B&K PRECISION®

MODEL 4045
20MHz DDS Sweep Function Generator with Arb Function

OPERATING MANUAL

V021114

Limited Three-Year Warranty

B&K Precision warrants to the original purchaser that its products and the component parts thereof, will be free from defects in workmanship and materials for a period of **three years** from date of purchase from an authorized B&K Precision distributor.

B&K Precision will, without charge, repair or replace, at its option, defective product or component parts. Returned product must be accompanied by proof of the purchase date in the form of a sales receipt.

To obtain warranty coverage in the U.S.A., this product must be registered by completing the warranty registration form on www.bkprecision.com within fifteen (15) days of purchase.

Exclusions: This warranty does not apply in the event of misuse or abuse of the product or as a result of unauthorized alterations or repairs. The warranty is void if the serial number is altered, defaced or removed.

B&K Precision shall not be liable for any consequential damages, including without limitation damages resulting from loss of use. Some states do not allow limitations of incidental or consequential damages. So the above limitation or exclusion may not apply to you.

This warranty gives you specific rights and you may have other rights, which vary from state-to-state.

Service Information

Warranty Service: Please return the product in the original packaging with proof of purchase to the address below. Clearly state in writing the performance problem and return any leads, probes, connectors and accessories that you are using with the device.

Non-Warranty Service: Return the product in the original packaging to the address below. Clearly state in writing the performance problem and return any leads, probes, connectors and accessories that you are using with the device. Customers not on open account must include payment in the form of a money order or credit card. For the most current repair charges please visit www.bkprecision.com and click on "service/repair".

Return all merchandise to B&K Precision with pre-paid shipping. The flat-rate repair charge for Non-Warranty Service **does not** include return shipping. Return shipping to locations in North American is included for Warranty Service only. For overnight shipments and non-North American shipping fees please contact B&K Precision.

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Include with the returned instrument your complete return shipping address, contact name, phone number and description of problem.

Safety Summary

The following safety precautions apply to both operating and maintenance personnel and must be observed during all phases of operation, service, and repair of this instrument. Before applying power, follow the installation instructions and become familiar with the operating instructions for this instrument.

Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. B&K PRECISION assumes no liability for a customer's failure to comply with these requirements. This is a Safety Class I instrument.

GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. This instrument is grounded through the ground conductor of the supplied, three-conductor ac power cable. The power cable must be plugged into an approved three-conductor electrical outlet. Do not alter the ground connection. Without the protective ground connection, all accessible conductive parts (including control knobs) can render an electric shock. The power jack and mating plug of the power cable meet IEC safety standards.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

KEEP AWAY FROM LIVE CIRCUITS

Instrument covers must not be removed by operating personnel. Component replacement and internal adjustments must be made by qualified maintenance personnel. Disconnect the power cord before removing the instrument covers and replacing components. Under certain conditions, even with the power cable removed, dangerous voltages may exist. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE

Do not attempt any internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY THE INSTRUMENT

Do not install substitute parts or perform any unauthorized modifications to this instrument. Return the instrument to TEXIO for service and repair to ensure that safety features are maintained.

WARNINGS AND CAUTIONS

WARNING and *CAUTION* statements, such as the following examples, denote a hazard and appear throughout this manual. Follow all instructions contained in these statements.

A *WARNING* statement calls attention to an operating procedure, practice, or condition, which, if not followed correctly, could result in injury or death to personnel.

A *CAUTION* statement calls attention to an operating procedure, practice, or condition, which, if not followed correctly, could result in damage to or destruction of part or all of the product.

WARNING: *Do not alter the ground connection. Without the protective ground connection, all accessible conductive parts (including control knobs) can render an electric shock. The power jack and mating plug of the power cable meet IEC safety standards.*

WARNING: *To avoid electrical shock hazard, disconnect power cord before removing covers. Refer servicing to qualified personnel.*

CAUTION: *Before connecting the line cord to the AC mains, check the rear panel AC line voltage indicator. Applying a line voltage other than the indicated voltage can destroy the AC line fuses. For continued fire protection, replace fuses only with those of the specified voltage and current ratings.*

CAUTION: *This product uses components which can be damaged by electro-static discharge (ESD). To avoid damage, be sure to follow proper procedures for handling, storing and transporting parts and subassemblies which contain ESD-sensitive components.*

Contents

Section 1

Introduction

1.1 Introduction

This manual contains information required to operate, program and test the Model 4045 - 20MHz DDS Sweep Function Generator with Arb Function. This section covers the instrument general description, instrument specifications and characteristics.

1.2 Description

The Model 4045 is a versatile high performance arbitrary waveform generator. Arbitrary waveforms can be programmed and generated with 12 bit resolution and up to 1,000 points length. Waveforms can be output in continuous, triggered, gated or burst mode. AM and FM modulation combined with versatile Sweep capabilities make the unit suitable for a wide range of applications.
Editing is flexible and easy including auto increment, line draw and predefined waveform facilities. The instrument can be remotely operated via the USB virtual COM serial interface bus and it is SCPI compatible.

1.3 Memory Architecture

The waveform memory consists of 1,000 points. The user can edit arbitrary waveforms in waveform memory and can specify any data value in the range from -2047 to 2047 for any point in waveform memory.

The following operations can be performed in the waveform memory:

- Insert and scale any of the following predefined waveforms:
    sine
    triangle
    square
    ramp up
    ramp down
    noise

- Draw a line between any two points
- Clear (set to zero) any set of points or all points
- Set individual point values

Up to 1000 continuous points of waveform memory can be executed by specifying a starting address in waveform memory and length.
After specifying a section of waveform memory for execution, the following parameters can be set:

- Point rate (frequency)
- Peak-to-peak amplitude
- Offset voltage

MODEL 4045 - SPECIFICATIONS

GENERAL DESCRIPTION

The Model 4045 is a programmable arbitrary waveform generator that can generate arbitrary waveforms and predefined signal as: Sine, Triangle, Square, Pulse, etc.

FREQUENCY CHARACTERISTICS (STANDARD WAVEFORMS)

Sine - 0.01 Hz to 20 MHz
Square - 0.01 Hz to 20 MHz
Triangle , Ramp - 0.01 Hz to 2 MHz
Accuracy - 0.005 %   (50 ppm)
  at <100 Hz = 0.005 % $\pm$ 0.006 Hz
Resolution - 6 digits or 10 mHz

ARBITRARY CHARACTERISTICS

Waveform length - 2 points to 1,000 points
Vertical resolution - 12 bits
Sampling rate - 20ns to 50s
Accuracy - 0.005 %   (50 ppm)
Resolution - 4 digits

OUTPUT CHARACTERISTICS

Amplitude Range - 10mV to 10Vp-p into 50 ohms
Resolution - 3 digits (1000 counts)
Amplitude Accuracy - $\pm$ 2% $\pm$ 20mV of the programmed output from 1.01V- 10V
Flatness - 0.5 dB at 1MHz
(for sine wave at 5Vpp into 50 Ω) - 1 dB to 20 MHz
Offset Range - $\pm$ 4.5V into 50 ohms, depending on the Amplitude setting
Offset Resolution - 10 mV with 3 digits resolution
Offset Accuracy - $\pm$ 2% $\pm$ 10mV into 50 ohms
Output Impedance - 50 ohms
Output Protection - The instrument output is protected against short circuit or accidental voltage practically available in electronic laboratories, applied to the main output connector
Filter - 9 pole Elliptic

WAVEFORM CHARACTERISTICS

Harmonic Distortion	- DC-20 KHz	-55 dBc
(for sine wave at 5Vpp into 50 Ω)	- 20 KHz-100 KHz	-50 dBc
	- 100 KHz-1 MHz	-40 dBc
	- 1 MHz-20 MHz	-30 dBc
Spurious	- DC-1MHz	<-60 dBc
Square Rise/Fall Time	- < 18 ns (10% to 90%) at full amplitude into 50 ohms	

Variable Duty Cycle	- 20% to 80% to 2 MHz for Square and 10%-90% for Triangle
Symmetry at 50%	- < 1 %

OPERATING MODES

Continuous	- Output continuous at programmed parameters.
Triggered	- Output quiescent until triggered by an internal or external trigger, then one waveform cycle is generated to programmed parameters. Up to 10MHz trig rate for ARB waveforms and 1 MHz in DDS mode.
Gate	- Same as triggered mode, except waveform is executed for the duration of the gate signal. The last cycle started is completed.
Burst	- 2- 65,535 cycles
Trigger Source	- Trigger source may be internal, external or manual. Internal trigger rate 0.1Hz-1MHz (1us – 10s)

MODULATION CHARACTERISTICS

Amplitude Modulation
- Internal:	0.1Hz-20KHz sine , square or triangle waveform
	Variable modulation from 0% to 100%.
- External:	5 Vp-p for 100% modulation, 10 Kohms input impedance.

Frequency Modulation
- Internal:	0.1Hz-20KHz sine wave, square or triangle
- External:	5 Vp-p for 100% deviation, 10 Kohms input impedance.

SWEEP CHARACTERISTICS

Sweep Shape:	Linear and Logarithmic, up or down
Sweep Time:	10 ms to 100 s
Sweep Trigger:	internal, external, continuous or burst

INPUTS AND OUTPUTS

Trigger In	- TTL compatible.
	- Max. rate 10MHz.
	- Minimum width 50ns.
Sync Out	- TTL pulse at programmed frequency, 50 ohms source impedance.
Modulation IN	- 5 Vp-p for 100% modulation .
	- 10 KΩ input impedance.
	- DC to >20 KHz minimum bandwidth.

GENERAL

Store memory	20 full panel settings at power-off
Arbitrary memory	1,000 points in flash memory
Dimensions	- 8.4 inch (213 mm) wide
	- 3.5 inch (88 mm) high
	- 8.3 inch (210 mm) deep
Weight	- Approximately 2.5 Kg.

