WaveWorks Jr.
Manual 810023-CD
Rev. A

The TEGAM WaveWorks™ Jr. 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 2711 A and 2714A Arbitrary Waveform Generators. TEGAM WaveWorks Jr.'s key features allow you to:

• Create, edit and analyze arbitrary waveforms up to 32,000 points in length.

• Access 21 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 popular spreadsheet formats.

• Transfer waveforms to TEGAM 2711A and 2714A 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 Jr.

AWG Arbitrary Waveform Generator

WWJ WaveWorks Jr.

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 Jr., the computer requirements and specific interface requirements to allow you to work with TEGAM 2711A and 2714A AWGs.

Chapter 2 - Quick Start provides an overview of WaveWorks Jr. 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 Jr. offers an introduction to arbitrary waveforms. In addition, this chapter describes the 20 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 Jr.

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

Chapter 6 - Standard Functions provides detailed descriptions of 21 standard functions. The computation methods, the parameter limits and the default values are given.

Chapter 7 - Transfer Functions describes 12 math transfer functions, parameters and default settings.

Chapter 8 - Math Operators describes 6 math operations available in WaveWorks Jr. Their parameters and default values are included.

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TEGAM WaveWorks Jr. Waveform Creation Software

STANDARD WAVES

All 21 standard waves with the required parameters are set up in the selected screen for instantaneous use.

Sine	Square	Triangle	DC
Ramp	Squine	Gaussian	Pulsel
Pulse2	SinX/X	AM	FM
PWM	BFSK	BPSK	Comb
Steps	Cont.	Sweep	Exponential
Analog Noise	Digital Noise		

WAVEFORM GRAPHIC MATH

Math Transfer Function

All 12 transfer functions including integration and differentiation are available to modify the waveform in the specified manner.

Math Operator

Complex waveforms are readily created by use of the 6 operators. Each of the waveforms in the set are included in developing the final result which is down-loaded to the generator memory.

Addition	Subtraction	Multiplication
Cascade	INTO (Insert Into)	ADIN(Add Into)

SEQUENCE PROGRAMMING

Sequence offers virtual memory expansion and comprehensive real-world simulations. Any waveform stored in memory may be output in any order in a seamless manner and be repeated up to 1,000,000 times. Test profiles are easily defined by the use of a table to select each waveform in turn and designating the number of times each is looped.

EDIT

Copy	Paste	Point	Vertex
Digital Pattern	Harmonics	(FFT,IFFT)	
Sequence			

AUXILIARY FEATURES

Fast Fourier transform offers frequency analysis and graphical presentation for frequency spectrum editing. Recreation of the time-domain waveform is offered using the inverse transform. A complete sample value tabulation of each waveform allows for point-by-point modification. A digital pattern describes the bit-by-bit synthesis of each waveform for editing in this arena.

Waveform Analysis/Synthesis

Frequency Domain: FFT and IFFT
      Harmonics: up to 500th
      Displays: graphic and tabulation
      Entry: tabulation
      Units:Sin-Cos(Ampl),Sin (Ampl-Phase), Cos (Ampl-Phase), Sin (dB-Phase), Cos (dB-Phase)
      Other feature: random phase entry
Time Domain: Digital Pattern
      Display: graphic
      Edit: mouse

COMPUTER REQUIREMENTS

Operating System

Windows 95 or 3.1, 95 or later.

PC Requirements

486DX or better with 4MB free RAM space

Interface

Serial: COM port
      RS-232C, up to 19.2 kBaud
GPIB: National Instruments AT-GPIB card (or equivalent)
      IEEE standard 488.2-1987

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.
- PC with CD ROM.
- 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

<u>IEEE-488 Interface Requirements.</u> To use an IEEE-488 interface with TEGAM WaveWorks Jr. 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

<u>RS-232 Requirements.</u> To use RS-232 with TEGAM WaveWorks Jr. you must have the RS-232 cable supplied with the software and an available Asynchronous Serial (COM) port on your PC.

Installing the TEGAM WaveWorks Jr. Software

1. Insert the TEGAM WaveWorks Jr. 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**).
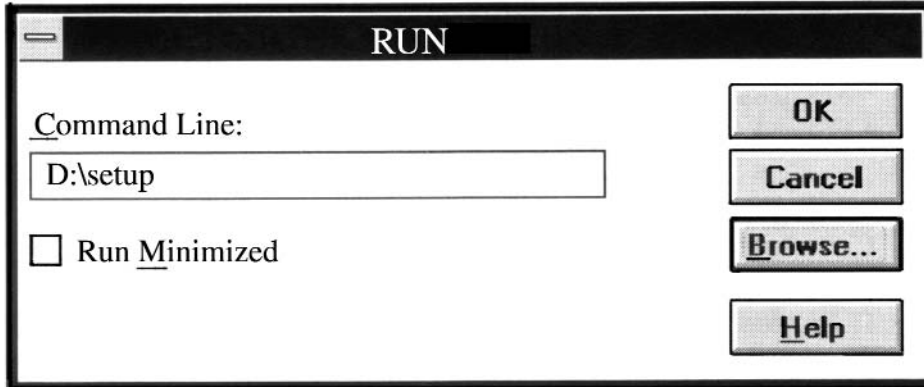
During the installation process, the setup program will prompt you for the
directory to receive the files. Press **ENTER** to accept the default installa-
tion directory. Type a new drive and directory in the **INSTALL TO**: text
box if needed.
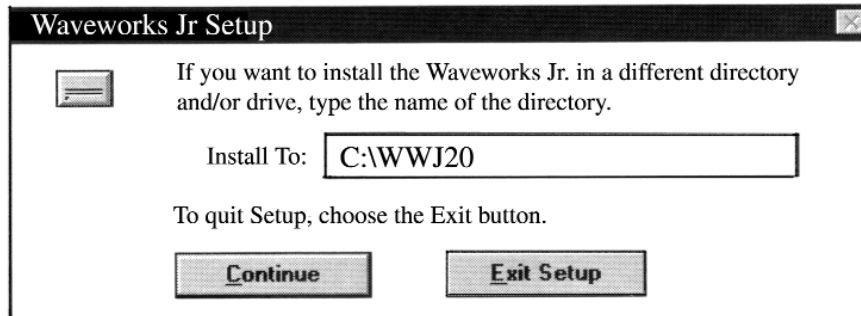
The installation program will create a new program group in the Program
Manager and add the TEGAM WaveWorks Jr. icon to the group.

If you encounter problems

• Check the system and interface requirements.

• If you are using RS-232, be sure to use the cable supplied with the software.

• 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 Jr. GPEB.DLL file must be located in your WaveWorks Jr. directory, the Windows directory or a directory included in the PATH command in your AUTOEX EC.BAT file. For specific details, refer to your IEEE-488 Interface card installation guide.

Quick Start

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

TEGAM WaveWorks Jr Screen Components

Title Bar
In the Title Bar, WWJ displays WaveWorks Jr. 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 WWJ waveform windows.

- **Edit** Menu - contains commands for copy and paste between the waveform windows, and editing and analyzing waveforms such as Point, Vertex and Harmonics Editors and Digital Pattern Analyzer.

- **Wave** Menu - contains commands for new, delete, setup, and list of WWJ 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 Jr.

TEGAM WaveWorks Jr Components
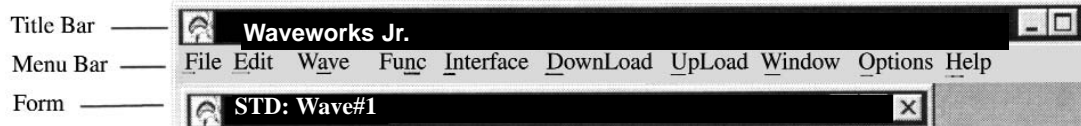
Title Bar

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 Jr. 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 Jr.

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

• From the WaveWorks Jr. program group, double-click on the TEGAM WaveWorks Jr. icon.

• From the Windows File menu, choose **Run...** and assuming TEGAM WaveWorks Jr was loaded in a directory named 'WWJ20', enter: **c:\wwj20\wwj20.** Once started, the TEGAM WaveWorks Jr. 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 Jr. was loaded in a directory named 'wwj', type: **win c:\wwj20\wwj20**

Closing. You can exit from TEGAM WaveWorks Jr. in one of two ways:
• Double-click the Windows Control-menu box on the Main form.
• From the TEGAM WaveWorks Jr. Menu Bar, choose **File | Exit**.

To Create, Save, and Output an Arbitrary Waveform

This example demonstrates how to use TEGAM WaveWorks Jr. An arbitrary wave-
form is created, edited, saved, and output to the selected TEGAM arbitrary waveform
generator.

