SE2022

DSP Lock-In Amplifier

User Manual

Revision 1.1.0, 2026-03-06

Content

Chapter 1 Technical Parameters

Input Signal Channel

Input Channel Number	2
Input Mode	
Voltage	Single-ended or Differential
Current	Single-ended
Full-Scale Sensitivity	1 nV to 5 Vrms
Range Levels	2mV to 5V, total 7 levels
Input Coupling Mode	DC or AC coupling
Input Impedance	10 MΩ ‖ 25 pF (Voltage) 100Ω or1 kΩ (Current)
Input Shield Grounding floating	Grounding or 10 kΩ
Dynamic Reserve	>130 dB
Gain Accuracy	0.5% typical, 1% max
Input Voltage Noise	3.5 nV/ Hz（f≥ 1 kHz） 2.5 nV/ Hz（f≥ 10 kHz）
Input Current Noise	20 fA/ Hz（f= 97Hz）
ADC Bit	24 bit

Reference Signal Channel

Reference Channel Number	2
Reference Signal	
Frequency Range	10 µHz – 1.5 MHz
Supported Waveform	Square or sine wave
Input Impedance	1 MΩ
Reference Levels	
Square	$3V<V_{IH}<5V$, $-0.1V<V_{IL}<0.5V$
Sine	$300\ mV < V_{pp} < 10\ V$
Phase	
Resolution	1.0 µdeg
Phase Error	±0.5 deg typical, ±1 deg max
Temperature Drift	< 200 ppm/°C
Harmonic Detection	1-10000F (nF < 1.5 MHz)
Internal Reference	Instantaneous acquisition
External Reference	10 or 100 signal cycles

Oscillator

Oscillator Number	2
Oscillator Parameters	
Accuracy	0.3 ppm
Temperature Stability	0.5 ppm / ℃
Aging Rate	<1 ppm/year
Phase Noise	-145 dBc/Hz (@1kHz)

Output Signal Channel

Output Channel Number	2
Frequency Range	DC – 1.5MHz
Frequency Accuracy	2 ppm + 1 µHz
Frequency Resolution	1 nHz
Sine Amplitude	0. 1 µVrms to 5 Vrms
Accuracy	0.5% typical, 2% max
Resolution	0.1 µVrms
Driving Current	± 80 mA max
Temperature Stability	<200 ppm/°C
Output Impedance	50 Ω
Adjustable DC Offset	$-5\ V_{DC}$ to $5\ V_{DC}$
Synchronous Output level	3.3V TTL/CMOS output impedance 50 Ω
Additional Features	AM/FM/PM modulation output
DAC Parameter	16 bit, 32 MSPS

Demodulator

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

Auxiliary Inputs/Outputs

AUX Input	
Function	4-channel input
Amplitude	±10V, 0. 1 mV resolution
Input	1MΩ
ADC	16 bit, 150 kSPS
AUX Output	
Function	4-channel output
Amplitude resolution	±10V, 0. 1 mV
Driving Current	±30 mA max
DAC	16 bit, 500 kSPS

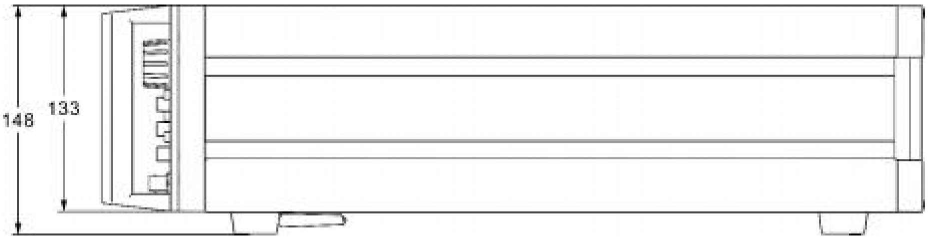
Communication Interfaces

RS-232	DB-9 female interface
USB2.0 interface	480 Mbpshigh-speed
Ethernet	RJ45-1000Mbps
	wireless network interface
GPIB	IEEE 488 2interface

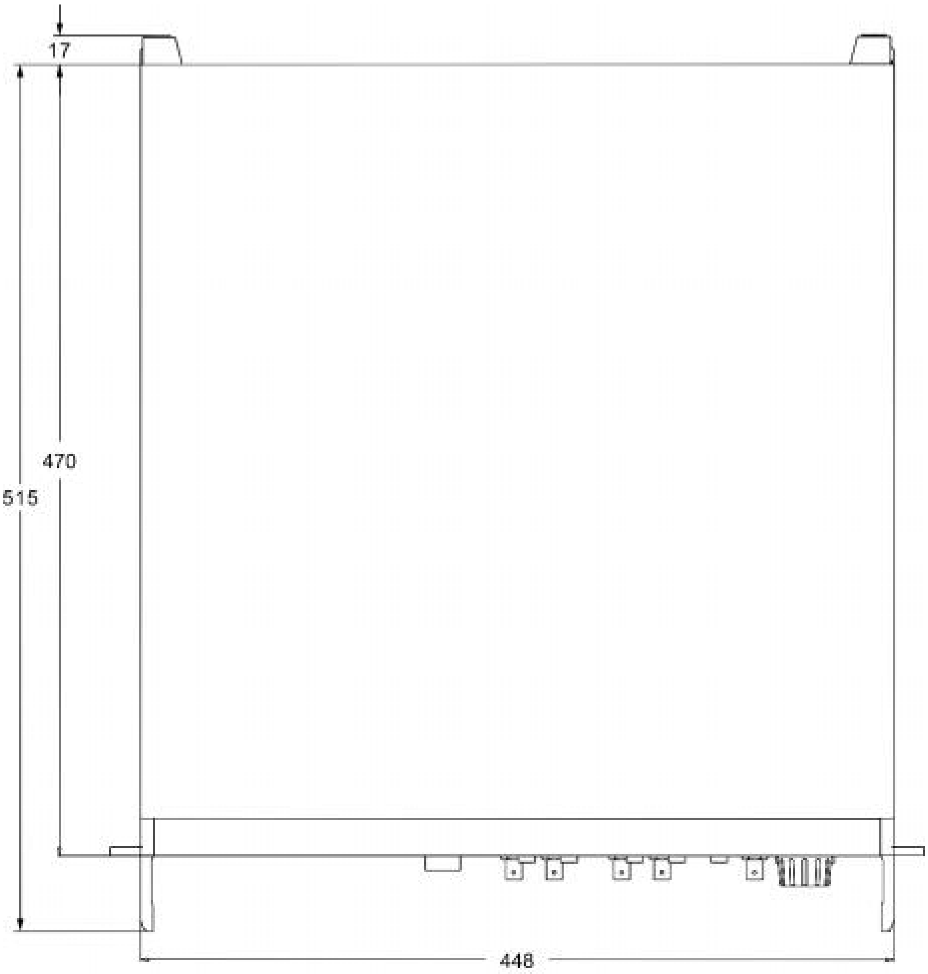
Others

Power Supply	
Voltage	220~240 VAC
	100~ 120 VAC(optional)
Power	50 W typical, 70 W max
Power Noise Suppression	70dB@1MHz
Dimensions	448mm×532mm×148mm
Weight	12 kg

- Product dimension drawing (side view)



- Product dimensions (top view)



Chapter 2 Fundamentals of Phase-Locked Amplifiers

2.1 Introduction to Phase-Locked Amplifier

A phase-locked amplifier (PLA) is a device designed for weak signal detection. Weak signals are often overwhelmed by various noises, and the PLA can extract these signals from the noise background for accurate measurement, as illustrated in Figure 1. Based on mutual interference methods, the PLA employs phase-sensitive detection technology as its core mechanism. By using a reference signal with identical frequency and fixed phase relationship to the target signal as a baseline, it extracts signal components correlated with the reference signal while filtering out noise components outside the reference frequency range.

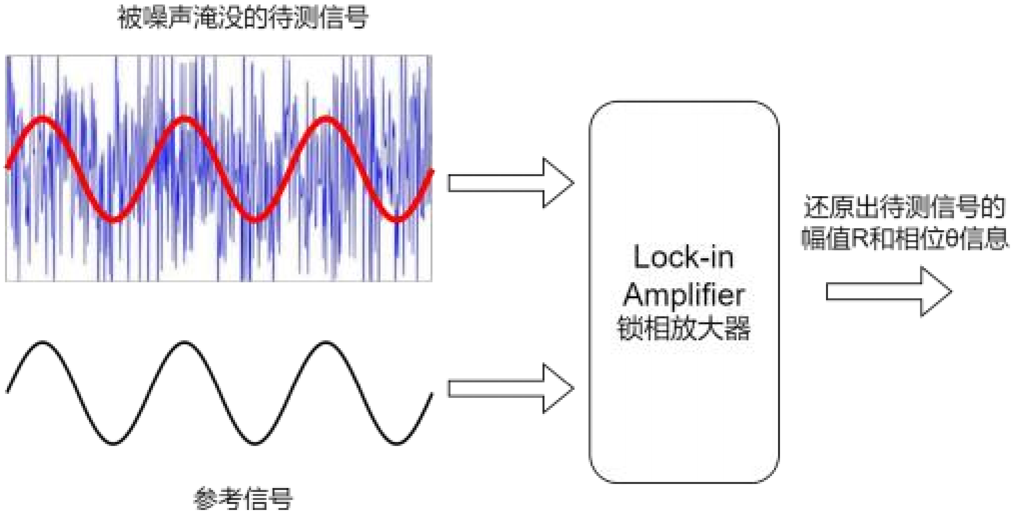


Figure 1. Schematic Diagram of Phase-Locked Amplifier

The most fundamental processing technique for weak signals is amplification. Traditional amplification methods amplify both the signal and noise; moreover, without bandwidth limiting or filtering, any amplification operation reduces the signal-to-noise ratio (SNR). Therefore, filtering techniques are essential to purify the signal and improve the SNR for accurate weak signal measurement. The optimal filter choice is a bandpass filter; however, achieving a bandpass filter with adjustable center frequency, stability, and a high Q factor is often challenging.

Phase-Sensitive Detectors (PSDs) can replace high-Q-value band-pass filters. Their basic architecture consists of a multiplication module that multiplies the input signal with a reference signal and a filtering module that applies low-pass filtering to the multiplication result. In some implementations, PSDs refer specifically to the multiplication module alone, omitting the filtering module, as illustrated in Figure 2.

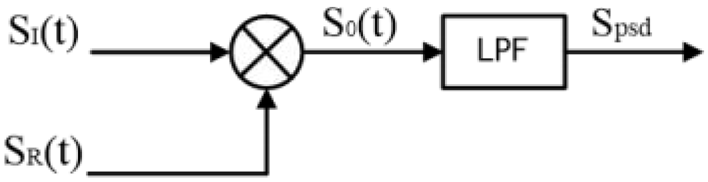


Figure 2. Schematic Diagram of Phase-Sensitive Detection

SI(t) denotes the time-domain input signal contaminated with noise, while SR(t) represents the reference signal sharing identical frequency characteristics with the target input signal. By integrating both the target signal channel and reference signal channel, the Power Spectral Density (PSD) configuration establishes a complete phase-locked amplifier functional architecture, referred to as a single-phase phase-locked amplifier. The schematic diagram illustrating its structural principle is shown in Figure 3.

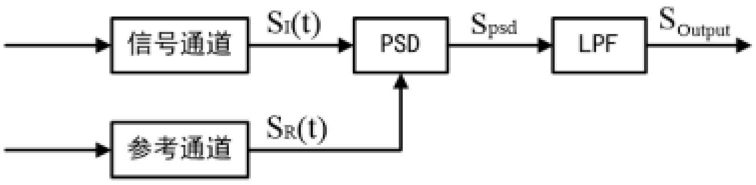


Figure 3. Structural Diagram of a Single-Phase Phase-Locking Amplifier

The signal entering the PSD module via the signal channel can be defined as:

$$S_I\ (t) = A_I\sin(wt + \varphi) + B(t)$$

Here, (1) denotes the frequency of the test signal, where A ∈ (1, t + φ) represents the test signal and B(t) denotes the doped noise.

The standard reference signal output from the reference signal channel can be defined as:

$$S_R\ (t) = A_R\sin(wt + \delta)$$

Two input signals are simultaneously fed into the PSD module for multiplication operation, yielding the following output:

$$\begin{aligned} S_{psd} &= S_I\ (t)\ S_R\ (t) = A_I A_R\sin(wt + \varphi)\sin(wt + \delta) + B(t)A_R\sin(wt + \delta) \\ &= \frac{1}{2}A_I A_R\cos(\varphi - \delta) - \frac{1}{2}A_I A_R\mathrm{COs}(2wt + \varphi + \delta) + B(t)A_R\sin(wt + \delta) \end{aligned}$$

The above equation yields three components. The first component comprises the cosine value of the test signal amplitude AI, reference signal amplitude AR, and the phase difference (φδ) between the input signal and reference signal. When both the useful portion of the input signal and the reference signal remain stable, this component can be considered a constant value, equivalent to a DC signal. Similarly, the second component represents the reference signal's doubled-frequency AC signal. The third component is the product of the noise signal and the reference signal. Given the completeness of sine wave signals, random signals exhibit no correlation with this product, resulting in an integral value of zero.

On the other hand, from a spectral perspective, the first portion of the result lies in the DC region, the second portion is at the frequency double that of the reference signal, and the third portion represents the original random signal after undergoing a spectral shift (e.g., in the case of white noise, the shifted signal remains white noise). Therefore, applying the result to a low-pass filter yields the following DC component:

$$S_{output} = \frac{1}{2}A_I A_R\cos(\varphi - \delta)$$

The frequency-domain observation of the phase-locked amplifier's spectral shift process is illustrated in the figure below:

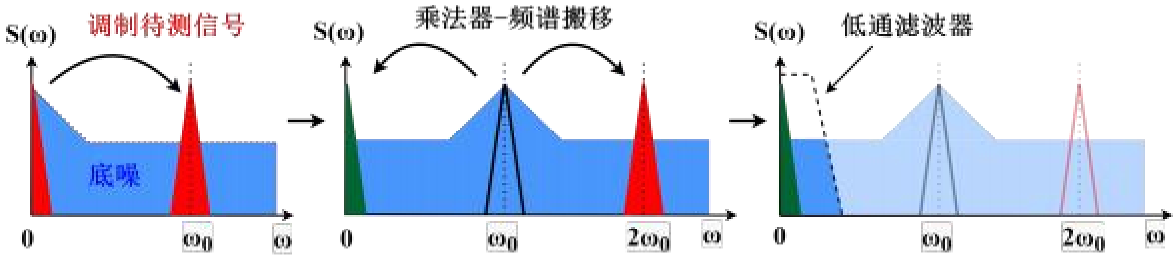


Figure 4. Phase-Locking Amplifier Spectrum Shift Process

The amplitude of the measured signal can be determined by adjusting the phase difference (φδ) between the measured signal and the reference signal, but achieving precise adjustment is challenging. The dual-phase lock-in amplifier effectively addresses this issue. As shown in Figure 5, this diagram illustrates the schematic architecture of a dual-phase lock-in amplifier.

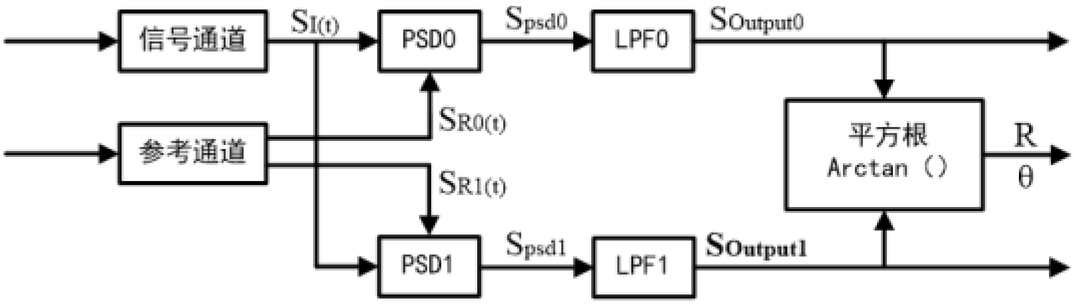


Figure 5. Structural Diagram of a Dual-Phase Lock-in Amplifier

Define the phase difference $\theta = \varphi \ \_\delta$, where the reference channel generates two sine signals with a 90° phase difference:

$$S_{R0}(t) = A_R\sin(wt+\delta),\ \ S_{R1}(t) = A_R\cos(wt+\delta),$$

The output result can be calculated as: $S_{output0} = \frac{1}{2}A_I A_R\cos\theta$, $S_{output1} = \frac{1}{2}A_I A_R\sin\theta$。

Define $X = A_I\cos\theta$ and $Y = A_I\sin\theta$, thus the output amplitude independent of phase difference can be calculated:

$$R = \sqrt{X^2 + Y^2} = A_I = \frac{2 \times \sqrt{S_{Output0}{}^2 + S_{Output1}{}^2}}{A_R}$$

The phase difference between the reference signal and the measured signal can be calculated using the following formula:

$$\theta = \tan^{-1}(y/x)$$

2.2 SE2022 Function Schematic

The schematic diagram illustrating the operating principle of the digital phase-locking amplifier SE2022 is shown below:

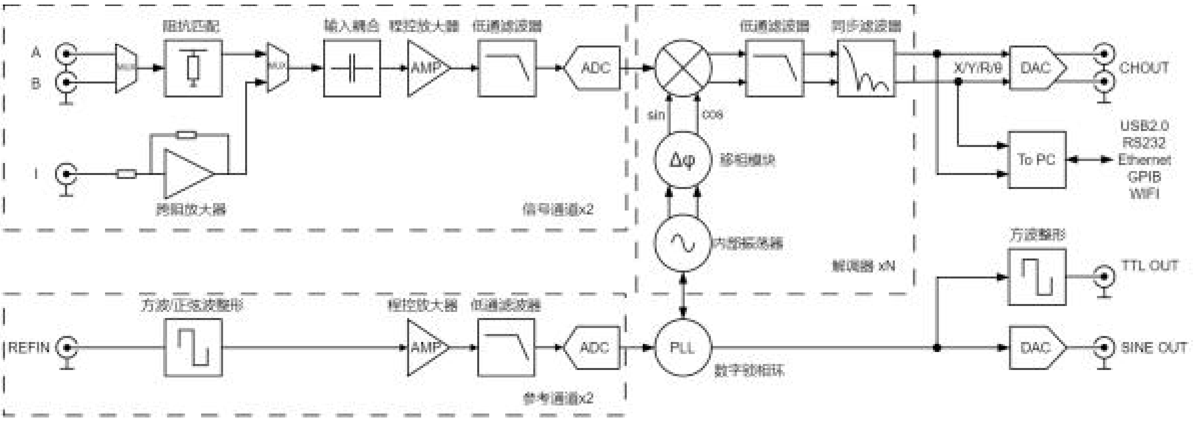


Figure 6. Principle Block Diagram ofSE2022

Overall, the SE2022 functional modules are primarily divided into signal conditioning channels, reference signal processing channels, demodulator modules, and system main control units. The left interface serves as the input interface, while the right interface functions as the output interface.

When the test signal is connected to the voltage or current input interface of the phase-locking amplifier, it is amplified to an appropriate range and then digitized by the analog-to-digital converter (ADC), resulting in a digital signal. The digitized signal is processed through eight demodulator channels for signal demodulation, with the output delivered to the CHOUT interface. Users can observe the results using oscilloscopes or other tools, or transmit them via the communication interface to a host system.

Users can observe the device using the SSI Lucid Suite software included with the instrument.

The EO2022 features two digital phase-locked loops (PLLs), capable of simultaneously locking onto two reference/synchronization signals. The PLL outputs are available at the Sineout and TTLout interfaces, facilitating easy control of other instruments and equipment.

2.3 Reference Channel

The reference channel provides a control signal coherent with the detected signal for phase-sensitive detectors. The SE2022 supports sine or square wave reference signals based on operational requirements, featuring 1 MΩ input impedance. With two REF IN reference signal input channels, the device enables simultaneous demodulation of dual frequency components and supports harmonic/difference frequency signal processing.

Both reference waveforms can generally be used. For TTL reference, the high level must exceed 3V and the low level must be below 0.5V. The sine reference requires AC coupling, with effective amplitude exceeding 0.3V pp.**However, when operating below 1Hz frequency, the TTL level signal mode must be employed.**Since sine wave signals exhibit low signal-to-noise ratios at low output amplitudes and may experience amplitude jitter, while most function generators can produce stable TTL synchronization signals, square wave signals are more recommended as reference signals.

The SE2022 phase-lock amplifier offers two reference source modes: internal reference mode and external input mode.

When set to the internal reference signal mode, the instrument's high-precision oscillator and synthesis algorithm generate a sine wave signal for multiplication with the input signal. In this configuration, no phase-locked loop (PLL) is required for phase synchronization, and the internal reference signal remains largely unaffected by phase noise. The internal reference mode operates effectively across a frequency range of 10 μHz to 1.5 MHz. However, due to inherent frequency deviations between the internal oscillator and the external signal source, coupled with the absence of PLL tracking, a frequency difference exists between the internally generated sine wave and the measured signal, and phase stability between them cannot be guaranteed.

The EO2022 can also operate in external reference signal mode, where sine wave signals or TTL logic levels serve as external reference signals. When this mode is used, the internal oscillator automatically tracks the external reference signal, maintaining identical frequency and phase. However, phase jitter may occur in practical operation, potentially introducing measurement errors. This jitter introduces noise at various frequencies into the reference signal; according to the PSD coherence principle, the output signal contains not only the measured signal at the reference frequency but also noise from other frequencies present in the reference signal. In practice, phase jitter is typically minimal and does not cause measurement issues. For jitter-free measurements, the internal reference mode is recommended. Since this mode does not utilize a phase-locked loop, the internal oscillator is directly connected to the reference signal, eliminating additional phase jitter interference.

2.4 Phase Sensitive Detector

The phase-sensitive detector (PSD) in SE2022 is implemented using a digital multiplier. The input signal, after amplification and filtering, is converted into a digital signal by a 24-bit A/D converter and then fed into the phase-sensitive detector. The phase-sensitive detection module of this product achieves a precision of 64 bits.

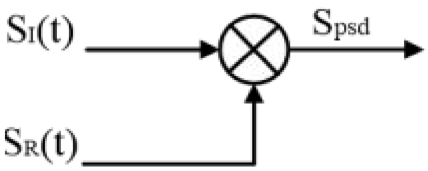


Figure 7. Core Components of Coherence Detection

The phase-sensitive detector module in phase-locked amplifiers primarily achieves coherent modulation between input signals and reference signals. Traditional phase-locked amplifiers implement this function using an analog multiplier. However, this analog-based coherent modulation approach presents multiple limitations: it not only severely restricts the precision of phase-sensitive detectors but also introduces significant background noise, which poses substantial challenges for weak signal measurements.

Based on the aforementioned considerations, this product employs digital technology to achieve coherent signal modulation. Since the reference signal generated by the internal signal generator is a 24-bit digital signal, it significantly mitigates the impact of harmonic components on coherent modulation. In practice, harmonic components

The suppression can reach-120 dB, indicating that harmonic components have almost no effect during coherent modulation.

Furthermore, phase-sensitive detectors implemented using analog technology exhibit temperature drift and DC bias, resulting in output deviations from actual measurements (i.e., systematic errors with inherent uncertainty). Digital-phase-sensitive detectors, however, effectively eliminate these issues. Under normal operating conditions, they generate negligible systematic errors. Since analog multipliers process analog input signals, their reference signals are also susceptible to temperature drift effects. This leads to reference signal deviations, consequently increasing systematic errors in coherent modulation results.

The dynamic headroom of phase-sensitive detectors implemented using analog technology is typically limited to below 60 dB, due to the prevalent background noise in analog systems. Since phase-lock amplifiers are primarily designed for detecting weak signals, coherent modulation results in errors when the background noise amplitude approaches or exceeds that of the signal. In contrast, digitally implemented phase-sensitive detectors avoid such issues, with their dynamic headroom primarily determined by the quality of the A/D conversion. Once the input signal is digitized, no additional errors are introduced during coherent modulation. In fact, the SE2022 achieves a dynamic headroom exceeding 120 dB.

