CATHODE-RAY OSCILLOSCOPE TYPE 545

INSTRUCTION MANUAL

TEKTRONIX

LIVINGSTON LABORATORIES LIMITED
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ARCHWAY 6251

MANUFACTURERS OF CATHODE-RAY AND VIDEO TEST INSTRUMENTS

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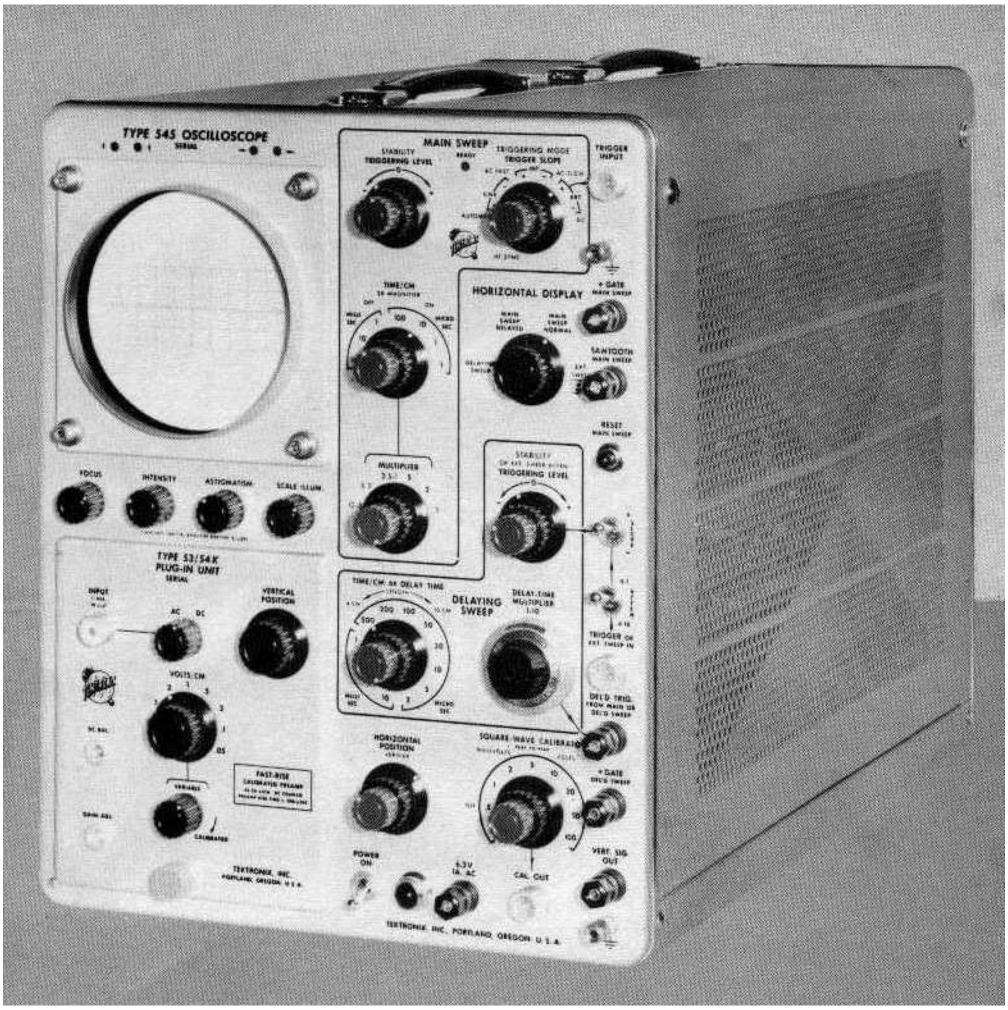
TYPE 545 SERIAL NUMBER

NOTE : Pages 4-3 tp 4-7 were missing from the original manual


TYPE 545 OSCILLOSCOPE
MAIN SWEEP
TRIGGERING LEVEL
TRIGGER SLOPE
TRIGGER INPUT
TIME/CM
HORIZONTAL DISPLAY
MULTIPLIER
RESET
TRIGGERING LEVEL
FOCUS
INTENSITY
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SCALE ILLUM
TYPE 53/54K
PLUG-IN UNIT
VERTICAL POSITION
VOLTS/CM
DELAYING SWEEP
HORIZONTAL POSITION
SQUARE-WAVE CALIBRATOR
POWER ON
CAL OUT
VERT. SIG OUT
TEKTRONIX, INC. PORTLAND, OREGON U.S.A.

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SPECIFICATIONS

The Type 545 is a high-speed laboratory oscilloscope. Its fast rise time coupled with wide sweep-speed range and 10-kilovolt accelerating voltage opens the way to faster, easier analyses of fast-rising waveforms. Additional adaptability is provided by plug-in preamplifiers which extend its use to almost all laboratory-oscilloscope applications. Accurately calibrated sweep speeds and vertical-deflection sensitivity permit quantitative time and amplitude measurements to be made. Accurately-delayed triggered sweeps make possible the selection and detailed observation of minute portions of voltage waves.

Vertical-Deflection System

Output Amplifier

DC Coupled
Rise time — .01 μsec.

Delay Line

Balanced Network
Signal Delay — .2 μsec.

Linear Deflection — 4 cm.

With 53/54K Plug-In Unit (in 545)

Deflection Factor — .05 v/cm, ac or dc.

Rise Time — 12 millimicroseconds.

Frequency Response — DC to 30 mc.

2 cps to 30 mc, ac. Down 3 db ±½ db at 30 mc, 6 db at approximately 41 mc.

Step Attenuator

Nine positions, calibrated, from .05 v/cm to 20 v/cm, accurate within 3% when set on any one step.

Maximum Allowable Combined DC and Peak AC Voltage Input — 600 v.

Input Impedance — 1 megohm, 20 μμf.
With P410 probe — 10 megohms, 8 μμf.

Horizontal-Deflection System

Calibrated Sweeps

Twenty-four calibrated speeds from .1 μsec/cm to 5 sec/cm.
Accuracy — 3 per cent.
Continuously variable, uncalibrated, between ranges and to 12 sec/cm.

