair of tubes. Replace one or both tubes of any pair producing more than 2 mm trace shift. Recheck the bias (Para. 7-158 through 7-161) if tubes are replaced. After checking all six pair of tubes and replacing where necessary, recheck the total balance of the distributed amplifier.

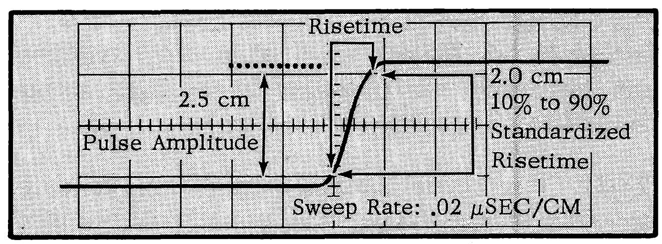



Fig. 7-24. Waveform for determining risetime.

**7-168.** If there is still more than 2 mm total trace shift, it may be eliminated by exchanging the two tubes of a single pair. For example, switch V40 and V46. Switching the two tubes reverses the direction of the trace shift produced by the pair. Total trace shift is approximately equal to the sum of the individual shifts. In order to produce a balance, the total deflection in one direction must equal the deflection in the other direction. Inspection of the record of amount and direction of trace deflection will show which pair should have its tubes interchanged to produce a balanced condition.

**7-169.** Exchange the two tubes of the selected pair and check the total balance of the D A again. If the trace shift is still in excess of 2 mm, it will be necessary to interchange another pair.

**7-170. Checking Driver Stage Balance**

**7-171.** Center a free-running trace on the graticule with the positioning controls. Check the balance of the input driver stage by shorting together the two grids (pin 2 of V34 and V36) with a resistive shorting bar. The trace should not shift more than 1/2 cm. If shift exceeds this amount replace one or both of the driver tubes to achieve balance.

**7-172. Checking Input Amplifier Balance**

**7-173.** Check the overall balance of the vertical amplifier again as in Para. 7-164. Since the D A and the driver tubes are now balanced, most of the unbalance now results from the input amplifier tubes. If trace shift is more than 1 cm, try interchanging the two tubes of this pair, V32 and V33. If this does not reduce trace shift to less than 1 cm, replace both of the tubes with new aged-and-matched tubes, available from Tektronix.

**7-174. Display-Linearity Check**

**7-175.** With a small cable, apply a 10 VOLT Amplitude Calibrator signal to the CHANNEL A INPUT. Set the front-panel controls for MAIN SWEEP NORMAL, TIME/CM switch at 10 $\mu$SEC, MULTIPLIER at 1, MAGNIFIER OFF, and adjust the VOLTS/CM and VARIABLE controls for exactly 2 cm vertical deflection. Adjust the STABILITY and TRIGGERING LEVEL controls to produce a stable display, and observe the trace closely as it is positioned to the top and to the bottom of the graticule. If there is compression or expansion exceeding 1/2 mm at the top or bottom, recheck Geometry Adj. control setting, D A bias and regulated power supplies. Also check the dc level at pins 1 and 3 of the preamplifier interconnecting socket for about +67 volts with the trace centered.

**7-176. Adjusting Vertical Controls**

**7-177.** Check and adjust the dc balance, ver-

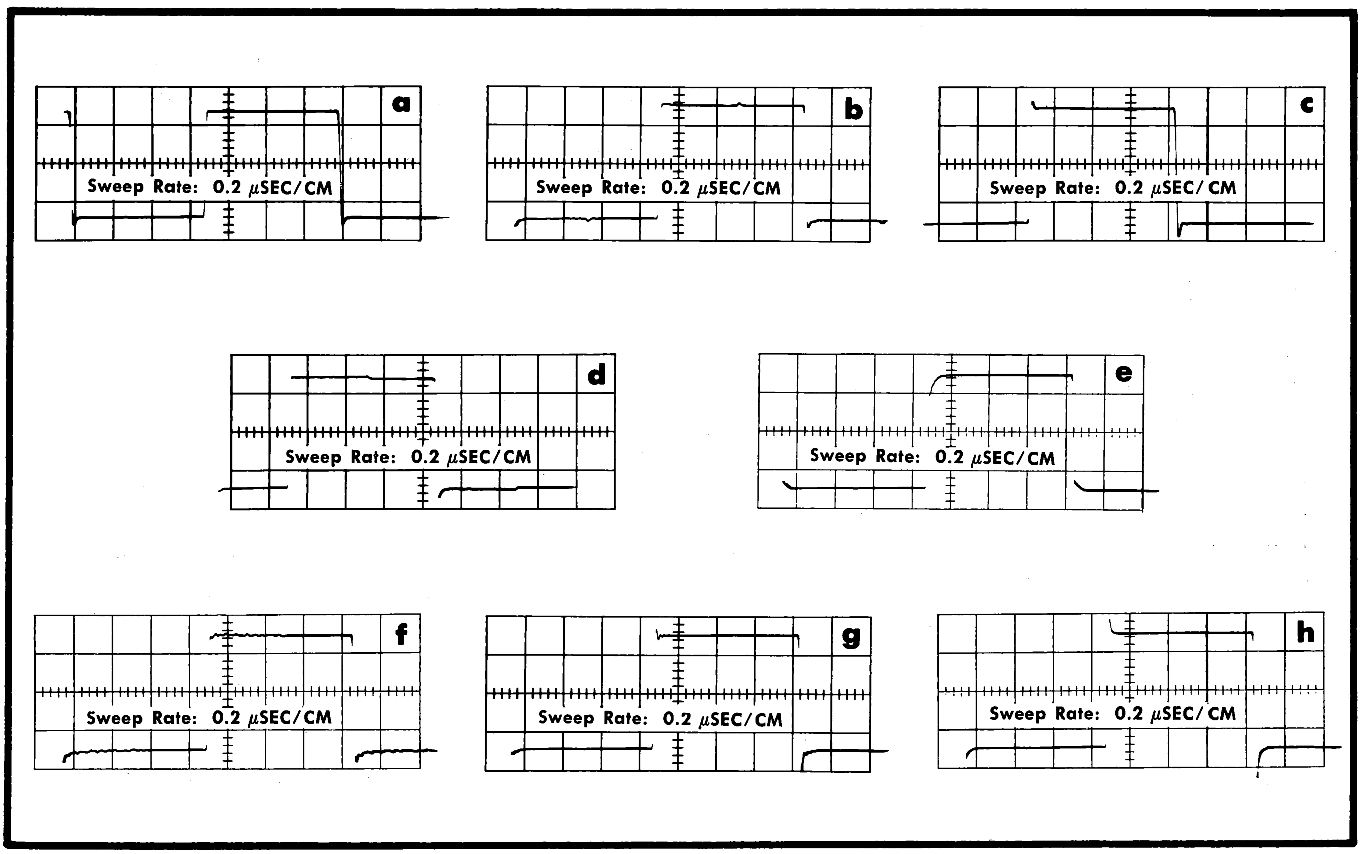



Fig. 7-25. Effects of specific misadjustments in Delay Line and Vertical Amplifier peaking coils. (a) waveform display of properly adjusted instrument, (b) excessive termination bump, (c) slight spike or slight rounding of corner, (d) first 0.4 $\mu$sec slightly higher or lower than display average, (e) rounded front corner, inadequate risetime and bandwidth, (f) irregularities in first 350 nsec region, (g) overshoot and ringing, (h) spiking, bandwidth too great.

tical amplifier gain and dc shift compensation, as in Paragraphs 7-48 through 7-55.

**7-178. Setting the High-Frequency Adjustments**

**7-179. Recheck the Waveform Characteristics**

**7-180.** With the Type 107 input to the Type MC/Type 945 combination, as in Paragraphs 7-137 through 7-141, recheck the characteristics of the square-wave display. Refer also to Figures 7-23 through 7-25. If no tube troubles were found or if some were found and corrected but there is still irregularity in the waveform presentation, the delay line and high-frequency compensation must be checked, and adjusted where necessary. However, if no difficulty is now indicated, omit Paragraphs 7-181 through 7-192.

**7-181.** The peaking coils in the vertical amplifier system are T1, T2, L3, L4, L6, L7, L8 and L9. Do not change the physical positions of the peaking-coil slugs before tuning the instrument. If a peaking coil has been replaced, however, the slug should be preset. All of these coils operate in pairs, so if any adjustment is made on a coil, it will be necessary to adjust the paired coil an equal amount. To determine the preset position when replacing a coil, match the slug position in the other coil of the pair. To find the slug setting in the coil which has not been removed, slowly turn the screw counterclockwise with a peaking tool, counting the number of turns necessary for the slug to touch bottom. Back off the screw the same number of turns to its original position. Now turn the screw of the new coil counterclockwise until the slug touches bottom, then back it off the same number of turns as the other coil.

**7-182.** To check for gross misadjustments of the trimmer capacitors, C112 through C179, refer to Figures 7-26 and 7-27 for the approximate positions in a properly adjusted instrument. The trimmer capacitors in the first section of the delay line (C112 through C157 at the rear of the scope) follow a wavy pattern as in Figure 7-27. Those closer to the crt, C160 through C179, appear fairly even. The last 3 or 4 (C176 through C179) may be irregular. No screw should extend as far as the hole in the delay-line shield.

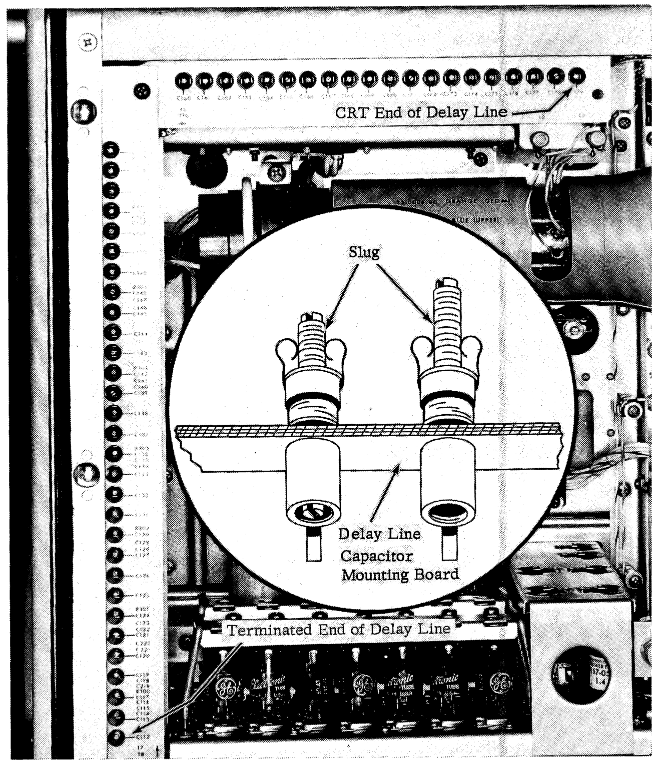



Fig. 7-26. Approximate maximum and minimum settings of trimmer capacitors in the Delay Line.

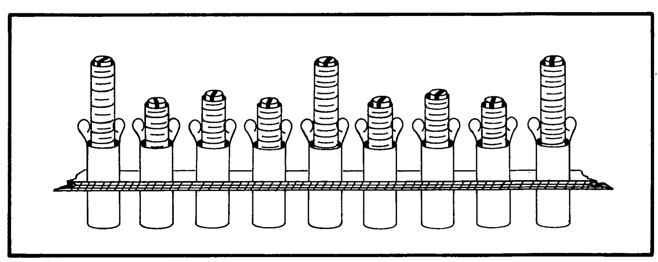


Fig. 7-27. Normal adjustment pattern of trimmer capacitors in first half of Delay Line. (Trimmers in final portion of Delay Line, near CRT, should be fairly even.)

**7-183. Tuning the Delay Line**

**NOTE**

Adjustments of the delay line and high-frequency compensation require very good eyesight. Each adjustment makes only a very slight change in the display. Do not attempt to tune the delay line unless you have excellent vision.

**7-184.** When rechecking (Para. 7-180), if the display had any of the following characteristics, need for a complete re-tuning is indicated: overshoot and ringing (Figure 7-25 g); many wrinkles, bumps or irregularities (Figure 7-25 f); or first 0.4 μSEC higher or lower than rest of display (Figure 7-25 d). Rolloff indicates either a general de-tuned condition or misadjusted peaking coils.

**7-185.** Turn OFF the 5X MAGNIFIER, set the TIME/CM switch at the .1 μSEC and the MULTIPLIER at 1. To determine the location of the point on the display affected by a particular capacitor, touch the tuning tool to the delay-line capacitor and watch the display for a very slight dip produced by the capacitance of the metal wire in the tool. If this dip is not obvious, rotate the slug slightly to locate the position on the waveform.

**7-186.** When adjusting capacitors in the delay line do not overadjust. Since the capacitors interact, it will be necessary in removing a bump to underadjust each capacitor at first. Later adjustments of neighboring capacitors will change the apparent adjustment of any particular capacitor.

**7-187.** Check for excessive termination bump (Figure 7-25 b). This is caused by misadjusted reverse termination capacitors, plate-line capacitors and the 3 or 4 delay-line capacitors nearest the crt (C82 through C84, C93 through C99 and C176 through C179, respectively). Readjust these capacitors while watching the effect on the oscilloscope display. If the delay line is generally de-tuned, there will be a slight termination bump which cannot be removed with these capacitors. This bump will disappear as the line is tuned.

**7-188.** For eliminating irregularities from the waveform, begin with the termination capacitors, C82-C84, and work toward the crt end of the delay line (plate-line capacitors, then C112 to C179). Check back and forth between the three fastest sweep rates while tuning the delay line in order to maintain a level display while eliminating small irregularities. (TIME/CM switch at .1 μSEC, MULTIPLIER at 1, 2 and MAGNIFIER OFF).

**7-189.** When the "front corner" (Figure 7-23, 3) is reached, capacitor adjustments are made for the squarest corner without overshoot. Do not adjust the peaking coils with the Type MC Unit.

**7-190. Adjusting Risetime**

**7-191.** Before adjusting the peaking coils, check the risetime again with the Type MC Unit in the scope. If the risetime is now 15 nanoseconds or less the adjustment is satisfactory.

**7-192.** If risetime with the Type MC is more than 15 nanoseconds, remove the Type MC and install the Type P Test Unit in the oscilloscope. Risetime is affected by the coil adjustments in the input amplifier, driver stage, termination network and crt input. To improve risetime, however, only the coils in the input amplifier (T1 and T2) need be adjusted. Decrease the risetime by turning the screws of these inductors counterclockwise equally a slight amount. This will cause some spiking which can be corrected with the three or four delay-line capacitors nearest the crt (C176-C179). If the spiking cannot be tuned out with these capacitors, the coils were turned too far and must be backed off slightly. Recheck the risetime (not longer than 10 nanoseconds with the Type P Unit) and repeat the adjustment if necessary.

**7-193.** The front corner and first 10 nanoseconds following the leading edge are also affected by the peaking coils in the Type MC Unit. Refer to the Calibration section of the Type MC Instruction Manual for the adjustment of these coils if there is rolloff, spiking or irregularity which cannot be eliminated with the Type 945 adjustments. Adjustment of these coils may necessitate readjustment of the last 3 or 4 capacitors at the crt end of the delay line.

**7-194. Measurement of Bandwidth**

**7-195.** Bandwidth measurement is a check on a correctly adjusted vertical system. Leaving the B52R terminating resistor on the Type MC, remove the coaxial cable and connect the Attenuator head from a Tektronix Type 190( ) Constant Amplitude Sine-Wave Generator. With the VOLTS/CM switch on the Type MC Plug-in set at .05, and the VARIABLE control in CALIBRATED position, apply a 50 kc signal. Adjust the amplitude of the display to exactly 3 cm of vertical deflection with the controls of the Type 190( ) and its Attenuator. Increase the signal frequency to about 24 MC without changing amplitude adjustments. Determine the point at which the display amplitude is down 30% by varying the frequency slightly and noting the precise frequency at which the vertical deflection is exactly 2.1 cm on the graticule. This is the upper limit of the band-pass and must be at least 24 MC, but not more than 27 MC.

**7-196.** If the 30%-down point is less than 24 MC, check and adjust the risetime again. See Para. 7-188 and 7-189.

**7-197.** If the 30%-down point is greater than 27 MC, inductors T1 and T2 are overpeaked. Repeat the risetime measurement and adjust to reduce peaking. See Figure 7-25 h.

**7-198. Final Adjustment Check**

**7-199.** Disconnect the Type 190( ) Attenuator combination and recheck the characteristics of the square-wave display with input from the Type 107 to the Type MC/Type 945 system, as in Paragraphs 7-137 through 7-141. If properly adjusted, there should be no wrinkles or irregularities in the display, and the rise-time should be 15 nanoseconds or less.

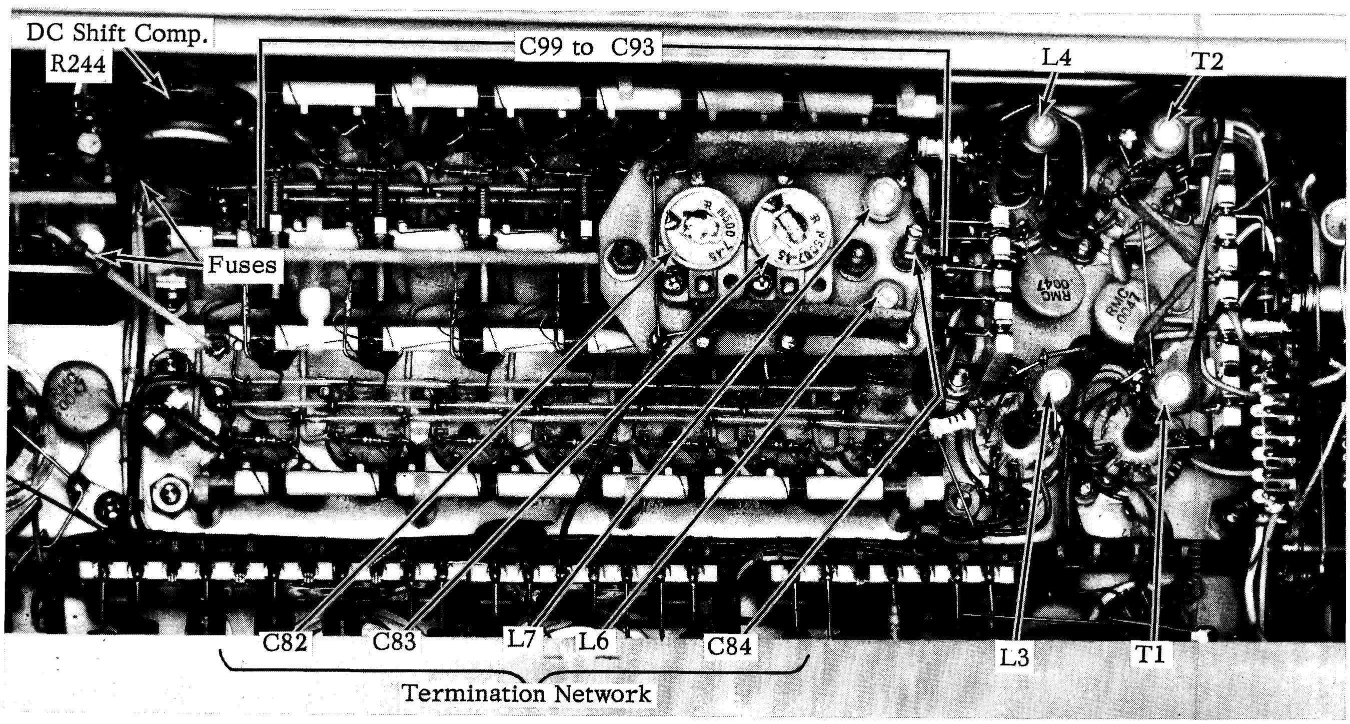



Fig. 7-28. Location of internal adjustments in the Vertical Amplifier section.

# SECTION 8

# INTRODUCTION TO PARTS LIST

**8-1. GENERAL**

**8-2.** Sections IX and X contain the parts lists for the TEKTRONIX Type 945 Oscilloscope manufactured by Tektronix, Inc., Beaverton (Portland), Oregon . Section IX covers all electrical items of the oscilloscope. Section X covers accessories and certain high-replacement-factor mechanical items.

**8-3. EXPLANATION OF ELECTRICAL PARTS LIST COLUMNS.** (Section XI)

**8-4. GENERAL.** The electrical items shown in Section IX are arranged in reference designation order. Each column is explained below:

a. REF DESIG (Reference Designation). The reference designations in this column are in accordance with MIL-STD-16.

b. EFF S/N RANGE (Effective Serial Number Range). Entries in this column indicate the serial-number range to which the part applies. If no entry appears in this column, the part is applicable to all serial numbers.

c. ITEM NAME. The item name consists of the basic noun plus modifiers as listed in Federal Cataloging Handbook H6-1. When no applicable item name appears in H6-1, an appropriate item name has been assigned to the item.

d. VALUE. The electrical value of the component is shown in this column.

e. TOLERANCE. The figure shown in this column is the amount of allowable variation from the specified value.

f. VOLTAGE. The direct-current working voltage rating is shown in this column.

g. ITEM CHARACTERISTIC. This column gives additional modifiers not included in the item name, but which further define the item.

h. DESCRIPTION. This column contains additional characteristics which might be pertinent to the identification of the part.

i. WATTAGE. The figure shown in this column is the maximum power dissipation for which the component is rated.

j. MFR CODE NO. (Manufacturers Code Number). Codes for this column are extracted from Cataloging Handbooks H4-1 and H4-2. See paragraph 8-7.

k. SOURCE INSPECTED (WHEN SPEC ) (Source Inspected [When Specified] ). This column contains the Tektronix, Inc., part number for goverment source-inspected items which may be specified in certain government contracts.

l. MFR P/N OR MIL DESIG. (Manufacturers Part Number or Military Designations). This column lists either the approved commercial manufacturers part number or the MIL part designations as prescribed by the applicable specification.

m. TEK UNWIRED PART NO. (Tektronix, Inc., Unwired Part Number). This part number applies to a rotary switch only.

n. TEK WIRED PART NO. (Tektronix, Inc., Wired Part Number), This part number applies to a rotary switch assembly consisting of an unwired rotary switch and one or more electrical components mounted thereon.

o. TEKTRONIX PART NO. (Tektronix, Inc., Part Number). This column gives the part number assigned to this item by Tektronix, Inc. When ordering parts from Tektronix, Inc., be sure to list all eight digits and dashes of the part number.

**8-5. EXPLANATION OF MECHANICAL AND ACCESSORIES PARTS LIST.** (Section XI)

**8-6. GENERAL.** The mechanical items and accessories shown in Section IX are not arranged in a particular order. For further identification many high-replacement-factor items are referenced by figure and index numbers to illustrations figure 10-1 thru 10-5. Each column is explained below:

a. FIG. AND INDEX NO. (Figure and Index Number). These columns give the figure and index no. of the illustration for further identification or placement.

b. EFF S/N RANGE (see paragraph 8-4b)

c. ITEM NAME (see paragraph 8-4c)

d. DESCRIPTION (see paragraph 8-4h)

e. MFR CODE NO. (see paragraph 8-4j and paragraph 8-7)

f. MFR P/N OR MIL DESIG (see paragraph 8-41)

g. TEKTRONIX PART NO. (see paragraph 8-4o)

**8-7. FEDERAL SUPPLY CODE NUMBERS FOR MANUFACTURERS.**

**8-8. GENERAL.** The following manufacturer's codes which appear in Cataloging Handbook H 4-1 and H 4-2 are used in Section IX and X. They are listed here for your convenience.

| CODE | MFR |
|---|---|
| 00373 | GARLOCK, INC., ELECTRONIC PRODUCTS DIVISION, CAMDEN, N.J. |
| 01121 | ALLEN-BRADLEY CO., MILWAUKEE, WISCONSIN |
| 01295 | TEXAS INSTRUMENTS, INC., TRANSISTOR PRODUCTS DIVISION, DALLAS, TEXAS |
| 02660 | AMPHENOL-BORG ELECTRONICS CORP., BROADVIEW (CHICAGO), ILLINOIS |
| 02735 | RCA SEMICONDUCTOR AND MATERIALS DIVISION OF RADIO CORP. OF AMERICA, SOMERVILLE, N. J. |
| 02799 | ARCO CAPACITORS, INC., LOS ANGELES, CALIFORNIA |
| 03797 | ELDEMA CORPORATION, EL MONTE, CALIF. |
| 03877 | TRANSITRON ELECTRONIC CORP., WAKEFIELD, MASS |
| 04713 | MOTOROLA, INC., SEMICONDUCTOR PRODUCTS DIVISION, PHOENIX, ARIZONA |
| 06151 | DIALTRON CORPORATION BROOKLYN, N. Y. |
| 08806 | GENERAL ELECTRIC CO., MINIATURE LAMP DEPARTMENT OF LAMP DIVISION OF CONSUMER PRODUCTS GROUP CLEVELAND, OHIO |
| 12697 | CLAROSTAT MFG. CO., INC., DOVER, N. H. |

| | |
|---|---|
| 33173 | GENERAL ELECTRIC CO., RECEIVING TUBE DEPARTMENT OF ELECTRONIC COMPONENTS DIVISION OF ELECTRONIC, ATOMIC AND DEFENSE SYSTEMS GROUP, OWENSBORO, KENTUCKY |
| 56289 | SPRAGUE ELECTRIC CO., NORTH ADAMS, MASS. |
| 71400 | BUSSMAN FUSE DIVISION OF MCGRAW EDISON CO., ST. LOUIS, MO. |
| 71450 | CTS CORP., ELKHART, INDIANA |
| 71482 | CLARE, C.P., AND CO., CHICAGO, ILLINOIS |
| 71785 | CINCH MFG. CORP., DIVISION OF UNITED-CARR FASTENER CORP., CHICAGO, ILLINOIS |
| 72982 | ERIE RESISTOR CORP., ERIE, PA. |
| 75915 | LITTELFUSE, INC., DES PLAINES, ILLINOIS |
| 78488 | STACKPOLE CARBON CO., ST. MARYS, PA. |
| 80009 | TEKTRONIX, INC., BEAVERTON, OREGON |
| 80131 | ELECTRONIC INDUSTRIES ASSOCIATION, WASHINGTON, D.C. |
| 81073 | GRAYHILL, INC., LA GRANGE, ILLINOIS |
| 81349 | U.S. GOVERNMENT MANUFACTURERS, DEPARTMENT OF DEFENSE ESTABLISHMENTS, DEPARTMENT OF DEFENSE, MILITARY SPECIFICATIONS, PROMULGATED BY STANDARDIZATION DIVISION, DEPARTMENT OF DEFENSE, ARMED FORCES SUPPLY SUPPORT CENTER. |
| 83298 | BENDIX CORP., RED BANK DIVISION RED BANK (EATONTOWN), N. J. |

| | |
|---|---|
| 83330 | SMITH, HERMAN H., INC. BROOKLYN, N. Y. |
| 91662 | ELCO CORPORATION, PHILADELPHIA, PA. |
| 93410 | STEVENS MFG. CO., INC., MANSFIELD, OHIO |
| 94154 | TUNG-SOL ELECTRIC, INC., NEWARK, N. J. |
| 94222 | SOUTHCO DIVISION OF SOUTH CHESTER CORP., LESTER, PA. |
| 95712 | DAGE ELECTRIC CO., INC., BEECH GROVE, INDIANA |

## 8-9. ABBREVIATIONS USED IN PARTS LIST

**8-10. GENERAL.** Many of the abbreviations used in the parts list are not in accordance with MIL-STD-12. Listed below are all the abbreviations with their correct identity.

| ABBREVIATIONS | DEFINITION |
|---|---|
| ALUM | ALUMINUM |
| AC | ALTERNATING CURRENT |
| AMP | AMPERE |
| BNC | BABY SERIES "N" CONNECTOR |
| X | BY |
| CAP. | CAPACITOR |
| CRT | CATHODE RAY TUBE |
| CER | CERAMIC |
| COMP | COMPOSITION |
| CONN | CONNECTOR |
| CPS | CYCLES PER SECOND |
| °C | DEGREES CENTIGRADE |
| °F | DEGREES FAHRENHEIT |
| DIA | DIAMETER |
| ELECTRO | ELECTROLYTIC |
| FXD | FIXED |
| H | HIGH OR HEIGHT |
| HP | HORSEPOWER |
| IN. | INCH OR INCHES |
| ID | INSIDE DIAMETER |
| LG | LENGTH OR LONG |
| μf | MICROFARAD |
| μh | MICROHENRY |
| μμf | MICROMICROFARAD |
| MEG | MILLION |
| MA | MILLIAMPERE |
| – | MINUS |
| MTG | MOUNTING |
| Ω | OHM |
| OD | OUTSIDE DIAMETER |
| P | PAPER |
| % | PERCENT |
| PH | PHASE |
| PLSTC | PLASTIC |
| + | PLUS |
| ± | PLUS OR MINUS |
| PWR | POWER |
| RF | RADIO FREQUENCY |
| R | RADIUS |
| RECP | RECEPTACLE |
| RES | RESISTOR |
| RPM | REVOLUTIONS PER MINUTE |
| RMS | ROOT MEAN SQUARE |
| SOC | SOCKET |
| SQ | SQUARE |
| SUP | SUPPLY |
| THK | THICK |
| THD | THREAD |
| - | TO |
| XMFR | TRANSFORMER |
| V | VOLTS |
| VDC | VOLTS DIRECT CURRENT |
| W | WIDE, WIDTH OR WATT |
| WW | WIREWOUND |

This change sheet lists changes that have been made to the parts list for the Tektronix Type 945 Oscilloscope that have occurred since the printing cut-off date.

