Model 7230

DSP Lock-in Amplifier

Instruction Manual

198004-D-MNL

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Firmware Version

The instructions in this manual apply to operation of a Model 7230 DSP Lock-in Amplifier that is fitted with **Version 2.20 or later** operating firmware. Users of instruments that are fitted with earlier firmware versions can update them to the current version free of charge by downloading an Update Pack from our website at **www.signalrecovery.com** The pack includes full instructions for use.

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General Safety Precautions

GENERAL SAFETY PRECAUTIONS

The equipment described in this manual has been designed in accordance with EN61010 "Safety requirements for electrical equipment for measurement, control, and laboratory use", and has been supplied in a safe condition. To avoid injury to an operator or service technician the safety precautions given below, and throughout the manual, must be strictly adhered to, whenever the equipment is operated, serviced, or repaired. For specific safety details, please refer to the relevant sections within the manual.

The equipment is intended solely for electronic measurement and should be used for no other purpose. ***SIGNAL RECOVERY*** accepts no responsibility for accidents or damage resulting from any failure to comply with these precautions.

Grounding

To minimize the hazard of electrical shock, it is essential that the equipment be connected to a protective ground through the AC supply cable. The continuity of the ground connection should be checked periodically.

AC Supply Voltage

Never operate the equipment from a line voltage or frequency in excess of that specified. Otherwise, the insulation of internal components may break down and cause excessive leakage currents.

Fuses

Before switching on the equipment check that the fuses accessible from the exterior of the equipment are of the correct rating. The rating of the AC line fuse must be in accordance with the voltage of the AC supply.

Should any fuse continually blow, do not insert a fuse of a higher rating. Switch the equipment off, clearly label it "unserviceable," and inform a service technician.

Explosive Atmospheres

This equipment must **NEVER BE OPERATED** in a potentially explosive atmosphere. The equipment is NOT designed for use in these conditions and could possibly cause an explosion.

Safety Symbols

For the guidance and protection of the user, the following safety symbols may appear on the equipment, together with details of the hazard where appropriate:

Symbol	*Meaning*
	General safety hazard. Refer to the operating manual for detailed instructions.
	Electrical safety hazard. This symbol may appear alongside the general safety hazard symbol, together with a voltage.

Notes and Cautions

For the guidance and protection of the user, Notes and Cautions appear throughout the manual. The significance of these are as follows:

NOTES highlight important information for the reader's special attention.

CAUTIONS guide the reader in avoiding damage to the equipment.

Avoid Unsafe Equipment

The equipment may be unsafe if any of the following statements apply:

- Equipment shows visible damage.
- Equipment has failed to perform an intended operation.
- Equipment has been stored in unfavorable conditions.
- Equipment has been subjected to severe physical stress.

If in any doubt as to the serviceability of the equipment, don't use it. Get it properly checked out by a qualified service technician.

Live Conductors

When the equipment is connected to its measurement inputs or supply, the opening of covers or removal of parts could expose live conductors. The equipment must be disconnected from all power and signal sources before it is opened for any adjustment, replacement, maintenance, or repair. Adjustments, maintenance, or repair must only be done by qualified personnel, who should refer to the relevant maintenance documentation.

Equipment Modification

To avoid introducing safety hazards, never install non-standard parts in the equipment, or make any unauthorized modification. To maintain safety, always return the equipment to a ***SIGNAL RECOVERY*** service provider for service and repair.

European WEEE Directive

This product is subject to Directive 2002/96/EC of the European Parliament and the Council of the European Union on waste electrical and electronic equipment (WEEE) and, in jurisdictions adopting that Directive, is marked as being put on the market after August 13, 2005, and should not be disposed of as unsorted municipal waste. Please use a local WEEE collection facilities for the disposal of this product and otherwise observe all applicable requirements.

FCC Notice

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with this instruction manual, may cause harmful interference with radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user is required to correct the interference at his own expense.

Acknowledgment

Operation of the Ethernet interface in the Model 7230 relies on software code developed by the Swedish Institute of Computer Science, copyright 2001-2004, all rights reserved. In accordance with the license under which it is used, we reproduce here the following disclaimer:

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DECLARATION OF CONFORMITY

The directives covered by this declaration

73/23/EEC Low Voltage Equipment Directive, amended by 93/68/EEC

89/336/EEC Electromagnetic Compatibility Directive, amended by 92/31/EEC & 93/68/EEC

Product(s)

Model 7230 DSP Lock-in Amplifier

Basis on which conformity is being declared

The product(s) identified above comply with the requirements of the EU directives by meeting the following standards:

BS EN61326-1:2006 Electrical equipment for measurement control and laboratory use - EMC requirements – Class A.

BS EN61010-1:2001 Safety requirements for electrical equipment for measurement, control, and laboratory use.

Accordingly, the CE mark has been applied to this product.



Signed

For and on behalf of ***SIGNAL RECOVERY***

Authority: **Business Element Manager**

CE

Date: **November 2010**

Introduction

Chapter 1

1.1 How to Use This Manual

This manual gives detailed instructions for setting up and operating the ***SIGNAL RECOVERY*** Model 7230 DSP Lock-in Amplifier. It is split into the following chapters:

Chapter 1 - Introduction
Provides an introduction to the manual, briefly describes the function of a lock-in amplifier and the types of measurements it may be used for and lists the major specifications of the Model 7230.

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

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

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

Chapter 5 - Web Control Panel Operation
Describes the capabilities of the instrument when operated via the built-in web control panels.

Chapter 6 - Computer Operation
This chapter provides detailed information on operating the instrument from a computer via the built-in interfaces. It includes information on how to establish communications, the functions available, the command syntax and a detailed command listing.

Appendix A
Gives the detailed specifications of the unit.

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

Appendix C
Shows the connection diagrams for suitable RS232 null-modem cables to couple the unit to a compatible computer.

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

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

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

1.2 What is a Lock-in Amplifier?

Since their invention back in the 1960's, lock-in amplifiers have been used whenever the need arises to measure the amplitude and/or phase of a signal of known frequency in the presence of noise. Unlike other AC measuring instruments, they have the ability to give accurate results even when the noise is much larger than the signal - in favorable conditions even up to a million times larger.

Early instruments used analog technology, with manual controls and switches, and with output readings being taken from large panel meters. Later, microprocessors were added to give more user-friendly operation, digital output displays, and to support computer control. More recently the analog phase sensitive detectors forming the heart of the instrument have been replaced by DSP (digital signal processing) designs, further improving performance.

The Model 7230 DSP lock-in amplifier uses the latest DSP technology for signal detection, and a powerful processor for easy user operation. The low-noise analog signal channel, with its choice of input mode and impedance, complements the digital technology, giving an instrument that will be of use in many fields of scientific research, such as optics, electrochemistry, materials science, fundamental physics and electrical engineering.

In these and other experiments it can function as a:

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

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

1.3 Key Specifications and Benefits

The ***SIGNAL RECOVERY*** Model 7230 represents a further significant advance in the application of DSP technology in the design of a lock-in amplifier.

Key specifications include:

- Frequency range:

Standard unit	0.001 Hz to 120.000 kHz
With 7230/99 option	0.001 Hz to 250.000 kHz

- Voltage sensitivity: 10 nV to 1 V full-scale
- Current input mode sensitivities: 10 fA to 1 μA full-scale
  10 fA to 10 nA full-scale
- Line frequency rejection filter
- Dual phase demodulator with X-Y and R-θ outputs
- Very low phase noise of < 0.0001˚ rms
- Output time constant: 10 μs to 100 ks
- 5-digit output readings
- Dual reference mode - allows simultaneous measurement of two signals at different reference frequencies
- Single and dual harmonic mode - allows simultaneous measurement of up to two different

harmonics of a signal

- Tandem demodulation capability - suitable for double demodulation experiments that would otherwise require two lock-in amplifiers
- Virtual reference mode - allows reference free measurements
- Direct Digital Synthesizer (DDS) oscillator with variable amplitude and frequency
- Oscillator frequency and amplitude sweep generator
- Voltage controlled oscillator frequency or amplitude
- 8-bit programmable digital I/O port for external system control
- Four configurable DAC outputs which can be used as analog signal outputs and/or as auxiliary DAC outputs
- Four auxiliary ADC inputs
- Full range of auto functions
- Standard USB, Ethernet, and RS232 interfaces
- 100,000-point internal curve storage buffer

Installation and Initial Checks

Chapter 2

2.1 Installation

2.1.01 Introduction

Installation of the Model 7230 is very straightforward. The instrument can be operated on almost any laboratory bench or be rack mounted 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 Model 7230 does not use forced-air ventilation; however, it should be located so that there is reasonable flow of air around it to aid cooling.

2.1.02 Rack Mounting

An optional accessory kit, part number K02006, is available from ***SIGNAL RECOVERY*** to allow the Model 7230 to be mounted in a standard 19-inch rack.

2.1.03 Inspection

Upon receipt the Model 7230 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

The Model 7230 is powered from the Model PS0110 remote power module that in turn is fitted with a standard IEC 320 input socket. A suitable line power cord is supplied.

2.1.05 Line Voltage Selection

The Model PS0110 is suitable for line voltages in the range 100 - 240 V AC, 47 - 63 Hz, and no adjustment is needed to accommodate this range. It is internally protected against short circuit and overload and in the event of failure cannot be repaired and must be replaced.

2.2 Initial Checks

2.2.01 Introduction

The following procedure checks the performance of the Model 7230. 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.

The procedure requires the use of a computer with an Ethernet 10 or 100 Base T adaptor with RJ45 connector set to support TCP/IP protocol with an installed web browser. As an example, a Windows 7 PC with Internet Explorer 11 is suitable, but so are many other computer systems.

2.2.02 Procedure

1) Check that the rear panel **Config 1** and **Config 2** switches are set to 0. This will set the Model 7230 to use the default static IP address of 169.254.150.230.

2) Close all open programs on the computer and unplug any existing network connection. Disable any wireless connection as well.

3) Plug one end of the supplied RJ45 patch cord into the computer and the other end into the **LAN** connector on the rear panel of the Model 7230.

4) With the rear-panel mounted power switch set to **0** (off), plug the line cord into the Model PS0110 power supply unit and the 5-pin DIN plug on the power cable from the PS0110 to the 7230's rear panel **POWER INPUT** connector.

5) Turn on the Model 7230. The front panel status light should be green.

6) Open a browser session on the computer. Since there is no connection to the internet the normal opening page will not be seen, but an error message. If using Internet Explorer on Windows 10 the message will be as shown in Figure 2-1; other browsers will generate similar messages.

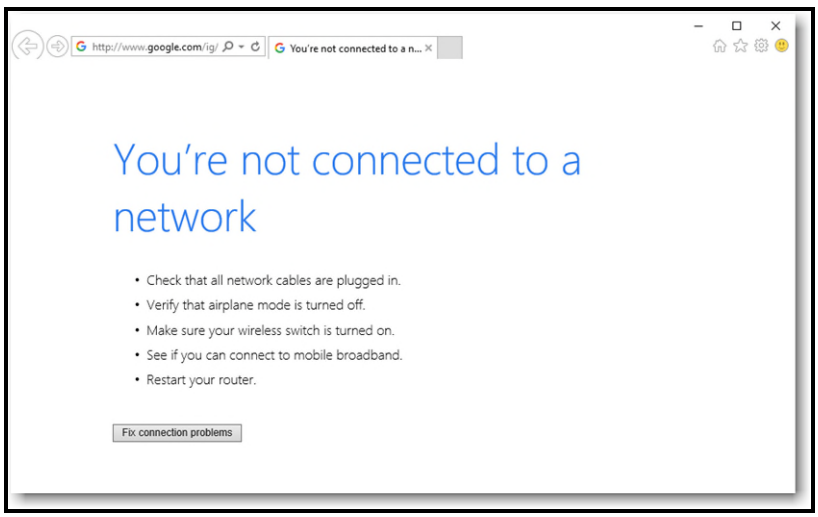


Figure 2-1. Initial Browser Window

7) Type 169.254.150.230 into the address bar and press <return>. The 7230's Main Controls panel should be displayed, as shown below in Figure 2-2.

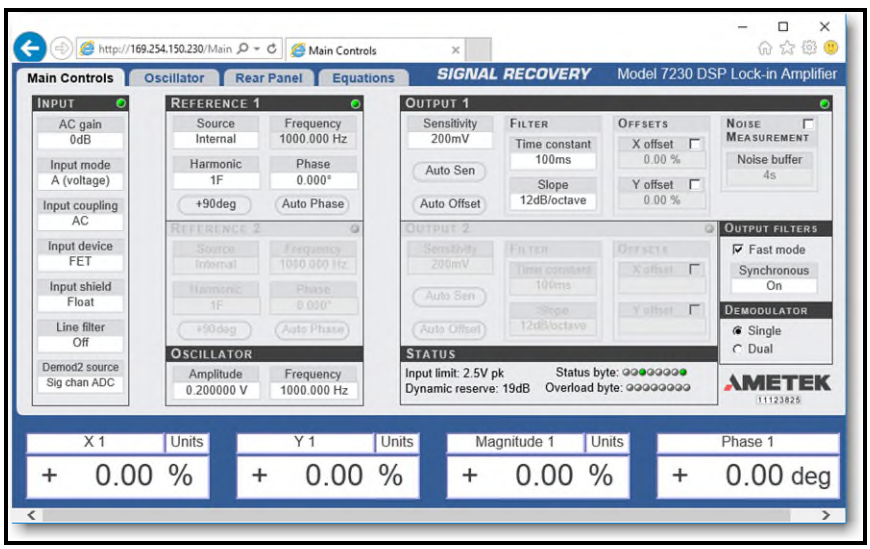


Figure 2-2. Model 7230 Main Controls Panel

8) Click the Equations tab, to show the Equations panel, as shown below in Figure 2-3.

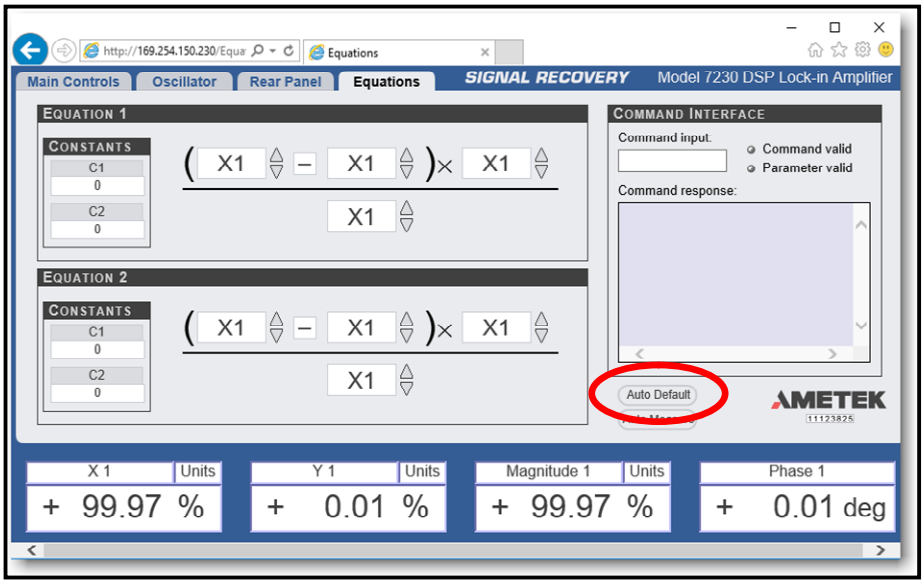


Figure 2-3. Model 7230 Equations Panel

9) Click the Auto Default button. This will set all instrument controls to the factory default values.

10) Connect a BNC cable from the front panel **OSC OUT** to the **A** input connector on the front panel. The X1 and Magnitude outputs should read 100 ± 1%, and the Y1 and Phase 1 outputs should read close to zero, as shown in Figure 2-4 below.

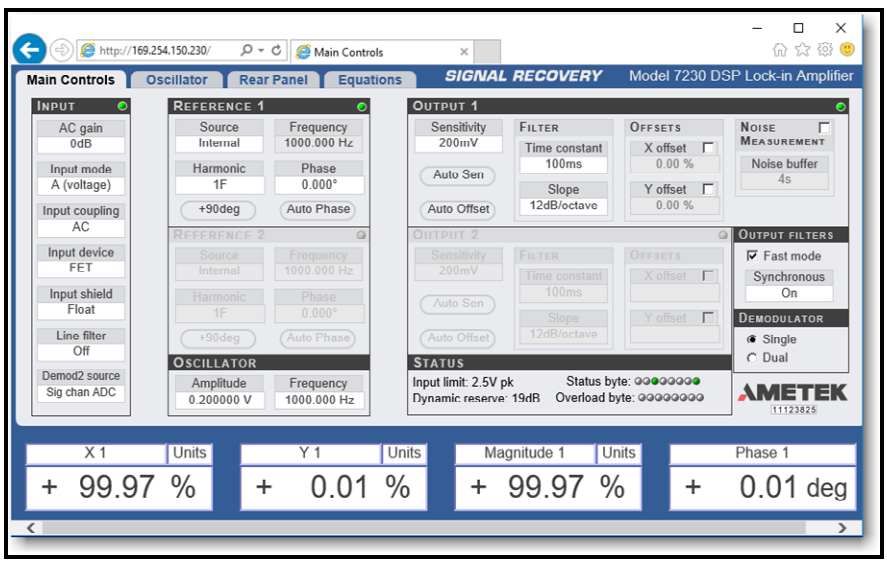


Figure 2-4. Model 7230 Main Controls Panel – Default Settings

11) Save the address as a favorite, bookmark, or shortcut (Figure 2-5) so that the Model 7230 can be quickly reached again if repeating the test, as in Figure 2-6.

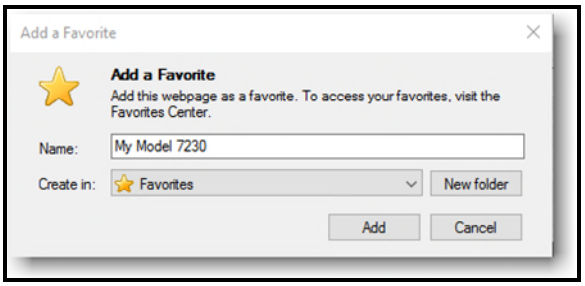


Figure 2-5. Saving the Model 7230's IP Address as a Favorite

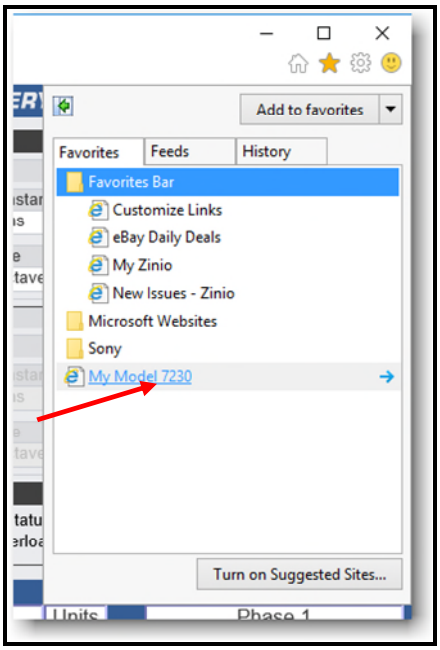


Figure 2-6. Accessing the Favorite

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

Technical Description

Chapter 3

3.1 Introduction

The Model 7230 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 7230 incorporates a number of different operating modes which are referred to in the following technical descriptions, 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 7230 this is referred to as the single reference mode.

The dual reference mode incorporated in the Model 7230 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, most notably that both signals be passed through the same input signal channel, which implies either that both signals are derived from the same detector (for example two chopped light beams falling onto a single photodiode) or that they can be summed prior to measurement, either externally or by using the differential input mode of the instrument. Nevertheless, the mode will prove invaluable in many experiments. Note that the restriction that that one reference frequency be from the internal oscillator and one from an external source which used to apply is removed for instruments with the latest firmware, allowing dual reference mode operation with two external reference signals. However, in this case one of the references is limited to a maximum of 3.0 kHz.

3.2.03 Tandem Demodulation

A further development of the dual reference mode is Tandem Demodulation. In this mode, the input to the second set of demodulators is taken not from the main ADC as is the case with normal dual reference mode, but from the filtered X-channel output of the first set of demodulators. Hence, for example, the mode can be used to measure the modulation amplitude of an amplitude-modulated “carrier” frequency. The first set of demodulators operates at the carrier frequency. If the output time constant of this first stage is short enough, then the X output will represent a signal at the modulation frequency. The second set of demodulators, this time operating at the modulation frequency, then measure the amplitude and/or phase of this modulation.

3.2.04 Single Harmonic/Dual Harmonic

Normally, a lock-in amplifier measures the applied signal at the reference frequency. However, in some applications such as Auger Spectroscopy and amplifier characterization, it is useful to be able to make measurements at some multiple *n*, or harmonic, of the reference frequency, *f*. The Model 7230 allows this multiple to be set to any value between 2 (i.e. the second harmonic) and 127, as well as unity, which is the normal mode. The only restriction is that the product $n \times f$ cannot exceed the upper frequency limit of the instrument, normally 120 kHz, but 250 kHz in instruments fitted with the 7230/99 option.

Dual harmonic mode allows the simultaneous measurement of two different harmonics of the input signal.

3.2.05 Internal/External Reference Mode

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

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

3.2.06 Virtual Reference Mode

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

In the virtual reference mode, 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 7230 is a very compact instrument that 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 unit is shown in Figure 3-1, and the sections that follow describe how each functional block operates and the effect it has on the instrument's performance.

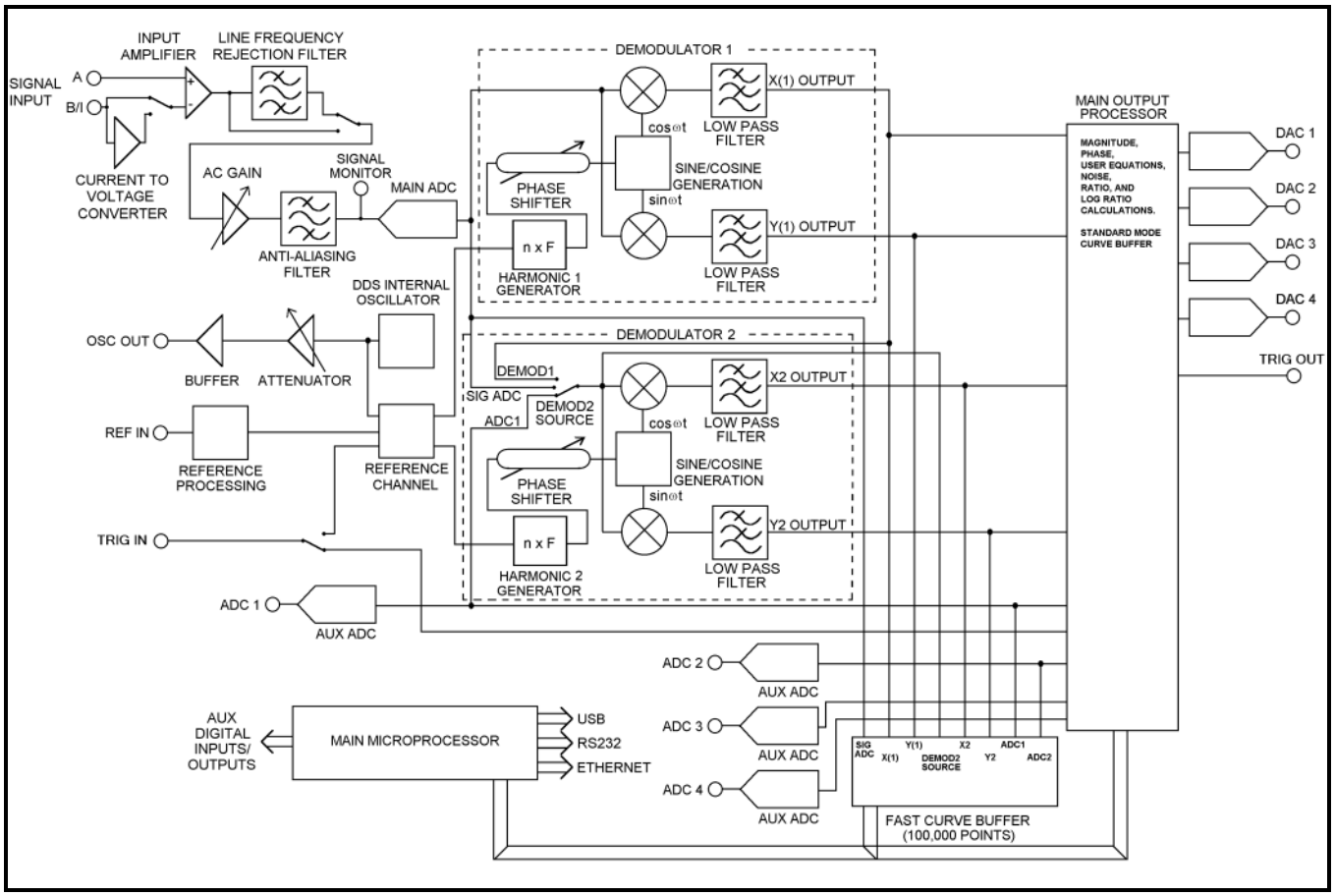


Figure 3-1. Model 7230 - Block Diagram

3.3.02 Signal Channel Inputs

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

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

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

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

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

The input can also be set to the **–**B mode, in which case the lock-in amplifier measures the voltage

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

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

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

The converter may be set to low-noise or wide bandwidth conversion settings, but it is worth noting 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.

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.

Table 3-1. Input Limit vs. AC Gain

AC Gain (dB)	INPUT LIMIT (Zero to Peak)
0	2.5 V
6	1.2 V
12	625 mV
18	312 mV
24	156 mV
30	78 mV
36	39 mV
42	19 mV
48	10 mV
54	5.0 mV
60	2.5 mV
66	1.2 mV
72	625 µV
78	312 µV
84	156 µV
90	78 µV

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 3.3.14) 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 that 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 that gives very good results in most cases. When this is active the AC Gain is automatically controlled by the instrument, which determines the optimum setting based on the full-scale sensitivity currently being used.

At any given setting, the ratio

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

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

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

Applying this formula to the Model 7230 at the maximum value of INPUT LIMIT (2.5 V) and the smallest available value of FULL-SCALE SENSITIVITY (10 nV), gives a maximum available dynamic

reserve of about 165 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

The signal then passes through an anti-aliasing filter to remove unwanted frequencies which would cause a spurious output from the main ADC as a result of the sampling process.

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

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

For example, at the sampling frequency of 1.0 MHz, half the sampling frequency is 500 kHz. If a signal of 40 kHz accompanied by an interfering signal of 950 kHz was then applied, the output of the ADC would include a sampled-data sinusoid of 40 kHz (the required signal) and, applying the above formula, an alias signal of 50 kHz (i.e. |950 kHz - 1000 kHz|). 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 400 kHz. 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 of the instrument; 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

The analog signal is then routed to the main analog-to-digital converter, which runs at a sampling rate of 1.0 MHz. The output from the converter feeds one of the two demodulators, which uses DSP techniques to implement the digital multipliers and output low-pass filters for each of the X and Y channels.

The ADC output also passes to the fast output curve buffer where it can be stored for direct user use by downloading the data to a computer.

In dual reference and dual harmonic mode, a second demodulator is active, and in normal operation, the input to this is also taken from the main ADC output.

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 Inputs

External reference signals are normally applied to the Model 7230 via the front panel **REF IN** connector. Internally this can be switched to function as a general-purpose input, designed to accept virtually any periodic waveform with a 50:50 mark-space ratio and of suitable amplitude, or specifically set to accept TTL-logic level signals. Following the trigger buffering circuitry, the selected reference signal is routed to the reference channel.

In dual reference mode where two external reference inputs can be used, one reference is applied to the front panel **REF IN** connector, while the second, which must be of 3.0 kHz or lower frequency, is applied to the rear-panel **TRIG IN** connector.

3.3.08 Reference Channel

The reference channel circuitry is responsible for implementing a phase-locked loop to lock onto the selected external reference signal (when in external reference mode), or processing signals from the internal oscillator (when in internal reference mode). The reference channel generates a series of phase values, output at a rate of one every 1 μs, which are used to drive the reference channel inputs of the two demodulators.

In dual reference mode, the two references can each be derived from the internal oscillator, the front panel **REF IN** reference input, or the rear panel **TRIG IN** input. The reference circuit generates new phase values for each individual channel and sends these to the demodulators.

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 is taken from the front panel external reference input, except in dual external reference mode, when the second reference is applied to the rear panel **TRIG IN** input.

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 that 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.

In all cases, it is possible to configure the rear panel **TRIG OUT** connector to output a TTL logic signal at the present reference frequency.