Power	- 90V-264V
	- 30 VA max
Temperature	
Operating	- 0ºC to +50ºC
Non-operating	- -10ºC to +70ºC
Humidity	- 95 % RH , 0ºC to 30ºC
EMC	- According to EN55011 for radiated and conducted emissions.
Electrical Discharge Immunity	- According to EN55082
Safety Specifications	- According to EN61010
CE Labeled	
Included Accessories	-Manual and software CD, power cord, USB cable, certificate of calibration

Specifications are subject to change without notice.
For the most current product information please visit www.bkprecision.com.

Section 2

Installation

2.1 Introduction

This section contains installation information, power requirements, initial inspection and signal connections for Model 4045 - Function Generator.

2.2 Mechanical Inspection

This instrument was carefully inspected before shipment. Upon receipt inspect the instrument for damage that might have occurred in transit. If there is damage due to shipping, file a claim with the carrier who transported the unit. The shipping and packing material should be saved if reshipment is required. If the original container is not to be used, then use a heavy carton box. Wrap the unit with plastic and place cardboard strips across the face for protection. Use packing material around all sides of the container and seal it with tape bands. Mark the box "FRAGILE".

2.3 Initial Inspection

After the mechanical inspection, verify the contents of the shipment (accessories and installed options). If the contents are incomplete, or if the instrument does not pass the specification acceptance tests, notify the local service center.

2.4 Instrument Mounting

The Model 4045 - Function Generator is intended for bench use. The instrument includes a front feet tilt mechanism for optimum panel viewing angle. The instrument does not require special cooling when operated within conventional temperature limits. The unit can be installed in a closed rack or test station if proper air flow is assured for removing about 15 W of power dissipation.

2.5 Power Requirements

The Model 4045 can be operated from any source of 90V to 264V AC, frequency from 48Hz to 66Hz. The maximum power consumption is 30 VA. Use a slow blow fuse UL/CSA approved of 1A as indicated on the rear panel of the instrument.

The instrument power fuse is located in the AC input plug. To access the fuse, first disconnect the power cord and then remove the fuse cartridge.

2.6 Grounding Requirements

For the safety of operating personnel, the instrument must be grounded. The central pin on the AC plug grounds the instrument when properly connected to the ground wire and plugged into proper receptacle.

WARNING

TO AVOID PERSONAL INJURY DUE TO SHOCK, THE THIRD WIRE EARTH GROUND MUST BE CONTINUOUS TO THE POWER OUTLET. BEFORE CONNECTION TO THE POWER OUTLET, EXAMINE ALL CABLES AND CONNECTIONS BETWEEN THE UNIT AND THE FACILITY POWER FOR A CONTINUOUS EARTH GROUND PATH. THE POWER CABLE MUST MEET IEC SAFETY STANDARDS.

2.7 Signal Connections

Use RG58U 50 Ohm or equivalent coaxial cables for all input and output signals to and from the instrument.

2.8 USB Virtual COM Configuration

The instrument uses 8 data bits, 1 stop bit, no parity and baud rate of 115200.

Section 3

Operating Instructions

3.1 General Description

This section describes the displays, controls and connectors of the Model 4045 - Function Generator. All controls for the instrument local operation are located on the front panel. The connectors are located on both front and rear panels.
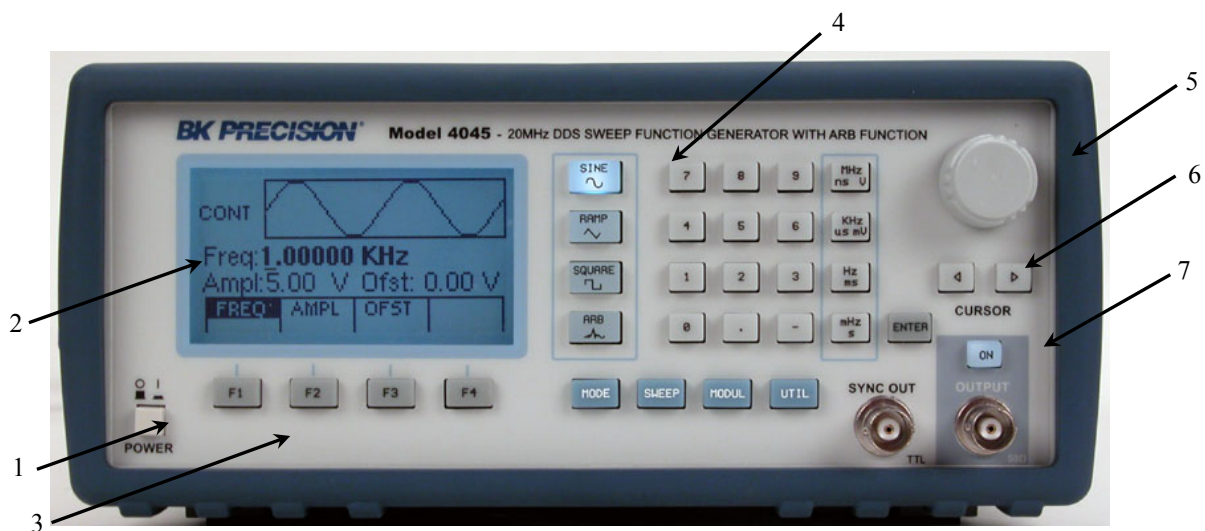
Figure 3.1 - Model 4045 Front Panel

1. Power ON-OFF   -Applies and removes AC power to the unit.

2. Display Window   -Displays all instrument data and settings on a LCD.

3. FI-F4 Keys   -Select the menu options that appear on the second line of the LCD display. Menus differ depending on the selected parameter, function or mode.

4. Function Keys   -Select the output waveform, Sine, Square, Triangle or Arbitrary.

5. Rotary Knob   -Used to increment/decrement numerical values or to scan through the possible selections.

6. Modify Keys   -Used to move the cursor (when visible) to either left or right.

7. Output ON   -Controls the main output signal. The output status is displayed on the LCD.

3.2 Display Window

The Model 4045 has a graphic LCD display that can display up to 124 x 64 dots. When you power-on the unit the SINE is selected and its current settings appear in the display. The bottom displays a menu that corresponds to the function, parameter or mode displayed selected.

3.3 Front Panel Controls

The front-panel controls select, display, and change parameter, function, and mode settings. They also include the keys you use to program and generate arbitrary waveform output.
Use the rotary input knob and the cursor movement keys to enter data into the waveform generator.

To change a setting:
1. Press the key that leads to a required item.
2. Move cursor using cursor keys to the appropriate position in the numeric field (if applicable).
3. Use the rotary input or the numerical keyboard to change the value of the displayed item. Changes take effect immediately.

The following subsections describe the function of each front panel key and connector.

3.4 Connectors

The function generator has two BNC connectors on the front panel and two on the rear panel where you can connect coaxial cables. These coaxial cables serve as carrier lines for input and output signals delivered to and from the function generator.

Output Connector
Use this connector to transfer the main output signal from the function generator.

Trig In Connector
Use this connector to apply an external trigger or gate signal, depending on the waveform generator setting, to the generator.

Sync Out Connector
Use this connector to output a positive TTL sync pulse generated at each waveform cycle.

Modulation In Connector
5V p-p signal for 100% modulation, 10Kohms input impedance with DC - >20 KHz bandwidth.

3.5 Output Connections

The waveform generator output circuits operate as a 50 ohms voltage source working into a 50 ohms load. At higher frequencies, non terminated or improperly terminated output cause aberrations on the output waveform. In addition, loads less than 50 ohms reduce the waveform amplitude, while loads more than 50 ohms increase waveform amplitude.

Excessive distortion or aberrations caused by improper termination are less noticeable at lower frequencies, especially with sine and triangle waveforms. To ensure waveform integrity, follow these precautions:

1. Use good quality 50 ohms coaxial cable and connectors.
2. Make all connections tight and as short as possible.
3. Use good quality attenuators if it is necessary to reduce waveform amplitudes applied to sensitive circuits.
4. Use termination or impedance-matching devices to avoid reflections.
5. Ensure that attenuators and terminations have adequate power handling capabilities.

If there is a DC voltage across the output load, use a coupling capacitor in series with the load. The time constant of the coupling capacitor and load must be long enough to maintain pulse flatness.

Impedance Matching
If the waveform generator is driving a high impedance, such as the 1 Mohm input impedance (paralleled by a stated capacitance) of an oscilloscope vertical input, connect the transmission line to a 50 ohms attenuator, a 50 ohms termination and to the oscilloscope input. The attenuator isolates the input capacitance of the device and terminates the waveform generator properly.

3.6 MENU Keys

These keys select the main menus for displaying or changing a parameter, function or mode.

3.6.1 WAVEFORM Keys

The keys select the waveform output and displays the waveform parameter menu (frequency, amplitude and offset). When the Arbitrary Waveform is selected, the display shows also the waveform rate.

Sine Menu

F1: FREQ - (Frequency) Selects and displays the frequency.
Change the frequency setting using the cursor keys, rotary knob or numerical keys. If a certain wavelength can't produce the waveform at the desired frequency, the waveform generator displays an "Out of Range" error message.

F1: FREQ/RATE - Selects and displays the Point Rate (for Arbitrary Waveform only).
The Rate parameter governs the rate at which waveform points are executed, and thus the frequency of the waveform output. When you set this parameter, the waveform generator will keep that execution rate for all waveform lengths until it is changed.

F2: AMPL - Selects the Amplitude parameter.
In Arbitrary mode this setting defines the maximum peak-to-peak amplitude of a full-scale waveform. If the waveform does not use the full scale of data (-2047 to +2047), then its actual amplitude will be smaller.

