THURLBY THANDAR INSTRUMENTS

TG4001
40MHz DDS FUNCTION/ARBITRARY GENERATOR

INSTRUCTION MANUAL

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Introduction

This synthesised programmable function generator has the following features:

- Sinewaves up to 40MHz, squarewaves up to 50MHz
- 11 standard waveforms available plus pulse and arbitrary
- User defined pulses and pulse trains with 10ns resolution
- Arbitrary waveforms up to 100MHz sampling frequency
- Up to 4 arbitrary waveforms of 4 to 64k points with 12 bit vertical resolution
- Triggering, summing and modulation of all output waveforms
- RS232 and USB and optional GPIB interfaces

The instrument uses a combination of direct digital synthesis and variable clock techniques to provide high performance and extensive facilities in a compact instrument. It can generate a wide variety of waveforms between 0·1mHz and 50MHz with high resolution and accuracy.

Arbitrary waveforms may be played back with 12 bit vertical resolution and from 4 to 65536 horizontal points.

All waveforms can be swept over their full frequency range at a rate variable between 1 millisecond and 15 minutes. Sweep can be linear or logarithmic, single or continuous. Single sweeps can be triggered from the front panel, the trigger input, or the digital interfaces. A sweep marker is provided.

Amplitude Modulation is available for all waveforms and is controlled from an external generator via the MODULATION input socket.

Signal Summing is available for all waveforms and is controlled from an external generator via the SUM input socket.

All waveforms are available as a Triggered Burst whereby each active edge of the trigger signal will produce one burst of the carrier. The number of cycles in the burst can be set between 1 and 1048575. The Gated mode turns the output signal On when the gating signal is true and Off when it is false. Both Triggered and Gated modes can be operated from the internal Trigger Generator (0.005Hz to 100kHz), from an external source (dc to 1MHz) or by a key press or remote command.

The signals from the REF IN/OUT socket and the SYNC OUT socket can be used to phase lock two instruments. This can be used to generate multi–phase waveforms or locked waveforms of different frequencies.

The generator parameters are clearly displayed on a backlit LCD with 4 rows of 20 characters. Soft–keys and sub menus are used to guide the user through even the most complex functions.

All parameters can be entered directly from the numeric keypad. Alternatively most parameters can be incremented or decremented using the rotary control. This system combines quick and easy numeric data entry with quasi–analogue adjustment when required.

The generator has RS232 and USB interfaces as standard which can be used for remote control of all of the instrument functions or for the down–loading of arbitrary waveforms. As well as operating in conventional RS232 mode the serial interface can also be used in addressable mode whereby up to 32 instruments can be linked to a single PC serial port.

There is also a GPIB option.

Specification

Specifications apply at 18–28ºC after 30 minutes warm−up, at maximum output into 50Ω.

WAVEFORMS

Standard Waveforms

Sine, square, triangle, DC, positive ramp, negative ramp, sin(x)/x, pulse, pulse train, cosine, haversine, havercosine and 4 user defined Arbitrary waveforms.

Sine, Cosine, Haversine, Havercosine

Range:	0·1mHz to 40MHz
Resolution:	0·1mHz or 10 digits
Accuracy:	10 ppm for 1 year
Temperature Stability:	Typically <1 ppm/ºC.
Output Level:	2.5mV to 10Vp−p into 50Ω
Harmonic Distortion:	<0.15% THD to 100kHz; <−60dBc to 20kHz
	<−50dBc to 1MHz,
	<−40dBc to 10MHz
	<−30dBc to 40MHz
Non−harmonic Spurii:	<−60dBc to 1MHz, <−60dBc + 6dB/octave 1MHz to 40MHz

Square

Range:	1mHz to 50MHz
Resolution:	1mHz (8 digits)
Accuracy:	10 ppm for 1 year
Output Level:	2.5mV to 10Vp−p into 50Ω
Rise and Fall Times:	<8ns

Triangle

Range:	0.1mHz to 500kHz
Resolution:	0.1mHz or 10 digits
Accuracy:	10 ppm for 1 year
Output Level:	2.5mV to 10Vp−p into 50Ω
Linearity Error:	<0.1% to 30 kHz

Ramps and Sin(x)/x

Range:	0.1mHz to 500kHz
Resolution:	0.1mHz (10 digits)
Accuracy:	10 ppm for 1 year
Output Level:	2.5mV to 10Vp−p into 50Ω
Linearity Error:	<0.1% to 30 kHz

Pulse and Pulse Train

Output Level: 2.5mV to 10Vp−p into 50Ω

Rise and Fall Times: <8ns

Period:

     Range: 40ns to 100s

     Resolution: 8 digit

     Accuracy: 10 ppm for 1 year

Delay:

     Range: −99·99s to + 99·99s

     Resolution: 0·001% of period or 10ns, whichever is greater

Width:

     Range: 10ns to 99·99s

     Resolution: 0·001% of period or 10ns, whichever is greater

Note that the pulse width and absolute value of the delay may not exceed the pulse period at any time.

Pulse trains of up to 10 pulses may be specified, each pulse having independently defined width, delay and level. The baseline voltage is separately defined and the sequence repetition rate is set by the pulse train period.

Arbitrary

Up to 4 user defined waveforms may be stored in non-volatile memory. Waveforms can be defined by downloading of waveform data via RS232, GPIB or USB.

Waveform Memory Size: 4 waveforms – maximum waveform size is 65536 points, minimum waveform size is 4 points

Vertical Resolution: 12 bits

Sample Clock Range: 100mHz to 100MHz

Resolution: 8 digits

Accuracy: 10 ppm for 1 year

Output Filter

Selectable between 40MHz Elliptic, 20MHz Bessel or none.

Noise

Digital noise generated by a 35-bit linear feedback register clocked at 100MHz. User's external filter defines bandwidth and response.

OPERATING MODES

Triggered Burst

Each active edge of the trigger signal will produce one burst of the waveform.

Carrier Waveforms: All standard and arbitrary

Maximum Carrier Frequency: The smaller of 2.5MHz or the maximum for the selected waveform. 100Msamples/s for ARB.

Number of Cycles: 1 to 1,048,575

Trigger Repetition Rate: 0.005Hz to 100kHz internal
dc to 1MHz external.

Trigger Signal Source: Internal from keyboard or trigger generator.
External from TRIG IN or remote interface.

Trigger Start/Stop Phase: ± 360° settable with 0.1° resolution, subject to waveform frequency and type.

Gated

Waveform will run while the Gate signal is true and stop while false.

Carrier Waveforms:	All standard and arbitrary.
Maximum Carrier Frequency:	The smaller of 2.5MHz or the maximum for the selected waveform. 100Msamples/s for ARB.
Trigger Repetition Rate:	0.005Hz to 100kHz internal; dc to 1MHz external.
Gate Signal Source:	Internal from keyboard or trigger generator.
	External from TRIG IN or remote interface.
Gate Start/Stop Phase:	± 360° settable with 0.1° resolution, subject to waveform frequency and type.

Sweep

Frequency sweep capability is provided for both standard and arbitrary waveforms. Arbitrary waveforms are expanded or condensed to exactly 4096 points and DDS techniques are used to perform the sweep.

Carrier Waveforms:	All standard and arbitrary except pulse and pulse train.
Sweep Mode:	Linear or logarithmic, triggered or continuous.
Sweep Direction:	Up, down, up/down or down/up.
Sweep Range:	From 1mHz to 40MHz in one range. Phase continuous. Independent setting of the start and stop frequency.
Sweep Time:	1ms to 999s (3 digit resolution).
Marker:	Variable during sweep.
Sweep Trigger Source:	The sweep may be free run or triggered from the following sources: Manually from keyboard. Externally from TRIG IN input or remote interface.

Tone Switching

Capability provided for both standard and arbitrary waveforms. Arbitrary waveforms are expanded or condensed to exactly 4096 points and DDS techniques are used to allow instantaneous frequency switching.

Carrier Waveforms:	All waveforms except pulse and pulse train.
Frequency List:	Up to 16 frequencies from 1mHz to 40MHz.
Trigger Repetition Rate:	0.005Hz to 100kHz internal; dc to 1MHz external. Usable repetition rate and waveform frequency depend on the tone switching mode.
Source:	Internal from keyboard or trigger generator. External from TRIG IN or remote interface.
Tone Switching Modes:	*Gated:* The tone is output while the trigger signal is true and stopped, at the end of the current waveform cycle, while the trigger signal is false. The next tone is output when the trigger signal is true again.
	Triggered: The tone is output when the trigger signal goes true and the next tone is output, at the end of the current waveform cycle, when the trigger signal goes true again.
	FSK: The tone is output when the trigger signal goes true and the next tone is output, immediately, when the trigger signal goes true again.

Using 2 instruments with their outputs summed together it is possible to generate DTMF test signals.

Trigger Generator

Internal source 0.005 Hz to 100kHz square wave adjustable in 10us steps. 3 digit resolution. Available for external use from the SYNC OUT socket.

OUTPUTS

Main Output

Output Impedance:	50Ω
Amplitude:	5mV to 20Vp−p open circuit (2.5mV to 10Vp−p into 50Ω). Amplitude can be specified open circuit (hi Z) or into an assumed load of 50Ω or 600Ω in Vpk−pk, Vrms or dBm.
Amplitude Accuracy:	2% ±1mV at 1kHz into 50Ω.
Amplitude Flatness:	± 0.2dB to 1MHz; ± 0.4dB to 40MHz
DC Offset Range:	±10V. DC offset plus signal peak limited to ±10V from 50Ω.
DC Offset Accuracy:	Typically 3% ±10mV, unattenuated.
Resolution:	3 digits or 1mV for both Amplitude and DC Offset.

Sync Out

Multifunction output user definable or automatically selected to be any of the following:

Waveform Sync: (all waveforms)	A square wave with 50% duty cycle at the main waveform frequency, or a pulse coincident with the first few points of an arbitrary waveform.
Burst Done:	Produces a pulse coincident with the last cycle of a burst.
Trigger:	Selects the current trigger signal. Useful for synchronizing burst or gated signals.
Sweep Sync:	Outputs a trigger signal at the start of sweep to synchronize an oscilloscope or recorder. Can additionally output a sweep marker.
Phase Lock Out:	Used to phase lock two generators. Produces a positive edge at the 0° phase point.
Output Signal Level:	Logic levels of <0.8V & >3V, except for Sweep Sync. Sweep Sync is a 3-level waveform: low at start of sweep, high for the duration of the last frequency step at end of sweep, with a narrow 1V pulse at the marker point.

INPUTS

Trig In

Frequency Range:	DC − 1MHz.
Signal Range:	Threshold level adjustable ±5V; maximum input ±10V.
Minimum Pulse Width:	50ns, for Trigger and Gate modes; 50us for Sweep mode.
Polarity:	Selectable as high/rising edge or low/falling edge.
Input Impedance:	10kΩ

Modulation In

Frequency Range:	DC − 100kHz.
Signal Range:	VCA: Approximately 1V pk−pk for 100% level change at maximum output; maximum input ± 10V.
	SCM: Approximately ± 1Vpk for maximum output.
Input Impedance:	Typically 1 kΩ.

Sum In

Frequency Range:	DC − 30 MHz .
Signal Range:	Approximately 2 Vpk−pk input for 20Vpk−pk output; maximum input ±10V.
Input Impedance:	Typically 1kΩ.

Ref Clock In/Out

Set to Input:	Input for an external 10MHz reference clock. TTL/CMOS threshold level.
Set to Output:	Buffered version of the internal 10MHz clock. Output levels nominally 1V and 4V from 50Ω.
Set to Phase Lock:	Used together with SYNC OUT on a master and TRIG IN on a slave to synchronise (phase lock) two separate generators.
Maximum Input Voltage:	+5V, −1V.

INTERFACES

Full remote control facilities are available through the RS232, USB or GPIB interfaces.

RS232:	Variable Baud rate, 38400 Baud maximum. 9−pin D−connector.
IEEE−488:	Optional - Conforms with IEEE488.1 and IEEE488.2
USB	1.1

GENERAL

Display:	20 character x 4 row alphanumeric LCD.
Data Entry:	Keyboard selection of mode, waveform etc.; value entry direct by numeric keys or by rotary control.
Stored Settings:	Up to 9 complete instrument set−ups may be stored and recalled from non-volatile memory.
Size:	3U (130mm) height; 212mm (½−rack) width; 335mm long.
Weight:	4.1kg (9lb).
Power:	220-240V nominal 50/60Hz; 110-120V or 100V nominal 50/60/400Hz; nominal voltage adjustable internally; operating range ±10% of nominal; 60VA max. Installation Category II.
Operating Range:	+5°C to 40°C, 20−80% RH.
Storage Range:	−20°C to + 60°C.
Environmental:	Indoor use at altitudes up to 2000m, Pollution Degree 2.
Options:	19 inch rack mounting kit, GPIB remote control interface.
Safety:	Complies with EN61010−1.
EMC:	Complies with EN61326

Safety

This generator is a Safety Class I instrument according to IEC classification and has been designed to meet the requirements of EN61010−1 (Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use). It is an Installation Category II instrument intended for operation from a normal single phase supply.

This instrument has been tested in accordance with EN61010−1 and has been supplied in a safe condition. This instruction manual contains some information and warnings which have to be followed by the user to ensure safe operation and to retain the instrument in a safe condition.

This instrument has been designed for indoor use in a Pollution Degree 2 environment in the temperature range 5°C to 40°C, 20% − 80% RH (non−condensing). It may occasionally be subjected to temperatures between +5° and −10°C without degradation of its safety. Do not operate while condensation is present.

Use of this instrument in a manner not specified by these instructions may impair the safety protection provided. Do not operate the instrument outside its rated supply voltages or environmental range.

WARNING! THIS INSTRUMENT MUST BE EARTHED

Any interruption of the mains earth conductor inside or outside the instrument will make the instrument dangerous. Intentional interruption is prohibited. The protective action must not be negated by the use of an extension cord without a protective conductor.

When the instrument is connected to its supply, terminals may be live and opening the covers or removal of parts (except those to which access can be gained by hand) is likely to expose live parts. The apparatus shall be disconnected from all voltage sources before it is opened for any adjustment, replacement, maintenance or repair.

Any adjustment, maintenance and repair of the opened instrument under voltage shall be avoided as far as possible and, if inevitable, shall be carried out only by a skilled person who is aware of the hazard involved.

If the instrument is clearly defective, has been subject to mechanical damage, excessive moisture or chemical corrosion the safety protection may be impaired and the apparatus should be withdrawn from use and returned for checking and repair.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of makeshift fuses and the short−circuiting of fuse holders is prohibited.

This instrument uses a Lithium button cell for non−volatile memory battery back−up; typical life is 5 years. In the event of replacement becoming necessary, replace only with a cell of the correct type, i.e. 3V Li/Mn0$_2$ 20mm button cell type 2032. Exhausted cells must be disposed of carefully in accordance with local regulations; do not cut open, incinerate, expose to temperatures above 60°C or attempt to recharge.

Do not wet the instrument when cleaning it and in particular use only a soft dry cloth to clean the LCD window. The following symbols are used on the instrument and in this manual:−

Caution −refer to the accompanying documentation, incorrect operation may damage the instrument.

terminal connected to chassis ground.

mains supply OFF.

mains supply ON.

alternating current.

EC Declaration of Conformity

We   Thurlby Thandar Instruments Ltd
Glebe Road
Huntingdon
Cambridgeshire PE29 7DR
England

declare that the

TG4001 40MHz DDS Function/Arbitrary Generator

meets the intent of the EMC Directive 2004/108/EC and the Low Voltage Directive 2006/95/EC. Compliance was demonstrated by conformance to the following specifications which have been listed in the Official Journal of the European Communities.

EMC

Emissions: a)   EN61326 (1998) Radiated, Class A

b)   EN61326 (1998) Conducted, Class B

c)   EN61326 (1998) Harmonics, referring to EN61000-3-2 (2000)

Immunity: EN61326 (1998) Immunity Table 1, Performance B, referring to:

a)   EN61000-4-2 (1995) Electrostatic Discharge

b)   EN61000-4-3 (1997) Electromagnetic Field

c)   EN61000-4-11 (1994) Voltage Interrupt

d)   EN61000-4-4 (1995) Fast Transient

e)   EN61000-4-5 (1995) Surge

f)   EN61000-4-6 (1996) Conducted RF

Safety
EN61010-1 (2001) Installation Category II, Pollution Degree 2.

Chris Wilding

CHRIS WILDING
TECHNICAL DIRECTOR
1 February 2007

EMC

This instrument has been designed to meet the requirements of the EMC Directive 2004/108/EC.

Compliance was demonstrated by meeting the test limits of the following standards:

Emissions

EN61326 (1998) EMC product standard for Electrical Equipment for Measurement, Control and Laboratory Use. Test limits used were:

a)   Radiated: Class A

b)   Conducted: Class B

c)   Harmonics: EN61000-3-2 (2000) Class A; the instrument is Class A by product category.

Immunity

EN61326 (1998) EMC product standard for Electrical Equipment for Measurement, Control and Laboratory Use.

Test methods, limits and performance achieved were:

a)   EN61000-4-2 (1995) Electrostatic Discharge : 4kV air, 4kV contact, Performance A.

b)   EN61000-4-3 (1997) Electromagnetic Field, 3V/m, 80% AM at 1kHz, Performance A.

c)   EN61000-4-11 (1994) Voltage Interrupt, 1 cycle, 100%, Performance A.

d)   EN61000-4-4 (1995) Fast Transient, 1kV peak (AC line), 0.5kV peak (signal lines and RS232/GPIB ports), Performance A.

e)   EN61000-4-5 (1995) Surge, 0.5kV (line to line), 1kV (line to ground), Performance A.

f)   EN61000-4-6 (1996) Conducted RF, 3V, 80% AM at 1kHz (AC line only; signal connections <3m not tested), Performance A.

According to EN61326 the definitions of performance criteria are:

Performance criterion A: 'During test normal performance within the specification limits.'

Performance criterion B: 'During test, temporary degradation, or loss of function or performance which is self-recovering'.

Performance criterion C: 'During test, temporary degradation, or loss of function or performance which requires operator intervention or system reset occurs.'

Cautions

To ensure continued compliance with the EMC directive the following precautions should be observed:

a)   connect the generator to other equipment using only high quality, double–screened cables.

b)   after opening the case for any reason ensure that all signal and ground connections are remade correctly before replacing the cover. Always ensure all case screws are correctly refitted and tightened.

c)   In the event of part replacement becoming necessary, only use components of an identical type, see the Service Manual.

Mains Operating Voltage

Check that the instrument operating voltage marked on the rear panel is suitable for the local supply. Should it be necessary to change the operating voltage, proceed as follows:

1) Disconnect the instrument from all voltage sources.

2) Remove the screws which retain the top cover and lift off the cover.

3) Change the transformer connections following the diagram below.

4) Refit the cover and the secure with the same screws.

5) To comply with safety standard requirements the operating voltage marked on the rear panel must be changed to clearly show the new voltage setting.

6) Change the fuse to one of the correct rating, see below.
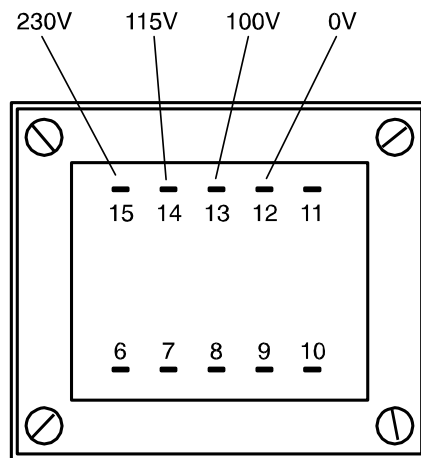
for 230V operation connect the live (brown) wire to pin 15
for 115V operation connect the live (brown) wire to pin 14
for 100V operation connect the live (brown) wire to pin 13

7) Refit the cover and the secure with the same screws.

