INSTRUCTION MANUAL

Serial Number B0 92710

7A11 AMPLIFIER

Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon 97005 ● Phone 644-0161 ● Cables: Tektronix

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SECTION 1
SPECIFICATION

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

Introduction

The 7A11 Amplifier is a versatile plug-in amplifier unit which provides a DC to 150 MHz bandwidth with Tektronix 7700-Series Oscilloscopes. When desired, the upper frequency −3 dB point can be limited to 20 MHz by a front-panel switch.

Calibrated deflection factors of from 5 mV to 20 V per division are provided in 1-2-5 sequence. In addition, a variable gain control makes it possible to set the amplifier to any deflection factor between 5 mV and 50 V per division.

A permanently attached probe provides low-input capacitance (2.0 pF at 2 V/division, 5.8 pF at 5 mV/division) while maintaining high input resistance (1 MΩ). BNC-connectors can be attached to the probe through a probe-tip to BNC-female adapter. This adapter serves as the probe's input connector when the probe is stored, but can be attached to the probe tip whether or not the probe is stored in the plug-in unit.

A 50 Ω termination/adapter (standard accessory) permits impedance matching for use of the probe in 50 Ω environments. When the termination/adapter is used, a low standing wave ratio (VSWR) can be expected. The VSWR can be further reduced by inserting a 2X attenuator in the signal path ahead of the 50 Ω termination/adapter. Approximate values of VSWR which can be expected under both conditions are shown in Fig. 1-4.

The performance specification of the 7A11 Amplifier is described in detail in Table 1-1. The specification is valid under the following conditions:

Calibration must have been performed at an ambient temperature between +20°C and +30°C.

Operation must be within any specified environment, in a calibrated Oscilloscope, after twenty minutes of warmup.

TABLE 1-1

7A11 Amplifier Specification

Characteristic	Performance Requirement
ELECTRICAL	
Deflection Factor (VOLTS/DIV)	
Calibrated Range	5 mV/div to 20 V/div; 12 steps in 5, 10, 20 sequence
Gain Ratio Accuracy	Within 2% of GAIN adjusted at 0.1 V/div
Uncalibrated	Continuously variable; extends deflection factor to at least 50 V/div
GAIN	Permits adjustment of deflection factor at 0.1 V/div for all Oscilloscopes
Frequency Response (8 Division Reference)	
Bandwidth, Direct Coupled Input	250 MHz in 7104
FULL Mode	DC to 150 MHz with 7700-Series Oscilloscope
	DC to 90 MHz with 7500-Series Oscilloscope
20 MHz Mode	DC to 20 MHz within 2 MHz
Capacitive Coupled Lower Frequency −3 dB Limit	15 Hz or less
Risetime	2.4 ns or less with 7700-Series Oscilloscope
	3.9 ns or less with 7500-Series Oscilloscope
Risetime (6 Div Reference)	1.40 ns or less 5 mV-20 V/div with 7904 oscilloscope.

TABLE 1-1 (cont)

Characteristic	Performance Requirement
Maximum Input Voltage With or Without AC Coupler Installed	
DC + Peak AC	200 V; AC component not to exceed amplitude specified under AC
AC, continuous wave	
5 mV thru 50 mV	200 V peak to 50 kHz; see Fig. 1-2 for amplitude derating due to frequencies above 50 kHz
0.1 V thru 1 V	200 V peak to 40 MHz; see Fig. 1-2 for amplitude derating due to frequencies above 40 MHz
2 V thru 20 V	200 V peak to 70 MHz; see Fig. 1-2 for amplitude derating due to frequencies above 70 MHz
DC, Capacitive Coupled (AC Coupler Installed)	200 V
Input R and C	
Resistance	1 MΩ within 1%
Capacitance	
5 mV/div thru 50 mV/div	Approximately 5.8 pF
0.1 V/div thru 1 V/div	Approximately 3.4 pF
2 V/div thru 20 V/div	Approximately 2.0 pF
Maximum Gate Current	0.25 nA or less at 25°C, increasing to 1.2 nA or less at 50°C
Noise (Tangentially measured in FULL Mode)	0.1 division (maximum), measured in 7000-Series Oscilloscope

TABLE 1-1 (cont)

Characteristic	Performance Requirement
DC Drift	
Drift With Time (Ambient Temperature and Line Voltage Constant)	
Short Term	0.1 division or less during any 1 minute interval within 1 hour after 20 minutes from turn-on
Long Term	0.3 division or less during any hour after 20 minutes from turn-on
Drift With Ambient Temperature change (Line Voltage Constant)	
Plug-In Only	200 μV/°C or less
Probe Only	200 μV/°C or less
Trace IDENTIFY	0.2 to 0.3 division upward trace shift
OFFSET Range	
5 mV/div thru 50 mV/div	+1 V to −1 V
0.1 V/div thru 1 V/div	+20 V to −20 V
2 V/div thru 20 V/div	+400 V to −400 V
OFFSET OUT	
Range	+1 V to −1 V (nominal)
Ratio of Offset Range to OFFSET OUT	
5 mV/div thru 50 mV/div	1:1 within 1% plus 0.5 mV at OFFSET OUT jack
0.1 V/div thru 1 V/div	20:1 within 1.5% plus 0.5 mV at OFFSET OUT jack
2 V/div thru 20 V/div	400:1 within 2% plus 0.5 mV at OFFSET OUT jack
Source Resistance	500 Ω within 3%

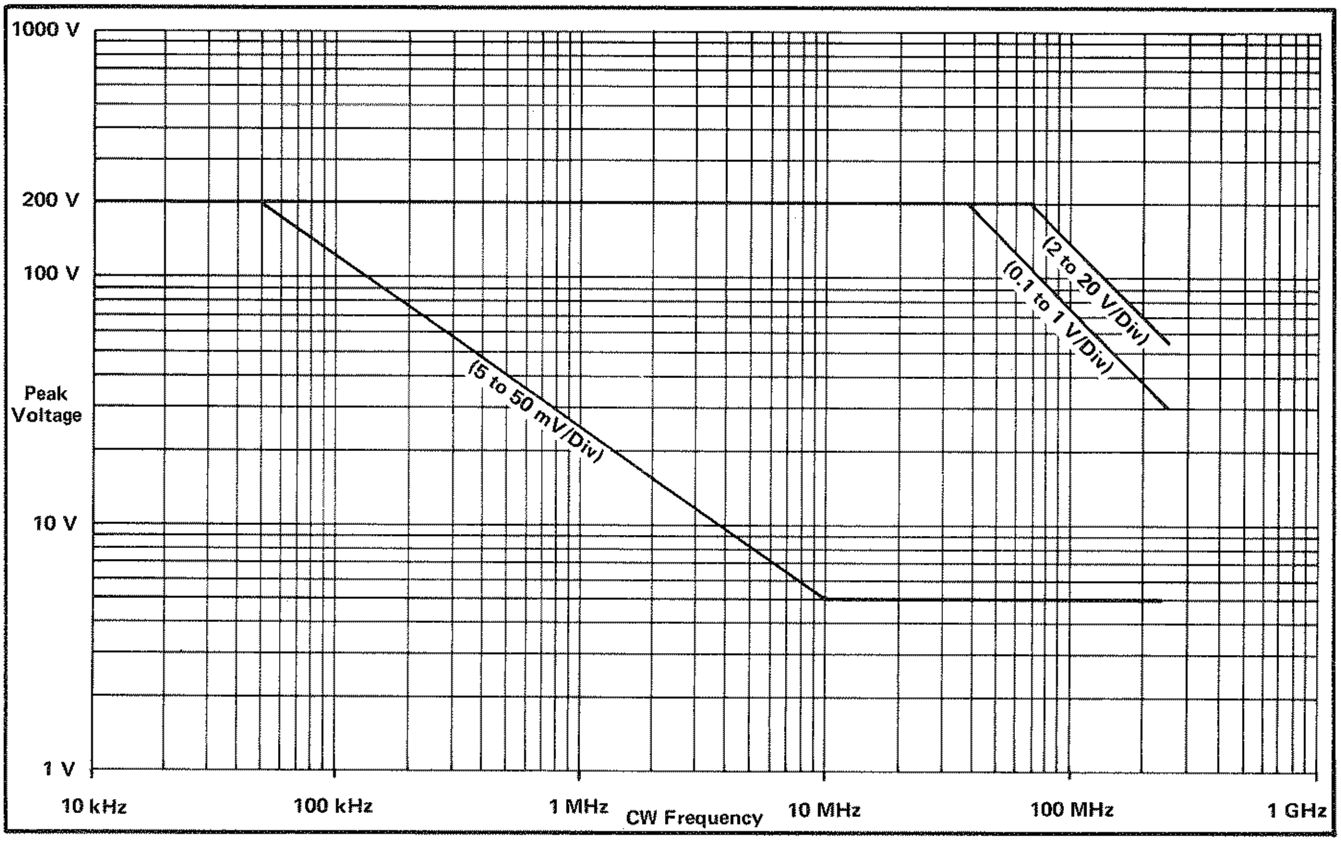

Fig. 1-2. Frequency versus maximum input amplitude derating graph.

