Model 7280

Wide Bandwidth
DSP Lock-in Amplifier

Instruction Manual

190398-A-MNL-C

Firmware Version

The instructions in this manual apply to operation of a Model 7280 DSP Lock-in Amplifier that is fitted with revision 5.0 or later operating firmware. Users of instruments that are fitted with earlier firmware revisions can update them to the current revision free of charge by downloading an Update Pack from our website at **www.signalrecovery.com** The pack includes full instructions for use.

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This equipment generates, uses, and can radiate radio-frequency energy and, if not installed and used in accordance with this manual, may cause interference to radio communications. As temporarily permitted by regulation, operation of this equipment in a residential area is likely to cause interference, in which case the user at his own facility will be required to take whatever measures may be required to correct the interference.

Company Names

SIGNAL RECOVERY is part of Advanced Measurement Technology, Inc, a division of AMETEK, Inc. It includes the businesses formerly trading as EG&G Princeton Applied Research, EG&G Instruments (Signal Recovery), EG&G Signal Recovery and PerkinElmer Instruments (Signal Recovery).

Declaration of Conformity

This product conforms to EC Directives 89/336/EEC Electromagnetic Compatibility Directive, amended by 92/31/EEC and 93/68/EEC, and Low Voltage Directive 73/23/EEC amended by 93/68/EEC.

This product has been designed in conformance with the following IEC/EN standards:

EMC: BS EN55011 (1991) Group 1, Class A (CSPIR 11:1990)
BS EN50082-1 (1992):
IEC 801-2:1991
IEC 801-3:1994
IEC 801-4:1988

Safety: BS EN61010-1: 1993 (IEC 1010-1:1990+A1:1992)

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Introduction

Chapter 1

1.1 How to Use This Manual

This manual gives detailed instructions for setting up and operating the ***SIGNAL RECOVERY*** Model 7280 Digital Signal Processing (DSP) dual phase, wide bandwidth, lock-in amplifier. It is split into the following chapters:-

Chapter 1 - Introduction
Provides an introduction to the manual, briefly describes what a lock-in amplifier is and the types of measurements it may be used for, and lists the major specifications of the model 7280.

Chapter 2 - Installation and Initial Checks
Describes how to install the instrument and gives a simple test procedure which may be used to check that the unit has arrived in full working order.

Chapter 3 - Technical Description
Provides an outline description of the design of the instrument and discusses the effect of the various controls. A good understanding of the design will enable the user to get the best possible performance from the unit.

Chapter 4 - Front and Rear Panels
Describes the instrument's connectors, controls and indicators as referred to in the subsequent chapters.

Chapter 5 - Front Panel Operation
Describes the capabilities of the instrument when used as a manually operated unit, and shows how to operate it using the front panel controls.

Chapter 6 - Computer Operation
This chapter provides detailed information on operating the instrument from a computer over either the GPIB (IEEE-488) or RS232 interfaces. It includes information on how to establish communications, the functions available, the command syntax and a detailed command listing.

Appendix A
Gives the detailed specifications of the unit.

Appendix B
Details the pinouts of the multi-way connectors on the rear panel.

Appendix C
Lists three simple terminal programs which may be used as the basis for more complex user-written programs.

Appendix D
Shows the connection diagrams for suitable RS232 null-modem cables to couple the unit to an IBM-PC or 100% compatible computer.

Appendix E
Provides a listing of the instrument settings produced by using the Auto-Default functions.

Appendix F
Gives an alphabetical listing of the computer commands for easy reference.

New users are recommended to unpack the instrument and carry out the procedure in chapter 2 to check that it is working satisfactorily. They should then make themselves familiar with the information in chapters 3, 4 and 5, even if they intend that the unit will eventually be used under computer control. Only when they are fully conversant with operation from the front panel should they then turn to chapter 6 for information on how to use the instrument remotely. Once the structure of the computer commands is familiar, appendix F will prove convenient as it provides a complete alphabetical listing of these commands in a single easy-to-use section.

1.2 What is a Lock-in Amplifier?

In its most basic form the lock-in amplifier is an instrument with dual capability. It can recover signals in the presence of an overwhelming noise background or alternatively it can provide high resolution measurements of relatively clean signals over several orders of magnitude and frequency.

Modern instruments, such as the model 7280, offer far more than these two basic characteristics and it is this increased capability which has led to their acceptance in many fields of scientific research, such as optics, electrochemistry, materials science, fundamental physics and electrical engineering, as units which can provide the optimum solution to a large range of measurement problems.

The model 7280 lock-in amplifier can function as a:-

- AC Signal Recovery Instrument
- Vector Voltmeter
- Phase Meter
- Spectrum Analyzer
- Transient Recorder
- Precision Oscillator
- Frequency Meter
- Noise Measurement Unit

These characteristics, all available in a single compact unit, make it an invaluable addition to any laboratory.

1.3 Key Specifications and Benefits

The ***SIGNAL RECOVERY*** Model 7280 represents a significant advance in the application of DSP technology in the design of a lock-in amplifier. Until now, limitations in the available semiconductor devices have restricted the operating frequency range of such instruments to at most a few hundred kilohertz. The model 7280, with its use of the latest technology, extends this limit to 2 MHz. What is more, it does this without compromising any other important specifications.

Key specifications include:

- Frequency range: 0.5 Hz to 2.0 MHz
- Voltage sensitivity: 10 nV to 1 V full-scale
- Current input mode sensitivities: 1 pA to 100 µA full-scale; 10 fA to 1 µA full-scale; 10 fA to 10 nA full-scale
- Line frequency rejection filter
- Dual phase demodulator with X-Y and R-θ outputs
- Very low phase noise of < 0.0001° rms
- Output time constant: 1 µs to 100 ks
- 5-digit output readings
- Dual reference mode - allows simultaneous measurement of two signals at different reference frequencies up to 20 kHz, or 800 kHz with option 7280/99 or 2.0 MHz with option 7280/98
- Single and dual harmonic mode - allows simultaneous measurement of up to two different harmonics of a signal at up to 20 kHz, or 800 kHz with option 7280/99 or 2.0 MHz with option 7280/98
- Virtual reference mode - allows reference free measurement of signals up to 2.0 MHz
- Spectral Display mode shows frequency spectrum of the signal prior to the demodulators to help in selecting a reference frequency
- Direct Digital Synthesizer (DDS) oscillator with variable amplitude and frequency
- Oscillator frequency and amplitude sweep generator
- 8-bit programmable digital I/O port for external system control
- Four auxiliary ADC inputs and two auxiliary DAC outputs

- Full range of auto-modes
- Non-volatile memory for 8 complete instrument settings
- Standard IEEE-488 and RS232 interfaces with RS232 daisy-chain capability for up to 16 instruments
- Large high-resolution electroluminescent display panel with menus for control and display of instrument outputs in both digital and graphical formats
- Easy entry of numerical control settings using keypad
- 32,768 point internal curve storage buffer

Installation & Initial Checks

Chapter 2

2.1 Installation

2.1.01 Introduction

Installation of the model 7280 in the laboratory or on the production line is very simple. It can be operated on almost any laboratory bench or be rack mounted, using the optional accessory kit, at the user's convenience. With an ambient operating temperature range of 0 °C to 35 °C, it is highly tolerant to environmental variables, needing only to be protected from exposure to corrosive agents and liquids.

The instrument uses forced-air ventilation and as such should be located so that the ventilation holes on the sides and rear panels are not obstructed. This condition is best satisfied by leaving a space of at least 2" (5 cm) between the side and rear panels and any adjacent surface.

2.1.02 Rack Mounting

An optional accessory kit, part number K02004, is available from ***SIGNAL RECOVERY*** to allow the model 7280 to be mounted in a standard 19-inch rack.

2.1.03 Inspection

Upon receipt the model 7280 Lock-in Amplifier should be inspected for shipping damage. If any is noted, ***SIGNAL RECOVERY*** should be notified immediately and a claim filed with the carrier. The shipping container should be saved for inspection by the carrier.

2.1.04 Line Cord Plug

A standard IEC 320 socket is mounted on the rear panel of the instrument and a suitable line cord is supplied.

2.1.05 Line Voltage Selection and Line Fuses

Before plugging in the line cord, ensure that the model 7280 is set to the voltage of the AC power supply to be used.

A detailed discussion of how to check and, if necessary, change the line voltage setting follows.

CAUTION: The model 7280 may be damaged if the line voltage is set for 110 V AC operation and it is turned on with 220 V AC applied to the power input connector.

The model 7280 can operate from any one of four different line voltage ranges, 90-110 V, 110-130 V, 200-240 V, and 220-260 V, at 50-60 Hz. The change from one range to another is made by repositioning a plug-in barrel selector internal to the Line

Input Assembly on the rear panel of the unit. Instruments are normally shipped from the factory with the line voltage selector set to 110-130 V AC, unless they are destined for an area known to use a line voltage in the 220-260 V range, in which case, they are shipped configured for operation from the higher range.

The line voltage setting can be seen through a small rectangular window in the line input assembly on the rear panel of the instrument (figure 2-1). If the number showing is incorrect for the prevailing line voltage (refer to table 2-1), then the barrel selector will need to be repositioned as follows.

Observing the instrument from the rear, note the plastic door immediately adjacent to the line cord connector (figure 2-1) on the left-hand side of the instrument. When the line cord is removed from the rear-panel connector, the plastic door can be opened outwards by placing a small, flat-bladed screwdriver in the slot on the right-hand side and levering gently. This gives access to the fuse and to the voltage barrel selector, which is located at the right-hand edge of the fuse compartment. Remove the barrel selector with the aid of a small screwdriver or similar tool. With the barrel selector removed, four numbers become visible on it: 100, 120, 220, and 240, only one of which is visible when the door is closed. Table 2-1 indicates the actual line voltage range represented by each number. Position the barrel selector such that the required number (see table 2-1) will be visible when the barrel selector is inserted and the door closed.

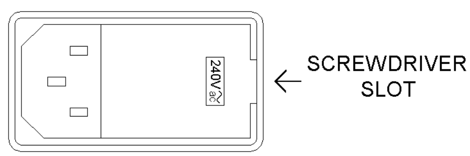

Figure 2-1, Line Input Assembly

VISIBLE #	VOLTAGE RANGE
100	90 - 110 V
120	110 - 130 V
220	200 - 240 V
240	220 - 260 V

Table 2-1, Range vs. Barrel Position

Next check the fuse rating. For operation from a nominal line voltage of 100 V or 120 V, use a 20 mm slow-blow fuse rated at 2.0 A, 250 V. For operation from a nominal line voltage of 220 V or 240 V, use a 20 mm slow-blow fuse rated at 1.0 A, 250 V.

To change the fuse, first remove the fuse holder by pulling the plastic tab marked with an arrow. Remove the fuse and replace with a slow-blow fuse of the correct voltage and current rating. Install the fuse holder by sliding it into place, making sure the arrow on the plastic tab is pointing downwards. When the proper fuse has been installed, close the plastic door firmly. The correct selected voltage setting should now be showing through the rectangular window. Ensure that only fuses with the required current and voltage ratings and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders is prohibited and potentially dangerous.

2.2 Initial Checks

2.2.01 Introduction

The following procedure checks the performance of the model 7280. In general, this procedure should be carried out after inspecting the instrument for obvious shipping damage.

NOTE: Any damage must be reported to the carrier and to SIGNAL RECOVERY immediately. In addition the shipping container must be retained for inspection by the carrier.

Note that this procedure is intended to demonstrate that the instrument has arrived in good working order, not that it meets specifications. Each instrument receives a careful and thorough checkout before leaving the factory, and normally, if no shipping damage has occurred, will perform within the limits of the quoted specifications. If any problems are encountered in carrying out these checks, contact ***SIGNAL RECOVERY*** or the nearest authorized representative for assistance.

2.2.02 Procedure

1) Ensure that the model 7280 is set to the line voltage of the power source to be used, as described in section 2.1.05.

2) With the rear-panel mounted power switch (located to the right of the line power input connector) set to **0** (off), plug in the line cord to an appropriate line source.

3) Turn the model 7280 power switch to the **I** (on) position.

4) The instrument's front panel display will now briefly display the following:-

Figure 2-2, Opening Display

5) Wait until the opening display has changed to the Main Display and then press the key under the bottom right hand corner of the display identified by the legend MENU on the display. This enters the first of the two main menus, Main Menu 1, shown below in figure 2-3.

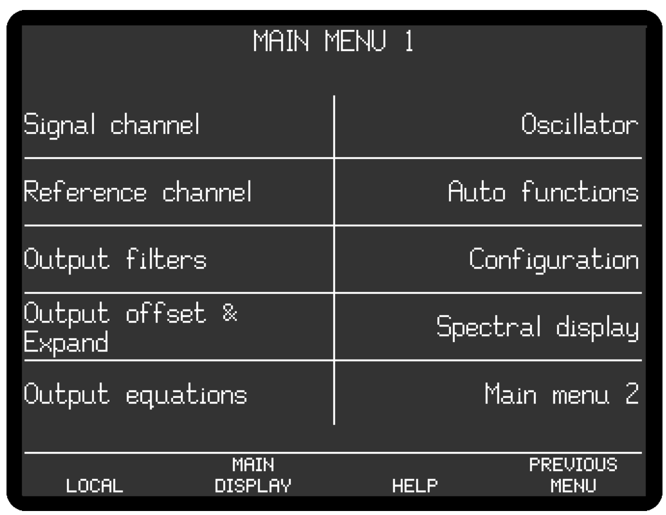

Figure 2-3, Main Menu 1

6) Press one of the keys adjacent to the Auto functions menu item to enter the Auto Functions menu, shown below in figure 2-4.

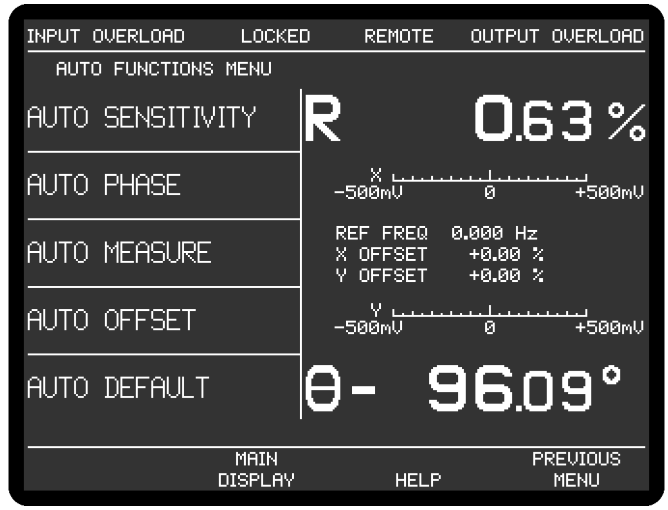

Figure 2-4, Auto Functions Menu

7) Press one of the keys adjacent to the Auto Default menu item. This will set all of the instrument's controls and the display to a defined state. The display will revert to the Main Display, as shown below in figure 2-5, with the right-hand side showing the vector magnitude, R, and the phase angle, θ, of the measured signal in digital form, with two bar-graphs showing the X channel output and Y channel output expressed in millivolts. The left-hand side shows five instrument controls, these being the AC Gain in decibels, full-scale sensitivity, output time constant, reference phase and internal oscillator frequency. The resulting dynamic reserve (DR), in decibels, is also shown.

Figure 2-5, Main Display

8) Connect a BNC cable between the **OSC OUT** and **A** input connectors on the front panel.

9) The right-hand side of the display should now indicate R, the vector magnitude, close to 100% of full-scale (i.e. the sinusoidal oscillator output, which was set to 1 kHz and a signal level of 0.5 V rms by the Auto-Default function, is being measured with a full-scale sensitivity of 500 mV rms) and θ, the phase angle, of near zero degrees, if a short cable is used.

This completes the initial checks. Even though the procedure leaves many functions untested, if the indicated results were obtained then the user can be reasonably sure that the unit incurred no hidden damage in shipment and is in good working order.

2.3 Line Frequency Filter Adjustment

2.3.01 Introduction

The model 7280 incorporates a line-frequency rejection filter which is normally supplied set to 60 Hz. If the power line frequency of the country in which the instrument is to be used is also 60 Hz then the setting does not need to be changed. If, however, the unit is to be used in an area with a 50 Hz power line frequency the setting should be changed using the following procedure.

2.3.02 Procedure

1) Turn the model 7280's power switch to the **I** (on) position.

2) The instrument's front panel display will now briefly display the following:-

Figure 2-6, Opening Display

3) Wait until the opening display has changed to the Main Display and then press the key under the bottom right hand corner of the display identified by the legend MENU on the display once. This enters the first of the two main menus, Main Menu 1, shown below in figure 2-7.

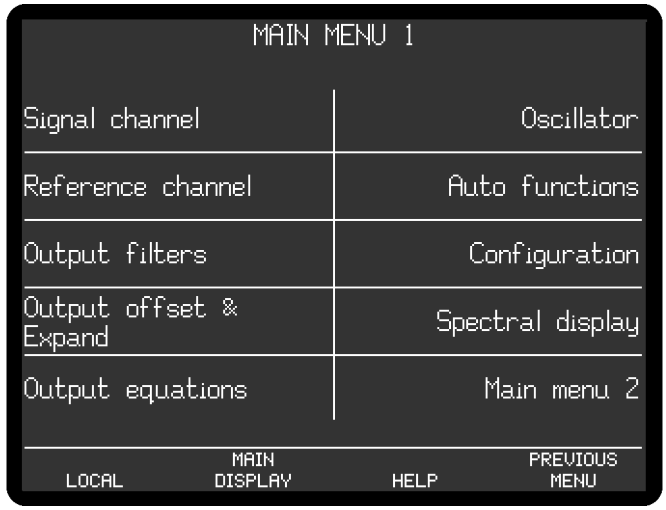

Figure 2-7, Main Menu 1

4) Press one of the keys adjacent to the Configuration menu item to enter the Configuration menu, shown below in figure 2-8.

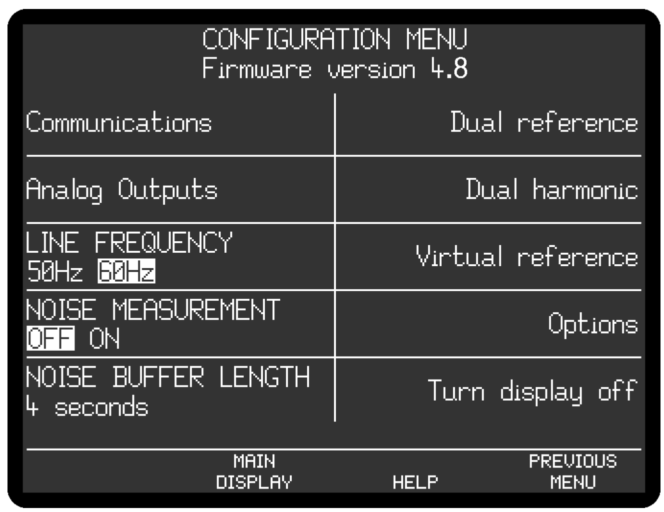

Figure 2-8, Configuration Menu

5) The present line frequency setting is shown in reversed text under the LINE FREQUENCY label and is either 50 or 60 Hz. In figure 2-8, the filter is set to 60 Hz. If this setting does not match the prevailing line frequency, then press a key adjacent to this item once to change it.

6) Press the key marked MAIN DISPLAY once to return to the Main Display.

This completes the procedure for adjusting the line frequency filter.

Technical Description

Chapter 3

3.1 Introduction

The model 7280 lock-in amplifier is a sophisticated instrument with many capabilities beyond those found in other lock-in amplifiers. This chapter discusses the various operating modes provided and then describes the design of the instrument by considering it as a series of functional blocks. In addition to describing how each block operates, the sections also include information on the effect of the various controls.

3.2 Operating Modes

3.2.01 Introduction

The model 7280 incorporates a number of different operating modes which are referred to in the following technical description, so in order to help the reader's understanding they are defined here.

3.2.02 Single Reference / Dual Reference

Conventionally, a lock-in amplifier makes measurements such as signal magnitude, phase, etc. on the applied signal at a single reference frequency. In the model 7280 this is referred to as the single reference mode.

The dual reference mode incorporated in the model 7280 allows the instrument to make simultaneous measurements at two different reference frequencies, an ability that previously required two lock-in amplifiers. This flexibility incurs a few restrictions, such as the requirement that one of the reference signals be external and the other be derived from the internal oscillator, the limitation of the maximum operating frequency to 20 kHz (unless the unit is equipped with the -/99 or -/98 extended frequency options) and the requirement that both signals be passed through the same input signal channel. This last restriction implies either that both signals are derived from the same detector (for example two chopped light beams falling onto a single photodiode) or that they can be summed prior to measurement, either externally or by using the differential input mode of the instrument. Nevertheless, the mode will prove invaluable in many experiments.

3.2.03 Single Harmonic / Dual Harmonic

Normally, a lock-in amplifier measures the applied signal at the reference frequency. However, in some applications such as Auger Spectroscopy and amplifier characterization, it is useful to be able to make measurements at some multiple n, or harmonic, of the reference frequency, f. The model 7280 allows this multiple to be set to any value between 2 (i.e. the second harmonic) and 32, as well as unity, which is the normal mode. The only restriction is that the product $n \times f$ cannot exceed 2 MHz.

Dual harmonic mode allows the simultaneous measurement of two different harmonics of the input signal. As with dual reference mode, there are a few restrictions, such as a maximum value of $n \times f$ of 20 kHz (800 kHz with the option -/99 or 2 MHz with the option -/98).

3.2.04 Internal / External Reference Mode

In the internal reference mode, the instrument's reference frequency is derived from its internal oscillator and the oscillator signal is used to drive the experiment.

In the external reference mode, the experiment includes some device, for example an optical chopper, which generates a reference frequency that is applied to one of the lock-in amplifier's external reference inputs. The instrument's reference channel "locks" to this signal and uses it to measure the applied input signal.

3.2.05 Virtual Reference Mode

If the instrument is operated in internal reference mode, measuring a signal which is phase-locked to the internal oscillator, with the reference phase correctly adjusted, then it will generate a stable non-zero X channel output and a zero Y channel output. If, however, the signal is derived from a separate oscillator, then the X channel and Y channel outputs will show variations at a frequency equal to the difference between the signal and internal oscillator frequencies. If the latter is now set to be equal to the former then in principle the variation in the outputs will cease, but in practice this will not happen because of slow changes in the relative phase of the two oscillators.

In the virtual reference mode, believed to be unique to ***SIGNAL RECOVERY*** lock-in amplifiers, the Y channel output is used to make continuous adjustments to the internal oscillator frequency and phase to achieve phase-lock with the applied signal, such that the X channel output is maximized and the Y channel output zeroed.

If the instrument is correctly adjusted, particularly ensuring that the full-scale sensitivity control is maintained at a suitable setting in relation to changes in the signal level, then the virtual reference mode is capable of making signal recovery measurements which are not possible with most other lock-in amplifiers.

3.3 Principles of Operation

3.3.01 Block Diagram

The model 7280 uses digital signal processing (DSP) techniques implemented in field-programmable gate arrays (FPGA), a microprocessor and very low-noise analog circuitry to achieve its specifications. A block diagram of the instrument is shown in figure 3-1. The sections that follow describe how each functional block operates and the effect it has on the instrument's performance.

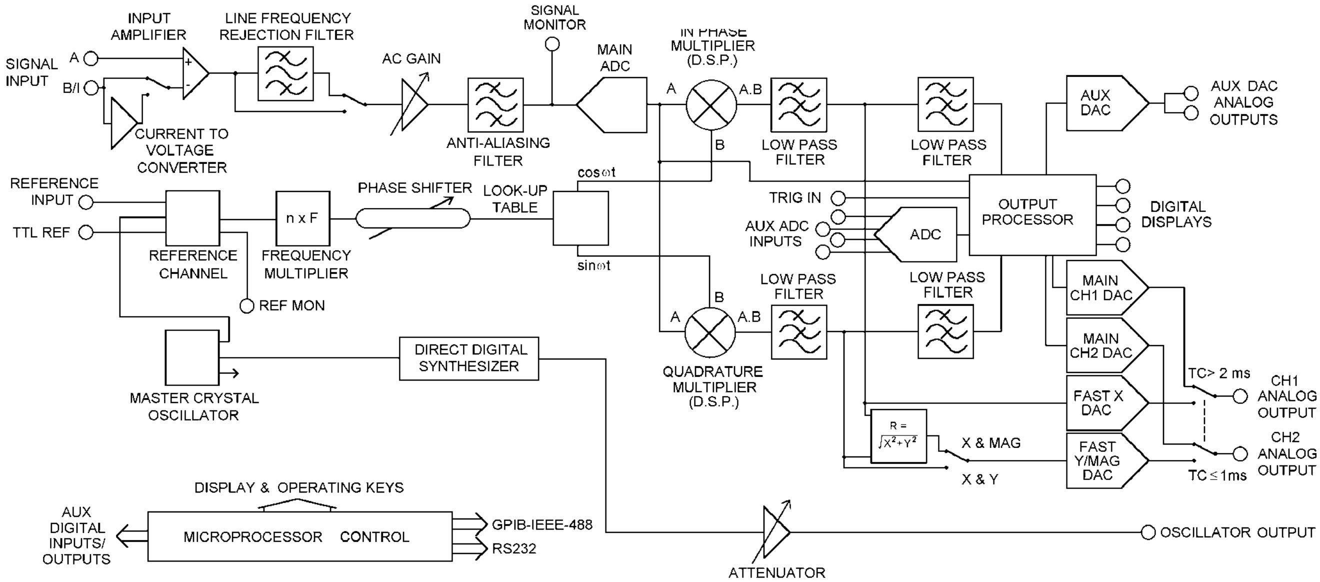

Figure 3-1, Model 7280 - Block Diagram

3.3.02 Signal Channel Inputs

The signal input amplifier can be set for either single-ended or differential voltage mode operation, or single-ended current mode operation. In voltage mode a choice of AC or DC coupling is available using an FET input device. In current mode a choice of three conversion gains is available to give optimum matching to the applied signal. In both modes the input connector shells may be either floated via a 1 kΩ resistor or grounded to the instrument's chassis ground. These various features are discussed in the following paragraphs.

Input Connector Selection, A / -B / A - B
When set to the A mode, the lock-in amplifier measures the voltage between the center and the shell of the **A** input BNC connector, whereas when set to the A-B mode it measures the difference in voltage between the center pins of the **A** and **B/I** input BNC connectors.

The latter, differential, mode is often used to eliminate ground loops, although it is worth noting that at very low signal levels it may be possible to make a substantial reduction in unwanted offsets by using this mode with a short-circuit terminator on the **B/I** connector, rather than by simply using the A input mode.

The specification defined as the Common Mode Rejection Ratio, C.M.R.R., describes how well the instrument rejects common mode signals applied to the **A** and **B/I** inputs when operating in differential input mode. It is usually given in decibels. Hence a specification of > 100 dB implies that a common mode signal (i.e. a signal simultaneously applied to both **A** and **B/I** inputs) of 1 V will give rise to less than 10 µV of signal out of the input amplifier.

The input can also be set to the -B mode, in which case the lock-in amplifier measures the voltage between the center and the shell of the **B/I** input connector. This extra mode effectively allows the input to be multiplexed between two different single-ended signals, subject to the limitation that the user must allow for the signal inversion (equivalent to a 180° phase-shift) which it introduces when reading the outputs.

Input Connector Shell, Ground / Float
The input connector shells may be connected either directly to the instrument's chassis ground or floated via a 1 kΩ resistor. When in the float mode, the presence of this resistor substantially reduces the problems which often occur in low-level lock-in amplifier measurements due to ground loops.

Input Coupling Mode, Fast/Slow
When the input coupling mode is set to Slow, the signal channel gain is essentially flat down to 0.5 Hz, but recovery from input overload conditions may take a long time. Conversely, when the coupling mode is set to Fast, recovery from overload is much faster, but there will be a noticeable roll-off in magnitude response and significant phase shifts at frequencies below typically 20 Hz.

Input Signal Selection, V / I
Although the voltage mode input is most commonly used, a current-to-voltage converter may be switched into use to provide current mode input capability, in which case the signal is connected to the **B/I** connector. High impedance sources (> 100 kΩ) are inherently current sources and need to be measured with a low impedance current mode input. Even when dealing with a voltage source in series with a high impedance, the use of the current mode input may provide advantages in terms of improved bandwidth and immunity from the effects of cable capacitance.

The converter may be set to low-noise, normal or wide bandwidth conversion settings, but it should be noted that if the best possible performance is required a separate current preamplifier, such as the ***SIGNAL RECOVERY*** models 181 or 5182, should be considered.

3.3.03 Line Frequency Rejection Filter

Following the signal input amplifier there is an option to pass the signal through a line frequency rejection filter, which is designed to give greater than 40 dB of attenuation at the power line frequencies of 50 Hz or 60 Hz and their second harmonics at 100 Hz and 120 Hz.

The filter uses two cascaded rejection stages with "notch" characteristics, allowing it to be set to reject signals at frequencies equal to either of, or both of, the fundamental and second harmonic of the line frequency.

Instruments are normally supplied with the line frequency filter set to 60 Hz with the filter turned off. If the prevailing line frequency is 50 Hz then the filter frequency should be set to this value using the control on the Configuration menu (see section 2.3).

3.3.04 AC Gain and Dynamic Reserve

The signal channel contains a number of analog filters and amplifiers whose overall gain is defined by the AC Gain parameter, which is specified in terms of decibels (dB). For each value of AC Gain there is a corresponding value of the INPUT LIMIT parameter, which is the maximum instantaneous (peak) voltage or current that can be applied to the input without causing input overload, as shown in table 3-1 below.

AC Gain (dB)	INPUT LIMIT (mV)
0	1600
6	800
14	320
20	160
26	80
34	32
40	16
46	8
54	3.2
60	1.6
66	0.8

Table 3-1, Input Limit vs. AC Gain

It is a basic property of the digital signal processing (DSP) lock-in amplifier that the best demodulator performance is obtained by presenting as large a signal as possible to the main analog-to-digital converter (ADC). Therefore, in principle, the AC Gain value should be made as large as possible without causing the signal channel amplifier or converter to overload. This constraint is not too critical however and the use of a value one or two steps below the optimum value makes little difference. Note that as the AC Gain value is changed, the demodulator gain (described later in section 3.3.12) is also adjusted in order to maintain the selected full-scale sensitivity.

The full-scale sensitivity is set by a combination of AC Gain and demodulator gain. Since the demodulator gain is entirely digital, changes in full-scale sensitivity which do not change the AC Gain do not cause any of the errors which might arise from a change in the AC Gain.

The user is prevented from setting an illegal AC Gain value, i.e. one that would result in overload on a full-scale input signal. Similarly, if the user selects a full-scale sensitivity which causes the present AC Gain value to be illegal, the AC Gain will change to the nearest legal value.

In practice, this system is very easy to operate. However, the user may prefer to make use of the AUTOMATIC AC Gain feature which gives very good results in most cases. When this is active the AC Gain is automatically controlled by the instrument, which determines the optimum setting based on the full-scale sensitivity currently being used.

At any given setting, the ratio

$$\mathrm{DR} = 0.7 \times \frac{\text{Input Limit}}{\text{Full-Scale Sensitivity}}$$

represents the factor by which the largest acceptable sinusoidal interference input exceeds the full-scale sensitivity and is called the Dynamic Reserve of the lock-in amplifier at that setting. (The factor 0.7 is a peak-to-rms conversion). The dynamic reserve is often expressed in decibels, for which

$$DR(\text{in dB}) = 20 \times \log(DR(\text{as a ratio}))$$

Applying this formula to the model 7280 at the maximum value of INPUT LIMIT (1.6 V) and the smallest available value of FULL-SCALE SENSITIVITY (10 nV), gives a maximum available dynamic reserve of about 1×10^8 or 160 dB. Figures of this magnitude are available from any DSP lock-in amplifier but are based only on arithmetical identities and do not give any indication of how the instrument actually performs. In fact, all current DSP lock-in amplifiers become too noisy and inaccurate for most purposes at reserves of greater than about 100 dB.

For the benefit of users who prefer to have the AC Gain value expressed in decibels, the model 7280 displays the current value of Dynamic Reserve (DR) in this form, on the input full-scale sensitivity control, for values up to 100 dB. Above 100 dB the legend changes to “DR>100”.

3.3.05 Anti-Aliasing Filter

Prior to the main analog-to-digital converter (ADC) the signal passes through an anti-aliasing filter to remove unwanted frequencies which would cause a spurious output from the ADC as a result of the sampling process.

Consider the situation when the lock-in amplifier is measuring a sinusoidal signal of frequency f_{signal} Hz, which is sampled by the main ADC at a sampling frequency $f_{sampling}$ Hz. In order to ensure correct operation of the instrument the output values representing the f_{signal} frequency must be uniquely generated by the signal to be measured, and not by any other process.

However, if the input to the ADC has, in addition, an unwanted sinusoidal signal with frequency f_1 Hz, where f_1 is greater than half the sampling frequency, then this will appear in the output as a sampled-data sinusoid with frequency less than half the sampling frequency, $f_{alias} = |f_1 - nf_{sampling}|$, where n is an integer. This alias signal is indistinguishable from the output generated when a genuine signal at frequency f_{alias} is sampled. Hence if the frequency of the unwanted signal were such that the alias signal frequency produced from it was close to, or equal to, that of the wanted signal then it is clear that a spurious output would result.

For example, if the sampling frequency were 7.5 MHz then half the sampling frequency would be 3.75 MHz. Assume for a moment that the instrument could operate at reference frequencies up to 3.75 MHz and let it be measuring a signal of 40 kHz accompanied by an interfering signal of 3.7 MHz. The output of the ADC would therefore include a sampled-data sinusoid of 40 kHz (the required signal) and, applying the above formula, an alias signal of 0.05 MHz, or 50 kHz (i.e. |3.75 MHz - 3.7 MHz|). If the signal frequency were now increased towards 50 kHz then the output of the lock-in amplifier would increasingly be affected by the presence of the alias signal and the accuracy of the measurement would deteriorate.

To overcome this problem the signal is fed through the anti-aliasing filter which restricts the signal bandwidth to an upper frequency of 2.0 MHz The filter is a conventional elliptic-type, low-pass, stage, giving the lowest possible noise bandwidth.

It should be noted that the dynamic range of a lock-in amplifier is normally so high that practical anti-alias filters are not capable of completely removing the effect of a full-scale alias. For instance, even if the filter gives 100 dB attenuation, an alias at the input limit and at the reference frequency will give a one percent output error when the dynamic reserve is set to 60 dB, or a ten percent error when the dynamic reserve is set to 80 dB.

In a typical low-level signal recovery situation, many unwanted inputs need to be dealt with and it is normal practice to make small adjustments to the reference frequency until a clear point on the frequency spectrum is reached. In this context an unwanted alias is treated as just another interfering signal and its frequency is avoided when setting the reference frequency.

A buffered version of the analog signal just prior to the main ADC is available at the signal monitor (**SIG MON**) connector on the rear panel; it may be viewed on an oscilloscope to monitor the effect of the line frequency rejection and anti-aliasing filters and signal-channel amplifiers.

3.3.06 Main Analog-to-Digital Converter

Following the anti-alias filter the signal passes to the main analog-to-digital converter running at a sampling rate of 7.5 MHz. The output from the converter feeds the demodulator circuitry, which uses DSP techniques to implement the digital multipliers and the first stage of the output low-pass filtering for each of the X and Y channels.

The ADC output also passes to the output processor to allow the power spectral density of the input signal to be calculated using a discrete Fourier transform, which in many ways is similar to a fast Fourier transform (FFT). The results of this calculation are shown on the Spectral Display menu.

However, before discussing the demodulators and the output stages of the lock-in amplifier, the reference channel which provides the other input to the demodulators, will be described.

3.3.07 Reference Channel

The reference channel in the instrument is responsible for implementing the reference trigger/phase-locked loop, digital phase-shifter and internal oscillator look-up table functional blocks on the block diagram (see figure 3-1). The processor generates a series of phase values, output at a rate of one every 133 ns, which are used to drive the reference channel inputs of the demodulators.

In dual reference mode operation, an externally derived reference frequency is connected to the external reference input and a second reference is derived from the internal oscillator. The reference circuit generates new phase values for each individual channel and sends these to the demodulators. Further discussion of dual reference mode occurs in section 3.3.12.

In single harmonic mode, the reference circuit generates the phase values of a waveform at the selected harmonic of the reference frequency. Dual harmonic mode operates in a similar way to dual reference mode, but in this case the reference circuit generates phase values for both of the selected harmonics of the reference frequency. Dual harmonic mode may therefore be used with either internal or external references.

External Reference Mode
In external reference mode the reference source may be applied to either a general purpose input, designed to accept virtually any periodic waveform with a 50:50 mark-space ratio and of suitable amplitude, or to a TTL-logic level input. Following the trigger buffering circuitry the reference signal is passed to a digital phase-locked loop (PLL) implemented in the reference circuit. This measures the period of the applied reference waveform and from this generates the phase values.

Internal Reference Mode
With internal reference operation the reference circuit is free-running at the selected reference frequency and is not dependent on a phase-locked loop (PLL), as is the case in most other lock-in amplifiers. Consequently, the phase noise is extremely low, and because no time is required for a PLL to acquire lock, reference acquisition is immediate.

Both the signal channel and the reference channel contain calibration parameters which are dependent on the reference frequency. These include corrections to the anti-alias filter and to the analog circuits in the reference channel. In external reference operation the processor uses a reference frequency meter to monitor the reference frequency and updates these parameters when a change of about 2 percent has been detected.

A TTL logic signal at the present reference frequency is provided at the **REF MON** connector on the rear panel.

3.3.08 Phase-Shifter

The reference circuit also implements a digital reference phase-shifter, allowing the phase values being sent to the demodulator DSP to be adjusted to the required value. If the reference input is a sinusoid applied to the **REF IN** socket, the reference phase is defined as the phase of the X demodulation function with respect to the reference input.

This means that when the reference phase is zero and the signal input to the demodulator is a full-scale sinusoid in phase with the reference input sinusoid, the X channel output of the demodulator is a full-scale positive value and the Y channel output is zero.

The circuits connected to the **REF IN** socket detect a positive-going crossing of the mean value of the applied reference voltage. Therefore when the reference input is not sinusoidal, its effective phase is the phase of a sinusoid with a positive-going zero crossing at the same point in time, and accordingly the reference phase is defined with respect to this waveform. Similarly, the effective phase of a reference input to the **TTL REF IN** socket is that of a sinusoid with a positive-going zero crossing at the same point in time.

In basic lock-in amplifier applications the purpose of the experiment is to measure the amplitude of a signal which is of fixed frequency and whose phase with respect to the reference input does not vary. This is the *scalar* measurement, often implemented with a chopped optical beam. Many other lock-in amplifier applications are of the *signed scalar* type, in which the purpose of the experiment is to measure the amplitude and sign of a signal which is of fixed frequency and whose phase with respect to the reference input does not vary apart from reversals of phase corresponding to changes in the sign of the signal. A well-known example of this situation is the case of a resistive bridge, one arm of which contains the sample to be measured. Other examples occur in derivative spectroscopy, where a small modulation is applied to the angle of the grating (in optical spectroscopy) or to the applied magnetic field (in magnetic resonance spectroscopy). Double beam spectroscopy is a further common example.

In this signed scalar measurement the phase-shifter must be set, after removal of any zero errors, to maximize the X channel or the Y channel output of the demodulator. This is the only method that will give correct operation as the output signal passes through zero, and is also the best method to be used in an unsigned scalar measurement where any significant amount of noise is present.

3.3.09 Internal Oscillator - General

The model 7280, in common with many other lock-in amplifiers, incorporates an internal oscillator which may be used to drive an experiment. However, unlike most other instruments, the oscillator in the model 7280 is digitally synthesized with the result that the output frequency is extremely accurate and stable. The oscillator operates over the same frequency range as the lock-in amplifier, that is 500 mHz to 2.0 MHz, and is implemented using a dedicated direct digital synthesis circuit.

3.3.10 Internal Oscillator - Update Rate

The direct digital synthesis (DDS) technique generates a waveform at the DAC output which is not a pure sinusoid, but rather a stepped approximation to one. This is then filtered by the buffer stage, which follows the DAC, to reduce the harmonic distortion to an acceptable level. The update rate is 22.5 MHz.

3.3.11 Internal Oscillator - Frequency & Amplitude Sweeps

The internal oscillator output may be swept in both frequency and amplitude. In both cases the sweeps take the form of a series of steps between starting and finishing values. Frequency sweeps may use equal increment step sizes, giving a linear change of frequency with time as the sweep proceeds, or may use step sizes proportional to the present frequency, which produces a logarithmic sweep. The amplitude sweep function offers only linear sweeps.

A special form of the frequency sweep function is used to acquire lock when the instrument is operating in the virtual reference mode. When this "seek" sweep is activated, the oscillator starts at a user-specified frequency, which should be just below that of the applied signal, and increments until the calculated magnitude output is greater than 50%. At this point the sweep then stops and the virtual reference mode achieves lock, by continuously adjusting the internal oscillator frequency to maintain the Y channel output at zero.

It is important to note that this type of phase-locked loop, unlike a conventional edge-triggered type using a clean reference, does not automatically re-acquire lock after it has been lost. Lock can be lost as a result of a signal channel transient or a phase reversal of the signal, in which case it may be necessary to repeat the lock acquisition procedure. However, if the measurement system is set up with sufficient precautions, particularly ensuring that the full-scale sensitivity is maintained at a suitable setting in relation to the signal level, then the virtual reference mode is capable of making signal recovery measurements which are not possible with other lock-in amplifiers.

When virtual reference mode is in use, the signal at the **OSC OUT** connector is a sinusoid which is phase-locked to the signal. Naturally, this cannot be used as a source for the measurement.

3.3.12 Demodulators

The essential operation of the demodulators is to multiply the digitized output of the signal channel by data sequences, called the X and Y demodulation functions, and to operate on the results with digital low-pass filters (the output filters). The demodulation functions, which are derived by use of a look-up table from the phase values supplied by the reference channel DSP, are sinusoids with a frequency equal to an integer multiple, $n \times f$, of the reference frequency f. The Y demodulation function is the X demodulation function delayed by a quarter of a period. The integer n is called the reference harmonic number and in normal lock-in amplifier operation is set to unity. Throughout this chapter, the reference harmonic number is assumed to be unity unless otherwise stated.

The outputs from the X channel and Y channel multipliers feed the first stage of the X channel and Y channel output filters, implemented as Finite Impulse Response (FIR) stages with selectable 6 or 12 dB/octave roll-off. The filtered X channel signal drives a 16-bit DAC that, for short time-constant settings, generates the signal at the instrument's **CH 1** analog output connector. Both signals are combined by a fast magnitude algorithm and a switch then allows either the filtered Y channel signal or the magnitude signal, again when using short time-constant settings, to be passed to a second 16-bit DAC to give the signal at the instrument's **CH 2** analog output. The significance of the magnitude output is discussed later in section 3.3.15.

In addition the X and Y channel signals are fed to further low-pass filters before subsequent processing by the instrument’s host microprocessor.

The demodulator output is digitally scaled to provide the demodulator gain control. As discussed earlier in section 3.3.04 this gain is adjusted as the AC Gain is adjusted to maintain a given full-scale sensitivity.

In dual reference and dual harmonic modes, the demodulators generate two sets of outputs, one for each of the two references or harmonics, and includes two sets (four channels) of initial output filtering. These outputs are passed to the host processor for further processing and, when the time constant is less than 1 ms, the X_1 and X_2 outputs are also converted by fast DACs to analog signals that appear at the **CH 1** and **CH 2** analog output connectors.

3.3.13 Output Processor - Output Filters

Although shown on the block diagram as a separate entity, the output processor is in fact part of the instrument's main microprocessor. It provides more digital filtering of the X channel and Y channel signals if this is needed in addition to that already performed by the demodulators. As with most lock-in amplifiers, the output filter configuration in the model 7280 is controlled by the slope control. This may seem somewhat strange, and a few words of explanation may be helpful.

In traditional audio terminology, a first-order low-pass filter is described as having a slope of 6 dB per octave because in the high frequency limit its gain is inversely proportional to frequency (6 dB is approximately a factor of 2 in amplitude and an octave is a factor of 2 in frequency); similarly a second-order low-pass filter is described as having a slope of 12 dB per octave. These terms have become part of the accepted terminology relating to lock-in amplifier output filters and are used in the model 7280 to apply to the envelope of the frequency response function of the digital finite impulse response (FIR) output filters. Accordingly the front-panel control which selects the configuration of the output filters is labeled SLOPE and the options are labeled 6, 12, 18, 24 dB/octave.

The 6 dB/octave filters are not satisfactory for most purposes because they do not give good rejection of non-random interfering signals which can cause aliasing problems as a result of the sampling process in the main ADC. However, the 6 dB/octave filter finds use where the lock-in amplifier is incorporated in a feedback control loop, and in some situations where the form of the time-domain response is critical. The user is recommended to use 12 dB/octave unless there is some definite reason for not doing so.

Note that at short time constant settings the filter slope options are limited to 6 or 12 dB/octave.

The output time constant can be varied between 1 µs and 100 ks. When set to a value between 1 µs and 1 ms or 4 ms, X and Y or X and Magnitude outputs are available at the **CH 1** and **CH 2** outputs. At longer time constant settings, all outputs are valid and available at the **CH 1** and **CH 2** outputs and as the internal digital values reported to a remote computer or stored to the internal curve buffer. The large digital displays and bar-graph indicators on the front panel have an effective minimum time constant limit imposed by their update rates, which are 512 ms and 64 ms respectively. As noted in section 3.3.12 above, in dual reference and dual harmonic modes the analog outputs at time constants shorter than 1 ms are limited to X_1 and X_2.

The filters are of the finite impulse response type with the averaging time of each section being equal to double the nominal time constant. These filters offer a substantial advantage in response time compared with analog filters or digital infinite impulse response (IIR) filters.

When the reference frequency is below 10 Hz the synchronous filter option is available. This means that the actual time constant of the filter is not generally the selected value T, but a value which is equal to an integer number of reference cycles. If T is greater than 1 reference cycle, then the time constant is between T/2 and T.

Where random noise is relatively small, synchronous filter operation gives a major advantage in low-frequency measurements by enabling the system to give a constant output even when the output time constant is equal to only 1 reference cycle.

3.3.14 Output Processor - Output Offset and Expand

Following the output filter, an output offset facility enables ±300% full-scale offset to be applied to the X, Y or both displays and to the analog outputs.

The output expand facility allows a ×10 expansion, performed by simple internal digital multiplication, to be applied to the X, Y, both or neither outputs, and hence to the bar-graph displays and the **CH 1** and **CH 2** analog outputs, if these are set to output X or Y values.

3.3.15 Output Processor - Vector Magnitude and Phase

The processor also implements the magnitude and signal phase calculation which is useful in many situations. If the input signal $V_s(t)$ is a reference frequency sinusoid of constant amplitude, and the output filters are set to a sufficiently long time constant, the demodulator outputs are constant levels V_x and V_y. The function $\sqrt{(V_x^2 + V_y^2)}$ is dependent only on the amplitude of the required signal $V_s(t)$ (i.e. it is not dependent on the phase of $V_s(t)$ with respect to the reference input) and is computed by the output processor in the lock-in amplifier and made available as the magnitude output. The phase angle between $V_s(t)$ and the X demodulation function is called the signal phase: this is equal to the angle of the complex quantity $(V_x + jV_y)$ (where j is the square root of -1) and is also computed by the processor by means of a fast arc tan algorithm.

The magnitude and signal phase outputs are used in cases where phase is to be measured, or alternatively where the magnitude is to be measured under conditions of uncertain or varying phase.

One case of varying phase is that in which the reference input is not derived from the same source as that which generates the signal, and is therefore not at exactly the same frequency. In this case, if the input signal is a sinusoid of constant amplitude, the X channel and Y channel demodulator outputs show slow sinusoidal variations at the difference frequency, and the magnitude output remains steady.

However, the magnitude output has disadvantages where significant noise is present at the outputs of the demodulator. When the required signal outputs (i.e. the mean values of the demodulator outputs) are less than the noise, the outputs take both positive and negative values but the magnitude algorithm gives only positive values: this effect, sometimes called noise rectification, gives rise to a zero error which in the case of a Gaussian process has a mean value equal to 0.798 times the combined root-mean-square (rms) value of the X and Y demodulator noise. Note that unlike other forms of zero error this is not a constant quantity which can be subtracted from all readings, because when the square root of the sum of the squares of the required outputs becomes greater than the total rms noise the error due to this mechanism disappears.

