MODEL 2711A
2MS/s Arbitrary Waveform Generator
Operation Manual 810021-CD
Rev. D

The TEGAM 2711A is a high resolution 2 MS/s Arbitrary Waveform Generator with integrated Windows® based waveform creation capability. The simplified front panel and the WaveWorks™ Jr. waveform creation software make the 2711A the easiest way to create and output the waveforms you need. The additional channels needed for multi-phase applications can be met with a simple connection between two or more 2711As. Its combination of bench-top and system features, GPIB and RS232 interfaces and the integrated software which is included and runs under Windows make this waveform generator package a versatile tool useful to create your waveforms for mechanical simulation, engine simulation, medical electronics, modulated sine wave applications and many more applications.

Lab-quality performance
• 10 commonly used waveforms front-panel selectable
• Continuous or triggered output--6 standard modes
• 16-bit high-fidelity waveforms--high resolution output up to 2 MS/s
• Very large waveform memory--64k words
• Loop and link up to 100 waveforms (Sequence option)

Convenient bench-top features
• Simplified front panel includes control knob and back-lighted LCD
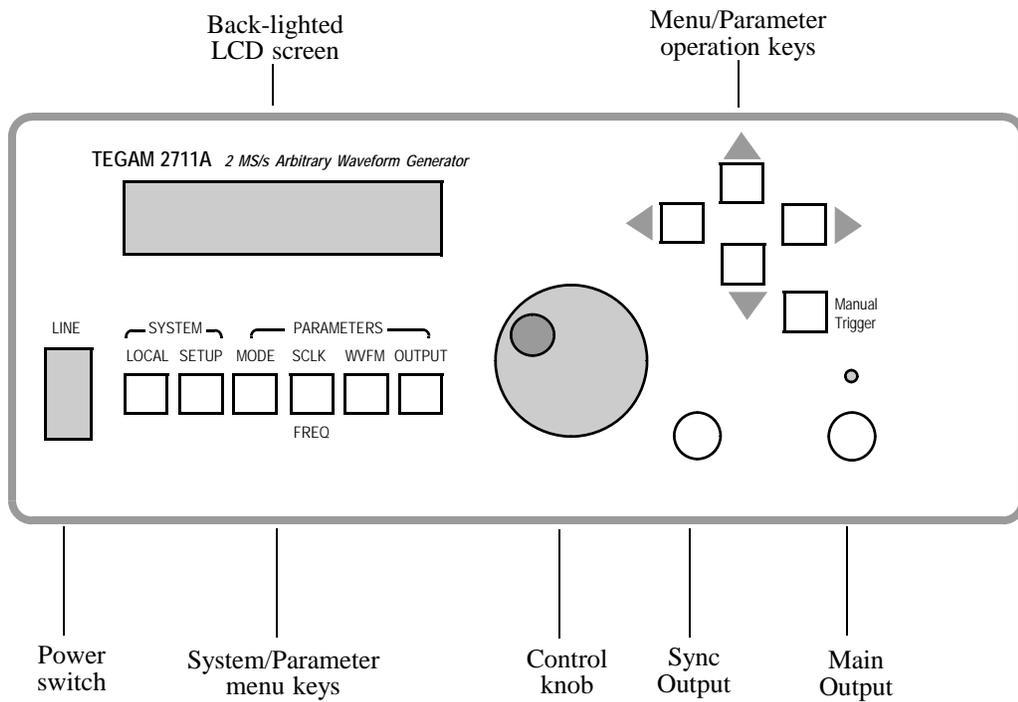• Portable, small profile package

System features
• Waveform creation software under Windows included
• RS-232 and GPIB (IEEE488.2) included
• Multiple channel operation (multiple units)

TEGAM 2711A
2 MS/s Arbitrary Waveform Generator

The Front Panel

Back-lighted
LCD screen

Menu/Parameter
operation keys

TEGAM 2711A *2 MS/s Arbitrary Waveform Generator*

Manual
Trigger

LINE

SYSTEM
LOCAL SETUP

PARAMETERS
MODE SCLK WVFM OUTPUT

FREQ

Power
switch

System/Parameter
menu keys
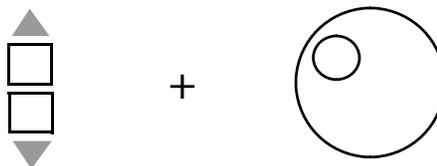
Control
knob

Sync
Output

Main
Output

Front-Panel Entry

Use the knob and the arrow keys to modify the displayed number.
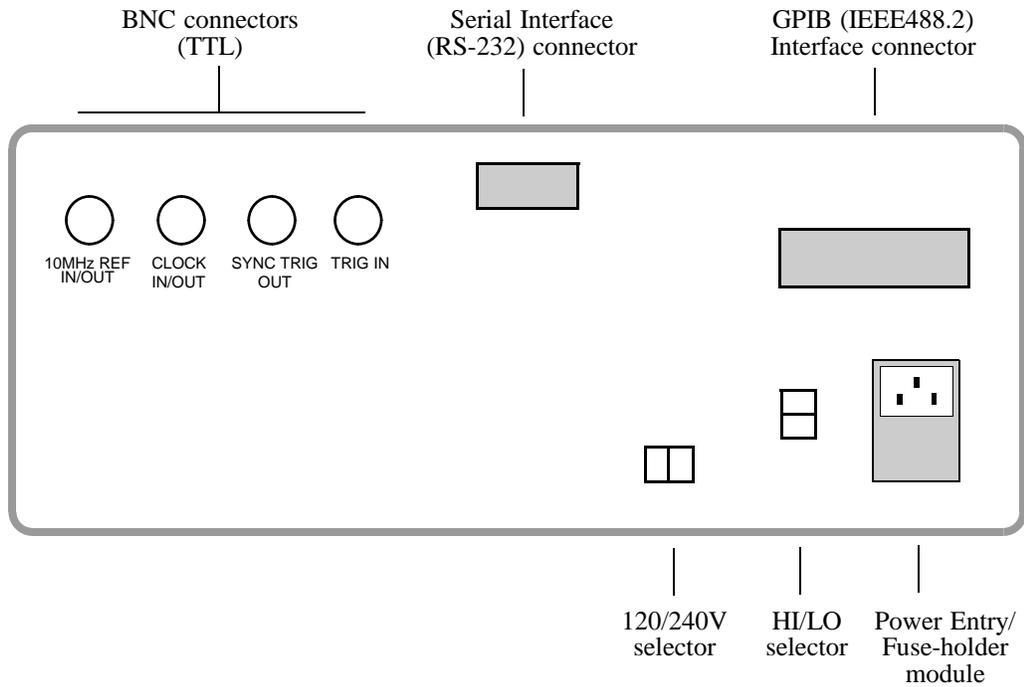
+

Use the System/Parameter menu keys and the knob to make selection.

MODE

+

Use the arrow keys and the knob to select the menu parameter.

+

The Rear Panel

Mains Voltage Range (V)	Power Mains Setting		Fuse Rating
	Hi / Lo Selector	Range Selector	
90 ~ 105	Lo	120V	0.8A GDC
108 ~ 126	Hi		
198 ~231	Lo	240V	0.4A GDC
216 ~ 252	Hi		

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Chapter 6 - Performance Verification

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Technical Data Sheet
TEGAM 2711A 2MS/s Arbitrary Waveform Generator

Output Waveforms
Up to 100 High-Definition User-defined Waveforms,
Standard Waveforms: Sine, Square, Triangle, Ramp, DC,
Exponential, Haversine, Pulse, Gaussian, Sin x/x (Sinc).

Sequence Generator (Optional)
Waveform: Transient-free Loop and Link
Repetitions: Loop: 1,048,575 times Link: 100 waveforms
Program: 100 Steps per Sequence
File: 10 Sequences

Waveform
Storage: 100 waveforms
Resolution:
   Horizontal Points: 65,500 max.
   Vertical Points:16 bits, 65,536 (-32768 to +32767)
Sample Rate:
   Range: 0.1Hz to 2MHz (10s to 500ns)
   Resolution: 4 digits
   Accuracy:±50ppm
Transition Time: <150ns
(Tested with square wave, filter off, 10Vp-p, 50Ω
termination.)
THD + Noise: -86dB typical (2kHz sinewave)
*(Tested with 80kHz measurement bandwidth, 2MHz clock, sinewave, 1000
points, filter on, full amplitude, 50Ω termination.)*

Amplitude and Offset

Range	Resolution	Accuracy
±1.00 to 10V	10mV	1% of setting + 20mV
±100mV to 999mV	1mV	3% of setting + 5mV
±10mV to 99.9mV	100μV	5% of setting + 1mV

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

Selectable Analog Filter
Cutoff: 700kHz, 7th order; 40kHz, 3rd order

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

Outputs
Output: Front-panel main waveform output, 50Ω
impedance.
Sync Output: Front-panel TTL sync output, 50Ω
impedance.
Clock Out: Rear-panel AWG waveform sample clock
output (TTL). x2 sample clock.
Reference Out: Rear-panel internal 10MHz reference
output (TTL).
Sync Trigger Out: Triggers additional units

Inputs
Trigger Input: Rear-panel TTL trigger input for triggered,
gated, burst, toggled and master-slave modes.
External TTL Sample Clock Input: ≤ 4MHz
Reference In: Rear-panel 10MHz reference input will
phase lock the internal crystal-controlled oscillator.

Trigger Sources
External Trigger Input
Manual Trigger

Waveform Creation Tools
Software: WaveWorks Jr. for Windows
Operating System: Windows 95 or 3.1; MS-DOS 6.2
PC Requirements: 486DX or better with 4MB RAM space
Interface: COM port or National Instrument AT-GPIB card
(or equivalent)
Standard Function: 21
Math Operation:
   Operators: 6
   Transfer Function: 12
Sequence Creation (optional hardware required)
Waveform Analysis:

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

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

Computer Interface
RS-232C: 19.2kBaud. max.
GPIB: IEEE Std. 488.2-1987

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

Weight and dimensions are approximate. Errors and omissions excepted.
Prices and specifications subject to change without notice.

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

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

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

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

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

Performance Verification: Chapter 6 describes the procedure to verify the 2711A specification.

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

Advanced Remote Operation: Chapter 8 describes in details the remote interfaces. It is intended for use by experienced systems programmers to control every feature of the 2711A from both RS-232 and GPIB.

In this manual

1

Quick Start

To prepare the generator for use

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

1. Check the list of supplied items.

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

• One power cord
• WaveWorks Jr. waveform creation software with manual
• The instrument operation manual

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

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

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

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

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

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

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

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

To set the output frequency for standard waveforms.

At power-on, the generator outputs a cw sine wave at 1 kHz. The following steps will show you how to change the output frequency to 1.2 kHz. Remember that the output frequency is computed as shown. Please note that the standard waveforms are restricted to one cycle of the selected waveform for the simplicity of operation. Therefore, the frame rate is the same as the frequency of the waveform.

Waveform Frequency
       = [(Sample Clock) / (Waveform Length)]*(Number of Cycles in the Waveform Frame)

Standard Waveform Frequency = (Sample Clock) /1000   (default value)

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

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

```
STDW:SINE:
Freq =        1.000 kHz
```

2. Enter the magnitude of the desired frequency.

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

```
STDW:SINE:
Freq =        1.200 kHz
```

3. Select the desired frequency range.

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

```
STDW:SINE:
Freq =        1.200 kHz
```

1

To set the sample clock rate.

At power-on, the generator outputs a free-running sine wave at 1 kHz with an amplitude of 1.0 V peak-to-peak (into 50Ω termination). If you select any of the standard waveforms, you can only control the frequency. If you select a user-defined waveform or sequence, you can control only the sample clock rate. The following steps will show you how to change the sample clock rate of a user-defined waveform or an optional sequence. The output frequency of any waveform is:

Waveform Frequency
    = [(Sample Clock) / (Waveform Length)]*(Number of Cycles in the Waveform Frame)

1. Press WVFM (waveform) button and turn the knob to select a User-defined waveform.

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

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

```
USER:WAV#0:
Sclk =        1.000 MHz
```

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

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

```
USER:WAV#0:
Sclk =        1.200 MHz
```

4. Select the range of the desired frequency.

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

```
USER:WAV#0:
Sclk =        1.200 MHz
```

To set the output amplitude

At the initial power-on, the generator outputs a cw sine wave at 1 kHz with an amplitude of 1V peak-to-peak (into 50Ω termination). The following steps will show you how to change the amplitude to 2.5 V peak-to-peak.

