NOTE

A nomenclature change has been introduced for the 5000 Series products. The 5103N/D13 is now called the 5113 Dual Beam Storage Oscilloscope.

This composite manual incorporates the 5103N and D13 manuals, formerly bound under separate cover.

TEKTRONIX®

5113 DUAL BEAM STORAGE OSCILLOSCOPE

INSTRUCTION MANUAL

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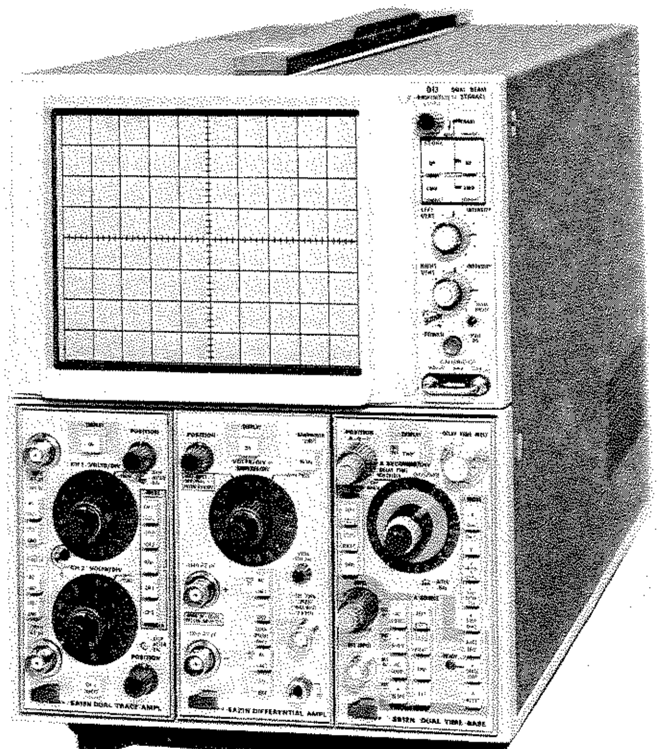

Fig. 1-1. 5103N Oscilloscope with a Dual-Beam Display Unit.

SECTION 1
OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

D12 and D13 General Description

The D12 Dual Beam Display Unit or the D13 Dual Beam Storage Display Unit provides a dual-beam cathode-ray tube (CRT) display for Tektronix 5100-series oscilloscopes. Either module is operated with a power supply/amplifier module, and comprises one-half of the oscilloscope mainframe. It has an electrostatic-deflection CRT with an 8 X 10 division (one-half inch per division) internal black graticule. A bright display is provided by a 3.5-kilovolt accelerating potential. Active geometry correction ensures display accuracy throughout the graticule area. Provision is made for application of Z-axis signals, and a front-panel loop provides a calibration signal.

The D13 has a direct-view, bistable storage tube with two 4 X 10 division screens, which can be independently controlled for split-screen applications. A variable Brightness control permits extended storage time and can be used to integrate fast, repetitive displays.

The electrical characteristics on page 1-5 apply over a room temperature range of 0°C to +50°C (+32°F to +90°F). Refer to the 5100-series Oscilloscope System manual for environmental characteristics.

NOTE

Reference to storage controls or storage operation in this manual applies to the D13 only.

Preliminary Information

The Operating Instruction section of the 5100-series Oscilloscope System instruction manual should be referred to for initial preparation. It contains information for installation of modules and plug-ins, correct operating voltage and temperature, and general oscilloscope usage.

CONTROLS AND CONNECTORS

This is a brief description of the function or operation of the front- and rear-panel controls and connectors. More detailed information is given under General Information.

UPPER and LOWER STORE	Button pushed in selects storage operation of associated storage screen. Button out selects normal operation without storage. Each button has push-push action and operates independently of the other.
UPPER and LOWER ERASE	Self-cancelling switch selects screen to be erased. Both buttons pushed in selects both screens.
ERASE	Momentary contact pushbutton initiates erasure of the storage display selected to be erased.
BRIGHTNESS (Y-T)	Provides continuously variable flood-gun current duty cycle from about 10% to 100%, permitting the intensity of a storage display to be varied. Permits extended retention of displayed information; also serves as an integrator for storing fast, repetitive signals.
LEFT VERT INTENSITY	Controls brightness of display associated with the left vertical plug-in unit.
LEFT VERT FOCUS	Provides adjustment to obtain a well-defined display.
RIGHT VERT INTENSITY	Controls brightness of display associated with the right vertical plug-in unit.
RIGHT VERT FOCUS	Provides adjustment to obtain a well-defined display.
POWER	Used to turn instrument power on or off.
BEAM FINDER	Brings both beams on-screen; limits displays to area inside graticule and intensifies both beams.
CALIBRATOR Loop	Provides positive-going accurate 400-millivolt and 4-milliampere square wave at a frequency of twice the line frequency for calibration and probe compensation.
LEFT VERTICAL EXT INTENSITY INPUT (Rear Panel)	Permits application of Z-axis signals to the CRT (DC coupled). Positive-going signal increases intensity of CRT beam associated with the left vertical plug-in unit.
RIGHT VERTICAL EXT INTENSITY INPUT (Rear Panel)	Permits application of Z-axis signals to the CRT (DC coupled). Positive-going signal increases intensity of CRT beam associated with the right vertical plug-in unit.
TRACE ROTATION (Rear Panel)	Permits alignment of the trace with respect to the graticule lines.

