
Model 2414B

20 MS/s Arbitrary Waveform Generator

Operation Manual

810030-CD

Rev E

This owner's manual was as current as possible when this product was manufactured. However, products are constantly being updated and improved. Because of this, some differences may occur between the description in this manual and the product you received.

TEGAM, INC.
TEN TEGAM WAY
GENEVA, OH 44041
TEL: (440) 466-6100
FAX: (440) 466-6110
www.tegam.com

Publication Date: October 2006

WARRANTY

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of 3 years from date of shipment. During the warranty period, we will at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, contact TEGAM, Inc., Ten Tegam Way, Geneva, Ohio 44041/FAX (440) 466-6110/(440) 466-6100, M-F, 8 a.m.- 5 p.m. ET. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty, or at least 90 days, whichever is longer.

LIMATION OF WARRANTY

TEGAM, Inc. warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. TEGAM, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by TEGAM, Inc.

This accuracy and calibration of this instrument are traceable to the National Institute of Standards and Technology through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of TEGAM, Inc..

The Model 2414B is a high resolution 20 MS/s Arbitrary Waveform Generator with optional Windows® based waveform creation capability. The updated front panel and the optional WaveWorks™ Pro. waveform creation software make the 2414B the easiest way to create and output the waveforms you need. The additional channels needed for multi-phase applications can be met with a simple connection between two or more 2414Bs. Its combination of bench-top and system features, GPIB and RS232C interfaces and the integrated software which is optional and runs under Windows make this waveform generator package a versatile tool useful to create your waveforms for mechanical simulation, engine simulation, medical electronics, modulated sine wave applications and many more applications.

Lab-quality performance

- 20 commonly used standard waveforms front-panel selectable
- Continuous or triggered output--5 standard modes
- 12-bit waveforms--precision output up to 20 MS/s
- Very large waveform memory--128k words
- Loop and link up to 1000 waveforms and 4096 steps (Sequence option)

Convenient bench-top features

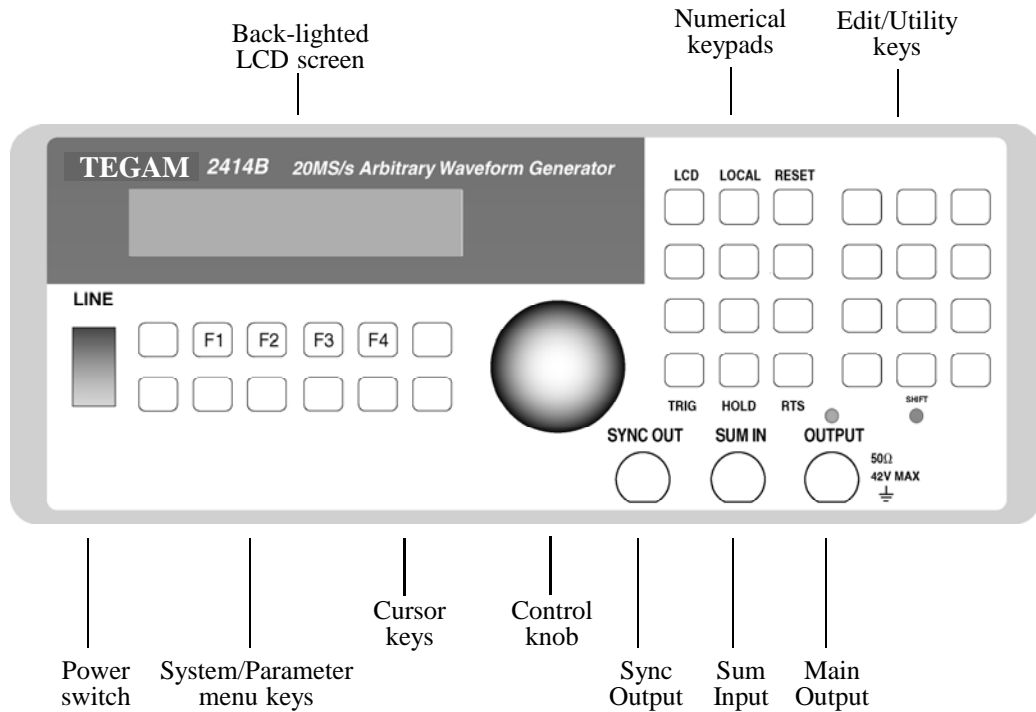
- Updated front panel includes control knob and back-lighted LCD
- Cursor control of amplitude, offset, sample clock and frequency.
- Portable, small profile package

System features

- RS-232C included
- Multiple channel operation (multiple units required)
- Waveform creation software under Windows available
- 4 programmable sync pulses per waveform

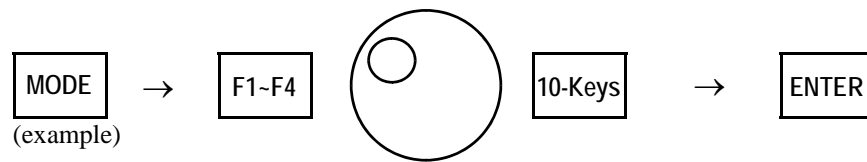
Model 2414B 20 MS/s Arbitrary Waveform Generator

The Front Panel

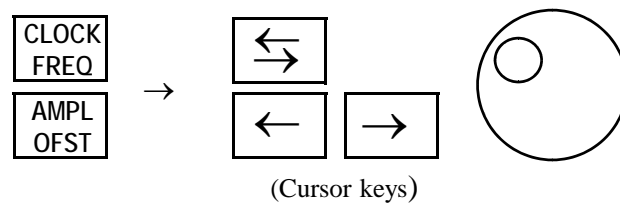


Front-Panel Entry

Press one of the System/Parameter menu keys or the Utility/Edit menu keys, and use soft keys (F1 ~ F4), knob or 10-keys to make selection. Then, press ENTER key.



Use the CLOCK/FREQ or AMPL/OFST key and the knob to make parameter changes. Use double arrow key to switch parameter selection. Use arrow keys to select digits and ranges.



The Rear Panel

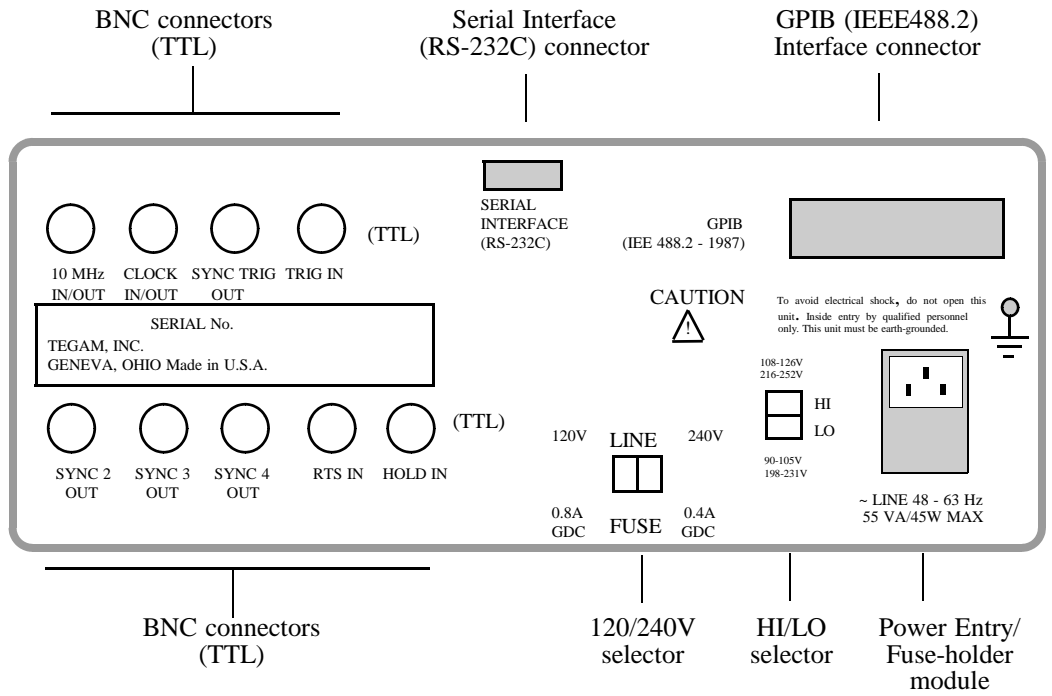


Table of Contents

The Front Panel	II
Front Panel Entry	II
The Rear Panel / Power Mains Setting	III
Technical Specification	VII
In This Manual	VIII

Chapter 1 - Quick Start

To prepare the generator for use	1 - 2
To set the output frequency for standard waveforms	1 - 3
To set the sample clock rate	1 - 4
To set the output amplitude	1 - 5
To set the output offset voltage	1 - 6
To select a standard waveform	1 - 7
To change the default length of standard waveform	1 - 8
To select a user-defined waveform	1 - 9
To select a sequence waveform (option)	1 - 10
To select operating mode	1 - 12

Chapter 2 - About Arbitrary Waveforms

Waveform Generation	2 - 2
Waveform Cycle	2 - 2
More on Waveform Cycle	2 - 3
Digital and Analog Scaling	2 - 3
Other Considerations	2 - 3
Examples-Digital and Analog Scaling	2 - 4
Waveform Types	2 - 5
Sync Pulse	2 - 6
Sync Outputs	2 - 7
2414B Block Diagram	2 - 8

Chapter 3 - Front-Panel Menu Operation

Parameter Control	
MODE menu	3 - 2
Sample Clock and Frequency (SCLK/FREQ) menu	3 - 2
FUNCTION menu	3 - 3
OUTPUT menu	3 - 4
Waveform Setup	3 - 4
Waveform Edit	3 - 4
System Control	3 - 5
Default Settings	3 - 6
Standard Waveform List	3 - 9

Chapter 4 - Waveform Creation System

Components	4 - 2
User Interface	4 - 2
Memory Organization	
Introduction	4 - 4
Default Partitioning	4 - 4
Waveform Numbering	4 - 4
Changing Waveform Block length	4 - 4
Waveform Number Block Length	4 - 5
Deleting Waveform	4 - 5
Inserting New Waveform numbers	4 - 5

Table of Contents

Waveform Creation Using Front Panel	
Introduction	4 - 6
Line Mode	4 - 6
Waveform Creation Using Front Panel	
Line Mode	4 - 6
Vertex Mode	4 - 9
Math Operation	4 - 13
Examples	4 - 14
Sequence Generator (Option)	
Introduction	4 - 17
Programming a Sequence	4 - 17
Deleting a Sequence	4 - 18
Adding a Step into an Existing Sequence	4 - 18
Deleting a Step from an Existing Sequence	4 - 19
Modyfying a Step within an Existing Sequence	4 - 19
WaveWorks Pro Software (Option)	4 - 20

Chapter 5 - Multi-Instrument Operation

Basic Connection	5 - 2
Multiple Phase Connection	5 - 3
Multiple Phase Operation	5 - 3
Multiple Phase Setup	5 - 6

Chapter 6 - Performance Verification

Introduction.....	6 - 2
Test Equipment Required	6 - 2
Verification Test	6 - 2
Verification Test Sheet	6 - 4

Chapter 7 - Remote Interface Operation

Introduction	7 - 2
To set the GPIB address	7 - 2
To set the RS-232C parameters	7 - 3
RS-232C Adapter Cables	7 - 3
Before sending commands	7 - 5
Command Features	
Command Execution	7 - 5
Waveform Selection	7 - 6
Waveform Deletion	7 - 6
Command Set	7 - 7
Reset and Default Values	7 - 13
RS-232C Programming Example	7 - 15
GPIB Programming Example	7 - 17

Chapter 8 - Advanced Remote Operation

RS-232C Overview	
Introduction	8 - 2
Interface Requirements	8 - 2
Verification of Communication	8 - 3
Command Syntax	8 - 3
Event Register and Status and Error Reporting	8 - 4
Functional Syntax Elements	8 - 4

Table of Contents

GPIB (IEEE-488.2) Overview (Optional)	
Introduction	8 - 7
Common Commands	8 - 8
Status and Event Registers	8 - 9
Functional Elements - Syntax and Nomenclature	8 - 11
Error Reporting	8 - 12
Data Formats	
Decimal Numeric Program Data	8 - 13
Arbitrary Block Program Data	8 - 14
Remote Command Set	
Introduction	8 - 15
Command Sequence	8 - 15
Command Execution	8 - 15
Command Set Hierarchy	8 - 16
Stacked Queries	8 - 16
Command Set	8 - 17
Waveform Editing Principles.....	8 - 19
Waveform Memory Format	
Decimal Waveform Download	8 - 21
Binary Waveform Download	8 - 22
Example	8 - 23
Binary Download Test Program for GPIB	8 - 25
Arbitrary Sync Pattern Programming	
Overview.....	8 - 28
Start/Length Sync Programming	8 - 28
Block Sync Programming	8 - 29
Combined Waveform and Sync Programming	8 - 30
Single Point Sync Query	8 - 31
Multiple Point Sync Query	8 - 31
Sequence Generator Operation (Option)	
Add Sequence	8 - 33
Auto Sequence	8 - 33
Sequence	8 - 33
Sequence Burst	8 - 34
Sequence Burst Number	8 - 34

Appendix

- Menu Logic Tree
- Standard Waveshape Equations
- Amplitude/Offset Graph

Index

Technical Data Sheet

Model 2414B 20MS/s Arbitrary Waveform Generator

Output Waveforms

Up to 1000 High-Precision User-defined Waveforms,
Standard Waveforms: Sine, Square, Triangle, \pm Sawtooth,
DC, \pm Pulse, \pm Exponential, AM, SCM, FM, Lin/Log Sweep,
Sin x/x (Sinc), Gaussian, Haversine, Circle, Noise.
4 programmable sync pulses per waveform.

Sequence Generator (Optional)

Waveform: Transient-free Loop and Link
Repetitions: Loop: 1,048,575 times Link: 1000 waveforms
Program: 4096 Steps total
File: 100 Sequences

Waveform

Storage: 1000 waveforms
Resolution:
Horizontal Points: 131,036 max.
Vertical Points: 12 bits, 4096 (-2048 to +2047)
Sample Rate:
Range: 0.1Hz to 20MHz (10s to 50ns)
Resolution: 4 digits
Accuracy: ± 50 ppm
Transition Time: <20ns
(Tested with square wave, filter off, 10Vp-p, 50 Ω termination.)

THD + Noise: -65dB typical (20kHz sinewave)
(Tested with 80kHz measurement bandwidth, 20MHz clock, sinewave, 1000 points, filter on, full amplitude, 50 Ω termination.)

Amplitude and Offset

<u>Range</u>	<u>Resolution</u>	<u>Accuracy</u>
± 1.00 to 10V	10mV	1% of setting + 20mV
± 100 mV to 999mV	1mV	3% of setting + 5mV
± 10 mV to 99.9mV	100 μ V	5% of setting + 1mV

(Tested with 1kHz sinewave plus DC offset, 50 Ω source impedance, open circuit.)

Selectable Analog Filter

Cutoff: 7MHz, 7th order

Operational Modes

Continuous: Output runs continuously between selected memory address locations.
Triggered: Output at start point until triggered, then runs once.
Gated: As triggered except output is continuous until gate signal ends.
Burst: Each trigger outputs a preprogrammed number of waveforms from 1 to 1,048,575.
Toggled: Alternate triggers gate the output waveform.
Master-Slave Operation: For multi-phase operation.
Continuous-Sync: multiple units run continuously in sync with the master unit
Trigger-Sync: multiple units run in sync with the master unit for one cycle when the master unit is triggered.
Trigger-Sequence: a tail-chasing mode between the master and the slave unit initiated by triggering the master unit.

Outputs

Output: Front-panel main waveform output, 50 Ω impedance.
Sync Outputs: Front-panel TTL sync output, 50 Ω impedance plus 3 rear-panel TTL outputs. Programmable.
Clock Out: Rear-panel AWG waveform sample clock output (TTL).
Reference Out: Rear-panel internal 10MHz reference output (TTL).
Sync Trigger Out: Triggers additional units

Inputs

Trigger Input: Rear-panel TTL trigger input for triggered, gated, burst, toggled and master-slave modes.
External TTL Sample Clock Input: ≤ 20 MHz
Reference In: Rear-panel 10MHz reference input will phase lock the internal crystal-controlled oscillator.

Trigger Sources

External Trigger Input
Manual Trigger

Waveform Creation Tools (Option)

Software: WaveWorks Pro for Windows
Operating System: Windows 98, 95 or 3.1; MS-DOS 6.2
PC Requirements: 486DX or better with 4MB RAM space
Interface: COM port or National Instrument AT-GPIB card (or equivalent)

Standard Function: 30

Math Operation:

Operators: 13
Transfer Function: 20

Sequence Creation (optional hardware required)

Waveform Analysis:

Frequency Domain: FFT and IFFT: up to 500th harmonic, graphic display and tabulation
Time Domain: Waveform and Digital Pattern

Edit: Point, Vertex and Harmonics (FFT, IFFT).

Computer Interface

RS-232C: 19.2kBaud. max.
GPIB: IEEE Std. 488.2-1987 (Optional)

General

Stored Settings: 20
Temperature Range: +23 $^{\circ}$ C \pm 3 $^{\circ}$ C for specified operation. Operates 0 $^{\circ}$ C to +50 $^{\circ}$ C. Storage -20 $^{\circ}$ C to +60 $^{\circ}$ C.
Dimensions: 11.5cm (4.53 in.) H; 25.8cm (10.14 in.) W; 30cm (11.81 in.) D.
Weight: 5.0kg (11 lbs)
Power: 55VA; 45W (max) 100/120/220/240 VAC. +5%, -10%; 48 to 63 Hz.

Weight and dimensions are approximate. Errors and omissions excepted. Prices and specifications subject to change without notice. TEGAM is the registered trademark of TEGAM, Inc.
© Copyright 2000 TEGAM, Inc. All rights reserved.

Quick Start: Chapter 1 will prepare you to use the basic parameters of the arbitrary waveform generator within a short time.

1

About Arbitrary Waveforms: Chapter 2 provides you the basic concept of arbitrary waveform generation.

2

Front-Panel Menu Operation: Chapter 3 describes the front-panel menu operation.

3

Waveform Creation System: Chapter 4 describes the overview of waveform creation system.

4

Multi-Instrument Operation: Chapter 5 describes the basic connection and the multiple unit operation for multiphase applications. You will learn about the hardware connections and the available master-slave mode.

5

Performance Verification: Chapter 6 describes the procedure to verify the 2414B specification.

6

Remote Interface Operation: Chapter 7 describes the remote interfaces. You will learn how to send simple commands over RS-232C or GPIB. The detail command list is included in this chapter.

7

Advanced Remote Operation: Chapter 8 describes in details the remote interfaces. It is intended for use by experienced systems programmers to control every feature of the 2414B from both RS-232C and GPIB.

8

In this manual



Quick Start

To prepare the generator for use

The following steps will help you verify that the generator is ready for use.

1. Check the list of supplied items.

Verify that you have received the following items with your arbitrary waveform generator.

- One power cord
- The instrument operation manual

2. Check the power mains voltage setting on the rear-panel.

Verify that the mains voltage is set to the range for your location. You can verify the setting by observing the position of the slide switches on the rear panel. Refer to the rear panel diagram on page III.

3. Connect the power cord and turn on the generator.

The generator power switch is located at the lower left corner of the front-panel. The front-panel display will light up and indicate the name, the model number and the firmware version release level.

4. Press OUTPUT button, select ON (F1 softkey) and then press ENTER.

The LED above OUTPUT connector turns on. Now, the generator output is on.

5. Connect a BNC cable from the OUTPUT connector to an oscilloscope input.

Terminate the cable at the oscilloscope input with 50Ω load.

6. Connect a BNC cable from the front panel SYNC OUT connector to the external sync input of the oscilloscope.

Make an adjustment to the oscilloscope to synchronize the output waveform on the display.

To set the output frequency for standard waveforms.

At the initial power-on, the generator output is turned off. Be sure to follow the step 4 of the page 1-2 if you have not yet turned on the generator output. The following steps will show you how to change the output frequency to 12 kHz. Remember that the output frequency is computed as shown.

$$\text{Waveform Frequency} = \frac{[(\text{Sample Clock}) / (\text{Waveform Length})] * (\text{Number of Cycles in the Waveform Frame})}{1}$$

1. Press SCLK (Sample Clock) / FREQ (Frequency) button. Then, press double arrow button to exchange the parameters.

The displayed frequency is either the power-on value or the previously selected

FREQ =	10.00 kHz
SCLK =	10.00 MHz

2. Enter the magnitude of the desired frequency.

Use the right-arrow button to place the cursor under the selected digit. Turn the knob to set the digit to 2. The frequency will indicate 12.00 kHz.

FREQ =	12.00 kHz
SCLK =	12.00 MHz

3. Select the desired frequency range.

Use the right-arrow button to place the cursor under the multiplier (k). Turn the knob counterclockwise to switch the range by a decade.

FREQ =	1.200 kHz
SCLK =	1.200 MHz

To set the sample clock rate .

At the initial power-on, the generator outputs a free-running sine wave at 10kHz with an amplitude of 5.0 V peak-to-peak (into 50Ω termination) after the output is turned on. The following steps will show you how to change the sample clock rate of a user-defined waveform or an optional sequence. The output frequency of any waveform is:

$$\text{Waveform Frequency} = [(\text{Sample Clock}) / (\text{Waveform Length})] * (\text{Number of Cycles in the Waveform Frame})$$

1. Press FUNC (function) key and select a user-defined waveform, WAV#. Select WAV#0 and press ENTER.

The default length of a user-defined waveform is 2000 points.

2. Press SCLK/FREQ (Sample Clock/Frequency) button.

The displayed sample clock is either the power-on value or the previous sample clock rate selected.

SCLK =	10.00 MHz
FREQ =	5.000 kHz

3. Enter the magnitude of the desired sample clock rate.

Use the right-arrow button to place the cursor under the selected digit. Turn the knob to set the digit to 2.

SCLK =	1 <u>2</u> .00 MHz
FREQ =	6.000 kHz

4. Select the range of the desired frequency.

Use the right-arrow button to place the cursor under the multiplier (M). Turn the knob counterclockwise to switch the range by a decade. Observe the output frequency has changed by a decade.

SCLK =	1.200 <u>M</u> Hz
FREQ =	600.0 Hz

To set the output amplitude

At the initial power-on, the generator outputs a cw sine wave at 10 kHz with an amplitude of 5V peak-to-peak (into 50Ω termination) after the output is turned on. The following steps will show you how to change the amplitude to 2.5V peak-to-peak.

1. Press AMPL/OFST (Amplitude/Offset) button.

The displayed amplitude is either the power-on value or the previous amplitude selected.

AMPL =	5.000	V
OFST =	0.000	V

2. Select the digit you are going to modify.

Use the left-arrow button to place the cursor under the selected digit.

AMPL =	<u>5</u> .000	V
OFST =	0.000	V

3. Enter the magnitude of the desired amplitude.

Turn the knob counter clockwise to set the digit to 2.

AMPL =	<u>2</u> .000	V
OFST =	0.000	V

4. Enter the magnitude of the desired amplitude.

Use the right-arrow button to place the cursor under the selected digit. Turn the knob to set the digit to 5 to change the magnitude.

AMPL =	2. <u>5</u> 00	V
OFST =	0.000	V

To set the output offset voltage.

At the initial power-on, the generator outputs a cw sine wave at 1 kHz with an offset voltage of 0 V (into 50Ω termination) after the output is turned on. The following steps will show you how to add 1.0 V offset to the output.

1. Press **AMPL/OFST** button twice or press the double arrow button to exchange the parameters.

OFST =	0.000 V
AMPL =	2.500 V

2. Select the digit and enter the desired offset voltage.

Use the left-arrow button to place the cursor under the number 0. Turn the knob to select the desired offset voltage. You must observe some restrictions for the magnitude of the offset voltage. The sum of the offset and peak amplitude can not exceed +/- 5 volts when terminated with 50Ω.

OFST =	1.000 V
AMPL =	2.500 V

Amplitude and DC Offset Ranges

TEGAM 2414B utilizes unique combinations of the input and output attenuators for the output amplifier in order to accomplish the optimized signal attenuation. Therefore, if DC offset is applied to the signal, the following restrictions must be observed.

Amplitude Range

1V ~ 10.2V
 100mV ~ 999mV
 10mV ~ 99mV

Legal Amplitude+DC Offset Limits

Amplitude + | DC Offset | ≤ 10.4V
 Amplitude + | DC Offset | ≤ 1.00V
 Amplitude + | DC Offset | ≤ 100mV

To select a standard waveform.

At the initial power-on, the generator outputs a free-running sinewave at 1 kHz after the output is turned on. The following steps will show you how to select another standard waveform.

1. Press FUNC (function) button.

```
FUNC:
wav# seq# STDW view
```

Select standard waveforms by pressing **STDW** (standard wave). The default length is set to 1000 points.

```
FUNC:STDW:
SIN squ tri saw+
```

2. Use the right and left arrow buttons to view the selection menu.

Select one of the 20 standard waveforms.

```
FUNC:STDW:
am scm fm hsin
```

3. Press SIN (sinewave) button to select parameter(s).

Use the double arrow button to exchange the parameters. Press the waveform button again to select more parameters if available.

```
N=1.00 P=0.000
SIN squ tri saw+
```

4. Turn the knob or key in the parameters on the 10-key to enter parameters.

To select a standard waveform. (continued)

5. Press ENTER button to set parameters.

Note: the standard waveform data is recomputed after the parameters are changed. It may take a fraction of a second to several seconds to compute and draw the new waveshape. The time to draw the waveform depends on the sample length and type of waveform selected.

To change the default length of standard waveform.

The default length of 1000 points will create the maximum frequency of 2kHz sinewave. If higher frequency is required, the default length must be changed. The minimum length is 16 points.

1. Press SETUP button.

```

SETUP:
WAV# STDW SEQ#
  
```

2. Press STDW (F2 soft key).

The display indicates standard waveform is located at the memory address of 10000 and the length is 1000. The 2414B automatically select the waveform memory location.

```

01000 @10000 STDW
SYNC          LEN
  
```

3. Press LEN (F4 soft key).

```

free=54504    L=1000
              OK  CANC
  
```

4. Turn the knob or key in the length on the 10-key to enter new length. Then, press OK (F3 soft key).

To select a user-defined waveform.

At the initial power-on with the factory setting, the generator outputs free-running sinewave at 10 kHz after the output is turned on. The following steps will show you how to select a user-defined arbitrary waveform. All user-defined waveforms must be created on the PC and downloaded to the 2414B using WaveWorks Pro or other software, or created using the edit utility prior to the selection. However, we have loaded the first five user-defined waveform locations with sample waveforms for your verification.

1. Press FUNC (function) button.

```
FUNC:  
wav# seq# STDW view
```

2. Press WAV# (F1 softkey).

If the waveform does not contain any data, it will not be displayed.

```
*WAV# = 0  
WAV# seq# stdw view
```

3. Turn the knob to select one of the user-defined waveforms.

If the waveform does not contain any data, it will not be displayed.

```
*WAV# = 2  
WAV# seq# stdw view
```

4. Press ENTER button to select the user-defined waveform.

Whenever an asterisk is displayed on the LCD screen, the parameter selection is pending. You must press **ENTER** button to complete the selection.

```
WAV# = 2  
WAV# seq# stdw view
```

To select a sequence waveform. (option)

The following steps will show you how to select a sequence waveform. The sequence generator option must be installed in the 2414B prior to proceeding with the following steps. All user-defined waveforms must be created on the PC and downloaded to the 2414B by using WaveWorks Pro or must be created using the internal **EDIT** function before making the sequence selection. However, we have pre-loaded the first five user-defined waveforms with the sample waveforms. We will utilize these waveforms to demonstrate the sample sequence.

