



**PLEASE CHECK FOR CHANGE INFORMATION  
AT THE REAR OF THIS MANUAL.**

**7104  
OSCILLOSCOPE  
WITH OPTIONS  
OPERATORS**

**INSTRUCTION MANUAL**

**Tektronix, Inc.  
P.O. Box 500  
Beaverton, Oregon 97077**


**070-2315-00  
Product Group 42**

Serial Number \_\_\_\_\_

**First Printing NOV 1978  
Revised MAR 1988**

Copyright © 1978 Tektronix, Inc. All rights reserved.  
Contents of this publication may not be reproduced in any  
form without the written permission of Tektronix, Inc.

Products of Tektronix, Inc. and its subsidiaries are covered  
by U.S. and foreign patents and/or pending patents.

TEKTRONIX, TEK, SCOPE-MOBILE, and  are  
registered trademarks of Tektronix, Inc. TELEQUIPMENT  
is a registered trademark of Tektronix U.K. Limited.

Printed in U.S.A. Specification and price change privileges  
are reserved.

### INSTRUMENT SERIAL NUMBERS

Each instrument has a serial number on a panel insert, tag,  
or stamped on the chassis. The first number or letter  
designates the country of manufacture. The last five digits  
of the serial number are assigned sequentially and are  
unique to each instrument. Those manufactured in the  
United States have six unique digits. The country of  
manufacture is identified as follows:

B000000	Tektronix, Inc., Beaverton, Oregon, USA
100000	Tektronix Guernsey, Ltd., Channel Islands
200000	Tektronix United Kingdom, Ltd., London
300000	Sony/Tektronix, Japan
700000	Tektronix Holland, NV, Heerenveen, The Netherlands

# TABLE OF CONTENTS

	PAGE		PAGE
LIST OF ILLUSTRATIONS .....	ii	READOUT .....	2-7
LIST OF TABLES .....	iii	BEAMFINDER .....	2-8
OPERATORS SAFETY SUMMARY .....	iv	CALIBRATOR .....	2-8
		Z-AXIS INPUT .....	2-8
		INTENSITY LIMITING .....	2-8
<b>SECTION 1 GENERAL INFORMATION</b>		DETAILED OPERATING INFORMATION .....	2-8
INTRODUCTION .....	1-1	GRATICULE .....	2-8
OPERATORS MANUAL .....	1-1	GRATICULE ILLUMINATION .....	2-8
INSTRUCTION MANUAL .....	1-1	LIGHT FILTER .....	2-9
INSTALLATION .....	1-1	CONTROL ILLUMINATION .....	2-9
INITIAL INSPECTION .....	1-1	INTENSITY CONTROLS .....	2-9
OPERATING-POWER INFORMATION .....	1-1	DISPLAY FOCUS .....	2-9
OPERATING VOLTAGE .....	1-2	ASTIGMATISM-FOCUS ADJUSTMENTS .....	2-9
OPERATING TEMPERATURE .....	1-2	BEAMFINDER .....	2-10
OPERATING POSITION .....	1-2	TRACE ALIGNMENT .....	2-10
PACKAGING FOR SHIPMENT .....	1-3	READOUT DISPLAY .....	2-10
SPECIFICATION .....	1-3	CARE OF CRT SCREEN .....	2-11
SYSTEM ELECTRICAL SPECIFICATION .....	1-11	VERTICAL AND HORIZONTAL MODE	
STANDARD ACCESSORIES .....	1-14	COMBINATIONS .....	2-11
		VERTICAL TRACE SEPARATION .....	2-13
<b>SECTION 2 OPERATING INSTRUCTIONS</b>		TRIGGER SOURCE .....	2-13
PRELIMINARY OPERATION .....	2-1	CALIBRATOR OUTPUT .....	2-13
REDUCTION OF DISPLAY GAIN WITH DISPLAY		DISPLAY PHOTOGRAPHY .....	2-14
OUTPUT CHARGE .....	2-1	INTENSITY MODULATION .....	2-15
PLUG-IN UNITS .....	2-1	REMOTE INPUT SIGNALS .....	2-15
CONTROLS AND CONNECTORS .....	2-2	APPLICATIONS .....	2-15
OPERATORS CHECKOUT PROCEDURE .....	2-2	VERTICAL AMPLIFIER PLUG-IN UNITS .....	2-15
PRELIMINARY SETUP .....	2-2	TIME-BASE PLUG-IN UNITS .....	2-16
DISPLAY FOCUS .....	2-3	SAMPLING DISPLAYS .....	2-16
TRACE ALIGNMENT .....	2-3	SPECIAL PURPOSE PLUG-IN UNITS .....	2-16
GRATICULE ILLUMINATION .....	2-3	X-Y OPERATION .....	2-17
CONTROL ILLUMINATION .....	2-3	RASTER DISPLAYS .....	2-17
VERTICAL DEFLECTION SYSTEM .....	2-3		
HORIZONTAL DEFLECTION SYSTEM .....	2-3	<b>SECTION 3 INSTRUMENT OPTIONS</b>	
TRIGGERING .....	2-7	OPTION 2 .....	3-1
		OPTION 3 .....	3-1

# LIST OF ILLUSTRATIONS

FIGURE NO.		PAGE
Frontis- piece	7104 Features .....	vi
1-1	7104 dimensional drawing .....	1-12
2-1	Front-panel controls, connectors and indicators.....	2-4
2-2	Rear-panel controls and connectors.....	2-6
2-3	Definition of graticule measurement lines.....	2-8
2-4	Location of readout on the crt identifying the originating plug-in and channel .....	2-10

# LIST OF TABLES

TABLE NO.		PAGE
1-1	Power-Cord Conductor Identification .....	1-2
1-2	Power-Cord Plug Configuration .....	1-2
1-3	Shipping Carton Test Strength .....	1-3
1-4	Electrical Characteristics .....	1-3
1-5	Environmental Characteristics .....	1-10
1-6	Physical Characteristics .....	1-11
1-7	Plug-In Incompatibilities .....	1-11
1-8	7104 Oscilloscope Vertical System Specification .....	1-13
1-9	7104 Oscilloscope System Horizontal Specification .....	1-14
1-10	Special Purpose Plug-In Units .....	1-14
2-1	Display Combinations .....	2-11
3-1	Option Information Locator .....	3-1

# OPERATORS SAFETY SUMMARY

The following general safety information applies to all operators and service personnel. Specific warnings and cautions will be found throughout the manual where they apply and should be followed in each instance.

## TERMS

### In This Manual

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

### As Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

## SYMBOLS

### In This Manual



This symbol indicates where applicable cautionary or other information is to be found.

### As Marked on Equipment



DANGER—High voltage.



Protective ground (earth) terminal.



ATTENTION—Refer to manual.

## WARNINGS

### Power Source

This product is intended to operate from a power source that will not apply more than 250 volts rms between the supply conductors or between either supply conductors and ground. A protective ground connection, by way of the grounding conductor in the power cord, is essential for safe operation.

### Grounding the Instrument

This instrument is grounded through the grounding conductor of the power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting to the input or output terminals of the instrument. A protective ground connection, by way of the grounding conductor in the power cord, is essential for safe operation.

### Use the Proper Power Cord

Use only the power cord and connector specified for your instrument. Use only a power cord that is in good condition. For detailed information on power cords and connectors, see page 1-2 of this manual.

Refer cord and connector changes to qualified service personnel.

**Use the Proper Fuse**

To avoid fire hazard, use only the fuse specified in the parts list for this instrument, and which is identical in type, voltage rating, and current rating.

Refer fuse replacement to qualified service personnel.

**Do Not Operate in Explosive Atmosphere**

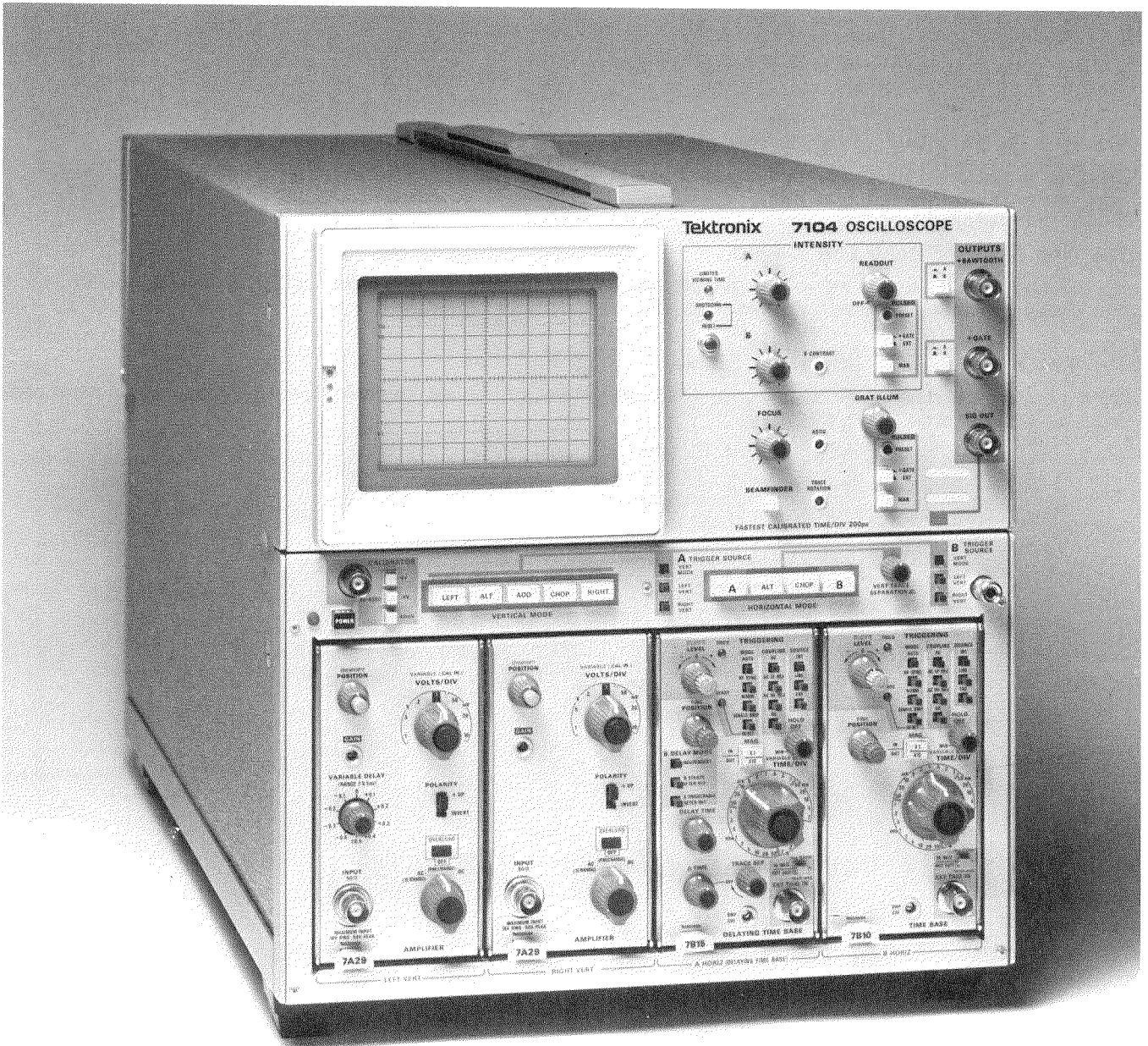
To avoid explosion, do not operate this instrument in an atmosphere of explosive gasses until it has been specifically certified for such operation.

**Do Not Remove Panels or Covers**

To avoid personal injury, do not remove the protective cabinet panels or covers. Do not operate this instrument without the panels or covers properly installed.

**Do Not Remove CRT Implosion Shield**

Do not remove the clear plastic implosion shield covering the crt faceplate. This shield provides protection to the operator from crt implosion.



### 7104 Features

The TEKTRONIX 7104 Oscilloscope is a solid-state, wide-bandwidth instrument designed for general-purpose applications. The 7104 can also be used to observe or photograph very fast repetitive or single shot waveforms.

The 7104 accepts Tektronix 7000-series plug-in units; the flexibility of the plug-in feature and variety of plug-in units available allows the system to be used for many measurement applications. The left pair of plug-in compartments are for vertical deflection and the right pair are for horizontal deflection. Electronic switching between each pair will produce multitrace vertical and/or horizontal displays.



# GENERAL INFORMATION

## INTRODUCTION

### OPERATORS MANUAL

The Operators Manual is divided into the following three sections:

Section 1—General Information contains instrument description, electrical specifications, environmental characteristics, standard and recommended accessories, installation, and packaging for shipment instructions.

Section 2—Operating Instructions contain information relative to operating and checking the instrument operation.

Section 3—Instrument Options contains a description of available options and gives the location of the incorporated information for those options.

Section 6—Instrument Options contains a description of available options and locations of incorporated information for those options.

Section 7—Replaceable Electrical Parts contains information necessary to order replaceable parts and assemblies related to the electrical functions of the instrument.

Section 8—Diagrams and Circuit Board Illustrations includes detailed circuit schematics, locations of assembled boards within the instrument, voltage and waveform information, circuit board component locators, and locations of adjustments to aid in the performing of the Adjustment and Performance Check portion of the Calibration procedure.

Section 9—Replaceable Mechanical Parts includes information necessary to order replaceable mechanical parts and shows exploded drawings which identify assemblies.

### INSTRUCTION MANUAL

The first two sections of the Instruction Manual contain operating instructions which are identical to the first two sections of the Operators Manual.

#### WARNING

*THE REMAINING PORTIONS OF THE INSTRUCTION MANUAL CONTAIN SERVICING INSTRUCTIONS. THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED SERVICE PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK OR OTHER PERSONAL INJURY, DO NOT PERFORM ANY SERVICING OTHER THAN THAT DESCRIBED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.*

Section 3—Theory of Operation contains basic and general circuit analysis that may be useful for servicing or operating the instrument.

Section 4—Maintenance describes routine and corrective maintenance procedures with detailed instructions for replacing assemblies, subassemblies, and individual components.

Section 5—Calibration contains procedures to check the operational performance and electrical characteristics of the instrument. Procedures also include methods for adjustment of the instrument to meet specifications.

## INSTALLATION

### INITIAL INSPECTION

This instrument was inspected both mechanically and electrically before shipment. It should be free of marks or scratches and should meet or exceed all electrical specifications. To confirm this, inspect the instrument for physical damage incurred in transit and test the electrical performance by following the Operators Checkout Procedure in Section 2, Operating Instructions. Verify Performance Requirements by referring a qualified service person to the servicing sections of the Instruction Manual. If there is damage or deficiency, contact your local Tektronix Field Office or representative.

