545B

SALES

ENGINEERING

PE\PEM

BOOK 1

TEKTRONIX

PE\PEM

INSTRUMENT REFERENCE BOOK

for the Tektronix type

545B
RM545B

oscilloscopes

For all serial numbers

SALES

CONTENTS-SALES

CATALOG

Catalog #26 corrections
Recent advertising may not identify use of projected graticule, 9-4-64
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RACKMOUNTS

Installation
Dimension drawing
040-0281-00 cradle mount

ADVERTISING CORRECTION HISTORY NOTICE

Instrument: 545B

Publication	Present Form:	Correct Form:	Date
Catalog #26, page 86	Under VERTICAL PLUG-IN UNITS, DEFLECTION FACTOR, Type H, 50 mV/cm.	Type H, 5 mV/cm.	4/4/67

RECENT ADVERTISING MAY NOT IDENTIFY USE OF PROJECTED GRATICULE

FEN 9-4-64

Because of uneven light distribution over the graticules of the 540B and 544-6-7 scopes, waveform pictures for the new catalog were taken using, in some cases, the projected graticule. These waveform pictures, some of which were used in earlier product literature, appear on catalog pages 75, 82, 86, and 186. The problem is that we slipped up and didn't identify the graticules in these photos as being different than the internal graticule that is part of what we ship. -- Chuck Gasser.

Some current brochures, the Short-Form Catalog, and sections of our new Long-Form Catalog describing the Types 543B, 545B, 544, 546, and 547, include some oscillograms of internal graticules and some of projected graticules. This difference is not designated and in some photos it is not apparent.

Original prints of the photos taken with a Projected Graticule show superior evenness of graticule line illumination and none of the objectionable phosphor background lighting typical of the internal graticule lighting system.

In some cases, the printing reproduction process improved the contrast and quality so much over the original photo that it is difficult to tell whether the reproduced oscillogram is of an internal graticule or a projected graticule.

It's too late to change the catalog, but we can identify the photos here so that you can answer customer questions that are sure to arise:

Catalog 23, Mid 1964, Mid 1965

Page 75	Projected Graticule
78	Internal Graticule
82	Projected Graticule
86	Projected Graticule
88	Internal Graticule
186	Projected Graticule

Short-Form Catalog No. A-2201

Page 2 photo taken with Internal Graticule.

543B Brochure No. A-2219 "The Big Difference Is Inside."

Photo taken with Projected Graticule.

545B Brochure No. A-2215 "The Big Difference Is Inside."

Photo taken with Projected Graticule.

547 Brochure No. A-2207-1 "Introducing Automatic Display Switching in the Tektronix Type 547."

Photos on Pages 2, 3, and 8 taken with internal graticule. Photo on Page 7 was taken with an internal graticule, and then retouched.

Brochure No. A-2218 "A New Generation of Type 540 Series Oscilloscopes."

Three photos taken with internal graticule, and retouched. -- Earl Williams.

NEW 400-CYCLE FAN MOD REPLACES MOD 101G FOR 530, 540 SERIES SCOPES

FEN 1-29-65

The optional solid-state converter Mod 101G, as described in the catalog, is discontinued. The converter SCR's contributed excessive RFI, and the frequency range of operation around 400 cps was very narrow. Its replacement is Mod 101M, a saucer fan, for 50 to 60 and 400-cycle operation.

Address all inquiries for price and delivery to Ron Goard.

-- Bob Beville, Syracuse Field Office.

SECTION 1
CHARACTERISTICS

Introduction

The Type 545B oscilloscope is a laboratory instrument designed to operate with all Tektronix letter-series or 1-series plug-in units. It features two separate time-base generators which may be used to provide delayed sweep operation. This feature permits very accurate time measurements and detailed observation of a waveform.

The instrument is ventilated with filtered forced air. To insure proper airflow through it, operation with the side panels removed is not recommended except as necessary for required maintenance or calibration. A minimum clearance of two inches around the instrument should be maintained. The Type 545B will perform to requirements over an ambient temperature range from 0°C to +50°C after a warmup time of twenty minutes.

There are three categories of characteristics for the Type 545B; Electrical, Environmental, Mechanical. In the following table the characteristic and the performance to expect is stated, followed by information relating to the characteristic and performance.

ELECTRICAL

VERTICAL DEFLECTION SYSTEM

Characteristic	Performance Requirements	Supplemental Information
Frequency Response	DC to 33 MHz at 3 dB down	With Type 1A1 Plug-In Unit. 50 mV/cm
Risetime		10 nsec or less with a Tektronix 067-0521-00 Test Load Plug-In Unit.
Transient Response	Not more than 1.25% overshoot, rolloff, tilt or ringing.	067-0521-00 Test Load Unit installed and a 5 cm step.
Positioning Effect on Transient Response	Not more than 1.25% change in transient response when display is moved towards graticule edge.	Exclude the top and bottom 0.5 cm of the graticule.
Low Frequency Linearity	Not more than 1.5 mm compression or expansion.	2 cm square wave at graticule center positioned to top and bottom graticule.
Deflection Factor	0.1 V (±3%) per cm of display.	
DC Balance	Within ±2 cm of graticule center.	Adjustable to zero.
DC (thermal) Shift	Less than 1.25% tilt to flat top of an applied square wave.	Adjustable to zero.
Trace Drift with Line Voltage Change	Not more than 1 cm.	With line variations to ± 10% from nominal value.
Gain Change with Line Voltage Change	Not more than 1%.	With line variations to ± 10% from nominal value.
Positioning Indicators		One on, one off, with trace at graticule limits.

TRIGGERING

Time Base A		
Trigger Sensitivity—INT		Triggering checked with sine wave input.
AC	Must trigger with 2 mm of deflection from 150 Hz to 10 MHz.	Increases to 1 cm at 30 MHz. Will trigger below 150 Hz with increased deflection.
AC LF REJECT	Must trigger with 2 mm of deflection from 30 kHz to 10 MHz.	Increases to 1 cm at 30 MHz. Will trigger below 30 kHz with increased deflection.
DC	Must trigger with 6 mm of deflection to 10 MHz.	
AUTO	Must trigger with 5 mm of deflection at 150 Hz.	Will trigger down to 50 Hz and up to 10 MHz with increased deflection.
Trigger Sensitivity—EXT		Triggering checked with sine wave input.
AC	Must trigger on 0.2 V from 150 Hz to 10 MHz.	Increases to 1 V at 30 MHz. Will trigger below 150 Hz with increased deflection.

TRIGGERING *(cont)*

Characteristic	Performance Requirements	Supplemental Information
AC LF REJECT	Must trigger on 0.2 V from 30 kHz to 10 MHz.	Increases to 1 V at 30 MHz. Will trigger below 30 kHz with increased deflection.
DC	Must trigger on 0.2 V up to 10 MHz.	Increases to 1 V at 30 MHz.
AUTO	Must trigger on 0.5 V at 150 Hz.	Will trigger down to 50 Hz and up to 10 MHz with increased signal.
		Maximum input signal voltages for all external modes is 50 V (DC + peak AC).
Time Base B		
Trigger Sensitivity—INT		
AC	Must trigger with 2 mm of deflection from 300 Hz to 5 MHz.	Increases to 1 cm at 10 MHz. Will trigger below 300 Hz with increased deflection.
DC	Must trigger with 6 mm of deflection up to 5 MHz.	
AUTO	Must trigger wth 5 mm of deflection at 300 Hz.	Will trigger down to 50 Hz and up to 5 MHz with increased deflection.
Trigger Sensitivity—EXT		
AC	Must trigger on 0.2 V from 300 Hz to 5 MHz.	Increases to 1 V at 10 MHz. Will trigger below 300 Hz with increased deflection.
DC	Must trigger on 0.2 V up to 5 MHz.	Increases to 1 V at 10 MHz.
AUTO	Must trigger on 0.5 V at 300 Hz.	Will trigger down to 50 Hz and up to 5 MHz with increased signal.
		Maximum input signal voltage for all external modes is 50 V (DC + peak AC).

HORIZONTAL DEFLECTION SYSTEM

Sweep Rates		
Time Base A	Accuracy within 3% of indicated rate.	VARIABLE control in CALIBRATED position. Sweep range from .1 μsec/cm to 1 sec/cm in 18 calibrated steps. 1-2-5 sequence.
VARIABLE TIME/CM Range	Not less than 2.5:1.	Extends slowest sweep rate to about 12.5 sec.
Sweep Length	10.5 ± 0.3 cm.	Set at 1 msec/cm.
Time Base B	Accuracy within ±3% of indicated rate.	Sweep range from 2 μsec/cm to 1 sec/cm in 18 calibrated steps. 1-2-5 sequence.
Sweep Length	Variable from greater than 10 cm to less than 4 cm.	

SWEEP MAGNIFIER

Magnification Factor	×5	Extends fastest A sweep rate to 20 nsec/cm.
Magnified Sweep Accuracy	± 5%	
Sweep/Mag Registration	Not more than ± 5 mm.	Trace shift at graticule center when switching 5× magnifier from on to off.

VARIABLE TIME DELAY

Calibrated Delay Time Range	Continuous from 2 μsec to 10 sec.	
Delay Time Accuracy	± 1%	
Multiplier Incremental Linearity	±0.2%	B sweep at 1 msec/cm, A sweep at 10 μsec/cm.
Delay Time Jitter	Not more than 1 part in 20,000 of 10 times the B TIME/cm setting.	Equal to 5 mm with B sweep at 1 msec/cm A sweep at 1 μsec/cm.

EXTERNAL HORIZONTAL AMPLIFIER

Characteristic	Performance Requirements	Supplemental Information
Deflection Factor		
×1	0.2 V/cm with 1 kHz signal applied.	VARIABLE 10-1 fully clockwise. Maximum input voltage, 50 V (DC + peak AC).
×10	2.0 V/cm with 1 kHz signal applied.	
Variable Range	10:1 or more.	
×10 Attenuator Compensation	Not more than 5% aberration or tilt refferenced to ×1.	
×1 DC Balance	Not more than 2 cm of horizontal shift when VARIABLE 10-1 is rotated.	Adjustable to zero.
Frequency Response	DC to 350 kHz or more at 3 dB down.	VARIABLE 10-1 fully clockwise.
		Maximum EXT HORIZONTAL INPUT voltage is 50 V (DC + peak AC).

AMPLITUDE CALIBRATOR

Characteristic	Performance Requirements	Supplemental Information
Voltage Output	0.2 mV to 100 V.	18 steps in a 1-2-5 sequence.
Accuracy	± 3%	
Symmetry	45% to 55%	
Repetition Rate	1 kHz ± 25%	
Risetime		Typically 1 μsec.
Waveform		Square wave, positive going with baseline at zero volts.
Special Output	0.1 V ± 3% into 50 Ω	Measured with a 0.1% 50 Ω resistor at the .5 V position.

FRONT-PANEL OUTPUT SIGNALS

Characteristic	Performance Requirements	Supplemental Information
DLY'D TRIG		A positive-going pulse of approximately 5 V occurring at the end of the delay period.
+ GATE B and + GATE A		20 V or greater, positive going with baseline at zero volts. Time coincident with respective sweep. Recommended load at least 5 kΩ.
SAWTOOTH A		130 V or greater with same time duration as the A sweep. Recommended load of at least 10 kΩ.
VERT SIG OUT		1.2 V or greater per cm of display.

CATHODE-RAY TUBE

Characteristic	Performance Requirements	Supplemental Information
Tube Type		T5470-31-2
Phosphor		P31 normally supplied. Other phosphors available.
Accelerating Potential		10 kV.
Geometry		
Vertical	Not more than 1.5 mm bowing or tilt.	
Horizontal	Not more than 2 mm bowing or tilt.	
Focus		
Vertical	2 horizontal lines/mm distinguishable over center 4 cm of graticule.	
Horizontal	2 time marks/mm distinguishable over middle 8 cm of graticule.	
Trace Rotation Range	Sufficient to align trace with center horizontal graticule line.	
Graticule		Internal, 6 × 10 cm with 1 cm vertical and horizontal divisions, 2 mm markings on the centerlines. Marks for measuring risetime provided. Variable edge-lighted.

INSTRUMENT POWER

Characteristic	Performance Requirements	Supplemental Information
Line Frequency	50 to 60 Hz, single phase.	400 Hz operation requires fan modification.
Line Voltage Range, RMS	108, 115, 122, 216, 230 or 244 V AC.	Will regulate within $\pm 10\%$ of design center
Input Power		Approximately 585 watts. voltage.
Thermal Cutout		An automatically resetting thermal cutout interrupts instrument power if internal operating temperature exceeds a safe level.

EXTERNAL CRT CATHODE CONNECTIONS

Z-Axis Modulation	Noticeable intensity modulation with 15 V or less peak-to-peak square wave.	Free-running sweep at 1 msec/cm. 1 kHz square wave applied.
Input R and C		Typically 1 MΩ, 10 pF.

ENVIRONMENTAL

The following environmental test limits apply when tested in accordance with the recommended test procedure. This instrument will meet the electrical performance requirements given in this section following environmental test. Details on environmental tests may be obtained from Tektronix, Inc. Contact your local Tektronix Field Office or representative.

Temperature		
Operating	0° C to +50° C.	Fan at rear circulates air throughout instrument.
Non-operating	—40° C to +65° C.	
Altitude		
Operating	15,000 feet maximum.	
Non-operating	50,000 feet maximum.	
Transportation		The instrument is packaged to meet National Safe Transit requirements.

MECHANICAL

Characteristic	Information
Construction	
Chassis	Aluminum alloy
Front-Panel	Aluminum alloy with anodized finish.
Cabinet	Blue vinyl painted.
Dimensions	
Height	17 in (43.2 cm).
Width	$12^{15}/_{66}$ in (32.9 cm).
Depth	$23^{7}/_{8}$ in (60.7 cm).
Connectors	A TRIGGER INPUT, B TRIGGER INPUT, and CAL OUT connectors are BNC type. All other front-panel connectors are 5-way binding post type.

MODIFIED PRODUCTS

	Product	Mod	Description
	545B	101G	60 or 400 Hz. Standard fan motor with Tek chopper.
	545B	101M	60 or 400 Hz. with 2 Spartan fans.
##	545B	101N	Fan converter for 50-440 Hz Power Line.
	545B	108A	12 kV high voltage supply.
	545B	116C	Raster mod.
	545/E/D/M	163F	RFI with test data and certification by SN.
	545B	172Z	External graticule.
	545B	211M	Raster (Mod 116C) and 12 kV (Mod 108A). P11.
	545B	806T	Three connectors changed to UHF.
	RM545B	101M	50 to 60 or 400 Hz.
	RM545B	101N	50-800 Hz operation.
	RM545B	116C	Raster mod.
	RM545B	163B	RFI.
	RM545B	211M	Raster (Mod 116C) and 12 kV (Mod 108A). P11.
	RM545B	222G	2 trigger inputs paralleled to rear, BNC (Mod 803X) Iridite subpanel, oversized panel and subpanel (15.719 X 14"), line voltage range, rod-type handles, 4 vertical inputs paralleled to rear, BNC.
	RM545B	247F	Connectors paralleled to rear, BNC. RFI line filter, Jonathan slides, painted panel.
	RM545B/CA	258E	Oversize painted panel. RFI.
	RM545B	801H	Gate out, swatooth out, gate in and trigger in paralleled to rear, BNC.
	RM545B	802X	Two verticals paralleled to rear through Delrin, BNC.
	RM545B	804A	Four verticals paralleled to rear, BNC.

SECTION 7
INSTALLATION

Mounting Methods (Figs. 7-1 and 7-2)

This instrument will fit most 19-inch wide racks whose dimensions conform to EIA specifications. The instrument cabinet is intended to be fastened directly to the front rails of a *relay rack or a cabinet rack* by means of the hardware supplied with the instrument. For example, Fig. 7-1 shows the instrument cabinet installed in a cabinet rack. The rear of the instrument normally needs no support, providing it is not subjected to any great amount of shock or vibration. If the instrument is to be subjected to severe shock or vibration it will be necessary to rigidly mount the rear of the cabinet to the rack. Fig. 7-1 shows the rear of the cabinet mounted to the rack with hardware provided in modification kit 016-060.

The instrument is locked into its cabinet by means of four slotted LOCK knobs on the front panel. When these knobs are turned to release the instrument, it can be pulled out of the cabinet like a drawer to its fully extended position (see Fig. 7-2) and then tilted up or down and locked in one of several positions—horizontal, or 45°, 90°, and 105° from horizontal. These various positions permit many routine maintenance functions to be performed without completely removing the instrument from the rack.

Instrument Dimensions

The last pullout page in this section shows dimensional drawings of the instrument exclusive of the plug-in unit and probes.

Rack Dimensions

Width — A standard 19″ rack may be used. The dimension of opening between the front rails of the rack must be at least $17\frac{5}{8}$″.

Depth — For circulation of cooling air, allow at least 3″ behind the rear and at least 2″ between each side of the instrument cabinet and any enclosure on the rack. The space allowed can be reduced slightly so long as the instrument receives at least 250 cu. ft/min of air not exceeding 50°C in temperature.

In addition to the area left at the rear of the oscilloscope, about four feet should be left free in front of the instrument rack. This space will permit extending the instrument fully out of the cabinet and still have working room in front.

Rackmounting (Fig. 7-1)

To mount the instrument cabinet directly to the front and rear rails of the rack as shown in Fig. 7-1, proceed as follows:

1. Select the height on the rack where the top of the front panel is to be and mark both front rails.
2. Measure down $1\frac{1}{2}$ inches from the marks placed in step 1. Mark this point on both front rails. This mark is the location of the top mounting screw on each side of the cabinet.
3. Measure down 11 inches from the point found on each rail in step 2. This is the location of the bottom screws on each side of the cabinet.
4. Hold the cabinet in place and mount it with the screws provided.
5. If the instrument is to be subjected to severe shock or vibration, it will be necessary to attach the rear of the cabinet to the rack rails, using the brackets supplied in modification kit 016-060. If the amount of shock or vibration is small, additional mounting screws attaching the cabinet to the rack may provide enough support.

Slideout Tracks (Fig. 7-2)

The slideout tracks for the instrument consist of two assemblies, one each for the right and left sides. Each assembly consists of three sections as illustrated in Fig. 7-3. The stationary section attaches to the cabinet front and rear, the chassis section attaches to the instrument, and the intermediate section fits between the other two sections to allow the oscilloscope to fully extend out of the rack.

The stationary and intermediate sections for both sides of the cabinet rack are a matched set and should not be separated.

Adjustments

To adjust the slideout tracks for smooth operation, proceed as follows:

1. Insert the instrument into the cabinet as shown in Fig. 7-4.
2. If the oscilloscope does not slide smoothly the detent assembly of the chassis sections may not be parallel to the bottom of the instrument and/or the eccentric pivot screws may not be set evenly so the slides are not parallel to each other. Adjust as shown in Fig. 7-5.

NOTE

If the eccentric pivot screw does not turn freely when adjusting it, the slot in the detent plate is fitting too tightly around the ¼″ diameter roll pin. This condition can be corrected as follows: Remove the nut, lockwasher and flat washer from the eccentric pivot screw. Remove the outer slide, pivot screw and dial plate. Using a round file, slightly enlarge the slot in the dial plate where the roll pin fits. Then re-mount the parts.

Maintenance

The slideout tracks require no lubrication. The special gray finish on the sliding parts is a permanent lubricant.

Front Panel Alignment and Anchor Castings (Fig. 7-1)

The four alignment and anchor castings are used to secure the instrument into the cabinet. It is possible to adjust them to position the front panel up or down, against or slightly away from the cabinet. The effect of the adjustment can only be seen when the instrument is secured in the cabinet.

Adjustment

This adjustment must be performed before mounting the cabinet and instrument into a rack.

1. Turn the slotted LOCK knobs to release the oscilloscope from the cabinet.
2. Pull the instrument about 2 inches out of the cabinet.
3. Loosen the three screws holding the casting to be adjusted.
4. Insert the instrument all the way into the cabinet and engage the appropriate thumb screw into the casting being adjusted. Engaging the thumb screw into the casting will position it to the proper position.
5. Tighten the three screws holding the casting.

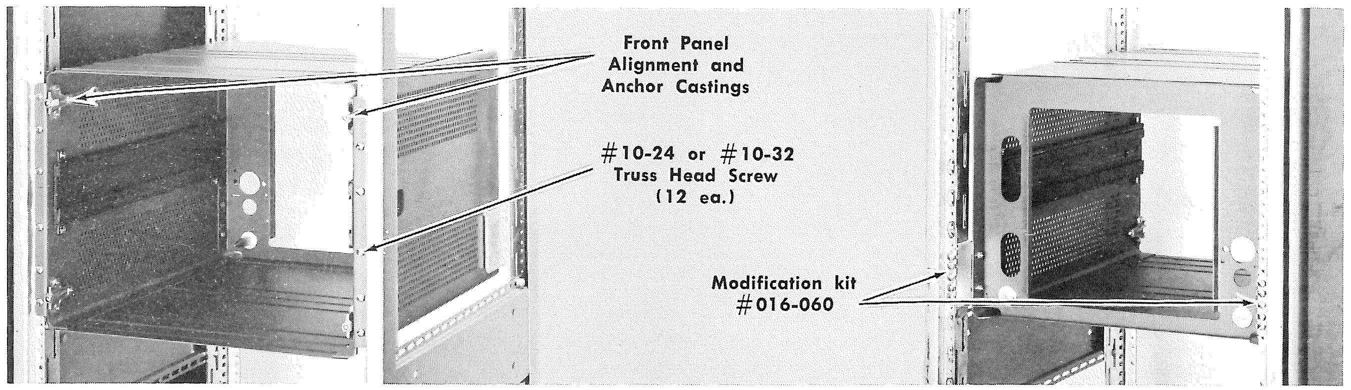


Fig. 7-1. Front and rear views of the instrument cabinet mounting.

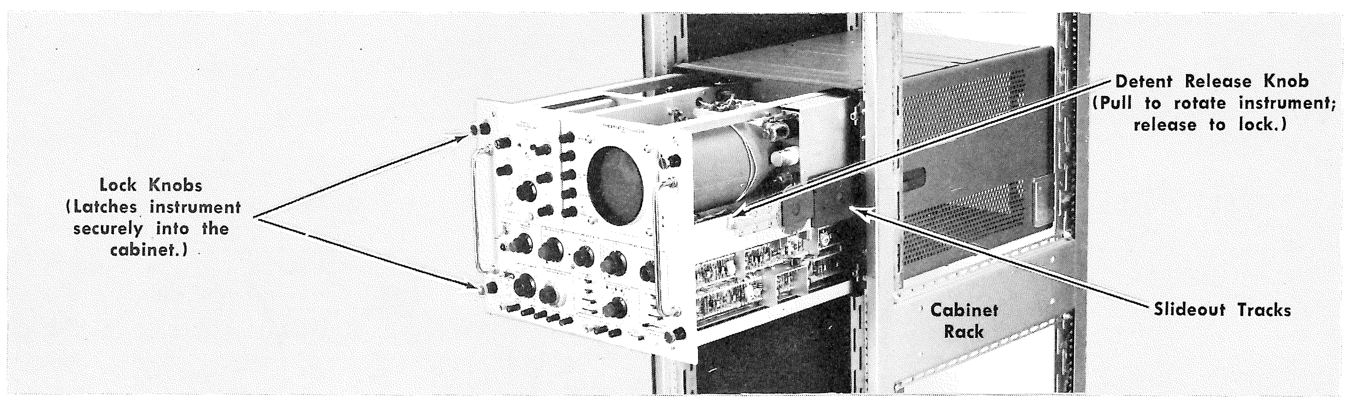


Fig. 7-2. Instrument extended from its cabinet.

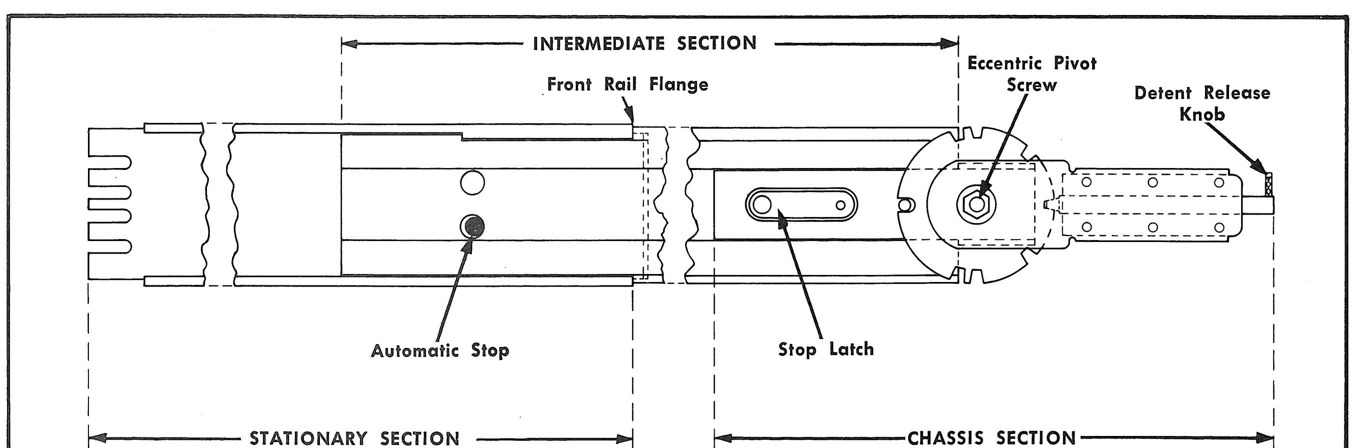


Fig. 7-3. Illustration showing the slideout track assembly for the right side.

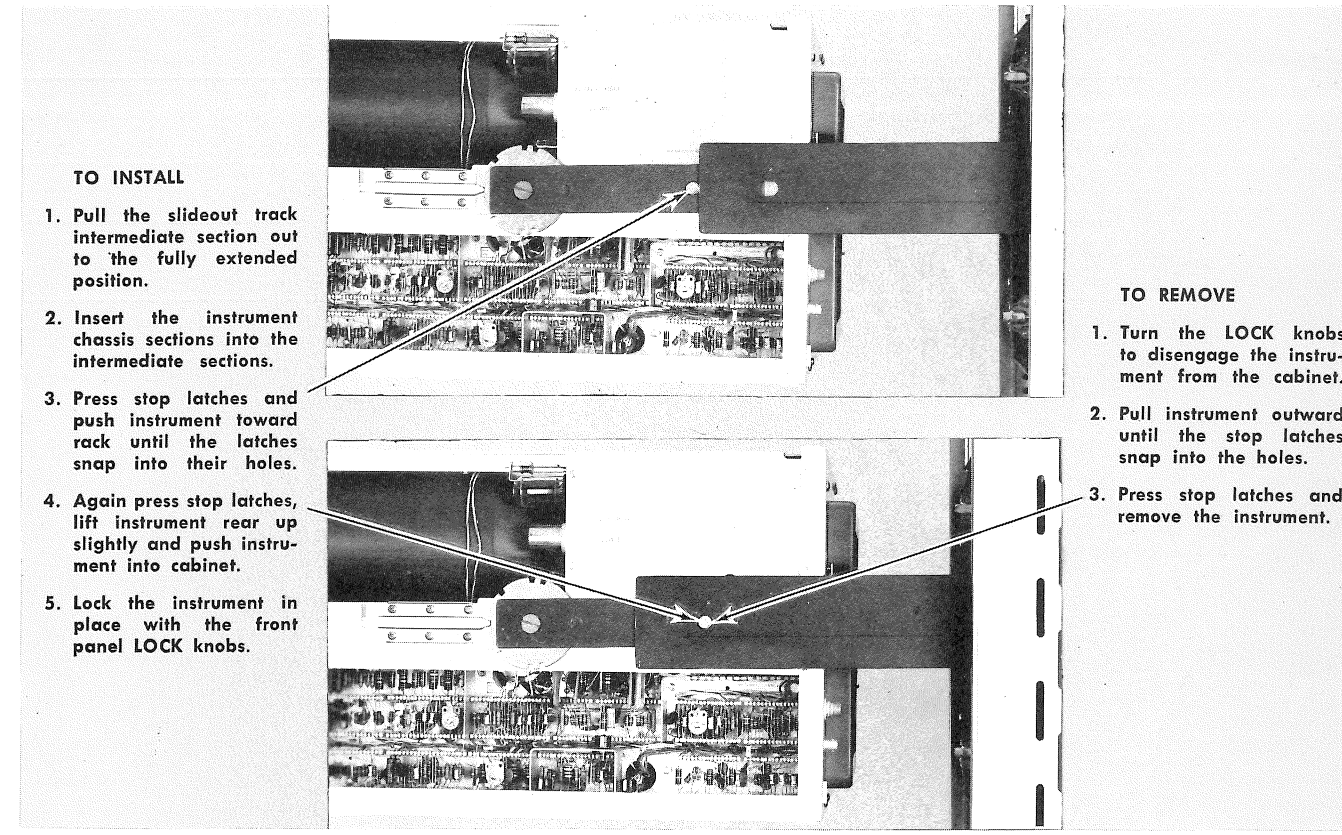


Fig. 7-4. Installing and removing the instrument.

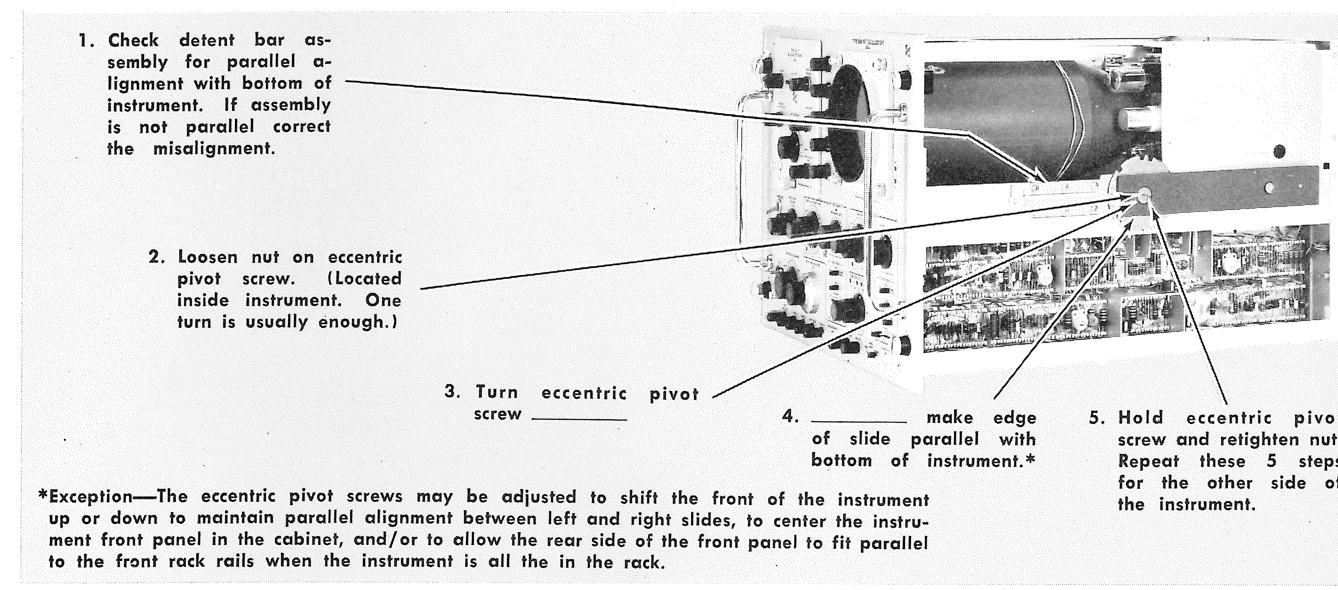
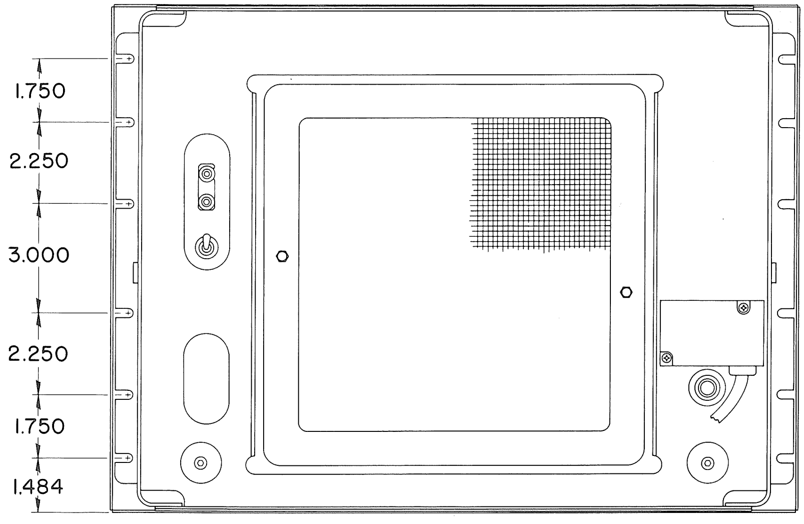
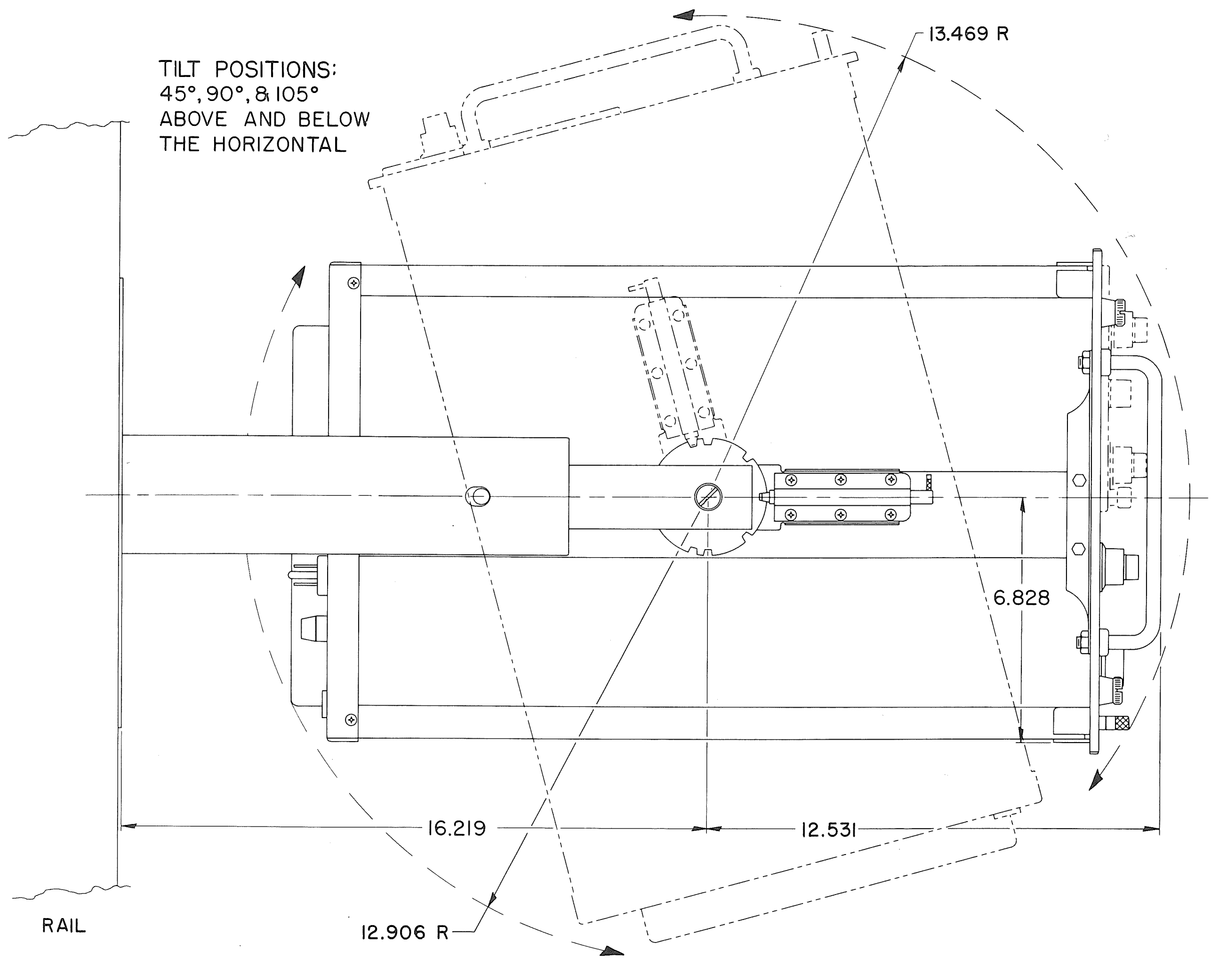