Calibrated Sweep Delay

Delay Time — 1 μsec to .1 sec, continuously variable.
Time Jitter — Less than 1 part in 20,000, untriggered; jitter free when triggered.
Range Accuracy — 2 per cent.
Incremental accuracy .2 per cent of full scale.

Magnifier

Magnification — 5 times to left and right of center. Extends fastest sweep speed to .02 μsec/cm.

Unblanking — DC coupled

Trigger Requirements

Internal — 2 mm of deflection.
External — .2 volts to 100 volts.
Frequency Range — dc to 30 mc.

Horizontal Input

Deflection Factor
Continuously variable, .2 v/cm to 20 v/cm.
Frequency Response
DC to 240 kc.

Other Characteristics

Cathode-Ray Tube

Type T54P2
P1, P7, and P11 phosphors optional.
Accelerating Potential — 10,000 volts.
Deflection Factor, Direct Connection
Vertical — 7 v/cm.
Horizontal — 30 v/cm.

Voltage Calibrator

Eighteen fixed voltages from .2 millivolts to 100 volts.

Accuracy — 3 per cent.

Waveform — square wave at about 1 kc.

Trigger-Rate Source — 10 cps to 40 kc, continuously variable, using free running delaying sweep as generator.

Output Waveforms Available

Positive gate of same duration as main sweep, 20 volts.

Positive gate of same duration as delaying sweep, 20 volts.

Main-sweep sawtooth waveform, 150 volts.

Delayed trigger pulse from main or delaying sweep, 5 volts.

A sample of the vertical signal with a limited passband, 20 cps to 4.5 mc.

Heater voltage, 6.3 v ac, 1 amp.

Beam Position Indicators

Indicator lights show direction of beam when it is off the screen.

Mechanical Specifications

Power Supply

Electronically regulated

Power Requirements — 105 to 125, or 210 to 250 v, 50-60 cycles, 545 watts with Type 53K/54K unit.

Ventilation — Filtered, forced air ventilation.

Finish — Photo-etched, anodized panel, blue wrinkle cabinet.

Dimensions — 24" long, 13" wide, 16¾" high.

Weight — 65 pounds.

Accessories Include:

2 — P410 probes

2 — Binding post adaptors

1 — Test lead

1 — Light filter

1 — Instruction manual

OPERATING INSTRUCTIONS

PRELIMINARY INSTRUCTIONS

Cooling

The Type 545 Oscilloscope is cooled by filtered, forced-air ventilation. The instrument must therefore be placed so the air intake is not blocked, and the filter must be clean enough to permit adequate air circulation. If the interior temperature does rise too high for some reason, a thermal cutout switch will disconnect the power and keep it disconnected until the temperature drops to a safe value.

Time-Delay DC Power Relay

A time-delay relay delays application of the rectified dc to the circuits long enough for all heaters to reach operating temperature. The time delay is approximately 25 seconds. If you switch the ac power off, even briefly, the time-delay relay will delay reapplication of the dc.

Cathode-Ray-Tube Controls

The Tektronix Type T54 cathode-ray tube in this instrument has a total accelerating voltage of 10,000 volts. The spot intensity with this amount of acceleration can be bright enough to damage the screen in a short time if the spot is left in one place. Be careful not to leave a fixed bright spot or slow sweep on the screen. Turn the **INTENSITY** control counterclockwise so that the spot is dim whenever you leave the instrument unattended.

Illuminated Graticule

The adjustable graticule lighting control labeled **SCALE ILLUM**, can be adjusted to suit the lighting conditions of the room. The colored filter supplied is colored to provide the maximum trace contrast for the P2 phosphor in the presence of room light. The colored filter should be mounted next to the crt so it does not block the light from the graticule lines.

The graticule is accurately scribed in centimeters and fifths of centimeters. These scale markings and the calibrated fixed vertical-deflection sensitivities and sweep times, can be used to convert deflection in centimeters into volts and seconds. Vertical sensitivities are calibrated in volts per centimeter, and horizontal sweep-times are calibrated in seconds per centimeter, which, if multiplied by centimeters of deflection, give volts and seconds.

The graticule can be mounted in either of two positions rotated 180 degrees from each other. In one position, the graticule illumination is colored red, and in the other position in white. The white will reproduce well photographically.

Probes

Do not use the P510A Probe with an wide-band or fast-rise plug-in unit. This probe tends to ring at about 50 megacycles and the wide passband of the Type 541 Oscilloscope allows any ringing which may occur to be presented on the screen.

The Type P410 Probe, furnished with the oscilloscope, is free from ringing. This probe or any other P400-series Probe should be used with the wide-band or fast-rise plug-in units.

FUNCTIONS OF CONTROLS AND CONNECTORS

HORIZONTAL DISPLAY	Four-position switch arranges sweep circuits for four kinds of display: **MAIN SWEEP NORMAL, DELAYING SWEEP, MAIN SWEEP DELAYED** and **EXT. SWEEP.**

Main Sweep

TRIGGERING MODE (red knob)	Five-position switch arranges trigger circuits for four kinds of triggering: **AUTOMATIC, AC FAST, AC SLOW,** and **DC,** and for synchronized sweeps, **HF SYNC.**
TRIGGER SLOPE	Six-position switch selects source of trigger signal and converts to negative-going output, either negative-going or positive-going input.
TRIGGER INPUT	UHF coax connector to triggering circuits through **EXT** positions of **TRIGGER SLOPE** switch.

STABILITY (red knob)	Adjustment of multivibrator bias in region for recurrent or triggered operation.
TRIGGERING LEVEL	Potentiometer determines part of triggering waveform where sweep triggers.
TIME/CM	Eight-position switch selects timing capacitors to determine sweep speeds, and determine duration of trigger holdoff period.
MULTIPLIER	Six-position switch. Three positions place precision charging resistors in series with timing capacitors to determine sweep speeds in conjunction with selected timing capacitor. Three positions, marked in red, place adjustable charging voltages in series with timing capacitors for continuous control of sweep speeds.
5X MAGNIFIER (red knob)	Two-position switch removes or inserts feedback in sweep amplifier to change sweep speeds by a factor of five.
+GATE	Connector supplying 20-volt positive pulse via cathode follower synchronized with main sweep, duration same as sweep.
SAWTOOTH	Connector supplying 150-volt positive-going sawtooth via cathode follower synchronized with main sweep.