1. In Section 8, page 8-4, paragraph 8-10, column 4, line 3, change MILLION to read: "MILLION OHMS."

2. In Section 9, page 9-9, Ref Desig C206 thru C216, immediately after existing note--encapsulated high-voltage power supply add the following: "(See Ref Desig A1)."

3. In Section 9, page 9-26, Ref Desig V34 and V36, in Eff S/N Range column add: "101-203" (two places) and add double asterisks immediately before Tektronix Part No. 60-0002-01 in last column (two places). Add new line items immediately below existing V34 and V36 line items to read as follows:

| Ref Desig | Eff S/N Range | Item Name | Source Inspected (when Spec. by Contract) | Mfr Code No. | Mfr P/N Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| V34 | 204-up | Electron Tube | 60-0022-00 | 80131 | 7308 | 60-0022-01 |
| V36 | 204-up | Electron Tube | 60-0022-00 | 80131 | 7308 | 60-0022-01 |

At bottom of page 9-26 immediately below existing footnote add another footnote as follows:

"**Recommended replacement for V34 and V36 is Type 7308 (P/N 60-0022-01)."

# SECTION 9
# ELECTRICAL PARTS LIST

## Power Supply

| Ref Desig | Eff S/N Range | Item Name | Voltage | Mfr Code No. | Tektronix Part No. |
|---|---|---|---|---|---|
| A1 | | Pwr sup, high voltage, encapsulated | 10,000V | 80009 | 72-0009-05 |

## Motor

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Tektronix Part No. |
|---|---|---|---|---|---|
| B1 | | Motor, a c | $\frac{10\text{-}10}{10\text{-}10}$ vac, rms, 100 cps, 2500 rpm, 2 ph, .01 hp | 80009 | 58-0003-00 |

## Capacitors

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C1 | | Cap., fxd, cer dielectric | 5 μμf | 10% | 500 v | 81349 | CC21SH050D | 40-0017-00 |
| C2 | | Cap., fxd, paper dielectric | .0047 μf | 20% | 600 v | 81349 | CP09A1KF472M | 42-0005-00 |
| C3 | | Cap., fxd, cer dielectric | 100 μμf | 5% | 500 v | 81349 | CC26UJ101J | 40-0027-00 |
| C4 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C5 | | Cap., fxd, cer dielectric | 47 μμf | 5% | 500 v | 81349 | CC21UJ470J | 40-0023-00 |
| C6 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C7 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C8 | | Cap., fxd, cer dielectric | 22 μμf | 5% | 500 v | 81349 | CC21UJ220J | 40-0021-00 |
| C9 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C10 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C11 | | Cap., fxd, cer dielectric | .01 μf | +100% −20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C12 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C13 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C14 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C15 | | Cap., fxd, cer dielectric | 12 μμf | 5% | 500 v | 81349 | CC21UJ120J | 40-0019-00 |
| C16 | | Cap., fxd, cer dielectric | 27 μμf | 5% | 500 v | 81349 | CC21UJ270J | 40-0022-00 |
| C17 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C18 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C19 | | Cap., fxd, cer dielectric | 8 μμf | ±.5 μμf | 500 v | 81349 | CC21CH080D | 40-0018-00 |
| C20 | | Cap., fxd, cer dielectric | 8 μμf | ±.5 μμf | 500 v | 81349 | CC21CH080D | 40-0018-00 |
| C21A | | Cap., fxd, paper dielectric | .22 μf | 20% | 200 v | 81349 | CP09A1KC224M | 42-0004-00 |
| C21B | | Cap., fxd, paper dielectric | .022 μf | 20% | 200 v | 81349 | CP09A1KC223M | 42-0002-00 |
| C21C | | Cap., fxd, paper dielectric | .0022 μf | 20% | 600 v | 81349 | CP09A1KF222M | 42-0003-00 |
| C21D | | Cap., fxd, mica dielectric | 220 μμf | 5% | 500 v | 81349 | CM20D221J | 43-0002-00 |
| C22 | | Cap., fxd, cer dielectric | .0047 μf | +100% —20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C23 | | Cap., fxd, cer dielectric | 82 μμf | 5% | 500 v | 81349 | CC26UJ820J | 40-0024-00 |
| C24 | | Cap., fxd, cer dielectric | 18 μμf | 5% | 500 v | 81349 | CC21UJ180J | 40-0020-00 |
| C25 | | Cap., fxd, cer dielectric | .0047 μf | +100% —20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C26A, B, C, | | Cap., fxd, plstc dielectric | 1x.1x.01 μf | .5% | 500 v | 80009 | | 44-0001-00 |
| C26D | | Cap., fxd, plstc dielectric | .001 μf | .5% | 500 v | 80009 | | 49-0001-00 |
| C26E | | Cap., fxd, mica dielectric | 82 μμf | 5% | 500 v | 81349 | CM20D820J | 43-0001-00 |
| C26F | | Cap., variable, cer dielectric | 4.5-25 μμf | | 500 v | 81349 | CV11A250 | 45-0001-00 |
| C26G | | Cap., fxd, mica dielectric | 82 μμf | 5% | 500 v | 81349 | CM20D820J | 43-0001-00 |
| C26H | | Cap., variable, cer dielectric | 4.5-25 μμf | | 500 v | 81349 | CV11A250 | 45-0001-00 |
| C26J | | Cap., variable, cer dielectric | 3-12 μμf | | 500 v | 81349 | CV11A120 | 45-0006-00 |
| C27 | | Cap., fxd, cer dielectric | 82 μμf | 5% | 500 v | 81349 | CC26UJ820J | 40-0024-00 |
| C28 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C29 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C30 | | Cap., fxd, cer dielectric | 39 μμf | 5% | 500 v | 81349 | CC21UJ390J | 40-0025-00 |
| C31 | | Cap., variable, cer dielectric | 7-45 μμf | | 500 v | 81349 | CV11C450 | 45-0003-00 |
| C32 | | Cap., variable, cer dielectric | 4.5-25 μμf | | 500 v | 81349 | CV11A250 | 45-0001-00 |
| C33 | | Cap., fxd, cer dielectric | 100 μμf | 2% | 350 v | 81349 | CC32CG101G | 40-0036-00 |
| C34 | | Cap., variable, cer dielectric | 4.5-25 μμf | | 500 v | 81349 | CV11A250 | 45-0001-00 |
| C35 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C36 | | Cap., fxd, cer dielectric | 22 μμf | 5% | 500 v | 81349 | CC21UJ220J | 40-0021-00 |
| C37 | | Cap., fxd, cer dielectric | 47 μμf | 5% | 500 v | 81349 | CC21UJ470J | 40-0023-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C38A | | Cap., fxd, paper dielectric | .047 μf | 20% | 200 v | 81349 | CP09A1KC473M | 42-0006-00 |
| C38B | | Cap., fxd, paper dielectric | .0047 μf | 20% | 200 v | 81349 | CP09A1KC472M | 42-0014-00 |
| C38C | | Cap., fxd, cer dielectric | 470 μμf | 5% | 500 v | 81349 | CC37UJ471J | 40-0028-00 |
| C38D | | Cap., fxd, cer dielectric | 22 μμf | 5% | 500 v | 81349 | CC21UJ220J | 40-0021-00 |
| C39 | | Cap., fxd, cer dielectric | 12 μμf | 5% | 500 v | 81349 | CC21UJ120J | 40-0019-00 |
| C40 | | Cap., fxd, cer dielectric | 12 μμf | 5% | 500 v | 81349 | CC21UJ120J | 40-0019-00 |
| C41 | | Cap., fxd, cer dielectric | 39 μμf | 5% | 500 v | 81349 | CC21UJ390J | 40-0025-00 |
| C42A, B, C | 101-196 | Cap., fxd, plstc dielectric | .05x.005x .00046 μf | .5% | 500 v | 80009 | | *42-0002-00 |
| C42A, B, C | 197-up | Cap., fxd, plstc dielectric | .05x.005x .00048 μf | .5% | 500 v | 80009 | | 42-0002-08 |
| C42D | | Cap., variable, cer dielectric | 7-45 μμf | | 500 v | 81349 | CV11C450 | 45-0003-00 |
| C42E | | Cap., fxd, mica dielectric | 39 μμf | 5% | 500 v | 81349 | CB11RD751K | 43-0004-00 |
| C42F | | Cap., variable, cer, dielectric | 3-12 μμf | | 500 v | 81349 | CV11A120 | 45-0006-00 |
| C43 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C44 | | Cap., fxd, cer dielectric | .0047 μf | +100% —20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C45 | | Cap., fxd, cer dielectric | .01 μf | +100% —20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C46 | | Cap., fxd, cer dielectric | 22 μμf | 5% | 500 v | 81349 | CC21UJ220J | 40-0021-00 |
| C47 | | Cap., fxd, cer dielectric | 47 μμf | 5% | 500 v | 81349 | CC21UJ470J | 40-0023-00 |
| C48 | | Cap., fxd, cer dielectric | .01 μf | +100% —20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C49 | | Cap., fxd, cer dielectric | 22 μμf | 5% | 500 v | 81349 | CC21UJ220J | 40-0021-00 |
| C50 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C51 | | Cap., variable, cer dielectric | 3-12 μμf | | 500 v | 81349 | CV11A120 | 45-0006-00 |
| C52 | | Cap., fxd, cer dielectric | 5 μμf | 10% | 500 v | 81349 | CC21SH050D | 40-0017-00 |
| C53 | | Cap., fxd, cer dielectric | .0047 μf | +100% —20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C54 | | Cap., fxd, cer dielectric | 1.5 μμf | 5% | 500 v | 81349 | CC21SK1R5D | 40-0016-00 |
| C55 | | Cap., fxd, cer dielectric | .0047 μf | +100% —20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C56 | | Cap., variable, cer dielectric | 3-12 μμf | | 500 v | 81349 | CV11A120 | 45-0006-00 |
| C57 | | Cap., variable cer dielectric | 3-12 μμf | | 500 v | 81349 | CV11A120 | 45-0006-00 |
| C58 | | Cap., variable, mica dielectric | 9-180 μμf | | 175 v | 02799 | 463 | 45-0005-00 |

* P/N 42-0002-00 obsolete. Use P/N 42-0002-08.

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C59 | | Cap., fxd, electro | 10x10 μf | +75% −10% | 400 v | 56289 | D32651 | 41-0016-00 |
| C60 | | Cap., fxd, paper dielectric | .047 μf | 20% | 200 v | 81349 | CP09A1KC473M | 42-0006-00 |
| C61 | | Cap., fxd, cer dielectric | 5 μμf | 10% | 500 v | 81349 | CC21SH050D | 40-0017-00 |
| C62 | | Cap., variable, cer dielectric | 3-12 μμf | | 500 v | 81349 | CV11A120 | 45-0006-00 |
| C63 | | Cap, fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C64 | | Cap., fxd, electro | 25x25 μf | +75% −10% | 150 v | 56289 | D32307 | 41-0013-00 |
| C65 | | Cap., fxd, electro | 35x35x35 μf | +75% −10% | 350 v | 56289 | D32310 | 41-0015-00 |
| C66 | | Cap., fxd, paper dielectric | .1 μf | 20% | 400 v | 81349 | CP10A1KE104M | 42-0007-00 |
| C67 | | Cap., fxd, electro | 75x75 μf | +75% −10% | 150 v | 56289 | D30779 | 41-0014-00 |
| C68 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C69 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C70 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C71 | | Cap., fxd, electro | 75x75 μf | +75% −10% | 150 v | 56289 | D30779 | 41-0014-00 |
| C72 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C73 | | Cap., fxd, cer dielectric | 1000 μμf | 10% | 500 v | 72982 | 301-000X5U0102K | 40-0035-00 |
| C74 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C75 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C76 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-000X5U0151M | 40-0026-00 |
| C77 | | Cap., fxd, cer dielectric | 1000 μμf | 10% | 500 v | 72982 | 301-000X5U0102K | 40-0035-00 |
| C78 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C79 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C80 | | Cap., fxd, paper dielectric | .022 μf | 20% | 600 v | 81349 | CP09A1KF223M | 42-0011-00 |
| C81 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C82 | | Cap., variable, cer dielectric | 7-45 μμf | | 500 v | 81349 | CV11C450 | 45-0003-00 |
| C83 | | Cap., variable, cer dielectric | 7-45 μμf | | 500 v | 81349 | CV11C450 | 45-0003-00 |
| C84 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | C5350484R | 45-0004-00 |
| C85 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C86 | | Cap., fxd, cer dielectric | .001 μf | +100% −20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C87 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C88 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C89 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C90 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C91 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C92 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-000X5U0151M | 40-0026-00 |
| C93 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C94 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C95 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C96 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C97 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C98 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-000X5U0151M | 40-0026-00 |
| C99 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C100 | | Cap., fxd, cer dielectric | .0047 μf | +100% —20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C101 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-000X5U0151M | 40-0026-00 |
| C102 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-000X5U0151M | 40-0026-00 |
| C103 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-00X5U0151M | 40-0026-00 |
| C104 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-00X5U0151M | 40-0026-00 |
| C105 | | Cap., fxd, cer dielectric | 150 μμf | 20% | 500 v | 72982 | 301-00X5U0151M | 40-0026-00 |
| C106 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C107 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C108 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C109 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C110 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C111 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C112 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C113 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C114 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C115 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C116 | | Cap., fxd, cer dielectric | .68 μμf | ±.136 μμf | 500 v | 72982 | 315-005C0K0688M | 40-0032-00 |
| C117 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C118 | | Cap., fxd, cer dielectric | 1 μμf | 20% | 500 v | 78488 | 1.0MMFD±20% | 40-0033-00 |
| C119 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C120 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C121 | | Cap., variable plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C122 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C123 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C124 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C125 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C126 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C127 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C128 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C129 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C130 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C131 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C132 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C133 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C134 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C135 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C136 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C137 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C138 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C139 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C140 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C141 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C142 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C143 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C144 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C145 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C146 | | Cap., fix, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20K1R5C | 40-0031-00 |
| C147 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20K1R5C | 40-0031-00 |
| C148 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C149 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C150 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C151 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C152 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C153 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C154 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C155 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C156 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C157 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C158 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C159 | | Cap., fxd, cer dielectric | 1.5 μμf | ±.25 μμf | 500 v | 81349 | CC20CK1R5C | 40-0031-00 |
| C160 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C161 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C162 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C163 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C164 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C165 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C166 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C167 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C168 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C169 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C170 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C171 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C172 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C173 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C174 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C175 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C176 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C177 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C178 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C179 | | Cap., variable, plstc dielectric | .7-3 μμf | | 350 v | 72982 | 0535048 4R | 45-0004-00 |
| C180 | | Cap., fxd, mica dielectric | 330 μμf | 5% | 500 v | 81349 | CM20D331J | 43-0003-00 |
| C181 | | Cap., fxd, mica dielectric | 330 μμf | 5% | 500 v | 81349 | CM20D331J | 43-0003-00 |
| C182 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61X1022 | 40-0001-00 |
| C183 | | Cap., fxd, electro | 40x40 | +75% —10% | 350 v | 56289 | D32309 | 41-0003-00 |
| C184 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 40-0008-00 |
| C185 | | Cap., fxd, electro | 60x60 μf | +75% —10% | 350 v | 56289 | D30778 | 41-0001-00 |
| C186 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C187 | | Cap., fxd, electro | 10x10 μf | +75% —10% | 400 v | 56289 | D32651 | 41-0016-00 |
| C188 | | Cap., fxd, electro | 40x40 μf | +75% —10% | 400 v | 56289 | D30776 | 41-0005-00 |
| C189 | | Cap., fxd, electro | 2000 μf | +75% —10% | 25 v | 56289 | D32378 | 41-0006-00 |
| C190 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C191 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C192 | | Cap., fxd, electro | 75x75 μf | +75% —10% | 250 v | 56289 | D30777 | 41-0002-00 |
| C193 | | Cap., fxd, electro | 75x75 μf | +75% —10% | 250 v | 56289 | D30777 | 41-0002-00 |
| C194 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C195 | | Cap., fxd, electro | 60x60 μf | +75% —10% | 350 v | 56289 | D30778 | 41-0001-00 |
| C196 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C197 | | Cap., fxd, paper dieletcric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C198 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C199 | | Cap., fxd, electro | 45x45 | +75% —10% | 150 v | 56289 | D32308 | 41-0004-00 |
| C200 | | Cap., fxd, cer dielectric | .01 μf | +100% —20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C201 | | Cap., fxd, paper dielectric | .1 μf | 20% | 600 v | 81349 | CP11A3KF104M | 42-0013-00 |
| C202 | | Cap., fxd, cer dielectric | .001 μf | +100% —20% | 500 v | 81349 | CK61Y102Z | 40-0001-00 |
| C203 | | Cap., fxd, paper dielectric | .01 μf | 20% | 600 v | 81349 | CP09A1KF103M | 42-0008-00 |
| C204 | | Cap., fxd, paper dielectric | .001 μf | 20% | 600 v | 81349 | CP09A1KF102M | 42-0009-00 |
| C205 | | Cap., fxd, cer dielectric | .01 μf | +100% —20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C206<br>C207<br>C208A<br>C208B<br>C209<br>C210<br>C211<br>C212<br>C213<br>C214<br>C215<br>C216 | These parts are included in encapsulated high voltage power supply. | | | | | | | |
| C217 | | Cap., fxd, cer dielectric | .01 μf | +100% —20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C218 | | Cap., fxd, cer dielectric | .01 μf | +100% —20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C219 | | Cap., fxd, cer dielectric | .68 μμf | ±.136 μμf | 500 v | 72982 | 315-005C0K0688M | 40-0032-00 |
| C220 | | Cap., fxd, cer dielectric | .68 μμf | ±.136 μμf | 500 v | 72982 | 315-005C0K0688M | 40-0032-00 |
| C221 | | Cap., fxd, cer dielectric | .68 μμf | ±.136 μμf | 500 v | 72982 | 315-005C0K0699M | 40-0032-00 |
| C222 | | Cap., fxd, cer dielectric | 27 μμf | 5% | 500 v | 81349 | CC21UJ270J | 40-0022-00 |
| C223 | | Not assigned | | | | | | |
| C224 | | Cap., fxd, electro | 2000x2000 μf | +75% —10% | 25 v | 56289 | D32807 | 41-0008-00 |
| C225 | | Cap., fxd, electro | 22 μf | 20% | 35 v | 56289 | 150D226X0035RO | 41-0010-00 |
| C226 | | Cap., fxd, electro | 22 μf | 20% | 35 v | 56289 | 150D226X0035RO | 41-0010-00 |
| C227 | | Cap., fxd, electro | 82 μμf | 5% | 500 v | 56289 | D32849 | 41-0009-00 |
| C228 | | Cap., fxd, electro | 2.7 μf | 5% | 35 v | 56289 | 150D275X9035BO | 41-0011-00 |

## Capacitors (continued)

| Ref Desig | Eff S/N Range | Item Name | Value | Tolerance | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| C229 | | Cap., fxd, electro | 2.7 μf | 5% | 35 v | 56289 | 150D275X9035BO | 41-0011-00 |
| C230 | | Cap., fxd, cer dielectric | .01 μf | +100% −20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C231 | | Cap., fxd, paper dielectric | .1 μf | 20% | 100 v | 81349 | CPO9A1KB104M | 42-0012-00 |
| C232 | | Cap., fxd, cer dielectric | .01 μf | +100% −20% | 500 v | 81349 | CK63Y103Z | 40-0003-00 |
| C233 | | Cap., fxd, electro | 45x45 μf | +75% −10% | 400 v | 56289 | D30776 | 41-0005-00 |
| C234 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C235 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C236 | | Cap., fxd, cer dielectric | .0047 μf | +100% −20% | 500 v | 81349 | CK62Y472Z | 40-0002-00 |
| C237 | | Cap., fxd, electro | .47 μf | 20% | 35 v | 56289 | 150D474X0035A0 | 41-0012-00 |
| C238 | | Cap., fxd, cer dielectric | 100 μμf | 20% | 350 v | 72982 | 301-000U2MC101M | 40-0034-00 |

## Semiconductors

| Ref Desig | Eff S/N Range | Item Name | Source Inspected Tubes When Spec by Contract. Tektronix Part Number | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| CR1 | | Semiconductor device, diode | 61-0004-00 | 03877 | 1N281 | 61-0004-01 |
| CR2 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR3 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR4 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR5 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR6 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR7 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR8 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR9 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR10 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR11 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR12 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |

## Semiconductors (continued)

| Ref Desig | Eff S/N Range | Item Name | Source Inspected Tubes When Spec by Contract Tektronix Part Number | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| CR13 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR14 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR15 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR16 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR17 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR18 | | Semiconductor device, diode | 61-0003-02 | 96214 | 1N1124A | 61-0003-01 |
| CR19 | | Semiconductor device, diode | 61-0003-02 | 96214 | 1N1124A | 61-0003-01 |
| CR20 | | Semiconductor device, diode | 61-0003-02 | 96214 | 1N1124A | 61-0003-01 |
| CR21 | | Semiconductor device, diode | 61-0003-02 | 96214 | 1N1124A | 61-0003-01 |
| CR22 | | Semiconductor device, diode | 61-0004-00 | 03877 | 1N281 | 61-0004-01 |
| CR23 | | Semiconductor device, diode | 61-0004-00 | 03877 | 1N281 | 61-0004-01 |
| CR24 | | Semiconductor device, diode | | 02735 | 1N2682 | 61-0001-00 |
| CR25 | | Semiconductor device, diode | | 04713 | 1N3027B | 61-0006-00 |

## Lamps

| Ref Desig | Eff S/N Range | Item Name | Current | Voltage | Source Inspected Tubes When Spec by Contract Tektronix Part No. | Mfr Code No | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|
| DS1 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS2 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS3 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS4 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS5 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS6 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS7 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS8 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS9 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS10 | | Lamp, glow | | | 60-9001-01 | 08806 | NE2A | 60-9001-00 |
| DS11 | | Lamp, incandescent | 150 ma | 6.3 v | | 33173 | 47 | 60-9005-00 |
| DS12 | | Lamp, incandescent | 150 ma | 6.3 v | | 33173 | 47 | 60-9005-00 |
| DS13 | | Lamp, incandescent | 200 ma | 12-16 v | | 94154 | 1815 | 60-9003-00 |
| DS14 | | Lamp, incandescent | .08 ma | 14 v | | 03797 | 1CF3-6764 | 60-9002-00 |

## Fuses

| Ref Desig | Eff S/N Range | Item Name | Current | Voltage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| F1 | | Fuse, cartridge | 7 amp | 125 v | 71400 | MDX-7 | 60-9004-02 |
| F2 | | Fuse, cartridge | 7 amp | 125 v | 71400 | MDX-7 | 60-9004-02 |
| F3 | | Fuse, cartridge | .10 amp. | 125 v | 71400 | GFA 1/10 | 60-9008-00 |
| F4 | | Fuse, cartridge | .10 amp. | 125 v | 71400 | GFA 1/10 | 60-9008-00 |

## Filter

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| FL1 | | Filter pad, interference | 2x6 amp, 220 vac 400 cps | 56289 | JN10-400 | 58-0004-00 |

## Connectors

| Ref Desig | Eff S/N Range | Item Name | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|
| J1 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J2 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J3 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J4 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J5 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J6 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J7 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J8 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J10 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |
| J11 | | Conn, recp, electrical | 81349 | UG1094/U | 14-1006-00 |

## Relays

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mil Desig Mfr P/N or | Part No. Tektronix |
|---|---|---|---|---|---|---|
| K1 | | Relay, thermal | Time delay, 45 sec ±10% | 06151 | FR-45S-NO-13-5 | 58-0001-00 |
| K2 | | Relay, armature | 13.5 vdc supply, pull in 9.3 vdc, drop out 6.9 vdc | 71482 | RP3716G147 | 58-0002-00 |

## Inductors

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Description | Mfr. Code No. | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| L1 | | Coil, rf | Fixed | 1000 $\mu$h | One section | 80009 | 50-0004-00 |
| L2 | | Coil, rf | Fixed | 280 $\mu$h | Four section | 80009 | 50-0005-00 |
| L3 | | Coil, rf | Variable | .3—.55 $\mu$h | One section | 80009 | 50-5005-00 |
| L4 | | Coil, rf | Variable | .3—.55 $\mu$h | One section | 80009 | 50-5005-00 |

## Inductors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Description | Mfr Code No. | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| L5 | | Coil, rf | Fixed | 8.4 μh | One section | 80009 | 50-0003-00 |
| L6 | | Coil, rf | Variable | .3—.5 μh | One section | 80009 | 50-5003-00 |
| L7 | | Coil, rf | Variable | .3—.5 μh | One section | 80009 | 50-5003-00 |
| L8 | | Coil, rf | Variable | .6—1.2 μh | One section | 80009 | 50-5006-00 |
| L9 | | Coil, rf | Variable | .6—1.2 μh | One section | 80009 | 50-5006-00 |

## Transistors

| Ref Desig | Eff S/N Range | Item Name | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|
| Q1 | | Transistor | 16758 | 2N297A | 61-2001-01 |
| Q2 | | Transistor | 16758 | 2N297A | 61-2001-01 |
| Q3 | | Transistor | 01295 | 2N1375 | 61-2005-00 |
| Q4 | | Transistor | 01295 | 2N1375 | 61-2005-00 |
| Q5 | | Transistor | 01295 | 2N277 | 61-2002-00 |
| Q6 | | Transistor | 01295 | 2N277 | 61-2002-00 |
| Q7 | | Transistor | 01295 | 2N277 | 61-2002-00 |
| Q8 | | Transistor | 01295 | 2N277 | 61-2002-00 |
| Q9 | | Transistor | 01295 | 2N1042 | 61-2003-00 |
| Q10 | | Transistor | 01295 | 2N1302 | 61-2004-00 |

## Resistors

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R1 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R2 | | Res, variable | Comp | 50,000 Ω | 20% | 2 w | 81349 | RV4LAYSA503B | 33-0017-00 |
| R3 | | Res, fxd, comp | | 1meg | 5% | ½ w | 81349 | RC20GF105J | 30-4105-00 |
| R4 | | Res, fxd, comp | | 390,000 Ω | 5% | ½ w | 81349 | RC20GF394J | 30-4394-00 |
| R5 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R6 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R7 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC20GF474K | 30-5474-00 |
| R8 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R9 | | Res, fxd, comp | | 4,700 Ω | 10% | 1 w | 81349 | RC32GF472K | 30-7472-00 |
| R10 | | Res, fxd, comp | | 4,700 Ω | 10% | 1 w | 81349 | RC32GF472K | 30-7472-00 |
| R11 | | Res, fxd, comp | | 33,000 Ω | 10% | 2 w | 81349 | RC42GF333K | 30-9333-00 |
| R12 | | Res, fxd, comp | | 39,000 Ω | 10% | 2 w | 81349 | RC42GF393K | 30-9393-00 |
| R13 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R14* | | Res, variable | Comp | 100,000 Ω | 20% | 1 w | 71450 | HM20398 | 33-0027-00 |
| R15 | | Res, fxd, comp | | 22,000 Ω | 10% | ½ w | 81349 | RC20GF223K | 30-5223-00 |
| R16 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R17 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R18 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R19 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R20 | | Res, fxd, comp | | 56,000 Ω | 10% | ½ w | 81349 | RC20GF563K | 30-5563-00 |

* R14 concentric with R39 and S3. Furnished as a unit.

