Model 7260

DSP Lock-in Amplifier

Instruction Manual

190163-A-MNL-D

FCC Notice

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.

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)	

Trademarks

IBM is a registered trademark of International Business Machines Corporation
Microsoft, MS-DOS, QBASIC, GWBASIC and QuickBASIC are registered trademarks and Windows is a trademark of Microsoft Corporation
National Instruments is a registered trademark of National Instruments Corporation

Table of Contents

Chapter 1, Introduction

Chapter 2, Installation & Initial Checks

Chapter 3, Technical Description

Chapter 4, Front and Rear Panels

Chapter 5, Front Panel Operation

Chapter 6, Computer Operation

Appendix C, Demonstration Programs

Appendix D, Cable Diagrams

Appendix E, Alphabetical Listing of Commands

Appendix F, Default Settings

Index

Introduction

Chapter 1

1.1 How to Use This Manual

This manual gives detailed instructions for setting up and operating the EG&G Instruments Model 7260 Digital Signal Processing (DSP) dual phase 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 7260.

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 connectors, controls and indicators which are found on the unit and which are 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
Gives an alphabetical listing of the computer commands for easy reference.

Appendix F
Provides a listing of the instrument settings produced by using the Auto-Default function.

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 E 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 7260, 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 7260 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 EG&G Instruments Model 7260 represents the latest in DSP Lock-in Amplifier technology at an affordable price and offers:-

- Frequency range: 0.001 Hz to 250 kHz
- Voltage sensitivity: 2 nV to 1 V full-scale
- Current input mode sensitivities: 2 fA to 1 µA full-scale
2 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
- 5-digit output readings
- Dual reference mode - allows simultaneous measurement of two signals at different reference frequencies up to 20 kHz
- Single and dual harmonic mode - allows simultaneous measurement of up to two different harmonics of a signal
- Virtual reference mode - allows reference free measurement of signals up to 60 kHz
- Direct Digital Synthesizer (DDS) oscillator with variable amplitude and frequency
- Oscillator frequency and amplitude sweep generator
- Output time constant: 10 µs to 100 ks
- 8-bit programmable digital output port for external system control
- Three external ADCs, four external DACs
- Full range of auto-modes
- Standard IEEE-488 and RS232 interfaces with RS232 daisy-chain capability for up to 16 instruments
- Large back-lit liquid crystal display (LCD) with menus for control and display of instrument outputs in both digital and graphical formats
- 32768 point internal curve storage buffer

Installation & Initial Checks

Chapter 2

2.1 Installation

2.1.01 Introduction

Installation of the model 7260 in the laboratory or on the production line is very simple. Because of its low power consumption, the model 7260 does not incorporate forced-air ventilation. 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.

2.1.02 Rack Mounting

An optional accessory kit, part number K02003, is available from EG&G Instruments to allow the model 7260 to be mounted in a standard 19-inch rack.

2.1.03 Inspection

Upon receipt the model 7260 Lock-in Amplifier should be inspected for shipping damage. If any is noted, EG&G INSTRUMENTS 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 7260 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 7260 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 7260 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), 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.

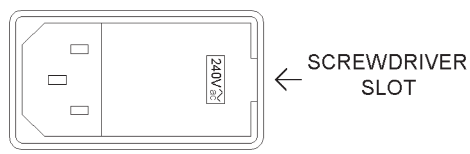

Figure 2-1, Line Input Assembly

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 1.0 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 0.5 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 7260. 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 EG&G INSTRUMENTS 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 EG&G INSTRUMENTS or the nearest authorized representative for assistance.

2.2.02 Procedure

1) Ensure that the model 7260 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 at the extreme top left-hand corner of the instrument when viewed from the rear) set to **0** (off), plug in the line cord to an appropriate line source.

3) Turn the model 7260 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 front panel key marked **MENU** once to enter the Main Menu, shown below in figure 2-3.

Figure 2-3, Main Menu

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 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 R, the vector magnitude, and θ, the phase, of the measured signal in digital form, with two bar-graphs showing the X channel output and Y channel output as a percentage of the full-scale sensitivity. The left-hand side shows four instrument controls, these being the AC Gain and dynamic reserve (DR) in decibels, full-scale sensitivity (SEN), output time constant (TC) and internal oscillator frequency (OSC).

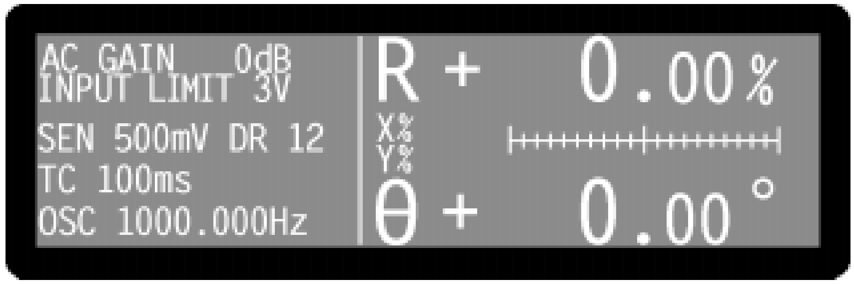

Figure 2-5, Main Display

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, 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.

Technical Description

Chapter 3

3.1 Introduction

The model 7260 lock-in amplifier is a sophisticated instrument with many capabilities beyond those found in similarly-priced units. 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 7260 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 Signal Recovery / Vector Voltmeter

The model 7260 is primarily intended for signal recovery applications, where the requirement is usually for an instrument offering the best rejection of interfering signals and the lowest possible noise. Although a dual phase unit like the model 7260 may be used for measuring the phase of the applied signal with respect to the reference, the accuracy of this measurement is not usually paramount. This operating mode is called the signal recovery mode and is the default mode on power-up.

In situations where the applied signal is essentially free of noise some of the circuitry needed for best signal recovery performance may be bypassed, giving an improvement in the accuracy of phase measurements but at the expense of increased noise. In the model 7260 this can be done by selecting the vector voltmeter mode.

3.2.03 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 7260 this is referred to as the single reference mode.

The dual reference mode incorporated in the model 7260 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 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. Note that in dual reference mode there is no advantage in using vector voltmeter mode and this is not recommended.

3.2.04 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 7260 allows this multiple to be set to any value between 2 (i.e. the second harmonic) and 65535, as well as unity, which is the normal mode. The only restriction is that the product “nF” cannot exceed 250 kHz.

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 “nF” of 20 kHz. Again, it should be noted that in dual harmonic mode there is no advantage in using vector voltmeter mode as well, so this is not recommended.

3.2.05 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 which is applied to the lock-in amplifier’s external reference input. The instrument’s reference channel “locks” to this signal and uses it to measure the applied input signal.

3.2.06 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 EG&G Instruments, 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 other lock-in amplifiers.

3.3 Principles of Operation

3.3.01 Block Diagram

The model 7260 utilizes two digital signal processors (DSP), a microprocessor and a dedicated digital waveform synthesizer, together with 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.

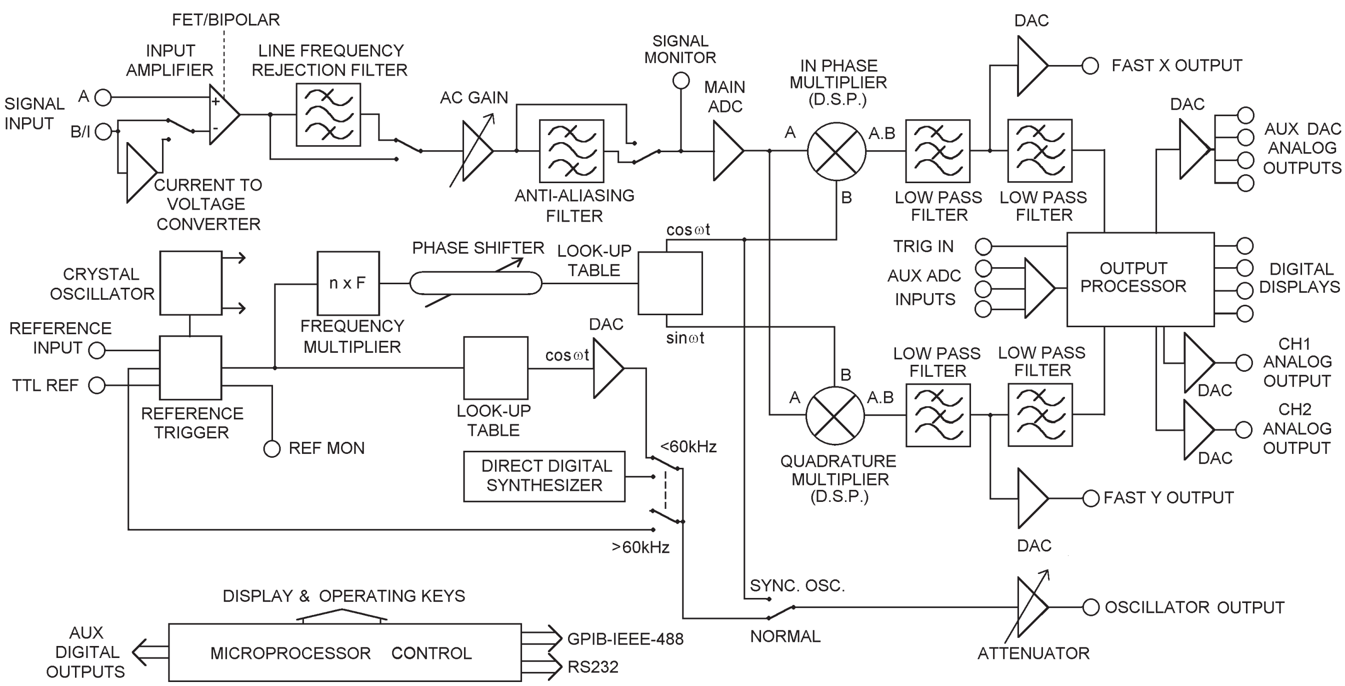

Figure 3-1, Model 7260 - Block Diagram

3.3.02 Signal Channel Inputs

The signal input amplifier may be configured 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 and the input may be switched between FET and bipolar devices. In current mode a choice of two conversion gains is available to give optimum matching to the signal input. 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., defines 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 they can be floated by being connected 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 Device Selection, FET / Bipolar
The voltage preamplifier may be switched between bipolar and FET input devices. The bipolar device, which has an input impedance of 10 kΩ, shows a relatively high level of added current noise (2 pA/√Hz), but less than 50 percent of the voltage noise of the FET device. As such, it is intended for use where the source impedance is resistive or inductive with a resistance of 100 Ω or less, and there is no input voltage offset.

NOTE: Signal channel overload may occur if the bipolar device is selected and no DC bias path is provided.

The FET device provides an input impedance of 10 MΩ with a voltage noise at 1 kHz of less than 5 nV√Hz.

AC / DC Coupling
In normal operation, with reference frequencies above a few hertz, AC-coupled operation is always used.

The primary purpose of the DC-coupling facility is to enable the use of the instrument at reference frequencies below 0.5 Hz. It may also be used to reduce the effect of phase and magnitude errors introduced by the AC-coupling circuitry below a few hertz.

However, the use of DC coupling introduces serious problems where the source has a DC offset or is of such high impedance that bias currents cause significant offsets. In these cases it may be necessary to include some form of signal conditioning between the signal source and the lock-in amplifier.

The instrument always reverts to the AC-coupled mode on power-up, to protect the input circuitry.

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 or wide bandwidth conversion settings, but it should be noted that even at the wide bandwidth setting the -3 dB point is at 50 kHz. Better performance may be achieved using a separate current preamplifier, such as the EG&G model 5182.

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.

Instruments manufactured prior to July 1996 use a simple single-stage band-rejection filter, which has a relatively broad bandwidth. This introduces significant gain and phase errors, at least in the range 5 to 500 Hz, and this should be taken into account if it is used in conjunction with reference frequencies in or near to this range. The filter control settings for these units are simply “ON” or “OFF”.

Instruments manufactured after June 1996 use a more sophisticated type of filter, which uses two cascaded rejection stages with “notch” characteristics. This allows the filter to be set to reject signals at frequencies equal to either of, or both of, the fundamental and second harmonic of the line frequency. Hence the filter control settings for these instruments are “OFF”, “F”, “2F” or “F & 2F”.

Although these later instruments are supplied with the line frequency filter set to match the line frequency of the country for which they are destined, it should be appreciated that if a unit is moved from a 50 Hz area to a 60 Hz area then the filter will need to be adjusted. The instruments therefore respond to a computer command, LINE50, which allows this to be done (see section 6.4.01). There is no provision for changing the line filter frequency from the front panel.

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	3000
10	1000
20	300
30	10
40	30
50	10
60	3
70	1
80	0.3
90	0.1

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 10 or 20 dB 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.

Note that when signal overload occurs, the only action required is to reduce the AC Gain value.

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 r.m.s. conversion). The dynamic reserve is often expressed in decibels, for which

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

Applying this formula to the model 7260 at the maximum value of INPUT LIMIT (3 V) and the smallest available value of FULL-SCALE SENSITIVITY (2 nV), gives a maximum available dynamic reserve of about 1×10^9 or 180 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 this form, the model 7260 displays the current value of Dynamic Reserve in decibels, on the input full-scale sensitivity control, up to a value of 100 dB above which the legend “> 100 dB” appears on the control.

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 due to the nature 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 160 kHz then half the sampling frequency would be 80 kHz. Let the instrument be measuring a signal of 55 kHz accompanied by an interfering signal of 100 kHz. The output of the ADC would therefore include a sampled-data sinusoid of 55 kHz (the required signal) and, applying the above formula, an alias signal of 60 kHz (i.e. |100 kHz - 160 kHz|). If the signal frequency were now increased towards 60 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. When operating in signal recovery mode, at reference frequencies below 60 kHz, the reference frequency is less than half the sampling frequency and a conventional elliptic-type, low-pass anti-alias filter is used. This enables the system to provide the lowest possible noise bandwidth. In signal recovery mode at frequencies above 60 kHz an adaptive bandpass anti-alias filter is used. The noise bandwidth of this filter is dependent on the reference frequency and is higher than that of the conventional type of filter, but typically the noise penalty is negligible.

In vector voltmeter mode the anti-alias filter is a simple Butterworth low-pass design with a passband covering the whole range of the instrument. This arrangement leaves more aliases unattenuated and gives a random noise penalty of 5 dB when compared with signal recovery baseband mode (i.e. at reference frequencies ≤ 60 kHz), but may be preferable in some situations because of its slightly better gain and phase accuracy.

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 full-scale error when the dynamic reserve is set to 100 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 signal channel filters and amplifiers.

3.3.06 Main Analog-to-digital Converter

Following the anti-alias filter the signal passes to the main 18-bit analog-to-digital converter running at a sampling rate of 166 kHz. This rate is not fixed but is reduced automatically by up to 4 %, as a function of the reference frequency, to ensure that the sampling process does not generate a beat frequency close to zero hertz. For example, if the reference frequency were 82.95 kHz and the sampling frequency were not adjusted, a beat frequency of 50 Hz (|82.95 kHz - (166 kHz/2)|) would be generated and, after demodulation, would appear at the output as a 100 Hz signal, if the time constant were not set to a large enough value.

There is one situation where this automatic correction might not be sufficient to give good performance. Consider the case where the signal being measured is at 73 kHz, which is 10 kHz away from half the sampling frequency. If there were also a strong interfering signal at 93 kHz (i.e. 166 kHz/2 + 10 kHz), then an alias of this would give rise to a spurious output. Note that under these circumstances, the reference frequency is not sufficiently close to half the sampling frequency to cause the latter to be automatically adjusted. The problem is overcome by providing the Sample Rate control which allows the user to adjust the main ADC sampling rate in steps of about 2 %. A 2 % change moves the alias by about 2 kHz, which is normally sufficient to ensure rejection by the output low-pass filters and thereby remove any error.

The output from the converter feeds the first of the digital signal processors, the demodulator DSP, which implements the digital multipliers and the first stage of the output low-pass filtering for each of the X and Y channels. Before discussing this DSP and the output stages of the lock-in amplifier we will look at the reference channel which provides the other input to the demodulators.

3.3.07 Reference Channel DSP

The second, or reference, DSP 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 two main outputs, the first being a series of phase values, output at a rate of one every 6 µs, which is used to drive the reference channel input of the demodulator DSP, and the second being a sinusoidal signal which may be used as the instrument's internal oscillator output.

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 DSP code for the internal and external channels runs as an interleaved sequence, producing new phase values of each individual channel once every 12 µs and sending these values to the demodulator DSP alternately at a rate of one every 6 µs. Further discussion of dual reference mode occurs in section 3.3.12.

In single harmonic mode, the reference DSP generates 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 DSP 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.

The instrument incorporates two reference frequency ranges, namely the baseband from 1 mHz to 60 kHz and the highband from 60 kHz to 250 kHz. Different hardware configurations are used in the two bands, transitions between which are made automatically according to the value of the reference frequency. These transitions are generally transparent to the user.

External Reference Mode

In external reference mode at frequencies above 300 mHz, 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. At frequencies below 300 mHz the TTL-logic level input must be used. Following the trigger buffering circuitry the reference signal is passed to a digital phase-locked loop (PLL) implemented in the reference DSP. This measures the period of the applied reference waveform and from this generates the phase values.

Internal Reference Mode

With internal reference operation in the baseband mode (i.e. at reference frequencies < 60 kHz), the reference processor 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. See appendix A for numerical values of phase noise.

In the internal reference highband mode (i.e. reference frequencies > 60 kHz), the instrument essentially operates as if in external mode, except that the reference trigger input is now provided by an internal link from the output of the direct digital synthesizer.

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.

All the parameters are also updated when the **SET** key is pressed or the LOCK command is executed. Therefore, if the most accurate and reproducible settings are required when in the external reference modes, the **SET** key should be pressed or the LOCK command executed after every intentional change in reference frequency. Note that sufficient time must be allowed for the frequency meter to give a fully accurate value.

With internal reference operation, regardless of the frequency mode, the frequency-dependent parameters are updated on any change of reference frequency, without the need to press the front panel **SET** key or to issue the LOCK command.

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

3.3.08 Phase-shifter

The reference DSP 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 7260, 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 7260 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 1 mHz to 250 kHz.

The source of the oscillator depends on whether the instrument is operating in internal or external reference mode, in signal recovery or vector voltmeter mode and on the selected frequency, as follows:-

Signal Recovery Mode
In internal reference baseband mode (< 60 kHz) the oscillator is derived from the reference channel DSP. This outputs a series of digital values, corresponding to a unity amplitude sinusoid of the required frequency, to a 16-bit digital-to-analog converter (DAC) which in turn feeds a variable attenuator. The output of the attenuator is the internal oscillator output.

In internal reference highband mode (> 60 kHz) and external reference mode, the oscillator is derived from a dedicated direct digital synthesizer (DDS).

Vector Voltmeter Mode
In this mode, the oscillator is derived from a dedicated direct digital synthesizer (DDS).

3.3.10 Internal Oscillator - Update Rate

The direct digital synthesis 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.

It will be appreciated that, for a given total harmonic distortion, the update rate at which new values are written to the oscillator output DAC need not be the same over the whole range of oscillator frequencies. The model 7260 selects one of four values, as defined in table 3-2 below.

Mode	Update rate (period)			
	$\frac{1}{20}$ MHz 20µs	$\frac{1}{6}$ MHz 6µs	1 MHz 1µs	16 MHz 62.5ns
Signal Recovery Mode				
Internal Reference mode				
1 mHz < f < 1 Hz	✓			
1 Hz < f < 60 kHz			✓	
60 kHz < f < 250 kHz				✓
External Reference mode				
1 mHz < f < 1 kHz			✓	
1 kHz < f < 250 kHz				✓
Dual Reference mode				
1 mHz < f < 20 kHz		✓		
Dual Harmonic mode				
1 mHz < f < 20 kHz			✓	
Vector Voltmeter Mode				
Internal & External Reference modes				
1 mHz < f < 1 kHz			✓	
1 kHz < f < 250 kHz				✓

Table 3-2, Internal Oscillator Output DAC Update Rate

Generally, the update rate will not be apparent to the user, except in two situations. The first of these occurs when operating in dual reference mode at reference frequencies approaching the upper limit of 20 kHz, where the 1/6 MHz (166.6 kHz) update rate may be seen, since at a frequency of 20 kHz the oscillator waveform will be composed of just over 8 steps per cycle.

The second occurs when the synchronous oscillator is switched on. In this mode, available only in external single reference mode, the digital samples representing the sinusoidal signal at the reference input to the X channel demodulator are converted to an analog signal and routed via an adjustable-gain amplifier to the **OSC OUT** connector. Since these samples are generated, and hence the output is updated, at a fixed rate of 1/6 MHz (166.6 kHz), the **OSC OUT** signal becomes increasingly difficult to interpret, when viewed on an oscilloscope, as the frequency increases above about 20 kHz. In some applications these limitations may be overcome by the use of a simple RC low-pass filter following the output.

When used in the synchronous oscillator mode, the signal at the **OSC OUT** connector is affected by both the reference phase-shifter and harmonic controls of the reference channel. For example, if an external reference at 1 kHz were applied, the unit were set to operate in the 2F mode and the synchronous oscillator were turned on, then the signal at the **OSC OUT** connector would be a 2 kHz sinusoid whose phase relative to the applied reference could be adjusted using the reference phase-shifter. The oscillator amplitude control affects the variable-gain amplifier and allows the amplitude of the signal at the **OSC OUT** connector to be adjusted, but the oscillator frequency control has no effect.

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 reaches a maximum. At this point the internal oscillator frequency and signal frequency are locked. The sweep then stops and the oscillator frequency is continuously adjusted 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 measurement 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 Demodulator DSP

The essential operation of the demodulator DSP 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, nF, 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. The outputs of these in turn drive two 16-bit DACs which generate the instrument’s **FAST X** and **FAST Y** analog output connectors. In addition, the 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 demodulator DSP generates two sets of outputs, one for each of the two references or harmonics, and includes two sets (four channels) of initial output filtering. These signals are passed to the host processor in interleaved format, with every other signal, resulting from the $Reference_1$ or $Harmonic_1$ measurement, also being converted and appearing at the **FAST X** and **FAST Y** analog output connectors. However, particularly when in the dual reference mode, these signals are not easy to interpret when viewed on an oscilloscope and hence we do not recommend their use. Consequently, in these modes the minimum usable output time constant is that of the digital displays or **CH1**/**CH2** analog outputs, i.e. 5 ms.

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 demodulator DSP. As with most lock-in amplifiers, the output filter configuration in the model 7260 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 7260 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 the filter slope for the **FAST X** and **FAST Y** outputs on the rear panel is fixed at 6 dB/octave.

The output time constant can be varied between 10 µs and 100 ks. Values from 10 µs to 640 µs are available at the **FAST X** and **FAST Y** outputs, while values from 5 ms to 100 ks apply to all other outputs, including **CH1**, **CH2** and the internal digital values as 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 640 ms and 80 ms respectively. As noted in section 3.3.12 above, in dual reference and dual harmonic modes the minimum output time constant is 5 ms, so that if an analog output is required then the **CH1** or **CH2** connectors should be used.

The filters are of the finite impulse response (FIR) 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. Note that although the digital displays do not limit until a level of ±300 % full-scale has been reached, the rear-panel **CH1** and **CH2** analog outputs limit at ±120 % full-scale.

The output expand facility allows a x10 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 **CH1** and **CH2** 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 (r.m.s.) 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 r.m.s. 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 3.3.19 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 is available only in the baseband mode (i.e. at reference frequencies less than 60 kHz) and uses the output processor to perform a noise computation on the Y output where it is assumed that the amplitude distribution of the waveform is *Gaussian with zero mean.* The zero mean is usually obtained by first using the reference phase control or the Auto-Phase function with a comparatively long time constant (say 1 s) and then reducing the time constant (to say 10 ms) for the actual noise measurement.

The user is strongly advised to use an oscilloscope attached to the **SIG MON** (signal monitor) output on the rear panel when making noise measurements as this is the best way of ensuring that one is measuring a random process rather than line pick-up or other non-random signals.

The indicated value of the noise (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. This bandwidth is given for the typical range of time constants used for such measurements and each of the four possible filter slope settings in table 3.3 below.

