



User Manual Model 645

Arbitrary Waveform Generator



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1 General Information

This chapter contains general information about BERKELEY NUCLEONICS CORPORATION Model 645 Waveform Generator. The information includes:

- Feature Overview
- Warranty Information
- Precaution of Operation
- Upkeep of Model 645
- Safety Information
- Symbols and Terms
- Inspection
- Options and Accessories

You can contact Berkeley Nucleonics Corporation. via the following telephone number for warranty, service, or technical support information.

Telephone: 415-453-9955

Website <http://www.berkeleynucleonics.com>

Or contact Berkeley Nucleonics Corporation for more help by email.

Email: info@berkeleynucleonics.com

1.1 Feature Overview

Model 645 offers:

- 50 MHz sine and 25 MHz square waveforms.
- 14-bits, 125 MSa/s, 256 k-point arbitrary waveforms.
- Pulse, ramp, noise, and dc waveforms.
- AM, FM, PM, FSK, and PWM modulation types.
- Linear and logarithmic sweeps and burst operation.
- Built-in external timebase (10MHz +/- 500Hz) synchronization.

- 16 bits pattern out with a synchronized clock (up to 50MHz).
- Connection via USB, LAN, and GPIB (optional).
- Graph mode for visual verification of signal settings.
- Store up to 4 waveforms in nonvolatile memory.
- Easy-to-use shortcut keys and knobs.
- Free and easy-to-use PC applications.

※ **Note:** Full Model 645 specifications are included in Appendix A.

1.2 Warranty Information

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

1. **Warranty:** BERKELEY NUCLEONICS CORPORATION guarantees that this product meets its published specifications. Under correct installation it should work as expected.
2. **Warranty Period:** This equipment is warranted against defects in material and manufacturing for a period of one year from the date of shipment. During the warranty period, BERKELEY NUCLEONICS CORPORATION is responsible for necessary repairs as long as the product can be proved to be defective.
For warranty service or repair this product must be returned to a service facility designated by BERKELEY NUCLEONICS CORPORATION. Please contact your local service representative for further assistance.
3. **Excluded Items:** This warranty does not include consumptive parts such as fuses, buttons and relays. Neither does this warranty cover defects caused by improper installation, improper or insufficient maintenance, unauthorized modification, improper operation, ignorance of environmental specifications or improper software or interfacing.
4. **Remarks:**
 - No other warranty is expressed or implied, except for the above mentioned.
 - The remedies provided herein are the buyer's sole and exclusive

remedies. BERKELEY NUCLEONICS CORPORATION shall not be liable for any direct, indirect, special, incidental or consequential damages.

Limitation of warranty

- 1.** Our warranties do not cover any damage resulting from unauthorized modification or misuse.
- 2.** Unless mentioned elsewhere in this document, our warranty does not apply to fuses, probes, and problems arising from normal wear or user's failure to follow instructions.
- 3.** Our warranties do not apply on any direct, incidental, special, or consequential damages.
- 4.** The above warranties are exclusive and no other warranty is expressed or implied. Berkeley Nucleonics Corporation disclaims any implied warranties of MERCHANTABILITY, SATISFACTORY QUALITY, and FITNESS for any particular reasons.

1.3 Precaution of Operation

- Please carefully read the manual before operating this device.
- This manual is for reference only. Please consult your local service representative for further assistance.
- The contents of this manual may be amended by the manufacturer without notice.
- Never dismantle the equipment by any unauthorized person, or equipment may be damaged.
- The equipment has been strictly tested for quality before delivery from our factory. However, this equipment must not be used in dangerous situations where damage may result.
- This product should be placed in a safe area in case of unauthorized use.
- The rear protective conduct terminal needs to be connected to the actual earth ground or electrical shock may occur.
- The patent and the copyrights of the related documents for the equipment belong to BERKELEY NUCLEONICS CORPORATION, any reproduction would be illegal.

1.4 Upkeep of Model 645

- Although Model 645 waveform generator is very durable and weather resistant, care should be taken not to expose it to severe impact or pressure.
- Keep Model 645 far from water and damp environment.
- Calibration will be taken every year. Please contact your local service representative for more information.
- If the incorrect display or abnormal beeps occurred, you should stop using the equipment at once.
- Do not use the waveform generator around explosive gas or inflammable vapor.
- To clean the surface of the waveform generator, wipe it with a piece of dry and clean cloth.

1.5 Safety Information



Caution! Please read through the following safety information before using the product.

To avoid possible electrical shock or personal injury, please read and follow these guidelines carefully:

- Follow the guidelines in this manual and DO NOT use the waveform generator if the case is damaged. Check the case and terminals, and make sure all the devices are in the proper positions.
- The waveform generator should be connected to the actual earth ground to avoid electrical shock.
- Do not apply excessive voltage to the waveform generator. Apply voltage within the rated range only.
- If you need to open the instrument case or replace any parts, follow the instructions in this manual. You must be a qualified technician to perform this action.
- The main power supply module contains a fuse rated 3.15A/250V. When replacing the fuse (BUSSMANN F3.15A250V), use only the

same types and same rating as specified.

- Do not try to operate the waveform generator if it is damaged. Disconnect the power from the equipment and consult the local service representative. Return the product to Berkeley Nucleonics Corporation service department if necessary.

1.6 Symbols and Terms



This symbol indicates hazards that may cause damages to the instrument or even result in personal injury.



This symbol indicates high voltage may be present. Use extra caution before taking any action.



This symbol indicates the frame or chassis terminal presented need to be connected to the actual earth ground.



This symbol indicates "Protective Conductor Terminal".



Underwriters Laboratories®.



This symbol indicates earth (ground) terminal.



This symbol indicates this product complies with the essential requirements or the applicable European laws or directives with respect to safety, health, environment and consumer protections.

1.7 Inspection

Your product package is supplied with the following items:

- One Model 645 waveform generator unit. [107(H) x 224(W) x 380(D) mm, approx. 3.6Kg]
- One power cord¹.
- One USB cable.
- One pattern generator cable
- One CD (including this electronic User's Manual and software applications).
- Optional accessories as you ordered.

¹ The Model 645 is provided with a Standard Test lead set, described below.

Test Lead Ratings:

IEC 61010-031 CAT III

Operating Voltage: 1000V DC

Current: 10 Amperes

UL/CE Rated

Material:

Probe Body: Outer Insulation-Santoprene Rubber.

Banana Plug: Body Brass, Nickel Plated Spring Beryllium Copper, Nickel Plated.

Insulation: Polypropylene Resin Flame Retardant Grade 2038.

Others

If any part of the Test Lead Set is damaged, please do not use and replace with a new set.

※ **Warning:** If users use the Test Lead Set without following the specification of Berkeley Nucleonics Corporation, the protection of the Test Lead Set could be impaired. In addition, please don't use a damaged Test Lead Set against the instrument break or personal injury.

- GPIB interface card. (Optional)
-

1.8 Options and Accessories

The following options and accessories are available from Berkeley Nucleonics Corporation for use with Model 645. Please refer to **Table 1-1**.

Table 1-1 Accessory list.

Part Name	Part Number
GPIB Card	645-opt04

2 Overview

This chapter prepares you for using the Model 645 waveform generator. You may want to check if you have all the parts with your waveform generator first. All our products are handled and inspected professionally before shipping out to our customers. If you find any damaged/missing parts or have any doubts about the product, please contact your local service representative immediately and do not attempt to operate the damaged product.

2.1 To Adjust the Handle

You may adjust the carrying handle to suit your needs. The following figures show you how to do it.

I. Taking off the handle from the Waveform generator

【Step 1】 (Turn up the handle)

Pull slightly outward on both sides of the handle and slowly rotate it up as shown in **Figure 2-1**.

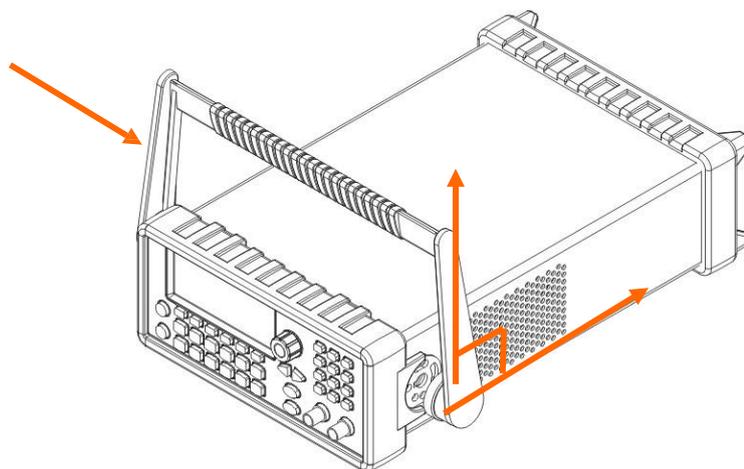


Figure 2-1

【Step 2】 (Pull out the handle)

When the handle is turned up to 90°, pull out the handle from the waveform generator as shown in **Figure 2-2**.

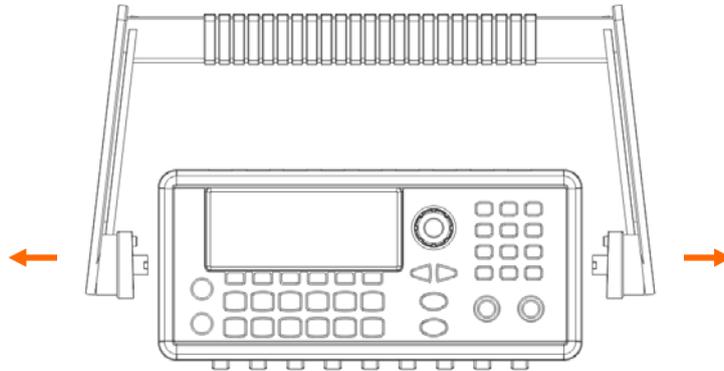


Figure 2-2

II. Adjusting the position for your convenience

Here are some example positions for different needs.

【Position 1】

The default position is for packing as shown in **Figure 2-3**.

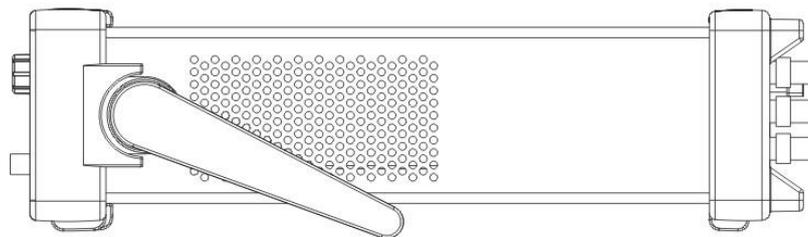


Figure 2-3

【Position 2】

The adjusted position is for operation as shown in **Figure 2-4**.

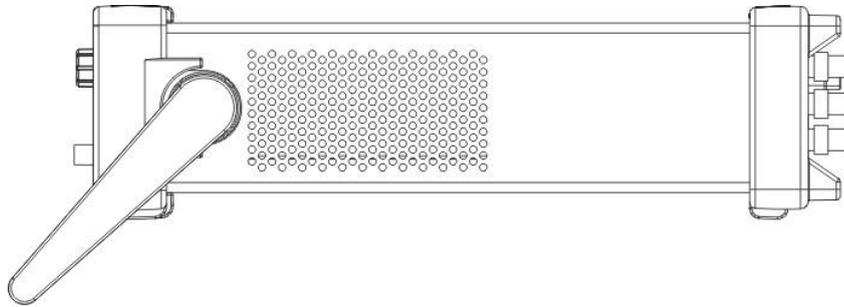


Figure 2-4

【Position 3】

The carrying position is shown in **Figure 2-5**.

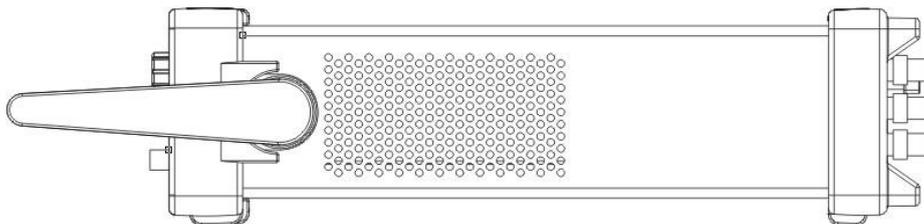


Figure 2-5

2.2 Factory Default Settings

Table 2-1 shows the factory default settings of Model 645 when it is powered on the very first time.

Table 2-1 Factory default settings

Parameters marked with a star (*) are stored in non-volatile memory.

<i>Output Configuration</i>	<i>Default Setting</i>
Function	Sine wave
Frequency	1 kHz
Amplitude/Offset	100 mVpp/0.000Vdc
Output Units	Vpp
Output Termination	50Ω
Autorange	On
<i>Modulation</i>	
Carrier	1 kHz Sine (AM, FM, PM, FSK)
	1 kHz Pulse (PWM)
Mod. Waveform(AM)	100 Hz Sine
Mod. Waveform(PM, FM, PWM)	10 Hz Sine
AM Depth	100%
FM Deviation	100 Hz
PM Deviation	180 degrees
FSK Hop Frequency	100 Hz
FSK Rate	10 Hz
PWM Width Deviation	10 μs
Modulation State	Off

Sweep	
Start/Stop Frequency	100 Hz/1 kHz
Sweep Time	1 sec.
Sweep Mode	Linear
Sweep State	Off
Burst	
Burst Count	1 Cycle
Burst Period	10 ms
Burst Start Phase	0 degree
Burst State	Off
System-Related Operations	
Power-Down Recall	Disabled
Display Mode	ON
Error Queue	0 errors
Stored States, Stored Arbs	
Output State	Off
Triggering Operations	
Trigger Source	Internal (Immediate)
Remote Interface Configuration	
GPIB Address	10
DHCP	On
IP Address	169.254.02.020
Subnet Mask	255.255.0.0
Default Getaway	0.0.0.0
DNS Server	0.0.0.0
Host Name	None
Domain Name	None

2.3 Model 645 Operation Panels

Brief descriptions are provided in this chapter for all the connectors and buttons on both front and rear panels of Model 645 waveform generator.

2.3.1 Front Panel

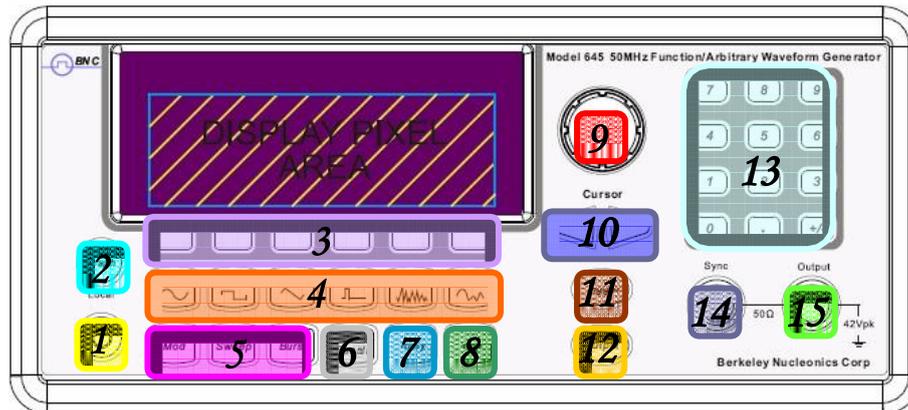


Figure 2-6

1. Power
2. Graph/Local
3. Menu Operation Softkeys (in color grey)
4. Waveform selection keys
5. Modulation/Sweep/Burst keys
6. Store/Recall Menu Key
7. Utility Menu Key
8. Help Key
9. Knob
10. Cursor Keys
11. Manual Trigger Key
12. Output Key
13. Numeric Keypad
14. Sync output Connector
15. Main signal output Connector

※ Note: When using the Menu Operation Softkeys, make sure your selection is highlighted after you press one of the softkeys.

2.3.2Rear Panel

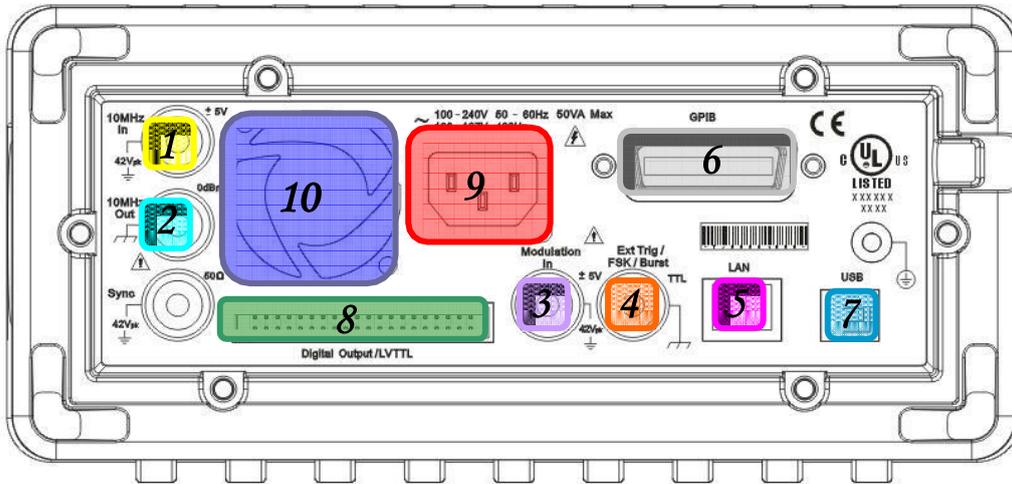


Figure 2-7

1. 10MHz In (External 10 MHz Reference Input) Connector
2. 10MHz Out (Internal 10 MHz Reference Output) Connector
3. Modulation In (External Modulation Input) Connector
4. Trig In/Out, FSK/Burst Connector
5. LAN Port
6. GPIB Connector(Optional)
7. USB Port
8. Digital Pattern Output / LVTTTL
9. Power cord Connector
10. Vent

3 Common Operations

This chapter describes the basic operations and configurations that are commonly used to set up a waveform output. Operations for outputting specific waveforms are covered in chapter 4.

3.1 Graph Mode

Pressing the Graph button enables the graph mode. You can view the waveform visually in the graph mode and change the waveform parameters by using the knob and the cursor keys. The parameter values that the knob can reach in the graph mode are limited due to resolution. To fine-adjust the parameters, use the numeric keypad to input the desired value or return to the menu mode. Press the Graph button again to leave the graph mode and return to the menu mode.



Figure 3-1 menu mode

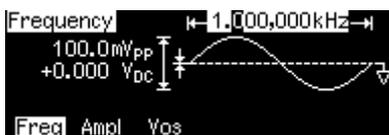


Figure 3-2 graph mode

3.2 Numerical/Alphabetical Entry

There are 12 buttons on the numeric keypad, two cursor keys and a turning knob on the front panel provided for the numeric entry.

- **Numerical entry** ---- When entering a numeric value, you can select

a desired value directly on the numeric keypad or use the cursor keys to move the cursor on the display and increase or decrease the digit by turning the knob.

When you use the numeric keypad, all the available units for the entry will be shown on the display. Press the softkey under the desired unit to finish the entry, or press Cancel to withdraw the changes.

- **Alphabetical entry**-----If you are asked to enter a string of alphabetic letters, turn the knob until the desired letter appears on the display. Use the cursor keys to move the cursor for entering next letter or modify the letter previously entered. You may also use the +/- key on keypad to delete the letter previously entered.

3.3 To Select Output Function

Model 645 provides various output functionality:

- **Standard waveforms:** Model 645 provides five standard waveforms: sine, square, ramp, pulse and noise. The default waveform output is sine wave.
- **Arbitrary waveforms:** There are additional five built-in arbitrary waveforms available. Or you can create your own custom waveform with Wavepatt software which came with the unit.
- **Modulation:** The waveform generator also provides modulation for sine, square, ramp and arbitrary waveforms using AM, FM, PM, or FSK. You can also use PWM to modulate pulse waveform.
- **Frequency sweeping:** Linear and logarithmic frequency sweeping modes are available for sine, square, ramp and arbitrary waveforms.
- **Burst operation:** The burst waveforms can be generated with any one of the standard or arbitrary waveforms (except dc).

Front-panel Operation

To select a desired output function, press the corresponding button and then set up related parameters as needed. Refer to Chapter 4 for setting up each individual waveform type.

Remote Interface Operation

FUNCTion {SINusoid|SQUare|RAMP|PULSe|NOISe|DC|USER|PATTern}

You may also use the APPLy command to select the function, frequency, amplitude, and offset in one shot.

Notes

- Frequency limitation: When the newly-selected function has a smaller maximum frequency, the waveform generator will automatically adjust the frequency from the old value to the new, smaller maximum value.
- Amplitude limitation: When the newly-selected function has a smaller maximum amplitude, the waveform generator will automatically adjust the amplitude from the old value to the new smaller maximum value. This may occur when the output units are Vrms or dBm due to the differences in crest factor for the various output functions.

3.4 To Set Output Frequency/Period

The current frequency setting comes from the factory default or a previously set value. The steps for setting a new frequency are listed below. If you need to set the period instead, press the Freq/Perd softkey to toggle between frequency and period.



Figure 3-3 frequency setting



Figure 3-4 Period setting

Front-panel Operation

1. Select your desired function by pressing one of the function keys.
2. Press the softkey under Freq/Perd and make sure Freq is highlighted (indicating the frequency mode is selected).
3. Use the numeric keypad or the knob with cursor keys to change the value.

Remote Interface Operation

FREQUENCY {<frequency>|MINimum|MAXimum}

Notes

- Each waveform function has its own frequency range, but the default frequency is 1 kHz for all functions. The table below lists the frequency ranges for different functions:

Function	Frequency Range
Sine	1 μ Hz ~ 50 MHz
Square	1 μ Hz ~ 25 MHz
Ramp	1 μ Hz ~ 200 kHz
Pulse	500 μ Hz ~ 10 MHz
Arbitrary	1 μ Hz ~ 10 MHz

- Frequency limitation: When you choose a new function and the current frequency setting is larger than the maximum frequency of the new function, the waveform generator will automatically adjust the frequency to the smaller maximum value.
- Burst limitation: For internally-triggered bursts, the minimum frequency is 2.001 mHz. For sine and square waveforms, frequencies above 10 MHz are allowed only with an "infinite" burst count.
- Duty Cycle Limitation: There are some limits on duty cycle for square waveforms. When the frequency is greater than 10 MHz, the range of the duty cycle is 40% to 60%. For other frequencies, the range of the duty cycle is 20% to 80%. If you set an out-of-limit duty cycle, the waveform generator will adjust

automatically to the maximum value of the duty cycle limit range.

3.5 To Set Output Amplitude

The default amplitude for all functions is 100 mVpp (into 50 ohms). The procedure to set a new amplitude value is described as follows.



Figure 3-5

Front-panel Operation

1. Select your desired function by pressing one of the function keys.
2. Press the softkey under Ampl/High and make sure Ampl is highlighted. Use the numeric keypad or the knob with cursor keys to change the value.

Remote Interface Operation

VOLTage {<amplitude>|MINimum|MAXimum}

Use this command to set units:

VOLTage:UNIT {VPP|VRMS|DBM}

Notes

- Specifying a high (voltage) level and a low level (Section 3.7) is equivalent to specifying amplitude and DC offset (Section 3.6). For example, if you set the high level to +2 volts and the low level to -3 volts, the resulting amplitude will be 5 Vpp, with an offset voltage at -0.5 V.



Figure 3-6



Figure 3-7

- The default output unit is Vpp, but one may also choose from Vrms and dBm. But the output unit cannot be set to dBm if the output termination is set to “high impedance”. In such a case, the unit is automatically reset to Vpp.
The unit setting is stored in volatile memory. The default unit (Vpp) will be restored after a power-on cycle or a remote interface reset.
- Offset Voltage limitations: The value of output amplitude is constrained by the equation below:

$$V_{pp} \leq 2 \times (V_{max} - |V_{offset}|)$$

where Vmax is the maximum peak voltage allowed for the selected output termination (5 volts for a 50 Ω load or 10 volts for a high-impedance load).

- Limits with Unit Selection: The output amplitude limits may be affected by the output units selected. You may encounter this when the units are Vrms or dBm due to the differences in crest factor for the various output functions. For instance, if you output a 5 Vrms square wave (into 50 ohms) and then change it to the sine wave function, the waveform generator automatically adjust the output amplitude to 3.536 Vrms, which is the maximum for sine waves in Vrms.
- Output Termination Limits: When the Output Termination Setting is changed, the Output Amplitude is automatically adjusted. For instance, when you change the output termination from 50 ohms to “high impedance”, your offset voltage doubles, thus it affects your output amplitude, and when Output Termination has been changed from “high impedance” to 50 ohms, the offset voltage decreases by half.
- Arbitrary Waveform Limitations: For arbitrary waveforms, if the data points do not span the full range of the output DAC (Digital-to-Analog converter), the maximum amplitude will be

limited. For example, the built-in Sinc wave does not span the full ± 1 range and thus its maximum amplitude is limited to 6.087 Vpp (into 50 Ω).

- While changing amplitude, you may notice a momentary disruption in the output waveform at certain voltages due to switching of the output attenuators. The amplitude is controlled, however, so the output voltage will never exceed the current setting while switching ranges. You may disable the voltage autoranging to prevent this output disruption.

3.6 To Set DC Offset Voltage

The default DC offset voltage is 0 volt for all functions. To specify a non-zero DC offset value, follow the steps below.

Front-panel Operation

1. Select your desired function by pressing one of the function keys.
2. Press the softkey under Vos/Low and make sure Vos is highlighted. Use the numeric keypad or the knob with cursor keys to change the value.

DC offset setting can also be changed from the Utility menu.

1. Press the Utility button.
2. Press the softkey under DC to toggle between DC ON and OFF. Make sure ON is selected on the display. Use the numeric keypad or the knob with cursor keys to change the value.

Remote Interface Operation

VOLTage :OFFSet {<offset>|MINimum|MAXimum}

Notes

- Specifying a high (voltage) level and a low level (Section 3.7) is equivalent to specifying amplitude (Section 3.5) and DC offset. For example, if you set the high level to +2 volts and the low level to -3 volts, the resulting amplitude will be 5 Vpp, with DC offset at -0.5 V.



Figure 3-8

- Limits with amplitude and output termination: DC offset value is constrained by the equation below:

$$|V_{\text{offset}}| \leq V_{\text{max}} - \frac{V_{\text{pp}}}{2}$$

where V_{max} is the maximum peak voltage allowed for the selected output termination (5 volts for a 50 Ω load or 10 volts for a high-impedance load).

If the specified dc offset is not valid, the waveform generator automatically adjusts it to the maximum value allowed with the specified amplitude.

- Arbitrary Waveforms Limitations: For arbitrary waveforms, if the waveform data points do not span the full range of output DAC (Digital-to-Analog Converter), the maximum offset and amplitude will be limited.
- For dc volts, the output level is actually controlled by setting the offset voltage. You can set the dc level to any value between ± 5 Vdc into 50 ohms or ± 10 Vdc into an open circuit.

3.7 To Set High-Level and Low-Level Bounds

Setting high-level and low-level bounds provides an equivalent way to specifying amplitude and DC offset. The procedure is as follows.

Front-panel Operation

1. Select your desired function by pressing one of the function keys.
2. Press the softkey under Ampl/High to toggle and make sure the High is highlighted. Use the numeric keypad or the knob with cursor keys to change the value.
3. Press the softkey under Vos/Low to toggle and make sure Low is highlighted. Use the numeric keypad or the knob with cursor keys to change the value.

4. See Figure 3-6 and Figure 3-7 as sample displays.

Remote Interface Operation

VOLTage:HIGH {<voltage>|MINimum|MAXimum}

VOLTage:LOW {<voltage>|MINimum|MAXimum}

3.8 To Set Waveform Polarity

The default waveform polarity mode is Normal, in which the waveform goes positive during the first part of the wave cycle. One may change it to the Inverted mode where the waveform goes negative during the first part of the wave cycle. To set the waveform polarity mode, follow the steps below.

Front-panel Operation

- Press Utility button and then the softkey under Output Setup.
- Press the softkey under NormInvt to toggle between Normal and Inverted. Make sure your choice is highlighted.
- Press the softkey under DONE to finish the selection.



Figure 3-9

Remote Interface Operation

OUTPut: POLarity {NORMal|INVERTed}

Notes

- When a non-zero offset is used, the waveform is inverted relative to the offset voltage, so the offset remains the same in the inverted waveform.
- When the waveform is inverted, the Sync signal associated with the waveform is not inverted.

3.9 To Set Output Termination

A fixed series output impedance of 50 ohms to the front-panel *Output* connector is set in Model 645 by default. If the actual load impedance does not match the value specified, the output amplitude and offset levels will be incorrect. To change this setting, follow the steps below.

Front-panel Operation

1. Press the Utility button and then press the softkey under Output Setup.
2. Make sure the Load softkey is highlighted. If not, press the softkey to toggle. Use the numeric keypad or the knob with cursor keys to change the value.
3. If you wish to choose high impedance, press the softkey under Load to toggle and make sure High Z is highlighted.
4. Press DONE to finish the entry.
5. See Figure 3-9 as a sample display.

Remote Interface Operation

Use this command for output termination setting:

```
OUTPut:LOAD {<ohms>|INFinity|MINimum|MAXimum}
```

Notes

- The range for Output Termination is from 1 ohm to 10k ohms, or Infinite. The default is 50 ohms.
- The output termination setting is stored in non-volatile memory and it stays after power-off or a remote interface reset.
- When the output termination is set to be "high impedance", the units is automatically set to be Vpp if dBm is previously selected.

3.10 To Enable/Disable Voltage Autoranging

The waveform generator by default turns on autoranging at power-on and finds optimal settings for the output amplifier and attenuators. If autoranging is turned off, Model 645 uses the current amplifier and attenuator settings. To enable/disable voltage autoranging, follow the steps below.

Front-panel Operation

1. Press the Utility button and then the softkey under Output Setup.
2. Press the softkey under Rang to toggle between Auto and Hold for auto-ranging setting.
3. Press the softkey under DONE to finish the selection.



Figure 3-10



Figure 3-11

Remote Interface Operation

VOLTage:RANGe:AUTO {OFF|ON|ONCE}

Notes

- While changing amplitude, you may notice a momentary disruption in the output waveform at certain voltages due to switching of the output attenuators. You may use disable the voltage autoranging to prevent this output disruption.
- With auto-ranging off, the resolution and accuracy of amplitude and offset may be affected when reducing the amplitude below the expected range change. And you may not be able to achieve the minimum amplitude that is available when autoranging is on.

3.11 To Control Output Connector

Model 645 output is controlled by the output button. The output is disabled at power on by default to protect the equipment connected to Model 645.

Front-panel Operation

- To enable/disable output, press the Output button to toggle. The

Output button becomes lit when output is enabled.

Remote Interface Operation

OUTPut {OFF|ON}

Notes

- The Output is automatically disabled when an excessive external voltage is applied to the Output connector on the front panel and an error will be generated and the error message will be shown. Remove the overload from the Output connector and enable the Output again.

3.12 To Enabled/Disable Sync Out Signal

All the standard output functions, except dc and noise, can be associated with a sync-out signal. It is outputted at the Sync connector on the front panel.

Front-panel Operation

- To enable/disable the sync out signal, press the Utility button, and then the Sync softkey to toggle the setting.