1. Start WaveWorks Jr. as described on the previous page. You shoud have an empty
    waveform window #1 displayed if the default setting is chosen. The waveform
    length is set to 1000 points. Click **OK**.
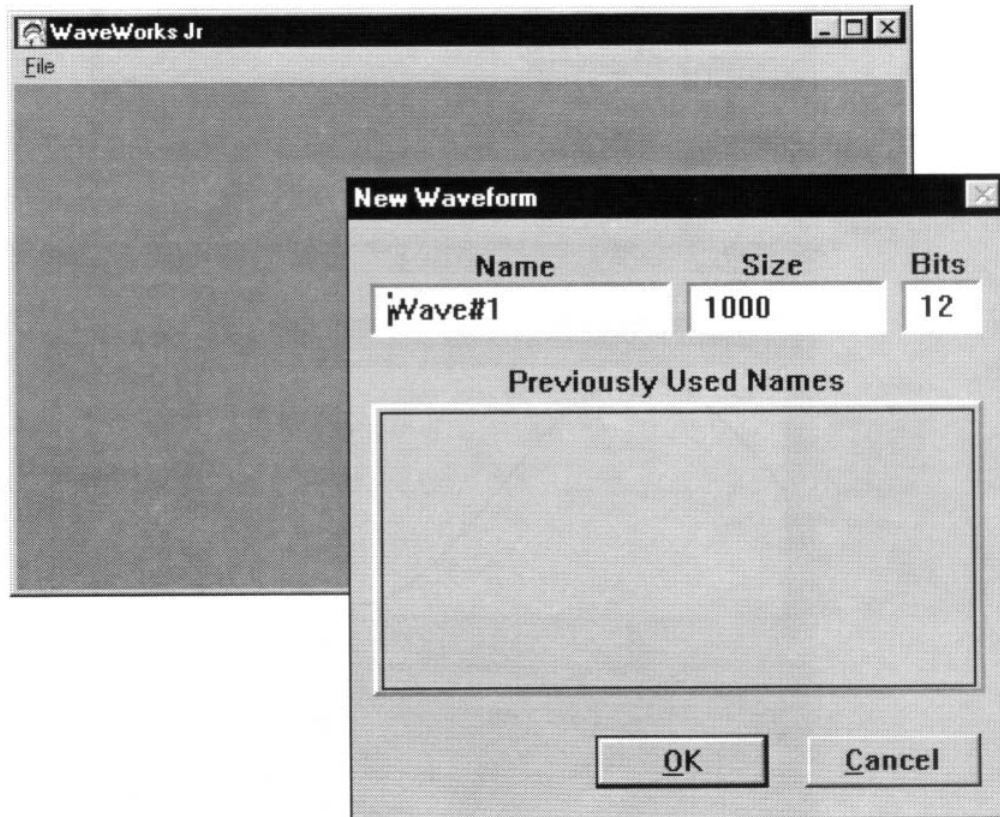
2.   Place a sine wave in the waveform window by choosing **Func | Stdwave.** Select
      SineWave and then click **SHOW** to view and **OK** to accept the waveform. If
      you used the default parameters, the waveform is a one cycle sinewave starting
      at 0° with 100% amplitude.
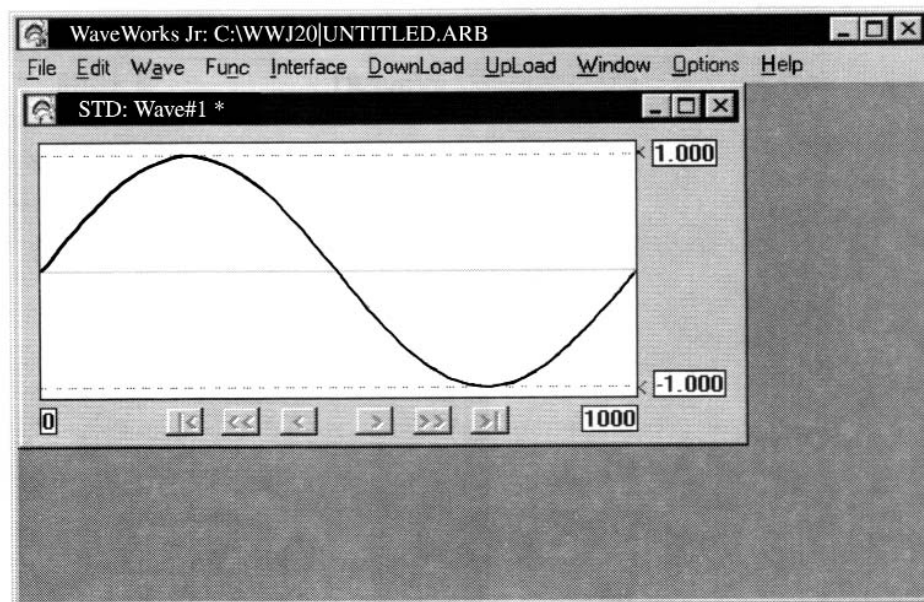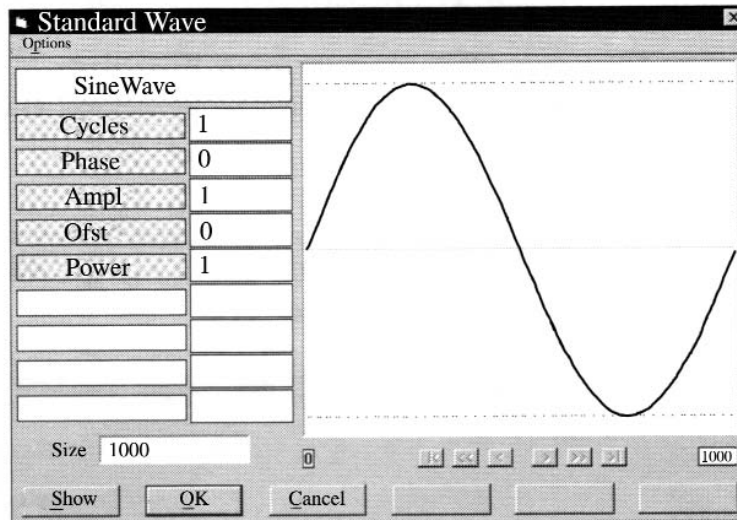
3.   Choose **Wave | New.** Click **OK** to create waveform window #2.

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.
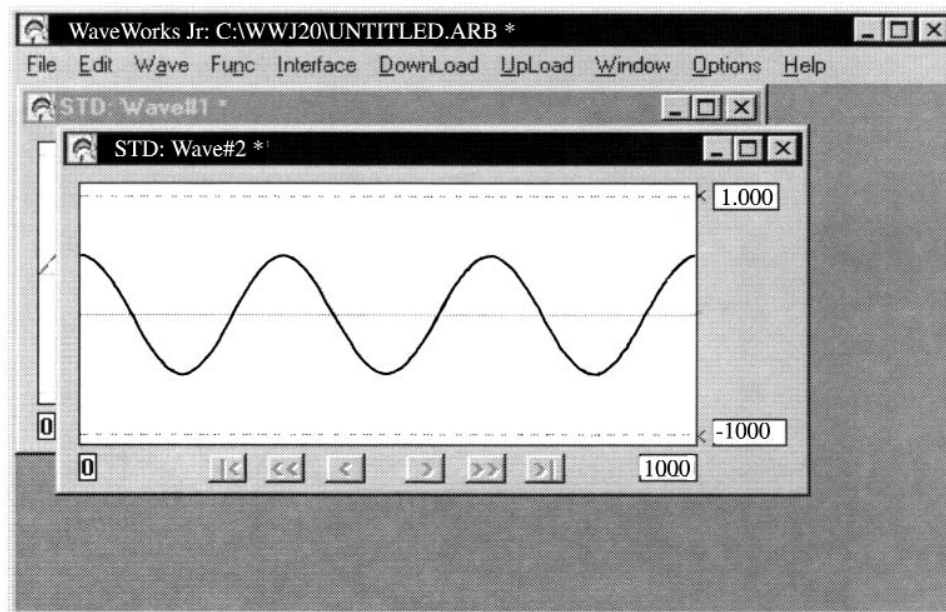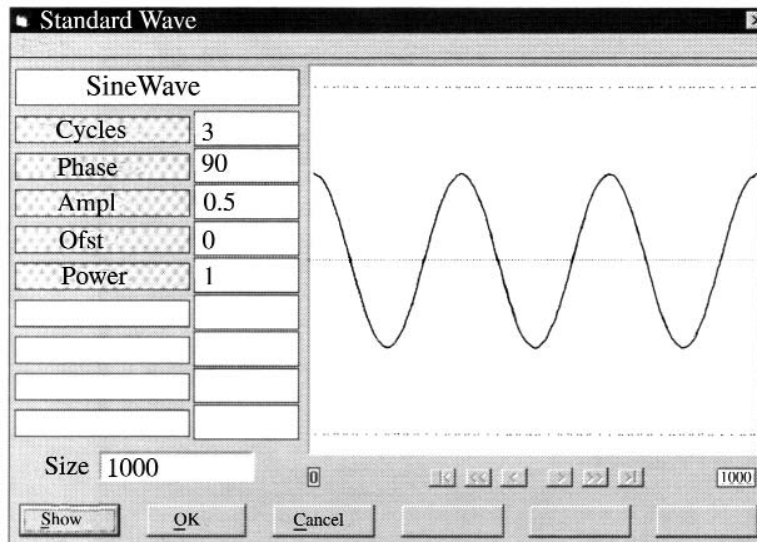
5.   Choose **Wave | New.** Click **OK** to create waveform window #3.