3.3.09 Phase-Shifter

Each demodulator has a digital reference phase-shifter, allowing the phase values being sent to the in-phase and quadrature multipliers to be adjusted to the required value. If the reference input is a sinusoid

applied to the front panel **REF IN** connector, 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 general-purpose setting of the external reference channel input detects positive-going crossings 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 when the channel is configured for TTL-logic level signals 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.

3.3.10 Internal Oscillator - General

The Model 7230, in common with many other lock-in amplifiers, incorporates an internal oscillator, which may be used to drive the experiment. However, unlike older instruments, the oscillator in the Model 7230 is digitally synthesized with the result that the output frequency is extremely accurate and stable. The oscillator operates over the same frequency range as the lock-in amplifier, that is 1 mHz to 120.0 or 250.0 kHz. The oscillator signal is available at the **OSC OUT** connector.

3.3.11 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 2.0 MHz.

3.3.12 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. This cannot, of course, be used as a source for the measurement.

3.3.13 Internal Oscillator - Voltage Control

The auxiliary ADC 1 input can be used to modulate the internal oscillator output frequency or amplitude. Controls allow a quiescent amplitude and/or frequency to be set, and a translation function (i.e. frequency and/or amplitude change per volt change at the input) to be specified.

3.3.14 Demodulators - Dual Phase Multipliers

The function of each of the two demodulators is to multiply the digitized output of the signal channel by digital representations of cosine and sine waves at the demodulation frequency, to generate respectively the X and Y channel outputs. In normal operation, the demodulation frequency is at the internal or external reference frequency, but when detecting at a harmonic of this then it is at some multiple, *n* (the reference harmonic number) of it.

The demodulator outputs are 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 the selected full-scale sensitivities.

In normal single reference mode, the Demodulator 2 function is inactive, but it is brought into operation when dual reference or dual harmonic modes are selected.

3.3.15 Demodulators - Output Filters

The outputs from the X channel and Y channel multipliers feed the X channel and Y channel output low-pass filters, implemented as Finite Impulse Response (FIR) stages with selectable 6 or 12 dB/octave slope (roll-off). Further filtering can be carried out within the main output processor to allow 18 and 24 dB/octave slopes.

In traditional audio terminology, a first-order low-pass filter is described as having a slope of 6 dB per octave. This is 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 7230 to apply to the envelope of the frequency response function of the digital finite impulse response (FIR) output filters. Accordingly, the web control panel control which selects the configuration of the output filters is labeled SLOPE and the options are labeled 6, 12, 18, 24 dB/octave. Note that at the shorter time constant settings the filter slope options are limited to 6 or 12 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.

The filters are of the finite impulse response type with the averaging time of each section being equal to double the nominal time constant. This in turn defines the settling time following a step change in input signal as being $2 \times TC \times n$, where TC is the time constant and n = 1 for 6 dB, 2 for 12 dB, 3 for 18 dB and

4 for 24 dB slope settings. Hence, for example, the settling time after a step change at the input when the TC is 100 ms and the slope is 12 dB/octave will be 400 ms.

When the reference frequency is below 10 Hz, the synchronous filter option is available. When selected, the actual time constant of the filters is not generally the selected value TC, but the closest smaller value equal to an integer number of reference cycles. If TC is greater than 1 reference cycle, then the time constant is between TC/2 and TC. 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.

3.3.16 Fast Curve Buffer

The fast curve buffer is a feature common to the Models 7124, 7270, and 7230 lock-in amplifiers. It allows up to 100,000 sets of eight signals to be recorded at rates of up to 1 MSa/s (1 µs per point) and supports a variety of trigger modes. The buffer can also be used in a circular fashion, with new data overwriting the oldest data, to allow capture of events up to the time of an applied trigger.

Although eight signals can be recorded, these include the X2 and Y2 outputs that are only generated in the dual reference and dual harmonic modes, and the input to the second demodulator. Hence unless one of these modes is selected, only five signals are stored.

The signals that are stored are therefore as follows:

Single Reference/Virtual Reference Mode

SIG ADC	This is the raw digitized data out of the main ADC
X(1)	The X channel output from the first demodulator
Y(1)	The Y channel output from the first demodulator
ADC 1	The digitized representation of the input to the auxiliary ADC1
ADC 2	The digitized representation of the input to the auxiliary ADC2

Dual Reference/Dual Harmonic Mode

DEMOD 2	The digital signal input to the second demodulator
X2	The X channel output from the second demodulator
Y2	The Y channel output from the second demodulator

Data that has been stored to the buffer can be downloaded to a computer.

3.3.17 Main Output Processor - General

The same eight signals that pass to the fast curve buffer also pass to the main output processor. This carries out further output filtering if required, generates derived outputs, such as signal magnitude and phase, drives four DACs that in turn generate analog representations of the instrument outputs, and implements the standard curve buffer. These features are described in more detail in the following sections.

3.3.18 Main Output Processor - Output Offset and Expand

Following the output filter, an output offset facility enables ±300% full-scale offset to be applied to any of the X(1), Y(1), X2, Y2 output signals. The output expand facility allows a ×10 expansion, performed by simple internal digital multiplication, to be applied to the same output signals.

3.3.19 Main 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 X and Y channel demodulator outputs are constant levels. The function $\sqrt{(X^2 + Y^2)}$ 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, 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 ($X + jY$) (where j is the square root of -1) and is also computed by the processor.

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.

Hence when the magnitude output is being used, the output filter time constants should be set to give the required signal-to-noise ratio at the X channel and Y channel demodulator outputs, rather than attempting to improve the signal-to-noise ratio by averaging the magnitude output.

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 3.3.26 for further information on the correct use of the Auto-Phase function for this purpose.)

3.3.20 Main Output Processor - Noise Measurements

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

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

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

Time Constant	Equivalent Noise Bandwidth at Output Filter Slope (Hz)	
	6 dB/octave	12 dB/octave
500 µs	500.00	333.33
1 ms	250.00	166.67
2 ms	125.00	83.33
5 ms	50.00	33.33
10 ms	25.00	16.67

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. Hence the control on the Main Controls web panel that adjusts this buffer length is labeled Noise Buffer Length and can be set to Off, 1 s, 2 s, 3 s, or 4 s. Setting a shorter time means that the system responds more quickly to changes in the mean X-output level, but the noise reading itself exhibits more fluctuation. Conversely, the fluctuation can be reduced by setting a longer time, but at the expense of increased settling time following changes in the mean X-output level.

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

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

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

3.3.21 Main Output Processor - Standard Curve Buffer

The output processor also operates the standard curve buffer, which is a 100,000-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 instrument outputs, such as the X channel and Y channel output signals, it may also be used to store derived outputs and reference frequency information.

Unlike the fast curve buffer, the available points are split between the number of outputs to be stored, so that if for example X1 and Y1 outputs were selected, the maximum recording length would be 50,000 points. Storage operates at rates of up to 1 kSa/s (1 ms per point).

3.3.22 Analog Outputs (DACs)

Earlier ***SIGNAL RECOVERY*** DSP lock-in amplifiers provided two different types of analog outputs. Typically, there were two outputs driven by DACs that in turn were connected to the main instrument outputs, and separate auxiliary outputs, essentially simply programmable DC voltages typically used as control signals for the experiment. However, this architecture created a number of restrictions. In particular, in the dual modes it was not possible to get both X and Y outputs for both demodulators when using short time constants, and in some cases, it was necessary to take the analog output from different connectors for different time constant ranges.

This design has been updated and so the 7230 is fitted with four general-purpose DAC outputs, which can

be driven from a variety of output signals, as well as the traditional programmable “auxiliary DAC” signal, now referred to as the “User DACs”.

Selection of the required outputs for the DACs is made on the Rear Panel web control panel or via a command sent over one of the interfaces. For each DAC output there is a selection control, which is used to choose which instrument output will be sent to the relevant DAC, or to specify that it will be a User DAC. If the latter is selected, then a further control allows the DAC voltage to be set.

Each DAC output is driven by a 16-bit converter operating at a raw update rate of 1 MSa/s, although depending on the output it is generating the actual update rate is either 1 MSa/s or 1 kSa/s. When used for instrument outputs, full scale corresponds to ±2.5 V, but the output remains linear to up to ±7.5 V; when used as a User DAC, the range is ±10.000 V.

3.3.23 Auxiliary Analog Inputs (ADCs)

The Model 7230 incorporates four auxiliary ADC inputs offering a resolution of 1 mV in ±10.000 V. These converters may be used at slow sample rates for digitizing slowly changing or DC signals which are associated with an experiment, such as those generated by temperature and pressure transducers, so that they can be incorporated into ratio calculations or transferred to a controlling computer. They may also be used in conjunction with the instrument's fast curve buffer to form a transient recorder operating at sample rates of up to 200 kHz (one channel) or 40 kHz (two channels).

3.3.24 Main Microprocessor - General

All functions of the instrument are under the control of a microprocessor, which in addition supports the computer interfaces. It also controls 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.

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 USB or RS232 computer interface, using an update pack that can be downloaded from the **www.signalrecovery.com** website.

3.3.25 Main Microprocessor - Auto Functions

The microprocessor also controls the instrument's auto functions. These allow easier, faster operation in most applications, although direct manual operation or special purpose control programs may give better results in certain circumstances. During operation of several of the auto functions, decisions are made on the basis of output readings taken 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 that 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.

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 ±1.0 percent of the full-scale sensitivity and ±0.5 degree respectively.

3.4.02 Power-up Defaults

When the rear panel **CONFIG** Switch 1 is set to 1, 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 curve buffer is cleared.
b) Any sweep that was in progress at switch-off is terminated.

Front and Rear Panels

Chapter 4

4.1 Front Panel

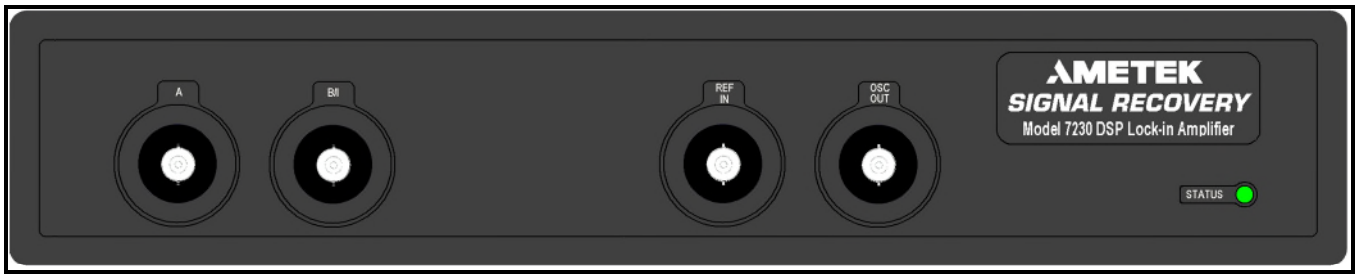


Figure 4-1. Model 7230 Front Panel Layout

As shown in Figure 4-1, the Model 7230's front panel has four BNC connectors and an LED Status indicator. The following sections describe the function and location of these items.

4.1.01 A and B (I) Signal Input Connectors

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

4.1.02 REF IN Connector

This is the general-purpose input connector for the external reference signal. It will accept either analog waveforms (e.g. sinusoidal or pulse), or TTL logic signals, depending on the setting of the reference input control.

NOTE: If the best possible phase accuracy at low external reference frequencies is required, then a TTL reference signal should be used.

When using dual external reference modes, one of the external references is applied to this connector and the other to the rear-panel **TRIG IN** connector (see Section 4.2.09).

4.1.03 OSC OUT Connector

This is the output connector for the internal oscillator.

4.1.04 STATUS Indicator

This bicolor LED indicates various operating conditions within the instrument, as follows:

Instrument Turned Off
The Status indicator is unlit.

Instrument Turned On and Operating Normally
The Status indicator is permanently green.

Instrument Turned On and Displaying Ethernet IP Address
When the Model 7230 is turned on and has determined a valid IP address, either from a DHCP server, or the Auto IP address function, or is using a static address, then the Status indicator flashes as it “counts out” the actual IP address. If these flashes are counted then it is possible to determine the address, as follows.

An IP address consists of four numbers, each known as an octet and each of which can range from 0 to 255. The Model 7230 displays these numbers by using red and green flashes of the Status indicator, as

follows. A long red flash indicates the start and end of the address, short red flashes are digit separators, and the number of green flashes equals the digit value, except that 10 green flashes equates to a value of 0.

Table 4-1. IP Address Status Indicator Guide

Step No.	Status Color	Description
1	Long Red	Start of 1st octet
2	Green Flashes	Octet 1, digit 1
3	Short Red	End of 1st digit, start of 2nd
4	Green Flashes	Octet 1, digit 2
5	Short Red	End of 2nd digit, start of 3rd
6	Green Flashes	Octet 1, digit 3
7	Short Red	End of 1st octet, start of 2nd
8	Green Flashes	Octet 2, digit 1
9	Short Red	End of 1st digit, start of 2nd
10	Green Flashes	Octet 2, digit 2
11	Short Red	End of 2nd digit, start of 3rd
12	Green Flashes	Octet 2, digit 3
13	Short Red	End of 2nd octet, start of 3rd
14	Green Flashes	Octet 3, digit 1
15	Short Red	End of 1st digit, start of 2nd
16	Green Flashes	Octet 3, digit 2
17	Short Red	End of 2nd digit, start of 3rd
18	Green Flashes	Octet 3, digit 3
19	Short Red	End of 3rd octet, start of 4th
20	Green Flashes	Octet 4, digit 1
21	Short Red	End of 1st digit, start of 2nd
22	Green Flashes	Octet 4, digit 2
23	Short Red	End of 2nd digit, start of 3rd
24	Green Flashes	Octet 4, digit 3
25	Long Red	End of 4th octet and address

If one loses track of the number of flashes, or miscounts them, then the display process can be restarted by changing the setting of the rear panel **Config 3** switch, as described in Section 4.2.07. It can also be restarted by cycling the instrument's power, but if using an auto IP allocated address, or if the DHCP server takes time to allocate an address, then it cannot begin until the new IP address has been determined, so it will take longer.

4.2 Rear Panel

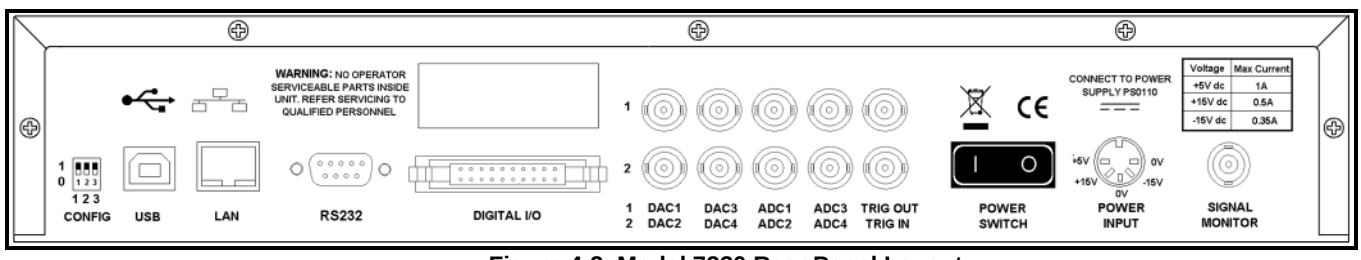


Figure 4-2. Model 7230 Rear Panel Layout

As shown in Figure 4-2, the power input socket, power switch, digital I/O port, RS232, USB, LAN

connectors, and eleven 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 Power Input Connector

The Model 7230 requires regulated DC power supply voltages of ±15 V and +5 V to operate, which are provided via the ***SIGNAL RECOVERY*** Model PS0110 power supply module that plugs into this 5-pin DIN power input connector.

CAUTION: The Model 7230 must only be powered from the Model PS0110 power supply module provided with it. Use of other power supplies, except with the prior written permission of SIGNAL RECOVERY, will invalidate the warranty.

4.2.02 Power Switch

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

4.2.03 DIGITAL I/O Connector

This connector provides eight TTL lines, each of which can be configured as an input or output. When set as an output, the line can be set high or low, 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.

4.2.04 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 C 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.

4.2.05 LAN Connector

This connector allows the instrument to be connected to a 100-BaseT or 10-BaseT network for control from a computer connected to the same network using either the built-in web based control panels or separate software packages, such as a LabVIEW driver, ***SIGNAL RECOVERY*** Acquire, or SRInstComms. The IP address can be set to a static value, or to use an automatic IP address assignment, or to accept an address allocated by a DHCP server on the network. The position of **CONFIG Switch 2** (see Section 4.2.07) controls this behavior.

4.2.06 USB Connector

This connector allows the instrument to be connected to a PC-style computer running a Windows operating system via the USB bus. The instrument supports connection at both Full Speed and Hi-Speed (USB 2.0) protocols.

4.2.07 CONFIG Switches

These three switches are used to set the instrument’s configuration, as follows:

Switch 1: Retain Settings
This switch determines whether the instrument will retain its settings during power-down, according to the following:

Position	Description
0	Unit powers on with all settings set to factory default values (see Appendix D)
1	Unit powers on with the same settings as when it was powered off

Hence to perform a reset to the factory default settings, turn off the power switch, set **Switch 1** to position **0**, and turn the power switch back on. **Switch 1** can then be set back to **1** if desired.

Switch 2: IP Address Control
This switch selects the mode of operation of the Ethernet interface, according to the following:

Position	Description
0	The Model 7230 uses a static IP address, as set by the command IPADDR. This command can be sent via any one of the three interfaces, but if used via the Ethernet interface and specifying a different address to that currently in use, then communications will be lost.
1	Unit uses a DHCP or AutoIP allocated address. It initially tries to get an IP address via a DHCP server but if one is not assigned then it will auto assign an IP address and test that it does not conflict with anything else on the network. The AutoIP address will be in the range 169.254.XXX.XXX.

Switch 3: IP Address Display
When this is switch is changed from 0 to 1 or from 1 to 0 then the current IP address (static, DHCP, or Auto IP allocated) will be shown by means of flashing the front panel **STATUS** light red and green.

4.2.08 SIG MON Connector

The signal at this connector is that immediately prior to conversion by the main ADC.

4.2.09 TRIG IN 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), and for triggering acquisition into the data buffer. The input operates on the positive edge only.

In dual reference mode where “Rear Panel” is selected as one of the external reference inputs, a TTL reference signal (3.0 kHz or lower) should be applied to this connector. Naturally this precludes using the same input for ADC triggering at the same time.

4.2.10 TRIG OUT Connector

This connector can be set to generate a TTL-compatible output pulse, for example to indicate when data is being sampled when using the internal curve buffer. It can also be switched to perform an alternative function as a Reference Monitor, in which case it outputs a TTL signal at the same frequency as the main reference channel.

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

The input voltages at these connectors are sampled and held when the ADC is triggered and are then digitized. Several different trigger modes are available. The input voltage range is ±10.000 V and the resolution is 1 mV.

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

There are four digital-to-analog converter (DAC) output connectors. The output voltages at these connectors can be configured to represent instrument outputs (e.g. X and Y channel outputs) or be used as general purpose programmable voltages. When used as instrument outputs the full-scale output range is ±2.500 V, with the ability to operate linearly at up to three times this range. When used as general-purpose outputs, the output range is ±10.000 V.

Web Control Panel Operation

Chapter 5

5.1 Introduction

This chapter describes how to operate the Model 7230 using the built-in web control panels via the Ethernet interface, and discusses its capabilities when used in this way. Chapter 6 provides similar information for when the unit is operated remotely by commands sent via the Ethernet, USB, or serial interfaces.

In order to use the built-in web control panels, the instrument must be connected to an Ethernet network, it must be possible to access this same network from the computer that will be used to operate it, and the instrument's IP address must be known. The following sections describe four different configurations that allow this; use whichever is appropriate to the user's requirements.

5.2 Ethernet Connection Methods

5.2.01 Direct Wired Connection to a Single Computer

This is the method described in Section 2.2.02 in which the Model 7230 is operated using its default static IP address of 169.254.150.230. It has the advantage of simplicity but the disadvantage that the controlling computer does not have access to other network resources or the internet.

With this configuration, it is possible to add internet access to the computer by adding a second Ethernet interface, either internal or via a USB-Ethernet adaptor, and connecting this second port to an Ethernet network that has internet access. However, the Model 7230 will still only be able to be controlled from the original computer.

5.2.02 Wireless Connection to an iPad, Tablet, Laptop, or Netbook Computer

To operate the instrument from a wireless device, such as an iPad, the user will need a wireless router that includes a DHCP server. These are widely available from electronics stores and there are many different suppliers. The following procedure uses a TP-Link Model TL-MR3020, but the same principles can be applied to using routers from other manufacturers. Proceed as follows:

1) Unpack the wireless router and follow the instructions supplied with it to connect it to the local line power.
2) Set the switch on the side of it to WISP (Wireless Internet Service Provider).
3) Turn the router on. After a short delay its wireless network will be activated.
4) Using the wireless device that will be used to control the Model 7230, such as an iPad, laptop, or smartphone, find the wireless network that has just been created. For the TP-Link Model TL-MR3020, the default wireless network name is TP-LINK_POCKET_3020_XXXXXX (where XXXXXX is the last six characters of the router's MAC address), as shown in Figure 5-1 below.

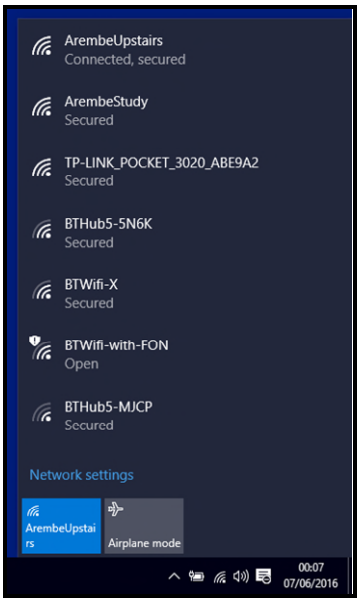


Figure 5-1. Connecting to a Wireless Network

5) Connect to this network. In the example shown in Figure 5-1, click the TP-LINK_POCKET_3020_ABE9A2.

6) Enter the wireless network security information, if required. In the case of the TP-Link Model TL-MR3020, the wireless security key is printed on a label fixed to the unit.

7) The user will now need to access the router's web control panel, for which he will need to know its IP address, which is typically at the beginning or end of one of the private IP address ranges, such as 192.168.0.1 or 192.168.0.254, or 10.0.0.1 or 10.0.0.254. Consult the documentation that came with the router to find out more. For the TP-Link Model TL-MR3020, the default address is 192.168.0.254.

8) Open a browser session and type the router's IP address into the address bar. The user may then be prompted for a username and password as in Figure 5-2, which in the case of the TP-Link Model TL-MR3020 are simply both "admin" by default.

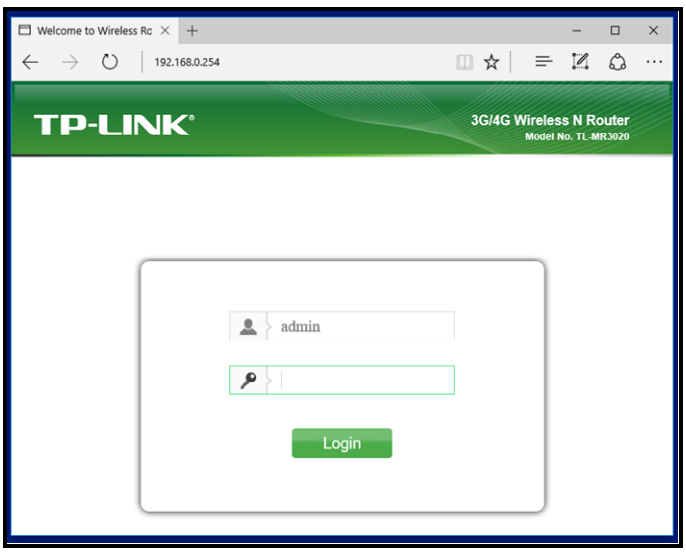


Figure 5-2. Router Home Page Login Screen

9) Enter the username and password to access the configuration page; the panel for the TP-Link

Model TL-MR3020 is shown in Figure 5-3 below.

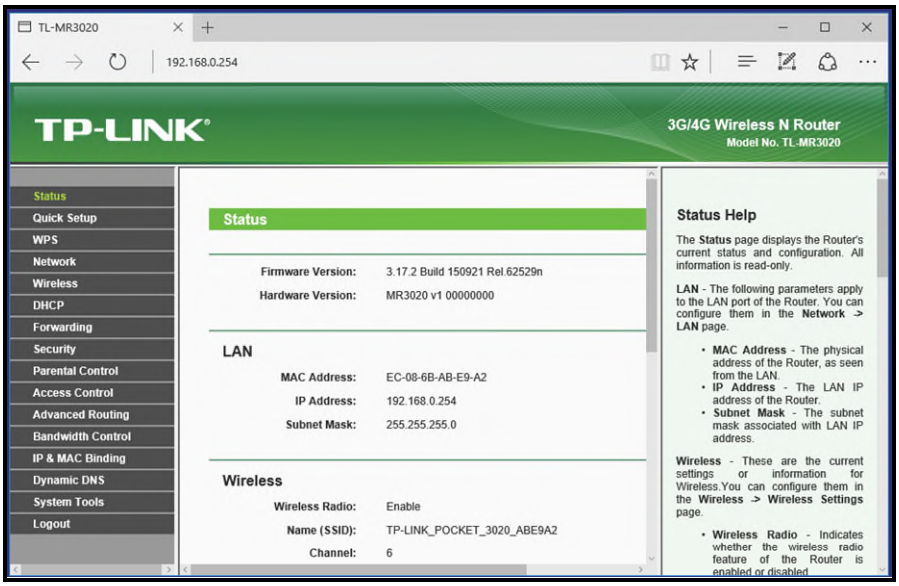


Figure 5-3. Router Home Page

10) Locate the DHCP information/controls page. For the TP-Link Model TL-MR3020, this is done by clicking the DHCP link and then the DHCP Clients List. The page is shown in Figure 5-4.

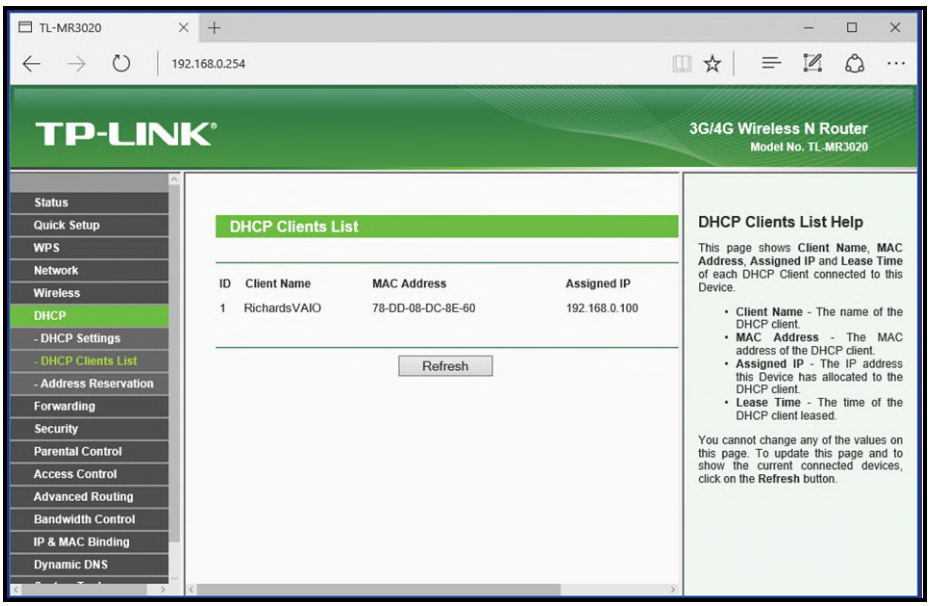


Figure 5-4. Router DHCP Status Page

11) Allow a few minutes for the router to be updated. After this, the DHCP server page should show a single IP address – this will be address of the computer from which the router is being accessed. In the above example, the controlling computer's IP address is 192.168.0.100, and the router's address (as shown, in the address bar) is 192.168.0.254.

12) Take the RJ45 patch cord and plug one end into the router and other into the **LAN** connector of the rear panel of the Model 7230.

13) Set the **Config 2** switch on the rear panel of the Model 7230 to Position 1. This will cause the instrument to be allocated an IP address by the DHCP server in the router.

14) With the rear-panel mounted power switch set to **0** (off), plug the line cord into the Model PS0110

power supply unit and the 5-pin DIN plug on the power cable from the PS0110 to the 7230's rear panel **POWER INPUT** connector.

15) Turn on the Model 7230. The front panel status light should initially be green but will then flash red and green as it "counts out" the IP address it has been allocated by the router. It is not necessary to wait until this finishes before continuing.

16) Refresh the router's control DHCP control panel. The newly connected Model 7230 will now appear as a second entry in the table.

