Analog Lock-In Amplifier

SR2124 — Analog lock-in amplifier



SR2124 Analog Lock-In Amplifier

- Low-noise, all analog design
- No digital interference
- 0.2 Hz to 200 kHz measurement range
- Low-noise current and voltage inputs
- Harmonic detection (f, 2f, or 3f)
- Selectable input filtering

For over a half century, the lock-in amplifier has been the instrument of choice for measuring small AC signals in the presence of noise. Early instruments were designed with analog electronics, multi-gang mechanical switches, needle indicators, etc., and measurements were often monitored with chart recorders. Microprocessor based designs emerged in the 1980s, and by the early 1990s even the lock-in's analog demodulators were replaced by high-resolution ADCs and digital signal processors (DSP). Remote computer control, digital readouts and user-friendly front panels all resulted.

The capabilities of the modern DSP lock-in amplifier in stability, dynamic reserve, and flexibility were revolutionary, making it a mainstay for researchers and engineers across multiple fields. But in moving forward, something was left behind. For a core group of users, including low-temperature researchers in particular, the new instruments became a potential source of high-frequency interference. This is best reflected in the persistence of one instrument — the PAR124A — still actively used by many researchers decades after discontinuation by its long-gone manufacturer.

Back to Analog

Recognizing that one size shouldn't have to fit all, SRS is proud to introduce the SR2124 Dual-Phase Analog Lock-In Amplifier. Inspired by the best of an earlier generation's lock-ins, but availing itself of today's low-noise analog components and design methodologies, the SR2124 is a tour de force in low-noise, high-performance analog instrumentation.

Architecture

The SR2124 designs follows two basic themes. First, the signal path is entirely built from low-noise analog electronics: the best JFETs, transistors, op-amps, and discrete components. Second, configuration control is managed by a microcontroller whose system clock only oscillates during the brief moments needed to change gains or filter settings. This "clock-stopping" architecture, first introduced by SRS in the SR560 Voltage Preamplifier, eliminates the inconvenience and reliability issues associated with mechanical panel controls, and makes full remote operation of these lock-ins possible.

Don't let the numeric displays fool you — the SR2124 really stops all digital clocks during operation. The numeric displays show precision setting information, such as input filter frequency, demodulator phase shift, and source output amplitude. The drive electronics are completely static, with no "scanning" or refresh to generate the slightest interference.

Whenever the microcontroller becomes active, the "CPU Activity" indicator illuminates, clearly showing when the digital clock is running. This occurs in response to front-panel button presses or remote computer commands.

When it Really Matters — Run Silent!

Sometimes, you need to be confident your experiment will be undisturbed: you've cooled your sample to a few millikelvin, all your wiring is still intact, and the best device you've built all year is ready for measurement. A locking toggle switch on the front panel can be set to "LOCKED OUT", forcing the digital clock to remain off, even if you press other buttons or knobs. The analog configuration of the lock-in stays steady, letting you run for minutes, hours, days — as long as you need.

Low Noise Input Amplifiers

The SR2124 has both voltage and current inputs. The voltage input is a single-ended/differential FET preamp with ultra-low 2.5 nV/√Hz input noise. The input impedance is 10 MΩ, and minimum full-scale input voltage sensitivity is 100 nV. The current input preamp has selectable gains of 10^6 and 10^8 V/A. Both AC and DC coupling is provided, and the instrument can operate in Ground or Float mode.

SRS also makes a variety of remote preamplifiers including the SR550 (FET input), SR551 (Hi-Z input), SR552 (BJT input), and SR554 (transformer input) which can all be powered directly from the SR2124's rear-panel preamp power port. These preamplifiers have unique characteristics which are optimized for a variety of experimental conditions. When used with the SR2124, they can often significantly improve your measurements.

Input Filters

The SR2124 provide several filter types for preconditioning your signal before it reaches the phase-sensitive detector. A choice of flat (no filtering), band pass, high pass, low pass, and notch filtering can be selected, and the Q-factor for the filter can be set between 1 and 100.

In band pass mode, a tunable narrow-band amplifier rejects signals outside of the passband, providing as much as an additional 60 dB of dynamic reserve.

