

WaveWorks Pro +™

Waveform Creation Software for Windows™

Instruction Manual

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REV. C

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

WaveWorks Pro +™ Software

TEGAM is a manufacturer of electronic test and measurement equipment for metrology, calibration, and production test. We also provide repair, calibration, and other support services for a wide variety of test and measurement equipment including RF power sensor calibration systems, RF attenuation measurement systems, resistance standards, ratio transformers, arbitrary waveform generators, micro-ohmmeters, LCR meters, handheld temperature calibrators, thermometers, humidity and temperature control devices, and more.

TEGAM also repairs and calibrates test and measurement equipment formerly manufactured by Electro-Scientific Industries (ESI), Gertsch, Keithley Instruments, Lucas Weinschel, and Pragmatic Instruments. A complete list can be viewed on our Product Service Directory at www.tegam.com

For more information about TEGAM and our products, please visit our website at www.tegam.com; or contact one of our customer service representatives at sales@tegam.com or 800-666-1010.



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The TEGAM WaveWorks Pro+ Software allows you to create, edit and analyze waveforms in a Windows™ environment. The software package provides a communications link between a personal computer (PC) and TEGAM Arbitrary Waveform Generators. In addition, you may retrieve and modify the data you have captured on a digital storage oscilloscope (DSO) using this software. TEGAM WaveWorks Pro's key features allow you to:

- Create, edit and analyze arbitrary waveforms up to 32,000 points in length.
- Access 32 commonly-used standard waveforms with parameters.
- Create new waveforms using a graphical and comprehensive waveform math package.
- Create new waveforms using an optional sequence generator. Repeat and link waveforms.
- Analyze and edit waveforms in the frequency, time or digital data domain.
- Import and export data files in 8 formats including popular spreadsheet formats.
- Transfer waveforms to TEGAM Arbitrary WaveformGenerators.
- Save waveforms to a project file for later use.
- Print waveforms to use in your documentation.

Conventions Used in this Manual

Throughout this manual the following typeface or abbreviations are used to improve the readability and enable you to find the information you need.

Ver software version of WaveWorks Pro +

AWG Arbitrary Waveform Generator

DSO Digital Storage Oscilloscope

WWP WaveWorks Pro

CANCEL This typeface is used to indicate the label on a button or other control.

b:\setup This typeface indicates that input from the key board can be typed or indicates a menu command to be selected.

For example:

”Type **b:\ setup**” or ”Select **File | Open...** from menuBar”. **File | Open...** is separated by a bar

because you must first select the File menu, then select Open.

Recommended Reading

Please review the Microsoft Windows User’s Guide. This manual assumes that you have experience using Microsoft Windows 3.1 or later version. You must know how to use the basic features of Windows or are familiar with terms such as click, double click, resizing, and dragging.

In This Manual

Chapter 1 - Installation describes how to install WaveWorks Pro, the computer requirements and specific interface requirements and specific interface requirements to allow you to work with any TEGAM AWG.

Chapter 2 - Quick Start provides an overview of WaveWorks Pro +. Display components and how to start and close the software are illustrated. A complete example is given demonstrating the steps used to create, save, and output an arbitrary waveform.

Chapter 3 - Using WaveWorks Pro + offers an introduction to arbitrary waveforms. In addition, this chapter describes the 32 standard waveshapes, the mathematical operations capability and the techniques of sequenced waveforms. It covers the waveform setup and file system, details included in the editors, and other operational facilities of the software.

Chapter 4 - Waveform Creation gives the detail descriptions for creating waveforms in WaveWorks Pro +.

Chapter 5 - Sample Waveforms provide real-world examples of arbitrary waveforms. These waveform files are included in your WaveWorks Pro+.

Chapter 6 - Standard Functions provides detailed descriptions of 32 standard functions. The computation methods, the parameter limits and the default values are given.

Chapter 7 - Transfer Functions describes 20 math transfer functions, parameters and default settings.

Chapter 8 - Math Operators describes 13 math operations available in WaveWorks Pro+. Their parameters and default values are included.

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Chapter 1

Installation

Equipment Required

Personal Computer Requirements

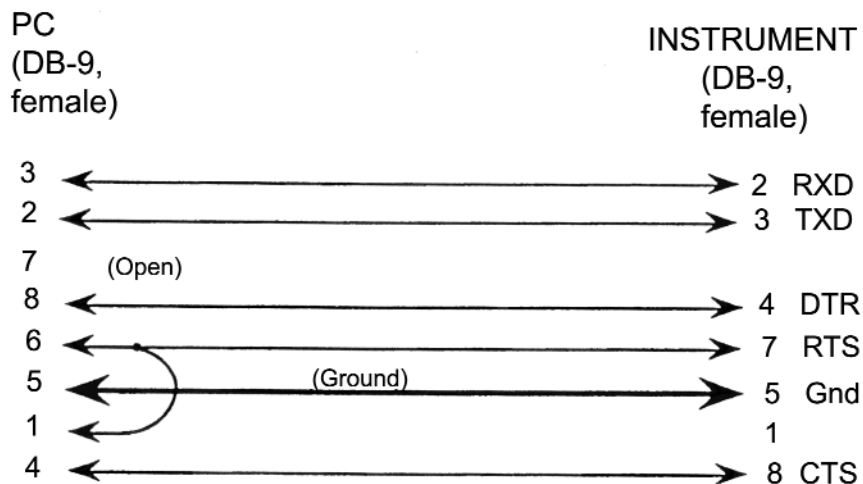
- IBM® (or compatible) 386 PC with math coprocessor or IBM (or compatible) 486-DX PC or better. 486DX2-66 or better PC recommended.
- CD ROM DRIVE.
- Microsoft™ (or compatible) mouse.
- Color VGA or SVGA display.
- 8 MB memory.
- 2 MB free disk space (additional space may be required for waveform storage)
- Microsoft Windows version 3.1 or higher.
- Microsoft MS-DOS version 6.20 or higher.
- Either RS-232 or IEEE-488 (GPIB) interface.

Computer Interface Requirements

IEEE-488 Interface Requirements. To use an IEEE-488 interface with TEGAM WaveWorks Pro + you must have a GPIB cable and one of the following IEEE-488 interface cards already installed in your computer:

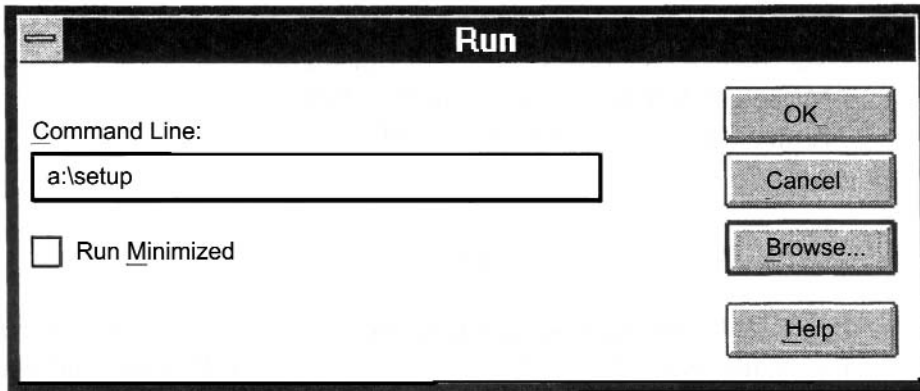
- National Instruments® AT-GPIB
- National Instruments GPIB-PCII/IIA

RS-232 Requirements. To use RS-232 with TEGAM WaveWorks Pro + you must have an RS-232 cable configured as shown in the figure below, and an available Asynchronous Serial (COM) port on your PC.

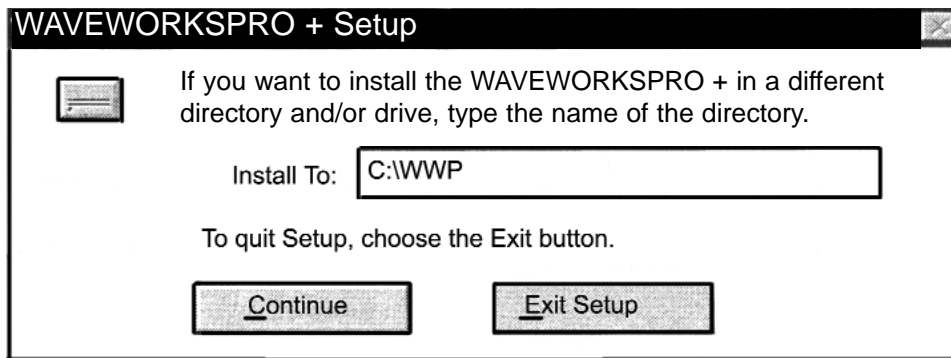


Installing the TEGAM WaveWorks Pro + Software

1. Insert the TEGAM WaveWorks Pro + software in your computer disk drive.
2. Save any work in progress. Close unneeded applications.
3. Select **File | Run** at the Program Manager. Type **D:\setup** in the COMMAND LINE text box and press ENTER or click OK. Change the drive letter if needed (i.e., **E:\setup**).



During the installation process, the setup program will prompt you for the directory to receive the files. Press **ENTER** to accept the default installation directory. Type a new drive and directory in the **INSTALL TO:** text box if needed.



The installation program will create a new program group in the Program Manager and add the TEGAM WaveWorks Pro + icon to the group.

If you encounter problems

- Check the system and interface requirements.
- If you are using RS-232, be sure to use a cable wired as shown on 1-3.
- If your PC is configured to use extended memory management (such as EMM386.EXE) and you are using a GPIB Interface card, you must ensure that the memory management does not conflict with the interface card. Refer to the installation section of your GPIB interface card user's manual.
- If you are using an IEEE-488 Interface card, ensure that you have correctly installed the interface software before running TEGAM WaveWorks Pro +. GPIB.DLL file must be located in your WaveWorks Pro directory, the Windows directory or a directory included in the PATH command in your AUTOEXEC.BAT file. For specific details, refer to your IEEE-488 Interface card installation guide.

Chapter 2

Quick Start

This chapter provides an overview of TEGAM WaveWorks Pro + and gives you a few examples to help you get started using the software. Also included is the interface setup procedure.

TEGAM WaveWorks Pro + Screen Components

Title Bar

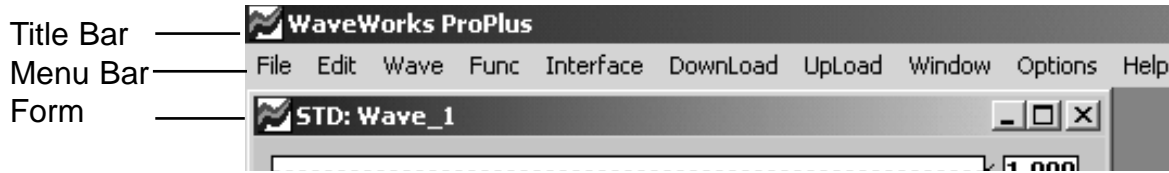
In the Title Bar, WWP + displays WaveWorks Pro + and the name of the project and the file directory.

Menu Bar

The Menu Bar offers the following pull-down menus:

- **File** Menu - contains commands for opening, closing, saving projects and waveforms, importing and exporting data, and printing WWP + waveform windows.
- **Edit** Menu - contains commands for copy and paste between the waveform windows, and editing and analyzing waveforms such as Point, Vertex , Digital Pattern and Harmonic Editors.
- **Wave** Menu - contains commands for new, delete, setup, and list of WWP + waveform windows.
- **Func** Menu - contains extensive commands for creating waveforms with standard functions, math operations, and sequences.
- **Interface** Menu - contains commands for configuring and testing the PC to AWG interface.
- **Download** Menu - contains commands for sending the contents of the waveform window and the parameter controls to the arbitrary waveform generator.
- **Upload** Menu - contains commands for reading the contents of the specified waveform data and the parameter settings of the arbitrary waveform generator.
- **Windows** Menu - contains commands for standard Windows operations such as cascade, tile, and arrange icons.
- **Options** Menu - contains unzoom, span, x-increment, y-axis labels, and pointers commands for the waveform window's operations.
- **Help** Menu - contains information on WaveWorks Pro +.

TEGAM WaveWorks Pro + Components



Title Bar

The Title Bar provides the standard Windows Control-menu box and sizing buttons.

Menu Bar

The Menu Bar contains pull-down menus. Position your cursor over a menu item and click the mouse button to view the menu choices. You can also select the menus by holding the Alt key and typing the underlined letter of the menu choice (for example, Alt + E will display the Edit menu).

Waveform Windows

Waveforms created in TEGAM WaveWorks Pro + are displayed in waveform windows. Waveforms consist of one or more segments which can be created by inserting standard functions, point editing, line drawing, and performing extensive mathematical operations. In addition, waveforms may be linked and repeated by using sequence edit to create a long complex waveform. Viewing of digital pattern of waveform is also available. You can create virtually any arbitrary waveform you need in the graphical comfort of the Windows.

Starting and Closing TEGAM WaveWorks Pro +

Starting. TEGAM WaveWorks Pro + can be started in one of three ways:

- From the WaveWorks Pro + program group, double-click on the TEGAM WaveWorks Pro + icon.
- From the Windows File menu, choose **Run...** and assuming TEGAM WaveWorks Pro + was loaded in a directory named 'WWP', enter:
c:\wwp\wwp. Once started, the TEGAM WaveWorks Pro + screen can be positioned, sized, maximized, or reduced to an icon using the standard Windows controls in the Title Bar.
- From the DOS prompt, assuming TEGAM WaveWorks Pro + was loaded in a directory named 'wwp', type: **win c:\wwp\wwp**

To Create, Save, and Output an Arbitrary Waveform

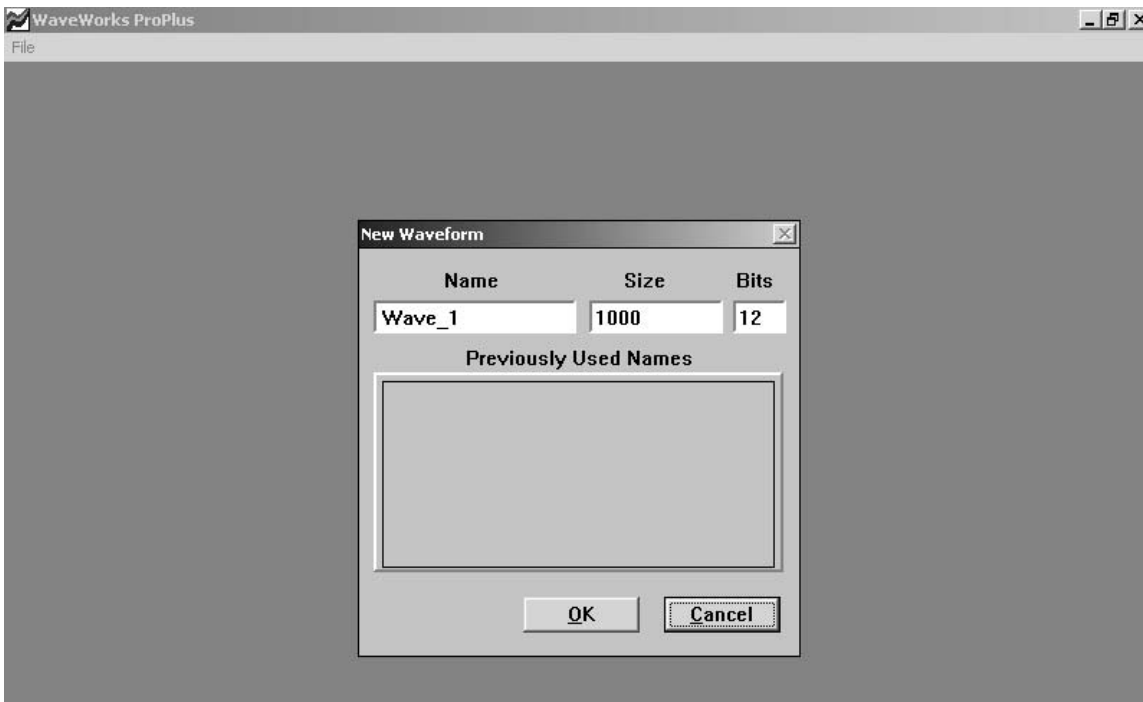
Closing. You can exit from TEGAM WaveWorks Pro + in one of two ways:

- Double-click the Windows Control-menu box on the Main form.
- From the TEGAM WaveWorks Pro + Menu Bar, choose **File | Exit**.

To Create, Save, and Output an Arbitrary Waveform

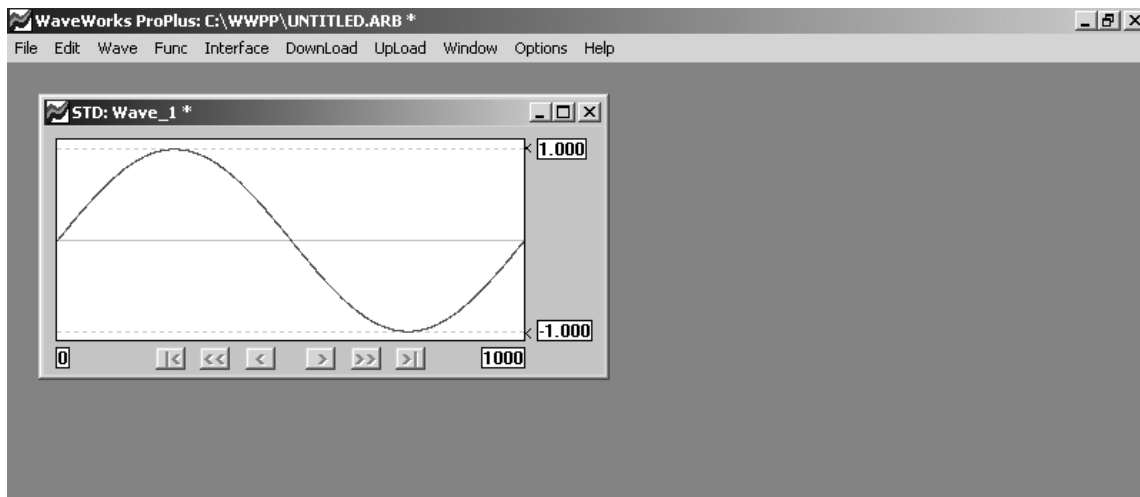
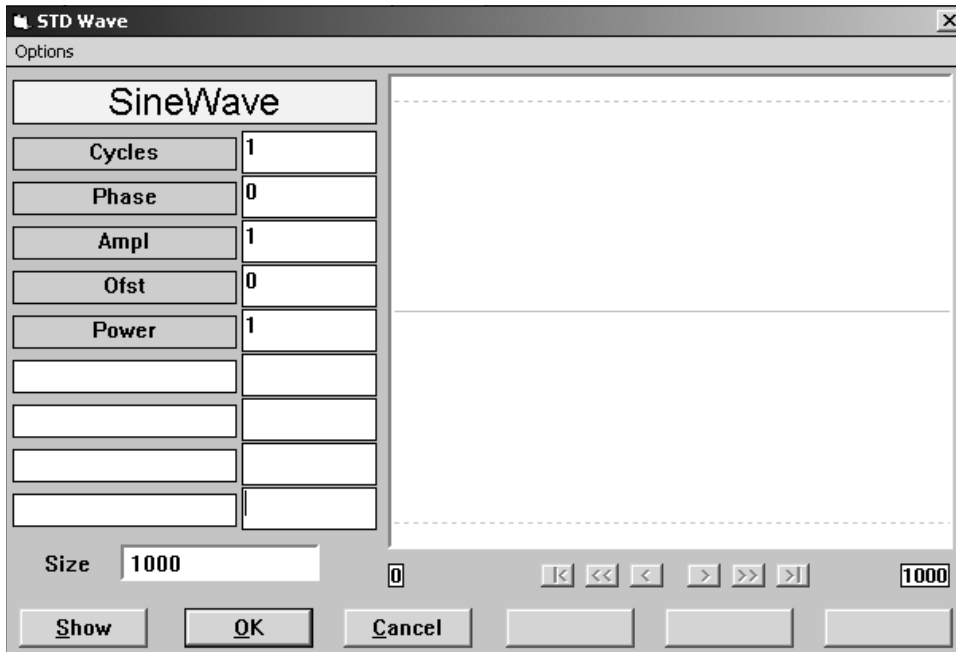
This example demonstrates how to use TEGAM WaveWorks Pro + An arbitrary waveform is created, edited, saved, and output to the selected TEGAM arbitrary waveform generator.

1. Start WaveWorks Pro + as described on the previous page. You should have an empty waveform window #1 displayed if the default setting is chosen. The waveform length is set to 1000 points. Click **OK**.