BASIC OPERATION

General

The following steps show the use of the controls and connectors of the display unit. It is recommended that this procedure be followed completely for familiarization with this instrument.

Preparation

1. Make sure the oscilloscope system is complete. The display unit must be properly connected to the power supply/amplifier module and the dual-beam auxiliary board must be installed on the plug-in interface board. A 5A-series amplifier plug-in should be in each vertical (left and center) compartments, and a 5B-series time-base plug-in should be in the horizontal (right) compartment.

Turn On Procedure

Follow this procedure when first receiving the instrument and when it has been turned OFF for two weeks or more.

Turn BRIGHTNESS control fully CW.

Place the push-push STORE switches (UPPER & LOWER) in the depressed position. Turn the power ON and note that after a short delay the screen will become fully illuminated. Leave the instrument in this mode for 5 minutes before erasing or going to non-store mode.

This procedure reduces the ion content in the CRT and maximizes life.

2. Set the POWER switch off (push in) and connect the display unit to a power source that meets the voltage and frequency requirements of this instrument. See Operating Voltage (Preliminary Procedure) in the Operating Instructions section of the 5100-series Oscilloscope System manual.

3. Turn both INTENSITY controls counterclockwise and pull the POWER switch out to turn the instrument on. Set the front-panel controls as follows:

Display Unit (D12 or D13)

FOCUS (both)	Centered
UPPER and LOWER STORE	Non-store (buttons out)
BRIGHTNESS (Y-T)	Clockwise

Amplifier Plug-ins (both)

Display	On
Position	Centered
Volts/Div	.2
Variable Volts/Div	Cal (fully clockwise)
Input Coupling	DC

Time-Base Plug-in

Display	Alternate (button out)
Position	Centered
Seconds/Div	5 ms
Variable Seconds/Div	Cal (fully clockwise)
Sweep Magnifier	Off
Trigggering Level	Counterclockwise
Triggering Source	Dis Play (Left and Right button in)
Triggering/Sweep Mode	Auto Trig, DC Coupling, +Slope, Normal Sweep

4. Advance the INTENSITY controls until the traces are at the desired viewing level. The traces should appear near the graticule center.

5. Apply a signal from the CALIBRATOR loop to the input connectors of both amplifier plug-ins through a 1× probe or test lead and a dual input cable.

6. Turn the Triggering Level control clockwise until a stable display is obtained. Adjust the vertical and horizontal Position controls so the left vertical display is in the top half of the graticule area and the right vertical display is in the bottom half, and the displays start at the left edge of the graticule.

7. Adjust the FOCUS controls for sharp, well defined displays over the entire trace length.

8. Disconnect the input signal and position either trace vertically so it coincides with the center horizontal line of the graticule.

9. If the trace is not parallel with the center horizontal line, see Trace Adjustment in this section.

Calibration Check

10. Set the Volts/Div switches of both vertical plug-ins to .1, and move both traces two divisions below graticule center. Reconnect the calibration signal to the input connectors of both vertical amplifier plug-ins.

11. The display should be four divisions in amplitude with six complete cycles (five complete cycles for 50-hertz line frequency) shown horizontally. An incorrect display indicates that the oscilloscope mainframe or plug-ins need to be recalibrated.

12. Rotate the RIGHT VERT INTENSITY control counterclockwise and set the time-base Triggering Source to Left.

NOTE

The remainder of the procedure is performed using the Left Vertical controls only, since just one display is needed to demonstrate the remaining control functions.

Beam Finder

13. Move the display off-screen with the left vertical amplifier Position control.

14. Push the BEAM FINDER button and observe that the display compresses into the screen area. Reposition the display to screen center and release the BEAM FINDER button.

External Intensity Input

15. Move the calibrator signal from the amplifier plug-in input connectors and apply it to the LEFT VERTICAL EXT INTENSITY INPUT connector on the rear panel.

16. Set the Triggering Source to Line and slowly rotate the LEFT VERT INTENSITY control counterclockwise until the trace appears to be a series of dimmed and brightened segments. The brightened segments correspond with the tops of the calibrator square waves.