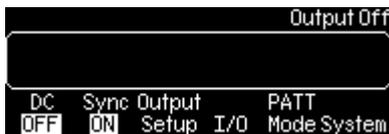


Figure 3-12

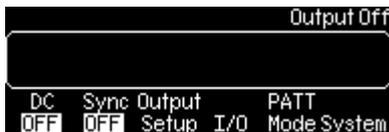


Figure 3-13

Remote Interface Operation

OUTPut:SYNC {OFF|ON}

Notes

- If the Sync connector is disabled, the output signal is at a logic "low" level.
- The Sync setting is stored in non-volatile memory, so it does not change after power-off or a remote reset command is issued.
- For Sine, ramp and pulse waveforms, the Sync signal is a square waveform with a 50% duty cycle. The Sync signal is a TTL "high" when the waveform output is positive, relative to zero volts (discard the dc offset setting). The Sync signal is a TTL "low" when the waveform output is negative, relative to zero volts (discard the dc offset setting).
- For Square waveforms, the Sync signal is a square waveform with the same duty cycle.
- For arbitrary waveforms, the Sync signal is a square waveform with a 50% duty cycle. The Sync signal is a TTL "high" when the first waveform point is outputted.
- For internal-modulated AM, FM, PM, and PWM, the Sync signal is aligned with the modulating waveform and is a square wave with a 50% duty cycle. The Sync signal is a TTL "high" during the first half of the modulating waveform.
- For external-modulated AM, FM, PM, and PWM, the Sync signal is aligned with the carrier waveform and is a square wave with a 50% duty cycle.
- For FSK, the Sync signal is aligned with shifts in frequency. The Sync signal is a TTL "high" during the output of the "hop" frequency and "low" during that of the "carrier" frequency.
- For frequency sweeps with Marker Off, the Sync signal is a square wave with a 50% duty cycle. The Sync signal is a TTL "high" in the first half of the sweep and "low" in the second half. The frequency of the sync signal is equal to the reciprocal of the sweep time. If the Marker is enabled, the Sync signal setting will be ignored and the Sync signal is a TTL "high" at the beginning of the sweep and transitions to "low" at the marker frequency.
- For a triggered burst, the Sync signal becomes a TTL "high" when the burst is triggered. The Sync signal transitions to a TTL "low" at the end of the specified number of cycles (may not be the

zero-crossing point if the waveform has a non-zero phase). If the burst count is infinite, the Sync signal works the same way described above for continuous waveforms.

- If the burst generation is externally gated, the Sync signal starts at a TTL "high" with the external gate signal. However, the sync signal will not transition to a TTL "low" until the end of the last cycle (may not be the zero-crossing point if the waveform has a non-zero phase).
- When the output waveform polarity is inverted, the associated sync out signal is not affected.

3.13 To Restore the Factory Default Settings

To reset the waveform generator to its factory default settings, press "Store/Recall" button and then choose "Set to Def" softkey. See Figure 3-12 and Figure 3-13. After choosing "Yes" to make confirmation, the waveform generator has been restored to factory default settings.

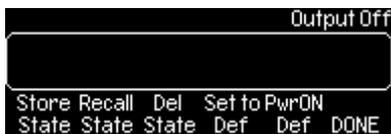


Figure 3-14

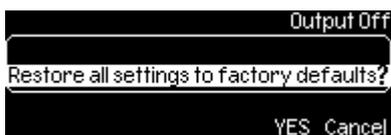


Figure 3-15

For the default settings, please refer to Table 2.1 for Model 645 factory default settings.

To set the power-on state, please refer to Section 5.2 Storing the instrument state.

4 Waveform Output Operations

This chapter describes each of the waveforms that Model 645 provides and also the detailed front-panel, menu and remote interface operations for outputting the waveforms.

4.1 Sine Wave

How to generate a sine wave

1. The default waveform output of Model 645 is sine wave. To select sine wave while the current output function is not it, press the Sine button to make the selection.
2. Refer to Chapter 3 for configuring common parameters, which include frequency/period, amplitude and dc offset voltage.
3. To view the waveform parameters in the graph mode, press the Graph button.



Figure 4-1

Remote interface operation

APPLY:SINusoid [<frequency>[,<amplitude>[,<offset>]]]

or

FUNCTION {SINusoid}

FREQUENCY {<frequency> | MINimum | MAXimum}

VOLTage {<amplitude> | MINimum | MAXimum }

VOLTage:OFFSet {<offset> | MINimum | MAXimum }

4.2 Square Wave

A square wave consists of instantaneous transitions between two voltage levels. The *duty cycle* of a square wave represents the amount of time in each cycle during which the wave is at the high level (assuming that the waveform is not inverted):

$$\text{DutyCycle} = (\text{Time Interval at High Level}) / \text{Period} \times 100\%$$

How to generate a square wave

1. Press the Square button to select the square wave function.
2. Refer to Chapter 3 for configuring common parameters, including frequency/period, amplitude and dc offset voltage.
3. Press the softkey under DutyCycle for configuring the value.
4. Use the knob with the cursor keys to change the value, or
5. Use the numeric keypad to enter a desired value and then press the softkey under % to finish the entry or the softkey under Cancel to cancel the changes.
6. To view all the waveform parameters, press the Graph button.



Figure 4-2

Remote interface operation

APPLY:SQUare [<frequency>[,<amplitude>[,<offset>]]]

or

FUNCTION {SQUare}

FREQUency {<frequency> | MINimum | MAXimum}

VOLTage {<amplitude> | MINimum | MAXimum }

VOLTage:OFFSet {<offset> | MINimum | MAXimum }

FUNCTION:SQUare:DCYCLE {<percent> | MINimum | MAXimum }

Notes

- The default value for duty cycle is 50% and will be restored after power off or a remote interface reset as the setting is stored in

volatile memory.

- When you change the output function from square wave to another, the previously-set duty cycle is remembered and will be resumed when square wave is re-selected.
- For square waves with frequency higher than 10 MHz, the range of the duty cycle is from 40% to 60%, and for square waves with lower frequency, the range of the duty cycle is from 20% to 80%.
- If you change frequency to a new value with which Model 645 cannot produce the current duty cycle, it will automatically adjust the duty cycle to the closest possible value for the new frequency.
- When square wave is selected as the modulating waveform, the duty cycle is fixed at 50%. The duty cycle setting applies to square wave carrier waveform for AM, FM, PM or PWM.

4.3 Ramp Wave

A ramp wave is a triangle waveform with adjustable symmetry. Symmetry represents the percentage of time in a cycle when the ramp wave is rising (assuming that the waveform polarity is not inverted). The default symmetry is 100%.

How to generate a ramp wave

1. Press the Ramp button to select the output function.
2. Refer to Chapter 3 for configuring common parameters, including frequency/period, amplitude and dc offset voltage.
3. Press the softkey under Symmetry for configuring the value.
4. Use the knob with the cursor keys to change the symmetry setting. Or use the numeric keypad to enter a new value and then press the softkey under % to finish the entry or the softkey under Cancel to withdraw the changes.
5. Press the Graph button to view all the waveform parameters.



Figure 4-3

Remote interface operation

APPLY:RAMP [<frequency>[,<amplitude>[,<offset>]]]

(The command generates ramp wave with 100% symmetry)

Or

FUNCTION {RAMP}

FREQUENCY {<frequency> | MINIMUM | MAXIMUM}

VOLTAGE {<amplitude> | MINIMUM | MAXIMUM }

VOLTAGE:OFFSET {<offset> | MINIMUM | MAXIMUM }

FUNCTION:RAMP:SYMMETRY {<percent>|MINIMUM|MAXIMUM}

Notes

- Symmetry value is stored in volatile memory so the default setting (100%) will be restored after power-off or a remote interface reset.
- When you change the output function from ramp wave to another, the previously-set symmetry is remembered and will be resumed when ramp wave is re-selected.
- The symmetry setting does not apply to the case where ramp wave is used as the modulating wave for AM, FM, PM, or PWM.

4.4 Noise Waveform

How to generate a noise wave

1. Press the Noise button to select the output function.
2. Refer to Chapter 3 for configuring common parameters such as amplitude and dc offset voltage for noise wave.
3. Press the Graph button to view all the waveform parameters.



Figure 4-4

Remote interface operation

APPLY:NOISE [<frequency | DEF>[,<amplitude>[,<offset>]]]

FUNCTION {RAMP}

VOLTAGE {<amplitude> | MINIMUM | MAXIMUM }

VOLTage:OFFSet {<offset> | MINimum | MAXimum }

Notes

- In the APPL:NOIS command, the frequency parameter has no effect, but you still need to specify a value or "Default" for it.

4.5 Pulse Waveform

A pulse waveform consists of a period, a pulse width, an ascending edge and a descending edge. The parameters are described further below.

Pulse Period / Frequency

The default pulse period is 1 ms (or 1kHz in frequency), and the allowable value is ranged from 100 ns to 2000s (or 10 MHz down to 0.5mHz in frequency). Pulse period constrains the other parameters with the following equation:

$$\text{PulsePeriod} \geq \text{PulseWidth} + 1.6 \times \text{EdgeTime}$$

The waveform generator adjusts the other parameters when needed to accommodate the given pulse period.

Pulse Width

The pulse width represents the time from the 50% point of the ascending edge to the 50% point of the following descending edge. The default pulse width is 100 μ s, and the possible value is ranged from 20 ns to 2000s. The actual allowable range is determined as follows:

$$1.6 \times \text{EdgeTime} \leq \text{PulseWidth} \leq \text{PulsePeriod} - 1.6 \times \text{EdgeTime}$$
$$W_{\text{min}} \leq \text{PulseWidth} \leq \text{PulsePeriod} - W_{\text{min}}$$

where W_{min} is the minimum allowable value determined by the following conditions on PulsePeriod:

$$W_{\min} = \begin{cases} 20 \text{ ns}, & \text{if PulsePeriod} \leq 10\text{s} \\ 200 \text{ ns}, & \text{if } 10\text{s} < \text{PulsePeriod} \leq 100\text{s} \\ 2 \mu\text{s}, & \text{if } 100\text{s} < \text{PulsePeriod} \leq 1000\text{s} \\ 20 \mu\text{s}, & \text{if } 1000\text{s} < \text{PulsePeriod} \end{cases}$$

If the specified value for PulseWidth is outside of the allowable range, the waveform generator will automatically adjust it to accommodate the given pulse period.

Edge Time

The edge time represents the time from the 10% point to the 90% point of an ascending or descending edge. The default edge time is 5 ns, and the possible value is ranged from 5 ns to 100 ns, with the following constraint on the maximum allowable value:

$$\text{EdgeTime} \leq 0.625 \times \text{PulseWidth}$$

Model 645 will alter the edge time when needed to accommodate the specified pulse width.

Pulse Duty Cycle

Specifying pulse duty cycle is another way to define a pulse wave than specifying pulse width. Pulse duty cycle is defined as follows:

$$\text{DutyCycle} = \text{PulseWidth} / \text{PulsePeriod} \times 100\%$$

If the specified pulse duty cycle conflicts with the specified pulse width or vice versa, the most recently specified pulse duty cycle or pulse width will be accepted over the other. The default duty cycle is 10%, and the acceptable range is from 0% to 100%, with the following constraints:

$$\begin{aligned} \text{DutyCycle} &\geq W_{\min} / \text{PulsePeriod} \times 100\% \\ \text{DutyCycle} &\leq (1.0 - W_{\min} / \text{PulsePeriod}) \times 100\% \end{aligned}$$

where W_{\min} is the minimum allowable value for pulse width defined in the previous section on pulse width. The waveform generator will adjust it to accommodate the given pulse period.

How to generate a pulse wave

1. Press the Pulse button to choose pulse wave output.
2. Refer to Chapter 3 for specifying the common parameters, including frequency/period, amplitude and dc offset voltage.
3. Press the softkey under Width/Duty to Toggle between setting pulse width or duty cycle.
4. Use the knob with the cursor keys to change the value. Or use the numeric keypad to enter a new value and then press the softkey under % to finish the entry or the softkey under Cancel to withdraw the changes.
5. Press the softkey under Edge Time and then follow step 4 to enter your desired value for both edges.
6. Press the Graph button to view all the waveform parameters.



Figure 4-5

Remote interface operation

APPLY:PULSE [<frequency>[,<amplitude>[,<offset>]]]

Or use the following commands for setting parameters of your pulse waveform:

FUNCTION{PULSE}

FREQUENCY {<frequency> | MINimum | MAXimum }

VOLTage {<amplitude> | MINimum | MAXimum }

VOLTage:OFFSet {<offset> | MINimum | MAXimum }

PULSE:PERiod {<seconds>|MINimum|MAXimum}

FUNCTION:PULSE:WIDTH {<seconds>|MINimum|MAXimum }

FUNCTION:PULSE:DCYCLE {<percent>|MINimum|MAXimum }

FUNCTION:PULSE:TRANSition {<percent>|MINimum|MAXimum }

4.6 Arbitrary Waveform

Model 645 waveform generator provides five built-in arbitrary waveforms and up to four user-defined arbitrary waveforms that are stored in non-volatile memory. The built-in waveforms are

exponential-rise, exponential-fall, negative-ramp, sinc, and cardiac. The default arbitrary waveform is an exponential-rise wave.

For each user-defined waveform, one may create up to 262,144 (256k) points from the remote interface. If you choose an arbitrary waveform as the modulating waveform for AM, FM, PM, or PWM, the waveform is automatically limited to 4k points and the extra points will be removed by decimation.

User-defined waveforms

Model 645 supports user-defined waveforms. You may use the **Wavepatt** waveform and pattern editor to create the waveforms you want or import the waveforms from the oscilloscope that you captured previously. For more information on the user-defined waveforms, please refer to the on-line help of **Wavepatt**.

How to output a built-in arbitrary waveform

1. Press the Arb button to choose arbitrary waveform output.
2. Press the softkey under Select Wform and then the softkey under Built In.
3. Choose the desired waveform from the five built-ins by pressing the corresponding softkey.
4. Refer to Chapter 3 for configuring frequency/period, amplitude and dc offset voltage.
5. Press the Graph button to view all the waveform parameters.



Figure 4-6



Figure 4-7



Figure 4-8

Remote interface operation

FUNCTION USER {EXP_RISE | EXP_FALL | NEG_RAMP | SINC | CARDIAC}

Remote interface operation

DATA:DAC VOLATILE, {<binary block>|<value>, <value>, ...}

DATA VOLATILE, <value>, <value>, ...

FORMat:BORDER {NORMal | SWAPped}

DATA:COPY <destination arb name> [,VOLATILE]

DATA:CATalog?

DATA:NVOLatile:CATalog?

DATA:NVOLatile:FREE?

DATA:ATTRibute:AVERAge? [<arb name>]

DATA:ATTRibute:CFACTOR? [<arb name>]

DATA:ATTRibute:POINTS? [<arb name>]

DATA:ATTRibute:PTPeak? [<arb name>]

4.7 Amplitude Modulation

Amplitude modulation provides a waveform in which the amplitude of the carrier waveform varies with the modulating waveform.

Carrier Waveform

The default carrier waveform is sine. One may also choose from square, ramp and arbitrary waveforms but not pulse, noise and dc waveforms. The default carrier frequency is 1kHz for all waveforms. Each carrier waveform has its own acceptable range of frequencies. Refer to the table in Section 3.4 "To Set Output Frequency/Period" for details.

Modulating Waveform

Model 645 accepts either internal or external modulating source but not both at the same time. The default source is internal, and the default

internal modulating waveform is sine wave. For internal source, one may also choose from square with 50% duty cycle, URamp (Up or Positive Ramp with 100% symmetry), DRamp (Down or Negative Ramp with 0% symmetry), triangle (ramp with 50% symmetry), noise and arbitrary waveforms. If an arbitrary waveform is chosen, the number of points in the waveform is limited to 4k points with an automatic decimation process. The default frequency for internal modulating waveform is 100Hz, and the acceptable range is from 2 mHz to 20 kHz.

When external source is selected, the carrier waveform is modulated with an external waveform present at the *Modulation In* connector on the rear panel.

Modulation Depth

The modulation depth controls the magnitude of the amplitude variation of the modulation output. It is defined as the following formula:

$$\text{ModulationDepth} = (\text{MaxAmplitude} - \text{MinAmplitude}) / \text{Amplitude} \times 100\%$$

where Amplitude is the specified amplitude of the carrier waveform; MaxAmplitude and MinAmplitude are the maximum and minimum amplitudes of the resulting modulation waveform. Model 645 is so designed that when Modulation Depth is 0%, the amplitude of the modulation waveform stays at half of the specified amplitude of the carrier waveform. As a result, MinAmplitude may be negative when ModulationDepth is larger than 100%. The default Modulation Depth is 100% and the allowable range is from 0% to 120%.

When external source is selected as the source of modulating waveform, the modulation is controlled by the specified modulation depth and the $\pm 5\text{v}$ signal levels of the external waveform. When the external waveform is at +5v, the amplitude of the output will reach MaxAmplitude. When the external waveform is at -5v, the amplitude of the output will reach MinAmplitude.

Note that the modulation output of Model 645 will not exceed $\pm 5\text{V}$ peak

(into a 50-ohm load) even if the modulation depth is greater than 100%.

How to set up amplitude modulation

1. Press one of the following function buttons to choose your carrier waveform: Sine, Square, Ramp, Arb. Specify all the necessary waveform parameters for the carrier waveform as described in Section 4.1, 4.2, 4.3 and 4.6.



Figure 4-9

2. Press the Mod button to toggle on the modulation output.
3. Press the softkey under Type and press the softkey under AM to select amplitude modulation. An amplitude modulation output will be generated with the current parameters.
4. Press the softkey under Src to toggle between internal source (Int) and external source (Ext) for selecting modulating waveform source.
5. If internal source is selected:
 - a. Press the softkey under Shape to toggle between different types of modulating waveform. If arbitrary waveform (Arb) is selected as modulating signal source, the modulating signal source is depending on the previous waveform selection in arbitrary function. One may toggle the Mod key to see the arbitrary modulating waveform message that temporarily displayed on the screen.
 - b. Press the softkey under AM Freq and use numeric keypad or the knob with the cursor keys to set the desired modulating frequency.
6. Press the softkey under AM Depth and use numeric keypad or the knob with the cursor keys to set the modulation depth.
7. Press the Graph button to view all the waveform parameters.

Remote interface operation

Use these commands to output an amplitude modulation waveform:

FUNCTION {SINusoid|SQUare|RAMP|USER}
FREQUency {<frequency> | MINimum|MAXimum}
VOLTage {<amplitude> | MINimum|MAXimum}
VOLTage:OFFSet {<offset> | MINimum|MAXimum}
AM:INTernal:FUNctIon
 {SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}
AM:INTernal:FREQUency {<frequency> | MINimum|MAXimum}
AM:SOURce {INTernal|EXTernal}
AM:STATe ON

Notes

- Only one type of modulation can be activated at one time. When amplitude modulation is enabled, the previously selected modulation is automatically disabled.
- Amplitude modulation cannot be enabled with sweep or burst mode at the same time. When amplitude modulation is enabled, sweep or burst mode will be disabled.

4.8 Frequency Modulation

Frequency modulation provides a waveform in which the frequency of the carrier waveform varies with the modulating waveform.

Carrier Waveform

The default carrier waveform is sine. One may also choose from square, ramp and arbitrary waveforms but not pulse, noise and dc waveforms. The default carrier frequency is 1 kHz for all waveforms. Each carrier waveform has its own acceptable range of frequencies. Refer to the table in Section 3.4 "To Set Output Frequency/Period" for details.

Modulating Waveform

Model 645 accepts either internal or external modulating source but not both at the same time. The default source is internal, and the default internal modulating waveform is sine wave. For internal source, one may also choose from square with 50% duty cycle, URamp (Up or Positive ramp with 100% symmetry), DRamp (Down or Negative ramp with 0%

symmetry), triangle (ramp with 50% symmetry), noise and arbitrary waveforms. If an arbitrary waveform is chosen, the number of points in the waveform is limited to 4k points with an automatic decimation process. The default frequency for internal modulating waveform is 10Hz, and the acceptable range is from 2 mHz to 20 kHz.

When external source is selected, the carrier waveform is modulated with an external waveform present at the *Modulation In* connector on the rear panel.

Frequency Deviation

The frequency deviation represents the peak variation in the frequency of the modulation output based on that of the carrier waveform. The default value is 100 Hz. Each type of carrier waveform has a different acceptable range as follows:

- Sine: 1 μ Hz to 25.05 MHz(at carrier frequency = 25.05 MHz).
- Square: 1 μ Hz to 12.55 MHz(at carrier frequency = 12.55 MHz).
- Ramp: 1 μ Hz to 150 kHz(at carrier frequency = 150 kHz).
- Arbitrary: 1 μ Hz to 5.05 MHz(at carrier frequency = 5.05MHz).

In addition, the maximum allowable value is constrained by the following two conditions:

- The frequency deviation must not be greater than the carrier frequency.
- The sum of frequency deviation and the carrier frequency must not be greater than the maximum frequency of the selected carrier waveform plus 100 kHz; that is, 50.1 MHz for sine, 25.1MHz for square, 300 kHz for ramp, and 10.1 MHz for arbitrary waveforms.

If a value is set greater than one of the above constraints, Model 645 will automatically adjust it to the maximum value allowed.

When external source is selected as the source of modulating waveform, the modulation is controlled by the specified frequency deviation and the ± 5 v signal levels of the external waveform. When the external waveform is at +5v, the output will reach positive maximum frequency deviation; e.g., 100 kHz increase from carrier frequency if the specified frequency

deviation is 100 kHz. When the external waveform is at -5v, the output will reach negative maximum frequency deviation; e.g., 100 kHz decrease from carrier frequency if the specified frequency deviation is 100 kHz.

How to set up frequency modulation

1. Press one of the following function buttons to choose your carrier waveform: Sine, Square, Ramp, Arb. Specify all the necessary waveform parameters for the carrier waveform as described in Section 4.1, 4.2, 4.3 and 4.6.



Figure 4-10

2. Press the Mod button to toggle on the modulation output.
3. Press the softkey under Type and press the softkey under FM to select frequency modulation. A frequency modulation output will be generated with the current parameters.
4. Press the softkey under Src to toggle between internal source (Int) and external source (Ext) for selecting modulating waveform source.
5. If internal source is selected:
 - a. Press the softkey under Shape to toggle between different types of modulating waveform. If arbitrary waveform (Arb) is selected as modulating signal source, the modulating signal source is depending on the previous waveform selection in arbitrary function. One may toggle the Mod key to see the arbitrary modulating waveform message that temporarily displayed on the screen.
 - b. Press the softkey under FM Freq and use numeric keypad or the knob with the cursor keys to set the desired modulating frequency.
6. Press the softkey under FreqDev to set the frequency deviation if needed. Use numeric keypad or the knob with the cursor keys to enter your value.

7. Press the Graph button to view all the waveform parameters.

Remote interface operation

Use these commands to output a frequency modulation waveform:

```
FUNCTION {SINusoid|SQUare|RAMP|USER}  
FREQUency {<frequency> | MINimum|MAXimum}  
VOLTage {<amplitude> | MINimum|MAXimum}  
VOLTage:OFFSet {<offset> | MINimum|MAXimum}  
FM:INTernal:FUNCTion  
    {SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}  
FM:INTernal:FREQUency {<frequency>MINimum|MAXimum}  
FM:DEVIation {<peak deviation in Hz> | MINimum|MAXimum }  
FM:SOURce {INTernal|EXTernal}  
FM:STATe ON
```

Notes

- Only one type of modulation can be activated at one time. When frequency modulation is enabled, the previously selected modulation is automatically disabled.
- Frequency modulation cannot be enabled with sweep or burst mode at the same time. When frequency modulation is enabled, sweep or burst mode will be disabled.

4.9 Phase Modulation

Phase modulation provides a waveform in which the phase of the carrier waveform varies with the modulating waveform.

Carrier Waveform

The default carrier waveform is sine. One may also choose from square, ramp and arbitrary waveforms but not pulse, noise and dc waveforms. The default carrier frequency is 1 kHz for all waveforms. Each carrier waveform has its own acceptable range of frequencies. Refer to the table in Section 3.4 "To Set Output Frequency/Period" for details.

Modulating Waveform

Model 645 accepts either internal or external modulating source but not

both at the same time. The default source is internal, and the default internal modulating waveform is sine wave. For internal source, one may also choose from square with 50% duty cycle, URamp (Up or Positive ramp with 100% symmetry), DRamp (Down or Negative ramp with 0% symmetry), triangle (ramp with 50% symmetry), noise and arbitrary waveforms. If an arbitrary waveform is chosen, the number of points in the waveform is limited to 4k points with an automatic decimation process. The default frequency for internal modulating waveform is 10Hz, and the acceptable range is from 2 mHz to 20 kHz.

When external source is selected, the carrier waveform is modulated with an external waveform present at the *Modulation In* connector on the rear panel.

Phase Deviation

The phase deviation represents the peak variation in the phase of the modulation output based on that of the carrier waveform. The range of the phase deviation is from 0 to 360 degrees, and the default is 180 degrees.

When external source is selected as the source of modulating waveform, the modulation is controlled by the specified phase deviation and the $\pm 5\text{v}$ levels of the external waveform. When the external waveform is at +5v, the output will reach positive maximum phase deviation; e.g., +180 degree phase shift if the specified phase deviation is 180 degrees. When the external waveform is at -5v, the output will reach negative maximum phase deviation; e.g., -180 degree phase shift if the specified phase deviation is 180 degrees.

How to set up phase modulation

1. Press one of the following function buttons to choose your carrier waveform: Sine, Square, Ramp, Arb. Specify all the necessary waveform parameters for the carrier waveform as described in Section 4.1, 4.2, 4.3 and 4.6.



Figure 4-11

2. Press the Mod button to toggle on the modulation output.
3. Press the softkey under Type and press the softkey under PM to select phase modulation. A phase modulation output will be generated with the current parameters.
4. Press the softkey under Src to toggle between internal source (Int) and external source (Ext) for selecting modulating waveform source.
5. If internal source is selected:
 - a. Press the softkey under Shape to toggle between different types of modulating waveform. If arbitrary waveform (Arb) is selected as modulating signal source, the modulating signal source is depending on the previous waveform selection in arbitrary function. One may toggle the Mod key to see the arbitrary modulating waveform message that temporarily displayed on the screen.
 - b. Press the softkey under PM Freq and use numeric keypad or the knob with the cursor keys to set the desired modulating frequency.
6. Press the softkey under PhaseDev to set the phase deviation if needed. Use numeric keypad or the knob with the cursor keys to enter your value.
7. Press the Graph button to view all the waveform parameters.

Remote interface operation

Use these commands to output a phase modulation waveform:

FUNCTION {SINusoid|SQUare|RAMP|USER}

FREQuency {<frequency>|MINimum|MAXimum}

VOLTage {<amplitude>|MINimum|MAXimum }

VOLTage:OFFSet {<offset>|MINimum|MAXimum }

PM:INTernal:FUNctioN

{SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}

PM:INTernal:FREQuency {<frequency> | MINimum|MAXimum}

PM:DEVIation {<deviation in degrees> | MINimum|MAXimum }
PM:SOURce {INTernal|EXTernal}
PM:STATe ON

4.10 FSK Modulation

Model 645 provides the capability to output FSK (Frequency-Shift Keying) modulation where the frequency of the waveform shifts between two frequencies (called "carrier frequency" and "hop frequency"). The shifting rate is determined by the internal or external modulating signal.

Carrier Waveform

The default carrier waveform is sine. One may also choose from square, ramp and arbitrary waveforms but not pulse, noise and dc waveforms. The default carrier frequency is 1 kHz for all waveforms. Each carrier waveform has its own acceptable range of frequencies. Refer to the table in Section 3.4 "To Set Output Frequency/Period" for details.

Modulating Waveform

Model 645 accepts either internal or external modulating source but not both at the same time. The default source is internal, and the only choice is square wave with a 50% duty cycle. When external source is selected, the carrier waveform is modulated with an external waveform present at the *Trig In* connector on the rear panel. The *Trig In* connector does not have adjustable edge polarity when used in FSK.

"Hop" Frequency

The default is 100Hz for all functions. Each carrier waveform has its own acceptable range of allowable hop frequency as follows.

- Sine: 1 μ Hz to 50 MHz(at carrier frequency = 1 μ Hz).
- Square: 1 μ Hz to 25 MHz(at carrier frequency = 1 μ Hz).
- Ramp: 1 μ Hz to 200 kHz(at carrier frequency = 1 μ Hz).
- Arbitrary: 1 μ Hz to 10 MHz(at carrier frequency = 1 μ Hz).

When external source is selected as the source of modulating waveform, the modulation is controlled by the signal level of the external waveform.

When the external waveform is at the logic *low* level, the carrier frequency is outputted. When a logic *high* is present, the hop frequency is outputted.

FSK Rate

This is the rate at which the output frequency shifts between the carrier frequency and the hop frequency when internal source is selected. The default FSK rate is 10 Hz and the range is from 2 mHz to 100 kHz.

How to generate a FSK waveform

1. Press one of the following function buttons to choose your carrier waveform: Sine, Square, Ramp, Arb. Specify all the necessary waveform parameters for the carrier waveform as described in Section 4.1, 4.2, 4.3 and 4.6.



Figure 4-12

2. Press the Mod button to toggle on the modulation output.
3. Press the softkey under Type and press the softkey under FSK to select FSK modulation. An FSK modulation output will be generated with the current parameters.
4. Press the softkey under Src to toggle between internal source (Int) and external source (Ext) for selecting modulating waveform source.
5. If internal source is selected, press the softkey under FSK Rate and set the desired shift rate using the numeric keypad or the knob with the cursor keys.
6. Press the softkey under Hop Freq and set the desired hop frequency using the numeric keypad or the knob with the cursor keys.
7. Press the Graph button to view all the waveform parameters.

Remote interface operation

FUNCTION {SINusoid|SQUare|RAMP|USER}

FREQuency {<frequency>|MINimum|MAXimum}
VOLTage {<amplitude>|MINimum|MAXimum }
VOLTage:OFFSet {<offset>|MINimum|MAXimum }
FSKey: FREQuency {<frequency>|MINimum|MAXimum}
FSKey:INTernal:RATE {<rate in Hz>|MINimum|MAXimum }
FSKey:SOURce {INTernal|EXTernal}
FSKey:STATe ON

4.11 PWM Waveform

Model 645 waveform generator provides the capability to output a pulse width modulation (PWM) for pulse carrier waveforms. In PWM, the pulse width of the pulse carrier waveform varies with the modulating waveform. The pulse width can be expressed either in time units or duty cycle (i.e., percentage of the period).

Carrier Waveform

Pulse waveform is the only waveform that is available for PWM. The default period for the carrier pulse is 1 ms, and the range is from 100 ns to 2000 s.

Modulating waveform

Model 645 accepts either internal or external modulating source but not both at the same time. The default source is internal, and the default internal modulating waveform is sine wave. For internal source, one may also choose from square with 50% duty cycle, URamp (Up or Positive ramp with 100% symmetry), DRamp (Down or Negative ramp with 0% symmetry), triangle (ramp with 50% symmetry), noise and arbitrary waveforms. If an arbitrary waveform is chosen, the number of points in the waveform is limited to 4k points with an automatic decimation process. The default frequency for internal modulating waveform is 10Hz, and the acceptable range is from 2 mHz to 20 kHz.

When an external source is selected, the carrier waveform is modulated with an external waveform coming from the *Modulation In* connector on the rear panel.

Width Deviation

The width deviation represents the peak variation in the pulse width of the modulation output based on that of the original pulse carrier waveform. The default deviation is 10 μ s, and the range is from 0s to 1000s. In addition, it must not be greater than the pulse width of the carrier waveform and is also constrained by the following formulas:

$$\text{WidthDeviation} \leq \text{PulseWidth} - \text{Wmin}$$
$$\text{WidthDeviation} \leq \text{Period} - (\text{PulseWidth} + \text{Wmin})$$

where Wmin is the minimum pulse width as described in Section 4.5.

When external source is selected as the source of modulating waveform, the modulation is controlled by the specified width deviation and the ± 5 v levels of the external waveform. When the external waveform is at +5v, the output will reach the maximum pulse width. When the external waveform is at -5v, the output will reach the minimum pulse width.

How to set up PWM (pulse width modulation)

1. Press the Pulse button to select the pulse carrier waveform and then set the waveform parameters as described in Section 4.5.



Figure 4-13

2. Press the Mod button to toggle the PWM output.
3. Press the softkey under Src to toggle between internal source (Int) and external source (Ext) for selecting modulating waveform source.
4. If internal source is selected:
 - a. Press the softkey under Shape to toggle between different types of modulating waveform. If arbitrary waveform (Arb) is selected as modulating signal source, the modulating signal source is depending on the previous waveform selection in arbitrary function. One may toggle the Mod key to see the arbitrary modulating waveform message that temporarily

- displayed on the screen.
- b. Press the softkey under PWM Freq and use numeric keypad or the knob with the cursor keys to set the desired modulating frequency.
5. Press the softkey under Width Dev and set the desired value for width deviation by the numeric keypad or the knob with the cursor keys.
 6. Press the Graph button to view all the waveform parameters.

