

# **Model 7280BFP**

## **Wide Bandwidth DSP Lock-in Amplifier**

*Instruction Manual*

197330-A-MNL-A

## 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.

## Company Names

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## Declaration of Conformity

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

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

EMC: BS EN55011 (1991) Group 1, Class A (CSPIR 11:1990)

BS EN50082-1 (1992):

IEC 801-2:1991

IEC 801-3:1994

IEC 801-4:1988

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

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## 1.1 How to Use This Manual

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

### **Chapter 1 - Introduction**

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

### **Chapter 2 - Installation and Initial Checks**

Describes how to install the instrument and gives a simple test procedure which may be performed to check that it has arrived in full working order. It also describes how to install firmware options that are available for the instrument.

### **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 you to get the best possible performance from the unit.

### **Chapter 4 - Front and Rear Panels**

Describes the instrument's connectors, switches and indicators as referred to throughout this manual.

### **Chapter 5 - Remote 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 instrument.

### **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 instrument to an IBM-PC or 100% compatible computer.

### **Appendix E**

Provides a listing of the instrument settings produced by using the Auto-Default

functions.

### **Appendix F**

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

If you are a new user, it is suggested that you unpack the instrument and carry out the procedure in chapter 2 to check that it is working satisfactorily. You should then make yourself familiar with the information in chapters 3, 4 and 5. Once you are familiar with the structure of the computer commands, appendix F will prove convenient as it provides a complete alphabetical listing of these commands in a single easy-to-use section.

## **1.2 What is a Lock-in Amplifier?**

In its most basic form the lock-in amplifier is an instrument with dual capability. On the one hand 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 7280BFP, 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 7280BFP lock-in amplifier can function as a:-

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

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

## 1.3 Key Specifications and Benefits

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

Key specifications include:

- Frequency range: 0.5 Hz to 2.0 MHz
- Voltage sensitivity: 10 nV to 1 V full-scale
- Current input mode sensitivities: 1 pA to 100  $\mu$ A full-scale  
10 fA to 1  $\mu$ A full-scale  
10 fA to 10 nA full-scale
- Line frequency rejection filter
- Dual phase demodulator with X-Y and R- $\theta$  outputs
- Very low phase noise of  $< 0.0001^\circ$  rms
- Output time constant: 1  $\mu$ s to 100 ks
- Output values with resolution of 1 part in  $\pm 30,000$
- Dual reference mode - allows simultaneous measurement of two signals at different reference frequencies up to 20 kHz, or 800 kHz with option 7280/99 or 2.0 MHz with option 7280/98
- Single and dual harmonic mode - allows simultaneous measurement of up to two different harmonics of a signal at up to 20 kHz, or 800 kHz with option 7280/99 or 2.0 MHz with option 7280/98
- Virtual reference mode - allows reference free measurement of signals up to 2.0 MHz
- Direct Digital Synthesizer (DDS) oscillator with variable amplitude and frequency
- Oscillator frequency and amplitude sweep generator
- 8-bit programmable digital I/O port for external system control
- Four auxiliary ADC inputs and two auxiliary DAC outputs
- Full range of auto-modes
- Standard IEEE-488 (GPIB) and RS232 interfaces with RS232 daisy-chain capability for up to 16 instruments
- 32,768 point internal curve storage buffer



# Installation & Initial Checks

## 2.1 Installation

### 2.1.01 Introduction

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

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

### 2.1.02 Rack Mounting

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

### 2.1.03 Inspection

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

### 2.1.04 Line Cord Plug

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

### 2.1.05 Line Voltage Selection and Line Fuses

Before plugging in the line cord, ensure that the model 7280BFP 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 7280BFP 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 7280BFP 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. Instruments are normally shipped from the factory with the line voltage selector set to 110-130 V AC, unless they are destined for an area known to use a line voltage in the 220-260 V range, in which case, they are shipped configured for operation from the higher range.

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

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

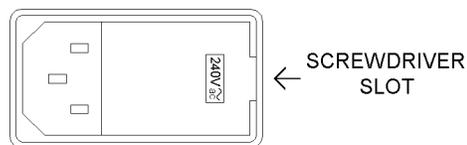


Figure 2-1, Line Input Assembly

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

Table 2-1, Range vs. Barrel Position

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

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

## 2.2 Initial Checks

### 2.2.01 Introduction

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

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

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

### 2.2.02 Initial Checks Software

The model 7280BFP is supplied with a 3.5 inch floppy disk containing the Initial Checks software program and a model C01003 9-pin female to 9-pin male modem eliminator RS232 cable. An computer running Windows 95 or later with a standard RS232 interface COM1 or COM2 port is required to use the software which provides a quick and simple check of instrument operation. The program also allows the user to set the GPIB communications interface parameters if values other than the factory defaults are to be used, and to install available firmware options that extend the operating modes.

Note that before the initial checks procedure can be performed it is essential to establish proper RS232 communications between the host computer and the model 7280BFP. If the supplied C01003 cable is not available, or unsuitable for the computer's connectors, then please refer to appendix D, RS232 Cable Diagrams, for information on the correct cable type to be used with your computer.

### 2.2.03 Procedure

- 1) Ensure that the model 7280BFP 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 left-hand side of the instrument when viewed from the rear) set to **0** (off), plug in the line cord to an appropriate line source.
- 3) Connect a 9-way RS232 cable to the lower RS232 connector on the model 7280BFP's rear panel, marked **RS232**. Connect the other end of the RS232 cable to the host computers COM1 or COM 2 RS232 connector. If the host computer has a 25-way connector then a 25-way to 9-way cable must be used or alternatively a 9-way to 25-way adapter used with a 9-way to 9-way cable.
- 4) Using a BNC cable, connect the **OSC** output connector to the **A** input connector on the rear panel of the model 7280BFP.
- 5) Turn the model 7280BFP power switch to the **I** (on) position.
- 6) Turn on the host computer and wait for it to boot and display the Windows desktop.
- 7) Put the Initial Checks disk in the disk drive and use Run on the Start menu to start the program INITCHECKS.EXE
- 8) The Initial Checks program will now run. The opening screen will appear, as shown in figure 2-2.



Figure 2-2, Initial Checks Procedure, Opening Screen

Click the Next button to continue, which displays a second screen where the model number of the instrument being checked is entered. Click the model 7280BFP button and then click Next. The following screen shows the required connections, but since these have already been made, click the Next button again. This accesses the Program Options menu, shown in figure 2-3 below.

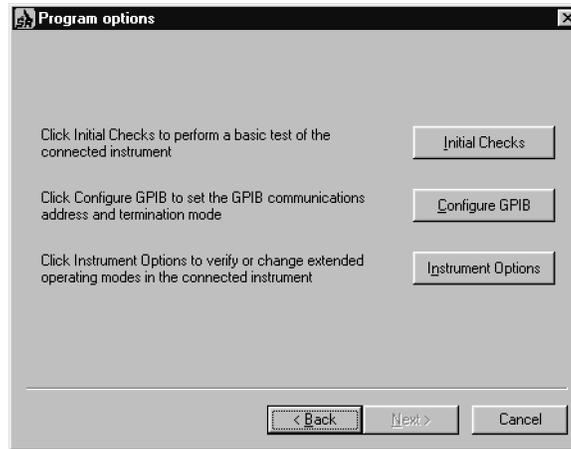


Figure 2-3, Initial Checks Procedure, Program Options Menu

- 9) The instrument is supplied set to a GPIB address of 12 and with a GPIB termination of <CR><LF> character pair. In addition the GPIB line EOI is asserted with the last character of each transmission from the lock-in. If the unit will be used under GPIB control and these settings are not acceptable then it is useful to adjust them at this stage. Click the Configure GPIB button to access the Configure GPIB menu, shown below in figure 2-4. Note that it will take a few seconds for the controls to activate after the menu is displayed.

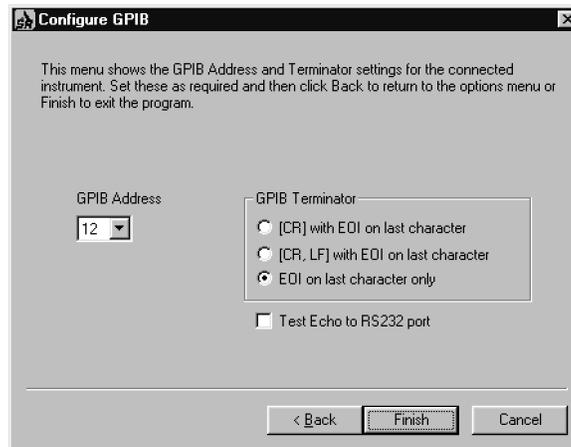
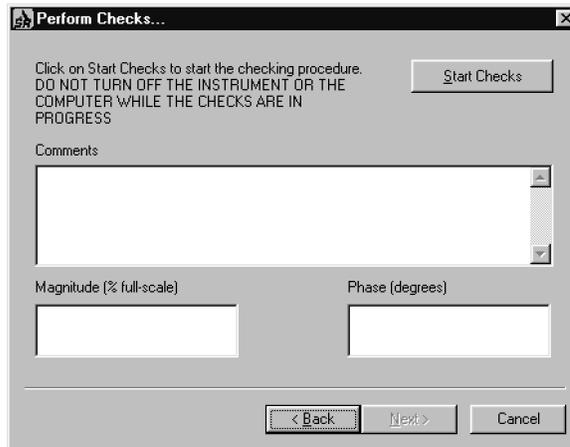


Figure 2-4, Initial Checks Procedure, Configure GPIB Menu

- 10) Set the GPIB address and terminator settings as required. Note that when the **Test Echo to RS232 port** box is checked, commands sent to the instrument and responses from it via the GPIB interface are echoed to the RS232 port. This can be of use during program debugging but in normal use the option should not be selected.

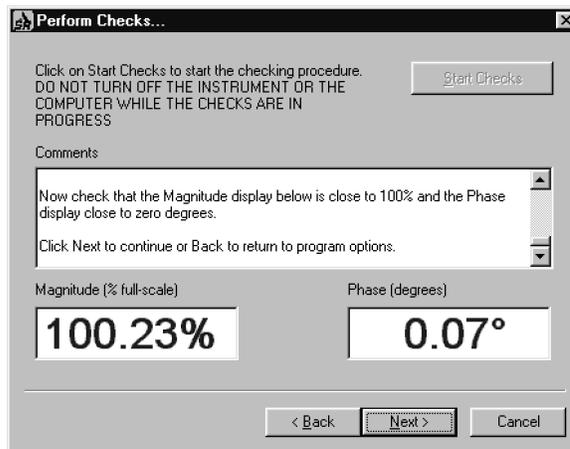
Once the required settings have been entered, click Back to return to the Program Options menu.

- 11) Click on the Initial Checks button to access the Perform Checks menu, shown below in figure 2-5.



**Figure 2-5, Initial Checks Procedure, Perform Checks Menu - Opening Screen**

- 12) Click on the Start Checks button. The program automatically checks for and switches to the serial port (COM 1 or COM 2) to which the lock-in amplifier is connected.
- 13) Once communications have been established the Comments section shows details of the commands being sent to the model 7280BFP which set it to a defined state. Once this has happened, the signal magnitude and reference phase are shown in the lower section of the display, as shown in figure 2-6.



**Figure 2-6, Initial Checks Procedure, Perform Checks Screen - Outputs Displayed**

- 14) Note that although the actual output readings may vary from the those shown above, they should be close to 100 % full-scale (magnitude) and 0° (phase). If this is achieved then one can be reasonably confident that the model 7280BFP has not suffered any shipping damage and is in good working order. Click on the Next button to finish the procedure.

*Note: The initial checks program can only work if the instrument's RS232 communications settings are set to use a baud rate of either 9600 or 19200 and Echo handshaking. This includes the factory default setting of 9600 baud with Echo handshaking enabled, so new units should work without problem. However if for any reason these settings are changed (using the RS command) then before any subsequent use of the Initial Checks disk it will be necessary to change them back (again using the RS command) to match the factory set values. The Windows HyperTerminal program can be of use in such cases.*

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 instrument incurred no hidden damage in shipment and is in good working order.

## 2.3 Installing Options

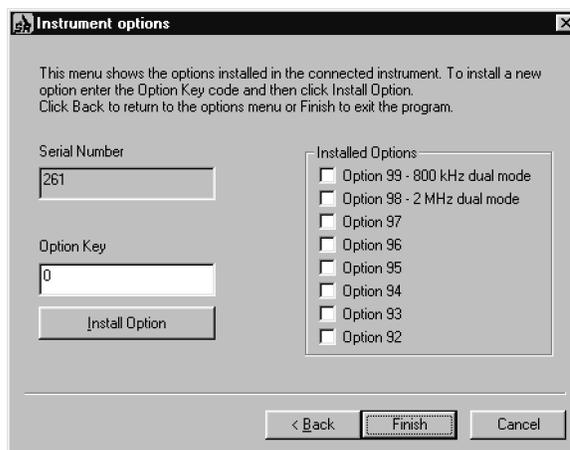
### 2.3.01 Introduction

The model 7280BFP may be upgraded by installing additional firmware options. Purchase of the option requires the instrument serial number, which may be found from the serial number label applied to the rear panel or via the SERIAL computer command.

The option is installed by entering an "Option Key" code number which activates the extended firmware. In order to enter this number, proceed as described in the following section.

### 2.3.02 Procedure

- 1) Follow the procedure outline in section 2.2.03 above until you reach the screen shown in figure 2-3.
- 2) Click on the Instrument Options button to display the menu shown in figure 2-7 below. Note that it will take a few seconds for the controls to activate after the menu is displayed. During this time the instrument serial number is read and any installed options are determined.



**Figure 2-7, Instrument Options Menu**

- 3) Enter the Option Key number you have been given in the Option Key box and click Install Option to activate it.
- 4) When the option is correctly installed, the list on the right hand side of the screen will be updated, with a check next to each installed option.
- 5) Click Finish to end the procedure.

### 3.1 Introduction

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

### 3.2 Operating Modes

#### 3.2.01 Introduction

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

#### 3.2.02 Single Reference / Dual Reference

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

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

#### 3.2.03 Single Harmonic / Dual Harmonic

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

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

option -/98).

### 3.2.04 Internal / External Reference Mode

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

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

### 3.2.05 Virtual Reference Mode

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

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

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

## 3.3 Principles of Operation

### 3.3.01 Block Diagram

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

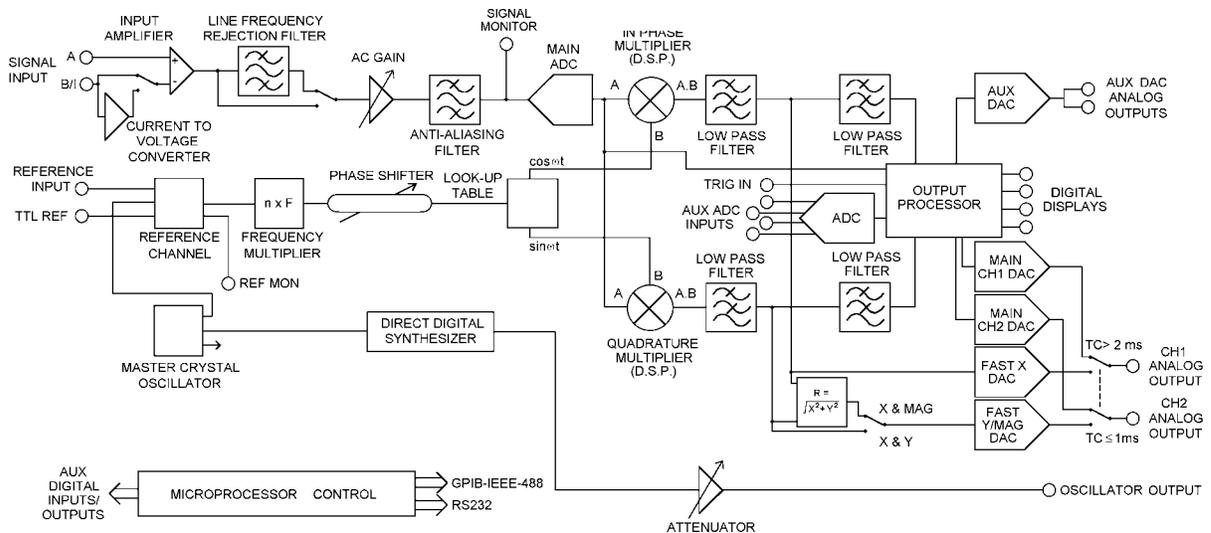


Figure 3-1, Model 7280BFP - Block Diagram

### 3.3.02 Signal Channel Inputs

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

#### Input Connector Selection, A / -B / A - B

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

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

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

The input can also be set to the -B mode, in which case the lock-in amplifier measures the voltage between the center and the shell of the B/I input connector. This extra mode effectively allows the input to be multiplexed between two different single-ended signals, subject to the limitation that the user must allow for the signal inversion

(equivalent to a 180° phase-shift) which it introduces when reading the outputs.