TABLE 1-1 (cont)

Characteristic	Performance Requirement
50 Ω Termination/ Adapter	
Input Impedance	50 Ω within 1%
Power Rating	1 Watt
ENVIRONMENTAL	
Probe	
Temperature	
Non-operating	−55°C to +75°C
Operating	0°C to +65°C
Altitude	
Non-operating	To 50,000 feet
Operating	To 15,000 feet
Vibration	15 minutes along each axis at 0.025 inch P-P displacement (3.9 g's at 55 c/s) 10 to 55 to 10 c/s in

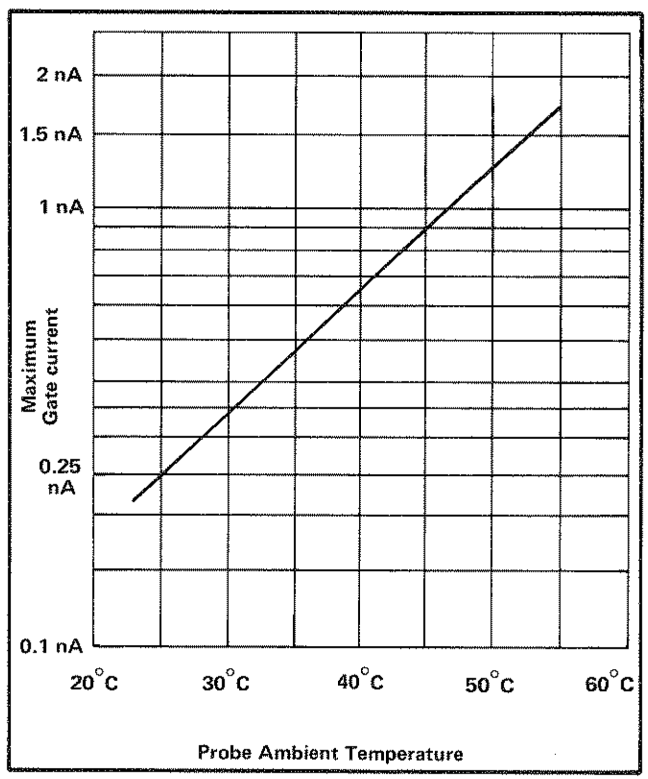

Fig. 1-3. 7A11 maximum gate current versus Probe ambient temperature in "non-stored" mode. To determine maximum gate current with Probe stored, add +11°C to Probe ambient temperature.

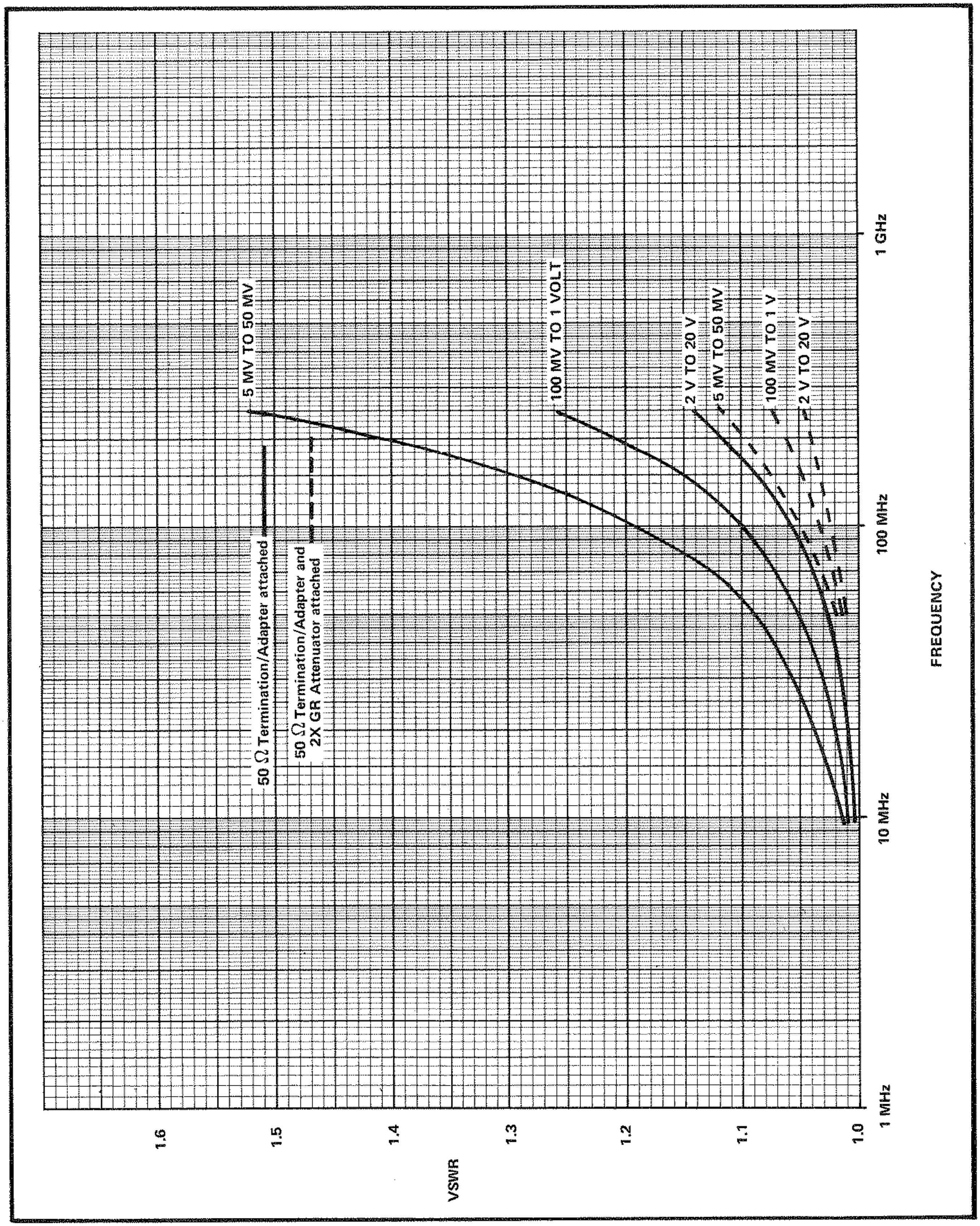

Fig. 1-4. Standing wave ratio graph showing approximate VSWR which can be expected when the 7A11 Probe is used with the 50 Ω Termination/Adapter attached.

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TABLE 1-1 (cont)

Characteristic	Performance Requirement
	1-minute cycles. Three minutes at any resonant point or, if none, at 55 c/s
Shock	400 g's, 1/2 sine; 3 shocks along each axis at 1/2 ms, 1 ms and 2 ms duration (total of 27 shocks)
Plug-In[1]	
Altitude	
Non-operating	To 50,000 feet and −55°C
PHYSICAL	
Finish	
Plug-In	Anodized aluminum front panel

[1]**The Plug-In environment is dependent upon the oscilloscope. See the environmental specification in the applicable oscilloscope manual.**

TABLE 1-1 (cont)

Characteristic	Performance Requirement
Probe Body	Grey plastic housing
Dimensions	
Plug-In	≈14.58 inches long, 2.75 inches wide, 4.98 inches high; overall
Probe Body	≈6.53 inches long, 0.63 inches wide, 0.66 inches high; overall
Probe Cable	≈8.83 feet long
Weight, Plug-In and Probe combined	
Net	≈2.75 pounds
Shipping	≈4.5 pounds

NOTES

SECTION 2
OPERATING INSTRUCTIONS

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

General

This section contains an explanation of external controls and connectors for the Plug-In Unit (Fig. 2-1) and its attached Probe (Fig. 2-2). It also contains an explanation of accessories, a first-time operating procedure and additional operating hints. It is recommended that this section be read in its entirety prior to normal usage of the 7A11 Plug-In Unit and Probe.

PLUG-IN INSERTION AND REMOVAL

The 7A11 is calibrated and ready for use as received. It can be installed in any compartment of 7000-Series oscilloscopes, but is intended for principal use in vertical plug-in compartments. To install, align the upper and lower rails of the 7A11 with the oscilloscope tracks and fully insert it. The front will be flush with the front of the oscilloscope when the 7A11 is fully inserted, and the latch at the bottom-left corner of the 7A11 will be in place against the front panel.

To remove the 7A11, pull on the latch (which is inscribed with the unit identification "7A11") and the 7A11 will unlatch. Continue pulling on the latch to slide the 7A11 out of the oscilloscope.

PROBE REMOVAL AND STORAGE

To remove the Probe: With the 7A11 Amplifier removed from the oscilloscope, locate the Probe and Stored Probe Input Adapter on the right side of the 7A11 (Fig. 2-2A). Move the Probe back, disconnecting it from the Adapter. Note the plastic latch (labeled PRESS) on the side of the Adapter housing. While holding this latch depressed, move the Adapter out through the front of the 7A11, as in Fig. 2-2(B).

Uncoil the desired number of turns of cable from the cable drum and remove the Probe through the Adapter access hole. When the Probe and cable have been removed far enough to take up the slack cable within the 7A11, clip the Adapter to the cable as shown in Fig. 2-2(C). Then insert the Stored Probe Input Adapter into its housing in the 7A11, as in Fig. 2-2(D). Reverse the procedure to reinstall the Probe.