1. Press OUTPUT button.

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

```
OUTPUT:
Ampl =        1.000   V
```

2. Select the digit you are going to modify.

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

```
OUTPUT:
Ampl =        1.000   V
```

3. Enter the magnitude of the desired amplitude.

Turn the knob to set the digit to 2.

```
OUTPUT:
Ampl =        2.000   V
```

4. Enter the magnitude of the desired amplitude.

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

```
OUTPUT:
Ampl =        2.500   V
```

To set the output offset voltage.

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

1. Press OUTPUT button.

Then, select Offset by turning the knob.

```
OUTPUT:
Ofst =        0.000   V
```

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

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

```
OUTPUT:
Ofst =        1.000   V
```

Amplitude and DC Offset Ranges
TEGAM 2711A utilizes unique combinations of the input and output attenuators for the output amplifier in order to accomplish the signal attenuation. Therefore, if DC offset is applied to the signal, the following restrictions must be observed.

Amplitude Range	Legal Amplitude+DC Offset Limits
10mV ~ 10.2V when | DC Offset | ≤ 10.2V	Amplitude + | DC Offset | ≤ 10.4V

To select a standard waveform.

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

1. Press WVFM (waveform) button.

Then, select Standard by turning the knob. The default length is set to 1000 points. You may change the length by placing the cursor under the number. If you change the length to 200 points, the output frequency will increase by 5 times.

```
WAVEFORM:
Standard    1000Pts    ↓
```

2. Press the down-arrow key to waveform selection menu.

Turn the knob to select one of the 10 standard waveforms.

```
WVFM:STDW:           ↑
Ramp                 ↓
```

3. Press the down-arrow key to select parameter(s).

```
STDW:RAMP            ↑
Duty Cycle  = 100.0%  ↓
```

4. Press the right-arrow key to set parameter.

```
STDW:RAMP            ↑
Duty Cycle  = 100.0%  ↓
```

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

1

To select a user-defined waveform.

At the initial power-on with the factory setting, the generator outputs
free-running sinewave at 1 kHz. The following steps will show you how to
select a user-defined arbitrary waveform. All user-defined waveforms must be
created on the PC and downloaded to the 2711A using WaveWorks Jr. or other
software prior to the selection. However, we have loaded the first three
user-defined waveform locations with the WaveWorks Jr. sample waveforms for
your verification.

1. Press WVFM (waveform) button.

Then, select **User defined** by turning the knob. You will be able to view the
following waveforms, unless you have already over-written the waveform
location with a new waveform or deleted the waveform.

> Wav# = 00 : Cardiac, Size = 1000 points
> Wav# = 01 : Gaussian Pulse, Size = 1000 points
> Wav# = 02 : Pulse, Size = 100 points
> Wav# = 03 : Sinc,   Size = 1000 points
> Wav# = 04 : DC, Size = 1000 points

```
┌─────────────────────────────┐
│ WAVEFORM:            ↓       │
│ User defined                │
└─────────────────────────────┘
```

2. Press the down-arrow key to waveform selection menu.

Turn the knob to select one of the user-defined waveforms. If the waveform
number shows (**Empty**), the waveform does not contain any data.

Note: The length can not be changed from the instrument front panel.

```
┌─────────────────────────────┐
│ WVFM:USER:             ↑    │
│ Wav#= 01         1000Pts    │
└─────────────────────────────┘
```

3. View the 5 preloaded waveforms or any other user-defined waveforms.

To select a sequence waveform. (option)

The following steps will show you how to select a sequence waveform. The sequence generator option must be installed in the 2711A prior to proceeding with the following steps. All user-defined waveforms must be created on the PC and downloaded to the 2711A by using WaveWorks Jr. software before making the sequence selection. However, we have pre-loaded the first three user-defined waveforms with the WaveWorks Jr. sample waveforms. We will utilize these waveforms to demonstrate the sample sequence.

1. Press WVFM (waveform) button.

Then, select **Sequence** by turning the knob.

```
WAVEFORM:          ↓
Sequence
```

2. Press the down-arrow key to waveform selection menu.

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

```
WVFM:SEQ:              ↑
Seq#= 0     (Loaded)   ↓
```

3. Press the down-arrow key to view step parameters or to modify the steps.

Turn the knob to select a step.

Note: Each **Seq#** may contain up to 100 steps, use up to 100 user-defined waveforms which may be repeated up to 1,000,000 repetitions (shown in the digits to the right of the asterisk (*****)). If the repetition is set to zero the step is deleted. If all steps are deleted, the **Seq#** will indicate **Empty**.

```
SEQ#0:                  ↑
Step00=Wav00*0000000
```

Note: Sequence waveforms do not run in Burst Mode. If you have set the 2711A to Burst Mode while selecting one of the standard waveforms or user-defined waveforms and then you select a sequence waveform, the instrument will automatically be set to Trigger Mode. If you select one of sequence waveforms and then select Mode, you will not be able to select Burst Mode until you select either standard or user-defined waveform.

To select operating mode

The following steps will show you how to select an operating mode and output one cycle of a sinewave when a trigger signal is applied.

1. Press WVFM (waveform) button.

Then, select **Standard** by turning the knob.

```
WAVEFORM:
Standard    1000 pts    ↓
```

2. Press the down-arrow key to waveform selection menu.

Turn the knob to select **Sinewave**. You will be able to view the sinewave, unless you have already altered the **Mode** setting, the default is Continuous..

```
WVFM:STDW:             ↑
Sine                   ↓
```

3. Press the Mode key to change the operating mode.

Turn the knob to select **Trigger** mode.

```
STDW:SINE;
Mode = Trigger
```

4. Press the Manual Trigger key to output a single cycle of a sinewave.

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

2

About Arbitrary Waveforms

2

Waveform Generation

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

The waveforms you create are a series of data points consisting of X- and Y-axis values. For 16-bit generators, such as the TEGAM 2711A, the Y values between +32767 and -32768 are used. In describing the first point, 0, is given a Y value. The next point has another Y value, and so on up to the last address in your waveform. This series of points make up the waveshape.
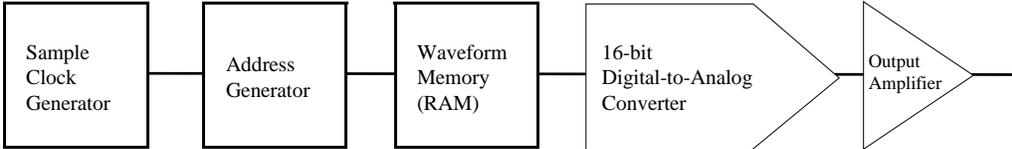
Waveform Cycle

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

Frequency=1X to 3X

1000 points   1000 points

2
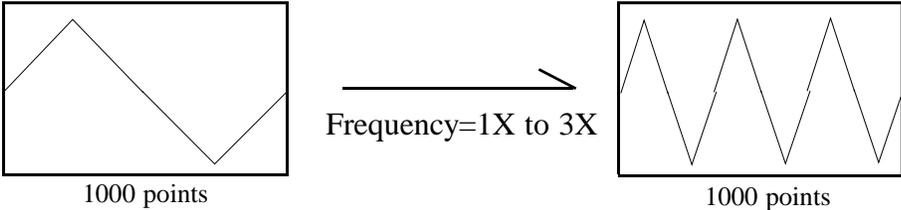
More on Waveform Cycle

TEGAM 2711A arbitrary waveform generator may sample the data points up to a maximum of 2 MS/s. The maximum frequency of the output is determined by the sample rate divided by the number of points. For a 2 MHz arbitrary waveform generator with a waveform length of 1000 points, the upper frequency limit appears to be 2 kHz, since 2 MS/s / 1000 = 2 kHz. However, if you repeat the segment, such as a sinewave, up to the minimum required number of samples (4 samples/segment), you can replicate up to 250 segments within the waveform length of 1000 points. Then, the output frequency of the sinewave will be 500 kHz, since 2 kHz x 250 = 500 kHz.

Digital and Analog Scaling

Whenever possible range the Y-values of a waveform between -32768 to +32767 in the memory 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 a simple command. For instance, if you have a sinewave in the waveform window that ranges from -32768 to +32767 you can specify the output at 5 volts peak-to-peak. Automatically the -32768 relative amplitude will be scaled to -2.5 volts and the +32767 relative amplitude will be scaled to +2.5 volts. The sinewave will be centered around zero volts. The desired output voltage may be set on the front panel of the generator or on the Download Setup form before the waveform is sent to the 2711A.
If you set the output amplitude to 10 volts peak-to-peak and then you download a waveform with Y-values between +16384 and -16384, you have the same +/-2.5 volt sinewave output. It is very important to understand the differences between digital scaling and analog scaling. See the following page for the illustration.

Other Considerations

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

2

Examples - Digital and Analog Scaling

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

Case 1
Ampl=5.0V
Waveform Vertical Size = 65536 points
Sinewave Amplitude = 5Vp-p
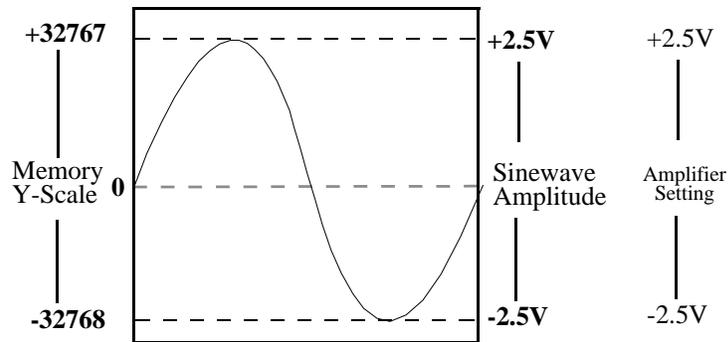
Case 2
Ampl=10.0V
Waveform Vertical Size = +/-16384 points
Sinewave Amplitude = 5Vp-p

2 - 4

2
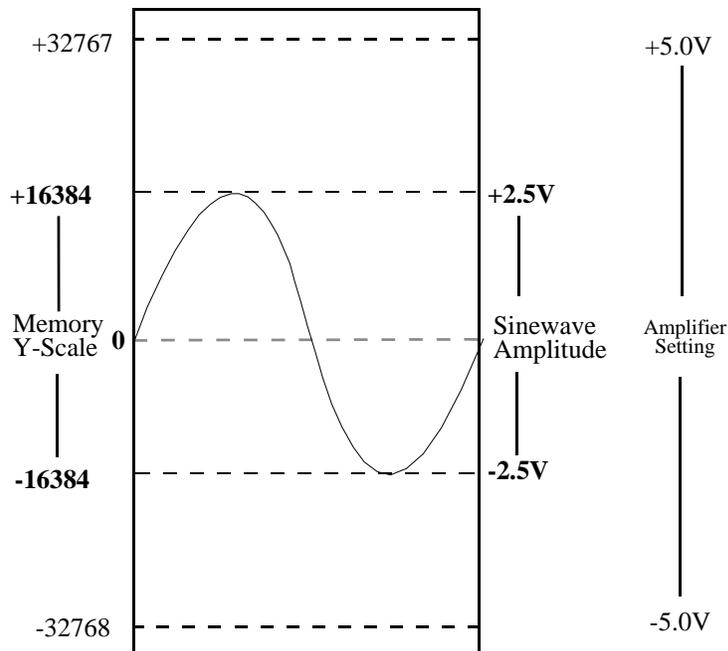
Waveform Types

TEGAM 2711A arbitrary waveform generators can create two types of waveforms, namely standard waveforms and user-defined waveforms. In addition, if you have installed the optional Sequence Generator in the 2711A, you may loop and link up to 100 user-defined waveforms.

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

User-defined Waveforms (Arbitrary Waveforms)
You must create user-defined waveforms on a PC and download them to the memory of the 2711A. You may use the WaveWorks Jr. software to create user-defined waveforms. User-defined waveforms are utilized to create sequence steps in the optional sequence operation.

Sequence Waveforms (optional)
You can create a virtual waveform using the user-defined waveforms in the waveform memory and repeating the waveforms any number of times without increasing the size of the waveform memory. Each step is defined with one of the user-defined waveforms and the number of repetition of this waveform. You may create up to 100 steps utilizing up to 100 user-defined waveforms in each sequence waveform.