#### **Input Connector Shell, Ground / Float**

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

#### **Input Coupling Mode, Fast/Slow**

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

#### **Input Signal Selection, V / I**

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

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

### **3.3.03 Line Frequency Rejection Filter**

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

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

The command, LF, that is used to control the line filter takes two parameters, the second of which sets the line frequency to either 50 or 60 Hz, so with proper use of this command there is no need to pre-configure the line frequency setting.

### **3.3.04 AC Gain and Dynamic Reserve**

The signal channel contains a number of analog filters and amplifiers whose overall gain is defined by the AC Gain parameter, which is specified in terms of decibels (dB). For each value of AC Gain there is a corresponding value of the INPUT LIMIT parameter, which is the maximum instantaneous (peak) voltage or current that can be

applied to the input without causing input overload, as shown in table 3-1 below.

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

**Table 3-1, Input Limit vs. AC Gain**

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

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

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

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

At any given setting, the ratio

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

represents the factor by which the largest acceptable sinusoidal interference input exceeds the full-scale sensitivity and is called the Dynamic Reserve of the lock-in

amplifier at that setting. (The factor 0.7 is a peak-to-rms conversion). The dynamic reserve is often expressed in decibels, for which

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

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

### 3.3.05 Anti-Aliasing Filter

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

Consider the situation when the lock-in amplifier is measuring a sinusoidal signal of frequency  $f_{\text{signal}}$  Hz, which is sampled by the main ADC at a sampling frequency  $f_{\text{sampling}}$  Hz. In order to ensure correct operation of the instrument the output values representing the  $f_{\text{signal}}$  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,  $f_{\text{alias}} = |f_1 - n f_{\text{sampling}}|$ , where  $n$  is an integer. This alias signal is indistinguishable from the output generated when a genuine signal at frequency  $f_{\text{alias}}$  is sampled. Hence if the frequency of the unwanted signal were such that the alias signal frequency produced from it was close to, or equal to, that of the wanted signal then it is clear that a spurious output would result.

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

To overcome this problem the signal is fed through the anti-aliasing filter which restricts the signal bandwidth to an upper frequency of 2.0 MHz. The filter is a conventional elliptic-type, low-pass, stage, giving the lowest possible noise bandwidth. It should be noted that the dynamic range of a lock-in amplifier is normally so high that practical anti-alias filters are not capable of completely removing the effect of a

full-scale alias. For instance, even if the filter gives 100 dB attenuation, an alias at the input limit and at the reference frequency will give a one percent output error when the dynamic reserve is set to 60 dB, or a ten percent error when the dynamic reserve is set to 80 dB.

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

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

### **3.3.06 Main Analog-to-Digital Converter**

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

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

### **3.3.07 Reference Channel**

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

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

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

#### **External Reference Mode**

In external reference mode the reference source may be applied to either a general purpose input, designed to accept virtually any periodic waveform with a 50:50 mark-

space ratio and of suitable amplitude, or to a TTL-logic level input. Following the trigger buffering circuitry the reference signal is passed to a digital phase-locked loop (PLL) implemented in the reference circuit. This measures the period of the applied reference waveform and from this generates the phase values.

#### **Internal Reference Mode**

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

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

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

### **3.3.08 Phase-Shifter**

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

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

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

In basic lock-in amplifier applications the purpose of the experiment is to measure the amplitude of a signal which is of fixed frequency and whose phase with respect to the reference input does not vary. This is the *scalar* measurement, often implemented with a chopped optical beam. Many other lock-in amplifier applications are of the *signed scalar* type, in which the purpose of the experiment is to measure the amplitude and sign of a signal which is of fixed frequency and whose phase with respect to the reference input does not vary apart from reversals of phase corresponding to changes in the sign of the signal. A well-known example of this situation is the case of a

resistive bridge, one arm of which contains the sample to be measured. Other examples occur in derivative spectroscopy, where a small modulation is applied to the angle of the grating (in optical spectroscopy) or to the applied magnetic field (in magnetic resonance spectroscopy). Double beam spectroscopy is a further common example.

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

### **3.3.09 Internal Oscillator - General**

The model 7280BFP, 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 7280BFP is digitally synthesized with the result that the output frequency is extremely accurate and stable. The oscillator operates over the same frequency range as the lock-in amplifier, that is 500 mHz to 2.0 MHz, and is implemented using a dedicated direct digital synthesis circuit.

### **3.3.10 Internal Oscillator - Update Rate**

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

### **3.3.11 Internal Oscillator - Frequency & Amplitude Sweeps**

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

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

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

relation to the signal level, then the virtual reference mode is capable of making signal recovery measurements which are not possible with other lock-in amplifiers.

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

### 3.3.12 Demodulators

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

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

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

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

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

### 3.3.13 Output Processor - Output Filters

Although shown on the block diagram as a separate entity, the output processor is in fact part of the instrument's main microprocessor. It provides more digital filtering of the X channel and Y channel signals if this is needed in addition to that already performed by the demodulators. As with most lock-in amplifiers, the output filter

configuration in the model 7280BFP is controlled by the slope control. This may seem somewhat strange, and a few words of explanation may be helpful.

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

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 7280BFP to apply to the envelope of the frequency response function of the digital finite impulse response (FIR) output filters. Accordingly the command that selects the configuration of the output filters is SLOPE, which offers a choice of four settings of 6, 12, 18 or 24 dB/octave.

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

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

The output time constant can be varied between 1  $\mu$ s and 100 ks. When set to a value between 1  $\mu$ s and 1 ms or 4 ms, X and Y or X and Magnitude outputs are available at the **CH 1** and **CH 2** outputs. At longer time constant settings, all outputs are valid and available at the **CH 1** and **CH 2** outputs and as the internal digital values reported to a remote computer or stored to the internal curve buffer. As noted in section 3.3.12 above, in dual reference and dual harmonic modes the analog outputs at time constants shorter than 1 ms are limited to  $X_1$  and  $X_2$ .

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  $\pm 300\%$  full-scale offset to be applied to the outputs, both digital (via the bus) and analog (**CH 1** and **CH 2**).

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

### 3.3.15 Output Processor - Vector Magnitude and Phase

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

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

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

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

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

These considerations lead to the conclusion that when the magnitude output is being used, the time constants of the demodulator should be set to give the required signal-

to-noise ratio at the X channel and Y channel demodulator outputs; improving the signal-to-noise ratio by averaging the magnitude output itself is not recommended.

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

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

### 3.3.16 Output Processor - Noise Measurements

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

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

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

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

The noise buffer length  $n$  can be set to 1, 1000, 2000, 3000 or 4000. Since new input values to the buffer are supplied at a 1 kHz rate, these correspond to averaging times of zero, 1 second, 2 seconds, 3 seconds and 4 seconds respectively, and so the command that adjusts this buffer length is NNBUF, offering five settings of Off, 1 s, 2 s, 3 s or 4 s. Setting a shorter time means that the system responds more quickly to

changes in the mean X-output level, but the noise reading itself exhibits more fluctuation. Conversely, the fluctuation can be reduced by setting a longer time, but at the expense of increased settling time following changes in the mean X-output level.

If a noise output value (N calibrated in volts or amps per root hertz, or as a percentage of full scale) is read via the computer interfaces while the time constant or slope are outside the permitted range, or if the synchronous time constant control is enabled, then the response will be -1. Since noise readings can only be zero or positive, this negative number clearly indicates that the reading is invalid and should be ignored.

In order to make noise measurements easier, the instrument includes a Noise Measurement Mode, activated by the NOISEMODE command. When this is turned on, the filter time constant, slope and synchronous time constant setting are forced to values within the permitted ranges. When turned off, these restrictions are removed.

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

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

### **3.3.17 Auxiliary Analog Inputs and Outputs (ADCs and DACs)**

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

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

### **3.3.18 Main Microprocessor - User Settings**

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

### **3.3.19 Main Microprocessor - General**

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

external logic lines.

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

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

### **3.3.20 Main Microprocessor - Auto Functions**

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

The following sections contain brief descriptions of the auto functions.

#### **Auto-Sensitivity**

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

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

#### **Auto-Phase**

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

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

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

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

- 1) Remove the source of input signal, without disturbing any of the connections to the signal input which might be picking up interfering signals from the reference channel. In an optical experiment, for example, this could be done by shielding the detector from the source of chopped light.
- 2) Execute an Auto-Offset operation, which will reduce the X channel and Y channel outputs to zero.
- 3) Re-establish the source of input signal. The X channel and Y channel outputs will now indicate the true level of input signal, *at the present reference phase setting*.
- 4) Execute an Auto-Phase operation. This will set the reference phase-shifter to the phase angle of the input signal. However, because the offset levels which were applied in step 2 were calculated at the original reference phase setting, they will not now be correct and the instrument will in general display a non-zero Y channel output value.
- 5) Remove the source of input signal again.
- 6) Execute a second Auto-Offset operation, which will reduce the X channel and Y channel outputs to zero at the new reference phase setting.
- 7) Re-establish the source of input signal.

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

#### **Auto-Offset**

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

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

#### **Auto-Measure**

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

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

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

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

#### **Auto-Default**

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

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

## **3.4 General**

### **3.4.01 Accuracy**

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

### **3.4.02 Power-up Defaults**

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

- a) The GPIB mask byte is set to zero.
- b) The curve buffer is cleared.
- c) Any sweep that was in progress at switch-off is terminated.
- d) Synchronous time constants are enabled.



### 4.1 Front Panel

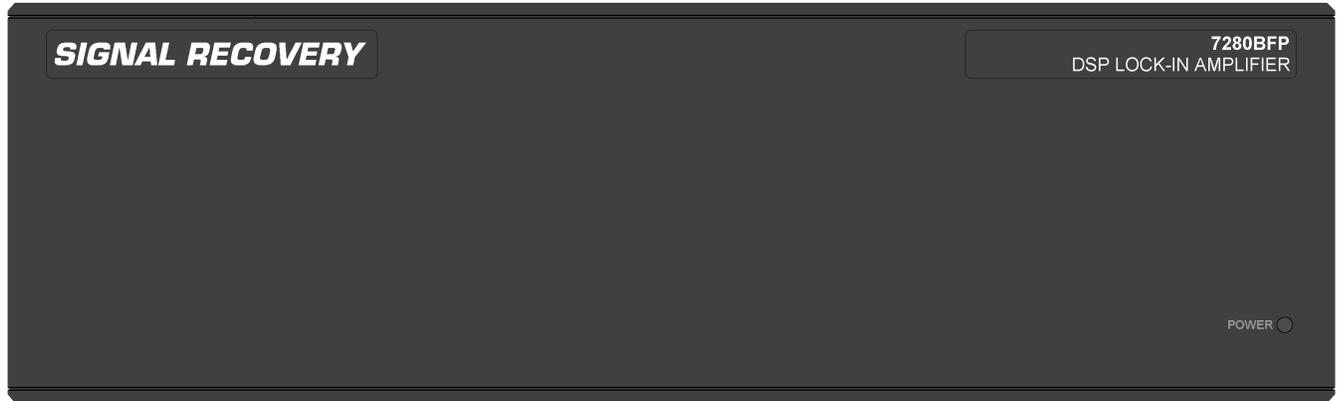


Figure 4-1, Model 7280BFP Front Panel Layout

As shown in figure 4-1, the model 7280BFP's front panel has only a single POWER LED indicator, with all the signal input and output connectors being located on the rear panel.

### 4.2 Rear Panel

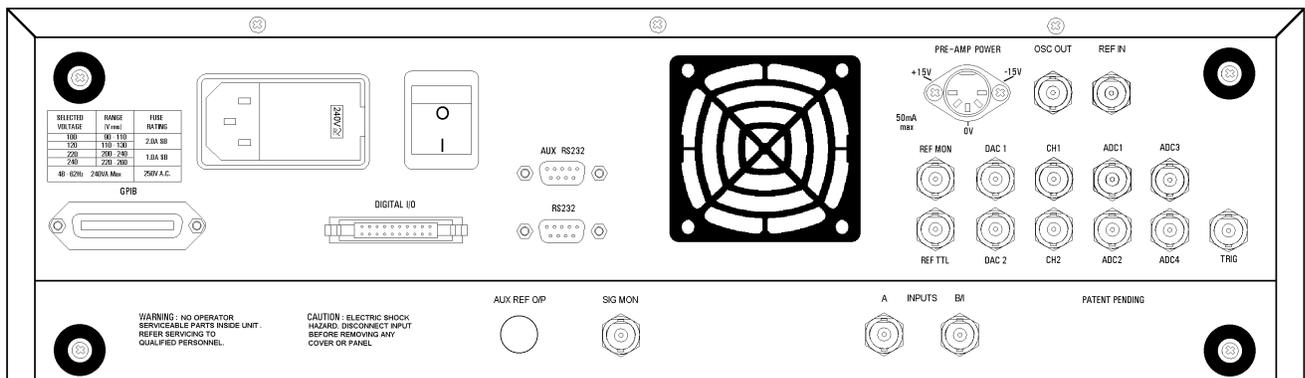


Figure 4-2, Model 7280BFP Rear Panel Layout

As shown in figure 4-2, the line power switch, line power voltage selector, two RS232 connectors, a GPIB (IEEE-488) connector, digital I/O port, preamplifier power connector and sixteen BNC signal connectors are mounted on the rear panel of the instrument. Brief descriptions of these are given in the following text.

#### 4.2.01 Line Power Switch

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

*connector. Please ensure that the line voltage selector is set to the correct line voltage before switching on.*

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

#### **4.2.02 Line Power Input Assembly**

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

#### **4.2.03 RS232 Connector**

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

#### **4.2.04 AUX RS232 Connector**

This connector is used to link other compatible **SIGNAL RECOVERY** equipment together in a "daisy-chain" configuration. Up to 16 instruments can be connected in this way. Each unit must be set to a unique address (see section 5.3.22). Pinouts for this connector are given in appendix B.

#### **4.2.05 GPIB Connector**

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

#### **4.2.06 DIGITAL I/O Connector**

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

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

#### **4.2.07 PRE-AMP POWER Connector**

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

### 4.2.08 OSC OUT Connector

This is the output connector for the internal oscillator and has a nominal impedance of  $50\ \Omega$

### 4.2.09 REF IN Connector

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

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

### 4.2.10 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.

### 4.2.11 REF TTL Connector

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

### 4.2.12 DAC 1 and DAC 2 Connectors

There are two digital-to-analog converter (DAC) output connectors. The output voltages at these connectors can be set by DAC command. The output range is  $\pm 10.000\ \text{V}$  and the resolution is  $1\ \text{mV}$ .

### 4.2.13 CH 1 and CH 2 Connectors

The signal at these connectors is an analog voltage corresponding to a selected output, such as X, Y, R,  $\theta$ , etc., as specified by the CH command. The full-scale output voltage range is  $\pm 2.500\ \text{V}$  although the outputs remain valid to  $\pm 7.500\ \text{V}$  to provide up to  $3 \times$  full-scale overload capability.

### 4.2.14 ADC 1, ADC 2, ADC 3 and ADC 4 Connectors

The input voltages at these connectors are digitized and can be read via the ADC command. The input voltages are sampled and held when the ADC is triggered, with several different trigger modes being available. These modes can be set by the TADC command. The input voltage range is  $\pm 10.000\ \text{V}$  and the resolution is  $1\ \text{mV}$ .

### 4.2.15 TRIG Connector

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

positive edge only.

#### **4.2.16 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.

## 5.1 Introduction

The model 7280BFP includes both RS232 and GPIB (IEEE-488) interface ports, designed to allow full control of the lock-in amplifier using the comprehensive command set (see section 5.4).

This chapter describes the capabilities of the instrument when operated remotely and discusses how this is done.

## 5.2 Capabilities

### 5.2.01 General

All instrument controls can be set remotely and the present setting of each control may be determined by the computer. All instrument may be read remotely.

In addition to the normal signal recovery functions of a lock-in amplifier, the instrument also provides the following features:-

### 5.2.02 Curve Storage

A 32,768 point memory is included in the instrument. This may be used as a single curve or split into a number of curves, each of which will record chosen instrument outputs when an acquisition is initiated. The memory is useful for overcoming speed limitations in the interfaces, allowing outputs to be recorded faster than would be possible by transferring them to the computer. It also finds use in experiments where data is recorded over a long period of time, since it frees the computer from the need to measure time intervals and send requests for output to the instrument. On completion of the acquisition, the stored curves are transferred to the computer for processing.

### 5.2.03 Burst Mode Acquisition

A special use of the curve storage memory is as a transient recorder, when the voltage at the ADC1 or ADC2 input is sampled and stored at rates up to 40 kHz. Again, stored curves are transferred to the computer for processing.