EXTERNAL CONTROLS AND CONNECTORS

Plug-In Unit

VOLTS/DIV	A 12-position switch graduated from 5 mV through 20 V in 5-10-20 sequence. In addition to selecting calibrated deflection factors, it indicates the input capacitance and offset voltage range applicable to each switch position.
VARIABLE (CAL IN)	Combination switch and potentiometer. When the control is in its inward position, deflection factors are as indicated by the VOLTS/DIV switch. Push and release knob to enable selection of uncalibrated deflection factors between the value indicated by the VOLTS/DIV switch and at least 2.5 times that value.
POSITION	Moves display vertically on CRT when Plug-In Unit is in vertical compartment of oscilloscope. Permits horizontal movement of display when Plug-In is in horizontal plug-in compartment of oscilloscope.
IDENTIFY	Located in center of POSITION knob. When pushed, causes approximately 1/4 division movement of display. Oscilloscopes equipped with readout simultaneously display the word "IDENTIFY" in the 7A11 readout area on the CRT.
OFFSET	
ON-OFF	Permits or inhibits operation of the OFFSET control.
COARSE	Outer of two concentric knobs. Stop-to-stop rotation injects offset voltage equivalent to +1 through −1, +20 through −20, or +400 through −400 volts at the inputs, depending upon position of

COARSE (cont.) — VOLTS/DIV switch. Counterclockwise position offsets the input with a negative voltage, clockwise position offsets the input with a positive voltage.

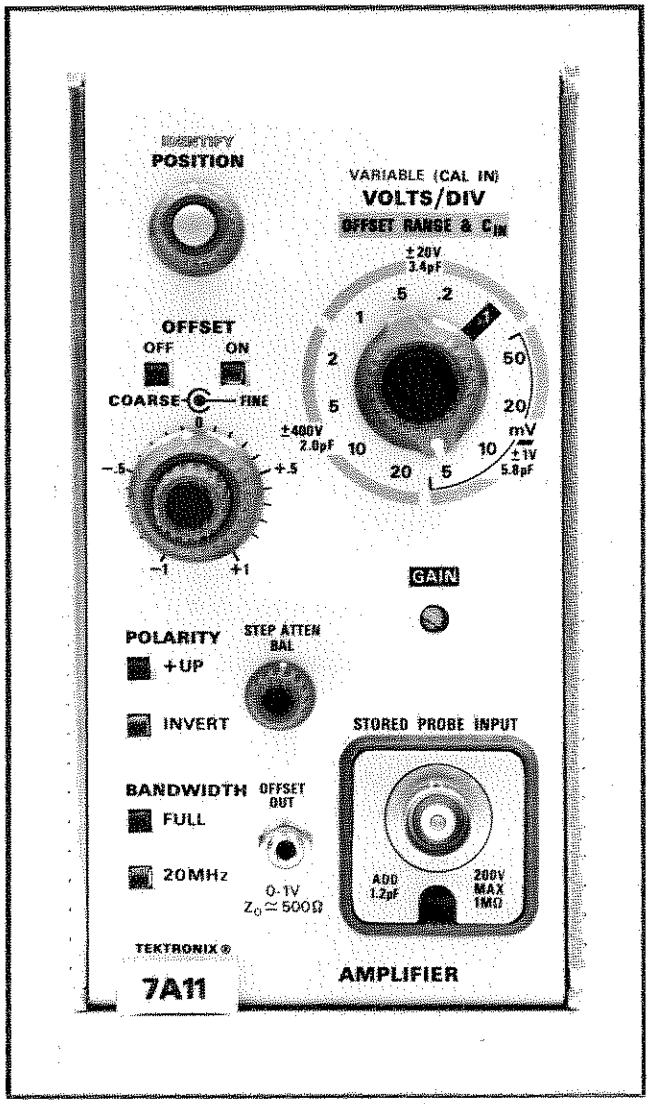


Fig. 2-1. 7A11 Front Panel.

FINE — Inner of two concentric knobs. One revolution injects an equivalent of approximately 0.4, 4, or 40 volts offset voltage, dependent upon position of VOLTS/DIV switch.

POLARITY

+UP — Selects upward deflection for positive-going input signals. If the 7A11 is used in a horizontal plug-in compartment, selects right deflection for positive-going signal.

INVERT — Selects downward deflection for positive-going input signal. If the 7A11 is being used in a horizontal plug-in compartment, selects left deflection for positive-going input signal. Upward (or right) deflection for positive going input signals is provided if both switches are in the outward position.

BANDWIDTH

FULL — Provides full bandwidth as specified for 7A11-oscilloscope combination.

20 MHz — Reduces upper frequency −3 dB limit of 7A11-oscilloscope to 20 MHz. Full bandwidth is provided if both switches are in the outward position.

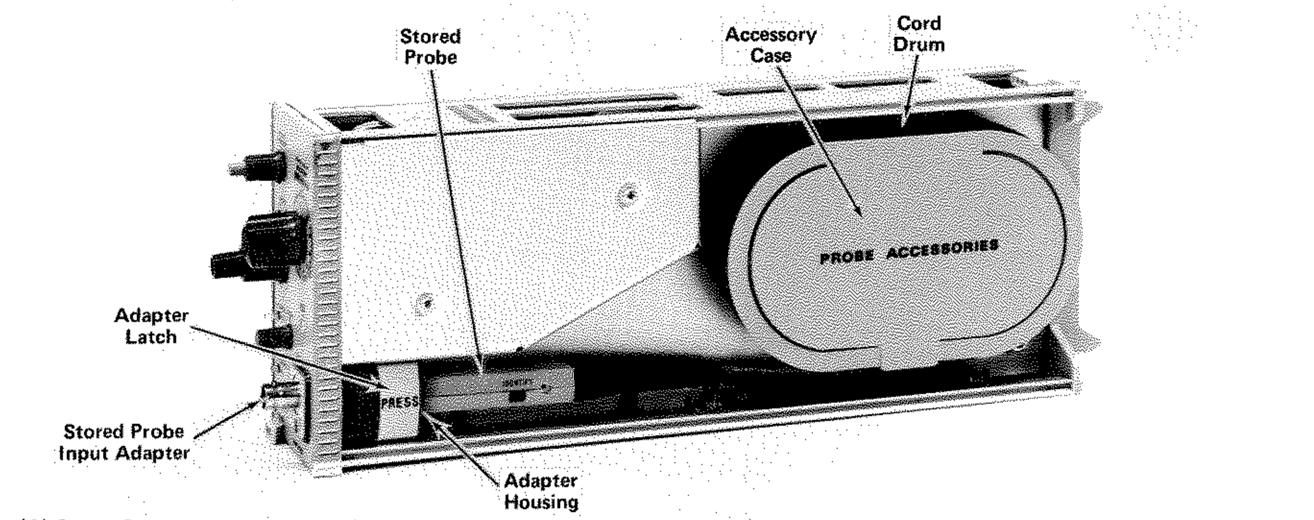
STEP ATTEN BAL — Externally balances circuitry to avoid shifting of no-signal trace when VOLTS/DIV switch position is changed.

OFFSET OUT — Miniature phone jack, making selected value of offset voltage available externally. No output provided when OFFSET switch is OFF.

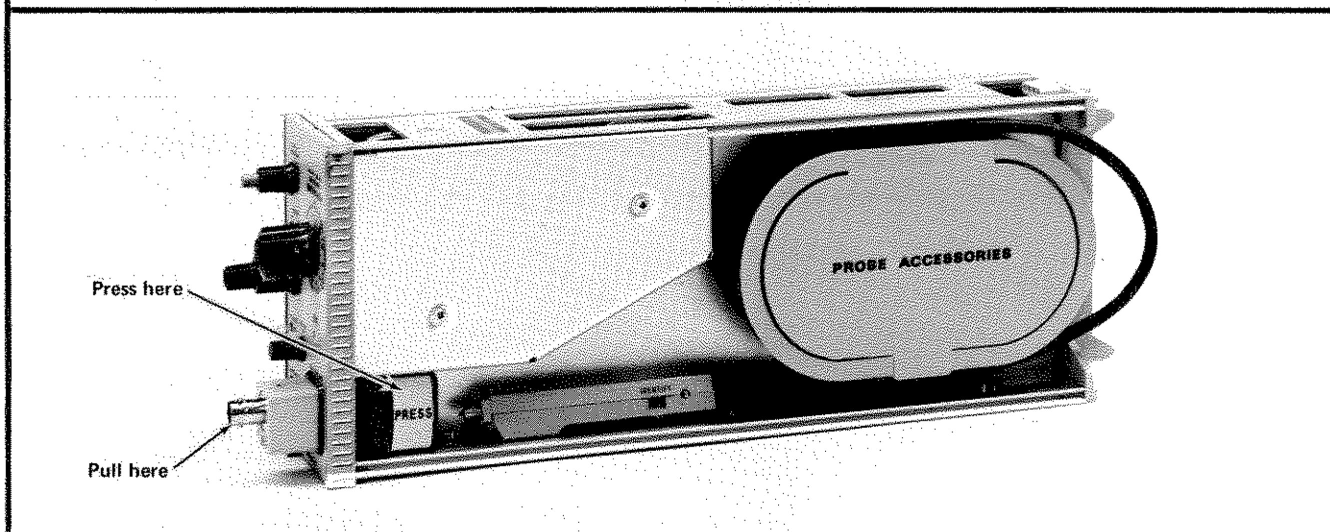
GAIN — Screwdriver adjustment permitting external calibration of VOLTS/DIV. Normally adjusted with VOLTS/DIV at .1 position as indicated by the shaded area surrounding the .1 at the VOLTS/DIV switch.

STORED PROBE INPUT — BNC jack connected to Probe tip when Probe is stored within 7A11 Amplifier. Note that value of capacitance indicated at VOLTS/DIV switch must be increased by 1.2 pF when the STORED PROBE INPUT Adapter is used. When Probe is withdrawn from 7A11 Amplifier, STORED PROBE INPUT is usually disconnected from the circuit. Maximum allowable DC plus peak AC input voltage is 200 volts. Consult specification section for derating due to frequency.

