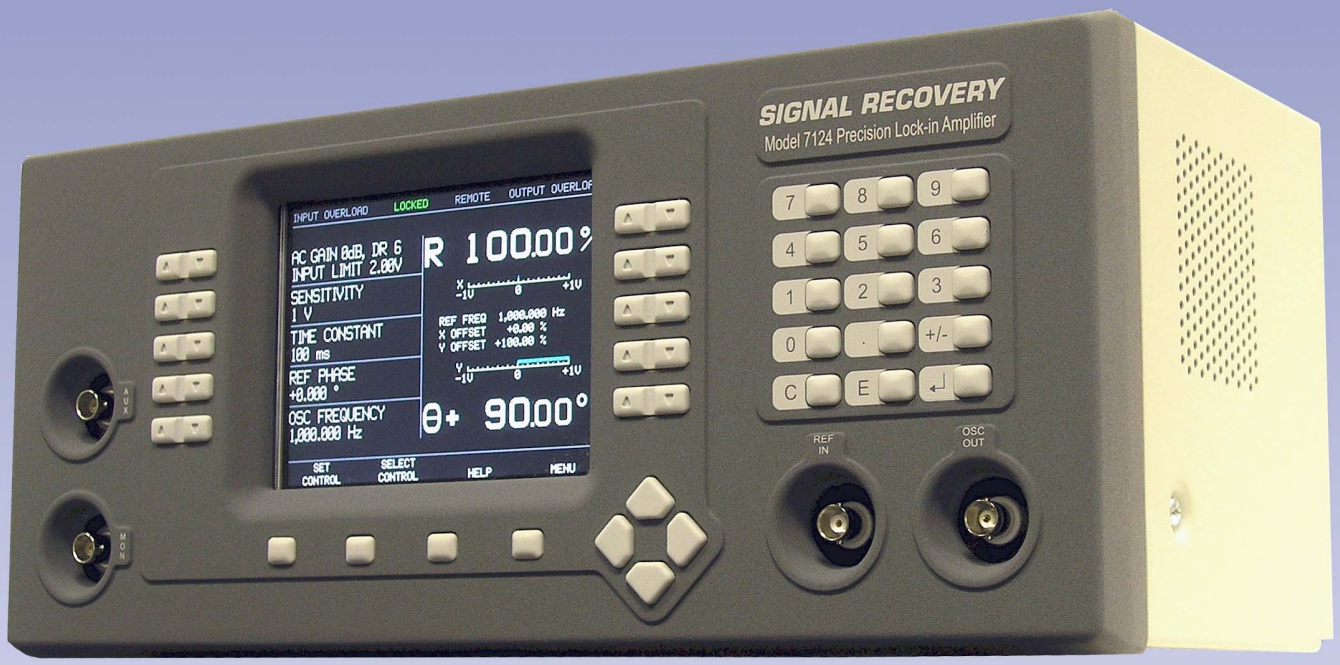
Model 7124

Precision Lock-in Amplifier

...with unique fiber optic link to prevent digital switching noise entering the experiment



the new standard for measurements in:

- ◆ low temperature physics
- ◆ electrical engineering
- ◆ electrochemistry
- ◆ optics

SIGNAL RECOVERY

...part of AMETEK® Advanced Measurement Technology

Model 7124 Precision Lock-in Amplifier

An all-analog front-end generating no digital clock or switching noise with fiber optic connections to a powerful DSP based instrument console

- **Unique analog fiber optic link between the RCU connection module and the main console**
- **No digital clock or switching noise present at the RCU connectors**
- **0.5 Hz to 150 kHz operating frequency range**
- **Voltage and current mode inputs**
- **1.0 MHz main ADC sampling rate**
- **10 µs to 100 ks output filter time constants**
- **Precision DDS sinewave oscillator with adjustable amplitude and frequency**
- **Harmonic measurements up to 127 × F**
- **Dual Reference, Dual Harmonic and Virtual Reference operating modes**
- **Easy manual operation using large full-color display**
- **Auxiliary analog and digital inputs and outputs**
- **Internal data buffer for logging instrument outputs**
- **USB, RS232, and Ethernet computer interfaces**

Overview

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 More recently the analog phase sensitive detectors forming the heart of the instrument have been replaced by DSP (digital signal processing) designs, further improving performance.