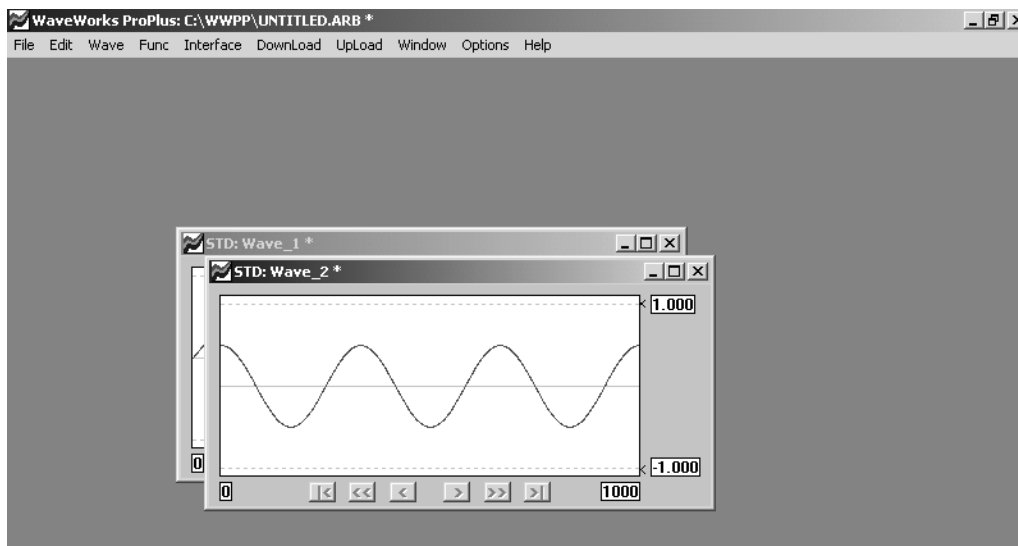
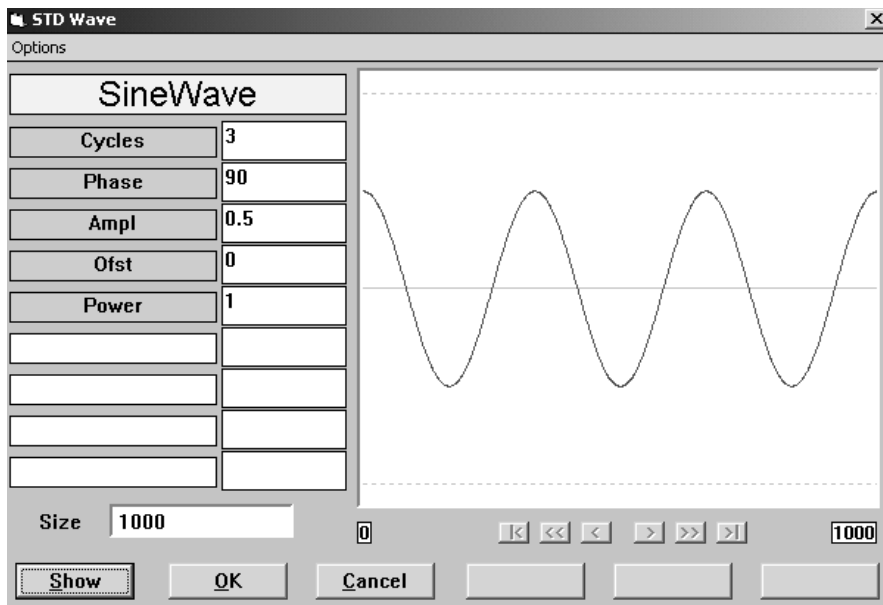
To Create, Save, and Output an Arbitrary Waveform

2. Place a sine wave in the waveform window by choosing **Func | Stdwave**. Select **SineWave** and then click **SHOW** to view and **OK** to accept the waveform. If you used the default parameters, the waveform is a one cycle sinewave starting at 0° with 100% amplitude.



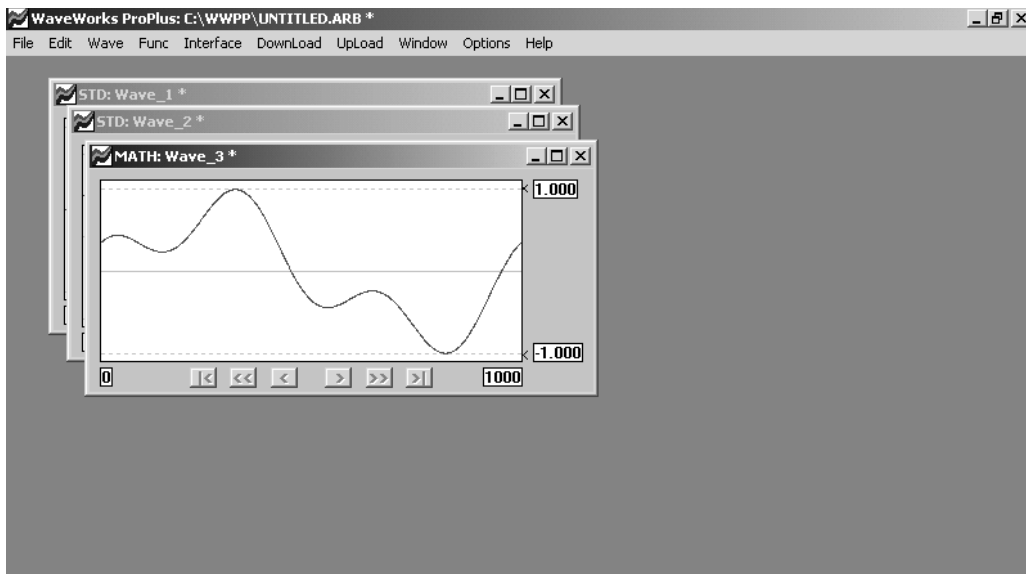
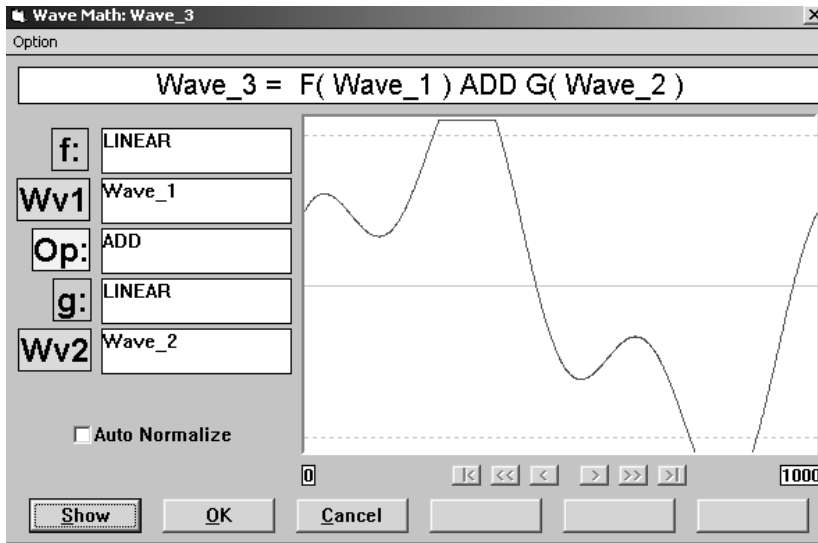
To Create, Save, and Output an Arbitrary Waveform

3. Choose **Wave | New**. Click **OK** to create waveform window #2.
4. Choose **Func | Stdwave**. Choose **SineWave**. Choose **Parameter** to set the sinewave parameters. Select Cycles = 3, Phase = 90, Ampl = 0.5 and then click **SHOW** to preview the waveform in the parameter form. You now have a 3 cycle sinewave starting at 90° with 50% amplitude. Click **OK** to transfer the waveform to waveform window #2.



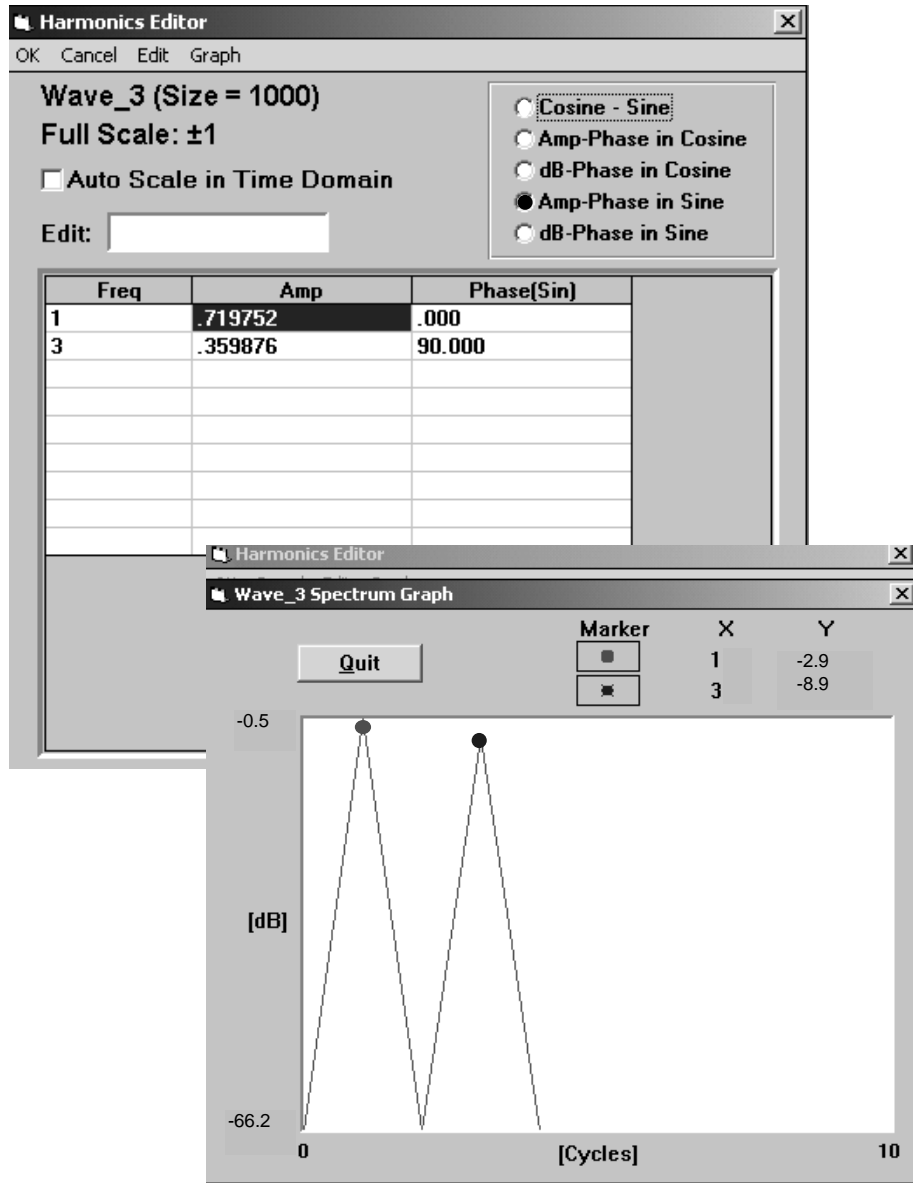
To Create, Save, and Output an Arbitrary Waveform

5. Choose **Wave | New**. Click **OK** to create waveform window #3.
6. Choose **Func | Math**. Click **Wave_1** and select Wave #1. Click **Wave_2** and select Wave#2. Click **OP** and select **ADD**. Use the default selection (Linear) for the transfer function (F and G). Click **SHOW** to preview the computed waveform--a saturated waveform. Check **Normalize** and then click **SHOW** to preview the normalized waveform. Click **OK** to transfer the waveform to waveform window #3.



To Create, Save, and Output an Arbitrary Waveform

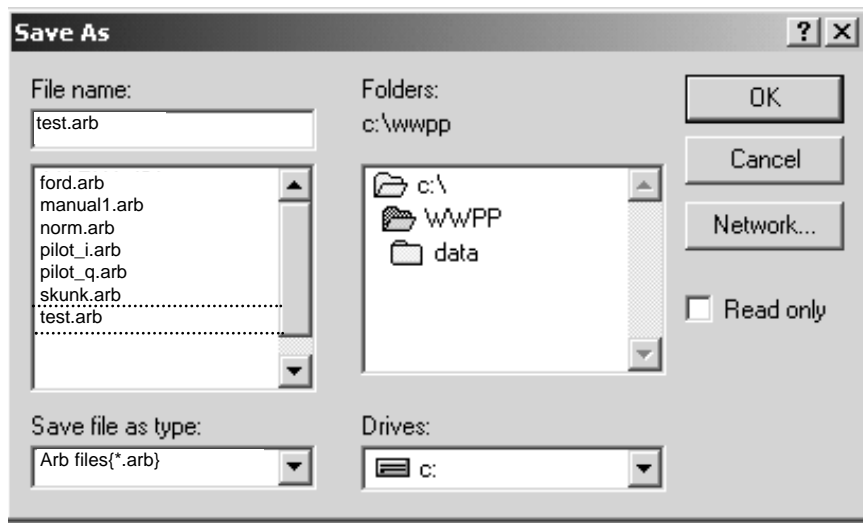
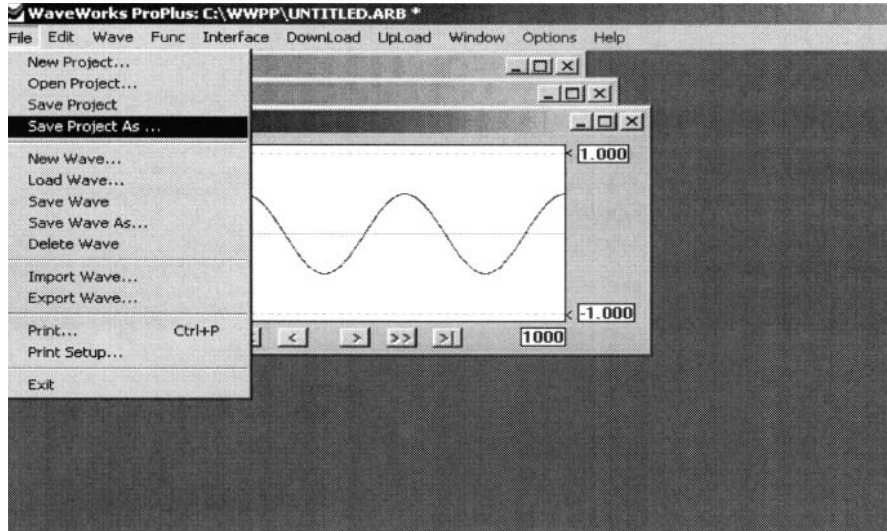
7. Choose **Edit | Harmonics**, while waveform window #3 is selected. You can view the frequency components of waveform #3. Click **Amp_Phys in sine** to list the two frequency components of the waveform. You may view the list in graphic form by choosing **Graph** on the Menu Bar. Click **Quit** to return to the harmonic listing. Click **CANCEL** or **OK** to return to the main form.



NOTE: Use the blue and red markers to indicate the frequency and amplitudes as shown on the X and Y axes. To zoom in on a specific frequency range, put the mouse pointer at the beginning frequency point within the Graph area. Click and drag the mouse pointer towards the right and a dotted box will outline the frequency range to be zoomed in on.

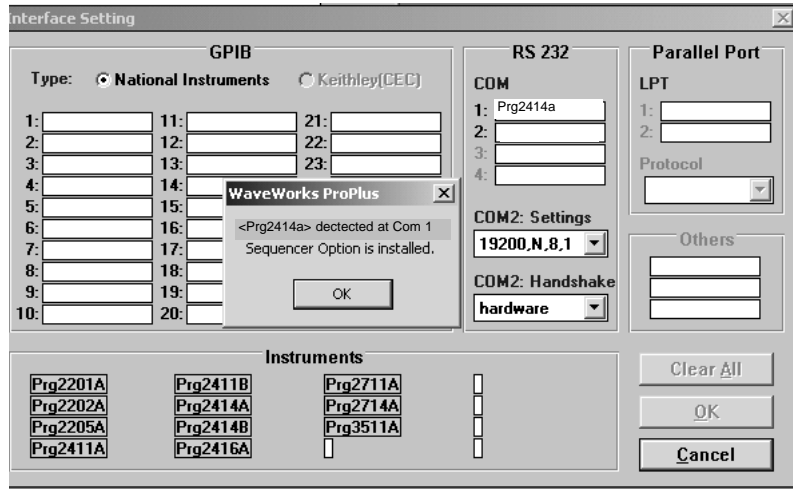
To Create, Save, and Output an Arbitrary Waveform

8. Choose **File | Save Project As** to save the waveforms in the project file. After each waveform is saved, asterisk (*) next to the waveform name in the title bar of the waveform window will be deleted.

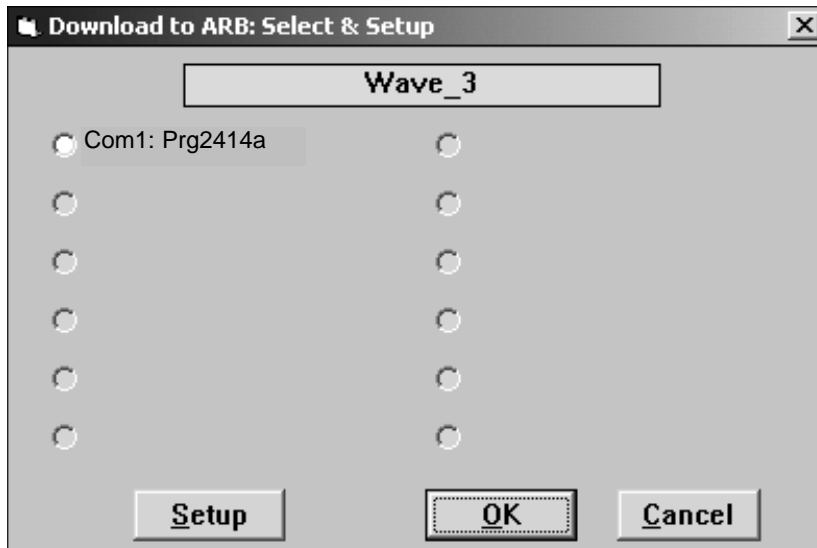


To Create, Save, and Output an Arbitrary Waveform

- Choose **INTERFACE** on the Menu Bar. Examine the TEGAM waveform generators listed at the lower left corner of the screen. If you have connected the TEGAM generators to one of the PC COM ports with the RS-232 cable shown on page 1-3, you are ready to initialize the communications link. The RS-232 settings of the generator must be the same as the PC COM port settings. Drag and drop the generator label on the selected COM port label. Click **OK** to initialize the connection. If the initial verification is successful, the software will report with an instrument model number in the message box.

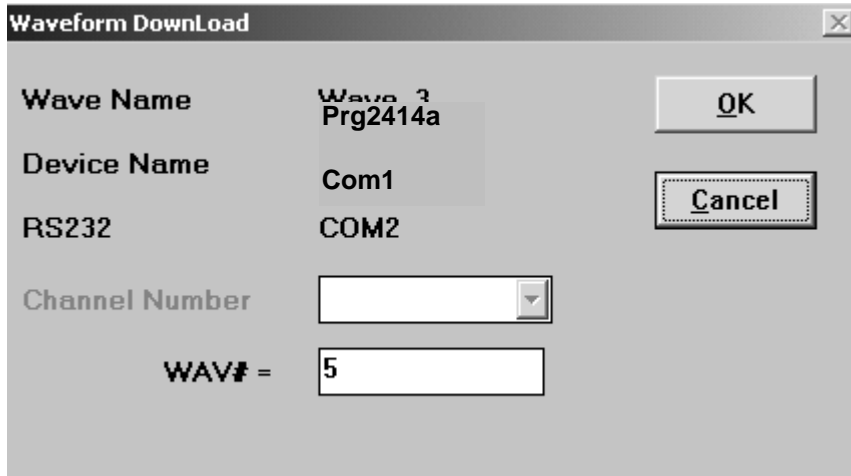


- Choose **Down | Setup** and select **Com1**.



To Create, Save, and Output an Arbitrary Waveform

11. Choose **Download | Go** on the menu bar to initiate the downloading of waveform #3 data. You may specify the destination waveform number in the generator on the Waveform Download screen. Click **OK** to start downloading the data.

