

# Digital Lock-In Amplifiers

SE2012 Dual-channel Lock-in Amplifier

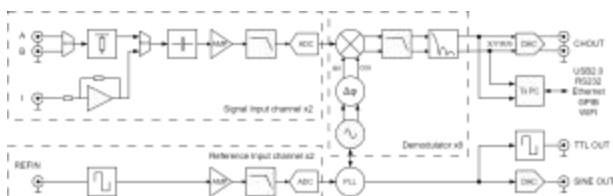
10 $\mu$ Hz to 250kHz



## Overview

The SE2012 dual-channel lock-in amplifier is the latest core technology product, featuring exceptional high performance and wide bandwidth measurement capabilities. This instrument is based on digital modulation technology and is equipped with a 24-bit high-precision analog-to-digital converter (ADC) and 16-bit high-speed digital-to-analog converter (DAC). With the newly launched LIUXI-architecture, it can accurately, quickly, and flexibly detect effective signal components hidden in strong noise.

The SE2012 has 2 independent and synchronized input channels, capable of simultaneously measuring the amplitude and phase information of two input signals. It achieves international leading levels in key performance indicators such as measurement accuracy, operating frequency range, signal-to-noise ratio, and dynamic reserve. Additionally, the newly added multi-harmonic measurement, oscilloscope, spectrum analyzer functions, and PID control capabilities make the SE2012 widely applicable to various needs in scientific research and industrial fields.



Block Diagram of SE2012

## Key Features

- 2 independent synchronized input channels
- Input noise as low as  $2.5\text{nV}/\sqrt{\text{Hz}}$
- Input range from 1 nV to 5 Vrms
- Frequency range from 10 $\mu$ Hz to 250kHz
- Dynamic reserve > 130dB
- 8-channel synchronous demodulators
- 2-channel oscilloscope with FFT analysis
- 2-channel PID controllers

## Input Signal Channel

The SE2012 is equipped with a low-noise analog amplifier that efficiently processes single-ended or differential signals, with an equivalent input noise as low as 2.5 nV/  $\sqrt{\text{Hz}}$ . The input impedance of this channel is 10 M $\Omega$ , and the full-scale range is from 1 nVrms to 5 Vrms. Furthermore, the signal input channel uses a high-precision 24-bit ADC, achieving a dynamic range over 130 dB.

## Reference Signal Channel

The reference signal of the SE2012 can be selected as either a sine wave or square wave signal based on user requirements, or it can use an internally digitally synthesized reference signal. When the SE2012 is set to internal reference signal mode, the instrument's internal high-precision oscillator and digital synthesis algorithm generate a sine wave signal for multiplication with the input signal, with the internal reference signal being nearly unaffected by phase noise. Through digital phase shifting technology, the phase resolution of the internal reference signal can reach 1  $\mu$ deg.

When the SE2012 operates in external reference signal mode, it accepts sine wave signals or TTL logic levels as external reference signals, which are locked by the internal digital phase-locked loop. Based on the frequency of the reference signal, the SE2012 can detect signals at the fundamental frequency and its harmonics, detecting up to 10,000 times the fundamental frequency. But it provided that the maximum harmonic frequency does not exceed the upper limit of the instrument's measurement bandwidth.

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## Output Signal Channel

The signal output ports of SE2012 is based on a 32 MSPS 16-bit DAC, capable of generating high-precision sine wave signals in the frequency range of 1 Hz to 1.5 MHz, with adjustable DC offset. The signal amplitude range is from 0.1 Vrms to 5 Vrms, and the DC offset range is  $\pm 5$  Vdc. For external devices requiring bias voltage, such as electro-optic modulators, the SE2012 can drive devices directly without the need for additional level conversion amplifiers. The output signal phase is synchronized with the instrument's internal oscillator. It can be independently set for phase offset.

Additionally, the SE2012 supports AM/FM/PM modulation functions, allowing users to perform modulation control of the system.

## Digital Demodulator

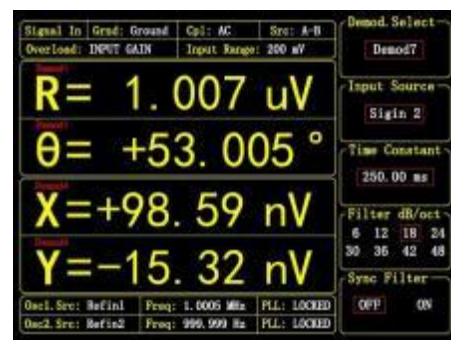
The SE2012 has 8 synchronized demodulators, which can be independently controlled. The time constant of the SE2012 can be flexibly set within the range of 100 ns to 3 ks, allowing users to customize the time constant according to their needs. The filter's roll-off rate can be selected from 6 to 48 dB/oct in 8 steps. Using digital modulation technology and advanced filter structures. The SE2012 offers higher dynamic reserve ( $>130$  dB), more precise phase (absolute phase error  $< 1^\circ$ ), zero DC drift, and excellent orthogonal performance compared to traditional analog lock-in amplifiers. Additionally, the SE2012 provides an optional synchronous filter that can quickly eliminate the effects of signal harmonics, ensuring that the instrument accurately detects low-frequency signals while responding rapidly.