But the addition of this digital technology has had one unfortunate side effect, which is that the instrument itself can act as a source of digital clock and switching noise, which is typically coupled back into the experiment via the signal or internal oscillator connectors. This noise is of course rejected by the lock-in and generally does not impair its performance, but the power it dissipates in the sample or device under test can cause serious problems. This is particularly the case in low temperature physics experiments.

SIGNAL RECOVERY is therefore proud to introduce the model 7124 precision lock-in amplifier, which is particularly suited to such work. It uses a unique analog fiber optic link to interconnect a remote connection unit (RCU), to which the experiment is connected, and a main instrument console. In normal operation there are no digital clock signals within the RCU, and so it can emit no switching noise.

This architecture gives an instrument with all the advantages of the latest DSP technology for signal detection, and a powerful processor for easy user operation, as well as the low noise performance that until now has only be available in instruments of all-analog design.

Signal and Reference Connections

In normal use the 7124's signal and reference connections are made at the RCU. The signal input can be switched to operate in single ended or differential voltage mode, or in current mode with a choice of two transimpedance settings. It can also be used to switch between two single-ended voltage signals, for simple sequential measurement, under computer control, of two inputs. In cases where further preamplification is needed then one of the ***SIGNAL RECOVERY*** remote preamplifiers can be used, with its output connected to the 7124's single ended voltage input. This flexible choice of input modes allows the best possible connection to be made to the experiment. The RCU also has both general purpose analog and TTL logic reference inputs, as well as the output for a precision DDS oscillator that generates a sinewave signal of adjustable frequency and amplitude.



The RCU is connected to the main instrument console via a 16ft (5 m) fiber cable bundle that carries the applied signal and oscillator outputs in analog form, and control signals to the RCU and the reference signal from it, in digital format. However, the RCU contains no digital clocks or oscillators that are running continuously, and so unlike all other lock-in amplifiers that use any form of logic control, there is no digital switch noise present at the signal connectors.

Main Console

The 7124's main console is a compact, benchtop unit with a color display, and keys for operating the instrument controls, accessing different menus, and easy entry of numeric values. It receives signals from the RCU module and processes them

using powerful DSP algorithms running in a dedicated field programmable gate array (FPGA), supported by a ColdFire processor.

Auxiliary Signal Input



The main console is fitted with an auxiliary signal voltage mode input of fixed full-scale sensitivity that can be used instead of the signal being received via the optical link from the RCU, or for test purposes.

Signal Path



Following input amplification in the RCU, the signal can optionally be passed through an analog line-frequency rejection filter, with configurable center frequency and mode, before reaching the main anti-alias filter. It is then transmitted over the analog fiber link to the main console, where it is applied the signal channel precision ADC. This operates at 1 MHz, delivering an accurate digital representation of the signal to be measured and the noise accompanying it to the signal inputs of the in-phase and quadrature demodulators, which are implemented in an FPGA.

Reference Channel



The reference channel signal from the RCU passes over another fiber link to the main console, where it drives a phase locked loop which in turn drives the reference channel. When the instrument is set to internal reference mode, the internal precision quartz stabilized oscillator is used to generate, via the fiber link, the sinewave output at the RCU.

When set to the harmonic detection mode, an internal frequency multiplier permits measurement of signals at frequencies up to 127 times the reference frequency, allowing distortion measurements to easily be made.

The reference channel also includes a precision phase shifter, to permit the phase of the reference inputs to the demodulator to be adjusted.

The output of the reference channel is a series of digital phase values, updated at the same 1 MHz rate as the signal channel ADC sampling rate. These are used to derive digital representations of cosinusoidal and sinusoidal waveforms, which are applied to the reference channel inputs of the in-phase and quadrature demodulators respectively.