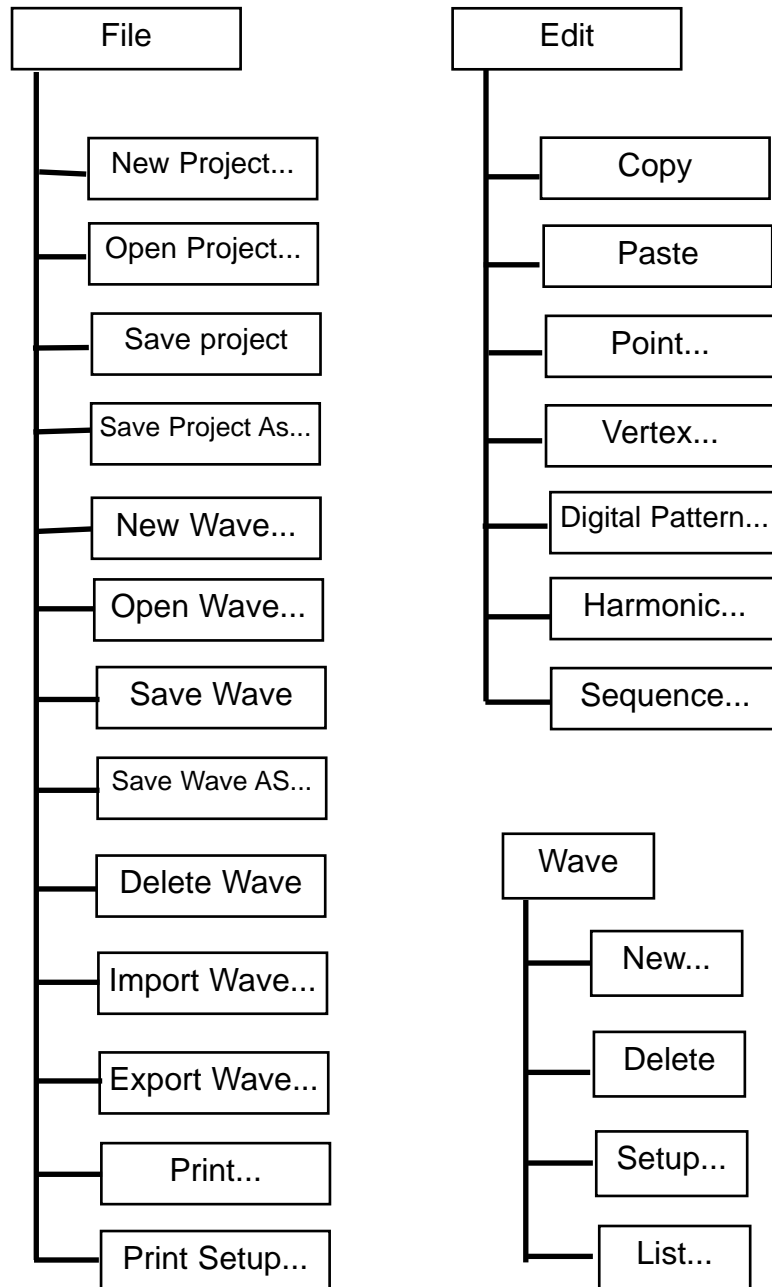


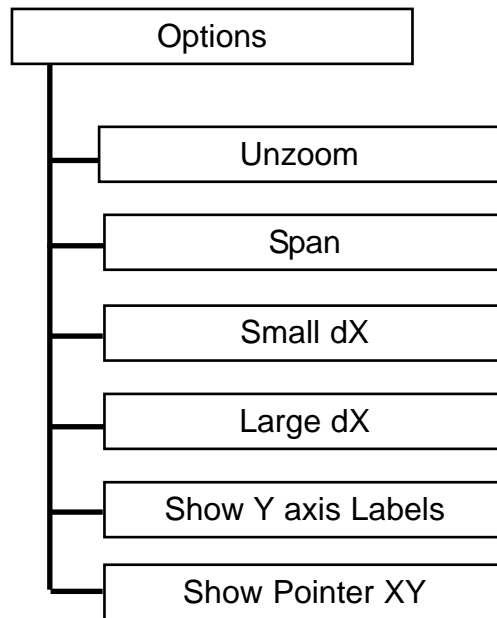
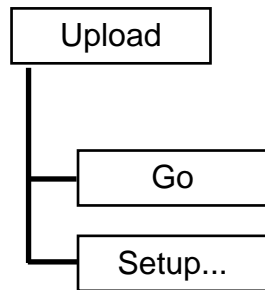
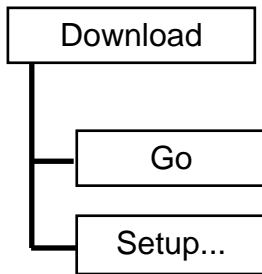
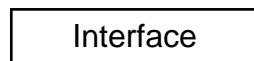
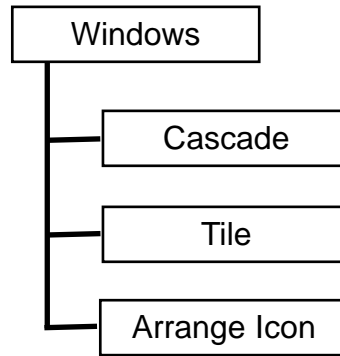
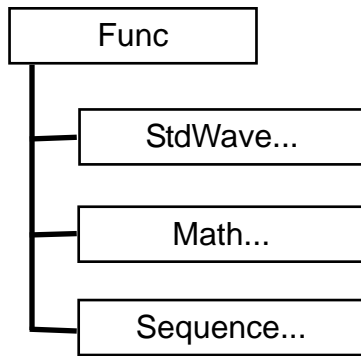
Make sure that you are using the correct cable with this software. It is important to connect the cable ends to the appropriate unit (i.e. **PC** to PC COM port, **Instrument** to the waveform generator RS-232 connector).

If the **Download | Go** menu is not active (gray), WaveWorks Pro + did not find a TEGAM Arbitrary Waveform Generator on the specified interface. Check that the arbitrary waveform generator is properly connected to the computer and turned on.

Chapter 3

Using WaveWorks Pro +





This chapter describes procedures, components, and features you will use in TEGAM WaveWorks Pro +.

About Arbitrary Waveforms

In an arbitrary waveform generator, you will define a waveform, using either the standard functions or custom profile data files to load waveform memory. An address generator sequentially presents data values to the digital-to-analog converter (DAC), which 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.

In WaveWorks Pro +, 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 2714A, the Y values between +2047 and -2047 are used. For 16-bit generators, such as the TEGAM 2711A, the Y values between +32767 and -32767 are used. You may also use the normalized values between +1 and -1 or custom limits in this software. All waveform data file calculations are made using 24-bit resolution in WaveWorks Pro+. 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.

All the data points in the waveform memory window make up one waveform generator cycle. When you send the data file to the waveform generator, it 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 memory window. If more than one cycle of the waveshape is entered into one waveform memory window, the output frequency will be a multiple of one waveform generator cycle. For example, if you create a waveform with 3 sinewave cycles using the same number of data points and the sample clock rate the frequency will be 3 times higher.

TEGAM arbitrary waveform generators may sample the data points at a maximum of 2MS/s to 100MS/s depending on the model. The maximum frequency of the output is determined by the sample rate divided by the number of points. For a 20MHz arbitrary waveform generator, such as TEGAM 2714A, with the waveform length of 1000 points, the upper frequency limit appears to be 20kHz, 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 repeat up to 250 segments within the waveform length of samples (4 samples/segment), you can repeat up to 250 segments within the

waveform length of 1000 points. Then, the output frequency of the sinewave will be 5MHz, since $20\text{kHz} \times 250 = 5\text{MHz}$. This concept is also applicable in understanding the frequency components of the harmonic analysis (FFT) feature. Harmonic analysis uses the total waveform length and defines this as the fundamental or the first (1) harmonic. Based on this interpretation all higher harmonics are a multiple of the fundamental. Because of this criteria certain restrictions are placed on the length of the complete waveform to obtain integer value lengths for all higher harmonics. Both the graph and the tabular presentation of the harmonic profile follow this rule using the total waveform length to determine the fundamental.

The amplitude values of your waveforms have several options in the way they may be displayed. For simplicity using a range of -1 to +1 to represent the minimum and maximum values is the more straight forward. Likewise, these limits will always correspond to the minimum and maximum values produced by the DAC and corresponds to the resolution of the waveform output by the waveform generator. Using this approach guarantees maximum resolution of the waveform and uses the scaling properties of the generator output amplifier to produced the required peak-to-peak output voltage.

Whenever possible range the waveform between -1 to +1 in the waveform window 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 this simple command. For instance, if you have a sinewave in the waveform window that ranges from -1 to +1 you can specify the output at 5 volts peak-to-peak. Automatically the -1 relative amplitude will be scaled to -2.5 volts and the +1 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 when the waveform is sent to the AWG.

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 or in this software, 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.

About TEGAM WaveWorks Pro +

Waveforms consist of one or more segments of X and Y points which can be created in TEGAM WaveWorks Jr. in a number of ways, including drawing the waveform in line (vertex) mode, inserting standard waveshapes, applying mathematical operations, combining and repeating waveforms in sequence mode, and importing X, Y data from other applications or data files. Any of these methods can be combined to create more complex waveforms. Any waveform can be up to 32,000 points per waveform. For a combined waveform created using the sequence mode, the waveform length can be more than 2 billion points.

Waveform Types

Standard Waveshapes (Std)

32 standard functions are included in WaveWorks Pro + version 2.0. You can easily create standard waveshapes by specifying the waveform length, function, and the parameters. The length must be a minimum of 2 points and a maximum of 32,000 points.

Mathematical Operator Waveforms (Math)

A new waveform is created by applying mathematical operations on the previously created waveforms. The input waveforms can be any one of the four types (Std, Math, Seq, Dp). The lengths of the input waveforms must be equal to or less than 32,000 points. The resulting waveform length can vary depending on the mathematical operations and functions but can not be longer than 32,000 points. When a math operation is performed to create a new waveform, you do not have to specify the new waveform length prior to the operation. You may use the default length setting.

The following equation is used to compute the new waveform

$$\text{NewWave} = \mathbf{F} (\text{Wave\#1}) \mathbf{Op} \mathbf{G} (\text{Wave\#2})$$

where

Wave#1, Wave#2 waveforms created prior to math operation

F, G transfer functions

Op mathematical operations on two input waveforms.

Although you may change the input waveforms for the operations at a later time, the math operation will not take place automatically. In order to update the math waveform, select the waveform, choose **Func | Math**, and then press **OK**.

Sequenced Waveform (Seq)

You may create a long complex waveform by looping and linking previously created waveforms. The efficient use of the waveform memory is one of the key features of the sequence generator. WaveWorks Jr. will allow you to have up to 1,000 steps and perform a maximum of 1 million loopings. However, other limits may apply depending on the arbitrary waveform generator (AWG) selected. The waveform types used as parameters for the sequence can be any one of the four waveform types (Std, Math, Seq, and Dp).

If one of the waveforms in the sequence parameter is a sequenced waveform, the waveform must contain only non-sequenced waveforms as its parameters. When a sequence operation is performed to create a new waveform, you do not have to specify the new waveform length prior to the operation. You may use the default length setting. By using the sequence operation, the waveform length may be extended beyond the normal 32,000 points. The length must be less than 2,147,483,647 ($2^{31} - 1$) points. If you exceed this limit, you will be notified by an overflow error message. You may change the input waveforms for the sequence at a later time and the sequence waveform will be updated when the sequence waveform becomes active and is ready for editing. If the above mentioned conditions regarding the number of steps and the length have not been satisfied, an error message will indicate the faulty condition.

If an AWG is connected to the PC and the current waveform window (a sequenced waveform) has selected the waveform generator as the download target and the prior downloading of the parameter waveforms has been completed, then you may use the downloaded waveforms as the sequence parameters. In this case, some restrictions apply to the waveform naming.

Digital Pattern (Dp)

The three waveform types (Std, Math, Seq) are stored in the memory by waveshapes, equations and parameters. However, the waveform edited by the following editors (Point, Digital, Harmonic) or imported from other applications is stored in the memory using point-by-point waveform data (Dp). Using digital pattern (Dp) 4 bytes per point are required to store the data.

Waveform Setup

The waveform windows may be set up by **Wave | Setup** menu.

Waveform Name

You may change the waveform name. If the name is used as a parameter in the

other waveform window for Math or Sequence type, then the name change will automatically update the previous name.

Waveform Size

The maximum length must be less than 32,000. If the waveform type is either Math or Seq, you do not have to set the length. The adjustment is automatic. After changing the length, you must recompute the waveform.

Choose **Func | StdWave**, **Func | Math**, or **Func | Seq** menu to create the new waveform.

Waveform Resolution - number of bits

You may change the number of bits in the waveform. Normally, you must match the number of bits used in the target AWG (≤ 16). However, if the waveform is converted to a Dp-type, the recommendation is not to change the number of bits. When the waveform is Std, Math, or Seq type, the waveform is computed based on 32-bit single variables regardless of the bit setting. When Point Editor, Digital Pattern Editor, or Harmonic Editor is used to edit a waveform, the number of bits has significant impact on the operation. When downloading a waveform to an AWG, or uploading data from a DSO, the number of bits is automatically specified for the selected instrument. Therefore, you must specify the number of bits of the selected AWG for a waveform.

File Types

WaveWorks Pro + supports several types of files for the storage of data .

Project File (*.ARB)

This file contains the instrument setup file (*.STP) and the waveform file listing. Each waveform is read in the order of the listing beginning at the top. The order of the listing is very important for the math or sequence operation to perform properly. The waveform used as a parameter for the math or sequence operation must be read prior to the operation.

Instrument Setup File (*.STP)

The settings of the AWG or DSO used to perform the project are contained in this file. If you do not specify an AWG or a DSO for a project, this file will be empty.

Waveform Files

Waveform files are stored in 4 types. Depending on the types, the extensions are

changed. The extensions also contain the waveform numbers from 1 to 20 to denote the order of creation.

Std type ==> *.W##

Math type ==> *.M##

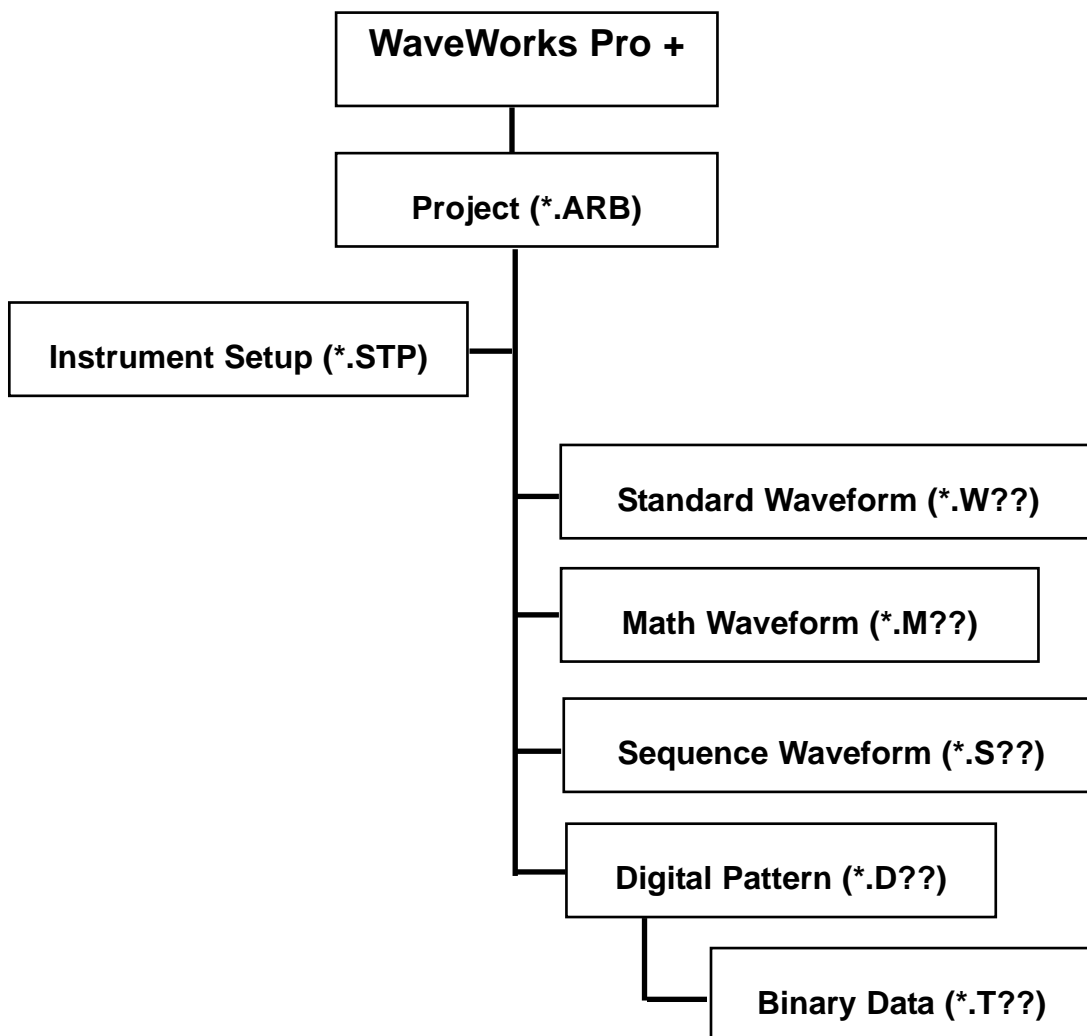
Seq type ==> *.S##

Dp type ==> *.D##

BIN type ==> *.T##

where ## denotes the order of the waveform creation (01~20).

Additional BIN-type file is required for the Dp-type waveform. This is a 32-bit, single-variable data array typical of Visual Basic.



File Structure

Editors

WaveWorks Pro + has the capability of editing the waveform data using several methods. Choose **EDIT** from the Menu Bar of the Main screen. Then, choose one of the four editors.

Point Editor

Choose **EDIT | Point** to activate this editor. It will allow you to edit point-by-point the selected waveform in the spreadsheet-style chart. The waveform length must be less than 32,000 points.

Vertex Editor

Choose **EDIT | Vertex**, or **Func | StdWave** and click **Lines** to bring up the screen. Next, select the specific vertex or segment change to be made and proceed with the editing process. This editor describes either the vertex or segment to be altered. Mouse controlled input and text entry of numerical values are supported in this software. X and Y axis values are displayed in the corresponding text boxes as you move the mouse on the waveform edit screen. The mouse entry of the points is limited by the increment values defined by Grid_X and Grid_Y. The point entry is possible only at the coordinates which are a multiple of Grid_X and Grid_Y.

Digital Pattern Analyzer

Choose **EDIT | Digital Pattern** analyzer to activate this editor. The waveform length must be less than 32,000 points to utilize this editor. After the selected waveform is separated into bits as specified by the waveform vertical resolution, you may graphically edit the waveform bit-by-bit. The values less than ± 1 LSB are deleted. The display of the bit pattern is based on unsigned integers. The screen is organized to show the LSB on the top line while the MSB is shown at the bottom.

Waveform Data Conversion

For 12-bit resolution data

<u>Waveform Data</u>		<u>Dp Editor</u>
1	==>	4095
0	==>	2048
-1	==>	1

For 16-bit resolution data

<u>Waveform Data</u>		<u>Dp Editor</u>
1	==>	65535
0	==>	32768
-1	==>	1

Mouse Operations on the Digital Pattern Analyzer Screen

Bit Selection

Click the left mouse button on the bit waveform or on the bit label to select the bit. The data is copied into the buffer in order to perform the UNDO function.

Bit 0 and 1 Settings by Address

If you click the left mouse button on the bit waveform, the selected portion will be highlighted. If you move the mouse vertically, while pressing the left button, the data value of the address will change. When you release the button, the data will change to the value at the time of the release.

Moving Pulse Edge

If you click the left mouse button at approximately the 50% level of a pulse edge, you can capture the edge. If you move the mouse to the left and right, while pressing the left button, you can move the pulse edge.

Logic 0 and 1 Settings by Pulse Level

You can change the level of a pulse by a single click when the pulse width is longer than two addresses. If you click the left mouse button at approximately the 50% level of a pulse, you can capture the entire pulse. If you move the mouse vertically, while pressing the left button, you can move the entire pulse level.

Horizontal Movement of Pulse Level

If you click the left mouse button at approximately the 50% level of a pulse, you can capture the entire pulse. If you move the mouse to the left and right, while pressing the left button, you can move the pulse level.

Change of X-Axis Span

If you click the mouse left button at the outside of the bit waveform display area and drag the mouse to the right, while pressing the button, and then release the button, the X-axis of the selected area will be expanded. The span will automatically adjust down to the minimum length of 20 points.

Copy between Bits

If you drag and drop a bit label to another label, you can copy the entire bit.

Harmonic Editor

Choose **Edit | Harmonics** on the Main Menu Bar to activate the Harmonic Editor. The discrete frequency components of a selected waveform are extracted by performing the FFT (Fast Fourier Transform) on the waveform. The analysis is carried out until the result represents a value corresponding to less than $\pm 1/2$ LSB. At this point the calculations are truncated. The results are presented in a spreadsheet form. Click the cell to be edited and enter the new value in the text box.

All frequency values are referenced to the fundamental which corresponds to the period of the entire waveform window. The fundamental carries the frequency value of 1 and the transform calculations extend to a maximum frequency value of 1000. All values above 1000 are excluded. Only the specified waveform lengths may be used when performing the harmonic edit function. If the selected length is not useable for the analysis, the program will present an error message.