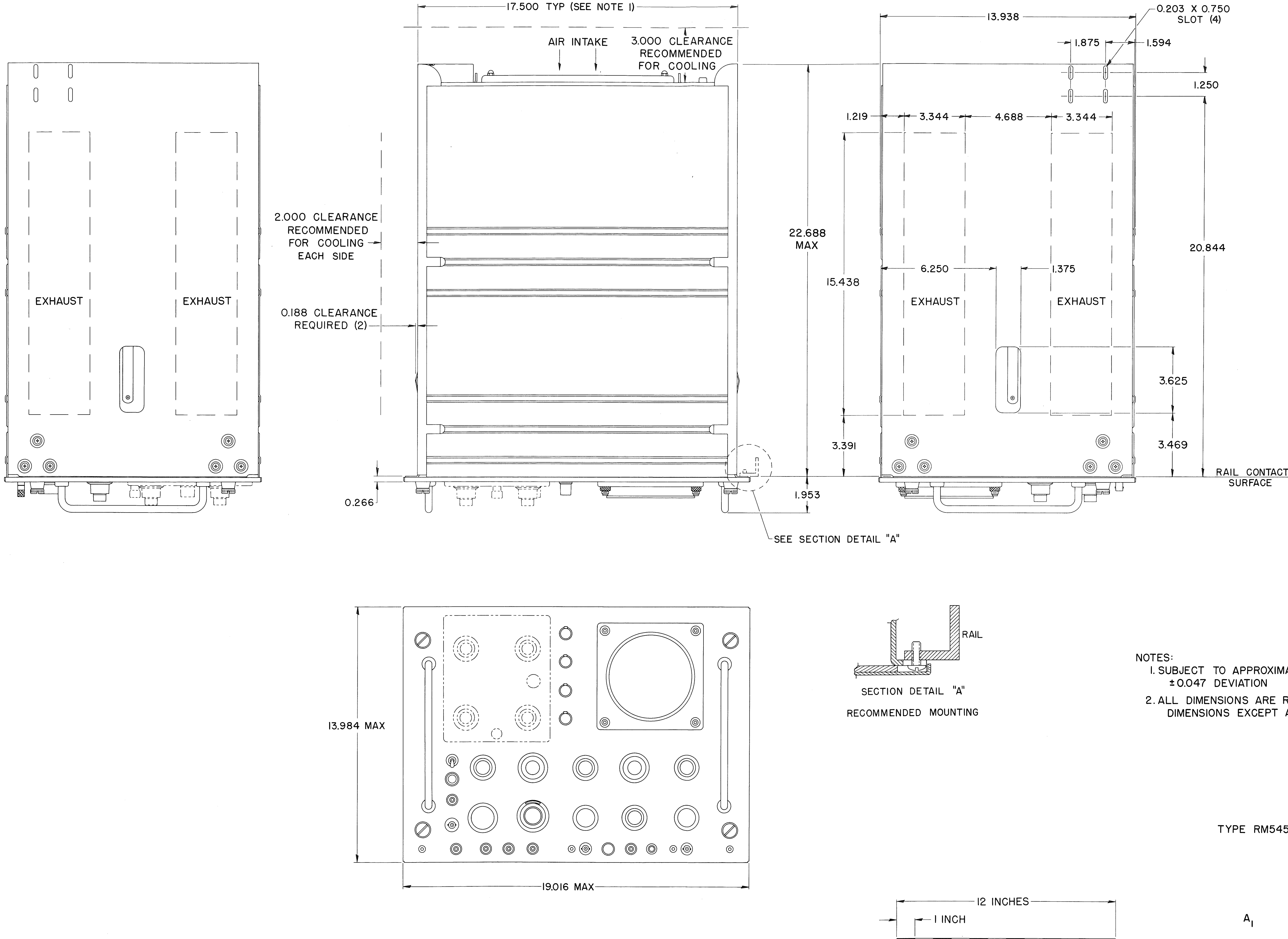
Fig. 7-5. Adjusting the chassis sections.



REAR VIEW



DIMENSION DRAWING



NOTES:
1. SUBJECT TO APPROXIMATELY ±0.047 DEVIATION
2. ALL DIMENSIONS ARE REFERENCE DIMENSIONS EXCEPT AS NOTED

TYPE RM545B

A1

DIMENSION DRAWING

MODIFICATION KIT

CRADLE MOUNT

For the following Tektronix Oscilloscopes:

Types 524AD, 531, 532, 535, 541, 545 and 570
Serial numbers 5001-up

Types 531A,533,533A,535A,536,541A,543,
543A,543B,544,545A,545B,546,547,
575,581,581A,585,585A, and 661
All serial numbers

040-0281-00

DESCRIPTION

This modification enables the above Tektronix instruments to be rackmounted in a standard 19 in. relay rack. A vertical front panel space of 17-1/2 in. is required.

Future instruments with the same front panel dimensions may also be used with this kit, providing they have bottom rails similar to those on the above listed instruments. This kit directly replaces 040-0182-00.

Publication:
Instructions for 040-0281-00
May 1965

Supersedes:
April 1964

PARTS LIST

Quantity	Description	Part Number
1 ea.	Assembly, cradle mount, oscilloscope, including:	426-0208-00
	2 ea. Screw, 4-40 x 3/8 FHS	(211-0025-00)
	4 ea. Screw, 8-32 x 3/8 BHS	(212-0023-00)
	1 ea. Bar, stiffening, 1/4 x 5/8 x 16-5/8	(381-0198-00)
	2 ea. Bar, mounting, 1/4 x 1/2 x 8-1/8	(381-0211-00)
1 ea.	Stop, instrument	105-0013-00
2 ea.	Lockwasher, int #8	210-0008-00
2 ea.	Nut, hex, 8-32 x 5/16	210-0409-00
2 ea.	Washer, flat, 8S x 3/8	210-0804-00
8 ea.	Washer, cup, #10	210-0833-00
2 ea.	Washer, spacer, 3/16 ID x 3/8 OD x 0.091	210-0852-00
6 ea.	Screw, 4-40 x 3/8 FHS	211-0025-00
2 ea.	Screw, 8-32 x 5/16 BHS	212-0004-00
8 ea.	Screw, 8-32 x 1/2 BHS	212-0008-00
8 ea.	Screw, 10-32 x 1/2 OHS	212-0512-00
1 ea.	Panel, front, mask for rackmounting	333-0491-00
2 ea.	Bar (guide rail), aluminum, angle, 18 in.	381-0202-00
2 ea.	Plate (slide), bakelite, 1-1/8 x 18 in.	387-0636-00
1 ea.	Bracket, hold-down	406-0424-00

INSTRUCTIONS

( ) 1. Mount the two guide rails and bakelite slides (from kit) on the cradle assembly, with the rail lip on the outside (Fig.1A). Use the threaded holes in the cradle, spaced according to the lengths listed for the kits in Fig.1B. Mount the rails with the 4-40 x 3/8 FHS screws from the kit.

( ) 2. Fasten each side of the cradle assembly to the front flange of the relay rack, with three 8-32 x 1/2 BHS screws from the kit (see Figs. 2 and 6). Each mounting bar is fastened to the cradle by a single 4-40 screw, allowing it to be adjusted for slight variations in rack width.

NOTE: To install the cradle assembly in channel-type racks, it will be necessary to tilt the assembly sideways, while bending one side inward.

( ) 3. Remove the voltage tag on the rear right hand side of the instrument.

( ) 4. Relocate the voltage tag on the middle left hand side of the instrument, use a #43 drill (see Fig. 3).

( ) 5. Mount the hold-down bracket (from kit) on the rear panel of the instrument, as near to the vertical center line as possible (see Fig. 3).

( ) a. Drill and tap the two holes in the rear panel shown in Fig. 3. Use a #29 drill and an 8-32 tap.

CAUTION: BE CAREFUL NOT TO DRILL INTO COMPONENTS MOUNTED BEHIND THE REAR SUB-PANEL.

( ) b. Mount the hold-down bracket, using two 8-32 x 1/2 BHS screws from the kit.

( ) c. If the instrument will be subject to excessive vibration, the 8-32 nuts (from kit) should be added.

( ) 6. Place the instrument on the cradle guide rails and slide it into place.

( ) 7. Temporarily mount the mask (from kit) on the front of the relay rack, over the instrument front panel, and hold it in place with three or four of the 10-32 x 1/2 OHS screws from the kit.

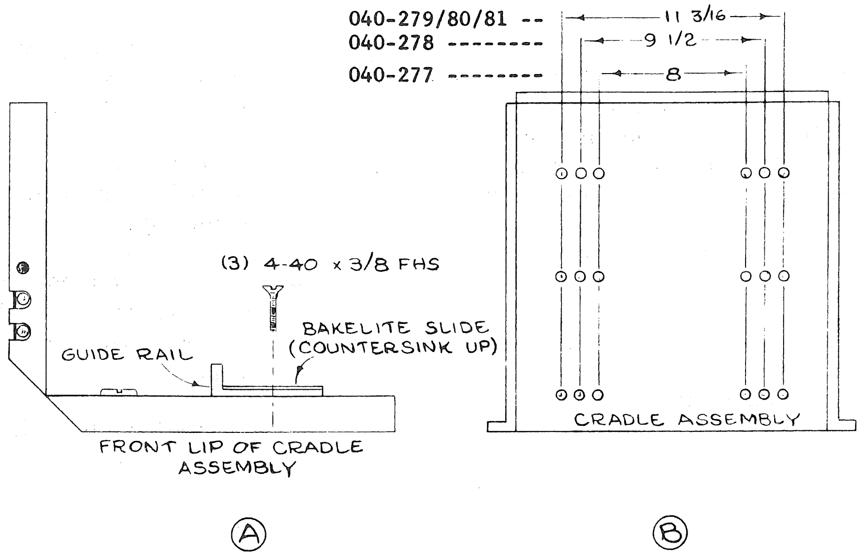


FIG. 1

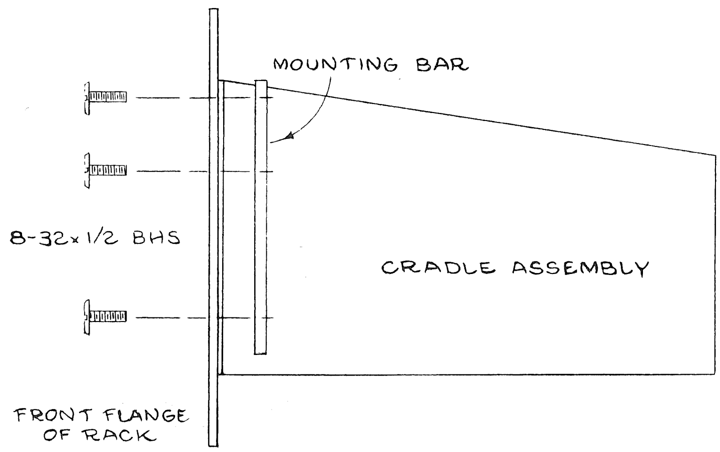


FIG. 2

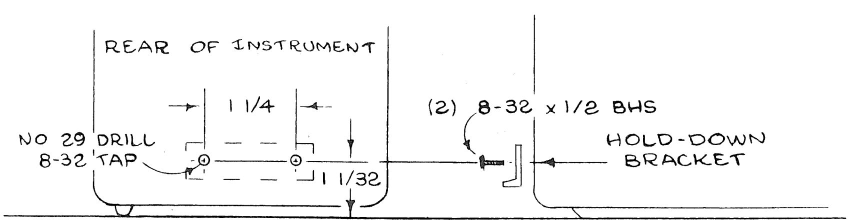


FIG. 3

INSTRUCTIONS (con'd)

( ) 8. Position the instrument so that the stainless steel ring touches the mask all the way around the instrument (see Fig. 4).

( ) 9. Place the instrument stop (from kit) on the cradle so that it meshes with the hold-down bracket on the instrument (see Fig. 5). If necessary, the hold-down bracket may be adjusted up or down.

( ) Mark the exact location of the stop on the cradle.

( ) 10. Remove the mask and the instrument.

( ) 11. Place the instrument stop in the location marked in step 7. Select two of the tapped holes in the stop, and mark and drill 11/64 in. holes in the cradle at these points.

( ) 12. Mount the stop, using the 8-32 x 5/16 BHS screws, flat washers and lock-washers from the kit (see Fig. 5).

( ) 13. Replace the instrument. Make sure the hold-down bracket and instrument stop come together properly.

( ) 14. Replace the mask, using the 10-32 x 1/2 OHS screws, the #10 cup washers, and the two spacer washers from the kit (see Fig. 6).

THIS COMPLETES THE INSTALLATION.

JT:ls

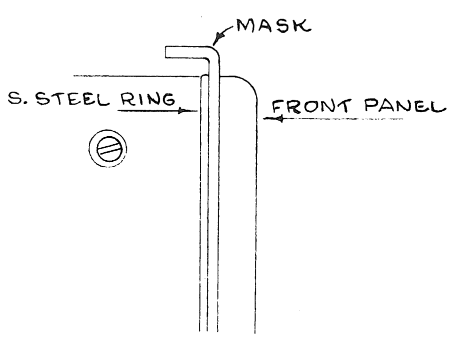


FIG. 4

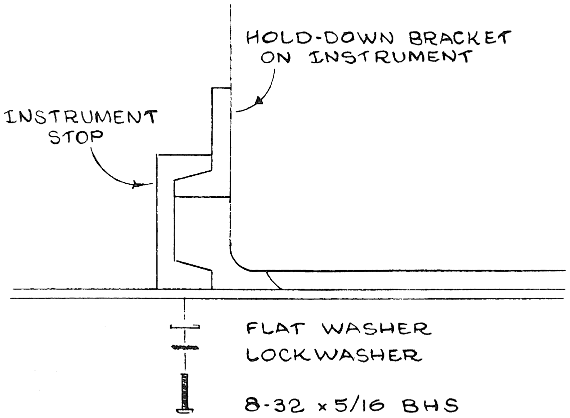
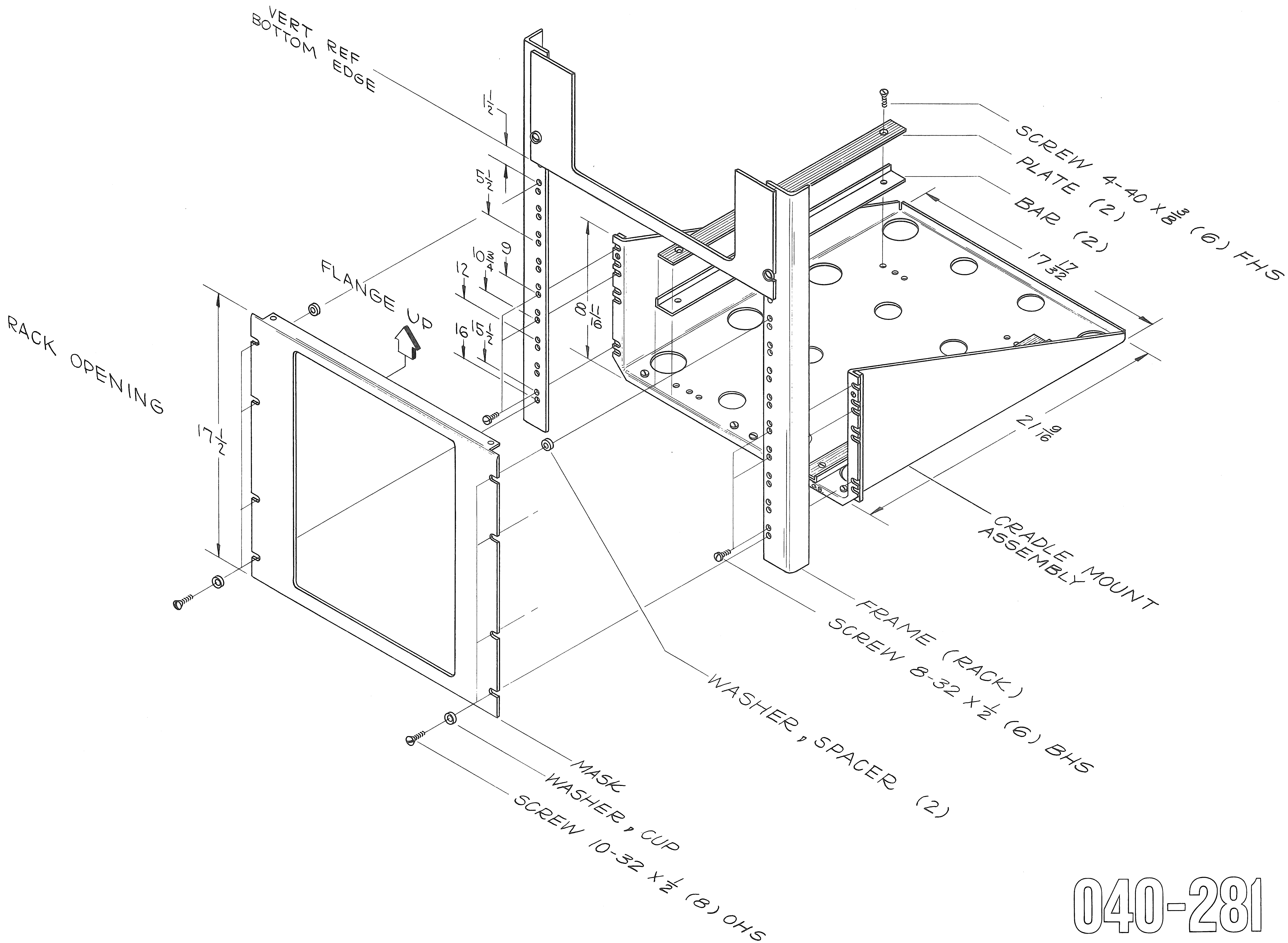


FIG. 5


VERT REF
BOTTOM EDGE
SCREW 4-40 X 3/8 (6) FHS
PLATE (2)
BAR (2)
17 17/32
RACK OPENING
FLANGE UP
1 1/2
5 1/2
9
10 3/4
12
15 1/2
16
8 11/16
17 1/2
21 9/16
CRADLE MOUNT
ASSEMBLY
FRAME (RACK)
SCREW 8-32 X 1/2 (6) BHS
WASHER, SPACER (2)
MASK
WASHER, CUP
SCREW 10-32 X 1/2 (8) OHS

040-281

ENGINEERING

Inter-City Mfg. Co., Inc.
St. Louis 11, Mo.

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Change No. 101/104A-6

ENGINEERING INSTRUMENT SPECIFICATION

CHANGE NOTICE

Instrument Type: 545B/RM545B Oscilloscope

Publication affected: Engineering Instrument Spec. No. 101/104A Dated 5/10/65

Page: 1-9, 1-10 Item 1.1.5 Power

Changed from:

Regulation: +100 V, 10 mV max P-P ripple

Changed to:

Regulation: +100 V, 15 mV max P-P ripple

Move: "Tolerance" and "Ripple" tables (page 1-9) and "DC Change with Line Voltage Change" tables (page 1-10) to Supplemental Information column.

NOTE: The enclosed slit-punched page replaces the corresponding page in the EIS.

Reason for change:

Instrument modified with new power transformer to conform to new line voltage ranges.

Approved by: Phillip A Crosby for CWR (Project Manager) Effective date 3/21/68

1.1.4 OUTPUT SIGNAL AMPLITUDE

Characteristic	Performance Requirement	Code	Supplemental Information
Vertical Signal Out	≥ 1.2 v per displayed cm	GA	
Sawtooth A	0 ± 5 v to ≥ + 130 v	GA	
+ Gate A	0 to ≥ + 20 v	GA	
+ Gate B	0 to ≥ + 20 v	GA	
Delay Trigger	≥ 5 v	GA	

1.1.5 POWER

Characteristic	Performance Requirement	Code	Supplemental Information
Line Frequency	50 to 60 cps, single Ø.		Can be modified for 400 c/s.
Line Voltage Range, RMS	(see table below)		
Line Voltage Range, Peak			(not determined at the date of this publication.)
Power Input			*500 watts (max), 5 amps (max), at 115 V, 60 Hz*

Line Voltage Range, RMS

	115 V	*230 V*
Low	*90 V to 110 V*	*180 V to 220 V*
Medium	*104 V to 126 V*	*208 V to 252 V*
High	*112 V to 136 V*	*224 V to 272 V*

\# Regulation, 115 v ± 10% or 230 v ± 10%

Supply	Performance Requirement	Code	*Tolerance*	*Maximum P-P Ripple*
		IA		
-150 v			*±3%*	*5 mV*
+100 v			*±3%*	*15 mV*
+225 v			*±3%*	*5 mV*
+350 v			*±3%*	*20 mV*
+500 v			*±5%*	*20 mV*

See page 1-1 for coding legend

1.1.5 POWER (continued)			
Characteristic	**Performance Requirement**	**Code**	**Supplemental Information**
# DC Change with Line Voltage Change, 103.5 to 126.5 or 207 to 253 v		IS	
-150 v			≤ ±0.05%
+100 v			≤ ±0.5%
+225 v			≤ ±0.1%
+350 v			≤ ±0.5%
+500 v			≤ ±0.5%
Time Delay	≥ 15 sec	GA	
Thermal Cutout Operation			52°C ambient typical
Current Available to Plug-in Connector			Supply / Min. / Max.: -150 / 3.4 ma / 6.4 ma +100 / 1.4 ma / 54 ma +225 / 14 ma / 88 ma +350 / 0 / 25 ma + 75 / / 150 ma

1.1.6 CRT CIRCUIT			
Tube Type			T5470-31-2
Cathode Voltage	- 1700 ± 3%	GA	Gun voltage ≈ 2 kv
Visual Writing Rate	Visible trace in darkened room with no bright spot at start of trace. Sweep rate at 0.02 μsec/cm and Trigger rate at 10 c/s	GS	
HV Oscillator Frequency			50 kc typical
Trace Rotation Range	Sufficient to align trace with horizontal graticule lines	GA	

See page 1-1 for coding legend

3/21/68

PERFORMANCE

INTERNAL GRATICULE PHOTOGRAPHY PROBLEMS FEN 9-4-64

Our present method for illuminating the internal graticule of 5" round CRT's such as T5470P results in lower graticule illumination and lower contrast between the graticule and phosphor than our conventional external graticule system.

This is especially apparent in the typical oscillogram and even the best of photos display some undesired background light patterns due to illumination of the phosphor.

Engineering is working hard on some promising improvements, but it will be several months before we can expect these improvements in our production instruments.

In the meantime, the only way to avoid the problem is to use an external graticule CRT or the Projected Graticule.

Scopes equipped with an internal graticule 5" round CRT can be easily converted in the field to external graticule CRT's by installing a regular CRT, an external graticule and an adjusting cam. A hole is provided in the front panel for the standard self-tapping screw which retains the adjusting cam. The NPR "description" of a standard CRT includes 2 sets of digits (such as a T5470-31). An internal graticule CRT "description" includes 3 sets of digits (such as a T5470-31-2). -- Earl Williams

---

Specification 101/104-A

ENGINEERING INSTRUMENT SPECIFICATION

TYPE 545B RM545B

FOR INTERNAL USE ONLY

TEKTRONIX, INC.

Specification 101/104-A

Revised May 10, 1965

ENGINEERING

INSTRUMENT SPECIFICATION

TYPE 545B/RM545B

OSCILLOSCOPE

Prepared by Technical Writing Department

Preproduction Engineering

Sunset Ext. 279 Daniel J. La Grange Daniel J. La Grange

Approval:

Project Manager Charles W Rhodes Charles Rhodes

Project Engineer (E) Carl E Hollingsworth Carl Hollingsworth

Project Engineer (M) Bud Diebele Bud Diebele

Evaluation Engineer (E) Gordon Mery Gordon Mery

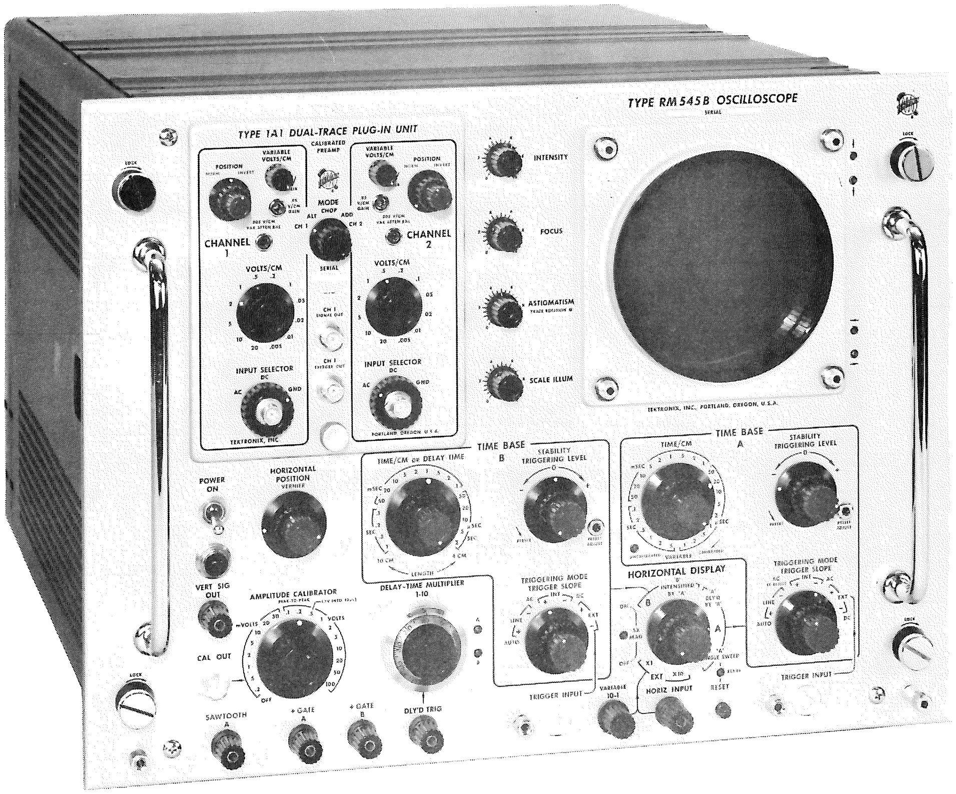
Evaluation Engineer (M) Jim Russo Jim Russo

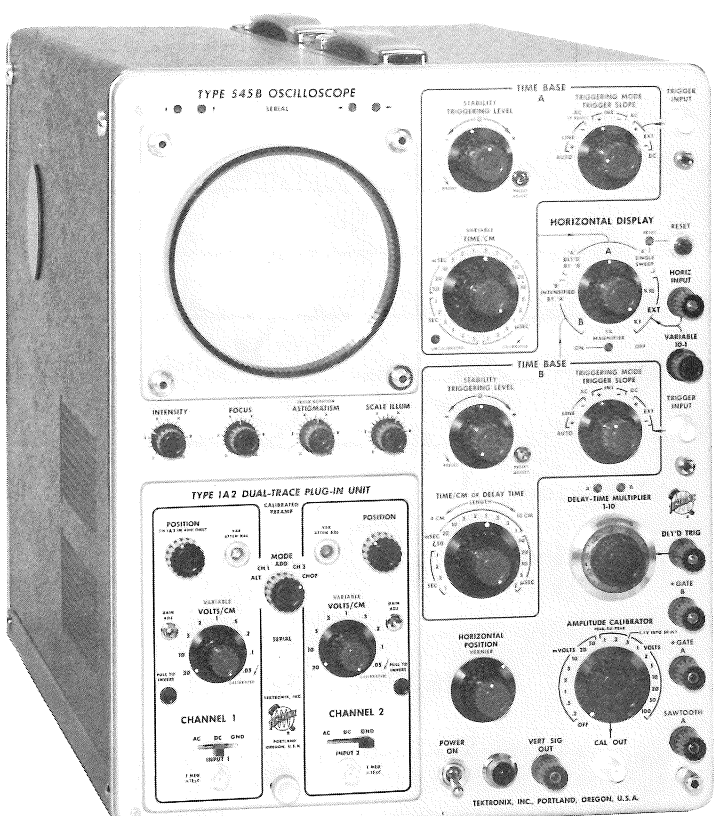
Legend: (E) = Electrical

(M) = Mechanical

FOR INTERNAL USE ONLY

TEKTRONIX, INC.


TYPE RM 545B OSCILLOSCOPE
TYPE 1A1 DUAL-TRACE PLUG-IN UNIT
CHANNEL 1
CHANNEL 2
VOLTS/CM
INPUT SELECTOR
TEKTRONIX, INC.
PORTLAND, OREGON U.S.A.
INTENSITY
FOCUS
ASTIGMATISM
SCALE ILLUM
TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.
TIME BASE B
TIME BASE A
HORIZONTAL DISPLAY
HORIZONTAL POSITION
POWER ON
VERT SIG OUT
AMPLITUDE CALIBRATOR
CAL OUT
DELAY-TIME MULTIPLIER 1-10
TRIGGERING MODE TRIGGER SLOPE
TRIGGER INPUT
HORIZ INPUT
RESET
SAWTOOTH A
+GATE A
+GATE B
DLY'D TRIG


TYPE 545B OSCILLOSCOPE
TIME BASE A
HORIZONTAL DISPLAY
TIME BASE B
INTENSITY
FOCUS
ASTIGMATISM
SCALE ILLUM
TYPE 1A2 DUAL-TRACE PLUG-IN UNIT
CHANNEL 1
CHANNEL 2
DELAY-TIME MULTIPLIER 1-10
HORIZONTAL POSITION
AMPLITUDE CALIBRATOR
POWER ON
VERT SIG OUT
CAL OUT
SAWTOOTH A
TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.

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INTRODUCTION

This is the Instrument Specification for the Types 545B and RM545B Oscilloscopes, and is the reference document for all company activity concerning performance requirements. This specification is for internal use only. It supersedes and replaces Specification 101/104 dated March 16, 1964.

General Information

The Types 545B and RM545B are improved models of the Types 545A and RM545A, respectively, and are intended for laboratory or nonsevere environments.

The following "B" version characteristics represent changes from or additions to the "A" version.

1. 6-cm vertical scan
2. Nondistributed vertical amplifier
3. Fixed-tuned delay line
4. Triggering to 30 mc (no HF Sync)
5. Trace Rotator
6. Internal graticule, illuminated, risetime type
7. 0.1 v into 50 Ω added to Calibrator output
8. Gray knobs instead of black

Characteristic Summary

Vertical Deflection	
Risetime	≤ 10 nsec
Signal Delay	200 nsec
Calibrated Scan	6 cm
Deflection Factor	.1 volts c/m push-pull deflection
Amplitude Calibrator	
Voltage Range	0.2 mv to 100 v
Special Output	0.1 v into 50 Ω
Horizontal Deflection	
Time Base A	
Time/cm Range	5 sec/cm to 0.1 μsec/cm
Variable Range	2.5:1
Trigger Mode	DC, AC, AC LF Reject, Auto
Trigger Slope	+ or -
Trigger Source	Internal, External, Line
Time Base B	
Time/cm Range	1 sec/cm to 2 μsec/cm
Trigger Modes	DC, AC, Auto
Trigger Slope	+ or -
Trigger Source	Internal, External, Line
Sweep Magnification	5X (extends fastest sweep rate to 20 nsec/cm)
Variable Time Delay	1 μsec to 10 sec, calibrated
External Horizontal Amplifier	
Deflection Factor	0.15 v/cm, variable 10:1
Input Attenuation	1X or 10X
Frequency Response	DC to ≥ 350 kc

Characteristic Summary (continued)

Output Signal Amplitude	
Vertical Signal Out	1.2 v per displayed cm
Time Base A Sawtooth	0 ± 5 v to ≥ 130 v
Time Base A + Gate	0 to 20 v
Time Base B + Gate	0 to 20 v
Delay Trigger	≥ 5 v
Power Source	
Regulation	115 v ±10% or 230 v ±10%
Watts	585 watts maximum
Line Frequency	50-60 cps (400 cps available as a modification)
CRT Circuit	
Tube Type	T5470-31-2 standard
Cathode Voltage	- 1700 v
Internal Graticule	Illuminated risetime type, 6 x 10 cm
Environment	
Storage	- 40°C to + 65°C, to 50,000 ft
Operating Temperature	0°C to + 50°C
Operating Altitude	To 15,000 ft
Maximum Overall Dimensions	
Type 545B	16.750"H x 12.875"W x 23.812"L
Type RM545B	Front panel: 13.984"H x 23.812"L Depth behind front panel: 22.688" *See outline drawing at rear of this specification
Weight	
Type 545B	65 lbs maximum, without plug-in unit
Type RM545B	86 lbs maximum, without plug-in unit

SECTION 1

1.0 Performance Requirements

1.1 Electrical Characteristics

Performance requirements listed for the characteristics in this section are valid throughout the environment specified in Section 1.2 unless there is a statement to the contrary.

