INSTRUCTION MANUAL

MODEL 175 ARBITRARY WAVEFORM GENERATOR

WAVETEK®

SAN DIEGO

9045 Balboa Ave., San Diego, CA 92123
P.O. Box 651, San Diego, Calif. 92112
Tel 714/279-2200 TWX 910-335-2007

619-565 9234

Jim Wookey

Manual Revision 5/80
Instrument Release D-2/80

WARRANTY

All Wavetek instruments are warranteed against defects in material and workmanship for a period of one year after date of manufacture. Wavetek agrees to repair or replace any assembly or component (except batteries) found to be defective, under normal use, during this period. Wavetek's obligation under this warranty is limited solely to repairing any such instrument which in Wavetek's sole opinion proves to be defective within the scope of the warranty when returned to the factory or to an authorized service center. Transportation to the factory or service center is to be prepaid by purchaser. Shipment should not be made without prior authorization by Wavetek.

This warranty does not apply to any products repaired or altered by persons not authorized by Wavetek, or not in accordance with instructions furnished by Wavetek. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

Wavetek assumes no responsibility for its product being used in a hazardous or dangerous manner either alone or in conjunction with other equipment. High voltage used in some instruments may be dangerous if misused. Special disclaimers apply to these instruments. Wavetek assumes no liability for secondary charges or consequential damages and, in any event, Wavetek's liability for breach of warranty under any contract or otherwise, shall not exceed the purchase price of the specific instrument shipped and against which a claim is made.

Any recommendations made by Wavetek for use of its products are based upon tests believed to be reliable, but Wavetek makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, expressed or implied, and no representative or person is authorized to represent or assume for Wavetek any liability in connection with the sale of our products other than set forth herein.

SAFETY

This instrument is wired for earth grounding via the facility power wiring. Do not bypass earth grounding with two wire extension cords, plug adapters, etc.

BEFORE PLUGGING IN the instrument, comply with installation instructions.

MAINTENANCE may require power on with the instrument covers removed. This should be done only by qualified personnel aware of the electrical hazards.

WARNING notes call attention to possible injury or death hazards in subsequent operation.

CAUTION notes call attention to possible equipment damage in subsequent operations.

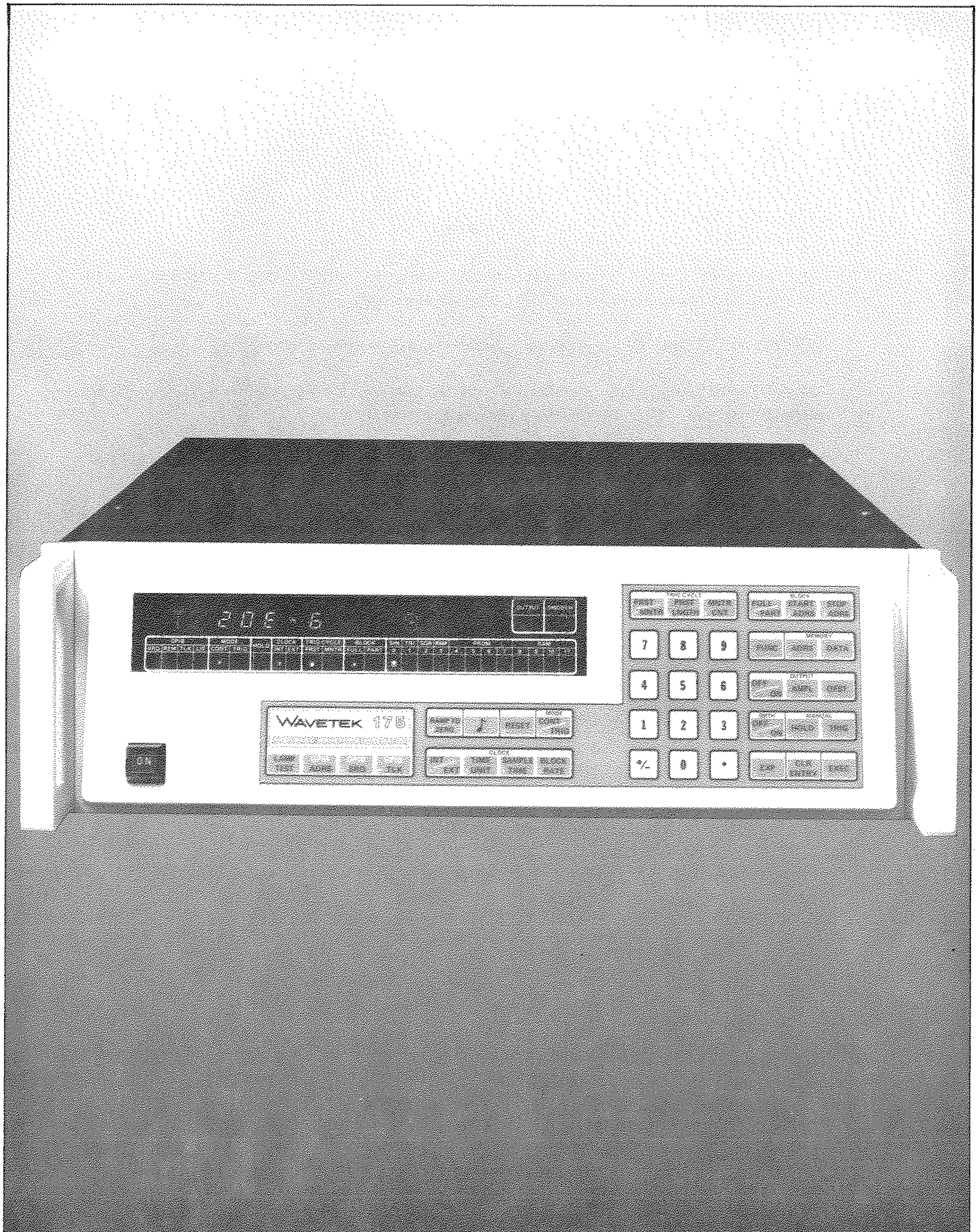


Figure i — Model 175 Arbitrary Waveform Generator

SECTION 1
GENERAL DESCRIPTION

1.1 THE MODEL 175

The Model 175, Arbitrary Waveform Generator (Arb), generates any waveform that can be expressed as a function of time. The working Random Access Memory (RAM) has four sets of 256 addresses and each address accepts an 8 bit word. This corresponds to a 1024 (time) by 255 (amplitude) matrix in which to draw waveforms. These storage addresses can be manually loaded by front panel controls or remotely loaded via the GPIB interface. The stored waveform, or any portion thereof, then can be generated at selectable clock rates and amplitudes.

In addition to the four working Random Access Memories (RAMs), four optional Programmable Read Only Memories (PROMs) allow the same capacity for permanent waveform storage. Sine, triangle, square and ramp waveforms are always available.

Operation can be continuous or triggered. Triggering can be for a preset number of cycles or the number of cycles triggered can be monitored and displayed. Start and stop addresses are selectable for partial waveform output. At low frequencies, point-to-point smoothing can be selected to minimize digital step size. Output may be held at any level, or amplitude and offset can be slowly ramped to zero when a ramp to zero command is given.

Front panel operation is by keyboard and display which gives immediate verification of parameter and value in memory.

The Model 175 is fully compatible with the requirements of IEEE Standard 488-1975 for integration into a General Purpose Interface Bus (GPIB).

1.2 SPECIFICATIONS

1.2.1 Versatility

1.2.1.1 Waveforms

Sine, square, triangle, ramp, arbitrary waveforms and TTL sync. (See figure 1-1.)

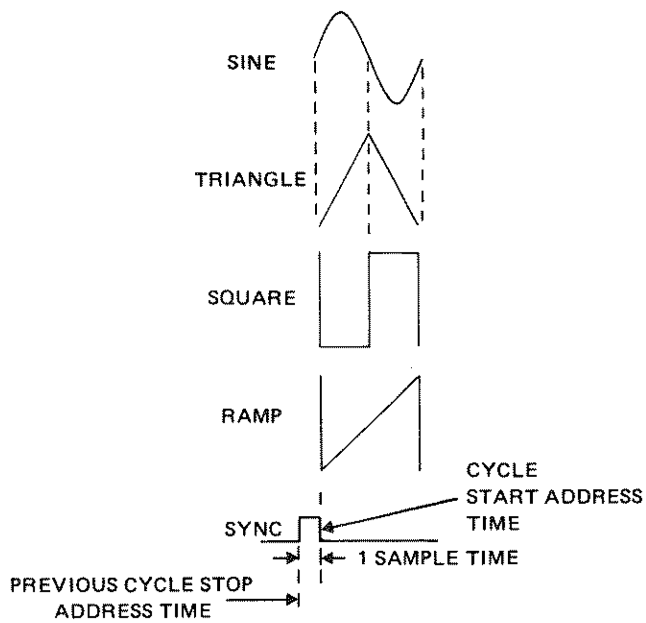


Figure 1-1. Fixed Waveforms

1.2.1.2 Arbitrary Waveforms

Arbitrary waveforms are stored on four 256 X 255 point RAM matrices and four 256 X 255 user-supplied PROM matrices. Each PROM or RAM block can be addressed individually or they can be addressed in sequence; e.g., PROMs 1 and 2, PROMs 1, 2 and 3 or PROMs 1, 2, 3 and 4. This feature allows additional address resolution of custom waveforms. Block length can be from 2 to 256 address points, or when blocks are stacked, up to 1024 address points.

1.2.1.3 Digital Smoothing

When smoothing is selected, each change in amplitude data is subdivided into 100 substeps per sample time. Smoothing is automatically limited to 20 μs or slower sampling times and to point-to-point data differentials less than 64.

1.2.1.4 Sync Output

TTL level pulse with a trailing edge coincident with the start address. Pulse width is one sample time. Available at rear panel BNC.

1.2.1.5 Cursor Output

TTL level output coincident with a selected data address. Available at rear panel BNC.

1.2.1.6 Operational Modes

Continuous: Generator operates continuously at selected frequency.

Preset Triggered: Generator quiescent until triggered via front panel key, GPIB program or TTL pulse at rear panel BNC; then a preset number of cycles to 9999 are generated at a selected frequency.

Monitor Triggered: As for Preset Triggered, except the cycles are output continuously after triggering, until a hold command (via front panel key, GPIB program or TTL low at rear panel BNC) is given. The number of cycles generated up to 9999 can be displayed.

Hold Control: Front panel key, GPIB program or TTL low at rear panel BNC can stop the waveform asynchronously to the reference clock. Triggered modes only. (Restart from the held level by trigger signal.)

Ramp-to-Zero: Front panel key, TTL low at rear panel BNC or GPIB program can step output linearly to 0V in approximately 15 seconds.

1.2.2 Timing Precision

1.2.2.1 Sample Time

The stepping time from data point to adjacent data point is selectable as 200 ns to 999.9s for fixed waveforms and optional PROM stored data points (500 ns to 999.9s for RAM stored data points). Sample time accuracy is ±0.03% of setting. Resolution is 100 ns (10 µs when smoothing). Output frequency is 19.5 kHz to 3.90 µHz (71 hr/cycle) rate for a 256 word block. Sample time can be displayed and programmed in seconds, minutes, hours or as data block rate in hertz.

1.2.2.2 Reference Clock

Internal 10 MHz crystal controlled oscillator or external TTL compatible frequency source input at rear panel BNC. TTL compatible reference clock output provided.

1.2.2.3 External Clock

TTL compatible signal applied at rear panel BNC. Permissible external clock frequency is dc to 11 MHz for continuous modes. Ratio of external clock to reference clock determines output frequency.

1.2.3 Amplitude Precision

1.2.3.1 Main Output (Attenuated, 50Ω Source)

∿, ⊓⊔, ⋀⋁, ⟋| and arbitrary waveform selectable. Full block amplitude variable from 2 mV to 20V peak-to-peak into open circuit (10V peak-to-peak into 50Ω) with 3 digit resolution. Amplitude accuracy with 0 Vdc offset between 2 and 20V p-p is ±2% of setting plus 2 digits. Signal offset is from 0 to ±10V into open circuit (0 ±5V into 50Ω) with 3 digit resolution. Offset accuracy is ±2% of setting plus 2 digits.

