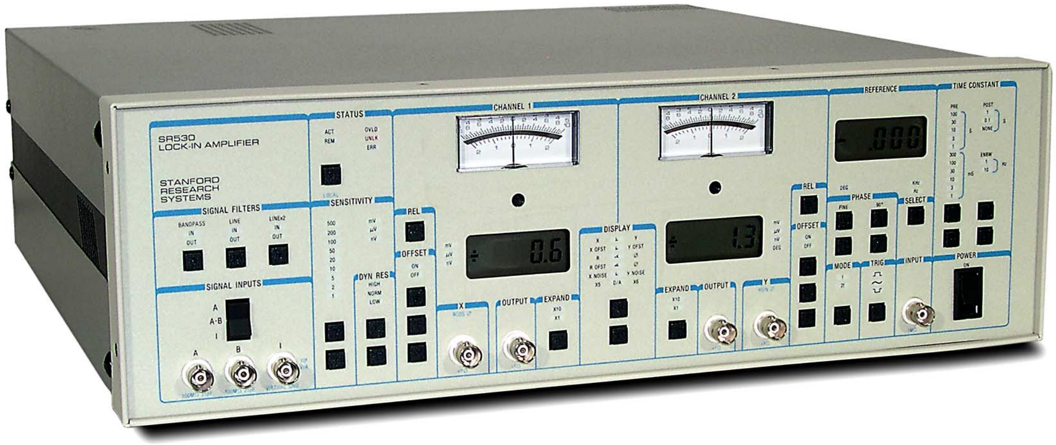
Lock-In Amplifiers

SR510 and SR530 — Analog lock-in amplifiers



SR510/SR530 Lock-In Amplifiers

- **0.5 Hz to 100 kHz frequency range**
- **Current and voltage inputs**
- **Up to 80 dB dynamic reserve**
- **Tracking band-pass and line filters**
- **Internal reference oscillator**
- **Four ADC inputs, two DAC outputs**
- **GPIB and RS-232 interfaces**

- **SR510 ... $2495** *(U.S. list)*
- **SR530 ... $2995** *(U.S. list)*

The SR510 and SR530 are analog lock-in amplifiers which can measure AC signals as small as nanovolts in the presence of much larger noise levels. Both the single phase SR510 and the dual phase SR530 have low-noise voltage and current inputs, high dynamic reserve, two stages of time constants, and an internal oscillator. In addition, both lock-ins come equipped with a variety of features designed to make them simple to use.

Sine Wave Mixing

The core of the SR510/SR530 is a precision analog sine-wave multiplier. Lock-ins use a multiplier (demodulator) to translate the input signal (at the reference frequency) down to DC where it can be filtered and amplified. Many lock-ins use square wave multipliers which introduce spurious harmonic responses. The SR510/SR530 use clean sine-wave multipliers which are inherently free of unwanted harmonics.

Signal Input

The SR510 and SR530 have differential inputs with 7 nV/√Hz of input noise and a 100 MΩ input impedance. The input can be configured as a voltage input, or as a current input with 10^6 V/A gain and an input impedance of 1 kΩ to virtual ground. Full-scale sensitivities from 500 mV down to 100 nV are available.

Three input prefilters can be selected. The first is a line notch filter providing 50 dB of rejection at the line frequency. The second filter similarly provides 50 dB of rejection at the second harmonic of the line frequency. The third filter is a band pass filter which automatically tracks the reference frequency. These three filters can eliminate much of the noise in the signal before it is amplified.

Reference Input

The reference input can be set to lock to sine waves or to either edge of a pulsed reference. The reference frequency range is 0.5 Hz to 100 kHz, and detection at both the fundamental and second harmonic of the reference is allowed. A convenient, built-in frequency meter constantly measures and displays the reference frequency with 4-digit resolution. The reference can be phase shifted with 0.025° resolution from the front panel, or shifted in 90° increments for easy measurement of quadrature signals. On the SR530, an auto-phase feature lets you quickly determine the phase of the signal relative to the reference with a single key-press.

Output Time Constants

Two stages of filtering after the phase sensitive detector are provided. Time constants can be chosen as long as 100 seconds for maximum noise reduction, or as short as 1 ms (20 µs with modification) for use in real-time servo loops. The two filter stages allow a rolloff of 6 or 12 dB/octave.