### OPERATING-POWER INFORMATION

This instrument can be operated from either a 115-volt or 230-volt nominal supply source, 48 to 440 hertz. The line fuse remains the same for both 115-volt and 230-volt operation.

#### CAUTION

*To prevent damage to the instrument, always check the LINE VOLTAGE SELECTOR switch located on the rear of the instrument before connecting the instrument to the supply circuit.*

**WARNING**

**AC POWER SOURCE AND CONNECTION.** This instrument operates from a single-phase power source. It has a three-wire power cord and two-pole, three-terminal grounding-type plug. The voltage to ground (earth) from either pole of the power source must not exceed the maximum rated operating voltage, 250 volts.

Before making connection to the power source, determine that the instrument is adjusted to match the voltage of the power source, and has a suitable two-pole, three-terminal grounding-type plug. Refer any changes to qualified service personnel.

**GROUNDING.** This instrument is safety class I equipment (IEC designation). All accessible conductive parts are directly connected through the grounding conductor of the power cord to the grounding contact of the power plug.

The power input plug must only be inserted in a mating receptacle with a grounding contact. Do not defeat the grounding connection. Any interruption of the grounding connection can create an electric shock hazard.

For electric shock protection, the grounding connection must be made before making connection to the instrument's input or output terminals.

**TABLE 1-1  
Power-Cord Conductor Identification**

Conductor	Color	Alternate Color
Ungrounded (Line)	Brown	Black
Grounded (Neutral)	Blue	White
Grounded (Earthing)	Green-Yellow	Green-Yellow

The power-cord plug required depends upon the ac input voltage and the country in which the instrument is to be used. Should you require a power-cord plug other than that supplied with your instrument, refer to the standards listed in Table 1-2.

**TABLE 1-2  
Power-Cord Plug Configuration**

Nominal Line Voltage	Reference Standards
115 V AC	<sup>1</sup> ANSI C73.11
	<sup>2</sup> NEMA 5-15-P
	<sup>3</sup> IEC 83
230 V AC	<sup>1</sup> ANSI C73.20
	<sup>2</sup> NEMA 6-15-P
	<sup>3</sup> IEC 83
	<sup>4</sup> BS 1363
	<sup>5</sup> CEE 7, sheets IV, VI, & VII
	<sup>6</sup> AS C112

- <sup>1</sup>ANSI—American National Standards Institute
- <sup>2</sup>NEMA—National Electrical Manufacturer's Association
- <sup>3</sup>IEC—International Electrotechnical Commission
- <sup>4</sup>BS—British Standards Institution
- <sup>5</sup>CEE—International Commission on Rules for the Approval of Electrical Equipment
- <sup>6</sup>AS—Standards Association of Australia

**OPERATING VOLTAGE**

The LINE VOLTAGE SELECTOR switch (located on the rear panel) allows selection of 115-volt or 230-volt nominal line voltage operation. To convert from 115-volt to 230-volt operation, change the power cord and plug to match the power-source receptacle, then use a small screwdriver to move the LINE VOLTAGE SELECTOR switch to the desired range. The line fuse remains the same for both 115-volt and 230-volt operation.

**OPERATING TEMPERATURE**

The 7104 can be operated where the ambient air temperature is between 0° and +50° C and can be stored in ambient temperatures from -55° to +75° C. After storage at temperatures outside the operating limits, allow the chassis temperature to reach a safe operating limit before applying power.

The 7104 is cooled by air drawn in through holes in the top, side, and bottom panels and blown out through the fan exhaust. To ensure proper cooling of the instrument, maintain the clearance provided by the feet on the bottom and allow at least 2 inches clearance (more if possible) at the top, sides, and rear of the instrument.

**OPERATING POSITION**

A bail-type stand, mounted on the bottom of the instrument, permits the instrument to be tilted up about 10° for more convenient crt viewing.

## PACKAGING FOR SHIPMENT

If the Tektronix instrument is to be shipped to a Tektronix Service Center for service or repair, attach a tag showing: owner (with address) and the name of an individual at your firm that can be contacted. Include complete instrument serial number and a description of the service required.

Save and re-use the package in which your instrument was shipped. If the original packaging is unfit for use or not available, repackaging the instrument as follows:

Surround the instrument with polyethylene sheeting to protect the finish of the instrument. Obtain a carton of corrugated cardboard of the correct carton strength and having inside dimensions of no less than six inches more than the instrument dimensions. Cushion the instrument by tightly packing three inches of dunnage or urethane foam between carton and instrument, on all sides. Seal carton with shipping tape or industrial stapler.

The carton test strength for your instrument is 375 pounds.

## SPECIFICATION

The electrical characteristics listed in Table 1-4 apply when the following conditions are met: (1) Calibration of the instrument must have taken place at an ambient temperature between +20° and +30° C, (2) the instrument must be allowed a 20-minute warm-up period, (3) all specifications are valid at an ambient temperature of 0° to +50° C, unless otherwise stated, (4) the instrument must be in an environment that meets the limits described in Table 1-5.

Any applicable conditions not listed above are expressly stated as part of that characteristic. Environmental characteristics are listed in Table 1-5 and Physical characteristics are listed in Table 1-6.

**TABLE 1-4**  
**Electrical Characteristic**

Characteristic	Performance Requirement
----------------	-------------------------

### VERTICAL SYSTEM

Deflection Factor	Compatible with all 7000-series plug-in units.
Difference Between Vertical Compartments	1% or less.
Low-Frequency Linearity	0.1 div or less compression or expansion of a center-screen 2-div display positioned anywhere vertically within the graticule area.
Frequency Response	Varies with plug-in unit selected. See 7104 Oscilloscope Vertical Systems Specification, Table 1-7.
With 7A29 Amplifier Unit	1 GHz at 3 dB down; temperature range from 0° to 35° C.
Step Response	
Risetime (10 to 90%), with 7A29 Amplifier Unit	350 ps or less (calculated from bandwidth).

**TABLE 1-4 (CONT.)**  
**Electrical Characteristics**

Characteristic	Performance Requirement
Isolation Between Vertical Compartments (8 division signal)  LEFT, RIGHT, ALT Modes	At least 160:1 from dc to 100 MHz and at least 80:1 from 100 MHz to 1 GHz.
Delay Line	Permits viewing leading edge of triggering signal.  <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;"><i>7B50-series time-base units will not display leading edge of the trigger signal in 7104.</i></p>
Difference in Signal Delay Between Vertical Compartments	50 ps or less.
Vertical Display Modes	Selected by front-panel VERTICAL MODE switch.
LEFT	Left vertical-unit displayed.
ALT	Display alternates between Left and Right vertical units at a rate determined by the horizontal plug-in unit(s).
ADD	Display is algebraic sum of left and right vertical units.
CHOP	Display chops between Left and Right vertical units asynchronously.
Repetition Rate	1 MHz within 20%.
RIGHT	Right vertical unit displayed.
"Slaved ALT"	Slaved operation occurs if: (1) VERT MODE switch set to ALT, (2) HORIZ MODE switch set to ALT or CHOP, (3) time-base unit is installed in each horizontal compartment and (4) time-base unit installed in A HORIZ compartment operates in Independent mode.  When in slaved operation the display alternates between: (1) trace produced by LEFT VERT unit displayed at sweep rate of B time-base unit and (2) trace produced by RIGHT VERT unit displayed at sweep rate of A time-base unit.  <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;"><i>VERT TRACE SEPARATION (B) control is inoperative in "Slaved ALT" Mode.</i></p>
VERT TRACE SEPARATION (B)	Positions "B" trace at least 4 div above and below "A" trace, when 7104 operates in ALT or CHOP horizontal modes. See note concerning "Slaved ALT" vertical mode.

TABLE 1-4 (CONT.)  
Electrical Characteristics

Characteristic	Performance Requirement						
<b>TRIGGERING</b>							
A and B TRIGGER SOURCE	Selected by front-panel switches. Lights behind pushbuttons are illuminated to indicate trigger source.						
VERT MODE	The trigger source is controlled by vertical display mode selection. Source (sources) is (are) shown by the illumination of the LEFT and RIGHT trigger source buttons. Source follows (is same as) the vertical display with the following two exceptions:						
	<table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th>VERT MODE</th> <th>Trigger Source</th> </tr> </thead> <tbody> <tr> <td>CHOP</td> <td>LEFT</td> </tr> <tr> <td>"Slaved ALT"</td> <td>RIGHT for A TRIGGER LEFT for B TRIGGER</td> </tr> </tbody> </table>	VERT MODE	Trigger Source	CHOP	LEFT	"Slaved ALT"	RIGHT for A TRIGGER LEFT for B TRIGGER
VERT MODE	Trigger Source						
CHOP	LEFT						
"Slaved ALT"	RIGHT for A TRIGGER LEFT for B TRIGGER						
	See Vertical Display Modes for slaved operation.						
LEFT	Trigger source: LEFT vertical unit. LEFT trigger source button illuminated.						
RIGHT	Trigger source: RIGHT vertical unit. RIGHT trigger source button illuminated.						

### HORIZONTAL SYSTEM

Deflection Factor	Compatible with all 7000-series plug-in units.
Gain Difference Between Horizontal Compartments	1% or less.
DC Linearity	0.05 division or less error at each graticule line after adjusting for no error at second and tenth graticule lines.
Fastest Calibrated Sweep Rate	200 ps/div. See 7104 Oscilloscope System Horizontal Specification, Table 1-8.
Horizontal Display Modes	Selected by front-panel HORIZONTAL MODE switch.
A	A horizontal unit displayed.
ALT	Display alternates between A and B horizontal units.
CHOP	Display chops between A and B horizontal units.
B	B horizontal unit displayed.
Chopped Mode	
Repetition Rate	200 kHz within 20%.
Phase Shift Between Vertical and Horizontal Deflection Systems	2° or less from dc to at least 50 kHz.
Option 2 (B HORIZ compartment only) with 7A19s or 7A29s, at least one of which has the variable delay option	2° or less from dc to 50 MHz after adjusting variable delay for balance at 35 MHz. Phase balance can be obtained at any frequency up to 250 MHz.
Bandwidth	350 MHz

**TABLE 1-4 (CONT.)  
Electrical Characteristics**

Characteristic	Performance Requirement
X-Y Displays	X-Y displays can only be obtained in conjunction with a time-base unit. With an amplifier unit installed in the A(B) horizontal compartment the Z-axis can only be controlled by the time-base unit in the B(A) horizontal compartment. This is independent of the horizontal mode switch selection.

**CALIBRATOR**

Waveshape	Square wave.
Polarity	Positive going, with baseline near 0 volt.
Output Resistance	450 $\Omega$ .
Output Voltage	(Selected by front-panel CALIBRATOR switch.)
Into 100 k $\Omega$ or greater	40 mV, 0.4 V, 4 V.
Into 50 $\Omega$	4 mV, 40 mV, 0.4 V.
Output Current	40 mA available through CALIBRATOR output with optional bnc-to-Current Loop adapter. CALIBRATOR must be set to 4 V for calibrated output.
Amplitude Accuracy (P-P Voltage)	Within 1%.
Repetition Rate	1 kHz within 0.25%.
Duty Factor	49.8% to 50.2%.
Rise Time and Fall Time	500 ns or less into 100 pF or less.

**SIGNAL OUTPUTS**

+SAWTOOTH OUT	
Source	Selected by front-panel switch. A: A HORIZ time-base unit. B: B HORIZ time-base unit.
Polarity	Positive-going with baseline at 0 V within 1 V into 1 M $\Omega$ .
Output Voltage	
Rate of Rise	
Into 50 $\Omega$	50 mV/unit of time selected by time-base unit time/div switch, within 15%, 100 ns/div maximum sweep rate.
Into 1 M $\Omega$	1 V/unit of time selected by the time-base unit time/div switch, within 10%; 1 $\mu$ s/div maximum sweep rate.
Output Resistance	Approximately 950 $\Omega$ .
+GATE	
Source	Selected by front-panel switch. A: A Gate, derived from A HORIZ time-base unit main gate. B: B Gate, derived from B HORIZ time-base unit main gate.

**TABLE 1-4 (CONT.)  
Electrical Characteristics**

Characteristic	Performance Requirement
+GATE (continued)	
Polarity	Positive-going with baseline at 0 V within 1.0 V into 1 M $\Omega$ .
Output Voltage	
Into 50 $\Omega$	0.5 V within 10%.
Into 1 M $\Omega$	10 V within 10% (up to 1 $\mu$ s/div sweep rate).
Rise Time Into 50 $\Omega$	5 ns or less.
Fall Time Into 50 $\Omega$	15 ns or less.
Output Resistance	Approximately 950 $\Omega$ .
SIG OUT	
Source	Selected by B TRIGGER SOURCE switch.
Source	Same as B TRIGGER SOURCE.
Output Voltage	
Into 50 $\Omega$	25 mV/div of vertical deflection within 25%.
Into 1 M $\Omega$	For a maximum output of $\pm 2$ V: 0.5 V/div of vertical deflection within 25%.
Bandwidth Into 50 $\Omega$	Varies with vertical plug-in selected; see 7104 series Oscilloscope Systems Specification, Table 1-7.
DC Centering	0 V within 1 V into 1 M $\Omega$ .
Aberrations	15% or less p-p within 50 ns of step.
Output Resistance	Approximately 950 $\Omega$ .

### READOUT DISPLAY

Readout Modes	
Free-Run (Not Labeled)	Continuously displayed.
PULSED	
Pulse Source	Selected by front-panel switches.
	+GATE: Triggered by the trailing edge of the +GATE selected by the front-panel switch.
	EXT: Controlled through rear-panel remote control connector.
	MAN: Manual trigger, independent of other pulse sources.

**TABLE 1-4 (CONT.)  
Electrical Characteristics**

Characteristic	Performance Requirement
<b>DISPLAY</b>	
Graticule	
Type	Internal, illuminated with variable edge lighting.
Lighting	
Normal	Continuously lighted.
PULSED	Single-shot operation. Lights are pulsed on for approximately 0.5 seconds.
Pulse Source	Selected by front-panel switches.  +GATE: Triggered by trailing edge of +GATE selected by front-panel switch.  EXT: Controlled through rear-panel remote control connector.  MAN: Manual trigger, independent of other pulse sources.
Area	8 × 10 div 0.85 cm/div.
Phosphor	P31.
Vertical and Horizontal Resolution	17 lines/div.
High Voltage	
Screen Voltage	Approximately 12.5 kV.
Limited Viewing Time Indicator	
Steady Yellow	Crt display time is limited to approximately 1 hour.
Flashing Yellow	Crt display time is limited to approximately 1 minute and intensity is being limited.
Geometry	Within 0.1 div of vertical and horizontal graticule lines.
BEAMFINDER	When actuated, limits display to within graticule area and defocuses display.
Photographic Writing Speed	20 cm/nsec (without blue filter).  Phosphor: Standard P31.  Camera: TEKTRONIX C53; f/1.9 1:0.85 lens.  Film: Polaroid Type 107; 3000 ASA.