Storage Operation

17. Move the calibrator signal from the EXT INTENSITY INPUT connector to the left vertical amplifier plug-in unit input connector.

18. Set the Triggering Source to Left, turn the LEFT VERT INTENSITY control counterclockwise and press both the UPPER and LOWER STORE buttons. A background light level will be present on the storage screen.

19. Simultaneously press both the UPPER and LOWER ERASE screen-selector buttons and push the ERASE button to erase both screens and prepare the targets for storage.

20. Advance the INTENSITY control slowly in the clockwise direction to produce a waveform of normal intensity, then turn the control to the counterclockwise (minimum intensity) position. A stored waveform should remain on the storage screen.

21. Set the time-base plug-in to the Single Sweep Mode (Single Sweep button in).

22. Turn the BRIGHTNESS (Y-T) control counterclockwise and note that the stored display dims. Then turn the control clockwise to normal brightness.

23. To demonstrate independent screen operation, push the UPPER ERASE screen-selector button to release the LOWER ERASE button. Press the ERASE button and note that only the upper screen erases. Push the LOWER ERASE button (UPPER ERASE releases) and press the ERASE button. Set either screen to non-store (STORE button out) and note that the other screen is fully operable in the storage mode, permitting simultaneous store and non-store operation.

This completes the basic operating procedure of the display unit. Instrument operations not explained here, or operations which need further explanation are discussed under General Operating Information.

GENERAL INFORMATION

Graticule

The graticule of the display unit is internally marked on the faceplate of the CRT to provide accurate, no-parallax measurements. The graticule is marked with eight vertical and ten horizontal divisions. Each division is one-half inch square. In addition, each major division is divided into five minor divisions. The vertical gain and horizontal timing are calibrated to the graticule so accurate measurements can be made from the graticule.

Intensity Controls

Two INTENSITY controls are provided, one for each CRT beam. Each CRT beam is associated with one of the vertical deflection systems; thus, the LEFT VERT INTENSITY controls the intensity of the display associated with the left vertical plug-in unit and the RIGHT VERT INTENSITY controls the intensity of the display associated with the right vertical plug-in unit. These controls are adjusted so the displays are easily visible, but not overly bright. Readjustment will probably be required for different displays or sweep rates. Particular care should be exercised when only a spot is displayed. A high-intensity stationary spot may burn the CRT phosphor and cause permanent damage to the CRT if allowed to remain too long.

Display Focus

A FOCUS control is associated with each CRT beam. If a well-defined display cannot be obtained with the FOCUS control, even at low intensity settings, adjustment of the internal astigmatism control may be required.

To check for proper setting of the Astig control, slowly turn the FOCUS control through the optimum setting with a signal displayed on the CRT screen. If the Astig control is correctly set, the vertical and horizontal portions of the trace will come into sharpest focus at the same position of the FOCUS control.

Trace Alignment Adjustment

If a free-running trace is not parallel with the horizontal graticule lines, set the TRACE POSITION adjustment (rear panel) as follows: Position the trace to the center horizontal line and adjust the TRACE ROTATION control so the trace is parallel with the horizontal graticule lines.

Beam Finder

The BEAM FINDER switch provides a means of locating a display which overscans the viewing area either vertically or horizontally. When the BEAM FINDER switch is pressed, the display is compressed within the graticule area. To locate and reposition an overscanned display, use the following procedure.

1. Press the BEAM FINDER switch, and while holding it in, increase the vertical and horizontal deflection factors until the display is reduced to about two divisions vertically and four divisions horizontally (the horizontal deflection needs to be reduced only when in the X-Y mode of operation).

2. Adjust the vertical and horizontal position controls to center the display about the vertical and horizontal centerlines.

3. Release the BEAM FINDER switch; the display should remain within the viewing area.

Care of Storage Screens

To prolong the useful life of the storage screens, the following precautions should be observed when operating the D13.

1. Use minimum beam intensity required to produce a clear, well defined display. Care must be taken in the degree of writing-beam intensity that is used, particularly when using slow sweep rates and X-Y displays. Too-high beam intensity may permanently damage the CRT screen.

2. Avoid repeated use of the same area of the screen. If a particular display is being stored repeatedly, change the vertical position occasionally to use other portions of the display area.

3. Do not leave a stored display on the screen when it is no longer needed.

4. Turn the Store BRIGHTNESS (Y-T) control fully counterclockwise (with sweep held off) when storing a display for an extended period of time.

5. Operate in the non-store mode unless storage is required.

Storage Operation

General. Separate STORE switches are provided for both the upper and lower CRT storage screens, permitting independent screen operation. When both screens are operated in the non-stored mode (both the UPPER and LOWER STORE switches out), the instrument operates as a conventional oscilloscope. When either or both screens are operated in the storage mode (applicable STORE switch in), a display can be retained for further analysis.

