Models 5209 and 5210

Single and Dual-Phase Analog Lock-in Amplifiers

SIGNAL RECOVERY

FEATURES

- **0.5 Hz to 120 kHz operation**
- **Voltage and current mode inputs**
- **Continuous full-scale sensitivity control**
- **Sinewave or squarewave demodulation**
- **Powerful fourth-order signal channel Bandpass, Low Pass or Notch filter**
- **Up to 130 dB dynamic reserve**
- **Synchronous 15-bit ADC for lower output jitter**

APPLICATIONS

- **Auger spectroscopy**
- **Feedback control loops**
- **Replicating existing experimental setups**
- **Direct optical transmission/ reflection measurements**

DESCRIPTION

Over the past few years, the ***SIGNAL RECOVERY*** models 5209 (single-phase) and 5210 (dual-phase) have become the benchmark lock-in amplifiers against which others are judged. They are widely referenced in technical publications describing a diverse range of research applications including optical, electrochemical, electronic, mechanical and fundamental physical studies.

Although more recently the introduction of instruments using digital signal processing has brought advances in phase sensitive detection techniques, instruments using analog demodulators are still the first choice for many experiments. These include those requiring a true analog output, for example in some feedback control loops, or where the instrument is used to recover the envelope modulation of a carrier frequency. Of course, they are also chosen for compatibility with previous experimental setups.

Voltage or current inputs...
The instruments include a current preamplifier with two transimpedance settings and so can directly measure signals from current sources such as photodiodes. With an input impedance of down to typically only 25 Ω, the resulting voltage generated across the source by the signal current is minimized for the very best performance.

Continuous full-scale sensitivity control...
As with all lock-ins the models 5209 and 5210 have a range of calibrated full-scale sensitivity settings. However, unlike other units they also have a sensitivity vernier control, allowing the full-scale sensitivity to be set to any value between the calibrated values. Suppose you are performing an optical transmission experiment and you want to measure transmission in terms of a percentage relative to that of a “reference” sample. All you need to do is put the reference sample in the optical path and press the auto vernier control on the lock-in. It will then adjust the sensitivity so that the display reads 100%. Now replace the reference sample with the test sample and read the percentage transmission directly.

Unique Walsh Function Demodulators...
The simplest method of implementing the phase sensitive detector at the heart of an analog lock-in is with a reversing switch driven at the reference frequency, giving excellent linearity, dynamic range and stability. This is known as a “squarewave” demodulator since the instrument responds to signals not only at the reference frequency but also at its odd harmonics. It offers much better performance than can be achieved by using a true analog multiplier, which requires the synthesis of a very pure reference sinusoid and is very nonlinear when handling large levels of interfering signal.

Squarewave demodulation is ideal for many applications, such as experiments using chopped light beams where the signal being detected is a square-wave, since the odd harmonics contain useful information. However in other cases the requirement is for “sinewave” or “fundamental” response where only signals at the reference frequency are measured. In theory, a squarewave can be modified to a sinewave response by inserting a low-pass or bandpass filter in the signal channel ahead of the demodulator. However this requires a highly selective filter in order to reject signals at the third harmonic without at the same time causing significant phase and magnitude errors for signals at the reference frequency.

The ***SIGNAL RECOVERY*** models 5209 and 5210 use a modified form of switching demodulator, known as the Walsh demodulator, which multiplies the applied signal by a stepped approximation to the reference sinusoidal waveform. This gives a demodulator that does not respond to signals at the third and fifth harmonics, although it does respond to higher harmonics. A fourth-order signal channel filter is therefore included to reject these harmonics, giving an overall sinewave response. The advantages of the switching demodulator are thereby retained without the phase and magnitude errors associated with the use of highly selective filters.

The instruments can be switched to operate in either sinewave or squarewave mode, giving you the choice of the optimum detection method for your experiment. Only ***SIGNAL RECOVERY*** gives you this flexibility.

Choice of signal channel filter modes…
In the usual sinewave response mode, the filter is set to the bandpass or low-pass modes. But what if you are trying to measure a signal at twice the reference frequency in the presence of a strong signal at the reference frequency? In this case, the filter can be set to a notch (band-stop) mode and tuned to the reference frequency, leaving the signal at 2F unattenuated and easy to measure.

In addition to the main signal channel filter, a line-frequency rejection filter operating at 50/60 Hz and/or 100/120 Hz is also included, for elimination of troublesome line pickup.