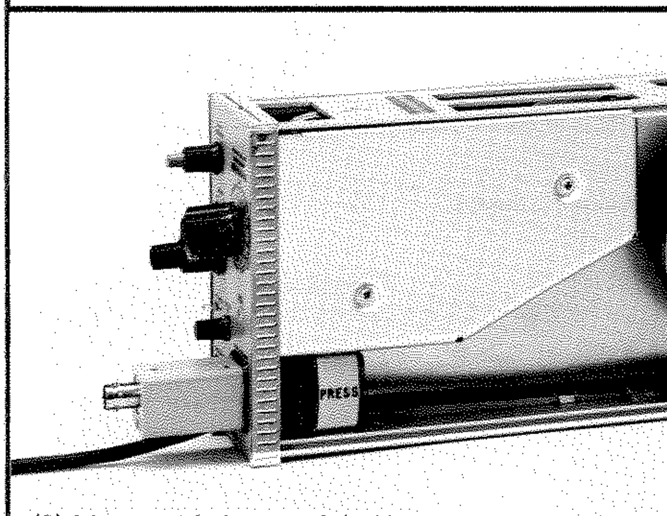
Release Latch — Latch inscribed with plug-in identification "7A11". Pull knob to release latch when removing 7A11 from oscilloscope.



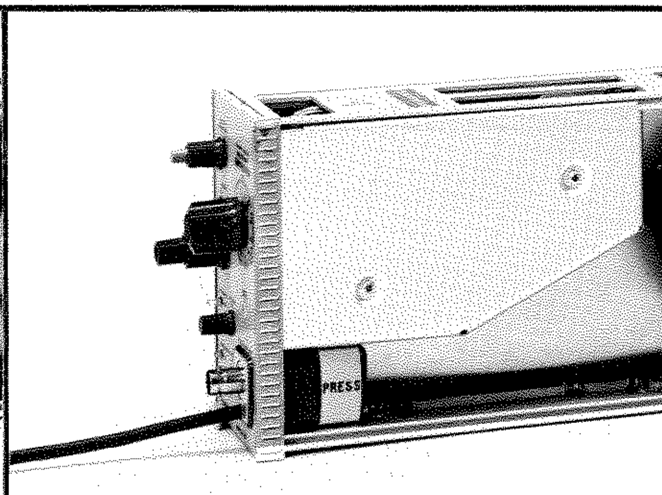
(A) Stored Probe component identification.



(B) Removing Stored Probe Input Adapter. Note that Probe has been disengaged from Adapter.



(C) Adapter attached to extended cable.



(D) Adapter installed with Probe and cable extended.

Fig. 2-2. Probe storage and removal.

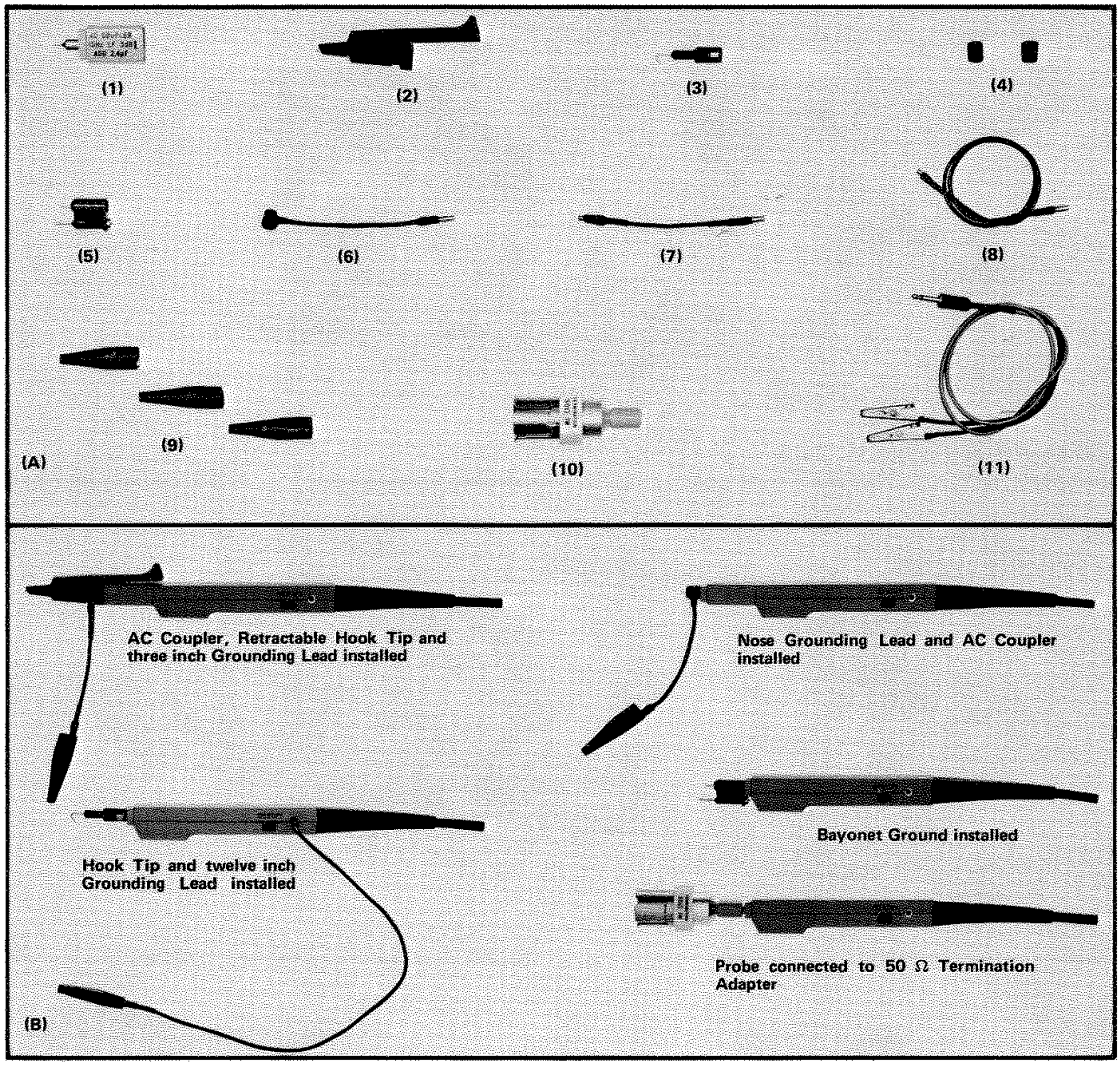


Fig. 2-3. (A) Accessories; (B) Accessories installed.

Probe

Tip	Miniature type, DC-coupled to internal circuitry. Can be equipped with DC blocking capacitor (see Accessory Information). Can also be equipped with pincher tip or hook tip for attaching Probe to circuitry. Maximum allowable DC + peak AC input is 200 volts. Consult specification section for derating due to frequency.
IDENTIFY pushbutton	Depressing it causes approximately 1/4 division trace shift. Also causes the word "IDENTIFY" to appear in 7A11 readout area on CRT if oscilloscope is equipped with readout circuitry.
Ground Contact	Female-threaded contact for attaching grounding lead.

ACCESSORIES INFORMATION

Accessories are supplied with the Probe to extend its operating capabilities. These accessories are shown in Fig. 2-3 and are intended to be utilized as follows:

1. AC Coupler. Slip-on type containing a .015 μF capacitor. Blocks DC from Probe. Has a 15 Hz low-frequency −3 dB point. Adds 2.4 pF to input capacitance indicated at VOLTS/DIV switch.

2. Retractable Hook Tip. Slip-on type for use with or without AC Coupler. Adds additional 1 pF input capacitance. Hook Tip body moves toward rear of Probe to expose hook. Contains female-threaded ground connection for use with either a 3 inch or 12 inch screw-in ground lead.

3. Hook Tip. Slip-on device for use with or without AC Coupler.

4. Insulating Tube. Slip-on device for insulating ground surface at Probe tip or AC Coupler tip.

5. Bayonet Ground. Slip-on device for use with or without AC Coupler. Spring loaded contact permits completing the Probe ground circuit immediately adjacent to Probe signal input tip.

6. Grounding Lead, Nose. Slip-on device which makes contact with ground surface at Probe or AC Coupler tip. Other end equipped with 6-32 male thread for attachment to alligator clip.

7. Grounding Lead, Screw-In, 3 inch. Primarily for use with Retractable Hook Tip. Threaded both ends. One end to be attached to Retractable Hook Tip, other end for use with alligator clip.

8. Grounding Lead, Screw-In, 12 inch. Threaded both ends. For use between threaded female grounding contact at Probe and alligator clip. Can also be attached between grounding female thread at Retractable Hook Tip and alligator clip.

9. Alligator Clips. For use with grounding leads.

10. 50 Ω Termination/Adapter, GR-to-probe tip. Can be used in any situation requiring 50 Ω probe input impedance.

11. Cable Assembly. Equipped with miniature telephone-jack plug, coaxial cable, and alligator clips. For use with OFFSET OUT jack.

FIRST TIME OPERATION

General

Operation of the 7A11 Amplifier and Probe in a vertical plug-in compartment of an oscilloscope is explained here. Operation of the unit with the Probe stored is explained first. This is followed by a description of operation with the Probe and its accessories.

Preliminary

Install the 7A11 Amplifier into a vertical compartment of a 7000-Series oscilloscope equipped with a time-base unit. Set the equipment controls as listed in Table 2-1.