The following waveform lengths are acceptable for FFT analysis:

100,200,300, 400, 500, 600, 700, 800, 900,1000
128,256, 512, 1024, 2048, 4096, 8192,
2000, 3000,4000, 5000, 6000,8000,10000,
12000, 16000, 20000, 24000, 32000

If you click **OK** on this screen, the frequency components of the waveform are converted to a set of time-domain data using IFFT and the waveform-type is converted to a DP-type. The frequency settings must be intergers larger than 0 and less than one half of the waveform length.

frequency = 0 ==> DC

frequency = 1 ==> one cycle of sinewave comprising the entire

waveform window

Since less than $1/2$ LSB values will be truncated after performing FFT, even if you did not change the data, you may not be able to recover the same waveshape after clicking **OK** due to elimination of harmonics greater than 1000.

You may select one of the five units available for the frequency grid display by clicking the selection button.

<u>Units</u>	<u>Amplitude</u>	<u>Phase</u>
Cos_Sin	± 1	$\pm 360^\circ$
Amp_Phs in cosine	± 1	$\pm 360^\circ$ (phase relative to cosine)
dB_Phs in cosine	0dB for ± 1	$\pm 360^\circ$ (phase relative to cosine)
Amp_Phs in sine	± 1	$\pm 360^\circ$ (phase relative to sine)
dB_Phs in sine	0dB for ± 1	$\pm 360^\circ$ (phase relative to sine)

If you change any data on the grid, you are not permitted to select another display unit.

Sync Pulse

Individual Waveforms

You may define up to four sync pulses in this application. The location of a sync pulse is synchronous to the waveform address as defined. You may not be able to use the sync pulses you define in this application if the AWG you are going to download the waveform into does not have the facility to utilize the sync data. Please review the sync pulse section of the AWG manual. To define and view the sync pulse:

1. Select a waveform window.
2. Choose **Wave | Setup** on the Menu Bar. You will have access to the sync setup frame which is located at the lower section of the screen.
3. Define the **Start** and **Length** for each sync pulse.
4. Click the corresponding check box to set the sync pulse on the waveform window. Click the check box again to turn off the sync pulse on the waveform window.

If the sync pulses are displayed on the waveform window when you are downloading the waveform to an AWG, the sync pulses will be downloaded simultaneously, provided that the AWG is capable of accepting the sync data.

Sequence-type Waveforms

If you are editing a sequence-type waveform in the selected waveform window, you are not allowed to set the **Start** and **Length** values, since sync pulses are defined only within the waveforms used as sequence parameters, or waveforms in the sequence steps.

If you are downloading a sequence-type waveform to an AWG without sequence capability, such as 2201A and 2205A, the waveform is first converted to a single waveform and then downloaded to an AWG as a single waveform without the Sync data. If you need a Sync pulse for a sequence waveform:

1. Choose **Wave | Setup... | Sync | Type | Mine**. This step will allow you to access the sync parameter frame.
2. Set Sync parameters.
3. Click **OK** to view the customized Sync pulse on the waveform window.
4. Download the sequence waveform.

Basic Operations of Mouse in WaveWorks Pro +

Zoom

On the waveform display screens (waveform windows, standard function, math and sequence preview screens), if you drag the mouse, while holding the left button, toward the right lower corner from the left upper corner of the screen and then release the button, the screen will display the zoomed portion of the waveform. If you double-click the left button while placing the mouse pointer on the screen, you may return to the unzoomed full screen display.

X-Axis Scroll

You may scroll on the X-axis by setting the ranges with **Wave | Setup, Options | Small dX**, or **Options | Large dX** menus.

< > left or right scroll with the increment set by Small dX
« » left or right scroll with the increment set by Large dX
|« »| scroll to the first or last address of the waveform

Alternatively, you may change the x-axis span by clicking the X-axis displays on the lower left and right corners of the screen.

Mouse left button will decrement the X-axis span by the Large dX value. If you hold the Shift key while clicking the X-axis display, the X-axis span is decremented by the Small dX value.

Mouse right button will increment the X-axis span by the Large dX value. If you hold the Shift key while clicking the X-axis display, the X-axis span is incremented by the Small dX value.

Y-Axis Scroll

Mouse left button will decrement the Y-axis span by the Large dY value. If you hold the Shift key while clicking the Y-axis display, the Y-axis span is decremented by the Small dY value.

Mouse right button will increment the Y-axis span by the Large dY value. If you hold the Shift key while clicking the Y-axis display, the Y-axis span is incremented by the Small dY value.

You can set the Small dY and Large dY values with **Wave | Setup** menu. You may change the Y-axis span by clicking the Y-axis displays on the upper and lower right corners of the screen.

Panning

If the waveform is zoomed, you may pan the expanded waveform by clicking the right mouse button. The panning range is limited by the zoomed area.

Chapter 4

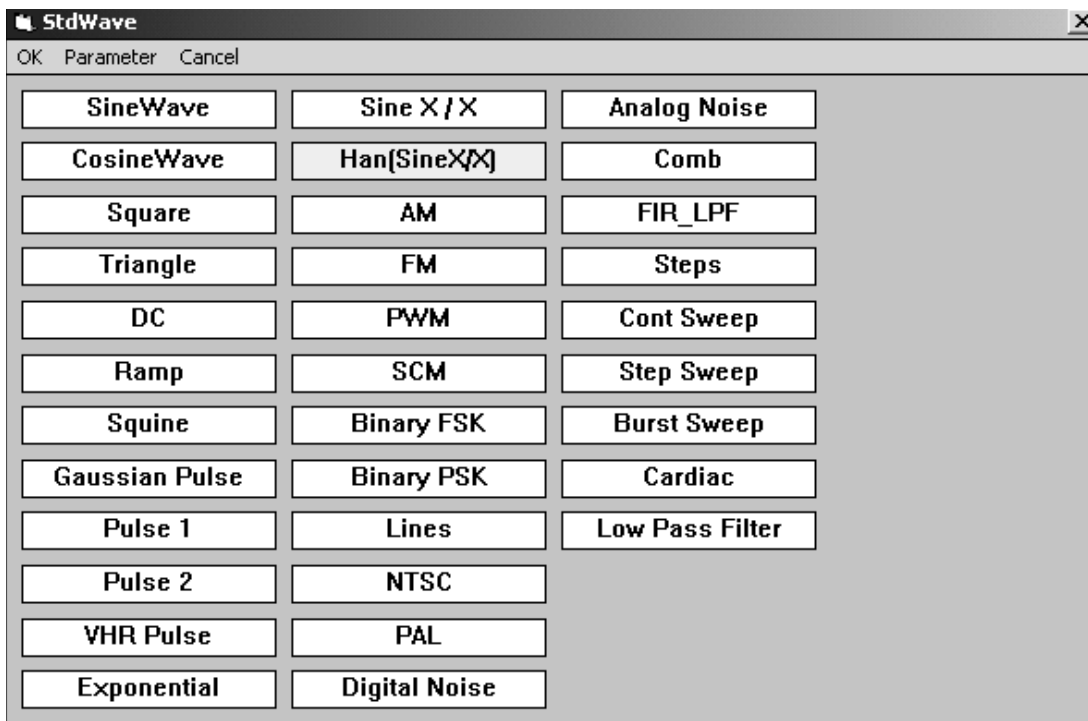
Waveform Creation

Creating Waveforms

The general file system of WaveWorks Pro + consists of two types. The project file contains the instrument setup (.STP) and all the waveforms needed to create the application. You may save any waveform as a single waveform file (.W##, .M##, .S##, .D##, or .T##) or as a project file (.ARB). In general it is easier to keep track of your project using the project file system.

To open a new project, select **File | New Project** from the Menu Bar. To open a waveform window, choose **Wave | New** from the Menu Bar. New Waveform dialog box will appear, allowing you to specify the waveform length and name. Click **OK** after you have specified the parameters. Then the new waveform window will be displayed.

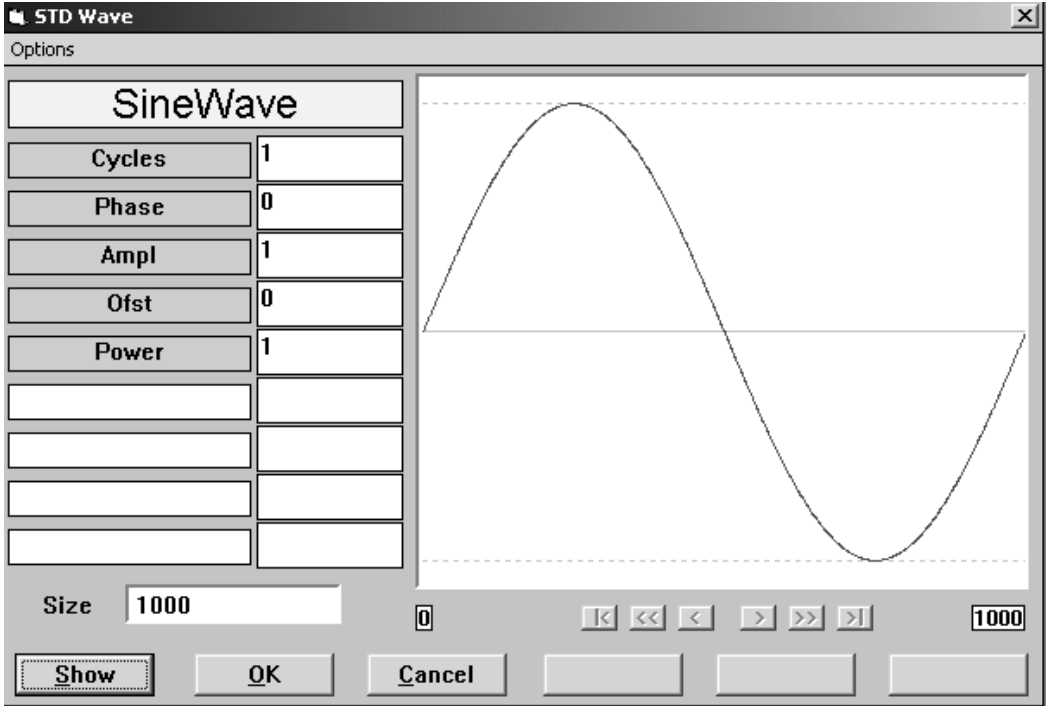
Form-Standard Waveform List



Standard Waveforms

Standard waveshapes can be inserted in the waveform window by choosing **Func | Stdwave...** and selecting commands from the Standard Waveform List. You may set the function parameters and preview the waveshape by clicking **SHOW**. Click **OK** to insert the waveshape into the waveform window.

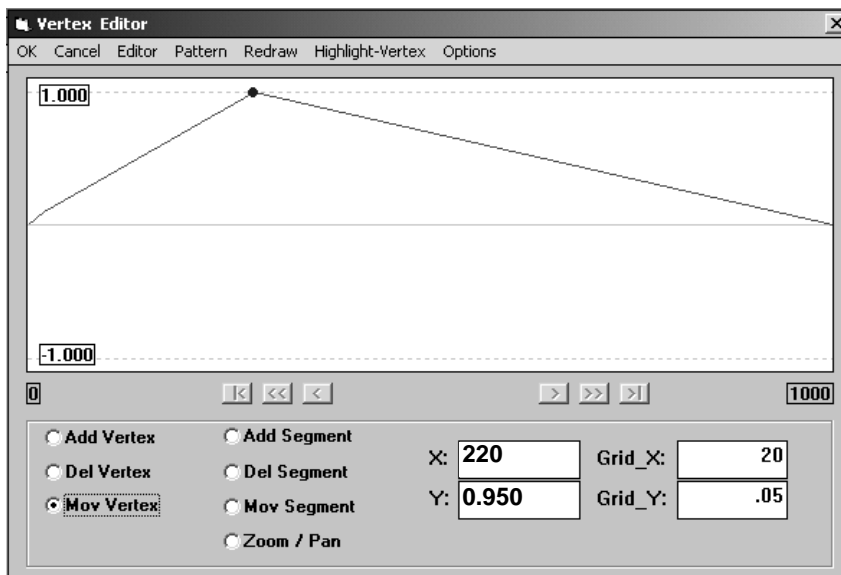
Form Standard Wave - Sinewave



LINE DRAWING

Choose **Func | Stdwave...** and click **Lines** or choose **Edit | Vertex**. Draw the desired line-based waveform by using vertex editing. Modify vertex or line segments on the preview screen. Click **OK** to insert the waveshape into the waveform window.

Form-Line Draw



Performing Waveform Math

The math menu contains 20 transfer functions and 13 operations to be performed on any type of waveform created in WaveWorks Pro +. The target waveform (New Wave) must be placed below the two operands (Wave#1 and Wave#2) in the Wave List. Choose **Wave | List...** to review and correct the waveform order.

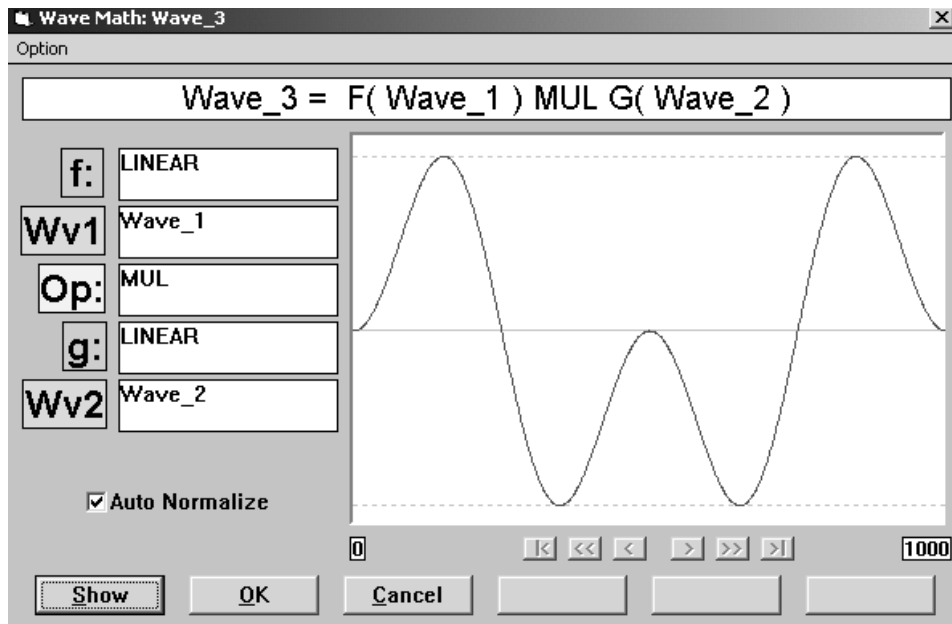
For this example New Project create the following:

- Wave#1: Sinewave, Cycles=1, Phase=0, Ampl=1, Ofst=0, Power=1, Size=1000
- Wave#2: Sinewave, Cycles=2, Phase=0, Ampl=1, Ofst=0, Power=1, Size=1000
- Wave#3: to accept the Math result, size=1000

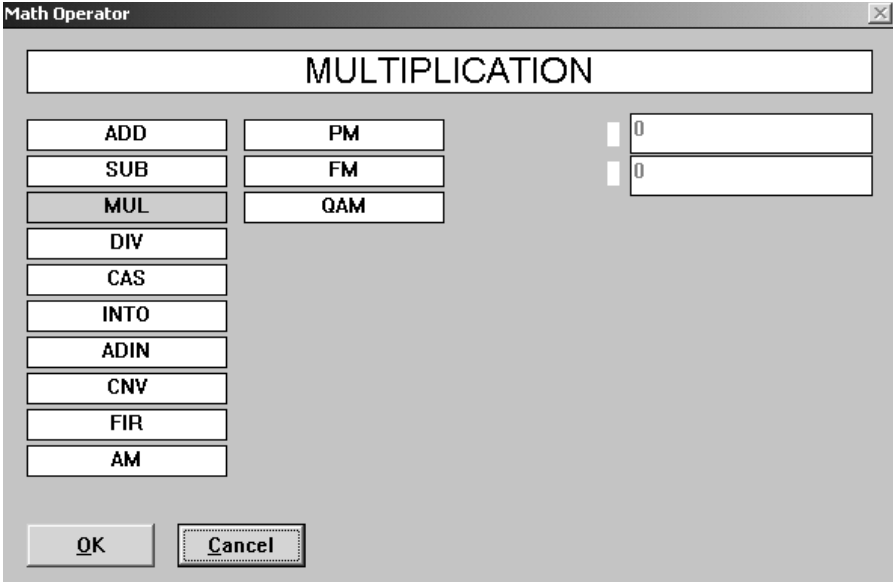
Chapter 4 Waveform Creation
Creating Waveforms

- 1 Choose **Wave | Math...** from the Menu Bar.
2. Select the first operand (Wave#1) by clicking **Wv#1**.
3. Select the first transfer function (F) by clicking **f**.
4. Select the second operand (Wave#2) by clicking **Wv#2**.
5. Select the second transfer function (G) by clicking **g**.
6. Select the operation (Op) by clicking **Op**.
7. Click **SHOW** to preview the computed waveform.
8. Click **Auto Normalize** and then **SHOW** to preview the normalized waveform.
9. Click **OK** to insert the waveshape into the waveform window or **CANCEL** to abort the operation.

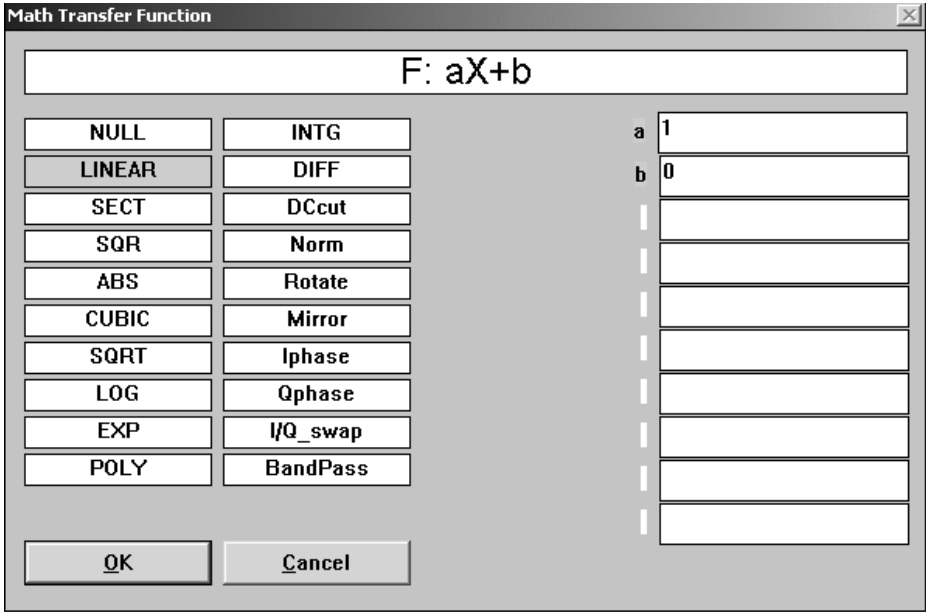
Form Math



Form OP



Forms F (or G)



Waveform Sequence

You may create a long and complex waveform by looping and linking previously created waveforms. For this example New Project create the following:

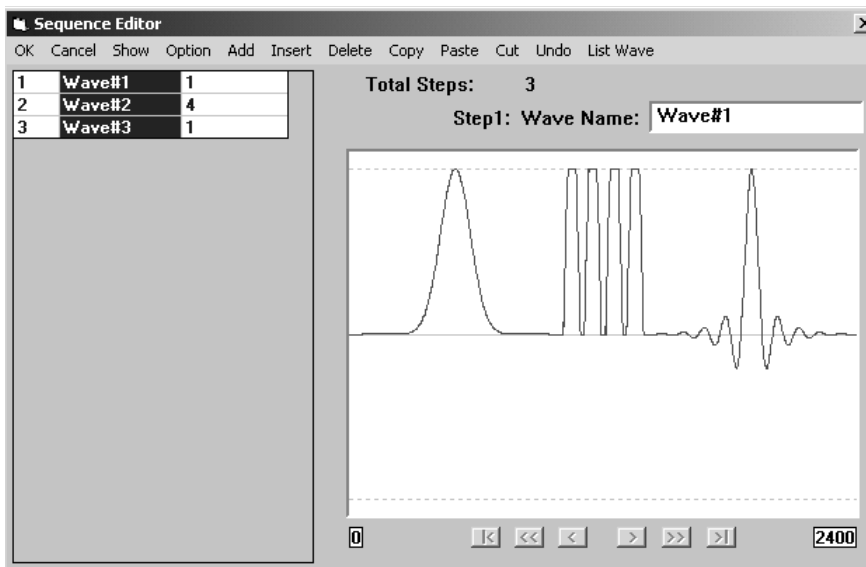
Wave#1: Gaussian Pulse, Time Const = 1, Ampl=1, Ofst=0, Size=1000

Wave#2: Pulse 2, Cycles=1, T Delay(%)=10, T Rise(%)=20, T High(%)=40,
T Fall(%)=20, High=1, Low=0, Trans Shape=0, Size=100

Wave#3: Han(Sin X/X), Width=100, Ampl=1, Ofst=0, Size=1000

Wave#4: to accept the Sequence result, Size=1000 (size will adjust automatically)

1. Select the target waveform window by clicking the Title Bar of the waveform.
2. Choose **Func | Sequence...** from the Menu Bar. (Wave#4)
3. Choose **Wave List** from the Menu Bar to select the first waveform in the sequence (Wave#1). Click the right column of the Wave List and enter the loop count in the text box (1).
4. Choose **ADD** from the Menu Bar to add number of steps in the sequence.
5. Click the center column of step 2 and select the second waveform in the sequence (Wave#2). Click the right column of the Wave List and enter the loop count in the text box (4).
6. Repeat the above steps 4 and 5 until the sequence list is completed (Wave#3, 1).
7. Click **SHOW** to preview the new sequence waveform. (To view the entire sequence waveform, click **Option | Xspan | Max** and note the total waveform.)
8. Click **OK** to complete the operation or **CANCEL** to abort the process.