### 5.2.04 Internal Oscillator Amplitude and Frequency Sweep Generator

The instrument's internal oscillator may be swept in frequency and/or amplitude over a predefined range. Amplitude sweeps are always linear with time, but frequency sweeps may be of linear or logarithmic format. These facilities allow the instrument to function as a simple swept-frequency oscillator, or, in conjunction with the curve storage capability, allow frequency response curves to be recorded.

## 5.3 RS232 and GPIB Operation

### 5.3.01 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 monitor screen.

The simplest way to establish the terminal mode is to connect a standard terminal, or a terminal emulator, to the RS232 port. A terminal emulator is a computer which runs special-purpose software that makes it act as a terminal. In the default (power-up) state of the port, the lock-in amplifier sends a convenient prompt character when it is ready to receive a command, and echoes each character that is received.

Microsoft Windows 95/98 includes a program called HyperTerminal, usually to be found in the Accessories group, which can be used as a terminal emulator. Alternatively a simple terminal program with minimal facilities can be written in a few lines of BASIC code (see appendix C.1).

### 5.3.02 RS232 Interface - General Features

The RS232 interface in the model 7280BFP 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  $\pm 12$  V referred to Logic Ground, and the connection may be a standard RS232 cable in conjunction with a null modem or, alternatively, may be made up from low-cost general purpose cable. The pinout of the RS232 connectors are shown in appendix B and cable diagrams suitable for coupling the instrument to a computer are shown in appendix D.

The main advantages of the RS232 interface are:

- 1) It communicates via a serial port which is present as standard equipment on nearly all computers, using leads and connectors which are available from suppliers of computer accessories or can be constructed at minimal cost in the user's

workshop.

- 2) It requires no more software support than is normally supplied with the computer, for example Microsoft's GWBASIC, QBASIC or Windows HyperTerminal.

A single RS232 transmission consists of a start bit followed by 7 or 8 data bits, an optional parity bit, and 1 stop bit. The rate of data transfer depends on the number of bits per second sent over the interface, usually called the baud rate. In the model 7280BFP 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 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.***

### 5.3.03 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.

### 5.3.04 Choice of Number of Data Bits

The model 7280BFP 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.

### 5.3.05 Choice of Parity Check Option

Parity checks are not required at the baud rates available in the model 7280BFP, 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 7280BFP 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 7280BFP the combination set at the factory is even parity check, 7 data bits, and one stop bit (fixed) because these are the MS-DOS defaults.

### 5.3.06 Auxiliary RS232 Interface

The auxiliary RS232 interface allows up to sixteen model 7280BFPs 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. Before using this facility, the address of each lock-in amplifier must first be set by connecting it on its own via a null modem cable to a PC running Windows HyperTerminal or other terminal emulator program. Once communication is established with the lock-in, use the RSADDR command to set the RS232 address. This setting will be retained on power-down and only reset to the default value of 1 if the ADF 1 command is sent.

Regardless of the RS232 address actually set, at power-up the RS232 port of each lock-in amplifier is fully active. Since this means that all lock-in amplifiers that are connected 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 `\\`*

### 5.3.07 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 7280BFP the address is set using 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.

### 5.3.08 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 7280BFP on a byte-by-byte basis and are not connected in the model 7280BFP 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.

### 5.3.09 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 7280BFP there are three input termination options for GPIB communications, selected 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.

### 5.3.10 Command Format

The simple commands listed in section 5.4 have one of five forms:

- CMDNAME terminator
- CMDNAME n terminator
- CMDNAME [n] terminator
- CMDNAME [n<sub>1</sub> [n<sub>2</sub>]] terminator
- CMDNAME n<sub>1</sub> [n<sub>2</sub>] terminator

where CMDNAME is an alphanumeric string that defines the command, and n, n<sub>1</sub>, n<sub>2</sub> are parameters separated by spaces. When n is not enclosed in square brackets it must be supplied. [n] means that n is optional. [n<sub>1</sub> [n<sub>2</sub>]] means that n<sub>1</sub> is optional and if present may optionally be followed by n<sub>2</sub>. Upper-case and lower-case characters are equivalent. Terminator bytes are defined in section 5.3.09.

**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 5.3.11).

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

### 5.3.11 Delimiters

Most response transmissions consist of one or two numbers followed by a response terminator. Where the response of the lock-in amplifier consists of two numbers in succession, they are separated by a byte called a delimiter. This delimiter can be any printing ASCII character and is selected by the DD command.

### 5.3.12 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.

### 5.3.13 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 7280BFP, bits 0 and 7 signify "command complete" and "data available"

respectively. In GPIB communications, the use of these bits can lead to a useful simplification of the control program by allowing the use of a single subroutine which is the same for all commands, whether or not they send a response over the bus. The subroutine should carry out the following sequence of events:

- 1) Send the command
- 2) Perform repeated serial poll operations in a loop until bit 0 (command complete) is zero. This implies that the command has been received by the instrument and is being processed. However, it is possible that if the command were a write-only command and a slow computer were being used then the instrument may actually clear and then reset bit 0 (i.e. actually complete the command) before the first serial poll operation were executed. Hence the loop must include the provision to timeout under these conditions; a value of 10 ms should be satisfactory in most cases.
- 3) If bit 0 clears, perform repeated serial polls testing both bit 0 and bit 7 (data available) and, if bit 7 is asserted then perform a read operation. This cycle (i.e. test bit 0 (command complete) and test bit 7 (data available)) should then continue until the lock-in amplifier asserts bit 0 to indicate that the command-response sequence is complete, so that the instrument will then be ready for the next command.

This procedure, although apparently complex, deals successfully with compound commands and responses to the curve transfer commands.

In RS232 communications, comparatively rapid access to the status byte is provided by the prompt character which is sent by the lock-in amplifier at the same time as bit 0 becomes asserted in the status byte. This character is sent out by the lock-in amplifier after each command response (whether or not the response includes a transmission over the interface) to indicate that the response is finished and the instrument is ready for a new command. The prompt takes one of two forms. If the command contained an error, either in syntax or by a command parameter being out of range, or alternatively if an overload or reference unlock is present, 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

### 5.3.14 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 7280BFP 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. 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.

## 5.4 Command Descriptions

This section lists the commands in logical groups, so that, for example, all commands associated with setting controls which affect the signal channel are shown together. Appendix G gives the same list of commands but in alphabetical order.

### 5.4.01 Signal Channel

IMODE [n]            Current/Voltage mode input selector

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

- n    Input mode
- 0    Current mode off - voltage mode input enabled
- 1    Normal current mode enabled - connect signal to **B** input connector
- 2    Low noise current mode enabled - connect signal to **B** input connector
- 3    High bandwidth current mode enabled - connect signal to **B** input connector

If n = 0 then the input configuration is determined by the VMODE command.

If n > 0 then current mode is enabled irrespective of the VMODE setting.

VMODE [n]            Voltage input configuration

The value of n sets up the input configuration according to the following table:

- n    Input configuration
- 0    Both inputs grounded (test mode)
- 1    A input only
- 2    -B input only
- 3    A-B differential mode

Note that the IMODE command takes precedence over the VMODE command.

CP [n]                Input connector coupling mode control

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

- n    Coupling mode
- 0    Fast
- 1    Slow

FLOAT [n]            Input connector shield float/ground control

The value of n sets the input connector shield switch according to the following table:

- n    Selection
- 0    Ground
- 1    Float (connected to ground via a 1 k $\Omega$  resistor)

SEN [n]

SEN.                 Full-scale sensitivity control

The value of n sets the full-scale sensitivity according to the following table, depending on the setting of the IMODE control:

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

Floating point mode can only be used for reading the sensitivity, which is reported in volts or amps. For example, if IMODE = 0 and the sensitivity is 1 mV the command SEN would report 18 and the command SEN. would report +1.0E-03. If IMODE was changed to 1, SEN would still report 18 but SEN. would report +1.0E-09

AS Perform an Auto-Sensitivity operation

The instrument adjusts its full-scale sensitivity so that the magnitude output lies between 30% and 90% of full-scale.

ASM Perform an Auto-Measure operation

The instrument adjusts its full-scale sensitivity so that the magnitude output lies between 30% and 90% of full-scale, and then performs an auto-phase operation to maximize the X channel output and minimize the Y channel output.

ACGAIN [n] AC Gain control

Sets the gain of the signal channel amplifier according to the following table:-

n	AC Gain
0	0 dB
1	6 dB
2	14 dB
3	20 dB
4	26 dB
5	34 dB
6	40 dB
7	46 dB
8	54 dB
9	60 dB
10	66 dB

**AUTOMATIC [n]** AC Gain automatic control

The value of n sets the status of the AC Gain control according to the following table:

n	Status
0	AC Gain is under manual control using the ACGAIN command
1	Automatic AC Gain control is activated, with the gain being adjusted according to the full-scale sensitivity setting

**LF [n<sub>1</sub> n<sub>2</sub>]** Signal channel line frequency rejection filter control

The LF command sets the mode and frequency of the line frequency rejection (notch) filter according to the following tables:

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

n <sub>2</sub>	Notch Filter Center Frequencies
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

## 5.4.02 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 5.4.14

- 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 rear panel analog input)    |
- REFN [n]** Reference harmonic mode control  
The value of n sets the reference channel to one of the NF modes, or restores it to the default 1F mode. The value of n is in the range 1 to 32.
- REFP[.] [n]** Reference phase control  
In fixed point mode n sets the phase in millidegrees in the range  $\pm 360000$ .
- 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 |

### 5.4.03 Signal Channel Output Filters

- NOISEMODE [n]** Noise Measurement Mode control  
The value of n sets the noise measurement mode according to the following table:

- n Function
- 0 Noise measurement mode off
- 1 Noise measurement mode on.

When the noise measurement mode is turned on, the output filter time constant is automatically adjusted so that it lies in the range 500  $\mu$ s to 10 ms inclusive, the synchronous time constant control is turned off, and the output filter slope is set to 12 dB/octave if it had previously been 18 or 24 dB/octave.

NNBUF [n] Noise Buffer Length control

The value of n sets the noise buffer length according to the following table:

- n Function
- 0 Noise buffer off
- 1 1 second noise buffer
- 2 2 second noise buffer
- 3 3 second noise buffer
- 4 4 second noise buffer

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

When the fast analog output mode and Noise Measurement mode are turned off (FASTMODE 0 and NOISEMODE 0), the selection is according to the following table:

- n Slope
- 0 6 dB/octave
- 1 12 dB/octave
- 2 18 dB/octave (TC  $\geq$  500  $\mu$ s)
- 3 24 dB/octave (TC  $\geq$  500  $\mu$ s)

When:

- a) The fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, or
- b) Noise measurement mode is turned ON (NOISEMODE 1)

the selection is according to the following table:

- n Slope
- 0 6 dB/octave
- 1 12 dB/octave

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is according to the following table:

n Slope  
0 6 dB/octave

TC [n]

TC.

Filter time constant control

The value of n sets the output filter time constant in accordance with the following table:

n	FASTMODE = 0, NOISEMODE = 0 time constant	FASTMODE = 1, NOISEMODE = 0 time constant	FASTMODE = 0, NOISEMODE = 1 time constant	FASTMODE = 1, NOISEMODE = 1 time constant
0	N/A	1 $\mu$ s	N/A	N/A
1	N/A	2 $\mu$ s	N/A	N/A
2	N/A	5 $\mu$ s	N/A	N/A
3	N/A	10 $\mu$ s	N/A	N/A
4	N/A	20 $\mu$ s	N/A	N/A
5	N/A	50 $\mu$ s	N/A	N/A
6	N/A	100 $\mu$ s	N/A	N/A
7	N/A	200 $\mu$ s	N/A	N/A
8	500 $\mu$ s	500 $\mu$ s	500 $\mu$ s	500 $\mu$ s
9	1 ms	1 ms	1 ms	1 ms
10	2 ms	2 ms	2 ms	2 ms
11	5 ms	4 ms	5 ms	4 ms
12	10 ms	10 ms	10 ms	10 ms
13	20 ms	20 ms	N/A	N/A
14	50 ms	50 ms	N/A	N/A
15	100 ms	100 ms	N/A	N/A
16	200 ms	200 ms	N/A	N/A
17	500 ms	500 ms	N/A	N/A
18	1 s	1 s	N/A	N/A
19	2 s	2 s	N/A	N/A
20	5 s	5 s	N/A	N/A
21	10 s	10 s	N/A	N/A
22	20 s	20 s	N/A	N/A
23	50 s	50 s	N/A	N/A
24	100 s	100 s	N/A	N/A
25	200 s	200 s	N/A	N/A
26	500 s	500 s	N/A	N/A
27	1 ks	1 ks	N/A	N/A
28	2 ks	2 ks	N/A	N/A
28	5 ks	5 ks	N/A	N/A
30	10 ks	10 ks	N/A	N/A
31	20 ks	20 ks	N/A	N/A
32	50 ks	50 ks	N/A	N/A
33	100 ks	100 ks	N/A	N/A

N/A means that n is an illegal value under these conditions.

The TC. command is only used for reading the time constant, and reports the current setting in seconds. Hence if a TC 15 command were sent and the noise measurement

mode was turned off, TC would report 15 and TC. would report 1.0E-01, i.e. 0.1 s or 100 ms.

SYNC [n]                    Synchronous time constant control

At reference frequencies below 10 Hz, if the synchronous time constant is enabled, then the actual time constant of the output filters is not generally the selected value T but rather a value equal to an integer number of reference cycles. If T is greater than 1 cycle, the time constant is between T/2 and T. The parameter n has the following significance:

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

#### 5.4.04 Signal Channel Output Amplifiers

XOF [n<sub>1</sub> [n<sub>2</sub>]]            X channel output offset control

The value of n<sub>1</sub> sets the status of the X offset facility according to the following table:

- n<sub>1</sub>   Selection
- 0    Disables offset
- 1    Enables offset facility

The range of n<sub>2</sub> is ±30000 corresponding to ±300% full-scale.

YOF [n<sub>1</sub> [n<sub>2</sub>]]            Y channel output offset control

The value of n<sub>1</sub> sets the status of the Y offset facility according to the following table:

- n<sub>1</sub>   Selection
- 0    Disables offset facility
- 1    Enables offset facility

The range of n<sub>2</sub> 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 CH1 and CH2 outputs full-scale to ±1000% if X or Y selected. The value of n has the following significance:

- n    Expand mode
- 0    Off
- 1    Expand X
- 2    Expand Y
- 3    Expand X and Y

## FASTMODE [n] Analog Output Mode Control

The value of n sets the fast analog output mode control according to the following table:

n	Function
0	Fast mode off
1	Fast mode on

When the fast analog output mode is turned on, the available settings for the **CH1/CH2** analog output controls are restricted, and hence affect the allowable parameter range for CH1 and CH2 commands. It also restricts the available range of output filter slope settings, limits the full-scale sensitivity to a maximum of 100  $\mu$ V and restricts the range of AC Gain settings if the AC Gain Automatic control is turned off. The effect is that the instrument's dynamic reserve is limited to a maximum value of 15 dB.

When fast mode is turned off, the output filter time constant is restricted to values of 500  $\mu$ s and longer, but the other restrictions on output filter slope, sensitivity and AC gain are removed.

CH  $n_1$  [ $n_2$ ] Analog output control

Defines what outputs appear on the **CH1** and **CH2** connectors on the rear panel.

When the fast analog output mode is turned off (FASTMODE 0), the selection is according to the following table:

$n_2$	Signal
0	X % (2.5 V FS)
1	Y % (2.5 V FS)
2	Magnitude % (2.5 V FS)
3	Phase 1: +9 V = +180°, -9 V = -180°
4	Phase 2: +9 V = 360°, -9 V = 0°
5	Noise % (2.5 V FS)
6	Ratio: (10 × X%/ADC 1)
7	Log Ratio: $\log_{10}$ (10 × X%/ADC1)
8	Equation 1
9	Equation 2

Dual modes only:-

10	X2 % (2.5 V FS)
11	Y2 % (2.5 V FS)
12	Magnitude2 %FS
13	Phase2 1: +9 V = +180°, -9 V = -180°
14	Phase2 2: +9 V = 360°, -9 V = 0°

$n_1$  is compulsory and is either 1 for CH1 or 2 for CH2

**Note:**  $n_2 = 5$  is only permitted if the noise measurement mode is on (**NOISEMODE 1**) or if the present settings of output filter slope and time constant are within the permitted range and the synchronous time constant control is off.

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, the selection is according to the following tables:

**n<sub>1</sub> = 1 (i.e. CH1 output)**

n<sub>2</sub> Signal  
0 X % (2.5 V FS)

**n<sub>1</sub> 2 (i.e. CH2output)**

n<sub>2</sub> Signal  
1 Y % (2.5 V FS)  
2 Magnitude % (2.5 V FS)

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is fixed according to the following tables:

**n<sub>1</sub> = 1 (i.e. CH1 output)**

n<sub>2</sub> Signal  
0 X1 % (2.5 V FS)

**n<sub>1</sub> 2 (i.e. CH2output)**

n<sub>2</sub> Signal  
10 X2 % (2.5 V FS)

### 5.4.05 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  $\pm 30000$ , full-scale being  $\pm 10000$ .

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  $\pm 30000$ , full-scale being  $\pm 10000$ .