8) To comply with safety standard requirements the operating voltage marked on the rear panel must be changed to clearly show the new voltage setting.

9) Change the fuse to one of the correct rating, see below.

Fuse

Ensure that the correct mains fuse is fitted for the set operating voltage. The correct mains fuse types are:

for 230V operation: 500 mA (T) 250V HRC
for 100V or 115V operation: 1A (T) 250V HRC

To replace the fuse, disconnect the mains lead from the inlet socket and withdraw the fuse drawer below the socket pins. Change the fuse and replace the drawer.

The use of makeshift fuses or the short−circuiting of the fuse holder is prohibited.

Mains Lead

When a three core mains lead with bare ends is provided it should be connected as follows:–

Brown – **Mains Live**
Blue – **Mains Neutral**
Green / Yellow – **Mains Earth**

WARNING! THIS INSTRUMENT MUST BE EARTHED

Any interruption of the mains earth conductor inside or outside the instrument will make the instrument dangerous. Intentional interruption is prohibited. The protective action must not be negated by the use of an extension cord without a protective conductor.

Mounting

This instrument is suitable both for bench use and rack mounting. It is delivered with feet for bench mounting. The front feet include a tilt mechanism for optimal panel angle.

A rack kit for mounting in a 19" rack is available from the Manufacturers or their overseas agents.

Ventilation

The generator uses a small fan fitted to the rear panel. Take care not to restrict the rear air inlet or the vents at the front (sides and underneath). In rack-mounted situations allow adequate space around the instrument and/or use a fan tray for forced cooling.

Connections

Front Panel Connections

MAIN OUT

This is the 50Ω output from the main generator. It will provide up to 20V peak–to–peak e.m.f. which will yield 10V peak–to–peak into a matched 50Ω load. It can tolerate a short circuit for 60 seconds.

⚠ Do not apply an external voltage to this output.

SYNC OUT

This is a TTL/CMOS level output which may be set to any of the following signals from the **SYNC OUT** screen.

waveform sync	A sync marker phase coincident with the MAIN OUT waveform. For standard waveforms, (sine, cosine, haversines, square, triangle, sinx/x and ramp), the sync marker is a squarewave with a 1:1 duty cycle with the rising edge at the 0º phase point and the falling edge at the 180º phase point. For arbitrary waveforms the sync marker is a positive pulse coincident with the first few points (addresses) of the waveform.
Burst done	Provides a signal during Gate or Trigger modes which is low while the waveform is active at the main output and high at all other times.
Trigger	Provides a positive going version of the actual trigger signal; internal, external, manual and remote all produce a trigger sync.
Sweep sync	Goes low at the start of sweep and high for the duration of the last frequency step at the end of the sweep. In addition, a half-amplitude marker pulse can be set to be output at any of the frequency steps.
Phase lock	Produces a positive edge coincident with the start of the current waveform; this is used for phase locking instruments. This waveform may not appear coherent.

SYNC OUT logic levels are nominally 0V and 5V from typically 50Ω. SYNC OUT will withstand a short circuit.

⚠ Do not apply an external voltage to this output.

TRIG IN

This is the external input for Trigger, Gate, Sweep and Sequence operations. It is also the input used to synchronise the generator (as a slave) to another (which is the master).

⚠ Do not apply an external voltage exceeding ±10V.

Rear Panel Connections

MODULATION IN

This is the input socket for external modulation.

⚠ Do not apply an external voltage exceeding ±10V.

SUM IN

This is the input socket for external signal summing.

⚠ Do not apply an external voltage exceeding ±10V.

REF CLOCK IN/OUT

The function of the CLOCK IN/OUT socket is set from the **ref clock i/o** menu on the **UTILITY** screen, see System Operations section.

input   This is the default setting. The socket becomes an input for an external 10MHz reference clock. The system automatically switches over from the internal clock when the external reference is applied.

output   The internal 10MHz clock is made available at the socket.

phase lock   When two or more generators are synchronised the slaves are set to **phase lock slave** and the master is set to **phase lock master**.

As an output the logic levels are nominally 1V and 4V from typically 50Ω. CLOCK OUT will withstand a short–circuit. As an input the threshold is TTL/CMOS compatible.

⚠ Do not apply external voltages exceeding + 5V or –1V to this signal connection.

Do not apply an external voltage exceeding + 5V or –1V.

MAIN OUT

This plugged panel position is provided for the user to fit a 50Ω BNC as an **alternative** to the front panel MAIN OUT socket where rear panel connections are required in a rack-mounted system. The front panel MAIN OUT connection must be carefully disconnected from the pcb and the pcb then rewired, using high quality 50Ω coax, to the new rear panel connector.

⚠ Do not apply an external voltage to this output.

RS232

9–pin D–connector compatible with addressable RS232 use. The pin connections are shown below:

Pin	Name	Description
1	–	No internal Connection
2	TXD	Transmitted data from instrument
3	RXD	Received data to instrument
4	–	No internal connection
5	GND	Signal ground
6	–	No internal connection
7	RXD2	Secondary received data
8	TXD2	Secondary transmitted data
9	GND	Signal ground

Pin 2, 3 and 5 may be used as a conventional RS232 interface with XON/XOFF handshaking. Pins 7, 8 and 9 are additionally used when the instrument is used in addressable RS232 mode. Signal grounds are connected to instrument ground. The RS232 address is set from the **remote** menu on the **UTILITY** screen, see System Operations section.

GPIB (IEEE–488) OPTIONAL

The GPIB interface is not isolated; the GPIB signal grounds are connected to the instrument ground.

The implemented subsets are:

SH1 AH1 T6 TE0 L4 LE0 SR1 RL1 PP1 DC1 DT1 C0 E2

The GPIB address is set from the **remote** menu on the **UTILITY** screen, see System Operations section.

USB

The USB port is connected to instrument ground. It accepts a standard USB cable. If USB has been selected as the current interface the Windows plug-and-play function should automatically recognise that the instrument has been connected.

Initial Operation

This section is a general introduction to the organisation of the instrument and is intended to be read before using the generator for the first time. Detailed operation is covered in later sections starting with Standard Waveform Operation.

In this manual front panel keys and sockets are shown in capitals, e.g. OFFSET, SYNC OUT; all soft–key labels, entry fields and messages displayed on the LCD are shown in a different type–font, e.g. **WAVEFORM FUNCTIONS**, **sine**.

Switching On

The power switch is located at the bottom left of the front panel.

At power up the generator displays the installed software revision whilst loading its waveform RAM; if an error is encountered the message **system ram error, battery fault or firmware updated** will be displayed, see the Warnings and Error Messages section.

Loading takes a few seconds, after which the status screen is displayed, showing the generator parameters set to their default values, with the MAIN OUT output set off. Refer to the System Operations section for how to change the power up settings to either those at power down or to any one of the stored settings. Recall the status screen at any time with the STATUS key; a second press returns the display to the previous screen.

Change the basic generator parameters as described in the Standard Waveform Operation section and switch the output on with the MAIN OUT key; the ON lamp will light to show that the output is on.

Display Contrast

All parameter settings are displayed on the 20 character x 4 row backlit liquid crystal display (LCD). The contrast may vary a little with changes of ambient temperature or viewing angle but can be optimised for a particular environment by using the front panel contrast control. Insert a small screwdriver or trimmer tool through the adjustment aperture marked LCD and rotate the control for optimum contrast.

Keyboard

Pressing the front panel keys displays screens which list parameters or choices relative to the key pressed. Selections are then made using the display soft–keys and numeric values are changed using the numeric keys or rotary control, see the Principles of Editing section.

The keys are grouped as follows:

- FUNCTION, FREQuency, AMPLitude, OFFSET and MODE keys display screens which permit their respective parameters to be edited either from the numeric keypad or using the rotary control/cursor keys.

- Numeric keys permit direct entry of a value for the parameter currently selected. Values are accepted in four formats: integer (20), floating point (20·0), exponential (2 EXP 1) and direct units selection (20Hz). For example, to set a new frequency of 50kHz press FREQ followed by 50000 ENTER or 5 EXP 4 ENTER or 50 kHz. ENTER or an appropriate units key confirms the numeric entry and changes the generator setting to the new value.
  CE (Clear Entry) undoes a numeric entry digit by digit. ESCAPE returns a setting being edited to its last value.

- MODULATION, SUM, TRIG IN and SYNC OUT call screens from which the parameters of those input/outputs can be set, including whether the port is on or off.

- SWEEP similarly calls screens from which all the parameters can be set and the function run.

- The MAIN OUT key simply switches the main output on or off.

- MAN TRIG is used for manual triggering (when TRIG IN is appropriately set) and for synchronising two or more generators when suitably connected together.

- UTILITY gives access to menus for a variety of functions such as remote control interface set–up, power–up parameters, error message settings and store/recall waveforms to/from non–volatile memory.

- Eight soft–keys around the display are used to directly set or select parameters from the currently displayed menu; their operation is described in more detail in the next section.

- The STATUS key always returns the display to the default start–up screen which gives an overview of the generators status. Pressing STATUS again returns the display to the previous screen.

Further explanations will be found in the detailed descriptions of the generator's operation.

Principles of Editing

Each screen called up by pressing a front panel key shows parameter value(s) and/or a list of choices. Parameter values can be edited by using the ROTARY CONTROL in combination with the left and right arrowed CURSOR keys, or by direct numeric keyboard entry; choices are made using the soft–key associated with the screen item to be selected. The examples which follow assume factory default settings.

A diamond beside a screen item indicates that it is selectable; hollow diamonds identify deselected items and filled diamonds denote selected items. For example, press MODE to get the screen shown below:

```
MODE:
♦continuous
◊gated       setup…◊
◊triggered   setup…◊
```

The filled diamond indicates that the selected mode is `continuous. Gated` or `Triggered` modes are selected by pressing the associated soft–key which will make the diamond beside that item filled and the diamond beside `continuous` hollow. This screen also illustrates how an ellipsis (three dots following the screen text) indicates that a further screen follows when that item is selected. In the case of the MODE screen illustrated, pressing the `setup...` soft–key on the bottom line brings up the `TRIGGER SETUP` menu; note that selecting this item does not change the `continuous/gated/triggered` selection.

Some screen items are marked with a double–headed arrow (a split diamond) when selected to indicate that the item's setting can be changed by further presses of the soft–key, by pressing either cursor key or by using the rotary control. For example, pressing FILTER brings up the screen shown below.

```
FILTER SETUP

⬍mode: auto
◊type: 40MHz eliptic
```

Repeated presses of the `mode` soft–key will toggle the mode between its two possible settings of `auto` and `manual`. Similarly, when `type` is selected, repeated presses of the `type` soft–key (or cursor keys or use of the rotary control) will step the selection through all possible settings of the filter type.

In addition to their use in editing items identified by a double–headed arrow as described above, the CURSOR keys and ROTARY CONTROL operate in two other modes.

In screens with lists of items that can be selected (i.e. items marked with a diamond) the cursor keys and rotary control are used to scroll all items through the display if the list has more than three items; look, for example at the FUNCTION and UTILITY screens.

In screens where a parameter with a numeric value is displayed the cursor keys move the edit cursor (a flashing underline) through the numeric field and the rotary control will increment or decrement the value; the step size is determined by the position of the edit cursor within the numeric field.

Thus for **FREQUENCY** set to **1.000000000 MHz** rotating the control will change the frequency in 1kHz steps. The display will auto−range up or down as the frequency is changed, provided that autoranging permits the increment size to be maintained; this will in turn determine the lowest or highest setting that can be achieved by turning the control. In the example above, the lowest frequency that can be set by rotating the control is 1 kHz, shown on the display as **1.000000000 kHz.**

This is the limit because to show a lower frequency the display would need to autorange below 1kHz to **xxx.xxxxxxx Hz** in which the most significant digit represents 100Hz, i.e. the 1kHz increment would be lost. If, however, the starting frequency had been set to **1.000000000 MHz**, i.e. a 100 Hz increment, the display would have autoranged at 1kHz to **900.0000000 Hz** and could then be decremented down to **100.0000000 Hz** without losing the 100 Hz increment.

Turning the control quickly will step numeric values in multiple increments.

Principles of Operation

The instrument operates in one of two different modes depending on the waveform selected. DDS mode is used for sine, cosine, haversine, triangle, sinx/x and ramp waveforms. Clock Synthesis mode (shown as vclk in the status menu) is used for square, pulse, pulse train, and arbitrary.

In both modes the waveform data is stored in RAM. As the RAM address is incremented the values are output sequentially to a Digital−to−Analogue Converter (DAC) which reconstructs the waveform as a series of voltages steps which are subsequently filtered before being passed to the main output connector.
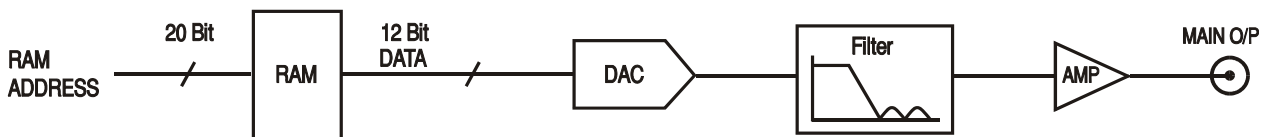
The main difference between DDS and Clock Synthesis modes is the way in which the addresses are generated for the RAM and the length of the waveform data.

Clock Synthesis Mode

In Clock Synthesis mode the addresses are always sequential (an increment of one) and the clock rate is adjusted by the user in the range 100MHz to 0·1Hz. The frequency of the waveform is clock frequency ÷ waveform length, thus allowing short waveforms to be played out at higher repetition rates than long waveforms, e.g. the maximum frequency of an 8 point waveform is 100e6÷8 or 12·5 MHz but a 1000 point waveform has a maximum frequency of 100e6÷1000 or 100kHz.
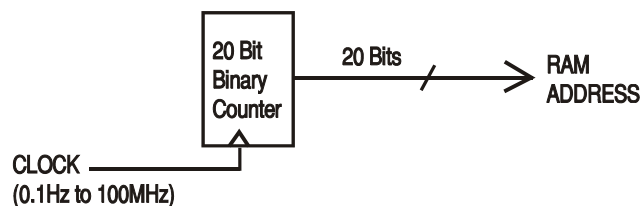
Arbitrary waveforms have a user defined length of 4 to 65536 points. Squarewaves use a fixed length of 2 points and pulse and pulse train have their length defined by the user selected period value.

DDS Mode

In DDS mode (Direct Digital Synthesis) all waveforms are stored in RAM as 4096 points. The frequency of the output waveform is determined by the rate at which the RAM addresses are changed. The address changes are generated as follows:
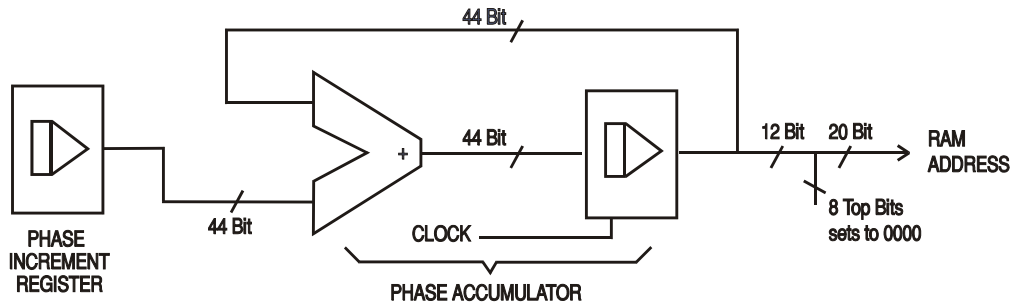
The RAM contains the amplitude values of all the individual points of one cycle (360⁰) of the waveform; each sequential address change corresponds to a phase increment of the waveform of 360⁰/4096. Instead of using a counter to generate sequential RAM addresses, a phase accumulator is used to increment the phase.

On each clock cycle the phase increment, which has been loaded into the phase increment register by the CPU, is added to the current result in the phase accumulator; the 12 most significant bits of the phase accumulator drive the lower 12 RAM address lines, the upper 4 RAM address lines are held low. The output waveform frequency is now determined by the size of the phase increment at each clock. If each increment is the same size then the output frequency is constant; if it changes, the output frequency changes as in sweep mode.

The generator uses a 44 bit accumulator and a 100 MHz clock frequency; the frequency setting resolution is 0·1 mHz.

Only the 12 most significant bits of the phase accumulator are used to address the RAM. At a waveform frequency of $F_{CLK}/4096$ (~24·4kHz), the natural frequency, the RAM address increments at every clock. At all frequencies below this (i.e. at smaller phase increments) one or more addresses are output for more than one clock period because the phase increment is not big enough to step the address at every clock. Similarly at frequencies above the natural frequency the larger phase increment causes some addresses to be skipped, giving the effect of the stored waveform being sampled; different points will be sampled on successive cycles of the waveform.

Function Generator Operation

This section deals with the use of the instrument as a function generator, i.e. generating sine, square, triangle, dc, ramp, haversine, cosine, havercosine and sinx/x waveforms. All but squarewave are generated by DDS which gives 10–digit frequency resolution; squarewave is generated by Clock Synthesis which results in 8–digit frequency resolution. Refer to Principles of Operation in the previous section for a fuller explanation of the differences involved.

The **WAVEFORM FUNCTIONS** screen lists all the waveforms that the instrument can produce including pulse, pulse-train and arbitrary which are described in detail in their appropriate sections.

Much of the following descriptions of amplitude and offset control, as well as of Mode, Sweep, etc., in following sections, apply to arbitrary waveforms as well as standard function generator waveforms; for clarity, any differences of operation with arbitrary, pulse and pulse–train are described only in those sections.

Setting Generator Parameters

Waveform Selection

```
WAVEFORM FUNCTIONS
♦sine
◊square
◊triangle
```

Pressing the FUNCTION key gives the **WAVEFORM FUNCTIONS** screen which lists all the waveforms available; the rotary control or cursor keys can be used to scroll the full list back and forward through the display. The currently selected waveform (sine with the factory defaults setting) is indicated by the filled diamond; the selection is changed by pressing the soft–key beside the required waveform.

Frequency

```
 SINE FREQUENCY
 10·00000000 kHz


♦freq        period◊
```

Pressing the FREQ key gives the **SINE FREQUENCY** screen. With **freq** selected as shown above, the frequency can be entered directly from the keyboard in integer, floating point exponential or direct units format, e.g. 12·34 kHz can be entered as 12340, 12340·00, 1·234 exp 4 or 12.34 kHz etc. However, the display will always show the entry in the most appropriate engineering units, in this case 12·34000000 kHz.

With **period** selected instead of **freq** the frequency can be set in terms of a period, e.g. 123·4μs can be entered as ·0001234 or 123·4e–6; again the display will always show the entry in the most appropriate engineering units.

Squarewave, generated by Clock Synthesis has 8–digit resolution for both frequency and period entry but the editing method is the same as for DDS generated waveforms.

Turning the rotary control will increment or decrement the numeric value in steps determined by the position of the edit cursor (flashing underline); the cursor is moved with the left and right arrowed cursor keys.

Note that the upper frequency limits vary for the different waveform types; refer to the Specifications section for details. Frequency setting for arbitrary, pulse and pulse–train is explained in the relevant sections; all use Clock Synthesis mode.

Amplitude

```
AMPLITUDE:
     +20·0  Vpp
♦Vpp            Vrms◊
◊dBm         load:hiZ◊
```

Pressing the AMPL key gives the **AMPLITUDE** screen.