TABLE 2-1

Preliminary Control Settings

7A11 Amplifier	
VOLTS/DIV	.1
POSITION	Midrange
OFFSET	OFF
POLARITY	+UP
BANDWIDTH	FULL
Time Base	
Triggering	
Mode	Auto
Coupling	AC
Source	Int
Magnifier	X1
Time/Div	1 mS
Variable	Calibrated
Oscilloscope	
Intensity and Focus	Adjusted for Optimum Trace
Beam Finder	Normal
Calibrator	.4 V
Rate	1 kHz

STEP ATTEN BAL Adjustment

1. Using the 7A11 POSITION control, set the trace to vertical center of the graticule. Then depress the INVERT button and note the trace position.

2. Using the STEP ATTEN BAL control, move the trace to a point midway between its present position and the vertical center of the graticule.

3. Again using the POSITION control, set the trace to graticule center. Then depress the +UP button and again note the trace position. It should have remained at graticule center. If not, again adjust STEP ATTEN BAL to position the trace midway between its present position and graticule vertical center.

4. Repeat this procedure until no trace shift accompanies switching between +UP and INVERT.

5. Check STEP ATTEN BAL adjustment by rotating the VOLTS/DIV switch through all positions and noting that no trace shift occurs.

6. The STEP ATTEN BAL adjustment should be rechecked each time the 7A11 is used. Do not use the STEP ATTEN BAL adjustment as a position control.

IDENTIFY

1. Depress the 7A11 IDENTIFY button while observing the trace. Note that the trace shifts upward approximately 1/4 division when the button is pushed, and returns to its previous position when the button is released.

2. If the oscilloscope is equipped with readout circuitry, note that the word "IDENTIFY" appears in the 7A11 readout area of the CRT while the IDENTIFY button is pushed. The deflection factor in use should appear in the readout area when the IDENTIFY button is released.

BANDWIDTH

1. Adjust the oscilloscope Intensity and Focus controls to obtain optimum trace sharpness.

2. Depress the FULL Bandwidth switch and note that the trace becomes slightly less clearly defined. This occurs because a much wider frequency range is now being displayed, and the total noise increases accordingly.

A better indication of bandwidth operation can be obtained by connecting the output from a high-frequency generator to the STORED PROBE INPUT. With 20 MHz applied from the signal generator, and FULL selected at 7A11, adjust for 5 divisions of vertical display. Then select 20 MHz at the 7A11 and note that the vertical amplitude decreases to approximately 3.5 divisions.

GAIN

1. Connect a 50 Ω coaxial cable between the STORED PROBE INPUT and the Calibrator output jack at the oscilloscope.

2. Note that with 0.4 V and 1 kHz selected at the Calibrator and .1 VOLTS/DIV selected at the 7A11, a display of approximately 4 divisions appears on the CRT.

Adjusting the GAIN control with the oscilloscope Calibrator signal applied provides absolute accuracy to within 2% in the adjusted position at temperatures between 0°C and 50°C. Other deflection factors will then be accurate to within 4% absolute between 0°C and 50°C.

If greater gain accuracy is required, a more accurate amplitude calibrator must be used and all instruments must be restricted to a temperature range of 15°C to 35°C. The Tektronix Amplitude Calibrator and Comparator, Part No. 067-0502-01 is recommended for this purpose. An absolute accuracy approaching 2% may then be obtained over the range of deflection factors.

POLARITY

1. Disconnect the coaxial cable from the STORED PROBE INPUT Adapter. Then adjust the 7A11 POSITION control as necessary to place the trace at graticule vertical center.

2. Re-connect the coaxial cable to the STORED PROBE INPUT Adapter and note that the 1 kHz square wave is displayed in a positive or upward direction from the reference position established at graticule center.

3. At the 7A11, depress the INVERT button. Note that now the positive-going square wave is deflected in a downward direction on the CRT.

4. Depress the +UP button to regain upward deflection of the positive-going square wave.

OFFSET

1. Adjust the outer OFFSET knob as necessary to place its white marker at 0.

2. Depress the OFFSET ON button. The trace may shift upward or downward.

3. Move the OFFSET controls and note trace reaction. Clockwise movement causes upward deflection, while counterclockwise movement causes downward deflection. Also note that the FINE control knob causes considerably less reaction than the COARSE control knob. (The two knobs have a ratio of approximately 10:1.)

4. Depress the OFFSET OFF button. The square wave display should now appear in the upper half of the CRT.

5. Switch the oscilloscope Calibrator to 4 V and note that the upper excursions of the square wave are no longer visible. If it is desired to display the upper portions of the square wave, pull out on the oscilloscope BEAM FINDER knob, causing the entire display to appear on the CRT.

6. Depress the OFFSET ON button and adjust the OFFSET control as necessary to place the top of the square waves at graticule center.

7. Return the BEAM FINDER to normal by depressing and releasing the button. Note that the upper portion of the square wave now appears near graticule center. Refine the OFFSET adjustment (if necessary) to align the tops of the square waves with the graticule vertical center.

8. Calculate the OFFSET voltage being applied. It is equal to the OFFSET decimal value (indicated by the OFFSET knob) multiplied by the OFFSET RANGE (indicated by the VOLTS/DIV switch). In this case, the calculation is –.2 X 20 V = –4 V. (–4 volts is needed to return a +4 V signal to graticule center.)

9. Using a DC voltmeter and the Cable Assembly, check the voltage available at the OFFSET OUT jack. It is equal to the value indicated by the OFFSET knob, and can never exceed approximately ±1 V. Note that only 0.2 V is present there, even though the offset voltage being applied to offset the incoming signal is equivalent to 4 V.

10. Turn the OFFSET button OFF and disconnect the coaxial cable from the oscilloscope and the STORED PROBE INPUT Adapter.

Probe Operation

1. Pull out on the 7A11 Locking Latch and remove the 7A11 from the oscilloscope plug-in unit compartment.

2. Lay the 7A11 on its left side and remove the Probe as explained in the beginning of this section. Replace the 7A11 in the oscilloscope plug-in compartment. Allow approximately 1 minute to elapse before continuing with the procedure.

3. Depress the IDENTIFY button near the rear of the Probe body and note that the trace moves approximately 1/4 division just as it did when the front panel IDENTIFY button was depressed. If the oscilloscope is equipped with readout circuitry, also notice that the word "IDENTIFY" appears in the 7A11 readout area of the CRT.

4. Switch the oscilloscope Calibrator to 0.4 V. Now touch the Probe tip to the Calibrator output jack center terminal and note that approximately 4 divisions of square wave appears on the upper half of the CRT.

5. Disconnect the Probe from the jack. Attach the AC Coupler accessory to the Probe tip. Connect the Coupler tip to the Calibrator jack and note that the 4 division square-wave display now straddles the vertical center of the graticule, since the capacitor in the AC Coupler blocks the DC component.

6. It is suggested that the Probe's other accessories be experimented with at this time for familiarization purposes. Note that when the Retractable Hook Tip is installed on either the Probe or the AC Coupler tip, the hook can be exposed by pulling back on the retracting tab. Also note that either the 3-inch or 12-inch screw-in grounding lead can be used with the AC Coupler tip. An alligator clip should be attached to the opposite end of the grounding leads for attaching to convenient grounded surfaces.

7. Remove the 7A11 from the plug-in compartment. Depress the tab on the side of the STORED PROBE INPUT Adapter and remove the Adapter through the front of the 7A11. Retract the cable into the 7A11 and wind it on the cable spool as necessary to draw the Probe through the 7A11 front panel. Snap the STORED PROBE INPUT Adapter into place and insert the Probe into the back of the Adapter. The 7A11 is again ready for use in the stored probe mode.

Unscaled Deflection Factors

On occasion, it may be convenient to establish vertical deflection factors other than those which are provided by specific positions of the VOLTS/DIV switch. For example, assume that 0.8 volts/division deflection factor is desired. If a 4-volt square wave calibrator signal is applied to a vertical unit having 0.8 volts deflection factor, the displayed signal amplitude is equal to the applied signal (4 volts) divided by the deflection factor, (0.8 volts) which is equal to 5 divisions of display. With this in mind, set the VOLTS/DIV to the next lower deflection factor (in this case, .5 volts) and apply a 4-volt signal from the oscilloscope Calibrator to the 7A11 Probe input. Then depress and release the VARIABLE knob and adjust it as necessary to obtain 5 divisions of deflection. A 0.8 volt/division deflection factor now is in effect.

It should be noted that the same ratio of actual deflection factor to VOLTS/DIV switch value exists in all other switch positions. Thus if the VARIABLE control is in the position established in the preceding paragraph and the VOLTS/DIV switch is placed in the 2 VOLTS/DIV position, a 3.2 volts/division deflection factor will be in effect (0.8 is to 0.5 as 3.2 is to 2).

Input Capacitance

The input capacitance of the 7A11 Amplifier and Probe has been designed to be extremely low. For example, in the 5 through 50 mV positions, input capacitance is 5.8 pF. In the .1 through 1 V position it is 3.4 pF, and it is 2.0 pF in the 2 through 20 V positions. These figures pertain when the Probe is connected directly to a circuit and must be modified whenever other coupling connectors are used. The AC Coupler device adds 2.4 pF. The Retractable Hook Tip adds 1 pF and the STORED PROBE INPUT Adapter adds 1.2 pF. Any additional devices such as connectors or cables between the signal source and the Probe or STORED PROBE INPUT connectors will further increase input capacitance.

SECTION 3
CIRCUIT DESCRIPTION

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

General

The descriptions contained in this section are referenced to the schematics contained in the back of this manual. Additional diagrams appear with the text as necessary to facilitate explanations. The schematic diagrams are coded with numbers contained in diamond shaped outlines. These numbers are used extensively on the schematics for cross-referencing.