A stored display is erased by first selecting the applicable screen for erasure and then pushing the ERASE button. The erasure of one screen has no effect on the other. The UPPER and LOWER ERASE switches are self-cancelling; when either button is pressed, the other button is released. Also, both switches can be pressed in or released at the same time. Thus either screen or both can be selected for erasure, or erasure of both screens can be prevented. The ERASE momentary-contact switch initiates the waveform required for erasure.

Holding and Viewing Modes. The BRIGHTNESS control permits extended retention of displayed information with negligible reduction in CRT life. The control provides continuously variable flood-gun current duty cycle from about 10% to 100%. To hold a stored display, set the time-base plug-in unit to Single Sweep and turn the control fully counterclockwise. In this position, the storage-target flood guns are on only 10% of the time, producing the effect of decreased intensity. A stored display will be very faint and may not be discernible from the background areas. Both screens are affected. To return the instrument to a viewing mode, turn the BRIGHTNESS control clockwise until the desired viewing level is achieved. In the full clockwise position, the flood guns are on 100% of the time and stored display will be its brightest. The BRIGHTNESS control is inoperable for X-Y displays and when the sweep is running. If the control is counterclockwise and the sweep is running, a blinking effect will be noticeable at the slower sweep rates because the CRT will revert to the hold mode between sweeps. To eliminate this effect, turn the control clockwise.

Integrating Fast Displays. If fast, repetitive displays cannot be stored even at maximum intensity settings, the BRIGHTNESS control can be used to increase the apparent writing speed of the CRT. To use this function, first obtain a triggered, well focused display of the signal in the non-store mode. Adjust the writing-beam INTENSITY control so the trace is just starting to defocus. Then press in both STORE buttons and erase the screen. Turn the BRIGHTNESS control counterclockwise and press the STORE button to obtain the non-store mode. Wait about two seconds, press in both STORE buttons and rotate the BRIGHTNESS control clockwise to view the integrated display. If all portions of the display are not properly stored, rotate the BRIGHTNESS control counterclockwise and return to the non-store mode to integrate the display for a few seconds more. If too much integration time is used, the stored image begins to broaden, or background fade-up may occur, obscuring the desired display. Some practice may be necessary to determine the proper intensity level and integration time required for obtaining best results.

Improving Writing Speed. After continued use (2 hours or more) in the non-store mode, or store mode with no display, fade the screen positive by obtaining a repetitive sweep in the store mode. Slowly position the trace from CRT top to bottom. Leave the CRT target fully stored for five minutes.

Intensity Modulation

Intensity (Z-axis) modulation can be used to relate a third item of electrical phenomena to the vertical (Y-axis) and the horizontal (X-axis) coordinates without affecting the waveshape of the displayed signal. The Z-axis modulating signal applied to the EXT INTENSITY INPUT changes the intensity of the displayed waveform to provide this type of display. The voltage amplitude required for visible trace modulation depends on the setting of the INTENSITY control. About +5 volts will turn on the display to a normal brightness level from an off level, and about —5 volts will turn the display off from a normal brightness level. "Gray scale" intensity modulation can be obtained by applying signals between these levels. Maximum safe input voltage is + or— 50 volts. Usable frequency range of the Z-axis circuit is DC to one megahertz.

Time markers applied to the EXT INTENSITY INPUT provide a direct time reference on the display. With uncalibrated horizontal sweep or X-Y operation, the time markers provide a means of reading time directly from the display. However, if the markers are not time-related to the displayed waveform, a single-sweep display should be used (for internal sweep only) to provide a stable display.

Intensity modulation can be used in the store mode as well as in the non-store mode; however, there is only one intensity level in a stored display. The stored waveform may be modified by either dimming portions of the waveform so they do not store, or brightening portions from a dim background so only the brightened portions store.

Calibrator

The internal calibrator of the display unit provides a convenient signal source for checking the basic vertical gain and sweep timing. The calibrated signal is also very useful for adjusting probe compensation as described in the probe instruction manual. The output square-wave voltage is 400 millivolts, within 1%, and the square-wave current is 4 milliamperes, within 1%. The frequency of the square-wave signal is twice the power-line frequency. The signal is obtained by clipping the probe to the loop.

Display Photography

A permanent record of the CRT display can be obtained with an oscilloscope camera system. The CRT bezel provides integral mounting for a Tektronix oscilloscope camera. A camera with a light source is required to illuminate the graticule in the non-store mode. The instruction manuals for the Tektronix oscilloscope cameras include complete instructions for obtaining waveform photographs. The following specific information is given for photographing stored displays.

When this instrument is operated in the storage mode, a photograph may easily be composed by erasing unwanted displays as many times as necessary before the desired display is obtained. This ability to compose a photograph in advance prevents wasted film due to incorrect displays.