1. Press FUNC (function) button.

```
FUNC:  
wav# seq# STDW view
```

2. Press SEQ# (F2 softkey).

Turn the knob to select the desired **Sequence** waveform number. Press **ENTER** button. You will be able to view the sequence waveform, unless you have already altered the sequence steps.

```
*SEQ# = 0  
wav# SEQ# stdw view
```

3. Turn the knob to select one of the user-defined waveforms.

If the sequence does not contain any data, it will not be displayed.

```
*SEQ# = 2  
wav# SEQ# stdw view
```

To select a sequence waveform. (continued)

4. Press ENTER button to select the sequence waveform.

Whenever an asterisk is displayed on the LCD screen, the parameter selection is pending. You must press **ENTER** button to complete the selection.

SEQ# = 2
wav# SEQ# stdw view

Note: Each **SEQ#** may contain up to 4096 steps, use up to 1000 user-defined waveforms which may be repeated up to 1,000,000 repetitions.

To select operating mode

The following steps will show you how to select an operating mode and output one cycle of a sinewave when a trigger signal is applied. The 2414B is initially set to **CONT** (continuous) mode.

1. Select a standard waveform.

See page 1-7 for the procedure.

2. Press **MODE** key to change the operating mode.

Press **TRIG** (F2 softkey) to select trigger mode.

```
*MODE:  
cont TRIG gate brst
```

3. Press **ENTER** button to select the mode.

Whenever an asterisk is displayed on the LCD screen, the parameter selection is pending. You must press **ENTER** button to complete the selection.

```
MODE:  
cont TRIG gate brst
```

4. Press **SHIFT** button and then press **TRIG** button (number 0 on 10-key) to output a single cycle of a sinewave.

Please note that LED light will turn on when **SHIFT** button is pressed. While the **SHIFT** light is on, the keypad will not function as a 10-keypad. Press again to disable the **SHIFT** button.

Note:

If you apply a single trigger pulse to the **TRIG IN** (TTL level) on the rear BNC connector, you can also output a single cycle of a sinewave.

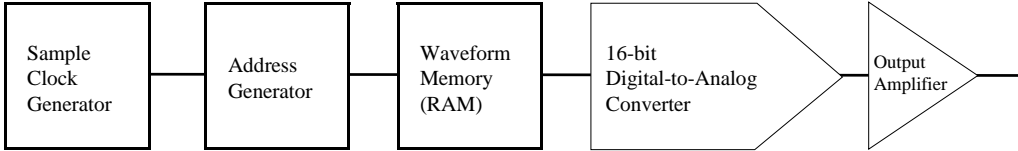
By selecting **UTIL** (UTILITY) button and then selecting **TGEN** (Trigger GENERator) (F4), you may activate the internal trigger generator. When the internal generator is not in use, make sure that the trigger generator is set to **OFF**. Otherwise, it may interfere with other operation modes.

About Arbitrary Waveforms

Waveform Generation

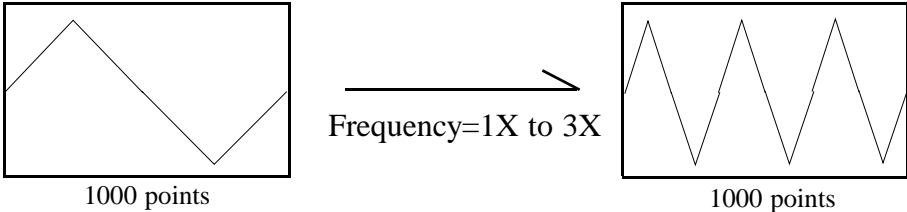
In an arbitrary waveform generator, you will define a waveform, using either the standard functions or custom profile data files to load waveform memory. A set of start and stop addresses which correspond to a waveform memory location is assigned with a waveform number. An address generator sequentially presents data values from the specified memory location to the digital-to-analog converter (DAC). The precision DAC converts the data into analog voltage values. This series of sequential voltage levels describes the output waveform with the frequency determined by the sample clock rate divided by the number of samples in the waveform. Changing the sample clock rate causes the address generator to change the speed at which the data is presented to the DAC, thereby changing the output frequency.

The waveforms you create are a series of data points consisting of X- and Y-axis values. For 12-bit generators, such as the TEGAM 2414B, the Y values between +2047 and -2048 are used. In describing the first point, 0, is given a Y value. The next point has another Y value, and so on up to the last address in your waveform. This series of points make up the waveshape.



Waveform Cycle

All the data points in the specified waveform memory location make up one waveform cycle. The waveform generator will output all the points in the waveform at the sample clock rate specified. The resulting frequency is equal to the sample clock rate divided by the number of data points in the waveform. If more than one cycle of the waveshape is entered into a waveform, the output frequency will be a multiple of one waveform generator cycle. For example, if you create a waveform with 3 triangle wave cycles using the same number of data points and the sample clock rate, the frequency will be 3 times higher.



More on Waveform Cycle

TEGAM 2414B arbitrary waveform generator may sample the data points up to a maximum of 20 MS/s. The maximum frequency of the output is determined by the sample rate divided by the number of points. For a 20 MHz arbitrary waveform generator with a waveform length of 1000 points, the upper frequency limit appears to be 20 kHz, since $20 \text{ MS/s} / 1000 = 20 \text{ kHz}$. However, if you repeat the segment, such as a sinewave, up to the minimum required number of samples (4 samples/segment), you can replicate up to 250 segments within the waveform length of 1000 points. Then, the output frequency of the sinewave will be 5 MHz, since $20 \text{ kHz} \times 250 = 5 \text{ MHz}$.

Digital and Analog Scaling

Whenever possible range the Y-values of a waveform between -2048 to +2047 in the memory to obtain maximum resolution and to maintain the desired dc integrity of the signal. WaveWorks Pro allows you to normalize any waveform in its Y values by a simple command. For instance, if you have a sinewave in the waveform window that ranges from -2048 to +2047 you can specify the output at 5 volts peak-to-peak. Automatically the -2048 relative amplitude will be scaled to -2.5 volts and the +2047 relative amplitude will be scaled to +2.5 volts. The sinewave will be centered around zero volts. The desired output voltage may be set on the front panel of the generator or on the Download Setup form before the waveform is sent to the 2414B.

If you set the output amplitude to 10 volts peak-to-peak and then you download a waveform with Y-values between +1024 and -1024, you have the same +/-2.5 volt sinewave output. It is very important to understand the differences between digital scaling and analog scaling. See the following page for the illustration.

Other Considerations

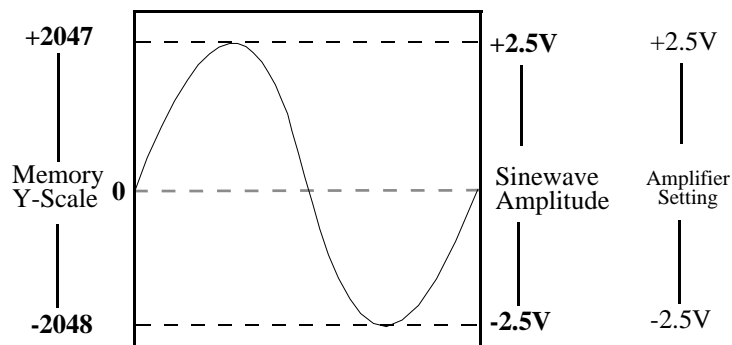
The Y values of the starting and ending points in your waveform can cause unexpected discontinuities if they are not the same value. The waveform generator output will jump from the ending value to the starting value each cycle. If you are using the sequence generator in an arbitrary waveform generator, the ending value of a waveform will jump to the starting value of the next waveform in the sequence. For a smooth, transient-free waveform output, be sure the starting and ending values are the same for a single waveform and the starting and ending values of adjacent waveforms are the same for a sequenced waveform.

Examples - Digital and Analog Scaling

Both case 1 and case 2 produce the same output amplitude with different vertical resolution.

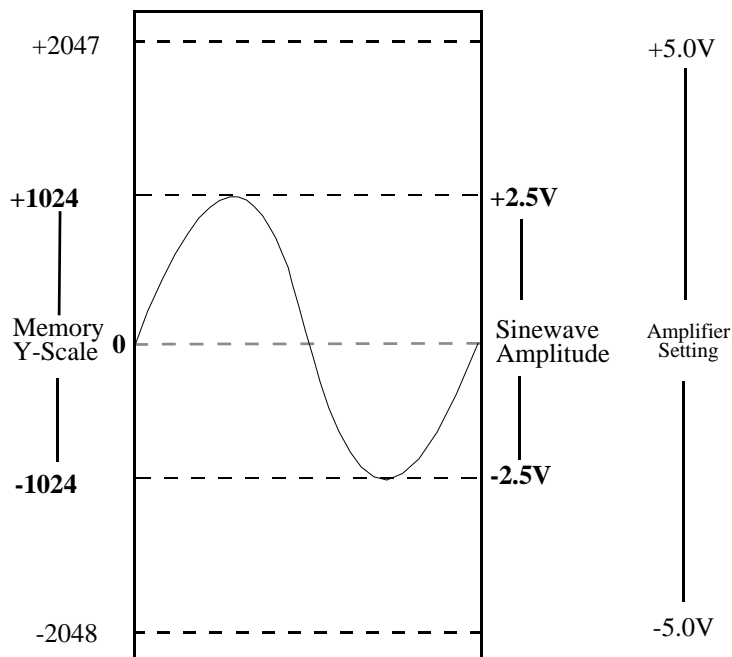
Case 1

Ampl=5.0V
Waveform Vertical Size = 4096 points
Sinewave Amplitude = 5Vp-p



Case 2

Ampl=10.0V
Waveform Vertical Size = +/-1024 points
Sinewave Amplitude = 5Vp-p



Waveform Types

TEGAM 2414B arbitrary waveform generators can create two types of waveforms, namely standard waveforms and user-defined waveforms. In addition, if you have installed the optional Sequence Generator in the 2414B, you may loop and link up to 1000 user-defined waveforms.

Standard Waveforms

You may access 20 commonly used standard waveforms from the front panel. These waveforms are not available for the sequence generator from the front panel.

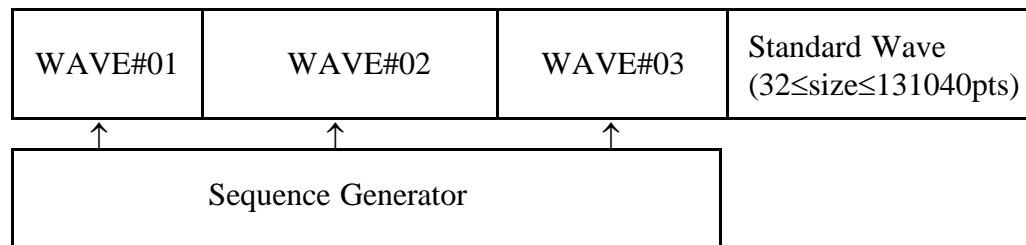
User-defined Waveforms (Arbitrary Waveforms)

You must create user-defined waveforms on a PC and download them to the memory of the 2414B or you must create them using the EDIT mode. You may use the optional WaveWorks Pro software to create user-defined waveforms. User-defined waveforms are utilized to create sequence steps in the optional sequence operation.

Sequence Waveforms (Optional)

You can create a virtual waveform using the user-defined waveforms in the waveform memory and repeating the waveforms any number of times without increasing the size of the waveform memory. Each step is defined with one of the user-defined waveforms and the number of repetition of this waveform. You may create up to 4096 steps utilizing up to 1000 user-defined waveforms in each sequence waveform.

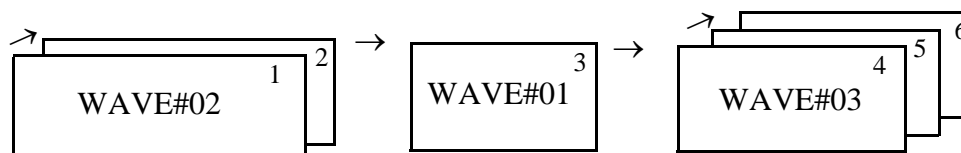
Waveform Memory



Sequenced Waveform

Example:

Step 1) WAVE#02, 2 times; **Step 2)** WAVE#01, 1 time; **Step 3)** WAVE#03, 3 times

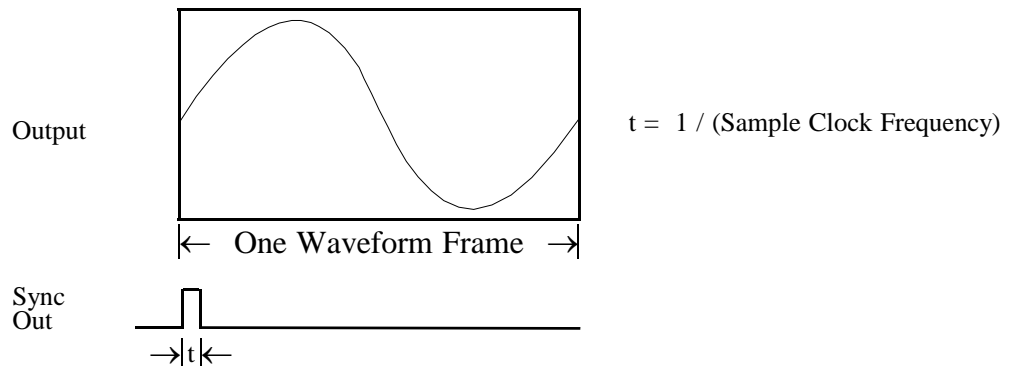


Sync Pulse

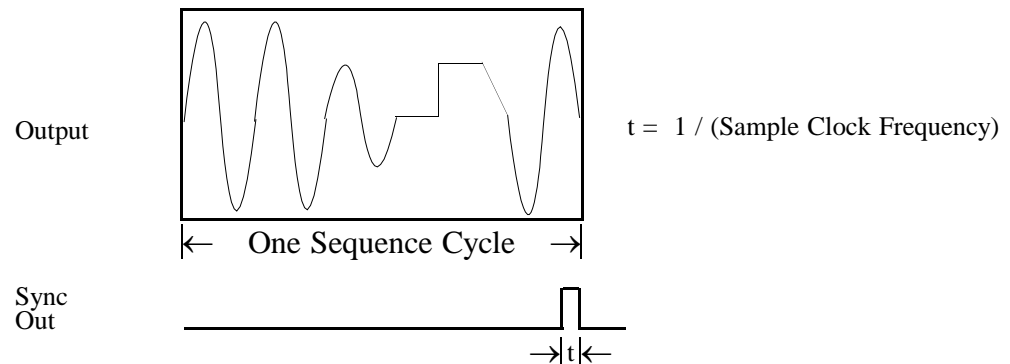
Four sync pulses are provided to synchronize the generator output waveform to trigger an external system, such as an oscilloscope.

For standard and user-defined waveforms, the sync pulse is typically placed at the start of the waveform frame. For sequence waveforms, the sync pulse is placed at the end to indicate the sequence completion. The detail description of the programmable sync pulse is given in chapter 8.

Standard and User-defined Waveforms



Sequence Waveforms



Note:

If you programmed only one step in a sequence, the sync pulse appears at the start of the waveform.

Sync Outputs

The 2414B is unique in having extremely flexible sync waveform features. Each of the four sync signals may be programmed via the remote interfaces to any binary valued pattern equal in length to the waveform with which each is associated. The electrical outputs are all TTL.

CAUTION: Remotely programmed sync patterns are overwritten if the user uses the front panel to edit the sync signal.

In addition to providing virtually infinite pattern flexibility using the remote programming interfaces, the sync signals have a second set of functional features. Each of the following sync signals may be programmed from the front panel or from the remote interface.

Sync 1 - Is located on the front panel where it may be set to End Pulse (a pulse of sample clock duration occurring during the last sample of the waveform), or be set to Programmable Address (a pulse having a start address and a length).

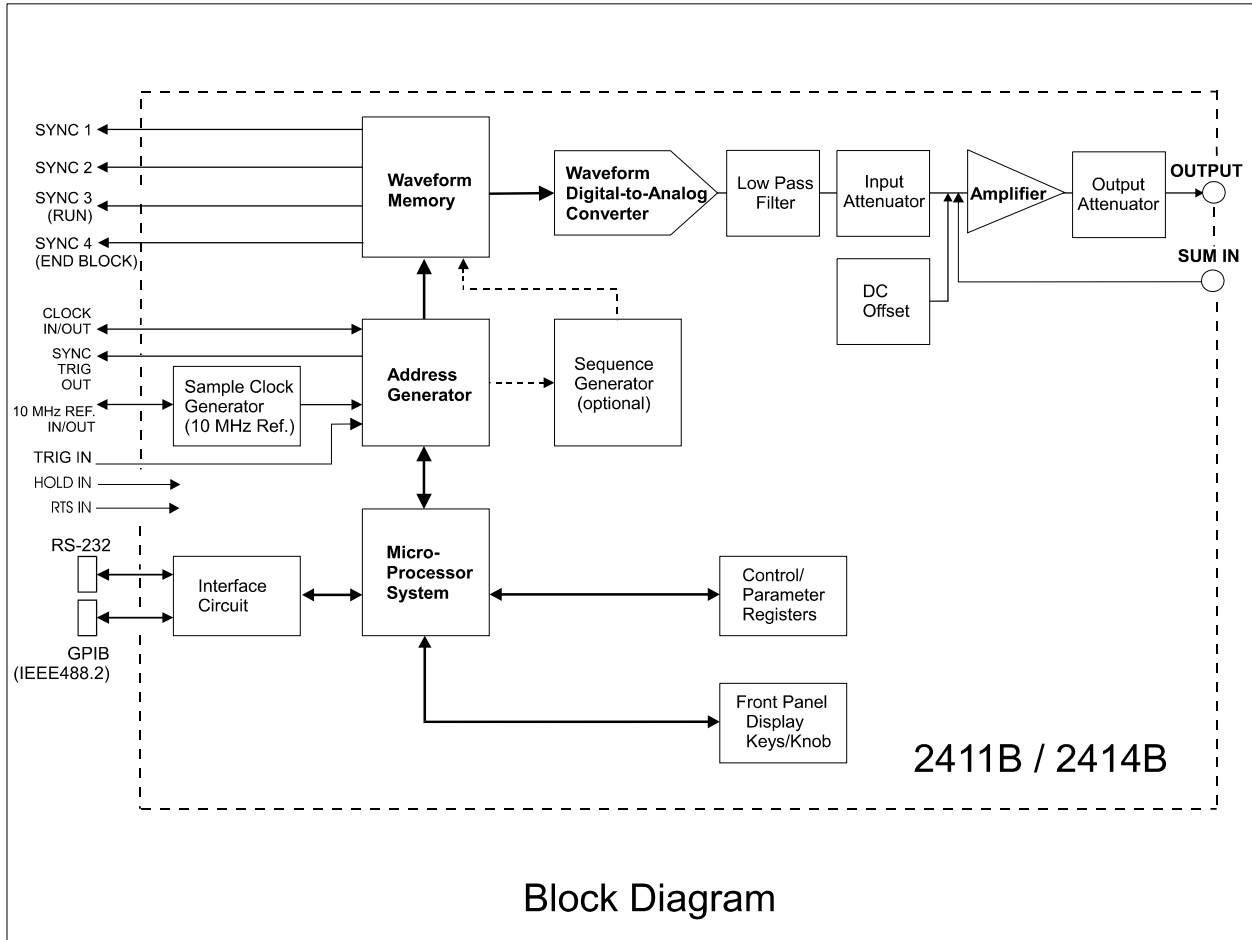
Sync 2 - Is located on the rear panel where it may be set to Programmable Address (a pulse having a start address and a length). Sync 2 has no secondary function.

Sync 3 - Is located on the rear panel where it may be set to Run (a high-level during the period of time the waveform is being samples), or be set to Programmable Address (a pulse having a start address and a length.)

Sync 4 - Is located on the rear panel where it may be set to End Block (a pulse of sample clock duration occurring during the last sample of each step in the sequence), or be set to Programmable Address (a pulse having a start address and a length).

Chapter 2 About Arbitrary Waveforms
2414B Block Diagram

2



Front-Panel Menu Operation

Parameter Control

A: MODE menu

1: CONT 2: TRIG 3: GATE 4: BRST 5:TOGL

1. **CONT** (Continuous): Select the continuous waveform output.
2. **TRIG** (Trigger): Select the triggered waveform output. Output one waveform frame when a trigger signal is applied.
3. **Gate**: Select the gated waveform output. Output multiple waveform frames as long as the trigger input signal is high or the manual button is pressed down.
4. **BRST** (Burst): Select the burst mode. Output multiple number of waveform frames set by the burst cycle parameter when a trigger signal is applied. The number of burst cycles may be set between 1 and 1,048,575.
Note: The Burst mode is not available for sequence waveform.
5. **TOGL** (Toggle): Select the toggle mode. Output multiple waveform frames when a trigger signal is applied and then return to the quiescent state when the second trigger signal is applied.

B: CLOCK/FREQ menu

1. **CLOCK** (Sample Clock) Sets the sample clock rate of the waveform frame.
CLOCK (Sample Clock) applies for **WAV#**, **SEQ#** and **STDW**.
2. **FREQ** (Frequency) Set the frequency of the waveform frame.
FREQ (Frequency) applies for **WAV#** and **STDW** only.

C: AMPL/OFSTmenu

1. **AMPL** (Amplitude) Sets the amplitude of the waveform frame.
 2. **OFST** (Offset) Set the dc offset voltage of the waveform frame.
- Note: See Chapter 2 to review the digital amplitude and offset settings.

D: FUNC (Function) menu

1: WAV# 2: SEQ# 3: STDW 4: VIEW

- 1: WAV#** Select a user-defined arbitrary waveform by the waveform number (0~999).
- 2: SEQ#** Select a user-defined sequence waveform by the sequence number (0~99).
- 3: STDW** Select a standard waveform.
- 4: VIEW** Select the left and right memory addresses to view the waveform memory contents. You may specify and select ALL, SEG1, SEG2 or SEG3.

Note: The sequence generaor option must be installed to select sequence waveforms. Sequence waveform is not available in burst mode.

D3: STDW (Standard Waveform)

1: SIN 2: SQR 3: TRI 4: SAW+ 5: SAW- 6: DC 7: EXP+ 8: EXP-

9: AM 10: SCM 11: FM 12: HSIN 13: SLIN 14: SLOG 15: PLS+ 16: PLS-

17: GAUS 18: SX/X 19: CIRC 20: NOIS

- 1: SIN** (Sine) Select sine wave.
- 2: SQR** (Square) Select square wave.
- 3: TRI** (Triangle) Select triangle wave.
- 4: SAW+** (Sawtooth+) Select positive-going ramp wave.
- 5: SAW-** (Sawtooth-) Select negative-going ramp wave.
- 6: DC** Select DC level.
- 7: EXP+** (Exponential+) Select positive-going exponential wave.
- 8: EXP-** (Exponential-) Select negative-going exponential wave.
- 9: AM** Select AM (Amplitude Modulation) wave.
- 10: SCM** Select SCM (Suppressed Carrier Modulation) wave.
- 11: FM** Select FM (Frequency Modulation) wave.
- 12: HSIN** (Haversine) Select haversine wave.
- 13: SLIN** (Sweep Linear) Select linear sweep wave.
- 14: SLOG** (Sweep Log) Select log sweep wave.
- 15: PLS+** (Pulse+) Select positive-going pulse wave.
- 16: PLS-** (Pulse-) Select negative-going pulse wave.
- 17: GAUS** (Gaussian Pulse) Select Gaussian pulse wave.
- 18: SX/X** (Sine X/X) Select (sine x)/x (or SINC) wave.
- 19: CIRC** (Circular) Select semi-circular wave.
- 20: NOIS** (Noise) Select random noise wave.

E: OUTPUT menu

1: ON 2: FLTR 3: SYNC 4: STRG

- | | |
|-------------------------------|---|
| 1: ON | Turn the generator output on. |
| 2: FLTR | Turn 7MHz low pass filter on. |
| 3: SYNC | Select the sync mode of SYNC 1, SYNC 3 and SYNC 4. |
| 4: STRG (Sync Trigger) | Select sync trigger operation mode (Series or Parallel) |

Waveform Setup (Refer to Chapter 4 for detail operations.)

SETUP menu

1: WAV# 2: STDW 3:SEQ#

- | | |
|----------------------------------|---|
| 1: WAV# (Waveform Number) | Select, allocate or delete a user-defined waveform and set up the waveform length and the parameter of 4 sync pulses. |
| 2: STDW (Standard Wave) | Select the standard waveform and set up the length and the parameter of 4 sync pulses. |
| 3: SEQ# (Sequence Number) | Select, create or delete a sequence waveform and edit the sequence steps. |

Waveform Edit (Refer to Chapter 4 for detail operations.)

EDIT menu

1: LINE 2: VRTX 3:MATH

- | | |
|-------------------------|--|
| 1: LINE | Line mode creates a line segment of a user-defined waveform using START, ANCHOR and CHORD commands. |
| 2: VRTX (Vertex) | VRTX (Vertex) mode creates a user-defined waveform using two anchor points and a vertex. This mode allows to insert a standard function, and scale and offset a portion of the waveform. |
| 3: MATH | Math mode allows the user to mathematically operate on existing waveforms. Addition, subtraction and multiplication are available on two selected user-defined waveforms . |

System Control

A: UTIL (Utility) menu

1: SCLK 2: RCLK 3: TGIN 4: TGEN 5: MBST 6: GPIB 7: R232

- | | |
|----------------|---|
| 1: SCLK | Select the sample clock source. |
| 2: RCLK | Select the reference clock source and make a fine adjustment to the internal reference clock. |
| 3: TGIN | Select the trigger type for multi-phase or single unit operations. |
| 4: TGEN | Select the internal trigger generator and the trigger rate. |
| 5: MBST | Select and display the monitor burst count. |
| 6: GPIB | Set the GPIB bus address (0-30). |
| 7: R232 | Set the RS232C serial interface parameters. |

B: LOCAL Select the front panel control when the instrument is in remote mode. Press **SHIFT** button and then press **LOCAL** (or number 8 key)

C: STOR/RECL Store and recall 19 additional sets of the 2414B status. Press **ENTER** to activate the recalled settings.

D: RESET Reset the 2414B. Press **SHIFT** button and then press **RESET** (or number 9 key). Select either **ALL** or **CURR**.

E: RTS Return to start address. Press **SHIFT** button and then press **RTS** (or number +/- key).

F: HOLD Hold the output at the current level until released. Press **SHIFT** button and then press **HOLD**.

G: TRIG Manual trigger button. Initiates GATE, TRIG, BURST and TOGGLE mode.

H: LCD Adjust the **LCD** screen viewing angle. Press **SHIFT** button and then press **LCD**. Turn knob to adjust viewing angle.

Default Settings

Important: By holding **RESET** key (or number 9 key on the 10-key pad) down while turning the **LINE** switch on, you can reset the 2414B settings to the factory defaults. If you want to save the waveform data, be sure to back up in a PC using WWP Pro or an appropriate software before resetting the 2414B.

Front-panel button Defaults

Buttons	Factory Defaults
MODE	CONT
FUNC	STDW (SIN)
CLOCK FREQ	SCLK=10.00MHz FREQ=10.00kHz
AMPL OFST	AMPL=5.000 V OFST=0.000 V
OUTPUT	<i>output and filters off</i>

UTILity Defaults

Buttons	Defaults
SCLK	INT
RCLK	INT
TGIN	ASYN
TGEN	OFF
MBST	n=3
GPIB	GADR=16
R232	BAUD=1.2K, PAR=NONE, BITS=8D1S, HAND=SW

Default Settings

User-Defined Waveform Defaults

WAV#	Size	Type	Sync Location			
			1	2	3	4
0	2000	Triangle	0	0	0	0
1	2000	DC 0V	0	0	0	0
2	2000	Pulse	0	0	0	0
3	2000	DC 0V	0	0	0	0
4	2000	DC 0V	0	0	0	0

Optional Sequence Waveform Defaults

SEQ#	Step	WAV#	Repeat
0	10	0	2
	20	2	1
	30	0	3
1	10	1	2
	20	3	4
	30	4	6
2	50	1	2
	60	3	4
	70	4	6

Default Settings (continued)

Standard Waveform Defaults

Default settings are listed in the following tables. The limits are shown in parenthesis.