1.2.3.2 Auxiliary Output (<1Ω Source)

Same waveform as main output from 0 to 10V peak (at fixed 0 dB attenuation). Same offset as main output and limited to 100 mA peak.

1.2.3.3 Output Amplifier Rise/Fall Time

Less than 500 ns, 50Ω termination, main output.

1.2.4 General

1.2.4.1 Display

LED seven segment display with alphabetical index of key functions and units. All status, modes and functions are shown by LED annunciator displays.

1.2.4.2 Keyboard

Membrane type with acoustic feedback. Acoustic tone may be turned off by front panel key.

1.2.4.3 External Program Interface

IEEE Standard 488-1975 compatible General Purpose Interface Bus (GPIB). Connector and address switch on rear panel. The interface provides listener (AH1 and L4), talker (SH1 and T6), service request (SR1), remote/local (RL1), device clear (DC1) and device trigger (DT1) capabilities. Handshake rate is 2 µs per character in command mode (10 µs typical for command sequence) and 220 µs per character in data mode, with data storage of up to 80 characters. The following table may be used to determine particular through-put times. Measurements were made with a 175 and an HP9825 controller. Data rates will follow the slowest listener on the bus and vary with different controllers.

Parameter	Time
Command Handshake	2 μs
Data Handshake	220 μs
Sample Time	35 ms
Block Rate	50 ms
Amplitude Setting	65 ms
DC Offset Setting	65 ms
Burst Length	20 ms
Function	20 ms
Int/Ext Clock	20 ms
Time Unit	25 ms
Mode CONT/TRIG	20 ms
PRST/MNTR Trigger	20 ms
FULL/PART Block	25 ms
Start Address	25 ms
Stop Address	25 ms
Output OFF/ON	20 ms
X Address	30 ms
Y Data	40 ms
Smoothing OFF/ON	35 ms
Execute	16 ms*
GET	1.6 ms

**2 ms when via GET*

1.2.4.4 Stability

Amplitude and DC Offset
Measured at full output and 25 ±1°C. Change is less than ±0.25% per day. Change with temperature is less than ±0.2% over 0 to 50°C.

Frequency
Crystal aging rate is less than 2 X 10^{-5} per year. Temperature coefficient is 1 X 10^{-6}/°C.

1.2.4.5 Environmental

Specifications apply for 25 ±10°C after ½ hour. Instrument will operate from 0 to 50°C to 10,000 ft altitude at 95% relative humidity.

1.2.4.6 Dimensions

Fits standard 48.3 cm (19 in.) rack. Dimensions behind front panel are 43.2 cm (17 in.) wide; 13.3 cm (5¼ in.) high; 51.4 cm (20¼ in.) deep.

1.2.4.7 Weight

15.9 kg (35 lb) net; 20.4 kg (45 lb) shipping.

1.2.4.8 Power

90 to 105V, 108 to 126V, 198 to 231V or 216 to 252V; 48 to 66 Hz; less than 120 watts.

SECTION 2
INSTALLATION AND INTERFACE

2.1 MECHANICAL INSTALLATION

After unpacking the instrument, visually inspect all external parts for possible damage to connectors, surface areas, etc. If damage is discovered, file a claim with the carrier who transported the unit. The shipping container and packing material should be saved in case reshipment is required.

The generator can be used as a bench instrument or rack mounted. In either use, ensure that there is no impedance to air flow at any surface of the instrument.

2.2 ELECTRICAL INSTALLATION

2.2.1 Power Connection

NOTE

Unless otherwise specified at the time of purchase, this instrument was shipped from the factory with the power transformer connected for operation on a 120 Vac line supply and with a 2 amp fuse.

Conversion to other input voltages requires a change in rear panel fuse holder voltage card position and fuse (figure 2-1) according to the following procedure.

Card Position	Input Vac	Fuse
100	90 to 105	2 amp
120	108 to 126	2 amp
220	198 to 231	1 amp
240	216 to 252	1 amp

1. Disconnect the power cord at the instrument, open fuse holder cover door and rotate fuse pull to left to remove the fuse.

2. Remove the small printed circuit board and select operating voltage by orienting the printed circuit board to position the desired voltage to the top left side. Push the board firmly into its module slot.

3. Rotate the fuse-pull back into the normal position and insert the correct fuse into the fuse holder. Close the cover door.

4. Connect the ac line cord to the mating connector at the rear of the unit and the power source.

2.2.2 Signal Connections

Use RG58U 50Ω shielded cables equipped with BNC connectors to distribute signals (figure 2-1) when connecting this instrument to associated equipment.

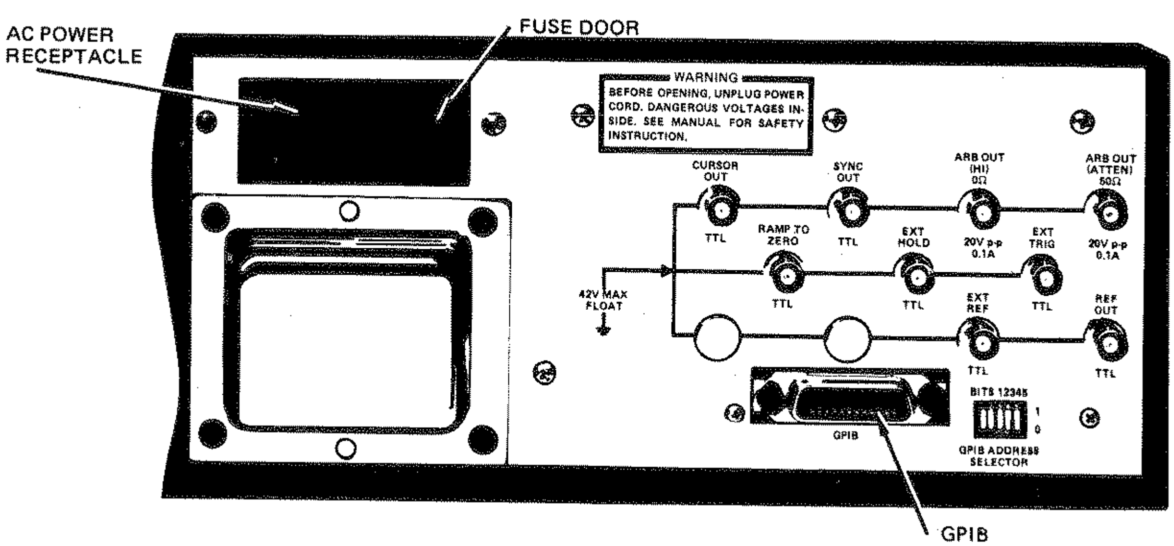


Figure 2-1. Rear Panel

2.2.3 General Purpose Interface Bus (GPIB) Connections

The GPIB I/O rear panel connection is shown in figure 2-1; pin connections and signal names are given in table 2-1. The panel connector is an Amphenol 57-10240 or equivalent and connects to a GPIB bus cable (available from Wavetek). The GPIB interface is optically isolated from the instrument.

2.2.4 GPIB Address

For instruments on the GPIB, ensure that the GPIB address is correct.

The GPIB address can be changed by the switch on the rear of the instrument (see figure 2-1) by simply setting the multiple section switch according to table 2-2. The switch sections are labeled from 1 through 5 and their open position noted (OPEN = "0" in table 2-2). To verify the address, press GPIB ADR on the front panel. The device number (decimal) will be displayed as "0, 1, — 30."

Table 2-1. GPIB Data In/Out

Pin	Signal	
1	DIO1	
2	DIO2	
3	DIO3	True When Low
4	DIO4	
5	EOI	
6	DAV	
7	NRFD	True When High
8	NDAC	
9	IFC	
10	SRQ	True When Low
11	ATN	
12	Safety Gnd	
13	DIO5	
14	DIO6	
15	DIO7	True When Low
16	DIO8	
17	REN	
18		
19		
20		
21		Signal Gnd
22		
23		
24		

Table 2-2. GPIB Address Codes

	Address								
	ASCII		Switch Position					Hexadecimal	
Device	Listen	Talk	1	2	3	4	5	Listen	Talk
0	(space)	@	0	0	0	0	0	20	40
1	!	A	1	0	0	0	0	21	41
2	"	B	0	1	0	0	0	22	42
3	#	C	1	1	0	0	0	23	43
4	$	D	0	0	1	0	0	24	44
5	%	E	1	0	1	0	0	25	45
6	&	F	0	1	1	0	0	26	46
7	'	G	1	1	1	0	0	27	47
8	(	H	0	0	0	1	0	28	48
9	)	I	1	0	0	1	0	29	49
10	*	J	0	1	0	1	0	2A	4A
11	+	K	1	1	0	1	0	2B	4B
12	,	L	0	0	1	1	0	2C	4C
13	—	M	1	0	1	1	0	2D	4D
14	•	N	0	1	1	1	0	2E	4E
15	/	O	1	1	1	1	0	2F	4F
16	0	P	0	0	0	0	1	30	50
17	1	Q	1	0	0	0	1	31	51
18	2	R	0	1	0	0	1	32	52
19	3	S	1	1	0	0	1	33	53
20	4	T	0	0	1	0	1	34	54
21	5	U	1	0	1	0	1	35	55
22	6	V	0	1	1	0	1	36	56
23	7	W	1	1	1	0	1	37	57
24	8	X	0	0	0	1	1	38	58
25	9	Y	1	0	0	1	1	39	59
26	:	Z	0	1	0	1	1	3A	5A
27	;	[	1	1	0	1	1	3B	5B
28	<	\	0	0	1	1	1	3C	5C
29	=	]	1	0	1	1	1	3D	5D
30	>	↑	0	1	1	1	1	3E	5E

2.2.5 Initial Checkout and Operation Verification

The equipment and procedures in tables 2-3 and 2-4 are recommended for incoming inspection and for testing the instrument after repair. However, additional after repair tests or calibration (Section 4) may be necessary for certain circuits.

Operation verification includes the following procedures.

1. **Power On:** Verifies initial conditions as determined by microprocessor and firmware circuits.
2. **Lamp Test:** Verifies condition of display lamps.
3. **Output Waveform Test:** Sine wave output is visually checked for correct frequency and visible irregularities. Smoothing also checked.
4. **Function Test:** Verifies standard waveforms.
5. **Waveform Generation Test:** Verifies data may be entered and appropriate waveform generated.
6. **Ramp To Zero Test:** Verifies ramp to zero operation.
7. **Reset Test:** Verifies proper resetting of instrument.
8. **Amplitude Accuracy Test:** Verifies amplitude accuracy of dc and ac operations.
9. **Frequency Accuracy Test:** Verifies block rate accuracy.
10. **Interface Test:** Verifies remote control capabilities of listening and talking.

Before making an initial checkout, review power and signal connection requirements (paragraphs 2.2.1 and 2.2.2) and ensure the availability of test equipment equivalent to that listed in table 2-3. An acceptance test record sheet (table 2-5) may be reproduced for recording checkout test results.

2.2.6 Permanent Custom Waveforms

Four 74S471 PROMs containing custom waveform data may be added in socket positions U7E through U10E on the generator board 1100-00-0644 (drawing 0101-00-0644).

Refer to Appendix C for PROM encoding and to paragraph 3.2.2(19) for operator access to these waveforms.

Table 2-3. Equipment Required for Incoming Inspection and Operation Verification

Instrument	Critical Specifications	Model Recommended
Oscilloscope	≥30 MHz vertical bandwidth	Tektronix 7903
50Ω Load	BNC feedthru	Tektronix 011009900
Voltmeter	0.1 to 10V ranges 3 digit resolution ±0.1% accuracy	Dana 6000 Series
Frequency Counter	20 MHz capability 5 digit resolution ±0.01% accuracy	Dana 9000 Series
Calculator	IEEE 488-1975 compatible	HP9825

Table 2-4. Operation Verification

Step	Test	Tester and Setup	Program	Desired Results
1	Power On	None.	Power ON	Several LEDs light momentarily, then darken, with only the following remaining lit: MODE — CONT; CLOCK — INT; TRIG CYCLE - PRST; BLOCK — FULL; Function — SIN 0.
2	Lamp Test	None.	LAMP TEST	All display LEDs lit. The last three 8's are not followed by decimal points.