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  $+1.000E-4$  to  $+0.001E-15$  amps.

- PHA[.]**                      Signal phase  
In fixed point mode causes the lock-in amplifier to respond with the signal phase in centidegrees, in the range  $\pm 18000$ .
- 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  $1000 \times X / \text{ADC1}$  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  $X / \text{ADC1}$ .
- LR[.]**                      Log Ratio output  
In integer mode, the LR command reports a number equivalent to  $1000 \times \log(X / \text{ADC1})$  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  $\log(X / \text{ADC1})$ . 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 X channel output, expressed in volts/ $\sqrt{\text{Hz}}$  or amps/ $\sqrt{\text{Hz}}$  referred to the input. This measurement assumes that the X channel output is Gaussian with zero mean. (Section 3.3.16). The command is only available in floating point mode.
- ENBW[.]**                      Equivalent noise bandwidth  
In fixed point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in microhertz.
- In floating point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in hertz.
- NN[.]**                      Noise output  
In fixed point mode causes the lock-in amplifier to respond with the noise spectral density measured at the X channel output in volts or amps referred to the input and in the range 0 to 12000, where full-scale (100%) is 10000. In floating point mode causes the lock-in amplifier to respond in volts or amps.
- If the value in volts or amps is divided by the square root of the response to the ENBW. command then the result is the same as that returned by the NHZ. command.

DEFEQU [n<sub>1</sub> n<sub>2</sub> n<sub>3</sub> n<sub>4</sub> n<sub>5</sub> n<sub>6</sub>]      Define user equation

The DEF EQU command is used to define the user equations, which take the following form:

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

Parameter n<sub>1</sub> is used to specify the equation to be modified, and is either 1 for Equation 1 or 2 for Equation 2.

Parameter n<sub>3</sub> is used to set the addition/subtraction operator in the numerator according to the following table:-

n <sub>3</sub>	Operator
0	Subtraction
1	Addition

The parameters n<sub>2</sub>, n<sub>4</sub>, n<sub>5</sub> and n<sub>6</sub> specify the variables A, B, C and D respectively according to the following table:

n	Variable	Range
0	X or X1	±30000
1	Y or Y1	±30000
2	MAG or MAG1	0 to 30000
3	PHA or PHA1	±18000
4	ADC1	±10000
5	ADC2	±10000
6	ADC3	±10000
7	ADC4	±10000
8	C1	0 to 100000
9	C2	0 to 100000
10	0	zero
11	1	unity
12	FRQ	0 to 2000000000 (i.e. reference frequency in mHz)
13	OSC	0 to 2000000000 (i.e. oscillator frequency in mHz)

Dual modes only:-

14	X2	±30000
15	Y2	±30000
16	MAG2	0 to 30000
17	PHA2	±18000

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 DEF EQU command (see section 5.4.05). The possible range is ±2,147,483,647 (signed 32-bit integer).

?      Fast Data Transfer command

The ? command offers a method of reading a combination of instrument outputs which

are sampled at the same time, thereby ensuring that they are correlated.

The response to the ? command is the output(s), expressed in floating point mode, specified by the present setting of the Curve Buffer Define (CBD) command (see section 5.4.09) and separated by delimiter character(s) defined by the DD command. Hence for example, if CBD is set to 19, the response to the ? command will be:

```
<X output, in floating point mode><delimiter>
<Y output, in floating point mode><terminator>
```

### 5.4.06 Internal Oscillator

**OA[.] [n]**            Oscillator amplitude control  
In fixed point mode n sets the oscillator amplitude in millivolts. The range of n is 0 to 1000 representing 0 to 1 V rms.

In floating point mode n sets the amplitude in volts.

**ASTART[.] [n]**      Oscillator amplitude sweep start amplitude  
Sets the start amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

**ASTOP[.] [n]**        Oscillator amplitude sweep stop amplitude  
Sets the stop amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V  
In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

**ASTEPI[.] [n]**        Oscillator amplitude sweep step size  
Sets the amplitude step size for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

**OF[.] [n]**            Oscillator frequency control  
In fixed point mode n sets the oscillator frequency in mHz. The range of n is 0 to 2000,000,000 representing 0 to 2.000 MHz.

In floating point mode n sets the oscillator frequency in Hz. The range of n is 0 to 2.0E6

**FSTART[.] [n]**        Oscillator frequency sweep start frequency  
Sets the start frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz and in floating point mode n is in hertz.

**FSTOP[.] [n]**         Oscillator frequency sweep stop frequency  
Sets the stop frequency for a subsequent sweep of the internal oscillator frequency, in

the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz and in floating point mode n is in hertz.

**FSSTEP[.] [n<sub>1</sub> n<sub>2</sub>]** Oscillator frequency sweep step size and type  
The frequency may be swept either linearly or logarithmically, as specified by parameter n<sub>2</sub>. The step size is specified by parameter n<sub>1</sub>.

Log sweep n<sub>2</sub> = 0

In fixed point mode, n<sub>1</sub> is the step size in thousandths of a percent.

In floating point mode n<sub>1</sub> is in percent. The range of n<sub>1</sub> is 0 to 100.00%

Linear sweep n<sub>2</sub> = 1

In fixed point mode, n<sub>1</sub> is the step size in millihertz.

In floating point mode n<sub>1</sub> is in hertz. The range of n<sub>1</sub> is 0 to 10 kHz

Linear seek sweep n<sub>2</sub> = 2

In fixed point mode, n<sub>1</sub> is the step size in millihertz.

In floating point mode n<sub>1</sub> is in hertz. The range of n<sub>1</sub> is 0 to 10 kHz

The seek sweep mode automatically stops when the signal magnitude exceeds 50% of full scale. This mode is most commonly used when setting up the virtual reference mode.

**SRATE[.] [n]** Oscillator frequency and amplitude sweep step rate  
Sets the sweep rate in 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.

### 5.4.07 Auxiliary Outputs

DAC[.] n<sub>1</sub> [n<sub>2</sub>]      Auxiliary DAC output controls

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

The first parameter n<sub>1</sub>, which specifies the DAC, is compulsory and is either 1 or 2. The value of n<sub>2</sub> specifies the voltage to be output.

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

PORTDIR [n]      Digital port direction control

The value of n determines which of the eight lines on the digital port are configured as inputs and which as outputs, according to the following table:

n	status
0	All lines configured as inputs
1	D0 = output, D1 - D7 = inputs
2	D0 and D1 = outputs, D2 - D7 = inputs
3	D0 - D2 = outputs, D3 - D7 = inputs
4	D0 - D3 = outputs, D4 - D7 = inputs
5	D0 - D4 = outputs, D5 - D7 = inputs
6	D0 - D5 = outputs, D6 and D7 = inputs
7	D0 - D6 = outputs, D7 = input
8	All lines configured as outputs

BYTE [n]      Digital port output control

The value of n, in the range 0 to 255, determines the bits to be output on those lines of the rear panel digital port that are configured as outputs. Hence, for example, if PORTDIR = 8 and BYTE = 0, all outputs are low, and when BYTE = 255, all are high.

READBYTE      Read digital port input

The response to the READBYTE command is an integer between 0 and 255 representing the binary value of all eight lines of the rear panel digital port. Hence, for example, if PORTDIR = 0 and the response to READBYTE is 255, then all lines are high, and if the response to READBYTE is 0, then all lines are low. Note that because the command does not differentiate between whether a line is configured as an input or output, it can be used as a single command to determine the present status of all eight lines, both inputs and outputs, of the port.

### 5.4.08 Auxiliary Inputs

ADC[.] n      Read auxiliary analog-to-digital inputs

Reads the voltage appearing at the **ADC1** (n = 1), **ADC2** (n = 2), **ADC3** (n = 3) or **ADC4** (n = 3) inputs on the rear panel.

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

## TADC [n] Auxiliary ADC trigger mode control

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

n	Trigger mode
0	Asynchronous (5 ms intervals)
1	External ADC1 and ADC 2 (rear panel <b>TRIG</b> input)
2	Burst mode, 25 $\mu$ s/point, triggered by command (ADC1 only)
3	Burst mode, 56 $\mu$ s/point, triggered by command (ADC1 and ADC2)
4	Burst mode, variable rate, triggered by command (ADC1 only)
5	Burst mode, variable rate, triggered by command (ADC1 and ADC2)
6	Burst mode, 25 $\mu$ s/point, External trigger with < 1.25 ms trigger indeterminacy (rear panel <b>TRIG</b> input) (ADC1 only)
7	Burst mode, 56 $\mu$ s/point, External trigger < 1.25 ms trigger indeterminacy (rear panel <b>TRIG</b> input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel <b>TRIG</b> input) (ADC1 only)
9	Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel <b>TRIG</b> input) (ADC1 and ADC2)
10	Burst mode, 25 $\mu$ s/point, External trigger with < 25 $\mu$ s trigger indeterminacy (rear panel <b>TRIG</b> input) (ADC1 only)
11	Burst mode, 56 $\mu$ s/point, External trigger with < 25 $\mu$ s trigger indeterminacy(rear panel <b>TRIG</b> input) (ADC1 and ADC2)
12	Burst mode, variable rate, External trigger with < 25 $\mu$ s trigger indeterminacy(rear panel <b>TRIG</b> input) (ADC1 only)
13	Burst mode, variable rate, External trigger with < 25 $\mu$ s trigger indeterminacy(rear panel <b>TRIG</b> input) (ADC1 and ADC2)

In the burst modes, data is stored in the curve buffer. Use the LEN command to set the number of points required. Note that it may be necessary to enter CBD 256 before setting the length, if the curve buffer has previously been used for more than one data type. The data is read out from the buffer using DC[.] 8 for ADC1 and DC[.] 9 for ADC2. If the length is set to more than 16384 and a burst mode which stores both ADC1 and ADC2 is specified then the curve length will automatically be reduced to 16384 points. Note also that setting the TADC parameter to any value other than 0 or 1 affects the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 256
3	automatically set to 768
4	automatically set to 256
5	automatically set to 768
6	automatically set to 256
7	automatically set to 768
8	automatically set to 256
9	automatically set to 768
10	automatically set to 256
11	automatically set to 768

TADC parameter	Effect on CBD parameter
12	automatically set to 256
13	automatically set to 768

The maximum sampling rate depends on the number of ADC inputs used, and is either 25  $\mu$ s when sampling ADC1 only, or 56  $\mu$ s when sampling both ADC1 and ADC2. In the Variable Rate modes, the sampling speed is set by the BURSTTPP (burst time per point) command.

**NOTE: TADC modes 10 to 13 cause all other functions of the host microprocessor to be suspended, including responding to computer commands, until a trigger is received at the TRIG input. Hence they should only be used when the user is certain that such a trigger will occur.**

BURSTTPP [n] Sets the burst mode time per point rate for ADC1 and ADC2  
n sets the time per point for the Variable Rate burst modes in microseconds, as follows:-

When storing only to ADC1:

(i.e. TADC 2, TADC 4, TADC 6, TADC 8, TADC10 and TADC12)

$$25 \leq n \leq 5000$$

When storing to ADC1 and ADC 2:

(i.e. TADC 3, TADC 5, TADC 7, TADC 9, TADC11 and TADC13)

$$56 \leq n \leq 5000$$

### 5.4.09 Output Data Curve Buffer

CBD [n] Curve buffer define

Defines which data outputs are stored in the curve buffer when subsequent TD (take data), TDT (take data triggered) or TDC (take data continuously) commands are issued. Up to 17 (or 22 in dual reference and dual harmonic modes) curves, or outputs, may be acquired, as specified by the CBD parameter.

The CBD parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary word. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit is asserted, the corresponding output is selected for storage. When a bit is negated, the output is not stored. The bit function and range for each output are shown in the table below:

Bit	Decimal value	Output and range
0*	1	X Output ( $\pm 10000$ FS)
1*	2	Y Output ( $\pm 10000$ FS)
2*	4	Magnitude Output (0 to +10000 FS)
3*	8	Phase ( $\pm 18000 = \pm 180^\circ$ )
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

Bit	Decimal value	Output and range
5*	32	Noise (0 to +10000 FS)
6*	64	Ratio ( $\pm 10000$ FS)
7*	128	Log ratio (-3000 to +2000)
8*	256	ADC1 ( $\pm 10000 = \pm 10.0$ V)
9*	512	ADC2 ( $\pm 10000 = \pm 10.0$ V)
10*	1024	ADC3 ( $\pm 10000 = \pm 10.0$ V)
11*	2048	ADC4 ( $\pm 10000 = \pm 10.0$ V)
12*	4096	DAC1 ( $\pm 10000 = \pm 10.0$ V)
13*	8192	DAC2 ( $\pm 10000 = \pm 10.0$ V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency bits 0 to 15 (millihertz)
16	65536	Reference frequency bits 16 to 31 (millihertz)

Dual modes only:-

17	131072	X <sub>2</sub> Output ( $\pm 10000$ FS)
18	262144	Y <sub>2</sub> Output ( $\pm 10000$ FS)
19	524288	Magnitude <sub>2</sub> Output (0 to +10000 FS)
20	1048576	Phase <sub>2</sub> Output ( $\pm 18000 = \pm 180^\circ$ )
21	2097152	Sensitivity <sub>2</sub> setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

32768 points are available for data storage, shared equally between the specified curves. For example, if 16 outputs are stored then the maximum number of storage points would be 2048 (i.e. 32768/16). The only exception to this rule is that the Frequency curve (curves 15 and 16) occupies the equivalent of any two other curves. The LEN command sets the actual curve length, which cannot therefore be longer than 32768 divided by the number of curves selected. If more curves are requested than can be stored with the current buffer length, then the buffer length will be automatically reduced. Its actual length can of course be determined by sending the LEN command without a parameter.

The reason why bit 4 and, for dual reference modes, bit 21, which store both the sensitivity and the IMODE setting, are needed, is to allow the instrument to transfer the acquired curves to the computer in floating point mode. Without this information, the unit would not be able to determine the correct calibration to apply.

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

Since the reference frequency requires 32-bit wide data points, it occupies two curve positions. For ease of use, if bit 15 is selected for storage then bit 16 will be automatically selected as well, and vice-versa.

**NOTE:** *At least one of the curves selected for storage in the curve buffer must be chosen from those marked with an asterisk(\*) in the above table.*

LEN [n]                      Curve length control

The value of n sets the curve buffer length in effect for data acquisition. The maximum

permitted value depends on the number of curves requested using the CBD command, and a parameter error results if the value given is too large. For this reason, if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.

- NC                      New curve  
Initializes the curve storage memory and status variables. All record of previously taken curves is removed.
- STR [n]                Storage interval control  
Sets the time interval between successive points being acquired under the TD or TDC commands. n specifies the time interval in 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 1.25 ms/point (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.
- 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 or set of curves, each one consisting of the number of points specified by the LEN command parameter, is acquired for each trigger
  - 1    One data point or set of data points is acquired for each trigger. Hence in order to store a complete curve or set of curves, the number of triggers applied must equal the number of points specified by the LEN command parameter. Note that in this mode the maximum trigger rate is 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. Similarly, if the dual reference or harmonic modes are active then the SEN2 curve (bit 21 in CBD) must have been stored in order to perform a conversion from %FS to volts or amps for X2, Y2 and Magnitude2.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16, or 0 to 21 if a dual mode is active. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be

stored. The permitted values of n would therefore be 0 and 2, so that DC 0 would transfer the X channel output curve and DC 2 the Magnitude curve.

**NOTE:** *When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.*

The computer program's subroutine which reads the responses to the DC command needs to run a program loop that continues until all the data has been transferred.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DC command, perform repeated serial polls until bit 7 is set, indicating that the instrument has an output waiting to be read. Then perform repeated reads in a loop, waiting each time until bit 7 is set indicating that a new value is available. The loop should continue until bit 1 is set, indicating that the transfer is completed.

DCT n                      Dump acquired curve(s) to computer in tabular format

This command is similar to the DC command described above, but allows transfer of several curves at a time and only operates in fixed point mode. Stored curve(s) are transferred via the computer interface in decimal format.