In conclusion, phase-sensitive detectors based on digital technology outperform their analog counterparts in all performance metrics. Moreover, digital-phase-sensitive detectors offer advantages such as simplified debugging processes, making them the optimal choice for this product.

2.5 Filter, Time Constant, and DC Gain

The output of a phase-sensitive detector contains signals with multiple frequency components, including both the sum frequency components of the input signal and reference signal, their difference frequency components, and noise signals. The difference frequency signal between the two signals becomes a DC component only when the input signal and reference signal are at the same frequency. The low-pass filter located downstream of the phase-sensitive detector (as shown in Figure 8) effectively removes noise signals and sum frequency components except for the DC component, enabling the phase-locked amplifier to function as a high-quality bandpass filter.

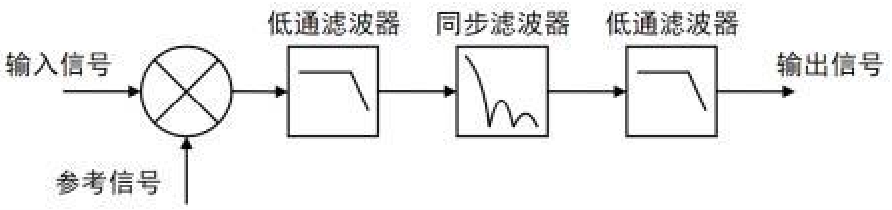


Figure 8. Filter Structure of the Phase-Sensitive Detector

time constant

The bandwidth configuration method for the low-pass filter at the rear end of the phase-sensitive detector is identical to that of conventional low-pass filters, both achieved through setting time constants. The calculation formula for the time constant TC is as follows:

$$TC = \frac{1}{2\pi f}$$

Here, f denotes the cutoff frequency at-3 dB of the filter. For instance, in a first-order RC low-pass filter, a time constant of 1 second indicates that its cutoff frequency at-3 dB is 0.16 Hz.

Typically, when noise exists at the system's input end, it will also generate noise at the output end. However, increasing the time constant value can enhance system stability and mitigate the impact of input noise on output performance. The time constant not only affects system stability and accuracy but also influences response time. For first-order RC low-pass filters, it takes at least five times the time constant duration for output stabilization. Figure 9 demonstrates the step-response characteristics of low-pass filters with different orders to input signals:

Furthermore, the time constant also determines the equivalent noise bandwidth (ENBW) during noise measurement. It is important to note that the equivalent noise bandwidth does not refer to the filter's 3 dB bandwidth; rather, it denotes the effective bandwidth for Gaussian noise.

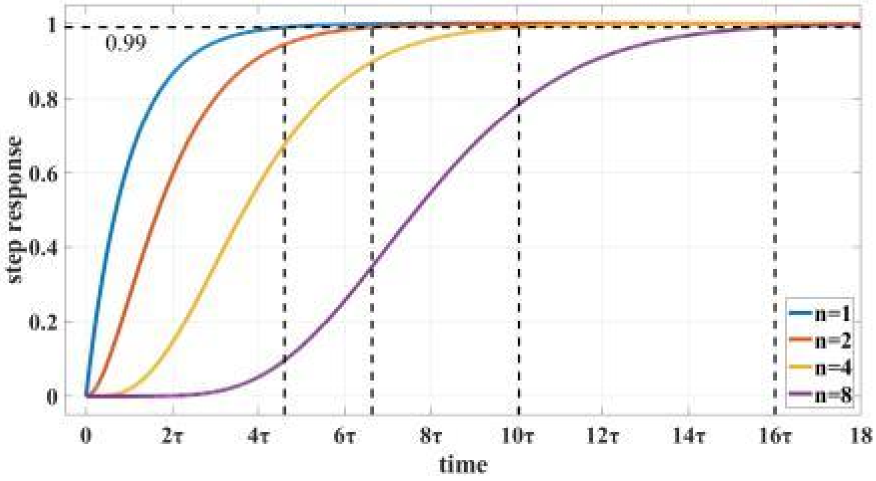


Figure 9. Step Response of a Low-Pass Filter

The equivalent noise bandwidth and response delay time of RC low-pass filters at each order are shown in Table 1:

Table 1. ENBW and Response Latency of RC Low-Pass Filters at Various Orders

Filter order	Steep drop	Equivalent noise bandwidth	Output reached 99% Time required for stability
1	6 dB/oct	0.25 ÷TC	4.6×TC
2	12 dB/oct	0.125 ÷TC	6.6×TC
3	18 dB/oct	0.09375 ÷TC	8.4×TC
4	24 dB/oct	0.07813 ÷TC	10.0×TC
5	30 dB/oct	0.06836 ÷TC	11.6×TC
6	36 dB/oct	0.06152 ÷TC	13.1 ×TC
7	42 dB/oct	0.0564 ÷TC	14.6×TC
8	48 dB/oct	0.05237 ÷TC	16.0×TC

Comparison between Digital Filters and Analog Filters

To maximize the performance of phase-locked amplifiers, we employ digital filters for low-pass filtering of coherent modulation signals. Similar to most analog-to-digital system comparisons, digital systems offer distinct advantages over analog counterparts. Firstly, inherent temperature drift and nonlinearity in analog components severely limit filter roll-off capabilities. Secondly, constructing high-quality low-pass filters with large time constants using analog devices requires substantial PCB space, which not only increases instrument costs but also complicates future debugging processes due to the extensive use of analog components.

This product employs a digital low-pass filter with 64-bit bit width, zero DC gain, and an equivalent Q value exceeding 145 dB, delivering high-performance narrowband filtering capabilities.

synchronous filter

Another advantage of digital filters is their ability to easily implement synchronous filtering. Even when the input signal is noise-free, the phase-sensitive detector output will still contain sum frequency components (twofold frequency components) from both the input and reference signals, with the amplitude of these sum components potentially exceeding the desired difference frequency components. At lower frequencies, the time constant required to filter out twofold frequency components becomes significantly large. For instance, if the input signal is a 1 Hz waveform, the twofold frequency component would be 2 Hz. Even a second-order RC filter with a 10-second time constant would struggle to effectively suppress such components.

The attenuation at the 2 Hz frequency position is also only slightly over 40 dB.

A synchronous filter employs an averaging algorithm over all data within one complete cycle of the reference frequency, effectively filtering out all frequency components that are integer multiples of the reference frequency. Its performance is equivalent to that of a Sinc filter with its zero point frequency set to the reference frequency. In the aforementioned example, using a synchronous filter requires only a one-second delay, achieving superior performance compared to an RC filter with a ten-second time constant.

In SE2022, the synchronous filter configuration becomes effective only when the detection frequency is below 250 kHz. At higher frequencies, harmonic components can be eliminated with shorter time constants, eliminating the need for prolonged waiting periods and thus making synchronous filtering unnecessary. Following the synchronous filter, we have implemented a multi-stage filter system. This integrated design not only removes harmonic components from the reference signal but also effectively suppresses other noise signals.

larger time constant

Filters implemented using analog technology struggle to achieve time constants exceeding 100 seconds, as the required capacitors become excessively large both in magnitude and specifications. However, such high time constants are necessary in certain scenarios where alternatives are unavailable. For instance, when the reference signal frequency is below 1 Hz and is subject to significant low-frequency noise interference, the phase-sensitive detector output contains substantial low-frequency components. While synchronization filters can only eliminate harmonic components of the reference signal, residual noise signals must be filtered by subsequent stages ofthe system.

Leveraging digital technology, SE2022 delivers a time constant of up to 3000 seconds, meeting the requirements of most measurement applications.

Selection of Time Constant and Filter Steepness

Both rapid signal measurement and enhanced signal stability can be achieved by adjusting the combination of time constants and filter steepness. While maintaining equivalent measurement accuracy, selecting higher filter steepness and correspondingly reducing the time constant can significantly improve measurement response speed. Conversely, when further stability enhancement of measurement results is required, increasing both the time constant and filter steepness simultaneously may be considered.

For specific application scenarios, the configuration of time constants and filter steepness should be flexibly selected based on actual conditions. A practical guideline is: as long as the stability of measurement results meets requirements, there's no need to excessively increase the set values of time constants and filter steepness to avoid unnecessary waiting time. Of course, if smoother measurement results are desired, appropriate adjustments to time constants and filter steepness can be made.

DC output gain

What is the maximum DC output level of a phase-sensitive detector? This depends on its dynamic range. With a dynamic range of 60 dB, this means the noise signal can be up to 1,000 times stronger than the full-scale signal. In a phase-sensitive detector, the noise signal must not exceed its input range. For example, in an analog phase-locking amplifier assuming a maximum input amplitude of 5 V, the detector's input signal would be only 5 mV when operating at a 60 dB dynamic range. Since the detector does not amplify signals, its output is merely a few millivolts. Even if the DC output is accurate, directly amplifying it 1,000 times to 5 V by the subsequent amplifier can easily cause signal distortion. A 1 mV offset in the PSD would result in an output of 1 V. This explains why analog-based phase-sensitive detectors cannot achieve excessively high dynamic ranges.

Since digital technology-based phase-locked amplifiers do not employ analog DC amplifiers, they inherently eliminate DC output bias and input offset issues. Digital DC amplifiers simply multiply received data with preset gain factors before outputting the result. This fundamental design principle explains why the SE2022 maintains bias-free performance even when achieving a dynamic range of 130 dB.

2.6 Dynamic Reserve

The dynamic reserve is defined as the ratio of the maximum tolerable noise signal to the full-scale signal. It indicates the phase-locking amplifier's noise tolerance, typically expressed in dB.

$$\text{动态储备} = 20 \lg \frac{OVL}{FS} (dB)$$

Here, OVL denotes the total input dynamic range, FS represents the maximum range, and indicates the output dynamic range. With a dynamic reserve of 100 dB, the system can tolerate noise levels up to 10^{5} times higher than the useful signal.

The dynamic reserve setting should ensure no overload occurs throughout the entire experimental process. Overloads may also appear at the input stage of the preamplifier and the signal output stage of the DC amplifier. The system's input gain is inversely proportional to dynamic reserve, as noise amplification increases with input gain. Therefore,**high dynamic reserve can be achieved by reducing input gain**. The preamplifier gain should be set within a reasonable range to prevent noise overload. After filtering out most noise through Power Spectral Density (PSD) analysis and low-pass filtering, the DC amplifier gain is configured at a higher value to amplify the signal to full scale.

The input signal of the phase-locking amplifier requires AC amplification before PSD processing, while DC amplification is sufficient afterward. With the total gain remaining constant, increasing the AC gain while reducing the DC gain can easily overload the PSD due to input noise amplification, thereby decreasing its dynamic headroom and outputting reduced DC drift. Conversely, increasing the DC gain and decreasing the AC gain enhances the dynamic headroom, improving the amplifier's anti-interference performance at the expense of output stability and measurement accuracy.

The accuracy of DC amplification output is affected by the frequency and amplitude of noise. Noise with high amplitude and matching the signal frequency converts into a DC signal after passing through the Power Spectral Density (PSD) filter. When this signal passes through a low-pass filter, it directly superimposes on the output, thereby distorting the final output result.

Dynamic reserve is frequency-dependent. It measures zero dB at the reference frequency and increases as the frequency deviates from this point, reaching maximum value at sufficiently distant frequencies. The dynamic reserve near the reference frequency is critical for instrument noise tolerance. Increasing the order of low-pass filters enhances filtering performance, thereby boosting the dynamic reserve in this region. While dynamic reserves at frequencies far from the reference are generally higher, they typically have minimal impact on measurement accuracy.

The SE2022 offers a dynamic range exceeding 130 dB, but this high dynamic range introduces output noise and drift. When the dynamic range is high, output errors increase due to noise present in the analog-to-digital converter. All signal sources contain background noise, which is incorporated during the PSD signal extraction process; significant noise levels result in substantial output errors during high-dynamic-range measurements. When external noise is minimal, the output is primarily influenced by the SE2022's inherent noise. In such cases, output errors can be reduced by lowering the dynamic range and DC gain. Therefore, practical applications should prioritize using a lower dynamic range, i.e., higher input gain.

2.7 Signal Input Amplification and Filtering

Phase-locked amplifiers can measure weak signals as low as the nanovolt level. Analog-to-digital converters (ADCs) digitize analog signals, but the signals must reach a detectable intensity. Therefore, low-noise signal amplifiers must provide sufficient gain to amplify signals to a level directly convertible by ADCs without degrading the signal-to-noise ratio. The OE 2022 offers an analog amplification gain range of approximately 0.2 to 1000x, but regardless of the gain setting, the input signal's signal-to-noise ratio remains unchanged.

The total gain of DC and AC signals is determined by sensitivity, while their individual gains are set by dynamic reserve.

input noise

If the input noise of the amplifier is 10 $nV_{rms}/\sqrt{Hz}$ and the gain is 1000 times, then the output will be 10 $\mu V_{rms}/\sqrt{Hz}$ noise. Assume the amplifier output is a first-order RC low-pass filter with a roll-off of 6 dB/oct, and the time constant ofthe RC filter is 100 ms. The input noise of the amplifier and the Johnson noise of the resistor exhibit Gaussian noise characteristics, with their noise levels proportional to the square root of the noise bandwidth. The equivalent noise bandwidth (ENBW) of a single-stage RC filter is 1/(4×TC). This implies that the Gaussian noise at the filter input is filtered out.

The wave, whose effective bandwidth equals ENBW. In this example, the filter input has $10\ \mu V_{rms}/\sqrt{\ }$ The Hz noise has an equivalent noise bandwidth of 2.5 Hz, and the filter's output voltage noise is $10\ \mu V_{rms}/\sqrt{Hz}\times\sqrt{2.5\ Hz} = 15.8\ \mu V_{rms}$. For Gaussian noise, the noise peak-to-peak value is approximately 6.6 times the noise root mean square value. Therefore, the output exhibits a peak-to-peak noise of about 104 μV.

The same principle applies to the input noise of a phase-locked amplifier. When the gain is set to 1000 times, the input gain reaches its maximum, and the magnitude of the input noise determines the output noise level. Similarly, the equivalent noise bandwidth of a low-pass filter affects the output noise quantity.

The equivalent noise bandwidth depends on the time constant and filter roll-off (see Chapter 2.5). For example, setting the SE2022 to the <1 mV> range (with a gain of 1000×), a time constant of <100 ms>, and a roll-off of <6 dB/oct> yields an equivalent noise bandwidth of 2.5 Hz. The input noise of the SE2022 is approximately $2.5\ nV_{rms}/\sqrt{Hz}$. Under these settings, the total filter output noise is $3.9\ \mu V_{rms}$, equivalent to $3.9\ nV_{rms}$ at the input end, resulting in a noise-to-total-range ratio of 3.9 ppm (i.e., 3.9 nV/1 mV).

Assume the signal is emitted by a low-impedance signal source. The Johnson noise is $0.13\times\sqrt{R}$. Taking a 100 Ω resistor as an example, its Johnson noise at room temperature is $1.3\ nV_{rms}/\sqrt{Hz}$. For a signal source with impedance of 10 k Ω, the Johnson noise of $13\ nV_{rms}/\sqrt{Hz}$ exceeds the input noise of the SE2022 itself. The total system noise level is calculated by summing the squares of individual noise sources and taking the square root. For instance, when a 10 kΩ impedance signal source is connected to a phase-locked amplifier, its own Johnson noise and the input noise of the SE2022 combine, resulting in a total noise level of $\sqrt{2.5^2 + 13^2} = 13.2\ nV_{rms}/\sqrt{Hz}$. It can be observed that when the input noise is significant (one order of magnitude higher than the instrument's inherent input noise), the impact of the SE2022's input noise on the total system noise becomes negligible.

At low gain levels, the amplified noise signal remains below the analog-to-digital converter's inherent noise. In this scenario, the system's output noise is predominantly attributable to the converter noise; however, the DC gain after the filter becomes extremely low, rendering the output noise negligible relative to the useful signal.

anti-aliasing filter

After passing through the notch filter and amplification circuit, the input signal undergoes an anti-aliasing filter—a mandatory step before digital processing. According to Nyquist's theorem, the sampling frequency must be at least twice the signal frequency to fully preserve the original signal information. For example, a signal with a frequency of 100 kHz requires a sampling frequency of at least 200 kHz. The SE2022 A/D converter has a sampling frequency of 4 MHz; it cannot convert signals above 2 MHz, as such frequencies violate Nyquist's theorem, resulting in undersampling. This causes high-frequency components to appear in the low-frequency portion of the A/D converter's output stream—leading to aliasing and measurement errors.

To prevent undersampling, the analog signal is first processed through low-pass filtering to eliminate high-frequency components exceeding 1.5 MHz. The low-pass filter maintains a flat passband (0-1.5 MHz), leaving signals within this range unaffected. High-frequency components above 1.5 MHz are progressively attenuated, with a transition zone between 1.5 MHz and 2.5 MHz. Signals and noise exceeding 2.5 MHz experience attenuation exceeding 100 dB.

input impedence

The SE2022 has an input impedance of 10 MΩ. For higher input impedance requirements, the OE400 X series preamplifier compatible with SE2022 can be utilized. The OE400X series preamplifiers offer input impedances up to 100 MΩ or higher, catering to diverse application scenarios.

current input

The SE2022 can directly measure current signals. Users simply need to connect the current signal to the current input port of the SE2022 and switch to the corresponding current mode to perform the measurement. The measurement principle of current signals involves converting the current signal through a precision transimpedance amplifier circuit.

The signal is converted into a voltage signal and then measured by the phase-locking amplifier. The gain setting for the current input differs from that for the voltage input; users can select an appropriate range setting based on their specific requirements to ensure accurate and stable measurement results.

2.8 Input Port Connection

Noise is inherent in all electrical circuits. Even at high signal amplitudes, noise can degrade measurement accuracy. To achieve optimal precision, it is essential to minimize avoidable noise sources in experimental environments. Beyond system inherent noise, other interference factors—including mains power fluctuations, signal generator noise, spatially distributed electromagnetic fields—along with ground potential differences and ground loop interference between instruments, can be effectively mitigated at the input wiring stage.

Our instrument features two input connection modes: single-ended connection and differential connection. The single-ended connection offers great convenience, while the differential connection effectively mitigates noise interference.

Single-end connection mode (IN+)

In single-ended connection mode, use the |N+ input terminal. The phase-locking amplifier detects the voltage difference between the center conductor and the housing conductor at the |N+ input interface.

It is generally accepted that the ground level is a constant of 0 V; however, there may be slight variations in ground levels across different instruments. When the ground level of a signal source is directly connected to that of a detection instrument, the voltage difference generates a significant current—a ground loop. In this scenario, current from instruments operating at higher ground levels flows back to the earth through instruments at lower ground levels, leading to two critical issues: direct noise ingress from higher-ground-level instruments into lower-ground-level instruments, and potential damage to lower-ground-level instruments due to excessive current. To address this, connecting a resistor between the two ground levels eliminates the ground loop. The SE2022 offers two resistor configuration options: Float and Ground. The Float configuration employs a 10 kΩ resistor, while the Ground configuration uses a 10 Ω resistor for shorting.

Additionally, the single-ended connection mode exhibits weaker noise immunity. A single signal line functions like an antenna, susceptible to environmental electromagnetic interference. The shielding layer absorbs such noise, as the single-ended connection mode detects the voltage difference between the central signal line and the shielding layer. Consequently, this noise is introduced into the phase-locked amplifier.

DIFF connection mode

In differential connection mode, two signal lines are connected to the signal source, with each line linked to the corresponding input terminal (|N+ or |N-). Under this configuration, the voltage difference between the central conductors of the |N+ and |N- interfaces is detected. Noise absorbed by the shielding layers of the two interface housings is not captured by the lock-in amplifier.

When using differential connection mode, one key consideration is that cables at both input terminals must be tightly wrapped without forming loops to prevent electromagnetic induction, which could introduce measurement errors.

AC coupling and DC coupling modes

The SE2022 supports two input signal coupling modes: AC coupling and DC coupling. The AC coupling mode utilizes a first-order RC high-pass filter (with a 3 dB cutoff frequency of 0.16 Hz) to eliminate DC and low-frequency components. This mode should be employed when the signal frequency exceeds 10 Hz to ensure passband flatness. For signals below 10 Hz, DC coupling mode is recommended as it imposes no interference on the input signal.

If the input signal contains DC components that are not removed, several potential issues may arise: In amplification circuits, the DC components will also be amplified. If the amplified signal exceeds the input range of the A/D converter, it may cause measurement errors or even damage the A/D converter. Additionally, after quantization into digital signals by the A/D converter, the DC components will be multiplied with the reference sine wave in the Power Spectral Density (PSD). This requires more powerful low-pass filters to remove these components, resulting in prolonged measurement times.

When the frequency of the signal under test exceeds 10 Hz, AC coupling mode is recommended.

2.9 Background Noise

Noise

From a subjective perspective, any input or influence that is undesirable or hinders accurate measurement can be classified as noise. Noise exhibits transient characteristics and unpredictable randomness. In nearly all measurement domains, the ultimate limiting factor for detecting weak signals lies in noise. Even when measuring relatively strong signals, the presence of noise can compromise measurement accuracy. Certain types of noise are unavoidable (e.g., signal jitter), which can only be mitigated through techniques like signal averaging and bandwidth reduction. Other forms of noise (such as radio frequency interference and ground loops) can be eliminated or reduced using various methods including filtering, optimized circuit design, and proper component placement. Additionally, amplifiers themselves generate noise during operation, a challenge that can be addressed through low-noise amplifier design techniques.

There are various inherent noise sources in electronic systems, each with its own physical significance.

Johnson noise

In any passive device, electrons within its conductors always move randomly, generating a noise voltage across its terminals. This phenomenon is known as Johnson noise, also referred to as white noise or thermal noise. It exists in all electronic devices and transmission media. While affected by temperature variations, it remains independent of frequency changes. From a frequency-domain perspective, thermal noise exhibits a uniform power spectral density across the entire frequency range—similar to a white spectrum—which cannot be eliminated. Consequently, it serves as one of the limiting factors affecting the performance of electronic systems. At temperature T, the actual noise voltage produced by a resistor R can be calculated using the following formula:

$$V = \sqrt{4KTRB}$$

where k is the Boltzmann constant, $k = 1.38 \times 10^{-23}$ J/K, T is the thermodynamic temperature in Kelvin (the conversion relationship between thermodynamic temperature and Celsius is: $0\ K \equiv 0\ C + 273.16$), and B is the bandwidth in Hertz.

Subsequently, Nyquist employed thermodynamic reasoning to mathematically characterize the statistical properties of thermal noise and demonstrated that the power spectral function of thermal noise is

$$st(f) = 4KTR(V^2/Hz)$$

For example, at room temperature, a 10-kΩ resistor was connected to the input terminal of a high-fidelity amplifier, with its output connected to a voltmeter. The open-circuit effective voltage was measured using a 10 kHz bandwidth filter, yielding a result of 1.3 μV.

The instantaneous amplitude of thermal noise voltage is generally unpredictable under any circumstances, yet it follows a Gaussian distribution. Its significance lies in representing the lower limit of noise voltage for any detector, signal source, or amplifier. The impedance component of source internal resistance generates thermal noise, as do the bias and load resistances of amplifiers.

Shot noise

Current is actually a discrete flow of electric charges rather than a true fluid. The finite nature of charge quantities leads to statistical fluctuations in current. If charges do not interact with each other, the fluctuations of current are given by the following equation:

$$I_{noise} = \sqrt{2qIB}$$

Here, q represents the electron charge (1.6×10^{-19} C), I denotes the RMS current value in the circuit, and B indicates the measurement bandwidth. For instance, a stable 1 A current measured within the 10 kHz range exhibits an RMS fluctuation of 57 nA, corresponding to fluctuations of approximately 0.000,006%. For smaller currents, the fluctuations become more pronounced: A stable 1 μA current shows an RMS current fluctuation of 57 pA (equivalent to 0.006% fluctuation) when measured at 10 kHz. For 1 pA currents, the RMS current noise fluctuation reaches 56 fA (measured under identical bandwidth conditions), representing a fluctuation of 5.6%!