Due to the background glow of the stored display produced by the flood guns, special care must be taken in determining the exposure time and f-stop settings. Of course, exact settings will depend upon the specific types of film. After the correct settings are obtained for a specific oscilloscope-camera-film combination, record these figures for future reference. Since the background glow does not change substantially between displays, these settings should produce satisfactory results for most displays. Background glow may be altered by adjustment of the BRIGHTNESS control.

Oscilloscope Applications

The 5100-series Oscilloscope, including its associated display module and plug-ins, provides a very flexible measurement system. Specific application for the individual plug-ins are described in the manuals for those units. Refer to the Operating Instructions section of the 5100-series Oscilloscope manual for basic oscilloscope applications, including peak-to-peak AC voltage measurements, instantaneous DC voltage measurements, comparison measurements, time duration measurements, determining frequency, risetime measurements, and X-Y measurements.

Electrical Characteristics

Cathode-Ray Tube. Size is 6½ inches with an 8 X 10 division (½ inch/div.) display area. P31 phosphor is standard for the D12; similar to P1 for the D13. Accelerating voltage is 3.5 kV; orthogonality, 90° (within 1°); geometry, 0.1 division or less.

Storage Display (D13 Only). Writing speed is at least 20 divisions per millisecond; storage time, one hour (longer at low brightness); erase time, about 250 milliseconds.

External Intensity Input. +5 volts will turn on display to a normal brightness level from an off level; −5 volts will turn display off from a normal brightness level. Usable frequency range is DC to one megahertz; input R and C, about 100 kΩ paralleled by about 40 pF; maximum safe input, +50 volts (DC+ peak AC).

Calibrator. Voltage amplitude is 400 mV, within 1%; current, 4 mA, within 1%. Frequency of square-wave signal is twice the line frequency.

Power Input. With the standard transformer, the 5103N Oscilloscope will operate from nominal 110V and 120V (within 10%) line voltage sources having frequencies of 60 hertz or 400 hertz. With the optional export transformer, the 5103N Oscilloscope will operate from nominal 100V, 110V, 120V, 200V, 220V and 240V (all within 10%) line voltage sources having frequencies of 50 to 60 hertz or 400 hertz.

NOTES

SECTION 2
THEORY OF OPERATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual contains an electrical description of the circuits in the D12 and D13 Display Units. An overall block diagram of these units and complete schematics are given on pullout pages at the rear of this manual.

BLOCK DIAGRAM DESCRIPTION

The Vertical and Horizontal Deflection Amplifiers provide final amplification of the signals from the plug-in units. They produce push-pull outputs suitable to drive the CRT vertical and horizontal deflection plates. Separate vertical amplifiers are provided for independent dual-beam display of signals from the left and right vertical plug-in units. Beam-finding circuitry limits the display within the screen area when the front-panel BEAM FINDER button is pressed.

The CRT Circuit produces the high voltage (about —3400 volts) and contains the controls necessary for operation of the cathode-ray tube. The CRT Circuit also contains the Z-Axis Amplifier, which provides drive signals to control the intensity levels of the displays produced by both CRT beams.

The Storage Circuit provides the voltage levels necessary to operate the storage elements associated with the CRT in the D13. The circuit includes the erase-pulse generator for erasing stored information and a multivibrator which permits the flood-gun duty cycle to be varied.

CIRCUIT DESCRIPTION

Deflection Amplifiers

Vertical Deflection Amplifiers. The left and right Vertical Deflection Amplifiers provide the final amplification of signals applied to the left and right vertical plug-in units. These are differential amplifiers which produce push-pull outputs suitable to drive the CRT left and right vertical deflection plates for independent dual-beam displays. The left amplifier consists of Q164, Q166, Q174 and Q176, and the right amplifier consists of Q104, Q106, Q114 and Q116.

The input signal arrives via P612 from the plug-in interface circuit (power supply/amplifier module). The output signal is developed across the collector-load resistors of the output transistors, and is about 50 times the magnitude of the input signal. Variable resistors R116 and R176 (Right and Left Vert Gain) provide emitter degeneration to set the gain of their respective amplifiers to provide a calibrated vertical display.

Horizontal Deflection Amplifier. The Horizontal Deflection Amplifier consists of Q124, Q126, Q134 and Q136, and is basically the same as the Vertical Deflection Amplifiers just described. It provides final amplification of signals from the horizontal plug-in unit, which arrive via P611. Gain of the stage is set by R136, Horiz Gain, to provide a calibrated horizontal display.