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.
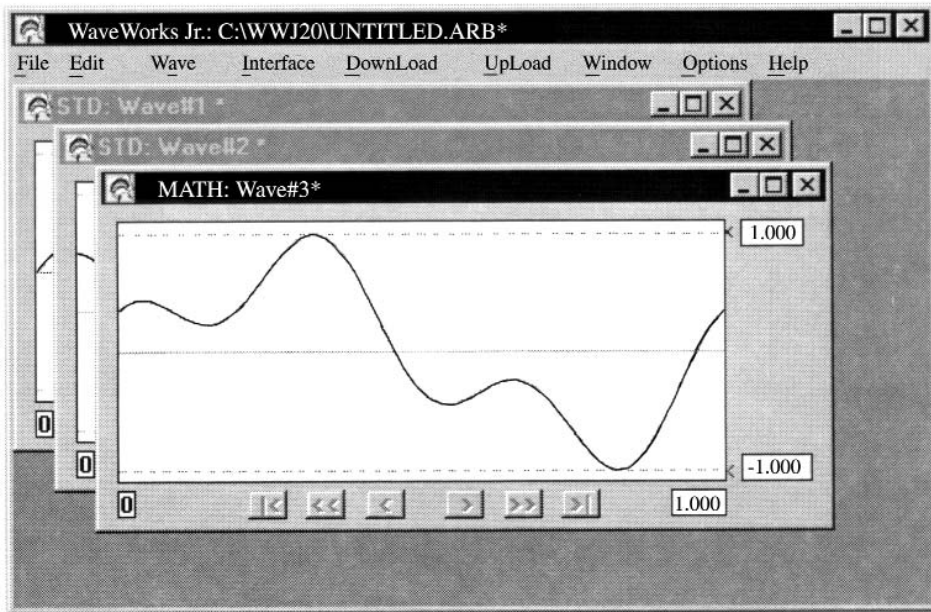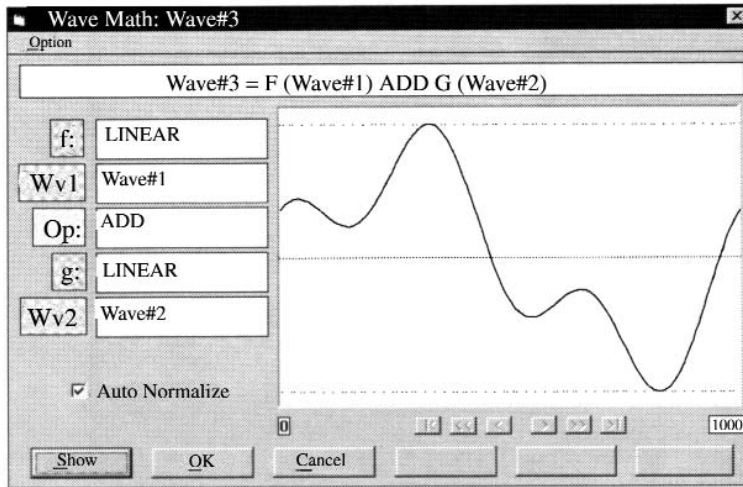
7. Choose **Edit | Harmonics,** while waveform window #3 is selected.
    You can view the frequency components of waveform #3. Click
    Amp_Phs in sine to list the two frequency components of the waveform.
    You may view the list in graphic form by choosing **Graph** on the Menu
    Bar. Click **Quit** to return to the harmonic listing. Click **CANCEL** or **OK**
    to return to the main form.
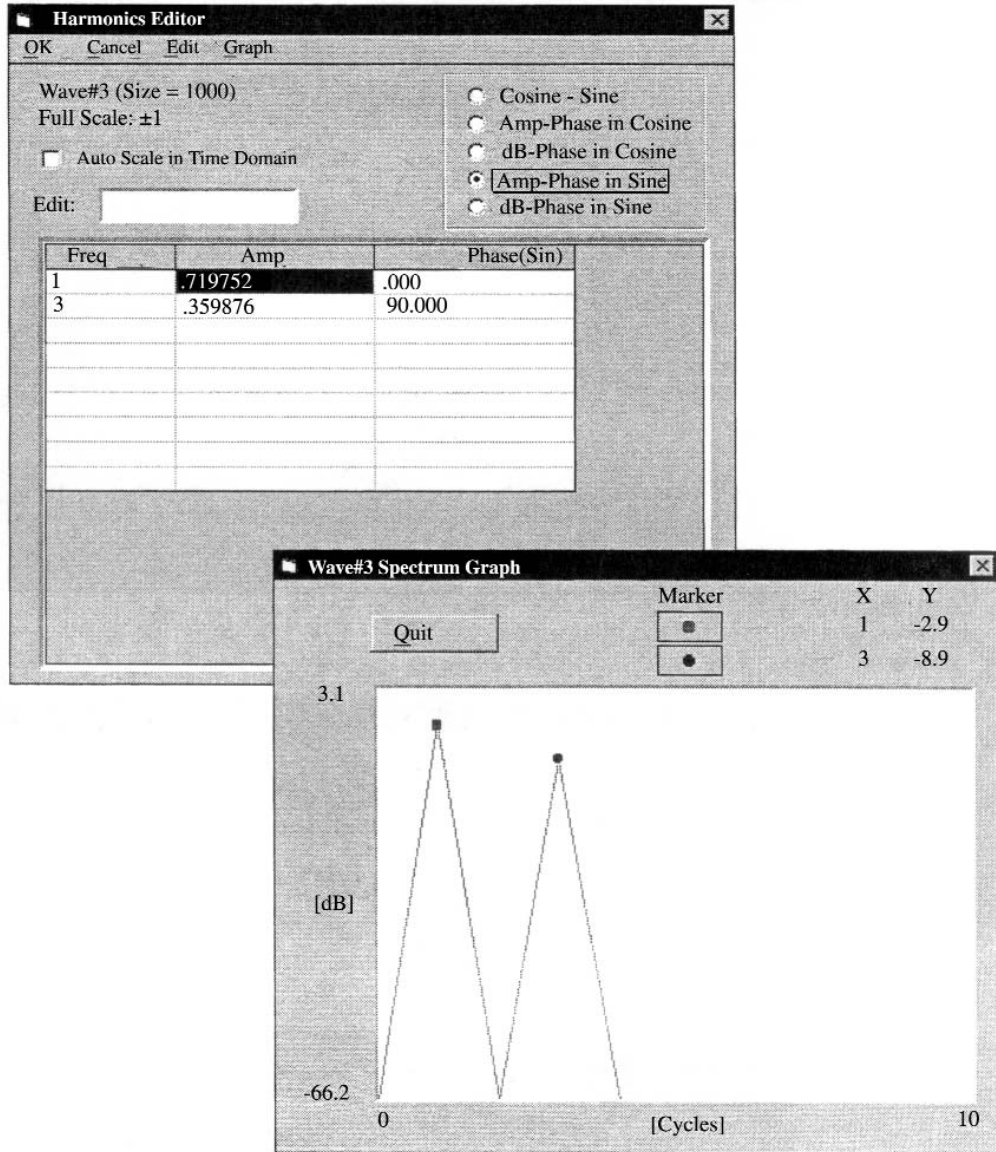
8. Choose **File | Save Project As** to save the waveforms in the project file. After each waveform is saved, asterisk (*) next to the waveform name in the title bar of the waveform window will be deleted.
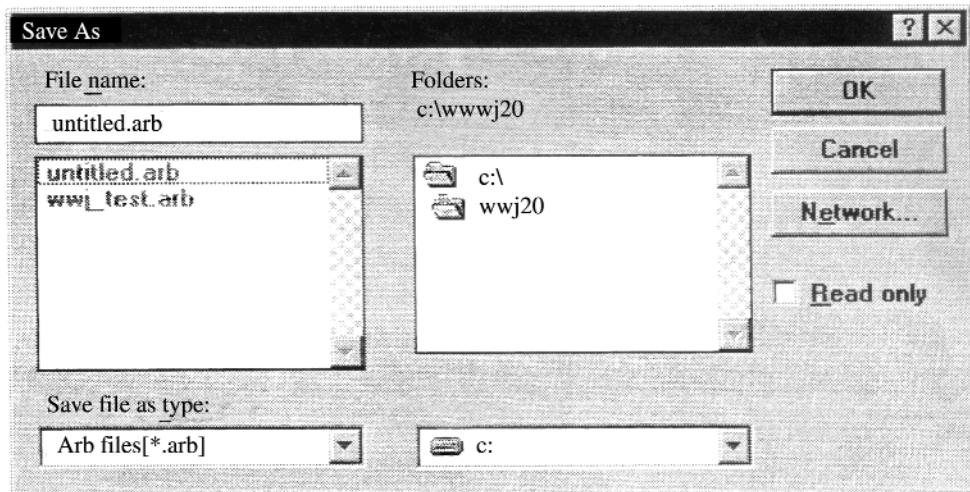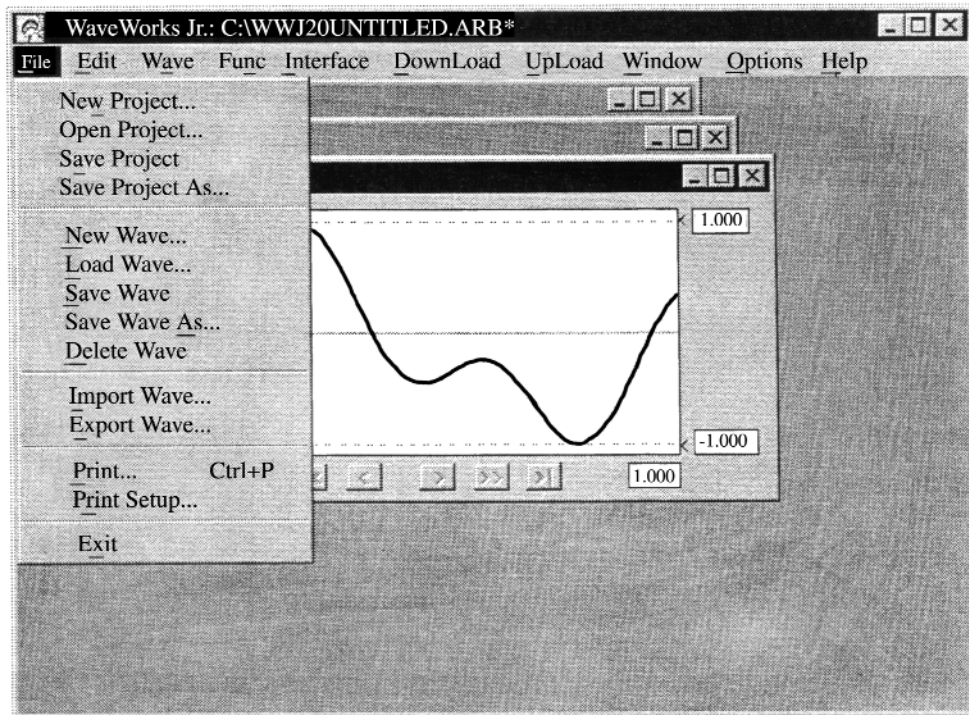
9.   Choose **INTERFACE** on the Menu Bar. Examine the TEGAM waveform generators listed at the lower left corner of the screen. If you have connected the 2711A/2714A TEGAM generators to one of the PC COM ports with the RS-232 cable supplied with the software, you are ready to initialize the communications 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.

```
Interface Setting                                                    ☒

                        GPIB                                  RS 232

   1:  [          ]  [          ]  [          ]      Com1   [ Prg2711a ]
   2:  [          ]                                  Com2   [          ]
   3:  [          ]   ┌─────────────────────────┐    Com3   [          ]
   4:  [          ]   │  WaveWorks Jr.        ☒ │    Com4   [          ]
   5:  [          ]   │                         │
   6:  [          ]   │   Prg2711a detected at Com1 │
   7:  [          ]   │                         │    Settings
   8:  [          ]   │        ┌─────────┐      │    [ 19200,N,8,1  ▼ ]
   9:  [          ]   │        │   OK    │      │    Handshake
  10:  [          ]   │        └─────────┘      │    [ hardware     ▼ ]
                      └─────────────────────────┘

                      Instruments
   [ Prg2711a ]   ▯           ▯           ▯           [  Clear All  ]
   [ Prg2714a ]   ▯           ▯           ▯
   ▯           ▯           ▯           ▯              [    OK    ]
   ▯           ▯           ▯           ▯
                                                      [  Cancel  ]
```
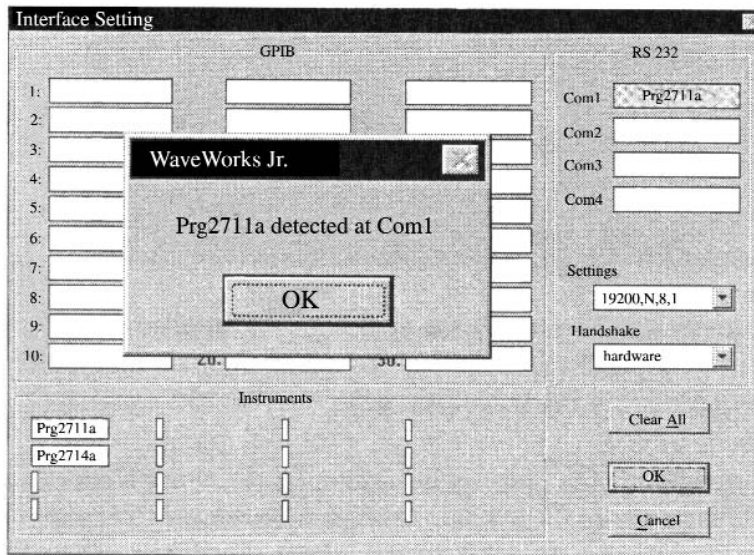
10. Choose **Down | Setup** and select **Com1.**

```
Download to ARB: Select & Setup                                      ☒

                          ▓▓▓▓▓▓▓  Wave#1  ▓▓▓▓▓▓▓

   ⊙  Com1: Prg2711a                        ○
   ○                                        ○
   ○                                        ○
   ○                                        ○
   ○                                        ○

        [  Setup  ]              [   OK   ]        [  Cancel  ]
```
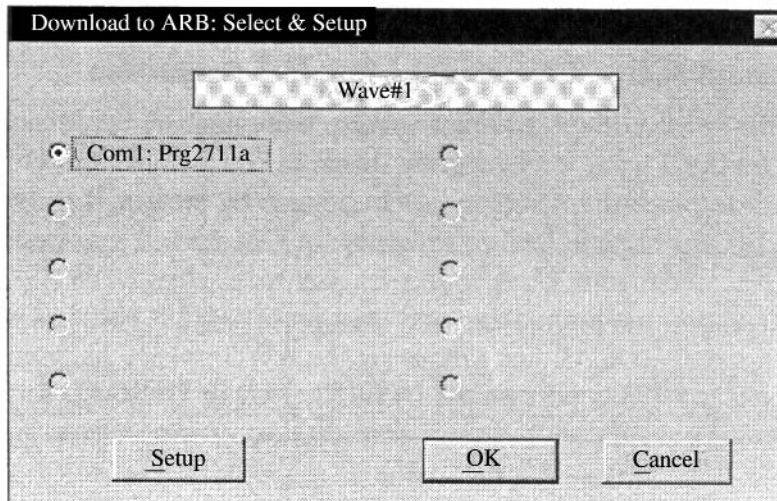
11. Choose **Download | Go** on the menu bar to initiate the downloading of waveform #3 data. You may specify the destination waveform number in the generator on the Waveform Download screen. Click **OK** to start downloading the data.
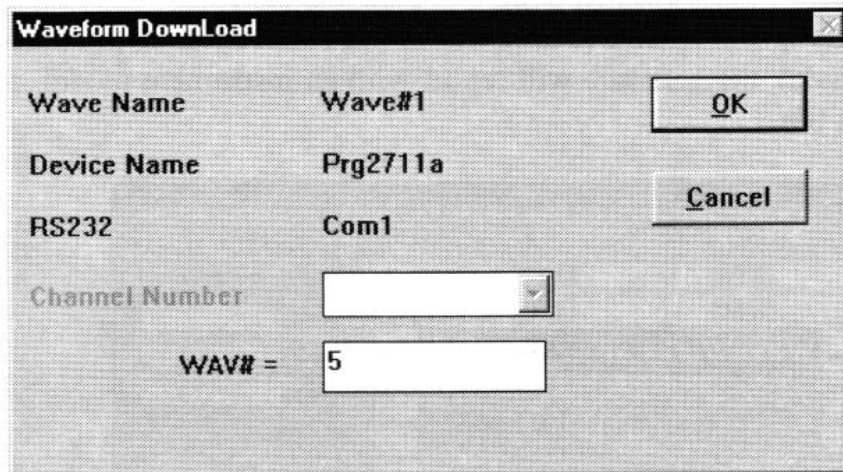
Make sure that you are using the correct cable supplied with this software. It is important to connect the cable ends to the appropriate unit (i.e. **PC** to PC COM port, **Instrument** to the waveform generator RS-232 connector).