It was later proven that the shot noise current is also a type of white noise, with its power spectral density function given by

$$s_{sl}(f) = 2qI(A2/Hz)$$

The scattering noise formula presented earlier is derived under the assumption that charge carriers in a current do not interact with each other. While this assumption holds true when charges traverse a potential barrier—such as in surface-contact diodes where current propagates through charge diffusion—the same cannot be said for most common metallic conductors, where charge carriers exhibit strong interdependence.

1/f Flicker Noise

In 1925, Johnson first identified the 1/f noise in electron tube currents, characterized by its power spectrum function being directly proportional to 1/f. The noise intensity increases with decreasing frequency, hence its designation as low-frequency noise. The microscopic mechanism involves random fluctuations in contact resistance when two conductors have imperfect contact, which generates the noise.

Although research on 1/f noise has spanned several decades, its applicable scenarios vary, leading to numerous descriptive models. The current amplitude follows a Gaussian distribution, and the power spectral density is proportional to the reciprocal of the operating frequency. The power spectral density function is expressed as:

$$S(f) = \frac{KI_d^2}{f}(V^2/Hz)$$

1/f noise, also known as flicker noise, arises from random fluctuations in carrier density within active devices. It modulates the central frequency signal and generates two sidebands at the central frequency, thereby reducing the oscillator's Q factor. As 1/f noise constitutes the predominant noise source near the central frequency, its impact must be considered during device model design.

Both scattering noise and thermal noise are inevitable phenomena arising from physical characteristics. For resistors with identical resistance values, high-quality resistors and inexpensive carbon resistors generate identical thermal noise levels. Additionally, actual equipment systems contain various sources of excess noise. Real-world resistors exhibit resistance fluctuations, resulting in an additional noise voltage (superimposed on the inherently present thermal noise) proportional to the DC current flowing through them. This noise is closely related to multiple factors associated with resistor construction, including material composition and particularly packaging techniques. Taking pure carbon resistors, carbon film resistors, metal film resistors, and wound resistors as examples, wound resistors demonstrate the lowest noise levels, followed by metal film resistors, carbon film resistors, with pure carbon resistors exhibiting the highest noise levels.

2.10 External Noise Source

Internal inherent noise is unavoidable and can only be minimized through targeted mitigation measures. In contrast to inherent noise, external noise manifests in diverse forms with asynchronous characteristics. External noise sources primarily affect measurement timing by increasing requirements for dynamic reserve capacity and time constants. A minority of noise sources exhibit strong correlations with reference signals, which may interfere with actual measurement signals through additive or subtractive effects, leading to measurement errors. Fortunately, external noise sources can be effectively reduced through multiple approaches.

Capacitive coupling

Since there is always mutual capacitance between wiring lines, this phenomenon—referred to as parasitic capacitance or stray capacitance—acts like a parasitic element between the conductors. Capacitive interactions also occur between plates and surrounding objects (including various components and even human bodies). AC voltage signals near phase-locked amplifiers can couple onto devices through these parasitic capacitances. Although parasitic capacitance may be minimal, the resulting coupled voltage signals can still exceed the faint signals being measured.

The effect of parasitic capacitance can be calculated using the following formula:

$$I = wC_{stray} V_{noise}$$

Where, (1) is 2π times the noise frequency, c_{stray} is the parasitic capacitance value, and v_{noise} is the noise amplitude.

As the noise source frequency increases, the coupled noise also increases. When the noise source and reference frequency are identical, the measurement results are significantly affected. This occurs because the phase-locking amplifier filters out noise at other frequencies but measures the noise matching the reference frequency as the signal.

Methods for reducing capacitive coupling:

- Remove the noise source, or keep it as far away from the instrument and signal lines as possible.
- A low-impedance experimental setup is designed to ensure that the coupled noise current generates only minimal noise voltage.
- Capacitive shielding, for example, by placing the entire experimental apparatus inside a metal box.

Inductive coupling

Alternating current generates a magnetic field nearby. When a device is placed near an alternating current source, the induced magnetic field couples into the circuit, affecting its operation. The varying alternating current produces a changing magnetic field, which induces electromotive force (EMF). This induced EMF alters the current and voltage in the circuit, leading to measurement deviations in experiments. The magnitude of EMF correlates with the frequency of magnetic field changes—higher frequencies result in stronger EMF, thereby exacerbating measurement inaccuracies.

Methods to reduce emotional coupling:

- Remove noise sources near the instrument as much as possible.
- Use twisted pair cables or two tightly wrapped coaxial cables to minimize loop effects.
- Magnetic shielding should be applied to the instrument to prevent magnetic fields from entering and penetrating the measurement area.

Resistive coupling and grounding loops

Ground loops can also become interference sources, generating noise voltages between grounding points at transmission ends. If the noise voltage becomes sufficiently high, it may lead to measurement errors. Ground loops refer to physical circuit paths in system grounding schemes, formed by multiple grounding routes between circuits. These paths can function as large loop antennas, capturing ambient noise and inducing voltage fluctuations within grounding systems. The 50 Hz magnetic field from industrial-frequency AC power supplies is a common noise source captured by ground loops. Similarly, in distributed grounding systems, ground voltages originating from specific locations may cause current flow through grounding loops. Due to low impedance characteristics of ground conductors, noise currents often become significant—hundreds of millivolts of noise can generate currents reaching several amperes through grounding loops.

Methods to eliminate ground loop current:

- Connect all points to the same location.
- The ground bus should be as wide as possible to reduce impedance in the ground connection.
- Large current grounding circuits should be avoided when connecting to the ground wire of small signals.

Tremor noise effect

Most noise sources affect circuits in electrical form; however, mechanical vibration noise can also be converted into electrical form through the flutter noise effect. Mechanical vibrations induced by micro-vibrations in transmission cables or the measured signal generate electrical noise with varying frequencies.

Methods for eliminating tremor noise effects:

- During measurement, minimize mechanical vibration as much as possible.
- Transmission lines carrying weak signals should be securely fastened to minimize signal fluctuations.
- Replace conventional cables with low-noise cables to reduce the flutter noise effect.

thermocouple effect

The thermocouple effect refers to the electric potential difference generated between two different metals when they are in contact. The contact potential difference is produced by

The reasons are: (1) The different work functions for electron emission between the two metals. (2) The varying electron concentrations ofthe two metals. If the work functions for emission of electrons in metals A and B are v_a and vb respectively, and their electron concentrations are N_a and Nb respectively, then the contact potential difference between them is

$$V_{ab} = V_a - V_b + \frac{kT}{q} \times \ln\left(\frac{Na}{N_b}\right)$$

Here, k denotes the Boltzmann constant, with k = 1.38×10^{-23} J/K. T represents the thermodynamic temperature in Kelvin (the conversion relationship between thermodynamic temperature and Celsius is:0 K =0 C + 273. 16), while q refers to the electron charge (1.60 × 10—19 C). The above equation indicates that the contact potential value depends on the metal properties and contact surface temperature, which varies due to differences in work functions (the energy required for electrons to escape from the metal surface) among different metals.

When two metals come into contact, the electromotive force generated at the contact point increases by a slowly varying millivolt-level increment relative to the baseline. This noise exhibits strong temperature dependence, with its low frequency characteristics resulting from gradual temperature fluctuations. The thermocouple effect intensifies as detector output increases, demonstrating pronounced influence at low frequencies—particularly during measurements in the mHz range where the impact becomes more significant.

Methods for eliminating the thermocouple effect:

- The measuring instrument should be kept at a constant temperature as much as possible.
- Use nodes with compensation properties.

2.11 Noise Measurement

SE2022 features noise measurement capability, enabling the detection of noise in input signals at reference frequencies. For noise sources exhibiting frequency dependence, the phase-locked amplifier (PLA) facilitates their measurement.

Based on the bandwidth ofthe RC filter configured by the user, the phase-locked amplifier can be conceptualized as a bandpass filter centered at the reference frequency, with a passband bandwidth twice that of the RC filter. Consequently, noise near the reference frequency remains at the output stage. When the input signal serves as a noise source, the phase-locked amplifier can measure its noise level at the specified frequency. By performing frequency-scan measurements, the noise power spectrum of the source can also be obtained. The SE2022's host software includes a Sweeper parameter scanner function, which enables noise spectrum measurements through this capability.

SE2022 employs the total noise integration method within the frequency band to measure noise near the reference frequency. First, X-component data from the demodulator output is collected over a specified time period, and its root mean square (RMS) value is calculated. This value represents the total noise amplitude within a specific bandwidth near the reference frequency. Subsequently, the total noise value undergoes normalization to eliminate the impact of digital filter bandwidth. The normalization process involves dividing the calculated RMS value by the square root of the equivalent noise bandwidth (ENBW) of the digital filter (i.e., √ ENBW). The resulting value, expressed in units of V/√ Hz, represents the noise spectral density. For detailed calculation methods and parameter selection regarding equivalent noise bandwidth, please refer to Table 1 in Section 2.5 of this manual.

2.12 Channel Output and Gain (CHOUT/AUXOUT)

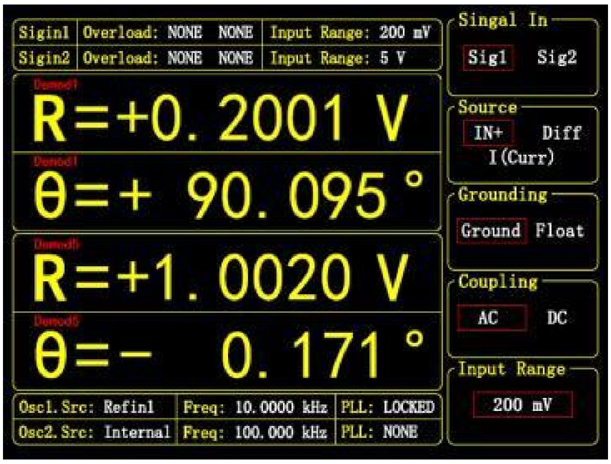
The SE2022 features six auxiliary output channels (CHOUT1 to CHOUT2 and AUXOUT1 to AUXOUT4) on its rear panel.

The outputs and display of CHOUT1 to CHOUT2

The CHOUT1 to CHOUT2 output range spans from-10 V to 10 V, with a refresh rate of 1 MSa/s and a 16-bit digital-to-analog converter. The output is proportional to the current measurement results relative to the set measurement range. Additionally, the SE2022 can display the data sources of CHOUT1 to CHOUT2 on the front panel's screen, including measured signal parameters such as X value, Y value, R value, and θ value.

The outputs from AUXOUT1 to AUXOUT4 are connected to the display.

The AUXOUT1 to AUXOUT4 interface operates within a 10V output range, features a refresh rate of 500 kSa/s, and utilizes a 16-bit digital-to-analog converter. Functionally similar to CHOUT1 to CHOUT2, it allows users to select output parameters including X-value, Y-value, R-value, and θ-value of the measured signal.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1
R=+0. 2001 V

Demod1
θ=+ 90. 095 °

Demod5
R=+1. 0020 V

Demod5
θ=− 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Figure 10. SE2022 Output Settings Interface

The output offsets and gains of X, Y, and R

The SE2022 can compensate for measurement errors by adjusting the offset. This feature is particularly useful when measurements exhibit inaccuracies near specific nominal values. Since the offset can be set arbitrarily within the range, the resulting offset is virtually zero. The output variation can be directly read from the display or the panel's output terminal. The offset is expressed as a percentage of full-scale output, and this ratio remains constant regardless of sensitivity changes. The offset can be set up to ±100% of full-scale output.

Furthermore, the system enables amplification of output values along the X, Y, and R axes. This functionality is achieved by multiplying the output data with a specific gain coefficient. Consequently, even signals measuring merely one-tenth of the full-scale range can be amplified from their original 1 V to 10 V. The primary benefit of output signal gain is its ability to significantly enhance measurement accuracy and resolution near specific non-zero values.

The SE2022 delivers output gain across multiple ranges with a gain coefficient of +0.001 to +10,000, without exceeding the full-scale range. The output is calculated as follows:

$$\text{Output} = \left(\frac{Signal}{Sensitivity} + Offset \right) \times Expand \times 10\,\text{V}$$

<Offset> can be set between-100% and 100%, entered directly via the numeric keypad with a minimum increment of 0.01%; <Expand> values can be set between +0.001 and +10,000, entered directly via the numeric keypad with a minimum increment of 0.001. For example:

$$\text{Output} = \frac{0.1\,\text{mV}}{1\,\text{mV}} + 0.2 \times 2 \times 10\,\text{V} = 6\,\text{V}$$

2.13 Auxiliary Analog Input (AUX IN)

The SE2022 features four 16-bit high-precision auxiliary AUX |N input channels with an input voltage range of ±10 V, minimum resolution of 0.3 mV, and sampling rate of 150 kSa/s. These four ADCs provide input signal clamping protection and internal differential amplification, with an input impedance of up to 1 MΩ. They enable simultaneous signal acquisition for measuring low-speed analog signals or DC signals derived from experiments (e.g., temperature or pressure sensors), facilitating P|D calculations and data transmission to control computers.

The AUX |N interface uses standard BNC connectors and is integrated into the rear panel of the OE 2022. The AUX |N value display settings are configured in the [D|S_ PLAY] submenu.

2.14 Signal Generator

The SE2022 supports dual internal oscillator selection (OSC1 or OSC2) to generate sine wave signals with adjustable amplitude ranging from 100 nV to 5 V_{rms}, featuring 50 Ω output impedance and 80 mA drive current capacity. The output signal maintains phase synchronization with the internal oscillator while allowing independent phase offset configuration.

For external devices requiring bias voltage, such as electro-optic modulators, the SE2022 leverages its superior driving capability to directly drive the device without additional level conversion amplifiers. The SE2022 internally supports a ±5 V DC range for DC bias voltage superposition.

The EO2022 signal generator supports AM/FM/PM modulation functions, enabling users to easily control system modulation.

2.15 Dual Harmonic Measurement

Harmonics refer to the components in periodic functions or periodic waveforms that can be expressed as linear combinations of constants and sine/cosine functions with periods identical to the original function's minimum period. According to Fourier series theory, all periodic functions can be decomposed into constant terms plus a set of sine/cosine functions sharing the same period. Within this decomposition: the constant term constitutes the DC component; the portion with the original function's minimum positive period is termed the fundamental wave or first harmonic; while higher-order harmonics correspond to multiples of the original function's minimum positive period.

In traditional phase-locked amplifiers, only the fundamental frequency signal or a specific harmonic component can be measured simultaneously. In many practical applications, simultaneous measurement and recording of multiple harmonics are often required. Under such circumstances, current phase-locked amplifiers struggle to meet these demands.

The SE2022 has made a breakthrough in developing simultaneous multi-harmonic measurement functionality, with 8 independent demodulator channels capable of measuring up to 6 harmonic components simultaneously. Tasks previously requiring 8 phase-locked amplifiers can now be accomplished by a single SE2022 unit.

The measurement settings for harmonics are configured in the [DEMOD REF] menu.

In addition to its multi-harmonic measurement capabilities, the SE2022 also features arbitrary-frequency demodulation and frequency synthesis demodulation functions.

Chapter 3: Interface Introduction

3.1 Front Panel

Figure 11. SE2022 Front Panel

3.1.1. Display Screen

The SE2022 features a 5.6-inch TFT display for user data presentation and interactive control. With a resolution of 640*480, it offers 8 adjustable backlight brightness levels configurable via the [SYSTEM] submenu.

The left side of the screen features a large area for displaying measurement results of input signals, supporting dual-column dynamic graphs and full data display. The dual-column dynamic graph supports both numerical and bar chart formats, while full data display accommodates all measurement parameters. These settings can be configured in the <Display Mode> option within [D|SPLAY].

The right area of the screen is used to select and modify measurement control conditions.

3.1.2. A Soft Key

On the right side of the display, there are five soft keys. Each soft key performs different functions depending on the current directory. Overall, soft keys serve two primary purposes: first, to select among various settings options, and second, to highlight specific parameters for subsequent input via knobs or the keyboard. Regardless of the function, soft keys only affect the parameters adjacent to them on the right side of the screen.

3.1.3. Knob

The knob allows you to adjust parameters highlighted by soft keys. Most parameters can be adjusted using the knob. Turning clockwise increases the parameter, while turning counterclockwise decreases it.

3.1.4. Fingerboard

The keyboard consists of three key groups. The ENTRY area enables data input in format for parameters highlighted by soft keys. The MENU area displays a parameter list on the right side of the screen and offers 10 distinct function menus. The ARROW area provides options for selected highlighted parameters, such as setting |nput Range ranges or modifying individual bits of frequency values.

3.1.5. BNC Connector

The front panel features eight BNC connectors arranged from left to right as follows: SINE OUT 1, SINE OUT 2, REF IN 1, REF IN 2, SIGNAL IN 1 IN_, SIGNAL IN 1 IN+/I, SIGNAL IN 2 IN_, and SIGNAL IN 2 IN+/I.

SINE OUT 1/2

The signal generator provides an amplitude-programmable sine wave output of up to V_{rms} with an output impedance of 50 Ω. When an external reference signal is used, the signal source of the generator is locked in phase with the reference signal via a phase-locked loop.

REF IN 1 / 2

The reference signal input can be driven by a sine wave or a TTL square wave, with an input impedance of 50 Ω or 1 MΩ. The sine wave input is AC-coupled and supports signals above 1 Hz. For low-frequency applications (<1 Hz), a TTL square wave reference signal is recommended.

SIGNAL IN 1 IN_/ IN+ / I and SIGNAL IN 2 IN_/ IN+ / I

Signal input options include single-ended voltage input IN+, differential voltage input DIFF (IN+ and IN difference), and single-ended current input I. The SIGNAL IN+ and I interfaces share the same BNC connector. When measuring voltage signals, both IN_ and IN+ interfaces have an input impedance of 10 MΩ||25 pF. For current signal measurements, the I interface has an input impedance of 100 Ω or 1 kΩ.

3.2 Back Panel

Figure 12. Rear Panel

The rear panel of the EO2022, as shown in Figure 12, includes a cooling fan, power ports, a ground terminal, USB 2.0 ports, an RS-232 interface, an Ethernet interface, a GPIB interface, a Digital-IO interface, and expansion auxiliary function interfaces. The expansion auxiliary function interfaces comprise AUXIN/OUT, CH OUT, CLKIN/OUT, TRIGGERIN/OUT, and MONITOR OUT.

3.2.1. Power Interface

The power interface serves as the main power input for the entire instrument, accepting alternating current mains power ranging from 100 to 240 V at 50 Hz/60 Hz. It incorporates an integrated fuse and simultaneously functions as a high-frequency noise filter to eliminate interference.

3.2.2. USB2.0

The USB 2.0 high-speed interface enables communication between the SE2022 phase-locking amplifier and a PC, allowing control and data reading from the SE2022 via the PC.

3.2.3. RS232

The RS232 interface is a standard 9-pin RS-232 female connector that enables communication between the SE2022 and other devices.

3.2.4. GPIB

The standard GPIB master interface, compliant with the IEEE_488.2 standard, enables communication between the SE2022 and other devices.

3.2.5. Ethernet Interface

The Ethernet interface supports data transmission speeds of up to 1000 Mbit/s, enabling rapid communication with PCs.

3.2.6. AUX IN

Four-channel AUX IN auxiliary input interfaces with an input range of ±10 V and a minimum resolution of 0.3 mV.

3.2.7. AUX OUT/CH OUT

The device features four AUX OUT and two CH OUT auxiliary output interfaces, with an output range of ±10 V and a minimum resolution of 0.3 mV.

3.2.8. TTL OUT

The TTL OUT output interface delivers a 3.3 V TTL square wave signal with the same frequency and phase as the Sineout signal.

3.2.9. CLK IN & OUT

CLK IN is an external clock input interface that accepts clock signals at 10 MHz and 3.3 V TTL/ CMOS levels, designed for clock synchronization with external instruments.

. Note that unstable external clock sources may degrade the performance of the SE2022.

CLK OUT provides a 10 MHz clock output interface with a 3.3 V TTL/CMOS operating voltage.

3.2.10. TRIG IN & OUT

The trigger input/output interface is designed to acquire test signals based on external reference signals, and can also be used for synchronization among multiple SE2022 devices.

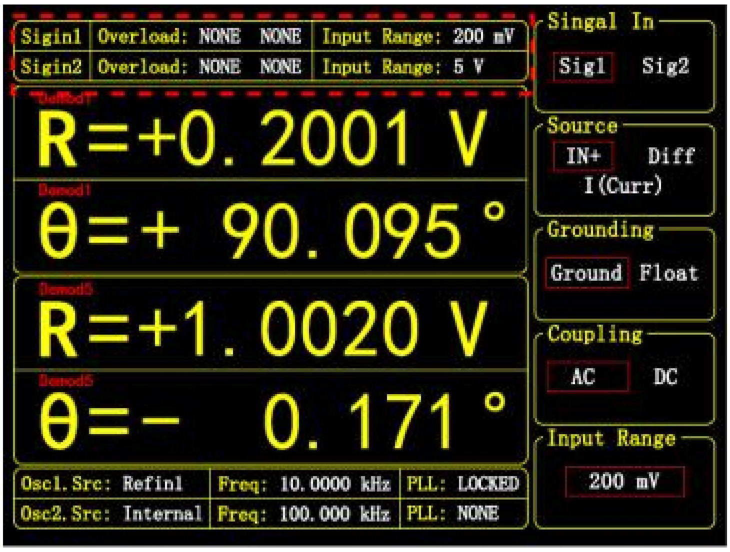
3.2.11. MONITOR OUT

MONITOR provides a mirrored signal after analog amplification and filtering, which is the mirror image of the signal acquired by the ADC (analog-to-digital converter). Since analog amplification also amplifies noise, the MONITOR output is not suitable for observing signals with low original amplitude.

3.3 Main Interface

The main interface ofSE2022 consists of four sections.

3.3.1. Status Bar

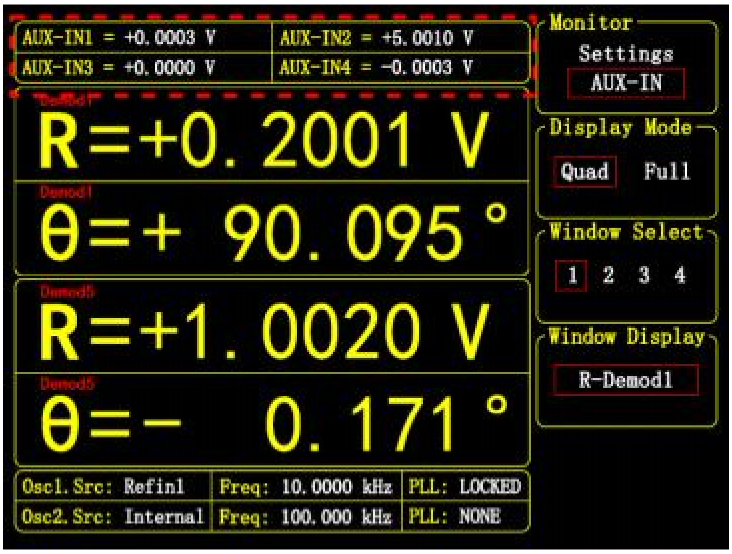


Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1 R=+0.2001 V
Demod1 θ=+ 90.095 °
Demod5 R=+1.0020 V
Demod5 θ=− 0.171 °

Osc1.Src: Refin1 Freq: 10.0000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 100.000 kHz PLL: NONE

Figure 13. Main Interface - Status Bar 1



AUX-IN1 = +0.0003 V AUX-IN2 = +5.0010 V
AUX-IN3 = +0.0000 V AUX-IN4 = −0.0003 V

Demod1 R=+0.2001 V
Demod1 θ=+ 90.095 °
Demod5 R=+1.0020 V
Demod5 θ=− 0.171 °

Osc1.Src: Refin1 Freq: 10.0000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 100.000 kHz PLL: NONE

Figure 14. Main Interface-Status Bar 2

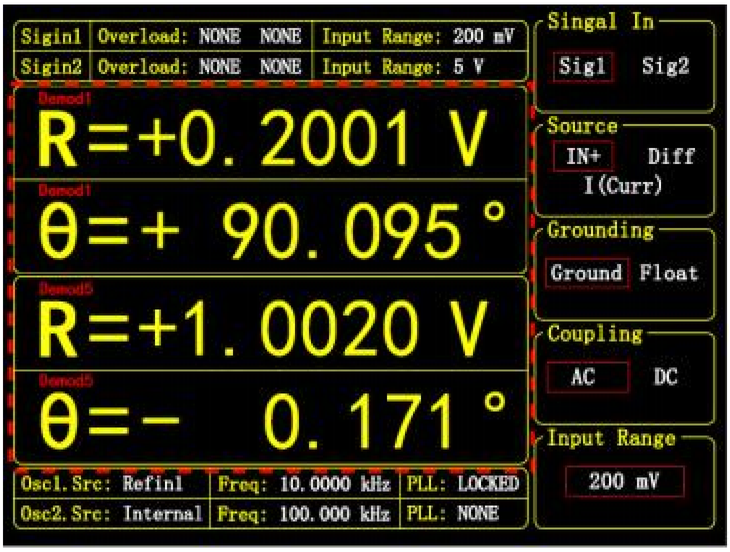
The status bar is positioned as shown in the red box areas of Figure 13 and Figure 14. This bar displays the current system configuration and measured values, which can be toggled in the [DISPLAY] submenu. The displayed content includes:

<Overload>: Indicates the state of input overload or overflow, alerting whether the preceding input or gain factor has overflowed. If no overflow occurs, display:Overload: NONE NONE; If the preceding input overflows (determined by voltage being ±7 V, with warnings triggered when input voltage exceeds 7 V or falls below-7 V [corresponding to the peak-to-valley level of 5 V_{rms}]), display Overload:INPUT NONE; If the gain factor overflows, display Overload: NONE GAIN; If both overflow conditions occur simultaneously, display Overload:INPUT GAIN. In all cases of overflow, promptly reduce the input signal and gain to prevent overvoltage damage to the device.