Digital Demodulators

The heart of the instrument are the demodulators, implemented using DSP techniques. Unlike the analog multipliers or switches used in traditional lock-in amplifiers, this type of demodulator does not use DC coupled electronics. Hence it is immune from the potential errors caused by DC drift and offset introduced by such designs. But because the demodulators are located within the main instrument console, their digital switching signals are completely isolated from the signal input and oscillator output on the RCU.

Output Channel

Following the demodulators, the first stage of output filtering, providing time constants in the range 10 µs to 500 ms, is carried out using digital finite impulse response (FIR) filters implemented within the FPGA and updated at the 1 MHz signal sampling rate. Further filtering, if required, is implemented using similar filters but this time realized in the instrument's main microprocessor.



After filtering, the output signals are potentially further modified by offset and expansion controls, before being displayed either as basic X-output and Y-output values or being processed to give derived outputs, including signal vector magnitude and phase. The instrument can also be used to measure the noise accompanying the signal and the ratio or logarithm of the ratio of the X-channel output to other signals, such as the voltage at the auxiliary ADC inputs.

The main console is fitted with four DAC outputs that can be set to convert the internal digital output values back to analog signals, at the same 1 MHz update rate, thereby making them usable down to the shortest possible output filter time constant settings.

Extended Operating Modes

The instrument includes the extended operating modes made popular by other ***SIGNAL RECOVERY*** lock-in amplifiers, such as the 7265 and 7280.

In normal **Single Reference** mode, harmonic analysis can be performed on harmonics up to 127 × F, while in **Dual Harmonic** mode the signals at two harmonics of the reference signal can be simultaneously measured. The instrument can therefore be used to measure a fundamental frequency and one harmonic of it at the same time.

Dual Reference mode permits measurement of two signals at two unrelated frequencies to be performed simultaneously. For example, in an optical experiment the signals passing through two different paths can be independently measured if they are modulated at two different modulation frequencies.

The instrument also includes a **"tandem" demodulation** mode which allows an amplitude-modulated signal to be first demodulated at a carrier frequency, with the output from this demodulation being processed by a second demodulator running at a lower frequency.

The **Synchronous Oscillator** output is an analog sinusoidal signal equivalent to that being used to drive the in-phase demodulator, and available in both internal and external reference modes. Hence, for example, if the instrument is set to 2F reference mode and a 1 kHz reference is applied, then this output will be a 2 kHz sine wave.

- **Dual Reference - Simultaneously measure two signals at different frequencies**
- **Spectral Display - See the power spectral density of the input signal plus noise**
- **Dual Harmonic - Simultaneously measure two harmonics of the reference frequency**
- **Virtual Reference - Make reference-free measurements even on noisy signals**
- **VCO - Use external analog signal to control the frequency and/or amplitude of the precision internal oscillator**
- **Synchronous Oscillator Output - Access the sinewave being used for demodulation, including any frequency multiplication and/or phase shift**

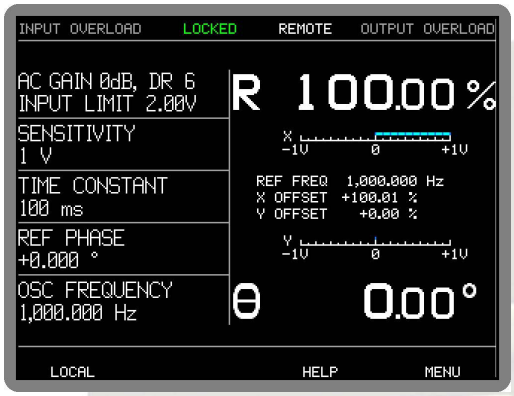
Manual Operation

Just like other ***SIGNAL RECOVERY*** instruments, the 7124 is exceptionally easy to use, both manually and when operated from a remote computer.

In manual use, the color TFT display panel is used in conjunction with the keys grouped around it and the numeric keypad to adjust the instrument's controls, with the selected outputs being shown both on the display and being available as analog signals from four rear-panel connectors.