Waveform Memory

WAVE#01	WAVE#02	WAVE#03	Standard Wave (4≤size≤1000 pts)

Sequence Generator
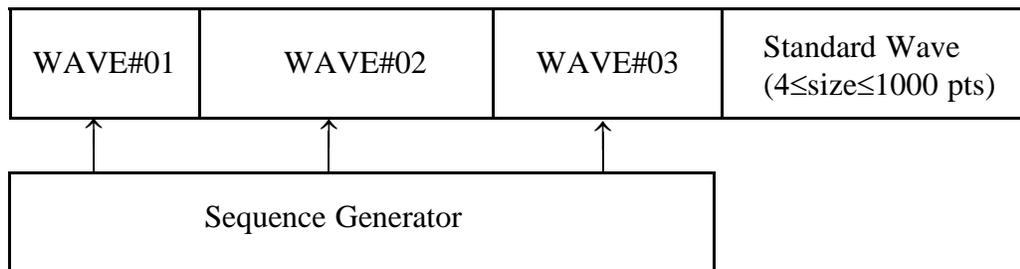
Sequenced Waveform

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

WAVE#02 1 2 → WAVE#01 3 → WAVE#03 4 5 6

2
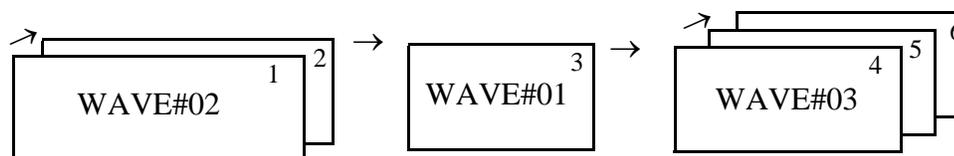
Sync Pulse

A sync pulse is provided to synchronize the generator output waveform to an external system such as an oscilloscope.
For standard and user-defined waveforms, the sync pulse is placed at the start of the waveform frame. For sequence waveforms, the sync pulse is placed at the end to indicate the sequence completion.

Standard and User-defined Waveforms

Output

$t = 1 / (\text{Sample Clock Frequency})$

← One Waveform Frame →

Sync
Out

→|t|←

Sequence Waveforms

Output

$t = 1 / (\text{Sample Clock Frequency})$

← One Sequence Cycle →

Sync
Out

→|t|←
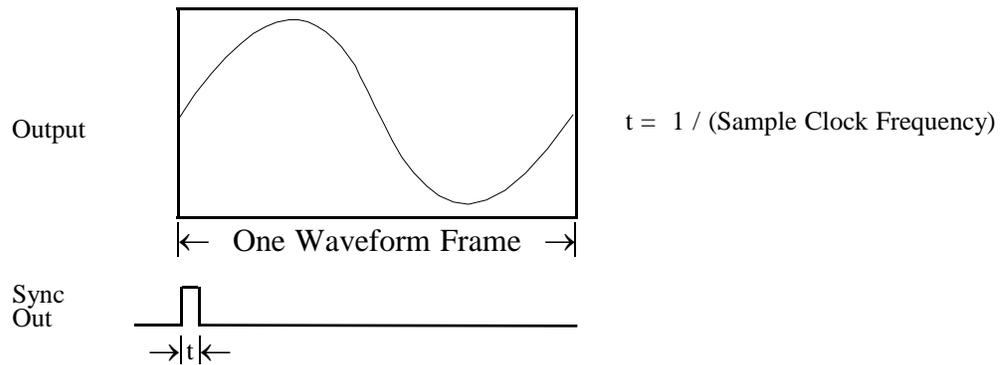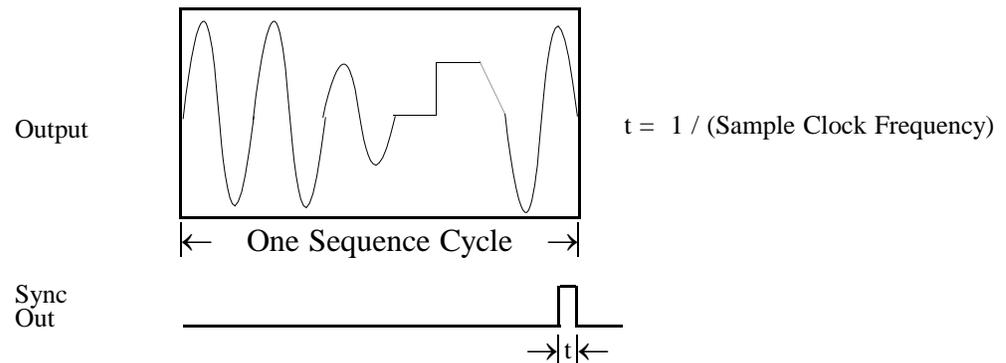
Note:
If you programmed only one step in a sequence, the sync pulse appears at the start of the waveform.

2

3

Front-Panel Menu Operation

3

Parameter Control

A: MODE menu

1: Continuous → 2: Trigger → 3: Gate → 4: Burst → 5:Toggle →

6: Master → 7: Slave

1: Continuous: Select the continuous waveform output.

2: Trigger: Select the triggered waveform output. Output one waveform frame when a trigger signal is applied.

3: Gate: Select the gated waveform output. Output multiple waveform frames as long as the trigger input signal is high or the manual button is pressed down.

4: Burst: Select the burst mode. Output multiple number of waveform frames set by the burst cycle parameter when a trigger signal is applied. The number of burst cycles may be set between 1 and 1,048,575.

> *Note: The Burst mode is not available for sequence waveform.*

5: Toggle: Select the toggle mode. Output multiple waveform frames when a trigger signal is applied and then return to the quiescent state when the second trigger signal is applied.

6. Master: Set up the instrument to function as the master unit for multi-unit operation.

7. Slave: Set up the instrument to function as the slave unit for multi-unit operation.

Note: If you are using the 2711A as a stand-alone instrument, select only the first five modes. Othewise, the 2711A may not function properly.

A6: Master

1: Cont-Sync → 2: Trig-Sync → 3: Trig-Seq

A7: Slave

1: Cont-Sync → 2: Trig-Sync → 3: Trig-Seq

Select the same mode for both Master and Slave.
Review chapter 5 (Multi-instrument Operation) for the detail description of the modes.

Parameter Control (continued)

B: SCLK/FREQ menu

1: SCLK (Sample Clock)	Sets the sample clock rate of the waveform frame when	
	User-defined or **Sequence** (option) waveforms are selected..	
2: FREQ (Frequency)	Set the frequency of standard waveforms.	

3

C: WVFM (Waveform) menu

1: Standard $\rightarrow$ 2: User defined $\rightarrow$ 3: Sequence

1: Standard   Select a standard waveform.

2: User defined Select a user-defined arbitrary waveform by the waveform number (00~99).

3: Sequence   Select a user-defined sequence waveform by the sequence number (0~9).

Note: The user-defined waveforms must be created on the PC and then downloaded into the instrument using the WaveWorks Jr. software. The sequence generaor option must be installed to select sequence waveforms. Sequence waveform is not available in burst mode.

C1: Standard

1: Sine $\rightarrow$ 2: Square $\rightarrow$ 3: Triangle $\rightarrow$ 4: Ramp $\rightarrow$ 5: DC $\rightarrow$ 6: Exponential $\rightarrow$

7: Haversine $\rightarrow$ 8: Pulse $\rightarrow$ 9: Gaussian $\rightarrow$ 10: Sin(x)/x

1: Sine	Select sine wave. The start phase may be set.
2: Square	Select square wave. The duty cycle may be set.
3: Triangle	Select triangle wave.
4: Ramp	Select ramp wave. The duty cycle may be set.
5: DC	Select DC. The DC levels in DAC vertical points may be set.
6: Exponential	Select exponential wave. The time constant may be set. The quiescent level is mid-point of the range.
7: Haversine	Select haversine. The quiescent level is mid-point of the range.
8: Pulse	Select pulse waveform. The delay, rise and fall times and the duration of the high level may be set. The quiescent level is mid-point of the range.
9: Gaussian	Select gaussian pulse waveform. The exponent is fixed to 100. The quiescent level is mid-point of the range.
10:Sin(x)/x	Select sinc (sineX/X) waveform.The number of the cycle is fixed to 9.5.

3

<p style="text-align:center">**Parameter Control (continued)**</p>

D: OUTPUT menu

1: Ampl → 2: Ofst → 3: State → 4: Filter

1: Ampl	Set the magnitude of output waveforms.
2: Ofst	Set the dc offset of output waveforms.
3: State	Set the ac signal to zero while maintaining the dc offset level. The deglitcher may be turned on or off.
4: Filter	Select one of the two low pass filters (40kHz /700kHz) or off.

<h2 style="text-align:center">System Control</h2>

A: SETUP menu

1: RS232 → 2: GPIB Addr → 3: 10MHz Ref → 4: Sample Clock

1: RS232	Set the RS232 serial interface parameters.
2: GPIB Addr	Set the GPIB bus address (0-30).
3: 10MHz Ref	Select the reference clock source.
4: Sample Clock	Select the sample clock source.

A1: RS232

1: 19200 → 2: 1200 → 3: 2400 → 4: 9600

Select the baud rate of 1200, 2400, 9600, 19200.
Bits=8, **Parity**=None, **Handshake**=Hardware are not programmable.

A3: 10MHz Ref

1: Int → 2: Ext

1: Int	Select the internal reference clock for the generator.
2: Ext	Select the external reference clock for the generator.

A4: Sample Clock

1: Int → 2: Ext

1: Int	Select the internal sample clock source.
2: Ext	Select the external sample clock source.

B: LOCAL   Select the front panel control when the instrument is in remote mode.

Default Settings

Important: By holding **LOCAL** key down while turning the **LINE** switch on, you can reset the 2711A settings. If you want to save the waveform data, be sure to back up in a PC using WWP Jr. before resetting the 2711A.

3

Front-panel key defaults

KEYS	Defaults
SETUP	RS232:19200,N81
MODE	Continuous
SCLK/FREQ	Freq=1.000 kHz (STDW:SINE)
OUTPUT	Ampl=1.000 V
	Ofst=0.000 V
	State=On, Deglitch=On
	Filter=Off

Setup defaults

SETUP	Default Settings			
	1	2	3	4
RS232	*Baud Rate =19200*	*Bits = 8D1S*	*Parity = None*	*Handshake = HW*
GPIB	*Addr = 16*			
Sample Clock	Int			
10MHz Ref	Int			

User-defined waveform defaults

User-Defined Waveforms		
Wave #	Size	Type
00	1000	Cardiac
01	1000	Gaussian pulse
02	100	Pulse
03	1000	Sin(X)/X (SINC)
04~99	1000	DC (zero)

Sequence waveform defaults

Sequence Waveforms			
Seq #	Step	Wave#	Repeat
00	01	00	2
	02	04	10
01	01	01	1
	02	02	4
	03	03	1
02~99	(Empty)		

Default Settings (continued)

Standard waveform defaults

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

Standard Waveforms Size=1000 pts (4~65500 pts)	Parameter Limits and Defaults					
	Phase	Duty Cycle	Level	Time Constant	Transition	Polarity
Sine	0.00 degree (-359.99~+359.99)					
Square		50.0 % (0~100.0%)				
Triangle						
Ramp		100.0 % (0~100.0%)				Normal (Normal/Invert)
DC			0 pts (-32768~+32767pts)			
Exponential				5.00 (0.00~20.00)	Rise (Rise/Decay)	Normal (Normal/Invert)

Standard Waveforms Size=1000 pts (4~65500 pts)	Parameter Limits and Defaults						
	Delay	Rise	High	Fall	Exponents	No. of Cycles	Polarity
Haversine							
Pulse	0.0% (0.0~100.0%)	10.0% (0.0~100.0%)	30.0% (0.0~100.0%)	10.0% (0.0~100.0%)			Normal (Normal/Invert)
Gaussian					100 (fixed)		
Sin(X)/X						9.5 (fixed)	

Standard Waveform List

The following list shows you the standard waveforms available from the 2711A front panel and in the WaveWorks Jr. software. You can create a standard waveform in WaveWorks Jr. and download it to an arbitrary waveform location. Now, you can select the customized standard waveform from the front panel as a user-defined waveform.

Standard Waveforms			
2711A	WaveWorks Jr.		
Sine	Sine	**Squine**	**Cont Sweep**
Square	Square	**AM**	
Triangle	Triangle	**FM**	
Ramp	Ramp	**PWM**	
DC	DC	**Binary FSK**	
Exponential	Exponential	**Binary PSK**	
Haversine	**Pulse 1**	**Digital Noise**	
Pulse	Pulse 2	**Analog Noise**	
Gaussian	Gaussian	**Comb**	
Sin(x)/x	Sin(x)/x	**Steps**	

3

4

Waveform Creation System

4

Components

The following components are included in the 2711A waveform creation system.