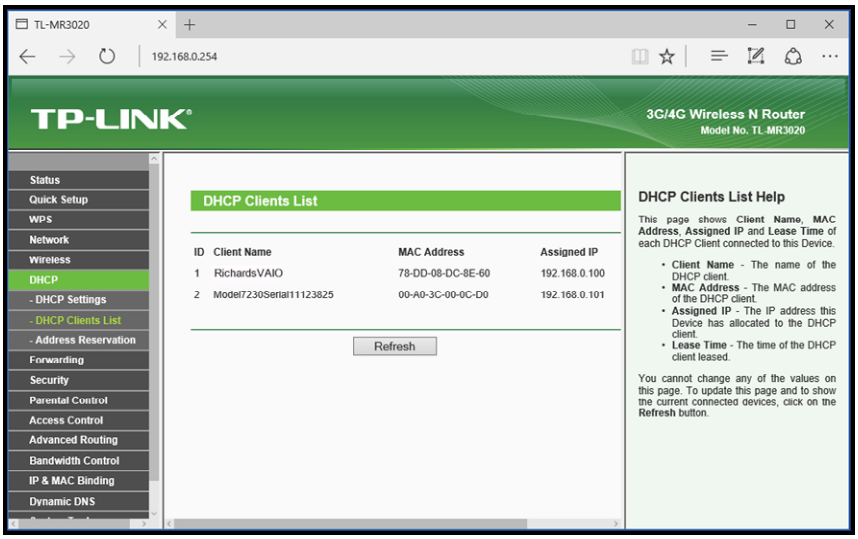


Figure 5-5. Router DHCP Status Page with Model 7230 Active

In the above example the controlling computer's IP address is 192.168.0.100 and the Model 7230 has been allocated an IP address of 192.168.0.101.

17) Open a new browser session and type the IP address for the Model 7230 determined in Step 14, which in this example is 192.168.0.101, into the address bar and press <return>. The 7230's Main Controls panel should be displayed, as shown below in Figure 5-6.

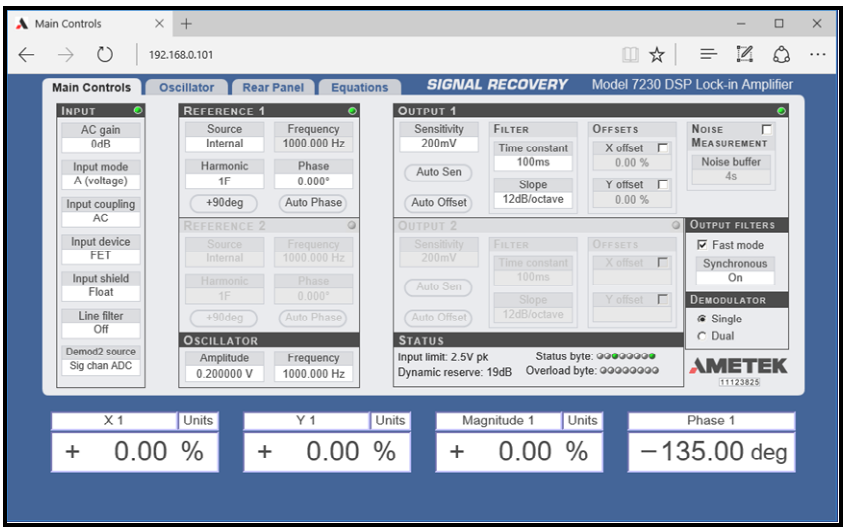


Figure 5-6. Model 7230 Main Controls Panel

18) Save the address as a favorite, bookmark, or shortcut so that the Model 7230 can quickly be reached again.

With this configuration the user should always be able to access the 7230 again in future if he is

connected to the same wireless network, simply by selecting the favorite, bookmark, or shortcut. This is because the DHCP server in the wireless router will generally allocate the same IP address to the Model 7230 each time they are both powered up and connected.

As with the wired connection described in Section 5.2.01, the iPad or other wireless device will have no general internet access while it is connected to the wireless router to which the 7230 is wired, but can of course switch to another wireless network to reach the internet, although obviously at that point losing connection to the Model 7230.

5.2.03 Wired Connection to a Company or Corporate Network Using a Static IP Address

Consult the user's network administrator to see if they can allocate a static IP address on the network for the Model 7230. If this is possible, then use the following procedure to program this address into the Model 7230 – this must be done before connecting the instrument to the network.

The procedure requires the use of a computer with an Ethernet 10 or 100 Base T adaptor with RJ45 connector set to support TCP/IP protocol with an installed web browser. As an example, a Windows 7 PC with Internet Explorer 8 is suitable, but so are many other computer systems.

1) Close all open programs on the computer and unplug any existing network connection.
2) Plug one end of the supplied RJ45 patch cord to the computer and the other end into the **LAN** connector on the rear panel of the Model 7230.
3) With the rear-panel mounted power switch set to **0** (off), plug the line cord into the Model PS0110 power supply unit and the 5-pin DIN plug on the power cable from the PS0110 to the 7230's rear panel **POWER INPUT** connector.
4) Set the rear panel **Config 2** switch to position 0.
5) Turn on the Model 7230. The front panel status light should be green.
6) Open a browser session on the computer. Since there is no connection to the internet the normal opening page will not be seen, but an error message will be seen instead. If using Internet Explorer, the message will be as shown in Figure 5-7.

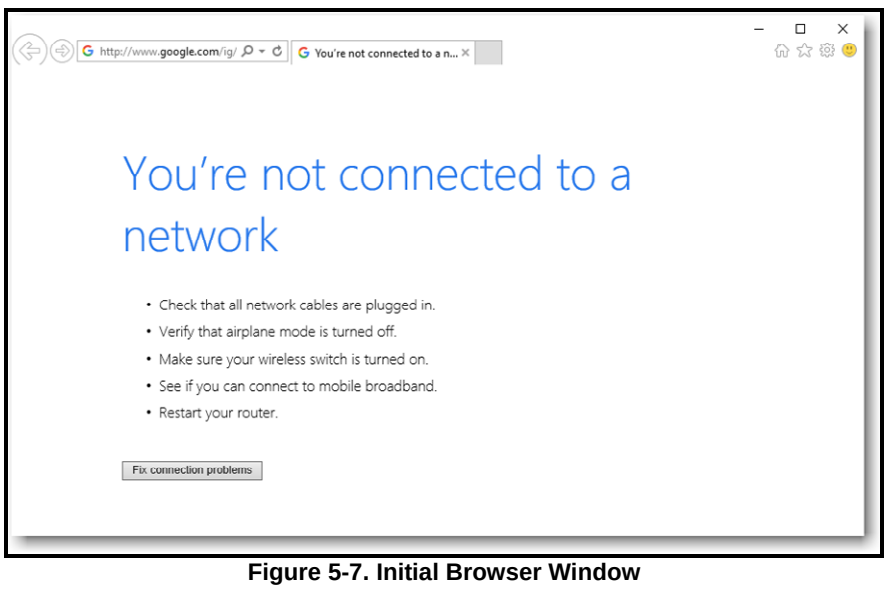


Figure 5-7. Initial Browser Window

7) Type 169.254.150.230 into the address bar and press <return>. The 7230's Main Controls panel should be displayed, as shown below in Figure 5-8.

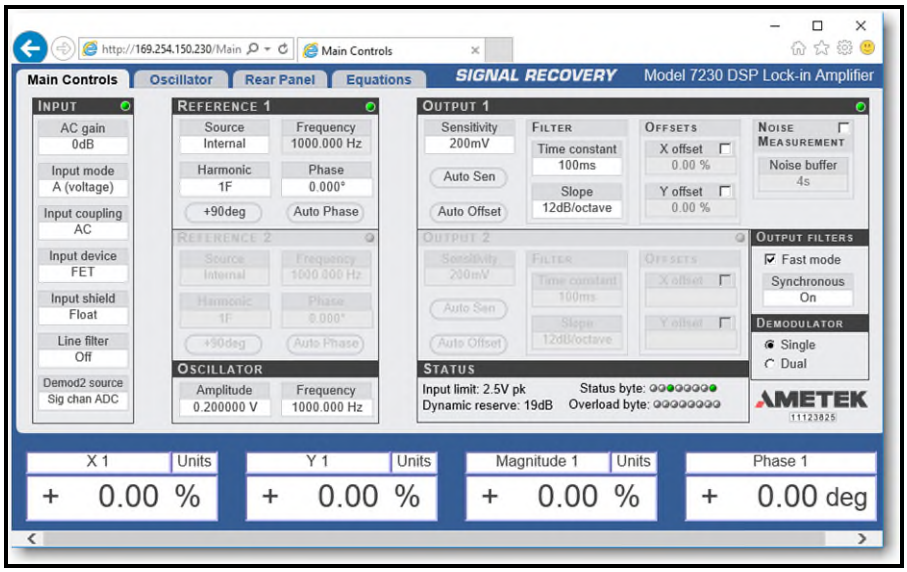


Figure 5-8. Model 7230 Main Controls Panel

8) Click the Equations tab, to show the Equations panel, as shown below in Figure 5-9.

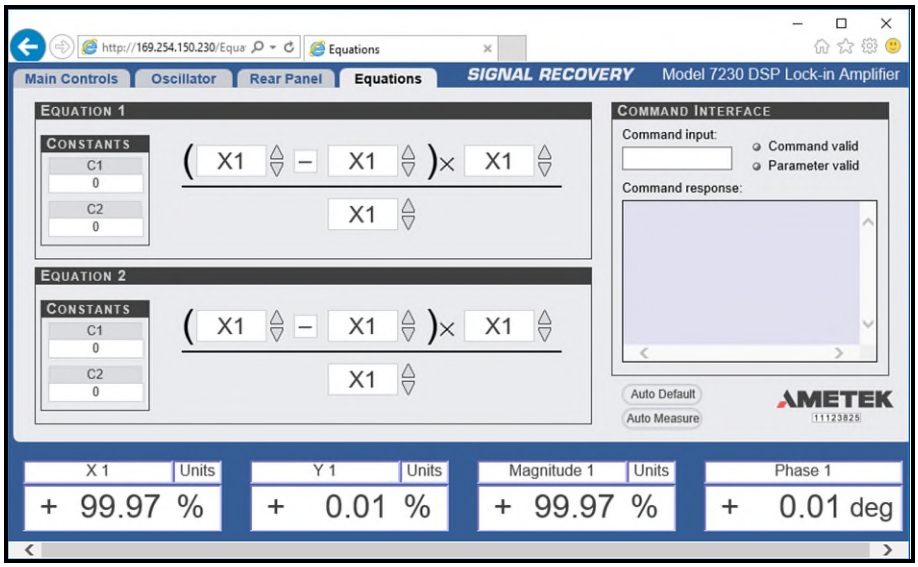


Figure 5-9. Model 7230 Equations Panel

9) In the Command input box type

IPADDR XXX XXX XXX XXX

where XXX XXX XXX XXX is the static IP address given to the user by his/her network administrator. Note that there are no periods (full stops) between the digit groups. So, if, for example, the user was given an IP address of 10.150.11.2, type IPADDR 10 150 11 2 as shown in Figure 5-10, and press <return>.

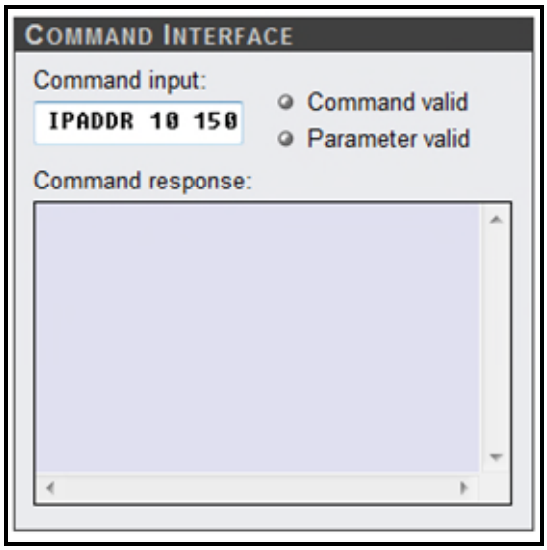


Figure 5-10. Entering New IP Address

10) Once this is done, communications will immediately be lost and an error message, similar to that shown in Figure 5-11, will be shown.

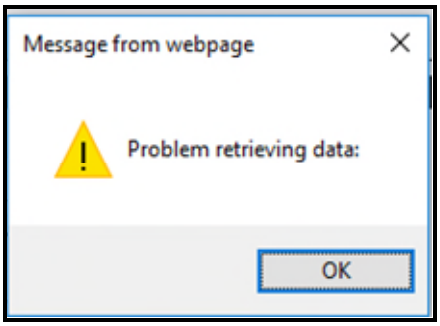


Figure 5-11. Communication Error Message

11) Now unplug the network connection linking the Model 7230 and the computer. Connect the 7230's **LAN** connector to the company or corporate network. Similarly, connect the computer back to the corporate network.

12) Open a browser session and use the saved a shortcut, bookmark, or favorite to verify that the Model 7230 can be accessed.

With this configuration, the user should always be able to access the 7230 again in future simply by selecting the favorite, bookmark, or shortcut. In addition, of course, he/she will also have access to the internet, and the Model 7230 can be controlled from any computer on the same network. If the network has wireless access points, then it will also be possible to control the Model 7230 from wireless devices.

5.2.04 Wired Connection to a Company or Corporate Network Using a DHCP Allocated IP Address

Connecting the Model 7230 to a company or corporate network using that network's DHCP server involves no effort from the corporate or company IT department in allocating a fixed IP address, but consequently can require a little more effort by the end user.

1) Connect the **LAN** connector on the rear panel of the Model 7230 to an active network connection on the company or corporate network.

2) Set the rear panel **Config 2** switch to Position 1. This will cause the Model 7230 to be allocated an IP address by the DHCP server in company network.

3) With the rear-panel mounted power switch set to **0** (off), plug the line cord into the Model PS0110 power supply unit and the 5-pin DIN plug on the power cable from the PS0110 to the 7230's rear panel **POWER INPUT** connector.

4) Turn on the Model 7230. The front panel status light should initially be green but will then flash red and green as it "counts out" the IP address it has been allocated by the network DHCP server.

5) Most company and corporate networks use a domain controller, but the Model 7230 cannot log onto a domain and so the user will not in general be able to "see" it by browsing network resources. However, once the allocated IP address is known, the user will be able to access the instrument by typing this into a browser's address bar.

   There are several possible ways of identifying the IP address.

   Using SRInstFinder
   This is a simple utility for a PC which searches for any Model 7230's on the network. It can be downloaded from the **www.signalrecovery.com** website. When run, it displays the dialog shown in Figure 5-12 below.

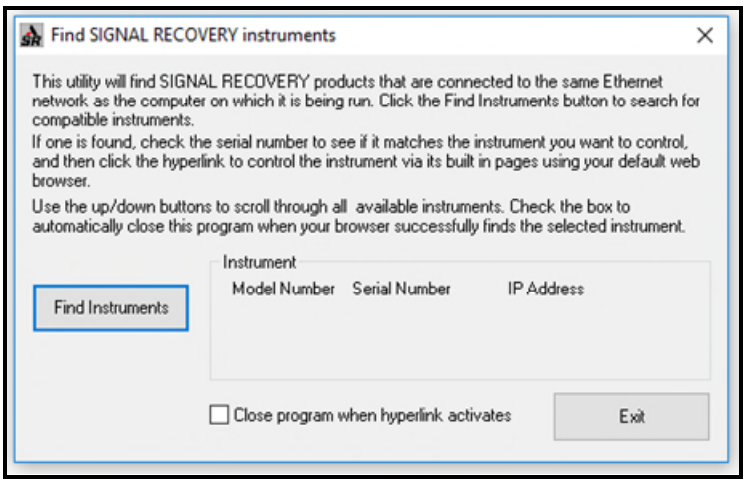


Figure 5-12. SRInstFinder Utility

Click the Find Instruments button. If any Model 7230s are found on the network, the Instrument field will be updated, as shown in Figure 5-13.

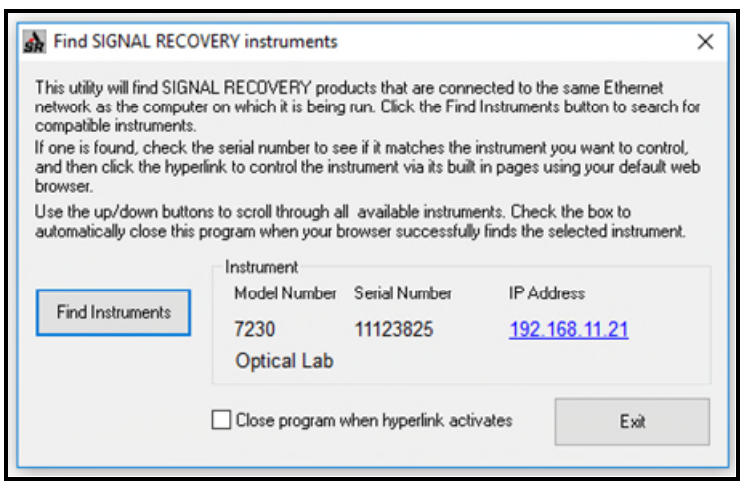


Figure 5-13. SRInstFinder Utility, Model 7230S/N 11123825 Found at IP Address 192.168.11.21

If there are several instruments, then the up/down buttons allow the user to scroll through them

until the required unit is found. The Instrument field displays the stored instrument name (see command NAME in Section 6.7.12) that can be used in addition to the serial number to aid identification. In the case of Figure 5-13, the name is “Optical Lab”.

Click the IP address hyperlink to access the Model 7230. This will open the default browser and display the Model 7230’s Main Controls page. If the user checks the “Close program…” box, then the SRInstFinder utility will also be closed automatically.

Use the FindLockin Page on the www.signalrecovery.com website.
This page, accessible via a link from the Model 7230 page on the website, will search for Model 7230s on the same network where their IP address shares the same first three octets as the computer from which it is being run. This will typically be the case where the controlling computer is in the same location or department as the Model 7230 (there can be up to 255 devices with IP addresses that share the first three octets) so in most cases this will not be a limitation.

Count the Status Light Flashes
If neither of the above methods will work, then it is possible to count the flashes of the front panel **STATUS** light, in accordance with the information in Section 4.1.04.

6) Once the IP address for the 7230 has been found, type it into the browser's address bar and press <return>. The 7230's Main Controls panel should be displayed.

7) Save the address as a shortcut, bookmark, or favorite.

Using this configuration, one should be able to access the 7230 again in future simply by selecting the favorite, bookmark, or shortcut. However, depending on the policy of the DHCP server, and the length of leases that it grants, it may be that if the Model 7230 is powered down and then turned back on again after a delay (e.g. over a weekend) it may be allocated a different IP address by the DHCP server.

However, many DHCP servers keep a table of past IP address assignments, so that they can preferentially assign to a client (such as the Model 7230) the same IP address that the client previously had. In this case the 7230 will normally get the same address.

If, however, the address changes, then the user will need to repeat the above procedure to find the new address. One way of avoiding having to do this is, of course, to leave the Model 7230 permanently switched on and connected to the network.

5.3 Web Control Panels

5.3.01 Main Controls: Overview

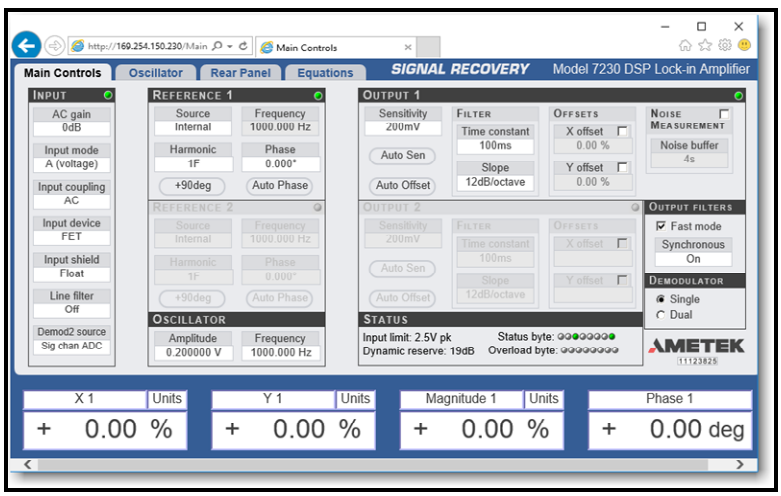


Figure 5-14. Main Controls Panel

The Main Controls panel, shown above in Figure 5-14, is displayed when a browser session is opened on the instrument's IP address. There are four digital indicators along the bottom of the screen, and controls for all the most common functions in the upper section.

There are several ways of operating the controls. Some, such as the Sensitivity control, have a range of fixed settings. To adjust these, simply click on the control and then click the required setting (see Figure 5-15).

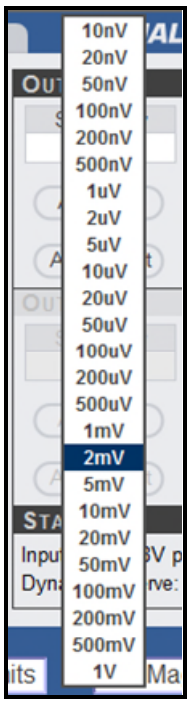


Figure 5-15. Adjusting Sensitivity Control

Other controls, such as the Phase and Oscillator Frequency controls, are adjusted by typing the required value directly into a text box.

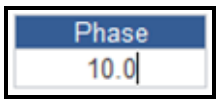


Figure 5-16. Adjusting Phase Control

To change the units applying to the digital indicators between "%" (percentage of full-scale sensitivity) and calibrated units (e.g. mV or mA), click the Units indicator, as shown in Figure 5.17.

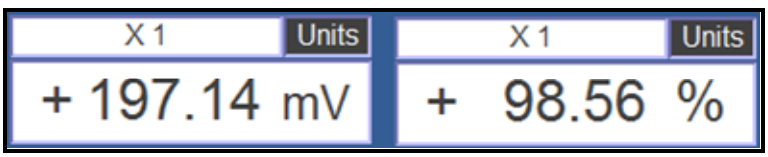


Figure 5-17. Switching Between % and mV Units

Operation of radio button and check boxes is the same as on other web pages.

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

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

Virtual Reference
Virtual reference mode is an extension of internal single reference mode operation, where the Y channel output is used to make continuous adjustments to the internal oscillator frequency and phase. The effect is to achieve phase-lock with the applied signal such that the X channel output is maximized, and the Y channel output is zeroed. Virtual reference mode operation is only possible with signals at frequencies between 100 Hz and 250 kHz.

Dual Reference
In dual reference mode the Model 7230 can make simultaneous measurements at two different reference frequencies, internal or external. If using two external references, one of them is restricted to being no greater than 3.0 kHz.

Tandem Demodulation
Some experiments, such as pump-probe optical work, generate an amplitude modulated carrier signal. The carrier signal is at one, typically higher, frequency, and the modulation at another, lower, frequency. The required measurement is the amplitude and/or phase of the modulation.

Conventionally, lock-in detection of this signal would require two instruments. The first would be run at the carrier frequency with its output filters set to a sufficiently short time constant to allow the amplitude modulation to pass. Hence the X-channel analog output would be the modulation that was to be measured; to achieve this, the signal would then be passed to the signal input of a second lock-in amplifier running at the modulation frequency.

The built-in Tandem Demodulation mode, which is essentially the same as dual reference mode but with the input to the second set of demodulators taken as the X-channel output from the first, allows the 7230 to make this measurement in a single instrument.

Dual Harmonic
Dual harmonic mode allows the simultaneous measurement of two different harmonics of the input signal.

5.3.02 Main Controls: Display Indicators

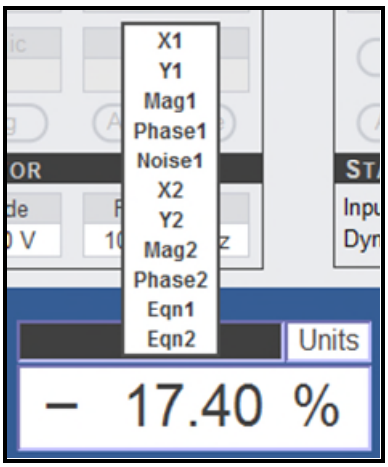


Figure 5-18. Selecting Instrument Outputs

Each of the four digital indicators along the bottom of the screen can be set to display the following instrument outputs (see Figure 5-18).

Output	Description
X1	X1 channel output. In Single Reference mode this is the X output.
Y1	Y1 channel output. In Single Reference mode this is the Y output.
Mag1	Resultant (Magnitude1) output. In Single Reference mode this is the Mag output.
Phase1	Phase 1 output. In Single Reference mode this is the Phase output.
Noise1	Noise output for the first demodulator.
X2	X2 channel output, valid only in when demodulator 2 is active.
Y2	Y2 channel output, valid only in when demodulator 2 is active.
Mag2	Resultant (Magnitude2) output, valid only in when demodulator 2 is active.
Phase2	Phase 2 output, valid only in when demodulator 2 is active.
Eqn1	Output value of User Equation 1.
Eqn2	Output value of User Equation 2.

If an output is in overload, the display is shown in red text (Figure 5-19).

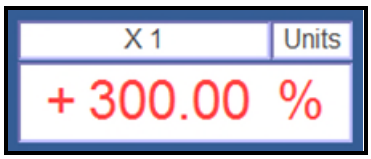


Figure 5-19. Output Overload Indication

5.3.03 Main Controls: Input

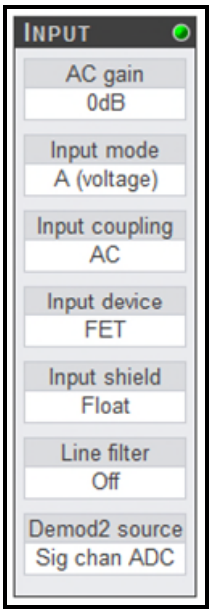


Figure 5-20. Main Controls: Input

The Input controls, shown in Figure 5-20, affect the signal channel.

AC Gain

The AC gain control allows the AC gain to be adjusted from 0 dB to 90 dB in 6 dB steps, although not all settings are available at all full-scale sensitivity settings.

To obtain the best accuracy, use the highest value of AC Gain that is possible without causing signal input overload, indicated by bit 6 in the Status Byte (see Section 5.3.11) being red. The Input Limit value, displayed in the Status panel, is the zero to peak signal that may be applied without causing signal overload.

Input mode
This control sets the preamplifier input configuration to either voltage or current mode.

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

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

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

B (current^6)
In this setting the signal channel input is a single-ended current input connected to the BNC connector on the front panel marked **B (I)** and uses the wide bandwidth current-to-voltage converter (10E6 V/A transimpedance).

B (current^8)
In this setting the signal channel input is a single-ended current input connected to the BNC connector on the front panel marked **B (I)** and uses the low noise current-to-voltage converter (10E8 V/A transimpedance).

Off
In this setting, used for test purposes, the signal channel input is disconnected.

Input coupling
The input coupling can be set as follows:

AC
The signal channel is AC coupled at the input with a lower-frequency –3 dB cut-off of < 0.2 Hz, although it is recommended to use DC coupling at frequencies < 1.0 Hz for best results. If phase (as opposed to magnitude) readings are important then DC coupling should be used at higher frequencies, since no correction is made for amplitude or phase changes caused by the AC coupling capacitor. Bipolar mode cannot be AC coupled.

DC
The signal channel is DC coupled.

Input device
This control selects the type of input device used for the signal channel connections in voltage mode input settings.

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

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

Input shield
The input connector shells can optionally be floated or connected to chassis ground as follows:

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

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

Line filter
This control selects the mode of operation of the line frequency rejection filter and offers the following settings:

Selection	Function
50 Hz	Enable 50 Hz notch filter
100 Hz	Enable 100 Hz notch filter
50Hz + 100Hz	Enable 50 and 100 Hz notch filters
60Hz	Enable 60 Hz notch filter
120Hz	Enable 120 Hz notch filter
60Hz + 120Hz	Enable 60 and 120 Hz notch filters

Demod2 source
When the demodulators are configured for dual reference operation, this control selects the signal source for the second set of demodulators.

Sig Chan ADC
In this setting, the signal input to the second set of demodulators is taken from the main signal channel ADC. This is the normal mode of operation. In dual reference or dual harmonic mode this means that the two signals being measured are applied to the same input connector and share a common path through the main ADC.

Rear ADC1
In this setting, the signal input to the second set of demodulators is taken from the rear panel auxiliary input ADC1. The full-scale sensitivity is adjustable over the normal range of 1 V to 2 nV, but because there is no AC Gain, the effective maximum sensitivity is 1 mV.

Demod1 output (Tandem demodulator mode)
In this setting the signal input to the second set of demodulators is taken from the X-channel output of the first set of demodulators.