A second type of signal-dependent error in the mean of the magnitude output occurs as a result of the inherent non-linearity of the magnitude formula: this error is always positive and its value, expressed as a fraction of the signal level, is half the ratio of the mean-square value of the noise to the square of the signal.

These considerations lead to the conclusion that when the magnitude output is being used, the time constants of the demodulator should be set to give the required signal-to-noise ratio at the X channel and Y channel demodulator outputs; improving the signal-to-noise ratio by averaging the magnitude output itself is not to be recommended.

For analogous reasons, the magnitude function also shows signal-dependent errors when zero offsets are present in the demodulator. For this reason, it is essential to reduce zero offsets to an insignificant level (usually by the use of the Auto-Offset function) when the magnitude output is to be used.

Note that the majority of signal recovery applications are scalar measurements, where the phase between the required signal and the reference voltage is constant apart from possible phase reversals corresponding to changes in the sign of the quantity being measured. In this situation the lock-in amplifier is used in the normal X-Y mode, with the phase-shifter adjusted to maximize the X output and to bring the mean Y output to zero. (Refer to section 3.3.21 for further information on the correct use of the Auto-Phase function for this purpose.)

3.3.16 Output Processor - Noise Measurements

The noise measurement facility uses the output processor to perform a noise computation on the X output of the demodulator. A noise buffer continuously calculates the mean level of X, representing the measured output signal, by summing the last *n* samples of the X output and dividing by *n*. The processor then calculates the modulus of the difference between each X-output value and the mean value and uses this figure to derive the noise. The displayed noise value is correct for input noise where the amplitude distribution of the waveform is *Gaussian,* which is normally the case. The indicated value (in V/√Hz or A/√Hz) is the square root of the mean spectral density over the equivalent noise bandwidth defined by the setting of the output filter time constant and slope.

When used for noise measurements, the available range of output time constants is restricted to 500 µs to 10 ms inclusive, and the slope to 6 or 12 dB/octave. The corresponding actual bandwidth for the present time constant and slope settings can be found from the table 3-2 below, or by using the ENBW. command. In addition, the Synchronous Time Constant control is turned off.

Time	**Equivalent Noise Bandwidth at Output Filter Slope (Hz)**	
Constant	**6 dB/octave**	**12 dB/octave**
500 µs	335	276
1 ms	209	158
2 ms	115	82
4 ms	60	42
5 ms	48	33
10 ms	24	17

Table 3-2, ENBW vs. Time Constant and Slope

The noise buffer length *n* can be set to 1, 1000, 2000, 3000 or 4000. Since new input values to the buffer are supplied at a 1 kHz rate, these correspond to averaging times of zero, 1 second, 2 seconds, 3 seconds and 4 seconds respectively, and so the control on the Configuration Menu that adjusts this buffer length is labeled Noise Buffer Length and can be set to Off, 1 s, 2 s, 3 s or 4 s. Setting a shorter time means that the system responds more quickly to changes in the mean X-output level, but the noise reading itself exhibits more fluctuation. Conversely, the fluctuation can be reduced by setting a longer time, but at the expense of increased settling time following changes in the mean X-output level.

If a noise output (N calibrated in volts or amps per root hertz, or as a percentage of full scale) is selected as one of the outputs on the Main Display or for conversion to an analog signal for output to the **CH1**/**CH2** outputs, and the time constant is not within the permitted range then a warning message is displayed on the screen. Similarly, if a noise output value is read via the computer interfaces while the time constant or slope are outside the permitted range, or if the synchronous time constant control is enabled, then the response will be -1. Since noise readings can only be zero or positive, this negative number clearly indicates that the reading is invalid and should be ignored.

In order to make noise measurements easier, the instrument includes a Noise Measurement Mode, activated by a control on the Configuration menu or by a computer command. When this is turned on, the Main Display outputs are set to the four types most commonly required, and the filter time constant, slope and synchronous time constant setting are forced to values within the permitted ranges. When turned off, these restrictions are removed.

When making noise measurements the user is strongly advised to use an oscilloscope to monitor the signal at the **SIG MON** output on the rear panel as this is the best way of ensuring that a random process is being measured rather than line pick-up or other non-random signals.

Any two of the outputs, including X channel and Y channel signals, vector magnitude, and phase angle, and even noise may be represented in analog form by being routed via two further 16-bit DACs to the unit's **CH 1** and **CH 2** output connectors.

3.3.17 Auxiliary Analog Inputs and Outputs (ADCs and DACs)

The model 7280 incorporates four auxiliary ADC inputs of conventional sampled design offering a resolution of 1 mV in ±10.000 V. These converters may be used at slow sample rates for digitizing slowly changing or DC signals which are associated with an experiment, such as those generated by temperature and pressure transducers, so that they can be incorporated into ratio calculations or transferred to a controlling computer. They may also be used in conjunction with the instrument's curve buffer to form a transient recorder operating at sample rates of up to 40 kHz.

Two auxiliary DAC outputs are also provided which offer the same resolution as the ADCs, namely 1 mV in ±10.000 V.

3.3.18 Main Microprocessor - Spectral Display

In some cases it can be useful to determine the spectral power distribution of the input signal. The model 7280 can do this, since when the Spectral Display menu is selected, the output processor performs a discrete Fourier transform on the digitized input signal and displays the resulting spectrum.

3.3.19 Main Microprocessor - User Settings

The non-volatile memory associated with the main microprocessor is used to store up to eight complete instrument settings, which may be recalled or changed as required. This makes it much easier for an instrument to be quickly configured for different experiments.

3.3.20 Main Microprocessor - General

All functions of the instrument are under the control of a microprocessor which in addition drives the front-panel display, processes front-panel key operations and supports the RS232 and GPIB (IEEE-488) computer interfaces. This processor also drives the instrument's 8-bit digital (TTL) programmable input/output port, which may be used for controlling auxiliary apparatus or reading the status of external logic lines.

The microprocessor has access to a 32,768 point memory which can be used for storage of selected instrument outputs as curves, prior to their transfer to a computer via the computer interfaces. In addition to using this function for the normal outputs, such as the X channel and Y channel output signals, it may also be used with two of the auxiliary ADC inputs to allow the instrument to operate as a transient recorder. The internal oscillator frequency and amplitude sweep functions are also controlled by the microprocessor.

A particularly useful feature of the design is that only part of the controlling firmware program code, which the microprocessor runs, is permanently resident in the instrument. The remainder is held in a flash EEPROM and can be updated via the RS232 computer interface. It is therefore possible to change the functionality of the instrument, perhaps to include a new feature or update the computer command set, simply by connecting it to a computer and running an update program.

3.3.21 Main Microprocessor - Auto Functions

The microprocessor also controls the instrument's auto functions, which are control operations executed by means of a single command or two key-presses. These functions allow easier, faster operation in most applications, although direct manual operation or special purpose control programs may give better results in certain circumstances. During application of several of the auto functions, decisions are made on the basis of output readings made at a particular moment. Where this is the case, it is important for the output time constant set by the user to be long enough to reduce the output noise to a sufficiently low level so that valid decisions can be made and that sufficient time is allowed for the output to settle.

The following sections contain brief descriptions of the auto functions.

Auto-Sensitivity
This function only operates when the reference frequency is above 1 Hz. A single Auto-Sensitivity operation consists of decreasing the full-scale sensitivity range if the magnitude output is greater than 90% of full-scale, or increasing the full-scale sensitivity range if the magnitude output is less than 30% of full-scale. After the Auto-Sensitivity function is called, Auto-Sensitivity operations continue to be made until the required criterion is met.

In the presence of noise, or a time-varying input signal, it may be a long time before the Auto-Sensitivity sequence comes to an end, and the resulting setting may not be what is really required.

Auto-Phase
In an Auto-Phase operation the value of the signal phase is computed and an appropriate phase-shift is then introduced into the reference channel so as to bring the value of the signal phase to zero. The intended result is to null the output of the Y channel while maximizing the output of the X channel.

Any small residual phase can normally be removed by calling Auto-Phase for a second time, after a suitable delay to allow the outputs to settle.

The Auto-Phase facility is normally used with a clean signal which is known to be of stable phase. It usually gives very good results provided that the X channel and Y channel outputs are steady when the procedure is called.

If a zero error is present on the outputs, such as may be caused by unwanted coupling between the reference and signal channel inputs, then the following procedure should be adopted:-

1) Remove the source of input signal, without disturbing any of the connections to the signal input which might be picking up interfering signals from the reference channel. In an optical experiment, for example, this could be done by shielding the detector from the source of chopped light.

2) Execute an Auto-Offset operation, which will reduce the X channel and Y channel outputs to zero.

3) Re-establish the source of input signal. The X channel and Y channel outputs will now indicate the true level of input signal, *at the present reference phase setting*.

4) Execute an Auto-Phase operation. This will set the reference phase-shifter to the phase angle of the input signal. However, because the offset levels which were applied in step 2 were calculated at the original reference phase setting, they will not now be correct and the instrument will in general display a non-zero Y channel output value.

5) Remove the source of input signal again.

6) Execute a second Auto-Offset operation, which will reduce the X channel and Y channel outputs to zero at the new reference phase setting.

7) Re-establish the source of input signal.

This technique, although apparently complex, is the only way of removing the effect of crosstalk which is not generally in the same phase as the required signal.

Auto-Offset
In an Auto-Offset operation the X offset and Y offset functions are turned on and are automatically set to the values required to give zero values at both the X and the Y outputs. Any small residual values can normally be removed by calling Auto-Offset for a second time after a suitable delay to allow the outputs to settle.

The primary use of the Auto-Offset is to cancel out zero errors which are usually caused by unwanted coupling or crosstalk between the signal channel and the reference channel, either in the external connections or possibly under some conditions in the instrument itself. Note that if a zero error is present, the Auto-Offset function should be executed before any execution of Auto-Phase.

Auto-Measure
This function only operates when the reference frequency is greater than 1 Hz. It performs the following operations:

The AC GAIN value is adjusted to maximize the input to the main ADC without causing overload, and the time-constant is set to an appropriate value for the present reference frequency. An auto-sensitivity operation is then performed, followed by an auto-phase.

The Auto-Measure function is intended to give a quick setting of the instrument which will be approximately correct in typical simple measurement situations. For optimum results in any given situation, it may be convenient to start with Auto-Measure and to make subsequent modifications to individual controls.

NOTE: The Auto-Measure function affects the setting of the AC Gain and AC Gain Automatic controls during execution. Consequently, it may not operate correctly if the AC Gain Automatic control is turned off. In this case, better results will be obtained by performing Auto-Sensitivity followed by Auto-Phase functions.

Auto-Default
With an instrument of the design of the model 7280, where there are many controls of which only a few are regularly adjusted, it is very easy to overlook the setting of one of them. Consequently an Auto-Default function is provided, which sets all the controls to a defined state. This is most often used as a rescue operation to bring the instrument into a known condition when it is giving unexpected results. A listing of the settings which are invoked by the use of this function can be found in appendix E.

This completes the description of the main functional blocks of the instrument.

3.4 General

3.4.01 Accuracy

When the demodulator is operating under correct conditions, the absolute gain accuracy of the instrument is limited by the analog components in the signal channel, and the absolute phase accuracy is limited by the analog components in both the signal channel and the reference channel. The resulting typical accuracy is ±0.3 percent of the full-scale sensitivity and ±0.25 degree respectively. When the higher values of AC Gain are in use, the errors tend to increase above 25 kHz.

3.4.02 Power-up Defaults

All instrument settings are retained when the unit is switched off. When the instrument is switched on again the settings are restored but with the following exceptions:-

a) The GPIB mask byte is set to zero.
b) The REMOTE parameter is set to zero (front-panel control enabled).
c) The curve buffer is cleared.
d) Any sweep that was in progress at switch-off is terminated.
e) Synchronous time constants are enabled.
f) The display is turned on.

Front and Rear Panels

Chapter 4

4.1 Front Panel

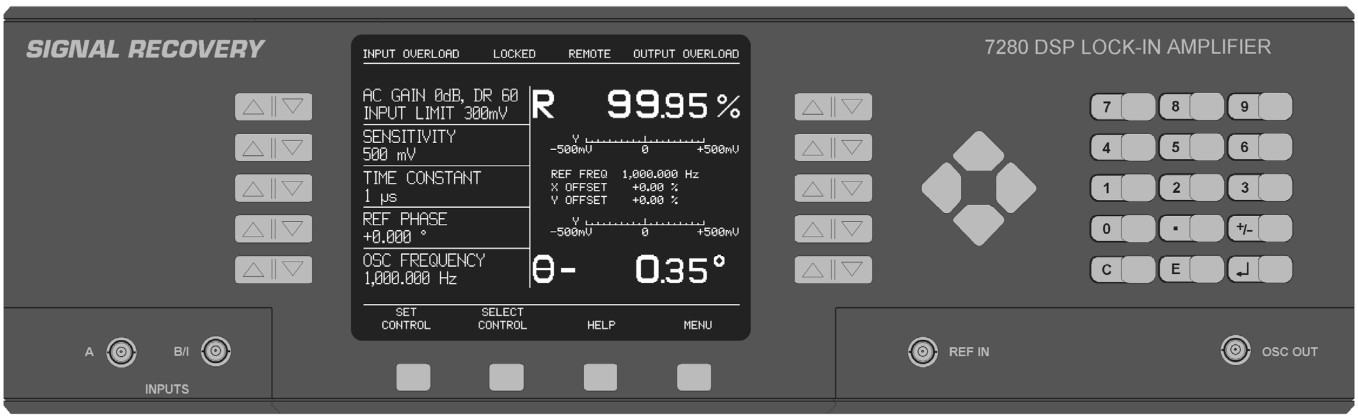

Figure 4-1, Model 7280 Front Panel Layout

As shown in figure 4-1, the model 7280's front panel has four BNC connectors, a 320 × 240 pixel electroluminescent screen, ten double and four single keys positioned adjacent to the screen, four cursor-movement keys and a 12-button keypad. The following sections describe the function and location of these items.

4.1.01 A and B/I Signal Input Connectors

The **A** connector is the signal input connector for use in single-ended and differential voltage mode. The **B/I** connector is the signal input connector for use in differential voltage mode (**A-B**) and for inverting single-ended voltage mode (**-B** mode). It is also the signal input connector when the current input mode is selected.

When either input is overloaded the words INPUT OVERLOAD, in the top left-hand corner of the screen, flash.

4.1.02 OSC OUT Connector

This is the output connector for the internal oscillator and has a nominal impedance of 50 Ω

4.1.03 REF IN Connector

This is the general purpose input connector for external reference signals.

Note: If the best possible phase accuracy at low external reference frequencies is required, then a TTL reference signal should be applied to the rear panel REF TTL input instead.

When external reference mode is selected the word LOCKED appears in highlighted text along the top edge of the screen. Under unlock conditions the word LOCKED flashes.

4.1.04 Electroluminescent Screen

This screen, the five pairs of keys on each side of it and the four keys under it are used to adjust the instrument's controls and display the measured outputs, by the use of a series of menus. The model 7280 is a very sophisticated instrument with many features and consequently had the traditional approach of using one button per control been adopted the front panel would have been very large. Adopting a menu-based control and display system, with the function of each key being dependent on the displayed menu, gives a much cleaner design, with controls that need to be changed only occasionally being hidden in normal use.

The ten pairs of keys on either side of the screen have the following functions, depending on the displayed menu.

Function 1: To adjust the setting of a control.
If a control, such as time constant, full-scale sensitivity, or input coupling mode is displayed on the screen then the adjacent △▽ key pair is used to adjust its setting. Some controls, such as AC Gain and full-scale sensitivity, have only a limited range of settings, and so the use of the △ and ▽ keys allows the required value to be chosen with only a few key-presses. Other controls, such as the internal oscillator amplitude and frequency, may be set over a wide range of values and to a high precision. In these cases a significant number of key-presses might be needed to set the control to the required setting.

Adjustment of the latter type of control is made easier by any of the four methods described below.

Keypad Data Entry
Pressing the single key below the lower left-hand corner of the screen marked SET CONTROL followed by either side of the △▽ key adjacent to a control requiring numerical entry activates the keypad. This is indicated by the SET CONTROL key changing to ABORT KEYPAD and a small keypad icon appearing adjacent to the selected control, as shown in figure 4-2.

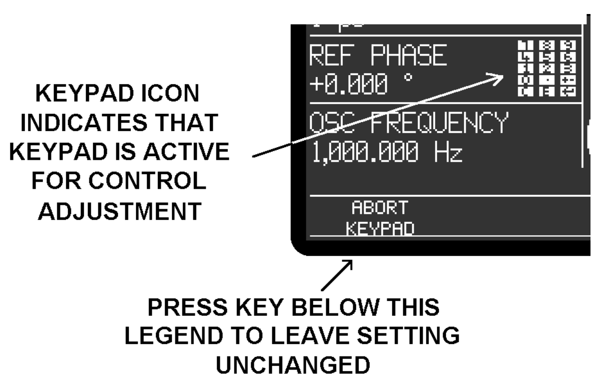

Figure 4-2, Numerical Entry Keypad

Use the keypad to enter the required setting of the control. The numerical keys and decimal point (•), sign (+/-) and engineering exponent (E) keys are self-explanatory, while the (C) (clear) key can be pressed at any time to clear any digits already entered, which are shown in dimmed text next to the control.

Once the required value is set, there are two choices:

If the (enter) key is pressed, then the value entered will be accepted as the new control setting, the setting will be shown in normal, bright, text and the keypad icon will be removed. If however the ABORT KEYPAD key is pressed, then the control will be left at its previous setting and the keypad icon will be removed.

The following example should make this clear.

Example: Setting Internal Oscillator Frequency to 100.3 Hz
If the internal oscillator frequency is 1000 Hz and it is required to change it to 100.3 Hz, then press the front-panel SET CONTROL key followed by the key adjacent to the Main Display OSC FREQUENCY control. The keypad icon will appear and the keypad will be activated.

Press the keys corresponding to the digits “1”, “0”, “0”, and “3” to set the oscillator frequency to 100.3 Hz. Finally, press the key to accept the value and remove the keypad icon.

Active Cursor XE "Active cursor"
In some cases it is useful to be able to quickly adjust a control in equal increments, for example when monitoring the effect of changing the oscillator frequency about a given value. This is easily done in the model 7280 using a control setting feature known as Active Cursor operation.

A cursor can be placed under any digit of a displayed control where that control requires numerical data entry. Thereafter, the keys adjacent to the control increment or decrement the setting of that digit.

The positioning of the cursor can be done in one of two ways:

Using Cursor Movement Keys
The , , and cursor movement keys move the active cursor between all digits to which it can apply on the relevant controls. The keys and keys adjust the position of the cursor within a control while the and keys move the cursor between controls.

This method of cursor positioning is very easy, but for compatibility with other ***SIGNAL RECOVERY*** lock-in amplifiers, particularly the models 7220 and 7265, the double key-press method of cursor positioning is also included.

Using the Double Keypress

Step 1 Simultaneously press both sides of the key adjacent to the control. In the example shown in figure 4-3 the internal oscillator frequency will be adjusted, since this is the control displayed adjacent to the keys. A cursor appears under one of the displayed digits (see also figure 4-4).

Step 2 With the cursor visible, repeating step 1 causes the cursor to move to the left. When the cursor reaches the most significant digit available (left end of control setting) the next key-press returns the cursor to the least significant digit (right end of control setting). Continue this action until the cursor is under the required digit.

Step 3 Press the △ or ▽ key to change the digit to the required value.

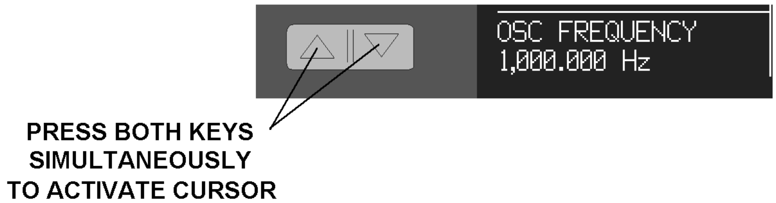

Figure 4-3, Active Cursor Activation

As an example of this operation, suppose that the oscillator frequency is 1000.000 Hz and it is required to change it to 1001.000 Hz. Simultaneously press both △ and ▽ keys adjacent to the oscillator frequency display. Move the cursor, by repeated double-key presses, until it is under the digit that is to be changed, in this case the zero to the left of the decimal point. Then press the △ key to increment the frequency by 1 Hz. The cursor will disappear as soon as the frequency is adjusted but its position remains active until changed (see figure 4-4).

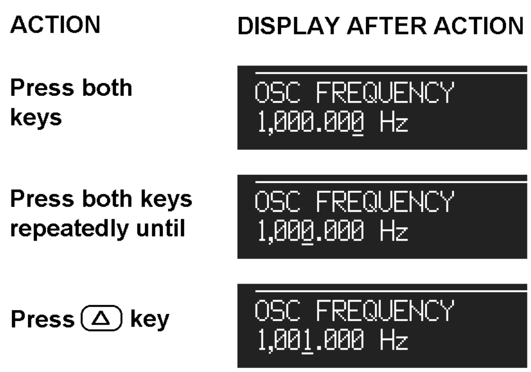

Figure 4-4, Active Cursor Operation

The double-key press action can also be performed with one finger by firmly pressing the center of the △▽ key rocker which will deform to press both keys. The active cursor can be used to set any particular digit. For example, if you only want to adjust the reference phase in 1 degree steps leave the cursor over the first digit to the left of the decimal point of the reference phase value.

Auto Repeat

If a △ or ▽ key adjacent to a control is pressed and held, then its action is automatically repeated such that the control setting is incremented or decremented at a rate approximately ten times faster than can be achieved by repeated manual key-presses.

Function 2: To Select a Menu or Sub-Menu

When the screen adjacent to a △▽ key pair displays a menu name, then pressing either the △ or ▽ key selects that menu.

Function 3: To Execute a Pre-Programmed Function

When the screen adjacent to a △▽ key pair displays a pre-programmed function, such as Auto-Measure or start frequency sweep, then pressing either the △ or ▽

key executes that function.

4.1.05 HELP Key

The model 7280 includes context-sensitive on-screen help. In many menus, pressing the HELP key followed by a key adjacent to any displayed control or menu selection provides information about that control or menu.

If information is required on other topics, then pressing HELP twice, when in the Main Display, accesses the main Help menu, from which the required subject may be obtained by pressing the relevant key.

To exit the Help screens and return to normal operation press the HELP key again.

4.1.06 MENU Key

The model 7280 is controlled by a series of on-screen menus. When the Main Display is shown the MENU key is used to access Main Menu 1, from which other menus may be accessed.

The structure of the menus is fully discussed in chapter 5.

4.1.07 SELECT CONTROL Key

This key allows the user to select which four out of the possible eleven basic instrument controls, including those such as full-scale sensitivity, time constant and oscillator frequency, are shown on and can therefore be directly adjusted from the Main Display.

The selection operates as follows:

Step 1 Press the SELECT CONTROL key.

Step 2 Press either the △ or ▽ key next to the position to wish to allocate to a particular control. Although five controls can be adjusted from the Main Display, only the controls allocated to the lower four can be selected by the user, since the topmost one is always used for the AC Gain control.

Each press of the △ or ▽ key changes the control allocated to the adjacent position. Repeat until the control you require is shown.

Step 3 Press the SELECTION COMPLETE key to return to the Main Display.

4.2 Rear Panel

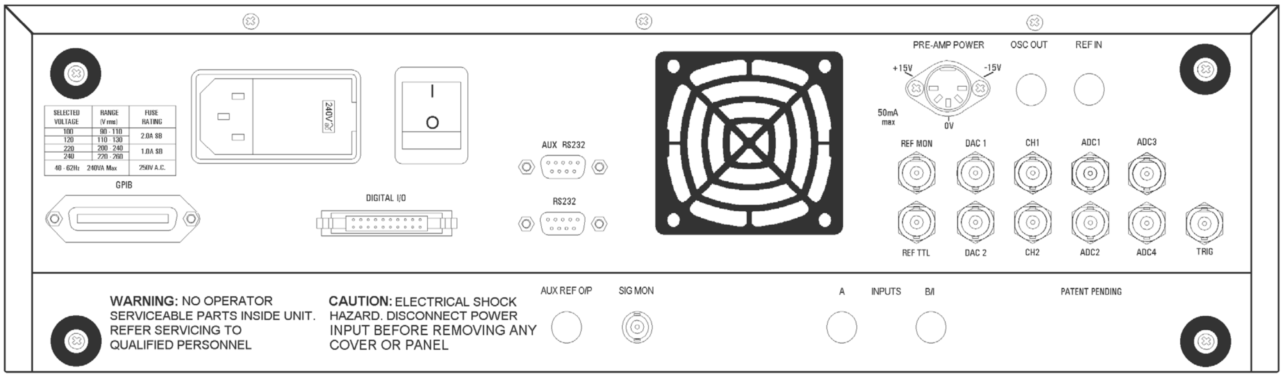

Figure 4-5, Model 7280 Rear Panel Layout

As shown in figure 4-5, the line power switch, line power voltage selector, two RS232 connectors, a GPIB (IEEE-488) connector, digital I/O port, preamplifier power connector and twelve BNC signal connectors are mounted on the rear panel of the instrument. Brief descriptions of these are given in the following text.

4.2.01 Line Power Switch

CAUTION: The model 7280 may be damaged if the line voltage is set for 110 V AC operation and it is turned on with 220 V AC applied to the power input connector. Please ensure that the line voltage selector is set to the correct line voltage before switching on.

Press the end of the switch marked **I** to turn on the instrument's power, and the other end marked **O** to turn it off.

4.2.02 Line Power Input Assembly

This houses the line voltage selector and line input fuse. To check, and if necessary change, the fuse or line voltage see the procedure in section 2.1.05.

4.2.03 RS232 Connector

This 9-pin D type RS232 interface connector implements pins 1, 2, 3 and 7 (Earth Ground, Transmit Data, Receive Data, Logic Ground) of a standard DTE interface. To make a connection to a PC-compatible computer, it is normally sufficient to use a three-wire cable connecting Transmit Data to Receive Data, Receive Data to Transmit Data, and Logic Ground to Logic Ground. Appendix D shows the connection diagrams of cables suitable for computers with 9-pin and 25-pin serial connectors. Pinouts for this connector are given in appendix B.

4.2.04 AUX RS232 Connector

This connector is used to link other compatible EG&G equipment together in a "daisy-chain" configuration. Up to an additional 15 units can be connected in this way. Each unit must be set to a unique address (see section 5.3.22). Pinouts for this connector are given in appendix B.

4.2.05 GPIB Connector

The GPIB interface connector conforms to the IEEE-488 1978 Instrument Bus Standard. The standard defines all voltage and current levels, connector specifications, timing and handshake requirements.

4.2.06 DIGITAL I/O Connector

This connector provides eight TTL lines, each of which can be configured as inputs or outputs. When set as an output, each line can be set high or low by the use of the Digital Port menu or via the computer interfaces, and when set as an input, the applied logic state can be read.

The port is most commonly used for controlling auxiliary apparatus, such as lamps, shutters and heaters, and reading status signals from auxiliary equipment. Pinouts for this connector are given in appendix B.

4.2.07 PRE-AMP POWER Connector

This connector supplies ±15 V at up to 100 mA and can be used for powering optional remote preamplifiers available from ***SIGNAL RECOVERY***. Pinouts for this connector are given in appendix B.

4.2.08 REF MON Connector

The signal at this connector is a TTL-compatible waveform synchronous with the reference. This output monitors correct reference channel operation but its polarity is not uniquely defined so that it does not necessarily show the correct phase relationship with the **SIG MON** output.

4.2.09 REF TTL Connector

This connector is provided to allow TTL-compatible pulses to be used as the reference input, if the best possible phase accuracy at low external reference frequencies is required, when it usually gives better results than the **REF IN** connector on the front panel.

4.2.10 DAC 1 and DAC 2 Connectors

There are two digital-to-analog converter (DAC) output connectors. The output voltages at these connectors can be set either from the front panel or by the use of remote computer commands. The output range is ±10.000 V and the resolution is 1 mV.

4.2.11 CH 1 and CH 2 Connectors

The signal at these connectors is an analog voltage corresponding to a selected output, such as X, Y, R, θ, etc., as specified in the Analog Outputs menu. The full-scale output voltage range is ±2.500 V although the outputs remain valid to ±7.500 V to provide up to 3 × full-scale overload capability.

4.2.12 ADC 1, ADC 2, ADC 3 and ADC 4 Connectors

The input voltages at these connectors may be digitized using the auxiliary ADCs and read either from the front panel or by the use of a computer command. The input voltages are sampled and held when the ADC is triggered, and several different trigger modes are available. These modes can be set either from the front panel or by using a remote computer command. The input voltage range is ±10.000 V and the resolution is 1 mV.

4.2.13 TRIG Connector

This connector accepts a TTL-compatible input and can be used for triggering the digitization of the voltages present at the auxiliary analog-to-digital converters (ADCs) or for triggering data acquisition to the internal curve buffer. The input operates on the positive edge only.

4.2.14 SIG MON Connector

The signal at this connector is that immediately prior to the main analog-to-digital converter and after the preamplifier, line filter and anti-alias filters.

Front Panel Operation

Chapter 5

5.1 Introduction

This chapter describes how to operate the model 7280 using the front panel controls, and discusses its capabilities when used in this way. Chapter 6 provides similar information for when the unit is operated remotely using one of the computer interfaces.

It is assumed that readers are already familiar with the use of the front panel △ and ▽ keys, but if not then they should refer to the detailed description of their operation given in chapter 4.

The model 7280 uses a flexible, menu-based, control structure which allows many instrument controls to be adjusted from the front panel with only a few key presses. Furthermore this design makes it very easy to introduce new features or improve existing ones without the restrictions which would result from a fixed front panel layout.

The instrument may be operated in one of four modes, as follows:-

Single Reference
This is the normal operating mode of the unit, where it functions as a conventional dual phase lock-in amplifier. It includes both internal and external reference modes and provides detection either at the reference frequency or one harmonic of it.

Virtual Reference
Virtual reference mode is an extension of internal single reference mode operation, where the Y channel output is used to make continuous adjustments to the internal oscillator frequency and phase to achieve phase-lock with the applied signal such that the X channel output is maximized and the Y channel output is zeroed. Virtual reference mode operation is only possible with signals at frequencies between 100 Hz and 2.0 MHz.

Dual Reference
In dual reference mode the model 7280 can make simultaneous measurements at two different reference frequencies, of which one must be external and the other must be derived from the internal oscillator. In standard instruments, the maximum detection frequency for either reference_1 or reference_2 is 20 kHz, but units fitted with the 7280/99 option allow operation to 800 kHz and those with the 7280/98 option allow operation to 2.0 MHz

Dual Harmonic
Dual harmonic mode allows the simultaneous measurement of two different harmonics of the input signal. As with dual reference mode, in standard instruments, the maximum detection frequency for either harmonic_1 or harmonic_2 is 20 kHz, but units fitted with the 7280/99 option allow operation to 800 kHz and those with the 7280/98 option allow operation to 2.0 MHz

The sections which follow describe the menus as they appear when the unit is being used in single reference mode. The menus range from the Main Display, used most of the time for instrument control and display of data, through to those menus accessing controls which typically only need changing occasionally.

The menus for the other three operating modes are then described, since in some cases these differ from those used in single reference mode to accommodate the additional controls and displays that are needed.

5.2 Menu Structure

Figure 5-1 shows the basic structure of the main instrument control menus which, it will be seen, has a hierarchical, or "tree", structure.

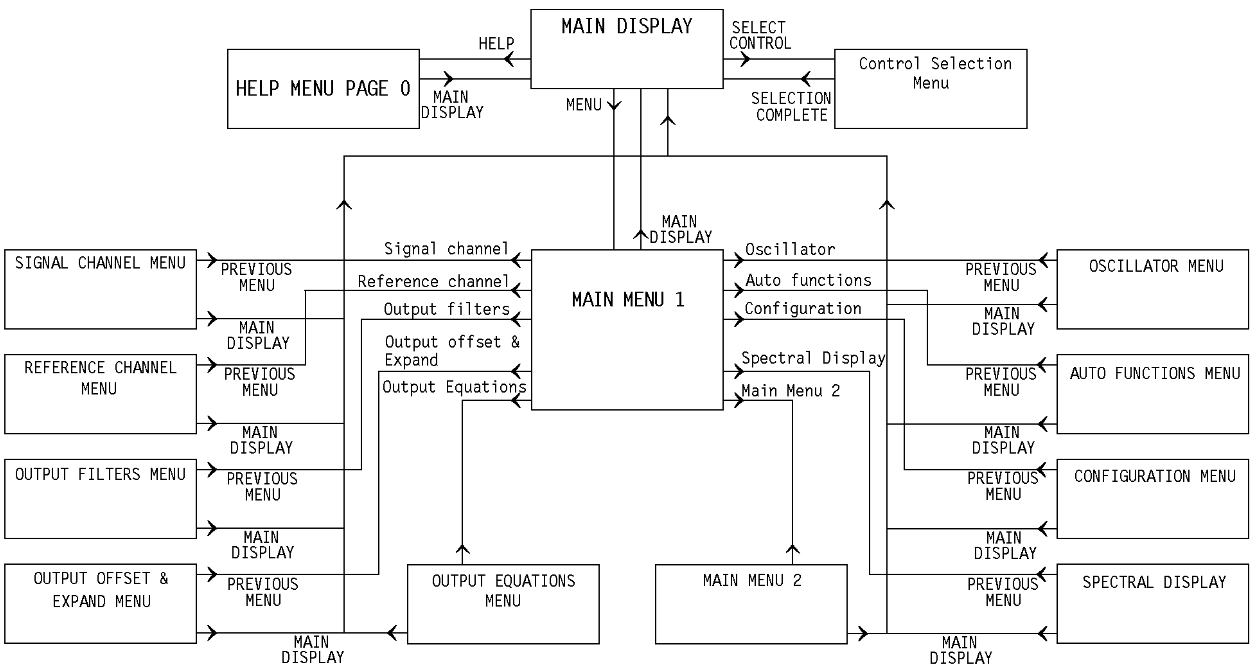

Figure 5-1, Main Menu Structure

In the diagram, although not in the rest of this manual, the following syntax is used:- The menus are shown as boxes, with menu names in gothic typeface, e.g. MAIN MENU, and arrows on the lines connecting the menus and the text adjacent to them indicate the keys which need to be pressed to move between menus.

The following examples should make this clear.

To access Main Menu 1 from the Main Display, press the Menu key in the lower right-hand corner of the screen.

To access the Signal Channel menu from the Main Display, press the Menu key followed by the Signal Channel key shown in Main Menu 1; to return to Main Menu 1 press the Previous Menu key on the Signal Channel menu.
Note that all menus provide a Previous Menu key allowing the user to return one step up the menu "tree". In addition, when in any menu, pressing the Main Display key on the front panel provides a direct return route to the Main Display.

Some menus, such as the Oscillator menu, have further sub-menus which are discussed later. These have been omitted from figure 5-1 for the sake of clarity.

5.3 Menu Descriptions - Single Reference Mode

5.3.01 Main Display

Figure 5-2, Main Display - Single Reference Mode

The Main Display always appears on power-up and is similar to that shown in figure 5-2 above. It is divided into two sections by a single vertical line. Five instrument controls appear on the left-hand side, of which the topmost one, AC Gain, is always displayed, whereas the other four are user-specified using the Control Selection menu, discussed later in section 5.3.02. On the right-hand side, four instrument outputs are displayed in one of the three following formats:-

a) Two large numeric and two bar-graphs
b) Four bar-graphs
c) Four large numeric displays

The display mode is selected via the center key pair of the five keys to the right of the screen, with each key press changing the mode. In any given display mode, the choice of the output that will actually be shown in each of the four positions is made using the corresponding right-hand keys. In single reference mode, there are thirteen possible outputs to choose from for each numeric display, with nine choices for the bar-graph displays, as listed in table 5-1.

Output Title	**Description**
Numeric Displays only:	
R%	Resultant (Magnitude) output as a percentage of full-scale sensitivity
N%	Noise output as a percentage of full-scale sensitivity
θ°	Phase output in degrees
X%	X channel output as a percentage of full-scale sensitivity
Y%	Y channel output as a percentage of full-scale sensitivity
R	Resultant (Magnitude) output in volts or amps
Numeric and Bar-Graph Displays:	
X	X channel output in volts or amps
Y	Y channel output in volts or amps
N	Noise output in volts or amps per root hertz
ADC1	ADC1 input, ±10.000 V full-scale
ADC2	ADC2 input, ±10.000 V full-scale
ADC3	ADC3 input, ±10.000 V full-scale
ADC4	ADC4 input, ±10.000 V full-scale
Bar-Graph Displays only:	
MAG	Resultant (Magnitude) output in volts or amps
PHA°	Phase output in degrees

Table 5-1, Output Display Choices - Single Reference Mode

The instrument provides a means of switching quickly between the following pairs of outputs, simply by pressing simultaneously both ends of the △▽ keys adjacent to their description:-

X %fs	←→	X volts or amps
Y %fs	←→	Y volts or amps
R %fs	←→	R volts or amps
Noise %fs	←→	Noise volts/√Hz or amps/√Hz

In the center right-hand section of the Main Display the current reference frequency, as measured by the reference frequency meter, is shown, together with the current levels of X and Y output offsets.

Warning Indicators

Along the top edge of the Main Display are four warning indicators. Input Overload and Output Overload are normally shown in dimmed text, but in the event of an overload occurring, flash on and off. Similarly, Locked appears in bright text when the instrument is locked to a suitable reference, and flashes when the reference channel is unlocked. Remote is normally shown in dimmed text but appears in bright text when the instrument is being operated via one of the computer interfaces.

Controls

`AC GAIN`

The AC Gain control is always displayed in the top left-hand corner of the Main Display. If the automatic AC Gain control is turned off (using the Signal Channel menu - see section 5.3.04), then this control allows the AC Gain to be adjusted from 0 dB to 66 dB in 6 or 8 dB steps, although not all settings are available at all full-scale sensitivity settings. If the automatic control is turned on, then the control cannot be adjusted, but the present value of AC Gain is still displayed. In either mode, changing the full-scale sensitivity may result in a change to the AC Gain.

To obtain the best accuracy, use the highest value of AC Gain that is possible without causing signal input overload, indicated by the words Input Overload in the top left-hand corner of the screen flashing on and off. The Input Limit value, displayed immediately under the AC Gain control, is the largest value of rms signal that may be applied without causing signal overload.

5.3.02 Control Selection Menu

The four user-selectable controls on the Main Display may be chosen from those available by pressing the Set Control key. The Control Selection menu appears, as shown in figure 5-3.

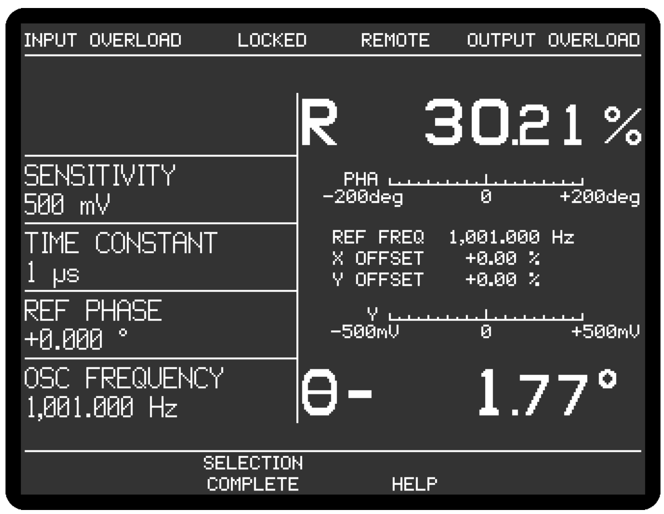

Figure 5-3, Control Selection Setup Menu

Press the △▽ keys adjacent to each of the four control descriptions on the left-hand side until the required controls are selected. Note that it is not possible to display the same control in more than one position simultaneously.

The available controls have the following functions:-

`SENSITIVITY`

When set to voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity may be set to any value between 10 nV and 1 V in a 1-2-5 sequence.

When set to current input mode, using the Signal Channel menu, the instrument's full-scale current sensitivity may be set to any value between 1 pA and 100 µA (wide bandwidth mode), 10 fA and 1 µA (normal mode), or 10 fA and 10 nA (low-noise mode), in a 1-2-5 sequence.

The number reported after the letters DR is the instrument's Dynamic Reserve, expressed in decibels, as calculated by the following equation:-

$$DR = 20 \times \log_{10}\left(\frac{2}{SEN}\right) - \text{ACGain (in dB)}$$

Example:-

If AC Gain = 14 dB and SEN = 2 mV then

$$DR = 20 \times \log_{10}\left(\frac{2}{0.002}\right) - 14$$

$$DR = 46 \text{ dB}$$

TIME CONSTANT

The time constant of the output filters is set using this control, in the range 1 µs to 100 ks in a 1-2-5 sequence. Settings of 1 ms and below restrict the choice of instrument outputs at the rear-panel **CH1** and **CH2** outputs to X, Y and Magnitude.

REF PHASE

This control allows the reference phase to be adjusted over the range -180° to +180° in 1 m° steps. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

REF PHASE ±90°

This control allows the reference phase to be adjusted in steps of ±90°.

X OFFSET **and** Y OFFSET

These are the manual X channel and Y channel output offset controls. The offset levels set by these controls, which can be any value between -300% and +300% in 0.01% steps, are added to the X channel or Y channel outputs when the X channel or Y channel offsets are switched on using the Output Channels menu. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The values are set automatically by the Auto-Offset function. Note that the Auto-Offset function automatically switches on both X and Y channel output offsets.

REF HARMONIC

This control sets the harmonic of the applied reference frequency, either internal or external, at which the lock-in amplifier's reference channel operates, in the range 1 st (fundamental mode) to 32 nd. For example, if the control is set to 2 nd and a reference signal of 1 MHz is applied, the instrument will measure signals at its input at a frequency of 2 MHz.

RELOCK EXT. REFERENCE

The 7280 includes frequency-dependent calibration parameters. When operating in Internal reference mode the correct parameters can be chosen because the reference frequency is equal to the specified oscillator frequency. In External reference mode the applied frequency is measured, and the measured value is used to select the correct parameters. If , however, the external reference frequency drifts or changes with time then the lock-in amplifier may need to use different calibration parameters. It therefore includes an automatic algorithm that detects significant changes in reference frequency, and if these occur, updates all the frequency-dependent calibration values.

Pressing this key has the effect of manually updating these calibration parameters. This should be done when operating in External reference mode after each intentional change to the applied reference frequency.

AUX DAC 1 **and** AUX DAC 2

These two controls set the voltage appearing at the **DAC1** and **DAC2** output connectors on the rear panel to any value between +10 V and -10 V with a resolution of 1 mV. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC FREQUENCY

The frequency of the instrument's internal oscillator may be set, using this control, to any value between 0.5 Hz and 2.000 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC AMPLITUDE

This control may be set to any value between 1 mV and 1 V rms. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

Once the required controls have been selected, press the Selection Complete key on the front panel to return to the Main Display.

5.3.03 Main Menu 1

When in the Main Display, press the Menu key once to access Main Menu 1, which is shown in figure 5-4.

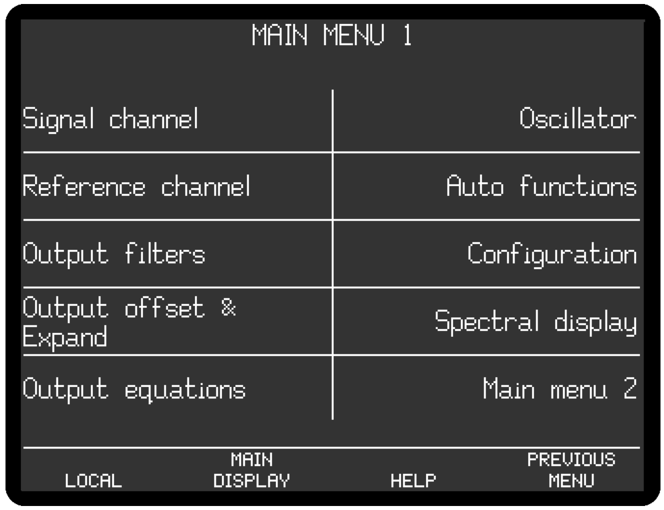

Figure 5-4, Main Menu

Main Menu 1 is used to access all of the remaining instrument controls via a series of sub-menus, which are selected simply by pressing the key adjacent to the required menu. These sub-menus are described in the following sections.

5.3.04 Signal Channel Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Signal Channel item accesses the Signal Channel menu, which is shown in figures 5-5 and 5-6.

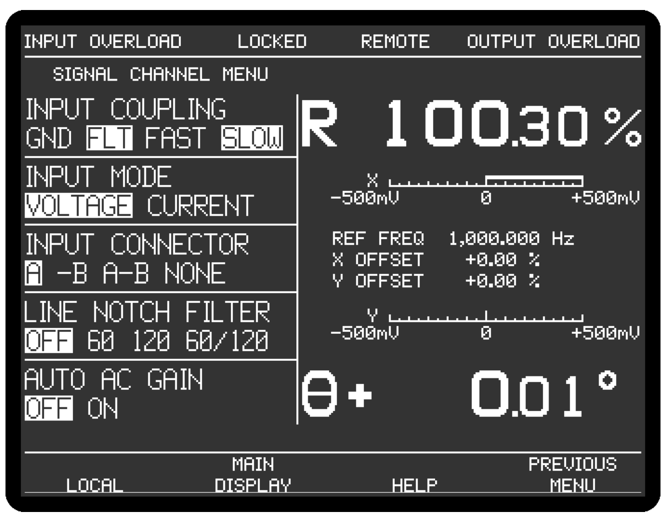

Figure 5-5, Signal Channel Menu - Voltage Input Mode

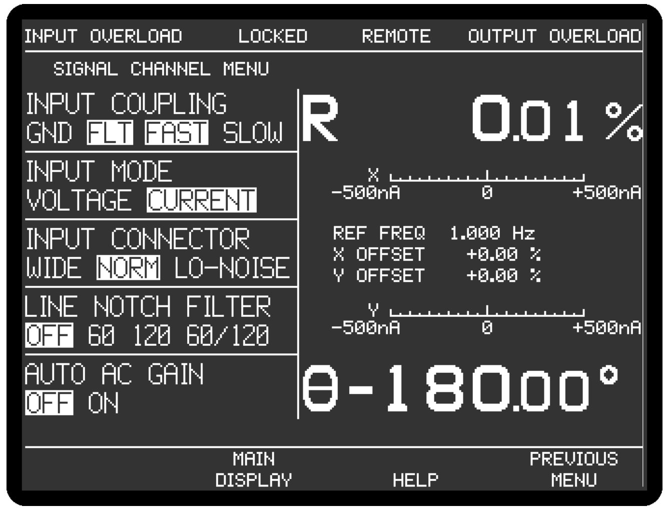

Figure 5-6, Signal Channel Menu - Current Input Mode

The Signal Channel menu has five controls affecting the instrument's signal input channel. Changes to the setting of these controls can be made by using the adjacent △ ▽ keys, with the currently active selection being shown in reversed text.

INPUT COUPLING

The input coupling can be set as follows:-

GND

The shells of the **A** and **B/I** connectors are connected directly to chassis ground.

FLT

The shells of the **A** and **B/I** connectors are connected to chassis ground via a 1 kΩ resistor.

FAST

The input coupling mode is set for fast recovery from input overload conditions. Significant phase and magnitude errors will occur at frequencies below 20 Hz.

SLOW

The input coupling mode is set for slow recovery from input overload conditions, but there will be smaller phase and magnitude errors at frequencies below 20 Hz than when using the Fast mode.

INPUT MODE

This control sets the preamplifier input configuration to either voltage or current mode, and also changes the function of the INPUT CONNECTOR control.

INPUT CONNECTOR

In voltage input mode, as shown in figure 5-5, this control has four settings:-

A

The signal channel input is a single-ended voltage input to the BNC connector on the front panel marked **A**.

-B
The signal channel input is an inverting single-ended voltage input to the BNC connector on the front panel marked **B/I**.

A-B
In this setting the signal channel input is a differential voltage input connected to the BNC connectors on the front panel marked **A** and **B/I**.

NONE
The input is disconnected in this setting.

In current input mode, shown in figure 5-6, this control has three settings:-

WIDE **(Wide Bandwidth Converter)**
In this setting the signal channel input is a single-ended current input connected to the BNC connector on the front panel marked **B/I**, and uses the wide bandwidth current-to-voltage converter.