Table 2-4. Operation Verification (Continued)

Step	Test	Tester and Setup	Program	Desired Results
3	Output Waveform	Oscilloscope. Connect ARB OUT (ATTEN) 50Ω with 50Ω load at the scope input. Set for 2 V/div, horizontal 1 ms/div, external auto trigger. Connect ARB SYNC OUT to scope external trigger input.	OUTPUT: OFF/ON 1 AMPL 10 SMTH: OFF/ON 1 EXEC	Approximately 5 div per cycle, 10V p-p visually nondistorted sine wave.
4		Oscilloscope. Set horizontal for .02 ms/div.		Nearly straight line (expanded sine curve) on scope.
5			SMTH: OFF/ON 0 EXEC	Stair step waveform on scope.
6		Oscilloscope. Set horizontal for 1 ms/div.		Sine waveform on scope.
7	Function		FUNC 1 EXEC	Triangle waveform on scope.
8			FUNC 2 EXEC	Square waveform on scope.
9			FUNC 3 EXEC	Ramp waveform on scope.
10	Waveform Generation		SMTH 1 FUNC 8 EXEC MEMORY: ADRS 0 DATA 0 ADRS 50 DATA 127 ADRS 100 DATA −127 ADRS 150 DATA +35 ADRS 255 DATA 0 EXEC	Triangle waveform followed by down slope ramp waveform on scope.
11	Ramp To Zero	Oscilloscope. Set horizontal to .2s/div. Adjust scope intensity to safe level.	BLOCK RATE .1 EXEC	Trace moves slowly across scope.
12			Depress RAMP TO ZERO key when scope trace is near a + or − peak on waveform.	HOLD LED lights. Trace changes desired waveform to a ramp that slowly approaches zero. The ARB display indicates a 'G' within 15 seconds.
13	Reset		EXEC	Trace same as in step 11.
14		Oscilloscope. Set horizontal for .02 ms/div.	RESET	Scope display is 0 volts. The following LED display indicators are lit: MODE — CONT; CLOCK — INT; TRIG CYCLE — PRST; BLOCK — FULL; FUNCTION — SIN 0.

Table 2-4. Operation Verification (Continued)

Step	Test	Tester and Setup	Program	Desired Results
15		Oscilloscope. Set horizontal for 1 ms/div.	OUTPUT: OFF/ON 1 AMPL 10 SMTH: OFF/ON 1 EXEC	Visually nondistorted sine wave.
		NOTE: Allow 30 minute warm-up before performing the following tests.		
16	Amplitude Accuracy	(Disconnect oscilloscope.) Voltmeter. Set to Vrms, ac. Connect to ARB OUT (ATTEN) 50Ω with a precision 50Ω load at voltmeter input.		3.35 to 3.71 Vrms.
17		Voltmeter. Set to read Vdc.	AMPL 0 OFST 5 EXEC	+4.75 to +5.25 Vdc.
18	Frequency Accuracy	(Disconnect voltmeter.) Counter. Set to read frequency nominal 200 Hz at 10V p-p input. Connect to ARB OUT (ATTEN) 50Ω with 50Ω load at counter input.	AMPL 5 OFST 0 EXEC FUNC 2	192 to 198 Hz.
19	Interface	Oscilloscope. Connect ARB OUT (ATTEN) 50Ω with 50Ω load at the scope input. Set trigger to ext, dc, normal. Calculator. Connect to ARB GPIB connector. Set ARB rear panel GPIB ADDRESS SWITCH to 00100. Press GPIB ADRS key and verify GPIB address is "4" on display.	Calculator: 0: dim A$[100] 1: fxd 2 2: wrt 704,"ZI" 3: wait 1000 4: wrt 704, "A5O1 P1I" 5: stp	10V p-p sine wave of 5.12 ms period.
20			6: wrt 704,"C11I X100Y-127X153Y1 27X154Y-127IB1D 0M0L3U1V100W154 T5E-6I" 7: wait 500 8: for I=1 to 20 9: wait 500 10: trg 704 11: next I 12: stp	20 bursts of 3 partial ramp waveforms in approximately 0.5s intervals.
21			13: wrt 704,"ZI" ;wait 1000 14: wrt 704,"R3I F" 15: red 704,A$ 16: prt A$;stp 17: lcl 704 18: prt "175 test complete" 19: stp	Calculator printout. V F 195.31

Table 2-5. Acceptance Test Record
(for reproduction)

Location ______________________________

QA Inspector ______________________________

Date ______________________________

Instrument S/N ______________________________

		Acceptable (✓)
A. Manual Checks, Data Entry and Visual Checks (steps 1 through 15)		________
B. Amplitude Accuracy		
	(step 16) ________ Vrms	________
	(step 17) ________ Vdc	________
C. Frequency Accuracy		
	(step 18) ________ Hz	________
D. Interface-GPIB (steps 19 through 21)		________

SECTION 3
OPERATION

3.1 GENERAL

The waveforms to be output are contained as a series of values in storage, which are read and output at some selected rate. There are 12 blocks each of 256 addresses (4 blocks are optional). Four blocks have fixed waveforms of sine, triangle, square and ramp, respectively. For example, in the sine wave block, the values for each address determine 256 data points that approximate the shape of a sine wave. Four optional PROM blocks each contain custom waveforms. Four RAM blocks may be loaded with waveform data and erased, as required.

The selected block of waveform may be output from address zero to address 255 (one cycle) repeatedly to form a continuous waveform output. As a variation, any start address and any stop address may be specified for the cycle. Or, two, three or four blocks may be linked together for one cycle of the output waveform. Blocks that can be linked are PROM blocks 1 and 2; 1, 2 and 3; 1, 2, 3 and 4. Similarly, the RAM blocks may be linked. The dwell time at each address, the time the output is the value for that address, can be selected as either sample time (in seconds, minutes or hours) or block rate (in Hertz).

Besides the continuous output of a waveform, triggered output may be selected. A preset number of cycles may be output when the Arb is triggered. Or, when triggered, the output waveform can be continuous until stopped by a Hold command. The number of cycles output can then be read by a Monitor Count command.

The waveform amplitude may be dc offset, attenuated and smoothed. Smoothing minimizes the transition between amplitude steps for amplitude step differences less than 64.

The 50Ω output is off at power on time, which allows programming before electrically connecting the Arb output to the outside world. To change the output, the change must be programmed or keyed and then executed by an Execute command or pressing the EXEC key. An example of front panel operation is given in table 3-1.

Table 3-1. Example of Front Panel Data Entry

Instruction	Front Panel Entry (Press Keys)	Equivalent Program	Front Panel Display
1. Power on. The display shows most of the initial conditions.	[OFF] (becomes [ON])		See figure 3-1.
2. Test lamps. (27 status lamps, a 5 X 7 dot matrix, four 8's with decimals, three 8's without decimals and an asterisk.	[LAMP TEST]		All lamps should be lit.
3. Check initial conditions at every key.	Press each front panel key		See paragraph 3.2
4. Connect an oscilloscope to the ARB OUT (ATTEN) 50Ω connector using a 50Ω load. Enable the output and observe the sine waveform.	OUTPUT [OFF/ON] [1] [EXEC]	P1 I	P1 I [OUTPUT ●]
5. Use the oscilloscope to amplify the waveform until the individual steps of the waveform can be seen. Smooth the waveform.	SMTH [OFF/ON] [1] [EXEC]	01 I	01 I [SMOOTH ●]

Table 3-1. Example of Front Panel Data Entry (Continued)

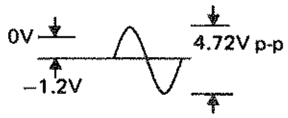
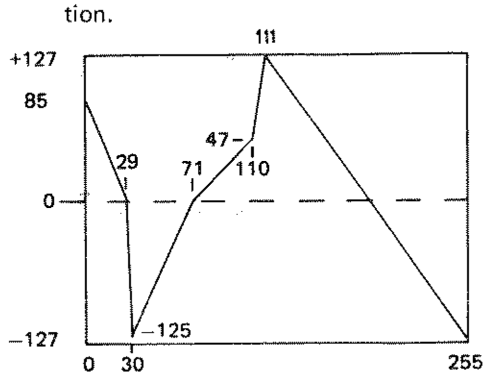
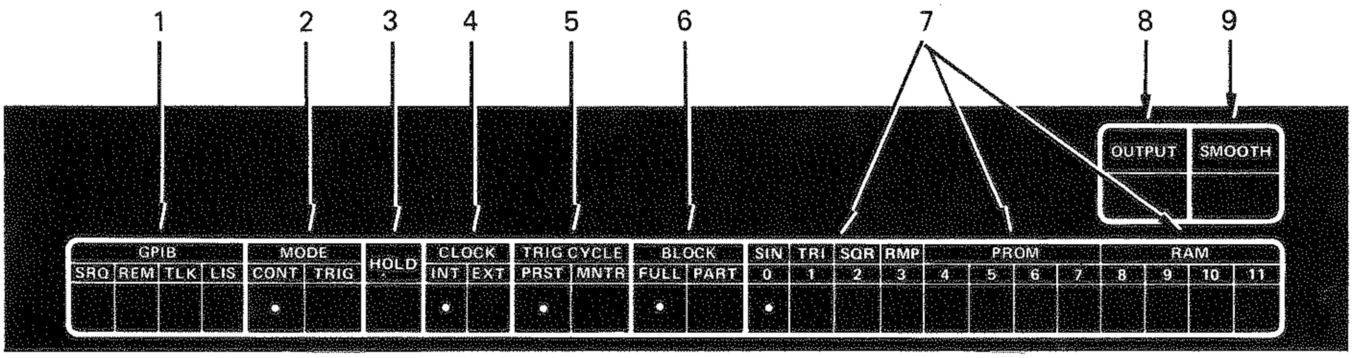
Instruction	Front Panel Entry (Press Keys)	Equivalent Program	Front Panel Display
6. Change the amplitude and offset to: 	[AMPL] [4] [•] [7] [2]	A4.72	A4.72
	[OFST] [+/−] [1] [•] [2]	D−1.2	D−1.2
	[EXEC]	I	I
7. Oberserve the other waveforms. (There may be no waveforms in C4 thru C7.) C8 thru C11 will have a 0V baseline.	[FUNC] [1]	C1	C1
	[EXEC]	I	I [TRI / 1 / •]
	[FUNC] [2]	C2	C2
	[EXEC]	I	I [SQR / 2 / •]
	[FUNC] [3]	C3	C3
	[EXEC]	I	I [RMP / 3 / •]
	[FUNC] [4]	C4	C4
	[EXEC]	I	I [PROM / 4 / •]
	(etc. to C11)		
8. Design a simple waveform in C11. This illustrates the use of automatic interpolation.	[ADRS] [0]	X0	X0
	[DATA] [8] [5]	Y85	Y85
	[ADRS] [2] [9]	X29	X29
	[DATA] [0]	Y0	Y0
	[ADRS] [3] [0]	X30	X30
	[DATA] [+/−] [1] [2] [5]	Y−125	Y−125
	[ADRS] [7] [1]	X71	X71
	[DATA] [0]	Y0	Y0
	[ADRS] [1] [1] [0]	X110	X110
	[DATA] [4] [7]	Y47	Y47
	[ADRS] [1] [1] [1]	X111	X111
A line is drawn to the plotted point when the following ADR key is pressed.	[DATA] [1] [2] [7]	Y127	Y127
	[ADRS] [2] [5] [5]	X255	X255
	[DATA] [+/−] [1] [2] [7]	Y−127	Y−127
9. Observe this waveform on the oscilloscope.	[EXEC]	I	I