- Model 2711A Arbitrary Waveform Generator.
- WaveWorks Jr. Wavform Creation Software.

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

- IBM (or compatible) 386 PC with math coprocessor, 8MB memory
- 2MB free harddisk space, Windows 3.1 or higher operating system
- MS-DOS version 6.20 or higher.

Recommendation

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

User Interface

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

Front Panel (2711A)
This is used primarily to select and control the hardware parameters, such as mode, sample clock rate, amplitude, offset, and waveform selection. 10 standard waveforms may be created from the front panel. Arbitrary waveforms and sequence waveforms can not be edited from the front panel.

Waveform Windows (WaveWorks Jr.)
The WaveWorks Jr., which runs under Windows, is the main interface for waveform creation tasks. You can create up to 21 standard waveforms and unlimited number of arbitrary and sequence waveforms using Point Edit and Waveform Math.

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

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

IBM Compatible Personal Computer

WaveWorks Jr. Files

Save As   Open

Export

Other
Applications

WaveWorks Jr.

ASCII Files
(*.CSV, *.PRN)

Import

User Interface 2
(**Waveform Windows** on PC)
* 21 Standard Waveforms
* Arbitrary Waveform Creation
* Sequence Creation (optional)
* Data Analysis (FFT, Digital Pattern, Point)
* Data Synthesis (IFFT, Point)
* Data Exchange with other applications
* Waveform Data Download/Upload

4

Upload   Download

- - - - - - - - RS-232 or GPIB

**Arbitrary
Waveform
Generator**

User Interface 1
(**Front Panel** on AWG)
* 10 Standard Waveforms
* Custom Waveform Selections
   (Arbitrary and Sequence)
* Parameter Settings
   (Amplitude, Offset, Sample Clock)
* Mode Selection

Signal
Output

Device Under Test

User Interface for the Waveform Creation System

4

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

Waveform Creation using WaveWorks Jr.

1. Select **File | New Project** and create a New Waveform.
2. Select **Func | Std** and select one of the 20 standard waveforms.
3. Press Show to view the waveform and **OK** to enter the selected waveform into the New Waveform.

Download WaveWorks Jr. Data using RS-232

Waveform Generator Setup (See Chapter 7 for more details.)
1. Connect the RS-232 cable part number 740560 to the waveform generator RS-232 port and the PC COM port. Make sure each end is connected properly.
2. Set the RS-232 baud rate of the waveform generator to 19200.

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

5

Multi-Instrument Operation

5

Basic Connection

The following diagram illustrates the basic connections and setups for single unit operation.
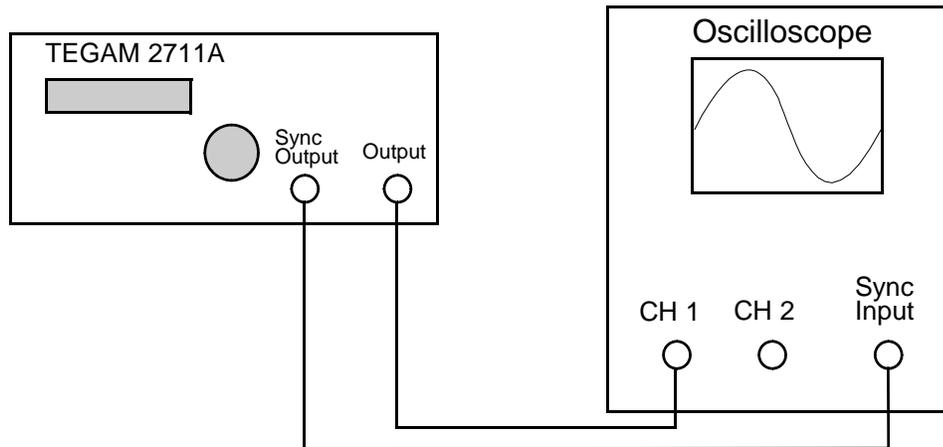
Note: The rear BNC connectors are available for the following functions:

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

CLOCK IN/OUT; The sample clock may be brought in from the external source through this connector. TTL level. The clock frequency must be twice the internal sample clock rate, i.e. 4MHz for the internal sample clock rate of 2MHz. At the default setting the internal sample clock generator is connected to the instrument and twice the frequency of the internal sample clock is present at the output.

SYNC TRIG OUT; The signal required for multiple unit operation to guarantee the proper phase between the generators.

TRIG IN; The external trigger input. TTL level.

Multiple Phase Connection

The following diagram illustrates the connections and setups for the multiple phase operation using Master-Slave mode.
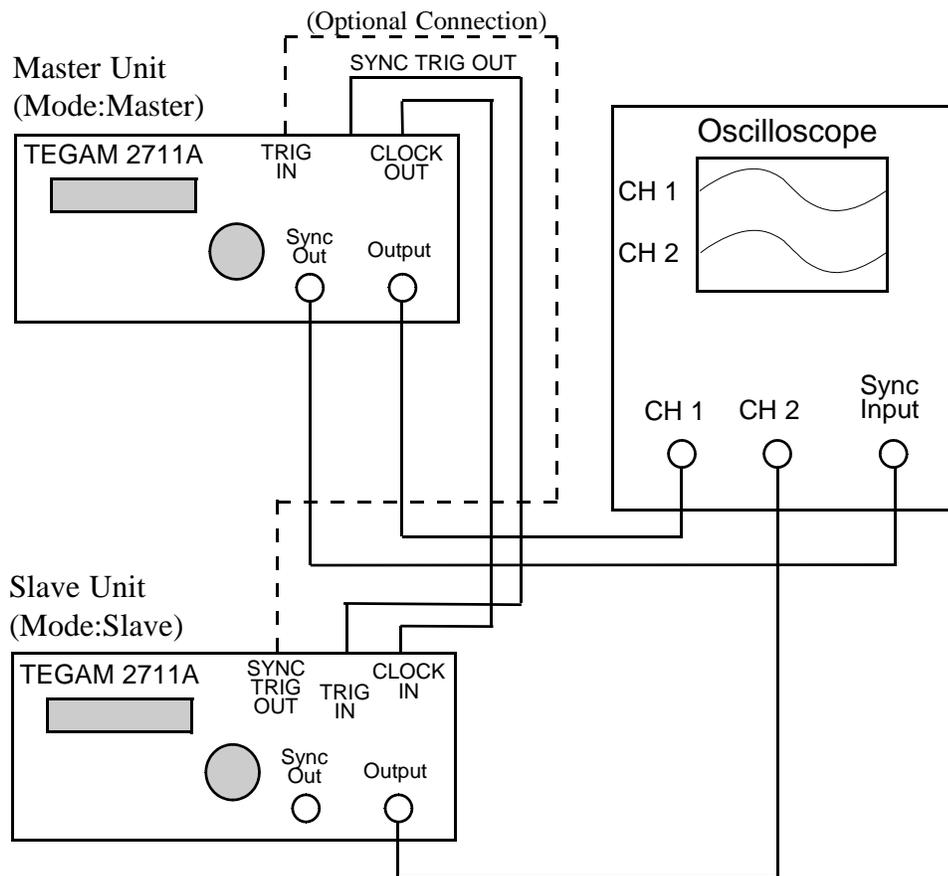
Note: The rear BNC connectors are available for the following functions:
10 MHz REF. IN/OUT
CLOCK IN/OUT
SYNC TRIG OUT
TRIG IN
For the description of each function, refer to the bottom of the previous page.

5

Multiple Phase Operation

Three types of multi-phase operation are available:
1. Continuous Synchronous (Cont-Sync)
2. Trigger Synchronous (Trig-Sync)
3. Trigger Sequential (Trig-Seq)

Case 1 -- **Continuous-Synchronous**
The master unit runs continuously. The Sync Trig pulse of the master unit forces the free-running slave unit to reset to the first address at the phase zero of the master unit. The waveform size of the slave unit should be the same length as the master to avoid the discontinuity.
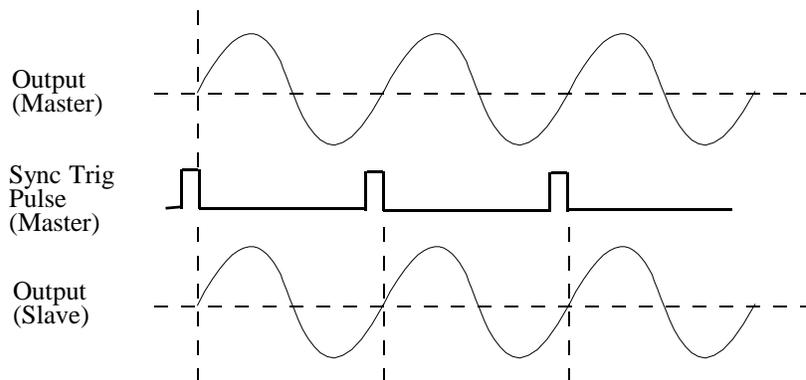
Case 2 -- **Trigger-Synchronous**
Both units are in TRIG mode. Upon receiving the trigger signal (external or manual), the master unit prepares to run while the SYNC TRIG pulse of the master unit forces the slave unit to start to run synchronously at the phase zero of the master unit.
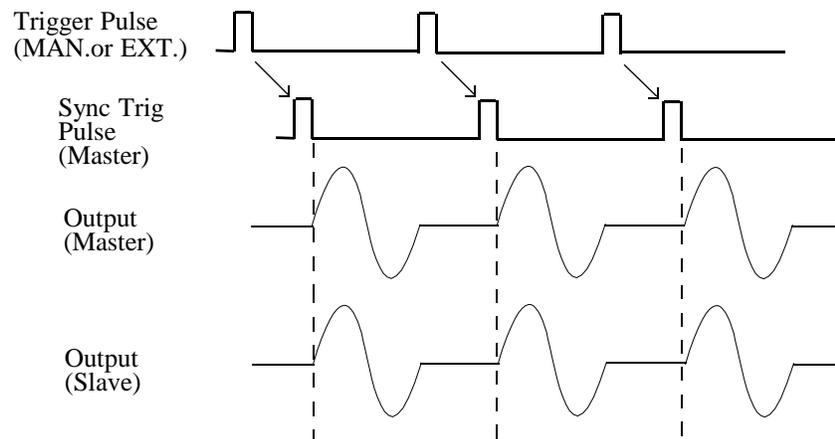
Multiple Phase Operation (continued)

<u>Case 3</u> -- **Trigger-Sequential**

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

5

5

6
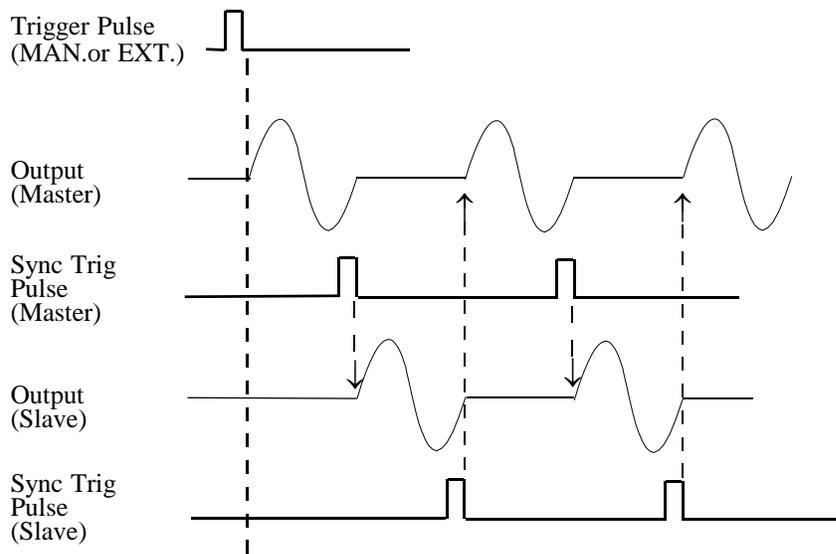
Performance Verification

Introduction

This chapter provides a procedure to verify that the Model 2711A has met the specifications published in the manual within the tolerances. *There are no user accessible calibration points in the unit.* TEGAM, Inc. recommends an annual calibration verification interval. It is recommended that Chapter 1 Quick Start should be followed first in order to verify proper operation of the unit. Copy the Verification Test Sheet at the end of this chapter to record the data.