NORM **(Normal Converter)**
In this setting the signal channel input is a single-ended current input connected to the BNC connector on the front panel marked **B/I**, and uses the normal current-to-voltage converter.

LO-NOISE **(Low Noise Converter)**
In this setting the signal channel input is a single-ended current input connected to the BNC connector on the front panel marked **B/I**, and uses the low-noise current-to-voltage converter.

LINE NOTCH FILTER
This control selects the mode of operation of the line frequency rejection filter and offers four possible settings out of the seven described in the following table:-

Legend	Function
OFF	Line filter inactive
50	Enable 50 Hz notch filter
60	Enable 60 Hz notch filter
100	Enable 100 Hz notch filter
120	Enable 120 Hz notch filter
50/100	Enable 50 and 100 Hz notch filters
60/120	Enable 60 and 120 Hz notch filters

The filter frequencies available (i.e. 50/100 Hz or 60/120 Hz) depend on the setting of the LINE FREQUENCY control on the Configuration Menu - see section 5.3.13

AUTO AC GAIN
The final control on the Signal Channel menu selects whether or not the Automatic AC Gain function is active. As discussed in section 3.3.04, the correct adjustment of the AC Gain in a DSP lock-in amplifier is necessary to achieve the best results. This control allows the user to select whether this adjustment is carried out automatically or remains under manual control.

AUTO AC GAIN OFF
In this setting the AC Gain may be manually adjusted from the Main Display.

AUTO AC GAIN ON
In this setting the AC Gain value is automatically selected by the instrument, depending on the full-scale sensitivity. In the mid-range full-scale sensitivity ranges the resulting dynamic reserve is between 20 and 26 dB.

Pressing the Previous Menu key returns control to Main Menu 1.

5.3.05 Reference Channel Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Reference Channel item accesses the Reference Channel menu, which is shown in figure 5-7.

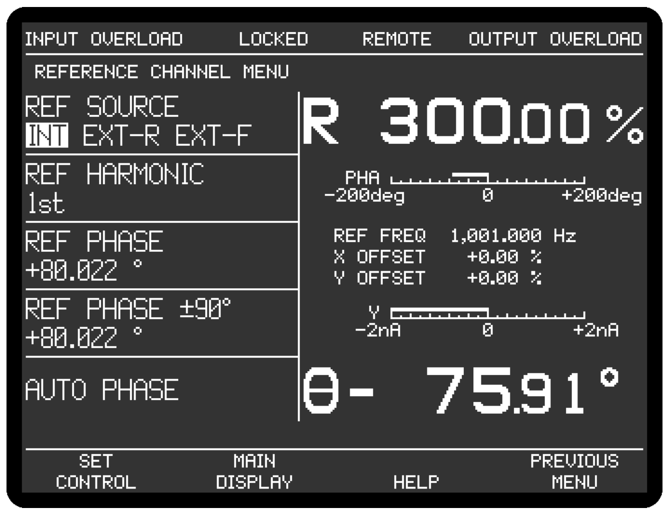

Figure 5-7, Reference Channel Menu

The Reference Channel menu has five controls affecting the instrument's reference channel. Changes to the setting of these controls can be made by using the adjacent (△)(▽) keys.

REF SOURCE
This control allows selection of the source of reference signal used to drive the reference circuitry, and has three settings:-

INT
The lock-in amplifier's reference is taken from the instrument's internal oscillator. Note that this setting gives the best phase and gain measurement accuracy under all operating conditions, and it is always to be preferred, if possible, to design the experiment so that the lock-in amplifier acts as the source of the reference signal.

EXT-R
In this setting the reference channel is configured to accept a suitable external reference source applied to the rear panel **REF TLL** input connector

EXT-F

In this setting the reference channel is configured to accept a suitable external reference source applied to the front panel **REF IN** input connector

REF HARMONIC

This control allows selection of the harmonic of the reference frequency at which the lock-in amplifier will detect. It can be set to any value between 1st and 32nd, but most commonly is set to 1st. Note that the "2F" setting commonly found on other lock-in amplifiers corresponds to setting this control to 2nd. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

REF PHASE

This control allows the reference phase to be adjusted over the range -180° to +180° in 1 m° steps. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

REF PHASE ±90°

This control allows the reference phase to be adjusted in steps of ±90°.

AUTO PHASE

In an Auto-Phase operation the value of the signal phase with respect to the reference is computed and an appropriate phase-shift is then introduced into the reference channel so as to bring the difference between them to zero. The intended result is to null the output of the Y channel while maximizing the output of the X channel.

Pressing the Previous Menu key returns control to Main Menu 1.

5.3.06 Output Filters Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Output Filters item accesses the Output Filters menu, which is shown in figure 5-8.

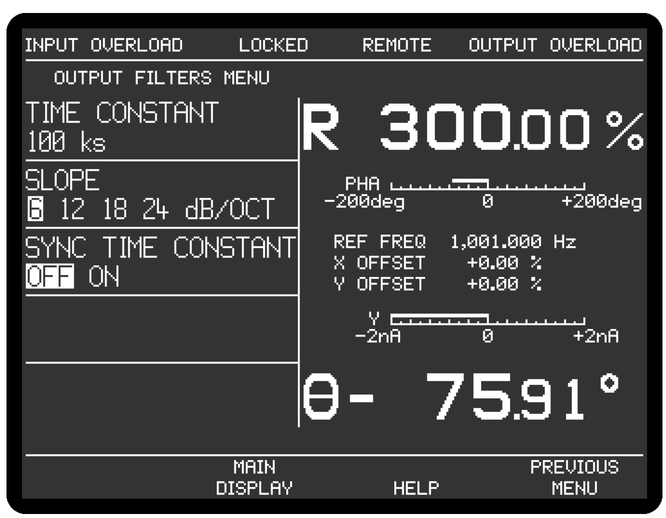

Figure 5-8, Output Filters Menu

The Output Filters menu has three controls affecting the instrument's main X and Y channel output filters. Changes to the setting of these controls can be made by using the adjacent △▽ keys.

TIME CONSTANT
This control, which duplicates the Main Display TIME CONSTANT control, is used to set the time constant of the output filters.

SLOPE
The roll-off of the output filters is set, using this control, to any value from 6 dB to 24 dB/octave, in 6 dB steps. Note that there are some restrictions in that it is not possible to select 18 or 24 dB/octave settings at Time constants of 1 ms or shorter.

SYNC TIME CONSTANT
This control has two settings, as follows:-

OFF
In this setting, which is the normal mode, time constants are not related to the reference frequency period.

ON
In this setting, the actual time constant used is chosen to be some multiple of the reference frequency period, giving a much more stable output at low frequencies than would otherwise be the case. Note that, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

Pressing the Previous Menu key returns control to Main Menu 1.

5.3.07 Output Offset & Expand Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Offset & Expand item accesses the Offset & Expand menu, which is shown in figure 5-9.

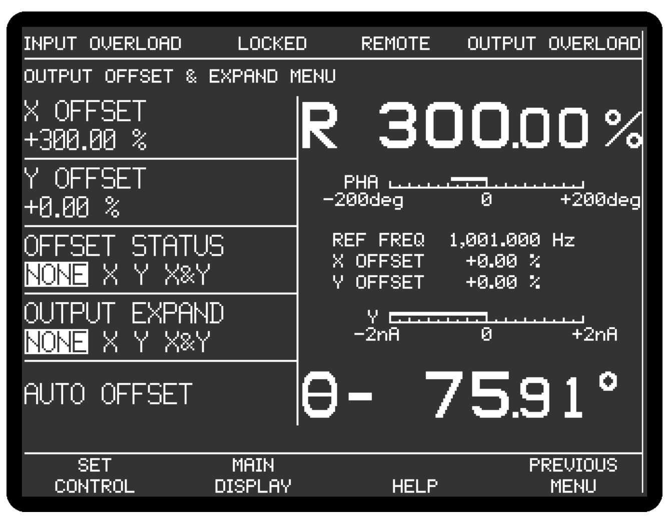

Figure 5-9, Offset & Expand Menu

The Offset & Expand menu has five controls affecting the instrument's X channel and Y channel outputs. Changes to the setting of these controls can be made by using the adjacent △▽ keys, with the currently active selection being highlighted.

`X OFFSET` **and** `Y OFFSET`

These controls, which duplicate the Main Display `X OFFSET` and `YOFFSET` controls, allow manual adjustment of the X channel and Y channel output offsets. The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X channel or Y channel output when the X channel or Y channel offset is switched on. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.
The values are set automatically by the Auto-Offset function, which also switches on both X channel and Y channel output offsets.

`OFFSET STATUS`

This control allows the X channel and Y channel output offsets, set by the above level controls, to be switched on to either or both outputs, or to be switched off. It therefore has four settings, as follows:-

`NONE`
Both X channel and Y channel output offsets are switched off.

`X`
The X channel output offset is switched on.

`Y`
The Y channel output offset is switched on.

`X&Y`
Both X channel and Y channel output offsets are switched on.

`OUTPUT EXPAND`

This control allows a ×10 output expansion to be applied to the X, Y or both output channels, or to be switched off:-

`NONE`
Output expansion is turned off.

`X`
A ×10 output expansion is applied to the X channel output only.

`Y`
A ×10 output expansion is applied to the Y channel output only.

`X&Y`
A ×10 output expansion is applied to both the X channel and Y channel outputs.

Pressing the Previous Menu key returns control to Main Menu 1.

5.3.08 Output Equations Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Output Equations item opens the Output Equations Menu, shown in figure 5-10.

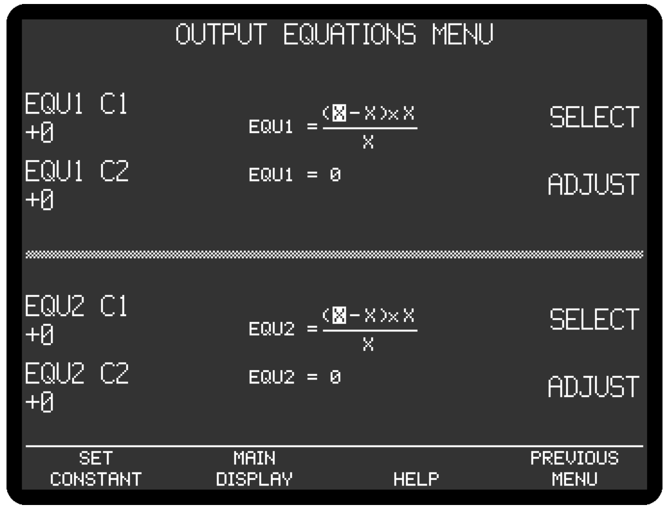

Figure 5-10, Output Equations Menu

The Output Equations menu is used to define more complex calculations on the instrument outputs than are possible using the basic ratio and log ratio options. There are two user-defined equations, Equation 1 and Equation 2, which take the following form:-

$$\text{Equation} = \left(\frac{(A \pm B) \times C}{D}\right)$$

where the operator "±" may be set to either addition or subtraction, and the variables A, B, C and D can be chosen from the following list:-

Variable	Range
X	±30000
Y	±30000
MAG	0 to +30000
PHA (Phase)	±18000
ADC1	±10000
ADC2	±10000
ADC3	±10000
ADC4	±10000
C1	0 to 100000
C2	0 to 100000
0	Zero
1	Unity
FRQ (Reference Frequency)	0 to 2000000000 (Only available in position C)
OSCF(Oscillator Frequency)	0 to 2000000000 (Only available in position C)

The select △▽ keys are used to highlight the required variable, and then the adjust △▽ keys are used to change it.

The values C1 and C2 within each equation are user-defined integer constants and are adjusted using the two corresponding △▽ keys. They may also be set using the keypad, by pressing SET CONSTANT followed by the required value on the keypad, or by using the Active Cursor.

The calculation is performed using 64-bit integers to maintain full accuracy through to the 32-bit result that is displayed immediately below the equation and is constantly updated. Care must be taken in defining the equations so as to make the best use of the available output range.

If the equation outputs are set to appear at the **CH1** or **CH2** connectors on the rear panel using the Configuration menu, then the output range should be adjusted to lie in the range -10000 to +10000. Values outside this range will result in these analog outputs limiting at ±10.000 V, although the digital value will still appear correctly on the screen and can be read via the computer interfaces.

Note that the equations continue to be calculated even when the Output Equations menu is not displayed, if they are selected for output to the **CH1** or **CH2** connectors. Otherwise they are calculated when requested by computer command.

Pressing the Previous Menu key returns control to Main Menu 1.

5.3.09 Oscillator Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Oscillator item accesses the Oscillator menu, which is shown in figure 5-11.

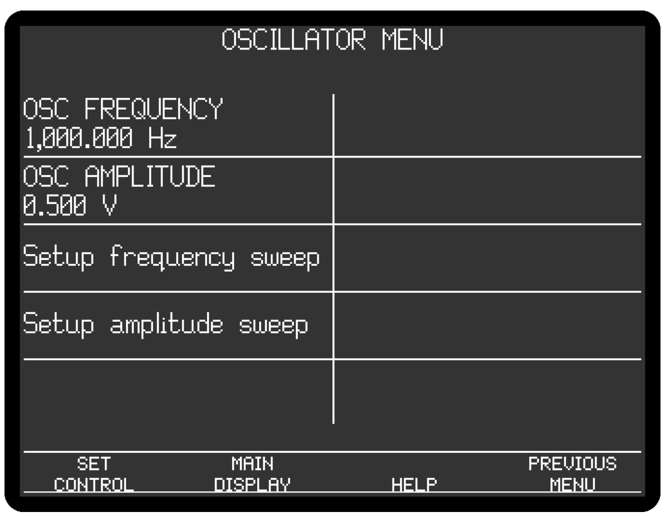

Figure 5-11, Oscillator Menu

The Oscillator menu has two controls affecting the instrument's internal oscillator, and is also used for accessing two sub-menus which control oscillator frequency and amplitude sweeps. The relationship of these menus to Main Menu 1 is shown in figure 5-12. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the Main Display key, but this has been omitted from figure 5-12 for the sake of clarity.

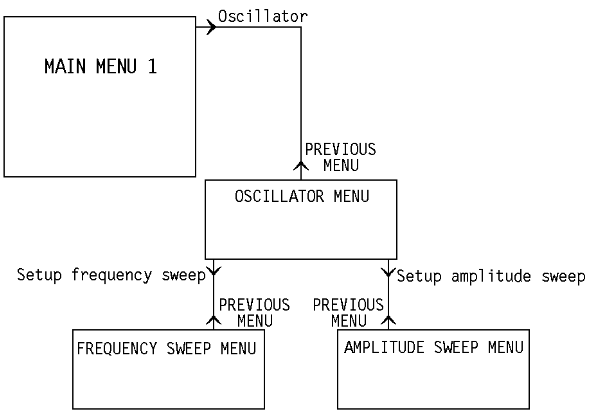

Figure 5-12, Oscillator Menu Structure

Changes to the setting of the controls on the Oscillator menu can be made by using the adjacent △▽ keys.

OSC FREQUENCY

This control, which duplicates the Main Display OSC FREQUENCY control, allows the instrument's internal oscillator frequency to be set to any value between 0.5 Hz and 2.0 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC AMPLITUDE

This control, which duplicates the Main Display OSC AMPLITUDE control, may be set to any value between 1 mV and 1 V rms in 1 mV increments. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The Oscillator menu is also used to access two sub-menus, as follows:-

5.3.10 Frequency Sweep Menu

When the Oscillator menu is displayed, pressing a key adjacent to the Setup frequency sweep item accesses the Frequency Sweep menu, which is shown in figure 5-13.

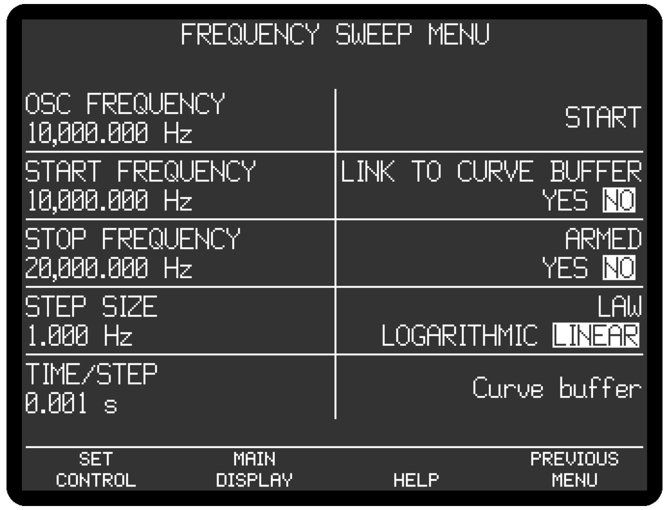

Figure 5-13, Frequency Sweep Menu

The Frequency Sweep menu has nine controls affecting the instrument's internal oscillator, and one link to the Curve Buffer menu (see section 5.3.22). Changes to the setting of the controls can be made by using the adjacent △▽ keys.

When a frequency sweep is run, the internal oscillator frequency starts at the defined start frequency and is changed in discrete steps until it reaches the stop frequency. Steps may be of equal size, which gives a linear relationship of output frequency to time, or may be proportional to the present frequency, which gives a logarithmic relationship. The controls operate as follows:-

`OSC FREQUENCY`

This control, which duplicates the Main Display `OSC FREQUENCY` control, allows the instrument's internal oscillator frequency to be set to any value between 0.5 Hz and 2.0 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`START FREQUENCY`

This control defines the start frequency for the frequency sweep, which may be set to any value between 0.5 Hz and 2.0 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`STOP FREQUENCY`

This control defines the stop frequency for the frequency sweep, which may be set to any value between 0.5 Hz and 2.0 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`STEP SIZE`

This control defines the amount by which the oscillator frequency is changed at each step. Depending on the sweep law selected (linear or logarithmic) it is set either in hertz, or as a percentage of the present frequency. If Start Frequency is greater than Stop Frequency then the output frequency will decrease with time.

TIME/STEP

This control defines the time that the oscillator frequency remains at each step of the complete frequency sweep. The range of available values depends on the setting of the OPERATING MODE control on the Analog Outputs Menu (section 5.3.18), as follows:

Operating Mode	Time/Step
FAST	140 ms to 1000 s in 1 ms increments
NORMAL	1 ms to 1000 s in 1 ms increments

Note that the time per step defined here also applies to oscillator amplitude sweeps - see section 5.3.11.

ARMED

When this control is set to YES, the frequency sweep is armed. The sweep can then be started in one of two ways:

a) If the LINK TO CURVE BUFFER control is set to YES then the sweep will be started at the same time as a curve buffer acquisition starts (see section 5.3.22). This mode allows the buffer to be used for frequency response measurements, whereby the response of an external network or system is measured by sweeping the oscillator frequency while recording the lock-in amplifier's outputs, for example magnitude and phase. Since the curve buffer can be started using internal or external triggers, and in the latter case on a per curve or per point basis, there is considerable flexibility for designing experiments.

   In this mode the START control is grayed out as it is inactive.

b) If the LINK TO CURVE BUFFER control is set to NO then the START control above it is shown in bright text, to indicate that it is active. In this mode, the frequency sweep is independent of the curve buffer and is operated by pressing the adjacent △▽ key. The control annotation changes depending on whether a sweep is running, as follows:

   START

   Pressing the adjacent △▽ key starts the frequency sweep. The ARMED control changes to PAUSE

   STOP

   Pressing the adjacent △▽ key stops the frequency sweep.

   When a sweep ahs been started and the ARMED control is not shown, the following two options are also available.

   PAUSE

   Pressing the adjacent △▽ key pauses the frequency sweep at the present frequency. The control changes to CONTINUE

   CONTINUE

   Pressing the adjacent △▽ key restarts the paused frequency sweep from the present frequency. The control changes to PAUSE

Note that if the oscillator amplitude sweep (see section 5.3.11) is also armed then the controls that start, pause, continue and stop on the Frequency Sweep menu will also control the amplitude sweep. Similarly, if the frequency sweep is linked to the curve buffer then the amplitude sweep will be as well.

LAW
This control defines the relationship of output frequency to time for the frequency sweep, and has three options:-

LOGARITHMIC
Selects a logarithmic relationship. When in this mode, the frequency is defined in terms of a percentage of the current frequency. For example, if the step size were set to 10%, the start frequency to 1 kHz and the stop frequency to 2 kHz, then the frequencies generated during the sweep would be:-
1000.000 Hz
1100.000 Hz
1210.000 Hz
1331.000 Hz
1464.100 Hz
1610.510 Hz
1771.561 Hz
1948.717 Hz
2000.000 Hz

LINEAR
Selects a linear relationship.

Pressing the Curve Buffer key accesses the Previous Menu key returns control to the Oscillator Menu.

5.3.11 Amplitude Sweep Menu

When the Oscillator menu is displayed, pressing a key adjacent to the Setup amplitude sweep item accesses the Amplitude Sweep menu, which is shown in figure 5-14.

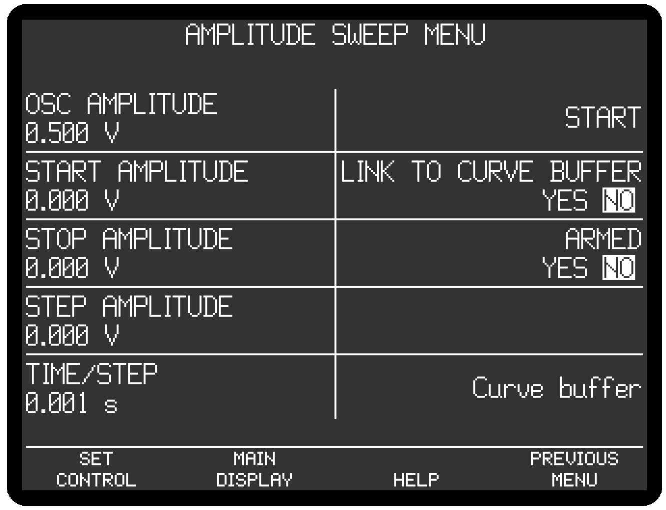

Figure 5-14, Amplitude Sweep Menu

The Amplitude Sweep menu has eight controls affecting the instrument's internal oscillator, and one link to the Curve Buffer menu (see section 5.3.22). Changes to the setting of the controls can be made by using the adjacent $\triangle$ $\triangledown$ keys.

When an amplitude sweep is run, the internal oscillator output starts at the defined start amplitude and is changed in discrete steps until it reaches the stop amplitude. Steps are always of equal size, giving a linear relationship of output amplitude to time. The controls operate as follows:-

`OSC AMPLITUDE`
This control may be set to any value between 1 mV and 1 V rms. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`START AMPLITUDE`
This control defines the start amplitude for the amplitude sweep, which may be set to any value between 0.000 V rms and 1.000V rms with a 1 mV resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`STOP AMPLITUDE`
This control defines the stop amplitude for the amplitude sweep, which may be set to any value between 0.000 V rms and 1.000V rms with a 1 mV resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`STEP AMPLITUDE`
This control defines the amount by which the oscillator amplitude is changed at each step. It may be set to any value between 0.000 V rms and 1.000V rms with a 1 mV resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

If Start Amplitude is greater than Stop Amplitude then the oscillator amplitude will decrease with time.

`TIME/STEP`

This control defines the time that the oscillator frequency remains at each step of the complete frequency sweep. The range of available values depends on the setting of the `OPERATING MODE` control on the Analog Outputs Menu (section 5.3.18), as follows:

Operating Mode	Time/Step
`FAST`	140 ms to 1000 s in 1 ms increments
`NORMAL`	1 ms to 1000 s in 1 ms increments

Note that the time per step defined here also applies to oscillator amplitude sweeps - see section 5.3.12

`ARMED`

When this control is set to `YES`, the frequency sweep is armed. The sweep can then be started in one of two ways:

a) If the `LINK TO CURVE BUFFER` control is set to `YES` then the sweep will be started at the same time as a curve buffer acquisition starts (see section 5.3.22). This mode allows the buffer to be used for linearity measurements, whereby the response of an external network or system is measured by sweeping the oscillator amplitude while recording the lock-in amplifier's outputs, for example magnitude and phase. Since the curve buffer can be started using internal or external triggers, and in the latter case on a per curve or per point basis, there is considerable flexibility for designing experiments.

   In this mode the `START` control is grayed out as it is inactive.

b) If the `LINK TO CURVE BUFFER` control is set to `NO` then the `START` control above it is shown in bright text, to indicate that it is active. In this mode, the amplitude sweep is independent of the curve buffer and is operated by pressing the adjacent △▽ key. The control annotation changes depending on whether a sweep is running, as follows:

   `START`

   Pressing the adjacent △▽ key starts the amplitude sweep. The `ARMED` control changes to `PAUSE`

   `STOP`

   Pressing the adjacent △▽ key stops the amplitude sweep.

   When a sweep ahs been started and the `ARMED` control is not shown, the following two options are also available.

   `PAUSE`

   Pressing the adjacent △▽ key pauses the amplitude sweep at the present amplitude. The control changes to `CONTINUE`

CONTINUE

Pressing the adjacent △▽ key restarts the paused amplitude sweep from the present amplitude. The control changes to PAUSE

Note that if the oscillator frequency sweep (see section 5.3.10) is also armed then the controls that start, pause, continue and stop on the Amplitude Sweep menu will also control the frequency sweep. Similarly, if the amplitude sweep is linked to the curve buffer then the frequency sweep will be as well.

Pressing the Previous Menu key returns control to the Oscillator Menu.

5.3.12 Auto Functions Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Auto Functions item accesses the Auto Functions menu, which is shown in figure 5-15

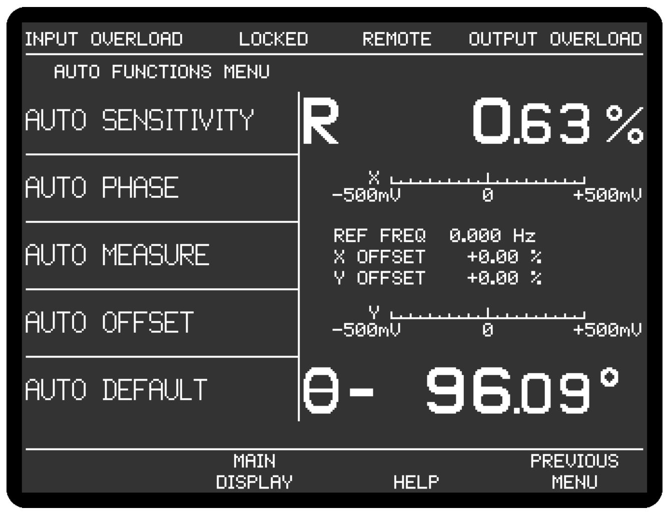

Figure 5-15, Auto Functions Menu

This menu has five controls for activating the auto functions built into the instrument. Note that once these functions complete, the Auto Functions menu is replaced by the Main Display. The functions operate as follows:-

AUTO SENSITIVITY

This function only operates when the reference frequency is above 1 Hz. A single Auto-Sensitivity operation consists of increasing the full-scale sensitivity range if the magnitude output is greater than 90% of full-scale, or reducing the range if the magnitude output is less than 30% of full-scale. After the Auto-Sensitivity function is called, Auto-Sensitivity operations continue to be made until the required criterion is met.

In the presence of noise, or a time-varying input signal, it may be a long time before the Auto-Sensitivity sequence comes to an end, and the resulting setting may not be necessarily what is really required.

AUTO PHASE

In an Auto-Phase operation the value of the signal phase with respect to the reference is computed and an appropriate phase-shift is then introduced into the reference channel so as to bring the difference between them to zero. The intended result is to null the output of the Y channel while maximizing the output of the X channel.

Any small residual phase difference can normally be removed by calling Auto-Phase for a second time after a suitable delay to allow the outputs to settle.

The Auto-Phase facility is normally used with a clean signal which is known to be of stable phase. It usually gives very good results provided that the X channel and Y channel outputs are steady when the procedure is called.

If a zero error is present on the outputs, such as may be caused by unwanted coupling between the reference and signal channel inputs, then the following procedure should be adopted:-

1) Remove the source of input signal, without disturbing any of the connections to the instrument signal input which might be picking up interfering signals from the reference channel. In an optical experiment, for example, this could be done by shielding the detector from the source of chopped light.

2) Execute an Auto-Offset operation, which will reduce the X channel and Y channel outputs to zero.

3) Re-establish the source of input signal. The X channel and Y channel outputs will now indicate the true level of input signal, *at the present reference phase setting*.

4) Execute an Auto-Phase operation. This will set the reference phase-shifter to the phase angle of the input signal. However, because the offset levels which were applied in step 2 were calculated at the original reference phase setting, they will not now be correct and the instrument will in general display a non-zero Y channel output value.

5) Remove the source of input signal again.

6) Execute a second Auto-Offset operation, which will reduce the X channel and Y channel outputs to zero at the new reference phase setting.

7) Re-establish the source of input signal.

This technique, although apparently complex, is the only way of removing the effect of crosstalk which is not generally in the same phase as the required signal.

AUTO MEASURE

This function only operates when the reference frequency is greater than 1 Hz. It performs the following operations:

The instrument is set to AC-coupled and input FLOAT mode. If the reference frequency is more than 10 Hz the output time constant is set to 10 ms, otherwise it is set to the lowest synchronous value, the filter slope is set to 12 dB/octave, output expand is switched off, the reference harmonic mode is set to 1, the X offset and Y offset functions are switched off and the Auto-Sensitivity and Auto-Phase functions are called. The Auto-Sensitivity function also adjusts the AC Gain if required.

The Auto-Measure function is intended to provide a means of setting the instrument quickly to conditions which will be approximately correct in typical simple measurement situations. For optimum results in any given situation, it may be convenient to start with Auto-Measure and to make subsequent modifications to individual controls.

NOTE: The Auto-Measure function affects the setting of the AC Gain and AC Gain Automatic controls during execution. Consequently, it may not operate correctly if the AC Gain Automatic control is turned off. In this case, better results will be obtained by performing Auto-Sensitivity followed by Auto-Phase functions.

AUTO OFFSET

In an Auto-Offset operation the X offset and Y offset functions are turned on and are automatically set to the values required to give zero values at both the X channel and Y channel outputs. Any small residual values can normally be removed by calling Auto-Offset for a second time after a suitable delay to allow the outputs to settle.

The primary use of the Auto-Offset is to cancel out zero errors which are usually caused by unwanted coupling or crosstalk between the signal channel and the reference channel, either in the external connections or possibly under some conditions in the instrument itself. Note that if a zero error is present, the Auto-Offset function should be executed before any execution of Auto-Phase.

AUTO DEFAULT

With an instrument of the design of the model 7280, where there are many controls of which only a few are regularly adjusted, it is very easy to overlook the setting of one of them. Consequently an Auto-Default function is provided, which sets all the controls to a defined state. This is most often used as a rescue operation to bring the instrument into a known condition when it is giving unexpected results. A listing of the settings which are invoked by the use of this function can be found in appendix E.

Pressing the Previous Menu key returns control to Main Menu 1

5.3.13 Configuration Menu

When Main Menu 1 is displayed, pressing a key adjacent to the Configuration item accesses the Configuration menu, which is shown in figure 5-16.

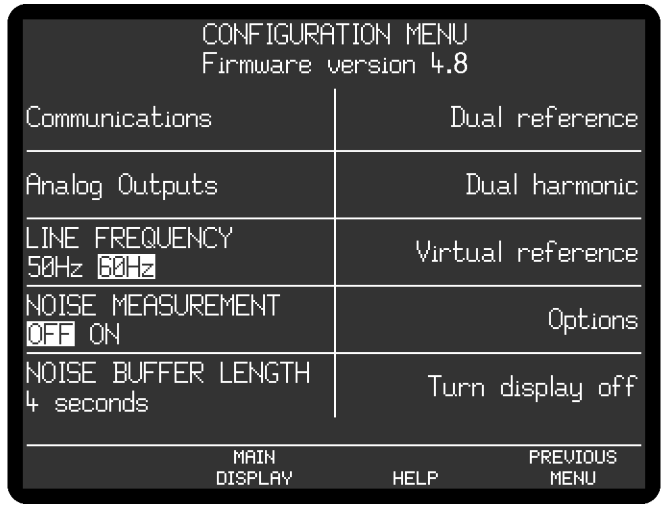

Figure 5-16, Configuration Menu, Single Reference Mode

The Configuration menu has three controls used to set the instrument's basic operating mode and controls to adjust the line-frequency rejection filter's center frequency, the Noise Measurement mode and the Noise Buffer Length. Changes to the setting of these controls can be made by using the adjacent △▽ keys.

It is also used to access the Communications, Options and Analog Outputs menus. The relationship of the these menus to Main Menu 1 is shown in figure 5-17. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the Main Display key, but this has been omitted from figure 5-17 for the sake of clarity.

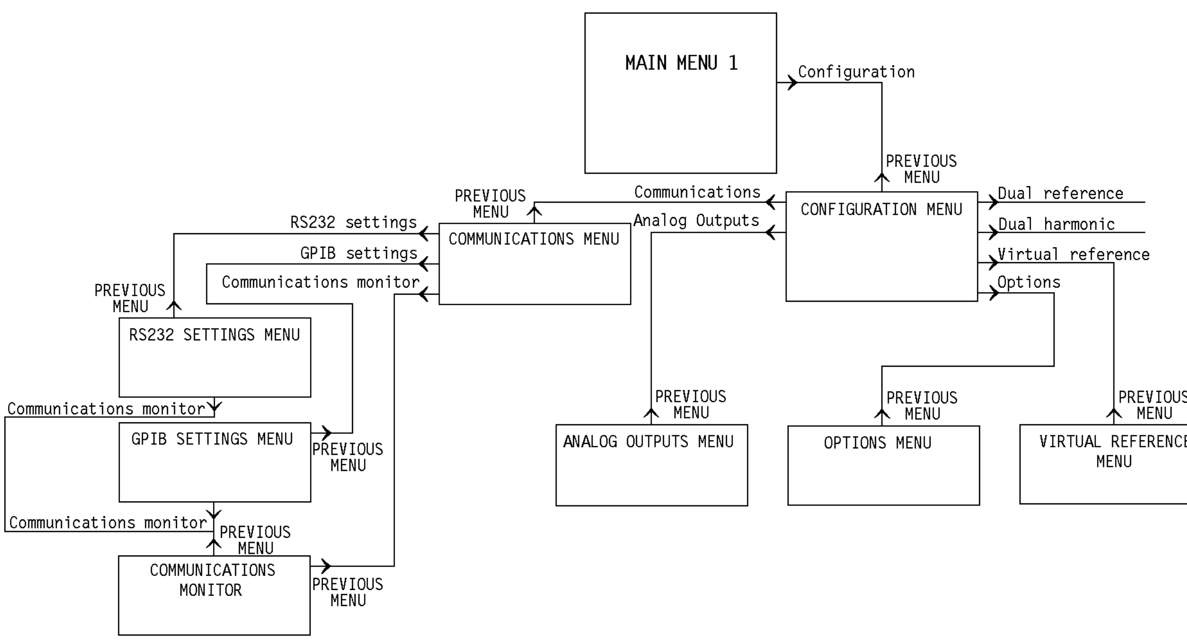

Figure 5-17, Configuration Menu Structure

The controls on the Configuration menu operate as follows.

LINE FREQUENCY

This control is used to set the center frequency of the line frequency rejection filter, and so should be set to the prevailing line frequency, i.e. 50 or 60 Hz.

NOISE MEASUREMENT

This control is used to configure the instrument for noise measurements. When turned ON, the Main Display output displays (see section 5.3.01) are set as follows:

Display Position	**Displayed Output**
1	Noise expressed in V/√Hz in large digits
2	Noise expressed in V/√Hz as a bar-graph
3	X output in expressed as a percentage of the full-scale sensitivity as a bar-graph
4	Magnitude output (R) output in expressed as a percentage of the full-scale sensitivity in large digits.

The available output time constant is restricted to the values in the range 500 µs to 10 ms inclusive, since it is only at these values that the noise measurements are calibrated, and the Synchronous time constant control (section 5.3.06) is turned off The output filter slope is also restricted to either 6 or 12 dB/octave.

When the noise measurement control is turned OFF then the instrument is configured for normal lock-in amplifier operation.

NOISE BUFFER LENGTH

This control, which is only active when the above NOISE MEASUREMENT control is turned ON, sets the averaging time of the buffer used to determine the mean value of the output signal when making noise measurements. Settings of Off, 1 s, 2 s, 3 s and 4 s can set using the adjacent △▽ key.

The operation of this control is described in more detail in section 3.3.16

Firmware version X.X

This line, immediately under the menu title, gives the version number of the instrument's operating firmware. The firmware in the instrument can be updated to the latest revision by connecting it to a PC via the RS232 interface and running an Update program.

Analog Outputs

Pressing a key adjacent to this item displays the Analog Outputs menu, which is used to define which instrument outputs are converted to analog voltages and made available at the **CH1** and **CH2** connectors on the rear panel. This menu is described later in section 5.3.18

Options

The key gives access to the Options Menu, which is used to install firmware options within the instrument. It is discussed later in section 5.3.19

`Turn display off`

Pressing this key turns off the display panel. Press any key to turn it back on, when the display reverts to the Main Display.

Pressing the Previous Menu key returns control to the Main Menu 1

The Virtual Reference, Dual Reference and Dual Harmonic modes are discussed later in sections 5.4, 5.5 and 5.6 respectively.

5.3.14 Communications Menu

When the Configuration menu is displayed, pressing the Communications key accesses the Communications Menu, shown in figure 5-18.

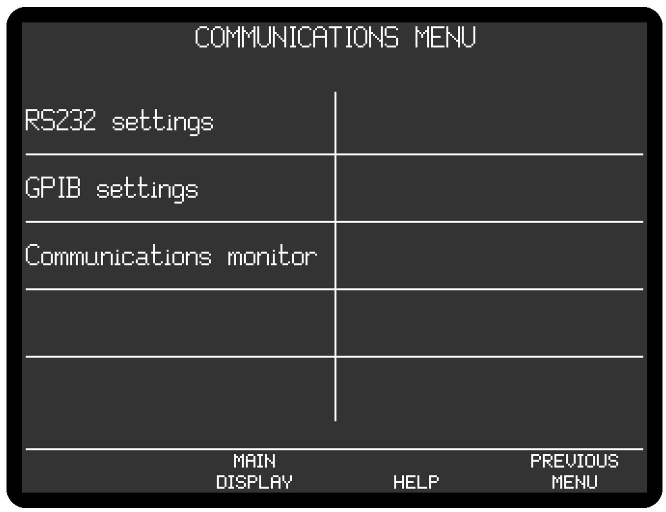

Figure 5-18, Communications Menu

The Communications menu has keys to access three sub-menus.

Pressing the Previous Menu key returns control to the Configuration Menu.

5.3.15 RS232 Settings Menu

When the Communications menu is displayed, pressing the RS232 Settings key accesses the RS232 Settings menu, which is shown in figure 5-19.

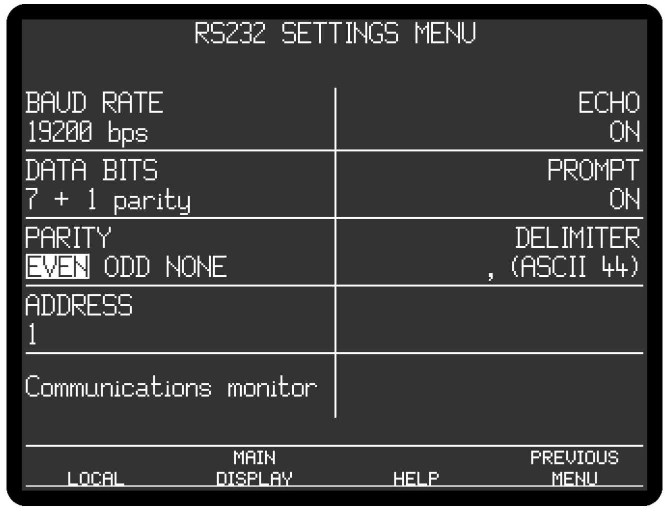

Figure 5-19, RS232 Settings Menu

This menu has seven controls affecting the RS232 computer interface, as follows:-

BAUD RATE

This control sets the baud rate to one of the following values:-

Baud Rate (bits per second)
75
110
134.5
150
300
600
1200
1800
2000
2400
4800
9600
19200

DATA BITS

This control sets the data transmission to one of four formats:-

Data Bits	Description
7 + 1 parity	7 data bits + 1 parity bit
8 + 1 parity	8 data bits + 1 parity bit
8 + no parity	8 data bits + 0 parity bit
9 + no parity	9 data bits + 0 parity bit

ADDRESS

When more than one compatible instrument is connected in "daisy-chain" fashion by coupling the **AUX RS232** rear panel port on one to the **RS232** port on the next, then this control is used to define the instrument's RS232 address. All daisy-chained instruments receive commands but only the instrument currently being addressed will implement or respond to them, except of course the command that changes the instrument to be addressed.

ECHO

This control, when switched on, causes the model 7280 to echo each character received over the RS232 interface back to the controlling computer. The computer should wait until the echoed character is returned before it sends the next character. When switched off, character echo is suppressed.

NOTE: Character echo should always be switched on, except when controlling the instrument manually from a simple RS232 terminal where the maximum speed with which characters can be sent to the instrument is limited by the speed of human typing.

PROMPT

This control has two settings, as follows:-

ON

A prompt character is generated by the model 7280 after each command response to indicate that the instrument is ready for a new command. The prompt character is either a "*" or a "?" If a "?" is generated, it indicates that an overload, reference unlock, parameter error or command error has occurred.

OFF

No prompt character is generated.

DELIMITER

The character shown is that sent by the lock-in amplifier to separate two numeric values in a two-value response, such as that generated by the MP command. The corresponding ASCII value of this character is also shown in brackets. For example, value 44 corresponds to a “,” (comma).

PARITY

This control sets the parity check polarity when the Data Bits control specifies that a parity bit should be used. It should be set to match the setting of the controlling computer.

Pressing the Previous Menu key returns control to the Configuration Menu, and pressing the Communications Monitor key accesses the Communications Monitor display.

5.3.16 GPIB Settings Menu

When the Configuration menu is displayed, pressing a key adjacent to the GPIB Settings item accesses the GPIB Settings menu, which is shown in figure 5-20.

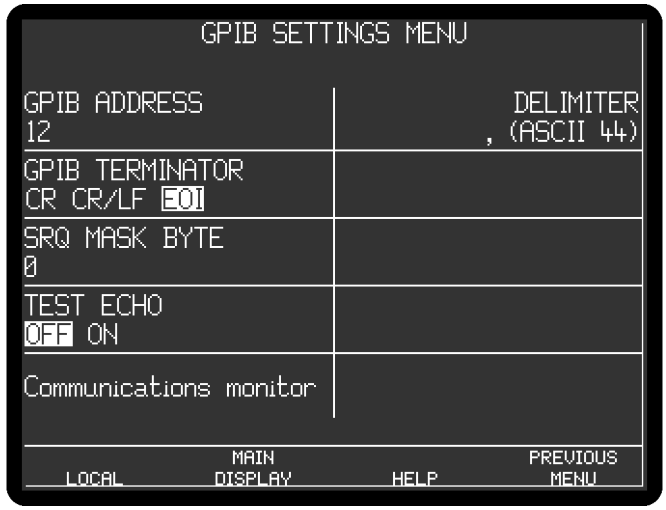

Figure 5-20, GPIB Settings Menu

This menu has five controls affecting the GPIB computer interface and a key for accessing the Communications Monitor display, as follows:-

GPIB ADDRESS
This control sets the GPIB communications address to any value between 0 and 31. Each instrument used on the GPIB bus must have a unique address setting.

GPIB TERMINATOR
This has three possible settings, as follows:-

CR
A carriage return is transmitted at the end of a response string, and in addition the GPIB interface line EOI (end of instruction) is asserted.

CR/LF
A carriage return followed by a line feed are transmitted at the end of a response string, and in addition the GPIB interface line EOI (end of instruction) is asserted with the line feed character.

EOI
The GPIB interface line EOI (end of instruction) is asserted at the end of the response string. This gives the fastest possible operation since other termination characters are not needed.

SRQ MASK
The instrument has the ability to generate a service request on the GPIB interface, to signal to the controlling computer that urgent attention is required. The request is generated when the result of a logical bit-wise AND operation between the Service Request Mask Byte, set by this control as a decimal value, and the instrument's Status Byte, is non-zero. The bit assignments for the Status Byte are as follows:-

Bit	Decimal Value	Status Byte
0	1	command complete
1	2	invalid command
2	4	command parameter error
3	8	reference unlock
4	16	overload
5	32	new ADC values available after external trigger
6	64	asserted SRQ
7	128	data available

Hence, for example, if the SRQ mask byte is set to decimal 16 (i.e. bit 4 asserted), a service request would be generated as soon as an overload occurred; if the SRQ mask byte were set to 0 (i.e. no bits asserted), then service requests would never be generated.

TEST ECHO

When this control is enabled, all transmissions to and from the instrument via the GPIB interface are echoed to the RS232 interface. Hence if a terminal is connected to the latter port, it will display any commands sent to the instrument and any responses generated, which can be useful during program development. When disabled, echoing does not occur. The control should always be disabled when not using this feature, since it slows down communications.

DELIMITER

The character shown is that sent by the lock-in amplifier to separate two numeric values in a two-value response, such as that generated by the MP command. The corresponding ASCII value of this character is also shown in brackets. For example, value 44 corresponds to a “,” (comma).

Pressing the Previous Menu key returns control to the Configuration Menu, and pressing the Communications Monitor key accesses the Communications Monitor display.

5.3.17 Communications Monitor

When the Communications Menu is displayed, pressing the Communications monitor key accesses the Communications monitor display, shown in figure 5-21. It may also be accessed via the RS232 Settings and GPIB Settings menus.

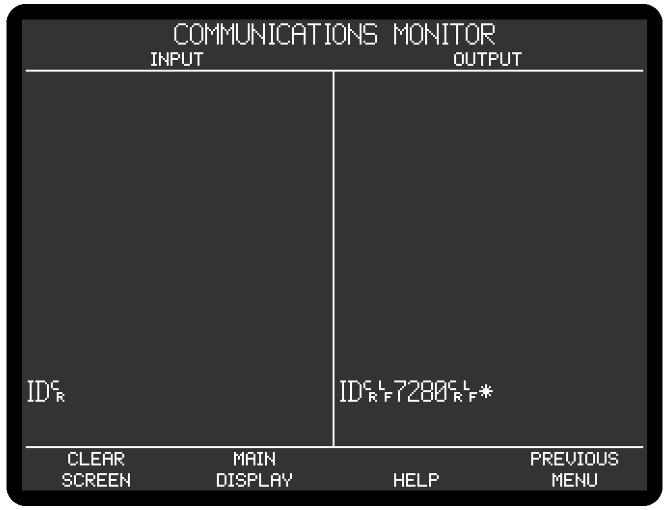

Figure 5-21, Communications Monitor

The monitor is useful when attempting to establish communications via the computer interfaces for the first time, or if a problem is suspected.

The Input side of the display shows all of the characters that have been received from the interface, whether valid or not. The Output side of the display shows all the characters that have been generated by the instrument and sent to the interface.

If characters received do not match those sent by the controlling computer then this indicates that an error has occurred either in the host computer or interface cable. If the interface cable is known to be good, then re-check either the GPIB or RS232 communications settings.

CLEAR SCREEN

The input and output displays scroll once they are full so that they always display the most recent characters received and sent. Pressing the Clear Screen key clears both areas.

Pressing the Previous Menu key returns control to either the Communications menu or the GPIB Settings menu, or the RS232 Setting menu, depending on how the Communications Monitor display was accessed.

5.3.18 Analog Outputs Menu - Single & Virtual Reference Modes

When the Configuration menu is displayed, pressing the Analog Outputs key accesses the Analog Outputs Menu, shown in figure 5-22.