Delaying Sweep

STABILITY (red knob)	Adjustment of multivibrator bias in region for recurrent or triggered sweeps.
TRIGGERING LEVEL	Potentiometer determines part of triggering waveform where sweep triggers.
TIME/CM	Twelve-position switch selects twelve fixed sweep speeds.
LENGTH (red knob)	Sweep-length control permits delaying sweep to be reverted immediately after delayed main sweep is triggered to increase possible duty cycle. Normally will be left at 10 cm.
DELAY-TIME MULTIPLIER	Ten-turn helical resistor adjusts pickoff voltage on sawtooth-voltage comparator to determine timing of delayed trigger.
RESET MAIN SWEEP	Pushbutton arms main-sweep triggering circuit to accept trigger for **MAIN SWEEP DELAYED** circuit.
DEL'D TRIGGER	Connector from cathode follower supplies delayed trigger from main sweep or from delaying sweep.
+GATE	Connector via cathode follower supplies 20-volt positive pulse synchronized with delaying sweep.
SLOPE +, −	Toggle switch selects inverted or in-phase output from trigger inverter for triggering sweep-gating multivibrator, or selects polarity for external sweeps.
ATTEN, X1, X10	Toggle switch inserts or bypasses 10-to-1 compensated attenuator in delaying-sweep trigger-input circuit, or external sweep circuit.
EXT SWEEP	Continuously adjustable gain control for horizontal amplifier. Switched out of circuit for internal sweeps.

EXTERNAL SWEEP IN	Front-panel connector to horizontal amplifier through **HORIZONTAL DISPLAY** switch. Magnifier must be switched to **ON** for undistorted 10-cm deflection.
HORIZONTAL POSITION	Positions trace along horizontal axis.
VERNIER (red knob)	Fine adjustments of horizontal positioning, with 5 times the resolution of the coarse adjustment.

Other Output Waveforms

SQUARE-WAVE CALIBRATOR (red knob)	Three-position switch turns on calibrator plate voltage and switches in or out 1000-to-1 voltage divider to give either volts or millivolts output.
(black knob)	Nine-position switch selects nine taps on precision voltage divider in calibrator circuit. Provides accurate peak-to-peak voltages of .2, .5, 1, 2, 5, 10, 20, 50, and 100 volts in **VOLTS** position, or millivolts in the **MILLIVOLTS** position of the red concentric control knob.
VERT. SIG. OUT	Connector via cathode follower supplies a sample of the vertical-deflection signal.
CAL OUT	UHF coax front-panel connector from the calibrator.

Auxiliary Controls

POWER	On-off switch in primary of power transformer and ventilating-fan lead.
FOCUS	Adjustable voltage for the cathode-ray tube focusing grid.
INTENSITY	Bias adjustment to cathode-ray tube control grid.
ASTIGMATISM	Adjustable voltage for the astigmatism grid of the cathode-ray tube.
SCALE ILLUM	Adjustable series resistor controls voltage across graticule lights.

Beam-position indicators, unlabeled, marked with arrows. The arrow nearest the illuminated indicator shows which way the beam is off the screen if it cannot be seen.

Rear of Cabinet

CRT CATHODE	Binding post connects to crt cathode through high-voltage capacitor. Input impedance 8 k to 15 k. Discharge time constant about 15 milliseconds.

FIRST-TIME OPERATION

Control Settings

First get a trace on the screen with the main sweep by the simplest method, and then proceed with the presentation you want after you get an idea of the functions of the controls. To get a simple trace on the screen, insert a preamplifier, for example the 53K/54K, and proceed as follows:

Turn the **POWER** switch to **OFF.** Connect the power cord to a source of 117-volt, 60-cycle power. Then set the front-panel controls as follows:

INTENSITY	Counterclockwise (CCW)
FOCUS	Center
ASTIGMATISM	Center
POWER	**ON**

Main Sweep

TRIGGERING LEVEL	CCW
STABILITY (red knob)	CW
TRIGGER SLOPE	+INT
TRIGGERING MODE (red)	**AUTOMATIC**
TIME/CM	**100 MICROSEC**
MULTIPLIER	**2**
HORIZONTAL DISPLAY	**MAIN SWEEP NORMAL**

Delaying Sweep

TRIGGERING LEVEL	Center
STABILITY	CCW
HORIZONTAL POSITION	Center
SQUARE-WAVE CALIBRATOR	**5**
VOLTS, MILLIVOLTS, OFF	**VOLTS**

Connect a lead between the **CAL OUT** terminal and the **INPUT** terminal of the 53K/54K unit. Set the controls of the 53K/54K unit as follows:

INPUT SELECTOR	**INPUT A, AC**
VOLTS/CM	**2**
VARIABLE (red)	Clockwise
VERTICAL POSITION	Center

When the **POWER** switch has been turned on for about one minute, turn the **INTENSITY** control clockwise until you can see a trace on the screen. With the calibrator waveform displayed, you can set the **FOCUS, INTENSITY** and **ASTIGMATISM** controls for a sharp line, and position the trace near the screen center with the **HORIZONTAL POSITION** and **VERTICAL POSITION** controls.

Triggering Modes

1. **Automatic**

The triggering method just described is the **AUTOMATIC** mode of triggering. This is about the simplest mode of triggering. It is useful for general-purpose viewing, and will operate satisfactorily for a wide variety of trigger signals whose repetition rates are between sixty cycles and about two megacycles.

2. **AC Slow**

When you have a good, well focused trace of the calibrating waveform by the **AUTOMATIC** mode of triggering, try the other four **TRIGGERING MODE** switch positions. Turn the switch to the **AC SLOW** positions. Advance the **STABILITY** control until the sweep free runs and back it off about ten degrees. Advance the **TRIGGERING LEVEL** control clockwise until you get a stable trace again. There may be a considerable range of the **TRIGGERING LEVEL** control over which you can get a stable trace, and the start of the trace will move up and down the edge of the square wave within this range. Notice that the trace starts on the upgoing part of the calibrator square wave.

Now turn the **TRIGGER SLOPE** switch to the **—INT** position, and readjust the **TRIGGERING LEVEL** to obtain a stable trace again. Notice now that the trace starts on the down-going portion of the trace and that the position of the start can again be changed somewhat with the **LEVEL** control.