<ninput Range>: Input range; the input signal must not exceed this range.

<AUX_|N1>: Input amplitude of the AUX_|N1 interface.
<AUX_|N2>: Input amplitude of the AUX_|N2 interface.
<AUX_|N3>: Input amplitude of the AUX_|N3 interface.
<AUX_|N4>: Input amplitude of the AUX_|N4 interface.

3.3.2. Data Bar



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

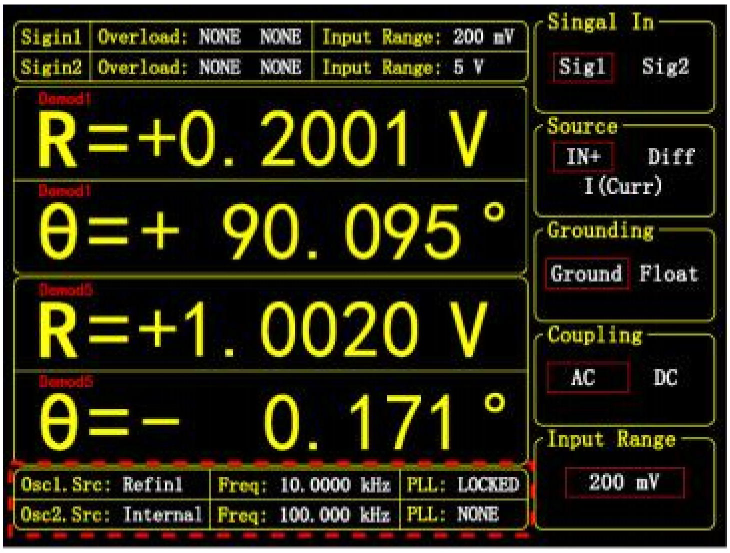
Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 15. Main Interface-Data Bar

The data bar position is shown in the red box area of Figure 15. You can select to display <X>, <Y>, <R>, and <θ> values in the [D|SPLAY] submenu. Display options include four-column dynamic chart or full data display chart. For detailed settings, refer to the [D|SPLAY] submenu.

3.3.3. Monitoring Bar



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 16.Main Interface-

Monitoring Bar Location of the Monitoring Bar (red Box Area in Figure 16) Displays Three Items in Total, Including:

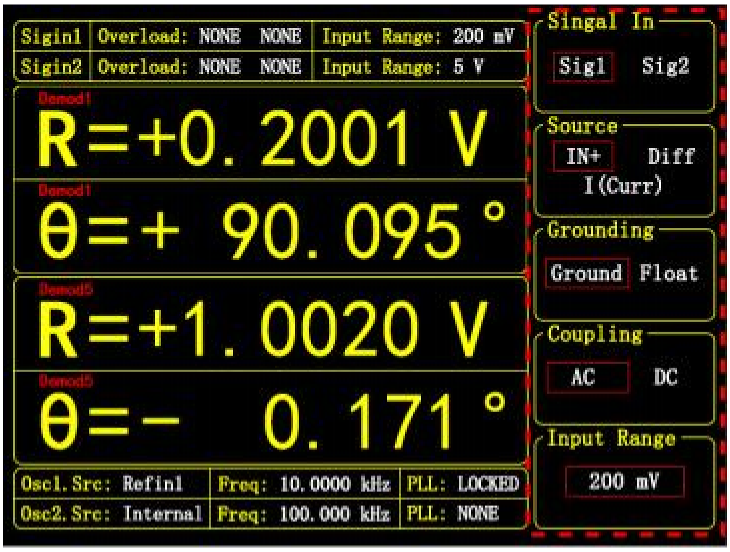
<Osc.Src> : The input source of the oscillator. Indicates whether the selected reference signal source is internal or external.

<Freq> : Input signal frequency. Displays the frequency of the input signal.

<PLL> : The phase-locking indication of the phase-locked loop indicates whether the phase is locked. When the phase- locked loop is locked, it displays PLL: LOCKED;

Display PLL:UNLOCKED when there is no reference signal or the PLL is not locked; display PLL: NONE when using an internal reference.

3.3.4. Function Bar



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V
Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=- 0. 171 °
Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

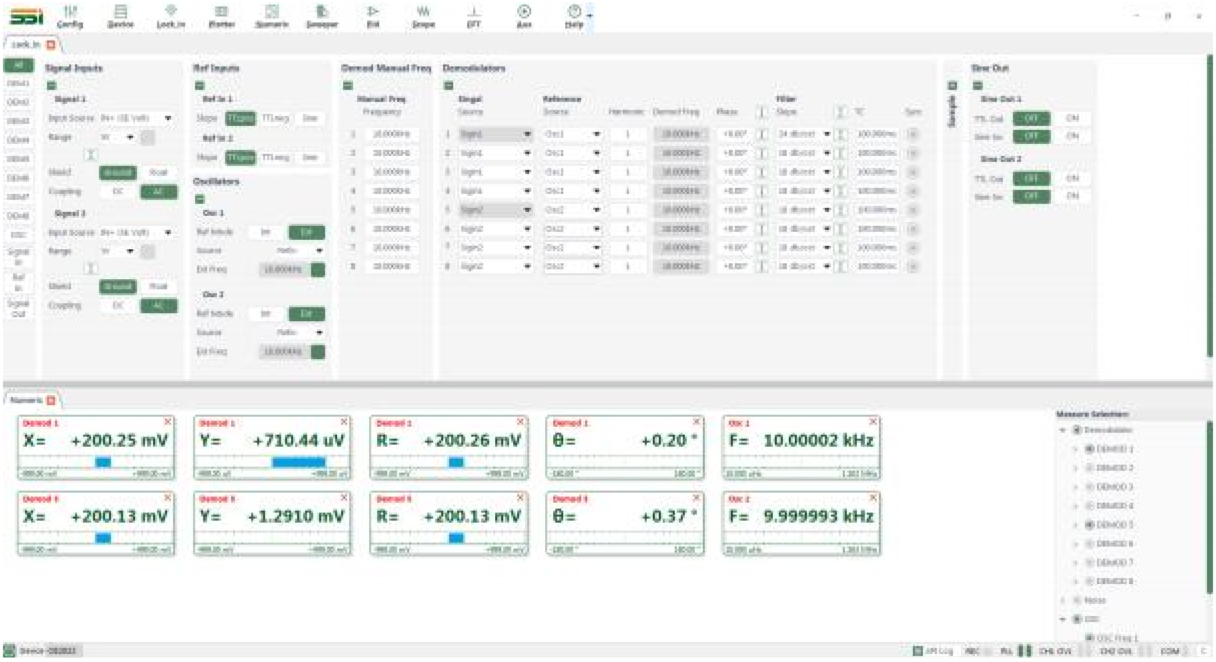
Figure 17. Main Interface-Function Bar

The function bar is positioned as indicated by the red box in Figure 17. The function settings panel contains multiple options corresponding to the five dark gray buttons on the front panel, each serving distinct purposes within different sub menus and constituting the primary means of instrument control.

Chapter 4 Introduction to Host Computer

4.1 Overview of Host Computer

SE2022 is equipped with the host software SSI Lucid Suite. Developed on the QT platform, SSI Lucid Suite features a next-generation graphical interface that visually demonstrates phase-locked amplifier configurations through flowcharts. Compared to traditional screen interfaces, this system offers enhanced usability and intuitive operation. Additionally, SSI Lucid Suite supports high-speed data transmission and local storage capabilities, facilitating post-processing and analysis of experimental data. The interface layout of SSI Lucid Suite is illustrated in Figure 18:


X= +200.25 mV

Y= +710.44 uV

R= +200.26 mV

θ= +0.20 °

F= 10.00002 kHz

X= +200.13 mV

Y= +1.2910 mV

R= +200.13 mV

θ= +0.37 °

F= 9.999993 kHz

Figure 18. SSI Lucid Suite Software Interface

The SSI Lucid Suite primarily consists of four tab areas: the Function Menu Area, Upper Configuration Area, Lower Configuration Area, and Status Bar Area. Each area serves the following functions:

Function menu area: Here you can select different instrument functions. Each selected function will create a corresponding tab interface in the configuration area.

Top and bottom configuration zones: The system divides the configuration area into upper and lower sections. Each zone can host function-specific tab interfaces with interchangeable layouts. By default, the upper zone displays the Lock-in interface for configuring core functions of the lock-in amplifier demodulator, while the lower zone shows the Numeric interface presenting measurement results in numerical format.

Status bar area: Displays the basic status of the phase-lock amplifier, including command setting history, data recording status, Overload status, and communication status.

The locations of each region are shown in Figure 19.

Figure 19. Regional Location of SSI Lucid Suite

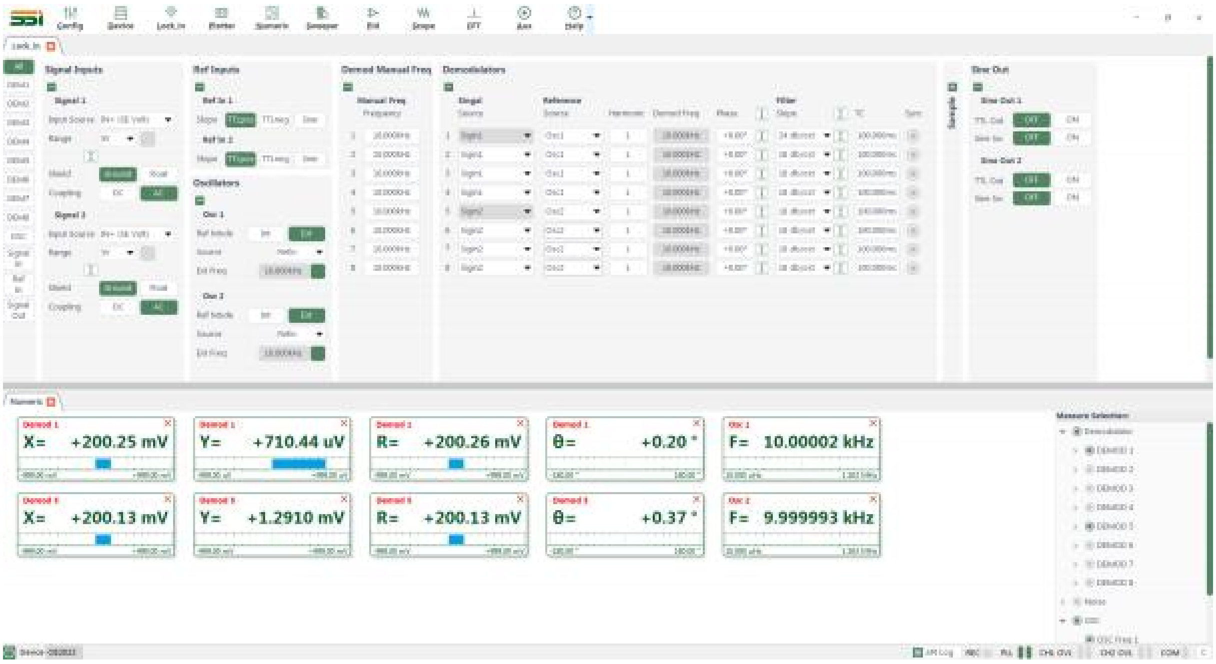
4.2 Connect to the Host Computer

The SE2022 comes with a USB flash drive included with the instrument. Insert it into your PC to access the SSI Lucid Suite software. Connect the PC and SE2022 via a USB or Ethernet cable, then run the "SSI Lucid Suite.exe" file. After the software launches, wait a few seconds; it will automatically identify the instruments connected to the PC, as shown in Figure 20.

Serial Number: LD621052530

Figure 20. SSI Lucid Suite Startup Interface

Click to proceed The button will connect to the instrument. After successful connection, the SSI Lucid Suite interface will display as shown in Figure 21.



X= +200.25 mV
Y= +710.44 uV
R= +200.26 mV
θ= +0.20 °
F= 10.00002 kHz
X= +200.13 mV
Y= +1.2910 mV
R= +200.13 mV
θ= +0.37 °
F= 9.999993 kHz

Figure 21. SSI Lucid Suite Interface

4.3 Introduction to Host Machine Functions

4.3.1. Function Menu

As shown in Figure 22, this is the function menu area of the host software on the SSI Lucid Suite. The functions from left to right are: Config: Instrument connection menu, which allows disconnecting or reconnecting the instrument.

Device: View basic information such as the instrument model, serial number, version number, and interface status.

Lock_in: permite setting and querying configurations related to the core functions of the lock-in amplifier.

Plotter: Displays curves of demodulator measurements.

Numeric: Displays the numerical values of measurements from each demodulator and oscillator.

Sweeper: The instrument's internal scanning function allows selection of scanning modes based on frequency or amplitude. The Sweeper can scan specified parameters within the instrument, facilitating users in measuring system response curves.

PID: The instrument's built-in PID module. The SE2022 features two PID modules to control multiple variables of the lock-in amplifier.

Scope: Oscilloscope function, achieving virtual oscilloscope capabilities through the instrument's internal high-speed ADC. It assists in visualizing the waveform of the test signal.

FFT: View the FFT frequency-domain waveform corresponding to the oscilloscope data.

Aux: Queries the measurement value of the instrument's Aux In and sets the output formula for Aux Out.

Help: View company information and access features such as instrument upgrades.

Figure 22. Function Menu Area

4.3.2. Lock In Tab

The Lock-in (Phase Lock) Configuration Tab, as shown in Figure 23, contains the core functions of the phase-lock amplifier—the detailed configuration of the demodulator and phase-lock loop—where various parameters can be set. In the sidebar at the far left of this tab, users can select tabs such as ALL, DEM 1-8, Osc, and Signal In to switch between the parameter table view and the flowchart display. The parameter table view provides detailed information on each parameter, while the flowchart offers a visual representation of the instrument's internal hardware and algorithm architecture (Figure 24), facilitating user understanding of each parameter's role.

Figure 23. Lock-in Configuration Tab (Parameter Table View)

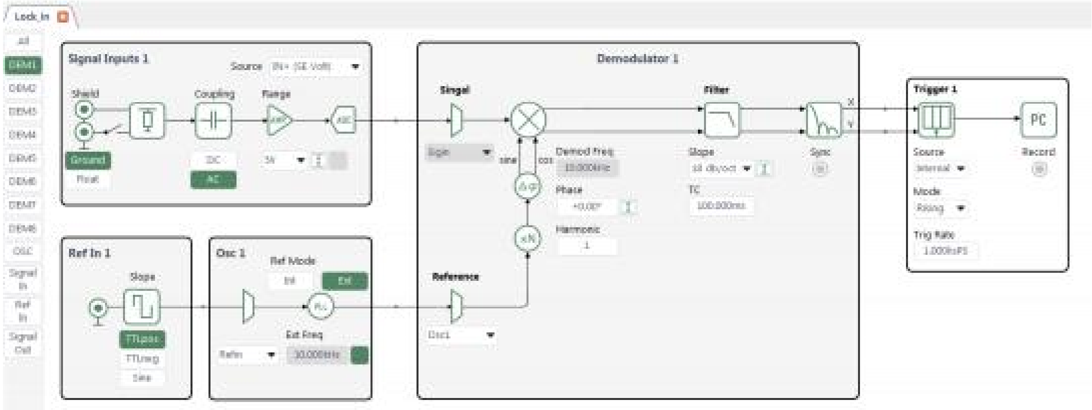


Figure 24. Lock-in Configuration Tab (Flowchart)

4.3.3. Plotter Tab

The Plotter tab, as shown in Figure 25, offers comprehensive functionality including scrollable time-domain data visualization, flexible scaling of horizontal and vertical axes, display of multiple measurement values, switching between linear and logarithmic coordinates, and showing current waveform maximums and minimums. Users can also save individual waveform data for subsequent analysis and processing.

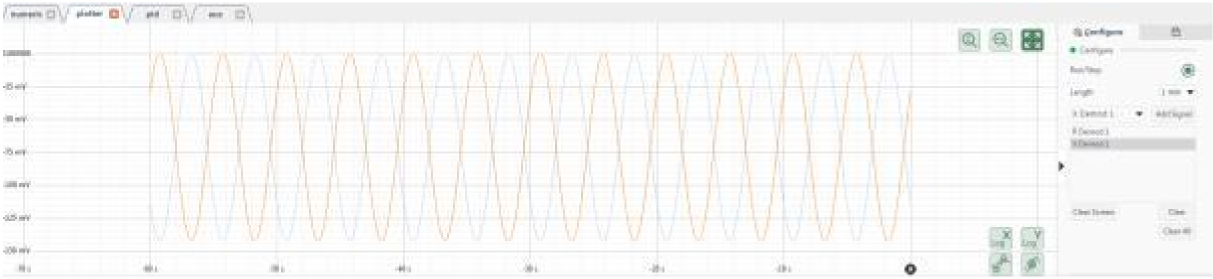


Figure 25. Plotter Tab

4.3.4. Scope Tab

The Scope (Oscilloscope) tab, as shown in Figure 26, utilizes the instrument's internal high-speed ADC to provide virtual oscilloscope functionality, enabling real-time display of current measurement signal waveforms. Users can flexibly adjust scales for both horizontal and vertical axes, while enjoying essential oscilloscope features including waveform measurement statistics, cursor functionality, and trigger capabilities. The system also supports independent waveform data storage for subsequent analysis and processing.

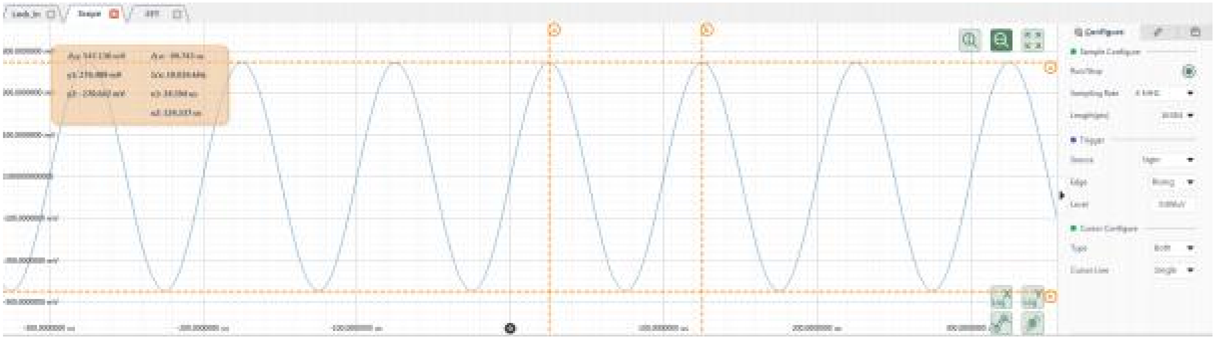


Figure 26. Scope (Oscilloscope) Tab

4.3.5. FFT Tab Control

As shown in Figure 27, the FFT (Fast Fourier Transform) tab converts oscilloscope data into a frequency-domain plot through a fast Fourier transform, aiding in the analysis of the effective components of the input signal and helping users identify harmonic signals and interference components.

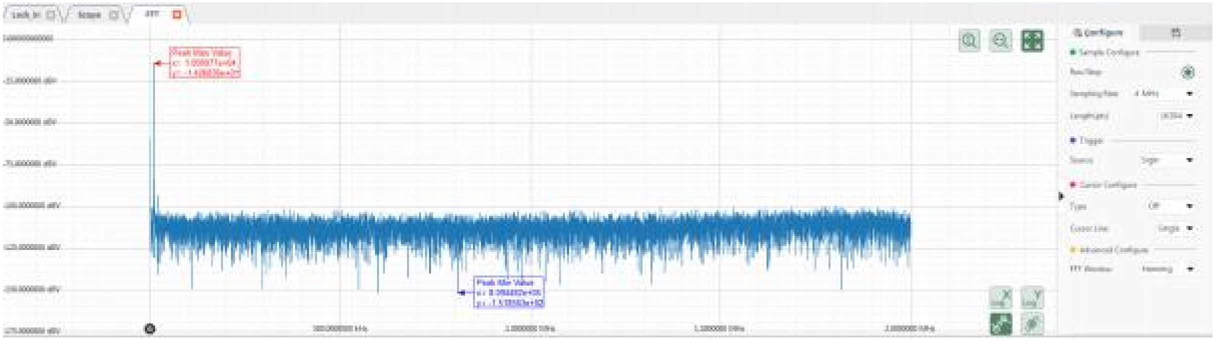


Figure 27. FFT (Fast Fourier Transform) Tab

4.3.6. Sweeper Tab

As shown in Figure 28, the Sweeper (Parameter Scanner) tab enables scanning of instrument parameters within a specified range, facilitating users in measuring system response curves. It supports testing of amplitude-frequency characteristic curves, phase-frequency characteristic curves, noise spectrum curves, and amplitude linearity for the system under evaluation.

The Sweeper (parameter scanner) supports selectable frequency/ amplitude scanning modes, including linear and proportional step scanning. Each scan captures all measurement data from the SE2022, enabling multidimensional analysis of the results.

