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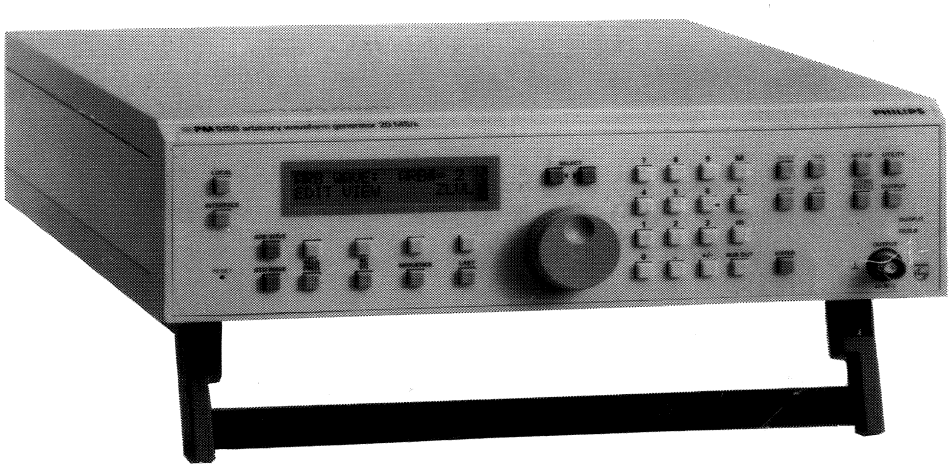
PM 5150
ARBITRARY WAVEFORM GENERATOR 20 MS/s

Operating Manual



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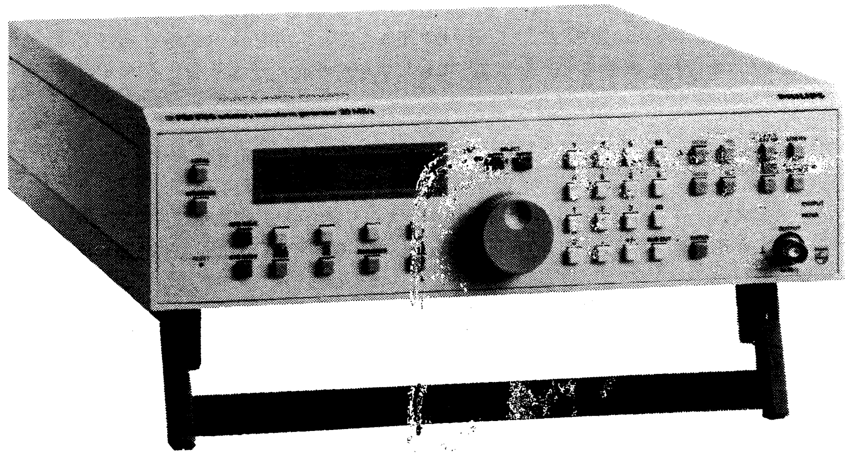

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List of Tables

List of Illustrations

1 INTRODUCTION AND SPECIFICATIONS

1.1 INTRODUCTION

This manual is the primary source of operating and programming information for the PM 5150 Arbitrary Waveform Generator. The PM 5150 provides an unlimited variety of signal source waveshapes and sequences. Twenty standard waveshapes are preprogrammed for instant recall, and arbitrary waveshapes can be created locally or downloaded from a computer or digital storage oscilloscope. Featuring an impressive array of waveform editing and mathematical capabilities, the PM 5150 can create or duplicate any imaginable waveshape.

All standard and custom waveshapes are digitally synthesized with 12 bits (4095 points) of amplitude resolution. The total available waveform memory is 32 k. An accurate internal clock up to 20 MHz provides an extremely wide range of output frequencies.

The instrument is easy to operate, with an intuitive front panel and easy to read display. Waveform parameters are changed conveniently either by numeric keypad or rotary edit knob. Two previously stored waveforms can be added, subtracted, or multiplied to create new functions.

An optional mouse makes it possible to literally draw a waveshape by viewing it on an oscilloscope as it is being constructed.

The Sequence Generator option easily creates diverse waveform sequences because it permits different waveform segments to be repeated and/or linked in any order.

All waveforms and instrument setups are completely nonvolatile. RS-232-C and IEEE-488 interfaces are standard. High-quality, state-of-the-art components assure the utmost in reliability and performance.

1.2 KEY FEATURES

20 standard waveshapes
32k waveform memory
Programmable sample clock, 20 MHz maximum
12 bits amplitude resolution
Waveform creation and editing
Drawing of waveshapes with mouse and pad (optional)
Addition, subtraction, and multiplication of waveforms
Looping and linking of waveforms with Sequence Generator (optional)
Backlit 40-character display
RS-232-C interface
IEEE-488 interface

1.3 ORGANIZATION OF THIS MANUAL

The following paragraphs describe the structure of this manual. This information is provided to assist you in making the best use of the manual.

The PM 5150 Operating Manual is divided into eight sections and a number of appendices. The following list describes each of these:

1. Introduction and Specifications

The section you are currently reading provides a general introduction to the instrument. Besides listing the key features of the PM 5150, Section 1 contains the complete Specification Table. Begin here if you need to know about the capabilities and specifications of the instrument.

2. Installation

Section 2 begins with important safety information that should be read by anyone who must set up or operate the PM 5150. The section also covers grounding, fuses, and connecting the instrument to an oscilloscope.

3. Getting Started

Section 3 is an introduction to the operation of the PM 5150. This section explains how to set up the instrument to output the standard waveforms. Read this section when you are ready to begin operating the instrument.

4. Principles of Operation

Section 4 describes how the instrument works. This information may require some study; it is similar to the "Theory of Operation" section that is frequently included in service manuals for electronic equipment. The information in Section 4 serves a similar purpose: to assist interested users in attaining a more thorough understanding of the instrument's operation. Armed with this information, the user of the instrument can become much more proficient at operating it. This material is necessary background for effective programming of custom waveforms.

Topics in Section 4 include the initial operating state of the instrument and the organization of the waveform memory.

5. Creating and Editing Arbitrary Waveforms

Section 5 explains how to use all the power of the PM 5150 to obtain waveforms of every description. This section includes procedures for using the various waveform editing capabilities to create functions by simply drawing them, scaling, smoothing, or performing mathematical operations on them, as well as complete details about the use of the Sequence Generator option.

6. Special Applications

Section 6 describes how to perform operations that may not be needed very frequently, but which represent powerful features of the instrument, such as downloading waveforms from a DSO or setting up special synchronization conditions.

7. Performance Test

Section 7 provides a series of tests that can be used for incoming inspection to be sure the instrument has arrived in perfect condition, or at any time to reconfirm proper operation and that it meets specification.

8. Remote Control

Standard built-in RS-232-C and IEEE-488 ports provide flexibility for remote operation of the PM 5150. Most of the remote commands are available for either interface, and the device-specific command set covers all the functions of the instrument. This section gives complete information about the PM 5150 command set, as well as illustrating the connections and wiring. The section includes an example IEEE-488 program written in GWBASIC.

Introductory IEEE-488 programming information is available from Philips and from Fluke. Ask for Philips Part Number 4822 872 80148, or Fluke Application Bulletin 36.

Appendices

Appendices provide important but little-used information. Here you will find an explanation of error messages, a function/menu tree, a graph showing amplitude/offset versus range, the response curve of the output filter, and a waveform design worksheet suitable for photocopying.

1.4 SPECIFICATIONS

Instrument specifications appear in Table 1-1.

Table 1-1. Specifications

PM 5150 SPECIFICATIONS

STANDARD WAVEFORMS

Sine	Gaussian	Lin Sweep
Square	Haversine	Log Sweep
Pulse ±	Circle	AM
Triangle	Sine-x over x	SCM
Sawtooth ±	Noise	FM
Exponential ±		DC

ARBITRARY WAVEFORMS	Up to 100 Custom Waveforms
SEQUENCE GENERATOR (Optional)	
Maximum number of sequences	100
Maximum number of steps in entire instrument sequence file......	1000
Maximum number of different waveforms	100
Maximum number of waveform cycles per step	1,048,575
MAXIMUM WAVEFORM RESOLUTION	
Horizontal Resolution	32,768 points maximum; 1,000 points default for standard waves
Vertical Resolution	12 bits; 4095 points (-2048 - +2047)
WAVEFORM SAMPLING FREQUENCY	0.1 Hz to 20 MHz in 9 ranges
Frequency Subrange	Resolution of Keypad and Rotary Knob
100.0 - 999.9 mHz	0.1 mHz
1.000 - 9.999 Hz	1 mHz
10.00 - 99.99 Hz	10 mHz
100.0 - 999.9 Hz	100 mHz
1.000 - 9.999 kHz	1 Hz
10.00 - 99.99 kHz	10 Hz
100.0 - 999.9 kHz	100 Hz
1.000 - 9.999 MHz	1 kHz
10.000 - 20.000 MHz	2 kHz
LCD resolution	5 digits
Accuracy	± 50 ppm
WAVEFORM RISE/FALL TIME	Less than 20 ns

Test Conditions:
- Square wave
- Filter off
- 10 Vpp
- 50Ω termination

SPECTRAL PURITY

THD + Noise:	-60 dBc typical at 100 mV -65 dBc typical at 1 V -65 dBc typical at 20 V

Test Conditions:
- 20 kHz sinewave (20 MHz sample clock)
- Filter on
- 50Ω termination
- Measurement frequency band 0 - 80 kHz

Table 1-1. Specifications (cont)

PM 5150 SPECIFICATIONS

AMPLITUDE AC voltage p-p open circuit

Range	Resolution of keypad and rotary knob	Accuracy
2.00 V to 20.00 V	10 mV	± 1% of setting ± 40 mV
200 mV to 2.000 V	1 mV	± 3% of setting ± 10 mV
20.0 mV to 200.0 mV	0.1 mV	± 5% of setting ± 2 mV

Test Conditions:
- 1 kHz sinewave
- Filter off
- Open circuit output
- Note: Stated ranges are valid for zero DC offset; otherwise the ranges apply to *amplitude + 2 * ABS (DC offset)*. See diagram in Appendix D.

FREQUENCY RESPONSE Test Conditions: Sinewave up to 1 MHz Filter on 50 Ω termination	± 0.2 dB typical
ANALOG FILTER	User-selectable, 7 MHz, 7th-order low-pass filter
OPERATIONAL MODES	
Continuous	Output runs continuously between selected memory address locations.
Triggered	Output at start point until triggered, then runs once.
Gated	Same as triggered except output is continuous until gate signal ends.
Burst	Each trigger outputs a pre-programmed number of waveforms from 1 to 1,048,575.
Toggled	The output wave is keyed on/off alternately by triggers.
Hold	Front-panel button or external signal stops waveform at present memory location while applied.
RTS	Front-panel button or external signal interrupts the output waveform and instantly returns it to the start level. The waveform then proceeds from that level.
INPUTS AND OUTPUTS	
FRONT PANEL OUTPUT	Front-panel main waveform output, 50Ω impedance
10 MHZ REFERENCE CLOCK IN/OUT	
RCLK In	Rear-panel external 10 MHz reference input (TTL). The internal crystal-controlled oscillator will phaselock to the input.
Frequency	10 MHz ± 10 ppm
Minimum level	-0.4 V (absolute maximum rating)
Maximum level	6.3 V (absolute maximum rating)
Minimum AC p-p voltage	1.5 V
Input load	10 kΩ, AC coupled
RCLK Out	Rear-panel internal 10 MHz reference output (TTL)
Fanout	3 standard TTL loads

Table 1-1. Specifications (cont)

PM 5150 SPECIFICATIONS	
SAMPLE CLOCK IN/OUT	
SCLK In	Rear-panel sample clock digital input
Maximum frequency	20 MHz
Minimum level	-0.4 V (absolute maximum rating)
Maximum level	6.3 V (absolute maximum rating)
Maximum low-level	0.9 V
Minimum high-level	3.2 V
Load	10 kΩ
SCLK Out	Rear-panel sample clock output (TTL)
Fanout	3 standard TTL loads
SYNC TRIG OUT	Rear-panel TTL sync for triggering additional units in parallel
Fanout	3 standard TTL loads
TRIG IN	Rear-panel TTL trigger input for triggered, gated, burst, and toggled modes.
Maximum frequency	20 MHz
Minimum level	-0.4 V (absolute maximum rating)
Maximum level	6.3 V (absolute maximum rating)
Maximum low-level	1.1 V
Minimum high-level	2.0 V
Load	10 kΩ
SYNC 1 / END PULSE OUT	
Sync1	Programmable rear-panel TTL output.
End pulse out	High at end of signal period (default mode)
Programmed mode	Programmable address and length
Fanout	3 standard TTL loads
Z AXIS OUTPUT	Rear-panel Z Axis output in edit mode.
Level	Programmable; 0 - 9 V (open circuit) typical
Impedance	75Ω
SYNC 2 / RUN OUT	
Sync 2	Programmable rear-panel TTL output
Run out	High when output signal is on (default mode)
Programmed Mode	Programmable address and length
Fanout	3 standard TTL loads
SYNC 3 / END BLOCK OUT	
Sync 3	Programmable rear-panel TTL output
End block out	Single pulse at end of every step in the sequence, applies to sequence operation only (default mode)
Programmed mode	Programmable address and length
Fanout	3 standard TTL loads

Table 1-1. Specifications (cont)

	PM 5150 SPECIFICATIONS
RTS IN	Rear panel TTL input for initiating RTS
Minimum level	-0.4 V (absolute maximum rating)
Maximum level	6.3 V (absolute maximum rating)
Maximum low-level	1.1 V
Minimum high-level	2.0 V
Load	10 kΩ
HOLD IN	Rear-panel TTL input for initiating Hold
Minimum level	-0.4 V (absolute maximum rating)
Maximum level	6.3 V (absolute maximum rating)
Maximum low-level	1.1 V
Minimum high-level	2.0 V
Load	10 kΩ
SUM IN	Rear-panel input allows external signal to be added to output, Gain = -2 for open-circuit output, 50Ω impedance
Minimum frequency	0 Hz
Maximum frequency 20 MHz	20 MHz
Minimum level	-5.0 V (absolute maximum rating)
Maximum level	5.0 V (absolute maximum rating)
Impedance	50Ω
TRIGGER SOURCES	Internal via programmable trigger generator. Manual triggering via front panel "TRIG" key. External via "TRIG IN".
CREATION TOOLS	
Waveform editing Line Mode	Line Mode
Vertex Mode	Vertex Mode with insert function, sum function, digital amplitude and offset, and smooth function.
Waveform maths	(A + B) / 2 (A - B) / 2 A * B
STORED SETTINGS	31 Setups numbered 0 - 30
REMOTE INTERFACE	RS-232-C 19.2 kBaud maximum GPIB; IEEE STD 488.2-1987
POWER SUPPLY	Line Power (ac mains voltage)
Nominal voltages	100 / 120 / 220 / 240 V
Operating range	± 10 % of nominal voltage
Nominal frequency range	50 Hz - 60 Hz
Operating limits	47.5 Hz - 63 Hz
Power Consumption	52 VA
ENVIRONMENTAL CONDITIONS	
Temperature	
Reference range	+23°C ± 3 Kelvin for specified operation (+ 73°F ± 3 Kelvin)
Operating	0°C - 50°C (32°F - 122°F)
Storage and transport	-25°C - +70°C (-4°F - +158°F)
Relative Humidity	
Reference range	45% - 75% for specified operation
Operating range	15% - 95%
Storage and transport	5% - 95%
Air Pressure	
Reference range	800 - 1100 hPa for specified operation
Nominal working range	700 - 1100 hPa

Table 1-1. Specifications (cont)

PM 5150 SPECIFICATIONS	
Air Speed	
Reference range	0 - 0.2 m/s (0 - 0.45 mph) for specified operation
Nominal working range	0 - 0.5 m/s (0 - 1.1 mph)
Heat radiation	direct sunlight radiation not allowed
Vibration	
Operating Range	maximum amplitude 0.17 mm (0.0069 inch) @ 5-55 Hz
Limits for storage and transport	maximum amplitude 0.35 mm (0.0138 inch) @ 10-60 Hz maximum acceleration 5g @ 60 - 150 Hz
Shock limit	10 g
Bump acceleration limit	25 g; 6 ms duration bumps (1000 per axis)
Operating position	normally upright on feet or with bow folded down
Warm-up time	20 minutes
SAFETY AND QUALITY DATA; CABINET	
Protection type	IP 20 (DIN 40 050)
Protection class	Class I, protective conductor (IEC 348)
Radio interference voltage and radiation	Meets or exceeds the requirements of CISPR 11, EN 55011, and VDE 0871 Part 1/Class B
Overall dimensions	
Width	315 mm (12.4 inches)
Height	105 mm (4.13 inches)
Depth	405 mm (15.94 inches)
Weight	6.7 kg (14.74 lb)
Call Rate	< 0.15/year
MTBF	15,000 hours
INSTRUMENT VERSIONS	
PM 5150/05x	basic version
PM 5150/55x	basic version + sequencer

The last digit x of the type number indicates the power line option:

X	Countries	Voltage
1	Universal European	220
3	Standard North American	120
4	United Kingdom	240
5	Switzerland	220
8	Australia	240

ACCESSORIES

Standard	Operating Manual Quick Operating Guide Power (mains) cable Fuses
Optional	Mouse (with pad), PM 9515 RS-232 cable set, PM 9536/501 Adapter, BNC/banana jack, PM 9051 50 Ω termination, 1 W, PM 9585 50 Ω termination, 3 W, PM 9581 19" rack mount adapters, PM 9563, PM 9564

2 INSTALLATION

2.1 INITIAL INSPECTION

Check the contents of the shipment for completeness and note whether any damage is evident. If the contents are incomplete or if there is damage, file a claim with the carrier immediately, and notify the Fluke/Philips Sales or Service organization to facilitate repair or replacement of the instrument.

2.1.1 Packing List

Check the following list to be sure you have received the entire shipment. If any items you have ordered are missing, notify your local Fluke/Philips Sales or Service organization immediately.

Standard

- Operating Manual
- Quick Operating Guide
- Power (mains) cable
- Fuses

Optional

- Mouse (with pad), PM 9515
- RS-232 cable set, PM 9536/501
- Adapter, BNC/banana jack, PM 9051
- 50 ohm termination, 1 W, PM 9585
- 50 ohm termination, 3 W, PM 9581
- 19 inch rack mount adapters, PM 9563, PM 9564

2.2 SAFETY INSTRUCTIONS

When it is delivered from the factory, the instrument complies with the requirements of the safety regulations shown in the Specification Table in Section 1.

To maintain compliance and to ensure safe operation, carefully follow the instructions in this section.

2.2.1 Maintenance and Repair

If the instrument is suspected of being unsafe, remove it from operation and secure it against unintended use. The instrument is considered to be unsafe if it exhibits any of the following:

- Shows physical damage
- Does not function
- Has been stressed beyond limits described in the Specifications

The PM 5150 is not considered to be serviceable by the user. If you believe your instrument requires service, contact the nearest Fluke/Philips Service organization. These facilities are listed at the back of this manual.

WARNING

Shock hazard. If the case or other parts are removed for any reason, high voltage parts or terminals could be exposed. Before opening the instrument, disconnect it from all power sources. If the open live instrument needs calibration, maintenance, or repair, such service must be performed only by trained personnel who are aware of the risks. Even after disconnection from all power sources, capacitors inside the instrument may remain charged for some time.

2.2.2 Grounding

Before any other connection is made, the instrument must be connected to a protective ground by way of a three-conductor power cable.

The power cable must be inserted into an outlet equipped with protective ground contact.

Grounding must not be defeated by use of an extension cord that does not include the protective conductor.

The external contacts of BNC sockets must not be used to connect a protective conductor.

WARNING

Shock hazard. Do not disconnect the protective ground connection for any reason. The instrument must always be grounded for safe operation. Any interruption of the protective conductor inside or outside the instrument, or disconnection of the protective ground terminal, is likely to result in the creation of a dangerous shock hazard condition. Intentional interruption is prohibited.

The circuit ground potential is applied to the external contacts of the BNC sockets and to the cabinet through parallel capacitors. This avoids ground loops (hum) while providing clear RF grounding.

If the circuit ground potential in a measurement setup is different from the protective earth ground, note the following two points:

1. The BNC sockets must not be live when touched. See the safety requirements of IEC 348/VDE 0411 for more information.
2. All BNC socket housings are internally connected.

2.2.3 Line Power Setting and Fuses

Before inserting the power cable into the power outlet, make sure the instrument is set to the local line voltage.

WARNING

Shock hazard. If the power cable requires adaptation to the local outlet style, such adaptation should be performed only by qualified personnel.

On delivery from the factory, the instrument is set to one of the following line voltages:

TYPE	CODE NUMBER	LINE VOLTAGE	DELIVERED POWER CABLE
PM 5150/..1	9445 051 50..1	220V	Europe, Schuko
PM 5150/..3	9445 051 50..3	120V	North America
PM 5150/..4	9445 051 50..4	240V	England (U.K.)
PM 5150/..5	9445 051 50..5	220V	Switzerland
PM 5150/..8	9445 051 50..8	240V	Australia

The line power setting and the corresponding fuse are indicated on the rear panel.

Make sure that only fuses of the specified type and current rating are used for replacement. Never use repaired fuses or short-circuit the fuse holders.

WARNING

Death or injury hazard due to electric shock. The PM 5150 must be disconnected from all power sources when you replace fuses or change the line power setting.

The PM 5150 can be set to the following AC voltages: 100V, 120V, 220V, and 240V. These nominal voltages are set by a voltage selector located on the rear panel. The fuse holder is located within the same assembly.

For voltage selection or fuse replacement, remove the power cable and pry open the compartment using a small screwdriver as shown in the following drawing.

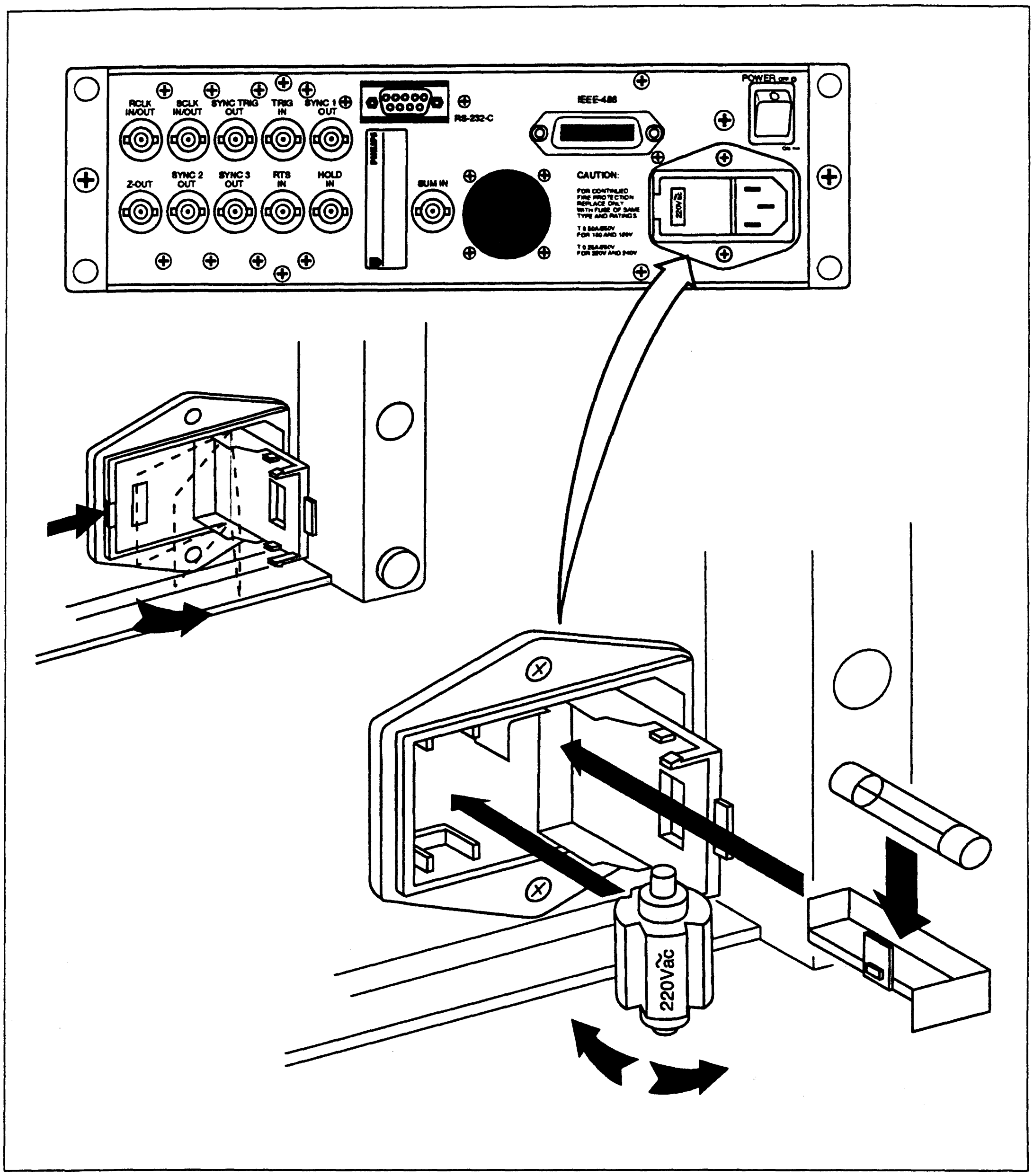


Figure 2-1. Power Selection and Fuse Replacement

Select the appropriate voltage range by turning the selector, If necessary, insert the corresponding fuse into the fuse holder. Select the correct fuse by referring to the following:

100V, 120V ________ T0.5A

220V, 240V ________ T0.25A

2.3 OPERATING POSITION OF THE INSTRUMENT

The instrument can be used in two positions, depending on whether the handle is folded up or down. Specifications are not guaranteed for operation in any other orientation. Be sure that the ventilation holes are unobstructed. Never place the instrument in direct sunlight or on a surface that radiates heat or electromagnetic energy.

2.4 RADIO INTERFERENCE SUPPRESSION

Radio interference of the instrument is suppressed and checked carefully before shipment to the customer. However, if the instrument is connected to other units that are not properly suppressed, radio interference can be generated. It is the responsibility of the equipment owner to take the steps necessary to suppress such interference.

BNC cables used must be properly shielded, for example type RG223. IEEE-488 cables must also be properly shielded and the connectors must have metal housings.

2.5 CONNECTING THE PM 5150 TO AN OSCILLOSCOPE

The next few pages explain how to connect the PM 5150. After connections are complete, you can go to Section 3 to quickly obtain waveforms.

2.5.1 Output Connector

The front panel output connector and the rear panel trigger and sync outputs are BNC sockets.

Using properly shielded BNC cables, connect the front panel OUTPUT and the rear panel SYNC1 OUTPUT connectors to an oscilloscope as shown in Figure 2-2. A connection between the PM 5150's rear panel Z-OUT socket and the Z-IN socket of the oscilloscope can also be made at this time.

2.5.2 Mouse Connection

As shown in Figure 2-2, the mouse is connected to the RS-232 connector on the rear panel of the PM 5150. For remote programming via the RS-232 port, it is necessary to disconnect the mouse.

The optional PM 9515 mouse must be switched to two-button operation before connection to the instrument.

To initialize the mouse, the instrument must be switched on with the mouse connected.

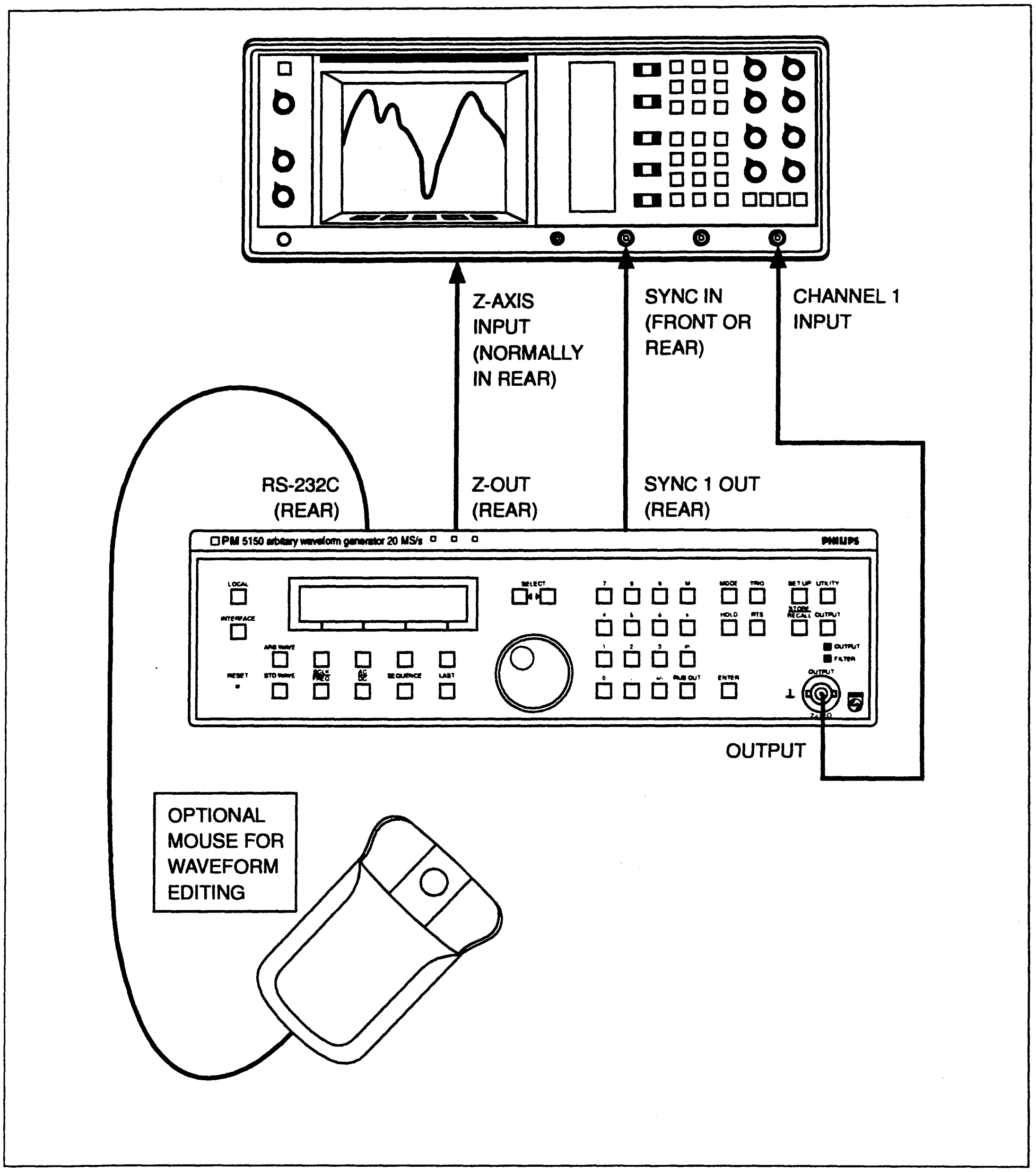


Figure 2-2. Connecting the PM 5150

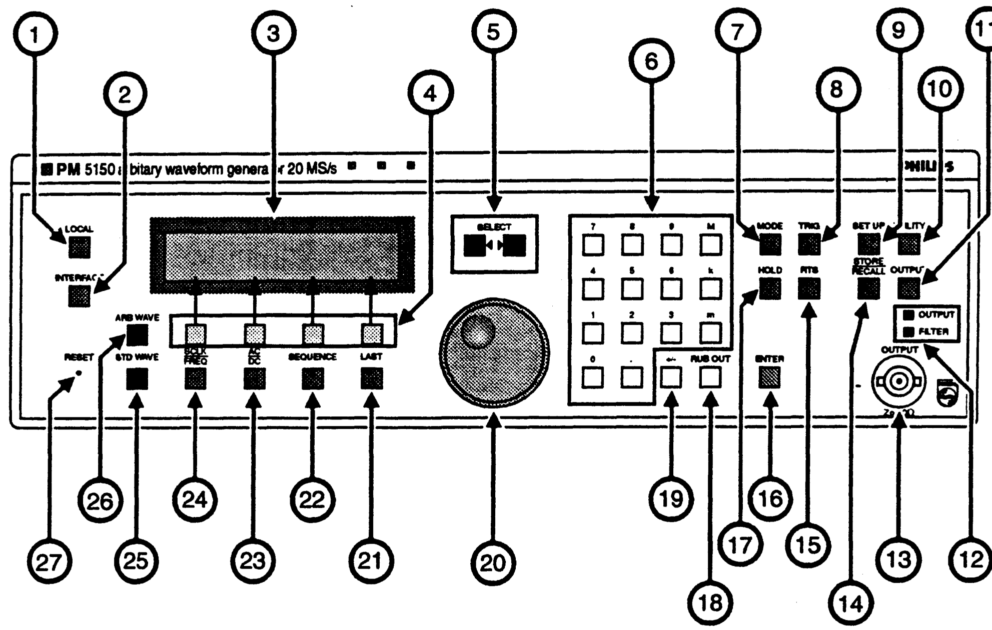
3 GETTING STARTED

3.1 INTRODUCTION

This section explains how to begin using the PM 5150 to view standard waveforms. The section begins with a description of the front and rear panels, then explains how to view and modify the standard waveforms.

3.1.1 Front Panel

Figure 3-1 illustrates the front panel, and Table 3-1 gives a short description of each of the features. Also note that a large foldout illustration of the front and rear panels is provided at the back of the manual.