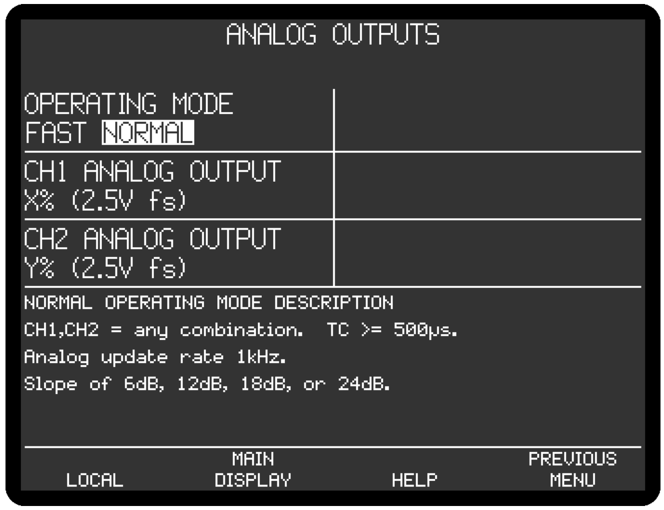

Figure 5-22, Analog Outputs Menu, Normal Operating Mode, Single/Virtual Reference Modes

The Analog Outputs menu has three controls, changes to the setting of which can be made by using the adjacent △▽ keys.

`OPERATING MODE`
This control determines the position from which the analog outputs are derived in the circuit (see figure 3-1), and hence the rate at which they are updated. It also affects the available output filter slope, the permitted range of time constants, and the rate at which oscillator frequency and amplitude sweeps can be carried out (see sections 5.3.10 and 5.3.11). It has two settings, as follows:

`NORMAL`
In this setting, the **CH1** and **CH2** analog outputs are derived from the output processor. The update rate is always 1 kHz, the output filter time constant can be set to values between 500 µs and 100 ks in a 1-2-5 sequence, and all four output filter slope settings are available. The minimum step time per point for oscillator amplitude and frequency sweeps is 1 ms.

In this mode, the `CH1 ANALOG OUTPUT` and `CH2 ANALOG OUTPUT` controls can each be set to any of the following ten available settings.

`X% (2.5V fs)`
When set to X% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the X%fs front panel display as follows:-

X%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`Y% (2.5V fs)`

When set to Y% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the Y%fs front panel display as follows:-

Y%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`MAG% (2.5V fs)`

When set to MAG% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the MAG%fs or R% front panel displays as follows:-

MAG%fs	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

`PHASE (+9 V = +180°)`

When in this setting the corresponding **CH1/CH2** connector on the rear panel will output a voltage related to the PHA or θ front panel displays as follows:-

PHA or θ deg	CH1/2 Voltage
+180	9.0 V
+90	4.5 V
0	0.0 V
-90	-4.5 V
-180	-9.0 V

`PHASE (+9 V = +360°)`

When in this setting the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the PHA or θ front panel display as follows:-

PHA or θ deg	CH1/2 Voltage
+180	0.0 V
+90	-4.5 V
+0	-9.0 V
-0	9.0 V
-90	4.5 V
-180	0.0 V

`NOISE (2.5 V fs)`

When set to NOISE the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the N%fs front panel display as follows:-

N%fs	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

Note: When NOISE is selected as an output, the Noise Measurement Mode (Configuration Menu) must be ON. If it is not, a warning message is displayed which offers the option of turning it on or deselecting NOISE as an analog output.

`RATIO`

When set to RATIO the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the result of the RATIO calculation, which is defined as follows:-

$$\mathrm{RATIO} = \left(\frac{10 \times \mathrm{X\ output}}{\mathrm{ADC1\ Input}} \right)$$

where X output is the X channel output as a percentage of the full-scale sensitivity and ADC 1 is the voltage applied to the **ADC1** input connector on the rear panel expressed in volts. Hence, for example, if the instrument were measuring a 100 mV signal when set to the 500 mV sensitivity setting, the X channel output were maximized and a 1 V signal were applied to the ADC1 input, then the value of RATIO would be:-

$$\mathrm{RATIO} = \left(\frac{10 \times \frac{0.1}{0.5}}{1.000} \right)$$

$$\mathrm{RATIO} = 2$$

The relationship between the voltage at the **CH1**/**CH2** connector and the RATIO value is defined as follows:-

RATIO	CH1/2 Voltage
+7.5	7.5 V
+2.5	2.5 V
0	0.0 V
-2.5	-2.5 V
-7.5	-7.5 V

`LOG RATIO`

When set to LOG RATIO the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the LOG RATIO calculation, which is defined as follows:-

$$\mathrm{LOG\quad RATIO} = \log_{10} \left(\frac{10 \times \mathrm{X\ output}}{\mathrm{ADC1\ input}} \right)$$

where X output is the X channel output as a percentage of the full-scale sensitivity and ADC 1 is the voltage applied to the **ADC1** input connector on the rear panel expressed in volts. Hence, for example, if the instrument were measuring a 100 mV signal when set to the 500 mV sensitivity setting, the X channel output were maximized and a 1 V signal were applied to the ADC1 input, then the value of LOG RATIO would be:-

$$\text{LOG RATIO} = \log_{10}\left(\frac{10 \times \frac{0.1}{0.5}}{1.000}\right)$$

$$\text{LOG RATIO} = 0.301$$

The relationship between the voltage at the **CH1**/**CH2** connector and the LOG RATIO value is defined as follows:-

LOG RATIO	CH1/2 Voltage
+2.000	2.000 V
0	0.0 V
-3.000	-3.000 V

Note: If RATIO < 0 then LOG RATIO = -3.000

EQUATION #1

When set to EQUATION #1 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to Equation 1, which is defined using the Output Equations menu (see section 5.3.08), as follows:-

EQUATION #1	CH1/2 Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

EQUATION #2

When set to EQUATION #2 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to Equation 2, which is defined using the User Equation 2 menu (see section 5.3.08), as follows:-

EQUATION #2	CH1/2 Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

FAST

When the operating mode is set to Fast, the **CH1** and **CH2** analog outputs are derived from the first stage of output filtering or the fast magnitude converter. The update rate is increased to 7.5 MHz when the time constant is set to any value from 1 µs to 4 ms but remains at 1 kHz for longer time constants. The output filter slope is restricted to either 6 or 12 dB/octave. The minimum step time per point for oscillator amplitude and frequency sweeps is 140 ms.

The available options for the `CH1 ANALOG OUTPUT` and `CH2 ANALOG OUTPUT` controls are reduced to the following:

`CH1 ANALOG OUTPUT`
In the Fast mode, this can only be set to:

`X% (2.5V fs)`
The **CH1** connector on the rear panel will output a voltage related to the X%fs front panel display as follows:-

X%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`CH2 ANALOG OUTPUT`
In the Fast mode, this can only be set to either:

`Y% (2.5V fs)`
When set to Y% the **CH2** connector on the rear panel will output a voltage related to the Y%fs front panel display as follows:-

Y%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

or:

`MAG% (2.5V fs)`
When set to MAG% the **CH2** connector on the rear panel will output a voltage related to the MAG%fs or R% front panel displays as follows:-

MAG%fs	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

Pressing the Previous Menu key returns control to the Configuration Menu.

5.3.19 Options Menu

When the Configuration menu is displayed, pressing the Options key accesses the Options Menu, shown in figure 5-23.

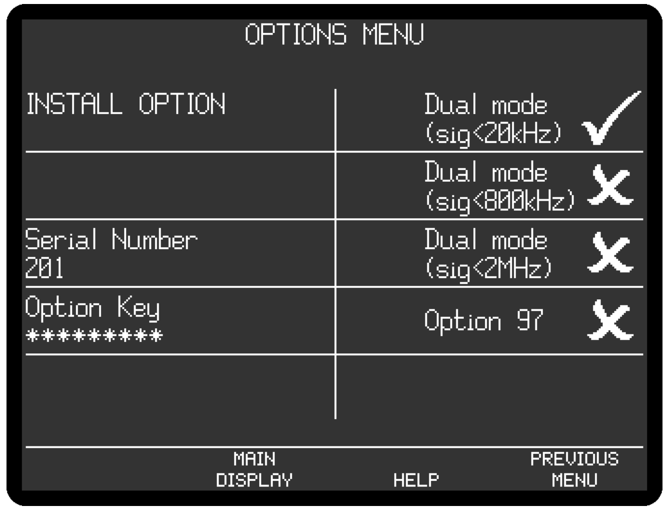

Figure 5-23, Options Menu

The options menu is used to install additional firmware options and shows which options are already fitted. If an option is purchased at the same time as the instrument, then the factory will install it and no further action is required. If however it is bought at a later date then the user will need to provide details of the instrument's serial number with his order. In return, he will be given a certificate with a unique eight-digit Option Key number which can be used to enable the option on the instrument.

The controls on the Options Menu operate as follows.

`INSTALL OPTION`

Pressing this key displays the keypad icon. Enter the Option Key number you have been given using the numerical keypad, and press the ↵ to enter the number. The × symbol next to the option being installed in the list of available options on the right hand side of the screen will change to a ✓ to indicate successful installation. Pressing the Previous Menu key returns control to the Configuration Menu.

5.3.20 Spectral Display

When Main Menu 1 is displayed, pressing the Spectral display key accesses the Spectral Display menu, a typical example of which is shown in figure 5-24.

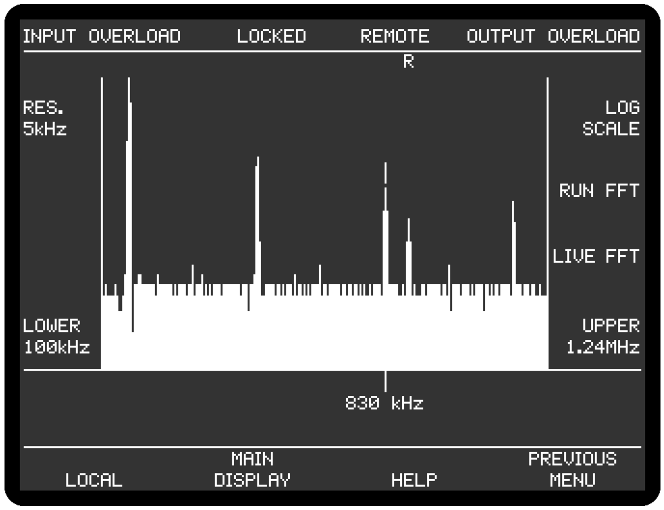

Figure 5-24, Spectral Display Menu

The Spectral Display menu shows the result of a discrete Fourier transform (DFT) of the signal at the input, following amplification and filtering by the line frequency rejection and anti-aliasing filters but prior to the demodulators. Its principal function is to allow the user to determine the relative spectral density of the total signal plus noise being measured, so that changes can be made to the reference frequency to avoid particularly noisy regions.

Note that the Spectral Display menu does not have a calibrated vertical axis and hence is not intended for measuring or comparing signal amplitudes.

The central section of the display shows a plot of spectral density (vertical axis) versus frequency (horizontal axis). The measurement frequency resolution is adjusted by using either the Res. △▽ keys or by the ⇧ or ⇩ keys and can be set to bin widths of 3 kHz, 5 kHz, 10 kHz and 15 kHz, as indicated by the control annotation. In figure 5-23 above it is set to 5 kHz.

The measurement resolution sets the overall frequency range of the X-axis. At a resolution of 15 kHz, the nominal range is 0 kHz to 3.43 MHz, although frequencies above 2 MHz are not usually of interest since they lie outside the frequency range of signals that the 7280 can measure. With the finest resolution of 3 kHz, the display range is nominally 687 kHz.

When the resolution is set to 10 kHz or finer then the △▽ keys adjacent to the Lower and Upper frequency limit indicators at each of the X-axis can be used to scroll through the whole of the available frequency range. When either limit is changed, the other one changes by the same amount, thereby maintaining the frequency resolution.

LOG SCALE / LINEAR SCALE

The △▽ keys at the top right-hand corner of the display change the vertical display between linear and logarithmic calibration, with the presently active selection being shown.

RUN FFT

When the key adjacent to the Run FFT control is pressed, the instrument acquires a new set of data, performs an FFT on it and displays the resulting spectrum. A change in the reference frequency also causes the displayed spectrum to be updated.

LIVE FFT

When the key adjacent to the Live FFT control is pressed, the instrument acquires data repeatedly, performs an FFT on it and displays the resulting spectrum until the Stop key is pressed.

Note: Live data acquisition is not available at 3 kHz and 5 kHz measurement resolutions.

Cursor

The and cursor movement keys move the display cursor from side to side. The cursor takes the form of a short vertical line that is positioned just above the top of the data curve at the selected frequency, which appears just below the X-axis. In figure 5-23 the cursor can be seen positioned at 830 kHz. The cursor makes it possible to obtain an approximate frequency for any peak on the display, thereby possibly assisting in identifying its source.

Reference Frequency Indicator

The display shows the letter "R" centered above the frequency at which the lock-in's reference channel is currently operating. This makes it possible to quickly identify the signal of interest from all the other signals present.

Using the Spectral Display Mode

In a typical experiment, if the lock-in amplifier's output is more noisy than might be expected with the given settings, then the spectrum of the total input signal being measured can be determined and displayed using the Spectral Display menu. If strong interfering signals close to the reference frequency are observed, then the reference frequency should if possible be changed so that operation occurs in a quieter region. Alternatively it may be possible to switch off the source of the interference, which might for example be caused by a computer monitor.

For example, in figure 5-23 the cursor has first been used to identify the strong signals at 166 kHz, 498 kHz, 830 kHz and 1.162 MHz and then the reference frequency has been set to 890 kHz. Finally the spectral display has been re-run to confirm that the reference frequency is well separated from the interfering frequencies.

Pressing the Previous Menu key exits the Spectral Display menu and returns to Main Menu 1.

5.3.21 Main Menu 2

When Main Menu 1 is displayed, pressing the Main menu 2 key accesses Main Menu 2, which is shown in figure 5-25.

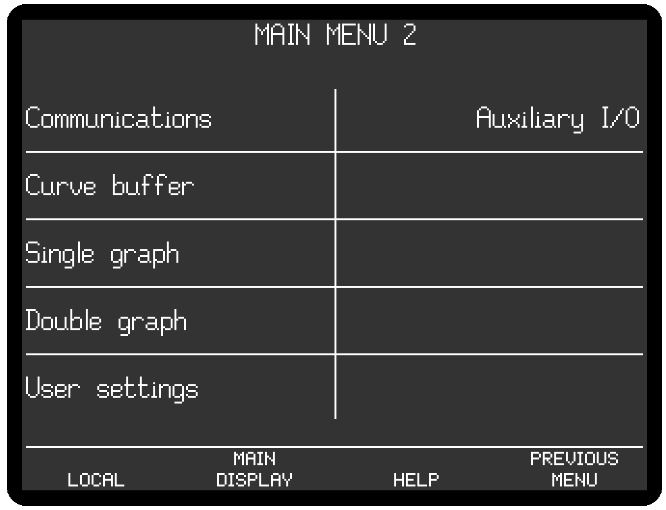

Figure 5-25, Main Menu 2

Main Menu 2 has keys used to access the extended features found in the model 7280, via a series of sub-menus. The relationship of these sub-menus to Main Menu 2 is shown in figure 5-26. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from the sub-menus by pressing the Main Display key, but this has been omitted from figure 5-26 for the sake of clarity.

Pressing the Previous Menu key returns control to Main Menu 1.

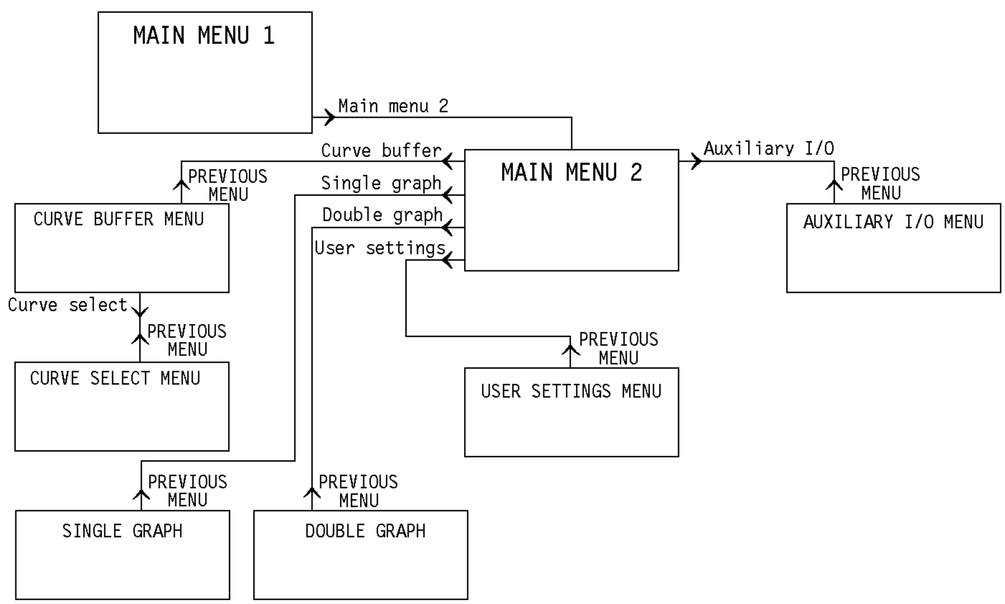

Figure 5-26, Main Menu 2 Menu Structure

5.3.22 Curve Buffer Menu

When Main Menu 2 is displayed, pressing the Curve buffer key accesses the Curve Buffer menu, which is shown in figure 5-27.

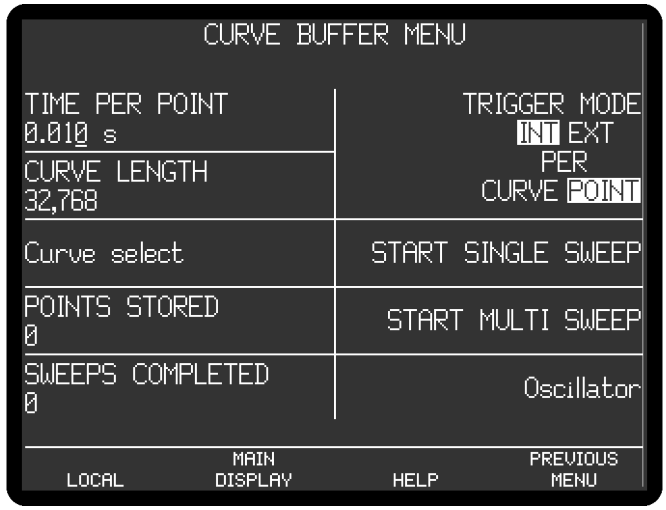

Figure 5-27, Curve Buffer Menu

The curve buffer menu has three controls affecting the instrument's internal 32768 point curve buffer, two status indicators and keys to access the Curve Select sub-menu and menus associated with the oscillator..

`TIME PER POINT`

This control defines the interval between each data point in the curve buffer. It may be set to any value between 1 ms and 1×10^6 s in 1 ms increments.

If using the curve buffer to take data at the same time as an Oscillator Frequency or Amplitude sweep by setting the `LINK TO CURVE BUFFER` control on the relevant menu to `YES` (sections 5.3.10 and 5.3.11), then the user should note the following limitation: If the `OPERATING MODE` control on the Analog Outputs Menu (section 5.3.18) is also set to `FAST` then the minimum time per point for the oscillator sweep will be 140 ms. Hence, although it remains possible to set the `TIME PER POINT` control to settings shorter than 140 ms in this case, the effect will be that the instrument takes several data points at each oscillator setting. For example, if the `TIME PER POINT` control were set to 14 ms but the `TIME/STEP` oscillator sweep control were 140 ms then ten data points would be taken into the buffer at each oscillator setting.

`CURVE LENGTH`

This control defines the number of points to be stored in the internal curve buffer when either single or repetitive sweeps are executed. The buffer can hold a maximum of 32768 points, shared equally between the curve types as defined by the Curve Select menu. Hence, for example, if 16 curve types are to be stored then the maximum curve length for each curve is 2048 points.

Note that if the number of curves to be stored is increased beyond that which may be stored at the current curve length, then the curve length is reduced automatically.

`POINTS STORED`

This shows the number of points stored in the curve buffer. The number is incremented at the rate defined by the Time per Point control. On completion of a sweep, in single-sweep mode, the number will be the same as the Curve Length control, whereas in multi-sweep mode the number increments continuously.

SWEEPS COMPLETED

This shows the number of completed sweeps, where one sweep is equal to the Length control setting. On completion of a sweep, in single-sweep mode, the number will be "1", whereas in multi-sweep mode the number increments continuously.

TRIGGER MODE INT/EXT PER CURVE/POINT

These two controls determine how data acquisition is triggered.

INT

In this setting acquisition starts when a Start key is pressed or on receipt of a valid computer command

EXT

In this setting acquisition is triggered by the rising edge of a TLL pulse applied to the rear-panel **TRIG** connector.

PER CURVE

Each valid trigger, whether internal or external, cause a complete curve of data to be acquired at the selected Time per Point rate.

PER POINT

The Time per Point control is inactive and each data point (or set of data points in the case where more than one output is being recorded) is acquired on receipt of a valid trigger.

START SINGLE SWEEP

This key initiates a single sweep. If the Length control is greater than 1 and a single sweep is in progress, then the controls change to Pause Single Sweep and Stop Single Sweep.

PAUSE SINGLE SWEEP

This key stops data acquisition at the current point, but acquisition may be restarted by pressing Cont. Single Sweep.

CONT. SINGLE SWEEP

This key restarts data acquisition from the current point.

STOP SINGLE SWEEP

This key stops data acquisition at the current point. Data already acquired remains in the curve buffer.

START MULTI SWEEP

This key initiates multiple sweeps. The controls change to Pause Multi Sweep and Stop Multi Sweep.

PAUSE MULTI SWEEP

This key stops data acquisition at the current point, but acquisition may be restarted by pressing Cont. Multi Sweep.

`CONT. MULTI SWEEP`
This key restarts data acquisition from the current point.

`STOP MULTI SWEEP`
This key stops data acquisition at the current point. Data already acquired remains in the curve buffer.

One of the following links to other menus will also be shown, allowing quick access between the oscillator frequency and amplitude sweep setup menus and the curve buffer, which is useful when defining oscillator sweeps linked to the curve buffer.

`Oscillator`
Pressing a key adjacent to this item accesses the Oscillator menu - see section 5.3.09

`Setup Frequency Sweep`
Pressing a key adjacent to this item accesses the Frequency Sweep menu - see section 5.3.10

`Setup Amplitude Sweep`
Pressing a key adjacent to this item accesses the Amplitude Sweep menu - see section 5.3.11

Pressing the Previous Menu key returns control to the Main Menu 2.

5.3.23 Curve Select Menu

When the Curve Buffer menu is displayed, pressing the Curve select key accesses the Curve Select menu, which is shown in figure 5-28.

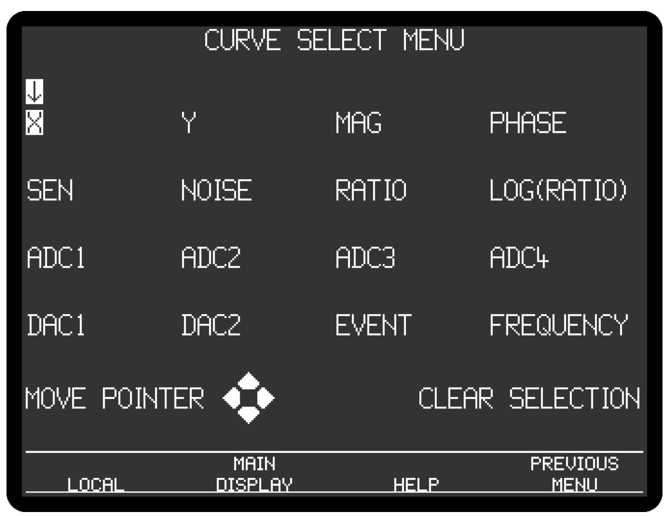

Figure 5-28, Curve Select Menu

The upper section of the Curve Select menu has a list of sixteen possible data types that can be stored to the curve buffer, arranged in four rows of four columns. Three controls allow between one and sixteen of these data types to be selected for storage, with those that are selected being indicated by being shown in reversed text.

MOVE POINTER
This control allows the ↓ pointer to be moved to any one of the possible data types. The ◁, △, ▷ and ▽ cursor-movement keys can be also be used to do this.

ENTER SELECTION / CLEAR SELECTION
If the data type adjacent to the ↓ pointer is not selected, then pressing this key causes it to be selected, as indicated by its being displayed in reversed text. If it is already selected, then pressing the key deselects it.

NOTE: The data types selected for storage may be changed by controls on other menus, as follows:-

Auxiliary I/O Menu (section 5.3.27)
Selecting any of the burst acquisition modes automatically selects the ADC1 or ADC1 and ADC2 outputs for storage.

Pressing the Previous Menu key returns control to the Curve Buffer menu.

5.3.24 Single Graph Menu

When Main Menu 2 is displayed, pressing a key adjacent to the Single Graph item accesses the Single Graph menu, which is shown in figure 5-29.

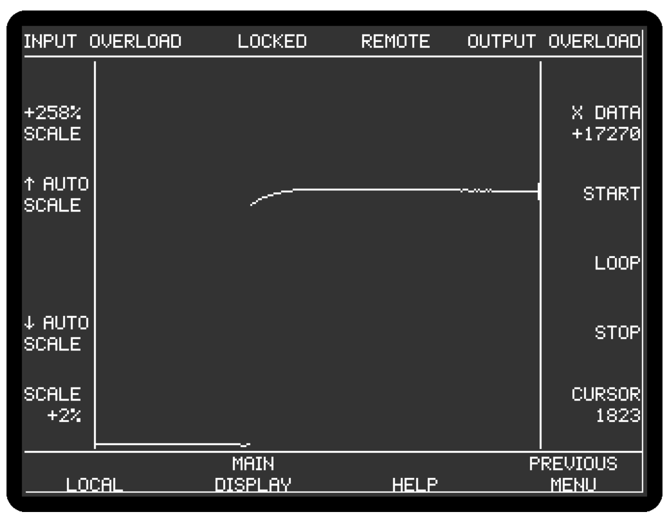

Figure 5-29, Single Graph Menu

The Single Graph menu plots the data of one curve stored in the curve buffer. This allows real-time or post-acquisition display of selected instrument outputs in "strip chart" format, and has a cursor which allows accurate determination of the output value at a given sample point.

If there is no data in the curve buffer then the graph will show a straight line

representing zero. If curve storage is already running, or if there is data in the curve buffer, then a curve will be displayed with the most recent value at the right-hand side of the screen.
Figure 5-27 shows the layout of the Single Graph menu. The curve is displayed in the central section of the display, with the keys on either side being used to adjust the axes and to select the data to be shown, as follows:-

SCALE keys
The top and bottom left-hand △▽ keys are used to adjust the upper and lower limits of the vertical axis with a 1% resolution, the set maximum and minimum values being shown adjacent to them.

AUTO SCALE keys
The upper and lower middle pairs of left-hand △▽ keys are used to autoscale the upper and lower limits of the vertical axis to match the range present in the visible section of the displayed curve.
There is no facility for adjusting the x-axis scale, which always shows up to 243 points. Hence if a curve of more than this number of points is acquired it will not be possible to show all of the points on the display at the same time.

Curve Selection keys
The keys on the top right-hand side of the display are used to select the curve to be shown from those stored in the curve buffer. All curves that can be stored may be selected for display, except for EVENT, the two curves recording the reference frequency (FRQ0 and FRQ1) and the curves recording instrument sensitivity settings. For example, if only X DATA and Y DATA curves were specified, using the Curve Select sub-menu, as being required then these would be the only two selections available.

START/STOP/PAUSE/CONT. keys
In the single graph display mode, acquisition to the curve buffer, and hence display of data, can be initiated using the Start or Loop △▽ keys. The Start keys start acquisition in the one-shot mode. This causes data to be acquired for the number of points specified by the curve length control in the Curve Buffer menu and once complete, acquisition ceases. During data acquisition, the control key annotation changes to Pause; if pressed again, acquisition will pause at the current data point and the annotation changes again to Cont. (Continue). If the key is pressed again acquisition continues from the present data point.

The Loop keys also start data acquisition, but in the loop mode, in which the curve buffer fills to capacity and is then sequentially overwritten by new data. Once this mode is running, the Loop control key annotation changes to Stop, and pressing the adjacent key will then stop acquisition at the present data point.

CURSOR keys
The bottom right-hand △▽ keys and the ◁ and ▷ cursor-movement keys move the displayed cursor, which is only active when data is not being stored, from side to side. The present point number is shown in the bottom right-hand corner of the screen and the value of the curve at its intersection with the cursor appears in the top right-hand corner. Where applicable, values are always given as a percentage of full-scale, since there is no facility to display them in floating-point format. If the cursor is

moved fully to the left then the displayed data scrolls to the right in groups of ten points, allowing earlier data to be shown.

If acquisition is in progress then the cursor is automatically positioned at the right-hand side of the display area and cannot be moved.

Pressing the Previous Menu key on the front panel exits the Single Graph menu and returns to Main Menu 2.

5.3.25 Double Graph Menu

When Main Menu 2 is displayed, pressing a key adjacent to the Double Graph item accesses the Double Graph menu, which is shown in figure 5-30.

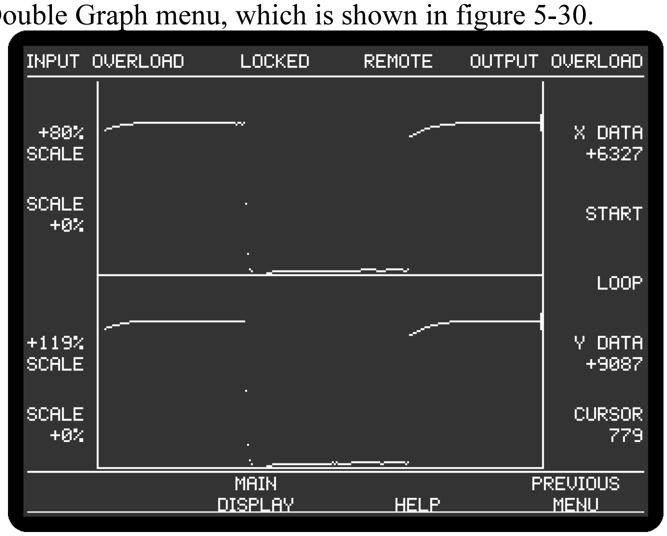

Figure 5-30, Double Graph Menu

The double graph display is similar to that of the single graph, but displays two curves.

If there is no data in the curve buffer then the graph will show two horizontal straight lines representing zero. If curve storage is already running, or if there is data in the curve buffer, then two curves will be displayed with the most recent values at the right-hand side of the screen.

Figure 5-28 shows the layout of the double graph display. The two curves are displayed in the central section of the display, with the keys on either side being used to adjust the axes and to select the data to be shown, as follows:-

SCALE **keys**

The keys to the left-hand side of the display are used to set the upper and lower limits of the vertical axis in 1% increments, with the top and upper-middle △▽ keys being used for the upper curve (Curve 1) and the lower-middle and bottom △▽ keys for the lower curve (Curve 2). Pressing both sides of one of the key pairs simultaneously automatically sets the relevant limit to match the range present in the visible section of the displayed curve.

As in single graph mode, there is no facility for adjusting the x-axis scale, which always shows up to 243 points. Furthermore both the upper and lower curves are shown over the same range of points; it is not possible, for example, to show Curve 1 for data points 1 to 243 and Curve 2 for points 243 to 486.

Curve Selection keys

The keys on the top right-hand side of the display are used to select the curve to be shown in the upper half of the display, Curve 1, from those stored in the curve buffer. The lower-middle right-hand keys perform an equivalent function for Curve 2, which is shown in the lower half of the display. All curves that can be stored may be selected for display, except for EVENT and the curve recording instrument sensitivity settings.

`START/STOP/PAUSE/CONT.` **keys**

In the single graph display mode, acquisition to the curve buffer, and hence display of data, can be initiated using the Start or Loop keys. The Start keys start acquisition in the one-shot mode. This causes data to be acquired for the number of points specified by the curve length control in the Curve Buffer menu and once complete, acquisition ceases. During data acquisition, the control key annotation changes to Pause; if pressed again, acquisition will pause at the current data point and the annotation changes again to Cont. (Continue). If the key is pressed again acquisition continues from the present data point.

The Loop keys also start data acquisition, but in the loop mode, in which the curve buffer fills to capacity and is then sequentially overwritten by new data. Once this mode is running, the Loop control key annotation changes to Stop, and pressing the adjacent key will then stop acquisition at the present data point.

`CURSOR` **keys**

As with the single graph mode, the bottom right-hand keys and the and cursor-movement keys control the position of the cursor. The current point number is displayed in the bottom right-hand corner of the display and the value of the curves at their intersection with the cursor appear above the relevant Curve 1 and Curve 2 data types. Where applicable, values are always given as a percentage of full-scale, since there is no facility to display them in floating-point format. If the cursor is moved fully to the left then the displayed data scrolls to the right in groups of ten points, allowing earlier data to be shown.

Pressing the Previous Menu key exits the Double Graph menu and returns to Main Menu 2.

5.3.26 User Settings Menu

When Main Menu 2 is displayed, pressing a key adjacent to the User Settings item accesses the User Settings menu, which is used to save and recall up to eight complete instrument settings from memory. This feature is particularly useful when a number of users share an instrument since it allows each user to quickly reset the instrument to a known setting.

When the menu is first displayed, the Memory keys on the display are not shown.

Pressing the △▽ Save settings, Restore settings or Delete memory keys causes Select Memory Number and the Memory keys to be displayed. For example, when the Save settings key is pressed, the menu changes to that shown in figure 5-31.

Figure 5-31, User Settings Menu - Save Settings

To use the user settings feature, proceed as follows:

Saving an Instrument Setting
Press the △▽ Save settings key, which will cause the Memory keys to appear. Press either side of the △▽ key next to the Memory number in which the settings are to be stored. A message will be displayed while the settings are saved.

Restoring an Instrument Setting
Press the △▽ Restore settings key, which will cause the Memory keys to appear. Press either side of the △▽ key next to the Memory number from which the settings are to be restored. A message will be displayed while the settings are restored.

Deleting an Instrument Setting
Press the △▽ Delete memory key, which will cause the Memory keys or those memories containing settings information to appear. Press either side of the △▽ key next to the Memory number at which the settings are to be deleted. A message will be displayed while this happens.

If the menu is inadvertently activated, pressing the Previous Menu key returns control to Main Menu 2 without saving or restoring any settings.

5.3.27 Auxiliary I/O Menu

When Main Menu 2 is displayed, pressing the Auxiliary I/O key accesses the Auxiliary I/O menu, which is shown in figure 5-32.

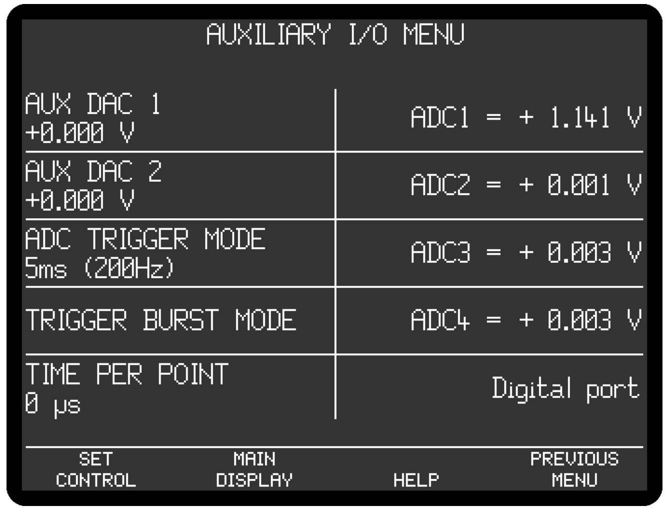

Figure 5-32, Auxiliary I/O Menu

The Auxiliary I/O menu has five controls, which are used to set the voltages appearing at the **DAC1** and **DAC2** connectors on the rear panel and configure the auxiliary ADC trigger mode, four displays to show the voltages at the rear-panel **ADC1** to **ADC4** inputs and a key access a further sub-menu.

The five controls operate as follows:

AUX DAC 1 **and** AUX DAC 2

These two controls set the voltages appearing at the **DAC1** and **DAC2** connectors on the rear panel to any value between -10.000 V and +10.000 V in 1 mV increments. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

ADC TRIGGER MODE

This has eleven possible settings, as follows:-

5ms (200Hz)

A conversion is performed on ADC1, ADC2, ADC3 and ADC4 every 5 ms, with the results being displayed on the right of the screen and being available via the computer interfaces.

EXTERNAL (Rear Panel)

A conversion is performed on ADC1, ADC2, ADC3 and ADC4 on receipt of a rising edge at the TTL **TRIG** connector on the rear panel. The maximum trigger rate is 200 Hz. The results are displayed on the right of the screen and are available via the computer interfaces.

BURST ADC1

A burst of conversions at 40 kHz (25 µs/point) is performed on ADC1 only, either on receipt of the TADC2 computer command or when the Trigger Burst Mode key is pressed. The results are stored to the curve buffer, with the number of conversions being set by the curve length control on the Curve Buffer menu - see section 5.3.22.

BURST ADC1&2

A burst of conversions at exactly 56 µs/point (approximately 18 kHz) is performed on both ADC1 and ADC2, either on receipt of the TADC3 computer command or when the Trigger Burst Mode key is pressed. The results are stored to the curve buffer, with the number of conversions being set by the curve length control on the Curve Buffer menu - see section 5.3.22.

BURST ADC1 (VT)

This is the same as the BURST ADC1 mode, except that the sampling rate may be set using the Time/Point control and that the computer command to initiate acquisition is TADC4.

BURST ADC1 & 2 (VT)

This is the same as the BURST ADC1 & 2 mode, except that the sampling rate may be set using the Time/Point control and that the computer command to initiate acquisition is TADC5.

BURST ADC1 (RP)

This is the same as the BURST ADC1 mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIG** connector on the rear panel.

BURST ADC1 & 2 (RP)

This is the same as the BURST ADC1 & 2 mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIG** connector on the rear panel.

BURST ADC1 (RP VT)

This is the same as the BURST ADC1 (T) mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIG** connector on the rear panel.

BURST ADC1 & 2 (RP VT)

This is the same as the BURST ADC1 & 2 (T) mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIG** connector on the rear panel.

NOTE: When any of the burst acquisition modes are selected, the instrument automatically changes the curves selected for storage, as shown on the Curve Select menu (section 5.3.23), to be either ADC1 or ADC1 and ADC2.

TRIGGER BURST MODE

When one of the triggered burst modes is selected, this control is active and is shown in bright text. Press the key adjacent to it to trigger data acquisition.

TIME/POINT

When one of the timed burst modes is selected, the time per point control is active and is shown in bright text. This can be set to any value between 25 µs (ADC1 only) or 56 µs (ADC1 and 2) and 5 ms in 1 µs increments.

Pressing the Previous Menu key returns control to Main Menu 2.

5.3.28 Digital Port Menu

When the Auxiliary I/O menu is displayed, pressing a key adjacent to the Digital Port item accesses the Digital Port menu, shown in figure 5-33.

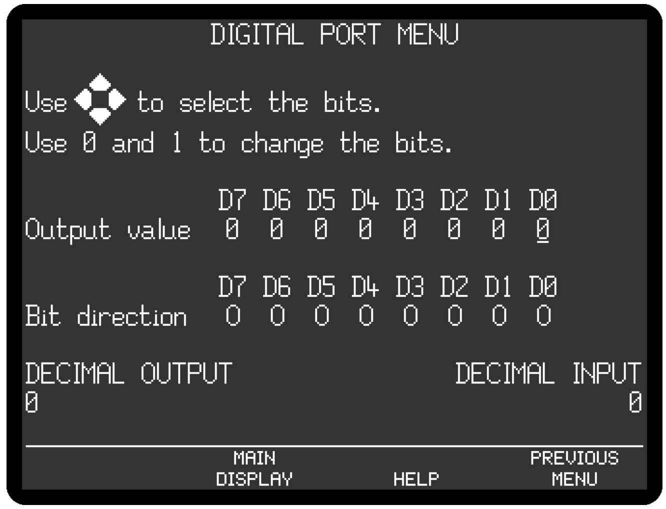

Figure 5-33, Digital Port Menu

The Digital Port menu allows the operating mode of each of the eight pins of the **DIGITAL I/O** connector on the rear panel to be set and its logic status to be set and read. This port may be used for controlling or reading the status of external equipment, for example the switching of heaters or attenuators, via a suitable user-supplied external interface circuit.

Each of the eight pins is configured as an input or output by the Bit direction digits; when the digit is a 1, the corresponding bit is an input; when it is 0 it is an output. For those bits configured as outputs, the Output value digits define whether they are high (value = 1) or low (value = 0)

To change a given bit, use the , , and to move the underscore (_) cursor until it is under the digit to be changed. Set the require status, either 1 or 0, by using the numeric keys.

DECIMAL OUTPUT

This control offers an alternative way of changing the output value. The number is the decimal equivalent of the displayed output value bit pattern, and consequently can be set to any number between 0 (all bits at logic "0") and 255 (all bits at logic "1").

DECIMAL INPUT

This displays the current logic state of all eight bits, regardless of whether they are inputs or outputs. The number shown is the decimal equivalent of the 8-bit value, and consequently can range between 0 (all bits at logic "0") and 255 (all bits at logic "1").

Pressing the Previous Menu key returns control to the Auxiliary I/O menu.

This completes the description of the single reference mode menus.

5.4 Menu Descriptions - Virtual Reference Mode

5.4.01 Virtual Reference Menus

The virtual reference mode is very similar to the single reference mode with internal reference, and is the simplest of the three additional modes of operation.

NOTE: This mode is only suitable for signals at frequencies between 100 Hz and 2.0 MHz.

The mode is accessed via a sub-menu of the Configuration menu, as shown in figure 5-34. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the Previous Menu key, but this has been omitted from figure 5-34 for the sake of clarity. Except as discussed in this and the following sections, the remainder of the instrument control and display menus operate in the same way as in single reference mode.

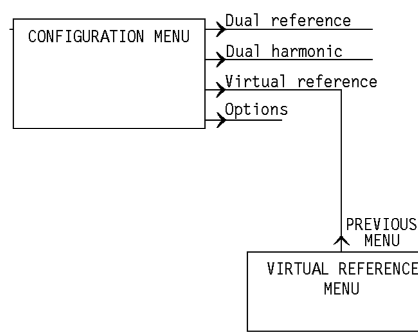

Figure 5-34, Virtual Reference Menu Structure

When the Configuration menu is displayed and the Virtual Reference key is pressed, the Virtual Reference menu, shown in figure 5-33, will appear.

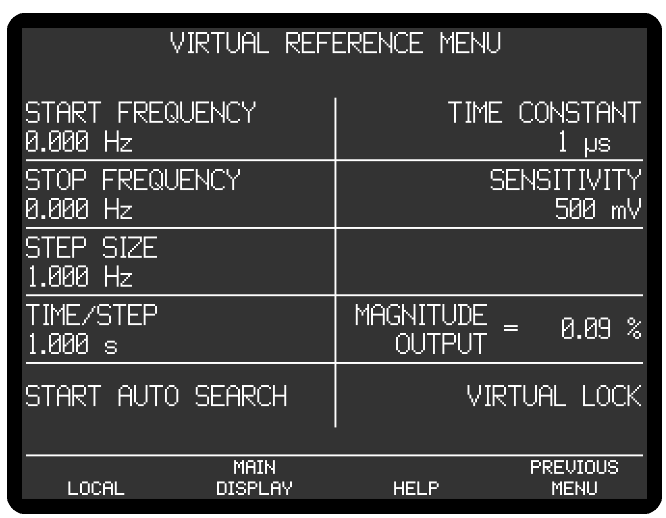

Figure 5-35, Virtual Reference Menu

This menu has six controls affecting the virtual reference mode, a single display, and two keys to establish virtual lock. The left-hand side of the display is used for the semi-automatic method of establishing Virtual Reference mode, with the right-hand side being used for the manual mode.

The controls operate as follows:-

Semi-Automatic Method

START FREQUENCY

This control defines the start frequency from which the instrument will begin to try to find the applied signal. It should be set to a value close to, but less than, the expected signal frequency. If the start frequency is within 100 Hz of the signal frequency then there is no need to set the stop frequency control. Adjusting the Start Frequency control also sets the present Oscillator Frequency to the same value.

STOP FREQUENCY

This control defines the stop frequency at which the instrument abandons its search for the signal, and should be set to a value greater than the expected signal frequency. If the start frequency is within 100 Hz of the signal frequency then there is no need to set this control.

STEP SIZE

This control defines the frequency step size used during the automatic search.

TIME/STEP

This control defines the time per point within the automatic search.

START AUTO SEARCH

Pressing the Start Auto Search key starts the internal oscillator at the defined start frequency and increases it at a rate of 1 Hz per second. If the instrument detects a signal greater than 50% of full-scale then the search stops, the unit locks on to that signal, and the Main Display - Virtual Reference Mode appears, as shown in figure 5-34.

Manual Setup

If the semi-automatic setup method does not work because the signal requires a time constant longer than 100 ms then the initial search can be performed manually. This can be done using the controls on the right-hand side of the display, and the Start Frequency control on the left-hand side.

The controls operate as follows:-

TIME CONSTANT

This control sets the instrument's output time constant.

SENSITIVITY

This control should be set so that the amplitude of the expected signal will be at least 50% of full-scale. For example, if the signal is expected to be about 10 µV then set the full-scale sensitivity to be either 5 µV or 10 µV.

NOTE: If the full-scale sensitivity is set so that the signal is less than 50% full-scale then it will not be found.

START FREQUENCY
Once the Time Constant and Sensitivity Controls have been set to suitable values, the Start Frequency control should be slowly adjusted from below the expected signal frequency, until the Magnitude display reads in excess of 50%. The easiest way to do this is by using the active cursor control to place a cursor under an appropriate digit of the Start Frequency display and then using the △▽ control to adjust the frequency.

MAGNITUDE
This displays the present signal magnitude as a percentage of the set full-scale sensitivity.

VIRTUAL LOCK
When the instrument's internal oscillator and full-scale sensitivity are set so that the signal is measured as 50% of full-scale or greater, then pressing this key enters the virtual reference mode, and the Main Display - Virtual Reference Mode appears, as shown in figure 5-34.

5.4.02 Main Display - Virtual Reference Mode

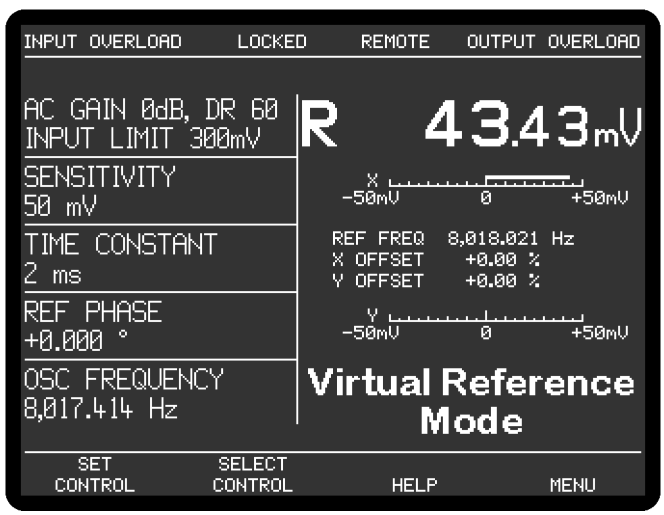

Figure 5-36, Main Display - Virtual Reference Mode

In virtual reference mode, the instrument operates exactly as in single reference mode, with the following exceptions:-

The Main Display always shows the annotation "Virtual Reference Mode" in the bottom right-hand section of the display as a warning to the user that this mode is being used.

Although the upper three display positions can be reconfigured to display magnitude and/or phase information, neither of these is relevant since there is no reference signal to which the phase can be related, and the magnitude equals the X channel output. Similarly, controls affecting the instrument's reference phase, such as Ref

Phase and Ref Phase ±90°, have no effect.

Harmonics greater than unity should not be used in virtual reference mode since the harmonic number relates to the reference frequency. Nevertheless, detection at harmonics of the signal frequency is possible by searching for the required harmonic frequency. For example, if the signal frequency is 1 kHz and a measurement at the second harmonic is required, set the harmonic to 1st and search for a signal at 2 kHz.

The signals at the **OSC OUT** connector on the front panel and the **REF MON** connector on the rear panel are at the virtual reference frequency.

Since none of the controls on the Reference menu are relevant, it is not possible to access it.