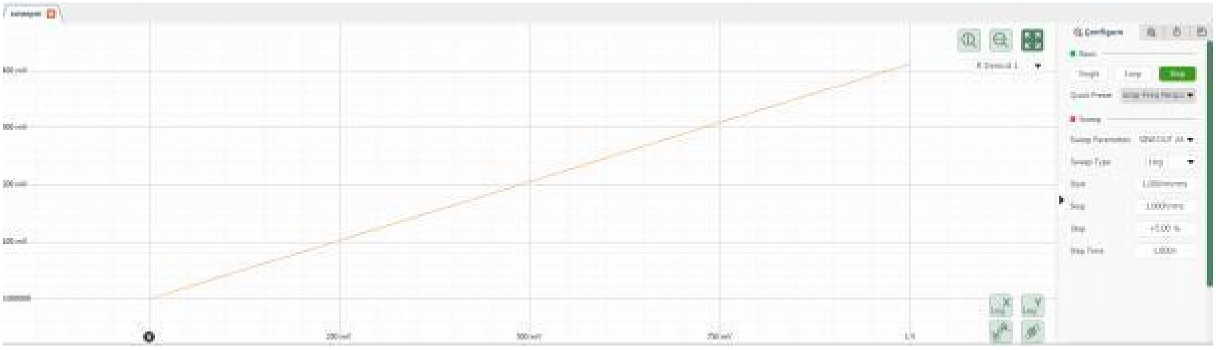
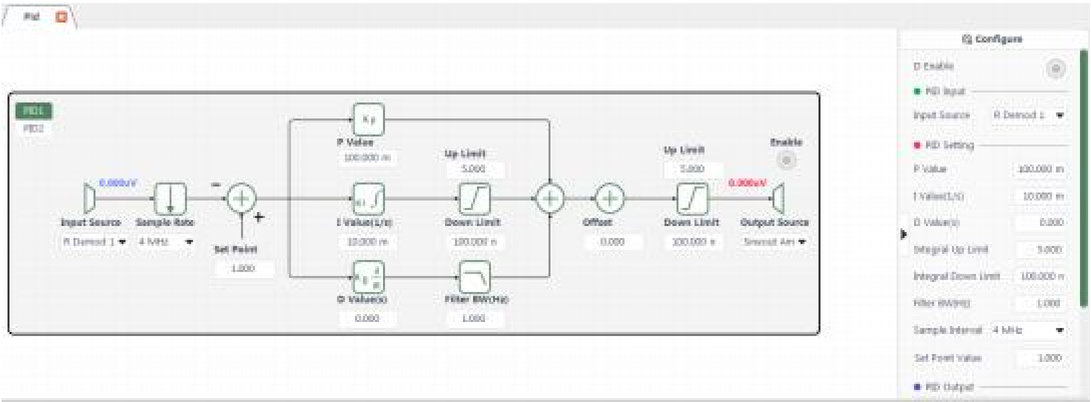


Figure 28. Sweeper (Parameter Scanner) Tab

4.3.7. PID Tab Control

The SE2022 features a dual-channel PID controller as shown in Figure 29. With a maximum sampling rate of 4 MHz, the PID controller allows selection of multiple instrument parameters for both input and output signals, offering extensive applicability across diverse scenarios such as laser synchronization frequency locking or high-speed SPM systems. All connectable interfaces are illustrated in Figure 30.



D Enable
PID Input
Input Source: R Demod 1
PID Setting
P Value: 100.000 m
I Value(1/s): 10.000 m
D Value(s): 0.000
Integral Up Limit: 5.000
Integral Down Limit: 100.000 n
Filter BW(Hz): 1.000
Sample Interval: 4 MHz
Set Point Value: 1.000
PID Output

Figure 29. PID Tab

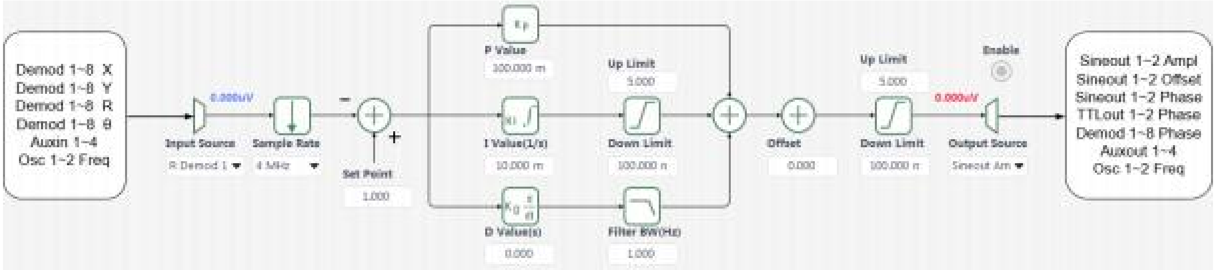


Figure 30. PID Controller Input and Output Source Selection

Some settings in the PID tab share common configurations accessible across other tabs. When the PID output controls a variable (e.g., Sineout Amplitude), this variable appears read-only in adjacent tabs (such as the Lock-in tab in this example), and the PID output value will override the original parameter settings.

4.4 Software Usage Example

This usage example will demonstrate how to configure parameters of a lock-in amplifier and observe/record R, X, Y, and θ values using the SE2022 host software.

First, follow the instructions in 4.2 to successfully connect the SE2022 to the PC, and then you can begin the configuration.

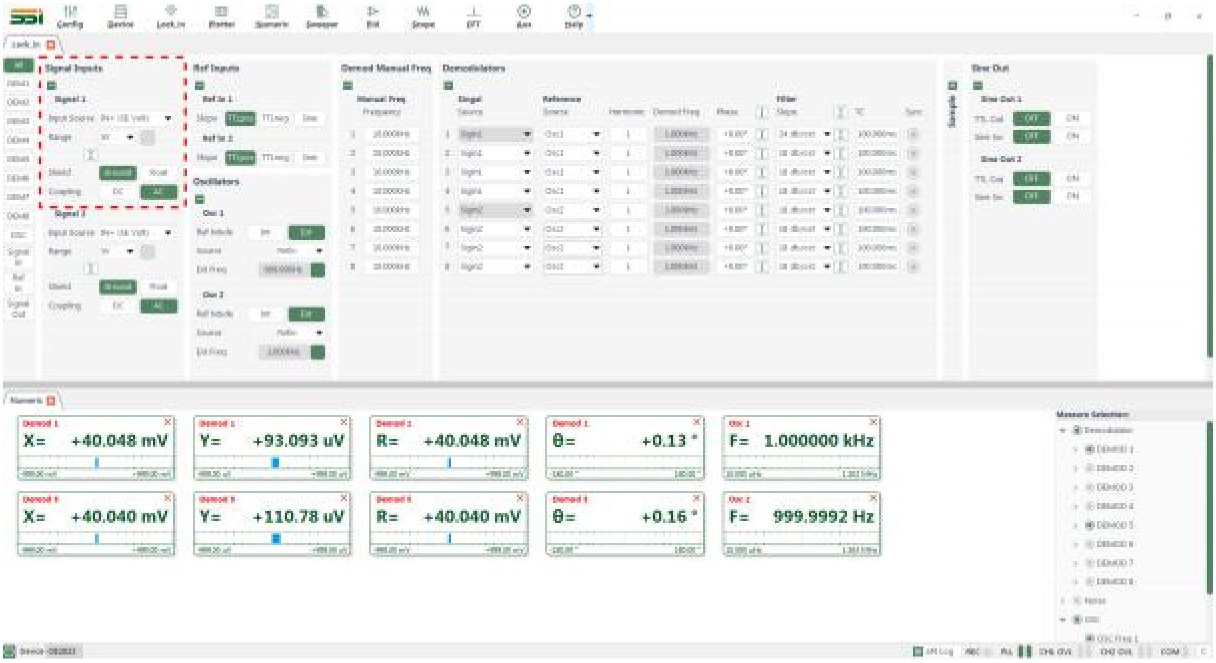
Assuming the user needs to configure the function generator and phase-lock amplifier according to Table 2 and save the data:

Table 2. Instance Configuration Table

Input signal type	Single-ended voltage input
Input signal magnitude	40 mV
Input coupling mode	AC
Input gain	100 mV
Reference signal input	Use external reference at 1000 Hz
Reference signal triggering method	TTL rising edge triggering
Modulator phase-shift angle	0°
Time constant of a low-pass filter	100 ms
Filter Steep Fall	24 dB/oct
Data sampling rate	100 Sa/s

To complete the above settings, follow these steps:

1. According to the configuration in Table 2, modify the input signal type, input coupling method, and input range in the input signal configuration. Other options remain default, as shown in Figures 31 and 32. Select one of the methods for modification.



X= +40.048 mV

Y= +93.093 uV

R= +40.048 mV

θ= +0.13 °

F= 1.000000 kHz

X= +40.040 mV

Y= +110.78 uV

R= +40.040 mV

θ= +0.16 °

F= 999.9992 Hz

Figure 31. Input Signal Configuration Area

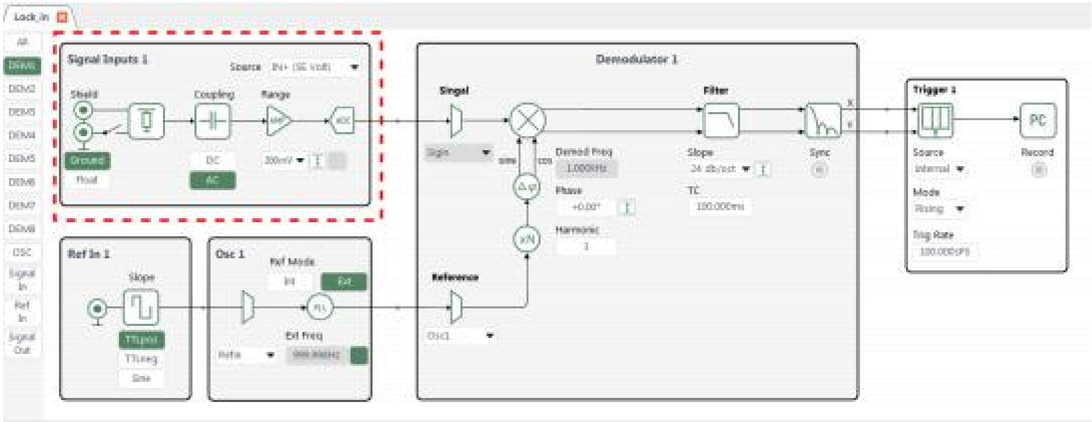
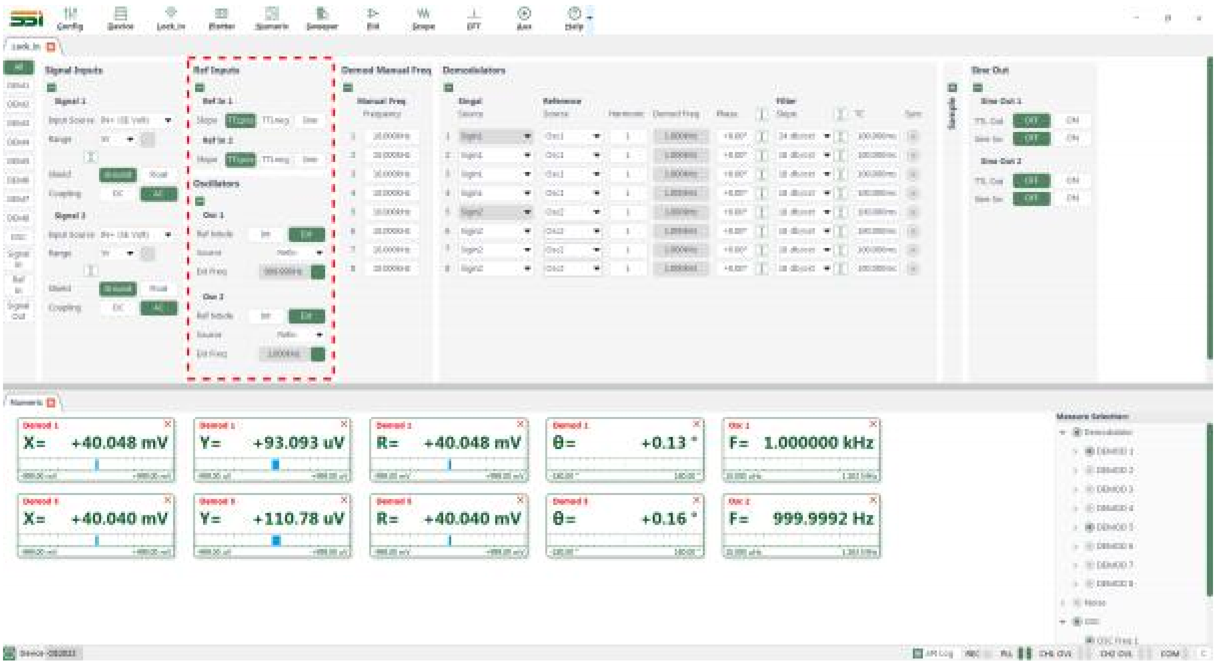


Figure 32. Input Signal Configuration Area of the Flowchart

2. According to the configuration in Table 2, select the reference signal source type and external reference in the reference signal configuration area, with other options left default, as shown in Figure 33 and Figure 34. Choose one of the methods to make modifications.



X= +40.048 mV
Y= +93.093 uV
R= +40.048 mV
θ= +0.13 °
F= 1.000000 kHz
X= +40.040 mV
Y= +110.78 uV
R= +40.040 mV
θ= +0.16 °
F= 999.9992 Hz

Figure 33. Reference Signal Configuration Diagram

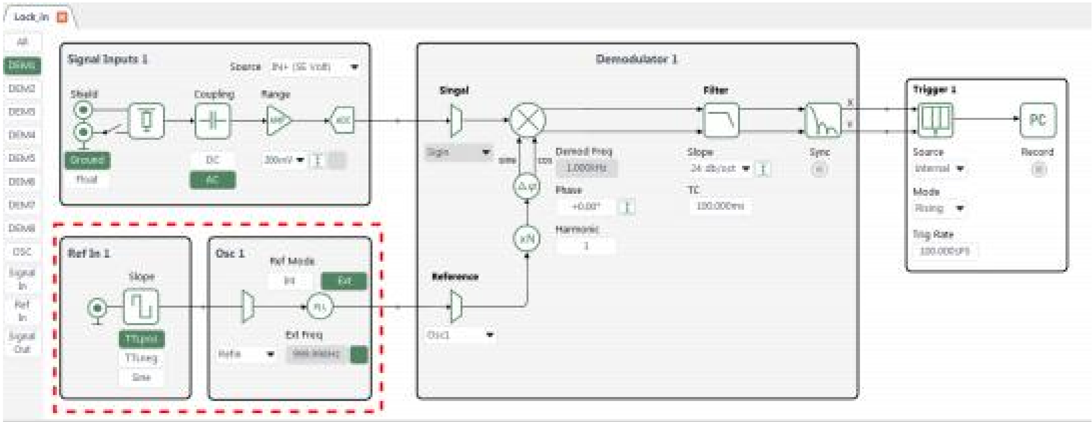
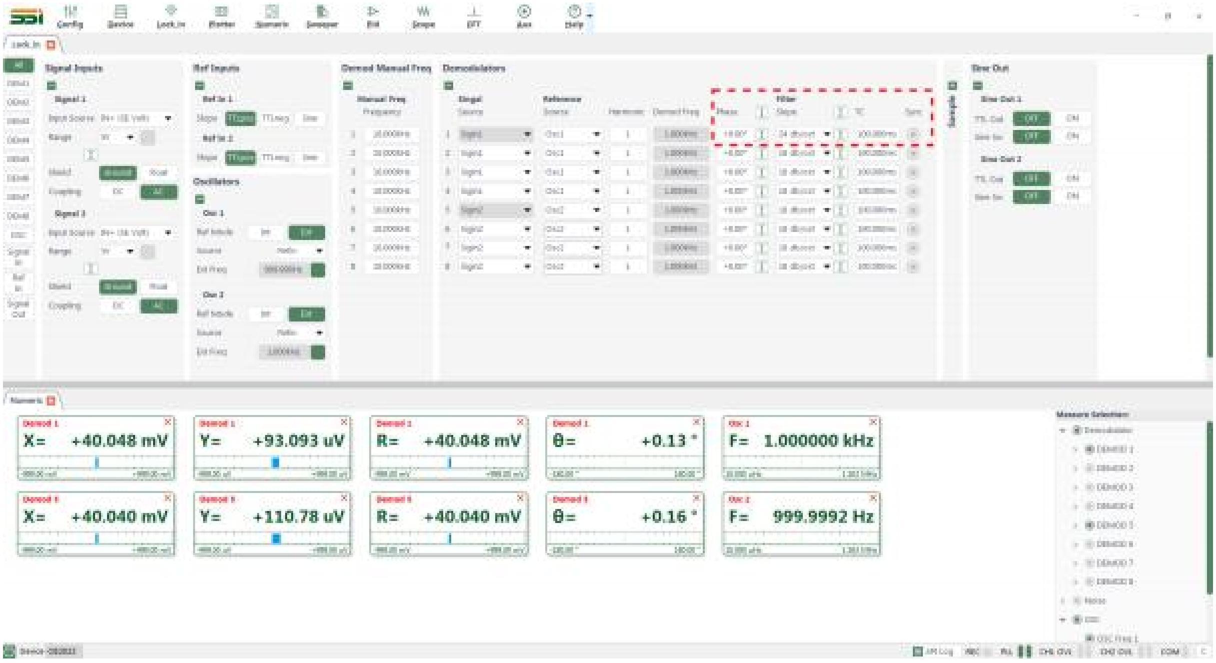


Figure 34. Reference Signal Configuration Area in Process Flow Diagram

3. According to Table 2, select the demodulator time constant, filter steepness, and phase adjustment values in the filter configuration area, with other options left default. As shown in Figures 35 and 36, choose one of the methods to modify and complete the configuration.



Demod 1 X= +40.048 mV

Demod 1 Y= +93.093 uV

Demod 1 R= +40.048 mV

Demod 1 θ= +0.13 °

Osc 1 F= 1.000000 kHz

Demod 5 X= +40.040 mV

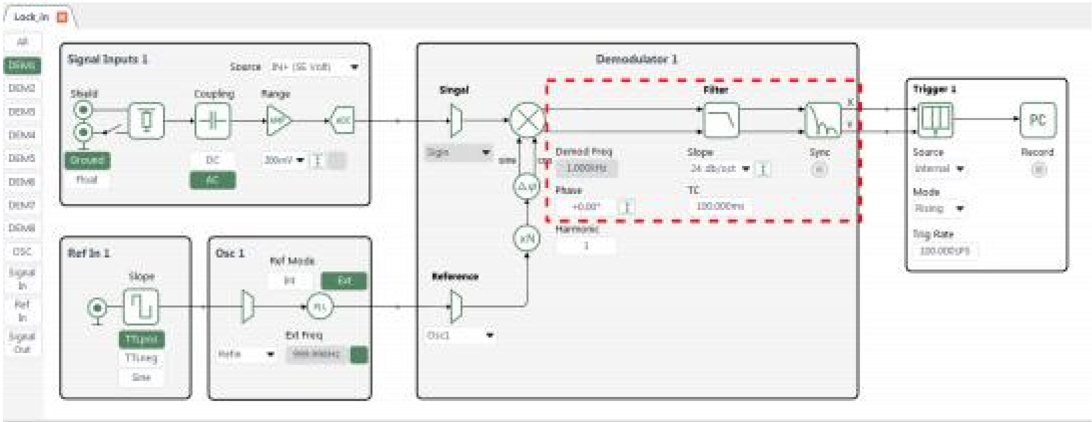
Demod 5 Y= +110.78 uV

Demod 5 R= +40.040 mV

Demod 5 θ= +0.16 °

Osc 2 F= 999.9992 Hz

Figure 35. Filter Configuration Diagram



Signal Inputs 1

Source IN+ (SE Volt)

Shield: Ground

Coupling: AC

Range: 200mV

Demodulator 1

Singal: Sigin

Filter

Demod Freq 1.000kHz

Slope 24 db/oct

Phase +0.00°

TC 100.000ms

Harmonic 1

Reference: Osc1

Ref In 1

Slope: TTLpos

Osc 1

Ref Mode: Ext

Ext Freq 999.998kHz

Trigger 1

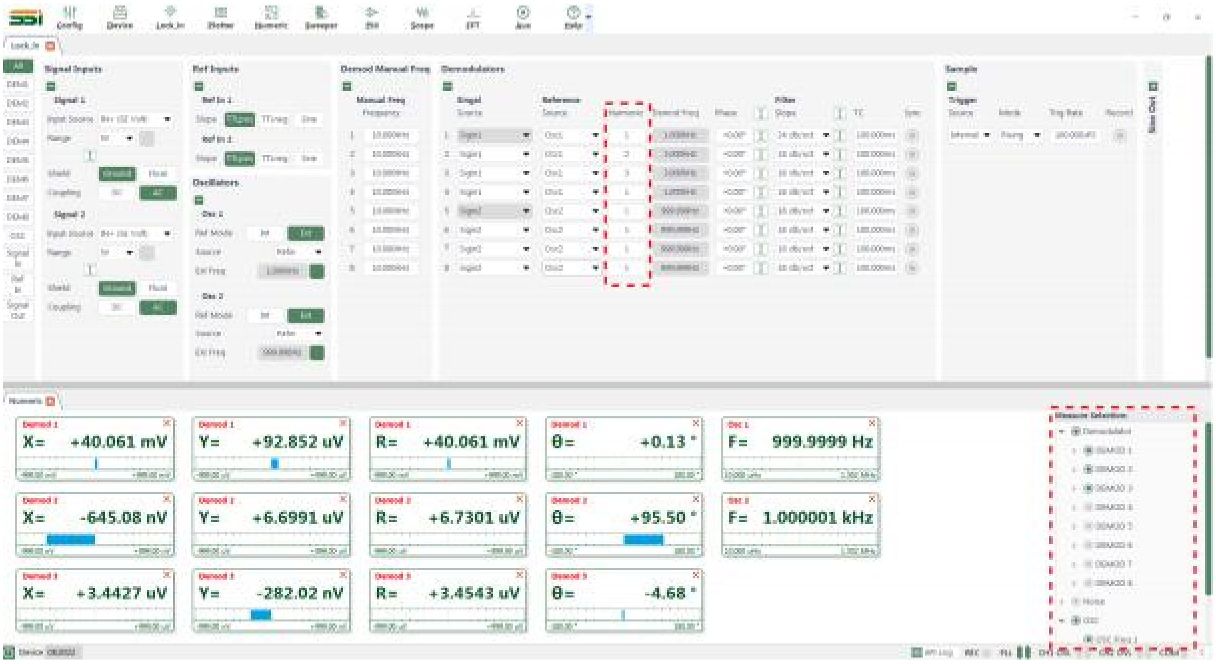
Source Internal

Mode Rising

Trig Rate 100.000kPS

Figure 36. Filter Configuration Area in the Flowchart

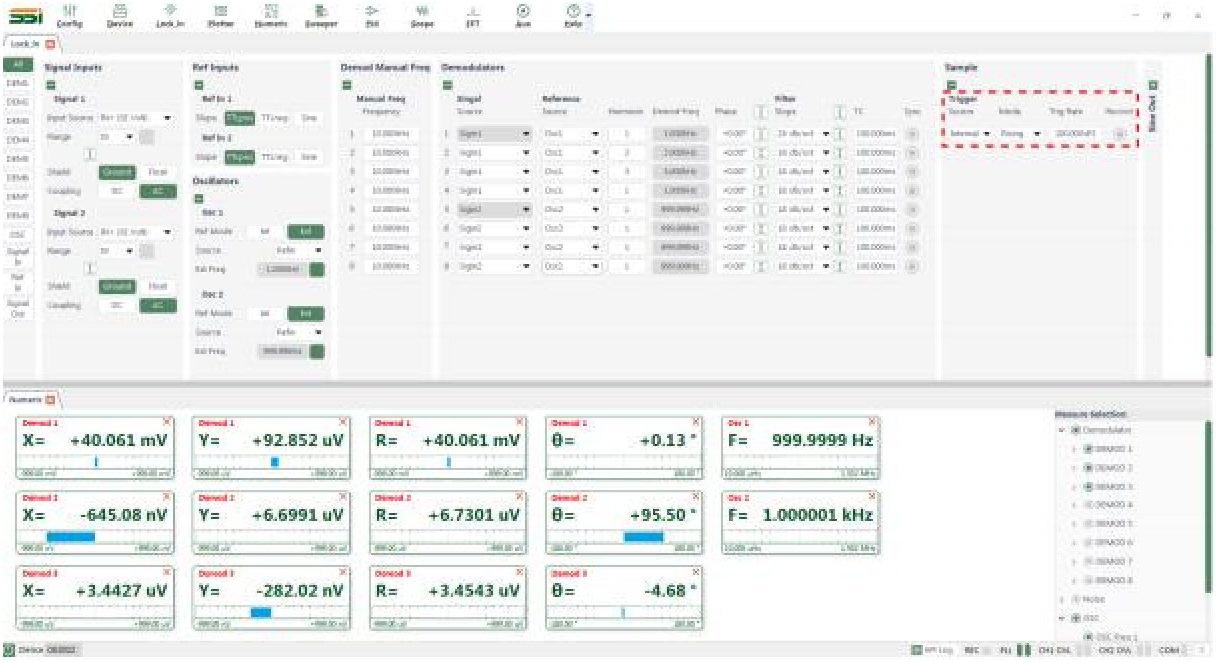
4. To configure another modem, within the red-boxed area shown in Figure 37, set the harmonic order of Modem 2 to 3 and enable the display of its measurement results. This allows simultaneous measurement of both the fundamental component and the third harmonic component of the input signal.