If the **Download | Go** menu is not active (gray), WaveWorks Jr. did not find the model 2711A/2714A TEGAM Arbitrary Waveform Generator on the specified interface. Check that the arbitrary waveform generator is properly connected to the computer and turned on.

> **Important Note--Changing the Interface Connection**
> If GPIB is the current interface used to communitcate between an AWG and a PC and you want to change the interface connection from GPIB to RS-232, be sure to place the AWG in LOCAL mode by pressing LOCAL button on the AWG front panel before selecting a COM port. If you want to select LOCAL mode from WaveWorks Jr., you may select DOWNLOAD or UPLOAD on the main menu and then press SETUP button. On the SETUP screen, press LOCAL and OK to set the AWG to LOCAL mode. Now, you may select a COM port on the DOWNLOAD or UPLOAD screen.

Using WaveWorks Jr

File

- New Project...
- Open Project...
- Save project
- Save Project As...
- New Wave...
- Open Wave...
- Save Wave
- Save Wave AS...
- Delete Wave
- Import Wave...
- Export Wave...
- Print...
- Print Setup...

Edit

- Copy
- Paste
- Point...
- Vertex...
- Digital Pattern...
- Harmonic...
- Sequence...

Wave

- New...
- Delete
- Setup...
- List...

Menu - WaveWorks Jr.

Func
- StdWave...
- Math...
- Sequence...

Windows
- Cascade
- Tile
- Arrange Icon

Interface

Options
- Unzoom
- Span
- Small dX
- Large dX
- Show Y axis Labels
- Show Pointer XY

Download
- Go
- Setup...

Upload
- Go
- Setup...

Menu - WaveWorks Jr.

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

About Arbitrary Waveforms

In an Arbitrary Waveform Generator (AWG), you will define a waveform, using
either the standard functions or custom profile data files to load waveform mem-
ory. An address generator sequentially presents data values to the digital-to-ana-
log converter (DAC), which converts the data into analog voltage values. This
series of sequential voltage levels describes the output waveform with the fre-
quency 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 Jr., 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 Jr. 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 Pragmatic 2714A,
with the waveform length of 1000 points, the upper frequency limit appears to
be 20kHz, since 20MS/S / 1000 = 20kHz. 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

1000 points. Then, the output frequency of the sinewave will be 5MHz, since 20kHz x 250 = 5MHz. 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 Jr. 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 Jr.

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)

21 standard functions are included in WaveWorks Jr. 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 4 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

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

where
Wave#l, 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 (231 - 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 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, 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 Jr. 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 used to perform the project are contained in this file. If you do not specify an AWG 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.

```
                    ┌─────────────────────────┐
                    │      WaveWorks Jr.       │
                    └────────────┬────────────┘
                    ┌────────────┴────────────┐
                    │     Project (*.ARB)      │
                    └────────────┬────────────┘
      ┌──────────────────────────┤
┌─────┴────────────────────┐     │
│ Instrument Setup (*.STP) │     │
└──────────────────────────┘     │
                         ┌────────┴──────────────────────────┐
                         │   Standard Waveform (*.W??)        │
                         └───────────────────────────────────┘
                         ┌───────────────────────────────────┐
                         │     Math Waveform (*.M??)          │
                         └───────────────────────────────────┘
                         ┌───────────────────────────────────┐
                         │   Sequence Waveform (*.S??)        │
                         └───────────────────────────────────┘
                         ┌───────────────────────────────────┐
                         │    Digital Pattern (*.D??)         │
                         └─────────────┬─────────────────────┘
                                 ┌─────┴─────────────────────┐
                                 │   Binary Data (*.T??)      │
                                 └───────────────────────────┘
```
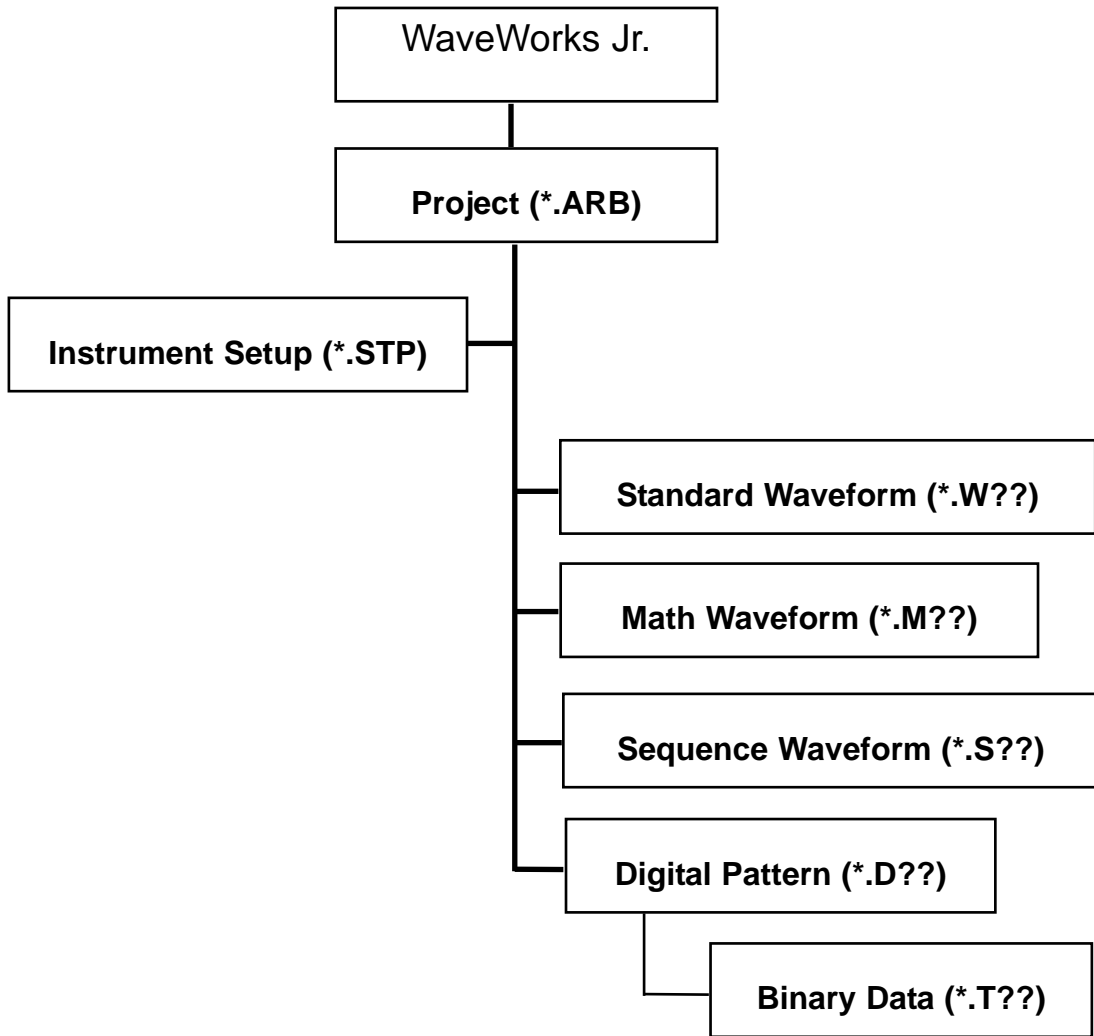
File Structure

Editors

WaveWorks Jr. 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 viewer. The waveform length must be less than 32,000 points to utilize this analyzer. After the selected waveform is separated into bits as specified by the waveform vertical resolution, you may graphically view 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

Waveform Data		Dp Editor
1	==>	4095
0	==>	2048
-1	==>	1

For 16-bit resolution data

Waveform Data		Dp Editor
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.

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 ± Vi 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.

Units	Amplitude	Phase
Cos_Sin	±1	±360°
Amp_Phs in cosine	±1	±360° (phase relative to cosine)
dB_Phs in cosine	0dB for ±1	±360° (phase relative to cosine)
Amp_Phs in sine	±1	±360° (phase relative to sine)
dB_Phs in sine	0dB for ±1	±360° (phase relative to sine)

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

Basic Operations of Mouse in WaveWorks Jr.