The waveform amplitude can be set in terms of peak–to–peak Volts (Vpp), r.m.s. Volts (Vrms) or dBm (referenced to a 50Ω or 600Ω load). For Vpp and Vrms the level can be set assuming that the output is open–circuit (**load:hiZ**) or terminated (**load:50Ω** or **load:600Ω**); when dBm is selected termination is always assumed and the **load:hiZ** setting is automatically changed to **load:50Ω**. Note that the actual generator output impedance is always 50Ω; the displayed amplitude values for 600Ω termination take this into account.

With the appropriate form of the amplitude selected (indicated by the filled diamond) the amplitude can be entered directly from the keyboard in integer, floating point, exponential or direct units format, e.g. 250mV can be entered as ·250 or 250 exp –3, etc., However, the display will always show the entry in the most appropriate engineering units, in this case 250mV.

Turning the rotary control will increment or decrement the numeric value in steps determined by the position of the edit cursor (flashing underline); the cursor is moved with the left and right arrowed cursor keys.

Alternate presses of the ± key will invert the MAIN OUT output; if DC OFFSET is non–zero, the signal is inverted about the same offset. The exception to this is if the amplitude is specified in dBm; since low level signals are specified in –dBm (0dBm = 1mW into 50Ω = 224mVrms) the – sign is interpreted as part of a new amplitude entry and not as a command to invert the signal.

Note that for DC, sinx/x, pulse, pulse-train and arbitrary amplitude can only be displayed and entered in the Vpp form; further limitations on pulse, pulse–train and arbitrary amplitude are discussed in the appropriate sections.

DC Offset

```
DC OFFSET:
 program +0·00 mVdc
 (actual +0·00 mVdc)
             load:hiZ◊
```

Pressing the OFFSET key gives the **DC OFFSET** screen. The offset can be entered directly from the keyboard in integer, floating point, exponential or direct units format, e.g. 100mV can be entered as ·1 or 100 exp –3, etc. However, the display will always show the entry in the most appropriate engineering units, in this case 100mV. During a new offset entry the ± key can be used at any time to set the offset negative; alternate presses toggle the sign between + and –.

Turning the rotary control will increment or decrement the numeric value in steps determined by the position of the edit cursor (flashing underline); the cursor is moved by the left and right arrowed cursor keys. Because DC offset can have negative values, the rotary control can take the value below zero; although the display may autorange to a higher resolution if a step takes the value close to zero, the increment size is maintained correctly as the offset is stepped negative. For example, if the display shows

```
program = +205· mVdc
```

with the cursor in the most significant digit, the rotary control will decrement the offset in 100mV steps as follows:

```
program = +205· mVdc
program = +105· mVdc
program = +5·00 mVdc
program = –95·0 mVdc
program = –195· mVdc
```

The actual DC offset at the MAIN OUT socket is attenuated by the fixed−step output attenuator when this is in use. Since it is not obvious when the signal is being attenuated the actual offset is shown in brackets as a non−editable field below the programmed value.

For example, if the amplitude is set to 2·5Vpp the output is not attenuated by the fixed attenuator and the actual DC offset (in brackets) is the same as that set. The `DC OFFSET` display shows:

```
DC OFFSET:
 program +1.50  Vdc
 (actual +1.50  Vdc)
             load: hiZ◊
```

If the amplitude is now reduced to 250mVpp which introduces the attenuator, the actual DC offset changes by the appropriate factor:

```
DC OFFSET:
 program +1.50  Vdc
 (actual +151. mVdc)
             load: hiZ◊
```

The above display shows that the set DC offset is +1·50V but the actual offset is +151mV.   Note that the actual offset value also takes into account the true attenuation provided by the fixed attenuator, using the values determined during the calibration procedure. In the example displayed the output signal is 250mVpp exactly and takes account of the small error in the fixed attenuator; the offset is 151.mV exactly, taking account of the effect of the known attenuation (slightly less than the nominal) on the set offset of 1·50V.

Whenever the set DC offset is modified by a change in output level in this way a warning message that this has happened will be displayed. Similarly, because the DC offset plus signal peak is limited to ± 10V to avoid waveform clipping, a warning message will be displayed if this condition is set. This is explained more fully in the Warnings and Error Messages section.

The output attenuation is controlled intelligently to minimise the difference between the programmed and actual offset when the combination of programmed amplitude and offset allows this. Thus when the offset is set to 150mV, for example, the amplitude can be reduced to nominally 50mVpp before the fixed attenuator causes the actual offset to be different from the programmed value.

Warnings and Error Messages

Two classes of message are displayed on the screen when an illegal combination of parameters is attempted.

WARNING messages are shown when the entered setting causes some change which the user might not necessarily expect. Examples are:

1.   Changing the amplitude from, for example, 2·5 Volts pk−pk to 25mV pk−pk brings in the step attenuator; if a non−zero offset has been set then this will now be attenuated too. The message `DC offset changed by amplitude`   will be shown temporarily on the screen but the setting will be accepted; in this case the actual, attenuated, offset will be shown in brackets below the set value.

2.   With the output level set to 10V pk−pk, increasing the DC offset beyond ± 5V will cause the message `Offset + Sum + level may cause clipping.` The offset change will be accepted (producing a clipped waveform) and the user may then choose to change the output level or the offset to produce a signal which is not clipped. `(clip?)` will show in the display beside `AMPLITUDE` or `DC OFFSET` while the clipped condition exists.

ERROR messages are shown when an illegal setting is attempted, most generally a number outside the range of values permitted. In this case the entry is rejected and the parameter setting is left unchanged. Examples are:

1.   Entering a frequency of 1MHz for a triangle waveform. The error message:

  Frequency out of range for the selected waveform is shown.

2.   Entering an amplitude of 25Vpp. The error message:

  Maximum output level exceeded is shown.

3.   Entering a DC offset of 20V. The error message:

  Maximum DC offset value exceeded is shown.

The messages are shown on the display for approximately two seconds. The last two messages can be viewed again by pressing the **last error...** soft−key on the UTILITY screen, see System Operations section.

Each message has a number and the full list appears in Appendix 1.

The default set−up is for all warning and error messages to be displayed and for a beep to sound with each message. This set−up can be changed on the **error...** menu on the UTILITY screen. The **error** menu is shown below:

```
◊error beep: ON
◊error message: ON
⬥warn beep: ON
◊warn message: ON
```

Each feature can be turned ON and OFF with alternate presses of the associated soft−key; the factory default is for all features to be ON.

SYNC Output

SYNC OUT is a multifunction CMOS/TTL level output that can be automatically or manually set to be any of the following:

- **waveform sync** : A square wave with 50% duty cycle at the main waveform frequency, or a pulse coincident with the first few points of an arbitrary waveform. Can be selected for all waveforms.

- **burst done** : Produces a pulse coincident with the last cycle of the burst.

- **trigger** : Selects the current trigger signal (internal, external or manual). Useful for synchronising burst or gated signals.

- **sweep sync** : Outputs the sweep trigger and sweep marker signals.

- **phase lock** : Used to lock two or more generators. Produces a positive edge at the 0º phase point.

The setting up of the signals themselves is discussed in the relevant sections later in this manual, e.g. **trigger** is described in the Triggered Burst/Gate section. Pressing the SYNC OUT key calls the **SYNC OUT** setup screen.

```
SYNC OUT:
⬥output: on
◊mode: auto
⬥src: waveform sync
```

SYNC OUT is turned on and off by alternate presses of the **output** soft−key.

The selection of the signal to be output from the SYNC OUT socket is made using the **src** (source) soft−key; repeated presses of **src** cycle the selection through all the choices (**waveform sync, burst done**, etc.) listed above. Alternatively, with the **src** selected (double−headed arrow) the rotary control or cursor keys can be used to step backwards and forwards through the choices.

The source selection of the SYNC OUT waveform can be made automatic (**auto**) or user−defined (**manual**) with alternate presses of the **mode** soft−key. In automatic mode the SYNC OUT waveform most appropriate for the current main waveform is selected.

For example, **waveform sync** is automatically selected for all continuous waveforms, but **trigger** is selected in trigger or gated waveform modes. The automatic selection will be mentioned in each of the appropriate main waveform mode sections and a full table is given in Appendix 2.

The automatic selection can still be changed manually by the **src** soft−key even when **auto** mode has been selected but the selection will immediately revert to the automatic choice as soon as any relevant parameter (e.g. main waveform frequency or amplitude) is adjusted. **Manual** must be selected by the **mode** soft−key for a source other than the automatic choice to remain set. The **auto** selection will generally set the most frequently used signal, e.g. **waveform sync** for all continuous main waveforms, but **manual** will need to be used for special requirements.

Sweep Operation

General

Principles of Sweep Operation

All standard and arbitrary waveforms can be swept with the exception of pulse and pulse–train. During Sweep all waveforms are generated in DDS mode because this offers the significant advantage of phase–continuous sweeps over a very wide frequency range (up to 10^{10}). However, it must be remembered that the frequency is actually stepped, not truly linearly swept, and thought needs to be given as to what the instrument is actually doing when using extreme combinations of sweep range and time.

For DDS operation during Sweep all waveforms must be 4096 points in length; this is the natural length for standard waveforms but all arbitrary waveforms are expanded or condensed in software to 4096 points when Sweep is turned on. This does not affect the original data.

Sweep mode is turned on and off either by the **on** or **off** soft–key on the **SWEEP SETUP** screen accessed by pressing the SWEEP front panel key, or by the **sweep** soft–key on the **MODE** screen.

When sweep is turned on the software creates a table of 2000 frequencies between, and including, the specified start and stop values. Because any frequency used in sweep mode must be one of the tabled values, the centre frequency displayed (see Sweep Range) may not be the exact mid–point and markers (see Sweep Marker) may not be exactly at the programmed frequency. The frequency resolution of the steps will be particularly coarse with wide sweeps.

Connections for Sweep Operation. Sync Out and Trig In

Sweeps are generally used with an oscilloscope or hard–copy device to investigate the frequency response of a circuit. The MAIN OUT is connected to the circuit input and the circuit output is connected to an oscilloscope or, for slow sweeps, a recorder.

An oscilloscope or recorder can be triggered by connecting its trigger input to the generator's SYNC OUT; SYNC OUT defaults to **sweep sync** when sweep is turned on. **sweep sync** goes low at the start of sweep and high for the duration of the last frequency step at the end of sweep; depending on the sweep time set this should be long enough for an oscilloscope to retrace, for example.

To show a marker on the display instrument the SYNC OUT can be set to additionally output a marker pulse. See Sweep Marker section for setting marker frequency.

For triggered sweeps, a trigger signal may be provided by any of the possible trigger sources, i.e. internal, external, manual or remote.

The generator does not provide a ramp output for use with X–Y displays or recorders.

Setting Sweep Parameters

Pressing the SWEEP key (or the **sweep setup** soft–key on the **MODE** screen) displays the **SWEEP SETUP** screen.

```
SWEEP SETUP:   off ⬍
◊range…          type…◊
◊time…       spacing…◊
                marker…◊
```

Menus for setting up the range, time (sweep rate), type (continuous, triggered, etc.) spacing (lin/log) and marker position are all accessed from this screen using the appropriate soft−key. In addition Sweep Mode itself is turned on and off with alternate presses of the `on/off` soft−key; sweep can also be turned on by the `sweep` soft−key on the `MODE` screen. On all the following menus, pressing the `done` soft−key returns the display to this `SWEEP SETUP` screen.

Sweep Range

Pressing the `range...` soft−key calls the `SWEEP RANGE` screen.

```
SWEEP RANGE:
♦start: 100·0    kHz
◊stop:  10·00    MHz
◊centr/span    done◊
```

The maximum sweep range for all waveforms is 1mHz to 40MHz, including triangle, ramp and squarewave which have different limits in unswept operation.

Sweep range can be defined by start and stop frequencies or in terms of a centre frequency and span. `Start` and `Stop` soft−keys permit the two end points of the sweep to be set directly from the keyboard or by using the rotary control; the start frequency must be lower than the stop frequency (but see Sweep Type for selecting sweep direction).

Pressing the `centr/span` soft−key changes the screen to permit entry in terms of `centr` frequency and sweep `span` about that frequency; pressing the `start/stop` soft−key on that screen returns the display to the start and stop frequency form of entry.

Note that when the sweep is displayed in terms of centre frequency and span the span will always be the exact difference between start and stop frequencies but the centre frequency shown will be that of the frequency step nearest the true centre frequency, see Principles of Sweep Operation section.

Sweep Time

Pressing the `time...` soft−key calls the `SWEEP TIME` screen.

```
SWEEP TIME:
     0·05 sec


          done◊
```

The sweep time can be set from 1ms to 999s with 3−digit resolution by direct keyboard entry or by using the rotary control.

Sweep Type

Pressing the `type` soft−key calls the `SWEEP TYPE` screen.

```
SWEEP TYPE:
♦continuous
◊direction: up
◊sync: on      done◊
```

This screen is used to set the sweep mode (continuous; triggered; triggered, hold and reset) and sweep direction.

Successive presses of the `direction` soft–key select one of the following sweep directions:

`up`	start frequency to stop frequency.
`down`	stop frequency to start frequency.
`up/down`	start frequency to stop frequency and back to start frequency.
`down/up`	stop frequency to start frequency and back to stop frequency.

The total sweep time is always that set on the `SWEEP TIME` screen, i.e. for `up/down` and `down/up` operation the sweep time in each direction is half the total. Similarly the total number of steps is the same for all choices, i.e. there will be half the number of steps in each direction for `up/down` and `down/up` operation. In the sweep mode descriptions which follow the direction is assumed to be `up` but all modes can be used with all sweep directions.

In `continuous` mode the generator sweeps continuously between the start and stop frequencies, triggered repetitively by an internal trigger generator whose frequency is determined by the sweep time setting. At the stop frequency the generator resets to the start frequency and begins a new sweep. If `sync` is set to `on` (the default) the generator actually steps immediately from the stop frequency to zero frequency (i.e. it does not dwell at the stop frequency for the full step interval) and then starts the next sweep from the first point of the waveform, synchronised to the (internally generated) trigger signal.

This is useful because the sweep always starts from the same point in the waveform but the waveform discontinuity can be undesirable in some circumstances, e.g. filter evaluation. With `sync` set to `off`, the frequency steps directly and phase continuously from the stop frequency to the start frequency (after dwelling at the Stop frequency for the full step interval) but is not synchronised to the software–generated trigger signal.

In `triggered` mode the generator holds the output at the start frequency until it recognises a trigger. When triggered, the frequency sweeps to the stop frequency, resets, as follows, and awaits the next trigger. If `sync` if set to `on` the frequency resets to zero frequency (i.e. no waveform) and starts a new sweep at the first point of the waveform when the next trigger is recognised. If `sync` is set to `off` the waveform resets to the start frequency and runs at that frequency until the next trigger initiates a new sweep.

In `trig'd,hold/reset` mode the generator holds the output at the start frequency until it recognises a trigger; when triggered, the frequency sweeps to the stop frequency and holds. At the next trigger the output is reset to the start frequency where it is held until the next sweep is initiated by a further trigger. If `sync` is set to `off` the output operates exactly as described above; if `sync` is set to `on` the frequency actual goes to zero at the start and begins each new sweep at the first point of the waveform.

For triggered sweeps, a trigger signal may be provided by any of the possible trigger sources, i.e. internal, external, manual or remote.

The generator does not provide a ramp output for use with X–Y displays or recorders.

Sweep Spacing

Pressing the `spacing...` soft–key on the `SWEEP SETUP` screen calls the `SWEEP SPACING` screen.

```
SWEEP SPACING:
♦logarithmic
◊linear
                    done◊
```

With `linear` selected the sweep changes the frequency at a linear rate; with `logarithmic` selected the sweep spends an equal time in each frequency decade.

Sweep Marker

A sweep marker pulse is also available from the SYNC OUT socket when **sweep sync** (the default condition) is selected. The marker pulse is differentiated from the sweep sync pulse by being approximately half the amplitude of the sync pulse; this permits the trigger level of the display oscilloscope to be adjusted for the sweep sync pulse without additionally triggering on the marker pulse.

The marker pulse frequency is set from the **SWEEP MARKER FREQ** menu, called by pressing the **marker...** soft−key on the **SWEEP SETUP** screen.

```
SWEEP MARKER FREQ:
progrm: 5·000    MHz
actual: 4·977    MHz
                done ◊
```

A new marker frequency can be programmed directly from the keyboard or by using the rotary control and cursor keys. Note that the marker frequency can only be one of the values in the sweep frequency table; any value in the sweep range can be entered but the actual value will be the nearest frequency in the table. When sweep is turned on, the actual marker frequency is shown in the non−editable field below the programmed frequency. For the default sweep setting of 100kHz to 10MHz in 50ms, the actual frequency of a 5MHz marker is 4·998 MHz.

The marker duration is Sweep time/2000, i.e. the dwell time at a single frequency step.

To avoid displaying a sweep marker, the marker frequency is simply set to a value outside the current sweep frequency range.

Triggered Burst and Gate

General

Triggered Burst and Gated modes are selected from the **MODE** screen, called by the MODE key, as alternatives to the default continuous mode.

```
MODE:
♦continuous
◊gated        setup…◊
◊triggered    setup…◊
```

In Triggered Burst mode a defined number of cycles are generated following each trigger event. This mode is edge triggered.

In gated mode the generator runs whenever the gating signal is true. This mode is level sensitive.

Triggered Burst mode can be controlled by either the Internal Trigger Generator, an external trigger input, by the front panel MAN TRIG key or by remote control. Gated mode can be controlled by the Internal Trigger Generator or on external trigger input.

In both modes the start phase, i.e. the starting point on the waveform cycle, can be specified.

Internal Trigger Generator

The period of the Internal Trigger Generator is set with the **period** soft–key on the **TRIGGER IN** set-up screen called by the TRIG IN key.

```
⬍source: int  force ◊
◊slope:  positive
◊level:  +1·4 V
◊period: 1·00ms
```

The Internal Trigger Generator divides down a crystal oscillator to produce a 1:1 square wave with a period from 0·01ms (100kHz) to 200s (·005Hz). Generator period entries that cannot be exactly set are accepted and rounded up to the nearest available value, e.g. ·109ms is rounded to ·11ms.

When Triggered Burst or Gated modes are selected the SYNC OUT source automatically defaults to **trigger** which is the output of the internal trigger generator when internal triggering or gating is specified.

In Triggered Burst mode the selected edge of each cycle of the trigger generator is used to initiate a burst; the interval between bursts is therefore 0·01ms to 200s as set by the generator period.

In Gated mode the output of the main generator is gated on whilst the Internal Trigger Generator output is true; the duration of the gate is therefore ·005ms to 100s in step with trigger generator periods of ·01ms to 200s.

External Trigger Input

External trigger or gate signals are applied to the front panel TRIG IN socket which has a variable threshold level set using the **level** soft-key; the level can be set from −5·0V to +5·0V by direct keyboard entry or by using the rotary control. In Triggered Burst mode the input is edge sensitive; the selected edge of each external trigger initiates the specified burst. In Gated mode the input is level sensitive; the output of the main generator is on whilst the gate signal is true.

The minimum pulse width that can be used with TRIG IN in Triggered Burst and Gated mode is 50ns and the maximum repetition rate is 1MHz. The maximum signal level that can be applied without damage is ±10V.

When Triggered Burst or Gated modes are selected the SYNC OUT source automatically defaults to **trigger** which is always a positive−edged version of the external trigger or gate signal when external triggering or gating is specified.