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R21 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R22 | | Res, fxd, comp | | 2.7 meg | 10% | ½ w | 81349 | RC20GF275K | 30-5275-00 |
| R23 | | Res, fxd, comp | | 680 Ω | 10% | ½ w | 81349 | RC20GF681K | 30-5681-00 |
| R24 | | Res, fxd, comp | | 1,500 Ω | 10% | ½ w | 81349 | RC20GF152K | 30-5152-00 |
| R25 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R26 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R27 | | Res, fxd, comp | | 120,000 Ω | 10% | ½ w | 81349 | RC20GF124K | 30-5124-00 |
| R28 | | Res. variable | Comp | 100,000 Ω | 20% | 2 w | 81349 | RV4LAYSA104B | 33-0018-00 |
| R29 | | Res. variable | Comp | 500 Ω | 20% | 2 w | 81349 | RV4LAYSA501B | 33-0016-00 |
| R30 | | Res, fxd, comp | | 18,000 Ω | 10% | 1 w | 81349 | RC32GF183K | 30-7183-00 |
| R31 | | Res, fxd, comp | | 18,000 Ω | 10% | 1 w | 81349 | RC32GF183K | 30-7183-00 |
| R32 | | Res, fxd, comp | | 820 Ω | 10% | ½ w | 81349 | RC20GF821K | 30-5821-00 |
| R33 | | Res, fxd, comp | | 1 meg | 10% | ¼ w | 81349 | RC07GF105K | 30-3105-00 |
| R34 | | Res, fxd, comp | | 390,000 Ω | 10% | ½ w | 81349 | RC20GF394K | 30-5394-00 |
| R35 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R36 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R37 | | Res, fxd, comp | | 220,000 Ω | 10% | ½ w | 81349 | RC20GF224K | 30-5224-00 |
| R38 | | Res, fxd, comp | | 68,000 Ω | 10% | 1 w | 81349 | RC32GF683K | 30-7683-00 |
| R39* | | Res, variable | Comp | 100,000 Ω | 20% | 1 w | 71450 | HM20398 | 33-0027-00 |
| R40 | | Res, variable | Comp | 100,000 Ω | 20% | ½ w | 81349 | RV6LAYSA104B | 33-0022-00 |
| R41 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R42 | | Res, fxd, comp | | 100,000 Ω | 5% | ½ w | 81349 | RC20GF104J | 30-4104-00 |
| R43 | | Res, fxd, comp | | 180,000 Ω | 5% | ½ w | 81349 | RC20GF184J | 30-4184-00 |
| R44 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R45 | | Res, fxd, comp | | 47 Ω | 10% | ½ w | 81349 | RC20GF470K | 30-5470-00 |
| R46 | | Res, fxd, comp | | 4.7 meg | 10% | ½ w | 81349 | RC20GF475K | 30-5475-00 |
| R47 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R48 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R49 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R50 | | Res, fxd, comp | | 68,000 Ω | 10% | 2 w | 81349 | RC42GF683K | 30-9683-00 |
| R51 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R52 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R53 | | Res, fxd, ww | | 6,000 tapped at 3,000 Ω | 1% | 3 w | 80009 | | 32-0026-00 |
| R54 | | Res, fxd, comp | | 47 Ω | 10% | ½ w | 81349 | RC20GF470K | 30-5470-00 |
| R55 | | Res, fxd, film | | 33,200 Ω | 1% | 1 w | 81349 | RN75G3322F | 31-6001-00 |
| R56 | | Res, fxd, film | | 30,100 Ω | 1% | 1 w | 81349 | RN75G3012F | 31-6002-00 |
| R57 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R58 | | Not assigned | | | | | | | |
| R59 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R60 | | Res, fxd, comp | | 12,000 Ω | 10% | ½ w | 81349 | RC20GF123K | 30-5123-00 |
| R61 | | Res, fxd, comp | | 10,000 Ω | 10% | ¼ w | 81349 | RC07GF103K | 30-5103-00 |
| R62 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-5102-00 |
| R63 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R64 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |

* R39 concentric with R14 and S3. Furnished as a unit.

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R65 | | Res, variable | Comp | 50,000 Ω | 20% | ½ w | 81349 | RV4LAYSA503B | 33-0023-00 |
| R66 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R67 | | Res, fxd, comp | | 270,000 Ω | 10% | ½ w | 81349 | RC20GF274K | 30-5274-00 |
| R68 | | Res, fxd, comp | | 22,000 Ω | 10% | 2 w | 81349 | RC42GF223K | 30-9223-00 |
| R69 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R70 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R71 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R72 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R73 | | Res, fxd, comp | | 4,700 Ω | 10% | 1 w | 81349 | RC32GF472K | 30-7472-00 |
| R74 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R75 | | Res, fxd, comp | | 270 Ω | 10% | ½ w | 81349 | RC20GF271K | 30-5271-00 |
| R76 | | Res, fxd, ww | | 8,000 Ω | 5% | 5 w | 81349 | RW57G802 | 32-0003-00 |
| R77 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R78 | | Res, fxd, comp | | 4.7 meg | 10% | ½ w | 81349 | RC20GF475K | 30-5475-00 |
| R79 | | Res, fxd, comp | | 68,000 Ω | 10% | ½ w | 81349 | RC20GF683K | 30-5683-00 |
| R80 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R81 | | Res, fxd, comp | | 10,000 Ω | 10% | ½ w | 81349 | RC20GF103K | 30-5103-00 |
| R82A | | Res, fxd, film | | 30 meg | 1% | 2 w | 01295 | CDH2-3004F | 31-8003-00 |
| R82B | | Res, fxd, film | | 10 meg | 1% | 1 w | 01295 | CDH1-1005F | 31-6012-00 |
| R82C | | Res, fxd, film | | 10 meg | 1% | 1 w | 01295 | CDH1-1005F | 31-6012-00 |
| R82D | | Res, fxd, film | | 3 meg | 1% | ½ w | 56289 | 402E30041 | 31-4014-00 |
| R82E | | Res, fxd, film | | 1 meg | 1% | ½ w | 81349 | RN70G1004F | 31-4012-00 |
| R82F | | Res, fxd, film | | 1 meg | 1% | ½ w | 81349 | RN70G1004F | 31-4012-00 |
| R82G | | Res, fxd, film | | 300,000 Ω | 1% | ½ w | 56289 | 402E30031 | 31-4015-00 |
| R82H | | Res, fxd, film | | 100,000 Ω | 1% | ½ w | 81349 | RN70G1003F | 31-4016-00 |
| R82J | | Res, fxd, film | | 100,000 Ω | 1% | ½ w | 81349 | RN70G1003F | 31-4016-00 |
| R82K | | Res, fxd, comp | | 6,800 Ω | 10% | 1 w | 81349 | RC32GF682K | 30-7682-00 |
| R82L | | Res, variable | Comp | 15,000 Ω | 20% | 2 w | 81349 | RV4LAYSA153B | 33-0010-00 |
| R82M | | Res, variable | Comp | 500 Ω | 20% | ½ w | 81349 | RV6LAYSA501B | 33-0009-00 |
| R83 | | Res, fxd, comp | | 22,000 Ω | 10% | 2 w | 81349 | RC42GF223K | 30-9223-00 |
| R84 | | Res, fxd, comp | | 22,000 Ω | 10% | 2 w | 81349 | RC42GF223K | 30-9223-00 |
| R85 | | Res, fxd, comp | | 22,000 Ω | 10% | 2 w | 81349 | RC42GF223K | 30-9223-00 |
| R86 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R87 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R88 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R89 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R90 | | Res, fxd, comp | | 470 Ω | 10% | ½ w | 81349 | RC20GF471K | 30-5471-00 |
| R91 | | Res, fxd, comp | | 6,800 Ω | 10% | 1 w | 81349 | RC32GF682K | 30-7682-00 |
| R92 | | Res, fxd, comp | | 12,000 Ω | 10% | 1 w | 81349 | RC32GF123K | 30-7123-00 |
| R93 | | Res, fxd, comp | | 1.8 meg | 10% | ½ w | 81349 | RC20GF185K | 30-5185-00 |
| R94 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R95 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R96 | | Res, fxd, comp | | 100,000 Ω | 10% | 1 w | 81349 | RC32GF104K | 30-7104-00 |
| R97 | | Res, fxd, ww | | 8,000 Ω | 5% | 5 w | 81349 | RW57G802 | 32-0003-00 |

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R98 | | Res, variable | Comp | 2,500 Ω | 20% | 2 w | 81349 | RV4LAYSA252B | 33-0015-00 |
| R99 | | Res, fxd, ww | | 4,000 Ω | 5% | 5 w | 81349 | RW57G402 | 32-0004-00 |
| R100A | | Res, fxd, comp | | 4.7 meg | 10% | ½ w | 81349 | RC20GF475K | 30-5475-00 |
| R100B | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R101 | | Res, fxd, comp | | 47 Ω | 10% | ½ w | 81349 | RC20GF470K | 30-5470-00 |
| R102 | | Res, fxd, film | | 900,000 Ω | 1% | ½ w | 56289 | 402E90031 | 31-4011-00 |
| R103 | | Res, fxd, film | | 111,000 Ω | 1% | ½ w | 56289 | 402E11131 | 31-4010-00 |
| R104 * | | Res, variable | Comp | 100,000 Ω | 20% | 1 w | 71450 | HM20396 | 33-0026-00 |
| R105 | | Res, fxd, comp | | 22,000 Ω | 10% | ½ w | 81349 | RC20GF223K | 30-5223-00 |
| R106 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R107 | | Res, fxd, comp | | 100,000 | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R108 | | Res, fxd, film | | 1 meg | 1% | ½ w | 81349 | RN70G1004F | 31-4012-00 |
| R109 | | Res, fxd, comp | | 33,000 Ω | 10% | 1 w | 81349 | RC32GF333K | 30-7333-00 |
| R110 | | Res, variable | Comp | 50,000 Ω | 20% | 2 w | 81349 | RV4LAYSA503B | 33-0017-00 |
| R111 | | Res, fxd, comp | | 47,000 Ω | 10% | 1 w | 81349 | RC32GF473K | 30-7473-00 |
| R112 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R113 | | Res, fxd, comp | | 33,000 Ω | 10% | 2 w | 81349 | RC42GF333K | 30-9333-00 |
| R114 | | Res, fxd, comp | | 47,000 Ω | 10% | 1 w | 81349 | RC32GF473K | 30-7473-00 |
| R115 * | | Res, variable | Comp | 15,000 Ω | 20% | 1 w | 71450 | HM20396 | 33-0026-00 |
| R116 | | Res, fxd, comp | | 47,000 Ω | 10% | 1 w | 81349 | RC32GF473K | 30-7473-00 |
| R117 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R118 | | Res, fxd, comp | | 3,300 Ω | 10% | ½ w | 81349 | RC20GF332K | 30-5332-00 |
| R119 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R120 | | Res, fxd, comp | | 270,000 Ω | 10% | ½ w | 81349 | RC20GF274K | 30-5274-00 |
| R121 | | Res, fxd, comp | | 33,000 Ω | 10% | 2 w | 81349 | RC42GF333K | 30-9333-00 |
| R122 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R123 | | Res, fxd, comp | | 1,200 Ω | 10% | ½ w | 81349 | RC20GF122K | 30-5122-00 |
| R124 * | | Res, variable | Comp | 100,000 Ω | 20% | 1 w | 71450 | HM20396 | 33-0026-00 |
| R125 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R126 | | Res, fxd, comp | | 27,000 Ω | 10% | ½ w | 81349 | RC20GF273K | 30-5273-00 |
| R127 | | Res, fxd, comp | | 39,000 Ω | 10% | ½ w | 81349 | RC20GF393K | 30-5393-00 |
| R128 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R129 | | Res, fxd, comp | | 22,000 Ω | 10% | 1 w | 81349 | RC32GF223K | 30-7223-00 |
| R130 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R131 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R132 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R133 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R134 | | Res, fxd, comp | | 10,000 Ω | 5% | 1 w | 81349 | RC32GF103J | 30-6103-00 |
| R135 | | Res, fxd, comp | | 330,000 Ω | 10% | ½ w | 81349 | RC20GF334K | 30-5334-00 |
| R136 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R137 | | Res, fxd, comp | | 39,000 Ω | 5% | 1 w | 81349 | RC32GF393J | 30-6393-00 |
| R138 | | Res, fxd, comp | | 33,000 Ω | 5% | 1 w | 81349 | RC32GF333J | 30-6333-00 |
| R139 | | Res, fxd, comp | | 15,000 Ω | 5% | 2 w | 81349 | RC42GF153J | 30-8153-00 |
| R140 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |

* R104 concentric with R115 and R124. Furnished as a unit.

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R141 | | Res, fxd, comp | | 2,200 Ω | 10% | ½ w | 81349 | RC20GF222K | 30-5222-00 |
| R142 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R143 | | Res, fxd, comp | | 2,700 Ω | 10% | ½ w | 81349 | RC20GF272K | 30-5272-00 |
| R144 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R145 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R146 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R147 | | Res, fxd, comp | | 10,000 Ω | 10% | ½ w | 81349 | RC07GF103K | 30-5103-00 |
| R148A,B | | Res, matched | | 1.01 meg | .25% | ½ w | 80009 | | 39-0004-00 |
| R148C,D | | Res, matched | | 606,000 Ω | .25% | ½ w | 80009 | | 39-0003-00 |
| R148E,F | | Res, matched | | 404,000 Ω | .25% | ½ w | 80009 | | 39-0002-00 |
| R149 | | Res, fxd, comp | | 220,000 Ω | 10% | 2 w | 81349 | RC42GF224K | 30-9224-00 |
| R150 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R151 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R152 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R153 | | Res, fxd, film | | 15,400 Ω | 2% | 2 w | 81349 | RD65P1542G | 31-8007-00 |
| R154 | | Res, variable | Comp | 5,000 Ω | 10% | 2 w | 81349 | RV4LAYSA502A | 33-0031-00 |
| R155 | | Res, fxd, comp | | 7,500 Ω | 5% | 2 w | 81349 | RC42GF752J | 30-8752-00 |
| R156 | | Res, variable | Comp | 5,000 Ω | 10% | 2 w | 81349 | RV4LAYSA502A | 33-0031-00 |
| R157 | | Res, fxd, comp | | 1 meg | 10% | ¼ w | 81349 | RC07GF105K | 30-3105-00 |
| R158 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R159 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R160 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R161 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R162 | | Res, fxd, comp | | 10,000 Ω | 10% | ½ w | 81349 | RC20GF103K | 30-5103-00 |
| R163 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R164 | | Res, fxd, comp | | 12,000 Ω | 10% | ½ w | 81349 | RC20GF123K | 30-5123-00 |
| R165 | | Res, fxd, comp | | 10,000 Ω | 10% | ½ w | 81349 | RC20GF103K | 30-5103-00 |
| R166 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R167 | | Res, fxd, film | | 10,000 Ω | 5% | 2 w | 81349 | RD65P1002J | 31-8006-00 |
| R168 | | Res, variable | WW | 10,000 Ω | 10% | 1 w | 12697 | CM26005 | 33-0020-00 |
| R169 * | | Res, variable | | 30,000 Ω | 3% | 8 w | 01121 | 860-23 | 33-0001-00 |
| R170 | | Res, variable | WW | 2,000 Ω | 10% | 1 w | 81349 | RA10LASM202A | 33-0019-00 |
| R171 | | Res, fxd, film | | 14,700 Ω | 5% | 7 w | 81349 | RD31P1472J | 31-8005-00 |
| R172 | | Res, fxd, comp | | 100 Ω | 10% | ½ w | 81349 | RC20GF101K | 30-5101-00 |
| R173 | | Res, fxd, comp | | 2,700 Ω | 10% | ½ w | 81349 | RC20GF272K | 30-5272-00 |
| R174 | | Res, fxd, film | | 95,000 Ω | 1% | ½ w | 56289 | 402E95021 | 31-4009-00 |
| R175 | | Res, fxd, film | | 150,000 Ω | 1% | ½ w | 81349 | RN70G1503F | 31-4008-00 |
| R176 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R177 | | Res, fxd, comp | | 39,000 Ω | 10% | 2 w | 81349 | RC42GF393K | 30-9393-00 |
| R178 | | Res, fxd, comp | | 3,300 Ω | 10% | ½ w | 81349 | RC20GF332K | 30-5332-00 |
| R179 | | Res, fxd, comp | | 10,000 Ω | 10% | ½ w | 81349 | RC20GF103K | 30-5103-00 |
| R180 | | Res, fxd, comp | | 270,000 Ω | 10% | ½ w | 81349 | RC20GF274K | 30-5274-00 |
| R181 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R182 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |

* Linear Precision Resistor.

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R183 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R184 | | Res, fxd, comp | | 22,000 Ω | 10% | ½ w | 81349 | RC20GF223K | 30-5223-00 |
| R185 | | Res, fxd, comp | | 22 meg | 10% | ½ w | 81349 | RC20GF226K | 30-5226-00 |
| R186 | | Res, fxd, film | | 1.94 meg | 1% | ½ w | 56289 | 402E19441 | 31-4007-00 |
| R187 | | Res, fxd, film | | 3.1 meg | 1% | ½ w | 56287 | 402E31041 | 31-4002-00 |
| R188 * | | Res, variable | Comp | 100,000 Ω | 20% | 1 w | 71450 | HM20397 | 33-0025-00 |
| R189 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R190 | | Res, fxd, comp | | 2,200 Ω | 10% | ½ w | 81349 | RC20GF222K | 30-5222-00 |
| R191 | | Res, fxd, comp | | 100,000 Ω | 10% | 1 w | 81349 | RC32GF104K | 30-7104-00 |
| R192 | | Res, fxd, film | | 9 meg | 2% | ½ w | 96214 | CDH½S 9M2% | 31-4017-00 |
| R193 | | Res, fxd, comp | | 33,000 Ω | 10% | ½ w | 81349 | RC20GF333K | 30-5333-00 |
| R194 * | | Res, variable | Comp | 100,000 Ω | 20% | 1 w | 71450 | HM20397 | 33-0025-00 |
| R195 | | Res, fxd, film | | 400,000 Ω | 1% | 1 w | 56289 | 403E40031 | 31-6003-00 |
| R196 | | Res, fxd, film | | 400,000 Ω | 1% | 1 w | 56289 | 403E40031 | 31-6003-00 |
| R197 | | Res, fxd, comp | | 22,000 Ω | 10% | ½ w | 81349 | RC20GF223K | 30-5223-00 |
| R198 | | Res, variable | Comp | 25,000 Ω | 20% | 2 w | 81349 | RVLAYSA253B | 33-0014-00 |
| R199 | | Res, fxd, film | | 111,000 Ω | 1% | ½ w | 56289 | 402E11131 | 31-4010-00 |
| R200 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R201 | | Res, fxd, comp | | 100,000 Ω | 10% | 1 w | 81349 | RC32GF104K | 30-7104-00 |
| R202 | | Res, fxd, ww | | 25,000 Ω tapped at 6,000 Ω | 1% | 5 w | 80009 | | 32-0009-00 |
| R203 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R204 | | Res, variable | Comp | 10,000 Ω | 10% | 2 w | 81349 | RV4LAYSA103Z | 33-0021-00 |
| R205 | | Res, fxd, comp | | 2,200 Ω | 10% | 1 w | 81349 | RC32GF222K | 30-7222-00 |
| R206 | | Res, fxd, ww | | 6,300 Ω | 5% | 5 w | 81349 | RW57G632 | 32-0005-00 |
| R207 | | Res, fxd, comp | | 2,200 Ω | 10% | 1 w | 81349 | RC32GF222K | 30-7222-00 |
| R208 | | Res, variable | Comp | 2,500 Ω | 20% | 2 w | 81349 | RV4LAYSA252B | 33-0015-00 |
| R209 | | Res, fxd, comp | | 100 Ω | 10% | ½ w | 81349 | RC20GF101K | 30-5101-00 |
| R210 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R211 | | Res, fxd, ww | | 30,000 Ω tapped at 6,000 Ω | 1% | 5 w | 80009 | | 32-0008-00 |
| R212 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R213 | | Res, fxd, comp | | 390 Ω | 10% | ½ w | 81349 | RC20GF391K | 30-5391-00 |
| R214 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R215 | | Res, fxd, comp | | 2,200 Ω | 10% | ½ w | 81349 | RC20GF222K | 30-5222-00 |
| R216 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R217 | | Res, fxd, comp | | 39,000 Ω | 10% | 2 w | 81349 | RC42GF393K | 30-9393-00 |
| R218 | | Res, fxd, comp | | 39,000 Ω | 10% | 2 w | 81349 | RC42GF393K | 30-9393-00 |
| R219 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R220 | | Res, fxd, comp | | 820,000 Ω | 10% | ½ w | 81349 | RC20GF824K | 30-5824-00 |
| R221 | | Res, fxd, comp | | 820,000 Ω | 10% | ½ w | 81349 | RC20GF824K | 30-5824-00 |
| R222 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R223 | | Res, fxd, comp | | 100 Ω | 10% | 1 w | 81349 | RC32GF101K | 30-7101-00 |
| R224 | | Res, fxd, comp | | 100 Ω | 10% | 1 w | 81349 | RC32GF101K | 30-7101-00 |
| R225 | | Res, fxd, comp | | 47 Ω | 10% | ½ w | 81349 | RC20GF470K | 30-5470-00 |
| R226 | | Res, fxd, comp | | 100 Ω | 10% | 1 w | 81349 | RC32GF101K | 30-7101-00 |

* R188 concentric with R194. Furnished as a unit.

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R227 | | Res, fxd, comp | | 68,000 Ω | 10% | 1/10 w | 01121 | TR-6831 | 30-1683-00 |
| R228 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R229 | | Res, fxd, comp | | 910 Ω | 5% | 2 w | 81349 | RC42GF911J | 30-8911-00 |
| R230 | | Res, fxd, ww | | 500 Ω | 2% | ½ w | 80009 | | 32-0025-00 |
| R231 | | Res, fxd, ww | | 500 Ω | 2% | ½ w | 80009 | | 32-0025-00 |
| R232 | | Res, fxd, comp | | 27 Ω | 10% | ½ w | 81349 | RC20GF270K | 30-5270-00 |
| R233 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R234 | | Res, fxd, comp | | 330 Ω | 10% | ½ w | 81349 | RC20GF331K | 30-5331-00 |
| R235 | | Res, fxd, ww | | 3,100 Ω | 5% | 5 w | 81349 | RW57G312 | 32-0001-00 |
| R236 | | Res, variable | Comp | 250 Ω | 20% | 2 w | 81349 | RV4LAYSA251B | 33-0029-00 |
| R237 | | Res, fxd, film | | 10,000 Ω | 5% | 7 w | 81349 | RD31P1002J | 31-8001-00 |
| R238 | | Res, fxd, comp | | 330 Ω | 10% | ½ w | 81349 | RC20GF331K | 30-5331-00 |
| R239 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R240 | | Res, fxd, comp | | 2,200 Ω | 10% | 1 w | 81349 | RC32GF222K | 30-7222-00 |
| R241 | | Res, fxd, comp | | 27 Ω | 10% | ½ w | 81349 | RC20GF270K | 30-5270-00 |
| R242 | | Res, fxd, comp | | 68,000 Ω | 10% | 1/10 w | 01121 | TR-6831 | 30-1683-00 |
| R243 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R244 | | Res, variable | Comp | 250,000 Ω | 20% | 2 w | 81349 | RV4NAYSB254B | 33-0011-00 |
| R245 | | Res, fxd, ww | | 2,500 Ω | 5% | 5 w | 81349 | RW57G252 | 32-0010-00 |
| R246 | | Res, fxd, comp | | 27,000 Ω | 10% | 2 w | 81349 | RC42GF273K | 30-9273-00 |
| R247 | | Res, fxd, comp | | 27,000 Ω | 10% | 2 w | 81349 | RC42GF273K | 30-9273-00 |
| R248 | | Res, fxd, comp | | 33 Ω | 10% | ½ w | 81349 | RC20GF330K | 30-5330-00 |
| R249 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R250 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R251 | | Res, fxd, ww | | 160 Ω | 5% | 5 w | 81349 | RW57G161 | 32-0012-00 |
| R252 | | Res, fxd, comp | | 33 Ω | 10% | ½ w | 81349 | RC20GF330K | 30-5330-00 |
| R253 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R254 | | Res, fxd, comp | | 150,000 Ω | 10% | ½ w | 81349 | RC20GF154K | 30-5154-00 |
| R255 | | Res, fxd, comp | | 390,000 Ω | 10% | ½ w | 81349 | RC20GF394K | 30-5394-00 |
| R256 | | Res, fxd, comp | | 330,000 Ω | 10% | ½ w | 81349 | RC20GF334K | 30-5334-00 |
| R257 | | Res, fxd, comp | | 8,200 Ω | 10% | ¼ w | 81349 | RC07GF822K | 30-3822-00 |
| R258 | | Res, fxd, comp | | 1 meg | 10% | ¼ w | 81349 | RC07GF105K | 30-3105-00 |
| R259 * | | Res, matched | | 600 Ω tapped at 70, 140, 390 Ω | 1% | 6 w | 80009 | | 39-0007-00 |
| R260 | | Res, fxd, comp | | 47 Ω | 10% | ½ w | 81349 | RC20GF470K | 30-5470-00 |
| R261 | | Res, fxd, comp | | 150,000 Ω | 10% | ½ w | 81349 | RC20GF145K | 30-5154-00 |
| R262 | | Res, fxd, comp | | 220 Ω | 10% | ¼ w | 81349 | RC07GF221K | 30-3221-00 |
| R263 | | Res, fxd, comp | | 47 Ω | 10% | ¼ w | 81349 | RC07GF470K | 30-3470-00 |
| R264 | | Res, fxd, comp | | 150 Ω | 10% | ¼ w | 81349 | RC07GF151K | 30-3151-00 |
| R265 | | Res, fxd, comp | | 680,000 Ω | 10% | ½ w | 81349 | RC20GF684K | 30-5684-00 |
| R266 * | | Res, matched | | 600 Ω tapped at 70, 140, 390 Ω | 1% | 6 w | 80009 | | 39-0007-00 |

* R259, R266 furnished as a matched pair.

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R267 | | Not assigned | | | | | | | |
| R268 | | Not assigned | | | | | | | |
| R269 | | Res, fxd, comp | | 390,000 Ω | 10% | ½ w | 81349 | RC20GF394K | 30-5394-00 |
| R270 | | Res, fxd, comp | | 1 meg | 10% | ¼ w | 81349 | RC07GF105K | 30-3105-00 |
| R271 | | Res, fxd, comp | | 8,200 Ω | 10% | ¼ w | 81349 | RC07GF822K | 30-3822-00 |
| R272 | | Res, fxd, comp | | 4,700 Ω | 10% | 2 w | 81349 | RC42GF472K | 30-9472-00 |
| R273 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R274 | | Res, fxd, film | | 30,100 Ω | 2% | 7 w | 81349 | RD31P3012G | 31-8004-00 |
| R275 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R276 | | Res, fxd, comp | | 15,000 Ω | 10% | 2 w | 81349 | RC42GF153K | 30-9153-00 |
| R277 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R278 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R279 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R280 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R280 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R281 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R282 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R283 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R284 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R285 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R286 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R287 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R288 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R289 | | Res, fxd, ww | | 4,500 Ω | 5% | 8 w | 81349 | RW29G452 | 32-0016-00 |
| R290 | | Res, fxd, comp | | 360 Ω | 5% | ½ w | 81349 | RC20GF361J | 30-4361-00 |
| R291 | | Res, fxd, film | | 12,100 Ω | 5% | 7 w | 81349 | RD31P1212J | 31-8002-00 |
| R292 | | Res, fxd, ww | | 1,000 Ω | 5% | 5 w | 81349 | RW57G102 | 32-0011-00 |
| R293 | | Res, fxd, comp | | 360 Ω | 5% | ½ w | 81349 | RC20GF361J | 30-4361-00 |
| R294 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R295 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R296 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R297 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R298 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R299 | | Res, fxd, comp | | 470,000 Ω | 10% | ¼ w | 81349 | RC07GF474K | 30-3474-00 |
| R300 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R301 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R302 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R303 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R304 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R305 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R306 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R307 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R308 | | Res, fxd, comp | | 150,000 Ω | 10% | ½ w | 81349 | RC20GF154K | 30-5154-00 |
| R309 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R310 | | Res, fxd, comp | | 3.9 meg | 10% | ½ w | 81349 | RC20GF395K | 30-5395-00 |
| R311 | | Res, fxd, comp | | 2.7 meg | 10% | ½ w | 81349 | RC20GF275K | 30-5275-00 |
| R312 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R313 | | Res, fxd, comp | | 68,000 Ω | 10% | ½ w | 81349 | RC20GF683K | 30-5683-00 |
| R314 | | Res, variable | Comp | 10,000 Ω | 10% | 2 w | 81349 | RV4LAYSA103B | 33-0013-00 |
| R315 | | Res, fxd, comp | | 68,000 Ω | 10% | ½ w | 81349 | RC20GF683K | 30-5683-00 |
| R316 | | Res, fxd, comp | | 33,000 Ω | 10% | 1 w | 81349 | RC32GF333K | 30-7333-00 |
| R317 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R318 | | Res, fxd, comp | | 100 Ω | 10% | ¼ w | 81349 | RC07GF101K | 30-3101-00 |
| R319 | | Res, fxd, film | | 9,500 Ω | 1% | ¼ w | 81349 | RN65G9501F | 31-2010-00 |
| R320 | | Res, fxd, film | | 6,380 Ω | 1% | ¼ w | 56289 | 401E63811 | 31-2029-00 |
| R321 | | Res, fxd, film | | 2,100 Ω | 1% | ¼ w | 81349 | RN65G2101F | 31-2008-00 |
| R322 | | Res, fxd, film | | 1,020 Ω | 1% | ¼ w | 81349 | RN65G1021F | 31-2007-00 |
| R323 | | Res, fxd, film | | 610 Ω | 1% | ¼ w | 56289 | 401E61001 | 31-2006-00 |
| R324 | | Res, fxd, film | | 200 Ω | 1% | ¼ w | 81349 | RN65B2000F | 31-2005-00 |
| R325 | | Res, fxd, film | | 100 Ω | 1% | ¼ w | 81349 | RN65G1000F | 31-2011-00 |
| R326 | | Res, fxd, film | | 60 Ω | 1% | ¼ w | 56289 | 401E60R01 | 31-2004-00 |
| R327 | | Res, fxd, film | | 40 Ω | 1% | ¼ w | 56289 | 401E40R01 | 31-2003-00 |
| R328 | | Res, fxd, film | | 100,000 Ω | 1% | ½ w | 81349 | RN70G1003F | 31-4016-00 |
| R329 | | Res, fxd, film | | 100 Ω | 1% | ½ w | 81349 | RN70G101F | 21-4005-00 |
| R330 | | Res, fxd, comp | | 100 Ω | 10% | ½ w | 81349 | RC20GF101K | 31-5101-00 |
| R331 | | Res, fxd, ww | | .25 Ω | 10% | 3 w | 81349 | RW31V282 | 32-0023-00 |
| R332 | | Res, fxd, comp | | 10 Ω | 10% | ½ w | 81349 | RC20GF100K | 30-5100-00 |
| R333 | | Res, fxd, comp | | 120,000 Ω | 10% | ½ w | 81349 | RC20GF124K | 30-5124-00 |
| R334 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R335 | | Res, fxd, comp | | 120,000 Ω | 10% | ½ w | 81349 | RC20GF124K | 30-5124-00 |
| R336 | | Res, fxd, comp | | 27,000 Ω | 10% | ½ w | 81349 | RC20GF273K | 30-5273-00 |
| R337 | | Res, fxd, ww | | 3,100 Ω | 5% | 11 w | 81349 | RW39V312 | 32-0024-00 |
| R338 | | Res, fxd, film | | 200,000 Ω | 1% | 1 w | 81349 | RN75G2003F | 31-6006-00 |
| R339 | | Res, fxd, film | | 655,000 Ω | 1% | 1 w | 56289 | 403E65531 | 31-6009-00 |
| R340 | | Res, fxd, comp | | 10 Ω | 10% | 1 w | 81349 | RC32GF100K | 30-7100-00 |
| R341 | | Res, fxd, comp | | 10 Ω | 10% | 1 w | 81349 | RC32GF100K | 30-7100-00 |
| R342 | | Res, fxd, comp | | 82,000 Ω | 10% | 2 w | 81349 | RC42GF823K | 30-9823-00 |
| R343 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R344 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R345 | | Res, fxd, comp | | 560,000 Ω | 10% | ½ w | 81349 | RC20GF564K | 30-5564-00 |
| R346 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R347 | | Res, fxd, ww | | 2,800 Ω | 5% | 14 w | 81349 | RW31V282 | 32-0023-00 |
| R348 | | Res, fxd, ww | | 2,800 Ω | 5% | 14 w | 81349 | RW31V282 | 32-0023-00 |
| R349 | | Res, fxd, ww | | 2,800 Ω | 5% | 14 w | 81349 | RW31V282 | 32-0023-00 |
| R350 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R351 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R352 | | Res, fxd, film | | 237,000 Ω | 1% | 1 w | 81349 | RN75G2373F | 31-6011-00 |
| R353 | | Res, fxd, film | | 100,000 Ω | 1% | 1 w | 81349 | RN75G1003F | 31-6010-00 |