1. LOCAL
2. INTERFACE
3. Display
4. Softkeys
5. SELECT Keys
6. Numeric Keypad
7. MODE
8. TRIG
9. SET UP
10. UTILITY
11. OUTPUT Key
12. OUTPUT and FILTER Indicators
13. OUTPUT Connector
14. STORE / RECALL
15. RTS
16. ENTER
17. HOLD
18. RUB OUT
19. +/–
20. Rotary Edit Knob
21. LAST
22. SEQUENCE
23. AC / DC
24. SCLK / FREQ
25. STD WAVE
26. ARB WAVE
27. RESET

Figure 3-1. PM 5150 Arbitrary Waveform Generator Front Panel

Table 3-1. PM 5150 Front Panel Features

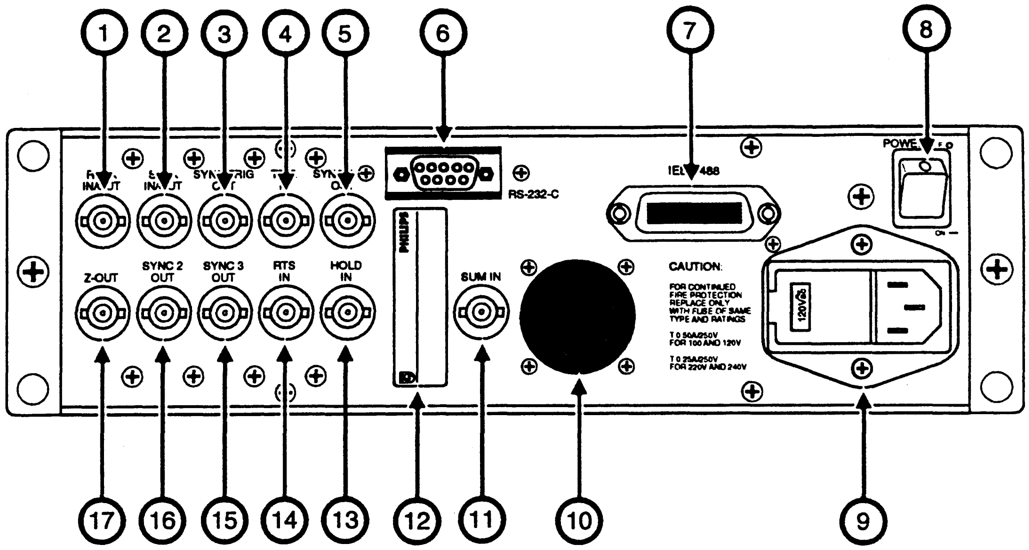
1	LOCAL	Switches the intrument to local operation.
2	INTERFACE	Selects GPIB (IEEE-488.2) or RS-232-C remote operation. Softkeys select GPIB address and RS-232 communication parameters (baud rate, parity, data bits, stop bits, handshaking), and DSO facilities.
3	Display	A two-line by 40-character LCD alphanumeric display. Values, modes, and functions are indicated here. Also, softkey meanings appear in the lower line of the display. Selections change to FULL CAPITAL LETTERS. A triangular indicator may signify that there are more selections available, or point to the currently selected field.
4	Soft keys	Associated with selections that appear immediately above them in the display, these keys change their use depending on the current operating state.
5	SELECT keys	These keys choose the currently editable field on the display.
6	Numeric Input Keys	The numeric keys input values to the PM 5150. Values can be programmed only in decimal from the front panel. Remote operation permits hexadecimal, octal, and binary input as well.
7	MODE	Selects waveform output mode: Continuous, Triggered, Gated, Burst, or Toggled.
8	TRIG	Front panel trigger key. Triggers the output in triggered, gated, burst, and toggled modes.
9	SET UP	Establishes the memory length and synchronization style for standard and arbitrary waveforms. Note that addresses are independently programmable if syncing to an address; however if a default sync mode (End Pulse, Run, or End Block) is chosen for one wave, that style is used for all waves, regardless whether an address is programmed.
10	UTILITY	Accesses two utility operations; one for setting up a multiple unit system, and the other for adjusting the LCD contrast level.
11	OUTPUT	Accesses the output and filter controls. These can be turned ON or OFF by way of softkeys. Note that the OUTPUT OFF selection only stops the waveform output; it does not remove from the output the DC OFFSET achieved using the AC/DC key.
12	OUTPUT LED FILTER LED	Indicate the status of the output and filter; lit = ON.
13	OUTPUT Connector	Instrument output BNC connector; impedance 50 ohms nominal. External voltage 42V maximum.
14	STORE / RECALL	Stores and retrieves up to 31 sets of complete instrument settings, numbered 0 through 30. See Table 6-2 for a listing of stored and not stored settings.
15	RTS	Return To Start. This key causes the waveform to begin again from the start point.
16	ENTER	Terminates keypad entries or command chains.
17	HOLD	Stops the waveform at its current level. The output remains at that level until HOLD is released.
18	RUB OUT	Erases the value in the current field. When a value is being edited, RUBOUT clears it digit by digit.
19	+ / -	Changes the sign of the currently displayed value in the field being edited on the display.
20	Edit knob	Rotary knob used to input waveform parameter values to the instrument.
21	LAST	Accesses the command input memory. Each successive press of the LAST key cycles the previous command to the display. Command input memory holds the history of about 15 operations.

Table 3-1. PM 5150 Front Panel Features (cont)

22	SEQUENCE	Only functions if the Sequence Generator Option is installed. Permits creation and editing of waveform sequences made up of Arbitrary waves in any order. Standard waves can be sequenced if they are first placed into ARB memories using the EDIT mode. The Sequence Generator option lets you loop between waveform sequences and link them together.
23	AC / DC	Sets the amplitude and offset of the waveform being edited.
24	SCLK / FREQ	Adjusts the sample clock frequency (SCLK) or the frequency of the output waveform.
25	STD WAVE	Selects a standard waveform. Use SELECT keys to cycle all 20 selections to the display. Use softkeys to select a standard waveform, then a submenu permits adjusting the parameters of the waveform.
26	ARB WAVE	Selects an arbitrary waveform. Softkeys access submenus to enter Editing mode (Line, Vertex, and Math), View mode to view all or a portion of waveform memory, and set the amplitude of the Z-Axis output (ZLVL).
27	RESET	Activated by pressing a pointed tool, such as a paper clip or ballpoint pen tip into the hole, RESET performs a “soft reset” when pressed alone, and a “cold start” if held depressed during power on of the PM 5150. See Paragraph 3.2.1 for details.

3.1.2 Rear Panel

Figure 3-2 illustrates the rear panel and Table 3-2 gives a short description of each of the features.



1	RCLK IN/OUT	10	Fan
2	SCLK IN/OUT	11	SUM IN
3	SYNC TRIG OUT	12	Manufacturers Label
4	TRIG IN	13	HOLD IN
5	SYNC 1 OUT	14	RTS IN
6	RS-232C Connector	15	SYNC 3 OUT
7	IEEE-488 Connector	16	SYNC 2 OUT
8	POWER Switch	17	Z-OUT
9	Line Cord Connector		

Figure 3-2. PM 5150 Arbitrary Waveform Generator Rear Panel

Table 3-2. PM 5150 Rear Panel Features

1	RCLK IN/OUT	10 MHz Reference Clock; TTL Input/Output. Default is to output the reference clock. The internal crystal-controlled oscillator will phase lock to the input.
2	SCLK IN/OUT	Sample Clock Input/Output. Default is to output the sample clock. If the instrument is programmed as a slave in a multiple unit set up, this is the sample clock input from the master.
3	SYNC TRIG OUT	Sync Trigger Output, a TTL sync for triggering additional units when they are operated in parallel.

Table 3-2. PM 5150 Rear Panel Features (cont)

4	TRIG IN	Trigger Input, a TTL trigger input for triggered, gated, toggled, and burst modes.
5	SYNC 1 OUT	Sync 1 / End Pulse Output. Programmable TTL output. End Pulse provides a single pulse during the last clock interval of the output waveform (the default).
6	RS-232-C	Connection point for optional mouse or for serial communication link to a computer.
7	IEEE-488	Connection point for IEEE-488.2 interface bus.
8	Power Switch	Main power on/off switch.
9	Power Connector	Line power connector with integral voltage selector and fuse.
10	Fan	Cooling fan, should run continuously when power is applied.
11	SUM IN	Permits external signal to be added to output, gain = -2 for open-circuit output. 50 ohm impedance, 0 - 20 MHz, -5 V to +5 V
12	Instrument Label	Location of type number and serial number.
13	HOLD IN	Hold Input, TTL input for initiating Hold
14	RTS IN	Return To Start Input, TTL input for initiating RTS.
15	SYNC 3 OUT	Sync 3 / End Block Output Programmable TTL sync output. End Block provides a single pulse at the end of each step in a sequence (default if Sequencer option is installed).
16	SYNC 2 OUT	Sync 2 / Run Output. Programmable TTL output. Run Out is high when output signal is on (default).
17	Z-OUT	Z-Axis Output, programmable between 0 and 9 volts open circuit, impedance 75 ohms.

3.2 GETTING STARTED

All waveforms are obtained from the OUTPUT BNC connector on the front panel. A TTL sync pulse is available from the SYNC1 OUT connector on the rear panel. If the instrument has not yet been connected to an oscilloscope, refer to Section 2, Installation, and connect the OUTPUT and SYNC1 OUT as illustrated. When it is first powered on, the PM 5150 displays an identification screen as shown below:

```
ARBITRARY GENERATOR
PM 5150       SWx.yz
```

The number that appears on the display after "SW" is the software release version number. After a few moments, the instrument automatically selects STD WAVE, and displays the available selections of Standard Waveforms.

3.2.1 Displaying the Standard Waveforms

Twenty standard waveforms can be readily recalled from stored algorithms.

The PM 5150 automatically provides a continuous sine wave signal after the instrument is reset. To reset the PM 5150:

1. Insert a paper clip, ballpoint pen tip, or pointed tool into the hole on the front panel labeled RESET. Momentarily press just hard enough to activate the internal switch.

2. The display labels two softkeys CURR and ALL. Select ALL by pressing the blue softkey just below the label. The ALL softkey resets all waveform and sequence programming and stored settings. The following table shows the main parameters after RESET ALL. Appendix F contains a table showing the complete set of reset default values.

Reset Default Values

Function	Sine
Mode	Continuous
Amplitude	10.00 Volts
Offset	0.000 V
Clock	10.000 MHz
Output	Off
IEEE-488 Address	16

3. Press the OK softkey to reset, or the CANC softkey to cancel.
4. Press the STD WAVE key to access the Standard Waves. The display should appear as follows:

```
STD WAVE
SIN sqr pls+ pls- ◄
```

5. Select a standard wave by pressing the blue softkey immediately below the name of the waveform. Confirm the selection by pressing the orange ENTER key. Twenty standard waves are available; press the SELECT keys to display all the groups.
6. Press OUTPUT, then the ON softkey to display the selected standard waveform.

3.2.2 How to Change the Default Parameters

All of the standard waveforms have programmable parameters such as phase, number of cycles, duty cycle, rise and fall times, and so on. These are listed in Table 3-3. Instructions following the table describe how to change these parameters.

3.2.3 Amplitude and Offset

Output signal amplitude can be changed from the default value of 10 volts peak-to-peak (open circuit) to any value between 20 mV and 20.40 V, within the limits of resolution. See the instrument specifications listed in Section 1.

Press the AC/DC key to display the value. Either the edit knob or the numeric keypad can be used to obtain the new value.

NOTE

The edit knob and keypad operate only on the parameter displayed on the top row of the LCD. Use the SELECT keys to exchange the position of the displayed parameters.

DC offset can be changed from the default value of zero to any value between ± 9.4 V, depending on the amplitude setting. See the diagram in Appendix D for more details.

3.2.4 Sample Clock and Output Frequency

The frequency of the output waveform is a function of the clock frequency and the number of samples, as described by the formula:

Output Frequency = Sample Clock Frequency / Number of Samples

Since the default sample clock frequency is 10 MHz and the standard waveform default memory allocation is 1000 samples, the default output frequency is 10 MHz / 1000 = 10 kHz.

The following steps change the output frequency:

1. Press the SCLK/FREQ key. The current setting of SCLK appears on the top row of the display, with a triangular indicator showing that the sample clock frequency can be edited.

2. Use the edit knob or keypad to set the clock frequency to any value from 0.1 Hz to 20 MHz. Note the new output frequency is computed and displayed automatically. Any change in the number of waveform samples will also affect the output frequency, as previously discussed.

   While it is possible to set the output frequency directly from the front panel, remote operation only permits indirectly changing FREQ by adjusting SCLK.

3.2.5 Output Modes

Change the output mode by pressing the MODE key. The first four modes are displayed with the triangular "more" indicator. Press SELECT to see the fifth available mode, toggle. Use the softkeys to select a mode, then press ENTER. The modes perform as follows:

continuous	Output runs continuously between selected memory address locations.
triggered	Output at start point until triggered, then runs once.
gated	Same as triggered except the output is continuous until the gate signal ends.
burst	Each trigger outputs a preprogrammed number of waveforms from 1 to 1,048,575.
toggled	Alternate triggers start and stop the output waveform.

3.2.6 Engaging the Output Filter

A 7-MHz, 7th-order low-pass filter can be switched into the output signal circuit. This filter is effective in removing sampling step noise when a clock frequency ≥ 10 MHz is used. The default setting for the output filter is OFF.

1. Press the OUTPUT key.

2. Press the ON softkey under FILTER.

3. The LED labeled FILTER just below the OUTPUT LED lights immediately, indicating that the output is now being filtered.

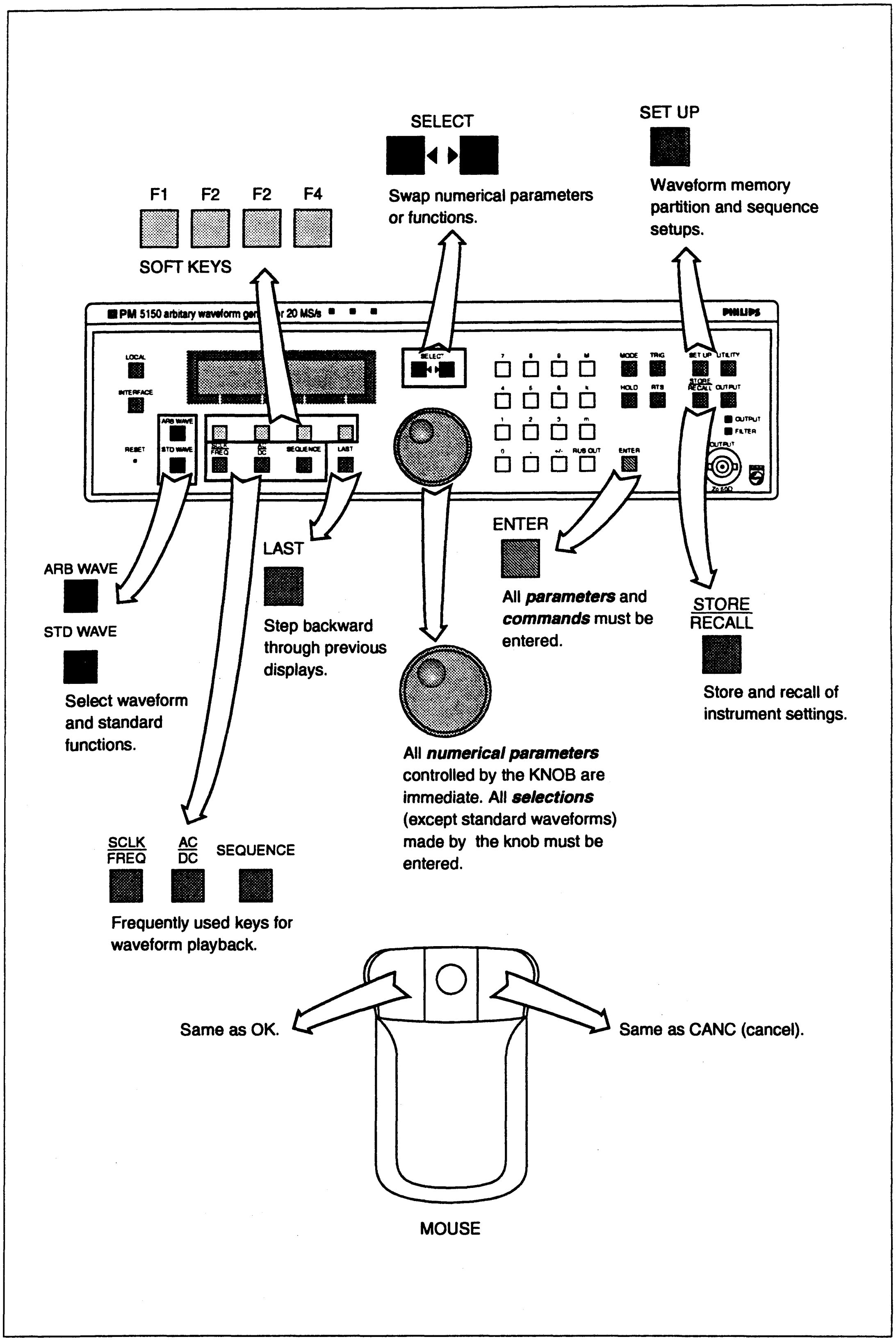


Figure 3-3. Front Panel Controls

Table 3-3. Programmable Parameters of the Standard Waveforms

FUNCTION	PARAMETER	DISPLAY IDENTIFIER	RANGE AND RESOLUTION	DEFAULT VALUE
SINE	Phase Number of Repetitions	P N	0.000° to 360.000° 0.01 to 1000.00	0.000° 1.00
SQUARE	Number of Repetitions Duty Cycle	N DTY	1 to 1000 1 to 100%	1 50%
PULSE	Delay Rise Time High Time Fall Time Number of Repetitions	DLY RIS HI FAL N	0 to 100% 0 to 100% 0 to 100% 0 to 100% 0 to 1000	0% 10% 30% 10% 1
TRIANGLE	Number of Repetitions	N	1 to 1000	1
SAWTOOTH	Number of Repetitions Duty Cycle	N DTY	1 to 1000 1 to 100%	1 100%
EXPONENTIAL	Time Constant	EXP	0.01 to 20.00	5.00
GAUSSIAN	Exponent Power	EXP	0.01 to 20.00	2.00
HAVERSINE	Number of Repetitions	N	0.01 to 1000.00	1.00
CIRCLE	Number of Repetitions Phase	N P	0.01 to 1000.00 0.00 to 360.00	1.00 0.00
SINE X/X	Ringing Frequency Multiplier	N	4.00 to 1000.00	5.50
NOISE	—	—	—	—
LINEAR SWEEP	Begin End	B E	x1 to x1000 x1 to x1000	x1 x10
LOG SWEEP	Begin End	B E	x1 to x1000 x1 to x1000	x1 x10
AM	Carrier Frequency Modulation Frequency Modulation Index Modulation Phase Carrier Phase	CF MF IX MP CP	x1 to x8183 x1 to x8183 0 to 100 % 0 to 360° 0 to 360°	x20 x1 50% 0° 0°
SCM	Carrier Frequency Modulation Frequency Modulation Phase Carrier Phase	CF MF MP CP	x1 to x8183 x1 to x8183 0 to 360° 0 to 360°	x20 x1 0° 0°
FM	Carrier Frequency Modulation Frequency Modulation Index Modulation Phase Carrier Phase	CF MF IX MP CP	x1 to x8183 x1 to x8183 0.01 to 100.00 0 to 360° 0 to 360°	x20 x1 10.00 0° 0°
DC	Level	DC	-2048 to + 2047	0

NOTE:

At least 3 to 10 samples are required to represent any given function. Therefore, the length of the waveform must be taken into consideration when selecting range and resolution values.

4 PRINCIPLES OF OPERATION

4.1 INTRODUCTION

This section provides information about how the PM 5150 operates. The topics discussed in this section include the following:

- Digital synthesis of waveforms
- Memory organization
- Command chaining and the LAST Key

4.2 DIGITAL SYNTHESIS OF WAVEFORMS

The output signals of the PM 5150 are high resolution sample and hold functions of the ideal waves. The value of the individual amplitude sample is designated as Y. The corresponding normalized time position is X. The pairs of X,Y values are stored in waveform memory (RAM). The X value is used as the address of a memory location, and the sample amplitude value in this location is Y. Thus a complete arbitrary wave is defined by the finite set of values stored in the waveform memory.

For example, consider the following waveform:

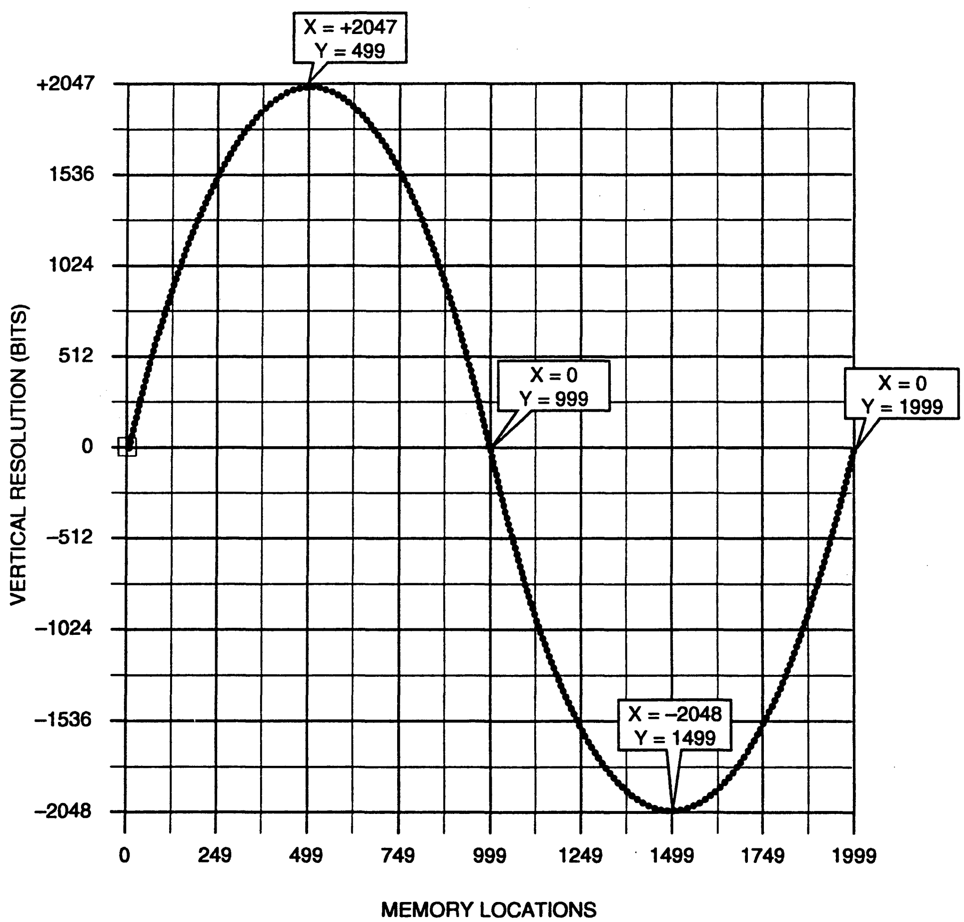


Figure 4-1. Sine Wave to be Stored in Memory

The X and Y axes are labeled as they are to illustrate how this waveform would be stored. The Y axis is scaled in terms of a digital value with a resolution of 12 bits. This means that there are 4095 points of amplitude, referred to as the resolution of the waveform.

The X axis is scaled in terms of memory addresses, and as shown here, the default length for an arbitrary waveform is 2,000 addresses, 0 through 1999. Each location stores one amplitude value, and the entire waveform can be reconstructed (played back) at any time later by reading the corresponding section of memory. The entire waveform memory is 32,768 addresses long.

The waveform memory can be loaded in the following ways:

- The STANDARD WAVEFORMS have their X and Y values loaded automatically from stored algorithms.
- ARBITRARY WAVESHAPES are created by entering the values manually using the front panel keypad or edit knob, or by means of the optional mouse. Arbitrary waveshapes can also be copied, edited, or combined with previously stored Standard or Arbitrary Waveforms.
- A Digital Storage Oscilloscope can download values from a captured waveform.
- A computer can create the X and Y values and transfer them to the generator.

4.2.1 How Analog Waveforms are Obtained

Analog waveshapes are obtained by converting the digital amplitude samples Y to analog voltages. This is performed by a digital-to-analog converter (DAC). See Figure 4-2.

The conversion rate is the programmed sample (SCLK), which is derived from the sample clock generator. The range is 0.1 Hz - 20 MHz, with a resolution of 4 1/2 digits and and accuracy of +/- 50 ppm.

The following formula illustrates how the output frequency is calculated:

output frequency f = sample clock frequency (SCLK) / total number of waveform samples

For a given output frequency *f*, it is best to use the maximum possible sample clock rate in order to obtain high phase resolution and high spectral performance of the output wave.

The user defines a waveform using standard functions or custom profile data files to load the waveform memory. An address generator sequentially addresses the waveform memory, whose output presents the data values to the DAC. This circuitry converts the digital data into analog voltage levels. The series of sequential voltage levels describes the output waveform whose frequency is determined by the rate of the sample clock divided by the number of samples in the waveform. Changing the sample clock speed causes the address generator to change the speed at which the date goes into the DAC, thereby changing the output frequency of the waveform.

As the digital waveform data stored in the waveform memory is clocked out of waveform memory and through the DAC, the output creates the analog representation of the signal. A low-pass filter can be switched in to remove the sampling noise.

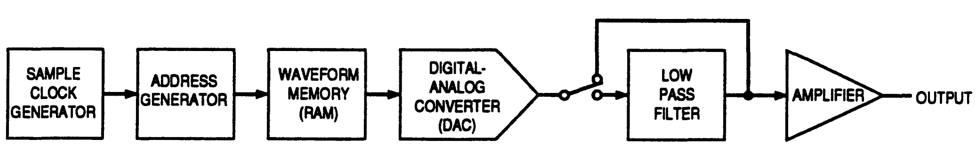


Figure 4-2. Analog Waveform Creation

In the PM 5150, amplitude and offset can be controlled in both the digital and analog domains. Digital control is accomplished by scaling the image in the waveform memory, while a front panel key allows you to set these levels directly.

4.3 MEMORY ORGANIZATION

The following paragraphs explain how the waveform memory is organized, the system of waveform numbering, and how the default memory segments can be changed.

Each time a RESET ALL is performed, the waveform memory is reinitialized. The initial configuration of the waveform memory is described in the following table.

Initial Memory Map

LOCATIONS	CONTENTS
0 - 1999	Reserved for Arbitrary Waveform #0 Preloaded with Standard Triangle Wave
2000 - 3999	Reserved for Arbitrary Waveform #1 Initially blank
4000 - 5999	Reserved for Arbitrary Waveform #2 Preloaded with Standard Pulse Waveform
6000 - 7999	Reserved for Arbitrary Waveform #3 Initially blank
8000 - 9999	Reserved for Arbitrary Waveform #4 Initially blank
10000 - 10999	Reserved for Standard Wave Preloaded with SIN wave

When the front panel ARB WAVE key is pressed, the wave is always loaded into memory locations 0 to 9999. Locations 11,000 through 32,767 are the area in which other arbitrary waves can be created. Note, though, that the standard wave area is always at the highest memory locations. So, for example, if you create an arbitrary wave in locations 11,000 through 24,000, the next time you need a standard wave, the PM 5150 will create it beginning at location 24,001.

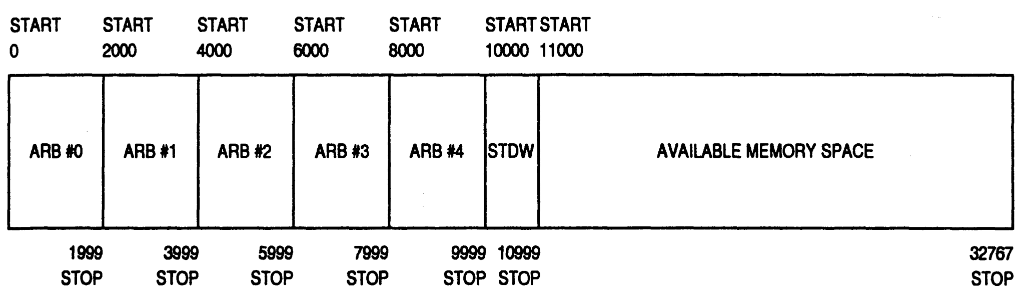


Figure 4-3. PM 5150 Memory Map

4.3.1 Default Partitioning

The total available waveform memory is 32,768 points. The memory is initially divided into partitions to provide easy programming of six different waveforms. Five blocks of 2000 points each occupy the first 10K of memory. In addition, one of 20 standard waveforms can be downloaded to 1000 points of memory from 10K on. The default standard wave is a sine wave.

4.3.2 Waveform Numbering

The first five blocks of memory are assigned ARB waveform numbers. These waveform numbers are used for accessing the individual memory blocks. They are arrayed in the memory in ascending order. Additional ARB waveform numbers can be assigned up to a maximum of 100, restricted by the total of the individual block lengths. The last block of memory is referred to as STD WAVE.

4.3.3 Changing Waveform Block Lengths

Waveform lengths in the numbered blocks default to 2000 points. This value is easily changed, from the minimum waveform length of 32 points up to the length of available memory. The following steps demonstrate how to change the length of a waveform block:

1. Press the SETUP key, and then press the ARB# softkey.
2. Select the desired Waveform number using the edit knob. The display will indicate the current settings for the start address and length of the selected ARB wave. For example, the following would display for the default sine wave:

```
02000 @00000    ARB 00
SYN1 SYN2 SYN3  LEN
```

   The numbers in the first line indicate the length and starting address of the block.

3. Press the LEN softkey. The display indicates the available free memory. For the default setting, for example, the display would show:

```
free=21736 L=2000
           OK   CANC
```

4. Use the edit knob or keypad to change the waveform block length. If you attempt to exceed the available memory, the PM 5150 sets the length to the maximum available.
5. Press OK to enter the change, or CANC to cancel it. The PM 5150 returns you to the previous menu level.

To change the length of the standard wave, first press the SETUP key, then the STDW softkey. Proceed as in steps 3, 4, and 5.

4.3.4 Deleting Waveforms

A waveform that is no longer needed can be deleted from memory as follows:

1. Press the SETUP key, then the ARB number softkey (ARB#).
2. Use the edit knob to select the number of the waveform to delete.
3. Press the Delete softkey (DEL).
4. Press OK to delete or CANC to cancel.

Note that the standarad wave (STDW) cannot be deleted.

4.3.5 Creating a New Waveform Number

Unused Waveform Numbers can be activated as follows:

1. Press the SETUP key, then the ARB# softkey.
2. Press the NEW softkey.
3. Turn the edit knob. The display shows all unused Waveform Numbers. Select the desired number.
4. When the PM 5150 returns you to the ARB# display, press the Length softkey (LEN) if you wish to change the waveform memory length. Proceed as described in Paragraph 4.3.3 to change the length.

4.4 COMMAND CHAINING AND THE LAST KEY

Mastery of the operation of the PM 5150 Arbitrary Waveform Generator requires some understanding of the design of the user interface software that monitors front panel activity and its behavior in response to keypad input.

Each time a front panel key is pressed, the event is stored even if the ENTER key does not complete the selection. This is similar to the operation of the remote interface which permits chained Program Message Units to be terminated with a single EXEC command.

In most cases, keystroke memory is helpful because it provides the mechanism whereby the LAST key recalls previously selected modes and functions. However, the actions of this memory can sometimes result in unintended selections being made. For example, consider the following sequence of keypad and softkey selections:

- MODE key
- TRIG softkey
- STD WAVE key
- SIN softkey
- ENTER

The MODE-TRIG selection became a pending command, so it is also executed when you press the ENTER key. This may not be the intended selection.

The philosophy behind this "command chaining" is based on the idea that all user input is important and will be used at some time. By keeping this concept in mind as you use the PM 5150, you can minimize such surprises. In the above example, the unintended side-effect would have been avoided by not selecting TRIG after MODE, but instead going immediately to the next intended selection, STD WAVE.

The LAST key can help you determine whether you have made an unintended selection, because you can use it to step backward through the displays you have accessed. In this case, the LAST key would step you backward through your selections. When you reached the MODE display, the word MODE would be preceded by an asterisk indicating it is a pending command, and the TRIG selection would be shown in upper case letters, indicating the new Trigger Mode that will take effect when you next press ENTER. If this is not the action you had intended, you could reselect the desired mode, and then press ENTER.

5 CREATING AND EDITING ARBITRARY WAVEFORMS

5.1 INTRODUCTION

This section explains how to create arbitrary, non-standard waveshapes. These custom waveforms can be created using a variety of techniques as follows:

- By building up a waveform a segment at a time using line or vertex edit modes.
- By performing mathematical operations on waveforms.
- By downloading files from a computer or digital storage oscilloscope.
- By constructing waveform sequences out of parts of other waveforms, either standard or arbitrary.

Each step in the waveform construction can be viewed on an oscilloscope connected to the instrument output. See Section 2 if you need details on how to connect the PM 5150 to an oscilloscope. The optional mouse is recommended for line and vertex editing, although it is possible to construct waveforms without it. Arbitrary and standard waveforms can be interspersed. More complex waveforms can be created by adding, subtracting, and multiplying any two standard or arbitrary waveforms that have been previously stored in memory. It is also possible to download waveforms from a computer using the RS-232-C or IEEE-448 interface. In addition, two methods are provided to download previously captured waveforms from a digital storage oscilloscope using the RS-232 or IEEE-488 interface.

NOTE

To be sure that you allow enough memory space for the arbitrary waveform, define the Waveform Number block length before creating an arbitrary waveshape. See Section 4 for more information.

5.2 LINE MODE

The line editing mode is best suited to creating waveforms a segment at a time from a left-hand start or anchor point. A line is drawn from the start point or anchor to some other point to the right. That point is called the *vertex* (VRTX), and becomes a new anchor. The process is repeated until the new arbitrary waveform is completed.

The line mode process is illustrated in Figure 5-1.

All or any portion of a selected waveform block can be edited. Editing begins either at a start point or left anchor. A start point can be placed at any X and Y position within the selected waveform block. Alternatively, a left anchor can be positioned at any X address, but the Y value follows that of any previously programmed waveform or baseline.

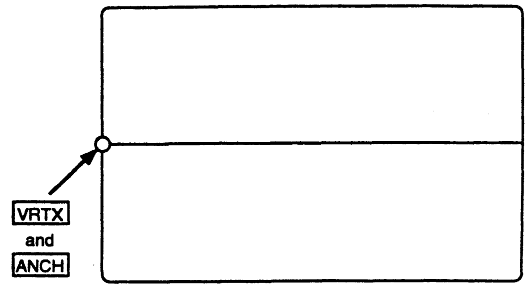
5.2.1 Editing from a Start Point

1. Press the ARB WAVE key.
2. Press the EDIT and LINE softkeys.
3. Select a waveform number using the edit knob or keypad. Press ENTER after using the keypad.
4. Arbitrary waveform construction can begin at any point within the selected waveform number block. Press the STRT softkey.
5. Use the edit knob or keypad to select X and Y positions to start waveform editing within the selected block. Use the SELECT keys to move each active parameter to the right side of the display. (Remember to press ENTER if using the keypad.)
6. Press OK to store the start point or CANC to cancel.
7. Press the ANCH softkey.
8. Use the SELECT keys to move the Right Anchor (AR) to the right side of the display. Use the edit knob or keypad to select X address for the end of the edited portion of the waveform.
9. Press OK to store the right anchor or CANC to cancel.

LINE MODE

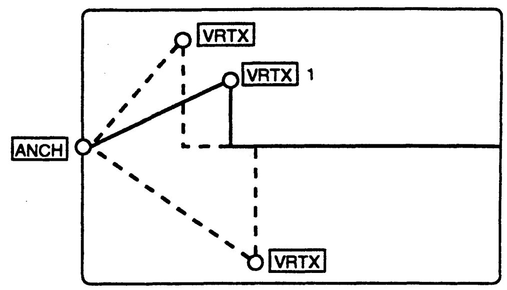
1. Select LINE mode.

   View startup screen on scope.



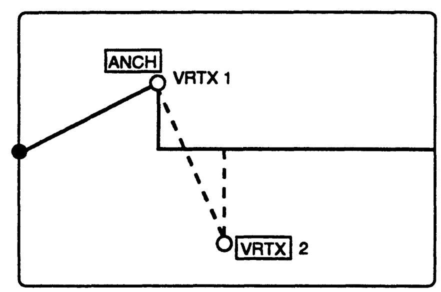
2. Move VRTX (Vertex) with mouse.

   Monitor VRTX coordinate (X, Y) on PM 5150 front panel. Press LEFT mouse button to anchor VRTX 1.



3. Anchor the vertex and create a new line.

   The anchor automatically moves to a new location and is ready to start a new vertex.