Triggered Burst

Triggered Burst mode is turned on with the **triggered** soft−key on the **MODE** screen. The **setup…** soft−key on this screen accesses the **TRIGGER/GATE SETUP** screen on which the burst count and start phase are set. The other trigger parameters are set on the **TRIGGER IN** setup screen called by pressing the TRIG IN key.

```
⬍source: int  force ◊
◊slope:  positive
◊level:  +1·4 V
◊period: 1·00ms
```

Trigger Source

The trigger source can be selected with the **source** soft−key on the **TRIGGER IN** setup screen to be **int, ext** or **man**.

With **int** selected the internal trigger generator is used to initiate a burst; this generator is set up as described in the previous section.

With **ext** selected the specified edge of the signal at TRIG IN is used to initiate a burst.

With **man** selected as the source only pressing the MAN TRIG key or a remote command can be used to initiate a burst.

Trigger Edge

The **slope** soft−key is used to select the edge (**positive** or **negative**) of the external trigger signal that is used to initiate a burst. The default setting of **positive** should be used for triggering by the Internal Trigger Generator.

Note that the **trigger** signal from SYNC OUT, used for synchronising the display of a triggered burst on an oscilloscope for example, is always positive−going at the start of the burst.

Burst Count

The number of complete cycles in each burst following the trigger is set from the **TRIGGER/GATE SETUP** screen called by pressing **setup** on the **MODE** screen.

```
TRIGGER/GATE SETUP:
◆burst cnt: 0000001
◊phase:    +000·0°
 (actual: +000·0°)
```

The required count can be set by pressing the **burst cnt** soft−key followed by direct entries from the keyboard or by using the rotary control. The maximum number of waveform cycles that can be counted is 1048575 (2^{20}−1).

Start Phase

The start phase, i.e. the point on the waveform cycle at which the burst starts, can be selected by pressing the **phase** soft−key followed by direct entries from the keyboard or by using the rotary control. Since the waveform cycle is always completed at the end of the burst the start phase is also the stop phase.

The phase can be set with a precision of 0·1° but the actual resolution is limited with some waveforms and at certain waveform frequencies as detailed below. To indicate when this is the case the actual phase is shown in brackets as a non−editable field below the programmed value.

To achieve start phase precision all waveforms are run in Clock Synthesis mode, i.e. as if they were arbitrary waveforms, when Triggered Burst is specified; this limits actual frequency resolution to 8 digits for all waveforms although the normally DDS generated waveforms are still entered with 10−digit precision. Sine/cosine/haversine/etc. waveforms are created as if they were arbitrary waveforms with the first point of the waveform exactly at the start phase; each time the phase or frequency is changed the waveform is recalculated which can cause a slight lag if these parameters are being changed quickly with the rotary knob.

The phase resolution of true arbitrary waveforms is limited by the waveform length since the maximum resolution is 1 clock; thus waveforms with a length >3600 points will have a resolution of 0·1° but below this number of points the maximum resolution becomes 360° ÷ number of points.

Square waves, pulse and pulse train have no start phase adjustment; phase is fixed at 0°. A summary of start phase capabilities in Triggered Burst mode is shown in the table below:

Waveform	Max Wfm Freq	Phase Control Range & Resolution
Sine, cosine, haversine, havercosine	2·5MHz	± 360°, 0·1°
Square	2·5MHz	0° only
Triangle	500kHz	± 360°, 0·1°
Ramp	500kHz	± 360°, 0·1°
Sin(x)/x	500kHz	± 360°, 0·1°
Pulse & Pulse Train	10MHz	0° only
Arbitrary	100MS/s clock	± 360°, 360 ÷ length or 0·1°

Gated Mode

Gated mode is turned on with the **gated** soft−key on the **MODE** screen. The **setup...** soft−key on this screen accesses the **TRIGGER/GATE SETUP** screen on which the start phase is set. The other parameters associated with Gated are set on the **TRIGGER IN** setup screen called by pressing the TRIG IN key.

```
⬍source: int  force◊
◊slope:  positive
◊level:  +1·4 V
◊period: 1·00ms
```

Gate Source

The gate signal source can be selected with the **source** soft−key on the **TRIGGER IN** setup screen to be **int** or **ext**.

With **int** selected the internal trigger generator is used to gate the waveform; the duration of the gate is half the generator period, see Internal Trigger Generator section.

With **ext** selected the gate duration is from the threshold level set on the specified edge of the signal at TRIG IN until the same level on the opposite edge; the threshold and edge are set using the **level** and **slope** soft-keys respectively.

Gate Polarity

If **slope** on the **TRIGGER IN** setup screen is set to **positive** the gate will open at the threshold on the rising edge and close on the threshold of the falling edge of an external gating signal, i.e. the gate signal is true when the TRIG IN signal is high. If the **slope** is set **negative** the gate signal is true when the TRIG IN signal is low. The default setting of positive should be used for gating with the Internal Trigger Generator.

Start Phase

Press **setup...** on the **MODE** screen to access the **TRIGGER/GATE SETUP** screen on which the start phase can be set.

```
TRIGGER/GATE SETUP:
◆BURST CNT: 0000001
◇PHASE:    +000·0°
  (actual: +000·0°)
```

The start phase, i.e. the point on the waveform cycle at which the gated waveform starts, can be selected by pressing the **phase** soft–key followed by direct entries from the keyboard or by using the rotary control. Since the waveform cycle is always completed at the end of the gated period the start phase is also the stop phase.

The phase can be set with a precision of 0·1° but the actual resolution is limited with some waveforms and at certain waveform frequencies as detailed below. To indicate when this is the case the actual phase is shown in brackets as a non–editable field below the programmed value.

To achieve start phase precision all waveforms are run in Clock Synthesis mode, i.e. as if they were arbitrary waveforms, when Gated mode is specified; this limits actual frequency resolution to 8 digits for all waveforms although the normally DDS generated waveforms are still entered with 10–digit precision. Sine/cosine/haversine/etc. waveforms are created as if they were arbitrary waveforms with the first point of the waveform exactly at the start phase; each time the phase or frequency is changed the waveform is recalculate which can cause a slight lag if these parameters are being changed quickly with the rotary knob.

The phase resolution of true arbitrary waveforms is limited by the waveform length since the maximum resolution is 1 clock; thus waveforms with a length >3600 points will have a resolution of 0·1° but below this number of points the maximum resolution becomes 360° number of points.

Square waves, pulse and pulse trains have no start phase adjustment; phase is fixed at 0°. Refer to the table in the Triggered Burst section for a summary of start phase capabilities.

Sync Out in Triggered Burst and Gated Mode

When Triggered Burst or Gated modes are selected the SYNC OUT source automatically defaults to **trigger; trigger** is a positive–edged signal synchronised to the actual trigger used whether internal (from the Internal Trigger Generator) or external of either polarity.

Alternatively, SYNC OUT can be set to **burst done** on the **SYNC OUT** setup screen; sync out then provides a signal which is low while the waveform is running and high at all other times.

Tone Mode

General

In Tone mode the output is stepped through a user–defined list of up to 16 frequencies under the control of the signal set by the **source** soft–key on the **TRIGGER IN** setup screen. This signal can be the Internal Trigger Generator, an external trigger input, the front panel MAN TRIG key or a remote command.

All standard and arbitrary waveforms can be used in Tone mode with the exception of pulse and pulse–train. During Tone all waveforms are generated in DDS mode for fast phase–continuous switching between frequencies. For DDS operation all waveforms must be 4096 points in length; this is the natural length for standard waveforms but all arbitrary waveforms are expanded or condensed in software to 4096 points when the Tone list is built. This does not affect the original data.

Because DDS mode is used the frequency range for all waveforms is 1mHz to 10MHz in Tone mode, including triangle, ramp and squarewave which have different limits in continuous operation.

Tone Frequency

Press the **tone setup...** soft–key on the **MODE** screen, called by pressing the MODE key, to get the **TONE** setup screen:

```
TONE      type: trig◊
◊2·000000 kHz #2
♦3·000000 kHz   del◊
◊end of list  #4
```

Each frequency in the list can be changed by pressing the appropriate soft–key and entering the new value from the keyboard. The selected frequency can be deleted from the list by pressing the **del** (delete) soft–key. Additional frequencies can be added to the end of the list by selecting **end of list** with the appropriate soft–key and entering the new frequency from the keyboard.

The whole list can be scrolled back and forward through the display using the rotary control.

Tone Type

The **type** soft–key on the **TONE** setup screen permits three types of tone switching to be specified.

With **type** set to **trig** the frequency changes after each occurrence of the signal edge specified in the **source** and **slope** fields on the **TRIGGER IN** screen but only after completing the last cycle of the current frequency.

With **type** set to **gate** the frequency changes when the signal specified in the **source** field goes to the level specified in the **slope** field on the **TRIGGER IN** screen and continues until the level changes again at which point the current cycle is completed; the output is then gated off until the next occurrence of the gating signal at which time the next frequency in the list is gated on. The difference between triggered and gated tone changes is therefore that in triggered mode the signal changes phase–continuously from one frequency to the next at the waveform zero–crossing point immediately after the trigger signal whereas in gated mode there can be an 'off' period between successive frequencies whilst the gate signal is not true.

With **type** set to **fsk** the frequency changes instantaneously (and phase–continuously) at each occurrence of the signal edge specified in the **source** and **slope** fields on the **TRIGGER IN** screen **without completing the current waveform cycle**; this is true FSK (Frequency Shift Keying) tone switching.

The following diagrams demonstrate the differences between trigger, gate and FSK tone switching for a list of 2 frequencies switched by a square wave (positive slope specified on TRIGGER IN setup).

The maximum recommended tone frequencies and trigger/gate switching frequencies for the three modes are as follows:

GATE: Maximum tone frequency 50kHz; maximum switching frequency <lowest tone frequency.

TRIGGER: Maximum tone frequency 50kHz; maximum switching frequency 1MHz.

FSK: Maximum tone frequency 1MHz; maximum switching frequency 1MHz.
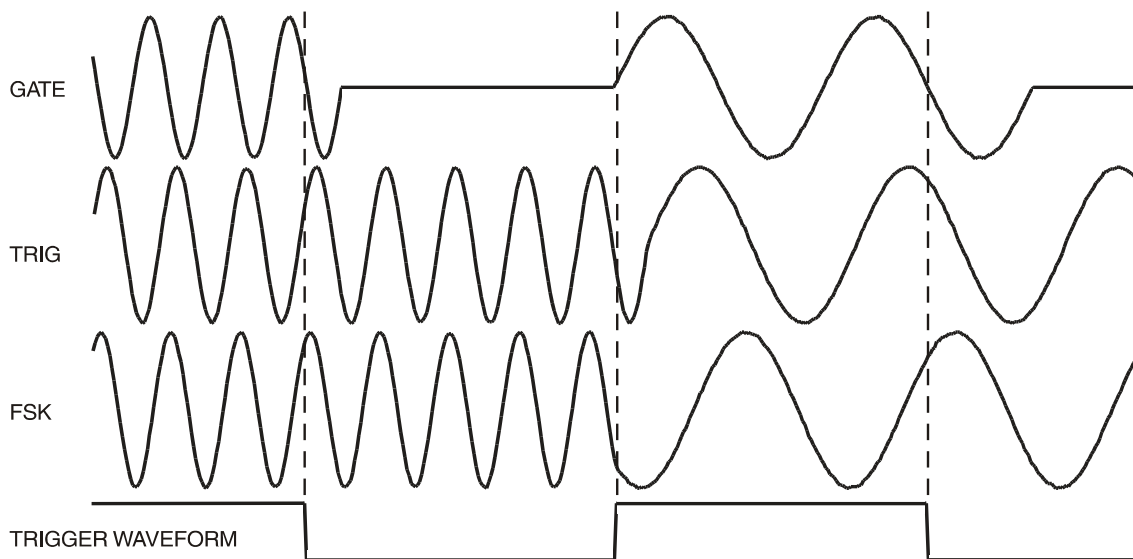
Tone Waveform Types

Tone Switching Source

The signal which controls the frequency switching is that set by the **source** soft–key on the **TRIGGER IN** setup screen. The **slope** field on the same screen sets the active polarity of that signal; when set to **positive** the rising edge of the trigger signal is active or the high level of the gating signal is true and the reverse is true for a **negative** setting. The signal that can be selected by the **source** soft–key can be the Internal Trigger Generator, an external trigger input, the front panel MAN TRIG key or a remote command. A full explanation for each of these can be found in the Triggered Burst and Gate chapter.

DTMF Testing with Two Generators

An important use of Tone mode is DTMF (Dual Tone Multiple Frequency) testing in which 2 instruments are set up with equal length lists of different frequencies and are triggered from a common external signal. The outputs are summed together using the external SUM capability, see the Sum chapter. DTMF testing generally uses sinewaves in the frequency range 600Hz to 1·6kHz.

Arbitrary Waveform Generation

Introduction

Arbitrary (Arb) waveforms are generated by sequentially addressing the RAM containing the waveform data with the arbitrary clock. The frequency of the arb waveform is determined both by the arb clock and the total number of data points in the cycle.

In this instrument an arb waveform can have up to 65536 horizontal points. The vertical range is −2048 to +2047, corresponding to a maximum peak−peak output of 20 Volts. Four waveforms can be specified and they are listed at the bottom of the **WAVEFORM FUNCTIONS** screen.

```
WAVEFORM FUNCTIONS
◊pulse-train setup…◊
◊arb1   1000 points
◊arb2   1000 points
```

The four arbs have names (arb1, arb2,arb3, and arb4) which cannot be changed. As it is not possible to delete these arbs a new instrument has four default arbs installed each 1000 points long. Each arb has its current length specifies on the **WAVEFORM FUNCTIONS** screen as shown above.

Arb waveforms can be created using the supplied waveform design software that enables the user to create waveforms from mathematical expressions, from combinations of other waveforms, or freehand on a pc, see Appendix 4. These waveforms may then be downloaded to the instrument via one of the remote control interfaces.

Arb Waveform Terms

The following terms are used in describing arb waveforms:

- *Horizontal Size.* The number of horizontal points is the time component of the waveform. The minimum size is 4 points and the maximum is 65536 points.
- *Waveform Address.* Each horizontal point on an arb waveform has a unique address. Addresses always start at 0000, thus the end address is always one less than the horizontal size.
- *Arb Frequency and Waveform Frequency.* The arb frequency is the clock rate of the data RAM address counters and has a range of 0·1Hz to 100MHz (internal clock) or DC to 50MHz (external clock) on this instrument. The waveform frequency depends on both the arb frequency and horizontal size. A 1000 point waveform clocked at an arb frequency of 100MHz has a waveform frequency of 100e6÷1000 = 100kHz.
- *Data Value.* Each point in the waveform has an amplitude value in the range −2048 to +2047.
- *Arb Waveform Amplitude.* When playing arb waveforms the maximum output amplitude will depend on both the range of data values and the output amplitude setting. A waveform that contains data values ranging from −2048 to +2047 will produce a maximum output which is 100% of the programmed peak−to−peak amplitude; if the maximum range of the data values is only −1024 to +1023, for example, the maximum output will only be 50% of the programmed level.

Selecting and Outputting Arbitrary Waveforms

From the **WAVEFORM FUNCTIONS** screen the rotary knob or cursor keys can be used to scroll the list forwards through the display. Select the required arb waveform by pressing the associated soft-key.

```
WAVEFORM FUNCTIONS
◊pulse-train setup…◊
♦arb1   1000 points
◊arb2   1000 points
```

Frequency and Amplitude Control with Arbitrary Waveforms

Frequency and Amplitude control work in essentially the same way as for standard waveforms with the following differences.

Frequency

Pressing the FREQuency key with an arbitrary waveform selected calls the `ARB FREQUENCY` screen:

```
 ARB FREQUENCY
  100·00000   MHz
♦sample     waveform◊
♦freq         period◊
```

Arbitrary mode uses Clock Synthesis generation, see Principles of Operation section, which has a setting resolution of 8 digits.

Frequency can be set in terms of frequency or period as for standard waveforms by pressing the `freq` or `period` soft–key respectively. Additionally, for arbitrary waveforms, frequency/period can be set in terms of the sample clock frequency, by pressing the `sample` soft–key, or in terms of the waveform frequency, by pressing the `waveform` soft–key. The relationship between them is

waveform frequency = sample frequency ÷ waveform size.

Frequency/period entries are made direct from the keyboard or by using the rotary control in the usual way.

Amplitude

Pressing the AMPLitude key with an arbitrary waveform selected calls the `AMPLITUDE` screen.

```
AMPLITUDE:
     +20·0   Vpp
♦Vpp
             load:hiZ◊
```

This differs from the `AMPLITUDE` screen for standard waveforms in that amplitude can now only be entered in volts peak–to–peak.

Note that the peak–to–peak amplitude set will only actually be output if the arbitrary waveform has addresses with values which reach −2048 and +2047; if the maximum value range is −1024 to +1023 for example then the maximum peak–to–peak voltage will only be 10Vpp for the instrument set to 20Vpp.

Sync Out Settings with Arbitrary Waveforms

The default setting for Sync Out when arbitrary waveforms are selected is `waveform sync`; this is a pulse that starts coincident with the first point of the waveform and is a few points wide.

Output Filter Setting

The output filter type is automatically chosen by the software to give the best signal quality for the selected waveform. The choice can, however, be overridden by the user and this is most probably a requirement with arbitrary waveforms.

To change the filter, press the FILTER key to call the `FILTER SETUP` screen.

```
FILTER SETUP

◊mode: auto
⬍type: 40MHz eliptic
```

The default **mode** is **auto** which means that the software selects the most appropriate filter. With the setting on **auto** the **type** can be changed manually but the choice will revert to the automatic selection as soon as any relevant parameter is changed. To override the automatic choice press the **mode** soft−key to select **manual**.

The three filter choices, which are either automatically selected or set manually with the **type** soft−key, are as follows:

- *40MHz elliptic:*   The automatic choice for sine, cosine, haversine, havercosine, sinx/x and triangle. Would be the better choice for arb waveforms with an essentially sinusoidal content.

- *20MHz Bessel:*   The automatic choice for positive and negative ramps, arb and sequence.

- *No filter:*   The automatic choice for squarewave, pulse and pulse−trains. May be the better choice for arb waveforms with an essentially rectangular content.

Pulse and Pulse-trains

Pulse and pulse–trains are both selected and set–up from independent menus on the **WAVEFORM FUNCTIONS** screen called by pressing the FUNCTION key. Pulse and pulse–trains have similar timing set–ups and considerations but pulses are only unipolar, with a maximum amplitude of 10Vpp, whereas pulse–trains can be bipolar, with a maximum peak–to–peak of 20Vpp.

Pulse Set-up

Pulse waveforms are turned on with the **pulse** soft–key on the **WAVEFORM FUNCTIONS** screen; pressing the **setup...** soft–key beside **pulse** calls the first of the pulse set–up screens:

```
Enter pulse period:
    100·00000 us
10000pts*10.000000ns
◊exit           next◊
```

The pulse period can be set between 40·00ns and 100s, with 8–digit resolution, by direct entries from the keyboard or by using the rotary control. Pressing the **next** soft–key calls the pulse width screen:

```
Enter pulse width:
program 50·000000 us
 actual 50·000000 us
◊exit           next◊
```

The width can be entered directly from the keyboard or by using the rotary control. Any value in the range 10·00ns to 99·99s can be programmed but the **actual** value may differ because of the considerations discussed below; for this reason the **actual** pulse width is shown below the **program** width.

Pressing the **next** soft–key calls the pulse delay screen:

```
Enter pulse delay:
progrm +0·0000000 ns
actual +0·0000000 ns
◊exit           done◊
```

This is very similar to the pulse width screen and, again, the **actual** delay is shown below the **program** delay. The delay value that can be entered must be in the range ± (pulse period −1 point); positive values delay the pulse output with respect to waveform sync from SYNC OUT; negative values cause the pulse to be output before the waveform sync. Pressing the **done** soft–key on this screen returns the display to the **WAVEFORM FUNCTIONS** screen.