Remote interface operation

Use the following commands for PWM:

FUNC PULSe

VOLTage {<amplitude> | MINimum|MAXimum}

VOLTage:OFFSet {<offset> | MINimum|MAXimum}

PULSe:PERiod {<seconds>|MINimum|MAXimum}

FUNcTION:PULSe:WIDTh {<seconds>|MINimum|MAXimum}

FUNcTION:PULSe:TRANsition {<seconds>|MINimum|MAXimum}

FUNcTION:PULSe:DCYCLe{<percent>|MINimum|MAXimum}

PWM:INTernal:FUNcTION

{SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}

PWM:INTernal:FREQuency {<frequency>|MINimum|MAXimum }

PWM:DEVIation {<deviation in seconds>|Minimum|Maximum}

PWM:DEVIation:DCYCLe {<deviation in seconds>|Minimum|Maximum}

PWM:SOURce {INTernal|EXTernal}

PWM:STATe ON

4.12 Frequency Sweep

Frequency Sweep provides the capability to generate a waveform which gradually steps from a start frequency to a stop frequency at a specified rate. It can sweep up or down in frequency with logarithmic or linear spacing. Only sine, square, ramp and arbitrary waveforms are allowed to work with frequency sweep.

Sweep Mode

The default sweep mode is linear where the waveform generator sweeps the frequency with spacing calculated in a linear function. In logarithmic sweep mode, the waveform generator sweeps with spacing calculated in a logarithmic function.

Start Frequency and Stop Frequency

The waveform generator begins sweeping from the start frequency to the stop frequency. The waveform generator will sweep down when the start frequency is greater than the stop frequency. The waveform generator will sweep up when the stop frequency is greater than the start frequency.

The default start frequency is 100 Hz and the stop frequency is 1 kHz. The allowable range is 1 μ Hz to 50 MHz for sine, 1 μ Hz to 25 MHz square, 1 μ Hz to 200 kHz for ramp, and 1 μ Hz to 10 MHz for arbitrary waveforms.

Center Frequency and Frequency Span

Center frequency and frequency span provide another way to set the frequency sweep range. The default center frequency is 550 Hz. The allowable range is 1 μ Hz to 50 MHz for sine, 1 μ Hz to 25 MHz for square, 1 μ Hz to 200 kHz for ramp, and 1 μ Hz to 10 MHz for arbitrary waveforms. The default frequency span is 900 Hz. The allowable range of the frequency span is depending on center frequency setting and waveform selection. Set positive frequency span for sweeping up and negative frequency span for sweeping down.

Sweep Time

The sweep time is the period of time (in seconds) required to sweep from the start frequency to the stop frequency. The number of discrete frequency points is calculated by the waveform generator according to the sweep time specified. The default sweep time is 1 second, and the range is from 1 ms to 500 s.

Marker Frequency

Marker frequency provides a way to control the Sync signal outputted on the front panel *Sync* connector. For sweeps with Marker On, the Sync

signal is a TTL "high" at the beginning of the sweep and turns to "low" at the marker frequency. For sweeps with Marker Off, the Sync signal is a square waveform with a 50% duty cycle. That is, the Sync signal is a TTL "high" at the beginning of a sweep and turns to "low" at the midpoint of the sweep. The frequency of the Sync signal is the reciprocal of the specified sweep time.

The default marker frequency is 500 Hz. The range of the marker frequency is depending on stop frequency setting or frequency span setting. The marker frequency must be less than or equal to the maximum output frequency.

Trigger Source

The waveform generator outputs a single sweep when it receives a trigger signal, and it keeps outputting the same type of waveform with the start frequency before it receives next trigger and sends out another sweep.

Trigger Source can be internal, external or manual, and the default is Internal.

- With internal trigger source, the waveform generator continuously outputs sweeps with the specified sweep time.
- With external trigger source, the trigger signal is a TTL pulse with specified polarity applied to the *Ext Trig* connector on the rear panel. Note that the trigger period must not be less than 1 ms plus the specified sweep time.
- If manual trigger is selected, the waveform generator sends out a sweep each time the Trigger button on the front panel is pressed.

Trigger out Signal

A "trigger out" signal is provided on the rear panel *Ext Trig / FSK / Burst* connector. When enabled, a TTL-compatible square waveform with either a rising or falling edge is outputted at the *Ext Trig / FSK / Burst* connector with the sweep output.

- With internal trigger source, a square waveform with 50% duty cycle is outputted at the Trig Out connector with the sweep output.
- With external trigger source, there is no signal outputted at the

Ext Trig / FSK / Burst connector because it shares the same connector with Ext Trig for receiving the external trigger signal.

- With manual trigger, the waveform generator outputs a pulse, with pulse width $> 1 \mu\text{s}$, at the Trig Out connector at the beginning of each sweep.

How to set up frequency sweep

1. Press one of the following function buttons to choose your waveform for sweeping: Sine, Square, Ramp, Arb. Specify all the necessary waveform parameters for the waveform as described in Section 4.1, 4.2, 4.3 and 4.6.



Figure 4-14

2. Press the Sweep button to enable or disable the sweep mode. To enable the sweep mode, make sure the Sweep button is lit.
3. Press the softkey under Linear/Log to toggle between the linear or logarithmic mode.
4. To specify the start frequency, press the softkey under Start/Cntr to toggle. Make sure both Start and Stop are highlighted. Use the numeric keypad or the knob with cursor keys to change the value. Follow the same step to specify the stop frequency under the softkey Stop/Span.
5. To specify the center frequency, press the softkey under Start/Cntr to toggle. Make sure both Cntr and Span are highlighted. Use the numeric keypad or the knob with cursor keys to change the value. Follow the same step to specify the frequency span under the softkey Stop/Span.
6. To specify a desired sweep time, press the softkey under Sweep Time. Use the numeric keypad or the knob with cursor keys to change the value.
7. To configure the marker, press the softkey under Mkr to toggle between Freq and OFF. If Freq is selected, Use the numeric keypad or the knob with cursor keys to set the marker frequency.
8. To configure the trigger setting, press the softkey under Trig

Setup to enter the trigger setup menu:

- a. To specify the trigger source, press the softkey under Src and then select among Int (internal), Ext (external) and Man (manual).
- b. If internal source or manual trigger is selected, you may configure the trigger out signal by pressing the softkey under Trig Out and then select among OFF, rising-edge trigger and falling-edge trigger.
- c. If external source is selected, you may press the softkey under Slope to toggle between rising edge trigger and falling edge trigger.
- d. Press the softkey under DONE to finish the trigger setting.



Figure 4-15

9. Press the Graph button to view all the waveform parameters.

Remote interface operation

SWEep:SPACing {LINear|LOGarithmic}

SWEep:TIME {<seconds>|MINimum|MAXimum }

FREQuency:STARt {<frequency>|MINimum|MAXimum }

FREQuency:STOP {<frequency>|MINimum|MAXimum }

FREQuency:CENTer {<frequency>|MINimum|MAXimum }

FREQuency:SPAN {<frequency>|MINimum|MAXimum }

MARKer:FREQuency {<frequency>|MINimum|MAXimum }

MARKer {OFF|ON}

SWEep:STATe ON

Use this command to specify the trigger source:

TRIGger:SOURce {IMMediate|EXTernal|BUS}

Use this command to specify whether the sweep is triggered on the rising or falling edge:

TRIGger:SLOPe {POSitive|NEGative}

Use the following commands to configure the *Trig Out* signal:
OUTPut:TRIGger:SLOPe {POSitive|NEGative}
OUTPut:TRIGger {OFF|ON}

4.13 Burst Operation

Model 645 offers the burst operation to generate the selected type of waveform with specified number of cycles, called a *burst*. Bursts may be triggered internally or manually. Bursts can also be triggered or gated externally by the signal applied to the *Ext Trig / FSK / Burst* connector on the rear panel. Sine, ramp, pulse, square and arbitrary waveforms are allowed to output in both the triggered and gated burst modes. Noise is available only in the gated burst mode.

Triggered Burst Mode

This is the default burst mode. Model 645 outputs a waveform with a specified number of cycles, called *burst count*, each time it receives a trigger. When the specified number of cycles is outputted, the waveform generator pauses and waits for next trigger. One may choose to trigger the bursts using internal source, to manually press the *Trigger* button on the front panel to trigger a burst, to apply an external signal at the *Ext Trig / FSK / Burst* connector on the rear panel, or to send a software trigger through the remote interface.

External Gated Burst Mode

In gated burst mode, the length of a burst is determined by the voltage level of the external signal applied at the *Ext Trig / FSK / Burst* connector on the rear panel. During the time when the external signal is logic true, the waveform generator outputs a continuous waveform. When the gate signal is logic false, the output wave remains at the same voltage level as the starting burst phase of the selected waveform. The output stops immediately following a noise burst when the gate signal becomes logic false.

Table 4.13-1

The available parameters in each burst mode.

		Burst Count	Burst Period	Burst Phase	Ext Trig Signal Polarity
Triggered mode	Internal	✓	✓	✓	
	External, Manual	✓		✓	
Gated mode				✓	✓

Burst Count

The Burst Count represents the number of cycles appeared in each burst. It is only used in the triggered burst mode. The default burst count is 1 cycle, and the range is from 1 to 50,000 cycles in 1 cycle increment. One may also set an infinite burst count.

When the trigger source is set to internal, the waveform generator outputs bursts repeatedly at a rate determined by the specified burst period, which represents the time interval between the start times of two consecutive bursts. The burst count must be less than the product of the burst period and the waveform frequency:

$$\text{BurstCount} < \text{BurstPeriod} \times \text{WaveformFrequency}$$

The waveform generator will automatically increase the burst period up to its maximum allowable value to accommodate the specified burst count. The waveform frequency is not affected by burst count.

The burst count does not apply in the gated mode. If a new burst count is specified in the gated mode, the waveform generator will remember it and use it when the triggered mode is selected.

Waveform Frequency

The *waveform frequency* defines the frequency of the output waveform while trigger signal is logic true. In the triggered mode, the specified number of cycles is outputted at the waveform frequency. In the gated

mode, the waveform frequency is outputted when the external gate signal is true.

The default waveform frequency is 1 kHz. The range is from 1 μ Hz to 200 kHz for ramps, 1 μ Hz to 25 MHz for square, 1 μ Hz to 10 MHz for pulse and arbitrary waveforms, 1 μ Hz to 50 MHz for Sine. In internally triggered burst mode, the minimum frequency is 2.001 mHz. For sine and square waveforms, frequencies greater than 10 MHz are allowed only when an infinite burst count is set.

Burst Period

The burst period represents the time interval between the start times of two consecutive bursts. It is only used in the internally triggered burst mode. The default burst period is 10 ms and the range is from 1 μ s to 500 seconds.

The burst period must be long enough for the generator to output the specified burst count. If the burst period is set too short, the waveform generator automatically adjusts it to the shortest value that can accommodate the specified burst count and waveform frequency:

$$\text{BurstPeriod} > \frac{\text{BurstCount}}{\text{WaveformFrequency}} + 200\text{ns}$$

Burst Phase

Burst Phase defines the starting phase of a burst. The default is 0 degree and the range is from -360 degrees to +360 degrees. You can only set the burst phase in degree from the front panel operation, while degrees and radians are both available from the remote interface operation.

For sine, square and ramp waveforms, zero degree is the point at which the waveform crosses zero volt or the dc offset when ascending. For arbitrary waveform, it is the first waveform point specified. The burst phase has no effect on pulse or noise waveform.

In the gated burst mode, when the gate signal turns false, the waveform generator will complete the current waveform and then stops. At this

point, the output will remain at the same voltage level as the starting burst phase.

Trigger Source

The default trigger source is internal, and the available options are internal, external and manual. When the waveform generator is set to be in the triggered burst mode, it generates a burst with specific number of cycles each time a trigger is received. Then it stops and waits for the next trigger event to occur. When the trigger source is internal, the bursts are outputted at a rate determined by the burst period. When the trigger source is manual, the burst is outputted only when the Trigger button is pressed.

When the trigger source is external, the waveform generator outputs a burst each time a TTL pulse with specified polarity is received at the *Ext Trig* connector on the rear panel. A received trigger signal is ignored during the output of a burst.

When the trigger source is set to be external or manual, the burst count and burst phase remain the same but the burst period is ignored.

Trigger Out Signal

In internally or manually triggered burst mode, one may enable to output a *trigger out* signal at the Ext Trig connector on the rear panel that is synchronized with the burst output. When enabled, a TTL-compatible square waveform with either a rising or falling edge is outputted at the Ext Trig connector at the beginning of the burst. The trigger out signal is not available in the externally triggered burst mode as an external trigger signal is applied to the same Ext Trig connector.

With internal trigger source, the trigger out signal is a square waveform with 50% duty cycle. With manual trigger source, the trigger out signal is a pulse with pulse width $> 1 \mu\text{s}$.

How to set up burst output

1. Press one of the function buttons to select the burst waveform (dc is not allowed and noise is allowed only in the gated burst mode).

2. Refer to Section 3.4 for specifying the waveform frequency for the selected function.
3. Press the Burst button to toggle the burst mode.
4. Press the N Cyc/Gated softkey to toggle between the triggered burst mode and the external gated mode. Make sure that your selection is highlighted.



Figure 4-16

- Triggered burst mode

1. Press the #Cyc/Inf softkey to toggle between finite and infinite burst count:
 - To set finite burst count, make sure #Cyc is highlighted. Then set the burst count using the numeric keypad or the knob with the cursor keys.
 - To set infinite burst count, press the #Cyc/Inf softkey to toggle and make sure Inf is highlighted.
2. Press the Start Phase softkey and enter the desired phase using numeric keypad or the knob with the cursor keys.
3. Press the Trig Setup softkey to enter the triggering setup menu:
 - a. To select a trigger source, press the Src softkey and then select among Int (internal), Ext (external) and Man (manual).
 - b. If internal source or manual trigger is selected, you may configure the trigger out signal by pressing the softkey under Trig Out and then select among OFF, rising-edge trigger and falling-edge trigger.
 - c. If external source is selected, you may press the softkey under Slope to toggle between rising edge trigger and falling edge trigger.
 - d. Press the softkey under DONE to finish the trigger setting.

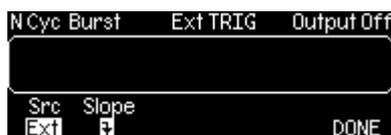


Figure 4-17

4. If internal trigger source is selected, press the Burst Perd softkey and enter the desired burst period using the numeric keypad or the knob with the cursor keys.
 5. Press the Graph button to view all the burst parameters.
- External gated burst
 1. To specify the polarity of the external signal for gating, press the Polar softkey to toggle between Neg and. Make sure that your selection is highlighted.
 2. Press the Start Phase softkey and enter the desired phase using numeric keypad or the knob with cursor keys.
 3. Press the Graph button to view all the burst parameters.



Figure 4-18

Remote interface operation

```

FUNCTION {SINusoid|SQUare|RAMP|PULSe | USER}
FREQUENCY {<frequency>|MINimum|MAXimum}
BURSt:MODE {TRIGgered|GATed}
BURSt:GATE:POLarity { NORMAl|INVerted }
BURSt:NCYCles {<#cycles>INFinity|MINimum|MAXimum}
BURSt:INTernal:PERiod {<seconds>|MINimum|MAXimum}
BURSt:PHASe {<angle>|MINimum|MAXimum}
UNIT:ANGLE {DEGREE|RADIAn}
TRIGger:SOURce {IMMediate|EXTernal|BUS}
TRIGger:SLOPe {POSitive|NEGative}
OUTPut:TRIGger:SLOPe{POSitive|NEGative}
OUTPut:TRIGger {OFF|ON}
BURSt:STATe ON

```

4.14 Pattern Output

In addition to defining arbitrary waveforms as described in Section 4.6, Model 645 waveform generator provides the capability of outputting a specified pattern of up to 256k points in 16-bit resolution. Similar to

arbitrary waveforms, pattern output provides five built-in patterns and up to four user-defined patterns that are stored in non-volatile memory. The built-in patterns are exponential-rise, exponential-fall, negative-ramp, sinc, and cardiac. The default pattern output is an exponential-rise wave.

User-defined patterns

Model 645 supports user-defined patterns. You may use the **Wavepatt** waveform and pattern editor to create the patterns you want or import the waveforms from the oscilloscope that you captured previously. For more information on the user-defined patterns, please refer to the on-line help of **Wavepatt**.

How to set up pattern output

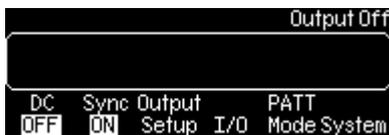
1. Press the Utility button to enter the utility menu.
2. Press the softkey under [PATT MODE] to enter the PATTERN menu.
3. Press the softkey under Fclk/Perd to toggle between Fclk (frequency) and Perd (period). Refer to Section 3.4 for specifying the frequency/period value.
4. Press the softkey under Start Addr (End Addr) for setting the start (end) point of the pattern to output. Use the knob with the cursor keys to change the value. Or use the numeric keypad to enter a new value and then press the softkey under Enter to finish the entry or the softkey under Cancel to withdraw the changes.
5. Press the softkey under RPT. to toggle between ON and OFF to enable/disable repeating output of the pattern.
6. Press the softkey under Select Pattern to enter selection menu:
 - a. Press the softkey under Built In and choose the desired pattern from the five built-ins by pressing the corresponding softkey.
 - b. Press the softkey under Store Wform and choose the desired user-defined pattern by pressing the corresponding softkey.
 - c. One may delete a user-defined pattern by pressing the softkey under Delete Store and choose the pattern to delete by pressing the corresponding softkey.
7. To configure the trigger setting, press the softkey under Trig Setup to enter the trigger setup menu:

- a. To specify the trigger source, press the softkey under Src and then select among Ext (external) and Man (manual).
- b. If manual trigger is selected, you may configure the trigger out signal by pressing the softkey under Trig Out and then select among OFF, rising-edge trigger and falling-edge trigger.
- c. If external source is selected, you may press the softkey under Slope to toggle between rising edge trigger and falling edge trigger.
- d. Press the softkey under DONE to finish the trigger setting.

Pattern Out

This is a parallel interface including an edge-selectable clock and 16-bit data. You can use this interface to send any data through this interface at the speed 1uHz to 50MHz.

Press the soft key [PATT Mode] to select Pattern Mode



Set the frequency of the pattern clock, 1uHz ~ 50MHz. This setting is familiar with Figure 3-3 frequency setting.



Select file name of the pattern, such as EXP_RISE, EXP_FALL, NEG_RAMP, SINC, CARDIAC. This setting is same as arbitrary waveform selection.



Set the start address (min. 1) of the pattern.

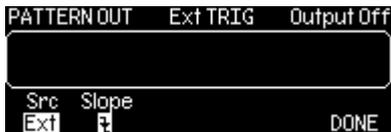


Set the end address of the pattern.



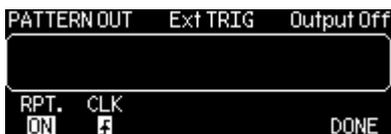
Set the trigger source of the pattern, such as from EXT or BUS. (Please note that there is no IMM internal trigger.)

Set the Trigger slope of the pattern out to be a positive (rising) edge or a negative (falling) edge.



Set the pattern repeat again, yes (ON) or no (OFF).

Select which clock edge to latching data of the pattern, positive (rising) edge or negative (falling) edge.



PATTERN OUT Commands: (Add Pattern Out Commands)

FUNCTION:PATTERN {data name}

Select file name of the pattern, such as EXP_RISE, EXP_FALL, NEG_RAMP, SINC, CARDIAC.

FUNCTION:PATTERN?

Inquire and gain the file name of the pattern.

DIGital:PATtern:FREQuency {<frequency>, MINimum, MAXimum}
Set the frequency of the pattern, 1uHz ~ 50MHz.

DIGital:PATtern:FREQuency? {MINimum, MAXimum}
Inquire and gain the minimum or maximum frequency of the pattern.

DIGital:PATtern:STARt {<address>, MINimum, MAXimum}
Set the start address (min. 1) of the pattern.

DIGital:PATtern:STARt? {MINimum, MAXimum}
Inquire and gain the start address of the pattern.

DIGital:PATtern:STOP {<address>, MINimum, MAXimum}
Set the end address of the pattern.

DIGital:PATtern:STOP? {MINimum, MAXimum}
Inquire and gain the end address of the pattern.

DIGital:PATtern:REPeat {ON, OFF}
Set the pattern repeat again, yes (ON) or no (OFF).

DIGital:PATtern:REPeat?
Inquire and gain the pattern out status, repeated or not.

DIGital:PATtern:CLOCK {POS, NEG}
Set the latching data clock of the pattern to be a positive (rising) edge or a negative (falling) edge.

DIGital:PATtern:CLOCK?
Inquire and gain the latch data clock status of the pattern in positive (rising) or negative (falling) edge.

DIGital:PATtern:TRIGger:SOURce {EXT, BUS}
Set the trigger source of the pattern, such as from EXT or BUS. (Please note that there is no IMM internal trigger.

DIGital:PATtern:TRIGger:SOURce?
Inquire and gain the trigger source of the pattern.

DIGital:PATtern:TRIGger:SLOPe {POS, NEG}

Set the Trigger slope of the pattern to be a positive (rising) edge or a negative (falling) edge.

DIGital:PATtern:TRIGger:SLOPe?

Inquire and gain the trigger slope status of the pattern.

DIGital:PATtern:OUTPut:TRIGger {OFF, ON}

Set the trigger of the pattern out to be ON or OFF.

DIGital:PATtern:OUTPut:TRIGger?

Inquire or gain the trigger status of the pattern out.

DIGital:PATtern:OUTPut:TRIGger:SLOPe {POS, NEG}

Set the Trigger slope of the pattern out to be a positive (rising) edge or a negative (falling) edge.

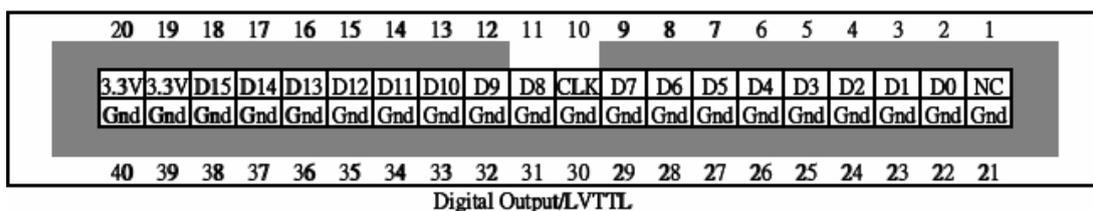
DIGital:PATtern:OUTPut:TRIGger:SLOPe?

Inquire and gain the trigger slope status of the pattern out in positive (rising) or negative (falling) edge.

DATA:PATTERN VOLATILE, <binary block>

Download binary values into volatile memory. You can download from 1 to 262144 (256K) points per waveform in IEEE-488.2 binary block format.

Socket pin out structure



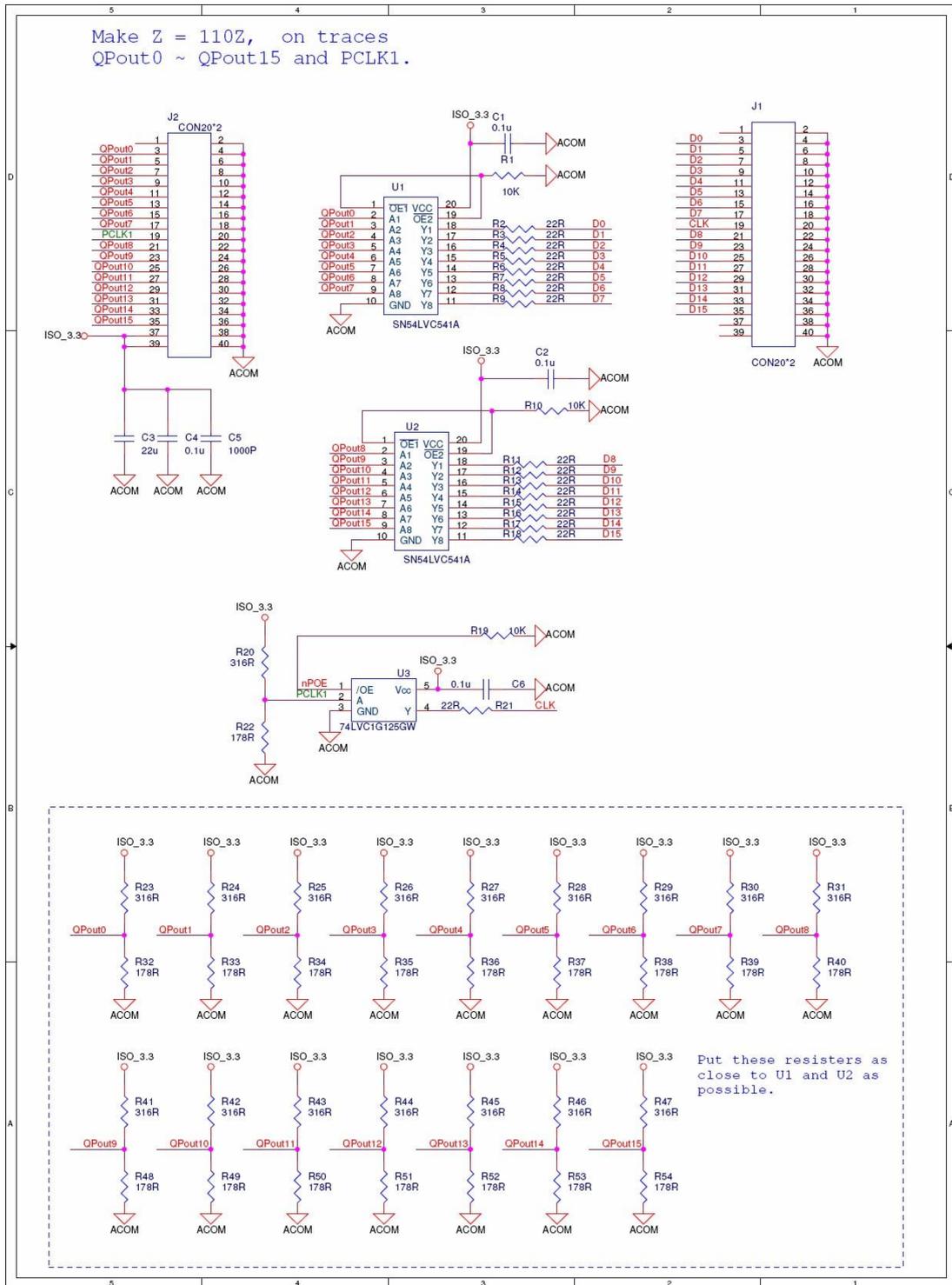
Pattern Generator Cable

The 40-pin cable is used to connector the socket and you board or device.

Connector pin out structure of Pattern Generator Cable

40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21
Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd
3.3V	3.3V	D15	D14	D13	D12	D11	D10	D9	D8	CLK	D7	D6	D5	D4	D3	D2	D1	D0	NC
20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Schematic of Receiver



5 System Operations

5.1 Triggering

This feature is only available for bursts and sweeps. There are three options to choose from: internal triggering, external triggering and manual triggering. The default is the internal triggering in which the waveform generator continuously outputs the selected waveform.

The Ext Trig connector on the rear panel is used to receive the external trigger signal. The waveform generator outputs a burst or a sweep each time the Ext Trig connector receives a TTL pulse. One may instruct the waveform generator to trigger on the ascending edge or the descending edge of the external trigger signal.

In manual triggering, the waveform generator outputs a burst or a sweep each time the Trigger button on the front panel is pressed. The Trigger button is lit when the waveform generator is waiting for the next trigger event. Triggering is disabled when functions other than burst or sweep is chosen.

How to choose a trigger source

1. Press the Trig Setup softkey after burst or sweep is activated.
2. Press the Src softkey and then select among Int (internal), Ext (external) and Man (manual). After your selection is made, the trigger setting will be shown on the display.
3. Press the DONE softkey to finish the setting.

Note that the trigger source setting is stored in volatile memory. The default setting will be restored after the power is cycled.

Remote interface operation

TRIGger:SOURce {IMMediate|EXTernal|BUS}

How to specify the trigger slope with external trigger source

1. After choosing Ext as your trigger source, press the softkey under

Slope to toggle between rising edge trigger and falling edge trigger.

2. Press DONE to finish the setting.

Remote interface operation

TRIGger:SLOPe {POSitive|NEGative}

Software Triggering

In software triggering, a bus command is sent through the remote interface to trigger the waveform generator. The waveform generator outputs a burst or a sweep when it receives one such command. The operation is similar to the Trigger button on the front panel for manual triggering.

Remote interface operation

To trigger the waveform generator from the remote interface, choose BUS as the trigger source:

TRIGger:SOURCe BUS

and send one of the following commands to trigger:

*TRG

TRIGger

External Triggering

An external signal is applied at the Ext Trig connector on the rear panel in the following five operation modes:

- **Externally-modulated FSK mode:** The carrier frequency is outputted when a logic low level is present at the connector, and the hop frequency is outputted when a logic high level is present. The maximum shifting rate is 100 kHz.
- **Triggered sweep mode:** The waveform generator outputs a sweep on the specified edge each time a TTL pulse is received at the Ext Trig connector.
- **Triggered burst mode:** The waveform generator outputs a burst each time a TTL pulse with specified polarity is received at the Ext Trig connector.
- **External gated burst mode:** The waveform generator outputs a continuous waveform when the external signal is true. When the external signal turns false, the waveform generator completes the

current cycle and then stops at the same voltage level as the starting burst phase. For noise waveform, the output stops immediately when the external signal turns false.

Trigger Out Signal

Model 645 may be configured to send out a TTL-compatible square wave at the Ext Trig connector on the rear panel with either a rising or a falling edge at the beginning of a sweep or burst.

- With internal trigger source, the trigger out signal is a square wave with 50% duty cycle. The period of the trigger out signal is equal to the sweep time or the burst period.
- With the manual trigger or BUS trigger source, the trigger out signal is a pulse with pulse width > 1 μ s.
- With external trigger source, there is no trigger out signal as the Ext Trig connector is used to receive the trigger input signal.

How to set up the trigger out signal

1. After sweep or burst mode is activated, press the Trig Setup softkey to enter the trigger setup submenu.
2. Press the Trig Out softkey and then select among OFF, rising-edge trigger and falling-edge trigger.
3. Press the softkey under DONE to finish the setting.

Remote interface operation

OutPut:TRIGger {OFF|ON}

OutPut:TRIGger:SLOPe {POSitive|NEGative}

5.2 Storing the instrument state

Model 645 provides five storage locations in non-volatile memory for user to store instrument state. The stored instrument state holds all the parameters for the selected function, including the waveform, frequency, dc offset, amplitude, duty cycle, symmetry, modulation type and modulation parameters.

The first location, indexed at "0", is automatically assigned for instrument state at power-down, but you can use any of these locations

for storing a user-defined instrument state. The location "0" can only be accessed from the remote interface. Although you may store an instrument state in it, it is always preserved for power-down state. Anything previously stored in it will be overwritten with the power-down state when the waveform generator is turned off.

Although you may assign a custom name to any of these locations from the remote interface, you cannot assign a name for location "0" from the front panel. The name can contain up to 12 characters, but the first character has to be a letter and the rest of them can be numbers, letters or the underscore character ("_").

How to store/recall the instrument state

1. Press the Store/Recall button to enter the instrument state submenu.

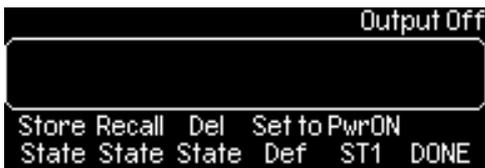


Figure 4-19

2. To store an instrument state, press the softkey under Store State to enter the store-state submenu:
 - a. Press the softkey under your desired location number to choose the location (only 1 to 4 are available from front panel operation).
 - b. You may specify a name for the selected memory location. Use the numeric keypad and the knob with the cursor keys for entry.
 - c. Press the Store State softkey to store the present setting in the memory or the Cancel softkey to cancel.