**REMOTE CONNECTORS AND SWITCHES**

Control Illumination	HIGH, MEDIUM and OFF. Three position switch located on rear panel of power supply.
Camera Power	Three-contact connector compatible with TEKTRONIX C-50 Series Cameras.
Bottom Pin	Ground
Center Pin	Single sweep reset.
Top Pin	+15 V.



**TABLE 1-4 (CONT)**  
**Electrical Characteristics**

Characteristic	Performance Requirement
REMOTE RESET INPUT	Input to reset single-sweep function of time-base units installed in A and B HORIZ compartments.
Signal Required	Closure to ground or switching from the high level (+50 to +10 V; sink less than 40 $\mu$ A) to low level (+0.5 V to -5 V; sink less than 12 mA) in less than 1 msec, resets the sweep. Compatible to 15 V open collector TTL source.
Minimum Pulse Width	10 $\mu$ s at 50% amplitude points.
Maximum Safe Input Voltage	+50 V to -5 V (dc + peak ac).
A SINGLE SWEEP READY	Connector (bnc) on rear panel. Remote ready indicator for A HORIZ time-base unit.
Output Signal	Open when not ready. +5 V at 47 $\Omega$ source impedance when ready. Output will light a No. 49 bulb.
B SINGLE SWEEP READY	Connector (bnc) on rear panel. Remote ready indicator for B HORIZ time-base unit.
Output Signal	Open when not ready. +5 V at 47 $\Omega$ source impedance when ready. Output will light a No. 49 bulb.
GRATICULE/READOUT SINGLE SHOT	Connector (bnc) on rear panel. Switching to the low level (+1 V to -5 V; sink less than 2 mA) from the high level (+10 V to +15 V; sink less than 0.3 mA), in less than 1 $\mu$ sec, triggers the readout to display one complete readout frame and the GRAT ILLUM to be illuminated for approximately 0.5 sec.  Compatible to 15 V open collector TTL source.
Maximum Open Circuit Voltage	+15 V.
Maximum Safe Input Voltage	+15 V to -5 V (dc plus peak ac).
Probe Power	Two probe power connectors on rear panel.
Pin 1	+5 V.
Pin 2	Chassis ground.
Pin 3	-15 V.
Pin 4	+15 V.
Z-AXIS INPUT (External)	Connector (bnc) on rear panel.
Polarity and Sensitivity	Positive 2 V provides complete blanking from maximum intensity condition. Negative 2 V provides complete unblanking from minimum intensity condition.
Low Frequency Limit	Dc.
Input Resistance	Approximately 500 $\Omega$ .
Input Capacitance	Less than 50 pF.
Open Circuit Voltage	0 V.
Maximum Safe Input Voltage	15 V, dc plus peak ac.
Maximum Repetition Rate	1 MHz.

**TABLE 1-4 (CONT.)  
Electrical Characteristics**

Characteristic	Performance Requirement
<b>POWER SOURCE</b>	
Voltage Range (AC, RMS)	Selected by rear-panel LINE VOLTAGE SELECTOR switch.
115 V Rated	From 90 V to 132 V.
230 V Rated	From 180 V to 250 V.
Line Frequency	From 48 Hz to 440 Hz.
Maximum Power Consumption	215 W.
Maximum Current	3.3 A at 60 Hz, 90 V Line. 1.7 A at 60 Hz, 180 V Line.
Fuse Data Line (P1200)	4 A fast blow. (For both LINE VOLTAGE SELECTOR ranges.)

**TABLE 1-5  
Environmental Characteristics**

Characteristic	Information
----------------	-------------

**NOTE**

*This instrument will meet the electrical characteristics given in the Performance Requirement column of Table 1-4 over the following environmental limits.*

Temperature	
Operating	0° to +50° C.
Storage	-55° to +75° C.
Altitude	
Operating	5 km (15,000 feet).
Storage	15 km (50,000 feet).
EMC (Electromagnetic Compatibility Option 3 Only)	<p style="text-align: center;"><b>NOTE</b></p> <p><i>Any unused plug-in compartments must be covered with a blank plug-in panel (EMI shielded) in order to meet EMC specifications. See Instrument Options section for additional information.</i></p> <p>Meets requirements of MIL-STD-461 A, when tested in accordance with the following test methods of MIL-STD-462: CE-01, CE-03, CS-01, CS-02, CS-06, RE-02, (Limited to 1 GHz), (T) RE-04, RS-01, and RS-03 (Limited to 1 GHz).</p>

**TABLE 1-6**  
**Physical Characteristics**

Characteristic	Information
Ventilation	Safe operating temperature maintained by dc fan. Automatic resetting thermal cutout protects instrument from overheating.
Finish	Anodized front- and rear-panel with blue-vinyl painted aluminum cabinet.
Overall Dimensions (measured at maximum points)	See Figure 1-1.
Height	13.6 inches. 34.5 cm.
Width	12.0 inches. 30.5 cm
Length	23.5 inches. 59.2 cm.
Net Weight (Instrument without Plug-Ins)	43.6 lb. 19.8 kg.

**SYSTEM ELECTRICAL SPECIFICATION**

Your TEKTRONIX 7104 Oscilloscope system provides exceptional flexibility in operation with a wide choice of general- and special-purpose plug-in units. The type number of a particular plug-in unit identifies its usage as follows:

The first digit (7) denotes the oscilloscope system for which the plug-in is designed (7000-series).

The second letter describes the purpose of the plug-in unit:

- A – Amplifier unit
- B – “Real time” time-base unit
- C – Curve tracer
- D – Digital unit
- L – Spectrum analyzer
- M – Miscellaneous
- S – Sampling unit
- T – Sampling time-base unit

The third and fourth digits of the plug-in type number do not carry any special connotation.

A “N” suffix letter added to the normal four-digit type number identifies a unit not equipped with the circuitry necessary to encode data for the 7000-series readout system.

Table 1-7 lists plug-in incompatibilities.

Table 1-8 lists the vertical specifications which are system dependent. For more complete specifications on plug-in units for the 7000-series oscilloscope system, refer to the Tektronix Products catalog.

Table 1-9 lists the horizontal specifications which are system dependent. For more complete specifications on plug-in units for the 7000-series oscilloscope system, refer to the Tektronix Products catalog.

Table 1-10 lists some special purpose plug-in units available for use with the 7104 Oscilloscope.

**TABLE 1-7**  
**Plug-In Incompatibilities**

The 7104 Oscilloscope is compatible with Tektronix 7000-Series Plug-In Units with the exceptions listed in the following table:

Plug-In Unit	Operating Condition	Symptom	Cause
<b>LOGIC ANALYZER UNITS</b>			
7D01 & 7D02	Any	Not compatible for use with the 7104 Oscilloscope. Any CRT damage caused by the use of the 7D01 or 7D02 in the 7104 Oscilloscope will not be covered under instrument warranty.	The 7104 display from these Logic Analyzers can cause permanent reduction in CRT microchannel plate gain; consequently, a permanent reduction in writing rate. For more information refer to “Reduction of Display Gain with Display Output Change” in the 7104 Service Manual.

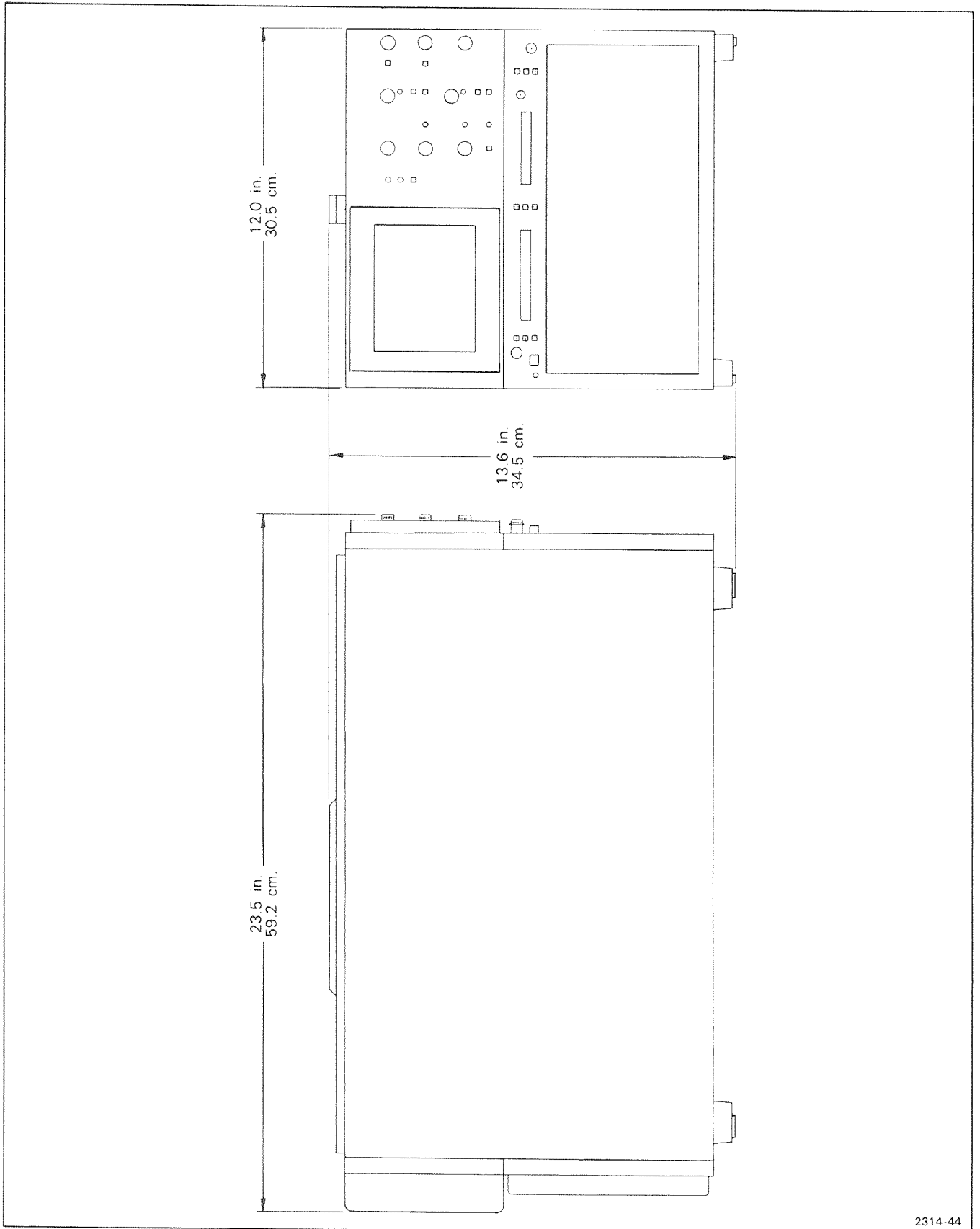


Figure 1-1. 7104 dimensional drawing.

**TABLE 1-8**  
**7104 Oscilloscope Vertical System Specification**

Amplifier Plug-In Unit	Probe	Bandwidth (MHz)	RiseTime (ns)	Accuracy (%) <sup>1</sup>		VERT SIG OUT	
				0°C to +50°C EXT CAL	0° to +50°C INT CAL	BW (MHz)	Tr (ns)
7A11	Integral	250	1.4	2	3	150 MHz	2.4 ns
7A12	None	105	3.4	2	3	110 MHz	3.2 ns
	P6053B			3	4		
7A13	None	100	3.5	1.5	2.5	100 MHz	3.5 ns
	P6053B					100 MHz	3.5 ns
	P6055	65	5.4			65 MHz	5.4 ns
7A14	P6021	55	6.4	2	3	50 MHz	7.0 ns
	P6022	110	3.2			100 MHz	3.5 ns
7A15A/N	None	80	4.4	2	3	70 MHz	5.0 ns
	P6053A			3	4		
7A16A	None	225	1.6	2	3	150 MHz	2.4 ns
	P6053B			3	4		
7A17	None	150	2.4			15 MHz	24 ns
7A18	None	75	4.7	2	3	70 MHz	5.0 ns
	P6053B			3	4		
7A19	None	600	0.6	3	4	600 MHz	0.6 ns
	P6056			4	5		
	P6057			5	5		
	P6201	500	0.7	4	5	500 MHz	0.7 ns
7A22	None or Any	1 Mhz (within 10%)	350 (within 9%)	2	3	1.0 MHz ±10%	350 ns ±9%
7A24	None	400	0.9	3	4	200 MHz	1.75 ns
	P6056, P6057	400	0.9	4	5		
	P6201	350	1.0	4	5		
7A26	None	200 <sup>2</sup>	1.75 <sup>2</sup>	2	3	150 MHz	2.4 ns
	P6053B			3	4		
7A29	None	1000 <sup>3</sup>	0.35 <sup>3,4</sup>	3	4	750 MHz	0.47 ns
	P6056	1000 <sup>3</sup>	0.35 <sup>3,4</sup>	4	5	700 MHz	0.50 ns
	P6057	800	0.45			600 mHz	0.60 ns
	P6201	600	0.60	4	5	500 MHz	0.70 ns

<sup>1</sup> Deflection Factor accuracy is checked as follows:  
 EXT CAL 0° to +50°C: Plug-in gain set at a temperature within 10°C of operating temperature, using an external calibrator with accuracy within 0.25%.  
 INT CAL 0° to +50°C: Plug-in gain set using the oscilloscope calibrator (within 10°C of the operating temperature) in a temperature range between 0° and +50°C.  
<sup>2</sup> System temperature range from 0° to +35°C; derate 10% from +35° to +50°C.  
<sup>3</sup> System temperature range from 0° to +35°C.  
<sup>4</sup> Risetime calculated from measured bandwidth using the formula: (Tr=0.35/BW).