Function	Parameters	Range	Defaults
Sine (SIN)	Phase	0.000 ~ 360.000°	0.000°
	Number of Cycles	0.01 ~ 1000.00	1.00
Square (SQU)	Number of Cycles	1 ~ 1000	1
	Duty Cycle	1 ~ 100%	50%
Triangle (TRI)	Number of Cycles	1 ~ 1000	1
Sawtooth (SAW+/-)	Number of Cycles	1 ~ 1000	1
	Duty Cycle	1 ~ 100%	100%
DC	DC	-32768 ~ +32767	0
Exponential (EXP+/-)	Time Constant	0.01 ~ 20.00	5
Amplitude Modulation (AM)	Carrier Frequency	1 ~ 10000	20
	Modulation Freq.	1 ~ 10000	1
	Modulation Index	0 ~ 200%	100%
	Modulation Phase	0 ~ 360°	0°
	Carrier Phase	0 ~ 360°	0°
Supressed Carrier Modulation (SCM)	Carrier Frequency	1 ~ 10000	20
	Modulation Freq.	1 ~ 10000	1
	Modulation Phase	0 ~ 360°	0°
	Carrier Phase	0 ~ 360°	0°
Haversine (HSIN)	Number of Cycles	0.01 ~ 1000.00	1.00
Linear Sweep (SLIN)	Begin	1 ~ 1000	1
	End	1 ~ 1000	10
Log Sweep (SLOG)	Begin	1 ~ 1000	1
	End	1 ~ 1000	10
Pulse (PLS+/-)	Delay	0 ~ 100%	0%
	Rise Time	0 ~ 100%	10%
	High Time	0 ~ 100%	30%
	Fall Time	0 ~ 100%	10%
	Number of Cycles	1 ~ 1000	1
Gaussian (GAUS)	Exponent	0.01 ~ 20.00	2
Sine X/X (SX/X)	Number	4.00 ~ 1000.00	5.50
Circle (CIRC)	Number of Cycles	0.01 ~ 1000.00	1.00
	Phase	0.01 ~ 360.00°	0.00°

Standard Waveform List

The following list shows you the standard waveforms available from the 2414B front panel and in the optional WaveWorks Pro software. You can create a standard waveform in WaveWorks Pro and download it to an arbitrary waveform location. Now, you can select the customized standard waveform from the front panel as a user-defined waveform.

2414B	WaveWorks Pro	
Sine	Sine	Cosine
Square	Square	Squine
Triangle	Triangle	Lines
Sawtooth (+/-)	Ramp	Steps
DC	DC	Binary FSK
Exponential (+/-)	Exponential	Binary PSK
AM	AM	NTSC
SCM	SCM	PAL
FM	FM	PWM
Haversine	Pulse1	VHR Pulse
Linear Sweep	Cont Sweep	Burst Sweep
Log Sweep	Step Sweep	Digital Noise
Pulse (+/-)	Pulse 2	FIR_LPF
Gaussian	Gaussian	Han(SinX/X)
Sine(X)/X	Sin(X)/X	Comb
Circle	Cardiac	
Noise	Analog Noise	

Waveform Creation System

Components

The following components are required for the 2414B waveform creation system.

- Model 2414B Arbitrary Waveform Generator
- WaveWorks Pro Wavform Creation Software
- RS-232C Cable

It is recommended that you install the optional WaveWorks Pro in a PC equipped with the following minimum configuration. For more details, see page 1-3 of the WaveWorks Pro manual.

- IBM (or compatible) 386 PC with math coprocessor, 8MB memory
- 2MB free harddisk space, Windows 3.1 or higher operating system

Recommendation

It is recommended that you try operating WaveWorks Pro software using the PC asynchronous serial port (COM port) since you do not have to have the specified GPIB card and software installed in your PC. Follow the installation instruction on page 1-4 of the WaveWorks Pro manual.

User Interface

When the system is completely installed, the following interfaces are used to control the waveform creation system.

Front Panel (2414B)

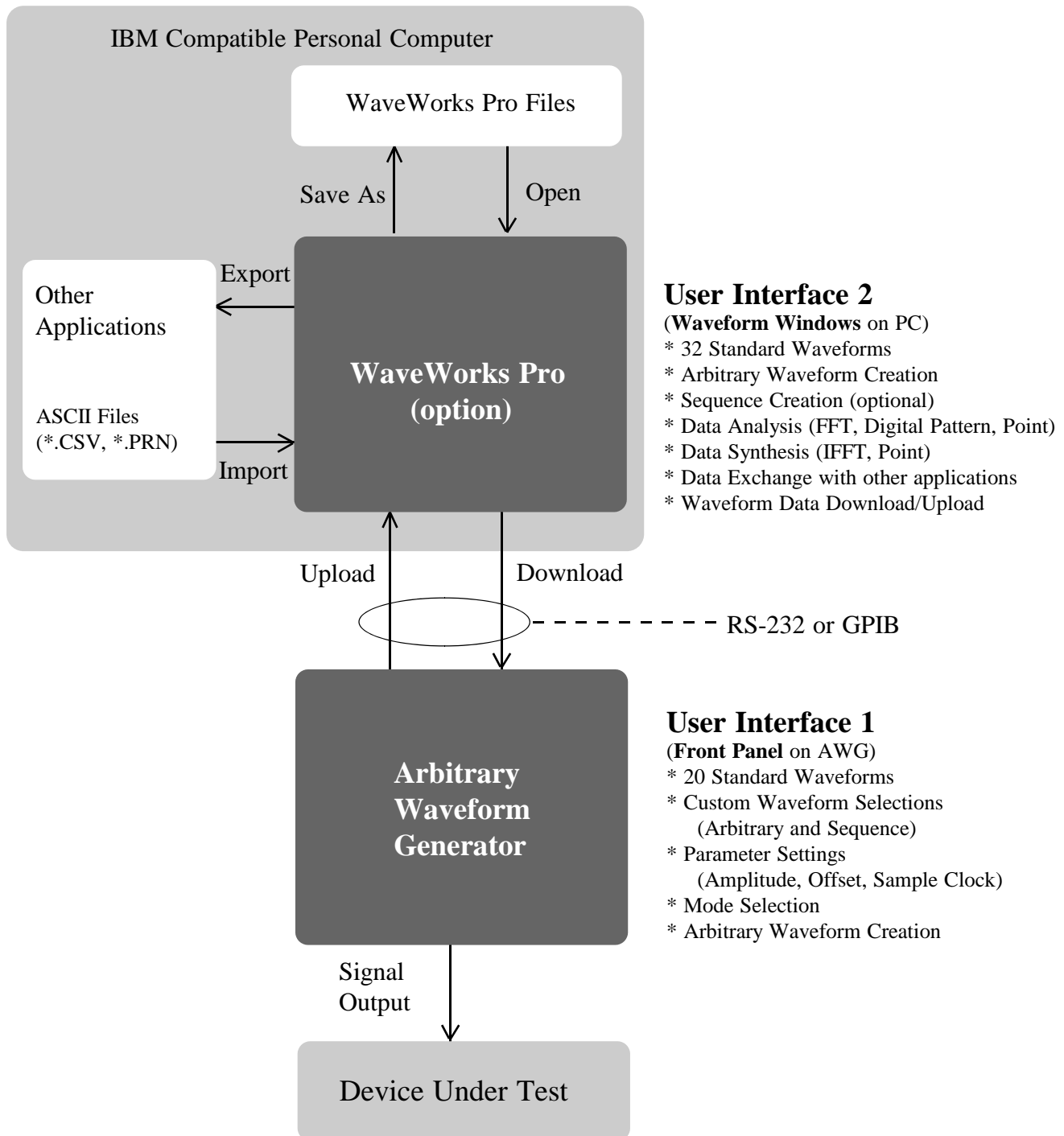
This is used primarily to select and control the hardware parameters, such as mode, sample clock rate, amplitude, offset, and waveform selection. 20 standard waveforms may be created from the front panel. Arbitrary waveforms and sequence waveforms can be edited from the front panel.

Waveform Windows (WaveWorks Pro)

The WaveWorks Pro, which runs under Windows, is the main interface for waveform creation tasks. You can create up to 32 standard waveforms and unlimited number of arbitrary and sequence waveforms using Point Edit and Waveform Math.

You may also analyze and edit the waveforms using the FFT and Digital Pattern Generator while exchanging the ASCII data with other applications.

Once the communications link is established between the PC and the waveform generator, downloading a waveform is as simple as selecting the download waveform location and clicking the OK button.



User Interface for the Waveform Creation System

Memory Organization

Introduction

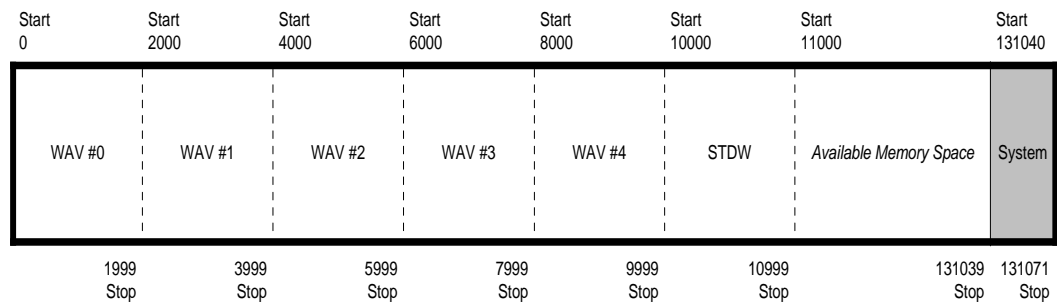
This section explains how the waveform memory is organized, the system of waveform numbering, how default memory segments can be changed, and how standard functions can be inserted.

Default Partitioning

The total available waveform memory is 131,040 points. The memory is initially divided into partitions to provide easy programming of 6 different waveforms. Five blocks of 2000 points each occupy the first 10K of memory. In addition, one of 20 standard waveforms can be readily recalled from the Function menu and downloaded to 1000 points of memory from 10k to 11k. (A sinewave is the default Standard Wave.)

Waveform Numbering

The first 5 blocks of memory are assigned Waveform Numbers. Additional Waveform Numbers can be assigned (up to total of 1000, depending on the number of points). Waveform Numbers are used to access the memory blocks for initial waveform programming and to recall the waveforms later. Waveform Numbers are arrayed in the memory in ascending order. Figure below shows the default waveform numbers and partitioning.



Waveform Numbers and Memory Partitions

Changing Waveform Block Length

Standard Wave

The standard wave memory can be changed from its default value of 1000 points. (Minimum waveform length is 32 points.)

Changing Waveform Block Length (continued)

- 1) Press **SETUP** key.
- 2) Press **STDW** softkey (F2). The display indicates the present length of the standard wave and the address where it begins in memory.
- 3) Press **LEN** softkey (F4). The display indicates the available free memory.
- 4) Select desired standard wave length with edit knob or keypad.
(Do not attempt to exceed the amount of memory available.)
- 5) Press **OK** (F3) to enter change or **CANC** (F4) to cancel.
- 6) Press **ENTER**.

Waveform Number Block Lengths

The waveform lengths of the numbered blocks can be changed from their default values of 2000 points. (Minimum waveform length is 32 points.)

- 1) Press **SETUP** key.
- 2) Press **WAV#** softkey (F1).
- 3) Select Waveform Number with edit knob. The display indicates the present length and start address of the waveform.
- 4) Press **LEN** softkey. The display indicates the available free memory.
- 5) Select desired waveform block length with edit knob or keypad. (Do not attempt to exceed the amount of memory available.)
- 6) Press **OK** to enter change or **CANC** to cancel.

Deleting Waveform

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

- 1) Press **SETUP** key.
- 2) Press **WAV#** softkey.
- 3) Select Waveform Number with edit knob.
- 4) Press **DEL** softkey.
- 5) Press **OK** to delete or **CANC** to cancel.

Inserting New Waveform Numbers

Unused Waveform Numbers can be activated as follows:

- 1) Press **SETUP** key.
- 2) Press **WAV#** softkey.
- 3) Press **NEW** softkey.
- 4) Screen will show all unused Waveform Numbers when edit knob is turned. Select desired number.
- 5) Move waveform length to right side of display with double-arrow key and set desired length with edit knob or keypad.
(New waveform cannot be longer than available free memory.)
- 6) Press **OK** to insert new Waveform Number or **CANC** to cancel.

Waveform Creation using Front Panel

Introduction

This section explains how to create arbitrary, non-standard waveshapes. These custom waveforms can be created a segment at a time using **LINE** or **VERTEX** edit modes. Each step in the waveform construction may be viewed on an oscilloscope connected to the instrument output. 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.

NOTE: Define waveform number block length before creating an arbitrary waveshape.

Line Mode

With the line editing mode, waveforms are created a segment at a time from a left-hand start or anchor point. A line is drawn from the start point or anchor to a "vertex" point which is positioned to the right. The vertex becomes a new anchor and the process is interactively repeated until the new arbitrary waveform is completed. This process is illustrated in page 4-8. All or any portion of a selected waveform block can be edited. Editing begins at the start point. 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 if no waveform was programmed).

Editing From Start Point

- 1) Press **EDIT** key.
- 2) Press **LINE** softkey (F1).
- 3) Select Waveform Number using edit knob or keypad (press **ENTER** after using keypad).
- 4) Arbitrary waveform construction can begin at any point within the selected waveform number block. Press **STRT** softkey (F1).
- 5) Use edit knob or keypad to select X and Y addresses to start waveform editing within the selected block. Use double-arrow key to move each active parameter to right side of display. (Remember to press **ENTER** if keypad is used.)
- 6) Press **OK** (F3) to store start point or **CANC** (F4) to cancel.
- 7) Press **ANCH** softkey (F2).
- 8) Use double-arrow key to move Right Anchor (**AR**) to right side of

Line Mode (continued)

LCD. Use edit knob or keypad to select X address for the end of the edited portion of the waveform.

- 9) Press **OK** (F3) to store right anchor or **CANC** (F4) to cancel.

Editing From Left Anchor

- 1) Press **EDIT** key.
- 2) Press **LINE** softkey (F1).
- 3) Select Waveform Number using edit knob or keypad (press **ENTER** after using keypad).
- 4) Arbitrary waveform construction can begin at any X address within the selected waveform number block. Press **ANCH** softkey (F2). (If the Start Point is to be uniquely defined, see previous section.)
- 5) Use double-arrow key to move Left Anchor (**AL**) to right side of display. Use edit knob or keypad to select X address. (Remember to press **ENTER** if keypad is used.)
- 6) Use double-arrow key to move Right Anchor (**AR**) to right side of LCD. Use edit knob or keypad to select X address for the end of the edited portion of the waveform.
- 7) Press **OK** (F3) to store anchors or **CANC** (F4) to cancel.

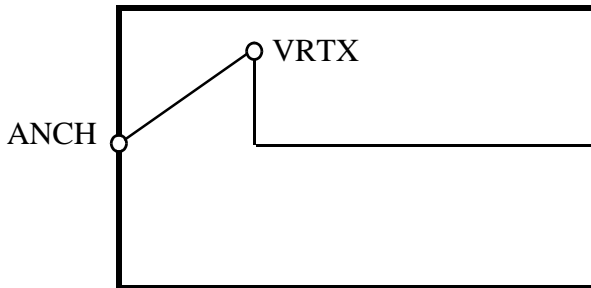
Creating Line Segments

- 1) Press **CHRD** (chord) softkey (F3). (Set anchors first per previous section.)
- 2) Use edit knob, keypad or optional mouse to select X and Y addresses for the destination of the first line segment (chord). If the mouse is used, LCD readouts will continually indicate mouse position.
- 3) When the desired position is reached, press **OK** (F3) and the line segment will be stored. Press **CANC** (F4) to cancel.
- 4) Create the next line segment by again using the knob or keypad to set the next X-Y coordinate, as before.
- 5) Continue adding line segments up to the limit established in step 5 of **Editing from Start Point** section.

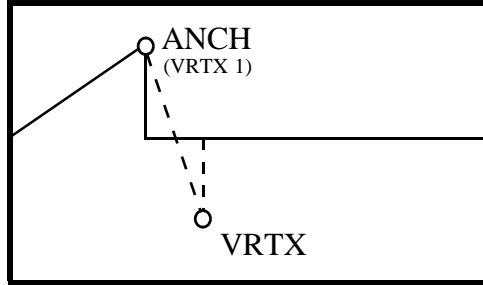
Chapter 4 Waveform Creation System
Waveform Creation using Front Panel-Line Mode



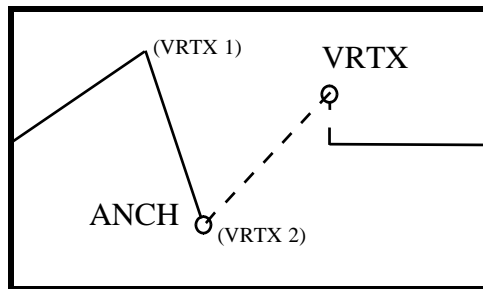
1. Select LINE mode.



2. Move VRTX.



3. Anchor the vertex and create a new line.



4. Continue this process until desired waveform is created.

Line Mode Waveform Creation and Editing

Vertex Mode

With the vertex editing mode, waveforms are created 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 permits waveform scaling and the insertion of standard functions. Vertex editing is illustrated in page 4-10.

- 1) Press **EDIT** key.
- 2) Press **VRTX** softkey (F2).
- 3) Select Waveform Number using edit knob or keypad (press **ENTER** after using keypad).

Selecting Left and Right Anchor Points

- 1) Press **ANCH** softkey (F3).
- 2) Set left anchor (**AL**) X value using edit knob or keypad. Press **ENTER** if keypad is used.
- 3) Use double-arrow key to move right anchor (**AR**) to right side of LCD. Set right anchor X value using edit knob, keypad or optional mouse.
- 4) Press **OK** (F3) to store anchors or **CANC** (F4) to cancel.

NOTE

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

Selecting Vertex Point

- 1) Press **ADDV** softkey (F1).
- 2) Set vertex X and Y values using edit knob, keypad or optional mouse.
- 3) When the desired position is reached, press **OK** (F3) and the two line segments will be stored. Press **CANC** (F4) to cancel.
- 4) Continue adding anchors and vertices until the waveform is completed.

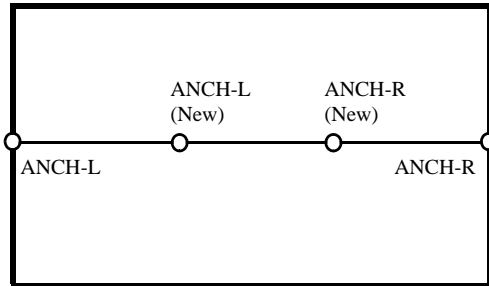
Scaling

Scaling allows any portion of a waveform designated by the left and right anchors to be scaled in amplitude and offset.

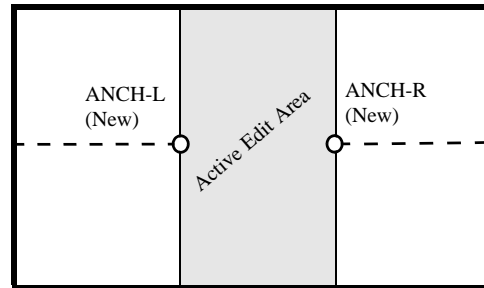
- 1) Select anchors as in page 4-6.
- 2) Press **SCAL** softkey (F2).
- 3) Set digital amplitude (DA) and digital offset (DO) values for selected portion of waveform using edit knob or keypad. Observe changes on output oscilloscope. Use double-arrow key to select active parameter.
- 4) Press **OK** (F3) to store the scaled waveform or **CANC** (F4) to cancel.

Chapter 4 Waveform Creation System
Waveform Creation using Front Panel-Vertex Mode

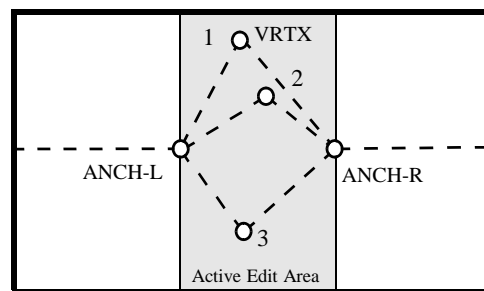
1. Select VERTEX mode.



2. Active edit area is defined.



3. Select (a) Vertex, (b) Sum, (c) Insert Function or (d) Scale.



Vertex Mode Waveform Creation and Editing

Vertex Mode (continued)

NOTE

The digital amplitude default value is 4095. The available range of settings is ± 8191 . A negative setting inverts the edited waveform portion. Re-scaling amplitude from the default value of 4095 to the maximum value of 8191 doubles the output amplitude. Steps 1 - 4 above can be repeated as necessary to enlarge small signals.

CAUTION

The waveform will be clipped if the scaling factors exceed the 4095 points available in the waveform memory.

Smoothing

A smoothing factor may 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 in **Selecting Left and Right Anchor Points** section.
- 2) Press either the left or right arrow key.
- 3) Press **SMOO** softkey (F3).
- 4) Select the number of samples to be averaged (up to 250) using the edit knob or keypad.
- 5) Press **SHOW** softkey (F2) to preview.
- 6) Press **CANC** softkey (F4) to cancel.
- 7) Press **OK** softkey (F3) to store smoothed waveform.

Inserting Standard Functions

Any one of 20 standard functions can be inserted between the left and right anchors.

- 1) Select anchors as in **Selecting Left and Right Anchor Points** section.
- 2) Press **INSF** softkey (F4).
- 3) Select desired standard waveshape by pressing softkey. Use left and right arrow keys to view all 20 waveshapes. Access any desired ancillary functions by pressing the right arrow (->) softkey (F1).
- 4) Press **SHOW** softkey (F2) to preview selection.
- 5) Press **CANC** softkey (F4) to cancel selection.
- 6) Press **OK** softkey (F3) to store selection.

Vertex Mode (continued)

Summing Standard Functions

Any one of the 20 standard functions can be algebraically summed to any part or all of any other standard function.

- 1) Select the first standard waveshape as in previous section.
- 2) If the second standard waveshape is to be summed to only a portion of the first standard waveshape, reposition the anchors as described in previous section.
- 3) Press either the left or right arrow key.
- 4) Press **SUMF** softkey (F1).
- 5) Select desired standard waveshape by pressing softkey. Use left and right arrow keys to view all 20 waveshapes. Access any desired ancillary functions by pressing the --> softkey (F1). (Reduce the digital amplitude value as necessary to prevent clipping.)
- 6) Press **SHOW** softkey (F2) to preview summed waveforms.
- 7) Press **CANC** softkey (F4) to cancel.
- 8) Press **OK** softkey (F3) to store summed waveforms.

Dump Function

Dump Function permits a standard waveform to be conveniently loaded into the entire length of a Waveform Number without specifying left and right anchors. Thus, standard waveforms can be inserted in Waveform Numbers with lengths greater than 8000 points.

- 1) Select the desired Waveform Number.
- 2) Press either the left or right arrow key.
- 3) Press **DMPF** softkey (F2).
- 4) Select desired standard waveshape by pressing softkey. Use left and right arrow keys to view all 20 waveshapes. Access any desired ancillary functions by pressing the --> softkey (F1).
- 5) Press **DO** softkey (F2) to store the waveform in memory and permit further changes or press **OK** softkey (F3) to store waveform and return to previous menu.

CAUTION

It is not possible to preview a function when using Dump Function. Both the DO and OK commands above will cause the new waveform to write over any previous waveforms.

Waveform Creation using Front Panel-Vertex Mode (continued)

Move

The Move commands allow a section of a waveform as defined by the left and right anchors to be copied and pasted into another section of the same or another Waveform Number.

- 1) Select the desired Waveform Number.
- 2) Press either the left or right arrow key.
- 3) Press **MOVE** softkey (F4).
- 4) Set left and right anchors to the waveform section to be copied.
- 5) Press **COPY** softkey (F1).
- *6) Press **LAST** key.
- *7) Set Waveform Number to receive pasted section.
- *8) Press **MOVE** softkey (F4).
- 9) Set left and right anchors to the destination waveform section.
- 10) Press **PSTE** softkey (F2).

* These steps may be omitted if copy and paste are within the same Waveform Number.

NOTE

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

Math Operations

Math operations permit the contents of any two Waveform Numbers of equal size to be algebraically added, subtracted or multiplied together. Complex composite signals can thus be created, such as shaped tone bursts, amplitude modulation, etc. To enter the Math Mode:

- 1) Press **EDIT** key.
- 2) Press **MATH** softkey (F3).

Selecting Math Function

The three math functions have the following forms:

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

Waveform Creation using Front Panel-Math Operation (continued)

To select one of the math functions:

- 1) Press **OP** softkey (F2).
- 2) Press the softkey for the desired math function. The selected function will be capitalized.

Selecting Waveform Numbers

Waveform Numbers to be combined must be selected and a destination assigned for the combined waveform. (To assign a destination Waveform Number, refer to page 4-5.)

- 1) Press the arrowhead softkey (F1).
- 2) The displayed equation has the following form:
Destination Waveform ## = Waveform ## (*,+ or -) Waveform ##.
- 3) Define each Waveform Number by moving the arrowhead to each location in the equation and selecting a Waveform Number with the edit knob or keypad (followed by **ENTER**).
- 4) Press the **DO** softkey (F4) after the three Waveform Numbers have been assigned. The result is visible at the output.

CAUTION

Be sure only equal-length waveform blocks are combined using a math function. The destination waveform may be larger.

Examples

Waveform editing in the Model 2414B is so flexible that often the same complex waveform can be created several different ways. For example, let us construct a waveform described by the equation: $A = \sin \omega t + 1/6 \sin 3\omega t$. (It is presumed that the waveform lengths are at the default values of $LEN = 2000$.)

Insert and Sum Functions

- 1) Press **SETUP** key.
- 2) Press **WAV#** softkey (F1).
- 3) Press **NEW** softkey (F3) to select a new Waveform Number.
- 4) Press **OK** softkey (F3).
- 5) Press **EDIT** key.
- 6) Press **VRTX** softkey (F2).
- 7) Press **ANCH** softkey (F3). Set **AL** (Left Anchor) = 0 and **AR** (Right Anchor) = 1999.

Chapter 4 Waveform Creation System

Waveform Creation using Front Panel-Examples

Examples (continued)

- 8) Press **OK** softkey (F3).
- 9) Press **INSF** softkey (F4).
- 10) Press **SIN** softkey (F1).
- 11) Set **P** (Phase) = 0.000 and **N** (Number) = 1.00.
- 12) Press --> softkey (F1).
- 13) Set **DO** (Digital Offset) = 0 and **DA** (Digital Amplitude) = 4095.
(A full-amplitude signal is obtained with DA = 4095.)
- 14) Press **OK** softkey (F3). Observe that the fundamental frequency (sin ωt) at the waveform peaks.
- 15) Press either left or right arrow key.
- 16) Press **SUMF** softkey (F1).
- 17) Press **SIN** softkey (F1).
- 18) Set Phase = 0.000 and Number = 3.00.
- 19) Press --> softkey (F1).
- 20) Set **DO** (Digital Offset) = 0 and **DA** (Digital Amplitude) = 683.
(Scaling of the amplitude adjusts for the 1/6 amplitude coefficient.)
- 21) Press **SHOW** softkey (F2) to preview the results and monitor the output for the desired signal. (Care must be exercised to limit the final waveforms to be within the memory limits.)
- 22) Press **OK** softkey (F3).
- 23) Observe the resulting composite waveform at the output.