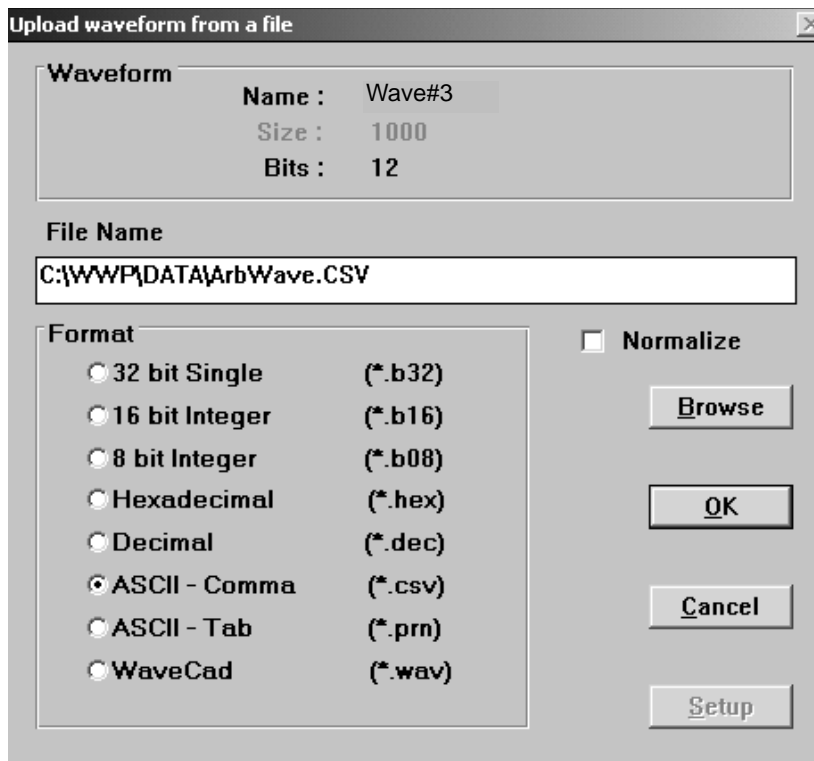


Importing Data Saved from Other Applications

WaveWorks Pro +. will allow you to import waveform data created in the other applications, such as Microsoft Excel™ or HP™ BenchLink/Arb. Although the software is capable of importing of 8 file formats; the most commonly used formats are the comma separated value (.CSV) or the tab or line separated (.PRN) formats. The data values saved must be equal to or less than ± 1 .

To import data saved by other applications in either .PRN or .CSV format:

1. Select the Waveform Window to import the file.
2. Select **File | Import Wave...** from the Menu Bar. The Upload File dialog box will be displayed, prompting you to enter the file name of the file you wish to import. Click **.PRN** or **.CSV** for the file format selection. Skip step 3 if you know the file name, directory, and the extension.
3. Click the **Browse** button on the Upload File screen to display the Open dialog box and select the file you wish to import. Choose the appropriate file extension from the file type list, select the desired file and click the **OK** button, allowing you to return to the Upload File screen.
4. Click the **OK** button to import the data into the selected Waveform Window.

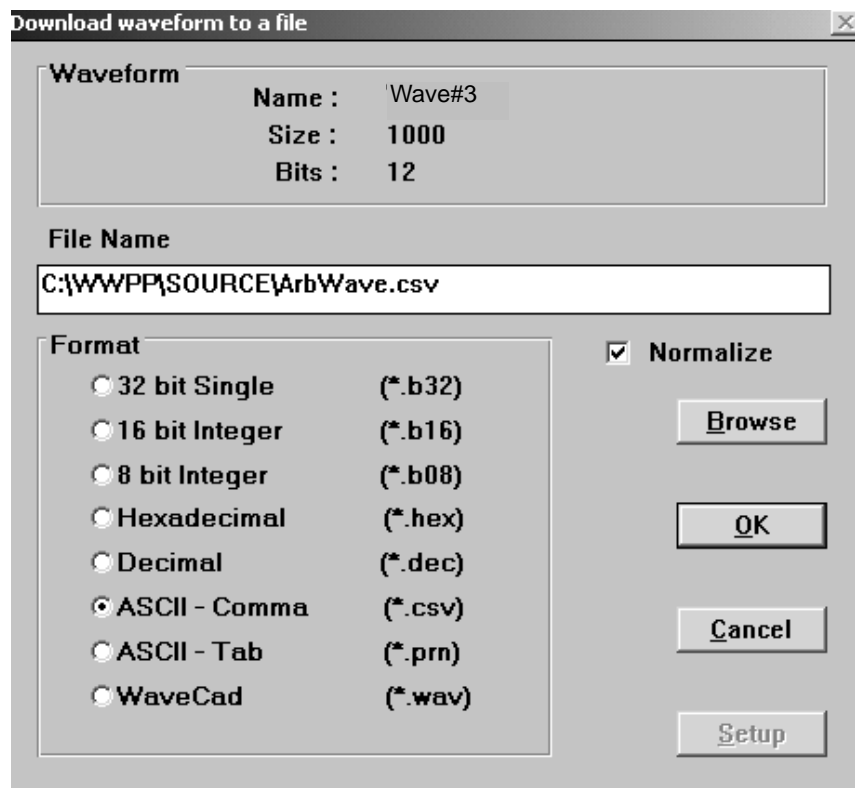


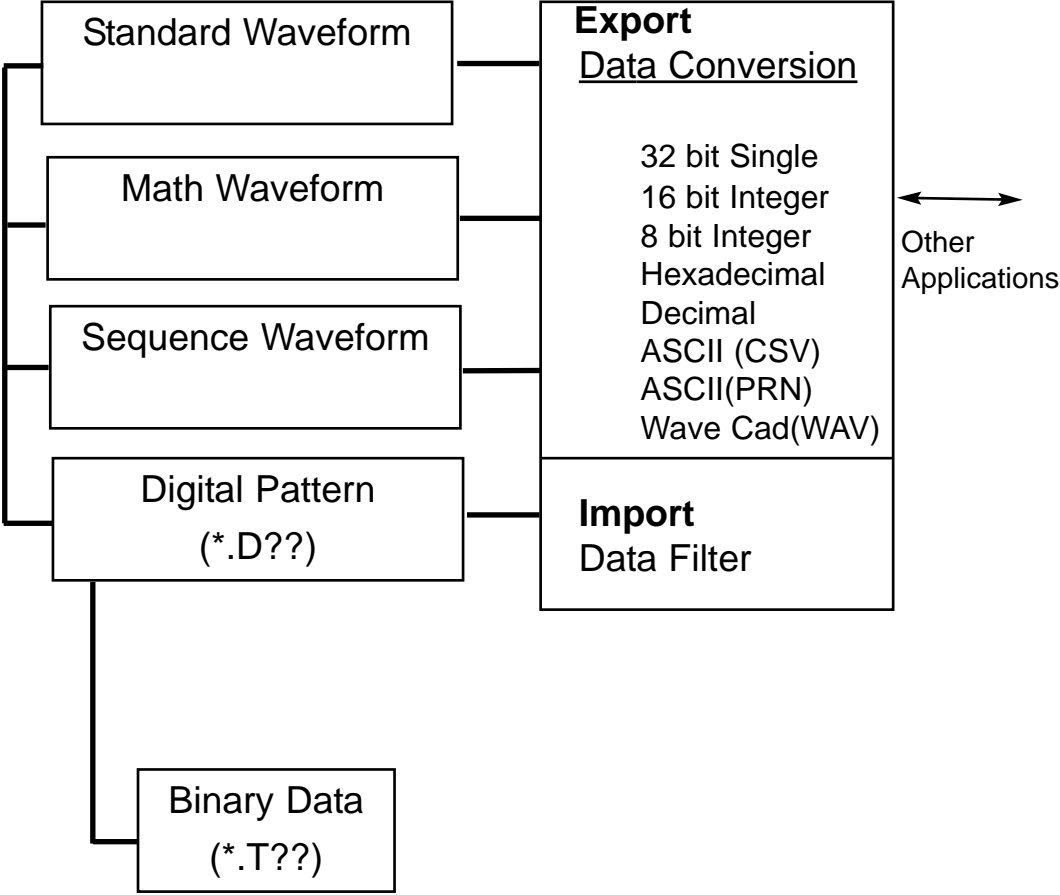
Exporting Data to Other Applications

WaveWorks Pro + will allow you to export waveform data created in this application to other applications. Although the application is capable of exporting in 8 file formats; the most commonly used formats are the comma separated value (.CSV) or the tab or line separated (.PRN) formats.

To export data created by WaveWorks Pro + in either .PRN or .CSV format:

1. Select the Waveform Window to export the data.
2. Choose **File | Export Wave...** from the Menu Bar. The **Download Waveform to File** dialog box will be displayed, prompting you to enter the file name of the waveform data you wish to export. Click **.PRN or .CSV** for the file format selection. Skip step 3, if you know the file name, directory, and the extension.
3. Click the **Browse** button on the **Download Waveform to File** screen to display the **Save As** dialog box and select the file name you wish to export. Choose the appropriate file extension from the file type list, select the desired file and click the **OK** button, allowing you to return to the **Download Waveform to File** dialog box screen.
4. Click the **OK** button to export the data into the selected file.

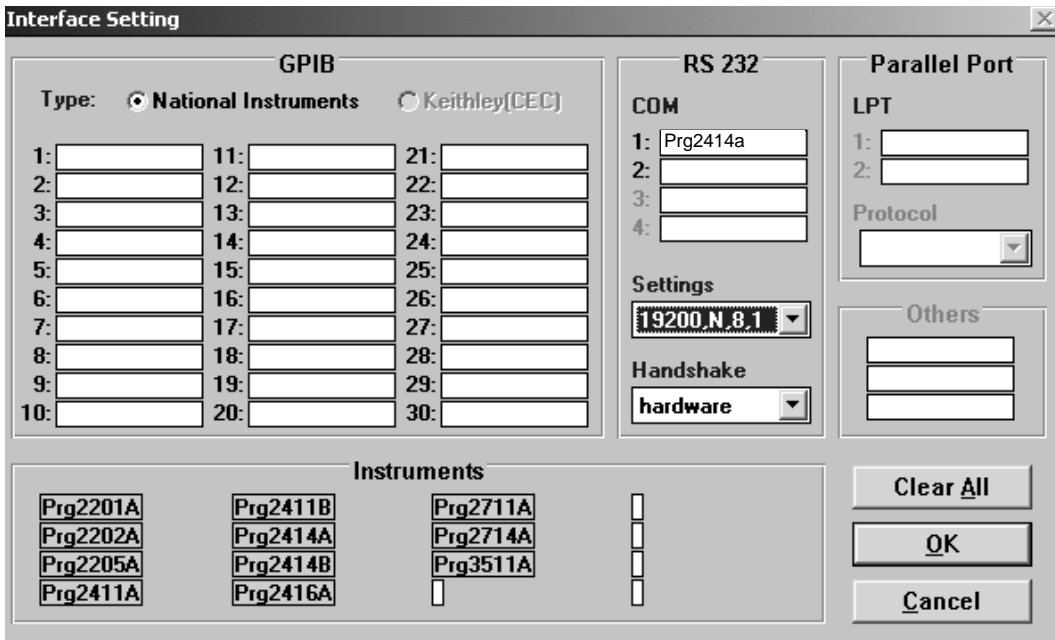




Importing and Exporting Data Files

Configuring the Interface

Before the WaveWorks Pro + application is started, check the GPIB (IEEE-488) address or RS-232 settings of the target AWG. Check the electrical connections between the PC and the AWG. For the serial interface (RS-232), use the cable shown on 1-3. Make sure that the PC end is connected to one of the PC serial ports (COM 1, 2, 3, 4) and the instrument end is connected to the RS-232 connector of the AWG.



For the GPIB Setup

1. Choose **INTERFACE** on the Menu Bar.
2. Drag and drop an AWG label from the selection on the GPIB address.
3. Click the **OK** button to initialize the AWG connection. If the initialization is successful, the message box will indicate the connected instrument. When you acknowledge the connection by clicking the **OK** button, the screen will return to the Main Menu. If an error is detected, the dialog box will indicate the error message. Click the **CANCEL** button to return to the Main Menu without initializing the interface connection.

For the RS-232 Setup

1. Choose **INTERFACE** on the Menu Bar.
 2. Drag and drop an AWG label from the selection on one of the COM ports.
 3. Select the RS-232 setup to match the AWG serial setup.
 4. Click the **OK** button to initialize the AWG connection. If the initialization is successful, the message box will indicate the connected instrument. When you acknowledge the connection by clicking the **OK** button, the screen will return to the Main Menu. If an error is detected, the dialog box will indicate the error message. Click the **CANCEL** button to return to the Main Menu without initializing the interface connection.
-

Transferring Waveforms to the AWG

When you have finished creating and editing your waveform, and you have completed the interface configuration and initialization, you are ready to download the waveform data to the AWG. The waveform names in the WaveWorks Pro + application can not be downloaded to the AWGs.

For all TEGAM AWGs, except 2201A and 2205A, specify waveform and sequence numbers.

For Std, Math, Dp type waveform

WAV#N N = 0~99

For SEQ type waveform

SEQ#N N = 0~9

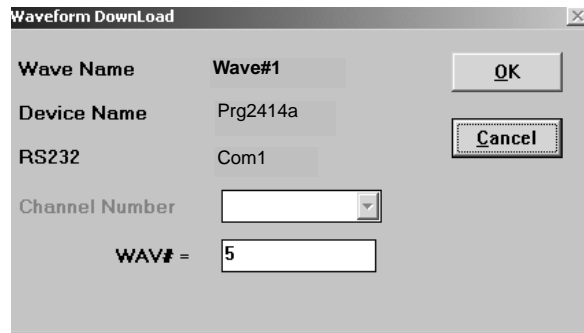
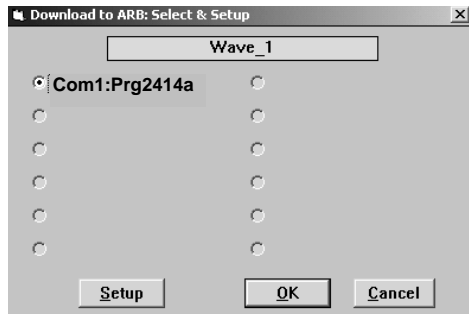
You may select the N before downloading. It is recommended that you use the same waveform number (N) for WaveWorks Pro + and the target AWG.

For the 2201A and 2205A AWGs, specify the channel number and the memory location by the start and stop addresses. The sequence data created in WaveWorks Pro + will be downloaded to the AWG as data points.

To download the contents of the waveform window:

1. Choose **Download | Setup** to open the 'Download to ARB' screen. Click one of the interface selections. If you want to set up the AWG parameters, click the **SETUP** button to configure the AWG. Click **OK** to return to the Main Menu.
2. Choose **Download | GO** to open the 'DownLoad Waveform' screen. Select the target waveform number in the AWG.
3. Click **OK** to initiate the data transfer.

Form Download

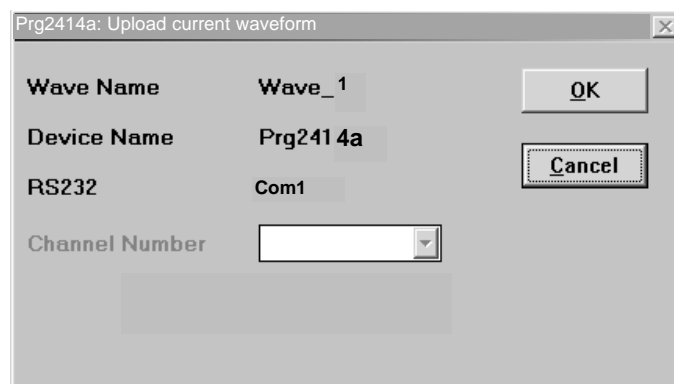
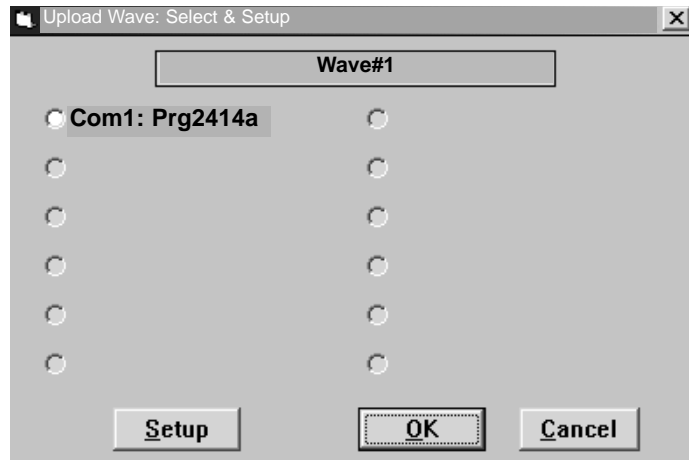


Waveform Upload

You may upload the waveform data from all TEGAM AWGs except 2201A and 2205A after the interface is initialized. The waveform (WAV#0~99 and SEQ#0~99), selected at the time of the initialization, will be uploaded.

For the TEGAM 2201A and 2205A AWGs, you may upload the waveform after selecting the channel number and specifying the memory location with 'Scan From' and 'Scan To'.

Form Upload



Printing Waveforms

Waveforms can be printed when a waveform window is selected in WaveWorks Pro +. The waveform does not have to be a saved file to be printed.

1. If more than one waveform window is open, make sure that the window you want to print is the active window by clicking on it with your mouse.
2. Select **File | Print...** from the Menu Bar.
3. The Print dialog box is displayed. You may change printer setup by clicking the **SETUP...** button. Click the **OK** button to start the print process or choose **CANCEL** to abort the printing.

Saving Projects and Waveforms

Arbitrary waveforms can be saved from WaveWorks Pro + as an individual waveform (STD, MATH, SEQ or DP type) or as the components of a project file (.ARB). If you save a project, the dialog box will prompt you to save all the waveforms used in the project. All the unsaved waveforms are marked with asterisks on the title bar of each waveform window. All the waveform data is stored in a binary format or equations. To store the data in any other format, such as .CSV or .PRN format, review the section for importing and exporting waveform data.

To save a project:

1. Select **File | Save Project As...** from the Menu Bar. The 'Save As' dialog box will appear.
2. Enter the desired file name and click the **OK** button to save the file to disk. If the waveforms, which are the components of the project, are not saved, the 'Save As' dialog box for each unsaved waveform will prompt you to save in a proper format. Click the **OK** button to save each waveform.

To save a waveform:

1. Select **File | Save Wave As...** from the Menu Bar. The 'Save As' dialog box will appear.
2. Enter the desired file name, assign a number for the extension and click the **OK** button to save the file to disk.

Chapter 5

Sample Waveforms

Sample Files

This chapter describes sample waveforms you can create in TEGAM WaveWorks Pro +.

Sample Files

The following sample project files were placed in the **WWP\SAMPLES** directory during installation. Most of these waveforms in the project files were created in WaveWorks Pro +.

Project Files

Use **File | Open...** to open one of these files. Once a file is opened, the waveforms can be edited, analyzed, and saved.