The keypad makes it simple to set controls, such as the oscillator frequency, that can be adjusted over a wide range and to a high precision. But once at the desired setting, the corresponding "increment/decrement" keys make it simple to change the set value by the required amount.

The Main Display is used in normal operation and shows four user-selected instrument controls on the left-hand side and four user-selected outputs, output offset status, and the present reference frequency, on the right.



Main Display

The output display selections include digital and bar-graph displays in a variety of formats. Error information, such as input and output overload, and reference unlock indication, is clearly shown along the top edge of the display, while soft keys along the bottom edge are used for selecting controls and to initiate numerical keypad data entry.

Pressing the Menu key accesses the Main Menu, from which other menus may be reached. Some, such as those affecting the communications interface settings, occupy the full display. Others, such as the Signal Channel menu, occupy only the left-hand side of the display, with the right-hand side continuing to show the selected outputs. This feature gives instant feedback on the effect of adjusting the controls.

User Settings

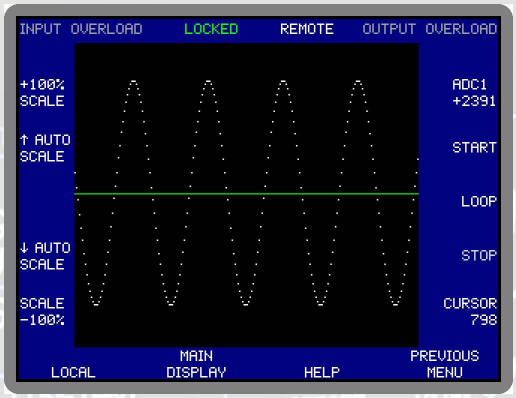
Sophisticated instruments such as the model 7124 are often used by several users for different types of experiment, and setting all the controls to the required state each time the unit is moved can waste precious time. The instrument therefore includes the ability to store up to eight complete records of all control settings, which can be recalled when required.

Auto Functions

Any one of the five auto functions can be reached with just two key presses from the Main Display, and on completion of the selected function the Main Display returns. When activated, these functions adjust the associated control to the optimum setting for the present input signal.

Data Storage

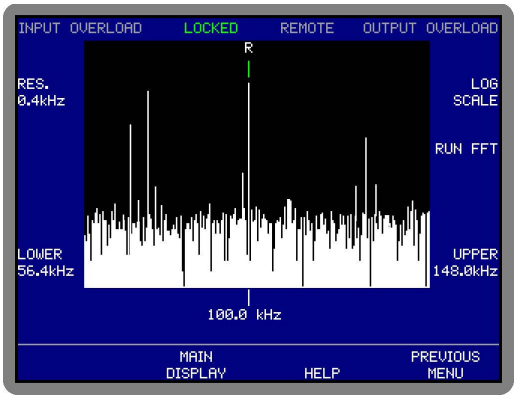
An internal, 100k-point buffer memory can be used to store selected outputs. Digitized information from the auxiliary ADCs can also be stored, which is especially useful when using the highest ADC sampling rates. If required, the data buffer can be sub-divided to allow several outputs to be stored simultaneously giving, for example, the ability to store lock-in amplifier outputs and auxiliary ADC input signals on the same time axis.



Graphical Output Display

The resulting data curves can be shown graphically on the display as they are acquired in a "strip chart" mode, which can prove very useful while making adjustments to the experiment. The instrument also includes a Spectral Display mode (unique to ***SIGNAL RECOVERY*** lock-in amplifiers), which shows the power spectral density of the input signal plus accompanying noise, and which can prove an invaluable aid to selecting a reference frequency that is away from interfering signals.





Spectral Display Mode

Remote Operation

The model 7124 includes USB, RS232 and Ethernet bidirectional control interfaces, allowing controls to be set or interrogated, and instrument outputs to be read.

The command set is based on the use of simple ASCII mnemonics, making user written source code very easy to read and understand. In addition, a Communications Monitor display menu is available that shows all commands received and responses generated by the instrument. This is invaluable during program development and debugging.