Table 3-1. Example of Front Panel Data Entry (Continued)

Instruction	Front Panel Entry (Press Keys)	Equivalent Program	Front Panel Display
10. Select only one portion of this waveform and observe it on the oscilloscope. (Frequency increases because there are less data points being sampled. The sampling rate has remained the same.)	[FULL/PART] [1]	U1	U1
	[START ADRS] [2] [0]	V20	V20 BLOCK FULL | PART ●
	[STOP ADRS] [1] [1] [1]	W111	W111
	[EXEC]	I	I
11. Prepare to output exactly 321 cycles of this waveform.	[CONT/TRIG] [1]	B1	B1
	[PRST/MNTR] [0]	M0	M0
	[PRST LNGTH] [3] [2] [1]	L321	L321
	[EXEC]	I	I
12. When triggering, observe the Hold status light.	[TRIG]	J	J HOLD then HOLD ●
13. Return to full block mode.	[FULL/PART] [0]	U0	U0
14 Change the frequency to approximately 10 kHz.	[BLOCK RATE] [1] [0] [E] [3]	F10E3	F10E3
	[EXEC]	I	I
15. Examine the actual sample time.	[SAMPLE TIME]	T	T400E−9 S
16. Examine the actual frequency.	[BLOCK RATE]	F	F9.7656E3 Hz

NOTE: Frequency is determined by the number of blocks stacked, the number of data points in a cycle and the sample time per data point. Therefore, desired frequencies can only be approximate.

$$\text{Actual Frequency} = \frac{1}{\text{(Sample Time) (No. of Data Points in a Block) (Number of Blocks Stacked)}}$$



1. **GPIB Status:** SRQ — Service request being sent; REM — Remote (GPIB) control; TLK — Arb talking on the GPIB; LIS — Arb listening on the GPIB } if lit

2. **Mode Status:** Continuous or triggered output.

3. **Hold Status:** Output is being held at some data point if lamp is lit.

4. **Clock Status:** Internal 10 MHz clock or external clock (11 MHz maximum).

5. **Triggered Cycle Status:** Preset number of cycles or monitor the number of cycles output.

6. **Block Status:** The full block or a partial block of data points is being used.

7. **Function Status:** Sine, triangle, square, ramp, PROM stored or RAM stored waveform output. The lamp of the selected block is lit. If multiple blocks of RAM or of PROM are being stacked together, then the lamps of the stacked blocks are lit.

8. **Output Status:** Output on if lamp is lit.

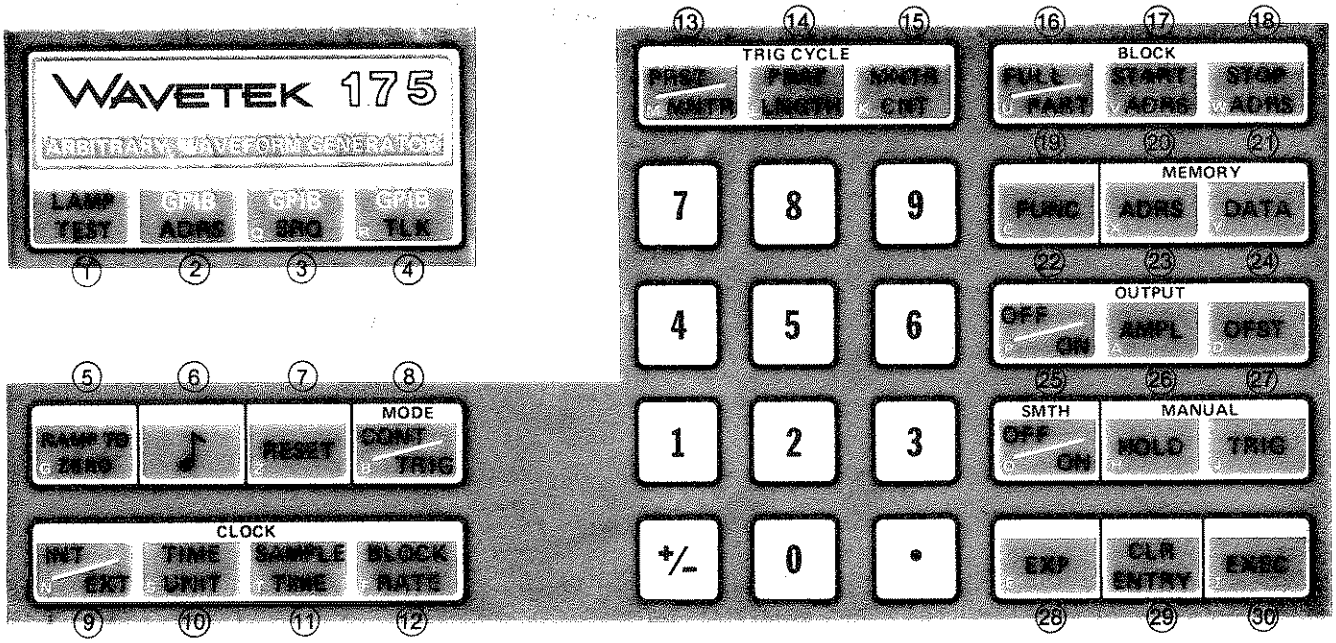
9. **Smoothing Status:** Smoothing of digital waveform steps active if lamp is lit.

NOTES:

"Power On" condition shown:

1. *Local Control — Not GPIB (Remote Control)*
2. *Continuous Mode*
3. *Generator Running*
4. *Internal Clock*
5. *Preset Number of Triggered Cycles (however, mode is continuous)*
6. *Full Block of 256 Data Points Used*
7. *Sine Waveform*
8. *Output Off*
9. *Smoothing Off*

Figure 3-1. Status Display



NOTE: See paragraph 3.2 for item descriptions.

Figure 3-2. Keyboard

3.2 KEYBOARD

3.2.1 Notes

1. Most keys (figure 3-2) are associated with a parameter and, when pressed, give the status of that parameter. The parameter status or value is changed by pressing number keys after the parameter key. Other keys give immediate action when pressed.

2. The key functions that can be GPIB programmed have their GPIB ASCII character in the lower left corner and are called alpha keys. (The block of number keys may also be programmed.)

3. Because of the variety of format that the operator can use when entering values, the microprocessor does not assume that programming is complete until another alpha key (except EXP) is pressed. At this time, the value is tested and, if ok, placed in a scratch pad memory.

4. When an asterisk (*) appears in the display, it indicates that a number is being entered from either the keyboard or GPIB.

5. Initial conditions (*I/C*) at power-on time are noted in paragraph 3.2.2.

6. Brief key descriptions are given in paragraph 3.2.2. Details on the use of the keys are in the following paragraphs and referenced where applicable.

7. Errors detected are flagged by an "ERROR" in the display. Refer to paragraph 3.14.

3.2.2 Key Descriptions

The following item numbers correspond to those in figure 3-2.

1. **Lamp Test** – Lights all display status blocks and display segments.

2. **GPIB Address** – Shows GPIB decimal address set by switches on rear panel.

3. **GPIB Service Request Enable (Q)** – Shows what conditions will cause the Arb to send a service request over the GPIB:

   Q0 – Suppresses all service requests.
   Q1 – Enables service request for errors (*I/C*).
   Q2 – Enables service request when the waveform generation circuits make a transition from not holding to holding.
   Q3 – Enables service request for errors and transition to holding.

   Refer to paragraph 3-16 for related GPIB data.

4. **GPIB Talk (R)** – Shows the status of two parameters: The particular type of talk message that will be given when the Arb is addressed to talk over the GPIB is shown on the left of the display. A minus sign prefix and the decimal equivalent of the ASCII coded terminator character is shown on the right. The talk message codes are:

   R0 – State of hold status (returns "0" if not holding, "1" if holding (*I/C*).
   R1 – List of first nine errors since this message was last read.
   R2 – Reason why this instrument is requesting service.
   R3 – Current value of the setting, if any, selected by the last alphabetical character used.

   Refer to paragraph 3.16.4 for details.

5. **Ramp to Zero (G)** – An abort action that increments the amplitude and offset in linear steps to zero in about 15 seconds. The Arb does not respond to new inputs during ramping. "G" is not displayed until zero is reached. Press EXEC to restore prior status.

6. **Musical Note** – Key tone (*I/C*) is cut out or, if out, restored.

7. **Reset (Z)** – Sets everything to initial conditions except RAM storage (waveforms programmed are not lost as long as power is on). Initial conditions for items in paragraph 3.2.2 are annotated with (*I/C*).

   When programming this action via the GPIB, the controller should wait for the instrument to start resetting before sending any futher commands. If the instrument microprocessor is idle, a 3 millisecond wait will suffice, but if it is busy scanning an input buffer (refer to paragraph 3.16.3), the wait required could be as long as a second. The wait is necessary to avoid losing the commands following the reset command.

8. **Mode, Continuous or Triggered (B)** – Shows status:

   B0 – Continuous (*I/C*).
   B1 – Triggered.

   In continuous mode, the Arb continuously generates the selected waveform, and it cannot be triggered or held. In triggered mode, the Arb is idle until a trigger stimulus is received.

When a trigger (J) occurs, the Arb starts to generate the selected waveform until a hold (H) command is received or, if the trigger cycle parameter (M) is set to the preset mode, until the number of blocks specified by the preset length parameter (L) have been generated. Refer to item 13 and paragraph 3.15 for details.

9. **Clock, Internal or External (N)** – Shows source status:

N0 – Internal 10 MHz clock (*I/C*).
N1 – External clock ($\leqslant$ 11 MHz).

This parameter selects the source of the clock which provides timing for the waveform generator circuits. If the external clock is selected, it must be within these limits:

dc - 11 MHz, if mode is continuous (B0)
500 kHz - 11 MHz, if mode is triggered (B1)

10. **Clock, Time Unit (S)** – Shows the units used for sample time:

S0 – Seconds (*I/C*)
S1 – Minutes
S2 – Hours

Refer to paragraph 3.10 for conditions that affect time unit.

11. **Clock, Sample Time (T)** – Shows duration of each data point of the output waveform.

Example: T20E–6s = 20 μs (*I/C*)

See paragraph 3.12 for conditions that affect sample time.

12. **Clock, Block Rate (F)** – Shows frequency of the output waveform.

Example: F195.313 Hz (*I/C*)

See paragraph 3.12 for conditions that affect block rate.

13. **Trigger Cycle, Preset or Monitor (M)** – Shows status:

M0 – Preset Mode (*I/C*). A preset number of cycles will be output following a trigger signal. (Refer to item 14.)
M1 – Monitor Mode. When triggered (J) output is continuous.

Refer to paragraph 3.15 for details.

14. **Trigger Cycle, Preset Length (L)** – Shows the number of waveform blocks generated when a trigger (J) is received in triggered mode (B0) with preset trigger cycle mode (M0) selected.

Example: L216 – When in preset mode (M0) and triggered (J), 216 cycles of waveform will be output. L1 (*I/C*)

15. **Trigger Cycle, Monitor Count (K)** – This is an interrogating action which reads the value of the triggered waveform cycle counter. If continuous mode (B0) is selected, the value readout is always zero. If triggered mode (B1) is selected, the value readout is the number of complete blocks generated since the generator was last triggered. While the generator is running (not holding), the cycle counter is incremented when the last point in a block is being output. When holding, the counter is not incremented. Refer to paragraph 3.15 for more details.

16. **Block, Full or Partial (U)** – Shows status:

U0 – A full 256 address block (or several blocks) forms one cycle of waveform (*I/C*).
U1 – A partial block forms one cycle. (Refer to items 17 and 18.)

Refer to paragraph 3.11 for operation.

17. **Block, Start Address (V)** – Shows block start address of waveform.

Example: V93 – One cycle of waveform starts at address 93 in 0 - 255 block. V0 (*I/C*)

18. **Block, Stop Address (W)** – Shows block stop address of waveform.