Performance requirements are validated by Engineering according to Sections 3 and 4. Production test methods may differ.

The following codes are used to categorize performance requirements.

G (General Use)	This performance requirement may, but not necessarily will, be quoted to a customer.
I (Internal Use Only)	This is a customer type performance requirement (not a factory test limit), but will not be quoted to a customer.
A (All)	It is recommended by Engineering that electrical testing of this performance requirement be performed on 100% of instruments. Environmental testing is performed on a sample basis.
S (Sampled)	This performance requirement carries a high confidence level and may be tested on a sample basis.

Conditions under which a performance requirement is valid may be listed under Supplemental Information or in Section 3 (Electrical Test Methods). These conditions are an essential part of the performance requirement.

1.1.1 VERTICAL AMPLIFIER

Characteristic	Performance Requirement	Code	Supplemental Information
Input DC Level			+ 67.5 v, trace centered
Deflection Factor	0.1 v ± 3%, per displayed cm	GA	Push-pull deflection
Gain Control Range	± 10%	IA	Relative to calibrated setting
Risetime	≤ 10 nsec	GA	With TU-7
Frequency Response	DC to ≥ 30 mc (with Type K)	GA	≥ 30 mc at 70% amplitude
DC (Thermal) Shift	≤ 1.25% of initial deflection, after initial deflection	GA	Thermal Bal Adjustable to Zero
Transient Response	≤ 1.25% overshoot, rolloff, ringing, or tilt	GA	With TU-7, 5 cm step
Positioning Effect on Transient Response	≤ 1.25% change in transient response	GA	Exclude top and bottom 0.5 cm of graticule
Low Frequency Linearity	≤ 1.5 mm compression or expansion	GA	2-cm square wave positioned to top and bottom of screen
Signal Delay			200 nsec delay line
DC Balance	± 2 cm	GA	Adjustable to zero
DC Balance Range	± 2 cm of center	IA	

See page 1-1 for coding legend

1.1.1 VERTICAL AMPLIFIER (continued)			
Characteristic	Performance Requirement	Code	Supplemental Information
Trace Drift with Line Voltage Change	≤ 1 cm	GA	With line variations to ± 10%
Positioning Indicators	one on, one off with spot at graticule limit	GA	
Gain Change with Line Voltage Change	≤ 1%	GA	With line variations to ± 10%
1.1.2 AMPLITUDE CALIBRATOR			
Voltage Range	0.2 mv to 100 v in 1-2-5 sequence	GA	Verified in accuracy tests
Accuracy	± 3%	GA	Checked against mixing type Standard Calibrator
Symmetry	45% to 55%	GA	
Repetition Rate	1 kc ± 25%	GA	
Risetime			Typically 1 µsec
Special Output	0.1 v ± 3% into 50 Ω	GA	Measured with 0.1% 50 Ω resistor

See page 1-1 for coding legend

1.1.3 SWEEP AND TRIGGER

Characteristic	Performance Requirement	Code	Supplemental Information
Time Base A			
Calibrated Sweep Range	0.1 μsec/cm to 5 sec/cm, in 1-2-5 sequence	GA	Verified in accuracy tests
Accuracy	± 3%	GA	All sweep rates
Variable Time/cm Range	≥ 2.5:1	GA	Extends slowest sweep to about 12.5 sec/cm
Sweep Length	10.5 ± 0.3 cm	GA	set at 1 msec/cm
Triggering Level		GA	
INT			
AC	2mm deflection 150 c/s to 10 mc, increasing to 1 cm at 30 mc (< 1 mm display ditter). Will trigger below 150 c/s with increased deflection		With sinewaves from audio generator and Type 190B
AC LF Reject	2mm deflection 30 kc to 10 mc, increasing to 1 cm at 30 mc (< 1 mm display jitter). Will trigger below 30 kc with increased deflection		
DC	6mm deflection to 10 mc		
Auto	5mm deflection at 150 c/s. Will trigger from 50 c/s to 10 mc with increased deflection		

See page 1-1 for coding legend

ENGINEERING

INSTRUMENT SPECIFICATION

CHANGE NOTICE

Instrument Type 545B/RM545B

Specification No. 101/104-A **Dated** May 10, 1965

Page 1-5, 1-7 **Item** Time Base A, Time Base B

Now reads:

ADD:
~~Change to:~~

External Trigger Input			
Maximum Input Signal	50 V, combined DC + peak AC	GA	

Effective date of change January 5, 1966

Carl H. Neuman
(Signature)

PREPRODUCTION ENGINEERING PROJECT REPORT

545B		PE Report No.	428067
File Topic		Corporate No.	

Title

Report By: Hans Geerling	Requested By: Richard Nute
Department: PE/PE&M	Department: PE/PE&M
Date: Received: 5-10-68	Delivery Station: 50-429
Tent. Comp.: 6-28-68	Account Number:
Actual Comp.: FEB 11 1969	Subject: (Inst. Type, P/N, etc.)
Additional Routing: Jess Gard, Jack Millay, Warren Collier, Charles Chartrey, Roger Haight, Bob LeBrun, Leon Orchard, Charles Rhodes	

PROBLEM/OBJECT: Since the line voltage selector mod was added to 540B instruments, some instruments show excessive jitter on the sweeps. Please evaluate.

CONCLUSION: This was corrected by transposing two wires of a filament winding in the power transformer.

DETAILS OF PROCEDURE:

Transformer has been corrected.

Hans Geerling

HG/cr

1.1.3 SWEEP AND TRIGGER (continued)			
Characteristic	**Performance Requirement**	**Code**	**Supplemental Information**
Time Base A (continued)			
EXT — AC	0.2 v 150 c/s to 10 mc, increasing to 1 v at 30 mc (< 1 mm display jitter). Will trigger below 150 c/s with increased signal.	GA	Checked with sinewaves from audio generator and Type 190B
EXT — AC LF Reject	0.2 v 30 kc to 10 mc, increasing to 1 v at 30 mc (< 1 mm display jitter). Will trigger below 30 kc with increased signal.	GA	
EXT — DC	0.2 v to 10 mc, increasing to 1 v at 30 mc (< 1 mm display jitter).	GA	
EXT — Auto	0.5 v 150 c/s. Will trigger from 50 c/s to 10 mc with increased signal.	GA	
External Trigger Input R and C			Typically 1 megohm (except 91 kilohm at AC LF Reject) and 25 pf
No Signal Auto Trigger Repetition Rate	40 c/s ± 10%	GA	
Single Sweep	Must operate at internal triggering level of 0.5 cm.	GA	No miss or repetitive firing

See page 1-1 for coding legend

1.1.3 SWEEP AND TRIGGER (continued)

Characteristic	Performance Requirement	Code	Supplemental Information
TIME BASE B			
Calibrated Sweep Range	1 sec/cm to 2 μsec/cm in 1-2-5 sequence	GA	Verified in accuracy tests
Display Accuracy	± 3%	GA	
Sweep Length Adjustment	≤ 4 cm to ≥ 10 cm, variable	GA	
Triggering Level			
INT AC	2 mm deflection 300 c/s to 5 mc, increasing to 1 cm at 10 mc (< 1 mm display jitter). Will trigger below 300 c/s with increased deflection.	GA	
INT DC	6 mm deflection to 5 mc	GA	
INT AUTO	5 mm deflection at 300 c/s. Will trigger from 50 c/s to 5 mc with increased deflection.	GA	
EXT AC	0.2 v 300 c/s to 5 mc, increasing to 1 v at 10 mc (< 1 mm display jitter). Will trigger below 300 c/s with increased signal.	GA	
EXT DC	0.2 v to 5 mc, increasing to 1 v at 10 mc (< 1 mm display jitter)	GA	
EXT AUTO	0.5 v at 300 c/s. Will trigger from 50 c/s to 5 mc with increased signal.	GA	

See page 1-1 for coding legend

ENGINEERING

INSTRUMENT SPECIFICATION

CHANGE NOTICE

Instrument Type 545B/RM545B

Specification No. 101/104-A Dated May 10, 1965

Page 1-5, 1-7 Item Time Base A, Time Base B

Now reads:

ADD:
~~Change to:~~

External Trigger Input				
	Maximum Input	50 V, combined DC	GA	
	Signal	+ peak AC		

Effective date of change January 5, 1966

Carl H. Heuman
(Signature)

Change No. 101/104A-3

INSTRUMENT PERFORMANCE CHARACTERISTIC

CHANGE NOTICE

Instrument Type: 545B/RM545B

Publication affected: Engineering Instrument Spec. No. 101/104A Dated May 10, 1965

Page: 1-7 Item VARIABLE TIME DELAY (Delay Time Range)

Change to/~~add~~

Characteristic	Performance Requirement	Code	Supplemental Information
Delay Time Range	2 μs to 10 s, calibrated continously	GA	Range verified in accuracy tests

Reason for change:

Standardization with 535A and 549

Approved by: CWRhodes
(Project Manager)

Effective date 12/12/66

1.1.3 SWEEP AND TRIGGER (continued)

Characteristic	Performance Requirement	Code	Supplemental Information
TIME BASE B (continued)			
External Trigger Input R and C			Typically 1 megohm paralleled by 47 pf
No Signal Auto Trigger Rep Rate			40 c/s typical
B Intensified by A Unblanking Pulse Amplitude Differential			5 v typical
VARIABLE TIME DELAY			
Delay Time Range	1 μsec to 10 sec, calibrated, continously	GA	Range verified in accuracy tests
Accuracy			
Delay Range	± 1%	GA	
Incremental	± 0.2%	GA	B Sweep at 1 msec/cm
Delay Pickoff	≤ 1/20,000 of 10 times the B time/cm setting	GA	
Fixed Delay in System			200 nsec typical

See page 1-1 for coding legend

1.1.3 SWEEP AND TRIGGER (continued)			
Characteristic	Performance Requirement	Code	Supplemental Information
Horizontal Amplifier			
Sweep Magnification			
Magnification Factor	X5	GA	Extends fastest calibrated sweep rate to 0.02 µsec/cm
Timing Accuracy	± 5%	GA	
Sweep/Mag Registration	± 5 mm	GA	
Positioning Indicators	One on, one off before spot reaches ± 4.5 cm of center	GA	
External Horizontal Amplifier			
* Deflection Factor		3.3.6	
X1	*≤ 0.2 V/cm at 1 kHz*	GA	
X10	*≤ 2 V/cm at 1 kHz*		
* 10:1 Attenuator Accuracy	± 3%	3.3.6 GA	
X10 Attenuator Compensation	≤ 5% aberration or tilt referenced to X1	GA	
Input R and C			Typically 1 meg, 45 pf
X1 DC Balance	≤ 2 cm	GA	Adjustable to zero
Frequency Response	DC to ≥ 350 kc, at 30% down (with maximum gain)	GA	
* *Variable 10:1*	*≥ 10:1*	*3.3.6 GA*	

Change Notice #101/104A-1, 10-17-66

See page 1-1 for coding legend

ENGINEERING

INSTRUMENT SPECIFICATION

CHANGE NOTICE

Instrument Type 545B/RM545B

Specification No. 101/104A **Dated** May 10, 1965

Page 1 - 8 **Item** EXTERNAL HORIZONTAL AMPLIFIER

Now reads:

ADD:
~~**Change to:**~~

Maximum Input	50 V, combined DC +	GA	
Signal	peak AC		

Effective date of change January 5, 1966

Earl H. Neuman
(Signature)

1.1.4 OUTPUT SIGNAL AMPLITUDE

Characteristic	Performance Requirement	Code	Supplemental Information
Vertical Signal Out	≥ 1.2 v per displayed cm	GA	
Sawtooth A	0 ± 5 v to ≥ + 130 v	GA	
+ Gate A	0 to ≥ + 20 v	GA	
+ Gate B	0 to ≥ + 20 v	GA	
Delay Trigger	≥ 5 v	GA	

1.1.5 POWER

Characteristic	Performance Requirement	Code	Supplemental Information
Line Frequency	50 to 60 cps, single Ø.		Can be modified for 400 c/s.
# *Line Voltage Range, RMS*			

	115 V	*230 V*
Low	*90 V to 110 V*	*180 V to 220 V*
Medium	*104 V to 126 V*	*208 V to 252 V*
High	*112 V to 136 V*	*224 V to 272 V*

Characteristic	Performance Requirement	Code	Supplemental Information
Line Voltage Range, Peak			(not determined at the date of this publication.)
# Power Input			*500 watts (max), 5 amps (max), at 115 V, 60 Hz*
Regulation, 115 v ± 10% or 230 v ± 10%		IA	

Supply	Tolerance	Maximum p-p Ripple
-150 v	± 3%	5 mv
+100 v	± 3%	~~10 mv~~ 15 mV
+225 v	± 3%	5 mv
+350 v	± 3%	20 mv
+500 v	± 5%	20 mv

See page 1-1 for coding legend

1.1.5 POWER (continued)			
Characteristic	**Performance Requirement**	**Code**	**Supplemental Information**
DC Change with Line Voltage Change, 103.5 to 126.5 or 207 to 253 v			
-150 v	≤ ± 0.05%	IS	
+100 v	≤ ± 0.5%		
+225 v	≤ ± 0.1%		
+350 v	≤ ± 0.5%		
+500 v	≤ ± 0.5%		
Time Delay	≥ 15 sec	GA	
Thermal Cutout Operation			52°C ambient typical
Current Available to Plug-in Connector			Supply / Min. / Max. -150 / 3.4 ma / 6.4 ma +100 / 1.4 ma / 54 ma +225 / 14 ma / 88 ma +350 / 0 / 25 ma + 75 / / 150 ma
1.1.6 CRT CIRCUIT			
Tube Type			T5470-31-2
Cathode Voltage	- 1700 ± 3%	GA	Gun voltage ≈ 2 kv
Visual Writing Rate	Visible trace in darkened room with no bright spot at start of trace. Sweep rate at 0.02 µsec/cm and Trigger rate at 10 c/s	GS	
HV Oscillator Frequency			50 kc typical
Trace Rotation Range	Sufficient to align trace with horizontal graticule lines	GA	

See page 1-1 for coding legend

1.1.6 CRT CIRCUIT (continued)			
Characteristic	**Performance Requirement**	**Code**	**Supplemental Information**
Z Axis Modulation			
Voltage	Intensity modulates at ≤ 15 v	GA	
Low Frequency Cutoff			600 c/s typical
Input R and C			Typically 1 meg, 10 pf
Geometry			
Vertical	≤ 1.5 mm bowing or tilt	GA	
Horizontal	≤ 2 mm bowing or tilt	GA	
Focus			
Vertical	2 horizontal line/mm distinguishable over center 4 cm of graticule. 1.5 lines/mm in top and bottom cm	GA	
Horizontal	2 time mark/mm distinguishable over middle 8 cm of graticule. 1.5 marks/cm in 1st and last cm	GA	

See page 1-1 for coding legend

1.2 Environmental

The Types 545B and RM545B are laboratory instruments. Only the following environmental limits are applicable.

1.2.1 Storage

No visible damage or electrical malfunction after storage at -40°C to +65°C and 50,000 ft., as described in Sections 4.1 and 4.2. Adjustments may be performed to meet required accuracy after storage tests.

1.2.2 Temperature

The instrument will perform to limits indicated in Section 1.1 over a range from 0°C to 50°C when tested according to Section 4.1. Thermal cutout is incorporated to protect instrument from overheating.

1.2.3 Altitude

The instrument will perform to limits indicated in Section 1.1 to 15,000 ft.

1.2.4 Vibration

The instrument will perform to limits indicated in Section 1.1 following vibration tests described in Section 4.3.

1.2.5 Transportation

The instrument will be so packed that it will meet the National Safe Transit requirements described in Section 4.4.

SECTION 2

2.0 Miscellaneous Information

2.1 Ventilation

Safe operating temperature is maintained by filtered, forced-air ventilation. A minimum of 2" unobstructed clearance around the instrument is recommended for adequate ventilation. Thermal cutout protects instrument from overheating.

2.2 Finish

Front panel has an anodized finish; the cabinet is finished in a blue vinyl paint.

2.3 Connectors

A TRIGGER INPUT, B TRIGGER INPUT, and CAL OUT are BNC type. HORIZ INPUT, DLY'D TRIG, +GATE B, +GATE A, and SAWTOOTH A are 5-way binding posts.

2.4 Warm-up Time

Twenty minutes for rated accuracies at 25°C ±5°C.

2.5 Accessories

2.5.1 Type 545B Accessories

2 070-428 Instruction Manuals
2 010-127 P6006 Probes
2 103-033 BNC to Binding Post Adapters
1 012-031 Test Lead
1 161-010 Power Cord
1 103-013 3-Wire to 2-Wire Adapter
1 012-076 50 Ω Cable, BNC to BNC, 18"
1 103-015 Adapter, BNC to UHF
1 387-918 CRT Protector Plate

2.5.2 Type RM545B Accessories

2 070-438 Instruction Manuals
2 010-127 P6006 Probes
2 103-033 BNC to Binding Post Adapters
1 012-031 Test Lead
1 161-010 Power Cord
1 103-013 3-Wire to 2-Wire Adapter
1 012-076 50 Ω Cable, BNC to BNC, 18"
1 103-015 Adapter, BNC to UHF
1 387-918 CRT Protector Plate
12 212-533 10-24 x 5/16 THS Screws
12 212-535 10-32 x 5/16 THS Screws

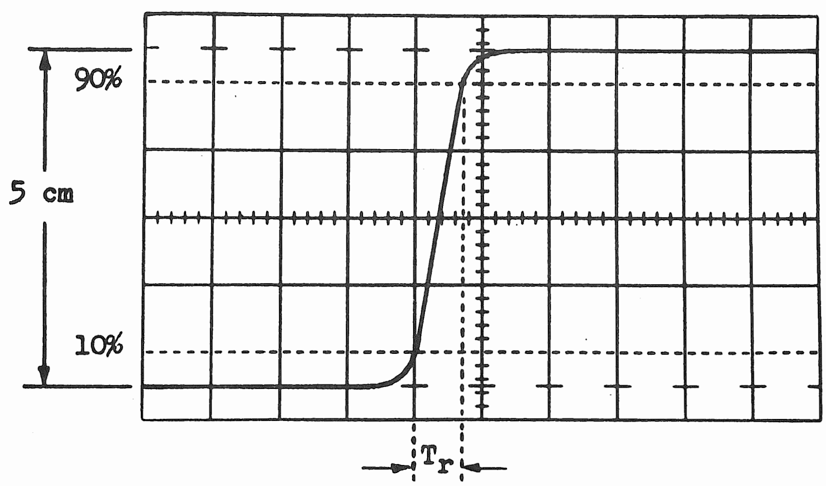
SECTION 3

3.0 Method of Measurement of Electrical Performance

3.1 Vertical Amplifier

3.1.1 Risetime

Risetime is measured using a pulse from the TU-7. Risetime is the time interval between the 10% and 90% amplitude points on the leading edge of the pulse. Using exactly a 5-cm pulse positioned as shown in the following illustration, the 10% and 90% amplitude points occur at the dotted lines.



3.1.2 High-Frequency Response

The 30%-down high frequency is calculated from the risetime according to $f = \frac{0.35}{T_r}$, where T_r is the risetime.

3.1.3 Transient Response

Transient response is measured with the same setup used for risetime. Transient response is calculated by measuring the maximum peak-peak pulse aberration in the form of overshoot, rolloff, ringing, or tilt along the entire pulse top. It is generally expressed in percentage of pulse amplitude.

3.1.4 Positioning Effect on Transient Response

To measure the effect of positioning on transient response, the pulse is positioned down 5 cm so that the pulse top occurs at the lower dashed graticule line.

3.1.5 LF Linearity

Linearity is measured using a low repetition rate pulse from the TU-7, exactly 2 cm amplitude, centered vertically on the graticule. Positioning the display vertically + and - 2 cm from center, linearity is the maximum change in pulse amplitude occurring at the defined limits.

3.1.6 Gain Change With Line Voltage Change

Amplifier regulation is checked by observing for a change in gain with line voltage. With the TU-7 set to GAIN SET, a 100-volt signal from a precision voltage calibrator (0.25%) will produce 4 cm of deflection at 115-volt (design-center) line. With the line voltage varied between the specified limits (103.5 and 126.5 volts), regulation is the change in deflection expressed as a percentage of 4 cm.

3.2 Amplitude Calibrator

3.2.1 Accuracy

Calibrator accuracy is checked by applying each output voltage to a precision (0.25%) mixing-type voltage calibrator, and comparing the outputs on an oscilloscope. The deviation at any calibrator voltage cannot exceed 2.75% for the Amplitude Calibrator to remain within its 3% specification.

3.2.2 Symmetry (Duty Cycle)

Calibrator waveform symmetry or duty cycle is determined by measuring the dc voltage at the Calibrator Test Point jack, when the Calibrator is set to any output voltage. Symmetry or duty cycle is defined as the ratio of the voltmeter reading to 100 volts, expressed as a percentage.

3.2.3 Special Output Accuracy

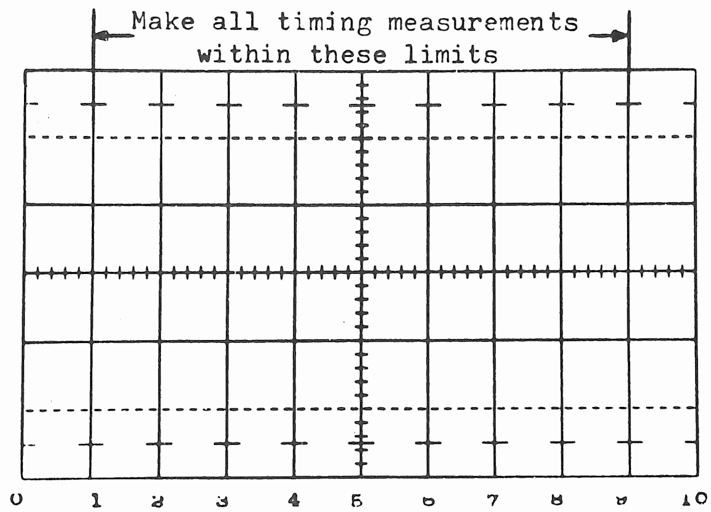
The accuracy of the 0.1 volt into 50 Ω output is determined by applying this output voltage to a standard 50 Ω ±0.1% resistor, and measuring the voltage across the resistor with a precision voltmeter. Accuracy is defined as any deviation from 0.1 v. expressed as a percentage of 0.1 v.

3.3 Sweep and Trigger

3.3.1 Sweep Accuracy

Sweep accuracy is determined by applying time markers from a 180A through a TU-7 (or other plug-in). Time markers should be selected so that there is 1 mark/cm at all "1, 5, 10" ranges, and 2 marks/cm at all "2" ranges (exception: At 0.5 µsec/cm sweep rate, 1 mark/2 cm will be obtained with 1-µsec markers, or 2-1/2 cycles/cm with 5-mc signal). All timing measurements are made over the middle 8 centimeters of the graticule, as shown in the illustration. The first and last centimeters should not be included in the measurement because of CRT nonlinearity.

Sweep accuracy is defined as the amount of any deviation between the 9th-cm graticule mark and the corresponding timing marker in mm, expressed as a percentage of 80 mm.



3.3.2 Triggering Level

Triggering level is measured with the following signals: Below 5 mc, use sine wave signal from audio generator; above 5 mc, use sine wave signal from Type 190B.

3.3.3 Time Delay Accuracy

Delay range and incremental accuracy are measured with time markers from a Type 180A and the DELAY-TIME MULTIPLIER dial. A "B" INTENSIFIED by "A" display is first obtained, with the A sweep time/cm chosen to be at least 1/10 that of B sweep. The timing check is then made in the "A" DLY'D by "B" mode. Delay range accuracy is the deviation in a total of 800 minor divisions, from approximately 1.00 to 9.00 on the DELAY-TIME MULTIPLIER dial. A 1% accuracy is equivalent to an 8-division deviation in 800. Incremental accuracy is the percent deviation from periodic major divisions. Since the beginning and ending major divisions are seldom even numbers (1.00 and 9.00), the procedure for obtaining percentage deviation is a little involved. Essentially, it is a matter of first determining the periodic major divisions, then calculating the deviation that exists at each setting of the dial.

For example, suppose a time marker were exactly aligned with a reference graticule mark at the following DELAY-TIME MULTIPLIER dial readings.

1.000	5.980
1.995	6.970
2.995	7.995
3.990	8.960
4.990	

Then 8.960 - 1.000 = 7.960 or 796.0 minor divisions. And $\frac{796.0}{8}$ = 99.5 minor divisions between each periodic major division for perfect linearity.

Periodic Major Divisions	Delay-Time Multiplier Readings	Deviation in Minor Divisions
1.000	1.000	0
1.000 + 0.995 = 1.995	1.995	0
1.995 + 0.995 = 2.990	2.995	+0.5
2.990 + 0.995 = 3.985	3.990	+0.5
3.985 + 0.995 = 4.980	4.990	+1.0
4.980 + 0.995 = 5.975	5.980	+0.5
5.975 + 0.995 = 6.970	6.970	0
6.970 + 0.995 = 7.965	7.960	-0.5
7.965 + 0.995 = 8.960	8.960	0

Each deviation at the major dial points is within 1.6 minor divisions, or within 0.2% of 800.

3.3.4 Delay Pickoff Jitter

Jitter is measured by setting up B sweep at 1 msec/cm and A sweep at 1 µsec/cm, free running. This effectively produces a 1000:1 magnification. In the "A" DLY'D by "B" mode, 5 mm represents 1 part in 20,000. The first major division and ninth major division of the DELAY-TIME MULTIPLIER dial are check points.

3.3.5 Sweep/Magnifier Registration

Magnifier registration is checked by positioning a timing marker to the exact center of the graticule with the 5X magnifier on, then switching the magnifier off. Registration is the amount of any deviation between the timing marker and the center graticule. mark.

3.3.6 External Horizontal Amplifier

**Performance Requirement:*

Deflection Factor	*X1*	*≤0.2 V/cm at 1 kHz*
	X10	*≤2 V/cm at 1 kHz*
10:1 Attenuator Accuracy		*±3% ±*
Variable 10:1		*≥10:1*

Measurement: Connect Standard Amplitude Calibrator to EXT HORZ INPUT. Set VARIABLE 10:1 fully cw and HORIZONTAL DISPLAY to X1, and apply a 1 V signal from the SAC. Horizontal deflection must be $\geq$ 5 cm. Change HORIZONTAL DISPLAY TO X10 and SAC to 10 V. The horizontal deflection must be $\geq$5 cm, and match the deflection in the X1 position within ±3%.

Turn HORIZONTAL DISPLAY to X1 and SAC to 1 V, and note horizontal deflection. Turn VARIABLE fully ccw and SAC to 10 V. The horizontal deflection must be equal to or less than the deflection noted before.

Attenuator compensation is checked by applying an approximate 1-kc square wave, having a risetime of from 1 to 5 µsec.

High frequency response is measured by applying a 50-kc reference signal from a Type 190B. Set amplitude for 6 cm, increase the frequency to the point where amplitude falls to 4.2 cm, then note the frequency.

3.4 Power

3.4.1 Regulation

Regulation is checked by monitoring each output voltage with a 20,000 Ω/v meter while varying the line voltage between 103.5 and 126.5 v or between 207 and 253 v. Regulation is the maximum change in any supply voltage, expressed as a percentage of the correct voltage. Ripple is measured with a test oscilloscope and a 1X probe.

If the power supply or ripple requirements are exceeded with the line voltage within the rms limits, peaks should be checked for flattening or distortion.

3.5 CRT Circuit

3.5.1 Z Axis Modulation

Checked by free-running the sweep at 1 msec/cm, connecting the specified voltage from a calibrator to the External CRT Cathode connector, and ascertaining that intensity modulation is present at some setting of the Intensity control.

Note: Grounding strap must be removed from External CRT Cathode connectors and switch must be in External CRT Cathode position.

3.5.2 Geometry

Checked by applying a calibrator signal of sufficient amplitude to exceed the graticule height, at a triggered sweep rate of 2 msec/cm. Horizontal geometry is checked by positioning a 0.5 msec/cm free-running sweep trace to the top and bottom of the graticule.

SECTION 4

4.0 Environmental Test Methods

4.1 Temperature

4.1.1 Non-operating

Store for 4 hours at -40°C and 4 hours at +65°C. One cycle only.

4.1.2 Operating

Perform complete electrical checks at room ambient. Turn off instrument and store at 0°C for 4 hours. After 20 minutes, check the following electrical characteristics: Risetime, thermal shift, transient response, vertical amplifier gain, triggering, time-base timing, and power supply voltages.

Raise ambient temperature to 50°C with instrument operating. Hold for 4 hours and again check above characteristics.

Return instrument to room temperature and after 4 hours (or temperature stabilization) perform complete electrical checks.

4.1.3 Failure Criteria

Non-operating

Instrument and components must meet performance requirements before and after storage. (Adjustments may be performed if necessary to meet required accuracies).

Cracking, warping, and significant color discoloration or deformation which interferes with the normal mechanical function will not be permitted.

Operating

Instrument must be within indicated performance characteristics at each step of the operating temperature check. Controls and switches shall be checked for ease of operation.

4.2 Altitude

4.2.1 Non-operating

Store at -40°C and 50,000 feet altitude for 4 hours. This may be performed along with the storage tests.

4.2.2 Operating

The instrument while operating will be maintained at an altitude of 15,000 feet for 4 hours and with the necessary thermal derating. At the end of this period and while the above conditions are maintained, the most important electrical checks will be performed. When necessary, the vacuum chamber may be opened and the necessary switching performed as rapidly as possible. The instrument will then be allowed to stabilize for 1 hour at the above conditions before completing the electrical checks.

4.2.3 Failure Criteria

Non-operating

Instrument will meet performance requirements before and after the 50,000 feet storage test.

Operating

Instrument will meet performance requirement during operation at altitude. Any evidence of malfunction will constitute failure, i.e., random trace modulation, noise, corona, etc.

4.3 Vibration

4.3.1 Operating

4.3.2.1 Type 545B

Vibrate for 15 minutes along each of the 3 axes at a total displacement of 0.015" (1.9 g at 50 cps) with the frequency varied from 10-50-10 cps in 1 minute cycles. Hold at resonant points for 3 minutes. If no resonances are present vibrate at 50 cps for 3 minutes in each axis. Total vibration time about 55 minutes. Sporadic output will be permitted during vibration.

4.3.2.2 Type RM545B

Vibrate for 15 minutes along each of the 3 axes at a total displacement of 0.010" at the instrument center of gravity (1.25 g at 50 cps) with the frequency varied from 10-50-10 cps in 1 minute cycles. Hold at resonant points for 3 minutes. If no resonances are present vibrate at 50 cps for 3 minutes in each axis. Total vibration time about 60 minutes. Sporadic output will be permitted during vibration.

4.3.2 Failure Criteria

Broken leads, chassis or other components, loose parts, excessive wear or component fatigue. Change in value of any component outside its normal rated tolerance. Deformation which interferes with the normal mechanical function.

The test will be completely re-run after repairing any of these failures.

Tube failures will be permitted during test and when replaced the test will be continued from that point - CRT's or transistors will not be included in this.

Instrument must meet performance requirements before and after the operating vibration test.

Engineering tests will be performed with the instrument "dogged" to the table. Tests on completed instruments will be performed with panels removed when possible and straps used for hold downs.

4.4 Transportation

The instrument when packaged must meet the National Safe Transit type of test.

4.4.1 Vibration

One hour on the vibration platform with an amplitude slightly in excess of 1 g and causing the package to just leave the vibration surface.

4.4.2 Drop Test

Drop from a height of 12 inches on all corners, edges, and flat surfaces.

4.4.3 Failure Criteria

Instrument must meet performance requirements before and after the transportation tests.

There must be no serious damage such as broken components, leads, or chassis, and no deformation of components or chassis in excess of 0.100". Deformation which interferes with normal mechanical function will not be permitted.

CALL REPORT EXTRACTS
PERFORMANCE

DOUBLE TRIGGERING

CUSTOMER A. B. McMahan Company	FIELD ENGINEER Joe Gardner-Minneapolis C
CITY AND STATE Minneapolis, Minnesota	JAN 2 8 1965 · MONTH-DAY-YEAR 1-15-65 · CALL #
GROUP	GROUP FUNCTION Automatic display signs 1-2

NAMES E.W.
Samuel Proctor

547 triggering problem. Customer found double triggering, i.e., triggering on both + and - slope of the input wave form, when triggering on 60-cycle sine waves with plug-in in chopped mode and sweep time/cm uncalibrated. This becomes particularly annoying when the time base is set up for one cycle of 60 cycle information in ten centimeters.

Observation. Checked into problem further back at the field office with demos 547 serial numbers 254 and 199, 1A1 serial numbers 221 and 873, and 1A2 serial number 126 and here is what I found. The signal on the trigger tunnel contains a small amount of chopper signal--amount depends on vertical position. Most of the time I was using line, but chopper signal is present on all positions of trigger selector switch. This chopper signal seems to cause oscillation to occur at the point where the relatively slow changing sine wave is just about to switch the tunnel. If the trigger tunnel switches to its high state, its output switches the sweep tunnel with no apparent effect from the oscillation. But, when the trigger tunnel switches back to its low state, the oscillation is enough to again supply a positive going signal to the sweep tunnel and if the sweep has recovered and the sweep tunnel is rearmed, it is going to be switched again. Thus, we can have triggering on both the positive and the negative slope when the trigger slope switch is set for positive. For some reason that as yet I can't explain, the oscillation seems to be reduced when the slope switch is set to negative.

Conclusions. We have a definite problem triggering on slow changing wave forms when the plug-in is set for chopped mode. Since we generally will want chopped for any slow sweep dual-trace displays we had better fix this problem.

Problem is due to trigger regenerator responding to chopper overshoot spikes appearing with signals going to trigger circuits. Chopper spikes show up in different sections of Trigger Mode switch by virtue of crosstalk between switch sections. Engineering feels that an attempt at switch redesign or reduction of chopper overshoot spikes in plug-ins would not be feasible at this time. (PROBLEM COMMON TO 544, 546, 543B & 545B) E.S.H.

An application solution can be effected by triggering scope externally from front panel Trig Out. A series RC of 1k and .001 connected from the EXT TRIG input jack to ground will reduce the spikes by X4 and enable stable triggering.