Auxiliary Features

The model 7124 is much more than just a lock-in, since it includes a number of auxiliary inputs and outputs to further increase its versatility.

Four sampled ADC inputs on the rear panel of the instrument can be used to digitize external voltage signals, such as those from transducers measuring variables like temperature, pressure, flow rate, optical intensity or liquid level. Various trigger modes are provided. For example, the instrument can function as a 15-bit ADC 250 kSa/s transient recorder with a 100k-point data memory.

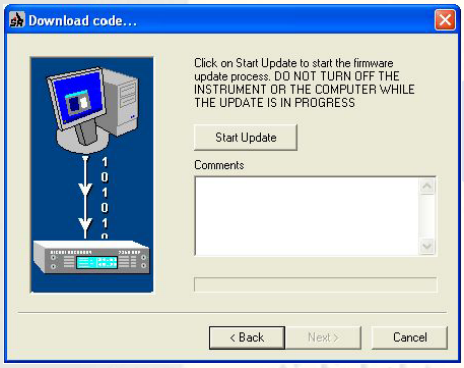
Calculations can be performed between any of the instrument's outputs and the digitized ADC inputs, allowing corrections for such variations as signal strength and standing offsets to be made.

The instrument also has four digital-to-analog converter (DAC) outputs that can be used to generate analog signals representing the instrument outputs (e.g. X, Y, Magnitude and Phase values) and voltages for the control of external equipment, such as motor speed, lamp intensity, or fluid flow rate.

The main console includes an eight bit bidirectional TTL port, while the RCU module has an 8-bit TTL output port. These can be used to switch external equipment, such as relay input or output multiplexers.

User-Upgradeable Firmware

In common with most other ***SIGNAL RECOVERY*** instruments, the 7124's operating firmware can be updated via the USB or RS232 port simply by downloading new code into it using a firmware update pack, which can be obtained free of charge from our website. You can therefore be sure you are always using the latest code. No other lock-in manufacturer offers this capability.



Firmware Update Utility



Specifications

Measurement Modes

X In-phase **Y Quadrature** **R Magnitude** **θ Phase Angle** **Noise**	The instrument can simultaneously show any four of these outputs on the front panel display
Harmonic	n × F, 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 is the external and F_2 the internal reference
Tandem Demodulation	Demodulates the signal using the internal reference frequency F_1, and then passes the resulting X channel output 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 ≤ 150 kHz)
Noise	Measures noise in a selected bandwidth centered at the reference frequency F
Spectral Display	Gives a visual indication of the spectral power distribution of the input signal in a user-selected frequency range lying between 1 Hz and 250 kHz. The display is calibrated for frequency, but not amplitude, and is intended to assist in choosing the best reference frequency

Display

320 × 240 pixel (¼ VGA) color TFT display panel giving digital, analog bar-graph and graphical indication of measured signals. Menu system with dynamic key function allocation.

Signal Channel - Remote Connection Unit

Voltage Input

Modes	A only, –B only or Differential (A–B)
Frequency Response	0.5 Hz ≤ F ≤ 150 kHz (–3dB)
Full-scale Sensitivity	2 nV to 1 V in a 1-2-5 sequence (e.g. 2 nV, 5 nV, 10 nV, 20 nV, etc.)
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	5 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 Bandwidth (10^6 V/A)
Full-scale Sensitivity	
Low Noise	2 fA to 10 nA in a 1-2-5 sequence
Wide Bandwidth	2 fA to 1 µA in a 1-2-5 sequence
Frequency Response (-3dB)	
Low Noise	0.5 Hz ≤ F ≤ 500 Hz minimum
Wide Bandwidth	0.5 Hz ≤ F ≤ 5 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, but before transmission over the optical link
Output Impedance	1 kΩ

Signal Channel - Main Console

Auxiliary Input

Mode	Single-ended voltage mode input
Impedance	10 MΩ // 25 pF
Maximum Safe Input	±12.0 V
Full-scale Sensitivity	1 V