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R354 | | Res, fxd, comp | | 10 Ω | 10% | 2 w | 81349 | RC42GF100K | 30-9100-00 |
| R355 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R356 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R357 | | Res, fxd, ww | | 1,600 Ω | 5% | 14 w | 81349 | RW29V711 | 32-0022-00 |
| R358 | | Res, fxd, comp | | 270,000 Ω | 10% | ½ w | 81349 | RC20GF274K | 30-5274-00 |
| R359 | | Res, fxd, comp | | 56,000 Ω | 10% | ½ w | 81349 | RC20GF563K | 30-5563-00 |
| R360 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R361 | | Res, fxd, comp | | 2.2 meg | 10% | ½ w | 81349 | RC20GF225K | 30-5225-00 |
| R362 | | Res, fxd, comp | | 180,000 Ω | 10% | ½ w | 81349 | RC20GF184K | 30-5184-00 |
| R363 | | Res, fxd, film | | 301,000 Ω | 1% | 1 w | 81349 | RN75G3013F | 31-6005-00 |
| R364 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R365 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R366 | | Res, fxd, film | | 200,000 Ω | 1% | 1 w | 81349 | RN75G2003F | 31-6006-00 |
| R367 | | Res, fxd, comp | | 82,000 Ω | 10% | 1 w | 81349 | RC32GF823K | 30-7823-00 |
| R368 | | Res, fxd, comp | | 10 Ω | 10% | 1 w | 81349 | RC32GF100K | 30-7100-00 |
| R369 | | Res, fxd, comp | | 1.5 meg | 10% | ½ w | 81349 | RC20GF155K | 30-5155-00 |
| R370 | | Res, fxd, ww | | 4,000 Ω | 5% | 8 w | 81349 | RW29G402 | 32-0033-00 |
| R371 | | Res, fxd, ww | | 4,000 Ω | 5% | 8 w | 81349 | RW29G402 | 32-0033-00 |
| R372 | | Res, fxd, comp | | 680,000 Ω | 10% | ½ w | 81349 | RC20GF684K | 30-5684-00 |
| R373 | | Res, fxd, comp | | 47,000 Ω | 10% | ½ w | 81349 | RC20GF473K | 30-5473-00 |
| R374 | | Res, fxd, comp | | 39,000 Ω | 10% | ½ w | 81349 | RC20GF393K | 30-5393-00 |
| R375 | | Res, fxd, film | | 301,000 Ω | 1% | 1 w | 81349 | RN75G3013F | 31-6005-00 |
| R376 | | Res, fxd, film | | 442,000 Ω | 1% | 1 w | 81349 | RN75G4423F | 31-6004-00 |
| R377 | | Res, fxd, comp | | 10 Ω | 10% | 1 w | 81349 | RC32GF100K | 30-7100-00 |
| R378 | | Res, fxd, comp | | 10 Ω | 10% | 1 w | 81349 | RC32GF100K | 30-7100-00 |
| R379 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC32GF823K | 30-7823-00 |
| R380 | | Res, fxd, ww | | 1,600 Ω | 5% | 14 w | 81349 | RW29V711 | 32-0022-00 |
| R381 | | Res, fxd, comp | | 150,000 Ω | 10% | ½ w | 81349 | RC20GF154K | 30-5154-00 |
| R382 | | Res, fxd, comp | | 27,000 Ω | 10% | ½ w | 81349 | RC20GF273K | 30-5273-00 |
| R383 | | Res, fxd, comp | | 68,000 Ω | 10% | ½ w | 81349 | RC20GF683K | 30-5683-00 |
| R384 | | Res, fxd, comp | | 2.7 meg | 10% | ½ w | 81349 | RC20GF275K | 30-5275-00 |
| R385 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R386 | | Res, fxd, film | | 68,100 Ω | 1% | 1 w | 81349 | RN75G6812F | 31-6008-00 |
| R387 | | Res, fxd, comp | | 10 Ω | 10% | ½ w | 81349 | RC20GF100K | 30-5100-00 |
| R388 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R389 | | Res, fxd, comp | | 1,000 Ω | 10% | ¼ w | 81349 | RC07GF102K | 30-3102-00 |
| R390 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R391 | | Res, variable | WW | 10,000 Ω | 10% | 2 w | 81349 | RA20LASB103A | 33-0012-00 |
| R392 | | Res, fxd, comp | | 15,000 Ω | 10% | 1 w | 81349 | RC32GF153K | 30-7153-00 |
| R393 | | Res, fxd, comp | | 15,000 Ω | 10% | 1 w | 81349 | RC32GF153K | 30-7153-00 |
| R394 | | Res, fxd, comp | | 2.7 meg | 10% | ½ w | 81349 | RC20GF275K | 30-5275-00 |
| R395 | | Res, fxd, comp | | 33,000 Ω | 10% | ½ w | 81349 | RC20GF333K | 30-5333-00 |
| R396 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R397 | | Res, fxd, film | | 50,000 Ω | 1% | 1 w | 56289 | 403E50021 | 31-6007-00 |

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R398 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R399 | | Res, fxd, comp | | 22,000 Ω | 10% | 2 w | 81349 | RC42GF223K | 30-9223-00 |
| R400 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R401 | | Res, fxd, comp | | 1,000 Ω | 10% | ½ w | 81349 | RC20GF102K | 30-5102-00 |
| R402 | | Res, fxd, comp | | 470,000 Ω | 10% | ½ w | 81349 | RC20GF474K | 30-5474-00 |
| R403 | | Res, fxd, comp | | 390 Ω | 10% | 2 w | 81349 | RC42GF391K | 30-9391-00 |
| R404 * | | | | | | | | | |
| R405 * | | | | | | | | | |
| R406 * | | | | | | | | | |
| R407 | | Res, variable | Comp | 1 meg | 20% | 2 w | 81349 | RV4NAYSD105B | 33-0033-00 |
| R408 * | | | | | | | | | |
| R409 * | | | | | | | | | |
| R410 * | | | | | | | | | |
| R411 | | Res, fxd, comp | | 820,000 Ω | 10% | ½ w | 81349 | RC20GF824K | 30-5824-00 |
| R412 | | Res, variable | Comp | 2 meg | 20% | 2 w | 81349 | RV4LAYSA205B | 33-0024-00 |
| R413 * | | | | | | | | | |
| R414 * | | | | | | | | | |
| R415 | | Res, variable | Comp | 2 meg | 20% | 2 w | 81349 | RV4NAYSD205B | 33-0034-00 |
| R416 * | | | | | | | | | |
| R417 * | | | | | | | | | |
| R418 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R419 | | Res, fxd, comp | | 150,000 Ω | 10% | ½ w | 81349 | RC20GF154K | 30-5154-00 |
| R420 | | Res, variable | Comp | 100,000 Ω | 20% | 2 w | 81349 | RV4LAYSA104B | 33-0018-00 |
| R421 | | Res, variable | Comp | 50,000 Ω | 20% | 2 w | 81349 | RV4SAYSD503B | 33-0007-00 |
| R422 | | Res, fxd, comp | | 27,000 Ω | 10% | ½ w | 81349 | RC20GF273K | 30-5273-00 |
| R423 | | Res, fxd, comp | | 1 meg | 10% | ½ w | 81349 | RC20GF105K | 30-5105-00 |
| R424 | | Res. variable | WW | 50 Ω | 10% | 2 w | 81349 | RA20SASD500A | 33-0008-00 |
| R425 | | Res, fxd, comp | | 100,000 Ω | 10% | ½ w | 81349 | RC20GF104K | 30-5104-00 |
| R426 | | Res, fxd, comp | | 47 Ω | 10% | 1 w | 81349 | RC32GF470K | 30-7470-00 |
| R427 | | Res, fxd, comp | | 15 Ω | 10% | 2 w | 81349 | RC42GF150K | 30-9150-00 |
| R428 | | Res, fxd, comp | | 27 Ω | 10% | 2 w | 81349 | RC42GF270K | 30-9270-00 |
| R429 | | Res, fxd, ww | | 1 Ω | 5% | 14 w | 81349 | RW31V1RO | 32-0018-00 |
| R430 | | Res, fxd, comp | | 27,000 Ω | 10% | 1 w | 81349 | RC32GF273K | 30-7273-00 |
| R431 | | Res, fxd, comp | | 220 Ω | 10% | ½ w | 81349 | RC20GF221K | 30-5221-00 |
| R432 | | Res, fxd, comp | | 180 Ω | 10% | 1 w | 81349 | RC32GF181K | 30-7181-00 |
| R433 | | Res, fxd, comp | | 27,000 Ω | 10% | 1 w | 81349 | RC32GF273K | 30-7273-00 |
| R434 | | Res, fxd, comp | | 220 Ω | 10% | ½ w | 81349 | RC20GF221K | 30-5221-00 |
| R435 | | Res, fxd, film | | 2,800 Ω | 1% | ½ w | 81349 | RN70G2801F | 31-4013-00 |
| R436 | | Res, fxd, film | | 2,800 Ω | 1% | ½ w | 81349 | RN70G2801F | 31-4013-00 |
| R437 | | Res, variable | Comp | 500 Ω | 20% | ½ w | 81349 | RV6LAYSA501B | 33-0009-00 |
| R438 | | Res, fxd, comp | | 180 Ω | 10% | 1 w | 81349 | RC32GF181K | 30-7181-00 |
| R439 | | Res, fxd, ww | | 1 Ω | 5% | 3 w | 81349 | RW59V1R0 | 32-0013-00 |
| R440 | | Res, fxd, comp | | 270 Ω | 10% | 1 w | 81349 | RC32GF271K | 30-7271-00 |
| R441 | | Res, fxd, ww | | 1 Ω | 5% | 3 w | 81349 | RW59V1RO | 32-0013-00 |

* Not replaceable. Parts are included in encapsulated high voltage power supply. (Ref Des A1)

## Resistors (continued)

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Tolerance | Wattage | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|---|---|
| R442 | | Res, fxd, ww | | 1 Ω | 5% | 3 w | 81349 | RW59V1R0 | 32-0013-00 |
| R443 | | Res, fxd, ww | | 1 Ω | 5% | 3 w | 81349 | RW59V1R0 | 32-0013-00 |
| R444 | | Res, fxd, comp | | 22 Ω | 10% | ½ w | 81349 | RC20GF220K | 30-5220-00 |
| R445 | | Res, fxd, comp | | 2,900 Ω | 10% | 2 w | 81349 | RC42GF292K | 30-9292-00 |
| R446 | | Res, fxd, comp | | 18,000 Ω | 10% | ½ w | 81349 | RC20GF183K | 30-5183-00 |
| R447 | | Res, fxd, film | | 20 000 Ω | 1% | 1 w | 81349 | RN75G2002F | 31-6013-00 |
| R448 | | Res, fxd, comp | | 12,000 Ω | 10% | ½ w | 81349 | RC20GF123K | 30-5123-00 |
| R449 | | Res, fxd, film | | 2,100 Ω | 1% | ½ w | 81349 | RN70G2101F | 31-4004-00 |
| R450 | | Res, variable | Comp | 500 Ω | 20% | ½ w | 81349 | RV6LAYSA501B | 33-0009-00 |
| R451 * | | | | | | | | | |
| R452 | | Res, fxd, comp | | 4,700 Ω | 10% | 1 w | 81349 | RC32GF472K | 30-7472-00 |
| R453 | | Res, fxd, ww | | .25 Ω | 10% | 3 w | 81349 | RW59VR25 | 32-0006-00 |
| R454 | | Res, fxd, ww | | .25 Ω | 10% | 3 w | 81349 | RW59VR25 | 32-0006-00 |
| R455 | | Res, fxd, ww | | .25 Ω | 10% | 3 w | 81349 | RW59VR25 | 32-0006-00 |
| R456 | | Res, fxd, ww | | .25 Ω | 10% | 3 w | 81349 | RW59VR25 | 32-0006-00 |

* Not replaceable. Parts are included in encapsulated high voltage power supply. (Ref Des A1)

## Switches

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tek Unwired Part No. | Tek Wired Part No. |
|---|---|---|---|---|---|---|---|
| S1-S2 | | Switch, rotary | A two section switch. Front section has two wafers, six positions. Rear section has three wafers, five positions. Has concentric shafts. | 80009 | | 64-0003-00 | 76-0004-05 |
| S3* | | Switch, res, variable | Single pole, double throw | 71450 | HM20398 | 33-0027-00 | |
| S4 | | Switch, rotary | A one section switch, four wafers, four position | 80009 | | 64-0004-00 | 76-0007-05 |
| S5-S11 | | Switch, rotary | A two section switch. Front section has five wafers, eight positions. Rear section has one wafer, two position. Has concentric shafts. | 80009 | | 64-0002-00 | 76-0006-05 |
| S6 | | Switch, rotary | A one section switch having three wafers, six positions. | 80009 | | 64-0005-00 | 76-0005-05 |
| S7-S8 | | Switch, toggle | Double pole, double throw. | 81349 | MS25100-23 | 64-0010-00 | 76-0009-05 |
| S9 | | Switch, rotary | A one section switch having four wafers, twelve positions. | 80009 | | 64-0006-00 | 76-0003-05 |
| S10 | | Switch, push | ¼ amp at 115 vac, 0.004 Ω contact resistance. | 81073 | 23YY2007 | 64-0011-00 | |

* S3 Concentric with R14 and R39. Furnished as a unit.

## Switches (continued)

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tek Unwired Part No. | Tek Wired Part No. |
|---|---|---|---|---|---|---|---|
| S12-S13 | | Switch, rotary | A two section switch. Front section has two wafers, nine positions. Rear section has one wafer, three positions. Has concentric shafts. | 80009 | | 64-0001-00 | 76-0008-05 |
| S14 | | Switch, thermostatic | Normally colsed. Points open at 187° F ±3° F. Points close at 167° F ±5° F. | 93410 | A-605 | 64-0014-00 | |
| S15 | | Switch, toggle | Double pole, single throw. | 81349 | MS35059-22 | 64-0028-00 | |
| S16 | | Switch, thermostatic | Normally open. Closed at 159° F ±3° F. Opens at 20° F ±7° F. | 93410 | C-206 | 64-0015-00 | |

## Transformers

| Ref Desig | Eff S/N Range | Item Name | Item Characteristic | Value | Description | Mfr Code No. | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| T1 | | Transformer, rf | Variable | 1.8-3.7 μh | | 80009 | 51-5002-01 |
| T2 | | Transformer, rf | Variable | 1.8-3.7 μh | | 80009 | 51-5002-01 |
| T3 | | Transformer, rf | Fixed | | Seven sections, one having eight turns, six having twenty-six turns. | 80009 | 51-0004-00 |
| T4 | | Transformer, rf | Fixed | | Six sections, each having twenty turns. | 80009 | 51-0003-00 |
| T5 | | Transformer, rf | Fixed | | Six sections, each having twenty turns. | 80009 | 51-0003-00 |
| T6 | | Transformer, rf | Fixed | | Seven sections, one having eight turns, six having twenty-six turns. | 80009 | 51-0004-00 |
| T7 | | Transformer, rf | Fixed | | Thirty sections each having twenty-five turns. | 80009 | 51-0002-00 |
| T8 | | Transformer, rf | Fixed | | Thirty sections each having twenty-five turns. | 80009 | 51-0002-00 |
| T9 | | Transformer, rf | Fixed | | Twenty sections each having twenty-five turns. | 80009 | 51-0001-00 |
| T10 | | Transformer, rf | Fixed | | Twenty sections each having twenty-five turns. | 80009 | 51-0001-00 |
| T11 | | Xmfr, step-down and step-up | | | 115/230 vac, 50 to 400 cps. | 80009 | 52-0002-00 |
| T12 * | | Xmfr, step-down and step-up | | | | | |

* Not replaceable. Parts are included in encapsulated high voltage power supply. (Ref Des A1)

## Jack

| Ref Desig | Eff S/N Range | Item name | Mfr Code No. | Mfr Part No. | Tektronix Part No. |
|---|---|---|---|---|---|
| TPJ | | Tip, Jack | 83330 | 1099-AX | 14-1014-00 |

## Electron Tubes

| Ref Desig | Eff S/N Range | Item Name | Source Inspected (When Spec. by Contract) | Mfr Code No. | Mfr P/N Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| V1 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V2 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V3 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V4 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V5 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V6 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V7 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V8 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V9 | | Electron tube | | 80131 | 12BY7A | 60-0010-01 |
| V10 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V11 | | Electron tube | 60-0003-00 | 80131 | 5726/6AL5W | 60-0003-01 |
| V12 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V13 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V14 | | Electron tube | 60-0009-00 | 80131 | 5814A | 60-0009-01 |
| V15 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V16 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V17 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V18 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V19 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V20 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V21 | | Electron tube | 60-0007-00 | 80131 | 5751 | 60-0007-01 |
| V22 | | Electron tube | 60-0005-00 | 80131 | 12AU6 | 60-0005-01 |
| V23 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V24 | | Electron tube | 60-0002-00 | 80131 | 6AU6WA | 60-0001-01 |
| V25 | | Electron tube | 60-0002-00 | 80131 | 6AU6WA | 60-0001-01 |
| V26 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V27 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V28 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V29 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V30 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V31 | | Electron tube | 60-0014-00 | 80131 | 6CL6 | 60-0014-01 |
| V32 * | | Electron tube | | 80009 | 12BY7 | 69-0001-00 |
| V33 * | | Electron tube | | 80009 | 12BY7 | 69-0001-00 |
| V34 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V35 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V36 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V37 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V38 | | Electron tube | 60-0009-00 | 80131 | 5814A | 60-0009-01 |
| V39 | | Electron tube | 60-0002-00 | 80131 | 6922 | 60-0002-01 |
| V40 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V41 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V42 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V43 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V44 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |

* V32 and V33 furnished as a matched pair.

## Electron Tubes (continued)

| Ref Desig | Eff S/N Range | Item Name | Source Inspected (When Spec. by Contract) | Mfr Code No. | Mfr P/N Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| V45 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V46 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V47 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V48 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V49 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V50 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V51 | | Electron tube | | 80131 | 6DK6 | 60-0011-01 |
| V52 | | Electron tube | 60-0009-00 | 80131 | 5814A | 60-0009-01 |
| V53 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V54 | | Electron tube | 60-0006-00 | 80131 | 6080WA | 60-0006-01 |
| V55 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V56 | | Electron tube | 60-0006-00 | 80131 | 6080WA | 60-0006-01 |
| V57 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V58 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V59 | | Electron tube | 60-0007-00 | 80131 | 5751 | 60-0007-01 |
| V60 | | Electron tube | 60-0006-00 | 80131 | 6080WA | 60-0006-01 |
| V61 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V62 | | Electron tube | 60-0001-00 | 80131 | 6AU6WA | 60-0001-01 |
| V63 | | Electron tube | 60-0013-00 | 80131 | 5651WA | 60-0013-01 |
| V64 | | Electron tube | 60-0007-00 | 80131 | 5751 | 60-0007-01 |
| V65 | | Electron tube | 60-0015-00 | 80131 | 6L6WGB | 60-0015-01 |
| V66 | | Electron tube | 60-0009-00 | 80131 | 5814A | 60-0009-01 |
| V67 * | | | | | | |
| V68 * | | | | | | |
| V69 * | | | | | | |
| V70 * | | | | | | |
| V71 * | | | | | | |
| V72 | | Electron tube | Type T543 P2 CRT | 80009 | | 60-8001-00 |

* Not replaceable. Parts are included in encapsulated high voltage power supply. (Ref Desig A1)

## Lampholders

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| XDS1 | | Lampholder | Black plastic, for one bulb | 80009 | | 14-1012-00 |
| XDS7-8 | | Lampholder | Black plastic, for two bulbs | 80009 | | 14-1013-00 |
| XDS9-10 | | Lampholder | Black plastic, for two bulbs | 80009 | | 14-1013-00 |
| XDS11 | | Lampholder | | 81349 | LH22XX0 | 14-1018-00 |
| XDS12 | | Lampholder | | 81349 | LH22XX0 | 14-1018-00 |
| XDS13 | | Light, indicator | w/red lens | 81349 | LH50BR2 | 14-1009-00 |
| XDS14 | | Lampholder | | 03797 | 1DH | 14-1008-00 |

## Fuseholders

| Ref Desig | Eff S/N Range | Item Name | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|
| XF1 | | Fuseholder | 75915 | 342004 | 14-1011-00 |
| XF2 | | Fuseholder | 75915 | 342004 | 14-1011-00 |

## Sockets

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| XV1 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV2 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377B-.125 | 14-1002-00 |
| XV3 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV4 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV5 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV6 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV7 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV8 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV9 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV10 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV11 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV12 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV13 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV14 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV15 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV16 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| XV17 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV18 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV19 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV20 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV21 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV22 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV23 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV24 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV25 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV26 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV27 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV28 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV29 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV30 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV31 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV32 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 00373 | 69-005-7933 | 14-1028-00 |
| XV33 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 00373 | 69-005-7933 | 14-1028-00 |
| XV34 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 00373 | 69-005-7933 | 14-1028-00 |

## Sockets (continued)

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| XV35 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7724 | 14-1027-00 |
| XV36 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniture. | 00373 | 69005-7933 | 14-1028-00 |
| XV37 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7724 | 14-1027-00 |
| XV38 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV39 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV40 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7724 | 14-1027-00 |
| XV41 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7724 | 14-1027-00 |
| XV42 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV43 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV44 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV45 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV46 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV47 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV48 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV49 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV50 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV51 | | Soc, electron tube | Seven pin, top mounting, saddle type, without ground lugs, sub minitaure. | 00373 | 69005-7224 | 14-1027-00 |
| XV52 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |

## Sockets (continued)

| Ref Desig | Eff S/N Range | Item Name | Description | Mfr Code No. | Mil P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|
| XV53 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 366BC-.125 | 14-1001-00 |
| XV54 | | Soc, electron tube | Eight pin, bottom mounting, saddle type, with ground lugs. | 81349 | TS101PO1 | 14-1003-00 |
| XV55 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV56 | | Soc, electron tube | Eight pin, bottom mounting, saddle type, with ground lugs. | 81349 | TS101PO1 | 14-1003-00 |
| XV57 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV58 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 316BC-.125 | 14-1001-00 |
| XV59 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV60 | | Soc, electron tube | Eight pin, bottom mounting, saddle type, with ground lugs. | 81349 | TS101PO1 | 14-1003-00 |
| XV61 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 366BC-.125 | 14-1001-00 |
| XV62 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 366BC-.125 | 14-1001-00 |
| XV63 | | Soc, electron tube | Seven pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 366BC-.125 | 14-1001-00 |
| XV64 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV65 | | Soc, electron tube | Eight pin, bottom mounting, saddle type, with ground lugs. | 81349 | TS101PO1 | 14-1003-00 |
| XV66 | | Soc, electron tube | Nine pin, bottom mounting, saddle type, with ground lugs, sub miniature. | 91662 | 377BC-.125 | 14-1002-00 |
| XV72 | | Soc, electron tube | Fourteen pin, tube mounting, CRT | 71785 | 9453-14 | 14-1017-00 |

# SECTION 10
# MECHANICAL PARTS LIST

| Fig. No. | Index No. | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| 10-1 | 1 | | Connector, plug, electrical | BNC plug, binding post. | 95712 | 4767-1 | 14-1043-00 |
| 10-1 | 2 | | Filter, light, CRT | Green, 5 in. sq. | 80009 | | 23-0014-00 |
| 10-1 | 3 | | Cable assembly, radio frequency | 24.00 in. lg cable with BNC connectors on each end. | 80009 | | 74-0027-00 |
| 10-2 | | | Lead, test | 42 inch, with tips. | 80009 | | 70-6001-00 |
| 10-2 | 1 | | Holder, test prod | ¼ inch slot, with banana plug mounting. | 80009 | | 13-8031-00 |
| 10-2 | 2 | | Tip, test prod | Pincer nose 3.67 in. lg. | 80009 | | 13-8048-00 |
| 10-2 | 3 | | Tip, test prod | Banana plug 0.940 in. lg. | 80009 | | 13-8049-00 |
| 10-2 | 4 | | Tip, test prod | Long straight shank 1.00 in. lg. | 80009 | | 13-8050-00 |
| 10-2 | 5 | | Tip, test prod | Long hooked shank 0.95 in. lg. | 80009 | | 13-8050-01 |
| 10-2 | 6 | | Tip, test prod | Short straight shank 0.630 in. lg. | 80009 | | 13-8051-00 |
| 10-2 | 7 | | Lead, electrical | Probe grounding lead, 5.00 in. lg. | 80009 | | 74-0037-00 |
| 10-2 | 8 | | Lead, test | Can not be purchased separately, order p/n 70-6001-00. | 80009 | | No No., NHA |
| Top | | | Cover, oscilloscope | 20.260 in. lg x 12.880 in. w x 0.050 in. thk alum, gray paint, with attaching hardware. | 80009 | | 23-0002-00 |
| Bottom | | | Cover, oscilloscope | 20.300 in. lg x 10.060 in. w x 0.050 in. thk alum, gray paint, with attaching hardware. | 80009 | | 23-0003-00 |
| Left side | | | Cover, oscilloscope | 20.260 in. lg x 15.640 in. w x 0.050 in. thk alum, gray paint, with attaching hardware. | 80009 | | 23-0004-05 |
| Right side | | | Cover, oscilloscope | 20.260 in. lg x 15.640 in. w x 0.050 in. thk alum, gray paint, with attaching hardware. | 80009 | | 23-0005-05 |
| Left side | | | Button, plug | Cover for CRT access opening, gray paint, part of cover oscilloscope p/n 23-0004-05. | 80009 | | 14-1031-01 |
| 10-3 | 1 | | Knob | 0.750 in. od x 0.740 in. lg with 0.252 in. id. Shaft hole part way through, black. | 80009 | | 15-8001-06 |
| 10-3 | 2 | | Knob | 1.500 in. od x 0.800 in. lg with 0.252 in. id. Shaft hole part way through, black. | 80009 | | 15-8002-06 |
| 10-3 | 3 | | Knob | 1.500 in. od x 0.800 in. lg with 0.252 in. id. Shaft hole through, black. | 80009 | | 15-8002-08 |
| 10-3 | 4 | | Knob | 1.500 in. od x 0.800 in. lg with 0.267 in. id. Shaft hole through, black. | 80009 | | 15-8002-10 |

| Fig. No. | Index No. | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| 10-3 | 5 | | Knob | 0.750 in. od x 0.630 in. lg with 0.189 in. dia. Shaft hole partway through, red. | 80009 | | 15-8003-04 |
| 10-3 | 6 | | Knob | 0.750 in. od x 0.630 in. lg with 0.127 in. dia. Shaft hole part way through, red. | 80009 | | 15-8003-06 |
| 10-3 | 7 | | Dial, control | 1.81 in. od x 1.00 in. thk and has two counting scales. The inner scale counts hundredths of a turn, the outer scale counts turns. | 80009 | | 22-0005-00 |
| 10-3 | 8 | | Nut, plain, knurled | 0.375 in. dia x 0.62 in. lg, drilled through, tapped to ¼-28 thread, brass, silver plated. | 80009 | | 12-9010-01 |
| 10-3 | 9 | | Cover, electrical connector | Grounding type BNC connector cover with attaching chain. Use on CRT CATHODE input only. | 95712 | CW 159/U | 23-0017-00 |
| 10-3 | 10 | | Cover, electrical connector | Non-grounding type BNC connector cover with attaching chain. Use on all front panel connectors except CRT input | 95712 | CU 123A/U | 23-0018-00 |
| 10-3 | 11 | | Bezel, instrument mounting | 5.75 in. sq with 4.795 in. dia opening for viewing of CRT. | 80009 | | 13-8015-01 |
| 10-3 | 12 | | Nut, plain, knurled | 0.540 in. od x 0.294 in. id x 0.225 in. w x ⅜-24 thd. | 80009 | | 12-9011-01 |
| 10-3 | 13 | | Washer, non-metallic | 0.63 in. od x 0.41 in. id x 0.06 in. thk, rubber. | 80009 | | 12-9001-00 |
| 10-3 | 14 | | Scale, cathode ray tube | 5.68 in. lg x 5.50 in. w x 0.125 in. thk clear plastic. | 80009 | | 22-0004-00 |
| 10-4 | 1 | | Adjusting ring, cathode ray tube | A white plastic handle for rotating CRT. | 80009 | | 24-0011-00 |
| 10-4 | 2 | | Insulator, pincap | A black plastic right angle post cap, 0.400 in. w x 0.400 in. lg x 0.150 in. h, 0.144 in. dia mounting hole. | 80009 | | 15-0009-01 |
| 10-4 | 3 | | Insulator, pincap | A black plastic right angle post section, 0.400 in. w x 0.140 in. lg x 0.404 in. h, 0.144 in. dia mounting hole. | 80009 | | 15-0009-00 |
| 10-4 | 4 | | Deflector, air | A half circle piece of metal having a 2.15 in. r x 3.50 in. w. | 80009 | | 21-0027-00 |
| 10-4 | 5 | | Seal, rubber, special shape | 0.250 in. w x 0.170 in. h with 0.065 in. w groove, neoprene. | 80009 | | 04-0012-00 |
| 10-4 | 6 | | Impellor, fan, axial | 6.50 in. dia x 0.78 in. w counter clockwise rotation. | 80009 | | 25-0001-00 |
| 10-4 | 7 | | Ring, retaining | Vinyl 0.110 in. id x 0.260 in. od x 0.075 in. thk. | 94222 | 58-42-0-63 | 13-8039-43 |
| 10-4 | 8 | | Stud, turnlock | 0.325 in. fastening length with grip range of 0.170 in. to 0.189 in., 0.375 in. dia oval head, slotted. 0.565 in. overall length | 94222 | 2-0-180 | 13-8039-05 |
| 10-4 | 9 | | Spring, helical, compression | 0.375 in. major dia x 0.275 in. minor dia x 0.19 in. free length. | | 43-13-1-23 | 13-8039-60 |
| 10-4 | 10 | | Washer, flanged | 0.425 in. od x 0.242 in. id x 0.090 in. h, black plastic. | 94222 | 82-46-101-41 | 13-8039-50 |