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 comer from the left upper comer 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

1« »1   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 I 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 Jr. 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.
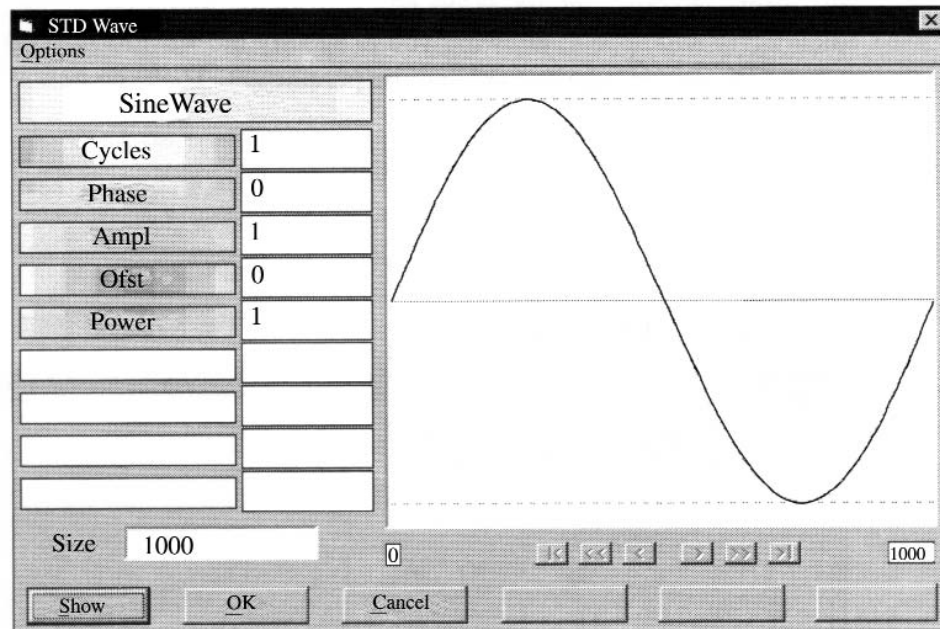
Form-Standard Waveform List
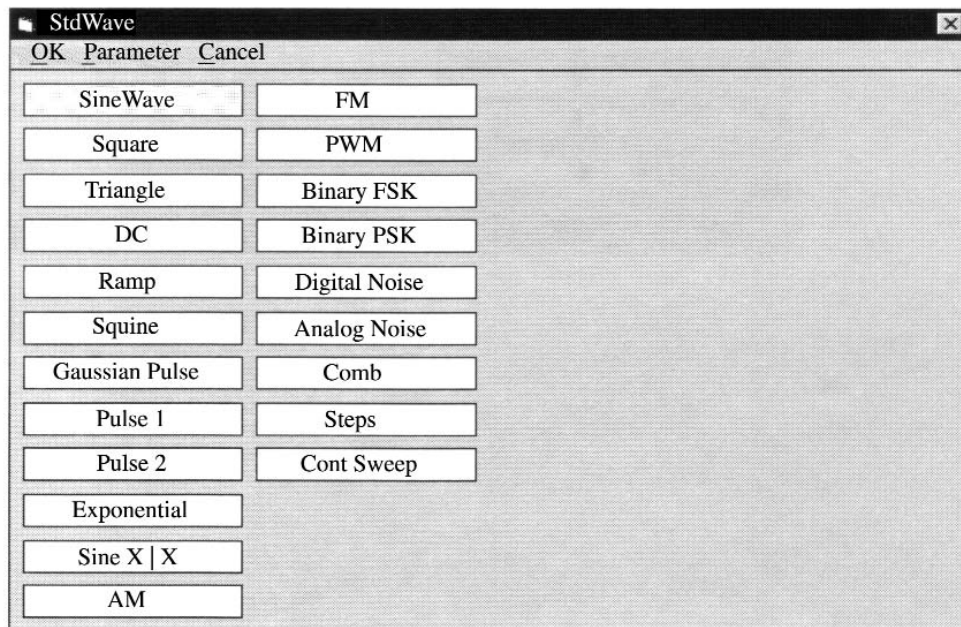
Standard Waveforms

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 **Edit | Vertex**. Draw the desired line-based waveform by using vetex editing. Modify vertex or line segments on the preview screen. Click **OK** to insert the waveshape into the waveform window.

Form-Line Draw
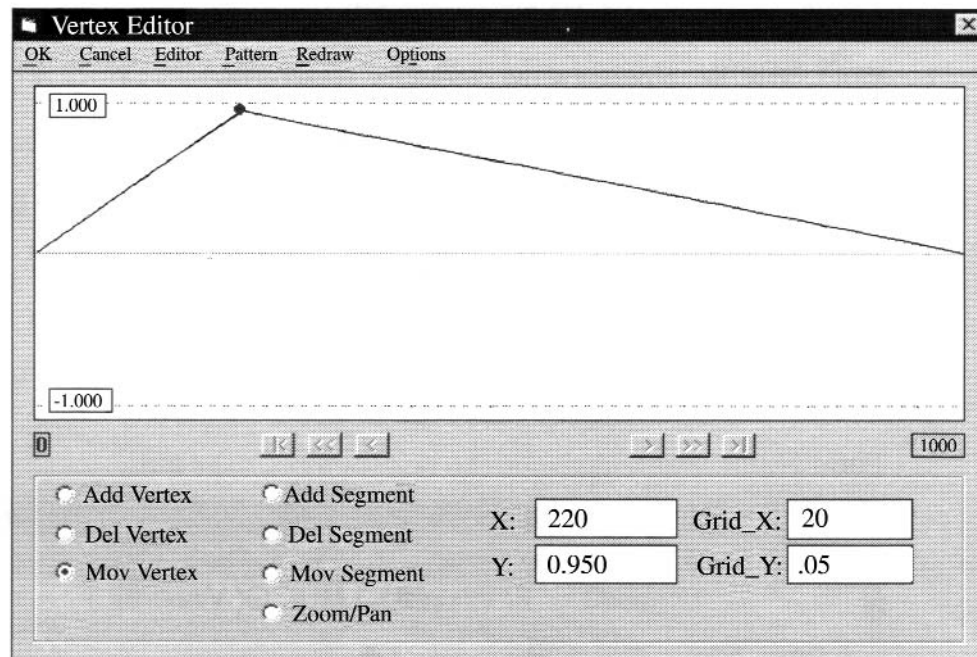
Performing Waveform Math

The math menu contains 12 transfer functions and 6 operations to be performed on any type of waveform created in WaveWorks Jr. 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

      1 Choose **Wave | Math...** from the Menu Bar.

      2. Select the first operand (Wave#l) 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

```
Math Operator                                    ⊠
┌─────────────────────────────────────────────┐
│                 ADDITION                     │
└─────────────────────────────────────────────┘

   ┌──────────┐                      ┌─────────┐
   │   ADD    │                    ▐ │0        │
   ├──────────┤                      └─────────┘
   │   SUB    │                    ▐ │0        │
   ├──────────┤                      └─────────┘
   │   MUL    │
   ├──────────┤
   │   CAS    │
   ├──────────┤
   │   INTO   │
   ├──────────┤
   │   ADIN   │
   └──────────┘


   ┌──────────┐   ┌──────────┐
   │   Ok     │   │  Cancel  │
   └──────────┘   └──────────┘
```

Form F (or G)

```
Math Transfer Function                           ⊠
┌─────────────────────────────────────────────┐
│                 F: aX+b                      │
└─────────────────────────────────────────────┘

   ┌──────────┐  ┌──────────┐   a  │1       │
   │   NULL   │  │  Rotate  │      └────────┘
   ├──────────┤  ├──────────┤   b  │0       │
   │  LINEAR  │  │  Mirror  │      └────────┘
   ├──────────┤  └──────────┘      │        │
   │   SECT   │                    └────────┘
   ├──────────┤                    │        │
   │   SQR    │                    └────────┘
   ├──────────┤                    │        │
   │   ABS    │                    └────────┘
   ├──────────┤                    │        │
   │   SQRT   │                    └────────┘
   ├──────────┤                    │        │
   │   LOG    │                    └────────┘
   ├──────────┤                    │        │
   │   POLY   │                    └────────┘
   ├──────────┤                    │        │
   │  DCcut   │                    └────────┘
   ├──────────┤                    │        │
   │   Norm   │                    └────────┘
   └──────────┘

   ┌──────────┐   ┌──────────┐
   │   Ok     │   │  Cancel  │
   └──────────┘   └──────────┘
```

Waveform Sequence

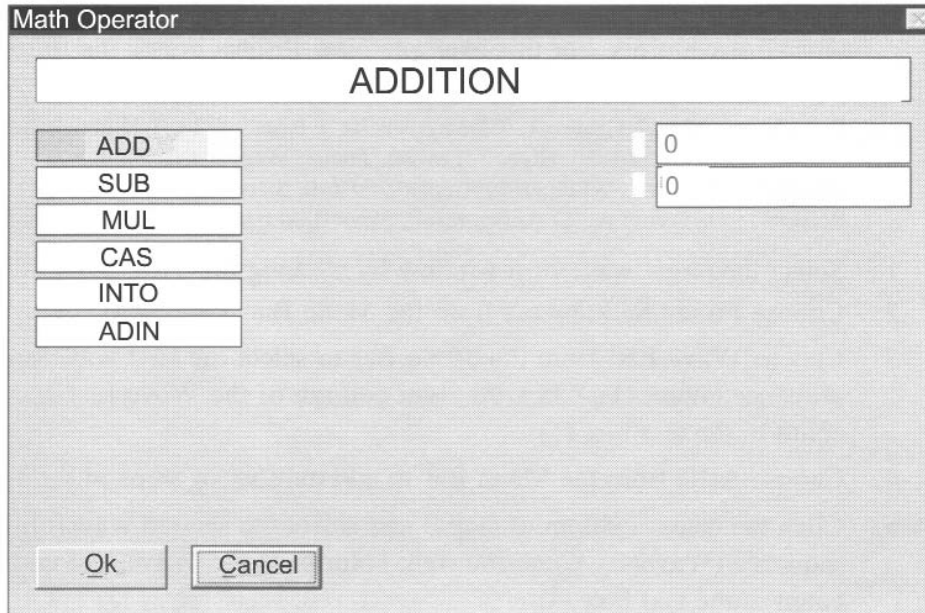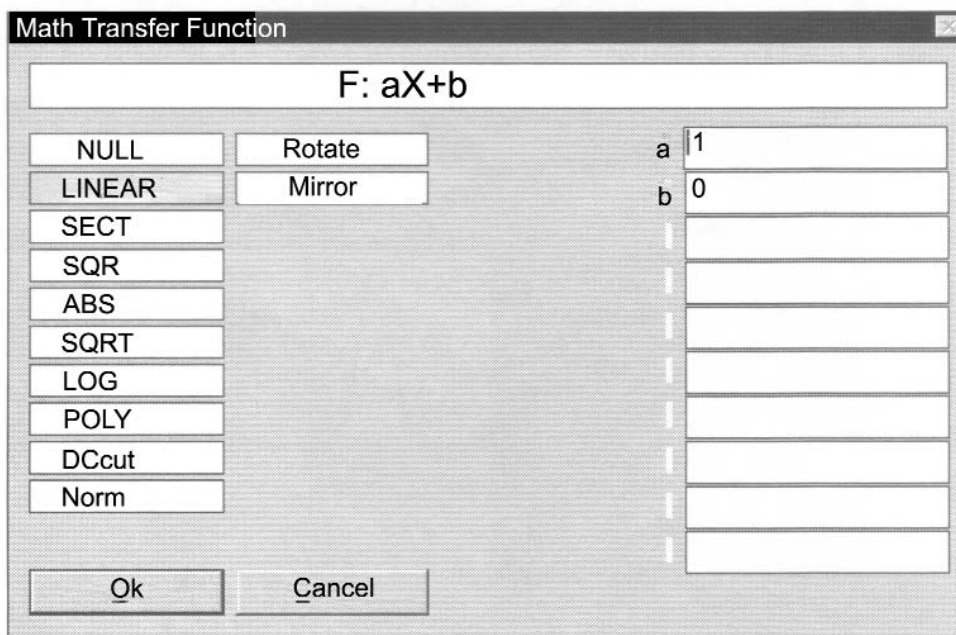You may create a long and complex waveform by looping and linking previously created waveforms. For this example New Project create the following:

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

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

Wave#3: Sin X/X, Width=100, Ampl=l, Ofst=0, Size=1000

Wave#4: to accept the Sequence result, Size^l000 (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#l). 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 **Options | Xspan | Max** and note the total waveform.)
8. Click **OK** to complete the operation or **CANCEL** to abort the process.
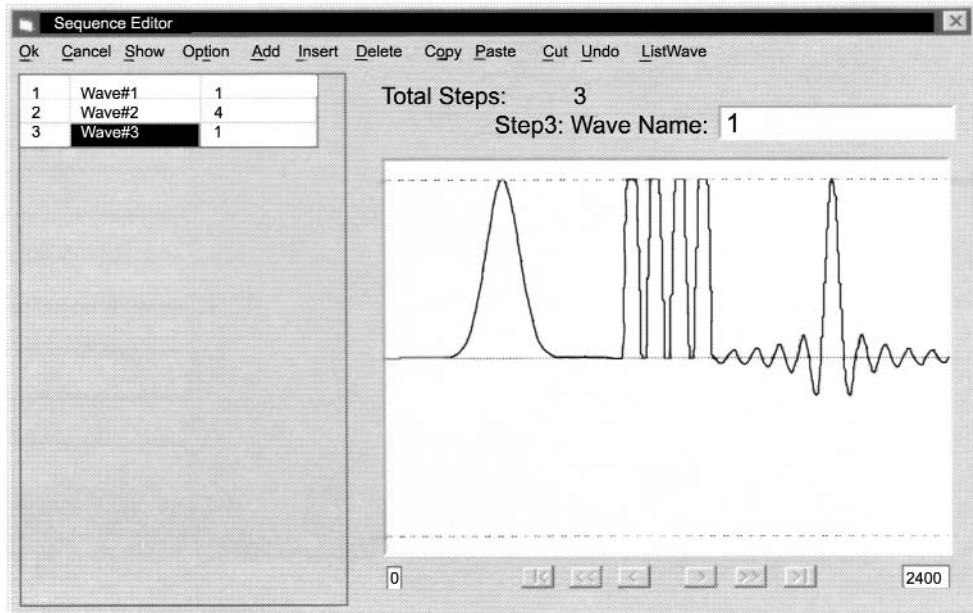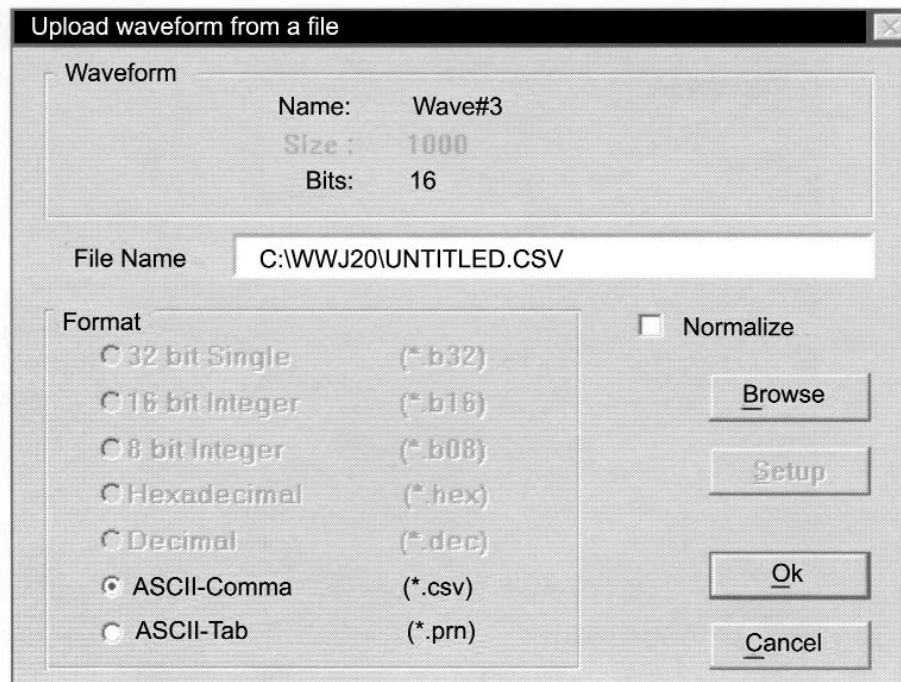
Importing Data Saved from Other Applications

WaveWorks Jr. will allow you to import waveform data created in the other applications, such as Microsoft Excel or HP® BenchLink/Arb. The application is capable of exporting in 2 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.
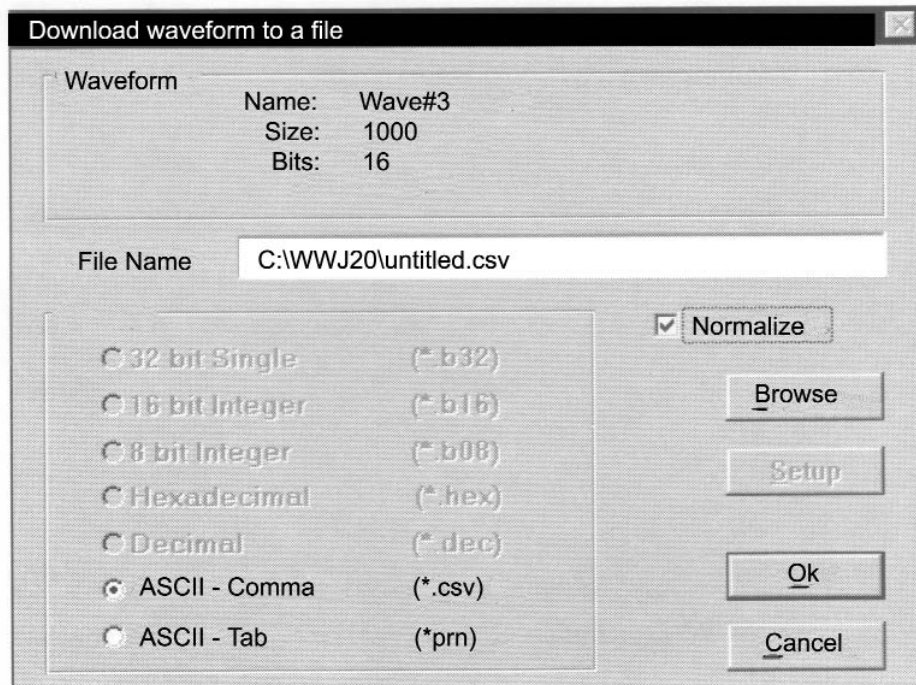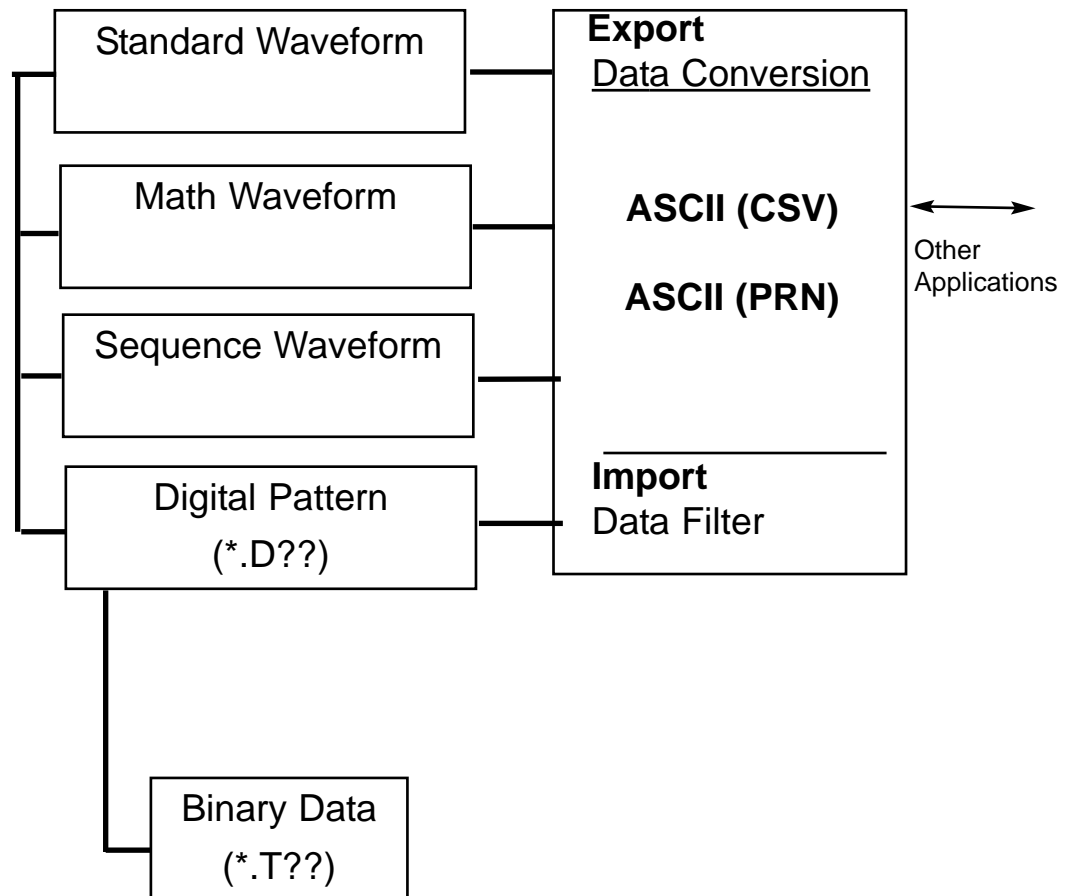
Exporting Data to Other Applications

WaveWorks Jr. will allow you to export waveform data created in this application to other applications. The application is capable of exporting in 2 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 Jr. 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 Wavefrom 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 Wavefrom to File** dialog box screen.

4. Click the **OK** button to export the data into the selected file.

```
┌─────────────────────────┐    ┌─────────────────────────┐
│   Standard Waveform     │────│ **Export**              │
│                         │    │ Data Conversion         │
└─────────────────────────┘    │                         │
                               │                         │
┌─────────────────────────┐    │   **ASCII (CSV)**       │←──→
│     Math Waveform        │────│                         │   Other
│                         │    │   **ASCII (PRN)**       │   Applications
└─────────────────────────┘    │                         │
                               │                         │
┌─────────────────────────┐    │                         │
│   Sequence Waveform     │────│ ─────────────────────── │
│                         │    │ **Import**              │
└─────────────────────────┘    │ Data Filter             │
                               │                         │
┌─────────────────────────┐    │                         │
│     Digital Pattern     │────│                         │
│       (*.D??)           │    └─────────────────────────┘
└─────────────────────────┘

   ┌─────────────────────┐
   │     Binary Data     │
   │      (*.T??)        │
   └─────────────────────┘
```

Importing and Exporting Data Files

Configuring the Interface

Before the WaveWorks Jr. 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 supplied with the instrument. 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 Jr. application can not be downloaded to the AWGs.