Time Constant	Equivalent Noise Bandwidth (Hz) at Filter Slope			
	6 dB/octave	12 dB/octave	18 dB/octave	24 dB/octave
5 ms	50	37.5	31.25	27.35
10 ms	25	17.2	14.15	12.35
20 ms	12.5	8.3375	6.875	5.9875
50 ms	5	3.335	2.75	2.395
100 ms	2.5	1.6675	1.375	1.1975
200 ms	1.25	0.83375	0.6875	0.59875
500 ms	0.5	0.3335	0.275	0.2395
1 s	0.25	0.16675	0.1375	0.11975
2 s	0.125	0.083375	0.06875	0.059875
5 s	0.05	0.03335	0.0275	0.02395
10 s	0.025	0.016675	0.01375	0.011975

Table 3-3, ENBW vs Filter Time Constant and Slope

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 **CH1** and **CH2** output connectors.

3.3.17 Auxiliary Analog Inputs and Outputs (ADCs and DACs)

The model 7260 incorporates three auxiliary ADC inputs, two of which are conventional sampled converters 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 in 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.

The third ADC is an integrating converter which integrates the applied voltage for a defined period between 10 ms and 2 s, giving an effective resolution of between 12 and 20 bits.

Four 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 - 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 output port, which may be used for controlling auxiliary apparatus.

The microprocessor has access to a 32768 point memory which may 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.

3.3.19 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 instrument is set to signal recovery mode, line filter is disabled, AC coupling is established, the FET input device is selected and the FLOAT mode is set. 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 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 7260, 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 F.

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 ±0.2 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 in the upper part of the frequency range (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 signal channel reverts to AC coupling.
b) The GPIB mask byte is set to zero.
c) The REMOTE parameter is set to zero (front-panel control enabled).
d) The curve buffer is cleared.
e) Any sweep that was in progress at switch-off is terminated.
f) Synchronous time constants are enabled.
g) The display backlight is turned on

Front and Rear Panels

Chapter 4

4.1 Front Panel

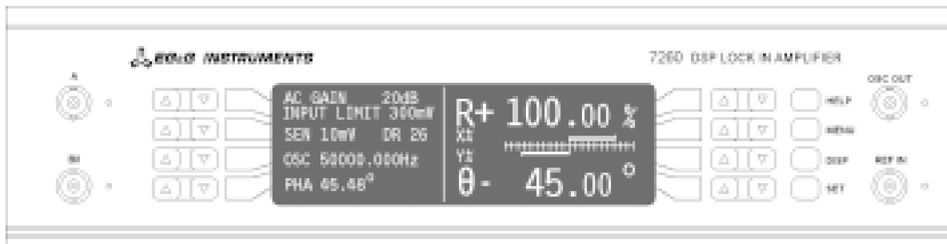

Figure 4-1, Model 7260 Front Panel Layout

As shown in figure 4-1, there are four BNC connectors with associated LED indicators, a 64 × 240 pixel backlit LCD display panel, eight double and four single keys mounted on the model 7260's front panel. 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 current input mode is selected. LEDs adjacent to the connectors light continuously to indicate which of them is active when a particular input mode is selected, or flash to indicate that the input is in overload (see figure 4-2).

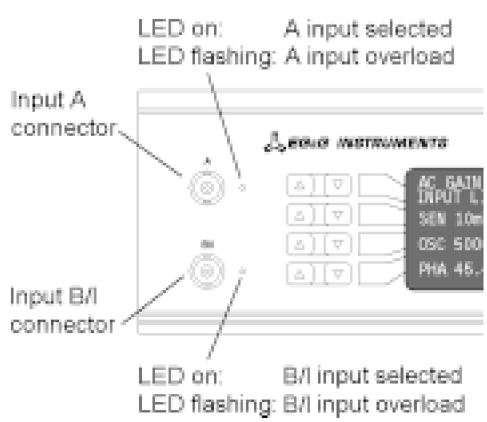

Figure 4-2, Signal Inputs

4.1.02 OSC OUT Connector

This is the output connector for the internal oscillator. When internal reference mode is selected the LED adjacent to the connector will be lit (see figure 4-3).

4.1.03 REF IN Connector

This is the input connector for a general purpose external reference signal > 300 mHz. If external reference operation at lower frequencies is required, the **REF TTL** input on the rear panel should be used. When external reference mode is selected the LED adjacent to the connector will be lit (see figure 4-3). Under unlock conditions the LED will flash.

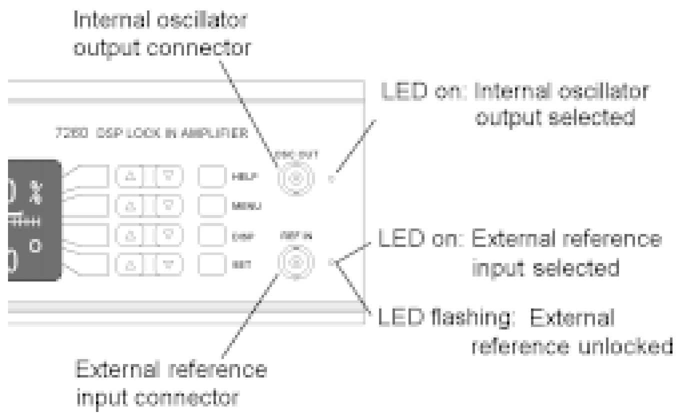

Figure 4-3, OSC OUT and REF IN Connectors

4.1.04 LCD Display Panel

This panel and the four pairs of keys on each side of it are used to adjust the instrument's controls and display the measured outputs, by the use of a series of menus. The model 7260 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 needed to be made very large. Adopting a menu-based control and display system, with the function of each key being dependent on the displayed menu, allows the instrument to be made much more compact and additionally controls which need to be changed only occasionally can be hidden in normal use.

The eight pairs of keys 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 are required to make adjustments.

Adjustment of the latter type of control is made easier by the use of either or all of the three methods described below.

Auto Repeat
If an △ or ▽ key is pressed and held, then its action is automatically repeated such that the displayed control setting will increment or decrement at a rate approximately ten times faster than can be achieved by repeated manual key-presses.

Active Cursor
The keys can be used initially to place a cursor over a given digit in the displayed control setting, prior to changing that digit. This is done by using the procedure described below.

Step 1 Press both the △ and ▽ keys simultaneously. In the example shown in figure 4-4 the internal oscillator frequency is to be adjusted, since this is the control displayed adjacent to the keys. A cursor appears under one of the displayed digits (see also figure 4-5).

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.

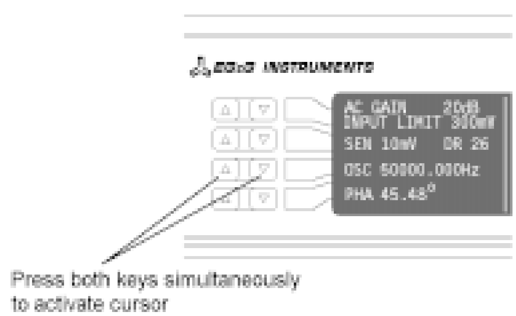

Figure 4-4, Active Cursor Activation

As an example of this operation, suppose that the oscillator frequency is 50 kHz and it is required to change it to 51 kHz. Simultaneously press both △ and ▽ keys adjacent to the oscillator frequency display. Move the cursor, by repeated double-key presses, until it is under the required digit, in this case the zero to the right of the leading 5. Then press the △ key to increment the frequency by 1 kHz. The cursor will disappear as soon as the frequency is adjusted but its position remains active until changed (see figure 4-5).

Action	Display after action	
	OSC: 50000.000Hz	
Press both keys	OSC: 50000.000Hz	(where the cursor appears depends on where it was previously left)
Press both keys repeatedly until	OSC: 50000.000Hz	
Press △ key	OSC: 51000.000Hz	

Figure 4-5, 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.

Control Zeroing

Any control may be set to zero, e.g. the oscillator frequency may be set to 0.000 Hz, by pressing and holding both sides of the adjacent △▽ key simultaneously until the control display changes to zero.

Function 2: To Select a Menu or Sub-Menu

When the display 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 display 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 7260 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 7260 is controlled by a series of on-screen menus. When the Main Display, which is used to adjust up to four selected controls and to display the instrument outputs, is shown the **MENU** key is used to access the Main Menu, from which other menus may be accessed. Pressing the **MENU** key a second time returns the display to the Main Display.

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

4.1.07 DISP Key

This key provides convenient single-button access to the menu in which the user may choose which three out of the possible thirteen basic instrument controls, including those such as full-scale sensitivity, time constant and oscillator frequency, may be directly adjusted from the Main Display.

Once these controls have been selected, pressing the **DISP** key a second time returns to the Main Display.

4.1.08 SET Key

This key updates all frequency-dependent parameters within the lock-in amplifier. This key should be pressed, when using external reference modes, after any change to the external reference frequency.

4.2 Rear Panel

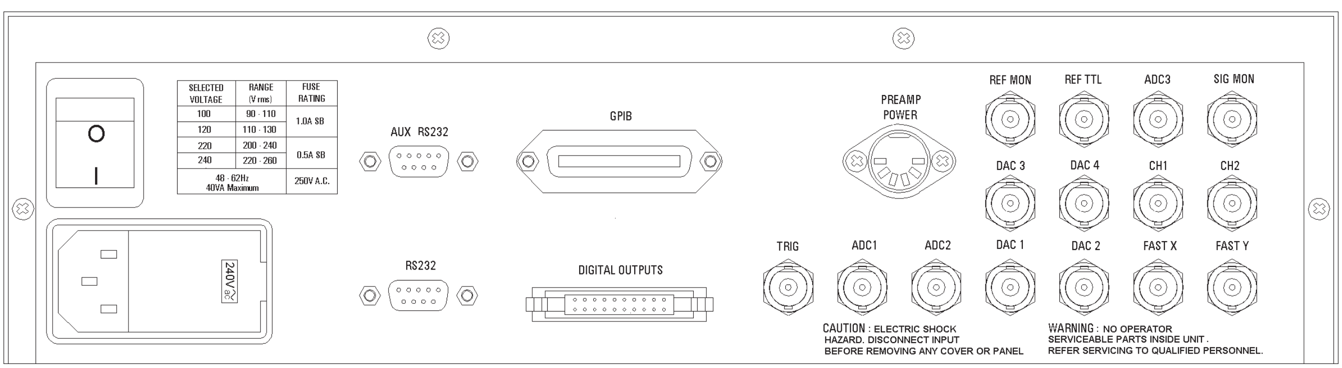

Figure 4-6, Model 7260 Rear Panel Layout

As shown in figure 4-6, the line power switch, line power voltage selector, two RS232 connectors, a GPIB (IEEE-488) connector, digital output port, preamplifier power connector and fifteen 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

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 OUTPUTS Connector

This connector provides eight TTL output lines, each of which can be set high or low by the use of the Digital Port menu or via the computer interfaces. It is most commonly used for controlling auxiliary apparatus, such as lamps, shutters and heaters. Pinouts for this connector are given in appendix B.

4.2.07 PREAMP POWER Connector

This connector supplies ±15 V at up to 100 mA and can be used for powering any of several optional remote preamplifiers available from EG&G Instruments. 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. At reference frequencies < 300 mHz, it should always be used in preference to the **REF IN** connector on the front panel.

4.2.10 ADC3 Connector

This is the input connector for the third analog-to-digital converter (ADC) which uses a voltage-to-frequency converter (VFC) followed by a counter to implement the conversion. The VFC is driven by the signal at this connector, which should be limited to a full-scale range of ±10.0 V. The value returned by the converter and viewed on the ADC3 menu or returned in response to a computer command is proportional to the integral of the voltage waveform for the specified sampling time.

4.2.11 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.

4.2.12 CH1 and CH2 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 User Options 1 menu. The minimum time constant that can be used is 5 ms. The full-scale output voltage range is ±10.0 V although the outputs remain valid to ±12.0 V to provide some overload capability.

4.2.13 TRIG Connector

This connector accepts a TTL-compatible input and can be used for triggering the auxiliary analog-to-digital converters (ADCs). The input operates on the positive edge only.

4.2.14 ADC1 and ADC2 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 ±10.0 V and the resolution is 1 mV.

4.2.15 DAC1, DAC2, DAC3 and DAC4 Connectors

There are four 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 ±10.0 V and the resolution is 1 mV.

4.2.16 FAST X and FAST Y Connectors

The signals at these two connectors are the X channel and Y channel output signals derived from a point after the first stage of output low-pass filtering. The range of time constants that can be used is from 10 µs to 640 µs, with a fixed slope of 6 dB/octave. Visual interpretation of the waveforms at these connectors, as displayed on an oscilloscope, when the instrument is operating in the highband mode (i.e. above 60 kHz) or in dual reference or dual harmonic modes is difficult.

Front Panel Operation

Chapter 5

5.1 Introduction

This chapter describes how to operate the model 7260 using the front panel controls, and discusses its capabilities when used in this way. Chapter 6 provides similar information in the situation where 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 7260 uses a flexible, menu-based, control structure which allows many instrument controls to be adjusted from the front panel with only a few keys. 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. Signal recovery or vector voltmeter modes may be used.

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 60 kHz.

Dual Reference
In dual reference mode the model 7260 can make simultaneous measurements at two different reference frequencies, one of which is external and the other is derived from the internal oscillator. The maximum frequency for either reference is 20 kHz.

Dual Harmonic
Dual harmonic mode allows the simultaneous measurement of two different harmonics of the input signal. As with dual reference mode, the maximum frequency for either harmonic is 20 kHz.

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.

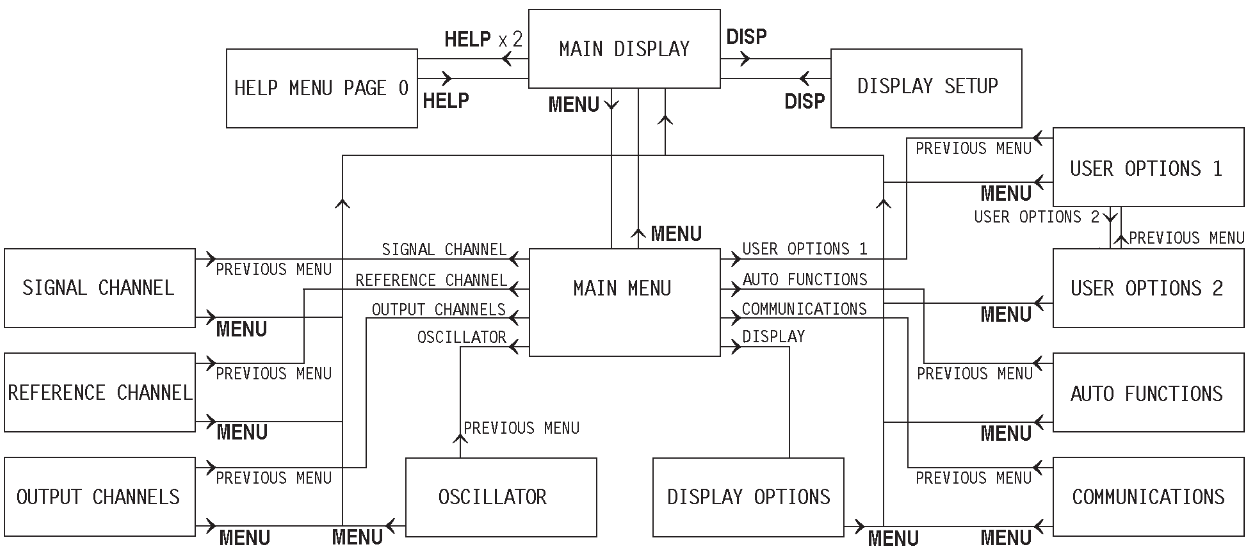

Figure 5-1, Main Menu Structure

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. Front-panel keys are shown in bold sans serif typeface, as they appear on the front panel, e.g. **DISP** and **MENU**. 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 the Main Menu from the Main Display, press the **MENU** key on the front panel once; to return to the Main Display from the Main Menu, press the **MENU** key once more.

To access the Communications menu from the Main Display, press the **MENU** key on the front panel followed by the key adjacent to the word Communications shown in the Main Menu; to return to Main Menu press the Previous Menu key on the Communications menu.

Note that all menus, with the exception of the Display Options menu, provide a Previous Menu choice allowing the user to return one step up the menu “tree”. In addition, when in any menu, pressing the **MENU** key on the front panel provides a direct return 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

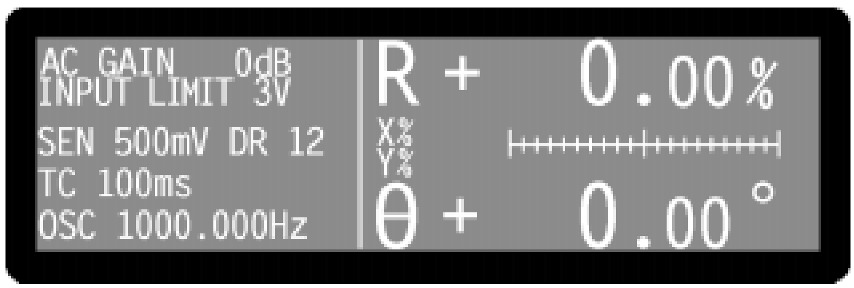

Figure 5-2, Main Display - Single Reference Mode

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. Four instrument controls appear on the left-hand side, of which one, AC Gain, is always displayed, whereas the other three are user-specified using the Display Setup 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) Two large and two small numeric displays

The display mode is selected via the Display Options menu, discussed later in section 5.3.27. However, for 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 eleven possible outputs to choose from for each display in numerical form, with seven 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
θ°	Phase output in degrees
X	X channel output in volts or amps
Y	Y channel output in volts or amps
R	Resultant (Magnitude) output in volts or amps
N	Noise output in volts or amps per root hertz
xxxx Hz	Reference frequency in hertz
Numeric & Bar-Graph Displays:	
X%	X channel output as a percentage of full-scale sensitivity
Y%	Y channel output as a percentage of full-scale sensitivity
N%	Noise output as a percentage of full-scale sensitivity
ADC1	ADC1 input, ±10.000 V full-scale
ADC2	ADC2 input, ±10.000 V full-scale
Bar-Graph Displays Only:	
MAG%	Magnitude output as a percentage of full-scale sensitivity
PHA	Phase output, full-scale = ±200°

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

AC GAIN

The AC Gain control is always displayed in the top left-hand corner of the Main Display. If the AC Gain control is set to Manual (using the Signal Channel menu - see section 5.3.04), then this control allows it to be adjusted from 0 dB to 90 dB in 10 dB steps, although not all settings are available at all full-scale sensitivity settings. If it is set to Automatic, 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 overload. 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 Display Setup Menu

The three user-specified controls on the Main Display may be chosen from those available by pressing the **DISP** key on the front panel. The Display Setup menu appears, as shown in figure 5-3.

Figure 5-3, Display Setup Menu

Press the (△)(▽) keys adjacent to each of the three 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:-

SEN **(Full-scale 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 2 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 2 fA and 1 µA (wide bandwidth mode) or 2 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 = 10 dB and SEN = 2 mV then

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

$$DR = 50 \text{ dB}$$

TC (Time Constant)
The time constant of the output filters is set using this control. Settings between 10 µs and 640 µs are in a binary sequence and apply only to the **FAST X** and **FAST Y** outputs on the rear panel. Settings between 5 ms and 100 ks are in a 1-2-5 sequence and apply to all the other instrument outputs.

OSC xxxx Hz (Oscillator Frequency)
The frequency of the instrument's internal oscillator may be set, using this control, to any value between 1 mHz and 250 kHz with a 1 mHz resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

OSC xxxx V (Oscillator Amplitude)
The amplitude of the instrument's internal oscillator may be set, using this control, to any value between 1 mV and 5 V rms with a 1 mV resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

DAC1 to DAC4
These four controls set the voltage appearing at the **DAC1** to **DAC4** output connectors on the rear panel to any value between +10 V and -10 V with a resolution of 1 mV. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

XOF and YOF (X channel and Y channel output offsets)
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 if use is made of the Active Cursor control - 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.

FRQ (Reference Frequency Display)
Although not a control, it is possible to display the current reference frequency on the left-hand side of the display by selecting this option. Naturally, when this is done the adjacent △▽ keys have no effect.

PHA (Reference Phase)
This control allows the reference phase to be adjusted over the range -180° to +180° in 10m° steps. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The Auto-Phase function also affects the setting of this control.

QUAD (Reference Phase Quadrant)
This control allows the reference phase to be adjusted in steps of ±90°.

The Auto-Phase function also affects the setting of this control.

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

5.3.03 Main Menu

When in the Main Display, press the **MENU** key on the front panel once to access the Main Menu, which is shown in figure 5-4.

Figure 5-4, Main Menu

The Main Menu 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 the Main Menu 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.

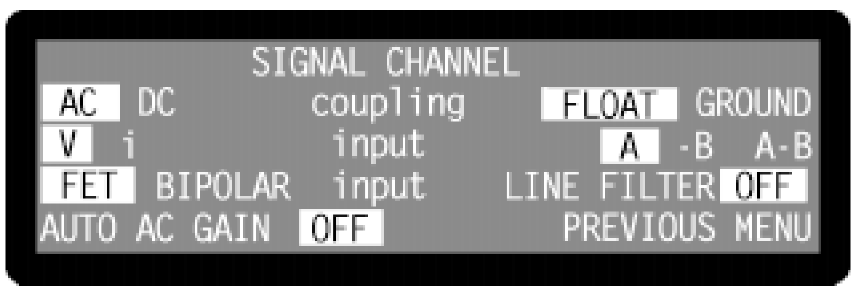

Figure 5-5, Signal Channel Menu - Voltage Input Mode

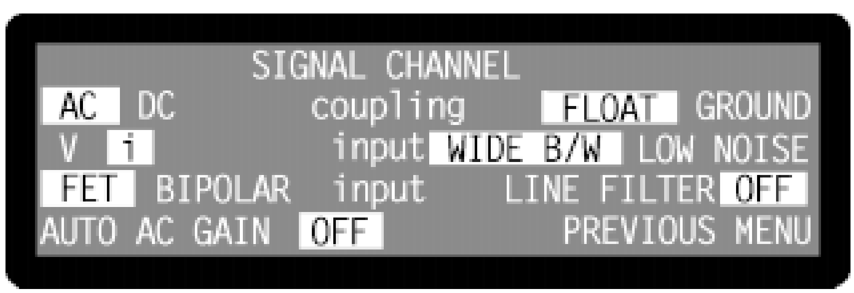

Figure 5-6, Signal Channel Menu - Current Input Mode

The Signal Channel menu has seven 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 highlighted.

Coupling
There are two independent switchable coupling modes, AC or DC and Float or Ground, as follows:-

AC
The voltage inputs are AC coupled

DC
The voltage inputs are DC coupled. Note that DC coupling should be used at frequencies of < 1 Hz.

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

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

Input
The upper pair of Input controls is used to select voltage or current input mode and depending on this mode, the input connectors or current conversion ratio which will used.

V **(Voltage input mode)**
In this setting the signal channel input is a voltage input, and the menu appears as in figure 5-5. It is connected according to the setting of the corresponding right-hand input control, as follows:-

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**.

i **(Current input mode)**
In this setting the signal channel input is a current input, and the menu appears as in figure 5-6. The current-to-voltage converter may be switched to low-noise or wide bandwidth settings depending on the corresponding right-hand input control, as follows:-

`WIDE B/W` **(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 a wide bandwidth current-to-voltage converter.

`LOW 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 a low-noise current-to-voltage converter.

Input
The left-hand of the lower pair of input controls selects the voltage mode input device. It has no effect when operating in current input mode. Operation is as follows:-

`FET` **(FET input device)**
Uses a FET as the input device, for which case the input impedance is 10 MΩ. This is the usual setting.

`BIPOLAR` **(Bipolar input device)**
Uses a bipolar device in the input stage, for the lowest possible voltage input noise. In this case the input impedance is 10 kΩ. Note that this selection is not possible when using the AC-coupled input modes.

The right-hand of the lower pair of input controls selects the mode of operation of the line frequency rejection filter.

Early instruments have two possible settings for this control, ON or OFF. Note that in these units the filter introduces significant gain and phase errors when measuring signals in the frequency range from 5 Hz to 500 Hz.