## Mechanical Parts List *(continued)*

| Fig. No. | Index No. | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| 10-5 | 1 | | Bracket, power plug | 2.35 in. lg x 1.22 in. w x 0.90 in. h, electro polished. | 80009 | | 21-0048-00 |
| 10-5 | 2 | | Clip, spring tension | 0.80 in. lg x 0.87 in. w x 0.012 in. thk, electro polished. | 80009 | | 13-8043-00 |
| 10-5 | 3 | | Holder, air filter | 10.50 in. sq x 1.00 in. h with 8.62 in. sq opening for passage of air. | 80009 | | 13-8014-00 |
| 10-5 | 4 | | Nut, self-locking, cap | 8-32 x 3/8 in. with self-locking features. | 80009 | | 12-0092-00 |
| 10-5 | 5 | | Filter, air conditioning | 10.00 in. sq x 0.85 in. thk special oil coating. | 80009 | | 23-0013-00 |
| 10-5 | 6 | | Cable assembly, power, electrical | A cut length of three conductor power cord. | 80009 | | 74-0026-01 |
| 10-5 | 7 | | Connector, plug, electrical | Three conductor power plug | 97539 | UP121M | 14-1015-00 |
| | | | Retainer, electron tube | 1.50 in. od x 1.22 in. id, stainless steel. | 00335 | 002/3010 | 13-8025-00 |
| | | | Retainer, electron tube | 4.04 in. lg x 0.80 in. w, has positions for 4 tubes. | 80009 | | 13-8006-08 |
| | | | Shield, electron tube | 1.031 in. id x 1.938 in. h, with coil spring. | 91662 | TS103U02 | 23-0024-00 |
| | | | Retainer, electron tube | 9.04 in. lg x 0.80 in. w, with springs, positions for 9 tubes. | 80009 | | 13-8006-00 |
| | | | Retainer, electron tube | 5.44 in. lg x 0.80 in. w, with springs, positions for 5 tubes. | 80009 | | 13-8006-06 |
| | | | Retainer, electron tube | 6.02 in. lg x 0.80 in. w, with springs, positions for 7 tubes. | 80009 | | 13-8006-04 |
| | | | Retainer, electron tube | 6.33 in. lg x 2.91 in. h x 2.00 in. w, with springs, positions for 6 tubes. | 80009 | | 13-8034-00 |
| | | | Retainer, electron tube | 9.02 in. lg x 0.80 in. w with springs, positions for 8 tubes. | 80009 | | 13-8006-02 |
| | | | Terminal board | 1.176 in. lg x 0.750 in. h x 0.140 in. w, 4 silvered tinned notches, ceramic, with mtg studs. | 80009 | | 14-0002-00 |
| | | | Terminal board | 1.958 in. lg x 0.750 in. h x 0.140 in. w, 7 silver tinned notches, ceramic, with mtg studs. | 80009 | | 14-0003-00 |
| | | | Terminal board | 2.479 in. lg x 0.750 in. h x 0.140 in. w, 9 silver tinned notches, ceramic, with mtg studs. | 80009 | | 14-0004-00 |
| | | | Terminal board | 2.990 in. lg x 0.750 in. h x 0.140 in. w, 11 silver tinned notches, ceramic, with mtg studs. | 80009 | | 14-0005-00 |
| | | | Terminal board | 0.394 in. lg x 0.438 in. h x 0.140 in. w, 1 silver tinned notch, ceramic, with mtg studs. | 80009 | | 14-0006-00 |
| | | | Terminal board | 1.437 in. lg x 0.438 in. h x 0.140 in. w, 5 silver tinned notches, ceramic, with mtg studs. | 80009 | | 14-0008-00 |

| Fig. No. | Index No. | Eff S/N Range | Item Name | Description | Mfr Code No. | Mfr P/N or Mil Desig | Tektronix Part No. |
|---|---|---|---|---|---|---|---|
| | | | Terminal board | 2.479 in. lg x 0.438 in. h x 0.140 in w, 9 silver tinned notches, ceramic, with mtg studs. | 80009 | | 14-0009-00 |
| | | | Spacer, sleeve | Provides 0.063 in. spacing, 0.111 in hole dia x 0.156 in. pin dia x 0.250 in. spacer dia. | 80009 | | 15-0001-00 |
| | | | Spacer, sleeve | Provides 0.156 in. spacing, 0.111 in hole dia x 0.156 in. pin dia x 0.250 in. spacer dia. | 80009 | | 15-0001-02 |

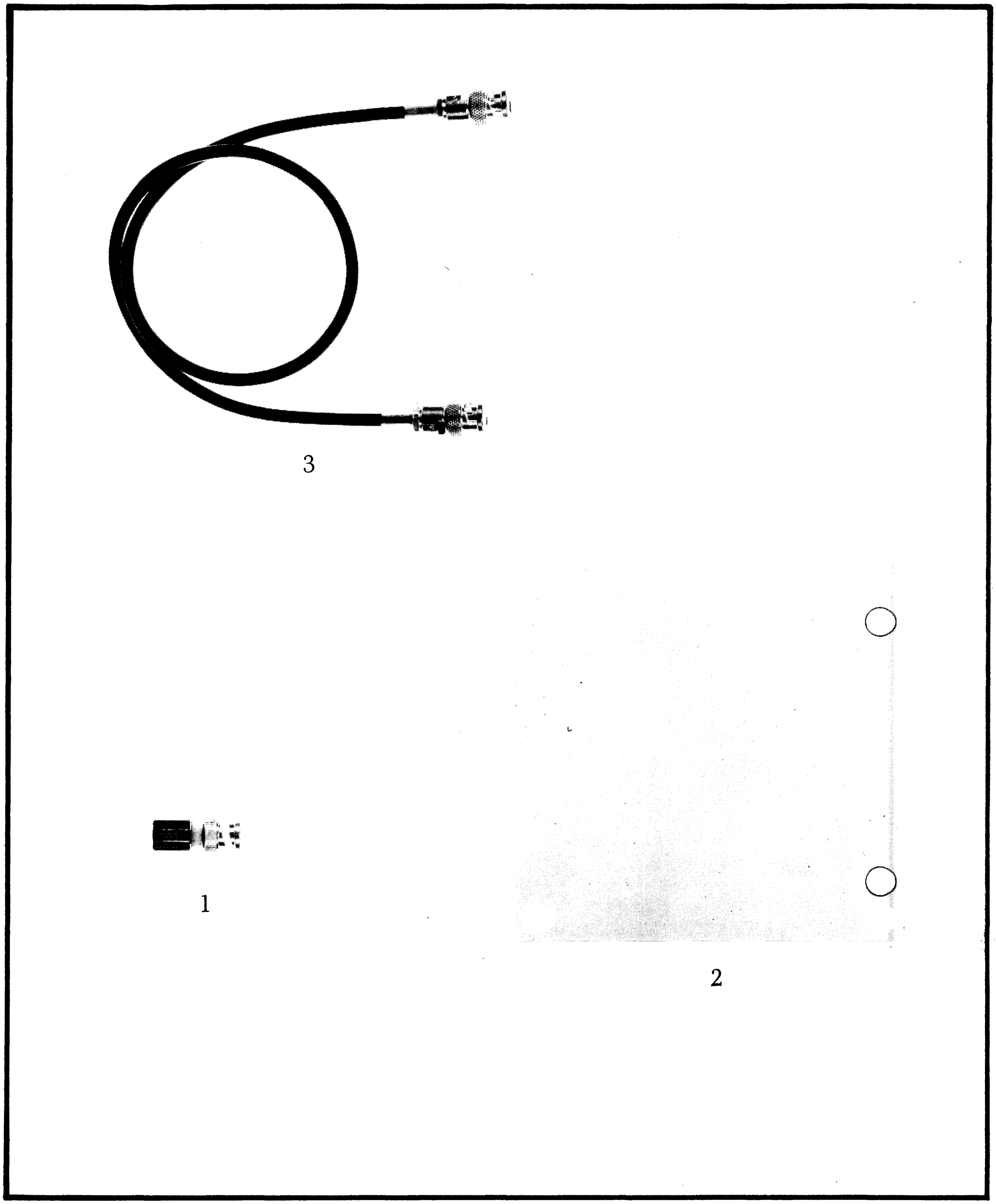


Fig. 10-1. Accessories

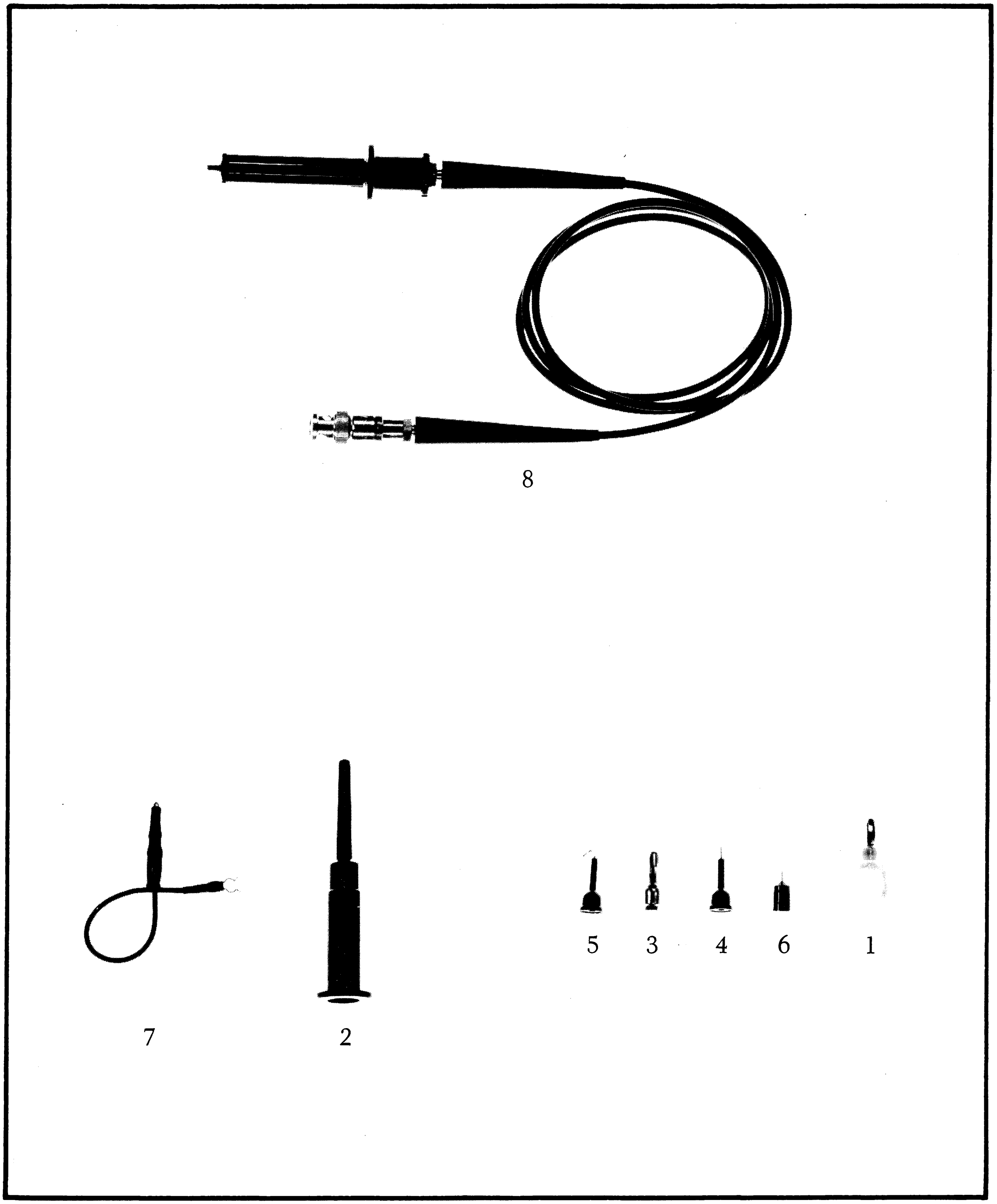
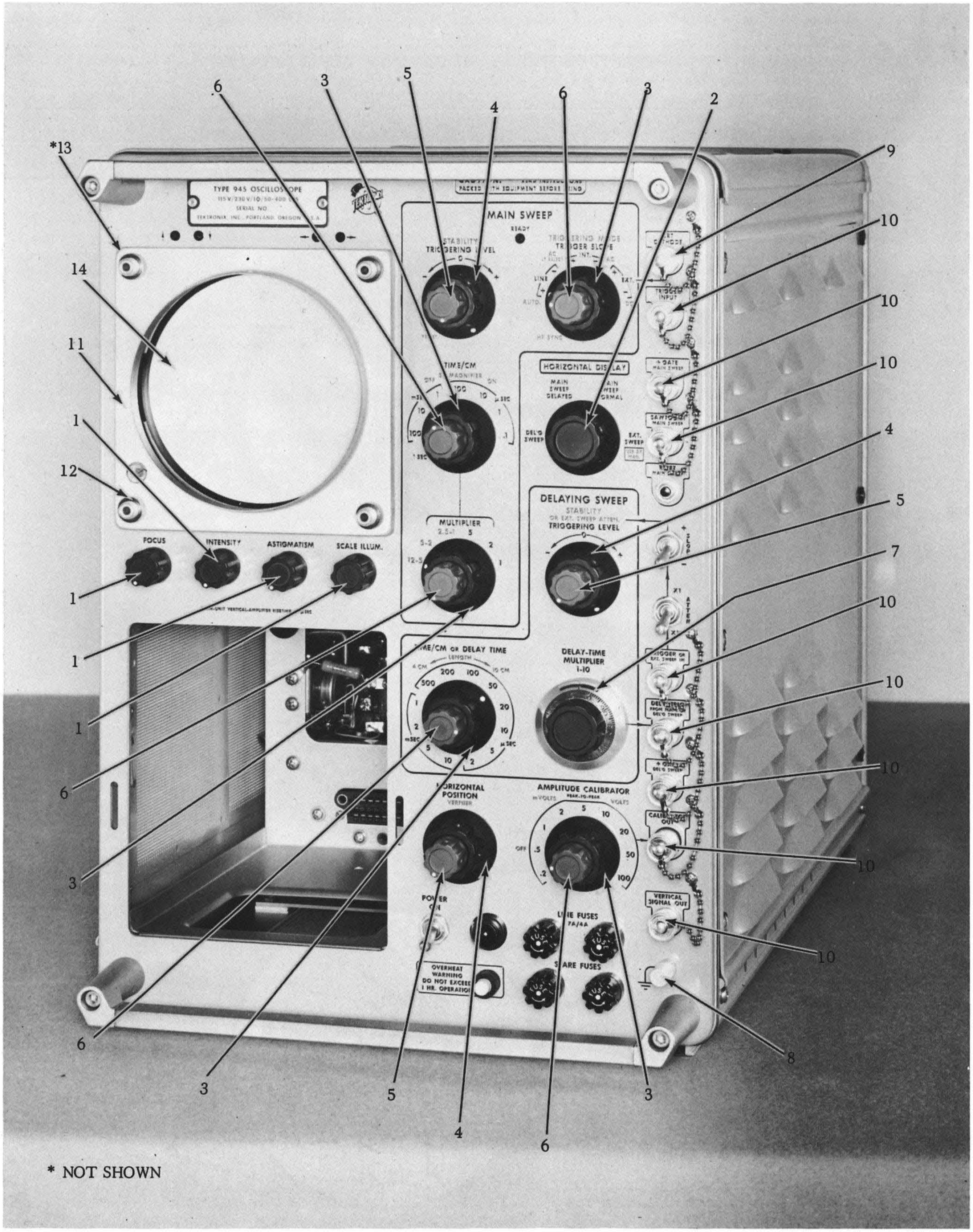



Fig. 10-2. Lead, Test Assembly P/N 70-6001-00




* NOT SHOWN

Fig. 10-3. Type 945 Oscilloscope

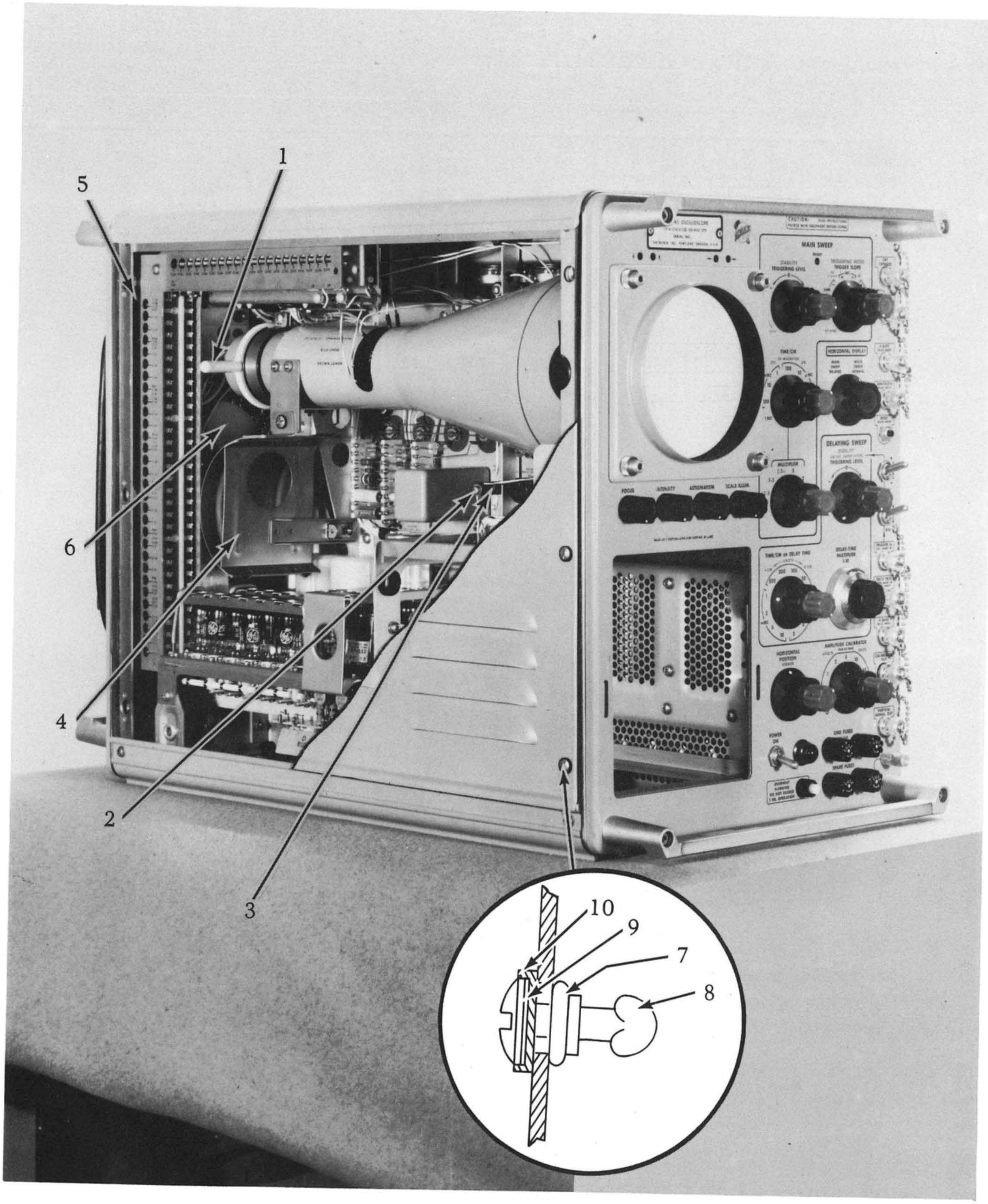



Fig. 10-4. Type 945 Oscilloscope (Front and Left Side, With Cabinet Cut Away)

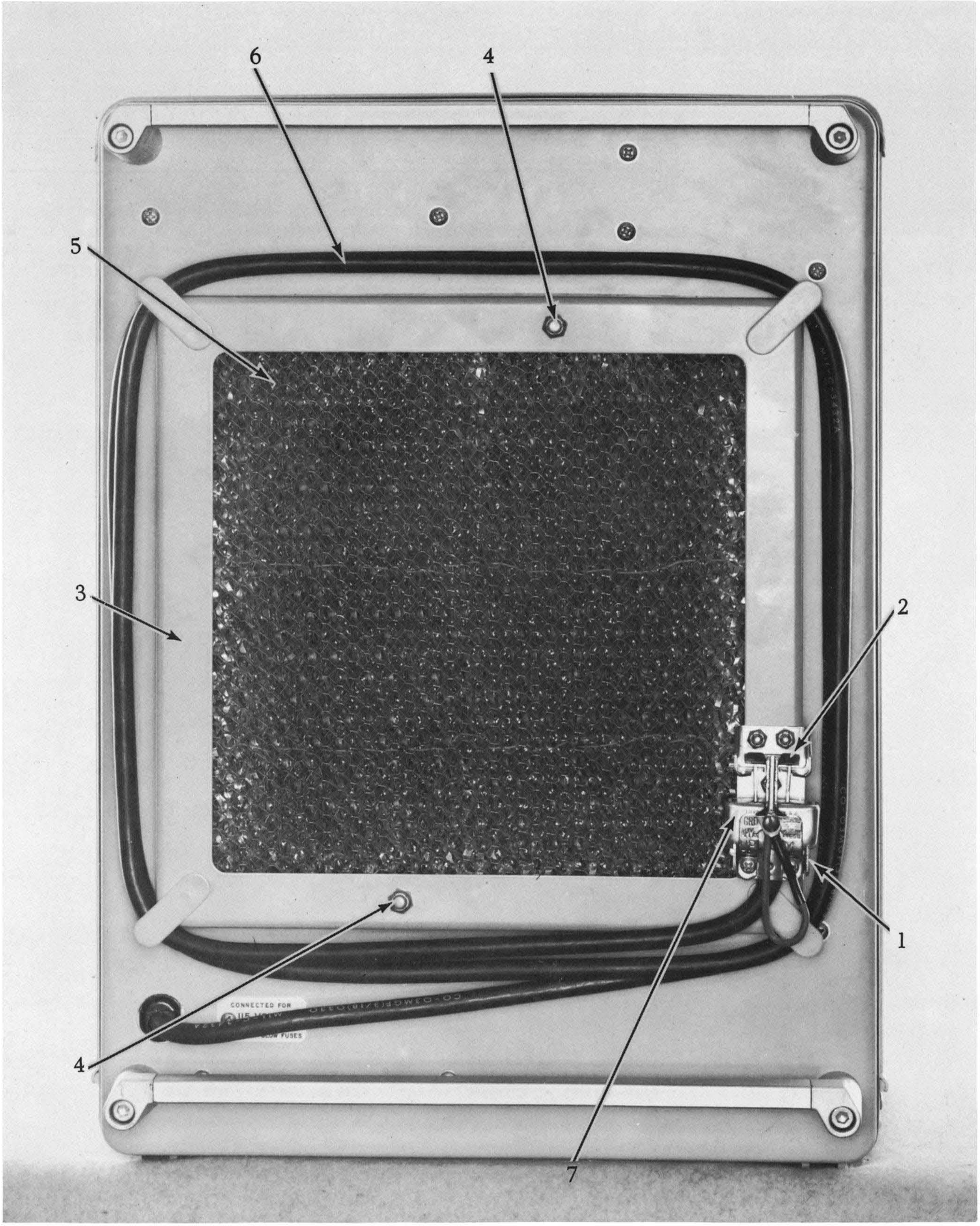



Fig. 10-5. Type 945 Oscilloscope (Rear)

# Explanation of Schematic Diagrams

## Capacitors

Where values are given in whole numbers, they are in micromicrofarads unless otherwise indicated. Where values are in decimal numbers, they are in microfarads unless otherwise indicated. Multi-section capacitors are indicated by value times number of section—thus 30 x 30 $\mu$F indicates a capacitor with 2 sections, 30 microfarads each.

| | |
|---|---|
| $\mu$F | microfarads |
| $\mu\mu$F | micromicrofarads |

## Resistors

Resistor values below 1000 ohms are indicated by whole numbers only. For example—680 would indicate a 680-ohm resistor. Resistors whose values are above one thousand or above one million ohms are labeled "K" or "M" to indicate kilohms or megohms—as 1.5 K or 5 M. Multi-section variable resistors are indicated by value times number of sections—thus, 100 K x 100 K indicates a resistor with 2 sections, 100,000 ohms each.