Math Function

- 1) Press **SETUP** key.
- 2) Press **WAV#** softkey (F1).
- 3) Use existing Waveform Numbers or press **NEW** (F3) and **OK** (F3) softkeys three times to select three new Waveform Numbers. (As in the previous example, the waveform length is presumed to be LEN = 2000.)
- 4) Press **EDIT** key.
- 5) Press **VRTX** softkey (F2).
- 6) Select first Waveform Number from step 3.
- 7) Press **ANCH** softkey (F3). Set **AL** (Left Anchor) = 0 and **AR** (Right Anchor) = 1999.
- 8) Press **OK** softkey (F3).
- 9) Press **INSF** softkey (F4).
- 10) Press **SIN** softkey (F1).
- 11) Set **P** (Phase) = 0.000 and **N** (Number) = 1.00.

Examples (continued)

- 12) Press --> softkey (F1).
- 13) Set **DO** (Digital Offset) = 0 and **DA** (Digital Amplitude) = 4095.
- 14) Press **OK** softkey (F3) and observe fundamental output.
- 15) Select second Waveform Number from step 3.
- 16) Press **ANCH** softkey (F3). Set **AL** (Left Anchor) = 0 and **AR** (Right Anchor) = 1999.
- 17) Press **OK** softkey (F3).
- 18) Press **INSF** softkey (F4).
- 19) Press **SIN** softkey (F1).
- 20) Set **P** (Phase) = 0.000 and **N** (Number) = 3.00.
- 21) Press --> softkey (F1).
- 22) Set **DO** (Digital Offset) = 0 and **DA** (Digital Amplitude) = 683 (4095/6).
- 23) Press **OK** softkey (F3) and observe third harmonic at the output.
- 24) Press **LAST** key.
- 25) Press **MATH** softkey (F3).
- 26) Setup the equation so that the third Waveform Number from step 3 equals the sum of the first waveform (step 6) and the second waveform (step 15).
- 27) Press **DO** softkey (F4). Note the result of the math summing operation is to multiply the signal by 1/2.
- 28) Press **EDIT** key and perform the following four steps to increase the amplitude to the level attained in the prior exercise:
- 29) Press **VRTX** softkey (F2).
- 30) Press **SCAL** softkey (F2).
- 31) Set **DO** (Digital Offset) = 0 and **DA** (Digital Amplitude) = 8191.
- 32) Press **OK** softkey (F3).
- 33) Press **FUNC** key.
- 34) Press **WAV#** softkey (F1).
- 35) Select third Waveform Number.
- 36) Observe the resulting composite waveform at the output.

Sequence Generator

Introduction

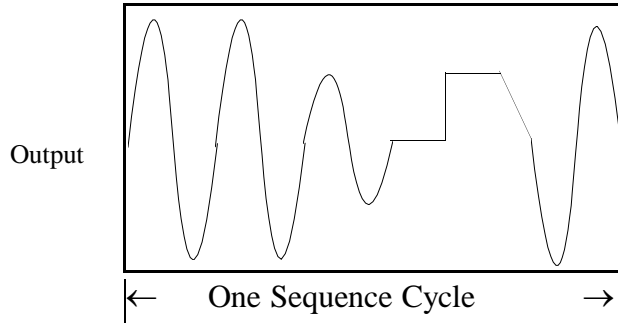
This section explains how to program and use the optional Sequence Generator. The Sequence Generator permits different waveforms to be repeated and/or linked with each other in any order. The list of programmed instructions for each "loop and link" series is called a Sequence. Up to 100 different Sequences can be programmed. All sequences combined can have up to 4096 steps. Each step defines one Waveform Number (up to 1000) and the number of times it repeats (up to 1, 048, 575). The following figure shows a typical sequence of waveforms. Table shows a Sequence Programming Worksheet with sample entries corresponding to the example. A blank worksheet suitable for reproduction is located in the Appendix.

Programming a Sequence

Before programming a sequence, be sure each desired waveform has been created and stored in a Waveform Number location. In addition, prepare a programming worksheet in a manner similar to the sample table. Then, follow this procedure:

- 1) Press **SETUP** key.
- 2) Press **SEQ#** softkey (F4).
- 3) Press **NEW** softkey (F3).
- 4) Select desired new sequence file number with edit knob or keypad.
- 5) Press **OK** (F3) to enter number or **CANC** (F4) to cancel.
- 6) Press **OPEN** softkey (F2). (A message "STEP=-1" indicates no steps have previously been programmed.)
- 7) Press **ADDS** softkey (F3).
- 8) Select first step number with edit knob or keypad. (To allow for future changes to the program, it is a good idea to leave room between step numbers, i.e., 10, 20, 30etc.)
- 9) Select desired Waveform Number for this step with edit knob or keypad.
- 10) Press double-arrow key to move burst number to right side of display.
- 11) Set desired number of waveform repetitions with edit knob or keypad.
- 12) Press **OK** to enter numbers or **CANC** to cancel.
- 13) Select next step number, repeating steps 7 through 12 above.
- 14) After all steps have been programmed, view finished results by selecting Sequence Number in Function menu and pressing **ENTER**. Additional sequences can be programmed and stored by selecting a different sequence file number in the steps above.

Sequence Generator-Programming a Sequence (continued)



Custom Waveforms

WAV#	Length	Type
1	2000	Sine
2	2000	Sine (Half Amplitude)
3	4000	Arbitrary
4	2000	Sine (Phase =180°)

Sequence Waveform

STEP#	WAV#	Number of Burst
10	1	2
20	2	1
30	3	1
40	4	1

Typical Waveform Sequence

Deleting a Sequence

Sequences no longer required may be deleted from memory by the following procedure:

- 1) Press **SETUP** key.
- 2) Press **SEQ#** softkey (F4).
- 3) Select sequence file number to be deleted with edit knob or keypad.
- 4) Press **DELF** softkey (F1).
- 5) Press **OK** (F3) to delete step or **CANC** (F4) to cancel.

Adding a Step into an Existing Sequence

To add a step to an existing sequence:

- 1) Press **SETUP** key.
- 2) Press **SEQ#** softkey (F4).
- 3) Select appropriate sequence file number.
- 4) Press **OPEN** softkey (F2).
- 5) Press **ADDS** softkey (F3).
- 6) Select desired new step number with edit knob or keypad..
- 7) Program new step as in **Programming a Sequence**, steps 8 to 12.

Chapter 4 Waveform Creation System
Sequence Generator-Deleting a Step from an Existing Sequence

Sequence Generator (continued)

Deleting a Step from an Existing Sequence

- 1) Press **SETUP** key.
- 2) Press **SEQ#** softkey (F4).
- 3) Select appropriate sequence file number.
- 4) Press **OPEN** softkey (F2).
- 5) Select step number to be deleted with edit knob or keypad.
- 6) Press **DELS** softkey (F1).
- 7) Press **OK** (F3) to delete step or **CANC** (F4) to cancel.

Modifying a Step within an Existing Sequence

- 1) Press **SETUP** key.
- 2) Press **SEQ#** softkey (F4).
- 3) Select appropriate sequence file number.
- 4) Press **OPEN** softkey (F2).
- 5) Select step number to be modified with edit knob or keypad.
- 6) Press **MODS** softkey (F2).
- 7) Select desired Waveform Number for this step with edit knob or keypad.
- 8) Press double-arrow key to move burst number to right side of display.
- 9) Set desired number of waveform repetitions with edit knob or keypad.
- 10) Press **OK** (F3) to delete step or **CANC** (F4) to cancel.

WaveWorks Pro Software (Option)

Waveform Creation using optional WaveWorks Pro software

The following is the abbreviated procedure to illustrate the waveform creation and data download to the waveform generator using WaveWorks Pro. For detail descriptions and the tutorial, refer to the WaveWorks Pro manual.

1. Select **File | New Project** and create a New Waveform.
2. Select **Func | Std** and select one of the 32 standard waveforms.
3. Press Show to view the waveform and **OK** to enter the selected waveform into the New Waveform.

Download WaveWorks Pro Data using RS-232

Waveform Generator Setup (See Chapter 7 for more details.)

1. Connect the RS-232C cable specified by TEGAM to the waveform generator RS-232C port and the PC COM port. Make sure each end is connected properly.
2. Set the RS-232C baud rate of the waveform generator to 19200.

WaveWorks Pro Setup

1. Select the Interface menu and set the RS-232C to the proper setting, i.e. 19200,N,8D1S and Hardware. Press **OK** button to confirm that the interface is properly connected.
2. Select the **Download | Setup** menu and select **COM1**. Press **OK**.
3. Select the **Download | Go** menu and then select the **WAV#** (download waveform location). Then, press **OK**.

Download WaveWorks Pro Data using GPIB

Waveform Generator Setup (See Chapter 7 for more details.)

1. Connect the GPIB cable to the waveform generator GPIB connector and the GPIB connector of the controller (PC).
2. Set the GPIB Address of the waveform generator. (The default address is 16.)

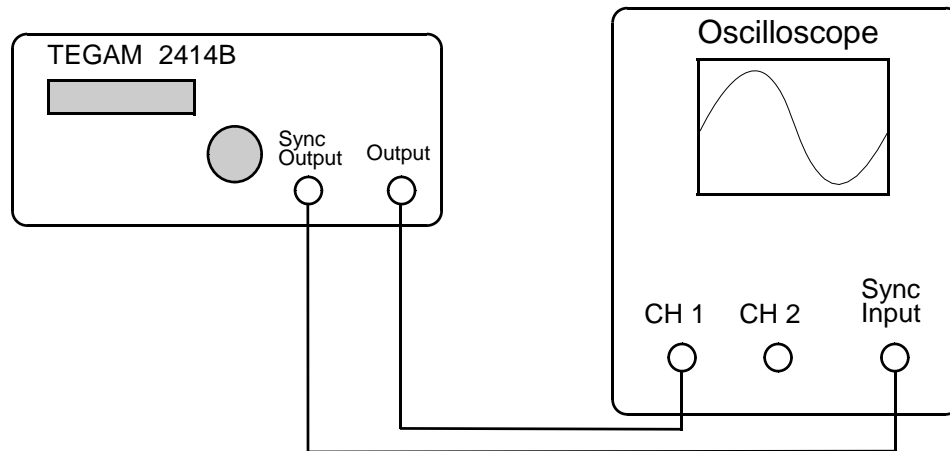
WaveWorks Pro Setup

1. Select the Interface menu. Select the instrument and drag and drop the instrument model to the proper GPIB address. Press **OK** button to confirm that the interface is properly connected.
2. Select the **Download | Setup** menu and select the proper GPIB address. Press **OK**.
3. Select the **Download | Go** menu and then select the **WAV#** (download waveform location). Then, press **OK**.

Multi-Instrument Operation

Basic Connection

The following diagram illustrates the basic connections and setups for single unit operation.



Note: The rear BNC connectors are available for the following functions:

10 MHz REF. IN/OUT;

External 10 MHz reference clock may be connected at this connector. TTL level. At the default setting the internal reference is connected to the internal sample clock generator and the output is a 10 MHz internal oscillator signal.

CLOCK IN/OUT;

The sample clock may be brought in from the external source through this connector. TTL level. At the default setting the internal sample clock generator is connected to the instrument and the frequency of the internal sample clock is present at the output.

SYNC TRIG OUT (1-4);

The signal required for multiple unit operation to guarantee the proper phase between the generators.

TRIG IN;

The external trigger input. TTL level.

RTS IN;

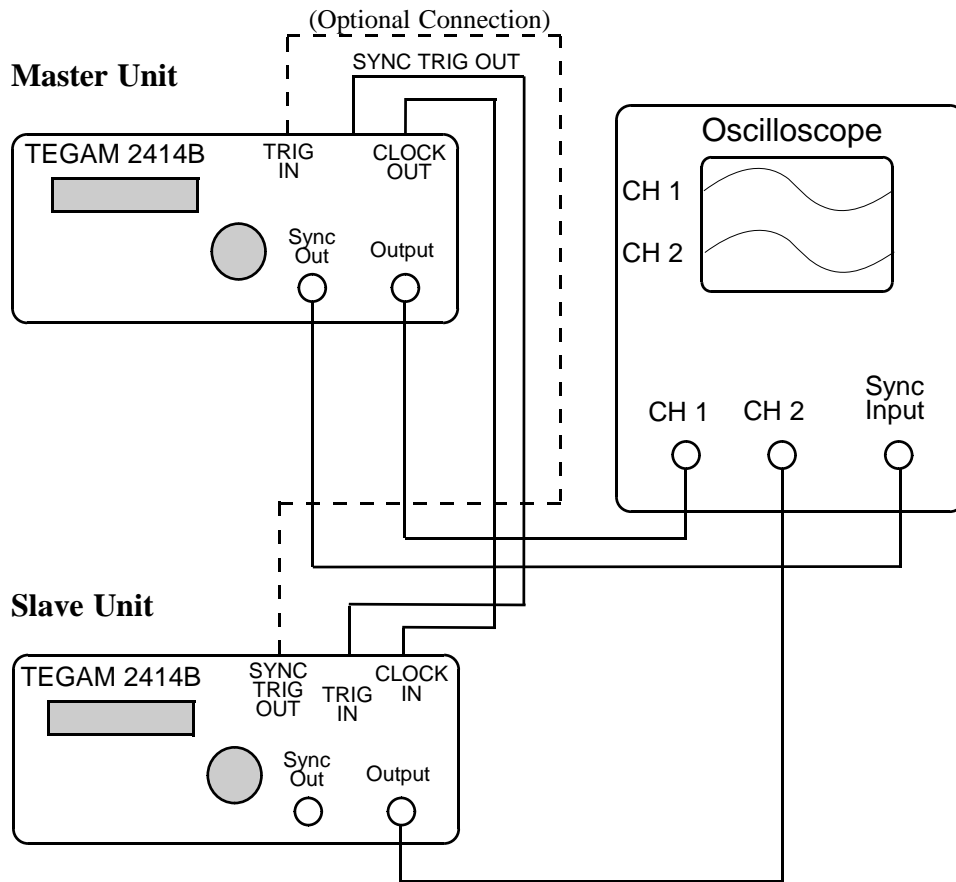
TTL level signal, when high, returns output to the beginning of the waveform.

HOLD IN;

When a TTL level signal is applied, the output is held at a fixed amplitude until the TTL level goes low. The fixed amplitude is dependent on wave location when the TTL level goes high.

Multiple Phase Connection

The following diagram illustrates the connections and setups for the multiple phase operation using two or more 2414B's.



Note: The rear BNC connectors are available for the following functions:

- | | |
|---------------------------|----------------|
| 10 MHz REF. IN/OUT | TRIG IN |
| CLOCK IN/OUT | RTS IN |
| SYNC TRIG OUT | HOLD IN |

For the description of each function, refer to the bottom of the previous page.

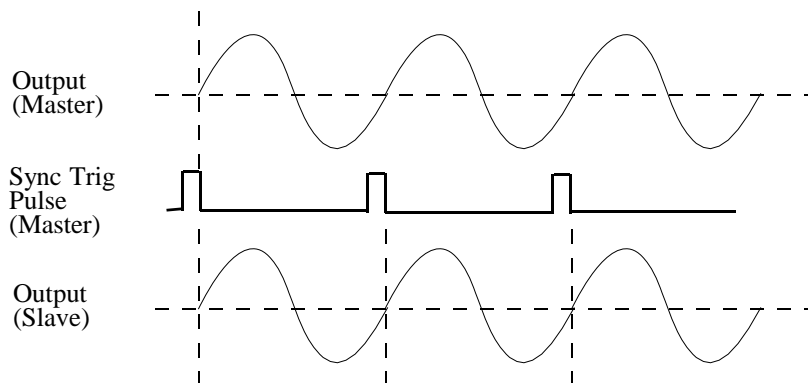
Multiple Phase Operation

Three types of multi-phase operation are available:

1. Continuous-Synchronous
2. Trigger-Synchronous
3. Trigger-Sequential

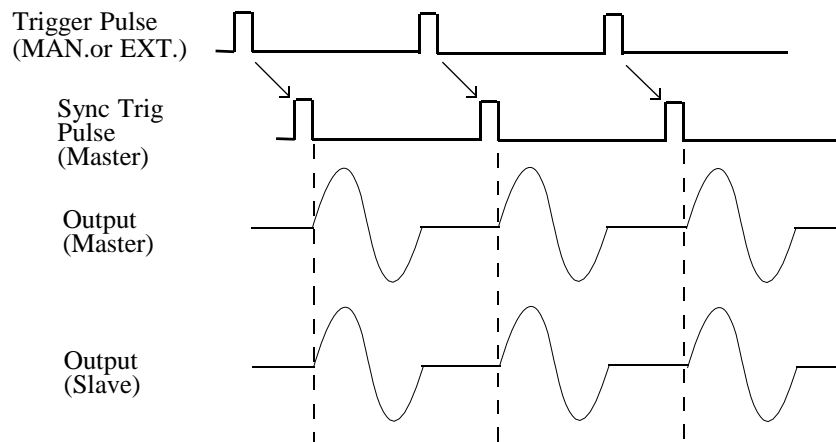
Case 1 -- Continuous-Synchronous

The master unit runs continuously. The SYNC TRIG pulse of the master unit forces the free-running slave unit to reset to the first address at the phase zero of the master unit. The waveform size of the slave unit should be the same length as the master unit to avoid the discontinuity.



Case 2 -- Trigger-Synchronous

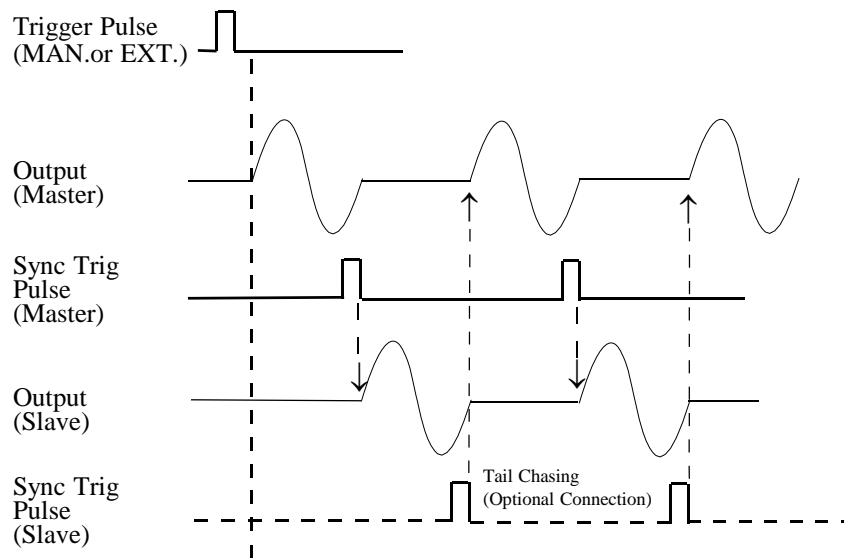
Both units are in TRIG mode. Upon receiving the trigger signal (external or manual), the master unit prepares to run while the SYNC TRIG pulse of the master unit forces the slave unit to start to run synchronously at the phase zero of the master unit.



Multiple Phase Operation (continued)

Case 3 -- Trigger-Sequential

This is a special case of TRIG mode which allows you to output the signal from each unit sequentially. Both units are in TRIG mode. Upon receiving the trigger signal (external or manual), the master unit starts to run while the slave unit waits to receive the SYNC TRIG pulse from the master unit. Upon receiving the pulse, the slave unit runs for one cycle and stops. If the feedback connection is made from the SYNC TRIG OUT of the slave unit to the TRIG IN of the master unit, then you can create the configuration which indefinitely outputs the signal from each unit upon completion of the other unit. In this case, you must start the master unit by pressing the manual TRIG button (SHIFT-0) on the front panel.



Multiple Phase Setup

Multiple Model 2414B's can be operated synchronously in parallel or series. Synchronous operation of multiple units eliminates triggering jitter and minimizes clock delays. In synchronous operation, the units must share the same sample clock and be programmed for a synchronous trigger interconnect. Refer to the diagram on page 5-3.

1. Sample Clock Setup

To operate multiple units in synchronous, designate one unit as the master unit and another unit as the slave unit. Program the slave unit clock inputs to be external as follows:

- 1) Press **UTIL** button.
- 2) Press **SCLK** (F1) softkey.
- 3) Press **EXT** (F2) softkey to select external sample clock.
- 4) Press **ENTER** button.

Note: the master unit operates with its normal internal sample clock. If the sample clock of the master unit is connected to an external source, then, the clock of both units must be programmed to **EXT** and the external clock must be supplied to both units.

2. Trigger Setup

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 for serial or parallel operation as follows:

- 1) Press **OUTPUT** button.
- 2) Press **>>** (F4) softkey.
- 3) Press **STRG** (Sync Trigger) (F2) softkey.
- 4) Press **SER** (Serial) (F1) or **PAR** (Parallel) (F2) softkey.
- 5) Press **ENTER** button.

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

- 1) Press **UTIL** (Utility) button.
- 2) Press **TGIN** (Trig In) (F3) softkey.
- 3) Press **SYNC** (F1) softkey to select synchronous trigger input.

Chapter 5 Multi-Instrument Operation
Multiple Phase Setup

Multiple Phase Setup (continued)

Summary of Setup

CASE	SCLK		TRIG		MODE		OUTPUT	
	Master	Slave	Master	Slave	Master	Slave	Master	Slave
1	INT or EXT	EXT	ASYNC	SYNC	CONT		SER	
2	INT or EXT	EXT	ASYNC	SYNC	TRIG		PAR	
3	INT or EXT	EXT	ASYNC		TRIG		SER	

Performance Verification

Introduction

This chapter provides a procedure to verify that the Model 2414B has met the specifications published in the manual within the tolerances. *There are no user accessible calibration points in the unit.* TEGAM, INC. recommends an annual calibration verification interval. It is recommended that Chapter 1 Quick Start should be followed first in order to verify proper operation of the unit. Copy the Verification Test Sheet at the end of this chapter to record the data.

Test Equipment Required

Analog Oscilloscope: 100 MHz or greater bandwidth.

Frequency Counter: 1 PPM or better accuracy.

True-RMS Digital Multimeter: 5½ digit, 0.1% or better accuracy.

Distortion Analyzer: 0.01% or better THD measurement at 80 kHz bandwidth.

Precision Load: 50Ω, ± 0.1%

Verification Test

Frequency Accuracy

1. Connect frequency counter to 10 MHz Reference Output on the rear panel.
2. Verify that the frequency is 10 MHz ± 50 PPM.

The following procedures require the instrument to be reset to the default settings. Please save the pertinent waveform file data in the 2414B in the PC by using WaveWorks Pro or other appropriate software before proceeding to the next test.

Reset the 2414B

Turn on the power switch while holding the **RESET** key (Number 9) down.

Caution: Reset erases waveform memory and inserts the default files. Store all waveform required for future use as noted in the preceding step.

Waveform Rise/Fall Time

1. Set Amplitude to 10 V.
2. Select Standard wave as Square wave.
3. Connect OUTPUT to an oscilloscope input terminating with a 50Ω load.
4. Verify the Rise and Fall Times to be less than 20 ns.

Verification Test (continued)

DC Offset Accuracy

1. Set Amplitude to 1.00 V.
2. Select Standard wave as Sinewave (1000 points).
3. Connect OUTPUT to DMM Input without the terminating load.
4. Set DC Offset to 9.000 V.
5. Set DMM to DC measurement and verify that DC Offset measures between 8.890 V and 9.110 V.
6. Set DC Offset to 899 mV.
7. Set Amplitude to 100 mV.
8. Verify that DC Offset measures between 867 mV and 931 mV.
9. Set DC Offset to 89 mV.
10. Set Amplitude to 10 mV.
11. Verify that the DC Offset measures between 83.5 mV and 94.5 mV.

Amplitude Accuracy

1. Select Standard wave as Sinewave (1000 points).
2. Set Frequency to 1.000 kHz.
3. Connect OUTPUT to DMM without terminating load.
4. Set Amplitude to 10.20 V.
5. Measure true-RMS amplitude on DMM and convert the data to peak value by multiplying by 1.414.
6. Verify the peak value is between 10.078 V and 10.322 V.
7. Set Amplitude to 900 mV.
8. Measure true-RMS amplitude on DMM and convert the data to peak value by multiplying by 1.414.
9. Verify the peak value is between 868 mV and 932 mV.
10. Set Amplitude to 90 mV.
11. Measure true-RMS amplitude on DMM and convert the data to peak value by multiplying by 1.414.
12. Verify the peak value is between 84.5 mV and 95.5 mV.

Total Harmonic Distortion (THD) plus Noise

1. Select Standard wave as Sinewave.
2. Set Amplitude to 9.10 V.
3. Select low pass filter from OUTPUT menu.
4. Set Frequency to 20.00 kHz.
5. Connect OUTPUT to the distortion analyzer input using a 50 ohm load.
6. Set the distortion analyzer for a 20 kHz signal and 80 kHz measurement bandwidth.
7. Verify THD+Noise measures less than -65 dB (0.06%).

Chapter 6 Performance Verification
Verification Test Sheet

Model: TEGAM 2414B

Date: _____

Serial Number: _____

Tested by: _____

Verification Test						
Test Parameters		Limits			Test	
		Low	Nominal	High	Pass	Fail
Frequency Accuracy	Test Spec	9.99995 MHz	10.0000 MHz	10.0005 MHz		
	Data					
Rise/Fall Time	Spec	<20 ns				
	Data					
DC Offset	Test Spec 1	8.890 V	9.000 V	9.110 V		
	Data 1					
	Test Spec 2	867 mV	899 mV	931 mV		
	Data 2					
	Test Spec 3	83.5 mV	89 mV	94.5 mV		
	Data 3					
Amplitude [Peak=RMS x 1.414]	Test Spec 1	10.078 V	10.20 V	10.322 V		
	Data 1(RMS)					
	Data 1 (Pk)					
	Test Spec 2	868 mV	900 mV	932 mV		
	Data 2(RMS)					
	Data 2(Pk)					
	Test Spec 3	84.5 mV	90 mV	95.5 mV		
	Data 3(RMS)					
Data 3(Pk)						
THD	Typical Spec.	-65 dB (0.06 %)				
	Data					

Note: _____



Remote Interface Operation

Introduction

This section describes how to remotely control all instrument functions and how to download and upload waveform data using either the RS-232C or GPIB interface. If you are using the WaveWorks Pro, it is only necessary to read the section on how to set the GPIB address or RS-232C parameters on the 2414B if you have already installed a GPIB card and the required software on your computer. Included are an overview of remote control, a complete tabulation and explanation of control commands, and programming examples. More details are given in chapter 8 for the advanced users of the instrument.

To set the GPIB address

Each device on the GPIB (IEEE-488) interface must have a unique address. You can set the waveform generator's address to any value between 0 and 30. *The address is set to 16 when the generator is shipped from the factory.*

- 1. Press the **UTIL** (Utility) button.

```
UTIL:  
SCLK RCLK TGIN TGEN
```

- 2. Press the right arrow button to view the next menu.

```
UTIL:  
MBST      GPIB R232
```

- 3. Press **GPIB** (F3)

```
          GADR=16  
MBST      GPIB R232
```

- 4. Set the GPIB address (GADR) by turning the knob or using the 10-keypad.
- 5. Press **ENTER**.