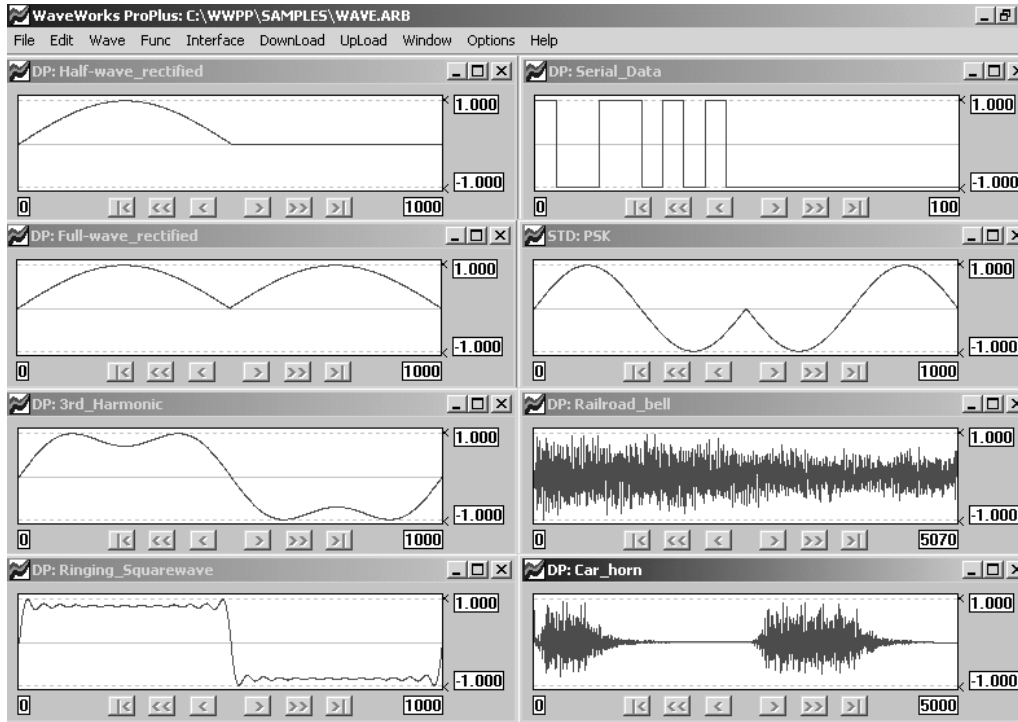
Project File Name	Description
WAV.ARB	8 sample waveforms
MATH.ARB	MATH example - 10% noise added to sinewave
SEQ.ARB	Sequence example - 3 step sequence of 3 waveforms

Waveform Examples (WAVE.ARB)

Waveform Name	Size	Sample Clock	Description
Half-wave_rectified	1000	60 kHz	60Hz half-wave rectified waveform
Full-wave_rectified	1000	60 kHz	60Hz full-wave rectified waveform
3rd_harmonic	1000	...	Sinewave with 3rd harmonic distortion
Ringing_squarewave	1000	...	Squarewave with odd harmonics to 25th
Serial_data	100	...	11-bit frame of serial data
PSK	1000	...	Phase Shift Key modulated signal
Railroad_bell	5070	~18 kHz	Sound of railroad_bell captured by DSO
Car_horn	5000	~10 kHz	Sound of car horn captured by DSO

Chapter 5 Sample Waveforms
Waveform Examples (WAV.ARB)

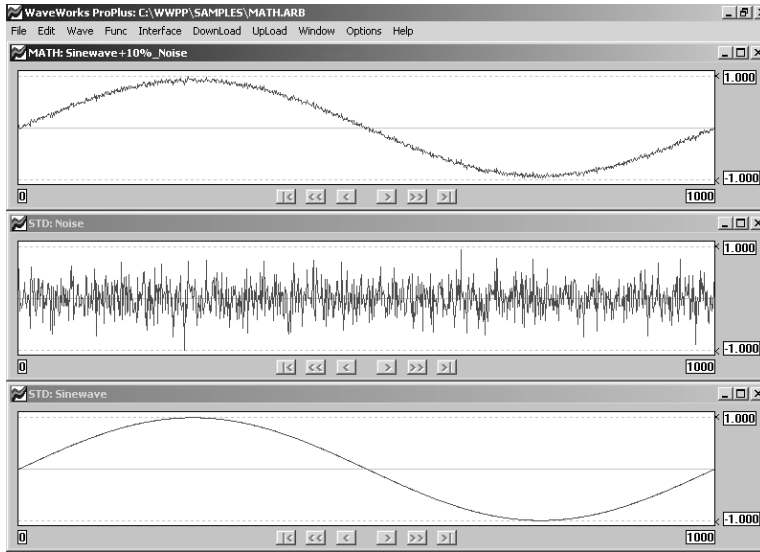
Waveform Windows



Wave List

frmWaveList							
OK Cancel MoveUp MoveDown							
	NAME	SIZE	TYPE	FileName	SAVED	DEVICE	Downloaded
1	Half-wave_rectified	1000	DP	WAVE.D01	Yes	Not Found	No
2	Full-wave_rectified	1000	DP	WAVE.D02	Yes		No
3	3rd_Harmonic	1000	DP	WAVE.D03	Yes		No
4	Ringing_Squarewave	1000	DP	WAVE.D04	Yes		No
5	Serial_Data	100	DP	WAVE.D05	Yes		No
6	PSK	1000	STD	WAVE.W06	Yes		No
7	Railroad_bell	5070	DP	WAVE.D07	Yes		No
8	Car_horn	5000	DP	WAVE.D08	Yes		No

MATH Waveform Example (MATH.ARB)



Wave List

NAME	SIZE	TYPE	FileName	SAVED	DEVICE	Downloaded
1 STD:	1000	STD		No		No
2 STD: Noise	1000	STD		No		No
3 Math:	1000	MATH		No		No

Wave MATH screen

Wave Math: Sinewave+10%_Noise

Option

Math: Sinewave = F(STD: Sinewave) ADD G(STD: Noise)

f: LINEAR

Wv1 STD: Sinewave

Op: ADD

g: LINEAR

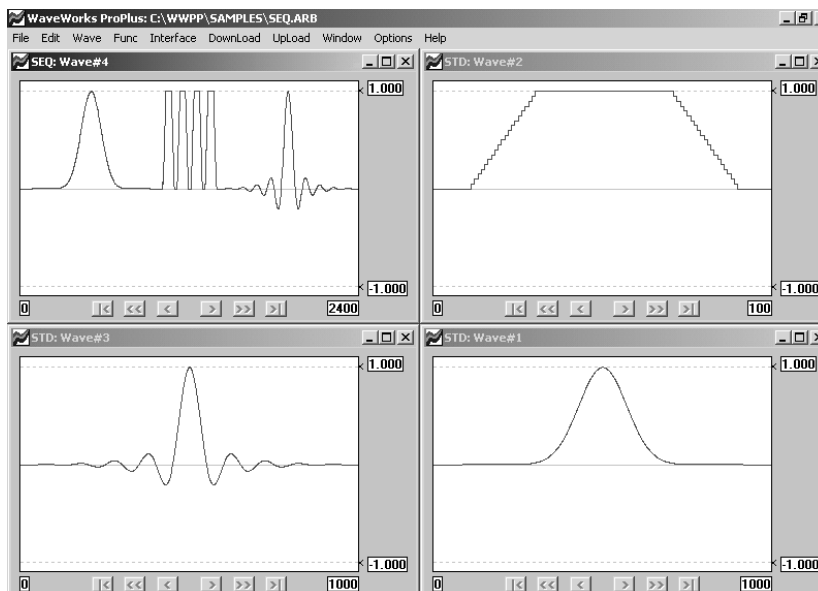
Wv2 STD: Noise

Auto Normalize

0 << < > >> 1000

Show OK Cancel

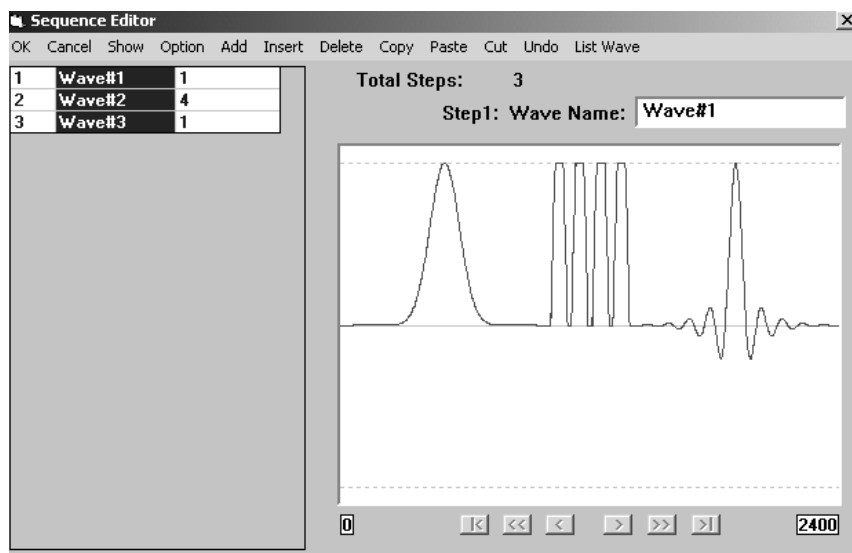
SEQUENCE Waveform Example (SEQ.ARB)



Wave List

frmWaveList								
OK Cancel MoveUp MoveDown								
	NAME	SIZE	TYPE	FileName	SAVED	DEVICE	Downloaded	
1	Wave_1	1000	STD	MATH.W01	Yes		No	
2	Wave_2	1000	STD	MATH.W02	Yes		No	
3	Wave_3	1000	MATH	MATH.M03	Yes		No	

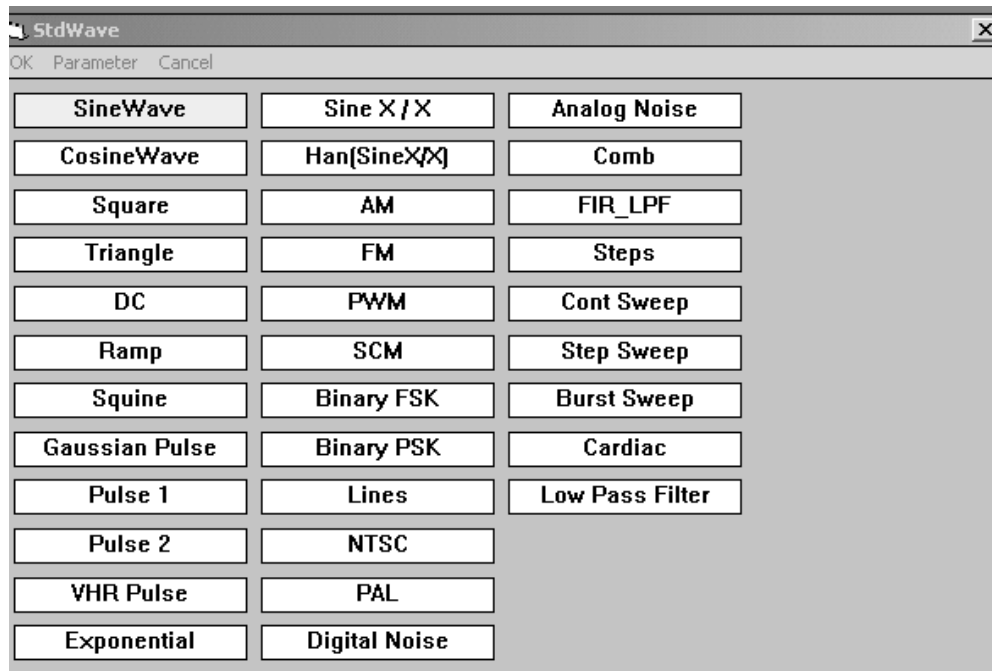
Sequence Editor



Chapter 6

Standard Functions

Waveform List



Sine wave

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.1
Phrase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001
Power	1	0	20	1

2. Computation

Cycles: number of cycles of sinewave
Phase: initial phase of sinewave
Ampl: amplitude
Ofst: offset
Power: exponent

The waveform is computed by the following formula.

```
N = waveform length
 $\omega = 2 * \pi * \text{Cycles} / N$ 
 $\Phi = \text{Phase} / 180 * \pi$ 
FOR i = 0 to N-1
    Wave(i) = Ampl * ( SIN ( $\omega * i + \Phi$  )) ^ Power + Ofst
NEXT i
```


Cosinewave

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.01
Phase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001
Power	1	0	20	1

2. Computation

Cycles: number of cycles of cosinewave
Phase: initial phase of cosinewave
Ampl: amplitude
Ofst: offset
Power: exponent

The waveform is computed by the following formula.

$N = \text{waveform length}$
 $\omega = 2 * \pi * \text{Cycles} / N$
 $\Phi = \text{Phase} / 180 * \pi$

```
FOR i = 0 to N-1  
    Wave(i) = Ampl * ( COS (  $\omega * i + \Phi$  ) ) ^ Power + Ofst  
NEXT i
```

Square wave

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.1
Phase	0	-360	360	0.001
High	1	-1	1	0.001
Low	-1	-1	1	0.001
Rise Time (%Step)	0	0	60	0.001

2. Computation

Cycles: number of cycles of square wave
Phase: initial phase of square wave (same as the zero-crossing of sinewave)
High: output level of phase 0° to 180°
Low: output level of phase 180° to 360°
Rise Time: time to transition from 10% to 90% of waveform level

The relationship of the waveform phase and amplitude is defined as follows.

$$\begin{aligned} 0^\circ \leq \text{Phase} < 180^\circ & \quad \text{Amplitude} = 1 \\ 180^\circ \leq \text{Phase} < 360^\circ & \quad \text{Amplitude} = -1 \end{aligned}$$

Cosine wave (-90° to 90°) is used for the shaping of Rise Time contour. Therefore, square wave becomes sinewave at Rise Time % = 60.

Triangle wave

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.1
Phase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001
Power	1	0	20	1
Symmetry	50	0	100	0.001

2. Computation

Cycles: number of cycles of triangle wave
Phase: initial phase of triangle wave
Ampl: amplitude
Ofst: offset
Power: exponent
Symmetry: symmetry of triangle wave

At the Symmetry = 50, the relationship of the waveform phase and amplitude is defined as follows.

0° : Amplitude = 0
90°: Amplitude = 1
180°: Amplitude = 0
270°: Amplitude = -1
360°: Amplitude = 0

Between the specified phases, the waveform is a linear ramp.

At Symmetry = 0, the waveform is Ramp Down.

At Symmetry = 100, the waveform is Ramp Up.

DC

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Ofst	0	-1	1	0.001

2. Computation

All the points in the waveform is set to the value of Ofst.
The default values of all the standard functions are DC.

Ramp

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.1
Phase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

Cycles: number of cycles of ramp wave
Phase: initial phase of ramp wave
Ampl: output amplitude of ramp wave
Ofst: output offset of ramp wave

The relationship between the ramp phase and amplitude is defined as follows.

0°: Amplitude = -1
180°: Amplitude = 0
360°: Amplitude = 1

Between the specified phases, the waveform is a linear ramp.

The waveform is computed by the following formula.

N = waveform length
 $\omega = 2 * \pi * \text{Cycles} / N$
 $\Phi = \text{Phase} / 180 * \pi$

FOR $i = 0$ to $N-1$
 Wave(i) = $\text{Ampl} * m \text{RAMP}(\omega * i + \Phi) + \text{Ofst}$
NEXT i

where, for $0 \leq \theta < 2 \pi$, $m\text{RAMP}(\theta) = \theta / \pi - 1$

Squine

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Transition %	10	0	50	0.001
Phase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofstl	0	-1	1	0.001

2. Computation

Transition%: ratio in % of number of points used to define the rise and fall edge of the waveform by utilizing a half-sinewave to the total length. The 10% to 90% portion of the waveform which defines the rise and fall times is approximately 59% of this parameter.

$$(\text{ArcSin}(0.8) / \pi / 2 * 100)$$

Phase: initial phase of squine wave

Ampl: output amplitude of squine wave

Ofst: output offset of squine wave

The waveform utilizes a portion of a sinewave to smooth the rise and fall edge of a square wave. At Transition% = 50, the waveform is a sinewave. The waveform name, squine, was derived from the fact that the waveform was synthesized by connecting a sinewave and a square wave. For the explanation of Phase, Ampl and Ofst, review the section on square wave. The rising edge utilizes a half-sinewave from -90° to 90°. The falling edge utilizes a half-sinewave from 90° to 270°.

Gaussian Pulse

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Time Const	100	1	100000	1
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

Gaussian pulse is created in the center of the waveform screen. In order to maintain the fidelity of the waveform, try to keep the Time Constant value to be less than 1/5 of the waveform length. The pulse becomes narrower as the Time Constant value is set to a smaller value.

The waveform is computed by the following formula.

N = waveform length

FOR i = 0 to N-1

Wave(i) = Ampl*EXP(-(i-N/2)^2/TimeConst^2) + Ofst

NEXT i

Pulse 1

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.1
Phase	0	-360	360	0.001
High	1	-1	1	0.001
Low	0	-1	1	0.001
Duty %	50	0	100	0.001

2. Computation

With the exception of Duty % parameter, all other parameters are similar to those of square wave. At Duty % = 50, the waveform is a square wave. Review the section on square wave.

Pulse 2

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cycles	1	0	1000	0.1
T_Delay %	0.1	0	1	0.001
T_Rise %	0.2	0	1	0.001
T_High %	0.4	0	1	0.001
T_Fall %	0.2	0	1	0.001
High	1	-1	1	0.001
Low	0	-1	1	0.001
Trans_shape	0	0	1	1

2. Computation

Cycles: number of cycles in a waveform

The following four parameters are based on one cycle = 100%.

T_Delay %: time in % from the start of waveform to the rising edge of the pulse. The pulse level is at Low up to the start of the rising edge.

T_Rise %: time in % from the start of the pulse to High level.

T_High %: time in % from the start of High level to the start of the Fall edge.

T_Fall %: time in % from the start of the pulse falling edge to the Low level.

High: high level of pulse

Low: T_Delay and Low level of pulse

Trans_shape: shape of rise and fall transitions

0: Linear

1: Sinusoid

VHR Pulse

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
To	5	0	10000	1
T1	10	0	10000	1
AMPL	1	-1	1	0.001
OFST	0	-1	1	0.001
SyncBit	1	1	4	1

2. Computation

This waveform is used for the measurement of the voltage retention rate of liquid crystal displays (LCD). The waveform defines the pulse in the specified SyncBit. Two pulses are specified in SyncBit. Since two pulses are specified in each waveform, use of some waveform generators may be limited.

There are three levels in this waveform.

PULSE_HIGH: Output level = AMPL + OFST
ZERO: Output level = OFST
PULSE_LOW: Output level = AMPL - OFST

T0 and T1 are specified by the number of points in the waveform. Pulse widths of PULSE_HIGH and PULSE_LOW are defined as $2 * T0 + T1$ and the pulse width of the specified SyncBit is defined as T1. The location of the sync pulse is in the mid point of PULSE_HIGH and PULSE_LOW. PULSE_HIGH starts at the beginning of the waveform and PULSE_LOW starts at the mid point of the waveform.

Exponential

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Time Const	100	1	10000	1
V First	1	-1	1	0.001
V Last	0	-1	1	0.001

2. Computation

TimeConst: time constant of waveform expressed in number of points
VFirst: the initial value of the waveform
VLast: the final value of the waveform.

If the waveform length is sufficiently long compared to the value of TimeConst, the waveform value will infinitely approach the VLast value.

The waveform is computed by the following formula.

N = waveform length

FOR i = 0 to N-1

Wave(i) = (VFirst - VLast) * Exp (-i/TimeConst) + VLast

NEXT i

Sine X / X (Sinc)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Width	100	1	10000	1
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

The Sin X / X waveform is created from the mid point of the waveform. This waveform is also called as SINC pulse.

Width: Specifies the number of points for the zero-crossing pulse centered around the mid-point of the waveform. The value is equivalent to 2π .

Ampl: amplitude

Ofst: offset

The waveform is computed by the following formula.

N = waveform length

FOR i = 0 to N-1

$\Phi_c = 2 * \pi * (i - N/2) / \text{Width}$

Wave(i) = Ampl * SIN(Φ) / Φ + Ofst

NEXT i

HAN (Sine X / X)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Width	100	1	10000	1
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

The Sin X / X waveform with Hanning window is created from the mid point of the waveform. The waveform settings are identical to Sin X / X.

Width: Specifies the number of points for the zero-crossing pulse centered around the mid-point of the waveform. The value is equivalent to 2π .

Ampl: amplitude

Ofst: offset

The waveform is computed by the following formula.

N = waveform length

FOR i = 0 to N-1

HAN = $1/2 - \text{COS}(2 * \pi / N * i) / 2$

$\Phi = 2 * \pi * (i - N/2) / \text{Width}$

Wave(i) = $\text{Ampl} * \text{SIN}(\Phi) / \Phi * \text{HAN} + \text{Ofst}$

NEXT i

AM (Amplitude Modulation)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Mod Freq	1	0	10	1
Mod Phase	0	-360	360	0.001
Crr Freq	20	0	1000	1
Crr Phase	0	-360	360	0.001
Index	100	0	200	0.1
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

ModFreq: frequency of modulating sinewave
 ModPhase: initial phase of modulating sinewave
 CrrFreq: frequency of carrier sinewave
 CrrPhase: initial phase of carrier sinewave
 Index: modulation index
 Ampl: amplitude of carrier sinewave
 Ofst: DC offset of carrier sinewave

The waveform is computed by the following formula.