Test Equipment Required

Analog Oscilloscope: 100 MHz or greater bandwidth.
Frequency Counter: 1 PPM or better accuracy.
True-RMS Digital Multimeter: 5½ digit, 0.1% or better accuracy.
Distortion Analyzer: 0.002% or better THD measurement at 80 kHz
                              bandwidth.
Precision Load: 50 Ω, ± 0.1%

Verification Test

Frequency Accuracy

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

The following procedures require the instrument to be reset to the default settings. Please save the pertinent waveform file data in the 2711A in the PC by using WaveWorks Jr. before proceeding to the next test.

Reset the 2711A

Turn on the power switch while holding the LOCAL key down.
Caution: Reset erases waveform memory and inserts the default files. Store all waveform required for future use as noted in the preceding step.

Waveform Rise/Fall Time

1. Set Amplitude to 10 V.
2. Select Standard wave as Square wave.
3. Connect OUTPUT to an oscilloscope input terminating with a 50-ohm load.
4. Verify the Rise and Fall Times to be less than 150 ns.

Verification Test (continued)

DC Offset Accuracy

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

Amplitude Accuracy

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

Total Harmonic Distortion (THD) plus Noise

1. Select Standard wave as Sinewave.
2. Set Amplitude to 9.10 V.
3. Select 700 kHz low pass filter from OUTPUT menu.
4. Set Frequency to 2.000 kHz.
5. Connect OUTPUT to the distortion analyzer input using a 50 ohm load.
6. Set the distortion analyzer for a 2 kHz signal and 80 kHz measurement bandwidth.
7. Verify THD+Noise measures less than -86 dB (0.005%).

6

Verification Test Sheet

Model: TEGAM 2711A

Date:_____

Serial Number:_____

Tested by:_____

Verification Test						
Test Parameters		Limits			Test	
		Low	Nominal	High	Pass	Fail
Frequency Accuracy	Test Spec	9.99995 MHz	**10.0000 MHz**	10.0005 MHz		
	Data					
Rise/Fall Time	Spec	**<150 ns**				
	Data					
DC Offset	Test Spec 1	8.890 V	**9.000 V**	9.110 V		
	Data 1					
	Test Spec 2	867 mV	**899 mV**	931 mV		
	Data 2					
	Test Spec 3	83.5 mV	**89 mV**	94.5 mV		
	Data 3					
Amplitude [Peak=RMS x 1.414]	Test Spec 1	10.078 V	**10.20 V**	10.322 V		
	Data 1(RMS)					
	Data 1 (Pk)					
	Test Spec 2	868 mV	**900 mV**	932 mV		
	Data 2(RMS)					
	Data 2(Pk)					
	Test Spec 3	84.5 mV	**90 mV**	95.5 mV		
	Data 3(RMS)					
	Data 3(Pk)					
THD	Typical Spec.	-86 dB (0.005 %)				
	Data					

Note: _____
_____
_____
_____

7

Remote Interface Operation

Introduction

This section describes how to remotely control all instrument functions and how to download and upload waveform data using either the RS-232C or GPIB interface. If you are using the WaveWorks Jr., it is only necessary to read the section on how to set the GPIB address or RS-232 parameters on the 2711A if you have already installed a GPIB card and the required software on your computer. Included are an overview of remote control, a complete tabulation and explanation of control commands, and programming examples. More details are given in chapter 8 for the advanced users of the instrument.

To set the GPIB address

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

1. Press the SETUP button.

> RS232=19200,N81

2. Select GPIB by turning the knob.

> GPIB Addr = 16

3. Move the cursor to the numerical field by pressing the right arrow key.

> GPIB Addr = 16

4. Set the GPIB address by turning the knob.

7

To set the RS-232 parameters

You must select the proper RS-232 settings to communicate between the
waveform generator and a computer. The following procedure will let you
change the generator to required settings. *The generator is set to the following
factory defaults: Baud Rate = 19200, Bits = 8D1S, Parity = None, Handshake =
HW (hardware). The only programmable parameter is Baud Rate.*

1. Press the SETUP button.

<u>R</u>S232 = 19200,N81

2. Press the right-arrow key to select the parameter field and then select
   the baud rate by turning the knob.

RS232 = 1<u>9</u>200,N81

RS-232 Adapter Cables

The following wiring diagrams illustrate proper interconnections between the
serial port of an IBM (or compatible) PC and the model 2711A RS-232
connector. The proper cable to connect DB-9 can be purchased from TEGAM
Inc. under part number 740560.

7

RS-232 Cable for the 2711A part number 740560.

PC (DB9, female)   **Model 2711A** (DB9, female)

3 ———————————— 2	RXD
2 ———————————— 3	TXD
7 (open)	
8 ———————————— 4	DTR
6 ————●———————— 7	RTS
5 ━━━━━━━━━━━━━━━ 5	**Ground**
1 ———┘ 1	
4 ———————————— 8	CTS
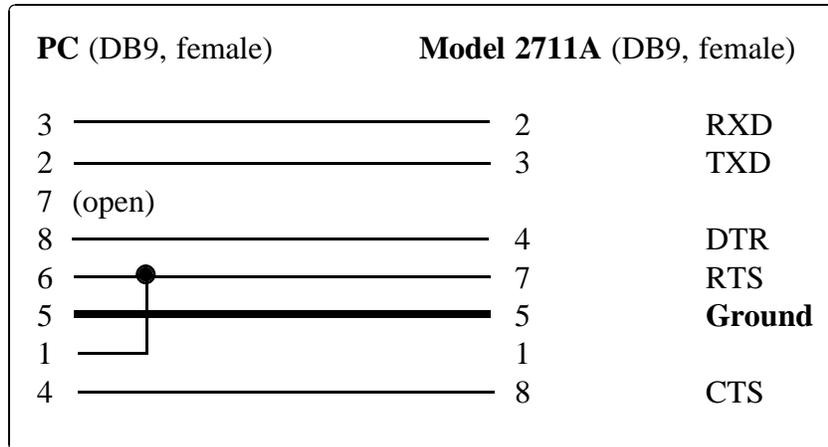
RS-232 Cable required for the 25 pin connector.

PC (DB25, female)   **Model 2711A** (DB9, female)

2 ———————————— 2	RXD
3 ———————————— 3	TXD
4 (open)	
5 ———————————— 4	DTR
6 ————●———————— 7	RTS
7 ━━━━━━━━━━━━━━━ 5	**Ground**
8 ———┘ 1	
20 ———————————— 8	CTS
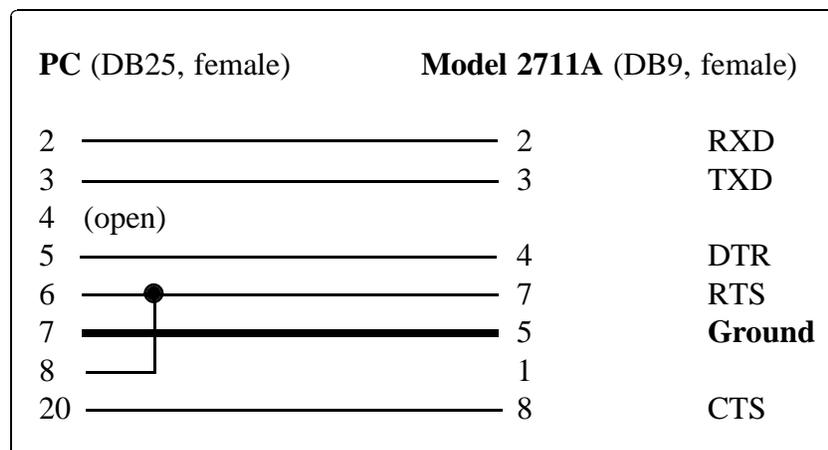
Before sending commands

Whether you use RS-232 or GPIB as the communication interface to the 2711A, you should examine the following.

For RS-232
1. Check the cable connection.
Make sure the proper end (**PC** or **Instrument**) of the cable is connected to the respective ends.
>   **PC** to PC COM port
>   **Instrument** to 2711A RS-232 connector
2. Setup the PC Port.
Select a COM port on the PC. Make sure that the baud rate and other interface parameters are set to the same parameters as the 2711A.

For GPIB
1. Check the cable connection.
2. Set up the GPIB board on the PC to a proper setting.
3. Make sure that the GPIB address set on the PC matches the 2711A address.

Command Features

The following examples will illustrate the specific features of the 2711A remote programming commands using RS-232 or GPIB.

Command Execution

All commands are executed immediately.
You must send commands in proper sequence in some cases. For example, if you send DC offset value first, then the command may be rejected if the total of DC offset and the peak amplitude exceed the maximum allowable peak limit (+/- 10.4V -- open circuit). In this case, you must send the smaller value of amplitude first, then you can DC offset properly. In general the following formula applies.

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

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

>   **AMPL 1.0;OFFSET 7.5** --- OK
>   OFFSET 7.5;AMPL 1.0   --- ERROR

Command Features (continued)

Waveform Selection

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

To select a type of waveform, use FUNCTION (FUNC) command.
    :FUNCTION WAVE,12   --- select user-defined waveform #12
    :FUNCTION WAVE,STDW --- select standard waveform
    :FUNCTION SEQ,10   --- select sequence waveform #10 (optional)

      ↑——**A space is required after the command headers.**

To select a standard waveform
    :WVMF:SINE;:FUNC WAVE,STDW --- select and output sine wave.

      ↑——**Select sine wave as Standard Wave.**

Waveform Deletion

There are no delete command for waveforms or sequences. In all cases, to delete

To delete a user-defined waveform, set the size to zero (0).
      :WVFM:WAVE 10;SIZE 0   **---** delete WAVE#10

        ↑——**The size is set to zero.**

To delete a sequence, send the sequence number which you want to delete
and eliminate the step data.
      :WVFM:SEQ 12   --- delete SEQ#12 if it exists.

To delete a step in a sequence, set the repeat to zero (0).
      :WVFM:ADDSEQ 12,1,0,5   --- delete SEQ#12 Step#5

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

Command Set

Command Set				
Command		Data Format	Limits	
Normal	Short Form		Min	Max
Common Commands				
*CLS				
*ESE (GPIB only)		<8-bit mask>	0	255
*ESE? (GPIB only)		<NR1>	0	255
*ESR?		<NR1>	0	255
*SRE? (GPIB only)		<NR1>	0	255
*SRE? (GPIB only)		<NR1>	0	255
*SRE? (GPIB only)		<NR1>	0	255
*IDN?				
*RST				
*TRG				
*TST?				
*WAI				
*SRE? (GPIB only)				
*OPC?				
*OPT?				
Configuration Commands				
CONFIGURE	CONF			
HEADERS	HDRS	ON|OFF		
HEADERS?		ON|OFF		
System Commands				
REF_CLOCK	RCLK	INT|EXT		
REF_CLOCK?	RCLK?	INT|EXT		
RESET		CURR|ALL		
CLOCK_SEL	CLKSEL	INT|EXT		
CLOCK_SEL?	CLKSEL?	INT|EXT		
TRIGGER	TRIG	ON|OFF|PULSE		

7

Command Set (continued)

Command Set				
Command		Data Format	Limits	
Normal	Short Form		Min	Max
Instrument Status Commands				
STATUS				
INSTRUMENT	INST			
CLEAR	CLR			
ENABLE	ENBL	<16-bit mask>	0	65535
ENABLE?	ENBL?	<NR1>	0	65535
EVENT?	EVNT?	<NR1>	0	65535
SYSTEM	SYST			
LOCAL (RS-232 only)	LOC			
REMOTE (RS-232 only)	REM			
RWLOCK (RS-232 only)	RWL			

7

Command Set (continued)

Command		Data Format	Limits	
Normal	Short Form		Min	Max
Mode Commands				
MODE		CONT|TRIG|GATE|BURST| TOGGLE|MASTER|SLAVE		
MODE?		CONT|TRIG|GATE|BURST| TOGGLE|MASTER|SLAVE		
BURST		<burst #>	1	1048575
BURST?		<NR1>	1	1048575
MULTIPHASE	MPH	<CONTSYNC=0 TRIGSYNC=1 TRIGSEQ=2>		
MULTIPHASE?	MPH?	<CONTSYNC=0 TRIGSYNC=1 TRIGSEQ=2>		
Sample Clock / Frequency Commands				
SAMPLECLOCK	SCLK	<frequency>	0.1	2.000 E6
SAMPLECLOCK?	SCLK?	<NR3>	0.1	2.000 E6
FREQUENCY	FREQ	<frequency>	1.527 E-6	5.000 E5
FREQUENCY?	FREQ?	<NR3>	0.1	5.000 E5
Waveform Selection Commands				
FUNCTION	FUNC	WAVE,<NR>	0	99
		SEQ,<NR>	0	9
		WAVE,STDW		
FUNCTION?	FUNC?			
Standard Waveform Definition Commands				
WAVEFORM	WVFM			
SINE	SIN	<starting phase>	-359.99	+359.99
SQUARE	SQU	<duty cycle>	0	100
TRIANGLE	TRI			
RAMP		<duty cycle>	0	100.00
		NORM|INVERT		
DC		<level>	-32768	32767
EXPONENTIAL	EXP	<time constant>	0	20
		RISE|DECAY		
		NORM|INVERT		
HAVERSINE	HSIN			
PULSE		<delay>	0	100.00
		<rise>	0	100
		<high>	0	100
		<fall>	0	100
		NORM|INVERT		