The means by which pulse period is set–up in the hardware requires an understanding because it affects the setting resolution of both pulse width and delay. Pulse is actually a particular form of arbitrary waveform made up of between 4 and 100,000 points; each point has a minimum time of 10·00ns corresponding to the fastest clock frequency of 100MHz.

At short pulse periods, i.e. only a few points in the waveform, the period setting resolution is, however, much better than 10·00ns because the time−per−point is adjusted as well as the number of points; since the pulse width and delay are also defined in terms of the same point time, varying the time−per−point affects their resolution. For example, if the period is set to 200ns, the minimum pulse width, when set to 10·00ns, will actually be 10·00ns; 20 points at 10·00ns each exactly define the 200ns period. However, if the period is set to 199·0ns, 20 points at the minimum point time of 10·00ns will be too long so 19 points are used and the point time is adjusted to 10.473684ns (199·0÷19); 10.473684ns is now the increment size used when changing the pulse width and delay.

For periods above 1·00ms the maximum number of points in the waveform (100,000) becomes the factor determining pulse width and delay resolution. For example, with the period set to 100ms, the smallest pulse width and delay increment is 1μs (100ms÷100,000). This may appear to cause significant "errors" at extreme settings (e.g. setting 10ns in the above example will still give an actual width of 1μs) but in practical terms a 1 in 100,000 resolution (0·001%) is quite acceptable.

Pulse period can be adjusted irrespective of the pulse width and delay setting (e.g. can be set smaller than the programmed pulse width) because, unlike a conventional pulse generator, pulse width and delay are adjusted **proportionally** as the period is changed. For example, if, from the default pulse settings of 100μs period/50μs width, the period is changed to 60μs the pulse width `actual` changes to 30μs even though the `program` width is still 50μs; to get a 50μs width with the period at 60μs the width must be re−entered as 50μs after the period has been changed.

Period can also be changed from the `PULSE PERIOD` screen called by pressing the FREQ key with Pulse mode selected.

```
┌─────────────────────────┐
│  PULSE PERIOD:          │
│    100·00000   us       │
│                         │
│ ◊freq         period♦   │
└─────────────────────────┘
```

The new setting can be entered either as a period in the way already described or as a frequency by first pressing the `freq` soft−key. However, changing the period/frequency from this screen is slightly different from changing period on the `pulse setup` screen. When changing from this screen the number of points in the waveform is never changed (just as with a true arb) which means that the shortest period/highest frequency that can be set is number of waveform points x10·00ns. To achieve faster frequencies (up to the specification limit) the period must be changed from the pulse set−up screen; changing the frequency from the pulse set-up screen causes the number of points to be reduced as the period is reduced (for periods <1ms).

Pulse-train Setup

Pulse−trains are turned on with the `pulse-train` soft-key on the `WAVEFORM FUNCTIONS` screen; pressing the `setup...` soft-key beside `pulse-train` calls the first of the setup screens:

```
┌─────────────────────────┐
│  Enter no of pulses     │
│  in train (1-10):       │
│            2            │
│ ◊done         next◊     │
└─────────────────────────┘
```

The number of screens used for the setup depends on the number of pulses in the pulse−train. The first three screens define the parameters that apply to the whole pattern (number of pulses, overall pulse−train period and baseline voltage); subsequent screens define the pulse level, width and delay for each pulse in turn (3 screens for pulse 1, then 3 screens for pulse 2, etc.). Pressing **next** on any screen calls the next setup screen, finally returning the display to the **WAVEFORM FUNCTIONS** screen from which pulse−train can be turned on and off; pressing **done** returns the display directly to the **WAVEFORM FUNCTIONS** screen from any setup screen. The pulse−train is built only after **next** is pressed after the last parameter setup or whenever **done** is pressed, assuming a change has been made. The first screen, shown above, sets the number of pulses (1−10) in the pattern; enter the number of pulses directly from the keyboard or by using the rotary control.

Pressing **next** calls the pulse train period screen:

```
┌─────────────────────────┐
│ Pulse train period:     │
│    100·00000 us          │
│  10000pt*10.000000ns     │
│ ◊done          next◊     │
└─────────────────────────┘
```

The period can be set, with 8−digit resolution, from 40·00ns to 100s by direct keyboard entries or by using the rotary control.

Pressing **next** calls the baseline voltage screen, the last of the general setup screens:

```
┌─────────────────────────┐
│  Enter the baseline     │
│      voltage:           │
│      +0·000 V           │
│ ◊done          next◊     │
└─────────────────────────┘
```

The baseline is the signal level between the end of one pulse and the start of the next, i.e. it is the level all pulses start and finish at. The baseline can be set between −5·0V and +5·0V by direct keyboard entries or by using the rotary control. Note that the **actual** baseline level at the output will only be as set in this field if the output amplitude is set to maximum (10Vpp into 50Ω) on the AMPLITUDE screen and terminated in 50Ω. If the amplitude was set to 5Vpp into 50Ω then the actual baseline range would be −2·5V to +2·5V for set values of −5·0 to +5·0V, i.e. the amplitude control "scales" the baseline setting. The actual output levels are doubled when the output is unterminated.

Pressing **next** on this screen calls the first of 3 screens for the first pulse in the pattern:

```
┌─────────────────────────┐
│ ◊Pulse  1 level         │
│                         │
│ ♦      +5·000 V         │
│ ◊done          next◊     │
└─────────────────────────┘
```

The pulse level can be set on this screen between −5·0V and +5·0V by direct keyboard entries or by using the rotary control. As with the baseline level described above the set pulse levels are only output if the amplitude setting is set to maximum (10Vpp into 50Ω) on the AMPLITUDE screen and terminated in 50Ω. Adjusting the amplitude "scales" both the peak pulse levels and baseline together, thus keeping the pulse shape in proportion as the amplitude is changed, exactly as for arb waveforms. Actual output levels are doubled when the output is unterminated.

Note that by pressing the **Pulse** soft−key on this (and subsequent screens) the pulse to be edited can be directly set from the keyboard or by using the rotary control; this is useful in directly accessing a particular pulse in a long pulse train instead of having to step through the whole sequence.

Pressing **next** calls the pulse width screen for the first pulse:

```
◊Pulse  1 width
♦progrm 25·000000 us
 actual 25·000000 us
◊done        next◊
```

The width can be entered directly from the keyboard or by using the rotary control. Any value in the range 10·00ns to 99·99s can be programmed but the **actual** value may differ; for this reason the **actual** pulse width is shown below the **program** width. The variation between **program** and **actual** will only really be noticeable for very short pulse−train periods (only a few points in the pulse−train) and very long periods (each of the 50,000 points has a long dwell time) for exactly the same reasons as described in the Pulse Setup section; refer to that section for a detailed explanation.

Pressing **next** calls the pulse delay screen for the first pulse:

```
◊Pulse  1 delay
♦progm +0·0000000 ns
actual +0·0000000 ns
◊done        next◊
```

The pulse delay is entered in the same way as pulse width and, again, the **actual** delay is shown below the **program** delay for the same reasons. The delay value that can be entered must be in the range ± (pulse−train period −1 point); positive values delay the pulse with respect to waveform sync from SYNC OUT; negative values cause the pulse to be output before the waveform sync.

Pressing **next** on this screen calls the first of the 3 screens for setting the parameters of Pulse 2, and so on through all the pulses in the pulse−train. In this way all parameters of all pulses are set. The pulse−train is built when **next** is pressed on the last screen of the last pulse or if **done** is pressed on any screen.

Care must be taken that the set widths and delays of the individual pulses are compatible with each other and the overall pulse−train period, i.e. delays must not be such that pulses overlap each other and delays + widths must not exceed the pulse−train period; unpredictable results will occur if these rules are not followed.

Once the pulse−train has been defined the period can be adjusted irrespective of the pulse width and delay settings for the individual pulses because, unlike a conventional pulse generator, the individual pulse widths and delays are adjusted **proportionally** to the period as the period is changed.

Period can also be changed from the **PULSE−TRN PERIOD** screen called by pressing the FREQ key with pulse−train mode selected:

```
 PULS−TRN PER:
   100·00000    us

◊freq       period♦
```

The new setting can be entered either as a period in the way already described or as a frequency by first pressing the **freq** soft−key. However, changing the period/frequency from this screen is slightly different from changing period on the **pulse−train setup** screen. When changing from this screen the number of points in the waveform is never changed (just as with a true arb) which means that the shortest period/highest frequency that can be set is the number of waveform points x 10·00ns. To achieve faster frequencies (up to the specification limit) the period must be changed from the pulse-train set-up screen; changing the frequency from the pulse-train set-up screen causes the number of points to be reduced as the period is reduced (for period <1·00ms).

Modulation

External modulation can be set to VCA (Voltage Controlled Amplitude) or SCM (Suppressed Carrier Modulation) modes.

Pressing the MODULATION key calls the **MODULATION** set–up screen.

```
MODULATION
⬍ source: ext
◊ type: VCA
```

The **source** soft–key steps the modulation choice between **off** and **ext**ernal. With **ext** selected the modulation can be switched between **VCA** and **SCM** with alternate presses of the **type** soft–key. External modulation can be used with external Sum.

External VCA

Select **VCA** with the **type** soft–key on the **MODULATION** screen. Connect the modulating signal to the MODULATION IN socket on the rear panel (nominally 1kΩ input impedance); a positive voltage increases the output amplitude and a negative voltage decreases the amplitude. Note that clipping will occur if the combination of amplitude setting and VCA signal attempts to drive the output above 20Vpp open–circuit voltage.

External AM is achieved by setting the required output level and applying the modulation signal (which can be AC coupled if required) at the appropriate level to obtain the modulation depth required. If the output level is changed the amplitude of the modulating signal will have to be changed to maintain the same modulation depth.

The VCA signal is applied to the amplifier chain prior to the output attenuators. The amplifier itself is controlled over a limited range (~10dB) and the full amplitude range is achieved by switching in up to five −10dB attenuation stages. Peak modulation cannot exceed the maximum of the "range" within which the channel output has been set by choice of amplitude setting; it is up to the user to observe the waveforms when using external VCA and to make adjustments if the waveform is clipping. Note that it is not possible to give a simple guide as to where the "range" breakpoints are because the use of DC Offset, for example, changes these points.

Within each "range" the maximum output setting at which clipping is avoided is reduced from range maximum to half this value as modulation is increased from 0% to 100%; 100% modulation will be achieved at this mid–range setting with an external VCA signal of approximately 1Vpp. Modulation frequency range is DC to 100kHz.

It is also possible to modulate a DC level from the generator with a signal applied to the MODULATION IN socket, as follows. Set the generator to external trigger on the **TRIGGER IN** setup screen but do not apply a trigger signal to TRIG IN; select squarewave. The MAIN OUT is now set at the peak positive voltage defined by the amplitude setting; pressing the ± key with **AMPLITUDE** displayed will set the level to the peak negative voltage. This DC level can now be modulated by the signal applied to the MODULATION IN input.

External SCM

Select **SCM** with the **type** soft–key on the **MODULATION** screen. Connect the modulating signal to the MODULATION IN input on the rear panel (nominally 1kΩ input impedance). With no signal the carrier is fully suppressed; a positive or negative level change at the modulation input increases the amplitude of the carrier. Note that clipping will occur if the SCM signal attempts to drive the output above the 20Vpp open–circuit voltage.

Peak modulation, i.e. maximum carrier amplitude (20Vpp), is achieved with an external SCM level of approximately ±1V, i.e. a 2Vpp signal. Modulation frequency range is DC to 100kHz.

When external SCM is selected the amplitude control is disabled; the **AMPLITUDE** setup screen shows the message **fixed by SCM**.

Sum

External summing can be used to add 'noise' to a waveform, for example, or to add two signals for DTMF (Dual Tone Multiple Frequency) testing.

In Sum mode an external signal applied to the SUM input on the rear panel is summed with the selected waveform. Pressing the SUM key calls the `SUM` set–up screen.

```
SUM       source: ext⬍

◊CH1      +2·00  Vpp
```

Pressing the `source` soft–key steps the Sum sources between `off` and `ext`ernal.

With `ext` selected the screen is as shown above.

Clipping will occur if the Sum input level attempts to drive the channel amplitude above the maximum 20Vpp open–circuit voltage. However, the relationship between the SUM input and the maximum summed output depends not only on the Sum input level but also on the generator amplitude setting. This is because the Sum input is applied to the amplifier chain prior to the output attenuators; the amplifier itself is controlled over a limited range (~10dB) and the full amplitude range is achieved by switching in up to five –10dB attenuation stages. The summed output cannot exceed the maximum of the "range" within which the output has been set by choice of amplitude setting; it is up to the user to observe the waveforms when using external sum and to make adjustments if the waveform is clipping. Note that it is not possible to give a simple guide as to where the "range" breakpoints are because the use of DC Offset, for example, changes these points.

Within each "range" a SUM signal of ~2Vpp will force the channel output from range minimum to range maximum; if the amplitude is set to mid–range the SUM signal needed to force the output to range maximum is about half, i.e. ~1Vpp.

To facilitate the setting of appropriate Sum and amplitude levels the output amplitude can also be changed from the `SUM` set–up screen. Press the `CH1` soft–key and adjust the amplitude with direct keyboard entries or by using the rotary knob.

Synchronising Two Generators

Two generators can be synchronised together following the procedure outlined below. It is possible to link more than two generators in this way but results are not guaranteed.

Synchronising Principles

Frequency locking is achieved by using the clock output from the 'master' generator to drive the clock input of a slave. The additional connection of an initialising SYNC signal permits the slave to be synchronised such that the phase relationship between master and slave outputs is that specified on the slave generator's TRIGGER/GATE set–up screen.

Synchronisation is only possible between generators when the ratio of the master and slave frequencies is rational, e.g. 3kHz can be synchronised with 2kHz but not with 7kHz. Special considerations arise with waveforms generated by Clock Synthesis mode (squarewave, arbitrary, pulse, pulse–train and sequence) because of the relatively poor precision with which the frequency is actually derived in the hardware. With these waveforms, frequencies with an apparently rational relationship (e.g. 3:1) may be individually synthesised such that the ratio is not close enough to e.g. 3:1 to maintain phase lock over a period of time; the only relationships guaranteed to be realised precisely are 2^n:1 because the division stages in Clock Synthesis mode are binary. A further complication arises with arb waveforms because waveform frequency depends on both waveform size and clock frequency (waveform frequency = clock frequency ÷ waveform size). The important relationship with arbs is the ratio of **clock** frequencies and the above considerations on precision apply to them. The most practical use of synchronisation will be to provide outputs at the same frequency, or maybe harmonics, but with phase differences.

Connections for Synchronisation

The clock connection arrangement is for the rear panel REF CLOCK IN/OUT of the master (which will be set to **master**) to be connected directly to the REF CLOCK IN/OUT socket of the slave (which will be set to **slave**).

Similarly the synchronising connection is from the SYNC OUT of the master, which defaults to **phase lock**, to the TRIG IN input of the slave.

Generator Set-ups

Each generator can have its main parameters set to any value, with the exception that the ratio of frequencies between master and slave must be rational and each generator can be set to any waveform, but see Synchronising Principles section above.

The master has its REF CLOCK IN/OUT set to **master** on the **REF. CLOCK:** menu called by the **ref. clock** soft–key on the UTILITY screen, see System Operations section.

```
REF.  CLOCK:


⬥ref clk: input
```
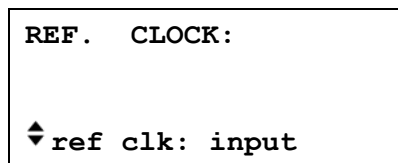
Repeated presses of the **ref clk** soft–key toggle between **input, output, master** and **slave**.

The slave is set to **slave.** Setting the slave generator to **slave** forces the slave's mode to continuous and defaults the SYNC OUT output to phase lock. The phase relationship between the slave and the master is set on the TRIGGER/GATE set–up screen of the slave, accessed by pressing the **triggered set-up...** soft-key on the **MODE** screen, see the Start Phase section of the Triggered Burst and Gate chapter.

```
TRIGGER/GATE SETUP:
♦burst cnt: 0000001
◊phase:   +000.0°
 (actual: +000·0°)
```

The convention adopted for the phase relationship between generators is that a positive phase setting advances the slave generator with respect to the master and a negative setting delays the slave generator.

Hardware delays become increasingly significant as frequency increases causing additional phase delay between the master and slave. However, these delays can be largely nulled−out by 'backing−off' the phase settings of the slave.

Typically these hardware delays are as follows:

> DDS waveforms: <± 25ns; <1° to 100kHz
>
> Clock Synthesised waveforms: <300ns; <1° to 10kHz.

Synchronising

Having made the connections and set up the generators as described in the preceding paragraphs, synchronisation is achieved by pressing the MAN TRIG key of the slave. Once synchronised any change to the setup will require resynchronisation with the MAN TRIG key again.

Other Phase-Locking Considerations

The following further points should also be considered.

- The waveform filters introduce a frequency−dependent delay above ~1MHz; this will affect the accuracy of the phase between locked waveforms at different frequencies, e.g. 500kHz and 5MHz.

- Square waves, which are 2−point Clock Synthesised waveforms will not reliably lock to other Clock Synthesised waveforms.

- Pulse and Pulse train waveforms will lock to other Pulse and Pulse−trains (and each other) but should be **built** with equal periods.

- Arb waveforms should be the same length (although this is not forced and does not create an error message).

- To avoid excessive locking times when using DDS waveforms the actual frequency is offset by a small amount (<1ppm) to ensure that no frequency is an exact sub-multiple of the 100MHz clock frequency. This in turn ensures that the master instrument will always produce the required locking signal from the SYNC OUT socket. This frequency offset is applied in three ranges: 0 to 25kHz, 25kHz to 1MHz and 1MHz to 40MHz. It is **not** possible to lock frequencies from different ranges.

System Operations from the Utility Menu

Pressing the UTILITY key calls a list of menus which give access to various system operations including storing/recalling set−ups from battery backed memory, error messages, power on settings and calibration.

Each of the following operations are accessed by pressing the appropriate soft-key on the **UTILITY MENU**. Press UTILITY again at any time to return to the main Utility menu.

Storing and Recalling Set-ups

Complete set-ups can be stored to or recalled from non-volatile memory using the screens called by the **store** and **recall** soft-keys.

Pressing **store...** calls the screen:

```
Save to store No: 1


◊ execute
```

Nine stores numbered 1 to 9 inclusive are available. Select the store using the rotary control or direct keyboard entry and press to **execute** implement the store function.

Pressing **recall...** (or the RECALL front panel key) calls the **RECALL** screen:

```
Recall store No: 1:

◊set defaults
◊execute
```

The required set-up is selected using the rotary control or direct keyboard entry and the recall is actioned with the **execute** soft-key. The factory defaults (see Appendix 3) can be recalled using the **set defaults** soft-key. Note that loading the defaults does not change any arbitrary waveforms or stored setups or the RS232/GPIB/USB interface settings.

Warnings and Error messages

The default setup is for all warning and error messages to be displayed and for a beep to sound with each message. This setup can be changed on the **error**... menu:

```
◊error beep: ON
◊error message: ON
⬍ warn beep: ON
◊ warn message: ON
```

Each feature can be turned ON or OFF with alternate presses of the appropriate soft−key.

The last two error messages can be viewed by pressing the **last error**... soft−key. Each message has a number and the full list appears in Appendix 1. See also Warnings and Error Messages in the Standard Waveform Operation section.