X= +40.061 mV
Y= +92.852 uV
R= +40.061 mV
θ= +0.13 °
F= 999.9999 Hz
X= -645.08 nV
Y= +6.6991 uV
R= +6.7301 uV
θ= +95.50 °
F= 1.000001 kHz
X= +3.4427 uV
Y= -282.02 nV
R= +3.4543 uV
θ= -4.68 °

Figure 37. Other Modem Configuration Diagram

5. After completing the configuration of SE2022 as outlined in steps 1-4 with all other options set to default, you can now proceed with data collection and storage.



X= +40.061 mV
Y= +92.852 uV
R= +40.061 mV
θ= +0.13 °
F= 999.9999 Hz
X= -645.08 nV
Y= +6.6991 uV
R= +6.7301 uV
θ= +95.50 °
F= 1.000001 kHz
X= +3.4427 uV
Y= -282.02 nV
R= +3.4543 uV
θ= -4.68 °

Figure 38. Data Saving in Progress

As shown in Figure 38, clicking the "Record" button within the red box indicates that the current collected data is being saved when the button is selected.

The data is saved in an Excel sheet in the program directory, named "data_lock_in_xxxxx.csv", containing data from 8 modems, as shown in Figure 39.

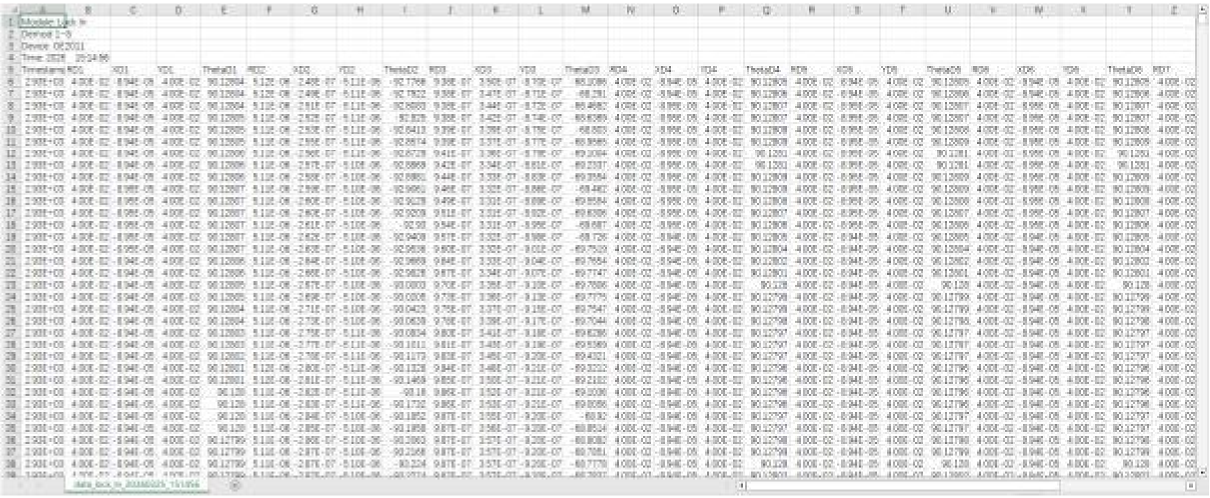


Figure 39. Example of Data Recording Document Content

Chapter 5 Interface and Host Functionality

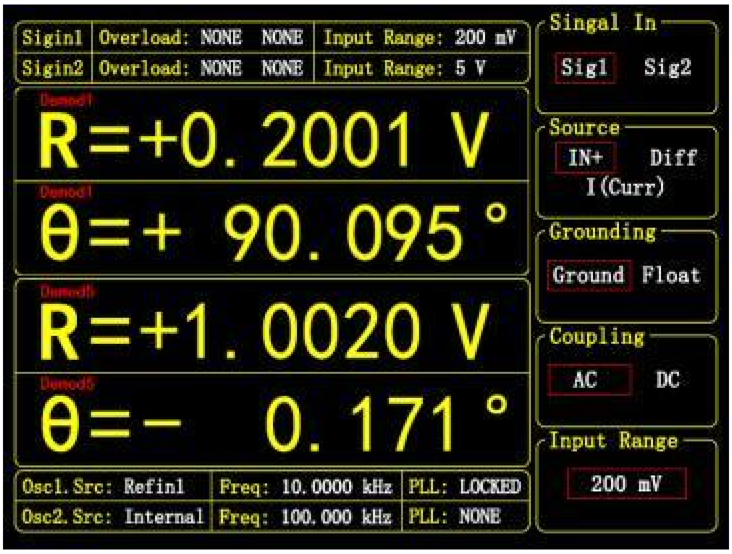
The main control unit of SE2022 is located in the MENU section of the front panel keyboard. The MENU main menu consists of ten submenus: [S|GNAL |NPUT], [OSC REF], [DEMOD F|LTER], [DEMOD REF], [D|SPLAY], [S|GNAL OUTPUT], [AUTO SET], [CHANNEL OUTPUT], [SYSTEM], and [AUX OUTPUT]. Pressing each button switches to the corresponding submenu interface.

The SE2022 system can also be controlled and data read via a host computer.

5.1 [SIGNAL LNPUT] Submenu

5.1.1. Front Panel Interface Configuration

Select [S|GNAL |NPUT] from the front panel menu bar to access this interface. This menu allows hardware configuration for signal input channels, as shown in the right sidebar of Figure 40:



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1
R=+0. 2001 V

Demod1
θ=+ 90. 095 °

Demod5
R=+1. 0020 V

Demod5
θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 40. [|NPUT/F|LTERS] Sub-Menu

This submenu includes five function settings: <Signal |n>, <Source>, <Grounding>, <Coupling>, and <ninput Range>.

- <Signal |n>: Input channel selection

Pressing the button can switch between the parameter display and configuration of <Sig1> and <Sig2> input channels. For example, when switching to <Sig1>, the configurations of <Source>, <Grounding>, <Coupling>, and <nput Range> are all the current configurations of <Sig1>. Changing the configuration at this time does not affect the configuration of <Sig2>.

- <Source>: Input signal type settings

<N+>: Single-ended voltage signal input mode.

<Diff>: Differential voltage signal input mode. When selecting this mode, connect one end of the differential signal to interface |N+ and the other end to interface |N_. The measured signal is the voltage difference between |N+ and |N_.

<I> Single-ended current signal input mode.

I **Note: Whether using voltage or current levels, the maximum input signal amplitude must not exceed the <lnput Range> range.**

- <Grounding>: Enter the shielding layer grounding settings

<html>: |N+/|N- The housing of the input interface is isolated from the instrument ground via a 10 kΩ resistor.

<Ground>: |N+/|N-The enclosure of the input interface is shorted to the instrument ground (which is already connected to the earth-municipal power GND) through a 10 Ω resistor.

Generally, it is assumed that the signal's ability to draw inrush current is not strong enough to damage instrument interface chips. Alternatively, ensure that the signal ground and instrument ground are at the same electrical level by setting <Ground> to short-circuit the signal ground to the system ground, thereby preventing signal drift caused by floating signal grounds. When there is a significant absolute potential difference between the signal ground and instrument ground, and the signal ground exhibits strong inrush current capability, use the <Float> option to float the signal ground while providing current limiting protection.

I **When measuring weak signals (<1 mV), it is recommended to use the Ground mode, provided that the signal and the instrument's ground are at the same electrical level.**

- <Coupling>: Input coupling settings

<AC> AC coupled input. The cutoff frequency of AC coupling is 0.16 Hz, which is used to block DC components in the input signal.

For signal frequencies above 10 Hz, <AC> AC coupling is recommended.

<DC> DC coupled input. DC coupling does not block any input signal; if the signal frequency is below 10 Hz, the coupling effect is negligible.

Use <DC> DC coupling. However, be aware that the input signal bias may cause signal overflow.

- Input range setting

When <Signal Type> is set to <Voltage> mode, the allowed configurations for <nput Range> are as follows:
<5 V> The maximum effective voltage value allowed for the input signal is 5 V_{rms}.
<1 V> The maximum effective voltage value allowed for the input signal is 1 V_{rms}.
<200 mV>: The maximum allowable input signal voltage effective value is 200 mV_{rms}.
<50 mV> The maximum effective voltage value allowed for the input signal is 50 mV_{rms}.
<10 mV> The maximum voltage effective value of the allowed input signal is 1 mV_{rms}.
<2 mV> The maximum voltage effective value of the allowed input signal is 2 mV_{rms}.
<1 mV> The maximum voltage effective value of the allowed input signal is 1 mV_{rms}.
When <Signal Type> is set to <Current> mode, the allowed configurations for <nput Range> are as follows:
<5 mA> The maximum voltage effective value of the allowed input signal is 5 mA_{rms}.
<500 µA> The maximum voltage effective value of the allowed input signal is 500 µ A_{rms}.
<50 µA> The maximum effective voltage value allowed for the input signal is 50 µ A_{rms}.
<5 µA> The maximum effective voltage value allowed for the input signal is 5 µ A_{rms}.
<500 nA> The maximum voltage effective value of the allowed input signal is 500 nA_{rms}.
<50 nA> The maximum allowable effective voltage value of the input signal is 50 nA_{rms}.
<5 nA> The maximum voltage effective value of the allowed input signal is 5 nA_{rms}.

For general measurement scenarios, gain selection should be based on the absence of overload or overflow in the monitoring panel. Under non-overload conditions, selecting a range closer to the signal amplitude enhances measurement stability and accuracy.

When using the automatic gain setting function <Auto Range>, the system automatically adjusts to the closest input range based on the maximum amplitude of the input signal to ensure measurement accuracy.

5.1.2. Upper Computer Configuration

As shown in the red box on Figure 41, the configuration area corresponds to [S|GNAL |NPUT]. Users can configure signal input channels within the parameter table or flowchart section, where configuration details for <Signal Type>, <nput Port>, <Grounding>, <Coupling>, and <nput Range> can be modified and confirmed.

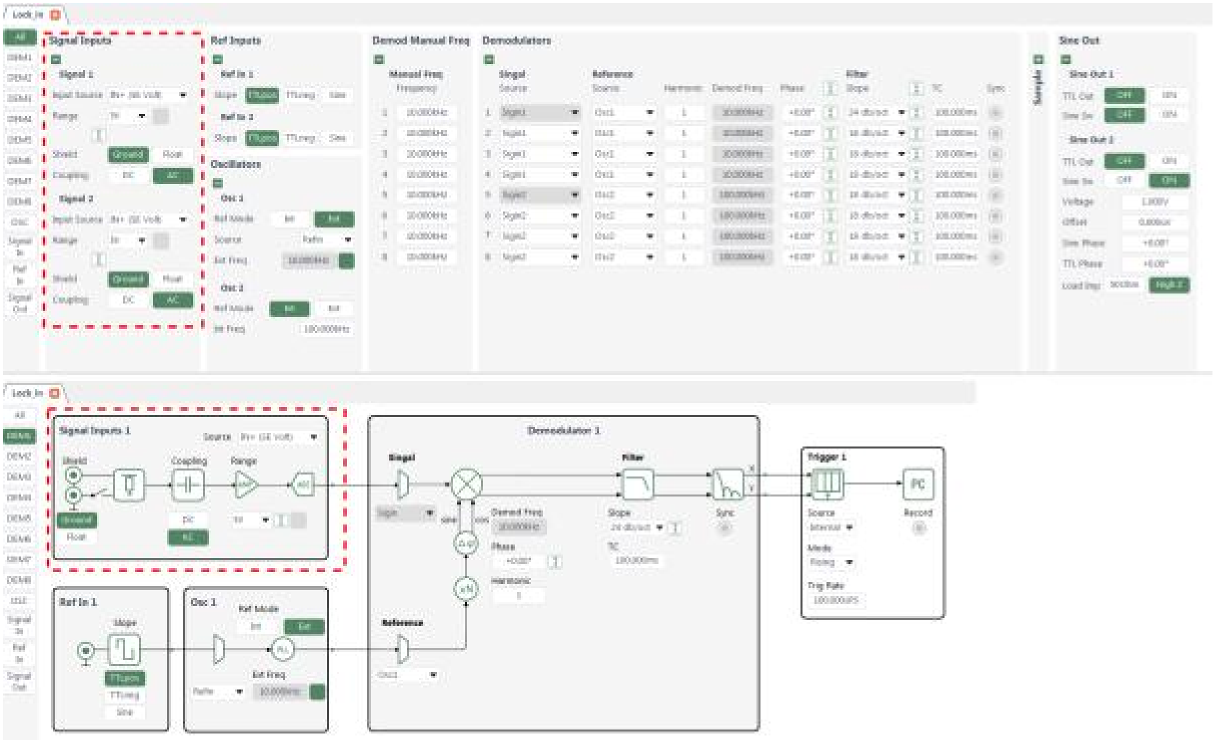
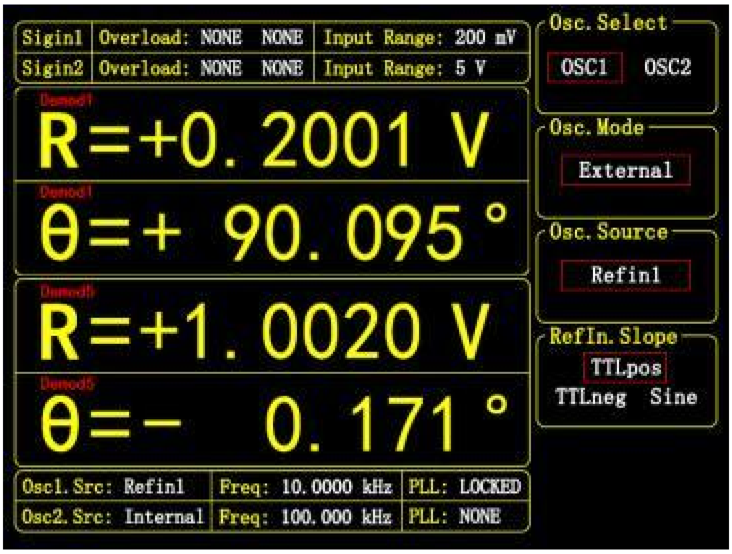


Figure 41. Configuration Area of [S|GNAL |NPUT]

5.2 [OSC REF] Sub-Menu

5.2.1. Front Panel Interface Configuration

Select the [OSC REF] submenu from the front panel menu bar to access this interface. It displays hardware configurations for reference input channels and mode settings for two oscillators (OSC1 and OSC2). Different configuration modes will trigger corresponding interface transitions, as illustrated in Figures 42 and 43.



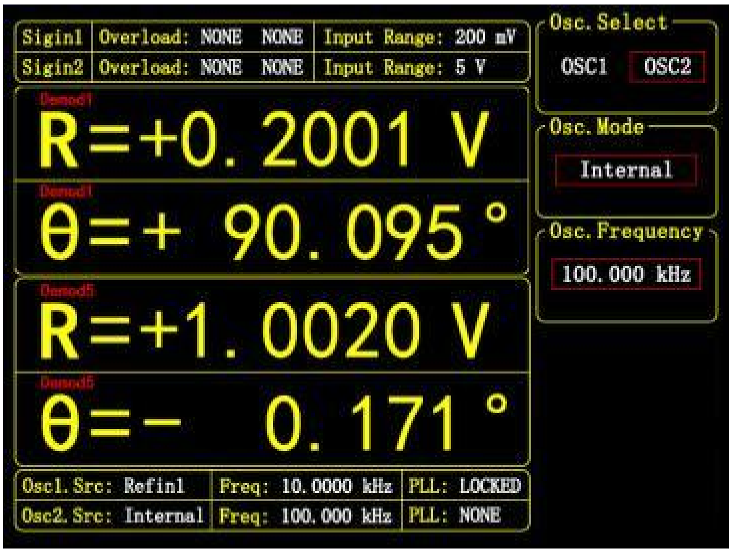
Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1
R=+0.2001 V
Demod1
θ=+ 90.095 °
Demod5
R=+1.0020 V
Demod5
θ=− 0.171 °

Osc1.Src: RefIn1 Freq: 10.0000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 100.000 kHz PLL: NONE

Osc.Select: OSC1 OSC2
Osc.Mode: External
Osc.Source: RefIn1
RefIn.Slope: TTLpos TTLneg Sine

Figure 42. [OSC REF] Sub-Menu <External>



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=- 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Osc. Select: OSC1 OSC2
Osc. Mode: Internal
Osc. Frequency: 100. 000 kHz

Figure 43. [OSC REF] Sub-Menu_<|nternal>

This submenu includes five function settings: <Osc.Select>, <Osc. Mode>, <Osc.Source>, <Osc. Frequency>, and <Re f|n.Slope>.

- <Oosc.Select>: OSC channel selection

Pressing the button allows you to switch between the parameter display and configuration of <OSC1> and <OSC2> oscillators. For example, when switching to <OSC1>, the configurations of <Osc. Mode>, <Osc.Source>, and <Osc. Frequency> will reflect <OSC1> 's current settings. Any changes made at this point will not affect <OSC2>' s configuration.

- <Osc. Mode>: Oscillator mode settings

<External>: External Mode. SE2022 sets the current oscillator to external mode, where the reference signal from the REF|N_BNC input is connected to the oscillator for phase-locking within the instrument. Due to the phase-locked loop, the oscillator's output signal tracks the external reference signal in real time. The interface at this stage is shown in Figure 42, where <Osc.Source> can be configured.

Internal Mode. The SE2022 sets the current oscillator to internal mode, where the oscillator connects to the instrument's internal crystal oscillator and generates reference signals autonomously. The REF |N input signal becomes inactive. The interface is shown in Figure 43, allowing configuration of <Osc. Frequency>.

- .<source>: Reference signal source settings

<Refin1/2>: Set the reference input source for the oscillator's external mode to REF |N. The waveform category of the REF |N signal can be configured via <Ref.Slope>. Note that the <OSC1> corresponding reference interface is <Refin 1>, and the <OSC2> corresponding reference interface is <Refin 2>.

<Sigin1>: Set the reference input source for the oscillator's external mode to the S|GNAL |N 1 interface.

<Sigin2>: Set the reference input source for the oscillator's external mode to the S|GNAL |N 2 interface.

<Auxin1>: Set the reference input source for the oscillator's external mode to the AUX |N 1 interface.

<Auxin2>: Set the reference input source for the oscillator's external mode to the AUX |N 2 interface.

<Auxin3>: Set the reference input source for the oscillator's external mode to the AUX |N 3 interface.

<Auxin4>: Set the reference input source for the oscillator's external mode to the AUX |N 4 interface.

<Trigin>: Set the reference input source for the oscillator's external mode to the TR|GGER |N interface.

- <Ref.Slope>: REF|N Interface reference signal type setting

This setting can be performed when <Osc. Mode> is selected <External> and <Osc Src> is selected <Refin 1/2>. Choose the appropriate signal type based on the type of the external reference signal.

<TTLpos>: Select this option when the external input signal is a square wave. The system will lock phase to the rising edge of the reference signal.

<TTLneg>: Select this option when the external input signal is a square wave. Phase locking is performed on the falling edge of the reference signal.

<Sine>: Select this option when the external input signal is a sine wave. Phase locking is performed at the zero-crossing point of the reference signal's rising edge.

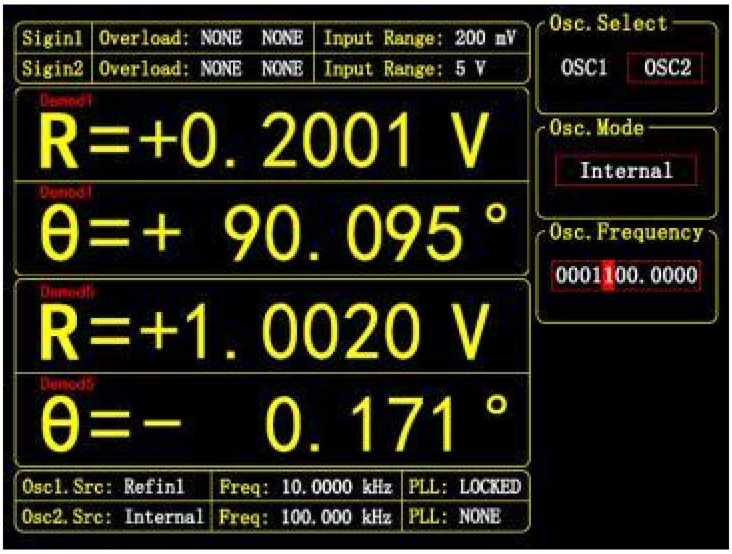
When the input reference signal is at TTL logic level, TTL triggering is recommended. Note that even if the REF IN reference signal is a square wave, unstable triggering may occur if its voltage levels fail to meet TTL logic thresholds (3 V <VIH <5 V, 0.1 V <VIL <0.5 V), potentially leading to inaccurate measurements. In such cases, SINE triggering is advised. Additionally, TTL references should be used for extremely low frequencies (<1 Hz).

When the reference signal input to REF IN is a sine wave, the SINE trigger is recommended. The SINE trigger performs precise shaping of the REF IN input internally before detecting frequency and phase information.

Additionally, the system imposes no requirements on the duty cycle for both <TTL> and <SINE> triggering modes, though a standard 50% duty cycle is recommended. Lower duty cycles result in more severe high-order harmonics and stronger external radiation interference.

- <Osc. Frequency>: Internal reference signal frequency setting

This setting can be configured when <Osc.Source> selects <Internal>, with a frequency range of 10 μHz to 1.5 MHz and a default value of 10.000 kHz. Frequency adjustments can be made via keyboard input, with a minimum resolution of 1 nHz. Additionally, when <Ref_frequency> is selected, individual digit changes can be made using the four directional keys in the [ARROW] area. For example, to quickly adjust 1000 Hz to 1100 Hz: First select <Ref_frequency>, then use [→] and [←] to move the cursor to the hundred position. Next, change the digit to 1 using [↑] and [↓], and confirm with <Enter> to complete the adjustment. See Figure 44.



Sigin1 | Overload: NONE NONE | Input Range: 200 mV

Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1

R=+0. 2001 V

Demod1

θ=+ 90. 095 °

Demod5

R=+1. 0020 V

Demod5

θ=- 0. 171 °

Osc1. Src: RefIn1 | Freq: 10. 0000 kHz | PLL: LOCKED

Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Osc. Select: OSC1 OSC2

Osc. Mode: Internal

Osc. Frequency: 0001100. 0000

Figure 44. Schematic Diagram of Frequency Adjustment Via [ARROW]

5.2.2. Upper Computer Configuration

As shown in Figure 45, the configuration area marked in red box on the host computer corresponds to the [OSC REF] configuration zone. Users can configure hardware settings for reference input channels and internal oscillator parameters within the parameter table or flowchart section. Configuration information for <Osc.Select>, <Osc.Mode>, <Osc.Source>, <Osc. Frequency>, and <RefIn.Slope> can all be modified and confirmed within the red box.