3. **DC Triggering**

Now turn the **TRIGGERING MODE** switch to **DC**. Adjust the **LEVEL** control for stable triggering, and then position the trace with the vertical positioning control. You will notice that triggering occurs at a vertical level on the screen selected by the **LEVEL** control, and that the triggering point changes relative to the waveform as the waveform is positioned vertically. This effect will be more noticeable if you look at a low-frequency sine wave.

4. **AC Fast**

In the **AC FAST** position of the **TRIGGERING MODE** switch, the circuit is quite similar to that in the **AC SLOW** position, and you will notice no difference when displaying the calibrator waveform. The only difference is that an rc filter is inserted in the circuit, making it insensitive to low frequencies, and allowing it to recover quickly from dc level changes. This is the position to use when there is hum present. This is also the best position to use with the alternate sweep feature of the 53/54C unit if you use INTernal triggering with signals having frequency components above 10 kc.

5. **HF Sync**

The **HF SYNC** position of the **TRIGGERING MODE** switch is primarily for signals having a repetition rate in excess of ten megacycles. In this position the sweep will trigger poorly, if at all, on the calibrator waveform. To trigger on a high-frequency signal, simply advance the **STABILITY** control until a stable trace is obtained. The **LEVEL** control is not used in this position.

TRIGGERING INSTRUCTIONS

General

The Type 545 triggering system is very flexible and stable. However, if you are not familiar with the **TRIGGERING LEVEL** control used on this instrument, you will need to distinguish between its operation and that of the trigger amplitude control used on some other Tektronix oscilloscopes.

Triggering Level

The **TRIGGERING LEVEL** control selects the point on the triggering waveform at which triggering will occur. To trigger on small signals this control must be set near 0, or near the dc level with dc triggering. The levels are indicated on the panel as positive to the right and negative to the left. Negative positions of the **LEVEL** control cause triggering to occur during negative level of the triggering waveform and positive positions cause triggering during positive levels. This control is not used in the **AUTOMATIC** and **HF SYNC** positions of the **TRIGGERING MODE** switch.

Trigger Slope

The + positions of the **TRIGGER SLOPE** switch (black knob) cause triggering to occur during the rising portion of the triggering waveform. The level may be either negative or positive. The — positions cause triggering to occur during the falling portion of the waveform. Thus for slow rising waveforms such as sine waves, the triggering point can be caused to occur at almost any point in the waveform.

An additional function of the **TRIGGER SLOPE** switch selects the source of trigger signals. For each of the available signal sources, the switch provides a choice of positive or negative slope.

Triggering Mode

The **TRIGGERING MODE** switch arranges the circuits to provide the kind of triggering you need. This is the red knob and the positions it selects are labeled in red on the panel.

Slowly changing waveforms work best on the **AC SLOW** and **DC** positions. In the **AC SLOW** position, a capacitor removes the dc component of the triggering waveform and makes triggering on the vertical signal independent of trace position. This position is suitable for signals from twenty cycles up to about five or ten megacycles. The **DC** position is the same except that it responds to dc as well. In the **AC FAST** position, the circuit includes an rc filter, useful for preventing 60-cycle, or other low-frequency components, from triggering the sweep when both high- and low-frequency components are present in the triggering waveform. The low-frequency limit is about two kilocycles. In these three positions, if the **STABILITY** control is properly set, the sweep will not run unless triggered by a signal.

The **AUTOMATIC** and the **HF SYNC** switch positions both arrange synchronizing circuits, rather than strictly triggering circuits. The **AUTOMATIC** circuit provides a free-running multivibrator having a normal repetition rate of about 50 cycles. This locks in, and runs synchronously with, recurrent triggering waveforms from

60 cycles to about 2 megacycles. The synchronized multivibrator then triggers the sweep-gating multivibrator.

The **HF SYNC** switch setting arranges a circuit which connects the triggering source directly to the sweep-gating multivibrator so that it can synchronize with the triggering waveform. The sweep-gating multivibrator must be free-running for this type of operation. It free-runs at advanced settings of the **STABILITY** control. It will synchronize with signals whose frequencies are as high as 30 megacycles, at a sweep-repetition rate up to 200 kilocycles.

Stability

The **STABILITY** control adjusts bias level on the sweep-gating multivibrator near the level at which it will free-run. Three principal settings of the **STABILITY** control are used; the first setting is with the control advanced to the right, just past the point where the sweep-gating multivibrator free-runs; second, retarded to the left about 5 or 10 degrees from the point where the free-running ceases; and third, retarded all the way to the left, to make the multivibrator inoperative.

For synchronized operation of the sweep-gating multivibrator, as used in the **HF SYNC** position, set the **STABILITY** control to the advanced position so that the sweep just free-runs, and keep it to the right of this point while adjusting its position to synchronize the sweep.

For all triggered operations, the **STABILITY** control should be retarded to the left from the free-run point 5 to 10 degrees. Note that in the **AUTOMATIC** mode the **STABILITY** control is replaced by an internal control which is preset for optimum triggering.

SWEEP OPERATION

The four positions of the **HORIZONTAL DISPLAY SELECTOR** arrange for the horizontal deflection of the beam by the main sweep, the delaying sweep, the main sweep delayed, or by an external sweep signal.

Main Sweep Normal

For the **MAIN SWEEP NORMAL** position of the **HORIZONTAL DISPLAY SELECTOR** only the main-sweep is displayed. Triggering can be produced from the displayed signal internally, or external trigger signals can be connected to the upper **TRIGGER INPUT** connector.

Delaying Sweep

In the **DELAYING SWEEP** position, the sawtooth that is normally used to delay the main sweep is connected to the horizontal amplifier to provide the sweep. This delaying sweep can only be triggered by applying a trigger to the **TRIGGER** connector near the delaying sweep controls. This trigger signal can be obtained from an external source or a test lead can be connected from the **TRIGGER** connector to the **VERT. SIG. OUT** connector to trigger the delaying sweep on the vertical signal. The **SLOPE, +, —,** switch selects the desired slope and the **ATTEN X10** toggle switch provides attenuation if desired. Other triggering adjustments operate the same as for the main sweep.