Dynamic Reserve

The dynamic reserve of a lock-in amplifier at a given full-scale input voltage is the ratio (in dB) of the largest interfering signal to the full-scale input voltage. The largest interfering signal is defined as the amplitude of the largest signal at any frequency that can be applied to the input before the lock-in cannot measure a signal with its specified accuracy.

The SR510 and SR530 have a dynamic reserve of between 20 dB and 60 dB depending on the sensitivity scale. Selecting the band pass filter adds an additional 20 dB of dynamic reserve making the maximum dynamic reserve for these lock-ins 80 dB.

Offset and Expand

The SR510/SR530's offset and expand features make it easy to look at small changes in a large signal. Output offsets of 0 % to 100 % of full scale can be selected manually, or by using auto-offset, which automatically selects an offset equal to the signal value. Once the signal is offset, a 10× expand is available to provide increased resolution when looking at small changes from a nominal value.

Analog and Digital Displays

Precision analog meters, and 4-digit digital displays are standard on both lock-ins. On the SR510, you can select displays of the signal amplitude, the signal offset or the measured noise. On the SR530, the first pair of displays show the signal components in rectangular form (X and Y), polar form (R and θ), the offset, noise, or the value of the rear-panel D/A outputs. The other digital display on both lock-ins can be configured to show either the reference phase or the reference frequency.

Noise Measurement

The SR510/SR530's noise measurement feature lets you directly measure the noise in your signal at the reference frequency. Noise is defined as the rms deviation of the signal from its mean. The SR510/SR530 will report the value of the noise in both a 1 Hz and 10 Hz bandwidth around the reference frequency.

Internal Oscillator

An internal voltage-controlled oscillator provides both an adjustable amplitude sine wave output and a synchronous, fixed amplitude reference output. The sine wave amplitude can be set to 0.01, 0.1 or 1 Vrms and can drive up to 20 mA. The oscillator frequency is controlled by a rear-panel voltage input and can be adjusted between 1 Hz and 100 kHz. Typically, the sine wave output is used to excite some aspect of an experiment, while the reference output provides a frequency reference to the lock-in.

SR510 Lock-In Amplifier

A/Ds and D/As

There are four A/Ds and two D/As on the rear panel that provide flexibility in interfacing the SR510/SR530 with external signals. These input/output ports measure and supply analog voltages with a range of ±10.24 VDC and a resolution of 2.5 mV. The A/Ds digitize signals at a rate of 1 kHz. The D/A output is ideal for controlling the frequency of the SR510/530's internal voltage-controlled oscillator. A built-in ratio feature allows the SR510/SR530 to calculate the ratio of its output to a signal at one of the A/D ports. This feature is important in servo applications to maintain a constant loop gain, or in experiments that normalize a signal to an intensity level.

Available Preamplifiers

Although the SR510 and SR530 are completely self contained and require no preamplification, sometimes an external preamplifier can be useful. Remote preamplifiers provide gain where it's most important, right at the detector, before the signal-to-noise ratio is permanently degraded by cable noise and pickup. The SR550 FET-input preamplifier, the SR552 bipolar-input preamplifier, and the SR554 transformer-input preamplifier are ideally suited for use with the SR510/SR530 lock-ins. These preamplifiers are especially useful when measuring extremely low-level signals.

Computer Interfaces

An RS-232 computer interface is standard on both the SR510 and SR530. An optional GPIB interface is also available. All features of the instruments can be queried and set via the computer interfaces.

Ordering Information

SR510	Single phase lock-in amplifier (w/ rack mount)	$2495
SR530	Dual phase lock-in amplifier (w/ rack mount)	$2995
Option 01	GPIB interface for SR510/SR530	$495
SR550	Voltage preamplifier (100 MΩ, 3.6 nV/√Hz)	$595
SR552	Voltage preamplifier (100 kΩ, 1.4 nV/√Hz)	$595
SR554	Transformer preamplifier (0.091 nV/√Hz)	$995
SR540	Optical chopper	$1095

SR510 and SR530 rear panels (with opt. 01)