Command Set (continued)

Command		Data Format	Limits	
Normal	Short Form		Min	Max
Standard Waveform Definition Commands				
WAVEFORM	WVFM			
Gaussian	Gauss			
SINE_X_OVR_X	SXX			
SIZE		<waveform size>	4	1000
SIZE?		<NR1>	4	1000
FREE? (query)		WVFM		
		SEQ, <seq #>	0	99
FREE? (response)		Waveform: number of free points in waveform memory		
		Sequence: number of free steps in <seq #>		
Output Commands				
AMPLITUDE	AMPL	<peak>, Hi Z	0	10.2
AMPLITUDE?	AMPL?	<NR2>	0	10.2
OFFSET	OFST	<level>, Hi Z	-10.2	10.2
OFFSET?	OFST?	<NR2>	-10.2	10.2
OUTPUT_SWTCH	OUTSW	ON|MUTE		
OUTPUT_SWTCH?	OUTSW?	ON|MUTE		
FILTER		OFF|LPF40K|LPF700K		
FILTER?		OFF|LPF40K|LPF700K		
DEGL		ON|OFF		
DEGL?		ON|OFF		
READ_BURST?	RBRS?			
Arbitrary Waveform Commands				
WAVE		<wave number>	0	99
WAVE?		<NR1>	0	99
SIZE		<size>	32* (4 for STDW)	65500
SIZE?		<NR1>	32* (4 for STDW)	65500
MEMORY	MEM	<start address>	0	65499
		<data> (CSV or binary)	-32768	32767
MEMORY?	MEM?	<address>	0	65499
MEM_BLOCK?	MBLK?	<address>	0	65499
		<length>	0	2048

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Command Set (continued)

Command Set				
Command		Data Format	Limits	
Normal	Short Form		Min	Max
Sequence Commands				
SEQUENCE	SEQ	<sequence #>	0	9
		<waveform #>	0	99
AUTOSEQUENCE	AUTO	<1st step #>	0	99
		<step increment>	0	99
SEQBURST	SEQB	<sequence number> (uses AUTO)	0	99
		<wave number>	0	99
		<burst>	0	1048575
SEQBURSTNUM	SEQBN	<sequence number>	0	99
		<wave number>	0	99
		<burst>	0	1048575
		<step number>	0	99
ADDSEQUENCE	ADDSEQ	<sequence number>	0	99
		<wave number>	0	99
		<burst>	0	1048575
		<step number>	0	99
ADDSEQUENCE?	ADDSEQ? (Query Command)	<sequence #>	0	9
		<step #>	0	99
	ADDSEQ? (Query Response)	Waveform#, Burst Count, Step#		

Reset and Default Values

The following Table lists the parameter values which are affected for both defaults and reset setting conditions. Defaults can be accessed over the GPIB or RS232 with the RESET-ALL command. Reset settings can be accessed over the GPIB or RS232 with the *RST or RESET-CURR commands. To accomplish RESET-ALL from the front panel, hold down the LOCAL button while turning

Reset			
Parameters	Default Values	RESET-ALL	RESET-CURR (*RST)
Mode	CONTinuous	√	√
Burst Count	3	√	√
Sample Clock Frequency	1.000 MHz	√	√
Frequency	1.000 kHz	√	√
Waveform			
Function	STDW Wave	√	√
Waveform Parameters:		√	√
DC	0	√	√
Exponential	TC=+5, Direction=Rising, Polarity=Normal	√	√
Gaussian Pulse	Exponent=100 (fixed)	√	√
Haversine	Cycle=1(fixed)	√	√
Pulse	Delay=0% Rise Time=10% High Time=30% Fall Time=10% Polarity=Normal	√	√
Ramp	Duty Cycle=100% Polarity=Normal	√	√
Sine	Phase=0	√	√
Sin(x)/x (Sinc)	Cycle=9.5 (fixed)	√	√
Square	Duty Cycle=50%	√	√
Triangle	Cycle=1(fixed)	√	√
Output			
Amplitude	1.000 V	√	√
Offset	0 V	√	√
Output Switch	ON	√	√
Filter	OFF	√	√
Deglitcher	OFF	√	√

Reset and Default Values (continued)

Reset			
Parameters	Default Values	RESET-ALL	RESET-CURR (*RST)
Waveform Memory:			
Wave			
Wave#	00 to 99	√	Unchanged
Size	5 waves	√	Unchanged
Data	Affected	√	Unchanged
STDW			
Size	1000	√	Unchanged
Data	1 cycle Sinewave	√	√
Sequence Generator:			
SEQ	0 to 9	√	Unchanged
GPIB			
Address	16	*Unchanged* *	Unchanged
RS-232			
Baud	19200	*Unchanged* **	Unchanged
PAR	none (fixed)	Fixed	Fixed
BITS	8d1s(fixed)	Fixed	Fixed
Handshake	Hardware (fixed)	Fixed	Fixed

Note:
If you reset the 2711A from the front panel at the time of power-on by holding down the LOCAL button:

  *   GPIB Address will change to 16.
  **   RS-232 Baud Rate will change to 19200.

7

RS-232 Programming Example

' This program shows how to set up the 2711A for a continuous sinewave 2 Vp-p, 1.2 kHz

' over the RS232 interface (COM1).

' The 2711A communication settings must be programmed to:

' **BAUD: 19.2K**   BITS: 8D1S   PAR: NONE   HAND: HW

' *Bits, parity and handshake parameters are fixed and are not programmable in the 2711A.*

' *You must use TEGAM part number 740560 RS-232 or equivalent cable.*

```
DECLARE SUB SendRS232Cmmd (OutputString$)
COMMON SHARED OutputString$, InputString$, CrLf$, Listen$
CrLf$ = CHR$(13) + CHR$(10)                          'RS232 command terminator
Listen$ = CHR$(4)                                    'request query response
StartProgram:
        'Connect to 2711A and initialize.
        OPEN "COM1:19200, N, 8, 1, CS1000, DS1000, BIN" FOR RANDOM AS #1
        PRINT #1, CrLf$ + CrLf$              'Flush RS232 receive buffer
        SendRS232Cmmd ("*cls")              'clear 2711A Event Status Register
        SendRS232Cmmd ("*rst")              'reset 2711A
        'Set up continuous sinewave 2 Vp-p, 1.2kHz.
        CALL SendRS232Cmmd("MODE CONT")           'Mode = Cont
        CALL SendRS232Cmmd("WVFM:SINE")           'Waveform = Sine
        CALL SendRS232Cmmd("AMPL 2.0")            'Amplitude = 2.0 V
        CALL SendRS232Cmmd("FREQ 1.2E3")          'Frequency = 1.2 kHz
STOP
```

RS-232 Programming Example (continued)

```
END
SUB SendRS232Cmmd (OutputString$)
      PRINT #1, OutputString$ + CrLf$;                      'send command to 2711A
      PRINT #1, "*esr?" + CrLf$;                            'check error code
      PRINT #1, Listen$;
      LINE INPUT #1, QueryResponse$
      StringPos = 0
TrimRxString:                                               'flush 'LFs' from
                                                            'previous LINE

      StringPos = StringPos + 1
      IF MID$(QueryResponse$, StringPos, 1) < " " THEN GOTO TrimRxString
      QueryResponse = VAL(RIGHT$(QueryResponse$, StringPos))
            'Print the description of error if any
      IF QueryResponse AND 1 THEN PRINT ">> Operation Complete <<";
      IF QueryResponse AND 2 THEN PRINT ">> Request Control ( N/I ) <<";
      IF QueryResponse AND 4 THEN PRINT ">> QUERY ERROR <<";
      IF QueryResponse AND 8 THEN PRINT ">> Device Dependant ERROR <<";
      IF QueryResponse AND 16 THEN PRINT ">> Execution ERROR <<";
      IF QueryResponse AND 32 THEN PRINT ">> Command ERROR <<";
      IF QueryResponse AND 64 THEN PRINT ">> User Request ( N/I ) <<";
      IF QueryResponse AND 128 THEN PRINT ">> Power On <<";
      IF QueryResponse > 0 THEN PRINT " Status read : "; QueryResponse
END SUB
```

7

GPIB Programming Example

```
' This program shows how to set up the 2711A for a continuous sinewave 2 Vp-p, 1.2 kHz
' over the GPIB interface.
'
DECLARE SUB SendGpibCmmd (OutputString$)
DECLARE SUB WaitDelay (Sec!)
REM $INCLUDE: 'qbdecl.bas'                          'National Instruments GPIB
                                                    'driver software
COMMON SHARED ArbGen%, OutputString$, InputString$
StartProgram:
        'Connect to 2711A and initialize.
        CALL ibdev(0, 16, 0, 12, 1, 0, ArbGen%)     'connect 2711A at addr 16
        CALL IBCLR(ArbGen%)
        CALL SendGpibCmmd("*cls")                    'clear 2711A Event Status
                                                     'Register
        CALL SendGpibCmmd("*rst")                    'reset 2711A
        'Set up continuous sinewave 2 Vp-p, 1.2kHz.
        CALL SendGpibCmmd("MODE CONT")               'Mode = Cont
        CALL SendGpibCmmd("WVFM:SINE")               'Waveform = Sine
        CALL SendGpibCmmd("AMPL 2.0")                'Amplitude = 2.0 V
        CALL SendGpibCmmd("FREQ 1.2E3")              'Frequency = 1.2 kHz
        IBLOC (ArbGen%)
STOP
END
```