In single reference mode, the DCT parameter is an integer between 1 and 131,071 being the decimal equivalent of a 17-bit binary number. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit in the number is asserted, the corresponding curve is selected for transfer. When a bit is negated, the curve is not transferred. The bit corresponding to each curve is shown in the table below:

Bit	Decimal value	Output and range
0	1	X Output ( $\pm 10000$ FS)
1	2	Y Output ( $\pm 10000$ FS)
2	4	Magnitude Output (0 to +10000 FS)
3	8	Phase ( $\pm 18000 = \pm 180^\circ$ )
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5	32	Noise (0 to +10000 FS)
6	64	Ratio ( $\pm 10000$ FS)
7	128	Log ratio (-3000 to +2000)
8	256	ADC1 ( $\pm 10000 = \pm 10.0$ V)
9	512	ADC2 ( $\pm 10000 = \pm 10.0$ V)
10	1024	ADC3 ( $\pm 10000 = \pm 10.0$ V)
11	2048	ADC4 ( $\pm 10000 = \pm 10.0$ V)
12	4096	DAC1 ( $\pm 10000 = \pm 10.0$ V)
13	8192	DAC2 ( $\pm 10000 = \pm 10.0$ V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency (millihertz)

Bit	Decimal value	Output and range
Dual modes only:-		
17	131072	X <sub>2</sub> Output ( $\pm 10000$ FS)
18	262144	Y <sub>2</sub> Output ( $\pm 10000$ FS)
19	524288	Magnitude <sub>2</sub> Output (0 to +10000 FS)
20	1048576	Phase <sub>2</sub> Output ( $\pm 18000 = \pm 180^\circ$ )
21	2097152	Sensitivity <sub>2</sub> setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

The values of the selected curves at the same sample point are transferred as a group in the order of the above table, separated by the chosen delimiter character and terminated with the selected terminator. This continues until all the points have been transferred.

**NOTE:** *When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.*

DCB n                      Dump acquired curves to computer in binary format

This command causes a stored curve to be dumped via the computer interface in binary format, using two bytes per point. All curves other than the lower 16-bits of the reference frequency curve (curve 15) use 16-bit 2's complement encoding, and all data points are sent with the MSB first. The number of data bytes sent is therefore equal to twice the current curve length. Each point is sent in fixed point mode, there being no floating point version of the command, and hence if floating point values are required the user may need to additionally store and read the Sensitivity curve and then perform the correction in their own software. In order to achieve the maximum transfer rate, no terminators are used within the transmission, although the response is terminated normally at the end.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16 in Single Reference Mode, and 0 to 21 in the dual modes. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DCB 0 would transfer the X channel output curve and DCB 2 the Magnitude curve.

Curves 15 and 16 store the reference frequency in millihertz. When using the DCB command (although not with the other curve transfer commands), both curves need to be transferred separately. They should then be converted to two arrays of integer values, allowing for the fact that the data points in curve 15 are unsigned 16-bit values, while those in curve 16 are signed 2's complement 16-bit values (although in practice they are never negative). Finally they should be assembled into a single curve using the following algorithm:

$$\text{Reference Frequency} = (65536 \times \text{value in Curve 16}) + (\text{value in Curve 15})$$

The computer program's subroutine which reads the responses to the DCB command

needs to be able to handle the potentially very large data blocks (64 k bytes in the case of one 32 k curve) that can be generated.

**NOTE:** *When using RS232 communications, the interface must be set to use 8 data bit transmission.*

### 5.4.10 Computer Interfaces (RS232 and GPIB)

RS [n<sub>1</sub> [n<sub>2</sub>]]      Set/read RS232 interface parameters

The value of n<sub>1</sub> sets the baud rate of the RS232 interface according to the following table:

n <sub>1</sub>	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<sub>2</sub> control the other RS232 parameters according to the following table:

bit number	bit negated	bit asserted
0	data + parity = 8 bits	data + parity = 9 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

RSADDR [n]      Set/read RS232 address

The value of n sets the RS232 address. This is relevant only when using more than one instrument connected via the RS232 “daisy-chain” method. Each instrument must be set to a unique address.

GP [n<sub>1</sub> [n<sub>2</sub>]]            Set/Read GPIB parameters  
n<sub>1</sub> sets the GPIB address in the range 0 to 31

n<sub>2</sub> 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 7280BFP 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 (> ±300 %FS)
Bit 2	CH2 output overload (> ±300 %FS)
Bit 3	Y channel output overload (> ±300 %FS)
Bit 4	X channel output overload (> ±300 %FS)
Bit 5	not used
Bit 6	input overload
Bit 7	reference unlock

**MSK [n]** Set/read service request mask byte  
The value of n sets the SRQ mask byte in the range 0 to 255

### 5.4.11 Instrument Identification

**ID** Identification  
Causes the lock-in amplifier to respond with the number 7280BFP.

**SERIAL** Serial Number  
Causes the lock-in amplifier to respond with its serial number. This number is needed to place an order for the 7280/99 or 7280/98 options at a time other than the initial purchase of the instrument.

**VER** Report firmware version  
Causes the lock-in amplifier to respond with the firmware version number.

### 5.4.12 Auto Default

**ADF n** Auto Default command  
This command will automatically set all the instrument controls and displays to the predefined states. The value of n is used to define what controls are affected, according to the following table:

n	effect
0	Complete reset to factory set default values (listed in appendix E), equivalent to using the front-panel Auto Default function. However, if this command is used when the interface parameters are at values other than their default settings, then communication will be lost.
1	Reset to factory set default values (listed in appendix E), with the exception of the RS232 and GPIB communications interface settings.

### 5.4.13 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 <sub>1</sub> [n <sub>2</sub> ]]	XOF1[n <sub>1</sub> [n <sub>2</sub> ]] XOF2[n <sub>1</sub> [n <sub>2</sub> ]]
XY[.]	XY1[.] XY2[.]
Y[.]	Y1[.] Y2[.]
YOF[n <sub>1</sub> [n <sub>2</sub> ]]	YOF1[n <sub>1</sub> [n <sub>2</sub> ]] YOF2[n <sub>1</sub> [n <sub>2</sub> ]]
AQN	AQN1 AQN2
AS	AS1 AS2
AXO	AXO1 AXO2

## 5.5 Programming Examples

### 5.5.01 Introduction

This section gives some examples of the commands that need to be sent to the lock-in amplifier for typical experimental situations.

### 5.5.02 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 REF IN input
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 k $\Omega$ to ground
LF 0	Turn off line frequency rejection filter
ASM	Auto-Measure (assumes reference frequency > 1 Hz)
TC 16	Set time constant to 200 ms, since previous ASM changed it

Then the outputs could be read as follows:

X.	Reads X channel output in volts
Y.	Reads Y channel output in volts
MAG.	Reads Magnitude in volts
PHA.	Reads Phase in degrees
FRQ.	Reads reference frequency in hertz

The controlling program would send a new output command each time a new reading were required. Note that when using an output filter slope of 12 dB/octave a good "rule of thumb" is to wait for a period of four time-constants after the input signal has changed before recording a new value. Hence in a scanning type experiment, the program should issue the commands to whatever equipment causes the input signal to the lock-in amplifier to change, wait for four time-constants, and then record the required output.

### 5.5.03 Frequency Response Measurement

In this example, the lock-in amplifier's internal oscillator output signal is fed via the filter stage under test back to the instrument's signal input. The oscillator frequency is stepped between a lower and an upper frequency and the signal magnitude and phase recorded. At sampling rates of up to a few points per second, there is no need to use the internal curve buffer or oscillator frequency sweep generator. The commands to achieve this would therefore be similar to the following sequence:

IE 0	Set reference mode to internal
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic

FLOAT 1	Float input connector shell using 1 k $\Omega$ to ground
LF 0	Turn off line frequency rejection filter
OA. 1.0	Set oscillator amplitude to 1.0 V rms
OF. 100.0	Set oscillator frequency to 100 Hz (starting frequency)
SEN 27	Set sensitivity to 1 V full-scale
TC 14	Set time constant to 50 ms
AQN	Auto-Phase

The frequency sweep would be performed and the outputs recorded by sending the following commands from a FOR...NEXT program loop:

OF. XX	Set oscillator frequency to new value XX hertz Software delay of 200 ms ( $4 \times 50$ 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.

#### 5.5.04 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 rear panel REF IN input
IMODE 1	Normal current input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 k $\Omega$ to ground
LF 0	Turn off line frequency rejection filter
SEN 18	Set sensitivity to 1 nA full-scale
TC 14	Set time constant to 50 ms
AQN	Auto-Phase

Now the curve storage needs to be set up:

NC	Clear and reset curve buffer
CBD 19	Stores X channel output, Y channel output and sensitivity (i.e. bits 0, 1 and 4)
LEN 1000	Number of points = 100 Hz $\times$ 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.

### 5.5.05 Transient Recorder

In this example, the signal recovery capabilities of the lock-in amplifier are not used, but the auxiliary inputs are. The voltage applied to the **ADC1** input on the rear panel is sampled and digitized at a rate of 40 kHz, with the values being stored to the curve buffer. Sampling is required to start on receipt of a trigger at the **TRIG IN** connector on the rear panel and must last for 500 ms.

The sequence of commands is therefore as follows:

NC	Clear and reset curve buffer
LEN 20000	500 ms recording time at 40 kHz = 20,000 points
TADC 6	Set ADC1 sampling to burst mode, fixed rate (25 $\mu$ s per point, or 40 kHz), external trigger, and arm trigger

As soon as a trigger occurs, the acquisition starts. Once it completes the acquired data may be transferred to the computer using:-

DC. 5	Transfers ADC1 values in floating point mode
-------	--

The input routine of the program must be prepared to read and store 20,000 responses to this command.

### 5.5.06 Frequency Response Measurement using Curve Storage and Frequency Sweep

In this example, a more sophisticated version of that given in section 5.5.03, the internal oscillator frequency sweep generator is used in conjunction with curve storage, allowing the acquisition of a frequency response without the need for the computer to perform the frequency setting function for each point.

As before, the lock-in amplifier's internal oscillator output signal is fed via the filter stage under test to the signal input. The oscillator frequency is stepped between a lower and an upper frequency and the signal magnitude and phase are recorded. The required sequence of commands is therefore as follows:-

IE 0	Set reference mode to internal
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 k $\Omega$ to ground

LF 0	Turn off line frequency rejection filter
OA. 1.0	Set oscillator amplitude to 1.0 V rms
OF. 100.0	Set initial oscillator frequency to 100 Hz so that AQN runs correctly
SEN 27	Set sensitivity to 1 V full-scale
TC 12	Set time constant to 10 ms
AQN	Auto-Phase

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 32796	Stores Magnitude, Phase, Sensitivity and Frequency (i.e. bits 2, 3, 4 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 15	Transfers Reference frequency

# Specifications

## Measurement Modes

<p><b>X In-phase</b>  <b>Y Quadrature</b>  <b>R Magnitude</b>  <b>θ Phase Angle</b>  <b>Noise</b></p>	<p>}   }   }</p>	<p>The unit can measure and report via the bus the value of any of these outputs</p>
<b>Harmonic</b>		$nF, n \geq 32$
<b>Dual Harmonic</b>		Simultaneously measures the signal at two different harmonics $F_1$ and $F_2$ of the reference frequency
<b>Standard Unit</b>		$F_1$ and $F_2 \leq 20$ kHz.
<b>With option -/99</b>		$F_1$ and $F_2 \leq 800$ kHz.
<b>With option -/98</b>		$F_1$ and $F_2 \leq 2.0$ MHz.
<b>Dual Reference</b>		Simultaneously measures the signal at two different reference frequencies, $F_1$ and $F_2$ where $F_1$ is the external and $F_2$ the internal reference.
<b>Standard Unit</b>		$F_1$ and $F_2 \leq 20$ kHz
<b>With option -/99</b>		$F_1$ and $F_2 \leq 800$ kHz.
<b>With option -/98</b>		$F_1$ and $F_2 \leq 2.0$ MHz.
<b>Virtual Reference</b>		Locks to and detects a signal without a reference ( $100 \text{ Hz} \leq F \leq 2.0 \text{ MHz}$ )
<b>Noise</b>		Measures noise in a given bandwidth centered at the reference frequency $F$

## Signal Channel

<b>Voltage Inputs</b>	
Modes	A only, -B only or Differential (A-B)
Full-scale Sensitivity	
$0.5 \text{ Hz} \leq F \leq 250 \text{ kHz}$	10 nV to 1 V in a 1-2-5 sequence
$250 \text{ kHz} \leq F \leq 2.0 \text{ MHz}$	100 nV to 1 V in a 1-2-5 sequence
Dynamic Reserve	> 100 dB
Impedance	100 MΩ // 25 pF
Maximum Safe Input	20 V pk-pk
Voltage Noise	5 nV/√Hz at 1 kHz
C.M.R.R.	> 100 dB at 1 kHz degrading by 6 dB/octave
Frequency Response	0.5 Hz to 2.0 MHz
Gain Accuracy	0.3% typ, 0.6% max.(full bandwidth)
Distortion	-90 dB THD (60 dB AC gain, 1 kHz)
Line Filter	attenuates 50, 60, 100, 120 Hz
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

**Current Input**

Mode	Low Noise, Normal or Wide Bandwidth
Full-scale Sensitivity	
Low Noise	10 fA to 10 nA in a 1-2-5 sequence
Normal	10 fA to 1 $\mu$ A in a 1-2-5 sequence
Wide Bandwidth	
F $\leq$ 250 kHz	10 fA to 100 $\mu$ A in a 1-2-5 sequence
F > 250 kHz	100 fA to 100 $\mu$ A in a 1-2-5 sequence
Dynamic Reserve	> 100 dB (with no signal filters)
Frequency Response	
Low Noise	-3 dB at 500 Hz
Normal	-3 dB at 50 kHz
Wide Bandwidth	-3 dB at 1 MHz
Impedance	
Low Noise	< 2.5 k $\Omega$ at 100 Hz
Normal	< 250 $\Omega$ at 1 kHz
Wide Bandwidth	< 25 $\Omega$ at 10 kHz
Noise	
Low Noise	13 fA/ $\sqrt{\text{Hz}}$ at 500 Hz
Normal	130 fA/ $\sqrt{\text{Hz}}$ at 1 kHz
Wide Bandwidth	1.3 pA/ $\sqrt{\text{Hz}}$ at 1 kHz
Gain Accuracy (midband)	$\leq$ 0.6% typ
Line Filter	attenuates 50, 60, 100, 120 Hz
Grounding	BNC shield can be grounded or floated via 1 k $\Omega$ to ground

**Reference Channel**

**TTL Input (REF TTL)**

Frequency Range	0.5 Hz to 2.0 MHz
-----------------	-------------------

**Analog Input (REF IN)**

Impedance	1 M $\Omega$ // 30 pF
Sinusoidal Input	
Level	1.0 V rms**
Frequency Range	0.5 Hz to 2.0 MHz
Squarewave Input	
Level	250 mV rms**
Frequency Range	2 Hz to 2 MHz

\*\*Note: Lower levels can be used with the analog input at the expense of increased phase errors.

**Phase**

Set Resolution	0.001 $^\circ$ increments
Noise at 100 ms TC, 12 dB/octave slope	
Internal Reference	$\leq$ 0.0001 $^\circ$ rms
External Reference	$\leq$ 0.01 $^\circ$ rms @ 1 kHz

Orthogonality	90° ±0.0001°
---------------	--------------

**Acquisition Time**

Internal Reference	instantaneous acquisition
External Reference	2 cycles + 50 ms

**Reference Frequency Meter Resolution**

	1 mHz
--	-------

**Demodulator and Output Processing****Output Zero Stability**

Digital Outputs	No zero drift on all settings
Displays	No zero drift on all settings
Analog Outputs	< 5 ppm/°C

**Harmonic Rejection**

	-90 dB
--	--------

**Output Filters**

X, Y and R outputs only:	
--------------------------	--

Time Constant	1 μs to 1 ms in a 1-2-5 sequence
Slope (roll-off)	6 and 12 dB/octave

All outputs	
-------------	--

Time Constant	2 ms to 100 ks in a 1-2-5 sequence
Slope	6, 12, 18 and 24 dB/octave

**Synchronous Filter Operation**

	Available for F < 20 Hz
--	-------------------------

**Offset**

	Auto and Manual on X and/or Y: ±300% FS
--	---

**Absolute Phase Measurement Accuracy**

	≤ 0.01°
--	---------

**Oscillator****Frequency**

Range	0.5 Hz to 2.0 MHz
Setting Resolution	1 mHz
Absolute Accuracy	25 ppm

**Distortion (THD)**

	-80 dB at 1 kHz and 100 mV rms
--	--------------------------------

**Amplitude (rms)**

Range	1 mV to 1 V
Setting Resolution	1 mV
Accuracy	±0.2%
Stability	50 ppm/°C

**Output**

Impedance	50 Ω
-----------	------

**Sweep**

Amplitude Sweep	
Output Range	0.000 to 1.000 V rms
Law	Linear
Step Rate	20 Hz maximum (50 ms/step)
Frequency	
Output Range	0.5 Hz to 2.0 MHz
Law	Linear or Logarithmic
Step Rate	20 Hz maximum (50 ms/step)

**Auxiliary Inputs**

**ADC 1, 2, 3 and 4**

Maximum Input	±10 V
Resolution	1 mV
Accuracy	±1 mV
Input Impedance	1 MΩ // 30 pF
Sample Rate	
ADC 1 only	40 kHz max.
ADC 1 and 2	17.8 kHz max.
Trigger Mode	Internal, External or burst
Trigger input	TTL compatible

**Outputs**

**CH1 CH2 Outputs**

Function	X, Y, R, $\theta$ , Noise, Ratio, Log Ratio and User Equations 1 & 2.
Amplitude	±2.5 V full-scale but capable of operating to ±300 % full-scale
Impedance	1 kΩ
Update Rate:	
X, Y or R	
TC ≤ 500 μs	7.5 MHz
1 ms ≤ TC ≤ 4 ms	7.5 MHz or 1 kHz
TC ≥ 5 ms	1 kHz
All other outputs	1 kHz

**Signal Monitor**

Amplitude	±1 V FS
Impedance	1 kΩ

**Auxiliary D/A Output 1 and 2**

Maximum Output	±10 V
Resolution	1 mV
Output Impedance	1 kΩ

**8-bit Digital Port**

Mode	0 to 8 lines can be configured as inputs, with the remainder being outputs.
Status	Each output line can be set high or low and each input line read to allow interaction with external equipment
Trigger Input	Extra line acts as extra trigger input

**Reference Output**

Waveform	0 to 3 V rectangular wave
Impedance	TTL-compatible

**Power - Low Voltage**

±15 V at 100 mA rear panel 5-pin 180° DIN connector for powering **SIGNAL RECOVERY** preamplifiers

**Data Storage****Data Buffer**

Size	32k × 16-bit data points, may be organized as 1×32k, 2×16k, 3×10.6k, 4×8k, etc.
Max Storage Rate	
From LIA	up to 1000 16-bit values per second
From ADC1	up to 40,000 16-bit values per second

**Interfaces**

RS232, IEEE-488. A second RS232 port is provided to allow "daisy-chain" connection and control of up to 16 units from a single RS232 computer port.