5.4.03 Configuration Menu - Virtual Reference Mode

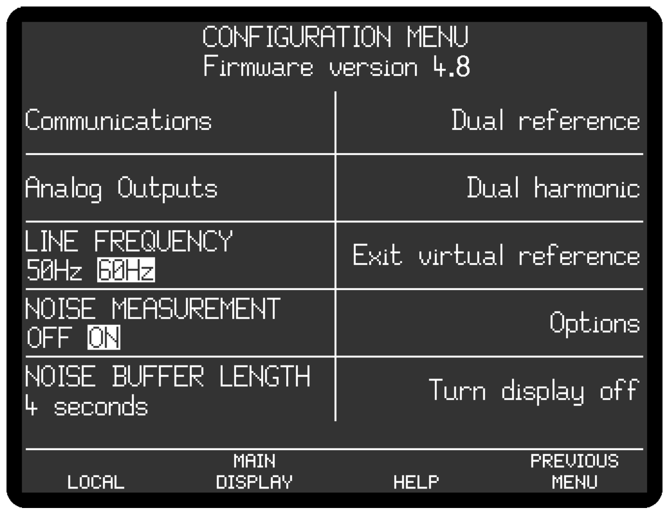

Figure 5-37, Configuration Menu - Virtual Reference Mode

In virtual reference mode, the choices available on the Configuration menu are as shown in figure 5-35. To leave virtual reference mode and return to single reference mode press the Exit Virtual Reference key, to switch to dual reference mode, press the Dual Reference key, and to switch to dual harmonic mode, press the Dual Reference key. The remaining controls, including the sub-menus, operate as already described in section 5.3.13

This completes the description of the virtual reference mode menus.

5.5 Menu Descriptions - Dual Reference Mode

5.5.01 Dual Reference Setup Menu

The dual reference mode allows the model 7280 to measure simultaneously signals applied to the signal input at two different reference frequencies. One reference must be supplied to the external reference input, and the second has to be the internal oscillator.

During dual reference mode operation, some of the control and display menus differ from those used for single reference mode, so these are described in the following sections. The remaining menus operate in the same way as in single reference mode, as already described in section 5.3.

When the Configuration menu is displayed, pressing the Dual Reference key activates the dual reference mode. While the instrument switches to this mode, the Dual Reference Setup menu is displayed, as shown in figure 5-38.

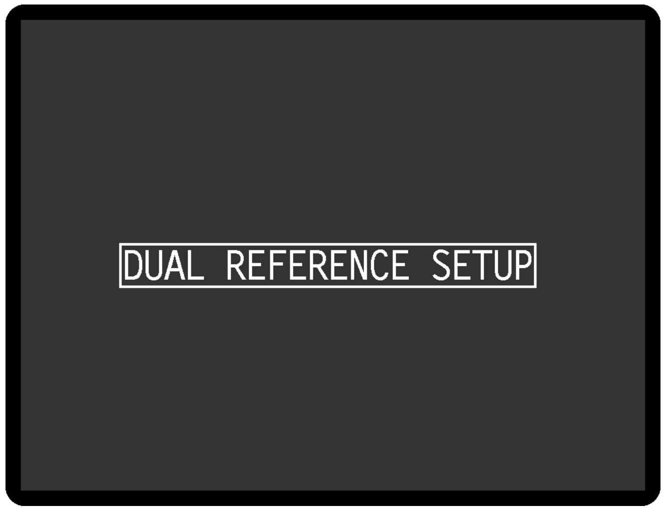

Figure 5-38, Dual reference Setup Menu

5.5.02 Dual Reference Main Display

Once dual reference has been activated, the Main Display - Dual reference Mode is displayed, as shown in figure 5-39.

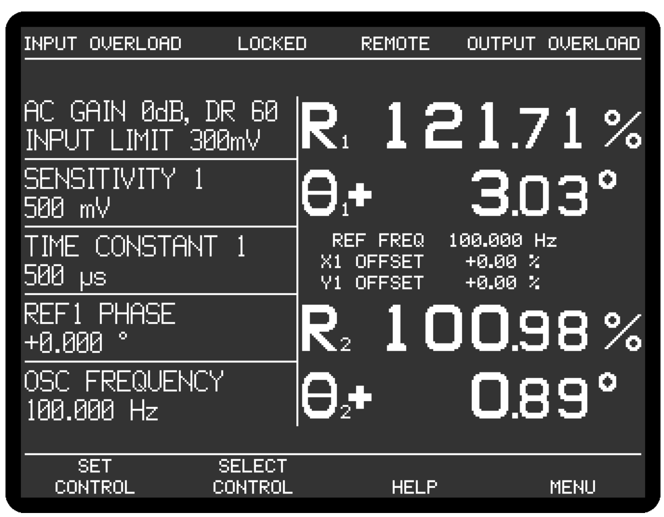

Figure 5-39, Main Display - Dual reference Mode

In dual reference mode, controls and displays relating to the external reference signal carry the suffix "1" and those for the internal reference, the suffix "2". Hence, for example, if an external reference frequency of 1 kHz is applied and the instrument's internal oscillator is set to 15 kHz, the unit will measure signals at both 1 kHz and 15 kHz. The Sensitivity 1, Time Constant 1 and Ref Phase 1 controls will affect the signal being measured at 1 kHz, while the Sensitivity 2, Time Constant 2 and Ref Phase 2 controls will affect the signal being measured at 15 kHz.

The range of controls that can be placed on the left-hand side of the Main Display using the SELECT CONTROL key is therefore extended to include those relating to both reference signals, as follows:-

SENSITIVITY 1

SENSITIVITY 2

When set to voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity may be set to any value between 10 nV and 1 V in a 1-2-5 sequence.

When set to current input mode, using the Signal Channel menu, the instrument's full-scale current sensitivity may be set to any value between 1 pA and 100 µA (wide bandwidth mode), 10 fA and 1 µA (normal mode), or 10 fA and 10 nA (low-noise mode), in a 1-2-5 sequence.

The number reported after the letters DR is the instrument's Dynamic Reserve, expressed in decibels, as calculated by the following equation:-

$$\mathrm{DR} = 20 \times \log_{10}\left(\frac{2}{\mathrm{SEN}}\right) - \mathrm{ACGain\ (in\ dB)}$$

Example:-

If AC Gain = 14 dB and SEN = 2 mV then

$$\mathrm{DR} = 20 \times \log_{10}\left(\frac{2}{0.002}\right) - 14$$

DR = 46 dB

TIME CONSTANT 1

TIME CONSTANT 2

The time constant of the output filters is set using this control, in the range 1 µs to 100 ks in a 1-2-5 sequence. Settings of 1 ms and below restrict the choice of instrument outputs to X1/X2, Y1/Y2 and Magnitude1/Magnitude2.

REF1 PHASE

REF2 PHASE

These controls allows the reference phase of each detection channel to be adjusted over the range -180° to +180° in 1 m° steps. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

REF1 PHASE ±90°

REF1 PHASE ±90°

These controls allow the relevant reference phase to be adjusted in steps of ±90°.

X1 OFFSET, Y1 OFFSET, X2 OFFSET **and** Y2 OFFSET

These are the manual X1/X2 channel and Y1/Y2 channel output offset controls. The offset levels set by these controls, which can be any value between -300% and +300% in 0.01% steps, are added to the X1, X2, Y1 or Y2 channel outputs when the relevant channel offsets are switched on using the Output Channels menu. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04. The values are set automatically by the Auto-Offset function. Note that the Auto-Offset function automatically switches on all output offsets

REF1 HARMONIC

This control sets the harmonic of the applied external reference frequency at which the lock-in amplifier's reference 1 channel operates, in the range 1 st (fundamental mode) to 32 nd.

RELOCK EXT. REFERENCE

The 7280 includes frequency-dependent calibration parameters. In Dual reference mode the correct parameters can be chosen for the internal reference channel because its frequency is equal to the specified oscillator frequency. The parameters for the external reference channel are selected by measuring the applied frequency. If, however, the external reference frequency drifts or changes with time then the lock-in amplifier may need to use different calibration parameters. It therefore includes an automatic algorithm that detects significant changes in reference frequency, and if these occur, updates all the frequency-dependent calibration values.

Pressing this key has the effect of manually updating these calibration parameters. This should be done when operating in Dual reference mode after each intentional change to the external reference frequency.

REF2 HARMONIC

This control sets the harmonic of the internal reference frequency at which the lock-in amplifier's reference 2 channel operates, in the range 1 st (fundamental mode) to 32 nd.

For example, if Ref1 Harmonic is set to 3rd, Ref2 Harmonic is set to 1st, an external reference signal of 1 kHz is applied and the internal oscillator set to 12 kHz, the instrument will measure signals at its input at frequencies of both 3 kHz and 12 kHz.

AUX DAC 1 **and** AUX DAC 2

These two controls set the voltage appearing at the **DAC1** and **DAC2** output connectors on the rear panel to any value between +10 V and -10 V with a resolution of 1 mV. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC FREQUENCY

The frequency of the instrument's internal oscillator, used for the reference 2 detection channel, may be set using this control to any value between 0.5 Hz and 2.000 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC AMPLITUDE

This control may be set to any value between 1 mV and 1 V rms. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

Since the instrument is now generating two sets of outputs (one for the external and one for the internal reference signals) there are more output display choices in this mode than in single reference mode, and these are listed in table 5-2. The outputs corresponding to the two references are identified by the suffices "1" and "2" respectively.

Output Title	**Description**
Numeric Displays only:	
R_1%	Resultant (Magnitude) output, reference 1, %FS
R_2%	Resultant (Magnitude) output, reference 2, %FS
N_1%	Noise output about reference 1, % FS
N_2%	Noise output about reference 2, % FS
θ_1°	Phase output, reference 1, in degrees
θ_2°	Phase output, reference 2, in degrees
X_1%	X channel output, reference 1, % FS
Numeric Displays only (continued):	
X_2%	X channel output, reference 2, % FS
Y_1%	Y channel output, reference 1, % FS
Y_2%	Y channel output, reference 2, % FS
R_1	Resultant (Magnitude) output, reference 1, in volts or amps
R_2	Resultant (Magnitude) output, reference 2, in volts or amps
Numeric and Bar-Graph Displays:	
X_1	X channel output, reference 1, in volts or amps
X_2	X channel output, reference 2, in volts or amps
Y_1	Y channel output, reference 1, in volts or amps
Y_2	Y channel output, reference 2, in volts or amps
N_1	Noise output about reference 1 in volts or amps per root hertz
N_1	Noise output about reference 1 in volts or amps per root hertz
ADC1	ADC1 input, ±10.000 V full-scale
ADC2	ADC2 input, ±10.000 V full-scale
ADC3	ADC3 input, ±10.000 V full-scale
ADC4	ADC4 input, ±10.000 V full-scale
Bar-Graph Displays only:	
MAG_1	Resultant (Magnitude) output, reference 1, in volts or amps
MAG_2	Resultant (Magnitude) output, reference 2, in volts or amps
PHA_1°	Phase output, reference 1, in degrees
PHA_2°	Phase output, reference 2, in degrees

Table 5-2, Output Display Choices - Dual Reference Mode

The additional outputs may be stored to the curve buffer, but only when the curve selection is made via the computer interface. The Curve Select menu only allows selection of the same sixteen data types as in single reference mode.

When in dual reference mode, the user-defined equations, specified on the Output Equations menu, allow the selection of the additional outputs as variables. For example, it is possible to calculate a value proportional to the ratio of the X_1 channel output to that of the X_2 channel output. With suitable scaling, this can be output to the **CH1** or **CH2** connectors on the rear panel as an analog voltage.

Naturally, the signals at the two frequencies that are being measured share a common signal path and hence controls affecting the signal channel, such as AC Gain and the line filter controls, apply to both reference frequencies. Although the full-scale sensitivity setting can be independently set for both references, the maximum AC Gain that is possible is defined by the least sensitive setting of the two.

In standard instruments, the maximum detection frequency for either regference_1 or reference_2 is 20 kHz; units fitted with the 7280/99 option allow operation to 800 kHz and those with the 7280/98 option allow operation to 2.0 MHz

5.5.03 Reference Channel Menu

In dual reference mode, the reference channel is controlled by the Dual Reference Channel menu, which differs from the Reference Channel menu used in the other three modes. In addition, controls are needed for the corresponding output channels, and so the Output Filters and Output Offset sub-menus also change. The relationship of all these menus to Main Menu 1 is shown in figure 5-40. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the Previous Menu key, but this has been omitted from figure 5-40 for the sake of clarity.

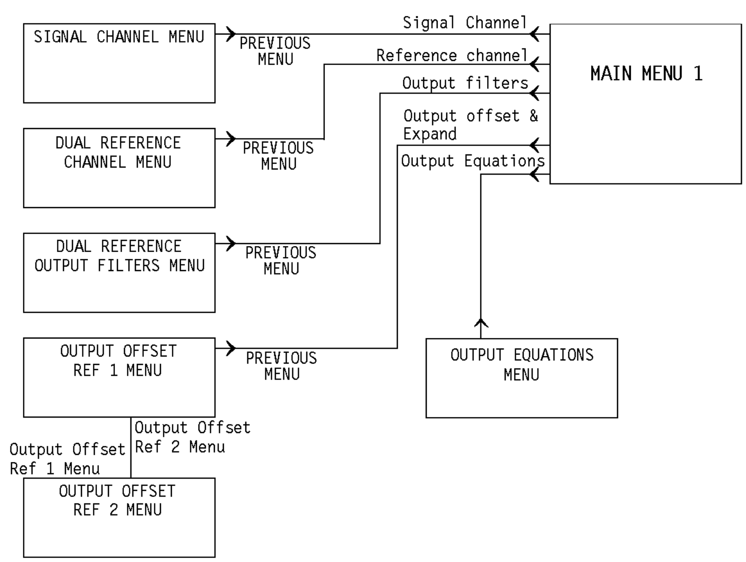

Figure 5-40, Dual Reference Mode Menu Structure

In dual reference mode, pressing a key adjacent to the Reference Channel item on

Main Menu 1 accesses the Dual Reference Channel menu, shown in figure 5-39.

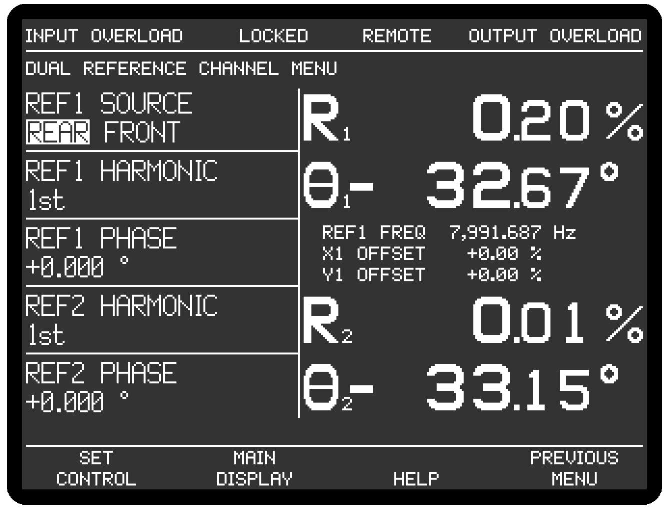

Figure 5-40, Dual Reference Channel Menu

The Dual Reference Channel menu has five controls affecting the instrument's reference channel. Changes to the setting of these controls can be made by using the adjacent △▽ keys.

REF SOURCE1

This control allows selection of the source of reference signal used to drive the reference 1 circuitry, and has two settings:-

REAR

In this setting the reference1 channel is configured to accept a suitable external reference source applied to the rear panel **REF TLL** input connector

FRONT

In this setting the reference1 channel is configured to accept a suitable external reference source applied to the front panel **REF IN** input connector

REF1 HARMONIC

This control sets the harmonic of the applied external reference frequency at which the lock-in amplifier's reference 1 channel operates, in the range 1 st (fundamental mode) to 32 nd.

REF2 HARMONIC

This control sets the harmonic of the internal reference frequency at which the lock-in amplifier's reference 2 channel operates, in the range 1 st (fundamental mode) to 32 nd.

REF1 PHASE

REF2 PHASE

These two controls allow the reference phase of reference_1 and reference_2 to be independently adjusted over the range -180° to +180° in 10m° steps. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The Auto-Phase1 and Auto-Phase 2 functions (see section 5.5.07) also affect the settings of these controls.

Pressing the Previous Menu key returns control to Main Menu 1.

5.5.04 Dual reference Output Filters Menu

In dual reference mode, pressing the Output Filters key on Main Menu 1 access the Dual Reference Output Filters Menu, shown in figure 5-41.

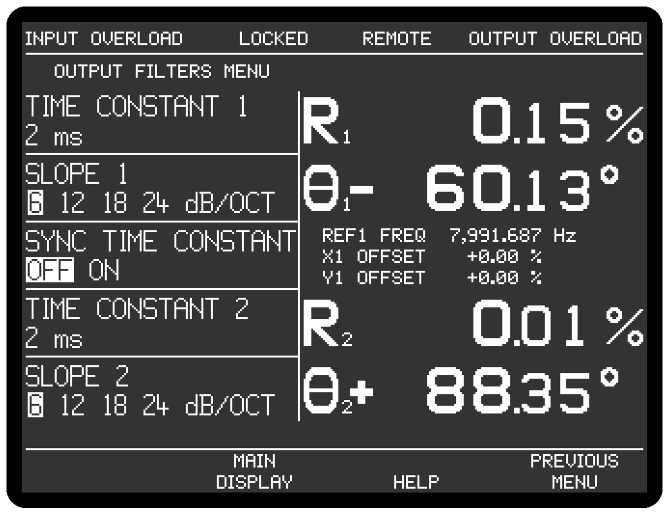

Figure 5-41, Dual Reference Output Filters Menu

The Dual Reference Output Filters menu has five controls affecting the instrument's output low-pass filters. Changes to the setting of these controls can be made by using the adjacent △▽ keys.

The controls operate as follows:-

TIME CONSTANT 1
TIME CONSTANT 2
These controls, which duplicate the Main Display controls of the same name, are used to set the time constant of each of the output filters.

SLOPE 1
SLOPE 2
The roll-off of each of the outputs filters can be set, using this control, to either 6 dB or 12 dB per octave.

SYNC TIME CONSTANT
This control has two settings, as follows:-

OFF
In this setting, which is the normal mode, time constants are not related to the reference frequency period.

`ON`

In this setting, the actual time constant used is chosen to be some multiple of the reference frequency period, giving a much more stable output at low frequencies than would otherwise be the case. Note that, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

Pressing the Previous Menu key returns control to Main Menu 1.

5.5.05 Output Offset Ref 1 Menu

In dual reference mode, when Main Menu 1 is displayed, pressing a key adjacent to the Output Offset item accesses the Output Offset Ref 1 menu, which is shown in figure 5-42.

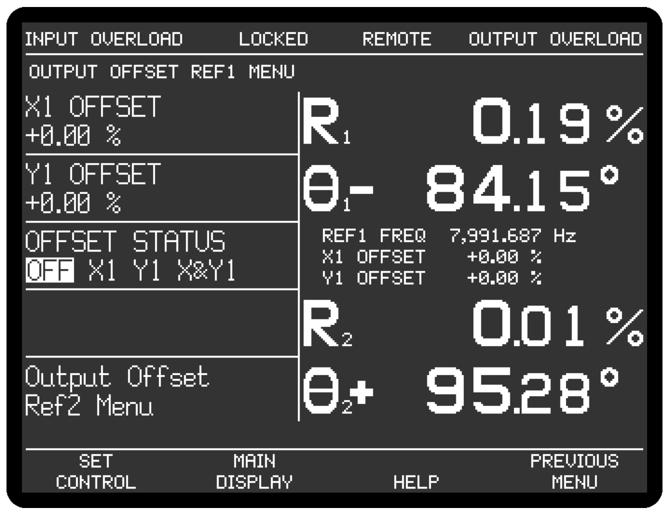

Figure 5-42, Output Offset Ref 1 Menu

The Output Offset Ref 1 menu has three controls affecting the instrument's X1 channel and Y1 channel outputs and a key to access a further sub-menu which has corresponding controls for the X2 channel and Y2 channel. Changes to the setting of these controls can be made by using the adjacent △▽ keys, with the currently active selection being highlighted.

`X1 OFFSET` **and** `Y1 OFFSET`

These controls, which duplicate the Main Display `X1 OFFSET` and `Y1 OFFSET` controls, allow manual adjustment of the X1 channel and Y1 channel output offsets. The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X1 channel or Y1 channel output when the X1 channel or Y1 channel offset is switched on. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The values are set automatically by the Auto-Offset 1 function, which also switches on both X1 channel and Y1 channel output offsets.

`OFFSET 1 STATUS`

This control allows the X1 channel and Y1 channel output offsets, set by the above level controls, to be switched on to either or both outputs, or to be switched off. It therefore has four settings, as follows:-

NONE
Both X1 channel and Y1 channel output offsets are switched off.

X
The X1 channel output offset is switched on.

Y
The Y1 channel output offset is switched on.

X&Y
Both X1 channel and Y1 channel output offsets are switched on.

Pressing the Output Offset Ref 2 key access the Output Offset Ref 2 menu, and pressing the Previous Menu key returns control to Main Menu 1.

5.5.06 Output Offset Ref 2 Menu

In dual reference mode, when Output Offset Ref 1 Menu is displayed, pressing the Output Offset Ref 2 Menu key accesses the Output Offset Ref 2 menu, which is shown in figure 5-43.

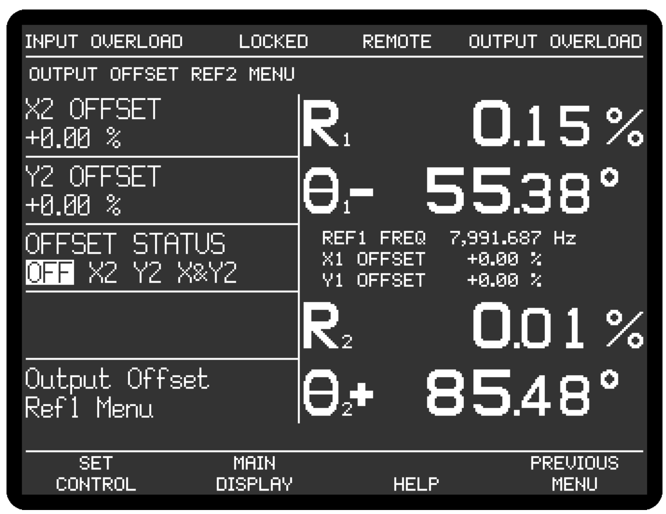

Figure 5-43, Output Offset Ref 2 Menu

The Output Offset Ref 2 menu has three controls affecting the instrument's X2 channel and Y2 channel outputs, and a key to return to the Output Offset Ref 1 menu. Changes to the setting of these controls can be made by using the adjacent (△)(▽) keys, with the currently active selection being highlighted.

X2 OFFSET **and** Y2 OFFSET
These controls, which duplicate the Main Display X2 OFFSET and Y2 OFFSET controls, allow manual adjustment of the X2 channel and Y2 channel output offsets.

The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X2 channel or Y2 channel output when the X2 channel or Y2 channel offset is switched on. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The values are set automatically by the Auto-Offset 2 function, which also switches on both X2 channel and Y2 channel output offsets.

OFFSET 2 STATUS

This control allows the X2 channel and Y2 channel output offsets, set by the above level controls, to be switched on to either or both outputs, or to be switched off. It therefore has four settings, as follows:-

NONE

Both X2 channel and Y2 channel output offsets are switched off.

X

The X2 channel output offset is switched on.

Y

The Y2 channel output offset is switched on.

X&Y

Both X2 channel and Y2 channel output offsets are switched on.

Pressing the Previous Menu or Output Offset Ref 1 Menu keys returns control to the Output Offset Ref 1 Menu.

5.5.07 Auto Functions Menu

In dual reference mode, pressing a key adjacent to the Auto Functions item on Main Menu 1 accesses the Auto Functions menu, shown in figure 5-44.

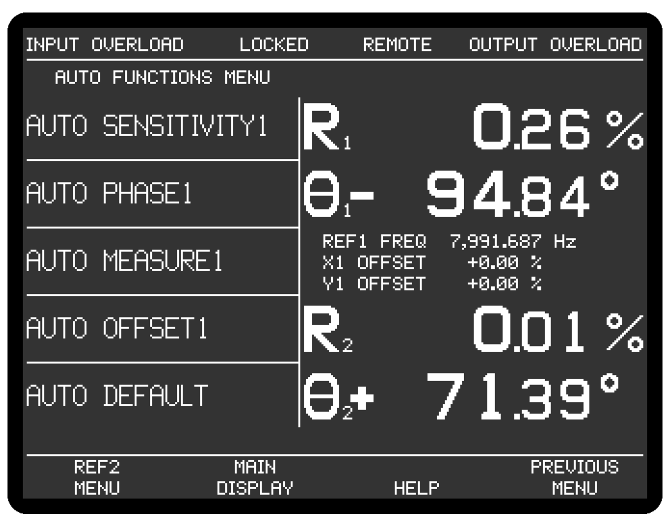

Figure 5-44, Auto Functions Menu - Dual Reference Mode

This menu is virtually identical to the normal single reference mode Auto Functions menu, except that the an additional key appears in the lower left-hand corner, marked Ref 2 Menu or Ref 1 Menu. Each press of this key toggles the displayed set of auto function controls between those applying to reference 1 and those applying to reference 2.

Note that once these functions complete, the Auto Functions menu is replaced by the Main Display. There are four auto functions for each of the two reference channels, which operate exactly as described for single reference mode in section 5.3.12.

Pressing a key adjacent to the Auto-Default item carries out an Auto-Default operation and resets the instrument to single reference mode.

5.5.08 Configuration Menu - Dual Reference Mode

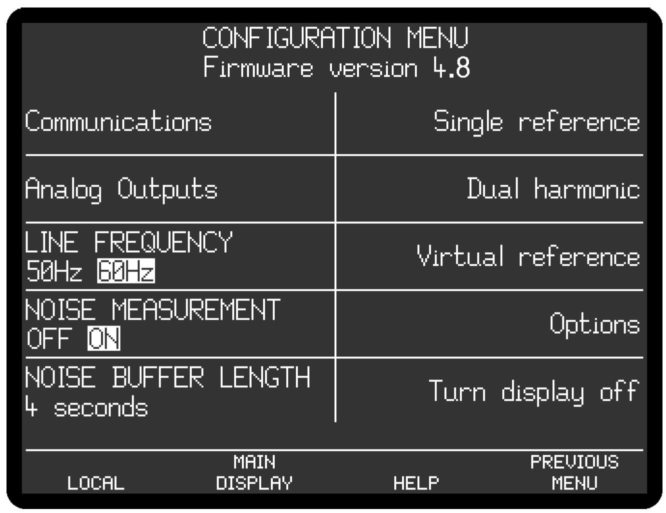

Figure 5-45, Configuration Menu - Dual reference Mode

In dual reference mode, the Dual Reference key displayed on the Configuration menu when in single reference mode is replaced by a key marked Single Reference, as shown in figure 5-45. To leave dual reference mode and return to single reference mode press the Single Reference key, to switch to dual harmonic mode, press the Dual Harmonic key and to switch to virtual reference mode, press the Virtual Reference key. The remaining controls operate as already described in section 5.3.13, except that the Analog Outputs sub-menu is slightly different, as discussed in the following section, 5.5.09

5.5.09 Analog Outputs Menu - Dual Reference and Dual Harmonic Modes

When operating in Dual Reference or Dual Harmonic modes the 7280 can generate analog outputs representing the in-phase components of the two detected signals updated at a rate of 7.5 MHz, making it possible to use output time constants in the range 1 µs to 200 µs

As with the single and virtual reference modes, changing the outputs selected for conversion to analog voltages may affect the rate at which these outputs are updated and the range of output time constants and filter slopes available. The Analog Outputs menu is used to select the outputs to be converted, which in dual reference or dual harmonic modes appears as shown in figure 5.46 below.

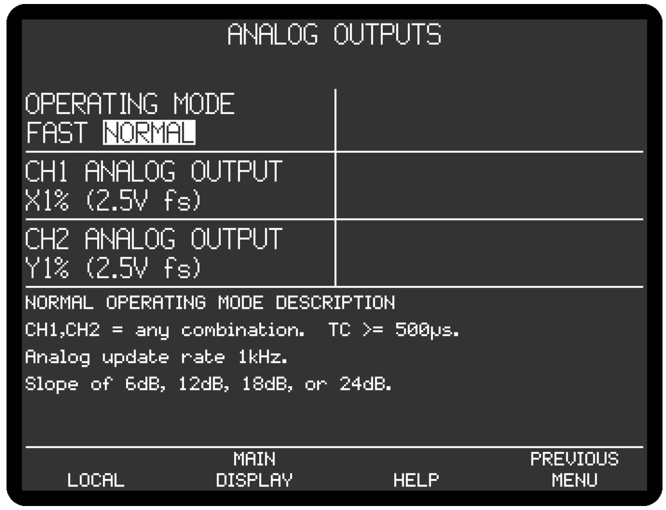

Figure 5-46, Analog Outputs Menu, Normal Operating Mode, Dual Reference/Dual Harmonic Modes

The Analog Outputs menu has three controls, changes to the setting of which can be made by using the adjacent △▽ keys.

`OPERATING MODE`
This control determines the position from which the analog outputs are derived in the circuit (see figure 3-1), and hence the rate at which they are updated. It also affects the available output filter slope, the permitted range of time constants, and the rate at which oscillator frequency and amplitude sweeps can be carried out (see sections 5.3.10 and 5.3.11). It has two settings, as follows:

`NORMAL`
In this setting, the **CH1** and **CH2** analog outputs are derived from the output processor. The update rate is always 1 kHz, the output filter time constant can be set to values between 500 µs and 100 ks in a ,1-2-5 sequence, and all four output filter slope setting are available. The minimum step time per point for oscillator amplitude and frequency sweeps is 1 ms.

In this mode, the `CH1 ANALOG OUTPUT` and `CH2 ANALOG OUTPUT` controls can each be set to any of the following fourteen available settings.

> `X1% (2.5V fs)`
> When set to X1% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the X1%fs front panel display as follows:-

X1%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`Y1% (2.5V fs)`

When set to Y1% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the Y1%fs front panel display as follows:-

Y1%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`MAG1% (2.5V fs)`

When set to MAG1% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the MAG1%fs or R_1% front panel displays as follows:-

MAG1%fs	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

`PHASE1 (+9 V = +180°)`

When in this setting the corresponding CH1/CH2 connector on the rear panel will output a voltage related to the PHA1 or θ_1 front panel displays as follows:-

PHA1 or θ_1 deg	CH1/2 Voltage
+180	9.0 V
+90	4.5 V
0	0.0 V
-90	-4.5 V
-180	-9.0 V

`PHASE1 (+9 V = +360°)`

When in this setting the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the PHA1 or θ_1 front panel display as follows:-

PHA1 or θ_1 deg	CH1/2 Voltage
+180	0.0 V
+90	-4.5 V
+0	-9.0 V
-0	9.0 V
-90	4.5 V
-180	0.0 V

`NOISE1 (2.5V fs)`

When set to NOISE1 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the N_1%fs front panel display as follows:-

N_1%fs	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

Note: When NOISE1 is selected as an output, the Noise Measurement Mode (Configuration Menu) must be ON. If it is not, a warning message is displayed which offers the option of turning it on or deselecting NOISE as an analog output.

`RATIO1`

When set to RATIO1 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the result of the RATIO1 calculation, which is defined as follows:-

$$\mathrm{RATIO1} = \left(\frac{10 \times \mathrm{X1\,output}}{\mathrm{ADC1\,Input}} \right)$$

where X1 output is the X1 channel output as a percentage of the full-scale sensitivity and ADC 1 is the voltage applied to the **ADC1** input connector on the rear panel expressed in volts. Hence, for example, if the instrument were measuring a 100 mV signal when set to the 500 mV sensitivity setting, the X1 channel output were maximized and a 1 V signal were applied to the ADC1 input, then the value of RATIO1 would be:-

$$\mathrm{RATIO1} = \left(\frac{10 \times \frac{0.1}{0.5}}{1.000} \right)$$

$$\mathrm{RATIO1} = 2$$

The relationship between the voltage at the **CH1**/**CH2** connector and the RATIO1 value is defined as follows:-

RATIO1	CH1/2 Voltage
+7.5	7.5 V
+2.5	2.5 V
0	0.0 V
-2.5	-2.5 V
-7.5	-7.5 V

`LOG RATIO1`

When set to LOG RATIO1 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the LOG RATIO1 calculation, which is defined as follows:-

$$\text{LOG RATIO1} = \log_{10}\left(\frac{10 \times \text{X1 output}}{\text{ADC1 input}}\right)$$

where X1 output is the X1 channel output as a percentage of the full-scale sensitivity and ADC 1 is the voltage applied to the **ADC1** input connector on the rear panel expressed in volts. Hence, for example, if the instrument were measuring a 100 mV signal when set to the 500 mV sensitivity setting, the X1 channel output were maximized and a 1 V signal were applied to the ADC1 input, then the value of LOG RATIO1 would be:-

$$\text{LOG RATIO1} = \log_{10}\left(\frac{10 \times \frac{0.1}{0.5}}{1.000}\right)$$

$$\text{LOG RATIO1} = 0.301$$

The relationship between the voltage at the **CH1**/**CH2** connector and the LOG RATIO1 value is defined as follows:-

LOG RATIO1	CH1/2 Voltage
+2.000	2.000 V
0	0.0 V
-3.000	-3.000 V

Note: If RATIO1 < 0 then LOG RATIO1 = -3.000

EQUATION #1

When set to EQUATION #1 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to Equation 1, which is defined using the Output Equations menu (see section 5.3.08), as follows:-

EQUATION #1	CH1/2 Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

EQUATION #2

When set to EQUATION #2 the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to Equation 2, which is defined using the User Equation 2 menu (see section 5.3.08), as follows:-

EQUATION #2	CH1/2 Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

`X2% (2.5V fs)`

When set to X2% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the X2%fs front panel display as follows:-

X2%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`Y2% (2.5V fs)`

When set to Y2% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the Y2%fs front panel display as follows:-

Y2%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

`MAG2% (2.5V fs)`

When set to MAG2% the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the MAG2%fs or R_2% front panel displays as follows:-

MAG2%fs	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

`PHASE2 (+9 V = +180°)`

When in this setting the corresponding CH1/CH2 connector on the rear panel will output a voltage related to the PHA2 or θ_2 front panel displays as follows:-

PHA2 or θ_2 deg	CH1/2 Voltage
+180	9.0 V
+90	4.5 V
0	0.0 V
-90	-4.5 V
-180	-9.0 V

`PHASE2 (+9 V = +360°)`

When in this setting the corresponding **CH1**/**CH2** connector on the rear panel will output a voltage related to the PHA2 or θ_2 front panel display as follows:-

PHA or θ deg	CH1/2 Voltage
+180	0.0 V
+90	-4.5 V
-0	-9.0 V
+0	9.0 V
-90	4.5 V
-180	0.0 V

FAST

In dual reference or dual harmonic mode when the analog outputs operating mode is set to Fast, the **CH1** and **CH2** analog outputs are derived either from the first stage of output filtering or from the output processor. The selection of which connection is made, and the resulting output update rate, depends on the setting of the two output time constant controls, as shown in table 5-3 below.

Time Constant 1 (Harmonic 1 or Internal Reference)	Time Constant 2 (Harmonic 2 or External Reference)	CH1/CH2 Analog Output Update Rate	Effective maximum TC at CH1 or CH2 Analog Outputs
≤ 4 ms	≤ 4 ms	7.5 MHz	4 ms
≤ 4 ms	≥ 10 ms	7.5 MHz	4 ms
≥ 10 ms	≤ 4 ms	7.5 MHz	4 ms
≥ 10 ms	≥ 10 ms	1 kHz	100 ks

Table 5-3, Analog Output Update Rate - Fast Mode - vs. TC1/TC2

Note that although the maximum effective time constant of the analog outputs is limited in the first three cases to 4 ms, the time constant applying to the digital outputs (i.e. front panel displays and values returned over the computer interfaces) is always the set value. For example, if TC1 were set to 500 µs and TC2 to 100 ms with Fast mode selected then the time constant applying to the digital outputs of Harmonic 2 or the External Reference (i.e. TC2) would be 100 ms.

In the Fast mode with dual reference or dual harmonic mode the output filter slope is fixed at 6 dB/octave and there is no choice as to the setting for the CH1 ANALOG OUTPUT and CH2 ANALOG OUTPUT controls, which are fixed as follows:-

CH1 ANALOG OUTPUT

X1% (2.5V fs)

The **CH1** connector on the rear panel will output a voltage related to the X1%fs front panel display as follows:-

X1%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

CH2 ANALOG OUTPUT

X2% (2.5V fs)

The **CH2** connector on the rear panel will output a voltage related to the X2%fs front panel display as follows:-

X2%	CH1/2 Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

The minimum step time per point for oscillator amplitude and frequency sweeps in FAST mode is 140 ms.

Pressing the Previous Menu key returns control to the Configuration Menu.

This completes the description of the dual reference mode menus.

5.6 Menu Descriptions - Dual Harmonic Mode

5.6.01 Dual Harmonic Setup Menu

The dual harmonic mode allows the model 7280 to measure signals, applied to the signal input, at two different harmonics of the reference frequency simultaneously. The reference may be either externally supplied or derived from the internal oscillator. During dual harmonic mode operation, some of the control and display menus differ from those used for single reference mode, so these are described in the following sections. The remaining menus operate in the same way as in single reference mode, as already described in section 5.3.

When the Configuration menu is displayed, pressing the Dual Harmonic key activates the dual harmonic mode. While the instrument switches to this mode, the Dual Harmonic Setup menu is displayed, as shown in figure 5-47.

Figure 5-47, Dual Harmonic Setup Menu

5.6.02 Dual Harmonic Main Display

Once dual harmonic has been activated, the Main Display - Dual Harmonic Mode is displayed, as shown in figure 5-48.

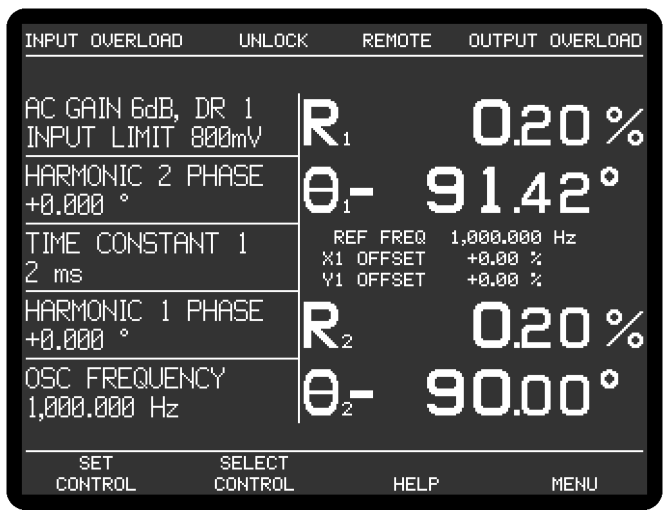

Figure 5-48, Main Display - Dual Harmonic Mode

In dual harmonic mode, controls and displays relating to the first detection harmonic carry the suffix "1" and those for the second, the suffix "2". Hence, for example, if a reference frequency of 1 kHz is applied, Harmonic 1 is set to 3 and Harmonic 2 to 5, the instrument will measure signals at both 3 kHz and 5 kHz. The Sensitivity 1, Time Constant 1 and Harmonic 1 Phase controls will affect the signal being measured at 3 kHz, while the Sensitivity 2, Time Constant 2 and Harmonic 2 Phase controls will affect the signal being measured at 5 kHz.

The range of controls that can be placed on the left-hand side of the Main Display using the Select Control key is therefore extended to include those relating to both harmonics of the reference, as follows:-

`SENSITIVITY 1`
`SENSITIVITY 2`
When set to voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity may be set to any value between 10 nV and 1 V in a 1-2-5 sequence.

When set to current input mode, using the Signal Channel menu, the instrument's full-scale current sensitivity may be set to any value between 1 pA and 100 µA (wide bandwidth mode), 10 fA and 1 µA (normal mode), or 10 fA and 10 nA (low-noise mode), in a 1-2-5 sequence.

The number reported after the letters DR is the instrument's Dynamic Reserve, expressed in decibels, as calculated by the following equation:-

$$DR = 20 \times \log_{10}\left(\frac{2}{SEN}\right) - \text{ACGain (in dB)}$$

Example:-

If AC Gain = 14 dB and SEN = 2 mV then

$$DR = 20 \times \log_{10}\left(\frac{2}{0.002}\right) - 14$$

$$DR = 46 \text{ dB}$$

`TIME CONSTANT 1`
`TIME CONSTANT 2`
The time constant of the output filters is set using this control, in the range 1 µs to 100 ks in a 1-2-5 sequence. Settings of 1 ms and below restrict the choice of instrument outputs to X, Y and Magnitude.

`HARMONIC 1 PHASE`
`HARMONIC 2 PHASE`
These controls allows the reference phase of each detection channel to be adjusted over the range -180° to +180° in 1 m° steps. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

`HARMONIC 1 PHASE ±90°`
`HARMONIC 2 PHASE ±90°`
These controls allow the relevant reference phase to be adjusted in steps of ±90°.

`X1 OFFSET, Y1 OFFSET, X2 OFFSET` **and** `Y2 OFFSET`
These are the manual X1/X2 channel and Y1/Y2 channel output offset controls. The offset levels set by these controls, which can be any value between -300% and +300% in 0.01% steps, are added to the X1, X2, Y1 or Y2 channel outputs when the relevant channel offsets are switched on using the Output Channels menu. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04. The values are set automatically by the Auto-Offset function. Note that the Auto-

Offset function automatically switches on all output offsets

HARMONIC 1
HARMONIC 2
These controls set the harmonic of the applied reference frequency, either internal or external, at which the lock-in amplifier's two reference channels operate, in the range 1 st (fundamental mode) to 32 nd. For example, if a reference frequency of 1 kHz is applied, Harmonic 1 is set to 3 and Harmonic 2 to 5, the instrument will measure signals at both 3 kHz and 5 kHz.

RELOCK EXT. REFERENCE
The 7280 includes frequency-dependent calibration parameters. When operating in Internal reference mode the correct parameters can be chosen because the reference frequency is equal to the specified oscillator frequency. In External reference mode the applied frequency is measured, and the measured value is used to select the correct parameters. If , however, the external reference frequency drifts or changes with time then the lock-in amplifier may need to use different calibration parameters. It therefore includes an automatic algorithm that detects significant changes in reference frequency, and if these occur, updates all the frequency-dependent calibration values.

Pressing this key has the effect of manually updating these calibration parameters. This should be done when operating in External reference mode after each intentional change to the applied reference frequency.

AUX DAC 1 **and** AUX DAC 2
These two controls set the voltage appearing at the **DAC1** and **DAC2** output connectors on the rear panel to any value between +10 V and -10 V with a resolution of 1 mV. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC FREQUENCY
The frequency of the instrument's internal oscillator may be set, using this control, to any value between 0.5 Hz and 2.000 MHz with a 1 mHz resolution. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

OSC AMPLITUDE
This control may be set to any value between 1 mV and 1 V rms. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

Since the instrument is now generating two sets of outputs (one for each harmonic of the reference) there are more output display choices in this mode than in single reference mode, and these are listed in table 5-4. The outputs corresponding to the two harmonics are identified by the suffices "1" and "2" respectively.

Output Title	Description
Numeric Displays only:	
$R_1\%$	Resultant (Magnitude) output, harmonic 1, %FS
$R_2\%$	Resultant (Magnitude) output, harmonic 2, %FS
$N_1\%$	Noise output about harmonic 1, % FS
$N_2\%$	Noise output about harmonic 2, % FS
$\theta_1°$	Phase output, harmonic 1, in degrees
$\theta_2°$	Phase output, harmonic 2, in degrees
$X_1\%$	X channel output, harmonic 1, % FS
$X_2\%$	X channel output, harmonic 2, % FS
$Y_1\%$	Y channel output, harmonic 1, % FS
$Y_2\%$	Y channel output, harmonic 2, % FS
Numeric Displays only: (continued)	
R_1	Resultant (Magnitude) output, harmonic 1, in volts or amps
R_2	Resultant (Magnitude) output, harmonic 2, in volts or amps
Numeric and Bar-Graph Displays:	
X_1	X channel output, harmonic 1, in volts or amps
X_2	X channel output, harmonic 2, in volts or amps
Y_1	Y channel output, harmonic 1, in volts or amps
Y_2	Y channel output, harmonic 2, in volts or amps
N_1	Noise output about harmonic 1 in volts or amps per root hertz
N_1	Noise output about harmonic 1 in volts or amps per root hertz
ADC1	ADC1 input, ±10.000 V full-scale
ADC2	ADC2 input, ±10.000 V full-scale
ADC3	ADC3 input, ±10.000 V full-scale
ADC4	ADC4 input, ±10.000 V full-scale
Bar-Graph Displays only:	
MAG_1	Resultant (Magnitude) output, harmonic 1, in volts or amps
MAG_2	Resultant (Magnitude) output, harmonic 2, in volts or amps
$PHA_1°$	Phase output, harmonic 1, in degrees
$PHA_2°$	Phase output, harmonic 2, in degrees

Table 5-4, Output Display Choices - Dual Harmonic Mode

The additional outputs may be stored to the curve buffer, but only when the curve selection is made via the computer interface. The Curve Select menu only allows selection of the same sixteen data types as in single reference mode.

When in dual harmonic mode, the user-defined equations, specified on the Output Equations menu, allow the selection of the additional outputs as variables. For example, it is possible to calculate a value proportional to the ratio of the X_1 channel output to that of the X_2 channel output. With suitable scaling, this can be output to the **CH1** or **CH2** connectors on the rear panel as an analog voltage.

Naturally, the two harmonics of the signal being measured share a common signal path and hence controls affecting the signal channel, such as AC Gain and the line filter controls, apply to both harmonics. Although the full-scale sensitivity setting can be independently set for both harmonics, the maximum AC Gain that is possible depends on the greater of these two values.

In standard instruments, the maximum detection frequency for either $harmonic_1$ or $harmonic_2$ is 20 kHz; units fitted with the 7280/99 allow operation to 800 kHz and those with th2 7280/98 allow operation to 2.0 MHz

5.6.03 Reference Channel Menu

In dual harmonic mode, the reference channel is controlled by the Dual Harmonic Reference menu, which differs from the Reference Channel menu used in the other three modes. In addition, controls are needed for the corresponding output channels, and so the Output Filters and Output Offset and Expand sub-menus also change. The relationship of all these menus to Main Menu 1 is shown in figure 5-49. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the Previous Menu key, but this has been omitted from figure 5-49 for the sake of clarity.

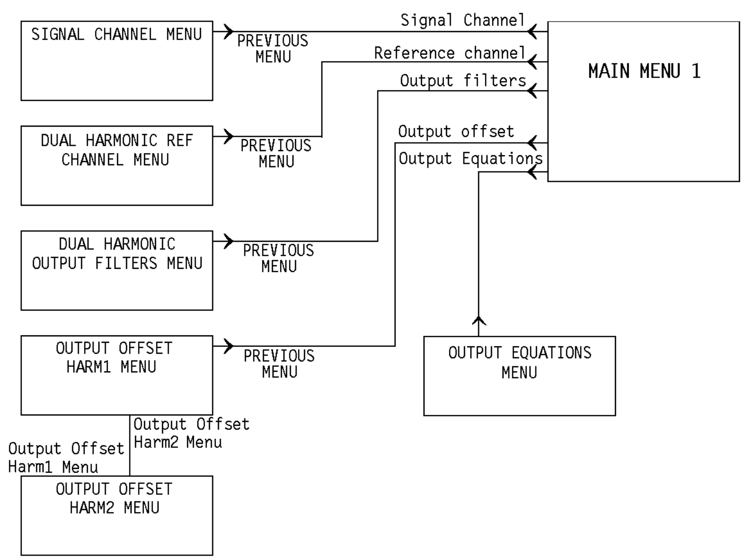

Figure 5-49, Dual Harmonic Mode Menu Structure

In dual harmonic mode, pressing a key adjacent to the Reference Channel item on Main Menu 1 accesses the Dual Harmonic Reference menu, shown in figure 5-50.