**TABLE 1-9**  
**7104 Oscilloscope System Horizontal Specification**

Time-Base Unit	Performance Feature	Maximum Calibrated Sweep Rate	Triggering Frequency Range
7B10	Delayed Sweep	200 psec/div	Dc to 1000 MHz
7B15	Delaying Sweep	200 psec/div	Dc to 1000 MHz
7B92A	Display Switching	500 psec/div	Dc to 500 MHz
7B80	Delayed Sweep	1 ns/div	Dc to 400 MHz
7B85	Delaying Sweep	1 ns/div	Dc to 400 MHz
7B50A	Delayed Sweep	5 ns/div	Dc to 150 MHz
7B50 Series (not 7B50A0) 7B70 Series 7B92 Series (not 7B92A)	NOT RECOMMENDED. These time base units are not optimized for the extremely wide bandwidth of the 7104 and will likely exhibit unacceptable degradation in sweep accuracy and linearity.		

**TABLE 1-10**  
**Special Purpose Plug-In Units**

Plug-In	Performance Feature
7CT1N	Low-Power Semiconductor Curve Tracer
7D10	Digital Events Delay
7D11	Digital Delay
7D12	A/D Converter; plug-in modules provide flexible measurement capability
7D13	Measures Temperature, Voltage, Current and Resistance
7D14	Directly Gated Counter to 525 MHz
7K11	CATV Preamplifier
7L12	100 kHz to 1.8 GHz Spectrum Analyzer
7L13	1 kHz to 1.8 GHz Spectrum Analyzer
7M11	Dual Delay Line
7M13	Readout Access Unit
7S11	Accepts Plug-In Sampling Heads
7S12	Time Domain Reflectometer and Sampling Applications
7S14	Dual Trace Delayed Sweep Sampler
7T11	Random or Sequential; equivalent or Real-Time Sampling

## STANDARD ACCESSORIES

- 1 ea ..... Operators Manual
- 1 ea ..... Instruction Manual
- 1 ea ..... Blue Faceplate Filter (installed)
- 1 ea ..... Power Cord

# OPERATING INSTRUCTIONS

## PRELIMINARY OPERATION

To operate this instrument effectively, the user must become familiar with the operation and capabilities of the instrument. This section describes the use of front- and rear-panel controls and connectors.

### WARNING

*To avoid electric-shock hazard, see Installation in the General Information section of this manual before operating this instrument.*

## REDUCTION OF DISPLAY GAIN WITH DISPLAY OUTPUT CHARGE

It is a characteristic of the 7104 crt to have permanently diminished display gain in the locations of sustained trace operation. This gain reduction manifests itself as reduced writing speed. The gain is diminished in proportion to the logarithm of the charge output (current-time product) from a given display area of the microchannel plate image amplifier.

The limited viewing time system with its two panel indicators, LIMITED VIEWING TIME and SHUTDOWN, and its RESET pushbutton is included to enable long-term use of the crt display by discouraging (1) high continuous trace current operation and (2) long-term, unattended trace-on operation:

For average display currents below 25 nA the yellow LIMITED VIEWING TIME indicator remains off and display shutdown does not occur. When the average display current is 25 nA, the indicator comes on and shutdown occurs in 1 hour. This time drops to one minute for an average display current of 1.8  $\mu$ A. The average display current is limited by feedback to the 1.8  $\mu$ A value. (Singleshot display current is not limited by this system.)

The user can minimize gain loss by taking precautions in three areas: (1) Readout intensity, (2) Trace baselines, and (3) X-Y displays.

### 1. Readout intensity

The fixed location, small area, and often fixed pattern of the readout tends to aggravate the gain loss in this area so it is advised that the readout display intensity be kept low.

### 2. Trace baselines

There will, in time, be distinguishable gain loss in the region of the trace baseline(s). Less severe gain loss will result by using different baseline locations rather than repeatedly using fixed locations for these, such as the 0% line. Operating the timebase in NORMAL trigger mode rather than AUTO trigger mode (bright baseline) will reduce the trace baseline gain loss by removing the trace in the absence of a triggering signal.

### 3. X-Y displays

Operating in an X-Y mode often means more concentrated display current and hence more concentrated associated gain loss. The user will want to take care that stationary spots or small area displays are not allowed to be operated for extended time periods.

## PLUG-IN UNITS

The 7104 accepts up to four Tektronix 7000-series plug-in units, allowing selection of bandwidth, sensitivity, display mode, etc., and provides for future expansion of the system. Refer to Tables 1-7 through 1-10.

The overall capabilities of the system are mainly determined by the characteristics of the selected plug-ins. Some typical combinations are given under Applications, in this section, along with simplified set up instructions. For information on other plug-in units, refer to the current Tektronix Products catalog.

### Installation of Plug-In Units



*To prevent instrument damage plug-in units should not be installed or removed without first turning the instrument power off.*

To install a plug-in unit into a compartment, align the slots in the top and bottom of the plug-in unit with the associated guide rails in the plug-in compartment. Insert the plug-in unit into the compartment until it locks into place. To remove a plug-in unit, pull out on the release latch to disengage the plug-in. To meet the EMC (electromagnetic compatibility) specifications, cover all unused plug-in compartments with an EMC shielded blank plug-in panel, Tektronix Part 016-0155-00.

The gain of the 7104 vertical and horizontal systems have been normalized to allow plug-in units to be interchanged among plug-in compartments without adjustment of the system. The basic calibration of the plug-in units should be checked when installed to verify their accuracy (refer to the operating instructions in the plug-in manual).

## CONTROLS AND CONNECTORS

The 7104 front and rear panels are shown in Figure 2-1 and Figure 2-2. A brief, functional description of each control and connector is included in the illustration. Refer to Detailed Operating Information for additional information.

### Front-Panel Color Coding

The 7104 front panel is color coded to define areas by function. Blue identifies the display mode controls; green identifies triggering controls.

Other colors such as gray, orange and yellow, have no functional assignment, but indicate the relationship among controls and/or connectors.

## OPERATORS CHECKOUT PROCEDURE

The Operators Checkout Procedure may be used to verify proper operation of the front-panel controls and for familiarization with the instrument. Only instrument functions (not measurement quantities or specifications) are checked in the procedure; therefore, a minimum amount of test equipment is required. If performing the Operators Checkout Procedure reveals improper performance or instrument malfunction, check the operation of associated equipment; then refer to qualified service personnel for repair or adjustment of the instrument.

### Test Equipment Required

The following test equipment was used in preparing the Operators Checkout Procedure. Other test equipment which meets these requirements may be substituted. When other equipment is substituted, the control settings or setup may need to be altered.

#### 1. Function Generator

**Description:** Frequency range, 250 kilohertz to 1 megahertz; output amplitude, two volts peak-to-peak into 50 ohms; waveform, sine wave.

**Type Used:** TEKTRONIX SG 503 (used with TM 500 power module).

#### 2. Cables (2 Required)

**Description:** Length, 42 inches; connectors, bnc.

**Type Used:** Type RG-58/U, 50-ohm coaxial, Tektronix Part 012-0057-01.

#### 3. T Connector

**Description:** Connectors, bnc-to-bnc.

**Type Used:** Bnc-to-bnc connector, Tektronix Part 103-0030-00.

#### 4. Adapter

**Description:** Connectors, bnc female-to-bnc female.

**Type Used:** Bnc female-to-bnc female, Tektronix Part 103-0028-00.

## PRELIMINARY SETUP

1. Set the front-panel controls as follows:

- A INTENSITY ..... counterclockwise
- FOCUS ..... midrange
- B INTENSITY ..... counterclockwise
- READOUT ..... OFF
- GRAT ILLUM ..... counterclockwise
- POWER ..... OFF
- CALIBRATOR ..... 4 V
- VERTICAL MODE ..... LEFT
- A TRIGGER SOURCE ..... VERT MODE
- HORIZONTAL MODE ..... A
- VERT TRACE SEPARATION (B) ..... midrange
- B TRIGGER SOURCE ..... VERT MODE



2. Connect the 7104 to a power source that meets the voltage and frequency requirements of this instrument. If the available line voltage is outside the limits of the LINE VOLTAGE SELECTOR switch setting (on rear panel), see Operating Power Information under Installation (General Information section).

3. Install Tektronix 7A-series amplifier units in the LEFT VERT and RIGHT VERT compartments. Install Tektronix 7B-series time-base units in the A HORIZ and B HORIZ compartments.

4. Press the POWER switch to the on (locked in) position.

5. Set both time-base units to 1 millisecond/division and triggering to auto mode with ac coupling from the internal source.

6. Rotate the A INTENSITY control until the trace is at a desirable viewing level (near midrange).

7. Connect the CALIBRATOR output to the input of the left amplifier unit with a 42-inch bnc cable.

8. Set the left amplifier deflection factor to display a signal amplitude of 2 divisions on the crt.

9. Set the A horizontal time-base triggering for a stable display.

### DISPLAY FOCUS

10. Rotate the FOCUS and ASTIG controls and observe the square-wave display. Notice that the thickness of the trace varies. Set the FOCUS and ASTIG controls for a well-defined trace.

### TRACE ALIGNMENT

11. Disconnect the input signal. Using the left amplifier position control align the trace with the center horizontal graticule line. If necessary use the TRACE ROTATION control to align the trace with the center graticule line.

### GRATICULE ILLUMINATION

12. Rotate the GRAT ILLUM control throughout its range and notice that the graticule lines are illuminated as the control is turned clockwise.

### CONTROL ILLUMINATION

13. Set the rear-panel CONTROL ILLUMINATION switch to HIGH. Notice that the A INTENSITY indicator and the lighted pushbutton switches are all illuminated. Sequentially press all of the HORIZONTAL MODE switch positions and notice the A and B INTENSITY lights; these lights indicate which intensity control is active. Set the CONTROL ILLUMINATION switch to the MEDIUM position. Observe that the selected intensity indicator and the lighted push-button switches on the plug-in units are dimmed.

14. Set the rear-panel CONTROL ILLUMINATION switch to the HIGH position. Return the HORIZONTAL MODE switch to A.

### VERTICAL DEFLECTION SYSTEM

15. Connect the 4 V CALIBRATOR output to the input connectors of both amplifier units with two 42-inch bnc cables and a bnc T connector. Set the deflection factor of the left amplifier unit to display about 2 divisions of signal on the crt.

16. Notice that the position control of only the left amplifier unit affects the vertical position of the displayed trace. Position the trace to the upper half of the graticule.

17. Set the VERTICAL MODE switch to RIGHT. Set the deflection factor of the right amplifier unit to display about 2 divisions of signal on the crt.

18. Notice that the position control of only the right amplifier unit affects the vertical position of the displayed trace. Position the trace to the lower half of the graticule.

19. Set the VERTICAL MODE switch to ALT. Two traces should be displayed on the crt. The top trace is produced by the left amplifier unit and the bottom trace is produced by the right amplifier unit; the sweep for both traces is produced by the A time-base unit. Set the sweep rate of the A time-base unit to 50 milliseconds/division; notice the display alternates between the left and right amplifier plug-in units after each sweep. Turn the A time-base sweep rate switch through its range; notice that the display alternates between amplifier units at all sweep rates.

20. Set the VERTICAL MODE switch to CHOP. Turn the A time-base unit sweep rate switch throughout its range. A dual-trace display will be presented at all sweep rates, and both amplifier units are displayed by the A time-base unit on a time-sharing basis. Set the A time-base unit sweep rate switch to 0.5 millisecond/division.

21. Set the VERTICAL MODE switch to ADD. The display should be four divisions in amplitude. Notice that the position control of either amplifier unit moves the display. Set the VERTICAL MODE switch to LEFT.

### HORIZONTAL DEFLECTION SYSTEM

22. Position the start of the trace to the left graticule line with the A time-base unit position control. Notice that the position control of only the A time-base unit affects the horizontal position of the displayed trace (not the position of the B time-base unit).