BLOCK DIAGRAM DESCRIPTION

Refer to Fig. 3-1. Major components of the 7A11 Amplifier are the Probe, the Input Amplifier, the Output Amplifier, the Offset Generator and the Readout Control. When a signal is applied to the probe tip, a single-ended signal passes from the Probe to the Input Amplifier, where it is converted to a push-pull signal. It is then applied to the Output Amplifier, where it is amplified and sent through the interconnecting plug to the oscilloscope. The Output Amplifier also provides a push-pull trigger signal to the oscilloscope for time base triggering purposes.

An Offset Generator permits application of a DC offset voltage to the Input Amplifier, thus enabling the viewing of AC signal components in the presence of DC at a much higher sensitivity than would otherwise be possible. A

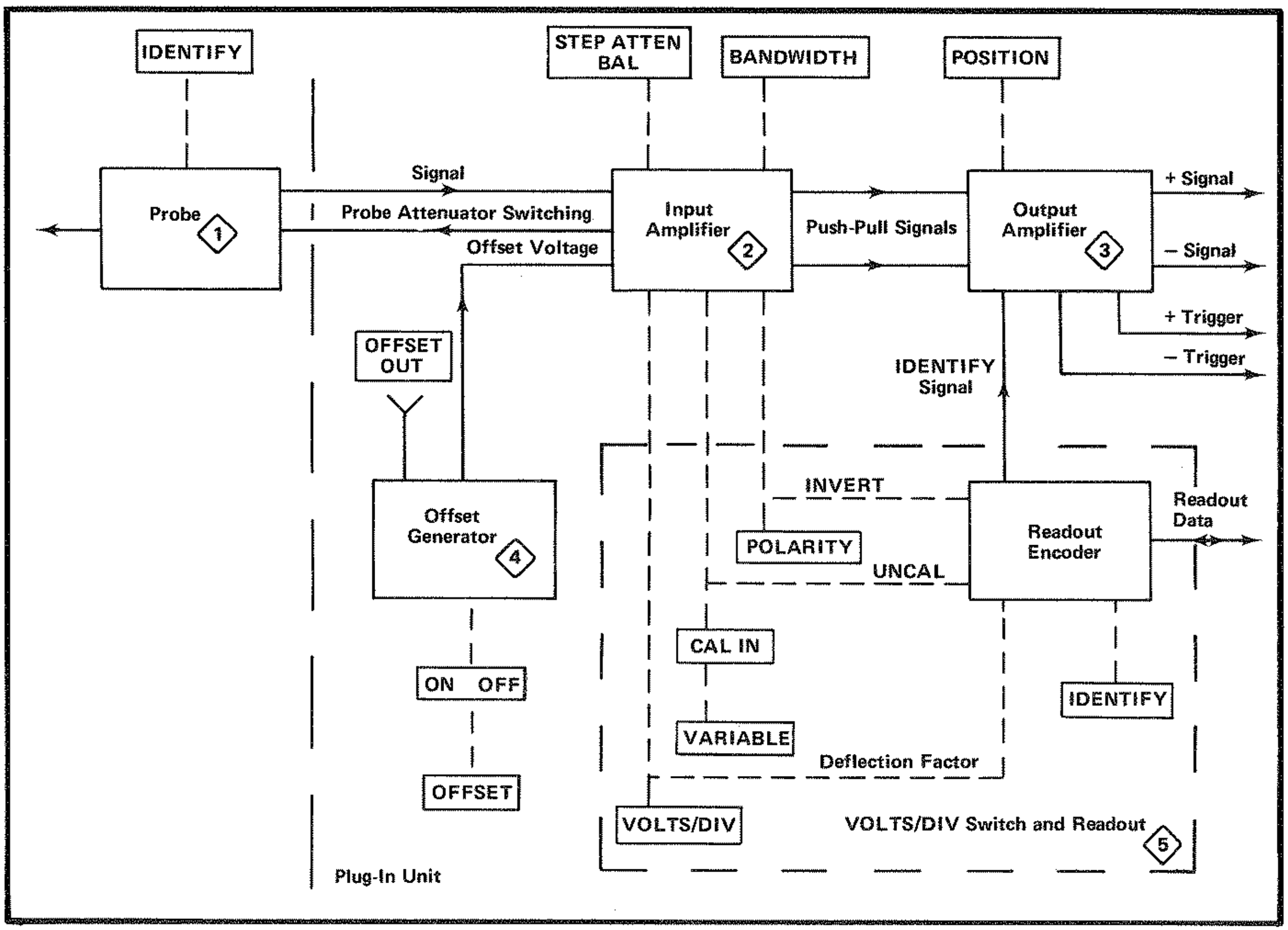


Fig. 3-1. 7A11 block diagram.

separate miniature phone jack makes the selected offset voltage available at the front panel for monitoring or for external use. The offset is operative and the DC offset voltage is available at the OFFSET OUT jack only when the OFFSET ON button is depressed.

The sensitivity of the 7A11 Amplifier is determined by the VOLTS/DIV switch, which causes attenuation of the applied signal to occur in the Probe, in the Plug-In Unit, or in both. The deflection factor can be modified by use of the VARIABLE control. Whenever the CAL IN button is in the outward position, the VARIABLE control can change the deflection factor to as much as 2-1/2 times the value indicated by the VOLTS/DIV knob position.

The signal being sent to the oscilloscope can be inverted by use of the POLARITY switch. IDENTIFY buttons are present at both the Probe and the Amplifier to permit display identification. A BANDWIDTH control permits reduction of the 7A11 bandwidth, allowing the operator to greatly attenuate signals above 20 MHz when their appearance on the CRT display is not desired. The POSITION control permits the operator to move the 7A11 trace vertically on the CRT when the 7A11 is in a vertical compartment, or horizontally when the 7A11 is in a horizontal compartment. The VOLTS/DIV, CAL IN, POLARITY and IDENTIFY controls provide the Readout Encoder with information to be relayed to the Oscilloscope. The 7A11 status is thereby available for decoding and display. If equipped with readout circuitry, the oscilloscope decodes and displays the 7A11 status on the CRT.

PROBE CIRCUIT DESCRIPTION

Refer to the Probe diagram in the back of this manual. The probe circuitry consists of the Attenuators, the Input Field Effect Transistors (FETs), and two Emitter Followers. The Attenuator circuitry has three possible configurations. These are the straight through condition as shown on the schematic, the divide-by-twenty condition during which time the K55A contact is in the downward position, and the divide-by-400 condition during which time both the K55A and K59A contacts are in the downward position. In the straight-through position, suppressors C1, R1, C18, R18, and R19 aid in smoothing the transient response. Incoming signals are developed across R21 and applied through R22-C22 to the gate of Q23A. R22 provides protection to Q23A and C22 permits high-frequency signals to by-pass R22. Low-frequency signals are not affected by R22, since Q23A has very high input impedance at low frequencies.

When divide-by-20 relay K55 is de-energized, its contact drops to the lower position. This places R12 in series between the probe tip and R21. At the same time, it places the R13-C13-R15-C15-R16-C16 combination in parallel with R21. The net result is that a 1 MΩ input resistance is maintained although the signal being developed across R21 has been reduced to 1/20 of its previous value.

When K59 is also de-energized, R5, R4, C4, C5, C6 and R6 are inserted into the circuit in such a manner as to maintain the 1 MΩ input resistance, while reducing the signal developed across R21 to 1/400 of that applied at the probe tip. (C5 exists only in instruments below SN B020190.)

When K55A and K59A are de-energized, the capacitance inherent in those switch contacts is automatically placed in parallel with R5 and R12. The capacitance inserted by the attenuators is therefore adjustable (C6 and C13) to provide the same attenuation ratio (due to capacitance) at high frequencies as is provided by the resistors at low frequencies. (C5 exists only in instruments below SN B020190.)

The attenuator relay circuits are designed so that when no power is applied to the relays, they are de-energized and a 400-to-1 attenuation ratio exists between the probe tip and the Q23A gate. This situation safeguards against accidental damage to the input FETs when the equipment is de-energized.

When the equipment is energized and a straight-through attenuator condition is selected, 5 V is applied to the divide-by-20 and divide-by-400 relay lines. Current from the +5 V supply then flows up through both halves of K55 and through both halves of K59, energizing the two relays. When a divide-by-20 signal is initiated, the divide-by-20 line is grounded. Current now flows from the +2.5 V line through the two halves of K55 to ground. The net effect is that equal but opposite polarity fields are developed in K55 which cancel each other. K55 is thus permitted to de-energize, inserting the divide-by-20 attenuator components in the signal path. A similar effect occurs when the divide-by-400 signal is initiated. At this time both K55 and K59 fields are neutralized and both relays are de-energized. This method of controlling the relays maintains constant power consumption, regardless of relay status.

The input FET circuit current is determined by Q23B and R26, its self-biasing resistor. This current causes the drop across R24 to be identical to that across R26. Assuming identical biasing of Q23A and Q23B, the bottom of R24 is held at the same potential as the Q23A gate. Under no-signal conditions this value is zero volts. Under signal conditions, both points follow the voltage which exists at the top of R21. The high impedance offered by the drain of Q23B prevents changes in circuit current despite changes in voltage at the drain. R28 provides a small amount of current (about 0.1 mA) to offset that required by the base circuit of Q33.

The signal is coupled through Emitter Followers Q33 and Q43 and then applied through the C44-R44-R45-R46-R47 network to a 93 Ω coaxial cable which applies the signal to the Input Amplifier. C44, R44, R45, R46 and R47 provide reverse termination for the 93 Ω cable.