Main Sweep Delayed

Display the waveform you want to observe with the delaying sweep. Set the **DELAY-TIME MULTIPLIER** control to **2** or **3**, and set the main-sweep **TIME/CM** several times faster than the delaying sweep time. Switch to **MAIN SWEEP DELAYED** and adjust the main sweep triggering circuits until the main sweep runs recurrently, and switch back again to the delaying sweep. When the main sweep operates it brightens the trace while it runs.

The brightening helps determine what part of the waveform displayed by the delaying sweep will be displayed by the delayed sweep. Increasing the main-sweep speed narrows the brightened portion, and increasing the **DELAY-TIME MULTIPLIER** control clockwise moves the brightened portion to the right. If desirable, adjust the delaying-sweep **LENGTH** control until the delaying sawtooth stops just after it passes the brightened portion of the trace. This causes the delaying sawtooth to revert after the main-sweep sawtooth reverts, and also increases the possible duty cycle of the main sweep.

Triggered Delayed Sweeps

Now if you back the **STABILITY** control to the left a little more the delay trigger signal will not trigger the main sweep, but will arm it for trigger signals connected into the main-sweep trigger input circuit, and permit you to display delayed signals without jitter, even if the signal itself does jitter. The **HF SYNC** triggering mode is not suitable for this operation.

Single Sweeps (Reset Main-Sweep Control)

The **RESET** button provides a means of obtaining a single sweep. Depending on the setting of the main-sweep **STABILITY** control, this sweep can occur immediately when the button is depressed or the sweep will wait until it is triggered, at which time only one sweep will occur.

Turn the delaying-sweep **STABILITY** control counterclockwise and leave the other controls as set for main-sweep-delayed operation. Depress the **RESET** button. If the main-sweep **STABILITY** control is set to the position where it requires no trigger, there will be a single trace. If it is backed off to the position where it requires a trigger the **READY** indicator will light, indicating that the trigger circuit is armed and waiting for a trigger. Upon the occurance of a trigger, there will be a single sweep and the ready light will go out.

External Sweep

Switch the **HORIZONTAL DISPLAY** control to **EXT SWEEP** and turn the **5X MAGNIFIER** to **ON**. Connect the source of external horizontal signal to the **EXT SWEEP IN** connector. The signal can then be attenuated by the **10X** attenuator and inverted by the **SLOPE** switch, or continuously adjusted by the **EXT SWEEP ATTEN** control. There should be no dc component to the external sweep signal. If there is, the continuous gain adjustment will also position the trace horizontally, and may move the signal out of range of the **HORIZONTAL POSITION** control.

Because this amplifier was designed for optimum performance with a sawtooth, its performance with sine waves is limited. This sine-wave limitation can best be defined by an amplitude-frequency product, which can be exceeded only at the expense of considerable distortion. The amplitude-frequency product is 2.4 centimeter-megacycles. Thus a full 10 centimeters of deflection can be used at 240 kc, and a 2.4-mc sine wave can be viewed if the amplitude is one centimeter peak to peak or less. The amplifier frequency response to a sine wave is down less than 30% at 800 kc when the amplitude is within this limitation.

Main-Sweep Time/CM and Multiplier

These controls determine the speed of the horizontal trace. The time per centimeter of horizontal deflection is equal to the product of the **MULTIPLIER** setting and the **TIME/CM** setting. Times per centimeter from .1 microsecond to 1 second in steps of 10 can be selected with the **TIME/CM** switch, and accurate fixed multipliers of 1, 2, and 5 times can be selected with the **MULTIPLIER** switch. The sweep times so selected can be depended on within three per cent of their indicated value. The variable sweep time positions can be checked at the limits of the 2.5-to-1 times, and 5-to-2 times positions against the accurate fixed multipliers, to improve their accuracy.

Magnifier

This control inserts or removes a feedback network in the sweep amplifier that changes the gain five times. The linearity of the amplifier is somewhat better when the feedback circuit is included. The center one fifth of the trace is expanded to fill the graticule when the magnifier is switched on. When you use the sweep magnifier to realize the fastest sweep time, .02 microseconds per centimeter, the linearity is reduced from three per cent to about five per cent.

Delaying-Sweep Time/cm

The delaying-sweep **TIME/CM** control provides twelve fixed sweep speeds. The **LENGTH** control provides a means of adjusting the sweep length from four to ten centimeters. If it is desired to measure the time between two points on the trace, this time can normally be read directly from the graticule. However, if slightly greater accuracy is required, you can use the **DELAY TIME MULTIPLIER** dial. Set the main sweep to run several times faster than the delaying sweep and advance the main-sweep **STABILITY** control so it is triggered by the delaying sweep. When start of the brightened portion of the delaying sweep trace corresponds with the point you wish to measure, the **DELAY TIME** and **DELAY TIME MULTIPLIER** dials will read the time from the start of the trace to the point you wish to measure.

The accuracy of any particular range can be maximized by adjusting the DELAY START and DELAY STOP controls on that range as explained in the maintenance section of this manual.

AUXILIARY FUNCTIONS

Square-Wave Calibrator

Accuracy of the open-circuit voltage of the calibrator is within 3 per cent of the indicated voltage . However, since the output impedance at the **CAL. OUT** terminal varies with the setting of the voltage selector switch, you must be careful that the load impedance you connect it to does not change the output voltage. The output impedance varies between about 100 ohms over the millivolt range to about 5000 ohms at the 50-volt tap. Except at the 100-volt tap, the output voltage depends on the division ratio of a voltage divider. Any appreciable change in impedance of the shunt leg of the divider will therefore reduce the output approximately in proportion to the reduction of impedance. The 1-megohm input impedance of the Type 545 will cause no appreciable change in voltage at any setting of the selector switch. At the 100-volt tap, the output impedance is that of the cathode follower, about 250 ohms.

The rising portion of the calibrator waveform follows an rc charge curve with a time constant such that it requires about 1 microsecond to reach 90 per cent of the peak. Millivolt settings provide a slightly better rise time of about 0.7 microseconds to the 90 per cent point. Reactive loads will affect these times.

The frequency of the calibrator multivibrator is nominally 1000 cycles, but may vary 30 per cent either way. Do not use it for more than a rough check of sweep-timing accuracy.