Instruments manufactured after June 1996 which are fitted with updated filter hardware offer four possible settings for the control, as defined by the following table:-

Legend	Function
`OFF`	Line filter inactive
`F`	Enable 50 or 60 Hz notch filter
`2F`	Enable 100 or 120 Hz notch filter
`F&2F`	Enable both filters

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.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.05 Reference Channel Menu

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

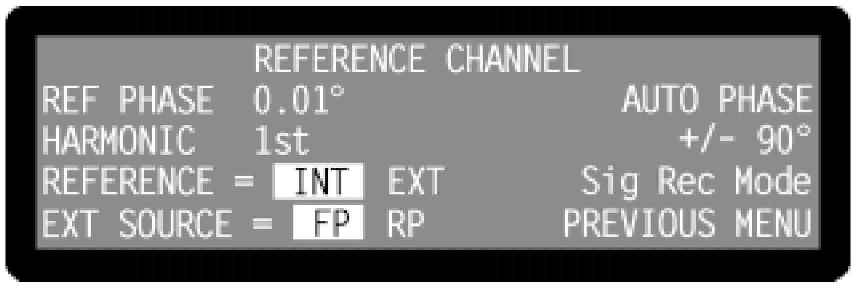

Figure 5-7, Reference Channel Menu

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

REF PHASE **(Reference Phase)**
This control, which duplicates the Main Display PHA control, allows the reference phase to be adjusted over the range -180° to + 180° in 10m° steps. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The Auto-Phase function also affects the setting of this control.

HARMONIC **(Reference 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 65535, but most commonly is set to 1st. Note that the "2F" setting found on other lock-in amplifiers corresponds to setting this control to 2nd. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

REFERENCE **(Reference Source)**
This control allows selection of the source of reference signal used to drive the reference circuitry, and has two 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

In this setting the reference channel is configured to accept a suitable external reference source. The actual connector which should be used for this reference is set by the EXT SOURCE control.

EXT SOURCE

This control has two settings and is used to specify the connector to which the external reference source is connected.

FP **(Front Panel)**

In this setting, which is suitable for use with reference frequencies above 300 mHz, the lock-in amplifier's reference should be applied to the **REF IN** connector on the front panel. A wide variety of signal waveforms may be employed but at frequencies lower than 1 Hz, square waveforms should be used.

RP **(Rear Panel)**

In this setting, the lock-in amplifier's reference should be applied to the TTL-compatible **REF TTL** connector on the rear panel. The use of this input is preferable to the front panel input when a TTL logic reference signal is available. This setting should always be used when operating with external reference frequencies < 300 mHz.

AUTO PHASE

Pressing a key adjacent to the Auto Phase item performs a single Auto-Phase operation. This control duplicates the Auto Phase control on the Auto Functions menu, and its operation is more fully discussed in section 5.3.20

+/- 90°

This control, which duplicates the Main Display QUAD control, allows the reference phase to be adjusted in steps of ±90°.

Sig Rec Mode/Vector VM Mode

This control allows the instrument to be switched from the default Signal Recovery mode to Vector Voltmeter mode, which may give slightly better phase accuracy when measuring clean signals. These two modes are discussed further in section 3.2.02. Note that the instrument always reverts to Signal Recovery mode on power-up.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.06 Output Channels Menu

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

Figure 5-8, Output Channels Menu

The Output Channels menu has seven 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 XOF and YOF 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 if use is made of the Active Cursor control - see section 4.1.04.

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

OFFSET

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:-

X OFF, Y OFF
Both X channel and Y channel output offsets are switched off.

X ON, Y OFF
The X channel output offset is switched on.

X OFF, Y ON
The Y channel output offset is switched on.

X ON , Y ON
Both X channel and Y channel output offsets are switched on.

EXPAND

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

X OFF, Y OFF

Output expansion is turned off.

X ON, Y OFF

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

X OFF, Y ON

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

X ON, Y ON

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

TC **(Time Constant)**

This control, which duplicates the Main Display TC control, is used to set the time constant of the output filters. The settings between 10 µs and 640 µs are in a binary sequence and apply only to the **FAST X** and **FAST Y** outputs on the rear panel. Settings between 5 ms and 100 ks are in a 1-2-5 sequence and apply to all of the other instrument outputs.

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 this control does not affect the roll-off of the **FAST X** and **FAST Y** outputs which are fixed at 6 dB/octave.

TCs **(Time Constant Mode)**

This control has two settings, as follows:-

TCs SYNC **(Synchronous Time Constants)**

In this setting, the actual time constant used is chosen to be some multiple of the reference frequency period. This mode provides an output which will be much more stable at low frequencies than it would otherwise be. Note that, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

TCs ASYNC **(Asynchronous Time Constants)**

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

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.07 Oscillator Menu

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

Figure 5-9, Oscillator Menu

The Oscillator menu has three 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 the Main Menu is shown in figure 5-10. 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 **MENU** key on the front panel, but this has been omitted from figure 5-10 for the sake of clarity.

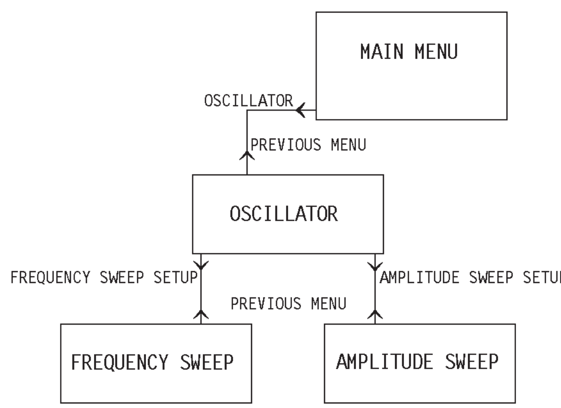

Figure 5-10, Oscillator Menu Structure

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

FREQUENCY

This control, which duplicates the Main Display OSC control, allows the instrument's internal oscillator frequency to be set to any value between 1 mHz and 250 kHz with a 1 mHz resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

AMPLITUDE

This control, which duplicates the Main Display OSC control, allows the instrument's internal oscillator amplitude to be set to any value between 1 mV and 5 V rms with a 1 mV resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

SYNC OSC **(Synchronous Oscillator Output)**

This control has two settings, ON and OFF, which are only meaningful when the lock-in amplifier is operated in external reference mode:-

ON

When the Synchronous Oscillator is switched ON and the instrument is operating in External Reference mode, the signal at the **OSC OUT** connector changes from that of the internal oscillator to an analog representation of the drive from the reference channel to the X channel output demodulator. The amplitude of this signal may be controlled by the internal oscillator amplitude controls, but the internal oscillator frequency control has no effect since the frequency is related to the external reference.

For example, if the harmonic mode is set to 1st, the signal at the **OSC OUT** connector will be at the same frequency as the applied reference, but if it is set to any other harmonic then the output will be at that harmonic of the reference frequency. Note that at high output frequencies (> 20 kHz) the output update rate is apparent - see section 3.3.09.

OFF

When the Synchronous Oscillator is switched OFF the **OSC OUT** connector functions as the output from the internal oscillator. The signal provided at it may be adjusted both in amplitude and frequency using the instrument's controls. This is the most common setting.

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

5.3.08 Frequency Sweep Menu

When the Oscillator menu is displayed, pressing a key adjacent to the Frequency Sweep Setup item accesses the Frequency Sweep menu, which is shown in figure 5-11.

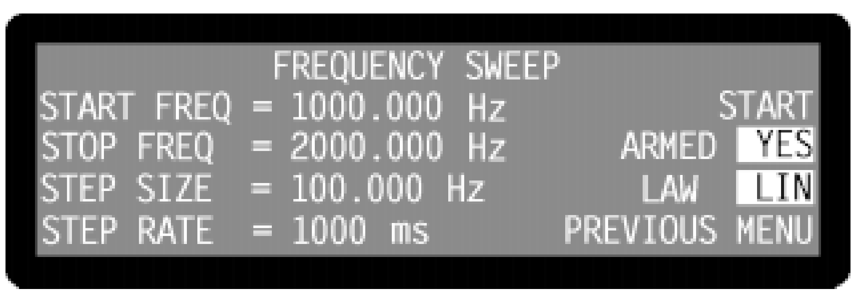

Figure 5-11, Frequency Sweep Menu

The Frequency Sweep menu has seven controls affecting the instrument's internal oscillator. Changes to the setting of these controls can be made by using the adjacent (△)(▽) keys, with the currently active selection being highlighted.

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:-

START FREQ
This control defines the start frequency for the frequency sweep, which may be set to any value between 1 mHz and 250 kHz to a 1 mHz resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

STOP FREQ
This control defines the stop frequency for the frequency sweep, which may be set to any value between 1 mHz and 250 kHz to a 1 mHz resolution. Adjustment is faster if use is made of the Active Cursor control - 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 > Stop Frequency then the output frequency will decrease with time.

STEP RATE
This control defines the time that the oscillator frequency remains at each step of the complete frequency sweep. Values between 50 ms and 100 s may be set to a 5 ms resolution. Note that the step rate defined here also applies to oscillator amplitude sweeps - see section 5.3.09.

ARMED
When this control is set to YES, one or more of the following controls will be displayed.

START
Pressing the adjacent (△)(▽) key starts the frequency sweep. The display changes to give two options, Stop and Pause.

STOP
Pressing the adjacent (△)(▽) key stops the frequency sweep.

PAUSE
Pressing the adjacent (△)(▽) key pauses the frequency sweep at the present frequency. The display changes to Continue.

CONTINUE
Pressing the adjacent (△)(▽) key restarts the paused frequency sweep from the present frequency. The display changes to Pause.

Note that if the oscillator amplitude sweep is also armed (see section 5.3.09) then pressing Start on the Frequency Sweep menu will also start the amplitude sweep. The armed control cannot be changed when a sweep is in progress.

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

`LIN`
Selects a linear relationship.

`LOG`
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

SEEK
This is the same as the linear sweep mode, except that the sweep stops automatically as soon as the signal magnitude exceeds 50 % of the current full-scale sensitivity. It is used during setting up of the virtual reference mode - see section 5.4.

Pressing a key adjacent to the Previous Menu item returns control to the Oscillator menu.

5.3.09 Amplitude Sweep Menu

When the Oscillator menu is displayed, pressing a key adjacent to the Amplitude Sweep Setup item accesses the Amplitude Sweep menu, which is shown in figure 5-12.

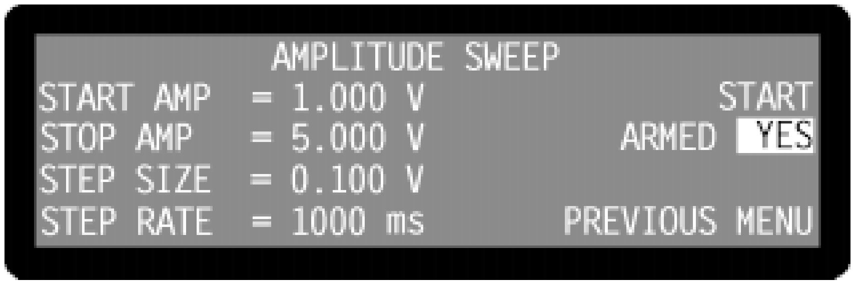

Figure 5-12, Amplitude Sweep Menu

The Amplitude Sweep menu has six controls affecting the instrument's internal oscillator. Changes to the setting of these controls can be made by using the adjacent △ ▽ keys, with the currently active selection being highlighted.

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:-

START AMP
This control defines the start amplitude for the amplitude sweep, which may be set to any value between 0.000 V rms and 5.000 V rms to a 1 mV resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

STOP AMP
This control defines the stop amplitude for the amplitude sweep, which may be set to any value between 0.000 V rms and 5.000 V rms to a 1 mV resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

STEP SIZE
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 5.000 V rms to a 1 mV resolution. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

If Start Amp > Stop Amp then the oscillator amplitude will decrease with time.

STEP RATE
This control defines the time that the oscillator amplitude remains at each step of the complete amplitude sweep. Values between 50 ms and 100 s may be set to a 5 ms resolution. Note that the step rate defined here also applies to oscillator frequency sweeps - see section 5.3.08.

ARMED
When this control is set to YES, one or more of the following controls will be displayed.

START
Pressing the adjacent (△)(▽) key starts the amplitude sweep. The display changes to give two options, Stop and Pause.

STOP
Pressing the adjacent (△)(▽) key stops the amplitude sweep.

PAUSE
Pressing the adjacent (△)(▽) key pauses the amplitude sweep at the present amplitude. The display changes to Continue.

CONTINUE
Pressing the adjacent (△)(▽) key restarts the paused amplitude sweep from the present amplitude. The display changes to Pause.

Note that if the oscillator frequency sweep is also armed (see section 5.3.08) then pressing Start on the Amplitude Sweep menu will also start the frequency sweep. The armed control cannot be changed when a sweep is in progress.

Pressing a key adjacent to the Previous Menu item returns control to the Oscillator menu.

5.3.10 User Options 1 Menu

When the Main Menu is displayed, pressing a key adjacent to the User Options 1 item accesses the User Options 1 menu, which is shown in figure 5-13.

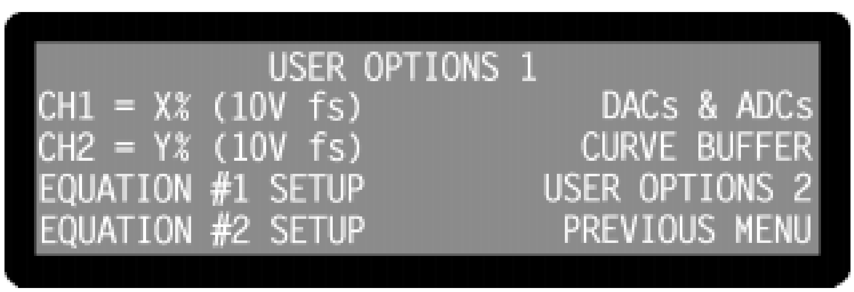

Figure 5-13, User Options 1 Menu

The User Options 1 menu has two controls which are used to select the outputs to be provided at the **CH1** and **CH2** connectors on the rear panel. This menu is also used for accessing five sub-menus, some of which have further sub-menus and all of which have further instrument controls. The relationship of these menus to the Main Menu is shown in figure 5-14. 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 **MENU** key on the front panel, but this has been omitted from figure 5-14 for the sake of clarity.

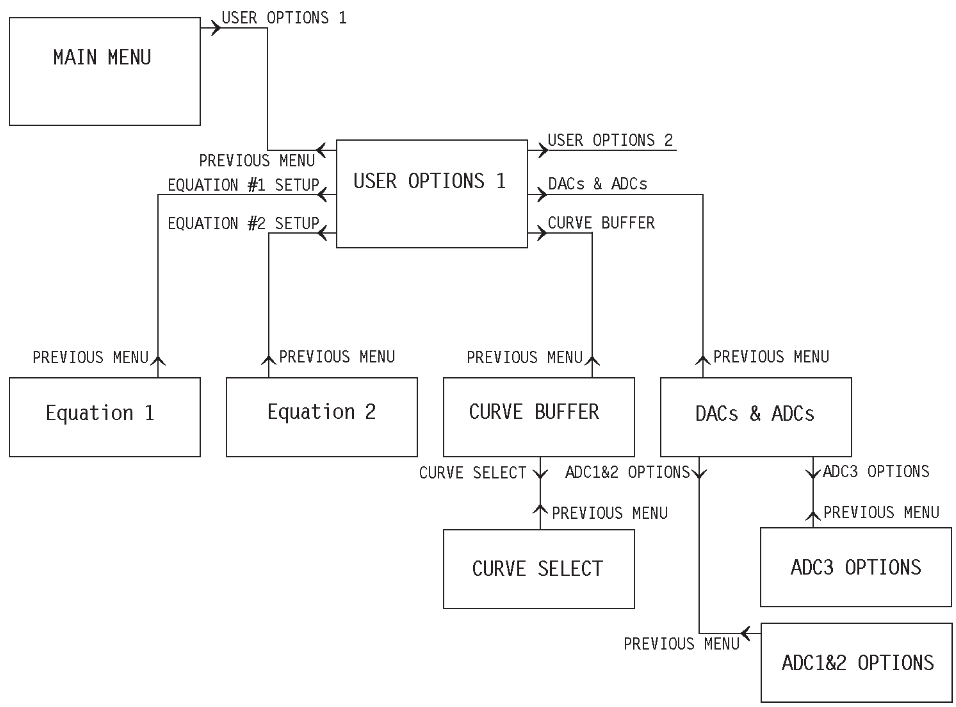

Figure 5-14, User Options 1 Menu Structure

Changes to the setting of the controls on the User Options 1 menu can be made by using the adjacent (△)(▽) keys.

CH1/CH2

These two controls define which instrument output will be converted to an analog voltage and made available at the **CH1** and **CH2** connectors on the rear panel. The following ten options are available:-

X% (10V fs)

When set to X % (10V fs) the corresponding CH1/CH2 connector on the rear panel will output a voltage related to the X %fs front panel display as follows:-

X % (10V fs)	CH1/2 Voltage
+120	12.0 V
+100	10.0 V
0	0.0 V
-100	-10.0 V
-120	-12.0 V

Y% (10V fs)

When set to Y % (10V fs) the corresponding CH1/CH2 connector on the rear panel will output a voltage related to the Y %fs front panel display as follows:-

Y % (10V fs)	CH1/2 Voltage
+120	12.0 V
+100	10.0 V
0	0.0 V
-100	-10.0 V
-120	-12.0 V

`MAG% (10V fs)`

When set to MAG % (10V fs) 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
+120	12.0 V
+100	10.0 V
0	0.0 V
-100	-10.0 V
-120	-12.0 V

```
PHASE (+9 V = +180°)
      (-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°)
      (-9 V =    0°)
```

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
+360	+9.0 V
+180	0.0 V
0	-9.0 V

`NOISE (10V 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
+120	12.0 V
+100	10.0 V
0	0.0 V
-100	-10.0 V
-120	-12.0 V

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:-

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

where X output is the X channel output with +10 V = 100 % full-scale sensitivity and ADC 1 is the voltage applied to the **ADC1** input connector on the rear panel. 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:-

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

$$RATIO = 2$$

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

RATIO	CH1/2 Voltage
+12	12.0 V
+10	10.0 V
0	0.0 V
-10	-10.0 V
-12	-12.0 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:-

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

where X output is the X channel output with +10 V = 100 % full-scale sensitivity and ADC 1 input is the voltage applied to the **ADC1** input connector on the rear panel. 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:-

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

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
+3.000	3.000 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 Equation 1 menu (see section 5.3.11), as follows:-

EQUATION #1	CH1/2 Voltage
+12000	12.0 V
+10000	10.0 V
0	0.0 V
-10000	-10.0 V
-12000	-12.0 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 Equation 2 menu (see section 5.3.11), as follows:-

EQUATION #2	CH1/2 Voltage
+12000	12.0 V
+10000	10.0 V
0	0.0 V
-10000	-10.0 V
-12000	-12.0 V

5.3.11 Equation #1 / Equation #2 Setup Menus

When the User Options 1 menu is displayed, pressing a key adjacent to the Equation #1 Setup or Equation #2 Setup items accesses the Equation #1 or Equation #2 Setup menus, one of which is shown in figure 5-15.

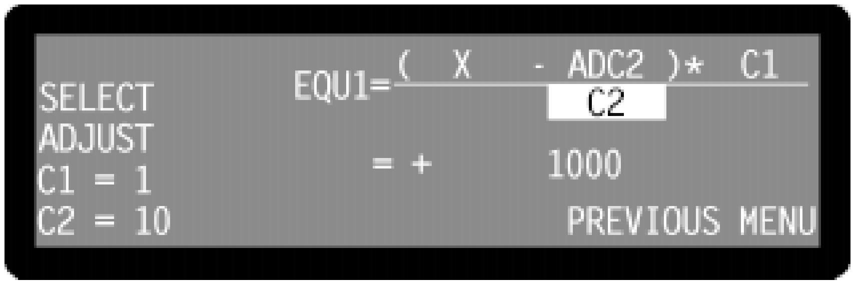

Figure 5-15, Equation #1 Setup Menu

The Equation setup menus are 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 are setup using the relevant setup menus. The equations 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
C1	0 to 100000
C2	0 to 100000
FRQ (Frequency)	0 to 250000000

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 are user-defined integer constants and are adjusted using the two controls on the lower left-hand side of the display.

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 User Options 1 menu, then the output range should be adjusted to lie in the range -12000 to +12000. Values outside this range will result in these analog outputs limiting at ±12.000 V, although the digital value will still appear correctly on the display and can be read via the computer interfaces.

Note that the equations continue to be calculated even when the Equation Setup menus are not displayed.

Pressing a key adjacent to the Previous Menu item returns control to the User Options 1 menu.

5.3.12 DACs & ADCs Menu

When the User Options 1 menu is displayed, pressing a key adjacent to the DACs & ADCs item accesses the DACs & ADCs menu, which is shown in figure 5-16.

Figure 5-16, DACs & ADCs Menu

The DACs & ADCs menu has four controls, which are used to set the voltages appearing at the **DAC1, DAC2, DAC3 & DAC4** connectors on the rear panel, and keys to access two further sub-menus.

DAC1, DAC2, DAC3 **and** DAC4
These four controls set each of the voltages appearing at the **DAC1, DAC2, DAC3** or **DAC4** connector on the rear panel to any value between -10.000 V and +10.000 V in 1 mV increments. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

5.3.13 ADC1 & 2 Options Menu

When the DACs & ADCs menu is displayed, pressing a key adjacent to the ADC1&2 Options item accesses the ADC1 & 2 Options menu, which is shown in figure 5-17.

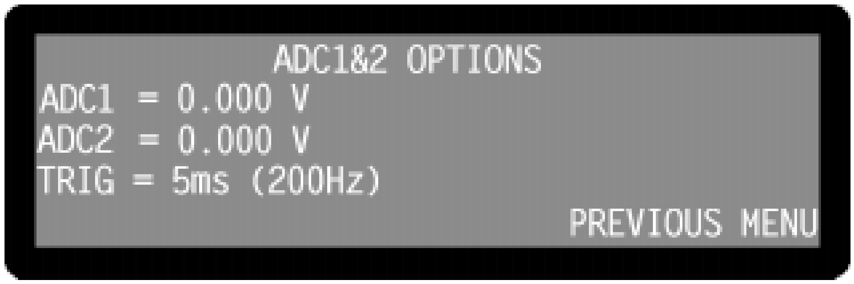

Figure 5-17, ADC1 & 2 Options Menu

The ADC1 & 2 Options menu has one control, which is used to set the trigger mode for the analog-to-digital conversion of the voltages applied to the **ADC1** and **ADC2** connectors on the rear panel, and two displays for the current value of these two voltages.

TRIG **(ADC Trigger Mode Control)**
This has ten possible settings, as follows:-

5ms (200Hz)
A conversion is performed on both ADC1 and ADC2 every 5 ms and the results are displayed on the ADC1 & 2 Options menu and are available via the computer interfaces.

EXTERNAL (RP)
A conversion is performed on both ADC1 and ADC2 on receipt of a rising edge at the TTL **TRIG** connector on the rear panel. The maximum trigger rate is 400 Hz. The results are displayed on the ADC1 & 2 Options menu and are available via the computer interfaces.

BURST ADC1
A burst of conversions at approximately 40 kHz 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 5.3.15.

BURST ADC1&2
A burst of conversions at approximately 13 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 5.3.15.

BURST ADC1 (T)
This is the same as the BURST ADC1 mode, except that the sampling rate may be set using the Rate control and that the computer command to initiate acquisition is TADC4.

BURST ADC1 & 2 (T)
This is the same as the BURST ADC1 & 2 mode, except that the sampling rate may be set using the Rate 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 T)
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 T)
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 5.3.16), to be either ADC1 or ADC1 and ADC2.

TRIGGER BURST MODE
When one of the triggered burst modes is selected, this control is displayed. Press the key adjacent to it to trigger data acquisition.

RATE
When one of the timed burst modes is selected, the rate control is active. The number displayed, n, sets the sample rate according to the following equations:-

When storing only to ADC1:
(i.e. BURST ADC1 (T), BURST ADC1 (RP) and BURST ADC1 (RP T)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 157}\right) \text{Hz}$$

When storing to ADC1 and ADC 2:
(i.e. BURST ADC1 & 2 (T), BURST ADC1 & 2 (RP) and
BURST ADC1 & 2 (RP T)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 1031} \right) \text{Hz}$$

Note that these equations apply only to units manufactured after December 1995. Earlier instruments used a 16.384 MHz instead of a 16.0 MHz crystal, so the above equations should be modified accordingly by replacing the 16,000,000 figure with 16,384,000.

For convenience, the result of this calculation is shown on the display.

For example, when n = 20, the sample rate will be 24,353 Hz for ADC1 when the instrument has a 16.0 MHz crystal, and 24,937 Hz when it has a 16.384 MHz crystal.