High dynamic reserve...
The combination of the Walsh demodulator(s) and the signal channel filter gives the instruments a dynamic reserve of up to 130 dB - implying that you can, for example, measure a signal of 1 µV in the presence of an interfering signal of more than 1 V. No other analog lock-in amplifiers can deliver this performance.

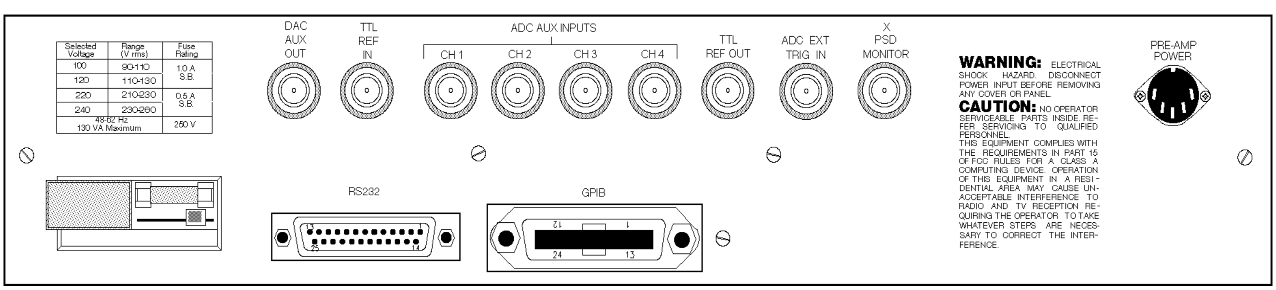
Output filters...
The output low-pass filters offer time constants in the range 1 ms to 3 ks, with all settings available at slopes of both 6 and 12 dB/octave. In addition, the instruments include a rear-panel connector giving the signal at the output of the in-phase (X-channel) demodulator with a time constant of typically only 100 µs, for use in those applications such as tandem demodulation where the largest output bandwidth is required.

Synchronous ADC trigger...
The analog outputs from the demodulator(s), after filtering by the output low-pass filter(s), need to be digitized by an analog to digital converter (ADC) for display or for transfer to the controlling computer. If this conversion is carried out asynchronously then the resulting values can display significant jitter. This is because the demodulator output contains not only the required DC level, but also signals at twice the reference frequency. When the output is sampled for conversion, this 2F signal means that some samples will be smaller and some larger than the mean.
Of course, the 2F component can be reduced to any arbitrarily small value by increasing the time constant, but this reduces the response time to changes in input signal, slowing down data throughput. The ***SIGNAL RECOVERY*** models 5209 and 5210 therefore offer a unique reference synchronous ADC trigger mode, which guarantees that the output is sampled at the same point in time relative to the reference waveform and thereby removes this source of error.

Internal oscillator...
With the models 5209 and 5210 there is no need to buy a separate oscillator to use as an excitation source for your experiment, since both instruments include one capable of generating a low distortion sinewave output signal over a frequency range of 0.5 Hz to 120 kHz. Although in most lock-ins the frequency of the internal oscillator can be adjusted, in the models 5209 and 5210 the amplitude can also be controlled over the range 1 mV to 2 V rms.

Manual or computer control...
In manual operation the backlit control setting indicators, the two digital displays and the analog panel meter make the instruments very easy to use, with the settings of all the important controls being instantly visible. Six auto functions further simplify control adjustment, while red overload and reference unlock LEDs warn of conditions which will result in measurement errors. All the front panel indicators can be turned off for use in blackout conditions.

The instruments include GPIB (IEEE-488) and RS232 computer interfaces, allowing virtually all the controls to be operated, and all the outputs that can be displayed to be read, via simple ASCII mnemonic-type commands. The communications interface parameters, such as baud rate and GPIB address are set by front-panel controls, with no difficult DIP switches to adjust.



Model 5210 Rear Panel Layout

Specifications

General

Single-phase (model 5209) and dual-phase (model 5210) analog lock-in amplifiers operating over a reference frequency range of 0.5 Hz to 120 kHz. Wide range of auxiliary inputs and outputs.