Figure 4-23

3. To recall a saved state, press the Recall State softkey to enter the recall-state submenu:
 - a. Press the softkey under your desired location number to recall the state from that memory location.
 - b. Press the Recall State softkey to restore from the selected state in the memory or the Cancel softkey to cancel.



Figure 4-21

4. To delete a saved state, press the Del State softkey to enter the delete-state submenu:
 - a. Press the softkey under your desired location number for deletion.
 - b. Press the Delete State softkey to delete the selected state or the Cancel softkey to cancel.

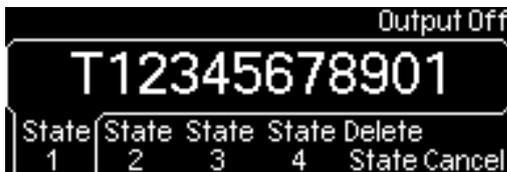


Figure 4-22

5. To set the power-on state (i.e., the instrument state restored when the waveform generator is powered on), press the Power On softkey to enter the power-on-state submenu:
 - a. Press the softkey under your desired location number or the softkey under State Def (factory default).
 - b. Make sure your selection is present under the Power On softkey.

6. To restore the instrument state to the factory default, press the softkey under Set to Def. A message will be displayed for you to confirm the action. Press the Yes softkey to confirm or the Cancel key to cancel the operation. See Figure 4-19.

Remote interface operation

*SAV {0|1|2|3|4}

*RCL {0|1|2|3|4}

Memory:STATe:NAME {0|1|2|3|4} [,<name>]

5.3 Display Control

Model 645 provides an option to turn off the front display screen. One may choose to do it for security reason or for speeding up the command execution from the remote interface. This option is available from the remote operation only.

Remote interface operation (only)

Use this command to turn off the front panel display:

DISP OFF

Use this command to display a message and turn the display back on:

DISP:TEXT `message to display`

Use this command to clear the current message on display.

DISP:TEXT CLEAR

Notes

- The display is automatically enabled when the waveform generator is powered on, the *RST (reset) command is issued or it is returned to the local front-panel operation.
- Error messages are always displayed even when the display is turned off.
- The display setting may be saved with the *SAV command. When the instrument state is restored using the *RCL command, the display setting will return to the saved state.

5.4 Beeper

Model 645 normally lets out a beeper when an error is detected. One may turn off the beep when needed. The beeper setting is stored in non-volatile memory, so the setting remains even after the waveform generator is turned off or the reset command is issued from the remote operation.

How to turn on/off the beeper

1. Press the Utility button and then press the softkey under System to enter system related submenu.
2. Press the Beep softkey to toggle between ON and OFF.

Remote interface operation

SYSTem:BEEPer

SYSTem:BEEPer:STATe {OFF|ON}

5.5 Sound

Model 645 normally sounds when the operation buttons and knob are used. One may turn off the sound when needed. The sound setting is stored in non-volatile memory, so the setting remains even after the waveform generator is turned off or the reset command is issued from the remote operation.

How to turn on/off the beeper

1. Press the Utility button and then press the softkey under System to enter system related submenu.
2. Press the Sound softkey to toggle between ON and OFF.

Remote interface operation

SYSTem:SOUNd

SYSTem:SOUNd:STATe {OFF|ON}

5.6 Error Display

The waveform generator can store up to 20 syntax or hardware errors in its error queue. Each error string may contain up to 255 characters. The waveform generator beeps every time it detects an error (unless the beeper is turned off). Errors are stored in first-in-first-out (FIFO) order and they are cleared once read. To clear the error queue from the remote interface, use the *CLS command. The error queue will not be cleared by the *RST command, but will be cleared when the waveform generator is turned off. Refer to Chapter 7 for more details about the error queue and error messages.

How to read error messages

1. Press the Help button to enter the help topic selection.
2. Use the up and down softkeys to scroll the topic selection until "View remote command error queue" is highlighted.
3. Press the softkey under "Select" to display the error messages.
4. Press the softkey under DONE to leave the help topics.

Remote interface operation

Use this command to read one error from the error queue:

SYSTem:ERRor?

Use this command to clear all the errors in the error queue:

*CLS

5.7 Calibration

You need a security code to calibrate or perform self-test on the waveform generator.

Front panel operation

1. Press the Utility button and then the softkey under System to enter the system related submenu.
2. Press the softkey under Test/Cal. Enter your security code by using the numeric keypad.

6 Remote Interface Operations

Model 645 supports three remote interfaces: USB, LAN and GPIB (IEEE-488). For GPIB, you will need an additional GPIB interface card installed. This chapter describes the operations for setting up these remote interfaces and lists the SCPI (Standard Commands for Programmable Instrument) commands available to control the waveform generator remotely. For first time SCPI users, refer to Appendix B for the introductory materials on SCPI commands.

6.1 Remote Interface Configuration

Model 645 have built in a web server, one may use the Internet Explorer of Microsoft® or Firefox of Mozilla Foundation to remotely control the waveform generator through the LAN interface. No extra software is needed.

6.1.1 USB Interface

How to set up USB interface

Connect the proper USB cable to the USB connector on the rear panel and your computer. The waveform generator sets up the USB interface automatically once the cable is properly connected. You may navigate from the Utility button, the IO softkey and then the Show USB Id softkey to verify the USB interface ID.

6.1.2 GPIB Interface

Before you may set up the GPIB interface, you need to insert the GPIB interface card into the interface slot on the rear panel, install the Model 645 application in your PC and execute the application. To set up the GPIB interface, connect the waveform generator and your computer with a proper GPIB cable and assign a GPIB address for the waveform generator. The factory default GPIB address is 10. It can be set to any number between 0 and 30. The address is stored in non-volatile memory,

so it is not affected by power cycle or a remote interface reset command. Avoid using the same address for the GPIB interface card in your computer.

How to set up GPIB interface

1. Press the Utility button and then the I/O softkey.
2. Press the softkey under GPIB Addr and enter a GPIB address using the numeric keypad or the knob.
3. Press the softkey under DONE to finish the entry.

6.1.3 LAN Interface

You need to set up a few parameters before you can use the LAN (Local Area Network) interface. Contact your network administrator to obtain the correct LAN settings for your waveform generator. These settings and the corresponding configurations are described below.

IP Address

An IP address is a unique identifier assigned to a device in the network. It is expressed in the dot notation: "nnn.nnn.nnn.nnn" where "nnn" is a byte value from 0 to 255. The value is stored in non-volatile memory, so it is not affected by power cycle or the remoter interface reset command.

If DHCP is used, the device will automatically obtain an IP address from the DHCP server in the network. If Model 645 fails to get an IP address from DHCP, the current IP address setting will be used.

Subnet Mask

Networking administrator uses *subnetting* to divide a network so that the network traffic is well distributed and the administration process is simplified. The subnet mask represents the portion of the host address to be used to identify the subnet. For example, the subnet mask 255.255.255.0 for a host IP address 10.10.3.101 indicates that the host belongs to the subnet of hosts addressed from 10.10.3.1 to 10.10.3.254 (10.10.3.0 and 10.10.3.255 are reserved for special purposes). The subnet mask setting is stored in non-volatile memory, so it is not affected by power cycle or the remoter interface reset command.

If DHCP is used, the device will automatically obtain a subnet mask from the DHCP server.

Default Gateway

A gateway is a network device that provides connectivity between two networks. The default gateway setting is the IP address of the gateway that the waveform generator is connected to. The value is stored in non-volatile memory, so it is not affected by power cycle or the remoter interface reset command.

If DHCP is used, the device will automatically obtain the IP address of the default gateway from the DHCP server.

Host Name

Host name is the human-readable identifier for the device. Together with the domain name (see below), the host name can uniquely represent the device in the networks just like its host IP address. Each character in the name can be a number, letter, dash ("–") or underscore ("_").

Domain Name

A domain is an administration unit for managing hosts in the networks. The name of a domain, just like host name, is in human-readable format. Each character in the name can be a number, letter, dash ("–") or underscore ("_").

Domains are hierarchically structured. There are top domains such as edu, com, org etc. And a sub-domain under a top domain usually represents an organization such as a company, a school, a government office etc. The smallest domain is a host itself. For example, domain "www.Berkeley Nucleonics Corporation.com.tw" consists of a host name "www" and three domains "Berkeley Nucleonics Corporation", "com" and the country domain "tw". The host name and names of its domains are concatenated with the period "." in the full domain name of the host.

DNS Server

DNS (Domain Name Service) is an internet service that translates a domain

name into IP address. The DNS server address is the IP address of the server that provides this service. The setting is stored in non-volatile memory, so it is not affected by power cycle or the remoter interface reset command.

How to set up LAN interface

1. Press the Utility button and then the softkey under I/O.
2. Press the softkey under LAN to enter the LAN submenu. You have the options to set up IP address and related parameters (under the IP Setup softkey), DNS configuration (under the DNS Setup softkey) or to view the current LAN configuration (under the Current Config softkey).

IP Setup Submenu

3. Press IP Setup softkey to enter the submenu.
4. DHCP
 - a. Press the softkey under DHCP to toggle between DHCP OFF and DHCP ON.
 - b. With DHCP OFF, you need to enter IP address, subnet mask and default gateway as the steps shown below. With DHCP ON, all these settings will be automatically obtained from the DHCP server.
5. IP Address
 - a. If DHCP is off, press the softkey under IP Addr to set an IP address.
 - b. Use only the numeric keys to enter an IP address.
 - c. Press the softkey under Enter to finish the entry or the softkey under Cancel to withdraw the changes.
6. Subnet Mask
 - a. If DHCP is off, press the softkey under SubMask to set subnet mask.
 - b. Use only the numeric keys to enter the value.
 - c. Press the softkey under Enter to finish the entry or the softkey under Cancel to withdraw the changes.
7. Default Gateway
 - a. If DHCP is off, press the softkey under Def Gate to set up the IP address of the default gateway.
 - b. Use only the numeric keys to enter the value.
 - c. Press the softkey under Enter to finish the entry or the softkey

under Cancel to withdraw the changes.

8. Press the DONE softkey to return to the LAN submenu.

DNS Setup Submenu

9. Press the softkey under DNS Setup to enter the submenu.

10. Host Name

- a. Press the softkey under Host Name to set the host name for your waveform generator.
- b. Use the numeric keys and the knob with the arrow keys to enter your desired letters or symbols.

11. Domain Name

- a. Press the softkey under Domain Name.
- b. Use the numeric keys and the knob with the arrow keys to enter your desired letters or symbols.

12. DNS Server

- a. Press the softkey under DNS Serv.
- b. Use the numeric keys to enter the IP address of the DNS server.
- c. Press the softkey under Enter to finish the entry or the softkey under Cancel to withdraw the changes.

13. Press the DONE softkey to return to the LAN submenu.

View Current Configuration

14. Press the softkey under Current Conf to display the current LAN configuration.

6.2 Remote Interface Commands

You may instruct your Model 645 waveform generator to output waveforms using the SCPI (Standard Commands for Programmable Instrument) commands after the selected remote interface is appropriately set up. This section lists the SCPI commands available for remotely controlling the waveform generator. For first time SCPI users, refer to Appendix B for the introductory materials on SCPI commands.

Note that the following conventions are used in SCPI command syntax. The triangle brackets, <>, indicate that you must specify a value for the enclosed parameter. The square brackets, [], indicate that the

parameter is optional and can be omitted. The curly braces, {}, enclose the parameter choices for a given command string. A vertical bar, |, separates several choices for a parameter.

The APPLY Commands

APPLY:SINusoid [<frequency>[,<amplitude>[,<offset>]]]
APPLY:SQUare [<frequency>[,<amplitude>[,<offset>]]]
APPLY:RAMP [<frequency>[,<amplitude>[,<offset>]]]
APPLY:PULSe [<frequency>[,<amplitude>[,<offset>]]]
APPLY:NOISe [<frequency|DEF>[,<amplitude>[,<offset>]]]
APPLY:DC [<frequency|DEF>[,<amplitude>[,<offset>]]]
APPLY:USER [<frequency>[,<amplitude>[,<offset>]]]
APPLY?

Output Configuration Commands

FUNcTION {SINusoid|SQUare|RAMP|PULSe|NOISe|DC|USER}
FUNcTION?
FREQuency {<frequency>|MINimum|MAXimum}
FREQuency? [MINimum|MAXimum]
VOLTagE {<amplitude>|MINimum|MAXimum}
VOLTagE? [MINimum|MAXimum]
VOLTagE:OFFSet {<offset>|MINimum|MAXimum}
VOLTagE:OFFSet ?[MINimum|MAXimum]
VOLTagE:HIGH {<voltage>|MINimum|MAXimum}
VOLTagE:HIGH? [MINimum|MAXimum]
VOLTagE:LOW {<voltage>|MINimum|MAXimum}
VOLTagE:LOW? [MINimum|MAXimum]
VOLTagE:RANGe:AUTO {OFF|ON|ONCE}
VOLTagE:RANGe:AUTO?
VOLTagE:UNIT {Vpp|Vrms|dBm}
VOLTagE:UNIT?
FUNcTION:SQUare:DCYCLE {<percent> | MINimum | MAXimum}
FUNcTION:SQUare:DCYCLE? [MINimum | MAXimum]
FUNcTION:RAMP:SYMMetry {<percent> | MINimum | MAXimum}
FUNcTION:RAMP:SYMMetry? [MINimum | MAXimum]
OUTPut {OFF | ON}
OUTPut?

OUTPut:LOAD {<ohms> | INFinity | MINimum | MAXimum}
OUTPut:LOAD? [MINimum | MAXimum]
OUTPut:POLarity {NORMAL | INVerted}
OUTPut:POLarity?
OUTPut:SYNC {OFF | ON}
OUTPut:SYNC?

Pulse Configuration Commands

PULSe:PERiod {<seconds>|MINimum|MAXimum}
PULSe:PERiod? [MINimum|MAXimum]
FUNction:PULSe:HOLD {WIDTh | DCYClE}
FUNction:PULSe:HOLD? [WIDTh | DCYClE]
FUNction:PULSe:WIDTh {<seconds>|MINimum|MAXimum }
FUNction:PULSe:WIDTh? [MINimum|MAXimum]
FUNction:PULSe:DCYClE {<percent>|MINimum|MAXimum }
FUNction:PULSe:DCYClE ? [MINimum|MAXimum]
FUNction:PULSe:TRANSition {<seconds>|MINimum|MAXimum }
FUNction:PULSe:TRANSition? [MINimum|MAXimum]

Amplitude Modulation Commands

AM:INTernal:FUNction{SINusoid | SQUare | RAMP | NRAMp |
TRIangle | NOISe | USER}
AM:INTernal:FUNction?
AM:INTernal:FREQUency {<frequency> | MINimum | MAXimum}
AM:INTernal:FREQUency? [MINimum | MAXimum]
AM:DEPTTh {<depth in percent> | MINimum | MAXimum }
AM:DEPTTh? [MINimum | MAXimum]
AM:SOURce {INTernal | EXTernal}
AM:SOURce?
AM:STATe {OFF | ON}
AM:STATe?

Frequency Modulation Commands

FM:INTernal:FUNction{SINusoid | SQUare | RAMP | NRAMp |
TRIangle | NOISe | USER}
FM:INTernal:FUNction?

FM:INTernal:FREQuency {<frequency> | MINimum | MAXimum}
FM:INTernal:FREQuency? [MINimum | MAXimum]
FM:DEVIation {<peak deviation in Hz> | MINimum | MAXimum}
FM:DEVIation? [MINimum | MAXimum]
FM:SOURce {INTernal | EXTernal}
FM:SOURce?
FM:STATe {OFF | ON}
FM:STATe?

Phase Modulation Commands

PM:INTernal:FUNcTion{SINusoid | SQUare | RAMP | NRAMp |
TRIangle | NOISe | USER}
PM:INTernal:FUNcTion?
PM:INTernal:FREQuency {<frequency> | MINimum | MAXimum}
PM:INTernal:FREQuency? [MINimum | MAXimum]
PM:DEVIation {<peak deviation in Hz> | MINimum | MAXimum}
PM:DEVIation? [MINimum | MAXimum]
PM:SOURce {INTernal | EXTernal}
PM:SOURce?
PM:STATe {OFF | ON}
PM:STATe?

FSK Commands

FSKey: FREQuency {<frequency> | MINimum | MAXimum }
FSKey: FREQuency? [MINimum | MAXimum]
FSKey:INTernal:RATE{<rate in Hz> | MINimum | MAXimum }
FSKey:INTernal:RATE? [MINimum | MAXimum]
FSKey:SOURce {INTernal | EXTernal}
FSKey:SOURce?
FSKey:STATe {OFF | ON}
FSKey:STATe?

PWM Commands

PWM:INTernal:FUNcTion{SINusoid | SQUare | RAMP | NRAMp |
TRIangle | NOISe | USER}
PWM:INTernal:FUNcTion?
PWM:INTernal:FREQuency {<frequency> | MINimum | MAXimum}

PWM:INTernal:FREQuency? [MINimum | MAXimum]
PWM:DEVIation {<deviation in seconds> | MINimum | MAXimum}
PWM:DEVIation? [MINimum | MAXimum]
PWM:DEVIation:DCYClE {<deviation in percent> | MINimum | MAXimum}
PWM:DEVIation:DCYClE? [MINimum | MAXimum]

PWM:SOURce {INTernal | EXTernal}
PWM:SOURce?
PWM:STATe {OFF | ON}
PWM:STATe?

Sweeps Commands

FREQuency:STARt {<frequency> | MINimum | MAXimum}
FREQuency:STARt? [MINimum | MAXimum]
FREQuency:STOP{<frequency> | MINimum | MAXimum}
FREQuency:STOP? [MINimum | MAXimum]
FREQuency:CENTer {<frequency> | MINimum | MAXimum}
FREQuency:CENTer? [MINimum | MAXimum]
FREQuency:SPAN{<frequency> | MINimum | MAXimum}
FREQuency:SPAN? [MINimum | MAXimum]
SWEep:SPACing {LINear | LOGarithmic}
SWEep:SPACing?
SWEep:TIME {<seconds> | MINimum | MAXimum}
SWEep:TIME? [MINimum | MAXimum]
SWEep:STATe {OFF | ON}
SWEep:STATe?
TRIGger:SOURce {IMMediate | EXTernal | BUS}
TRIGger:SOURce?
TRIGger:SLOPe {POSitive | NEGative}
TRIGger:SLOPe?
OUTPut:TRIGger:SLOPe {POSitive | NEGative}
OUTPut:TRIGger:SLOPe?
OUTPut:TRIGger {OFF | ON}
OUTPut:TRIGger?
MARKer:FREQuency {<frequency> | MINimum | MAXimum}
MARKer:FREQuency? [MINimum | MAXimum]
MARKer {OFF | ON}

MARKer?

Burst Commands

BURSt:MODE {TRIGgered | GATED}

BURSt:MODE?

BURSt:NCYCles {<#cycles> | INFinity | MINimum | MAXimum}

BURSt:NCYCles? [MINimum | MAXimum]

BURSt:INTernal:PERiod {<seconds> | MINimum | MAXimum }

BURSt:INTernal:PERiod? [MINimum | MAXimum]

BURSt:PHASe {<angle> | MINimum | MAXimum }

BURSt:PHASe? [MINimum | MAXimum]

BURSt:STATe {OFF | ON}

BURSt:STATe?

UNIT:ANGLE {DEGree | RAdIAN}

UNIT:ANGLE?

For triggered burst

TRIGger:SOURce {IMMediate | EXTernal | BUS}

TRIGger:SOURce?

For external source on "Ext Trig" connector

TRIGger:SLOPe {POSitive | NEGative}

TRIGger:SLOPe?

For external gated burst

Burst:GATE:POLarity {NORMal | INVerted}

Burst:GATE:POLarity?

For trigger out

OUTPut:TRIGger:SLOPe {POSitive | NEGative}

OUTPut:TRIGger:SLOPe?

OUTPut:TRIGger {OFF | ON}

OUTPut:TRIGger?

Arbitrary Waveform Commands

DATA VOLATILE, <value>, <value>,...
DATA:DAC VOLATILE. {<binary block> | <value>, <value>,...}
FORMat:BORDER {NORMal | SWAPped}
FORMat:BORDER?
DATA:COPY <destination arb name> [, VOLATILE]
FUNctio:n:USER {<arb name> | VOLATILE}
FUNctio:n:USER?
FUNctio:n USER
FUNctio:n?
DATA:CATalog?
DATA:NVOLatile:CATalog?
DATA:NVOLatile:FREE?
DATA:ATTRibute:AVERage? [<arb name>]
DATA:ATTRibute:CFACTOR? [<arb name>]
DATA:ATTRibute:POINts? [<arb name>]
DATA:ATTRibute:PTPeak? [<arb name>]

Triggering Commands

TRIGger:SOURce {IMMediate | EXTernal | BUS}
TRIGger:SOURce?
TRIGger
*TRG

For external source on "Ext Trig" connector

TRIGger:SLOPe {POSitive | NEGative}
TRIGger:SLOPe?

For external gated burst

Burst:GATE:POLarity {NORMal | INVerted}
Burst:GATE:POLarity?

For trigger out

OUTPut:TRIGger:SLOPe {POSitive | NEGative}
OUTPut:TRIGger:SLOPe?
OUTPut:TRIGger {OFF | ON}
OUTPut:TRIGger?

State Storage Commands

*SAV{0 | 1 | 2 | 3 | 4}
*RCL{0 | 1 | 2 | 3 | 4}
MEMory:STATe:NAME {0 | 1 | 2 | 3 | 4} [,<name>]
MEMory:STATe:NAME? {0 | 1 | 2 | 3 | 4}
MEMory:STATe:DELeTe {0 | 1 | 2 | 3 | 4}
MEMory:STATe:RECall:AUTO {OFF | ON}
MEMory:STATe:RECall:AUTO?
MEMory:STATe:VALid? {0 | 1 | 2 | 3 | 4}
MEMory:NSTates?

System-related Commands

SYSTem:ERRor?
*IDN?
DISPlay {OFF | ON}
DISPlay?
DISPlay:TEXT <quoted string>
DISPlay:TEXT?
DISPlay:TEXT:CLEar
*RST
*TST?
SYSTem:VERsion?
SYSTem:BEEPer
SYSTem:BEEPer:STATe {OFF | ON}
SYSTem:BEEPer:STATe?
SYSTem:KLOCK[:STATe] {OFF | ON}
SYSTem:KLOCK:EXCLude {NONE | LOCAL}
SYSTem:KLOCK:EXCLude?
SYSTem:SECurity:IMMediate
*LRN?
*OPC
*OPC?
*WAI

Interface Configuration Commands

SYSTem:COMMunication:RLState {LOCAL | REMote | RWLock}

Phase-lock Commands

PHASe {<angle> | MINimum | MAXimum}
PHASe? [MINimum | MAXimum]
PHASe:REFerence
PHASe:UNLock:ERRor:STATe {OFF | ON}
PHASe:UNLock:ERRor:STATe?
UNIT:ANGLE {DEGREE | RADian}
UNIT:ANGLE?

Status Reporting Commands

*STB?
*SRE <enable value>
*SRE?
STATus:QUEStionable:CONDition?
STATus:QUEStionable[:EVENT]?
STATus:QUEStionable:ENABle <enable value>
STATus:QUEStionable:ENABle?
*ESR?
*ESE <enable value>
*ESE?
*CLS
STATus:PRESet
*PSC {0 | 1}
*OPC

Calibration Commands

CALibration?
CALibration:COUNT?
CALibration:SECure:CODE <*new code*>
CALibration:SECure:STATe {OFF|ON},<*code*>
CALibration:SECure:STATe?
CALibration:SETup <0 | 1 | 2 | 3 | ... | 94>
CALibration:SETup?
CALibration:STRing<*quoted string*>
CALibration:STRing?
CALibration:VALue<*value*>
CALibration:VALue?

IEEE 488.2 Common Commands

*CLS

*CLS

*CLS

*ESE<enable value>

*ESE?

*ESR?

*IDN?

*LRN?

*OPC

*OPC?

*PSC {0|1}

*PSC?

*RST

*SAV{0 | 1 | 2 | 3 | 4}

*RCL{0 | 1 | 2 | 3 | 4}

*SRE <enable value>

*SRE?

*STB?

*TRG

*TST?

7 Error Messages

Error messages are issued when an incorrect remote command is sent to your Model 645 waveform generator for execution. This may occur for reasons such as incorrect command syntax, giving the parameters of a command that violate some system constraints, hardware failures and so. All possible error messages are categorized and listed in this chapter for your reference. If you cannot find a particular error message in this chapter, contact your service representative.

Error messages are stored in an error queue in Model 645 and may be retrieved in the first-in-first-out (FIFO) order. The first error returned is the first error that was stored. Model 645 beeps once each time an error occurs and the ERROR annunciator is lit whenever there are error messages in the error queue. Only when all the errors in the queue are read, the ERROR annunciator is turned off.

Should more than 20 errors have existed, the last error stored in the queue (the most recent error) is replaced with -350, "Queue Overflow". No additional errors are saved until errors are read and cleared from the queue. If there is no error in the error queue, the waveform generator responds with +0, "No Error".

The error queue is cleared with a power cycle or a *CLS (clear status) command. The *RST (reset) command does not clear the error queue.

How to read error messages

5. Press the Help button to enter the help topic selection.
6. Use the up and down softkeys to scroll the topic selection until "View remote command error queue" is highlighted.
7. Press the softkey under "Select" to display the error messages.
8. Press the softkey under DONE to leave the help topics.

Remote interface operation

Use this command to read one error from the error queue:

SYSTem:ERRor?

Use this command to clear all the errors in the error queue:

*CLS

7.1 Command Errors

-101 Invalid character

An invalid character was detected in the command string.

-102 Syntax error

Invalid syntax was detected in the command string.

-103 Invalid separator

An invalid separator was detected in the command string.

-105 GET not allowed

GET is not allowed in a command string.

-108 Parameter not allowed

More parameters than expected were received.

-109 Missing parameter

Fewer parameters than expected were received.

-112 Program mnemonic too long

More characters than allowed in the command header were received.

-113 Undefined header

An invalid command was received.

-123 Exponent too large

A numeric parameter with exponent larger than 32,759 was detected.

-124 Too many digits

A numeric parameter with too many digits was detected.

-128 Numeric data not allowed

A numeric parameter was received when the waveform generator was expecting a string parameter.

-131 Invalid suffix

A suffix was incorrectly specified for a numeric parameter.

-138 Suffix not allowed

A suffix is not supported for this command.

-148 Character data not allowed

A discrete parameter was received when it was not expected.

-151 Invalid string data

An invalid character string was received.

-158 String data not allowed

A character string was received when it was not allowed for this command.

-161 Invalid block data

For a definite-length block, the number of bytes of data sent does not match the number of bytes that you specified in the block header.

-168 Block data not allowed

This command does not accept the data format.

-170 to -178 Expression errors

Mathematical expressions are not acceptable for the instrument.

7.2 Execution Errors

-211 Trigger ignored

AGET or *TRG was received but the trigger was ignored.

-221 Settings conflict; turned off infinite burst to allow immediate trigger source

An infinite burst count is only allowed when an external or bus (software) trigger source is used.

-221 Settings conflict; infinite burst changed trigger source to BUS

An infinite burst count is only allowed when an external or bus (software) trigger source is used.

-221 Settings conflict; burst period increased to fit entire burst

The specified number of cycles in the BURS:NYNC command takes priority over the burst period and the waveform generator increased the burst period to accommodate the burst count or the waveform frequency.

-221 Settings conflict; burst count reduced to fit entire burst

Since the burst period is currently at its maximum, the waveform generator has adjusted the burst count to accommodate the waveform frequency.

-221 Settings conflict; triggered burst not available for noise

Noise function is not allowed in the triggered burst mode.

-221 Settings conflict; amplitude units changed to Vpp due to high-Z load

dBm is not available as unit when the output termination is set to "high impedance".

-221 Settings conflict; trigger output disabled by trigger external

When using the external trigger source, the *Trig Out* signal is automatically disabled.

-221 Settings conflict; trigger output connector used by burst gate

If you have enabled burst , and selected gated burst mode, the *Trig Out* signal is automatically disabled.

-221 Settings conflict; trigger output connector used by FSK

If you have enabled FSK and is using the external trigger source, the *Trig Out* signal is automatically disabled.

-221 Settings conflict; trigger output connector used by trigger external

When using the external trigger source, the *Trig Out* signal is automatically disabled.

-221 Settings conflict; frequency reduced for user function

The maximum output frequency for arbitrary waveform is 10 MHz. When you change function from one allowing higher frequency to arbitrary waveform, the frequency is adjusted to 10 MHz.

-221 Settings conflict; frequency changed for pulse function

The maximum output frequency for pulse waveform is 5 MHz. When you change function from one allowing higher frequency to pulse waveform, the frequency is adjusted to 5 MHz.

-221 Settings conflict; frequency reduced for ramp function

The maximum output frequency for ramp waveform is 200 kHz. When you change function from one allowing higher frequency to ramp waveform, the frequency is adjusted to 500 kHz.

-221 Settings conflict; frequency made compatible with burst mode

The maximum output frequency for an internal-triggered burst is 2.001 MHz. The waveform generator has adjusted the frequency to be compatible with the current setting.

-221 Settings conflict; burst turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; FSK turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; FM turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; AM turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; PM turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; PWM turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; sweep turned off by selection of other mode or modulation

Only one modulation can be enabled at one time.

-221 Settings conflict; not able to modulate this function

This waveform generator cannot generate an AM, FM, PM, FSK modulated waveform using the pulse, noise, or dc voltage function.

-221 Settings conflict; PWM only available in pulse function

The waveform generator can only generate PWM modulated waveform using pulse function.

-221 Settings conflict; not able to sweep this function

The waveform generator cannot generate a sweep using the pulse, noise or dc voltage function.

-221 Settings conflict; not able to burst this function

The waveform generator cannot generate a burst using the dc voltage function.

-221 Settings conflict; not able to modulate noise, modulation turned off

The waveform generator cannot generate a modulated waveform using the noise function.

-221 Settings conflict; not able to sweep pulse, sweep turned off

The waveform generator cannot generate a sweep using the pulse function.

-221 Settings conflict; not able to modulate dc, modulation turned off

The waveform generator cannot generate a dc voltage function.

-221 Settings conflict; Not able to sweep dc, sweep turned off

The waveform generator cannot generate a sweep using the dc voltage function.

-221 Settings conflict; not able to burst dc, burst turned off

The waveform generator cannot generate a burst using the dc voltage function.

-221 Settings conflict; not able to sweep noise, sweep turned off

The waveform generator cannot generate a sweep using the noise function.

-221 Settings conflict; pulse width decreased due to period

With edge time at its minimum, the waveform generator has adjusted the pulse width to accommodate the specified period.

-221 Settings conflict; pulse duty cycle decreased due to period

With edge time at its minimum, the waveform generator has adjusted pulse the duty cycle to accommodate the specified period.

-221 Settings conflict; edge time decreased due to period

The edge time has been decreased to accommodate the period.

-221 Settings conflict; pulse width increased due to large period

The waveform generator has adjusted the pulse width to a greater minimum determined by the current period.

-221 Settings conflict; edge time decreased due to pulse width

The waveform generator adjusts first the edge time then the pulse width or duty cycle, then period if needed to accommodate the following the limitation: $\text{EdgeTime} \leq 0.625 \times \text{PulseWidth}$. In this case, the edge time is decreased by the waveform generator to accommodate the specified pulse width.

-221 Settings conflict; edge time decreased due to pulse duty cycle

The waveform generator adjusts first the edge time then the pulse width or duty cycle, the period if needed to accommodate the following the limitation: $\text{EdgeTime} \leq 0.625 \times \text{Period} \times \text{DutyCycle}$. In this case, the edge time is decreased by the waveform generator to accommodate the pulse duty cycle.

-221 Settings conflict; amplitude changed due to function

When the new function chosen has a smaller maximum amplitude, the waveform generator will automatically adjust the amplitude from the old value to the new smaller maximum value. This may occur when the output units are Vrms or dBm due to the differences in crest factor for the various output functions.