## Communication Interface

The SE2012 includes USB 2.0, 1000 Mbps RJ45 Ethernet port, WIFI network interface, RS232 serial port, and GPIB interface. Through these interfaces, users can effectively utilize all testing functions of the SE2012 on a controlling computer, setting reasonable control parameters and reading the data measured by the instrument.

## Color Display Screen

The SE2012 features a 5.6-inch TFT color display with a resolution of 640 $\times$ 480, serving as the main user interface, allowing full independent control of the instrument via keyboard. On the display, users can easily heed parameters such as demodulator X, Y, R,  $\theta$ , and configure various basic settings like filter constants, making the operation intuitive and convenient.



## PC Software

The SE2012 provides professional PC software that allows configuration of each demodulator, input channel, and output channel through schematic diagrams or control panels, combining professionalism and practicality with simplicity and intuitiveness. The software features clear numerical display and real-time waveform display functions. Users can save the measurement results exportable as CSV files for subsequent analysis using professional software, enhancing the ease of testing. Furthermore, we fully support application programming interfaces (API) in Python, MATLAB, and LabVIEW.



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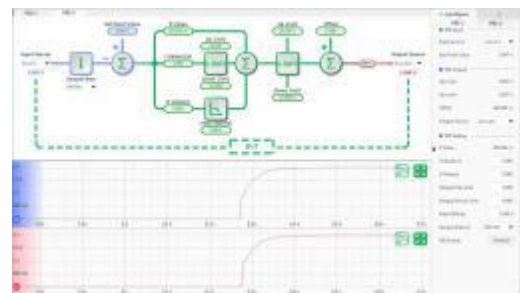
## Oscilloscope

The oscilloscope function features 2 signal channels, selectable for signal input, reference input, signal output, and auxiliary input/output, providing various triggering methods for real-time display of time-domain signals. Each channel has a maximum sampling depth of 65,536 and adjustable sampling durations from 65  $\mu$ s to 1 s.



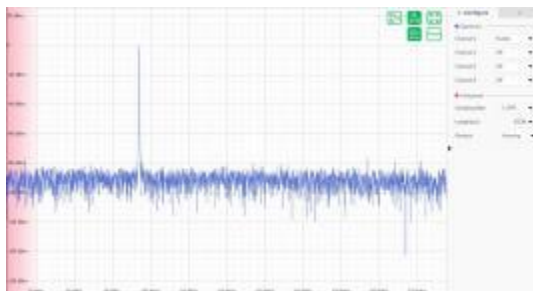
## PID Controllers

The SE2012 has an internal independent 2-channel digital PID controller with a maximum sampling rate of 4 MSPS. The PID controller is closely linked with the lock-in amplifier, controlling the output signal's amplitude, phase, frequency, and other signals based on the measurements from the demodulator, achieving precise control of multiple parameters.



## FFT Spectrum Analyzer

The FFT spectrum analyzer analyzes the frequency domain information of signals based on waveforms captured by the oscilloscope. Depending on the sampling rate and sampling depth, the frequency resolution range of the spectrum analyzer is approximately 1 Hz to 31 kHz.



## Parametric Scanner

The parameter scanner provides users with convenient quick scanning capabilities, allowing for the instant plotting of frequency response, amplitude response curves, and offering single or loop scanning modes.



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## Input Signal Channel

|                        |                                                                                                                 |
|------------------------|-----------------------------------------------------------------------------------------------------------------|
| Input Channel Number   | 2                                                                                                               |
| Input Mode             |                                                                                                                 |
| Voltage                | Single-ended or Differential                                                                                    |
| Current                | Single-ended                                                                                                    |
| Full-Scale Sensitivity | 1 nV to 5 V; 1fA-5mA;                                                                                           |
| Range Levels           | 1mV to 5V, total 7 levels                                                                                       |
| Input Coupling Mode    | DC or AC coupling                                                                                               |
| Input Impedance        | 10 M $\Omega$    25 pF (Voltage)<br>100 $\Omega$ or 1 k $\Omega$ (Current)                                      |
| Input Shield Grounding | Grounding or 10 k $\Omega$ floating                                                                             |
| Dynamic Reserve        | >130 dB                                                                                                         |
| Gain Accuracy          | 0.5% typical, 1% max                                                                                            |
| Input Voltage Noise    | 3.5 nV/ $\sqrt{\text{Hz}}$ ( $f \geq 1 \text{ kHz}$ )<br>2.5 nV/ $\sqrt{\text{Hz}}$ ( $f \geq 10 \text{ kHz}$ ) |
| Input Current Noise    | 20 fA/ $\sqrt{\text{Hz}}$ ( $f = 97 \text{ Hz}$ )                                                               |
| ADC Bit                | 24 bit                                                                                                          |