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 Jr. and the target AWG.

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
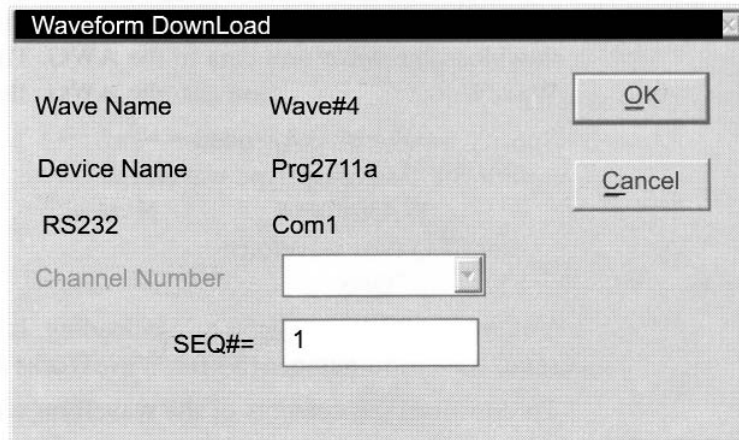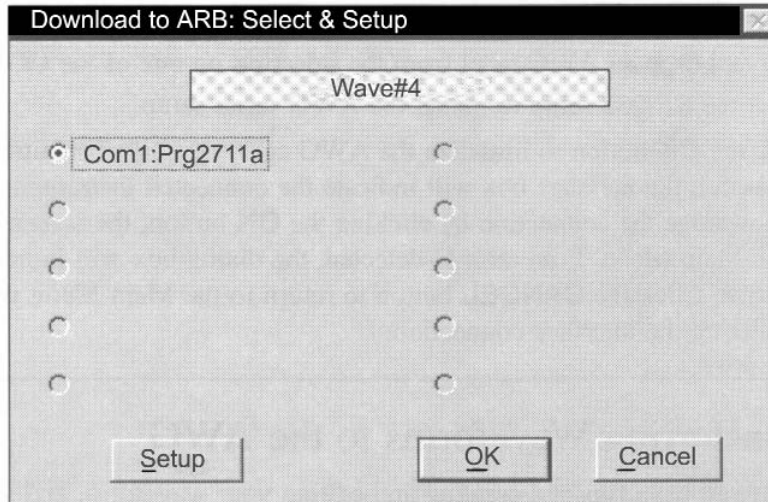
Waveform Upload

You may upload the waveform data from AWGs after the interface is initialized.
The waveform (WAV#0~99 and SEQ#0-9), selected at the time of the
initialization, will be uploaded. You may select a waveform from the Setup
screen. All the forms are identical to the Download forms.

Controlling the AWGs from WaveWorks Jr.

When you have completed the interface configuration and initialization, you are ready to communicate with the AWG. There are two important house keeping tasks to be performed on the AWG;
1) Reset the AWG to the initial states.
2) Delete unwanted user-defined waveforms or sequences in the AWG.

To reset the AWG to the initial states:

1. Choose **Download | Setup** to open the 'Download to ARE' screen.
   Click one of the interface selection buttons.
2. Click the **SETUP** button to open the AWG setup screen.
3. Click the **RESET** button to initialize the AWG.
4. Click **OK** to return to the 'Download to ARB' screen.

*This procedure is the same as sending ***RST** (or **RESET-CURR**) command over the interface and will not affect the waveform data.*

*If you wish to restore the initial states including the waveform data, follow the reset instruction in page 6-2 of the 2711A/2714A manual. This procedure is the same as sending **RESET-ALL** command over the interface.*

See pages 7-12 and 7-13 of the 2711A/2714A manual for the reset parameter listing.

To delete unwanted user-defined waveforms or sequences in the AWG:

1. Choose **Download | Setup** to open the 'Download to ARB' screen.
   Click one of the interface selection buttons.
2. Click the SETUP button to open the AWG setup screen.
3. Choose **Wave#** or **Seq#** to be deleted from the pull-down list.
   Then, click the **SELECT** button.
4. Choose **Wave | Remove** from the menu bar.
5. Click **OK** on the message screen.
6. Click **OK** to return to the 'Download to ARB' screen.

Saving Projects and Waveforms

Arbitrary waveforms can be saved from WaveWorks Jr. 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.

Printing Waveforms

Waveforms can be printed when a waveform window is selected in WaveWorks Jr. 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.

Chapter 5

Sample Waveforms

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

Sample Files

The following sample project files were placed in the **\WWJ20\SAMPLES** directory during installation. Most of these waveforms in the project files were created in WaveWorks Jr.

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

ASCII Files (*.csv,*.prn)

Use **File | Import...** to import one of these files into a waveform window. Once a file is imported, the waveforms can be edited, analyzed, and saved.

ASCII File Name	Description
SINEWAVE.CSV	100 point sinewave in comma separated value (csv)
SINC.PRN	100 point sinc wave in tab separated format

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
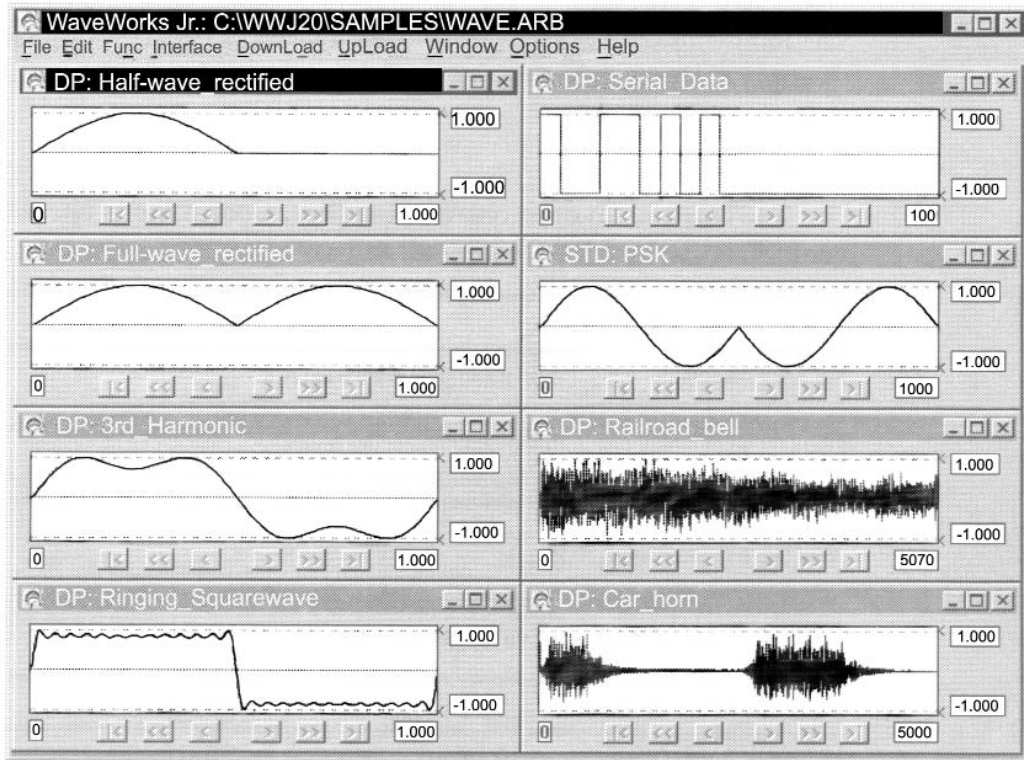
Waveform Windows

Wave List

	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)
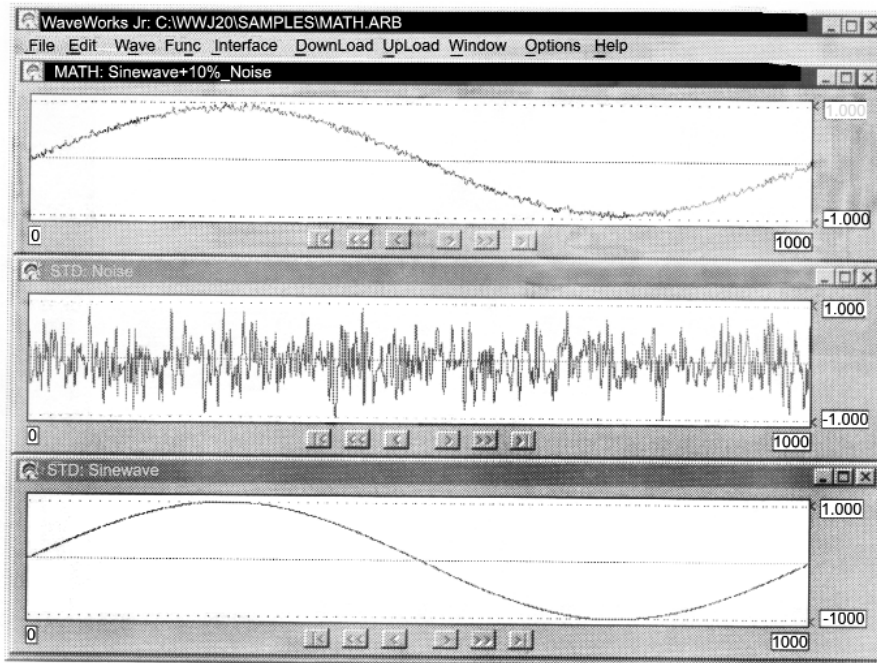
Wave List

	NAME	SIZE	TYPE	FileName	SAVED	DEVICE	Downloaded
1	Sinewave	1000	STD	MATH.W01	Yes		No
2	Noise	1000	STD	MATH.W02	Yes		No
3	Sinewave+10%_Noise	1000	MATH	MATH.W03	Yes		No