**General****Power Requirements**

Voltage	110/120/220/240 VAC
Frequency	50/60 Hz
Power	200 VA Max

**Dimensions**

Width	17¼" (435 mm)
Depth	19" (485 mm)
Height	
With feet	6" (150 mm)
Without feet	5¼" (130 mm)

**Weight**

25.4 lb. (11.5 kg)

*All specifications subject to change without notification*



## B.1 RS232 Connector Pinout

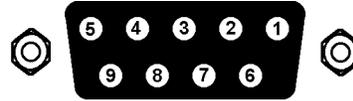


Figure B-1, RS232 and AUX RS232 Connector (Female)

Pin	Function	Description
2	RXD	Data In
3	TXD	Data Out
5	GND	Signal Ground
7	RTS	Request to Send - Always +12 V

All other pins are not connected

## B.2 Preamplifier Power Connector Pinout

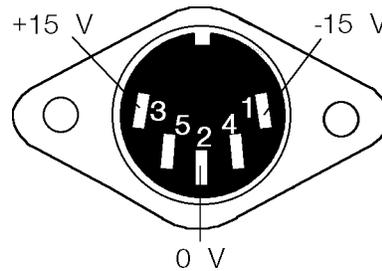


Figure B-2, Preamplifier Power Connector

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

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

## B.3 Digital I/O Port Connector

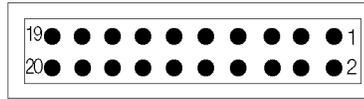


Figure B-3, Digital I/O Port Connector

8-bit TTL-compatible input/output port with each bit being configurable as an input or output. If configured as an output, the bit status can be set, and if configured as an input it can be read via the computer interfaces. Each output line can drive three LSTTL loads, and each input presents one LSTTL load. The connector will mate with a 20-pin IDC header plug (not supplied). The pinout is as follows:-

Pin	Function
1	Ground
2	Ground
3	D0
4	Ground
5	D1
6	Ground
7	D2
8	Ground
9	D3
10	Ground
11	D4
12	Ground
13	D5
14	Ground
15	D6
16	Ground
17	D7
18	Ground
19	TTL Trigger Input
20	+5 V

D0 = Least Significant Bit

D7 = Most Significant Bit

# Demonstration Programs

## C.1 Simple Terminal Emulator

This is a short terminal emulator with minimal facilities, which will run on a PC-compatible computer in a Microsoft GWBASIC or QuickBASIC environment, or can be compiled with a suitable compiler.

```
10 'MINITERM 9-Feb-96
20 CLS : PRINT "Lockin RS232 parameters must be set to 9600 baud, 7 DATA bits, 1 stop
   bit and even parity"
30 PRINT "Hit <ESC> key to exit"
40 OPEN "COM1:9600,E,7,1,CS,DS" FOR RANDOM AS #1
50 '.....
60 ON ERROR GOTO 180
70 '.....
100 WHILE (1)
110     B$ = INKEY$
120     IF B$ = CHR$(27) THEN CLOSE #1: ON ERROR GOTO 0: END
130     IF B$ <> "" THEN PRINT #1, B$;
140     LL% = LOC(1)
150     IF LL% > 0 THEN A$ = INPUT$(LL%, #1): PRINT A$;
160 WEND
170 '.....
180 PRINT "ERROR NO."; ERR: RESUME
```

## C.2 RS232 Control Program with Handshakes

RSCOM2.BAS is a user interface program which illustrates the principles of the echo handshake. The program will run on a PC-compatible computer either in a Microsoft GWBASIC or QuickBASIC environment, or in compiled form.

The subroutines in RSCOM2 are recommended for incorporation in the user's own programs.

```
10 'RSCOM2 9-Feb-96
20 CLS : PRINT "Lockin RS232 parameters must be set to 9600 baud, 7 data bits, 1 stop
   bit, even parity"
30 OPEN "COM1:9600,E,7,1,CS,DS" FOR RANDOM AS #1
40 CR$ = CHR$(13)           ' carriage return
50 '
60 '...main loop.....
70 WHILE 1                 ' infinite loop
80     INPUT "command (00 to exit) "; B$   ' no commas are allowed in B$
90     IF B$ = "00" THEN END
100    B$ = B$ + CR$       ' append a carriage return
110    GOSUB 180           ' output the command B$
```

Appendix C, DEMONSTRATION PROGRAMS

---

```

120     GOSUB 310: PRINT Z$;           ' read and display response
130     IF A$ = "?" THEN GOSUB 410: GOSUB 470 ' if "?" prompt fetch STATUS%
140                                           ' and display message
150 WEND                               ' return to start of loop
160 '
170 '
180 '...output the string B$.....
190 ON ERROR GOTO 510                   ' enable error trapping
200 IF LOC(1) > 0 THEN A$ = INPUT$(LOC(1), #1) ' clear input buffer
210 ON ERROR GOTO 0                     ' disable error trapping
220 FOR J1% = 1 TO LEN(B$)              ' LEN(B$) is number of bytes
230     C$ = MID$(B$, J1%, 1): PRINT #1, C$; ' send byte
240     WHILE LOC(1) = 0: WEND           ' wait for byte in input buffer
250     A$ = INPUT$(1, #1)               ' read input buffer
260     IF A$ <> C$ THEN PRINT "handshake error" ' input byte should be echo
270 NEXT J1%                             ' next byte to be sent or
280 RETURN                               ' return if no more bytes
290 '
300 '
310 '....read response.....
320 A$ = "": Z$ = ""
330 WHILE (A$ <> "*" AND A$ <> "?")     ' read until prompt received
340     Z$ = Z$ + A$                     ' append next byte to string
350     WHILE LOC(1) = 0: WEND           ' wait for byte in input buffer
360     A$ = INPUT$(1, #1)               ' read byte from buffer
370 WEND                                 ' next byte to be read
380 RETURN                               ' return if it is a prompt
390 '
400 '
410 '....fetch status byte.....
420 B$ = "ST" + CR$                      ' "ST" is the status command
430 GOSUB 180                             ' output the command
440 GOSUB 310                             ' read response into Z$
450 STATUS% = VAL(Z$)                     ' convert to integer
460 RETURN
470 '....instrument error message.....
480 PRINT "Error prompt, status byte = "; STATUS% ' bits are defined in manual
490 PRINT
500 RETURN
510 '....I/O error routine.....
520 RESUME

```

## C.3 GPIB User Interface Program

GPCOM.BAS is a user interface program which illustrates the principles of the use of the serial poll status byte to coordinate the command and data transfer.

The program runs under Microsoft GWBASIC or QuickBASIC on a PC-compatible computer fitted with a National Instruments IEEE-488 interface card and the GPIB.COM software installed in the CONFIG.SYS file. The program BIB.M, and the first three lines of GPCOM, are supplied by the card manufacturer and must be the correct version for the particular version of the interface card in use. The interface card may be set up, using the program IBCONF.EXE, to set EOI with the last byte of Write in which case no terminator is required. (Read operations are automatically terminated on EOI which is always sent by the lock-in amplifier). Normally, the options called 'high-speed timing', 'interrupt jumper setting', and 'DMA channel' should all be disabled.