BINDING POSTS VS BNC CONNECTORS

CUSTOMER
Olmsted Air Force Base

FIELD ENGINEER
Mitch Elliott   E

CITY AND STATE
Pennsylvania

MONTH-DAY-YEAR: 2/17/65   CALL #: 3

GROUP
Tech Services

GROUP FUNCTION
Procurement Assistance   MAR 4 1965

NAMES
EW Joe Scheinman, RCA Engineer

REACTION

DISLIKES BINDING POST CONNECTORS ON TYPE 545B

Joe had seen the Type 545B's undergoing test here under MIL-0-9960. He expressed the opinion that the existing binding post connectors for output waveforms and external horizontal input should also be converted to BNC connectors. Although the horizontal input could easily stand a low frequency type connector, I had to admit that his proposal made sense for delayed trigger out and for the other waveform connectors.

545B BINDING POST CONNECTORS CAN BE REPLACED IN THE FIELD WITH 131-012600 ½" D-HOLE BNC CONNECTOR.

ME:pi

NEW INSTRUMENTS WITH ALL BNC'S CAN BE NEGOTIATED THRU RON WARD AS A SPECIAL

Ernor

RECEIVED
MAR 1 1965
TEKTRONIX, INC.
PHILA. REGION

SECTION 2

OPERATING INSTRUCTIONS

FUNCTION OF CONTROLS AND CONNECTORS

NOTE

The Time Base A and Time Base B controls serve identical functions with the exception of the LENGTH control.

TRIGGERING LEVEL	Selects the amplitude point on the triggering signal where sweep-triggering occurs.
STABILITY	Adjusts the oscilloscope for a stable displayed waveform. The STABILITY control can be set to the PRESET position and left there. This position provides for convenient triggering since only the TRIGGERING LEVEL control needs to be adjusted to obtain a stable display.
TRIGGERING MODE	AUTO: Permits normal triggering on simple waveforms with repetition rates higher than about 50 cps. With no trigger signal, or with a lower repetition rate, the trigger circuit free runs at approximately 40 cps and triggers the time base at this rate, providing a reference trace.
	AC LF REJ: Attenuates trigger-signal frequencies below about 17 kc, allowing the trigger circuit to respond only to higher frequencies.
	AC: Blocks the dc component of the triggering signal and allows triggering to take place only on the changing portion of the signal.
	For frequencies below about 30 cps, use the DC position.
	For best triggering at high frequencies, use an ac coupling position of the TRIGGERING MODE switch.
	DC: Permits triggering on both high- and low-frequency (to dc) signals.
TRIGGER SLOPE	Determines whether the time base is triggered on the negative- (—) or positive- (+) going slope of the signal.
	LINE: Uses a line-frequency signal as a trigger.
	INT: Uses a portion of the signal applied to the vertical deflection plates of the crt as a trigger signal.
	EXT: Provides external triggering on a signal applied to the TRIGGER INPUT connector.
TIME/CM	Selects the time-base sweep rate.
TIME/CM VARIABLE (Time Base A)	Provides an uncalibrated sweep rate adjustment. The sweep rate can be slowed by a factor of at least 2.5X. An UNCALIBRATED lamp lights when the VARIABLE control is not in the CALIBRATED position.
LENGTH (Time Base B)	Controls the length of the B sweep.
HORIZONTAL DISPLAY	A: Allows only Time Base A to display on the crt.
	B: Allows only Time Base B to display on the crt.
	'B' INTENSIFIED BY 'A': One of the delayed-sweep functions. In this position, a portion of Time Base B is intensified during the time that Time Base A (the delayed sweep) is in operation.
	'A' DLY'D BY 'B': One of the delayed sweep functions. In this position, Time Base A is displayed at the end of each delay period as determined by the B TIME/CM OR DELAY TIME and DELAY-TIME MULTIPLIER controls.
	'A' SINGLE SWEEP: Allows the Time Base A generator to sweep once upon receipt of trigger signal and not sweep again until the circuit has been reset with the RESET button. Single sweep permits photographing nonrepetitive waveforms, which otherwise would not be photographed clearly.
	EXT ×1 and ×10: Permit an external signal to be applied to the horizontal deflection circuit. Sensitivity is continuously variable (with the VARIABLE 10-1 control).
READY Lamp	Lights when time-base circuit is ready for triggering after being reset.
5× MAGNIFIER	Expands the sweep from the center of the graticule at any setting of the TIME/CM switch by 5 times.
DELAY-TIME MULTIPLIER 1-10	Works in conjunction with the Time Base B TIME/CM OR DELAY TIME switch.
	Varies sweep delay from 0 to 10 times the rate indicated by the Time Base B TIME/CM OR DELAY TIME switch.
HORIZONTAL POSITION and VERNIER	Positions the display along the horizontal axis of the crt.
AMPLITUDE CALIBRATOR	Determines the peak-to-peak voltage available at the CAL OUT connector.
POWER ON	Toggle switch for turning the instrument power on and off.
INTENSITY	Controls brightness of the display.

FOCUS	Used in conjunction with the INTENSITY and ASTIGMATISM controls for obtaining a well-defined display.
ASTIGMATISM	Used in conjunction with the INTENSITY and FOCUS controls for obtaining a well-defined display.
TRACE ROTATION	Permits horizontal alignment of the trace with respect to the horizontal lines of the graticule. The TRACE ROTATION control is a screwdriver adjustment concentric with the ASTIGMATISM control.
SCALE ILLUM	Varies illumination of the graticule grid lines.
Beam Position	Four neon lamps with accompanying arrows indicate the direction when the display is deflected out of the viewing area.
TRIGGER INPUT (Time Base A and B)	Connector for applying an external trigger signal to the time base when its TRIGGER SLOPE switch is set to the EXT position.
HORIZ INPUT	Jack for applying external horizontal signal when the HORIZONTAL DISPLAY switch is set to either ×1 or ×10 EXT.
+GATE B	Supplies approximately a 20-volt square-wave pulse when Time Base B is operating. Pulse duration is approximately 10.5× the setting of the TIME/CM OR DELAY TIME switch.
DLY'D TRIG	Supplies a sharp positive-going trigger spike of about 5 volts at the end of the delay period as set by the TIME/CM OR DELAY TIME switch and the DELAY-TIME MULTIPLIER dial.
SAWTOOTH A	Supplies the sawtooth voltage of Time Base A. Peak amplitude is about +130 volts.
+GATE A	Same as +GATE B except applies to TIME BASE A.
VERT SIG OUT	Vertical signal output connector. Output amplitude is approximately 1.2 volts/cm of deflection.
CRT CATHODE SELECTOR (rear panel)	Provides blanking of between-channel switching transients (in the CHOPPED BLANKING positions) when using multi-channel plug-in units in the chopped mode. The CRT CATHODE SELECTOR switch should always be in the EXTERNAL CRT CATHODE position except when using the chopped mode.
EXTERNAL CRT CATHODE	With the ground strap disconnected, this connector applies Z-axis modulation signals to the crt cathode. The Z-axis signals should be at least 20 volts in amplitude to cause intensity modulation.

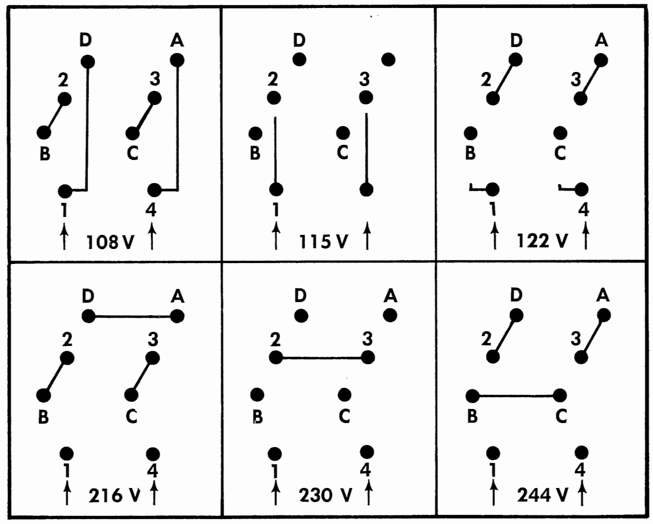


Fig. 2-1. Transformer connections for 108 to 244 volts, 50 to 60 cps and 400 cps operation (when used with mod 101M).

Always have the ground strap connected except when applying Z-axis modulation signals.

POWER CONNECTIONS

Unless otherwise indicated, the Type 545B is shipped with the power transformer and fan wired for 115-volt ac input. A connection diagram on the side of the transformer and Fig. 2-1 show alternative connections for other input voltages to the power transformer. When the transformer is changed from a 108-122 volts to a 216-244 volts connection, the fan wiring must be changed. Fig. 2-2 shows the fan connections for each voltage range.

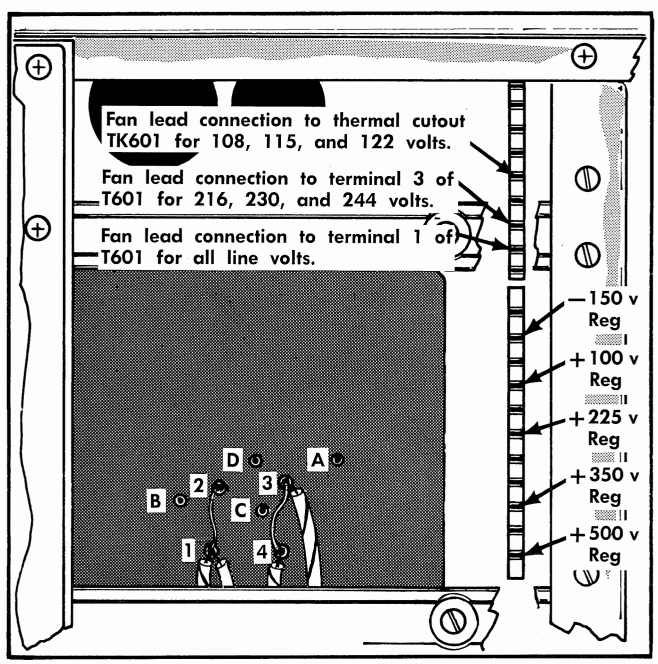


Fig. 2-2. Fan connection for 108 to 244 volts.

NORMAL (NON-DELAYED) SWEEP

The Type 545B Oscilloscope features two independent time-base circuits: Time Base A and Time Base B.

Sweep Triggering

Proper sweep triggering is essential for a stable presentation of an input signal. For a stable display, the sweep must be triggered at the same time relative to the displayed signal. Thus, the sweep must be triggered by the input signal or by some external signal that has a fixed time relationship with the displayed signal. The external trigger signal must be the same frequency or a sub-multiple of the input signal.

Selecting the Trigger Source

The TRIGGER SLOPE switch selects one of a variety of possible triggering signals. For most applications, the sweep can be triggered internally from the displayed signal. This occurs with the TRIGGER SLOPE switch set at either + or — INT.

The LINE positions of the TRIGGER SLOPE switch connect a line-frequency signal to the triggering input. Line triggering is useful whenever the input signal is frequency-related to the line signal.

To trigger the time base from an external signal, set the TRIGGER SLOPE switch to an EXT position and connect the trigger signal to the TRIGGER INPUT connector. External triggering is often used when signal tracing in amplifiers, phase-shift networks, and wave-shaping circuits. The signal from a single point in the circuit can be used as an external trigger signal. With this arrangement, it is possible to observe the polarity, shaping and/or ampification of a signal at various points through the circuit without resetting the triggering controls for each new display.

Selecting Triggering Mode

Four means of trigger coupling are available with the TRIGGERING MODE switch. The different coupling positions permit you to accept or reject certain frequency components of the triggering signal.

With the switch set at DC, the time base can be triggered with all frequency components of the triggering signal within the trigger amplifier bandpass, including dc levels.

With the switch set at AC LF REJ, dc and low-frequency signals (below about 17 kc) are rejected or attenuated. Thus, the trigger circuit will respond best to the higher-frequency components of the triggering signal.

With the switch set to AUTO, proper triggering automatically takes place providing that the signal waveform is comparatively simple and approximately symmetrical. With no trigger signal, or with a lower repetition rate, the trigger circuit free runs at approximately 40 cps and triggers the time base at this rate, providing a reference trace.

In general, use AC coupling. However, it will be necessary to use DC coupling for very low-frequency signals. When line-frequency hum is mixed with the triggering signal, it is best to use AC LF REJ coupling so that triggering takes place only on the signal of interest (if the signal of interest contains frequency components above about 17 kc).

The AC LF REJ position is also useful when triggering internally from multi-channel plug-in units operated in the alternate dual-trace mode. AC LF REJ coupling has a faster recovery time when subjected to the alternate dc levels from the multi-channel plug-in unit.

Selecting Trigger Slope

The TRIGGER SLOPE switch determines whether the triggering circuit responds on the rising (+ setting) or the falling (— setting) portion of the triggering signal. When several cycles of a signal appear in the display, the setting of the TRIGGER SLOPE switch will probably be unimportant. However, if you wish to look at only a certain portion of a cycle, the TRIGGER SLOPE switch will help start the display on the desired slope of the input signal. Fig. 2-3 illustrates the effect of both the TRIGGER SLOPE and TRIGGERING LEVEL controls.

Setting Stability Control

In nearly all triggering applications, satisfactory operation can be obtained with the STABILITY control in the PRESET (fully counterclockwise) position. The PRESET position has the advantage of requiring no further adjustment of the STABILITY control when switching from one triggering signal to another. However, if stable triggering becomes difficult with the STABILITY control at PRESET, it will be necessary to adjust the control for proper triggering. To adjust the STABILITY control, place the TRIGGERING LEVEL control in the fully counterclockwise position, then turn the STABILITY control slowly clockwise until a trace appears on the crt. The correct setting is obtained by turning the control counterclockwise three to five degrees from the point where the trace appears.

Setting Triggering Level

The TRIGGERING LEVEL control determines the amplitude point on the signal where triggering occurs.

The trigger circuit is most sensitive to ac triggering signals with the TRIGGERING LEVEL control set near zero. Moving the TRIGGERING LEVEL control in the + direction causes the trigger circuit to respond at some higher positive amplitude on the triggering signal. Moving the TRIGGERING LEVEL control in the — direction causes the trigger circuit to respond at some higher negative amplitude on the triggering signal.

Selecting Time/Cm (Sweep Rate)

The TIME/CM and 5× MAGNIFIER switches control sweep rate. The 5× MAGNIFIER switch expands both time bases.

The TIME/CM and 5× MAGNIFIER switches allows you to view an applied signal at a wide variety of calibrated sweep rates. When making time measurements from the crt, be sure the VARIABLE control is set to CALIBRATED (Time Base A).

When the 5× MAGNIFIER switch is set to OFF, the TIME/CM switch indicates the true sweep rate. However, with the 5× MAGNIFIER switch set to ON, the setting of the

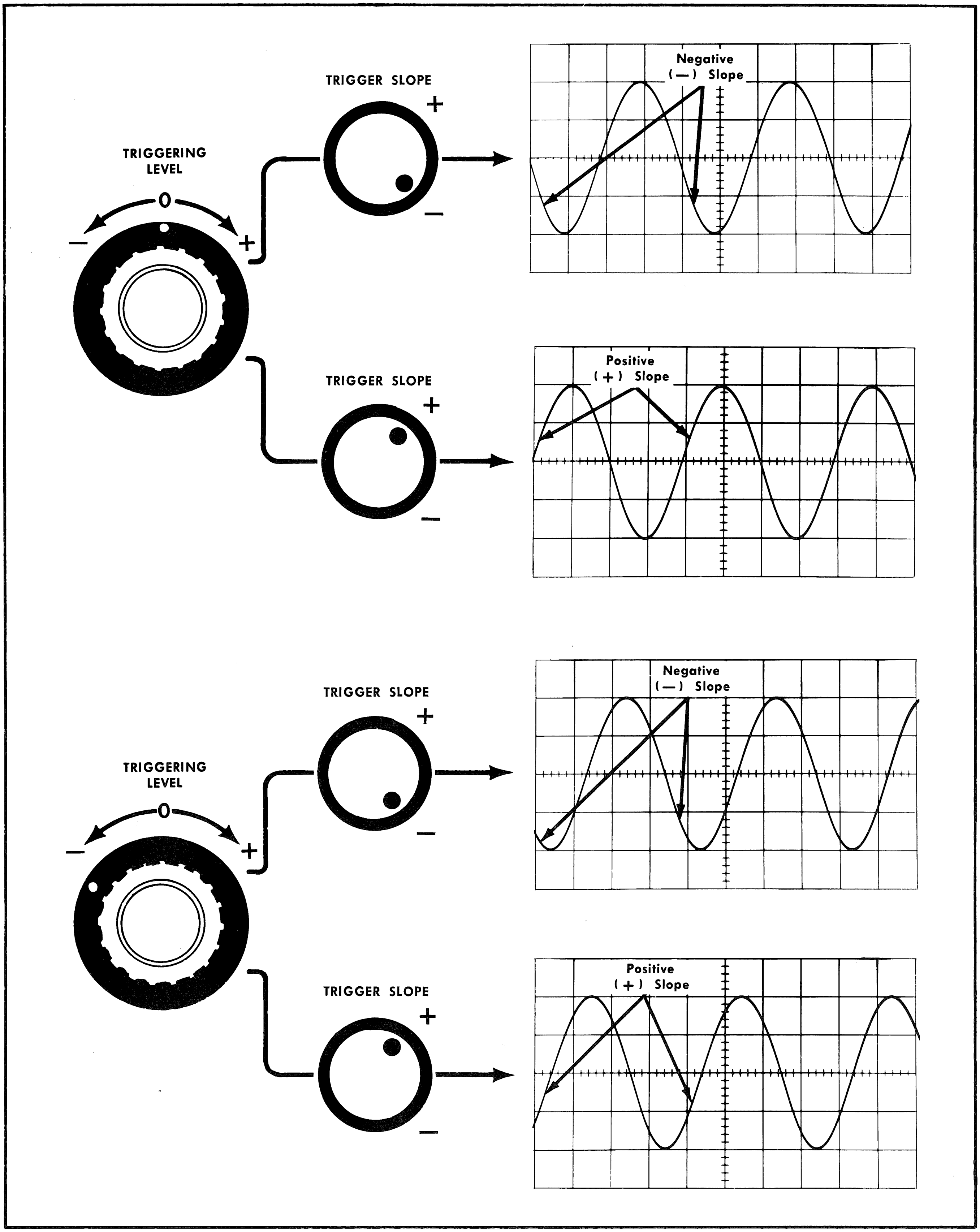
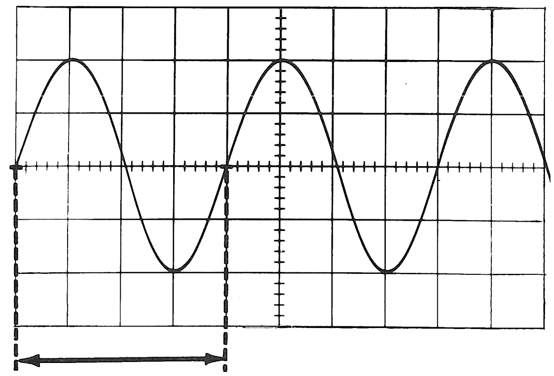


Fig. 2-3. Effects on the oscilloscope display produced by + and — settings of the TRIGGERING LEVEL control. When the TRIGGERING LEVEL control is set in the + region, the sweep is triggered on the upper portion of the input waveform; when it is set in the — region, the sweep is triggered on the lower 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.

TIME/CM switch must be divided by 5 to determine the true sweep rate. For example, assume that the TIME/CM switch is set at 1 mSEC and the 5× MAGNIFIER is set to ON. In this case, the true sweep rate would be 1 msec divided by 5 (5× MAGNIFIER setting); resulting in a displayed sweep rate of 0.2 msec/div. Fig. 2-4 illustrates how to make time measurements from the graticule.



$$\frac{\text{Number of Centimeters} \times \text{TIME/CM Switch Setting}}{\text{SWEEP MAGNIFIER Setting}} = \text{Time Duration}$$

Fig. 2-4. Time measurement from the graticule.

Single-Sweep Operation

In applications where the displayed signal is not repetitive or varies in amplitude, shape, or time, a photograph of a conventional repetitive display may produce a jumbled presentation. To avoid this, use the single-sweep feature of the Type 545B to photograph this type of display. To use single sweep, first make sure the trigger circuit will trigger on the event you wish to display. Do this in the conventional manner with the HORIZONTAL DISPLAY switch set to either time base. Then, after setting the HORIZONTAL DISPLAY switch to 'A' SINGLE SWEEP, press the RESET switch and release. When this is completed, the next trigger pulse will actuate the sweep and the Type 545B will display the event on a single trace. The READY lamp, near the HORIZONTAL DISPLAY switch, first lights when the sweep is ready to accept a trigger and then goes out after triggering has taken place. To ready the circuit for another single display, press the RESET switch and release. In single-sweep operation, make sure the TRIGGER MODE switch is not set to AUTO.

NON-TRIGGERED DELAYED SWEEP

The following procedures describe various measurements, the accuracy of those measurements, and other operations that can be performed using delayed sweep.

Insert a vertical plug-in unit and set the controls and switches on the instruments as listed in Table 2-1.

TABLE 2-1

B TRIGGERING MODE	AC
B TRIGGER SLOPE	+INT
B TRIGGERING LEVEL	0
B STABILITY	Fully clockwise
B TIME/CM OR DELAY TIME	1 mSEC
B LENGTH	Fully clockwise
A TRIGGERING MODE	AC
A TRIGGER SLOPE	+EXT
A TRIGGERING LEVEL	0
A STABILITY	Fully clockwise
A TIME/CM	.1 mSEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	'B' INTENSIFIED BY 'A'
SWEEP MAGNIFIER	OFF
DELAY-TIME MULTIPLIER	5.00
AMPLITUDE CALIBRATOR	10 Volts
HORIZONTAL POSITION	Centered
INTENSITY	So both intensity levels in the trace are easily seen.

Set the applicable controls and switches of the vertical plug-in unit as follows:

Volts/Div	5
Variable	Calibrated
Ac-Dc-Gnd	Dc
Position	Trace centered

Set the HORIZONTAL POSITION control so the trace begins precisely at the left-hand edge of the graticule. Notice the position of the intensified segment in the trace.

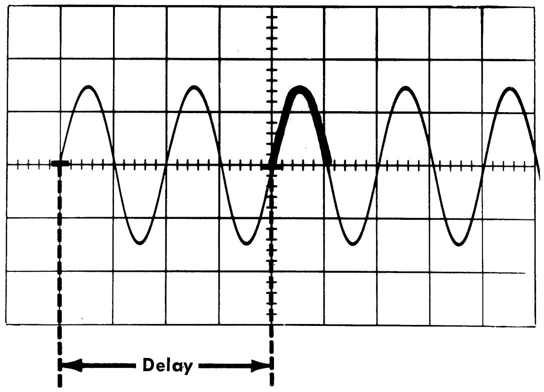
Now set the TIME/CM OR DELAY TIME switch to .2 SEC and A TIME/CM switch to 20 mSEC. The intensified segment should be at the same position as with the previous sweep rates.

Connect the SAWTOOTH A output to the vertical plug-in unit input. Notice that the A sweep sawtooth and the intensified segment in the trace start and end at the same time. This display shows that Time Base A produces one sweep during the intensified segment of each B sweep. The A TRIGGERING LEVEL control has no effect.

The B sweep rate is 0.2 sec/cm. The intensified segment begins 5 cm after the beginning of the trace. Hence, the A sweep starts 1 sec after the B sweep (0.2 sec/cm × 5 cm).

The number of centimeters between the beginning of the trace and the beginning of the intensified segment is established by the setting of the DELAY-TIME MULTIPLIER dial. Therefore, with any dial setting, the time difference between the beginning of the A and B sweeps is the product of the TIME/CM OR DELAY TIME switch and the DELAY-TIME MULTIPLIER dial setting (see Fig. 2-5).

The following procedures describe five common applications of the delayed-sweep feature. These applications are more accurate than time measurements taken directly from the crt display.



B TIME/CM or DELAY TIME Switch Setting X DELAY-TIME MULTIPLIER Dial Setting = Amount of delay between the start of the B (delaying) and the start of the A (delayed) sweep.

Fig. 2-5. Determining delay time.

Demonstration 1

This procedure describes how to measure pulse duration with the pulse triggering Time Base B.

Set the controls and switches as listed in Table 2-1 except at follows:

B TIME/CM OR DELAY TIME	.1 mSEC
A TIME/CM	1 μSEC

Apply the AMPLITUDE CALIBRATOR signal to the input of the vertical plug-in unit. Adjust the B triggering controls to obtain a stable display. The display should consist of nearly 1 cycle of the square-wave signal.

Turn down the intensity until the brightened portion of the trace is easily seen. Using the DELAY-TIME MULTIPLIER dial, position the brightened portion of the trace to the falling portion of the square wave. Record the setting of the DELAY-TIME MULTIPLIER dial. Now position the brightened portion to the adjacent rising portion of the square wave. Again record the setting of the DELAY-TIME MULTIPLIER dial.

Subtract the first DELAY-TIME MULTIPLIER dial setting from the second and multiply the result by the setting of the TIME/CM OR DELAY TIME switch. The figure obtained is the same as the interval measured.

Accuracy: Determined by the combination of all the following factors:

1. The basic accuracy of time measurements made by using the sweep delay is as stated in Section 1.
2. The Delay Pickoff and Time Base A generator circuits typically require a net total of about 75 to 100 nsec to respond to the signal event which triggers Delayed Sweep (A). This small inherent delay need not be considered unless it is a significant percentage of the measured time or when measuring time differences using the same sweep rate. When necessary, add the net circuit delay time to the measured time; that is, when measuring the time from the start of the B sweep.

Summary: The method described in Demonstration 1 provides a time measurement accuracy within 1% of reading, $\pm$2 minor divisions of the DELAY-TIME MULTIPLIER dial.

By comparing the delay reading to an accurate external timing standard (such as a Tektronix Type 180A Time-Mark Generator) and applying a correction factor, an accuracy of $\pm$ 2 minor divisions of the DELAY-TIME MULTIPLIER dial can be achieved.

Demonstration 2

This procedure describes how to measure time between two pulses, neither of which triggers Time Base A.

Set the controls and switches as listed in Table 2-1 except as follows:

B TIME/CM OR DELAY TIME	.2 mSEC
A TIME/CM	2 μSEC

Apply the AMPLITUDE CALIBRATOR signal to the vertical input. Adjust the B triggering controls to obtain a stable display. The display should consist of about 2 cycles of the square wave. Set the DELAY-TIME MULTIPLIER dial so the square-wave rise located near the center of the display is intensified.

Turn down the intensity until the brightened portion of the trace is easily seen. Using the DELAY-TIME MULTIPLIER dial, position the start of the brightened portion to the 50% point on the square-wave rise for the first positive half-cycle. Record the setting of the DELAY-TIME MULTIPLIER dial. Now position the start of the brightened portion of the trace to the 50% point of the fall time for the first half-cycle of the square wave. Again record the setting of the DELAY-TIME MULTIPLIER dial.

Subtract the first dial setting from the second setting. The product of the difference times the TIME/CM OR DELAY TIME switch setting equals the time duration of the square-wave positive-going half cycle (between the 50% amplitude points). This measurement should indicate a time of about 0.5 msec.

Accuracy: Determined by the combination of the following factors:

1. The basic accuracy of the sweep delay as described in Demonstration 1.
2. The error added by the sweep-delay system linearity is $\pm$ 2 minor dial divisions. Hence, percentage of measurement error decreases as the numerical dial difference increases.

NOTE

When the separation between dial settings is 100 minor dial divisions or less, the time measurement can often be made more accurate by direct reading from a magnified crt display. See Demonstration 3: Magnification.

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3. The accuracy of time measurements made in Demonstration 2 is independent of the inherent circuit delays, provided the B TRIGGERING LEVEL control setting is the same for each of the two dial readings.

Demonstration 3

Complex signals contain a number of individual events of different amplitudes. Since the trigger circuits of the Type 545B respond to signal amplitude, a stable display will normally be obtained only when the sweep is triggered by the event having the greatest amplitude. The A delayed by B mode permits the start of the A sweep to be delayed for a selected time after the signal event having the greatest amplitude. Any event within the series of events may then be displayed in magnified form as follows:

Set the controls and switches on the instrument as listed in Table 2-1. Apply the AMPLITUDE CALIBRATOR signal to the vertical input. If necessary, adjust the B triggering controls to obtain a stable display. The display should consist of several cycles of the square-wave signal. Set the DELAY-TIME MULTIPLIER dial to intensify one of the positive-going pulses.

Set the HORIZONTAL DISPLAY switch to 'A' DLY'D BY 'B'. The display should now include the same signal information as the intensified trace segment, but horizontally expanded (magnified) ten times.

Increase the A sweep rate to 1 μsec/div. The INTENSITY control may require readjustment. Set the DELAY-TIME MULTIPLIER dial to position a square-wave rise on the crt. The display now gives $\times$1000 magnification of the intensified segment.

Slowly turn the DELAY-TIME MULTIPLIER dial. Note that any portion of the square wave can be brought into view in magnified form.

The DELAY-TIME MULTIPLIER dial reading corresponds to the number of centimeters between the beginning of the Time Base B trace and the beginning of the Time Base A (intensified) trace (e.g. 7.00 = 7 major graticule divisions).

The A delayed display will probably exhibit some horizontal jitter. The time jitter contributed by the delay system is less than 5×10^{-4} times the TIME/CM OR DELAY TIME switch setting. Since the sweep rate of the delayed sweep is now 1 μsec/cm, the jitter due to the delay system is less than one-half centimeter.

Accuracy: Depends solely on the B sweep-rate accuracy as listed in Section 1.

Demonstration 4

Ordinarily, the displayed signal is also used to trigger the oscilloscope sweep. In some situations, it may be desirable to reverse this situation. The sweep-related output pulses, available from the front-panel of the Type 545B, can be used as a triggering signal for an external device. The output signal of the external device can then produce a stable display while the oscilloscope sweep free runs.

To demonstrate one method of performing this operation, proceed as follows:

Set the controls and switches as listed in Table 2-1 except as follows:

B TRIGGER SLOPE	+EXT
DELAY-TIME MULTIPLIER	1.00
B TIME/CM OR DELAY TIME	10 μSEC
A TIME/CM	1 μSEC

Connect a lead from the DLY'D TRIG connector to the vertical input. The display should consist of a positive-going spike.

The oscilloscope display is the pulse that is available at the DLY'D TRIG connector at the end of each delay period. In a practical application, the pulse would not be applied to the vertical input but instead to some external device to be tested. The pulse would then serve as the trigger pulse or input signal from the external device, and the output of the device would provide a stable display on the oscilloscope, as though the oscilloscope were triggererd in the normal manner.

Demonstration 5

The +GATE B connector output signal can be used as a variable repetition rate, variable duty-factor pulse generator. To use the Type 545B in this manner, proceed as follows:

Set the controls and switches as listed in Table 2-1 except as follows:

HORIZONTAL DISPLAY	B
B TRIGGERING MODE	AUTO

Monitor the signal available at the +GATE connector on another oscilloscope and establish the desired pulse repetition rate by setting the TIME/CM OR DELAY TIME switch. Establish the desired duty factor by setting the LENGTH control.

TRIGGERED DELAYED SWEEP

Complex signals contain a number of individual events at different amplitudes. Since the trigger circuits in the Type 545B respond to signal amplitude, a stable display will normally be obtained only when the sweep is triggered by the event having the greatest amplitude.

The following instructions demonstrate that Time Base A can be triggered by any event within a series of events, regardless of relative amplitude.

Set the controls and switches on the instrument as listed in Table 2-1.

Connect the AMPLITUDE CALIBRATOR signal to the vertical input. Using the B triggering controls, obtain a stable display.

Turn the DELAY-TIME MULTIPLIER dial about 2 turns in either direction. Notice that the brightened segment in the display moves smoothly across the crt.

Set the DELAY-TIME MULTIPLIER dial so the brightened segment begins about in the middle of a pulse top. Now turn the HORIZONTAL DISPLAY switch to A and the TRIG-

GER SLOPE switch to +INT. Using the A triggering controls, obtain a stable display. Return the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A'. Notice that the brightened segment in the display has shifted to the next pulse on the right. (If the brightened segment is not present, or is unstable, readjust the A triggering controls.) Turn the DELAY-TIME MULTIPLIER dial several full turns. The brightened segment in the display should jump from one pulse to the next. Set the HORIZONTAL DISPLAY switch to 'A' DLY'D BY 'B' and note that the display now begins on the rising portion of the pulse. With the present display, turning the DELAY-TIME MULTIPLIER dial should not change the display since all of the AMPLITUDE CALIBRATOR pulses are the same shape. However, if the input signal consisted of a repeating series of several dissimilar pulses, turning the dial would provide a triggered display of each pulse in the series provided the A triggering controls are set for triggering on the smallest pulse.

The display is produced in the following manner:

Time Base A produces one sweep during each B sweep. The Time Base A sweep will begin some time after the start of B sweep. This time is the total of the TIME/CM OR DELAY TIME switch setting multiplied by the DELAY-TIME MULTIPLIER dial setting, plus the time between the end of this delay interval and the next event in the signal which can trigger Time Base B.

With the A triggering control set for triggered operation, the Time Base A sweep will occur only if A is armed and triggered before the B sweep ends. If Time Base A is not triggered, the scope waits.

Light Filter

The light filter provided with the Type 545B minimizes undesirable reflections when viewing the display under high ambient light conditions. The filter may be left on when taking waveform photographs unless a high writing rate is required.

If the light filter is removed, the crt protector plate should be installed to prevent scratches to the crt face plate.

EXTERNAL HORIZONTAL DEFLECTION

For special applications, horizontal deflection can be produced with an externally derived signal. Thus, the oscilloscope system can be used to plot one function against another (e.g. Lissajous figures). However, the system is not intended for precise phase-angle measurements.

To use an external signal for horizontal deflection, connect the signal to the HORIZ INPUT connector. Set the HORIZONTAL DISPLAY switch to EXT ×10 or ×1. The signal is dc coupled to the deflection amplifier. The MAG switch is inoperative when the HORIZONTAL DISPLAY switch is set to either external horizontal position.

DUAL-TRACE CHOPPED BLANKING

A multi-channel plug-in unit provides two separate traces on the crt and thus permits two functions to be displayed simultaneously. Detailed instructions for operating the multi-channel plug-in unit in conjunction with the Type 545B Oscilloscope are contained in the plug-in unit instruction manual.

When the multi-channel plug-in unit is operated in the chopped mode to obtain a dual-trace presentation, switching transients will be displayed on the crt. These switching transients can be reduced by placing the CRT CATHODE SELECTOR switch at the rear of the instrument in the CHOPPED BLANKING position.

INTENSITY MODULATION

The Type 545B crt display can be intensity modulated by an external signal to display additional information. This is done by disconnecting the grounding bar from the EXTERNAL CRT CATHODE connector at the rear of the instrument and connecting the external signal to this terminal. The CRT CATHODE SELECTOR switch must be in the EXERNAL CRT CATHODE position.