$N = \text{waveform length}$

$\omega_m = 2 * \pi * \text{ModFreq} / N$

$\Phi_m = \text{ModPhase} / 180 * \pi$

$\omega_c = 2 * \pi * \text{CrrFreq} / N$

$\Phi_c = \text{CrrPhase} / 180 * \pi$

FOR $i = 0$ to $N-1$

 MOD = SIN ($\omega_m * i + \Phi_m$)

 CARRIER = SIN ($\omega_c * i + \Phi_c$)

 Wave(i) = Ampl * (1 + Index / 100 * MOD) / 2 * CARRIER + Ofst

NEXT i

FM (Frequency Modulation)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Mod Freq	1	0	10	1
Mod Phase	0	-360	360	0.001
Crr Freq	20	0	1000	1
Crr Phase	0	-360	360	0.001
Index	5	0	200	0.1
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

ModFreq: frequency of modulating sinewave
 ModPhase: initial phase of modulating sinewave
 CrrFreq: frequency of carrier sinewave
 CrrPhase: initial phase of carrier sinewave
 Index: modulation index ($= \Delta \phi / \text{ModFreq}$)
 Ampl: amplitude of carrier sinewave
 Ofst: DC offset of carrier sinewave

The waveform is computed by the following formula.

```

N = waveform length
 $\omega_m = 2 * \pi * \text{ModFreq} / N$ 
 $\Phi_m = \text{ModPhase} / 180 * \pi$ 
 $\omega_c = 2 * \pi * \text{CrrFreq} / N$ 
 $\Phi_c = \text{CrrPhase} / 180 * \pi$ 

FOR i = 0 to N-1
  MOD = COS (  $\omega_m * i + \Phi_m$  )
  Wave(i) = Ampl * SIN (  $\omega_c * i + \Phi_c - \text{Index} * \text{MOD}$  ) + Ofst
NEXT i
  
```

PWM (Pulse Width Modulation)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Mod Freq	1	0	10	1
Mod Phase	0	-360	360	0.001
Crr Freq	20	0	1000	1
Crr Phase	0	-360	360	0.001
Index	50	0	100	0.1
High	1	-1	1	0.001
Low	-1	-1	1	0.001

2. Computation

ModFreq: frequency of modulating sinewave
ModPhase: initial phase of modulating sinewave
CrrFreq: frequency of carrier square wave
CrrPhase: initial phase of carrier square wave
Index: pulse width modulation index
High: high level of square wave
Low: low level of square wave

SCM (Supressed Carrier Modulation)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Mod Freq	1	0	10	1
Mod Phase	0	-360	360	0.001
Crr Freq	20	0	1000	1
Crr Phase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

Suppressed carrier modulated (SCM) sinewave. The waveform is the same as AM without carrier.

ModFreq: frequency of modulating sinewave
 ModPhase: initial phase of modulating sinewave
 CrrFreq: frequency of carrier sinewave
 CrrPhase: initial phase of carrier sinewave
 Ampl: amplitude of carrier sinewave
 Ofst: DC offset of carrier sinewave

The waveform is computed by the following formula.

```

N = waveform length
 $\omega_m = 2 * \pi * \text{ModFreq} / N$ 
 $\Phi_m = \text{ModPhase} / 180 * \pi$ 
 $\omega_c = 2 * \pi * \text{CrrFreq} / N$ 
 $\Phi_c = \text{CrrPhase} / 180 * \pi$ 

FOR i = 0 to N-1
  MOD = SIN (  $\omega_m * i + \Phi_m$  )
  CARRIER = SIN (  $\omega_c * i + \Phi_c$  )
  Wave( i ) = Ampl * MOD * CARRIER + Ofst
NEXT i
  
```

BFSK (Binary Frequency Shift Keying)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Mod Cycles	1	0	10	1
Mod Phase	0	-360	360	0.001
Freq_High	20	0	1000	1
Freq_Low	10	0	1000	1
Rise Time % (Stp)	0	0	60	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

This is a frequency-modulated sinewave by a pulse waveform as the modulating source.

ModCycles: number of cycles of modulating pulse wave
ModPhase: initial phase of modulating pulse wave
Freq_High: frequency of sinewave which represents logic "1"
Freq_Low: frequency of sinewave which represents logic "0"
RiseTime%(Stp): rise/fall time of modulating pulse between logic "0" and "1"
Ampl: amplitude of modulated sinewave
Ofst: DC offset of modulated sinewave

BPSK (Binary Phase Shift Keying)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Mod Cycles	1	0	10	1
Mod Phase	0	-360	360	0.001
Crr Freq	20	0	1000	1
Crr Phase	10	0	1000	1
Rise Time %(Stp)	0	0	60	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

This is a phase-modulated sinewave by a pulse waveform as the modulating source.

Logic"1" = phase 0° Logic"0" = 180°

ModCycles:	number of cycles of modulating pulse wave
ModPhase:	initial phase of modulating pulse wave
CrrFreq:	frequency of modulated sinewave carrier
CrrPhase:	initial phase of modulated sinewave carrier
RiseTime%(Stp):	rise/fall time of modulating pulse between logic "0" and "1".
Ampl:	amplitude of modulated sinewave carrier
Ofst:	DC offset of modulated sinewave carrier

Lines

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
Lines	1	1	100	1

2. Computation

This standard waveform can be edited by using Vertex Editor. For the details, please refer to the Vertex Editor section.

NTSC

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Cir Bst_Phs	0	-360	360	1
Cir Bst_Cyc	10	8	15	1
White_Level	0.55	0	1	0.001
Black_Level	0	-1	1	0.001
Blank_Level	0	-1	1	0.001
Sync_Level	-0.286	-1	0	0.001
Pattern	1	0	10	1
Amp_Correct	1	0.9	1.5	0.001

2. Computation

The waveform, NTSC_CLRS is 1H (one horizontal line) of a color bar pattern for an NTSC color monitor. For the detail description, please refer to the NTSC specification.

ClrBst_Phs: color burst phase
 ClrBst_Cyc: number of cycles of sine waves in a color burst signal
 White_Level: white level
 Black_Level: black level
 Blank_Leve: blank level
 Sync_Level: sync pulse level
 Pattern: color bar pattern number
 Amp_Correct: amplitude correction of Chrominance

To select a color pattern, click [Color Bars] and then use Color Bar Editor.

The following restrictions apply if you are intending to drive an NTSC color monitor.

- 1) Waveform Length = 910 points or integer multiple of 910 points
- 2) Sample Clock of AWG = 14.31818 MHz or integer multiple of 14.31818 MHz

Assuming the above conditions are met, the following parameters can not be changed.

- (1) Front Porch = 1.5 μ sec

PAL

- (2) Back Porch = 4.7 μ sec
 - (3) Width of Horizontal Synch Signal = 4.7 μ sec
 - (4) Width of Horizontal Blanking Signal = 10.9 μ sec
 - (5) Rise / Fall Time of Synch Signal = 140 n sec
 - (6) Rise / Fall Time of Color Signal = 250 n sec
 - (7) Delay from the falling edge of Horizontal Synch Signal to the start of Color Burst Signal = 19 cycles
 - (8) Rise / Fall Time of Color Burst Signal = 250 n sec
- Automatic amplitude correction is provided based on the number of points in one color burst cycle.
-

PAL

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Clr Bst_Phs	0	-360	360	1
Cir Bst_Cyc	10	8	15	1
White_Level	0.55	0	1	0.001
Black_Level	0	-1	1	0.001
Blank_Level	0	-1	1	0.001
Sync_Level	-0.286	-1	0	0.001
Pattern	1	0	10	1
Amp_Correct	1	0.9	1.5	0.001

2. Computation

PAL signal is very similar to the NTSC signal.

For the color bar signal, use color bar pattern number (Pattern) = 5 for PAL_I and color bar pattern (Pattern) = 6 for PAL_BG.

Since the timing is different from NTSC signal and 1H = 64 μ sec, use 1024 points for 16 MHz sample clock. Since one horizontal line (1H) contains 1135 / 4 cycle of color carrier frequency, do not use waveform length less than 1024 points. By using 0, 90, 180 or 270 for "By_Phase", phase between carrier and video signal will be adjusted automatically.

Digital Noise

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
High	1	-1	1	0.001
Low	-1	-1	1	0.001
Step Width	1	1	32000	1

2. Computation

Random patterns of High or Low values are repeated in every interval of Step Width. Since you do not specify the seed values, the pattern will not likely repeat again.

Analog Noise

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
Band Width	1	1	10000	1

2. Computation

The function synthesizes white noise up to the specified BandWidth.

Comb

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Freq_Start	1	1	10000	1
Freq_Spacing	1	1	10000	1
Combs	1	1	10000	1
Phase_Pattern	1	1	10000	1

2. Computation

- Freq_Start: minimum frequency of Comb
- Freq_Spacing: frequency spacing of Comb
- Combs: number of Combs
- Phase_Pattern:
 - 0: random phase between 0° and 360°
 - 1: repetition of 0° and 180°
 - 2: repetition of 90° and 270°

FIR - Low Pass Filter

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a0	0.5	-1	1	0.001
a1	-0.5	-1	1	0.001
a2...a8	0	-1	1	0.001

2. Computation

This waveform is the waveshape of the windowing function for a non-recursive filter. The default setting is Hanning window. Various filter types may be constructed by entering proper values in parameters, a2 ~ a8.

Type	a0	a1	a2	a3	a4	a5 -a8
Hanning	0.5	-0.5	0	0	0	0
Hamming	0.54	-0.46	0	0	0	0
Blackman	0.42	-0.5	0.08	0	0	0
COS ³	0.375	-0.5	0.125	0	0	0
COS ⁴	0.3125	-0.46875	0.1875	-0.03125	0	0
Blackman-Harris						
3 term, -61 dB	0.44959	-0.49364	0.05677	0	0	0
3 term, -67 dB	0.42323	-0.49755	0.07922	0	0	0
4 term, -74 dB	0.40217	-0.49703	0.09392	-0.00183	0	0
4 term, -92 dB	0.35875	-0.48829	0.14128	-0.01168	0	0

Steps

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Level_Start	0.5	-1	1	0.001
Level_Stop	-0.5	-1	1	0.001
Steps	10	2	100	1
Rise Time (% Stp)	0	0	60	0.001

2. Computation

A staircase-like step waveform is defined by the following parameters.

Level_Start: first level of step waveform
Level_Stop: last level of step waveform
Steps: number of steps in step waveform
Rise Time (%Stp): rise / fall time (10 ~ 90% of level) of each step
For Rise Time (%Stp) = 60, there will be no flat portion of steps.

Continuous Sweep

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Ampl	1	-1	1	0.001
Offset	0	-1	1	0.001
Phase	0	-360	360	0.001
F_Start	1	0	10000	1
F_Stop	1	0	10000	1
Sweep_Type	1	1	2	1

2. Computation

Frequency-swept sine wave is created with the following parameters.

- Ampl: amplitude of sine wave
- Offset: DC offset of sine wave
- Phase: initial phase of sine wave
- F_Start: starting frequency of swept sine wave
- F_Stop: ending frequency of swept sine wave
- Sweep_type: frequency sweep profile
 - 1. linear sweep
 - 2. logarithmic sweep

Step Sweep

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Steps	20	2	100	1

2. Computation

The waveform is similar to Continuous Sweep except that the frequency sweep is divided into discrete steps. The number of steps are equally divided between the start and stop frequency values. All remaining parameters are identical to Continuous Sweep.

Burst Sweep

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Steps	20	2	100	1
Rise Time(%Stp)	0	0	60	0.001
OffTime(%Stp)	7	0	100	0.001

2. Computation

The finite swept frequency is created by dividing a waveform into equal frequency steps defined by the number of steps. The waveform is similar to Step Sweep. In addition, the rise time and the off time may be defined.

If Rise Time (%Stp) \neq 0, then the rise and fall times are added to the waveshape which has the equivalent rise or fall time of the sinewave at the step.

If OffTime (%Stp) \neq 0, then zero output of the off time of the first frequency step is added to the initial portion of each frequency step. Otherwise, the waveform is similar to Cont Sweep.

Cardiac (EKG Waveform)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
H1	0.1	-1	1	0.001
H2	-0.1	-1	1	0.001
H3	-0.25	-1	1	0.001
H4	0.2	-1	1	0.001
W1 (%)	15	0	100	0.001
W2 (%)	15	0	100	0.001
W3 (%)	25	0	100	0.001
T1 (%)	40	0	100	0.001
T2 (%)	60	0	100	0.001

2. Computation

See the diagram for the definition of parameters.

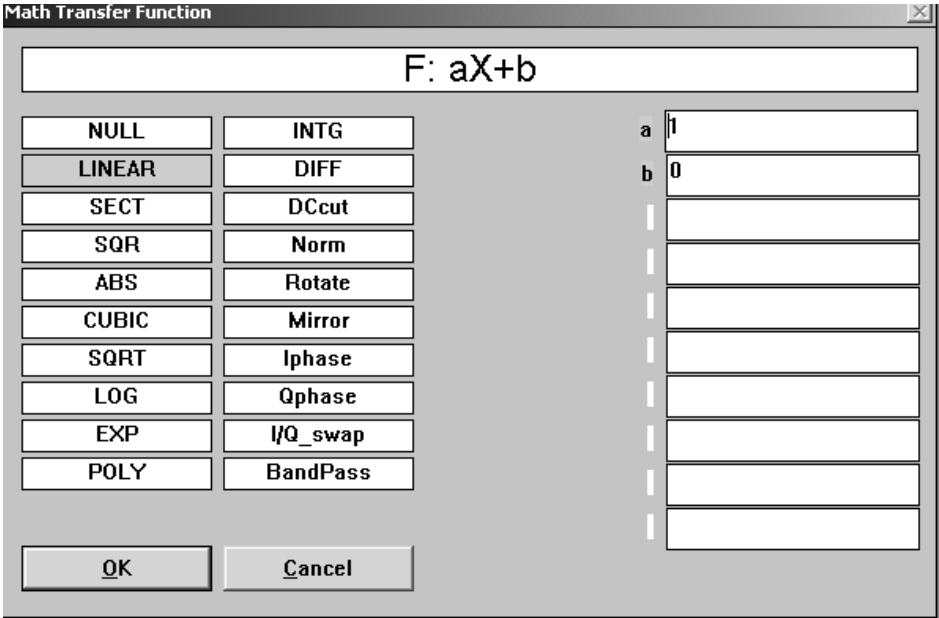


Chapter 7

Transfer Functions

Chapter 7 Transfer Functions
Transfer Function List

Transfer Function List



Null

1. Parameters

None

2. Computation

The output waveform is the result of all the input waveform data replaced with zero values. The output waveform length is same as the input waveform.

For an equation

$$\text{WAVE_OUT} = \mathbf{F} (\text{WAVE_1}) \mathbf{Op} \mathbf{G} (\text{WAVE_2})$$

if “**Op G (WAVE_2)**” is not required, use the following equation

$$\text{WAVE_OUT} = \mathbf{F} (\text{WAVE_1}) \mathbf{ADD NULL} (\text{WAVE_1})$$

to create

$$\text{WAVE_OUT} = \mathbf{F} (\text{WAVE_1})$$

LINEAR (aX + b)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is the result of an input waveform modified with gain (a) and offset (b). The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
 WAVE_IN (i): input waveform (i = 0 ~ N-1)
 WAVE_OUT (i): output waveform (i = 0 ~ N-1)

FOR i = 0 to N-1

$$\text{WAVE_OUT} (i) = a * \text{WAVE_IN} (i) + b$$

NEXT i

Sect (Section_of)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
FROM	0	0	32000	1
TO	100	0	32000	1
GAIN	1	0	2	0.001
OFST	0	-1	1	0.001

2. Computation

The output waveform is the result of data extracted between the specified addresses (FROM ~ TO) of an input waveform and then modified with gain (a) and offset (b). The output waveform length is (TO - FROM + 1). For a waveform with length = 1000, you may specify the FROM and TO values, minimum of 0 to maximum of 999. When a section of a waveform is needed in another application, this function is very useful.

The following equation is used to compute the output waveform.

N: input waveform length
 WAVE_IN (i): input waveform (i = 0 ~ N-1)
 WAVE_OUT (i): output waveform (i = 0 ~ TO-FROM-1)

```
FOR i = 0 ~ TO-FROM
    WAVE_OUT (i) = a*WAVE_IN (FROM + i) + b
NEXT i
```

SQR (a X² + b)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is the result of squared values of input waveform data modified with gain (a) and offset (b). The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
WAVE_IN (i): input waveform (i = 0 ~ N-1)
WAVE_OUT (i): output waveform (i = 0 ~ N-1)

```
FOR i = 0 to N-1  
    WAVE_OUT (i) = a * WAVE_IN (i) ^ 2 + b  
NEXT i
```

ABS (a |X| + b)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is absolute values of all data points of an input waveform modified with gain (a) and offset (b). The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
WAVE_IN (i): input waveform (i = 0 ~ N-1)
WAVE_OUT (i): output waveform (i = 0 ~ N-1)

```
FOR i = 0 to N-1  
    WAVE_OUT (i) = a * | WAVE_IN (i) | + b  
NEXT i
```

CUBIC (a X³ + b)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is cubed values of all data points of an input waveform modified with gain (a) and offset (b). The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
WAVE_IN (i): input waveform (i = 0 ~ N-1)
WAVE_OUT (i): output waveform (i = 0 ~ N-1)

```
FOR i = 0 to N-1  
    WAVE_OUT (i) = a* WAVE_IN (i) ^ 3 + b  
NEXT i
```

SQRT (a X^(1/2) + b)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is square-root values of all data points of an input waveform modified with gain (a) and offset (b). The output waveform length is same as the input waveform. When the input data is a negative value, the square-root of the absolute value is first computed and then negative sign is assigned.

The following equation is used to compute the output waveform.

N: input waveform length
WAVE_IN (i): input waveform (i = 0 ~ N-1)
WAVE_OUT (i): output waveform (i = 0 ~ N-1)

```
FOR i = 0 to N-1  
    WAVE_OUT (i) = a * WAVE_IN (i) ^ (1/2) + b  
NEXT i
```

LOG ($\pm a \text{ LOG } |X+1| + b$)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	3.322	-100	100	0.001
b	0	-1	1	0.001

2. Computation

The equation used to compute the output is dependent on the sign of the input data. If the input data is a positive value, the transfer function utilizes the right half of $y = \log(x-1)$. If the input data is a negative value, the transfer function utilizes the left half value of $y = \log(x-1)$ after the equation is rotated 180° around the origin. Values are modified with gain (a) and offset (b). The output waveform length is same as the input waveform. The default parameter of “a” is $1/\log(2)$.

The following equation is used to compute the output waveform.

N: input waveform length
 WAVE_IN (i): input waveform (i = 0 ~ N-1)
 WAVE_OUT (i): output waveform (i = 0 ~ N-1)

```

FOR i = 0 to N-1
    IF WAVE_IN (i) ≥ 0 THEN
        WAVE_OUT (i) = a * LOG ( WAVE_IN (i) + 1) + b
    ELSE
        WAVE_OUT (i) = -a * LOG ( 1 - WAVE_IN (i)) + b
    ENDIF
NEXT i
    
```


EXP ($\pm a$ (EXP |X| - 1) + b)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	0.582	-100	100	0.001
b	0	-1	1	0.001

2. Computation

The equation used to compute the output is dependent on the sign of the input data. If the input data is a positive value, the transfer function utilizes the right half of $y = \exp(x)-1$. If the input data is a negative value, the transfer function utilizes the left half value of $y = \exp(x)-1$ after the equation is rotated 180° around the origin. Values are modified with gain (a) and offset (b). The output waveform length is same as the input waveform. The default parameter of “a” is $1/(\exp(1)-1)$.