To set the RS-232 parameters

You must select the proper RS-232C settings to communicate between the waveform generator and a computer. The following procedure will let you change the generator to required settings. *The generator is set to the following factory defaults: Baud Rate = 1200, Parity=NONE, Bits = 8D1S, Handshake = SW (software).*

1. Press the **UTIL** (Utility) button.

```
UTIL:
SCLK RCLK TGIN TGEN
```

2. Press the right arrow button to view the next menu.

```
UTIL:
MBST      GPIB R232
```

3. Press **R232** (F4)

```
UTIL:RS232:
BAUD PAR BITS HAND
```

4. Press **BAUD** (F1) to set the baud rate to 19.2k.

```
*RS232:BAUD:
1.2k  2.4k  9.6k  19.2K
```

5. Press **LAST** button to return to the previous menu. Then, press **PAR** (Parity) to select **NONE** (F3).

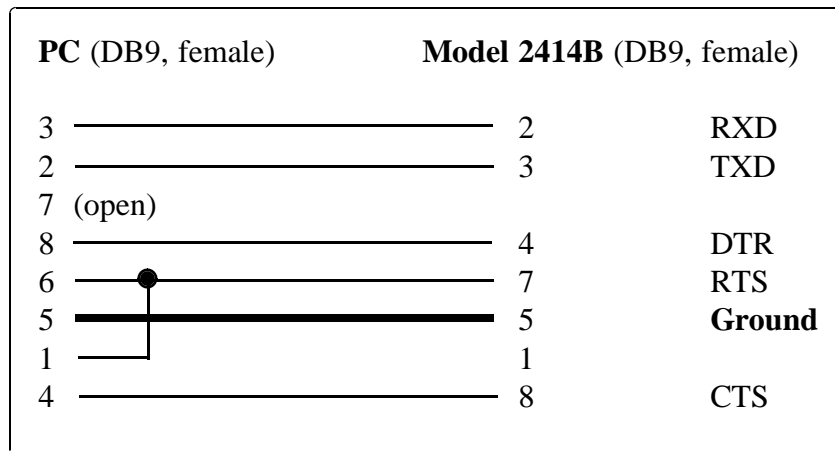
```
RS232:PAR:
odd  even  NONE
```

6. Press **LAST** button to return to the previous menu. Then, press **BITS** to select **8D1S** (F3).
7. Press **LAST** button to return to the previous menu. Then, press **HAND** (Handshake) to select **HW** (Hardware) (F3).
8. Press **ENTER**.

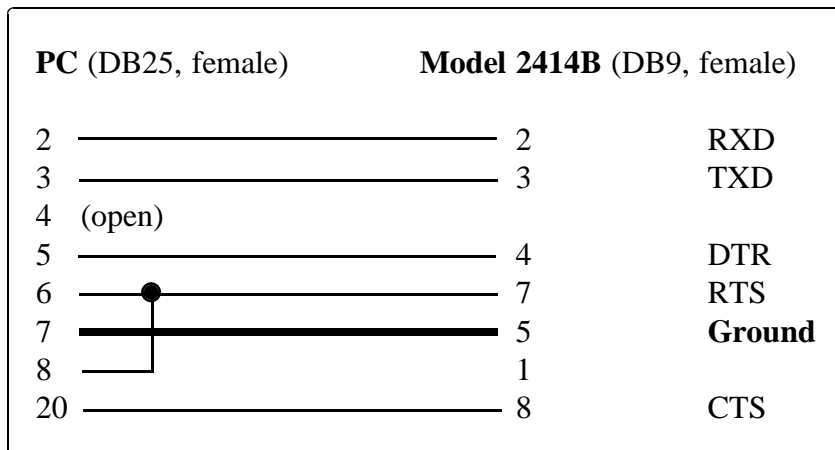
RS-232 Adapter Cables

The following wiring diagrams illustrate proper interconnections between the serial port of an IBM (or compatible) PC and the model 2414B RS-232C connector. The proper cable to connect DB-9 connectors can be obtained from TEGAM, Inc.

RS-232 Cable required for the 2414B



RS-232 Cable required for the 25 pin connector.



Before sending commands

Whether you use RS-232C or GPIB as the communication interface to the 2414B, you should examine the following.

For RS-232C

1. Check the cable connection.

Make sure the proper end (**PC** or **Instrument**) of the cable specified by TEGAM is connected to the respective ends.

PC to PC COM port

Instrument to 2414B RS-232C connector

2. Setup the PC Port.

Select a COM port on the PC. Make sure that the baud rate and other interface parameters are set to the same parameters as the 2414B.

For GPIB

1. Check the cable connection.

2. Set up the GPIB board on the PC to a proper setting.

3. Make sure that the GPIB address set on the PC matches the 2414B address.

Command Features

The following examples will illustrate the specific features of the 2414B remote programming commands using RS-232C or GPIB.

Command Execution

All commands are executed after the execute command (EXEC) is sent.

The only exception is the waveform command (**WVFM**). It does not require the execute command (**EXEC**). You do not have to send commands in any particular sequence. For example, if you want to change DC offset value and amplitude, you do not have to send and execute the smaller value of amplitude first.

In general the following formula applies. See page 1-6 for dc offset.

$$|V_{offset}| + V_{pp}/2 < V_{max}$$

If the output is set to 10.0V and the DC offset is zero and you want to change to the amplitude to 1.0 V and the DC offset to 7.5V,

AMPL 1.0;OFFSET 7.5;:EXEC --- OK

OFFSET 7.5;AMPL 1.0;:EXEC --- OK

Command Features (continued)

Waveform Selection

Waveform selection takes two steps to complete the process.

- 1) Select one of the three types of function; standard wave (STDW), user-defined wave (WAVE) and sequence (SEQ). You can only point to the type and the waveform and sequence number. You can not select the content of the standard wave but you will get the last standard waveform selected.
- 2) Select one of the standard waveform from the waveform (WVFM) command.

To select a type of waveform, use FUNCTION (FUNC) command.

:FUNCTION WAVE,12;:EXEC --- select user-defined waveform #12
:FUNCTION WAVE,STDW;:EXEC --- select standard waveform
:FUNCTION SEQ,10;:EXEC --- select sequence waveform #10

↑—A space is required after the command headers.

To select a standard waveform

:WVFM:SINE;:FUNC WAVE,STDW;:EXEC --- select sinewave.

↑—Select sine wave as Standard Wave.

Waveform Deletion

There are no delete command for waveforms or sequences. In all cases, to delete an item you must set it to zero.

To delete a user-defined waveform, set the size to zero (0).

:WVFM:WAVE 10;SIZE 0 --- delete WAVE#10

↑—The size is set to zero.

To delete a sequence, send the sequence number which you want to delete and eliminate the step data.

:WVFM:SEQ 12 --- delete SEQ#12 if it exists.

To delete a step in a sequence, set the repeat to zero (0).

:WVFM:ADDSEQ 12,1,0,5 -- delete SEQ#12 Step#5

↑—STEP#
↑—The repeat is set to zero.
↑—WAVE#
↑—SEQ#

Chapter 7 Remote Interface Operation Command Set

Command Set

Command Set					
Commands		Data	Data Format	Limits Min / Max	Description
Normal	Short				
Common Commands					
*CLS					Clears all event and status registers. Will also clear output queue if it immediately follows a <PMT>.
*ESE		<8-bit mask> (GPIB only)	<NR>	0/255	Sets the 8-bit mask in the ESE register.
*ESE?		(GPIB only)	<NR1>	0/255	Returns the contents of the ESE register.
*ESR?			<NR1>	0/255	Returns the contents of the ESR register. Once read, the ESR register is cleared.
*IDN?					The specific response to this query is: Pragmatic Instruments, Model 2411B,0, <firmware level>, where <firmware level> is of the form Vx.xx .
*OPC		(GPIB only)			Sets the OPC bit (bit 0) in the ESR register, when all pending instrument operations are complete.
*OPC?					This query waits for all pending instrument operations to complete, then places an ASCII "1" in the output queue.
*RST					Equivalent to the front panel RESET CURRENT Key, this returns the instrument to a factory default state.
*SRE		<8-bit mask> (GPIB only)	<NR>	0/255	Sets the 8-bit mask to enable/disable bits in the STB register.
*SRE?		(GPIB only)	<NR1>	0/255	Returns the value of the SRE register.
*STB?		(GPIB only)	<NR1>	0/255	Returns the value of the STATUS BYTE. The Master Summary Status bit (bit 6) is cleared with the first read, but all other bits remain unchanged until the conditions are cleared.
*TRG					Equivalent to the front panel TRIG key.
*TST?					Generally this is a selftest command, however it presently does not initiate any action, except to return an ASCII "1".
*WAI					This Wait-to-Continue command has no effect, since commands are processed sequentially.
OPT?					No Option Installed: ASCII "0". Option(s) Installed: SEQ, GPIB. (ASCII "0" appears in any one option not installed.)
Configuration Commands					
CONFIGURE	CONF				
HEADERS	HDRS	<state>	ON OFF		With headers ON, query responses include the header. With headers OFF, responses return only the data.
HEADERS?	HDRS?		0 1		Returns the current header configuration.
System Commands					
EXECUTE	EXEC				Instructs the instrument to execute pending commands. Equivalent to the front panel ENTER key.
HOLD		<state>	ON OFF		Holds or releases the present level of the output voltage. Equivalent to a front panel HOLD.
RECALL	RCLL	<memory #>	<NR>	0/18	Recall front panel setups from specified memory.
REF_CLK_ADJ	RADJ	<correction #>	<NR>	-128/127	Adjusts reference clock by the specified factor.
REF_CLK_ADJ?	RADJ?		<NR1>	-128/127	Returns current ref. clock adjustment factor.
REF_CLOCK	RCLK		INT EXT		Sets reference clock source to INTERNAL or EXTERNAL
REF_CLOCK?	RCLK?		INT EXT		Returns the present state of the reference clock source.
RESET			CURR ALL		Resets instrument settings to default values.
RTNTOSTRT	RTST		ON OFF		Returns to the starting point of the output waveform when ON. Equivalent to front panel RTS.
SAMPLECLOCK	SCLK	<frequency>	<NR>	0.1/20E6	Sets the sample clock frequency.
SAMPLECLOCK?	SCLK?		<NR3>	0.1/20E6	Returns the present sample clock frequency.
STORE	STOR	<memory #>	<NR>	0/18	Store front panel setups into specified memory.
TGENERATOR	TGEN		ON OFF		Sets trigger generator ON or OFF.
TGENERATOR?	TGEN?		ON OFF		Returns the present state of the trigger generator.
TGRRATE	TGRR	<rate>	<NR>	0.02/10	Sets the trigger rate in seconds.
TGRRATE?	TGRR?	<rate>	<NR3>	0.02/10	Returns the current trigger rate.
TRIGGER	TRIG	<state>	ON OFF PULSE		Sets the trigger ON, OFF, or PULSED.

Chapter 7 Remote Interface Operation
Command Set (continued)

Command Set (continued)

Command Set					
Commands		Data	Data Format	Limits	Description
Normal	Short			Min / Max	
Instrument Status Commands					
STATUS					
INSTRUMENT	INST				
CLEAR	CLR				Clears Instrument Status Register
ENABLE	ENBL		<NR>	0 / 65535	Sets the Mask in the Instrument Status Event Register. Bit#0 enables ENDP (End Pulse) and Bit#1 enables ENDB (End Block).
ENABLE?	ENBL?		<NR1>	0 / 65535	Returns the contents of the Instrument Status Event Enable Register.
EVENT?	EVNT?		<NR1>	0 / 65535	Returns the contents of the Instrument Status Event Register. BIT #0: ENDP (End Pulse) BIT #1: ENDB (End Block)

Chapter 7 Remote Interface Operation
Command Set (continued)

Command Set (continued)

Command Set					
Command		Data	Data Format	Limits	Description
Normal	Short			Min/Max	
Mode Commands					
MODE		<setting>	CONT TRIG GATE BURST TOGGLE		Sets the output signal mode to CONTinuous, TRIGgered, GATEd, BURST, or TOGGLEd.
MODE?					
BURST		<burst #>	<NR>	1/1048575	Sets the burst count.
BURST?			<NR1>	1/1048575	Returns the present burst number setting.
Sample Clock / Frequency Commands					
SAMPLECLOCK	SCLK	<frequency>	<NR>	0.1/ 20E6	Sets the sample clock frequency.
SAMPLECLOCK?	SCLK?		<NR3>	0.1/ 20E6	Returns the present sample clock frequency.
FREQUENCY	FREQ	<frequency>	<NR>	0/10E6	Sets the output frequency.
FREQUENCY?	FREQ?		<NR3>	0/ 10E6	Returns the calculated output frequency.
Waveform Selection Commands					
FUNCTION	FUNC	<type> <WAV/SEQ#>	WAVE,<NR>	0/999	Selects the specified WAVEform or SEQuence number to send to the output, e.g., FUNC WAVE,1; FUNC WAVE,STDW.
			SEQ,<NR>	0/99	
			STDW		
FUNCTION?	FUNC?	<type> <WAV/SEQ#>	WAVE,<NR1>		Returns the currently selected WAVEform or SEQuence number in the form WAVE[SEQ],<# or STDW>.
			SEQ,<NR1>		
			STDW		
Standard Waveform Definition Commands					
WAVEFORM	WVFM				
SINE	SIN	<# of cycle>	<NR>	1E-3/1E4	Generates a sinewave with the number of cycles as specified.
		<starting phase>	<NR>	-360/360	
SQUARE	SQU	<# of cycles>	<NR>	1/1E4	Generates a squarewave with the number of cycles as specified. The keyword sets the first half of the squarewave high (NORMal), or low (INVERTed).
		<duty cycle>	<NR>	1/100	
		<invert>	NORM INVERT		
TRIANGLE	TRI	<# of cycles>	<NR>	1/1E4	Generates a triangle wave, in the currently selected waveform memory, with the number of specified cycles. The keyword sets the output to initially rise (NORMal), or fall (INVERTed).
		<invert>	NORM INVERT		
SAWTOOTH	SAW	<# of cycles>	<NR>	1/1E4	Generates a sawtooth waveform with the number of cycles as specified. The keyword sets the sawtooth to a NORMal (rising) or INVERTed (falling) waveform
		<duty cycle>	<NR>	1	
		<invert>	NORM INVERT		
DC		<Y value>	<NR>	-32768 /32767	Generates a horizontal line at "Y value" in the selected waveform memory.
EXPONENTIAL	EXP	<exponent>	<NR>	0/20	Generates a decaying exponential with the specified exponent, e-x, in the selected waveform memory. The keyword sets the waveform to a NORMal or INVERTed (positive going or negative going, resp.) decay.
		<invert>	NORM INVERT		
AM		<# of carrier cycles>	<NR>	0/1E4	Generates a sinewave amplitude-modulated by a sinewave, in the selected waveform memory. (Ref. WAVE command.) The first two parameters specify the carrier characteristics, and the second two the modulating waveform. Modulation index can vary from 0 to 200%.
		<starting carrier phase>	<NR>	-360/360	
		<# of modulation cycles>	<NR>	0/1E4	
		<starting modulation phase>	<NR>	-360/360	
		<modulation index>	<NR>	0/200	

Chapter 7 Remote Interface Operation Command Set (continued)

Command Set (continued)

Command Set					
Command		Data	Data Format	Limits	Description
Normal	Short			Min/Max	
Standard Waveform Definition Commands (continued)					
SCM		<# of carrier cycles>	<NR>	0/1E4	Generates a sinewave amplitude-modulated waveform with suppressed carrier, in the selected waveform memory. (Ref. WAVE command.) The first two parameters specify the carrier characteristics, and the second two the modulating waveform.
		<starting carrier phase>	<NR>	-360/360	
		<# of modulation cycles>	<NR>	0/1E4	
		<starting mod. phase>	<NR>	-360/360	
FM		<# of carrier cycles>	<NR>	0/1E4	Generates a sinewave frequency-modulated by a sinewave, in the selected waveform memory. The first two parameters specify the carrier characteristics, and the second two the modulating waveform. Modulation index can vary from 0 to 1000.
		<starting carrier phase>	<NR>	-360/360	
		<# of modulation cycles>	<NR>	0/1E4	
		<starting mod. phase>	<NR>	-360/360	
		<modulation index>	<NR>	0/1000	
HAVERSINE	HSIN	<# of cycles>	<NR>	0/1E4	Generates a haversine wave, with the number of cycles specified. The basic shape of this waveform is a sinewave shifted by -90o.
LINEARSWEEP	LINS	<starting # of cycles>	<NR>	0.001/1E4	Generates a linearly-swept sinewave, with the number of starting and ending cycles as specified
		<ending # of cycles>	<NR>	0.001/1E4	
		<starting phase>	<NR>	-360/360	
LOGSWEEP	LOGS	<starting # of cycles>	<NR>	0.001/1E4	Generates a logarithmically-swept sinewave, with the number of starting and ending cycles as specified.
		<ending # of cycles>	<NR>	0.001/1E4	
		<starting phase>	<NR>	-360/360	
PULSE		<# of pulses>	<NR>	1/1E4	Generates a pulse train, with the number of pulses as specified in the first parameter. Delay, rise/high/falltime are all expressed in percentages of the period of the pulse.
		<delay>	<NR>	0/100	
		<rise time>	<NR>	0/100	
		<high time>	<NR>	0/100	
		<fall time>	<NR>	0/100	
	<invert>		NORM INVERT		
GAUSSIAN	GAUSS	<exponent>	<NR>	0/20	Generates a gaussian pulse with the specified exponent, $e^{-(x^2)}$. Where x varies between +/- <exponent>.
SIN_X_OVR_X	SXX	<# of cycles>	<NR>	4/1E4	Generates the function $\sin(x)/x$ as a waveform, with the number of specified cycles. The keyword sets the waveform NORMal or INVERTed.
		<invert>		NORM INVERT	
CIRCLE		<# of cycles>	<NR>	0/1E4	Generates a semicircle in the selected waveform memory. The first parameter specifies the number of cycles, while the second specifies starting phase in degrees. The keyword sets the first part of the waveform NORMal or INVERTed (first half cycle positive or negative, resp.).
		<starting phase>	<NR>	-360/360	
		<invert>		NORM INVERT	
NOISE					Generates psuedo-random noise in the selected waveform memory.
Waveform Edit Commands					
Waveform	WVFM				
LINE		<starting Y value>	<NR>	-2048/2047	Generates a straight line in the selected waveform memory, with the specified starting and ending Y coordinates.
		<ending Y value>	<NR>	-2048/2047	
LENGTH	LEN	<length>	<NR>	0/131008	Sets the length (in data points) that any succeeding waveform generation function will create, for the selected waveform. Functional limits are 0 to SIZE-POSITION, otherwise a device error is generated.
LENGTH?	LEN?		<NR1>	0/131008	Returns the current value for LENGTH.
MAXY		<value>	<NR>	-2048/2047	Selects the maximum Y value to be produced when generating a waveform. This command is not valid when the standard waveform is selected.
MAXY?		<value>	<NR1>	-2048/2047	Returns the currently selected maximum Y value

Chapter 7 Remote Interface Operation Command Set (continued)

Command Set (continued)

Command Set					
Command		Data	Data Format	Limits	Description
Normal	Short			Min/Max	
Waveform Edit Commands (continued)					
MINY		<value>	<NR>	-2048/2047	Selects the minimum Y value to be produced when generating a waveform. This command is not valid when the standard waveform is selected.
MINY?			<NR1>	-2048/2047	Returns the currently selected minimum Y value.
POSITION	POSN	<write position>	<NR>	0/131007	Sets 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 -1. (Ref. SIZE command.) This command is not valid when the standard waveform is selected. After a function such as SINE, etc. is written, POSITION is automatically incremented to "POSITION SIZE" to point to the next "new" data point.
POSITION?	POSN?		<NR1>	0/131007	Returns the current starting position for writing into waveform memory.
SIZE		<waveform size>	<NR>	0, 32 /131008	Sets the memory size of the currently selected waveform, in number of points. The size can be from zero to the total amount of free memory space. If the selected waveform is the standard waveform (STDW), the existing waveform is stretched or squeezed to fit the new size. If the selected waveform is other than the STDW, if enlarging the size, new points (set to 0) are added at the end of the waveform reducing the size. Sending "zero" size will delete waveform.
SIZE?			<NR1>	0/131008	Returns the present value of SIZE.
WAVE		<waveform #> <selector>	<NR> or STDW WVFM	0/999	Selects either the Standard Waveform (STDW) or one of the numbered locations within the waveform memories. POSITION is set to 0, and LENGTH is set to SIZE.
WAVE?			<NR1> or STDW WVFM	0/999 or STDW	Returns the number of the currently selected waveform memory.
Waveform Transfer Commands					
WAVEFORM	WVFM				
MEMORY (except STDW)	MEM	<address> <data>	<NR> <NR> or <arblk>	0/131007 -2048/2047	This command applies to all waveforms except STDW. Sends either individual data points or a block of data into the selected waveform memory, beginning at the address specified. The data block may be sent either as individual data points in the <NR> format, or as an arbitrary block of data, high byte first
MEMORY? (STDW / WVFM)	MEM?	<address>	<NR>	0/131007	Returns a single word of data in the range of -2048 to 2047, beginning at the specified address. (For both ARB and STDW waves).
MEM_BLOCK?	MBLK?	<address> <length>	<NR> <NR>	0/131007 0/2048	Returns the number of data points as specified in length (each data point is a 2-byte word, high byte first), beginning at the address as stipulated. The response is made up of the data in the definite length arbitrary block data format
FREE?		<selector>	WVFM SEQ		Returns the number of unused data points in WVFM memory or the number of unused sequence steps in the SEQUENCE file system. This command provides support for applications programs to check resource availability before allocating new waveform data or sequence steps.
Output Commands					
AMPLITUDE	AMPL	<peak-to-peak>	<NR>	0.10/10.2	(Amplitude levels are referenced from 50 ohm source impedance into 50 ohm load impedance.) Sets the peak-to-peak output voltage.
AMPLITUDE?	AMPL?		<NR2>	0.10/10.2	Returns the peak-to-peak output voltage.
OFFSET	OFST	<level>	<NR>	-10.2/10.2	Sets output offset voltage.
OFFSET?	OFST?		<NR2>	-10.2/10.2	Returns present offset voltage value.
OUTPUT_SWITCH	OUTSW	<state>	ON MUTE		Turns ON, or MUTES the output.
OUTPUT_SWITCH?	OUTSW?		ON MUTE		Returns the state of output switch.
FILTER		<state>	LPF40k LPF700k OFF		Sets output low pass filter to 40k, 700k or OFF.
FILTER?					Returns the present output filter state.
DEGL			ON OFF		Turn the Deglitcher ON or OFF.
DEGL?			ON OFF		Returns the state of the Deglitcher.
CLOCK_SEL	CLKSEL		INT EXT		Selects either INTERNAL or EXTERNAL sample clock source.
CLOCK_SEL?	CLKSEL?		INT EXT		Returns the present setting for the sample clock source.
READ_BURST?	RBRBS?		<NR1>	1/1048575	Returns the value of the completed burst count
SYNCSSEL		<sync #> <state>	<NR> ADDR/STATE	1, 3, 4	Sets the selected SYNC pulse to either an ADDRESS, or specific STATE within the waveform. For SYNC1, STATE inserts a pulse at the waveform END Point (or ENDP). For SYNC3, STATE sets the sync pulse high during Waveform RUN (WRUN), and for SYNC4, STATE sets the sync pulse at the END point of each waveform Burst (ENDB) within a sequence.
SYNCSSEL?		<sync #> <state>	<NR> ADDR/STATE	1, 3, 4	Returns the present state (ADDR or STATE) of the specified SYNC pulse.
TRGINMODE		<state>	SYNCS ASYNCS		Sets the trigger input mode to SYNC-hronous or ASYNChronous.
TRGINMODE?		<state>	SYNCS ASYNCS		Returns the present mode of the input trigger.
TRGOUTMODE		<state>	SERIAL PARALLEL		For multi-instrument triggering, sets out-puts to trigger in serial or parallel.
TRGOUTMODE?		<state>	SERIAL PARALLEL		Returns the current output trigger mode.

Chapter 7 Remote Interface Operation
Command Set (continued)

Command Set (continued)

Command Set			
Command	Data Format	Limits	
		Min	Max
Arbitrary Sync Pulse Pattern			
WVFM:SYNCS	<SYNC_NR>	1	4
	<SYNC_START>	0	<SIZE>-1
	<SYNC_LEN>	0	<SIZE> - <SYNC_START>
WVFM:MEMS	<SYNC_START>	0	<SIZE>-1
	<decimal_data_val>	0	15
	<arb_data_block>	See description.	
WVFM:MEMX	<SYNC_START>	0	<SIZE>-1
	<sync_val>,<wvfm_val>	0	15
	<arb_data_block>	See description.	
WVFM:MEMS?	<start_addr>	0	<SIZE>-1
WVFM:MEMX?	<start_addr> ,	0	<SIZE>-1
	<wvfm_val>	-2048	2047
WVFM:MBLKS?	<start_addr>	0	<SIZE>-1
	<nr_of_points>	1	4096
WVFM:MBLKX?	<start_addr>	0	<SIZE>-1
	<nr_of_points>	See description.	

Chapter 7 Remote Interface Operation
Command Set (continued)

Command Set (continued)

Command Set				
Command		Data Format	Limits	Description
Normal	Short Form		Min/Max	
Sequence Commands				
SEQUENCE	SEQ	<sequence #>	0/99	Constructs a sequence with the specified sequence number, composed of a series of waveforms as specified. The burst count is set to 1 for each waveform. If no waveform number is supplied, the sequence is deleted.
		<waveform #>	0/999	
AUTOSEQUENCE	AUTO	<1st step #>	0/4095	Configures the automatic sequence step generator to begin at the selected first sequence step, and increment by the step number to the next sequence step number. This command is used in conjunction with SEQ, SEQB.
		<step increment>	0/4095	
SEQBURST	SEQB	<sequence #>	0/99	Constructs a sequence with the specified sequence number, composed of a series of waveforms. Waveform parameters come in pairs, with the first being the number of the next waveform in sequence, and the second being the number of times the waveform is repeated
		<WAV #>	0/999	
		<burst count>	0/1048575	
SEQBURSTNUM	SEQBN	<sequence #>	0/99	Constructs a sequence with the specified sequence number, composed of a series of waveforms. Waveform parameters come in triplets. The first specifies the number of the waveform, the second, the number of times the waveform is repeated, and the third indicates the sequence step # for that waveform.
		<WAV #>	0/999	
		<burst count>	0	
		<sequence step number>	0/4095	
ADDSEQUENCE	ADDSEQ	<sequence #>	0/99	Adds to the specified sequence a series of waveforms. Waveform parameters come in triplets. The first specifies the number of the waveform, the second, the number of times the waveform is repeated, and the third indicates the sequence step # for that waveform
		<waveform #>	0/999	
		<burst count>	0/1048575	
		<sequence step number>	0/4095	
ADDSEQUENCE?	ADDSEQ? (Query Command)	<sequence #>	0/99	Returns the waveform #, burst count, and step number (all as integers) of the specified sequence and step number.
		<sequence step number>	0/4095	
	ADDSEQ? (Query Response)	<waveform #>	0/999	
		<burst count>	0/1048575	
		<sequence step number>	0/4095	

Reset and Default Values

The following Table lists the parameter values which are affected for both defaults and reset setting conditions. Defaults can be accessed over the GPIB or RS232C with the RESET-ALL command. Reset settings can be accessed over the GPIB or RS232C with the *RST or RESET-CURR commands. To accomplish RESET-ALL from the front panel, hold down the number 9 button of the 10-keypad while turning on the power switch.