The principles of using the Serial Poll Status Byte to control data transfer, as implemented in the main loop of GPCOM, are recommended for incorporation in the user's own programs.

```

10 'GPCOM 9-Feb-96
20 '....the following three lines and BIB.M are supplied by the.....
30 '....manufacturer of the GPIB card, must be correct version.....
40 CLEAR , 60000!: IBINIT1 = 60000!: IBINIT2 = IBINIT1 + 3: BLOAD "BIB.M", IBINIT1
50 CALL IBINIT1 (IBFIND, IBTRG, IBCLR, IBPCT, IBSIC, IBLOC, IBPPC, IBNA, 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 BDNAM$ = "GPIB0"
110 CALL IBFIND(BDNAM$, GPIB0%)
120 IF GPIB0% < 0 THEN PRINT "board assignment error": END
130 '....send INTERFACE CLEAR.....
140 CALL IBSIC(GPIB0%)
150 '....set bus address, assign access code to device.....
160 SUCCESS% = 0
170 WHILE SUCCESS% = 0
180     INPUT "BUS ADDRESS "; A%
190     DEVNAM$ = "DEV" + RIGHT$(STR$(A%), LEN(STR$(A%)) - 1)
200     CALL IBFIND(DEVNAM$, 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

## D.1 RS232 Cable Diagrams

Users who choose to use the RS232 interface to connect the model 7280BFP lock-in amplifier to a standard serial port on a computer will need to use one of two types of cable. The only difference between them is the number of pins used on the connector which goes to the computer. One has 9 pins and the other 25; both are null-modem (also called modem eliminator) cables in that some of the pins are cross-connected.

Users with reasonable practical skills can easily assemble the required cables from parts which are widely available through computer stores and electronics components suppliers. The required interconnections are given in figures D-1 and D-2.

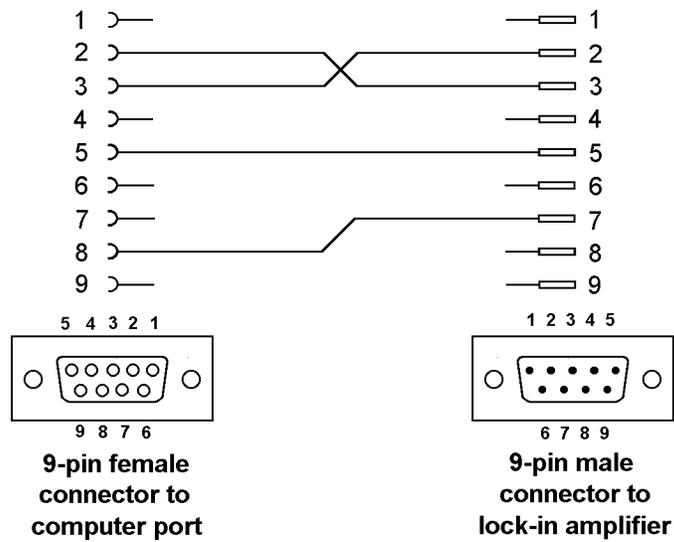


Figure D-1, Interconnecting RS232 Cable Wiring Diagram

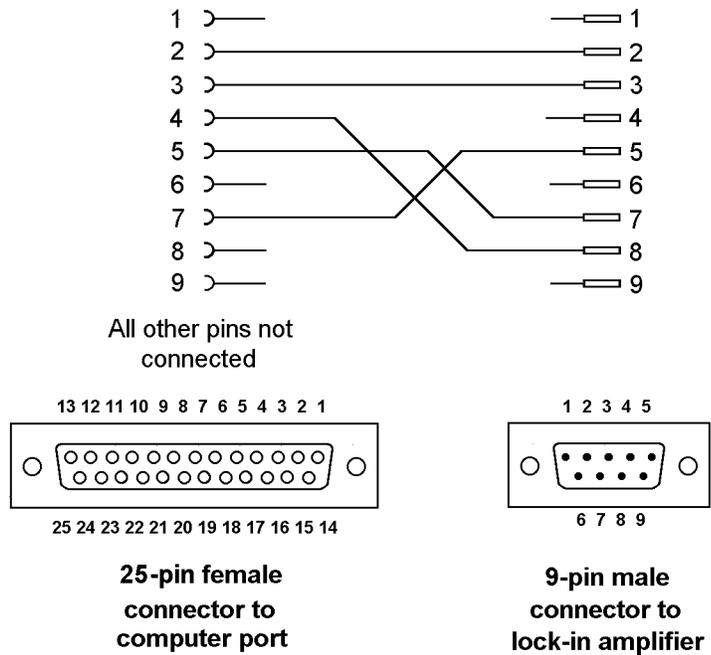


Figure D-2, Interconnecting RS232 Cable Wiring Diagram

# Default Settings

## Auto Default Function

The Auto-Default computer command ADF 1 sets the model 7280BFP's controls as follows:-

### Signal Channel

Input coupling	Ground
Input mode	Single-ended voltage mode
Input connector	A input connector
Line notch filter	Off
Automatic AC Gain	Off

### Reference Channel

Reference mode	Internal
Reference harmonic	1st

### Output Filters

Slope	12 dB/octave
Sync Time Constant	ON

### Output Offset & Expand

Offset Status	Off
Output Expand	Off

### Output Equations

Equation #1	$((X-X) \times X)/X = \text{zero}$
Equation #2	$((X-X) \times X)/X = \text{zero}$

### Oscillator Frequency Sweep

Start Frequency	0.000 Hz
Stop Frequency	0.000 Hz
Step Size	0.000 Hz
Time/Step	0.000 s
Armed	No
Law	Logarithmic

### Oscillator Amplitude Sweep

Start Amplitude	0.000 V
Stop Amplitude	0.000 V
Step Size	0.000 V
Time/Step	0.000 s
Armed	No

### Configuration

Operating mode	Single Reference
CH1 analog output	X% (2.5 V FS)
CH2 analog output	Y% (2.5 V FS)

## Appendix E, DEFAULT SETTINGS

---

Analog Outputs	Fast Mode
Noise Measurement Mode	OFF
Noise Buffer Length	4 seconds
<b>Curve Buffer</b>	
Time/Point	10 ms
Length	32,768
<b>Curve Select</b>	
Selected curve	X
<b>Auxiliary I/O</b>	
DAC1 and DAC2	0.000 V
ADC Trigger Mode	5 ms
<b>Digital Port</b>	
D0 to D7 direction	All configured as outputs
D0 to D7 status	Logic zero

The Auto-Default computer command ADF 0 sets the model 7280BFP's controls as above, and in addition sets the communications interface parameters as follows:-

### RS232 Settings

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

### GPIB Settings

GPIB Address	12
Terminator	[CR],[LF]
Test Echo	Off
SRQ mask byte	0
Delimiter	, (044)

# Alphabetical Listing of Commands

ACGAIN [n]      AC Gain control

Sets the gain of the signal channel amplifier according to the following table:-

n	AC Gain
0	0 dB
1	6 dB
2	14 dB
3	20 dB
4	26 dB
5	34 dB
6	40 dB
7	46 dB
8	54 dB
9	60 dB
10	66 dB

ADC[.] n      Read auxiliary analog-to-digital inputs

The response for ADC1 to ADC4 (n = 1 to 4 respectively) in fixed point mode is an integer in the range -12000 to +12000, corresponding to voltages from -12.000 V to +12.000 V, and in floating point mode it is in volts.

ADF n      Auto Default

The ADF command performs an auto-default operation according to the following table:

n	Significance
0	All instrument settings are returned to their factory default values
1	All instrument settings, with the exception of the communications settings, are returned to their factory default values

**NOTE: If the ADF 0 command is used when the communications settings are at values other than their default settings, then communication will be lost.**

AQN      Auto-Phase (auto quadrature null)

AS      Perform an Auto-Sensitivity operation

ASM      Perform an Auto-Measure operation

ASTART[.] [n]      Oscillator amplitude sweep start amplitude

Sets the start amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V

In fixed point mode, n is in millivolts rms, and in floating point mode n is in volts rms

- ASTEPP[.] [n]      Oscillator amplitude sweep step size  
Sets the amplitude step size for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V
- In fixed point mode, n is in millivolts rms and in floating point mode n is in volts rms
- ASTOP[.] [n]      Oscillator amplitude sweep stop amplitude  
Sets the stop amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 1.000 V
- In fixed point mode, n is in millivolts rms and in floating point mode n is in volts rms
- AUTOMATIC [n] AC Gain automatic control  
n    Status  
0    AC Gain is under manual control using the ACGAIN command  
1    Automatic AC Gain control is activated, with the gain being adjusted according to the full-scale sensitivity setting
- AXO                    Auto-Offset
- BURSTTPP [n]      Sets the burst mode time per point rate for ADC1 and ADC2  
n sets the time per point for the Variable Rate burst modes in microseconds, as follows:-
- When storing only to ADC1:  
(i.e. TADC 2, TADC 4, TADC 6, TADC 8, TADC10 and TADC12)
- $25 \leq n \leq 5000$
- When storing to ADC1 and ADC 2:  
(i.e. TADC 3, TADC 5, TADC 7, TADC 9, TADC11 and TADC13)
- $56 \leq n \leq 5000$
- BYTE [n]            Digital port output control  
The value of n, in the range 0 to 255, determines the bits to be output on those lines of the rear panel digital port that are configured as outputs. Hence, for example, if PORTDIR = 8 and BYTE = 0, all outputs are low, and when BYTE = 255, all are high.
- CBD [n]              Curve buffer define  
Defines which data outputs are stored in the curve buffer when subsequent TD (take data), TDT (take data triggered) or TDC (take data continuously) commands are issued. Up to 17 (or 22 in dual reference and dual harmonic modes) curves, or outputs, may be acquired, as specified by the CBD parameter.
- The CBD parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary word. In either of the dual reference modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit is asserted, the corresponding output is selected for storage. When a bit is

negated, the output is not stored. The bit function and range for each output are shown in the table below:

Bit	Decimal value	Output and range
0*	1	X Output ( $\pm 10000$ FS)
1*	2	Y Output ( $\pm 10000$ FS)
2*	4	Magnitude Output (0 to +10000 FS)
3*	8	Phase ( $\pm 18000 = \pm 180^\circ$ )
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5*	32	Noise (0 to +10000 FS)
6*	64	Ratio ( $\pm 10000$ FS)
7*	128	Log ratio (-3000 to +2000)
8*	256	ADC1 ( $\pm 10000 = \pm 10.0$ V)
9*	512	ADC2 ( $\pm 10000 = \pm 10.0$ V)
10*	1024	ADC3 ( $\pm 10000 = \pm 10.0$ V)
11*	2048	ADC4 ( $\pm 10000 = \pm 10.0$ V)
12*	4096	DAC1 ( $\pm 10000 = \pm 10.0$ V)
13*	8192	DAC2 ( $\pm 10000 = \pm 10.0$ V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency bits 0 to 15 (millihertz)
16	65536	Reference frequency bits 16 to 31 (millihertz)

Dual modes only:-

17	131072	X <sub>2</sub> Output ( $\pm 10000$ FS)
18	262144	Y <sub>2</sub> Output ( $\pm 10000$ FS)
19	524288	Magnitude <sub>2</sub> Output (0 to +10000 FS)
20	1048576	Phase <sub>2</sub> Output ( $\pm 18000 = \pm 180^\circ$ )
21	2097152	Sensitivity <sub>2</sub> setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

32768 points are available for data storage, shared equally between the specified curves. For example, if 16 outputs are stored then the maximum number of storage points would be 2048 (i.e. 32768/16). The only exception to this rule is that the Frequency curve (curves 15 and 16) occupies the equivalent of any two other curves. The LEN command sets the actual curve length, which cannot therefore be longer than 32768 divided by the number of curves selected. If more curves are requested than can be stored with the current buffer length, then the buffer length will be automatically reduced. Its actual length can of course be determined by sending the LEN command without a parameter.

The reason why bit 4 and, for dual reference modes, bit 21, which store both the sensitivity and the IMODE setting, are needed, is to allow the instrument to transfer the acquired curves to the computer in floating point mode. Without this information, the unit would not be able to determine the correct calibration to apply.

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

Since the reference frequency requires 32-bit wide data points, it occupies two curve

positions. For ease of use, if bit 15 is selected for storage then bit 16 will be automatically selected as well, and vice-versa.

**NOTE: At least one of the curves selected for storage in the curve buffer must be chosen from those marked with an asterisk(\*) in the above table.**

CH  $n_1$  [ $n_2$ ]            Analog output control  
 Defines what outputs appear on the **CH1** and **CH2** connectors on the rear panel.

When the fast analog output mode is turned off (FASTMODE 0), the selection is according to the following table:

- $n_2$     Signal
- 0    X % (2.5 V FS)
- 1    Y % (2.5 V FS)
- 2    Magnitude % (2.5 V FS)
- 3    Phase 1: +9 V = +180°, -9 V = -180°
- 4    Phase 2: +9 V = 360°, -9 V = 0°
- 5    Noise % (2.5 V FS)
- 6    Ratio: (10 × X%/ADC 1)
- 7    Log Ratio:  $\log_{10}$  (10 × X%/ADC1)
- 8    Equation 1
- 9    Equation 2

Dual modes only:-

- 10    X2 % (2.5 V FS)
- 11    Y2 % (2.5 V FS)
- 12    Magnitude2 %FS
- 13    Phase2 1: +9 V = +180°, -9 V = -180°
- 14    Phase2 2: +9 V = 360°, -9 V = 0°

$n_1$  is compulsory and is either 1 for CH1 or 2 for CH2

**Note:  $n_2 = 5$  is only permitted if the noise measurement mode is on (NOISEMODE 1) or if the present settings of output filter slope and time constant are within the permitted range and the synchronous time constant control is off.**

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, the selection is according to the following tables:

**$n_1 = 1$  (i.e. CH1 output)**

- $n_2$     Signal
- 0    X % (2.5 V FS)

**$n_1 = 2$  (i.e. CH2output)**

- $n_2$     Signal
- 1    Y % (2.5 V FS)
- 2    Magnitude % (2.5 V FS)

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is

in dual harmonic or dual reference mode, the selection is fixed according to the following tables:

**$n_1 = 1$  (i.e. CH1 output)**

$n_2$  Signal  
0 X1 % (2.5 V FS)

**$n_1 = 2$  (i.e. CH2output)**

$n_2$  Signal  
10 X2 % (2.5 V FS)

CP [n] Input connector coupling mode control

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

n Coupling mode  
0 Fast  
1 Slow

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

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

The value of  $n_2$  specifies the voltage to be output.

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

DC[.] n Dump acquired curves to computer

In fixed point mode, causes a stored curve to be dumped via the computer interface in decimal format.

In floating point mode the SEN curve (bit 4 in CBD) must have been stored if one or more of the following outputs are required in order that the lock-in amplifier can perform the necessary conversion from %FS to volts or amps:- X, Y, Magnitude, Noise. Similarly, if the dual reference or harmonic modes are active then the SEN2 curve (bit 21 in CBD) must have been stored in order to perform a conversion from %FS to volts or amps for X2, Y2 and Magnitude2.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16, or 0 to 21 if a dual mode is active. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DC 0 would transfer the X channel output curve and DC 2 the Magnitude curve.

***NOTE: When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.***

The computer program's subroutine which reads the responses to the DC command needs to run a program loop that continues until all the data has been transferred.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DC command, perform repeated serial polls until bit 7 is set, indicating that the instrument has an output waiting to be read. Then perform repeated reads in a loop, waiting each time until bit 7 is set indicating that a new value is available. The loop should continue until bit 1 is set, indicating that the transfer is completed.

DCB n                      Dump acquired curves to computer in binary format

This command causes a stored curve to be dumped via the computer interface in binary format, using two bytes per point. All curves other than the lower 16-bits of the reference frequency curve (curve 15) use 16-bit 2's complement encoding, and all data points are sent with the MSB first. The number of data bytes sent is therefore equal to twice the current curve length. Each point is sent in fixed point mode, there being no floating point version of the command, and hence if floating point values are required the user may need to additionally store and read the Sensitivity curve and then perform the correction in his own software. In order to achieve the maximum transfer rate, no terminators are used within the transmission, although the response is terminated normally at the end.

One curve at a time is transferred. The value of n is the bit number of the required curve, which must have been stored by the most recent CBD command. Hence n can range from 0 to 16 in Single Reference Mode, and 0 to 21 in the dual modes. If for example CBD 5 had been sent, equivalent to asserting bits 0 and 2, then the X and Magnitude outputs would be stored. The permitted values of n would therefore be 0 and 2, so that DCB 0 would transfer the X channel output curve and DCB 2 the Magnitude curve.

Curves 15 and 16 store the reference frequency in millihertz. When using the DCB command (although not with the other curve transfer commands), both curves need to be transferred separately. They should then be converted to two arrays of integer values, allowing for the fact that the data points in curve 15 are unsigned 16-bit values, while those in curve 16 are signed 2's complement 16-bit values (although in practice they are never negative). Finally they should be assembled into a single curve using the following algorithm:

$$\text{Reference Frequency} = (65536 \times \text{value in Curve 16}) + (\text{value in Curve 15})$$

The computer program's subroutine which reads the responses to the DCB command needs to be able to handle the potentially very large data blocks (64 k bytes in the case of one 32 k curve) that can be generated.

***NOTE: When using RS232 communications, the interface must be set to use 8 data bit transmission.***

DCT n                      Dump acquired curve(s) to computer in tabular format

This command is similar to the DC command described above, but allows transfer of several curves at a time and only operates in fixed point mode. Stored curve(s) are transferred via the computer interface in decimal format.

In single reference mode, the DCT parameter is an integer between 1 and 131,071, being the decimal equivalent of a 17-bit binary number. In either of the dual reference

modes, it is an integer between 1 and 4,194,303, being the decimal equivalent of a 22-bit binary number. When a given bit in the number is asserted, the corresponding curve is selected for transfer. When a bit is negated, the curve is not transferred. The bit corresponding to each curve is shown in the table below:

Bit	Decimal value	Output and range
0	1	X Output ( $\pm 10000$ FS)
1	2	Y Output ( $\pm 10000$ FS)
2	4	Magnitude Output (0 to +10000 FS)
3	8	Phase ( $\pm 18000 = \pm 180^\circ$ )
4	16	Sensitivity setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5	32	Noise (0 to +10000 FS)
6	64	Ratio ( $\pm 10000$ FS)
7	128	Log ratio (-3000 to +2000)
8	256	ADC1 ( $\pm 10000 = \pm 10.0$ V)
9	512	ADC2 ( $\pm 10000 = \pm 10.0$ V)
10	1024	ADC3 ( $\pm 10000 = \pm 10.0$ V)
11	2048	ADC4 ( $\pm 10000 = \pm 10.0$ V)
12	4096	DAC1 ( $\pm 10000 = \pm 10.0$ V)
13	8192	DAC2 ( $\pm 10000 = \pm 10.0$ V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency (millihertz)

Dual modes only:-

17	131072	X <sub>2</sub> Output ( $\pm 10000$ FS)
18	262144	Y <sub>2</sub> Output ( $\pm 10000$ FS)
19	524288	Magnitude <sub>2</sub> Output (0 to +10000 FS)
20	1048576	Phase <sub>2</sub> Output ( $\pm 18000 = \pm 180^\circ$ )
21	2097152	Sensitivity <sub>2</sub> setting (3 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)

The values of the selected curves at the same sample point are transferred as a group in the order of the above table, separated by the chosen delimiter character and terminated with the selected terminator. This continues until all the points have been transferred.

**NOTE:** When transferring the Frequency curve, which is saved when bit 15 in the CBD parameter is asserted, the instrument automatically reads the data for each stored point in both frequency curves (i.e. the lower and upper 16 bits) and sends it as a single data point.

DD [n] Define delimiter control

The value of n, which can be set to 13 or from 32 to 125, determines the ASCII value of the character sent by the lock-in amplifier to separate two numeric values in a two-value response, such as that generated by the MP (magnitude and phase) command.

DEFEQU [ $n_1 n_2 n_3 n_4 n_5 n_6$ ]      Define user equation

The DEF EQU command is used to define the user equations, which take the following form:

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

Parameter  $n_1$  is used to specify the equation to be modified, and is either 1 for Equation 1 or 2 for Equation 2.

Parameter  $n_3$  is used to set the addition/subtraction operator in the numerator according to the following table:-

$n_3$	Operator
0	Subtraction
1	Addition

The parameters  $n_2, n_4, n_5$  and  $n_6$  specify the variables A, B, C and D respectively according to the following table:

n	Variable	Range
0	X or X1	$\pm 30000$
1	Y or Y1	$\pm 30000$
2	MAG or MAG1	0 to 30000
3	PHA or PHA1	$\pm 18000$
4	ADC1	$\pm 10000$
5	ADC2	$\pm 10000$
6	ADC3	$\pm 10000$
7	ADC4	$\pm 10000$
8	C1	0 to 100000
9	C2	0 to 100000
10	0	zero
11	1	unity
12	FRQ	0 to 2000000000 (i.e. reference frequency in mHz)
13	OSC	0 to 2000000000 (i.e. oscillator frequency in mHz)

Dual modes only:-

14	X2	$\pm 30000$
15	Y2	$\pm 30000$
16	MAG2	0 to 30000
17	PHA2	$\pm 18000$

ENBW[.]      Equivalent noise bandwidth

In fixed point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in microhertz.

In floating point mode, reports the equivalent noise bandwidth of the output low-pass filters at the current time constant setting in hertz.

**EQU n**                      Output result of equation #1 or equation #2  
 The value returned is the output of the user equation #1 ( $n = 1$ ) or equation #2 ( $n = 2$ ), where the equations are defined using the DEFEQU command (see section 5.4.05). The possible range is  $\pm 2,147,483,647$  (signed 32-bit integer).

**EVENT [n]**                Event marker control  
 During a curve acquisition, if bit 13 in the CBD command has been asserted, the lock-in amplifier stores the value of the Event variable at each sample point. This can be used as a marker indicating the point at which an experimental parameter was changed. The EVENT command is used to set this variable to any value between 0 and 32767.

**EX [n]**                      Output expansion control

n	Expand mode
0	Off
1	Expand X
2	Expand Y
3	Expand X and Y

**FASTMODE [n]** Analog Output Mode Control  
 The value of n sets the fast analog output mode control according to the following table:

n	Function
0	Fast mode off
1	Fast mode on