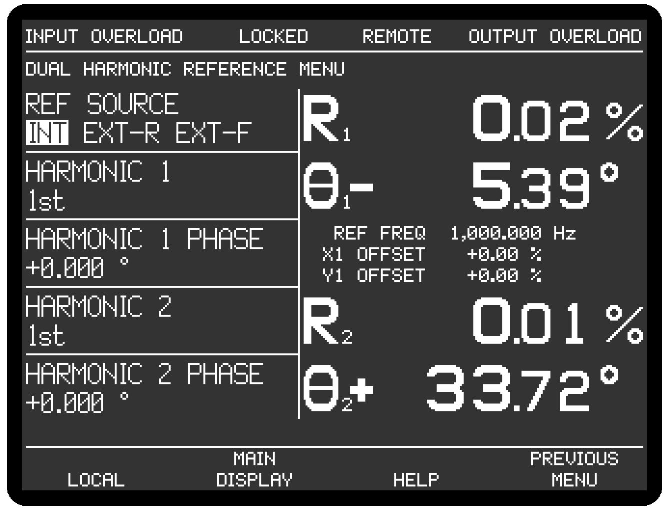

Figure 5-50, Dual Harmonic Reference Menu

The Dual Harmonic Reference menu has five controls affecting the instrument's reference channel. Changes to the setting of these controls can be made by using the adjacent △▽ keys.

REF SOURCE

This control allows selection of the source of reference signal used to drive the reference circuitry, and has three settings:-

INT

The lock-in amplifier's reference is taken from the instrument's internal oscillator. Note that this setting gives the best phase and gain measurement accuracy under all operating conditions, and it is always to be preferred, if possible, to design the experiment so that the lock-in amplifier acts as the source of the reference signal.

EXT-R

In this setting the reference channel is configured to accept a suitable external reference source applied to the rear panel **REF TLL** input connector

EXT-F

In this setting the reference channel is configured to accept a suitable external reference source applied to the front panel **REF IN** input connector

HARMONIC 1

HARMONIC 2

These two controls allow selection of the two harmonics of the reference frequency at which the lock-in amplifier will detect. They can be set to any value between 1st and 32nd. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

HARMONIC 1 PHASE

HARMONIC 2 PHASE

These two controls allow the reference phase of harmonic_1 and harmonic_2 to be independently adjusted over the range -180° to +180° in 10m° steps. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The Auto-Phase1 and Auto-Phase 2 functions (see section 5.6.06) also affect the settings of these controls.

Pressing the Previous Menu key returns control to Main Menu 1.

5.6.04 Dual Harmonic Output Filters Menu

In dual harmonic mode, pressing the Output Filters key on Main Menu 1 access the Dual Harmonic Output Filters Menu, shown in figure 5-51.

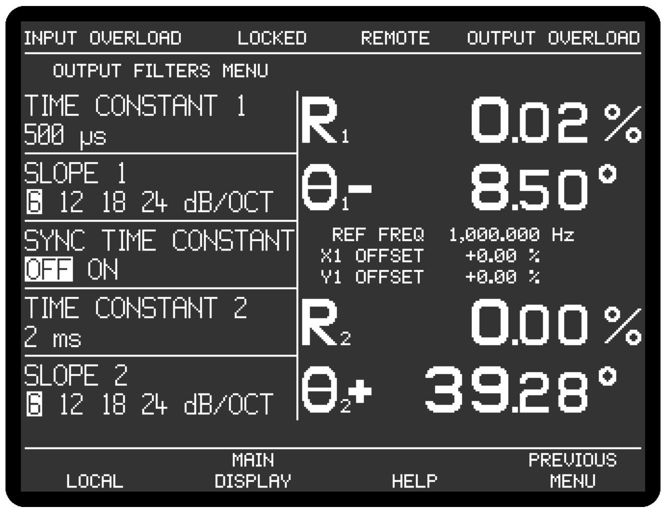

Figure 5-51, Dual Harmonic Output Filters Menu

The Dual Harmonic Output Filters menu has five controls affecting the instrument's output low-pass filters. Changes to the setting of these controls can be made by using the adjacent △▽ keys.

The controls operate as follows:-

`TIME CONSTANT 1`
`TIME CONSTANT 2`
These controls, which duplicate the Main Display controls of the same name, are used to set the time constant of each of the output filters.

`SLOPE 1`
`SLOPE 2`
The roll-off of each of the outputs filters can be set, using this control, to either 6 dB or 12 dB per octave.

`SYNC TIME CONSTANT`
This control has two settings, as follows:-

`OFF`
In this setting, which is the normal mode, time constants are not related to the

reference frequency period.

ON

In this setting, the actual time constant used is chosen to be some multiple of the reference frequency period, giving a much more stable output at low frequencies than would otherwise be the case. Note that, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

Pressing the Previous Menu key returns control to Main Menu 1.

5.6.05 Output Offset Harm 1 Menu

In dual harmonic mode, when Main Menu 1 is displayed, pressing a key adjacent to the Output Offset & Expand item accesses the Output Offset Harm 1 menu, which is shown in figure 5-52.

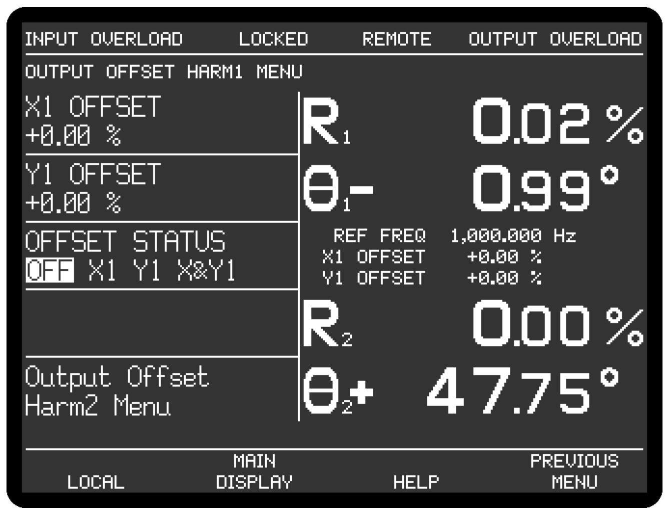

Figure 5-52, Output Offset Harm 1 Menu

The Output Offset Harm 1 menu has three controls affecting the instrument's X1 channel and Y1 channel outputs and a key to access a further sub-menu which has corresponding controls for the X2 channel and Y2 channel. Changes to the setting of these controls can be made by using the adjacent △▽ keys, with the currently active selection being highlighted.

X1 OFFSET **and** Y1 OFFSET

These controls, which duplicate the Main Display X1 OFFSET and Y1 OFFSET controls, allow manual adjustment of the X1 channel and Y1 channel output offsets. The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X1 channel or Y1 channel output when the X1 channel or Y1 channel offset is switched on. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The values are set automatically by the Auto-Offset 1 function, which also switches on both X1 channel and Y1 channel output offsets.

OFFSET 1 STATUS
This control allows the X1 channel and Y1 channel output offsets, set by the above level controls, to be switched on to either or both outputs, or to be switched off. It therefore has four settings, as follows:-

NONE
Both X1 channel and Y1 channel output offsets are switched off.

X
The X1 channel output offset is switched on.

Y
The Y1 channel output offset is switched on.

X&Y
Both X1 channel and Y1 channel output offsets are switched on.

Pressing the Output Offset Harm 2 key access the Output Offset Harm 2 menu, and pressing the Previous Menu key returns control to Main Menu 1.

5.6.06 Output Offset Harm 2 Menu

In dual harmonic mode, when Output Offset Harm 1 Menu is displayed, pressing the Output Offset Harm 1 Menu key accesses the Output Offset Harm 2 menu, which is shown in figure 5-53.

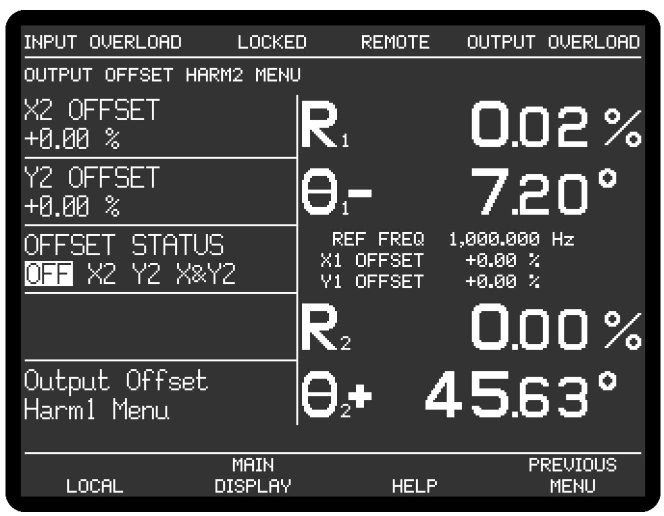

Figure 5-53, Output Offset Harm 2 Menu

The Output Offset Harm 2 menu has three controls affecting the instrument's X2 channel and Y2 channel outputs and a key to return to the Output Offset Harm 1 menu.. Changes to the setting of these controls can be made by using the adjacent △▽ keys, with the currently active selection being highlighted.

`X2 OFFSET` **and** `Y2 OFFSET`

These controls, which duplicate the Main Display `X2 OFFSET` and `Y2 OFFSET` controls, allow manual adjustment of the X2 channel and Y2 channel output offsets. The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X2 channel or Y2 channel output when the X2 channel or Y2 channel offset is switched on. Adjustment is faster using the Keypad or Active Cursor controls - see section 4.1.04.

The values are set automatically by the Auto-Offset 2 function, which also switches on both X2 channel and Y2 channel output offsets.

`OFFSET 2 STATUS`

This control allows the X2 channel and Y2 channel output offsets, set by the above level controls, to be switched on to either or both outputs, or to be switched off. It therefore has four settings, as follows:-

`NONE`

Both X2 channel and Y2 channel output offsets are switched off.

`X`

The X2 channel output offset is switched on.

`Y`

The Y2 channel output offset is switched on.

`X&Y`

Both X2 channel and Y2 channel output offsets are switched on.

Pressing the Previous Menu key returns control to the Output Offset Harm 1 Menu.

5.6.07 Auto Functions Menu

In dual harmonic mode, pressing a key adjacent to the Auto Functions item on Main Menu 1 accesses the Auto Functions menu, shown in figure 5-54.

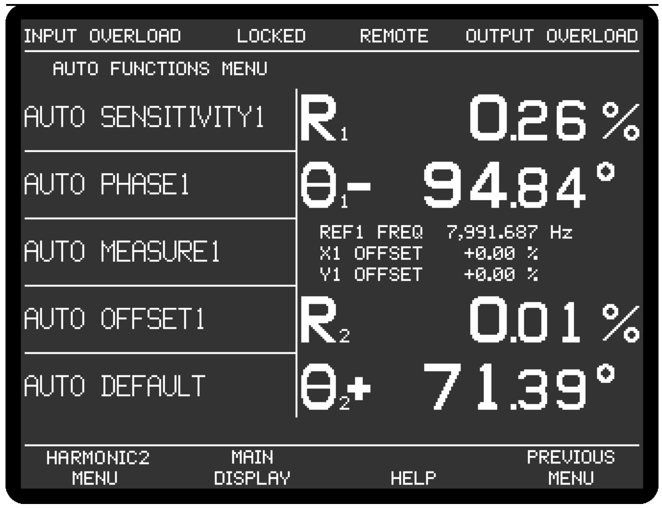

Figure 5-54, Auto Functions Menu - Dual Harmonic Mode

This menu is virtually identical to the normal single reference mode Auto Functions menu, except that the an additional key appears in the lower left-hand corner, marked Harmonic3 menu or Harmomic1 menu. Each press of this key toggles the displayed set of auto function controls between those applying to harmonic 1 and those applying to harmonic 2.

Note that once these functions complete, the Auto Functions menu is replaced by the Main Display. There are four auto functions for each of the two harmonic reference channels, which operate exactly as described for single reference mode in section 5.3.12.

Pressing a key adjacent to the Auto-Default item carries out an Auto-Default operation and resets the instrument to single reference mode.

5.6.08 Configuration Menu - Dual Harmonic Mode

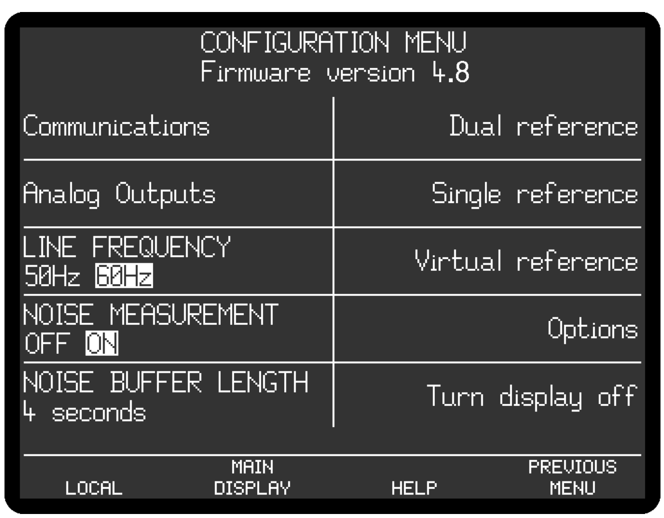

Figure 5-55, Configuration Menu - Dual Harmonic Mode

In dual harmonic mode, the Dual Harmonic key displayed on the Configuration menu when in single reference mode is replaced by a key marked Single Reference, as shown in figure 5-55. To leave dual harmonic mode and return to single reference mode press the Single Reference key, to switch to dual reference mode, press the Dual Reference key and to switch to virtual reference mode, press the Virtual Reference key. The remaining controls operate as already described in section 5.3.13, except that the Analog Outputs menu operates as described in section 5.5.09

This completes the description of the dual harmonic mode menus.

5.7 Typical Lock-in Amplifier Experiment

The model 7280 is a complex instrument which has many controls and the following basic checklist may be helpful in setting up the instrument for manual operation in single reference mode.

Auto-Default
Use the Auto-Default function on the Auto Functions menu to set the instrument to a defined state.

Selection of Signal Input
Use the Signal Channel menu to select voltage (single-ended or differential) or current input mode, and connect the signal source to the relevant **A** and/or **B/I** input connector(s) on the front panel.

Selection of Reference Mode
The default setting function will have set the reference mode to internal, which assumes that the internal oscillator will be used as a source of excitation to your experiment. Use the Internal Oscillator amplitude and frequency controls to set the required oscillator output, and connect the output signal from the **OSC OUT** connector on the front panel to the experiment.

If using external reference mode, use the Reference Channel menu to select one of the two external modes, and connect the reference signal to the correct connector.

Auto-Measure
Use the Auto-Measure function on the Auto Functions menu to set the instrument so that it is correctly displaying the signal.

Other Adjustments
Use the center right-hand △▽ key on the Main Display to select the display format required, and the upper and lower right-hand △▽ keys to select the outputs allocated to the four display positions. The four user-selected Main Display controls can be chosen using the Select Control key. If the analog outputs of the instrument are to be used, use the Analog Outputs menu to specify what the output signals at the **CH1** and **CH2** connectors on the rear panel should represent.

Computer Operation

Chapter 6

6.1 Introduction

The model 7280 includes both RS232 and GPIB (IEEE-488) interface ports, designed to allow the lock-in amplifier to be completely controlled from a remote computer. Virtually all of the instrument's controls may be operated, and all of the outputs can be read, via these interfaces. In addition, there are a few functions, such as curve storage of the second reference channel outputs in dual reference and dual harmonic modes, which can only be accessed remotely.

This chapter describes the capabilities of the instrument when operated remotely and discusses how this is done

6.2 Capabilities

6.2.01 General

All instrument controls, which can be set using the front-panel display menus, can also be set remotely, with the exception of the Spectral Display controls, and the User Settings. In addition, the present setting of each control can be determined by the computer. All instrument outputs which can be displayed on the front panel, with the exception of the Spectral Display, may also be read remotely.

There are no commands to select which menu is displayed on the instrument, although if the Main Display menu is shown then the outputs allocated to the four right-hand positions and the three user-specified controls can be selected.

When operated via the interfaces, the following features are also available:-

6.2.02 Curve Storage

The Curve Select menu allows only the basic sixteen data types associated with single reference and virtual reference modes of operation to be selected although, as discussed in sections 5.5 and 5.6, in both of the dual modes a second set of outputs is generated by the instrument. If it is required to store these additional outputs in the instrument's internal 32768 point memory then this can only be done using computer commands.

6.2.03 Curve Display

The Single and Double Graph menus allow only the display of stored curves of the sixteen data types associated with single reference mode. If the additional curves generated by the two dual modes are stored then these must be transferred to the computer for display or processing.

6.3 RS232 and GPIB Operation

6.3.01 Introduction

Control of the lock-in amplifier from a computer is accomplished by means of communications over the RS232 or GPIB interfaces. The communication activity consists of the computer sending commands to the lock-in amplifier, and the lock-in amplifier responding, either by sending back some data or by changing the setting of one of its controls. The commands and responses are encoded in standard 7-bit ASCII format, with one or more additional bits as required by the interface (see below).

The two ports cannot be used simultaneously, but when a command has been completed, the lock-in amplifier will accept a command at either port. Also when the test echo facility has been activated all output from the computer to the GPIB can be monitored by a terminal attached to the RS232 connector.

Although the interface is primarily intended to enable the lock-in amplifier to be operated by a computer program specially written for an application, it can also be used in the direct, or terminal, mode. In this mode the user enters commands on a keyboard and reads the results on a video screen.

The simplest way to establish the terminal mode is to connect a standard terminal, or a terminal emulator, to the RS232 port. A terminal emulator is a computer which runs special-purpose software that makes it act as a terminal. In the default (power-up) state of the port, the lock-in amplifier sends a convenient prompt character when it is ready to receive a command, and echoes each character that is received.

Microsoft Windows 95/98 includes a program called HyperTerminal, usually to be found in the Accessories group, which can be used as a terminal emulator. Alternatively a simple terminal program with minimal facilities can be written in a few lines of BASIC code (see appendix C.1).

6.3.02 RS232 Interface - General Features

The RS232 interface in the model 7280 is implemented with three wires; one carries digital transmissions from the computer to the lock-in amplifier, the second carries digital transmissions from the lock-in amplifier to the computer and the third is the Logic Ground to which both signals are referred. The logic levels are ±12 V referred to Logic Ground, and the connection may be a standard RS232 cable in conjunction with a null modem or, alternatively, may be made up from low-cost general purpose cable. The pinout of the RS232 connectors are shown in appendix B and cable diagrams suitable for coupling the instrument to a computer are shown in appendix D.

The main advantages of the RS232 interface are:

1) It communicates via a serial port which is present as standard equipment on nearly all computers, using leads and connectors which are available from suppliers of computer accessories or can be constructed at minimal cost in the user's workshop.

2) It requires no more software support than is normally supplied with the computer, for example Microsoft's GWBASIC, QBASIC or Windows HyperTerminal.

A single RS232 transmission consists of a start bit followed by 7 or 8 data bits, an optional parity bit, and 1 stop bit. The rate of data transfer depends on the number of bits per second sent over the interface, usually called the baud rate. In the model 7280 the baud rate can be set to a range of different values up to 19,200, corresponding to a minimum time of less than 0.5 ms for a single character.

Mostly for historical reasons, there are a very large number of different ways in which RS232 communications can be implemented. Apart from the baud rate options, there are choices of data word length (7 or 8 bits), parity check operation (even, odd or none), and number of stop bits (1 or 2). With the exception of the number of stop bits, which is fixed at 1, these settings may be adjusted using the RS232 Settings menu, discussed in chapter 5. They may also be adjusted by means of the RS command.

NOTE: In order to achieve satisfactory operation, the RS232 settings must be set to exactly the same values in the terminal or computer as in the lock-in amplifier.

6.3.03 Choice of Baud Rate

Where the lock-in amplifier is connected to a terminal or to a computer implementing an echo handshake, the highest available baud rate of 19,200 is normally used if, as is usually the case, this rate is supported by the terminal or computer. Lower baud rates may be used in order to achieve compatibility with older equipment or where there is some special reason for reducing the communication rate.

6.3.04 Choice of Number of Data Bits

The model 7280 lock-in amplifier uses the standard ASCII character set, containing 127 characters represented by 7-bit binary words. If an 8-bit data word is selected, the most significant bit is set to zero on output from the lock-in amplifier and ignored on input. The result is that either the 8-bit or the 7-bit option may be used, but the 7-bit option can result in slightly faster communication.

6.3.05 Choice of Parity Check Option

Parity checks are not required at the baud rates available in the model 7280, that is up to 19,200 baud, with typical cable lengths of up to a few meters. Therefore no software is provided in the model 7280 for dealing with parity errors. Where long cables are in use, it may be advisable to make use of a lower baud rate. The result is that any of the parity check options may be used, but the no-parity option will result in slightly faster communication.

Where the RS232 parameters of the terminal or computer are capable of being set to any desired value, an arbitrary choice must be made. In the model 7280 the combination set at the factory is even parity check, 7 data bits, and one stop bit (fixed) because these are the MS-DOS defaults.

6.3.06 Auxiliary RS232 Interface

The auxiliary RS232 interface allows up to sixteen model 7280s or a mixture of compatible instruments to be connected to one serial port on the computer. The first lock-in amplifier is connected to the computer in the usual way. Additional lock-in amplifiers are connected in a daisy-chain fashion using null-modem cables, the **AUX RS232** port of the first to the **RS232** port of the second, the **AUX RS232** port of the second to the **RS232** port of the third, etc. The address of the lock-in amplifiers must be set up from the front panel before any communication takes place. At power-up the RS232 port of each lock-in amplifier is fully active irrespective of its address. Since this means that all lock-in amplifiers in the daisy-chain are active on power-up, the first command must be \N n where n is the address of one of the lock-in amplifiers. This will deselect all but the addressed lock-in amplifier. When it is required to communicate with another lock-in amplifier, send a new \N n command using the relevant address.

***NOTE: When programming in C remember that in order to send the character \ in a string it is necessary to type in ***

6.3.07 GPIB Interface - General Features

The GPIB is a parallel digital interface with 8 bi-directional data lines, and 8 further lines which implement additional control and communication functions. Communication is through 24-wire cables (including 8 ground connections) with special-purpose connectors which are constructed in such a way that they can be stacked on top of one another to enable numerous instruments to be connected in parallel. By means of internal hardware or software switches, each instrument is set to a different address on the bus, usually a number in the range 0 to 31. In the model 7280 the address is set using the GPIB Settings menu or by means of the GP command.

A most important aspect of the GPIB is that its operation is defined in minute detail by the IEEE-488 standard, usually implemented by special-purpose semiconductor devices that are present in each instrument and communicate with the instrument's microprocessor. The existence of this standard greatly simplifies the problem of programming the bus controller, i.e. the computer, to implement complex measurement and test systems involving the interaction of numerous instruments. There are fewer interface parameters to be set than with RS232 communications.

The operation of the GPIB requires the computer to be equipped with special-purpose hardware, usually in the form of a plug-in card, and associated software which enable it to act as a bus controller. The control program is written in a high-level language, usually BASIC or C, containing additional subroutines implemented by software supplied by the manufacturer of the interface card.

Because of the parallel nature of the GPIB and its very effective use of the control lines, including the implementation of a three-wire handshake (see below), comparatively high data rates, up to a few hundred thousand bytes per second, are possible. In typical setups the data rate of the GPIB itself is not the factor that limits the rate of operation of the control program.

6.3.08 Handshaking and Echoes

A handshake is a method of ensuring that the transmitter does not send a byte until the receiver is ready to receive it, and, in the case of a parallel interface, that the receiver reads the data lines only when they contain a valid byte.

GPIB Handshaking
The GPIB interface includes three lines (*DAV, *NRFD, *NDAC) which are used to implement a three-wire handshake. The operation of this is completely defined by the IEEE-488 standard and is fully automatic, so that the user does not need to know anything about the handshake when writing programs for the GPIB. Note that each command must be correctly terminated.

RS232 Handshaking
In the RS232 standard there are several control lines called handshake lines (RTS, DTR outputs and CTS, DSR, DCD inputs) in addition to the data lines (TD output and RD input). However, these lines are not capable of implementing the handshaking function required by the model 7280 on a byte-by-byte basis and are not connected in the model 7280 apart from the RTS and DTR outputs which are constantly asserted.

Note that some computer applications require one or more of the computer's RS232 handshake lines to be asserted. If this is the case, and if the requirement cannot be changed by the use of a software switch, the cable may be used in conjunction with a null modem. A null modem is an adapter which connects TD on each side through to RD on the other side, and asserts CTS, DSR, and DCD on each side when RTS and DTR are asserted on the opposite sides.

With most modern software there is no need to assert any RS232 handshake lines and a simple three-wire connection can be used. The actual handshake function is performed by means of bytes transmitted over the interface.

The more critical handshake is the one controlling the transfer of a command from the computer to the lock-in amplifier, because the computer typically operates much faster than the lock-in amplifier and bytes can easily be lost if the command is sent from a program. (Note that because of the limited speed of human typing, there is no problem in the terminal mode.) To overcome the problem an echo handshake is used. This works in the following way: after receiving each byte, the lock-in amplifier sends back an echo, that is a byte which is a copy of the one that it has just received, to indicate that it is ready to receive the next byte. Correspondingly, the computer does not send the next byte until it has read the echo of the previous one. Usually the computer makes a comparison of each byte with its echo, and this constitutes a useful check on the validity of the communications.

Where the echo is not required, it can be suppressed by negating bit 3 in the RS232 parameter byte. The default (power-up) state of this bit is for it to be asserted.

The program RSCOM2.BAS in section C.2 illustrates the use of the echo handshake.

6.3.09 Terminators

In order for communications to be successfully established between the lock-in amplifier and the computer, it is essential that each transmission, i.e. command or command response, is terminated in a way which is recognizable by the computer and the lock-in amplifier as signifying the end of that transmission.

In the model 7280 there are three input termination options for GPIB communications, selected from the front panel under the GPIB Settings menu or by means of the GP command. The lock-in amplifier may be set to expect the <CR> byte (ASCII 13) or the <CR,LF> sequence (ASCII 13 followed by ASCII 10) to be appended by the controller as a terminator to the end of each command. Alternatively instead of a terminator it may expect the EOI signal line (pin 5 on the GPIB connector) to be asserted during the transmission of the last character of the command. The third option is normally to be preferred with modern interface cards which can easily be set to a wide variety of configurations.

The selected GPIB termination option applies also to the output termination of any responses sent back by the lock-in amplifier to the controller, i.e. the lock-in amplifier will send <CR> or <CR,LF> or no byte as appropriate. In all cases the lock-in amplifier asserts the EOI signal line during the transmission of the last byte of a response.

In RS232 communications, the lock-in amplifier automatically accepts either <CR> or <CR,LF> as an input command terminator, and sends out <CR,LF> as an output response terminator except when the noprompt bit (bit 4 in the RS232 parameter byte) is set, in which case the terminator is <CR>. The default (power-up) state of this bit is zero.

6.3.10 Command Format

The simple commands listed in section 6.4 have one of five forms:

CMDNAME terminator
CMDNAME n terminator
CMDNAME [n] terminator
CMDNAME [n_1 [n_2]] terminator
CMDNAME n_1 [n_2] terminator

where CMDNAME is an alphanumeric string that defines the command, and n, n_1, n_2 are parameters separated by spaces. When n is not enclosed in square brackets it must be supplied. [n] means that n is optional. [n_1 [n_2]] means that n_1 is optional and if present may optionally be followed by n_2. Upper-case and lower-case characters are equivalent. Terminator bytes are defined in section 6.3.09.

Where the command syntax includes optional parameters and the command is sent without the optional parameters, the response consists of a transmission of the present values of the parameter(s).

Any response transmission consists of one or more numbers followed by a response terminator. Where the response consists of two or more numbers in succession, they are separated by a delimiter (section 6.3.11).

Some commands have an optional floating point mode which is invoked by appending a **.** (full stop) character to the end of the command and before the parameters. This allows some parameters to be entered or read in floating point format. The floating point output format is given below.

±1.234E±01

The number of digits between the decimal point and the exponent varies depending on the number but is a minimum of one and a maximum of eight. The input format is not as strict but if a decimal point is used there must be a digit before it. An exponent is optional. The following are all legal commands for setting the oscillator frequency to 100.1 Hz:-

OF. 100.1
OF. 1.001E2
OF. +1.001E+02
OF. 1001E-1

6.3.11 Delimiters

Most response transmissions consist of one or two numbers followed by a response terminator. Where the response of the lock-in amplifier consists of two numbers in succession, they are separated by a byte called a delimiter. This delimiter can be any printing ASCII character and is selected via the RS232 Settings menu or by the use of the DD command.

6.3.12 Compound Commands

A compound command consists of two or more simple commands separated by semicolons (ASCII 59) and terminated by a single command terminator. If any of the responses involve data transmissions, each one is followed by an output terminator.

6.3.13 Status Byte, Prompts and Overload Byte

An important feature of the IEEE-488 standard is the serial poll operation by which a special byte, the status byte, may be read at any time from any instrument on the bus. This contains information which must be urgently conveyed from the instrument to the controller.

The function of the individual bits in the status byte is instrument dependent, apart from bit 6 (the request service bit) whose functions are defined by the standard.

In the model 7280, bits 0 and 7 signify "command complete" and "data available" respectively. In GPIB communications, the use of these bits can lead to a useful simplification of the control program by allowing the use of a single subroutine which is the same for all commands, whether or not they send a response over the bus. The subroutine should carry out the following sequence of events:

1) Send the command

2) Perform repeated serial poll operations in a loop until bit 0 (command complete) is zero. This implies that the command has been received by the instrument and is being processed. However, it is possible that if the command were a write-only

command and a slow computer were being used then the instrument may actually clear and then reset bit 0 (i.e. actually complete the command) before the first serial poll operation were executed. Hence the loop must include the provision to timeout under these conditions; a value of 10 ms should be satisfactory in most cases.

3) If bit 0 clears, perform repeated serial polls testing both bit 0 and bit 7 (data available) and, if bit 7 is asserted then perform a read operation. This cycle (i.e. test bit 0 (command complete) and test bit 7 (data available)) should then continue until the lock-in amplifier asserts bit 0 to indicate that the command-response sequence is complete, so that the instrument will then be ready for the next command.

This procedure, although apparently complex, deals successfully with compound commands and responses to the curve transfer commands.

In RS232 communications, comparatively rapid access to the status byte is provided by the prompt character which is sent by the lock-in amplifier at the same time as bit 0 becomes asserted in the status byte. This character is sent out by the lock-in amplifier after each command response (whether or not the response includes a transmission over the interface) to indicate that the response is finished and the instrument is ready for a new command. The prompt takes one of two forms. If the command contained an error, either in syntax or by a command parameter being out of range, or alternatively if an overload or reference unlock is currently being reported by the front panel indicators, the prompt is ? (ASCII 63). Otherwise the prompt is * (ASCII 42).

These error conditions correspond to the assertion of bits 1, 2, 3 or 4 in the status byte. When the ? prompt is received by the computer, the ST command may be issued in order to discover which type of fault exists and to take appropriate action.

The prompts are a rapid way of checking on the instrument status and enable a convenient keyboard control system to be set up simply by attaching a standard terminal, or a simple computer-based terminal emulator, to the RS232 port. Where the prompt is not required it can be suppressed by setting the noprompt bit, bit 4 in the RS232 parameter byte. The default (power-up) state of this bit is zero.

Because of the limited number of bits in the status byte, it can indicate that an overload exists but cannot give more detail. An auxiliary byte, the overload byte returned by the N command, gives details of the location of the overload.

A summary of the bit assignments in the status byte and the overload byte is given below.

Bit	Status Byte	Overload Byte
bit 0	command complete	not used
bit 1	invalid command	CH1 output overload
bit 2	command parameter error	CH2 output overload
bit 3	reference unlock	Y channel output overload
bit 4	overload	X channel output overload
bit 5	new ADC values available after external trigger	not used
bit 6	asserted SRQ	input overload
bit 7	data available	reference unlock

6.3.14 Service Requests

The interface defined by the IEEE-488 standard includes a line (pin 10 on the connector) called the SRQ (service request) line which is used by the instrument to signal to the controller that urgent attention is required. At the same time that the instrument asserts the SRQ line, it also asserts bit 6 in the status byte. The controller responds by executing a serial poll of all the instruments on the bus in turn and testing bit 6 of the status byte in order to discover which instrument was responsible for asserting the SRQ line. The status byte of that instrument is then further tested in order to discover the reason for the service request and to take appropriate action.

In the model 7280 the assertion of the SRQ line is under the control of a byte called the SRQ mask byte which can be set by the user with the MSK command or via the GPIB Settings menu. If any bit in the status byte becomes asserted, and the corresponding bit in the mask byte has a non-zero value, the SRQ line is automatically asserted. If the value of the mask byte is zero, the SRQ line is never asserted.

Hence, for example, if the SRQ mask byte is set to 16, a service request would be generated as soon as an overload occurred; if the SRQ mask byte were set to 0, then service requests would never be generated.

6.3.15 Communication Monitor Menu

A most useful feature of the model 7280 when troubleshooting communications problems is the Communications Monitor menu, which is described in detail in section 5.3.17. However, once the problem has been resolved it is recommended that the instrument be reset to Main Display mode to avoid slowing down communications.

6.4 Command Descriptions

This section lists the commands in logical groups, so that, for example, all commands associated with setting controls which affect the signal channel are shown together. Appendix G gives the same list of commands but in alphabetical order.

6.4.01 Signal Channel

IMODE [n] Current/Voltage mode input selector

The value of n sets the input mode according to the following table:

n	Input mode
0	Current mode off - voltage mode input enabled
1	Normal current mode enabled - connect signal to **B** input connector
2	Low noise current mode enabled - connect signal to **B** input connector
3	High bandwidth current mode enabled - connect signal to **B** input connector

If n = 0 then the input configuration is determined by the VMODE command.
If n > 0 then current mode is enabled irrespective of the VMODE setting.

VMODE [n] Voltage input configuration

The value of n sets up the input configuration according to the following table:

n	Input configuration
0	Both inputs grounded (test mode)
1	A input only
2	-B input only
3	A-B differential mode

Note that the IMODE command takes precedence over the VMODE command.

CP [n] Input connector coupling mode control

The value of n sets up the input coupling mode according to the following table:

n	Coupling mode
0	Fast
1	Slow

FLOAT [n] Input connector shield float/ground control

The value of n sets the input connector shield switch according to the following table:

n	Selection
0	Ground
1	Float (connected to ground via a 1 kΩ resistor)

SEN [n]
SEN. Full-scale sensitivity control

The value of n sets the full-scale sensitivity according to the following table, depending on the setting of the IMODE control:

n	full-scale sensitivity			
	IMODE=0	IMODE=1	IMODE=2	IMODE=3
3	10 nV	10 fA	n/a	1 pA
4	20 nV	20 fA	n/a	2 pA
5	50 nV	50 fA	n/a	5 pA
6	100 nV	100 fA	n/a	10 pA
7	200 nV	200 fA	n/a	20 pA
8	500 nV	500 fA	n/a	50 pA
9	1 µV	1 pA	10 fA	100 pA
10	2 µV	2 pA	20 fA	200 pA
11	5 µV	5 pA	50 fA	500 pA
12	10 µV	10 pA	100 fA	1 nA
13	20 µV	20 pA	200 fA	2 nA
14	50 µV	50 pA	500 fA	5 nA
15	100 µV	100 pA	1 pA	10 nA
16	200 µV	200 pA	2 pA	20 nA
17	500 µV	500 pA	5 pA	50 nA
18	1 mV	1 nA	10 pA	100 nA
19	2 mV	2 nA	20 pA	200 nA
20	5 mV	5 nA	50 pA	500 nA
21	10 mV	10 nA	100 pA	1 µA
22	20 mV	20 nA	200 pA	2 µA
23	50 mV	50 nA	500 pA	5 µA
24	100 mV	100 nA	1 nA	10 µA
25	200 mV	200 nA	2 nA	20 µA
26	500 mV	500 nA	5 nA	50 µA
27	1 V	1 µA	10 nA	100 µA

Floating point mode can only be used for reading the sensitivity, which is reported in volts or amps. For example, if IMODE = 0 and the sensitivity is 1 mV the command SEN would report 18 and the command SEN. would report +1.0E-03. If IMODE was changed to 1, SEN would still report 18 but SEN. would report +1.0E-09

AS Perform an Auto-Sensitivity operation

The instrument adjusts its full-scale sensitivity so that the magnitude output lies between 30% and 90% of full-scale.

ASM Perform an Auto-Measure operation

The instrument adjusts its full-scale sensitivity so that the magnitude output lies between 30% and 90% of full-scale, and then performs an auto-phase operation to maximize the X channel output and minimize the Y channel output.

ACGAIN [n] AC Gain control

Sets the gain of the signal channel amplifier according to the following table:-

n	AC Gain
0	0 dB
1	6 dB
2	14 dB
3	20 dB
4	26 dB
5	34 dB
6	40 dB
7	46 dB
8	54 dB
9	60 dB
10	66 dB

AUTOMATIC [n] AC Gain automatic control

The value of n sets the status of the AC Gain control according to the following table:

n	Status
0	AC Gain is under manual control, either using the front panel or the ACGAIN command
1	Automatic AC Gain control is activated, with the gain being adjusted according to the full-scale sensitivity setting

LF [n_1 n_2] Signal channel line frequency rejection filter control

The LF command sets the mode and frequency of the line frequency rejection (notch) filter according to the following tables:

n_1	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

n_2	Notch Filter Center Frequencies
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

6.4.02 Reference Channel

REFMODE [n] Reference mode selector

The value of n sets the reference mode of the instrument according to the following table:

n	Mode
0	Single Reference / Virtual Reference mode
1	Dual Harmonic mode
2	Dual Reference mode

NOTE: When in either of the dual reference modes the command set changes to accommodate the additional controls. These changes are detailed in section 6.4.14

IE [n] Reference channel source control (Internal/External)

The value of n sets the reference input mode according to the following table:

n	Selection
0	INT (internal)
1	EXT LOGIC (external rear panel TTL input)
2	EXT (external front panel analog input)

REFN [n] Reference harmonic mode control

The value of n sets the reference channel to one of the NF modes, or restores it to the default 1F mode. The value of n is in the range 1 to 32.

REFP[.] [n] Reference phase control

In fixed point mode n sets the phase in millidegrees in the range ±360000.

In floating point mode n sets the phase in degrees.

AQN Auto-Phase (auto quadrature null)

The instrument adjusts the reference phase to maximize the X channel output and minimize the Y channel output signals.

FRQ[.] Reference frequency meter

If the lock-in amplifier is in the external reference source modes, the FRQ command causes the lock-in amplifier to respond with 0 if the reference channel is unlocked, or with the reference input frequency if it is locked.

If the lock-in amplifier is in the internal reference source mode, it responds with the frequency of the internal oscillator.

In fixed point mode the frequency is in mHz.

In floating point mode the frequency is in Hz.

LOCK System lock control

Updates all frequency-dependent gain and phase correction parameters.

VRLOCK [n] Virtual reference mode lock

The Seek option of the frequency sweep mode must be used before issuing this command, for which the value of n has the following significance:

n	Mode
0	Disables virtual reference mode
1	Enters virtual reference mode by enabling tracking of the signal frequency

6.4.03 Signal Channel Output Filters

NOISEMODE [n] Noise Measurement Mode control

The value of n sets the noise measurement mode according to the following table:

n	Function
0	Noise measurement mode off
1	Noise measurement mode on.

When the noise measurement mode is turned on, the output filter time constant is automatically adjusted until it lies in the range 500 µs to 10 ms inclusive, the synchronous time constant control is turned off, and the output filter slope is set to 12 dB/octave if it had previously been 18 or 24 dB/octave.

NNBUF [n] Noise Buffer Length control

The value of n sets the noise buffer length according to the following table:

n	Function
0	Noise buffer off
1	1 second noise buffer
2	2 second noise buffer
3	3 second noise buffer
4	4 second noise buffer

SLOPE [n] Output low-pass filter slope (roll-off) control

When the fast analog output mode and Noise Measurement mode are turned off (FASTMODE 0 and NOISEMODE 0), the selection is according to the following table:

n	Slope	
0	6 dB/octave	
1	12 dB/octave	
2	18 dB/octave	(TC ≥ 500 µs)
3	24 dB/octave	(TC ≥ 500 µs)

When:

a) The fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, or

b) Noise measurement mode is turned ON (NOISEMODE 1)

the selection is according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is according to the following table:

n	Slope
0	6 dB/octave

TC [n]
TC. Filter time constant control

The value of n sets the output filter time constant in accordance with the following table:

n	FASTMODE = 0, NOISEMODE = 0 time constant	FASTMODE = 1, NOISEMODE = 0 time constant	FASTMODE = 0, NOISEMODE = 1 time constant	FASTMODE = 1, NOISEMODE = 1 time constant
0	N/A	1 µs	N/A	N/A
1	N/A	2 µs	N/A	N/A
2	N/A	5 µs	N/A	N/A
3	N/A	10 µs	N/A	N/A
4	N/A	20 µs	N/A	N/A
5	N/A	50 µs	N/A	N/A
6	N/A	100 µs	N/A	N/A
7	N/A	200 µs	N/A	N/A
8	500 µs	500 µs	500 µs	500 µs
9	1 ms	1 ms	1 ms	1 ms
10	2 ms	2 ms	2 ms	2 ms
11	5 ms	4 ms	5 ms	4 ms
12	10 ms	10 ms	10 ms	10 ms
13	20 ms	20 ms	N/A	N/A
14	50 ms	50 ms	N/A	N/A
15	100 ms	100 ms	N/A	N/A
16	200 ms	200 ms	N/A	N/A
17	500 ms	500 ms	N/A	N/A
18	1 s	1 s	N/A	N/A
19	2 s	2 s	N/A	N/A
20	5 s	5 s	N/A	N/A
21	10 s	10 s	N/A	N/A
22	20 s	20 s	N/A	N/A
23	50 s	50 s	N/A	N/A
24	100 s	100 s	N/A	N/A
25	200 s	200 s	N/A	N/A
26	500 s	500 s	N/A	N/A
27	1 ks	1 ks	N/A	N/A
28	2 ks	2 ks	N/A	N/A
28	5 ks	5 ks	N/A	N/A
30	10 ks	10 ks	N/A	N/A
31	20 ks	20 ks	N/A	N/A
32	50 ks	50 ks	N/A	N/A
33	100 ks	100 ks	N/A	N/A

N/A means that n is an illegal value under these conditions.

The TC. command is only used for reading the time constant, and reports the current setting in seconds. Hence if a TC 15 command were sent and the noise measurement mode was turned off, TC would report 15 and TC. would report 1.0E-01, i.e. 0.1 s or 100 ms.

SYNC [n] Synchronous time constant control

At reference frequencies below 10 Hz, if the synchronous time constant is enabled, then the actual time constant of the output filters is not generally the selected value T but rather a value equal to an integer number of reference cycles. If T is greater than 1 cycle, the time constant is between T/2 and T. The parameter n has the following significance:

n	Effect
0	Synchronous time constant disabled
1	Synchronous time constant enabled

6.4.04 Signal Channel Output Amplifiers

XOF [n_1 [n_2]] X channel output offset control

The value of n_1 sets the status of the X offset facility according to the following table:

n_1	Selection
0	Disables offset
1	Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

YOF [n_1 [n_2]] Y channel output offset control

The value of n_1 sets the status of the Y offset facility according to the following table:

n_1	Selection
0	Disables offset facility
1	Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

AXO Auto-Offset

The X and Y channel output offsets are turned on and set to levels giving zero X and Y channel outputs. Any changes in the input signal then appear as changes about zero in the outputs.

EX [n] Output expansion control

Expands X and/or Y channel outputs by a factor of 10. Changes bar-graphs, **CH1** and **CH2** outputs full-scale to ±1000% if X or Y selected. The value of n has the following significance:

n	Expand mode
0	Off
1	Expand X
2	Expand Y
3	Expand X and Y

FASTMODE [n] Analog Output Mode Control

The value of n sets the fast analog output mode control according to the following table:

n	Function
0	Fast mode off
1	Fast mode on

When the fast analog output mode is turned on, the available settings for the **CH1/CH2** analog output controls are restricted, and hence affect the allowable parameter range for CH1 and CH2 commands. It also restricts the available range of output filter slope settings, limits the full-scale sensitivity to a maximum of 100 µV and restricts the range of AC Gain settings if the AC Gain Automatic control is turned off. The effect is that the instrument's dynamic reserve is limited to a maximum value of 15 dB.

When fast mode is turned off, the output filter time constant is restricted to values of 500 µs and longer, but the other restrictions on output filter slope, sensitivity and AC gain are removed.

CH n_1 [n_2] Analog output control

Defines what outputs appear on the **CH1** and **CH2** connectors on the rear panel.

When the fast analog output mode is turned off (FASTMODE 0), the selection is according to the following table:

n_2	Signal
0	X % (2.5 V FS)
1	Y % (2.5 V FS)
2	Magnitude % (2.5 V FS)
3	Phase 1: +9 V = +180°, -9 V = -180°
4	Phase 2: +9 V = 360°, - 9 V = 0°
5	Noise % (2.5 V FS)
6	Ratio: (10 × X%/ADC 1)
7	Log Ratio: $\log_{10}$ (10 × X%/ADC1)
8	Equation 1
9	Equation 2

Dual modes only:-

10	X2 % (2.5 V FS)
11	Y2 % (2.5 V FS)
12	Magnitude2 %FS
13	Phase2 1: +9 V = +180°, -9 V = -180°
14	Phase2 2: +9 V = 360°, -9 V = 0°

n_1 is compulsory and is either 1 for CH1 or 2 for CH2

Note: n_2 = 5 is only permitted if the noise measurement mode is on (NOISEMODE 1) or if the present settings of output filter slope and time constant are within the permitted range and the synchronous time constant control is off.

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, the selection is according to the following tables:

n_1 = 1 (i.e. CH1 output)
n_2 Signal
0 X % (2.5 V FS)

n_1 2 (i.e. CH2output)
n_2 Signal
1 Y % (2.5 V FS)
2 Magnitude % (2.5 V FS)

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is fixed according to the following tables:

n_1 = 1 (i.e. CH1 output)
n_2 Signal
0 X1 % (2.5 V FS)

n_1 2 (i.e. CH2output)
n_2 Signal
10 X2 % (2.5 V FS)

6.4.05 Instrument Outputs

X[.] X channel output
In fixed point mode causes the lock-in amplifier to respond with the X demodulator output in the range ±30000, full-scale being ±10000.

In floating point mode causes the lock-in amplifier to respond with the X demodulator output in volts or amps.

XER X channel output - enhanced resolution
This command, which is only active when the X channel × 10 output expansion is turned ON, causes the lock-in amplifier to respond with the X demodulator output in the range ±300000, full-scale being ±100000. No floating-point version of the command is available.

Y[.] Y channel output
In fixed point mode causes the lock-in amplifier to respond with the Y demodulator output in the range ±30000, full-scale being ±10000.

In floating point mode causes the lock-in amplifier to respond with the Y demodulator output in volts or amps.

YER Y channel output - enhanced resolution
This command, which is only active when the Y channel × 10 output expansion is turned ON, causes the lock-in amplifier to respond with the Y demodulator output in the range ±300000, full-scale being ±100000. No floating-point version of the command is available.

XY[.] X, Y channel outputs

Equivalent to the compound command X[.];Y[.]

XYER X, Y channel outputs - enhanced resolution

Equivalent to the compound command XER;YER. Active only when both X and Y $\times$ 10 output expansion is turned ON.

MAG[.] Magnitude

In fixed point mode causes the lock-in amplifier to respond with the magnitude value in the range 0 to 30000, full-scale being 10000.

In floating point mode causes the lock-in amplifier to respond with the magnitude value in the range +3.000E0 to +0.001E-9 volts or +1.000E-4 to +0.001E-15 amps.

PHA[.] Signal phase

In fixed point mode causes the lock-in amplifier to respond with the signal phase in centidegrees, in the range ±18000.

In floating point mode causes the lock-in amplifier to respond with the signal phase in degrees.

MP[.] Magnitude, phase

Equivalent to the compound command MAG[.];PHA[.]

RT[.] Ratio output

In integer mode the RT command reports a number equivalent to 1000×X/ADC1 where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command.

In floating point mode the RT. command reports a number equivalent to X/ADC1.

LR[.] Log Ratio output

In integer mode, the LR command reports a number equivalent to 1000×log(X/ADC1) where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command. The response range is -3000 to +2079

In floating point mode, the LR. command reports a number equivalent to log(X/ADC1). The response range is -3.000 to +2.079

NHZ.

Causes the lock-in amplifier to respond with the square root of the noise spectral density measured at the Y channel output, expressed in volt/√Hz or amps/√Hz referred to the input. This measurement assumes that the Y channel output is Gaussian with zero mean. (Section 3.3.16). The command is only available in floating point mode.

ENBW[.] Equivalent noise bandwidth

In fixed point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in microhertz.

In floating point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in hertz.