Trigger Rate Generator

The delaying-sweep generator can be used as a trigger-rate generator by advancing the **STABILITY** control to the free-run position and using the **+ GATE** from the delaying sweep as the trigger output. The trigger rate can be varied from 10 cps to 40 kc by the delaying-sweep **TIME/CM** and **LENGTH** controls.

Trace-Brightness Modulation

To couple time markers into the cathode circuit for brightness modulation, disconnect the ground strap at the rear of the instrument and connect the source of modulating voltage to the **CRT CATHODE** post. A peak-to-peak voltage of about 50 volts is required to turn the beam on and off. Input impedance is 8 k to 15 k, depending on the **INTENSITY** control setting. The circuit is ac coupled through a high-voltage capacitor, discharge time constant about 15 milliseconds.

Direct Connection to Deflection Plates

A plastic plate is attached to the neck of the crt for your convenience in mounting hardware for direct connections to the deflection plates. This plate is accessible when the left side panel is removed. Holes can be drilled in this plate for wire guides or for mounting coaxial connectors. The two pins on the left-hand side of the crt neck are the vertical deflection plates.

To avoid distortion the average dc potential on these plates should be 300 volts. If you use a different voltage the distortion can be minimized by adjusting the GEOM. ADJ. control at the rear of the sweep chassis.

Unless dc coupling is required, connect coupling capacitors in series with the leads to the deflection plates and connect one-megohm resistors from the deflection plates to the leads from the vertical amplifier. With this connection the plates are maintained at the proper operating potential and positioning control is retained by the front-panel controls.

Vertical Signal Out

The signal applied to the vertical amplifier is available at the front-panel **VERT. SIG. OUT** binding post. A signal which will cause one centimeter of deflection will produce a signal of about two volts, peak to peak, at the binding post. The signal is applied to the binding post at a relatively low impedance from a cathode follower. The passband is dependent on the external load. With a one megohm resistor shunted by a 50 $\mu\mu$f capacitor as a load, it extends from about 20 cycles to 4.5 megacycles at the 3-db points. Without the capacitive load the high-frequency 3-db point is extended to about 6 megacycles.

FUNCTIONAL BLOCK DIAGRAM

General

The functional block diagram shows the functional relationships of the basic elements of the sweep system. A four-position switch in the center of the diagram, labeled **HORIZONTAL DISPLAY**, sets up the circuits for the four kinds of sweep operation. The four positions of the switch are labeled **MAIN SWEEP NORMAL, MAIN SWEEP DELAYED, DELAYING SWEEP,** and **EXT. SWEEP.**

Horizontal Display Selector

When the **HORIZONTAL DISPLAY** switch is in the **MAIN SWEEP NORMAL** position, the triggered main sweep circuit shown in the upper half of the diagram, moves the cathode-ray spot across the screen in the normal manner.

When the switch is in the **DELAYING SWEEP** position, the triggered delaying sweep circuit, shown in the lower half of the diagram, moves the cathode-ray spot across the screen in the same manner as the main sweep.

When the switch is in the **MAIN SWEEP DELAYED** position both the main sweep circuit and the delaying sweep circuits run. The delaying sweep starts first and starts the main sweep later. There are two modes of operation in which the main sweep is delayed.

Delayed Sweeps

In one mode the delaying sweep receives the external trigger signal while the main sweep receives its trigger signal later from the delaying sweep, and the main sweep then moves the cathode-ray beam across the screen. The trigger signal for the main sweep in this mode is derived from the delaying sweep at the instant the delaying-sweep sawtooth reaches a level determined by the adjustment of the delay-pickoff circuit.

In the second mode of delayed-sweep operation, both the main sweep and the delaying sweep run, as in the first mode, but in this mode the main sweep is triggered by a selected external trigger signal. All trigger signals except the desired one are locked out until a signal from the delaying sweep opens the trigger circuit into the main sweep. Then the next external trigger signal that comes along will trigger the main sweep. The circuit into the main sweep is completed when the gating circuit is opened by the delay-pickoff signal. The delay-pickoff signal originates when the delaying-sweep sawtooth reaches the level determined by the adjustment of the delay-pickoff circuit.

Trace Brightening

The cathode-ray beam is kept turned off when a sweep is not moving the beam across the screen. When a sweep is in process the beam is turned on by an unblanking signal that lasts only as long as the sweep and then turns the beam back off after the sweep is completed. If both sweeps are running, each produces its own unblanking signal and both unblanking signals help to turn on the beam. The main-sweep unblanking pulse makes a brighter trace than the delaying-sweep pulse.

The difference in brightness for the two pulses is useful for finding out where to set the delay-pickoff circuit to display the part of a signal you want to examine. To make use of this characteristic, display the signal with the delaying-sweep and adjust the delay-pickoff circuit so that the brightening that occurs brightens the place on the trace you want to examine. Then adjust the speed of the main sweep so that the brightening covers the amount of trace you want to examine, and display the signal with the main sweep delayed. The part of the trace you have brightened will then be clear across the screen.

External Sweeps

When the **HORIZONTAL DISPLAY** switch is in the **EXT. SWEEP** position, any signal connected to the **TRIGGER** binding post will move the cathode-ray spot back and forth across the screen. There is a continuous unblanking signal with this switch setting so that the spot is visible all the time. The arrangement is useful for displaying Lissajous figures and for similar applications not requiring a linear sweep.

SIMPLIFIED SWEEP DIAGRAMS

Main-Sweep Simplified Diagram

The trigger signal is normally coupled to the multivibrator by way of the main-sweep trigger amplifier. The trigger signal trips the multivibrator, which sends a negative gate through the disconnect diodes to two points on the sweep generator. The sweep generator makes a positive-going sawtooth that is amplified and used to sweep the beam across the cathode-ray tube.

The speed of the sawtooth depends on the capacitance of the timing capacitor and the resistance of the charging resistor. The height of the sawtooth depends on the setting of the sweep length adjustment. A portion of the sawtooth voltage is coupled back to the multivibrator control grid via the sweep-length and holdoff tubes, where it reverts the multivibrator and turns the sawtooth generator off.