Pressing a key adjacent to the Previous Menu item returns control to the DACs & ADCs menu.

5.3.14 ADC3 Options Menu

When the DACs & ADCs menu is displayed, pressing a key adjacent to the ADC3 Options item accesses the ADC 3 menu, which is shown in figure 5-18.

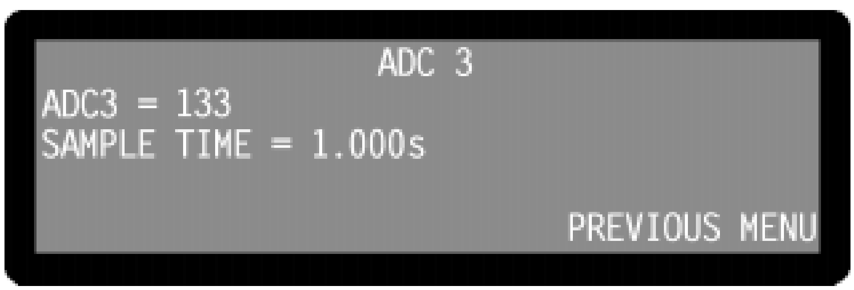

Figure 5-18, ADC 3 Menu

ADC 3 is an integrating converter whose response is proportional to the sample time. The full-scale response with a 1 s sample time is nominally ±500000 for ±10.000 V input, and the full-scale response with a 100 ms sample time is nominally ±50000. The ADC 3 menu has one control, which is used to set this sample time, and a display of the current value of this integral.

SAMPLE TIME
This control allows the sample time to be set to any value between 10 ms and 2.000 s in 10 ms increments. Converter resolution is proportional to sample time, so that when the sample time is 10 ms a full-scale response is equivalent to 13 bits (12 bit + sign) of accuracy, whereas with a sample time of 1.05 s the accuracy is 20 bits (19 bit + sign).

Pressing a key adjacent to the Previous Menu item returns control to the DACs & ADCs menu.

5.3.15 Curve Buffer Menu

When the User Options 1 menu is displayed, pressing a key adjacent to the Curve Buffer item accesses the Curve Buffer menu, which is shown in figure 5-19.

Figure 5-19, Curve Buffer Menu

The curve buffer menu has four controls affecting the instrument's internal 32768 point curve buffer, two status indicators and a key to access a further sub-menu, the Curve Select menu.

RATE
This control defines the interval between each data point in the curve buffer. It may be set to any value between 5 ms and 1×10^6 s in 5 ms increments. In addition, it may also be set to 800 Hz, at which setting only the X channel and Y channel outputs are stored.

NOTE: If set to 800 Hz then the curves selected for storage as shown in the Curve Select menu (see section 5.3.16) are automatically set to the X channel and Y channel outputs when an acquisition is started by pressing either the Start Single Sweep or Start Multi Sweep keys.

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.

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

SWEEPS

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.

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.

Pressing a key adjacent to the Previous Menu item returns control to the User Options 1 menu.

5.3.16 Curve Select Menu

When the Curve Buffer menu is displayed, pressing a key adjacent to the Curve Select item accesses the Curve Select menu, which is shown in figure 5-20.

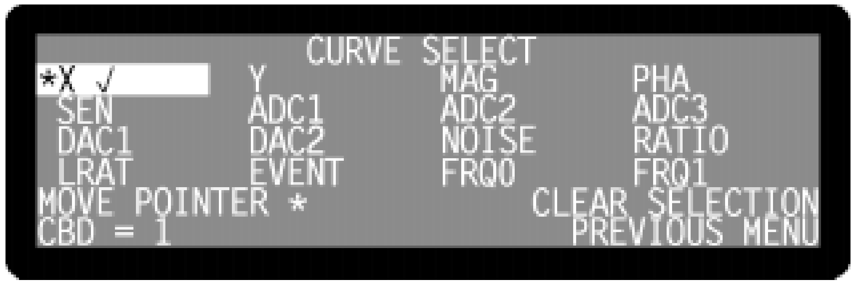

Figure 5-20, Curve Select Menu

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 a tick mark and by being shown in reverse text.

`MOVE POINTER *`
This control allows the ***** pointer to be moved to any one of the possible data types.

`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 a tick mark adjacent to it and by its being displayed in reverse text. If it is already selected, then pressing the key deselects it.

`CBD = x`
An alternative way of selecting curves is to use the CBD control. The number is the same as that used with the CBD computer command (see section 6.4.09).

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

ADC1&2 Options Menu (section 5.3.13)
Selecting any of the burst acquisition modes automatically selects the ADC1 or ADC1 and ADC2 outputs for storage.

Curve Buffer Menu (section 5.3.15)
Setting the Rate control to 800 Hz and starting an acquisition by pressing either the Start Single Sweep or Start Multi Sweep keys automatically selects the X channel and Y channel outputs for storage.

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

5.3.17 User Options 2 Menu

When the User Options 1 menu is displayed, pressing a key adjacent to the User Options 2 item accesses the User Options 2 menu, which is shown in figure 5-21.

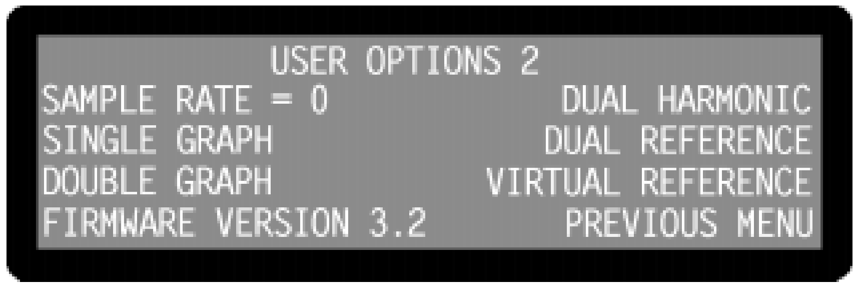

Figure 5-21, User Options 2 Menu

The User Options 2 menu has one control, which is used to adjust the sampling rate of the instrument's main analog to digital converter, keys to access two sub-menus, and keys to change the operating mode of the instrument. The relationship of the sub-menus to the User Options 1 menu is shown in figure 5-22. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from the User Options 1, User Options 2 and Main Menus by pressing the **MENU** key on the front panel, but this has been omitted from figure 5-22 for the sake of clarity. However the Single Graph and Double Graph menus do not have a Previous Menu key, so the **MENU** key is used to leave these menus and return to the User Options 2 menu.

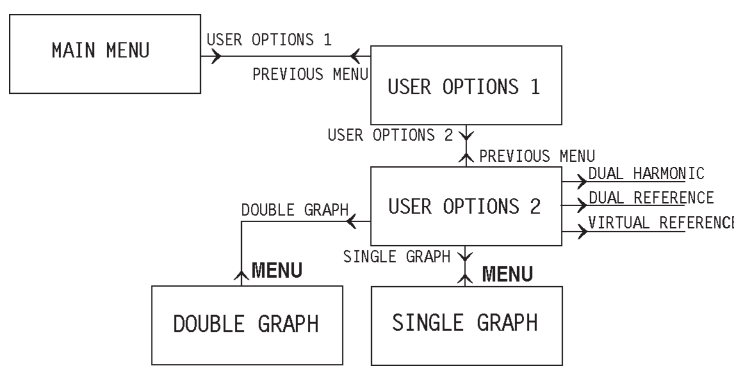

Figure 5-22, User Options 2 Menu Structure

SAMPLE RATE
This control allows the sampling rate of the main ADC to be adjusted to one of four values near 166 kHz, to remove problems caused by aliasing of interfering signals into the output passband (see also section 3.3.06).

FIRMWARE VERSION xxxx
This line reports the version number of the instrument's operating firmware.

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

5.3.18 Single Graph Menu

When the User Options 2 menu is displayed, pressing a key adjacent to the Single Graph item accesses the Single Graph menu, which is shown in figure 5-23.

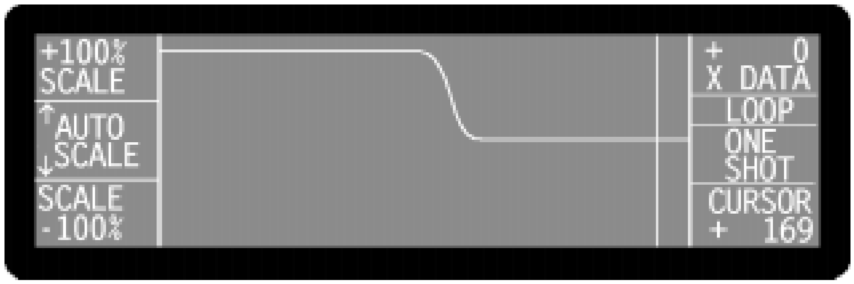

Figure 5-23, Single Graph Menu

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 5-23 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 to a 1 % resolution, with the set maximum and minimum values being shown adjacent to them.

AUTO SCALE **keys**
The two 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 156 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.

LOOP/STOP and ONE SHOT/PAUSE/CONTINUE keys

In the single graph display mode, acquisition to the curve buffer, and hence display of data, can be initiated using the middle two right-hand (△)(▽) keys. The upper pair start data acquisition 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.

The lower pair also start acquisition, but 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.

CURSOR keys

The bottom right-hand (△)(▽) 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 display 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 **MENU** key on the front panel exits the Single Graph menu and returns to the User Options 2 menu.

5.3.19 Double Graph Menu

When the User Options 2 menu is displayed, pressing a key adjacent to the Double Graph item accesses the Double Graph menu, which is shown in figure 5-24.

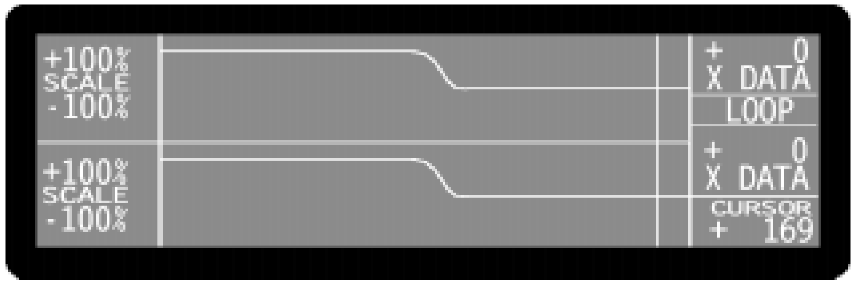

Figure 5-24, Double Graph Menu

The double graph display is similar to that of the single graph with the exception that one shot data acquisition cannot be initiated. If this mode of acquisition is required then it can be started from either the Single Graph or Curve Buffer menus prior to selecting Double Graph.

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 5-24 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 156 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 156 and Curve 2 for points 201 to 356.

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, the two curves recording the reference frequency (FRQ0 and FRQ1) and the curves recording instrument sensitivity settings.

LOOP/STOP **keys**

In the double graph display mode only the loop method of data acquisition may be initiated. The upper-middle right-hand keys are used to start this mode, in which the curve buffer fills to capacity and is then sequentially overwritten by new data. During data acquisition, 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 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 **MENU** key on the front panel exits the Double Graph menu and returns to the User Options 2 menu.

5.3.20 Auto Functions Menu

When the Main Menu is displayed, pressing a key adjacent to the Auto Functions item accesses the Auto Functions menu, which is shown in figure 5-25.

Figure 5-25, 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 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 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 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 MEASURE

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

The instrument is set to signal recovery mode, line filter is disabled, AC coupling is established, the FET input device is selected and the FLOAT mode is set. 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 DEFAULT

With an instrument of the design of the model 7260, 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 F.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.21 Communications Menu

When the Main Menu is displayed, pressing a key adjacent to the Communications item accesses the Communications menu, which is shown in figure 5-26.

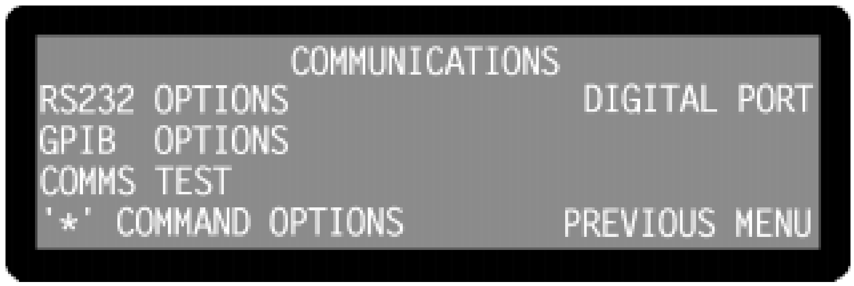

Figure 5-26, Communications Menu

The Communications menu is used to access five sub-menus, the relationship of which to the Communications menu is shown in figure 5-27. 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 **MENU** key on the front panel, but this has been omitted from figure 5-27 for the sake of clarity.

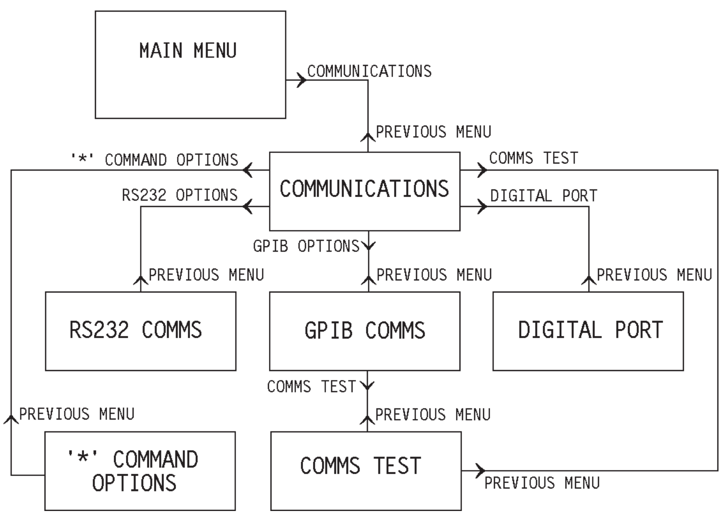

Figure 5-27, Communications Menu Structure

5.3.22 RS232 Comms Menu

When the Communications menu is displayed, pressing a key adjacent to the RS232 Options item accesses the RS232 Comms menu, which is shown in figure 5-28.

Figure 5-28, RS232 Comms 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

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).

RS232 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 7260 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 from a simple RS232 terminal where operation without it might be possible.

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.

PROMPT

This control has two settings, as follows:-

PROMPT ON

A prompt character is generated by the model 7260 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.

PROMPT OFF

No prompt character is generated.

Pressing a key adjacent to the Previous Menu item returns control to the Communications menu.

5.3.23 GPIB Comms Menu

When the Communications menu is displayed, pressing a key adjacent to the GPIB Options item accesses the GPIB Comms menu, which is shown in figure 5-29.

Figure 5-29, GPIB Comms Menu

This menu has four controls affecting the GPIB computer interface and a key for accessing the Comms Test menu, as follows:-

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.

TERMINATOR
This has three possible settings, as follows:-

TERMINATOR = [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.

TERMINATOR = [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.

TERMINATOR = [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.

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.

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.

Pressing a key next to the Comms Test item accesses the Comms Test menu, and pressing a key adjacent to the Previous Menu item returns control to the Communications menu.

5.3.24 Comms Test Menu

When the Communications menu is displayed, pressing a key adjacent to the Comms Test item accesses the Comms Test menu. It may also be accessed via the GPIB Comms menu, and is shown in figure 5-30.

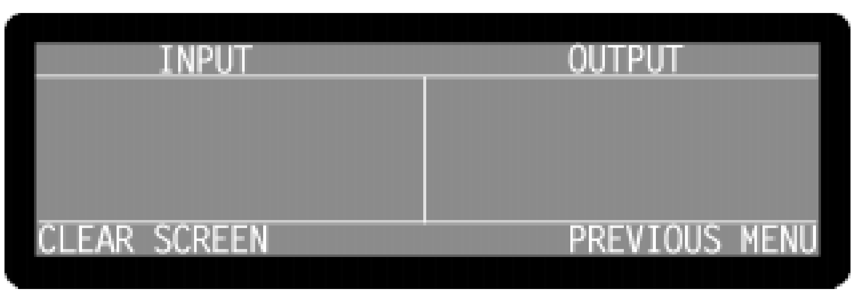

Figure 5-30, Comms Test Menu

This menu 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 a key adjacent to the Previous Menu item returns control to either the Communications menu or the GPIB Comms menu, depending on how the Comms Test menu was accessed.

5.3.25 '*' Command Options Menu

When the Communications menu is displayed, pressing a key adjacent to the '*' Command Options item accesses the '*' Command Options menu, shown in figure 5-31.

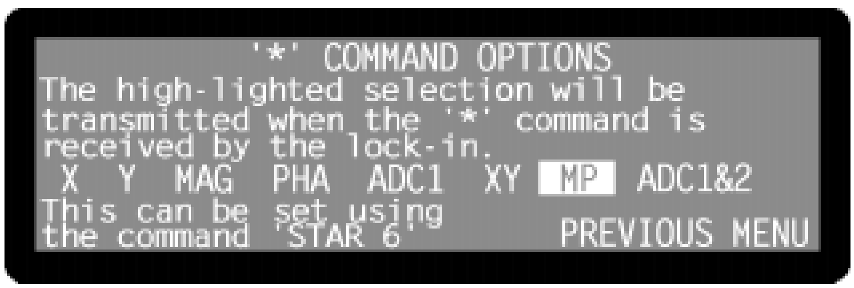

Figure 5-31, '*' Command Options Menu

The star data transfer mode, which applies only to the GPIB interface, allows faster access to a subset of the instrument outputs than is possible using the normal commands to request the return of output values. The mode can be set up using either the computer command STAR [n], or via the '*' Command Options menu.

The menu shows eight possible instrument outputs, one of which can be selected. This output will then be returned when the controlling computer sends an asterisk character. The required output is selected using the adjacent △ ▽ keys, and its selection is indicated by being shown in reverse text. Note that when set up using the computer command an additional four options, allowing transfer of outputs generated in the dual harmonic and dual reference modes, are also available.

5.3.26 Digital Port Menu

When the Communications menu is displayed, pressing a key adjacent to the Digital Port item accesses the Digital Port menu, shown in figure 5-32.

Figure 5-32, Digital Port Menu

The Digital Port menu allows the status of each of the eight pins of the **DIGITAL OUTPUTS** connector on the rear panel to be set. This port may be used for controlling external equipment, for example the switching of heaters or attenuators, via a suitable user-supplied external interface circuit.

The eight outputs are TTL compatible and are controlled by the digital output port byte, shown towards the upper right-hand side of the display as D7 - D0. Immediately under each of these bit-identifiers is a single character showing the current bit status, which is either a “0”, in which case the output is at logic 0, (i.e. < 0.7 V), or a “1”, in which case it is at logic 1, (i.e. > 2.4 V).

The four △▽ keys on the left-hand side of the display are used to toggle the status of the bits, the keys being treated for this purpose as eight single keys corresponding to the eight bit identifiers shown on the left-hand side of the display. Each press of a given key toggles the status of the corresponding bit.

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

5.3.27 Display Options Menu

When the Main Menu is displayed, pressing a key adjacent to the Display item accesses the Display Options menu, shown in figure 5-33.

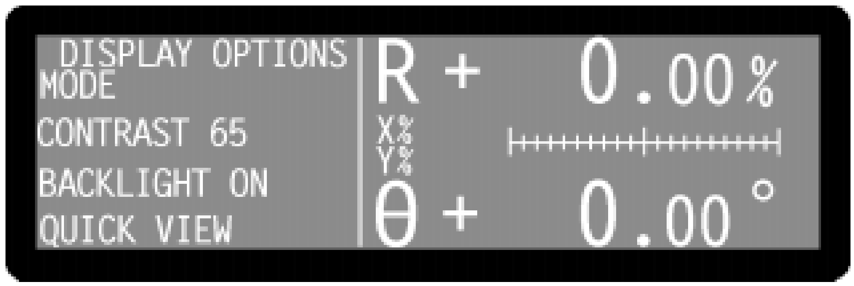

Figure 5-33, Display Options Menu

This menu has four controls affecting the instrument's display, as follows:-

MODE
This control cycles through the three possible output display types, namely:

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

The output that actually appears in each of the four display positions is selected using the corresponding right-hand (△)(▽) keys - see section 5.3.01.

CONTRAST
This control adjusts the contrast of the LCD display panel.

BACKLIGHT
This control allows the instrument's LCD display panel backlight and the front panel LEDs to be switched on or off.

QUICKVIEW
Pressing this key displays a listing of the settings of the main instrument controls. To leave this display, press any key.

Press the **MENU** key on the front panel to return to the Main Display from the Display Options 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 60 kHz.

The mode is accessed via two additional sub-menus of the User Options 2 menu, the relationship of which to the User Options 2 menu is 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 **MENU** key on the front panel, 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.

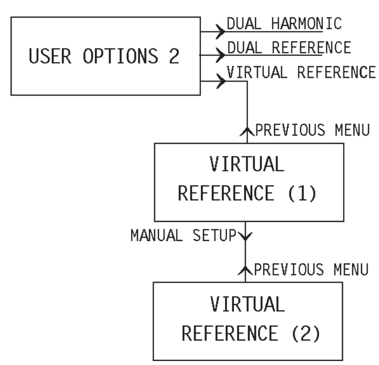

Figure 5-34, Virtual Reference Menu Structure

There are two ways of invoking this mode, the first being via a semi-automatic sequence, which can be used if the signal to be measured can be acquired with a time constant of 100 ms or shorter, and the second being a manual technique used in all other cases.

Semi-Automatic Setup
The first step is to decide what the amplitude of the signal is expected to be. Set the full-scale sensitivity so that the expected signal is between one and three times the full-scale sensitivity. 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.

Next, go to the User Options 2 menu and press a key adjacent to the Virtual Reference item. The Virtual Reference (1) menu, shown in figure 5-35, will appear.

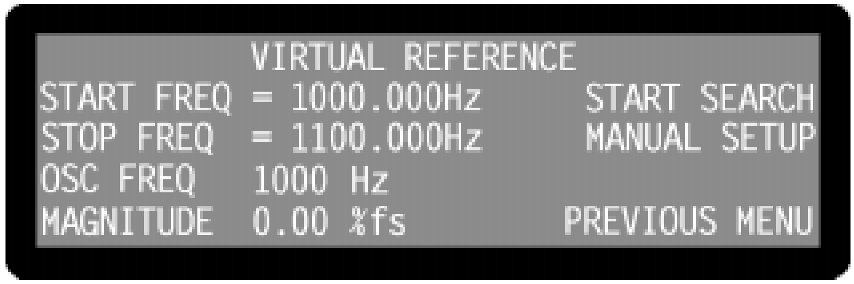

Figure 5-35, Virtual Reference (1) Menu

This menu has three controls affecting the virtual reference mode, two displays, and one key to access the Virtual Reference(2) sub-menu.

The controls operate as follows:-

START FREQ
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.

STOP FREQ
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.

OSC FREQ
This displays the present internal oscillator frequency. When a seek frequency sweep is run the value shown will increase from the defined start frequency until either the signal magnitude exceeds 50% of full-scale or until the stop frequency is reached.

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

START SEARCH
Pressing a key adjacent to the Start Search item 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 5-37.

MANUAL SETUP
This key is used to access the Virtual Reference (2) menu, used for manual setup of the virtual reference mode, as discussed in the following section.

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.

The first step is to decide what the amplitude of the signal is expected to be. Set the full-scale sensitivity so that the expected signal is between one and three times the full-scale sensitivity. 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.

Set the required time constant and go to the Oscillator menu and from there to the Frequency Sweep menu. Set the start frequency in the same way as was discussed above for the semi-automatic setup, set the stop frequency to a value above the signal frequency and set the sweep law to Seek.

The step size and step rate depend on the time constant. Table 5-2 gives the suggested values to which these two controls should be set when the output filter slope is set to 12 dB/octave. The slope can be adjusted once the signal has been found.

Time Constant	Step Size	Step Rate
100 ms	1.000 Hz	1000 ms
200 ms	0.500 Hz	1000 ms
500 ms	0.200 Hz	2000 ms
1 s	0.100 Hz	4000 ms
2 s	0.050 Hz	8000 ms
5 s	0.020 Hz	20000 ms

Table 5-2, Step Size and Step Rate vs Time Constant Setting

Arm the Seek mode and start the frequency sweep, using the Start key. Press the **MENU** key on the front panel to return to the Main Display in order to monitor progress. If and when a signal of greater than 50% of full-scale is found the sweep will stop.