Beam Finder. If a high-amplitude signal or a misadjusted control has deflected the trace or display off-screen, it can be located by pressing the front-panel BEAM FINDER pushbutton. This opens S223 (CRT Circuit diagram), allowing current to flow through R179 into the emitter circuits of the deflection amplifiers. R179 limits the current available to the transistors, and hence, to the collector-load resistors. Thus the dynamic range of the deflection plates is limited to an on-screen level, and the display is compressed within the viewing area. The intensification function of the Beam Finder is discussed in the Z-Axis Amplifier description.

X-Y Phasing. Variable capacitors C115 and C175 are connected across the output collectors of their respective Vertical Deflection Amplifiers. These capacitors are adjusted to eliminate the inherent phase difference between the vertical and horizontal deflection systems when operating in the X-Y mode.

Dynamic Geometry. Because each CRT gun is physically located off-center in the vertical plane, the beams emitted by these guns pass through an uneven magnetic field as they sweep across the screen. To compensate for the effects that the unbalanced field would have on display geometry, a dynamic geometry circuit made up of full-wave rectifier CR141-CR142 and operational amplifier Q148 applies a voltage to the vertical deflection plate shield. As the beam moves from the left towards CRT center, CR142 conducts, and the voltage applied to the shield increases in a sawtooth fashion. When the beam passes the center and continues toward the right edge of the screen, CR142 turns off and CR141 turns on, and the voltage applied to the shield decreases in a sawtooth fashion. The peak of this voltage waveform corresponds to the CRT center, and the ramp voltages are directly proportional to the distance of the CRT spot from the screen center. R145, Dynamic Geometry, adjusts the constant factor of the ratio.

Because the unregulated +200-volt collector supply of Q148 may have an undesirable effect on geometry due to ripple, the ripple component is injected via operational amplifier Q154 to the base of Q148 to cancel this effect.

CRT Circuit

General. The CRT Circuit produces the high-voltage potential and provides the control circuits necessary for operation of the cathode-ray tube (CRT). This circuit also includes the Z-Axis Amplifier circuit, which controls the CRT intensity level of both beams from several inputs.

Z-Axis Amplifier. The Z-Axis Amplifiers establish the biasing conditions of the CRT to control the intensity levels of both beams. They are current-driven, shunt-feedback operational amplifiers with voltage outputs; they consist of Q232-Q234 for the left electron gun, and Q432-Q434 for the right electron gun.

The output levels of the Z-Axis Amplifiers are established by the voltage drops across feedback resistors R236 and R436 in reference to virtual ground at the operational amplifier summing points (Q232 and Q432 bases). The currents through these feedback resistors are determined by input currents from any combination of several sources. Individual INTENSITY controls, R200A and R400A, permit the quiescent intensity levels of both beams to be adjusted independently. An EXT INTENS INPUT, J203 or J403, is provided for each Z-Axis Amplifier; the external signals are applied via operational amplifiers Q206 and Q406. The remaining inputs are simultaneous to both Z-Axis Amplifiers, and thus affect both CRT beams. The sweep blanking and chop blanking inputs are applied via emitter followers Q214 and Q218 to turn off the CRT beams during sweep retrace and during the chop-switching transitions. When BEAM FINDER switch S223 is pressed, Q224 saturates, resulting in a slight increase in the CRT beam intensity levels.

High-Voltage Primary. A repetitive, non-sinusoidal signal is produced by a phase-modulated switching circuit in the primary of T240 and induced into the secondaries. Current drive for the primary winding is furnished by Q252 in its conduction state. Q252 is turned on by positive-going feedback applied through C259 and L259 from the feedback winding, and then turned off by switching action from Q262. A sample of the output DC voltage is modulated by the AC from another feedback winding at the gate of Q268 to establish the conduction time of Q252, and thus maintain the proper output level. Q252 delivers energy to T240 only once each cycle.

Assuming Q262 and Q264 are off initially, R262 provides base drive for Q252, causing it to deliver current to T240 primary. As Q252 conducts, its increasing current through the primary winding induces a voltage into the secondaries. The gate of Q268 is driven negative by the voltage from the feedback winding, switching Q264 and Q262 on. With conduction of Q262, base drive for Q252 is removed.

With Q252 off, the transformer field collapses, reversing the polarity of the voltage induced into the secondaries. When the gate of Q268 is driven sufficiently positive to switch Q264 and Q262 off, Q252 is switched on again. Q252 again delivers energy to the primary winding and the action is repeated.

High-Voltage Regulation. Regulation is accomplished as follows: Feedback from the —3400-volt cathode supply is summed with the low-voltage levels through the voltage divider consisting of resistors R272A, R272B, R274, R275 and R276 to establish the DC level at the gate of Q268. The AC component, which is the switching signal, is derived from the transformer as described previously. If the output level of the cathode supply drops below the nominal —3400-volts (becomes more positive), the level at the gate of Q268 rises. A new point is selected on the varying AC component to cause Q262-Q264 to switch later and thus increase the conduction time of Q252. This allows more energy to be delivered to the primary winding of T240, resulting in an increase of voltage in the secondaries. Conversely, if the output level increases, Q252 is allowed to conduct for a shorter length of time. The DC level at the gate of Q268 is adjusted by R275, High Voltage, to set the voltage on the CRT cathode to exactly —3400 volts.