Very accurate time measurements can be made by intensity modulating the beam with time markers and measuring directly from the time markers on the crt. A positive signal of approximatly 20 volts is required to cut off the beam from normal intensity. The low-frequency cutoff point for Z-axis modulation is 600 cps.

SECTION 3
CIRCUIT DESCRIPTION

Introduction

This section describes the operation of the various circuits in the Type 545B. A simplified block diagram description is given first to explain the general operation of each circuit, then the operation of each circuit is covered in detail.

BLOCK DIAGRAM DESCRIPTION

Low-Voltage Power Supply

The low-voltage power supply produces all operating voltages for the oscilloscope with the exception of parts of the crt circuit. The low-voltage supply provides regulated −150, +100, +225, +350, and +500 volts. It also provides heater voltages and an unregulated +325-volt output.

Vertical Plug-In Preamplifier

Any Tektronix letter- or 1-series vertical plug-in preamplifier can be used with the Type 545B. For a circuit description of the plug-in unit, refer to the plug-in unit instruction manual.

Vertical Input Amplifier

The vertical input amplifier is a balanced hybrid amplifier that amplifies the output of the plug-in vertical preamplifier and applies the amplified vertical signal to the trigger-pickoff circuit and the vertical output amplifier.

Delay Line

The push-pull output of the vertical input amplifier is applied through the balanced delay line to the vertical output amplifier. The delay line is a specially braided 186 Ω line which delays the application of the vertical signal to the vertical output amplifier for about 200 nsec. This provides time for unblanking the crt and starting the horizontal sweep before the vertical signal reaches the deflection plates. The delay allows the leading edge of a single fast rising pulse to be displayed. The delay line requires no adjustment because of the precision construction.

Vertical Output Amplifier

The vertical output amplifier is a push-pull cascode amplifier that takes the output of the delay line and amplifies it to a level sufficient to drive the vertical deflection plates of the crt.

Trigger-Pickoff Circuit

The trigger-pickoff circuit applies a sample of the input waveform to the trigger circuits of both time bases. The trigger is picked off at the output of the vertical input amplifier.

Time Base A Generator

The Time Base A generator provides accurate ramp voltages for the horizontal deflection system, unblanking for the crt, and a +gate to a front-panel connector. The Time Base A generator may be triggered by signals from either internal or external sources.

Time Base B Generator

The Time Base B generator closely resembles the Time Base A generator. Thus, the functions and the circuit description given for the Time Base A generator, in most instances, apply also to the Time Base B generator.

Delay-Pickoff Circuit

The delay-pickoff circuit compares the ramp-voltage output of the Time Base B generator with a variable reference voltage, and assuming identical characteristics in the two halves of the comparator, generates a trigger pulse when the two voltages are equal. The trigger output of the delay-pickoff circuit may be used to arm or trigger Time Base A, and is also available at a front-panel connector.

Horizontal Amplifier

The input to the horizontal amplifier is selected from the outputs of the Time Base B generator, Time Base A generator, or the external horizontal input amplifier. The selected input is split in phase and amplified to provide push-pull drive to the crt horizontal deflection plates.

External Horizontal Amplifier

The external horizontal amplifier provides the necessary gain to drive the horizontal amplifier from external signals. An input attenuator and a gain control provide horizontal deflection factors from about 0.2 to 15 volts/cm.

Crt Power Supply

The crt power supply provides the high voltages for operating the crt. The power supply is of the rf type, using a 50 kc Hartley oscillator. Secondary windings on the oscillator transformer supply voltages to the high-voltage rectifiers.

Cathode-Ray Tube (Crt)

The cathode-ray tube used in the Type 545B is a flat-faced, internal graticule, 5-inch tube with 6 cm of usable vertical scan area. The tube is designed for low-input capacitance to the vertical deflection plates and minimum x-axis center-to-edge defocusing.

Calibrator

The calibrator in the Type 545B is a multivibrator and cathode follower that provides a square-wave output with a maximum amplitude of 100 volts at a nominal 1 kc. A step attenuator permits switching the output amplitude from the front panel.

CIRCUIT DESCRIPTION

The following is a detailed discussion of the operation of each circuit in the Type 545B. While reading through the description of a particular circuit, refer to the proper schematic diagram in Section 6.

Low-Voltage Power Supply

The low-voltage power supply in the Type 545B (see Power Supply schematic diagram) actually consists of five interrelated supplies that operate together as a system. This system delivers filtered and regulated voltages of —150, +100, +225, +350, and +500 volts as well as an unregulated dc voltage of +325 volts. A common power transformer, T601, supplies the input power to each of the supplies, as well as heater power to thermal time-delay relay K600 and the tubes in the oscilloscope. Unless otherwise specified, the Type 545B is shipped with T601 wired for 115-volt ac input. A connection diagram on the side of the transformer shows alternative connections for other input voltages.

The 115-volt ac input power is applied to T601 through POWER ON switch SW601. Overload protection is provided by fuse F601. Thermal cutout TK601 in the primary circuit of T601 is a protective device that opens the transformer primary circuit if the temperature inside the oscilloscope rises above a safe level. TK601 resets automatically when temperature returns to normal; and to shorten the cooling time, the fan continues to run while TK601 is open (except when T601 is connected for 216-, 230- or 244-volt operation). Thermal time-delay relay K600 provides a filament warmup time of approximately 30 seconds before the dc power supplies are activated. The heater of K600 is rated at 6 volts and is connected to 6.3 volts on the T601 secondary winding. During heater warmup time, contacts 4 and 9 of K600 remain open. At the end of heater warmup time, contacts 4 and 9 close and apply power to magnetic relay K601. Contacts K601-1 of K601 remove the heater power from K600, but before K600 can open, contacts K601-1 lock the holding circuit to the coil of K601. K601 now remains energized until the power to the oscilloscope is switched off or otherwise interrupted. When K601 is energized, contacts K601-2, K601-3, and K601-4 are also closed and thus activate their respective dc supplies.

— 150-Volt Supply. The —150-volt supply in the Type 545B is the reference voltage source for the other supplies and must be very stable. The —150-volt supply includes a high-gain electronic voltage regulator designed to give good regulation under extreme operating conditions. This regulator circuit contains a series regulator, a glow-discharge tube reference source, an error detector, and an amplifier.

In operation, the input power to the —150-volt supply is supplied by one secondary winding (pins 6-11) of T601. The ac output of the secondary winding is rectified by silicon diode rectifier bridge D642 and filtered by C640. In series with the positive side of the supply and ground are series regulators V627, V637, and V647, paralleled by shunting resistor R647. The output of the —150-volt supply is taken from the negative side.

Error sensing in the voltage-regulator circuit is accomplished by comparator V624. Current through V624 is established by the setting of the tap on R616 in the voltage divider R615, R616, and R617. The voltage on the grid of V624A is held at approximately —85 volts by reference stage V609. Assuming that the output voltage of the —150-volt supply increases, (e.g. increased line voltage) the voltage increase appears on the cathodes of V624 and, through the tap on R616, on the grid of V624B. Due to the voltage divider, only a part of the voltage increase appears between the grid and cathode of V624B, but the full change appears on the grid and cathode of V624A. The increase is in the negative direction, therefore, V624A increases its conduction to maintain the proper bias between grid and cathode. Thus, both cathodes are held nearly fixed while the grid of V624B is pulled negative by the increasing negative voltage across the voltage divider. The increasing negative voltage on the grid of V624B causes a decrease in current; thus the plate voltage goes positive.

The positive change in plate voltage is amplified and inverted to a negative change by amplifier V634. The amplified error signal from V634 is applied to the grids of series regulators V627, V637, and V647. The negative-going error signal on the grids of V627, V637, and V647 decreases the current through the tubes, effectively increasing their resistance and the voltage drop across them. The voltage necessary to provide the increased drop across the series regulator tubes and shunt resistor can only be obtained by subtracting it from the negative side of the supply, so the undesired increase in negative voltage is absorbed in the series regulators and shunt resistor.

If the output of the —150-volt supply decreases instead of increases, then the error voltage applied to the grids of the series regulators would be positive-going. The positive-going error voltage on the grids of the series regulators would lower their resistance, and the voltage drop across them would decrease, leaving more voltage for the negative side of the supply. Since the output voltage of the —150-volt supply depends upon the relationship of the voltage on the tap of R616 and the reference voltage from V609, accurate adjustment of the output voltage is provided by making R616 variable.

Filter capacitor C640 does not remove all the ripple from the output of the bridge rectifier, and the series regulator circuit also reduces the output ripple voltage. Any ripple between the —150-volt output point and ground reaches the grid of V624B via C617. This input ripple voltage is amplified by V624 acting as a cathode-coupled amplifier. The ripple output voltage at the plate of V624 has the same polarity as the ripple voltage at the —150-volt output. C628 couples this ripple voltage to the grid of V634 where it is further amplified and applied to the grids of the series regulator tubes with a polarity that opposes the original ripple voltage. Ripple in the positive side of the —150-volt supply is coupled through R637 to a degenerative feedback loop and the screen of V634.

Some of the components in the —150-volt supply are not necessary in normal operation but are included to insure proper operation of the circuit under adverse conditions. R640 and R641 protect against large surge currents, while C649 suppresses sudden load changes that fall outside the bandwidth of the regulator circuit.

+100-Volt Supply. The input to the +100-volt supply is the output of the secondary winding (pins 8-15) of transformer T601 and silicon diode bridge D672. In addition to its other loads, the +100-volt supply is required to supply current to a series filament string at all times. When the Type 545B is first turned on, relay K601 contacts are open and all the regulated supplies are inoperative. During this time, the series filaments are supplied by the unregulated side of the +100-volt supply through relay contacts K601-3 and R675. By the time thermal relay K600 activates K601, the series filaments have reached operating temperature. When activated by K600, K601-3 switches the series filaments to the regulated output of the +100-volt supply.

The reference voltage source is the regulated output of the —150-volt supply. V664 is an error amplifier, and V677A is a series regulator tube. The error-feedback circuit, R650 and R651, is connected to the grid of V664. The top end of R650 is connected to the regulated +100-volt output and the lower end of R651 provides a reference voltage from the regulated —150-volt supply. With normal line voltages and loads, the bias voltage at the grid of V664 is about —1.7 volts.

If the load current, output voltage, or the input voltage changes (including changes due to ripple), the output of the regulated +100-volt supply starts to change also, but any change appears across R650 and R651 and is applied to the grid of V664 as a change in operating bias. Assuming that the output of the regulated +100-volt supply tries to decrease, the reduced voltage at the top of R650 permits the voltage at the junction of R650 and R651 to go more negative than the normal —1.7-volt level. The increase in negative bias on the grid of V664 reduces the plate current of V664. The voltage drop across plate-load resistor R663 decreases and the plate voltage of V664 and the grid bias of V677A go more positive. As the grid of V677A goes more positive, the resistance of V677A is decreased and the output voltage rises, compensating for the drop in output voltage. The regulator circuit can never completely compensate for a change in output voltage because there must be an error input for the circuit to operate. However, any error in output is reduced by a factor equal to the loop gain of the regulator circuit.

The screen grid of V664 is used as a signal grid for injecting a sample of any ripple or transient voltage present in the unregulated side of the +100-volt supply into the regulator circuit. The regulator circuit thereby becomes a dynamic filter for ripple reduction. The ripple signal applied to the screen of V664 is amplified, inverted, and applied to the grid of V677A. The amplified and inverted ripple at the grid of V677A is of proper amplitude and phase to cancel out the ripple appearing at the plate of V677A.

Unregulated +325-volt Supply. The voltage source for the unregulated +325-volt supply differs somewhat from the voltage sources for the —150- and +100-volt supplies. The secondary of T601 (pins 5, 7, 10, and 14) and D702 and D732 form a center-tapped bridge rectifier circuit. The negative side of the bridge rectifier is connected back to ground through the rectifier circuit of the +100-volt supply; thus elevating this point and the output of the bridge rectifier circuit by the unregulated output voltage of the +100-volt rectifier circuit. The unregulated output of the +100-volt rectifier circuit is approximately +180 volts.

The unregulated output of the center-tapped bridge rectifier circuit is about +290 volts. Since the output of this circuit is elevated by the unregulated output of the +180-volt supply, the total output of this circuit is +470 volts. (This total output is the unregulated source for the regulated +350-volt supply.) However, the unregulated +325-volt output, obtained from the center tap of the bridge rectifier (+145 volts), elevated by the unregulated output of the +100-volt supply, provides a total unregulated output of +325 volts.

+225-Volt Supply. The voltage source for the regulated +225-volt supply is the unregulated +325-volt supply described in the preceding paragraphs. The regulator circuit is similar to the regulator circuit in the —150-volt supply; the main difference being that instead of using a glow discharge tube as a reference voltage source, the reference voltage is from the —150-volt supply. The error signal is picked off the junction of precision resistors R680 and R681. The upper end of R680 is connected to the +225-volt output, and the lower end of R681 is connected to the regulated —150-volt supply. The voltage at the junction between R680 and R681 is approximately —0.1 volt which is applied through R682 and R683 to the grid of V684B. The cathodes of V684 are long-tailed to the —150-volt supply through R685. The grid of V684A is grounded. The error signal is fed from the grid of V684B through the common-cathode circuit to the A side of the tube. Notice that this comparator is somewhat different from the comparator used in the —150-volt supply; the output is taken from the A side. The error signal is amplified by V684 and fed, unchanged and in phase, to the voltage divider in the grid of V694. V694 also amplifies and inverts the error signal and applies it out of phase with any change in the +225-volt output, to the grids of series regulators V677B and V737B.

Here again, the screen of the error amplifier is acting as an injection grid for ripple reduction. A sample of the unregulated supply ripple is applied to the screen of V694. V694 amplifies the ripple, inverts it, and applies it to the grids of series regulators V677B and V737B. The result is that the same ripple appears simultaneously on the grids and plates of V677B and V737B, but 180° out of phase; thus the ripple cancels out.

+350-Volt Supply. The input to the +350-volt supply is the full voltage output of the center-tapped bridge (see description of unregulated +325-volt supply) added to the unregulated side of the +100-volt supply. The operation of the regulator circuit is very similar to the operation of the +100-volt regulator except for different component values.

+500-Volt Supply Rectified voltage from terminals 20 and 21 of T601 via D762 is added to the regulated voltage of the +350-volt supply to provide the necessary voltage for the +500-volt supply. The operation of the regulator circuit is similar to that of the +100-volt regulator except for different component values.

Crt Circuit

The crt circuit (see Crt schematic diagram) includes the crt, the high-voltage power supply, and the controls necessary to focus and orient the display. The crt (Tektronix Type T5470-31-2) is an aluminized, 5-inch, flat-faced, glass crt with a helical post-accelerator and electrostatic focus and deflection. The crt circuit provides connections for externally modulating the crt cathode. The high-voltage power supply is composed of a dc-to-50-kc power converter, a voltage regulator circuit, and three high-voltage outputs. Front-panel controls in the crt circuit adjust the trace rotation (screwdriver adjustment), intensity, focus, and astigmatism. Internal controls adjust the geometry and high-voltage output level.

High-Voltage Power Supply. The high-voltage power supply is an oscillator operating at approximately 50 kc with the transformer providing three high-voltage outputs. A modified Hartley oscillator converts dc from the +325-volt unregulated supply to the 50-kc input required by high-voltage transformer T801. C808 and the primary of T801 form the oscillator resonant tank circuit. No provisions are made for precise tuning of the oscillator tank since the exact frequency of oscillation is not important.

Voltage Regulation. Voltage regulation of the high-voltage outputs is accomplished by regulating the amplitude of oscillations in the Hartley oscillator. The —1700-volt output is referenced to the +350-volt regulated supply through a voltage divider composed of R841, R842, R843, R845, R847, R853, and variable resistors R840 and R846. Through a tap on the voltage divider, the regulator circuit samples the —1700-volt output of the supply, amplifies any errors and uses the amplified error voltage to adjust the screen voltage of Hartley oscillator V800. If the —1700-volt output changes, the change is detected at the grid of V814B. The detected error is amplified by V814B and V814A. The error signal at the plate of V814A is direct coupled to the screen of V800 by making the plate-load resistor of V814A serve as the screen-dropping resistor for V800. Any change in the —1700-volt output thus changes the screen voltage of V800 and the amplitude of the 50-kc oscillations. R840 provides a means of controlling the high-voltage output through controlling oscillation amplitude.

Crt Grid Supply. The approximate 1700-volt output of the high-voltage power supply is the rectified output of one of the two high-voltage secondaries on T801. To provide dc-coupled unblanking signals to the crt grid, the crt grid supply is floating (the dc voltage on the components shift in accordance with the unblanking signals). The positive side of the crt grid supply is returned to the —150-volt supply through the unblanking cathode-follower load resistor of the selected sweep generator. The negative side of the crt grid supply is applied through the INTENSITY control to the crt grid.

At the fastest sweep rates, the stray capacitance of the floating crt grid circuit makes it difficult for the crt grid to rise fast enough to unblank the crt in the required time. An isolation network consisting of R827, C829, and C830 isolates the capacitive loading. By this arrangement the fast leading edge of the unblanking pulse is coupled through C830 and C829 to the grid of the crt. For short-duration unblanking pulses such as those that occur at the fastest sweep rates, the dc levels on the rectifier and secondary winding are not appreciably affected. Longer unblanking pulses such as those that occur at the slower sweep rates, charge the stray capacitance in the 1700-volt output through R827. This pulls up the floating crt grid circuit and holds the crt grid at the unblanked potential for the duration of the unblanking pulse.

+8300- and —1700-volt Outputs. Both the +8300- and the —1700-volt outputs are derived from the same secondary winding on T801. The full secondary voltage of approximately 2900 volts is applied to a voltage tripler consisting of rectifiers V832, V842, and V852 and associated capacitors. A tap on the secondary provides the input for half-wave rectifier V862 in the —1700-volt output. The 1700-volt supply is referenced to the regulated +350-volt supply through a voltage divider network. The +8300-volt output is connected to the crt post-deflection-accelerator anode and the —1700-volt output is connected to the crt cathode via R857 to provide a total accelerating voltage of 10,000 volts.

Crt Circuit Controls and Connectors. Optimum size and shape of the fluorescent spot on the crt is obtained by adjusting the front-panel FOCUS and ASTIGMATISM controls. FOCUS control R846 provides the correct voltage for the second anode (focus ring) in the crt. Proper voltage for the third anode is obtained by adjusting ASTIGMATISM control R864. To obtain optimum spot size and shape, both the FOCUS and ASTIGMATISM controls are adjusted to provide the proper electronic lens configuration in the region of the second and third anodes of the crt. Spot intensity is adjusted by means of front-panel INTENSITY control R826. Varying the INTENSITY control changes the voltage on the crt grid, which in turn varies the beam current. Internal GEOMETRY control R861 adjusts the isolation shield voltage in the crt, and is adjusted to minimize "bowing" or "tilting" of the display. Front-panel TRACE ROTATION control R778 permits minor adjustments in trace orientation. By adjusting the TRACE ROTATION control, the trace can be made parallel with the horizontal lines on the graticule.

An input binding post on the rear panel of the Type 545B provides an input for externally modulating the crt cathode. The input binding post is normally grounded by a link. If it is desired to intensity modulate the display from an external source, the link is opened, and the modulating signal is coupled to the crt cathode through C858.

When the Type 545B is used with a multi-channel vertical plug-in preamplifier that provides dual-trace chopped blanking pulses, the blanking pulses are applied to rear-panel CRT CATHODE SELECTOR switch SW858. With the vertical plug-in preamplifier operating in the chopped mode and SW858 set to the CHOPPED BLANKING position, a positive pulse of approximately 20-volts amplitude is applied through C858 to the cathode of the crt. At normal intensity levels, this pulse is sufficient to cut off the crt during the time the amplifier channels in the vertical plug-in preamplifiers are being switched.

Vertical Amplifier System

The vertical amplifier system in the Type 545B consists of an appropriate vertical plug-in preamplifier, a push-pull cathode-follower input stage, a push-pull hybrid delay-line driver, a 186 Ω delay line, and a push-pull hybrid output amplifier. In addition, the trigger-pickoff circuit functions as a part of the vertical amplifier by providing reverse termination for the delay line.

Vertical Input Amplifier. The push-pull output of the vertical plug-in preamplifier, with a fixed dc level of approximately +67.5 volts, is applied to the input of the vertical amplifier through terminals 1 and 3 of the plug-in connector.

R491 and R498, in series with the grids of the push-pull cathode-follower stage, as well as T500 are parasitic suppressors. The cathodes of cathode followers V494A and V494B are returned to ground through vertical DC BAL control R495, which is adjusted to equalize the dc voltage (about +68.5 volts) on the bases of delay-line driver transistors Q514 and Q524. The DC SHIFT control R502 varies operating voltage and compensates for errors of thermal balance in Q514 and Q524 as well as Q584 and Q594.

The balanced delay-line driver stage is a push-pull cascode amplifier with an adjustable vertical gain control (R520) connected in the emitter circuit of the two transistors. Gain is adjusted by controlling the amount of degeneration in the emitter circuit of the transistors. R532 and R533 set the operation points of Q513 and Q523 which provide the reverse termination for the delay line.

The RC networks in the collectors of Q514, Q524, Q584, and Q594 set the individual transistor operating points for thermal balance.

Vertical Output Amplifier. The vertical output amplifier must properly terminate the 186 Ω delay line and provide broadband amplification of the vertical signals. The delay line is properly terminated by adjusting C568, L554, and L560.

The output amplifier is a wideband amplifier stage consisting of Q584, Q594, V584 and V594 and associated elements. High-frequency compensation in this stage is provided by peaking coils L588, L589, L598, and L599 in the plate circuits of V584 and V594. The high-frequency response is varied by adjusting C581 and R580, which provide variable high-frequency degeneration in the emitter circuit of Q584 and Q594.

The output stage of the vertical amplifier is a hybrid push-pull cascode amplifier. This circuit configuration is used to match the low impedance of the transistorized vertical-amplifier system to the higher impedance required at the crt vertical deflection plates.

Trigger-Pickoff Circuit. The trigger-pickoff transistor amplifier Q543 provides trigger signals to the two time bases, and also supplies the VERT SIG OUT connector with a vertical signal.

Beam-Position Indicators. The beam-position indicators B538 and B539 driven by Q534 (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 is insufficient to light either neon. The current through Q534, and thus the voltage across the neons, will change as the beam is positioned up or down on the crt. The voltage across one neon will increase, causing it to light, and the voltage across the other neon will decrease, causing it to remain extinguished. The neon that lights will indicate the direction in which the beam has been moved.

Time Base A

The Time Base A consists of the A sweep trigger and the A sweep generator circuits. The A sweep trigger circuit includes controls for selecting the type, source, and level of the trigger to be used, and circuit elements for regenerating the selected trigger into a pulse suitable for triggering the A sweep generator. The A sweep generator is basically a Miller-runup circuit. The A sweep generator provides ramp voltages for the horizontal deflection system and the SAWTOOTH A connector, unblanking pulses, and +gate pulses.

Trigger Generator. The input to the A sweep trigger circuit is selected by TRIGGER SLOPE switch SW10A from the trigger-pickoff circuit in the vertical amplifier, the power transformer for line triggering, or from the front-panel TRIGGER INPUT connector. TRIGGERING MODE switch SW10B permits further selection of the type of triggering signal; either automatic, ac low-frequency reject, ac or dc. Once the type and source of triggering signal has been selected, the slope on which triggering is desired is selected by TRIGGER SLOPE switch SW10A. The level of the triggering signal required by the A sweep trigger circuit is selected by adjusting TRIGGERING LEVEL control R17. After this triggering signal has been selected by the preceding control and switches, it is applied to trigger input amplifier V24.

The trigger-input amplifier provides a source of positive-going signal to drive the following stage and, by means of the TRIGGERING LEVEL control, enables the operator to select the point on the signal at which triggered operation will occur.

To trigger from a positive-going signal, the grid of the V24A section is connected to the input signal source. The grid of the V24B section is connected to a dc bias source, which is adjustable with the TRIGGERING LEVEL control. This bias voltage establishes the voltage present at the plate under no-signal conditions.

The voltage at the grid of V24A and the voltage at the plate of V24B are in phase; that is, they both go through ac zero in the same direction at the same time. Thus, the V24A section acts as a cathode-follower, and the signal voltage developed across the cathode resistors becomes the input signal to the V24B section.

To trigger from a negative-going signal, the grid of the V24A section is connected to the TRIGGERING LEVEL control, and the grid of V24B is connected to the input signal. With this configuration, the voltage at the plate of the V24B section will be 180 degrees out of phase with the input-signal voltage.

In each of the cases outlined above, a positive-going signal is produced at the plate of the V24B section of the Trigger-Input Amplifier irrespective of input signal polarity.

D29 and D30 are limiters and allow the trigger circuit to count down to provide triggers at a slow enough rate for the sweep gating multivibrator to react. The quiescent voltage level on the base of Q35 is set by the collector of Q34 whose base voltage is set by R39 (TRIG LEVEL CENTERING).

The amplitude of the triggering signal necessary to cause operation of the trigger multivibrator is determined by the setting of the TRIGGERING LEVEL control.

Trigger amplifier Q34 provides additional amplification to the trigger signal before applying the signal to the base of Q35. The additional stage of amplification requires that the input triggering signal be applied to the opposite section of the trigger-input amplifier than is done in the B trigger generator.

In the quiescent state, ready to receive a signal, Q35 of the trigger multivibrator is conducting and the collector voltage is down. Since the collector is dc coupled to the base of Q45, that base is held below cutoff. With Q45 cut off its collector voltage is up and no output is developed.

The negative-going portion of the signal from the trigger amplifier is required to drive the base of Q35 down. As the Q35 base is driven negative, the current flow through the transistor is restricted and the voltage at the collector starts to rise.

The rise in voltage at the collector of Q35 carries the base of Q45 in the positive direction.

The emitters of both transistors are coupled together, and follow the action of the bases. With the Q45 base going in a positive direction, and the emitter in a negative direction, Q45 starts to conduct. As Q45 starts to conduct, the emitters of both transistors follow the action of the Q45 base, hence the emitter voltage starts to rise.

As the base goes down and the emitter goes up, Q35 stops conducting. As Q45 conducts, its voltage drops, creating a negative step at the output. This transition occurs rapidly, regardless of how slowly the base falls.

When the signal applied to the base of Q35 goes in a positive direction, the action described in the previous paragraphs reverses itself. That is, Q35 will start to conduct once more, while Q45 will be cut off.

In the AUTO position of the TRIGGERING MODE switch the trigger multivibrator is converted from a bistable to a recurrent configuration. This is accomplished by disconnecting +100 volts from the junction of D49 and R38, thereby allowing C49 to charge and discharge.

In this mode of operation, the trigger multivibrator will run in the absence of a triggering signal. For example, assume that the base of Q35 is just being driven into cutoff. The voltage at the collector of Q35 will rise, carrying with it the base of Q45. As the voltage at the base of Q45 starts to rise, Q45 starts to conduct. The falling voltage at the collector of Q45 is coupled to the base of Q34.

Since the voltage at the base of Q34 is falling, the collector voltage is rising. This rising collector voltage of Q34 is then coupled to the base of Q35. The base of Q34 is prevented from falling immediately by the action of C49, which must discharge sufficiently to lower the voltage at the base of Q34 into cutoff.

As the collector voltage of Q34 raises the base of Q35 sufficiently to bring Q35 out of cutoff, its collector voltage will in turn lower. The lowering collector voltage of Q35 is coupled through D43 to the base of Q45, thus causing Q45 to cut off. When Q45 reaches cutoff, the circuit has completed one cycle of an approximately 40-cycle repetition rate.

During calibration, the repetition rate for the AUTO mode is adjusted by R47 (TRIG SENS).

Sweep Generator. The time-base generator consists of three main circuits: the sweep gating multivibrator, the Miller-runup circuit, and the holdoff circuit.

The time-base trigger circuit furnishes the waveform which initiates a cycle of action in the time-base generator. Square waves from the output of the trigger multivibrator are fed to the time-base generator where they are differentiated and used as trigger pulses. To explain the action of the time-base generator assume it is in the quiescent state, just before the arrival of a suitable trigger pulse, with V135A conducting.

Square waves, generated by the time-base trigger circuitry, are differentiated by the C131-R131 network.

If STABILITY control R110 is advanced, the grid of V135A will become more negative. As the grid of V135A becomes more negative, a point is reached at which a negative-going triggering pulse from the C131-R131 network will drive V135A into cutoff.

As V135A is driven to cutoff, the plate voltage rises, carrying with it the grid of cathode-follower V135B. V135B, used as a cathode follower between the two halves of the multivibrator isolates the positive-going plate of V135A from the capacitance of the loads requiring a positive-going pulse. This results in a faster rise of the positive-going pulse at the plate of V135A.

The cathode of V135B is long-tailed through R141 and R143, and closely follows the action of the grid. Since the grid of V145 has a certain shunt capacitance to ground, C141 is connected in parallel with R141 to compensate for this capacitance.

The voltage rise at the cathode of V135B drives the grid of V145 above cutoff. As V145 begins to conduct, its plate voltage drops rapidly. Any spiking which may occur is attenuated by the C150-R150 network.

When V145 is conducting at the maximum determined by circuit parameters, the sweep gating multivibrator has reached its other stable state and the action of the Miller runup circuit has been initiated.

The Miller runup circuit is essentially a Class A amplifier employing negative feedback. The positive-going voltage at the plate of the Miller tube is fed back to the grid through runup cathode follower V173 and opposes the attempt of the grid to go negative. Because the gain of the Miller tube is high, (approximately 200) it is possible to maintain an essentially linear rate of charge on the timing capacitor.

In the quiescent state of the time-base generator, the voltage at the plate of the Miller tube is determined by the voltage drop across the dc network formed by neon lamp B167, the runup cathode follower, and the disconnect diodes. The purpose of this dc network is to establish a voltage at the plate of the Miller tube of such value that the tube will operate above the knee, and hence over the linear region of its characteristic curve.

The grid of Miller tube V161 is returned to the —150-volt supply through timing resistor R160. In the quiescent state of the time-base generator, the grid of the Miller tube is held slightly negative but well above cutoff by the flow of the current through the A section of the disconnect diode. When the disconnect diodes stop conducting, the grid of the Miller tube tends to become more negative.

As the grid of the Miller tube starts negative, the plate becomes more positive. This positive-going excursion of the plate carries the grids of runup cathode follower V173 with it. The voltage at the grids of V173 is maintained at a constant difference with respect to the Miller-tube plate voltage by the voltage drop across neon bulb B167. C167 and R168 form a network connected around B167 to improve the risetime.

Bootstrap capacitor C165 is connected between a tap on the Miller-tube plate load and the cathode of V173. This bootstrap capacitor increases the charging rate of the stray capacitances in the Miller-tube plate circuit. Its action is most important in the generation of fast sweep rates.

The cathode of V173 follows the action of the grids closely. This results in a linear rise in the voltage at the upper end of timing capacitor C160. Since the charge on the capacitor cannot change instantaneously, this voltage is coupled to the grid of the Miller tube in a direction to correct for the attempt of the Miller-tube grid to go negative.

Current to charge timing capacitor is supplied through timing resistor R160. Since the voltage across the timing resistor is virtually constant, a constant current source is thus provided for charging the timing capacitor.

The linear voltage rise at the cathode of V173 is used as the time-base sawtooth. This voltage rise continues until a positive step from the sweep gating multivibrator raises the plate voltage on the disconnect diodes to the point where they begin to conduct.

The positive-going voltage at the cathode of V173 is coupled back to the input of the sweep gating multivibrator and causes that circuit to revert to its other state. It is kept from acting on further trigger pulses by the action of the holdoff circuit.

The waveform coupled to the time-base generator from the time-base trigger circuit contains both positive- and negative-going pulses. To prevent a negative-going pulse from triggering the sweep gating multivibrator before the action of the time-base generator is completed, the grid of V135A must be held above cutoff.

The holdoff circuit keeps the grid of V135A above cutoff until the capacitances in the time-base generator have had time to reach their quiescent state. The point at which the holdoff circuit will allow the sweep-gating multivibrator to return to its quiescent state is determined by the adjustment of R176 (SWEEP LENGTH).

The sawtooth present at the cathode of the runup cathode follower is coupled to the grid of V183A through R176. During calibration, R176 is adjusted so that the time base terminates after it has passed the right-hand limit of the graticule. R176 adjusts the voltage at the grid of V183A and consequently at the cathode of V183A and also on capacitor C180, thus determining when the sweep ends.

The positive-going pulse from the cathode of V183A is coupled to the grid of V133B. The action of capacitor C180 retards the voltage at the grid of V133B. The value of C180 is chosen so that its capacitance will prevent the voltage at the grid of V133B from falling until all capacitance in the time-base generator have returned to their quiescent level.

Unblanking Circuit. In the quiescent state of the time-base generator, the crt beam is cut off. To allow the crt beam to be seen, the potential at the control grid of the crt must be raised. The voltage rise appearing at the cathode of V135A in the time-base generator is used to drive cathode follower V183B. The signal on the cathode of V183B unblanks the beam during the time a sawtooth is generated, permitting the left-to-right motion on the beam to be seen.

The end of the unblanking pulse coincides with the end of the time base, and the crt is blanked during the retrace portion of the sweep and during quiescent periods of the time-base generator.

Output Waveforms. The time-base sawtooth from the cathode of V173 is fed through cathode-follower V193B and is available at the SAWTOOTH A front-panel connector.

The same pulse that is fed to the grid of V183B for unblanking purposes is also fed to cathode-follower V193A which makes the pulse available at the +GATE A front-panel connector.

Single Sweep Circuit. When the HORIZONTAL DISPLAY switch is in the A SINGLE SWEEP position, plate voltage is applied to V133A and this tube operates in conjunction with V125 as a bistable multivibrator.

In the first stable state that exists after the completion of a sweep, V125 is cut off and V133A is conducting. In this state, the divider between the plate of V125 and the grid of V133A sets the cathode voltage of the lockout multivibrator and consequently the grid voltage of V135A. LOCKOUT LEVEL ADJ R125 is adjusted to set the grid of V135A high enough so that the sweep-gating multivibrator cannot be triggered; this locks out the sweep.

Depressing the RESET switch grounds C102 and R102. The resulting positive pulse at the grid of V114 forces the lockout multivibrator into its other stable state with V125 conducting and V133A cut off. With V133A cut off, its plate voltage rises and lights the READY lamp. With V125 conducting, the STABILITY control regains control over the grid level of V135A.

Depending on the adjustment of the STABILITY control, a sweep can now be produced in one of two ways. If the STABILITY control is turned fully clockwise, the grid of V135A will be pulled down and cause the sweep gating multivibrator to switch to its other state and initiate a sweep. Or, if the STABILITY control is adjusted for triggered operation, the sweep will be initiated by the first negative trigger pulse to arrive at the grid of V135A.