Once the sweep has stopped, go to the User Options 2 menu and select the Virtual Reference menu. Select the Manual Setup item and the Virtual Reference (2) menu will appear, as shown in figure 5-36.

5.4.02 Virtual Reference (2) Menu

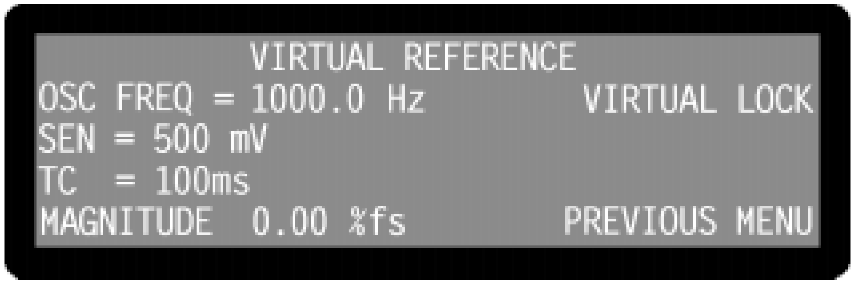

Figure 5-36, Virtual Reference (2) Menu

This menu has three controls affecting the instrument's full-scale sensitivity, internal oscillator frequency and time constant, a display of signal magnitude and a key to activate the virtual reference mode lock.

The controls operate as follows:-

OSC FREQ
This control allows the instrument's internal oscillator frequency to be set to any value between 1 Hz and 60 kHz with a 100 mHz resolution.

SEN **(Full-scale 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 2 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 2 fA and 1 µA (wide bandwidth mode) or 2 fA and 10 nA (low-noise mode), in a 1-2-5 sequence.

TC
This control sets the instrument's output time constant. It should be set to the value used for the oscillator frequency sweep during manual setup of the virtual reference mode.

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 5-37.

If the signal frequency is known and the time constant is 1 s or shorter then the frequency seek step can be bypassed. Go straight to the Virtual Reference (2) menu and adjust the oscillator frequency control until greater than 50 % full-scale is reported. Then press the Virtual Lock key to enter virtual reference mode and complete the procedure.

5.4.03 Main Display - Virtual Reference Mode

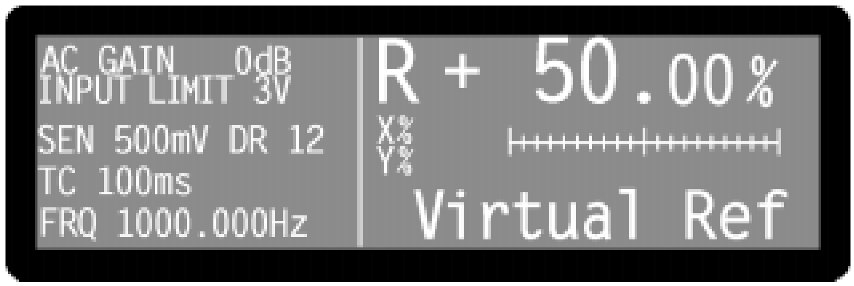

Figure 5-37, Main Display - Virtual Reference Mode

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 Ref" 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 PHA and QUAD, 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.

5.4.04 User Options 2 Menu - Virtual Reference Mode

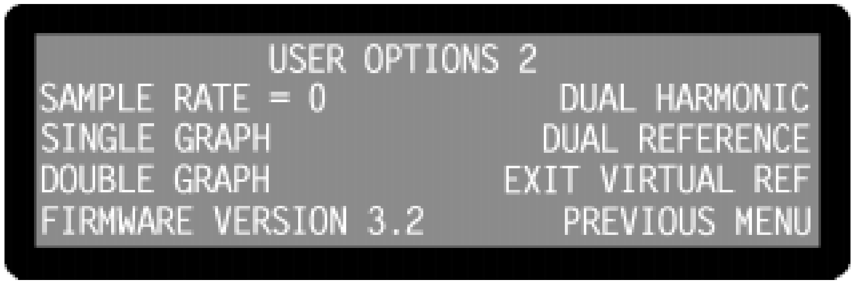

Figure 5-38, User Options 2 Menu - Virtual Reference Mode

In virtual reference mode, the choices available on the User Options 2 menu are as shown in figure 5-38. To leave virtual reference mode and return to single reference mode press a key adjacent to the Exit Virtual Ref item, to switch to dual reference mode, press a key adjacent to the Dual Reference item, and to switch to dual harmonic mode, press a key adjacent to the Dual Harmonic item. The remaining controls operate as already described in section 5.3.17.

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 7260 to measure signals, applied to the signal input, at two different reference frequencies simultaneously. 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 as for single reference mode, and are described in section 5.3.

When the User Options 2 menu is displayed, pressing a key adjacent to the Dual Reference item activates the dual reference mode. While the instrument switches to this mode, the Dual Reference Setup menu is displayed, as shown in figure 5-39.

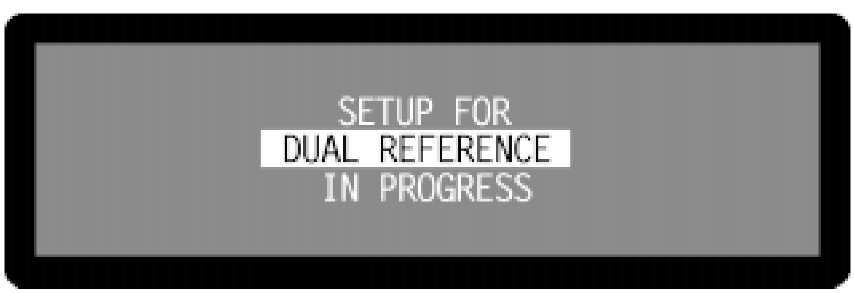

Figure 5-39, Dual Reference Setup Menu

5.5.02 Dual Reference Main Display

Once dual reference mode has been activated, the Main Display - Dual Reference Mode is displayed, as shown in figure 5-40.

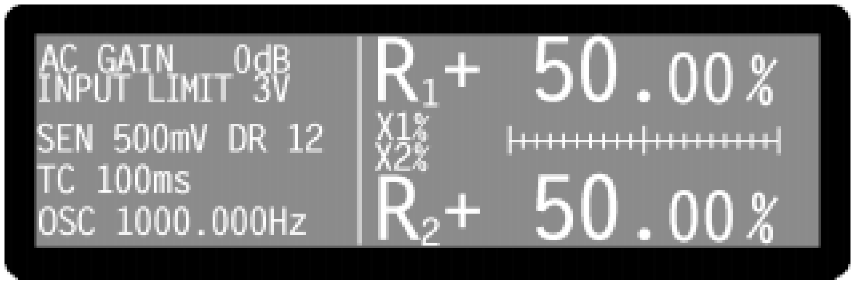

Figure 5-40, Main Display - Dual Reference Mode

In dual reference mode the controls, on the left-hand side of the Main Display, which relate to the reference channel apply only to the reference derived from the external reference input, which in this mode is called reference_1. Controls applying to the second reference, that from the internal oscillator, known as reference_2, are accessed via the Dual Reference menu. This menu is described later in section 5.5.03.

Since the instrument is now generating two sets of outputs (one for each reference) there are more output display choices in this mode than in single reference mode, and these are listed in table 5-3. The outputs corresponding to the two references are identified by the suffices “1” and “2” respectively.

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 are available in single reference mode.

When in dual reference mode, the user-defined equations, specified on the Equation #1 Setup and Equation #2 Setup menus, allow the selection of the additional outputs as variables. Hence, 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 even be output to the **CH1** or **CH2** connectors on the rear panel as an analog voltage.

Naturally, the two signals share a common signal path and hence controls affecting the signal channel, such as AC Gain and the line filter controls, apply to both signals. Although the full-scale sensitivity setting can be independently set for both signals, the maximum AC Gain that is possible depends on the greater of these two values.
In dual reference mode the maximum detection frequency for either ($\text{reference}_1 \times \text{harmonic}_1$) or reference_2 is 20 kHz.

Output Title	Description
Numeric Displays Only:	
R_1%	Resultant (Magnitude) output, $reference_1$, %fs
R_2%	Resultant (Magnitude) output, $reference_2$, %fs
θ_1°	Phase output, $reference_1$, in degrees
θ_2°	Phase output, $reference_2$, in degrees
X_1	X_1 channel output in volts or amps
X_2	X_2 channel output in volts or amps
Y_1	Y_1 channel output in volts or amps
Y_2	Y_2 channel output in volts or amps
R_1	Resultant (Magnitude) output, $reference_1$, in volts or amps
R_2	Resultant (Magnitude) output, $reference_2$, in volts or amps
N	Noise output, $reference_1$, in volts or amps per root hertz
xxxx Hz	$Reference_1$ (external) frequency in hertz
Numeric & Bar-Graph Displays:	
X_1%	X_1 channel output as a percentage of full-scale sensitivity
X_2%	X_2 channel output as a percentage of full-scale sensitivity
Y_1%	Y_1 channel output as a percentage of full-scale sensitivity
Y_2%	Y_2 channel output as a percentage of full-scale sensitivity
N%	Noise output, $reference_1$, as a percentage of full-scale sensitivity
ADC1	ADC1 input, ±10.000 V full-scale
ADC2	ADC2 input, ±10.000 V full-scale
Bar-Graph Displays Only:	
MAG1%	Resultant (Magnitude) output, $reference_1$, %fs
MAG2%	Resultant (Magnitude) output, $reference_2$, %fs
PHA1	Phase output, $reference_1$, full-scale = ±200°
PHA2	Phase output, $reference_2$, full-scale = ±200°

Table 5-3, Output Display Choices - Dual Reference Mode

NOTE: It is not possible to measure or display the noise at the $reference_2$ frequency.

5.5.03 Dual Reference Channel Menu

In dual reference mode, the two reference channels are controlled by the Dual Reference Channel menu, which replaces the Reference Channel menu used in the other three modes. In addition, controls are needed for the corresponding output channels, and so there are now two Output Channel menus. The relationship of these menus to the Main Menu is shown in figure 5-41. 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 **MENU** key on the front panel, but this has been omitted from figure 5-41 for the sake of clarity.

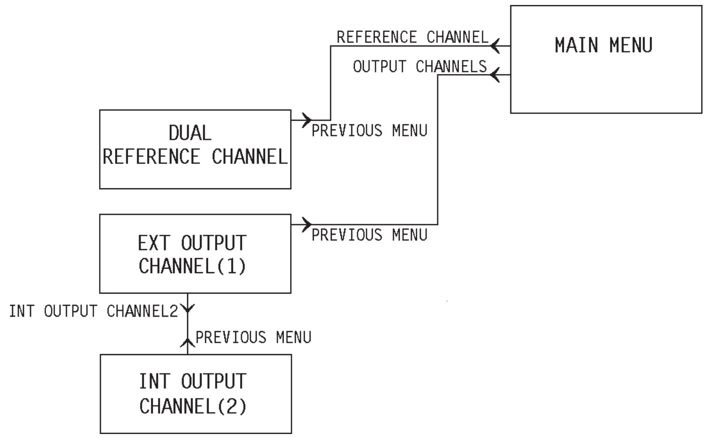

Figure 5-41, Dual Reference Mode Menu Structure

In dual reference mode, pressing a key adjacent to the Reference Channel item on the Main Display accesses the Dual Reference Channel menu, shown in figure 5-42.

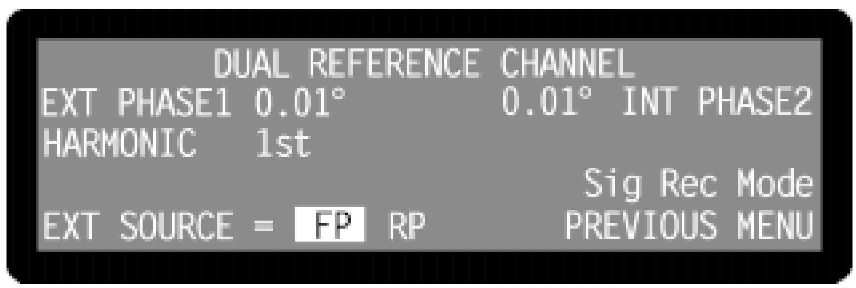

Figure 5-42, Dual Reference Channel Menu

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

EXT PHASE1 **(Reference$_1$ Phase)**
This control, which duplicates the Main Display PHA control, allows the reference$_1$ phase to be adjusted over the range -180° to +180° in 10m° steps. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The Auto-Phase1 function (see section 5.5.06) also affects the setting of this control.

INT PHASE2 **(Reference$_2$ Phase)**
This control allows the reference$_2$ phase to be adjusted over the range -180° to +180° in 10m° steps.

The Auto-Phase2 function (see section 5.5.06) also affects the setting of this control.

HARMONIC1 **(Reference Harmonic)**
This control allows selection of the harmonic of the reference$_1$ frequency at which the lock-in amplifier will detect. It can be set to any value between 1st and 65535, but most commonly is set to 1st. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

Detection is always at the fundamental frequency of reference$_2$, i.e. at the same frequency as that generated by the internal oscillator. There is no provision for detecting at its harmonics.

EXT SOURCE
This control has two settings and is used to specify the connector to which the external reference$_1$ source is connected.

FP **(Front Panel)**
In this setting, which is suitable for use with reference$_1$ frequencies above 300 mHz, the lock-in amplifier's reference$_1$ should be applied to the **REF IN** connector on the front panel. A wide variety of signal waveforms may be employed but at frequencies lower than 1 Hz, square waveforms should be used.

RP **(Rear Panel)**
In this setting, the lock-in amplifier's reference$_1$ should be applied to the TTL-compatible **REF TTL** connector on the rear panel. The use of this input is preferable to the front panel input when a TTL logic reference signal is available. This setting should always be used when operating with external reference$_1$ frequencies less than 300 mHz.

Sig Rec Mode/Vector VM Mode
This control should always be left set to Sig Rec Mode (signal recovery mode).

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.5.04 Ext Output Channel (1) Menu

When in dual reference mode, pressing a key adjacent to the Output Channels item on the Main Menu accesses the Ext Output Channel (1) menu, shown in figure 5-43.

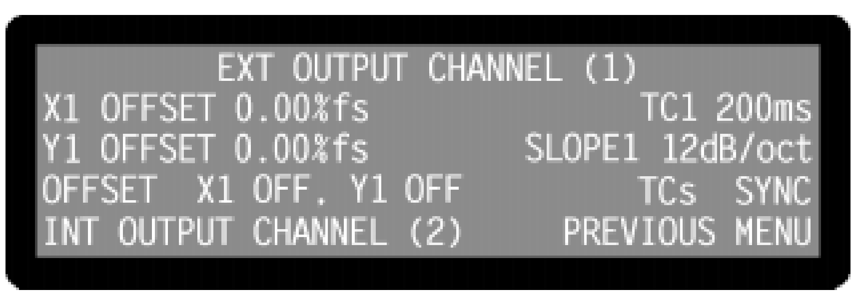

Figure 5-43, Ext Output Channel (1) Menu

The Ext Output Channel (1) menu has six controls affecting the instrument's outputs generated by the reference$_1$ channel and a key to access the Int Output Channel (2) menu. Changes to the setting of these controls can be made by using the adjacent (△)(▽) keys.

The controls operate as follows:-

X1 OFFSET **and** Y1 OFFSET
These controls, which duplicate the Main Display XOF and YOF controls, allow manual adjustment of the X_1 channel and Y_1 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_1 channel or Y_1 channel output when the X_1 channel or Y_1 channel offset is switched on. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The values are set automatically by the Auto-Offset1 function. Note that the Auto-Offset1 function automatically switches both X_1 channel and Y_1 channel output offsets on.

OFFSET
This control allows the X_1 channel and Y_1 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:-

X1 OFF, Y1 OFF
Both X_1 channel and Y_1 channel output offsets are switched off.

X1 ON, Y1 OFF
The X_1 channel output offset is switched on.

X1 OFF, Y1 ON
The Y_1 channel output offset is switched on.

X1 ON , Y1 ON
Both X_1 channel and Y_1 channel output offsets are switched on.

TC1 **(Time Constant)**
This control, which duplicates the Main Display TC control, is used to set the time constant of the output filters. The range of possible settings is 10 ms to 100 ks in a 1-2 -5 sequence and applies to all instrument outputs other than those at the **FAST X** and **FAST Y** connectors on the rear panel. In dual reference mode the signals at these connectors are complex and generally unsuitable for further use.

SLOPE1
The roll-off of the output filters for the output channels corresponding to reference_1 is set using this control to any value from 6 dB to 24 dB/octave, in 6 dB steps.

TCs **(Time Constant Mode)**
This control has two settings, as follows:-

TCs SYNC **(Synchronous Time Constants)**
In this setting, the actual time constant used is chosen to be some multiple of the

reference frequency period. In this mode the output will be much more stable at low frequencies than it would otherwise be. Note that, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

`TCs ASYNC` **(Asynchronous Time Constants)**
In this setting, the normal mode, time constants are not related to the reference frequency period.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.5.05 Int Output Channel (2) Menu

In dual reference mode, pressing a key adjacent to the Int Output Channel (2) item on the Ext Output Channel (1) menu accesses the Int Output Channel (2) menu, shown in figure 5-44.

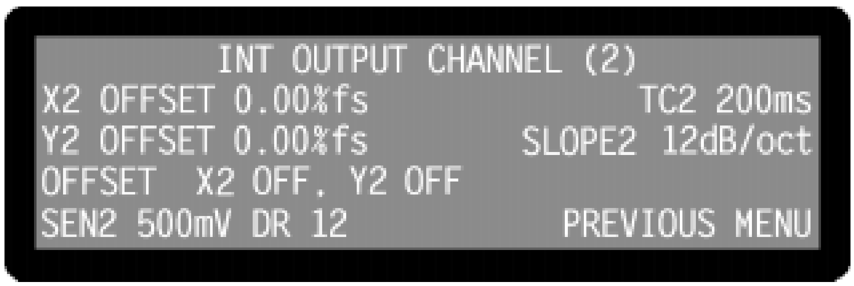

Figure 5-44, Int Output Channel (2) Menu

The Int Output Channel (2) menu has six controls affecting the instrument's outputs generated by the $reference_2$ channel and one display function. Changes to the setting of these controls can be made by using the adjacent △ ▽ keys.
The controls operate as follows:-

`X2 OFFSET` **and** `Y2 OFFSET`
These controls allow manual adjustment of the X_2 channel and Y_2 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_2 channel or Y_2 channel output when the X_2 channel or Y_2 channel offset is switched on. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The values are set automatically by the Auto-Offset2 function. Note that the Auto-Offset2 function automatically switches both X_2 channel and Y_2 channel output offsets on.

`OFFSET`
This control allows the X_2 channel and Y_2 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:-

X2 OFF, Y2 OFF
Both X_2 channel and Y_2 channel output offsets are switched off.

X2 ON, Y2 OFF
The X_2 channel output offset is switched on.

X2 OFF, Y2 ON
The Y_2 channel output offset is switched on.

X2 ON, Y2 ON
Both X_2 channel and Y_2 channel output offsets are switched on.

SEN2 **(Full-scale Sensitivity - reference$_2$ channel)**
When set to voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity for the reference$_2$ channel may be set by this control to any value between 2 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 for the reference$_2$ channel may be set by this control to any value between 2 fA and 1 µA (wide bandwidth mode) or 2 fA and 10 nA (low-noise mode), in a 1-2-5 sequence.

The setting may be changed by the Auto-Sen2 function.

The number reported after the letters **DR** is the instrument's Dynamic Reserve, expressed in decibels and is calculated by the equation given in section 5.3.02.

TC2 **(Time Constant)**
This control is used to set the time constant of the output filters corresponding to reference$_2$. The range of possible settings is 10 ms to 100 ks in a 1-2-5 sequence and applies to all instrument outputs other than those at the **FAST X** and **FAST Y** connectors on the rear panel. In dual reference mode the signals at these connectors are complex and generally unsuitable for further use.

SLOPE2
The roll-off of the output filters for the output channels corresponding to reference$_2$ is set using this control to any value from 6 dB to 24 dB/octave, in 6 dB steps.

Pressing a key adjacent to the Previous Menu item returns control to the Ext Output Channel (1) menu.

5.5.06 Auto Functions Menu

In dual reference mode, pressing a key adjacent to the Auto Functions item on the Main Menu accesses the Auto Functions menu, shown in figure 5-45.

Figure 5-45, Auto Functions Menu - Dual Reference Mode

This menu has seven 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. There are three auto functions for each of the two reference channels, which operate exactly as described for single reference mode in section 5.3.20. Although there is no Auto-Measure function, the same result may be achieved by executing Auto-Sensitivity followed by Auto-Phase operations.

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

5.5.07 User Options 2 Menu - Dual Reference Mode

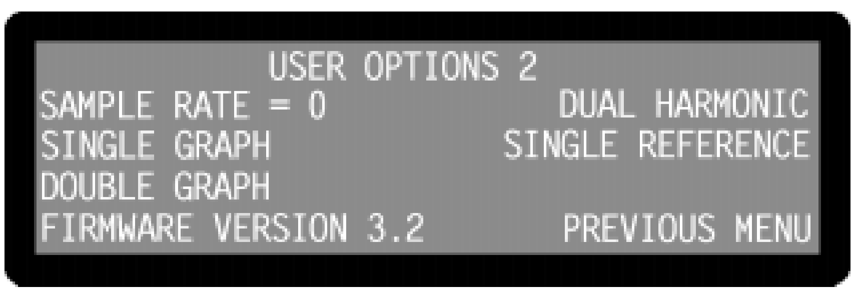

Figure 5-46, User Options 2 Menu - Dual Reference Mode

In dual reference mode, the choices available on the User Options 2 menu, shown in figure 5-46, are different to those available when in the other three modes. To leave virtual reference mode and return to single reference mode press a key adjacent to the Single Reference item and to switch to dual harmonic mode, press a key adjacent to the Dual Harmonic item. The remaining controls operate as already described in section 5.3.17.

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 7260 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 User Options 2 menu is displayed, pressing a key adjacent to the Dual Harmonic item 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.

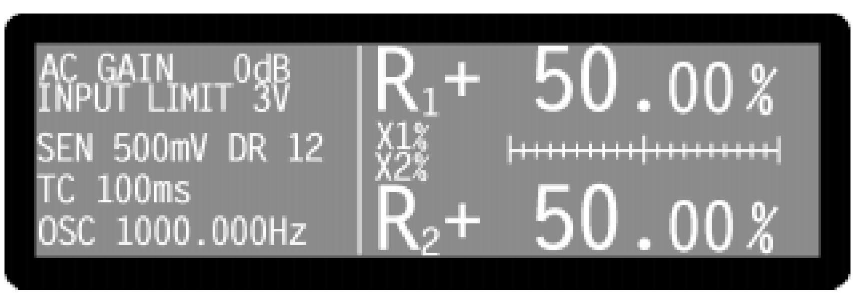

Figure 5-48, Main Display - Dual Harmonic Mode

In dual harmonic mode, the controls on the left-hand side of the Main Display which relate to the reference channel apply only to the $harmonic_1$ of the reference. Controls applying to the second harmonic, known as $harmonic_2$, are accessed via the Reference Channel menu. This menu differs from that used in single reference mode and is described later in section 5.6.03.

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
θ_1°	Phase output, $harmonic_1$, in degrees
θ_2°	Phase output, $harmonic_2$, in degrees
X_1	X_1 channel output in volts or amps
X_2	X_2 channel output in volts or amps
Y_1	Y_1 channel output in volts or amps
Y_2	Y_2 channel output in volts or amps
R_1	Resultant (Magnitude) output, $harmonic_1$, in volts or amps
R_2	Resultant (Magnitude) output, $harmonic_2$, in volts or amps
N	Noise output, $harmonic_1$, in volts or amps per root hertz
xxxx Hz	Reference frequency (fundamental) in hertz
Numeric & Bar-Graph Displays:	
X_1%	X_1 channel output as a percentage of full-scale sensitivity
X_2%	X_2 channel output as a percentage of full-scale sensitivity
Y_1%	Y_1 channel output as a percentage of full-scale sensitivity
Y_2%	Y_2 channel output as a percentage of full-scale sensitivity
N%	Noise, $harmonic_1$ output as a percentage of full-scale sensitivity
ADC1	ADC1 input, ±10.000 V full-scale
ADC2	ADC2 input, ±10.000 V full-scale
Bar-Graph Displays Only:	
MAG1%	Resultant (Magnitude) output, $harmonic_1$, %fs
MAG2%	Resultant (Magnitude) output, $harmonic_2$, %fs
PHA1	Phase output, $harmonic_1$, full-scale = ±200°
PHA2	Phase output, $harmonic_2$, full-scale = ±200°

Table 5-4, Output Display Choices - Dual Harmonic Mode

NOTE: It is not possible to measure or display the noise at the $harmonic_2$ frequency.