5.3.04 Main Controls: Reference 1

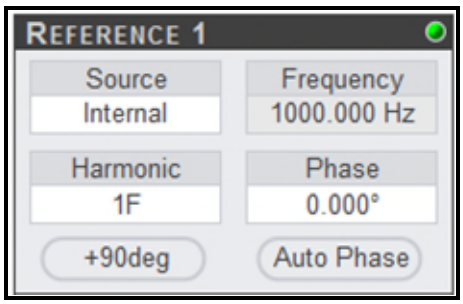


Figure 5-21. Main Controls: Reference 1

The Reference 1 controls, Figure 5-21, affect the reference channel of the first set of demodulators.

Source
This control allows selection of the source of reference signal used to drive the Reference 1 circuitry and has four settings:

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

External digital

In this setting the reference channel is configured to accept a TTL reference source applied to the front panel **REF IN** input connector, except if using the Dual Demodulator mode and the Reference 2 input selection is set to **External Analog.** In this case a TTL reference at a frequency no greater than 3.0 kHz should be applied to the rear panel **TRIG IN** connector.

External analog

In this setting the reference channel is configured to accept an analog reference source applied to the front panel **REF IN** input connector.

Virtual

This activates the virtual reference mode, and the Main Controls page is reconfigured to support the additional controls that are required (Figure 5-22).

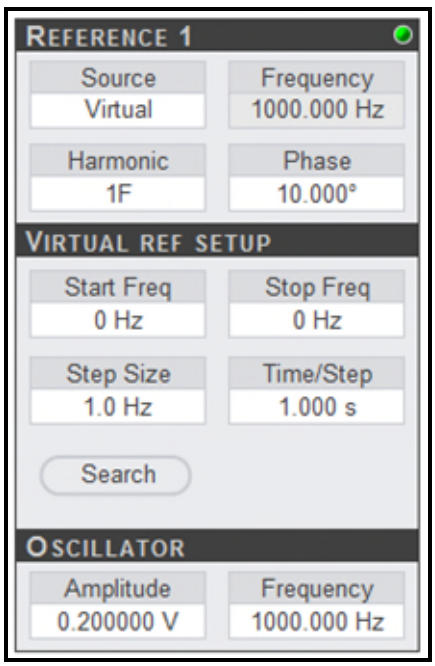


Figure 5-22. Virtual Reference Controls

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

NOTE: This mode is only suitable for signals at frequencies between 100 Hz and the upper frequency limit of the instrument (120 or 250 kHz).

The controls operate as follows:

Start Freq

This control defines the start frequency from which the instrument will begin to try to find the applied signal. It should be set to a value close to, but less than, the expected signal frequency.

Stop Freq

This control defines the stop frequency at which the instrument abandons its search for the signal and should be set to a value greater than the expected signal frequency.

Step Size

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

Time/Step
This control defines the time per point within the automatic search.

Search
Clicking the Search button starts the internal oscillator at the defined start frequency and increases it at the selected step size and rate. If the instrument detects a signal greater than 50% of full-scale then the search stops.

Frequency

This indicator shows the current frequency at which the Reference 1 channel is operating.

Harmonic
This control allows selection of the harmonic of the reference frequency at which the Reference 1 channel of the lock-in amplifier operates. It can be set to any value between 1F and 127F, but most commonly is set to 1F.

Phase
This control allows the reference phase for the first set of demodulators to be adjusted over the range -180° to +180° in 1 m° steps.

+90 Deg
Each click of this button adds 90° to the Reference 1 phase setting.

Auto Phase
Clicking this button initiates an Auto-Phase operation, where the value of the signal phase with respect to the reference is computed and an appropriate phase-shift is then introduced into the Reference 1 channel so as to bring the difference between them to zero. The intended result is to null the output of the Y channel while maximizing the output of the X channel.

5.3.05 Main Controls: Oscillator

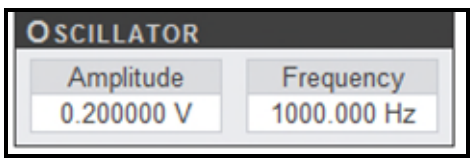


Figure 5-23. Oscillator Controls

The Oscillator controls, shown in Figure 5-23, affect the internal oscillator.

Amplitude
This control sets the amplitude of the signal at the front panel **OSC OUT** connector to any value between 1 mV and 5 V rms.

Frequency
The frequency of the instrument's internal oscillator may be set, using this control, to any value between 0.001 Hz and 120.000 kHz (or 250.000 kHz if the instrument is fitted with the 7230/99 option) with a 1 mHz resolution.

5.3.06 Main Controls: Output 1

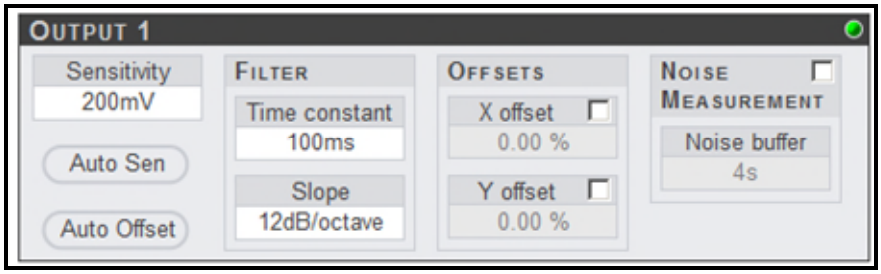


Figure 5-24. Output 1 Controls

The Output 1 controls, shown in Figure 5-24, affect the first set of demodulators.

Sensitivity

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

When set to current input mode, using the control in the Input section, the instrument's full-scale current sensitivity may be set to any value between 10 fA and 1 µA (wide bandwidth 10^6 mode), or 10 fA and 10 nA (low-noise 10^8 mode), in a 1-2-5 sequence.

The Dynamic Reserve figure, expressed in decibels, as calculated by the following equation and shown on the display in the Status block:

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

Example:

If AC Gain = 12 dB and SEN = 2 mV, then

$$DR = 20 \times \log_{10}\left(\frac{2}{0.002}\right) - 12$$

$$DR = 48 \text{ dB}$$

Auto Sen

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

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

Time Constant

The time constant of the output filters is set using this control. When the Fast control in the Output Filters section is checked, the range is 10 µs to 100 ks in a 1-2-5 sequence; when it is not checked the minimum time constant is 5 ms.

Slope

The roll-off of the output filters is set, using this control, to values from 6 dB to 24 dB/octave, in 6 dB steps. Note that there are some restrictions in that it is not possible to select 18 or 24 dB/octave settings at Time Constants of 500 ms or shorter when using the fast time constant mode.

X Offset and Y Offset

These controls allow manual adjustment of the X1 channel and Y1 channel output offsets. The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X1 channel or Y1 channel output when the corresponding check boxes are checked.

The values are also set automatically and turned on by the Auto-Offset function, which is activated by clicking the Auto Offset button.

Auto Offset

This button adjusts the X1 offset and Y1 offset values so that the X1 channel and Y1 channel outputs are zero. 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.

Noise Measurement

This control is used to configure the instrument for noise measurements. When checked, the available output time constant is restricted to the values in the range 500 µs to 10 ms inclusive, since it is only at these values that the noise measurements are calibrated, and the synchronous time constant control is turned off.

The output filter slope is also restricted to either 6 or 12 dB/octave.

When the control is unchecked then the instrument is configured for normal lock-in amplifier operation.

Noise Buffer Length

This control, which is only active when the above Noise Measurement control is checked, sets the averaging time of the buffer used to determine the mean value of the output signal when making noise measurements. Settings of Off, 1 s, 2 s, 3 s, and 4 s can be selected.

The operation of this feature is described in more detail in Section 3.3.20.

5.3.07 Main Controls: Reference 2

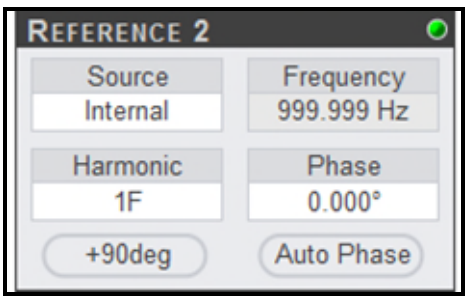


Figure 5-25. Main Controls: Reference 2

When the Demodulator is set to Dual mode, the Reference 2 controls section of the panel, shown in Figure 5-25, is active. These controls affect the second set of demodulators.

Source

This control allows selection of the source of reference signal used to drive the Reference 2 circuitry and has three settings. The corresponding control in the Reference 1 section also offers the same choices when in dual mode:

Internal

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

External digital

In this setting the reference channel is configured to accept a TTL reference source applied to the

front panel **REF IN** input connector, except if the Reference 1 input selection is set to **External Analog**, in which case a TTL reference at a frequency no greater than 3.0 kHz should be applied to the rear panel **TRIG IN** connector.

External analog
In this setting the reference channel is configured to accept an analog reference source applied to the front panel **REF IN** input connector.

Note that it is not possible to use virtual reference mode when the instrument is in dual mode, so there is no selection to allow this.

Frequency
This indicator shows the current frequency at which the Reference 2 channel is operating.

Harmonic
This control allows selection of the harmonic of the reference frequency at which the Reference 2 channel of the lock-in amplifier operates. It can be set to any value between 1F and 127F, but most commonly is set to 1F.

Phase
This control allows the reference phase for the second set of demodulators to be adjusted over the range -180° to +180° in 1 m° steps.

+90 Deg
Each click of this button adds 90° to the Reference 2 phase setting.

Auto Phase
Clicking this button initiates an Auto-Phase operation, where the value of the signal phase with respect to the reference is computed and an appropriate phase-shift is then introduced into the Reference 2 channel so as to bring the difference between them to zero. The intended result is to null the output of the Y channel while maximizing the output of the X channel.

5.3.08 Main Controls: Output 2

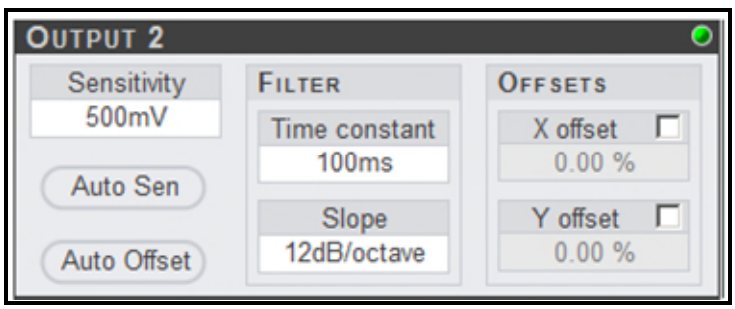


Figure 5-26. Output 2 Controls

The Output 2 controls, shown in Figure 5-26, affect the second set of demodulators.

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

When set to current input mode, using the control in the Input section, the instrument's full-scale current sensitivity may be set to any value between 10 fA and 1 µA (wide bandwidth 10^6 mode), or 10 fA and 10 nA (low-noise 10^8 mode), in a 1-2-5 sequence.

Auto Sen
This function only operates when the reference frequency is above 1 Hz. A single Auto-Sensitivity operation consists of increasing the full-scale sensitivity range if the magnitude output is greater than 90% of full-scale or reducing the range if the magnitude output is less than 30% of full-scale. After the

Auto-Sensitivity function is called, Auto-Sensitivity operations continue to be made until the required criterion is met.

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

Time Constant

The time constant of the output filters is set using this control. When the Fast control in the Output Filters section is checked, the range is 10 µs to 100 ks in a 1-2-5 sequence; when it is not checked the minimum time constant is 5 ms.

Slope

The roll-off of the output filters is set, using this control, to values from 6 dB to 24 dB/octave, in 6 dB steps. Note that there are some restrictions in that it is not possible to select 18 or 24 dB/octave settings at Time Constants of 500 ms or shorter when using the fast time constant mode.

X Offset and Y Offset

These controls allow manual adjustment of the X2 channel and Y2 channel output offsets. The offset level set by the controls, which can be any value between -300% and +300% in 0.01% steps, is added to the X2 channel or Y2 channel output when the corresponding check boxes are checked.

The values are also set automatically and turned on by the Auto-Offset function, which is activated by clicking the Auto Offset button.

Auto Offset

This control adjusts the X2 offset and Y2 offset values so that the X2 channel and Y2 channel outputs are zero. 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.

5.3.09 Main Controls: Output Filters

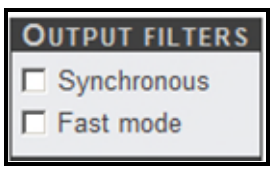


Figure 5-27. Output 2 Controls

The Output Filters controls, shown in Figure 5-27, affect both sets of demodulators.

Synchronous

When this box is unchecked, which is the normal mode, time constants are not related to the reference frequency period. When it is checked and the reference frequency is 10 Hz or lower, the actual time constant used is chosen to be some multiple of the reference frequency period, giving a much more stable output at low frequencies than would otherwise be the case. Note that in this mode, depending on the reference frequency, output time constants shorter than 100 ms cannot be used.

Fast mode

When this box is unchecked, the instrument's analog outputs are derived from the output processor. The update rate is always 1 kHz, the output filter time constant can be set to values between 5 ms and 100 ks in a 1-2-5 sequence, and all four output filter slope settings are available.

When it is checked, the analog outputs are derived directly from the core FPGA running the demodulator algorithms. The update rate is increased to 1.0 MHz when the time constant is set to any value from 10 µs to 500 ms but remains at 1 kHz for longer time constants. The output filter slope is restricted to either 6 or 12 dB/octave.

5.3.10 Main Controls: Demodulator Control

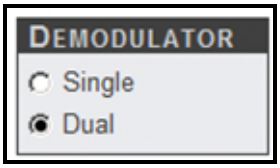


Figure 5-28. Demodulator Control

The Demodulator control, shown in Figure 5-28, determines whether the second set of demodulators is active.

Single

When selected the instrument functions as a conventional dual phase lock-in amplifier, and only the first set of demodulators is active. It includes both internal and external reference modes and provides detection either at the reference frequency or one harmonic of it. Virtual Reference mode can only be used when in Single Reference mode.

Dual

When selected both sets of demodulators are active, and can be used in the following ways:

Dual Reference

In dual reference mode, the Model 7230 can make simultaneous measurements at two different reference frequencies. These can be internal or external, subject to the limitation that if two external references are used, one of them cannot be greater than 3.0 kHz. The reference controls under Reference 1 and Reference 2 are used to select the source of reference for each demodulator, and for this mode will be set to different sources.

Dual Channel Detection

Normally the signal input in dual reference mode is common to both demodulators and uses the main signal channel. However, it is possible to use the auxiliary ADC 1 input as the signal input to the second set of demodulators, allowing the instrument to function as two independent lock-in amplifiers. Note, however, that in this mode there is no adjustable AC Gain in the ADC 1 input channel so the range of full-scale sensitivity settings for the second set of demodulators is limited.

Dual Harmonic

Dual harmonic mode allows the simultaneous measurement of two different harmonics of the input signal. The reference controls under Reference 1 and Reference 2 are used to select the source of reference for each demodulator, and for this mode will be set to the same source, with each Harmonic control set to a different value.

Tandem Demodulation

This is essentially the same as dual reference mode but with the input to the second set of demodulators taken not from the main signal channel or ADC 1 input but from the X-channel output from the first set of demodulators. It allows the instrument to detect the amplitude of a low frequency modulation of a higher-frequency carrier signal.

5.3.11 Main Controls: Status Indicators

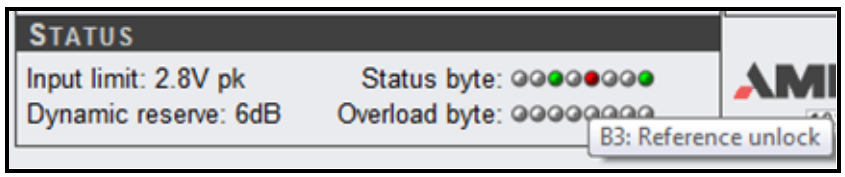


Figure 5-29. Status Indicators

The Status section gives a quick overview of the instrument status.

Input Limit

This is the zero to peak value above which the instrument will be in input overload, based on the present AC gain setting.

Dynamic Reserve

This is the calculated level of Dynamic Reserve based on the present sensitivity and AC gain settings.

Status Byte and Overload Byte

These two arrays of LED's show the bit values in these two bytes, which are defined in the following table:

Table 5-1. Status and Overload Byte Bit Definitions

Bit	Status Byte	Overload Byte
bit 0	command complete	X(1) output overload
bit 1	invalid command	Y(1) output overload
bit 2	command parameter error	X(2) output overload
bit 3	reference unlock	Y(2) output overload
bit 4	output overload	CH1 output overload
bit 5	new ADC values available after trigger	CH2 output overload
bit 6	input overload	CH3 output overload
bit 7	data available	CH4 output overload

The LEDs are green when the corresponding bit is asserted and when this is a "no fault" condition, and red when it is asserted but this indicates a fault. Bit 0 in each case is on the right and bit 7 on the left.

If the mouse cursor is hovered over a bit, then the bit function is indicated in a pop-up box. In Figure 5-29, for example, the cursor has been hovered over bit 3 in the Status byte; the fact that this is red indicates a loss of reference lock, while bit 1 indicates "command done" and bit 5 that the auxiliary ADC inputs have been triggered.

This completes the description of the Main Controls panel.

5.3.12 Oscillator: Overview

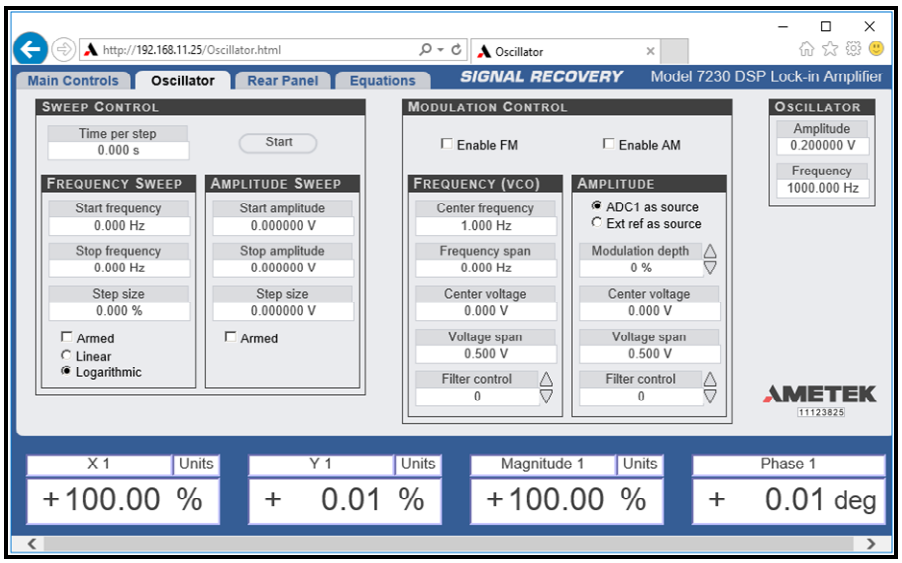


Figure 5-30. Oscillator Panel

The Oscillator panel, shown above in Figure 5-30, gives access to the full set of controls for the internal oscillator. Note, however, that the basic controls setting its amplitude and frequency are also displayed on the Main Controls panel.

5.3.13 Oscillator: Sweep Control

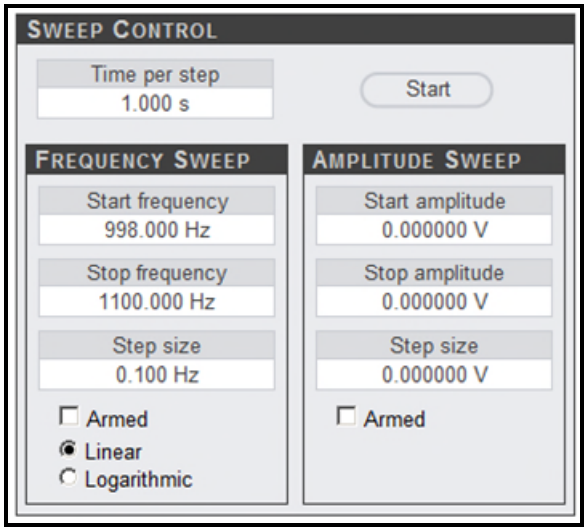


Figure 5-31. Oscillator Panel, Sweep Controls

The internal oscillator output in the Model 7230 can be swept in frequency or amplitude, or in both parameters, using these controls.

Time/Step
This control defines the time per point during a frequency or amplitude sweep.

Start
This button is used to start or stop a frequency and/or amplitude sweep. The Armed checkbox in the required sweep type controls must also be checked in order to run a sweep.

Frequency Sweep Group

Start Frequency
This control defines the start frequency from which the instrument will start a frequency sweep.

Stop Frequency
This control defines the end frequency for the frequency sweep.

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

Armed
If this box is checked then the defined sweep will be run when the Start button is clicked.

Linear
When this radio button is selected, all frequency steps are equal, and the frequency increases linearly with time.

Logarithmic
When this radio button is selected, the frequency is defined in terms of a percentage of the current frequency. For example, if the step size were set to 10%, the start frequency to 1 kHz and the stop frequency to 2 kHz, then the frequencies generated during the sweep would be:

1000.000 Hz
1100.000 Hz

1210.000 Hz
1331.000 Hz
1464.100 Hz
1610.510 Hz
1771.561 Hz
1948.717 Hz
2000.000 Hz

Amplitude Sweep Group

Start Amplitude
This control defines the start amplitude for the amplitude sweep, which may be set to any value between 0.000 V rms and 5.000V rms with a 1 µV resolution.

Stop Amplitude
This control defines the stop amplitude for the amplitude sweep, which may be set to any value between 0.000 V rms and 5.000V rms with a 1 µV resolution.

Step Size
This control defines the amount by which the oscillator amplitude is changed at each step. It may be set to any value between 0.000 V rms and 5.000V rms with a 1 µV resolution.

Armed
If this box is checked then the defined sweep will be run when the Start button is clicked. If Start Amplitude is greater than Stop Amplitude, then the oscillator amplitude will decrease with time.

5.3.14 Oscillator: Modulation Control

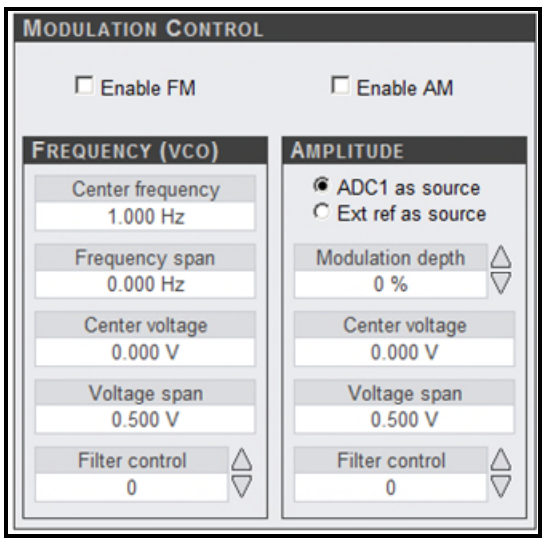


Figure 5-32. Oscillator Panel, Modulation Controls

The internal oscillator output in the Model 7230 can be amplitude or frequency modulated using an external control voltage using the controls on this panel, shown on Figure 5-32.

Frequency (VCO) Group

Enable FM
When checked, this control turns the frequency modulation on; when cleared, it turns it off.

Center Frequency
This control may be set to any value between 0.001 Hz and 120.000 or 250.000 kHz.

Frequency Span
This control defines the maximum frequency span that will be applied to the oscillator signal. For example, when set to ±100.00 Hz, the change will be ±100.00 Hz about the center frequency.

Note: The center frequency ± the span frequency must not exceed the frequency limits of the oscillator (0 to 120 or 250 kHz). Hence the center frequency plus the span frequency cannot exceed 120 or 250.0 kHz and the center frequency must be greater than or equal to the span frequency. For example, for an instrument fitted with the 7230/99 option at 125 kHz center frequency the maximum span frequency is ± 125 kHz; at 10k Hz center frequency the maximum span frequency is ± 10 kHz; at 240 kHz center frequency the maximum span frequency is also ± 10 kHz..

Center voltage
This control sets the input voltage corresponding to the center frequency.

Voltage Span
This control sets the range of input voltages that will be translated into the specified frequency span.

Filter Control
The FM control signal can be filtered by a simple digital low-pass FIR filter before being applied to the oscillator, which can be useful for eliminating noise or glitches on the signal. This control adjusts the filter; when set to 0 the filter is turned off; as the number is increased, increased filtering is applied.

Amplitude Group

Enable AM
When checked, this control turns the amplitude modulation on; when cleared, it turns it off.

ADC1 as Source and Ext Ref as Source
These radio buttons set the source of the signal that is used for amplitude modulation. When set to **ADC1 as source**, the signal should be applied to the rear panel ADC1 input, and the **Center voltage** and **Voltage span** controls are active.

When set to **Ext ref as source** the control signal should be applied to the external reference channel **REF IN** input. Because the reference channel internally generates a fixed signal amplitude that is used as the control signal for the amplitude modulation, the **Center voltage** and **Voltage span** controls are inactive.

Modulation Depth
This control defines the maximum amplitude change that will be applied to the oscillator signal. For example, when set to 100%, the change can be from full signal output to zero; while if set to 50% the amplitude will change by 50% of its quiescent level.

Center Voltage
This control sets the input voltage corresponding to the quiescent oscillator output amplitude.

Voltage Span
This control sets the range of input voltages that will be translated into the set range of modulation.

Filter Control
The AM control signal can be filtered by a simple digital low-pass FIR filter before being applied to the oscillator, which can be useful for eliminating noise or glitches on the signal. This control adjusts the filter; when set to 0 the filter is turned off; as the number is increased, increased filtering is applied.

5.3.15 Oscillator: Amplitude and Frequency Controls

These two controls duplicate the controls on the Main Controls panel.

Amplitude

This control sets the amplitude of the signal at the front panel **OSC OUT** connector to any value between 1 µV and 5 V rms.

Frequency

The frequency of the instrument's internal oscillator may be set, using this control, to any value between 0.001 Hz and 120.000 kHz (or 250.000 kHz if the instrument is fitted with the 7230/99 option) with a 1 mHz resolution.

This completes the description of the Oscillator panel.

5.3.16 Rear Panel: Overview

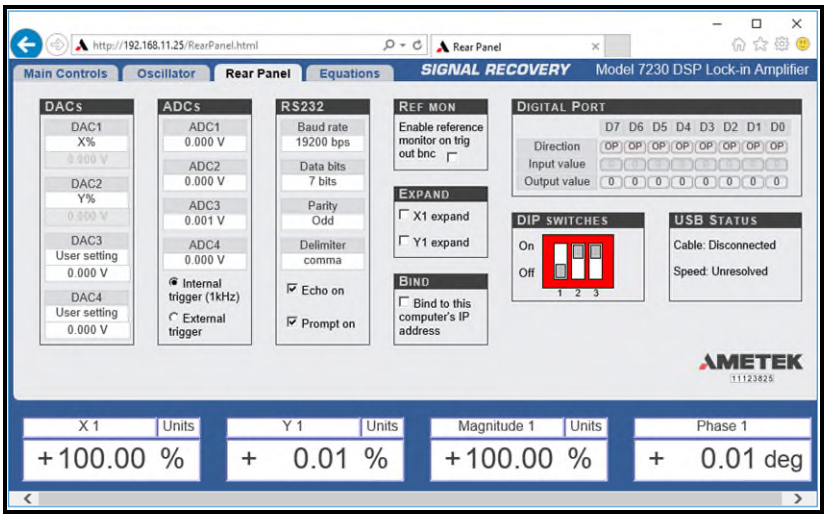


Figure 5-33. Rear Panel Controls

The Rear Panel, shown above in Figure 5-33, is used to configure the instrument's analog outputs, to read the auxiliary ADC input voltages, to set the communications parameters used for the RS232 interface, to set and read the digital IO port, and for other peripheral controls.

5.3.17 Rear Panel: DACs

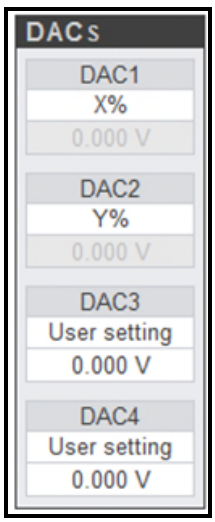


Figure 5-34. DACs Controls

These controls, shown in Figure 5-34, are used to configure the signals that will appear on the four DAC connectors on the rear panel of the instrument. Each control has a signal selector; if this is set to **User setting** then the text box below is used to specify the corresponding voltage; otherwise it is grayed out.