As the sweep begins, the rising sawtooth voltage pulls up the cathode of V133B by the holdoff action previously described. As the cathode of the lockout multivibrator follows the cathode of V133B up, V125 cuts off and V133A conducts. As the cathodes continue to rise (following the rise in the sawtooth sweep voltage) V133A cuts off again.

Both tubes are then held cut off for the remainder of the sweep and the READY lamp stays on. When the grid of V135A rises to the point at which the sweep gating multivibrator reverts, the sweep is terminated.

As hold-off capacitor C180 discharges, the cathodes of the lockout multivibrator starts to fall. The grid level of V133A is such that this tube comes out of cutoff first, thus V133A conducts and V125 remains in cutoff. As V133A conducts, its plate drops and extinguishes the READY lamp. A new sweep cannot be initiated until the RESET switch is pressed again.

Dual-Trace Sync Pulse and Chopped Blanking Circuitry. Synchronizing pulses for dual-trace plug-in preamplifiers are supplied by V154A. When multivibrator V145 cuts off, a sharply differentiated positive pulse is developed at its screen. This pulse, coupled to the grid of V154A, produces a negative trigger at the plate of V154A. This trigger then switches the multivibrator in the dual-trace unit employed for alternate sweeps.

When the dual-trace multivibrator is connected for free-running operation to produce chopped sweeps, a negative pulse is coupled from the multivibrator to the grid of V154B. The resultant positive pulse at the plate of V154B is coupled to the cathode of the crt to blank out the beam during switching. Refer to the dual-trace plug-in unit instruction manual for a detailed description of the switching operation.

Time Base B

Time Base B is very similar to Time Base A. The major difference is the lack of the bootstrap capacitor in Time Base B and no sawtooth-output cathode follower or output connector on the front panel.

Trigger Generator. The input to the B sweep trigger circuit is selected by TRIGGER SLOPE switch SW60A either from the trigger-pickoff circuit in the vertical amplifier, the power transformer for line triggering, or from the front-panel TRIGGER INPUT connector. TRIGGERING MODE switch SW60B permits further selection of the type of triggering signal; either automatic, ac or dc. Once the type and source of triggering signal has been selected, the slope on which triggering is desired is selected by TRIGGER SLOPE switch SW60A. The level of the triggering signal required by the B sweep trigger circuit is selected by adjusting TRIGGERING LEVEL control R67. After the triggering signal has been selected by the preceding controls and switches, it is applied to trigger-input amplifier V74.

The trigger-input amplifier is a polarity-inverting cathode-coupled amplifier which serves two basic functions. First, it provides a source of negative-going signal to drive the following stage. Secondly, it enables the operator to select the point on the signal at which triggered operation will occur with the TRIGGERING LEVEL control.

To trigger from a negative-going signal, the grid of the V74A section is connected to the input-signal source. The grid of the V74B section is connected to a dc-bias source, which is adjustable with the TRIGGERING LEVEL control. This bias voltage establishes the voltage present at the plate under no-signal conditions.

The voltage at the grid of V74A and the voltage at the plate of V74B are in phase with each other; that is, they both go through ac zero in the same direction at the same time. Thus, the V74A section acts as a cathode follower, and the signal voltage developed across the cathode resistors becomes the input signal to the V74B section.

To trigger from a positive-going signal, the grid of the V74A section is connected to the TRIGGERING LEVEL control, and the grid of V74B is connected to the input signal. With this configuration, the voltage at the plate of the V74B section will be 180 degrees out of phase with the input-signal voltage.

In each of the cases described previously, a negative-going signal is produced at the plate of the V74B section of the Trigger-Input Amplifier regardless of the polarity of the input signal.

D81 and D82 are limiters and allow the trigger circuit to count down to provide triggers at a slow enough rate for the sweep gating multivibrator to react. The quiescent voltage level on the base of Q85 is set by TRIG LEVEL CENTERING R82. The amplitude of the triggering signal necessary to cause operation of the trigger multivibrator is determined by the setting of the TRIGGERING LEVEL control.

In the quiescent state, ready to receive a signal, Q85 of the trigger multivibrator is conducting and the collector voltage is down. The Q85 collector is dc coupled to the base of Q95, thus Q95 is held below cutoff. With Q95 cut off, its collector voltage is up and no output is developed. The negative-going portion of the signal from the trigger-input amplifier is required to drive the base of Q85 down. As the Q85 base is driven negative, the current flow through the transistor is restricted and the voltage at the collector starts to rise. The rise in voltage at the collector of Q85 carries the base of Q95 in the positive direction. The emitters of both transistors are coupled together and follow the action of the bases. With the Q95 base going in a positive direction, and the emitter in a negative direction, Q95 starts to conduct. As Q95 starts to conduct, the emitters of both transistors follow the action of the Q95 base; hence the emitter voltage starts to rise. As Q85 stops conducting the base goes down and the emitter goes up. As Q95 conducts, its voltage drops, creating a negative step at the output. This transition occurs rapidly, regardless of how slowly the base falls. When the signal applied to the base of Q85 goes in a positive direction, the action described in the previous paragraphs reverses itself. That is, Q85 will start to conduct while Q95 will be cut off.

In the AUTO position of the TRIGGERING MODE switch, the trigger multivibrator is converted from a bistable to a recurrent configuration. This is accomplished by ac coupling the +100 volts to the collector of Q95. In this mode of operation the trigger multivibrator will run in the absence of a triggering signal. For example, assume that the base of Q95 is just being driven into cutoff. The collector of Q95 starts to rise causing C90 and C95 to start charging. The charging of C90 and C95 prevents the base of Q95, which is connected back to its collector, from rising immediately. The emitter of Q95 which follows the base is going negative as Q95 cuts off. The negative-going emitter of Q95 is directly coupled to the emitter of Q85, thus pulling it negative and turning on Q85. When the capacitors have charged sufficiently to allow the base of Q95 to rise and turn on Q95, one cycle of an approximately 40-cycle repetition rate will have been completed.

Delay-Pickoff Circuit. Delayed triggers can be applied to sweep generator A in the 'B' INTENSIFIED BY 'A' and 'A' DLY'D BY 'B' positions of the HORIZONTAL DISPLAY switch. The trigger pulses are applied to the sweep generator from delayed trigger amplifier V114 through V133A which acts as a coupling cathode follower to apply delayed triggers to the sweep gating multivibrator. Delayed trigger pulses are applied to the grid of V114 from the cathode of V428B.

These pulses are shaped and amplified in the delay pick-off circuit composed of V414, V424, V445, and V428. V414 and V424 are combined to form a difference amplifier which picks off a sample of the sawtooth output from sweep generator A or B and converts it into a positive step pulse. Before the pickoff time, V414 is cut off and V424 is conducting. Since the cathodes of V414 and V424 are tied together, V424 determines the common-cathode voltage.

The common-cathode voltage is adjustable by means of DELAY-TIME MAGNIFIER 1-10 R433, a 10-turn helical resistor. V428A is a constant-current triode supplying cathode current to the difference amplifiers from the —150-volt supply. This arrangement permits the cathode of V424 to follow its grid over a wide range with very little variation in cathode current.

Plate current through R424 and L424 remains very nearly constant while V424 is conducting, regardless of the grid voltage set by DELAY-TIME MULTIPLIER R433. This is important since the plate voltage of V424 holds the grid voltage of shaper stage V445A near the triggering points.

The positive-going delayed sweep sawtooth raises the grid of V414 toward its cathode voltage. When the grid rises past the cathode voltage set by the DELAY-TIME MULTIPLIER control, R414 conducts and V424 cuts off. When V424 cuts off, its plate rises, carrying the grid of trigger shaper V445A positive past its transition point. The trigger-shaper stage is regenerative to produce a fast transition. The regulating positive step at the plate of V445B is differentiated through C454 and used to arm or to trigger the Time Base A sweep circuits. The sharp differentiated pulse is transmitted to the succeeding circuits through cathode follower V428B.

The DELAY START and DELAY STOP controls (located on the swingout gate of the oscilloscope) precisely adjust the upper and lower grid voltage limits of V424 as set by the DELAY-TIME MULTIPLIER so that delay can be read accurately from the DELAY-TIME MULTIPLIER dial.

Horizontal Amplifier

The Horizontal Amplifier converts the single-ended sawtooth output of the time-base generator into a push-pull signal suitable for driving the horizontal plates of the crt.

The gain of the amplifier may be varied by a factor of five with the 5× MAGNIFIER switch. Controls are also provided for horizontal positioning and adjustment of the horizontal linearity.

The sawtooth waveform from the time-base generator is coupled to the input cathode follower through the R330, C330, network. This network attenuates the input signal and provides a means of compensating the input circuitry for optimum frequency response.

The HORIZONTAL POSITION and VERNIER controls adjust the dc level at the grid of V343A. 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.

Coupling between the input cathode follower and the driver cathode follower is made by the 5× MAGNIFIER switch. When the 5× MAGNIFIER switch is in the OFF position, the signal from the input cathode follower must pass through the network formed by C348 in parallel with the series combination of R348 and R349. Variable resistor R348 adjusts the length of the time base by varying the attenuation applied to the signal. Variable capacitor C348 is adjusted to provide optimum linearity on the time base. The R348, R349, C348 network attenuates the signal by a factor of five. To provide magnification of the sweep, the network is removed when the 5× MAGNIFIER switch is turned to the ON position.

The gain of the horizontal amplifier is controlled by a negative-feedback circuit. The signal appearing at the left-hand deflection plate is fed back to the input of driver cathode follower V343B. NORM/MAG REGIS R358 varies the dc voltage applied to the feedback loop.

By changing the dc voltage at this point, the position of the unmagnified sweep can be adjusted so that it will correspond with the position of the magnified sweep in the center of the graticule.

The output waveform from the horizontal amplifier is taken from V364A and V384A. The cathodes of these tubes are connected through a network which includes the MAG GAIN control. The MAG GAIN control adjusts the gain of the horizontal amplifier when the 5× MAGNIFIER switch is in the ON position. C375, in parallel with the MAG GAIN control, effects the linearity at the beginning of the sweep for high sweep rates.

Part of the signal appearing at the plates of the output amplifiers is used to drive the output cathode followers. Note that the cathode of V364B is connected to the plate of V398. The function of the output cathode followers is to drive the capacitance of the horizontal deflection plates and the associated wiring. To assure a sufficient flow of current at fast sweep rates, V398 is used to supply current to the output cathode follower which drives the negative-going, or left-hand deflection plate. The pulse to drive the grid of V398 is derived from the waveform at the right-hand deflection plate. This waveform is differentiated by the C390, R390 network before being applied to the grid. Thus, its amplitude is proportional to the sweep rate.

Bootstrap capacitors C364 and C384 are used to help supply the necessary charging current for fast sweep rates.

Beam-Position Indicators. The beam-position indicators B397 and B398 located on the front panel above the crt indicate the relative horizontal position of the spot or center of the trace with respect to the center of the graticule. When the spot or trace is centered horizontally, the potential across either neon is insufficient to light it. As the beam is positioned left or right on the crt, the voltage across the neons will change. The voltage across one neon will increase, causing it to light, and the voltage across the other neon will decrease, causing it to remain extinguished. The neon that lights will indicate the direction in which the spot or trace has been moved.

CRT Protection Circuit (SN 8590-up). A CRT protection circuit at the input of the Horizontal Amplifier keeps the CRT beam deflected off-screen during the initial application of power supply voltages. This will prevent possible CRT phosphor burns due to an initially high intensity beam on the face of the CRT.

When the time thermal relay cuts out, K601 energizes and the +225 volts is applied to the circuit, a positive voltage jump across R306 biases Q307 into saturation causing the collector of Q307 to instantaneously decrease to approximately +0.3 volts, allowing it to conduct and clamping the grid of V343A at approximately +0.3 volts. This keeps the CRT beam deflected off-screen and prevents the sweep sawtooth from deflecting the beam across the CRT.

As the charge on C307 increases, Q307 becomes biased to cut-off allowing the collector to go towards +225 volts, back-biasing D307 so that the grid of V343A is no longer clamped to +0.3 volts. After this initial action occurs, D307 will remain back-biased, permitting the voltage at the grid of V343A to function normally.

External Horizontal Amplifier. When HORIZONTAL DISPLAY switch SW301 is in either the EXT ×1 or ×10 position, an external signal can be fed through the HORIZ INPUT connector to an auxiliary amplifier whose output is then fed to the horizontal amplifier.

External signals are either applied to the grid of V314A directly or through a ×10 attenuator. The signal applied to the grid of V314A is then cathode coupled to V314B. The amplifier gain can be adjusted by varying VARIABLE 10-1 R314 which determines the amount of cathode coupling. The two cathodes must be at the same dc voltage, or varying R314 will change the dc level. EXT HORIZ DC BAL R317 can be adjusted so that the cathodes of V314A and V314B are at the same voltage.

Plate output from V314B is connected to input cathode follower V343A in the horizontal amplifier when the HORIZONTAL DISPLAY switch is in either of the EXT positions.

Amplitude Calibrator

The amplitude calibrator is a square-wave generator with approximately a 1-kc output available at the front-panel CAL OUT connector. The amplitude calibrator consists of multivibrator V875 and V885A connected to switch cathode follower V885B between two operating states: cutoff and conduction.

During the negative portion of the multivibrator waveform, the grid of V885B is driven well below cutoff and its cathode rests at ground potential. During the positive portion of the waveform, V875 is cut off and its plate rests slightly below +100 volts. The cutoff voltage at the plate of V875 is determined by the setting of CAL ADJ CONTROL R879 (part of the divider connected between +100 volts and ground).

Cathode follower V885B has a precision tapped divider for its cathode resistor. When the CAL ADJ control is properly adjusted, the cathode of V885B is at +100 volts when V875 is cut off. 18 output voltages from 0.2 mvolts to 100 volts are available through tapped divider, R885, R893, and 1000/1 divider R896-R897. C885, connected beween the cathode of V885B and ground, corrects the output waveform for overshoot.

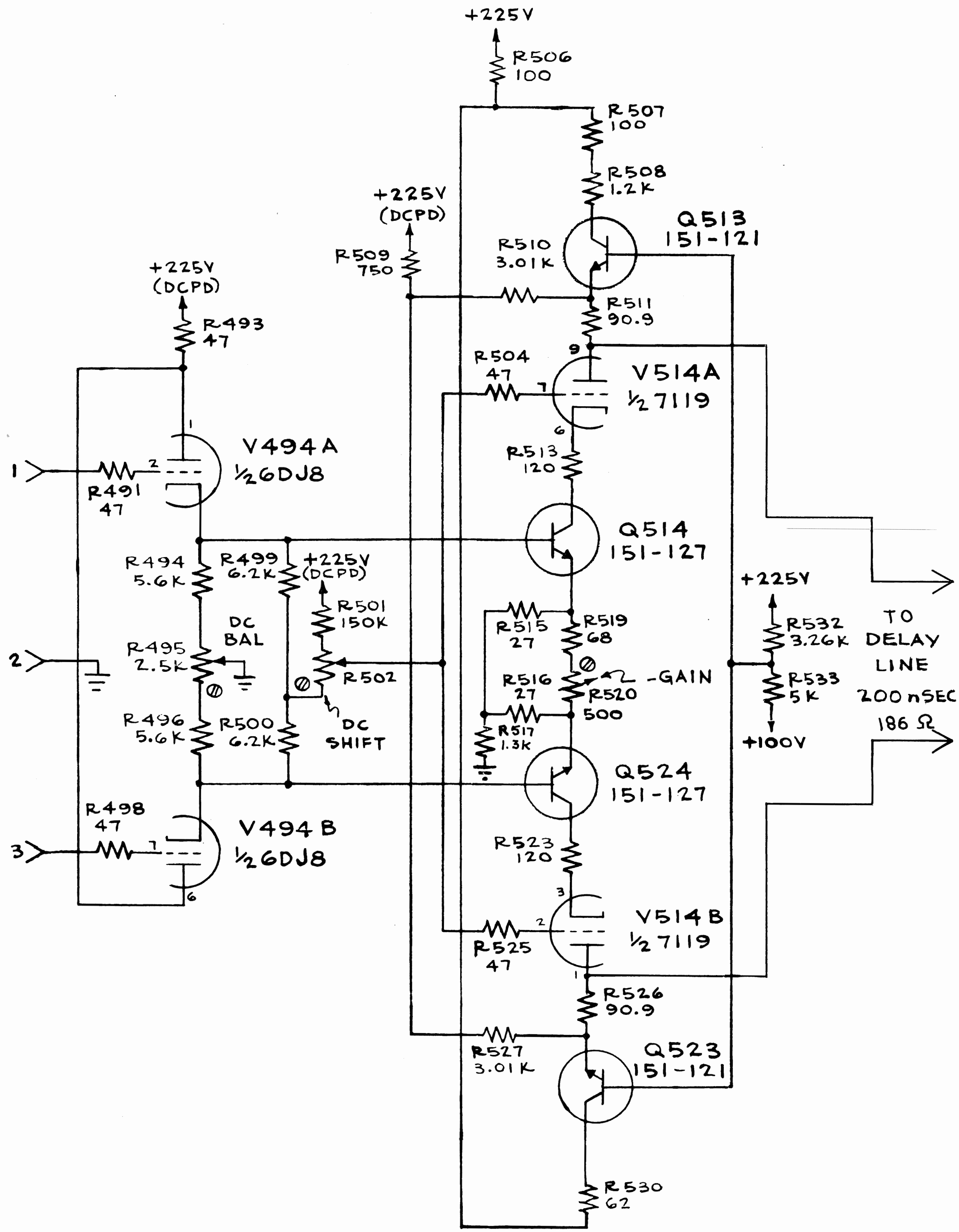
The amplitude calibrator provides a 0.1-volt output when the AMPLITUDE CALIBRATOR switch is set to 0.5 volt and a 50 Ω load is connected to the CAL OUT connector.

CIRCUIT DESCRIPTION - 545B and 543B

The following circuits are discussed in detail in this section:

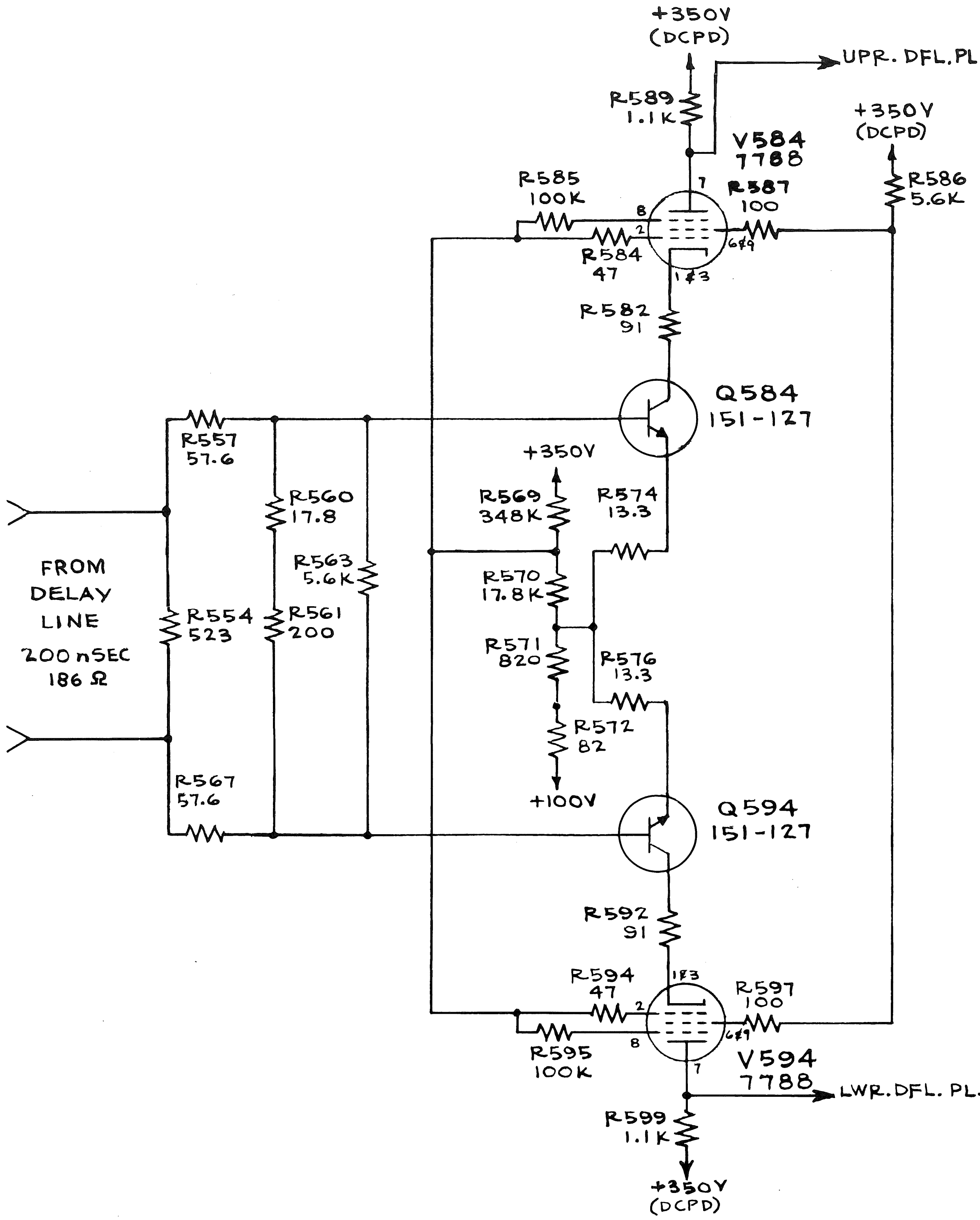
1. Vertical Amplifier
2. A Sweep Trigger
3. B Sweep Trigger

Following these discussions, a section (Section 4) is devoted to other circuits of the oscilloscope. These other circuits all are taken from previous design, and the discussion is limited to the identification of the circuit and significant changes that have been made. Block operation of the circuits is the same as in the 543A and 545A. The change from A to B is that of modifying blocks to improve performance.



1st Cascode LF Model

Figure 1-1



2nd Cascode LF Model

Figure 1-2

1. Vertical Amplifier

1. 3 stages, taking output from plug-in and feeding it to CRT plates. Figure 1-1 and 1-2 are a low frequency version of the circuit to simplify study.
   a. Input sensitivity is 100 mv/cm, elevated 67.5 volts, by the plug-in.
   b. Output is 7.2 volts/cm elevated 300 volts.
   c. Controls on main amplifier are:
      (1) DC BAL: Provides DC balance of amplifier.
      (2) DC SHIFT: Sets operation point of circuit transistors for balanced dissipation over operating range. Note that dissipation curve is bell shaped; control cancels effects of errors in thermal balance of both cascode amplifier stages. This prevents thermal drift.
      (3) GAIN: Sets gain of amplifier to give 100 mv/cm input sensitivity over range of CRT sensitivity and other tolerances.
      (4) DAMPING: Allows critical coupling between output stage emitters without circuit ringing.
   d. Design is around two cascode push-pull amplifiers:
      (1) Input cascode amplifier is driven by cathode followers, which have low output impedance.
      (2) Both cascode amplifiers look like ordinary emitter-coupled and collector-loaded push-pull amplifiers, driving grounded grid tube amplifiers.
      (3) This configuration allows a stable high current gain, with high output impedance. The tubes allow for a large DC shift between stages.
   e. Delay line is between the two cascode amplifiers:

(1) This allows a 93 ohm per side line to be used, since the second cascode can raise the impedance before driving the CRT.

(2) Delay line can be terminated at both ends in this design. Double termination allows attenuation of reflections at both ends. In the 545A design, the delay line had no protection against reflections bouncing back and forth, since it was terminated only at the input end.

(3) The signal delay is now 200 nsec, rather than the older design's 250. Reworking the trigger circuits to make them faster makes it possible to reduce delay. Shortening the delay is desirable because (A) cable costs money, (B) losses (such as dribble up from skin effect rise substantially as delay is increased.

(4) The delay line is now a cable, instead of lumped type. Improvements in dielectrics and cable winding techniques since the original 1953 design make the building of a fixed delay line reasonable now, where it was not so then.

2. Input Stage (V494A and B)

a. These are cathode followers, coupling the signal in to the first cascode amplifier.

(1) Input impedance is very high (tens of megohms), and input voltage DC level is not critical, making the input compatible with all letter-series plug-ins. With design plug-in output DC level of 67.5 volts/10 ma flow through each tube.

(2) Output impedance is low (about 100 ohms), providing drive for Q514 and Q524 bases.

(3) DC balance of the whole amplifier is set by R495. The control is set to place a no signal trace at electrical center of the CRT. This control allows the plug-in to have 0 output (differential voltage

between terminals 1 and 3 of the connector) at centered trace, preventing signal compression in the plug-in which would result from bottoming out of an amplifier.

(4) Voltage divider R501, R502, R499, and R500 sets the voltage on the grids of V514A and B. With the DC SHIFT adjustment of R502, the voltage at the grids of V514A and B is 7 to 11 volts higher than the output voltage of the plug-in. Note that the voltage sent to the grids of the tubes will nearly follow the voltage on the cathodes of V494A and B, allowing the adjustment to be correct when different plug-ins of different output DC levels are used. The DC SHIFT adjustments sets the DC collector level on Q514 and Q524.

3. First Cascode Amplifier (Q514, Q524, V514A and B, Q513, Q523).

a. Cascode amplifier is used to give constant gain over frequency range, and impedance matching into the delay line.

b. Q514 and Q524 are the input stage, and are like an ordinary collector loaded amplifier with controlled coupling between the emitters. Total emitter current through R517, R515, and R516 is 5.2 ma, with 67.5 VDC at the emitters. R515 and R516 provide 54 ohms between emitters, which is decreased by R519, R520 and (as frequency rises) C520.

c. C520 must be readjusted, using either a TU-7 or a TU-5 with a known plug-in, each time GAIN (R520) is readjusted. This is a nuisance, but it seems that there is no simple, inexpensive way to avoid needing a peaking capacitor between these emitters. However, gain stability is much higher than in 545A.

d. Collector load is the cathode impedance of V514A and B, and R513, R526.

(1) Collector voltage is set by the adjustment of R502, and is adjustable between 7 and 11 volts (with 67 volts at the emitters of Q514 and Q524, collector voltage is

adjustable between 74 and 78 volts above ground). The adjustment is provided to set the operating point of transistors for best square wave flat top. The response, over a time constant of about 1 msec, is affected by transistor collector voltage. The adjustment must be made before the C520 and other high frequency adjustments.

(2) The output load each transistor sees, in addition to the 120 ohm resistor, is the dynamic impedance of the tube cathode (V514), computed by $\frac{R_p}{mu} + R_L$ which comes out around 100 ohms. The output load on V514A and B is not greatly reflected back to the transistor. The transistor can amplify, without its output being modified by the characteristic of the load. This is true as long as the tube is operated in the linear region of its plate curve. The output of the transistor is a high impedance, and the plate circuit of the tube has to look back into not only R_p but $(mu + 1)\ R_c$ added to it, where R_c is 120 ohms plus transistor collector impedance which means that the current drawn by the output circuit is controlled by the forward bias current of the transistor alone.

e. Q513 and Q523 supply current to the plate circuit of V514A and B.

(1) The emitters are held at a constant voltage by the fixed base voltage, with current fed from the collector circuits. Voltage at the plates of V514A and B is 170 volts.

(2) Dynamic impedance, looking back into the transistor emitter circuit, is about 3 ohms. This includes the shunting effect of R510 and R527, which carry some of the plate current for V514A and B. Added to R511 and R526, this impedance terminates the input to the delay

line, which has an impedance of 186 ohms across the line, or 93 ohms per side. Since the dynamic impedance of the plate circuit of V514A and B is very high, the terminating impedance is not effected by operation of the cascode amplifier. Q513 and Q523 are part of the termination, and allow takeoff for trigger and other signals.

f. The collector circuits of Q513 and Q523 drive, respectively, the beam position indicators and the trigger takeoff circuit.

(1) These circuits are not symmetrical. However, operation of the cascode amplifier is not affected, because the collector circuit characteristics are not reflected into the emitters of Q513 and Q523. The circuits are thermally balanced to prevent leakage current from imbalancing the output.

(2) R507 is a current sampling resistor in the collector circuit of Q513. This controls the current through Q534, which in turn raises or lowers the voltage across B538 and B539. These neons are on the front panel as position indicators.

(3) LR528, R529, L529, and R530 are collector loading for Q523. The voltage developed across this network is a function of current through Q523, and increases as frequency rises, because of the reactance of LR528 and L529. The signal at the collector of Q523 is fed to the base of emitter follower Q543. Signal taken from the emitter is then fed to the internal trigger source on the trigger selector switch(es). The signal is also fed through blocking capacitor C546 to J549, as Vertical Signal Out. Measured output was 1.43 v/cm at the jack. We measured (with internal trigger) stable sine wave triggering with 6mm of display at the measured 3db down point of 32 mc; and with 4 cm of display at 50 mc. Output at front panel connector (Vert Sig Out) was down 20db at 32 mc.

g. R530 is a current-sampling resistor that responds to changes in common mode (as well as signal) voltages. The connection through R541 to the base of Q534 is a common-mode balancing circuit that prevents the DC levels operating the beam position indicators from changing substantially because of common mode changes introduced in preceding stages.

4. Second Cascode Amplifier (Q584, Q594, V584, V594)
   a. Input to this amplifier is 93 ohms impedance per side, serving as termination for the delay line. Output is to the CRT plates.
   b. Q584 and Q594 look like emitter coupled collector loaded amplifiers, driving grounded grid amplifiers V584 and V594. For operation of the cascode amplifier, see discussion of operation of first cascode amplifier.
   c. DC termination for the delay line (see Figure 1-1 and 1-2 for DC equivalent of the vertical amplifier) is through three parallel resistive paths, paralleled by the transistor base circuits.
   d. T555 is a phase balancing transformer which attenuates high frequency common mode signals.
      (1) A similar circuit is used in 580 series and in second generation sampling bridges.
      (2) Push-pull signals have a magnetic flux cancellation. Common mode signals drive the transformer core, coupling equal and opposite signals to opposite windings.
   e. At higher frequencies, more signal is coupled across R557 and R567, to make up for losses from skin effect (dribble-up) in the delay line cable.
      (1) R556-C556, and C557, on one side; C567, C568, and R566-C566, on the other, increase signal coupling at higher frequencies. C568 controls the amount of coupling available.

(2) Because this coupling across R557 and R567 tends to lower the input impedance to the transistors, seen by the delay line, L560, L561, and L554 raise the shunt impedance, maintaining the 93 ohms per side, environment.

(3) R563 provides the third shunt path for maintaining impedance match.

(4) L554 and L560 are adjustable, to control the impedance correction vs. frequency.

f. DC level at the delay line, and at the bases of Q584 and Q594 is 175 volts. The DC level is set by the plate voltage of V514A and B.

(1) If you will look back at the first cascode amplifier, you will see that this plate voltage is set by the current through Q514 and Q524. This in turn is set by the voltage across R515, R516, and R517, which is set by the input voltage from the plug-in to cathode followers V494A and B.

g. Voltage gain between the input (100 mv/cm) and the bases of Q584 and Q594 is 0.93.

(1) The gain at this point appears actually as a loss. The impedance here is 93 ohms per side, while in most letter series plug-ins, the output impedance is near 100 ohms. The preceding circuitry has elevated the signal DC level from 67 to 175 volts, and has driven the delay line and terminated it, with characteristic impedance at both ends. The signal is now at a standardized AC and DC level, and the second cascode stage provides the voltage gain of about 77.

h. The emitter current supply is from R569, R570, R571, and R572, then through emitter degeneration resistors R574 and R576.

(1) Common mode signals reaching this stage cause a voltage to be devleoped (component corresponds to common mode change) across R569 and R571, primarily. R570 provides a DC offset of about 5 volts that is used to set the grid voltage on V584 and V594. Because these tubes

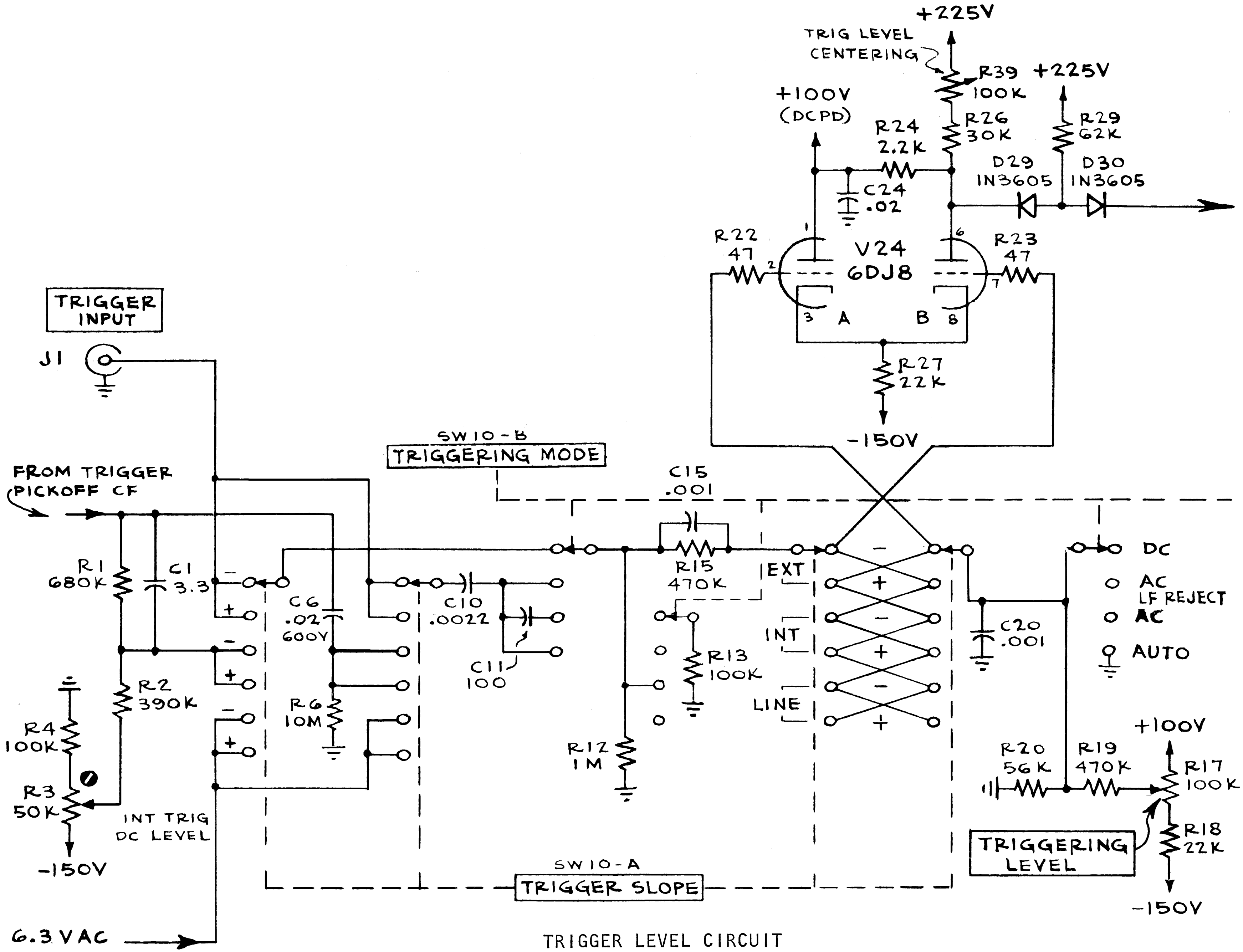
operate as grounded grid amplifiers, there is no signal to couple in at this point. Controlling grid voltage at this point holds the tube cathodes 8 volts above the transistor emitters (allowing for bias considerations between these points).

j. High frequency boosting is provided at several points in the circuit. This boosting compensates for frequency rolloff seen in the amplifiers and dribble up caused by the delay line.