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 Equation #1 Setup and Equation #2 Setup menus, 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 dual harmonic mode the maximum detection frequency for either $harmonic_1$ or $harmonic_2$ is 20 kHz.

5.6.03 Reference Channel Menu

In dual harmonic mode, the reference channel is controlled by the Reference Channel menu, which differs from the Reference Channel menu used in the other three modes. Additional controls are needed for the corresponding output channels, and so there are now two Output Channel menus. The relationship of these menus to the Main Menu 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 **MENU** key on the front panel, but this has been omitted from figure 5-49 for the sake of clarity.

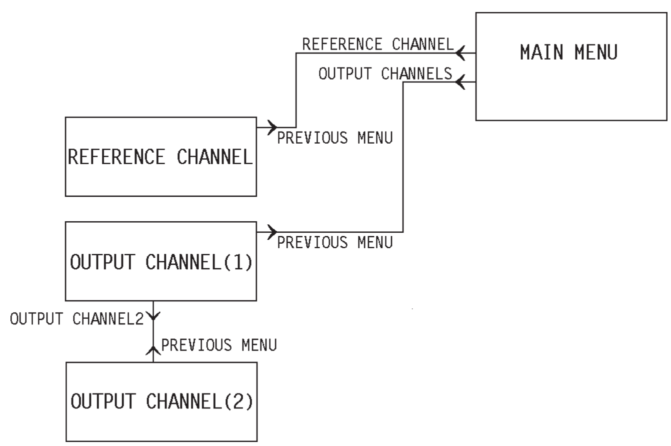

Figure 5-49, Dual Harmonic Mode Menu Structure

In dual harmonic mode, pressing a key adjacent to the Reference Channel item on the Main Menu accesses the Reference Channel menu, shown in figure 5-50.

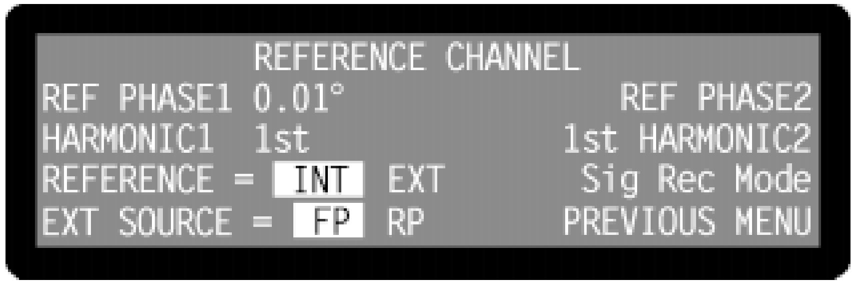

Figure 5-50, Reference Channel Menu - Dual Harmonic Mode

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

REF PHASE1 **(Harmonic$_1$ Phase)**
This control, which duplicates the Main Display PHA control, allows the reference phase of harmonic$_1$ to be adjusted over the range -180° to +180° in 10 m° steps. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The Auto-Phase1 function (see section 5.6.06) also affects the setting of this control.

HARMONIC1 **(Reference Harmonic)**
This control allows selection of harmonic$_1$ of the reference frequency at which the lock-in amplifier will detect. It can be set to any value between 1st and 65535. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

REFERENCE **(Reference Source)**
This control allows selection of the source of the reference signal used to drive the reference circuitry, and has two 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
In this setting the reference channel is configured to accept a suitable external reference source. The actual connector which should be used for this reference is set by the Ext Source control.

EXT SOURCE
This control has two settings and is used to specify the connector to which the external reference source is connected.

FP **(Front Panel)**
In this setting, which is suitable for use with reference frequencies above 300 mHz, the lock-in amplifier's reference should be applied to the **REF IN** connector on the front panel. A wide variety of signal waveforms may be

employed but at frequencies lower than 1 Hz, square waveforms should be used.

RP **(Rear Panel)**
In this setting, the lock-in amplifier's reference should be applied to the TTL-compatible **REF TTL** connector on the rear panel. The use of this input is preferable to the front panel input when a TTL logic reference signal is available. This setting should always be used when operating with external reference frequencies less than 300 mHz.

REF PHASE2 **(Harmonic$_2$ Phase)**
This control allows the reference phase of harmonic$_2$ to be adjusted over the range -180° to +180° in 10 m° steps.

The Auto-Phase2 function (see section 5.6.06) also affects the setting of this control.

HARMONIC2 **(Reference Harmonic)**
This control allows selection of harmonic$_2$ of the reference frequency at which the lock-in amplifier will detect. It can be set to any value between 1st and 65535. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

Sig Rec Mode/Vector VM Mode
This control should always be left set to Sig Rec Mode (signal recovery mode).

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.6.04 Output Channel (1) Menu

When in dual harmonic mode, pressing a key adjacent to the Output Channels item on the Main Menu accesses the Output Channel (1) menu, shown in figure 5-51.

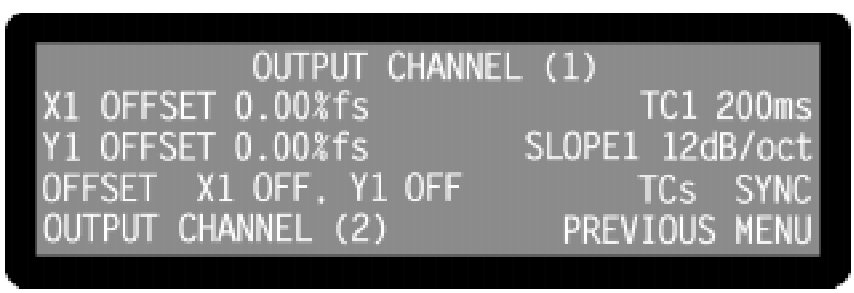

Figure 5-51, Output Channel (1) Menu

The Output Channel (1) menu has six controls affecting the instrument's outputs generated by harmonic$_1$ of the reference frequency and a key to access the Output Channel (2) menu. Changes to the setting of these controls can be made by using the adjacent △ ▽ keys.

The controls operate as follows:-

X1 OFFSET **and** Y1 OFFSET
These controls, which duplicate the Main Display XOF and YOF controls, allow

manual adjustment of the X_1 channel and Y_1 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_1 channel or Y_1 channel output when the X_1 channel or Y_1 channel offset is switched on. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The values are set automatically by the Auto-Offset1 function. Note that the Auto-Offset1 function automatically switches both X_1 channel and Y_1 channel output offsets on.

`OFFSET`
This control allows the X_1 channel and Y_1 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:-

`X1 OFF, Y1 OFF`
Both X_1 channel and Y_1 channel output offsets are switched off.

`X1 ON, Y1 OFF`
The X_1 channel output offset is switched on.

`X1 OFF, Y1 ON`
The Y_1 channel output offset is switched on.

`X1 ON, Y1 ON`
Both X_1 channel and Y_1 channel output offsets are switched on.

`TC1` **(Time Constant)**
This control, which duplicates the Main Display TC control, is used to set the time constant of the channel 1 output filters. The range of possible settings is 10 ms to 100 ks in a 1-2-5 sequence and applies to all instrument outputs other than those at the **FAST X** and **FAST Y** connectors on the rear panel. In dual harmonic mode the signals at these connectors are complex and generally unsuitable for further use.

`SLOPE1`
The roll-off of the output filters for the output channels corresponding to $harmonic_1$ of the reference is set using this control to any value from 6 dB to 24 dB/octave, in 6 dB steps.

`TCs` **(Time Constant Mode)**
This control has two settings, as follows:-

`TCs SYNC` **(Synchronous Time Constants)**
In this setting, the actual time constant used is chosen to be some multiple of the reference frequency period. In this mode the output will be much more stable at low frequencies than it would otherwise be. Note that, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

TCs ASYNC **(Asynchronous Time Constants)**
In this setting, the normal mode, time constants are not related to the reference frequency period.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.6.05 Output Channel (2) Menu

In dual harmonic mode, pressing a key adjacent to the Output Channel (2) item on the Output Channel (1) menu accesses the Output Channel (2) menu, shown in figure 5-52.

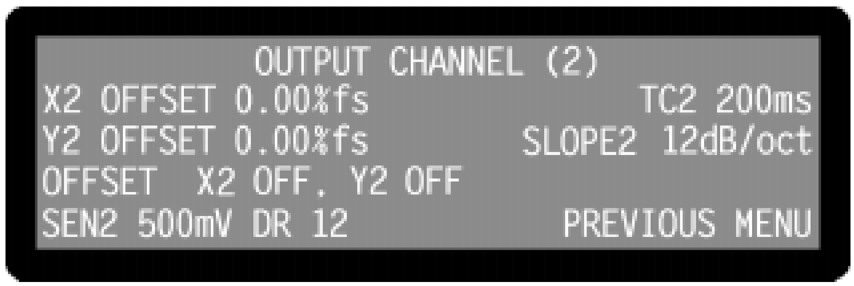

Figure 5-52, Output Channel (2) Menu

The Output Channel (2) menu has six controls affecting the instrument's outputs generated by $harmonic_2$ of the reference frequency and one display function. Changes to the setting of these controls can be made by using the adjacent (△)(▽) keys.

The controls operate as follows:-

X2 OFFSET **and** Y2 OFFSET
These controls allow manual adjustment of the X_2 channel and Y_2 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_2 channel or Y_2 channel output when the X_2 channel or Y_2 channel offset is switched on. Adjustment is faster if use is made of the Active Cursor control - see section 4.1.04.

The values are set automatically by the Auto-Offset2 function. Note that the Auto-Offset2 function automatically switches both X_2 channel and Y_2 channel output offsets on.

OFFSET
This control allows the X_2 channel and Y_2 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:-

X2 OFF, Y2 OFF
Both X_2 channel and Y_2 channel output offsets are switched off.

X2 ON, Y2 OFF
The X_2 channel output offset is switched on.

X2 OFF, Y2 ON
The Y_2 channel output offset is switched on.

X2 ON Y2 ON
Both X_2 channel and Y_2 channel output offsets are switched on.

SEN2 **(Full-scale Sensitivity - reference$_2$ channel)**
When set to voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity for the harmonic$_2$ channel may be set by this control to any value between 2 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 for the harmonic$_2$ channel may be set by this control to any value between 2 fA and 1 µA (wide bandwidth mode) or 2 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 and is calculated by the equation given in section 5.3.02.

The setting may be changed by the Auto-Sen2 function.

TC2 **(Time Constant)**
This control is used to set the time constant of the channel 2 output filters. The range of possible settings is 10 ms to 100 ks in a 1-2-5 sequence and applies to all instrument outputs other than those at the **FAST X** and **FAST Y** connectors on the rear panel. In dual harmonic mode the signals at these connectors are complex and generally unsuitable for further use.

SLOPE2
The roll-off of the output filters for the output channel corresponding to harmonic$_2$ of the reference frequency is set using this control to any value from 6 dB to 24 dB/octave, in 6 dB steps.

Pressing a key adjacent to the Previous Menu item returns control to the Output Channel (1) menu.

5.6.06 Auto Functions Menu

In dual harmonic mode, pressing a key adjacent to the Auto Functions item on the Main Menu accesses the Auto Functions menu, shown in figure 5-53.

Figure 5-53, Auto Functions Menu - Dual Harmonic Mode

This menu has seven 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. There are three auto functions for each of the two reference channels, which operate exactly as described for single reference mode in section 5.3.20. Although there is no Auto-Measure function, the same result may be achieved by executing Auto-Sensitivity followed by Auto-Phase operations.

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

5.6.07 User Options 2 Menu - Dual Harmonic Mode

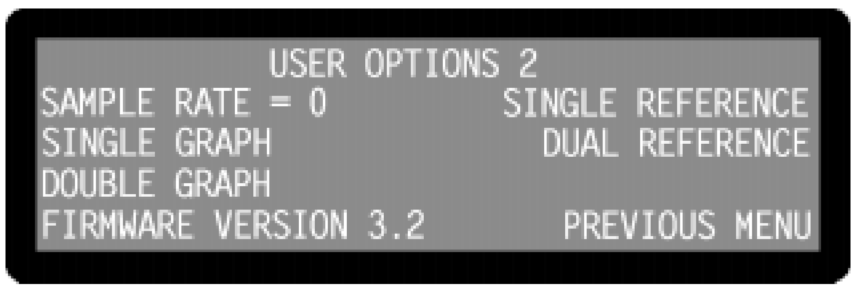

Figure 5-54, User Options 2 Menu - Dual Harmonic Mode

In dual harmonic mode, the choices available on the User Options 2 menu, shown in figure 5-54, are different to those available when in the other three modes. To leave dual harmonic mode and return to single reference mode press a key adjacent to the Single Reference item and to switch to dual reference mode, press a key adjacent to the Dual Reference item. The remaining controls operate as already described in section 5.3.17.

This completes the description of the dual harmonic mode menus.

5.7 Typical Lock-in Amplifier Experiment

The model 7260 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 specified 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 Display Options menu to select the display format required, and the right-hand △ ▽ keys on the Main Display to select the outputs allocated to the four display positions. The three user-selected Main Display controls can be chosen using the Display Setup menu. If the analog outputs of the instrument are to be used, use the User Options 1 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 7260 includes both RS232 and GPIB (IEEE-488) interface ports, designed to allow the lock-in amplifier to be completely controlled from a remote computer. All the instrument's controls may be operated, and all the outputs 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 may 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, may also be set remotely, with the exception of the two user-defined equations that must be set up using the front panel menus. 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, may also be read remotely.

There is no command 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 front panel 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 versions 3.1 and 3.11 include a program called Terminal, and Windows 95 a program called Hyperterminal, usually to be found in the Accessories group, which may 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 7260 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 Terminal mode.

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 7260 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 Comms 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 7260 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 7260, 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 7260 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 7260 the combination set at the factory is even parity check, 7 data bits, and one stop bit (fixed) because these are the MS-DOS default.

6.3.06 Auxiliary RS232 Interface

The auxiliary RS232 interface allows up to sixteen model 7260s 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 7260 the address is set using the GPIB Comms 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 7260 on a byte-by-byte basis and are not connected in the model 7260 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 7260 there are three input termination options for GPIB communications, selected from the front panel under the GPIB Comms 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

Any 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 Comms 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 7260, 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 providing a response subroutine which is the same for all commands, whether or not they send a response over the bus. The principle is that after any command is sent, serial poll operations are repeatedly executed. After each operation bit 0 is tested; if this is found to be negated then bit 7 is repeatedly tested, and if this is asserted then a read operation is performed. Serial poll operations continue until the lock-in amplifier asserts bit 0 to indicate that the command-response sequence is complete. This method deals successfully with compound 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 7260 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 Comms 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 Comms Test Menu

A most useful feature of the model 7260 when troubleshooting communications problems is the Comms Test menu, which is described in detail in section 5.3.24. 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 E 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	High bandwidth (HB) current mode enabled - connect signal to **B** input connector
2	Low noise (LN) 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.

FET [n] Voltage mode input device control

The value of n selects the input device according to the following table:

n	Selection
0	Bipolar device, 10 kΩ input impedance, 2 nV/√Hz voltage noise at 1 kHz
1	FET, 10 MΩ input impedance, 5 nV/√Hz voltage noise at 1 kHz

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)

CP [n] Input connector shield float/ground control

The value of n sets the input coupling mode according to the following table:

n	Coupling mode
0	AC
1	DC

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
1	2 nV	2 fA	n/a
2	5 nV	5 fA	n/a
3	10 nV	10 fA	n/a
4	20 nV	20 fA	n/a
5	50 nV	50 fA	n/a
6	100 nV	100 fA	n/a
7	200 nV	200 fA	2 fA
8	500 nV	500 fA	5 fA
9	1 µV	1 pA	10 fA
10	2 µV	2 pA	20 fA
11	5 µV	5 pA	50 fA

n	full-scale sensitivity		
	IMODE=0	IMODE=1	IMODE=2
12	10 µV	10 pA	100 fA
13	20 µV	20 pA	200 fA
14	50 µV	50 pA	500 fA
15	100 µV	100 pA	1 pA
16	200 µV	200 pA	2 pA
17	500 µV	500 pA	5 pA
18	1 mV	1 nA	10 pA
19	2 mV	2 nA	20 pA
20	5 mV	5 nA	50 pA
21	10 mV	10 nA	100 pA
22	20 mV	20 nA	200 pA
23	50 mV	50 nA	500 pA
24	100 mV	100 nA	1 nA
25	200 mV	200 nA	2 nA
26	500 mV	500 nA	5 nA
27	1 V	1 µA	10 nA

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. Values of n from 0 to 9 can be entered, corresponding to the range 0 dB to 90 dB in 10 dB steps.

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] Signal channel line frequency rejection filter control

In instruments manufactured up to June 1996, the value of n sets the mode of the line frequency notch filter according to the following table:

n	Selection
0	Off
1	On (i.e. reject 50/60 Hz and 100/120 Hz)

In instruments manufactured after June 1996, the value of n sets the mode of the line frequency notch filter according to the following table:

n	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

Users may identify which version of the instrument they have by sending the command LF 3; if this is accepted by the instrument, it was made after June 1996, but if it generates a command error, it was made prior to this date.

Additionally units made after June 1996 respond to the command, LINE50, which sets the notch filter center frequency.

LINE50 [n] Signal channel line frequency rejection filter center frequency control

The value of n sets the line frequency notch filter center frequency according to the following table:

n	Notch filter mode
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

Units made prior to July 1996 generate an Invalid Command (bit 1 of the serial poll status byte is asserted) to the LINE50 command.

SAMPLE [n] Main analog to digital converter sample rate control

The sampling rate of the main analog to digital converter, which is nominally 166 kHz, may be adjusted from this value to avoid problems caused by the aliasing of interfering signals into the output passband.

n may be set to 0, 1, 2 or 3, corresponding to four different sampling rates (not specified) near 166 kHz.

RANGE [n] Signal Recovery/Vector Voltmeter mode selector

The value of n sets the operating mode of the instrument as follows:

n	Mode
0	Signal Recovery
1	Vector Voltmeter

NOTE: Instrument always reverts to signal recovery mode (n=0) on power-up.

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 65535.

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

SLOPE [n] Output low-pass filter slope (roll-off) control

The value of n sets the slope of the output filters according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave
2	18 dB/octave
3	24 dB/octave

TC [n]
TC. Filter time constant control

The value of n sets the time constant of the output according to the following table:

n	time constant
0	10 µs
1	20 µs
2	40 µs
3	80 µs
4	160 µs
5	320 µs
6	640 µs
7	5 ms
8	10 ms
9	20 ms
1	50 ms
11	100 ms
12	200 ms
13	500 ms
14	1 s
15	2 s
16	5 s
17	10 s
18	20 s
19	50 s
20	100 s
21	200 s
22	500 s
23	1 ks
24	2 ks

n	time constant
25	5 ks
26	10 ks
27	20 ks
28	50 ks
29	100 ks

The TC. command is only used for reading the time constant, and reports the current setting in seconds. Hence if a TC 11 command were sent, TC would report 11 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 ±10 % 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

CH n_1 [n_2] Analog output control

Defines what outputs appear on the **CH1** and **CH2** connectors on the rear panel according to the following table:

n_2	Signal
0	X %FS
1	Y %FS
2	Magnitude %FS
3	Phase 1:- +9 V = +180°, -9 V = -180°
4	Phase 2:- +9 V = 360°, - 9 V = 0°
5	Noise %FS
6	Ratio:- (1000 × X)/ADC 1
7	Log Ratio:- $\log_{10}$ (X/ADC1)
8	Equation 1
9	Equation 2

Dual modes only:-

10	X2 %FS
11	Y2 %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.

n_2 may only be set to values between 10 and 14 if one of the dual modes is active. If set to one of these values and the unit is then switched back to single reference mode the output will change to the corresponding single reference equivalent. (e.g. n_2 = 10, X2 %FS, will change to n_2 = 0, X %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.

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.

XY[.] X, Y channel outputs

Equivalent to the compound command X[.];Y[.]

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.

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. (See section 3.10). The command is only available in floating point mode.

NOTE: This command is not available when the reference frequency exceeds 60 kHz.

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.

NOTE: This command is not available when the reference frequency exceeds 60 kHz.

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.

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 5.3.11). The possible range is ±2,147,483,647 (signed 32-bit integer).

NOTE: There are no computer commands for defining the equations, so this must be done manually using the Equation Setup menus.

STAR [n] Star mode setup command

The star mode allows faster access to instrument outputs than is possible using the conventional commands. The mode is set up using the STAR command to specify the output(s) required and invoked by sending an asterisk (ASCII 42) to request the data. The data returned is specified by the value of n, as follows:

n	Data returned by * command
0	X
1	Y
2	MAG
3	PHA
4	ADC1
5	XY
6	MP
7	ADC1;ADC2
8	X_1;X_2
9	Y_1;Y_2
10	MAG_1;MAG_2
11	PHA_1;PHA_2

* Transfer command

This command establishes the high-speed transfer mode. Use the STAR command to set up the desired response to the * command, and then send an * (ASCII 42), without terminator, to the instrument. The instrument will reply with the selected output as quickly as possible, and then wait for another *. If the computer processes the reply quickly and responds immediately with another *, then very rapid controlled data transfer is possible.

The first transfer takes a little longer than subsequent ones because some overhead time is required for the model 7260 to get into the high-speed transfer mode. When in this mode, the front panel controls are inactive and the display is frozen.

The mode is terminated either by sending any command other than an *, when the instrument will exit the mode and process the new command, or after a period of 10 seconds following the last * command.

NOTE: Check that the computer program does not automatically add a carriage return or carriage return-line feed terminator to the * command, since these characters will slow down communications.

6.4.06 Internal Oscillator

OA[.] [n] Oscillator amplitude control

In fixed point mode n sets the oscillator amplitude in mV. The range of n is 0 to 5000 representing 0 to 5 V r.m.s..

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 5.000 V.

In fixed point mode, n is in millivolts r.m.s..
In floating point mode n is in volts r.m.s..

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 5.000 V.

In fixed point mode, n is in millivolts r.m.s.
In floating point mode n is in volts r.m.s.

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 5.000 V.

In fixed point mode, n is in millivolts r.m.s.
In floating point mode n is in volts r.m.s.

OF[.] [n] Oscillator frequency control

In fixed point mode n sets the oscillator frequency in mHz. The range of n is 0 to 250,000,000 representing 0 to 250 kHz.

In floating point mode n sets the oscillator frequency in Hz. The range of n is 0 to 2.5E5.

SYNCOSC [n] Synchronous oscillator (demodulator monitor) control

This control operates only in external reference mode. The parameter n has the following significance:

n	Effect
0	Synchronous Oscillator (Demodulator Monitor) disabled
1	Synchronous Oscillator (Demodulator Monitor) enabled

When enabled and in external reference mode, the instrument's **OSC OUT** connector functions as a demodulator monitor of the X channel demodulation function.

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 250 kHz.

In fixed point mode, n is in millihertz.
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 250 kHz.

In fixed point mode, n is in millihertz.
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

SRATE[.] [n] Oscillator frequency and amplitude sweep step rate

Sets the sweep rate in time per step in the range 50 ms to 1000 s, in 5 ms increments.

SWEEP [n] Oscillator frequency and amplitude sweep start/stop

Starts/stops the internal oscillator frequency and amplitude sweeps depending on the value of n according to the following table:

n	Sweep status
0	Stop/Pause
1	Start frequency sweep
2	Start amplitude sweep
3	Start frequency sweep and amplitude sweep

When a frequency and/or amplitude sweep has been defined, applying SWEEP 1 will start it. The sweep will continue until the stop frequency or amplitude is reached. If, during the sweep, SWEEP 0 is applied, the sweep will stop at the current frequency. If SWEEP 1 is then applied, the sweep will restart from this point. Once the sweep reaches the stop frequency or amplitude and stops, the next SWEEP 1 command will reset the frequency or amplitude to the start frequency or amplitude and restart the sweep.

6.4.07 Auxiliary Outputs

DAC[.] n_1 [n_2]   Auxiliary DAC output controls

Sets the voltage appearing at the **DAC1**, **DAC2**, **DAC1** and **DAC2** outputs on the rear panel.