Signal Monitor

Amplitude	±1 V FS. This is the signal received from the Remote Connection Unit immediately prior to conversion by the main ADC
Output Impedance	1 kΩ

Reference Input - Remote Connection Unit or Main Console

TTL Input (rear panel)

Frequency Range	0.5 Hz to 150 kHz

Analog Input (front panel)

Impedance	1 MΩ // 30 pF
Sinusoidal Input	
Level	1.0 V rms
Frequency Range	0.5 Hz to 150 kHz
Squarewave Input	
Level	250 mV rms
Frequency Range	2 Hz to 150 kHz

Reference Channel

Phase Set Resolution	0.001° increments
Phase Noise at 100 ms TC, 12 dB/octave slope	
Internal Reference	< 0.0001° rms
External Reference	< 0.01° rms @ 1 kHz
Orthogonality	90° ±0.0001°
Acquisition Time	
Internal Reference	instantaneous acquisition
External Reference	2 cycles + 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/°C
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 < 20 Hz
Offset	Auto/Manual on X and/or Y: ±300% F.S.
Phase Measurement Resolution	≤ 0.01°
Reference Monitor	TTL signal at current reference frequency, internal or external

Oscillator - General

Frequency

Range	0.5 Hz to 150 kHz
Setting Resolution	1 mHz
Absolute Accuracy	± 50 ppm

Specifications - continued

Amplitude

Range	1 mV to 5 V
Setting Resolution	1 mV

Output Impedance 50 Ω

Sweep

Frequency

Output Range	0.5 Hz to 150 kHz
Law	Linear or Logarithmic
Step Rate	1000 Hz maximum (1 ms/step)

Amplitude Sweep

Output Range	0.000 to 1.000 V rms
Law	Linear
Step Rate	
Main Console	20 Hz maximum (50 ms/step)
RCU	1 Hz maximum (1 s/step)

Oscillator Output - Remote Connection Unit

Amplitude

Accuracy	±1.0% typ
Stability	100 ppm/ºC

Distortion (THD) -80 dB @ 1 kHz and 100 mV rms

Oscillator Output - Main Console

Amplitude

Accuracy	±0.2% typ
Stability	50 ppm/ºC

Distortion (THD) -80 dB @ 1 kHz and 100 mV rms

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	250 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 - RCU

Mode	8 TTL outputs
Status	Each output line can be set high or low

8-bit Digital Port - Main Console

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

Power - Low Voltage ±15 V at 100 mA 5-pin 180° DIN connectors on both main console and remote connection unit for powering compatible preamplifiers

Data Storage Buffer

Size	100,000 data points
Max Storage Rate	
Fast Mode	1 MHz (X1, Y1, X2, Y2, ADC1, Demod I/P 1, Demod I/P 2)
Normal Mode	1 kHz

User Settings

Up to 8 complete instrument settings can be saved or recalled from memory as required

Interfaces

USB 2.0, Ethernet, and RS232 on main console allow complete control of instrument settings, and data readout. Four channel 5 m (16ft) fiber optic link between main console and remote connection unit.

continued...