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Setting the Amplitude

The following equation represents the relative output amplitude voltage relationship between the front panel amplitude peak-to-peak setting and the data point values in waveform memory:

$$\text{Output voltage} = \frac{\text{amplitude p-p setting x data point value}}{4095} + \text{offset}$$

Where 4095 is the data point value range in waveform memory.

Examples

Front Panel Amplitude Setting	Data Point Value	Relative Output Amplitude Voltage
5 Vp-p	2047	+2.5 V
5 Vp-p	1024	+1.25 V
5 Vp-p	0	0V (offset voltage)
9 Vp-p	300	659 mV
9 Vp-p	-1000	-2.198 V
4 Vp-p	-2047	-2 V

F3:OFST   -Selects the Offset parameter. Change the offset by using the cursor keys, rotary dial or numerical keys. If a certain setting cannot be produced, the waveform generator will display a "Setting Conflict" message.

Amplitude and Offset Interaction:

Amplitude and offset settings interact and are bound by hardware restrictions. In order to obtain the desired waveform the following amplitude and offset hardware limitations must be considered:

The offset voltage has three ranges as follows:

Output Voltage Range	Constraints of Amplitude + Offset
1.01 volt to 10.00 volts	(Vp-p)/2 + |offset| <= 5 volts
0.101 volt to 1 volt	(Vp-p)/2 + |offset| <= 0.5 volts
0.010 volt to 0.100 volt	(Vp-p)/2 + |offset| <= 0.05 volts

F4:SYM   - When the Square or Triangle waveforms are selected, the SYMMETRY is available. Change the symmetry by using the cursor keys, rotary dial or numerical keys. If a certain setting cannot be produced, the waveform generator will display a warning message.
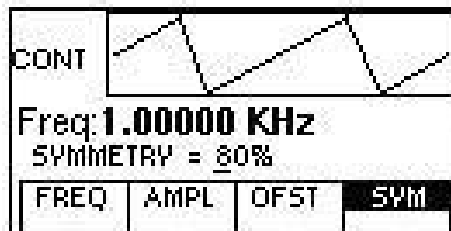
Triangle Menu

3.6.2 MODE Key

Selects the output mode: CONT (Continuous), TRIG (Triggered), GATE (Gated), and BRST (Burst).
To select the output mode, press MODE, then press the function key that corresponds to the desired Mode menu option, as shown:

Mode Menu

F1: CONT   - (Continuous) - Selects continuous output.

F2: TRIG   - (Triggered) - Triggers one output cycle of the selected waveform for each trigger event.

F3: GATE   - (Gated) - Triggers output cycles as long as the trigger source asserts the gate signal.

F4: BRST   - (Burst) - Triggers output N output cycles for each trigger event, where N ranges from 2 to 65,535.

After selecting the TRIG , GATE or BURST menu, the trigger source menu is available:
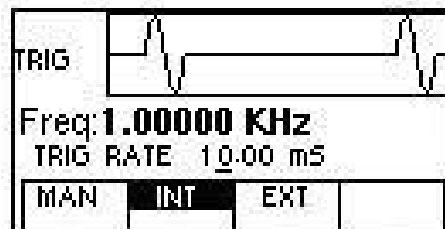
Trigger Menu

F1: MAN   - Selects manual as the trigger source. To trigger the waveform generator,
        press this MAN TRIG again.

F2: INT   - Selects the internal trigger generator as the trigger source. Change the
        internal trigger rate displayed with the rotary input knob.

F3: EXT   - Selects the external trigger signal as the trigger source. The trigger source
        is supplied through the TRIG IN connector.

In BURST mode, the **F4** displays **NBRST**, the number of burst pulses to be output with each trigger. The N can be changed from 2 to 65,535.

3.6.3 ARBITRARY Key

When selected displays the following screen:

CONT

Freq: 1.000 KHz
Ampl:5.00 V Ofst: 0.00 V
FREQ RATE | AMPL | OFST | ARB
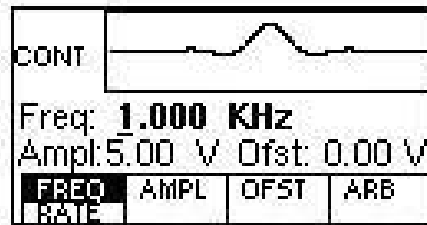
Arbitrary Menu

F1: FREQ/RATE — (Frequency) Selects and displays the frequency. Change the frequency setting using the cursor keys, rotary knob or numerical keys. If a certain wavelength can't produce the waveform at the desired frequency, the waveform generator displays an "Out of Range" error message. Displays the Point Rate (for Arbitrary Waveform only). The Rate parameter governs the rate at which waveform points are executed, and thus the frequency of the waveform output. When you set this parameter, the waveform generator will keep that execution rate for all waveform lengths until it is changed.

F2: AMPL — Selects the Amplitude parameter.

In Arbitrary mode this setting defines the maximum peak-to-peak amplitude of a full-scale waveform. If the waveform does not use the full scale of data (-2047 to +2047), then its actual amplitude will be smaller.

F3:OFST — Selects the Offset parameter. Change the offset by using the cursor keys, rotary dial or numerical keys. If a certain setting cannot be produced, the waveform generator will display a "Setting Conflict" message.

F5: ARB — Selects the Arbitrary editing menu:

CONT

Freq: 1.000 KHz
START 1
START | LENGTH | EDIT | PREV
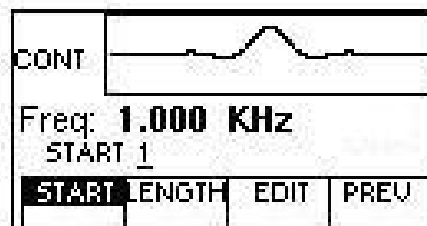
Arbitrary Editing Menu

F1: START — Selects the arbitrary waveform start address.

F2: LENGTH — Selects the arbitrary waveform length. Use the START and LENGTH keys to mark a selection of the waveform memory that will be executed.

Changing one of the arbitrary parameters as start and length cause an updating of the output waveform to the new parameters. When exiting the Arbitrary Menu by selecting a different waveform, a message to save

the Arbitrary wave will be displayed is the Arb data was changed. Select YES or NO to save the new waveform.

3.6.4 Arbitrary EDIT Menu

Enters data for creating arbitrary waveforms. You can enter data one point at a time, as a value at an address, draw a line from one point (a value at an address) to another point, create a predefined waveform, or combine these to create complex waveforms. The valid data values range is -2047 to 2047. The valid waveform memory addresses range from 1 to 1,000.
The data value governs the output amplitude of that point of the waveform, scaled to the instrument output amplitude. Therefore, a value of 2047 corresponds to positive peak amplitude, 0 corresponds to the waveform offset, and -2047 corresponds to the negative peak amplitude.
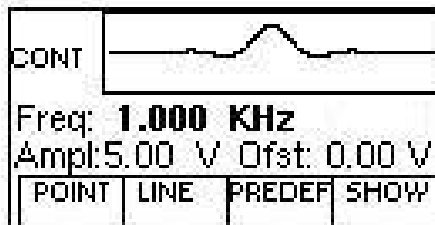
Edit Menu

F1: POINT - This menu allows the point by point waveform editing. When selected, the following menu is displayed:
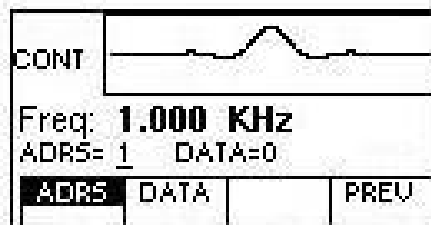
Point Menu

F1: ADRS - Select the current address in the arbitrary waveform memory.

F2: DATA - Selects the data point value at the current address. You can change the point value from -2047 to 2047.

F2: LINE - This menu allows a line drawing between two selected points. Displays the following menu:

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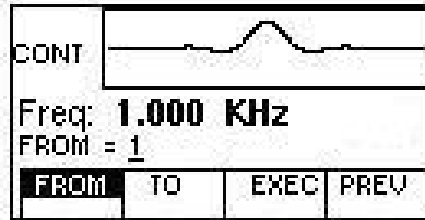
Line Menu

F1: FROM   **-** Selects the starting point address.

F2: TO   - Selects the ending point address.

F4: EXEC   - Displays the Confirmation menu, **F1:NO** and **F3:YES**
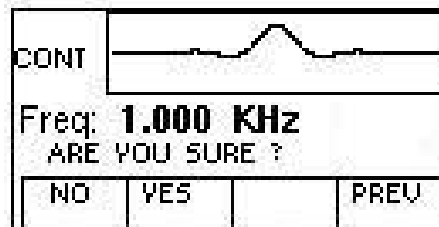
Confirmation Menu

F3: PREDEF   - (Predefined Waveforms) Selects one of the predefined waveforms: Sine, Triangle, Square and Noise. Displays the Predefined waveforms menu:
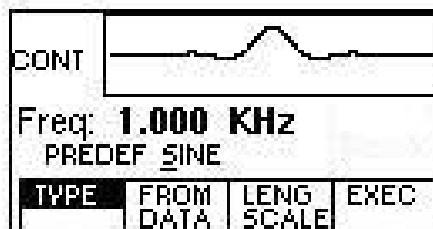
Predefine Menu

F1: TYPE   - Selects the waveform Sine, Triangle, Square or Noise. If Noise function is selected, a submenu is displayed to allow adding the noise to an available waveform or to generate it as a new noise waveform.

F2: FROM DATA   - Selects the starting point of the generated waveform and data value.

F3: LENG/SCALE   - Selects the length of the predefined waveform (number of points for a full wave). Different waveforms have different limitations on the length, as shown in Table 3-1.

Table 3-1: Waveform Length Limits for Predefined Waveforms

Wave	Minimum length	Divisible by
Sine	16	4
Triangle	16	4
Square	2	2

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Noise	16	1

F3: SCALE   - Selects the scale factor of the waveform. 100% means that the waveform spans the full scale of -2047 to 2047. Scale factors are limited by the point data value of the starting point and automatically calculated by the unit.