23. Set the HORIZONTAL MODE switch to B.

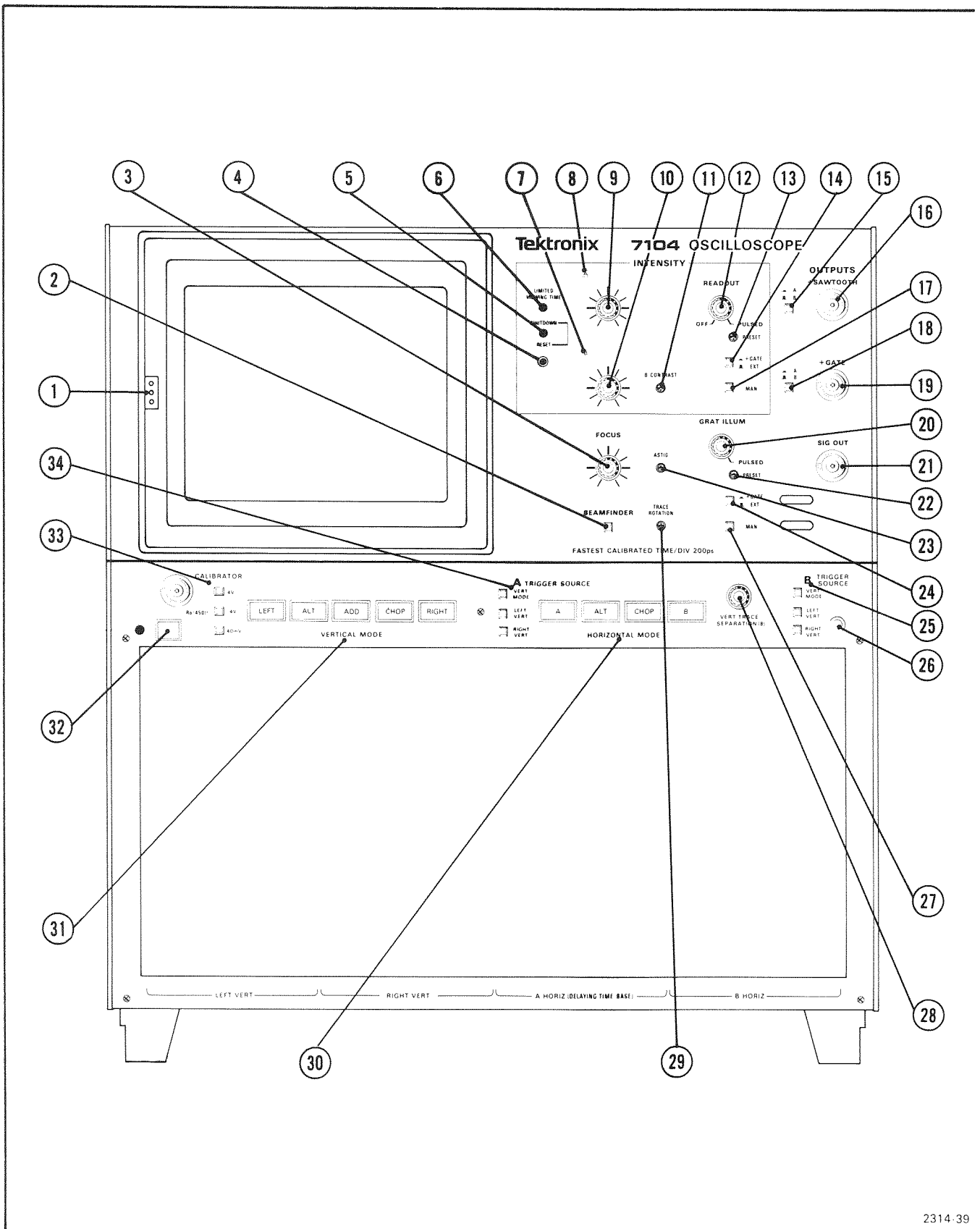
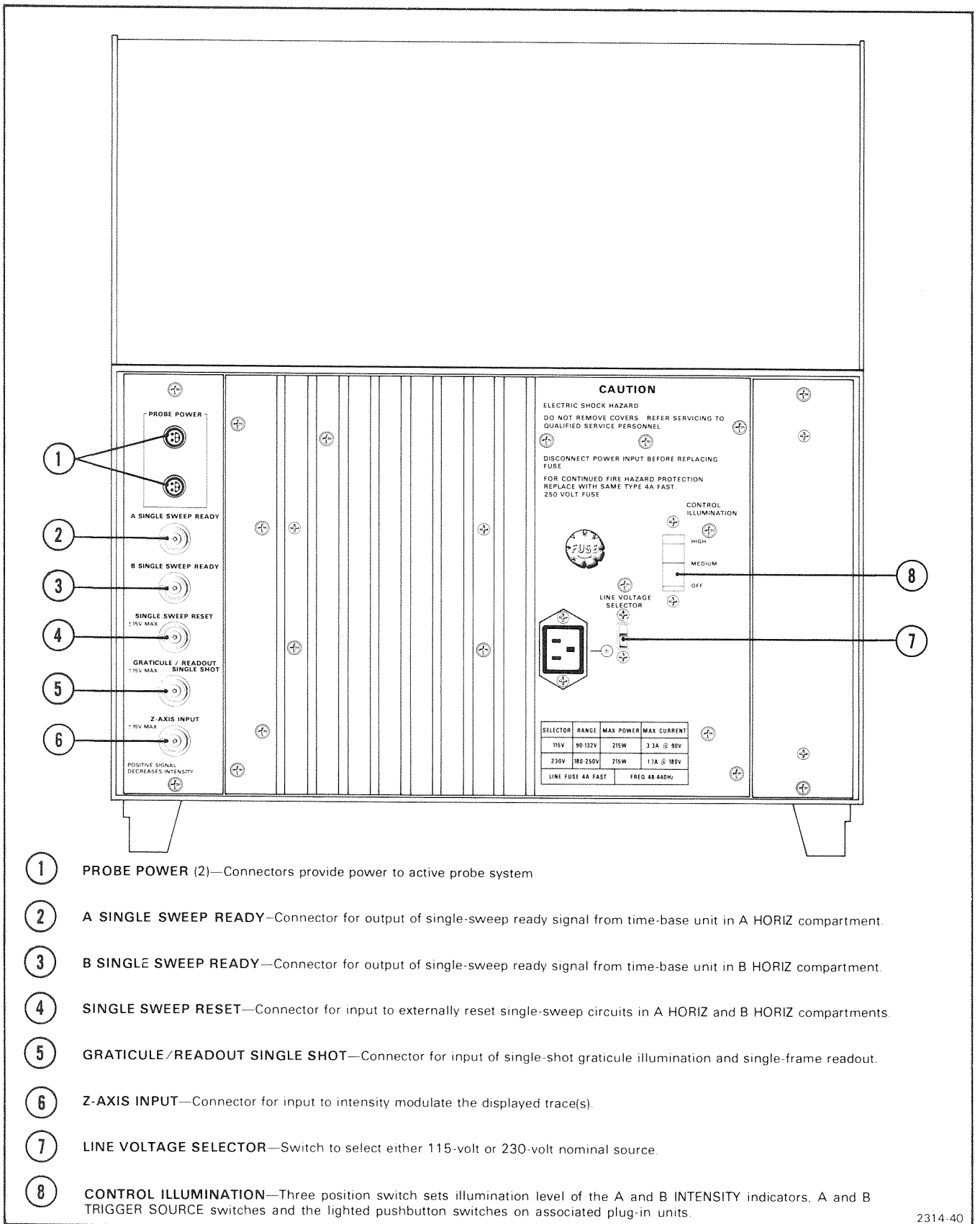


Figure 2-1. Front-panel controls, connectors and indicators.

- ① **Camera Power Connector (not labeled)**—Three-pin connector provides power for camera operation and receives single sweep-reset signal.
- ② **BEAMFINDER**—Switch when pressed compresses and defocuses display within graticule area.
- ③ **FOCUS**—Control optimizes crt trace definition.
- ④ **RESET**—Switch when pressed initiates another cycle of viewing time.
- ⑤ **SHUTDOWN**—Indicator to signal that crt display is off.
- ⑥ **LIMITED VIEWING TIME**—Indicator to signal that crt display shutdown will occur.
- ⑦ **B INTENSITY**—Indicator illuminates when selected by the HORIZONTAL MODE switch.
- ⑧ **A INTENSITY**—Indicator illuminates when selected by the HORIZONTAL MODE switch.
- ⑨ **A INTENSITY**—Control to determine brightness of trace produced by the plug-in unit installed in the A HORIZ compartment.
- ⑩ **B INTENSITY**—Control to determine brightness of trace produced by the plug-in unit installed in the B HORIZ compartment.
- ⑪ **B CONTRAST**—Control varies brightness of intensified portion of display.
- ⑫ **READOUT INTENSITY**—Control to determine brightness of readout display. Disables Readout System in counterclockwise detent position. Activates PULSE in clockwise detent position.
- ⑬ **READOUT PRESET**—Adjustment (PULSED operation only) sets PULSED readout intensity.
- ⑭ **READOUT +GATE OR EXT**—Switch to select either +GATE or EXT actuation of the PULSED readout mode.
- ⑮ **A OR B +SAWTOOTH**—Switch to select A or B time-base unit as source for +SAWTOOTH OUTPUT signal.
- ⑯ **+SAWTOOTH**—Connector to output signal derived from the A or B time-base unit.
- ⑰ **READOUT MAN**—Switch when pressed actuates one frame of readout display.
- ⑱ **A OR B +GATE**—Switch to select either A or B time-base unit as source of +GATE output.
- ⑲ **+GATE**—Connector to output positive-going gate signal from the time-base unit in the A or B horizontal compartment.
- ⑳ **GRAT ILLUM**—Control varies level of graticule illumination or activates PULSED GRAT ILLUM functions.
- ㉑ **SIG OUT**—Connector to output signal derived from vertical signal as selected by B TRIGGER SOURCE switch.
- ㉒ **GRAT ILLUM PRESET**—Screwdriver adjustment to vary level of graticule illumination in GRAT ILLUM PULSED mode.
- ㉓ **ASTIG**—Screwdriver adjustment used in conjunction with FOCUS control to obtain a well defined display.
- ㉔ **GRAT ILLUM +GATE OR EXT**—Switch to select between +GATE or EXT actuation of graticule illumination.
- ㉕ **B TRIGGER SOURCE**—Switches select internal trigger source for B HORIZ plug-in unit.
- ㉖ **Ground (not labeled)**—Binding post to establish common ground between associated equipment.
- ㉗ **GRAT ILLUM MAN**—Switch when pressed actuates one graticule illumination.
- ㉘ **VERT TRACE SEPARATION (B)**—Control vertically positions the B HORIZ trace with respect to the A HORIZ trace (dual-sweep only).
- ㉙ **TRACE ROTATION**—Screwdriver adjustment to align trace(s) with graticule lines.
- ㉚ **HORIZONTAL MODE**—Switches select input source for horizontal deflection.
- ㉛ **VERTICAL MODE**—Switches select source of input for vertical deflection.
- ㉜ **POWER (Switch and Indicator)**—Switch controls power to instrument; indicator illuminates when power is on.
- ㉝ **CALIBRATOR**—Switches select 4 V, 0.4 V, and 40 mV calibrated square-wave voltages at 1 kHz repetition rate at connector output.
- ㉞ **A TRIGGER SOURCE**—Switches select internal trigger source for A HORIZ plug-in unit.

2314-39

Figure 2-1. Front-panel controls, connectors and indicators (continued).



2314-40

Figure 2-2. Rear-panel controls and connectors.

24. Notice that the position control of only the B time-base unit affects the horizontal position of the displayed trace. Position the start of the trace to the left graticule line with the B time-base unit position control.

25. Set the HORIZONTAL MODE switch to ALT. Two traces should be presented on the crt. If the traces overlap, adjust the VERT TRACE SEPARATION (B) control to position one trace to the bottom of the graticule area. Turn the sweep rate switches of both time-base units throughout their range. Observe that each time-base unit controls one of the traces independently of the other time-base unit. Also notice that when one of the time-base units is set to a slow sweep rate (below about 50 milliseconds/division), sweep alternation is evident (only 1 of the traces is presented on the crt at a time). Set the sweep rates of both time-base units to 0.5 milliseconds/division. Rotate the A INTENSITY control; notice that the intensity of the trace produced by the A time-base unit changes. Likewise, the B INTENSITY control changes the intensity of the trace produced by the B time-base unit only. Return both intensity controls to desirable levels.

26. Set the HORIZONTAL MODE switch to CHOP. Two traces should be displayed on the crt in a manner similar to that of the ALT display. Turn the sweep rate switches of both time-base units throughout their ranges.

27. Set the CALIBRATOR switch to 0.4 V. Set the VERTICAL MODE switch to CHOP. Four traces should be displayed on the crt. If not, adjust the position controls of the amplifier units and the VERT TRACE SEPARATION (B) control to position the four traces into view. Set the position controls of the plug-in units to identify which trace is produced from each plug-in unit (if amplifier units have the identify feature, it can be used to identify the traces). Set the A time-base unit for a sweep rate of 1 millisecond/division. The left amplifier unit should be displayed at the sweep rate of both time-base units.

28. Set the HORIZONTAL MODE switch to ALT. Observe that the display is very similar to that obtained in the previous sweep. The main difference in this display is that the traces are now displayed alternately (noticeable only at slow sweep rates).

29. Set the VERTICAL MODE switch to ALT. Set the CALIBRATOR switch to 4 V. The trace produced by the left amplifier unit should be displayed at the sweep rate of the B time-base unit and the trace produced by the right amplifier unit should be displayed at the A time-base unit sweep rate. This feature is called independent-pairs operation and is obtained only when the VERTICAL MODE switch is in the ALT position, the HORIZONTAL MODE switch is in either the ALT or the CHOP position, and the time-base units are in the independent mode.

## TRIGGERING

30. Set the VERTICAL MODE switch to LEFT and the HORIZONTAL MODE switch to A. Center the display on

the crt with the left amplifier unit position control. Disconnect the input signal from the right amplifier unit input connector. Sequentially select all of the VERTICAL MODE switch positions. Notice that a stable display is obtained for all positions of the VERTICAL MODE switch (straight line in RIGHT switch position).

31. Set the A TRIGGER SOURCE switch to LEFT VERT. Again, sequentially select all of the VERTICAL MODE switch positions; notice that the display is again stable in all positions, as in the previous step, and that the LEFT VERT pushbutton is illuminated.

32. Set the A TRIGGER SOURCE switch to RIGHT VERT. Sequentially select all of the VERTICAL MODE switch positions and notice that a stable display cannot be obtained in any position (this is because there is no input signal connected to the right vertical unit) and that the RIGHT VERT pushbutton is illuminated. Return the A TRIGGER SOURCE switch to VERT MODE and notice that it is illuminated.

33. The B TRIGGER SOURCE switch operates in a manner similar to the A TRIGGER SOURCE switch when the B time-base unit is selected to provide the display. Set the B TRIGGER SOURCE switch to VERT MODE and the VERTICAL MODE switch to ALT.

34. Set the HORIZONTAL MODE switch to ALT or CHOP. Notice that this is the same display obtained in step 29 (independent-pairs operation).

## READOUT

35. Turn the READOUT control clockwise until an alphanumeric display is visible within the top or bottom division of the crt. Change the deflection factor of the amplifier unit that is selected for display. The appropriate readout display should change as the deflection factor is changed. Likewise, change the sweep rate of the time-base unit which is selected for display; the readout display for the time-base unit should change as the sweep rate is changed.

36. Set the time-base unit for X10 magnification. Notice that the readout display will change to indicate the correct magnified sweep rate. If a readout-coded 10X probe is available for use with the amplifier unit, install it on the input connector of the right amplifier plug-in unit. Notice that the deflection factor indicated by the readout is increased by 10 times when probe is added. Return the time-base unit to normal sweep operation and disconnect the probe.

37. Sequentially select all of the VERTICAL MODE and HORIZONTAL MODE switch positions. Notice that the readout from a particular plug-in occupies a specific location on the display area. If either of the vertical plug-in units is a dual-trace unit, the readout for channel 2 is displayed within the lower division of the crt. Return the VERTICAL MODE switch to LEFT and the HORIZONTAL MODE switch to A. Set the READOUT control to OFF.

**BEAMFINDER**

38. Set the deflection factor of the left amplifier unit to 10 millivolts/division and the calibrator for a 4 V output. Notice that the square-wave display is not visible, since the deflection exceeds the scan area of the crt.

39. Press the BEAMFINDER pushbutton switch; notice that the display is returned to the viewing area in compressed form. Release the BEAMFINDER switch and notice that the display again disappears from the viewing area.

40. With the BEAMFINDER switch pushed in, increase the amplifier-unit deflection factor until the display is reduced to about 2 divisions vertically. Adjust the position control of the displayed amplifier unit to position the compressed display near the center of the graticule. Release the BEAMFINDER switch and observe that the display remains within the viewing area.

**CALIBRATOR**

41. Connect the CALIBRATOR output to both the left and right vertical units with two bnc cables and a bnc T connector. The display amplitude should be approximately 2 divisions. If not, adjust the deflection factor accordingly.

42. Select different CALIBRATOR pushbuttons (labeled 4 V, 0.4 V, and 40 mV) and notice that the displayed signal changes accordingly. (CALIBRATOR output must be terminated into more than a 100-kilohm load for stated output.) When the CALIBRATOR output is terminated into 50 ohms, the output is 0.1 times the stated output.