The OFFSET control causes a current to flow through the R20, R45, R46, R47 reverse termination network without changing the operating voltage of Q43.

The 7-V supply which is used to power the probe circuitry is boot-strapped to ensure that the active devices do not change their characteristics as a result of DC signal components being applied to the probe tip. See the Power Supply explanation for details.

The IDENTIFY switch, when actuated, interrupts a ground path to an identifying signal injection circuit. Details regarding the circuit are contained in the VOLTS/DIV Switch and Readout description.

INPUT AMPLIFIER

General Description

Refer to the Input Amplifier schematic in the back of this manual. The principal parts of the Input Amplifier are the Paraphase Amplifier, the attenuation network, the variable gain control circuit, the bandwidth and polarity circuits. Signals received from the Probe are applied to the base of Q124A, where they cause equal and opposite signals to be developed in the collector circuits of Q124A and Q124B. Signal current passes through the bandwidth limiting filter, the X2 attenuators, the X2.5 attenuator and through the polarity switch circuits, after which they are applied to the Output Amplifier. When the CAL IN button is in the out position, the VARIABLE control can cause signal current to be shunted through field effect transistor Q198 to attenuate the signal being applied to the Output Amplifier.

A STEP ATTEN BAL circuit permits balancing the current in the two sides of the amplifier under no-signal conditions. This ensures that no trace shift will occur when attenuators are switched into or out of the circuit during no-signal conditions.

An offset voltage can be applied to the base of Q124A. In normal usage, the amount of offset voltage injected at this point is only sufficient to cancel a DC voltage level existing on the incoming signal.

An additional function occurring at the Q124A base is the sampling of the DC voltage component of the incoming signal for use in boot-strapping the Probe power supplies. A detailed description of this boot strapping feature is contained in the power supply circuit description.

Detailed Description

The base of Q124B is connected to ground in the Probe, thus providing a reference point for the paraphase amplifier. Under no-signal conditions, the base of Q124A is also at zero potential. This places equal voltages at the emitters of Q124A and Q124B. The current that is available through R148 and R149 is evenly divided between R127 and R147, and passes through transistors Q124A and Q124B.

The principal load for Q124A consists of R126 in parallel with R175, providing approximately 40 Ω impedance as seen from the top of R124. If any or all of the Input Amplifier attenuators are switched into the circuit, they appear in series-parallel combination with R175 in a manner which maintains a 40 Ω impedance as viewed from the top of R124. Changes in attenuators therefore do not affect the parameters associated with Paraphase Amplifier Q124A-Q124B.

The gain of the circuit is approximately equal to the sum of the load resistances of Q124A and Q124B divided by the resistance separating the two emitters. Thus, 40 Ω plus 40 Ω divided by the effective impedance between the two emitters (R127 plus R147 in parallel with R137, R139 and the effective resistance of R138) is equal to approximately one. Half of this gain of 1 can be detected at L126 and half at L146. As previously mentioned, this gain remains one regardless of the attenuators inserted into the circuit. However, the attenuators combine with R175 and R176 to reduce the signal available to the Output Amplifier to one-half, one-fifth or one-tenth of the signal available at L126 and L146. The relays are energized to provide the straight-through condition. The signal is reduced to one half by de-energizing K405 and K407. It is reduced to one fourth by de-energizing K411 and K413. All three pairs of relays are de-energized to reduce the signal to one tenth.

Gain and frequency compensation adjustments are provided between the emitters of Q124A and Q124B. R124 and R144 provide thermal compensation, with C124 and C144 providing high-frequency signal by-pass. VR124 is normally non-conducting. It limits the voltage which can be dropped across R124 to approximately 3 V, maintaining good circuit response under large signal conditions.

In FULL bandwidth mode, relays K401 and K403 are activated. When 20 MHz bandwidth is selected at the front panel, L152, L155, C153 and C154 cause a bandwidth reduction. Polarity relay K431 is de-energized during + UP operation. When INVERT operation is selected at the front panel, K431 is activated and exchanges the connections being made between the two halves of the Input Amplifier and the two halves of the Output Amplifier.

The VARIABLE circuit consists of Q198, Q184, Q194, U194, and associated components. Q198 is held nonconducting during calibrated gain operation. During variable gain operation, it acts as a resistor with its value determined by the position of the VARIABLE control. Since Q198 is in parallel with R126-R146 and R175-R176, decreasing its resistance decreases the Q124A-Q124B load impedance, thereby decreasing stage gain.

Q198 is controlled as follows: When the VARIABLE control is at CAL IN (S180A open), the 6.72 mA demanded by the Q184-R184 circuit causes about −7.23 V to be developed at the R182-R183 junction. Since S180A is open, no current flows through R180 and this same voltage appears at the R180 wiper and at the non-inverting input of U194. The R192-R193 voltage divider applies approximately −7.20 V to the inverting input of U194. With the non-inverting input more negative than the inverting input, the U194 output is held below −12 V and the R195-R196 voltage divider applies approximately −16 V to the gates of Q194 and Q198, holding them both cut off.

When VARIABLE control is desired, the knob is placed in the outward position, closing S180A. A voltage more positive than that at the R182-R183 junction can then be selected at the VARIABLE wiper and applied to the U194 non-inverting input. The output of U194 then changes in a positive direction, with the amplified change appearing at the gates of Q194 and Q198. When the output moves sufficiently positive, Q194 conducts, becoming a resistive shunt across R191 and R192. When the Q194 resistance becomes low enough, the R192-R193 junction voltage rises to the same value as the R180 wiper voltage and the U194 output voltage stabilizes at the established value.

Circuit design causes equal currents to flow through R191 and R192. With their common junction tied to −7.1 V, the Q194 source and drain connections swing equally above and below −7.1 V respectively, simulating the push-pull conditions associated with Q198.

Since the Q194 gate potential is also being applied to the Q198 gate, the Q198 resistance duplicates the Q194 resistance, creating a shunt across the Q124A-Q124B push-pull load. Either source-to-drain or drain-to-source current flow can occur in Q198, depending upon the instantaneous polarity of push-pull signals.

The STEP ATTEN BAL circuit is capable of applying a small voltage at the base of Q124A, thus affecting the current being conducted by that transistor. When properly adjusted, equal current will flow through Q124A and Q124B. Thus, under no-signal conditions, when the POLARITY control is switched between +UP and INVERT, no trace shift will occur. The STEP ATTEN BAL CENTERING adjustment permits initial adjustment of the circuitry so that a balanced condition is obtainable with the front panel STEP ATTEN BAL adjustment near midrange.

The offset connection at the Q124A base permits between 0 and + or − 1 V to be applied to the base of Q124A when OFFSET ON is selected at the front panel. Normally, the offset voltage injected at this point is limited to an amount sufficient to cancel a DC or AC signal component, returning the desired portion of the display to the graticule center.

OUTPUT AMPLIFIER

General Description

The Output Amplifier is a balanced circuit consisting of four principal parts. They are: First Amplifier Q204A, Q224, Q204B, Q234; Second Amplifier Q244, Q248, Q254, Q258; Output Stage Q264, Q274; and Trigger Amplifier Q284, Q294. The Output Amplifier has a total voltage gain of about 12 which is distributed as follows: First Amplifier 2.8, Second Amplifier 3.7, Output Stage 1.25.

Detailed Description

The two sides of the First Amplifier stage share the current flowing in R213. Most of this current is obtained from R237. Under balanced no-signal conditions, the current is divided equally between R226 and R236, with the current in the upper half passing through load resistor R226, grounded base transistor Q224, thermal time constant circuit C204-R204, through Q204 and R202. Current flow in the lower side of this circuit passes through equivalent components. Under signal input conditions, an equal and opposite signal current change occurs in Q204A and Q204B. The resultant voltage changes across R226 and R236 are applied to the Second Amplifier stage. C203 and C234 provide frequency compensation for the First Amplifier stage. C211 and R211 provide frequency compensation for the probe.

Under balanced conditions, approximately +2 volts appears at the emitters of Q224 and Q234. When the POSITION control is electrically centered, it also has approximately +2 V at its wiper and no current flows in R206 and R216. When fully offset, the wiper senses −11 V or +15 V. R206 is thus able to either add or subtract approximately 0.65 mA to the upper side of the amplifier circuit, while R216 adds or subtracts an equal (and opposite) amount to the bottom side of the circuit. This increase or decrease of current develops a positioning signal across R226 in the upper half and R236 in the lower half of the First Amplifier stage. The POSITION CENTERING adjustment (which is in parallel with R226 and R236) functions in a similar manner to the POSITION adjustment. It is an internal adjustment for centering the range of the POSITION control.

The Second Amplifier stage is essentially the same as the First Amplifier stage. A noticeable exception is that PNP transistors are used instead of NPN transistors.

The Output Stage consists of a conventional amplifier operating into a 25 Ω load. For Q264, this 25 Ω is provided by R266 and a 50 Ω load contained in the oscilloscope. In addition to being a load for Q264, these two resistances provide termination on both ends of the 50 Ω transmission line which carries the vertical signal from the Output Stage to the vertical amplifier circuit in the oscilloscope. C261 provides frequency compensation for the stage. R264, C264, R274 and C274 are thermal compensation components. VR264 and VR274 maintain good circuit response under large-signal conditions by limiting the voltage which can be developed across R264 and R274.