F4: EXEC   - Prompts you to confirm whether to execute the selected predefined waveform. Press NO to abort executing the predefined waveform; press YES to execute the predefined waveform. On the NOISE function a menu of ADD and NEW is prompt to select a new noise waveform or to add noise to the existing waveform.

F4:SHOW WAVE   - Display the Arbitrary waveform on the full LCD display. By pressing any button, the display returns to the MENU selection.
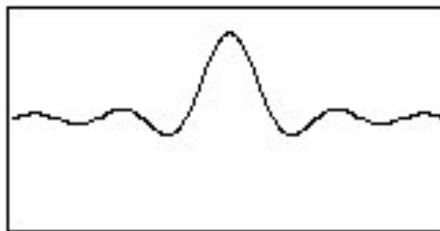
Full Display

3.6.5 UTILITY Key

Utility Menu

F1: RECALL   - Recalls a previously stored front-panel setup from the selected buffer. Change the buffer number by using the rotary input knob. Valid storage buffer numbers are from 1 to 19. Buffer 0 is the factory default setup.

F3: STORE   - Stores the current front-panel setup to the specified storage buffer. Change the buffer number by using the data keys or the rotary input knob. Valid storage buffer numbers range from 1 to 19.

3.6.6 SWEEP Key

Selects the Sweep Mode and allows the entering of sweep parameters as Sweep Start, Sweep Stop and Sweep Rate.

To select the sweep mode, press SWEEP, then press the function key that corresponds to the desired Sweep menu option, as shown:

Sweep Menu

F1: ON/OFF   - Operates the sweep function, selecting between Sweep On or Off.

F2: START/STOP   - Defines the Sweep Start and Stop frequencies.

F3: RATE   - Defines the Sweep Rate.

F4: LIN/LOG   - Selects the Sweep Shape, LIN or LOG.

Log Sweep Menu

3.6.7 MODULATION Key

Selects the Modulation mode **AM** or **FM** .
To select the output mode, press MODUL key, then press the function key that corresponds to the desired menu option, as shown:

Modulation Menu

If the **AM** is selected, the following menu is available:

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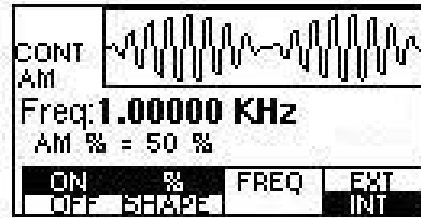
AM Menu

F1: ON/OFF   - Selects the Modulation ON or OFF operating mode.

F2: % /SHAPE   - Defines the modulation depth (from 0 to 100%) and the modulation shape between

SINE, TRIANGLE or SQUARE.

F3: MOD-FREQ - Selects the modulation frequency, from 0.1Hz to 20.00KHz.

F4: EXT/INT   - Selects and enables the external modulation by an external signal applied to the

Modulation In connector.

If the **FM** is selected, the following menu is available:

FM Menu

F1: ON/OFF   - Selects the Modulation ON or OFF operating mode.

F2: DEV/ SHAPE   - Defines the FM deviation frequency or the modulation shape, between SINE,

TRIANGLE or SQUARE.

F3: MOD-FREQ   - Selects the modulation frequency, from 0.1Hz to 20.00KHz.

F4: EXT/INT   - Selects and enables the external modulation by an external signal applied to the

Modulation In connector.

3.7 ON Key

Use these key to control the main output signal. When the output is active, an internal LED is illuminated.

3.8 Cursor Movement Keys

Use these keys to move the cursor (when visible) either left or right. They are used in conjunction with the rotary input knob to set the step size of the rotary input knob.

3.9 Rotary Input Knob

Use this knob to increase and decrease numeric values or to scroll through a list. The cursor indicates the low-order position of the displayed value which changes when you rotate the knob (for straight numeric entries only). For other types of data, the whole value changes when you rotate the knob.

3.10 Power-On Settings

At power-on, the waveform generator performs a diagnostic self-test procedure to check itself for errors. If it find an error, and error code and text appear in the display window. Other error codes appear when you enter and invalid front-panel setting. For more information on error codes, see the Error Indication section. When the waveform generator finishes the diagnostic self-test routine, it enters the local state (LOGS) and assumes power-on default settings. Table 3-2 lists the factory default settings. You can program the waveform generator for any settings you want at power on, as described earlier in this section.

Table 3-2
Power-on Default Settings

Key Function		Comments
FREQUENCY	100000 Hz	Wave frequency
RATE(ARB)	1 us	Sample time per point
AMPLITUDE	5.00V	Peak-to-peak output amplitude
FUNCTION	SINE	Output waveform
OFFSET	0.00V	Zero offset
REPITITION	10ms	Internal trigger rate
MODE	CONT	Waveform mode
N-BURST	2	Waves per burst
START ADRS	1	Start memory address
WAVELENGTH	500	Number of points per waveform
TRIG SOURCE	EXT	External trigger source
OUTPUT	ON	Output enabled
SWEEP	OFF	Sweep execution

MODULATION	OFF	Modulation execution

3.11   Memory

The waveform generator uses a Nonvolatile FLASH for storing arbitrary waveform data and front panel settings. Up to 1000 points Arbitrary waveform and 20 front panel settings are stored.

Because it is impossible to 100% guarantee against loss of stored data, you should maintain a record of the data stored in memory so that you can manually restore such data, if necessary.

3.12   Displaying Errors

At power-on, the waveform generator performs a diagnostic routine to check itself for problems. If the diagnostic routine finds an error, an error message is displayed. The waveform generator also displays error messages when front-panel settings are either invalid or may produce unexpected results.

Error messages for Model 4045

Message Text	Cause
Out of range	Attempt to set variable out of instrument limits.
Setting conflict	Can't have this parameter set with some other.
Trig rate short	Internal trigger rate too short for wave/burst.
Empty location	Attempt to restore non existent setting.
SCALE too high	Attempt to set scale too high for current dot value
Protected RAM	Attempt to write to protected RAM range.
RAM error	Error in testing RAM.
Save RAM	New firmware installed.
Must divide by 4	Predefined wave length must be divisible by 4.
Must divide by 2	Predefined wave length must be divisible by 2.

3.13   Using The Model 4045

This section explains how to generate various waveforms and modify the output waveform, including:

*   Generating a standard waveform
*   Creating an arbitrary waveform
*   Generating a waveform output
*   Modifying waveform output
*   Storing and recalling a waveform generator setup

3.13.1   Selecting a Standard Waveform

You can select several standard waveforms as: sine, triangle and square. Creating a standard waveform

requires selecting the waveform type, parameters, modes, etc., and their settings that define the waveform. Generating a standard waveform requires the following:

* Selecting the waveform
* Setting the output frequency
* Setting the output amplitude and offset

3.13.2 Setting the Output Mode

To set the output mode:
1. Press MODE to display the Mode menu on the display window.
2. Press the function key (Fl to F4) that corresponds to the desired mode.

3.13.3 Setting the Output

To set the output channel, press the Output ON key. An internal LED is illuminated to indicate that the Output is ON.

3.14   Examples

3.14.1 Creating an Arbitrary Waveform

You can create an arbitrary waveform using the following methods:

* Enter individual data points
* Draw lines between data points
* Create a predefined waveform
* Combine any of these methods

No need to use all 1,000 data points for one waveform. You can program any number of waveforms into waveform memory, keeping in mind the addresses where one waveform ends and the other begins. The waveform's frequency and amplitude are influenced by the number of data points and their value in the waveform. For further information on how the number of data points influence the frequency and amplitude of a waveform in execution memory, see the Setting the Frequency and Setting the Amplitude sections, respectively.

3.14.2 Entering Individual Data Points

The most basic way to program an arbitrary waveform is to enter data points for the waveform, one data point at a time. While this can become tedious the auto-increment function helps this process.
To enter individual data points into waveform memory, follow these steps:
1. Press ARB main key to display the selection menu.
2. Press F4 :ARB to display the arbitrary menu.
3. Press F3:EDIT to display the Edit menu.
4. Press F1:POINT, to select the point by point programming mode.
5. Press F1:ADDRESS
6. Use the rotary knob or the numerical keys to enter the address.

7. Press F2:DATA.
8. Use the rotary knob r the numerical keys to enter the value for the data point. Valid entries range from −2047 to 2047.
9. Repeat steps 5 through 9 until you finish programming your arbitrary waveform.

NOTE: *Each time you press ENTER to complete a data point entry in numerical mode, the auto-increment address advances the "A= value" by one.*

3.14.3 Setting the Arbitrary Frequency

The arbitrary waveform frequency is a function of the number of data points used to run the waveform (the length parameter in the ARBITRARY menu) and the waveform execution point rate. The waveform execution point rate is the execution time between each point in the waveform. The total time taken to run one period of the waveform is given by:

$$\text{number of points X rate}$$

Because the output frequency is a function of the rate and the number of points being executed, the output frequency other waveform is:

$$\text{frequency} = \frac{1}{\text{number of points X rate}}$$

For example, to set the output frequency to 1000Hz, given the number of data points used for the waveform output is 1000, calculate:

$$\text{rate} = \frac{1}{1000 \text{ points X } 1000Hz} = 1 \text{ us}$$

EXAMPLE: Setting the Output Frequency
To set the output frequency of a 1000 point waveform in execution memory to 1000Hz, set the rate to 1us:

ACTION	KEYSTROKES
Step 1. Set the output rate to 1 us (equivalent to 1000Hz output frequency)	PARAMETER F1 :RATE 1 KHz/us

3.14.4 Setting the Amplitude

The following equation represents the relative output amplitude voltage relationship between the front-panel amplitude peak-to-peak setting and the data point values in waveform memory:

$$\text{output voltage} = \frac{\text{amplitude p-p setting x data point value}}{4095} + \text{offset}$$

Where 4095 is the data point value range in waveform memory.