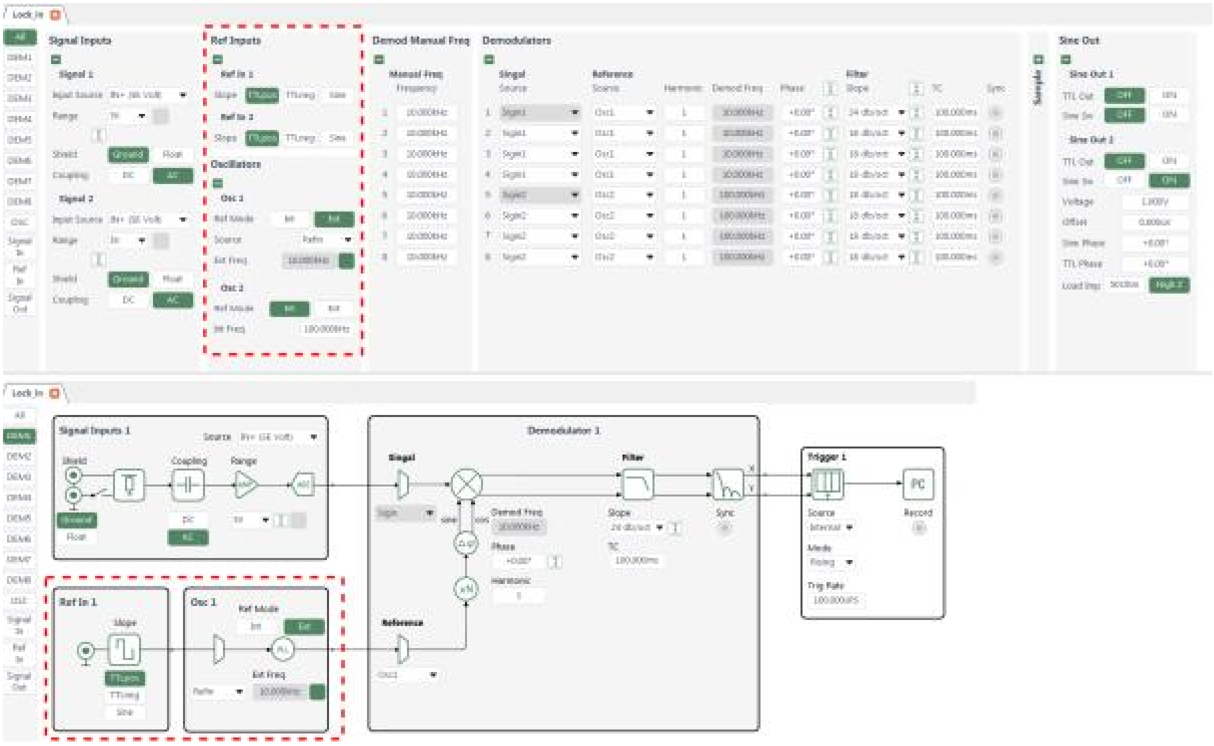
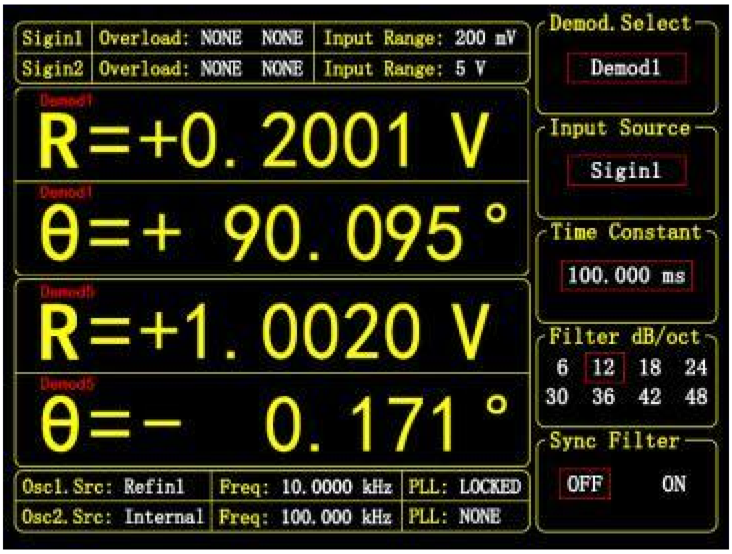


Figure 45. Configuration Area of [OSC REF]

5.3 [DEMOD Filter] Submenu

5.3.1. Front Panel Interface Configuration

Select [DEMOD FILTER] from the front panel menu bar to access this menu, which contains hardware configuration for signal input channels as shown in the right sidebar of Figure 46.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1
R=+0.2001 V

Demod1
θ=+ 90.095 °

Demod5
R=+1.0020 V

Demod5
θ=− 0.171 °

Osc1.Src: Refin1 Freq: 10.0000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 100.000 kHz PLL: NONE

Demod.Select: Demod1

Input Source: Sigin1

Time Constant: 100.000 ms

Filter dB/oct: 6 12 18 24 30 36 42 48

Sync Filter: OFF ON

Figure 46. [DEMOD FILTER] Submenu

This submenu includes five function settings: <Demod.Select>, <Input Source>, <Time Constant>, <Filter dB/oct>, and <Sync Filter>.

- <Demod.Select>: Modem channel selection settings

The knob and keyboard ARROW area allow switching between <Demod1> and <Demod8> to view and configure 8 demodulator parameters. For example, switching to <Demod1> maintains the current <Demod1> settings for <nput Source>, <Time Constant>, <Filter dB/oct>, and <Sync Filter>. Changing any of these parameters here will not affect the configurations of other demodulators.

- Demodulator signal input source selection settings

<Sigin1>	Set the signal input source of the current modem to the S|GNAL |N 1 interface.
<Sigin2>	Set the signal input source of the current modem to the S|GNAL |N 2 interface.
<Auxin1>	Set the signal input source of the current modem to the AUX |N 1 interface.
<Auxin2>	Set the signal input source of the current modem to the AUX |N 2 interface.
<Auxin3>	Set the signal input source of the current modem to the AUX |N 3 interface.
<Auxin4>	Set the signal input source of the current modem to the AUX |N 4 interface.
<X-Demod1>	Set the signal input source of the current demodulator to the X output value of demodulator Demod1.
<Y-Demod1>	Set the signal input source of the current modem to the output Y value of modem Demod1.
<R-Demod1>	Set the signal input source of the current demodulator to the R value output by Demod1.
<Theta-Demod1>:	Set the signal input source of the current demodulator to the Theta value output by Demod1.
<X-Demod5>	Set the current modem's signal input source to the output X value of Demod5.
<Y-Demod5>	Set the current modem's signal input source to the output Y value of Demod5.
<R-Demod5>	Set the signal input source of the current demodulator to the R value output by Demod5.

<Theta-Demod5>: Set the signal input source of the current demodulator to the Theta output value of demodulator Demod5.

When the signal input source of the demodulator is set to <X_Demod1>-<Theta-Demod5>, the SE2022 operates in cascade demodulation mode, enabling secondary demodulation of the modulated signal to recover both the carrier and modulated wave signals.

I **Note: Demod1 fixedly selects Sigin1 as the input source, and Demod5 fixedly selects Sigin2 as the input source.**

- <Time Constant>: Time constant setting

The time constant ranges from 100 ns to 3 ks. Enter values via the keyboard or adjust them using the ARROW keys.

The longer the time constant, the smaller the equivalent noise bandwidth, the longer the system's measurement response time, and the higher the measurement accuracy.

- <Filter dB/oct>: Low-pass filter rollover setting

<6 dB/oct>	First-order low-pass filter with a steep 6 dB/oct attenuation.
<12 dB/oct>	A second-order low-pass filter with a steep 12 dB/oct attenuation.
<18 dB/oct>	A third-order low-pass filter with a steep attenuation of 18 dB/oct.
<24 dB/oct>	A fourth-order low-pass filter with a steep attenuation of 24 dB/oct.
<30 dB/oct>	A fifth-order low-pass filter with a steep 30 dB/oct attenuation.
<36 dB/oct>	A sixth-order low-pass filter with a steep 36 dB/oct attenuation.
<42 dB/oct>	A seventh-order low-pass filter with a steep 42 dB/oct attenuation.
<48 dB/oct>	An eighth-order low-pass filter with a steep 48 dB/oct attenuation.

With equivalent measurement accuracy, employing higher filter steepness can reduce the time constant to achieve faster measurement response. The specific combination of time constant and filter steepness must be selected based on practical conditions. A key criterion is ensuring measurement stability meets requirements, in which case neither the time constant nor filter steepness needs to be excessively high to avoid prolonged waiting times. Of course, for enhanced stability, it may be advisable to moderately increase both the time constant and filter steepness.

- <Sync Filter>: Sync filter settings

<OFF>: Turn off the sync filter.

<ON>: Enable synchronization filter.

Synchronous filters can effectively remove signals at the reference frequency and its harmonics, thereby reducing the requirements for low-pass filters. Synchronous filters can be activated or deactivated in any state, but they only remain effective when the signal frequency is below 250 kHz.

Low-pass filters may fail to produce stable results or require prolonged processing time when the input signal frequency is low. In such cases, synchronization filters can be activated to enhance performance, as illustrated in Figure 47.

I **Note: When the synchronous filter is enabled, <Filter db/oct> must be above <18 dB/oct> and <Demod Frequency> below 250 kHz for it to take effect!**

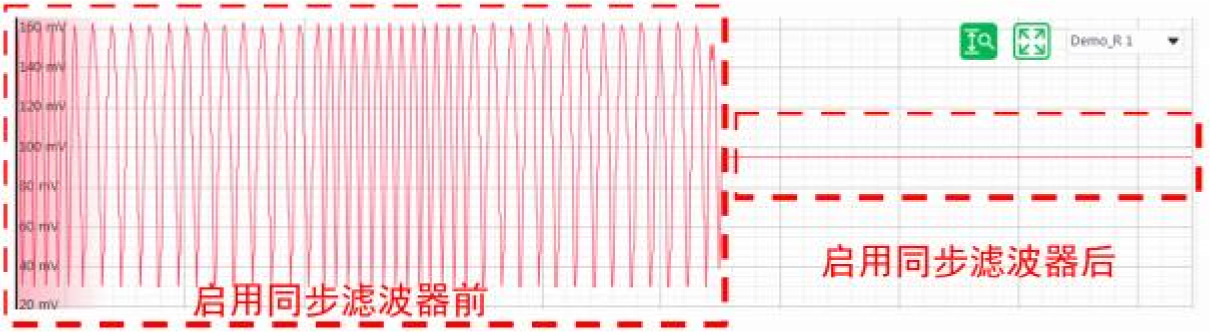


Figure 47. Render of the Enabled Synchronous Filter

5.3.2. Upper Computer Configuration

As shown in the red box on Figure 48, this area constitutes the configuration zone for [DEMOD FILTER]. Users can configure modem parameters—including <Input Source>, <Time Constant>, <Filter dB/oct>, and <Sync Filter>—either in the parameter table or within the flowchart section, with all settings adjustable and verifiable inside the red box.

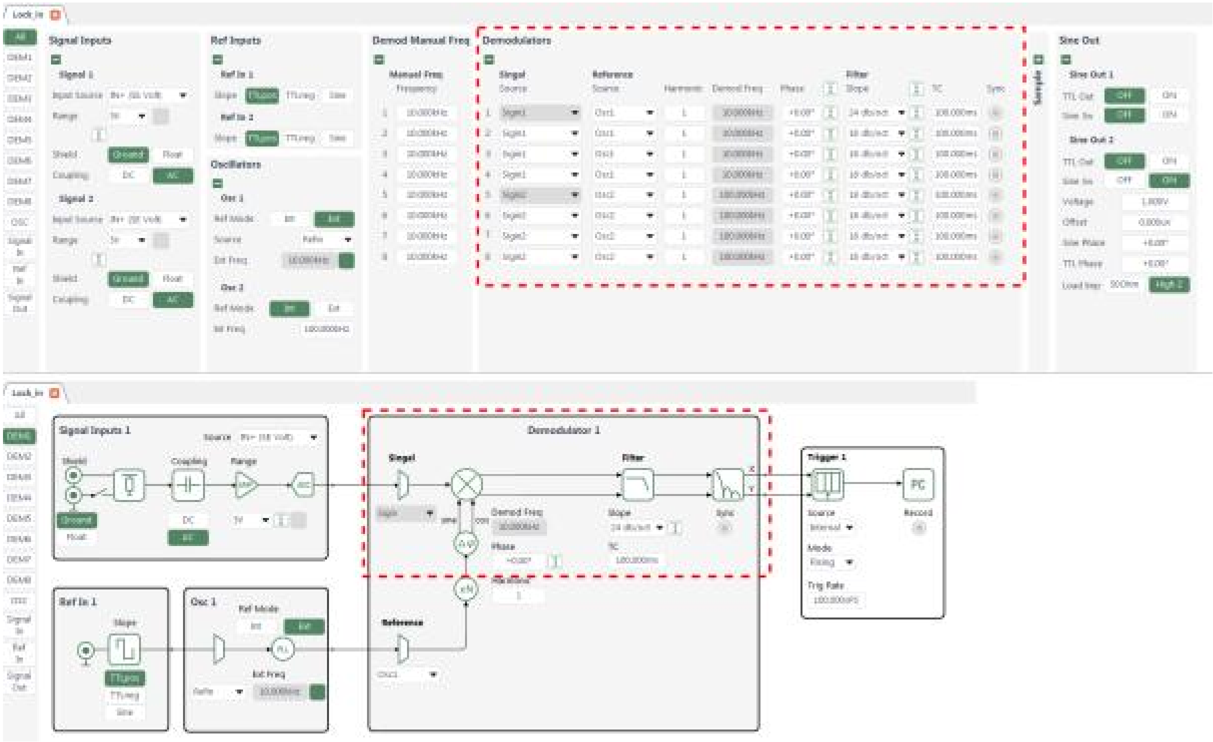
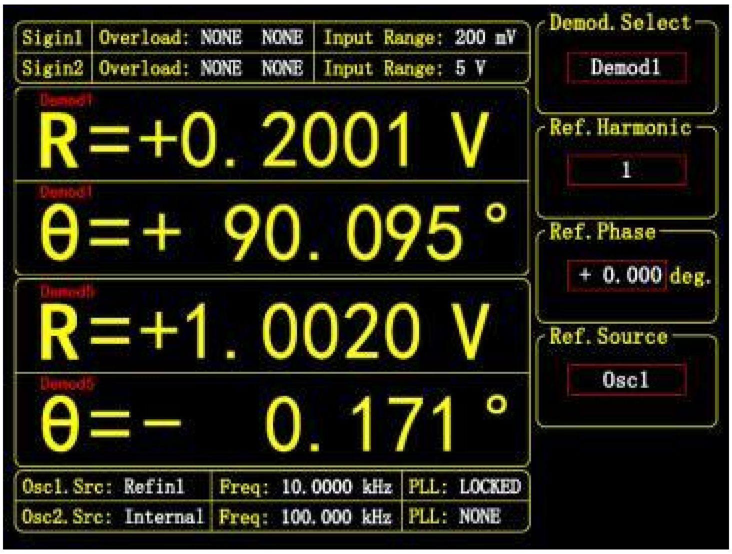


Figure 48. Configuration Area of [DEMOD FILTER]

5.4 [DEMOD REF] Sub-Menu

5.4.1. Front Panel Interface Configuration

Select the [DEMOD REF] submenu from the menu bar on the front panel to access this configuration menu for the demodulator reference reference source, as shown in the right sidebar of Figure 49.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1
R=+0. 2001 V
Demod1
θ=+ 90. 095 °
Demod5
R=+1. 0020 V
Demod5
θ=− 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Demod. Select: Demod1
Ref. Harmonic: 1
Ref. Phase: + 0. 000 deg.
Ref. Source: Osc1

Figure 49. [DEMOD REF] Sub-Menu

This submenu includes functional settings such as <Demod.Select>, <Ref. Harmonic>, <Ref. Phase>, <Ref Src>, <Frequency Set>, and <FreqComb Set>.

- <Demod.Select>: Modem channel selection settings

The knob and keyboard ARROW area allow switching between <Demod1> and <Demod8> to view and configure 8 demodulator parameters. For example, switching to <Demod1> maintains the current configurations of <Ref. Harmonic>, <Ref. Phase>, <Ref.Source>, and <Frequency Set>. Changing any of these settings will not affect the configurations of other demodulators.

- <Ref. Harmonic>: The harmonic order setting of the demodulator reference standard

The parameter ranges from 1 to 10,000 integers. Enter the desired harmonic order via the numeric keypad, with 1 displayed by default to indicate detection of the first harmonic (i.e., fundamental wave). <Ref. Harmonic> The harmonic order setting is valid only when the reference signal frequency (Harmonic*) ≤ 1.5 MHz.
Exceeding this upper frequency limit will not affect the preset value, but measurement results will be inaccurate. Users must manually adjust harmonic settings accordingly.

For example, when the input signal is a square wave with a frequency of 1 kHz, assuming its peak-to-peak value is A, set the <Ref. Harmonic> values as follows:

1、2、3、4、5、6- - At that time, the expected R values were 0.45 A, 0, 0.15 A, 0, 0.09 A, and 0.- - This sequence is precisely A times the coefficient sequence of the Fourier series of the square wave signal.

I **Note: To display multiple demodulator measurements simultaneously, select <Full> from the <Display Mode> option in the [DISPLAY] submenu. For details, see the [DISPLAY] submenu section.**

- <Ref. Phase>: Phase offset setting for the demodulator reference

The phase shift angle of two orthogonal reference signals for the PSD algorithm can be set via digital keyboard input, with an input range of-180° to 180° and a resolution of 0.001°.

For phase measurement, a reference point is essential to establish meaningful measurements. In our system, we conventionally use the zero-crossing point of the internal oscillator's rising edge as the phase reference, with all other phase values calculated relative to this baseline. When the internal oscillator's signal source is set to REF_IN, the oscillator achieves phase locking through a high-precision phase- locked loop (PLL). During this process, the system's phase reference tracks the REF_IN signal to ensure accurate phase synchronization.

The phase offset will affect the phase deviation of the demodulator reference against the internal oscillator. As shown in Figure 50, if phase offset is not required, keep <Ref. Phase> at 0°, at which point the demodulator reference remains in phase with the internal oscillator.

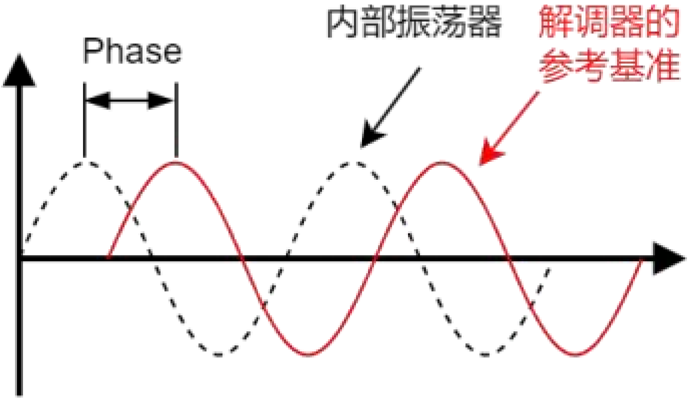


Figure 50. The Effect of Phase Offset on the Reference Datum

- <Ref Src>: Modulator reference reference source settings

<Osc1> Set the reference source for the current modem to the internal oscillator OSC1.

<Osc2> Set the reference source for the current modem to the internal oscillator OSC2.

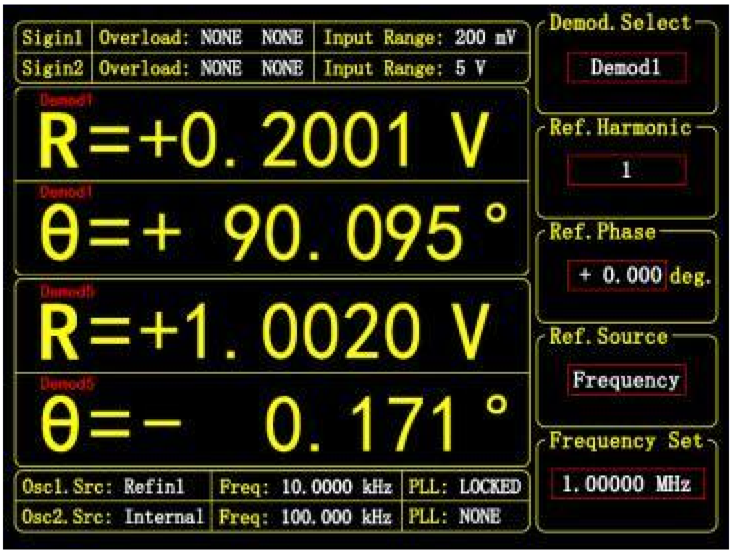
<Frequency>: Set the reference source of the current modem to any frequency. The interface for this mode is shown in Figure 51.

<FreqComb1>: Set the reference source of the current demodulator to frequency synthesis demodulation. The interface for this mode is shown in Figure 52. You can click <Menu Enter> to access the secondary menu and configure the frequency synthesis formula. The frequency synthesis mode supports 4 channels <FreqComb 1> to <FreqComb4>, independent of the demodulator channels. Each demodulator can either be configured individually or share the same <Fre qComb> channel.

<FreqComb2>: Ibid.

<FreqComb3>: Ibid.

<FreqComb4>: Ibid.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

R=+0. 2001 V

θ=+ 90. 095 °

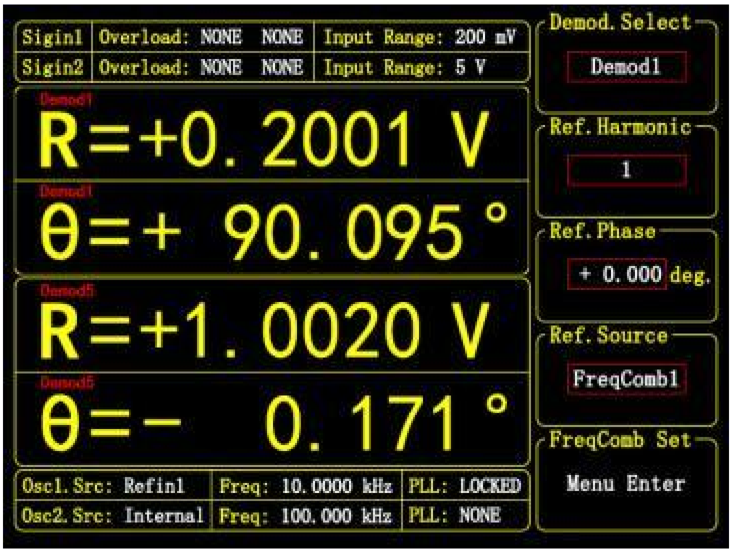
R=+1. 0020 V

θ=- 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Demod. Select: Demod1
Ref. Harmonic: 1
Ref. Phase: + 0. 000 deg.
Ref. Source: Frequency
Frequency Set: 1. 00000 MHz

Figure 51. <Frequency> Mode Interface



Sigin1 | Overload: NONE NONE | Input Range: 200 mV

Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V

Demod1 θ=+ 90. 095 °

Demod5 R=+1. 0020 V

Demod5 θ=- 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED

Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Demod. Select: Demod1

Ref. Harmonic: 1

Ref. Phase: + 0. 000 deg.

Ref. Source: FreqComb1

Figure 52. <FreqComb> Pattern Interface

- <Frequency Set>: Modulator reference frequency setting

This configuration item can be enabled when <Ref.Source> is set to <Frequency>. This setting follows the same rules as the <Ref.Frequency> in [OSC REF]. When <Frequency> is set to a specific frequency, the demodulator uses that frequency as the reference frequency for signal demodulation.

This mode proves particularly useful when input signals contain multiple frequency components that require separate extraction. The system enables eight demodulators to be configured with distinct demodulation frequencies, allowing simultaneous processing of eight frequency signals.

- <FreqComb Set>: Formula settings for frequency synthesis

This configuration item can be enabled when <Ref. Source> is set to <FreqComb1> through <FreqComb4>. In this case, you can click <Menu Enter> to access the secondary menu and configure the frequency synthesis formula, as shown in Figure 53. The calculation formula for <FreqComb> is as follows:

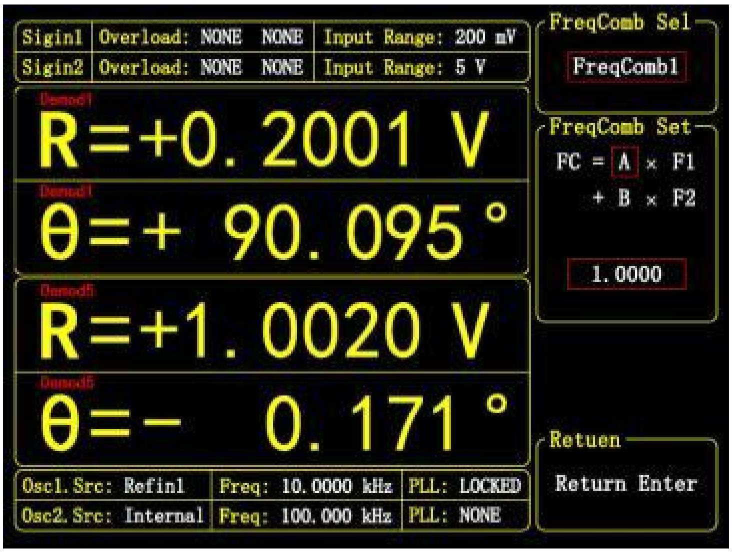
$$\text{Freqcomb} = A \times F_1 + B \times F_2$$

among:

A and B are signed real numbers with a value range of-10,000 to +10,000 and a resolution of 0.001.