Electron Gun Cathode and Grid Supplies. Half-wave rectifier CR247 produces —3500 volts DC, which is applied to Q454 and VR458. Each of these devices drops 100 volts, establishing the —3400-volt cathode potential. Conduction of Q454 in the right cathode circuit is controlled by R455, Horiz Bal, to balance the horizontal sensitivity of the two displayed traces. The 6.3-volt cathode heater is elevated to —3.5 kV through R459.

Bias voltage for each grid is supplied by identical DC restorer networks, which consist of CR243, CR244, and R244 for the right grid and CR443, CR444 and R444 for the left grid. These DC resistors have the —3400-volt cathode potential applied to them as a reference voltage, and they are driven by a varying voltage obtained from one side of the 400 VAC winding of T240. R242, Right Inten Range, and R442, Left Inten Range, provide a fine adjustment of the quiescent grid voltage to bias both electron guns just below cutoff when the Z-Axis Amplifier output is at its minimum quiescent level (INTENSITY controls counterclockwise and no intensifying or blanking inputs). A change in the Z-Axis Amplifier output produces an almost equal change of voltage on the control grid, allowing the Z-Axis Amplifier to control the beam current in the CRT.

CRT Control Circuits. In addition to the INTENSITY controls discussed previously, front-panel focus and internal astigmatism controls have been incorporated for arriving at an optimum CRT display. FOCUS controls R200B and R400B provide the correct voltage for the first anode of each gun. Proper voltages for the second anodes are obtained by adjusting the Right and Left Astig controls, R286 and R486. In order to obtain optimum spot size and shape, both the focusing and astigmatism controls are adjusted to provide the proper electrostatic lens configuration in the CRT.

Two adjustments control the trace alignment. TRACE ROTATION control R291 permits adjustment of the DC current through beam-rotation coil L291 to align the display with the horizontal graticule lines. Beam Regis control R285 varies the voltage between two special sets of deflection plates to align the two traces horizontally, ensuring correct time relationship (registration) between the traces and the vertical graticule lines. Geom control R289 varies the positive level on the horizontal deflection plate shield to control the overall geometry of the display. The dynamic geometry correction which is applied to the vertical deflection plate shields has been discussed previously.

Storage Circuit (D13 Only)

General. The CRT used in the D13 is a direct-view, bistable storage cathode-ray tube with a split-screen viewing area that permits each half to be operated individually for stored displays. Only those elements associated with the storage capability of the CRT are shown inside the CRT symbol on the right side of the Storage Circuit schematic diagram. The writing gun, its deflection systems and associated elements have been discussed previously.

Storage Operation. Four low-energy electron guns (flood guns) provide full coverage of the large screen area. Each consists of a heated cathode and an anode. The cathode heaters, which receive an unfiltered pulsating DC from full-wave rectifier CR329, are elevated to the cathode potential through R329. Quiescently, Q308 is saturated, providing current to the flood-gun cathodes. The anode potential is established by VR396 and supplied via emitter follower Q396.

The collimation electrode is a metallic band around the inner wall of the CRT envelope. It produces an electrostatic field to distribute the flood-gun electrons uniformly over the storage target. R390, CE1, provides adjustment of the flood-electron trajectories to cover the extreme rim of the targets and optimize uniformity of the target coverage. Emitter follower Q392 maintains a stable voltage on the collimation electrode, providing a low-impedance current path to absorb current variations.

The storage screen consists of a thin tin-oxide layer called the target backplate, which is coated with an insulator material containing finely-ground phosphor particles called the target. A positive voltage potential is applied via Q372 and S372 to the backplate to establish the operating level of the tube, which is the difference in potential between the backplate and the flood-gun cathodes. The CRT screen area is divided into two halves, which are electrically insulated from each other to permit independent operation.

The target operates in a bistable mode because of the secondary-emission properties of the insulator material. The stable state is the rest potential, at which the target has gathered low-energy flood-gun electrons, causing it to charge down to the flood-gun cathode potential. The second stable state is the stored state, at which the target (or portions of it) is shifted to the backplate potential by increasing the secondary emission. While the flood guns do not have sufficient energy to shift the target to the stored state, they do supply sufficient energy to hold the target in the stored state after it has been shifted by the high-energy writing-gun beam (CRT beam). This is because the landing energy of the flood electrons has increased with the increased potential difference between the flood-gun cathode and the target. These higher energy electrons yield a light output and produce a visual display as long as the flood beam covers the target.