Table 3-4: Relative Amplitude for Waveform Output (Examples)

Front panel Amplitude Setting	Data Point Value	Relative Output Amplitude Voltage

5V peak-to-peak	2047	2.5V positive peak
5V peak-to-peak	0	0V (offset voltage)
10V peak-to-peak	2047	5V positive peak

3.14.5   Executing an Arbitrary Waveform

To load a waveform into execution memory, specify its starting address and length in the ARBITRARY menu.

1.   Select the channel to ON.
2.   Press the ARB key and select the F4:ARB function.
3.   Press F1:START to set the address. Valid entries range from 1 to 999.
4.   Press F2:LENGTH to display the length of the waveform.
5.   Use the rotary input knob or the numerical keys to enter the waveform length. Valid entries range from 2 to 1000.

3.14.6   Using Voltage Offset

Through the offset parameter you can add a positive or negative DC level to the output waveform.

To set voltage offset:

1.   Press Waveform to display the menu.
2.   Press F3 :OFST to display the offset setting.
3.   Use the rotary input knob or the numerical keys to set the voltage offset.

To turn the voltage offset OFF, repeat the steps above, but set the offset voltage level to 0.

3.14.7   Storing and Recalling a Waveform Generator Setup

You can store up to 20 front-panel setups in a part of nonvolatile Flash known as the settings storage memory. When you recall a stored setup, the front-panel settings change to match the settings in the stored setup. These stored and recalled settings include the starting address and length of the arbitrary memory that is loaded in the execution memory.

Storing Setups
To store the front-panel setup:

1.   Press UTILITY to display the menu.
2.   Press F2:STORE to select the Store mode.
3.   Use the rotary input knob to select a buffer number. Valid buffer numbers range from 1 to 19. Buffer 0 is a read-only buffer that contains the power-on settings listed in Table 3-3.

The waveform generator does not warn you when you store a setup into a settings buffer that is already occupied.

Recalling Setups
To recall stored front-panel setup:

1.   Press UTILITY to display the menu.

2. Press F1:RECALL to select the Recall mode.
3. Use the rotary input knob to select a buffer number. Valid buffers numbers range from 0 to 19. Buffer 0 is a read-only buffer that contains the power-on settings listed in Table 3-3.

Programming

4.1 Overview

This section provides detailed information on programming the Model 4045 via the USB interface.

4.2 Device States

The device may be in one of the two possible states described below.

4.2.1 Local State (LOCS)

In the LOCS the device may be operated from the front panel.

4.2.2 Remote State (REMS)

In the REMS the device may be operated from the USB interface. Actuating any front panel key will cause the device state to revert to the LOCS.

4.3 Message Exchange Protocol

The device decodes messages using the Message Exchange Protocol similar to the one defined in IEEE 488.2. The following functions implemented in the MEP must be considered:

4.3.1 The Input Buffer

The device has a 128-byte long cyclic input buffer. Decoding of remote messages is begun as soon as the input buffer is not empty, that is, as soon as the controller has sent at least one byte to the device. Should the input buffer be filled up by the controller faster than the device can remove the bytes and decode them, the bus handshake (CTS/RTS) is used to pause data transfer until room has been made for more bytes in the buffer. This prevents the controller from overrunning the device with data.

4.3.2 The Output Queue

The device has a 100-byte long output queue in which it stores response messages for the controller to read. If at the time a response message is formatted the queue contains previously formatted response messages, such that there is not enough place in the queue for the new message, the device will put off putting the message in the queue until there is place for it.

4.3.3 Response Messages

The device sends a Response Message in response to a valid query. All queries return a single Response Message Unit. In only one case is the Response Message generated when the response is read (as opposed to when the response is parsed), and this is when querying Arbitrary Waveform data. All other queries generate the Response Message when they are parsed.

4.4 Instrument Identification

The *IDN? common query is used to read the instrument's identification string. The string returned is as follows:

B&K PRECISION,MODEL 4045,0,V0.1

The "V0.1" reflects the firmware version number and will change accordingly.

4.5 Instrument Reset

The *RST common command effects an instrument reset to the factory default power up state.

4.6 Command Syntax

4.6.1 General Command Structure

A Program Message is defined as a string containing one Program Message Units, which is an instrument command or query. The Program Message is terminated by the Program Message Terminator.

The Program Message Terminator consists of optional white space characters, followed by the Linefeed (LF) character (ASCII 0A);

The Program Message Unit can be divided into three sections as follows:

a) Program Header

The Program Header represents the operation to be performed, and consists of ASCII character mnemonics. Two types of Program Headers are used in the Model 4045: Instrument-control headers and Common Command and Query headers. Common Command and Query Program Headers consist of a single mnemonic prefixed by an asterisk ('*').

The mnemonics consist of upper - or lower-case alpha characters.

Example: The command to set the frequency to 1KHZ may be written in the following ways:

FREQ 1KHZ
FREQ 1000HZ
FREQ 1000
FREQ 1E3
freq 1khz

freq 1000hz
freq 1000
freq 1e3

b) Program Header Separator

The Program Header Separator is used to separate the program header from the program data. It consists of one or more white space characters, denoted as <ws>. Typically, it is a space.

c) Program Data

The Program Data represent the values of the parameters being set, for example, the '1KHZ' in the above examples. Different forms of program data are accepted, depending on the command. The Program Data types used in the instrument are:

i) Character program data

This form of data is comprised of a mnemonic made up of lower - or upper-case alpha characters. As with Program Header mnemonics, some Character Data mnemonics have short and long forms. Only the short or the long form may be used.

ii) Boolean data

Boolean data indicate that the parameter can take one of two states, ON or OFF. The parameter may be character type ON or OFF or numeric. A numeric value is rounded to an integer. A non-zero result is interpreted as 1 (ON), and a zero result as 0 (OFF). Queries return the values 0 or 1.

iii) NRf

This is a decimal numeric data type, where
NR1 indicates an integer number,
NR2 indicates a fixed point real number, and
NR3 indicates a floating point real number.

iv) Numeric value program data

This data type defines numeric values, as well as special cases of Character Data. Numeric values may be specified in any of Integer, Fixed Point or Floating Point format. All parameters which have associated units accept a suffix, which may be specified using upper or lower-case characters. When the suffix is not specified, the numeric value is accepted in the default units, which are Hertz for frequency, Seconds for time, and Volts for voltage. To set the frequency to 1KHz we can send one of the following commands:

FREQ 1000
FREQ 1E3

The special forms of character data accepted as numbers are

MAXimum: sets the parameter to its maximum value.
MINimum: sets the parameter to its minimum value.

For example, to set the frequency to it's maximum value we can send the command

FREQ MAX

vi) Arbitrary Block Data

The Arbitrary block data type is used to send arbitrary waveform data to the instrument. In this data type, the waveform points are specified in binary format, and each point consists of two bytes. Two types of arbitrary block data are defined (by IEEE 488.2):

Definite Form

The Definite Form has the structure:

-#-Byte Count Length - Byte Count - 8-bit byte

The Byte Count Length consists of a single ASCII digit from 1 to 9. It tells the parser how many digits are in the Byte Count.

The Byte Count is a decimal integer made up of the number of digits specified in the Byte Count Length. It tells the parser how many 8-bit bytes are being sent.

Indefinite Form

The Indefinite Form has the structure:

- # - 0 – 8-bit byte – LF

Some Program Message Units either require, or can accept, more than one data element. Program data elements are separated from each other by the Program Data Separator. It is defined as optional white space characters followed by a comma (','), which in turn is followed by optional white space characters.

There are two types of Program Message Units: Command Message Units and Query Message Units. A Query differs from a Command in that the Program Header is terminated with a question mark ('?'). For example, the frequency might be queried with the following query:

FREQ?

Some Query Message Units accept data, giving the device more specific information about what is being queried. In many cases the Query Message Unit may optionally be supplied with the MIN or MAX mnemonics as data. This tells the device to return the minimum or maximum value to which the parameter may currently be set. For example,

FREQ? MAX

will return the maximum value to which the frequency may currently be set.

Not all Program Message units have query forms (for example, SAV), and some Program Message Units might have only the query form (for example IDN?).

The instrument puts the response to the query into the output queue, from where it may be read by the controller.

4.7 Status Reporting

The instrument is capable of reporting status events and errors to the controller.

4.7.1 The Error Queue

The error queue is used to store codes of errors detected in the device. It is implemented as a cyclic buffer of length 10. The error queue is read with the following query:

ERR?

The first error in the queue is returned, and the queue is advanced.

4.7.2 Error Codes

The negative error codes are defined by SCPI. Positive codes are specific to the instrument.

The error message is returned in the form:

<error number>,"<error description>"

A table of error numbers and their descriptions is presented here.

No error reported

0 - No error

Command Errors

A command error is in the range -199 to -100, and indicates that a syntax error was detected. This includes the case of an unrecognized header.

-100	Command Error
-101	Invalid character
-102	Syntax error
-103	Invalid separator
-104	Data type error
-108	Parameter not allowed
	More parameters than allowed were received
-109	Missing parameter
	Fewer parameters than necessary were received
-110	Command header error
-111	Header separator error
-112	Program mnemonic too long
	The mnemonic must contain no more than 12 characters.
-113	Undefined header
-120	Numeric data error
-121	Invalid character in number
-123	Exponent too large
-124	Too many digits
-128	Numeric data not allowed
	A different data type was expected
-131	Invalid suffix
-134	Suffix too long
-138	Suffix not allowed
-140	Character data error.
-141	Invalid character data.