4. Continue this process until the desired waveform is created.

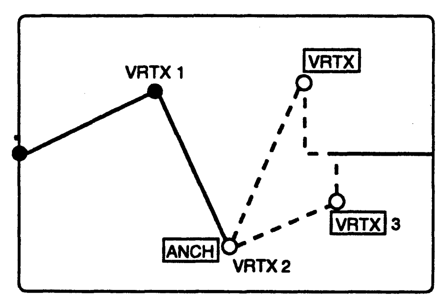


Figure 5-1. Line Mode Editing

5.2.2 Editing from the Left Anchor

1. Press the ARB WAVE key.
2. Press the EDIT softkey, then press the LINE softkey.
3. Select a Waveform Number using edit knob or keypad (press ENTER after using the keypad).
4. Arbitrary waveform construction can begin at any X address within the selected waveform number block. Press the ANCH softkey.
5. Use the SELECT keys to move Left Anchor (AL) to the right side of display. Use the edit knob or keypad to select X address. (Remember to press ENTER if you use the keypad.)
6. Use the SELECT keys to move the Right Anchor (AR) to the right side of the LCD. Use the edit knob or keypad to select an X address for the end of the edited portion of the waveform.
7. Press OK to store the anchors or CANC to cancel.

NOTE

Anchors and vertices appear on the oscilloscope screen as intensified points on the edited output waveform. Connect a BNC/BNC cable between the Z-OUT connector on the PM 5150 rear panel and the Z-AXIS input connector of the oscilloscope. Adjust the oscilloscope intensity for good cursor definition. If necessary, adjust the level by pressing ARB WAVE, then the ZLEVEL softkey (ZLVL). Adjust the cursor intensity by increasing or decreasing the number displayed.

5.2.3 Creating Line Segments

Refer to Figure 5-2 for the following discussion.

1. Set a start point and anchors as described previously.
2. Press the chord softkey (CHRD).
3. Use the edit knob, keypad, or optional mouse to select X and Y addresses for the destination (vertex, VRTX) of the first line segment (chord). If the mouse is used, LCD readouts continually indicate the changing mouse position.
4. When the desired position is reached, press the OK softkey or the left mouse button. This stores the line segment. Press CANC or the right mouse button to cancel segment editing.
5. Create the next line segment by again using the knob, keypad or optional mouse to set the next X-Y coordinate, as before.
6. Continue adding line segments up to the limit previously established for the right anchor point.

5.2.4 Waveshape Tracing

The optional mouse simplifies line mode editing, because the waveform can be viewed on the oscilloscope as it is being drawn. If the waveshape is readily available in hardcopy form, it can be drawn onto the Oscilloscope Overlay Grid (in the front pocket of this manual), and placed in front of the oscilloscope display. The mouse permits you to trace the drawn lines. Use a grease pencil or other non-permanent marker to draw on the overlay grid so that it can be erased and reused.

A similar method can be used if the desired signal already exists as a stored trace in a Digital Storage Oscilloscope. Display the waveshape on one channel while monitoring the PM 5150 output on a second channel. Again use the mouse to trace over the displayed waveform. If desired, the waveform can be smoothed as described further on in this section. See the discussion on smoothing under Vertex Mode.

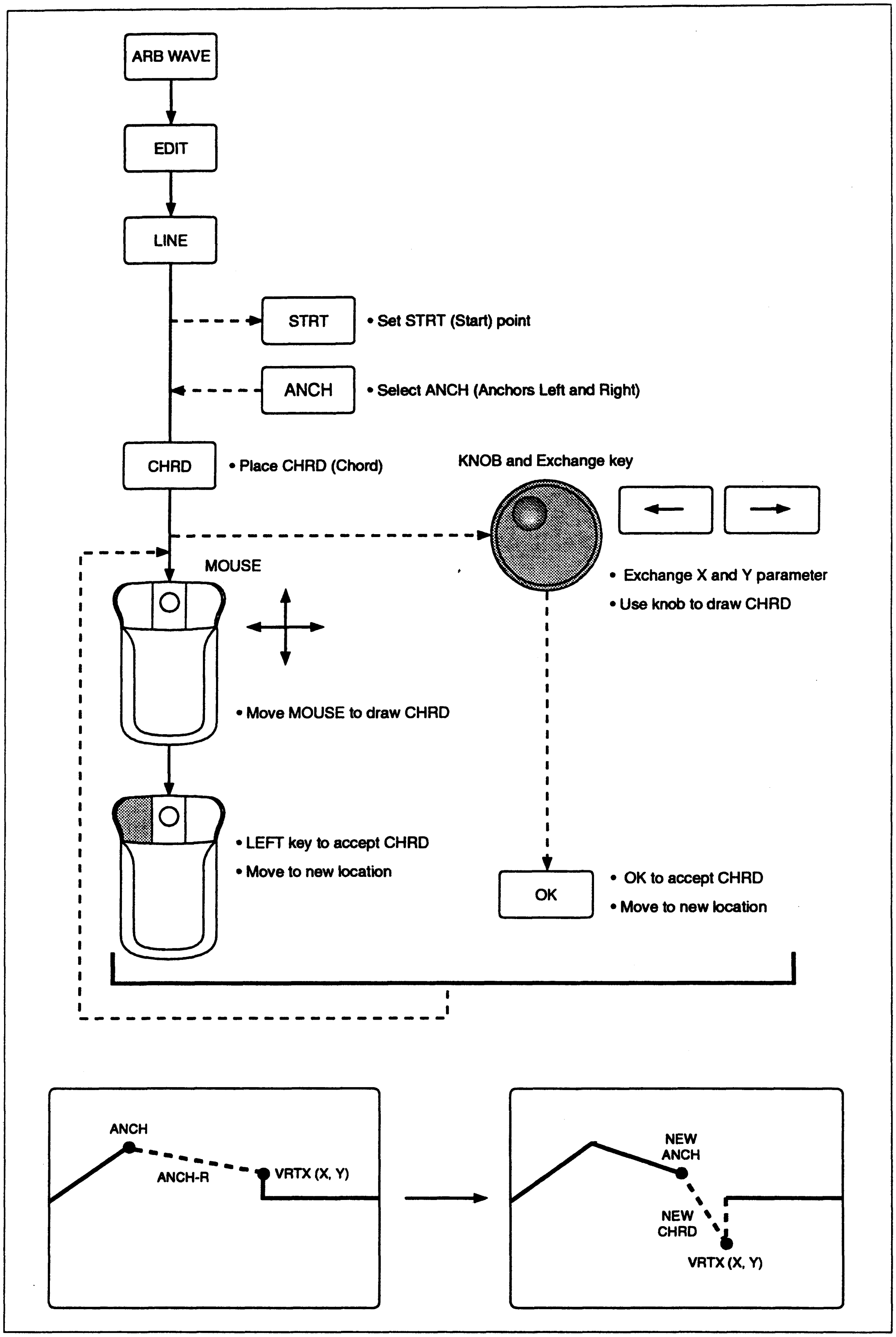


Figure 5-2. Creating Line Segments

5.2.5 Waveform Design Worksheet

An accurate but more time-intensive method of creating waveforms involves plotting the waveform onto graph paper, then transferring the X and Y coordinates to the PM 5150. For this purpose, a Waveform Design Worksheet suitable for duplication has been provided as an appendix to this manual. You can make an enlargement photocopy (scale factor 1:1.25) to produce a grid scaled in millimeters, making it possible to measure values directly.

5.3 VERTEX MODE

The vertex editing mode creates waveforms by establishing two anchor points at selected addresses, positioning a vertex in the active region between the two anchors, and then connecting the vertex to the anchors with two line segments. The vertex mode also makes available waveform scaling, smoothing, duplication, and the insertion, addition and "dumping" of standard functions.

Vertex editing is illustrated in Figures 5-3 and 5-4.

5.3.1 Setting the Z-Level

All vertex mode editing is made simpler by first setting the contrast of the anchor points that define the active region. When you first select ARB WAVE, note that one of the submenu selections is ZLVL.

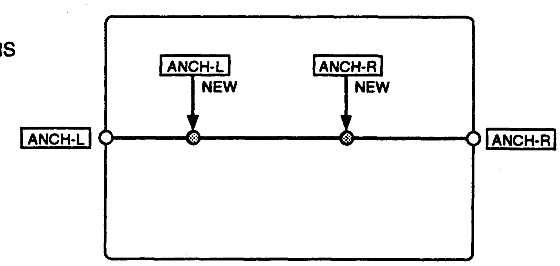
Z-Axis is the output from the rear panel Z-OUT connector. It provides a variable level pulse that occurs at times coincident with the trace between cursor and anchor positions when in the waveform edit modes.

When Z-OUT is connected to the Z-Axis input of the monitor oscilloscope, it provides intensity modulation of the display to show the cursor and anchor positions. The level setting depends upon the sensitivity of the oscilloscope.

VERTEX MODE

1. Select VRTX mode.

   View startup screen on scope.
   Place LEFT and RIGHT ANCHORS at desired addresses with mouse and front panel keys.



2. Active edit area is defined.

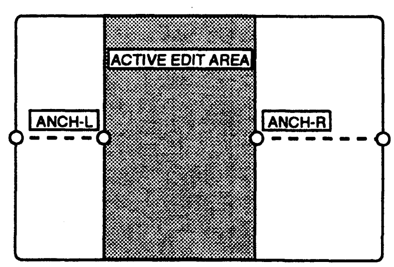


Figure 5-3. Vertex Mode Editing: The Active Area

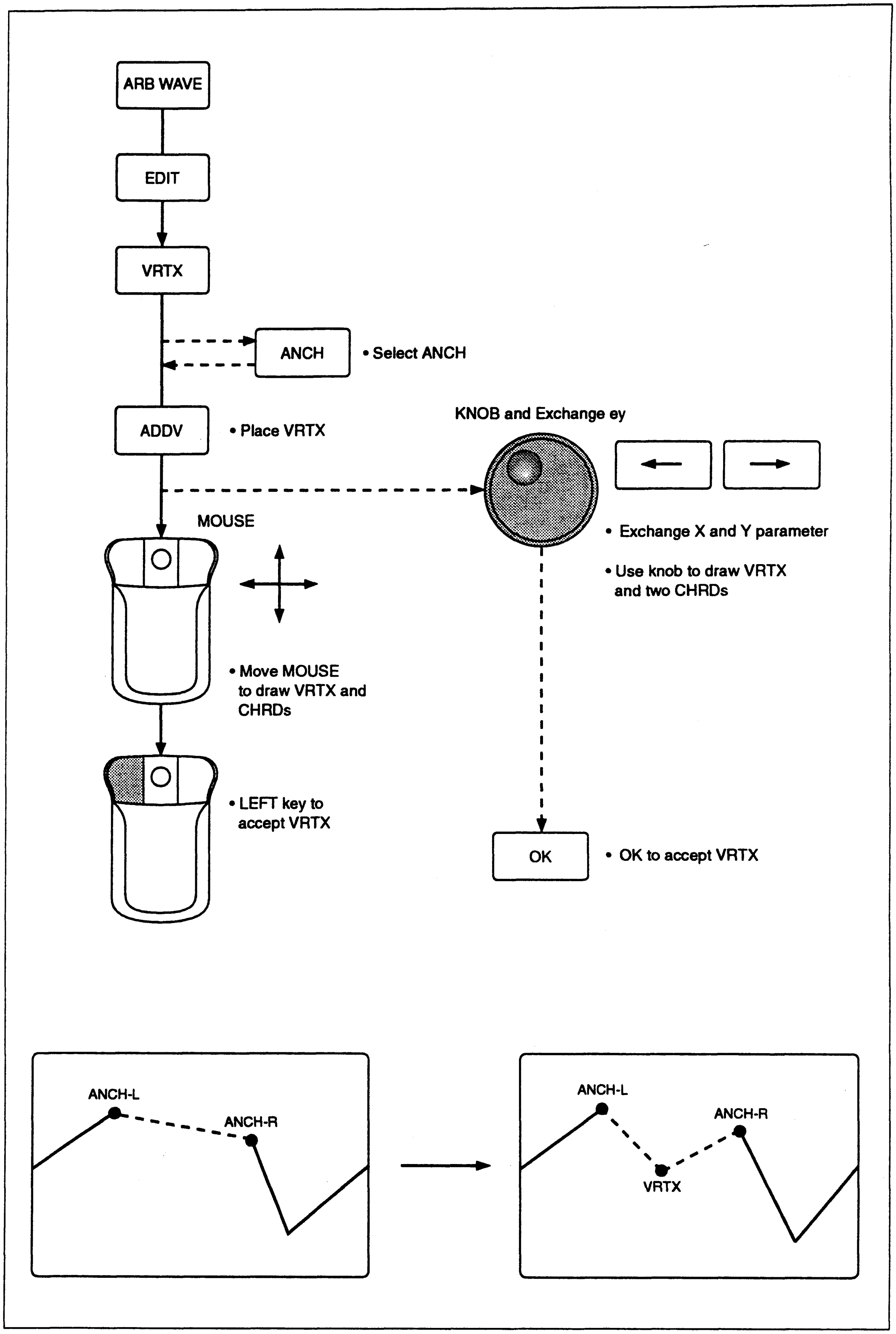


Figure 5-4. Setting Anchors in Vertex Modex

To adjust the Z-Axis level, perform the following steps:

1. Press the ARB WAVE key.

2. Press the ZLVL softkey.

3. Use the edit knob or keypad to set trace intensity in desired contrast with the cursor and anchor intensity. For best results, adjust the scope trace intensity at the same time.

In setting the Z-level, it is sometimes helpful to first define preliminary anchor points, then press the LAST softkey to return to the ZLVL selection. The range for ZLVL is between 0 and 3000, with 1500 as the default. This number represents the relative brightness of the trace Z-Axis.

5.3.2 Selecting Left and Right Anchor Points

Anchors define the active editing area of the waveform. Once they are set, all vertex mode editing takes place only on the portion of the waveform between the anchors. The default locations for the anchors are LEFT = 0, and RIGHT = 1999; in other words, the entire default length of the waveform.

1. Enter vertex edit mode by first pressing ARB WAVE, selecting an ARB number to work with, then pressing EDIT.

2. Press the ANCH softkey, and set the left anchor X value using edit knob, keypad, or optional mouse (press ENTER if using the keypad.)

3. Use the SELECT keys to move the right anchor (AR) to the right side of LCD. Set the right anchor X value using the edit knob, keypad, or optional mouse.

4. Press OK to store anchors or CANC to cancel.

NOTE

The difference between the left and right anchors is limited to 8000 points or the waveform length, whichever is less.

5.3.3 Adding a Vertex

1. Press the Add Vertex softkey (ADDV).

2. Set vertex X and Y values using the edit knob, keypad, or optional mouse.

3. When the desired position is reached, press the OK softkey or the left mouse button to store the two line segments. Press CANC or the right mouse button to cancel vertex editing.

4. Continue adding anchors and vertices until the waveform is completed.

5.3.4 Scaling

Scaling allows any portion of a waveform designated by the left and right anchors to be modified in amplitude and offset. Refer to Figure 5-5.

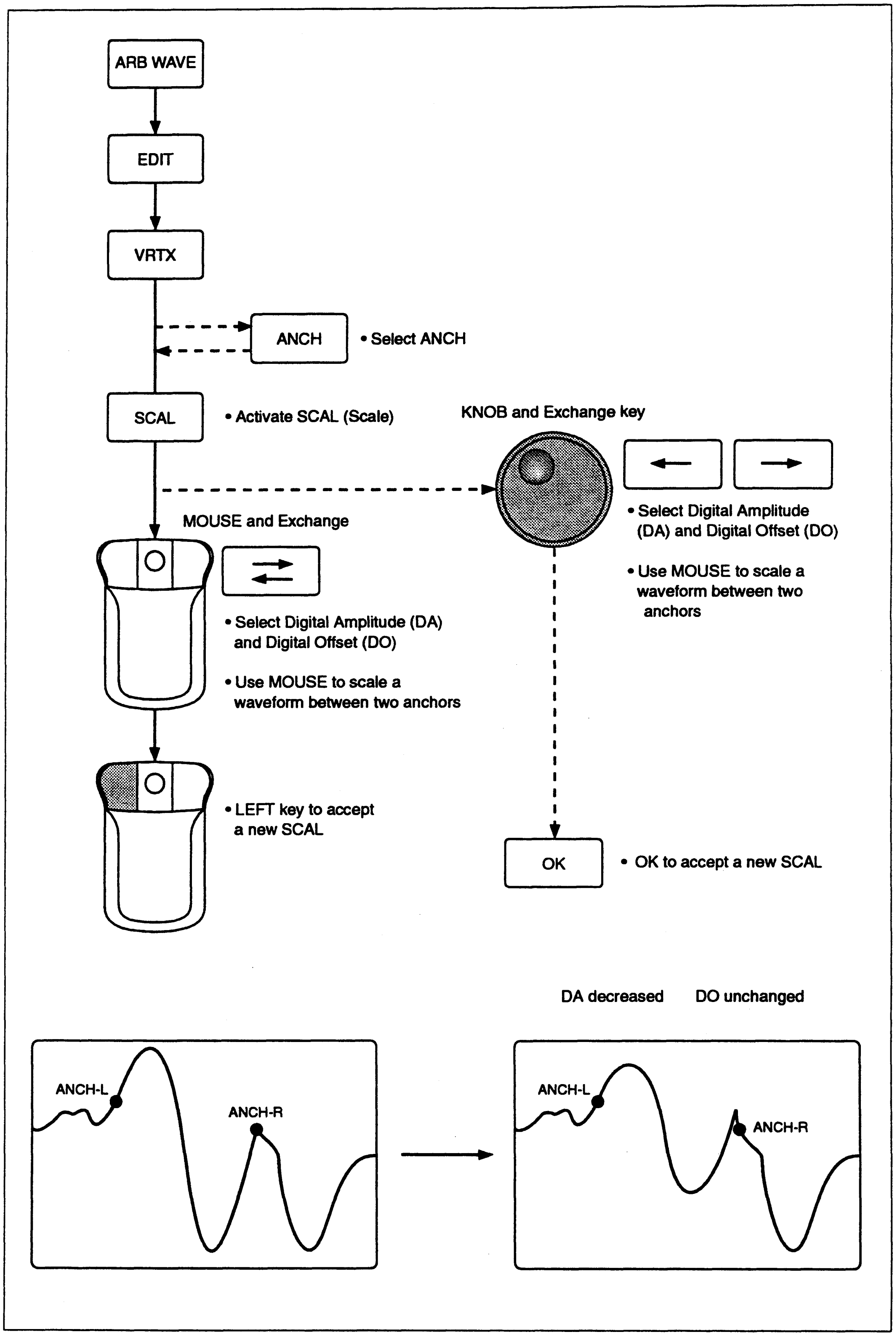


Figure 5-5. Scaling Function

To Scale a portion of a waveform, perform the following steps:

1. Select anchors.
2. Press the SCAL softkey.
3. Set digital amplitude (DA) and digital offset (DO) values for the selected portion of the waveform using the SELECT keys to select the active parameter. Observe the oscilloscope to see the changes in output.
4. Press OK to store the scaled waveform or CANC to cancel.

NOTE

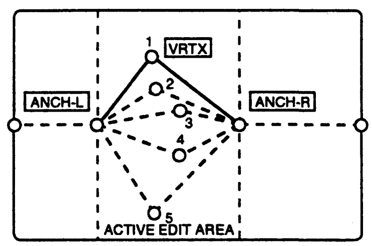
The SCAL function provides an extended digital amplitude working range of ± 8191. The default amplitude value is 4095, which corresponds to the amplitude range of the waveform memory. Setting the digital amplitude to negative values inverts the edited waveform portion. Absolute values greater than 4095 increase the amplitude. To enlarge small signals, repeat steps 2 through 4 as needed.

If the scaled portion of the waveform exceeds the 4095 points available in the waveform memory, the waveform will be clipped when you press OK to store the waveform.

Select (A) VRTX, (B) SUM or INSERT FUNCTION, or (C) SCAL.

(A) VRTX (Vertex)

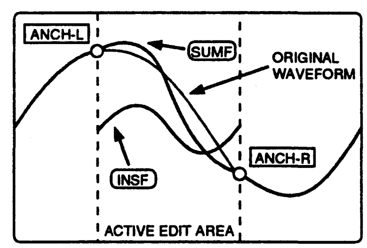
Place VRTX anywhere between the anchor points. After the placement, move two anchors to the new area.



(B) SUM or INSERT FUNCTION

SUM (Sum Function) is similar to analog sum.

INSF (Insert Function) cuts the active edit area of the waveform and pastes a new function.



(C) SCAL (Scale)

Between anchor-left and anchor-right, digitally rescale the waveform with DA (Digital Amplitude) and DO (Digital Offset).

NOTE

In this case, the waveform is clipped as a result of selecting DO and DA values that cause a portion of the waveform to exceed 10.4 volts.

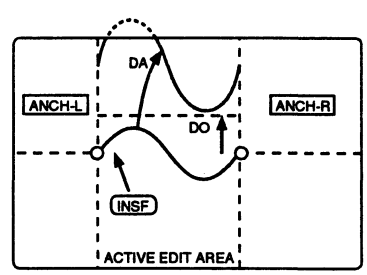


Figure 5-6. Vertex Mode Editing Functions

5.3.5 Smoothing

A smoothing factor can be applied to any part or all of a waveform. It is computed as a moving average over a specified number of samples.

1. Select anchors as previously described.
2. Press either the left or right arrow SELECT keys.
3. Press the Smoothing softkey (SMOO).
4. Select the number of samples to be averaged (up to 125) using the edit knob or keypad.
5. Press the SHOW softkey to preview.
6. Press the OK softkey to store the smoothed waveform or CANC to cancel.

5.3.6 Inserting Standard Functions

Any one of 20 standard functions can be inserted between the left and right anchors. The length is limited to 8000 points.

1. Select anchors.
2. Press the Insert Standard Function softkey (INSF).
3. Select the desired standard waveform by pressing its softkey. Use the SELECT keys to view all 20 waveshapes. You can modify the waveshape by changing any of its programmable parameters. See Table 3-3 for a complete listing of these parameters.
4. Press the SHOW softkey to preview the selection.
5. Press the OK softkey to store the selection, or CANC to cancel.

NOTE

To obtain maximum amplitude resolution, unipolar functions from the STD WAVE menu (e.g., PLS ± or SAW ±) are inserted as bipolar waves.

5.3.7 Dump Function

The Dump Function (DMPF) permits a standard waveform to be loaded into the entire length of an ARB waveform memory without specifiying left and right anchors. Thus, standard waveforms can be inserted in memories with their total available length.

1. Create or select an ARB waveform memory to work with. Adjust the memory length if desired.
2. Enter Vertex Edit mode, and press either the left or right arrow SELECT key.
3. Press the DMPF softkey.
4. Select the desired standard waveform by pressing its softkey. Use the SELECT keys to view all 20 waveshapes. You can modify the waveshape by changing any of its programmable parameters. These are listed in Table 3-3.
5. Press the EXEC softkey to store the waveform in memory and permit further changes, or press the OK softkey to store the waveform and return to the previous menu level.

CAUTION

It is not possible to preview a selection when using the Dump Function. Both the EXEC and OK softkeys will cause the new waveform to overwrite any previous waveform in the selected ARB memory.

5.3.8 Duplicate Function

The Duplicate Function (DUPL) allows a section of a waveform defined by left and right anchors to be copied and pasted into another section of the same waveform, or into another ARB waveform. See Figure 5-7.

1. Select the desired ARB waveform number.
2. Enter Vertex Edit mode and press either the left or right arrow SELECT key.
3. Press the DUPL softkey.
4. Set left and right anchors at the ends of the waveform section to be copied.
5. Press the COPY softkey. This stores the selected portion of the waveform in a buffer.
6. Press the LAST sofkey to return to the previous menu level.
7. Select the ARB waveform number that is to receive the pasted section.
8. Press the DUPL sofkey again.
9. Set left and right anchors on the destination waveform.
10. Press the PSTE (paste) softkey to paste the duplicated waveform. This retrieves the section of waveform from the buffer and stores it in the new location.

* You can omit steps 6, 7, and 8 if the copy and paste operation are performed within the same ARB waveform number.

NOTE

The pasted waveform will be truncated if the destination waveform section has fewer points than the original.

5.3.9 Summing Standard Functions

Any one of the 20 standard functions can be algebraically summed to any part or all of the wave being edited. Refer to Figure 5-8.

1. Select the first standard waveshape using the Insert Standard Function procedure just described.
2. If the second standard waveshape is to be summed to only a portion of the first standard waveshape, reposition the anchors.
3. Press either the left or right arrow SELECT keys.
4. Press the SUMF softkey.
5. Select the second standard waveshape by pressing its softkey. Use SELECT to view all 20 waveshapes. Modify the waveshape as desired by changing any of its parameters. Reduce the digital amplitude value as necessary to prevent clipping.
6. Press the SHOW softkey to preview summed waveforms, or CANC to cancel.
7. Press the OK softkey to store summed waveforms.

5.4 MATHEMATICAL OPERATIONS

Mathematical operations are the third major category of waveform editing. These operations permit the contents of any two Waveform Numbers of equal length to be algebraically added, subtracted, or multiplied. In this way, complex composite signals, such as shaped tone bursts, amplitude modulated signals, and so on, can be created.

To enter the Math Mode:

1. Press the ARB WAVE then the EDIT softkeys.
2. Press the MATH softkey.

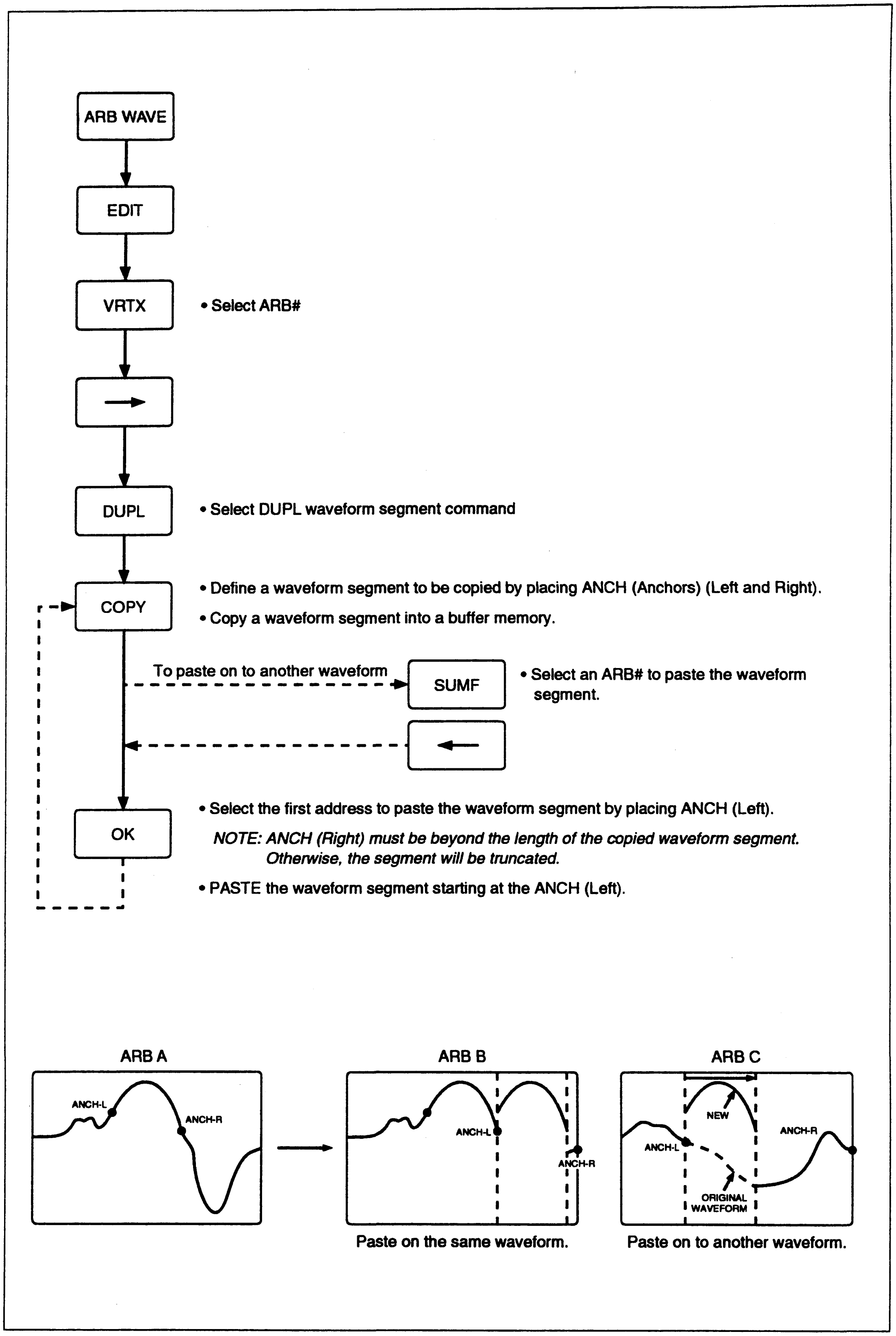


Figure 5-7. Duplicate Function

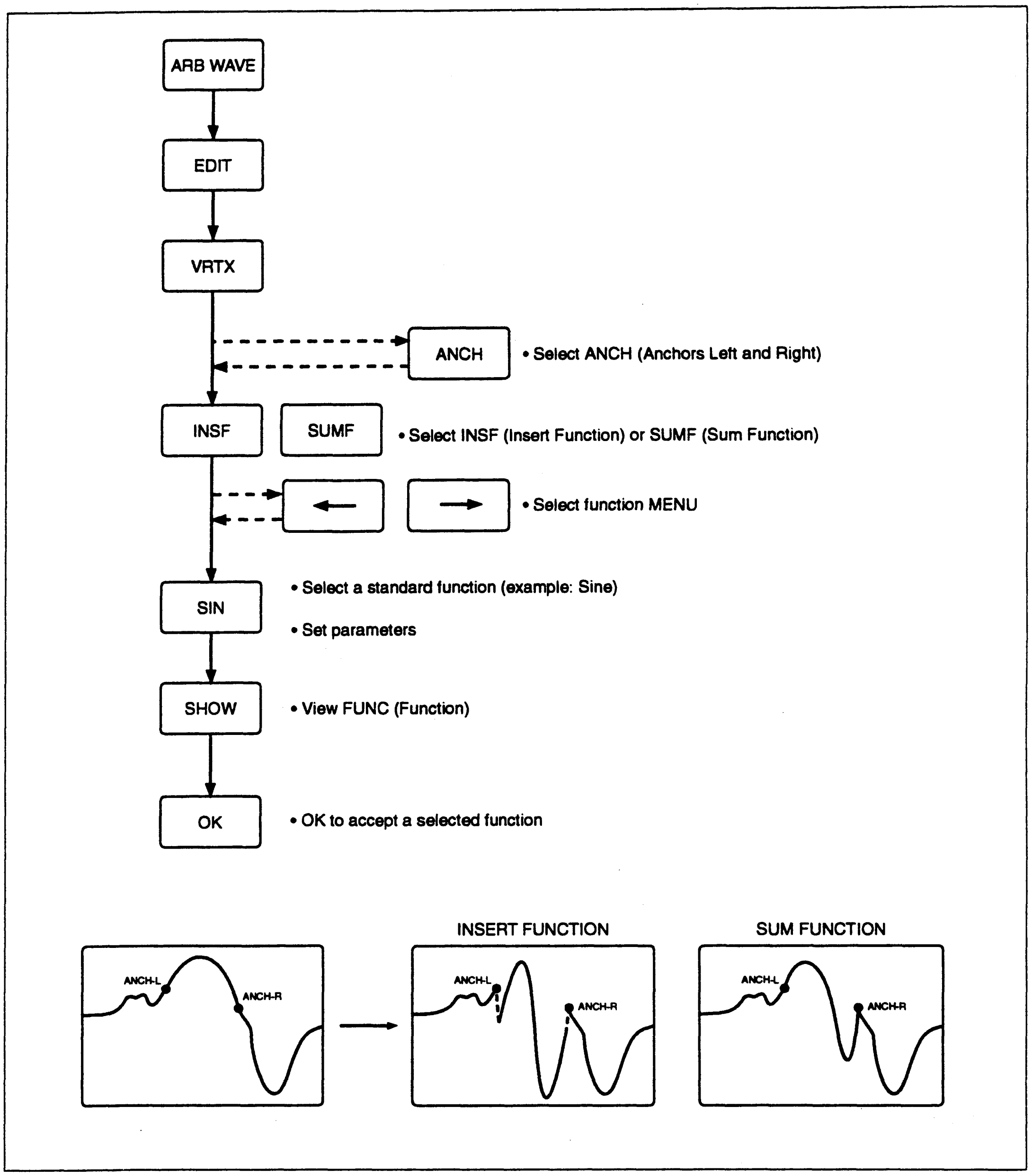


Figure 5-8. Insert and Sum Functions

The Math submenu includes its own version of the SELECT keys. The bracketed arrow on the display is the formula field selection pointer. When you press the corresponding softkey, this pointer circulates the active field among the three waveforms to be added, multiplied, or subtracted. Figure 5-9 shows an example of how the Math functions operate.

5.4.1 Selecting a Math Function

The three math functions have the following forms:

A * B	Multiply; output amplitude normalized to full-scale waveform memory.
(A + B) / 2	Add; output amplitude divided by two.
(A - B) / 2	Subtract; output amplitude divided by two.

To select one of the math functions:

1. Press the Math Operation softkey (OP).

2. The current function is displayed in capital letters. Press the softkey for the desired math function.

5.4.2 Selecting Waveform Numbers

Waveform Numbers to be combined must be selected and a destination assigned for each combined waveform. To assign a destination Waveform Number, press SETUP, then the ARB# and NEW softkeys. Turning the edit knob displays the available numbers. Complete instructions can be found in paragraph 4.3.5. under the heading "Creating a New Waveform Number".

1. Press the [◄] softkey.

2. The displayed equation has the following form:

   Destination ARB Waveform ## = ARB Waveform ## (*, +, or -) ARB Waveform ##.

3. Define each Waveform Number by moving the pointer to each location in the equation and selecting a Waveform Number with the edit knob or keypad followed by pressing ENTER.

4. Press the OK softkey after the three Waveform Numbers have been assigned. The result is visible at the output.

CAUTION

When using math functions, be sure to combine only waveform blocks of equal length. The destination waveform may be larger.

5.4.3 Examples of Waveform Mathematics

Many commonly seen waveforms can be duplicated by applying waveform mathematic operations on the standard waveforms. Following are a few examples:

Sine * Exp+	A decaying sine wave results from the multiplication of a sine wave by a unipolar exponential function.
Sine * Sine	Multiplying two equal sine waves results in a unipolar sine wave, shifted 90°, and at two times the frequency of the original (sine squared).
Sine * Square	A good approximation of a full-wave filtered AC power source can be obtained by multiplying a sine wave by a square wave of equal phase and frequency.
Sine + Noise	If the amplitude of the noise is chosen to be a small value (for example a Digital Amplitude of 300) while the sine wave is left at full-scale (4095), adding the two functions results in a noisy sine wave such as might be seen in an amplifier circuit with a noisy transistor.

5.4.4 Complex Waveforms

Waveform editing on the PM 5150 is so flexible that often the same complex waveform can be created several different ways. For example, the following steps demonstrate two different methods of constructing the same waveform.

In this example, the waveform to be created is described by the equation:

$$A(t) = \sin(\omega t) + 1/6 \sin(3\omega t)$$

The waveform lengths are assumed to be the default values of LEN = 2000. Figure 5-10 illustrates the waveforms that will be added using two different methods.