When the fast analog output mode is turned on, the available settings for the **CH1/CH2** analog output controls are restricted, and hence affect the allowable parameter range for CH1 and CH2 commands. It also restricts the available range of output filter slope settings, limits the full-scale sensitivity to a maximum of 100  $\mu\text{V}$  and restricts the range of AC Gain settings if the AC Gain Automatic control is turned off. The effect is that the instrument's dynamic reserve is limited to a maximum value of 15 dB.

When fast mode is turned off, the output filter time constant is restricted to values of 500  $\mu\text{s}$  and longer, but the other restrictions on output filter slope, sensitivity and AC gain are removed.

**FLOAT [n]**                Input connector shield float/ground control

n	Selection
0	Ground
1	Float (connected to ground via a 1 k $\Omega$ resistor)

**FRQ[.]**                    Reference frequency meter  
 If the lock-in amplifier is in the external reference source modes, the FRQ command causes the lock-in amplifier to respond with 0 if the reference channel is unlocked, or with the reference input frequency if it is locked.

If the lock-in amplifier is in the internal reference source mode, it responds with the

frequency of the internal oscillator.

In fixed point mode the frequency is in mHz, and in floating point mode the frequency is in Hz.

**FSTART[.] [n]** Oscillator frequency sweep start frequency  
Sets the start frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz, and in floating point mode n is in hertz.

**FSTEP[.] [n<sub>1</sub> n<sub>2</sub>]** Oscillator frequency sweep step size and type  
The frequency may be swept either linearly or logarithmically, as specified by parameter n<sub>2</sub>. The step size is specified by parameter n<sub>1</sub>.

Log sweep n<sub>2</sub> = 0

In fixed point mode, n<sub>1</sub> is the step size in thousandths of a percent.

In floating point mode n<sub>1</sub> is in percent. The range of n<sub>1</sub> is 0 to 100.00%

Linear sweep n<sub>2</sub> = 1

In fixed point mode, n<sub>1</sub> is the step size in millihertz.

In floating point mode n<sub>1</sub> is in hertz. The range of n<sub>1</sub> is 0 to 10 kHz

Linear seek sweep n<sub>2</sub> = 2

In fixed point mode, n<sub>1</sub> is the step size in millihertz.

In floating point mode n<sub>1</sub> is in hertz. The range of n<sub>1</sub> is 0 to 10 kHz

The seek sweep mode automatically stops when the signal magnitude exceeds 50% of full scale. This mode is most commonly used when setting up the virtual reference mode.

**FSTOP[.] [n]** Oscillator frequency sweep stop frequency  
Sets the stop frequency for a subsequent sweep of the internal oscillator frequency, in the range 0 to 2.000 MHz.

In fixed point mode, n is in millihertz and in floating point mode n is in hertz.

**GP [n<sub>1</sub> [n<sub>2</sub>]]** Set/Read GPIB parameters  
n<sub>1</sub> sets the GPIB address in the range 0 to 31

n<sub>2</sub> 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 7280BFP.
- IE [n]                  Reference channel source control (Internal/External)
- n    Selection
- 0    INT (internal)
- 1    EXT LOGIC (external rear panel TTL input)
- 2    EXT (external rear panel analog input)
- IMODE [n]             Current/Voltage mode input selector
- n    Input mode
- 0    Current mode off - voltage mode input enabled
- 1    Normal current mode enabled - connect signal to **B** input connector
- 2    Low noise current mode enabled - connect signal to **B** input connector
- 3    High bandwidth current mode enabled - connect signal to **B** input connector
- If n = 0 then the input configuration is determined by the VMODE command.  
 If n > 0 then current mode is enabled irrespective of the VMODE setting.
- LEN [n]                Curve length control
- The value of n sets the curve buffer length in effect for data acquisition. The maximum allowed value depends on the number of curves requested using the CBD command, and a parameter error results if the value given is too large. For this reason, if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.
- LF [n<sub>1</sub> n<sub>2</sub>]            Signal channel line frequency rejection filter control
- The LF command sets the mode and frequency of the line frequency rejection (notch) filter according to the following tables:
- n<sub>1</sub>    Selection
- 0    Off
- 1    Enable 50 or 60 Hz notch filter
- 2    Enable 100 or 120 Hz notch filter
- 3    Enable both filters
- n<sub>2</sub>    Notch Filter Center Frequencies
- 0    60 Hz (and/or 120 Hz)
- 1    50 Hz (and/or 100 Hz)
- LOCK                    System lock control
- Updates all frequency-dependent gain and phase correction parameters.
- LR[.]                  Log Ratio output
- In integer mode, the LR command reports a number equivalent to  $1000 \times \log(X/ADC1)$  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

**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 7280BFP 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 RS232 address set by the RSADDR command the instrument will switch into addressed mode. If *n* does not match the RS232 address the instrument will switch into unaddressed mode. Note that the **\N n** command does not change the address of an instrument but which instrument is addressed.

**NOTE: All instruments must have a unique address.**

**N**                              Report overload byte  
 Causes the lock-in amplifier to respond with the overload byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

- Bit 0            not used
- Bit 1            CH1 output overload (> ±300 %FS)
- Bit 2            CH2 output overload (> ±300 %FS)
- Bit 3            Y channel output overload (> ±300 %FS)
- Bit 4            X channel output overload (> ±300 %FS)
- Bit 5            not used
- Bit 6            input overload
- Bit 7            reference unlock

**NC**                              New curve  
 Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

**NHZ.**  
 Causes the lock-in amplifier to respond with the square root of the noise spectral density measured at the X channel output, expressed in volts/√Hz or amps/√Hz referred to the input. This measurement assumes that the X channel output is Gaussian with zero mean. (Section 3.3.16). The command is only available in floating point mode.

**NN[.]**                      Noise output  
 In fixed point mode causes the lock-in amplifier to respond with the noise spectral density measured at the X channel output in volts or amps referred to the input and in the range 0 to 12000, where full-scale (100%) is 10000. In floating point mode causes the lock-in amplifier to respond in volts or amps.

If the value in volts or amps is divided by the square root of the response to the ENBW. command then the result is the same as that returned by the NHZ. command.

**NNBUF [n]**                Noise Buffer Length control  
 The value of *n* sets the noise buffer length according to the following table:

- n Function
- 0 Noise buffer off
- 1 1 second noise buffer
- 2 2 second noise buffer
- 3 3 second noise buffer
- 4 4 second noise buffer

NOISEMODE [n] Noise Measurement Mode control

The value of n sets the noise measurement mode according to the following table:

- n Function
- 0 Noise measurement mode off
- 1 Noise measurement mode on.

When the noise measurement mode is turned on, the output filter time constant is automatically adjusted so that it lies in the range 500  $\mu$ s to 10 ms inclusive, the synchronous time constant control is turned off, and the output filter slope is set to 12 dB/octave if it had previously been 18 or 24 dB/octave.

OA[.] [n] Oscillator amplitude control

In fixed point mode n sets the oscillator amplitude in mV. The range of n is 0 to 1000 representing 0 to 1 V rms.

In floating point mode n sets the amplitude in volts.

OF[.] [n] Oscillator frequency control

In fixed point mode n sets the oscillator frequency in mHz. The range of n is 0 to 2,000,000,000 representing 0 to 2.000 MHz.

In floating point mode n sets the oscillator frequency in Hz. The range of n is 0 to 2.0E6

PHA[.] Signal phase

In fixed point mode causes the lock-in amplifier to respond with the signal phase in centidegrees, in the range  $\pm 18000$ .

In floating point mode causes the lock-in amplifier to respond with the signal phase in degrees.

PORTDIR [n] Digital port direction control

The value of n determines which of the eight lines on the digital port are configured as inputs and which as outputs, according to the following table:

- n status
- 0 All lines configured as inputs
- 1 D0 = output, D1 - D7 = inputs
- 2 D0 and D1 = outputs, D2 - D7 = inputs
- 3 D0 - D2 = outputs, D3 - D7 = inputs
- 4 D0 - D3 = outputs, D4 - D7 = inputs
- 5 D0 - D4 = outputs, D5 - D7 = inputs

- n status
- 6 D0 - D5 = outputs, D6 and D7 = inputs
- 7 D0 - D6 = outputs, D7 = input
- 8 All lines configured as outputs

**READBYTE**      Read digital port input  
 The response to the READBYTE command is an integer between 0 and 255 representing the binary value of all eight lines of the rear panel digital port. Hence, for example, if PORTDIR = 0 and the response to READBYTE is 255, then all lines are high, and if the response to READBYTE is 0, then all lines are low. Note that because the command does not differentiate between whether a line is configured as an input or output, it can be used as a single command to determine the present status of all eight lines, both inputs and outputs, of the port.

**REFMODE [n]**    Reference mode selector  
 n Mode  
 0 Single Reference / Virtual Reference mode  
 1 Dual Harmonic mode  
 2 Dual Reference mode

***NOTE: When in either of the dual reference modes the command set changes to accommodate the additional controls. These changes are detailed in section 6.4.14***

**REFN [n]**            Reference harmonic mode control  
 The value of n sets the reference channel to one of the NF modes, or restores it to the default 1F mode. The value of n is in the range 1 to 32.

**REFP[.] [n]**        Reference phase control  
 In fixed point mode n sets the phase in millidegrees in the range  $\pm 360000$ .  
  
 In floating point mode n sets the phase in degrees.

**RS [n<sub>1</sub> [n<sub>2</sub>]]**      Set/read RS232 interface parameters  
 n<sub>1</sub> 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<sub>2</sub> control the other RS232 parameters according to the following table:

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bit number	bit negated	bit asserted
0	data + parity = 8 bits	data + parity = 9 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

RSADDR [n]      Set/read RS232 address

The value of n sets the RS232 address. This is relevant only when using more than one instrument connected via the RS232 “daisy-chain” method. Each instrument must be set to a unique address.

RT[.]              Ratio output

In integer mode the RT command reports a number equivalent to  $1000 \times X / \text{ADC1}$  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  $X / \text{ADC1}$ .

SEN [n]

SEN.              Full-scale sensitivity control

The value of n sets the full-scale sensitivity according to the following table, depending on the setting of the IMODE control:

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

n	full-scale sensitivity			
	IMODE=0	IMODE=1	IMODE=2	IMODE=3
25	200 mV	200 nA	2 nA	20 $\mu$ A
26	500 mV	500 nA	5 nA	50 $\mu$ A
27	1 V	1 $\mu$ A	10 nA	100 $\mu$ A

**SERIAL**                      Serial Number

Causes the lock-in amplifier to respond with its serial number. This number is needed to place an order for the 7280/99 or 7280/98 options at a time other than the initial purchase of the instrument.

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

When the fast analog output mode and Noise Measurement mode are turned off (FASTMODE 0 and NOISEMODE 0), the selection is according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave
2	18 dB/octave (TC $\geq$ 500 $\mu$ s)
3	24 dB/octave (TC $\geq$ 500 $\mu$ s)

When:

- a) The fast analog output mode is turned on (FASTMODE 1) and the instrument is in single or virtual reference mode, or
- b) Noise measurement mode is turned ON (NOISEMODE 1)

the selection is according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave

When the fast analog output mode is turned on (FASTMODE 1) and the instrument is in dual harmonic or dual reference mode, the selection is according to the following table:

n	Slope
0	6 dB/octave

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

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.**

? Fast Data Transfer command  
 The ? command offers a method of reading a combination of instrument outputs which are sampled at the same time, thereby ensuring that they are correlated.

The response to the ? command is the output(s), expressed in floating point mode, specified by the present setting of the Curve Buffer Define (CBD) command (see section 6.4.09) and separated by delimiter character(s) defined by the DD command. Hence for example, if CBD is set to 19, the response to the ? command will be:

<X output, in floating point mode><delimiter>  
 <Y output, in floating point mode><terminator>

STR [n] Storage interval control  
 Sets the time interval between successive points being acquired under the TD or TDC commands. n specifies the time interval in 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.

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

TADC [n] Auxiliary ADC trigger mode control  
 The value of n sets the trigger mode of two of the auxiliary ADC inputs according to the following table:

- n Trigger mode
- 0 Asynchronous (5 ms intervals)
- 1 External ADC1 and ADC 2 (rear panel **TRIG** input)
- 2 Burst mode, 25  $\mu$ s/point, triggered by command (ADC1 only)
- 3 Burst mode, 56  $\mu$ s/point, triggered by command (ADC1 and ADC2)
- 4 Burst mode, variable rate, triggered by command (ADC1 only)
- 5 Burst mode, variable rate, triggered by command (ADC1 and ADC2)
- 6 Burst mode, 25  $\mu$ s/point, External trigger with < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
- 7 Burst mode, 56  $\mu$ s/point, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 and ADC2)
- 8 Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
- 9 Burst mode, variable rate, External trigger < 1.25 ms trigger indeterminacy (rear panel **TRIG** input) (ADC1 and ADC2)
- 10 Burst mode, 25  $\mu$ s/point, External trigger with < 25  $\mu$ s trigger indeterminacy (rear panel **TRIG** input) (ADC1 only)
- 11 Burst mode, 56  $\mu$ s/point, External trigger with < 25  $\mu$ s trigger indeterminacy(rear panel **TRIG** input) (ADC1 and ADC2)
- 12 Burst mode, variable rate, External trigger with < 25  $\mu$ s trigger indeterminacy(rear panel **TRIG** input) (ADC1 only)
- 13 Burst mode, variable rate, External trigger with < 25  $\mu$ s trigger indeterminacy(rear panel **TRIG** input) (ADC1 and ADC2)

In the burst modes, data is stored in the curve buffer. Use the LEN command to set the number of points required. Note that it may be necessary to enter CBD 256 before setting the length, if the curve buffer has previously been used for more than one data type. The data is read out from the buffer using DC[.] 8 for ADC1 and DC[.] 9 for ADC2. If the length is set to more than 16384 and a burst mode which stores both ADC1 and ADC2 is specified then the curve length will automatically be reduced to 16384 points. Note also that setting the TADC parameter to any value other than 0 or 1 affects the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 256
3	automatically set to 768
4	automatically set to 256
5	automatically set to 768
6	automatically set to 256
7	automatically set to 768
8	automatically set to 256
9	automatically set to 768
10	automatically set to 256
11	automatically set to 768
12	automatically set to 256
13	automatically set to 768

The maximum sampling rate depends on the number of ADC inputs used, and is either

25  $\mu$ s when sampling ADC1 only, or 56  $\mu$ s when sampling both ADC1 and ADC2. In the Variable Rate modes, the sampling speed is set by the BURSTTPP (burst time per point) command.

**NOTE: TADC modes 10 to 13 cause all other functions of the host microprocessor to be suspended, including responding to computer commands, until a trigger is received at the TRIG input. Hence they should only be used when the user is certain that such a trigger will occur.**

TC [n]

TC.

Filter time constant control

The value of n sets the output filter time constant in accordance with the following table:

n	FASTMODE = 0, NOISEMODE = 0 time constant	FASTMODE = 1, NOISEMODE = 0 time constant	FASTMODE = 0, NOISEMODE = 1 time constant	FASTMODE = 1, NOISEMODE = 1 time constant
0	N/A	1 $\mu$ s	N/A	N/A
1	N/A	2 $\mu$ s	N/A	N/A
2	N/A	5 $\mu$ s	N/A	N/A
3	N/A	10 $\mu$ s	N/A	N/A
4	N/A	20 $\mu$ s	N/A	N/A
5	N/A	50 $\mu$ s	N/A	N/A
6	N/A	100 $\mu$ s	N/A	N/A
7	N/A	200 $\mu$ s	N/A	N/A
8	500 $\mu$ s	500 $\mu$ s	500 $\mu$ s	500 $\mu$ s
9	1 ms	1 ms	1 ms	1 ms
10	2 ms	2 ms	2 ms	2 ms
11	5 ms	4 ms	5 ms	4 ms
12	10 ms	10 ms	10 ms	10 ms
13	20 ms	20 ms	N/A	N/A
14	50 ms	50 ms	N/A	N/A
15	100 ms	100 ms	N/A	N/A
16	200 ms	200 ms	N/A	N/A
17	500 ms	500 ms	N/A	N/A
18	1 s	1 s	N/A	N/A
19	2 s	2 s	N/A	N/A
20	5 s	5 s	N/A	N/A
21	10 s	10 s	N/A	N/A
22	20 s	20 s	N/A	N/A
23	50 s	50 s	N/A	N/A
24	100 s	100 s	N/A	N/A
25	200 s	200 s	N/A	N/A
26	500 s	500 s	N/A	N/A
27	1 ks	1 ks	N/A	N/A
28	2 ks	2 ks	N/A	N/A
28	5 ks	5 ks	N/A	N/A
30	10 ks	10 ks	N/A	N/A
31	20 ks	20 ks	N/A	N/A
32	50 ks	50 ks	N/A	N/A
33	100 ks	100 ks	N/A	N/A

N/A means that n is an illegal value under these conditions.

The TC. command is only used for reading the time constant, and reports the current setting in seconds. Hence if a TC 15 command were sent and the noise measurement mode was turned off, TC would report 15 and TC. would report 1.0E-01, i.e. 0.1 s or 100 ms.

- 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 or set of curves, each one consisting of the number of points specified by the LEN command parameter, is acquired for each trigger  
1    One data point or set of data points is acquired for each trigger. Hence in order to store a complete curve or set of curves, the number of triggers applied must equal the number of points specified by the LEN command parameter. Note that in this mode the maximum trigger rate is 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.
- 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  $\pm 30000$ , full-scale being  $\pm 10000$ .
- In floating point mode causes the lock-in amplifier to respond with the X demodulator output in volts or amps.
- XOF [n<sub>1</sub> [n<sub>2</sub>]]        X channel output offset control

- $n_1$  Selection
- 0 Disables offset
- 1 Enables offset facility

The range of  $n_2$  is  $\pm 30000$  corresponding to  $\pm 300\%$  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  $\pm 30000$ , full-scale being  $\pm 10000$ .

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  $\pm 30000$  corresponding to  $\pm 300\%$  full-scale.

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# WARRANTY

**SIGNAL RECOVERY**, a part of AMETEK Advanced Measurement Technology, Inc, 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 AMETEK Advanced Measurement Technology, Inc.

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 AMETEK Advanced Measurement Technology, Inc. When products manufactured by others are included AMETEK Advanced Measurement Technology, Inc equipment, the original manufacturers Warranty is extended to AMETEK Advanced Measurement Technology, Inc customers. AMETEK Advanced Measurement Technology, Inc 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 AMETEK ADVANCED MEASUREMENT TECHNOLOGY, INC, INCLUDING, BUT NOT LIMITED TO, SPECIAL OR CONSEQUENTIAL DAMAGES. NO PERSON, FIRM OR CORPORATION IS AUTHORIZED TO ASSUME FOR AMETEK ADVANCED MEASUREMENT TECHNOLOGY, INC ANY ADDITIONAL OBLIGATION OR LIABILITY NOT EXPRESSLY PROVIDED FOR HEREIN EXCEPT IN WRITING DULY EXECUTED BY AN OFFICER OF AMETEK ADVANCED MEASUREMENT TECHNOLOGY, INC.

## SHOULD YOUR EQUIPMENT REQUIRE SERVICE

- A. Contact your local **SIGNAL RECOVERY** 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 unit or cable.
- 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:

### **SIGNAL RECOVERY** Service

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or

### **SIGNAL RECOVERY** Service

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