The first parameter n_1, which specifies the DAC, is compulsory and is either 1, 2, 3 or 4.

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.

In floating point mode it is in volts.

BYTE [n]   Digital output port control

The value of n, in the range 0 to 255, determines the bits to be output on the rear panel digital output port. When n = 0, all outputs are low, and when n = 255, all are high.

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) or **ADC3** (n = 3) inputs on the rear panel.

The response for ADC1 and ADC2 in fixed point mode is an integer in the range -12000 to +12000, corresponding to voltages from -12.000 V to +12.000 V.

In floating point mode it is in volts.

ADC3 is an integrating converter. The response for ADC3 is fixed point only, and depends on the sample time as set by the ADC3TIME command. The full-scale response with a 1 s sample time is ±500000 for ±10 V input. The response is proportional to the sample time e.g. 100 ms sample time gives a full-scale response of ±50000.

ADC3TIME [n]   ADC3 Sample time

n sets the ADC3 sample time in milliseconds in the range 10 ms to 2 s in 10 ms increments. If a number is entered which is within the legal range but not a multiple of 10 ms then it will be rounded down to the nearest multiple of 10 ms.

TADC [n] Auxiliary ADC trigger mode control

The value of n sets the trigger mode of the auxiliary **ADC** inputs according to the following table:

n	Trigger mode
0	Asynchronous (5 ms intervals)
1	External (rear panel **TRIG** input)
2	Burst mode, fixed rate, triggered by command (ADC1 only)
3	Burst mode, fixed rate, 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, fixed rate, External trigger (rear panel **TRIG** input) (ADC1 only)
7	Burst mode, fixed rate, External trigger (rear panel **TRIG** input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger (rear panel **TRIG** input) (ADC1 only)
9	Burst mode, variable rate, External trigger (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 32 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[.] 5 for ADC1 and DC[.] 6 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 may affect the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 32
3	automatically set to 96
4	automatically set to 32
5	automatically set to 96
6	automatically set to 32
7	automatically set to 96
8	automatically set to 32
9	automatically set to 96

The maximum sampling rate depends on the number of ADC inputs used and whether the sampling is timed or simply runs as fast as possible. In the modes described above as Fixed Rate, sampling runs at the maximum possible rate, nominally 20 kHz, when sampling both ADC1 and ADC2, or 40 kHz when sampling ADC1 only. In the Variable Rate modes, the sampling speed is set by the BURSTRATE command.

BURSTRATE [n] Sets the burst mode sampling rate for ADC1 and ADC2

n sets the sample rate for the Variable Rate burst modes according to the following equations:

When storing only to ADC1:
(i.e. TADC 2, TADC 4, TADC 6 and TADC 8)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 157}\right) \text{Hz}$$

When storing to ADC1 and ADC 2:
(i.e. TADC 3, TADC 5, TADC 7 and TADC 9)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 1031}\right) \text{Hz}$$

Note that these equations apply only to units manufactured after December 1995. Earlier instruments used a 16.384 MHz instead of a 16.0 MHz crystal, so the above equations should be modified accordingly by replacing the 16,000,000 figure with 16,384,000.

For example when n = 20, the sample rate will be 24,353 Hz for ADC1 for an instrument with a 16.0 MHz crystal, and 24,937 Hz for a unit with a 16.384 MHz crystal.

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 16 (or 21 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 0 and 65,535, being the decimal equivalent of a 16-bit binary word. In either of the dual reference modes, it is an integer between 1 and 2,097,151, being the decimal equivalent of a 21-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 (+10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)
5	32	ADC1 (±10000 = ±10.0 V)
6	64	ADC2 (±10000 = ±10.0 V)
7	128	ADC3 (-32768 to + 32767)
8	256	DAC1 (±10000 = ±10.0 V)
9	512	DAC2 (±10000 = ±10.0 V)

Bit	Decimal value	Output and range
10	1024	Noise (±10000 FS)
11	2048	Ratio (±10000 FS)
12	4096	Log ratio (-3000 to +2000)
13	8192	EVENT variable (0 to 32767)
14	16384	Reference frequency bits 0 to 15 (mHz)
15	32768	Reference frequency bits 16 to 32 (mHz)
Dual modes only:-		
16	65536	X_2 Output (±10000 FS)
17	131072	Y_2 Output (±10000 FS)
18	262144	Magnitude2 Output (+10000 FS)
19	524288	$Phase_2$ Output (±18000 = ±180°)
20	1048576	$Sensitivity_2$ setting (4 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

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 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 20, 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.

Curves 14 and 15 store the reference frequency in millihertz. The calculation needed to translate these two 16-bit values to one 32-bit value is:

Reference Frequency = (65536 × value in Curve 15) + (value in Curve 14)

Note that the CBD command directly determines the allowable parameters for the DC and HC commands. It also interacts with the LEN command and affects the values reported by the M command.

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.

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 ms with a resolution of 5 ms, input values being rounded up to a multiple of 5. The longest interval that can be specified is 1000000 s corresponding to one point in about 12 days.

In addition, n may be set to 0, which sets the rate of data storage to the curve buffer to 800 Hz. However this only allows storage of the X and Y channel outputs. There is no need to issue a CBD 3 command to set this up since it happens automatically when acquisition starts.

If the time constant is set to 5 ms or longer, then the actual time constant applied to the stored X and Y channel output values will be 640 µs, but if it is set to a shorter value then this will be the time constant actually used.

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.

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. Two triggered modes are possible, as set by the value of n:

n	function
0	One complete curve is acquired for each trigger
1	One complete set of data points is acquired for each trigger. Note that in this mode the maximum trigger rate is 200 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.

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.

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 15, or 0 to 20 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.

The computer program's subroutine which reads the responses to the DC command needs to run a FOR...NEXT loop of length equal to the value set by the LEN (curve length) command.

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 table 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 65,535, being the decimal equivalent of a 16-bit binary number. In either of the dual reference modes it is an integer between 1 and 2,097,151, being the decimal equivalent of a 21-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	Curve and output range
0	1	X Output (±10000 FS)
1	2	Y Output (±10000 FS)
2	4	Magnitude Output (±10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)
5	32	ADC1 (±10000 = ±10.0 V)
6	64	ADC2 (±10000 = ±10.0 V)
7	128	ADC3 (-32768 to + 32767)
8	256	DAC1 (±10000 = ±10.0 V)
9	512	DAC2 (±10000 = ±10.0 V)
10	1024	Noise (±10000 FS)
11	2048	Ratio (±10000 FS)
12	4096	Log ratio (-3000 to +2000)
13	8192	EVENT variable (0 to 32767)
14	16384	Reference frequency bits 0 to 15 (mHz)
15	32768	Reference frequency bits 16 to 32 (mHz)

Dual modes only:-

16	65536	X_2 Output (±10000 FS)
17	131072	Y_2 Output (±10000 FS)
18	262144	$Magnitude_2$ Output (+10000 FS)
19	524288	$Phase_2$ Output (±18000 = ±180°)
20	1048576	$Sensitivity_2$ setting (4 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

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.

As an example, suppose 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 1, 4 and 5. DCT 1 and DCT 4 would only transfer one curve at a time, but DCT 5 would transfer the X channel output curve and the Magnitude curve simultaneously. A typical output data sequence would be:

<X channel output value$_1$><delim><Magnitude value$_1$><term>
<X channel output value$_2$><delim><Magnitude value$_2$><term>
<X channel output value$_3$><delim><Magnitude value$_3$><term>
<X channel output value$_4$><delim><Magnitude value$_4$><term>
<X channel output value$_5$><delim><Magnitude value$_5$><term>

etc., where <delim> and <term> are the delimiter and terminator characters respectively.

The computer program's subroutine which reads the responses to the DCT command needs to run a FOR...NEXT loop of length equal to the value set by the LEN (curve length) command, and must be able to separate the responses on each line for storage or processing.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DCT 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.

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.

\N n Address command

When the model 7260 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.

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 (> ±120 %FS)
Bit 2	CH2 output overload (> ±120 %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 7260.

REV Report firmware revision

Causes the lock-in amplifier to respond with the firmware revision number. This gives a four line response which the controlling program must be able to accept.

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 front panel UserOptions2 menu.

6.4.12 Front Panel

DISP n_1 [n_2] Main Display menu control selector

Defines the three user-specified instrument controls appearing on the Main Display menu (see section 5.3.01). n_1 is the line number and is 1, 2 or 3 corresponding to the upper-middle, lower-middle and bottom lines respectively and n_2 selects the control to be displayed on the specified line according to the following table:

n_2	Control
0	Oscillator amplitude
1	Oscillator frequency
2	Reference frequency (display only)
3	DAC 1
4	DAC 2
5	DAC 3
6	DAC 4
7	Reference phase shifter
8	Reference phase shift in ±90° increments
9	Full-scale sensitivity
10	Time constant
11	X offset
12	Y offset

DISPMODE [n] Main Display menu output display type selector

The value of n configures the output display on the Main Display menu according to the following table:

n	Display type
0	Two large digital displays and two bar-graphs
1	Two large digital displays and two small digital displays
2	Four bar-graph displays

Note that in virtual reference mode the words “Virtual Ref” are shown in the bottom display position.

DISPOUT n_1 [n_2] Main Display menu output selector

This command is used to specify which outputs are displayed on the Main Display menu. Parameter n_1 specifies the digital meter or bar-graph to modify, and can range from 0 to 3, corresponding to the top, upper-middle, lower-middle and bottom displays. Parameter n_2 is used to choose which output appears on the chosen meter or bar-graph, in accordance with the following table:-

Digital Meters and Bar-Graph Displays:-

n_2 Output
0 ADC1
1 ADC2
3 X% or X1%
4 Y% or X2%
5 MAG% or R% or MAG1% or R1%
6 NOISE%
7 θ or PHA; θ1 or PHA1

Digital Meters only

8 Frequency
9 X V/I or X1 V/I
10 Y V/I or Y1 V/I
11 MAG V/I or R V/I or MAG1 V/I or R1 V/I
12 NOISE V/√Hz or A/√Hz

In dual reference and dual harmonic modes parameter n_2 can also be set to the following values to allow the additional outputs given by the second detection channel to be displayed:-

Digital Meters and Bar-Graph Displays:-

n_2 Output
13 X2%
14 Y2%
15 MAG2% or R2%
16 θ2 or PHA2

Digital Meters only

17 X2 V/I
18 Y2 V/I
19 MAG2 V/I or R2 V/I

Hence in order to fully set up the output displays it is necessary to send a DISPMODE command and then send four DISPOUT commands to set up each of the four displays.

KP Key-press identifier

The response to the KP command depends on whether a front panel key has been pressed since the last time the command was issued, and if so, on the currently displayed menu and actual key pressed.

If a key has not been pressed since the last KP command, the response is 0.
If a key has been pressed then the response is a number calculated as follows:-

KP response = (menu number × 32) + key number,

where menu number and key number are defined as follows:

Menu	Menu Number
Main Display	0
Main Menu	1
Oscillator	2
Communications	3
RS232 Comms	4
Reference Channel or Dual Reference Channel	5
Signal Channel	6
Comms Test	7
Display Options	8
Display Setup	9
GPIB Comms	10
Output Channels or Output Channel (1)	11
“*” Command Options	12
DACs & ADCs	13
ADC3 Options	14
User Options 1	15
Equation 1	16
User Options 2	17
Auto Functions	18
Curve Buffer	19
Curve Select	20
ADC1&2 Options	21
Frequency Sweep	22
Amplitude Sweep	23
Virtual Reference (1)	24
Virtual Reference (2)	25
Output Channel (2)	26
Quick View	27
Equation 2	28
Digital Port	29
Single Graph	30
Double Graph	31

The key numbers generated by single key presses are shown in figure 6-1.

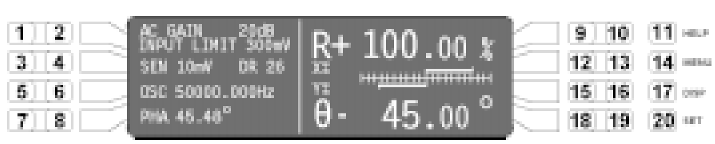

Figure 6-1, Key Number Identifier

If two keys are pressed simultaneously then the key number generated is as follows:

Pressing 1 and 2	=	21
Pressing 3 and 4	=	22
Pressing 5 and 6	=	23
Pressing 7 and 8	=	24
Pressing 9 and 10	=	25

Pressing 11 and 12	=	26
Pressing 13 and 14	=	27
Pressing 15 and 16	=	28

LTS [n] Lights on/off control

The value of n controls the front panel LEDs and LCD backlights according to the following table:

n	Selection
0	All lights off
1	Normal operation

6.4.13 Auto Default

ADF Auto Default command

This command will automatically set all the instrument controls and displays to the factory set default values. However, if the command is used when the interface parameters are at values other than their default settings, then communication will be lost.

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
FET 1	10 MΩ input impedance using FET stage
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
ASM	Auto-Measure (assumes reference frequency > 1 Hz)
TC 12	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 a good "rule of thumb" is to wait for a period of five 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 five 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
FET 1	10 MΩ input impedance using FET stage
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. 1.0	Set oscillator amplitude to 1.0 V r.m.s.
OF. 100.0	Set oscillator frequency to 100 Hz (starting frequency)
SEN 27	Set sensitivity to 1 V full-scale
TC 10	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 250 ms (5 × 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	High bandwidth current 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
SEN 18	Set sensitivity to 1 nA full-scale
TC 10	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 approximately 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 (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
FET 1	10 MΩ input impedance using FET stage
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. 1.0	Set oscillator amplitude to 1.0 V r.m.s.
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 8	Set time constant to 10 ms
AQN	Auto-Phase

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. 0.1	100 ms per step

There will therefore be 100 steps (100 Hz to 1000 Hz inclusive in 10 Hz steps). Now specify the curve storage:

NC	Clear and reset curve buffer
CBD 49180	Stores Magnitude, Phase, Sensitivity and Frequency (i.e. bits 2, 3, 4, 14 and 15)
LEN 100	Number of points = 100
STR 100	Store a point every 100 ms - must match SRATE parameter

The data may now be acquired by issuing the compound command:

TD; SWEEP 1   Starts sweep and curve acquisition

Note that the order of these two commands is important. If used as shown then the data will be acquired and the oscillator frequency will be changed at each data point, prior to waiting for the time set by the SRATE and STR commands. This gives sufficient time for the instrument amplitude output to stabilize after each change of frequency.

If the commands were used in the reverse order (i.e. SWEEP 1; TD) then the output(s) would never have time to settle by the time at which they were recorded.

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 14	Transfers Reference frequency - lower 16 bits
DC 15	Transfers Reference frequency - upper 16 bits

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 < 65536, nF < 60 kHz (internal reference)
n < 2048, nF < 250 kHz (external reference)

Dual Harmonic

Simultaneously measures the signal at two different harmonics of the reference frequency (F_1 and F_2 < 20 kHz)

Dual Reference

Simultaneously measures the signal at two different reference frequencies (F_1 and F_2 < 20 kHz)

Virtual Reference

Locks to and detects a signal without a reference (100 Hz ≤ F ≤ 60 kHz)

Noise

Measures noise in a given bandwidth centered at the reference frequency F (F ≤ 60 kHz)

Operational Modes

Signal Recovery

Normal low-noise mode, Baseband ≤ 60 kHz or Highband > 60 kHz

Vector Voltmeter

High precision mode (introduces 5 dB noise penalty)

Displays

Cold fluorescent backlit 64 × 240 pixel dot-matrix LCD 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	2 nV to 1 V in a 1-2-5 sequence
Dynamic Reserve	> 100 dB
Impedance	
FET Device	10 MΩ // 30 pF
Bipolar Device	10 kΩ // 30 pF
Maximum Safe Input	30 V pk-pk
Voltage Noise	
FET Device	5 nV/√Hz at 1 kHz
Bipolar Device	2 nV/√Hz at 1 kHz
C.M.R.R	> 100 dB at 1 kHz degrading by 6 dB/octave
Frequency Response	0.001 Hz to 250 kHz
Gain Accuracy	0.2 % 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 or Wide Bandwidth
Full-scale Sensitivity	
Low-noise	2 fA to 10 nA in a 1-2-5 sequence
Wide Bandwidth	2 fA to 1 µA in a 1-2-5 sequence
Dynamic Reserve	> 100 dB (with no signal filters)
Frequency Response	
Low Noise	-3 dB at 500 Hz
Wide Bandwidth	-3 dB at 50 kHz
Impedance	
Low Noise	< 2.5 kΩ at 100 Hz
Wide Bandwidth	< 250 Ω at 1 kHz
Noise	
Low Noise	13 fA/√Hz at 500 Hz
Wide Bandwidth	130 fA/√Hz at 1 kHz
Gain Accuracy (midband)	
Low Noise	≤ 0.6 % typ
Wide Bandwidth	≤ 0.6 % typ
Line Filter	attenuates 50, 60, 100, 120 Hz
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

Reference Channel

TTL Input (rear panel)

Frequency Range	1 mHz to 250 kHz

Analog Input (front panel)

Impedance	1 MΩ // 30 pF

Sinusoidal Input	
Level	1.0 V rms**
Frequency Range	1 Hz to 250 kHz
Squarewave Input	
Level	100 mV rms**
Frequency Range	300 mHz to 250 kHz
	**Note: Lower levels can be used with the analog input at the expense of increased phase errors.

Phase	
Set Resolution	0.01º increments
Accuracy	
Frequency ≤ 60 kHz	0.25° typ, 0.75° max
Frequency > 60 kHz	0.5° typ, 0.75° max.
Noise at 100 ms TC, 12 dB/octave	
Internal Reference	< 0.0001º rms
External Reference	< 0.01º rms at 1 kHz
Orthogonality	90º ±0.0001º
Drift	< 0.01º/ºC below 10 kHz < 0.1º/ºC above 10 kHz

Acquisition Time	
Internal Reference	instantaneous acquisition
External Reference	2 cycles + 50 ms

Demodulator and Output Processing

Description	2 x 18-bit ADCs driving two DSP elements managed by a powerful 68000-series host processor
Output Zero Stability	
Digital Outputs	No zero drift on all settings
Displays	No zero drift on all settings
Analog Outputs	< 5 ppm/ºC
Harmonic Rejection	-90 dB
Time Constants	
Digital Outputs	5 ms to 100 ks in a 1-2-5 sequence
Roll-off	6, 12, 18 and 24 dB/octave
Fast Outputs	10 µs to 640 µs in a binary sequence
Roll-off	6 dB/octave only
Synchronous Filter Operation	Available for F < 20 Hz
Offset	Auto and Manual on X and/or Y: ±300 % FS

Oscillator

Frequency	
Range	0.001 Hz to 250 kHz
Setting Resolution	0.001 Hz
Absolute Accuracy	25 ppm + 30 µHz
Distortion (THD)	-80 dB at 1 kHz
Amplitude	
Range	1 mV to 5 V
Setting Resolution	
1 mV to 500 mV	1 mV
501 mV to 2 V	4 mV
2.001 V to 5 V	10 mV
Accuracy	
0.001 Hz to 60 kHz	±0.3 %
60 kHz to 250 kHz	±0.5 %
Stability	50 ppm/ºC
Output	
Impedance	50 Ω
Sweep	
Amplitude Sweep	
Output Range	0.000 to 5.000 V
Law	Linear
Step Rate	20 Hz maximum (50 ms/step)
Frequency	
Output Range	0.001 to 250.000 Hz
Law	Linear or Logarithmic
Step Rate	20 Hz maximum (50 ms/step)

Auxiliary Inputs

ADC 1 and 2	
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	13 kHz max.
Trigger Mode	Internal, External or burst
Trigger input	TTL compatible
ADC3 (integrating)	
Maximum Input	±10 V
Input Impedance	1 MΩ // 30 pF
Sampling Time	10 ms to 2 s
Equivalent Resolution	12 to 20 bits, depending on sampling time

Outputs

CH1 CH2 Outputs	
Function	X, Y, R, θ, Noise, Ratio, Log Ratio and User Equations 1 & 2.
Amplitude	±10 V
Impedance	1 kΩ
Update Rate	200 Hz
Fast X Output	
Time Constant	10 µs to 640 µs in a binary sequence
Slope	6 dB/octave
Amplitude	±10 V (100 % = ±2.5 V)
Update Rate	166 kHz
Output Impedance	1 kΩ
Fast Y Output	
Time Constant	10 µs to 640 µs in a binary sequence
Slope	6 dB/octave
Amplitude	±10 V (100 % = ±2.5 V)
Update Rate	166 kHz
Output Impedance	1 kΩ
Signal Monitor	
Amplitude	±10 V FS
Impedance	1 kΩ
Aux D/A Output 1, 2, 3 & 4	
Maximum Output	±10 V
Resolution	1 mV
Output Impedance	1 kΩ
8-bit Digital Output	8 TTL compatible lines that can be independently set high or low to activate external equipment
Reference Output	
Waveform	0 to 5 V squarewave
Impedance	TTL compatible
Power - Low Voltage	±15 V at 100 mA rear panel 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 800 16-bit values per second
From ADC1	up to 40,000 16-bit values per second

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	< 40 VA
Dimensions	
Width	350 mm (13.75 ")
Depth	415 mm (16.5 “)
Height	
With feet	105 mm (4.1 “)
Without feet	91 mm (3.6 “)
Weight	8.1 kg (18 lb)

All specifications subject to change without notification

Pinouts

Appendix B

B.1 RS232 Connector Pinout

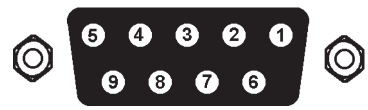

Figure B-1, RS232 and AUX RS232 Connector (Female)

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

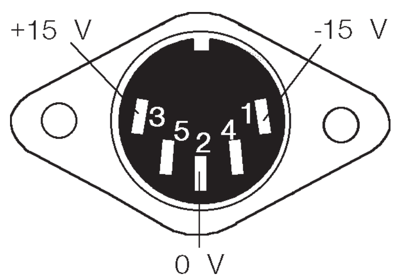

Figure B-2, Preamplifier Power Connector

Pin	Function
1	-15 V
2	Ground
3	+15 V

Pins 4 and 5 are not connected. Shell is shield ground.

B.3 Digital Output Port Connector

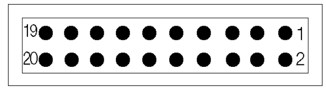

Figure B-3, Digital Output Port Connector

8-bit TTL-compatible output set from the front panel or via the computer interfaces; each line can drive 3 LSTTL loads. This connector mates with a 20-pin IDC Header Plug. 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	+5 V
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 into 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 into 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 7260 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.

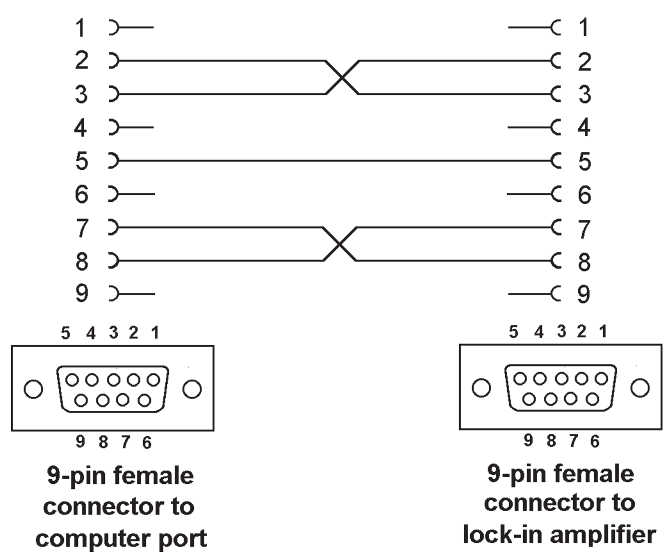

Figure D-1, Interconnecting RS232 Cable Wiring Diagram

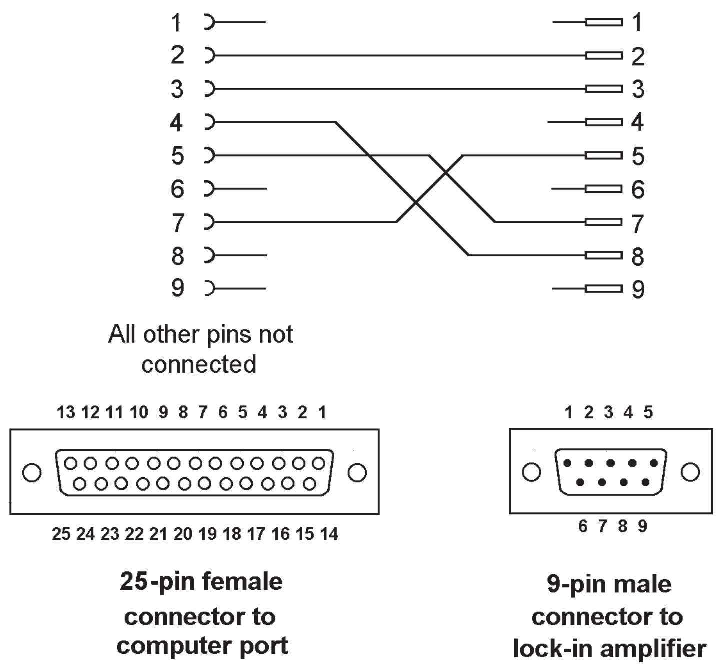

Figure D-2, Interconnecting RS232 Cable Wiring Diagram

Alphabetical Listing of Commands

Appendix E

ACGAIN [n] AC Gain control

Sets the gain of the signal channel amplifier. Values of n from 0 to 9 can be entered, corresponding to the range 0 dB to 90 dB in 10 dB steps.