Wave MATH screen
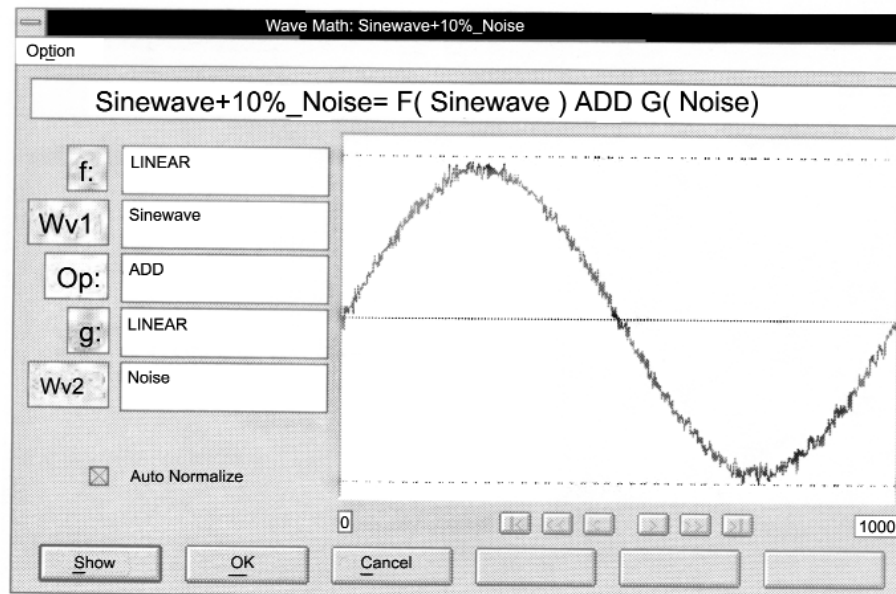
Sequence Waveform Example (SEQ.ARB)
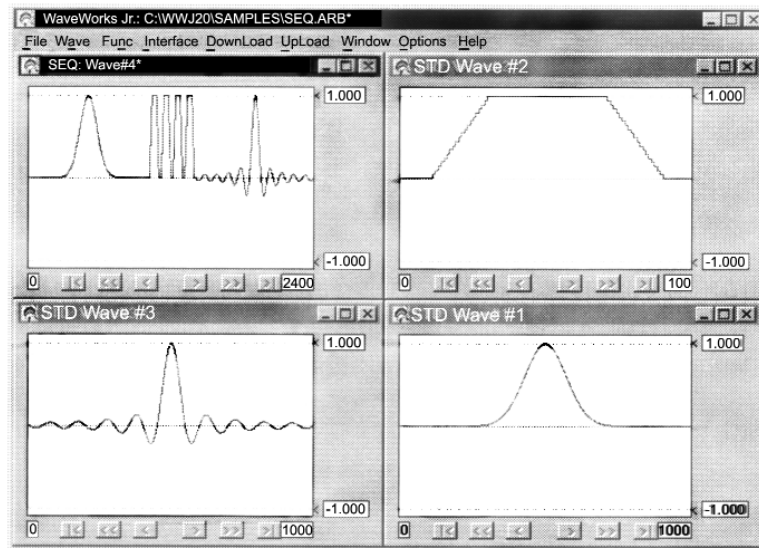
Wave List

Sequence Editor

Chapter 6

Standard Functions

Waveform List

StdWave

OK Parameter Cancel

SineWave	FM
Square	PWM
Triangle	Binary FSK
DC	Binary PSK
Ramp	Digital Noise
Squine	Analog Noise
Gaussian Pulse	Comb
Pulse 1	Steps
Pulse 2	Cont Sweep
Exponential	
Sine X/X	
AM	
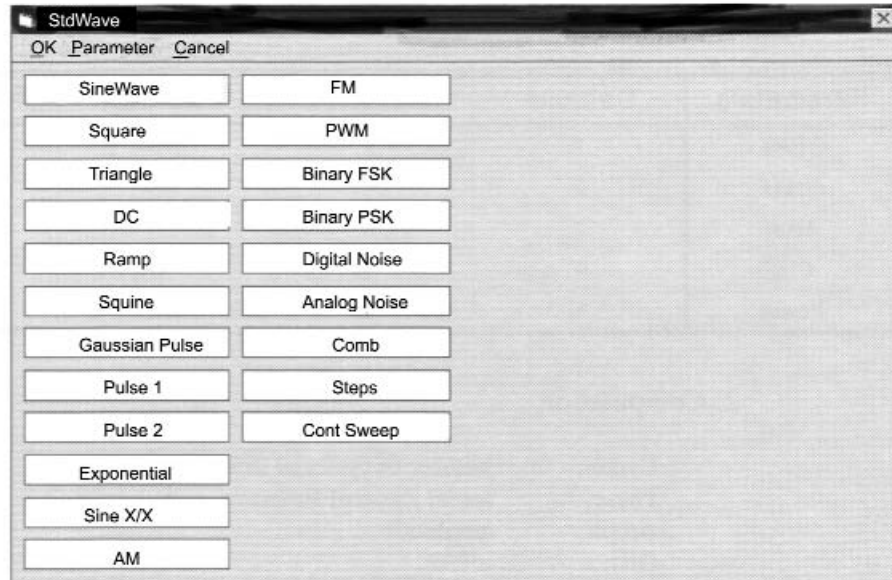
Sine wave

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

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
$\omega = 2 * \pi * Cycles / N$
$\Phi = Phase / 180 * \pi$
FOR i = 0 to N-l
        Wave(i) = Ampl * (SIN (ω * i +Φ)) ^ 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.

    $0° \leq$ Phase $< 180°$ Amplitude = 1

    $180° \leq$ Phase $< 360°$ Amplitude = -1

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. Parameter

Parameter	Default	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
$\omega = 2 * \pi * Cycles / N$
$\Phi = Phase / 180 * \pi$

FOR i = 0 to N-1
     Wave(i) = Ampl * m RAMP($\omega * i + \Phi$) + Ofst
NEXT i
     where, for $0 \leq \theta < 2\pi$, mRAMP $(\theta) = \theta/\pi - 1$

Squine

1. Parameters

Parameters	Defaults	Minimum	Maximum	Resolution
Transistion %	10	0	50	0.001
Phrase	0	-360	360	0.001
Ampl	1	-1	1	0.001
Ofst	0	-1	1	0.001

2. Computation

Transition%: ratio in % of number of points used to define the rise and fall edge of the waverform 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.
(ArcSin (0.8) / π / 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. 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

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

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

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-l
            $\Phi = 2 * \pi * (i - N / 2) /$ Width
            Wave(i) = Ampl * SIN (Φ) / Φ + 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 = waveform length
$\omega m = 2 * \pi * ModFreq / N$
$\Phi m = ModPhase / 180 * \pi$
$\omega c = 2 * \pi * CrrFreq / N$
$\Phi c = CrrPhase / 180 * \pi$

FOR $i = 0$ to N-l
   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-l
        MOD = COS ($\omega m * i + \Phi m$)
        Wave(i) = Ampl * SIN ($\omega c * i + \Phi c$ - Index * 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

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

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. Parameters

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°

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

Chapter 7

Transfer Functions

Transfer Function List

Math Transfer Function

F: aX+b

NULL	Rotate	a	1
LINEAR	Mirror	b	0
SECT			
SRQ			
ABS			
SQRT			
LOG			
POLY			
DC cut			
Norm			

OK   Cancel
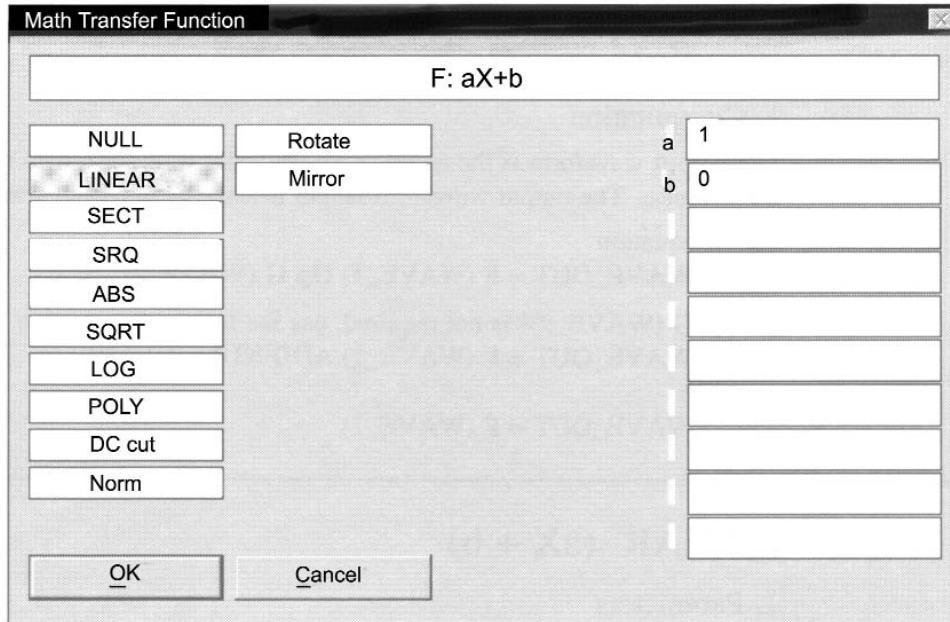
Null

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

  WAVE_OUT = **F** (WAVE_1) **Op G** (WAVE_2)

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

  WAVE_OUT = **F** (WAVE_1) **ADD NULL** (WAVE_1)

to create

  WAVE_OUT = **F** (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
    WAVE_OUT (i) = a*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 X^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 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

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 wave

form 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 (±a 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) $\geq$ 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

POLY (Σ [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

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

Parameter	Default	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.

Math Operators

Math Operator List

Math Operator		☒
ADDITION		

ADD		0
SUB		0
MUL		
CAS		
INTO		
ADIN		

OK   Cancel
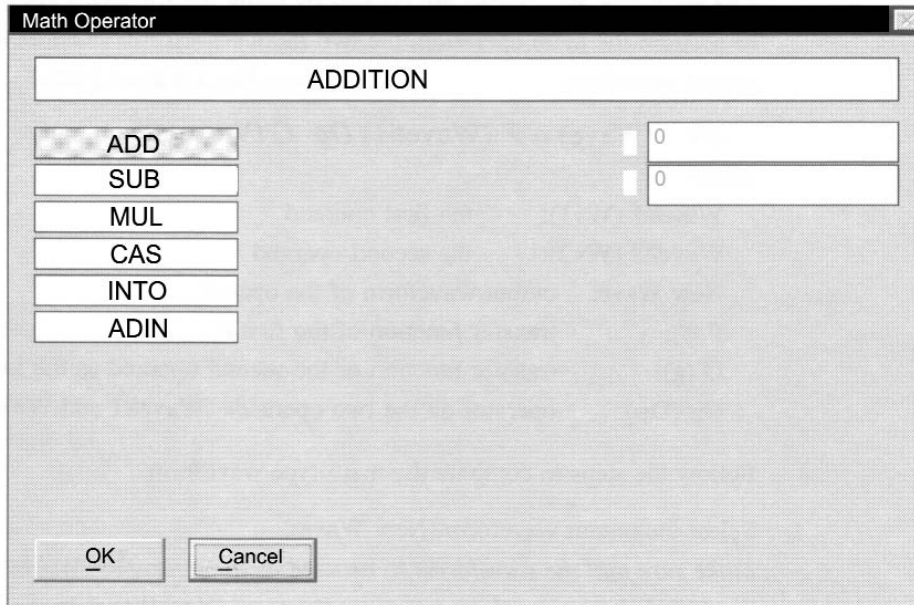
Introduction

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 (**W<u>a</u>ve** | **<u>L</u>ist**).

(New Wave) = F (Wave#1) Op G (Wave#2)
where

Wave#1 (**Wv1**):	the first operand
Wave#2 (**Wv2**):	the second operand
New Wave:	output waveform of the operation
F (**f**):	transfer function of the first operand as the input
G (**g**):	transfer function of the second operand as the input
Op (**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 opertaion 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 waverform 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 opera-
tion 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

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

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

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