Quiescent bias on the multivibrator is determined by the dc level of the stability cathode follower, which depends on the **STABILITY** control setting. The purpose of this control is to set the multivibrator bias near enough to triggering that the input trigger will trigger it. If the bias is lowered still further, the multivibrator will trigger itself again as soon as it is reverted, and run recurrently.

When used in delayed-trigger operation, the stability tube is combined with a second tube to form a bistable gate generator which can either trigger the multivibrator or place it near the point of triggering during its second stable state. The bistable gate generator is triggered by the delayed trigger to the second stable state where it remains until the main sweep reverts it and itself at the same time.

With low settings of the **STABILITY** control, during this period, the multivibrator will respond to trigger signals from the main-sweep trigger amplifier, but will not respond during the previous period when it is in the first stable state. Triggering of the main sweep is therefore held off until the delay trigger arrives and arms the main sweep.

With higher settings of the **STABILITY** control, the multivibrator will be triggered during the transition to the second stable state at the time of the delay-trigger signal. No trigger signal would normally be connected through the main-sweep trigger amplifier for this type of operation.

Delaying Sweep Simplified Diagram

The delaying-sweep circuit is similar to the main-sweep circuit. The trigger signal to the multivibrator control grid is coupled through the stability cathode follower. The sweep-length cathode follower operates in parallel with the stability tube, and is cut off until the sawtooth reaches the grid voltage of the stability tube. The sweep-length control determines the amplitude and dc level of the sawtooth voltage at the grid of the sweep-length tube. This control is the red knob concentric with the **TIME/CM** switch, labeled **LENGTH** in red on the front panel.

Delay-Pickoff Simplified Diagram

The delay pickoff generates a trigger when the delaying-sweep sawtooth reaches a prescribed level, determined by the **DELAY TIME** control setting. The delay comparator has the pentode section conducting until the sawtooth raises the triode grid above the pentode grid. The positive plate pulse, generated when the pentode cuts off, triggers the delay-trigger shaper. The **DELAY TIME** control can adjust the bias of the comparator over the same range as the delay sawtooth.

CIRCUIT DESCRIPTION

BLOCK DIAGRAM

The Block Diagram shows interconnections of the functional parts of the oscilloscope, except the power supplies. Functions of the switches are shown instead of their actual connections.

Vertical Amplifier

Plug-In Preamplifiers

In the upper left of the Block Diagram is shown the vertical-deflection system. The block labeled "Plug-Ins" represents one of the plug-in preamplifiers available. Connections for power in and signal out are made through a multiple-contact mating plug and socket. Output from these units is push-pull at low impedance.

Main-Unit Amplifier

The main-unit amplifier amplifies the signal and drives the delay line which terminates in the vertical deflection plates. The trigger pickoff circuits obtain a sample of the vertical signal for triggering the sweep.

Delay Line

The balanced, 50-section delay line adds .2 microseconds of delay to the signal so the sweep circuits will have time to get the cathode-ray spot unblanked and sweeping before the signal reaches the vertical deflection plates.

Trigger Cathode Followers

The trigger signal from the main-unit amplifier passes through two cathode followers. The first applies the signal at low impedance to the trigger amplifier and the second connects to the front-panel **VERT. SIG. OUT** binding post.

Main Sweep

Trigger Phase Inverter

This stage provides either in-phase or inverted output so as to provide negative-going output for either negative-going or positive-going input signals.

Trigger Shaper

The trigger-shaper makes a sharp pulse from the trigger signal at a time during the sloping part of the trigger signal determined by the setting of the triggering-level control. A sharpened negative-going pulse triggers the multivibrator.

Multivibrator

The multivibrator turns on the sweep generator and generates the cr-tube unblanking pulse when it is switched from its quiescent state. The sharp negative-going trigger signal from the trigger-shaper circuit trips the multivibrator, which thereafter stays in the second state until the sweep generator reverts it to its quiescent state.

Stability and Delayed-Trigger CF

When the main-sweep-normal function is in operation this circuit adjusts the dc level of the input grid of the gating multivibrator. When the delayed-trigger function is in operation the circuit sets the dc level and also amplifies the delayed trigger to trigger the multivibrator or sets a dc pedestal that places the multivibrator input grid within range of the main-sweep trigger signals.

Sweep Generator

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

Trigger Holdoff

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

Sweep Amplifier

The sweep amplifier converts the sawtooth output of the sweep generator into push-pull output at low impedance at the level required to sweep the beam across the cr-tube screen. The amplifier gain can be increased by a factor of five for sweep magnification. The horizontal-positioning control operates on this stage.

Delaying Sweep

The delaying sweep has essentially the same circuit elements as the main sweep. The phase inverter selects in-phase or inverted signals by means of a toggle switch. The trigger-shaper stage makes sharp pulses that trigger the multivibrator. The multivibrator turns on the sweep generator and is reverted by the sweep generator through a holdoff circuit.

Unblanking

Each multivibrator generates a positive unblanking pulse at the same time that it turns on the sweep generator. The main-sweep pulse is several volts higher than the delaying-sweep pulse and therefore brightens the trace more than the delaying sweep pulse. The pulses are transmitted to the crt grid by separate cathode followers with the same cathode resistor.

External Sweep Amplifier

The external-sweep amplifier uses the same tubes as the delayed-sweep trigger-inverter stage. One position of the **HORIZONTAL DISPLAY SWITCH** arranges the circuits so the amplified signal is connected to the sweep-output amplifier. A ten-to-one fixed attenuator and a continuous control of amplifier gain provide 100-to-1 adjustment of horizontal-deflection sensitivity.

Calibrator

The calibrator has no internal connection to the vertical amplifier system. It consists of a symmetrical multivibrator with a cathode-follower output tube whose cathode resistor is a calibrated voltage divider.

VERTICAL DEFLECTION SYSTEM

General

The vertical amplifier of the Type 545 Oscilloscope has separate preamplifier units that can be plugged into the main unit. These units provide a variety of passbands and sensitivities and allow for future developments in preamplifiers.

The plug-in units develop balanced push-pull output which is maintained push pull throughout the remainder of the amplifier. The units contain sensitivity adjustments and positioning controls.