Measurement Modes

The model 5209 can show one of these outputs on the front panel display:

X	In-phase
Noise	
Ratio	X/ADC1
Log Ratio	Log_{10}(X/ADC1)

The model 5210 can also simultaneously show one of these outputs on the front panel display:

Y	Quadrature
R	Magnitude
θ	Phase Angle

Harmonic — F or 2F

Noise

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

Displays

Two 3½-digit LCD displays and analog panel meter

Signal Channel

Voltage Input

Modes	A only or Differential (A-B)
Full-scale Sensitivity	100 nV to 3 V in a 1-3-10 sequence and vernier adjustment
Max. Dynamic Reserve	> 130 dB
Impedance	100 MΩ // 25 pF
Maximum Safe Input	30 V pk-pk
Voltage Noise	5 nV/√Hz @ 1 kHz
C.M.R.R.	> 100 dB @ 1 kHz
Frequency Response	0.001 Hz to 120 kHz
Gain Accuracy	1% typical in Flat mode, 2% typical in tracking Bandpass mode
Gain Stability	200 ppm/°C typical
Distortion	-90 dB THD (60 dB AC gain, 1 kHz)
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

Current Input

Mode	10^{-6} A/V or 10^{-8} A/V
Full-scale Sensitivity	
10^{-6} A/V	100 fA to 3 µA in a 1-3-10 sequence and vernier adjustment
10^{-8} A/V	1 pA to 300 µA in a 1-3-10 sequence and vernier adjustment
Max. Dynamic Reserve	> 130 dB
Impedance	
10^{-6} A/V	< 250 Ω at 1 kHz
10^{-8} A/V	< 2.5 kΩ at 100 Hz
Maximum Input	15 mA continuous, 1 A momentary without damage. 10 µA AC pk-pk without saturation on 10^{-6} A/V; 100 nA AC pk-pk without saturation on 10^{-8} A/V
Noise	
10^{-6} A/V	130 fA/√Hz at 1 kHz
10^{-8} A/V	13 fA/√Hz at 500 Hz
Frequency Response	
10^{-6} A/V	-3 dB at 60 kHz
10^{-8} A/V	-3 dB at 330 Hz
Gain Accuracy	1% typical in Flat mode, 2% typical in tracking Bandpass mode
Gain Stability	200 ppm/°C typical
Grounding	BNC shield can be grounded or floated via 1 kΩ to ground

Signal Channel Filters

Line Frequency Rejection Filter

Center frequency, F (factory set)	50/100 or 60/120 Hz
Mode	Off, F, 2F, F & 2F

Main Signal Channel Filter

Mode	Fourth-order Low-pass, Bandpass, Notch or Flat (Disabled)
Frequency	Auto or Manual tuning
Signal Monitor	Front-panel BNC connector allows viewing of signal immediately ahead of the demodulator(s)

Reference Channel

TTL Input (rear panel)	
Frequency Range	0.5 Hz to 120 kHz
Analog Input (front panel)	
Impedance	1 MΩ // 30 pF
Sinusoidal Input	
Level	1.0 V rms*
Frequency Range	0.5 Hz to 120 kHz
Squarewave Input	
Level	250 mV rms*
Frequency Range	2 Hz to 120 kHz

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

Phase Set Resolution	0.005° increments
Phase Set Accuracy	± 1°
Phase Noise	0.005° rms @ 1 kHz, 100 ms, 12 dB TC
Phase Drift	< 0.05°/°C
Orthogonality (model 5210 only)	± 0.5° above 5 Hz, degrading to ± 5° at 0.5 Hz
Acquisition Time	100 ms + 2 cycles max
Lock Indicator	LED warns of frequency/phase unlock

Demodulator and Output Processing

Mode — Sinewave (Walsh demodulator + BP/LP filter) or Squarewave

Zero stability/Dynamic Reserve

Mode	Dynamic Reserve Filter On	Filter Off	Zero Stability
High DR	130 dB	60 dB	500 ppm/°C
Normal	110 dB	40 dB	50 ppm/°C
High Stability	90 dB	20 dB	5 ppm/°C

Harmonic Rejection	> 80 dB with Low-pass, and > 60 dB with Bandpass main signal filter
Output Filters	
Time Constant	1 ms - 3 ks (1-3-10 sequence)
Roll -off	6 dB/oct or 12 dB/oct for all TC settings
Offset	Auto and Manual on X and/or Y: ±100% full-scale (±1000% full-scale with Expand on)

Oscillator

Frequency Range	0.5 Hz - 120 kHz
Amplitude Range	0 - 2 V rms (front panel or computer); 5 V rms fixed (computer only)
Amplitude Resolution	
0 - 500 mV	1 mV
500 mV - 2 V	4 mV
Distortion (THD)	0.5%
Output	sinewave from 900 Ω source