Remote Interface Setup

Pressing **remote...** calls the **REMOTE** setup screen which permits RS232/GPIB/USB choice and selection of address and Baud rate. Full details are given in the Remote Operation section.

Reference Clock In/Out Setting

The function of the rear panel REF CLOCK IN/OUT socket is set on the **REF. CLOCK** screen, called by pressing the **ref. clock** soft−key.

```
REF. CLOCK:


◆ ref clk: input
```

The default setting is for the socket to be set to **input**, i.e. an input for an external 10MHz reference clock. When set to **input** the system is automatically switched over to the external reference when an adequate signal level (TTL/CMOS threshold) is detected at REF CLOCK IN/OUT but will continue to run from the internal clock in the absence of such a signal.

With the clock set to **output** a buffered version of the internal 10MHz clock is made available at the socket.

Select **master** or **slave** when used for synchronising (phase−locking) multiple generators. See Synchronising Generators section for full details.

Power On Setting

Pressing the **power on**… soft−key calls the **POWER ON SETTING** screen:

```
POWER ON SETTING
◊default values
◊restore last setup
◆recall store 1
```

The setting loaded at power on can be selected with the appropriate soft−key to be **default values** (the default setting), **restore last setup** (i.e. the settings at power down are restored at power up) or any of the stored settings. The complete list of set-ups can be scrolled through with further presses of the **recall** soft-key, the cursor keys or the rotary control. **default values** restores the factory default settings, see Appendix 3.

System Information

The **system info**… soft−key calls the **SYSTEM INFO** screen which shows the instrument name and firmware revision. When **system info**… is pressed a checksum is also made of the firmware code and the result displayed; this can be used when a firmware fault is suspected, to check that the code has not got corrupted.

Calibration

Pressing **calibration** calls the calibration routine, see Calibration section.

All parameters can be calibrated without opening the case, i.e. the generator offers 'closed−box' calibration. All adjustments are made digitally with calibration constants stored in EEPROM. The calibration routine requires only a DVM and a frequency counter and takes no more than a few minutes.

The crystal in the timebase is pre−aged but a further ageing of up to ±5ppm can occur in the first year. Since the ageing rate decreases exponentially with time it is an advantage to recalibrate after the first 6 month's use. Apart from this it is unlikely that any other parameters will need adjustment.

Calibration should be carried out only after the generator has been operating for at least 30 minutes in normal ambient conditions.

Equipment Required

- 3½ digit DVM with 0·25% DC accuracy and 0·5% AC accuracy at 1kHz.
- Frequency counter capable of measuring 10·00000MHz.

The DVM is connected to the MAIN OUT and the counter to the SYNC OUT.

Frequency meter accuracy will determine the accuracy of the generator's clock setting and should ideally be ±1ppm.

Calibration Procedure

The calibration procedure is accessed by pressing the `calibration…` soft−key on the `UTILITY` screen.

```
CALIBRATION SELECTED
   Are you sure ?
◊password…    tests…◊
◊exit       continue◊
```

The software provides for a 4−digit password in the range 0000 to 9999 to be used to access the calibration procedure. If the password is left at the factory default of 0000 no messages are shown and calibration can proceed as described in the Calibration Routine section; only if a non−zero password has been set will the user be prompted to enter the password.

Setting the Password

On opening the Calibration screen press the `password…` soft−key to show the password screen:

```
ENTER NEW PASSWORD
     ────
```

Enter a 4−digit password from the keyboard; the display will show the message `NEW PASSWORD STORED!`   for two seconds and then revert to the `UTILITY` menu. If any keys other than 0−9 are pressed while entering the password the message `ILLEGAL PASSWORD!` will be shown.

Using the Password to Access Calibration or Change the Password

With the password set, pressing `calibration…` on the `UTILITY`   screen will now show:

```
ENTER PASSWORD
    ----
```

When the correct password has been entered from the keyboard the display changes to the opening screen of the calibration routine and calibration can proceed as described in the Calibration Routine section. If an incorrect password is entered the message `INCORRECT PASSWORD!` is shown for two seconds before the display reverts to the `UTILITY` menu.

With the opening screen of the calibration routine displayed after correctly entering the password, the password can be changed by pressing `password...` soft−key and following the procedure described in Setting the Password. If the password is set to 0000 again, password protection is removed.

The password is held in EEPROM and will not be lost when the memory battery back−up is lost. In the event of the password being forgotten, contact the manufacturer for help in resetting the instrument.

Calibration Routine

The calibration procedure proper is entered by pressing `continue` on the opening Calibration screen; pressing `exit` returns the display to the `UTILITY` menu. Pressing `tests`… calls a menu of basic hardware checks used at production test; these are largely self−explanatory but details can be found in the Service Manual if required. At each step the display changes to prompt the user to adjust the rotary control or cursor keys, until the reading on the specified instrument is at the value given. The cursor keys provide coarse adjustment, and the rotary control fine adjustment. Pressing `next` increments the procedure to the next step; pressing CE decrements back to the previous step. Alternatively, pressing `exit` returns the display to the last CAL screen at which the user can choose to either `save new values, recall old values` or `calibrate again.`

The first two displays (CAL 00 and CAL 01) specify the connections and adjustment method. The next display (CAL 02) allows the starting channel to be chosen; this allows quick access to any particular channel. To calibrate the complete instrument choose the default setting of CH1. The subsequent displays, CAL 03 to CAL 31, permit all adjustable parameters to be calibrated.

The full procedure is as follows:

CAL 03	CH1. DC offset zero.	Adjust for 0V ± 5mV
CAL 04	CH1. DC offset at + full scale.	Adjust for + 10V ± 10mV
CAL 05	CH1. DC offset at − full scale.	Check for −10V ± 3%
CAL 06	CH1. Multiplier zero.	Adjust for minimum Volts AC
CAL 07	CH1. Multiplier offset.	Adjust for 0V ± 5mV
CAL 08	CH1. Waveform offset.	Adjust for 0V ± 5mV
CAL 09	CH1. Output level at full−scale	Adjust for 10V ± 10mV
CAL 10	CH1. 20dB attenuator	Adjust for 1V ± 1mV
CAL 11	CH1. 40dB attenuator	Adjust for 0·1V ± ·1mV
CAL 12	CH1. 10dB attenuator	Adjust for 2·236V AC ± 10mV
CAL 13	CH1. Not used.	
CAL 14	CH1. Not used.	
CAL 15	CH1. Not used.	
CAL 16	Level 0.1 MHz	Note reading
CAL 17	Level 33MHz	Check reading
CAL 18	Level 1MHz	Adjust for same reading
CAL 19	Level 2MHz	Adjust for same reading
CAL 20	Level 4MHz	Adjust for same reading
CAL 21	Level 5MHz	Adjust for same reading
CAL 22	Level 10MHz	Adjust for same reading
CAL 23	Level 15MHz	Adjust for same reading
CAL 24	Level 20MHz	Adjust for same reading

CAL 25	Level 25MHz	Adjust for same reading
CAL 26	Level 30MHz	Adjust for same reading
CAL 27	Level 32·5MHz	Adjust for same reading
CAL 28	Level 35MHz	Adjust for same reading
CAL 29	Level 37·5MHz	Adjust for same reading
CAL 30	Level 40MHz	Adjust for same reading
CAL 31	Clock calibrate	Adjust for 10·00000 MHz at SYNC OUT.

Remote Calibration

Calibration of the instrument may be performed over the RS232 or GPIB interface. To completely automate the process the multimeter and frequency meter will also need to be remote controlled and the controller will need to run a calibration program unique to this instrument.

The remote calibration commands allow a simplified version of manual calibration to be performed by issuing commands from the controller. The controller must send the CALADJ command repeatedly and read the dmm or frequency meter until the required result for the selected calibration step is achieved. The CALSTEP command is then issued to accept the new value and move to the next step.

While in remote calibration mode very little error checking is performed and it is the controllers responsibility to ensure that everything progresses in an orderly way. Only the following commands should be used during calibration.

WARNING: Using any other commands while in calibration mode may give unpredictable results and could cause the instrument to lock up, requiring the power to be cycled to regain control.

CALIBRATION <cpd> [,nrf]   The calibration control command. <cpd> can be one of three sub−commands:−

     START   Enter calibration mode; this command must be issued before any other calibration commands will be recognised.

     SAVE   Finish calibration, save the new values and exit calibration mode.

     ABORT   Finish calibration, do not save the new values and exit calibration mode.

                 <nrf> represents the calibration password. The password is only required with CALIBRATION START and then only if a non−zero password has been set from the instrument's keyboard. The password will be ignored, and will give no errors, at all other times.

                  It is not possible to set or change the password using remote commands.

CALADJ <nrf>   Adjust the selected calibration value by <nrf>. The value must be in the range −100 to +100. Once an adjustment has been completed and the new value is as required the CALSTEP command must be issued for the new value to be accepted.

CALSTEP   Step to the next calibration point.

For general information on remote operation and remote command formats, refer to the following sections.

Remote Operation

The instrument can be remotely controlled via its RS232, USB or GPIB interfaces. When using RS232 it can either be the only instrument connected to the controller or it can be part of an addressable RS232 system which permits up to 32 instruments to be addressed from one RS232 port.

Some of the following sections are general and apply to all 4 modes (single instrument RS232, addressable RS232, USB and GPIB); others are clearly only relevant to a particular interface or mode. It is only necessary to read the general sections plus those specific to the intended remote control mode.

Remote command format and the remote commands themselves are detailed in the Remote Commands chapter.

Address and Baud Rate Selection

For successful operation, each instrument connected to the GPIB, USB or addressable RS232 system must be assigned a unique address and, in the case of addressable RS232, all must be set to the same Baud rate.

The instrument's remote address for operation on both the RS232 and GPIB interfaces is set via the **remote** screen on the UTILITY menu:

```
REMOTE:
⬦ interface: RS232
◊address:    05
◊baud rate: 9600
```

With **interface** selected with the **interface** soft−key, the selection can be stepped between RS232, USB and GPIB with successive presses of the soft−key, the cursor keys or by using the rotary control.

With **address** selected, the soft−key, cursor keys or rotary control can be used to set the address; the address setting is ignored in USB mode.

With **baud rate** selected, the soft−key, cursor keys or rotary control can be used to set the baud rate for the RS232 interface.

When operating on the GPIB all device operations are performed through a single primary address; no secondary addressing is used.

NOTE: GPIB address 31 is not allowed by the IEEE 488 standards but it is possible to select it as an RS232 address.

Remote/Local Operation

At power−on the instrument will be in the local state with the REMOTE lamp off. In this state all keyboard operations are possible. When the instrument is addressed to listen and a command is received the remote state will be entered and the REMOTE lamp will be turned on. In this state the keyboard is locked out and remote commands only will be processed. The instrument may be returned to the local state by pressing the LOCAL key; however, the effect of this action will remain only until the instrument is addressed again or receives another character from the interface, when the remote state will once again be entered.

RS232 Interface

RS232 Interface Connector

The 9–way D–type serial interface connector is located on the instrument rear panel. The pin connections are as shown below:

Pin	Name	Description
1	–	No internal connection
2	TXD	Transmitted data from instrument
3	RXD	Received data to instrument
4	–	No internal connection
5	GND	Signal ground
6	–	No internal connection
7	RXD2	Secondary received data (addressable RS232 only)
8	TXD2	Secondary transmitted data (addressable RS232 only)
9	GND	Signal ground (addressable RS232 only)

Single Instrument RS232 Connections

For single instrument remote control only pins 2, 3 and 5 are connected to the PC. However, for correct operation links must be made in the connector at the PC end between pins 1, 4 and 6 and between pins 7 and 8, see diagram. Pins 7 and 8 of the instrument must **not** be connected to the PC, i.e. do not use a fully wired 9–way cable.
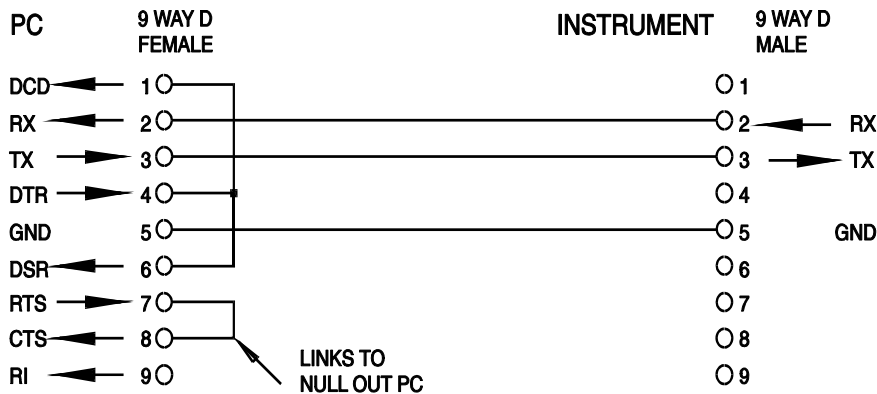
Baud Rate is set as described above in Address and Baud Rate Selection; the other parameters are fixed as follows:

Start Bits: 1	Parity: None
Data Bits: 8	Stop Bits: 1

Addressable RS232 Connections

For addressable RS232 operation pins 7, 8 and 9 of the instrument connector are also used. Using a simple cable assembly, a 'daisy chain' connection system between any number of instruments, up to the maximum of 32 can be made, as shown below:
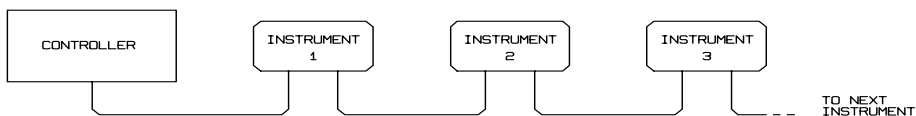
The daisy chain consists of the transmit data (TXD), receive date (RXD) and signal ground lines only. There are no control/handshake lines. This makes XON/XOFF protocol essential and allows the inter–connection between instruments to contain just 3 wires. The wiring of the adaptor cable is shown below:

9 WAY D
FEMALE

9 WAY D
MALE

```
DCD ◄──────  1 ○                                    ○ 1
RX  ◄──────  2 ○                                    ○ 2  ◄──── TX
TX  ──────►  3 ○                                    ○ 3  ────► RX
DTR ──────►  4 ○                                    ○ 4
GND          5 ○                                    ○ 5      GND
DSR ◄──────  6 ○                                    ○ 6
RTS ──────►  7 ○                                    ○ 7
CTS ◄──────  8 ○                                    ○ 8
RI  ◄──────  9 ○                                    ○ 9
```

UP TO
CONTROLLER

LINKS TO
NULL OUT PC

DOWN THE
CHAIN

AN INSTRUMENT
ON THE CHAIN

```
○ ○ ○ ○ ○ ○ ○ ○ ○    9 WAY D
1 2 3 4 5 6 7 8 9    MALE
```

TX RX   TXIN RXOUT
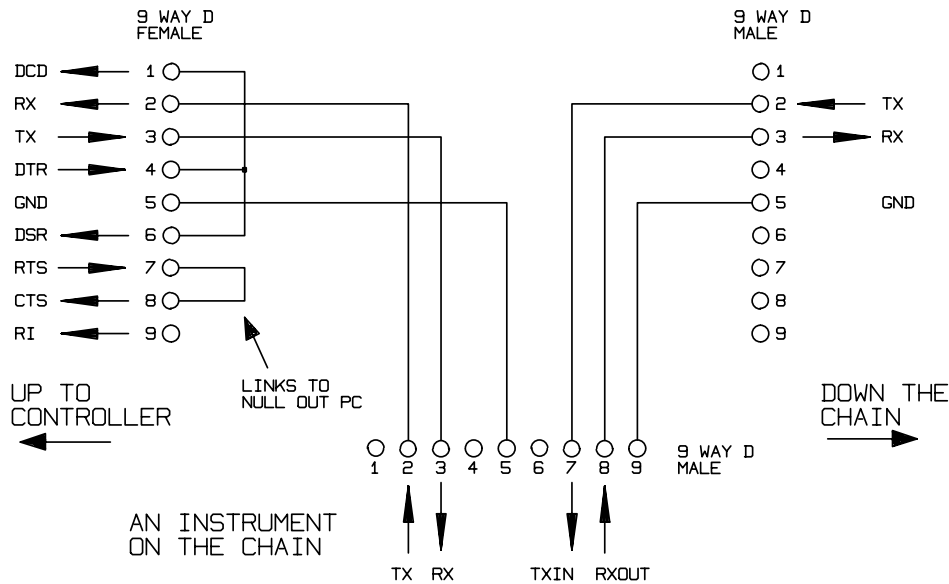
All instruments on the interface must be set to the same baud rate and all must be powered on, otherwise instruments further down the daisy chain will not receive any data or commands.

The other parameters are fixed as follows:

Start Bits: 1 Parity: None
Data Bits: 8 Stop Bits: 1

RS232 Character Set

Because of the need for XON/XOFF handshake it is possible to send ASCII coded data only; binary blocks are not allowed. Bit 7 of ASCII codes is ignored, i.e. assumed to be low. No distinction is made between upper and lower case characters in command mnemonics and they may be freely mixed. The ASCII codes below 20H (space) are reserved for addressable RS232 interface control. In this manual 20H, etc. means 20 in hexadecimal

Addressable RS232 Interface Control Codes

All instruments intended for use on the addressable RS232 bus use the following set of interface control codes. Codes between 00H and 1FH which are not listed here as having a particular meaning are reserved for future use and will be ignored. Mixing interface control codes inside instrument commands is not allowed except as stated below for CR and LF codes and XON and XOFF codes.

When an instrument is first powered on it will automatically enter the Non− Addressable mode. In this mode the instrument is not addressable and will not respond to any address commands. This allows the instrument to function as a normal RS232 controllable device. This mode may be locked by sending the Lock Non−Addressable mode control code, 04H. The controller and instrument can now freely use all 8 bit codes and binary blocks but all interface control codes are ignored. To return to addressable mode the instrument must be powered off.

To enable addressable mode after an instrument has been powered on the Set Addressable Mode control code, 02H, must be sent. This will then enable all instruments connected to the addressable RS232 bus to respond to all interface control codes. To return to Non−Addressable mode the Lock Non−Addressable mode control code must be sent which will disable addressable mode until the instruments are powered off.

Before an instrument is sent a command it must be addressed to listen by sending the Listen Address control code, 12H, followed by a single character which has the lower 5 bits corresponding to the unique address of the required instrument, e.g. the codes A−Z or a−z give the addresses 1−26 inclusive while @ is address 0 and so on. Once addressed to listen the instrument will read and act upon any commands sent until the listen mode is cancelled.

Because of the asynchronous nature of the interface it is necessary for the controller to be informed that an instrument has accepted the listen address sequence and is ready to receive commands. The controller will therefore wait for Acknowledge code, 06H, before sending any commands, The addressed instrument will provide this Acknowledge. The controller should time−out and try again if no Acknowledge is received within 5 seconds.

Listen mode will be cancelled by any of the following interface control codes being received:

12H   Listen Address followed by an address not belonging to this instrument.

14H   Talk Address for any instrument.

03H   Universal Unaddress control code.

04H   Lock Non−Addressable mode control code.

18H   Universal Device Clear.

Before a response can be read from an instrument it must be addressed to talk by sending the Talk Address control code, 14H, followed by a single character which has the lower 5 bits corresponding to the unique address of the required instrument, as for the listen address control code above. Once addressed to talk the instrument will send the response message it has available, if any, and then exit the talk addressed state. Only one response message will be sent each time the instrument is addressed to talk.

Talk mode will be cancelled by any of the following interface control codes being received:

12H   Listen Address for any instrument.

14H   Talk Address followed by an address not belonging to this instrument.

03H   Universal Unaddress control code.

04H   Lock Non−Addressable mode control code.