NN[.] Noise output

In fixed point mode causes the lock-in amplifier to respond with the mean absolute value of the Y channel output in the range 0 to 12000, full-scale being 10000. If the mean value of the Y channel output is zero, this is a measure of the output noise.

In floating point mode causes the lock-in amplifier to respond in volts.

DEFEQU [n_1 n_2 n_3 n_4 n_5 n_6] Define user equation

The DEFEQU command is used to define the user equations, which take the following form:

$$\text{Equation} = \left(\frac{(A \pm B) \times C}{D}\right)$$

Parameter n_1 is used to specify the equation to be modified, and is either 1 for Equation 1 or 2 for Equation 2.

Parameter n_3 is used to set the addition/subtraction operator in the numerator according to the following table:-

n_3	Operator
0	Subtraction
1	Addition

The parameters n_2, n_4, n_5 and n_6 specify the variables A, B, C and D respectively according to the following table:

n	Variable	Range
0	X or X1	±30000
1	Y or Y1	±30000
2	MAG or MAG1	0 to 30000
3	PHA or PHA1	±18000
4	ADC1	±10000
5	ADC2	±10000
6	ADC3	±10000
7	ADC4	±10000
8	C1	0 to 100000
9	C2	0 to 100000
10	0	zero
11	1	unity
12	FRQ	0 to 2000000000 (i.e. reference frequency in mHz)*
13	OSC	0 to 2000000000 (i.e. oscillator frequency in mHz)*
Dual modes only:-		
14	X2	±30000
15	Y2	±30000
16	MAG2	0 to 30000
17	PHA2	±18000

*Parameter n_5 is the only one that can be set to values of 12 or 13.

EQU n Output result of equation #1 or equation #2

The value returned is the output of the user equation #1 (n = 1) or equation #2 (n = 2), where the equations are defined using the Equation Setup menus (see section 5.3.09). The possible range is ±2,147,483,647 (signed 32-bit integer).

? Fast Data Transfer command

The ? command offers a method of reading a combination of instrument outputs which are sampled at the same time, thereby ensuring that they are correlated.

The response to the ? command is the output(s), expressed in floating point mode, specified by the present setting of the Curve Buffer Define (CBD) command (see section 6.4.09) and separated by delimiter character(s) defined by the DD command. Hence for example, if CBD is set to 19, the response to the ? command will be:

<X output, in floating point mode><delimiter>
<Y output, in floating point mode><terminator>

6.4.06 Internal Oscillator

OA[.] [n] Oscillator amplitude control

In fixed point mode n sets the oscillator amplitude in millivolts. The range of n is 0 to 1000 representing 0 to 1 V rms.

In floating point mode n sets the amplitude in volts.

ASTART[.] [n] Oscillator amplitude sweep start amplitude

Sets the start amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

ASTOP[.] [n] Oscillator amplitude sweep stop amplitude

Sets the stop amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V
In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

ASTEP[.] [n] Oscillator amplitude sweep step size

Sets the amplitude step size for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

OF[.] [n] Oscillator frequency control

In fixed point mode n sets the oscillator frequency in mHz. The range of n is 0 to 2000,000,000 representing 0 to 2.000 MHz.

In floating point mode n sets the oscillator frequency in Hz. The range of n is 0 to 2.0E6

FSTART[.] [n] Oscillator frequency sweep start frequency

Sets the start frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz and in floating point mode n is in hertz.

FSTOP[.] [n] Oscillator frequency sweep stop frequency

Sets the stop frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz and in floating point mode n is in hertz.

FSTEP[.] [n_1 n_2] Oscillator frequency sweep step size and type

The frequency may be swept either linearly or logarithmically, as specified by parameter n_2. The step size is specified by parameter n_1.

Log sweep $n_2 = 0$

In fixed point mode, n_1 is the step size in thousandths of a percent.

In floating point mode n_1 is in percent. The range of n_1 is 0 to 100.00%

Linear sweep $n_2 = 1$

In fixed point mode, n_1 is the step size in millihertz.

In floating point mode n_1 is in hertz. The range of n_1 is 0 to 10 kHz

Linear seek sweep $n_2 = 2$

In fixed point mode, n_1 is the step size in millihertz.

In floating point mode n_1 is in hertz. The range of n_1 is 0 to 10 kHz

The seek sweep mode automatically stops when the signal magnitude exceeds 50% of full scale. This mode is most commonly used when setting up the virtual reference mode.

SRATE[.] [n] Oscillator frequency and amplitude sweep step rate

Sets the sweep rate in milliseconds per step according to the following table:

Analog Outputs Mode	Legal range for n
NORMAL	1 to 1000000 (1 ms to 1000 s)
FAST	140 to 1000000 (140 ms to 1000 s)

SWEEP [n] Oscillator frequency and amplitude sweep control

n	Sweep status
0	Stop
1	Start/continue frequency sweep
2	Start/continue amplitude sweep
3	Start/continue frequency sweep and amplitude sweep
5	Pause frequency sweep
6	Pause amplitude sweep
7	Pause frequency sweep and amplitude sweep
9	Link frequency sweep to curve buffer acquisition

10 Link amplitude sweep to curve buffer acquisition
11 Link frequency and amplitude sweep to curve buffer acquisition

This command is used to start or stop the internal oscillator frequency or amplitude sweep, or to specify that the sweep should be linked to the curve buffer data acquisition.

In the normal mode, when a frequency and/or amplitude sweep has been defined, applying SWEEP with a parameter of 1 2 or 3 will start it. The sweep can be paused using the command with the correct value of n for the sweep in progress. For example, if a frequency sweep is started using SWEEP 1 then it can only be paused by sending SWEEP 5. Similarly, it can only be continued by sending SWEEP 1. The command SWEEP 0 will, however, stop either or both types of sweep.

When n is equal to 9, 10 or 11 the instrument is set to link the oscillator frequency and/or amplitude sweeps to the curve buffer. The SWEEP command continues to function as a write/read command except when the curve buffer acquisition is actually running. In such cases, the SWEEP command changes to read-only and will only report values of 9, 10 or 11, indicating what type of linking is active. The sweep can then only be stopped by stopping the curve buffer, using the HC command. However, the user can still determine the progress of the sweep using the curve buffer monitor “M” command and the OF and/or OA (oscillator frequency and amplitude) commands.

6.4.07 Auxiliary Outputs

DAC[.] n_1 [n_2]   Auxiliary DAC output controls

Sets the voltage appearing at the **DAC1** and **DAC2** outputs on the rear panel.

The first parameter n_1, which specifies the DAC, is compulsory and is either 1 or 2. The value of n_2 specifies the voltage to be output.

In fixed point mode it is an integer in the range -12000 to +12000, corresponding to voltages from -12.000 V to +12.000 V, and in floating point mode it is in volts.

PORTDIR [n]   Digital port direction control

The value of n determines which of the eight lines on the digital port are configured as inputs and which as outputs. The parameter n is a decimal number whose bit-wise interpretation defines whether the corresponding line is an input or output. The line is an input if the corresponding bit is a “1”. For example:

n	status
0	All lines configured as inputs
1	D0 = output, D1 - D7 = inputs
2	D1 = output, D0 and D2 - D7 = inputs
4	D2 = output, D0 - D1 and D3 - D7 = inputs
8	D3 = output, D0 - D2 and D4 - D7 = inputs
16	D4 = output, D0 - D3 and D5 - D7 = inputs
32	D5 = output, D0 - D4 and D6 - D7 = inputs
64	D6 = output, D0 - D5 and D7 = inputs
128	D7 = output, D0 - D6 inputs
255	All lines configured as outputs

BYTE [n] Digital port output control

The value of n, in the range 0 to 255, determines the bits to be output on those lines of the rear panel digital port that are configured as outputs. Hence, for example, if PORTDIR = 8 and BYTE = 0, all outputs are low, and when BYTE = 255, all are high.

READBYTE Read digital port input

The response to the READBYTE command is an integer between 0 and 255 representing the binary value of all eight lines of the rear panel digital port. Hence, for example, if PORTDIR = 0 and the response to READBYTE is 255, then all lines are high, and if the response to READBYTE is 0, then all lines are low. Note that because the command does not differentiate between whether a line is configured as an input or output, it can be used as a single command to determine the present status of all eight lines, both inputs and outputs, of the port.

6.4.08 Auxiliary Inputs

ADC[.] n Read auxiliary analog-to-digital inputs

Reads the voltage appearing at the **ADC1** (n = 1), **ADC2** (n = 2), **ADC3** (n = 3) or **ADC4** (n = 3) inputs on the rear panel.

The response is an integer in the range -12000 to +12000, corresponding to voltages from -12.000 V to +12.000 V, and in floating point mode it is in volts.

TADC [n] Auxiliary ADC trigger mode control

The value of n sets the trigger mode of two of the auxiliary **ADC** inputs according to the following table:

n	Trigger mode
0	Asynchronous (5 ms intervals)
1	External ADC1 and ADC 2 (rear panel **TRIG** input)
2	Burst mode, 25 µs/point, triggered by command (ADC1 only)
3	Burst mode, 56 µs/point, triggered by command (ADC1 and ADC2)
4	Burst mode, variable rate, triggered by command (ADC1 only)
5	Burst mode, variable rate, triggered by command (ADC1 and ADC2)
6	Burst mode, 25 µs/point, External trigger with < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
7	Burst mode, 56 µs/point, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
9	Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 and ADC2)
10	Burst mode, 25 µs/point, External trigger with < 25 µs trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
11	Burst mode, 56 µs/point, External trigger with < 25 µs trigger indeterminacy(rear panel **TRIG** input) (ADC1 and ADC2)
12	Burst mode, variable rate, External trigger with < 25 µs trigger indeterminacy(rear panel **TRIG** input) (ADC1 only)
13	Burst mode, variable rate, External trigger with < 25 µs trigger indeterminacy(rear panel **TRIG** input) (ADC1 and ADC2)

In the burst modes, data is stored in the curve buffer. Use the LEN command to set the number of points required. Note that it may be necessary to enter CBD 256 before setting the length, if the curve buffer has previously been used for more than one data type. The data is read out from the buffer using DC[.] 8 for ADC1 and DC[.] 9 for ADC2. If the length is set to more than 16384 and a burst mode which stores both ADC1 and ADC2 is specified then the curve length will automatically be reduced to 16384 points. Note also that setting the TADC parameter to any value other than 0 or 1 affects the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 256
3	automatically set to 768
4	automatically set to 256
5	automatically set to 768
6	automatically set to 256
7	automatically set to 768
8	automatically set to 256
9	automatically set to 768
10	automatically set to 256
11	automatically set to 768
12	automatically set to 256
13	automatically set to 768

The maximum sampling rate depends on the number of ADC inputs used, and is either 25 µs when sampling ADC1 only, or 56 µs when sampling both ADC1 and ADC2.
In the Variable Rate modes, the sampling speed is set by the BURSTTPP (burst time per point) command.

NOTE: TADC modes 10 to 13 cause all other functions of the host microprocessor to be suspended, including responding to computer commands, until a trigger is received at the TRIG input. Hence they should only be used when the user is certain that such a trigger will occur.

BURSTTPP [n]   Sets the burst mode time per point rate for ADC1 and ADC2
n sets the time per point for the Variable Rate burst modes in microseconds, as follows:-

When storing only to ADC1:
(i.e. TADC 2, TADC 4, TADC 6, TADC 8, TADC10 and TADC12)

$25 \leq n \leq 5000$

When storing to ADC1 and ADC 2:
(i.e. TADC 3, TADC 5, TADC 7, TADC 9, TADC11 and TADC13)

$56 \leq n \leq 5000$

6.4.09 Output Data Curve Buffer

CBD [n] Curve buffer define

Defines which data outputs are stored in the curve buffer when subsequent TD (take data), TDT (take data triggered) or TDC (take data continuously) commands are issued. Up to 17 (or 22 in dual reference and dual harmonic modes) curves, or outputs, may be acquired, as specified by the CBD parameter.

The CBD parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary word. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit is asserted, the corresponding output is selected for storage. When a bit is negated, the output is not stored. The bit function and range for each output are shown in the table below:

Bit	Decimal value	Output and range
0*	1	X Output (±10000 FS)
1*	2	Y Output (±10000 FS)
2*	4	Magnitude Output (0 to +10000 FS)
3*	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5*	32	Noise (0 to +10000 FS)
6*	64	Ratio (±10000 FS)
7*	128	Log ratio (-3000 to +2000)
8*	256	ADC1 (±10000 = ±10.0 V)
9*	512	ADC2 (±10000 = ±10.0 V)
10*	1024	ADC3 (±10000 = ±10.0 V)
11*	2048	ADC4 (±10000 = ±10.0 V)
12*	4096	DAC1 (±10000 = ±10.0 V)
13*	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency bits 0 to 15 (millihertz)
16	65536	Reference frequency bits 16 to 31 (millihertz)
Dual modes only:-		
17	131072	X_2 Output (±10000 FS)
18	262144	Y_2 Output (±10000 FS)
19	524288	Magnitude2 Output (0 to +10000 FS)
20	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

32768 points are available for data storage, shared equally between the specified curves. For example, if 16 outputs are stored then the maximum number of storage points would be 2048 (i.e. 32768/16). The only exception to this rule is that the Frequency curve (curves 15 and 16) occupies the equivalent of any two other curves. The LEN command sets the actual curve length, which cannot therefore be longer than 32768 divided by the number of curves selected. If more curves are requested than can be stored with the current buffer length, then the buffer length will be automatically reduced. Its actual length can of course be determined by sending the LEN command without a parameter.

The reason why bit 4 and, for dual reference modes, bit 21, which store both the sensitivity and the IMODE setting, are needed, is to allow the instrument to transfer the acquired curves to the computer in floating point mode. Without this information, the unit would not be able to determine the correct calibration to apply.

Note that the CBD command directly determines the allowable parameters for the DC, DCB and DCT commands. It also interacts with the LEN command and affects the values reported by the M command.

Since the reference frequency requires 32-bit wide data points, it occupies two curve positions. For ease of use, if bit 15 is selected for storage then bit 16 will be automatically selected as well, and vice-versa.

NOTE: At least one of the curves selected for storage in the curve buffer must be chosen from those marked with an asterisk(*) in the above table.

LEN [n] Curve length control

The value of n sets the curve buffer length in effect for data acquisition. The maximum permitted value depends on the number of curves requested using the CBD command, and a parameter error results if the value given is too large. For this reason, if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.

NC New curve

Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

STR [n] Storage interval control

Sets the time interval between successive points being acquired under the TD or TDC commands. n specifies the time interval in milliseconds with a resolution of 1 ms. The longest interval that can be specified is 1000000 s corresponding to one point in about 12 days.

TD Take data

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10 or 100, then this sweep will be started as well.

TDT n Take data triggered

Sets the instrument so that data acquisition will be initiated on receipt of a trigger at the **TRIG** connector on the rear panel. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10 or 100, then this sweep will be started as well.
Two triggered modes are possible, as set by the value of n:

n	function
0	One complete curve or set of curves, each one consisting of the number of points specified by the LEN command parameter, is acquired for each trigger
1	One data point or set of data points is acquired for each trigger. Hence in order to

store a complete curve or set of curves, the number of triggers applied must equal the number of points specified by the LEN command parameter. Note that in this mode the maximum trigger rate is 1000 Hz and the storage interval control setting has no effect.

TDC Take data continuously

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until halted by an HC command. The buffer is circular in the sense that when it has been filled, new data overwrites earlier points.

EVENT [n] Event marker control

During a curve acquisition, if bit 13 in the CBD command has been asserted, the lock-in amplifier stores the value of the Event variable at each sample point. This can be used as a marker indicating the point at which an experimental parameter was changed. The EVENT command is used to set this variable to any value between 0 and 32767.

HC Halt curve acquisition

Halts curve acquisition in progress. It is effective during both single (data acquisition initiated by TD command) and continuous (data acquisition initiated by TDC command) curve acquisitions. The curve may be restarted by means of the TD, TDT or TDC command, as appropriate. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10 or 100, then this sweep will be stopped as well.

M Curve acquisition status monitor

Causes the lock-in amplifier to respond with four values that provide information concerning data acquisition, as follows:

First value, Curve Acquisition Status: a number with five possible values, defined by the following table:

First Value	Significance
0	No curve activity in progress.
1	Acquisition via TD command in progress and running.
2	Acquisition via TDC command in progress and running.
5	Acquisition via TD command in progress but halted by HC command.
6	Acquisition via TDC command in progress but halted by HC command.

Second value, Number of Sweeps Acquired: This number is incremented each time a TD is completed and each time a full cycle is completed on a TDC acquisition. It is zeroed by the NC command and also whenever a CBD or LEN command is applied without parameters.

Third value, Status Byte: The same as the response to the ST command. The number returned is the decimal equivalent of the status byte and refers to the previously applied command.

Fourth value, Number of Points Acquired: This number is incremented each time a point is taken. It is zeroed by the NC command and whenever CBD or LEN is applied without parameters.

DC[.] n Dump acquired curve(s) to computer

In fixed point mode, causes a stored curve to be dumped via the computer interface in decimal format.

In floating point mode the SEN curve (bit 4 in CBD) must have been stored if one or more of the following outputs are required in order that the lock-in amplifier can perform the necessary conversion from %FS to volts or amps:- X, Y, Magnitude, Noise. Similarly, if the dual reference or harmonic modes are active then the SEN2 curve (bit 21 in CBD) must have been stored in order to perform a similar conversion from %FS to volts or amps for X2, Y2 and Magnitude2.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16, or 0 to 21 if a dual mode is active. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DC 0 would transfer the X channel output curve and DC 2 the Magnitude curve.

NOTE: When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.

The computer program's subroutine which reads the responses to the DC command needs to run a program loop that continues until all the data has been transferred.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DC command, perform repeated serial polls until bit 7 is set, indicating that the instrument has an output waiting to be read. Then perform repeated reads in a loop, waiting each time until bit 7 is set indicating that a new value is available. The loop should continue until bit 1 is set, indicating that the transfer is completed.

DCT n Dump acquired curves to computer in tabular format

This command is similar to the DC command described above, but allows transfer of several curves at a time and only operates in fixed point mode. Stored curve(s) are transferred via the computer interface in decimal format.

In single reference mode, the DCT parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary number. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit in the number is asserted, the corresponding curve is selected for transfer. When a bit is negated, the curve is not transferred. The bit corresponding to each curve is shown in the table below:

Bit	Decimal value	Output and range
0	1	X Output (±10000 FS)
1	2	Y Output (±10000 FS)
2	4	Magnitude Output (0 to +10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5	32	Noise (0 to +10000 FS)
6	64	Ratio (±10000 FS)
7	128	Log ratio (-3000 to +2000)
8	256	ADC1 (±10000 = ±10.0 V)
9	512	ADC2 (±10000 = ±10.0 V)
10	1024	ADC3 (±10000 = ±10.0 V)
11	2048	ADC4 (±10000 = ±10.0 V)
12	4096	DAC1 (±10000 = ±10.0 V)
13	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency (millihertz)
Dual modes only:-		
17	131072	X_2 Output (±10000 FS)
18	262144	Y_2 Output (±10000 FS)
19	524288	Magnitude2 Output (0 to +10000 FS)
20	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

The values of the selected curves at the same sample point are transferred as a group in the order of the above table, separated by the chosen delimiter character and terminated with the selected terminator. This continues until all the points have been transferred.

NOTE: When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.

DCB n Dump acquired curve(s) to computer in binary format

This command causes a stored curve to be dumped via the computer interface in binary format, using two bytes per point. All curves other than the lower 16-bits of the reference frequency curve (curve 15) use 16-bit 2's complement encoding, and all data points are sent with the MSB first. The number of data bytes sent is therefore equal to twice the current curve length. Each point is sent in fixed point mode, there being no floating point version of the command, and hence if floating point values are required the user may need to additionally store and read the Sensitivity curve and then perform the correction in his own software. In order to achieve the maximum transfer rate, no terminators are used within the transmission, although the response is terminated normally at the end.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16 in Single Reference Mode, and 0 to 21 in the dual modes. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and

Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DCB 0 would transfer the X channel output curve and DCB 2 the Magnitude curve.

Curves 15 and 16 store the reference frequency in millihertz. When using the DCB command (although not with the other curve transfer commands), both curves need to be transferred separately. They should then be converted to two arrays of integer values, allowing for the fact that the data points in curve 15 are unsigned 16-bit values, while those in curve 16 are signed 2's complement 16-bit values (although in practice they are never negative). Finally they should be assembled into a single curve using the following algorithm:

Reference Frequency = (65536 × value in Curve 16) + (value in Curve 15)

The computer program's subroutine which reads the responses to the DCB command needs to be able to handle the potentially very large data blocks (64 k bytes in the case of one 32 k curve) that can be generated.

NOTE: When using RS232 communications, the interface must be set to use 8 data bit transmission.

6.4.10 Computer Interfaces (RS232 and GPIB)

RS [n_1 [n_2]] Set/read RS232 interface parameters

The value of n_1 sets the baud rate of the RS232 interface according to the following table:

n_1	Baud rate (bits per second)
0	75
1	110
2	134.5
3	150
4	300
5	600
6	1200
7	1800
8	2000
9	2400
10	4800
11	9600
12	19200

The lowest five bits in n_2 control the other RS232 parameters according to the following table:

bit number	bit negated	bit asserted
0	data + parity = 8 bits	data + parity = 9 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

GP [n_1 [n_2]] Set/Read GPIB parameters

n_1 sets the GPIB address in the range 0 to 31

n_2 sets the GPIB terminator and the test echo function according to the following table:

n	Terminator
0	[CR], test echo disabled
1	[CR], test echo enabled
2	[CR,LF], test echo disabled
3	[CR,LF], test echo enabled
4	no terminator, test echo disabled
5	no terminator, test echo enabled

In all cases the EOI line is asserted with the last byte of a response.

When the test echo is on, every character transmitted or received via the GPIB port is echoed to the RS232 port. This is provided solely as an aid to program development and should not be enabled during normal operation of the instrument.

RSADD [n] Set/read RS232 address

The value of n sets the RS232 address in the range 0 to 15. This is relevant only when using more than one instrument connected via the RS232 “daisy-chain” method. Each instrument must be set to a unique address.

\N n Address command

When the model 7280 is daisy-chained with other compatible instruments this command will change which instrument is addressed. All daisy-chained instruments receive commands but only the currently addressed instrument will implement or respond to the commands. The exception is the \N n command. If n matches the address set from the front panel or via the RSADD command the instrument will switch into addressed mode. If n does not match the address set from the front panel the instrument will switch into unaddressed mode. Note that the \N n command does not change the address of an instrument but which instrument is addressed.

NOTE: All instruments must have a unique address.

DD [n] Define delimiter control

The value of n, which can be set to 13 or from 32 to 125, determines the ASCII value of the character sent by the lock-in amplifier to separate two numeric values in a two-value response, such as that generated by the MP (magnitude and phase) command.

ST Report status byte

Causes the lock-in amplifier to respond with the status byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

Bit 0	Command complete
Bit 1	Invalid command
Bit 2	Command parameter error
Bit 3	Reference unlock
Bit 4	Overload

Bit 5 New ADC values available after external trigger
Bit 6 Asserted SRQ
Bit 7 Data available

NOTE: this command is not normally used in GPIB communications, where the status byte is accessed by performing a serial poll.

N Report overload byte

Causes the lock-in amplifier to respond with the overload byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

Bit 0 not used
Bit 1 CH1 output overload (> ±300 %FS)
Bit 2 CH2 output overload (> ±300 %FS)
Bit 3 Y channel output overload (> ±300 %FS)
Bit 4 X channel output overload (> ±300 %FS)
Bit 5 not used
Bit 6 input overload
Bit 7 reference unlock

MSK [n] Set/read service request mask byte

The value of n sets the SRQ mask byte in the range 0 to 255

REMOTE [n] Remote only (front panel lock-out) control

Allowed values of n are 0 and 1. When n is equal to 1, the lock-in amplifier enters remote only mode in which the front panel control functions are inoperative and the instrument can only be controlled with the RS232 or the GPIB interfaces. When n is equal to 0, the front panel controls function normally.

6.4.11 Instrument Identification

ID Identification

Causes the lock-in amplifier to respond with the number 7280.

VER Report firmware version

Causes the lock-in amplifier to respond with the firmware version number. The firmware version number is the number displayed on the Configuration menu.

6.4.12 Front Panel

LTS [n] Display on/off control

The value of n controls the front panel electroluminescent display according to the following table:

n	Selection
0	Display off
1	Normal operation

6.4.13 Auto Default

ADF n Auto Default command

This command will automatically set all the instrument controls and displays to the predefined states. The value of n is used to define what controls are affected, according to the following table:

n	effect
0	Complete reset to factory set default values (listed in appendix E), equivalent to using the front-panel Auto Default function. However, if this command is used when the interface parameters are at values other than their default settings, then communication will be lost.
1	Reset to factory set default values (listed in appendix E), with the exception of the RS232 and GPIB communications interface settings.

6.4.14 Dual Mode Commands

When either dual reference or dual harmonic modes are selected, some commands change so that both channels can be controlled independently, as listed in the following table:

Single Reference or Virtual Reference mode command	Dual Reference or Dual Harmonic mode command
EX	not available
MAG[.]	MAG1[.] MAG2[.]
MP[.]	MP1[.] MP2[.]
PHA[.][n]	PHA1[.][n] PHA2[.][n]
REFP[.][n]	REFP1[.][n] REFP2[.][n]
REFN[n]	REFN1[n] REFN2[n] (n = 1 in dual reference mode)
SEN[.][n]	SEN1[.][n] SEN2[.][n]
SLOPE[n]	SLOPE1[n] SLOPE2[n]
SWEEP	not available
TC[.][n]	TC1[.][n] TC2[.][n]
X[.]	X1[.] X2[.]
XOF[n_1[n_2]]	XOF1[n_1[n_2]] XOF2[n_1[n_2]]
XY[.]	XY1[.] XY2[.]
Y[.]	Y1[.] Y2[.]
YOF[n_1[n_2]]	YOF1[n_1[n_2]] YOF2[n_1[n_2]]
AQN	AQN1 AQN2
AS	AS1 AS2

AXO	AXO1 AXO2

6.5 Programming Examples

6.5.01 Introduction

This section gives some examples of the commands that need to be sent to the lock-in amplifier for typical experimental situations.

6.5.02 Basic Signal Recovery

In a typical simple experiment, the computer is used to set the instrument controls and then to record the chosen outputs, perhaps as a function of time. At sampling rates of up to a few points per second, there is no need to use the internal curve buffer. The commands to achieve this would therefore be similar to the following sequence:

IE 2	Set reference to external front panel input
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 kΩ to ground
LF 0 0	Turn off line frequency rejection filter
ASM	Auto-Measure (assumes reference frequency > 1 Hz)
TC 16	Set time constant to 200 ms, since previous ASM changed it

Then the outputs could be read as follows:

X.	Reads X channel output in volts
Y.	Reads Y channel output in volts
MAG.	Reads Magnitude in volts
PHA.	Reads Phase in degrees
FRQ.	Reads reference frequency in hertz

The controlling program would send a new output command each time a new reading were required. Note that when using an output filter slope of 12 dB/octave a good "rule of thumb" is to wait for a period of four time-constants after the input signal has changed before recording a new value. Hence in a scanning type experiment, the program should issue the commands to whatever equipment causes the input signal to the lock-in amplifier to change, wait for four time-constants, and then record the required output.

6.5.03 Frequency Response Measurement

In this example, the lock-in amplifier's internal oscillator output signal is fed via the filter stage under test back to the instrument's signal input. The oscillator frequency is stepped between a lower and an upper frequency and the signal magnitude and phase recorded. At sampling rates of up to a few points per second, there is no need to use the internal curve buffer or oscillator frequency sweep generator. The commands to achieve this would therefore be similar to the following sequence:

IE 0	Set reference mode to internal
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic

FLOAT 1	Float input connector shell using 1 kΩ to ground
LF 0	Turn off line frequency rejection filter
OA. 1.0E0	Set oscillator amplitude to 1.0 V rms
OF. 100.0	Set oscillator frequency to 100 Hz (starting frequency)
SEN 27	Set sensitivity to 1 V full-scale
TC 14	Set time constant to 50 ms
AQN	Auto-Phase

The frequency sweep would be performed and the outputs recorded by sending the following commands from a FOR...NEXT program loop:

OF. XX	Set oscillator frequency to new value XX hertz
	Software delay of 200 ms (4 × 50 ms) allowing output to stabilize
MAG.	Read Magnitude in volts
PHA.	Read Phase in degrees
FRQ.	Read reference frequency in hertz. This would be same as the oscillator frequency since the unit is operating in the internal reference mode.

until the stop frequency is reached.

6.5.04 X and Y Output Curve Storage Measurement

In this example, the lock-in amplifier is measuring a current input signal applied to the **B** input connector and the measured X channel output and Y channel output are recorded for 10 seconds at a 100 Hz sampling rate. The acquired curves as read back to the computer are required in floating point mode.

The sequence of commands is therefore as follows:

IE 2	Set reference mode to external front panel input
IMODE 1	Normal current input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 kΩ to ground
LF 0 0	Turn off line frequency rejection filter
SEN 18	Set sensitivity to 1 nA full-scale
TC 14	Set time constant to 50 ms
AQN	Auto-Phase

Now the curve storage needs to be set up:

NC	Clear and reset curve buffer
CBD 19	Stores X channel output, Y channel output and sensitivity (i.e. bits 0, 1 and 4)
LEN 1000	Number of points = 100 Hz × 10 seconds
STR 10	Store a point every 10 ms (1/100 Hz)

The data is acquired by issuing:

TD	Acquires data

As the acquisition is running, the M command reports the status of the curve acquisition. Once this indicates the acquisition is complete (i.e. parameter 1 = 0, parameter 2 = 1), the acquired data may be transferred to the computer using:

DC. 0	Transfers X channel output values in floating point mode.
DC. 1	Transfers Y channel output values in floating point mode.

The input routine of the program must be prepared to read and store 1000 responses to each of these commands.

6.5.05 Transient Recorder

In this example, the signal recovery capabilities of the lock-in amplifier are not used, but the auxiliary inputs are. The voltage applied to the **ADC1** input on the rear panel is sampled and digitized at a rate of 40 kHz, with the values being stored to the curve buffer. Sampling is required to start on receipt of a trigger at the **TRIG IN** connector on the rear panel and must last for 500 ms.

The sequence of commands is therefore as follows:

NC	Clear and reset curve buffer
LEN 20000	500 ms recording time at 40 kHz = 20,000 points
TADC 6	Set ADC1 sampling to burst mode, fixed rate (25 µs per point, or 40 kHz), external trigger, and arm trigger

As soon as a trigger occurs, the acquisition starts. Once it completes the acquired data may be transferred to the computer using:-

DC. 5	Transfers ADC1 values in floating point mode

The input routine of the program must be prepared to read and store 20,000 responses to this command.

6.5.06 Frequency Response Measurement using Curve Storage and Frequency Sweep

In this example, a more sophisticated version of that given in section 6.5.03, the internal oscillator frequency sweep generator is used in conjunction with curve storage, allowing the acquisition of a frequency response without the need for the computer to perform the frequency setting function for each point.

As before, the lock-in amplifier's internal oscillator output signal is fed via the filter stage under test to the signal input. The oscillator frequency is stepped between a lower and an upper frequency and the signal magnitude and phase are recorded. The required sequence of commands is therefore as follows:-

IE 0	Set reference mode to internal
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 kΩ to ground

LF 0 0	Turn off line frequency rejection filter
OA. 1.0E0	Set oscillator amplitude to 1.0 V rms
OF. 100.0	Set initial oscillator frequency to 100 Hz so that AQN runs correctly
SEN 27	Set sensitivity to 1 V full-scale
TC 12	Set time constant to 10 ms
AQN	Auto-Phase
FASTMODE 0	Used to set the Analog Outputs to normal update rate, allowing faster frequency sweep rates.

The next group of commands set up the frequency sweep:

FSTART. 100.0	Set initial oscillator frequency to 100 Hz
FSTOP. 1000.0	Set final oscillator frequency to 1000 Hz
FSTEP. 10 1	Step size = 10 Hz, linear law
SRATE. 0.05	50 ms per step

There will therefore be 91 points (100 Hz to 1000 Hz inclusive in 10 Hz steps). Now specify the curve storage:

NC	Clear and reset curve buffer
CBD 32796	Stores Magnitude, Phase, Sensitivity and Frequency (i.e. bits 2, 3, 4 and 15)
LEN 91	Number of points = 91. The oscillator step size and this parameter need to be chosen so that the curve buffer will include the full frequency sweep. With 10 Hz steps from 100 Hz to 1000 Hz, there will be 91 points.
STR 50	Store a point every 50 ms - must match SRATE parameter
SWEEP 9	Sets frequency sweep to be linked to curve buffer acquisition

The data may now be acquired by issuing the command:

TD	Starts sweep and curve acquisition

The frequency sweep starts and the magnitude and phase outputs are recorded to the curve buffer. As it runs the M command reports the status of the acquisition, and once this indicates it is complete (i.e. parameter 1 = 0, parameter 2 = 1), the acquired data may be transferred to the computer using:

DC. 2	Transfers Magnitude curve
DC. 3	Transfers Phase curve
DC. 15	Transfers Reference frequency

Specifications

Appendix A

Measurement Modes

X	**In-phase**	The unit can simultaneously present any four of these as outputs
Y	**Quadrature**	
R	**Magnitude**	
θ	**Phase Angle**	
	Noise	

Harmonic — nF, $n \geq 32$

Dual Harmonic — Simultaneously measures the signal at two different harmonics F_1 and F_2 of the reference frequency

- **Standard Unit** — F_1 and $F_2 \leq 20$ kHz.
- **With option -/99** — F_1 and $F_2 \leq 800$ kHz.
- **With option -/98** — F_1 and $F_2 \leq 2.0$ MHz.

Dual Reference — Simultaneously measures the signal at two different reference frequencies, F_1 and F_2 where F_1 is the external and F_2 the internal reference.

- **Standard Unit** — F_1 and $F_2 \leq 20$ kHz
- **With option -/99** — F_1 and $F_2 \leq 800$ kHz.
- **With option -/98** — F_1 and $F_2 \leq 2.0$ MHz.

Virtual Reference — Locks to and detects a signal without a reference (100 Hz $\leq F \leq$ 2.0 MHz)

Noise — Measures noise in a given bandwidth centered at the reference frequency F

Spectral Display — Gives a visual indication of the spectral power distribution of the input signal in a user-selected frequency range lying between 1 Hz and 2.0 MHz. Note the display is not calibrated and is intended primarily to assist in choosing the optimum reference frequency

Display

320 × 240 pixel (¼ VGA) electroluminescent panel giving digital, analog bar-graph and graphical indication of measured signals. Menu system with dynamic key function allocation. On-screen context sensitive help.

Signal Channel

Voltage Inputs	
Modes	A only, -B only or Differential (A-B)
Full-scale Sensitivity	
$0.5\ Hz \le F \le 250\ kHz$	10 nV to 1 V in a 1-2-5 sequence
$250\ kHz \le F \le 2.0\ MHz$	100 nV to 1 V in a 1-2-5 sequence
Dynamic Reserve	> 100 dB
Impedance	100 MΩ // 25 pF
Maximum Safe Input	20 V pk-pk
Voltage Noise	5 nV/√Hz at 1 kHz
C.M.R.R.	> 100 dB at 1 kHz degrading by 6 dB/octave
Frequency Response	0.5 Hz to 2.0 MHz
Gain Accuracy	0.3% typ, 0.6% max.(full bandwidth)
Distortion	-90 dB THD (60 dB AC gain, 1 kHz)
Line Filter	attenuates 50, 60, 100, 120 Hz
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground
Current Input	
Mode	Low Noise, Normal or Wide Bandwidth
Full-scale Sensitivity	
Low Noise	10 fA to 10 nA in a 1-2-5 sequence
Normal	10 fA to 1 µA in a 1-2-5 sequence
Wide Bandwidth	
$F \le 250\ kHz$	10 fA to 100 µA in a 1-2-5 sequence
$F > 250\ kHz$	100 fA to 100 µA in a 1-2-5 sequence
Dynamic Reserve	> 100 dB (with no signal filters)
Frequency Response	
Low Noise	-3 dB at 500 Hz
Normal	-3 dB at 50 kHz
Wide Bandwidth	-3 dB at 1 MHz
Impedance	
Low Noise	< 2.5 kΩ at 100 Hz
Normal	< 250 Ω at 1 kHz
Wide Bandwidth	< 25 Ω at 10 kHz
Noise	
Low Noise	13 fA/√Hz at 500 Hz
Normal	130 fA/√Hz at 1 kHz
Wide Bandwidth	1.3 pA/√Hz at 1 kHz
Gain Accuracy (midband)	≤ 0.6% typ
Line Filter	attenuates 50, 60, 100, 120 Hz
Grounding	BNC shield can be grounded or floated via 1 kΩ to ground

Reference Channel

TTL Input (rear panel)	
Frequency Range	0.5 Hz to 2.0 MHz
Analog Input (front panel)	
Impedance	1 MΩ // 30 pF
Sinusoidal Input	
Level	1.0 V rms**
Frequency Range	0.5 Hz to 2.0 MHz
Squarewave Input	
Level	250 mV rms**
Frequency Range	2 Hz to 2 MHz
	**Note: Lower levels can be used with the analog input at the expense of increased phase errors.
Phase	
Set Resolution	0.001° increments
Noise at 100 ms TC, 12 dB/octave slope	
Internal Reference	≤ 0.0001° rms
External Reference	≤ 0.01° rms @ 1 kHz
Orthogonality	90° ±0.0001°
Acquisition Time	
Internal Reference	instantaneous acquisition
External Reference	2 cycles + 50 ms
Reference Frequency Meter Resolution	1 mHz

Demodulator and Output Processing

Output Zero Stability	
Digital Outputs	No zero drift on all settings
Displays	No zero drift on all settings
Analog Outputs	< 5 ppm/°C
Harmonic Rejection	-90 dB
Output Filters	
X, Y and R outputs only:	
Time Constant	1 µs to 1 ms in a 1-2-5 sequence
Slope (roll-off)	6 and 12 dB/octave
All outputs	
Time Constant	2 ms to 100 ks in a 1-2-5 sequence
Slope	6, 12, 18 and 24 dB/octave
Synchronous Filter Operation	Available for F < 20 Hz

Offset	Auto and Manual on X and/or Y: ±300% FS
Absolute Phase Measurement Accuracy	
	≤ 0.01°

Oscillator

Frequency	
Range	0.5 Hz to 2.0 MHz
Setting Resolution	1 mHz
Absolute Accuracy	25 ppm
Distortion (THD)	-80 dB at 1 kHz and 100 mV rms
Amplitude (rms)	
Range	1 mV to 1 V
Setting Resolution	1 mV
Accuracy	±0.2%
Stability	50 ppm/ºC
Output	
Impedance	50 Ω
Sweep	
Amplitude Sweep	
Output Range	0.000 to 1.000 V rms
Law	Linear
Step Rate	20 Hz maximum (50 ms/step)
Frequency	
Output Range	0.5 Hz to 2.0 MHz
Law	Linear or Logarithmic
Step Rate	20 Hz maximum (50 ms/step)

Auxiliary Inputs

ADC 1, 2, 3 and 4	
Maximum Input	±10 V
Resolution	1 mV
Accuracy	±1 mV
Input Impedance	1 MΩ // 30 pF
Sample Rate	
ADC 1 only	40 kHz max.
ADC 1 and 2	17.8 kHz max.
Trigger Mode	Internal, External or burst
Trigger input	TTL compatible

Outputs

CH1 CH2 Outputs	
Function	X, Y, R, θ, Noise, Ratio, Log Ratio and User Equations 1 & 2.
Amplitude	±2.5 V full-scale but capable of operating to ±300 % full-scale
Impedance	1 kΩ
Update Rate:	
X, Y or R	
TC ≤ 500 µs	7.5 MHz
1 ms ≤ TC ≤ 4 ms	7.5 MHz or 1 kHz
TC ≥ 5 ms	1 kHz
All other outputs	1 kHz
Signal Monitor	
Amplitude	±1 V FS
Impedance	1 kΩ
Auxiliary D/A Output 1 and 2	
Maximum Output	±10 V
Resolution	1 mV
Output Impedance	1 kΩ
8-bit Digital Port	
Mode	0 to 8 lines can be configured as inputs, with the remainder being outputs.
Status	Each output line can be set high or low and each input line read to allow interaction with external equipment
Trigger Input	Extra line acts as extra trigger input
Reference Output	
Waveform	0 to 3 V rectangular wave
Impedance	TTL-compatible
Power - Low Voltage	±15 V at 100 mA rear panel 5-pin 180° DIN connector for powering EG&G preamplifiers

Data Storage

Data Buffer	
Size	32k × 16-bit data points, may be organized as 1×32k, 2×16k, 3×10.6k, 4×8k, etc.
Max Storage Rate	
From LIA	up to 1000 16-bit values per second
From ADC1	up to 40,000 16-bit values per second

User Settings

Up to 8 complete instrument settings can be saved or recalled at will from non-volatile memory.

Interfaces

RS232, IEEE-488. A second RS232 port is provided to allow "daisy-chain" connection and control of up to 16 units from a single RS232 computer port.

General

Power Requirements	
Voltage	110/120/220/240 VAC
Frequency	50/60 Hz
Power	200 VA Max
Dimensions	
Width	17¼" (435 mm)
Depth	19" (485 mm)
Height	
With feet	6" (150 mm)
Without feet	5¼" (130 mm)
Weight	25.4 lb. (11.5 kg)

All specifications subject to change without notification

Pinouts

B.1 RS232 Connector Pinout

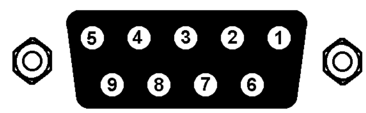

Figure B-1, RS232 and AUX RS232 Connector (Female)

Pin	Function	Description
2	RXD	Data In
3	TXD	Data Out
5	GND	Signal Ground
7	RTS	Request to Send - always +12 V

All other pins are not connected

B.2 Preamplifier Power Connector Pinout

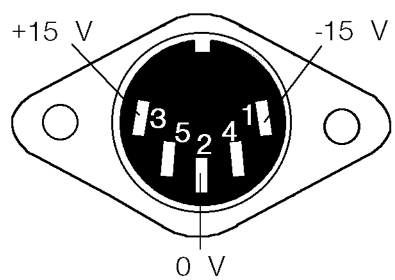

Figure B-2, Preamplifier Power Connector

Pin	Function
1	–15 V
2	Ground
3	+15 V

Pins 4 and 5 are not connected. Shell is shield ground.

B.3 Digital I/O Port Connector

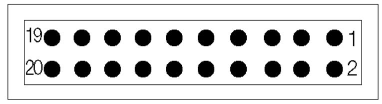

Figure B-3, Digital I/O Port Connector

8-bit TTL-compatible input/output port with each bit being configurable as an input or output. If configured as an output, the bit status can be set, and if configured as an input it can be read, from the front panel or via the computer interfaces. Each output line can drive three LSTTL loads, and each input presents one LSTTL load. The connector will mate with a 20-pin IDC header plug (not supplied). The pinout is as follows:-

Pin	Function
1	Ground
2	Ground
3	D0
4	Ground
5	D1
6	Ground
7	D2
8	Ground
9	D3
10	Ground
11	D4
12	Ground
13	D5
14	Ground
15	D6
16	Ground
17	D7
18	Ground
19	TTL Trigger Input
20	+5 V

D0 = Least Significant Bit
D7 = Most Significant Bit

Demonstration Programs

Appendix C

C.1 Simple Terminal Emulator

This is a short terminal emulator with minimal facilities, which will run on a PC-compatible computer in a Microsoft GWBASIC or QuickBASIC environment, or can be compiled with a suitable compiler.

```
10 'MINITERM 9-Feb-96
20 CLS : PRINT "Lockin RS232 parameters must be set to 9600 baud, 7 DATA bits, 1 stop
   bit and even parity"
30 PRINT "Hit <ESC> key to exit"
40 OPEN "COM1:9600,E,7,1,CS,DS" FOR RANDOM AS #1
50 '.............................
60 ON ERROR GOTO 180
70 '.............................
100 WHILE (1)
110     B$ = INKEY$
120     IF B$ = CHR$(27) THEN CLOSE #1: ON ERROR GOTO 0: END
130     IF B$ <> "" THEN PRINT #1, B$;
140     LL% = LOC(1)
150     IF LL% > 0 THEN A$ = INPUT$(LL%, #1): PRINT A$;
160 WEND
170 '.............................
180 PRINT "ERROR NO."; ERR: RESUME
```

C.2 RS232 Control Program with Handshakes

RSCOM2.BAS is a user interface program which illustrates the principles of the echo handshake. The program will run on a PC-compatible computer either in a Microsoft GWBASIC or QuickBASIC environment, or in compiled form.

The subroutines in RSCOM2 are recommended for incorporation in the user's own programs.

```
10 'RSCOM2 9-Feb-96
20 CLS : PRINT "Lockin RS232 parameters must be set to 9600 baud, 7 data bits, 1 stop
   bit, even parity"
30 OPEN "COM1:9600,E,7,1,CS,DS" FOR RANDOM AS #1
40 CR$ = CHR$(13)                                ' carriage return
50 '
60 '...main loop.................
70 WHILE 1                                       ' infinite loop
80     INPUT "command (00 to exit) "; B$         ' no commas are allowed in B$
90     IF B$ = "00" THEN END
100     B$ = B$ + CR$                            ' append a carriage return
110     GOSUB 180                                ' output the command B$
120     GOSUB 310: PRINT Z$;                     ' read and display response
```

```
130     IF A$ = "?" THEN GOSUB 410: GOSUB 470  ' if "?" prompt fetch STATUS%
140                                            ' and display message
150 WEND                                       ' return to start of loop
160 '
170 '
180 '...output the string B$.............
190 ON ERROR GOTO 510                          ' enable error trapping
200 IF LOC(1) > 0 THEN A$ = INPUT$(LOC(1), #1)' clear input buffer
210 ON ERROR GOTO 0                            ' disable error trapping
220 FOR J1% = 1 TO LEN(B$)                     ' LEN(B$) is number of bytes
230     C$ = MID$(B$, J1%, 1): PRINT #1, C$;   ' send byte
240     WHILE LOC(1) = 0: WEND                 ' wait for byte in input buffer
250     A$ = INPUT$(1, #1)                      ' read input buffer
260     IF A$ <> C$ THEN PRINT "handshake error"' input byte should be echo
270 NEXT J1%                                   ' next byte to be sent or
280 RETURN                                     ' return if no more bytes
290 '
300 '
310 '....read response..................
320 A$ = "": Z$ = ""
330 WHILE (A$ <> "*" AND A$ <> "?")            ' read until prompt received
340     Z$ = Z$ + A$                           ' append next byte to string
350     WHILE LOC(1) = 0: WEND                 ' wait for byte in input buffer
360     A$ = INPUT$(1, #1)                      ' read byte from buffer
370 WEND                                       ' next byte to be read
380 RETURN                                     ' return if it is a prompt
390 '
400 '
410 '....fetch status byte.............
420 B$ = "ST" + CR$                            ' "ST" is the status command
430 GOSUB 180                                  ' output the command
440 GOSUB 310                                  ' read response into Z$
450 STATUS% = VAL(Z$)                          ' convert to integer
460 RETURN
470 '....instrument error message.......
480 PRINT "Error prompt, status byte = "; STATUS% ' bits are defined in manual
490 PRINT
500 RETURN
510 '....I/O error routine.............
520 RESUME
```

C.3 GPIB User Interface Program

GPCOM.BAS is a user interface program which illustrates the principles of the use of the serial poll status byte to coordinate the command and data transfer.

The program runs under Microsoft GWBASIC or QuickBASIC on a PC-compatible computer fitted with a National Instruments IEEE-488 interface card and the GPIB.COM software installed in the CONFIG.SYS file. The program BIB.M, and the first three lines of GPCOM, are supplied by the card manufacturer and must be the correct version for the particular version of the interface card in use. The interface card may be set up, using the program IBCONF.EXE, to set EOI with the last byte of Write in which case no terminator is required. (Read operations are automatically terminated on EOI which is always sent by the lock-in amplifier). Normally, the options called 'high-speed timing', 'interrupt jumper setting', and 'DMA channel' should all be disabled.