When the stored display is no longer needed, the information is erased by first shifting the entire target to the stored state and then removing the charge. A positive-going, short duration pulse is first applied to the backplate, increasing the flood-gun electron landing energy and writing the entire target area. Next, the backplate voltage is pulled well below the rest potential of the target, which follows due to its inherent capacitive coupling. Then, as the backplate is gradually returned to its quiescent potential, the target charges to the rest potential and is ready to write again.

For a comprehensive study of storage tube operating principles, a Tektronix Circuit Concepts book entitled "Storage Cathode-Ray Tubes and Circuits" is available through your local Tektronix, Inc. Field Office or representative. Tektronix Part No. 062-0861-00.

Backplate Supply. A regulated +370-volt DC power supply is incorporated in the Storage Circuit to provide the storage level for the CRT and to ensure a potential sufficient for the erasure process. A winding of high-voltage transformer T240 supplies 400 volts RMS, which is rectified by CR386. Q386 and Q388 are connected as a feedback pair to provide the regulated +370-volt DC output. VR388 establishes the reference voltage, and R387, +370 V Adj, sets the current through Q386 to set the output level. VR387 is a protection device for the transistors, and is normally operated in a region of its characteristics curve below its Zener knee.

Backplate Control. Separate STORE switches, S375A and S375B, are provided for the target backplates to permit each storage screen to be operated individually. In the store mode, the store-level potential for the backplate is supplied by either Q372 or the erase-generator output operational amplifier, depending upon the setting of the ERASE SELECT switches, S372A and S372B.

A high degree of control of the target backplates is maintained by a feedback amplifier system consisting of Q356, Q358, Q362, and Q364. The operational amplifier summing point is at the base of Q356, and the feedback resistor is R355. Variable resistor R350, Store Level, provides an adjustment of the current to the null point, and hence sets the backplate voltage through R355 to an optimum storage level. R370, Store Bal, permits matching the backplate voltages for uniform screen luminance, whether they are selected for erasure or not.

When either or both screens are operated in the store mode, the divider network in the high-voltage regulator circuit is modified to shift the high voltage slightly, correcting for the deflection sensitivity changes that occur. The backplate voltage is applied through either R381 or R382 to the base of Q384, removing the ground potential from the Q384 collector. R385, Sens Correct, permits an adjustable sensitivity correction voltage to be applied to the high-voltage regulator.

Erase Generator. The previously discussed operational amplifier is driven by a monostable multivibrator when it is desired to erase a stored display. The multivibrator consists of Q334, which is normally on, and Q336, which is normally off. When ERASE button S330 is pressed, R330 is grounded, producing a negative-going step through C331 to cut Q334 off. Q336 turns on, and the negative-going step produced at its collector causes a corresponding positive-going step at the output of the operational amplifier. This positive-going step is applied to the target backplate, increasing the storage level and "writing" the entire target.

After an RC-controlled time of 10 milliseconds, the multivibrator reverts to its quiescent state, producing a positive-going step at the collector of Q336 as the transistor turns off. This positive-going step is coupled through C342, and the backplate is pulled negative through the action of the operational amplifier. The target is pulled well below its rest potential. As C342 charges, the voltage at the cathode of CR343 decays from about +20 volts toward the —30-volt supply at an RC-controlled rate until it is clamped at ground by conduction of CR343. This action allows the target backplate to be raised slowly to its operating level, while the target remains at the flood-gun cathode potential. The total time from initiation of erasure to the ready-to-write condition is about 250 milliseconds.

Flood-Gun Cathode Control. As previously mentioned, Q308 provides the current for the flood-gun cathodes. It operates at saturation, establishing a cathode potential of nearly —30 volts. Q308 is controlled by two circuits: a transistor switch activated by the sweep gate and a multivibrator. While the sweep is running, Q304 overrides the multivibrator output and holds Q308 in its conduction state. Emitter follower Q302 receives the sweep blanking input from R203 in the Z-Axis Amplifier circuit; however, the level of interest is the zero volts applied to the base of Q302 while the sweep is running. This level permits the base of Q304 to move slightly negative, biasing the transistor into saturation and grounding the collector of Q320. Through R307-R308 divider action, Q308 is held on.

Between sweeps or when the sweep is held off, the +5-volt sweep-blanking level is applied to Q302, raising its emitter positive. This level switches Q304 off, releasing its hold on Q308. In this condition, Q308 is controlled by collector-coupled multivibrator Q310-Q320. When Q320 conducts, Q308 conducts. Symmetry of the multivibrator is controlled by R313 and R325. R325, BRIGHTNESS, is adjustable to allow Q320 to conduct anywhere from 10% to 100% of the time. Thus the duty cycle of the flood-gun cathodes can be varied from 10% to 100%, which has the effect of varying the stored brightness.