An IDENTIFY signal is inserted at the R264-R266 junction through R269. When the IDENTIFY button is pressed at either the Probe or the front panel, approximately 0.5 mA of current is injected at this point to develop a 12.5 mV signal across the two paralleled 50 Ω load resistors. This causes the trace to shift approximately 1/4 division, enabling it to be distinguished from other traces which may exist on the CRT.

The Trigger Amplifier is also a conventional push-pull amplifier circuit. C295 and R296 provide it with transient response compensation. L282 and R282 terminate the etched-circuit transmission line which conducts the signals from the display-signal circuit to the trigger signal circuit. The TRIGGER BALANCE adjustment permits a balanced voltage output to be delivered to the oscilloscope under no-signal conditions when the trace has been positioned to CRT center.

OFFSET GENERATOR

Basic Description

Refer to the Offset Generator schematic in the back of this manual. The Offset Generator consists of the Offset Emitter Followers and the Offset Inverter. When the OFFSET switch is ON, the selected offset voltage is processed by the Offset Emitter Followers and is applied through R317 to the base of Q124A in the Input Amplifier, where it is accepted as a positioning signal. A voltage equal but opposite to that appearing at the R312-R314 junction is generated by the Offset Inverter and is applied to R49 in the Probe. The sum of R317, R44, R45, R46 and R47 is approximately equal to the R49 resistance. Since the offset voltage is equal to the inverted offset voltage, no offset current flows in the Q43 emitter.

Bootstrap Amplifier U345 is connected into the circuit in such a manner that it can offset the 7-V Probe power supplies in response to signals only. Signals at the Q124A base are reduced in amplitude by voltage divider R343-R344 and filtered by R345-C345. U345 amplifies the filtered signal. Any offset voltage appearing with the signal is cancelled by sensing the voltage at the OFFSET OUT jack through R340. If the signal voltage at the Q124A base goes positive by 1 volt, the Probe power supplies will also go positive by 1 volt. The +7 Volt supply will change to +8 volts with respect to ground and the −7 volt supply will change to −6 volts. At low frequencies, each of these two voltages will maintain its seven volt difference with respect to the signal voltage existing at the Q124A base.

With the OFFSET switch ON, OFFSET voltages are prevented from affecting the probe power supplies as follows: assume a +1 V DC signal is applied at the Probe tip. If the OFFSET switch is OFF, approximately 0.89 V DC appears at the base of Q124A. R344 and R343 reduce the signal amplitude to approximately 0.55 V at the non-inverting input of U345. U345 then amplifies the signal by a factor of 1 + R347 ÷ R340, causing the U345 output to go to 1.18 V. This causes a +1 V change at the R511-R512 junction and at the R531-R532 junction, which connect the bootstrap signal from U345 to the probe power supplies. The +7 V supply is thus shifted to +8 V and the −7 V supply changes to −6 V.

If the OFFSET control is then used to return the trace to center screen, the voltage at the Q124 base is reduced to zero, even though a +1 V DC input signal is applied to the Probe input. However, U345 derives offset information from the R320-R321 junction, amplifies it (by the ratio of R347 ÷ R340) to approximately +1.18 V, which is the same as existed at the U345 output without the OFFSET voltage. Thus the +7 V supply is held at +8 V and the −7 V supply is held at −6 V, exactly as without the offset, maintaining correct bootstrapping.

Additional Description

R306, R307, R308, R309 and thermal compensation diodes CR306 and CR309 form a voltage divider in the base circuits of Q312 and Q314. The large value of resistances used in the divider cause a relatively constant current to flow from the −50 V to the +50 V supply. The center tap of this divider is connected through a 1 kΩ resistor to the wiper of the OFFSET control, which is capable of modifying the voltage at the divider center tap by approximately + or −12.2 V. This change in voltage appears simultaneously at the bases of Q312 and Q314, which act as complementary emitter followers. Circuit losses reduce the maximum possible offset voltage to approximately + or −12.0 volts at the R312-R314 junction. When the OFFSET switch is ON, this voltage is applied through R317 to the base of Q124A in the Input Amplifier circuit.

The offset voltage appearing at the C317-R317 junction is also applied through R322 to the inverting input of amplifier U324. The output of this amplifier is applied to a circuit which is identical with the circuit connected to the OFFSET potentiometer. The output of this circuit is applied to R49 in the Probe as previously explained. It should be noticed that R322, U324, Q332, Q334 and R335 make up an operational amplifier. Feedback resistor R335 is equal to input resistor R322, and U324 has extremely high gain. The overall gain of the amplifier circuit is therefore equal to approximately one. This makes the inverted output equal in amplitude to the non-inverted output which is applied to the left side of R317.

VOLTS/DIV SWITCH AND READOUT

General

Refer to the VOLTS/DIV Switch and Readout schematic in the back of this manual. The VOLTS/DIV switch is of the cam type. Raised portions on individual sections engage spring contacts to make switch connections. Dots on the switch matrix indicate which contacts are closed in any given switch position. For example, the switch is shown in the 5 mV position. Dots in the 5 mV row indicate that the switch contacts associated with cams 1, 3, 5, 6, 7, 9, and 10 are closed. All other cam operated switches are shown in the open position.

The VOLTS/DIV switch cams can be grouped under three functions. Cams 1 through 4 control attenuator switching in the Probe. Cams 5, 6 and 7 control attenuator switching in the Input Amplifier. Cams 8 through 12 control readout circuitry. The functions associated with cams 1 through 7 are explained in the Probe and Input Amplifier circuit descriptions. The functions associated with cams 8 through 12 are explained here.

Readout Circuitry

Oscilloscopes can be equipped with readout circuits which are capable of displaying readout data associated with the traces being displayed on the CRT. This data must be encoded by the plug-in units in use. In the 7A11, the data is dependent upon the position of the VOLTS/DIV switch, the POLARITY switch, the CAL IN switch, and the IDENTIFY switch.

Encoding information is provided by two currents which are referred to as "column" current and "row" current. Any one of eleven discrete current values can be present on each line at any one time, making 121 possible current combinations available. When the indicator unit has been set to display the 7A11 readout data, a voltage pulse is sequentially applied to encoding lines B29, B32, A32, A30, A33, and B33.

For example, assume that a 15 volt pulse is applied to the A32 line and that the A37 and B37 lines are at zero potential. With the VOLTS/DIV switch in the position shown, 400 μA will flow through R451 and 200 μA will flow through R453. The combined 600 μA appears on the A37 line. Since no connection exists between A32 and B37, no current appears on the B37 line. The simultaneous occurence of 600 μA on A37 and zero current on B37 is decoded as the character 5 by the oscilloscope.

Assume now that the A32 line has been returned to zero potential and a 15 volt pulse is being applied to the A30 line. The contact associated with cam 9 is closed and 100 μA flows through R447 and appears on the A37 line. Simultaneously, 300 μA flows through R446 and appears on the B37 line. These two currents are decoded by the oscilloscope as the character m. A30 is then returned to zero potential and a voltage is applied to B29. The B29 current paths are not interrupted by switches, and therefore cause 200 μA on the A37 line and 400 μA on the B37 line whenever a 15 volt pulse is applied to B29. This causes the character V to be decoded by the oscilloscope. Thus, in the example just given, a deflection factor readout of 5 mV would be printed on oscilloscopes equipped with readout circuitry.

The other input lines function in a similar manner to provide information such as UNCAL, INVERTED, or to add a 0 or decimal point to the 1, 2 or 5 value coded by A32. Note that the CAL/UNCAL and POLARITY circuits are controlled by front-panel push switches rather than by the VOLTS/DIV switch. When UNCAL operation is selected, the symbol for "greater than" appears immediately preceding the deflection factor selected by the VOLTS/DIV switch.

Identify Circuit

The IDENTIFY circuit is normally connected to ground in the Probe. When either of the Probe or Plug-In IDENTIFY switches are depressed, this ground circuit becomes open and current through R421 causes Q424 to saturate. Its collector (which had previously been held at −15 volts by CR424 and R424) then goes to approximately ground potential, causing sufficient current through R269 to inject an approximately 1/4 division deflection signal into the output signal line at connector A11. The Q424 collector voltage is also applied to the input base of Darlington circuit Q444, causing it to conduct approximately 1.2 mA on the A37 line. This current causes the word "IDENTIFY" to appear in the 7A11 readout data area of the CRT, negating all other 7A11 readout data.

Bandwidth Control

The BANDWIDTH control circuit also appears on the Volts/Div Switch and Readout schematic. Bandwidth control relays K401 and K403 are energized whenever FULL bandwidth is selected. When 20 MHz bandwidth is selected, these relays de-energize, placing frequency limiting components in the signal path. See the Input Amplifier schematic for details regarding the switch contacts and frequency limiting components.

POWER SUPPLIES AND OUTPUT CONNECTORS

Refer to the Power Supply and Output Connectors schematic diagram. The Power Supplies contained in the Type 7A11 are conventional series-regulating types. The plus and minus 7-volt supplies may be considered as an exception to this, since they are referenced to a floating potential. The R512, R531 junction acts as a reference and is connected to the output of the U345 Bootstrap Amplifier which is contained on the Offset Generator schematic. Under no-signal conditions, the reference point is near zero volts, causing the absolute value of the plus and minus7-V supplies to be equal. Whenever the reference point is caused to go either positive or negative by the average value of the input signal, the plus and minus 7-V values change in the same direction.

R500 adjusts the +8.7-V supply and R540 adjusts the −7.1 and −8.7-V supplies. The +2.5-V supply is not adjustable.

All of the connections made to the Oscilloscope by the 7A11 are shown on the Power Supply And Output Connector diagram.

NOTES