Example: W107 – One cycle of waveform stops at address 107 in 0 - 255 block. W255 (*I/C*)

19. **Function (C)** – Shows which memory (or memories) will be used to generate the output waveform. Values 0 - 3 select standard waveforms:

C0 – Sine (*I/C*)
C1 – Triangle
C2 – Square
C3 – Ramp

Values 4 - 7 select the four user-supplied PROM blocks.

C4 – PROM block 1
C5 – PROM block 2

C6 — PROM block 3
C7 — PROM block 4

Values 8 - 11 select the four programmable RAM blocks.

C8 — RAM block 1
C9 — RAM block 2
C10 — RAM block 3
C11 — RAM block 4

Values 14 - 17 select joined together, user-supplied PROM blocks. The PROMs composing these are the same ones that are selected by function codes 4 - 7.

C14 — PROM block 1 (256 points maximum)
C15 — PROM blocks 1 & 2 (512 points maximum)
C16 — PROM blocks 1, 2 & 3 (768 points maximum)
C17 — PROM blocks 1, 2, 3 & 4 (1024 points maximum)

Values 18 - 21 select joined together, programmable RAM blocks. The RAMs composing these are the same ones that are selected by function codes 8 - 11.

C18 — RAM block 1 (256 points maximum)
C19 — RAM blocks 1 & 2 (512 points maximum)
C20 — RAM blocks 1, 2 & 3 (768 points maximum)
C21 — RAM blocks 1, 2, 3 & 4 (1024 points maximum)

Note that a set of joined together RAM blocks may not be programmed as a unit. Each block must first be separately selected (with function codes 8 - 11) and programmed. The start and stop addresses, if selected, will be applicable to each block of stacked PROMs or RAMs.

20. **Memory Address (X)** — Gives data (Y) value at the address (X) queried.

Example: X125 33Y — At address 125 in the 0 - 255 address block, the data value is 33 in a 0 ±127 range.

This parameter is used to select the address of the data point in the waveform memory which is read and programmed by the memory data (Y) parameter. This parameter also sets the cursor register (immediately, without Execute). This register is used to cause a pulse to occur on the rear panel CURSOR OUT BNC connector whenever the data point in the waveform memory at the address stored in the cursor register is being output.

This key has an automatic increment feature. If pressed (or "X" is programmed over the GPIB) twice without pressing any other key, then the second pressing will increment the memory address and display it and the data at the new address. Additional pressings will continue to increment until the sequence is broken by pressing another key. Holding the key down will continuously increment to the next address and show the corresponding data.

21. **Memory, Data (Y)** — Provides access to the waveform memory data point located at the address specified by the memory address parameter (X) in the memory block specified by the function parameter (C).

Example: Y33 — At last address (X) queried in the 0 - 255 address block, the data value is 33 in a 0 ±127 range.

This key has an automatic increment feature. If pressed (or "Y" is programmed over the GPIB) twice without pressing any other alpha key, then the second pressing will increment the memory address parameter (X) value and display the Y data at the next address. Additional pressings will continue to increment the address until the sequence is broken by pressing another alpha key. Holding the key down will continuously increment the address and data displayed.

Refer to paragraph 3-7 for operation.

22. **Output, Off or On (P)** — Shows connection or no connection between the output amplifier and the BNC connector. This parameter makes the connection by a relay.

P0 — Output to ARB OUT (ATTEN) BNC disconnected (*I/C*)
P1 — Output to ARB OUT (ATTEN) BNC connected

23. **Output, Amplitude (A)** — Shows status.

Example: A3.25V — The output voltage is 3.25V p-p into 50Ω in a range of 1 to 10V p-p. A1 (*I/C*)

Refer to paragraph 3.13 for operation.

24. **Output, Offset (D)** — Shows status.

Example: D2.05V — Output dc offset is 2.05V into 50Ω in a range of 0 ±5.00V. D0 (*I/C*)

Refer to paragraph 3.13 for operation.

25. **Smoothing, Off or On (O)** — Shows status:

O0 — Smoothing off (*I/C*)

01 – Steps of data making up the waveform are smoothed for a more continuous waveform.

Refer to paragraph 3.8 for operation.

26. **Manual, Hold (H)** – In triggered mode (B1), pressing the key stops and holds the output at the instantaneous value. The address stopped on is shown on the readout. Trigger (J) the generator to continue output waveform. Refer to paragraph 3.15 for hold use.

    Example: H102 – Holding at address 102.

27. **Manual, Trigger (J)** – Triggers the output when in trigger mode. Refer to item 13 and paragraph 3.15 for trigger use.

28. **Exponent (E)** – Consider this key (E) as part of the numbered key group. The value keyed after E is the exponent of a X 10 multiplier.

    Example: E6 = X 10^6

29. **Clear Entry** – Erases an incomplete numeric entry (indicated by a display with an asterisk on the right-hand side). The display is replaced by the previous value of the parameter that was being reprogrammed. This key is used to clear out a programming entry in case an incorrect key was pressed, or if the user changes his mind and decides not to change the parameter value. This key has no effect if there is no incomplete entry in progress (no asterisk on the right-hand side).

30. **Execute (I)** – This key causes an execute cycle which transfers from the display memory to the waveform generator circuits the values of the following parameters:

    Internal or External Clock (N)
    Sample Time (T)/Block Rate (F)
    Preset or Monitor Trigger Mode (M)
    Preset Length of Burst (L)
    Full or Partial Block (U)
    Start Address (V)
    Stop Address (W)
    Function (C)
    Output On or Off (P)
    Amplitude (A)
    Offset (D)
    Smoothing On or Off (O)

    Causing an execute cycle is the only way to update these parameters in the waveform generator circuits. An execute cycle also restores a ramp to zero (G) to the prior status. Note that the waveform memory data (Y) and cursor register (X) do not require an execute cycle; when either of them is programmed with a new value, that value is sent immediately to the waveform circuits.

31. **Plus and Minus** – Changes the sign on the displayed number. If the sign change is made after the exponent (E) is programmed, the sign change affects the exponent only.

    Example: –1.25E–2 = 1.25–E–2 = –1.25E2– = –0.0125 = -1.25×10^{-2}.

3.3 POWER

Power is turned on and off with a front panel pushbutton. When power is turned on, wait approximately two seconds before programming. When the power is turned on, the Arb is ready to accept commands. At least two seconds must elapse between power off and power on for proper reinitialization of logic. When the power comes on, the Arb output is automatically disconnected to allow loading of a program; line transients on the output are avoided. The Arb must get an execute command to provide an output.

3.4 INPUTS AND OUTPUTS

Refer to figure 2-1 for connector locations.

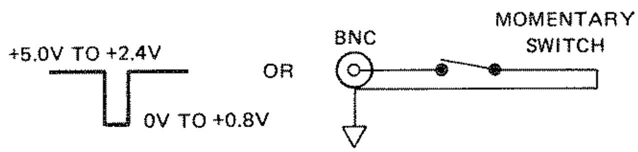
CURSOR OUT TTL Output – This output is a positive going TTL pulse coincident and of the same width with each output of a particular data point. The data point is designated by storing its memory address in the cursor register. Refer to paragraph 3.2.2, item 20.

SYNC OUT TTL Output – This output is a positive going TTL pulse whose leading edge is coincident with each stop address of a waveform and whose trailing edge is coincident with each start address of a waveform being output. In full block operation this pulse rises at address 255 and falls at address 0. During trigger mode the pulse rises and remains up until the Arb is triggered, which is coincident with the start address. The pulse normally appears at the end of each cycle and stays up after the last cycle of the triggered burst.

ARB OUT (HI) 0Ω Output – This output is a < 1Ω source of the generated waveforms. This BNC output is directly connected to the output amplifier.

ARB OUT (ATTEN) 50Ω Output – This output is a 50Ω source of the generated waveforms. The connnection of the BNC output with the amplifier output is program or front panel controlled via a relay.

The ramp to zero, external hold and external trigger BNC input connectors accept either a TTL low going pulse or momentary switch closure:



RAMP TO ZERO TTL Input – When this connector is pulsed, the waveform at the ARB OUT connectors is instantaneously held at its voltage level and ramped to 0 volts in approximately 15 seconds.

EXT HOLD TTL Input – When the Arb is operating in a trigger mode and this connector is pulsed, the waveform at the ARB OUT connectors is instantaneously (asynchronously to the reference clock) held at its voltage level. Use a manual, GPIB or rear panel applied trigger to continue operation. Refer to paragraph 3.15 for trigger and hold use.

EXT TRIG TTL Input – When the Arb is operating in a trigger mode and this connector is pulsed the output dictated by the trigger mode setting is initiated. Refer to paragraph 3.15 for triggered hold use.

EXT REF TTL Input – This input is used when the Arb is set to operate with an external clock reference. For proper operation, use a TTL signal of dc to 11 MHz, if the Arb is set to continuous mode or 500 kHz to 11 MHz, if set to trigger mode. The ratio of the external clock frequency to 10 MHz (standard internal clock) is a factor used in determining specific output frequencies.

REF OUT TTL Output – This connector is a TTL source at the reference clock frequency.

3.5 BASIC COMMAND STRUCTURE

The Arb is programmed by sending ASCII coded characters (refer to Appendix A) to the microprocessor via keyboard or GPIB (figure 3-3). If input characters are present on more than one input port, they are read first from the GPIB and last from the keyboard. Thus, if the GPIB is continuously supplied with characters, then no characters will ever be read from the keyboard.

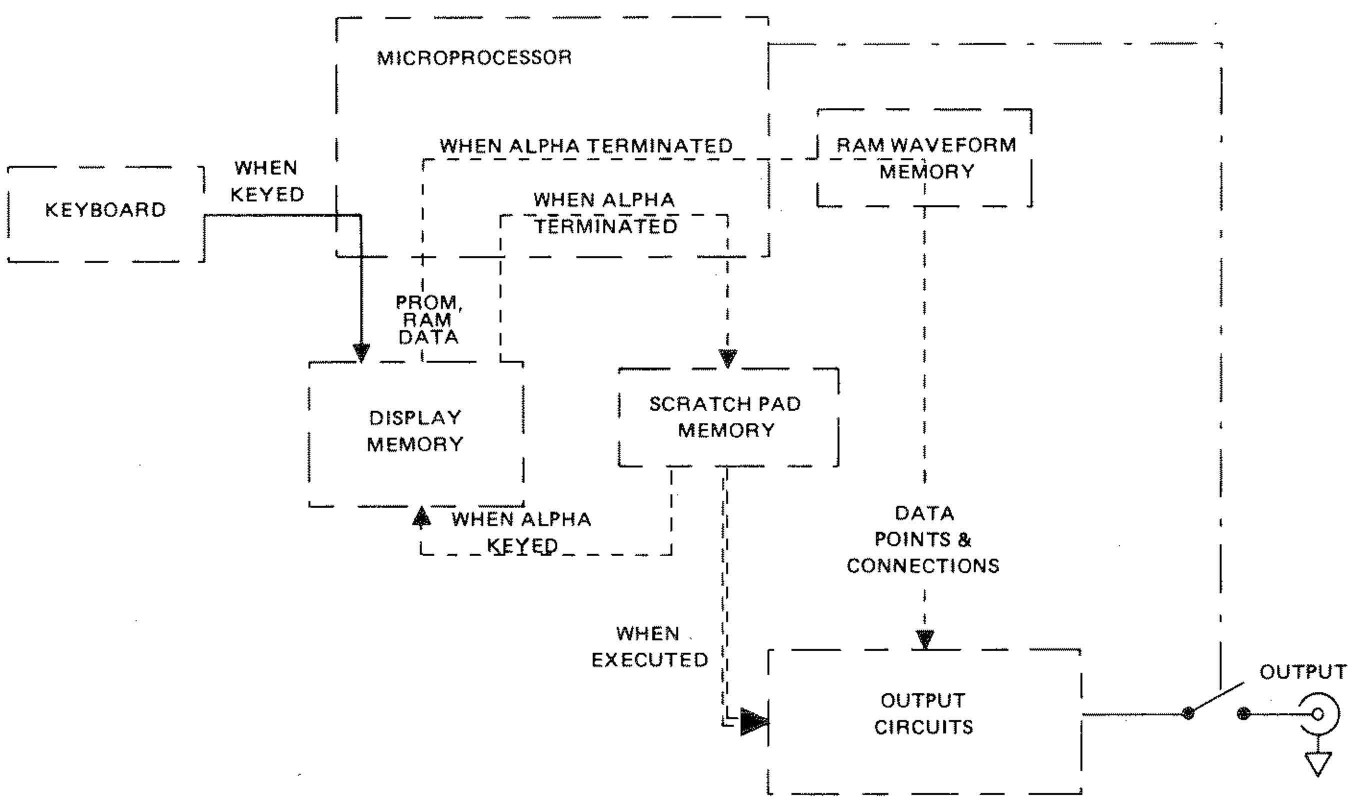


Figure 3-3. Command and Memory Structure

Characters used to program the Arb are divided into classes:

1. Alphabetic Characters — The characters A thru Z, except E (characters on lower left of front panel keys).

2. Numeric Characters — The characters 0 thru 9, E, –, decimal point (.).

3. Terminator Character — Initially the ASCII line feed character (LF). This can be changed by programming.

4. Nonprogramming Characters — Any character not in one of the above classes.

The alphabetic characters are used to select *actions* or parameters. An action is a sequence of events which happens immediately when the character which selects it is read by the microprocessor. A parameter is a number value which may be changed by programming.