**Z-AXIS INPUT**

43. If an external signal is available (+2 volts peak-to-peak minimum), the function of the Z-AXIS INPUT can be demonstrated. Connect the external signal to both the input connector of the displayed amplifier unit and the Z-AXIS INPUT connector. Set the sweep rate of the displayed time-base unit to display about 5 cycles of signal. Set the amplitude of the signal generator until intensity modulation is visible on the display (change the amplifier unit deflection factor as necessary to produce an on-screen display). The positive peaks of the waveform should be blanked out and the negative peaks intensified. Notice that the setting of the intensity control determines the amount of intensity modulation that is visible. Disconnect the cables.

**INTENSITY LIMITING**

44. Connect a sinewave signal to the input of the displayed amplifier unit. Set the amplifier deflection factor to display 8 divisions of signal. Set the displayed time-base unit to display at least 20 cycles. Rotate the A or B INTENSITY control clockwise and observe that the yellow LIMITED VIEWING TIME light turns on and then flashes on and off as the intensity control is rotated further clockwise. With the LIMITED VIEWING TIME light flashing, the intensity is limited. Rotating the intensity control clockwise does not increase the displayed

brightness. Notice that after about one minute the red SHUTDOWN light starts flashing and then after about 10 seconds turns on steady; at the same time the crt display is turned off. Press the RESET button and the display should return.

**DETAILED OPERATING INFORMATION**

**GRATICULE**

The graticule is marked on the inside of the crt faceplate, providing accurate, parallax-free measurements. The graticule is divided into eight vertical and ten horizontal divisions. Each division is a 0.85 centimeter square divided into five minor divisions along each axis. The vertical gain and horizontal timing of the plug-in units are calibrated to the graticule so that accurate measurements can be made from the crt. The illumination of the graticule lines can be varied with the GRAT ILLUM control.

Figure 2-3 shows the graticule and defines the various measurement lines. The terminology defined here will be used in all discussions involving measurements from the graticule. The markings: 0%, 10%, 90%, and 100% on the left side of the graticule are for accurate rise-time measurements.

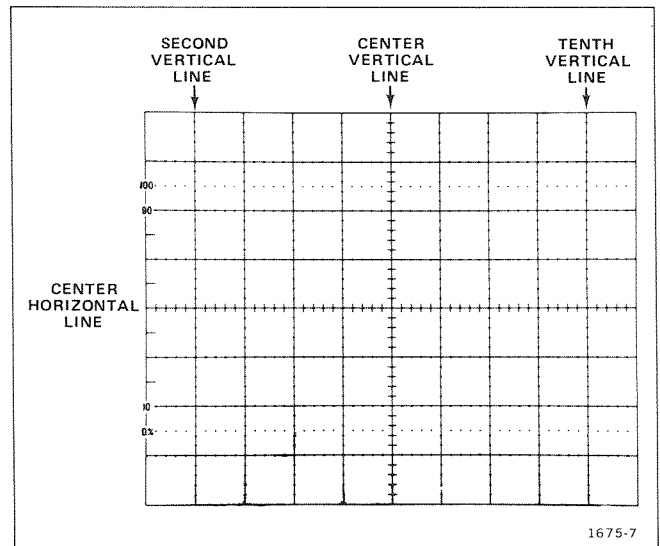


Figure 2-3. Definition of graticule measurement lines.

**GRATICULE ILLUMINATION**

The GRAT ILLUM control varies the illumination of the graticule lines. The GRAT ILLUM can also be operated in the PULSED mode. With the GRAT ILLUM control set to the PULSED detent position, and the + GATE/EXT switch set to + GATE, the graticule will be illuminated momentarily after the + GATE occurs. The + GATE

switch selects whether A gate or B gate triggers the graticule illumination. With the GRAT ILLUM + GATE/EXT switch set to EXT the momentary graticule illumination can be actuated by applying a remote signal to the rear panel GRATICULE/READOUT SINGLE SHOT connector (see Table 1-4 for specifications). When operating in the PULSED mode, the level of illumination is controlled by the GRAT ILLUM PRESET screwdriver adjustment.

### LIGHT FILTER

The tinted face-plate filter minimizes light reflections from the face of the crt to improve contrast when viewing the display under high-ambient-light conditions. This filter may be removed for waveform photographs or for viewing high-writing-rate displays. To remove the filter, pull outward on the bottom of the plastic crt mask and remove it from the crt bezel. Remove the tinted filter; leave the clear plastic face-protector (implosion shield) installed and replace the mask. The face-plate protector should be left in place at all times to protect the crt face from scratches and the operator from crt implosion.

### WARNING

*Do not remove the clear plastic implosion shield covering the crt face plate; the implosion shield provides protection to the operator from crt implosion.*

An optional mesh filter is available from Tektronix (included with Option 3). This filter provides shielding against radiated EMI (electromagnetic interference) from the face of the crt. It also serves as a light filter to make the trace more visible under high-ambient conditions. The mesh filter fits in place of the plastic tinted filter. Order the filter by Tektronix Part 378-0603-00.

### CONTROL ILLUMINATION

The CONTROL ILLUMINATION switch, located on the rear panel, sets the illumination level of the A and B INTENSITY indicators, the A and B TRIGGER SOURCE switches, and of the lighted pushbutton switches on the plug-in units. The positions available are OFF, MEDIUM, and HIGH. The CONTROL ILLUMINATION switch does not affect the function-indicator lights (such as triggered or single sweep ready lights).

### INTENSITY CONTROLS

The A INTENSITY control determines the brightness of the display produced by the plug-in unit installed in the A HORIZ compartment. The B INTENSITY control determines the brightness of the display produced by the plug-in unit installed in the B HORIZ compartment. The READOUT intensity control affects the brightness of only the readout portion of the crt display.



*Care should be taken when operating the intensity controls. See: Reduction of Display Gain with Display Output Charge in section 2.*

### DISPLAY FOCUS

This instrument contains an automatic-focusing circuit which maintains optimum focus for all intensity settings after a correct setting of the FOCUS control is established. The easiest way to obtain the correct setting of the FOCUS control is to set the READOUT INTENSITY control so that the readout portion of the display is clearly visible. Adjust the FOCUS control for the best definition of the readout display.

### ASTIGMATISM-FOCUS ADJUSTMENTS

If a well-defined display cannot be obtained with the FOCUS control, set the ASTIG adjustment as follows:

#### NOTE

*To check for proper setting of the ASTIG adjustment, slowly turn the FOCUS control through the optimum setting. If the ASTIG adjustment is correctly set, the vertical and horizontal portions of the display will focus at the same position of the FOCUS control. This setting of the ASTIG adjustment should be correct for any display.*

1. Install an amplifier unit in the LEFT VERT compartment and a time-base unit in the A HORIZ compartment.
2. Set the VERTICAL MODE switch to LEFT and the HORIZONTAL MODE switch to A.
3. Connect the output of a sine-wave generator to the input of the amplifier unit. Set the sine-wave generator repetition rate to 1 kilohertz and the vertical amplifier deflection factor for a 2-division display.
4. Set the time-base unit sweep rate for 0.2 millisecond/division and the triggering for a stable display. Set the A INTENSITY control so the display is at a usable intensity level (about midrange).
5. Turn the FOCUS control fully counterclockwise and set the ASTIG adjustment to midrange.
6. Set the FOCUS control so the thickness of the sine-wave trace is as thin as possible.
7. Adjust the ASTIG adjustment so the width of the sine-wave trace is as thin as possible.
8. Repeat steps 6 and 7 for the best overall focus.

## BEAMFINDER

The BEAMFINDER helps to locate a display that overscans the crt viewing area vertically and/or horizontally. When the BEAMFINDER button is pressed, the display is compressed and defocused within the graticule area. To locate and reposition an overscanned display, use the following procedure:

1. Press the BEAMFINDER pushbutton. While the display is compressed adjust the vertical and horizontal position controls to center the display. Change the vertical and horizontal deflection factors until the vertical deflection is about four divisions high and the horizontal deflection is about six divisions wide (the horizontal deflection needs to be reduced only when operating in an X-Y mode).
2. Release the BEAMFINDER pushbutton; the display should remain within the graticule area.

## TRACE ALIGNMENT

The TRACE ROTATION control allows the trace to be aligned with the horizontal graticule lines. To set the control, position the trace to the center horizontal line and adjust the TRACE ROTATION control so that the trace is parallel with the center horizontal graticule line.

## READOUT DISPLAY

The Readout System provides an alphanumeric display of information on the crt along with the analog waveform display. The information displayed by the Readout System is obtained from the plug-in units installed in the plug-in compartments.

The readout information from each channel of a plug-in unit is called a word. Up to eight words of readout information can be displayed on the crt (two channels from each of the four plug-in compartments). The location of each readout word is fixed and is directly related to the plug-in unit and channel from which it originated. Figure 2-4 shows the area of the graticule where the readout from each plug-in unit and/or channel is displayed. Notice that the readout from channel 1 of each plug-in unit is displayed in the top division of the graticule and the readout from channel 2 is displayed directly below in the bottom division of the graticule. Usually, the readout information for plug in units and/or channels, which are selected by the mode switches, appear in the readout display. (Some special purpose plug-in units may over-ride the mode switches to display readout even though the compartment is not selected for display.)

### Readout Identify

An "Identify" feature is provided by the Readout System to correlate the readout word with the originating plug-in unit and channel (amplifier units only). When the "identify" button of an amplifier unit is pressed, the word IDENTIFY appears in the readout location allocated to that plug-in and channel. Other readout words in the display remain unchanged. When the "identify" button is

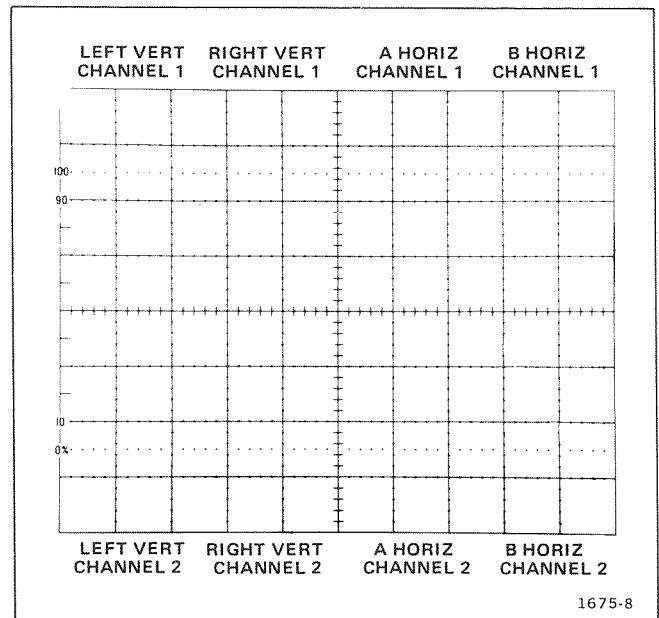


Figure 2-4. Location of readout on the crt identifying the originating plug-in and channel.

released, the readout display from this plug-in channel is again displayed. Circuitry may also be provided in the amplifier unit to produce a noticeable change in the analog waveform display to identify the associated trace when the "identify" button is pressed (see the plug-in unit instruction manual for details).

### Readout Intensity

The READOUT control determines the intensity of only the readout portion of the display, independently of the other traces. The Readout System is inoperative when the READOUT control is in the fully counterclockwise OFF position. This may be desirable when the top and bottom divisions of the graticule are to be used for waveform display or when the trace interruptions necessary to display characters interfere with the waveform display.

### Readout Modes

The READOUT control determines the operating mode of the Readout System. With the READOUT control set to free run (out of OFF or PULSED detent positions) the Readout System operates continuously, interrupting the crt display at random (for about 20 microseconds) in order to write each character on the crt. With the READOUT control set to the PULSED position, the Readout System operates in a triggered mode; one complete frame (up to eight words) of readout is displayed. The + GATE or EXT switch determines whether readout is displayed at the end of the + GATE or when an external signal is applied to the rear-panel GRATICULE/READOUT SINGLE SHOT input. The + GATE switch selects whether A gate or B gate triggers the readout.



One frame of readout information is also displayed each time the READOUT MAN (manual) pushbutton is pressed. The brightness of the readout display, when operating in the PULSED mode, is set by the READOUT PRESET control.

**CARE OF CRT SCREEN**

The following precautions will prolong the useful life of the crt screen used in this instrument.

1. Use minimum beam intensity to produce a clear, well-defined display.
2. Avoid repeated use of the same area of the screen. If a particular waveform is to be displayed for a long period of time, change the vertical position occasionally to use other portions of the display area.
3. Use minimum READOUT INTENSITY to display the readout. For more information see Reduction of Display Gain with Display Output Charge in section 2.

**VERTICAL AND HORIZONTAL MODE COMBINATIONS**

There are 20 possible combinations of VERTICAL MODE and HORIZONTAL MODE switch settings. The total possible number of display combinations is further multiplied by the variety of plug-in units available for use with this instrument, the interchangeability of plug-ins (i.e., either an amplifier or a time-base unit can be installed in any compartment), and by the capabilities of the plug-in units which are used in the instrument (e.g., a dual-trace amplifier unit can be used in either of the two single-channel modes, in the dual-trace mode or algebraically-added mode; a delaying time base may be used either for a sweep or for delayed sweep). Therefore, it is difficult to list all of the display combinations which can occur during use of the 7104 and available plug-in units. Table 2-1 lists the combination of VERTICAL MODE and HORIZONTAL MODE switch positions available and the type of display obtained with each combination.

**Vertical Modes**

When the LEFT or RIGHT button of the VERTICAL MODE switch is pressed, only the signal from the plug-in unit in the selected compartment is displayed.

**Alternate Mode.** The ALT position of the VERTICAL MODE switch produces a display which alternates between the LEFT VERT and RIGHT VERT compartments with each sweep of the crt. Although the ALT mode can be used at all sweep rates, the CHOP mode provides a more satisfactory display at sweep rates below 20 milliseconds/division. At these slower sweep rates, alternate-mode switching becomes perceptible.