## Inductors

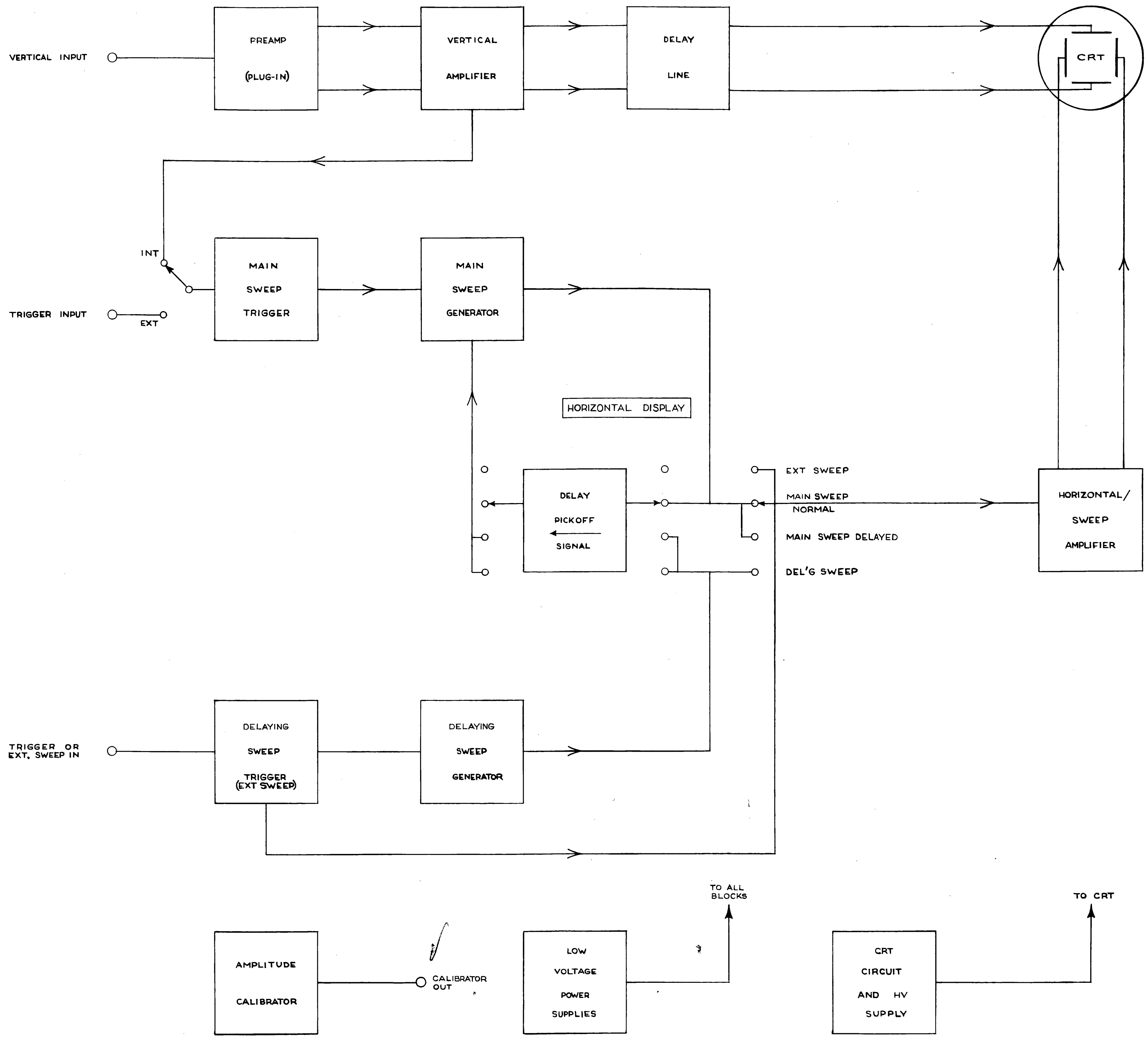
| | |
|---|---|
| $\mu$H | microhenries |

## Symbols

internal screwdriver adjustment

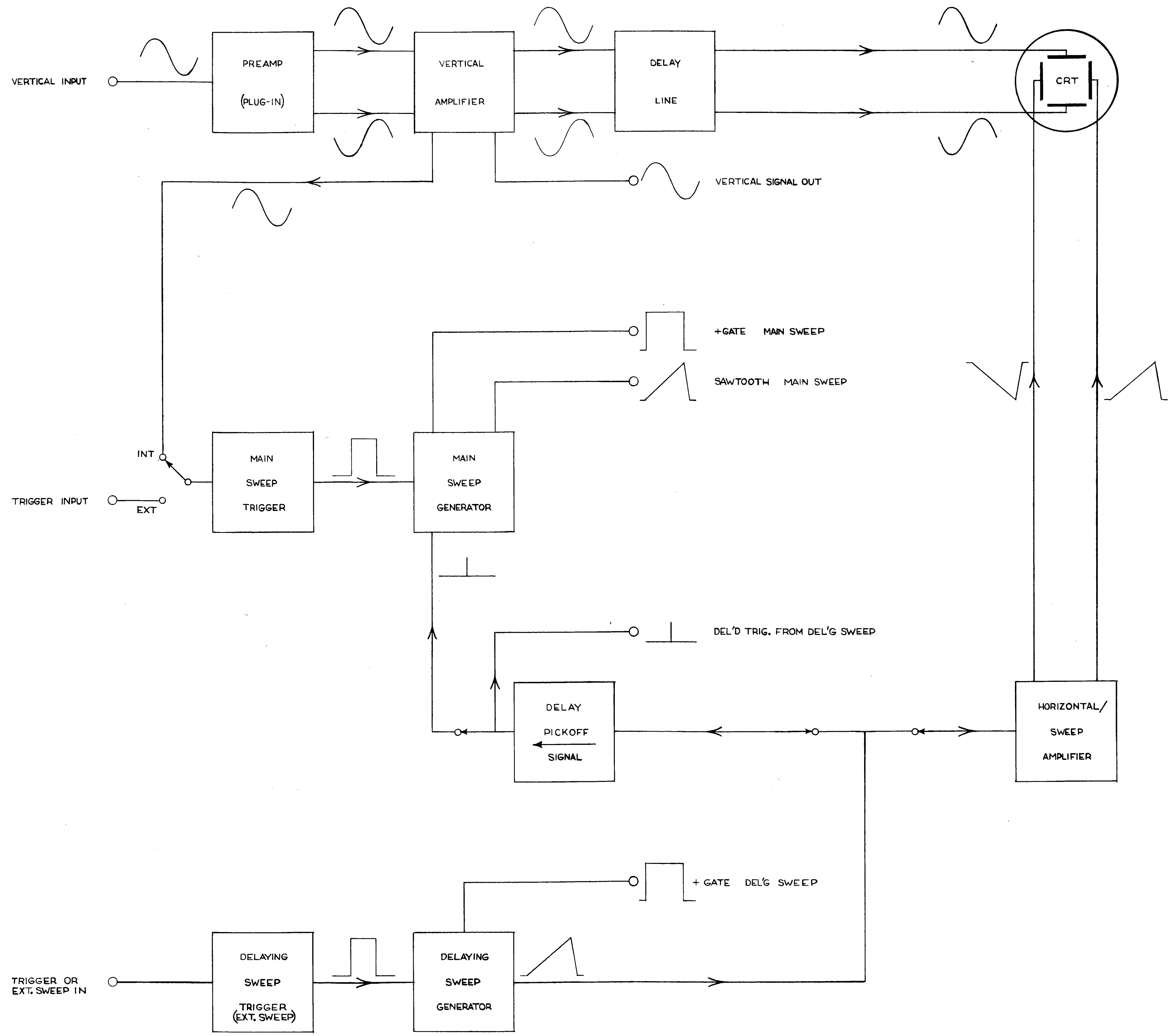
[box] around name of control — Front-panel adjustment or connector

DCPD. — decoupled voltage



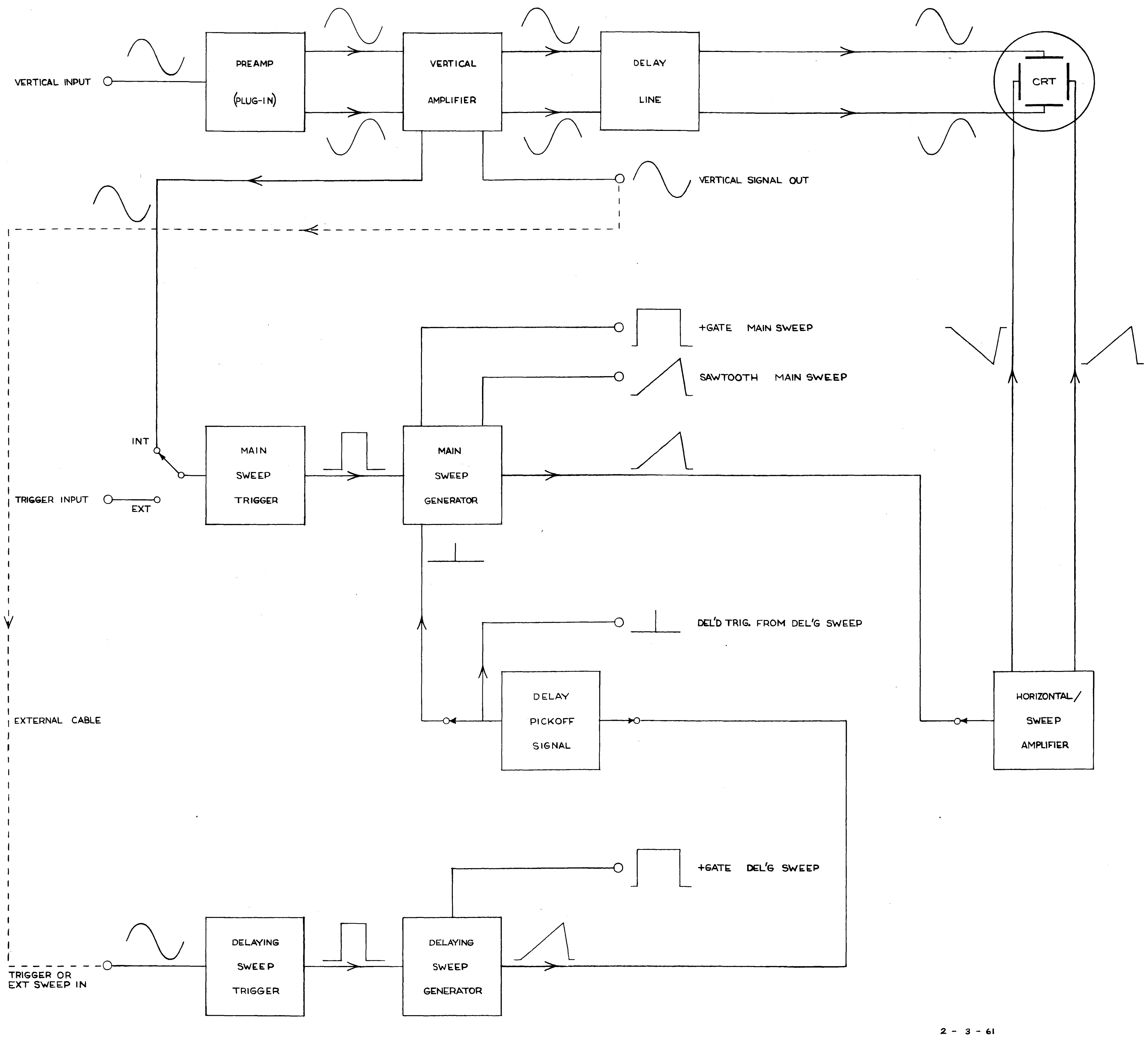

2 - 3 - 61

TYPE 945 OSCILLOSCOPE 81-0001-00 BASIC BLOCK DIAGRAM



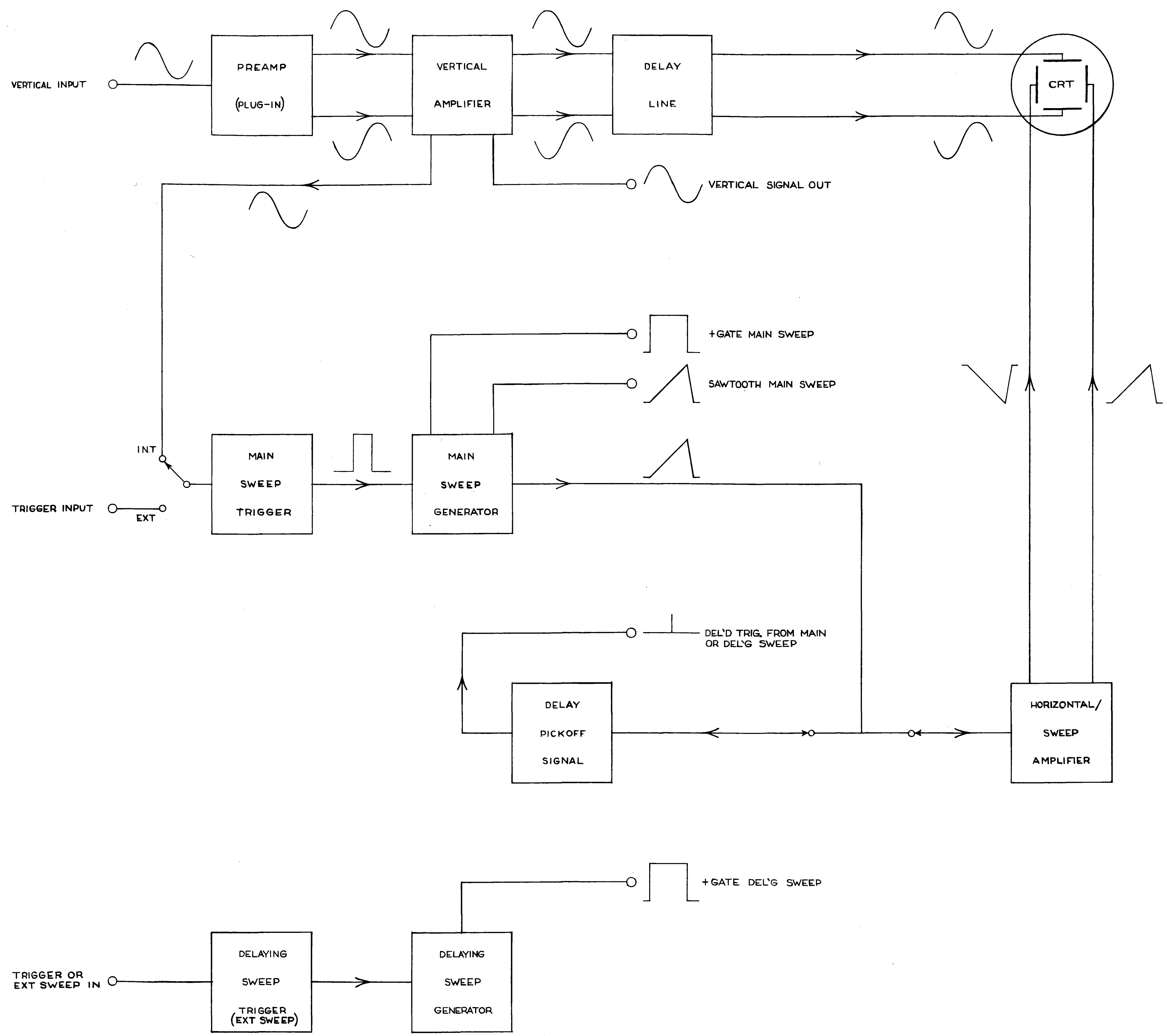

2 - 4 - 61

TYPE 945 OSCILLOSCOPE 81-0001-02 HORIZONTAL DISPLAY SWITCH "DELAYING SWEEP"




TYPE 945 OSCILLOSCOPE 81-0001-03 HORIZONTAL DISPLAY SWITCH "MAIN SWEEP DELAYED"

MAIN SWP DEL'D BLOCK



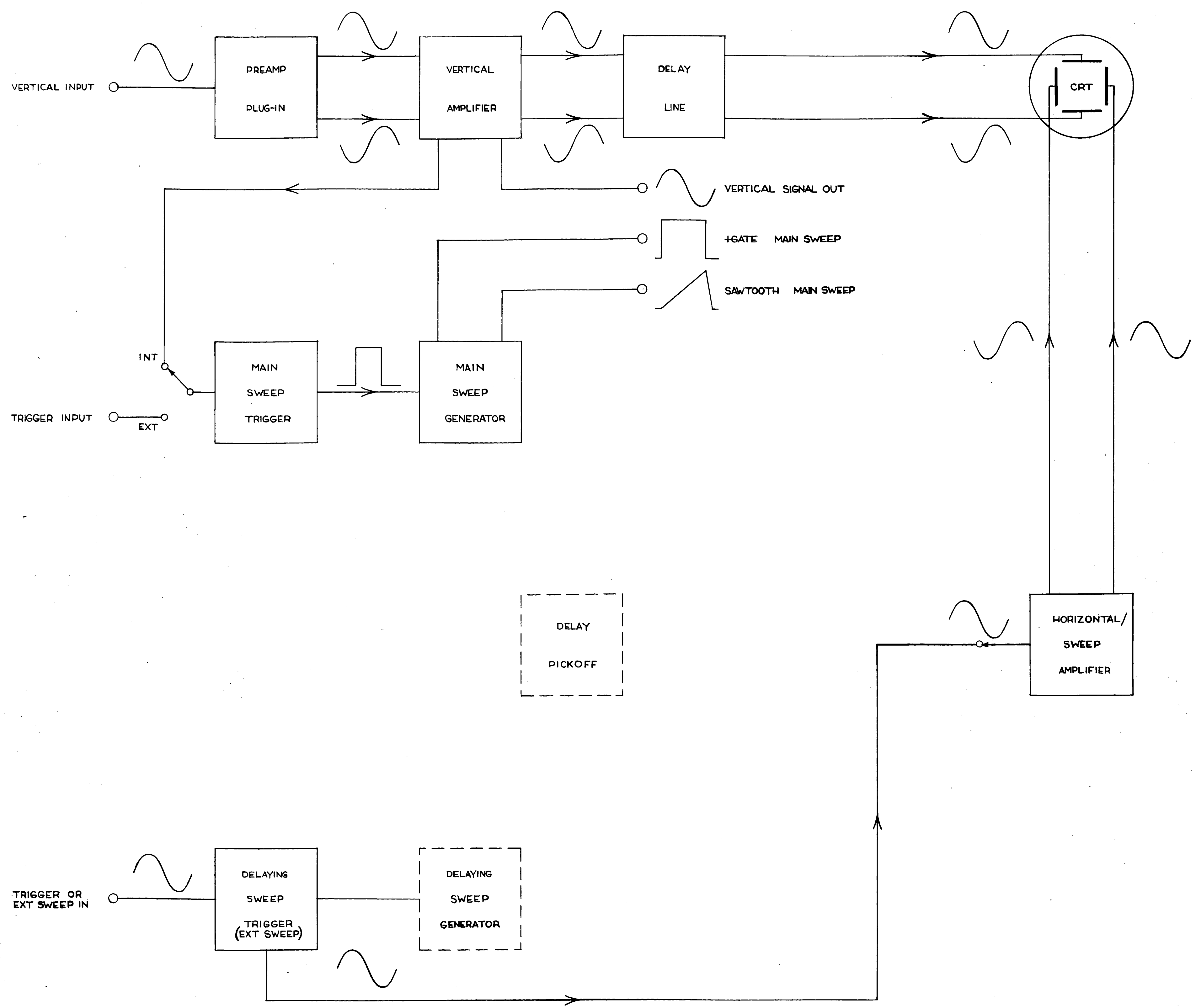

2-3-61

TYPE 945 OSCILLOSCOPE

81-0001-01

HORIZONTAL DISPLAY SWITCH "MAIN SWEEP NORMAL"

MAIN SWP NORM BLOCK

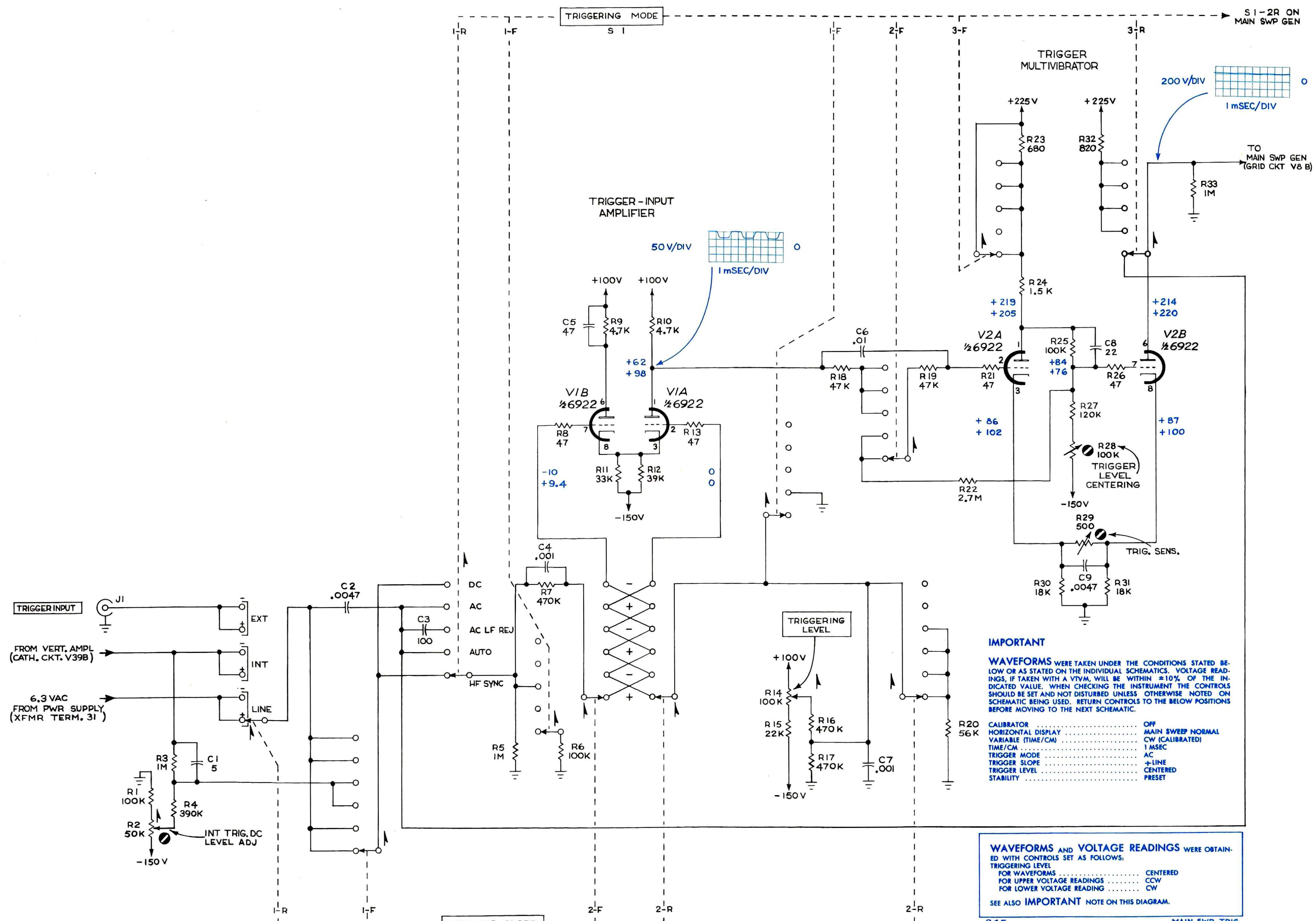



2-6-61

TYPE 945 OSCILLOSCOPE

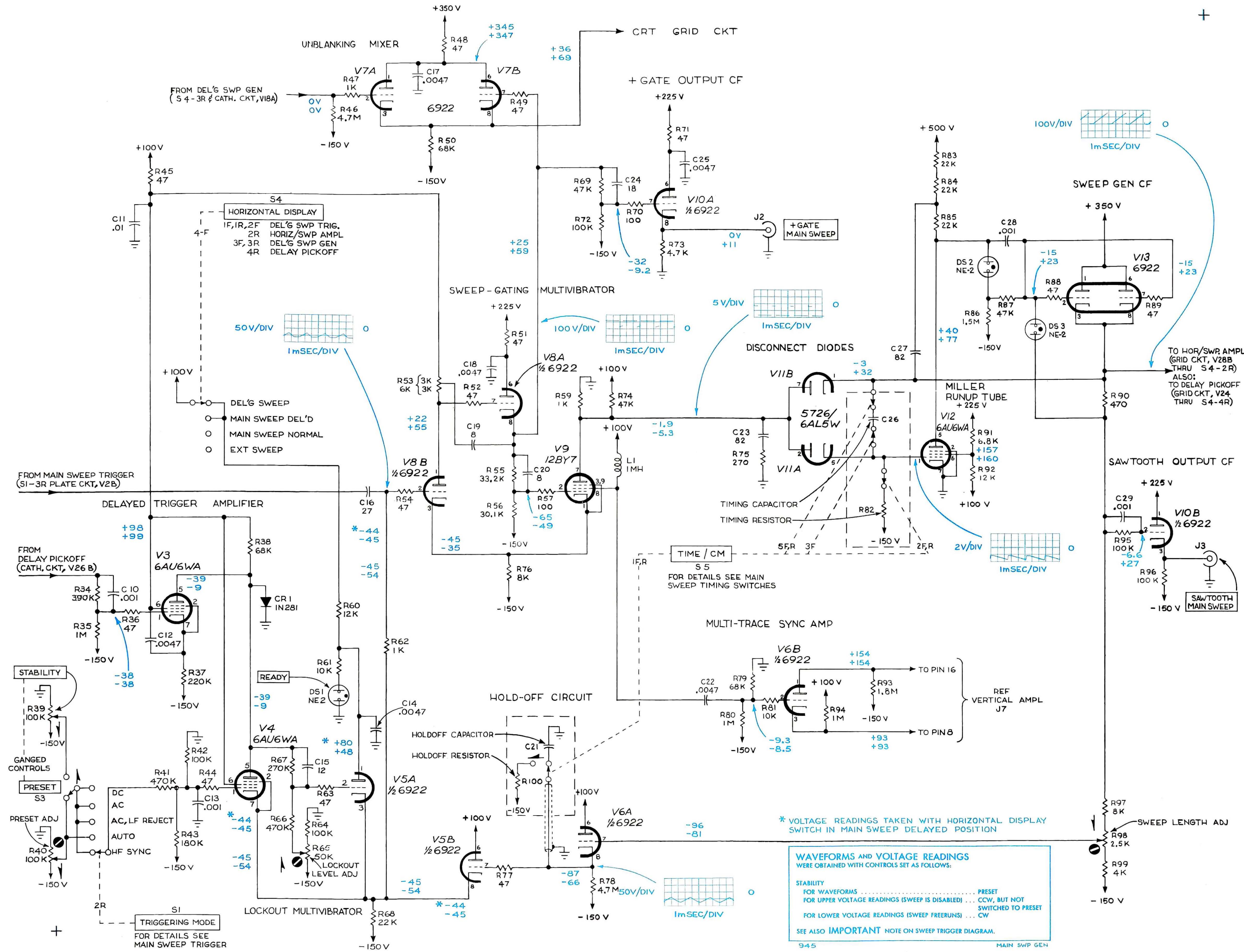
81-0001-04

HORIZONTAL DISPLAY SWITCH "EXTERNAL SWEEP"



TRIGGERING MODE
S 1
S 1-2R ON MAIN SWP GEN
TRIGGER MULTIVIBRATOR
200 V/DIV
1 mSEC/DIV
TO MAIN SWP GEN (GRID CKT V8 B)
TRIGGER-INPUT AMPLIFIER
50 V/DIV
1 mSEC/DIV
+100V
+225V
V1B ½6922
V1A ½6922
V2A ½6922
V2B ½6922
R28 100K TRIGGER LEVEL CENTERING
R29 500
TRIG. SENS.
-150V
TRIGGER INPUT
J1
EXT
INT
LINE
FROM VERT. AMPL (CATH. CKT. V39B)
6.3 VAC FROM PWR SUPPLY (XFMR TERM. 31)
DC
AC
AC LF REJ
AUTO
HF SYNC
TRIGGERING LEVEL
INT TRIG. DC LEVEL ADJ
TRIGGER SLOPE
S 2
IMPORTANT
WAVEFORMS WERE TAKEN UNDER THE CONDITIONS STATED BELOW OR AS STATED ON THE INDIVIDUAL SCHEMATICS. VOLTAGE READINGS, IF TAKEN WITH A VTVM, WILL BE WITHIN ±10% OF THE INDICATED VALUE. WHEN CHECKING THE INSTRUMENT THE CONTROLS SHOULD BE SET AND NOT DISTURBED UNLESS OTHERWISE NOTED ON SCHEMATIC BEING USED. RETURN CONTROLS TO THE BELOW POSITIONS BEFORE MOVING TO THE NEXT SCHEMATIC.
CALIBRATOR ........ OFF
HORIZONTAL DISPLAY ........ MAIN SWEEP NORMAL
VARIABLE (TIME/CM) ........ CW (CALIBRATED)
TIME/CM ........ 1 MSEC
TRIGGER MODE ........ AC
TRIGGER SLOPE ........ +LINE
TRIGGER LEVEL ........ CENTERED
STABILITY ........ PRESET
WAVEFORMS AND VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
TRIGGERING LEVEL
FOR WAVEFORMS ........ CENTERED
FOR UPPER VOLTAGE READINGS ........ CCW
FOR LOWER VOLTAGE READING ........ CW
SEE ALSO IMPORTANT NOTE ON THIS DIAGRAM.
945
MAIN SWP TRIG.