To program an action, simply program the proper alphabetic character from either input port. The action will then take place, but only if the instrument is in the *enabled* state at the moment when that character is read by the microprocessor. Enabled states are:

Input Port	Arb Condition
Keyboard	GPIB not in Remote
GPIB	GPIB in Remote

Refer to REN, paragraph 3.16.1 for selection.

To examine the current display value of a parameter, simply program the proper alphabetic character from either input port. The current value will then be displayed on the front panel. This occurs whether or not the instrument is enabled. If the character programmed does not correspond to a legal setting in the instrument, nothing happens.

The numeric characters are used to program new parameter values. To change a parameter value, first program the alphabetic character which selects the parameter (F = frequency, etc.). The instrument must be enabled at this time, or it will not allow the new value to be entered. Next, program the new value using numeric characters; the instrument must be enabled for these as well. Any sequence of characters (called the argument of the parameter) which gives the new value is acceptable. For example, all of the sequences in table 3-2 will cause the value 100 to be programmed.

The number to the left of the "E" is the mantissa; the number to the right (one or two digits allowed) is the exponent.

Table 3-2. Examples of Value Programming

ASCII	Keyboard	Std Notation
100	100	100
0100	0100	100 (leading zeros are ignored)
1E2	1 [EXP] 2	1 X 10^2
.01E4	.01 [EXP] 4	.01 X 10^4
.01E34	.01 [EXP] 34	.01 X 10^4 (last exponent digit only is used)
1000E-1	1000 [EXP] [+/–] 1	1000 X 10^{-1}
1E-2-	1 [EXP] [+/–] 2 [+/–]	1 X 10^2 (two minus signs cancel)
1E.2	1 [EXP] .2	1 X 10^2 (decimal points in exponent are ignored)

The resulting value is the mantissa times 10 to the exponent power. Only one decimal point and one "E" (keyboard EXP) are allowed per number; additional ones are ignored. The sign toggle character may appear any number of times. It causes the sign of the mantissa (if "E" has not been programmed) or the exponent (if "E" has been programmed) to be reversed (if negative, then positive, and vice versa) each time it appears. Any number of nonprogramming characters may be interspersed with the numeric characters, as they have no effect. If an undesired value is entered, the clear entry key can be used to erase it.

Several parameters require codes for specific selections; for example, the function codes of 0 thru 11 to select sine, triangle or square waves, etc. Refer to paragraph 3.2.2 for parameter codes.

Since the number input format is so general, the microprocessor must be told when the last numeric character has been entered so it can evaluate the number. This is done by programming either an alphabetic or terminator character. When this is done, the new value is first tested to see if it is a legal value for the setting being changed. If it is not legal, an error message is displayed on the front panel and the setting value in the display memory is not changed. If it is legal, the new value is entered into the display memory; however, it is not sent to the output circuits.* That can be done only by programming the "I" action (EXEC key on the front panel). When a new value is entered into the instrument memory, it is rounded to the number of significant digits specified by the parameter being changed, as specified by table 3-3.

Table 3-3. Round Offs

Letter	Parameter Name	Number of Digits
A	Amplitude	3
O	Offset	3
F	Block Rate	Not rounded
T	Sample Time	4**
All other settings		Nearest integer

*Exceptions: When a RAM waveform value (Y) is programmed, the value is sent immediately to the RAM memory and thus alters the output waveform without use of execute. Also, when a memory address (X) is programmed, the value in the cursor register is updated, thus changing the time when the CURSOR OUT pulse appears.

** Refer to paragraph 3.9.

3.6 COUNTER GENERATED WAVEFORMS

The counter generated waveforms, square, triangle and ramp (figure 3-4) are simply called up by function selection (paragraph 3.2.1, item 19). Their characteristics which are due to digital generation are discussed in section 4.

3.7 MEMORY DATA (Y) FOR ARBITRARY WAVEFORMS

This parameter is used to read and program data points in the waveform memory. The MEMORY DATA key provides access to the data point located at the address specified by the memory address parameter (X) in the memory block specified by the function parameter (C). Programming a value into this parameter changes the data point value if the memory block is a RAM block; otherwise, nothing happens. *This change occurs immediately without use of an execute.* This parameter has an automatic increment feature. If the memory data key (Y) is pressed (or Y is programmed over the GPIB) twice without pressing any other alpha key, then the second pressing will increment the memory address parameter (X) value and display the Y data at the new address. Additional pressings will continue to increment the address until the sequence is broken by pressing another alpha key. Note that it is possible to program a new Y value between pressings of the memory data key; this provides a convenient way to program successive data points using only the memory data key. For example, a ramp from 127 to −127 can be programmed as follows: Y127Y126Y125Y ..... Y−126Y−127Y−127 (a total of 256 settings). This parameter also provides an alternate "interpolation mode" form of programming used to draw straight line segments. This mode is activated when two pairs of X,Y data point settings are programmed with no other keys pressed (or no other alphabetic characters programmed over the GPIB). After the second pair is programmed, a line is drawn between the first and second points, approximating a straight line as closely as possible.* Additional X,Y pairs may be programmed and lines will then be drawn between the second and third, third and fourth, etc., points. To exit from interpolation mode, just press a key other than memory address or memory data. Table 3-1, step 8, shows an example of programming a complete block of RAM using the interpolation mode.

Important notes for the interpolation mode are:

1. Each parameter (X or Y) of the X,Y pairs must be programmed with a new value. Just pressing a memory address or data key is not sufficient.

2. The parameters must be entered in the order XYXY . . . (not YXYX).

3. No other alpha keys may be pressed during an XYXY . . . interpolation sequence.

   Example: X0Y0X100Y100I will draw a straight line from (0,0) to (100,100), but X0Y0AX100Y100 will only set the data points at memory locations 0 and 100 to 0 and 100, respectively, leaving the other 254 data points untouched.

3.8 SMOOTHING (O)

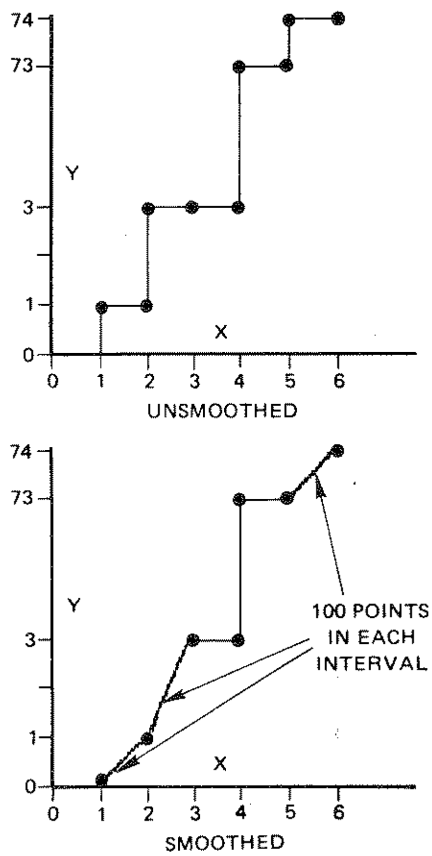
This parameter selects whether waveform smoothing is disabled (O0) or enabled (O1). If smoothing is enabled, and the sample time is 20 μs or longer, then 100 finely spaced data points are inserted on a straight line between every pair of data points as shown in figure 3-5. There is an exception: No smoothing is done between data points whose Y values differ by more than 63. For the effect of smoothing on sample time round off, refer to paragraph 3.9.

---

*When composing waveforms by entering data only when a change in slope is required, the microprocessor automatically draws the line (step linearly) between the points entered. If the slope

$$\frac{\text{Change in Y}}{\text{Change in X}}$$

is not a whole number, the microprocessor plots two or more line segments that approximate a single line segment as nearly as possible. ("Line segment" referred to here is a set of linear steps.)



NOTE

No smoothing during the time slot 4 to 5, because the data point values at X = 4 (3) and X = 5 (73) differ by more than 63. Smoothing does occur at all other times (0 to 4 and 5 to 6).

Figure 3-5. Waveform Smoothing

3.9 SAMPLE TIME (T) AND WAVEFORM SMOOTHING

Hardware dictates a stepping time resolution of 100 ns. This results in sample time round off, as shown in table 3-5. Sample time round off is also affected by waveform smoothing. Waveforms can be smoothed by incrementing between data points with 100 steps for each original step (with the exception of steps with greater than 63 point change which are not smoothed).

Both sample time steps and smoothing steps are clock controlled; PROM and counter waveforms have a minimum step time of 200 ns while RAM waveforms have a minimum step time of 500 ns. Arb software detects sample times of less than 200 ns and gives an ERROR readout when an attempt is made to place those times in scratch pad memory. Notice, then, that RAM waveforms may be programmed and output at faster sample times (200 through 700 ns) than specified. Waveform deterioration will result when this is done.

When smoothing is programmed (100 smoothing steps per sample time), smoothing cannot occur unless *sample time* is 100 times greater than the 200 ns stepping time minimum; i.e., 20 μs.

When the sample time is programmed, the unrounded value is retained. Rounding is done when the execute action takes place, allowing the precision of the programmed value to be the maximum possible. For example, assume that the sample time is programmed to be 23.45 μs with smoothing off. In this case, the sample time will be rounded to 3 digits (23.5 μs) when execute occurs. If smoothing is then turned on, rounding will be to one digit (20 μs) when execute occurs. If smoothing is subsequently turned off again, rounding will once more be to 3 digits, and the value programmed into the waveform generation circuits at execute time will again be 23.5 μs. When this parameter is displayed on the front panel, it is shown rounded to the proper number of digits.

3.10 CLOCK TIME UNITS (S)

This parameter selects whether the sample time parameter (T) is programmed and displayed in seconds, minutes or hours. However, since the Arb waveform generator circuits are programmed in seconds, sample times programmed in minutes or hours must be converted to seconds by the microprocessor. This may result in sample times which are not exactly equal to the programmed value. For example, 6.789 minutes is 407.34 seconds, which requires 5 digits of programming accuracy. Since the Arb has only 4 digits, the value programmed is 407.3 seconds, or 6.788333 minutes. The actual time programmed will be displayed when sample time (T) is selected.