18H   Universal Device Clear.

Talk mode will also be cancelled when the instrument has completed sending a response message or has nothing to say.

The interface code 0AH (LF) is the universal command and response terminator; it must be the last code sent in all commands and will be the last code sent in all responses.

The interface code 0DH (CR) may be used as required to aid the formatting of commands; it will be ignored by all instruments. Most instruments will terminate responses with CR followed by LF.

The interface code 13H (XOFF) may be sent at any time by a listener (instrument or controller) to suspend the output of a talker. The listener must send 11H (XON) before the talker will resume sending. This is the only form of handshake control supported by the addressable RS232 mode.

Full List of Addressable RS232 Interface Control Codes

02H   Set Addressable Mode.

03H   Universal Unaddress control code.

04H   Lock Non−Addressable mode control code.

06H   Acknowledge that listen address received.

0AH   Line Feed (LF); used as the universal command and response terminator.

0DH   Carriage Return (CR); formatting code, otherwise ignored.

11H   Restart transmission (XON).

12H   Listen Address − must be followed by an address belonging to the required instrument.

13H   Stop transmission (XOFF).

14H   Talk Address − must be followed by an address belonging to the required instrument.

18H   Universal Device Clear.

USB Interface

The USB interface allows the instrument to be controlled via a PC's USB port. The instrument is supplied with a CD containing drivers for various versions of Windows, including Win98 and 2000. Any driver updates are available via the TTi website, www.tti-test.com. The CD also contains a .pdf file with information and details of the software installation procedure.

Installation of the driver is achieved by connecting the instrument to a PC via a standard USB cable. The Windows' plug and play functions should automatically recognise the addition of new hardware attached to the USB interface and if this is the first time the connection has been made, prompt for the location of a suitable driver. Provided that the standard Windows prompts are followed correctly Windows will install the appropriate driver. The driver will remain installed on the PC and should be called automatically each time the instrument is connected to the PC via USB in the future.

The waveform design software supplied with this generator has been enhanced to permit downloads to the instrument using USB. For users wishing to write their own application software for USB communication with the generator, the relevant information is supplied on the CD containing the drivers themselves.

GPIB Interface

The 24−way GPIB connector is located on the instrument rear panel. The pin connections are as specified in IEEE Std. 488.1−1987 and the instrument complies with IEEE Std. 488.1−1987 and IEEE Std. 488.2−1987.

GPIB Subsets

This instrument contains the following IEEE 488.1 subsets:

Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T6
Listener	L4
Service Request	SR1
Remote Local	RL1
Parallel Poll	PP1
Device Clear	DC1
Device Trigger	DT1
Controller	C0
Electrical Interface	E2

GPIB IEEE Std. 488.2 Error Handling

The IEEE 488.2 UNTERMINATED error (addressed to talk with nothing to say) is handled as follows. If the instrument is addressed to talk and the response formatter is inactive and the input queue is empty then the UNTERMINATED error is generated. This will cause the Query Error bit to be set in the Standard Event Status Register, a value of 3 to be placed in the Query Error Register and the parser to be reset. See the Status Reporting section for further information.

The IEEE 488.2 INTERRUPTED error is handled as follows. If the response formatter is waiting to send a response message and a <PROGRAM MESSAGE TERMINATOR> has been read by the parser or the input queue contains more than one END message then the instrument has been INTERRUPTED and an error is generated. This will cause the Query Error bit to be set in the Standard Event Status Register, a value of 1 to be placed in the Query Error Register and the response formatter to be reset thus clearing the output queue. The parser will then start parsing the next <PROGRAM MESSAGE UNIT> from the input queue. See the Status Reporting section for further information.

The IEEE 488.2 DEADLOCK error is handled as follows. If the response formatter is waiting to send a response message and the input queue becomes full then the instrument enters the DEADLOCK state and an error is generated. This will cause the Query Error bit to be set in the Standard Event Status Register, a value of 2 to be placed in the Query Error Register and the response formatter to be reset thus clearing the output queue. The parser will then start parsing the next <PROGRAM MESSAGE UNIT> from the input queue. See the Status Reporting section for further information.

GPIB Parallel Poll

Complete parallel poll capabilities are offered on this generator. The Parallel Poll Enable Register is set to specify which bits in the Status Byte Register are to be used to form the ist local message The Parallel Poll Enable Register is set by the *PRE <nrf> command and read by the *PRE? command. The value in the Parallel Poll Enable Register is ANDed with the Status Byte Register; if the result is zero then the value of ist is 0 otherwise the value of ist is 1.

The instrument must also be configured so that the value of ist can be returned to the controller during a parallel poll operation. The instrument is configured by the controller sending a Parallel Poll Configure command (PPC) followed by a Parallel Poll Enable command (PPE). The bits in the PPE command are shown below:

bit 7 =	X	don't care
bit 6 =	1	
bit 5 =	1	Parallel poll enable
bit 4 =	0	
bit 3 =	Sense	sense of the response bit; 0 = low, 1 = high
bit 2 =	?	
bit 1 =	?	bit position of the response
bit 0 =	?	

Example. To return the RQS bit (bit 6 of the Status Byte Register) as a 1 when true and a 0 when false in bit position 1 in response to a parallel poll operation send the following commands

*PRE 64<pmt>, then PPC followed by 69H (PPE)

The parallel poll response from the generator will then be 00H if RQS is 0 and 01H if RQS is 1.

During parallel poll response the DIO interface lines are resistively terminated (passive termination). This allows multiple devices to share the same response bit position in either wired−AND or wired−OR configuration, see IEEE 488.1 for more information.

Status Reporting

This section describes the complete status model of the instrument. Note that some registers are specific to the GPIB section of the instrument and are of limited use in an RS232 environment.

Standard Event Status and Standard Event Status Enable Registers

These two registers are implemented as required by the IEEE std. 488.2.
Any bits set in the Standard Event Status Register which correspond to bits set in the Standard Event Status Enable Register will cause the ESB bit to be set in the Status Byte Register.

The Standard Event Status Register is read and cleared by the *ESR? command. The Standard Event Status Enable register is set by the *ESE <nrf> command and read by the *ESE? command.

Bit 7 −   Power On. Set when power is first applied to the instrument.

Bit 6 −   Not used.

Bit 5 −   Command Error. Set when a syntax type error is detected in a command from the bus. The parser is reset and parsing continues at the next byte in the input stream.

Bit 4 – Execution Error. Set when an error is encountered while attempting to execute a completely parsed command. The appropriate error number will be reported in the Execution Error Register.

Bit 3 – Not used.

Bit 2 – Query Error. Set when a query error occurs. The appropriate error number will be reported in the Query Error Register as listed below.
1. Interrupted error
2. Deadlock error
3. Unterminated error

Bit 1 – Not used.

Bit 0 – Operation Complete. Set in response to the *OPC command.

Status Byte Register and Service Request Enable Register

These two registers are implemented as required by the IEEE std. 488.2.
Any bits set in the Status Byte Register which correspond to bits set in the Service Request Enable Register will cause the RQS/MSS bit to be set in the Status Byte Register, thus generating a Service Request on the bus.

The Status Byte Register is read either by the *STB? command, which will return MSS in bit 6, or by a Serial Poll which will return RQS in bit 6. The Service Request Enable register is set by the *SRE <nrf> command and read by the *SRE? command.

Bit 7 – Not used.

Bit 6 – RQS/MSS. This bit, as defined by IEEE Std. 488.2, contains both the Requesting Service message and the Master Status Summary message. RQS is returned in response to a Serial Poll and MSS I–s returned in response to the *STB? command.

Bit 5 – ESB. The Event Status Bit. This bit is set if any bits set in the Standard Event Status Register correspond to bits set in the Standard Event Status Enable Register.

Bit 4 – MAV. The Message Available Bit. This will be set when the instrument has a response message formatted and ready to send to the controller. The bit will be cleared after the Response Message Terminator has been sent.

Bit 3 – Not used.

Bit 2 – Not used.

Bit 1 – Not used.

Bit 0 – Not used.

```
                    POWER ON
                        COMMAND ERROR
                            EXECUTION ERROR - ERROR NUMBER IN EXECUTION ERROR
                                           REGISTER
                                    EER? (READ AND CLEAR)
                              QUERY ERROR - ERROR NUMBER IN QUERY ERROR
                                           REGISTER
                                      QER? (READ AND CLEAR)
                                OPERATION COMPLETE
```

7	X	5	4	X	2	X	0

STANDARD EVENT STATUS REGISTER
*ESR? (READ AND CLEAR)

OR ← & — & & — & — &

7	X	5	4	3	2	X	0

STANDARD EVENT STATUS
ENABLE REGISTER
*ESE <NRF> (SET TO <NRF>)
*ESE? (READ)

RESPONSE READY

| SRQ GEN | | X | RQS / MSS | ESB | MAV | X | X | X | X |

STATUS BYTE REGISTER
SERIAL POLL (READ WITH RQS)
*STB? (READ WITH MSS)

OR
& ← & <

X	X	5	4	X	X	X	X

SERVICE REQUEST ENABLE REGISTER
*SRE <NRF> (SET TO <NRF>)
*SRE? (READ)

Status Model

Power on Settings

The following instrument status values are set at power on:

Status Byte Register	= 0
Service Request Enable Register †	= 0
Standard Event Status Register	= 128 (pon bit set)
Standard Event Status Enable Register †	= 0
Execution Error Register	= 0
Query Error Register	= 0
Parallel Poll Enable Register †	= 0

† Registers marked thus are specific to the GPIB section of the instrument and are of limited use in an RS232 environment.

The instrument will be in local state with the keyboard active.

The instrument parameters at power on are determined on the **POWER ON SETTING** screen accessed from the UTILITY menu. If **restore last setup** or **recall store no. nn** has been set and a defined state is required by the controller at start up then the command ∗RST should be used to load the system defaults.

If for any reason an error is detected at power up in the non−volatile ram a warning will be issued and all settings will be returned to their default states as for a *RST command.

Remote Commands

RS232 Remote Command Formats

Serial input to the instrument is buffered in a 256 byte input queue which is filled, under interrupt, in a manner transparent to all other instrument operations. The instrument will send XOFF when approximately 200 characters are in the queue. XON will be sent when approximately 100 free spaces become available in the queue after XOFF was sent. This queue contains raw (un–parsed) data which is taken, by the parser, as required. Commands (and queries) are executed in order and the parser will not start a new command until any previous command or query is complete. In non–addressable RS232 mode responses to commands or queries are sent immediately; there is no output queue. In addressable mode the response formatter will wait indefinitely if necessary, until the instrument is addressed to talk and the complete response message has been sent, before the parser is allowed to start the next command in the input queue.

Commands must be sent as specified in the commands list and must be terminated with the command terminator code 0AH (Line Feed, LF). Commands may be sent in groups with individual commands separated from each other by the code 3BH (;). The group must be terminated with command terminator 0AH (Line Feed, LF).

Responses from the instrument to the controller are sent as specified in the commands list. Each response is terminated by 0DH (Carriage Return, CR) followed by 0AH (Line Feed, LF).

<WHITE SPACE> is defined as character codes 00H to 20H inclusive with the exception of those which are specified as addressable RS232 control codes.

<WHITE SPACE> is ignored except in command identifiers. e.g. '*C LS' is not equivalent to '*CLS'.

The high bit of all characters is ignored.

The commands are case insensitive.

GPIB Remote Command Formats

GPIB input to the instrument is buffered in a 256 byte input queue which is filled, under interrupt, in a manner transparent to all other instrument operations. The queue contains raw (un–parsed) data which is taken, by the parser, as required. Commands (and queries) are executed in order and the parser will not start a new command until any previous command or query is complete. There is no output queue which means that the response formatter will wait, indefinitely if necessary, until the instrument is addressed to talk and the complete response message has been sent, before the parser is allowed to start the next command in the input queue.

Commands are sent as <PROGRAM MESSAGES> by the controller, each message consisting of zero or more <PROGRAM MESSAGE UNIT> elements separated by <PROGRAM MESSAGE UNIT SEPARATOR> elements.

A <PROGRAM MESSAGE UNIT> is any of the commands in the remote commands list.

A <PROGRAM MESSAGE UNIT SEPARATOR> is the semi–colon character ';' (3BH).

<PROGRAM MESSAGES> are separated by <PROGRAM MESSAGE TERMINATOR> elements which may be any of the following:

NL	The new line character (0AH)
NL^END	The new line character with the END message
^END	The END message with the last character of the message

Responses from the instrument to the controller are sent as <RESPONSE MESSAGES>. A <RESPONSE MESSAGE> consists of one <RESPONSE MESSAGE UNIT> followed by a <RESPONSE MESSAGE TERMINATOR>.

A <RESPONSE MESSAGE TERMINATOR> is the new line character with the END message NL^END.

Each query produces a specific <RESPONSE MESSAGE> which is listed along with the command in the remote commands list.

<WHITE SPACE> is ignored except in command identifiers. e.g. '*C LS' is not equivalent to '*CLS'. <WHITE SPACE> is defined as character codes 00H to 20H inclusive with the exception of the NL character (0AH).

The high bit of all characters is ignored.

The commands are case insensitive.

Command List

This section lists all commands and queries implemented in this instrument. The commands are listed in alphabetical order within the function groups.

Note that there are no dependent parameters, coupled parameters, overlapping commands, expression program data elements or compound command program headers; each command is completely executed before the next command is started. All commands are sequential and the operation complete message is generated immediately after execution in all cases.

The following nomenclature is used:

<rmt>   <RESPONSE MESSAGE TERMINATOR>

<cpd>   <CHARACTER PROGRAM DATA>, i.e. a short mnemonic or string such as ON or OFF.

<nrf>   A number in any format. e.g. 12, 12.00, 1.2 e 1 and 120 e−1 are all accepted as the number 12. Any number, when received, is converted to the required precision consistent with the use then rounded up to obtain the value of the command.

<nr1>   A number with no fractional part, i.e. an integer.

[…]   Any item(s) enclosed in these brackets are optional parameters. If more than one item is enclosed then all or none of the items are required.

The commands which begin with a * are those specified by IEEE Std. 488.2 as Common commands. All will function when used on the RS232 interface but some are of little use.

Frequency and Period

These commands set the frequency/period of the generator main output and are equivalent to pressing the FREQ key and editing that screen.

WAVFREQ <nrf>	Set the waveform frequency to <nrf> Hz.
WAVPER <nrf>	Set the waveform period to <nrf> sec.
CLKFREQ <nrf>	Set the arbitrary sample clock freq to <nrf> Hz.
CLKPER <nrf>	Set the arbitrary sample clock period to <nrf> sec.

Amplitude and DC Offset

AMPL <nrf>	Set the amplitude to <nrf> in the units as specified by the AMPUNIT command.
AMPUNIT <cpd>	Set the amplitude units to <VPP>, <VRMS> or <DBM>.
ZLOAD <cpd>	Set the output load, which the generator is to assume for amplitude and dc offset entries, to <50> (50Ω), <600> (600Ω) or <OPEN>.
DCOFFS <nrf>	Set the dc offset to <nrf> Volts.

Waveform Selection

WAVE <cpd>	Select the output waveform as <SINE>, <SQUARE>, <TRIANG>, <DC>, <POSRMP>, <NEGRMP>, <COSINE>, <HAVSIN>, <HAVCOS>, <SINC>, <PULSE>, <PULSTRN>, <NOISE> , <ARB1>, <ARB2>, <ARB3> or <ARB4>.
PULSPER <nrf>	Set the pulse period to <nrf> sec.
PULSWID <nrf>	Set the pulse width to <nrf> sec.
PULSDLY <nrf>	Set the pulse delay to <nrf> sec.
PULTRNLEN <nrf>	Set the number of pulses in the pulse−train to <nrf>.

PULTRNPER <nrf>	Set the pulse–train period to <nrf> sec.
PULTRNBASE <nrf>	Set the pulse–train base line to <nrf> Volts.
PULTRNLEV <nrf1>,<nrf2>	Set the level of pulse–train pulse number <nrf1> to <nrf2> Volts.
PULTRNWID <nrf1>,<nrf2>	Set the width of pulse–train pulse number <nrf1> to <nrf2> sec.
PULTRNDLY <nrf1>,<nrf2>	Set the delay of pulse–train pulse number <nrf1> to <nrf2> sec.
PULTRNMAKE	Makes the pulse–train and runs it – similar to the WAVE PULSTRN command.

Arbitrary Waveform Define

ARBDEFCSV <cpd>,<nrf>,<csv ascii data>	Define an arbitrary waveform with name <cpd> and length <nrf> and load with the data in <csv ascii data>. The name must be one of ARB1, ARB2, ARB3 or ARB4. The data will overwrite that currently stored for the specified arbitrary waveform and the waveform will be given the new length. The values are separated by a comma character and the data ends with <pmt>.
ARBDEF <cpd>,<nrf>,<bin data block>	Define an arbitrary waveform with name <cpd> and length <nrf> and load with the data in <bin data block>. The name must be one of ARB1, ARB2, ARB3 or ARB4. The data will overwrite that currently stored for the specified arbitrary waveform and the waveform will be given the new length. The data consists of two bytes per point with no characters between bytes or points. The point data is sent high byte first. The data block has a header which consists of the # character followed by several ascii coded numeric characters. The first if these defines the number of ascii characters to follow and these following characters define the length of the binary data in bytes. Due to the binary data block this command cannot be used over the RS232 interface.

Arbitrary Waveform Interrogation

ARBDATACSV? <cpd>	Returns the data from an existing arbitrary waveform. <cpd> must be one of ARB1, ARB2, ARB3 or ARB4. The data consists of ascii coded values as specified for the ARBDEFCSV command.
ARBDATA? <cpd>	Returns the data from an existing arbitrary waveform. <cpd> must be one of ARB1, ARB2, ARB3 or ARB4. The data consists of binary coded values as specified for the ARBDEF command. Due to the binary data block this command cannot be used over the RS232 interface.
ARBLEN? <cpd>	Returns the length, in points, of the arbitrary waveform <cpd>.

Mode Commands

MODE <cpd>	Set the mode to <CONT>, <GATE>, <TRIG>, <SWEEP> or <TONE>.
BSTCNT <nrf>	Set the burst count to <nrf>.
PHASE <nrf>	Set the generator phase to <nrf> degrees. This parameter is used for setting the trigger/gate mode start/stop phase and the phase difference when synchronising instruments.
TONEEND <nrf>	Delete tone frequency number <nrf> thus defining the end of the list.
TONEFREQ <nrf1>,<nrf2>,<nrf3>	Set tone frequency number <nrf1> to <nrf2> Hz. The third parameter sets the tone type; 1 will give Trig, 2 will give FSK, any other value gives Gate type.
SWPSTARTFRQ <nrf>	Set the sweep start frequency to <nrf> Hz.
SWPSTOPFRQ <nrf>	Set the sweep stop frequency to <nrf> Hz.
SWPCENTFRQ <nrf>	Set the sweep centre frequency to <nrf> Hz.
SWPSPAN <nrf>	Set the sweep frequency span to <nrf> Hz.
SWPTIME <nrf>	Set the sweep time to <nrf> sec.

SWPTYPE <cpd>	Set the sweep type to <CONT>, <TRIG> or <THLDRST> .
SWPDIRN <cpd>	Set the sweep direction to <UP>, <DOWN>, <UPDN> or <DNUP>.
SWPSYNC <cpd>	Set the sweep sync <ON> or <OFF>.
SWPSPACING <cpd>	Set the sweep spacing to <LIN> or <LOG>.
SWPMKR <nrf>	Set the sweep marker to <nrf> Hz.