The controls operate as follows:

DAC1, DAC2, DAC3, and DAC4

These four controls select which signal will be made available at the corresponding **DAC 1** to **DAC 4** connectors on the rear panel of the instrument. The following settings are available but note that internal connection limitations mean that not all settings are available for each **DAC** connector.

X% (2.5V fs)

In this setting the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the X1%fs display as follows:

X1%	DAC Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

Y% (2.5V fs)

In this setting the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the Y1%fs display as follows:

Y1%	DAC Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V
-100	-2.5 V
-300	-7.5 V

Magnitude% (2.5V fs)

In this setting the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the MAG1%fs display as follows:

MAG%fs	DAC Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

Phase (+9 V = +180°)

In this setting the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the Phase 1 display as follows:

PHA deg	DAC Voltage
+180	9.0 V
+90	4.5 V
0	0.0 V
-90	-4.5 V
-180	-9.0 V

Noise (2.5V fs)

When set to Noise the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the Noise%fs display as follows:

Noise%fs	DAC Voltage
+300	7.5 V
+100	2.5 V
0	0.0 V

NOTE: When Noise is selected as an output, the noise measurement mode (Main Controls panel) must be ON.

Ratio (10.X%/ADC1)

When set to Ratio the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the result of the Ratio calculation, which is defined as follows:

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

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

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

$$\text{RATIO} = 2$$

The relationship between the voltage at the **DAC** connector and the RATIO value is defined as follows:

RATIO	DAC Voltage
+7.5	7.5 V
+2.5	2.5 V
0	0.0 V
-2.5	-2.5 V
-7.5	-7.5 V

Log Ratio

When set to Log ratio the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to the Log ratio calculation, which is defined as follows:

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

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

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

LOG RATIO = 0.301

The relationship between the voltage at the **DAC** connector and the Log ratio value is defined as follows:

Log Ratio	DAC Voltage
+2.000	2.000 V
0	0.0 V
-3.000	-3.000 V

Note: If Ratio < 0 then Log ratio = -3.000.

Equation 1

When set to Equation 1, the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to Equation 1, which is defined using the Output Equations panel, as follows:

Equation 1	DAC Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

Equation 2

When set to Equation 2, the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage related to Equation 2, which is defined using the Output Equations panel, as follows:

Equation 2	DAC Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

User Setting

When User setting is selected, the corresponding **DAC** connector on the rear panel of the instrument outputs the voltage set by the corresponding control, in the range ±10.000 V.

Digital Sig Mon

When set to the Digital Sig Mon setting, the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage representing the digital output of the main signal channel ADC.

Digital Sig Mon2

When set to the Digital Sig Mon2 setting, the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage representing the digital input to the second demodulator.

ADC1 Monitor

When set to the ADC1 Monitor setting, the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage representing the voltage at the rear-panel **ADC1** input connector.

Sync Osc

When set to the Sync Osc setting, the corresponding **DAC** connector on the rear panel of the instrument outputs a voltage representing the sinusoidal waveform applied to the first in-phase demodulator. If the reference mode is external, this allows generation of a sinusoidal signal that is phase locked, and with adjustable phase relationship, to it.

5.3.18 Rear Panel: ADCs

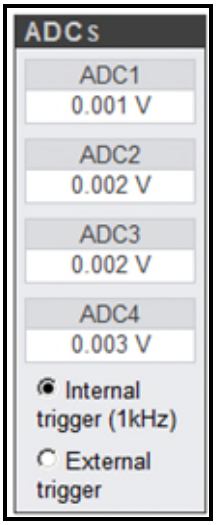


Figure 5-35. ADC Indicators

The ADCs indicators show the voltages present at the instrument's rear-panel **ADC1** to **ADC4** inputs and a radio button allows selection of two trigger modes, as follows.

Internal trigger (1kHz)
A conversion is performed on ADC1, ADC2, ADC3, and ADC4 every 1 ms, with the results being displayed above and being available via the computer interfaces.

External trigger (1kHz)
A conversion is performed on ADC1, ADC2, ADC3, and ADC4 on receipt of a rising edge at the TTL ADC TRIG IN connector on the rear panel on the instrument. The maximum trigger rate is 1 kHz. The results are displayed above and are available via the computer interfaces.

5.3.19 Rear Panel: RS232

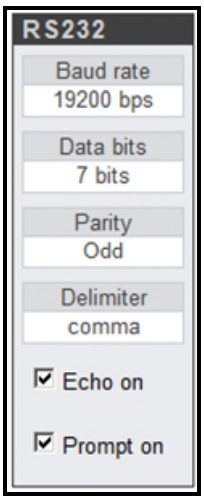


Figure 5-36. RS232 Controls

These controls, shown in Figure 5-36, set the parameters which control the RS232 communications port, as follows:

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

Baud Rate (bits per second)	Baud Rate (bits per second)
75	1800
110	2000
134.5	2400
150	4800
300	9600
600	19200
1200	38400

Data Bits
This control sets the data transmission to either 7 or 8 data bits.

Parity
This control sets the data transmission to use no parity bit, or one bit with either even or odd parity.

Delimiter
The character selected is that sent by the lock-in amplifier to separate two numeric values in a two-value response, such as that generated by the MP command.

Echo On
When this box is checked, the instrument echoes each character received over the RS232 interface back to the controlling computer. The computer should wait until the echoed character is returned before it sends the next character. When unchecked, character echo is suppressed.

Prompt On
When this box is checked, a prompt character is generated by the Model 7230 after each command response to indicate that the instrument is ready for a new command. The prompt character is either a "*" or a "?" If a "?" is generated, it indicates that an overload, reference unlock, parameter error or command error has occurred. When unchecked, no prompt character is generated.

5.3.20 Rear Panel: Ref Mon

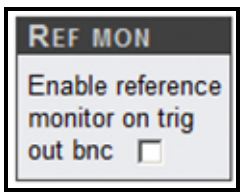


Figure 5-37. Ref Mon Control

When checked, this control, shown in Figure 5-37, is used to configure the rear-panel **TRIG OUT** connector as a TTL reference monitor output. In this setting the signal at this connector is a TTL signal at the present reference frequency (either internal or external) which can be used to monitor correct operation of the reference channel.

5.3.21 Rear Panel: Expand

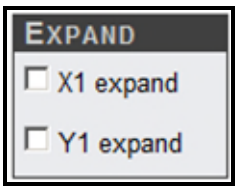


Figure 5-38. Expand Control

These two controls, shown in Figure 5-38, control the output expansion status of the X1 and Y1 outputs *when they are specified as analog signals at the DAC connectors.*

X1 Expand
When this box is checked and the DAC1 output is set to X%, the voltage present at the output will be multiplied by 10. Hence if the X% output is 10% and X1 expand is checked, the voltage at DAC1 will be 2.5 V rather than the 0.25 V that would apply otherwise.

Y1 Expand
When this box is checked and the DAC2 output is set to Y%, the voltage present at the output will be multiplied by 10. Hence if the Y% output is 10% and Y1 expand is checked, the voltage at DAC1 will be 2.5 V rather than the 0.25 V that would apply otherwise.

5.3.22 Rear Panel: Bind

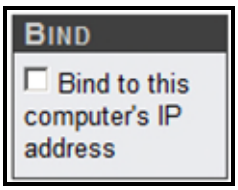


Figure 5-38. Bind Control

When the bind control, shown in Figure 5-38, is checked, it is only possible to operate the instrument using the web pages from the computer at which this box was checked. This prevents another user on the same network trying to control the same instrument.

5.3.23 Rear Panel: Digital Port

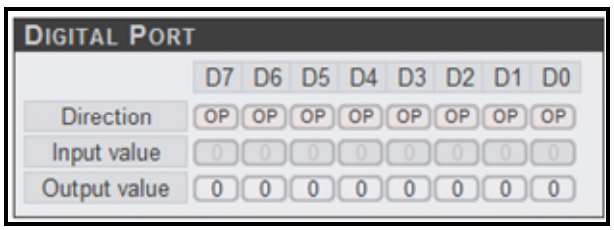


Figure 5-39. Digital Port

The Digital Port controls and indicators, shown above in Figure 5-39, allow the operating mode of each of the eight pins of the **DIGITAL I/O** connector on the rear panel of the instrument to be set and its logic status to be set and read. This port may be used for controlling or reading the status of external equipment, for example the switching of heaters or attenuators, via a suitable user-supplied external interface circuit.

Each of the eight pins is configured as an input or output by the **Direction** buttons; when the digit is set to **OP** it is an output; when set to **IP** it is an input.

For those bits configured as outputs, the **Output value** buttons define whether they are high (value = 1) or low (value = 0); simply click the buttons to change the value.

The **Input value** indicators show the current logic state of all eight bits, regardless of whether they are inputs or outputs.

5.3.24 Rear Panel: DIP switches

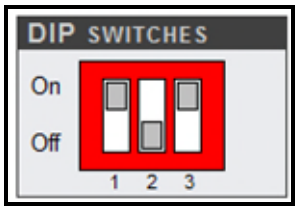


Figure 5-40. DIP Switches

The DIP switch indicator, shown above in Figure 5-40, displays the current position of the three rear panel **CONFIG** DIP switches. the function of these switches is as follows:

Switch 1: Retain Settings
This switch determines whether the instrument will retain its settings during power-down, according to the following:

Position	Description
0	Unit powers on with all settings set to factory default values (see Appendix D)
1	Unit powers on with the same settings as when it was powered off

Hence to perform a reset to the factory default settings, turn off the power switch, set **switch 1** to position **0**, and turn the power switch back on. **Switch 1** can then be set back to **1** if desired.

Switch 2: IP Address Control
This switch selects the mode of operation of the Ethernet interface, according to the following:

Position	Description
0	The Model 7230 uses a static IP address, as set by the command IPADDR. This command can be sent via any one of the three interfaces, but if used via the Ethernet interface and specifying a different address to that currently in use, then communications will be lost.
1	Unit uses a DHCP or AutoIP allocated address. It initially tries to get an IP address via a DHCP server but if one is not assigned then it will auto assign an IP address and test that it does not conflict with anything else on the network. The AutoIP address will be in the range 169.254.XXX.XXX.

Switch 3: IP Address Display
When this switch is changed from 0 to 1 or from 1 to 0, the current IP address (static, DHCP, or Auto IP allocated) will be shown by means of flashing the front panel **STATUS** light red and green.

5.3.25 Rear Panel: USB Status

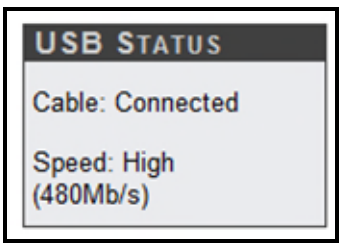


Figure 5-41. USB Status

The USB Status indicator, shown above in Figure 5-41, displays the current status of the USB communications port, and, if connected, the speed at which it is operating.

5.3.26 Equations: Overview

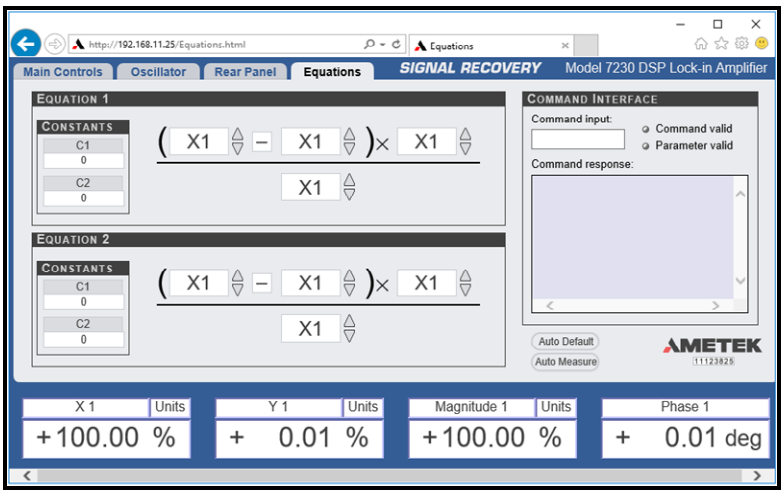


Figure 5-42. Equations

The Equations panel, shown above in Figure 5-42, allows the two user equations that are built in to the instrument to be defined, as well as giving access to a Command Interface that allows instrument commands to be sent to the unit and the response, if any, displayed.

5.3.27 Equations: Equation 1 and Equation 2

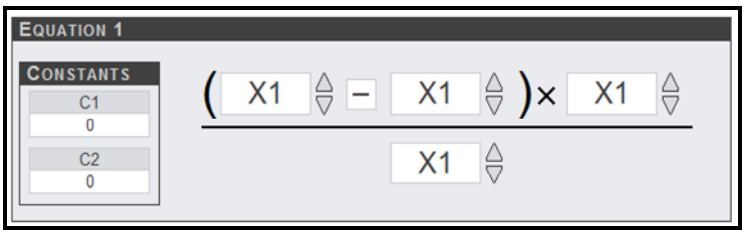


Figure 5-43. Equation 1

The Equation 1(shown above in Figure 5-43) and Equation 2 controls are used to define more complex calculations on the instrument outputs than are possible using the basic ratio and log ratio options. Each equation takes the following form:

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

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

Variable	Range
X1	±30000
Y1	±30000
MAG1	0 to +30000
PHA1 (Phase)	±18000
ADC1	±10000
ADC2	±10000
ADC3	±10000
ADC4	±10000
C1	0 to 100000
C2	0 to 100000
0	Zero
1	Unity
FRQ (Reference Frequency)	0 to 120000000 or 250000000 (Only available in position C)
OSCF (Oscillator Frequency)	0 to 120000000 or 250000000 (Only available in position C)

In the dual modes, X2, Y2, MAG2, and PHA2 variables can also be selected.

Use the up/down buttons to select the required variable settings.

The values C1 and C2 within each equation are user-defined integer constants and are adjusted by typing the required value into the text entry boxes and pressing <return>.

The equations are calculated using 64-bit integers to maintain full accuracy through to the 32-bit result that can be shown on the digital indicators. Care should be taken when defining the equations so as to make the best use of the available output range.

If the equation outputs are set to appear at any of the analog output connectors on the rear panel using the Configuration menu, then the output range should be adjusted to lie in the range -10000 to +10000. Values outside this range will result in these analog outputs limiting at ±10.000 V, although the digital value will still appear correctly on the screen.

Note that the equations continue to be calculated even when the Equations panel is not displayed, if they are selected for output to the analog output connectors. Otherwise they are calculated when requested by computer command.

5.3.28 Equations: Command Interface

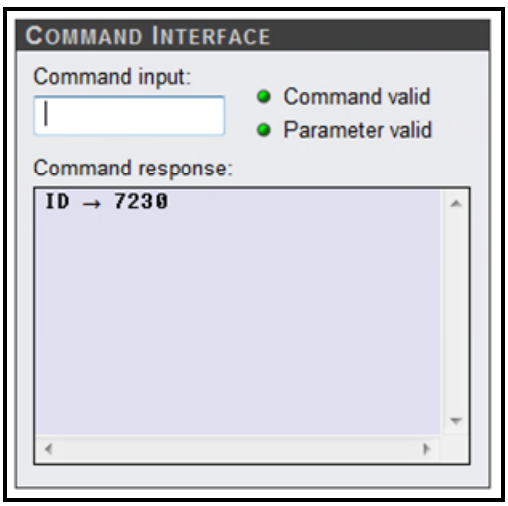


Figure 5-44. Command Interface

The Command interface, shown above in Figure 5-44, allows commands to be sent to the instrument and the response displayed. Commands are listed in Chapter 6 and Appendix E of this manual.

Type the command in the **Command input** box and press <return>. The response will be shown in the **Command response** box. In the figure above, the command ID was sent, and the response is "7230", the instrument's model number.

5.3.29 Equations: Auto Default



Figure 5-45. Auto Default Button

Clicking the Auto Default button, shown above in Figure 5-45, 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 D.

5.3.30 Equations: Auto Measure



Figure 5-46. Auto Measure Button

Clicking the Auto Measure button, shown above in Figure 5-46, adjusts the 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.

This completes the description of the instrument's web control panels.

Computer Operation

Chapter 6

6.1 Introduction

The Model 7230 includes RS232, USB and Ethernet interface ports, designed to allow it to be completely controlled from a remote computer. All of the instrument's controls may be operated, and all of the outputs can be read, via these interfaces.

This chapter describes the capabilities of the instrument when operated remotely and discusses how this is done. Refer to Chapter 5 for a description of how to operate the instrument via its built-in web control panels.

6.2 Capabilities

6.2.01 General

All instrument controls can be set, with the exception of the functions selected by the rear panel CONFIG switches, and all instrument outputs may be read remotely.

6.2.02 Operation

Control of the lock-in amplifier from a computer consists of the computer sending commands to the instrument, with it responding either by sending back some data or by changing the setting of one of its controls. The commands and responses are generally ASCII text strings, although transfer of data from the instrument's curve buffer can also be done using a binary dump of values, with each value being two bytes long.

The computer ports cannot be used simultaneously, but when a command has been completed, the lock-in amplifier will accept the next command from any port and respond to that port.

6.2.03 Compound Commands

Unlike some older ***SIGNAL RECOVERY*** instruments, the Model 7230 does not support compound commands, which were two or more simple commands separated by semicolons (ASCII 59) and terminated by a single command terminator.

6.3 RS232 Operation

6.3.01 Introduction

The RS232 interface is primarily intended to enable the lock-in amplifier to be operated from a computer program specially written for an application, although 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 from the display.

The simplest way to establish this terminal mode is to connect the instrument to a computer running a terminal emulator, such Windows HyperTerminal.

6.3.02 General Features

The RS232 interface in the Model 7230 is implemented with three wires; one carries digital transmissions from the computer to the lock-in amplifier, the second carries digital transmissions from the lock-in amplifier to the computer and the third is the Logic Ground to which both signals are referred. The logic levels are ±12 V referred to Logic Ground, and the connection may be a standard RS232 cable in conjunction with a null modem or, alternatively, may be made up from low-cost general-purpose cable. The pinout of the RS232 connectors is shown in Appendix B and cable diagrams suitable for coupling the instrument to a computer are shown in Appendix C.

The main advantages of the RS232 interface are:

1) It communicates via a serial port which is either already fitted or can be added at low cost via an adaptor to any computer, 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 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 7230 the baud rate can be set to a range of different values up to 38,400, corresponding to a minimum time of less than 0.25 ms for a single character.

Mainly for historical reasons, there are a very large number of different ways in which RS232 communications can be implemented. Apart from the baud rate options, there are choices of data word length (7 or 8 bits), parity check operation (even, odd, or none), and number of stop bits (1 or 2). With the exception of the number of stop bits, which is fixed at 1, these settings may be adjusted using the RS232 Settings controls, discussed in Chapter 5. They may also be adjusted by means of the RS command.

NOTE: In order to achieve satisfactory operation, the RS232 settings must be set to exactly the same values in the terminal or computer as in the lock-in amplifier.

6.3.03 Choice of Baud Rate

Where the lock-in amplifier is connected to a terminal or to a computer implementing an echo handshake, the highest available baud rate of 38,400 is normally used if, as is usually the case, this rate is supported by the terminal or computer. Lower baud rates may be used in order to achieve compatibility with older equipment or where there is some special reason for reducing the communication rate.

6.3.04 Choice of Number of Data Bits

For most transmissions, the Model 7230 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 binary dump commands, used for the fastest data transfer rates from the internal curve buffers, require 8-bit transmission.

6.3.05 Choice of Parity Check Option

Parity checks are not required at the baud rates available in the Model 7230 with typical cable lengths of up to a few meters. Therefore, no software is provided in the Model 7230 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 7230, the combination set at the factory is even parity check, 7 data bits, and one stop bit (fixed).

6.3.06 Handshaking and Echoes

A handshake is a method of ensuring that the transmitter does not send a data byte until the receiver is ready to receive it.

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 7230 on a byte-by-byte basis and are not connected in the Model 7230 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 that 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 then 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 should be 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 should not send the next byte until it has read the echo of the previous one. The computer can compare each byte with its echo to provide 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.

6.3.07 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 RS232 communications, the lock-in amplifier automatically accepts either <CR> or <CR,LF> as an input command terminator, and sends out <CR,LF> as an output response terminator except when the noprompt bit (bit 4 in the RS232 parameter byte) is set, in which case the terminator is <CR>. The default (power-up) state of this bit is zero.

6.3.08 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 one of several ASCII characters and is common to all interfaces; it is set via the RS232 Settings controls or by the use of the DD command. The default value is a comma.

6.3.09 Status Byte, Prompts and Overload Byte

It is useful for a controlling program to be able to quickly determine the status of the connected instrument. Internally, this is represented by two 8-bit values, known as the status and overload bytes.

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 (indicating command complete) becomes asserted in the status byte. This character is sent out by the lock-in amplifier after each command response (whether or not the response includes a transmission over the interface) to indicate that the response is finished, and the instrument is ready for a new command. The prompt takes one of two forms. If the command contained an error, either in syntax or by a command parameter being out of range, or alternatively if an overload or reference unlock is currently being reported by the web control panel indicators, the prompt is a question mark character ? (ASCII 63). Otherwise the prompt is an asterisk * (ASCII 42).

These error conditions correspond to the assertion of bits 1, 2, 3, 4, or 6 in the status byte. When the ?

prompt is received by the computer, the ST command may then 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 in Table 6-1 below.

Table 6-1. Status and Overload Byte Bit Definitions

Bit	Status Byte	Overload Byte
bit 0	command complete	X(1) output overload
bit 1	invalid command	Y(1) output overload
bit 2	command parameter error	X(2) output overload
bit 3	reference unlock	Y(2) output overload
bit 4	output overload – read overload byte to determine location	CH1 output overload
bit 5	new ADC values available after trigger	CH2 output overload
bit 6	input overload	CH3 output overload
bit 7	data available	CH4 output overload

6.4 USB Operation

6.4.01 Introduction

The USB interface in the instrument supports operation at both Full and High-Speed settings. It provides two bulk data transfer endpoints, with endpoint 1 being used to send commands to the instrument, and endpoint 2 being used to receive responses from it.

Operation of the instrument via the USB is made a great deal simpler if the user installs the relevant ***SIGNAL RECOVERY*** USB driver software. Two versions of driver are available; the first, a bulk USB driver SRUSBXP.SYS is compatible with several software packages supplied by ***SIGNAL RECOVERY***, while the second, based on National Instrument's VISA software, allows operation both from ***SIGNAL RECOVERY*** software and a free LabVIEW driver. The only disadvantage of using the VISA software driver is the need to download and install the complete VISA environment in order to use the driver.

Readers should refer to the document "USB Drivers for the Model 7124, 7230, and 7270 Lock-in Amplifiers", available from the **www.signalrecovery.com** website, for further information about installing these drivers.

6.4.02 General Features

Unlike the RS232 interface, there is no difficulty ensuring that the correct cable type is used for USB operation. All that is required is a standard USB-A to USB-B cable, which if the driver is correctly installed on the computer will then allow operation without further adjustment.

6.4.03 Terminator, Status Byte, and Overload Byte

Commands sent to the instrument over the USB interface should be terminated with a null character (ASCII 0).

Responses from the instrument consist of a string that is terminated with either one or three bytes, depending on the setting specified by the USBTERM command – see Section 6.7.11.

When USBTERM has been set to 0, the terminator is:

1) A null character (ASCII 0)

When USBTERM has been set to 1, the terminator bytes are, in the following order:

1) A null character (ASCII 0)

2) A byte representing the value of the Status Byte (Table 6-1)

3) A byte representing the value of the Overload Byte (Table 6-1)

In the case of commands that generate a single response, the controlling program should send the null-terminated command string to the instrument and then read the response bytes sent back from it until the null is detected. If USBTERM is set to 1 then two further bytes (the status and overload bytes) should also be read to complete the transfer.

Commands that do not return data still always return the one or three terminator bytes, allowing the controlling program to know that the command has been implemented.

Data stored in the instrument's curve buffer can be transferred in two ways. In the ASCII mode, each value is terminated in a null character until the last value, which is then terminated as above, whereas in the binary dump mode each data point occupies two bytes, with the complete dump being terminated as above.

In either case it is necessary to know how much data will be transferred before initiating the transfer, by sending the M (monitor) command and reading the response. This is because in the ASCII dump mode the controlling program needs to "count" each instance of a null character until all available points have been read, while in the binary dump mode it needs to know exactly how many bytes to read, since the data itself can contain null characters. Only by doing this can the program be prevented from requesting more data from the USB endpoint than the lock-in has actually sent.

6.4.04 Delimiters

Most response transmissions consist of one or two numbers (expressed as ASCII text) 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 one of several ASCII characters and is common to all interfaces; it is set via the DD command.

6.5 Ethernet Operation

6.5.01 Introduction

The Ethernet interface in the instrument supports operation on 10-BaseT and 100-BaseT networks via straight through or crossover RJ45 patch cables. The instrument includes a built-in web server allowing any browser to communicate with it using http protocol, as well as support for direct communication via TCP/IP.

6.5.02 IP Address

The IP address of the instrument needs to be unique on the network to which it is connected. Consult Section 5.2 for a discussion of the various ways of ensuring that this is the case.

6.5.03 Main Controls

When the instrument has a valid IP address the browser on a computer on the same network can then access it, simply by typing the IP address in the address bar. As discussed in Section 5.4, this will open the Main Controls remote front panel.

6.5.04 Sockets

The instrument normally accepts commands sent to sockets 50000 or 50001 on its IP address. Any response is sent back to the IP address from which the initiating command was sent.

Clearly, if an instrument is present on a large network then it is possible that several users may accidentally try to control the same instrument. To prevent this, it is possible to use the Bind control on the Rear Panel web control panel to restrict access to the computer from which it is being viewed, which then becomes the only one from which commands will be accepted.

6.5.05 Terminator, Status Byte, and Overload Byte

Commands sent to the instrument over the Ethernet interface should be terminated with a null character (ASCII 0).

Responses from the instrument depend on whether port 50000 or 50001 is being used, as follows:

Port 50000

Responses consist of a string that is terminated with three bytes, in the following order:

1) A null character (ASCII 0)

2) A byte representing the value of the Status Byte (Table 6-1)

3) A byte representing the value of the Overload Byte (Table 6-1)

In the case of commands that generate a single response, the controlling program should send the null-terminated command string to the instrument and then read the response bytes sent back from it until the null is detected. Two further bytes (the status and overload bytes) should then be read to complete the transfer.

Port 50001

Responses consist of a string that is terminated with one byte, as follows:

1) Carriage Return character (ASCII 13)

In the case of commands that generate a single response, the controlling program should send the null-terminated command string to the instrument and then read the response bytes sent back from it until the carriage return is detected.

Commands that do not return data still always return the one or three terminator bytes, allowing the controlling program to know that the command has been implemented.

Data stored in the instrument's curve buffer can be transferred in two ways. In the ASCII mode, each value is terminated in a null character until the last value, which is then terminated as above, whereas in the binary dump mode each data point occupies two bytes, with the complete dump being terminated as above.

In either case it is necessary to know how much data will be transferred before initiating the transfer, by sending the M (monitor) command and reading the response. This is because in the ASCII dump mode the controlling program needs to "count" each instance of a null character until all available points have been read, while in the binary dump mode it needs to know exactly how many bytes to read, since the data itself can contain null characters. Only by doing this can the program be prevented from requesting more data from the socket than the lock-in has actually sent.

6.5.06 Delimiters

Most response transmissions consist of one or two numbers (expressed as ASCII text) 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 one of several ASCII characters and is common to all interfaces; it is set via the DD command 6.6 Command Format.

The simple commands listed in Section 6.6 have one of five forms:

CMDNAME terminator
CMDNAME n terminator
CMDNAME [n] terminator
CMDNAME [n_1 [n_2]] terminator
CMDNAME n_1 [n_2] terminator

where CMDNAME is an alphanumeric string that defines the command, and n, n_1, n_2 are parameters separated by spaces. When n is not enclosed in square brackets it must be supplied. [n] means that n is optional. [n_1 [n_2]] means that n_1 is optional and if present may optionally be followed by n_2. Upper-case and lower-case characters are equivalent. Terminator bytes are defined in Section 6.3.09.

Where the command syntax includes optional parameters and the command is sent without the optional parameters, the response consists of a transmission of the present values of the parameter(s).

Any response transmission consists of one or more numbers followed by a response terminator. Where the response consists of two or more numbers in succession, they are separated by a delimiter (Sections 6.3.04, 6.3.09, and 6.5.05).

Some commands have an optional floating-point mode which is invoked by appending a **.** (full stop) character to the end of the command and before the parameters. This allows some parameters to be entered or read in floating-point format. The floating-point output format is given below.