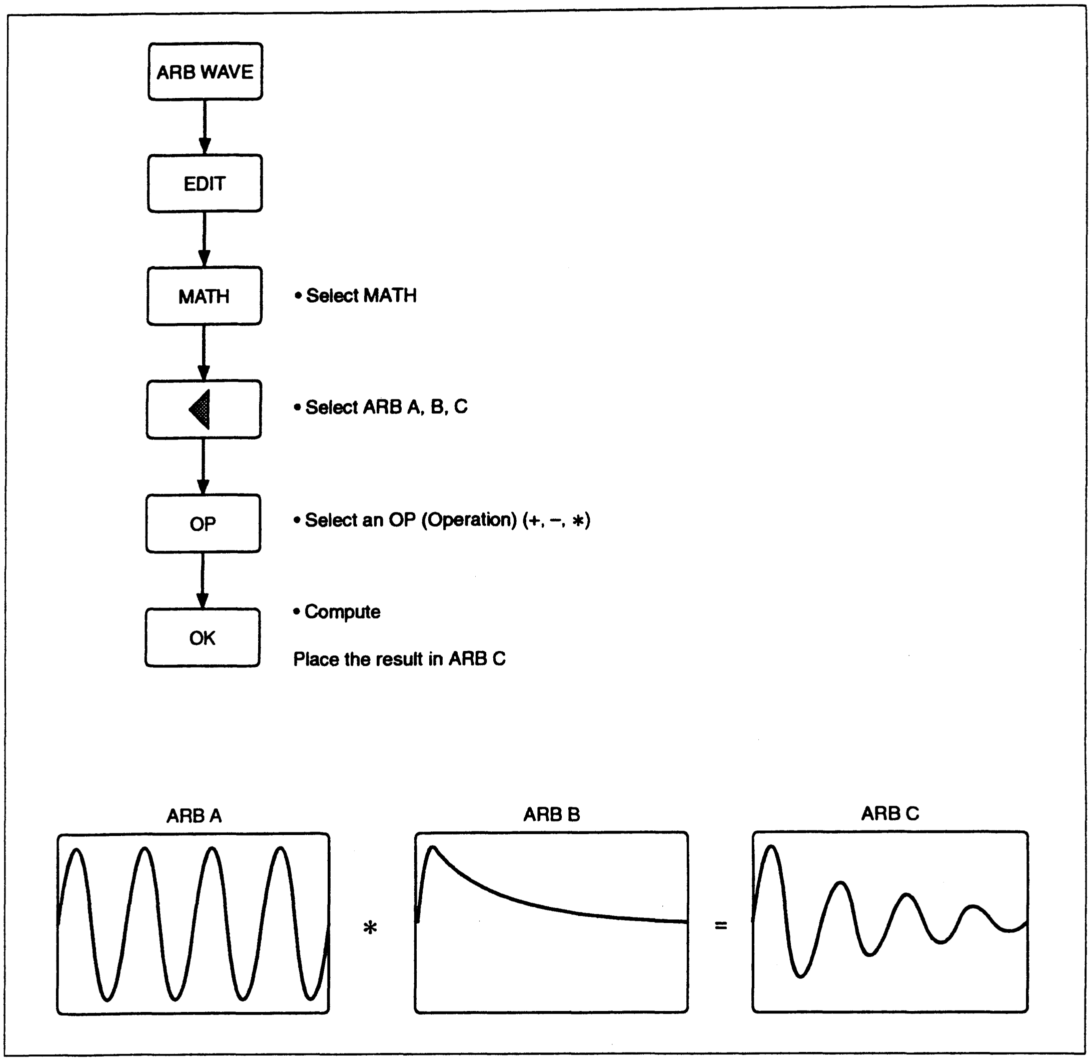


Figure 5-9. Math Function Example

5.4.4.1 METHOD 1: INSERT AND SUM FUNCTIONS

1. Use SETUP to create a new ARB number.
2. Use the EDIT-VERTEX-INSERT FUNCTION softkeys to store a sine wave into the new ARB. Give it values of N = 1 and Phase = 0.
3. Now, use the SUMF (summing function) to add another sine wave with a digital offset of 683 (1/6 of 4095, the full amplitude of the original wave.) Also select N = 3, Phase = 0.
4. Observe the resulting composite waveform at the output, as shown in Figure 5-10.

5.4.4.2 METHOD 2: MATH FUNCTION

1. Use SETUP to create three new ARB numbers.
2. Use the same INSF insert function method as before to store a full amplitude sine wave in the first ARB. Use INSF to store a 1/6 amplitude sine wave with N = 3 and Phase = 0 in the second ARB number.
3. Now use ARB WAVE-EDIT-MATH to set up an equation so that the last of the new ARB numbers will hold the sum of the first two.
4. Observe the resulting composite waveform. It should appear the same as the one created using the first method.

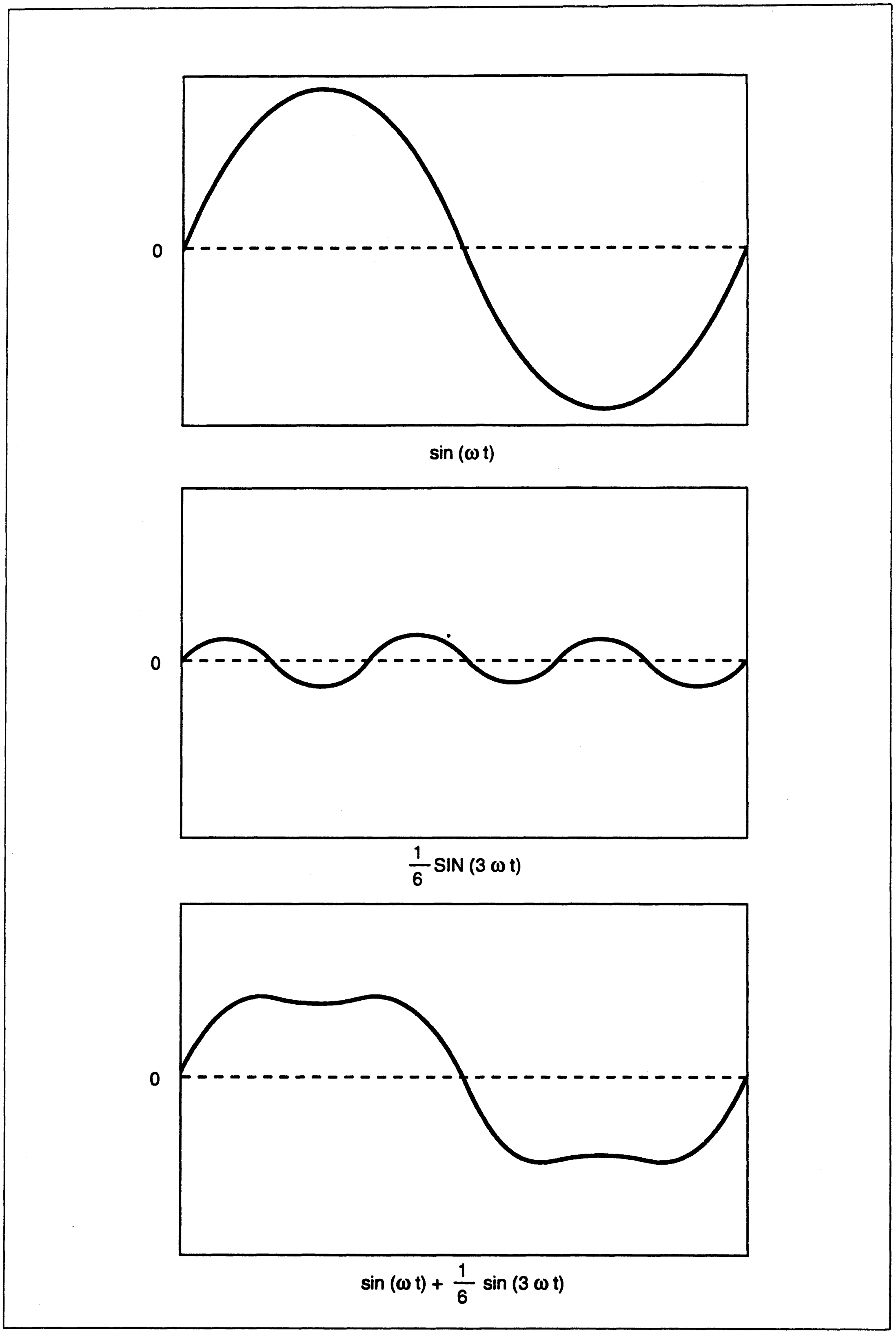


Figure 5-10. Complex Waveform

5.4.5 View Function

The View function allows all or any portion of the 32K waveform memory to be viewed at the output. The amount of memory to be viewed is selected by programming start and stop X addresses, rather than by Waveform Numbers. Thus, several consecutive waveforms occupying different Waveform Numbers can be viewed together.

1. Press the ARB WAVE key, then the VIEW softkey.
2. Press the softkey associated with the memory segment you wish to view. Select ALL to view the the entire 32,768 points in waveform memory.
3. Use the edit knob or the keypad to select the Left and Right addresses. The SELECT keys toggle the two addresses to the right of the display for editing.
4. Press the ENTER key to view the selected addresses/segments.

5.5 SEQUENCE GENERATOR OPTION

The next few paragraphs explain how to program and use the optional Sequence Generator. This information only applies if your instrument has the Sequence Generator option installed. This is easily checked by pressing the front panel SEQUENCE key. If the option is not installed, the display will so indicate.

The Sequence Generator permits different waveforms to be repeated and/or linked to each other in any order. The list of programmed instructions for each loop or link series is called a sequence. As many as 100 different sequences can be programmed, up to a total of 1000 steps. Each step calls for one Waveform Number (up to 100) and the number of times it repeats (up to 1,048,575).

Figure 5-11 shows a typical sequence of waveforms and the result when they are programmed in a sequence.

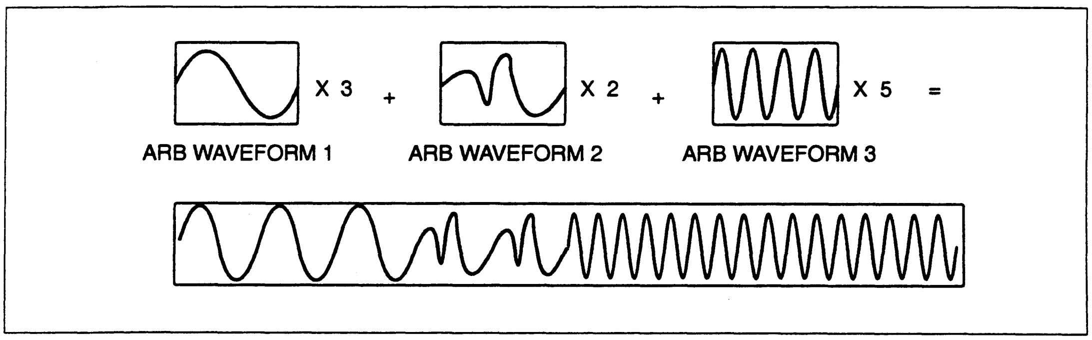


Figure 5-11. A Typical Sequence of Waveforms

5.5.1 Programming a Sequence

Before programming a sequence, be sure each desired waveform has been created and stored in a Waveform Number location.

1. Press the SEQUENCE key.
2. Press the NEW softkey.
3. Select desired new sequence file number with edit knob or keypad.
4. Press the OK softkey to enter a number or CANC to cancel.
5. Press the EDIT softkey. A message STEP=??? indicates that no steps have previously been programmed.

6. Press the ADD softkey.
7. Select the first step number with the edit knob or keypad. To allow for future changes to the program, it is a good practice to leave room between step numbers, e.g., 10, 20, 30....
8. Press the OK softkey to enter a number or CANC to cancel.
9. Select the desired Waveform Number for this step with the edit knob or keypad.
10. Press the SELECT keys to move the number of repetitions to the right side of display.
11. Use the edit knob or keypad to set the desired number of waveform repetitions.
12. Press OK to enter numbers or CANC to cancel.
13. Select the next step number and repeat steps 7 through 12 above.
14. After all steps have been programmed, view the finished results by pressing SEQUENCE and selecting the Sequence Number. Press ENTER.

Additional sequences can be programmed and stored by selecting a different sequence file number in the steps above.

5.5.2 Deleting a Sequence

Sequences that you no longer require can be deleted from memory by the following procedure:

1. Press SEQUENCE.
2. Use the edit knob or the keypad to select a sequence file number to be deleted.
3. Press the DEL softkey to mark the file.
4. Press OK to delete the file or CANC to cancel the deletion.

5.5.3 Adding a Step to an Existing Sequence

1. Press the SEQUENCE key.
2. Select the appropriate sequence file number.
3. Press the EDIT softkey.
4. Press the ADD softkey.
5. Use the edit knob or keypad to select the desired new step number.
6. Program the new step as previously described.

5.5.4 Deleting a Step from an Existing Sequence

1. Press SEQUENCE.
2. Select the appropriate sequence file number.
3. Press the EDIT softkey.
4. Use the edit knob or keypad to select the step number to be deleted.
5. Press the DEL softkey.
6. Press OK to delete the step or CANC to cancel.

5.5.5 Modifying a Step within an Existing Sequence

1. Press the SEQUENCE key.
2. Select the appropriate sequence file number.
3. Press the EDIT softkey.
4. Use the edit knob or keypad to select a step number to be modified.
5. Press the MOD softkey, then enter the desired Waveform Number for this step.
6. Press the SELECT keys to move the number of repetitions to the right side of the display, and enter the desired number of waveform repetitions.
7. Press OK to enter numbers or CANC to cancel.

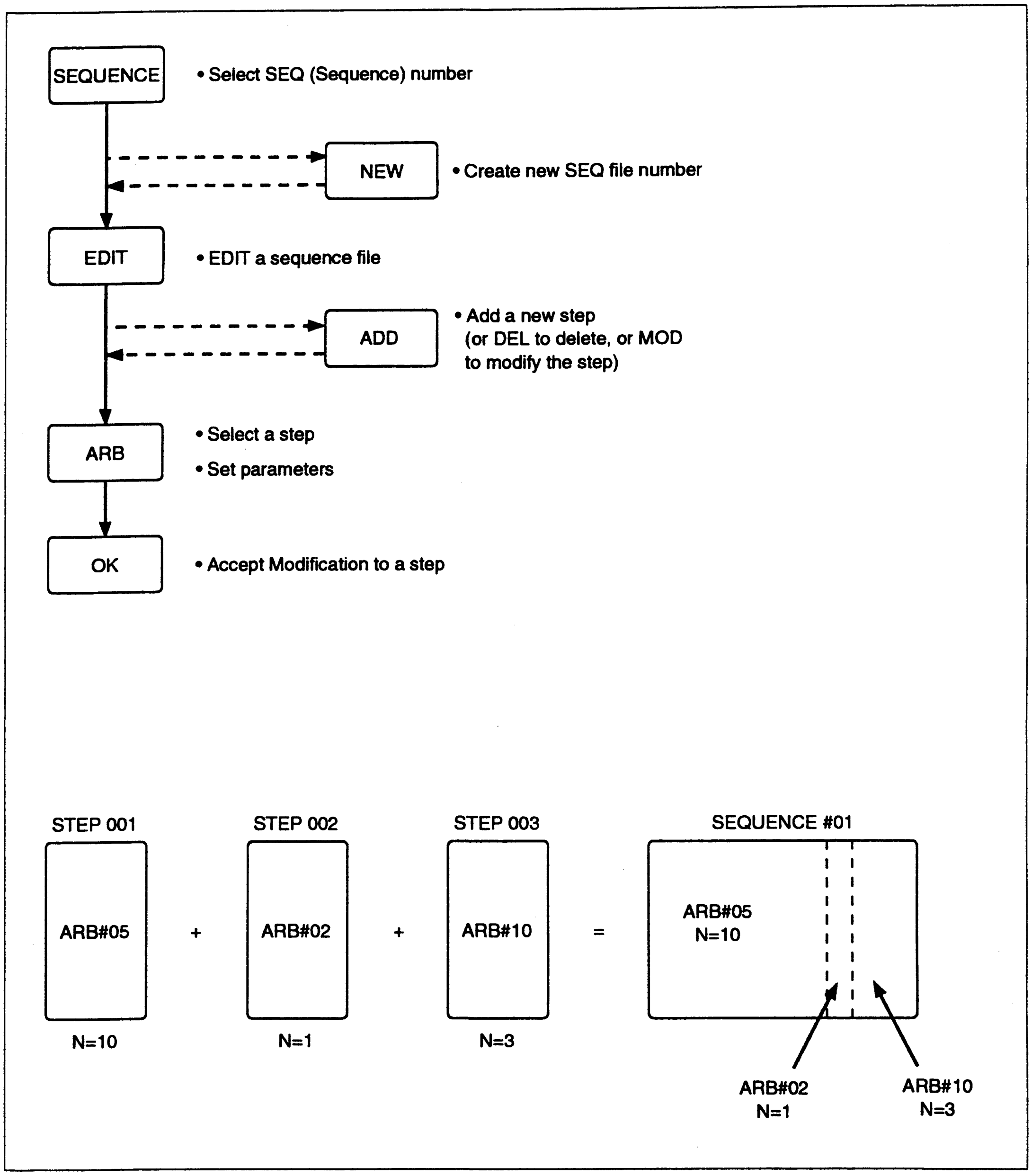


Figure 5-12. Editing a Sequence File

6 SPECIAL APPLICATIONS

6.1 INTRODUCTION

This section describes some special applications of the PM 5150. While some of these features may not be used regularly by every user, they demonstrate important features of the instrument.

Waveforms captured by a Digital Storage Oscilloscope (DSO) can be easily downloaded to the PM 5150. This capability can be particularly valuable in applications where the waveform to be replicated is difficult to obtain for some reason. For example, the output of an automobile decelerometer in a crash can be expensive to obtain! Captured once by a DSO, however, the waveform can be stored in the PM 5150 memory and recreated at no additional cost.

The PM 5150 Arbitrary Waveform Generator provides two ways to retrieve such DSO-captured signals: plotter mode and fast-transfer mode.

6.1.1 Plotter Mode

To transfer a waveform to the PM 5150 using Plotter Mode, connect the DSO (e.g., Philips PM 3350) to the Generator using either an RS-232 cable or IEEE-488 bus cable. You do not need to use any special commands or programming, because the transfer is carried out in the plotter language HPGL.

To use the RS-232 interface, set up the PM 5150 as follows:

1. Press the INTERFACE key.
2. Press the R232 softkey.
3. Now press the DSO softkey and select the ARB waveform number you wish to use for the waveform.
4. Use softkeys to program the RS-232 communication parameters. Push the LAST key each time to step back to the previous menu level.
5. Activate the interface by pressing the ENTER key.

To use the IEEE-488 interface, set up the instrument as follows:

1. Press the INTERFACE key.
2. Press the GPIB softkey.
3. Now press the DSO softkey and select the ARB waveform number you wish to use for the waveform.
4. Activate the interface by pressing the ENTER key.

When the transfer is under way, the PM 5150 resizes the selected ARB waveform memory to 4093 ... 4096 points, depending on the length of the DSO acquisition memory.

NOTE

The DSO display window doesn't necessarily show the entire amplitude range of its acquisition memory. This is done to reserve a certain amount of memory for signals that exceed expected limits. The memory is downloaded with full amplitude range, so the waveform may appear smaller when played back from the PM 5150 to the oscilloscope. If necessary, the waveform can be easily enlarged using the SCAL function. See Section 5 for more information.

Example:

The following paragraphs provide an example Plotter Mode download using a Philips PM 3350 oscilloscope with IEEE-488 interface.

Set the oscilloscope as the "Talker" in digital plot mode, and set the plotter type as PM 8153_6. The PM 5150 has already been set as the "Listener Only" when you pressed the front panel INTERFACE key, then the GPIB and +DSO softkeys and selecting an ARB number to store the waveform that is to be transferred.

At the start of plotting, (key PLOT on the scope), the generator displays the message "COMMUNICATION DSO" to indicate that the transfer is taking place. When the transfer is complete, the waveform is available just as any other ARB would be. The amplitude and frequency are adjustable within the normal limitations.

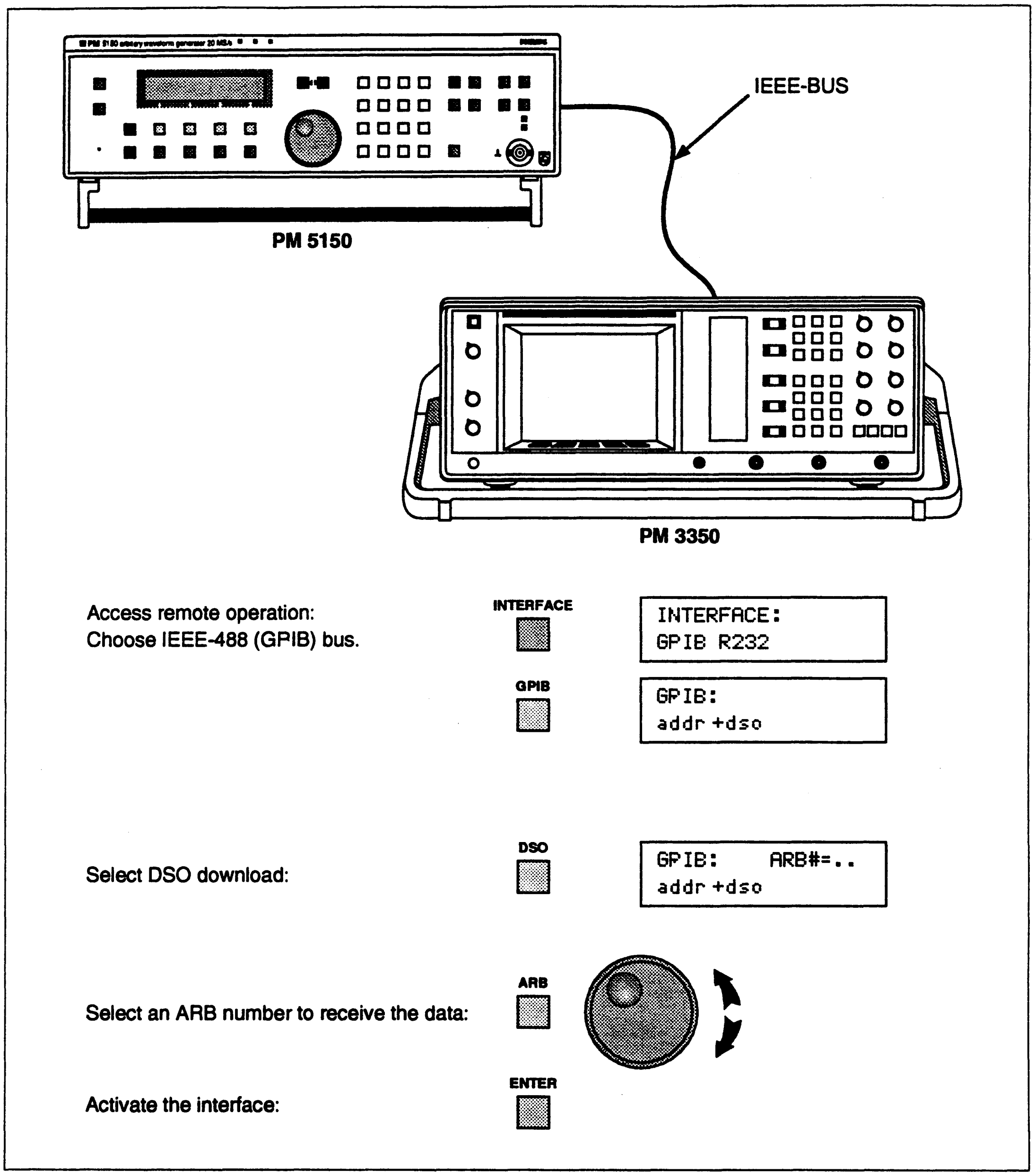


Figure 6-1. Setting up Plotter Mode Download via IEEE-488 Bus

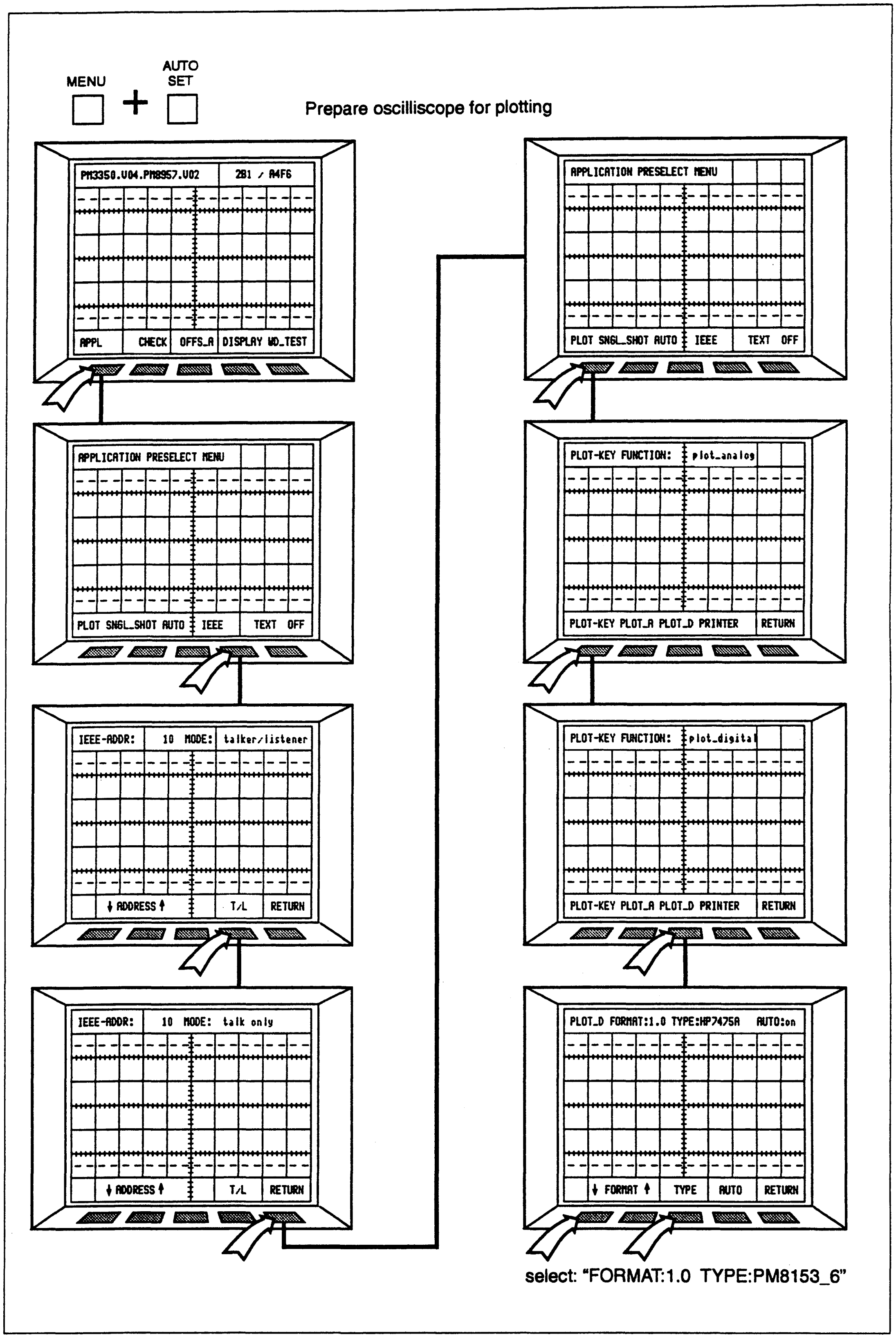


Figure 6-2. PM 3350 Selections for Plotter Mode Download

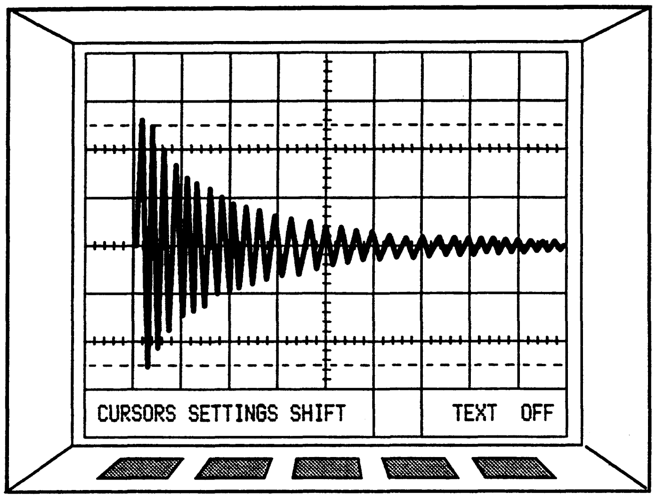
Feed signal to the Oscilloscope

AUTO
SET

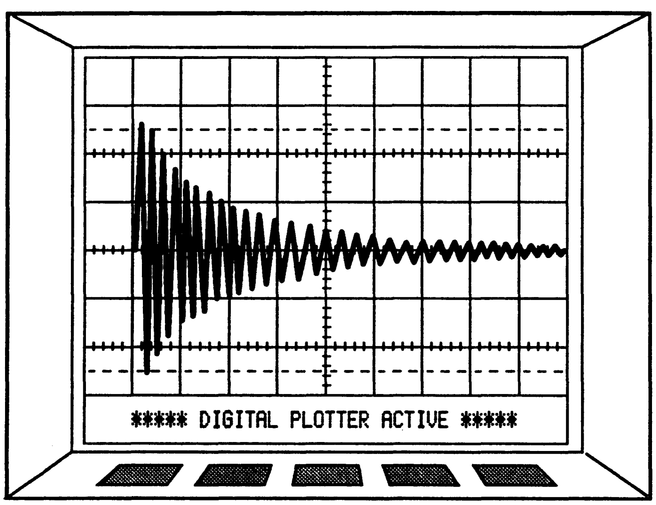
Set scope: trigger, timebase, amplitude, etc.

DIGITAL
MEMORY

LOCK



PLOT



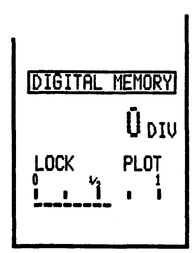


Figure 6-3. Initiating the Plotter Mode Download

The bargraph in the oscilloscope display shows the course of the plotting as data is transferred to the generator. The PM 5150 display shows "COMMUNICATION DSO" during the time the transfer is taking place. Once all the data has been transferred, the generator returns to its last display. If the ARB wave is now selected, the generator will output the signal that was transferred.

6.1.2 Fast Transfer Mode

The Fast Transfer Mode offers a quick download of waveforms captured in a DSO memory to the waveform memory of the generator. This method of transfer was specifically developed for use with arbitrary waveform generators; it works with a wide range of memory lengths and requires much less transfer time than transfering the same waveform using Plotter Mode.

Fast Transfer Mode is implemented in recent Philips DSOs using the IEEE-488 interface (Philips PM 3382, PM 3384, PM 3392 and PM 3394). The oscilloscope IEEE programming guide usually describes the Fast Transfer Mode under the heading "Trace Dump".

After establishing the IEEE connection between the PM 5150 and the DSO, set up the generator just the same as for Plotter Mode. The steps are repeated here:

1. Press the INTERFACE key.
2. Press the GPIB softkey.
3. Now press the DSO softkey, and select the ARB waveform number you wish to use for the waveform.
4. Activate the interface by pressing the ENTER key.

The number of waveform samples that will be transferred depends on the length of the DSO acquisition memory, any binary number from 512 samples up to 128K.

NOTE

The DSO display window may show only a portion of the captured waveform. However, in Fast Transfer Mode, the entire content of the acquisition memory will be downloaded.

When the transfer is under way, the PM 5150 resizes the selected ARB waveform memory to the nearest binary number. For example, if the default length (2000 points) is programmed, the PM 5150 automatically changes the length to 2024 points during the download. However, the PM 5150 does not have a full 32K available, so if this number of points (or more) is needed, the generator applies the maximum size instead.

In case the memory length does not coincide with the acquisition memory length of the DSO, the PM 5150 linearly compresses or expands the waveform to fit it into the memory.

NOTE

The DSO display window doesn't necessarily show the entire amplitude range of its acquisition memory. This is done to reserve a certain amount of memory for signals that exceed expected limits. The memory is downloaded with full amplitude range, so the waveform may appear smaller when played back from the PM 5150 to the oscilloscope. If necessary, the waveform can be easily enlarged using the SCAL function. See Section 5 for more information.

6.2 SETTING UP MULTIPLE UNITS

Multiple PM 5150's can be operated synchronously in parallel or series. Synchronous operation of multiple units eliminates triggering jitter and minimizes clock delays. For synchronous operation, the units must share the same sample clock and be programmed for a synchronous trigger interconnect. Refer to Figures 6-4 and 6-5 for diagrams of parallel and series operation.

Parallel operation is appropriate for applications requiring multiphase signals, X and Y sweeps, and so forth. Series operation is best suited to applications using complex signal sequences that require extra-long memory. For synchronization, both series and parallel operation require one unit to be designated as the master unit and the rest as slave units.

6.2.1 Sample Clock Connections

Connect the rear panel SCLK IN/OUT signal from the master unit to the SCLK IN/OUT connectors of the remaining slave units. The Master unit operates with its normal internal clock. Program the Slave unit clock inputs to be external as follows:

1. Press the UTILITY key.
2. Press the MULT softkey, then the SCLK softkey.
3. Press the EXT softkey to select external sample clock.
4. Press ENTER.

6.2.2 Reference Clock

To ensure that the internal crystal-controlled oscillators of the slave units will phase-lock to the master, all instruments must be set to the same RCLK value. For details, see the discussion under the heading Refrence Clock Adjustment further on in this section.

6.2.3 Trigger Connections

Connect the rear panel SYNC TRIG OUT signal from the master unit to the TRIG IN connectors of the slave units. Program the master unit sync trigger as follows:

1. Press the UTILITY key.
2. Press the MULT softkey, then the STRG softkey.
3. Press the PAR (parallel) or SER (serial) softkey.
4. Press ENTER.

Program the slave unit trigger inputs for synchronous operation as follows:

1. Press the UTILITY key.
2. Press the MULT softkey, then the TGIN softkey.
3. Press the SYNC softkey to select synchronous trigger input. Press ASNC to return to asynchronous mode when returning to single unit operation.

When the master unit is operated in the continuous mode, synchronize the units by pressing the TRIG key on the master unit (parallel operation only).