	Incorrect character data were received.
-144	Character data too long
	Character data may contain no more than 12 characters.
-148	Character data not allowed
-158	String data not allowed
-161	Invalid block data
	An error was found in the block data
-168	Block data not allowed
-178	Expression data not allowed

Execution Errors

An execution error indicates that the device could not execute a syntactically correct command, either since the data were out of the instrument's range, or due to a device condition.

-200	Execution error
	An attempt was made to RECALL the contents of an uninitialized stored setting buffer.
-211	Trigger ignored.
	The *TRG common command was ignored due to the device not being in the correct state to execute the trigger.
-220	Parameter error.
	A parameter is in the correct range, but conflicts with other parameters.
-221	Settings conflict.
	The parameter is out of range due to the current instrument state.
-222	Data out of range.
-223	Too much data.
	The arbitrary waveform memory limit has been exceeded.
-224	Illegal parameter value.
	The parameter value must be selected from a finite list of possibilities.

Device-Specific Errors

An error specific to the device occurred.

-315	Configuration memory lost.
	Device memory has been lost.
-330	Self-test failed.
-350	Queue overflow.
	Error codes have been lost due to more than 10 errors being reported without being read.

Query Errors

A query error indicates that the output queue control has detected a problem. This could occur if either an attempt was made to read data from the instrument if none was available, or when data were lost. Data could be lost when a query causes data to be formatted for the controller to be read, and the controller sends more commands without reading the data.

-410	Query INTERRUPTED.
	Data were sent before the entire response of a previous query was read.
-420	Query UNTERMINATED.

An attempt was made to read a response before the complete program message meant to generate that response was sent.

Warnings

The execution of some commands might cause an undesirable instrument state. The commands are executed, but a warning is issued.

500	Trigger rate short
510	Output overload

"Trigger rate short" means that the period of the waveform is larger than the value of the internal trigger rate. Thus not every trigger will generate a cycle (or burst) of the waveform.

4.8   Common Commands

4.8.1   System Data Commands

a) ***IDN?** - Identification query

The identification query enables unique identification of the device over the GPIB. This query should always be the last in a program message. It returns a string with four fields:

Manufacturer name
Model name
Serial number (0 if not relevant)
Version number

Command
Type: Common Query
Syntax: *IDN?
Response: B&K PRECISION, MODEL 4045,0,V1.1

4.8.2   Internal Operation Commands

a) ***RST** - Reset command

The Reset command performs a device reset. It causes the device to return to the factory default power up state.

Type: Common Command
Syntax: *RST

4.8.3   Device Trigger Commands

a) ***TRG** - Trigger command

> This command is analogous to the IEEE 488.1 Group Execute Trigger interface message, and has the same effect. It is used to trigger the device to output a wave, and is accepted only when the trigger mode is set to Trigger, Gate or Burst, and the trigger source is set to BUS.

Type: Common Command

Syntax: *TRG

4.8.4 Stored Settings Commands

a) ***RCL** - Recall instrument state

This command is used to restore the state of the device to that stored in the specified memory location.

Arguments
Type   <NRf>
Range   0 to 49. Non integer values are
                rounded before execution

Type: Common Command
Syntax: *RCL<ws><NRf>
Example: *RCL 0 (Recall default state)
                *RCL 49

Stored setting location 50 stores the last instrument setting before power down.

b) ***SAV** - Save instrument state

This command is used to store the current instrument state in the specified memory location.

Arguments
Type: <NRf>
Range: 1 to 49. Non integer values are rounded before execution
Type: Common Command
Syntax: *SAV<ws><NRf>
Example: *SAV 25

Stored setting location 0 stores the factory defaults, and is a read-only location. Location 50 stores a copy of the current instrument setting, and it, too, is read-only.

4.9 Instrument Control Commands

Instrument control commands are grouped into logical subsystems according to the SCPI instrument Model. The commands are comprised of mnemonics indicating the subsystem to which the command belongs, and the hierarchy within that subsystem. When the command is to be referred to the Root node, it should be prefixed with a colon (:). Mnemonics appearing in square brackets [...] are optional. The '|' character is used to denote a choice of specifications. The '<ws>' is used to denote a white space character.

4.9.1 Default Subsystem

The Source Subsystem controls the frequency, voltage, amplitude modulation and clock source. The command structure is as follows:

FUNCtion   SINusoid|SQUare|TRIangle||ARBitrary
FREQuency   <numeric value>
AMPLitude   <numeric value>
OFFSet   <numeric value>
DCYCle   **<numeric value>**

MODE	CONT/ TRIG / GATE / BRST
TRIG	INT / EXT
TRAte	<numeric value>
BURSt	<numeric value>
MODULation	OFF/AM/FM/INT/EXT
MODFRequency	<numeric value>
MODSHape	SIN/TRI/ SQU
DEViation	<numeric value>
DEPTh	<numeric value>
SWSTArt	<numeric value>
SWSTOp	<numeric value>
SWRAte	<numeric value>
SWEep	ON/OFF/LIN/LOG

4.9.1.1 *Frequency*

FREQuency <frequency>

The frequency command controls the frequency of the output waveform.

Arguments
Type:	Numeric
Units:	MHz, KHz, Hz (default)
Range:	For SIN and SQU - 10uHz to 31MHz,
	For TRI – 10uHz to 500KHz,
	For ARB - Dependent on the Point Rate and Wavelength.
	Fmax = 1/(20nS * Wavelength)
	Fmin = 1/(50S * Wavelength)
Rounding:	The value is rounded to 10 digits (DDS) or 4 digits (ARB).
Command Type:	Setting or Query
Setting	
Syntax:	FREQuency<ws><frequency>[units]
	FREQuency<ws>MINimum|MAXimum
Examples:	FREQ 5KHZ
	FREQ 5E3
	FREQ MAXIMUM
	FREQ MIN
Query	
Syntax:	FREQuency?[<ws>MAXimum|MINimum]
Examples:	FREQ?
	FREQ? MAX
Response:	NR3

Considerations:

1) The MIN | MAX arguments should be used for ARB waveform only in a Program Message that does NOT contain Program Message Units specifying Arbitrary Point Rate or Wavelength, since the MAXimum or MINimum value is calculated at the time the command is parsed.
2) The MIN and MAX arguments refer to currently settable minimum or maximum.
3) FIXed is alias for CW.

4.9.1.2 Point Rate

RATE <point rate>

This command is used to set the point rate. It is coupled with the frequency of the waveform by the relation:

Frequency = 1/(Point Rate * Wavelength)

Thus changing the point rate will result in a change in frequency.

Arguments
Type: Numeric
Units: s, ms, us, ns
Range: 20ns to 50s
Rounding: to 4 digits
Command Type: Setting or Query
Setting
Syntax: RATE<ws><point rate>[units]
                RATE<ws>MINimum|MAXimum
Examples: RATE 100NS
Query
Syntax: RATe?[<ws>MINimum|MAXimum]
Response: NR3

Note: You can alternately use the :ARB:PRATe command.

4.9.1.3 Amplitude

AMPLitude <p-p amplitude>

The amplitude command is used to set the peak-to-peak amplitude of the output waveform. Note that the amplitude and the offset are limited by the relation

Peak Amplitude + |Offset| <= 5V

Arguments
Type: Numeric
Units: V, mV, VPP, mVPP
Range: 10mV to 10V
Rounding: 1mV from 10mV to 999mV. 10mV from 1V to 10V.
Command Type: Setting or Query
Setting
Syntax: AMPLitude<ws><amplitude>[units]
                AMPLitude<ws>MINimum|MAXimum
Examples: AMPL 2.5
                AMPL 2.5V
                AMPL MAX
Query
Syntax: AMPLitude? <ws>MINimum|MAXimum]

Examples: AMPL?
                 AMPL? MAX
Response: NR2

Considerations:
    1) The MAXimum amplitude is dependent on the offset.
    2) The MAX and MIN arguments should not be used in a program message containing an OFFSet command, since these values are evaluated during parsing, based on the current value of the offset.

4.9.1.4 Offset

OFFSet <offset>

The offset command is used to set the DC offset of the output waveform. Note that the amplitude and the offset are limited by the relation

Peak Amplitude + |Offset| $\leq$ 5V

Arguments
Type: Numeric
Units: V, mV
Range: 10mV to 4.5V
Rounding: to 10mV
Command Type: Setting or Query
Setting
Syntax: OFFSet<ws><offset>[units]
                 OFFSet<ws>MINimum|MAXimum
Examples: OFFS 2.5
                 OFFS 2.5V
                 OFFS MAX
Query
Syntax: OFFSet?[<ws>MINimum|MAXimum]
Examples: OFFS?
                 OFFS? MAX
Response: NR2

Considerations:
    1) The MAXimum offset is dependent on the amplitude.
    2) The MAX and MIN arguments should not be used in a program message containing an AMPLitude command, since these values are evaluated during parsing, based on the current value of the amplitude.

4.9.1.5 Function

FUNCtion

The function command is used to set the type of waveform to be generated by the instrument.

Command Type: Setting or Query
Setting
Syntax: FUNCtion<WS><OPTION>
Examples: FUNC SIN
                 FUNC ARB
Query

Syntax: FUNCtion?
Examples: FUNC?
Response: SIN|TRI|SQU|ARB

The following functions are available:

SINusoid,SQUare, TRIangle, ARBitrary

4.9.1.6 Modulation

The following commands control the modulation:

MODULation

This command activates or deactivates modulation:

Command Type: Setting or Query
Setting
Syntax: MODULation OFF|AM|FM|INT|EXT
Examples: MODULation FM
                MODULation OFF
Query
Syntax: MODULation?
Response: OFF |
                AM INT |
                AM EXT |
                FM INT |
                FM EXT

DEPTh

This command sets the AM modulation depth in %

Arguments
Type: Numeric
Units: none (implied %)
Range: 0 to 100
Rounding: To integer
Command Type: Setting or Query
Setting
Syntax: DEPTh<ws><percent depth>
                DEPTh<ws>MINimum|MAXimum
Examples: DEPTh 50
Query
Syntax: DEPTh?[<ws>MINimum|MAXimum]
Response: NR3

MODFRequency

This command sets the AM and FM modulating waveform frequency

Arguments
Type: Numeric.
Units: MHz, KHz, Hz (default)
Range: Fmax = 20 KHz
                Fmin = 0.01 Hz
Rounding: The value is rounded to 4 digits.