Alternate Mode displays have three types of triggering available. When the A and B TRIGGER SOURCE switches

**TABLE 2-1**  
**Display Combinations<sup>1</sup>**

Vertical Mode	Horizontal Mode	Comments
LEFT	A or B	One trace. Vertical deflection from single unit; horizontal deflection from single unit.
	ALT or CHOP	Two traces. Vertical deflection from single unit; horizontal deflection from both units.
ALT	A or B	Two traces. Vertical deflection from both units; horizontal deflection from single unit.
	ALT or CHOP	Two traces. Vertical deflection from both units; horizontal deflection from both units.
ADD	A or B	One trace. Vertical deflection shows algebraic summation of signals from both units; horizontal deflection from single unit.
	ALT or CHOP	Two traces. Vertical deflection shows algebraic summation of signals from both units; horizontal deflection from both horizontal compartments.
CHOP	A or B	Two traces. Vertical deflection shows signals from both units; horizontal deflection from single unit.
	ALT or CHOP	Four traces. Vertical deflection shows signals from both units; horizontal deflection from both units.
RIGHT	A or B	One trace. Vertical deflection shows signal from single unit; horizontal deflection from single unit.
	ALT or CHOP	Two traces. Vertical deflection shows signal from single unit; horizontal deflection from both units.

<sup>1</sup>Combinations given for single-channel vertical and horizontal units only.

## Operating Instructions—7104 Operators

are set to the VERT MODE positions, each sweep is triggered by the signal being displayed on the crt. This provides a stable display of two unrelated signals, but does not indicate the time relationship between the signals. In either the LEFT VERT or RIGHT VERT positions of the TRIGGER SOURCE switches, the two signals are displayed showing true time relationship. However, if the signals are not time related, the display from the plug-in that is not providing a trigger signal will be unstable on the crt. The TRIGGER SOURCE switches are illuminated indicating the source of the trigger signal.

When the ALT VERTICAL MODE position is selected and either the ALT or CHOP button of the HORIZONTAL MODE switch is selected, the instrument operates in the independent-pairs mode. Under this condition, the signal from the LEFT VERT unit is always displayed at the sweep rate of the B HORIZ time-base unit, and the signal from the RIGHT VERT unit is displayed at the sweep rate of the A HORIZ time-base unit (non-delayed sweep only). This results in two displays that are completely independent as to vertical deflection and sweep rate. This display is equivalent to the display obtainable with a dual-beam oscilloscope for most repetitive-display combinations.

In independent-pairs mode with the A and B TRIGGER SOURCE switches set to VERT MODE the A time base receives a trigger from the right vertical, and the B time base receives a trigger from the left vertical. This is indicated by the illuminated trigger pushbuttons.

If a delayed-sweep operation is used with this mode, a different sequence is displayed. First, the LEFT VERT unit signal is displayed at the sweep rate of the A HORIZ time-base unit (delaying sweep) and then at the sweep rate of the B HORIZ time-base unit (delayed sweep). The vertical display then shifts to the RIGHT VERT unit and its signal is displayed consecutively at the delaying and delayed sweep rates.

**Chopped Mode.** The CHOP position of the VERTICAL MODE switch produces a display which is electronically switched between channels at about a one-megahertz rate. In general, the CHOP mode provides the best display at sweep rates slower than about 20 milliseconds/division or whenever dual-trace, single-shot phenomena are to be displayed. At faster sweep rates the chopped switching becomes apparent and may interfere with the display.

When the A or B TRIGGER SOURCE switches are set to VERT MODE, the time-base units are triggered from the left vertical plug-in trigger signal. The LEFT VERT or RIGHT VERT trigger-source positions provide trigger signals to the time-base units from the selected vertical unit only. The trigger source is indicated by the illuminated TRIGGER SOURCE pushbuttons. This allows two time-related signals to be displayed showing true-time relationship. (If the signals are not time-related, the display from the channel that is not providing the trigger signal will appear unstable.)

The CHOP mode can be used to compare two single-shot, transient, or random signals that occur within the time interval determined by the time-base unit (ten times selected sweep rate). To provide correct triggering, the displayed signal which provides the trigger signal must precede the second display in time. Since the signals show true-time relationship, time-difference measurements can be made from the display.

**Algebraic Addition.** The ADD position of the VERTICAL MODE switch can be used (1) to display the sum or difference of two signals, (2) for common-mode rejection to remove an undesired signal, or (3) for dc offset (applying a dc voltage to one channel to offset the dc component of a signal on the other channel). The common-mode rejection ratio between the vertical plug-in compartments is at least 160:1 from dc to 100 megahertz. The rejection ratio decreases to 80:1 from 100 megahertz to 1 gigahertz. The overall deflection on the crt in the ADD mode is the algebraic sum of the signals from the vertical plug-in units. It is difficult to determine the voltage amplitude of the resultant display unless the amplitude of the signal applied to one of the plug-ins is known. This is particularly true when the vertical units are set to different deflection factors, since it is not obvious which portion of the display results from the signal applied to a given plug-in unit. The polarity and repetition rate of the applied signals will also affect the ADD display.

The following precautions should be observed when using the ADD mode.

1. Do not exceed the input-voltage ratings of the plug-in units.
2. Do not apply large signals to the plug-in inputs. A good rule is not to apply a signal of more than about eight times the vertical deflection factor. Larger voltages may result in a distorted display.
3. To ensure the greatest dynamic range in the ADD mode, set the position controls of the plug-in units to a setting which would result in a mid-screen display if viewed in the LEFT or RIGHT positions of the VERTICAL MODE switch.
4. For familiar response from each channel, use identical plug-ins and set the plug-in units for the same type of input coupling mode.

### Horizontal Modes

When either the A or B button of the HORIZONTAL MODE switch is pressed, the signal is displayed at the sweep rate of the selected time-base unit. Set the applicable INTENSITY control and TRIGGER SOURCE switch for the desired display.

**Alternate Mode.** The ALT position of the HORIZONTAL MODE switch provides crt sweeps derived alternately

from the two time-base units. Although the ALT horizontal mode can be used at all sweep rates, the CHOP mode provides a more satisfactory display at sweep rates below about 20 milliseconds/division. At slower sweep rates, the switching between the alternate-mode traces becomes apparent and may interfere with correct analysis of the display.

#### NOTE

*This instrument will not operate in the ALT position of the HORIZONTAL MODE switch if either horizontal plug-in compartment is left vacant.*

The A and B INTENSITY controls allow individual adjustment of the traces produced by the time-base units in the A HORIZ and B HORIZ compartments. Correct triggering of both time-base units is essential in obtaining the correct display in the ALT horizontal mode. If either of the time-base units does not receive a correct trigger, and therefore does not produce a sweep, the other unit cannot produce a sweep either. This means that one time-base unit cannot begin its sweep until the previous unit has completed its entire display. This can be avoided if the time-base units are set for auto-mode triggering (sweep free runs if not correctly triggered). See Trigger Source for operation of the A and B TRIGGER SOURCE switches. Also, see Vertical Trace Separation for information on positioning the B HORIZ display when in the ALT dual-sweep mode.

**Chopped Mode.** When the CHOP button of the HORIZONTAL MODE switch is pressed, the display is electronically switched between the two time-base units at about a 200-kilohertz rate. In general, the CHOP horizontal mode provides the best display when either of the time-base units is set to a sweep rate lower than about 20 milliseconds/division. It also provides the best display when the two time-base units are set to widely differing sweep rates. In the CHOP horizontal mode, equal time segments are displayed from each of the time-base units. This provides a display which does not change greatly, in intensity, as the sweep rate of either time-base unit is reduced (in contrast to ALT horizontal mode operation where the slowest trace tends to be the brightest).

The A and B INTENSITY controls allow individual adjustment of the intensity of the traces produced by the time-base units in the A HORIZ and B HORIZ compartments. Triggering is not as critical in the CHOP horizontal mode as in ALT; if one of the units is not triggered properly, only the trace from the untriggered time-base unit is missing from the display. The other trace is presented in the normal manner. See Trigger Source and Vertical Trace Separation for information on positioning the trace produced by the B HORIZ unit in relation to the trace from the A HORIZ unit.

#### VERTICAL TRACE SEPARATION

When one of the dual-sweep horizontal modes is selected, the VERT TRACE SEPARATION (B) control

allows the trace produced by the B HORIZ sweep to be positioned above or below the trace produced by the A HORIZ sweep. To use the control, first position the trace produced by the A HORIZ plug-in unit. Then adjust the VERT TRACE SEPARATION (B) control to move the trace produced by the B HORIZ plug-in unit away from the A HORIZ display. If both waveforms are larger than four divisions in amplitude, the displays can only be positioned so they do not directly overlap since each waveform cannot be positioned to a unique area of the crt.

#### TRIGGER SOURCE

The A and B TRIGGER SOURCE switches select the internal trigger signals for the A HORIZ and B HORIZ time-base units. For most applications, these switches can be left in the VERT MODE position. This position is the most convenient since the internal trigger signal is automatically switched as the VERTICAL MODE switch is changed or as the display is electronically switched between the LEFT VERT and RIGHT VERT plug-ins, in the ALT position of the VERTICAL MODE switch. It also provides a usable trigger signal in the ADD position of the VERTICAL MODE switch, since the internal trigger signal in these modes is the algebraic sum of the signals applied to the vertical plug-in units. In the CHOP position the left vertical plug-in is the trigger source. Therefore, the VERT MODE position ensures that the time-base units receive a trigger signal regardless of the VERTICAL MODE switch setting without the need to change the trigger source selection. The A and B TRIGGER SOURCE switches are illuminated and indicate the source of the trigger.

If correct triggering for the desired display is not obtained in the VERT MODE position, the trigger source for either the A HORIZ or B HORIZ time-base unit can be changed to obtain the trigger signal from either the LEFT VERT or RIGHT VERT plug-in. The internal trigger signal is obtained from the selected vertical compartment whether the plug-in in that compartment is selected for display on the crt or not. If the internal trigger signal is obtained from one of the vertical units but the other vertical unit is selected for display, the internal signal must be time-related to the display signal in order to obtain a triggered (stable) display.

#### CALIBRATOR OUTPUT

The CALIBRATOR provides a convenient signal for checking basic vertical gain and sweep timing. The CALIBRATOR signal is also very useful for adjusting probe compensation as described in probe instruction manuals. In addition, the CALIBRATOR can be used as a convenient signal source for application to external equipment.

#### Voltage

The CALIBRATOR provides accurate output voltages of 40 millivolts, 0.4 volt, and 4 volts into high impedance loads. In addition, it provides 4 millivolts, 40 millivolts, and 0.4 volt into 50-ohm loads.

## Current

The optional current loop accessory provides a 40-milliampere output current (the CALIBRATOR must be set for a 4 volt output), which can be used to check and calibrate current-measuring probe systems. The current signal is obtained by clipping the probe around the current loop.

## Repetition Rate

The repetition rate of the CALIBRATOR is 1 kilohertz. The calibrator circuit uses frequency-stable components to maintain accurate frequency and a constant duty factor. Thus, the CALIBRATOR can be used for checking the basic sweep timing of time-base units (1-kilohertz rate only).

## Wave Shape

The square-wave output signal of the CALIBRATOR can be used as a reference wave shape when checking or adjusting the compensation of passive, high-resistance probes. The square-wave output from the CALIBRATOR has a flat top; any distortion in the displayed waveform is due to the probe compensation.

## SIGNAL OUTPUTS

### + Sawtooth Out

The + SAWTOOTH OUT connector provides a positive-going sawtooth signal derived from the time-base unit installed in the A HORIZ compartment or from the time-base unit installed in the B HORIZ compartment.

The front-panel A or B + SAWTOOTH switch determines whether the A HORIZ or the B HORIZ compartment is the source of the + SAWTOOTH output signal. The unit of time for the sawtooth output is determined by the setting of the time-base-unit Time/Division switch. Refer to Table 1-4, in the General Information section, for signal parameters.

### + Gate Out

The + GATE OUT connector provides a positive-going rectangular pulse which is derived from a time-base unit installed in either horizontal plug-in compartment. The A or B + GATE switch selects the source of the + GATE signal from the time-base unit installed in the A HORIZ compartment or the B HORIZ compartment. The duration of the + GATE signal is the same as the duration of the respective unmagnified sweep. The amplitude of the + GATE OUT signal is about 0.5 volt into 50 ohms or about 10 volts into 1 megohm.

### Signal Out

The SIG OUT connector provides a sample of the vertical deflection signal. The source of the output signal is determined by the B TRIGGER SOURCE switch. In the VERT MODE position of the B TRIGGER SOURCE switch, the output signal is determined by the setting of the VERTICAL MODE switch. The output signal in the LEFT and RIGHT positions of the VERTICAL MODE switch is obtained only from the selected vertical unit. In the ALT

position of the VERTICAL MODE switch, the output signal at the SIG OUT connector switches between signals from the two vertical units, along with the crt display. However, the vertical output signal in the ADD position is a composite signal. In the CHOP position the signal out is derived from the LEFT vertical plug-in. The LEFT VERT and RIGHT VERT positions of the B TRIGGER SOURCE switch are independent of the selection of the VERTICAL MODE switch and provide the vertical output signal only from the selected vertical unit even when it is not selected for display by the VERTICAL MODE switch.

## Probe Power

The two PROBE POWER connectors on the rear panel of this instrument provide operating power for active probe systems. It is not recommended that these connectors be used as a power source for applications other than the compatible probes or other accessories which are specifically designed for use with this system.

## DISPLAY PHOTOGRAPHY

A permanent record of the crt display can be obtained with an oscilloscope camera system. The instruction manual for the Tektronix oscilloscope cameras include complete instructions for obtaining waveform photographs.

The crt bezel provides integral mounting for Tektronix oscilloscope cameras. The three pins located on the left side of the crt bezel connect power to compatible camera systems. Control signals are also received from Tektronix automatic cameras to allow camera-controlled single-shot photography (see camera manual for further information).

If the readout portion of the display is to be included on waveform photographs, the following suggestions will aid in obtaining good photographs.

1. Focus the crt display. Focus the camera on the readout portion of the crt display. The auto-focus feature of this instrument will maintain the traces at optimum focus.

2. Set the READOUT INTENSITY control for the minimum setting that allows the characters to be written. This normally occurs at a slightly lower intensity level than is necessary for complete writing of the waveform display. Some experimentation may be necessary to establish the correct level. Too high a setting of the READOUT INTENSITY control will result in a broad, poorly defined photograph of the readout display.

3. If single-shot photography is used, set the READOUT and GRAT ILLUM controls to the PULSED position (see Readout Display and Graticule Illumination for complete operating information). Then, the readout display and graticule illumination occurs in a single-shot manner after the trace is complete (be sure the camera shutter remains open at least 0.5 second after the sweep is completed to photograph the entire readout and graticule).

## 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. This is accomplished by changing the intensity of the displayed waveform to provide a "gray scale" display.