-221 Settings conflict; offset changed on exit from dc function

In the dc voltage function, the voltage level is controlled by adjusting the offset voltage (the current amplitude is ignored). When you select a different function, the waveform generator will adjust the offset voltage as needed to be compatible with the current amplitude setting.

-221 Settings conflict; FM deviation cannot exceed carrier

The frequency deviation cannot exceed the carrier frequency, or the waveform generator will adjust the deviation to a maximum allowed value.

-221 Settings conflict; FM deviation exceeds max frequency

The sum of the carrier frequency and the deviation cannot exceed the maximum frequency for the chosen function plus 100 kHz (20.1 MHz for sine and square, 300 kHz for ramp, and 5.1 MHz for arbitrary waveforms). If you set the carrier to a value that is not valid, the waveform generator will adjust the deviation to the maximum value allowed.

-221 Settings conflict; PWM deviation decreased due to pulse parameters

The PWM deviation must follow the limitation concerning the pulse width or duty cycle, edge time, and period (see Ch 4.11 for these limitations), or the waveform generator will adjust it automatically.

-221 Settings conflict; frequency forced duty cycle change

In the square wave function, if you change the frequency to a value that cannot produce the current duty cycle, the duty cycle will be automatically adjusted to the maximum value for the new frequency.

-221 Settings conflict; marker forced into sweep span

The marker frequency must be a value between the start and the stop frequency.

-221 Settings conflict; selected arb is missing, changing selection to default

If you delete an arbitrary waveform after storing its instrument state, you will lose the waveform data and not able to output the waveform. The built-in exponential-rise wave is outputted instead.

-221 Settings conflict; offset changed due to amplitude

When the existing offset voltage does not conform the following limitation: $|V_{\text{offset}}| + V_{\text{pp}} / 2 \leq V_{\text{max}}$, it is adjusted automatically to the maximum dc voltage allowed with the specified amplitude.

-221 Settings conflict; amplitude changed due to offset

When the existing amplitude does not conform the following limitation: $|V_{\text{offset}}| + V_{\text{pp}} / 2 \leq V_{\text{max}}$, it is adjusted automatically to

the maximum value allowed with the specified offset voltage.

-221 Settings conflict; low level changed due to high level

The high level must always be greater than the low level. If you specify a high level that is smaller than the low level, the waveform generator will adjust the low level to be 1 mV less than the high level.

-221 Settings conflict; high level changed due to low level

The high level must always be greater than the low level. If you specify a low level that is greater than the high level, the waveform generator will adjust the high level to be 1 mV greater than the low level.

-222 Data out of range; value clipped to upper limit

The specified parameter is out of range and is adjusted to the maximum value allowed.

-222 Data out of range; value clipped to lower limit

The specified parameter is out of range and is adjusted to the minimum value allowed.

-222 Data out of range; pulse edge time limited by period; value clipped to upper limit

The specified edge time does not conform within the existing period and is adjusted to the maximum value allowed.

-222 Data out of range; pulse width time limited by period; value clipped to...

The specified pulse width does not conform to the following condition and is adjusted to accommodate the period:

$$\text{PulseWidth} \leq \text{Period} - (1.6 \times \text{EdgeTime})$$

-222 Data out of range; pulse duty cycle limited by period; value clipped to...

The specified duty cycle does not conform to the following condition and is adjusted to accommodate the period:

$$\text{DutyCycle} \leq (1 - 1.6 \times \text{Edge time} / \text{Period}) \times 100\%$$

-222 Data out of range; large period limits minimum pulse width

The minimum pulse width for pulse waves with period larger than 10 s is larger. Refer to the table of minimum pulse width in Section 4.5 for details.

-222 Data out of range; pulse edge time limited by width; value clipped to...

The specified pulse edge time does not conform to the following condition and is adjusted to accommodate the pulse width:

$$\text{EdgeTime} \leq 0.625 \times \text{PulseWidth}$$

-222 Data out of range; pulse edge time limited by duty cycle; value clipped to...

The specified pulse edge time does not conform to the following condition and is adjusted to accommodate the duty cycle:

$$\text{EdgeTime} \leq 0.625 \times \text{Period} \times \text{DutyCycle}$$

-222 Data out of range; period; value clipped to...

The pulse period is out of range and is adjusted.

-222 Data out of range; frequency; value clipped to...

The frequency is out of range and is adjusted.

-222 Data out of range; user frequency; value clipped to upper limit

The frequency is out of range and is adjusted to the maximum value allowed due to selection of arbitrary waveform.

-222 Data out of range; ramp frequency; value clipped to upper limit

The frequency is out of range and is adjusted to the maximum value allowed due to selection of ramp waveform.

-222 Data out of range; pulse frequency; value clipped to upper limit

The frequency is out of range and is adjusted to the maximum value

allowed due to selection of pulse waveform.

-222 Data out of range; burst period; value clipped to...

The burst period is out of range and is adjusted.

-222 Data out of range; burst count; value clipped to...

The burst count is out of range and is adjusted.

-222 Data out of range; burst period limited by length of burst; value clipped to lower limit

The burst period is too short to accommodate the burst count and frequency and is adjusted to the minimum value allowed.

-222 Data out of range; burst count limited by length of burst; value clipped to upper limit

The burst count is out of range. When the immediate trigger source is selected, the burst count must be less than the product of the burst period and the waveform frequency.

-222 Data out of range; amplitude; value clipped to...

The amplitude is out of range and is adjusted.

-222 Data out of range; offset; value clipped to...

The offset voltage is out of range and is adjusted.

-222 Data out of range; frequency in burst mode; value clipped to...

The frequency is adjusted as indicated by the burst period.

-222 Data out of range; frequency in FM; value clipped to...

This message indicates that the carrier frequency is adjusted to the lower boundary determined by the FM:DEV command. The carrier frequency must be greater than or equal to the frequency deviation.

-222 Data out of range; marker confined to sweep span; value clipped to...

The specified marker frequency is out of range and is adjusted to the

start or stop frequency, whichever is closer.

-222 Data out of range; pulse width; value clipped to...

The desired pulse width is limited to the upper or lower boundary as indicated by the instrument hardware.

-222 Data out of range; pulse edge time; value clipped to...

The desired edge time is limited to the upper or lower boundary as indicated by the instrument hardware.

-222 Data out of range; FM deviation; value clipped to...

The desired frequency deviation is limited to the upper or lower boundary set by the carrier frequency.

-222 Data out of range; FM deviation limited by minimum frequency

The frequency deviation is limited to the lower limit.

-222 Data out of range; FM deviation limited by maximum frequency; value clipped to upper limit

The frequency deviation cannot exceed the carrier frequency. The maximum should be limited to 25.05 MHz for sine, 12.55 MHz for square carrier waveforms and 5.05 MHz for an arbitrary waveform.

-222 Data out of range; PWM deviation

The width deviation is allowed to be in the range of 0 and the width of the underlying pulse waveform, while the duty cycle deviation is in the range of 0 and the duty cycle of the underlying pulse waveform. But this message indicates that either parameter is further limited by minimum pulse width and edge time parameters.

-222 Data out of range; PWM deviation limited by pulse parameters

The PWM deviation (width or duty cycle) is adjusted to accommodate the current pulse parameters such as pulse width/duty cycle, period and edge time.

-222 Data out of range; duty cycle; value clipped to...

The square wave duty cycle is adjusted to within 20% to 80%.

-222 Data out of range; duty cycle limited by frequency; value clipped to upper limit

The square wave duty cycle is adjusted to within 40% to 60% when the frequency is greater than 10 MHz.

-223 Too much data

An arbitrary waveform specified contains more than 65,536 points. Verify the number of points in the DATA VOLATILE or DATA:DAC VOLATILE command.

-224 Illegal parameter value

An exact parameter value was expected.

7.3 Device Dependent Errors

-313 Calibration memory lost; memory corruption detected

A checksum error was detected in the non-volatile memory used to store calibration constant.

-314 Save/recall memory lost; memory corruption detected

A checksum error was detected in the non-volatile memory used to store instrument states.

-315 Configuration memory lost; memory corruption detected

A checksum error was detected in the non-volatile memory used to store configuration settings.

-350 Queue overflow

More than 20 errors were found and the error queue was full.

7.4 Query Errors

-410 Query INTERRUPTED

A command was received, but the output buffer contained data from a previous command (the previous data is lost).

-420 Query UNTERMINATED

A query command was sent to read the output buffer over the interface, but no such command that generates data to the output buffer was previously sent for execution.

-430 Query DEADLOCKED

An executed command generated too much data for the output buffer and the input buffer is also full. The command continues to execute but the data is lost.

-440 Query UNTERMINATED after indefinite response

The *IDN? command must be the last query command within a series of commands in a command string.

7.5 Instrument Errors

501 Cross-isolation UART framing error

502 Cross-isolation UART overrun error

Internal hardware failure.

580 Reference phase-locked loop is unlocked

The PHAS:UNL:ERR:STAT has been turned on and the internal phase-locked loop is currently unlocked.

7.6 Self-Test Errors

621 Self-test failed; square-wave threshold DAC

A possible malfunctioning DAC, failed DAC multiplexer (U803) channels,

or associated circuitry.

623 Self-test failed; dc offset DAC

624 Self-test failed; null DAC

625 Self-test failed; amplitude DAC

A possible malfunctioning DAC, failed DAC multiplexer (U803) channels, or associated circuitry.

626 Self-test failed; waveform filter path select relay

627 Self-test failed; -10 dB attenuator path

628 Self-test failed; -20 dB attenuator path

629 Self-test failed; +20 dB amplifier path

These errors indicate that the specified relay is not properly switched or the attenuator/amplifier does not provide the expected attenuation or gain. These self-tests use the internal ADC to verify whether the output path relays, output amplifier (+20 dB), and output attenuators properly operate or not.

630 Self-test failed; internal ADC over-range; condition

A probable ADC failure.

631 Self-test failed; internal ADC measurement error

A probable ADC failure.

632 Self-test failed; square/pulse DAC test failure

A probable failure of the square/pulse DAC (U1002).

7.7 Calibration Errors

701 Calibration error; security defeated by hardware jumper

The calibration security feature has been disabled by shorting the two "CAL ENABLE" pads on the internal circuit board.

702 Calibration error; calibration memory is secured

The calibration memory is secured to disallow a calibration from

performing. Use the CAL:SEC:STAT ON command with correct security code to unsecure the calibration memory.

703 Calibration error; secure code provided was invalid

Security code provided in the CAL:SEC:STAT ON command was invalid.

706 Calibration error; provide value is out of range

The specified calibration value is out of range.

707 Calibration error; signal input is out of range

The analog-to-digital converter (ADC) verified that the signal applied to the *Modulation In* connector on the rear panel is out of range.

707 Calibration error; cal edge time: rise time cal error

707 Calibration error; cal edge time: fall time cal error

707 calibration error; cal edge time: default value loaded

A failure in the rise time or fall time circuitry has prevented calibration from going forward.

850 calibration error; setup is invalid

Invalid calibration setup number specified.

851 calibration error; setup is out of order

Calibration setup procedures must be performed in a specific sequence in order to be valid.

7.8 Arbitrary Waveform Errors

770 Nonvolatile arb waveform memory corruption detected

A checksum error was found in the non-volatile memory used to store arbitrary waveform. As a result, The arbitrary waveform cannot be retrieved.

781 Not enough memory to store new arb waveform; use DATA:DELETE

All non-volatile memory locations are occupied. There is no room to store a new waveform.

781 Not enough memory to store new arb waveform; bad sectors

Due to storage hardware failure, new waveforms cannot be saved.

782 Cannot overwrite a built-in waveform

The five built-in waveform names ("EXP_RISE", "EXP_FALL", "NEG_RAMP", "SINC", and "CARDIAC") are reserved and cannot be used with DATA:COPY command.

784 Name of source arb waveform for copy must be VOLATILE

When using the DATA:COPY command, the data source must be the VOLATILE one.

785 Specified arb waveform does not exist

Before using DATA:COPY command to copy from the volatile memory, be sure to download the waveform to it using the DATA VOLATILE or DATA:DAC VOLATILE command.

786 Not able to delete a built-in arb waveform

Deleting the built-in waveform is not allowed.

787 Not able to delete the currently selected active arb waveform

Deleting the waveform that is currently outputting is not allowed.

788 Cannot copy to VOLATILE arb waveform

You can only use DATA:COPY command to copy from VOLATILE, not to VOLATILE.

800 Block length must be even

The binary data are represented as 16-bit integers. They are sent in groups of two bytes (DATA:DAC VOLATILE command).

810 State has not been stored

The storage location specified in the *RCL command was never used in

previous *SAV commands. You cannot recall instrument state from an empty storage location.

Appendix

This appendix contains the performance specifications of the Model 645. It covers the AC, DC, Resistance, Temperature, and Frequency/Period characteristics under a variety of conditions. It also contains the general characteristics and accuracy calculations for your convenience. A lot of efforts are made to make sure these specifications serve your needs for production, engineering and/or research purposes. All specification applies to Model 645 unless noted otherwise.

A Specification List

Display	Graph mode for visual verification of signal settings	
Capability	Standard waveforms	Sine, Square, Ramp, Triangle, Pulse, Noise, DC
	Built-in arbitrary waveforms	Exponential Rise and Fall, Negative ramp, Sin(x)/x, Cardiac
WAVEFORM CHARACTERISTIC		
Sine	Frequency	1 uHz to 50 MHz
	Amplitude Flatness (Relative to 1K)	0.1dB(<100KHz)
		0.15dB(<5MHz)
		0.3dB(<20MHz)
		0.5dB(<50MHz)
	Harmonic distortion (unit: dBc)	DC to 20 kHz -70(< 1Vpp) -70(≥ 1Vpp)
		20 kHz to 100 KHz -65(< 1Vpp) -60(≥ 1Vpp)
		100 kHz to 1 MHz -50 (< 1Vpp) -45 (≥ 1Vpp)
		1 MHz to 20 MHz -40 (< 1Vpp) -35 (≥ 1Vpp)
		20 MHz to 50 MHz -35 (< 1Vpp) -30 (≥ 1Vpp)
	Total Harmonic distortion	DC to 20 kHz, Output ≥ 0.5Vpp THD+N ≤ 0.06%
	Spurious (non-harmonic)	DC to 1 MHz -70 dBc
		1 MHz to 50 MHz -70 dBc + 6 dB/octave
Phase Noise (10K Offset)	-115/dBc/Hz, typical when $f \geq 1\text{MHz}$, $V \geq 0.1\text{Vpp}$	

Square	Frequency	1 uHz to 25 MHz
	Rise/Fall time	< 10 ns
	Overshoot	< 2%
	Variable Duty Cycle	20% to 80% (to 10 MHz)
		40% to 60% (to 25 MHz)
	Asymmetry	1% of period + 5 ns (@ 50% duty)
Jitter (RMS)	200 ps when $f \geq 1\text{MHz}$, $V \geq 0.1\text{Vpp}$	
Ramp, Triangle	Frequency	1 μHz to 200 kHz
	Linearity	< 0.1% of peak output
	Symmetry	0.0% ~ 100.0%
Pulse	Frequency	500 μHz to 10 MHz
	Pulse width	20 ns minimum
		10 ns res. (period \leq 10s)
	Variable Edge Time	< 10 ns to 100 ns
	Overshoot	< 2%
Jitter (RMS)	200 ps when $f \geq 50\text{KHz}$, $V \geq 0.1\text{Vpp}$	
Noise	Bandwidth	20 MHz typical
Arbitrary	Frequency	1 μHz to 10 MHz
	Length	2 to 256 K
	Resolution	14 bits (including sign)
	Sample Rate	125 MSa/s
	Min Rise/Fall Time	30ns typical
	Linearity	< 0.1% of peak output
	Settling Time	< 250ns to 0.5% of final value
	Jitter(RMS)	6ns + 30ppm
	Non-volatile Memory	4 waveforms * 256K Points

COMMON CHARACTERISTIC		
Frequency	Resolution	1uHz
Amplitude	Range	10mVpp to 10Vpp in 50Ω
		20mVpp to 20Vpp in Hi-Z
	Accuracy (at 1KHz)	±1% Of setting ± 1mVpp
	Units	Vpp, Vrms, dBm
	Resolution	4 digits
DC Offset	Range (Peak AC +DC)	±5V in 50Ω
		±10V in Hi-Z
	Accuracy	±2% of offset setting ±0.5% of amplitude setting
	Resolution	4 digits
Main Output	Impedance	50 Ω typical
	Isolation	42 Vpk maximum to earth
	Protection	short-circuit protected; overload automatically disables main output
Internal Frequency reference Accuracy		±10ppm in 90 days
		±20ppm in 1 year
External Frequency reference	Standard /Option	Standard
External Frequency Input	Lock Range	10 MHz ± 500 Hz
	Level	100mVpp ~5Vpp
	Impedance	1KΩ typical, AC coupled
	Lock Time	< 2 Sec
External Frequency Output	Lock Range	10 MHz
	Level	632mVpp (0dBm), typical
	Impedance	50Ω typical, AC coupled
Phase Offset	Range	-360° to +360°
	Resolution	0.001°
	Accuracy	8ns

Modulation		
Modulation Type	AM, FM, PM, FSK, PWM, Sweep and Burst	
AM	Carrier	Sine, Square, Ramp, Arb
	Source	Internal / external
	Internal Modulation	Sine, Square, Ramp, Triangle, Noise, Arb
	Frequency (Internal)	2mHz to 20KHz
	Depth	0.0% ~ 120.0%
FM	Carrier	Sine, Square, Ramp, Arb
	Source	Internal / external
	Internal Modulation	Sine, Square, Ramp, Triangle, Noise, Arb
	Frequency (Internal)	2mHz to 20KHz
	Deviation	DC ~ 25MHz
PM	Carrier	Sine, Square, Ramp, Arb
	Source	Internal / external
	Internal Modulation	Sine, Square, Ramp, Triangle, Noise, Arb
	Frequency (Internal)	2mHz to 20KHz
	Deviation	0.0° to 360°
PWM	Carrier	Pulse
	Source	Internal / external
	Internal Modulation	Sine, Square, Ramp, Triangle, Noise, Arb
	Frequency (Internal)	2mHz to 20KHz
	Deviation	0% ~ 100% of pulse width
FSK	Carrier	Sine, Square, Ramp, Arb
	Source	Internal / external

	Internal Modulation	50% duty cycle Square
	Frequency (Internal)	2mHz to 100KHz
External Modulation Input	Voltage Range	±5V full scale
	Input Resistance	8.7KΩ typical
	Bandwidth	DC to 20KHz
SWEEP	Waveforms	Sine, Square, Ramp, Arb
	Type	Linear or logarithmic
	Direction	up or down
	Sweep Time	1 ms ~ 500 Sec
	Trigger	Internal , External or Manual
	Marker	falling edge of sync signal (programmable frequency)
BURST	Waveforms	Sine, Square, Ramp, Triangle, Noise, Arb
	Type	Internal / external
	Start/Stop Phase	-360° to +360°
	Internal Period	1uS ~ 500Sec
	Gated Source	External trigger
	Trigger Source	Internal , External or Manual
Trigger Input	Level	TTL compatible
	Slope	Rising or Falling (Selectable)
	Pulse width	> 100 ns
	Impedance	> 10KΩ, DC coupled
	Latency	< 500 ns
Trigger Output	Level	TTL compatible into ≥ 1 kΩ
	Pulse width	> 400 ns
	Output Impedance	50 Ω typical
	Maximum rate	1MHz
	Fan-out	≤ 4 Berkeley Nucleonics Corporation

		Model 645s
Pattern Mode CHARACTERISTIC		
Clock	Maximum rate	50MHz
Output	Level	TTL compatible into $\geq 2 \text{ k}\Omega$
	Output Impedance	110 Ω typical
Pattern	Length	2 to 256 K

B Remote Interface Reference

B.1 An Introduction to the SCPI Language

SCPI (Standard Commands for Programmable Instruments) is an ASCII-based instrument command language designed for testing and measurement instruments. It is based on a hierarchical structure, also known as a *tree system*. In this system, associated commands are grouped together under a common node or root, thus forming *subsystems*. A portion of the SOURce subsystem is shown below to explain the tree system.

SOURce:

FREQuency:

STARt {<frequency>|MINimum|MAXimum}

STARt? [MINimum|MAXimum]

FREQuency:

STOP {<frequency>|MINimum|MAXimum}

STOP? [MINimum|MAXimum]

SWEep:

SPACing {LINear|LOGarithmic}

SPACing?

SWEep:

TIME {<seconds>|MINimum|MAXimum}

TIME? [MINimum|MAXimum]

SOURce is the root keyword of the command, SWEep and FREQuency are second-level keywords, and STARt and STOP are third-level keywords. A colon (:) separates a command keyword from a lower-level keyword.

B.1.1 Command Format Used in This Manual

The command format used in this manual is shown below:

STARt {<frequency>|MINimum|MAXimum}

Most commands (and some parameters) are expressed as a mixture of upper- and lower-case letters. The upper-case letters indicate the abbreviated part that must be specified for the command. For shorter program lines, send the abbreviated form. For better program readability, use the long form. For example, in the above syntax statement, STAR and START are both acceptable forms for the same command. You may also mix upper- or lower-case letters in a command. For example, START, star, and Star are all acceptable for the same command. Other forms, such as STA will generate an error.

Braces ({ }) enclose parameter choices for a given command string. The braces are not sent with the command.

Vertical bars (|) separate multiple parameter choices for a given command string.

Triangle brackets (< >) indicate that you must specify a value for the enclosed parameter. For example, the above START command accepts a *frequency* parameter enclosed in triangle brackets. The brackets are not sent with the command string. You must specify a value for the parameter such as "STAR 6000".

Some parameters are enclosed in *square brackets* ([]). The brackets indicate that the parameter is optional and can be omitted. The brackets are not sent with the command string. If you do not specify a value for an optional parameter, the waveform generator uses the default value.

B.1.2 Command Separators

A *colon* (:) is used to separate a command keyword from a lower-level keyword. You must insert a *blank space* to separate a parameter from a command keyword. If a command requires more than one parameter, you must use a comma between two parameters:

"APPL:SIN 5 KHZ, 3.0 VPP, -2.5 V"

A *semicolon* (;) is used to separate commands within the *same* subsystem, and can reduce typing efforts. For example, sending the following command string:

```
"BURSt:MODE TRIG; NCYCles 10"
```

is the same as sending the following two commands:

```
"BURS:MODE TRIG"
```

```
"BURS:NCYCles 10"
```

Use a colon *and* a semicolon to link commands from different subsystems. For example, in the following command string, an error is generated if you do not use both the colon *and* semicolon:

```
"BURS:STATe ON;;TRIG:SOUR EXT"
```

B.1.3 Using the *MIN* and *MAX* Parameters

You may put MINimum or MAXimum in place of a parameter for many commands. For example, consider the following command:

```
FREQuency: START {<frequency>|MINimum|MAXimum}
```

Instead of specifying a specific frequency value, you may use MIN to set the frequency to its minimum value or MAX to its maximum value.

B.1.4 Querying Parameter Settings

You can query the current value of a parameter by adding a *question mark* (?) to the command. For example, the following command sets the start frequency to 5000 Hz:

```
"STAR 5000"
```

You can query the start frequency by executing:

```
"STAR?"
```

You can also query the minimum or maximum start frequency allowed for the current waveform function as follows:

```
"STAR? MIN"
```

```
"STAR? MAX"
```

Caution

- If you send two query commands without reading the response from the first, then when you attempt to read the response, you may receive some data from the first response followed by the complete second response. To avoid this, do not send a query command without reading the response. When you cannot avoid this situation, send a device clear before sending the second query command.

B.1.5 SCPI Command Terminators

A command string sent to the multimeter *must* terminate with a *<new line>* character. The IEEE-488 *EOI* (end-or-identify) message is interpreted as a *<new line>* character and can be used to terminate a command string in place of a *<new line>* character. A *<carriage return>* followed by a *<new line>* is also accepted. Command string termination will *always* reset the current SCPI command path to the root level.

B.1.6 IEEE-488.2 Common Commands

The IEEE-488.2 standard defines a set of *common commands* that perform functions like reset, self-test, and status operations. Common commands always begin with an asterisk (*), are four to five characters in length, and may include one or more parameters. The command keyword is separated from the first parameter by a *blank space*. Use a *semicolon* (;) to separate multiple commands as shown below:

```
"*RST; *CLS; *ESE 32; *OPC?"
```

B.1.7 SCPI Parameter Types

The SCPI language defines several different data formats to be used in program messages and response messages.

Numeric Parameters Commands that require numeric parameters will accept all commonly used decimal representations of numbers including optional signs, decimal points, and scientific notation. Special values for numeric parameters like MINimum, MAXimum, and DEFault are also accepted. You can also send engineering unit suffixes with numeric parameters (e.g., Mhz or Khz). If only specific numeric values are accepted, the waveform generator will automatically round the input numeric parameters. The following example demonstrates a command with a numeric parameter option:

```
FREQuency:START {<frequency>|MINimum|MAXimum}
```

Discrete Parameters Discrete parameters are used in the settings where only a limited number of values (like BUS, IMMEDIATE, EXTERNAL) are accepted. They have the short and long forms just like command keywords. You can mix upper- and lower-case letters. Query responses will *always* return the short form in all upper-case letters. The following example demonstrates a command with a discrete parameter:

```
TRIGger:SOURce {BUS|IMMEDIATE|EXTERNAL}
```

Boolean Parameters A Boolean parameter represents a condition that is either true or false. For a false condition, the waveform generator accepts "OFF" or "0" as parameter value. For a true condition, the multimeter accepts "ON" or "1" as parameter value. When you query a Boolean parameter, the instrument will *always* return "0" or "1". The following example demonstrates a command with a Boolean parameter:

```
SWEep:STATe {OFF|ON}
```

String Parameters A string parameter can contain any set of ASCII characters. A string *must* begin and end with matching quotes, either with single or double quotes. You can include the quote delimiter as part of the string by typing it twice without any characters in between. The following example demonstrates a command with a string parameter:

```
DISPlay:TEXT <quoted string>
```

B.2 Output Data Formats

Output data will be in one of formats shown in the table below.

Type of Output Data	Output Data Format
Non-reading queries	< 80 ASCII character string
Single reading (IEEE-488)	SD.DDDDDDDDESDD<nl>
Multiple readings (IEEE-488)	SD.DDDDDDDDESDD,.....,<nl>

S Negative sign or positive sign

D Numeric digits

E Exponent

<nl> newline character

<cr> carriage return character

B.3 Command Reference

-- A to F --

-- A --

AM:INTernal

:FUNction{SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}

Specify the modulating waveform for the modulation. This applies only when the modulating source is internal. Noise can be a modulating waveform, but cannot be used as a carrier waveform, neither do Pulse nor dc. The default modulating waveform is a sine waveform.

AM:INTernal

:FUNction?

Query the modulating function in amplitude modulation. "SIN", "SQU", "RAMP", "NRAM", "TRI", "NOIS" or "USER" string indicating the modulating function will be returned.

-- Square waveform has 50% duty cycle.

--Ramp waveform has 100% symmetry

--Triangle waveform has 50% symmetry.

--Negative Ramp waveform has 0% symmetry.

--If an Arbitrary(USER) waveform is chosen to be the modulating waveform, it is

automatically limited to 4k points. Extra points are removed using decimation.

AM:INTernal

:FREQuency{<frequency>|MINimum|MAXimum}

Specify the frequency of the modulating waveform. This applies only when the modulating source is internal. The range is from 2 mHz to 20 kHz and the default is 100 Hz.

AM:INTernal

:FREQuency? [MINimum|MAXimum]

Query the internal modulating frequency. The frequency (in hertz) of the internal modulating waveform is returned.

AM:DEPth {<depth in percent>|MINimum|MAXimum}

Specify the internal modulation depth (or "percent modulation") in percent. The range is from 0% to 120% and the default is 100%.

Notes:

- When an external source is selected, the modulation depth is controlled by the $\pm 5\text{v}$ external signal applied at the *Modulation In* connector on the rear panel. Specifically, the output will be at the maximum amplitude when the modulating signal is at +5v, and the output will be at the minimum amplitude when the modulating signal is at -5v.
- The modulation output of Model 645 will not exceed $\pm 5\text{V}$ peak (into a 50Ω load) even if the modulation depth is greater than 100%.

AM:DEPth? [MINimum|MAXimum]

Query the modulation depth in amplitude modulation. The modulation depth (in percent) is returned.

AM:SOURce {INTernal|EXTernal}

Specify the modulating signal source. If an External source is chosen, the carrier waveform is modulated with an external waveform. The modulation depth is controlled by the $\pm 5\text{v}$ external signal applied at the *Modulation In* connector on the rear panel. Specifically, the output will be at the maximum amplitude when the modulating signal is at +5v, and the output will be at the minimum amplitude when the modulating signal is at -5v.

AM:SOURce?

Query the modulating source in amplitude modulation. "INT" or "EXT" string indicating the modulating source will be returned.

AM:STATe {OFF|ON}

Disable or Enable the amplitude modulation. The default is OFF.

To avoid multiple waveform changes, you can enable AM after setting the modulation parameters.

AM:STATe?

"0" (OFF) or "1" (ON) will be returned.

APPLy:**SINusoid** [<frequency> [,<amplitude > [,<offset>]]]

Output a sine wave with specific frequency, amplitude and offset. The waveform is output as soon as the command is executed.

APPLy:**SQUare** [<frequency> [,<amplitude > [,<offset>]]]

Output a square wave with specific frequency, amplitude and offset. The duty cycle is set automatically to 50%. The waveform is output as soon as the command is executed.

APPLy:**RAMP** [<frequency> [,<amplitude > [,<offset>]]]

Output a ramp wave with specific frequency, amplitude and offset. The symmetry is set automatically to 100%. The waveform is output as soon as the command is executed.

APPLy:**PULSe** [<frequency> [,<amplitude > [,<offset>]]]

Output a pulse wave with specific frequency, amplitude and offset. The waveform is output as soon as the command is executed. This command works with the current edge time setting and the current duty cycle or pulse width setting, depending on which has been selected to "hold" (FUNC:PULS:HOLD command). However the waveform generator will adjust the pulse width or the edge time to comply with the frequency restrictions for pulse waveforms.

APPLy:**NOISe** [<frequency | DEF> [,<amplitude > [,<offset>]]]

Output Gaussian pulse wave with the specific frequency, amplitude and (dc) offset. The waveform is outputted as soon as the command is executed. The specified frequency has no effect on the noise wave, but is remembered by the

waveform generator and will be used on the next function you choose.

APPLY:

DC [<frequency> | DEF [,<amplitude | DEF> [,<offset>]]]

Output a dc voltage with the specified offset level. You can set the dc voltage to any value between $\pm 5\text{Vdc}$ into 50 ohms or $\pm 10\text{Vdc}$ into an open circuit. The waveform is output as soon as the command is executed. The specified frequency and amplitude have no effect on the pulse wave, but are remembered by the waveform generator and will be used on the next function you choose.

APPLY:

USER [<frequency> [,<amplitude > [,<offset>]]]

Output an arbitrary waveform currently chosen by the FUNC:USER command with the specific frequency, amplitude and offset. The waveform is output as soon as the command is executed.

APPLy?

Query the current configuration and return a quoted string. The quoted string includes the function, frequency, amplitude and offset as in the following format:

"function frequency amplitude offset"

This command allows you to append this query response to an APPL: command in your programming application and use the result to place the waveform generator in the specified state.

-- B --

BURSt:MODE {TRIGgered|GATed}

Specify the burst mode. The default is Triggered mode. In the triggered mode, the waveform generator outputs a waveform with specified number of cycles (burst count) each time a trigger is received from the specified trigger source. In the gated mode, the output waveform is either "on" or "off" based on the external signal level on the Ext Trig connector on the rear panel.

--Use BURS:GATE:POL command to specify the polarity of *Ext Trig* connector on the rear panel.

--When the gate signal is true, the waveform generator outputs a continuous waveform. When the gate signal is false, the current waveform is complete and

the waveform generator stops while remaining at the voltage level corresponding to the starting burst phase of the selected waveform. And the output stops immediately in a noise waveform when the gate signal is false.