3.11 FULL OR PARTIAL BLOCK (U)

The full or partial block parameter selects whether a block consists of either the entire 256 points available or a portion of them selected by the block start address (V) and block stop address (W) parameters. If a full block (U0) is selected, the waveform is output by sequentially reading the sample points from the selected block starting at address 0 and ending at address 255. If a partial block (U1) is selected, the sample points are sequentially read starting at the block start address parameter value and ending at the block stop address parameter value. The start and stop address parameters should not be set to the same value if a partial block is selected, because no waveform will be generated. If an execute (I) is done in this case, an ERROR will be displayed, although the start and stop addresses will be programmed into the waveform generator circuits anyway. If two or more blocks are joined together (see item 19) and partial block (U1) is selected, then the resulting waveform is composed of the selected portion of *each* block. The start address may be greater than the stop address; in this case, the block "wraps around" from address 255 to address 0.

Table 3-5. Sample Time Round Off

Sample Time	No. of Significant Digits	
	Smoothing Off	Smoothing On
200 to 900 ns*	1	1**
1 to 9.9 μs	2	2**
10 to 19.9 μs	3	3**
20 to 99.99 μs	3	1
100 to 999.9 μs	4	2
1 to 9.999 ms	4	3
10 ms or longer	4	4

*RAM waveforms are not spec'd for sample time of:

Smoothing off: 200 - 400 ns

**Even if smoothing is programmed, no smoothing occurs for sample times shorter than 20 μs.

3.12 BLOCK RATE (F)

The block rate parameter is not a separate parameter. Instead, it is an alternative means of setting the sample time parameter in terms of the repetition frequency of blocks. When a block rate is programmed, the sample time necessary to produce it is computed from the number of blocks stacked together; the programmed block rate and the current size of a block as selected by full/partial block parameter and the start and stop block address parameters.

NOTE

When partial block is selected, the block rate is the rate of the partial block.

It is not possible, in general, to compute a sample time which will produce the desired frequency exactly. Consequently, when the block rate is displayed on the front panel, the number displayed is not the block rate that was programmed, but the block rate actually being produced.

If the full/partial block parameter code is zero,

$$\text{Sample Time} = \frac{1}{\text{Block Rate} \cdot 256 \cdot \text{No. of Blocks}}$$

If the full/partial block parameter code is one and the stop address is greater than the start address,

$$\text{Sample Time} = \frac{1}{\text{Block Rate} \cdot (\text{Stop Adr} - \text{Start Adr} + 1) \cdot \text{No. of Blocks}}$$

If the full/partial block parameter code is one and the stop address is less than the start address,

$$\text{Sample Time} = \frac{1}{\text{Block Rate } (\text{Stop Adr} - \text{Start Adr} + 257) \cdot \text{No. of Blocks}}$$

3.13 AMPLITUDE (A) AND OFFSET (D)

The amplitude parameter selects the amplitude generated by a waveform memory data point value of +127 (or the negative amplitude generated by a value of −127) at the ARB OUT (ATTEN) BNC connector. Smaller data point values will produce proportionately smaller amplitudes. Values from 1 mV p-p to 10V p-p (and −1 mV p-p to −10V p-p) into 50Ω and 0 may be programmed with 3 digit resolution. Negative values of amplitude invert the waveform.

The offset parameter selects a dc offset to be added to the output waveform. Values from 1 mV to 5V (and −1 mV to −5V) and 0 may be programmed with 3 digit accuracy into 50Ω.

The amplitude and offset are not completely independent of one another, because they share a common output amplifier and attenuator (see figure 3-5). In certain cases it may become necessary to decrease the number of digits of resolution of amplitude or offset (or both) in order to either prevent clipping in the output amplifier or to make the programmed value of offset (or amplitude) appear at the output despite an unfavorable attenuator setting required by a larger value of amplitude (or offset). The sum of amplitude or offset controls the output amplifier and attenuator. The output amplifier is limited to 10V p-p (into 50Ω). The attenuator operates at one of the values of X 10^0, X 10^{-1}, X 10^{-2} or 10^{-3} (0 dB, −20 dB, −40 dB, −60 dB).

If the absolute peak value at the amplifier input (which is the sum of the absolute values of the amplitude and offset mantissas, when amplitude and offset are expressed in scientific notation) exceeds 10V, then logic divides the values programmed into the amplitude and offset by 10 and, to maintain the desired output level, decreases attenuation by a factor of 10 also. If this must be done, then one digit of resolution is lost from both amplitude and offset. This adjustment cannot be done if the sum of the absolute values of the programmed amplitude and offset (which is the X 10 multipliers as well as the mantissas) is greater than 10V; in this case, the output will be clipped.

To determine if there is clipping or loss of resolution, perform the following calculations.

1. Add twice the absolute value of the desired offset to the absolute value of the desired amplitude. If the sum exceeds 10, clipping will occur. If not, go to step 2 to determine a trial attenuator setting.

2. Write the larger of the absolute amplitude or twice absolute offset in the form N.NN X 10^X, where N.NN is between 1.00 and 9.99. Then X 10^X is the trial attenuator setting. Perform step 3 to determine if the amplifier output would be clipped for the trial attenuator setting.

3. Take the sum of amplitude and offset computed in step 1 and write it in the form MM.MM X 10^X, where x is the exponent computed in step 2. If MM.MM is greater than 9.99, then one digit of resolution must be lost from both amplitude and offset in order to prevent the output amplifier from clipping.. Perform step 4 if there was no loss of resolution to determine if the smallest amplifier input caused too many significant digits.

4. Write the amplitude or twice the offset, whichever is smaller in absolute value, in the form Y.YYZZZ X 10^X, where x is the exponent computed in step 2. If any of the digits ZZZ are not zero, then resolution is lost, because only Y.YY can be used to program the waveform generator circuits.

Example A

Ampl = –3.43
Offset = 2.33

Step 1. 4.66 + 3.43 = 8.09. There is no clipping.
Step 2. Twice absolute offset is larger. 4.66 = 4.66 X 10^0. Therefore, x = 0.
Step 3. 5.97 = 5.97 X 10^0. Therefore, there is no loss of resolution in either parameter.
Step 4. Absolute amplitude is smaller. –3.43 = –3.43000 X 10^0. ZZZ = 000 and there is no loss of resolution anywhere.

Example B

Ampl = 0.0456
Offset = 0.0393

Step 1. 0.0786 + 0.0456 = 0.1242. There is no clipping.
Step 2. 0.0786 = 7.86 X 10^{-2}. X = –2.
Step 3. 0.1245 = 12.45 X 10^{-2}. Since 12.45 exceeds 9.99, there is a loss of one digit of resolution in both amplitude and offset. This means that the offset will be 0.039 (not 0.0393) and the amplitude will be 0.045 (not 0.0456).
Step 4. Not required.

Example C

Ampl = 2.58
Offset = 0.123

Step 1. 0.246 + 2.58 = 2.826. There is no clipping.
Step 2. Absolute amplitude is larger. x = 0.
Step 3. 2.703 = 2.703 X 10^0. No loss of resolution so far.
Step 4. Absolute offset is smaller. 0.246 = 0.24600 X 10^0. Y.YY = 0.24 and ZZZ = 600. Therefore, one digit is lost in the offset value, which will be 0.120, not 0.123.

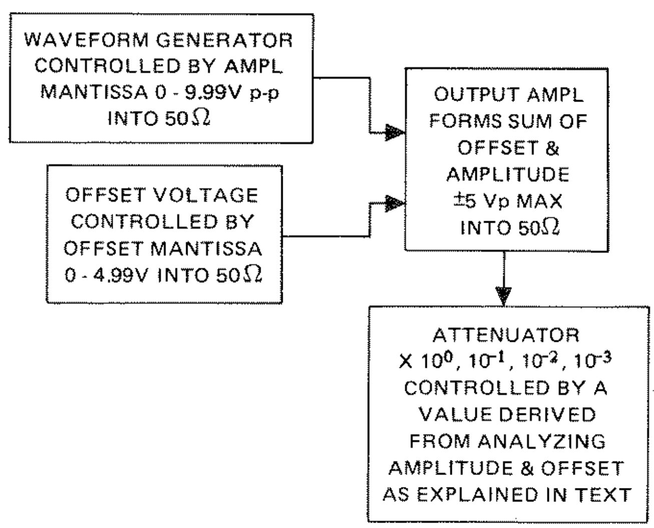


Figure 3-5. Hardware Diagram of Amplitude and Offset Generation

3.14 ERRORS

Programmed values are evaluated by the microprocessor when it receives a following alpha or terminator character. This character acts as a terminator, indicating that the operator is through selecting the numerical value. If, after round off, the value is out of range for the selected parameter, an

ERROR message is placed on the display and the scratch pad memory is not changed. If executed, output would be the current values in scratch pad memory.

When the execute key is pressed, two error tests are made: one for clipping (absolute value of amplitude plus absolute value of offset greater than 10V p-p into 50Ω) and one for misprogramming of the block start and stop addresses (start (V) and stop (W) addresses equal and partial block mode enabled (U1)). If clipping error is detected, ERROR will be displayed on the front panel and the incorrect parameters will be sent unaltered to the waveform circuits. If start and stop addresses are equal, ERROR is displayed and the last legal addresses are retained.

3.15 PRESET AND MONITOR TRIGGER (M)

In both modes the waveform may be stopped at any time with a hold command (H), and then resumed from the place where stopped with a trigger (J). If the preset mode is selected, the trigger will reset the cycle counter before resuming the waveform, thus restarting the process of generating a preset number of cycles. In this case, the preset length (L) parameter determines the number of cycles generated after the trigger, with the first cycle being composed of the remaining portion of the cycle that was interrupted by the hold command.

3.16 GPIB

The GPIB interface is an implementation of IEEE Standard 488-1975. It supports the following interface functions: Source Handshake (SH1), Acceptor Handshake (AH1), Talker (T6), Listener (L4), Service Request (SR1), Remote Local (RL2), Device Clear (DC1) and Device Trigger (DT1).

Devices connected to the GPIB can have one or more of the three capabilities: talk, listen and control. The talk capability allows a device to send data (such as voltmeter or counter readings) out over the bus. The listen capability allows a device to receive data (such as device programming information or a printer receiving data to be printed) from the bus. The control capability allows a device to control the flow of data over the bus. Although there may be more than one device connected to the GPIB with control capability, only one device at a time may exercise that capability on the bus. One device's control capability must be active at all times; this device is called the controller.
Programming examples are given in Appendex B.

NOTE

When ATN goes true, the GPIB interface will go from the AIDS state to the ACRS state in less than 200 nanoseconds and will ignore the status of the DAV signal, in accordance with the IEEE 488-1975 specifications. This action may create problems for controllers that try to Take Control Synchronously (TCS).*

**Refer to AH state diagram and C state diagram of the IEEE 488-1975 standard.*

3.16.1 Bus Lines Defined

The GPIB consists of 16 signal lines, as shown in table 3-6. Their functions are:

DIO1 - DIO8 — These eight lines (Data In/Out) are used to send commands and data encoded as 8-bit binary numbers (bytes).

ATN — This line (Attention) is operated only by the controller. It specifies whether the information on lines DIO1 - DIO8 is data (false) or a command (true). Whenever ATN is set true, no activity is allowed on the bus except for controller-originated messages; additionally, every device connected to the bus is required to receive and process every command sent by the controller.

DAV, NRFD, NDAC — These are the "handshake" lines (Data Valid, Ready For Data and Data Accepted) which regulate the transmission of information over the lines DIO1 - DIO8. For each command or data byte transferred, a complete handshake cycle must occur. This handshake is designed to hold up the bus until the slowest device has accepted the information.

EOI — When ATN is false, this line (End Or Identify) indicates that the data on lines DIO1 - DIO8 is (true) or is not (false) the last byte of a data message. Refer to paragraph 3.16.4 for terminator character identification.

REN — This line (Remote Enable) is used to control whether devices on the GPIB are in local or remote mode. In local mode, devices respond to front panel commands and do not respond to GPIB-originated commands. In remote mode the situation is reversed: GPIB-originated commands are obeyed while front panel commands are ignored. A device enters the remote state whenever it receives its listen address (refer to paragraph 3.16.2, GPIB Commands) at the same time as REN is in the remote state. The device then stays in the remote mode until either the REN line is put in the local state or the device receives a Go-To-Local (GTL) command.