The high pass and low pass filters allow you to limit the band of frequencies presented to the lock-in amplifier, and reject frequencies outside of the passband. The rolloff for these filters is –12 dB per octave.

In notch mode, a tunable band reject filter is engaged that provides up to 80 dB attenuation at a particular frequency.

Dynamic Reserve

The dynamic reserve of a lock-in amplifier, at a given full-scale input sensitivity, is the ratio 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 SR2124 has a dynamic reserve of up to 60 dB, depending on the sensitivity setting and the reserve mode. Engaging the input band pass filter can add an additional 20 to 60 dB of dynamic reserve, making the maximum achievable dynamic reserve 100 dB.

Output Time Constants

The SR2124 offers two stages of output low pass filtering. Time constants can be chosen as long as 300 s for maximum noise reduction, or as short as 1 ms. A choice of –6 dB or –12 dB per octave rolloff is selectable. The Minimum time constant setting bypasses the output filter, and the output signal bandwidth is simply determined by internal stray capacitance.

Offset

The lock-in's offset feature makes it easy to evaluate small changes in the presence of a full-scale signal. You can adjust the offset manually between ±1000 % (10×) of full-scale, or you can use the auto-offset feature to set the offset equal to the signal value with the push of a button. Once the offset has been adjusted, you can add gain (up to 10×) by decreasing the sensitivity setting.

Auto Features

Convenient auto features allow you to quickly configure the lock-in's optimum settings. Pressing the Gain, Phase, or Offset buttons starts the microcontroller, which then adjusts the instrument for either best sensitivity (Gain), phase shift to maximize signal (Phase), or null the output (Offset). The Ref Range button toggles the frequency auto-ranging feature on and off, which allows the SR2124 to automatically set the appropriate reference range whenever the oscillator unlocks.

Reference Channel

There are three reference modes in the SR2124: Internal, External, and Rear VCO. In all modes, the frequency range is first chosen in the reference section of the front panel — either manually or by the auto Ref Range feature.

In external reference mode, the instrumnent locks to external signals with at least 100 mVpp amplitude. The reference oscillator will phase-lock to the positive zero-crossings of the external reference input. Locking at f, 2f (second harmonic), or 3f (3rd harmonic) is supported.

Operated in internal mode, the reference frequency is set from the front panel with ±0.1 % accuracy. In addition to internal and external reference modes, the there is a built-in voltage controlled oscillator (VCO) that can be the lock-in's reference. The rear-panel VCO input accepts a 0 to +10 VDC signal which corresponds to the lowest and highest frequencies in the range set on the front panel. This convenient feature allows you to lock to a variable or swept control voltage.

A synchronous reference output signal is always present at the front-panel Ref Out BNC connector. Both sine and square waveforms are selectable, and the output amplitude can be set between 100 nV and 10 V. The reference is also available on the rear panel. Four phase-shifted 1 Vrms outputs at 0°, 90°, 180° and 270° can used for a variety of applications.

DC Bias

A bipolar DC bias voltage, independent of the AC reference amplitude, can be added to the reference output by switching "DC Bias" on. This feature is particularly helpful when making differential conductance and related transport measurements, where the small-signal AC response of your experiment must be measured at a range of different bias values. Bias values can be set up to ±1000× the reference amplitude, depending on amplitude.



SR2124 front panel



SR2124 rear panel

Phase Control

The SR2124 is a dual phase lock-in amplifier which has displays for both X and Y. The phase of the reference will often need to be adjusted. Manually nulling the phase is easy—press the phase button and turn the large knob until the signal is nulled, then shift the phase by 90°. Or, simply press the auto Phase button. The phase resolution is 0.01°, and phase accuracy is ±1° at mid-band frequencies.

AC Voltmeter Mode

For most applications, users will typically operate in Lock-In mode, but the mode can be changed to AC Volt allowing the lock-in to operate as a wideband or frequency selective AC voltmeter. In this mode, the average absolute value of an AC signal can be quickly measured without the need for a reference signal.

Computer Control

For those who need computer control of their lock-in amplifier, there is an RS-232 interface on the rear panel. All functions of the instrument can be set or read via the interface. When sending commands to the instrument, the microcontroller will be activated, and digital noise may be present. During these times, the front-panel Remote Activity LED alerts you that communications are taking place.