The voltage amplitude required for visible trace modulation depends on the setting of the A and B INTENSITY controls. A two-volt peak-to-peak signal will completely blank the display even at maximum intensity levels; lower amplitude signals can be used to change only the relative trace brightness. Negative-going signals increase the display intensity and positive-going signals decrease the display intensity. Refer to Table 1-4 in the General Information section for specifications on Z-axis signal requirements.

Time markers applied to the Z-AXIS INPUT connector provide a direct time reference on the display. With uncalibrated horizontal sweep or X-Y mode operation, the time markers provide a means of reading time directly from the display. If the markers are not time-related to the display waveform, use a singlesweep display.

## REMOTE INPUT SIGNALS

The signal source requirements to operate the remote input functions on the rear panel can be either active (pulse generator, logic circuit, etc.) or passive (switch or relay). Refer to Table 1-4, in the General Information section for specific parameters on each input.

### Remote Single Sweep Reset

An external single-sweep-reset signal can be applied to time-base units installed in the horizontal plug-in compartments through the rear-panel SINGLE SWEEP RESET input connector. This remote reset function is a duplication of the manually-operated single-sweep reset function (pushbutton) located on the front panel of the 7B-series time-base units. The signal source for the external single-sweep reset function can be either active (pulse generator, logic circuit, etc.) or passive (switch or relay).

A and B SINGLE SWEEP READY outputs are provided for external indicators. The indicators signify that the time-base unit has been reset, and is ready to present a single sweep when the next trigger pulse arrives. Refer to Table 1-4, in the General Information section of this manual, for signal parameters.

### Remote Graticule and Readout Single Shot

The GRATICULE/READOUT SINGLE SHOT bnc connector (located on the rear panel) allows an external signal to actuate one frame of readout information and one momentary illumination of the graticule when the READOUT INTENSITY and GRAT ILLUM controls are set to PULSED, and the + GATE/EXT pushbuttons for

READOUT and GRAT ILLUM are set to EXT. The signal source can be either active (pulse generator, logic circuit, etc.) or passive (switch or relay). Refer to Table 1-4, in the General Information section of this manual, for input requirements.

## APPLICATIONS

The 7104 Oscilloscope and associated plug-in units provide a flexible measurement system. The capabilities of the overall system depend mainly upon the plug-in units selected for use with this instrument. Specific applications for the individual plug-in units are described in the plug-in unit instruction manual. The overall system can also be used for many applications which are not described in detail, either in this manual or in the manuals for the individual plug-in units. Contact your Tektronix Field Office or representative for assistance in making specific measurements with this instrument.

The following books describe oscilloscope measurement techniques which can be adapted for use with this instrument.

John D. Lenk, *Handbook of Oscilloscopes, Theory and Application*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1968.

J. Czech, *Oscilloscope Measuring Techniques*, Springer-Verlag, New York, 1965.

J. F. Golding, *Measuring Oscilloscopes*, Transatlantic Arts, Inc., 1971.

Charles H. Roth, Jr., *Use of the Oscilloscope*, programmed text, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1970.

## VERTICAL AMPLIFIER PLUG-IN UNITS

All 7A-series plug-in units (except the 7A21N unit) can be used with the 7104. Bandwidth and sensitivity ranges should be taken into consideration when selecting amplifier plug-in units.

### Single-Trace

Any single-channel amplifier will display a signal, with the sweep provided by any 7B-series time-base plug-in. This combination leaves two unused compartments available for other special purpose units. Blank plug-in panels are available to cover any unfilled plug-in compartments.

### Dual-Trace

A dual-channel amplifier in either vertical compartment can display two separate signals with the other vertical compartment free for other uses.

### Three-Trace

A dual-channel amplifier can be used with any single-channel amplifier to display three separate signals. If two time-base plug-in units are used in the horizontal compartments, two signals can be displayed at one sweep rate while the other signal is displayed at the other sweep rate.

### Four-Trace

Two dual-channel amplifiers can display four separate signals. If one time-base unit is used, all four signals will be displayed at the same sweep rate.

## TIME-BASE PLUG-IN UNITS

The 7104 is compatible with time-base units of the 7B10 Series, 7B80 Series, 7B50A, and 7B92A. Sweep rates and triggering ranges should be taken into consideration when selecting time-base plug-in units.

To obtain a delayed sweep display, a delaying time-base unit must be installed in the A HORIZ compartment and a delayed time-base unit installed in the B HORIZ compartment. A delayed-sweep display can also be obtained with one horizontal compartment if a dual time-base unit is used. This leaves the other horizontal compartment available for other plug-in units as suggested later in this section.

#### NOTE

*The 7B50 series (except 7B50A), the 7B70 series, and 7B92 time base units are not optimized for the extremely wide horizontal bandwidth of the 7104 and will likely exhibit unacceptable degradation in sweep accuracy and linearity.*

## SAMPLING DISPLAYS

Sampling-system plug-in units for the 7000-series oscilloscopes provide displays of fast-changing signals that cannot be examined using any other method. For example, sampling systems available for the 7104 can resolve repetitive signals having less than 10 millivolts of peak amplitude and occurring in less than 1 nanosecond.

The technique used for sampling is very similar in principle to the use of stroboscopic light to study fast motion. Samples of successive waveforms are taken, amplified by a relatively low-bandwidth amplifier, and then displayed on the crt as a replica of the sampled waveforms.

Three sampling systems are available at this time for the 7104: (1) the 7S12, which provides time-domain-reflectometry displays and general-purpose sampling measurements, (2) the 7S11/7T11 system and (3) the 7S14, a dual-channel vertical sampling system, including main and delayed sweep functions. See the Tektronix Products catalog to determine the characteristics of individual units mentioned and of additional units made available after this manual is published.

## Single-Trace Sampling

A single-trace sampling display requires either a double-width 7S12 (which includes a time-base), or the 7S11 sampling unit and the 7T11 sampling sweep unit. Direct interconnections between the 7S11 and the 7T11 require these units to be adjacent, with the 7S11 in the RIGHT VERT compartment and the 7T11 in the A HORIZ compartment. If either the 7S12 or the 7S14 is used, it must be located in the middle two compartments to make proper connections with the 7104.

## Dual-Trace Sampling

Two 7S11's can be used with a single sampling time-base unit for time-related displays of two signals. Direct interconnections from the LEFT VERT 7S11 pass through the RIGHT VERT 7S11 to reach the A HORIZ time-base unit.

The 7S14 is a dual-channel sampling unit with delaying sweep capability. It must be used in the middle two plug-in compartments.

Dual-trace sampling displays can also be made by a 7S12 in the middle two compartments and a 7S11 in the LEFT VERT compartment. In this application, the 7S12 supplies the time-base for both traces.

## X-Y Sampling

One 7S11 inserted in the RIGHT VERT compartment and one in the adjacent A HORIZ compartment automatically share a 50 kilohertz free-running strobe condition specified for X-Y displays. The 7S14 has an X-Y operation incorporated as one of its normal mode functions.

## SPECIAL PURPOSE PLUG-IN UNITS

The variety of special-purpose plug-in units available allows the 7104 Oscilloscope to be used for many specialized applications. The following is a brief discussion of some of the available special-purpose plug-in units.

### Digital Counters and Multimeter Plug-In Units

The digital-multimeter plug-in units measure current, voltage, temperature and resistance; digital-frequency counter plug-in units measure frequency, from dc to above 500 megahertz. These units make use of the readout system to display the measured information on the crt and can function in any compartment, in combination with each other or with any other plug-in units available for use with the 7104 Oscilloscope system.

The ability of digital readout plug-in units to operate with other plug-in units makes it possible to process and monitor signals at the same time the digital measurement is being made. For example, by locating a frequency counter in one of the vertical compartments and an amplifier unit in the other vertical compartment, the crt can display the trigger waveform, superimposed on the displayed signal, to indicate the actual triggering

point. Or, if the counter is placed in a horizontal compartment, a low amplitude signal can be applied to a vertical amplifier and amplified before it is internally routed by the TRIGGER SOURCE switches to the counter trigger circuit. This allows the unit to be used on signals too small to trigger other counters.

### Readout Access Plug-In Unit

The 7M13 READOUT plug-in unit provides front-panel keyboard operation for convenient access to the crt readout characters. This allows information, such as dates and identifying nomenclature, to be displayed on the crt with the normal crt display. This capability is particularly useful when making photographs.

### Transistor Curve-Tracer Plug-In Units

The 7000-series transistor curve-tracer plug-in checks small signal transistors and diodes by producing a display showing the basic characteristic curves for the device being tested. Stepped sweep signals from an internal power supply are applied to the device under test. The resulting output signals are, in turn, applied to the horizontal and vertical deflection systems of the oscilloscope to plot a family of characteristic curves. This plot can be used to check for damaged transistors and diodes, or to select for special or matched characteristics and to calculate gain, leakage, breakdown voltage, etc.

### Spectrum Analyzer Plug-In Units

The 7000-series spectrum analyzer plug-in units display signal amplitudes dispersed over portions of the rf spectrum. Absolute signal energy is plotted on the vertical axis against frequency on the horizontal axis. Applications include waveform and distortion analysis, EMC and random noise measurements, filter design, spectrum surveillance, etc.

## X-Y OPERATION

In some applications, it is desirable to display one signal versus another (X-Y) rather than against time (interval sweep). The flexibility of the amplifier plug-in units available for use with the 7104 provide the means of applying external signals to the horizontal-deflection system.

Installation of a 7A-series amplifier plug-in unit in one of the horizontal and one of the vertical compartments provides X-Y operation. Using the 7104 in the X-Y mode can only be accomplished in conjunction with a horizontal time-base unit. When an amplifier is installed in a horizontal plug-in compartment, the control of the Z-axis is switched to the one remaining horizontal compartment as is indicated by the A or B intensity control indicator lights. This is independent of the HORIZONTAL MODE switch setting. The time base will control the Z-axis and should be internally triggered on the Y portion of the X-Y display. By varying the time/division switch, the Z-axis is duty cycled and a window can be selected during which the Z-axis is

turned on. By operating the instrument in a horizontal alternating mode (X-Y display, Y-T display) the optimum sweep speed is easily selected. For typical X-Y displays the spot velocity is unpredictable. For such displays a dc driven Z-axis produces displays with very nonuniform brightness levels. A display may consist of a very dim transition between two bright spots. In fact in some cases the transition may not be seen at all since there may be enough screen current in the bright spots to activate the intensity limiter. If the time base turns on the Z-axis only during the transition a uniform brightness display can be obtained. The high horizontal bandwidth in conjunction with Z-axis control by a time base allows observation of very fast transitions in X-Y displays. With Option 2, a horizontal delay line is added to the instrument permitting signal phase correction between the vertical and horizontal deflection systems. Some vertical plug-in units have a variable delay function that permits precise phase correction. For further information, refer to the horizontal specifications in this manual and to the individual instruction manuals for the amplifier units.

Some of the 7B-series time-base units can be operated as amplifiers in addition to their normal uses as time-base generators. This feature allows an external signal to provide the horizontal deflection to the crt. For most of the time-base units with the amplifier function, the X (horizontal) deflection signal can be connected either to an external input connector on the time-base unit, or it can be routed to the time-base unit through the internal triggering system (see time-base instruction manual for details). If the latter method is used the A and B TRIGGER SOURCE switches must be set so that the X (horizontal) deflection signal is obtained from one of the vertical amplifier units and Y (vertical) deflection signal is obtained from the other vertical unit. The attenuator switch on the amplifier unit can provide the horizontal with a preconditioned signal, compatible with the horizontal deflection factor. Also, plug-in units need not be moved from one compartment to another to change from X-Y operation to other modes of operation.

## RASTER DISPLAYS

A raster-type display can be used effectively to increase the apparent sweep length. For this type of display, the trace is deflected both vertically and horizontally by sawtooth signals. This is accomplished in the 7104 by installing a 7B-series time-base unit in one of the vertical plug-in compartments. Normally, the time-base unit in the vertical compartment should be set at a slower sweep rate than the time-base unit in the horizontal compartment; the number of horizontal traces in the raster depends upon the ratio between the two rates.

Information can be displayed on the raster using several different methods. In the ADD position of the VERTICAL MODE switch, the signal from an amplifier unit can be algebraically added to the vertical waveform. With this method, the vertical signal amplitude on the crt should not exceed the distance between the horizontal lines of

## Operating Instructions—7104 Operators

the raster. Another method of displaying information on the raster is to use the Z-AXIS INPUT to provide intensity modulation for the display. This type of raster display could be used to provide a television-type display. Complete information on operation using the Z-axis feature is given under Intensity Modulation.

To provide a stable raster display, both time-base units must be correctly triggered. Internal triggering is not provided for the time-base units when they are in the vertical compartments; external triggering must be used. Also, blanking is not provided from the time-base units when they are installed in a vertical compartment.



# INSTRUMENT OPTIONS

Your instrument may be equipped with one or more instrument options. A brief description of each available option is given in the following discussion. Option information is incorporated into the appropriate sections of the manual. Refer to Table 3-1 and the Table of Contents for location of option information. For further information on instrument options, see your Tektronix Products catalog or contact your Tektronix Field Office.

## WARNING

*To avoid electric shock hazard, operating personnel must not remove the protective instrument covers. Component replacement and internal adjustments must be made by qualified service personnel only.*

### OPTION 2

Option 2 provides X-Y Mode Phase Correction. A horizontal delay line and compensation network equalizes the signal delay between either vertical compartment and the B HORIZ compartment. When this network is installed and activated, the phase shift between the vertical and B horizontal channels is adjustable to less than 2° from dc to 50 megahertz (phase balance can be obtained at any frequency up to 250 MHz). This option is factory installed.

### OPTION 3

With Option 3 installed, the instrument will meet EMC (electromagnetic compatibility) specifications given in section 1. This option can be added at any time. Refer to the Tektronix Products catalog for part number.

**TABLE 3-1**  
Option Information Locator

Instrument Option	Manual Section	Location of Information
Option 2 (Provides X-Y Delay Compensation)	1 General Information	Specification Table 1-4 contains the electrical characteristics for Option 2.
	2 Operating Instructions	Applications Provides discussion on X-Y Operation.
	3 Instrument Options	Introductory page Includes a brief description of Option 2.
Option 3 (Provides EMC)	1 General Information	Specification Table 1-5 contains the electrical characteristics for Option 3.
	2 Operating Instructions	Detailed Operating Information Light Filter; includes basic description.  Installation of Plug-In Units Refers to EMC shielded blank plug-in panel.
	3 Instrument Options	Introductory page Includes brief description of Option 3.



## **MANUAL CHANGE INFORMATION**

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