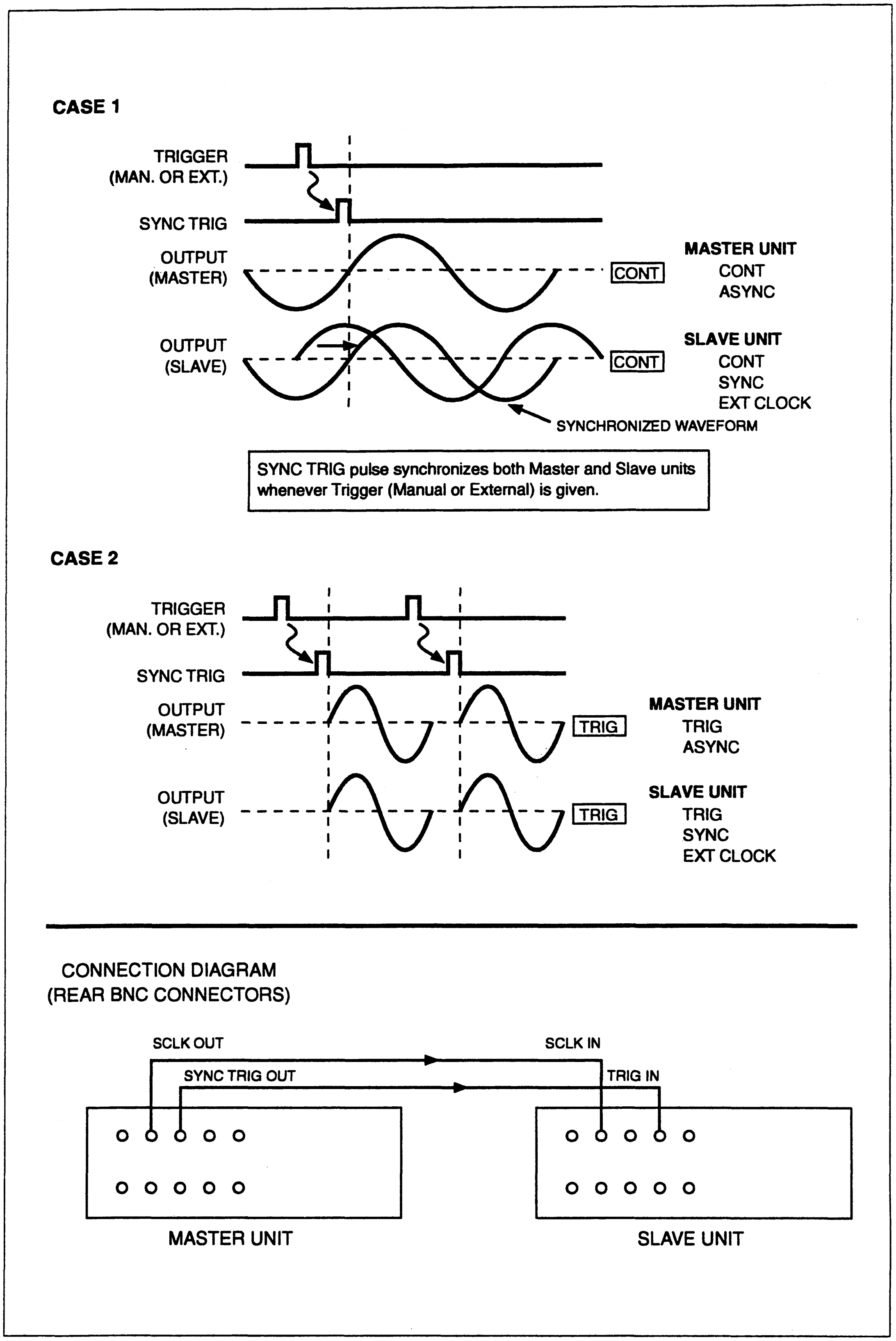


Figure 6-4. Parallel Operation of Multiple PM 5150s

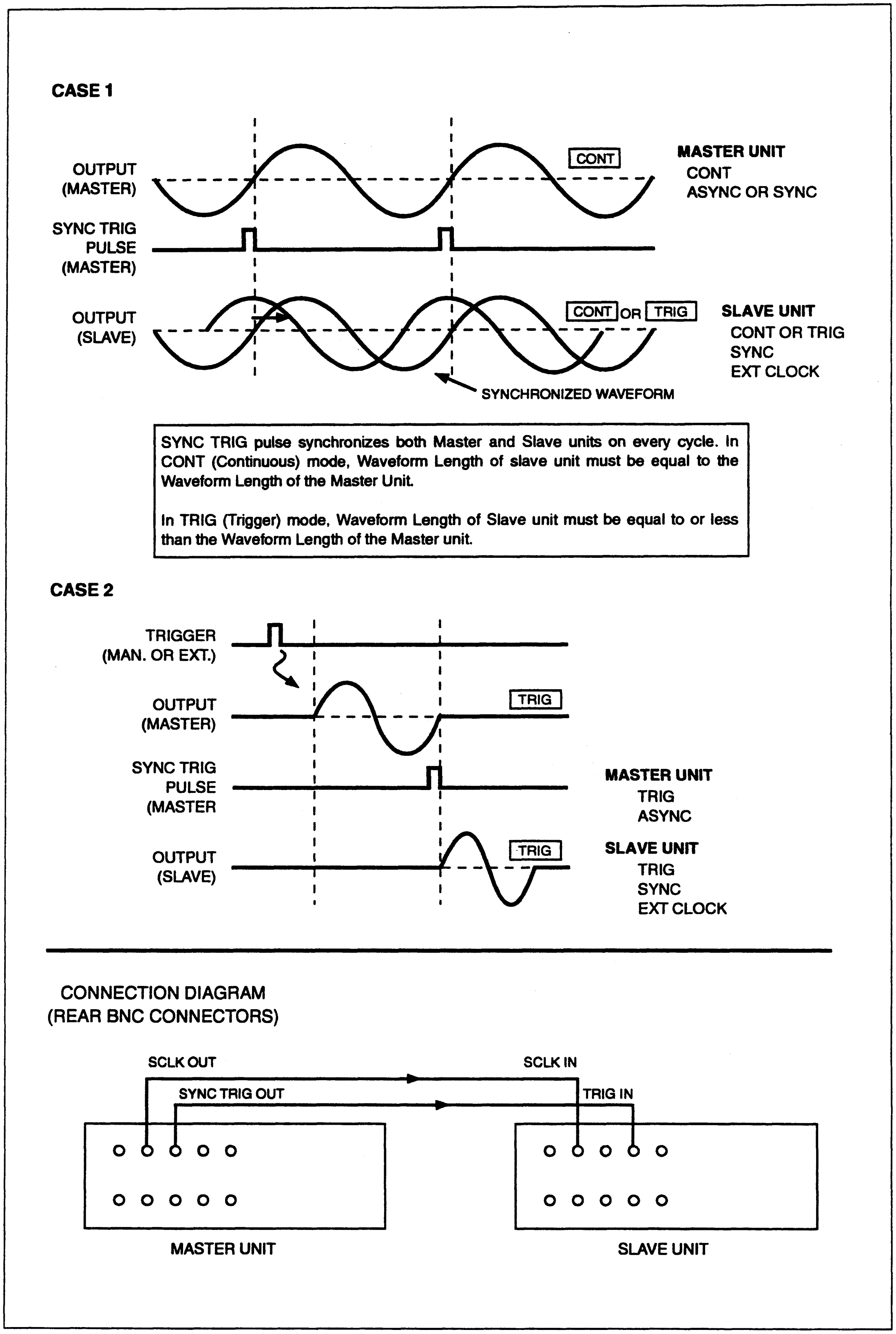


Figure 6-5. Series Operation of Multiple PM 5150s

6.3 PROGRAMMING THE SYNC OUTPUTS

The PM 5150 provides several synchronization output signals, as listed in Table 6-1.

Table 6-1. PM 5150 Synchronization Outputs

SIGNAL	FUNCTION
SYNC1 OUT	End Pulse or Programmable Address
SYNC2 OUT	Run or Programmable Address
SYNC3 OUT	End Block or Programmable Address

Each of the sync outputs has a unique default function. Instead of the default function, each can be programmed to provide a sync output pulse at any address and for any length for each waveform stored in the memory. To set up the Sync Outputs, follow these steps:

1. Press the SETUP key.
2. Select ARB or STDW to select the waveform that you will be synchronizing on. Next, press the SYN softkey to access the synchronization selections.
3. A menu displays SYN1, SYN2, and SYN3. Choose the sync you wish to use and modify it as appropriate for your application. The default sync address is 0 (zero, a relative address) and the default sync pulse length is one clock period.

NOTE

Programmable syncs may need to be reprogrammed if they are in a section of memory deleted when the length of a Waveform Number is shortened.

Addresses are independently programmable if synchronizing to an address; however if default sync is chosen for one wave, that style is used for all waves, regardless whether an address is programmed.

6.3.1 End Pulse (ENDP)

End Pulse is the normal output from the rear panel SYNC1 OUT connector. It is a high TTL level during the last clock interval of the output waveform. In continuous and triggered modes, it occurs at the end of each cycle. In gated and burst modes, it is at the end of the last cycle. With the optional sequence mode, the End Pulse occurs at the end of the sequence.

6.3.2 Run (WRUN)

Run is the normal output from the rear panel SYNC2 OUT connector. It is a high TTL level whenever an output signal is present.

6.3.3 End Block (ENDB)

End Block is the normal output from the rear panel SYNC3 OUT connector. It is used only with the optional Sequence Generator to provide a high TTL level during the last clock interval at the end of each step in the sequence.

6.4 INTERNAL TRIGGER GENERATOR

The triggered, toggled, and burst modes require a trigger. The trigger may be external, manual, or internal. Note that an external trigger source can be applied if MAN mode is selected. The internal trigger generator provides a periodic trigger at a variable rate from 0.02 to 10 seconds.

To select the internal trigger:

1. Press the MODE key.
2. Press the TRIG softkey.
3. Press the INT softkey. The display shows the current setting of the internal trigger.
4. Use the edit knob or keypad to set the desired trigger interval. Press the ENTER key if you use the keypad.

6.4.1 Return To Start

Return To Start (RTS) interrupts the output signal and returns it to the start level. Implement RTS by applying a TTL level to the rear panel RTS IN connector or by pressing the RTS key on the front panel.

6.4.2 HOLD

Hold stops the output signal and holds it at its present level as long as the HOLD signal is present. Implement HOLD by applying a TTL level to the rear panel HOLD IN connector or by pressing the HOLD key on the front panel.

6.4.3 Monitor Burst Count

In the burst mode, the output cycle count (remaining burst cycles) can be monitored at any time. This is most useful for slow, low-frequency signals. Perform the following steps to monitor the burst count:

1. Press the MODE key, then the BRST softkey.
2. Press the MBST softkey. The display indicates . . .

```
l=4711    N=10000
```

Each time the MBST softkey is pressed, the counter is updated and displays the number of burst cycles left (`l=` ...).

6.4.4 Reference Clock Adjustment

Adjusting the level of the Reference Clock is only needed if you must match the internal clock oscillator to an external 10 MHz reference. (In addition, you can vary the internal clock frequency within a small range.) Perform the following steps to adjust the reference clock level:

1. Press the UTILITY key.
2. Press the MULT softkey, then the RCLK softkey.
3. Press the ADJ sofkey. Use the edit knob or keypad to set the level to a digital value between -2048 and +2047.
4. Press ENTER.

6.5 STORING AND RECALLING INSTRUMENT SETUPS

Up to 31 different instrument setups can be stored as SET numbers 0 through 30. This capability is valuable for instantly setting the many instrument parameters that affect its output, such as triggering, Z Level, and so on.

1. To store or recall an instrument setup, first press the STORE/RECALL key and select the SET number desired.
2. A submenu displays STOR and RCLL. Press the softkey for the desired operation.
3. Press OK to Store or Recall the instrument setups, or CANC to cancel.

Table 6-2 following lists the instrument functions that are part of a stored setups as well as those that are not stored.

Table 6-2. Instrument Settings that are STORED and RECALLED

STORED	NOT STORED*
Sample Clock	LCD brightness
Sample Clock Select (INT/EXT)	GPIB address
Amplitude AC	RS-232 parameters (baud rate, parity, data and stop bits, handshaking)
DC Offset	Calibration constants
Mode	Setting numbers for stored and recalled settings
Output switch	Partitioning for ARB#00 .. ARB#99
Output filter	Sync start/length information
Sync select switch for SYNC1, 2, 3	
Function	
Edit Function	
Burst count	
Reference Clock Select (INT/EXT)	
Reference Clock Adjust	
Trigger output mode	
Trigger input mode	
Internal Trigger generator (ON/OFF)	* In general, all instrument settings are non-volatile, even if they are not stored under a particular setting number.
Internal Trigger generator repetition rate	
Smoothing value for edit	

7 PERFORMANCE TESTS

7.1 INTRODUCTION

A performance test may be used as an acceptance test when the instrument is received. If the test fails, an indication is given that repair and/or adjustment is required.

The PM 5150 must be warmed up with all covers in place for at least 20 minutes prior to starting the tests.

7.1.1 Recommended Test Equipment

Type of Equipment:	**Suggested Model:**
50Ω feed-thru termination	Philips PM 9585
AC rms voltmeter	Fluke 8840A-05
DC voltmeter	Philips PM 2535
Distortion analyzer	HP 339A
Frequency counter	Philips PM 6665
Wide-band oscilloscope (t_r < 3.5 ns)	Philips PM 3295

NOTE

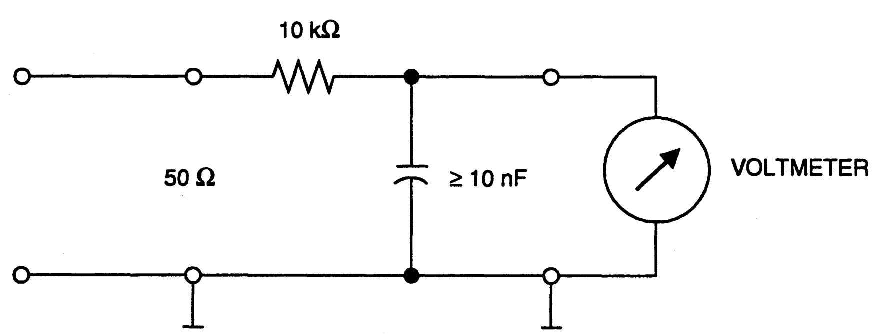
All test equipment has an output error of plus or minus a specified amount. Be sure to subtract this error from the Test Requirement tolerances listed in the following tests. Refer to the manufacturer's specifications in the opening sections of the instrument manual.

7.1.2 Performance Verification

7.1.2.1 AMPLITUDE ACCURACY AND OFFSET ERROR TEST

Test equipment: AC rms voltmeter DC voltmeter

Low-pass filter (see illustration below)



Generator settings:	WAVE:	STD WAVE, L = 1000, SIN, N = 1
	SAMPLE CLOCK:	1 MHZ
	MODE:	CONT
	OUTPUT:	ON
	FILTER:	OFF
	OFFSET:	0 V
Output socket:	Front-panel OUTPUT	
Condition:	Open-circuit output, voltmeters must have high impedance inputs	

AC Amplitude Setting	Test Result Requirements	
	ac output rms	dc output
10.00 V	3.486 V ... 3.585 V	-150 mV ... 150 mV
1.000 V	3 39.4 mV ... 367.7 mV	
100.0 mV	32.88 mV ... 37.83 mV	

7.1.2.2 THD + NOISE (SINAD)

Test Equipment:	50Ω feed-thru termination distortion analyzer	
Generator settings:	WAVE:	STD WAVE, L = 1000, SIN, N = 1
	SAMPLE CLOCK:	20 MHz
	MODE:	CONT
	OUTPUT:	ON
	FILTER:	ON
	AMPLITUDE	1 V
Condition:	Output 50Ω terminated, distortion analyzer set to 80 kHz measurement bandwidth	
Test requirement:	THD + Noise < -62 dBc	

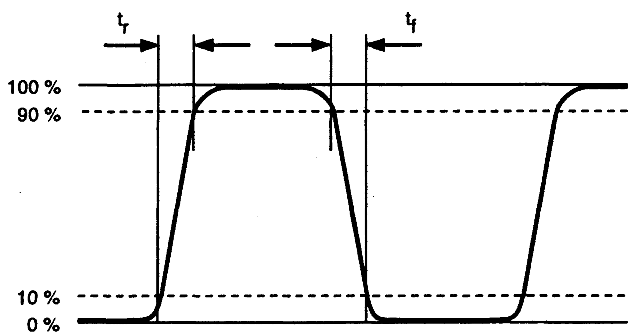
7.1.2.3 SAMPLE CLOCK FREQUENCY

Test Equipment:	Frequency counter	
Generator settings:	SAMPLE CLOCK:	20 MHz
	MODE:	CONT
Output socket:	Rear-panel SCLK	
Condition:	Open-circuit output counter set to high input impedance	
Test requirement:	SCLK: 19.99900 MHz ... 20.00100 MHz	

7.1.2.4 RISE/FALL TIME

Test Equipment:	50Ω feed-thru termination, wide-band oscilloscope	
Generator settings:	WAVE:	STD WAVE, L = 1000, SQR, N = 10
	SAMPLE CLOCK:	20 MHz
	MODE:	CONT
	OUTPUT:	ON
	FILTER:	OFF
	AMPLITUDE	20 V
Output socket:	Front-panel OUTPUT	
Synchronization:	Rear-panel SYNC 1 OUTPUT	
Condition:	Output 50Ω terminated, for oscilloscope connection see Paragraph 2.5.	
Test requirement:	t_r, t_f < 20 ns	

t_r = rise time
t_f = fall time



Rise/Fall Time Waveform

7.1.2.5 INPUT/OUTPUT SOCKETS TESTS

Test equipment:	Oscilloscope set to high input impedance 50Ω feed-thru termination
Generator settings:	
1. RESET:	RESET - ALL
2. SETUP STD WAVE:	SYNC 1, 2, 3 to ADDR mode
STD WAVE:	TRI
OUTPUT:	ON

Connect the oscilloscope directly to the rear-panel output sockets and verify that the following signals are present:

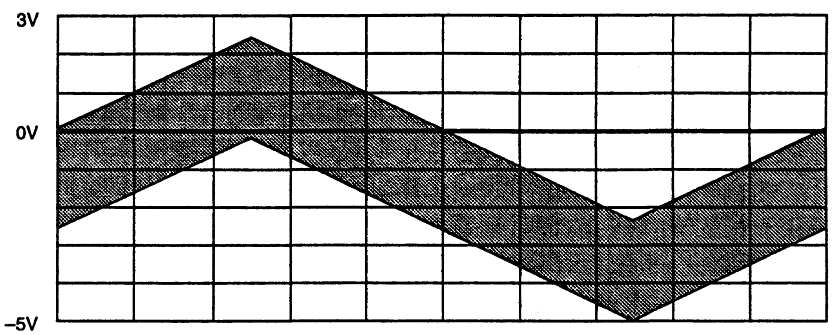
RCLK OUT:	TTL pulses with 10 MHz repetition rate
SCLK OUT:	TTL pulses with 10 MHz repetition rate
SYNC TRIG OUT:	100 ns TTL pulses with 10 MHz repetition rate
SYNC 1 OUT:	100 ns TTL pulses with 10 MHz repetition rate

Z-OUT:	instrument setting:	approximate voltage
	STD WAVE....................................	0V
	ARB WAVE, ZLVL = 1500	+3V
	ARB WAVE, ZLVL = 1000	+2V
SYNC 2 OUT:	100 ns TTL pulses with 10 MHz repetition rate	
SYNC 3 OUT:	100 ns TTL pulses with 10 MHz repetition rate	

Connect the oscilloscope to the front-panel output via the 50Ω feed-thru terminator. Use the rear-panel SYNC 1 OUTPUT to trigger the oscilloscope. The screen should display the standard triangular wave.

To check the rear-panel input sockets, perform the following connections and view the oscilloscope screen.

SUM IN: Connect SCLK output to SUM IN socket. The oscilloscope screen should change as shown in the following figure:



Rear-Panel Input Display

TRIG IN: Connect SCLK output to TRIG IN socket. Verify that the output signal changes to zero volts.

RTS IN: Connect SCLK output to RTS IN socket. Verify that the output signal changes to zero volts.

HOLD IN: Connect SCLK output to HOLD IN socket. Verify that the output signal remains at the current value.

8 REMOTE CONTROL

8.1 INTRODUCTION

The PM 5150 Arbitrary Waveform Generator can be controlled either via the RS-232-C serial port or over an IEEE-488 interface. When the optional mouse is installed, the preferred choice will probably be to use IEEE-488 communications to avoid disconnecting and reconnecting the mouse during operations.

The information in this section presupposes that you are acquainted with the operation of the instrument, its parameters, and limits.

8.2 RS-232 OPERATION

To establish a proper connection between the RS-232 serial port and a controller, optional cable set PM 9536/501 is available. The set consists of two parts: the cable itself used for hardware handshaking, and an adapter that is inserted between the cable and the generator if you are using software handshaking. Both parts of the cable set are shown schematically in Figure 8-6.

In hardware handshaking, the PM 5150 uses a DTR/CTS handshake. When CTS is not asserted (OFF), the transmitter interrupt to the processor is disabled. DTR is normally asserted (ON). When the instrument's receive buffer becomes 80% full, DTR is deasserted until the buffer empties to 20%. This handshaking requires only the use of part 1 of 2 of the RS-232 cable set (PM 9536/501).

For software handshaking, the adapter that is part 2 of the RS-232 cable set is installed on the cable. Software handshaking uses a CTRL/S at the buffer 80% full point to hold off more incoming data. When the receive buffer has emptied to 20%, the PM 5150 sends CTRL/Q to signal that more data can be sent.

8.2.1 Activating the RS-232 Interface

To activate the RS-232 interface, proceed as follows:

1. Press the INTERFACE key.
2. Press the R232 softkey, then the PC softkey.
3. Use softkeys to program RS-232 communication parameters. Push the LAST key each time to step back to the previous menu level.
4. Press ENTER to enable remote mode.

The RS-232 communication parameters are shown in the following list. The selection in bold is the default selection:

Baud Rate	**1.2K** 2.4k 9.6k 19k2
Parity	odd even **NONE**
Data and Stop Bits	7d1s 7d2s **8D1S** 8d2s (8D1S means 8 Data bits, 1 Stop bit)
Handshaking	**SW** HW
	SW means Software Handshake: X_{ON}/X_{OFF}, HW means Hardware Handshake: CTS/RTS

8.2.2 Special RS-232 Interface Functions

The PM 5150 implements three special interface functions for RS-232 operation. They are similar to addressed and unaddressed IEEE interface commands, and are described in the following table.

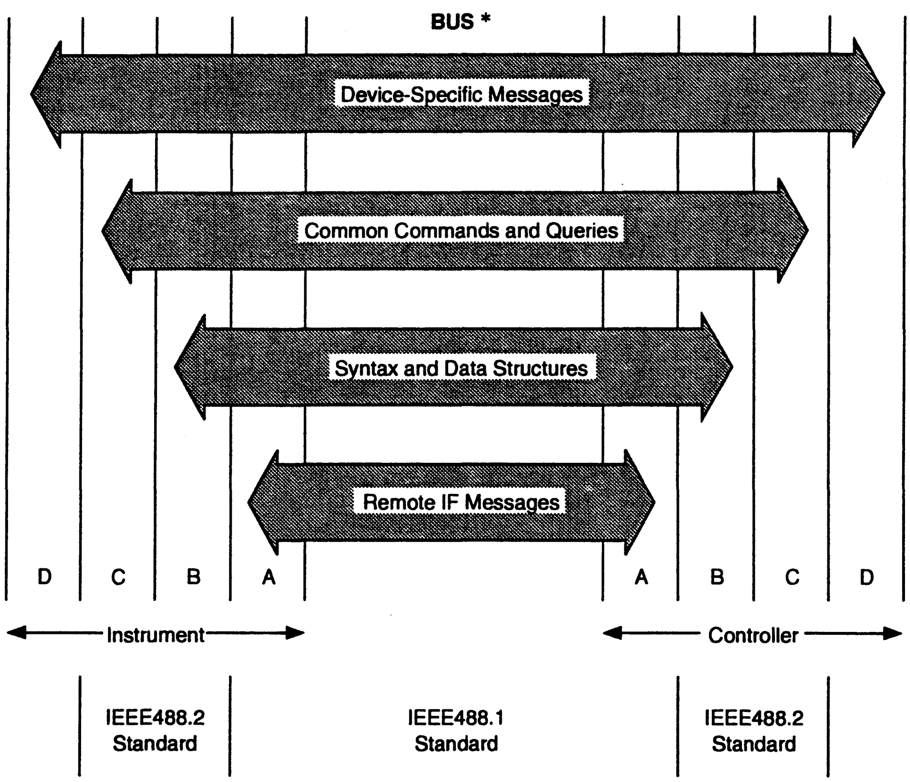
Special RS-232 Interface Functions

RS-232 Interface Command	Function	Similar to IEEE Command
ESC 1	go to local	GTL
ESC 2	go to remote control	GTR
ESC 5	local lock out	LLO

For these commands, send the ESC code, and then the required numeric code via the PC. A message generated by the instrument, can only be read-in via an RS-232-C interface by a controller when ^D has been sent.

8.3 IEEE-488 OPERATION

The PM 5150 with the IEEE-488.2 option conforms to the Institute of Electrical and Electronics Engineers (IEEE) Standard 488.2-1987. All instrument functions can be controlled via the IEEE-488 interface. Refer to Figure 8-1.



A = Device functions
B = Common system functions
C = Message communication functions
D = Interface functions

* This figure is in accordance with "IEEE Standard Codes, Formats, Protocols, and Common Commands" (ANSI.IEEE Std 488.2–1987).

Figure 8-1. IEEE-488 Bus Messages

Bus cables PM 2295/10 and PM 2295/20 are available for connecting the rear panel socket to a controller. The connector pinout is illustrated at the end of this section.

To activate the IEEE-488 interface, proceed as follows:

1. Press the INTERFACE key.
2. Press the GPIB softkey, then the ADDR softkey.
3. Use the edit knob or front panel keypad to select the device address (range 0 .. 30). The default address is 16.
4. Push ENTER to enable the address.

At power on, the instrument is in local mode, which permits input from the front panel. When addressed as listener by a controller, a message appears on the display reading:

IEEE-488:	RS-232-C:
`**   REMOTE GPIB    **` `*****  ADDR = 16  *****`	`*** REMOTE RS232 ***`

The rotary knob and all keys except LOCAL are locked and the instrument can now be operated in remote control. To return to local operation, press the front panel LOCAL key.

8.3.1 Common Commands

Commands can be divided into two major categories: common commands and device-specific commands. Device-specific commands are explained further on in this section. Common commands are defined by the IEEE-488 Standard, and among other things, are used to manage status registers and synchronization of the controller and the instrument. The following table is a list of common commands implemented in the PM 5150:

Table 8-1. IEEE-488 Functions and Subsets

Interface Function	Subset
Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T6
Listener	L4
Service Request	SR1
Remote/Local	RL1
No Parallel Poll	PP0
Device Clear	DC1
Device Trigger	DTI
No Controller function	C0
Electrical Interface	E2

Further descriptions of command formats, operation, and expected responses from queries, are described in the remainder of this section.

The following paragraphs describe the functions of the IEEE-488 interface bus, the commands and queries that are implemented in accordance with the IEEE-488.2 Standard, syntax and data formats, device specific commands, and error messages.

The specific implementation of IEEE-488 includes the functions and subsets shown in Table 8-2.

Table 8-2. PM 5150 Common Commands

Command	Description
*CLS	Clear Status
*ESE	Standard Event Status Enable
*ESE?	Standard Event Status Enable Query
*ESR?	Standard Event Status Register Query
*IDN?	Identification Query
*OPC	Operation Complete
*OPC?	Operation Complete Query
*RST	Reset
*SRE	Service Request Enable
*SRE?	Service Request Enable Query
*STB?	Status Byte Query
*TRG	Trigger Command
*TST?	Self-Test Query
*WAI	Wait-to-Continue
*OPT?	System Option Query

Hardware, connections and handshake procedure are in accordance with IEEE-488.1.

For a more detailed discussion of these topics, you may obtain a copy of IEEE Standard 488.2-1987 from:

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017

In addition, both Philips and Fluke publish brochures that summarize the IEEE-488 Standard. Ask your local representative for a copy of Philips' *General Purpose Interface Bus IEC 625-1 IEEE-488.1*; order Philips number 4822 872 80148, or Fluke Application Bulletin 36.

8.3.2 Service Request

Service Request is generated if one or more bits of the Status Byte Register are set to 1 and if the corresponding bits are enabled by the Service Request Enable Register. The controller asks for the contents of the Status Byte Register in Serial Poll Mode.

To use Service Request, those bits of the Standard Event Status Register must have been enabled by *ESE, and bit 5 of the Status Byte Register must have been enabled by *SRE.

⟨NRf⟩ represents a decimal value whose binary pattern sets the corresponding bits of the Enable Register to 1. In this way, the assigned bits of the Standard Event Status Register respective of the bits of the Status Byte Register are enabled.

All bits of the Standard Event Status Enable Register and of the Service Request Enable Register are set to 0 when the instrument is switched on. Therefore, it is necessary for user programs that require Service Request to set the required bits to 1 after power on.

8.3.3 Status and Event Registers

There are four required status or event registers, as follows:

1. Standard Event Status Enable Register (ESE)
2. Standard Event Status Register (ESR)
3. Service Request Enable Register (SRE)
4. Status Byte (STB)

These registers indicate device status and allow the programmer to specify which device events will enable a service request. Refer to Figure 8-2 for the following discussion.

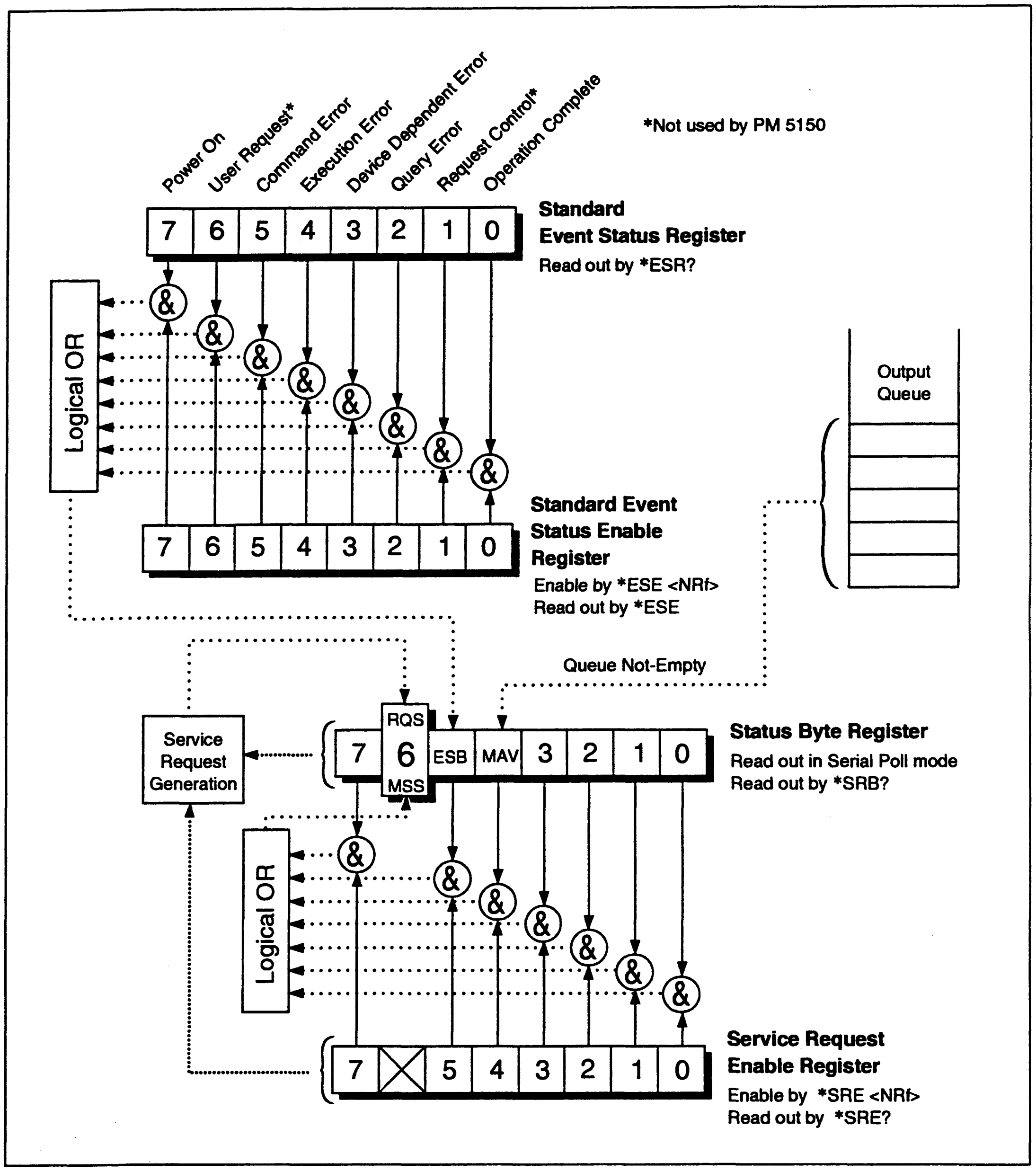


Figure 8-2. Status and Event Registers

Each of the 8 bits in the ESR Register indicates a different condition within the device. The ESE Register provides a bit-by-bit mask of the ESR register. When a bit in the ESE Register is set, it enables the corresponding ESR bit to generate a Service Request (SRQ), if bit 5 (ESB) in the SRE Register has also been enabled.

8.3.3.1 ESE AND ESR REGISTERS

Each bit of the 8 bit ESR Register indicates a different condition within the device. The ESE Register provides a bit-by-bit mask of the ESR register. When a bit in the ESE Register is set TRUE, it enables the corresponding ESR bit to generate a Service Request (SRQ), if the ESB bit (bit 5) in the SRE Register has also been enabled.

For example, to generate an SRQ on one of the following conditions:

- power on (bit 7)
- command error (bit 5)
- query error (bit 2)

... you would first enable the ESB bit in the SRE Register by *SRE 16 and then send the command *ESE 164 (164 is the decimal equivalent of binary 10100100).

8.3.3.2 SRE AND STB REGISTERS

The Status Byte Register (STB) of the PM 5150 has four active bits that summarize the current status of the event registers, output queue, and certain instrument specific functions. Similar to the ESE Register, the SRE Register provides an 8-bit mask to allow the programmer to enable each STB bit (with the exception of the MSS bit 6) to generate an SRQ.

For example, to enable the ESB and MAV bits, but not the USR0, of the Status Byte Register, you would send the following command:

```
*SRE 48   (48 = Decimal equivalent of B00110000)
```

The *SRE? and *STB? queries allow reading of the Service Request Enable and Status Byte Registers, respectively.

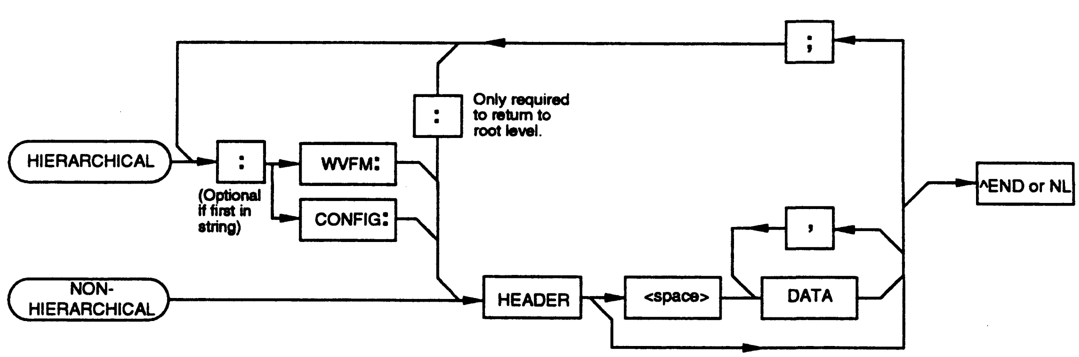
The USR0 (bit 0) is user defined, but not currently implemented.