±1.234E±01

The number of digits between the decimal point and the exponent varies depending on the number but is a minimum of one and a maximum of eight. The input format is not as strict but if a decimal point is used there must be a digit before it. An exponent is optional. The following are all legal commands for setting the oscillator frequency to 100.1 Hz:

OF. 100.1
OF. 1.001E2
OF. +1.001E+02
OF. 1001E-1

6.6 Command Descriptions

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

6.6.01 Signal Channel

IMODE [n] Current/Voltage mode input selector

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

n	Input mode
0	Current mode off - voltage mode input enabled
1	High bandwidth current mode enabled - connect signal to **B (I)** input connector
2	Low noise current mode enabled - connect signal to **B (I)** 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:

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.

DEMOD2SRC [n] Second stage demodulator signal source

In the dual reference mode, the value of n sets the source of the signal for the second stage demodulators according to the following:

n	Signal source
0	Main signal channel ADC (i.e. both demodulators are fed the same signal)
1	ADC1 - rear panel auxiliary ADC input
2	Demodulator 1 X channel output - this is the Tandem demodulation mode

FLOAT [n] Input connector shield float/ground control

n	Selection
0	Ground
1	Float (connected to ground via a 1 kΩ resistor)

FET [n] FET input selection

The value of n controls the input device used at the signal input according to the following:

n	Input device
0	Bipolar
1	FET

DCCOUPLE [n] Input coupling control

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

n	Coupling mode
0	AC coupled
1	DC coupled

SEN [n]
SEN. Full-scale sensitivity control

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

Table 6-2. IMODE Control

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

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 6-3. Gain Signal Channel Amplifier

n	AC Gain	n	AC Gain
0	0 dB	8	48 dB
1	6 dB	9	54 dB
2	12 dB	10	60 dB
3	18 dB	11	66 dB
4	24 dB	12	72 dB
5	30 dB	13	78 dB
6	36 dB	14	84 dB
7	42 dB	15	90 dB

AUTOMATIC [n] AC Gain automatic control

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

LF [n_1 n_2] Signal channel line frequency rejection filter control

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

n_1 Selection
0 Off
1 Enable 50 or 60 Hz notch filter
2 Enable 100 or 120 Hz notch filter
3 Enable both filters

n_2 Notch Filter Center Frequencies
0 60 Hz (and/or 120 Hz)
1 50 Hz (and/or 100 Hz)

6.6.02 Reference Channel

REFMODE [n] Reference mode selector

The value of n sets the reference mode of the instrument according to the following:

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 6.6.14.

IE [n] Reference channel source control (Internal/External)

In Single Reference and Dual Harmonic mode, the value of n sets the reference input mode according to the following:

n Selection
0 INT (internal)
1 EXT TTL (external front panel **REF** input)
2 EXT ANALOG (external front panel **REF** input)

This command is invalid in Dual Reference mode.

IE1 [n] Reference channel 1 source control, Dual Reference

In Dual Reference mode, the value of n sets the reference Channel 1 source according to the following:

n	Selection
0	INT (internal)
1	EXT TTL (external front panel **REF** input, except if IE2 = 2, when the reference should be applied to the rear panel **TRIG IN** input, and be no greater than 3.0 kHz)
2	EXT ANALOG (external front panel **REF** input)

This command is only valid in Dual Reference mode.

IE2 [n] Reference channel 2 source control, Dual Reference

In Dual Reference mode, the value of n sets the reference channel 2 source according to the following:

n	Selection
0	INT (internal)
1	EXT TTL (external front panel **REF** input except if IE1 = 2, when the reference should be applied to the rear panel **TRIG IN** input, and be no greater than 3.0 kHz)
2	EXT ANALOG (external front panel **REF** input)

This command is only valid in Dual Reference mode.

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 127.

REFMON [n] Reference monitor control

The value of n sets the function of the rear panel **TRIG OUT** connector according to the following:

n	Mode
0	Trig Out signal is generated by curve buffer triggering
1	Trig Out signal is a TTL signal at the reference frequency (i.e. it is a Reference Monitor output)

REFP[.] [n] Reference phase control

In fixed point mode, n sets the phase in millidegrees in the range ±360000.

In floating point mode, n sets the phase in degrees.

AQN Auto-Phase (auto quadrature null)

The instrument adjusts the reference phase to maximize the X channel output and minimize the Y channel output signals.

FRQ[.] Reference frequency meter

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

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

internal oscillator.

In dual reference mode it reports the frequency of the Reference 1 channel.

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

FRQ1[.] Reference frequency meter, Reference 1 channel

In dual reference modes, the FRQ1 command causes the lock-in amplifier to respond with 0 if the Reference 1 channel is unlocked, or with the reference input frequency if it is locked.

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

FRQ2[.] Reference frequency meter, Reference 2 channel

In dual reference modes, the FRQ2 command causes the lock-in amplifier to respond with 0 if the Reference 2 channel is unlocked, or with the reference input frequency if it is locked.

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

LOCK System lock control

Updates all frequency-dependent gain and phase correction parameters.

VRLOCK [n] Virtual reference mode lock

The Seek option of the frequency sweep mode must be used before issuing this command, for which the value of n has the following significance:

n	Mode
0	Disables virtual reference mode
1	Enters virtual reference mode by enabling tracking of the signal frequency

6.6.03 Signal Channel Output Filters

NOISEMODE [n] Noise Measurement Mode control

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

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

When the noise measurement mode is turned on, the output filter time constant is automatically adjusted until it lies in the range 500 µs to 10 ms inclusive, the synchronous time constant control is turned off, the fast analog output mode is turned on (FASTMODE 1), 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:

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

TC [n]
TC. Filter time constant control

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

Table 6-4. IMODE Control

	NOISEMODE = 0	NOISEMODE = 1		NOISEMODE = 0	NOISEMODE = 1
n	**time constant**	**time constant**	**n**	**time constant**	**time constant**
0	10 µs	N/A	16	2 s	N/A
1	20 µs	N/A	17	5 s	N/A
2	50 µs	N/A	18	10 s	N/A
3	100 µs	N/A	19	20 s	N/A
4	200 µs	N/A	20	50 s	N/A
5	500 µs	500 µs	21	100 s	N/A
6	1 ms	1 ms	22	200 s	N/A
7	2 ms	2 ms	23	500 s	N/A
8	5 ms	5 ms	24	1 ks	N/A
9	10 ms	10 ms	25	2 ks	N/A
10	20 ms	N/A	26	5 ks	N/A
11	50 ms	N/A	27	10 ks	N/A
12	100 ms	N/A	28	20 ks	N/A
13	200 ms	N/A	29	50 ks	N/A
14	500 ms	N/A	30	100 ks	N/A
15	1 s	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 12 command were sent and the noise measurement mode was turned off, TC would report 12 and TC. would report 1.0E-01, i.e. 0.1 s or 100 ms.

SYNC [n] Synchronous time constant control

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

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:

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

When:

a) The fast output filter mode is turned on, or
b) Noise measurement mode is turned ON (NOISEMODE 1)

the selection is according to the following:

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

6.6.04 Signal Channel Output Amplifiers

XOF [n_1 [n_2]] X channel output offset control

n_1 Selection
0 Disables offset
1 Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

YOF [n_1 [n_2]] Y channel output offset control

n_1 Selection
0 Disables offset facility
1 Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

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. This changes the analog outputs full-scale to ±10% if X or Y selected. The value of n has the following significance:

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

FASTMODE [n] Output Filter Mode Control

The value of n sets the output filter mode control according to the following:

n Function
0 Fast mode off
1 Fast mode on

When the fast-analog output mode is turned off, the available output filter time constant is restricted to 5 ms or greater, but all four filter slopes are available (i.e. 6, 12, 18, and 24 dB/octave). Conversely, when the mode is turned on, time constants down to 10 µs can be selected, but the slope is limited to either 6 or 12 dB/octave.

6.6.05 Instrument Outputs

X[.] X channel output

In fixed point, mode causes the lock-in amplifier to respond with the X demodulator output in the range ±30000, full-scale being ±10000.

In floating point, mode causes the lock-in amplifier to respond with the X demodulator output in volts or amps.

Y[.] Y channel output

In fixed point, mode causes the lock-in amplifier to respond with the Y demodulator output in the range ±30000, full-scale being ±10000.

In floating point, mode causes the lock-in amplifier to respond with the Y demodulator output in volts

or amps.

XY[.] X, Y channel outputs

This returns the X and Y outputs separated by the defined delimiter.

MAG[.] Magnitude

In fixed point, mode causes the lock-in amplifier to respond with the magnitude value in the range 0 to 30000, full-scale being 10000.

In floating point, mode causes the lock-in amplifier to respond with the magnitude value in the range +3.000E0 to +0.001E-9 volts or +3.000E-6 to +0.001E-15 amps.

PHA[.] Signal phase

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

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

PHASEPOL [n] Signal phase polarity control

n	Function
0	Operation is the same as earlier ***SIGNAL RECOVERY*** lock-in amplifiers, such as the Models 7220, 7225, 7265, 7265, 7280, 5209, and 5210.
1	Operation is the same as earlier versions of firmware in the Models 7270, 7124, and 7230.

MP[.] Magnitude, phase

This returns the MAG and PHA outputs separated by the defined delimiter.

RT[.] Ratio output

In integer mode, the RT command reports a number equivalent to 1000×X/ADC1 where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command.

In floating point mode, the RT. command reports a number equivalent to X/ADC1.

LR[.] Log Ratio output

In integer mode, the LR command reports a number equivalent to 1000×log(X/ADC1) where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command. The response range is -3000 to +2079.

In floating point mode, the LR. command reports a number equivalent to log(X/ADC1). The response range is -3.000 to +2.079.

NHZ.

Causes the lock-in amplifier to respond with the square root of the noise spectral density measured at the Y channel output, expressed in volt/√Hz or amps/√Hz referred to the input. This measurement assumes that the Y channel output is Gaussian with zero mean. (Section 3.3.20). The command is only available in floating point mode.

ENBW[.] Equivalent noise bandwidth

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

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

NN[.] Noise output

In fixed point mode, causes the lock-in amplifier to respond with the mean absolute value of the Y channel output in the range 0 to 12000, full-scale being 10000. If the mean value of the Y channel output is zero, this is a measure of the output noise.

In floating point mode, causes the lock-in amplifier to respond in volts.

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

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

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

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

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

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 6-5. DEFEQU Parameters

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 250000000 (i.e. reference frequency in mHz)*
13	OSC	0 to 250000000 (i.e. reference frequency in mHz)*
Dual modes only:		
14	X2	±30000
15	Y2	±30000
16	MAG2	0 to 30000
17	PHA2	±18000

*Parameter n_5 is the only one that can be set to values of 12 or 13.

EQU n Output result of equation #1 or equation #2

The value returned is the output of the user equation #1 (n = 1) or equation #2 (n = 2), where the equations are defined using the Output equations control panel (see Section 5.3.27). The possible range is ±2,147,483,647 (signed 32-bit integer).

C1 n_1 [n_2] Equation Constant C1

The value of n_2 sets the value of constant C1 for equation #1 (n_1 = 1) or equation #2 (n_1 = 2) in the range -30,000 to +30,000.

C2 n_1 [n_2] Equation Constant C2

The value of n_2 sets the value of constant C2 for equation #1 (n_1 = 1) or equation #2 (n_1 = 2) in the range -30,000 to +30,000.

? 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 6.7.09) and separated by delimiter character(s) defined by the DD command. Hence, for example, if CBD is set to 3, the response to the ? command will be:

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

6.6.06 Internal Oscillator

OA[.] [n] Oscillator amplitude control

In fixed point mode, n sets the oscillator amplitude in microvolts rms. The range of n is 0 to 5000000 representing 0 V to 5 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 5.000 V.

In fixed point mode, n is in microvolts 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 5.000 V.

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

ASTEP[.] [n] Oscillator amplitude sweep step size

Sets the amplitude step size for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 5.000 V.

In fixed point mode, n is in microvolts 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 120000000 or 250000000 representing 0 to 120 kHz or 250 kHz.

In floating point mode, n sets the oscillator frequency in Hz. The range of n is 0 to 1.2E5 or 2.5E5.

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 120 or 250 kHz.

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 120 or 250 kHz.

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

FSTEP[.] [n_1 n_2] Oscillator frequency sweep step size and type

The frequency may be swept either linearly or logarithmically, as specified by parameter n_2. The step size is specified by parameter n_1.

Log sweep $n_2 = 0$

In fixed point mode, n_1 is the step size in thousandths of a percent.
In floating point mode, n_1 is in percent. The range of n_1 is 0 to 100.000%.

Linear sweep $n_2 = 1$

In fixed point mode, n_1 is the step size in millihertz.
In floating point mode, n_1 is in hertz. The range of n_1 is 0 to 120 or 250 kHz.

Linear seek sweep $n_2 = 2$

In fixed point mode, n_1 is the step size in millihertz.
In floating point mode, n_1 is in hertz. The range of n_1 is 0 to 120 or 250 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

In fixed point mode, sets the sweep rate in milliseconds per step, and in floating point mode, sets the rate in seconds. The range of n is 1 to 1000000 (1 ms to 1000 s).

SWEEP [n] Oscillator frequency and amplitude sweep control

n	Sweep status
0	Stop
1	Start/continue frequency sweep
2	Start/continue amplitude sweep
3	Start/continue frequency sweep and amplitude sweep
5	Pause frequency sweep
6	Pause amplitude sweep
7	Pause frequency sweep and amplitude sweep
9	Link frequency sweep to curve buffer acquisition
10	Link amplitude sweep to curve buffer acquisition
11	Link frequency and amplitude sweep to curve buffer acquisition

This command is used to start or stop the internal oscillator frequency or amplitude sweep, or to specify that the sweep should be linked to the curve buffer data acquisition.

In the normal mode, when a frequency and/or amplitude sweep has been defined, applying SWEEP with a parameter of 1, 2, or 3 will start it. The sweep can be paused using the command with the correct value of n for the sweep in progress. For example, if a frequency sweep is started using SWEEP 1 then it can only be paused by sending SWEEP 5. Similarly, it can only be continued by sending SWEEP 1. The command SWEEP 0 will, however, stop either or both types of sweep.

When n is equal to 9, 10, or 11 the instrument is set to link the oscillator frequency and/or amplitude sweeps to the curve buffer. The SWEEP command continues to function as a write/read command except when the curve buffer acquisition is actually running. In such cases, the SWEEP command

changes to read-only and will only report values of 9, 10, or 11, indicating what type of linking is active. The sweep can then only be stopped by stopping the curve buffer, using the HC command. However, the user can still determine the progress of the sweep using the curve buffer monitor "M" command and the OF and/or OA (oscillator frequency and amplitude) commands.

MENABLE [n] **Oscillator amplitude/frequency modulation enable command**

The value of n enables the oscillator amplitude modulation function in accordance with the following table:

n	Function
0	Oscillator amplitude/frequency modulation disabled
1	Oscillator amplitude modulation enabled
2	Oscillator frequency modulation enabled

AMCENTERV[.] [n] **Oscillator amplitude modulation center voltage command**

The value of n sets the oscillator amplitude modulation center voltage; in fixed point mode, n is an integer in the range -10000 to +10000, corresponding to voltages from -10.000 V to +10.000 V, and in floating point mode, it is in volts.

Note: The span voltage plus the center voltage cannot exceed ±10.000 V.

AMDEPTH [n] **Oscillator amplitude modulation depth control**

The value of n sets the oscillator amplitude modulation depth in percent, from 0 to 100.

AMFILTER [n] **Oscillator amplitude modulation filter control command**

The value of n sets the oscillator amplitude modulation voltage low-pass filter control in the range 0 to 10. The value of 0 gives the widest bandwidth for this filter, with the value of 10 the lowest.

AMSOURCE [n] **Oscillator amplitude modulation voltage source command**

The value of n selects the source of signal used to modulate the oscillator amplitude in accordance with the following table:

n	Function
0	ADC 1 input
1	Signal from external reference channel

AMVSPAN[.] [n] **Oscillator amplitude modulation voltage span command**

The value of n sets the oscillator amplitude modulation span voltage; in fixed point mode n is an integer in the range 0 to +10000, corresponding to a range from ±0.000 V to ±10.000 V, and in floating point mode it is in volts.

Note: The span voltage plus the center voltage cannot exceed ±10.000 V.

FMCENTERF[.] [n] **Oscillator frequency modulation center frequency command**

In fixed point mode, n sets the oscillator frequency modulation center frequency in mHz. The range of n is 0 to 120000000 or 250000000 representing 0 to 120.0 or 250.0 kHz. In floating point mode, n sets the center frequency in the range 0 to 1.2E5 or 2.5E5.

Note: The span frequency plus the center frequency cannot exceed 120.0 or 250.0kHz; the center frequency must also be greater than the span frequency.

FMCENTERV[.] [n] **Oscillator frequency modulation center voltage command**

The value of n sets the oscillator frequency modulation center voltage; in fixed point mode, n is an integer in the range -10000 to +10000, corresponding to voltages from -10.000 V to +10.000 V, and in floating point mode, it is in volts.

Note: The span voltage plus the center voltage cannot exceed ±10.000 V

FMFILTER [n] **Oscillator frequency modulation filter control command**

The value of n sets the oscillator frequency modulation voltage low-pass filter control in the range 0 to 10. The value of 0 gives the widest bandwidth for this filter, with the value of 10 the lowest.

FMSPANF[.] [n] **Oscillator frequency modulation span frequency command**

In fixed point mode, n sets the oscillator frequency-modulation span frequency in mHz. The range of n is 0 to 60000000 or 125000000 representing 0 to ± 60 kHz or 125 kHz; in floating point mode, n sets the span frequency in the range 0 to 6.0E4 or 1.25E5.

Note: The center frequency ± the span frequency must not exceed the frequency limits of the oscillator (0 to 120 or 250 kHz). Hence the center frequency plus the span frequency cannot exceed 120.0 or 250.0 kHz and the center frequency must be greater than or equal to the span frequency. For example, with an instrument fitted with the 7230/99 upper frequency extension option and a 125 kHz center frequency the maximum span frequency is ± 125 kHz; at 10k Hz center frequency, the maximum span frequency is ± 10 kHz; at 240 kHz center frequency, the maximum span frequency is also ± 10 kHz. When setting the center frequency and span frequency under computer control it is recommended to first set the span frequency to zero followed by the center frequency to the required value and finally the span frequency to the required value. This will avoid potential problems with the new center frequency being rejected because it is not a legal value when compared with the old span frequency.

FMVSPAN[.] [n] **Oscillator frequency modulation voltage span command**

The value of n sets the oscillator frequency modulation span voltage; in fixed point mode n is an integer in the range 0 to +10000, corresponding to a range from ±0.000 V to ±10.000 V, and in floating point mode it is in volts.

Note: The span voltage plus the center voltage cannot exceed ±10.000 V.

6.6.07 Analog Outputs

CH n_1 [n_2] **DAC analog output control**

Defines what outputs appear on the **DAC1, DAC2, DAC3,** and **DAC4** connectors on the rear panel.

n_1 is compulsory and is 1 for DAC1, 2 for DAC2, 3 for DAC3, or 4 for DAC4

n_2	Signal (DAC1)
0	X1% (2.5 V FS)
1	Noise % (2.5 V FS)
2	Ratio: (10 × X1%/ADC 1)
3	Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4	Equation 1
5	Equation 2
6	User DAC1
7	Main signal channel ADC output (digital signal monitor 1)
8	Magnitude2 % (2.5 V FS) (dual mode only)

n_2 Signal (DAC2)
0 Y1 % (2.5 V FS)
1 Noise % (2.5 V FS)
2 Ratio: (10 × X1%/ADC 1)
3 Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4 Equation 1
5 Equation 2
6 User DAC2
7 Ext ADC1 monitor
8 Phase2: +9 V = +180°, -9 V = -180° (dual mode only)

n_2 Signal (DAC3)
0 Magnitude1 % (2.5 V FS)
1 Noise % (2.5 V FS)
2 Ratio: (10 × X1%/ADC 1)
3 Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4 Equation 1
5 Equation 2
6 User DAC3
7 Input to second demodulator (digital signal monitor 2)
8 X2 % (2.5 V FS) (dual mode only)

n_2 Signal (DAC4)
0 Phase1: +9 V = +180°, -9 V = -180°
1 Noise % (2.5 V FS)
2 Ratio: (10 × X1%/ADC 1)
3 Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4 Equation 1
5 Equation 2
6 User DAC4
7 Synchronous oscillator
8 Y2 % (2.5 V FS) (dual mode only)

NOTE: n_2 = 1 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.

DAC[.] n_1 [n_2] Set user DAC output voltage controls

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

The value of n_2 specifies the voltage to be output.

In fixed point mode, it is an integer in the range -10000 to +10000, corresponding to voltages from -10.000 V to +10.000 V, and in floating point mode, it is in volts.

6.6.08 Digital I/O

PORTDIR [n] Digital port direction control

The value of n determines which of the eight lines on the digital port are configured as inputs and which as outputs. The parameter n is a decimal number whose bit-wise interpretation defines whether the corresponding line is an input or output. The line is an input if the corresponding bit is a “1”. For example:

n	status
0	All lines configured as outputs
1	D0 = input, D1 - D7 = outputs
2	D1 = input, D0 and D2 - D7 = outputs
4	D2 = input, D0 - D1 and D3 - D7 = outputs
8	D3 = input, D0 - D2 and D4 - D7 = outputs
16	D4 = input, D0 - D3 and D5 - D7 = outputs
32	D5 = input, D0 - D4 and D6 - D7 = outputs
64	D6 = input, D0 - D5 and D7 = outputs
128	D7 = input, D0 - D6 outputs
255	All lines configured as inputs

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 = 255 and BYTE = 0, all outputs are low, and when BYTE = 255, all are high.

READBYTE Read digital port input

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

6.6.09 Auxiliary Inputs

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 -11000 to +11000, corresponding to voltages from -11.000 V to +11.000 V, and in floating point mode, it is in volts.

TADC [n] Auxiliary analog-to-digital input trigger mode

The value of n sets the trigger modes for the auxiliary ADC inputs according to the following:

n	Trigger Mode
0	Internal (1 kHz)
1	External - apply trigger to **ADC TRIG IN** connector
2	Burst ADC1 (5 µs per point, only ADC1 is converted)
3	Burst ADC1 & ADC2

6.6.10 Output Data Curve Buffer

CMODE [n] Curve buffer mode

The value of n sets the curve buffer acquisition mode in accordance with the following:

n	mode
0	Standard
1	Fast

CBD [n] Curve buffer define for Standard Mode Buffer

Defines which data outputs are stored in the standard 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:

Table 6-6. Output Bit Function and Range

Bit	Decimal Value	Output and Range
0*	1	X Output (±10000 FS)
1*	2	Y Output (±10000 FS)
2*	4	Magnitude Output (0 to +10000 FS)
3*	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5*	32	Noise (0 to +10000 FS)
6*	64	Ratio (±10000 FS)
7*	128	Log ratio (-3000 to +2000)
8*	256	ADC1 (±10000 = ±10.0 V)
9*	512	ADC2 (±10000 = ±10.0 V)
10*	1024	ADC3 (±10000 = ±10.0 V)
11*	2048	ADC4 (±10000 = ±10.0 V)
12*	4096	DAC1 (±10000 = ±10.0 V)
13*	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference Frequency bits 0 to 15 (millihertz)
16	65536	Reference Frequency bits 16 to 31 (millihertz)
Dual Modes Only:		
17*	131072	X_2 Output (±10000 FS)
18*	262144	Y_2 Output (±10000 FS)
19*	524288	Magnitude2 Output (0 to +10000 FS)
20*	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

100,000 points are available for data storage in the standard curve buffer mode, shared equally between the specified curves. For example, if 16 outputs are stored then the maximum number of storage points would be 6250 (i.e. 100000/16). 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 100000 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. In fast curve buffer mode, the maximum allowed value is 100,000; in standard mode, it 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, in standard mode, 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 into the curve buffer. N specifies the time interval in microseconds with a resolution of 1 µs. In fast curve buffer mode, the shortest time that can be specified is 1 µs; in standard mode it is 1000 µs, or 1 ms.

TD **Take data**

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10, or 11, then this sweep will be started as well.

TDT n **Take data triggered**

Sets the instrument so that data acquisition is initiated on receipt of various trigger conditions at the **TRIG** connector on the rear panel. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10, or 11, then this sweep will be started as well.

There are two basic triggers. The Acquisition trigger is a “per curve” (start) or “per point” (sample) trigger and can be active on either the rising or falling edge. The Stop trigger sets the condition by which acquisition finishes. In normal operation this is simply when the number of points specified by the LEN command parameter have been acquired, but it is also possible to leave acquisition running until an HC command is sent or until either a rising or falling edge occurs at the trigger input. The trigger modes, set by the value of n, are as follows:

Table 6-7. Trigger Modes

n	Start Condition	Sample Condition	Stop Condition
0	Ext rising edge	---	Points = LEN
1	On command	Ext rising edge	Points = LEN
2	Ext falling edge	---	Points = LEN
3	On command	Ext falling edge	Points = LEN
4	Ext rising edge	---	On HC Command
5	On command	Ext rising edge	On HC Command
6	Ext falling edge	---	On HC Command
7	On command	Ext falling edge	On HC Command
8	Ext rising edge	---	Ext falling edge
9	Ext falling edge	---	Ext rising edge

Note that in Modes 1, 3, 5, and 7, the maximum trigger rate is 1000 Hz and the storage interval control

setting have no effect.

TDC n 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 or on receipt of a trigger at the TRIG in connector, in accordance with the following:

n	Start condition	Stop condition
0	On command	On HC command
1	On command	Ext rising edge
2	On command	Ext falling edge

Note also that if sent without a parameter, the command functions as if TDT 0 had been sent. The buffer is circular in the sense that when it has been filled, new data overwrites earlier points.

TRIGOUT [n] Curve buffer trigger output

The value of n defines the type of trigger output generated when a buffer acquisition is run in accordance with the following:

n	Trigger
0	Trigger generated once per curve, at start of curve
1	Trigger generated once per point

TRIGOUTPOL [n] Curve buffer trigger output polarity

The value of n defines the polarity of the trigger output generated when a buffer acquisition is run in accordance with the following:

n	Trigger Output
0	Rising-edge
1	Falling edge

EVENT [n] Event marker control

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

HC Halt curve acquisition

Halts curve acquisition in progress. It is effective during both single (data acquisition initiated by TD command) and continuous (data acquisition initiated by TDC command) curve acquisitions. The curve may be restarted by means of the TD, TDT, or TDC command, as appropriate. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10, or 11, then this sweep will be stopped as well.

M Curve acquisition status monitor

Causes the lock-in amplifier to respond with four values that provide information concerning data acquisition, as follows:

First value, Curve Acquisition Status: a number with five possible values, defined by the following:

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

The operation of this command depends on whether data has been stored into the Standard or Fast Mode curve buffers.

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

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

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

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

Fast Mode
Only fixed point mode is supported. One curve at a time is transferred, with the selected curve being dumped via the computer interface in decimal format.

The value of n defines the curve to be transferred according to the following:

n	Output and range
0	X Output (±10000 FS)
1	Y Output (±10000 FS)
2	Main signal channel ADC output (digital signal monitor 1
3	ADC1 (±10000 = ±10.0 V)
4	ADC2 (±10000 = ±10.0 V)

Dual modes only:

5	X_2 Output (±10000 FS)
6	Y_2 Output (±10000 FS)
7	Input to second demodulator (digital signal monitor 2)

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.

DCB n Dump acquired curve(s) to computer in binary format

The operation of this command depends on whether data has been stored into the Standard or Fast Mode curve buffers.

Standard Mode

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

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

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

Reference Frequency = (65536 × value in Curve 16) + (value in Curve 15)

The computer program's subroutine which reads the responses to the DCB command needs to be able to handle the potentially very large data blocks (200 k bytes in the case of one 100 k curve) that can be generated.

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

Fast Mode

One curve at a time is transferred, with the selected curve being dumped via the computer interface in binary format, using two bytes per point. Data is sent using 16-bit 2's complement encoding, with the MSB sent first.

The value of n defines the curve to be transferred according to the following table:

n	Output and range
0	X Output (±10000 FS)
1	Y Output (±10000 FS)
2	Main signal channel ADC output (digital signal monitor 1
3	ADC1 (±10000 = ±10.0 V)
4	ADC2 (±10000 = ±10.0 V)

Dual modes only:

n	Output and range
5	X_2 Output (±10000 FS)
6	Y_2 Output (±10000 FS)
7	Input to second demodulator (digital signal monitor 2)

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.

DCT n Dump acquired curves to computer in tabular format

NOTE: This command is only available when the curve buffer is set to Standard Mode.