Auxiliary Inputs

ADC 1, 2, 3 and 4

Maximum Input	±15 V
Resolution	1 mV
Accuracy	±20 mV
Input Impedance	1 MΩ // 30 pF
Sample Rate	100 Hz
Trigger Mode	Internal, External or ref synchronous
Trigger Input	TTL compatible

Outputs

Demodulator Monitor	100 µs TC @ 6 dB/ octave (5210: X output only)
Main Analog (CH1 and CH2) Outputs	
5209:	One ±10 V FS
5210:	Two ±10 V FS (X, Y or R, θ)
Resolution	1 mV
Impedance	1 kΩ
Update Rate	100 Hz
Expand	Expands X output by factor of 10
Auxiliary D/A Outputs	
5210	One output, ±15 V
5209	Two outputs, ±15 V
Resolution	1 mV

Accuracy	±10 mV
Output Impedance	1 kΩ
Reference Output	
Waveform	0 to 5 V rectangular wave
Impedance	TTL-compatible
Power - Low Voltage	±15 V at 45 mA rear panel 5-pin 180° DIN connector for powering ***SIGNAL RECOVERY*** preamplifiers

Interfaces

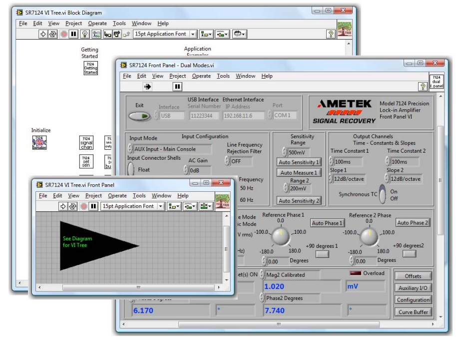
RS232 and GPIB (IEEE-488). All instrument controls except A, A-B, 10^{-6}A/V, 10^{-8}A/V and FLOAT/GND can be operated and all outputs that can be displayed can be read

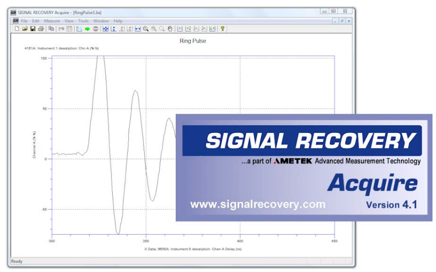
General

Power Requirements	
Voltage	110/120/220/240 VAC
Frequency	50/60 Hz
Power	130 VA max
Dimensions	
Width	17¼" (440 mm)
Depth	19½" (500 mm)
Height	3½" (90 mm)
Weight	16.8 lb (7.6 kg)
Temperature Range	0 - 50°C
Rack Mounting	Hardware included

LabVIEW Driver Software

A LabVIEW driver for these instruments is available from the **www.signalrecovery.com** website, offering example VIs for all their 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.





SIGNAL RECOVERY Acquire Software (see page 56)

Those users who do not wish to write their own control code but who still want to record the instrument's outputs to a computer file will find the ***SIGNAL RECOVERY*** Acquire Lock-in Amplifier Applications Software, available at a small extra cost, useful. This 32-bit package, suitable for Windows XP/Vista, extends the capabilities of the instrument by, for example, adding the ability to record swept frequency measurements.

Ordering Information

Each model 5209 and 5210 is supplied complete with a comprehensive instruction manual. Users may download the instrument's LabVIEW driver software and a free demonstration copy, DemoAcquire, of the ***SIGNAL RECOVERY*** lock-in amplifier applications software package, from the **www.signalrecovery.com** website.

Why should you choose ***SIGNAL RECOVERY*** products?

Models 5209 and 5210 Analog Lock-in Amplifiers

SIGNAL RECOVERY Product Features	Benefit to you
The benchmark analog lock-ins	It is likely that someone else has already successfully used one of these instruments in the same way as you intend
Continuous full-scale sensitivity control	Set up your "100%" signal level and then press Auto Vernier to set the output display to 100%. Read % transmission values directly, saving calculation time
Analog signal channel filtering	Exceptional dynamic reserve - up to 130 dB - means that these instruments can measure signals buried in noise when others can't
Choice of filter modes	Notch filter is especially useful when measuring a signal at 2*f* in the presence of a strong signal at *f*
Internal Oscillator can be used independently of rest of instrument.	Set OSC OUT to a different frequency to the reference e.g. Use it to control a ***SIGNAL RECOVERY*** chopper at *f* and then connect the lock-in's reference input to the chopper's *f*/10 SYNC output
Excellent LabVIEW driver	Saves programming time
Compatible with Acquire software	Eliminates the need to develop programs