8.3.4 Syntax

The IEEE-488.2 standard permits hierarchical command strings (called Program Message Units) to be sent from the controller to the instrument. The PM 5150 utilizes this capability for two of its device-dependent commands: WVFM and CONFIG. The syntax required to send such commands has the following rules:

1. After a normal (non-hierarchical) command, the next WVFM or CONFIG command must be preceded by a colon character (:).
2. Hierarchical commands are always followed by a colon character.
3. If a hierarchical command is the first command in a command string, the command can optionally begin with a colon character.
4. To change back to a higher level, the next command must be preceded by the colon character.

This syntax is illustrated in the following diagram:



IEEE-488 Syntax

For example, consider the following GPIB command string:

```
WVFM:SINE 1,0;:AMPLITUDE 10
```

The colon character ensures that the AMPLITUDE command is interpreted as a "root level" command, not another subcommand of WVFM.

8.3.5 Command Set Hierarchy

The command set of the PM 5150 uses a hierarchical command structure. Figure 8-3 shows an example of this structure.

root			WVFM		
level 1	LEN	POSN	SIZE	SYNC	WAVE

Figure 8-3. Hierarchical Command Structure

While the IEEE-488.2 Standard permits instruments to use several levels within the command set structure, the PM 5150 uses only two levels. The top level (represented here by the mnemonic WVFM) is called the *root,*, and the next lower level is level 1. Within this structure you must follow a path through the root in order to reach commands on level 1.

Referring to Figure 8-3, to execute the SIZE command, the path through the root would be indicated as follows:

```
WVFM:SIZE 100
```

Finally, note that the path rules of the PM 5150 allow the programmer to delete the root from the command if the level 1 command has the same root as the preceding command, and that if the preceding command is at level 1, you specify any new root by using a colon character (:) in front of the root mnemonic. The following illustrates this:

```
WVFM:WAVE 10;:WVFM:SIZE 100
```

is the same as

```
WVFM:WAVE 10;SIZE 100
```

Staying in the same level, ";" is sufficient. To change levels, ":" is required.

8.3.6 Stacked Queries

In general the PM 5150 allows stacked queries, returning the responses in the same order in which the queries are received, with two exceptions: any queries in a program message that come after the *IDN? or *OPT? queries will be ignored.

8.4 PROGRAM MESSAGES

A complete ⟨program message⟩ normally consist of a series of commands or ⟨program message units⟩. If the instrument is operated manually, the order of the commands may cause an error condition. For example, consider the following situation:

From the front panel, program a waveform with 2 Volts amplitude and an offset of 5 Volts.

Now change the setting to 1 Volt amplitude and 200 mV offset. If you try to program the new amplitude from the front panel, an error results, because it is not possible to combine 1 Volt amplitude with 5 Volts offset. (See the diagram in Appendix D.) If the offset value is changed first, however, there is no problem.

Because the PM 5150 is not sequence dependent in remote mode, the command order in a single ⟨program message⟩ is not important. Thus both of the following messages would execute properly without an execution error:

```
AMPL 1.0;OFFSET 0.2;EXEC

OFFSET 0.2;AMPL 1.0;EXEC
```

8.4.1 Command Execution

For the PM 5150 to recognize and execute a command or series of commands, they must be followed by the EXECUTE command (short form: EXEC). This GPIB command is equivalent to the front panel ENTER key, and allows programs to send a complete ⟨program message⟩ into an input buffer before executing any of the individual ⟨program message units⟩.

8.4.2 Example Program Message

A ⟨program message⟩ is a series of ⟨program message units⟩ sent to the device in a single string. For example, to set the currently selected waveform to the following:

- sine wave output with a single period
- burst mode
- a burst of 5
- an amplitude of 2.5 V

you would send the following ⟨program message⟩:

```
WVFM:SINE 1,0;:MODE BURST;:BURST 5;:AMPL 2.5;:EXEC
{  unit 1   }{    unit 2   }{ unit 3}{ unit 4 }
```

8.4.3 Program Message Unit

This is the basic message and represents an operation to be performed by the device. For example, if you wanted to create a sine wave with five cycles in the currently selected waveform, the appropriate ⟨program message unit⟩ would be:

```
WVFM:SINE 5,0
```

Notice that a colon (:) is used to separate the ⟨program mnemonic⟩ (short form of the command) WVFM from SINE. For query responses the similarly structured ⟨response message unit⟩ would be used.

Rules for ⟨program message units⟩

1. The ⟨program message unit⟩ is not case sensitive.

2. White space is permitted only at the end of the header or next to a comma or semicolon character.

Rules for ⟨response message unit⟩ (query responses)

1. ⟨program mnemonic⟩ contains upper case alpha characters only.

2. No ⟨white space⟩ is allowed in the message.

NOTE

⟨white space⟩ is defined as 1 or more single ASCII bytes in the range of 00 09 (0B-20 Hex).

8.4.4 Program Message Terminator ⟨PMT⟩

The semicolon (;) is required to separate ⟨program message units⟩ from the program message terminator ⟨pmt⟩.

For the device to recognize the end of a ⟨program message⟩, a special terminator is required. For command messages, the ⟨pmt⟩ can take one of three different formats:

^END	This is defined as sending EOI TRUE and ATN FALSE with the last byte of the message (IEEE-488 only).
NL	NL
NL ^END	^END sent along with NL as the last byte (IEEE-488 only).
^D	Control-D is used as a special terminator to read out messages (RS-232 operation only.)

8.4.5 Response Message Terminator ⟨RMT⟩ (IEEE-488 only)

For response messages the required terminator is:

```
NL ^END - A ^END sent along with NL as the last byte.
```

8.4.6 Device Specific Messages

Table 8-3 describes the device specific messages that are implemented in the PM 5150.

These commands need the command EXEC in order to execute; refer to "Command Execution" earlier in this section.

8.5 DATA FORMATS

Many ⟨program message units⟩ and ⟨response message units⟩ include numeric data in the message, for example the "5" in the message AMPL 5. The following paragraphs define acceptable data formats.

Table 8-3. PM 5150 Device Specific Commands

	COMMAND	DESCRIPTION
*	Configuration Command	The CONFiguration command is one of two hierarchical commands the PM 5150 implements; the other is the WAVEFORM command (the root level waveform editing command). CONF has only one subcommand: HEADERS. This command turns query response headers on and off. The Query form of the command returns the current header configuration.
*	System Commands	Control and return current system-level settings. System commands include EXECUTE (equivalent to front panel ENTER key), HOLD, RECALL, SAVE, Reference Clock Adjustment, RESET, RTS, Sample Clock, and Trigger Generator.
*	Output Commands	Control the generator's output and return current settings for amplitude, offset, burst, clock selection, filter, frequency, function, modes, offset, output, and synchronization.
	Waveform Editing Commands	All waveform editing commands are subcommands of the hierachical WAVEFORM (WVFM) command. These commands select the waveform and program its parameters.
	Waveform Transfer Commands	Construct an Arbitrary wave by sending data points or a block of data into waveform memory. Queries the waveform memory for its content (specified by address). Queries are valid for both Standard and Arbitrary Waves.
	Sequence Generator Commands	Configure the sequence generator option and control the generation of waveform sequences.

* *These commands require termination with the EXEC command.*
Refer to the heading Command Execution *earlier in this section.*

8.5.1 Decimal Numeric Program Data ⟨NRf⟩

This is the most flexible of the numeric representations and takes the following general form:

```
mantissa  --->  whitespace  --->  exponent --->
```

where

```
mantissa = [±][x...x][.x...x]
```

with a maximum length of 255 characters (excluding leading zeros), and

```
optional exponent = E[±][x...x] or e[±][x...x]
```

with a maximum value of ±32000.

NOTE

In the above definitions, x represents the digits 0-9, and characters enclosed in brackets [ ] are optional.

The following example demonstrates four different but equally acceptable ways to represent the number 1,234,567,890 in ⟨NRf⟩ format:

1. +1234567890
2. 1.234567890E+9
3. 123456.7890<white space>e04
4. +.1234567890E+10

8.5.2 Non-Decimal Numeric Program Data

Numeric values may also be represented as a binary, octal, or hex number, as follows:

Binary	#Bx[x...x] or #bx[x...x] where x is a 0 or 1
Octal	#Qx[x...x] or #qx[x...x] where x is a 0 through 7
Hexadecimal	#Hx[x...x] or #hx[x...x] where x is a 0 through F

8.5.3 Arbitrary Block Program Data

This data format speeds up the bus transfer when large amounts of data are sent to or from a device, such as waveform memory data.

Both ⟨indefinite length⟩ and ⟨definite length⟩ block data formats are acceptable.

⟨indefinite length⟩	#0[x...x] ⟨rmt⟩ where x is an 8-bit byte of decimal value 0-255.
⟨definite length⟩	#zy..yx...x where z is a number 1-9, and represents the number of y digit elements. The y digits taken together as a decimal integer equal the number of 8-bit bytes that follow.

For example, to send 4 data bytes ⟨dab⟩ using the ⟨definite length⟩ format, you could send:

#14⟨dab⟩ ⟨dab⟩ ⟨dab⟩ ⟨dab⟩

-or-

#204⟨dab⟩ ⟨dab⟩ ⟨dab⟩ ⟨dab⟩

Note that the length of a single block of arbitrary data is limited by the input buffer of the PM 5150 and is currently at least 4096 bytes.

8.6 COMMAND SUMMARY

This command summary is provided as a quick reference and overview of the complete command list for the PM 5150.

Table 8-4. PM 5150 Remote Command Set

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
Common Commands					
*CLS					Clears all event and status registers. Also clears output queue if it immediately follows a Program Message Terminator.
*ESE(?)		⟨NR⟩⟨ND⟩		0 - 255	Sets the 8-bit mask in the ESE register. Query form returns the contents of the ESE register.
*ESR?		⟨NR⟩		0 - 255	Returns the contents of the ESR register. Once read, the ESR register is cleared.
*IDN?					Queries the instrument for its identification. The specific response is: PHILIPS PM5150, x.y, where x.y is the firmware level.
*OPC(?)					Sets the OPC bit (bit 0) in the ESR register when all pending instrument operations are completed. The query waits for all pending operations to complete then places a "1" in the output queue.
*RST					Equivalent to front-panel RESET CURR; returning the instrument to a default state.
*SRE(?)		⟨NR⟩⟨ND⟩		0 - 255	Sets the 8-bit mask to enable and disable bits in the STB register. The query returns the value of the SRE register.
*STB?		⟨NR⟩		0 - 255	Returns the value of the Status Byte. The Master Summary Status Bit (bit 6) is cleared when first read, but all other bits remain unchanged until the conditions are cleared.
*TRG					Equivalent to front-panel TRIG key.
*TST?					Reserved for testing. No effect except to return ASCII "0".
*WAI					Wait-to-Continue. Has no effect since commands are processed sequentially.
OPT?					GPIB (always returned; no longer an option) Sequencer option installed: SEQ
Configuration Commands					
CONFIGURE	CONF				Root-level command for hierarchical Program Message Units.
⇒ HEADERS(?)	HDRS(?)		ON / OFF		ON = Query responses include header; OFF = Responses only return data. Query returns the current header configuration.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
System Commands					
EXECUTE	EXEC				Equivalent to front-panel ENTER key; instructs the instrument to execute pending commands.
HOLD			ON / OFF		Equivalent to front-panel HOLD key; holds or releases the present level of output voltage.
RECALL	RCLL	⟨NR⟩⟨ND⟩		0 - 30	Recalls front-panel setups from the specified memory.
REF_CLK_ADJ(?)	RADJ(?)	⟨NR⟩		-2048 - 2047	Adjusts reference clock by the specified factor. Query returns the current reference clock adjustment factor.
REF_CLOCK(?)	RCLK(?)		INT / EXT		Sets the reference clock source to INTernal or EXTernal. Query returns the current reference clock source.
RESET			CURR / ALL		Resets instrument settings to default values.
RTNTOSTRT	RTST		ON / OFF		Equivalent to front-panel RTS key; when ON, returns the starting point of the output waveform.
SAMPLECLOCK	SCLK	⟨NR⟩		0.1 - 20E6	Sets/returns the sample clock frequency.
STORE	STOR	⟨NR⟩⟨ND⟩		0 - 30	Stores front panel setups into the specified memory.
TRIGGER_SEL(?)	TRGSEL(?)		INT / MAN		Sets trigger function to internal trigger or to manual/external trigger. The query form returns the current state.
TGRRATE(?)	TGRR(?)	⟨NR⟩		0.02 - 10.0	Sets/returns the trigger rate in seconds.
TRIGGER	TRIG		ON / OFF / PULSE		Sets the trigger to ON, OFF, or PULSE.
Output Commands					
AMPLITUDE(?)	AMPL(?)	⟨NR⟩		0.02 - 20.40	Sets/returns the peak-to-peak output voltage.
BURST(?)		⟨NR⟩⟨ND⟩		1 - 1048575	Sets/returns the number of bursts.
CLOCK_SEL(?)	CLKSEL(?)		INT / EXT		Selects either internal or external sample clock source. Query returns current setting.
FILTER(?)			ON / OFF		Sets/returns output filter state ON or OFF.
FREQUENCY?	FREQ?	⟨NR⟩			Returns the calculated waveform repetition rate or the SCLK value with a negative sign if no FREQ value can be calculated, e.g., when a SEQUENCE is selected.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
FUNCTION(?)	FUNC(?)	⟨NR⟩⟨ND⟩ or Waveform	STDW ARB SEQ	 0 - 99 0 - 99	Selects the specified waveform or sequence to send to the output. E.g.: FUNC ARB,1 or FUNC STDW. Query returns the currently selected wave or sequence number.
MODE(?)			CONT/TRIG/GATE/BURST/ TOGGLE		Sets/returns the output signal mode.
OFFSET(?)	OFST(?)	⟨NR⟩		-9.4 - +9.4	Sets/returns output offset voltage.
OUTPUT_SWTCH(?)	OUTSW(?)		ON / OFF		Equivalent to front-panel OUTPUT key. Query returns the state of the OUTPUT switch.
READ_BURST?	RBRS?	⟨NR⟩		1 - 1048575	Returns the number of completed output bursts.
SYNCSEL(?)	SYSEL(?)	⟨NR⟩⟨ND⟩	ADDR / STATE	1, 2, 3	Sets the selected sync pulse either to an address or a specific state within a waveform. See the entry for SYNC later in this table. SYNC1: pulse at the end point (ENDP) SYNC2: pulse is high during waveform run (WRUN) SYNC3: pulse at end point of each waveform burst (ENDB) within a sequence. Query returns the current state of the specified SYNC pulse.
TRGINMODE(?)			SYNC / ASYNC		Sets the trigger input mode to synchronous or asynchronous. Query returns the current mode of the input trigger.
TRGOUTMODE(?)			SERIAL / PARALLEL		For multi-instrument triggering, sets the output to trigger in serial or parallel. Query returns the current output trigger mode.
Waveform Editing Commands					
WAVEFORM	WVFM				Root-level command for hierarchical Program Message Units.

NOTES:

1. *The remainder of this table consists of subcommands that must be preceded by* **WVFM:**
   The symbol ⇒ before the command name indicates that it is a subcommand of the WVFM hierarchical command.
2. *Waveforms are listed alphabetically, not arranged in the order that they appear on the display.*
3. *All Waveform Editing commands apply identically to Arbitrary and to Standard Waveforms, with the following exceptions, which are also noted in the table entries:*
   A. POSN, LEN, MINY, MAXY, and LINE do not apply to Standard Waveforms.
   B. INVERT keyword is only valid for EXP, SAW, PULSE, and CIRCLE Standard Waveforms.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
⇒ AM		⟨NR⟩ ⟨NR⟩ ⟨NR⟩ ⟨NR⟩ ⟨NR⟩	Carrier Frequency Carrier Phase Modulation Frequency Modulation Phase Modulation Index	1 - 8183 0° - 360° 1 - 8183 0° - 360° 0 - 100%	Generates a sine wave amplitude-modulated by a sine wave. The AM wave is stored in the currently selected waveform memory.
⇒ CIRCLE		⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Number of Repetitions Phase Slope	0 - 1000 0° - 360° NORM/ INVERT	Generates a semicircle in the selected waveform memory. The keywords NORM and INVERT are optional for Arbitrary Waveforms, not valid for STDW. NORM = positive-going first half cycle. INVERT = negative-going first half cycle.
⇒ DC		⟨NR⟩	Y value	-2048 - +2047	Generates a horizontal line at Y value in the selected waveform memory.
⇒ EXPONENTIAL	EXP	⟨NR⟩⟨ND⟩	Time Constant Decay	0 - 20 NORM/ INVERT	Generates a decaying exponential with the specified time constant (e^x) in the selected waveform memory. Decay specifier is optional for both Arbitrary and Standard Waveforms. NORM = positive decay INVERT = negative decay
⇒ FM		⟨NR⟩ ⟨NR⟩ ⟨NR⟩ ⟨NR⟩ ⟨NR⟩	Carrier Frequency Carrier Phase Modulation Frequency Modulation Phase Modulation Index	1 - 8183 0° - 360° 1 - 8183 0° - 360° 0.01 - 100.00	Generates a sine wave frequency-modulated by a sine wave in the selected waveform memory.
⇒ GAUSSIAN	GAUSS	⟨NR⟩	Exponent Power	0.01 - 20	Generates a gaussian pulse with the specified exponent, e^{-x^2} where x varies between +EXP and -EXP.
⇒ HAVERSINE	HSIN	⟨NR⟩	Number of Repetitions	0.01 - 1000.00	Generates a haversine wave with the number of cycles specified. The basic shape is a sine wave shifted by 90°.
⇒ LINE		⟨NR⟩	Starting Y value Ending Y value	-2048 - +2047	Generates a ramp with the specified coordinates in the selected waveform memory.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
⇒ LINEARSWEEP	LINS	⟨NR⟩ ⟨NR⟩	Starting no. of cycles Ending no. of cycles Starting Phase*	1 - 1000 1 - 1000 0° - 360°	Generates a linearly-swept sine wave with the number of starting and ending cycles specified. See note following table regarding Starting Phase parameter.
⇒ LOGSWEEP	LOGS	⟨NR⟩	Starting no. of cycles Ending no. of cycles Starting Phase*	1 - 1000 1 - 1000 0° - 360°	Generates a logarithmically-swept sine wave with the number of starting and ending cycles specified. See note following table regarding Starting Phase parameter.
⇒ NOISE					Generates pseudo-random noise in the selected waveform memory.
⇒ PULSE		⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Number of Repetitions Delay Rise Time High Time Fall Time Slope	0 - 1000 0 - 100% 0 - 100% 0 - 100% 0- 100% NORM/ INVERT	Generates a pulse train with the number of repetitions specified. Delay, rise, high, and fall time are expressed as percentages of the period of the pulse. Slope specifier is optional for Arbitrary and Standard Waveforms. If slope is not specified, defaults to normal, a positive-going pulse.
⇒ SAWTOOTH	SAW	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Number of Repetitions Duty Cycle Slope	1 - 1000 1 to 100% NORM/ INVERT	Generates a sawtooth waveform with the number of cycles specified. Duty cycle is optional; 50% if unspecified. Slope is optional for both Arbitrary and Standard Waveforms, defaults to normal (positive-going) if unspecified.
⇒ SINE		⟨NR⟩ ⟨NR⟩	Number of Repetitions Phase	0 - 1000.00 0.00 - 360.00°	Generates a sine wave with the number of repetitions specified, beginning at the specified phase angle.
⇒ SCM		⟨NR⟩ ⟨NR⟩ ⟨NR⟩ ⟨NR⟩	Carrier Frequency Carrier Phase Modulation Frequency Modulation Phase	1 - 8183 0° - 360° 1 - 8183 0° - 360°	Generates a sine wave AM waveform with suppressed carrier.
⇒ SQUARE		⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Number of Repetitions Duty Cycle Slope	1 - 1000 1 - 100% NORM/ INVERT	Generates a square wave with the number of repetitions specified. Duty cycle is optional, 50% if unspecified. Slope is optional for Arbitrary Waveforms, not valid for Standard Waveforms. Slope defaults to normal (positive-going first half-cycle) if unspecified.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
⇒ SINE_X_OVR_X	SXX	⟨NR⟩⟨ND⟩	Ringing frequency multiplier Slope	4 - 1000 NORM/ INVERT	Generates the function sine(x)/x as a waveform with the specified number of cycles. Slope is optional for Arbitrary Waveforms, not valid for Standard; defaults to normal (positive-going first half-cycle) if unspecified.
⇒ TRIANGLE		⟨NR⟩⟨ND⟩	Number of Repetitions Slope	1 - 1000 NORM/ INVERT	Generates a triangle wave in the currently selected waveform memory, with the specified number of cycles. Slope is optional for Arbitrary Waveforms, not valid for Standard Waveforms; if unspecified, slope defaults to normal (rising).
⇒ LENGTH(?)	LEN(?)	⟨NR⟩⟨ND⟩		0 - 32768	Sets the length in data points that any succeeding waveform generation function will create. Functional limits are 0 to SIZE minus POSITION, otherwise a device error occurs. Not valid for Standard Waveforms. Query returns the current value of LENGTH.
⇒ MAXY(?)		⟨NR⟩		-2048 - +2047	Sets the maximum Y value to be produced when generating a waveform. Not valid for Standard Waveforms. Query returns the current value of MAXY.
⇒ MINY(?)		⟨NR⟩		-2048 - +2047	Sets the minimum Y value to be produced when generating a waveform. Not valid for Standard Waveforms. Query returns the current value of MINY.
⇒ POSITION(?)	POSN(?)	⟨NR⟩⟨ND⟩		0 - 32768	Sets/returns the starting position, in the currently selected waveform memory, where new waveform points will be written. The maximum starting position is the size of the memory. Not valid for Standard Waveforms. After a function, (e.g., SINE), is written, POSITION automatically increments to the value of SIZE, to point to the next new data point.
⇒ SIZE(?)		⟨NR⟩⟨ND⟩		0, 32 - 32768	Sets/returns the memory size in number of points of the currently selected waveform. The size can be from zero to the total amount of free memory space. If the Standard Waveform (STDW) is currently selected, the existing waveform is stretched or squeezed to fit the new size. If the selected waveform is other than STDW, and SIZE is being enlarged, new points (set to 0) are added at the end of the waveform, reducing its size. Sending 0 size deletes the waveform.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
⇒ SYNC(?)		⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Sync Number Start Position Length	1, 2, 3 0 - 32767 0 - 32768	Installs a sync pulse into the specified channel. The Start Position specifies the location in the selected waveform memory where the pulse begins, and Length specifies the total length of the pulse. Start Position range: 0 to SIZE minus 1. Length range: 0 to SIZE minus POSITION. Query form returns the starting position and length of the specified sync pulse.
⇒ WAVE(?)		⟨NR⟩⟨ND⟩	Waveform Number -or- STDW	0 - 99 STDW	Selects one of the 100 waveform memories, or the Standard Waveform to be used for editing or creating waves, e.g., *WVFM:WAVE 0* or *WVFM:WAVE STDW*. POSITION is set to zero, LENGTH is set to SIZE. Query returns the number of the currently selected waveform memory, e.g., *WVFM:ARB 0* or *WVFM:ARB STDW*.
Waveform Transfer Commands					
⇒ MEMORY(?)	MEM(?)	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Starting Address Data	0 - 32767 -2048 - +2047	This command only applies to Arbitrary Waves. It sends either individual data points or a block of data into the selected waveform memory beginning at the specified address. The data block can be any length, and may be sent either as individual data points in the ⟨NR⟩ format, or as a data block, high byte first. The query applies to both Standard and Arbitrary waves and returns a single word of data in the range -2048 to +2047, beginning at the specified address.
⇒ MEM_BLOCK?	MBLK?	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Starting Address Length	0 - 32767 0 - 2048	Returns the number of data points specified in length beginning at the specified address. Each data point is a 2-byte word, high byte first. Response is constructed as follows: Address in <NRf> format Comma(,) Data in Definite Length Arbitrary Block format.

Table 8-4. PM 5150 Remote Command Set (cont)

COMMAND(QUERY)	SHORT FORM	DATA FORMAT	PARAMETERS	VALUES	DESCRIPTION
Sequence Generator Commands					
⇒ ADDSEQUENCE(?)	ADDSEQ(?)	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Sequence Number Waveform Number Burst Count Sequence Step Number	0 - 99 0 - 99 0 - 1048575 0 - 999	Adds a series of waveforms to a specified sequence. Waveform parameters are passed in groups of three: waveform, number of times to repeat the waveform, and the sequence number to use. In the query form, all values are returned as integers.
⇒ AUTOSEQUENCE	AUTO	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	First Sequence Step Step Number	0 - 999 0 - 999	Configures the automatic sequence step generator to begin at the specified first sequence step, and increment by the step number to the next sequence number. This command is always used in conjuction with the SEQ and SEQB commands (see below).
⇒ SEQUENCE	SEQ	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Sequence Number Waveform Numbers	0 - 99 0 - 99	Constructs a sequence having the specified sequence number composed of a series of waveforms as specified. Burst count is set to 1 for each waveform. If no waveform number is supplied, the block is deleted.
⇒ SEQBURST	SEQB	⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩ ⟨NR⟩⟨ND⟩	Sequence Number Waveform Number Burst Count	0 - 99 0 - 99 0 - 1048575	Constructs a sequence having the specified sequence number composed of a series of waveforms as specified. Waveform parameters are passed in sets of two: the next waveform in the sequence, and the number of times the waveform is to be repeated.

NOTES:

1. *The notation ⟨NR⟩ in the DATA FORMAT column indicates that the numeric value sent to the generator must be represented as a decimal number.*
2. *The notation ⟨ND⟩ in the DATA FORMAT column indicates that the numeric value sent to the generator can be represented as a binary, octal, or hexadecimal number as described under the heading "Non-Decimal Numeric Program Data" earlier in this section. Values returned by queries are real signed numbers.*
3. *When programming a sweep of standard waveforms (LINS or LOGS commands), a starting phase must be given even though it is ignored. Sweeps always start at 0°.*

8.7 ERROR REPORTING

There are four basic types of errors that are reported by a device:

Command — In general, when a ⟨program message⟩ is sent with an error in the syntax, a command error is reported. The command parser (the module that recognizes individual commands) will report the bad command, and look for the next valid command in sequence.

Execution — This error represents either program data that is out of range, or a message that was not properly executed due to some device condition. In this case the faulty command will generate the error, but not be performed.

Device Specific — As the name implies, this error is defined by the specific instrument. The PM 5150 generates no device-specific errors.

Query — When a controller or other device attempts to read data from the Output Queue when no data is present or pending, or when output data is lost, a query error is generated.

To clear an error:

1. Correct the condition that caused the error.

2. Send the *CLS command.

8.8 WAVEFORM EDITING PRINCIPLES

To successfully use the waveform editing commands of the PM 5150, it is important to understand the principles behind memory allocation, memory size, and the active memory area. Refer to Figure 8-4 for this discussion.

The entire waveform memory of 32,768 words is divided into two areas. One area is designated for the Standard Waveforms (STDW), and the rest of the memory which can be partitioned to hold custom waveforms numbered 0 through 99. The horizontal size (in digital words) of each partitioned waveform can be set by the SIZE command, and thus the total number of waveforms is limited by the cumulative size of the individual waveforms.

The minimum and maximum Y values for the waveform memory are -2048 and +2047 respectively.

When using the waveform editing commands to operate on a specific waveform memory, it is important to realize that these commands only affect the active area (See note below). In other words, if you wanted to create a sine wave with three cycles, starting at Φ 0, you would send the following remote command:

```
WVFM:SINE 3,0;:EXEC
```

This command stores three cycles of sine waves into the active area, with a maximum and minimum Y value the same as the active area. The commands LEN, MINY, MAXY, and POSN all affect the actual dimensions of the active area as follows:

LEN — The length command specifies the actual horizontal length of the active area. This maximum length is SIZE - POSN.

MINY — The minimum Y command sets the lowest Y value for the active area.

MAXY — The maximum Y command sets the highest Y value for the active area.

POSN — The position command determines the horizontal starting point for the active area. Note that once a waveform is written into the active area (using the waveform edit commands), POSN is changed to the point located at POSN + LEN + 1.

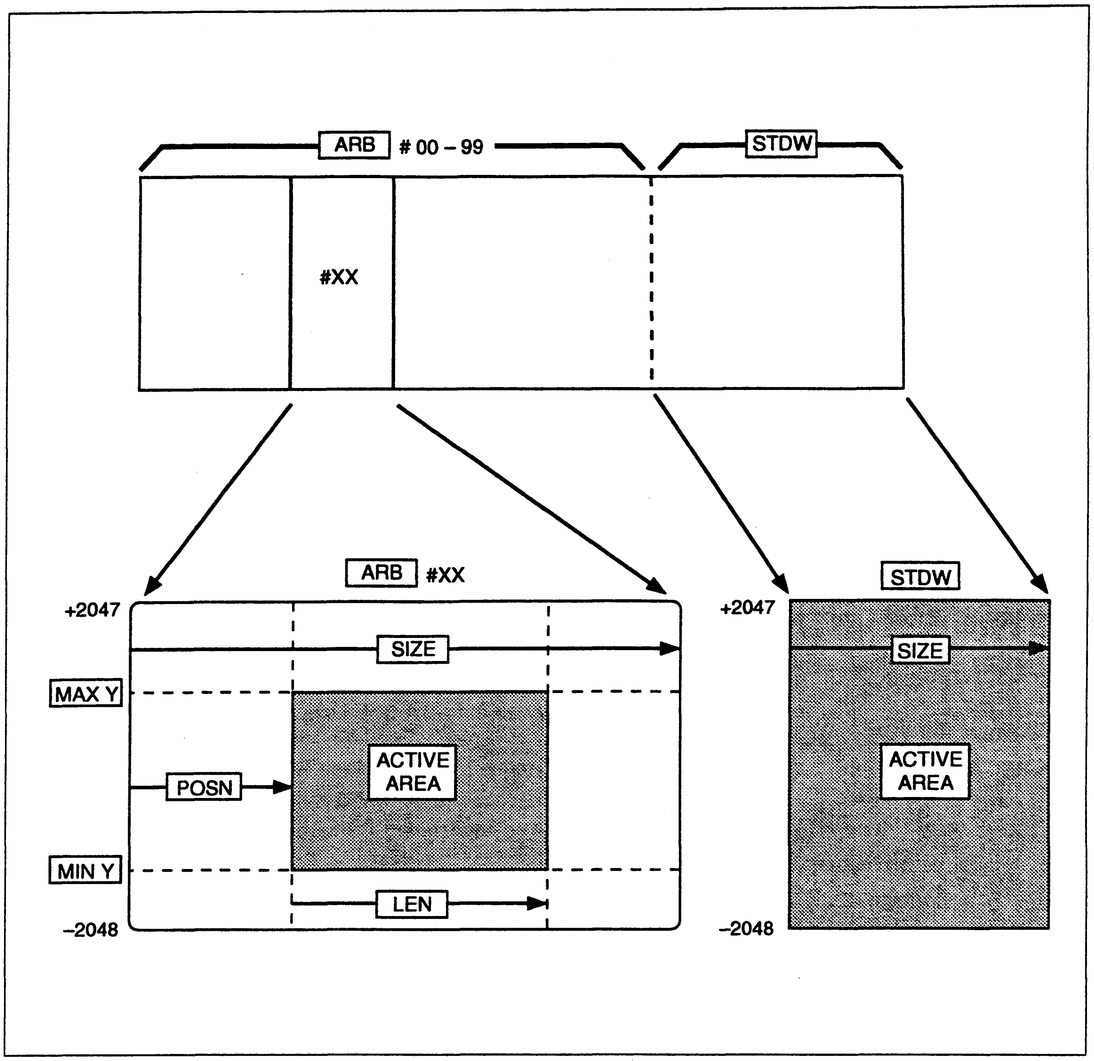


Figure 8-4. Waveform Editing

NOTE

For the Standard Waveform, the active area is always the entire area defined by SIZE. Thus, none of the four commands mentioned above affect the Standard Wave.

8.9 SEQUENCE GENERATOR APPLICATION NOTES

ADDSEQUENCE [ADDSEQ]

The ADD SEQUENCE command adds one or more sequence steps to a specified sequence file. This is the only way to modify an existing sequence file using GPIB or RS-232 once one has been entered.

The first parameter in the example names the sequence file to be modified. The following parameters are groups of three. The first parameter in the group indicates the sequence number of the waveform. The second is the number of times to repeat this waveform, and the third indicates the sequence step number for that waveform.

Example:

Assume that sequence file number 10 already exists and steps 35 and 53 are NOT used. The following command adds two steps (35 and 53) to sequence number 10. Step 35 will be wave number 3, repeated five times. Step 53 will be wave number 2, repeated four times.

```
WVFM:ADDSEQ 10,3,5,35,2,4,53
```

AUTOSEQUENCE [AUTO]

THe AUTOMATIC SEQUENCE command configures the automatic sequence step number generator by setting the sequence step number to start at the first parameter and the increment value for the following sequence step numbers. This command is used only for the SEQUENCE [SEQ] and SEQBURST [SEQB] commands.

Example:

The following command starts numbering the sequence steps at 10 and increments them by 10 (i.e., the first sequence step will be 10, the second sequence step will be 20, and so forth).

```
WVFM:AUTO 10, 10
```

SEQUENCE [SEQ]

The SEQUENCE command makes a new sequence file, DELETING any existing sequence file with the same number. The first parameter creates the sequence file. The following parameters are the waves to be sequenced. For the SEQUENCE [SEQ] command, the burst count (the number of times the wave is repeated) is always set to one. If no waves are supplied, then this command will only delete the specified waveform. The AUTO command is used in conjunction with this command.

Example:

The following command deletes sequence file number 23 (if it exists).

```
WVFM:SEQ 23
```

The following commands create a sequence file (called number 12) that will sequence waves 3, 1, 5, 8, and 3. Step 10 will be wave 3 repeated 1 time. Step 20 will be wave 1 repeated 1 time. Step 30 will be wave 5 repeated 1 time. Step 40 will be wave 8 repeated 1 time. Step 50 will be wave 3 repeated 1 time.

```
AUTO 10, 10
WVFM:SEQ 12,3,1,5,8,3
```

SEQBURST [SEQ]

The SEQUENCE BURST command makes a new sequence file, DELETING any existing sequence file with the same number. The first parameter is the sequence file to create. The following parameters are groups of two. The first parameter of the group is the wave number, the second parameter is the burst count (the number of times the wave is repeated). The AUTO command is used in conjunction with this command.

Example:

The following commands creates sequence file number 5. Step 10 will be wave 2 repeated 4 times. Step 20 will be wave 6 repeated 1,000 times. Step 30 will be wave 45 repeated 10,000 times.

```
AUTO 10,10
WVFM:SEQB 5,2,4,6,1000,45,10000
```

`SEQBURSTNUM [SEQBN]`

The SEQUENCE BURST NUMBER makes a new sequence file, DELETING any existing sequence file with the same number. The first parameter creates the sequence file. The following parameters are groups of three. The first parameter of the group is the wave number, the second is the burst count (the number of times the wave is repeated), and the third parameter indicates the sequence step number.

Example:

The following command creates sequence file number 23. Step 5 will be wave 1 repeated 2 times. Step 10 will be wave 3 repeated 4 times. Step 15 will be wave 5 repeated 6 times.

```
WVFM:SEQBN 23,1,2,5,3,4,10,5,6,15
```

8.10 EXAMPLE PROGRAM

The following example program is written in the GWBASIC programming language for the Philips PM 2201 IEEE-488/GPIB interface. Using this program requires some familiarity with the MS-DOS operating system and GWBASIC.