--The burst count, burst period and trigger source are for triggered burst mode only.

BURSt:MODE?

"TRIG" or "GAT" will be returned.

BURSt:NCYCles {<# cycles>|INFinity|MINimum|MAXimum}

Specify the number of cycles to be output in each burst (triggered burst mode only). The range is from 1 to 50,000 cycles in 1 cycle increments and the default is 1 cycle. The maximum value depends on the burst period and frequency as shown below. Specify Infinite to generate a continuous burst waveform. When using the Immediate(Internal) trigger source (**TRIG:SOUR IMM command**), the burst count must be less than the product of the maximum burst period and the waveform frequency:

Burst Count < Maximum period x Frequency.

-- The waveform generator will automatically increase the burst period up to its maximum value to accommodate the specified burst count, but it won't change the waveform frequency.

-- The burst count does not apply in the gated mode. However, if you specify a new burst count while in the gated mode, the waveform generator will remember it and use it when the triggered mode is selected.

BURSt:NCYCles?

The burst count will be returned. The range is from 1 to 50,000, and 9.9E+37 is returned if Infinite is specified.

BURSt:INTernal:PERiod {<seconds>|MINimum|MAXimum}

Specify the burst period for bursts with internal (immediate) trigger source. The burst period is ignored when external or manual trigger source is enabled (or when the gated burst mode is chosen). The range is from 1 μ s to 500 seconds and the default is 10 ms. The maximum value is 500 s, but the minimum value depends on the burst count and frequency as shown below:

$$\text{BurstPeriod} > \frac{\text{BurstCount}}{\text{WaveformFrequency}} + 200\text{ns}$$

BURSt:INTernal:PERiod? [MINimum|MAXimum]

The burst period in seconds will be returned.

BURSt:PHASe {<angle>|MINimum|MAXimum}

Specify the starting phase in degrees or radians according to UNIT:ANGL command. The range is from -360 degrees to +360 degrees (or from -2π to $+2\pi$ radians) and the default is 0 degree (0 radians).

--For sine, square and ramp waveform, zero degrees is the point at which the waveform crosses zero volts or the dc offset in a positive going direction. For arbitrary waveform, it is the first waveform point downloaded to memory. The burst phase has no effect on pulse or noise waveform.

--In the gated burst mode, when the gate signal turns false, the current waveform is complete and the waveform generator stops and the output remains at the voltage level corresponding to the starting burst phase.

BURSt:PHASe? [MINimum|MAXimum]

The starting phase in degree or radians will be returned.

BURSt:STATe {OFF|ON}

Disable or enable the burst mode. To avoid multiple waveform changes, you can enable burst after setting the modulation parameters. The waveform generator allows only one of burst, sweep and modulations enabled at one time. As long as one is enabled, the other will be turned off.

BURSt:STATe?

"0" (OFF) or "1" (ON) will be returned.

BURSt:GATE:POLarity {NORMal|INVerted}

Specify whether the waveform generator uses true-high or true-low logic levels on the rear-panel *Ext Trig* connector for an externally-gated burst. The default is NORM (true-high logic).

BUTSt:GATE:POLarity?

"NORM" or "INV" will be returned.

-- C --

CALibration?

Perform a calibration using the specified calibration value (CALibration:VALue command). You need to enter a correct security code (see CALibration:SECure:STATe) before you can calibrate the waveform generator.

CALibration:COUNT?

Query the number of times the waveform generator has been calibrated. Note that your instrument was calibrated before it left the factory. Check the calibration count when you receive your waveform generator to determine its initial value.

CALibration:SECure:CODE <new code>

Set a new security code. You have to first use the old security code to unsecure the waveform generator and then set a new security code. A security code may contain up to 12 characters and the first character must be a letter (A-Z). The rest of the characters can be any combination of numbers (0-9), letters and underscore character ("_").

CALibration:SECure:STATe {OFF|ON},<code>

Unsecure or secure the waveform generator for calibration.

CALibration:SECure:STATe?

Query the secured state of the waveform generator. Return "0" (OFF) or "1" (ON).

CALibration:SETup <0 | 1 | 2 | 3 | ... | 94>

Configure the waveform generator's internal state for each of the calibration steps to be performed.

CALibration:SETup?

Query the calibration setup number. Return a value from "0" to "94".

CALibration:STRing<quoted string>

Record information about calibration. For instance, the name of the person who did the calibration, the date of the last calibration, or the date of next scheduled calibration. This information is stored in non-volatile memory and newly recorded message will overwrite the previous one.

CALibration:STRing?

Query the information about the calibration. Return a quoted string.

CALibration:VALue<value>

Specify the value of the known calibration signal used by the calibration procedure.

CALibration:VALue?

Query the present calibration value. Return a number in the form of "+1.00000000000000E+01".

-- D --

DATA VOLATILE, <value>, <value>, ...

Download floating-point values from -1 to +1 into volatile memory. You can download from 1 to 65,536 points per waveform. The waveform generator takes the specified number of points and expands them to fill waveform memory. If the specified number is less than 16,384, the waveform generator automatically generates a waveform with 16,384 points, and if the specified number is more than 16,384, a waveform with 65,536 points will be generated.

- The values -1 and +1 correspond to the peak values of the waveform when the offset is zero volts.
- The maximum amplitude will be limited if the data points do not span the full range of the output DAC (Digital-to-Analog Converter).
- The DATA command overwrites the previous waveforms in volatile memory. If you need to save it, use DATA:COPY command to copy the waveform to non-volatile memory.
- Downloading floating-point values (using DATA VOLATILE) is slower than downloading binary values (using DATA:DAC VOLATILE) but is more convenient when using trigonometric functions which return

values from -1 to +1.

- After downloading the waveform data to memory, use the `FUNC:USER` command to choose the active waveform and the `FUNC USER` command to output it.
- The following statement shows how to use the `DATA` command to download seven points to volatile memory.

```
DATA VOLATILE, 1, .67, .33, 0, -.33, -.67, -1
```

DATA:DAC VOLATILE, {<binary block>|<value>, <value>, ...}

Download binary or decimal integer values from -8191 to +8191 into volatile memory. You can download from 1 to 65,536 (64K) points per waveform in IEEE-488.2 binary block format or as a list of values. The range of values corresponds to the values available using internal 14-bit DAC (digital-to-Analog Converter) codes. The waveform generator takes the specified number of points and expands them to fill waveform memory. If you download less than 16,384 (16K) points, a waveform with 16,384 points is automatically generated. If you download more than 16,384 points, a 65,536-point waveform is generated.

- The values -8191 and +8191 correspond to the peak values of the waveform (if the offset is 0 volts). For example, if you set the output amplitude to 10 Vpp, "+8191" corresponds to +5V and "-8191" corresponds to -5V.
- The maximum amplitude will be limited if the data points do not span the full range of the output DAC (Digital-to-Analog converter). For example, the built-in sine wave does not use the full range of binary values between ± 1 and therefore its maximum amplitude is 6.087 Vpp (into 50 ohms).
- The **DATA:DAC** command overwrites the previous waveform in volatile memory (and no error will be generated). Use the **DATA:COPY** command to copy the waveform to non-volatile memory.
- The on-volatile memory can store up to four user-defined waveforms. Use `DATA:CAT?` Command to list all waveforms stored in volatile and non-volatile memory.
- After downloading the waveform data to memory, use the `FUNC:USER` command to choose the active waveform and the `FUNC USER` command to output it.
- The following statement shows how to use the `DATA:DAC` command to download seven integer points using the binary block format.

DATA:DAC VOLATILE, #214

- The following statement shows how to use the DATA:DAC command to download five integer points in decimal format.

DATA:DAC VOLATILE, 8191, 4096, 0, -4096, -8191

IEEE-488.2 Binary Block Format

In the binary block format, a block header precedes the data points. The block header follows the format below:

```
# 5 32768
```

"#" starts the data block. The second number represents the number of digits to follow and the third number represents the number of bytes to follow (32,768 bytes = 16,384 points).

A waveform data point is represented as a 16-bit integer sent in two bytes. Therefore, the total number of bytes is always twice the number of data points in the waveform (and must always be an even number). For example, 32,768 bytes are required to load a waveform with 16,384 points.

Use the FORM:BORD command to select the byte order for binary block transfers. If you specify FORM:BORD NORM (the default setting), the most-significant byte (MSB) of each data point is sent first. If you specify FORM:BORD SWAP, the least-significant byte (LSB) of each data point is sent first. Most computers use the "swapped" byte order.

Notes:

- The values ± 8191 correspond to the peak values of the waveform (if the offset is 0 volts).
- The maximum amplitude will be limited if the data points do not span the full range of the output DAC (Digital-to-Analog converter). For example, the built-in sinc wave does not use the full range of binary values between ± 8191 and thus its maximum amplitude is limited to 6.087 V_{pp} (into 50 Ω).
- The **DATA:DAC** command overwrites the previous waveform in the volatile memory (and no error will be generated). Use the **DATA:COPY** command to copy the waveform to non-volatile memory.

DATA:CATalog?

List all waveform names available for use. The names of the five built-in waveforms (in non-volatile memory) and all user-defined waveforms (in volatile

memory) will be returned. "Volatile" will be returned when a built-in waveform is currently downloaded to volatile memory. To remove a waveform from volatile memory or any use-defined waveforms in non-volatile memory, use DATA:DEL command.

DATA:NVOLatile:CATalog?

List the names of all user-defined arbitrary waveforms downloaded to non-volatile memory. Up to four waveform names will be returned. If there is no waveform currently downloaded, a null string "" will be returned. To remove any use-defined waveforms in non-volatile memory, use DATA:DEL command.

DATA:NVOLatile:FREE?

Query the number of available slots for storing the user-defined waveforms.

DATA:DElete <arb name>

Remove the specific arbitrary waveform from memory. It can be the waveforms in volatile memory or the user-defined waveforms in non-volatile memory. You cannot delete an arbitrary waveform that is currently output, or an error will be generated.

DATA:DElete:ALL

Remove all user-defined waveforms from memory. All waveforms in volatile memory and user-defined waveforms in non-volatile memory will be deleted, but the built-in waveforms in non-volatile memory will not be deleted. You cannot delete an arbitrary waveform that is currently output, or an error will be generated.

DATA:ATTRibute:AVERAge? [<arb name>]

Query the arithmetic average of all data points for the specified waveform (-1 ≤). The default waveform is the currently active one (FUNC:USER command). If you query a waveform which is not stored in memory, an error "Specified arb waveform does not exist" will be generated.

DATA:ATTRibute:CFACTOR? [<arb name>]

Query the crest factor of all data points for the specified waveform. The crest factor represents the ratio of the peak value to the RMS value of the waveform. The default waveform is the currently active one (FUNC:USER command). If you

query a waveform which is not stored in memory, an error "Specified arb waveform does not exist" will be generated.

DATA:ATTRibute:POINts? [<arb name>]

Query the number of data points for the specified waveform. A value from 1 to 65,536 will be returned. The default waveform is the currently active one (FUNC:USER command). If you query a waveform which is not stored in memory, an error "Specified arb waveform does not exist" will be generated.

DATA:ATTRibute:PTPeak? [<arb name>]

Query the peak-to-peak value of all data points for the specified waveform. The default waveform is the currently active one (FUNC:USER command). A value from "0" to "+1.0" will be returned. "+1.0" indicates a full amplitude. The maximum amplitude will be limited if the data points do not span the full range of the output DAC (Digital-to-Analog converter). For example, the built-in sine wave does not use the full range of binary values between ± 1 and therefore its maximum amplitude is 6.087 Vpp (into 50 ohms). If you query a waveform which is not stored in memory, an error "Specified arb waveform does not exist" will be generated.

DISPlay {OFF|ON}

Turn off or on the display. Disabling the front-panel display may speed up the command execution for remote interface operation. Remote interface error messages will be shown even when the display is off. Displaying a message on the front-panel display overrides the display state.

The display is automatically enabled when the waveform generator has been turned off or after *RST command, or when you return to local (front-panel) operation.

The display state is saved when you store the instrument state using *SAV command. Use *RCL command to recall the instrument state and the front-panel display will return to the previous state.

DISPlay?

Query the display setting. Returns "0" (OFF) or "1" (ON).

DISPlay:TEXT <quoted string>

Show a message on the front panel display. This command overrides the display

state (DISP OFF command). The allowed message can be up to 12 characters in a large font and more characters in a small font; Any additional characters will be truncated.

With a message displaying on the front-panel display, information relating to the output waveform such as frequency is not shown on the display.

DISPlay:TEXT?

Query the message sent to the front panel display.

DISPlay:TEXT:CLEAr

Clear the message shown on the front panel display.

If the display is currently enabled, this command will clear the message on the front-panel display and return the normal front-panel display mode.

If the display is currently disabled, this command will clear the message on the display, but the display remains off.

-- F --

FM:INTernal:FUNction

{SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}

Specify the shape of the modulating waveform. This applies only when the modulation source is Internal (FM:SOUR INT command). Noise can be a modulating waveform, but cannot be used as a carrier waveform, neither do Pulse nor dc. The default modulating waveform is a sine waveform.

FM:INTernal:FUNction?

Query the modulating function used in frequency modulation. "SIN", "SQU", "RAMP", "NRAM", "TRI", "NOIS" or "USER" string indicating the modulating function will be returned.

-- Square waveform has 50% duty cycle.

--Ramp waveform has 100% symmetry

--Triangle waveform has 50% symmetry.

--Negative Ramp waveform has 0% symmetry.

--If an Arbitrary(USER) waveform is chosen to be the modulating waveform, it is automatically limited to 4k points. Extra points are removed using decimation.

FM:INTernal:FREQuency {<frequency>|MINimum|MAXimum}

Specify the frequency of the modulating waveform. This applies only when the modulating source is internal. The range is from 2 mHz to 20 kHz and the default is 10 Hz.

FM:INTernal:FREQuency? [MINimum|MAXimum]

Query the modulating frequency in frequency modulation. The modulating waveform frequency in hertz will be returned.

FM:DEVIation {<peak deviation in hertz>|MINimum|MAXimum}

Specify the peak frequency deviation in hertz. This value represents the peak variation in frequency of the modulated waveform from the carrier frequency. The range is from 1μHz to 150 kHz for ramps, from 1μHz to 5.05 MHz for arbitrary waveforms, from 1μHz to 12.55 MHz for square waveforms and from 1μHz to 25.05 MHz for sine waveforms and the default is 100 Hz. The minimum value is 1 μHz, but the maximum value is calculated based on the frequency of the carrier waveform as below:

Maximum deviation = carrier frequency

if the carrier frequency is less than Maximum frequency/2

Maximum deviation = Maximum frequency – carrier frequency

if the carrier frequency is greater than Maximum frequency/2

The frequency deviation must not be greater than the carrier frequency. If a greater value is set to be the deviation, MODEL 645 waveform generator will adjust it automatically to the maximum value allowed.

The sum of frequency deviation and the carrier frequency must not be greater than the maximum frequency of the function used plus 100 kHz (50.1 MHz for sine and 25.1 MHz for square, 300 kHz for ramp, and 10.1 MHz for arbitrary waveforms). If a greater frequency deviation is specified, the waveform generator will automatically adjust it to the maximum value allowed.

When an external source is selected, the carrier is modulated with an external waveform. The frequency deviation is controlled by the ±5v signal on the rear panel *Modulation In* connector. **For instance, if a deviation of 100kHz is specified, then a +5V signal level corresponds to a 100kHz increase in frequency. Lower external signal levels produce less deviation and negative signal levels reduce**

the frequency below the carrier frequency.

If the deviation causes the carrier waveform to exceed a frequency boundary for the current duty cycle (square waveform only), Model 645 will automatically adjust the duty cycle to the maximum value allowed with the present carrier frequency.

FM:DEVIation? [MINimum|MAXimum]

Query the peak frequency deviation in frequency modulation. The peak frequency deviation in hertz will be returned.

FM:SOURce {INTernal|EXTernal}

Specify the modulating signal source. The default is Internal. When an external source is selected, the carrier is modulated with an external waveform. The frequency deviation is controlled by the $\pm 5\text{v}$ signal on the rear panel *Modulation In* connector. For instance, if a deviation of 100kHz is specified, then a +5V signal level corresponds to a 100kHz increase in frequency. Lower external signal levels produce less deviation and negative signal levels reduce the frequency below the carrier frequency.

FM:SOURce?

Query the modulating source in frequency modulation. "INT" or "EXT" string indicating the modulating signal source will be returned.

FM:STATe {OFF|ON}

Disable or Enable the frequency modulation. To avoid multiple waveform changes, you can enable it after setting up the modulation parameters. The waveform generator allows only one of burst, sweep and modulations enabled at one time. As long as one is enabled, the other will be turned off.

FM:STATe?

"0" (OFF) or "1" (ON) will be returned.

FORMat:BORDER {NORMal | SWAPped}

Used only for binary block transfers. Select the byte order for binary transfers in the block mode using the DATA:DAC command. The default is NORM.

In NORM byte order, the most significant byte (MSB) of each data point is assumed first.

In SWAP byte order, the least significant byte (LSB) of each data point is assumed first. Most computers use the "swapped" byte order.

The waveform generator represents binary data as signed 16-bit integers, which are sent as two bytes. Therefore, each waveform data point requires 16 bits, which must be transferred as two bytes on the waveform generator's interfaces.

FORMat:BORDER?

Query the byte order for binary transfers in the block mode. "NORM" or "SWAP" will be returned.

FREQuency:START {<frequency>|MINimum|MAXimum }

Specify the start frequency in Sweeps. The range is from 1µHz to 200 kHz for ramps, from 1µHz to 10 MHz for arbitrary waveforms, from 1µHz to 25 MHz for square, and from 1µHz to 50 MHz for sine. The default is 100 Hz. The minimum value is 1µHz and the maximum value is 50 MHz.

FREQuency:START? [MINimum|MAXimum]

The start frequency in sweeps will be returned.

FREQuency:STOP {<frequency>|MINimum|MAXimum }

Specify the stop frequency in Sweeps. The range is from 1µHz to 200 kHz for ramps, from 1µHz to 10 MHz for arbitrary waveforms, from 1µHz to 25 MHz for square, and from 1µHz to 50 MHz for sine. The default is 1 KHz. The minimum value is 1µHz and the maximum value is 50 MHz.

FREQuency:STOP? [MINimum|MAXimum]

The stop frequency in sweeps will be returned.

FREQuency:CENTer {<frequency>|MINimum|MAXimum }

Specify the center frequency in sweeps. The range is from 1µHz to 200 kHz for ramps, from 1µHz to 10 MHz for arbitrary waveforms, from 1µHz to 25 MHz for square, and from 1µHz to 50 MHz for sine. The default is 550 Hz. The minimum value is 1µHz and the maximum value is calculated based on the frequency span

and the maximum frequency of the function used.

$$\text{Maximum center frequency} = \text{Maximum frequency} - \text{span}/2$$

FREQuency:CENTer? [MINimum|MAXimum]

The center frequency in sweeps will be returned in hertz.

FREQuency:SPAN{<frequency>|MINimum|MAXimum }

Specify the frequency span in sweeps. The range is from 0 Hz to 200 kHz for ramps, from 0 Hz to 10 MHz for arbitrary waveforms, from 1μHz to 25 MHz for square, and from 1μHz to 50 MHz for sine. The default is 900 Hz. The minimum value is 0 Hz and the maximum value is calculated based on the center frequency and the maximum frequency of the function used.

$$\text{Maximum frequency span} = 2 \times (\text{Maximum frequency} - \text{center frequency})$$

--To sweep up in frequency, specify a positive frequency span.

--To sweep down in frequency, specify a negative frequency span.

The following equation shows the relationship between frequency span and start/stop frequency.

$$\text{Frequency span} = \text{Stop frequency} - \text{Start frequency}$$

FREQuency:SPAN? [MINimum|MAXimum]

The frequency span in hertz will be returned.

FSKey: FREQuency {<frequency>|MINimum|MAXimum}

Specify the FSK alternate (or "hop") frequency. The range is from 1 μ Hz to 200 kHz for ramps, 1 μ Hz to 10 MHz for arbitrary waveforms, from 1μHz to 25 MHz for square, and from 1μHz to 50 MHz for sine, and the default is 100Hz.

FSKey: FREQuency? [MINimum|MAXimum]

Query the "hop" frequency in FSK. The "hop" frequency in hertz will be returned.

FSKey: INTernal:RATE {<rate in Hz>|MINimum|MAXimum }

Specify the rate at which the output frequency "shifts" between the carrier and the hop frequency. The range is from 2 mHz to 100 kHz and the default is 10 Hz. This FSK rate is used only when the FSK source is internal (FSK:SOUR INT).

--The modulating waveform is a square wave with a 50% duty cycle.

FSKey: INTernal:RATE? [MINimum|MAXimum]

Query the FSK rate. The FSK rate will be returned.

FSKey: SOURce {INTernal|EXTernal}

Specify the FSK source. The default is Internal.

FSKey: SOURce?

Query the FSK source. "INT" or "EXT" string indicating FSK source will be returned.

FSKey: STATe {OFF|ON}

Disable or enable FSK Modulation. The default is Off. To avoid multiple waveform changes, you can enable it after setting up the modulation parameters.

Only one type of modulation can be activated at one time. Also when FSK modulation is activated, sweep or burst mode will be disabled.

FSKey: STATe?

Query the FSK state. "0" (OFF) or "1" (ON) will be returned.

FUNCTION:PULSe:HOLD {WIDTH|DCYCLE}

Instruct the waveform generator to hold either the pulse width or the duty cycle.

- When the pulse width is held constant, the period is varied. (Minimum width and edge time restrictions apply.) If a command specifying the duty cycle is received, the duty cycle is converted into equivalent pulse width in seconds. If Pulse Width Modulation is turned on, the pulse width is held, and the width deviation is held too, as the period is varied. Duty cycle deviation commands are converted to width deviation values.
- When the duty cycle is held constant, the period is varied. (Minimum width and edge time restrictions apply.) If a command specifying the pulse width is received, the pulse width is converted into equivalent duty cycle in percent. If Pulse Width Modulation is turned on, the duty cycle is held, and the duty cycle deviation is held too, as the period is varied. Pulse width deviation commands are converted to duty cycle deviation values.

FUNCTION:PULSe:HOLD? [WIDTh|DCYCLe]

Query either the value of the pulse width or the duty cycle being held. The value of duty cycle in percent or the value of pulse width in seconds is returned.

FUNCTION:PULSe:WIDTh {<seconds>|MINimum|MAXimum }

Specify the pulse width in seconds. The range is from 20 ns to 2000 seconds. The default is 100 μ s.

- The pulse width represents the time from the 50% threshold of the rising edge of the pulse to the 50% threshold of the next falling edge.
- The minimum value of the pulse width is 20 ns and the maximum value is 1999.99 seconds.
- The minimum pulse width is restricted by the period as below:

$W_{min}=20$ ns when period is not greater than 10s.

$W_{min}=200$ ns when period is greater than 10 s, but not greater than 100s.

$W_{min}=2$ μ s when period is greater than 100d, not greater than 1000s.

$W_{min}=20$ μ s when period is greater than 1000s.

- The specified pulse width must be less than the difference between the period and the minimum pulse width.

$$\text{Pulse Width} \leq \text{Period} - W_{min}$$

The waveform generator adjusts the edge time first, and then the width if necessary to accommodate the period. From the remote interface, a "Setting conflict" error is generated and the pulse width is adjusted.

- The specified pulse width must be less than the difference between the period and the edge time.

$$\text{Pulse Width} \leq \text{Period} - (1.6 \times \text{Edge time})$$

The waveform generator adjusts the edge time first, and then the width if necessary to accommodate the period. From the remote interface, a "Data out of range" error is generated and the pulse width is adjusted.

- The specified pulse width must be greater than the total time of one edge:

$$\text{Pulse Width} \geq 1.6 \times \text{Edge time}$$

- Among the pulse width and pulse duty cycle, the FUNC:PULS:HOLD command determines which of them is to be held and it affects this function when the waveform generator adjusts the period.

FUNCTION:PULSe:WIDTh? [MINimum|MAXimum]

Query the pulse width. The pulse width in seconds will be returned.

FUNCTION:PULSe:DCYClE {<percent>| MINimum|MAXimum }

Specify the pulse duty cycle in percent. The range is from 0 percent to 100 percent. The default is 10 percent. The minimum value is approximately 0 percent and the maximum value is approximately 100 percent.

- The definition of the pulse duty cycle is described below:

$$\text{Duty Cycle} = 100 \times \text{Pulse width/Period}$$

Where the pulse width represents the time from the 50% threshold of the rising edge of the pulse to the 50% threshold of the next falling edge.

- The duty cycle is restricted by minimum pulse width and edge time, which prevents you from setting exactly 0 percent or 100 percent.
- The minimum pulse width affects the value of the specified pulse duty cycle as below:

$$\text{Duty Cycle} \geq 100 \times W_{\text{min}}/\text{Period}$$

And

$$\text{Duty Cycle} \leq 100 \times (1 - W_{\text{min}}/\text{Period})$$

where

$W_{\text{min}} = 20 \text{ ns}$ when period is not greater than 10s.

$W_{\text{min}} = 200 \text{ ns}$ when period is greater than 10 s, but not greater than 100s.

$W_{\text{min}} = 2 \mu\text{s}$ when period is greater than 100d, not greater than 1000s.

$W_{\text{min}} = 20 \mu\text{s}$ when period is greater than 1000s.

The waveform generator adjusts the pulse duty cycle when needed to accommodate the specified pulse period. From the remote interface, a "Data out of range" error is generated and the pulse duty cycle is adjusted.

- The specified pulse duty cycle may affect the edge time.

The waveform generator adjusts the edge time first, and then the duty cycle if necessary to accommodate the period. From the remote interface, a "Data out

of range" error is generated and the duty cycle and edge time will be restricted as below:

$$\text{Duty cycle} \cong 100 \times (1.6 \times \text{Edge time}) / \text{Period}$$

And

$$\text{Duty cycle} \leq 100 \times (1 - (1.6 \times \text{Edge time}) / \text{Period})$$

- Among the pulse width and pulse duty cycle, the FUNC:PULS:HOLD command determines which of them is to be held and it affects this function when the waveform generator adjusts the period.

FUNCTION:PULSe:DCYCLE? [MINimum|MAXimum]

Query the pulse duty cycle. The duty cycle in percent will be returned.

FUNCTION:PULSe:TRANSition { <seconds> MINimum|MAXimum }

Specify the edge time in seconds for both the rising and the falling edges.

The edge time represents the time from the 10% threshold to 90% threshold of each edge. The range for edge time is from 5 ns to 100 ns, and the default is 5 ns. The minimum value is 5 ns and the maximum value is 100 ns.

- The specified edge time must fit in within the specified pulse width as shown below. The waveform generator will adjust the edge time if necessary to accommodate the specified pulse width or duty cycle.

$$\text{Edge time} \leq 0.625 \times \text{Pulse width}$$

Or

$$\text{Edge time} \leq 0.625 \times \text{Period} \times \text{Duty cycle} / 100$$

FUNCTION:PULSe:TRANSition? [MINimum|MAXimum]

Query the edge time. The edge time in seconds is returned.

FUNCTION:RAMP:SYMMetry { <percent> | MINimum|MAXimum }

Specify the symmetry percentage for ramp waves. Symmetry represents the amount of time per cycle that the ramp wave is rising (supposing the waveform polarity is not inverted). The range is from 0% to 100% and the default is 100%.

- The APPLY command overrides the current symmetry setting and used 100% symmetry.
- The specified symmetry is remembered and will be used when you change the function and then come back to ramp waves.

- The symmetry setting does not apply when you use a ramp wave as the modulating wave in AM or FM.

FUNCTION:RAMP:SYMMetry? [MINimum|MAXimum]

Query the current symmetry setting in percent.

FUNCTION:SQUare:DCYCLE {<percent> | MINimum|MAXimum }

Specify the duty cycle percentage for square waves. Duty cycle represents the time per cycle that a square wave is at its high level (supposing the waveform polarity is not inverted). The default is 50%. The range is from 20% to 80% when the waveform frequency is not greater than 10 MHz and from 40% to 60% when the waveform frequency is greater than 10 MHz.

- The APPLY commands overrides this command and sets the duty cycle to 50%.
- The specified duty cycle is remembered and will be used when you change the function and then come back to square waves.
- The duty cycle setting does not apply when you use square wave as the modulating wave in AM, PM, FM, or PWM. The duty cycle of 50% for square waves is used.
- When you use the square waveforms, but then later specify a frequency that cannot produce the current duty cycle, the waveform generator automatically adjust the duty cycle to accommodate the newly specified frequency. From the remote interface, a "Settings conflict" error will be generated.

FUNCTION:SQUare:DCYCLE? [MINimum|MAXimum]

Query the current duty cycle in percent.

FUNCTION USER {<arb name> | VOLATILE}

Choose one of the five built-in arbitrary waveform functions, one of four user-defined waveforms, or the waveform currently downloaded to volatile memory.

The names of the five built-in arbitrary waveforms are "EXP_RISE", "EXP_FALL", "NEG_RAMP", "SINC", and "CARDIAC". The default is "EXP_RISE". If a waveform stored in volatile memory is desired, specify the VOLATILE parameter. This command does not output the chosen waveform. Use FUNCTION USER

command to output the waveform.

If you specify a waveform name that is not currently downloaded, a "Specified arb waveform does not exist" error is generated.

FUNCTION:USER?

Query the selection of waveform specified by FUNCTION USER {<arb name> | VOLATILE} command.

FUNCTION USER

Select the arbitrary waveform function and output the current arbitrary waveform. The selected waveform is output using the current frequency, amplitude and offset settings. You can use the APPLY command or the FREQ, VOLT, and VOLT:OFFS commands to specify the frequency, amplitude, and offset.

The maximum amplitude will be limited if the data points do not span the full range of the output DAC (Digital-to-Analog converter). For example, the built-in sine wave does not use the full range of binary values between ± 1 and therefore its maximum amplitude is 6.087 Vpp (into 50 ohms).

When you use an arbitrary waveform as your modulating waveform("USER"), the waveform is automatically limited to 4k points. Extra waveform points are removed using decimation.

FUNCTION?

Query the selection made by FUNCTION USER command. One of the strings "SIN", "SQU", "RAMP", "PULS", "NOIS", "DC", and "USER" will be returned.

-- I to O --

-- I --

***IDN?**

Query the waveform generator's identification string which contains four fields separated by commas. The descriptions of these four fields are shown below:

Manufacturer's Name, Model Number, Serial Number, Revision Code

- The Revision code contains four numbers separated by dashes.

Firmware revision number-Book kernel revision number-ASIC revision number-Printed circuit board revision number

-- L --

***LRN?**

Query the waveform generator and return a string of SCPI commands containing the current settings (learn string). You can then send the string back to the instrument to restore this state at a later time. For proper operation, do not modify the string before sending it back to the waveform generator. The string should contain about 1,500 characters. To avoid possible instrument errors, execute the *EST command first, and then send the string back to the waveform generator.

-- M --

MARKer {OFF | ON}

Disable or enable the frequency marker. The default is OFF. When the frequency marker is off, the signal output from the *Sync* connector is the normal Sync signal for the carrier waveform.

The OUTP:SYNC command is overridden by the setting of the MARK command, so when the marker frequency is turned on (and the sweep mode is also turned on), the OUTP:SYNC command is ignored.

MARKer?

"0" or "1" indicating the enable state of the frequency marker will be returned.

MARKer:FREQuency { <frequency> | MINimum | MAXimum }

Specify the marker frequency. The signal on the front-panel *Sync* connector goes to a logic low at the marker frequency during the sweep. The range is from 1 μ Hz to 200 MHz (limited to 200 kHz for ramps and 10MHz for arbitrary waveforms) and the default is 500 Hz. The minimum value is the lower one of the start and stop frequencies and the maximum value is the higher one of the start and stop frequencies.

The marker frequency must be a value between the specified start and stop frequencies. If you select an out-of-range value, a "Settings conflict" error is generated and the waveform generator will automatically set it to either the start or the stop frequency depending on which is the closer one.

MARKer:FREQuency? [MINimum | MAXimum]

Query the marker frequency.