2-8-61

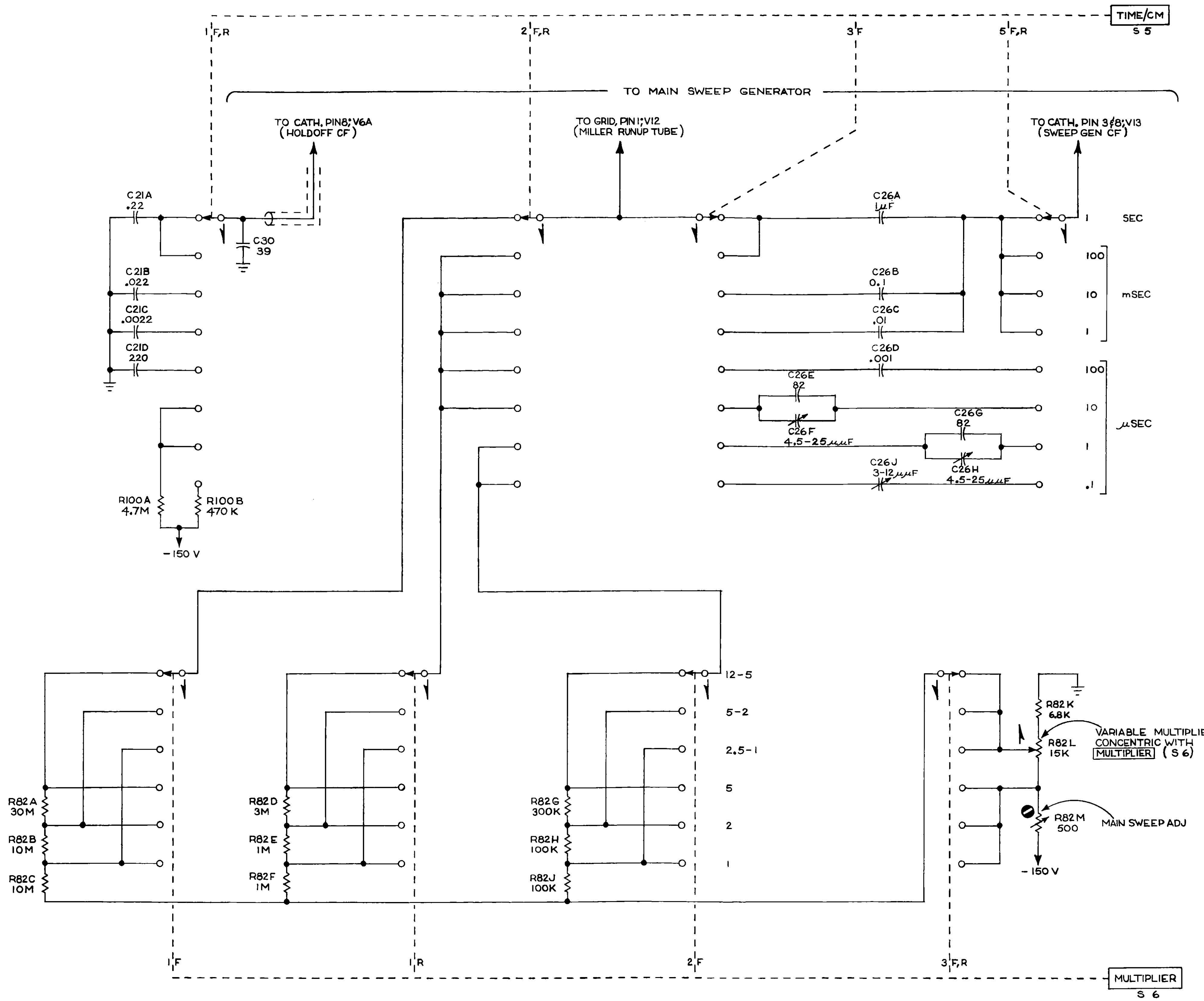



TYPE 945 OSCILLOSCOPE

81-0003-00

MAIN SWEEP GENERATOR

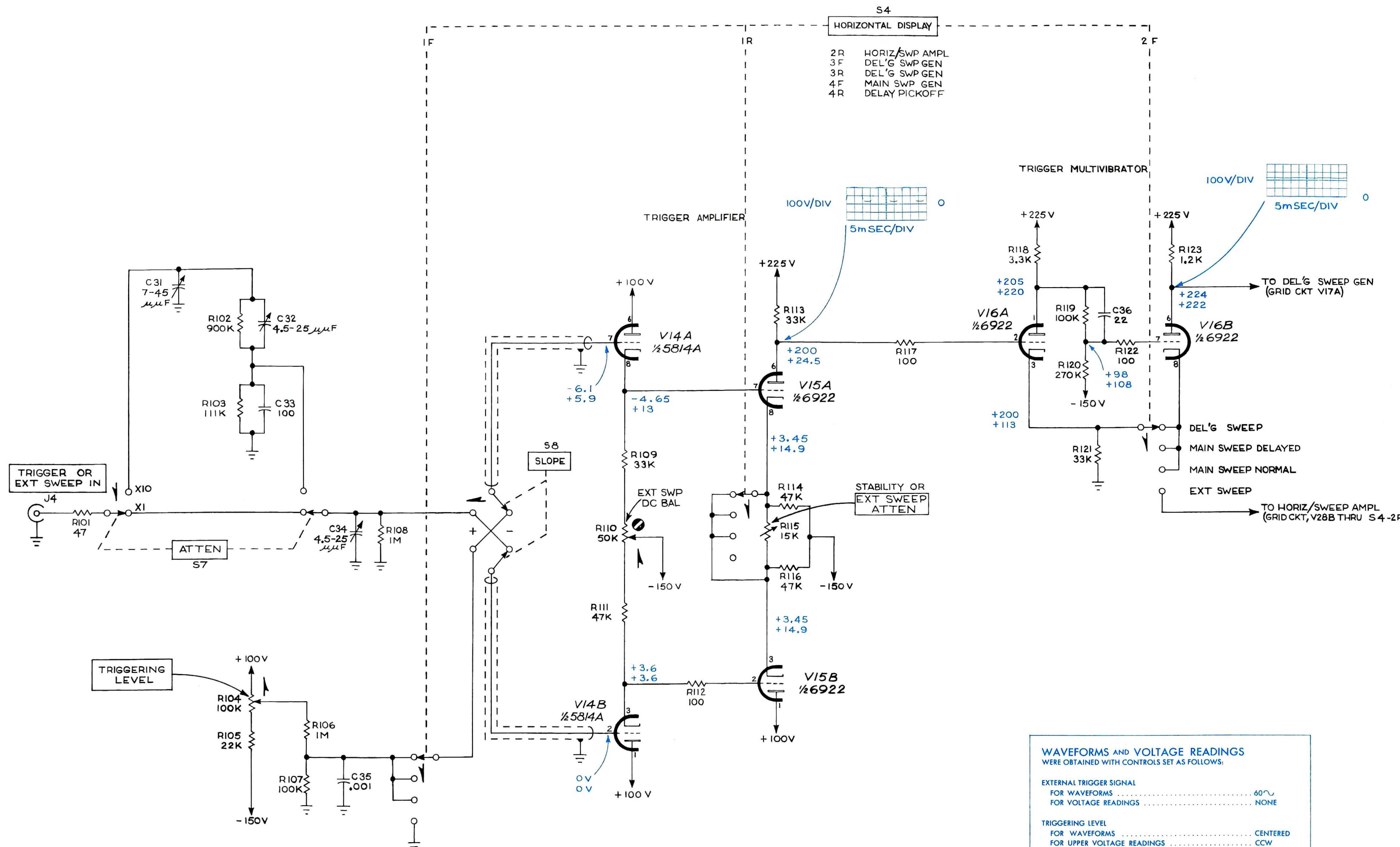
2-13-61




2 - 15 - 61

TYPE 945 OSCILLOSCOPE 81-0004-00 MAIN SWEEP TIMING SWITCHES

MAIN SWP TIM. SW




**WAVEFORMS AND VOLTAGE READINGS**
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

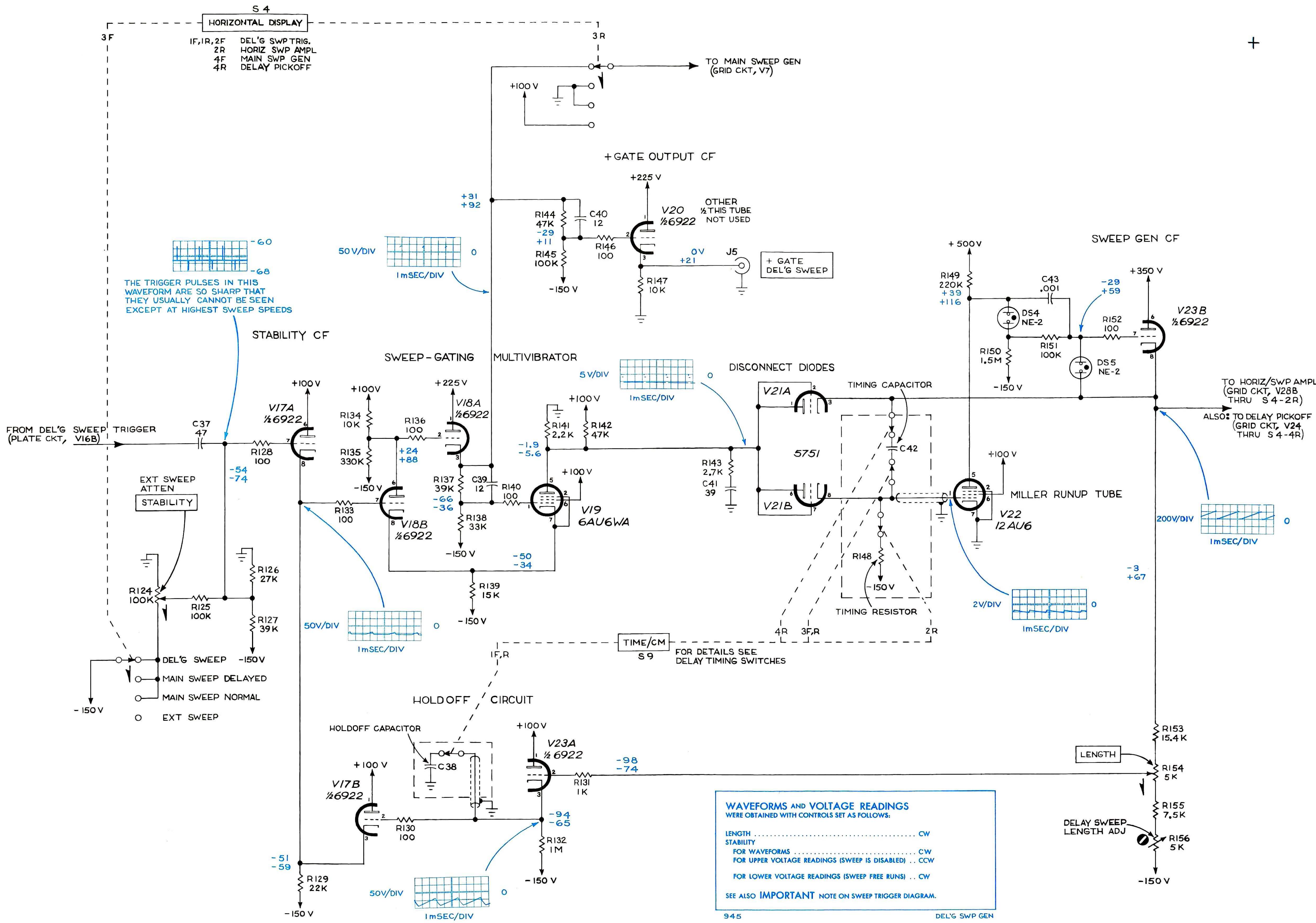
EXTERNAL TRIGGER SIGNAL
FOR WAVEFORMS ........ 60∿
FOR VOLTAGE READINGS ........ NONE

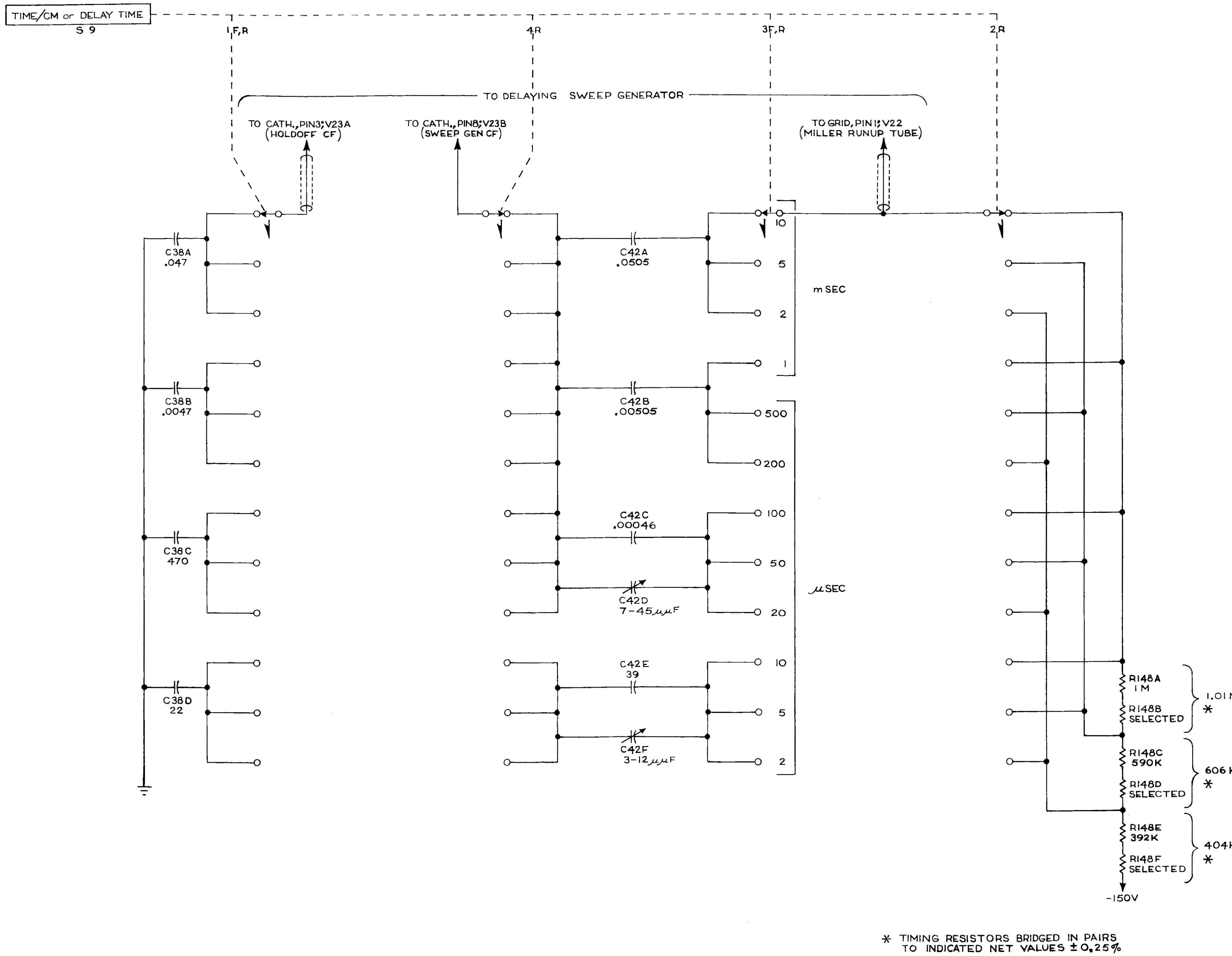
TRIGGERING LEVEL
FOR WAVEFORMS ........ CENTERED
FOR UPPER VOLTAGE READINGS ........ CCW
FOR LOWER VOLTAGE READINGS ........ CW

SEE ALSO IMPORTANT NOTE ON SWEEP TRIGGER DIAGRAM.

945 DEL SWP TRIG

2-17-61


S 4
HORIZONTAL DISPLAY
IF, IR, 2F DEL'G SWP TRIG.
2R HORIZ SWP AMPL
4F MAIN SWP GEN
4R DELAY PICKOFF
TO MAIN SWEEP GEN (GRID CKT, V7)
+GATE OUTPUT CF
OTHER ½ THIS TUBE NOT USED
+ GATE DEL'G SWEEP
THE TRIGGER PULSES IN THIS WAVEFORM ARE SO SHARP THAT THEY USUALLY CANNOT BE SEEN EXCEPT AT HIGHEST SWEEP SPEEDS
STABILITY CF
SWEEP-GATING MULTIVIBRATOR
DISCONNECT DIODES
TIMING CAPACITOR
SWEEP GEN CF
FROM DEL'G SWEEP TRIGGER (PLATE CKT, V16B)
EXT SWEEP ATTEN
STABILITY
MILLER RUNUP TUBE
TO HORIZ/SWP AMPL (GRID CKT, V28B THRU S 4-2R)
ALSO: TO DELAY PICKOFF (GRID CKT, V24 THRU S 4-4R)
TIMING RESISTOR
TIME/CM
S9
FOR DETAILS SEE DELAY TIMING SWITCHES
DEL'G SWEEP
MAIN SWEEP DELAYED
MAIN SWEEP NORMAL
EXT SWEEP
HOLDOFF CIRCUIT
HOLDOFF CAPACITOR
LENGTH
DELAY SWEEP LENGTH ADJ
WAVEFORMS AND VOLTAGE READINGS
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
LENGTH .......... CW
STABILITY
FOR WAVEFORMS .......... CW
FOR UPPER VOLTAGE READINGS (SWEEP IS DISABLED) .. CCW
FOR LOWER VOLTAGE READINGS (SWEEP FREE RUNS) .. CW
SEE ALSO IMPORTANT NOTE ON SWEEP TRIGGER DIAGRAM.
945
DEL'G SWP GEN

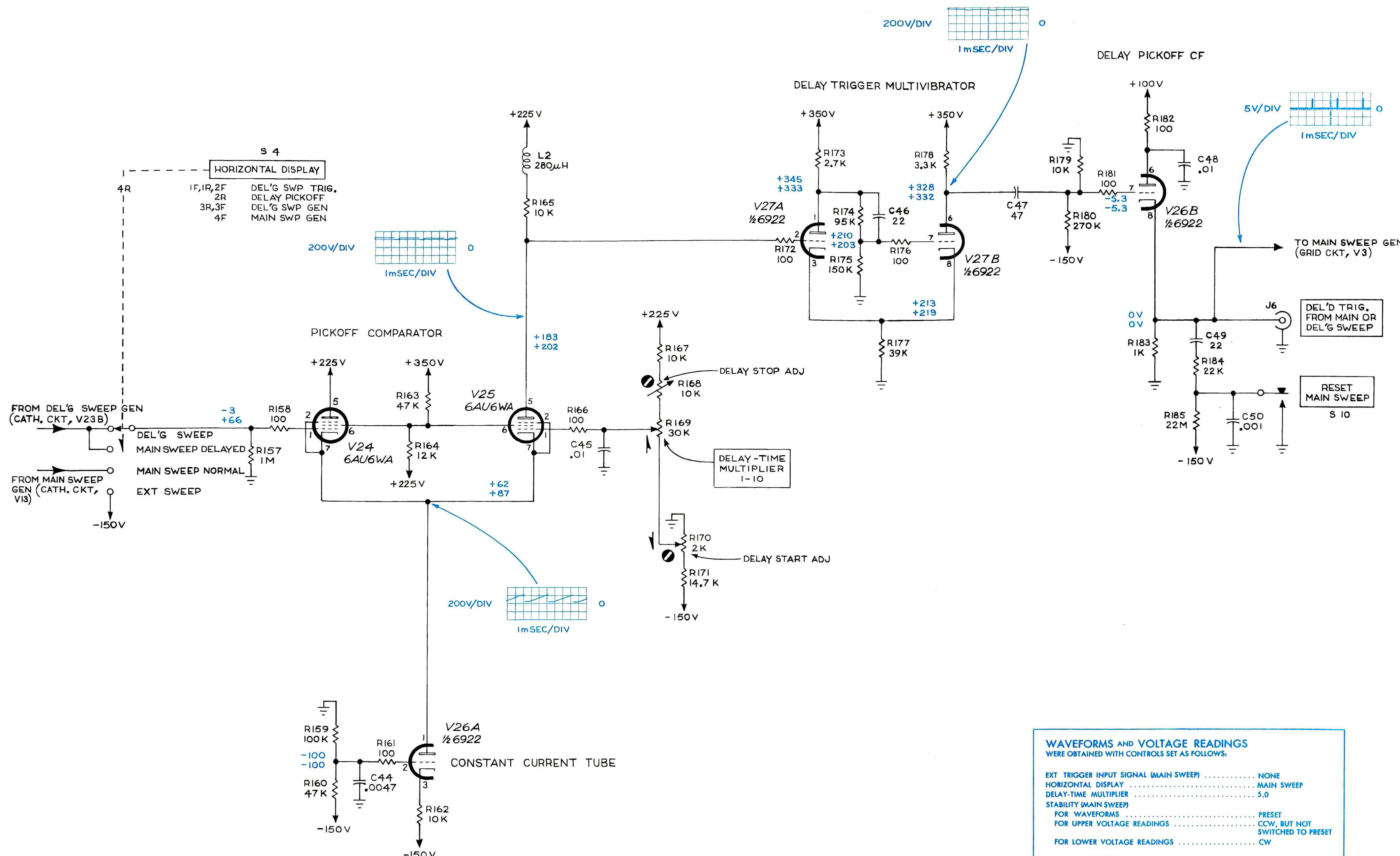



2 - 22 - 61

TYPE 945 OSCILLOSCOPE

81-0007-00

DELAY TIMING SWITCH



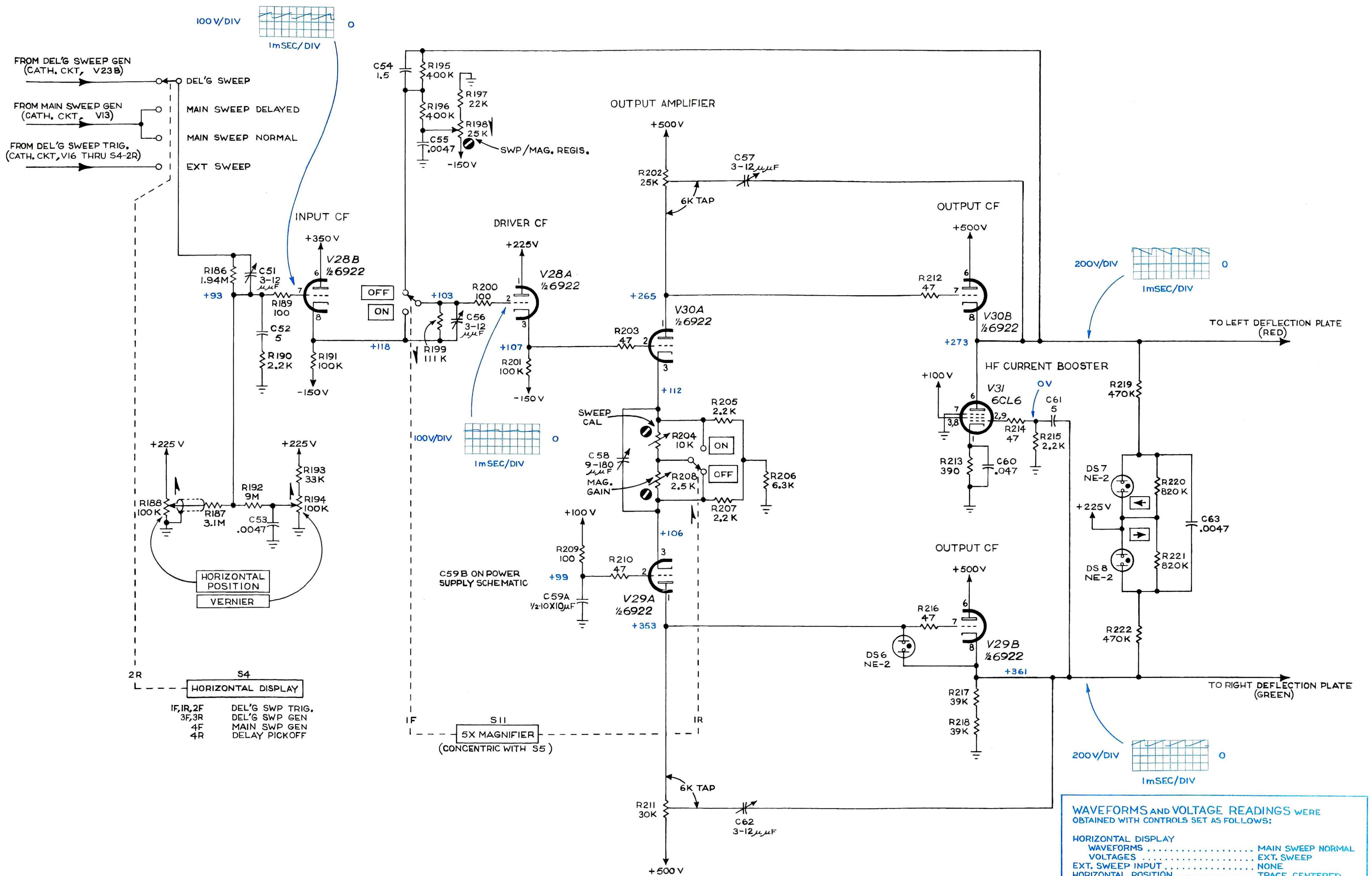

**WAVEFORMS AND VOLTAGE READINGS**
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

| | |
|---|---|
| EXT TRIGGER INPUT SIGNAL (MAIN SWEEP) | NONE |
| HORIZONTAL DISPLAY | MAIN SWEEP |
| DELAY-TIME MULTIPLIER | 5.0 |
| STABILITY (MAIN SWEEP) | |
| FOR WAVEFORMS | PRESET |
| FOR UPPER VOLTAGE READINGS | CCW, BUT NOT SWITCHED TO PRESET |
| FOR LOWER VOLTAGE READINGS | CW |

SEE ALSO **IMPORTANT** NOTE ON SWEEP TRIGGER DIAGRAM.

945 DELAY PICKOFF

2-24-61




**WAVEFORMS AND VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:**

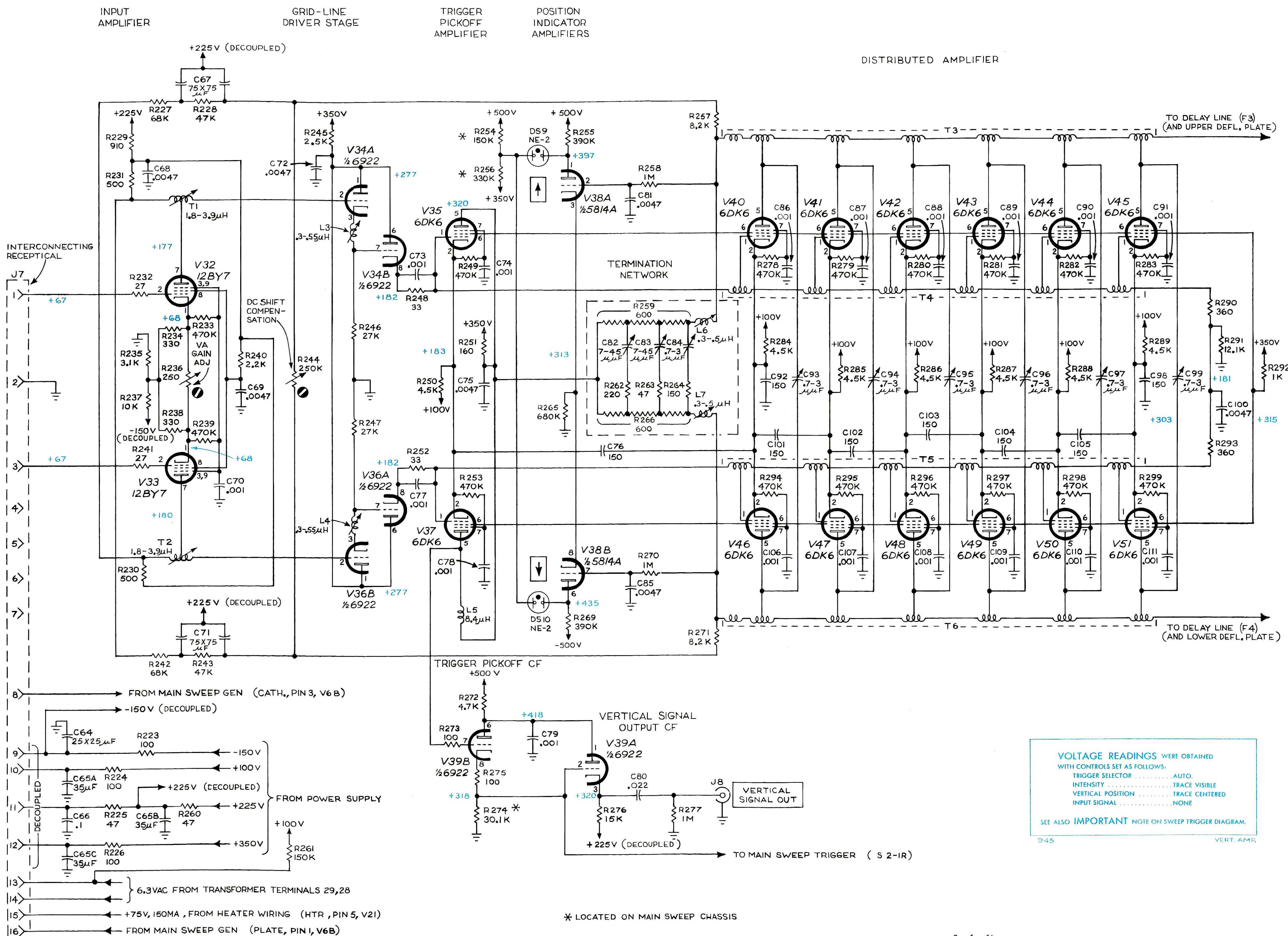
HORIZONTAL DISPLAY
- WAVEFORMS .................. MAIN SWEEP NORMAL
- VOLTAGES .................. EXT. SWEEP

EXT. SWEEP INPUT .................. NONE
HORIZONTAL POSITION .................. TRACE CENTERED
5X MAGNIFIER .................. OFF

SEE ALSO IMPORTANT NOTE ON MAIN SWEEP TRIGGER DIAGRAM

945 HORIZ/SWEEP AMP.

2-27-61




VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

| | |
|---|---|
| TRIGGER SELECTOR | AUTO. |
| INTENSITY | TRACE VISIBLE |
| VERTICAL POSITION | TRACE CENTERED |
| INPUT SIGNAL | NONE |

SEE ALSO IMPORTANT NOTE ON SWEEP TRIGGER DIAGRAM.