Model 7214 Remote Connection Unit Rear Panel



Model 7214 Main Console Rear Panel

Specifications - continued

General

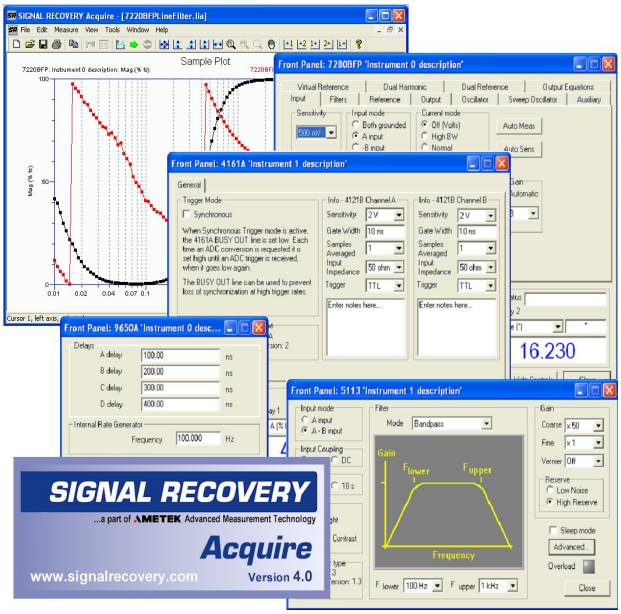
	Main Console	RCU
Power		
Voltage	110/120/220/240 VAC	110/120/220/240 VAC
Frequency	50/60 Hz	50/60 Hz
Power	40 VA max	15 VA max
Dimensions		
Width	15½" (390 mm)	15½" (390 mm)
Depth	7¼" (185 mm)	7¼" (185 mm)
Height		
With feet	7¼" (185 mm)	3" (75 mm)
Without feet	6½" (170 mm)	2½" (64 mm)
Weight	12.8 lb (5.8 kg)	7.9 lb (3.6 kg)

Preliminary specifications subject to change without notice

Software and Ordering Information

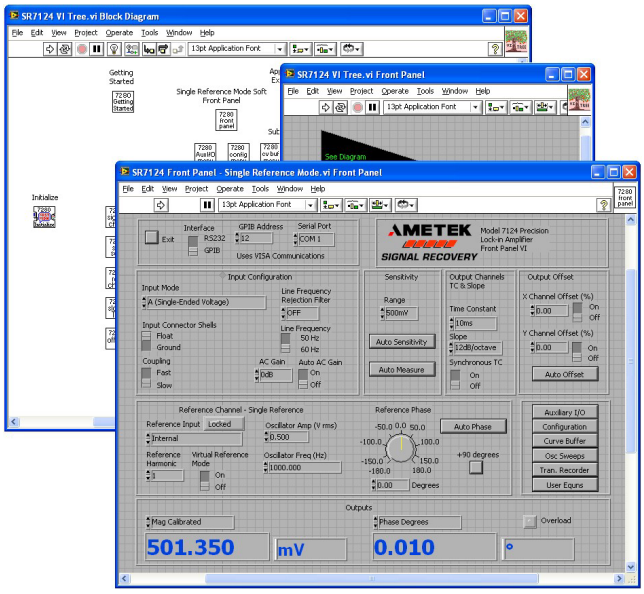
ACQUIRE Applications Software

The Acquire Data Acquisition Software significantly extends the capabilities of the instrument by, for example, adding the ability to make swept frequency measurements. The software is suitable for Windows XP and later operating systems and allows up to ten compatible ***SIGNAL RECOVERY*** instruments to be controlled at the same time. A free demonstration version is available from the **www.signalrecover.com** website, which can be upgraded to the full version by purchase of an activation key.



LabVIEW® Driver Software

A free LabVIEW® driver is available for the instrument, offering example VIs for all its controls and outputs, as well as the usual Getting Started and Utility VIs. It also includes example soft-front panels built using these VIs, demonstrating how you can incorporate them in more complex LabVIEW® programs.



Ordering Information

Each model 7124 system is supplied complete with comprehensive instruction manual , line power cord, and 5 m (16 ft) interconnecting fiber-optic cables

Optional Accessories

SRInstComms	ActiveX Control and Software Toolkit for simple instrument control from a PC. Includes sample programs in C++, Visual Basic, HTML, etc..
Acquire™	Comprehensive control and acquisition software for use with Windows XP/Vista operating systems
Model K02005	Rack mount to mount one model 7124 main console in a 19" rack

External Preamplifiers

The model 7124 may also be used in conjunction with ***SIGNAL RECOVERY*** model 5113, 181, 5182, 5183, 5184, and 5186 preamplifiers, and with the model 1900 impedance matching transformer.

SIGNAL RECOVERY

SIGNAL RECOVERY is part of AMETEK Advanced Measurement Technology, Inc

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