Signal Channel

Inputs	
Voltage	Single-ended or differential
Current	10^6 V/A
Impedance	
Voltage	100 MΩ + 25 pF, AC coupled
Current	1 kΩ to virtual ground
Full-scale sensitivity	
Voltage	100 nV to 500 mV
Current	100 fA to 0.5 µA
Maximum inputs	
Voltage	100 VDC, 10 VAC damage threshold, 2 Vpp saturation
Current	10 µA damage threshold, 1 µApp saturation
Noise	
Voltage	7 nV/√Hz at 1 kHz (typ.)
Current	0.13 pA/√Hz at 1 kHz (typ.)
Common Mode	
Range	1 Vp
Rejection	100 dB (DC to 1 kHz, degrades by 6 dB/oct above 1 kHz)
Gain accuracy	1 % (2 Hz to 100 kHz)
Gain stability	200 ppm/°C
Signal filters	60 Hz notch, −50 dB (Q=10, adjustable from 45 to 65 Hz) 120 Hz notch, −50 dB (Q=10, adjustable from 100 to 130 Hz) Tracking band pass (Q=5). Filter adds 20 dB to dynamic reserve.
Dynamic reserve	LOW (20 dB), 5 ppm/°C (1 µV to 500 mV sensitivity) NORM (40 dB), 50 ppm/°C (100 nV to 50 mV sensitivity) HIGH (60 dB), 500 ppm/°C (100 nV to 5 mV sensitivity)

Reference Channel

Frequency	0.5 Hz to 100 kHz
Input impedance	1 MΩ, AC coupled
Trigger	
Sine	100 mV minimum, 1 Vrms nominal
Pulse	±1 V, 1 µs minimum width
Mode	Fundamental (f), 2nd harmonic (2f)
Acquisition time	25 s (1 Hz ref.), 6 s (10 Hz ref.), 2 s (10 kHz ref.)
Slew rate	1 decade per 10 s at 1 kHz
Phase control	90° shifts, fine shifts in 0.025° steps
Phase noise	0.01° rms at 1 kHz (100 ms, 12 dB/oct rolloff time constant)
Phase drift	0.1°/°C
Phase error	Less than 1° above 10 Hz
Orthogonality*	90° ± 1°

Demodulator

Stability	5 ppm/°C (LOW reserve) 50 ppm/°C (NORM reserve) 500 ppm/°C (HIGH reserve)
Time constants	
Pre	1 ms to 100 s (6 dB/octave)
Post	1 s, 0.1 s, none (6 dB/octave)
Offset	Up to 1× full scale (10× on expand)
Harmonic rejection	−55 dB (band pass filter in)

Outputs and Interfaces

Channel 1 outputs	X (Rcosθ), X Offset, X Noise, R*, R Offset*, X5 (ext. D/A)*
Channel 2 outputs*	Y (Rsinθ), Y offset, θ, Y noise, X6 (ext. D/A)
Output meters	2 % precision analog meter
Output LCD	4-digit LCD display shows same values as the analog meters.
Output BNC	±10 V corresponds to full-scale input. <1 Ω output impedance
X output*	X (Rcosθ), ±10 V, <1 Ω output impedance
Y output*	Y (Rsinθ), ±10 V, <1 Ω output impedance
Reference output	4-digit LCD display for reference phase or frequency
X1 to X4	4 analog inputs, 13-bit, ±10.24 V
X5, X6	2 analog outputs, 13-bit, ±10.24 V
Ratio	Ratio output equals 10× signal output divided by the denominator of the input.
Internal oscillator	
Range	1 Hz to 100 kHz
Accuracy	1 %
Stability	150 ppm/°C (frequency) 500 ppm/°C (amplitude)
Distortion	2 % THD
Amplitude	10 mVrms, 100 mVrms, 1 Vrms
Computer interfaces	RS-232 standard, GPIB optional. All instrument functions can be controlled and read through the interfaces.

General

Power	35 W, 100/120/220/240 VAC, 50/60 Hz
Dimensions	(SR510) 17" × 3.5" × 17" (WHD) (SR530) 17" × 5.25" × 17" (WHD)
Weight	12 lbs. (SR510), 16 lbs. (SR530)
Warranty	One year parts and labor on defects in materials and workmanship