The program permits you to type in commands at the controller keyboard and send them to the PM 5150 over the IEEE-488 bus. This program can serve as a valuable tool for investigating the remote programming capabilities of the PM 5150.

To use the example program, first LOAD it under GWBASIC, then RUN it. The program asks for the IEEE-488 address of the PM 5150. Respond by typing the number 16 (the default address), followed by ⟨ENTER⟩. After checking the bus, the program displays:

```
MESSAGE:     PHILIPS, PM 5150, 0, SW 1.10

COMMAND:     _
```

The cursor indicates the location you can type in an IEEE-488 command. For example, the message shown above is a response to the following query:

```
*IDN?
```

To begin using this program, note the following:

- To display the various arbitrary waveforms you currently have stored in the PM 5150, use the FUNC command. The following example demonstrates what you would need to type if you wished to view ARB #2:

  ```
  func wave,2;exec
  ```

- When you display a waveform, you must use a variant of the WVFM command to reposition the current waveform memory location if you wish to store a new waveform in that workspace. For example, to store a new waveform into the currently displayed workspace (ARB #2), you would first send the command:

  ```
  wvfm:posn 0
  ```

- To store a different standard wave into ARB #2, you must send a variant of the WVFM command. For example, the following command would put an amplitude modulated wave into the currently displayed ARB. Notice that ALL parameters must be specified, even if you want the defaults!

  ```
  wvfm:am 100,0,1,0,100
  ```

```
1  'Copyright 1986, N.V. Philips Gloeilampenfabrieken
2  CLS
3  CLEAR ,64000!
4  GPIBINIT1 = 64000! : GPIBINIT2 = GPIBINIT1 + 2
5  DIM A%(26)
6  BLOAD "IOBIB.M",GPIBINIT1
7  CALL GPIBINIT1(A%(0),A%(1),A%(2),A%(3),A%(4),A%(5),A%(6),A%(7),A%(8),A%(9),
   A%(10),A%(11),A%(12),A%(13),A%(14),A%(15),A%(16),A%(17),A%(18),A%(19),
   A%(20),A%(21),A%(22),A%(23),A%(24))
8  CALL GPIBINIT2(A%(25),A%(26))
9  '
10  IOINIT       = GPIBINIT1 + A%(0)
11  IORESET      = GPIBINIT1 + A%(1)
12  IOABORT      = GPIBINIT1 + A%(2)
13  IOCONTROL    = GPIBINIT1 + A%(3)
14  IOEOI        = GPIBINIT1 + A%(4)
15  IOEOL        = GPIBINIT1 + A%(5)
16  IOGETTERM    = GPIBINIT1 + A%(6)
17  IOMATCH      = GPIBINIT1 + A%(7)
18  IOOUTPUTS    = GPIBINIT1 + A%(8)
19  IOOUTPUT     = GPIBINIT1 + A%(9)
20  IOOUTPUTA    = GPIBINIT1 + A%(10)
21  IOENTERS     = GPIBINIT1 + A%(11)
22  IOENTER      = GPIBINIT1 + A%(12)
23  IOENTERA     = GPIBINIT1 + A%(13)
24  IOSEND       = GPIBINIT1 + A%(14)
25  IOSPOLL      = GPIBINIT1 + A%(15)
26  IOSTATUS     = GPIBINIT1 + A%(16)
27  IOTIMEOUT    = GPIBINIT1 + A%(17)
28  IOREMOTE     = GPIBINIT1 + A%(18)
29  IOLOCAL      = GPIBINIT1 + A%(19)
30  IOLLOCKOUT   = GPIBINIT1 + A%(20)
31  IOCLEAR      = GPIBINIT1 + A%(21)
32  IOTRIGGER    = GPIBINIT1 + A%(22)
33  IOGTS        = GPIBINIT1 + A%(23)
34  IORSV        = GPIBINIT1 + A%(24)
35  IOWAIT       = GPIBINIT1 + A%(25)
36  '
37  DEF.ERR      = GPIBINIT1 + A%(26)
38  PCIB.ERR$    = SPACE$(40)
39  CALL DEF.ERR(PCIB.ERR, PCIB.ERR$)
40  FALSE        = 0
41  TRUE         = 1
42  NOERR        = 0
43  EOFLW        = 14
44  EUNKNOWN     = 100001!
45  ESEL         = 100002!
46  ERANGE       = 100003!
47  ETIME        = 100004!
48  ECTRL        = 100005!
49  EPASS        = 100006!
50  ENUM         = 100007!
51  EADDR        = 100008!
52  '
53  ERASE A%
54  '
```

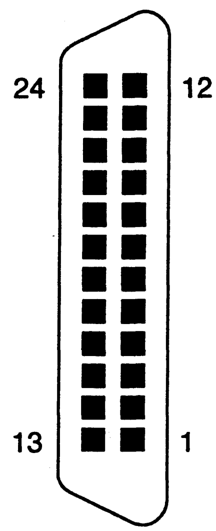
```
55  'Start application program after this line
100 CLS                                     'start of own program
110 PRINT" "
120 PRINT" "
130 PRINT"               ***** DEMO PROGRAM FOR PM 5150 *****"
140 PRINT" " : BEEP
150 INPUT"          Please type in IEEE-488 address of your instrument: ",GEN
160 PRINT" "
170 PRINT"                   PRESS  ''RETURN''  TO CONTINUE  "
180 PRINT" " : BEEP
190 PRINT"                 To leave running program type 'END' "
200 PRINT" "
210 B$=INKEY$
220 IF B$="" THEN GOTO 210              'waiting for ''RETURN''
230 IF ASC(B$) <> 13 THEN 250 ELSE 300
240 '
250 PRINT" " : PRINT" "
260 PRINT" "
270 PRINT"            Wrong key! Please press ''RETURN'' to continue
280 BEEP
290 GOTO 210


300 '
310 CLS                                 'clear screen
320 AD=7                                'adapter number is 7
330 GEN=GEN+AD*100                      'IEEE address of PM 5150 (GEN)
340 '
350 CALL IORESET(AD)                    'initialisation of GPIB
360 EOL$=CHR$(10) : L=LEN(EOL$) : CALL IOEOL(AD,EOL$,L) 'End of Line = LF
370 COND=1 : CALL IOEOI(AD,COND)        'enable End message
380 IF PCIB.ERR>0 THEN PRINT PCIB.ERR$
390 TIME=5 : CALL IOTIMEOUT(AD,TIME)    'timeout value is 5 seconds
400 IF PCIB.ERR>0 THEN PRINT PCIB.ERR$
410 '
420 WR$="*ESE 255;*CLS;*SRE 49" : NCHAR=LEN(WR$)  'enable ESR and STB registers
430 CALL IOOUTPUTS(GEN,WR$,NCHAR)       'send message to PM 5150
440 IF PCIB.ERR>0 THEN PRINT PCIB.ERR$
450 '
460 WR$="*IDN?;" : MAXIMUM=64           'asks for identity
470 NCHAR=LEN(WR$) : INFO$=SPACE$(MAXIMUM) : ACTUAL=0
480 CALL IOOUTPUTS(GEN,WR$,NCHAR)
490 IF PCIB.ERR=0 THEN 520              'bus error check
500 LOCATE 10,17 : PRINT"IEEE-BUS ERROR! CONNECTION? ADDRESS?
510 GOTO 140
520 CALL IOENTERS(GEN,INFO$,MAXIMUM,ACTUAL)
530 PRINT : PRINT"Connected instrument:  " : PRINT : PRINT INFO$
540 PRINT" "
```

```
550 '
560 PRINT" "
570 LINE INPUT"COMMAND :      ",A$          'reading keyboard input
580 IF A$="end" OR A$="END" THEN 650
590 WR$=A$                                  'input to WR-string
600 NCHAR=LEN(WR$)
610 CALL IOOUTPUTS(GEN,WR$,NCHAR)           'sends string to PM 5150
620 GOSUB 1000
630 GOTO 560
640 '
650 CALL IOLOCAL(GEN)                       'sets instrument to local,
660 CLS                                     'if keyboard input ''end''
670 END
680 '
690 '
700 '

1000 'Subroutine
1010 '
1020 IF (PCIB.ERR=100007!) OR (PCIB.ERR=0) THEN 1060
1030 PRINT : PRINT : PRINT : PRINT"BUS-ERROR!" : PRINT
1040 PRINT "PLEASE CHECK CONNECTIONS AND START PROGRAM AGAIN." : RETURN 670
1050 '
1060 STAT=0
1070 FOR I=1 TO 500 : NEXT I
1080 CALL IOSPOLL(GEN,STAT)
1090 IF (STAT AND 64)=0 THEN RETURN        'STB register = 0
1100 IF (STAT AND 32)=32 THEN 1140         'Event Status Bit = 1
1110 IF (STAT AND 16)=16 THEN 1240         'Message available
1120 GOTO 1200

1130 '
1140 WR$="*ESR?" : MAXIMUM=64              'error query to generator
1150 NCHAR=LEN(WR$) : INFO$=SPACE$(MAXIMUM) : ACTUAL=0
1160 CALL IOOUTPUTS(GEN,WR$,NCHAR)
1170 CALL IOENTERS(GEN,INFO$,MAXIMUM,ACTUAL)
1180 PRINT "ERROR: STAT=";STAT;"ESR= ";LEFT$(INFO$,ACTUAL)
1190 BEEP                                  'print error message
1200 WR$="*CLS" : NCHAR=LEN(WR$)
1210 CALL IOOUTPUTS(GEN,WR$,NCHAR)
1220 RETURN

1230 '
1240 MAXIMUM=100 : INFO$=SPACE$(MAXIMUM) : ACTUAL=0
1250 CALL IOENTERS(GEN,INFO$,MAXIMUM,ACTUAL)
1260 PRINT "MESSAGE :      ";LEFT$(INFO$,ACTUAL)       'print message
1270 RETURN
```

8.11 CABLE AND CONNECTOR DIAGRAMS

The diagrams that complete this section illustrate the IEEE-488 and RS-232-C connectors.

GPIB 24 PIN
(REAR VIEW)



24 : GND	12 : SHIELD (CHASSIS GND)
23 : GND	11 : ATN
22 : GND	10 : SRQ
21 : GND	9 : IFC
20 : GND	8 : NDAC
19 : GND	7 : NRFD
18 : GND	6 : DAV
17 : REN	5 : EOI
16 : DIO8	4 : DIO4
15 : DIO7	3 : DIO3
14 : DIO6	2 : DIO2
13 : DIO5	1 : DIO1

Figure 8-5. IEEE-488 Connector Pinout

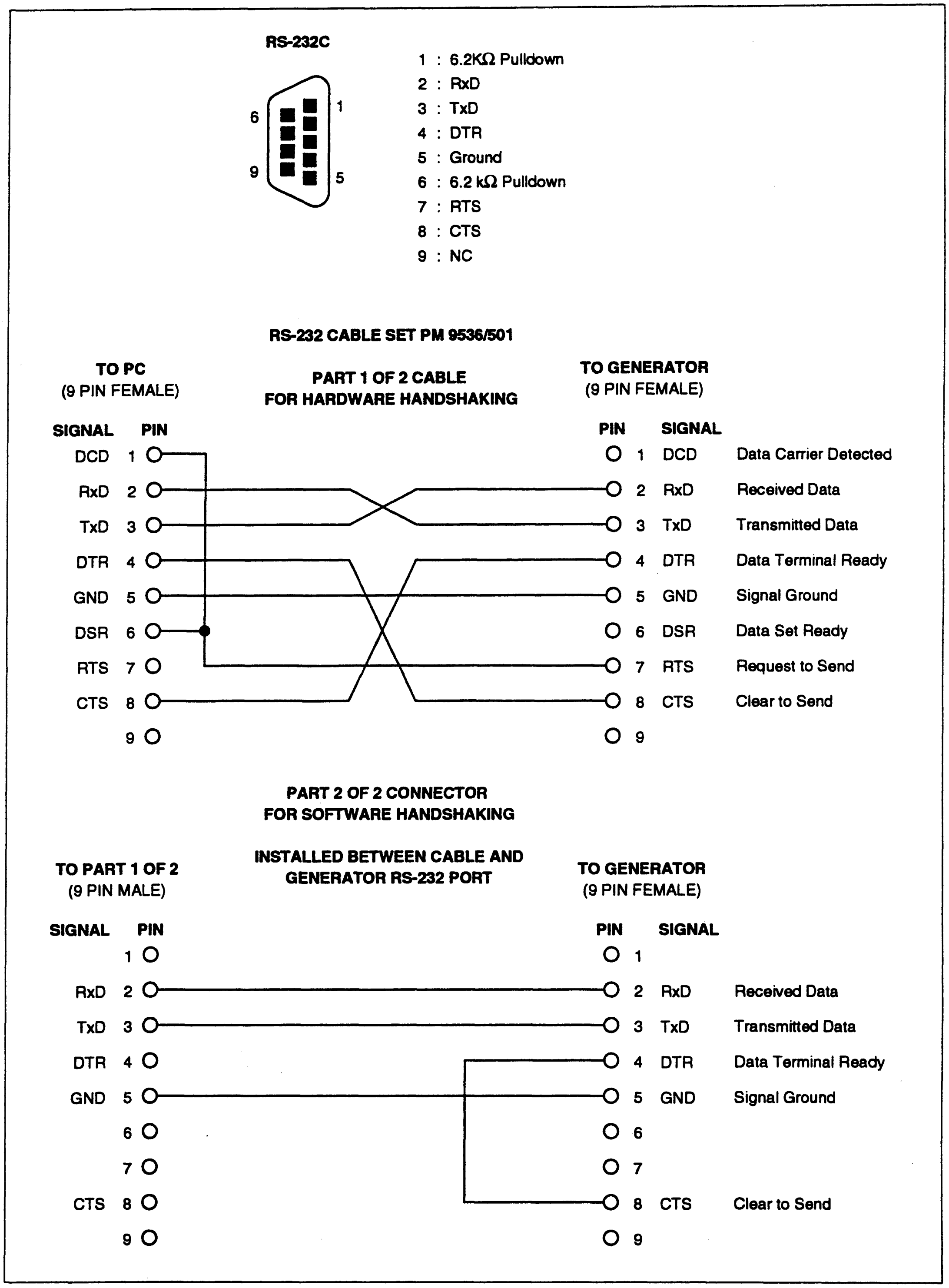


Figure 8-6. RS-232-C Connector and Cable Set

9 APPENDICES

9.1 APPENDIX A
ERROR MESSAGES

Many messages appear on the front panel display during normal operation. Most of these are self-explanatory, and are not truly "error messages"; they are better referred to simply as instrument messages because they convey some information to the operator about the current state of the instrument. These messages are not explained here, because the PM 5150 displays them in clear text that is easily understood.

However, a few messages that are not as simple to decode are listed in this appendix. All of these messages would be sent to a controller with the message "Execution Error".

Table A-1. Error Messages

ERROR CONDITION	FRONT PANEL MESSAGE	MESSAGE TO CONTROLLER
Illegal AMPL/OFST setting (see Appendix D)	101 AMPL/OFST Range	Execution error
Illegal setting of START/STOP values under ARB VIEW	102 START/STOP Range	
Illegal FUNC/MODE programming	104 FUNC/MODE Conflict	
FUNCTION parameters programming inconsistent with memory length	Error Cordic Limit	
Illegal FUNCTION parameter programming	Param out of range	
Programming GATE-INT via interface	*no message*	

* *There is no front panel message because it is not possible to program this combination at the front panel; it can be programmed only via remote control.*

9.2 APPENDIX B
CHARACTERISTICS OF THE STANDARD WAVEFORMS

SINE

Programmable Parameters:	N	Number of repetitions (frequency multiplier)
	P	Phase in degrees

Time Function:

$$v(t) = \frac{A}{2} \cdot \sin\left(2 \cdot \pi \cdot Nft + P \cdot \frac{\pi}{180}\right)$$

where:

A = programmed output amplitude
f = programmed frequency

SQUARE

Programmable Parameters:	N	Number of repetitions (frequency multiplier)
	DTY	Duty Cycle in percent

Time Function for $0 \leq t \leq T$:

$$v(t) = \begin{cases} \frac{A}{2} & \text{for} \quad 0 \leq t \leq D \cdot T \\ -\frac{A}{2} & \text{for} \quad D \cdot T < t \leq T \end{cases}$$

where:

A = programmed output amplitude
D = (DTY in %)/100
T = 1/(N f) = period; f = programmed frequency

PULSE +

Programmable Parameters:

DLY	Delay in percent
RIS	Rise Time in percent
HI	High Time in percent
FAL	Fall Time in percent
N	Number of repetitions (frequency multiplier)

Time Function for $0 \le t \le T$, RIS+HI+FAL ≤100% and DLY=0:

$$v(t) = \begin{cases} \dfrac{A \cdot t}{2 \cdot R \cdot T} & \text{for } 0 \le t \le R \cdot T \\[2ex] \dfrac{A}{2} & \text{for } R \cdot T \le t \le (R+H) \cdot T \\[2ex] -\dfrac{A\left(\dfrac{t}{T} - R - H - F\right)}{2 \cdot F} & \text{for } (R+H) \cdot T \le t \le (R+H+F) \cdot T \\[2ex] 0 & \text{for } (R+H+F) \cdot T \le t \le T \end{cases}$$

where:

A	=	programmed output amplitude
R	=	(RIS in %)/100
H	=	(HI in %)/100
F	=	(FAL in %)/100
T	=	1/(N f) = period; f = programmed frequency

PULSE –

Programmable Parameters:

DLY	Delay in percent
RIS	Rise Time in percent
HI	High Time in percent
FAL	Fall Time in percent
N	Number of repetitions (frequency multiplier)

Time Function for $0 \le t \le T$, RIS+HI+FAL ≤100% and DLY=0:

$$v(t) = \begin{cases} -\dfrac{A\,t}{2\,R\,T} & \text{for } 0 \le t \le R \cdot T \\[2ex] -\dfrac{A}{2} & \text{for } RT \le t \le (R+H)\,T \\[2ex] +\dfrac{A\left(\dfrac{t}{T} - R - H - F\right)}{2 \cdot F} & \text{for } (R+H)\,T \le t \le (R+H+F)\,T \\[2ex] 0 & \text{for } (R+H+F)\,T \le t \le T \end{cases}$$

where:

A	=	programmed output amplitude
R	=	(RIS in %)/100
F	=	(FAL in %)/100
T	=	1/(N f) = period; f = programmed frequency

TRIANGLE

Programmable Parameters: N Number of repetitions (frequency multiplier)

Time Function for $-\frac{T}{4} \leq t \leq \frac{3 \cdot T}{4}$:

$$v(t) = \begin{cases} A \dfrac{2t}{T} & \text{for } \dfrac{-T}{4} \leq t \leq \dfrac{T}{4} \\ -A\left(\dfrac{2 \cdot t}{T} - 1\right) & \text{for } \dfrac{T}{4} \leq t \leq \dfrac{3T}{4} \end{cases}$$

where:

A = programmed output amplitude
T = 1/(N f) = period (f = programmed frequency)

SAWTOOTH +

Programmable Parameters: N Number of repetitions (frequency multiplier)
DTY Duty Cycle in percent

Time Function for $0 \leq t \leq T$:

$$v(t) = \begin{cases} \dfrac{A}{2} \cdot \dfrac{t}{D \cdot T} & \text{for } 0 \leq t \leq D \cdot T \\ -\dfrac{A}{2} \cdot \dfrac{\frac{t}{T} - 1}{1 - D} & \text{for } D \cdot T \leq t \leq T \end{cases}$$

where:

A = programmed output amplitude
D = (DTY in %)/100
T = 1/(f) = period; f = programmed frequency

SAWTOOTH –

Programmable Parameters: N Number of repetitions (frequency multiplier)
DTY Duty Cycle in percent

Time Function for $0 \leq t \leq T$:

$$v(t) = \begin{cases} -\frac{A}{2} \cdot \frac{t}{D \cdot T} & \text{for } 0 \leq t \leq D \cdot T \\ \frac{A}{2} \cdot \frac{\frac{t}{T} - 1}{1 - D} & \text{for } D \cdot T \leq t \leq T \end{cases}$$

where:

A = programmed output amplitude
d = (DTY in %)/100
T = 1/(Nf) = period; f = programmed frequency

EXPONENTIAL +

Programmable Parameters: EXP Exponential power factor

Time Function for $0 \leq t \leq T$:

$$v(t) = \frac{A}{2} \cdot e^{-\frac{EXP \cdot t}{T}}$$

where:

A = programmed output amplitude
T = 1/f = repitition period; f = programmed frequency

EXPONENTIAL –

Programmable Parameters: EXP Exponential power factor

Time Function for $0 \leq t \leq T$:

$$v(t) = -\frac{A}{2} \cdot e^{-\frac{EXP \cdot t}{T}}$$

where:

A = programmed output amplitude
T = 1/f = repitition period; f = programmed frequency

GAUSSIAN

Programmable Parameters: EXP Exponent

Time Function for $0 \leq t \leq T$:

$$v(t) = \frac{A}{2} \cdot e^{-\left[EXP \cdot \left(\frac{2t}{T} - 1\right)\right]^2}$$

where:

A = programmed output amplitude
T = 1/f = repitition period; f = programmed frequency

HAVERSINE

Programmable Parameters: N Number of repetitions (frequency multiplier)

Time Function:

$$v(t) = \frac{A}{4} \cdot \left[1 - \cos(2\pi Nft)\right]$$

where:

A = programmed output amplitude
f = programmed frequency

CIRCLE

Programmable Parameters: N Number of repetitions (frequency multiplier)
P Phase in degrees

Time Function for $0 \leq t \leq T$:

$$v(t) = \frac{A}{2}\sqrt{1 - \left[2\left(\frac{t}{T} + \frac{P}{360}\right) - 1\right]^2}$$

where:

A = programmed output amplitude
T = 1/f = repitition period; f = programmed frequency

SIN X / X

Programmable Parameters: N Number of repetitions (frequency multiplier)

Time Function for $0 \leq t \leq T$:

$$v(t) = A \cdot \frac{\sin\left[N \cdot (2 \cdot ft - 1) \cdot \pi\right]}{N \cdot (2\pi ft - \pi)}$$

where:

A = programmed output amplitude
f = programmed frequency

NOISE

Programmable Parameters: None

Amplitude probability density:

$$p\left(v(t)\right) = \frac{1}{A}$$

where:

A = programmed output amplitude

$$\text{RMS voltage} = \frac{A}{\sqrt{12}}$$

LINEAR SWEEP

Programmable Parameters: B Beginning-frequency multiplier
E Ending-frequency multiplier

Time Function for $0 \leq t \leq T$:

$$v(t) = \frac{A}{2} \cdot \sin\left\{2\pi f_1 t \cdot \left[1 + \frac{\left(\frac{f_2}{f_1} - 1\right) \cdot t}{2T}\right]\right\}$$

$$f(t) = f_1 + \frac{(f_2 - f_1)}{T} \cdot t$$

where:

A = programmed output amplitude
f_1 = B-f = start frequency
f_2 = E f = stop frequency
T = 1/f = repitition period; f = programmed frequency

LOG SWEEP

Programmable Parameters:

	B	Beginning-frequency multiplier
	E	Ending-frequency multiplier

Time Function for $0 \le t \le T$:

$$v(t) = \frac{A}{2} \cdot \sin\left[\frac{2\pi f_1 T}{\ln\left(\frac{f_2}{f_1}\right)} \cdot \left[\left(\frac{f_2}{f_1}\right)^{\frac{t}{T}} - 1\right]\right]$$

$$f(t) = f_1 \cdot \left(\frac{f_2}{f_1}\right)^{\frac{t}{T}}$$

where:

A	=	programmed output amplitude
f_1	=	B-f = start frequency
f_2	=	E f = stop frequency
T	=	1/f = repitition period; f = programmed frequency

AM

Programmable Parameters:

	CF	Carrier Frequency multiplier
	MF	Modulation Frequency multiplier
	IX	Modulation Index in percent
	MP	Modulation Phase in degrees
	CP	Carrier Phase in degrees

Time Function for $0 \le t \le T$:

$$v(t) = \frac{A}{4}\left[1 + M \cdot \sin\left(2\pi f_m t + \frac{MP \cdot \pi}{180}\right)\right] \cdot \sin\left(2\pi f_c t + \frac{CP\pi}{180}\right)$$

where:

A	=	programmed output amplitude
M	=	(IX in %)/100
f_m	=	MF • f
f_c	=	CF • f
f	=	programmed frequency

SCM

Programmable Parameters:

	CF	Carrier Frequency multiplier
	MF	Modulation Frequency multiplier
	MP	Modulation Phase in degrees
	CP	Carrier Phase in degrees

Time Function for $0 \leq t \leq T$:

$$v(t) = \frac{A}{2} \cdot \sin\left(2\pi f_m t + \frac{MP \cdot \pi}{180}\right) \cdot \sin\left(2\pi f_c t + \frac{CP\pi}{180}\right)$$

where:

A = programmed output amplitude
f_m = MF • f
fc = CF • f
f = programmed frequency

FM

Programmable Parameters:

	CF	Carrier Frequency multiplier
	MF	Modulation Frequency multiplier
	IX	Modulation Index in percent
	MP	Modulation Phase in degrees
	CP	Carrier Phase in degrees

Time Function for $0 \leq t \leq T$:

$$v(t) = \frac{A}{2} \cdot \sin\left[2\pi f_c t - IX\left[\cos\left(2\pi f_m \cdot t + \frac{MP \cdot \pi}{180}\right) - \cos\left(\frac{MP \cdot \pi}{180}\right)\right] + \left(\frac{CP\pi}{180}\right)\right]$$

where

A = programmed output amplitude
f_m = MF • f
fc = CF • f
f = programmed frequency

DC

Programmable Parameters: DC Digital Offset

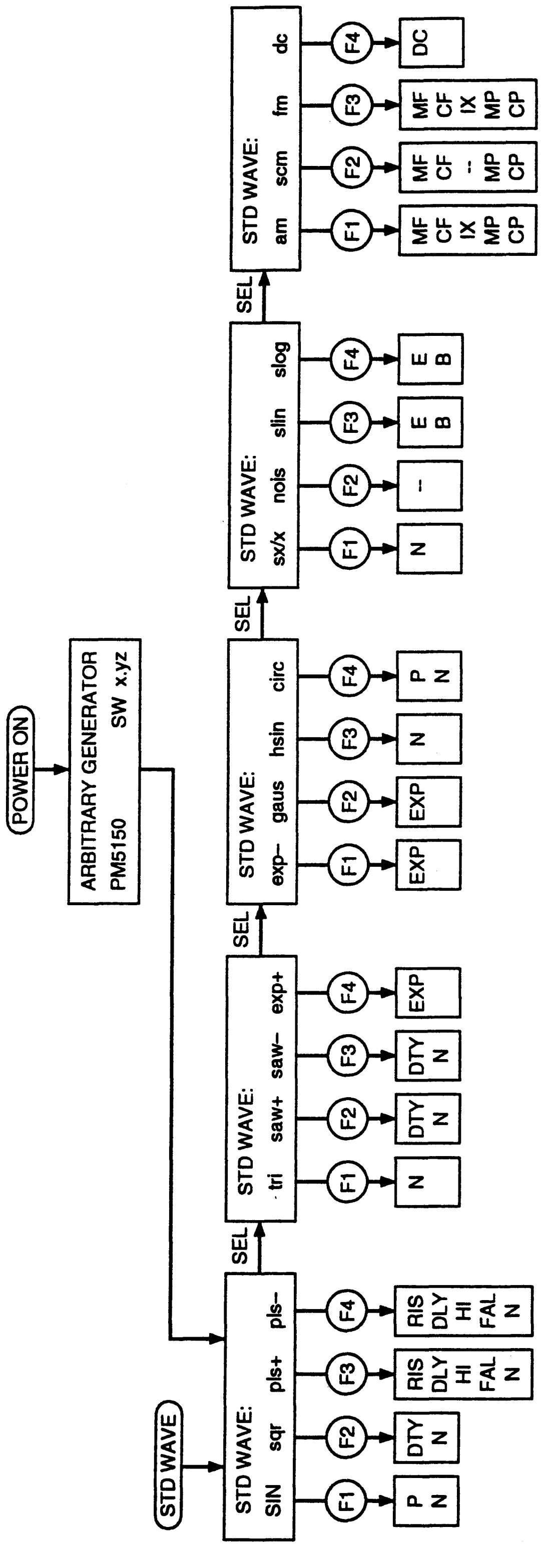
Time Function

$$v(t) = \frac{A \cdot DC}{4096}$$

where

A = programmed output amplitude

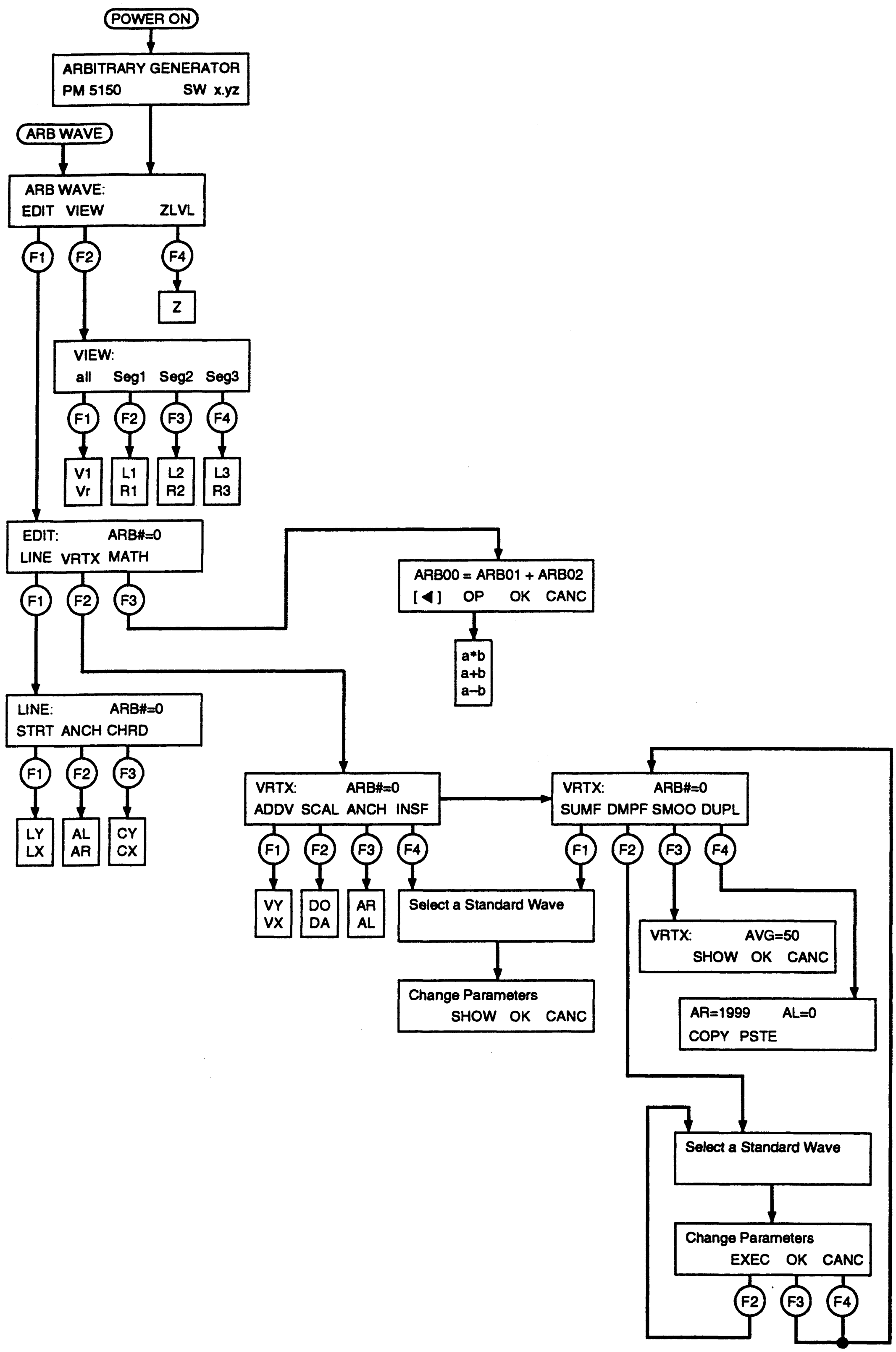
9.3 APPENDIX C
FUNCTION/MENU TREES



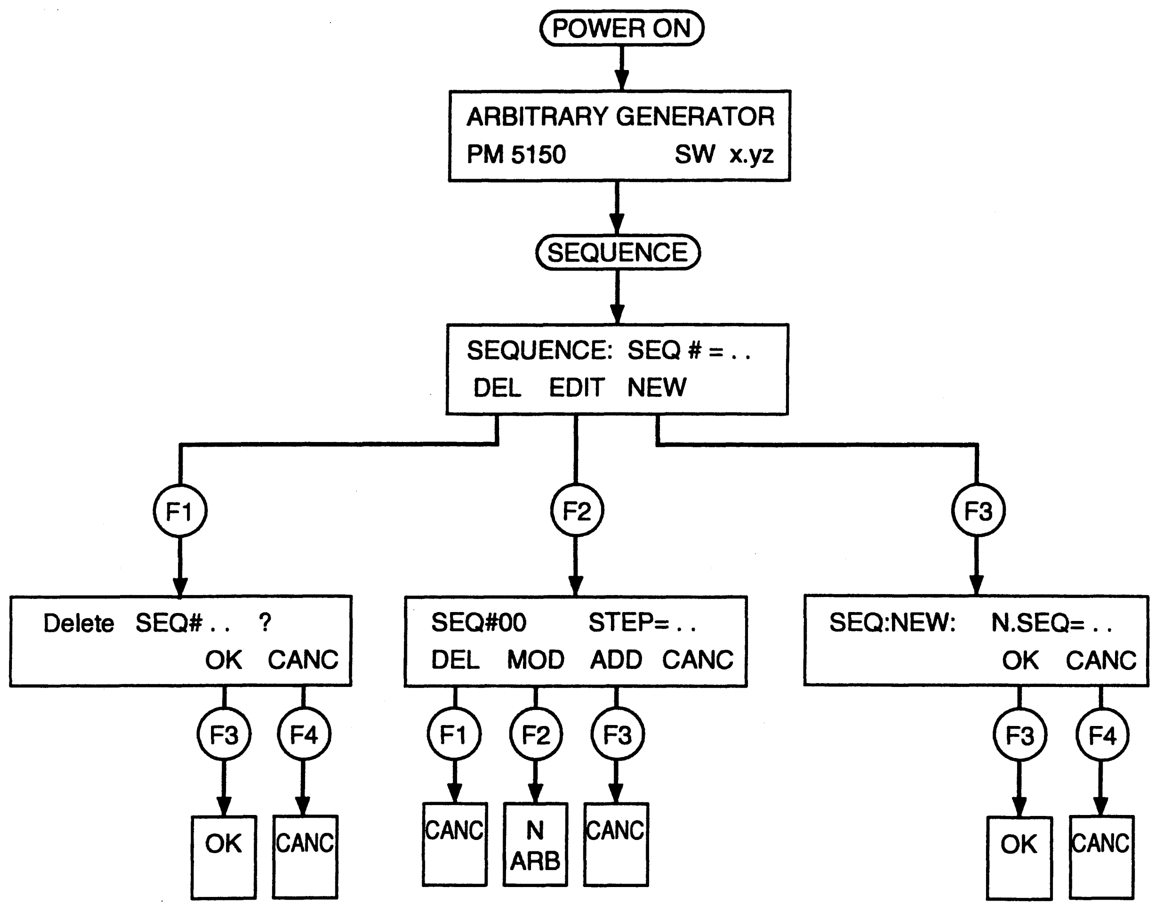
WAVEFORM PARAMETERS

P	= Phase in degrees	FAL	= Fall time in %	IX	= Modulation index
N	= Frequency multiplier	EXP	= Exponential – Power factor	MP	= Modulation Phase in degrees
DTY	= Duty cycle in %	E	= End, stop – frequency multiplier	CP	= Carrier Phase in degrees
RIS	= Rise time in %	B	= Begin, start – frequency multiplier	DC	= Voltage Offset
DLY	= Delay time in %	MF	= Modulation – frequency multiplier	DO	= Digital Offset
HI	= High time in %	CF	= Carrier – frequency multiplier	DA	= Digital Amplitude