MEMory:STATe:NAME {0 | 1 | 2 | 3 | 4} [,<name>]

Assign a custom name for the specified storage location. You can assign a name to a location from either the front panel or the remote interface, but you can only recall a state by name from the front panel.

The custom name can contain up to 12 characters. The first character must be a letter (A-Z), but the remaining characters can be letters, numbers or the underscore character ("_"). Blank spaces are not allowed. Assigning the same name to different locations is allowed. You cannot assign a name to storage location "0" from the front panel.

MEMory:STATe:NAME? {0 | 1 | 2 | 3 | 4}

Query the name of the specified storage location. If the specified location has no custom name, its default name will be returned.

MEMory:STATe:DELeTe {0 | 1 | 2 | 3 | 4}

Erase the instrument state from the specified storage location, including the custom name specified to that location, if any, and restore the default name. You cannot recall the instrument state from a storage location that is empty or an error will be generated.

MEMory:STATe:RECall:AUTO {OFF | ON}

Disable or enable the automatic recall of the power-down state from storage location "0" when power is turned on. The default is OFF and it resets (*RST command) the waveform generator when power is turned on.

MEMory:STATe:RECall:AUTO?

Query the state of the automatic recall of the power-down state. "0" (OFF) or "1" (ON) will be returned.

MEMory:STATe:VALid? {0 | 1 | 2 | 3 | 4}

Query the specified storage location to determine if it currently stores a valid instrument state. "0" is returned when there is no valid state stored in that location and "1" is returned when there is a valid state stored in that location.

MEMory:NStates?

Query the number of storage locations available for storing the states. "5" is returned.

-- O --

***OPC**

Set the "Operation complete" bit (bit 0) in the Standard Event Register after all of the previous commands have been completed. Other commands may be executed before the bit is set. This command is used in the triggered sweep or triggered burst modes to provide a way to poll or interrupt the computer when the *TRG command is complete.

***OPC?**

Returns "1" to the output buffer after the previous commands have been completed. Other commands can not be executed until this command completes.

OUTPut {OFF|ON}

Disable or enable the Output connector on the front panel. The default is OFF. The Output key is lit when enabled.

- The APPLY command overrides the current OUTP command setting and automatically enables the Output connector.
- The Output connector will be disabled when an excessive external voltage is applied to it. To re-enable it, remove the excessive voltage and use this command to enable it again.
- This command changes the state of the output connector by switching the output relay. However, this command does not zero the voltage to be output before switching the relay. Thus, the output signal may have "glitches" for about a millisecond until the signal stabilizes. You can minimize these glitches by first setting the amplitude to the minimum (using the VOLTage command) and the offset to zero (using the

VOLTage:OFFSet command) before changing the output state.

OUTPut?

"0" or "1" indicating the on/off state of the Output connector on the front panel is returned.

OUTPut:LOAD {<ohms>|INFinity|MINimum|MAXimum}

Select the desired output termination. It can be any value (in ohms) between 1 Ω and 10k Ω . INF sets the output termination to "high impedance" (>10 k Ω). The default is 50 Ω . The specified value is used for amplitude, offset, and high/low level settings.

- When the output termination is changed, the displayed output amplitude, offset, and high/low levels are automatically adjusted, and no errors will be generated.
- The waveform generator has a fixed series output impedance of 50 ohms to the front-panel Output connector. If the actual load impedance is different than the specified value, the displayed amplitude, offset and high/low levels will be incorrect.
- When the output termination is set to "high impedance", you cannot specify the output amplitude in dBm. The unit will be automatically converted to Vpp.

OUTPut:LOAD? [MINimum|MAXimum]

Query the current load setting in ohms. Return the current load setting or "9.9E+37" meaning "high impedance".

OUTPut:POLarity { NORMal|INVerted }

Invert the waveform relative to the offset voltage. The default is NORM, in which the waveform goes positive during the first part of the cycle and in INV mode the waveform goes negative during the first part of the cycle. The offset remains the same when the waveform is inverted and the Sync signal is not inverted.

OUTPut:POLarity?

Query the polarity of the waveform. "NORM" or "INV" indicating the polarity will be returned.

OUTPut:SYNC {OFF|ON}

Disable or enable the Sync connector on the front-panel. The default is ON. By disabling the Sync signal, you can reduce the output distortion at lower amplitude. When the Sync signal is disabled, the output level on the Sync connector is a logic "low" level.

- When a waveform is inverted, its Sync signal is not inverted.
- This command is overridden by the setting of the MARK command used with the sweep mode, therefore when the marker frequency is enabled (and the sweep is enabled too), the OUTP:SYNC is ignored.

OUTPut:SYNC?

"0" or "1" indicating the enable state of the Sync connector on the front panel will be returned.

OUTPut:TRIGger:SLOPe {POSitive|NEGative}

Specify an edge for the "trigger out" signal. When the trigger out signal is enabled by OUTP:TRIG command, a TTL-compatible square waveform with the specified edge is output from the *Ext Trig* connector on the rear panel at the beginning of the sweep or burst. For a pulse with a rising edge, use Positive and for a pulse with a falling edge, use Negative.

- When using the Immediate (internal) trigger source (the TRIG:SOUR IMM command), the waveform generator outputs a square waveform with a 50% duty cycle (the rising edge is the sweep trigger) from the Ext Trig connector on the rear panel. The period is equal to the sweep time.
- When using the External trigger source (the TRIG:SOUR EXT command), the waveform generator disables the "trigger out" signal and the Ext Trig connector is use for sending an externally-triggered sweep.
- When using the Bus (software) trigger source (the TRIG:SOUR BUS command), the waveform generator outputs a pulse (>1 μ s pulse width) from the Ext Trig connector at the beginning of the sweep.

OUTPut:TRIGger:SLOPe?

"POS" or "NEG" string indicating the edge for the "trigger out" signal will be returned.

OUTPut:TRIGger {OFF | ON}

Disable or enable the trigger out signal. The default is OFF. When the trigger out signal is enabled, a TTL-compatible square waveform with the specified edge is

output from the *Ext Trig* connector on the rear panel at the beginning of the sweep or burst.

OUTPut:TRIGger?

"0" or "1" indicating the trigger out signal state will be returned.

-- P to Z --

-- P --

PHASe {<angle> | MINimum | MAXimum}

Adjust the phase offset of the output waveform in degrees or radians as specified by the previous UNIT:ANGL command (not available for pulse and noise). The range is from -360 degrees to 360 degrees or -2π to $+2\pi$ radians. The default is 0 degrees.

- The specified phase adjustment causes a "bump" or "hop" in the output waveform in order to change the phase relationship to the external signal to which it is currently locked.
- The phase adjustment for phase-lock applications is independent of the burst phase as set by the BURS:PHAS command.

PHASe [MINimum | MAXimum]

Query the phase offset in degree or radians.

PHASe:REFerence

Set the zero-phase reference point immediately without changing the output. This command changes the phase reference only, and it does not change the phase offset as set with the PHAS command.

PHASe:UNLock:ERRor:STATe {OFF | ON}

Disable or enable the waveform generator to generate an error when the phase-lock is lost. The default is off. When the error is enabled, and the phase-lock is lost, a "Reference phase-lock loop is unlocked" error will be generated. The error setting is cleared after the waveform generator has been turned off.

PHASe:UNLock:ERRor:STATe?

Query the enable state of the lost phase-lock error.

PM:INTernal:FUNction

{SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}

Specify the shape of the modulating waveform. This applies only when the modulation source is Internal (PM:SOUR INT). Noise can be a modulating waveform, but cannot be used as a carrier waveform, neither do Pulse nor dc. The default modulating waveform is a sine waveform.

-- Square waveform has 50% duty cycle.

--Ramp waveform has 100% symmetry

--Triangle waveform has 50% symmetry.

--Negative Ramp waveform has 0% symmetry.

--If an Arbitrary(USER) waveform is chosen to be the modulating waveform, it is automatically limited to 4k points. Extra points are removed using decimation.

PM:INTernal:FUNction?

Query the modulating function used in phase modulation. "SIN", "SQU", "RAMP", "NRAM", "TRI", "NOIS" or "USER" string indicating the modulating function will be returned.

PM:INTernal:FREQuency {<frequency>|MINimum|MAXimum}

Specify the modulating waveform frequency. This applies only the modulation source is internal (PM:SOUR INT). The range is from 2 mHz to 20 kHz and the default is 10 Hz.

PM:INTernal:FREQuency? [MINimum|MAXimum]

Query the internal modulating frequency in Phase modulation. The internal modulating frequency in hertz will be returned.

PM:DEVIation {<peak deviation in hertz>|MINimum|MAXimum}

Specify the phase deviation in degrees. Phase deviation represents the peak variation in phase of the modulated waveform from the carrier waveform. The range is from 0 to 360 degrees and the default is 180 degrees. When an external source is selected, the carrier is modulated with an external waveform. The phase deviation is controlled by the $\pm 5\text{v}$ signal on the rear panel *Modulation In* connector. It means that when you choose to have a deviation of 180 degrees, then a +5V signal level corresponds to a 180 degree phase shift. Lower the external signal level is, less the deviation is.

PM:DEVIation? [MINimum|MAXimum]

Query the phase deviation in phase modulation. The phase deviation in degree will be returned.

PM:SOURce {INTernal|EXTernal}

Specify the modulating signal source. The default is INTernal. When an external source is selected, the carrier is modulated with an external waveform. The phase deviation is controlled by the $\pm 5\text{V}$ signal on the rear panel *Modulation In* connector. It means that when you choose to have a deviation of 180 degrees, then a +5V signal level corresponds to a 180 degree phase shift. Lower the external signal level is, less the deviation is.

PM:SOURce?

Query the modulating source in phase modulation. "INT" or "EXT" string indicating the modulating source will be returned.

PM:STATe {OFF|ON}

Disable or enable Phase Modulation. The default is Off. To avoid multiple waveform changes, you can enable it after setting up the modulation parameters.

Only one type of modulation can be activated at one time. Also when Phase modulation is activated, sweep or burst mode will be disabled.

PM:STATe?

"0" (OFF) or "1" (ON) will be returned.

PWM:INTernal:FUNCTion**{SINusoid|SQUare|RAMP|NRAMP|TRIangle|NOISe|USER}**

Specify the shape of the modulating waveform. The default is sine. This applies when the modulation source is internal (PWM:SOUR INT). The carrier is a pulse wave in PWM.

-- Square waveform has 50% duty cycle.

--Ramp waveform has 100% symmetry

--Triangle waveform has 50% symmetry.

--Negative Ramp waveform has 0% symmetry.

--If an Arbitrary(USER) waveform is chosen to be the modulating waveform, it is

automatically limited to 4k points. Extra points are removed using decimation.

PULSe:PERiod {<seconds> | MINimum | MAXimum}

Specify the pulse period. The range is from 200 ns to 2000 seconds. The default is 1 ms.

- The specified period must be greater than the sum of the pulse width and the edge time, if not, the waveform generator automatically adjust the edge time first and the pulse width (if needed) to accommodate the period.

$$\text{Period} \geq \text{Pulse Width} + (1.6 \times \text{Edge Time})$$

Or

$$\text{Period} \geq (\text{Period} \times \text{Duty Cycle}/100) + (1.6 \times \text{Edge Time})$$

- The specified period stays when the function changes. If you select pulse waveform and specify the period by PULS:PER command, and then choose another function, the period will be used on the new function.
- If you change to a function whose minimum period is greater than that for a pulse waveform, the period is adjusted to the minimum value allowed for the new function. For example, if you output a pulse waveform with a period of 200 ns and then change to the ramp function, the waveform generator will automatically adjust the period to 5 μ s (the lower limit for ramps). A "Settings conflict" error will be generated and the period will be adjusted.

PULSe:PERiod? [MINimum | MAXimum]

The period of the pulse waveform will be returned in seconds.

PWM:INTernal:FUNCTion?

Query the modulating function used in PWM. "SIN", "SQU", "RAMP", "NRAM", "TRI", "NOIS" or "USER" string indicating the modulating function will be returned.

PWM:INTernal:FREQuency {<frequency> | MINimum | MAXimum}

Specify the modulating waveform frequency. This applies only when the modulation source is internal (PWM:SOUR INT). The range is from 2 mHz to 20kHz and the default is 10 Hz.

PWM:INTernal:FREQuency? [MINimum|MAXimum]

Query the internal modulating frequency in PWM. The internal modulating frequency in hertz will be returned.

PWM:DEVIation {< deviation in seconds> |MINimum|MAXimum}

Specify the pulse width deviation in seconds. Pulse width deviation represents the variation in seconds from the pulse width of the carrier pulse width. The range is from 0 to 1000 seconds and the default is 10 μ s. The pulse width deviation cannot exceed the current pulse width. The minimum value is 0 seconds and the maximum value is determined by period, minimum pulse width and edge time.

Here's the constraints pulse width deviation has to conform:

$$\text{Width Deviation} \leq \text{Pulse Width} - W_{\text{min}}$$

And

$$\text{Width Deviation} \leq \text{Period} - \text{Pulse Width} - W_{\text{min}}$$

Where:

$$W_{\text{min}} = 20 \text{ ns for period} \leq 10 \text{ s.}$$

$$W_{\text{min}} = 20 \text{ ns for period} > 10 \text{ s, but} \leq 100 \text{ s.}$$

$$W_{\text{min}} = 2 \mu\text{s for period} > 100 \text{ s, but} \leq 1000 \text{ s.}$$

$$W_{\text{min}} = 20 \mu\text{s for period} > 1000 \text{ s.}$$

Also

$$\text{Width Deviation} \leq \text{Pulse width} - (1.6 \times \text{Edge time})$$

And

$$\text{Width Deviation} \leq \text{Period} - \text{Pulse width} - (1.6 \times \text{Edge time})$$

When you choose an external source (PWM:SOUR EXT), the width deviation is controlled by the $\pm 5\text{V}$ signal level shown on the *Modulation In* connector on the rear panel. **It means that when the modulating signal is at +5V, the output will be at its maximum width deviation, and when the modulating signal is at -5V, the output will be at its minimum duty cycle.** Lower external signal levels produce less deviation, and negative signal levels produce negative deviation.

Note: The operation of this command is affected by FUNC:PULS:HOLD command. FUNC:PULS:HOLD command decides if the pulse width or the duty cycles are to be held constant as the period varies. If the pulse width is held constant, so is the pulse width deviation; If the duty cycle is held constant, so is

the duty cycle deviation. If one is held constant, the other specified in the command will be automatically converted to the equivalent value.

PWM:DEVIation? [MINimum|MAXimum]

Query the pulse width deviation. The pulse width deviation in seconds will be returned.

PWM:DEVIation:DCYcle {< deviation in percent> |MINimum|MAXimum}

Specify the duty cycle deviation in percent. This value represents the duty cycle variation in the modulated waveform from the duty cycle in the original pulse waveform, and it is in the form of a percentage of the period.

The default duty cycle deviation is 1%, and the range is from 0% to 100%. The minimum value is 0% and the maximum value is approximately 100% (limited by the period, minimum pulse width, and edge time). Moreover, it must not be greater than the pulse duty cycle and is under the following constraints:

$$\text{Duty Cycle Deviation} \leq \text{Duty Cycle} - 100 \times \text{Minimum Width/Period}$$

And

$$\text{Duty Cycle Deviation} \leq 100 - \text{Duty Cycle} - 100 \times \text{Minimum Width/Period}$$

Where

$$W_{\min} = 20 \text{ ns for period} \leq 10 \text{ s.}$$

$$W_{\min} = 20 \text{ ns for period} > 10 \text{ s, but} \leq 100 \text{ s.}$$

$$W_{\min} = 2 \text{ } \mu\text{s for period} > 100 \text{ s, but} \leq 1000 \text{ s.}$$

$$W_{\min} = 20 \text{ } \mu\text{s for period} > 1000 \text{ s.}$$

The duty cycle deviation also needs to conform to the following rules:

$$\text{Duty Cycle Deviation} \leq \text{Duty Cycle} - (160 \times \text{Edge Time}) / \text{Period}$$

And

$$\text{Duty Cycle Deviation} \leq 100 - \text{Duty Cycle} - (160 \times \text{Edge Time}) / \text{Period}$$

When you choose an external source (PWM:SOUR EXT), the duty cycle deviation is controlled by the $\pm 5\text{V}$ signal level shown on the *Modulation In* connector on the rear panel. **It means that when the modulating signal is at +5V, the output will be at its maximum width deviation, and when the modulating signal is at -5V, the output will be at its minimum duty cycle.** Lower external signal levels

produce less deviation, and negative signal levels produce negative deviation. Note: The operation of this command is affected by FUNC:PULS:HOLD command. FUNC:PULS:HOLD command decides if the pulse width or the duty cycles are to be held constant as the period varies. If the pulse width is held constant, so is the pulse width deviation; If the duty cycle is held constant, so is the duty cycle deviation. If one is held constant, the other specified in the command will be automatically converted to the equivalent value.

PWM:DEVIation:DCYcles? [MINimum|MAXimum]

Query the duty cycle deviation in PWM. The duty cycle deviation in percent will be returned.

PWM:SOURce {INTernal|EXTernal}

Specify the modulating signal source. The waveform generator takes either an internal or an external source. The default is internal. When choosing an external source, the pulse waveform is modulated with an external waveform. The width/duty cycle deviation is controlled by the $\pm 5V$ signal level shown on the *Modulation In* connector on the rear panel. It means that when the modulating signal is at +5V, the output will be at its maximum duty cycle, and when the modulating signal is at -5V, the output will be at its minimum duty cycle.

PWM:SOURce?

Query the modulating source in PWM. "INT" or "EXT" string indicating modulating source will be returned.

PWM:STATe {OFF|ON}

Disable or enable PWM. The default is Off. To avoid multiple waveform changes, you can enable it after setting up the modulation parameters.

Only one type of modulation can be activated at one time. Also when PWM is activated, sweep or burst mode will be disabled. PWM is allowed only when pulse is used.

PWM:STATe?

Query the PWM state. "0" (OFF) or "1" (ON) will be returned.

-- R --

***RCL {0 | 1 | 2 | 3 | 4}**

Recall the instrument state previously stored in the non-volatile storage location.

- Storage location 0 stores the waveform generator's power-on state and storage location 1 to 4 are empty when the instrument is shipped out from the factory.
- You can not recall a state from a storage location which is empty.
- Storage location 0 is automatically overwritten when the power is cycled.

***RST**

Reset the waveform generator to its factory default, independent of the MEM:STAT:REC:AUTO command setting. This command does not affect any stored instrument states, arbitrary waveforms, or the I/O settings. It also enables the front-panel display if it has been turned off. This command will abort a sweep or burst in progress.

-- S --

***SAV {0 | 1 | 2 | 3 | 4}**

Store the current instrument state to the specified non-volatile storage location.

- If there is any instrument state stored in the specified location, it will be overwritten.
- You can store an instrument state into location 0 only from the remote interface. It is not accessible from the front panel.
- Storage location 0 is automatically overwritten when the power is cycled.
- If you store the instrument state for an arbitrary waveform and then delete it later, the waveform data is lost and the waveform generator is not able to output the waveform.
- When you store an instrument state, the selected function, frequency, amplitude, dc offset, duty cycle, symmetry, as well as any modulation parameters are saved also.

***TST?**

Order a complete self-test of the waveform generator. Returns "0" when the test runs successfully, or "1" when the test fails.

SWEep:SPACing {LINear | LOGarithmic}

Specify the spacing for the sweep. The default sweep mode is Linear, which waveform generator sweeps the frequency with spacing calculated in a linear function. In logarithmic sweep mode, the waveform generator sweeps with spacing calculated in a logarithmic function.

SWEep:SPACing?

Query the spacing used in sweeps. "LIN" or "LOG" string indicating the spacing will be returned.

SWEep:TIME {<seconds> | MINimum | MAXimum}

Specify the time duration in seconds to sweep from the start frequency to the stop frequency. The range is from 1 ms to 500 seconds and the default is 1 second.

The number of discrete frequency points in the sweep will be calculated according to the specified sweep time.

SWEep:TIME?

Query the sweep time. The sweep time in seconds will be returned.

SWEep:STATE{OFF | ON}

Disable or enable the sweep mode. The default is Off. To avoid multiple waveform changes, you can enable it after setting up the modulation parameters.

Only one type of modulation can be activated at one time. Also when Sweep is activated, modulation or burst mode will be disabled.

SWEep:STATE?

Query the sweep state. "0" (OFF) or "1" (ON) will be returned.

SYSTEM:ERRor?

Query and clear one error from the waveform generator's error queue. Up to 20 errors can be stored in the queue. Errors are retrieved in first-in-first-out (FIFO) order. Each error string may contain up to 255 characters. The waveform generator beeps every time it detects an error unless the beeper is turned off.

Errors are cleared once you read them.

If more than 20 errors are detected, "too many Errors" show up in the last place of the error queue. Unless user read the errors in the queue, the additional errors will not be stored. If there is no error in the error queue when you read it, "No error" string will be displayed.

SYSTem:BEEPer

Issue a single beeping tone.

SYSTem:BEEPer:STATe {OFF|ON}

Disable or enable the beeper.

SYSTem:BEEPer:STATe?

Query the beeper state. Return "0" (OFF) or "1" (ON).

SYSTem:COMMunicate:RLSTate {LOCAL | REMote | RWLock}

Set the remote/local state of the waveform generator over the LAN interface from a Telnet or socket session. Provides control analogous to the IEEE-488.2 commands such as GTL (Go To Local) over the GPIB and USB interfaces. The default is Local which sets the instrument state to local and removes any annunciator and locks the front-panel keyboard. The Remote parameter sets the instrument state to remote, display the annunciators and locks the keyboard. The RWLock parameter sets the instrument state to remote with lock and display the rwl annunciator and locks the keyboard.

SYSTem:VERSion?

Query the waveform generator's current SCPI version. A string in the form of "YYYY.V" will be returned. "YYYY" represents the year of the version and "V" represents the version number.

SYSTem:KLOCK[:STATe] {OFF | ON}

Disable or enable the front panel keyboard lock. The default is OFF(meaning the lock is off). When the lock is on, the front panel keyboard is locked. You can exclude "local" key when locking the front panel keyboard by using SYST:KLOC:EXCL LOC before you lock the keyboard.

SYSTem:KLOCK:EXCLude {NONE | LOCAL}

Specify if locking the front panel keyboard including the "local" key or excluding

the "local" key.

SYSTem:KLOCK:EXCLude?

Query which key is excluded when locking the front panel keyboard.

SYSTem:SECurity:IMMediate

Clears all instrument memory except for the boot parameters and calibration constants. Reset all instrument setting to their *RST values. This command clears all user-defined state information, user-defined arbitrary waveforms, and user-defined I/O settings. This command is usually used to clear all memory for security purpose, therefore it is not recommended for use in routine applications because of the possibility of unintended loss of data.

-- T --

TRIGger

Issue an immediate trigger from the remote interface. This command can trigger a sweep or burst with any available trigger source (TRIG:SOUR command).

TRIGger:SOURce {IMMediate | EXTErnal | BUS}

Specify a trigger source for the triggered burst mode only. The waveform generator accepts a software (BUS) trigger, an immediate (internal) trigger, or a hardware trigger from the rear-panel EXT TRIG connector. The default is IMM.

- When using the Immediate (internal) source, the frequency at which the burst is generated is determined by the burst period.
- When using the External source, the waveform generator takes hardware trigger from the *Trig In* connector on the rear panel.
- When using the Bus (software) trigger source, the waveform generator outputs one burst each time it receives a bus trigger command. Use *TRG to trigger from the remote interface. The *Trigger* button is lit when the waveform generator is waiting for a trigger.
- The APPLY automatically sets the trigger source to be Immediate.
- When the External or the Bus source is selected, the burst count and the burst phase remain in effect, but the burst period is ignored.
- To ensure synchronization when the Bus source is selected, send the *WAI (wait) command. When the *WAI command is executed, the waveform

generator waits for all pending operations to complete before executing any additional commands. For example, the following command string guarantees that the first trigger is accepted and the operation is executed before the second trigger is recognized.

TRIG:SOUR BUS;*TRG;*WAI;*TRG;*WAI

- You can use the *OPC? (operation complete query) command or the *OPC (operation complete) command to signal when the burst is complete. The *OPC? Command returns "1" to the output buffer when the burst is complete. The *OPC command sets the "Operation Complete" bit (bit 0) in the Standard Event register when the burst is complete.

TRIGger:SOURce?

Query the trigger source. "IMM" or "BUS" or "EXT" string indicating the trigger source will be returned.

TRIGger:SLOPe {POSitive | NEGative}

Specify whether the rising (positive) or falling (negative) edge of the trigger signal is to be used for an externally-triggered sweep. The default is POS.

TRIGger:SLOPe?

Query the trigger slope. "POS" or "NEG" string indicating the trigger slope will be returned.

-- U --

UNIT:ANGLE {DEGree | RADian}

Specified the unit of the starting phase for the burst with the BURS:PHAS command. The default is DEG. Radians are not available from the front panel, so if switching to the front panel operation after using radians on the remote interface operation, the waveform generator automatically converts the unit back to degrees for you.

UNIT:ANGLE?

"DEG" or "RAD" indicating the unit of the starting phase for the burst will be returned.

-- V --

VOLTage {<amplitude> | MINimum | MAXimum}

Specify the output amplitude. The minimum value is 10 mVpp into 50Ω and the maximum value is the largest amplitude for the chosen function (at most 10 Vpp into 50Ω depending on the chosen function and the offset voltage).

- The output amplitude and offset voltage are related to Vmax as shown below:

$$|V_{\text{offset}}| + V_{\text{pp}} \div 2 \leq V_{\text{max}}$$

Where Vmax is the maximum peak voltage for the selected output termination (5 volts for a 50Ω load or 10 volts for a high-impedance load). The function generator will take the new specified output amplitude, but the offset voltage may be reduced accordingly, and a "Settings conflict" error is generated.

- Output Termination Limits: When the Output Termination Setting is changed, the Output Amplitude is automatically adjusted. For instance, when you change the output termination from 50 ohms to "high impedance", your offset voltage doubles, thus it affects your output amplitude, and when Output Termination has been changed from "high impedance" to 50 ohms, the offset voltage decreases in half.
- Output amplitude in dBm is not available when the output termination is set to "high impedance". The units will be Vpp.
- For arbitrary waveforms, if the waveform data points do not span the full range of output DAC (Digital-to-Analog Converter), the maximum offset and amplitude will be limited.
- Setting a high level and low level is another way to specify the output amplitude. For instance, you will have an amplitude of 5 Vpp (with an associated offset voltage of -500 mV) when you set your high level to +2 Vpp and low level to -3 Vpp.
- While changing amplitude, you may notice a momentary disruption in the output waveform at certain voltages due to switching of the output attenuators. The amplitude is controlled, however, so the output voltage will never exceed the current setting while switching ranges. You may use the VOLT:RANG:AUTO command to disable the voltage autoranging to prevent this output disruption.
- To output a dc voltage level, select the dc voltage function using the FUNC DC command and then set the offset voltage level using the VOLT:OFFS

command. You can set the dc level to any value between ± 5 Vdc into 50 ohms or ± 10 Vdc into an open circuit.

VOLTage? [MINimum | MAXimum]

Query the output amplitude for the current function. The value is returned in the unit chosen by the VOLT:UNIT command.

VOLTage:OFFSet {<offset> | MINimum | MAXimum}

Specify the dc offset voltage. The default is 0 volts. The minimum value is the most negative dc offset for the chosen function and amplitude and the maximum value is the largest dc offset for the chosen function and amplitude.

- The output amplitude and offset voltage are related to V_{max} as shown below:

$$|V_{offset}| + V_{pp} \div 2 \leq V_{max}$$

Where V_{max} is the maximum peak voltage for the selected output termination (5 volts for a 50 Ω load or 10 volts for a high-impedance load). The function generator will take the new specified output amplitude, but the offset voltage may be reduced accordingly, and a "Settings conflict" error is generated.

- When the Output Termination Setting is changed, the offset limits are automatically adjusted. For instance, when you change the output termination from 50 ohms to "high impedance", your offset voltage doubles, thus it affects your output amplitude, and when Output Termination has been changed from "high impedance" to 50 ohms, the offset voltage decreases in half.
- For arbitrary waveforms, if the waveform data points do not span the full range of output DAC (Digital-to-Analog Converter), the maximum offset and amplitude will be limited.
- Setting a high level and low level is another way to specify the offset. For instance, you will have an amplitude of 5 Vpp (with an associated offset voltage of -500 mV) when you set your high level to +2 Vpp and low level to -3 Vpp.

VOLTage:OFFSet? [MINimum | MAXimum]

Query the dc offset voltage for the current function.

VOLTage:HIGh {<voltage> | MINimum | MAXimum}

Specify the high voltage level. The default high level for all functions is +50 mV.

The minimum value is the most negative voltage level and the maximum value is the largest voltage level for the chosen function.

- The high and low voltage level must conform the following restriction:

$$V_{\text{high}} - V_{\text{low}} \leq V_{\text{pp}} (\text{max}) \quad \text{and} \quad V_{\text{high}}, V_{\text{low}} \leq V_{\text{pp}} (\text{max})/2$$

Where $V_{\text{pp}} (\text{max})$ is the maximum peak-to-peak amplitude for the chosen output termination (10 Vpp for a 50-ohm load or 20 Vpp for a high-impedance load). If you specify an invalid voltage level, the waveform generator will adjust it automatically to the highest allowed value and "Data out of range" error is generated.

- The high voltage level should always be greater than the low level. If not, a "Setting conflict" error is generated and the waveform generator automatically set the high level to 1 mV larger than the specified low level.
- specifying a high level and low level also sets the offset. For instance, you will have an amplitude of 5 Vpp (with an associated offset voltage of -500 mV) when you set your high level to +2 Vpp and low level to -3 Vpp.
- When the Output Termination Setting is changed, the voltage levels are automatically adjusted. For instance, when you change the output termination from 50 ohms to "high impedance", your voltage shown on the display doubles, and when Output Termination has been changed from "high impedance" to 50 ohms, the voltage decreases in half.
- To invert the waveform relative to the offset voltage, you can use the OUTP:POL command.

VOLTage:HIGH? [MINimum | MAXimum]

Query the high voltage level.

VOLTage:LOW {<voltage> | MINimum | MAXimum}

Specify the low voltage level. The default low level for all functions is -50 mV. The minimum value is the most negative voltage level and the maximum value is the largest voltage level for the chosen function.

- The high and low voltage level must conform the following restriction:
$$V_{\text{high}} - V_{\text{low}} \leq V_{\text{pp}} (\text{max}) \quad \text{and} \quad V_{\text{high}}, V_{\text{low}} \leq V_{\text{pp}} (\text{max})/2$$

Where $V_{\text{pp}} (\text{max})$ is the maximum peak-to-peak amplitude for the chosen output termination (10 Vpp for a 50-ohm load or 20 Vpp for a high-impedance

load). If you specify an invalid voltage level, the waveform generator will adjust it automatically to the highest allowed value and "Data out of range" error is generated.

- The high voltage level should always be greater than the low level. If not, a "Setting conflict" error is generated and the waveform generator automatically set the high level to 1 mV larger than the specified low level.
- specifying a high level and low level also sets the offset. For instance, you will have an amplitude of 5 Vpp (with an associated offset voltage of -500 mV) when you set your high level to +2 Vpp and low level to -3 Vpp.
- When the Output Termination Setting is changed, the voltage levels are automatically adjusted. For instance, when you change the output termination from 50 ohms to "high impedance", your voltage shown on the display doubles, and when Output Termination has been changed from "high impedance" to 50 ohms, the voltage decreases in half.
- To invert the waveform relative to the offset voltage, you can use the OUTP:POL command.

VOLTage:LOW? [MINimum | MAXimum]

Query the low voltage level.

VOLTage: RANGE:AUTO{OFF | ON | ONCE}

Disable or enable the voltage auto-ranging. The default is "On" where the waveform generator selects an optimal setting for the output amplifier and attenuators. When the auto-ranging is "Off", the current setting is used.

- The "ONCE" parameter enables the auto-ranging, selects an optimal setting and then disables it.
- The APPLY command overrides this command and turns the auto-ranging on.
- Disabling the auto-ranging can avoid momentary disruption caused by attenuators switching while changing amplitudes. However, the amplitude and offset accuracy may be adversely affected when reducing the amplitude below the expected range change.