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 below:

Table 6-8. DCT Output and Range

Bit	Decimal Value	Output and Range
0	1	X Output (±10000 FS)
1	2	Y Output (±10000 FS)
2	4	Magnitude Output (0 to +10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5	32	Noise (0 to +10000 FS)
6	64	Ratio (±10000 FS)
7	128	Log ratio (-3000 to +2000)
8	256	ADC1 (±10000 = ±10.0 V)
9	512	ADC2 (±10000 = ±10.0 V)
10	1024	ADC3 (±10000 = ±10.0 V)
11	2048	ADC4 (±10000 = ±10.0 V)
12	4096	DAC1 (±10000 = ±10.0 V)
13	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency (millihertz)
16	65536	Reference frequency (milliherz)
Dual Modes Only:		
17*	131072	X_2 Output (±10000 FS)
18*	262144	Y_2 Output (±10000 FS)
19*	524288	Magnitude2 Output (0 to +10000 FS)
20*	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

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

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.

6.6.11 Computer Interfaces

RS [n_1 [n_2]] Set/read RS232 interface parameters

n_1	Baud rate (bits per second)	n_1	Baud rate (bits per second)
0	75	7	1800
1	110	8	2000
2	134.5	9	2400
3	150	10	4800
4	300	11	9600
5	600	12	19200
6	1200	13	38400

The lowest five bits in n_2 control the other RS232 parameters according to the following:

bit number	bit negated	bit asserted
0	data = 7 bits	data = 8 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

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	Output overload - read overload byte to determine location
Bit 5	New ADC values available after external trigger
Bit 6	Input overload
Bit 7	Data available

USBTERM [n] **Set/read USB terminator**

The value of n sets the USB terminator according to the following:

n	Function
0	A null character (ASCII 0)
1	A null character (ASCII 0), followed by a byte representing the value of the status Byte (Table 6-1), followed by a byte representing the value of the Overload Byte (Table 6-1)

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	X(1) channel output overload (> ±300 %FS)
Bit 1	Y(1) channel output overload (> ±300 %FS)
Bit 2	X2 channel output overload (> ±300 %FS)
Bit 3	Y2 channel output overload (> ±300 %FS)
Bit 4	CH1 output overload
Bit 5	CH2 output overload

Bit 6 CH3 output overload
Bit 7 CH4 output overload

IPADDR [n1 n2 n3 n4] Ethernet IP Address

When this command is sent without parameters, the instrument responds with the current IP address, e.g. 169.254.0.10.

When sent with the four parameters, the command sets the IP address that will be used when the Model 7230 is set to static IP address mode (via the rear panel Config Switch 2, see Section 4.2.07).

The parameters are separated by a space character and not by a dot, e.g.

IPADDR 169 254 0 10

sets the IP address to 169.254.0.10. Based on the IP address, this command will also generate a default subnet mask and gateway address so if values other than the defaults are required, set the IP address before setting the subnet mask and gateway address; otherwise, they will be overwritten.

SNMASK [n1 n2 n3 n4] Ethernet Subnet Mask

When this command is sent without parameters, the instrument responds with the current subnet mask, e.g. 255.255.0.0.

When sent with the four parameters, the command sets the subnet mask that will be used when the Model 7230 is set to static IP address mode (via the rear panel Config Switch 2, see Section 4.2.07).

The parameters are separated by a space character and not by a dot, e.g.

SNMASK 255 255 0 0 sets the subnet mask to 255.255.0.0.

Note that the setting can be overridden if the IP address is set using the IPADDR command.

GWADDR [n1 n2 n3 n4] Ethernet Gateway Address

When this command is sent without parameters, the instrument responds with the current gateway address, e.g. 169.254.0.1.

When sent with the four parameters, the command sets the gateway address that will be used when the Model 7230 is set to static IP address mode (via the rear panel Config Switch 2, see Section 4.2.07).

The parameters are separated by a space character and not by a dot, e.g.

GWADDR 169 254 0 1

sets the gateway address 169.254.0.1.

Note that the setting can be overridden if the IP address is set using the IPADDR command.

IPLOCK Restrict Ethernet Access

When this command is sent via the Ethernet interface, subsequent connection requests and hence commands will only be accepted if sent from the same IP address, preventing unauthorized access to the instrument.

IPUNLOCK Remove Ethernet Access Restrictions

When this command is sent via the Ethernet interface, subsequent connection requests and hence commands will be accepted from any computer on the same network as the instrument.

6.6.12 Instrument Identification

ID Identification

Causes the lock-in amplifier to respond with the number 7230.

VER **Report firmware version**

Causes the lock-in amplifier to respond with the firmware version number, as also displayed on the Configuration menu.

DATE **Last calibration date**

The response is a six-digit number giving the date of the last calibration where the first two digits are the day, the second two digits are the month, and the last two digits are the year (in the 21st century).

NAME **Set/Read Instrument Name**

The NAME command allows the user to store an ASCII text string as a "name" to help identify the instrument. This is especially useful when there are several instruments connected to the same Ethernet network, since it can be used as a more convenient alternative to the serial number as an aid to identification.

When sent with a string of up to 64 characters as a parameter, the string will be stored. When sent without characters the instrument will respond with the stored string. For example:

NAME Optical absorption lab lock-in amplifier

will set the name to "Optical absorption lab lock-in amplifier"; sending NAME with no parameters will return:

Optical absorption lab lock-in amplifier

6.6.13 Auto Default and Calibration

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.
2	All instrument settings, with the exception of the communications settings, are returned to their factory default values, except the oscillator amplitude is set to 0 V rms.

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.

6.6.14 Dual Mode Commands

When either dual reference or dual harmonic modes are selected, some commands change so that both channels can be controlled independently, as listed in the following:

Single Reference or Virtual Reference mode command	Dual Reference or Dual Harmonic mode command
EX	not available
MAG[.]	MAG1[.]
	MAG2[.]
MP[.]	MP1[.]
	MP2[.]
IE[n]	IE1[n]
	IE2[n]
FRQ	FRQ1
	FRQ2
PHA[.][n]	PHA1[.][n]

	PHA2[.][n]
REFP[.][n]	REFP1[.][n]
	REFP2[.][n]
REFN[n]	REFN1[n]
	REFN2[n] (n = 1 in dual reference mode)
SEN[.][n]	SEN1[.][n]
	SEN2[.][n]
SLOPE[n]	SLOPE1[n]
	SLOPE2[n]
SWEEP	not available
TC[.][n]	TC1[.][n]
	TC2[.][n]
X[.]	X1[.]
	X2[.]
XOF[n_1[n_2]]	XOF1[n_1[n_2]]
	XOF2[n_1[n_2]]
XY[.]	XY1[.]
	XY2[.]
Y[.]	Y1[.]
	Y2[.]
YOF[n_1[n_2]]	YOF1[n_1[n_2]]
	YOF2[n_1[n_2]]
AQN	AQN1
	AQN2
AS	AS1
	AS2
AXO	AXO1

6.7 Programming Examples

6.7.01 Introduction

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

6.7.02 Basic Signal Recovery

In a typical simple experiment, the computer is used to set the instrument controls and then to record the chosen outputs, perhaps as a function of time. At sampling rates of up to a few points per second, there is no need to use the internal curve buffer. The commands to achieve this would therefore be similar to the following sequence:

IE 2	Set reference to external front panel input
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 kΩ to ground
LF 0 0	Turn off line frequency rejection filter
ASM	Auto-Measure (assumes reference frequency > 1 Hz)
TC 13	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 was required. Note that when using an output filter slope of 12 dB/octave a good "rule of thumb" is to wait for a period of four time-constants after the input signal has changed before recording a new value. Hence in a scanning type experiment, the program should issue the commands to whatever equipment causes the input signal to the lock-in amplifier to change, wait for four time-constants, and then record the required output.

6.7.03 Frequency Response Measurement

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

IE 0	Set reference mode to internal
VMODE 1	Single-ended voltage input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 kΩ to ground
LF 0	Turn off line frequency rejection filter
OA. 1.0E0	Set oscillator amplitude to 1.0 V rms
OF. 100.0	Set oscillator frequency to 100 Hz (starting frequency)
SEN 27	Set sensitivity to 1 V full-scale
TC 11	Set time constant to 50 ms
AQN	Auto-Phase

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

OF. XX	Set oscillator frequency to new value XX hertz Software delay of 200 ms (4 × 50 ms) allowing output to stabilize
MAG.	Read Magnitude in volts
PHA.	Read Phase in degrees
FRQ.	Read reference frequency in hertz. This would be same as the oscillator frequency since the unit is operating in the internal reference mode.

until the stop frequency is reached.

6.7.04 X and Y Output Curve Storage Measurement

In this example, the lock-in amplifier is measuring a current input signal applied to the **B** input connector and the measured X channel output and Y channel output are recorded for 10 seconds at a 100 Hz sampling rate. The acquired curves as read back to the computer are required in floating point mode.

The sequence of commands is therefore as follows:

IE 2	Set reference mode to external front panel input
IMODE 1	Normal current input mode
AUTOMATIC 1	AC Gain control automatic
FLOAT 1	Float input connector shell using 1 kΩ to ground
LF 0 0	Turn off line frequency rejection filter
SEN 18	Set sensitivity to 1 nA full-scale
TC 11	Set time constant to 50 ms
AQN	Auto-Phase

Now the curve storage needs to be set up:

NC	Clear and reset curve buffer
CBD 19	Stores X channel output, Y channel output and sensitivity (i.e. bits 0, 1 and 4)
LEN 1000	Number of points = 100 Hz × 10 seconds
STR 10000	Store a point every 10 ms (10,000 μs)

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.

Specifications

Appendix A

Measurement Modes

X	**In-phase**	The unit can simultaneously show any four of these outputs on the front panel display
Y	**Quadrature**	
R	**Magnitude**	
θ	**Phase Angle**	
	Noise	

Harmonic nF, n ≤ 127

Dual Harmonic Simultaneously measures the signal at two different harmonics F_1 and F_2 of the reference frequency

Dual Reference Simultaneously measures the signal at two different reference frequencies, F_1 and F_2, where F_1 and F_2 can be set to be derived from the internal and/or external reference sources.

Tandem Reference A variation of the Dual Reference mode, where the signal is demodulated using the internal reference frequency F_1, and the resulting X1 channel output is passed to a second demodulator running at an external reference frequency F_2

Virtual Reference Locks to and detects a signal without a reference (100 Hz ≤ F ≤ 120 or 250 kHz)

Noise Measures noise in a given bandwidth centered at the reference frequency F

Signal Channel

Voltage Inputs

Modes	A only, -B only or Differential (A-B)
Frequency Response	0.001 Hz ≤ F ≤ 250 kHz
Full-scale Sensitivity	10 nV to 1 V in a 1-2-5 sequence (e.g. 10 nV, 20 nV, 50 nV)
Input Impedance	
FET Input	10 MΩ // 25 pF, AC or DC coupled
Bipolar Input	10 kΩ // 25 pF, input must be DC coupled
Maximum Safe Input	±12.0 V
Voltage Noise (typ)	
FET Input	5 nV/√Hz @ 1 kHz
Bipolar Input	2 nV/√Hz @ 1 kHz
C.M.R.R.	>100 dB @ 1 kHz degrading by no more than 6 dB/octave with increasing frequency
Gain Accuracy	±1.0% typ, ±2.0% max.
Distortion	–90 dB THD (60 dB AC gain, 1 kHz)

Current Input

Mode	Low Noise (10^8 V/A) or Wide B/W (10^6 V/A)
Full-scale Sensitivity	
Low Noise	10 fA to 10 nA in a 1-2-5 sequence
Wide Bandwidth	10 fA to 1 µA in a 1-2-5 sequence
Frequency Response (-3dB)	

Low Noise	0.001 Hz ≤ F ≤ 500 Hz minimum
Wide Bandwidth	0.001 Hz ≤ F ≤ 50 kHz minimum
Impedance	
Low Noise	< 2.5 kΩ @ 100 Hz
Wide Bandwidth	< 250 Ω @ 1 kHz
Noise	
Low Noise	13 fA/√Hz @ 500 Hz
Wide Bandwidth	130 fA/√Hz @ 1 kHz
Gain Accuracy	± 2.0% typ, midband
Either Input Mode:	
Max. Dynamic Reserve	> 100 dB
Line Filter	Filter can be set to attenuate 50/60 Hz, 100/120 Hz, or both frequency bands
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground
Signal Monitor	
Amplitude	±1 V FS. This is the signal after preamplification and filtering, immediately prior to the main ADC
Output Impedance	1 kΩ

Reference Input

TTL Signal	
Frequency Range	0.001 Hz to 120 or 250 kHz (Front panel input)
Frequency Range	0.001 Hz to 3.0 kHz (Rear panel TRIG IN input)
Analog Signal	
Impedance	1 MΩ // 30 pF
Sinusoidal Input	
Level	1.0 V rms
Frequency Range	0.3 Hz to 120 or 250 kHz
Squarewave Input	
Level	250 mV rms
Frequency Range	2 Hz to 120 or 250 kHz

Reference Channel

Phase Set Resolution	0.001º increments
Phase Noise at 100 ms TC, 12 dB/octave slope	
Internal Reference	< 0.0001º rms
External Reference	< 0.01º rms @ 1 kHz
Orthogonality	90º ±0.0001º
Acquisition Time	
Internal Reference	instantaneous acquisition
External Reference	2 cycles + 1 s
Reference Frequency Meter Resolution	4 ppm or 1 mHz, whichever is the greater

Demodulators and Output Processing

Output Zero Stability	
Digital Outputs	No zero drift on all settings
Displays	No zero drift on all settings
DAC Analog Outputs	< 100 ppm/ºC
Harmonic Rejection	-90 dB
Output Filters	

Time Constant	10 µs to 100 ks in a 1-2-5 sequence
Slope (roll-off)	
TC ≤ 5 ms	6 or 12 dB/octave
TC > 10 ms	6, 12, 18, or 24 dB/octave
Synchronous Filter	Available for F < 10 Hz
Offset	Auto/Manual on X and/or Y: ±300% F.S.
Phase Measurement Resolution	≤ 0.01º
Reference Monitor	Rear panel TRIG OUT connector can be configured to generate TTL signal at current reference frequency, internal or external

Oscillator - General

Frequency	
Range	0.001 Hz to 120 or 250 kHz
Setting Resolution	1 mHz
Absolute Accuracy	± 50 ppm
Amplitude	
Range	1 µV to 5 V
Setting Resolution	1 µV when set to less than 1 mV 10 µV when set between 1 mV and 40 mV 250 µV when set between 40.001 mV and 1 V 1.25 mV when set between 1.000001 V and 5 V
Accuracy	±0.2% typ
Stability	50 ppm/ºC
Distortion (THD)	-80 dB @ 1 kHz and 100 mV rms
Output Impedance	50 Ω
Sweep	
Frequency	
Output Range	0.001 Hz to 120 or 250 kHz
Law	Linear or Logarithmic
Step Rate	1000 Hz maximum (1 ms/step)
Amplitude Sweep	
Output Range	0.000000 to 5.000000 V rms
Law	Linear
Step Rate	20 Hz maximum (50 ms/step)

Auxiliary Inputs

ADC 1, 2, 3 and 4	
Maximum Input	±11 V
Resolution	1 mV
Accuracy	±20 mV
Input Impedance	1 MΩ // 30 pF
Sample Rate	200 kHz maximum (one ADC only)
Trigger Mode	Internal, External, or burst
Trigger Input	TTL compatible, rising, or falling edge

Outputs

Analog Outputs	
DAC1	X, X1, Mag2, User DAC1, Output function
DAC2	Y, Y1, Pha2, User DAC2, Output function
DAC3	X2, Mag, Mag1, User DAC3, Output function
DAC4	Y2, Pha, Pha2, User DAC4, Output function

Output Functions	Noise, Ratio, Log Ratio and User Equations 1 & 2.	
Amplitude		
X(1), Y(1), Mag(1), Pha(1)		±2.5 V full-scale; linear to ±300% F.S.
User DACs and Output Functions		±11.0 V full-scale
Impedance	1 kΩ	
Update Rate		
X(1/2), Y(1/2), Mag(1/2), Pha(1/2) @ TC < 1 s		1 MHz
User DACs, Output Functions and TC's ≥ 1 s		1 kHz
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 the status of each input line read	

Data Storage Buffer

Size	100,000 data points max.
Max Storage Rate	
Fast Mode	1 MHz (X1, Y1, X2, Y2, ADC1, Demod I/P 1, Demod I/P 2)
Normal Mode	1 kHz

Interfaces

Built-in web server displays pages containing instrument controls and outputs on any computer running a compatible browser that is connected to the same Ethernet network. USB 2.0, Ethernet, and RS232 allow complete control of instrument settings, and data readout, from other software packages.

General

Power	Via external Model PS0110 universal power supply
Voltage	100 - 240 VAC
Frequency	47 - 63 Hz
Power	40 VA max
Dimensions	
Width	15½" (390 mm)
Depth	10" (250 mm)
Height	
With feet	3" (75 mm)
Without feet	2½" (64 mm)
Weight	6.6 lb. (3.0 kg)

All specifications subject to change without notification

Pinouts

Appendix B

B.1 RS232 Connector Pinout

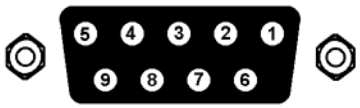


Figure B-1. RS232 Connector (Female)

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 Digital I/O Port Connector

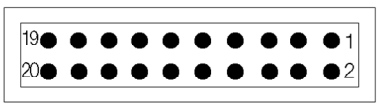


Figure B-2. Digital I/O Port Connector

8-bit TTL-compatible port. Each bit is configurable as an input or output. If configured as an output, the bit status can be set, and if configured as an input it can be read, from the front panel or via the computer interfaces.

When set as an output, each line can drive three LSTTL loads. When set as an input each input presents one LSTTL load. The connector will mate with a 20-pin IDC header plug (not supplied). The pinout is as follows:

Table B-1. Digital I/O Port Connector Pinout

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

D0 = Least Significant Bit
D7 = Most Significant Bit

Cable Diagrams

Appendix C

C.1 RS232 Cable Diagrams

Users who choose to use the RS232 interface to connect the Model 7230 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 C-1 and C-2.

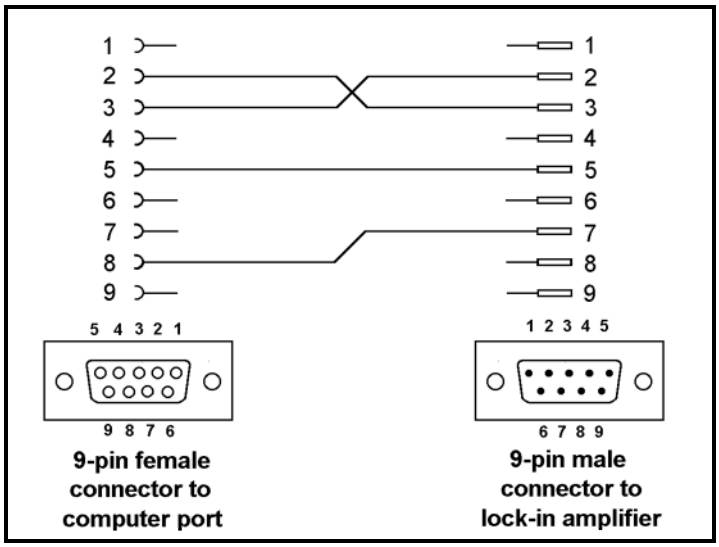


Figure C-1. Interconnecting RS232 Cable Wiring Diagram

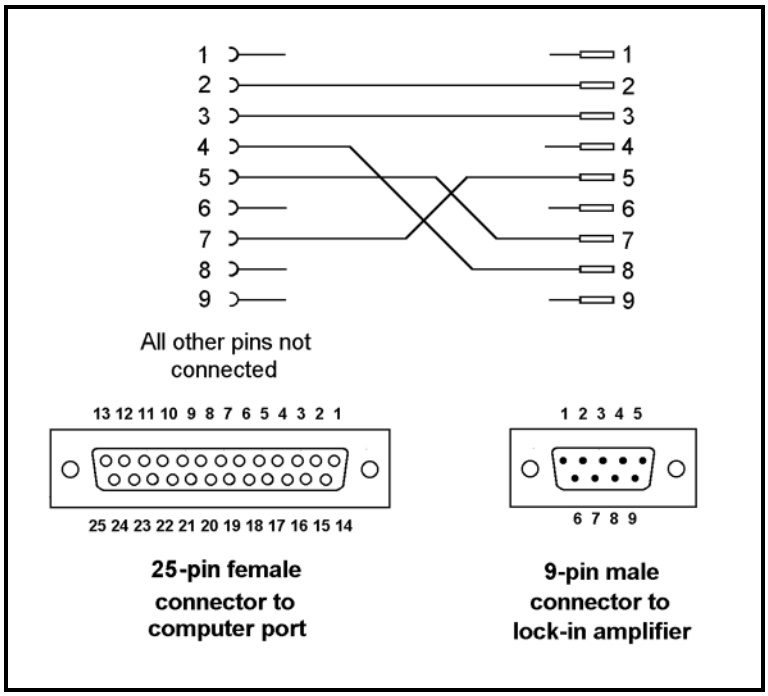


Figure C-2. Interconnecting RS232 Cable Wiring Diagram

Default Settings

Appendix D

Auto Default Function

The Auto-Default computer commands ADF 1 or ADF 2 set the Model 7230's controls as follows:

General	
Full-scale sensitivity	200 mV
AC Gain	0 dB
Time constant	100 ms
Oscillator frequency	1000.000 Hz
Oscillator amplitude	
ADF 1	200 mV
ADF 0	0 mV
AUX DAC1 output	0.000 V
AUX DAC2 output	0.000 V
AUX DAC3 output	0.000 V
AUX DAC4 output	0.000 V
Ref Phase	0.00°
Phase quadrant	0.00°
X channel output offset	0.00%
Y channel output offset	0.00%
Ref Harmonic	1st
Signal Channel	
Input coupling	AC
Input Shell	Ground
Input mode	Single-ended voltage mode
Input connector	**A** input connector
Input Device	FET
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
Time Constant Mode	FAST
Output Offset & Expand	
Offset Status	Off
Output Expand	Off
Output Equations	
Equation #1	((X-X) × X)/X = zero
Equation #2	((X-X) × X)/X = zero
Equations 1 & 2; C1, C2	0
Frequency Sweep	
Start Frequency	0.000 Hz
Stop Frequency	0.000 Hz
Step Size	0.000 Hz
Time/Step	0.000 s

Armed	No
Law	Logarithmic

Amplitude Sweep

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

Configuration

Operating mode	Single Reference
Display screen	Turned on
Noise Measurement Mode	OFF
Noise Buffer Length	4 seconds

Curve Buffer

Curve Mode	Standard
Time/Point	10 ms
Length	100,000
Curve Start Trigger	Internal
Curve Stop Trigger	Internal

Curve Select

Selected curve	X

ADC Menu

ADC Trigger Mode	Internal
Time Per Point	1 ms

DACs

USER DAC1 - USER DAC 4	0.000 V
DAC1	X%
DAC2	Y%
DAC3	User setting
DAC4	User setting

Digital Port

D0 to D7 direction	All configured as outputs
D0 to D7 status	Logic zero

The Auto-Default function on the Rear Panel web control page and the ADF 0 computer command set the Model 7230's controls and output displays as above, and in addition sets the communications interface parameters as follows:

RS232 Settings

Baud rate	19,200
Data bits	7 + 1 Parity
Delimiter	, (044)
Character echo	On
Parity	Even
Prompt character	On

Ethernet Settings (***Note: These only apply if the CONF1G switch 1 is set to position "0."***)

IP Address	169.254.150.230
Subnet Mask	255.255.255.000
Default Gateway	000.000.000.000

Alphabetical Listing of Commands

Appendix E

? 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 6.7.09) 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>

ACGAIN [n] AC Gain control

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

n	AC Gain	n	AC Gain
0	0 dB	8	48 dB
1	6 dB	9	54 dB
2	12 dB	10	60 dB
3	18 dB	11	66 dB
4	24 dB	12	72 dB
5	30 dB	13	78 dB
6	36 dB	14	84 dB
7	42 dB	15	90 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 -11000 to +11000, corresponding to voltages from -11.000 V to +11.000 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
2	All instrument settings, with the exception of the communications settings, are returned to their factory default values, except the oscillator amplitude is set to 0 V rms.

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.

AMCENTERV[.] [n] Oscillator amplitude modulation center voltage command

The value of n sets the oscillator amplitude modulation center voltage; in fixed point mode, n is an integer in the range -10000 to +10000, corresponding to voltages from -10.000 V to +10.000 V, and in floating point mode, it is in volts.

NOTE: The span voltage plus the center voltage cannot exceed ±10.000 V.

AMDEPTH [n] Oscillator amplitude modulation dept control

The value of n sets the oscillator amplitude modulation depth in percent, from 0 to 100.

AMFILTER [n] **Oscillator amplitude modulation filter control command**

The value of n sets the oscillator amplitude modulation voltage low-pass filter control in the range 0 to 10. The value of 0 gives the widest bandwidth for this filter, with the value of 10 the lowest.

AMSOURCE [n] **Oscillator amplitude modulation voltage source command**

The value of n selects the source of signal used to modulate the oscillator amplitude in accordance with the following table:

n	Function
0	ADC 1 input
1	Signal from external reference channel.

AMVSPAN[.] [n] **Oscillator amplitude modulation voltage span command**

The value of n sets the oscillator amplitude modulation span voltage; in fixed point mode, n is an integer in the range 0 to +10000, corresponding to a range from ±0.000 V to ±10.000 V, and in floating point mode, it is in volts.

NOTE: The span voltage plus the center voltage cannot exceed ±10.000 V.

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.

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.

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

Sets the start amplitude for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 5.000 V. In fixed point mode, n is in microvolts rms, and in floating point mode, n is in volts rms.

ASTEP[.] [n] **Oscillator amplitude sweep step size**

Sets the amplitude step size for a subsequent sweep of the internal oscillator amplitude, in the range 0 to 5.000 V. In fixed point mode, n is in microvolts 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 5.000 V. In fixed point mode, n is in microvolts rms and in floating point mode n is in volts rms.

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

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

AXO **Auto-Offset**

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.

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 = 0 and BYTE = 0, all outputs are low, and when BYTE = 255, all are high.

C1 n_1 [n_2] **Equation Constant C1**

The value of n_2 sets the value of constant C1 for equation #1 (n_1 = 1) or equation #2 (n_1 = 2) in the range -30,000 to +30,000.

C2 n_1 [n_2] **Equation Constant C2**

The value of n_2 sets the value of constant C2 for equation #1 (n_1 = 1) or equation #2 (n_1 = 2) in the range -30,000 to +30,000.

CBD [n] **Curve buffer define for Standard Mode Buffer**

Defines which data outputs are stored in the standard curve mode 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 below:

Table E-1. CBD Bit Function and Range

Bit	Decimal Value	Output and Range
0*	1	X Output (±10000 FS)
1*	2	Y Output (±10000 FS)
2*	4	Magnitude Output (0 to +10000 FS)
3*	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2, 3 =0, 32, 64, 128)
5*	32	Noise (0 to +10000 FS)
6*	64	Ratio (±10000 FS)
7*	128	Log ratio (-3000 to +2000)
8*	256	ADC1 (±10000 = ±10.0 V)
9*	512	ADC2 (±10000 = ±10.0 V)
10*	1024	ADC3 (±10000 = ±10.0 V)
11*	2048	ADC4 (±10000 = ±10.0 V)
12*	4096	DAC1 (±10000 = ±10.0 V)
13*	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference Frequency bits 0 to 15 (millihertz)
16	65536	Reference frequency bits 16 to 31 (millihertz)
Dual modes only:		
17	131072	X_2 Output (±10000 FS)
18	262144	Y_2 Output (±10000 FS)
19	524288	Magnitude2 Output (0 to +10000 FS)
20	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

100,000 points are available for data storage in the standard curve buffer mode, shared equally between the specified curves. For example, if 16 outputs are stored then the maximum number of storage points would be 6250 (i.e. 100000/16). 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 100000 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] DAC analog output control

Defines what outputs appear on the **DAC1, DAC2, DAC3,** and **DAC4** connectors on the rear panel.

n_1 is compulsory and is 1 for DAC1, 2 for DAC2, 3 for DAC3, or 4 for DAC4

n_2	Signal (DAC1)
0	X1% (2.5 V FS)
1	Noise % (2.5 V FS)
2	Ratio: (10 × X1%/ADC 1)
3	Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4	Equation 1
5	Equation 2
6	User DAC1
7	Main signal channel ADC output (digital signal monitor 1)
8	Magnitude2 % (2.5 V FS) (dual mode only)

n_2	Signal (DAC2)
0	Y1 % (2.5 V FS)
1	Noise % (2.5 V FS)
2	Ratio: (10 × X1%/ADC 1)
3	Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4	Equation 1
5	Equation 2
6	User DAC2
7	Ext ADC1 monitor
8	Phase2: +9 V = +180°, -9 V = -180° (dual mode only)

n_2	Signal (DAC3)
0	Magnitude1 % (2.5 V FS)
1	Noise % (2.5 V FS)
2	Ratio: (10 × X1%/ADC 1)
3	Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4	Equation 1

5 Equation 2
6 User DAC3
7 Input to second demodulator (digital signal monitor 2)
8 X2 % (2.5 V FS) (dual mode only)

n_2 Signal (DAC4)
0 Phase1: +9 V = +180°, -9 V = -180°
1 Noise % (2.5 V FS)
2 Ratio: (10 × X1%/ADC 1)
3 Log Ratio: $\log_{10}$ (10 × X1%/ADC1)
4 Equation 1
5 Equation 2
6 User DAC4
7 Synchronous oscillator
8 Y2 % (2.5 V FS) (dual mode only)

NOTE: n_2 = 1 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.