   (1) C574, C579-R579, C578-R578, C580-C581-R580 are all connected between the emitters of Q584 and Q594. The reactance of these networks is connected across the degeneration of R574 and R576 to increase gain as frequency rises.

   (2) R582 and R592, in series with the cathodes of V584 and V594, add 92 ohms resistance per side to the 100 ohms approximate that the tubes present as dynamic cathode impedance. As frequency goes up, C582 and C592 shunt these resistors, increasing signal transfer.

   (3) L589 and L599 are tee coils that isolate the CRT plate capacity from the output amplifier. These coils look like short lumped-section delay lines, using CRT plate capacity as the lumped delay line capacitance. L588 and L598 are input terminations (reverse terminations), similar to the technique used in the 545A, which prevent reflections from returning to the CRT. These four coils are adjusted to match the particular CRT used.



TRIGGER LEVEL CIRCUIT
Figure 2-1

2. TRIGGER CIRCUIT (A trigger in 545B)

1. The trigger circuit (A trigger only in 545B) has three sections. First is the familiar level amplifier, V24. This circuit is similar to that of the 545A. Second is a shaper-amplifier (Q34). Third is a transistorized Schmitt trigger (Q35, Q45). The Schmitt regenerator counts down at some point between 4 and 11 mc, depending on input signals.

2. The AUTO circuit is a feedback loop which causes the Schmitt regenerator to free run. However, the circuit is a different one from those used previously. The time constant is in the collector circuit of the output transistor, and feeds back to the base of the shaping amplifier that preceeds the Schmitt trigger. When AUTO is not selected, the time constant is shorted out by an alternate collector current supply for the Schmitt output transistor.

3. Level Amplifier (V24): (Figure 2-1)
   a. Signal and polarity to which the circuit is sensitive is selected from one of three sources, by SW10A, the TRIGGER SLOPE.
      (1) Internal trigger is selected from internal trigger pickoff in vertical amplifier. The DC level of the signal is set by divider network R3, R4, R2, and R1. C1 provides AC bypass for signals. (DC coupling position only.)
      (2) External is taken from front panel connector; signal is fed directly to level amplifier which has approximately a ten volt range of selection, either + or -, in either polarity.
      (3) Line signal is taken from 6.3AC bus from power transformer, and is useful when display ripple, servo-motor signals, etc. related to the line frequency.
   b. V24 is a cathode coupled amplifier. One side is fed the trigger signal, the other side is fed a signal from the

TRIGGERING LEVEL control and network.

The TRIGGER SLOPE switch, SW10A, determines which side is fed the trigger signal, and which side the level. The trigger regenerator operates to trigger the sweep generator when the plate of V24B is moving in a positive direction.

(1) The Schmitt circuit resets when the plate of V24B returns in a negative direction.

(2) In negative positions of the TRIGGER SLOPE switch, the trigger signal is fed to the grid of V24B. The DC level voltage is fed to the grid of V24A.

(3) In positive positions of the TRIGGER SLOPE switch, connections are reversed, and the signal is fed to the grid of V24A.

c. V24A and B share the current through R27. Since the tubes operate near ground potential, this current (total) is about 6.8 ma.

(1) The side of the tube with the higher voltage on the grid carries more of the current. V24B plate must have 100 volts on it when the LEVEL control is centered (zero volts on the grids). The TRIG LEVEL CENTERING control must be set to give 100 volts at the plate of V24B, with currents balanced between the tubes. The balanced current point, 3.4 ma per side, is the only point where the POLARITY switch can be moved from - to - without changing the currents through the tube sides. R39 is adjusted to set the plate voltage of V24B at 100 volts at the equal current point. 100 volts is an important level because only when the voltage travels through +100 volts is a signal provided to the base of Q34.

d. D29, R29, and D30 are a coupling circuit that couples the plate voltage from V24B to the base of Q34. This circuit does not couple directly, but provides a current change to the base of Q34 when the plate of V24 passes through 100 volts.

(1) Q34 is an operational amplifier. Its base is the

virtual signal ground. The voltage on the base is anchored at 100 volts, and does not change very much over the range of input current seen.

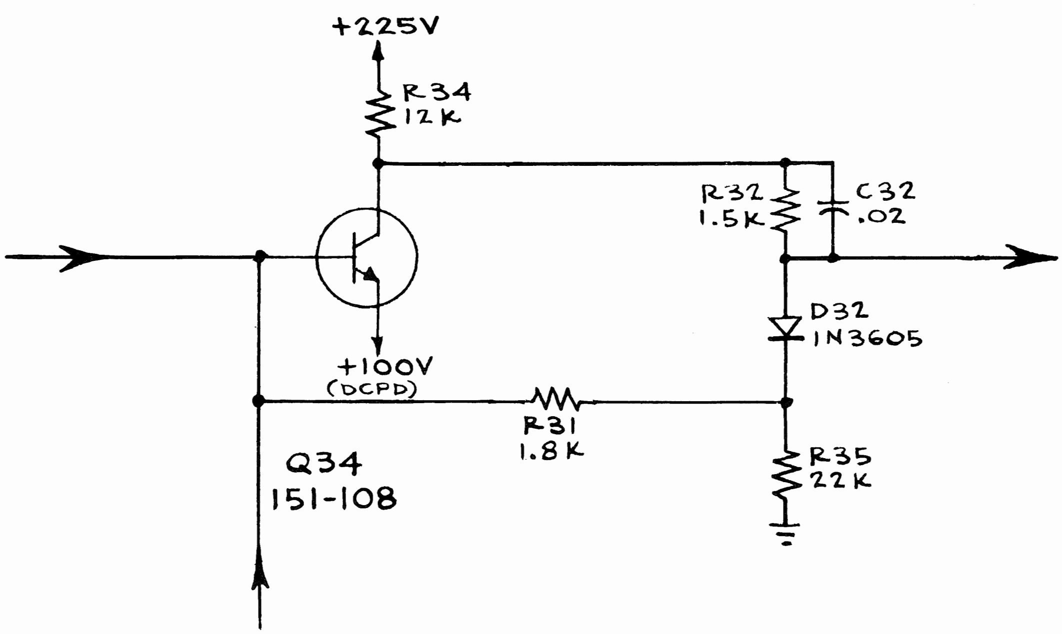
(2) When the plate of V24B is below 100 volts, D29 is forward biased, holding D30 reverse biased. No current from R29 flows to the base of Q34. This current is shunted through the plate of V24B. The collector of Q34 is at 108 volts, held there by current through R32, D32, and R31 which forward biases the transistor. (Q34)

(3) When the plate of V24B is above 100 volts, D30 is conducting, holding D29 cutoff. 2 ma through R29 now flows into the base circuit of Q34. This causes the collector of Q34 to drop to 102 volts, allowing for the added current input. In the operational amplifier, current in the feedback loop is decreased, to keep input current to the base constant.

(4) There is a 1 volt input signal transfer range in the D29-D30 logic circuit, where both diodes are conducting part of the current through R29. 1 volt input corresponds to 1/2 volt at the plate of V24B. Signals of 1 volt and less are reproduced in the Q34 operational amplifier. Signals of a higher level are clipped by the switching of D29 and D30.

(5) The reason this circuit has been installed is to clip the input current-output voltage waveform in the circuit of Q34. Clipping this signal between 102 and 108 assures a relatively constant voltage swing in the input to Q35 and Q45. It is important to limit this swing so that Q35 and Q45 are not overdriven. This assures proper countdown with high level high frequency signals.

4. Operational amplifier, Q34, (Figure 2-2).



OPERATIONAL AMPLIFIER

Figure 2-2

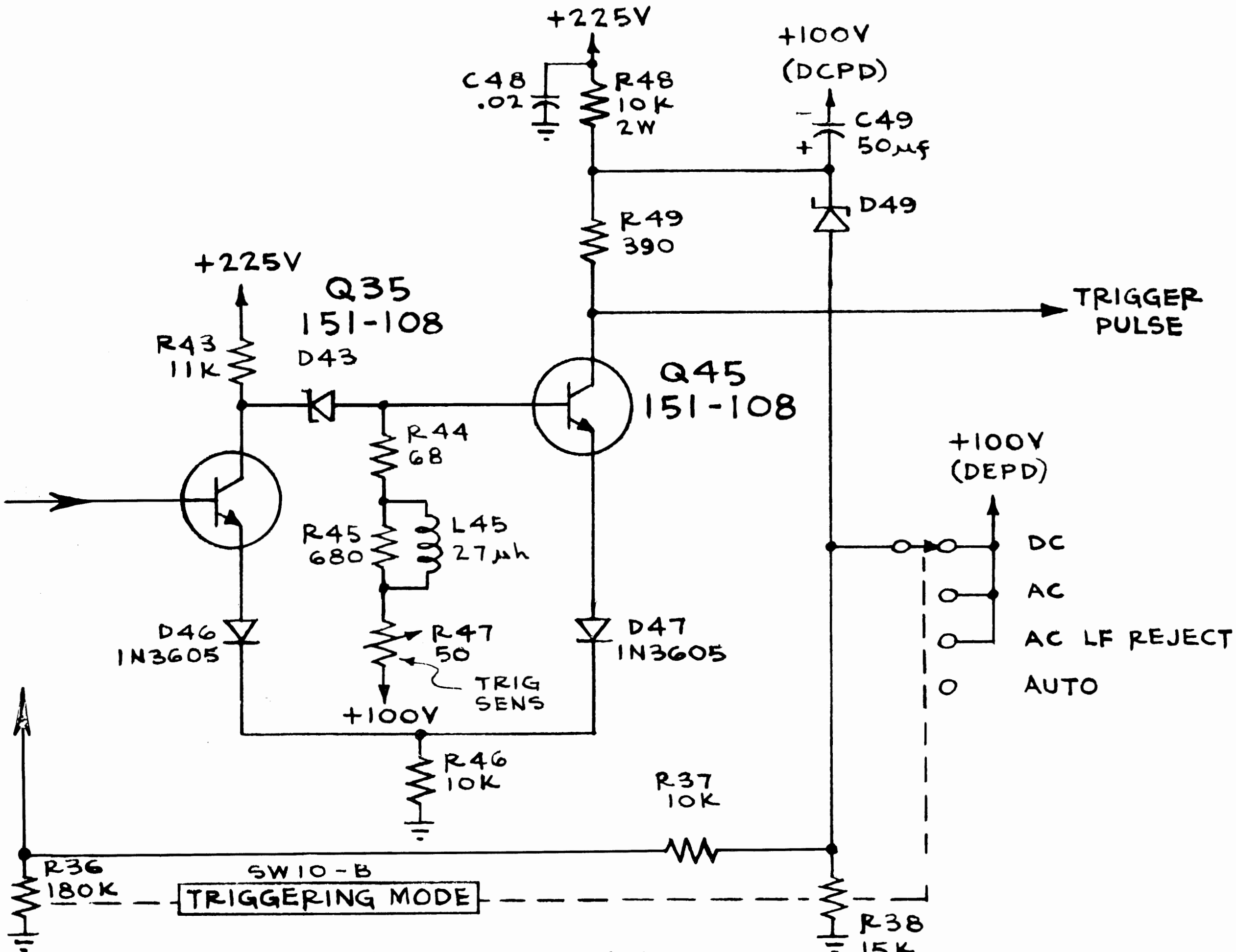
As previously mentioned, this amplifier has an output of fixed magnitude. Clipping, controlled by D29 and D30, begins when the trigger input reaches 1 volt (peak-to-peak) external, or about 2.5 cm internal.

a. The fact that the full excursion at the collector of 102 to 108 volts does not take place with 1 mm of display and internal trigger is not important. The hysteresis width of the Schmitt circuit is adjusted to about 1.2 volts, equal to about 2 volts at the collector of Q34.

b. The output of an operational amplifier is determined essentially by Ohm's law. $E_{feedback} = I_{in} R_{feedback}$ In the case of Q34, the input current changes by the 2 ma flowing through R29, when the plate of V24B goes through 100 volts. $E_{feedback}$ is the collector voltage. Actually measured, for the 2 ma excursion, was 6.2 volts. Assuming exactly 2 ma in, $R_{feedback}$ computes to 3.1K. The feedback resistors R31 and R32, adding up to 3.3K, with R35 and the input impedance of Q35 as current shunts in the middle of the feedback loop. These make the output voltage swing, and thus the computed resistance, a little high. More than 2 ma must flow through R32 to get 2 ma through R31.

c. D32 provides temperature compensation for the voltage across the base-emitter junction of Q34. The voltage drop across the diode parallels that across the transistor emitter-base with temperature changes, holding the output voltage constant. This prevents the 0 trigger level from shifting with ambient temperature.

5. Schmitt circuit Q35 and Q45, (Figure 2-3)



SCHMITT REGENERATOR

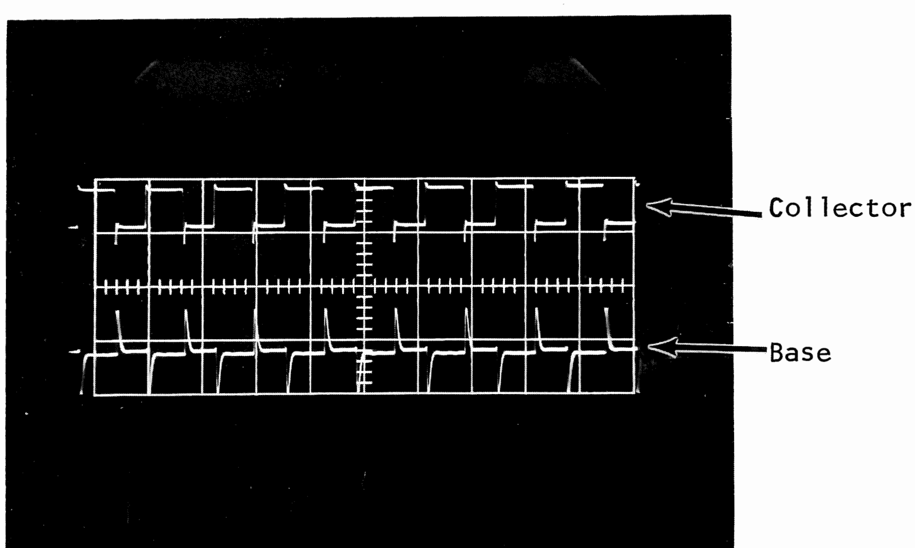
Figure 2-3

While transistorized, Figure 2-3 operates in the same manner as Schmitt circuits used in the older 530-540 series. There are two additions of note. First is the use of zener diode D43 (10 volts) to allow Q35 to have 10 volts on its collector. The zener diode allows direct low impedance coupling of voltage changes, while maintaining the 10 volt offset. The other addition is R45-L45, for countdown. When the multi switches, a current change occurs across the coil that causes a voltage to be developed, limiting the time before the circuit can be reset. The point at which countdown begins depends on the setting of the LEVEL control and the actual level of the trigger signal in. Countdown can occur anywhere between 4 and 11 mc, although the nominal frequency is 5 mc. Countdown allows regenerated signals to be wide enough to trigger the sweep gating multibibrator.

a. The Schmitt circuit consists of Q35 and Q45, and related components. This makes the circuit a bistable switching circuit instead of an amplifier. See "Typical Oscilloscope Circuitry," pp 10-20 to 10-27.

b. Sensitivity adjustment: Current through R43 is supplemented by current through R44, L45, and R47. R47 is adjustable. The additional current decreases the negative bias needed on the collector of Q35 to allow Q45 to turn on. The adjustment is set to give an auto rep rate of 40 cps.

c. Countdown: To limit the repetition rate at which the Schmitt circuit can operate, L45 and R45 are installed. R45 has not been mentioned so far, because L45, which is wound on it, shunts across it at low frequencies. When the Schmitt switches, the current through the base circuit of Q45 changes sharply. When Q45 turns on, the base current increases, and the inductance of L45 causes a sharp positive voltage spike (see Figure 2-4). This spike can prevent Q35 from turning



Base & Collector 1 µsec/cm   Q45 at 750 KC

Figure 2-4

back on. When Q35 does turn back on, a sharp negative voltage spike appears at the base of Q45, preventing Q45 from turning back on. Because Q35 is an amplifier, the amplitude of input signal swing can determine the signal sent to Q45, and can affect the period that the multi is held off. For very small signals, no switching will occur until these spikes have decayed, and the Schmitt will skip over input signals rather easily, because of the holdoff. With larger input signals, the signal can drive through the decay of the spike, and the repetition rate at which the multi skips signals will rise. This accounts for the wide range over which countdown actually occurs. With higher frequencies (30 mc, for instance), the Schmitt circuit will skip several input cycles; for example, it will only switch on every 6th input cycle if countdown is to 5 mc.

The total time duration of the fastest sweep, including holdoff, is about 8.5 microseconds. This is equivalent to a repetition rate of 118 kc. Thus, countdown, even from 4 back to 2 mc, will give 17 regenerated trigger signals for each one that the sweep gating multi can accept. Countdown from 11 to 6.5 mc will give 55 regenerated signals for each sweep. If countdown were not employed, the narrow signals reaching the sweep gating multi would prevent triggering, since the sweep gating multivibrator would not be triggered. Figure 2-5 shows the appearance of 8 megacycles regenerated trigger mixed with holdoff at the grid of V135A.

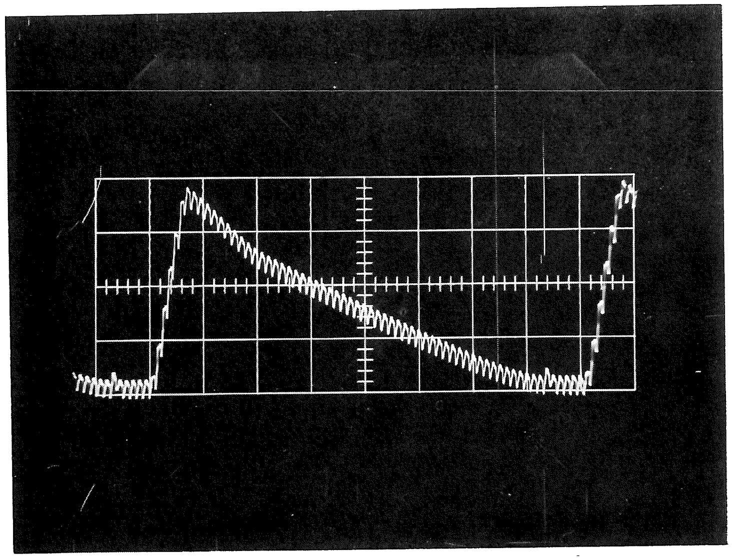


Figure 2-5

Figure 2-6 shows the same situation with the TRIGGER LEVEL control readjusted to give 2:1 countdown, at the same 8 mc. It took about 10 minutes of careful horsing to get a stable adjustment at 8 mc, and the picture shows why (Figure 2-5). It only took 5 seconds to reset to the countdown picture, 4 of which were spent reaching from the coffee to the knob (Figure 2-6).

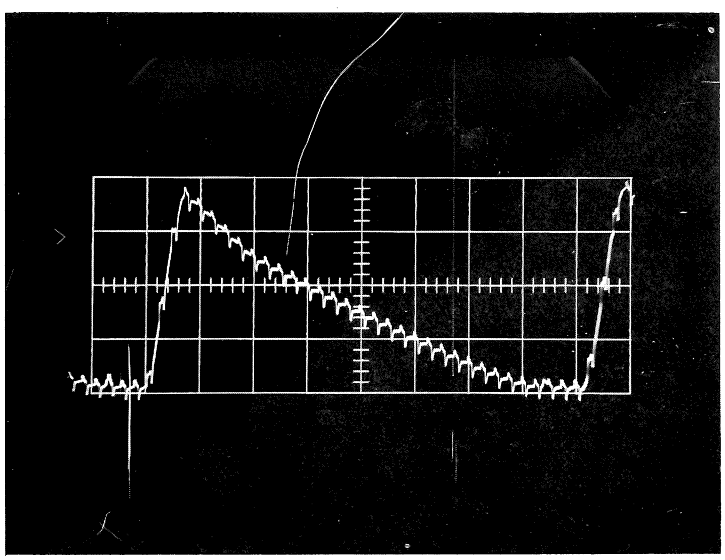


Figure 2-6

d. D46 and D47 are inserted in the Schmitt transistor emitter circuits to prevent reverse breakdown of the transistors from the voltage spike across L45. While breakdown would not damage the transistors, for the period of time that it would occur, it would discharge the voltage across L45, spoiling the countdown.

6. Auto Circuit: The Auto circuit is connected to the collector output of Q45 through R49. When not in use, SW 10-B, the MODE switch, connects the +100 volts, through 10 volt zener D49, to the junction of R49 and R48. When AUTO mode is selected, the collector of Q45 charges and discharges C49 through R49. The voltage at the junction of C49 and R49 is fed back through R37 to the base of Q34, where it supplies an input signal to the trigger generator. This circuit automatically operates the Schmitt circuit set at a 40 cps rate. When trigger signals are received from the trigger input circuits, they are mixed with the AUTO feedback signal. If the signals are at a greater than 40 cycle rate, they take over and operate the Schmitt circuit in the normal manner. In this case, there is insufficient time for C49 to charge and discharge far enough to give automatic operation. R38 keeps D49 in conduction, and R36-R37 provide the desired current division and isolation between the input and output sides of the circuit. At the same time, the LEVEL circuit is set to 0, AC coupled, by the MODE switch.

   a. The collector of Q45 swithces between 104 and 108 volts as the Schmitt circuit is switched. This change would be seen at the junction of R48 and R49, in normal operation, except that +100 is connected to D49, which raises it to +110 at low impedance, removing any change that might be seen. In AUTO, the +100 is no longer connected, and when Q45 conducts, C49 charges downward from 108 volts. As the voltage drops, the signal current provided by the AUTO circuit subracts from the total current to the base of Q34, until the collector of Q34 rises far enough for the Schmitt trigger to trip. The total movement at the base of Q35 will be the hysteresis width, 1.2 volts. This turns Q35 on and Q45 off.

b. With Q45 off, action at C49 is reversed, and current through R48 charges C49 back up again toward +225. This voltage is once again coupled to the base of Q34, and it lowers the base voltage of Q35 to turn Q35 off and Q45 on. The cycle then repeats itself.

c. When Q45 is off, current through R48 is about 12.5 ma. (ohm's law, with the voltage being 225-100) R38 carries a constant 6.7 ma, leaving 5.8 ma to charge C49. The total excursion seen at C49 is about 2 volts, which means that the capacitor charges 1.6% of the total on the R48-C49 circuit, with C49 at 100 volts. Thus, the charging appears nearly linear.

d. When Q45 is on, it draws (or provides, is more accurate) 10 ma, controlled by the voltage across R46. The current available to C49 is now -4.4, compared to the former +5.8 ma (5.8 ma - 10 ma - 4.2 ma). The different currents for up and down halves of the cycle is reflected by the 2 cm used in charging down and 1.5 cm in charging up. Repetition rate with no trigger in is 37 msec, equivalent to 27 cps.

e. When AUTO is selected, AC coupling, through C10, from the trigger source, is selected. The triggering level control voltage, seen at the junction of R19 and R20 is shunted to ground through a set of switch contacts, setting the triggering level side of V24 at 0 volts. POLARITY is still selected, since the sweep gating multivibrator is sensitive only to negative signals from Q45.

f. Trigger signals operate the trigger circuit in a normal manner, when the repetition rate exceeds the free-running rate of the trigger circuit. The trigger signal will operate the Schmitt circuit before C49 can charge far enough for automatic operation, allowing the triggering signal to take over operation. If the trigger signal is smaller than the normal 100 mv, or less frequent than the AUTO rep rate, the signals will mix randomly to give a jittery display. The solution is to use another mode than AUTO and/or to increase signal amplitude to the trigger circuit.

3. B Trigger (545B only)

1. The B trigger has the same functional blocks as the A trigger, except that the operational amplifier has been eliminated. High Frequency signals only are clipped in the plate circuit of V74B (the right section of the level amplifier), and the level amplifier, V74B, has a disconnect circuit in the cathode circuit. This circuit allows a sharp signal in the triggering region, which is supplied to the Schmitt multivibrator.

   The Schmitt multivibrator, which regenerates the trigger signal for use by the sweep gating circuit, is similar to the 545A B trigger Schmitt circuit. L84, in the collector circuit of Q85, limits the recovery time to provide a countdown that begins about 2.3 mc and ranges to about 2.9 mc. The actual frequency at which countdown occurs depends on the signal in and setting of the LEVEL control.

   The AUTO circuit is an R-C feedback loop between the collector and the base of Q95. This circuit will work because Q85 and Q95 are a Schmitt circuit which has a sharp switching characteristic, and will not "hang up" between bistable conditions.

2. Level Amplifier: Operation of the level amplifier is basically the same as in the A sweep trigger or the 545A B sweep circuit. No provision is made for adjustment of trigger sensitivity, but a centering control is provided in the plate circuit of V74B. Certain modifications have been made to the older (545A) circuit to improve frequency response of the trigger circuit.

   a. High Frequency Limiter: High frequency signals are coupled through C81 to D81 and D82. At high frequencies, these limit the voltage excursion at the junction of R75 and L75 to 1 volt AC. At the same time, they allow the portion of the signal actually used to trigger to be amplified without attenuation. Clipping allows the circuit to see no Miller effect beyond the 1 volt signal.

b. Shunt peaking: L75 boosts output at high frequencies, to make up for the effect of stray circuit capacitance. At 20 mc (twice the specified maximum frequency), the reactance of L75 is 37.5 ohms. At the same frequency, the reactance of C81 is 80 ohms. Since these are vector quantities, working in opposite directions, the net effect is to see 42.5 ohms capacitive reactive (at 20 mc) added in the plate circuit when D81 or D82 is conducting. Thus, there is no substantial buildup in signal output at the plate of V74B as might be suspected if a much larger shunt peaking coil is used.

c. Cathode coupling disconnect: In the older (545A circuit) design, the A side of the tube had no load resistance. Therefore, the degeneration due to Miller effect would be much larger on the B side than the A side. Thus, gain in the circuit with + and - high frequency inputs would be different. In this circuit, R74 and C74 provide additional decoupling, but C74 has a reactance at 20 mc of 014 ohms, which means that Miller effect is bypassed to ground. R77 and R79 provide about 3.9 ma for each section of V74. In addition, 2 more ma are available through R78 for the cathode having the higher potential, which will forward bias either C78 or D79. Let us examine the action with both + or - slope.

   (1) With + slope, the triggering signal drives the grid of V74B. D79 becomes forward biased, allowing R78 to parallel R79, providing more current for the cathode of V74. As this current becomes available, the plate voltage drops rapidly, since the current must pass through the plate circuit. At the same time, D78 cuts off, disconnecting R78 and the cathode circuit of V74B from the cathode circuit of V74A.

   (2) When - polarity is selected, the triggering signal is fed to V74A. As the voltage drops on the grid of V74A, its cathode voltage also drops, and D78 is cut

off. 2 additional ma are now available in the cathode circuit of V74B. Operation in this case is the same as in the preceding case except that the signal is fed through V74A.

(3) The voltage level where the current through R75 transfers from V74A to V74B is determined by the grid voltage on the section of the tube connected to the TRIGGERING LEVEL control and circuit. In the case of a - slope, the grid of V74B is connected to the TRIGGERING LEVEL circuit. The grid voltage of V74A must drop below that on the grid of V74B for the current to transfer from V74A to V74B. Use of this switching circuit sharpens the transitions, improving trigger circuit sensitivity, and disconnects the halves of the tubes from each other, decreasing the capacitance that the trigger signal must look into.

3. Schmitt multivibrator (Q85, Q95)

Operation of this Schmitt circuit is similar to that of the A sweep trigger Schmitt trigger regenerator. The B sweep, however, has a voltage divider (R87, R88, C87) between the collector of Q85 and base of Q95, instead of a zener diode. Countdown is provided by LR84, a choke wound on a resistor, in the collector circuit of Q85. No provision is made for sensitivity adjustment.

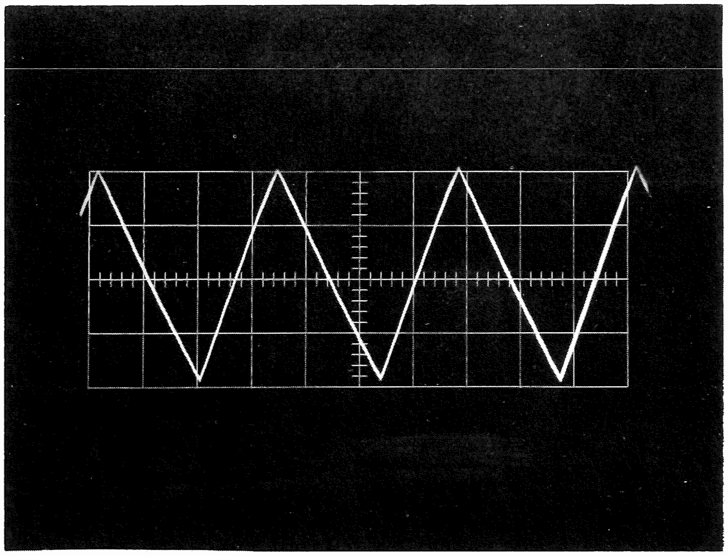
a. Sensitivity: Transistors Q85 and Q95 must have a minimum beta of 120. If they do not, the circuit will now operate properly. Lowered beta will decrease the hysteresis voltage width and make the trigger circuit too sensitive. Symptoms will be oscillation and false triggering on noise signals. We buy them as Fairchild 2N2484's with the specified high beta; thus do not select them ourselves.

b. Countdown: Provided by LR84. At low frequencies (when circuit is in one state or the other), LR84 looks like a very low DC resistance. When the multivibrator switches, the inductance of the coil attempts to maintain the original current, providing a voltage spike that limits the repetition rate of the circuit. When Q85 is turned on, a negative voltage peak is provided, which must decay before Q95 can be turned back on. When Q85 is turned off, a positive voltage peak is provided, which holds Q95 on. Clipping action in the level amplifier, described previously, limits the driving signal that the base of Q85 can receive. This assures that the countdown will not be overridden by large signals. Countdown frequency varies from about 2.3 to 2.9 mc, depending on signal amplitude and setting of the LEVEL control. Above this frequency, the Schmitt circuit will divide down the signal to a sub-multiple repetition rate. Thus, if the input signal is 4 mc, the circuit will repeat at 2 mc.

c. AUTO Circuit: R90, R92, R93, and C90 form the AUTO circuit. In modes other than AUTO, the TRIGGERING MODE switch connects 100 volts to the junction of R93 and R95, isolating R93 and R92 from the signal at the collector of Q95. In AUTO, the 100 volts isolation is disconnected.

(1) Assume that Q95 has just turned on. The voltage at the junction of R92 and R93 will drop, discharging C90. The current available through R90 to the base of Q95 decreases, allowing Q95 to shut off.

(2) When Q95 shuts off, it trips the remainder of the Schmitt trigger to turn Q85 on, because the voltage across R97 will drop until Q85 is on. Since no more current is taken by Q95, all current flowing through R92 is used to charge C90. Current can also flow through R90, as C90 charges, and when the current is sufficient to forward bias Q95, Q95 is turned on. Figure 3-1 shows the waveform at the junction of R92 and R93.



Auto .2 v/cm 5 msec

Figure 3-1

(3) C95 bypasses any noise signals that might return from the sweep gating multivibrator. This prevents mis-triggering of the trigger circuit.

(4) When a signal with a repetition rate shorter than 20 milliseconds is received, it will override the AUTO circuit to provide normal triggering. This is because the time allowed by the trigger rep rate will not be sufficient for C90 to charge in either direction to change the state of the multi.

(5) When AUTO is selected, AC coupling is switched in, and the level voltage from the TRIGGER LEVEL control is grounded out. The level amplifier is thus set to 0 volts. + and - polarity are still selected by the TRIGGER SLOPE switch, as well as the trigger source.

4. TIME BASE GENERATORS, CALIBRATOR, HORIZ AMP, AND POWER SUPPLIES

1. These circuits, except the high voltage supply, are nearly identical to those in use in the 545+543A. The high voltage supply is the same as used in 544-546-547. Discussion will be limited to changes.

2. Time base A (545B). R133 and D135, added in the plate circuit of V135A, clamp the plate at +100 volts when the Schmitt circuit switches. This provides a sharp corner on the unblanking waveform fed to the CRT and prevents an overpeaked spike from being fed to the CRT unblanking circuit. The spike results from coupling of the trigger signal through V135A. The clamping circuit allows fast unblanking without a flare at the beginning of the trace. No trigger bypass is provided for HF sync, since the trigger circuit will operate through scope bandpass.

3. Time base B (545B). The plate circuit of V235A has been changed to give the same +100 volt clamp as described for Time base A. The plate circuit has been separated from the voltage divider that drives V235B, and D233 has been added as a clamp diode. A comparison of the new circuit with the old will show the changes. Note also that the bootstrap capacitor, C234, is changed from 10 to 47 pf.

   The trigger signal is now fed directly to the grid of V235A. Positive signals are clipped by D231. This allows better coupling of the regenerated trigger signal to the multivibrator circuit. Values in the stability control circuit have been changed to allow a decoupling filter to be added to the grid circuit of V233B.

4. Time base (543B): The clamping circuit in the plate of V135A (D135, R135) is the same as in the 545B Time base A. It prevents over-brightening of the trace as the sweep gating multi switches.