Reset			
Parameters	Default Values	RESET-ALL	RESET-CURR (*RST)
MODE	CONTinuous	√	√
Burst Count	3	√	√
Sample Clock Frequency	1.00MHz	√	√
Frequency	1.00kHz	√	√
Amplitude	5.000V		
Offset	0.000V		
Waveform			
Function	STDW wave	√	√
Waveform Parameters			
AM	CF=20, MF=1, IX=100%, MP=0, CP=0	√	√
Circle	n=1.00, P=0.00	√	√
DC	DC=0	√	√
Exponential (+/-)	TC=5	√	√
FM	CF=20, MF=1, IX=10, MP=0, CP=0	√	√
Gaussian Pulse	EXP=2.00	√	√
Haversine	N=1	√	√
Pulse (+/-)	DLY=0%, RIS=10%, HI=30%, FAL=10%, N=1	√	√
Sawtooth (+/-)	N=1, DTY=100%	√	√
SCM	CF=20, MF=1, CP=0, MP=0	√	√
Sine	N=1, P=0.000	√	√
Sine(X)/X (SINC)	N=5.50	√	√
Square	N=1, DTY=50%	√	√
Sweep (Lin/Log)	B=1, E=10	√	√
Triangle	N=1	√	√
Output			
Output Switch	off	√	√
Filter	off	√	√
SYNC			
SYN1	ENDP	√	√
SYN3	WRUN	√	√
SYN4	ENDB	√	√
STRG	SER	√	√

Chapter 7 Remote Interface Operation
Reset and Default Values (continued)

Reset and Default Values (continued)

RESET			
Parameters	Default Values	RE-SET-ALL	RE-SET-CURR (*RST)
Waveform Memory			
Arbitrary Waveform			
Wave#	0, 1, 2, 3, 4	√	Unchanged
Size	2000	√	Unchanged
Sync (Start/Length)	0/1	√	Unchanged
Standard Waveform			
Function	Sine, N=1, P=0.000	√	Unchanged
Size	1000	√	Unchanged
Sync (Start/Length)	0/1	√	Unchanged
Sequence Generator			
SEQ#	0, 1, 2	√	Unchanged
GPIB			
GADR (GPIB Address)	16	√	Unchanged
RS-232			
BAUD (Baud Rate)	1.2k	√	Unchanged
PAR (Parity)	NONE	√	Unchanged
BITS (Stop Bits)	8D1S	√	Unchanged
HAND (Handshake)	SW	√	Unchanged

Note:

If you reset the 2414B from the front panel at the time of power-on by holding down the RESET button (number 9 button of the 10-key pad):

- * GPIB Address will change to 16.
- ** RS-232C Baud Rate will change to 1200.

RS-232C Programming Example

- ' This program shows how to set up the 2414B for a continuous sinewave 2 Vp-p, 1.2 kHz
- ' over the RS232C interface (COM1).
- ' The 2414B communication settings must be programmed to:
- ' BAUD: 19.2K BITS: 8DIS PAR: NONE HAND: HW
- ' Bits, parity and handshake parameters are programmable in the 2414B.
- ' You must use the correct RS-232C cable. (See page 7.4)

```
DECLARE SUB SendRS232Cmmd (OutputString$)
COMMON SHARED OutputString$, InputString$, CrLf$, Listen$
CrLf$ = CHR$(13) + CHR$(10)           'RS232 command terminator
Listen$ = CHR$(4)                     'request query response
StartProgram:
    'Connect to 2414B and inititalize.
    OPEN "COM1:19200, N, 8, 1, CS1000, DS1000, BIN" FOR RANDOM AS #1
    PRINT #1, CrLf$ + CrLf$           'Flush RS232 receive buffer
    SendRS232Cmmd ("*cls")            'clear 2414B Event Status Register
    SendRS232Cmmd ("*rst")            'reset 2414B
    'Set up continuous sinewave 2 Vp-p, 1.2kHz in STDW.
    CALL SendRS232Cmmd("outsw on")    'turn output on
    CALL SendRS232Cmmd("FUNC WAVE,STDW") 'select standard wave on
    CALL SendRS232Cmmd("WVFM:WAVE STDW;SINE 1,0") 'Waveform = Sine
    CALL SendRS232Cmmd("AMPL 2.0")   'Amplitude = 2.0 V
    CALL SendRS232Cmmd("SCLK 1.2E6") 'Sclk = 1.2 MHz
    CALL SendRS232Cmmd("exec")       'execute the above commands
STOP
END
```

Chapter 7 Remote Interface Operation
RS-232C Programming Example (continued)

RS-232C Programming Example (continued)

```
SUB SendRS232Cmmd (OutputString$)
    PRINT #1, OutputString$ + CrLf$;           'send command to 2414B
    PRINT #1, "*esr?" + CrLf$;                'check error code
    PRINT #1, Listen$;
    LINE INPUT #1, QueryResponse$
    StringPos = 0
TrimRxString:                                'flush 'LFs' from previous LINE
    StringPos = StringPos + 1
    IF MID$(QueryResponse$, StringPos, 1) < " " THEN GOTO TrimRxString
    QueryResponse = VAL(RIGHT$(QueryResponse$, StringPos))
        'Print the description of error if any
    IF QueryResponse AND 1 THEN PRINT ">> Operation Complete <<";
    IF QueryResponse AND 2 THEN PRINT ">> Request Control ( N/I ) <<";
    IF QueryResponse AND 4 THEN PRINT ">> QUERY ERROR <<";
    IF QueryResponse AND 8 THEN PRINT ">> Device Dependant ERROR <<";
    IF QueryResponse AND 16 THEN PRINT ">> Execution ERROR <<";
    IF QueryResponse AND 32 THEN PRINT ">> Command ERROR <<";
    IF QueryResponse AND 64 THEN PRINT ">> User Request ( N/I ) <<";
    IF QueryResponse AND 128 THEN PRINT ">> Power On <<";
    IF QueryResponse > 0 THEN PRINT " Status read : "; QueryResponse
END SUB
```

GPIB Programming Example

‘ This program shows how to set up the 2414B for a continuous sinewave 2 Vp-p, 1.2 kHz
‘ over the GPIB interface.
‘

```
DECLARE SUB SendGpibCmmd (OutputString$)
DECLARE SUB WaitDelay (Sec!)
REM $INCLUDE: 'qbdecl.bas'                                'National Instruments GPIB
                                                            'driver software

COMMON SHARED ArbGen%, OutputString$, InputString$
StartProgram:
    'Connect to 2414B and initialize.
    CALL ibdev(0, 16, 0, 12, 1, 0, ArbGen%)                'connect 2414B at addr 16
    CALL IBCLR(ArbGen%)
    CALL SendGpibCmmd("cIs")                               'clear 2414B Event Status
                                                            'Register
    CALL SendGpibCmmd("rst")                               'reset 2414B
    'Set up continuous sinewave 2 Vp-p, 1.2kHz in STDW.
    CALL SendGpibCmmd("outsw on")                          'turn output on
    CALL SendGpibCmmd("FUNC WAVE,STDW")                   'select standard wave on
    CALL SendGpibCmmd("WVFM:WAVE STDW;SINE 1,0")          'Waveform = Sine
    CALL SendGpibCmmd("AMPL 2.0")                          'Amplitude = 2.0 V
    CALL SendGpibCmmd("SCLK 1.2E6")                       'Sclk = 1.2 MHz
    CALL SendGpibCmmd("exec")                              'execute the above commands
    IBLOC (ArbGen%)

STOP
END
```

Chapter 7 Remote Interface Operation
GPIB Programming Example (continued)

GPIB Programming Example (continued)

```
SUB SendGpibCmmd (OutputString$)
    CALL ibwrt(ArbGen%, OutputString$)           'send command to 2414B
    CALL ibwrt(ArbGen%, "*ESR?")                 'check error code
    WaitDelay (.01)
    InputString$ = SPACES$(100)
    CALL IBRD(ArbGen%, InputString$)
    IF VAL(InputString$) AND 1 THEN PRINT ">> Operation Complete <<";
    IF VAL(InputString$) AND 2 THEN PRINT ">> Request Control ( N/I ) <<";
    IF VAL(InputString$) AND 4 THEN PRINT ">> QUERY ERROR <<";
    IF VAL(InputString$) AND 8 THEN PRINT ">> Device Dependant ERROR <<";
    IF VAL(InputString$) AND 16 THEN PRINT ">> Execution ERROR <<";
    IF VAL(InputString$) AND 32 THEN PRINT ">> Command ERROR <<";
    IF VAL(InputString$) AND 64 THEN PRINT ">> User Request ( N/I ) <<";
    IF VAL(InputString$) AND 128 THEN PRINT ">> Power On <<";
    IF VAL(InputString$) > 0 THEN PRINT "Status read : "; VAL(InputString$)
    IF VAL(InputString$) > 0 THEN CALL ibwrt(ArbGen%, "*cls")
    IF VAL(InputString$) > 0 THEN BEEP
    CALL ibwrt(ArbGen%, "*cls")
```

END SUB

```
SUB WaitDelay (Sec)
    StrtTime = TIMER
    CurrentTime = TIMER
    StpTime = StrtTime + (Sec)
    DO WHILE CurrentTime < StpTime
        CurrentTime = TIMER
    LOOP
```

END SUB

Advanced Remote Operation

RS 232C Overview

Introduction

RS-232C is an industry-standard method of sending data back and forth between two pieces of equipment. With the Model 2414B, a computer can remotely control the instrument, download waveform data and upload waveform data. This overview explains the interface requirements, 2414B setup, how to verify communications and the command syntax structure.

Interface Requirements

All IBM (or IBM compatible) personal computers (PCs) should be equipped with at least one serial interface port. It may be either a 9-pin DB-9 or a 25-pin DB-25 connector. If desired, a cable may be constructed as described in Chapter 7. Most any software which defines communication protocols may be used. This includes the programming languages Quick Basic, GW Basic, Visual Basic, Quick C, Turbo C and Turbo C++. Communications programs such as ProComm, a “shareware” version, are also usually acceptable. A “local echo” feature is helpful to monitor your typing.

To control the generator from the serial port

Hardware Handshake

This is the only handshake available on the 2414B.

With hardware handshaking, flow control of data to/from the instrument is controlled by the DTR/CTS lines of the RS-232C interface.

Sending data to 2414B:

Instrument will turn the DTR line off (-12V) when the instrument buffer fills to 200 characters. Instrument will turn the DTR line on (+12V) when the instrument buffer empties to 80 characters.

Receiving data from 2414B:

Instrument will stop sending data when the CTS line is off and resume sending data when it is on.

Verification of Communication

After the PC and the 2414B have been connected together and programmed for compatible interface parameters, the interface should be tested for proper operation. The following program notation conventions will be observed: The symbol ^ represents the computer Control Key. The use of braces { } around two characters means the two keys must be pressed simultaneously.

To test the interface, type the following:

***IDN?{^J}{^D}**

The 2414B should identify itself with the following:

Pragmatic Instruments, MODEL 2414B, 0, <firmware_rev_level>

Command Syntax

The command syntax of the Model 2414B closely relates to the Institute of Electrical and Electronics Engineers (IEEE) Standard 488.2 - 1987.

Commands can be divided into two major categories; common commands and instrument specific commands. Overviews of the following topics are provided, as they relate specifically to the RS-232C interface:

Common Commands

Event Register and Status and Error Reporting

Functional Syntax Elements

Instrument specific commands, which are identical to both RS-232C and GPIB interfaces, are listed in chapter 7.

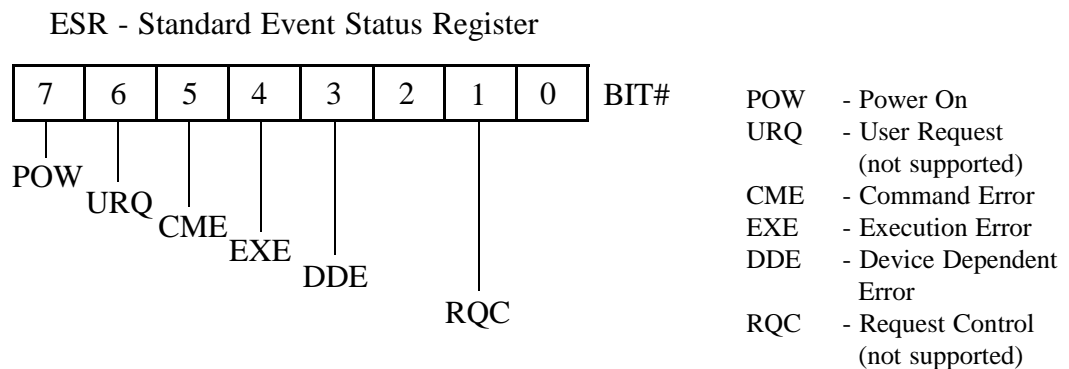
Common Commands

Common commands, recognizable by their leading “*” character, are defined by the IEEE 488.2 standard. Common commands dealing with GPIB protocols or status reporting are not supported in the RS-232C interface. Therefore, RS-232C uses the following subset of the mandated GPIB common commands:

<u>Command</u>	<u>Description</u>
*CLS	Clear Status
*ESR?	Standard Event Status Register Query
*IDN?	Identification Query
*OPC?	Operation Complete Query
*TRG	Trigger Command
*TST?	Self-Test Query
*WAI	Wait-to-Continue
*OPT?	System Option Query

Event Register and Status and Error Reporting

The standard Event Status Register (ESR) may be utilized to indicate the instrument status. Each of six bits within the eight-bit register indicates a different condition within the 2414B:



Functional Syntax Elements

In order to establish programming consistency among different manufacturers' devices, IEEE-488.2 has defined a set of rules governing message headers, mnemonics, separators and data types. The following overview which is very similar to the GPIB counterpart will familiarize the programmer with the fundamentals of these rules. As seen below, the rules for command and query messages are much more flexible than their precise response message counterparts. The rule can be summed up as "Forgiving" listening and "Precise" talking.

<**PROGRAM MESSAGE UNIT**> - This is the basic message, and represents an operation to be performed by the device. As an example, if you wanted to create a sinewave with 5 cycles in the currently selected waveform, the appropriate <PROGRAM MESSAGE UNIT> would be:

WVFM:SINE 5,0

Notice that a colon (ASCII 3A) is used to separate the <program mnemonic> WVFM from SINE. For query responses the similarly structured <RESPONSE MESSAGE UNIT> is used. A complete list of <PROGRAM MESSAGE UNITS> and <RESPONSE MESSAGE UNITS> for the 2414B, with definitions, mnemonics, and limitations is given in chapter 7.

Functional Syntax Elements (continued)

General rules:

1. <program mnemonic> shall have maximum length of 12 characters.
2. “:” is used to separate <program mnemonics>, and when preceding a <PROGRAM MESSAGE UNIT>, it indicates that the following <program mnemonic> is at the root level.

<PROGRAM MESSAGE UNIT>

1. <program mnemonic> can be either upper or lower case alpha.
2. <white space> is only allowed at the end of the header, or next to a “,” or a “;”.

(See note on <white space> below.)

<RESPONSE MESSAGE UNIT>

1. <program mnemonic> shall contain upper case alpha only.
2. No <white space> allowed in message header.

To receive a response to a query command, append “^D” (ASCII 4 or CTRL-D) to the <RESPONSE MESSAGE UNIT>. For example, after sending *IDN?<RMT> followed by “^D”, the 2414B will respond with “Pragmatic Instruments, Model 2414B, 0, <firmware_rev_lvl>”.

Note: <white space> is defined as a length of 1 or more of <white space characters>. A <white space character> is a single ASCII byte in the range of 00-09, 0B-20 Hex.

<PROGRAM MESSAGE> - This is a series of <PROGRAM MESSAGE UNITS> sent to the device in a single string. For example, to set the currently selected waveform to

1) a sinewave output with phase zero, 2) burst mode, 3) a burst of 5, and 4) an amplitude of 2.5Vp-p into 50 Ω, you would send the following <PROGRAM MESSAGE>:

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

The semicolon (ASCII 3B) is required to separate <PROGRAM MESSAGE UNITS> within a <PROGRAM MESSAGE>. For the 2414B a <PROGRAM MESSAGE> can be virtually any length. The structure for a <RESPONSE MESSAGE> for query responses is similar.

Functional Syntax Elements (continued)

<PROGRAM MESSAGE TERMINATOR> or <PMT> - In order 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 two different formats:

CR LF	CR represents carriage return and is an ASCII 0D.
	LF represents line feed and is an ASCII 0A.
LF	LF represents line feed and is an ASCII 0A.

<RESPONSE MESSAGE TERMINATOR> or <RMT> - For query messages the required terminator is:

CR LF	(as above)
-------	------------

GPIB (IEEE-488.2) Overview

Introduction

The Model 2414B with GPIB option conforms to the Institute of Electrical and Electronics Engineers (IEEE) Standard 488.2-1987. The specific implementation of IEEE-488.1 includes the following functions and subsets:

<u>Interface Function</u>	<u>Subset</u>
Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T6
Listener	L4
Service Request	SR1
Remote Local	RL1
Parallel Poll	PP0
Device Clear	DC1
Device Trigger	DT1
Controller	C0
Electrical Interface	E1

To facilitate programming, a brief overview of the IEEE-488.2 Standard (as it specifically applies to the 2414B) is provided.

This section includes: **Common Commands, Status and Event Registers, Functional Elements** (including syntax and nomenclature), **Data Formats**, and **Error Reporting**. For a more detailed discussion of these topics, a copy of IEEE Standard 488.2-1987 may be obtained from:

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

Common Commands

Commands can be divided into two major categories: common commands and instrument specific commands. Instrument specific commands are detailed in chapter 7. Common commands are defined by the standard, and, among other things, are used to manage status registers and synchronization. The following is a list of common commands as implemented in the 2414B:

<u>Command</u>	<u>Description</u>
*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

Status and Event Registers

There are four required status or event registers. They are:

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

The following diagram shows how the registers are related to each other. These registers indicate device status, and allow the programmer to specify which device events will enable a service request.

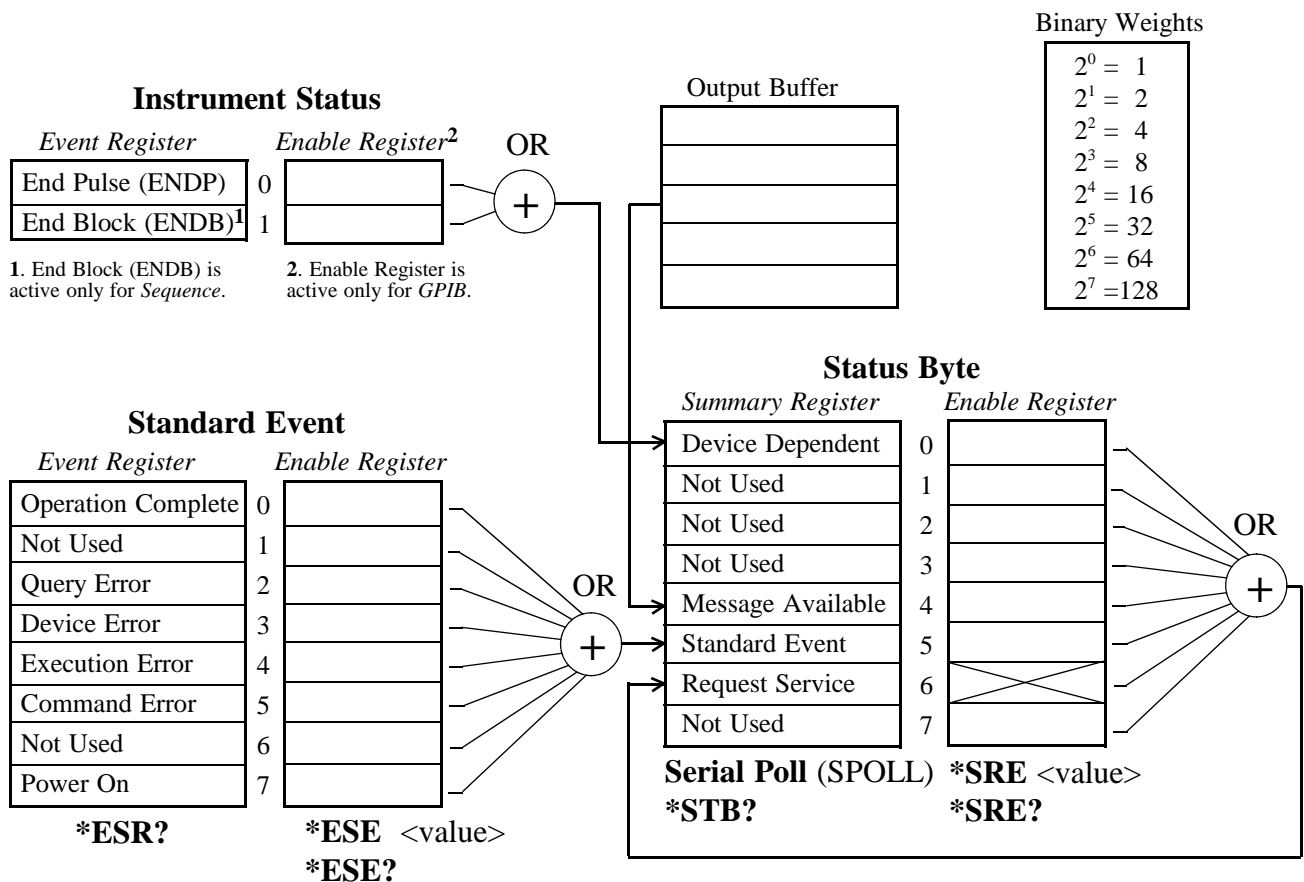


Diagram - Status and Event Registers

Status and Event Registers (continued)

ESR and ESE 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 Standard Event bit (bit 5) in the SRE Register has also been enabled.

For example, if you wanted to generate an SRQ on

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

you would first set the ESB bit in the SRE Register (see discussion below) and then send the following:

***ESE 164** (164 = decimal equivalent of binary 10100100)

The ***ESE?** and ***ESR?** command queries allow reading of the Standard Event Status Enable and Standard Event Status Registers, respectively.

SRE and STB Registers - The Status Byte (STB) Register of the 2414B has four active bits which 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 bit 6) to generate an SRQ.

As an example, to enable the Standard Event and Message Available bits, but not the Device Dependent (bit 0), of the Status Byte Register, you would send the following command:

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

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

The Device Dependent bit (bit 0) or USR0 is user-defined, and summarizes the instrument status registers.

Functional Elements - Syntax and Nomenclature

In order to establish programming consistency among different manufacturers' devices, IEEE-488.2 has defined a set of rules governing message headers, mnemonics, separators, data types and terminators. The following overview, which is very similar to the RS-232C counter part in the previous section, will familiarize the programmer with the fundamentals of these rules. As seen below, the rules for command and query messages are much more flexible than their precise response message counterparts.

<PROGRAM MESSAGE UNIT> - This is the basic message, and represents an operation to be performed by the device. As an example, if you wanted to create a sinewave with 5 cycles in the currently selected waveform, the appropriate **<PROGRAM MESSAGE UNIT>** would be:

WVFM:SINE 5,0

Notice that a colon (ASCII 3A) is used to separate the **<program mnemonic>** **WVFM** from **SINE**. For query responses the similarly structured **<RESPONSE MESSAGE UNIT>** is used. A complete list of **<PROGRAM MESSAGE UNITS>** and **<RESPONSE MESSAGE UNITS>** for the 2414B, with definitions, mnemonics, and limitations is given in chapter 7.

General rules:

1. **<program mnemonic>** shall have maximum length of 12 characters.
2. ":" is used to separate **<program mnemonics>**, and when preceding a **<PROGRAM MESSAGE UNIT>**, it indicates that the following **<program mnemonic>** is at the root level.

<PROGRAM MESSAGE UNIT>

1. **<program mnemonic>** can be either upper or lower case alpha.
2. **<white space>** is only allowed at the end of the header, or next to a ",", or a ";". (See note on **<white space>** below.)

<RESPONSE MESSAGE UNIT>

1. **<program mnemonic>** shall contain upper case alpha only.
2. No **<white space>** allowed in message.

Note: **<white space>** is defined as a length of 1 or more of **<white space characters>**. A **<white space character>** is a single ASCII byte in the range of 00-09, 0B-20 Hex.

<PROGRAM MESSAGE> - This is a series of **<PROGRAM MESSAGE UNITS>** sent to the device in a single string. For example, to set the waveform to 1) a sinewave output with a zero degree starting phase, 2) burst mode, 3) a burst of 5, and 4) an amplitude of 2.5V, you would send the following

Functional Elements (continued)

<PROGRAM MESSAGE>:

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

The semicolon (ASCII 3B) is required to separate <PROGRAM MESSAGE UNITS> within a <PROGRAM MESSAGE>. For the 2414B a <PROGRAM MESSAGE> can be virtually any length. The structure for a <RESPONSE MESSAGE> for query responses is similar.

<**PROGRAM MESSAGE TERMINATOR**> or <**PMT**> - In order 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.

NL - NL represents new line and is an ASCII 0A.

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

<**RESPONSE MESSAGE TERMINATOR**> or <**RMT**> - For query messages the required terminator is:

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

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 which is out of range, or a message which 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. Currently there are no Device Specific errors generated by the 2414B.

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:

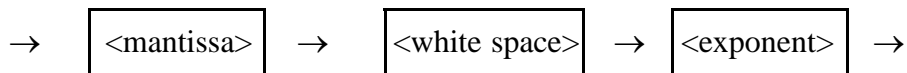
1. Correct the condition which caused the error.
2. Send the *CLS command or read the standard event status register by using the *ESR? query command.

Data Formats

Both RS-232C and GPIB share the same data formats except as noted. Many of the <PROGRAM MESSAGE UNITS> and <RESPONSE MESSAGE UNITS> include numeric data in the message, e.g., the '0' in the message **SINE 0**. This section defines acceptable data formats, and the complete command listing in chapter 7 indicates which formats are used with specific commands and responses.

DECIMAL NUMERIC PROGRAM DATA or <NRf>

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



where <mantissa> = $[\pm][x\dots x][.x\dots x]$ with a maximum length of 255 characters (excluding leading zeros), and the optional <exponent> = $E[\pm][x\dots x]$ or $e[\pm][x\dots x]$ with a maximum value of ± 32000 .

Note in the above definitions: x represents digits 0-9
 [] means enclosed characters are optional

The following example demonstrates several acceptable ways to represent the number 1,234,567,890 in <NRf> format:

+1234567890	123456.7890 <white space> e04
1.234567890E+9	+1.234567890E+10

Three other numeric data formats are used in <RESPONSE MESSAGE UNITS>, and are subsets of the more general <NRf> format.

<NR1 NUMERIC RESPONSE DATA> or <NR1> -
 $[\pm][x\dots x]$ e.g. -98765432

<NR2 NUMERIC RESPONSE DATA> or <NR2> -
 $[\pm]x[x\dots x].x[x\dots x]$ e.g. +98765.432

<NR3 NUMERIC RESPONSE DATA> or <NR3> -
 $[\pm]x[x\dots x].x[x\dots x]E\pm x[x\dots x]$ e.g. 987.65432E+05

<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**
- Hex - **#Hx[x...x]** or **#hx[x...x]** where x is a **0** through **F**

ARBITRARY BLOCK PROGRAM DATA

This data format is used to speed bus transfer in cases where large amounts of data are sent to or from a device (such as waveform or buffer memory data in the 2414B). *Only the <DEFINITE LENGTH> block data format is acceptable for RS-232 while both <DEFINITE LENGTH> and <INDEFINITE LENGTH> block data formats are acceptable for GPIB (IEEE488.2).*

<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>

In the binary definite-length block format, a block header precedes the waveform data. The block header has the following format.

#	5	64000
Start of Data Block	Number of Digits to Follow	Even Number of Bytes to Follow (64,000 bytes = 32,000 points)

The 2414B arbitrary waveform generator represents binary data as 16-bit integers, which is sent as two bytes. Therefore, the total number of bytes you send is always twice the number of data points in the waveform (and it must be always be an *even number*). For example, 64,000bytes are required to download a waveform with 32,000 points.

<INDEFINITE LENGTH> - #0[x...x]<rmt> where x is an 8-bit byte of decimal value 0-255, and <RMT> is the message terminator.