Command Type: Setting or Query
Setting
Syntax: MODFR<ws><frequency>[units]
                MODFR<ws>MINimum|MAXimum
Examples: MODFR 5KHZ
                MODFR 5E3
                MODFR MAXIMUM
                MODFR MIN
Query
Syntax: MODFR?[<ws>MAXimum|MINimum]
Examples: MODFR?
                MODFR? MAX
Response: NR3

MODSHape

This command selects the modulating waveform shape

Arguments
Type: Character
Options: SINusoid, TRIangle, SQUare
Command Type: Setting or Query
Setting
Syntax: MODSHape<ws><SIN|TRI|SQU>
Examples: MODSHape SIN
                MODSHape TRI
Query
Syntax: MODSHape?
Response: SIN|TRI|SQU

DEViation

This command sets the FM modulation deviation
Arguments
Type: Numeric.
Units: MHz, KHz, Hz (default)
Range: Dependent on the carrier frequency, up to 1.56MHz.
                Fmax = carrier frequency
                Fmin = 10 uHz
Rounding: The value is rounded to 4 digits.
Command Type: Setting or Query
Setting
Syntax: DEViation<ws><frequency>[units]
                DEViation<ws>MINimum|MAXimum
Examples: DEV 5KHZ
                DEV 5E3
                DEV MAXIMUM
                DEV MIN
Query
Syntax: DEViation?[<ws>MAXimum|MINimum]
Examples: DEV?
                DEV? MAX
Response: NR3

4.9.1.7   Sweep control

The following commands control the sweep functionality:

SWEep

This command activates or deactivates sweep:

Arguments
Type: Boolean
Command Type: Setting or Query
Setting
Syntax: SWE<ws>ON|OFF|LIN|LOG
Examples: SWE ON
                    SWE LIN
Query
Syntax: SWE?
Response: OFF|LIN|LOG

Note: Sweep cannot be activated in ARB or if FM is active.

SWRAte

This command sets the time for one complete sweep:

Arguments
Type: Numeric
Units: S, mS, uS, nS
Range: 10mS to 500S
Rounding: to 4 digits
Command Type: Setting or Query
Setting
Syntax: SWRAte<ws><time>[units]
                    SWRAte<ws>MINimum|MAXimum
Examples: SWRAte 50MS
Query
Syntax: SWRAte?[<ws>MINimum|MAXimum]
Response: NR3

SWSTArt

This command sets the start frequency of the sweep:

Arguments
Type: Numeric.
Units: MHz, KHz, Hz (default)
Range: Dependent on the frequency range of the current function.
                    Rounding: The value is rounded to 4 digits.
Command Type: Setting or Query
Setting
Syntax: SWSTArt<ws><frequency>[units]
                    SWSTArt<ws>MINimum|MAXimum
Examples: SWSTArt 5KHZ
                    SWSTArt 5E3
                    SWSTArt MAXIMUM
                    SWSTArt MIN
Query
Syntax: SWSTArt?[<ws>MAXimum|MINimum]

Examples: SWSTArt ?
                       SWSTArt ? MAX
Response: NR3

SWSTOp

This command sets the stop frequency of the sweep:

Arguments
Type: Numeric
Units: MHz, KHz, Hz (default)
Range: Dependent on the frequency range of the current function.
Rounding: The value is rounded to 4 digits.
Command Type: Setting or Query
Setting
Syntax: SWSTOp<ws><frequency>[units]
                  SWSTOp<ws>MINimum|MAXimum
Examples: SWSTOp 5KHZ
                  SWSTOp 5E3
                  SWSTOp MAXIMUM
                  SWSTOp MIN
Query
Syntax: SWSTOp?[<ws>MAXimum|MINimum]
Examples: SWSTOp ?
                  SWSTOp ? MAX
Response: NR3

4.9.1.8 Duty Cycle

DCYCle <duty cycle value>

This command is used to set the duty-cycle of the square wave or the symmetry of triangular wave.
The value is given in percent .

Arguments
Type: Numeric
Units: None (percent implied)
Range: 20 to 80
Rounding: To integer
Command Type: Setting or Query
Setting
Syntax: DCYCle <ws><duty cycle value>
                  DCYCle <ws>MINimum|MAXimum
Query
Syntax: DCYCle?[<ws>MINimum|MAXimum]
Response: NR3

4.9.1.9 Output State

:OUT <state 0,1>

 This command controls whether the output is ON or OFF.

Arguments
Type: Boolean
Command Type: Setting or Query
Setting
   Syntax: :OUT<ws>ON|1|OFF|0
   Examples: :OUT ON
                :OUT OFF
Query
   Syntax: :OUT?
   Response: 0|1

4.9.1.10 Trigger Mode

MODE <trigger mode>

This command is used to set the trigger mode.

Arguments
Type: Character
Options: CONTinuous
                 TRIGger
                 GATE
                 BURSt
Command Type: Setting or Query
Setting
Syntax: MODE<ws><option>
Examples: MODE CONT
                 MODE BURS
Query
Syntax: MODE?
Response: CONT|TRIG|GATE|BURS

4.9.3.2 Trigger Source

TRIGger<trigger source>

This command is used to select the trigger source, for use in the Trigger, Gate and Burst trigger modes.

Arguments
Type: Character
Options: INTernal - Internal trigger
                 EXTernal - External trigger
Command Type: Setting or Query
Setting
Syntax: TRIGger<ws><option>
Examples: TRIG EXT
                 TRIG INT
Query
Syntax: TRIGger?
Response: INT|EXT

4.9.3.3 Burst Count

BURSt <burst count>

Used to set the number of cycles to be output in the BURST mode. It is not a standard SCPI command.

Arguments
Type: Numeric
Range: 2 to 65535
Rounding: To integer value
Command Type: Setting or Query
Setting
Syntax   BURSt<ws><value>
Examples   BURS 100
                 BURS MAXIMUM
Query
Syntax: BURSt?[<ws>MAXimum|MINimum]
Response: NR1
Examples: BURST?
                 BURS? MAX

4.9.3.4 Internal Trigger Rate

TRAte <trigger rate>

Sets the rate of the internal trigger.

Arguments
Type: Numeric
Units: S, mS, uS, nS
Range: 1E-6S to 100S
Rounding: to 4 digits
Command Type: Setting or Query
Setting
Syntax: TRAte<ws><value>[units]
                 TRAte<ws>MINimum|MAXimum
Examples: TRAte 10E-6
                 TRAte MIN
Query
Syntax: TRAte?[<ws>MINimum|MAXimum]
Response: NR3
Examples: TRAte?
                 TRAte? MIN

4.9.4 Arbitrary Subsystem

The Arbitrary subsystem is not part of the SCPI standard. It was developed to suit the needs of the instrument. Within this subsystem are found commands to:
    1) control the point rate, start address, wavelength, and synchronization pulse address;
    2) set values of the arbitrary waveform, either discretely or using predefined, copy or draw functions;
    3) protect an area of waveform memory;
    4) set the state of the automatic update and increment features;
    5) update the waveform.
The following shows the structure of the ARBitrary subsystem:

:ARBitrary

:PRATe \<numeric value\>
:ADDRess \<numeric value\>
:DATA \<numeric value\>|\<arbitrary block\>
:DRAW \<numeric value\>,\<numeric value\>
:PREDefined \<shape\>,\<start address\>,\<length\>,\<scale\>
:STARt \<numeric value\>
:LENGth \<numeric value\>
:SAVe

4.9.4.1 Point Rate

ARBitrary:PRATe \<point rate\>

This command is used to set the point rate. It is coupled with the frequency of the waveform by the relation:

Frequency = 1/(Point Rate * Wavelength)

Thus changing the point rate will result in a change in frequency.

Arguments
Type: Numeric
Units: S, mS, uS, nS
Range: 20nS to 50S
Rounding: to 4 digits
Command Type: Setting or Query
Setting
Syntax: :ARBitrary:PRATe\<ws\>\<point rate\>[units]
                 :ARBitrary:PRATe\<ws\>MINimum|MAXimum
Examples: :ARB:PRAT 100NS
Query
Syntax**:**   :ARBitrary:PRATe?[\<ws\>MINimum|MAXimum]
Response: NR3

Note: You can alternately use the RATE command.

4.9.4.2 Address

:ARBitrary:ADDRess \<address\>

This command sets the current address of the waveform. It is used to determine where arbitrary data are to be written.

Arguments
Type: Numeric
Range: 1 to 1,000
Rounding: to integer value
Command Type: Setting or Query
Setting
Syntax: :ARBitrary:ADDRess\<ws\>\<address\>
                 :ARBitrary:ADDRess\<ws\>MINimum|MAXimum
Examples: :ARB:ADDR 100
Query

Syntax: :ARBitrary:ADDRess?[<ws>MINimum|MAXimum]
Response: NR1

4.9.4.3 Data

:ARBitrary:DATA <data>

This command is used to set the values of the waveform.

Arguments
Type: Numeric. Definite form arbitrary block. Indefinite form arbitrary block
Numeric Range: -2047 to 2047 ASCII
Rounding: to integer value
Command Type: Setting or Query
Setting Syntax
Numeric: :ARBitrary:DATA<ws><numeric>{[,<numeric]}
Example   :ARB:DATA 100,200,1000,2000,-2000
Query
Syntax: :ARBitrary:DATA?<ws><number of points>[, ASCii]
Response: Data are returned in the decimal numeric form.