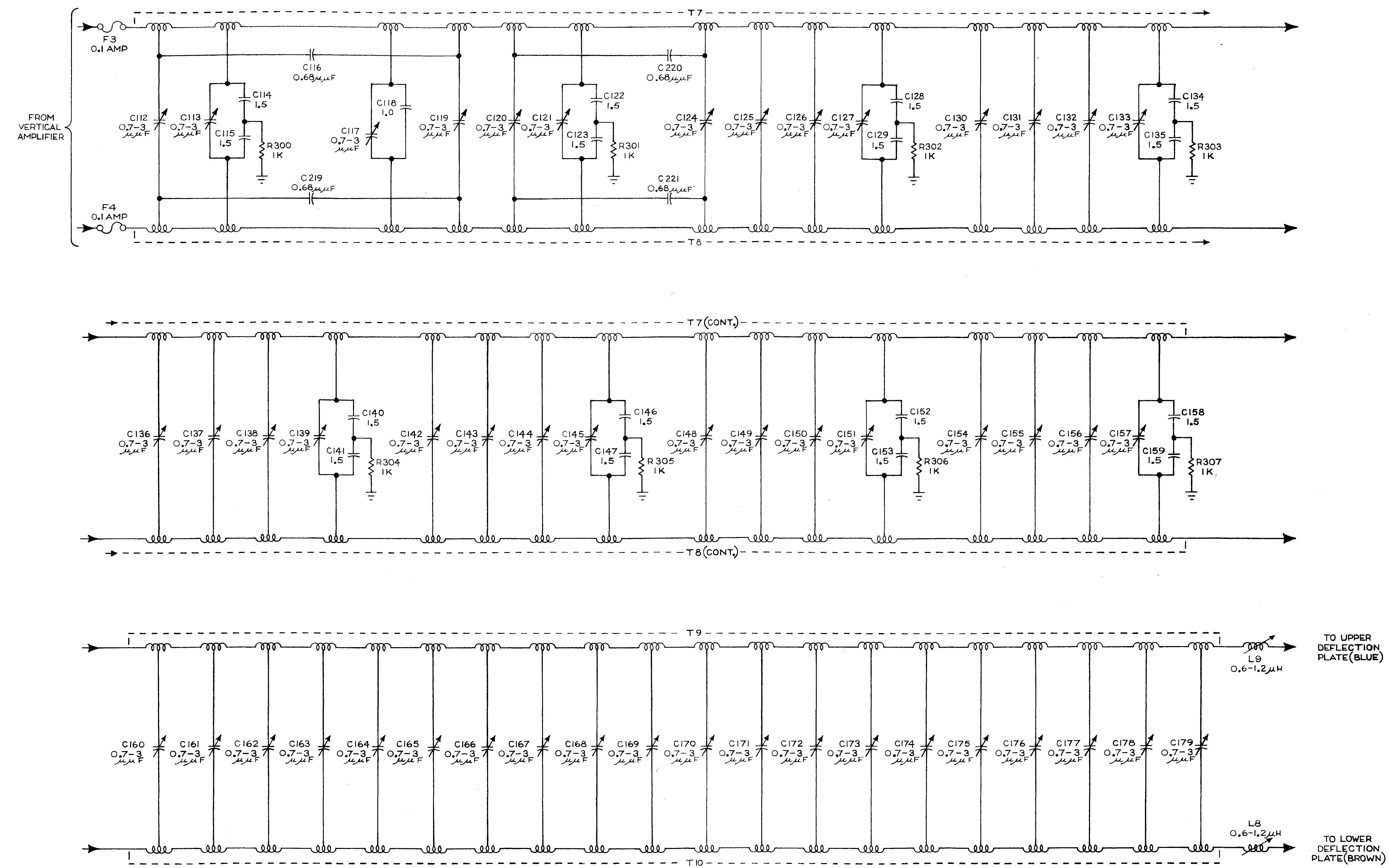
945 VERT. AMP.

TYPE 945 OSCILLOSCOPE

81-0010-00

3-6-61

VERTICAL AMPLIFIER



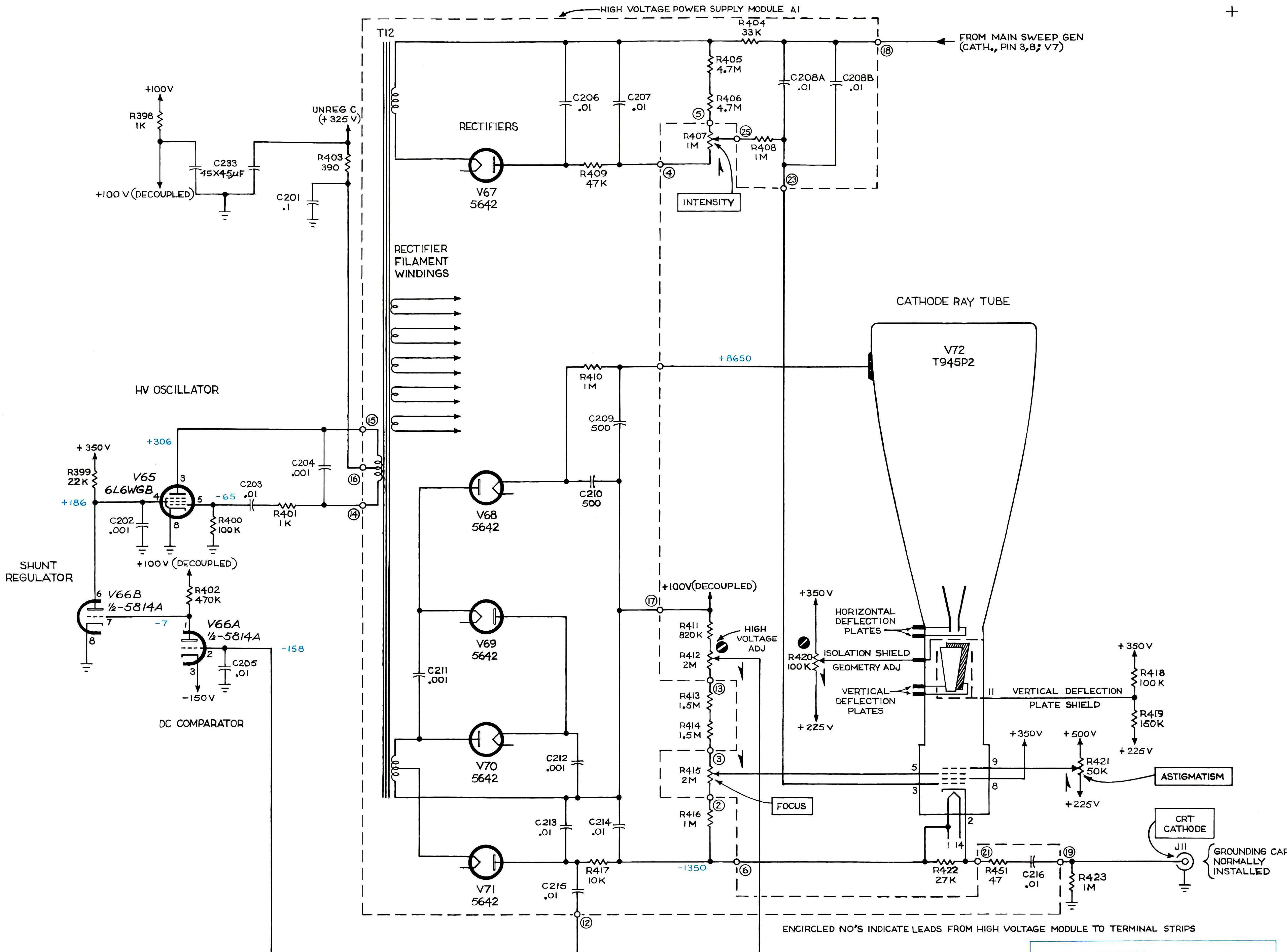

3-8-61

TYPE 945 OSCILLOSCOPE

81-0011-00

DELAY LINE NETWORK

DELAY LINE




VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

INTENSITY .................................... CCW

945 CRT

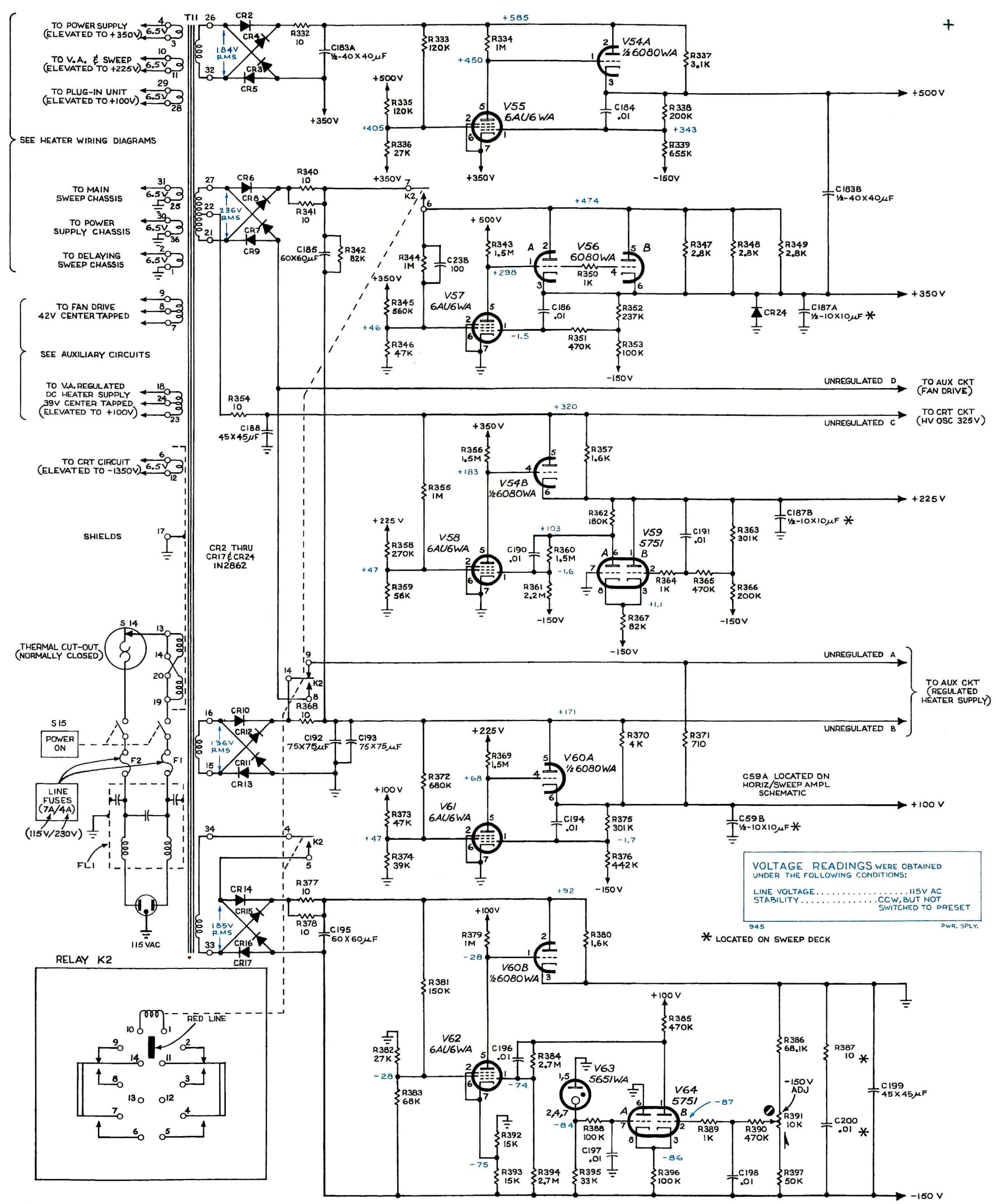
3-21-61

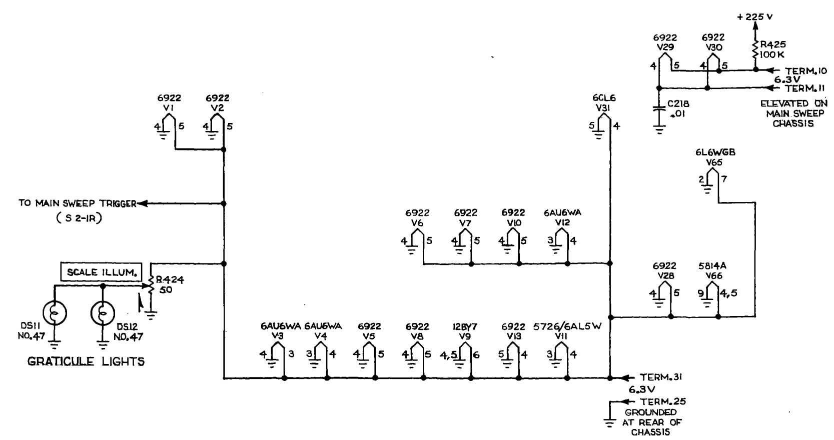
TYPE 945 OSCILLOSCOPE

81-0014-00

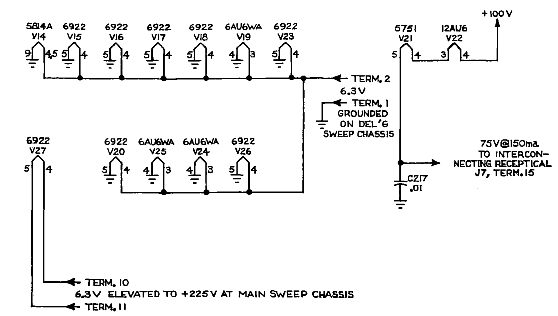
CRT CIRCUITS

CRT CIRCUIT

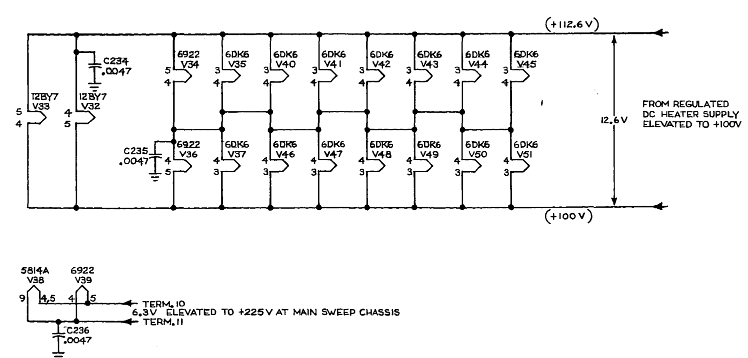

TO POWER SUPPLY (ELEVATED TO +350V)
TO V.A. & SWEEP (ELEVATED TO +225V)
TO PLUG-IN UNIT (ELEVATED TO +100V)
SEE HEATER WIRING DIAGRAMS
TO MAIN SWEEP CHASSIS
TO POWER SUPPLY CHASSIS
TO DELAYING SWEEP CHASSIS
TO FAN DRIVE 42V CENTER TAPPED
SEE AUXILIARY CIRCUITS
TO V.A. REGULATED DC HEATER SUPPLY 39V CENTER TAPPED (ELEVATED TO +100V)
TO CRT CIRCUIT (ELEVATED TO -1350V)
SHIELDS
CR2 THRU CR17 & CR24 1N2862
THERMAL CUT-OUT (NORMALLY CLOSED)
S15 POWER ON
LINE FUSES (7A/4A)
(115V/230V)
FL1
115 VAC
RELAY K2
RED LINE
T11
V54A ½6080WA
V55 6AU6WA
V56 6080WA
V57 6AU6WA
V54B ½6080WA
V58 6AU6WA
V59 5751
V60A ½6080WA
V61 6AU6WA
V60B ½6080WA
V62 6AU6WA
V63 5651WA
V64 5751
+500V
+350V
+225V
+100V
-150V
UNREGULATED D
TO AUX CKT (FAN DRIVE)
UNREGULATED C
TO CRT CKT (HV OSC 325V)
UNREGULATED A
UNREGULATED B
TO AUX CKT (REGULATED HEATER SUPPLY)
C59A LOCATED ON HORIZ/SWEEP AMPL SCHEMATIC
-150V ADJ
VOLTAGE READINGS WERE OBTAINED UNDER THE FOLLOWING CONDITIONS:
LINE VOLTAGE ................. 115V AC
STABILITY ............... CCW, BUT NOT SWITCHED TO PRESET
945
PWR. SPLY.
* LOCATED ON SWEEP DECK
4-11-61



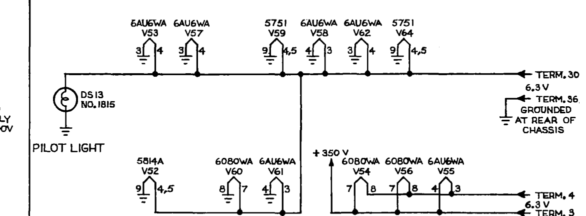

(V1 THRU V13; V28 THRU V31; V65 & V66) (19 TUBES)
MAIN SWEEP CHASSIS




(V14 THRU V27) (14 TUBES)
DELAYING SWEEP CHASSIS




(V32 THRU V51) (20 TUBES)
VERTICAL AMPLIFIER CHASSIS



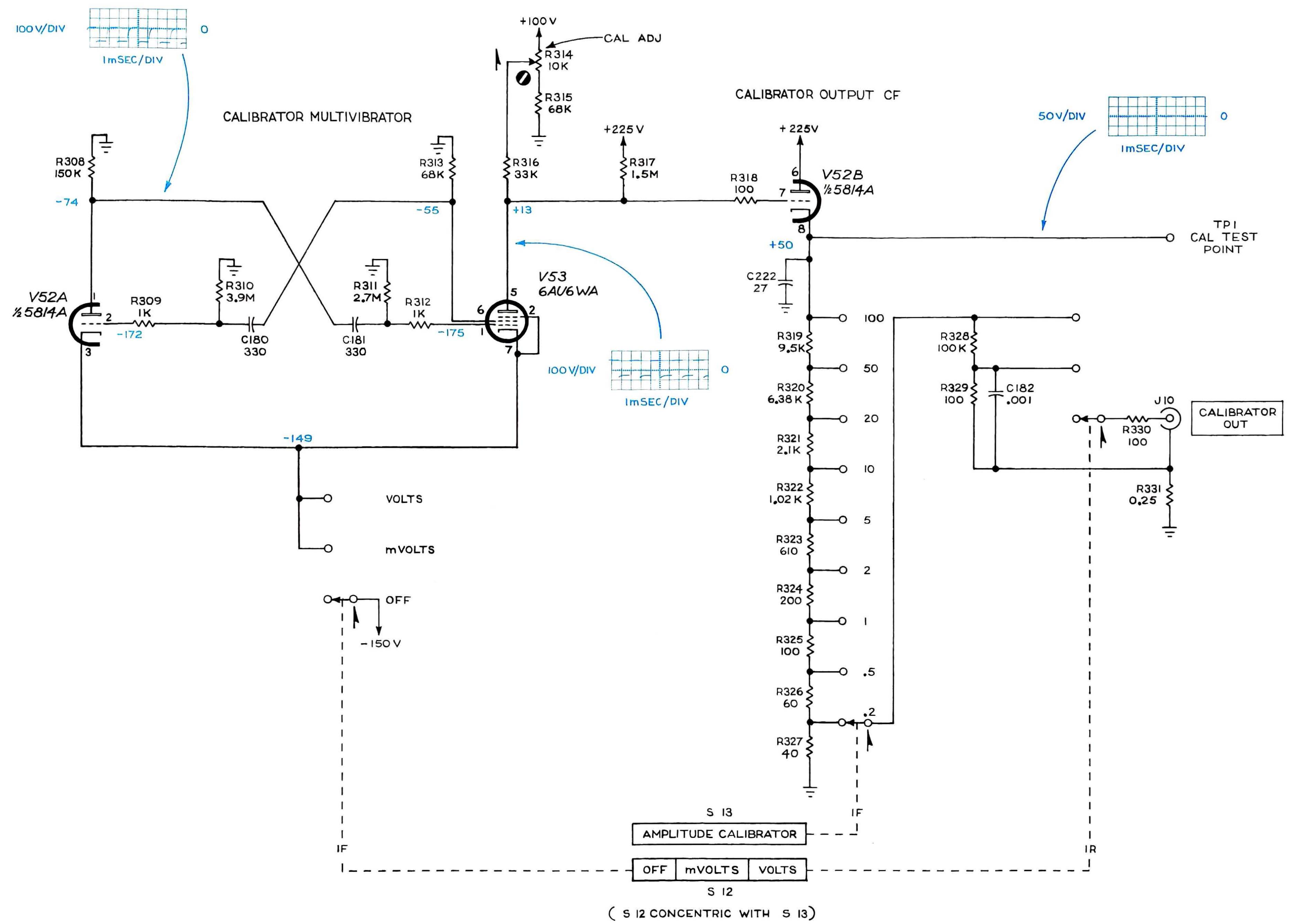

(V52 THRU V62 & V64) (12 TUBES)
POWER SUPPLY CHASSIS

TYPE 945 OSCILLOSCOPE

81-0015-00

3-23-61

HEATER WIRING DIAGRAMS




WAVEFORMS AND VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

AMPLITUDE CALIBRATOR .......................... ON

945 CAL.

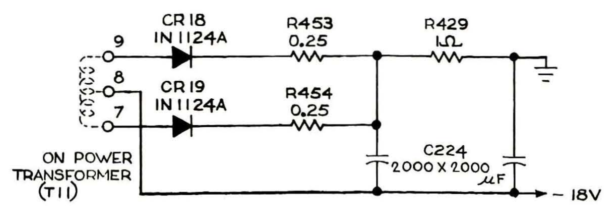
3-9-61

TYPE 945 OSCILLOSCOPE

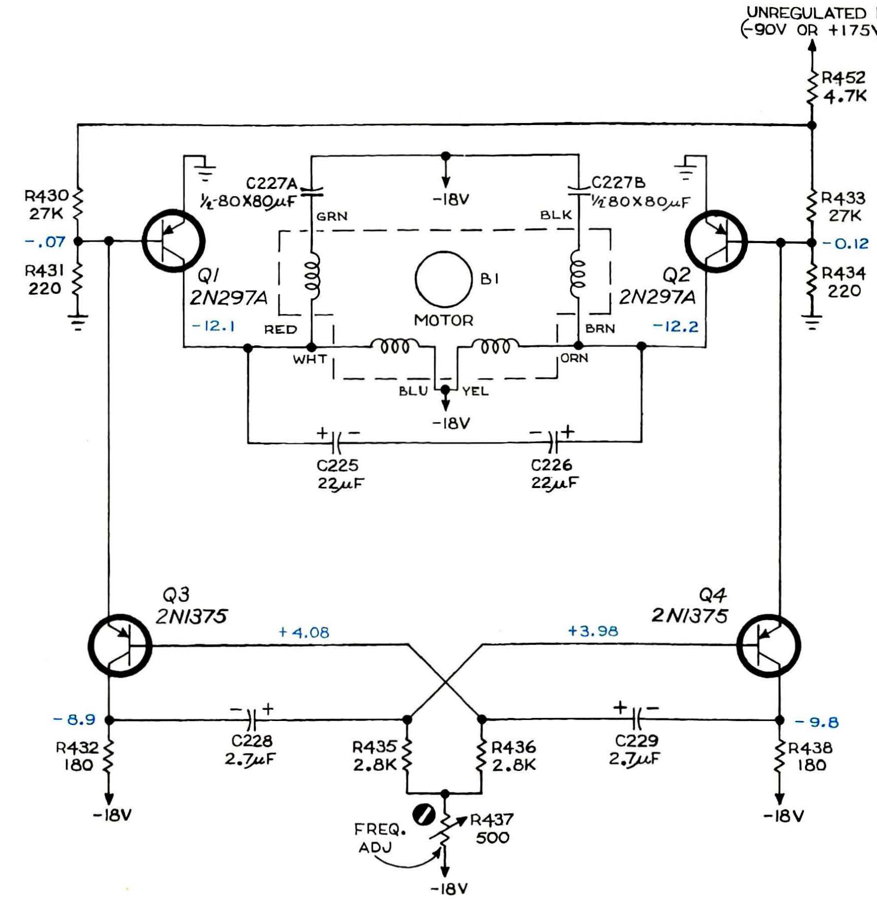
81-0012-00

AMPLITUDE CALIBRATOR

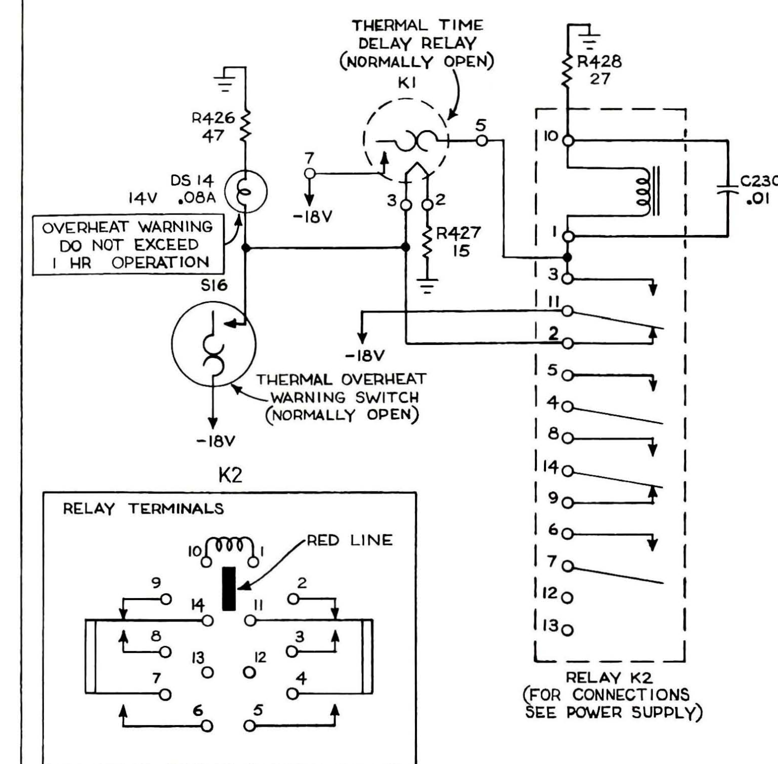
CALIBRATOR



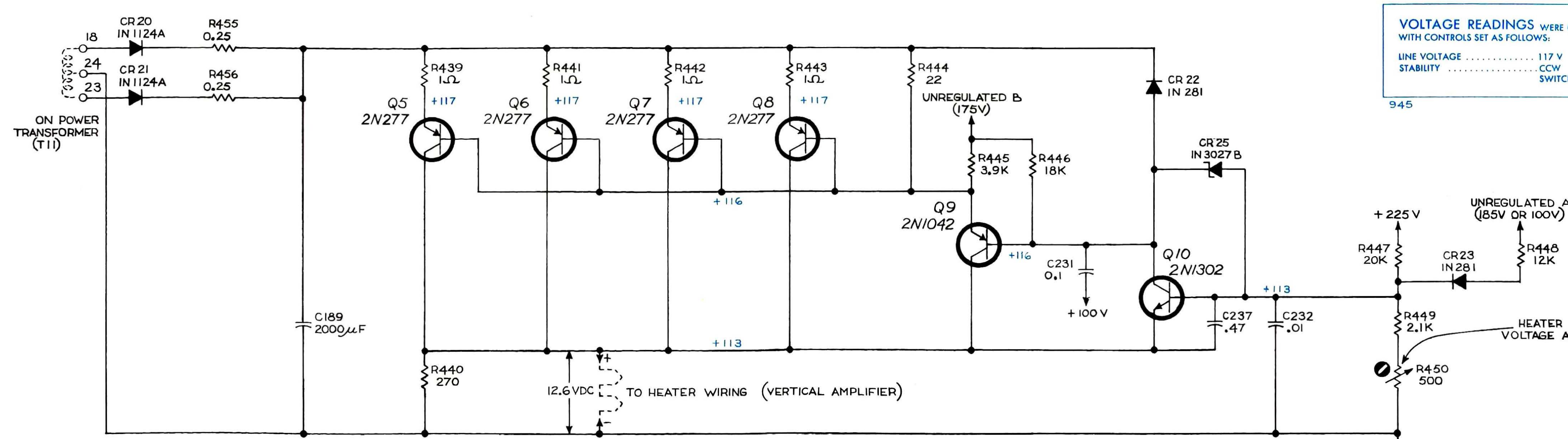

-18 VOLT SUPPLY




FAN DRIVE




TIME DELAY & OVERHEAT WARNING




REGULATED DC HEATER SUPPLY

**VOLTAGE READINGS** WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

LINE VOLTAGE .............. 117 V
STABILITY .................. CCW BUT NOT SWITCHED TO PRESET

945 AUX.CKT.