Input/Output control

OUTPUT <cpd>	Set the main output <ON>, <OFF>, <NORMAL> or <INVERT>.
SYNCOUT <cpd>	Set the sync output <ON>, <OFF>, <AUTO>, <WFMSYNC>, <POSNMKR>, <BSTDONE>, <SEQSYNC>, <TRIGGER>, <SWPSYNC> or <PHASLOC>.
TRIGIN <cpd>	Set the trig input to <INT>, <EXT>, <MAN>, <PREV>, <NEXT>, <POS> or <NEG>.
TRIGLEV <nrf>	Set the trigger threshold level to <nrf> Volts.
TRIGPER <nrf>	Set the internal trigger generator period to <nrf> sec.
FORCETRG	Force a trigger to the selected channel. Will function with any trigger source except MANUAL specified.

Modulation Commands

MOD <cpd>	Set the modulation source to <OFF> or <EXT>.
MODTYPE <cpd>	Set the modulation type to <AM> or <SCM>.
SUM <cpd>	Set the sum source to <OFF> or <EXT>.

Synchronising Commands

REFCLK <cpd>	Set the ref. clock bnc to <IN>, <OUT>, <MASTER> or <SLAVE>.
ABORT	Aborts an external phase synchronising operation.
PHASE <nrf>	Set the generator phase to <nrf> degrees. This parameter is used for setting the trigger/gate mode start/stop phase and the phase difference when synchronising instruments.

Status Commands

∗CLS	Clear status. Clears the Standard Event Status Register, Query Error Register and Execution Error Register. This indirectly clears the Status Byte Register.
∗ESE <nrf>	Set the Standard Event Status Enable Register to the value of <nrf>.
∗ESE?	Returns the value in the Standard Event Status Enable Register in <nr1> numeric format. The syntax of the response is <nr1><rmt>.
∗ESR?	Returns the value in the Standard Event Status Register in <nr1> numeric format. The register is then cleared. The syntax of the response is <nr1><rmt>.
∗IDN?	Returns the instrument identification. The exact response is determined by the instrument configuration and is of the form <NAME>, <model>, 0, <version><rmt>where <NAME> is the manufacturer's name, <MODEL> defines the type of instrument and <VERSION> is the revision level of the software installed.
∗IST?	Returns **ist** local message as defined by IEEE Std. 488.2. The syntax of the response if 0<rmt>, if the local message false or 1<rmt>, if the local message is true.
∗OPC	Sets the Operation Complete bit (bit 0) in the Standard Event Status Register. This will happen immediately the command is executed

	because of the sequential nature of all operations.
*OPC?	Query operation complete status. The syntax of the response is 1<rmt>. The response will be available immediately the command is executed because of the sequential nature of all operations.
*PRE <nrf>	Set the Parallel Poll Enable Register to the value <nrf>.
*PRE?	Returns the value in the Parallel Poll Enable Register in <nr1> numeric format. The syntax of the response is <nr1><rmt>.
*SRE <nrf>	Set the Service Request Enable Register to <nrf>.
*SRE?	Returns the value of the Service Request Enable Register in <nr1> numeric format. The Syntax of the response is <nr1><rmt>.
*STB?	Returns the value of the Status Byte Register in <nr1> numeric format. The syntax of the response is <nr1><rmt>.
*WAI	Wait for operation complete true. As all commands are completely executed before the next is started this command takes no additional action.
*TST?	The generator has no self−test capability and the response is always 0<rmt>.
EER?	Query and clear execution error number register. The response format is nr1<rmt>.
QER?	Query and clear query error number register. The response format is nr1<rmt>.

Miscellaneous Commands

*LRN?	Returns the complete set up of the instrument as a hexadecimal character data block. To re−install the set up the block should be returned to the instrument exactly as it is received. The syntax of the response is LRN <Character data><rmt>. The settings in the instrument are not affected by execution of the *LRN? command.
LRN <character data>	Install data for a previous *LRN? command.
*RST	Resets the instrument parameters to their default values (see DEFAULT INSTRUMENT SETTINGS).
*RCL <cpd>	Recalls the instrument set up contained in store <nrf>. The store number must be in the range 1 to 9.
*SAV <nrf>	Saves the complete instrument set up to the set-up file number <nrf>. The store number must be in the range 1 to 9.
*TRG	This command is the same as pressing the MAN/SYNC key. Its effect will depend on the context in which it is asserted. The interface command Group Execute Trigger (GET) will perform the same action as *TRG.
FILTER <cpd>	Set the output filter to <AUTO>, <ELIP>, <BESS> or <NONE>.
BEEPMODE <cpd>	Set beep mode to <ON>, <OFF>, <WARN>, or <ERROR>.
BEEP	Sound one beep.
LOCAL	Returns the instrument to local operation and unlocks the keyboard. Will not function if LLO is in force.
USBID?	Returns the instruments address.

Refer to Calibration section for remote calibration commands.

Remote Command Summary

∗CLS	Clear status.
∗ESE <nrf>	Set the Standard Event Status Enable Register to the value of <nrf>.
∗ESE?	Returns the value in the Standard Event Status Enable Register in <nr1> numeric format.
∗ESR?	Returns the value in the Standard Event Status Register in <nr1> numeric format.
∗IDN?	Returns the instrument identification.
∗IST?	Returns **ist** local message as defined by IEEE Std. 488.2.
∗LRN?	Returns the complete set up of the instrument as a hexadecimal character data block approximately 842 bytes long.
∗OPC	Sets the Operation Complete bit (bit 0) in the Standard Event Status Register.
∗OPC?	Query operation complete status.
∗PRE <nrf>	Set the Parallel Poll Enable Register to the value <nrf>.
∗PRE?	Returns the value in the Parallel Poll Enable Register in <nr1> numeric format.
∗RCL <cpd>	Recalls the instrument set up contained in store <nrf>.
∗RST	Resets the instrument parameters to their default values.
∗SAV <cpd>	Saves the complete instrument set up store number <nrf>.
∗SRE <nrf>	Set the Service Request Enable Register to <nrf>.
∗SRE?	Returns the value of the Service Request Enable Register in <nr1> numeric format.
∗STB?	Returns the value of the Status Byte Register in <nr1> numeric format.
∗TRG	This command is the same as pressing the MAN/SYNC key.
∗TST?	The generator has no self−test capability and the response is always 0<rmt>.
∗WAI	Wait for operation complete true. executed before the next is started
ABORT	Aborts a phase locking operation.
AMPL <nrf>	Set the amplitude to <nrf> in the units as specified by the AMPUNIT command.
AMPUNIT <cpd>	Set the amplitude units to <VPP>, <VRMS> or <DBM>.
ARBDATA? <cpd>	Returns the data from an arbitrary waveform.
ARBDATACSV? <cpd>	Returns the data from an arbitrary waveform.
ARBDEF <cpd>,<nrf>,<bin data block>	Define an arbitrary waveform with name <cpd> and length <nrf> and load with the data in <bin data block>.
ARBDEFCSV <cpd>,<nrf>,<csv ascii data>	Define an arbitrary waveform with name <cpd> and length <nrf> and load with the data in <csv ascii data>.
ARBLEN? <cpd>	Returns the length, in points, of the arbitrary waveform <cpd>.
BEEP	Set beep mode to <ON>, <OFF>, <WARN>, or <ERROR>.
BEEPMODE <cpd>	Sound one beep.
BSTCNT <nrf>	Set the burst count to <nrf>.
CLKFREQ <nrf>	Set the arbitrary sample clock freq to <nrf> Hz.

CLKPER <nrf>	Set the arbitrary sample clock period to <nrf> sec.
DCOFFS <nrf>	Set the dc offset to <nrf> Volts.
EER?	Query and clear execution error number register.
FILTER <cpd>	Set the output filter to <AUTO>, <ELIP>, <BESS> or <NONE>.
FORCETRG	Force a trigger to the selected channel.
LOCAL	Returns the instrument to local operation and unlocks the keyboard. Will not function if LLO is in force.
LRN <character data>	Install data for a previous *LRN? command.
MOD <cpd>	Set the modulation source to <OFF> or <EXT>.
MODE <cpd>	Set the mode to <CONT>, <GATE>, <TRIG>, <SWEEP> or <TONE>.
MODTYPE <cpd>	Set the modulation type to <AM> or <SCM>.
OUTPUT <cpd>	Set the main output <ON>, <OFF>, <NORMAL> or <INVERT>.
PHASE <nrf>	Set the slave generator phase to <nrf> degrees.
PULSDLY <nrf>	Set the pulse delay to <nrf> sec.
PULSPER <nrf>	Set the pulse period to <nrf> sec.
PULSWID <nrf>	Set the pulse width to <nrf> sec.
PULTRNBASE <nrf>	Set the pulse−train base line to <nrf> Volts.
PULTRNDLY <nrf1>,<nrf2>	Set the delay of pulse−train pulse number <nrf1> to <nrf2> sec.
PULTRNLEN <nrf>	Set the number of pulses in the pulse−train to <nrf>.
PULTRNLEV <nrf1>,<nrf2>	Set the level of pulse−train pulse number <nrf1> to <nrf2> Volts.
PULTRNMAKE	Makes the pulse−train and runs it − similar to the WAVE PULSTRN command.
PULTRNPER <nrf>	Set the pulse−train period to <nrf> sec.
PULTRNWID <nrf1>,<nrf2>	Set the width of pulse−train pulse number <nrf1> to <nrf2> sec.
QER?	Query and clear query error number register.
REFCLK <cpd>	Set the ref. clock bnc to <IN>, <OUT>, <MASTER> or <SLAVE>.
SUM <cpd>	Set the sum source to <OFF> or <EXT>.
SWPCENTFRQ <nrf>	Set the sweep centre frequency to <nrf> Hz.
SWPDIRN <cpd>	Set the sweep direction to <UP>, <DOWN>, <DNUP> or <UPDN>.
SWPMKR <nrf>	Set the sweep marker to <nrf> Hz.
SWPSPACING <cpd>	Set the sweep spacing to <LIN> or <LOG>.
SWPSPAN <nrf>	Set the sweep frequency span to <nrf> Hz.
SWPSTARTFRQ <nrf>	Set the sweep start frequency to <nrf> Hz.
SWPSTOPFRQ <nrf>	Set the sweep stop frequency to <nrf> Hz.
SWPSYNC <cpd>	Set the sweep sync <ON> or <OFF>.
SWPTIME <nrf>	Set the sweep time to <nrf> sec.
SWPTYPE <cpd>	Set the sweep type to <CONT>, <TRIG> or <THLDRST> .
SYNCOUT <cpd>	Set the sync output <ON>, <OFF>, <AUTO>, <WFMSYNC>, <POSNMKR>, <BSTDONE>, <SEQSYNC>, <TRIGGER>, <SWPSYNC> or <PHASLOC>.
TONEEND <nrf>	Delete tone frequency number <nrf> thus defining the end of the list.
TONEFREQ <nrf1>,<nrf2>,<nrf3>	Set tone frequency number <nrf1> to <nrf2> Hz. The third parameter sets the tone type; 1 will give Trig, 2 will give FSK, any other value gives Gate type.

TRIGIN <cpd>	Set the trig input to <INT>, <EXT>, <MAN>, <PREV>, <NEXT>, <POS> or <NEG>.
TRIGLEV <nrf>	Set the trigger threshold level to <nrf> Volts.
TRIGPER <nrf>	Set the internal trigger generator period to <nrf> sec.
USBID?	Returns the instruments address.
WAVE <cpd>	Select the output waveform as <SINE>, <SQUARE>, <TRIANG>, <DC>, <POSRMP>, <NEGRMP>, <COSINE>, <HAVSIN>, <HAVCOS>, <SINC>, <PULSE>, <PULSTRN>, <NOISE>, <ARB1>. <ARB2>, <ARB3> or <ARB4>.
WAVFREQ <nrf>	Set the waveform frequency to <nrf> Hz.
WAVPER <nrf>	Set the waveform period to <nrf> sec.
WFMCLKSRC <cpd>	Set the playback clock source of the selected waveform to <INT> or <EXT>.
ZLOAD <cpd>	Set the output load, which the generator is to assume for amplitude and dc offset entries, to <50> (50Ω), <600> (600Ω) or <OPEN>.

Maintenance

The Manufacturers or their agents overseas will provide a repair service for any unit developing a fault. Where owners wish to undertake their own maintenance work, this should only be done by skilled personnel in conjunction with the service manual which may be purchased directly from the Manufacturers or their agents overseas.

Cleaning

If the instrument requires cleaning use a cloth that is only lightly dampened with water or a mild detergent.

WARNING! TO AVOID ELECTRIC SHOCK, OR DAMAGE TO THE INSTRUMENT, NEVER ALLOW WATER TO GET INSIDE THE CASE. TO AVOID DAMAGE TO THE CASE NEVER CLEAN WITH SOLVENTS.

Appendix 1. Warning and Error Messages

Warning messages are given when a setting may not give the expected result, e.g. DC Offset attenuated by the output attenuator when a small amplitude is set; the setting is, however, implemented.

Error messages are given when an illegal setting is attempted; the previous setting is retained.

The last two warning/error messages can be reviewed by selecting LAST ERROR from the UTILITY screen, the latest is reported first.

Warning and error messages are reported with a number on the display; only the number is reported via the remote control interfaces.

The following is a complete list of messages as they appear on the display.

Warning Messages

00	No errors or warnings have been reported
13	DC offset changed by amplitude
14	Offset + Sum + level may cause clipping
23	Offset will clip the waveform
24	Instrument not calibrated
30	Amplitude will clip the waveform
42	Trigger source is fixed to external in SLAVE mode
59	Trigger slope is fixed to positive in SLAVE mode
81	The programmed mod depth cannot be set
83	Numeric value too large – switching to sample period

Error Messages

101	Frequency out of range for the selected waveform
102	Sample clock frequency required exceeds 100MHz
103	Sample clock frequency required is less than 0.1Hz
104	Pulse/pulse–train period out of range for current set–up
105	Pulse width cannot be greater than the period
106	Absolute value of pulse delay must be < period
107	Pulse width cannot be less than 10ns
108	Maximum output level exceeded
109	Minimum output level exceeded
110	Minimum dc offset value exceeded
111	Maximum dc offset value exceeded
112	The value entered is out of range
119	Arb waveform length cannot be less than four points
125	No GPIB available
127	System ram error battery fault or firmware updated
135	Trigger generator maximum period is 200s
136	Trigger generator minimum period is 10us
137	Waveform is not available with ext clock
138	Burst count value exceeds the maximum of 1048575
139	Burst count value cannot be less than 1
140	Trig/Gate freq too high. Max=2.5MHz. Continuous mode set
141	Selected function is illegal in tone mode TONE MODE CANCELLED!
144	Selected combination of function and mode is illegal
145	Locked master/slave is available with continuous mode only

148	Trig/gate mode and seq step value cause a trigger conflict
150	Number of pulses in train must be between 1 and 10
151	Pulse train base level must be >−5.0V and <+5.0V
152	Pulse level must be >−5.0V and <+5.0V
153	Pulse number must be between 1 and 10
154	Sweep frequency values must be 1mHz to 40MHz
155	Sweep start freq must be less than stop freq
156	Sweep stop freq must be greater than start freq
157	Sweep time value is out of range 0.001s < n < 999s
158	Sweep marker value is out of range 0.001Hz < n < 40MHz
160	Not locked. This error indicates that a phase locking operation has failed.
161	Illegal phase value
184	SUM or Modulation conflict
188	Maximum trigger level is +5.0V
189	Minimum trigger level is –5.0v

Remote Warnings

72	Length is different to that in the ARBDEF(CSV) command

Remote Errors

120	Waveform limit value out of range
126	Illegal store number requested
162	Byte value outside the range 0 to 255
163	Specified arb name does not exist
164	Command illegal in sweep or tone mode
166	Cannot set sample frequency or period for std waveforms
167	dBm output units assume a 50 Ohm termination
168	Specified units illegal for the selected waveform
169	Command not available for RS232
170	Length value error in binary block
171	Illegal value in arbitrary data
173	Illegal tone number
177	Illegal remote calibration command.
185	Command not available while sweeping.

Critical Stop Errors

These errors have no obvious recovery path and require user intervention. Some can be bypassed by a key press, some offer a choice of action. Possible hardware failures may be firmware induced and recover by cycling the power. Firmware errors all require a power cycle to recover.

Any of these errors may indicate an imminent system failure or a firmware bug.

201	CRITICAL STOP! Fault in clock circuit of channel <chan>	- possible hardware failure
202	CRITICAL STOP! Fault in calibration flash memory block	- flash write fault
205	CRITICAL STOP! Stack Overflow	- firmware error
206	CRITICAL STOP! Stack Underflow	- firmware error
207	CRITICAL STOP! Illegal instruction	- firmware error
208	CRITICAL STOP! Illegal NMI	- firmware error
209	CRITICAL STOP! Heap overflow	- firmware error

Appendix 2. SYNC OUT Automatic Settings

The following automatic source (`src`) settings are made when `auto` mode is selected on the
`SYNC OUT` screen.

MODE	WAVEFORM	Waveform Sync	Burst Done	Trigger	Sweep Trigger	Phase Lock
Continuous	All	✓				
Gate/Trig	All			✓		
Sweep	All				✓	
Tone	All			✓		
master/slave	All					✓

Appendix 3. Factory System Defaults

The factory system defaults are listed in full below. They can be recalled by pressing RECALL followed by `set defaults` or by the remote command ∗RST. All channels will be receive the same setup. All channels default to the same settings.

Main Parameters

Std. Wave:	Sine	
Frequency:	10kHz	
Output:	+2·0Vpp	; Output Off
DC Offset:	0V	
Zout:	HiZ	

Gate/Trigger Parameters

Source:	Internal
Period:	1ms
Slope:	Positive
Burst Count:	1
Phase	0deg

Modulation Parameters

Source:	Off
Type:	VCA
Sum:	Off

Sweep Parameters

Begin Frequency:	100kHz
End Frequency:	40MHz
Marker Frequency:	10MHz
Direction:	Up
Spacing:	Log
Sweep Time:	10ms
Type:	Continuous
Filter	Auto
Sync Out	Auto
Arbitrary	All unaffected by reset or ∗RST.

Appendix 4. Waveform Manager Plus Arbitrary Waveform Creation and Management Software

The Thurlby Thandar Waveform Manager Plus program allows construction, editing, exchange, translation and storage of many types of waveform data. It is compatible with many popular DSOs and all TTi waveform generation products.

Waveforms may be generated by equation entry, freehand drawing, combining existing waveforms or any combinations of these methods.

Data upload and download are possible via RS232 (COM1-4), USB or GPIB subject to a compatible GPIB card being correctly installed and configured in your PC.

Both upload and download of waveform data are possible and, where applicable, data exchange via 3.5 in floppy disks in the Tektronix *.ISF format is available.

Text data may be read from the Windows clipboard and used to create a waveform. The text data format is very free and will allow most lists of numbers, with or without intervening text, to be read as waveform data points. Waveform data may also be pasted to the clipboard for insertion into other programs.

Waveforms are displayed in fully scaleable windows and may be manipulated graphically. Any number of waveforms in any of the supported types may be displayed simultaneously.

On-line help is available in three ways.

1. The help menu contains a contents option from which you can go to any section of the on-line help file or browse particular areas or the whole file. It is also possible to use the Index and Find operations of the Windows help system to search for items which are not listed directly in the contents section.

2. Some dialog boxes have a Help button which, when clicked, will open the on-line help file at the section containing the description of that dialog box.

3. From most windows/dialogues the F1 key will open the help file at the relevant section.

Waveform Manager allows you to keep waveforms for different projects separate from each other on your hard drive. A project may be placed anywhere, in any directory (folder) and all waveform files for that project will be stored in a structure below that directory. A project is identified by a user defined name. Each project maintains its own library of expressions.