Signal connections to the vertical amplifier in the main unit are made by means of terminals in a mating multiple-contact plug and socket. Power connections from the main unit are made through other connectors on the same plug-and-socket assembly.

Type 53/54K Preamplifier

The Type 53/54K preamp is capable of utilizing the full 30-mc pass band of the main-unit amplifier. It includes an input attenuator and a vertical positioning control. Power for all circuits as well as the tube heaters is obtained from the main-unit regulated dc supplies.

Main-Unit Input Stage

Signal input from the preamp is connected through terminals 1 and 3 to the grids of input amplifiers V1052B and V1040B. The cathodes of these two tubes are connected together through the degenerative network, R1026, R1027 and R1028. R1027 labeled GAIN ADJ. is variable to allow the amplifier gain to be varied over a small range. L1022 and L1041 provide series peaking and L1021 and L1042 provide shunt peaking for the stage. Triodes V1050A and V1052A provide the low impedance necessary for driving the distributed-amplifier grid line.

Beam-Position Indicators

Triodes V1025A and V1040A have as their plate loads neon glow lamps B1010 and B1014 across 1-megohm resistors. When the trace is centered, the plate current is insufficient to ignite these lamps, but as the trace is positioned off the screen vertically the current through one triode will increase causing the corresponding lamp to glow showing which way the trace is off the screen.

Trigger Pickoff

The trigger pickoff tubes, V1060 and V1066, convert the push-pull vertical signal on the distributed-amplifier grid lines to single ended output without disrupting the balanced configuration of the grid lines. The trigger cathode follower supplies the amplified vertical signal at low impedance to the oscilloscope trigger circuits and to the vertical-signal-out cathode follower. This cathode follower applies a sample of the vertical signal, somewhat limited in pass band, to the front-panel binding post labeled **VERT. SIG. OUT.**

DC-Shift Compensation

DC-shift compensation is accomplished in two ways and corrects for two different time constants. The series combination of R1080 and C1045B on plate line L1080, and R1084 and C1050B on plate line L1083, lowers the termination resistance of these lines to all but the very low frequencies. They provide a time constant which corrects for the initial dc shift in the amplifier. The second time constant is corrected by R1045 and C1045A and R1050 and C1050A. These rc networks have a negligible loading effect on the distributed-amplifier plate lines, but provide low-frequency positive feedback to the input-amplifier plates. This feedback corrects for the longer-time-constant dc shift. R1059, labeled DC SHIFT COMP. permits the amount of compensation to be adjusted to accommodate tube differences.

Distributed Amplifier

The output amplifier is a six-section, balanced, distributed amplifier. The grid lines are driven by V1050A and V1052A through rc frequency-compensating networks. The plate lines, L1080 and L1083, drive the delay line directly. Each section of the plate lines is tuned for optimum response to a square wave by trimmers connected line to line.

Termination Network

Unless the plate lines are terminated at the reverse end with a resistance equal to their characteristic impedance, signals traveling the reverse direction down the line will be reflected and appear in the output. Since resistors are not available, in a suitable power rating, which appear resistive over the wide pass band of the Type 545, an adjustable terminating network is used. The coils, L1070 and L1071, are wound with resistance wire and have a total resistance of 595 ohms. Each section has a characteristic impedance which is approximately equal to the impedance of the plate lines less the series dc resistance between it and the plate lines.

Calibrator

The calibrator is a symmetrical multivibrator with V670A and V670B connected so as to turn cathode follower V246A on and off as it oscillates. During the negative pulse at multivibrator V670A, the grid of the cathode follower is driven well below cutoff, so the cathode is at ground voltage. During the positive pulse at the multivibrator the plate is cut off and rests slightly below +100 volts. The voltage of the plate during cutoff is determined by the setting of R679, part of a divider between +100 volts and ground. R679 is a screwdriver adjustment labeled CAL. ADJ. Cathodes of the multivibrator are returned to —150 volts. The multivibrator frequency is about one kilocycle.

Cathode follower V246A has a tapped calibrated voltage divider for its cathode resistor. When the CAL. ADJ control is properly set, the cathode-follower cathode is at +100 volts when V670A is cut off. Taps on the divider divide the 100 volts down to 50, 20, 10, 5, 2, 1, .5 and .2 volts. A second divider with a division ratio of 1000 to 1, can be switched in if desired to divide these voltages into millivolts. C682 from the cathode to ground corrects a slight overshoot. No internal connection from the calibrator to the vertical-deflection circuits is provided.

MAIN-SWEEP CIRCUITS

Trigger Amplifier

The **TRIGGER SLOPE** switch selects the source of triggering voltage and arranges the trigger-amplifier input circuit to produce negative-going output for either negative-going or positive-going portions of the input signal.

The trigger amplifier, V8, is a grounded-grid cathode-coupled linear amplifier. A capacitor, C3, can be switched into the grid circuit to remove the dc component of the trigger signal. Output is always taken from the A-section plate, but the **TRIGGER SLOPE** selector connects either the A-section grid or the B-section grid to the input signal source. For positive-going signals, connection is made to the A-section grid, and for negative-going signals, connection is made to the B-section grid, and in each case the opposite grid is connected to an adjustable dc bias source, adjustable by means of the **TRIGGERING LEVEL** control. R14, adjusts the bias on one half or the other of V8 to adjust the dc level of the A-section plate output. The dc level of the plate output is important to the circuit operation in three of the five positions of the **TRIGGERING MODE** switch because in these three switch positions the input grid to the trigger shaper stage, V20A, is dc coupled to the plate of V8. The effect of the dc level is shown in a later paragraph.

Triggering Mode Switch

The **TRIGGERING MODE** switch, SW5, has five positions marked in red in the upper right-hand corner of the instrument panel: **DC**, **AC SLOW**, **AC FAST**, **AUTOMATIC**, and **HF SYNC**. This switch arranges the circuits of the trigger-amplifier and trigger-shaping stages to accomodate the five types of triggering.

DC, AC Slow and AC Fast

When the **TRIGGERING MODE** switch is in the **DC** position, the triggering signal is direct coupled through the trigger amplifier so that the dc component of the signal is applied to the trigger shaper. In the **AC SLOW** position, C3 removes the dc component of the signal, and in the **AC FAST** position, C4 and R6 form an rc filter to remove the low-frequency