For remote interfacing with complete electrical isolation, there is a rear-panel fiber optic interface. When connected to the SX199 Remote Computer Interface Unit, this provides a path for controlling the the lock-in via GPIB (IEEE-488.2), Ethernet, and RS-232.

Ordering Information

SR2124	Dual phase lock-in amplifier
SX199	Remote computer interface unit

SR2124 Specifications

Signal Channel

Voltage inputs	Single-ended or differential
Sensitivity	100 nV to 500 mV
Current input	10^6 or 10^8 V/A
Input impedance	
Voltage	10 MΩ + 35 pF, AC or DC coupled
Current	1 kΩ to virtual ground
Gain accuracy	±1 %
Gain stability	100 ppm/°C (flat mode, normal reserve)
Noise (rms)	2.5 nV/√Hz at 1 kHz 0.14 pA/√Hz at 1 kHz (10^6 V/A) 0.014 pA/√Hz at 100 Hz (10^8 V/A)
Signal filters	(Tunable from 0.2 Hz to 200 kHz)
Flat	Flat response to within ±1 % from 10 Hz to 100 kHz, ±2 % from 100 kHz to 200 kHz, and ±10 % below 10 Hz.
Band pass	Bandwidth adjustable from 1 % to 100 % of center frequency (Q from 100 to 1).
High pass	–12 dB/oct rolloff
Low pass	–12 dB/oct rolloff
Notch	Up to 80 dB attenuation
CMRR	100 dB to 10 kHz, decreasing by 6 dB/oct above 10 kHz
Dynamic reserve	(without band pass filter)
Low noise	20 dB
Normal	40 dB
High reserve	60 dB

Reference Channel

Frequency range	0.2 Hz to 200 kHz
Reference input	TTL or sine (100 mVpp min.)
Input impedance	1 MΩ
Phase resolution	0.01°
Phase accuracy	±1° (2 to 20 kHz), ±5° (20 kHz to 200 kHz)
Harmonic detection	F, 2F and 3F (ext. ref)

Demodulator

Output stability	
Low noise	20 ppm/°C
Normal	100 ppm/°C
High reserve	1000 ppm/°C
Time constants	1 ms to 300 s (6 or 12 dB/oct rolloff). MINIMUM time position, typically 500 µs, is determined by stray capacitance. ±10 % (to 200 kHz)

Internal Oscillator

Range	0.2 Hz to 200 kHz
Outputs	Sine, square (selectable) (When using an external reference, output is phase locked to the external reference.)
Frequency accuracy	0.1 %
Frequency resolution	3½ digits or 1 mHz, whichever is greater
Amplitude	1 µV to 20 Vpp into 10 kΩ, 50 Ω output impedance.
Amplitude stability	50 ppm/°C

VCO

VCO input	A 0 to 10 V signal corresponds to the beginning and ending frequencies in the range set on the front panel.

Displays

Panel meters	Center-zero, mirror-backed
Offset	Output can be offset up to ±1000 % of full scale.
Reference	3½-digit LED display

Inputs and Outputs

Lock-In/AC Volt	Instrument can be operated as a lock-in amplifier or as a frequency selective AC voltmeter.
Output	
Lock-In	X (Rcosθ), ±10 V Y (Rsinθ), ±10 V
AC Volt	±10 V
Ref. Out	Analog output. Sine or square wave, up to ±20 Vpp
Remote preamp	Provides power to the optional SR55X preamps
Fiber optic interface	Connection for SX199 Remote Computer Interface Unit. The SX199 has GPIB (IEEE-488.2), RS-232, and Ethernet interfaces for remotely controlling the SR2124.
RS-232 interface	RS-232 interface is standard. All instrument functions can be controlled and read through the interface.
Quadrant outputs	Four phase-shifted outputs at 0°, 90°, 180° and 270° from the reference. Output levels are 1 Vrms sinewaves.

General

Power	40 W, 100/120/220/240 VAC, 50/60 Hz
Dimensions	17" × 5.25" × 19.5" (WHD)
Weight	23 lbs.
Warranty	One year parts and labor on defects in materials and workmanship