7

GPIB Programming Example (continued)

```
SUB SendGpibCmmd (OutputString$)
        CALL ibwrt(ArbGen%, OutputString$)                    'send command to 2711A
        CALL ibwrt(ArbGen%, "*ESR?")                          'check error code
        WaitDelay (.01)
        InputString$ = SPACE$(100)
        CALL IBRD(ArbGen%, InputString$)
        IF VAL(InputString$) AND 1 THEN PRINT ">> Operation Complete <<";
        IF VAL(InputString$) AND 2 THEN PRINT ">> Request Control ( N/I ) <<";
        IF VAL(InputString$) AND 4 THEN PRINT ">> QUERY ERROR <<";
        IF VAL(InputString$) AND 8 THEN PRINT ">> Device Dependant ERROR <<";
        IF VAL(InputString$) AND 16 THEN PRINT ">> Execution ERROR <<";
        IF VAL(InputString$) AND 32 THEN PRINT ">> Command ERROR <<";
        IF VAL(InputString$) AND 64 THEN PRINT ">> User Request ( N/I ) <<";
        IF VAL(InputString$) AND 128 THEN PRINT ">> Power On <<";
        IF VAL(InputString$) > 0 THEN PRINT "Status read : "; VAL(InputString$)
        IF VAL(InputString$) > 0 THEN CALL ibwrt(ArbGen%, "*cls")
        IF VAL(InputString$) > 0 THEN BEEP
        CALL ibwrt(ArbGen%, "*cls")
END SUB

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

7

7

8

8

Advanced Remote Operation

RS 232 Overview

Introduction
RS-232 is an industry-standard method of sending data back and forth between two pieces of equipment. With the Model 2711A, a computer can remotely control the instrument, download waveform data and upload waveform data. This overview explains the interface requirements, 2711A setup, how to verify communications and the command syntax structure.

Interface Requirements
All IBM (or IBM compatible) personal computers (PCs) should be equipped with at least one serial interface port. It may be either a 9-pin DB-9 or a 25-pin DB-25 connector. An 8-foot 9-pin to 9-pin cable can be purchased under TEGAM part number 740560. Most any software which defines communication protocols may be used. This includes the programming languages Quick Basic, GW Basic, Visual Basic, Quick C, Turbo C and Turbo C++. Communications programs such as ProComm, a "shareware" version, are also usually acceptable. A "local echo" feature is helpful to monitor your typing.

To control the generator from the serial port

Hardware Handshake
This is the only handshake available on the 2711A.
With hardware handshaking, flow control of data to/from the instrument is controlled by the DTR/CTS lines of the RS-232 interface.

Sending data to 2711A:
Instrument will turn the DTR line off (-12V) when the instrument buffer fills to 200 characters. Instrument will turn the DTR line on (+12V) when the instrument buffer empties to 80 characters.

Receiving data from 2711A:
Instrument will stop sending data when the CTS line is off and resume sending data when it is on.

8

Verification of Communication

After the PC and the 2711A have been connected together and programmed for compatible interface parameters, the interface should be tested for proper operation. The following program notation conventions will be observed: The symbol ^ represents the computer Control Key. The use of braces { } around two characters means the two keys must be pressed simultaneously.

To test the interface, type the following:

*IDN?{^J}{^D}

The 2711A should identify itself with the following:

Pragmatic Instruments, MODEL 2711A, 0, V1.XX

(XX represents the current firmware revision number.)

Command Syntax

The command syntax of the Model 2711A closely relates to the Institute of Electrical and Electronics Engineers (IEEE) Standard 488.2 - 1987.

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

> Common Commands
> Event Register and Status and Error Reporting
> Functional Syntax Elements

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

Common Commands

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

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

8

Event Register and Status and Error Reporting

The standard Event Staus Register (ESR) may be utilized to indicate the instrument status. Each of six bits within the eight-bit register indicates a different condition within the 2711A:

ESR - Standard Event Status Register

7	6	5	4	3	2	1	0	BIT#

POW
URQ
CME
EXE
DDE
RQC

POW - Power On
URQ - User Request
       (not supported)
CME - Command Error
EXE - Execution Error
DDE - Device Dependent
       Error
RQC - Request Control
       (not supported)
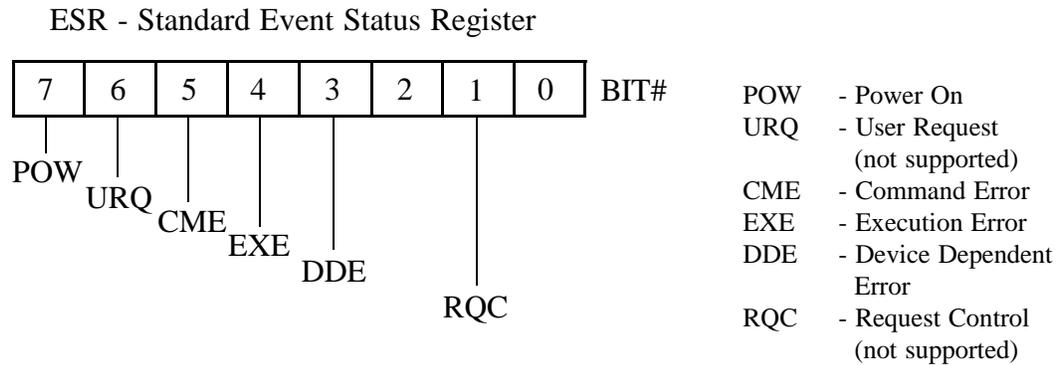
Functional Syntax Elements

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

<PROGRAM MESSAGE UNIT> - This is the basic message, and represents an operation to be performed by the device. As an example, if you wanted to create a sinewave with 90 degree phase shift in the standard waveform, the appropriate <PROGRAM MESSAGE UNIT> would be:

WVFM:SINE 90

Notice that a colon (ASCII 3A) is used to separate the <program mnemonic> WVFM from SINE. For query responses the similarly structured <RESPONSE MESSAGE UNIT> is used. A complete list of <PROGRAM MESSAGE UNITS> and <RESPONSE MESSAGE UNITS> for the 2711A, with definitions, mnemonics, and limitations is given in chapter 7.

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Functional Syntax Elements (continued)

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

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

<RESPONSE MESSAGE UNIT>
      1. <program mnemonic> shall contain upper case alpha only.
      2. No <white space> allowed in message header.
      To receive a response to a query command, append "^D" (ASCII 4 or
      CTRL-D) to the <RESPONSE MESSAGE UNIT>. For example, after
      sending *IDN?<RMT> followed by "^D", the 2711A will respond with
      "Pragmatic Instruments, Model 2711A, 0, V1.XX".

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

<PROGRAM MESSAGE> - This is a series of <PROGRAM MESSAGE
UNITS> sent to the device in a single string. For example, to set the currently
selected waveform to
1) a sinewave output with phase zero, 2) burst mode, 3)a burst of 5, and 4) an
amplitude of 2.5Vp-p into 50 Ω, you would send the following <PROGRAM
MESSAGE>:

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

The semicolon (ASCII 3B) is required to separate <PROGRAM MESSAGE
UNITS> within a <PROGRAM MESSAGE>. For the 2711A a <PROGRAM
MESSAGE> can be virtually any length. The structure for a <RESPONSE
MESSAGE> for query responses is similar.

Functional Syntax Elements (continued)

<PROGRAM MESSAGE TERMINATOR> or <PMT> - In order for the device to recognize the end of a <PROGRAM MESSAGE>, a special terminator is required.
For command messages, the <PMT> can take one of two different formats:

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

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

CR LF	(as above)	or a ";".

GPIB (IEEE-488.2) Overview

Introduction

The Model 2711A conforms to the Institute of Electrical and Electronics Engineers (IEEE) Standard 488.2-1987. The specific implementation of IEEE-488.1 includes the following functions and subsets:

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

To facilitate programming, a brief overview of the IEEE-488.2 Standard (as it specifically applies to the 2711A) is provided.

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

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

8

Common Commands

Commands can be divided into two major categories: common commands and instrument specific commands. Instrument specific commands are detailed in chapter 7. Common commands are defined by the standard, and, among other things, are used to manage status registers and synchronization. The following is a list of common commands as implemented in the 2711A:

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

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Status and Event Registers

There are four required status or event registers. They are:
1) **Standard Event Status Enable (ESE) Register**
2) **Standard Event Status (ESR) Register**
3) **Service Request Enable (SRE) Register**
4) **Status Byte (STB)**.

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

Binary Weights

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$

Instrument Status

Output Buffer

Event Register   *Enable Register*[2]   OR

| End Pulse (ENDP) | 0 |
| End Block (ENDB)[1] | 1 |

+

1. End Block (ENDB) is active only for *Sequence*.

2. Enable Register is active only for *GPIB*.

Status Byte

Summary Register   *Enable Register*

Standard Event

Event Register   *Enable Register*

Operation Complete	0
Not Used	1
Query Error	2
Device Error	3
Execution Error	4
Command Error	5
Not Used	6
Power On	7

OR

+

Device Dependent	0
Not Used	1
Not Used	2
Not Used	3
Message Available	4
Standard Event	5
Request Service	6
Not Used	7

OR

+

Serial Poll (SPOLL)
*STB?

*SRE <value>
*SRE?

*ESR?   ***ESE** <value>
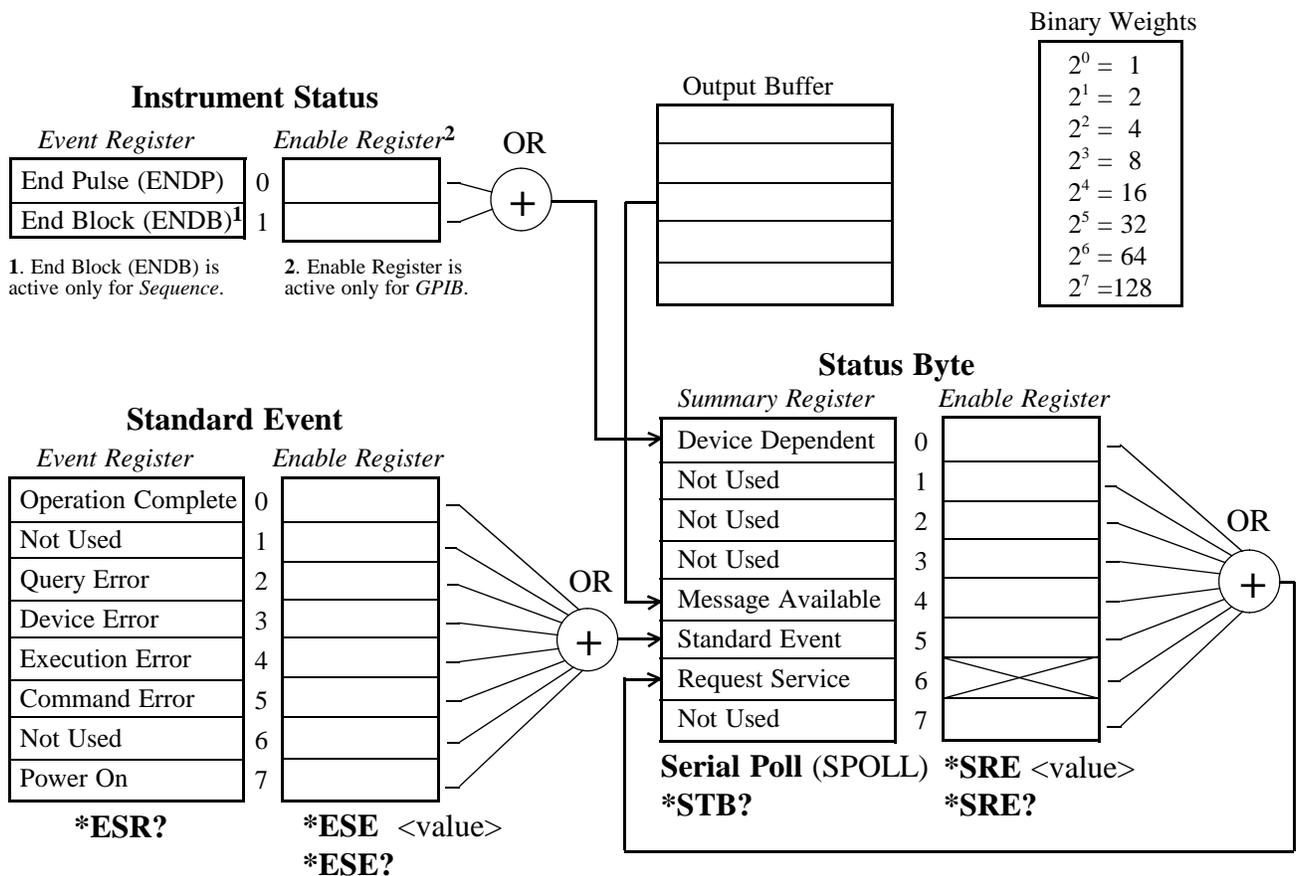   ***ESE?**

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Diagram - Status and Event Registers

Status and Event Registers (continued)

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

For example, if you wanted to generate an SRQ on
        1) power on (bit 7)
        2) command error (bit 5)
        3) query error (bit 2)
you would first set the ESB bit in the SRE Register (see discussion below) and then send the following:

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

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

SRE and STB Registers - The Status Byte (STB) Register of the 2711A has four active bits which summarize the current status of the event registers, output queue, and certain instrument specific functions. Similar to the ESE Register, the SRE Register provides an 8-bit mask to allow the programmer to enable each STB bit (with the exception of the bit 6) to generate an SRQ.

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

       *SRE 48   (48 = Decimal equivalent of B00110000)

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

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

Functional Elements - Syntax and Nomenclature

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

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

<div align="center">WVFM:SINE</div>

Notice that a colon (ASCII 3A) is used to separate the <program mnemonic> **WVFM** from **SINE**. For query responses the similarly structured <RESPONSE MESSAGE UNIT> is used. A complete list of <PROGRAM MESSAGE UNITS> and <RESPONSE MESSAGE UNITS> for the 2711A, with definitions, mnemonics, and limitations is given in chapter 7.

General rules:

     1. <program mnemonic> shall have maximum length of 12 characters.

     2. ":" is used to separate <program mnemonics>, and when preceding a <PROGRAM MESSAGE UNIT>, it indicates that the following <program mnemonic> is at the root level.

<PROGRAM MESSAGE UNIT>

     1. <program mnemonic> can be either upper or lower case alpha.

     2. <white space> is only allowed at the end of the header, or next to a "," or a ";". (See note on <white space> below.)

<RESPONSE MESSAGE UNIT>

     1. <program mnemonic> shall contain upper case alpha only.

     2. No <white space> allowed in message.

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

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

Functional Elements (continued)

<PROGRAM MESSAGE>:

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

The semicolon (ASCII 3B) is required to separate <PROGRAM MESSAGE UNITS> within a <PROGRAM MESSAGE>. For the 2711A a <PROGRAM MESSAGE> can be virtually any length. The structure for a <RESPONSE MESSAGE> for query responses is similar.

<PROGRAM MESSAGE TERMINATOR> or **<PMT>** - In order for the device to recognize the end of a <PROGRAM MESSAGE>, a special terminator is required.

For <u>command messages</u>, the <PMT> can take one of three different formats:

   ^END - This is defined as sending EOI TRUE and ATN FALSE with
          the last byte of the message.

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

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

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

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

Error Reporting

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

   Command - In general, when a <PROGRAM MESSAGE> is sent with an error in the syntax, a command error is reported. The command parser (the module that recognizes individual commands) will report the bad command, and look for the next valid command in sequence.

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

   Device Specific - As the name implies, this error is defined by the specific instrument. Currently there are no Device Specific errors generated by the 2711A.

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

To clear an error:

1. Correct the condition which caused the error.

2. Send the *CLS command or read the standard event status register by using the *ESR? query command.

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Data Formats

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

DECIMAL NUMERIC PROGRAM DATA or **<NRf>**
This is the most flexible of the numeric representations and takes the following

$$\rightarrow \quad \boxed{\text{<mantissa>}} \quad \rightarrow \quad \boxed{\text{<white space>}} \quad \rightarrow \quad \boxed{\text{<exponent>}} \quad \rightarrow$$

general form:

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

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

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

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

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

> **<NR1 NUMERIC RESPONSE DATA>** or **<NR1>** -
>   [±][**x**...**x**]   e.g. -98765432
>
> **<NR2 NUMERIC RESPONSE DATA>** or **<NR2>** -
>   [±]**x**[**x**...**x**]**.x**[**x**...**x**]   e.g. +98765.432
>
> **<NR3 NUMERIC RESPONSE DATA>** or **<NR3>** -
>   [±]**x**[**x**...**x**]**.x**[**x**...**x**]**E**±**x**[**x**..**x**]   e.g. 987.65432E+05
>
> **<NON-DECIMAL NUMERIC PROGRAM DATA>** -
>   Numeric values may also be represented as a binary, octal, or hex number, as follows:
>   Binary - **#Bx**[**x**...**x**] or **#bx**[**x**...**x**]   where x is a **0** or **1**

Octal - **#Qx**[**x**...**x**] or **#qx**[**x**...**x**]   where x is a **0** thru **7**
Hex - **#Hx**[**x**...**x**] or **#hx**[**x**...**x**]   where x is a **0** thru **F**

ARBITRARY BLOCK PROGRAM DATA

This data format is used to speed bus transfer in cases where large amounts of data are sent to or from a device (such as waveform or buffer memory data in the 2711A). *Only the <DEFINITE LENGTH> block data format is acceptable for RS-232 while both <DEFINITE LENGTH> and <INDEFINITE LENGTH> block data formats are acceptable for GPIB (IEEE488.2).*

<DEFINITE LENGTH> - **#zy**..**yx**...**x**   where z is a number 1-9, and represents the number of y digit elements. The y digits taken together as a decimal integer equal the number of 8-bit bytes that follow.

For example to send 4 data bytes<DAB> using the <DEFINITE LENGTH> format, you could send:

#14<DAB><DAB><DAB><DAB>

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

 #   5   64000

Start of
Data Block

Even Number of Bytes to Follow
(64,000 bytes = 32,000 points)

Number of Digits
to Follow

The 2711A arbitrary waveform generator represents binary data as 16-bit integers, which is sent as two bytes. Therefore, the total number of bytes you send is always twice the number of data points in the waveform (and it must be always be an *even number*). For example, 64,000bytes are required to download a waveform with 32,000 points.

or
#204<DAB><DAB><DAB><DAB>

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

Refer to the **Waveform Memory Format** section for detailed instructions on

Remote Command Set

Introduction

Both RS-232 and GPIB share the same command set except as noted. Many of the command set has an equivalent front panel counterpart. Therefore, it is recommended that you are thoroughly familiar with the front panel operation of the Model 2711A before beginning any programming.

IMPORTANT NOTE

In order to eliminate some of the common errors encountered while programming instruments, the Model 2711A has adopted a unique approach to sending and executing <PROGRAM MESSAGES>. The following discussions on **command sequence** and **command execution** explain this approach.

Command Sequence

Normally a series of commands (or <PROGRAM MESSAGE UNITS>) are sent as a single <PROGRAM MESSAGE> according to the rules outlined in page 8-11. While these commands are executed immediately, there are certain conditions where the absolute sequential execution of the commands would cause a device error. Take for example the following situation: Output amplitude is 5Vpp, with offset of 0V The new test setup calls for an output setting of 1Vpp with +7.5V offset.(Note: Maximum output amplitude is 10Vpeak)

With the 2711A which executes commands sequentially it would be <u>required</u> to first change the amplitude, then change the offset, in order to prevent a device error which is caused by the sum of amplitude and offset exceeding 10.4Vpeak. Thus one of the following messages would execute properly without a device error, while the other will cause a device error.

> **AMPL 1.0;OFFSET 7.5** ---executes properly
>
>   or
>
> **OFFSET 7.5;AMPL 1.0** ---causes a device error.

Command Execution - As already alluded to in the preceding paragraph, the 2711A executes the command as soon as received.

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Command Set Hierarchy

The command set of the Model 2711A uses a hierarchial structure similar to the file structure on many computer systems. The following figure shows an example of this structure.

Command Set Hierarchy (continued)

root   WVFM

level 1   SIZE   WAVE

While some instruments use several levels within the command set structure, the
Model 2711A uses mostly one or two levels. The top level (represented by the
mnemonic WVFM) is called the root, and the next lower level is level 1. With
this structure you must follow a path through the root in order to reach the
commands on level 1. Referring to the hierarchy diagram, if you wanted to
execute the command SIZE, you would need to indicate the path (through the
root) as follows:

WVFM:SIZE 100;

Finally, it is important to note that 1) the path rules of the Model 2711A, allow
the programmer to delete the root from the command if the level 1 command has
the same root as the preceding command, and 2) if the preceding command is at
level 1, you must specify any new root by using a ":" in front of the root
mnemonic.

To illustrate 1):

WVFM:WAVE 10;:WVFM:SIZE 100
is the same as
WVFM:WAVE 10;SIZE 100

Stacked Queries
In general the Model 2711A allows stacked queries, returning the responses in
the same order in which the queries were received. The only exceptions to this
are the ***IDN?** and ***OPT?** queries. Any queries that are placed after the ***IDN?**
or ***OPT?** queries in a <PROGRAM MESSAGE> will be ignored.

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

Command Summary - System

Command			
Common Commands		**Configuration Commands**	
Long Form	Short Form	Long Form	Short Form
*CLS		CONFIGURE	CONF
*ESE (GPIB only)		HEADERS	HDRS
*ESE? (GPIB only)		HEADERS?	HDRS?
*ESR?			
*IDN?			
*OPC		**System Commands**	
*OPC?		Long Form	Short Form
*RST		RESET	
*SRE (GPIB only)		TRIGGER	TRIG
*SRE? (GPIB only)			
*STB? (GPIB only)		*Note:*	
*OPT?		*All commands execute immediately.*	
*TRG			
*TST?			
*WAI			

Command Summary - Device Specific

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

Waveform Memory Format

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

Decimal Waveform Download

The contents of the waveform memory for wave X (X = 0..99) are changed by a single command formatted according to the IEEE 488.2-1987 standard, and has the following syntax:

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

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

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

Wave	Command Header Value
0	WVFM:WAVE 0;MEM
1	WVFM:WAVE 1;MEM
99	WVFM:WAVE 99;MEM

The <start address> is a decimal number between 0 and 65471.   It sets the starting address where the <data> will be downloaded in waveform memory. The <data> items are decimal numbers between -32768 and 32767. If the AMPL (Amplitude) parameter is set to 10V, the following data: -32768, 0, 32767 would produce -10 Volts, 0 Volts, and 10 Volts, respectively, on the output.

Examples:

An 8 point positive Ramp down loaded into wave 1, address 0.
WVFM:WAVE 1;MEM 0,0,4681,9362,14043,18724,23405,28086,32767

An 8 point sine wave down loaded into wave 2, address 48.
WVFM:WAVE 2;MEM 48,0,23169,32767,23169,0,-23170,-32768,-23170

Binary Waveform Download

The 2711A also supports binary format for waveform <data> items. Binary format is the fastest way to transfer data.

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

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

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

Where:

> <#> is the pound sign, ASCII(35).
> <num> is the number of digits in the length parameter. 1 to 9.
> <length> is the length in bytes (two bytes per waveform data point).
> <hi byte> contains the upper eight bits of a waveform data point .
> <lo byte> contains the lower eight bits of a waveform data point .
> <\n> is the new-line character, ASCII(10).

NOTE:

1. The range of a waveform data point is 0 to 65535. If the AMPL (Amplitude) parameter is set to 10V, the following waveform data point values: 0, 32768, and 65535, produce -10 Volts, 0 Volts, and 10 Volts, respectively, on the output. The waveform data point is converted to <hi byte><lo byte> format for binary downloading. Conversion from waveform data point to <hi byte><lo byte> can be accomplished as follows:

QuickBASIC

> high_byte = FIX(pointdata / 256)
> low_byte = pointdata MOD 256

C

> high_byte = pointdata / 256
> low_byte = pointdata % 256
> > Where point data is between 0 and 65535.

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

3. An example of downloading binary data is included in a Quick Basic program on page 8-23.

Example:

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

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

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

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

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

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

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

In **QuickBASIC**

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

In **C**

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

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Example:

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

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

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

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

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

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

In **BASIC**

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

In **C**

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

Binary Download Test Program for GPIB