In addition, the 543B time base has solid-state disconnect diodes, D150 and D152. These perform the same function as the older tube diodes. D152 provides the retrace current to operational amplifier (miller tube), and D150 is the clamp diode that balances out retrace current when the sweep has returned. D152 is Gallium Arsenide, for low leakage. In a pinch, it can be replaced with a IN3605, but leakage may alter the sweep rates, particularly at low sweep rates, where input current is low. Removing the tube removes a heater, and therein lies a chance to save a buck. The old circuit required a tube with a DC heater, which required a separate 6 volt DC power supply, to prevent jitter. Putting diodes in eliminates the whole separate supply. This was not done to the 545B because the DC supply is taken from the 100 volt supply, and using diodes would not eliminate any components. Also, the 545B has only 5X mag, and jitter does not become a problem.

5. Horizontal Amplifier: 545B horizontal amplifier has changes. This allows for the 20 v/cm CRT sensitivity. 543B horizontal amplifier is almost the same as 543A, except for changes in calibration adjustments. The old X10 adjustment, R342, now serves as an X1 adjustment. The old X1 adjustment has been eliminated, and feedback loops R367, R368, R369, R370 installed for better linearity control. Thus, there is no adjustment for X10 gain. The X100 adjustment has been removed from the cathode circuit of V354 and V364, and placed in the cathode circuit of V374A and V384A, placing it after the new feedback circuit. The Sweep/Mag registration control circuit has been changed to two equal 12K resistors and a balancing potentiometer, rather than the old one-leg-adjustable configuration. This keeps total resistance between the cathodes of V354 and V364 constant, eliminating gain change with registration adjustment.

The new feedback circuit helps balance signals in the two sides, preventing common mode signals from reaching the CRT. Since degeneration has been introduced in all cathode coupling circuits, separate means must be used to balance signals. Common mode signals produce no deflection at the CRT, and may cause defocusing. R360 and C368 provide cross-neutralization of capacity in the feedback loop. This neutralization is adjusted at a fast sweep rate for best linearity. C378 and C382, the output circuit feedback capacitors, are now fixed. The switched attenuator resistances (R361) have changed to compensate for the removal of the old X100 adjustment.

6. CRT circuit: The CRT circuit is the same as is used in the 546 and 544. This standardization cuts costs. The whole circuit is located above the CRT neck, which simplifies shielding. Gone are the old problems of high voltage in the horizontal. Since there is no red knob at the back of the CRT, there is no need to get at the rear of the left side. The area formerly occupied by the high voltage circuit is now left vacant, and has mounting holes for the 400 cps fan mod power supply. The trace rotation coil supplys current by being in series with the +75 volt bus to the plug-in heaters. Note that the new CRT (same as in 547) must have this rotating coil in order to register the deflection with the internal graticule.

   The trace rotation coil is simply a 400 turn coil of no. 23 wire. The magnetic field it sets up is parallel to the centered electron beam in the CRT. When the electrons are deflected by the deflection plates, they travel across lines of force in the field, since the electron beam flows at an angle when deflected. This sets up a vector cross product force which deflects the electron in a plane perpendicular to its travel from gun to screen. The cross product idea, simply restated, is the old righthand rule, or Lenz's Law, which says that the north pole is at the negative end of a right hand coil of wire.

The magnitude of force on an individual electron (remember that vectors have magnitude and direction both) is the product of the kinetic energy of the electron and the number of magnetic force lines crossed. A beam deflected to the edge of the CRT will cross quite a few lines, and be deflected substantially. Near the center, only a few lines will be crossed, and little deflection will be seen. A beam at the left side and a beam at the right side, will cross the magnetic field in opposite directions, and thus be deflected oppositely, one up and one down.

As the electrons travel through the magnetic field, they see a force perpendicular to both the direction of the kinetic energy of the electron (from gun, traveling to the screen) and the magnetic field (parallel to an undeflected beam). This places the direction of deflection in a plane parallel to the faceplate of the CRT.

Looking at the circuit, R778 controls the amount of current in the coil, and can reverse its direction, giving deflection in either direction. Because the magnitude of deflection is directly proportional to the deflection angle from center, the sweep remains a straight line with no curvature or rumdoolies introduced.

Changing the high voltage will, of course, change the electron velocity toward the screen, and change its kinetic energy. However, the rotation angle will remain constant. With the higher kinetic energy, the force on the electron created by the interaction with magnetic field will be higher, but the transit time from gun to screen will decrease. Thus, the electron will be deflected a constant distance in the PDA region (where the coil works), and the angle seen on the CRT will not change with change in high voltage.

For a linear rotation, the magnetic flux density must be constant in the volume of the CRT where the coil acts. This is achieved by using an air core for the coil (vacuum inside the CRT, of course). The magnetic shield and the coil do not interact because the shield metal requires a much higher magnetic force than that provided by the coil to change magnetization. (The force necessary to switch the magnetism of a material through 0 magnetism is called the coercive force).

This technique has been used in several previous designs (561A, 647, and others), where the principle of operation is the same.

7. Power Supply: The power supplies are the same as in the older scopes except for current levels. Since the distributed amplifier has been replaced, less current is needed from the +350 supply. One section of a 6080, V737B, is now used in the +225 supply, which is more heavily loaded. Less power is needed in the new design. No selenium rectifiers are used. Note D679, which is for protection. This diode was in the old design, but bears noticing. It clamps the +350 output at ground during warmup, when the time delay relay is open. The -500 volt supply is not switched by the time delay, and can drive the +350 output negative, seeking a return path through R710 and R711. During warmup, only the 150 volts of the 500 supply, which is stepladdered on the +350, are present. However, the negative end of the supply, if its potential goes below ground, can place a damaging reverse potential across C679C, as well as anything else connected to the +350. D679 prevents this reverse polarity by providing a ground return path. When the time delay relay closes, 350 volts reverse bias are applied to D679. The diode sometimes shorts, causing blown fuses, etc. when the relay pulls in.

Another thing to remember in dealing with power supplies is that 6080 tubes have internal fuse protection. Never ground the output of a 6080-regulated supply, because you will probably blow the cathode lead in the tube, leaving the tube NG for anything but conversation. Tek circuitry provides plenty of load for the supplies to develop voltage across, and a Simpson meter measurement should be made. The power transformers now have export tags, showing connections for different input voltages. Also ±10% input voltage variation at 400 cycles, as well as 50-60 cycles input can be tolerated. Note that for 400 cycle operation a separate fan supply must be installed.

CALL REPORT EXTRACTS
TECHNOLOGY

CUSTOMER	FIELD ENGINEER
	John West ε

CITY AND STATE	MONTH-DAY-YEAR	CALL #
	7/13/65	1

GROUP	GROUP FUNCTION
	JUL 2 9 1965

NAMES
ε W

USE

547 C.R.T. Blooming - Was called over to take a look at His new 547, which was supposed to have a defective C.R.T. He had mentioned to me that he could see the filaments through the phosphor when the intensity was turned up. After checking the C.R.T., I noticed that with the trace positioned vertically off screen, the C.R.T. developed quite a blooming condition at the center of the screen. When the trace is positioned back on the screen, the condition decreases slightly. He said that the blooming pre-exposed his film. The base line is positioned slightly off trace when they take pictures. By replacing the C.R.T. did not cure the trouble. After checking other 547's in the office, I found that they all exhibit the same condition.

Deflection plate bounce — Sandy

TECHNICAL DATA

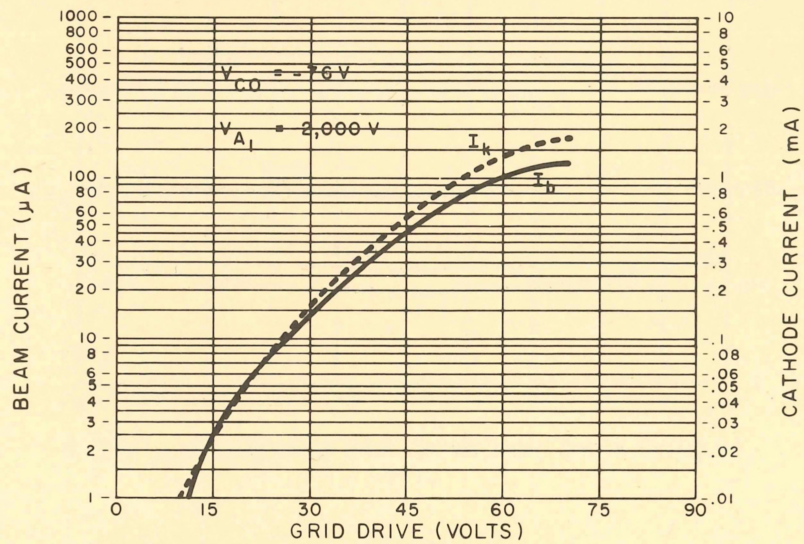
PERFORMANCE CURVES T5470

LIMITED DISTRIBUTION 7/28/64

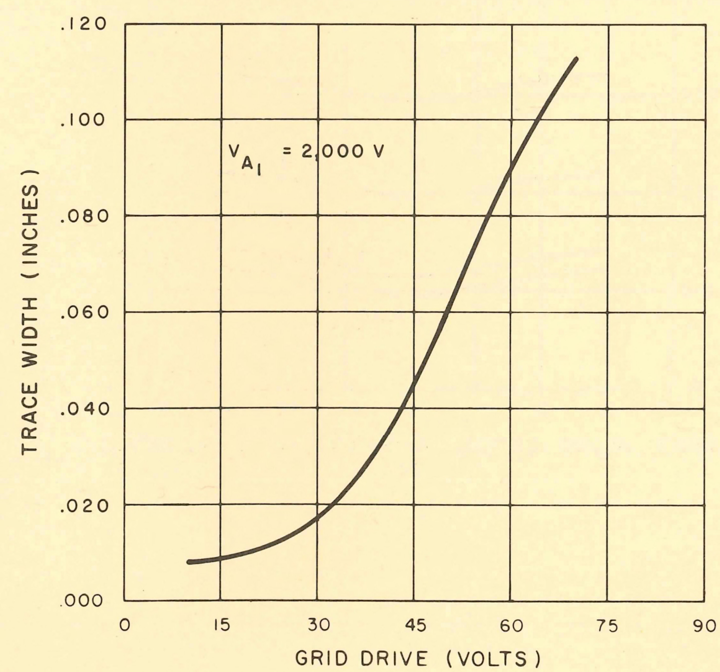
All measurements taken with voltages specified under Typical Operating Conditions on the T5470 Technical Data Sheet. This data is representative of the CRT alone dissociated from any operating circuitry.

AVERAGE GRID-DRIVE CHARACTERISTICS:

Grid drive measured as volts above cutoff.

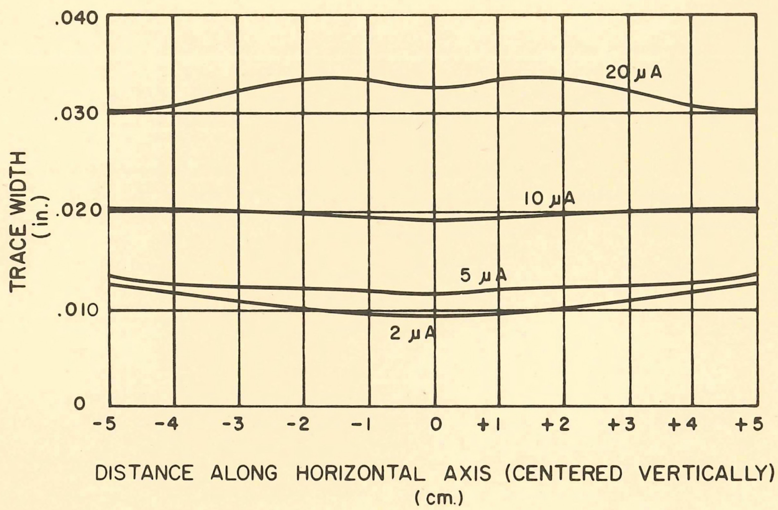


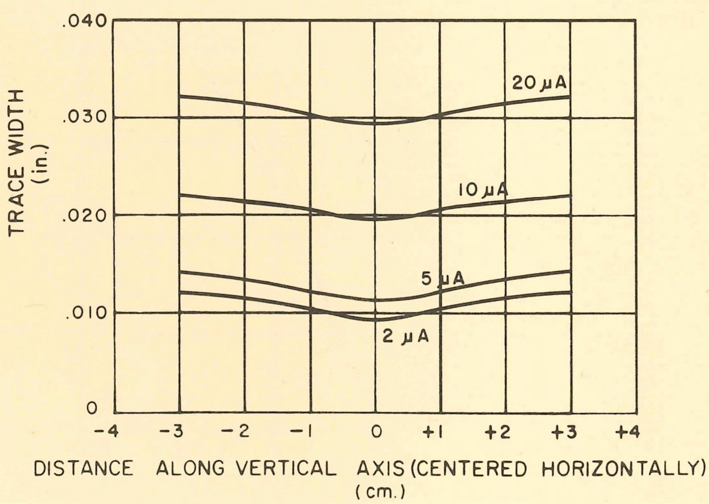
AVERAGE CENTER-SPOT-SIZE CHARACTERISTICS:



TRACE WIDTH VERSUS LOCATION ALONG AXIS:

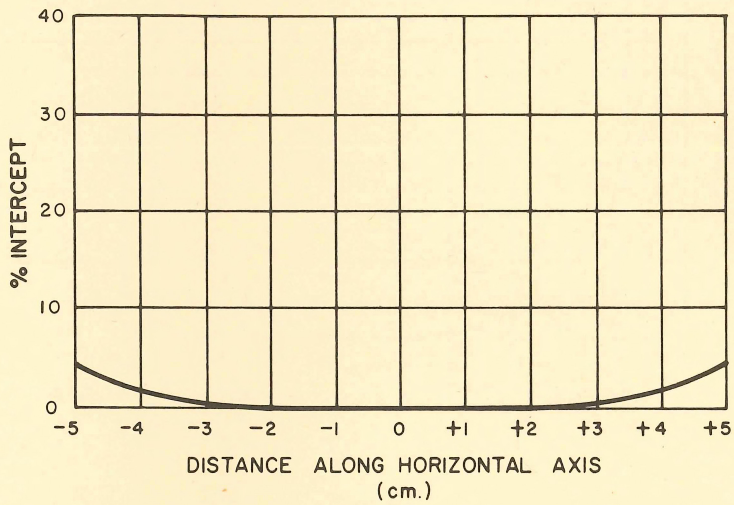
All trace width measurements taken using shrinking raster method with 11-line raster at 2 kc rep-rate.



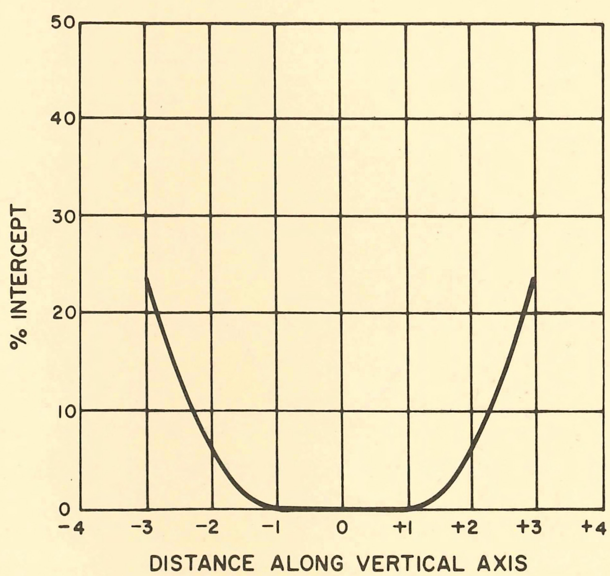


DEFLECTION PLATE I_b INTERCEPT:

Taken at normal viewing currents of 1-2 μamps.



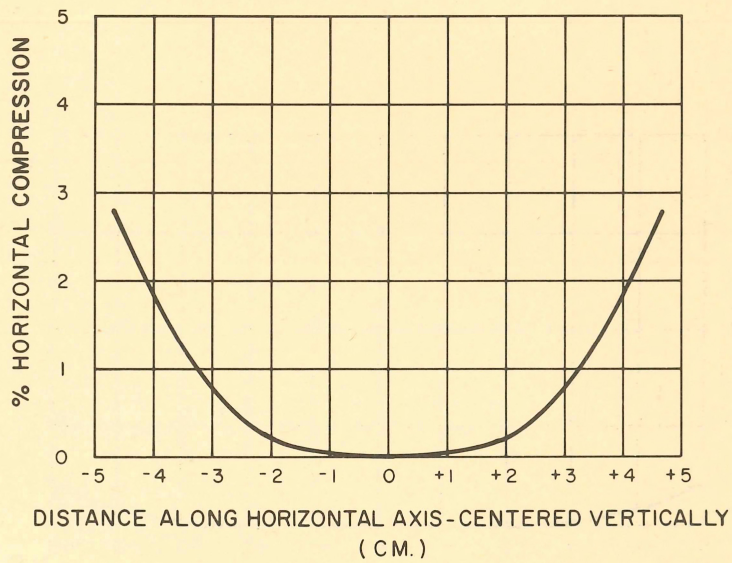
(CENTERED VERTICALLY)

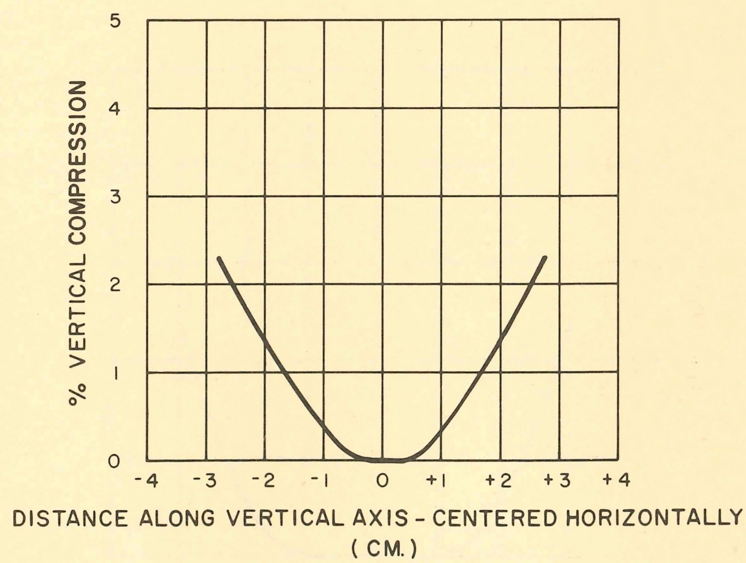


(CENTERED HORIZONTALLY)

LINEARITY CHARACTERISTICS:

Percent departure from the deflection factor measured at the axis:





T5470P CRT WRITING RATE

FEN 6-5-64

Earlier publications to the field quoted crt engineering to say that the T5470P crt used in Types 544, 546, 547, 543B, and 545B had about 25% more writing rate than the T543P.

Recent checks by crt engineering show that production T5470P and T543P crt's are about equal in gun writing-rate capability. Further tests are being run to gather typical data which will eventually be published in regular crt data sheets.

Initial photo tests, run by Tech Support on a standard 547/1A1/P31 combination, indicate that a single-shot display of a 6 cm, 7 ns risetime step function at 10 ns/cm sweep rate, can be usefully photographed on Polaroid Type 410 10,000 speed film exposed in a C-13 or C-19 camera frame, equipped with an f/1.9-1:0.5, f/1.3-1:0.5, or f/1.4-1:1 lens, if the film is lightly prefogged.

Further tests are being run to determine writing-rate capabilities of various camera frame, lens and crt phosphor combinations. Data will be published in a future FEN.

Because Polaroid Type 410 film is so fast and so light-sensitive, it is difficult to prefog to an optimum density without a controlled light source such as a Projected Graticule. The crt phosphor itself (P2 or P31) can provide a good, low-level light source if it is properly irradiated. One method is to irradiate the phosphor with a 75 watt tungsten bulb held about twelve inches in front of the crt faceplate. If using a P31 phosphor, irradiate it, then close and latch the camera; allow phosphor to decay for one second, then open the shutter to expose the film. Allow a P2 phosphor to decay ten seconds before opening the shutter. A little experimenting with shutter f-stop and speed controls should enable prefogging the film to an optimum density for maximum increase in system writing rate.

T5470 DATA

HLN 6-23-64

The T5470 CRT has an average horizontal resolution of 220 lines for 10 cm. Vertical resolution is the same since the spot is round. Spot size is 9 mils at the center and 12 mils at the edge (compared with 40 mils for the T543). Vertical linearity approximately 2.3%, horizontal linearity approximately 2.5%. Geometry is a little better than the T543, but the spec is the same.

SCRATCH SHIELD REPAIR

11-4-64

Scopes being shipped have a protective plastic scratch shield which can be removed and replaced. The T5470 CRT itself is being faced with a plastic implosion shield which cannot be replaced in the field. If the implosion shield does get scratched, you can solve the problem in one of three ways:

(1) Send the CRT back to the factory for replacement of the implosion shield;

(2) Use a small quantity of Johnson's Jubilee wax---which tends to fill-in small scratches;

(3) Polish-out the scratches (in either glass faceplaces or plastic implosion shields) by use of cerium oxide. Obtain a small quantity of cerium oxide from your local American Optical Company branch office. Mix cerium oxide with water to the consistency of whipping cream. Use a new buffing wheel or a new piece of soft cloth wet with the cerium oxide solution. If you use a buffing wheel, be very careful about heat by friction. Glass faceplates crack and plastic implosion shields melt. -- Sandy Sanford

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"High-Contrast" CRT's

Several years ago we introduced a new CRT design -- a parallax-eliminating internal graticule. After years of experience and solid customer acceptance of edge-illuminated external plastic graticules, we felt obliged to illuminate our internal graticules in much the same fashion as used for external graticules. Accordingly, a plastic implosion shield was cemented to the glass faceplate by a suitable adhesive -- and the edge of the plastic implosion shield was coupled optically to some beefed-up graticule lamps.

An undesirable side effect developed -- light rays transferred from the plastic implosion shield to the glass faceplate not only illuminated the graticule lines but also caused the phosphor to glow. Net result: Contrast between the phosphor and graticule lines was low -- much lower than our older CRT's with external graticules.

Coupled with a further problem of uneven illumination of the graticule lines, the low contrast ratio was called to our attention by a number of customers -- some of whom were unable to get photographs of high enough quality to do the job.

Experiments by CRT Engineering showed that an improvement in contrast ratio could be obtained by modifying the cohesive attachment between the phosphor and the faceplate. By suitable changes in processing, a spacing of 0.01 to 0.05 microns could be provided between phosphor and glass -- a spacing sufficient to attenuate the light moving from faceplate towards the phosphor.

As the result of these experiments, we began several months ago to ship certain CRT's (T5470, T5560, T5810) with "suspended" phosphors. Improvement in contrast ratio by use of the "suspended" phosphor technique is a design compromise having a corresponding disadvantage -- the "suspended" phosphor is about 5 or 10 times less resistant to tanning or burning than a non-suspended phosphor.

We depend upon intimate contact between the phosphor and the faceplate -- plus contact between phosphor and the aluminum "metallizing" layer -- to carry away most of the heat generated by electron beam energy. Spacing of .01-.05 microns reduces the rate of heat transfer between the hot phosphor and the heat sink (faceplate).

As you can guess, we don't like settling for a trade-off -- and intensive work is underway by CRT Engineering in an effort to find a new and really excellent solution -- a solution by which we can regain or surpass the contrast ratio of our older CRT's (having external graticules) and at the same time have uniform illumination of graticule lines. Along with these good results we also expect to regain or surpass the burn resistance of our external graticule CRT's. While the experimental results of the new faceplate design have been gratifying, design is not yet completed.

In the meantime, we must continue to produce internal graticule CRT's -- we seem to have made a compromise which is more acceptable to the majority of our customers than was the earlier problem of sharply reduced contrast. Those customers who were unable to make their measurements are now able to do so.

Here is a list of the starting Sequence Numbers (CRT Departmentese for Serial Number) of CRT's having a "suspended" phosphor. Reference must be by S/N because the difference between a "suspended" phosphor and an ordinary phosphor cannot be determined by eyeball -- or any other easy way.

T5470:

Phosphors affected:	P2, 7, 11, 31 were made with suspended phosphors; Special phosphors were not.
Suspended phosphor production began:	Week 41-5 with Sequence Number 41800.
Suspended phosphor production ceased for P2, 7, 11:	Week 46-6; P2, 7, 11 made by our ordinary processes will be available.
Suspended phosphor production continues for:	P31.

T5810:

Phosphors affected:	P2, 11, 31 were made with suspended phosphors; Special phosphors were not.
Suspended phosphor production began:	Week 1-6 with Sequence Number 01750;
Suspended phosphor production ceased for P2, P11:	Week 46-6; P2, P11 made by our ordinary processes will be available.
Suspended phosphor production continues for:	P31.

T5560:

Phosphors affected:	P1, 2, 7, 11, 31 were made with suspended phosphors; Special phosphors were not.
Suspended phosphor production began:	All CRT's made prior to Week 45-6; Only a few P1, 2, 7, and 11 were made.
Suspended phosphor production ceased for P1, 2, 7, 11 and 31:	Week 46-6. P1, 2, 7, 11 made by our ordinary processes will be available.
Ordinary phosphor production continues for:	P31.

Charles V. Sanford/cmh
Product Technical Information
11-15-66

TECHNIQUES

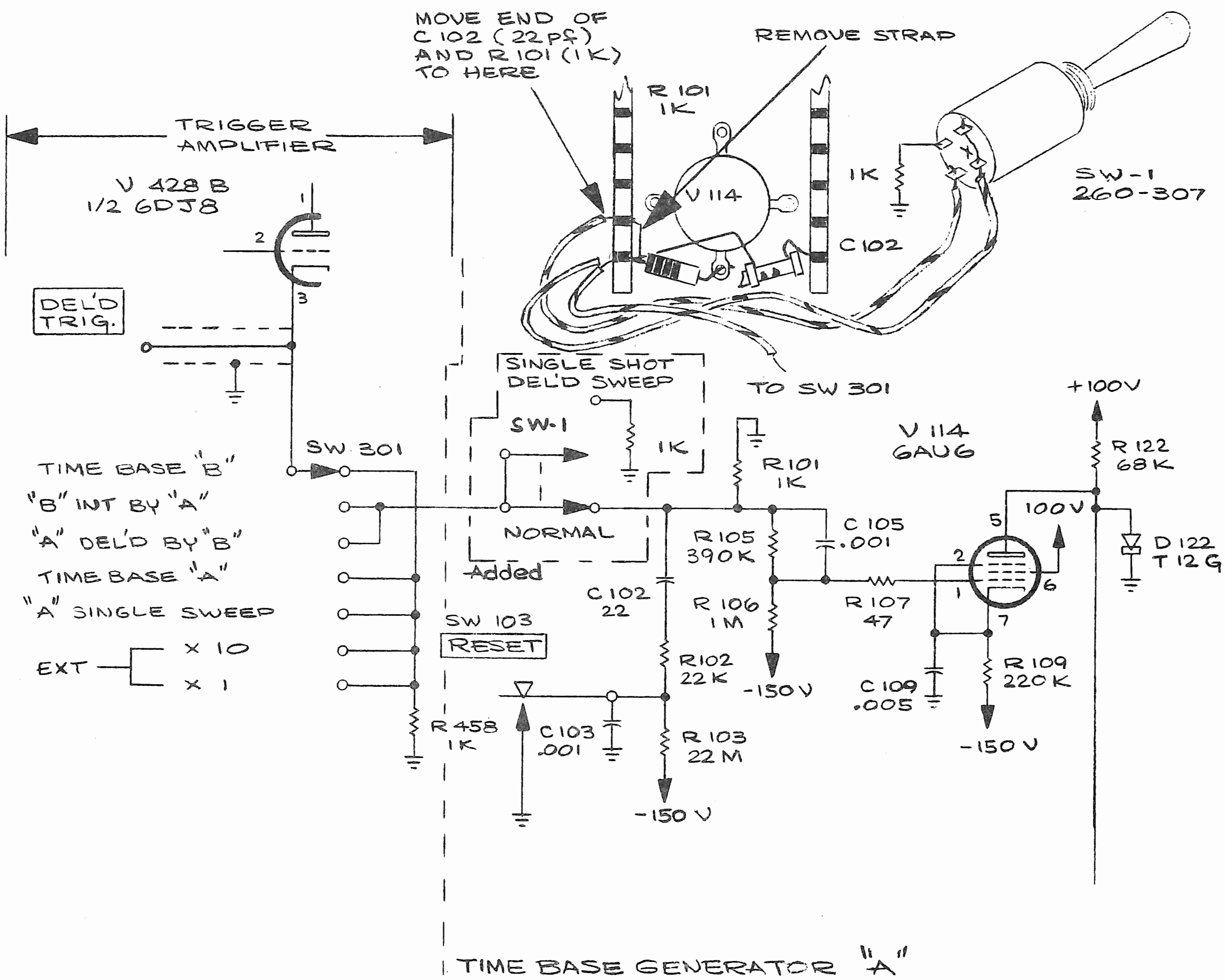
SINGLE SHOT DELAYED SWEEP MOD FOR TYPE 545B

A standard Type 545B can provide a repetitive delayed sweep and a single-shot *non*-delayed sweep, but *not* a single-shot delayed sweep.

All three functions can be provided by adding a switch, a 1k resistor and some minor wiring changes.

With the added switch (S1) in the SINGLE-SHOT DELAYED SWEEP position, both sweep generators can operate independently. With TIME BASE 'A' in SINGLE SWEEP mode, the DELY'D TRIG can be used to externally trigger TIME BASE 'A' after it has been armed with the RESET control.

A Type 321 power switch (260-307) makes a good S1. Mount it in place of the ground post below the front panel TRIGGER INPUT coax connector for TIME BASE 'A'.



Operation:

Set the HORIZONTAL DISPLAY to A DELAYED BY B, TIME BASE A TRIGGER SLOPE to +EXT and TIME BASE A TRIGGERING MODE to LF REJECT. Connect a jumper between the DEL'D TRIG binding post and TIME BASE A TRIGGER INPUT and set S1 to SINGLE-SHOT DELAYED SWEEP.

Set TIME BASE B SWEEP STABILITY full ccw (but not to PRESET), TIME BASE A TRIGGERING LEVEL slightly cw from zero and TIME BASE A STABILITY full ccw (but not to PRESET).

Check to see that the DELAY-TIME MULTIPLIER is not at zero. Slowly rotate TIME BASE A SWEEP STABILITY cw until you get a single sweep. Then rotate it back slightly ccw. Push the RESET button. The A SINGLE SWEEP READY light should light up.

Set TIME BASE B TIME/CM, DELAY TIME and DELAY TIME MULTIPLIER for your desired time delay. Rotate TIME BASE B STABILITY full cw.

You should be able to produce a single sweep each time you push the RESET button. If you can't, try a slight readjustment of TIME BASE A TRIGGERING LEVEL.

Connect your trigger signal to TIME BASE B TRIGGER INPUT, set TIME BASE B TRIGGERING LEVEL and STABILITY controls for proper triggering and you're in business.

A GREEN POWER-ON PILOT LAMP

Earl Williams, 12-15-65

A 378-0513-00 green jewel can be used in place of the standard red jewel in the POWER-ON pilot lamp assembly.

A GREEN POWER-ON PILOT LAMP

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MODIFICATION KIT

BLANK PLUG-IN

For all Tektronix Oscilloscopes using Letter Series Plug-ins -- including Types 581/A, 585/A, and RM585A with a Type 81 Adapter

DESCRIPTION

This kit, along with the enclosed information, allows the construction of special plug-in units for the above instruments.

040-0065-00

Publication:
Instructions for 040-0065-00
March 1968

Supersedes:
March 1967

PARTS LIST

Quantity	Description	Part Number
1 ea.	Connector, Amphenol, 16-pin	131-0017-00
1 ea.	Lockwasher, int #4	210-0004-00
1 ea.	Lug, solder, SE#4	210-0201-00
2 ea.	Nut, hex, 4-40 x 3/16	210-0406-00
1 ea.	Washer, fiber	210-0812-00
2 ea.	Screw, 4-40 x 5/16 PHS, Phillips	211-0097-00
4 ea.	Screw, 8-32 x 1/2 FHS, Phillips 100°	212-0043-00
##4 ea.	Screw, 8-32 x 1/2 PHS, Pozidriv	212-0008-00
1 ea.	Panel, front, special blank plug-in	333-0150-00
1 ea.	Ring, retaining	354-0025-00
1 ea.	Knob, retaining, gray	366-0125-00
1 ea.	Rod, securing, RS53	384-0510-00
4 ea.	Rod, spacer, plug-in	384-0631-00
1 ea.	Plate, sub-panel, special blank plug-in	386-0423-00
1 ea.	Plate, blank, FP 53 special	387-0549-00
1 ea.	Chassis, special blank, CH53	441-0108-00

GENERAL INFORMATION

The following chart is intended as a guide to the voltages and signals supplied by the various oscilloscopes at the plug-in connector. It lists the approximate load current requirements necessary to keep each power supply in regulation. In addition, it lists the inputs used by the oscilloscopes.

PIN NO.	DESCRIPTION	INSTRUMENTS	VOLTAGE	MAX LOAD CURRENT	MIN LOAD CURRENT	NOTES
1 3	Vertical Signal Input	All	See *Note			
2	Ground	All				Grounded in oscilloscope
4 5	Int Trig Sig Input	544, 546 547, 555** only	(See Manual)			These pins blank in all other oscilloscopes
6	Blank Pin	All				
7	Slave Pulse Output	547 only	(See Manual)			This pin blank in all other oscilloscopes
8 16	Alt Trace Sync Pulse Output	All	(See Manual)			Pin 8 grounded by Types CA, M, etc, in Alt Trace mode.
9	-150 v Supply	All	-150 v DC	60 ma	3.8 ma	
10	+100 v Supply	All	+100 v DC	50 ma	4.5 ma	
11	-225 v Supply	All	+225 v DC	75 ma	16.0 ma	
12	+350 v Supply	All	+350 v DC	20 ma	0 ma	
13 14	Heater Supply	All	6.3 v AC	2.8 amp	0 ma	Elevated to +100 v in some oscilloscopes (see Manuals). Do not ground either pin.
15	Series Heater String Supply	All	+ 75 v DC	150 ma	150 ma	Instrument should not be operated without loading this supply.

*NOTE: Bias required at both pins is +67.5 v (±2%). Signal Amplitude limited by sensitivity of oscilloscope (100 mv/cm).

** Used on Type 555 SN 7000-up, or Type 555 modified with Field Modification Kits 040-0328-00 or 040-0328-01.

DW:ls