VOLTage: RANGE:AUTO?

"0" (off) or "1" (on) indicating the auto-ranging enable state is returned.

VOLTage:UNIT {VPP | VRMS | DBM}

Select the unit of the output amplitude. The default is VPP. The waveform generator used the same unit for front panel and the remote interface, so the front panel display in the unit that you select from remote interface.

If you don't specify the unit in the APPLy or VOLT commands, the function generation uses the unit specified in this command.

When the output termination is set to "high impedance", you cannot specify the output amplitude in dBm. The unit will be automatically converted to Vpp.

VOLTage:UNIT?

Query the unit of the output amplitude. "VPP", "VRMS" or "DBM" will be returned.

-- W --

***WAI**

Wait for all pending operation to complete before executing any additional commands over the interface.

B.4 SCPI Compliance Information

This section encloses a list of commands that are device-specific to Model 645. Although not included in the 1999.0 version of the SCPI standard, these commands are designed with the SCPI format in mind and they follow all of the syntax rules of the standard.

Many of the required SCPI commands are accepted by the waveform generator but are not described in this manual for simplicity or clarity. Most of these non-documented commands duplicate the functionality of a command already described in this chapter.

B.5 IEEE-488 Compliance Information

The SCPI commands used in Model 645 are in conformance with the SCPI standard Version 1992.0. The common commands are listed below:

*CLS
*ESE<NRf>
*ESE?
*ESR?
*IDN?
*LRN?
*OPC
*OPC?
*PSC {0|1}
*PSC?
*RCL<0 | 1 | 2 | 3 | 4>
*RST
*SAV<0 | 1 | 2 | 3 | 4>
*SRE<NRf>
*SRE?
*STB?
*TRG
*TST?
*WAI

B.6 Using Device Clear to Halt Measurements

Device Clear is a special IEEE-488 low-level bus message. It is designed to be used to return the waveform generator to a responsive state. Different programming languages and IEEE-488 interface cards provide their own special commands to perform this function. The status registers, the error queue, and all configuration states are left intact when a device clear is performed. In particular, device clear performs the following actions:

- The input and output buffers are cleared.
- An overlapped command, if any, will be terminated without "Operation Complete" indication (applies to the *TRG command).
- Any sweep or burst in progress will be immediately aborted.
- Get the waveform generator ready to accept a new command string.

C. General Specifications

item	Limitation & description
Power Supply Voltage	100V/240V 50Hz~60Hz
	100V/120V 400Hz
Power Requirements	50 VA Maximum
Operating Humidity	1) 0 °C/30%RH 2) 18 °C/40%RH 3) 23 °C/40%RH 4) 28 °C/40%RH 5) 35 °C/80%RH 6) 50 °C/30%RH
Operating Environment	0 to 55 °C
Storage Temperature	- 40 °C to 70 °C
Operating Altitude	Up to 2000m
Bench Dimensions (WxHxD)	224mm x 107mm x 380mm
Weight	4.08 kg
Safety	IEC61010-1:2001/EN61010-1:2001 (2 nd Edition) UL61010-1:2004
EMC	EN61326:1997+A1:1998+A2:2001+A3:2003 EMI: CISPR 11:1997+A1:1999+A2:2002 Class A IEC61000-3-2:2000 IEC61000-3-3:1994+A1:2001 EMS: IEC61000-4-2:1995+A1:1998+A2:2000 IEC61000-4-3:2002 IEC61000-4-4:2004 IEC61000-4-5:1995+A1:2000 IEC61000-4-6:1996+A1:2000 IEC61000-4-8:1993+A1:2000 IEC61000-4-11:1994+A1:2000

D. Application Programs

This chapter contains several remote interface example programs to help you develop programs for your own application. "Remote Interface Reference" starting on page 173, lists the syntax for the SCPI (*Standard Commands for Programmable Instruments*) commands available to program the function generator.

Introduction

Five example programs are included in this chapter to demonstrate controlling the BERKELEY NUCLEONICS CORPORATION Model 645 using SCPI commands. All of these programs are written in Microsoft® Visual C++® 6.0 and use the NI-VISA.

If you want to modify the example programs, or write your own programs and compile them, you will need to install the NI-VISA.

- If you are using GPIB. The software should have been loaded when you installed your GPIB interface card in your PC.
- If you are using USB or LAN. You must have NI-VISA version to support USB and LAN.

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All of the sample application programs in this chapter are example programs intended for use with Microsoft Visual C++ 6.0 and the NI-VISA by USB.

To use VISA in another Visual C++ project, you have to set the environmental variable in Microsoft Visual C++ 6.0. The procedures are in the following.

- In the VC++, after the path Tools\Options\Directories\include has been entered, you have to add an "Include" path offered by NI-VISA, such as
C:\VXIPNP\WinNT\include.
- Add C:\VXIPNP\WinNT\lib\msc\visa32.lib to Project folder.

The command for USB interface in the following or others will be different on other unit. If you have to check the right information, please do the procedure of Utility/IO/Show USB Id (for USB interface) to get it.

```
char instrDesc[]="USB0::5710::4002::TW00009009::INSTR";
```

If the communication is via GPIB or LAN interface, you have to revise the following USB command 1). to be GPIB 2). or LAN 3). one.

```
1). char instrDesc[]="USB0::5710::4002::TW00009009::INSTR";  
2). char instrDesc[]="GPIB0::10:: INSTR"; //GPIB control,Address:10  
3). char instrDesc[]="TCPIP0::192.168.0.123::inst0::INSTR";//IP  
address:192.168.0.123
```

Program Listings

Example: A Simple Sine Waveform

This program (found in the "Examples\Sine" subdirectory on the CDROM) selects the function as "sine," and then sets the frequency, amplitude and offset of the waveform.

```
//A Simple Sine Waveform  
#include <visa.h>  
#include <stdio.h>  
#include <ctype.h>  
#include <dos.h>  
  
void main (int argc,char *argv[])  
{  
    ViSession defaultRM,vi=0;  
    ViStatus status;  
    char instrDesc[]="USB0::5710::4002::TW00009009::INSTR";  
  
    viOpenDefaultRM (&defaultRM);  
  
    status = viOpen(defaultRM,instrDesc, VI_NULL,VI_NULL, &vi);  
    if (status != VI_SUCCESS){  
        printf("Can not Open device: \"%s\"\n",instrDesc);  
        return;  
    }  
    //This program sets up a waveform by selecting the waveshape  
    //and adjusting the frequency, amplitude, and offset.
```

```

viPrintf(vi,"*RST\n");
viPrintf(vi,"FUNction SINusoid\n");//Select waveshape
// Other options are SQUARE, RAMP, PULSe, NOISe, DC, and USER
viPrintf(vi,"OUTPut:LOAD 50\n");      //Set the load impedance in Ohms
//(50 Ohms default)
// May also be INFINITY, as when using oscilloscope or DMM
viPrintf(vi,"FREQuency 12500\n");    //Set the frequency.
viPrintf(vi,"VOLTage 1.25\n");       //Set the amplitude in Vpp.
//Also see VOLTage:UNIT
viPrintf(vi,"VOLTage:OFFSet 0.5\n");  //Set the offset in Volts
//Voltage may also be set as VOLTage:HIGH and VOLTage:LOW for low level
//and high level
viPrintf(vi,"OUTPut ON\n");          // Turn on the instrument output

viClose (vi);
viClose (defaultRM);
}

```

Example: Amplitude Modulation

This program (found in the "Examples\ AM" subdirectory on the CDROM) configures a waveform with amplitude modulation using lower-level SCPI commands. It also shows how to use the *SAV command to store the instrument configuration in the function generator's internal memory.

```

//Amplitude Modulation
#include <visa.h>
#include <stdio.h>

void main (int argc,char *argv[])
{
    ViSession defaultRM,vi=0;
    ViStatus status;
    char instrDesc[]="USB0::5710::4002::TW00009009::0::INSTR";

    viOpenDefaultRM (&defaultRM);

```

```

status = viOpen(defaultRM,instrDesc, VI_NULL,VI_NULL, &vi);
if (status != VI_SUCCESS){
    printf("Can not Open device:\">%s\%n",instrDesc);
    return;
}
// This program uses low-level SCPI commands to configure
// the function gnerator to output an AM waveform.
// This program also shows how to use "state storage" to
// store the instrument configuration in memory.

viPrintf(vi,"*RST\n");
viPrintf(vi,"OUTPut:LOAD 50\n");           //Output termination is 50 Ohms
viPrintf(vi,"FUNCTion:SHAPE SINusoid\n"); //Carrier shape is sine
viPrintf(vi,"FREQuency 6000;VOLTage 3\n");//Carrier freq is 6 kHz @ 3 Vpp

viPrintf(vi,"AM:INTernal:FUNCTion SINusoid\n");//Modulating shape is sine

viPrintf(vi,"AM:INTernal:FREQuency 300\n"); //Modulation freq = 300 Hz
viPrintf(vi,"AM:DEPTth 90\n");           //Modulation depth = 90%
viPrintf(vi,"AM:STATe ON\n");           //Turn AM modulation on
viPrintf(vi,"OUTPut ON\n");           //Turn on the instrument output
viPrintf(vi,"*SAV 2\n");           //Store state in memory location 2
// Use the "*RCL 2" command to recall the stored state output

viClose (vi);
viClose (defaultRM);
}

```

Example: Linear Sweep

This program (found in the "Examples\Linear_Sweep" subdirectory on the CDROM) creates a linear sweep for a sine wave. It sets the start and stop frequencies, and the sweep time.

```

//Linear Sweep
#include <visa.h>
#include <stdio.h>

```

```

void main (int argc,char *argv[])
{
    ViSession defaultRM,vi=0;
    ViStatus status;
    char instrDesc[]="USB0::5710::4002::TW00009009::0::INSTR";

    viOpenDefaultRM (&defaultRM);

    status = viOpen(defaultRM,instrDesc, VI_NULL,VI_NULL, &vi);
    if (status != VI_SUCCESS){
        printf("Can not Open device:\'%s'\n",instrDesc);
        return;
    }
    //This program sets up a linear sweep using a sinusoid
    //waveform. It sets the start and stop frequency and sweep
    //time.

    viPrintf(vi,"*RST\n");
    viPrintf(vi,"FUNction SINusoid\n");    //Select waveshape
    viPrintf(vi,"OUTPut:LOAD 50\n");    //Set the load impedance to
    // 50 Ohms (default)
    viPrintf(vi,"VOLTagE 1\n");    //Set the amplitude to 1 Vpp.
    viPrintf(vi,"SWEep:SPACing LINear\n"); //Set Linear or LOG spacing
    viPrintf(vi,"SWEep:TIME 1\n");    //Sweep time is 1 second
    viPrintf(vi,"FREQUency:STARt 100\n"); //Start frequency is 100 Hz
    viPrintf(vi,"FREQUency:STOP 20e3\n"); //Stop frequency is 20 kHz
    //Frequency sweep limits may also be set as FREQUency:CENTer and
    viPrintf(vi,"OUTPut ON\n");    //Turn on the instrument output
    viPrintf(vi,"SWEep:STATe ON\n");    //Turn sweep on

    viClose (vi);
    viClose (defaultRM);
}

```

Example: A Pulse Waveform

This program (found in the "Examples\Pulse" subdirectory on the CD-ROM) configures a pulse waveform, setting pulse width, period, and high/low levels. The

edge

time is then incremented.

```
//A Pulse Waveform
#include <visa.h>
#include <stdio.h>
#include <windows.h>

void main (int argc,char *argv[])
{
    ViSession defaultRM,vi=0;
    ViStatus status;
    char instrDesc[]="USB0::5710::4002::TW00009009::0::INSTR";
    int i;

    viOpenDefaultRM (&defaultRM);

    status = viOpen(defaultRM,instrDesc, VI_NULL,VI_NULL, &vi);
    if (status != VI_SUCCESS){
        printf("Can not Open device:\'%s'\n",instrDesc);
        return;
    }
    //This program sets up a pulse waveshape and adjusts the edge
    //time. It also shows the use of high and low voltage levels
    //and period. The edge time is adjusted by 5 nsec increments.

    viPrintf(vi,"*RST\n");
    viPrintf(vi,"FUNCTION PULSe\n");           //Select pulse waveshape
    viPrintf(vi,"OUTPut:LOAD 50\n");           //Set the load impedance to
    // 50 Ohms (default)
    viPrintf(vi,"VOLTage:LOW 0\n");             //Low level = 0 V
    viPrintf(vi,"VOLTage:HIGh 0.75\n");         //High level = .75 V
    viPrintf(vi,"PULSe:PERiod 1e-3\n");         //1 ms intervals
    viPrintf(vi,"PULSe:WIDTh 100e-6\n");        //Pulse width is 100 us
    viPrintf(vi,"PULSe:TRANSition 10e-9\n");    //Edge time is 10 ns
    //(rise time = fall time)
    viPrintf(vi,"OUTPut ON\n");                 //Turn on the instrument output
```

```

for(i=0;i<19;i++){ //Vary edge by 5 nsec steps
    viPrintf(vi,"PULSe:TRANSition %E\n",0.00000001 + i * 0.000000005);
    Sleep(300); //Wait 300 msec
}

viClose (vi);
viClose (defaultRM);
}

```

Example: Pulse Width Modulation (PWM)

This program (found in the "Examples\PWM" subdirectory on the CD-ROM) configures a pulse waveform with duty cycle, which is then slowly modulated by a triangle waveform.

```

//Pulse Width Modulation (PWM)
#include <visa.h>
#include <stdio.h>

void main (int argc,char *argv[])
{
    ViSession defaultRM,vi=0;
    ViStatus status;
    char instrDesc[]="USB0::5710::4002::TW00009009::0::INSTR";

    viOpenDefaultRM (&defaultRM);

    status = viOpen(defaultRM,instrDesc, VI_NULL,VI_NULL, &vi);
    if (status != VI_SUCCESS){
        printf("Can not Open device: \"%s\"\n",instrDesc);
        return;
    }

    //This program uses low-level SCPI commands to configure
    //the function gnerator to output an PWM waveform.
    //The pulse is set up with a duty cycle of 35% and a depth
    //of 15%, and will vary in width from 20% to 50% with the

```

```

//modulation. The pulse may also be configured in time
//units (pulse width and deviation) rather than duty cycle
//if preferred.

viPrintf(vi,"*RST\n");
viPrintf(vi,"OUTPut:LOAD 50\n");      //Set the load impedance to
// 50 Ohms (default)
viPrintf(vi,"FUNction:SHAPE PULSe\n");//Carrier waveshape is pulse
viPrintf(vi,"FREQuency 5000\n");     //Carrier frequency is 5 kHz
viPrintf(vi,"VOLTage:LOW 0\n");       //Set parameters to 5 V TTL
viPrintf(vi,"VOLTage:HIGH 5\n");
viPrintf(vi,"FUNction:PULSe:DCYCLE 35\n");//Begin with 35% duty cycle
viPrintf(vi,"PWM:INTernal:FUNction TRIangle\n");//Modulating waveshape
//is triangle
viPrintf(vi,"PWM:INTernal:FREQuency 2\n");//Modulation frequency is 2 Hz
viPrintf(vi,"PWM:DEVIation:DCYCLE 15\n"); //Modulation depth is 15%
viPrintf(vi,"PWM:SOURce INTernal\n"); //Use internal signal for
//modulation
//If using an external signal for PWM, connect the signal to the
//rear-panel BNC and use the command PWM:SOURce EXTernal
viPrintf(vi,"PWM:STATe ON\n");       //Turn PWM modulation on
viPrintf(vi,"OUTPut ON\n");          //Turn on the instrument output

viClose (vi);
viClose (defaultRM);
}

```

Visual Basic

Learn how to create and use BERKELEY NUCLEONICS CORPORATION IOUtils components, controls, data access, and more with the Visual Basic sample applications. For an overview and installation details, see [Visual Basic: Explore the Samples](#).

Visual C++

In an MFC application, you can override BERKELEY NUCLEONICS CORPORATION IOUtils interfaces in a class as well as provide additional interfaces. The example in this article illustrates how to override an

interface in a class while preserving the original interface implementation so that it can be delegated to by the new interface implementation. Browse the Visual C++ samples code; see Visual C++ DEVQUERY Sample Application.

Using MEASure? for a Single Measurement

The following example uses the MEASure? command to make a single accurate current measurement. This is the easiest way to program the multimeter for measurements. However, MEASure? does not offer much flexibility. The example is shown in Visual Basic.

Creating the Application

Create a new Visual Basic project as follows:

1. Create a new Standar.EXE project.
2. To set the startup object for a Windows Application to Sub Main
3. Add New Module, and declare a Sub Main().

How to: Change the Startup Object for an Application

The Startup Object property for a project defines the entry point to be called when the application loads; generally this is set to either the main form in your application or to the Sub Main procedure that should run when the application starts. Since Class Libraries do not have an entry point, their only option for this property is (None).

For Windows Applications projects, only forms or classes with a Public Sub Main procedure are available as Startup objects unless you check the Startup with custom Sub Main checkbox; when this option is checked, you must add code in the Sub Main procedure for the form.

※ Note: When using a custom Sub Main procedure as the Startup object, code in the Application events (Startup, Shutdown, Startup Next Instance, and Unhandled Exception) is not executed. The Startup Object property can be set in the Application pane of the Project Designer.

To change the startup object

1. With a project selected in Solution Explorer, on the Project menu click Properties.
2. Select the Application pane.
3. Select a Startup object from the Startup object drop-down list.

To set the startup object for a Windows Application to Sub Main

1. With a project selected in Solution Explorer, on the Project menu click Properties.
2. Select the Application pane.
3. Check the Startup with custom Sub Main checkbox.
4. Select Sub Main from the Startup object drop-down list.

LISTING D.1. MEASure.bas--THE Sub Main FUNCTION IS WHERE YOU NEED TO ADD INITIALIZATION CODE.

```
Sub Main()  
    Dim Model 645 As Object  
    Dim Rdg as Double  
  
    ' To assign an object reference using CreateObject  
    Set Model 645 = CreateObject("Berkeley Nucleonics Corporation.IOUtils")  
  
    ' Address String Grammar for ResourceName Parameter  
  
    ' USB[board]::manufacturer ID::model code::serial number[:USB interface  
    ' number][:INSTR]  
    ' or  
    ' GPIB0::22  
    Model 645.Connect = "USB::5710::4002::tw00000001"  
  
    Model 645.Output = "*RST" ' Reset Model 645  
    Model 645.Output = "*CLS" ' Clear Model 645 status registers  
    Model 645.Output = "MEASURE:CURRENT:AC? 1A,0.001MA" ' Set to 1 amp ac range  
  
    Rdg = Model 645.Input  
    Debug.Print Rdg  
  
    ' Unload Object  
    Model 645.Close  
    Set Model 645 = Nothing  
End Sub
```

Using CONFigure with a Math Operation

The following example uses CONFigure with the dBm math operation. The CONFigure command gives you a little more programming flexibility than the MEASure? command. This allows you to “incrementally” change the multimeter’s configuration. The example is shown in Visual Basic.

Creating the Application

Create a new Visual Basic project as follows:

1. Create a new Standar.EXE project.
2. To set the startup object for a Windows Application to Sub Main
3. Add New Module, Declare a Sub Main().

LISTING D.2. THE CONFigure FUNCTION.

```
Sub Main()
    Dim Model 645 As Object
    Dim Rdgs(1 To 5) As Double
    Dim i As Integer ' Array Index

    ' To assign an object reference using CreateObject
    Set Model 645 = CreateObject("Berkeley Nucleonics Corporation.IOUtils")

    ' Address String Grammar for rsrcName Parameter
    Model 645.Connect = "USB::5710::4002::tw00000001"
    ' USB[board]::manufacturer ID::model code::serial number[::USB interface
    ' number][::INSTR]

    Model 645.Output = "*RST" ' Reset Model 645
    Model 645.Output = "*CLS" ' Clear Model 645 status registers
    Model 645.Output = "CALC:DBM:REF 50" ' 50 ohm reference resistance
    Model 645.Output = "CONF:VOLT:AC 1,0.001" ' Set Model 645 to 1 amp ac range
    Model 645.Output = "DET:BAND 200" ' Select 200 Hz (fast) ac filter
    Model 645.Output = "TRIG:COUN 5" ' Model 645 will accept 5 triggers
    Model 645.Output = "TRIG:SOUR IMM" ' Trigger source is IMMEDIATE
    Model 645.Output = "CALC:FUNC DBM" ' Select dBm function
    Model 645.Output = "CALC:STAT ON" ' Enable math
    Model 645.Output = "READ?" ' Take readings; send to output buffer
    Rdgs = Model 645.Input

    For i = LBound(Rdgs) To UBound(Rdgs)
        Debug.Print Rdgs(i)
    Next i

End Sub
```

Using the Status Registers

The following example shows how you can use the multimeter’s status

registers to determine when a command sequence is completed. The example is shown in Visual Basic.

Creating the Application

Create a new Visual Basic project as follows:

1. Create a new Standar.EXE project.
2. After you create the application shell, lay out the Form1 as shown earlier in Figure C.1.
3. Configure the control properties as specified in Table C.1.

Adding Controls to Your Window

The application you are going to build today will have a number of controls on a dialog window, as shown in Figure C.1. When the user selects clicks the Start Readings button t, the routine that sets up the meter will run. Setup Model 645 to return an SRQ event when readings are complete.

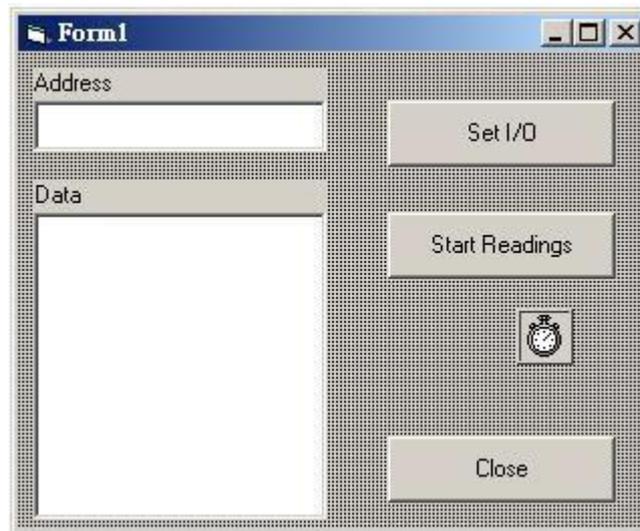


FIGURE D.1. The application will use a number of standard controls.

TABLE D.1.

PROPERTY SETTINGS FOR THE CONTROLS ON THE APPLICATION DIALOG.

<i>Object</i>	<i>Property</i>	<i>Setting</i>
---------------	-----------------	----------------

<i>Object</i>	<i>Property</i>	<i>Setting</i>
Command Button	Name	cmdSetIO
	Caption	Set I/O
Command Button	Name	cmdStartReading
	Caption	Start Readings
Command Button	Name	cmdClose
	Caption	Close
Label	Name	lblAddress
	Caption	Address
Label	Name	lblData
	Caption	Data
TextBox	Name	txtAddress
TextBox	Name	txtData
	MultiLine	True
Timer	Timer1	tmrPollForSRQ
	Interval	1000
	Enabled	False

LISTING D.3. THE SRQFetch FUNCTION.

```

Dim Model 645 As New IOUtils
Dim statusValue As Byte
Dim numberReadings As Long

Private Sub cmdClose_Click()           ' Command Button 1
    Unload Me
End Sub

Private Sub cmdSetIO_Click()           ' Command Button 2

    ' Set the io control address to the text box address
    ' we do this so the user can change address in text box
    ' and it will be reflected in the dialog
    txtAddress.Text = "GPIB0::22:INSTR"
    Model 645.Connect = txtAddress.Text

```

```

' Put the address from the communication dialog in text box
txtAddress.Text = Model 645.Address
End Sub

Private Sub cmdStartReading_Click()      ' Command Button 3
' Call the routine that sets up the meter

cmdStartReading.Enabled = False

startReadings

cmdStartReading.Enabled = True
End Sub

Private Sub Form_Load()                  ' Form1
' Load the forms address text box with persistant
' instrument address from BERKELEY NUCLEONICS CORPORATION.IOUtils object
txtAddress.Text = Model 645.Address
End Sub

Private Sub startReadings()

Dim Average As Double
Dim MinReading As Double
Dim MaxReading As Double
Dim Value As Integer
Dim Mask As Integer
Dim Task As Integer

Continued on next page
On Error GoTo StartReadingsError

' Clear out text box for the data so we can see
' when new data arrives
txtData.Text = ""
txtData.Refresh

*****
' Setup dmm to return an SRQ event when readings are complete
With Model 645
' Set the address from users text box
.Output = "*RST"      ' Reset dmm
.Output = "*CLS"      ' Clear dmm status registers
.Output = "*ESE 1"    ' Enable 'operation complete bit to
                    ' set 'standard event' bit in status byte
.Output = "*SRE 32"  ' Enable 'standard event' bit in status
                    ' byte to pull the IEEE-488 SRQ line
.Output = "*OPC?"    ' Assure synchronization
Value = .Input
End With

*****
' Enable the SRQ polling so we can poll for SRQ
Model 645.EnableSRQ = True
txtData.Refresh

*****
' Configure the meter to take readings
' and initiate the readings (source is set to immediate by default)
numberReadings = 10
With Model 645
.Output = "Configure:Voltage:dc 10" ' set dmm to 10 volt dc range"
.Output = "Voltage:DC:NPLC 10"      ' set integration time to 10 Power line cycles
(PLC)"
.Output = "Trigger:count" & Str$(numberReadings) ' set dmm to accept multiple

```

```

triggers
    .Output = "Init"           ' Place dmm in 'wait-for-trigger' state
    .Output = "*OPC"         ' Set 'operation complete' bit in standard
                             ' event registers when measurement is complete
End With

.....

' enable the timer to poll gpib once per second
tmrPollForSRQ.Enabled = True

' give message that meter is initialized
' give message that configuration is done
txtData.Text = "Meter configured and " & vbCrLf & _
               "Initialized"

Exit Sub

StartReadingsError:
    Debug.Print "Start Readings Error = "; Err.Description
End Sub

Private Sub tmrPollForSRQ_Timer() 'Timer1
    ' This timer when enabled will poll the GPIB
    ' and return the status byte to indicate if SRQ is set

    On Error GoTo pollerror

    Continued on next page

' this will also change the timeout
statusValue = Model 645.WaitOnSRQ(100) ' WaitOnSRQ(100ms)

' Set the timeout back to 10 sec,
Model 645.TimeOut = 10000
If statusValue = 64 Then ' SRQ from Operation complete
    ' Turn off the timer and stop polling.
    tmrPollForSRQ.Enabled = False
    Debug.Print "SRQ is set, getting data"
    ' Get the Data, the meter is ready
    ReadData
End If

Exit Sub

pollerror:
    Debug.Print "No SRQ yet, Poll error = "; Err.Description

End Sub

Private Sub ReadData()
    ' Once the SRQ is detected, this routine will
    ' get the data from the meter
    ' Called by: PollForSRQTimer_Timer
    ,

    Dim readings() As Double
    Dim i As Long

    On Error GoTo ReadDataError

    ' dimension the array for the number of readings

    With Model 645
        .Output = "Fetch?" ' Query for the data in memory
        readings = .Input ' get the data and parse into the array
    End With

```

```

' Insert data into text box
txtData.Text = ""
For i = 0 To UBound(readings)
    txtData.SelText = readings(i) & " Vdc" & vbCrLf
Next i

Exit Sub

ReadDataError:
    Debug.Print "ReadData Error = "; Err.Description

End Sub

Private Sub Form_Terminate()

    On Error Resume Next

    Set Model 645 = Nothing

End Sub

```

C++ DEVQUERY Sample Application

This C sample application is a Win32 console application. It illustrates how to use the BERKELEY NUCLEONICS CORPORATION IOutils COM. A Win32 console application is a Win32 application which uses text-based input and output, not a graphical interface. This allows you to quickly create a Win32 application by using simple input and output functions.

Creating the Application

Create a new Visual C++ project as follows:

1. Create a new Win32 Console Application project, calling the project DEVQUERY.
2. Specify that this project will be a simple application in the last AppWizard step.

LISTING D.4. THE DEVQUERY FUNCTION.

```

// DEVQUERY.cpp : Defines the entry point for the console application.
//

#include "stdafx.h"

//Purpose: To illustrate the use of the automation layer in a C++ program
//without the use of smart COM pointers. (In general I would advise using smart
//pointers but this example will allow the use of the automation layer without them.
//Note that this is a C++ program and not C, that is we use class structures, however
//it is 'bare bones' in the sense we use COM calls directly and no smart pointers)
//

```

```

//standard include for a Microsoft Visual C++ project
#include "stdio.h"

//need for COM
#include "windows.h"
#include "comdef.h"

//This is the 'Automation' object (COM class). It contains the IIOManager interface
//below

const CLSID CLSID_BERKELEY NUCLEONICS CORPORATIONIIOUtils =
{0xCF1DC41A,0x5E37,0x455E,{0xA3,0x88,0x17,0xB9,0x20,0x14,0x04,0xB1}};

//The IIO allows the opening of a device using its address in the 'ConnectToInstrument'
function. The IO
//class above exports this
//COM interface.

Continued on next page
//The IIO function 'ConnectToInstrument' will return the IIO interface
//this is an instance of the instrument.
const IID IID_IIOUtils=
{0x3E0AC3A2,0xB527,0x4741,{0x8D,0x3E,0x83,0xC8,0x13,0x59,0xA5,0xC6}};

//The following are the definitions needed to program the instrument. They
//can be placed in a header file for but are shown here to allow ease of
//perusal

/*****/
//This definition is to complete the IIO interface below. You needn't use this interface
directly to
//communicate with instruments
extern "C" {

interface IIOUtils : IDispatch {
    STDMETHOD (Count)(short *pVal);
    STDMETHOD (TimeOut)(short *pVal);
    STDMETHOD (TimeOut)(short newVal);
    STDMETHOD (Open)(void);
    STDMETHOD (Close)(void);
    STDMETHOD (Refresh)(void);
    STDMETHOD (Index)(short newVal);
    STDMETHOD (Index)(short *pVal);
    STDMETHOD (Output)(BSTR newVal);
    STDMETHOD (Input)(BSTR *pVal);
    STDMETHOD (Address)(BSTR *pVal);
    STDMETHOD (Query)(BSTR newValue, BSTR *pVal);
    STDMETHOD (ErrFlag)(long *pVal);
    STDMETHOD (Connect)(BSTR newVal);
};

} //extern "C"
/*****/

int main(int argc, char* argv[])
{
    IIOUtils *IIO; //The IO we'll be using to get to the instrument
    HRESULT hr; //check return values for failure

    _variant_t myCmd;
    _variant_t myResult;
    _bstr_t myInstrument, strTmp;
    BSTR bstr;
    printf("Start CExample program. We assume a Model 645 multimeter on

```

```

        USB::5710::4002::tw00000001\n\n");

//Initialize COM
CoInitialize(NULL);

//Create the BERKELEY NUCLEONICS CORPORATION IOUtils component
hr = CoCreateInstance(CLSID_BERKELEY NUCLEONICS
CORPORATIONIOUtils, NULL, CLSCTX_INPROC_SERVER, IID_IOUtils
, (LPVOID *) &IIO);
if FAILED(hr)
{
    printf("CoCreateInstance failed\n");
    return 0;
}

```

Continued on next page

```

//Connect String
myInstrument="USB::5710::4002::tw00000001";
IIO->Connect(_bstr_t(myInstrument));
IIO->Address(&bstr);
printf("%s\n", (char *)_bstr_t(bstr));
IIO->Output(_bstr_t("*IDN?\n"));
IIO->Input (&bstr);
printf("%s\n", (char *)_bstr_t(bstr));
IIO->Output(_bstr_t("READ?\n"));
IIO->Input (&bstr);
printf("%s\n", (char *)_bstr_t(bstr));
IIO->Close();
IIO->Release();

//Uninit so COM is exited clean.
CoUninitialize();
return 0;
}

```



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