```
REM   2711A Binary Download Test Program for GPIB
REM   Language: Microsoft Quick Basic
REM   Computer: IBM AT or better compatible
REM   GPIB Board: National Instruments AT-GPIB, IEEE 488.2
REM   Function: This program downloads a 3456 point, 2-cycle sinewave into Wave1, starting
REM   at Address 0.

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

Length = 3456
DIM ArbData&(Length)

'setup machine
      CALL IBWRT(Arb%, "*cls")
      CALL IBWRT(Arb%, "*rst")
      CALL IBWRT(Arb%, ":wvfm:wave 1;size " + STR$(Length))
      CALL IBWRT(Arb%, ":Func Wave,1")
      GOSUB CheckStatus

'create 2 cycle sinewave
      FOR x = 0 TO Length
      ArbData&(x) = 32767 * SIN((x / Length * 2) * 6.28) + 32767
      NEXT x
```

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Binary Download Test Program for GPIB (continued)

'assemble the data

```
      BinData$ = SPACE$(2 * Length)
      FOR Position = 0 TO Length - 1
      MID$(BinData$, Position * 2 + 1, 2) = CHR$(INT(ArbData&(Position) / 256)) +
CHR$(ArbData&(Position) AND 255)
      NEXT Position
```

'make the header

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

'write out the data

```
      CALL IBWRT(Arb%, "wvfm:wave 1;mem 0," + Header$ + BinData$ + CHR$(10))
      GOSUB CheckStatus
      CALL IBLOC(Arb%)
      STOP
END
'~~~~~~~~~~~
CheckStatus:

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

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Sequence Generator Operation

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

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

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

Example:

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

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

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

Example:

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

                    WVFM:AUTO 10,10

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

Sequence Generator operation (continued)

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

WVFM:SEQ 23

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

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

SEQBURST [SEQB] makes a new sequence file, DELETING the existing sequence file if one already exists. The first parameter is the sequence file to create. The following parameters are pairs, the first parameter of the pair is the wave number, the second parameter is the burst count (the number of times the wave is repeated). The AUTO command is used in conjunction with this command.

Example:
The following commands will create sequence file #5. Step 10 will be wave 2 repeated 4 times. Step 20 will be wave 6 repeated 1,000 times. Step 30 will be wave 45 repeated 10,000 times.

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

SEQBURSTNUM [SEQBN] makes a new sequence file, DELETING the existing sequence file if there is one. The first parameter is the sequence file to create. The following parameters are in triplets. First of the three is the wave number, second is the burst count (the number of times the wave is repeated), and the third and last indicates the sequence step number.

Example:
The following command will create sequence file #23. Step 5 will be wave 1 repeated 2 times. Step 10 will be wave 3 repeated 4 times. Step 15 will be wave 5 repeated 6 times.

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

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Warranty

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

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

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

STATEMENT OF CALIBRATION

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

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

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

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

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