Standard Wave Function/Menu Tree

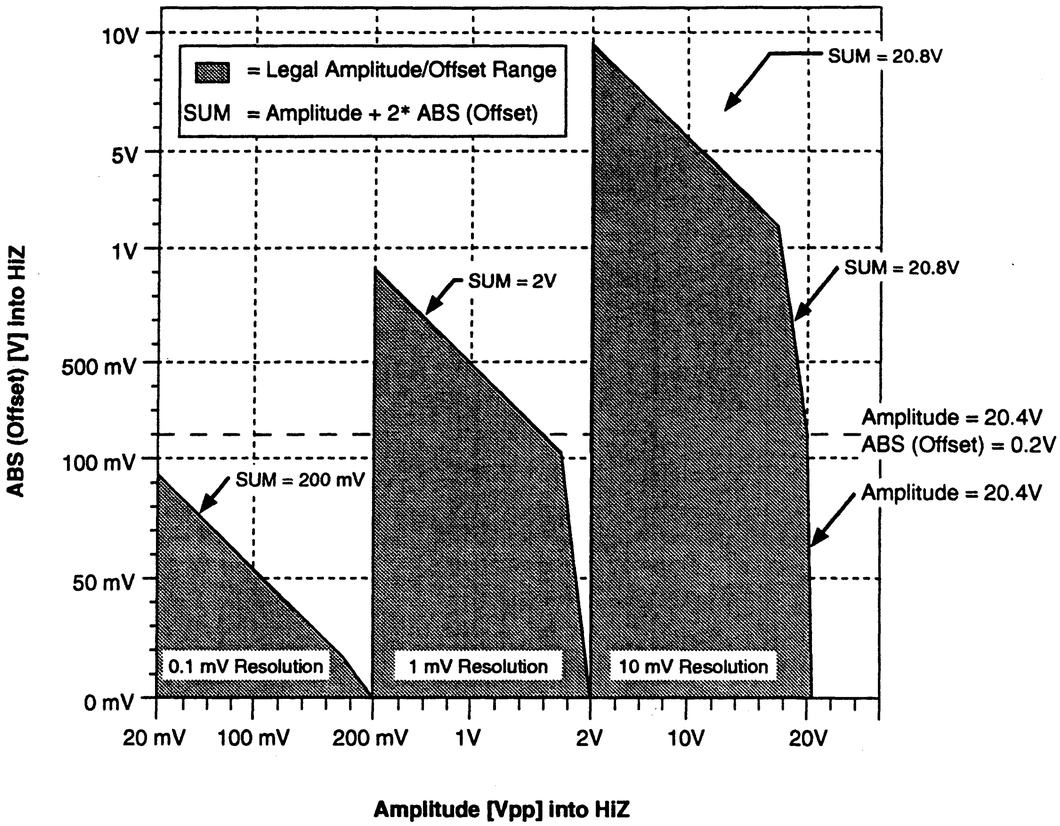


Arbitrary Wave Function/Menu Tree



Sequence Generator Function/Menu Tree

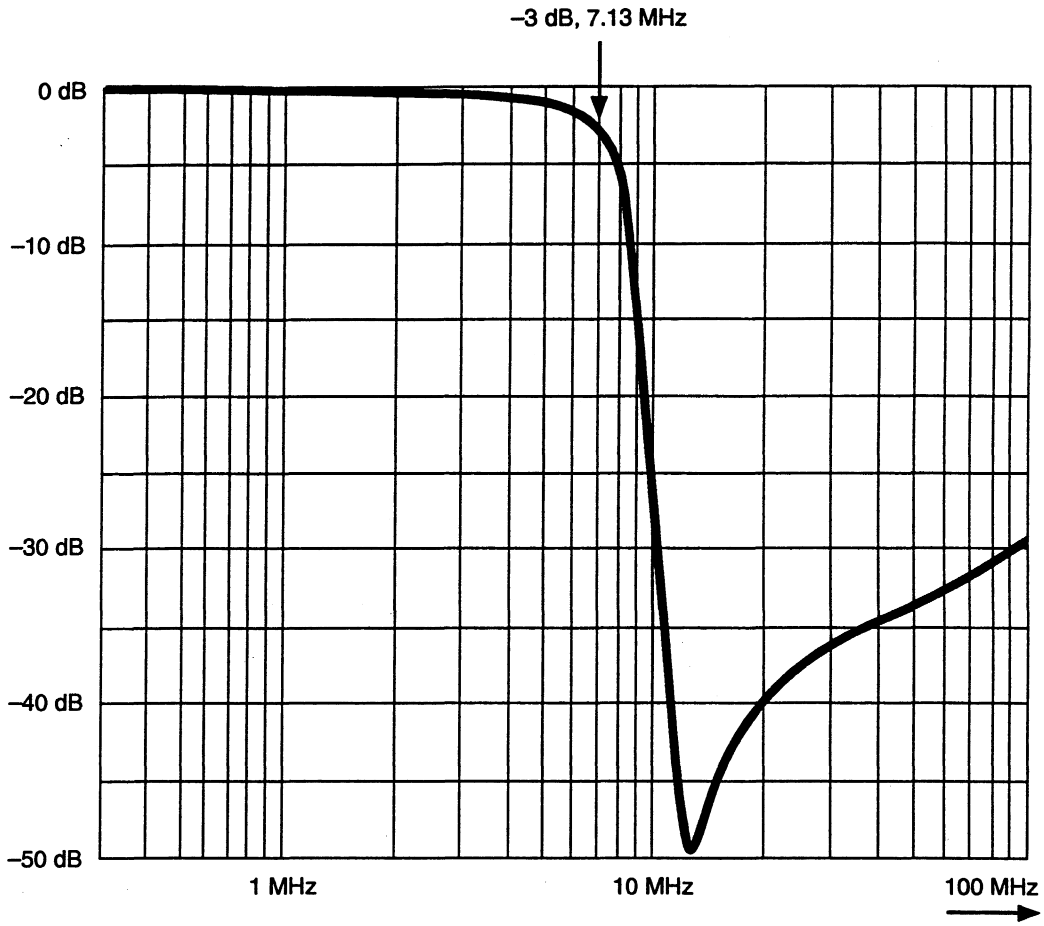
9.4 APPENDIX D
RESOLUTION/RANGE GRAPH



LEGAL AMPLITUDE/OFFSET RANGES:

Amplitude 20 mV	... 200 mV	:	ABS (Offset) ≤ 0.5 * (200 mV – Amplitude)
Amplitude >200 mV	... 2V	:	ABS (Offset) ≤ 0.5 * (2V – Amplitude)
Amplitude >2v	... 20.4V	:	ABS (Offset) ≤ 0.5 * (20.8V – Amplitude)

9.5 APPENDIX E
OUTPUT FILTER RESPONSE CURVE



9.6 APPENDIX F
RESET TABLE

The table that makes up this appendix shows the details of the RESET operation: which functions are reset, and which are not under the two types of reset.

RESET ALL — Via the front panel RESET key and ALL softkey, or by sending the remote message RESET ALL.

RESET CURR — Via the front panel RESET key and CURR softkey, or by sending the remote messages RESET CURR or *RST.

Checkmark √ = YES

RESET Functions

PARAMETER		VALUE/STATUS	RESET ALL	RESET CURR
Sample Clock Frequency		10.00 MHz	√	√
Sample Clock Select		INTernal	√	√
Trigger Generator Rate		50 mS	√	√
Trigger Generator State		OFF	√	√
Reference Clock Adjust		0	√	√
Reference Clock Select		INTernal	√	√
Amplitude peak to peak		10.00 V	√	√
Offset		0	√	√
Filter		OFF	√	√
Output Switch		OFF*	√	√
Function		STD WAVE	√	√
Mode		CONTinous	√	√
Burst Count		3	√	√
Trigger Input Mode		ASYNChronous	√	√
Trigger Output Mode		SERial	√	√
Standard Functions				
Sine	⟨cycles⟩	1	√	√
	⟨phase⟩	0	√	√
Square	⟨cycles⟩	1	√	√
	⟨duty cycle⟩	50%	√	√
Pulse ±	⟨cycles⟩	1	√	√
	⟨delay⟩	0%	√	√
	⟨risetime⟩	10%	√	√
	⟨hightime⟩	30%	√	√
	⟨falltime⟩	10%	√	√
Triangle	⟨cycles⟩	1	√	√
Sawtooth ±	⟨cycles⟩	1	√	√
	⟨duty cycle⟩	100%	√	√
Exponential ±	⟨exponent⟩	5.00	√	√
Gaussian ±	⟨exponent⟩	2.00	√	√
Haversine	⟨cycles⟩	1	√	√
Circle	⟨cycles⟩	1	√	√
	⟨phase⟩	0	√	√
Sine X over X	⟨cycles⟩	5.50	√	√
Linear Sweep	⟨start cycles⟩	1	√	√
	⟨stop cycles⟩	10	√	√
Log Sweep	⟨start cycles⟩	1	√	√
	⟨stop cycles⟩	10	√	√
AM	⟨carrier cycles⟩	20	√	√
	⟨carrier phase⟩	0	√	√
	⟨modulation cycles⟩	1	√	√
	⟨modulation phase⟩	0	√	√
	⟨modulation index⟩	50%	√	√
SCM	⟨carrier cycles⟩	20	√	√
	⟨carrier phase⟩	0	√	√
	⟨modulation cycles⟩	1	√	√

RESET Functions (cont)

PARAMETER		VALUE/STATUS	RESET ALL	RESET CURR
	⟨modulation phase⟩	0	√	√
FM	⟨carrier cycles⟩	20	√	√
	⟨carrier phase⟩	0	√	√
	⟨modulation cycles⟩	1	√	√
	⟨modulation phase⟩	0	√	√
	⟨index⟩	10.00	√	√
DC		0	√	√
Sync Selects	⟨SYNC1⟩	ENDPoint	√	√
	⟨SYNC2⟩	Waveform RUN	√	√
	⟨SYNC3⟩	ENDBlock	√	√
Waveform Memory				
ARB WAVE	⟨numbers⟩	00 - 04	√	NO
	⟨size⟩	2000 points	√	NO
	⟨data⟩	affected	√	NO
STD WAVE	⟨size⟩	1000 points	√	NO
	⟨data⟩	sine, 1 cycle	√	NO

* *When performing a RESET via the front panel, the instrument automatically changes to the OUTPUT menu.*

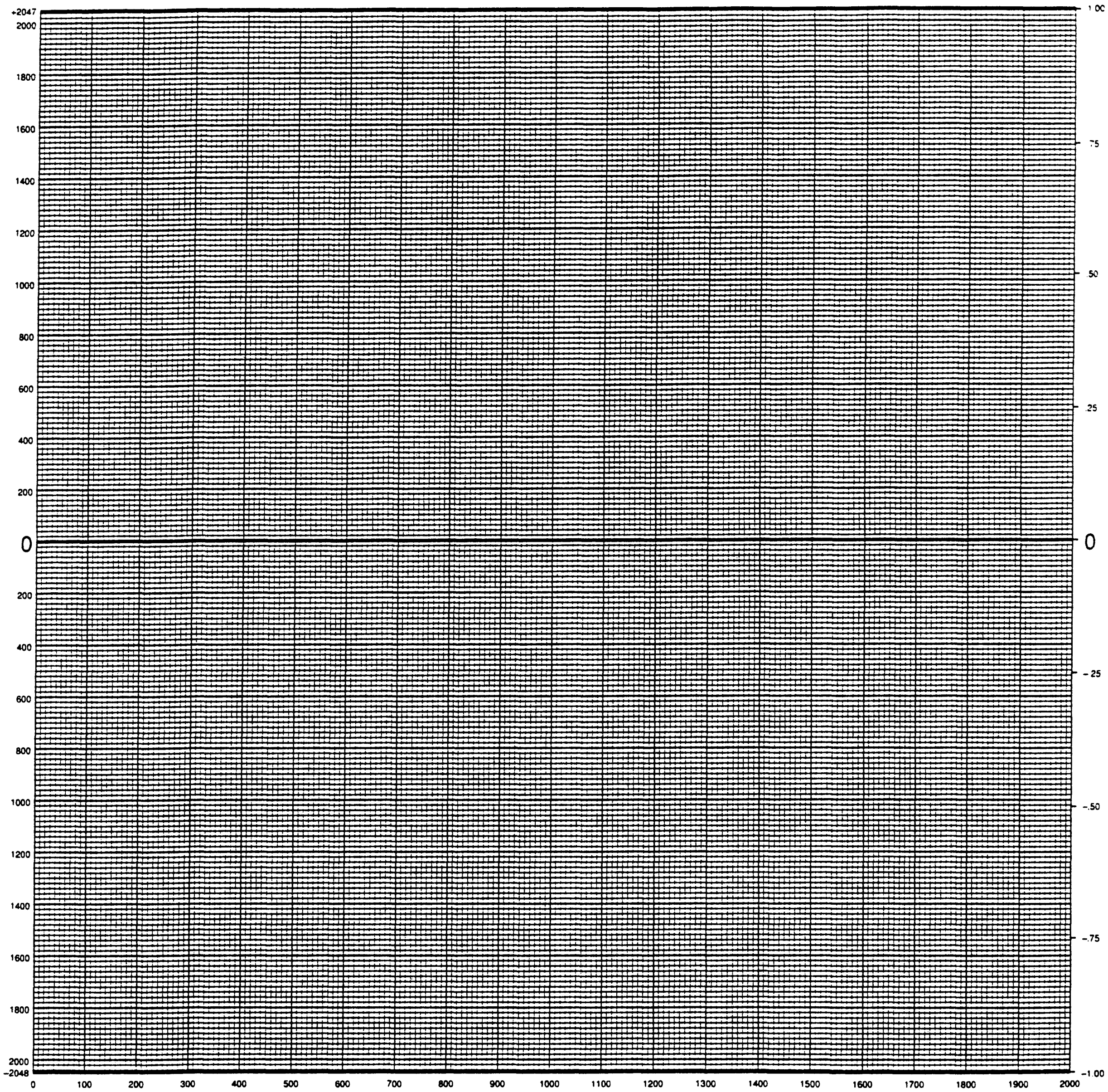
9.7 APPENDIX G
WAVEFORM DESIGN WORKSHEET

The graph on the next page is suitable for reproduction and has been provided as a worksheet for designing your own custom waveforms. If you wish, you can make an enlargement copy at a scale factor of 1:1.25 to obtain direct measurement in millimeters.

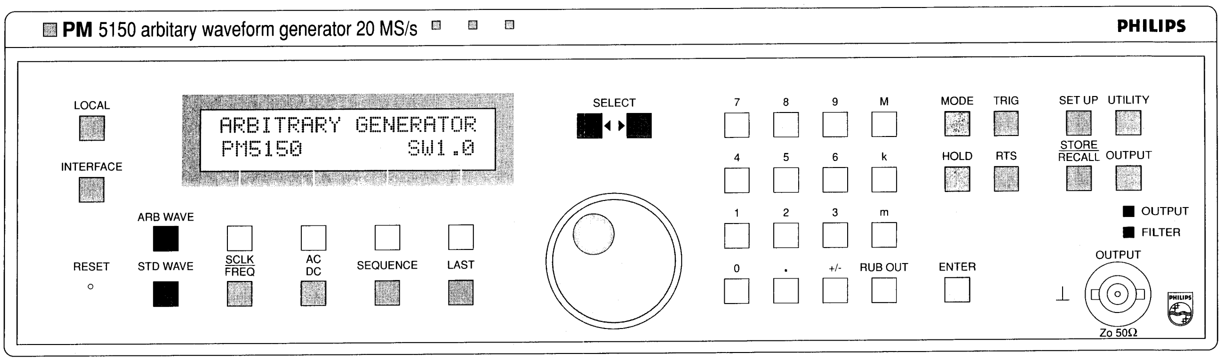
Waveform Design Worksheet

ARB # ______________________ Waveform Type ______________________

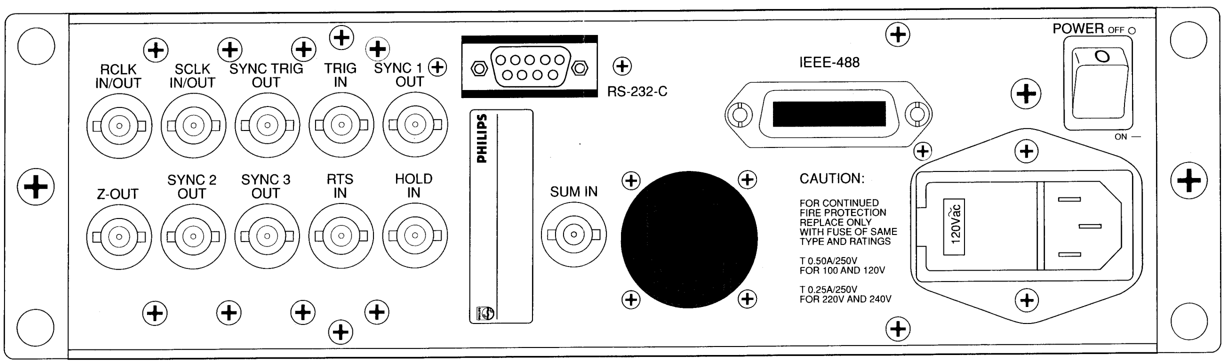
LEN (Length) ______________________ Application ______________________



Waveform Design Worksheet



FRONT PANEL



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Australia New Zealand
Philips Scientific & Industrial PTY Ltd.
Test & Measurement Dept.
NZ Head Office
2 Wagner Place
PO Box 4021
Auckland 3
New Zealand
Tel: 09-894160
Fax: 09-862728
TLX: NZ 2395

Australia Head Office
Philips Scientific & Industrial PTY Ltd.
Test & Measurement Dept.
Centrecourt 25-27 Paul Street
North Ryde
Sydney New South Wales 2113
Tel: 02-888 0416
Tel: 02-888 8222*
Fax: 02-888 0440
TLX: AA 20165 philind ausnrsi

Philips Scientific & Industrial PTY Ltd.
Test & Measurement
23 Lakeside Drive
East Burwood
Melbourne Victoria 3151
Tel: 03-235 3666
Fax: 03-235 3618

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Test & Measurement
348 Torrens Road
Croyden
Adelaide South Australia 5008
Tel: 08-3482888
Fax: 08-3482813

Philips Scientific & Industrial PTY Ltd.
Test & Measurement
299 Montagne Road
West End
Brisbane Queensland 4101
Tel: 07-8440191
Fax: 07-8448537

Philips Scientific & Industrial PTY Ltd.
Test & Measurement
1 Frederick Street
Belmont
Perth West Australia 6104
Tel: 09-277-4199
Fax: 09-277-1202

Austria
Philips Professionelle Elektronik GmbH
Marktbereich Test- und Messgeraete
Gutheil Schoder Gasse 10
A 1102 Wien
Tel: 0222/60101-0
Fax: 0222-6272165
TLX: 133129

Philips Professionelle Elektronik GmbH
Marktbereich Test- und Messgeraete
Technischer Kundendienst
Triesterstrasse 64
1101 Wien
Tel: 0222-60101 ext. 818

Bahrain
Messrs. Mohamed Fakhroo & Bros
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Bahrain
Tel: 973-253529
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TLX: Mannings 2355 WB

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Philips Professional Systems S.A.
Test & Measurement Department
Tweestationstraat 80
1070 Brussel
Tel: 02-525 6692
Tel: 02-525 6694*
Fax: 02-230-2856*
Fax: 02-525 6483
TLX: 61511 belbrms

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Hamilton
Tel: 809-2955000
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04661 Sao Paulo S.P.
Tel: 55-11-5234811
Fax: 55-11-5244873

ATP Hi-Tek Electronica Ltda.
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06400. Barueri
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L4Z 1X9 Canada
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Fax: (416) 890-6866

Fluke Electronics Canada Inc.
1690 Woodward Drive
Suite 216
Ottawa. Ontario
K2C 3R8 Canada
Tel: (613) 723-9453
Fax: (613) 723-9458

Fluke Electronica Canada Inc.
1255 Trans Canada Highway
Suite 120
Dorval. Quebec
H9P 2V4. Canada
Tel: (514) 685-0022
Fax: (514) 685-0039

Fluke Electronics Canada Inc.
101. 1144 - 29th Ave. N.E.
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T2E 7P1 Canada
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Santiago. Chile
Tel: (56) (2) 232-4308
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TLX: (332) 346351

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Philips HongKong Ltd.
Site 7 ground floor. Whampoa Garden
Hung Hom. Kowloon, HongKong
Tel: 7735588
Fax: (852) 3345496
TLX: 43752 PHILH HX

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Costa Rica
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Prags Boulevard 80
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Head Office
Miramstrasse 87
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Fax: 82-2-7978048
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Mijin Bld. 116-2 Samsung-Dong
Kangnam-Ku
Seoul
Korea
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Fax: 82-2-5566816
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Fax: 400577
TLX: 60572

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Fax: 60-3-7560761
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Fax: (525) 687-8695
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Casablanca 05
Tel: 308051/52
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Kathmandu, Nepal
Tel: 13868
TLX: (947) 2588 ASCENT NP

Netherlands
Philips Nederland B.V.
Test en Meetapparaten
Hoevenseweg 55A
Postbus 115
5000 AC Tilburg
Tel: 013-390112
Fax: 013-427528
TLX: 52683

Philips Nederland
Technische Service Prof. Akt.*
Hurksestraat 2C
Gebouw HBR
5652 AJ Eindhoven
Tel: 040-723293
Fax: 040-723337
TLX: 59279 MILAP NL

New Zealand
Philips Scientific & Industrial PTY Ltd.
Test & Measurement Dept.
2 Wagner Place
PO Box 4021
Auckland 3
Tel: 09-084-160
Fax: 09-862728
TLX: N2 2395

Nigeria
Associated Electronic Products
(Nigeria) Ltd.
KM 16, Ikorodu Road
Ojota
PO Box 1921
Lagos
Tel: 234-1-900160/69
Fax: 234-1-615601

Norway
Norsk A/S Philips
Dept. I & E Test & Measurement
Sandstuveien 70
PO Box 1 Manglerud
0612 Oslo 6
Tel: 47-2-741010
Tel: 47-2-290942
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TLX: 856-72640

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PO Box 7101
Karachi - 74400
Tel: 92-21-725772-8
Fax: 92-21-726694
TLX: 2874 PHPAK PH

International Operations (PAK Private), Ltd.
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505 Muhammadi House
I.I. Chundrigar Road
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TLX: py 215

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Fax: 51-14-350059 ext. 3294

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Philips Industrial Development Inc.
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106 Valero Street
Salcedo Village
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Fax: 817-3474

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Metro Manila 1502
Philippines
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Fax: (63) (2) 7220313
TLX: (712) 4005 RLA PH PU

Poland
Electronic Instrument Service*
(Philips Service)
Ul. Malechowska 6
60-188 PODZNAN
Tel: 48-61-481998
TLX: 0413791 PHIL PL

Portugal
Philips Portuguesa, S.A.R.L. Division of I & E Test & Measurement
Av. Eng. Duarte Pacheco 6
1009 Lisboa Codex
Tel: 1-657181
Fax: 1-658013

Philips Portuguesa* Division I & E
Rua Eng Erequli de Campos 182
4100 Porto
Tel: (2) 678278
TLX: 28790

Qatar
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Tel: 974-434308
Fax: 974-426378

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Messrs. A. Rajab & A. Silsilah
Head Office
PO Box 203
Jeddah 21411
Tel: 966-2-6610006
Fax: 966-2-6610164
TLX: 601180 arndas sj

Messrs. A. Rajab & A. Silsilah
PO Box 260
Riyadh 11411
Tel: 966-1-4122425
Fax: 966-1-4122366
TLX: 404787 arndas sj

Messrs. A. Rajab & A. Silsilah
PO Box 587
Damman
Tel: 966-3-8322596/8331870
Fax: 966-3-8271962
TLX: 601044 arndas sj

Singapore
Philips Project Development (S) PTY Ltd.
(For Philips products)
Lorong 1, Toa Payoh
Singapore 1231, PO Box 340
Toa Payoh Central Post Office
Singapore 9131
Tel: 65-3502000
Fax: 65-2535873
TLX: philips rs/21375

Rank O'Connor's Pte Ltd.
(For Fluke products)
O'Connor House
98 Pasir Panjang Road
Singapore 0511
Republic of Singapore
Tel: (65) 473-7944
Fax: (65) 472-4508
TLX: (766) RS 21023 OCONSIN

South Africa
South African Philips PTY Ltd. I & E Division Test & Measurement
10 Bondstreet, Randburg
Johannesburg 2000
Tel: 27-11-889-3911
Fax: 27-11-889-3098/889 3191
TLX: 4-26152-sa

South African Philips PTY Ltd.* I & E Customer Support Centre
195 Mai Road, PO Box 58088
Martindale, New Ville 2092
Tel: 27-11-470-5937
Fax: 27-11-470-5166
TLX: 4-26152 SA

Spain
Philips Iberica SAE
Depto Instrumentacion de Medida
Poligono Industrial Zona Franca
Sector C-calle F
08004 Barcelona
Tel: 34-3-3361061
Fax: 34-3-3355838
TLX: 51293/59292

Philips Iberica*
Depto Instrumentacion de Medida
Martinez Villergas 2
28027 Madrid
Tel: 34-1-4042200
Fax: 34-1-4048603
TLX: 27710

Philips Iberica SAE*
Jose Olabarria 6
48012 Bilbao
Tel: 34-4-4313800
Fax: 34-4-432 0961
TLX: 31230

Sri Lanka
Hayleys Electronics & Engineering Ltd.
400, Deans Road
P.O. Box 70
COLOMBO 10
Tel: 94-1-699087
Fax: 94-1-699299
TLX: 23059 SRLCOHA

Computerlink Data Systems, Ltd.
(For Fluke products)
68 Havelock Rd.
Colombo, 5, Sri Lanka
Tel: (94) (1) 502202/3
Fax: (94) 1-502203
TLX: (954) 22455 COLINK CE

Surinam
C. Kersten & Co. N.V.
P O Box 1808
PARIMARIBO

Surtel
P.O. Box 155
PARIMARIBO
Tel: 597-72118/77880
Fax: 597-52745
TLX: 162 SN

Sweden
Philips Kistaindustrier AB Test & Measurement
PO Box 33
16493 Kista
Tel: 46-8-7031370
Fax: 46-8-7520743
TLX: 17173 philkis

Switzerland
Philips AG Test und Messtechnik
Postfach 670
8027 Zurich
Tel: 01 4882390
Fax: 01 4828595
TLX: 815780-0

Philips SA Test et Mesure
Avenue du Mont Blanc
1196 Gland
Tel: 022/647171

Syria
Al-Shahed Electronics and Trading Co.
Fardoss Street 79
Kassas and Sadat Building
P.O. Box 2442
Damascus
Tel: 228003/218605
TLX: 411203 phisyr

* Sales and Service Centers

Sales and Service all over the world

Taiwan
Philips Taiwan Ltd.
(For Philips products)
581, Min Sheng East Road
10446 Taipei
Taiwan
Tel: 886-2-5097666
Fax: 886-2-5005899
Schmidt Scientific
5/F, 344 Min Sheng E. Rd.,
Taipei
Taiwan
Tel: 02-5005779
Fax: 886-2-5029692
TLX: 11111 Schmidt

Tanzania
Philips (Tanzania) Ltd.
Nkrumah Street
Dar es Salaam
Tel: 2555129571
TLX: 41016

Thailand
Philips Electrical Co. of Thailand Ltd.
(For Philips products)
283, Silom Road
PO Box 961
Bangkok 10500
Tel: 66-2-233-6330/9
TLX: 87327 philtha th
Measuretronix Ltd.
(For Fluke products)
210231 Ramkamhaeng Road
Bangkok 10240
Thailand
Tel: (66) (2) 375-2733
Fax: (66) 2-374-9965
TLX: (788) 82796 HUAMARK TH

Trinidad West Indies
Compression & Power Services (1988) Ltd.
P.O. Box 76
SAN FERNANDO By Pass
Tel: 653-5445/6/7
Fax: 1.809.657.0353
TLX. 32451 WG

Tunesia
S.T.I.E.T.
32 bis rue Ben Gheoanem
Tunis
Tel: 348666
TLX: 14512

Turkey
Turk Philips Ticaret A.S.
Talatpasa Caddesi no. 5
PO Box 161
80640 Levent-Istanbul
Tel: 90-1-1792770
Fax: 90-1-1693094
TLX: 24192 phtr tr

United Arab Emirates
Al Sanani Trading Est.
PO Box 7187
Abu Dhabi, U.A.E.
Tel: 971-2-771370
Fax: 971-2-728963
TLX: 23966 Sanani em
Haris Al-Afaq Ltd.
PO Box 8141
Dubai, U.A.E.
Tel: 971-4-283625
Fax: 971-4-281285

Uruguay
Industrias Philips del Uruguay S.A.
(For Philips products)
Avenida Uruguay 1287
Casilla de Correo 294
Montevideo, Uruguay
Tel: (598) (2) 921111
Fax: (598) (2) 920601

U.S.S.R.
N.V. Philips Gloeilampenfabrieken
Mytnaya Str.1
Fl. 7, Office 18
MOSCOW
Tel: 7095-2302485
Fax: 7095-2302485
TLX: 413961 PHIL SU

Infomedia Sotrudnichiestvo
Kievskaya, 2 - Office 106
121111 MOSCOW
Tel: 240 52 52
Fax: 230 28 18
TLX: 411670 DNEPR SU

Venezuela
Inds. Venezolanas Philips S.A.
(For Philips products)
Apartado Aereo 1167
Caracas 1010-A
Tel: 58-2-905.7061
Fax: 58-2-951.7339
TLX: 25267 ivpsa vc
Cossin C.A.
(For Fluke products)
Calle 9 Con Calle 4, Edifl Edinurbi
Apartado de Correos NR-70.136
Los Ruices
Caracas 1070-A, Venezuela
Tel: (58) (2) 241-03-09
TLX: (395) 21027EMVEN VC

Yemen
Rashed Trading & Travel Agency
Ali Abdulmugni st.
PO Box 1221
Sana'a, Yemen
Tel: 967-2-273231
TLX: 2230 abgbar ye

Yugoslavia
N.V. Philips Gloeilampenfabrieken
Strahinjica Bana 47/II
Postanksi fah 484
BEOGRAD
Tel: 38-11-625344
Fax: 38-11-635777
TLX: 12499 YU PHILIPS
Jugoelectro*
Jurija Gaganina 81
Block 70
11070 BEOGRAD
Tel: 38-11-178134
Fax: 38-11-175472
TLX: 12370 YUJUELB
Technicar Servis*
(For Fluke products)
Jurisiceva 25
41000 ZAGREB
Tel: 041-276333
Fax: 041-274416

Zaire
Philips Electronics S.A.R.L.
137 Boulevard du 30 Juin
BP 16636
Kinshasa
Tel: 31693
TLX: 21078 kinshasa

Zambia
Philips Electrical Zambia Ltd.
Mwembeshi Road
PO Box 31878
Lusaka
Tel: 218511/218701
TLX: za 41220

Zimbabwe
Philips Electrical (Pvt.) Ltd.
62 Mutare Road
PO Box 994
Harare
Tel: 263-4-47211
Fax: 263-4-47966
TLX: 2236 ZW

For Countries not listed above:
Philips Export B.V.
I & E Export
Test & Measurement
Building HVW-3
PO Box 218
5600 MD Eindhoven
The Netherlands
Tel: +31 40 766546
Fax: +31 40 766612
TLX 35000 phtc nl
Fluke Int'l Corp.
PO Box 9090
Mail Stop 206A
Everett, WA 98206-9090
Tel: 206-356-5500
Fax: (206) 356-5116
TLX: 185103 FLUKE UT

U.S.A.

Alabama
Huntsville
4920 Corporate Drive Suite J
Huntsville, AL 35805-6202
(205) 837-0581

Arizona
Phoenix
2211 S. 48th Street Suite B
Tempe, AZ 85282
(602) 438-8314

California
Irvine*
PO Box 19676
Irvine, CA 92714
(714) 863-9031
Nothern*
46610 Landing Parkway
Fremont, CA 94538
(415) 651-5112

Colorado
Denver*
14180 E. Evans Ave.
Aurora, CO 80014
(303) 695-1000

Connecticut
Hartford
Glen Lochen East
41-C New London Turnpike
Glastonbury, CT 06033
(203) 659-3541

Florida
Altamonte Springs*
550 South Northlake Blvd.
Altamonte Springs,
FL 32803
(407) 331-4881

Georgia
Atlanta
2700 Delk Road Suite 150
Marietta, GA 30067
(404) 953-4747

Illinios
Chicago*
1150 W. Euclid Avenue
Palatine, IL 60067
(708) 705-0500

Indiana
Indianapolis
8777 Purdue Road Suite 101
Indianapolis, IN 46268
(317) 875-7870

Massachusetts
Boston
900 Middlesex Technology Center
Building 8
Billercia, MA 01821
(508) 663-2400

Maryland
Rockville*
5640 Fishers Lane
Rockville, MD 20852
(301) 770-1570

Michigan
Detroit
45550 Helm Street
Plymouth, MI 48170
(313) 522-9140

Minnesota
Minneapolis
1380 Corporate Center Curve
Suite 113
Eagan, MN 55121
(612) 854-5526

Missouri
St. Louis
11756 Borman Drive Suite 160
St. Louis, MO 63146
(314) 993-3805

New Jersey
Paramus*
PO Box 930
Paramus, NJ 07652
(201) 262-9550

New York
Rochester
4515 Culver Road
Rochester, NY 14622
(716) 323-1400

North Carolina
Greensboro
1310 Beaman Place
Greensboro, NC 27408
(919) 273-1918

Ohio
Cleveland
Plaza South Three Suite 402
7271 Engle Road
Middleburg Heights, OH 44130
(216) 234-4540

Pennsylvania
Philadelphia
200 Lindenwood Drive
Malvern, PA 19355
(215) 647-9550

Texas
Dallas*
1801 Royal Lane Suite 307
Dallas, TX 75229
(214) 869-0311
San Antonio
10417 Gulfdale
San Antonio, TX 78216
(512) 340-0498

Washington
Seattle*
2375 130th Ave. N.E.
Suite 100
Bellevue, WA 98005
(206) 881-6966

* Sales and Service Centers