Refer to the **Waveform Memory Format** section for detailed instructions on how to download data into the waveform memory of the 2414B.

Remote Command Set

Introduction

Both RS-232C and GPIB share the same command set except as noted. Many of the command set has an equivalent front panel counterpart. Therefore, it is recommended that you are thoroughly familiar with the front panel operation of the Model 2414B before beginning any programming.

IMPORTANT NOTE

In order to eliminate some of the common errors encountered while programming instruments, the Model 2414B has adopted a unique approach to sending and executing <PROGRAM MESSAGES>. The following discussions on **command sequence** and **command execution** explain this approach.

Command Sequence

Normally a series of commands (or <PROGRAM MESSAGE UNITS>) are sent as a single <PROGRAM MESSAGE> according to the rules outlined in Section 10.4. While these commands are generally executed sequentially, there are certain conditions where the absolute sequential execution of the commands would cause a device error. Take for example the following situation:

Output amplitude is 5Vpp, with offset of 0V

The new test setup calls for an output setting of 1Vpp with +7.5V offset.

(Note: Maximum output amplitude is 10Vpeak)

With most instruments that execute commands sequentially it would be required to first change the amplitude, then change the offset, in order to prevent a device error (caused by the sum of amplitude and offset exceeding 10.4Vpeak; see “ERROR CODES” in the Appendix). Because the Model 2414B is not sequence dependent (except for “WVFM” commands), the command order (within a single <PROGRAM MESSAGE>) is of no consequence. Thus both of the following messages would execute properly without a device error.

AMPL 1.0;OFFSET 7.5

or

OFFSET 7.5;AMPL 1.0

Command Execution

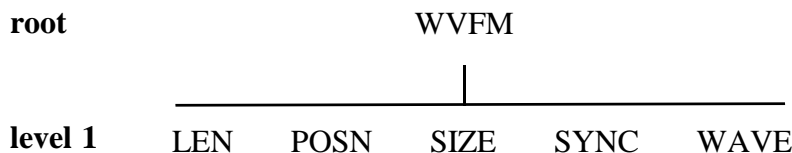
As already alluded to in the preceding paragraph, in order for the Model 2414B to recognize and execute a command, or series of commands, they usually must be followed by the EXECUTE command. This command is equivalent to the front panel <ENTER> button, and allows the programmer to send a complete

Command Execution (continued)

<PROGRAM MESSAGE> into an input buffer, before executing any of the individual <PROGRAM MESSAGE UNITS>. The advantage of this method is two fold: 1) it allows the Model 2414B to process the commands very quickly as a group, rather than wait for the slower bus transfers to complete, and 2) it offers the non-sequence dependent benefits as outlined above.

Command Set Hierarchy

The command set of the Model 2414B uses a hierarchial structure similar to the file structure on many computer systems. The following figure shows an example of this structure.



While some instruments use several levels within the command set structure, the Model 2414B uses mostly one or two levels. The top level (represented by the mnemonic WVFM) is called the root, and the next lower level is level 1. With this structure you must follow a path through the root in order to reach the commands on level 1. Referring to the hierarchy diagram, if you wanted to execute the command SIZE, you would need to indicate the path (through the root) as follows:

WVFM:SIZE 100;

Finally, it is important to note that 1) the path rules of the Model 2414B, allow the programmer to delete the root from the command if the level 1 command has the same root as the preceding command, and 2) if the preceding command is at level 1, you must specify any new root by using a “:” in front of the root mnemonic. To illustrate 1):

WVFM:WAVE 10;;WVFM:SIZE 100

is the same as

WVFM:WAVE 10;SIZE 100

Stacked Queries

In general the Model 2414B allows stacked queries, returning the responses in the same order in which the queries were received. The only exceptions to this are the ***IDN?** and ***OPT?** queries. **Any queries that are placed after the *IDN? or *OPT? queries in a <PROGRAM MESSAGE> will be ignored.**

Chapter 8 Advanced Remote Operation
Remote Command Set - Command Set

Command Set

The complete command set with parameters are given in chapter 7. The following summary is listed for your convenience.

Command Summary - System

Commands			
Common Commands		Configuration Commands	
Long Form	Short Form	Long Form	Short Form
*CLS		CONFIGURE	CONF
*ESE (GPIB only)		HEADERS	HDRS
*ESE? (GPIB only)		HEADERS?	HDRS?
*ESR?		System Commands	
*IDN?		Long Form	Short Form
*OPC		EXECUTE	EXEC
*OPC?		HOLD	
*RST		RECALL	RCLL
*SRE (GPIB only)		REF_CLK_ADJ	RADJ
SRE? (GPIB only)		REF_CLK_ADJ?	RADJ?
*STB? (GPIB only)		REF_CLOCK	RCLK
*OPT?		REF_CLOCK?	RCLK?
*TRG		RESET	
*TST?		RTNTOSTRT	RTST
*WAI		SAMPLECLOCK	SCLK
Instrument Status Commands		SAMPLECLOCK?	SCLK?
Long Form	Short Form	STORE	STOR
INSTRUMENT	INST	TGENERATOR	TGEN
CLEAR	CLR	TGENERATOR?	TGEN?
ENABLE	ENBL	TGRRATE	TGRR
ENABLE?	ENBL?	TGRRATE?	TGRR?
EVENT	EVNT?	TRIGGER	TRIG

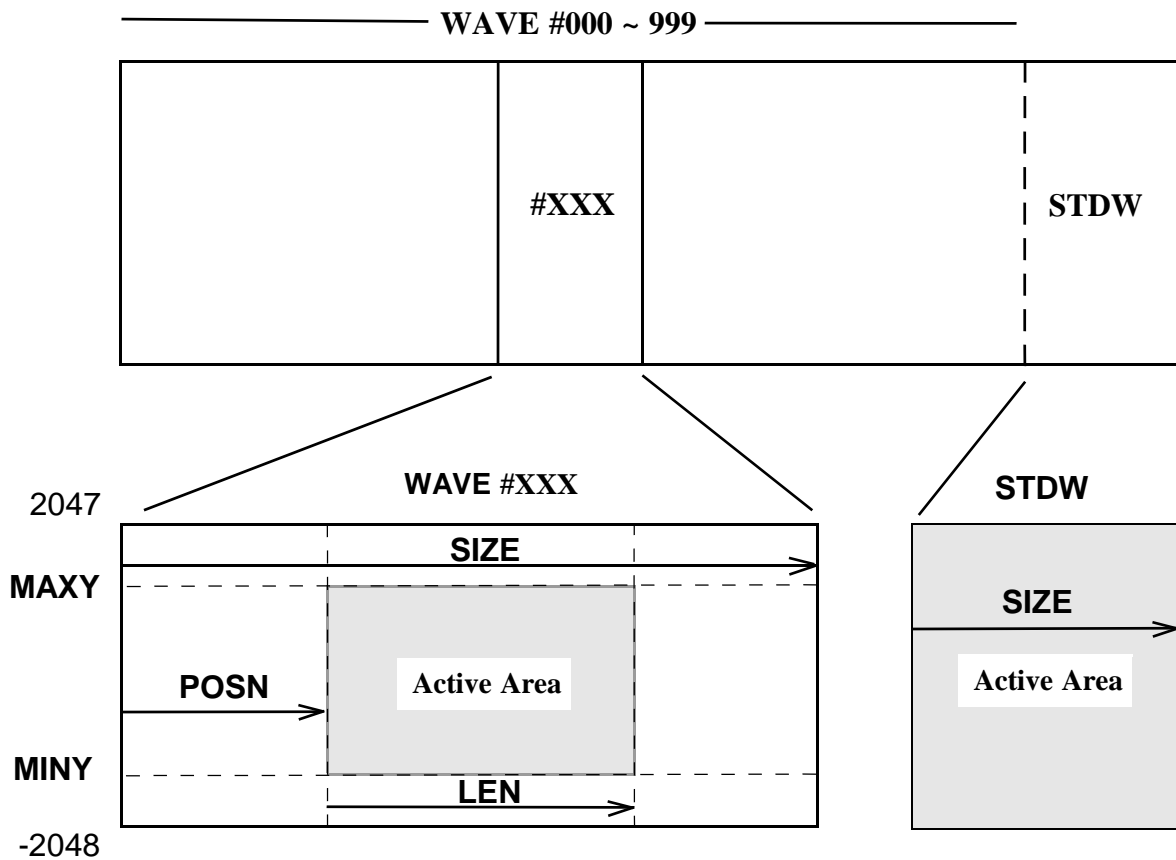
Command Summary - Device Specific

Commands			
Output Commands		Waveform Editing Commands	
Long Form	Short Form	Long Form	Short Form
AMPLITUDE	AMPL	WAVEFORM	WVFM
AMPLITUDE?	AMPL?	SIZE	
BURST		SIZE?	
BURST?		WAVE	
CLOCK_SEL	CLKSEL	WAVE?	
CLOCK_SEL?	CLKSEL?	MEMORY	MEM
FILTER		MEMORY?	MEM?
FILTER?		MEM_BLOCK?	MBLK?
FREQUENCY?	FREQ?	FREE?	
FUNCTION	FUNC	Sequence Generator Commands	
FUNCTION?	FUNC?	Long Form	Short Form
MODE		WAVEFORM	WVFM
MODE?		ADDSEQUENCE	ADDSEQ
OFFSET	OFST	ADDSEQUENCE?	ADDSEQ?
OFFSET?	OFST?	AUTOSEQUENCE	AUTO
OUTPUT_SWTCH	OUTSW	SEQUENCE	SEQ
OUTPUT_SWTCH?	OUTSW?	SEQBURST	SEQB
READ_BURST?	RBRS?	SEQBURSTNUM	SEQBN
SYNCSEL	SYSEL		
SYNCSEL?	SYSEL?		
TRGINMODE			
TRGINMODE?			
TRGOUTMODE			
TRGOUTMODE?			

Waveform Editing Principles

In order to successfully apply the waveform editing commands of the Model 2414B, it is important to understand the principles behind memory allocation, size and the active memory area. For the following discussion refer to Figure below.

There are 131040 words of active waveform memory. The active memory is divided up into an area designated for the Standard Waveform (STDW), and the rest of the memory which can be partitioned into waveform files numbered 0 to 999. 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.



Waveform Editing Commands

Waveform Editing Principles (continued)

The minimum and maximum y values for the two memories 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 effect the active area (See Note below). In other words, if you wanted to create a sinewave with three cycles, starting at 0 phase, you would send the following command:

WVFM:SINE 3,0;:EXEC

This command would place three cycles of sinewaves 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 determines 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 POSN + LEN.

Important Note: For the Standard Waveform (STDW), the active area is always the entire area defined by SIZE. Thus, none of the four commands mentioned above effect the STDW.

Waveform Memory Format

This section describes the formats of the commands which enter data into the wave memory of a TEGAM Inc. arbitrary waveform generator via the GPIB or RS-232C interface.

Decimal Waveform Download

The contents of the waveform memory for wave X (X = 0..999) are changed by a single command formatted according to the IEEE 488.2-1987 standard, and has the following syntax:

<command header> <start address>,<data>[,<data> ...];

As a command for the GPIB or RS-232C, a <command header>, followed by the address of the first memory cell to be set, followed by one or more <data> items and terminated by a semicolon. The <start address> and <data> items are separated by commas, with a space or tab separating the <command header> from the <start address> item. The numbers specified by the <data> items are stored in successive addresses of the wave memory.

The <command header> is a string, whose value depends only on the wave to be set:

<u>Wave</u>	<u>Command Header Value</u>
0	WVFM:WAVE 0;MEM
1	WVFM:WAVE 1;MEM
999	WVFM:WAVE 999;MEM

The <start address> is a decimal number between 0 and 131007. It sets the starting address where the <data> will be downloaded in waveform memory. The <data> items are decimal numbers between -2048 and 2047. If the AMPL (Amplitude) parameter is set to 10V, the following data: -2048, 0, 2047 would produce -10 Volts, 0 Volts, and 10 Volts, respectively, on the output.

Examples:

An 8 point positive Ramp down loaded into wave 1, address 0.
WVFM:WAVE 1;MEM 0,0,292,584,877,1169,1462,1754,2047;

An 8 point sine wave down loaded into wave 2, address 48.
WVFM:WAVE 2;MEM 48,0,1447,2047,1447,0,-1448,-2048,-1448;

Binary Waveform Download

The 2414B also supports binary format for waveform <data> items. Binary format is the fastest way to transfer data.

<command header> <start address>,<binary data><\n>

The <command header> and <start address> are the same as above. The <binary data> has the following format:

<#><num><length><hi byte><lo byte>[<hi><lo>...]<\n>

Where:

<#> is the pound sign, ASCII(35).

<num> is the number of digits in the length parameter. 1 to 9.

<length> is the length in bytes (two bytes per waveform data point).

<hi byte> contains the upper eight bits of a waveform data point .

<lo byte> contains the lower eight bits of a waveform data point .

<\n> is the new-line character, ASCII(10).

NOTE:

1.The range of a waveform data point is 0 to 4095. If the AMPL (Amplitude) parameter is set to 10V, the following waveform data point values: 0, 2048, and 4095, produce -10 Volts, 0 Volts, and 10 Volts, respectively, on the output. The waveform data point is converted to <hi byte><lo byte> format for binary downloading. Conversion from waveform data point to <hi byte><lo byte> can be accomplished as follows:

QuickBASIC

high_byte = FIX(pointdata / 256)

low_byte = pointdata MOD 256

C

high_byte = pointdata / 256

low_byte = pointdata % 256

Where point data is between 0 and 4095.

2. Since two bytes are required for each waveform data point, the length of bytes sent must always be even.

3. An example of downloading binary data is included in a Quick Basic program on page 8-25.

Chapter 8 Advanced Remote Operation Waveform Memory Format - Example

Example:

An 8 point positive Ramp down loaded into wave 1, address 0.

```
WVFM:WAVE 1;MEM 0,#40016binary_data\n
```

Where *binary_data* are the following values as bytes sent to the GPIB or RS-232.

```
|128|0|146|73|164|146|182|219|201|36|219|109|237|182|255|255|
```

The complete command as bytes in memory would look like the following:

```
['W'|'V'|'F'|'M'|':'|'W'|'A'|'V'|'E'|' '|'|'1'|';'|'M'|  
'|'E'|'M'|' '|'|'0'|','|'#'|'4'|'0'|'0'|'1'|'6'|128| 0 |  
|146| 73|164|146|182|219|201| 36|219|109|237|182|  
|255|255| 10|
```

Where '|A|' represents one byte in memory containing the character 'A' (i.e the value ASCII(65)) and '|219|' represents one byte in memory whose value is 219. Therefore: '|A|' and '|65|' are equal in value.

In QuickBASIC

```
A$= "WVFM:WAVE 1;MEM 0,#40016"+CHR$(128)+CHR$(0)  
+CHR$(146)+CHR$(73)+CHR$(164)+CHR$(146)  
+CHR$(182)+CHR$(219)+CHR$(201)+CHR$(36)  
+CHR$(219)+CHR$(109)+CHR$(237)+CHR$(182)  
+CHR$(255)+CHR$(255)+CHR$(10)
```

In C

```
{  
int i;  
char wvfm_buffer[100];  
char data[16]= {128,0,146,73,164,146,182,219,201,36,219,109,237,182,255,255}  
sprintf(wvfm_buffer,"WVFM:WAVE 1;MEM 0,#40016");  
for(i=0; i < 16; i++)  
    wvfm_buffer[i+24] = data[i]; /* 24 bytes in header */  
    wvfm_buffer[16+24] = '\n'; /* end of block */  
}
```

Chapter 8 Advanced Remote Operation Waveform Memory Format - Example

Example:

An 8 point sine wave down loaded into wave 2, address 48.

```
WVFM:WAVE 2;MEM 48,#40016binary_data\n
```

Where *binary_data* are the following values as bytes sent to the GPIB or RS-232.

```
|128| 0|218|129|255|255|218|129|128| 0|37|126| 0| 0| 37|126|
```

The complete command as bytes in memory would look like the following:

```
['W'|'V'|'F'|'M'|':'|'W'|'A'|'V'|'E'|' '|2'|':'|'M'|'E'|  
|'M'|' '|4'|'8'|','|'#'|4'|0'|0'|1'|'6'|128| 0 |218|  
|129|255|255|218|129|128| 0 | 37|126| 0 | 0 | 37|126| 10|
```

In BASIC

```
A$="WVFM:WAVE 2;MEM 48,#40016"+CHR$(128)+CHR$(0)  
+CHR$(218)+CHR$(129)+CHR$(255)+CHR$(255)  
+CHR$(218)+CHR$(129)+CHR$(128)+CHR$(0)+CHR$(37)+CHR$(126)  
+CHR$(0)+CHR$(0)+CHR$(37)+CHR$(126)+CHR$(10)
```

In C

```
{  
int i;  
char wvfm_buffer[100];  
char data[16]= {128,0,218,129,255,255,218,129,128,0,37,126,0, 0,37,126}  
sprintf(wvfm_buffer,"WVFM:WAVE 2;MEM 48,#40016");  
for(i=0; i < 16; i++)  
wvfm_buffer[i+25] = data[i]; /* 25 bytes in header */  
wvfm_buffer[16+25] = '\n'; /* end of block */  
}
```

Chapter 8 Advanced Remote Operation
Waveform Memory Format - Binary Download Test Program for GPIB

Binary Download Test Program for GPIB

```
REM 2414B BINARY DOWNLOAD TEST PROGRAM FOR GPIB
REM Language : Microsoft Quick Basic
REM Computer : IBM AT or better
REM GPIB Board : National Instruments AT-GPIB, IEEE488.2
REM Function : The program downloads a 8400 point Sine Wave into Wave 1, starting at
REM Address 0. The data transfer occurs in 5 blocks, the first four blocks containing 2048
REM Data Points and the last containing 208 Data Points.
REM $INCLUDE: 'qbdecl.bas'
```

```
COMMON SHARED Arb%
```

```
PRINT
PRINT "Initializing GPIB & resetting ARB"
PRINT
CALL IBDEV(0, 16, 0, 12, 1, 0, Arb%)'connect Arb at add 16
CALL ibwrt(Arb%, "*idn?")
ArbResponse$ = SPACE$(100)
CALL IBRD(Arb%, ArbResponse$)
IF IBCNT% > 0 THEN
    PRINT "Unit is a : "; MID$(ArbResponse$, 1, IBCNT%)
    GOTO GpibWasOk
END IF
PRINT ">>> GPIB ERROR <<<"
PRINT "Corrective Action REQUIRED"
STOP
```

```
GpibWasOk:
SetupParameters:
```

```
MaxBlockSize& = 2048
Length& = 8400
DIM ArbData&(Length&)

NumBlocks& = INT(Length& / MaxBlockSize&)
NumPartial& = Length& - NumBlocks& * MaxBlockSize&

PRINT "Calculating a sample Sinewave"

Pie = 3.141593

FOR x& = 0 TO Length&
    ArbData&(x&) = 2047*SIN((x& / Length& * 10)*2*Pie) + 2047
    IF ArbData&(x&) > 4095 OR ArbData&(x&) < 0 THEN STOP
NEXT x&

PRINT "Setting up machine"

CALL ibwrt(Arb%, "*cls") 'Start clean
```

Chapter 8 Advanced Remote Operation
Waveform Memory Format-Binary Download Test Program for GPIB (continued)

Binary Download Test Program for GPIB (continued)

```
CALL ibwrt(Arb%, "outsw on::exec")
CALL ibwrt(Arb%, ":wvfm:wave 1;size " + STR$(Length&) + ";len " + STR$(Length&))
CALL ibwrt(Arb%, ":wvfm:wave 1;posn 0;miny -2047;maxy 2047")
CALL ibwrt(Arb%, ":Func Wave,1::exec")
CALL ibwrt(Arb%, ":wvfm:Wave 1;Dc 0")
GOSUB CheckStatus

BlockNum& = 0

PRINT "Starting Binary Download of : "; Length&; " points"
PRINT "Start > "; TIME$

DO WHILE (BlockNum& < NumBlocks&)
  BlockSize& = MaxBlockSize&
  GOSUB MakeHeader
  StartIndex& = (BlockNum& * MaxBlockSize&)
  BlockNum& = BlockNum& + 1
  StopIndex& = (BlockNum& * MaxBlockSize&) - 1
  PRINT "Assembling Block : "; BlockNum&; " in progress";
  GOSUB AssembleData
  PRINT " > Downloading < ";
  CALL ibwrt(Arb%, "disp 'Block "+STR$(BlockNum&)+" processing" +CHR$(10))
  CALL ibwrt(Arb%, "wvfm:mem " + STR$(StartIndex&) + "," + Header$
  + BinData$ + CHR$(10))
  PRINT " >> completed <<"
  GOSUB CheckStatus
LOOP

DO WHILE (NumPartial&)
  StartIndex& = (BlockNum& * MaxBlockSize&)
  BlockSize& = NumPartial&
  GOSUB MakeHeader
  PRINT "Assembling a partial bock of : "; BlockSize&;
  CALL ibwrt(Arb%, "disp 'Partial Block "+STR$(BlockNum&)+"""+ CHR$(10))
  StopIndex& = NumPartial& - 1 + StartIndex&
  GOSUB AssembleData
  PRINT " > Downloading > ";
  CALL ibwrt(Arb%, "wvfm:mem " + STR$(StartIndex&)+"," + Header$
  + BinData$+CHR$(10))
  PRINT " >> completed <<"
  GOSUB CheckStatus
NumPartial& = 0
LOOP

PRINT " Stop > "; TIME$
CALL IBLOC(Arb%)
INPUT " >> Hit Return to continue <<", Scratch$

END
MakeHeader:

  temp1$ = "#6000000"
  temp2$ = LTRIM$(STR$(2 * BlockSize&))
  Header$ = LEFT$(temp1$, LEN(temp1$) - LEN(temp2$)) + temp2$
  RETURN
```

Chapter 8 Advanced Remote Operation
Waveform Memory Format - Binary Download Test Program for GPIB (continued)

Binary Download Test Program for GPIB (continued)

AssembleData:

```
CurrentPosition& = 1
BinData$ = SPACE$(2 * (StopIndex& - StartIndex& + 1))
FOR IndexPointer& = StartIndex& TO StopIndex&
MID$(BinData$,CurrentPosition&,2) = CHR$(INT(ArbData&( IndexPointer& ) / 256))
+ CHR$(ArbData&(IndexPointer&) AND 255)
CurrentPosition& = CurrentPosition& + 2
NEXT IndexPointer&
RETURN
```

CheckStatus:

```
CALL ibwrt(Arb%, "*ESR?")
InputString$ = SPACE$(100)
CALL IBRD(Arb%, InputString$)
IF VAL(InputString$) AND 1 THEN
PRINT ">> Operation Complete <<";
END IF
IF VAL(InputString$) AND 2 THEN
PRINT ">> Request Control ( N/I ) <<";
END IF
IF VAL(InputString$) AND 4 THEN
PRINT ">> QUERY ERROR <<";
END IF
IF VAL(InputString$) AND 8 THEN
PRINT ">> Device Dependant ERROR <<";
END IF
IF VAL(InputString$) AND 16 THEN
PRINT ">> Execution ERROR <<";
END IF
IF VAL(InputString$) AND 32 THEN
PRINT ">> Command ERROR <<";
END IF
IF VAL(InputString$) AND 64 THEN
PRINT ">> User Request ( N/I ) <<";
END IF
IF VAL(InputString$) AND 128 THEN
PRINT ">> Power On <<";
END IF
IF VAL(InputString$) > 0 THEN
PRINT " Status read : "; VAL(InputString$)
END IF
IF VAL(InputString$) > 0 THEN CALL ibwrt(Arb%, "*CLS")
RETURN
```

Arbitrary Sync Pattern Programming

Overview

Arbitrary pattern programming and query for SYNC1 ... SYNC4 is implemented by a group of remote commands.

Sync Data for spcified channel, Start/Length pairs (WVFM:SYNCX)
{<sync_nr>, <sync_start>, <sync_len> [,<sync_start>, <sync_len>]...}

Sync Data only (WVFM:MEMS)
{<start_addr>, <decimal_data_val | arb_data_block> [,<decimal_data_val | arb_data_block>]...}

Sync + Waveform Data (WVFM:MEMX)
{<start_addr>, <<<sync_val>,<wvfm_val>> | arb_data_block > [,<<<sync_val>,<wvfm_val>>| arb_data_block >]...}

Query Single Sync Data Value (WVFM:MEMS?)
{<start_addr>}

Query Single Sync + Waveform Data Value (WVFM:MEMX?)
{<start_addr>}

Query Block of Sync Data (WVFM:MBLKS?)
{<start_addr>, <nr_of_points>}

Query block of Sync + Waveform data (WVFM:MBLXX?)
{<start_addr>, <nr_of_points>}

Start/Length Sync Programming

Install a series of sync pulses into the specified sync channel.

WVFM:SYNCX
{<sync_nr>, <sync_start>, <sync_len> [,<sync_start>, <sync_len>]...}

<sync_nr>	Sync channel, is between 1 to 4.
<sync_start>	Specifies where in the selected waveform the pulse begins, can be from 0 to size of waveform - 1.
<sync_len>	Specifies the total length of the pulse. Ranges from 0 to size of waveform - <sync_start>.

Start/Length Sync Programming (continued)

Example: Set a sync pattern in Sync #2 with pulses beginning at 0, 30 and 50 with corresponding widths of 10, 15 and 20.

WVFM:SYNCX 2, 0,10, 30,15, 50,20

Block Sync Programming

Send either individual sync data values or a binary block of sync data to the waveform memory. Only sync data is affected, waveform data remains unchanged.

WVFM:MEMS

```
{<start_addr>,
 <decimal_data_val | arb_data_block> [,
 <decimal_data_val | arb_data_block>]... }
```

Each sync point is represented by the lower order 4 bits of a single byte as shown below:

7	6	5	4	3	2	1	0	Bit#
0	0	0	0	SYNC4	SYNC3	SYNC2	SYNC1	

<start_addr> Specifies the starting point of the programmed data in the selected waveform and ranges from 0 to the size of the waveform -1.

<decimal_data_val> A single data value between 0 and 15.

Example: 5 sync data points

WVFM:MEMS 0,1,2,4,8,8

Programs 4 sync points as shown below:

- SYNC1 Start=0 (Len=1)
- SYNC2 Start=1 (Len=1)
- SYNC3 Start=2 (Len=1)
- SYNC4 Start=3 (Len=2)

Block Sync Programming (continued)

<arb_data_block> A single binary data block holding up to 4096 sync values. A sequence of comma separated blocks may be used to cover large memory areas. This is fastest way for data transfer and thus the preferred method. The example above can be rewritten using the binary block. Note that the ASCII(10) new-line character '\n' is the last byte of the message.

Example:

WVFM:MEMS 0, #40005<DAB1><DAB2><DAB3><DAB4><DAB5>\n
 With <DAB1>=1, <DAB2>=2, <DAB3>=4, <DAB4>=8 and <DAB5>=8

Combined Waveform and Sync Programming

Send combined sync/waveform data values either as individual pair of points or as binary block data to the waveform memory. Both waveform and sync data will be changed.

For <arb_block_data>, each sync/waveform point consists of a 16 bit word, represented by 2 bytes:

WVFM:MEMX

```
{<start_addr>,
<<<sync_val>,<wvfm_val>> | arb_data_block>[,
<<<sync_val>,<wvfm_val>> | arb_data_block>]...}
```

<start_addr> Specifies the starting point of the programmed data in the selected waveform and ranges from 0 to the size of the waveform -1.

<decimal_sync_val> A bit field value between 0 and 15.

<decimal_wvfm_val>> The 16 bit waveform value between -2048 and 2047.

Example: 4 data points as comma separated pairs.