The following equation is used to compute the output waveform.

```

N:                input waveform length
WAVE_IN (i):     input waveform (i = 0 ~ N-1)
WAVE_OUT (i):    output waveform (i = 0 ~ N-1)

FOR i = 0 to N-1
  IF WAVE_IN (i) ≥ 0 THEN
    WAVE_OUT (i) = a * (EXP ( WAVE_IN (i)) - 1) + b
  ELSE
    WAVE_OUT (i) = -a * (EXP ( - WAVE_IN (i)) -1) + b
  ENDIF
NEXT i
  
```

POLY ($\Sigma [a_n X^n]$)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a1	1	-1	1	0.001
a2	0	-1	1	0.001
a3	0	-1	1	0.001
a4	0	-1	1	0.001
a5	0	-1	1	0.001
a6	0	-1	1	0.001
a7	0	-1	1	0.001
a8	0	-1	1	0.001
a9	0	-1	1	0.001

2. Computation

The output waveform is the addition of raised values by “n” of all data points of an input waveform, modified with gain (a). The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

```

N:                input waveform length
WAVE_IN (i):     input waveform (i = 0 ~ N-1)
WAVE_OUT (i):    output waveform (i = 0 ~ N-1)

FOR i = 0 to N-1
    WAVE_OUT (i) = 0           'clear the output
    FOR n = 1 to 9
        WAVE_OUT (i) = WAVE_OUT (i) + a n * WAVE_IN(i) ^ n
    NEXT n
NEXT i
    
```

INTG ($2\pi / N * a * \int dt + b$)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is an integration of the input waveform and then modified with gain (a) and offset (b). For example, data is added between the address 0 to i, multiplied with $2\pi / N$ and then modified with gain (a) and offset (b). The coefficient, $2\pi / N$, is used to compute the equal amplitude of sinewave for the output when the input waveform is cosinewave. (N = input waveform length) The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
 WAVE_IN (i): input waveform (i = 0 ~ N - 1)
 WAVE_OUT (i): output waveform (i = 0 ~ N - 1)

$$\text{WAVE_OUT}(0) = 2 * \pi / N * \text{WAVE_IN}(0) * a + b$$

FOR i = 1 to N - 1

$$\text{WAVE_OUT}(i) = \text{WAVE_OUT}(i - 1) + 2 * \pi / N * \text{WAVE_IN}(i) * a + b$$

NEXT i

DIFF (N / 2 / π * a * d / dt + b)

1. Parameters

Parameter	Default	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is a differentiation of the input waveform and then modified with gain (a) and offset (b). For example, output data at address “i” is the difference of the values of “i” and “i-1”, multiplied by N/2/π and then modified with gain (a) and offset (b). The coefficient, N/2/π, is used to compute the equal amplitude of cosinewave for the output when the input waveform is sinewave. (N = input waveform length)

The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
 WAVE_IN (i): input waveform (i = 0 ~ N - 1)
 WAVE_OUT (i): output waveform (i = 0 ~ N - 1)

WAVE_OUT (0) = N / 2 / π * (WAVE_IN (0) - WAVE_IN (N-1)) * a + b
FOR i = 1 to N - 1

WAVE_OUT (i) = N / 2 / π * (WAVE_IN (i) - WAVE_IN (i-1)) * a + b

NEXT i

DCcut (a = gain, b = offset)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is values, modified with gain (a) and offset (b), of all the waveform data minus the average value of the input waveform. The output waveform length is same as the input waveform.

Norm (Normalized to 1)

1. Parameters

No parameters are specified.

2. Computation

The output waveform is values of all the input waveform data divided by the peak value of the input waveform. If the absolute value of the positive peak is larger than the negative peak, the computation will be made to normalize the positive peak to be 1. If the absolute value of the negative peak is larger than the positive peak, the computation will be made to normalize the negative peak to be -1. When the peak value is 0, no computation will be made. The output waveform length is same as the input waveform.

Rotate (Rotate right by A)

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
a	0	0	1000	1

2. Computation

The output waveform is the result of all the input waveform data shifted by “A” on the x-axis. The output waveform length is same as the input waveform.

The following equation is used to compute the output waveform.

N: input waveform length
 WAVE_IN (i): input waveform (i = 0 ~ N-1)
 WAVE_OUT (i): output waveform (i = 0 ~ N-1)

```
FOR i = 0 to N-1
    WAVE_OUT ((i + A) Mod N) = WAVE_IN (i)
NEXT i
```

Mirror (a = gain, b = offset)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
a	1	-1	1	0.001
b	0	-1	1	0.001

2. Computation

The output waveform is the result of all input waveform data modified with gain (a), offset (b) and then reverse order the respective addresses. The output waveform length is same as the input waveform.

Iphase (In Phase)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
gain	1	-1	1	0.001
offset	0	-1	1	0.001

2. Computation

The output waveform is the result of all input waveform data modified with gain (a), offset (b) and extraction of the In_Phase components (cosine terms). The output waveform length is the same as the input waveform.

Qphase (Quadrature Phase)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
gain	1	-1	1	0.001
offset	0	-1	1	0.001

2. Computation

The output waveform is the result of all input waveform data modified with gain (a), offset (b) and extraction of the Quadrature_Phase components (sine terms). The output waveform length is the same as the input waveform.

IQ Swap (I/Q Swap)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
gain	1	-1	1	0.001
offset	0	-1	1	0.001

2. Computation

The output waveform is the result of all input waveform data modified with gain (a), offset (b) and the interchange of the Quadrature_Phase components (sine terms) and In_Phase components (cosine terms).

Quadrature Phase (sine terms) >> In Phase (cosine terms)

In Phase (cosine terms) * (-1) >> Quadrature Phase (sine terms)

As a result, all the frequency components of the input waveform are advanced by 90°. The output waveform length is the same as the input waveform.

Example:

Input Waveform

sine wave

cosine wave

Output Waveform

cosine wave

-sine wave

BandPass

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Freq_IOW	0	0	10000	1
Freq_High	10	0	10000	1

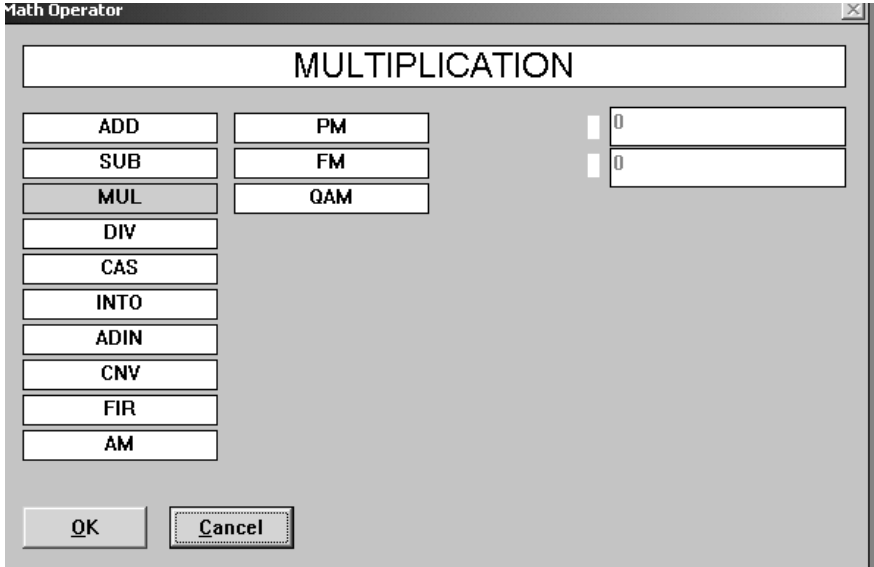
2. Computation

The output waveform is the result of the extraction of the input waveform frequency components between the specified frequency range (Freq_Low and Freq_High). The output waveform length is the same as the input waveform.

Chapter 8

Math Operators

Math Operator List



Introduction

The math-type waveforms are created by using the following equation. In order to perform the math operation, the two input waveforms must exist ahead of the output waveform (New Wave) in the Wave List (Wave | List).

$$(\text{New Wave}) = F (\text{Wave\#1}) \text{ Op } G (\text{Wave\#2})$$

where

Wave#1:	the first operand
Wave#2:	the second operand
New Wave:	output waveform of the operation
F:	transfer function of the first operand as the input
G:	transfer function of the second operand as the input
Op:	operator on the two operands (Wave#1 and Wave#2)

Follow the steps to compute the math-type waveform.

1. Select the output waveform (New Wave).
Make sure that the waveforms to be used as the operands (Wave#1 and Wave#2) are listed above the selected output waveform (New Wave) in the Wave List.
2. Select the first operand (Wave#1).
3. Select the second operand (Wave#2).
4. Select the first transfer function (F).
5. Select the second transfer function (G).
6. Select the operator (Op).
7. Click **SHOW** to view the computed waveform.
8. Click **OK** to save in the New Wave.

If only one transfer function is required and no math operation is necessary, use Op = ADD and G = NULL. This will allow the first transfer function (F) to be performed on the first operand (Wave#1).

ADD (Addition)

1. Parameters

None

2. Computation

The operator computes the addition of two input waveforms, 1 and 2. If the lengths of both input waveforms are equal, the output waveform length is same as the input waveform. If one of the input waveforms is longer than the other, then the output waveform length is the same as the length of the longer input waveform. In this case, the shorter input waveform will repeat the operation up to the end point of the longer waveform.

The following method is used to compute the output waveform.

N1: length of input waveform 1
N2: length of input waveform 2
N3: length of output waveform
WAVE_1 (i): input waveform 1 (i = 0 ~ N1-1)
WAVE_2 (i): input waveform 2 (i = 0 ~ N2-1)
WAVE_OUT (i): output waveform (i = 0 ~ N3-1)
 where N3 = LARGER_OF (N1, N2)

Assuming $N1 \leq N2$

```
FOR i = 0 to N2-1  
    WAVE_OUT (i) = WAVE_1 (i MOD N1) + WAVE_2 (i)  
NEXT i
```

SUB (Subtraction)

1. Parameters

None

2. Computation

The operator computes the subtraction of two input waveforms, 1 and 2. If the lengths of both input waveforms are equal, the output waveform length is same as the input waveform. If one of the input waveforms is longer than the other, then the output waveform length is the same as the length of the longer input waveform. In this case, the shorter input waveform will repeat the operation up to the end point of the longer waveform.

The following method is used to compute the output waveform.

N1: length of input waveform 1
N2: length of input waveform 2
N3: length of output waveform
WAVE_1 (i): input waveform 1 (i = 0 ~ N1-1)
WAVE_2 (i): input waveform 2 (i = 0 ~ N2-1)
WAVE_OUT (i): output waveform (i = 0 ~ N3-1)
 where N3 = LARGER_OF (N1, N2)

Assuming $N1 \leq N2$

```
FOR i = 0 to N2-1  
    WAVE_OUT (i)=WAVE_1 (i MOD N1) - WAVE_2 (i)  
NEXT i
```

Assuming $N1 \geq N2$

```
FOR i = 0 to N1-1  
    WAVE_OUT (i) = WAVE_1 (i) - WAVE_2(i MOD N2)  
NEXT i
```

MUL (Multiplication)

1. Parameters

None

2. Computation

The operator computes the multiplication of two input waveforms, 1 and 2. If the lengths of both input waveforms are equal, the output waveform length is same as the input waveform. If one of the input waveforms is longer than the other, then the output waveform length is the same as the length of the longer input waveform. In this case, the shorter input waveform will repeat the operation up to the end point of the longer waveform.

The following method is used to compute the output waveform.

N1: length of input waveform 1
N2: length of input waveform 2
N3: length of output waveform
WAVE_1 (i): input waveform 1 (i = 0 ~ N1-1)
WAVE_2 (i): input waveform 2 (i = 0 ~ N2-1)
WAVE_OUT (i): output waveform (i = 0 ~ N3-1)
 where N3 = LARGER_OF (N1, N2)

Assuming $N1 \leq N2$

```
FOR i = 0 to N2-1  
    WAVE_OUT (i) = WAVE_1 (i MOD N1) * WAVE_2 (i)  
NEXT i
```

DIV (Division)

1. Parameters

None

2. Computation

The operator computes the division of two input waveforms, 1 and 2. If the lengths of both input waveforms are equal, the output waveform length is the same as the input waveform. If one of the input waveforms is longer than the other, then the output waveform length is the same as the length of the longer input waveform. In this case, the shorter input waveform will repeat the operation up to the end point of the longer waveform. The division by zero (0) will always return zero (0).

The following method is used to compute the output waveform.

N1: length of input waveform 1
N2: length of input waveform 2
N3: length of output waveform
WAVE_1 (i): input waveform 1 (i = 0 ~ N1-1)
WAVE_2 (i): input waveform 2 (i = 0 ~ N2-1)
WAVE_OUT (i): output waveform (i = 0 ~ N3-1)
where N3 = LARGER_OF (N1, N2)

Assuming $N1 \leq N2$

```
FOR i = 0 to N2-1  
    IF WAVE_2 (i) <> 0 THEN  
        WAVE_OUT (i) = WAVE_1 (i MOD N1) / WAVE_2 (i)  
    ELSE WAVE_OUT (i) = 0  
NEXT i
```

Assuming $N1 \geq N2$

```
FOR i = 0 to N1 - 1  
    IF WAVE_2 (i MOD N2) <> 0 THEN  
        WAVE_OUT (i) = WAVE_1 (i) / WAVE_2 (i MOD N2)  
    ELSE WAVE_OUT (i) = 0  
NEXT i
```


CAS (Cascade)

1. Parameters

None

2. Computation

The operator connects two input waveforms, 1 and 2. The length of the output waveform is the sum of the lengths of two input waveforms.

The following method is used to compute the output waveform.

N1:	length of input waveform 1
N2:	length of input waveform 2
N3 = N1 + N2:	length of output waveform
WAVE_1 (i):	input waveform 1 (i = 0 ~ N1-1)
WAVE_2 (i):	input waveform 2 (i = 0 ~ N2-1)
WAVE_OUT (i):	output waveform (i = 0 ~ N3-1)

```
FOR i = 0 to N1-1  
    WAVE_OUT (i) = WAVE_1 (i)  
NEXT i
```

```
FOR i = 0 to N2-1  
    WAVE_OUT (N1 + i) = WAVE_2 (i)
```

```
NEXT i
```

CNV (Convolution)

1. Parameters

Type 1 ==> CIRCULAR CONVOLUTION

Type 2 ==> LINEAR CONVOLUTION

2. Computation

The operator performs the convolution of two input waveforms, 1 and 2. The entry order of two input waveforms is not significant.

For type 1, the output waveform length is the longer of the two input waveforms.

For type 2, the output waveform length is the sum of the two input waveform lengths.

When $N1 = \text{length of input waveform 1}$, $N2 = \text{length of input waveform 2}$ and $N1 \leq N2$, one of the following three conditions must be satisfied to perform the convolution.

1. When $N1 = N2$ and N is one of the following lengths
256, 512, 1024, 2048, 4096, 8192
2. When $N1 < N2$ and $N2$ is one of the following lengths
256, 512, 1024, 2048, 4096, 8192
3. When $N1 + N2 \leq 8192$

The following sequence is used to compute the output waveform.

For type 1

1. Perform FFT of input waveform 1 and 2.
2. Multiply the two frequency domain data values derived from step 1.
3. Perform IFFT of the result of step 2.
4. Extract the applicable portion of the result of step 3.

For type 2

1. Extend the length of the longer of the two input waveforms to the sum of two input waveform lengths and enter zero (0) into the extended portion of the waveform.
2. Perform type 1 convolution.

FIR (FIR_filter)

1. Parameters

Type 1 ==> CIRCULAR FIR_filter

Type 2 ==> LINEAR FIR_filter

2. Computation

The operator performs the **FIR** computation of two input waveforms, 1 and 2. The entry order of two input waveforms are not significant.

For type 1, the output waveform length is the longer of the two input waveforms.

For type 2, the output waveform length is the sum of the two input waveform lengths.

When $N1 = \text{length of input waveform 1}$, $N2 = \text{length of input waveform 2}$ and $N1 \leq N2$, input waveform 1 is the wave shape of **FIR** filter impulse response and input waveform 2 is the waveform being filtered by **FIR** filter.

First, $N1 * 2 \leq N2$ must be met. In addition, one of the following conditions must be satisfied to perform the **FIR** computation

1. When $N1 \leq 1024$ and $N2$ is one of the following lengths
1024, 2048, 4096, 8192
2. When $N1 \leq 1024$ and $N1 + N2 \leq 8192$
3. When $N1 \leq 2048$ and $N2 \leq 16000$
4. When $N1 \leq 4096$ and $N2 \leq 32000$

The following sequence is used to compute the output waveform.

For type 1

1. Divide the input waveform 2 into pieces if the waveform is too long for the CNV operation.
2. Perform CNV (convolution-type 1) of the input waveform 1 and the waveform portion derived from step 1.
3. Extract the applicable portion of the result of step 2.
4. Repeat steps 1, 2 and 3 if necessary.

For type 2

1. Extend the length of the longer of the two input waveforms to the sum of two input waveform lengths and enter zero (0) into the extended portion of the waveform.
2. Perform type 1 FIR computation.

INTO (Insert Into)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
FROM	0	0	32000	1
TO	10	10	32000	1

2. Computation

The operator inserts input waveform 1 into waveform 2 for the interval specified by the addresses (FROM and TO). The length of the output waveform is the sum of the two input waveform lengths.

If the value of “TO - FROM + 1” is shorter than the length of input waveform 1, the inserted data is extracted from the values between the address 0 and the “TO - FROM” of waveform 1. If the value of “TO - FROM + 1” is longer than the length of the input waveform 1, the inserted data will repeat the same data from address 0 until the data is filled to the end point of waveform 2.

The following method is used to compute the output waveform.

N1: length of input waveform 1
 N2: length of input waveform 2
 WAVE_1 (i): input waveform 1 (i = 0 ~ N1-1)
 WAVE_2 (i): input waveform 2 (i = 0 ~ N2-1)

1. Copy WAVE_2 to WAVE_OUT

```
FOR i = 0 to N2-1
    WAVE_OUT (i) = WAVE_2 (i)
NEXT i
```

2. Insert WAVE_1 into the address interval specified by FROM and TO-1

```
FOR i = 0 to TO - FROM
    WAVE_OUT (FROM + i) = WAVE_1 (i MOD N1)
NEXT i
```

ADIN (Add Into)

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
FROM	0	0	32000	1
TO	10	10	32000	1

2. Computation

The operator adds input waveform 1 into waveform 2 for the interval specified by the addresses (FROM and TO). The length of the output waveform is the same as input waveform 2. If the value of “TO - FROM + 1” is shorter than the length of the input waveform 1, the added data is extracted from the values between the address 0 and the “TO - FROM” of waveform 1. If the value of “TO - FROM + 1” is longer than the length of input waveform 1, the added data will repeat the same data from address 0 until the data is filled to the end point of waveform 2.

The following method is used to compute the output waveform.

N1: length of input waveform 1
 N2: length of input waveform 2
 WAVE_1 (i): input waveform 1 (i = 0 ~ N1-1)
 WAVE_2 (i): input waveform 2 (i = 0 ~ N2-1)
 WAVE_OUT(i): output waveform (i = 0 ~ N2-1)

1. Copy WAVE_2 to WAVE_OUT

```
FOR i = 0 to N2-1
    WAVE_OUT (i) = WAVE_2 (i)
NEXT i
```

2. Sum WAVE_1 into the address interval specified by FROM and TO-1

```
FOR i = 0 to TO-FROM-1
    WAVE_OUT (FROM + i) = WAVE_OUT (FROM + i)
    + WAVE_1 (i MOD N1)
NEXT i
```

AM (Amplitude Modulation)

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
AM_Index	100	0	100	0.001

2. Computation

The operation is AM (amplitude modulation) of input waveform 2 by input waveform 1. The waveform 2 is the carrier and the waveshape must be SIN (sinewave) of STD FUNC (standard function).

When AM_Index is set to 100 and the relative amplitude of waveform 1 is full scale (± 1), the output waveform is 100% modulated AM waveform. The output waveform length is the same as the input waveform 1.

PM (Phase Modulation)

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
Phase_dev	180	0	180000	0.001

2. Computation

The operation is PM (phase modulation) of input waveform 2 by input waveform 1. The waveform 2 is the carrier and the waveshape must be SIN (sinewave) of STD FUNC (standard function).

When the relative amplitude of waveform 1 is set to full scale (± 1), the output waveform is a phase modulated waveform where the phase deviation is specified by Phase_dev. The output waveform length is the same as the input waveform 1.

FM (Frequency Modulation)

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
Freq_dev	1	0	1000	0.001

2. Computation

The operation is FM (frequency modulation) of input waveform 2 by input waveform 1. The waveform 2 is the carrier and the waveshape must be SIN (sinewave) of STD FUNC (standard function).

When the relative amplitude of waveform 1 is set to full scale (± 1), the output waveform is a frequency-modulated waveform where the frequency deviation is specified by Freq_dev. The output waveform length is the same as the input waveform 1.

QAM (Quadrature Amplitude Modulation)

1. Parameter

Parameters	Defaults	Minimum	Maximum	Resolution
Carrier_Freq	20	1	1000	1
Phase_Ofst	0	-360	360	0.001

2. Computation

The output is a QAM (quadrature amplitude modulation) waveform which consists of two input waveforms, 1 and 2.

The following method is used to compute the output waveform.

$$\text{OUTPUT_WAVE} = (\text{INPUT_WAVE1} * \cos \Phi + \text{INPUT_WAVE2} * \sin \Phi) * 0.707$$
where $\Phi = 2 * \pi * \text{Carrier_Freq} * t + \text{Phase_Ofst} / 180 * \pi$



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