4.9.4.4 Line Draw

:ARBitrary:DRAW <start address>,<end address>

This command is used to generate a straight line between two points in the arbitrary waveform
memory.

Arguments
Type: Numeric.
Range: 1 to 500,000
Rounding: to integer value
Command Type: Setting only
Setting
Syntax: :ARBitrary:DRAW<ws><start address>, <end address>
Example: :ARB:DRAW 1,1000

Considerations:
1) The value of the data at the start and end points must first be set by the user, using the
   :ARB:DATA command.
2) The range of the straight line cannot overlap with protected memory.
3) The end address must be greater than the start address.

4.9.4.5 Predefined waveforms

:ARB:PRED <shape>,<start address>,<length>,<scale>

This command is used to load the waveform memory with a specific type of waveform.

Arguments
Shape
Type: Character

Options:	SINusoid
	SQUare
	TRIangle
	NOISe (Pseudo-Random Noise)
	ANOise (Noise added to the current waveform)

Start Address
Type:	Numeric. The MIN and MAX forms both set the address to 1
Range:	1 to 1000
Rounding:	to integer value

Length
Type:	Numeric
Range	

SIN:	16 to 1000; divisible by 4
SQU:	2 to 1000; divisible by 2
TRI:	16 to 1000; divisible by 4
NOIS:	16 to 1000,
ANO:	16 to 1000,
Rounding:	to integer value.

Scale
Type:	Numeric. MIN sets the scale to 1; MAX sets the scale to 100
Range:	1 to 100 (See considerations)
Rounding;	to integer value.
Command Type:	Setting only
Setting	
Syntax:	:ARBitrary:PREDefined<ws> <shape>, <start>, <length>,<scale>
Examples:	:ARB:PRED SIN,1,1e3,100

Considerations:
1) The start address and the length must meet the specification:
    Start address + Length - 1 <= 1,000
2) The 'scale' refers to the scaling of the waveform as a percentage of full scale. A scale of 100% will, under the correct conditions, generate a waveform whose data values range from -2047 to +2047. These 'correct conditions' are set by the 'offset' value. This offset is the value of the data at the start address, and determines the maximum scale settable. The following table shows the data values required in order to achieve maximum scale.

SHAPE	DATA
SIN	0
SQU	0
TRI	0
NOIS	0

4.9.4.6 Start Address

:ARBitrary:STARt <start address>

This command sets the start address of the waveform to be run.

Arguments
Type:	Numeric
Range:	1 to 999
Rounding:	to integer value
Command Type:	Setting or Query

Setting
Syntax: :ARBitrary:STARt<ws><start address>
             :ARBitrary:STARt<ws>MINimum|MAXimum
Example: :ARB:STAR 100
Query
Syntax: :ARBitrary:STARt?[<ws>MINimum|MAXimum]
Examples: :ARB:START?
             :ARB:STAR? MIN
Response: NR1

Considerations: The start address and length must meet the condition:
     Start Address + Length - 1 <= 1000

4.9.4.7 Wavelength

:ARBitrary:LENGth <length>

This command sets the length of the waveform being run.

Arguments
Type: Numeric
Range: 2 to 1000
Rounding: to integer value
Command Type: Setting or Query
Setting
Syntax: :ARBitrary:LENGth<ws><length>
               :ARBitrary:LENGth<ws>MINimum|MAXimum
Example: :ARB:LENG 1E3
Query
Syntax: :ARBitrary:LENGth?[<ws>MINimum|MAXimum]
Example: :ARB:LENG?
Response: NR1

Considerations:
     1) Changing the wavelength will change either the frequency.
     2) The minimum wavelength is 2.

4.9.4.8 Save

:ARBitrary:SAVe

This command is used to save all unsaved arbitrary waveform data into non-volatile memory..

Arguments
Type: none
Command Type: Setting only
Setting
Syntax: :ARBitrary: SAVe

4.9.5 Error Queue Reading

ERRor?
This query returns the first entry in the error queue, and removes that entry from the queue.

Command Type: Query only
Query
Syntax: ERRor?
Response: <Error number>, "<error description>"

ASCII & GPIB CODE CHART

BITS B4 B3 B2 B1	CONTROL		NUMBERS SYMBOLS		UPPER CASE		LOWER CASE	
0 0 0 0	0 NUL 0 (0)	20 DLE 10 (16)	40 SP 20 (32)	60 0 30 (48)	100 @ 40 (64)	120 P 50 (80)	140 ` 60 (96)	160 p 70 (112)
0 0 0 1	1 SOH 1 (1)	21 GTL / DC1 / LLO 11 (17)	41 ! 21 (33)	61 1 31 (49)	101 A 41 (65)	121 Q 51 (81)	141 a 61 (97)	161 q 71 (113)
0 0 1 0	2 STX 2 (2)	22 DC2 12 (18)	42 " 22 (34)	62 2 32 (50)	102 B 42 (66)	122 R 52 (82)	142 b 62 (98)	162 r 72 (114)
0 0 1 1	3 ETX 3 (3)	23 DC3 13 (19)	43 # 23 (35)	63 3 33 (51)	103 C 43 (67)	123 S 53 (83)	143 c 63 (99)	163 s 73 (115)
0 1 0 0	4 SDC / EOT 4 (4)	24 DC4 / OCL 14 (20)	44 $ 24 (36)	64 4 34 (52)	104 D 44 (68)	124 T 54 (84)	144 d 64 (100)	164 t 74 (116)
0 1 0 1	5 PPC / ENQ 5 (5)	25 PPU / NAK 15 (21)	45 % 25 (37)	65 5 35 (53)	105 E 45 (69)	125 U 55 (85)	145 e 65 (101)	165 u 75 (117)
0 1 1 0	6 ACK 6 (6)	26 SYN 16 (22)	46 & 26 (38)	66 6 36 (54)	106 F 46 (70)	126 V 56 (86)	146 f 66 (102)	166 v 76 (118)
0 1 1 1	7 BEL 7 (7)	27 ETB 17 (23)	47 ' 27 (39)	67 7 37 (55)	107 G 47 (71)	127 W 57 (87)	147 g 67 (103)	167 w 77 (119)
1 0 0 0	10 GET / BS 8 (8)	30 SPE / CAN 18 (24)	50 (28 (40)	70 8 38 (56)	110 H 48 (72)	130 X 58 (88)	150 h 68 (104)	170 x 78 (120)
1 0 0 1	11 TCT / HT 9 (9)	31 SPD / EM 19 (25)	51) 29 (41)	71 9 39 (57)	111 I 49 (73)	131 Y 59 (89)	151 i 69 (105)	171 y 79 (121)
1 0 1 0	12 LF 1A (10)	32 SUB 1A (26)	52 * 2A (42)	72 : 3A (58)	112 J 4A (74)	132 Z 5A (90)	152 j 6A (106)	172 z 7A (122)
1 0 1 1	13 VT 1B (11)	33 ESC 1B (27)	53 + 2B (43)	73 ; 3B (59)	113 K 4B (75)	133 [5B (91)	153 k 6B (107)	173 { 7B (123)
1 1 0 0	14 FF 1C (12)	34 FS 1C (28)	54 , 2C (44)	74 < 3C (60)	114 L 4C (76)	134 \ 5C (92)	154 l 6C (108)	174	7C (124)
1 1 0 1	15 CR 1D (13)	35 GS 1D (29)	55 - 2D (45)	75 = 3D (61)	115 M 4D (77)	135] 5D (93)	155 m 6D (109)	175 } 7D (125)
1 1 1 0	16 SO 1E (14)	36 RS 1E (30)	56 . 2E (46)	76 > 3E (62)	116 N 4E (78)	136 ^ 5E (94)	156 n 6E (110)	176 ~ 7E (126)
1 1 1 1	17 SI 1F (15)	37 US 1F (31)	57 / 2F (47)	77 ? / UNL 3F (63)	117 O 4F (79)	137 _ / UNT 5F (95)	157 o 6F (111)	177 DEL (RUBOUT) 7F (127)

| ADDRESSED COMMANDS | UNIVERSAL COMMANDS | LISTEN ADDRESSES | | TALK ADDRESSES | | SECONDARY ADDRESSES OR COMMANDS (PPE) (PPD) | |

octal 25 PPU — GPIB code
NAK — ASCII character
hex 15 21 — decimal

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4.10 USB Virtual COM Programming

4.10.1 General

The INSTALLATION section of this manual describes the USB virtual COM connection for the instrument.

A USB virtual COM port is a software interface that enables applications to access a USB device as if it were a built-in serial port.

The baud rate is the bit rate during the transmission of a word in bits per second. Different devices use many baud rates, but the baud rates of the two devices that are connected must be the same. The instrument is set to a fixed baud rate of 19200 (115200 for instrument with USB virtual COM) as described in Section 3, Operating Instructions.

Data signals over the serial interface use a voltage of +3V to +25V to represent a zero (called a space) and a voltage of -3V to -25V to represent a one (called a mark). Handshake and control lines use +3V to +25V to indicate a true condition and -3V to -25V to indicate a false condition.
When no data is being transmitted, the idle state of the data lines will be the mark state. To transmit a byte, the transmitting device first sends a start bit to synchronize the receiver.

4.10.2 USB Virtual COM Operation

The USB virtual COM standard is not very specific about many of the handshaking signals and it is therefore usually necessary to refer to the manuals for both of the devices being connected to determine the exact pin out, signal definition, and signal direction for the devices.

The instrument is programmed by sending ASCII coded characters to the instrument.
When the instrument is in the remote mode remote command input has priority over any front panel control. Therefore, as long as the serial interface is continuously supplied with data, the keyboard will appear to be inoperative to the user.

The instrument accepts a carriage return (CR) as an end of string (EOS) terminator and sends both a CR and LF as the EOS terminator.