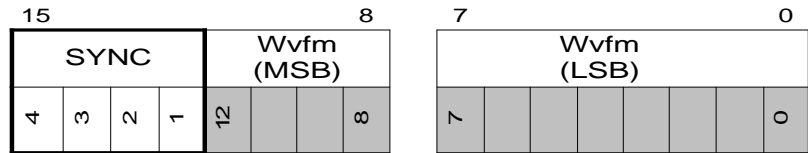
WVFM:MEMX 0, 1,0, 1,1, 2,2, 15,-1

Programs 4 sync points as shown below:

ADDR	SYNC4	SYNC3	SYNC2	SYNC1	WVFM
0	0	0	0	1	0
1	0	0	0	1	1
2	0	0	1	0	2
3	1	1	1	1	-1

Combined Waveform and Sync Programming (continued)

<arb_data_block> A single binary data block holding up to 2048 points (4096 bytes) of combined sync/waveform data. A sequence of comma separated blocks may be used to cover large memory areas. This is the fastest way for data transfer and thus the preferred method.



The example above can be rewritten using the finite length binary block:

```
WVFM:MEMX 0,
#40008<DAB1><DAB2><DAB3><DAB4><DAB5><DAB6>
<DAB7><DAB8>\n
```

With

```
<DAB1>= 18, <DAB2>= 00, <DAB3>=18,
<DAB4>= 01, <DAB5>= 28, <DAB6>=02,
<DAB7>=247 (f7 HEX), <DAB8>= 255 (ff HEX)
```

Single Point Sync Query

```
WVFM:MEMS? {<start_addr>}
```

Returns a single byte in the range of 0 to 15 representing a bit field with weights for SYNC1=1, SYNC2=2, SYNC3=4, SYNC4=8.

<start_addr> is in the range of 0 to length of waveform -1.

```
WVFM:MEMX? {<start_addr>}
```

Returns a single word of combined Sync/Wvfm data. Bits 0 to 11 represent the waveform data in offset binary and bits 12 to 15 hold SYNC1, SYNC2, SYNC3 and SYNC4 data respectively.

<start_addr> is in the range of 0 to length of waveform -1.

Multiple Point Sync Query

```
WVFM:MBLKS? {<start_addr>, <nr_of_points>}
```

Returns the number of Sync byte values as specified in <nr_of_points>.

No more than 4096 points can be requested at the time. The response consist of the <start_address> followed by a comma and the data in the definite length arbitrary block format.

Multiple Point Sync Query (continued)

Example:

WVFM:MBLKS? 0,4 →#500004<DAB1><DAB2><DAB3><DAB4>

With

<DAB1>= 1, <DAB2>=2,
<DAB3>=15, <DAB4>=0.

WVFM:MBLKX? {<start_addr>, <nr_of_points>}

Returns the number of 16 bit Sync/Wvfm values as specified in <nr_of_points> in a binary block. No more than 2048 points (4096 bytes) points can be requested at the time. The response consist of the <start_address> followed by a comma and the data in the definite length arbitrary block format, hbyte first.

Unpacking the 3 byte Sync/Wvfm data frame is accomplished as follows: Bits 0 to 15 is Wvfm data (0 = Zero Scale, 65535 = Full Scale) , Bit 16 = SYNC1, Bit 17 = SYNC2, Bit 18 = SYNC3 and Bit 19 corresponds to SYNC4.

Example:

WVFM:MBLKX? 0,4 →#500012<DAB1>...<DAB12>

With

<DAB1>=1,<DAB2>=128,<DAB3>=0,
<DAB4>= 1, <DAB5> =128, <DAB6>=1,
<DAB7>= 2, <DAB8> =128, <DAB9>=2,
<DAB10>=0, <DAB11>=127, <DAB12>=255

Sequence Generator Operation (Option)

The following section applies for both RS-232C and GPIB. The sequence generator option must be installed at the factory in order to utilize the following features.

ADDSEQUENCE [ADDSEQ] adds to the specific sequence file, one or more sequence steps. This is the only way to modify an existing sequence file using GPIB or RS-232C once it has been entered. The first parameter is the sequence file to be modified. After the first parameter, the following parameters always come in triplets.

The first of these three being the number of the waveform to be sequenced. The second is the number of times this waveform will be repeated, and the third indicates the sequence step # for that waveform.

Example:

Assume that sequence file #10 already exists and steps 35 and 53 are NOT used. The following command will add two steps (35 and 53) to sequence #10. Step #35 will be wave #3 repeated 5 times. Step #53 will be wave #2 repeated 4 times.

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

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

Example:

The following command will start numbering the sequence steps at 10 and increment them by 10, i.e., the first sequence step will be 10, the second sequence step will be 20, etc.

WVFM:AUTO 10,10

SEQUENCE [SEQ] makes a new sequence file, **DELETING** the existing sequence file if one already exists. The first parameter is the sequence file to create. The following parameters are the waves that are 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.

Sequence Generator Operation (continued)

Example:

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

WVFM:SEQ 23

The following commands will create a sequence file (#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 [SEQB] makes a new sequence file, **DELETING** the existing sequence file if one already exists. The first parameter is the sequence file to create. The following parameters are pairs, the first parameter of the pair 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 will create sequence file #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] makes a new sequence file, **DELETING** the existing sequence file if there is one. The first parameter is the sequence file to create. The following parameters are in triplets. First of the three is the wave number, second is the burst count (the number of times the wave is repeated), and the third and last indicates the sequence step number.

Example:

The following command will create sequence file #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

MENU LOGIC TREE - 2414B

This Menu Tree provides a complete list of all setup and control display menus.

Pressing a hard key opens a menu with additional choices. The submenus are shown horizontally to the right and below the main menu sections. The second branch submenus are shown vertically below the submenu selections. Keys are identified as shown below. Many selections provide softkey selections of DO, OK and CANCEL.



HARD KEY



**FIRST-LEVEL
SOFT KEY**

[SECOND-LEVEL SOFTKEY]

[THIRD-LEVEL SOFTKEY]

(FOURTH-LEVEL SOFTKEY)

WAVEFORM PARAMETER KEY GROUP



Set Waveform
Number



Set Sequence
Number



(See next page)

[SIN]

Set Phase
Set Number

[SOR]

Set Duty Cycle
Set Number

[TRI]

Set Number

[SAW+]

Set Duty Cycle
Set Number

[SAW-]

Set Duty Cycle
Set Number

[DC]

Set Value

[EXP+]

Set Time Constant

[EXP-]

Set Time Constant

[AM]

Set Carrier Freq.
Set Mod. Freq.
Set Carrier Phase
Set Mod. Phase
Set % Modulation

[SCM]

Set Carrier Freq.
Set Mod. Freq.
Set Carrier Phase
Set Mod. Phase

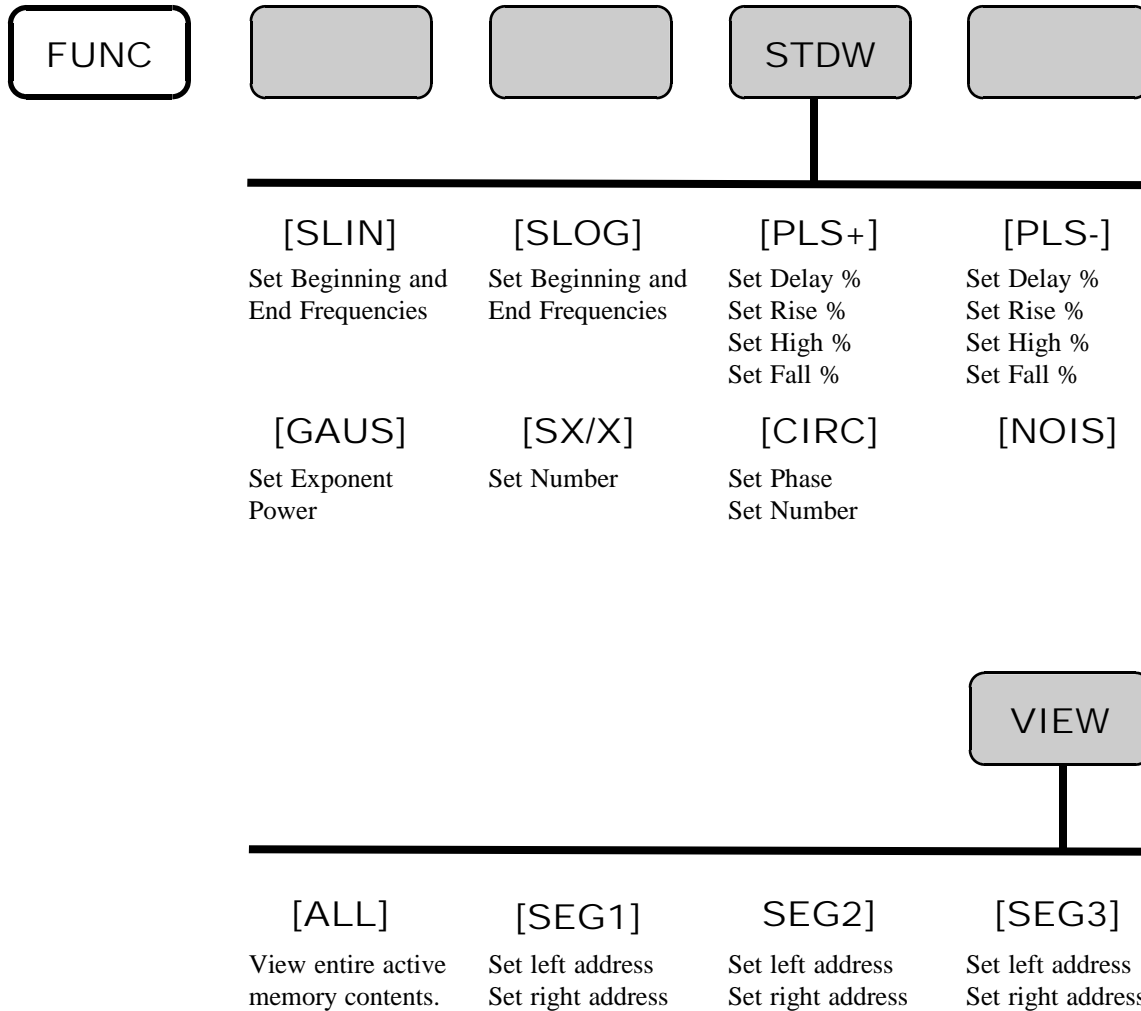
[FM]

Set Carrier Freq.
Set Mod. Freq.
Set Carrier Phase
Set Mod. Phase
Set Mod. Index

[HSIN]

Set Number

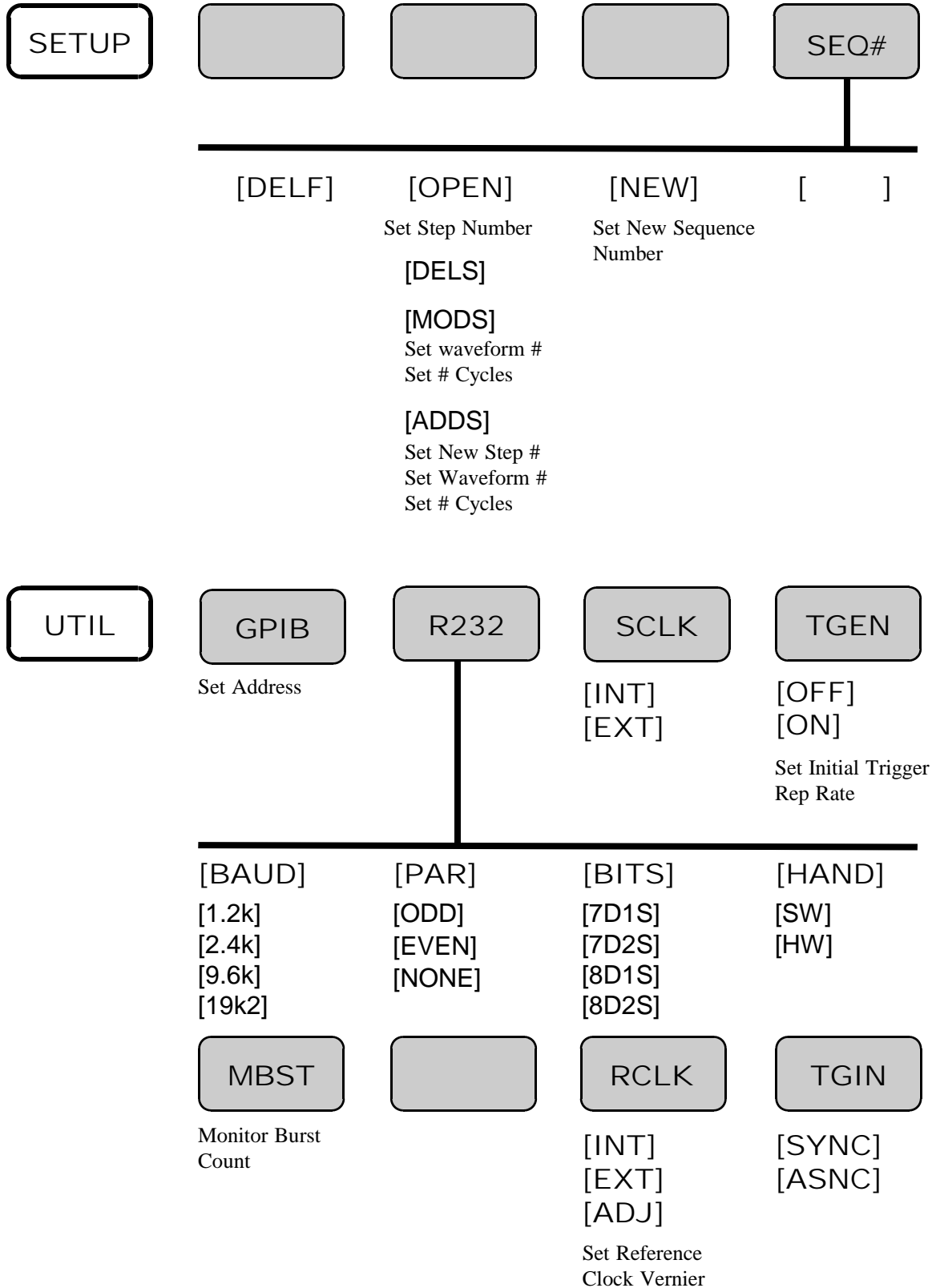
WAVEFORM PARAMETER KEY GROUP (Cont.)



CLOCK
FREQ
 Set Sample Clock
 Set Block Frequency

AMPL
OFST
 Set Amplitude
 Set DC Offset

SETUP, UTILITY and EDIT KEY GROUP (Cont.)



SETUP, UTILITY and EDIT KEY GROUP (Cont.)

EDIT

PNTS

LINE

VRTX

MATH

[ANCH]

* Set Left Anchor (AL)
* Set Right Anchor (AR)

[STRT]

* Set X Address (LX)
* Set Y Address (LY)

[ADDV]

* Set Vertex X Address (VX)
* Set Vertex Y Address (VY)

[<]

Select Three Waveform Numbers

[MODP]

* Increment X Value (PX+)
* Decrement X Value (PX-)

[ANCH]

* Set Left Anchor (AL)
* Set Right Anchor (AR)

[SCAL]

* Set Digital Amplitude (DA)
* Set Digital Offset (DO)

[OP]

[A*B]
[A+B]
[A-B]

[CHRD]

* Set Chord X Address (CX)
* Set Chord Y Address (CY)

[ANCH]

* Set Left Anchor (AL)
* Set Right Anchor (AR)

[INSF]

Select Function

[SHOW]

[-->]
Set Waveform Parameters

VRTX

-->

Select Waveform Number

[SUMF]

* Select Function
* Select Ancillary Function

[DMPF]

* Select Function
* Select Ancillary Function

[SMOO]

Select # of Samples to Average

[MOVE]

Select Anchors

[COPY]
[PSTE]

[SHOW]

[SHOW]

STORE/RECALL KEY



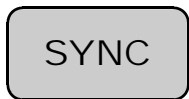
Set Stored Setting
Number



Set Stored Setting
Number



OUTPUT KEY



[SER]
[PAR]



[SYN1]
[ADDR]
[ENDP]

[]

[SYN3]
[ADDR]
[WRUN]

[SYN4]
[ADDR]
[ENDB]

STANDARD WAVESHAVE EQUATIONS

The following ten equations show the mathematical basis for the algorithms used to create the indicated waveforms:

$$fm(t) = \sin[\omega_c t + \beta \cos(\omega_m t + \phi_m) + \phi_c] \quad \beta = \text{Modulation Index}$$

$$am(t) = \sin(\omega_c t + \phi_c) * [1 + M \sin(\omega_m t + \phi_m)] \quad M = \text{Modulation Index}$$

$$scm(t) = \sin(\omega_c t + \phi_c) * \sin(\omega_m t + \phi_m)$$

$$\text{exp+}(t) = e^{-kt} \quad k = \text{Exponential Time Constant}$$

$$\text{exp-}(t) = 1 - e^{-kt} \quad k = \text{Exponential Time Constant}$$

$$\text{sinx/x}(t) = \frac{\sin(t)}{t}$$

$$\text{gauss}(t) = e^{-t^2}$$

$$\text{circle}(t) = \sqrt{1 - (1 - 2t)^2}$$

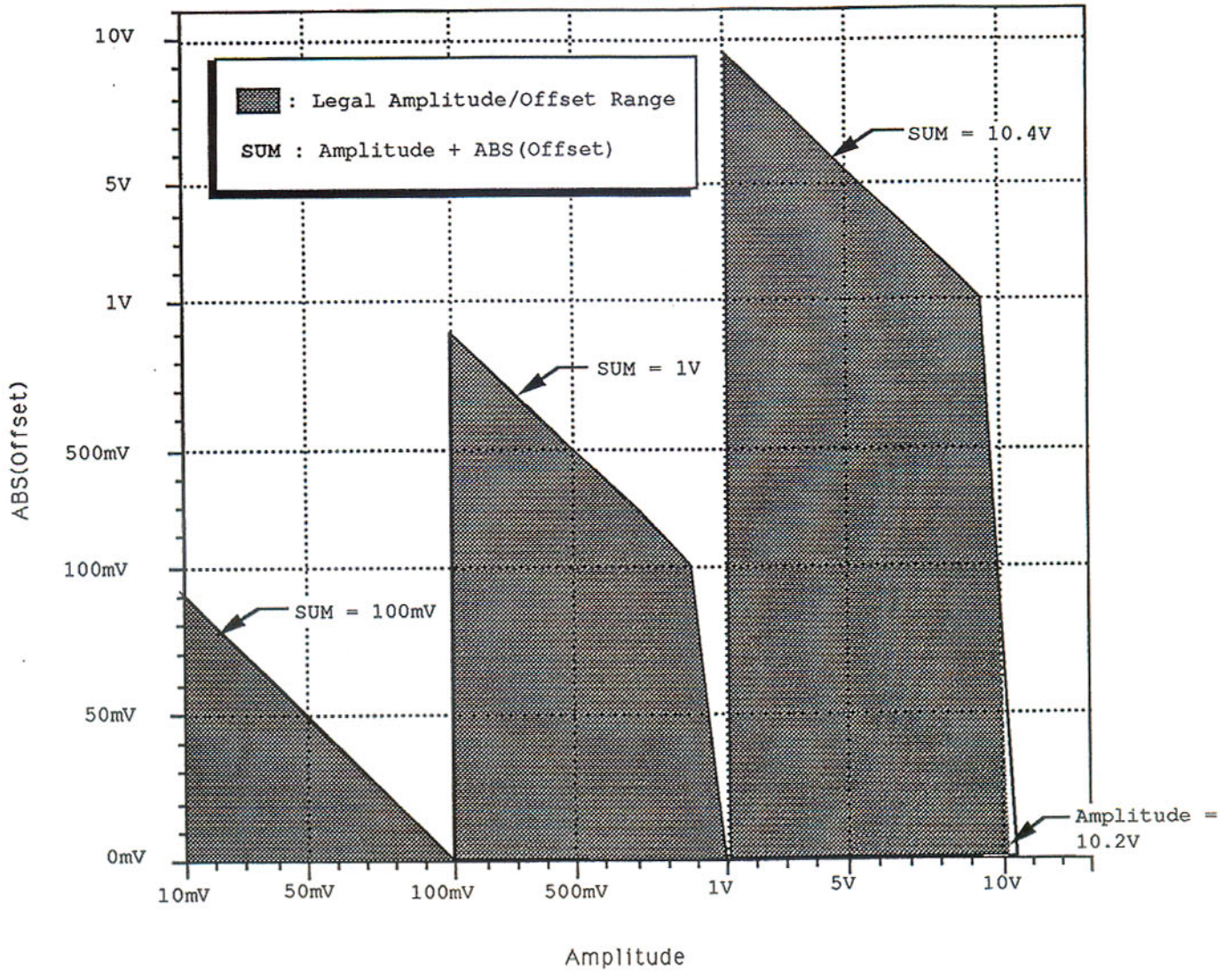
$$\text{linsweep}(t) = \sin\left(\omega_{\text{begin}} t + K \int t dt\right) \quad K \text{ is the slope of the sweep} = \frac{(\omega_{\text{end}} - \omega_{\text{begin}})}{2}$$

$$\text{logsweep}(T) = \sin\left(\omega_{\text{begin}} T * \int_0^T e^{tK} dt\right) \quad K = \frac{\log(\omega_{\text{end}}) - \log(\omega_{\text{begin}})}{\text{SweepTime}}$$

LEGAL AMPLITUDE/OFFSET RANGES:

Amplitude 10mV ... 100 mV : ABS(Offset) \leq 100mV - Amplitude
Amplitude >100mV ... 1 V : ABS(Offset) \leq 1V - Amplitude
Amplitude >1V ... 10.2V : ABS(Offset) \leq 10.4V - Amplitude

AMPLITUDE / OFFSET GRAPH



Index

INDEX

A

add sequence (ADDSEQ) 8-33
address (GPIB) 3-5, 7-2
amplitude (AMPL) 1-5, 1-6, 2-3, 2-4, 3-2, 7-5, 7-11
arbitrary sync pattern programming
 overview 8-28
 start/length sync 8-28
 block sync 8-29
 combined waveform and sync 8-30
 single point sync query 8-31
 multiple point sync query 8-32
arbitrary waveform (See user-defined) 1-9, 2-2, 2-5, 3-3, 3-4, 4-3 to 4-16, 7-6, 7-10
arbitrary block program data 8-14
auto sequence (AUTO) 7-13, 8-33

B

baud rate 7-3, 7-15
binary download test program for GPIB 8-25
binary waveform download 8-22
binary waveform download examples 8-23
block diagram 2-8
burst mode 3-2, 7-9

C

cable (RS-232) 7-4
command
 common commands 7-7, 8-3, 8-8, 8-17
 configuration 7-7, 8-17
 execution 7-5, 8-15
 hierarchy 8-16
 device specific commands 8-18
 mode commands 7-9
 output commands 7-11, 8-18
 path 8-16
 root 8-16
 sequence 8-15
 sequence generator commands 8-18
 standard waveform commands 7-9, 7-10
 sync (arbitrary sync pattern) commands 7-12, 8-28
 syntax, 8-3, 8-11
 system commands 7-7, 8-17

command

user-defined waveform (arbitrary waveform) commands 7-10, 7-11
continuous mode 3-2, 7-9

D

data formats 8-13
DC 3-3, 7-9
decimal numeric program data 8-13
decimal waveform download 8-21
defaults 7-14
delete
 user-defined waveform 7-6
 sequence 7-6, 8-32
digital and analog scaling 2-3, 2-4
download waveform 8-21, 8-22

E

error reporting 8-4, 8-12
event status register (ESR) 8-4, 8-9
event status enable (ESE) register 8-9
examples
 RS-232 programming 7-16
 GPIB programming 7-18
exponential wave 3-3, 7-9

F

filter 3-4, 7-11
frequency of waveforms 1-3, 2-2, 3-2, 7-9
fuse rating III

G

gate mode 3-2, 7-9
gaussian pulse 3-3, 7-10, 7-14
GPIB overview 8-7

H

handshake (RS-232) 8-2
haversine wave 3-3, 7-10, 7-14
horizontal resolution (See size)

I

IEEE-488.2 (See GPIB) 8-7
inputs
 10MHz reference 5-2
 clock 5-2
 trigger 5-2

L

LOCAL button 3-5

INDEX

L

loop and link waveforms (See sequence) 2-5
low-pass filter 3-4, 7-11

M

master unit 5-3, 5-7
memory 7-11
memory formats 8-21
mode 3-2, 5-3, 7-9
multiple phase
 connection 5-3
 operation 5-4

O

offset 1-6, 3-2, 7-5, 7-11
outputs
 clock 5-2
 output 1-2, 3-4
 10MHz reference 5-2
 sync 1-2, 2-6, 8-28
 sync trigger 5-2

P

panel
 front II
 rear III
power mains setting III
program message 8-5, 8-11
program message terminator 8-6, 8-12
program message unit 8-4, 8-5, 8-11
pulse wave 3-3, 7-10, 7-14

R

ramp (sawtooth) wave 3-3, 7-9, 7-14
reference clock 3-5, 7-7
remote command set 8-15
reset 3-5, 6-2, 7-7, 7-14
response message terminator 8-6, 8-12
response message unit 8-4, 8-5, 8-11
RS-232 overview 8-2

S

sample clock 1-4, 2-3, 3-2, 7-9
sample clock rate 1-4, 2-2
scaling 2-3
sequence
 commands 7-9, 7-13, 8-33, 8-34
 generator 2-5, 8-33

sequence

 waveforms 1-10, 2-5, 3-4, 7-6, 7-9
sequence (SEQUENCE or SEQ) 8-33
sequence burst (SEQBURST or SEQB) 8-34
sequence burst number (SEQBURSTNUM or SEQBN) 8-34
service request enable (SRE) 8-9, 8-10
sin(x)/x wave (sinc wave) 3-3, 7-10, 7-14
sine wave 3-3, 7-9, 7-14
size (waveform length) 2-5, 4-4, 7-11, 8-18, 8-19
slave unit 5-3, 5-7
specification VI
square wave 3-3, 7-9, 7-14
service request enable (SRE) register 8-9, 8-10
service request (SRQ) 8-10
stacked queries 8-16
standard waveforms 1-3, 1-7, 2-5, 7-6, 7-9, 7-10
standard waveform list 3-9
status and event registers 8-4, 8-9
status byte (STB) 8-9, 8-10
sync output 2-6, 2-7
sync trigger pulse 5-4
syntax 8-4, 8-11
system commands 7-7, 8-17

T

test equipment required 6-2
toggle mode 3-2, 7-9
triangle wave 3-3, 3-8, 7-9, 7-14
trigger input III, 2-7, 5-2, 5-3
trigger mode 3-2, 7-9

U

user-defined waveform (arbitrary waveform)
 1-9, 2-2, 2-5, 3-3, 3-4, 4-3 to 4-16, 7-6, 7-10

V

verification test
 amplitude accuracy 6-3
 DC offset accuracy 6-3
 frequency accuracy 6-2
 total harmonic distortion (THD) 6-3

INDEX

verification test

waveform rise/fall time 6-2

vertical resolution 2-4

W

waveform

commands 7-9, 7-10

cycle 2-2

editing principles 8-19

generation 2-2

samples 2-3

segments 2-3

sequence 1-10, 2-5, 3-3, 7-6, 7-13

size 2-5, 7-11, 8-18, 8-19

standard 1-3, 1-7, 2-5, 3-3, 3-8, 3-9, 7-6,
7-9, 7-10

user-defined (arbitrary) 1-9, 2-5, 3-3, 3-4,
7-6, 7-9, 7-10, 7-11

windows 4-2

waveform memory format 8-21

WaveWorksPro 3-9, 4-2, 4-3