ADC[.] n Read auxiliary analog to digital inputs

The response for ADC1 and ADC2 in fixed point mode is an integer in the range -12000 to +12000, corresponding to voltages from -12.000 V to +12.000 V. In floating point mode it is in volts.

ADC3 is an integrating converter. The response for ADC3 is fixed point only, and depends on the sample time as set by the ADC3TIME command. The full-scale response with a 1 s sample time is ±500000 for ±10 V input. The response is proportional to the sample time e.g. 100 ms sample time gives a full-scale response of ±50000.

ADC3TIME [n] ADC3 Sample time.

n sets the ADC3 sample time in milliseconds in the range 10 ms to 2 s in 10 ms increments. If a number is entered which is within the legal range but not a multiple of 10 ms then it will be rounded down to the nearest multiple of 10 ms.

ADF Auto Default command

This command will automatically set all the instrument controls and displays to the factory set default values. However, if the command is used when the interface parameters 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

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 5.000 V

In fixed point mode, n is in millivolts r.m.s.
In floating point mode n is in volts r.m.s.

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 5.000 V

In fixed point mode, n is in millivolts r.m.s.
In floating point mode n is in volts r.m.s.

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 5.000 V

In fixed point mode, n is in millivolts r.m.s.
In floating point mode n is in volts r.m.s.

ASM Perform an Auto-Measure operation

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

BURSTRATE [n] Sets the burst mode sampling rate for ADC1 and ADC2

n sets the sample rate for the Variable Rate burst modes according to the following equations:

When storing only to ADC1:
(i.e. TADC 2, TADC 4, TADC 6 and TADC 8)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 157} \right) \text{Hz}$$

When storing to ADC1 and ADC 2:
(i.e. TADC 3, TADC 5, TADC 7 and TADC 9)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 1031} \right) \text{Hz}$$

Note that these equations apply only to units manufactured after December 1995. Earlier instruments used a 16.384 MHz instead of a 16.0 MHz crystal, so the above equations should be modified accordingly by replacing the 16,000,000 figure with 16,384,000.

For example when n = 20, the sample rate will be 24,353 Hz for ADC1 for an instrument with a 16.0 MHz crystal, and 24,937 Hz for a unit with a 16.384 MHz crystal.

BYTE [n] Digital output port control

The value of n, in the range 0 to 255, determines the bits to be output on the rear panel digital output port. When n = 0, all outputs are low, and when n = 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 16 (or 21 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 0 and 65,535, being the decimal equivalent of a 16-bit binary word. In either of the dual reference modes, it is an integer between 1 and 2,097,151, being the decimal equivalent of a 21-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 (+10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)
5	32	ADC1 (±10000 = ±10.0 V)
6	64	ADC2 (±10000 = ±10.0 V)
7	128	ADC3 (-32768 to + 32767)
8	256	DAC1 (±10000 = ±10.0 V)
9	512	DAC2 (±10000 = ±10.0 V)
10	1024	Noise (±10000 FS)
11	2048	Ratio (±10000 FS)
12	4096	Log ratio (-3000 to +2000)
13	8192	EVENT variable (0 to 32767)
14	16384	Reference frequency bits 0 to 15 (mHz)
15	32768	Reference frequency bits 16 to 32 (mHz)
Dual modes only:-		
16	65536	X_2 Output (±10000 FS)
17	131072	Y_2 Output (±10000 FS)
18	262144	$Magnitude_2$ Output (+10000 FS)
19	524288	$Phase_2$ Output (±18000 = ±180°)
20	1048576	$Sensitivity_2$ setting (4 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

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 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 20, 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.

Curves 14 and 15 store the reference frequency in millihertz. The calculation needed to translate these two 16-bit values to one 32-bit value is:

Reference Frequency = (65536 × value in Curve 15) + (value in Curve 14)

Note that the CBD command directly determines the allowable parameters for the DC and HC commands. It also interacts with the LEN command and affects the values reported by the M command.

CH n_1 [n_2] Analog output control

Defines what outputs appear on the **CH1** and **CH2** connectors on the rear panel according to the following table:

n_2	Signal
0	X %FS
1	Y %FS
2	Magnitude %FS
3	Phase 1:- +9 V = +180°, -9 V = -180°
4	Phase 2:- +9 V = 360°, - 9 V = 0°
5	Noise %FS
6	Ratio:- (1000 × X)/ADC 1
7	Log Ratio:- $\log_{10}$ (X/ADC1)
8	Equation 1
9	Equation 2

Dual modes only:-

10	X2 %FS
11	Y2 %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

CP [n] Input connector shield float/ground control

n	Coupling mode
0	AC
1	DC

DAC[.] n_1 [n_2] Auxiliary DAC output controls

The first parameter n_1, which specifies the DAC, is compulsory and is either 1, 2, 3 or 4.

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.

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.

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 15, or 0 to 20 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.

The computer program's subroutine which reads the responses to the DC command needs to run a FOR...NEXT loop of length equal to the value set by the LEN (curve length) command.

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 table 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 65,535, being the decimal equivalent of a 16-bit binary number. In either of the dual reference modes it is an integer between 1 and 2,097,151, being the decimal equivalent of a 21-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	Curve and output range
0	1	X Output (±10000 FS)
1	2	Y Output (±10000 FS)
2	4	Magnitude Output (±10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)
5	32	ADC1 (±10000 = ±10.0 V)
6	64	ADC2 (±10000 = ±10.0 V)
7	128	ADC3 (-32768 to + 32767)
8	256	DAC1 (±10000 = ±10.0 V)
9	512	DAC2 (±10000 = ±10.0 V)

Bit	Decimal value	Curve and output range
10	1024	Noise (±10000 FS)
11	2048	Ratio (±10000 FS)
12	4096	Log ratio (-3000 to +2000)
13	8192	EVENT variable (0 to 32767)
14	16384	Reference frequency bits 0 to 15 (mHz)
15	32768	Reference frequency bits 16 to 32 (mHz)
Dual modes only:-		
16	65536	X_2 Output (±10000 FS)
17	131072	Y_2 Output (±10000 FS)
18	262144	$Magnitude_2$ Output (+10000 FS)
19	524288	$Phase_2$ Output (±18000 = ±180°)
20	1048576	$Sensitivity_2$ setting (4 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

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.

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.

DISP n_1 [n_2] Main Display menu control selector

Defines the three user-specified instrument controls appearing on the Main Display menu (see section 5.3.01). n_1 is the line number and is 1, 2 or 3 corresponding to the upper-middle, lower-middle and bottom lines respectively and n_2 selects the control to be displayed on the specified line according to the following table:

n_2	Control
0	Oscillator amplitude
1	Oscillator frequency
2	Reference frequency (display only)
3	DAC 1
4	DAC 2
5	DAC 3
6	DAC 4
7	Reference phase shifter
8	Reference phase shift in ±90° increments
9	Full-scale sensitivity
10	Time constant
11	X offset
12	Y offset

DISPMODE [n] Main Display menu output display type selector

n	Display type
0	Two large digital displays and two bar-graphs
1	Two large digital displays and two small digital displays
2	Four bar-graph displays

Note that in virtual reference mode the words “Virtual Ref” are shown in the bottom display position.

DISPOUT n_1 [n_2]   Main Display menu output selector

This command is used to specify which outputs are displayed on the Main Display menu. Parameter n_1 specifies the digital meter or bar-graph to modify, and can range from 0 to 3, corresponding to the top, upper-middle, lower-middle and bottom displays. Parameter n_2 is used to choose which output appears on the chosen meter or bar-graph, in accordance with the following table:-

Digital Meters and Bar-Graph Displays:-

n_2	Output
0	ADC1
1	ADC2
3	X% or X1%
4	Y% or X2%
5	MAG% or R% or MAG1% or R1%
6	NOISE%
7	θ or PHA; θ1 or PHA1

Digital Meters only

8	Frequency
9	X V/I or X1 V/I
10	Y V/I or Y1 V/I
11	MAG V/I or R V/I or MAG1 V/I or R1 V/I
12	NOISE V/√Hz or A/√Hz

In dual reference and dual harmonic modes parameter n_2 can also be set to the following values to allow the additional outputs given by the second detection channel to be displayed:-

Digital Meters and Bar-Graph Displays:-

n_2	Output
13	X2%
14	Y2%
15	MAG2% or R2%
16	θ2 or PHA2

Digital Meters only

17	X2 V/I
18	Y2 V/I
19	MAG2 V/I or R2 V/I

Hence in order to fully set up the output displays it is necessary to send a DISPMODE command and then send four DISPOUT commands to set up each of the four displays.

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.

NOTE: This command is not available when the reference frequency exceeds 60 kHz.

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 5.3.11). The possible range is ±2,147,483,647 (signed 32-bit integer).

NOTE: There are no computer commands for defining the equations, so this must be done manually using the Equation Setup menus.

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

FET [n] Voltage mode input device control

n	Selection
0	Bipolar device, 10 kΩ input impedance, 2 nV/√Hz voltage noise at 1 kHz
1	FET, 10 MΩ input impedance, 5 nV/√Hz voltage noise at 1 kHz

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.
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 250 kHz.

In fixed point mode, n is in millihertz.
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

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 250 kHz.

In fixed point mode, n is in millihertz
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 7260.

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	High bandwidth (HB) current mode enabled - connect signal to **B** input connector
2	Low noise (LN) 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.

KP Key-press identifier

The response to the KP command depends on whether a front panel key has been pressed since the last time the command was issued, and if so, on the currently displayed menu and actual key pressed.

If a key has not been pressed since the last KP command, the response is 0

If a key has been pressed then the response is a number calculated as follows:-

KP response = (menu number × 32) + key number,

where menu number and key number are defined as follows:

Menu	Menu Number
Main Display	0
Main Menu	1
Oscillator	2
Communications	3
RS232 Comms	4
Reference Channel or Dual Reference Channel	5
Signal Channel	6
Comms Test	7
Display Options	8
Display Setup	9
GPIB Comms	10
Output Channels or Output Channel (1)	11
“*” Command Options	12
DACs & ADCs	13
ADC3 Options	14
User Options 1	15
Equation 1	16
User Options 2	17
Auto Functions	18
Curve Buffer	19
Curve Select	20
ADC1&2 Options	21
Frequency Sweep	22
Amplitude Sweep	23
Virtual Reference (1)	24
Virtual Reference (2)	25
Output Channel (2)	26

Menu	Menu Number
Quick View	27
Equation 2	28
Digital Port	29
Single Graph	30
Double Graph	31

The key numbers generated by single key-presses are shown in figure E-1.

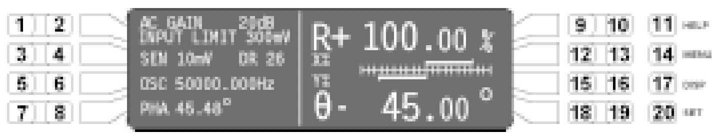

Figure E-1, Key Number identifier

If two keys are pressed simultaneously then the key number generated is as follows:

Pressing 1 and 2	=	21
Pressing 3 and 4	=	22
Pressing 5 and 6	=	23
Pressing 7 and 8	=	24
Pressing 9 and 10	=	25
Pressing 11 and 12	=	26
Pressing 13 and 14	=	27
Pressing 15 and 16	=	28

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] Signal channel line frequency rejection filter control

In instruments manufactured up to June 1996, the value of n sets the mode of the line frequency notch filter according to the following table:

n	Selection
0	Off
1	On (i.e. reject 50/60 Hz and 100/120 Hz)

In instruments manufactured after June 1996, the value of n sets the mode of the line frequency notch filter according to the following table:

n	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

Users may identify which version of the instrument they have by sending the command LF 3; if this is accepted by the instrument, it was made after June 1996, but if it generates a command error, it was made prior to this date.

Additionally units made after June 1996 respond to the command, LINE50, which sets the notch filter center frequency.

LINE50 [n] Signal channel line frequency rejection filter center frequency control

n	Notch filter mode
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

Units made prior to July 1996 generate an Invalid Command (bit 1 of the serial poll status byte is asserted) to the LINE50 command.

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] Lights on/off control

n	Selection
0	All lights 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 7260 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 (> ±120 %FS)
Bit 2	CH2 output overload (> ±120 %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 3.10). The command is only available in floating point mode.

NOTE: This command is not available when the reference frequency exceeds 60 kHz.

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.

OA[.] [n] Oscillator amplitude control

In fixed point mode n sets the oscillator amplitude in mV. The range of n is 0 to 5000 representing 0 to 5 V r.m.s..

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 250,000,000 representing 0 to 250 kHz.

In floating point mode n sets the oscillator frequency in Hz. The range of n is 0 to 2.5E5

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.

RANGE [n] Signal Recovery/Vector Voltmeter mode selector

n	Mode
0	Signal Recovery
1	Vector Voltmeter

NOTE: Instrument always reverts to signal recovery mode (n=0) on power-up

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 65535.

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.

REV Report firmware revision

Causes the lock-in amplifier to respond with the firmware revision number. This gives a four line response which the controlling program must be able to accept.

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
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

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.

SAMPLE [n] Main analog to digital converter sample rate control

n may be set to 0, 1, 2 or 3, corresponding to four different sampling rates (not specified) near 166 kHz.

SEN [n]
SEN. Full-scale sensitivity control

n	full-scale sensitivity		
	IMODE=0	IMODE=1	IMODE=2
1	2 nV	2 fA	n/a
2	5 nV	5 fA	n/a
3	10 nV	10 fA	n/a
4	20 nV	20 fA	n/a
5	50 nV	50 fA	n/a
6	100 nV	100 fA	n/a
7	200 nV	200 fA	2 fA
8	500 nV	500 fA	5 fA
9	1 µV	1 pA	10 fA
10	2 µV	2 pA	20 fA
11	5 µV	5 pA	50 fA
12	10 µV	10 pA	100 fA
13	20 µV	20 pA	200 fA
14	50 µV	50 pA	500 fA
15	100 µV	100 pA	1 pA
16	200 µV	200 pA	2 pA
17	500 µV	500 pA	5 pA
18	1 mV	1 nA	10 pA
19	2 mV	2 nA	20 pA
20	5 mV	5 nA	50 pA
21	10 mV	10 nA	100 pA
22	20 mV	20 nA	200 pA
23	50 mV	50 nA	500 pA
24	100 mV	100 nA	1 nA
25	200 mV	200 nA	2 nA
26	500 mV	500 nA	5 nA
27	1 V	1 µA	10 nA

SLOPE [n] Output low-pass filter slope (roll-off) control

n	Slope
0	6 dB/octave
1	12 dB/octave
2	18 dB/octave
3	24 dB/octave

SRATE[.] [n] Oscillator frequency and amplitude sweep step rate

Sets the sweep rate in time per step in the range 50 ms to 1000 s, in 5 ms increments.

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.

STAR [n] Star mode setup command

n	Data returned by * command
0	X
1	Y
2	MAG
3	PHA
4	ADC1
5	XY
6	MP
7	ADC1;ADC2
8	X_1;X_2
9	Y_1;Y_2
10	MAG_1;MAG_2
11	PHA_1;PHA_2

* Transfer command

This command establishes the high-speed transfer mode. Use the STAR command to set up the desired response to the * command, and then send an * (ASCII 42), without terminator, to the instrument. The instrument will reply with the selected output as quickly as possible, and then wait for another *. If the computer processes the reply quickly and responds immediately with another *, then very rapid controlled data transfer is possible.

The first transfer takes a little longer than subsequent ones because some overhead time is required for the model 7260 to get into the high-speed transfer mode. When in this mode, the front panel controls are inactive and the display is frozen.

The mode is terminated either by sending any command other than an *, when the instrument will exit the mode and process the new command, or after a period of 10 seconds following the last * command.

NOTE: Check that the computer program does not automatically add a carriage return or carriage return-line feed terminator to the * command, since these characters will slow down communications.

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 ms with a resolution of 5 ms, input values being rounded up to a multiple of 5. The longest interval that can be specified is 1000000 s corresponding to one point in about 12 days.

In addition, n may be set to 0, which sets the rate of data storage to the curve buffer to 800 Hz. However this only allows storage of the X and Y channel outputs. There is no need to issue a CBD 3 command to set this up since it happens automatically when acquisition starts.

If the time constant is set to 5 ms or longer, then the actual time constant applied to the stored X and Y channel output values will be 640 µs, but if it is set to a shorter value then this will be the time constant actually used.

SWEEP [n] Oscillator frequency and amplitude sweep start/stop

n	Sweep status
0	Stop/Pause
1	Start frequency sweep
2	Start amplitude sweep
3	Start frequency sweep and amplitude sweep

SYNC [n] Synchronous time constant control

n	Effect
0	Synchronous time constant disabled
1	Synchronous time constant enabled

SYNCOSC [n] Synchronous oscillator (demodulator monitor) control

This control operates only in external reference mode.

n	Effect
0	Synchronous Oscillator (Demodulator Monitor) disabled
1	Synchronous Oscillator (Demodulator Monitor) enabled

TADC [n] Auxiliary ADC trigger mode control

The value of n sets the trigger mode of the auxiliary **ADC** inputs according to the following table:

n	Trigger mode
0	Asynchronous 5 ms intervals)
1	External (rear panel **TRIG** input)
2	Burst mode, fixed rate, triggered by command (ADC1 only)
3	Burst mode, fixed rate, 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, fixed rate, External trigger (rear panel **TRIG** input) (ADC1 only)

n	Trigger mode
7	Burst mode, fixed rate, External trigger (rear panel **TRIG** input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger (rear panel **TRIG** input) (ADC1 only)
9	Burst mode, variable rate, External trigger (rear panel **TRIG** input) (ADC1 and ADC2)

TC [n]
TC. Filter time constant control

n	time constant
0	10 µs
1	20 µs
2	40 µs
3	80 µs
4	160 µs
5	320 µs
6	640 µs
7	5 ms
8	10 ms
9	20 ms
10	50 ms
11	100 ms
12	200 ms
13	500 ms
14	1 s
15	2 s
16	5 s
17	10 s
18	20 s
19	50 s
20	100 s
21	200 s
22	500 s
23	1 ks
24	2 ks
25	5 ks
26	10 ks
27	20 ks
28	50 ks
29	100 ks

The TC. command is only used for reading the time constant, and reports the current setting in seconds. Hence if a TC 11 command were sent, TC would report 11 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.

TDC Take data continuously

TDT n Take data triggered

n function
0 One complete curve is acquired for each trigger
1 One complete set of data points is acquired for each trigger. Note that in this mode the maximum trigger rate is 200 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 front panel UserOptions2 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.

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[.]

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.

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.

Default Settings

Appendix F

Auto Default Function

The Auto-Default function sets the model 7260's controls and output displays as follows:-

Main Display Menu
Displays the AC Gain, full-scale sensitivity, time constant 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 and X channel and Y channel outputs as a percentage of full-scale and signal phase in degrees.

The fourteen basic instrument controls are set to the following values:-

Full-scale sensitivity	500 mV
AC Gain	0 dB
Time constant	100 ms
Slope	12 dB/octave
Oscillator frequency	1000.000 Hz
Oscillator amplitude	0.500 mV rms
DAC1 output	0.000 V
DAC2 output	0.000 V
DAC3 output	0.000 V
DAC4 output	0.000 V
Phase	0.00°
Phase quadrant	0.00°
X channel output offset	0.00 %
Y channel output offset	0.00 %

The remaining instrument controls, accessed via the menus, are set as follows:-

Signal Channel

Input mode	Single-ended voltage mode, **A** input connector
Coupling	AC
Input connector shell	Floating
Input device	FET
Line frequency rejection filter	Off
Automatic AC Gain	Off

Reference Channel

Reference mode	Internal
Reference harmonic	1st
Ext source	FP
Synchronous oscillator	Off
Operating Mode	Signal Recovery, Single Reference

Output Channels	
Output expansion	Off
Output offset	Off
TC's	Sync
Frequency Sweep	
Start Frequency	0.000 Hz
Stop Frequency	0.000 Hz
Step Size	0.000 Hz
Step Rate	1000 ms
Armed	No
Law	Log
Amplitude Sweep	
Start Amplitude	0.000 V
Stop Amplitude	0.000 V
Step Size	0.000 V
Step Rate	1000 ms
Armed	No
User Options 1	
CH1 analog output	X %
CH2 analog output	Y %
Equation #1 Setup	
Equation #1	zero
Equation #2 Setup	
Equation #2	zero
ADC1&2 Options	
ADC1 & 2 Trigger Rate	5 ms
ADC3 Options	
ADC3 Sample Time	1.000 s
Curve Buffer	
Sample Rate	10 ms
Length	32768
Curve Select	
Selected curve	X (i.e. CBD = 1)
User Options 2	
Sample rate adjustment	0
Operating mode	Single Reference

RS232 Comms

Baud rate	9600
Data bits	7 + 1 Parity
Delimiter	, (044)
Address	1
Character echo	On
Parity	Even
Prompt character	On

GPIB Comms

Address	12
Terminator	[CR],[LF]
Test Echo	Disabled
SRQ mask byte	0

‘*’ Command Options

Selected output	MP

Digital Port

Digital outputs	0 (i.e. D0 - D7 are at logic zero)

Display Options

Display contrast	65
Backlight	On

Index

WARRANTY

EG&G Instruments Corporation warrants each instrument of its own manufacture to be free of defects in material and workmanship for a period of ONE year from the date of delivery to the original purchaser. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase, at our option, of any instruments returned, shipment prepaid, to our Service Department for that purpose, provided prior authorization for such return has been given by an authorized representative of EG&G Instruments Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unusable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. This Warranty shall not apply to any instrument or component not manufactured by EG&G Instruments Corporation. When products manufactured by others are included in EG&G Instruments Corporation equipment, the original manufacturers Warranty is extended to EG&G Instruments customers.

EG&G Instruments Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF. THIS WARRANTY IS IN LIEU OF, AND EXCLUDES ANY AND ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESSED, IMPLIED OR STATUTORY, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AS WELL AS ANY AND ALL OTHER OBLIGATIONS OR LIABILITIES OF EG&G INSTRUMENTS CORPORATION, INCLUDING, BUT NOT LIMITED TO, SPECIAL OR CONSEQUENTIAL DAMAGES. NO PERSON, FIRM OR CORPORATION IS AUTHORIZED TO ASSUME FOR EG&G INSTRUMENTS CORPORATION ANY ADDITIONAL OBLIGATION OR LIABILITY NOT EXPRESSLY PROVIDED FOR HEREIN EXCEPT IN WRITING DULY EXECUTED BY AN OFFICER OF EG&G INSTRUMENTS CORPORATION.

SHOULD YOUR EQUIPMENT REQUIRE SERVICE

A. Contact your local EG&G Instruments office, agent, representative or distributor to discuss the problem. In many cases it may be possible to expedite servicing by localizing the problem to a particular plug-in circuit board.

B. We will need the following information, a copy of which should also be attached to any equipment which is returned for service.

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

EG&G SIGNAL RECOVERY
Sorbus House
Mulberry Business Park
WOKINGHAM RG41 2GY
United Kingdom

Phone: +44 (0)118 977 3003
Fax: +44 (0)118 977 3493
E-mail: service_sigrecovery@egginc.com