SRQ — This line (Service Request) is used by the devices on the bus to signal the controller that they need attention. (Refer to paragraph 3.2.2, item 3, for Service Request Enable.) Since the SRQ line is common to all devices, additional tests must be made to determine which devices are signaling. The Serial Poll capability is usually employed to accomplish this.

IFC — This line (Interface Clear) is used by the controller to reset the interface logic in all devices connected to the bus to a known initial state.

Table 3-6. GPIB Lines and Commands

Bus Lines	
DIO1 - DIO8	Data In/Out Lines
ATN	Attention
DAV	Data Available
NRFD	Ready For Data
NDAC	Data Accepted
EOI	End Or Identify
REN	Remote Enable
SRQ	Service Request
IFC	Interface Clear
GPIB Commands	
Listen Address	
Talk Address	
Secondary Address	
Universal Commands	
DCL	Device Clear
SPE	Serial Poll Enable
SPD	Serial Poll Disable
Addressed Commands	
GTL	Go To Local
SDC	Selective Device Clear
GET	Group Executive Trigger

3.16.2 GPIB Commands

Commands are sent over lines DIO1 - DIO8 with ATN true. They are divided into five classes.

3.16.2.1 Listen Addresses

Listen addresses are used to command a device to read any data bytes transmitted over lines DIO1 - DIO8. There are 31 different available addresses (hexadecimal codes 20 thru 3E, ASCII codes "SP" thru ">"). A thirty-second address, called unlisten (hexadecimal 3F, ASCII "?"), is used to command all devices not to read data bytes. The Arb's listen address is selected by the rear panel DIP switch, which specifies the lower 5 bits of the address. (Refer to table 2-2.)

3.16.2.2 Talk Addresses

Talk addresses are used to command a device to transmit data over lines DIO1 - DIO8 whenever ATN is false. There are 31 different available addresses (hexadecimal codes 40 thru 5E, ASCII codes "@" thru "↑"). A thirty-second address, called untalk (hexadecimal 5F, ASCII "→") is used to command all devices to cease talking. The lower 5 bits of the Arb's talk address are selected by the same rear panel DIP switch used to select the listen address. Thus, if the Arb's listen address is hexadecimal 21 (ASCII "!"), the talk address is hexadecimal 41 (ASCII "A").

3.16.2.3 Secondary Addresses

Secondary addresses are used following a talk or listen address to provide the ability to address more than the 31 devices provided for by simple talk or listen addresses. Secondary addresses are ignored by the Arb.

3.16.2.4 Universal Commands

Universal commands are used to command a device to perform designated actions. Universal commands are recognized at all times. Universal commands performed by the Arb are:

a. **Device Clear (DCL).** Resets the following parameters to the power on state.

Amplitude	1 volt
Offset	0 volts
Mode	Continuous
Function	Sine
Output	Off
Clock Int/Ext	Internal
Time Unit	Seconds
Sample Time	20 μs
Preset/Monitor	Preset
Preset Length	1
Full/Part	Full
Start Address	0
Stop Address	255
Memory Address	0
Smoothing	Off

This information is also set into the waveform generating circuitry. The data in the waveform memory RAMs are not affected.

b. **Serial Poll Enable (SPE).** Causes the instrument to engage in a serial poll by responding with the serial poll status byte when addressed as a talker. Bit 7 of this byte will be on, if service is being requested on the SRQ line. When the status byte is read, it is reset to zero, and the SRQ line is released (of course, it may still be held down by other devices). The status byte is also available by reading the Arb's talk message number 2. When this message is read, the status byte is reset to 0 and SRQ released as for the serial poll.

c. **Serial Poll Disable (SPD).** Removes the instrument from the serial poll mode activated by the SPE command.

3.16.2.5 Addressed Commands

Addressed commands are used to command a device to perform designated actions. Addressed commands are recognized only when the instrument is addressed as a listener. Addressed commands performed by the Arb are:

a. **Go To Local (GTL).** Commands the Arb to go to the local mode (see explanation for REN line, paragraph 3.16.1).

b. **Selective Device Clear (SDC).** Same action as for Device Clear (DCL) command, paragraph 3.16.2.4.

c. **Group Execute Trigger (GET).** This command transfers the programmed waveform values to the waveform generation circuits, and then sends a trigger pulse. This is the same sequence of events that would happen if an execute, then a trigger action were processing a previously sent programming string), this command is completed within a few milliseconds of being received; otherwise, it is not done until the program string is completely processed to ensure that up-to-date values are sent to the instrument circuits.

3.16.3 GPIB Data Transfers

The Arb will both accept programming characters and transmit status information over the bus. To program the instrument, first send the listen address (with ATN on), followed by the programming data (in ASCII, with ATN off). The instrument microprocessor accepts the data as fast as possible, until either 40 characters are received or there is a pause during the transfer of data. At that time, the entire string of received characters is scanned by the microprocessor, which carries out the programming instructions contained in it. While this is happening, the instrument can accept an additional 40 characters of data over the bus; if more are sent, the bus will hang until the microprocessor completes a scan and accepts the next 40 character string. If the EOI line is asserted while sending a character to the Arb, the currently programmed terminator character will be put into the input string following the character with the EOI.

To read a message from the Arb, first send the talk address (with ATN on) over the bus. The instrument will then send the message currently selected by the talk message select (R) parameter. The last character of this message will be the currently programmed terminator character with the EOI line asserted.

3.16.4 GPIB Talk Message and Terminator Character (R)

One key (or "R" on GPIB) controls two parameters: the terminator character and the type of talk message sent when the Arb is addressed to talk over the GPIB. The terminator character is selected by programming a minus and the decimal value of the ASCII character that is to be the new terminator. Any ASCII character is acceptable except NUL (decimal code 0), so allowed values for programming the terminator range from −1 to −127. The terminator character has two uses. During output from the Arb over the GPIB, it is appended to every talk response. During input, it signals the end of a group of programming characters; in particular, it indicates the end of a number. At power on time, the terminator character is the line feed control character, decimal code 10. When the Arb sends a talk message, the terminator character is the last byte sent. In addition, the End Or Identify (EOI) line is pulled low (GPIB END message) during the terminator character transmission. If the device receiving the talk message requires a terminating character, but does not recognize either the line feed character or the END message, then a new terminator character must be programmed. For example, to change the terminator character to a carriage return (decimal code 13), program "R−13". Refer to Appendix A for ASCII codes.

The talk message parameter selects which of four messages will be sent when the Arb is addressed to talk over the GPIB. It is programmed with a positive integer code; allowed values are 0, 1, 2 and 3, with formats as follows:

R0 (*I/C*) State of Hold Status:
"H∧0" if generator is not holding
"H∧1" if generator is holding

R1 List of first nine errors since this message was last read. Each error is indicated by the GPIB programming letter of the parameter in which the error occurred.

Example: "E∧A∧B∧F∧A"

The first letter, "E", indicates that this is an error response string. The other four letters indicate that an error occurred while setting first amplitude, then mode, then block rate, and again amplitude.

R2 This message gives the current value of the GPIB service request poll response, which describes why the Arb is asserting the SRQ line. This is the same byte that a GPIB controller would receive if it addressed the Arb and did a serial poll. If the SRQ line is being asserted by the Arb when this message is read, it is released.

Possible values are (the letter "P" indicates a poll message):

"P∧∧"	SRQ is not being asserted by Arb.
"P∧E"	SRQ is asserted because of a programming error.
"P∧H"	SRQ is asserted because the waveform generator went from a not-holding state to a holding state.
"P∧M"	SRQ is asserted because both an error and a transition to holding occurred (conditions for "E" and "H" both true).

R3 This message gives the value currently associated with the parameter or status response selected by the last alphabetic character programmed to the Arb. If that character selects an action (such as execute or trigger), then the response is blank.

Examples (the letter V indicates a value of parameter message):

"V∧A∧6.5E—1"	response for amplitude = 650 mV.
"V∧C∧7"	response for function = PROM 3.
"V∧I∧"	response for execute (no numeric value returned).
"V∧K∧631"	response for monitor count (K) status showing a count of 631.
"V∧H∧49"	response for hold (H) action, showing address of sample point where held; hold is the only action which returns a numeric value.

The front panel display for this parameter shows the talk response code on the left and the decimal code (with a minus sign) for the terminator character on the right.

Example: R 0 −10

shows that the talk response code is zero and the terminator character is an ASCII line feed (whose decimal code is 10).

3.16.5 GPIB Service Request Enable (Q)

The key GPIB SRQ or the letter "Q" controls the conditions under which the Arb will make a service request (i.e., turn the SRQ line on). Note that programming this parameter does *not* change the state of the SRQ line. If SRQ is on, the only way to turn it off is to perform a serial poll or read talk message 2. If SRQ is off, the only way it can be turned on is by the occurrence of the condition(s) enabled by the SRQ enable parameter. Allowed values are 0, 1, 2 and 3, with the following effects.

Q0 SRQ disabled. The Arb will not turn SRQ on under any circumstances.

Q1 *(I/C).* SRQ enabled for programming errors. The Arb will turn SRQ on when a programming error is made from either the front panel or GPIB.

Q2 SRQ enabled for hold status coming on. The Arb will turn SRQ on when the waveform generator circuits go from a running to a holding state (refer to paragraph 3.15). Since the change is detected by the microprocessor, it may take as long as 10 ms between the transition to the holding state and the turning on of the SRQ (if a long block of data is being sent to the Arb via the GPIB, the maximum time increases to 20 ms).

Q3 SRQ enabled for both programming errors and hold status coming on. The Arb will turn SRQ on, if either a programming error (refer to explanation for Q1) or a transition to holding (refer to explanation for Q2) occurs. The status byte returned by a serial poll of the Arb will tell which condition turned SRQ on.

3.17 Input and Output Impedances

3.17.1 Arbitrary Waveform Outputs

The ARB OUT (ATTEN) connector is the main output and has a source impedance of 50Ω. Block amplitude in volts peak-to-peak and offset voltage in volts will be equal to programmed values when terminated into 50Ω.

The ARB OUT (HI) connector is an auxiliary output and has a source impedance of <1Ω. Since this output does not pass throujgh the 50Ω attenuator and is not halved when terminated, it has a block amplitude in volts *peak* (not peak-to-peak) equal to the mantissa of amplitude and an offset in volts of *twice* the offset mantissa. Refer to paragraph 3.13 for amplitude and offset mantissas and exponents. This output should be terminated so that peak output current does not exceed 100 mA.

3.17.2 TTL Outputs

SYNC OUT, CURSOR OUT and REF OUT connectors have TTL level signals driven by standard TTL devices, capable of driving up to 10 TTL inputs or a resistive load of not less than 600Ω. In case of damage to these outputs by improper termination, the standard 7404 devices are socket mounted on the generator board for convenient replacement. U16D drives the REF OUT and CURSOR OUT and U10C drives the SYNC OUT.

3.17.3 TTL Inputs

The EXT TRIG, EXT HOLD, RAMP TO ZERO and EXT REF connectors accept external TTL level inputs. EXT REF presents a single, standard TTL load and is protected against inputs greater than +5V or less than 0V with discrete diodes. The other inputs also have diode protection, and respond to either TTL levels or momentary external contact closure between BNC conductor and shell. When a TTL signal is used, the low level input must sink 2.3 mA for the discrete pull-up resistor plus the standard TTL load of 1.6 mA, resulting in an input loading approximating 2½ loads.

3.17.4 Changing Source Impedance of the Main Output

The output impedance of the attenuated output [ARB OUT (ATTEN) 50Ω Rear Panel BNC, Figure 2-1] may be changed by removing the jumper on the generator board labeled ARB OUT (ATTEN) and inserting an appropriate 1W, 1% resistor, which will be in series with an existing 50Ω. For example, inserting a 550Ω resistor will give a 600Ω output impedance.