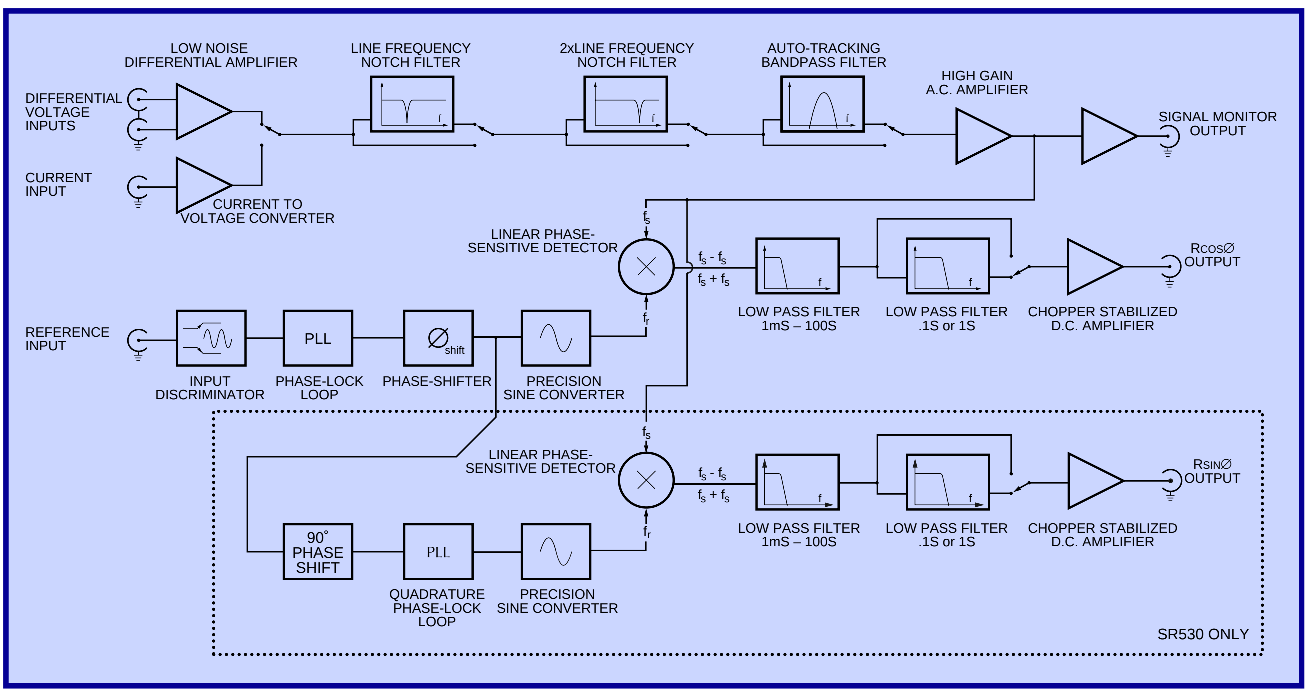
* SR530 only

Analog Lock-In Amplifiers

A block diagram of the SR510/SR530 Analog Lock-In Amplifiers is shown below. The input signal is amplified by a low-noise differential amplifier, selectively filtered to remove line frequency related interference and other unwanted signals, and amplified by a high-gain AC amplifier. The signal is then multiplied by a reference sine wave which is phase-locked to the reference input. The output of the multiplier contains the sum and difference frequency components (f_{signal}–$f_{reference}$) and (f_{signal}+$f_{reference}$). In the SR530, a second multiplier multiplies the signal by a reference that has been phase shifted by 90°, allowing the lock-in to measure the in-phase and quadrature components of the signal simultaneously.

Two stages of low pass filtering provide the lock-in's time constants. The purpose of the filtering is twofold. First, the filters remove the 2f components which are introduced by the multipliers. Secondly, the filters provide noise reduction by narrowing the lock-in's detection bandwidth. This is the essence of the lock-in technique. By only detecting signals in a narrow range of frequencies centered around the reference frequency, noise and interference at all other frequencies are rejected. The output of the filter stages is amplified by a chopper stabilized DC amplifier and becomes the lock-in's output.

The tradeoff between AC gain at the front end of the lock-in, and post-filter DC gain determines the dynamic reserve of the lock-in amplifier. If very little AC gain is used, large interfering signals can be present without overloading the front end. However, high DC gains must then be used which make the output more unstable. If the DC gain is lowered for more stability, higher AC gains must be used making the unit more susceptible to overloads. This tradeoff between dynamic reserve and stability is inherent to all analog lock-in amplifiers. The SR510 and SR530 allow you to manually select a dynamic reserve which is optimal for your experimental conditions.



Analog Lock-In Amplifier Block Diagram