## Reference Signal Channel

|                          |                                                                                        |
|--------------------------|----------------------------------------------------------------------------------------|
| Reference Channel Number | 2                                                                                      |
| Reference Signal         |                                                                                        |
| Frequency Range          | 10 $\mu$ Hz – 1.5 MHz                                                                  |
| Supported Waveform       | Square or sine wave                                                                    |
| Input Impedance          | 1 M $\Omega$                                                                           |
| Reference Levels         |                                                                                        |
| Square                   | $3\text{V} < V_{\text{IH}} < 5\text{V}$ , $-0.1\text{V} < V_{\text{IL}} < 0.5\text{V}$ |
| Sine                     | $300 \text{ mV} < V_{\text{pp}} < 10 \text{ V}$                                        |
| Phase                    |                                                                                        |
| Resolution               | 1.0 $\mu$ deg                                                                          |
| Phase Error              | $\pm 0.5 \text{ deg}$ typical, $\pm 1 \text{ deg}$ max                                 |
| Temperature Drift        | $< 200 \text{ ppm}/^\circ\text{C}$                                                     |
| Harmonic detection       | 1-10000F (nF $< 1.5 \text{ MHz}$ )                                                     |
| Acquisition Time         |                                                                                        |
| External Reference       | 10 or 100 signal cycles                                                                |

## Oscillator

|                       |                            |
|-----------------------|----------------------------|
| Oscillator Number     | 2                          |
| Oscillator Parameters |                            |
| Accuracy              | 0.3 ppm                    |
| Temperature Stability | 0.5 ppm / $^\circ\text{C}$ |
| Aging Rate            | $< 1 \text{ ppm/year}$     |
| Phase Noise           | -145 dBc/Hz (@1kHz)        |

## Communication Interfaces

|          |                                             |
|----------|---------------------------------------------|
| RS-232   | DB-9 female interface                       |
| USB2.0   | 480 Mbps high-speed interface               |
| Ethernet | RJ45-1000Mbps<br>wireless network interface |
| GPIB     | IEEE-488.2 interface                        |

## Output Signal Channel

|                       |                                                     |
|-----------------------|-----------------------------------------------------|
| Output Channel Number | 2                                                   |
| Frequency Range       | 10 $\mu$ Hz – 250kHz                                |
| Frequency Accuracy    | 2 ppm + 1 $\mu$ Hz                                  |
| Frequency Resolution  | 1 nHz                                               |
| Sine Amplitude        | 0.1 $\mu$ Vrms to 5 Vrms                            |
| Accuracy              | 0.5% typical, 2% max                                |
| Resolution            | 0.1 $\mu$ Vrms                                      |
| Driving Current       | $\pm 80 \text{ mA}$ max                             |
| Temperature Stability | $< 200 \text{ ppm}/^\circ\text{C}$                  |
| Output Impedance      | 50 $\Omega$                                         |
| Adjustable DC Offset  | -5 V <sub>DC</sub> to 5 V <sub>DC</sub>             |
| Synchronous Output    | 3.3V TTL/CMOS level<br>output impedance 50 $\Omega$ |
| Additional Features   | AM/FM/PM modulation output                          |
| DAC Parameter         | 16 bit, 32 MSPS                                     |

## Demodulator

|                       |                               |
|-----------------------|-------------------------------|
| Demodulator Number    | 8                             |
| Demodulator Bit       | 64 bit                        |
| Input Source Select   | 2 input channels selectable   |
| Time Constant         | 100ns - 3ks                   |
| Measurement Bandwidth | 50 $\mu$ Hz – 1.6 MHz         |
| Filter Slope (dB/oct) | 6, 12, 18, 24, 30, 36, 42, 48 |
| Synchronous Filter    | $< 1000 \text{ Hz}$ effective |

## Auxiliary Inputs/Outputs

|                 |                                      |
|-----------------|--------------------------------------|
| AUX Input       |                                      |
| Function        | 4-channel input                      |
| Amplitude       | $\pm 10\text{V}$ , 0.1 mV resolution |
| Input Impedance | 1M $\Omega$                          |
| ADC             | 16 bit, 150 kSPS                     |
| AUX Output      |                                      |
| Function        | 4-channel output                     |
| Amplitude       | $\pm 10\text{V}$ , 0.1 mV resolution |
| Driving Current | $\pm 30 \text{ mA}$ max              |
| DAC             | 16 bit, 500 kSPS                     |

## Others

|                         |                                      |
|-------------------------|--------------------------------------|
| Power Supply            |                                      |
| Voltage                 | 220~240 VAC<br>100~120 VAC(optional) |
| Power                   | 50 W typical, 70 W max               |
| Power Noise Suppression | 70dB@1MHz                            |
| Dimensions              | 448mm $\times$ 532mm $\times$ 148mm  |
| Weight                  | 12 kg                                |