The principles of using the Serial Poll Status Byte to control data transfer, as implemented in the main loop of GPCOM, are recommended for incorporation in the user's own programs.

```
10 'GPCOM 9-Feb-96
20 '....the following three lines and BIB.M are supplied by the.......
30 '....manufacturer of the GPIB card, must be correct version........
40 CLEAR , 60000!: IBINIT1 = 60000!: IBINIT2 = IBINIT1 + 3: BLOAD "BIB.M", IBINIT1
50 CALL IBINIT1 (IBFIND, IBTRG, IBCLR, IBPCT, IBSIC, IBLOC, IBPPC, IBBNA, IBONL, IBRSC,
   IBSRE, IBRSV, IBPAD, IBSAD, IBIST, IBDMA, IBEOS, IBTMO, IBEOT, IBRDF, IBWRTF,
   IBTRAP)
60 CALL IBINIT2 (IBGTS, IBCAC, IBWAIT, IBPOKE, IBWRT, IBWRTA, IBCMD, IBCMDA, IBRD,
   IBRDA, IBSTOP, IBRPP, IBRSP, IBDIAG, IBXTRC, IBRDI, IBWRTI, IBRDIA, IBWRTIA, IBSTA%,
   IBERR%, IBCNT%)
70 '................................................
80 CLS : PRINT "DEVICE MUST BE SET TO CR TERMINATOR"
90 '....assign access code to interface board........
100 BDNAME$ = "GPIB0"
110 CALL IBFIND(BDNAME$, GPIB0%)
120 IF GPIB0% < 0 THEN PRINT "board assignment error": END
130 '....send INTERFACE CLEAR........................
140 CALL IBSIC(GPIB0%)
150 '....set bus address, assign access code to device..........
160 SUCCESS% = 0
170 WHILE SUCCESS% = 0
180     INPUT "BUS ADDRESS "; A%
190     DEVNAME$ = "DEV" + RIGHT$(STR$(A%), LEN(STR$(A%)) - 1)
200     CALL IBFIND(DEVNAME$, DEV%)            ' assign access code
210     IF DEV% < 0 THEN PRINT "device assignment error": END
220     A$ = CHR$(13): GOSUB 480               ' test: write <CR> to bus
230     IF IBSTA% > 0 THEN SUCCESS% = 1
240     IF (IBSTA% < 0 AND IBERR% = 2) THEN BEEP: PRINT "NO DEVICE AT THAT ADDRESS ";
250 WEND
260 '....send SELECTED DEVICE CLEAR..................
```

```
270 CALL IBCLR(DEV%)
280 '....set timeout to 1 second.....................
290 V% = 11: CALL IBTMO(DEV%, V%)
300 '....set status print flag.......................
310 INPUT "Display status byte y/n "; R$
320 IF R$ = "Y" OR R$ = "y" THEN DS% = 1 ELSE DS% = 0
330 '....main loop...................................
340 WHILE 1                                 ' infinite loop
350     INPUT "command (00 to exit) "; A$
360     IF A$ = "00" THEN END
370     A$ = A$ ' CHR$(13)                  ' terminator is <CR>
380     GOSUB 480                           ' write A$ to bus
390     S% = 0                              ' initialize S%
400     WHILE (S% AND 1) = 0                ' while command not complete
410             GOSUB 530                   ' serial poll, returns S%
420             IF DS% THEN PRINT "S%= "; S%
430             IF (S% AND 128) THEN GOSUB 500: PRINT B$  ' read bus into B$ and print
440     WEND
445           IF (S% AND 4) THEN PRINT "parameter error"
450     IF (S% AND 2) THEN PRINT "invalid command"
460 WEND
470 '....end of main loop............................
480 '....write string to bus.........................
490 CALL IBWRT(DEV%, A$): RETURN
500 '....read string from bus........................
510 B$ = SPACE$(32)                        ' B$ is buffer
520 CALL IBRD(DEV%, B$): RETURN
530 '......serial poll...............................
540 CALL IBRSP(DEV%, S%): RETURN
```

Cable Diagrams

Appendix D

D.1 RS232 Cable Diagrams

Users who choose to use the RS232 interface to connect the model 7280 lock-in amplifier to a standard serial port on a computer will need to use one of two types of cable. The only difference between them is the number of pins used on the connector which goes to the computer. One has 9 pins and the other 25; both are null-modem (also called modem eliminator) cables in that some of the pins are cross-connected.

Users with reasonable practical skills can easily assemble the required cables from parts which are widely available through computer stores and electronics components suppliers. The required interconnections are given in figures D-1 and D-2.

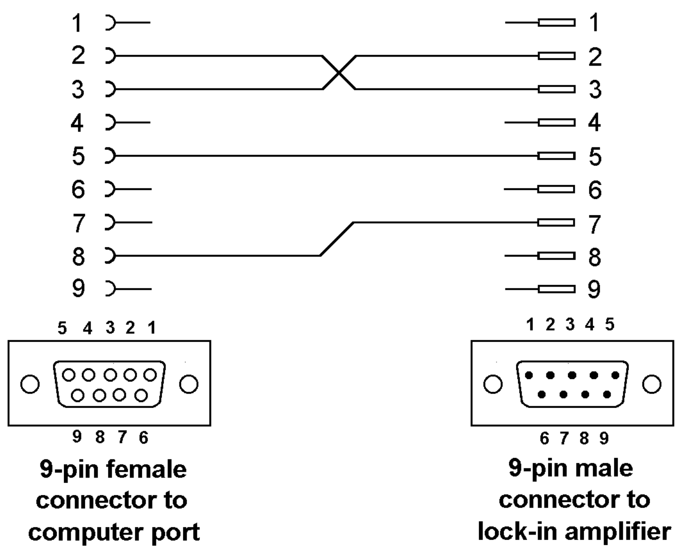

Figure D-1, Interconnecting RS232 Cable Wiring Diagram

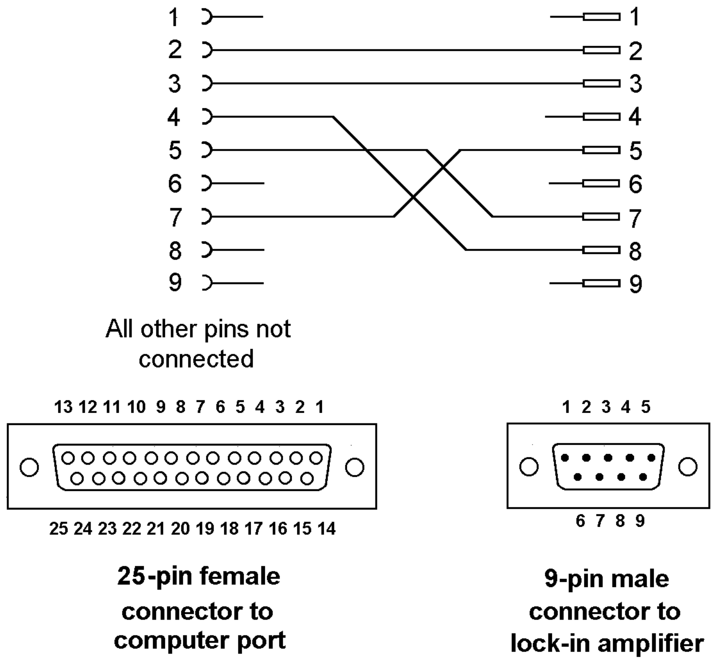

Figure D-2, Interconnecting RS232 Cable Wiring Diagram

Default Settings

Appendix E

Auto Default Function

The Auto-Default computer command ADF 1 sets the model 7280's controls and output displays as follows:-

Main Display
Displays the AC Gain, full-scale sensitivity, reference phase, time constant, reference phase and oscillator frequency controls on the left-hand side. On the right-hand side, the display mode is set to two bar-graphs and two large digital displays, showing signal magnitude as a percentage of full-scale, X channel and Y channel outputs in volts and signal phase in degrees.

The twelve basic instrument controls are set to the following values:-

Full-scale sensitivity	500 mV
AC Gain	0 dB
Time constant	2 ms
Oscillator frequency	1000.000 Hz
Oscillator amplitude	0.500 V rms
AUX DAC1 output	0.000 V
AUX DAC2 output	0.000 V
Ref Phase	0.00°
Phase quadrant	0.00°
X channel output offset	0.00%
Y channel output offset	0.00%
Ref Harmonic	1st

The remaining instrument controls, accessed via the menus, are set as follows:-

Signal Channel

Input coupling	Ground
Input mode	Single-ended voltage mode
Input connector	**A** input connector
Line notch filter	Off
Automatic AC Gain	Off

Reference Channel

Reference mode	Internal
Reference harmonic	1st

Output Filters

Slope	12 dB/octave
Sync Time Constant	ON

Output Offset & Expand

Offset Status	Off
Output Expand	Off

Output Equations	
Equation #1	$((X-X) \times X)/X$ = zero
Equation #2	$((X-X) \times X)/X$ = zero
Frequency Sweep	
Start Frequency	0.000 Hz
Stop Frequency	0.000 Hz
Step Size	0.000 Hz
Time/Step	0.000 s
Armed	No
Law	Logarithmic
Amplitude Sweep	
Start Amplitude	0.000 V
Stop Amplitude	0.000 V
Step Size	0.000 V
Time/Step	0.000 s
Armed	No
Configuration	
Operating mode	Single Reference
Display screen	Turned on
CH1 analog output	X% (2.5 V FS)
CH2 analog output	Y% (2.5 V FS)
Analog Outputs	Fast Mode
Noise Measurement Mode	OFF
Noise Buffer Length	4 seconds
Curve Buffer	
Time/Point e	10 ms
Length	32,768
Curve Select	
Selected curve	X
Auxiliary I/O	
DAC1 and DAC2	0.000 V
ADC Trigger Mode	5 ms
Digital Port	
D0 to D7 direction	All configured as outputs
D0 to D7 status	Logic zero

The Auto-Default function on the front-panel Auto Functions menu and the ADF 0 computer command set the model 7280's controls and output displays as above, and in addition sets the communications interface parameters as follows:-

RS232 Settings

Baud rate	9600
Data bits	7 + 1 Parity
Delimiter	, (044)
Address	1
Character echo	On
Parity	Even
Prompt character	On

GPIB Settings

GPIB Address	12
Terminator	[CR],[LF]
Test Echo	Off
SRQ mask byte	0
Delimiter	, (044)

Alphabetical Listing of Commands

Appendix F

ACGAIN [n] AC Gain control

Sets the gain of the signal channel amplifier according to the following table:-

n	AC Gain
0	0 dB
1	6 dB
2	14 dB
3	20 dB
4	26 dB
5	34 dB
6	40 dB
7	46 dB
8	54 dB
9	60 dB
10	66 dB

ADC[.] n Read auxiliary analog-to-digital inputs

The response for ADC1 to ADC4 (n = 1 to 4 respectively) in fixed point mode is an integer in the range -12000 to +12000, corresponding to voltages from -12.000 V to +12.000 V, and in floating point mode it is in volts.

ADF n Auto Default

The ADF command performs an auto-default operation according to the following table:

n	Significance
0	All instrument settings are returned to their factory default values
1	All instrument settings, with the exception of the communications settings, are returned to their factory default values

NOTE: If the ADF 0 command is used when the communications settings are at values other than their default settings, then communication will be lost.

AQN Auto-Phase (auto quadrature null)

AS Perform an Auto-Sensitivity operation

ASM Perform an Auto-Measure operation

ASTART[.] [n] Oscillator amplitude sweep start amplitude

Sets the start amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

ASTEP[.] [n] Oscillator amplitude sweep step size

Sets the amplitude step size for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms and in floating point mode n is in volts rms

ASTOP[.] [n] Oscillator amplitude sweep stop amplitude

Sets the stop amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms and in floating point mode n is in volts rms

AUTOMATIC [n] AC Gain automatic control

n Status
0 AC Gain is under manual control, either using the front panel or the ACGAIN command
1 Automatic AC Gain control is activated, with the gain being adjusted according to the full-scale sensitivity setting

AXO Auto-Offset

BURSTTPP [n] Sets the burst mode time per point rate for ADC1 and ADC2

n sets the time per point for the Variable Rate burst modes in microseconds, as follows:-

When storing only to ADC1:
(i.e. TADC 2, TADC 4, TADC 6, TADC 8, TADC10 and TADC12)

$25 \leq n \leq 5000$

When storing to ADC1 and ADC 2:
(i.e. TADC 3, TADC 5, TADC 7, TADC 9, TADC11 and TADC13)

$56 \leq n \leq 5000$

BYTE [n] Digital port output control

The value of n, in the range 0 to 255, determines the bits to be output on those lines of the rear panel digital port that are configured as outputs. Hence, for example, if PORTDIR = 8 and BYTE = 0, all outputs are low, and when BYTE = 255, all are high.

CBD [n] Curve buffer define

Defines which data outputs are stored in the curve buffer when subsequent TD (take data), TDT (take data triggered) or TDC (take data continuously) commands are issued. Up to 17 (or 22 in dual reference and dual harmonic modes) curves, or outputs, may be acquired, as specified by the CBD parameter.

The CBD parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary word. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit is asserted, the corresponding output is selected for storage. When a bit is negated, the output is not stored. The bit function and range for each output are shown in the table below:

Bit	Decimal value	Output and range
0*	1	X Output (±10000 FS)
1*	2	Y Output (±10000 FS)
2*	4	Magnitude Output (0 to +10000 FS)
3*	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5*	32	Noise (0 to +10000 FS)
6*	64	Ratio (±10000 FS)
7*	128	Log ratio (-3000 to +2000)
8*	256	ADC1 (±10000 = ±10.0 V)
9*	512	ADC2 (±10000 = ±10.0 V)
10*	1024	ADC3 (±10000 = ±10.0 V)
11*	2048	ADC4 (±10000 = ±10.0 V)
12*	4096	DAC1 (±10000 = ±10.0 V)
13*	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference Frequency bits 0 to 15 (millihertz)
16	65536	Reference frequency bits 16 to 31 (millihertz)
Dual modes only:-		
17	131072	X_2 Output (±10000 FS)
18	262144	Y_2 Output (±10000 FS)
19	524288	Magnitude2 Output (0 to +10000 FS)
20	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

32768 points are available for data storage, shared equally between the specified curves. For example, if 16 outputs are stored then the maximum number of storage points would be 2048 (i.e. 32768/16). The only exception to this rule is that the Frequency curve (curves 15 and 16) occupies the equivalent of any two other curves. The LEN command sets the actual curve length, which cannot therefore be longer than 32768 divided by the number of curves selected. If more curves are requested than can be stored with the current buffer length, then the buffer length will be automatically reduced. Its actual length can of course be determined by sending the LEN command without a parameter.

The reason why bit 4 and, for dual reference modes, bit 21, which store both the sensitivity and the IMODE setting, are needed, is to allow the instrument to transfer the acquired curves to the computer in floating point mode. Without this information, the unit would not be able to determine the correct calibration to apply.

Note that the CBD command directly determines the allowable parameters for the DC, DCB and DCT commands. It also interacts with the LEN command and affects the values reported by the M command.
Since the reference frequency requires 32-bit wide data points, it occupies two curve positions. For ease of use, if bit 15 is selected for storage then bit 16 will be automatically selected as well, and vice-versa.

NOTE: At least one of the curves selected for storage in the curve buffer must be chosen from those marked with an asterisk(*) in the above table.

CH n_1 [n_2] Analog output control

Defines what outputs appear on the **CH1** and **CH2** connectors on the rear panel.

When the fast analog output mode is turned off (FASTMODE 0), the selection is according to the following table:

n_2	Signal
0	X % (2.5 V FS)
1	Y % (2.5 V FS)
2	Magnitude % (2.5 V FS)
3	Phase 1: +9 V = +180°, -9 V = -180°
4	Phase 2: +9 V = 360°, - 9 V = 0°
5	Noise % (2.5 V FS)
6	Ratio: (10 × X%/ADC 1)
7	Log Ratio: $\log_{10}$ (10 × X%/ADC1)
8	Equation 1
9	Equation 2

Dual modes only:-

10	X2 % (2.5 V FS)
11	Y2 % (2.5 V FS)
12	Magnitude2 %FS
13	Phase2 1: +9 V = +180°, -9 V = -180°
14	Phase2 2: +9 V = 360°, -9 V = 0°

n_1 is compulsory and is either 1 for CH1 or 2 for CH2

Note: n_2 = 5 is only permitted if the noise measurement mode is on (NOISEMODE 1) or if the present settings of output filter slope and time constant are within the permitted range and the synchronous time constant control is off.

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, the selection is according to the following tables:

n_1 = 1 (i.e. CH1 output)

n_2	Signal
0	X % (2.5 V FS)

n_1 2 (i.e. CH2output)

n_2	Signal
1	Y % (2.5 V FS)
2	Magnitude % (2.5 V FS)

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is fixed according to the following tables:

n_1 = 1 (i.e. CH1 output)

n_2	Signal
0	X1 % (2.5 V FS)

n_1 2 (i.e. CH2output)

n_2	Signal
10	X2 % (2.5 V FS)

CP [n] Input connector coupling mode control

The value of n sets the input coupling mode according to the following table:

n	Coupling mode
0	Fast
1	Slow

DAC[.] n_1 [n_2] Auxiliary DAC output controls

The first parameter n_1, which specifies the DAC, is compulsory and is either 1 or 2.

The value of n_2 specifies the voltage to be output.

In fixed point mode it is an integer in the range -12000 to +12000, corresponding to voltages from -12.000V to +12.000V, and in floating point mode it is in volts.

DC[.] n Dump acquired curve(s) to computer

In fixed point mode, causes a stored curve to be dumped via the computer interface in decimal format.

In floating point mode the SEN curve (bit 4 in CBD) must have been stored if one or more of the following outputs are required in order that the lock-in amplifier can perform the necessary conversion from %FS to volts or amps:- X, Y, Magnitude, Noise. Similarly, if the dual reference or harmonic modes are active then the SEN2 curve (bit 21 in CBD) must have been stored in order to perform a similar conversion from %FS to volts or amps for X2, Y2 and Magnitude2.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16, or 0 to 21 if a dual mode is active. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DC 0 would transfer the X channel output curve and DC 2 the Magnitude curve.

NOTE: When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.

The computer program's subroutine which reads the responses to the DC command needs to run a program loop that continues until all the data has been transferred.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DC command, perform repeated serial polls until bit 7 is set, indicating that the instrument has an output waiting to be read. Then perform repeated reads in a loop, waiting each time until bit 7 is set indicating that a new value is available. The loop should continue until bit 1 is set, indicating that the transfer is completed.

DCB n Dump acquired curve(s) to computer in binary format

This command causes a stored curve to be dumped via the computer interface in binary format, using two bytes per point. All curves other than the lower 16-bits of the reference frequency curve (curve 15) use 16-bit 2’s complement encoding, and all data points are sent with the MSB first. The number of data bytes sent is therefore equal to twice the current curve length. Each point is sent in fixed point mode, there being no floating point version of the command, and hence if floating point values are required the user may need to additionally store and read the Sensitivity curve and then perform the correction in his own software. In order to achieve the maximum transfer rate, no terminators are used within the transmission, although the response is terminated normally at the end.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16 in Single Reference Mode, and 0 to 21 in the dual modes. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DCB 0 would transfer the X channel output curve and DCB 2 the Magnitude curve.

Curves 15 and 16 store the reference frequency in millihertz. When using the DCB command (although not with the other curve transfer commands), both curves need to be transferred separately. They should then be converted to two arrays of integer values, allowing for the fact that the data points in curve 15 are unsigned 16-bit values, while those in curve 16 are signed 2’s complement 16-bit values (although in practice they are never negative). Finally they should be assembled into a single curve using the following algorithm:

Reference Frequency = (65536 × value in Curve 16) + (value in Curve 15)

The computer program's subroutine which reads the responses to the DCB command needs to be able to handle the potentially very large data blocks (64 k bytes in the case of one 32 k curve) that can be generated.

NOTE: When using RS232 communications, the interface must be set to use 8 data bit transmission.

DCT n Dump acquired curves to computer in tabular format

This command is similar to the DC command described above, but allows transfer of several curves at a time and only operates in fixed point mode. Stored curve(s) are transferred via the computer interface in decimal format.
In single reference mode, the DCT parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary number. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit in the number is asserted, the corresponding curve is selected for transfer. When a bit is negated, the curve is not transferred. The bit corresponding to each curve is shown in the table below:

Bit	Decimal value	Output and range
0	1	X Output (±10000 FS)
1	2	Y Output (±10000 FS)
2	4	Magnitude Output (0 to +10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5	32	Noise (0 to +10000 FS)
6	64	Ratio (±10000 FS)
7	128	Log ratio (-3000 to +2000)
8	256	ADC1 (±10000 = ±10.0 V)
9	512	ADC2 (±10000 = ±10.0 V)
10	1024	ADC3 (±10000 = ±10.0 V)
11	2048	ADC4 (±10000 = ±10.0 V)
12	4096	DAC1 (±10000 = ±10.0 V)
13	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency (millihertz)
Dual modes only:-		
17	131072	X_2 Output (±10000 FS)
18	262144	Y_2 Output (±10000 FS)
19	524288	Magnitude2 Output (0 to +10000 FS)
20	1048576	Phase_2 Output (±18000 = ±180°)
21	2097152	Sensitivity_2 setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

The values of the selected curves at the same sample point are transferred as a group in the order of the above table, separated by the chosen delimiter character and terminated with the selected terminator. This continues until all the points have been transferred.

NOTE: When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.

DD [n] Define delimiter control

The value of n, which can be set to 13 or from 32 to 125, determines the ASCII value of the character sent by the lock-in amplifier to separate two numeric values in a two-value response, such as that generated by the MP (magnitude and phase) command.

DEFEQU [n_1 n_2 n_3 n_4 n_5 n_6] Define user equation

The DEFEQU command is used to define the user equations, which take the following form:

$$\text{Equation} = \left(\frac{(A \pm B) \times C}{D}\right)$$

Parameter n_1 is used to specify the equation to be modified, and is either 1 for Equation 1 or 2 for Equation 2.

Parameter n_3 is used to set the addition/subtraction operator in the numerator according to the following table:-

n_3	Operator
0	Subtraction
1	Addition

The parameters n_2, n_4, n_5 and n_6 specify the variables A, B, C and D respectively according to the following table:

n	Variable	Range
0	X or X1	±30000
1	Y or Y1	±30000
2	MAG or MAG1	0 to 30000
3	PHA or PHA1	±18000
4	ADC1	±10000
5	ADC2	±10000
6	ADC3	±10000
7	ADC4	±10000
8	C1	0 to 100000
9	C2	0 to 100000
10	0	zero
11	1	unity
12	FRQ	0 to 2000000000 (i.e. reference frequency in mHz)*
13	OSC	0 to 2000000000 (i.e. oscillator frequency in mHz)*
Dual modes only:-		
14	X2	±30000
15	Y2	±30000
16	MAG2	0 to 30000
17	PHA2	±18000

*Parameter n_5 is the only one that can be set to values of 12 or 13.

ENBW[.] Equivalent noise bandwidth

In fixed point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in microhertz.

In floating point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in hertz.

EQU n Output result of equation #1 or equation #2

The value returned is the output of the user equation #1 (n = 1) or equation #2 (n = 2), where the equations are defined using the Output equations menu (see section 5.3.11). The possible range is ±2,147,483,647 (signed 32-bit integer).

EVENT [n] Event marker control

During a curve acquisition, if bit 13 in the CBD command has been asserted, the lock-in amplifier stores the value of the Event variable at each sample point. This can be used as a marker indicating the point at which an experimental parameter was changed. The EVENT command is used to set this variable to any value between 0 and 32767.

EX [n] Output expansion control

n	Expand mode
0	Off
1	Expand X
2	Expand Y
3	Expand X and Y

FASTMODE [n] Analog Output Mode Control

The value of n sets the fast analog output mode control according to the following table:

n	Function
0	Fast mode off
1	Fast mode on

When the fast analog output mode is turned on, the available settings for the **CH1**/**CH2** analog output controls are restricted, and hence affect the allowable parameter range for CH1 and CH2 commands. It also restricts the available range of output filter slope settings, limits the full-scale sensitivity to a maximum of 100 µV and restricts the range of AC Gain settings if the AC Gain Automatic control is turned off. The effect is that the instrument's dynamic reserve is limited to a maximum value of 15 dB. Also, in this mode the minimum time per point for the oscillator frequency or amplitude sweeps is limited to 140 ms per point.

When fast mode is turned off, the output filter time constant is restricted to values of 500 µs and longer, but the other restrictions on output filter slope, sensitivity and AC gain are removed. In this mode the minimum time per point for the oscillator frequency or amplitude sweeps is 1 ms per point.

FLOAT [n] Input connector shield float/ground control

n	Selection
0	Ground
1	Float (connected to ground via a 1 kΩ resistor)

FRQ[.] Reference frequency meter

If the lock-in amplifier is in the external reference source modes, the FRQ command causes the lock-in amplifier to respond with 0 if the reference channel is unlocked, or with the reference input frequency if it is locked.

If the lock-in amplifier is in the internal reference source mode, it responds with the frequency of the internal oscillator.

In fixed point mode the frequency is in mHz, and in floating point mode the frequency is in Hz.

FSTART[.] [n] Oscillator frequency sweep start frequency

Sets the start frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.
In fixed point mode, n is in millihertz, and in floating point mode n is in hertz.

FSTEP[.] [n_1 n_2]   Oscillator frequency sweep step size and type

The frequency may be swept either linearly or logarithmically, as specified by parameter n_2. The step size is specified by parameter n_1.

Log sweep $n_2 = 0$

In fixed point mode, n_1 is the step size in thousandths of a percent.

In floating point mode n_1 is in percent. The range of n_1 is 0 to 100.00%

Linear sweep $n_2 = 1$

In fixed point mode, n_1 is the step size in millihertz.

In floating point mode n_1 is in hertz. The range of n_1 is 0 to 10 kHz

Linear seek sweep $n_2 = 2$

In fixed point mode, n_1 is the step size in millihertz.

In floating point mode n_1 is in hertz. The range of n_1 is 0 to 10 kHz

The seek sweep mode automatically stops when the signal magnitude exceeds 50% of full scale. This mode is most commonly used when setting up the virtual reference mode.

FSTOP[.] [n]   Oscillator frequency sweep stop frequency

Sets the stop frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz and in floating point mode n is in hertz.

GP [n_1 [n_2]]   Set/Read GPIB parameters

n_1 sets the GPIB address in the range 0 to 31

n_2	Terminator
0	[CR], test echo disabled
1	[CR], test echo enabled
2	[CR,LF], test echo disabled
3	[CR,LF], test echo enabled
4	no terminator, test echo disabled
5	no terminator, test echo enabled

HC   Halt curve acquisition

ID   Identification

Causes the lock-in amplifier to respond with the number 7280.

IE [n]   Reference channel source control (Internal/External)

n	Selection
0	INT (internal)
1	EXT LOGIC (external rear panel TTL input)
2	EXT (external front panel analog input)

IMODE [n] Current/Voltage mode input selector

n	Input mode
0	Current mode off - voltage mode input enabled
1	Normal current mode enabled - connect signal to **B** input connector
2	Low noise current mode enabled - connect signal to **B** input connector
3	High bandwidth current mode enabled - connect signal to **B** input connector

If n = 0 then the input configuration is determined by the VMODE command.
If n > 0 then current mode is enabled irrespective of the VMODE setting.

LEN [n] Curve length control

The value of n sets the curve buffer length in effect for data acquisition. The maximum allowed value depends on the number of curves requested using the CBD command, and a parameter error results if the value given is too large. For this reason, if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.

LF [n_1 n_2] Signal channel line frequency rejection filter control

The LF command sets the mode and frequency of the line frequency rejection (notch) filter according to the following tables:

n_1	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

n_2	Notch Filter Center Frequencies
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

LOCK System lock control

Updates all frequency-dependent gain and phase correction parameters.

LR[.] Log Ratio output

In integer mode, the LR command reports a number equivalent to 1000×log(X/ADC1) where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command. The response range is -3000 to +2079
In floating point mode, the LR. command reports a number equivalent to log(X/ADC1). The response range is -3.000 to +2.079

LTS [n] Display on/off control

n	Selection
0	Display off
1	Normal operation

M Curve acquisition status monitor

Causes the lock-in amplifier to respond with four values that provide information concerning data acquisition, as follows:

First value, Curve Acquisition Status: a number with five possible values, defined by the following table:

First Value	Significance
0	No curve activity in progress.
1	Acquisition via TD command in progress and running.
2	Acquisition via TDC command in progress and running.
5	Acquisition via TD command in progress but halted by HC command.
6	Acquisition via TDC command in progress but halted by HC command.

Second value, Number of Sweeps Acquired: This number is incremented each time a TD is completed and each time a full cycle is completed on a TDC acquisition. It is zeroed by the NC command and also whenever a CBD or LEN command is applied without parameters.

Third value, Status Byte: The same as the response to the ST command. The number returned is the decimal equivalent of the status byte and refers to the previously applied command.

Fourth value, Number of Points Acquired: This number is incremented each time a point is taken. It is zeroed by the NC command and whenever CBD or LEN is applied without parameters.

MAG[.] Magnitude

In fixed point mode causes the lock-in amplifier to respond with the magnitude value in the range 0 to 30000, full-scale being 10000.

In floating point mode causes the lock-in amplifier to respond with the magnitude value in the range +3.000E0 to +0.001E-9 volts or +3.000E-6 to +0.001E-15 amps.

MP[.] Magnitude, phase

Equivalent to the compound command MAG[.];PHA[.]

MSK [n] Set/read service request mask byte

The value of n sets the SRQ mask byte in the range 0 to 255

\N n Address command

When the model 7280 is daisy-chained with other compatible instruments this command will change which instrument is addressed. All daisy-chained instruments receive commands but only the currently addressed instrument will implement or respond to the commands. The exception is the \N n command. If n matches the address set from the front panel the instrument will switch into addressed mode. If n does not match the address set from the front panel the instrument will switch into unaddressed mode. Note that the \N n command does not change the address of an instrument but which instrument is addressed.

NOTE: All instruments must have a unique address.

N Report overload byte

Causes the lock-in amplifier to respond with the overload byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

Bit 0	not used
Bit 1	CH1 output overload (> ±300 %FS)
Bit 2	CH2 output overload (> ±300 %FS)
Bit 3	Y channel output overload (> ±300 %FS)
Bit 4	X channel output overload (> ±300 %FS)
Bit 5	not used
Bit 6	input overload
Bit 7	reference unlock

NC New curve

Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

NHZ.

Causes the lock-in amplifier to respond with the square root of the noise spectral density measured at the Y channel output, expressed in volt/√Hz or amps/√Hz referred to the input. This measurement assumes that the Y channel output is Gaussian with zero mean. (Section 3.3.16). The command is only available in floating point mode.

NN[.] Noise output

In fixed point mode causes the lock-in amplifier to respond with the mean absolute value of the Y channel output in the range 0 to 12000, full-scale being 10000. If the mean value of the Y channel output is zero, this is a measure of the output noise.

In floating point mode causes the lock-in amplifier to respond in volts.

NNBUF [n] Noise Buffer Length control

The value of n sets the noise buffer length according to the following table:

n	Function
0	Noise buffer off
1	1 second noise buffer
2	2 second noise buffer
3	3 second noise buffer
4	4 second noise buffer

NOISEMODE [n] Noise Measurement Mode control

The value of n sets the noise measurement mode according to the following table:

n	Function
0	Noise measurement mode off
1	Noise measurement mode on.

When the noise measurement mode is turned on, the output filter time constant is automatically adjusted until it lies in the range 500 µs to 10 ms inclusive, the synchronous time constant control is turned off, and the output filter slope is set to

12 dB/octave if it had previously been 18 or 24 dB/octave.

OA[.] [n] Oscillator amplitude control

In fixed point mode n sets the oscillator amplitude in mV. The range of n is 0 to 1000 representing 0 to 1 V rms.

In floating point mode n sets the amplitude in volts.

OF[.] [n] Oscillator frequency control

In fixed point mode n sets the oscillator frequency in mHz. The range of n is 0 to 2,000,000,000 representing 0 to 2.000 MHz.

In floating point mode n sets the oscillator frequency in Hz. The range of n is 0 to 2.0E6

PHA[.] Signal phase

In fixed point mode causes the lock-in amplifier to respond with the signal phase in centidegrees, in the range ±18000.

In floating point mode causes the lock-in amplifier to respond with the signal phase in degrees.

PORTDIR [n] Digital port direction control

The value of n determines which of the eight lines on the digital port are configured as inputs and which as outputs. The parameter n is a decimal number whose bit-wise interpretation defines whether the corresponding line is an input or output. The line is an input if the corresponding bit is a “1”. For example:

n	status
0	All lines configured as inputs
1	D0 = output, D1 - D7 = inputs
2	D1 = output, D0 and D2 - D7 = inputs
4	D2 = output, D0 - D1 and D3 - D7 = inputs
8	D3 = output, D0 - D2 and D4 - D7 = inputs
16	D4 = output, D0 - D3 and D5 - D7 = inputs
32	D5 = output, D0 - D4 and D6 - D7 = inputs
64	D6 = output, D0 - D5 and D7 = inputs
128	D7 = output, D0 - D6 inputs
255	All lines configured as outputs

READBYTE Read digital port input

The response to the READBYTE command is an integer between 0 and 255 representing the binary value of all eight lines of the rear panel digital port. Hence, for example, if PORTDIR = 0 and the response to READBYTE is 255, then all lines are high, and if the response to READBYTE is 0, then all lines are low. Note that because the command does not differentiate between whether a line is configured as an input or output, it can be used as a single command to determine the present status of all eight lines, both inputs and outputs, of the port.

REFMODE [n] Reference mode selector

n	Mode
0	Single Reference / Virtual Reference mode
1	Dual Harmonic mode
2	Dual Reference mode

NOTE: When in either of the dual reference modes the command set changes to accommodate the additional controls. These changes are detailed in section 6.4.14

REFN [n] Reference harmonic mode control

The value of n sets the reference channel to one of the NF modes, or restores it to the default 1F mode. The value of n is in the range 1 to 32.

REFP[.] [n] Reference phase control

In fixed point mode n sets the phase in millidegrees in the range ±360000.

In floating point mode n sets the phase in degrees.

REMOTE [n] Remote only (front panel lock-out) control

Allowed values of n are 0 and 1. When n is equal to 1, the lock-in amplifier enters remote only mode in which the front panel control functions are inoperative and the instrument can only be controlled with the RS232 or the GPIB interfaces. When n is equal to 0, the front panel controls function normally.

RS [n_1 [n_2]] Set/read RS232 interface parameters

n_1	Baud rate (bits per second)
0	75
1	110
2	134.5
3	150
4	300
5	600
6	1200
7	1800
8	2000
9	2400
n_1	Baud rate (bits per second)
10	4800
11	9600
12	19200

The lowest five bits in n_2 control the other RS232 parameters according to the following table:

bit number	bit negated	bit asserted
0	data + parity = 8 bits	data + parity = 9 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

RSADDR [n] Set/read RS232 address

The value of n sets the RS232 address in the range 0 to 15. This is relevant only when using more than one instrument connected via the RS232 “daisy-chain” method. Each instrument must be set to a unique address.

RT[.] Ratio output

In integer mode the RT command reports a number equivalent to 1000×X/ADC1 where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command.

In floating point mode the RT. command reports a number equivalent to X/ADC1.

SEN [n]
SEN. Full-scale sensitivity control

The value of n sets the full-scale sensitivity according to the following table, depending on the setting of the IMODE control:

n	full-scale sensitivity			
	IMODE=0	IMODE=1	IMODE=2	IMODE=3
3	10 nV	10 fA	n/a	1 pA
4	20 nV	20 fA	n/a	2 pA
5	50 nV	50 fA	n/a	5 pA
6	100 nV	100 fA	n/a	10 pA
7	200 nV	200 fA	n/a	20 pA
8	500 nV	500 fA	n/a	50 pA
9	1 µV	1 pA	10 fA	100 pA
10	2 µV	2 pA	20 fA	200 pA
11	5 µV	5 pA	50 fA	500 pA
12	10 µV	10 pA	100 fA	1 nA
13	20 µV	20 pA	200 fA	2 nA
14	50 µV	50 pA	500 fA	5 nA
15	100 µV	100 pA	1 pA	10 nA
16	200 µV	200 pA	2 pA	20 nA
17	500 µV	500 pA	5 pA	50 nA
18	1 mV	1 nA	10 pA	100 nA
19	2 mV	2 nA	20 pA	200 nA
20	5 mV	5 nA	50 pA	500 nA
21	10 mV	10 nA	100 pA	1 µA
22	20 mV	20 nA	200 pA	2 µA
23	50 mV	50 nA	500 pA	5 µA
24	100 mV	100 nA	1 nA	10 µA
25	200 mV	200 nA	2 nA	20 µA
26	500 mV	500 nA	5 nA	50 µA
27	1 V	1 µA	10 nA	100 µA

SLOPE [n] Output low-pass filter slope (roll-off) control

When the fast analog output mode and Noise Measurement mode are turned off (FASTMODE 0 and NOISEMODE 0), the selection is according to the following table:

n	Slope	
0	6 dB/octave	
1	12 dB/octave	
2	18 dB/octave	(TC ≥ 500 μs)
3	24 dB/octave	(TC ≥ 500 μs)

When:

a) The fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, or

b) Noise measurement mode is turned ON (NOISEMODE 1)

the selection is according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is according to the following table:

n	Slope
0	6 dB/octave

SRATE[.] [n] Oscillator frequency and amplitude sweep step rate

In fixed point mode, sets the sweep rate in milliseconds per step, and in floating point mode sets the rate in seconds, according to the following table:

Analog Outputs Mode	Legal range for n
NORMAL	1 to 1000000 (1 ms to 1000 s)
FAST	140 to 1000000 (140 ms to 1000 s)

ST Report status byte

Causes the lock-in amplifier to respond with the status byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

Bit 0	Command complete
Bit 1	Invalid command
Bit 2	Command parameter error
Bit 3	Reference unlock
Bit 4	Overload
Bit 5	New ADC values available after external trigger
Bit 6	Asserted SRQ
Bit 7	Data available

NOTE: this command is not normally used in GPIB communications, where the status byte is accessed by performing a serial poll.

? Fast Data Transfer command

The ? command offers a method of reading a combination of instrument outputs which are sampled at the same time, thereby ensuring that they are correlated.

The response to the ? command is the output(s), expressed in floating point mode, specified by the present setting of the Curve Buffer Define (CBD) command (see section 6.4.09) and separated by delimiter character(s) defined by the DD command. Hence for example, if CBD is set to 19, the response to the ? command will be:

<X output, in floating point mode><delimiter>
<Y output, in floating point mode><terminator>

STR [n] Storage interval control

Sets the time interval between successive points being acquired under the TD or TDC commands. n specifies the time interval in milliseconds with a resolution of 1 ms. The longest interval that can be specified is 1000000 s corresponding to one point in about 12 days.

SWEEP [n] Oscillator frequency and amplitude sweep control

n	Sweep status
0	Stop
1	Start/continue frequency sweep
2	Start/continue amplitude sweep
3	Start/continue frequency sweep and amplitude sweep
5	Pause frequency sweep
6	Pause amplitude sweep
7	Pause frequency sweep and amplitude sweep
9	Link frequency sweep to curve buffer acquisition
10	Link amplitude sweep to curve buffer acquisition
11	Link frequency and amplitude sweep to curve buffer acquisition

This command is used to start or stop the internal oscillator frequency or amplitude sweep, or to specify that the sweep should be linked to the curve buffer data acquisition.

In the normal mode, when a frequency and/or amplitude sweep has been defined, applying SWEEP with a parameter of 1 2 or 3 will start it. The sweep can be paused using the command with the correct value of n for the sweep in progress. For example, if a frequency sweep is started using SWEEP 1 then it can only be paused by sending SWEEP 5. Similarly, it can only be continued by sending SWEEP 1. The command SWEEP 0 will, however, stop either or both types of sweep.

When n is equal to 9, 10 or 11 the instrument is set to link the oscillator frequency and/or amplitude sweeps to the curve buffer. The SWEEP command continues to function as a write/read command except when the curve buffer acquisition is actually running. In such cases, the SWEEP command changes to read-only and will only report values of 9, 10 or 11, indicating what type of linking is active. The sweep can then only be stopped by stopping the curve buffer, using the HC command. However, the user can still determine the progress of the sweep using the curve buffer monitor “M” command and the OF and/or OA (oscillator frequency and amplitude) commands.

SYNC [n] Synchronous time constant control

n	Effect
0	Synchronous time constant disabled
1	Synchronous time constant enabled

TADC [n] Auxiliary ADC trigger mode control

The value of n sets the trigger mode of two of the auxiliary **ADC** inputs according to the following table:

n	Trigger mode
0	Asynchronous (5 ms intervals)
1	External ADC1 and ADC 2 (rear panel **TRIG** input)
2	Burst mode, 25 µs/point, triggered by command (ADC1 only)
3	Burst mode, 56 µs/point, triggered by command (ADC1 and ADC2)
4	Burst mode, variable rate, triggered by command (ADC1 only)
5	Burst mode, variable rate, triggered by command (ADC1 and ADC2)
6	Burst mode, 25 µs/point, External trigger with < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
7	Burst mode, 56 µs/point, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
9	Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 and ADC2)
10	Burst mode, 25 µs/point, External trigger with < 25 µs trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
11	Burst mode, 56 µs/point, External trigger with < 25 µs trigger indeterminacy(rear panel **TRIG** input) (ADC1 and ADC2)
12	Burst mode, variable rate, External trigger with < 25 µs trigger indeterminacy(rear panel **TRIG** input) (ADC1 only)
13	Burst mode, variable rate, External trigger with < 25 µs trigger indeterminacy(rear panel **TRIG** input) (ADC1 and ADC2)

In the burst modes, data is stored in the curve buffer. Use the LEN command to set the number of points required. Note that it may be necessary to enter CBD 256 before setting the length, if the curve buffer has previously been used for more than one data type. The data is read out from the buffer using DC[.] 8 for ADC1 and DC[.] 9 for ADC2. If the length is set to more than 16384 and a burst mode which stores both ADC1 and ADC2 is specified then the curve length will automatically be reduced to 16384 points. Note also that setting the TADC parameter to any value other than 0 or 1 affects the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 256
3	automatically set to 768
4	automatically set to 256
5	automatically set to 768

TADC parameter	Effect on CBD parameter
6	automatically set to 256
7	automatically set to 768
8	automatically set to 256
9	automatically set to 768
10	automatically set to 256
11	automatically set to 768
12	automatically set to 256
13	automatically set to 768

The maximum sampling rate depends on the number of ADC inputs used, and is either 25 µs when sampling ADC1 only, or 56 µs when sampling both ADC1 and ADC2.
In the Variable Rate modes, the sampling speed is set by the BURSTTPP (burst time per point) command.

NOTE: TADC modes 10 to 13 cause all other functions of the host microprocessor to be suspended, including responding to computer commands, until a trigger is received at the TRIG input. Hence they should only be used when the user is certain that such a trigger will occur.

TC [n]
TC. Filter time constant control

The value of n sets the output filter time constant in accordance with the following table:

n	FASTMODE = 0, NOISEMODE = 0 time constant	FASTMODE = 1, NOISEMODE = 0 time constant	FASTMODE = 0, NOISEMODE = 1 time constant	FASTMODE = 1, NOISEMODE = 1 time constant
0	N/A	1 µs	N/A	N/A
1	N/A	2 µs	N/A	N/A
2	N/A	5 µs	N/A	N/A
3	N/A	10 µs	N/A	N/A
4	N/A	20 µs	N/A	N/A
5	N/A	50 µs	N/A	N/A
6	N/A	100 µs	N/A	N/A
7	N/A	200 µs	N/A	N/A
8	500 µs	500 µs	500 µs	500 µs
9	1 ms	1 ms	1 ms	1 ms
10	2 ms	2 ms	2 ms	2 ms
11	5 ms	4 ms	5 ms	4 ms
12	10 ms	10 ms	10 ms	10 ms
13	20 ms	20 ms	N/A	N/A
14	50 ms	50 ms	N/A	N/A
15	100 ms	100 ms	N/A	N/A
16	200 ms	200 ms	N/A	N/A
17	500 ms	500 ms	N/A	N/A
18	1 s	1 s	N/A	N/A
19	2 s	2 s	N/A	N/A
20	5 s	5 s	N/A	N/A
21	10 s	10 s	N/A	N/A
22	20 s	20 s	N/A	N/A
23	50 s	50 s	N/A	N/A

n	FASTMODE = 0, NOISEMODE = 0 time constant	FASTMODE = 1, NOISEMODE = 0 time constant	FASTMODE = 0, NOISEMODE = 1 time constant	FASTMODE = 1, NOISEMODE = 1 time constant
24	100 s	100 s	N/A	N/A
25	200 s	200 s	N/A	N/A
26	500 s	500 s	N/A	N/A
27	1 ks	1 ks	N/A	N/A
28	2 ks	2 ks	N/A	N/A
28	5 ks	5 ks	N/A	N/A
30	10 ks	10 ks	N/A	N/A
31	20 ks	20 ks	N/A	N/A
32	50 ks	50 ks	N/A	N/A
33	100 ks	100 ks	N/A	N/A

N/A means that n is an illegal value under these conditions.

The TC. command is only used for reading the time constant, and reports the current setting in seconds. Hence if a TC 15 command were sent and the noise measurement mode was turned off, TC would report 15 and TC. would report 1.0E-01, i.e. 0.1 s or 100 ms.

TD Take data

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10 or 100, then this sweep will be started as well.

TDC Take data continuously

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until halted by an HC command. The buffer is circular in the sense that when it has been filled, new data overwrites earlier points.

TDT n Take data triggered

Sets the instrument so that data acquisition will be initiated on receipt of a trigger at the **TRIG** connector on the rear panel. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10 or 100, then this sweep will be started as well.
Two triggered modes are possible, as set by the value of n:

n	function
0	One complete curve or set of curves, each one consisting of the number of points specified by the LEN command parameter, is acquired for each trigger.
1	One data point or set of data points is acquired for each trigger. Hence in order to store a complete curve or set of curves, the number of triggers applied must equal the number of points specified by the LEN command parameter. Note that in this mode the maximum trigger rate is 1000 Hz and the storage interval control setting has no effect.

VER Report firmware version

Causes the lock-in amplifier to respond with the firmware version number. The firmware version number is the number displayed on the Configuration menu.

VMODE [n] Voltage input configuration

n Input configuration
0 Both inputs grounded (test mode)
1 A input only
2 -B input only
3 A-B differential mode

Note that the IMODE command takes precedence over the VMODE command.

VRLOCK [n] Virtual reference mode lock

The Seek option of the frequency sweep mode must be used before issuing this command, for which the value of n has the following significance:

n Mode
0 Disables virtual reference mode
1 Enters virtual reference mode by enabling tracking of the signal frequency

X[.] X channel output

In fixed point mode causes the lock-in amplifier to respond with the X demodulator output in the range ±30000, full-scale being ±10000.

In floating point mode causes the lock-in amplifier to respond with the X demodulator output in volts or amps.

XER X channel output - enhanced resolution

This command, which is only active when the X channel × 10 output expansion is turned ON, causes the lock-in amplifier to respond with the X demodulator output in the range ±300000, full-scale being ±100000. No floating-point version of the command is available.

XOF [n_1 [n_2]] X channel output offset control

n_1 Selection
0 Disables offset
1 Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

XY[.] X, Y channel outputs

Equivalent to the compound command X[.];Y[.]

XYER X, Y channel outputs - enhanced resolution

Equivalent to the compound command XER;YER. Active only when both X and Y × 10 output expansion is turned ON.

Y[.] Y channel output

In fixed point mode causes the lock-in amplifier to respond with the Y demodulator output in the range ±30000, full-scale being ±10000.

In floating point mode causes the lock-in amplifier to respond with the Y demodulator output in volts or amps.

YER Y channel output - enhanced resolution

This command, which is only active when the Y channel × 10 output expansion is turned ON, causes the lock-in amplifier to respond with the Y demodulator output in the range ±300000, full-scale being ±100000. No floating-point version of the command is available.

YOF [n_1 [n_2]] Y channel output offset control

n_1	Selection
0	Disables offset facility
1	Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

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1. Model number and serial number of instrument
2. Your name (instrument user)
3. Your address
4. Address to which the instrument should be returned
5. Your telephone number and extension
6. Symptoms (in detail, including control settings)
7. Your purchase order number for repair charges (does not apply to repairs in warranty)
8. Shipping instructions (if you wish to authorize shipment by any method other than normal surface transportation)

C. If you experience any difficulties in obtaining service please contact:

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