CMODE [n] Curve buffer mode

The value of n sets the curve buffer acquisition mode in accordance with the following:

n mode
0 Standard
1 Fast

DAC[.] n_1 [n_2] Set user DAC output voltage controls

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

The value of n_2 specifies the voltage to be output.

In fixed point mode, it is an integer in the range -10000 to +10000, corresponding to voltages from -10.000 V to +10.000 V, and in floating point mode, it is in volts.

DATE Last calibration date

The response is a six-digit number giving the date of the last calibration where the first two digits are the day, the second two digits are the month, and the last two digits are the year (in the 21st century).

DC[.] n Dump acquired curve(s) to computer

The operation of this command depends on whether data has been stored into the Standard or Fast Mode curve buffers.

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

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

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

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

Fast Mode
Only fixed point mode is supported. One curve at a time is transferred, with the selected curve being dumped via the computer interface in decimal format.

The value of n defines the curve to be transferred according to the following:

n	Output and range
0	X Output (±10000 FS)
1	Y Output (±10000 FS)
2	Main signal channel ADC output (digital signal monitor 1
3	ADC1 (±10000 = ±10.0 V)
4	ADC2 (±10000 = ±10.0 V)

Dual modes only:

5	X_2 Output (±10000 FS)
6	Y_2 Output (±10000 FS)
7	Input to second demodulator (digital signal monitor 2)

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.

DCB n Dump acquired curve(s) to computer in binary format

The operation of this command depends on whether data has been stored into the Standard or Fast Mode curve buffers.

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

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

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

Reference Frequency = (65536 × value in Curve 16) + (value in Curve 15)

The computer program's subroutine which reads the responses to the DCB command needs to be able to handle the potentially very large data blocks (200 k bytes in the case of one 100 k curve) that can be

generated.

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

Fast Mode
One curve at a time is transferred, with the selected curve being dumped via the computer interface in binary format, using two bytes per point. Data is sent using 16-bit 2's complement encoding, with the MSB sent first.

The value of n defines the curve to be transferred according to the following:

n	Output and range
0	X Output (±10000 FS)
1	Y Output (±10000 FS)
2	Main signal channel ADC output (digital signal monitor 1)
3	ADC1 (±10000 = ±10.0 V)
4	ADC2 (±10000 = ±10.0 V)

Dual modes only:

5	X_2 Output (±10000 FS)
6	Y_2 Output (±10000 FS)
7	Input to second demodulator (digital signal monitor 2)

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

DCCOUPLE [n] Input coupling control

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

n	Coupling mode
0	AC coupled
1	DC coupled

DCT n Dump acquired curves to computer in tabular format

NOTE: This command is only available when the curve buffer is set to Standard Mode.

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:

Table E-2. DCT Bit Function and Range

Bit	Decimal Value	Output and Range
0	1	X Output (±10000 FS)
1	2	Y Output (±10000 FS)
2	4	Magnitude Output (0 to +10000 FS)
3	8	Phase (±18000 = ±180°)
4	16	Sensitivity setting (1 to 27) + IMODE (0, 1, 2, 3 = 0, 32, 64, 128)
5	32	Noise (0 to +10000 FS)
6	64	Ratio (±10000 FS)
7	128	Log ratio (-3000 to +2000)
8	256	ADC1 (±10000 = ±10.0 V)
9	512	ADC2 (±10000 = ±10.0 V)
10	1024	ADC3 (±10000 = ±10.0 V)
11	2048	ADC4 (±10000 = ±10.0 V)
12	4096	DAC1 (±10000 = ±10.0 V)
13	8192	DAC2 (±10000 = ±10.0 V)
14	16384	EVENT variable (0 to 32767)
15	32768	Reference frequency (millihertz)
16	65536	Reference frequency (millihertz)
Dual modes only:		
17	131072	X_2 Output (±10000 FS)
18	262144	Y_2 Output (±10000 FS)
19	524288	Magnitude2 Output (0 to +10000 FS)
20	1048576	$Phase_2$ Output (±18000 = ±180°)
21	2097152	$Sensitivity_2$ setting (1 to 27) + IMODE (0, 1, 2 = 0, 32, 64)

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

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

DD [n] Define delimiter control

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

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

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

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

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

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

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:

Table E-3. DCT Bit Function and Range

n	Variable	Range
0	X or X1	±30000
1	Y or Y1	±30000
2	MAG or MAG1	0 to 30000
3	PHA or PHA1	±18000
4	ADC1	±10000
5	ADC2	±10000
6	ADC3	±10000
7	ADC4	±10000
8	C1	0 to 100000
9	C2	0 to 100000
10	0	zero
11	1	unity
12	FRQ	0 to 2000000000 (i.e. reference frequency in mHz)*
13	OSC	0 to 2000000000 (i.e. oscillator frequency in mHz)*
Dual modes only:		
14	X2	±30000
15	Y2	±30000
16	MAG2	0 to 30000
17	PHA2	±18000

*Parameter n_5 is the only one that can be set to values of 12 or 13.

DEMOD2SRC [n] Second stage demodulator signal source

In the dual reference mode, the value of n sets the source of the signal for the second stage demodulators according to the following:

n Signal source
0 Main signal channel ADC (i.e. both demodulators are fed the same signal)
1 ADC1 - rear panel auxiliary ADC input
2 Demodulator 1 X channel output - this is the Tandem demodulation 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.

EQU n Output result of equation #1 or equation #2

The value returned is the output of the user equation #1 (n = 1) or equation #2 (n = 2), where the equations are defined using the Output equations control panel (see Section 5.3.27). The possible range is ±2,147,483,647 (signed 32-bit integer).

EVENT [n] Event marker control

During a curve acquisition into the standard curve buffer, 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

Expands X and/or Y channel outputs by a factor of 10. This changes the analog outputs full-scale to ±10% if X or Y selected. The value of n has the following significance:

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

FASTMODE [n] Output Filter Mode Control

The value of n sets the output filter mode control according to the following:

n	Function
0	Fast mode off
1	Fast mode on

When the fast analog output mode is turned off, the available output filter time constant is restricted to 5 ms or greater, but all four filter slopes are available (i.e. 6, 12, 18, and 24 dB/octave). Conversely, when the mode is turned on, time constants down to 10 µs can be selected, but the slope is limited to either 6 or 12 dB/octave.

FET [n] FET input selection

The value of n controls the input device used at the signal input according to the following:

n	Input device
0	Bipolar
1	FET

FLOAT [n] Input connector shield float/ground control

n	Selection
0	Ground
1	Float (connected to ground via a 1 kΩ resistor)

FMCENTERF[.] [n] Oscillator frequency modulation center frequency command

In fixed point mode, n sets the oscillator frequency modulation center frequency in mHz. The range of n is 0 to 120000000 or 250000000 representing 0 to 120.0 or 250.0 kHz; in floating point mode, n sets the center frequency in the range 0 to 1.2E5 or 2.5E5.

Note: The span frequency plus the center frequency cannot exceed 120.0 or 250.0kHz; the center frequency must also be greater than the span frequency.

FMCENTERV[.] [n] Oscillator frequency modulation center voltage command

The value of n sets the oscillator frequency modulation center voltage; in fixed point mode, n is an integer in the range -10000 to +10000, corresponding to voltages from -10.000 V to +10.000 V, and in floating point mode, it is in volts.

NOTE: The span voltage plus the center voltage cannot exceed ±10.000 V.

FMFILTER [n] **Oscillator frequency modulation filter control command**

The value of n sets the oscillator frequency modulation voltage low-pass filter control in the range 0 to 10. The value of 0 gives the widest bandwidth for this filter, with the value of 10 the lowest.

FMSPANF[.] [n] **Oscillator frequency modulation span frequency command**

In fixed point mode, n sets the oscillator frequency-modulation span frequency in millihertz. The range of n is 0 to 60000000 or 125000000 representing 0 to ± 60 kHz or 125 kHz; in floating point mode, n sets the span frequency in the range 0 to 6.0E4 or 1.25E5.

Note: The center frequency ± the span frequency must not exceed the frequency limits of the oscillator (0 to 120 or 250 kHz). Hence the center frequency plus the span frequency cannot exceed 120.0 or 250.0 kHz and the center frequency must be greater than or equal to the span frequency. For example, with an instrument fitted with the 7230/99 upper frequency extension option and a 125 kHz center frequency the maximum span frequency is ± 125 kHz; at 10k Hz center frequency the maximum span frequency is ± 10 kHz; at 240 kHz center frequency the maximum span frequency is also ± 10 kHz. When setting the center frequency and span frequency under computer control, it is recommended to first set the span frequency to zero followed by the center frequency to the required value and finally the span frequency to the required value. This will avoid potential problems with the new center frequency being rejected because it is not a legal value when compared with the old span frequency.

FMVSPAN[.] [n] **Oscillator frequency modulation voltage span command**

The value of n sets the oscillator frequency modulation span voltage; in fixed point mode, n is an integer in the range 0 to +10000, corresponding to a range from ±0.000 V to ±10.000 V, and in floating point mode, it is in volts.

NOTE: The span voltage plus the center voltage cannot exceed ±10.000 V.

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 120 or 250 kHz. In fixed point mode, n is in millihertz, and in floating point mode, n is in hertz.

FSTEP[.] [n_1 n_2] **Oscillator frequency sweep step size and type**

The frequency may be swept either linearly or logarithmically, as specified by parameter n_2. The step size is specified by parameter n_1.

Log sweep $n_2 = 0$

In fixed point mode, n_1 is the step size in thousandths of a percent.

In floating point mode, n_1 is in percent. The range of n_1 is 0 to 100.000%.

Linear sweep $n_2 = 1$

In fixed point mode, n_1 is the step size in millihertz.

In floating point mode, n_1 is in hertz. The range of n_1 is 0 to 120 or 250 kHz.

Linear seek sweep $n_2 = 2$

In fixed point mode, n_1 is the step size in millihertz.

In floating point mode, n_1 is in hertz. The range of n_1 is 0 to 120 or 250 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 120 or 250 kHz. In fixed point mode, n is in millihertz, and in floating point mode, n is in hertz.

GWADDR [n1 n2 n3 n4] Ethernet Gateway Address

When this command is sent without parameters, the instrument responds with the current gateway address, e.g. 169.254.0.1.

When sent with the four parameters, the command sets the gateway address that will be used when the Model 7230 is set to static IP address mode (via the rear panel Config Switch 2, see Section 4.2.07).

The parameters are separated by a space character and not by a dot, e.g.

GWADDR 169 254 0 1

sets the gateway address 169.254.0.1

Note that the setting can be overridden if the IP address is set using the IPADDR command.

HC Halt curve acquisition

Halts curve acquisition in progress. It is effective during both single (data acquisition initiated by TD command) and continuous (data acquisition initiated by TDC command) curve acquisitions. The curve may be restarted by means of the TD, TDT or TDC command, as appropriate. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10, or 100, then this sweep will be stopped as well.

ID Identification

Causes the lock-in amplifier to respond with the number 7230.

IE [n] Reference channel source control (Internal/External)

In Single Reference and Dual Harmonic mode, the value of n sets the reference input mode according to the following:

n	Selection
0	INT (internal)
1	EXT TTL (external front panel **REF** input)
2	EXT ANALOG (external front panel **REF** input)

This command is invalid in Dual Reference mode.

IE1 [n] Reference channel 1 source control, Dual Reference

In Dual Reference mode, the value of n sets the reference channel 1 source according to the following table:

n	Selection
0	INT (internal)
1	EXT TTL (external front panel **REF** input, except if IE2 = 2, when the reference should be applied to the rear panel **TRIG IN** input, and be no greater than 3.0 kHz)
2	EXT ANALOG (external front panel **REF** input)

This command is only valid in Dual Reference mode.

IE2 [n] Reference channel 2 source control, Dual Reference

In Dual Reference mode, the value of n sets the reference channel 2 source according to the following:

n	Selection
0	INT (internal)
1	EXT TTL (external front panel **REF** input except if IE1 = 2, when the reference should be applied to the rear panel **TRIG IN** input, and be no greater than 3.0 kHz)
2	EXT ANALOG (external front panel **REF** input)

This command is only valid in Dual Reference mode

IMODE [n] Current/Voltage mode input selector

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

n	Input mode
0	Current mode off - voltage mode input enabled
1	High bandwidth current mode enabled - connect signal to **B (I)** input connector
2	Low noise current mode enabled - connect signal to **B (I)** 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.

IPADDR [n1 n2 n3 n4] Ethernet IP Address

When this command is sent without parameters, the instrument responds with the current IP address, e.g. 169.254.0.10.

When sent with the four parameters, the command sets the IP address that will be used when the Model 7230 is set to static IP address mode (via the rear panel Config Switch 2, see Section 4.2.07).

The parameters are separated by a space character and not by a dot, e.g.

IPADDR 169 254 0 10

sets the IP address to 169.254.0.10. Based on the IP address, this command will also generate a default subnet mask and gateway address so if values other than the defaults are required set the IP address before setting the subnet mask and gateway address otherwise, they will be overwritten.

IPLOCK Restrict Ethernet Access

When this command is sent via the Ethernet interface, subsequent connection requests and hence commands will only be accepted if sent from the same IP address, preventing unauthorized access to the instrument.

IPUNLOCK Remove Ethernet Access Restrictions

When this command is sent via the Ethernet interface, subsequent connection requests and hence commands will be accepted from any computer on the same network as the instrument.

LEN [n] Curve length control

The value of n sets the curve buffer length in effect for data acquisition. In fast curve buffer mode, the maximum allowed value is 100,000; in standard mode, it 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, in standard mode if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.

LF [n_1 n_2] Signal channel line frequency rejection filter control

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

n_1	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

n_2	Notch Filter Center Frequencies
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

LOCK System lock control

Updates all frequency-dependent gain and phase correction parameters.

LR[.] Log Ratio output

In integer mode, the LR command reports a number equivalent to 1000×log(X/ADC1) where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command. The response range is -3000 to +2079.

In floating point mode, the LR. command reports a number equivalent to log(X/ADC1). The response range is -3.000 to +2.079.

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:

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.

MENABLE [n] **Oscillator amplitude/frequency modulation enable command**

The value of n enables the oscillator amplitude modulation function in accordance with the following:

n	Function
0	Oscillator amplitude/frequency modulation disabled
1	Oscillator amplitude modulation enabled
2	Oscillator frequency modulation enabled

MP[.] **Magnitude, phase**

This returns the MAG and PHA outputs separated by the defined delimiter.

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	X channel output overload (> ±300 %FS)
Bit 1	Y channel output overload (> ±300 %FS)
Bit 2	X2 channel output overload (> ±300 %FS)
Bit 3	Y2 channel output overload (> ±300 %FS)
Bit 4	CH1 output overload
Bit 5	CH2 output overload
Bit 6	CH3 output overload
Bit 7	CH4 output overload

NAME **Set/Read Instrument Name**

The NAME command allows the user to store an ASCII text string as “name” to help identify the instrument. This is especially useful when there are several instruments connected to the same Ethernet network, since it can be used as a more convenient alternative to the serial number as an aid to identification.

When sent with a string of up to 64 characters as a parameter, the string will be stored. When sent without characters the instrument will respond with the stored string. For example:

NAME Optical absorption lab lock-in amplifier

will set the name to “Optical absorption lab lock-in amplifier”; sending NAME with no parameters will return:

Optical absorption lab lock-in amplifier

NC **New curve**

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

NHZ.

Causes the lock-in amplifier to respond with the square root of the noise spectral density measured at the Y channel output, expressed in volt/√Hz or amps/√Hz referred to the input. This measurement assumes that the Y channel output is Gaussian with zero mean (Section 3.3.20). The command is only available in floating point mode.

NN[.] **Noise output**

In fixed point mode, causes the lock-in amplifier to respond with the mean absolute value of the Y channel output in the range 0 to 12000, full-scale being 10000. If the mean value of the Y channel output is zero, this is a measure of the output noise.

In floating point mode, causes the lock-in amplifier to respond in volts.

NNBUF [n] Noise Buffer Length control

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

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:

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

When the noise measurement mode is turned on, the output filter time constant is automatically adjusted until it lies in the range 500 µs to 10 ms inclusive, the synchronous time constant control is turned off, the fast analog output mode is turned on (FASTMODE 1), 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

microvolts rms. The range of n is 0 to 5000000 representing 0 V to 5 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 120000000 or 250000000 representing 0 to 120 kHz or 250 kHz.

In floating point mode, n sets the oscillator frequency in Hz. The range of n is 0 to 1.2E5 or 2.5E5

PHA[.] Signal phase

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

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

PHASEPOL [n] Signal phase polarity control

n	Function
0	Operation is the same as earlier ***SIGNAL RECOVERY*** lock-in amplifiers, such as the Models 7220, 7225, 7265, 7265, 7280, 5209, and 5210.
1	Operation is the same as earlier versions of firmware in the Models 7270, 7124, and 7230

PORTDIR [n] Digital port direction control

The value of n determines which of the eight lines on the digital port are configured as inputs and which as outputs. The parameter n is a decimal number whose bit-wise interpretation defines whether the corresponding line is an input or output. The line is an input if the corresponding bit is a “1”. For example:

n	status
0	All lines configured as outputs
1	D0 = input, D1 - D7 = outputs
2	D1 = input, D0 and D2 - D7 = outputs
4	D2 = input, D0 - D1 and D3 - D7 = outputs
8	D3 = input, D0 - D2 and D4 - D7 = outputs
16	D4 = input, D0 - D3 and D5 - D7 = outputs
32	D5 = input, D0 - D4 and D6 - D7 = outputs
64	D6 = input, D0 - D5 and D7 = outputs
128	D7 = input, D0 - D6 outputs
255	All lines configured as inputs

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 instrument rear panel digital port. Hence, for example, if PORTDIR = 255 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

The value of n sets the reference mode of the instrument according to the following:

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 6.6.14.

REFMON [n] Reference monitor control

The value of n sets the function of the rear panel **TRIG OUT** connector according to the following:

n	Mode
0	Trig Out signal is generated by curve buffer triggering
1	Trig Out signal is a TTL signal at the reference frequency (i.e. it is a Reference Monitor output)

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 127.

REFP[.] [n] Reference phase control

In fixed point mode, n sets the phase in millidegrees in the range ±360000.

In floating point, mode n sets the phase in degrees.

RS [n_1 [n_2]] Set/read RS232 interface parameters

Table E-4. RS Baud Rates

n_1	Baud rate (bits per second)	n_1	Baud rate (bits per second)
0	75	7	1800
1	110	8	2000
2	134.5	9	2400
3	150	10	4800
4	300	11	9600
5	600	12	19200
6	1200	13	38400

The lowest five bits in n_2 control the other RS232 parameters according to the following table:

Table E-5. RS232 Parameters

Bit Number	Bit Negated	Bit Asserted
0	data = 7 bits	data = 8 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

RT[.] **Ratio output**

In integer mode, the RT command reports a number equivalent to 1000×X/ADC1 where X is the value that would be returned by the X command and ADC1 is the value that would be returned by the ADC1 command.

In floating point mode, the RT. command reports a number equivalent to X/ADC1.

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:

Table E-6. SEN IMODE Controls

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

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.

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:

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

When:

a) The fast output filter mode is turned on, or
b) Noise measurement mode is turned ON (NOISEMODE 1)

the selection is according to the following:

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

SNMASK [n1 n2 n3 n4] Ethernet Subnet Mask

When this command is sent without parameters, the instrument responds with the current subnet mask e.g. 255.255.0.0.

When sent with the four parameters, the command sets the subnet mask that will be used when the Model 7230 is set to static IP address mode (via the rear panel Config Switch 2, see Section 4.2.07).

The parameters are separated by a space character and not by a dot, e.g.

SNMASK 255 255 0 0 sets the subnet mask to 255.255.0.0.

Note that the setting can be overridden if the IP address is set using the IPADDR command.

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

In fixed point mode, sets the sweep rate in milliseconds per step, and in floating point mode, sets the rate in seconds. The range of n is 1 to 1000000 (1 ms to 1000 s).

ST Report status byte

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

Bit 0	Command complete
Bit 1	Invalid command
Bit 2	Command parameter error
Bit 3	Reference unlock
Bit 4	Output overload - read overload byte to determine location
Bit 5	New ADC values available after external trigger
Bit 6	Input overload
Bit 7	Data available

STR [n] Storage interval control

Sets the time interval between successive points being acquired into the curve buffer. n specifies the time interval in microseconds with a resolution of 1 µs. In fast curve buffer mode, the shortest time that can be specified is 1 µs; in standard mode, it is 1000 µs, or 1 ms.

SWEEP [n] Oscillator frequency and amplitude sweep control

n	Sweep status
0	Stop
1	Start/continue frequency sweep
2	Start/continue amplitude sweep
3	Start/continue frequency sweep and amplitude sweep
5	Pause frequency sweep
6	Pause amplitude sweep
7	Pause frequency sweep and amplitude sweep
9	Link frequency sweep to curve buffer acquisition
10	Link amplitude sweep to curve buffer acquisition
11	Link frequency and amplitude sweep to curve buffer acquisition

This command is used to start or stop the internal oscillator frequency or amplitude sweep, or to specify that the sweep should be linked to the curve buffer data acquisition.

In the normal mode, when a frequency and/or amplitude sweep has been defined, applying SWEEP with a parameter of 1, 2, or 3 will start it. The sweep can be paused using the command with the correct value of n for the sweep in progress. For example, if a frequency sweep is started using SWEEP 1 then it can only be paused by sending SWEEP 5. Similarly, it can only be continued by sending SWEEP 1. The command SWEEP 0 will, however, stop either or both types of sweep.

When n is equal to 9, 10, or 11 the instrument is set to link the oscillator frequency and/or amplitude sweeps to the curve buffer. The SWEEP command continues to function as a write/read command except when the curve buffer acquisition is actually running. In such cases, the SWEEP command changes to read-only and will only report values of 9, 10, or 11, indicating what type of linking is active. The sweep can then only be stopped by stopping the curve buffer, using the HC command. However, the user can still determine the progress of the sweep using the curve buffer monitor "M" command and the OF and/or OA (oscillator frequency and amplitude) commands.

SYNC [n] **Synchronous time constant control**

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

TADC [n] **Auxiliary analog-to-digital input trigger mode**

The value of n sets the trigger modes for the auxiliary ADC inputs according to the following:

n	Trigger Mode
0	Internal (1 kHz)
1	External - apply trigger to **ADC TRIG IN** connector
2	Burst ADC1 (5 µs per point, only ADC1 is converted)
3	Burst ADC1 & ADC2

TC [n]
TC. **Filter time constant control**

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

Table E-7. IMODE Control

	NOISEMODE = 0	NOISEMODE = 1		NOISEMODE = 0	NOISEMODE = 1
n	**time constant**	**time constant**	**n**	**time constant**	**time constant**
0	10 µs	N/A	16	2 s	N/A
1	20 µs	N/A	17	5 s	N/A
2	50 µs	N/A	18	10 s	N/A
3	100 µs	N/A	19	20 s	N/A
4	200 µs	N/A	20	50 s	N/A
5	500 µs	500 µs	21	100 s	N/A
6	1 ms	1 ms	22	200 s	N/A
7	2 ms	2 ms	23	500 s	N/A
8	5 ms	5 ms	24	1 ks	N/A
9	10 ms	10 ms	25	2 ks	N/A
10	20 ms	N/A	26	5 ks	N/A
11	50 ms	N/A	27	10 ks	N/A
12	100 ms	N/A	28	20 ks	N/A
13	200 ms	N/A	29	50 ks	N/A
14	500 ms	N/A	30	100 ks	N/A
15	1 s	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 12 command were sent and the noise measurement mode was turned off, TC would report 12 and TC. would report 1.0E-01, i.e. 0.1 s or 100 ms.

TD Take data

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10, or 11, then this sweep will be started as well.

TDC n 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 or on receipt of a trigger at the TRIG in connector, in accordance with the following:

n	Start condition	Stop condition
0	On command	On HC command
1	On command	Ext rising edge
2	On command	Ext falling edge

Note also that if sent without a parameter the command functions as if TDT 0 had been sent.

The buffer is circular in the sense that when it has been filled, new data overwrites earlier points.

TDT n Take data triggered

Sets the instrument so that data acquisition is initiated on receipt of various trigger conditions at the **TRIG** connector on the rear panel. If an oscillator frequency and/or amplitude sweep has been defined and linked to the curve buffer using the SWEEP command with a parameter of 9, 10, or 11, then this sweep will be started as well.

There are two basic triggers. The Acquisition trigger is a "per curve" (start) or "per point" (sample) trigger and can be active on either the rising or falling edge. The Stop trigger sets the condition by which acquisition finishes. In normal operation this is simply when the number of points specified by the LEN command parameter have been acquired, but it is also possible to leave acquisition running until an HC command is sent or until either a rising or falling edge occurs at the trigger input.

The trigger modes, set by the value of n, are as follows:

Table E-8. Trigger Modes

n	Start Condition	Sample Condition	Stop Condition
0	Ext rising edge	---	Points = LEN
1	On command	Ext rising edge	Points = LEN
2	Ext falling edge	---	Points = LEN
3	On command	Ext falling edge	Points = LEN
4	Ext rising edge	---	On HC Command
5	On command	Ext rising edge	On HC Command
6	Ext falling edge	---	On HC Command
7	On command	Ext falling edge	On HC Command
8	Ext rising edge	---	Ext falling edge
9	Ext falling edge	---	Ext rising edge

Note that in modes 1, 3, 5, and 7 the maximum trigger rate is 1000 Hz and the storage interval control setting have no effect.

TRIGOUT [n] **Curve buffer trigger output**

The value of n defines the type of trigger output generated when a buffer acquisition is run in accordance with the following:

n	Trigger
0	Trigger generated once per curve, at start of curve
1	Trigger generated once per point

TRIGOUTPOL [n] **Curve buffer trigger output polarity**

The value of n defines the polarity of the trigger output generated when a buffer acquisition is run in accordance with the following:

n	Trigger Output
0	Rising-edge
1	Falling edge

USBTERM [n] **Set/read USB terminator**

The value of n sets the USB terminator according to the following:

n	Function
0	A null character (ASCII 0)
1	A null character (ASCII 0), followed by a byte representing the value of the status Byte (Table 6-1), followed by a byte representing the value of the Overload Byte (Table 6-1)

VER **Report firmware version**

Causes the lock-in amplifier to respond with the firmware version number, as also displayed on the Configuration menu.

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.

VRLOCK [n] **Virtual reference mode lock**

The Seek option of the frequency sweep mode must be used before issuing this command, for which the value of n has the following significance:

n	Mode
0	Disables virtual reference mode
1	Enters virtual reference mode by enabling tracking of the signal frequency

X[.] **X channel output**

In fixed point mode causes the lock-in amplifier to respond with the X demodulator output in the range ±30000, full-scale being ±10000.

In floating point mode causes the lock-in amplifier to respond with the X demodulator output in volts or amps.

XOF [n_1 [n_2]] X channel output offset control

n_1 Selection
0 Disables offset
1 Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

XY[.] X, Y channel outputs

This returns the X and Y outputs separated by the defined delimiter.

Y[.] Y channel output

In fixed point mode, causes the lock-in amplifier to respond with the Y demodulator output in the range ±30000, full-scale being ±10000.

In floating point mode, causes the lock-in amplifier to respond with the Y demodulator output in volts or amps.

YOF [n_1 [n_2]] Y channel output offset control

n_1 Selection

0 Disables offset facility
1 Enables offset facility

The range of n_2 is ±30000 corresponding to ±300% full-scale.

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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 in AMETEK Advanced Measurement Technology, Inc equipment, the original manufacturer's 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.

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SHOULD THE EQUIPMENT REQUIRE SERVICE

A. Contact the 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. Ametek 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. Username (instrument user)
3. User address
4. Address to which the instrument should be returned
5. User telephone number and extension
6. Symptoms (in detail, including control settings)
7. The purchase order number for repair charges (does not apply to repairs in warranty)
8. Shipping instructions (if the user wishes to authorize shipment by any method other than normal surface transportation)

C. If any difficulties are experienced in obtaining service please contact:

SIGNAL RECOVERY Service
AMETEK Advanced Measurement Technology, Inc
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