F_1、F_2can select either the frequency output from OSC1 or OSC2, or any internal frequency from Demod1 to Demod 8.

If the FreqComb calculation result is 1500 Hz, the demodulator performs phase-sensitive detection using 1500 Hz as the reference frequency. This mode demonstrates excellent performance in demodulating AM, FM, and other signals (including the demodulation of sum and difference frequency signals).



Sigin1 | Overload: NONE NONE | Input Range: 200 mV

Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V

Demod1 θ=+ 90. 095 °

Demod5 R=+1. 0020 V

Demod5 θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED

Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 53. <FreqComb> Secondary Menu Settings Interface

5.4.2. Upper Computer Configuration

As shown in Figure 54, the configuration area marked in red box on the host computer corresponds to the [DEMOD REF] configuration zone. Users can configure the demodulator reference reference source parameters in either the parameter table or flowchart section. Configuration details for <Ref. Harmonic>, <Ref. Phase>, <Ref. Source>, <Frequency Set>, and <FreqComb Set> can all be modified and confirmed within the red box.

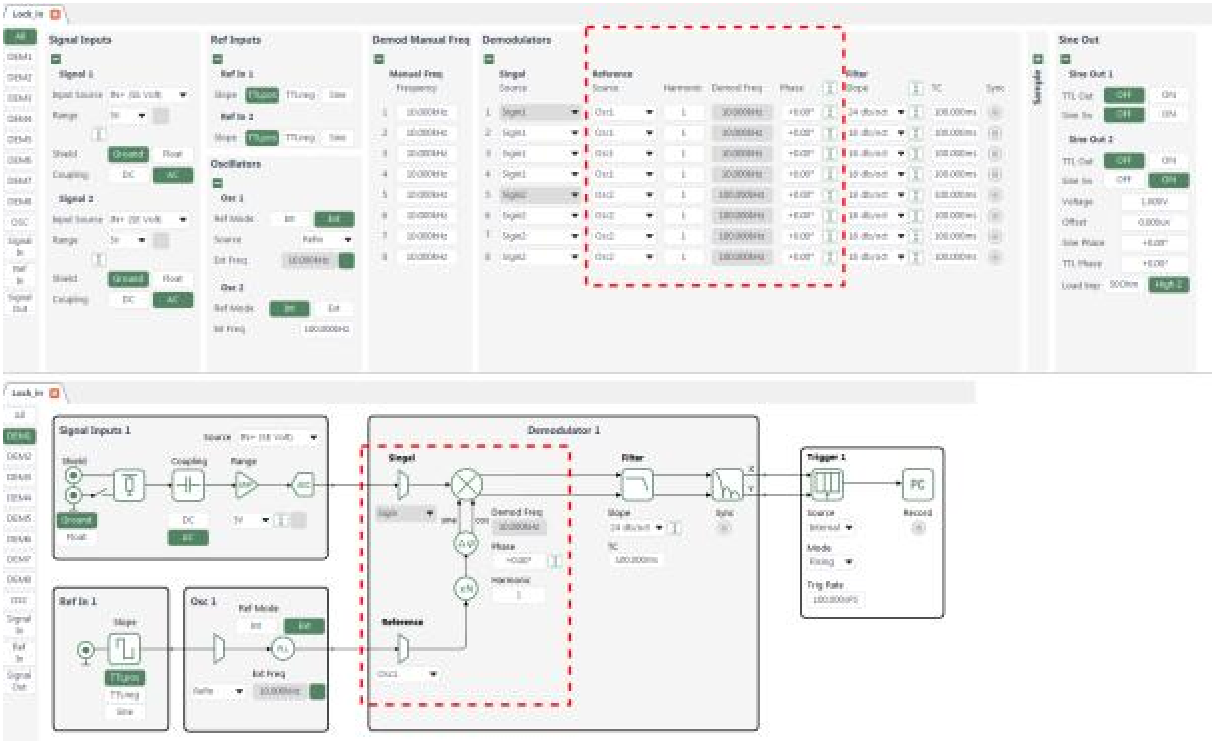


Figure 54. Configuration Area of [DEMOD REF]

The configuration interface of<FreqComb Set> is shown in Figure 55. Users can set the calculation formula for frequency synthesis in the flowchart area of the host computer, and the configuration information of A, B,F1、F2 can be modified and confirmed within the red box.

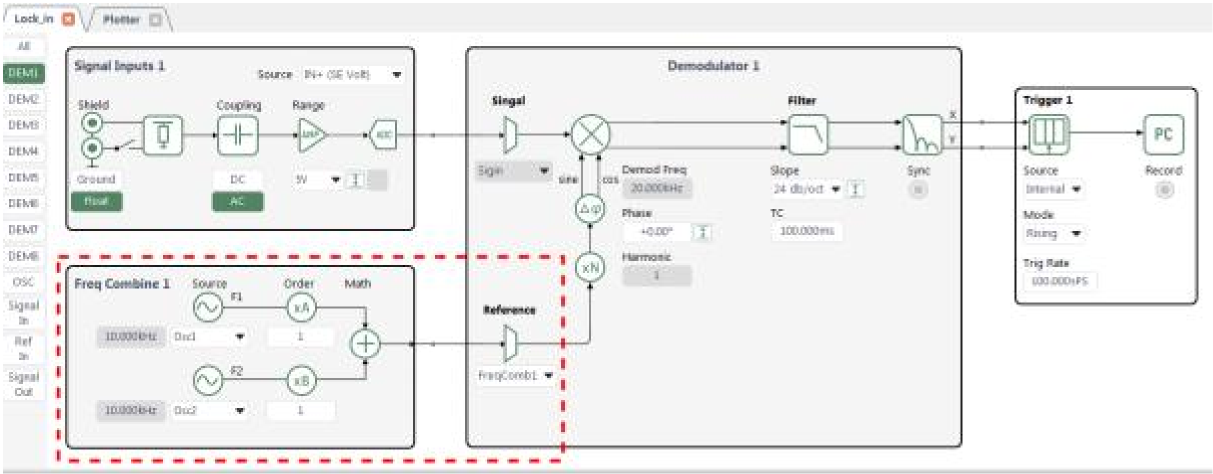
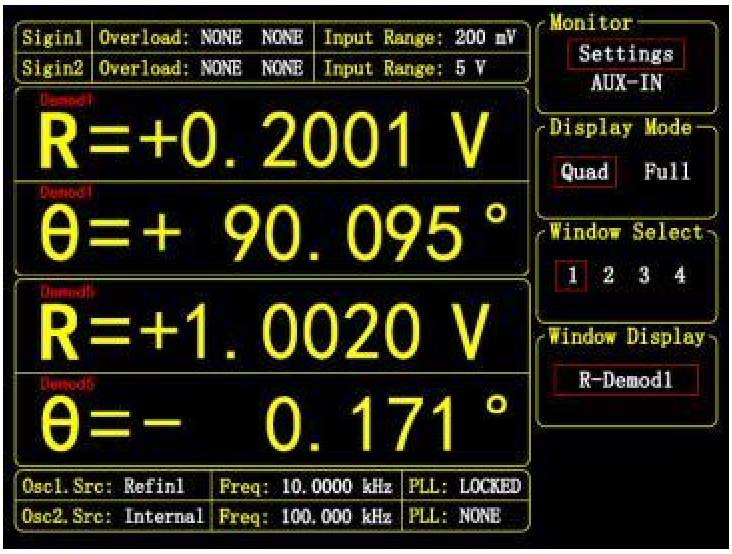


Figure 55. FreqComb Formula Configuration Area of [DEMOD REF]

5.5 [DISPLAY] Sub-Menu

5.5.1. Front Panel Interface Configuration

Select the [D|SPLAY] submenu from the MENU menu bar on the front panel to enter, as shown in the right sidebar of Figure 56:


Sigin1 Overload: NONE NONE Input Range: 200 mV

Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1 R=+0. 2001 V

Demod1 θ=+ 90. 095 °

Demod5 R=+1. 0020 V

Demod5 θ=− 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED

Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

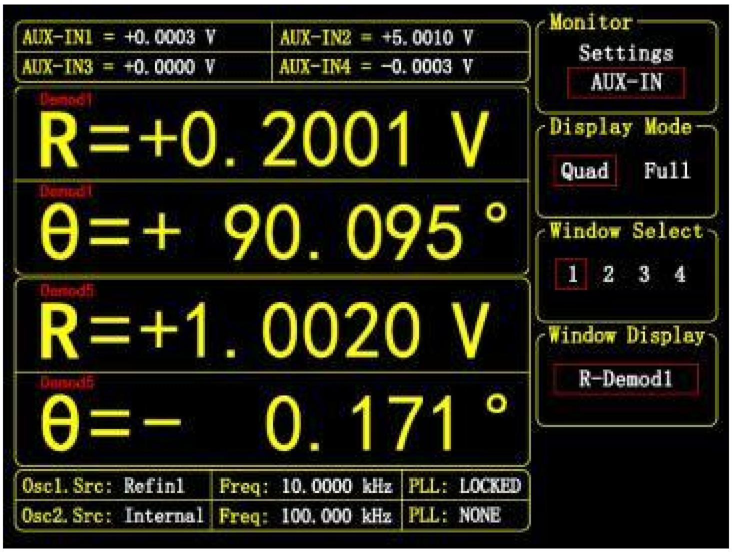
Figure 56. [D|SPLAY] Sub-Menu

The [D|SPLAY] submenu primarily includes five functional settings: <Monitor>, <Display Mode>, <Window Select>, <Window Display>, and <Full Window>. These can be selected and configured using the corresponding soft keys adjacent to the submenu.

- <Monitor>: Status bar display settings

<Settings>: Displays multiple current settings and statuses such as <nput Source> and <Overload> in the status bar above the LCD screen.

<AUX_|N>: Displays real-time input voltage amplitudes of the four BNC interfaces on the rear panel AUX_|N within the status bar above the LCD screen. The interface is shown in Figure 57:



AUX-IN1 = +0.0003 V
AUX-IN2 = +5.0010 V
AUX-IN3 = +0.0000 V
AUX-IN4 = −0.0003 V

Demod1
R=+0.2001 V
Demod1
θ=+ 90.095 °
Demod5
R=+1.0020 V
Demod5
θ=− 0.171 °

Osc1. Src: Refin1 | Freq: 10.0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100.000 kHz | PLL: NONE

Figure 57. <AUX_|N> Interface

- <Display Mode>: Dynamic area display mode settings

The <Display Mode> option is used to set the display type of the data bar. There are two types:

<Quad>: Four-column display mode, showing 4 measurement data simultaneously. This mode is shown in Figure 56.

<Full>: Full data display mode, showing measurement data from all 8 demodulators simultaneously. This mode is illustrated in Figure 58.

Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1	X = + 1.0000 V R = + 1.0001 V	Y = + 0.0001 V θ = +00.003 °
Demod2	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °
Demod3	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °
Demod4	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °
Demod5	X = − 1.0000 V R = + 1.0001 V	Y = + 0.0001 V θ = −179.997 °
Demod6	X = +100.001 nV R = +141.423 nV	Y = −100.001 nV θ = −45.000 °
Demod7	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °
Demod8	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °

Osc1. Src: Refin1 | Freq: 10.0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100.000 kHz | PLL: NONE

Figure 58. <Full> Display Mode

- <Window Select>&<Window Display>: Column-based window display settings

You can enable these two configuration items when <Display Mode> is set to <Quad>. Select the <Window Select> to choose the column window, and set the <Window Display> to specify the measurement data displayed in the column window. Available measurement data includes:

<X-Demod1>	The X value of the demodulation result from demodulator 1.
<Y-Demod1>	The Y value of the demodulation result from demodulator 1.
<R-Demod1>	The R value of the demodulation result from demodulator 1.
<θ-Demod1>	The θ value of the demodulation result from demodulator 1.
<X-Demod2>	The X-value of the demodulation result from Modulator 2.
<Y-Demod2>	The Y value of the demodulation result from demodulator 2.

<R-Demod2>	The R value of the demodulation result from demodulator 2.
<θ-Demod2>	The θ value of the demodulation result from demodulator 2.
<X-Demod3>	The X-value of the demodulation result from Modulator 3.
<Y-Demod3>	The Y value of the demodulation result from Modulator 3.
<R-Demod3>	The R value of the demodulation result from demodulator 3.
<θ-Demod3>	The θ value of the demodulation result from demodulator 3.
<X-demod4>	The X value of the demodulation result from demodulator 4.
<Y-demod4>	The Y value of the demodulation result from Modulator 4.
<R-demod4>	The R value of the demodulation result from Modulator 4.
<θ-Demod4>	The θ value of the demodulation result from demodulator 4.
<X-Demod5>	The X value of the demodulation result from demodulator 5.
<Y-Demod5>	The Y value of the demodulation result from demodulator 5.
<R-Demod5>	The R value of the demodulation result from demodulator 5.
<θ-Demod5>	The θ value of the demodulation result from demodulator 5.
<X-Demod6>	The X value of the demodulation result from demodulator 6.
<Y-Demod6>	The Y value of the demodulation result from demodulator 6.
<R-Demod6>	The R value of the demodulation result from demodulator 6.
<θ-demod6>	The θ value of the demodulation result from demodulator 6.
<X-Demod7>	The X value of the demodulation result from demodulator 7.
<Y-Demod7>	The Y value of the demodulation result from demodulator 7.
<R-Demod7>	The R value of the demodulation result from demodulator 7.
<θ-Demod7>	The θ value of the demodulation result from demodulator 7.
<X-Demod8>	The X-value of the demodulation result from Modulator 8.
<Y-Demod8>	The Y value of the demodulation result from demodulator 8.
<R-Demod8>	The R value of the demodulation result from Modulator 8.
<θ-Demod8>	The θ value of the demodulation result from demodulator 8.

<XNoise-Demod1>: The X_Noise value of the demodulation result from Demodulator 1.

<YNoise-Demod1>: The Y_Noise value of the demodulation result from demodulator 1.

<XNoise-Demod5>: The X_Noise value of the demodulation result from demodulator 5.

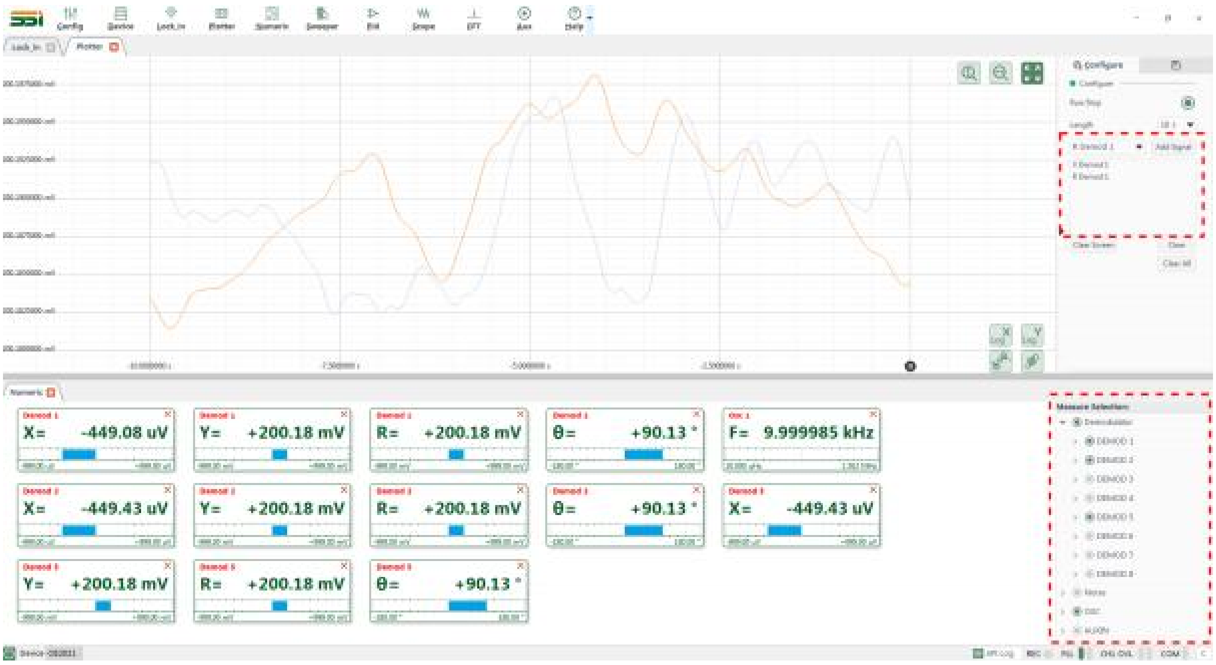
<YNoise-Demod5>: The Y_Noise value of the demodulation result from demodulator 5.

The four-column display window allows flexible selection of content to be shown, with the default being the <X>, <Y>, <R>, and < θ > values of Modulator 1.

5.5.2. Upper Computer Configuration

[DISPLAY] The submenu only configures the display results of the front panel interface without affecting the host computer's configuration information. The host computer's data measurement results can be configured for separate display, as shown in Figure 59. On the Numeric tab, users can select measurement results from any modem for display. Compared to the front panel interface, the host computer configuration offers greater flexibility and convenience.

Additionally, the host computer features a waveform display mode. By selecting the Plotter tab, users can observe one or multiple output results as waveforms.



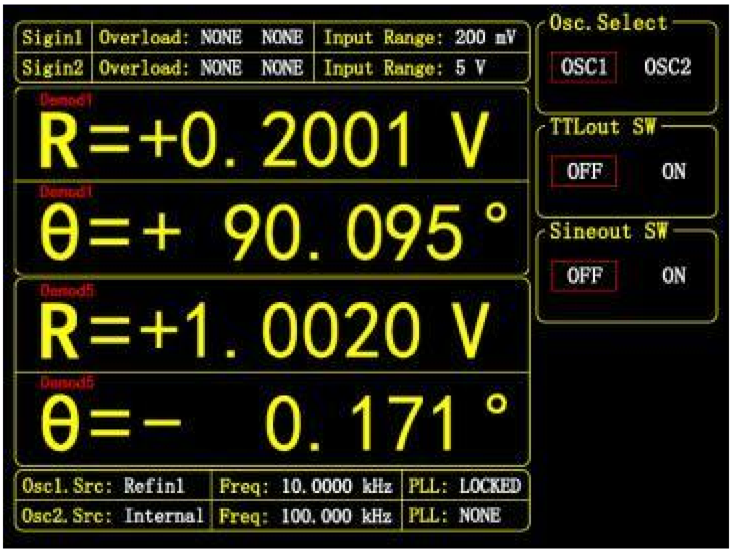
X= -449.08 uV
Y= +200.18 mV
R= +200.18 mV
θ= +90.13 °
F= 9.999985 kHz
X= -449.43 uV
Y= +200.18 mV
R= +200.18 mV
θ= +90.13 °
X= -449.43 uV
Y= +200.18 mV
R= +200.18 mV
θ= +90.13 °

Figure 59. Host Computer [DISPLAY] Related Settings

5.6 [SIGNAL OUTPUT] Sub-Menu

5.6.1. Front Panel Interface Configuration

Select the [SIGNAL OUTPUT] submenu from the MENU menu bar on the front panel to access this menu, which allows configuration of parameters for Sine Out and TTL out interfaces, as shown in the right panel of Figure 60:



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1
R=+0. 2001 V
Demod1
θ=+ 90. 095 °
Demod5
R=+1. 0020 V
Demod5
θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Osc. Select: OSC1 OSC2
TTLout SW: OFF ON
Sineout SW: OFF ON

Figure 60. [SIGNAL OUTPUT] Sub-Menu

This submenu includes five function settings: <Osc.Select>, <TTLout SW>, <Sineout SW>, <Amplitude>, and <Offset>.

The SE2022 can output amplitudes ranging from 100 nVrms to 5 Vrms through the "Sine Out 1" and "Sine Out 2" BNC connectors on the front panel. The sine wave signal has a reference source synchronized with an internal oscillator, which corresponds to the adjustable amplitude output of the internal oscillator. The frequency reference sources for "Sine Out 1" and "TTL Out 1" are synchronized with OSC1, while those for "Sine Out 2"
and "TTL Out 2" are synchronized with OSC2.

When <Osc. Mode> uses <External> external references, the "Sine Out" generates a sine signal with the same frequency and phase as the external reference; when using <Internal> internal references, the signal is produced by the instrument's own oscillator.

The BNC connector labeled 'TTL OUT' on the rear panel outputs a TTL signal with the same frequency and phase as 'Sine Out'.

- <Osc.Select>: SIGNAL OUTPUT channel selection

Pressing the button allows switching between the SIGNAL OUTPUT parameters display and configuration of<OSC 1> and <OSC2> oscillators. When switching to <OSC1>, the configurations of <TTLout SW>, <Sineout SW>, <Amplitude>, and <Offset> will reflect <OSC1> 's current settings. Any configuration changes made at this point will not affect <OSC2>' s settings.

- <TTLout SW>: TTL OUT interface output mode settings

<OFF>: Disabling TTLout output; TTLout consistently outputs 0 V.

<ON> Enable TTLout output, which will then deliver a 3.3V TTL square wave signal.

- <Sineout SW>: Output mode settings for the SINE OUT interface

<OFF>: Turn off Sineout output, which will then output a constant 0 V.

<ON>: Open the Sineout output, where the amplitude and offset of the output sine wave can be set according to <Amplitude> and <Offset>, as shown in Figure 61.

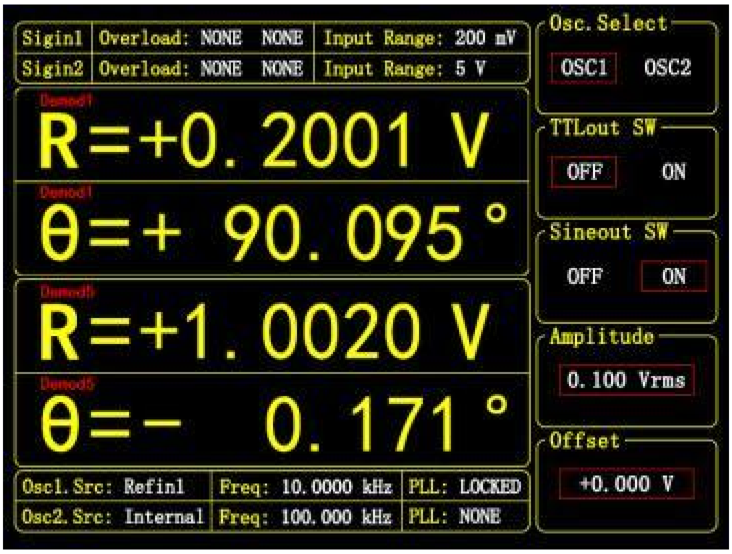
For extremely weak signal measurements (e.g., resistive thermal noise measurements or minute impedance measurements), it is recommended to disable the Sineout and TTLout outputs to minimize the impact of internal
system interference at the same frequency.

- Amplitude: Sineout output amplitude setting

The amplitude of Sineout can be input through the digital keyboard and knob, ranging from 0.1 μ V_{rms} to 5 V_{rms} RMS value, with a minimum resolution of 0.1 μ V_{rms}.

- Offset: Sineout output offset setting

The Sineout offset value can be input via digital keypad and rotary knob, with a range of-5 to 5 V DC and a minimum resolution of 0.001 V DC.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

R=+0. 2001 V
θ=+ 90. 095 °
R=+1. 0020 V
θ=- 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Osc. Select: OSC1 OSC2
TTLout SW: OFF ON
Sineout SW: OFF ON
Amplitude: 0. 100 Vrms
Offset: +0. 000 V

Figure 61. Menu When <Sineout SW> Is Opened

5.6.2. Upper Computer Configuration

As shown in Figure 62, the configuration area marked in red box on the host computer is designated for [SIGNAL OUTPUT]. Users can configure signal output channel parameters such as <Output Source>, <TTLout SW>, and <Sineout SW> within the parameter table or flowchart section.

The configuration information for <Amplitude> and <Offset> can be modified and confirmed within the red box.

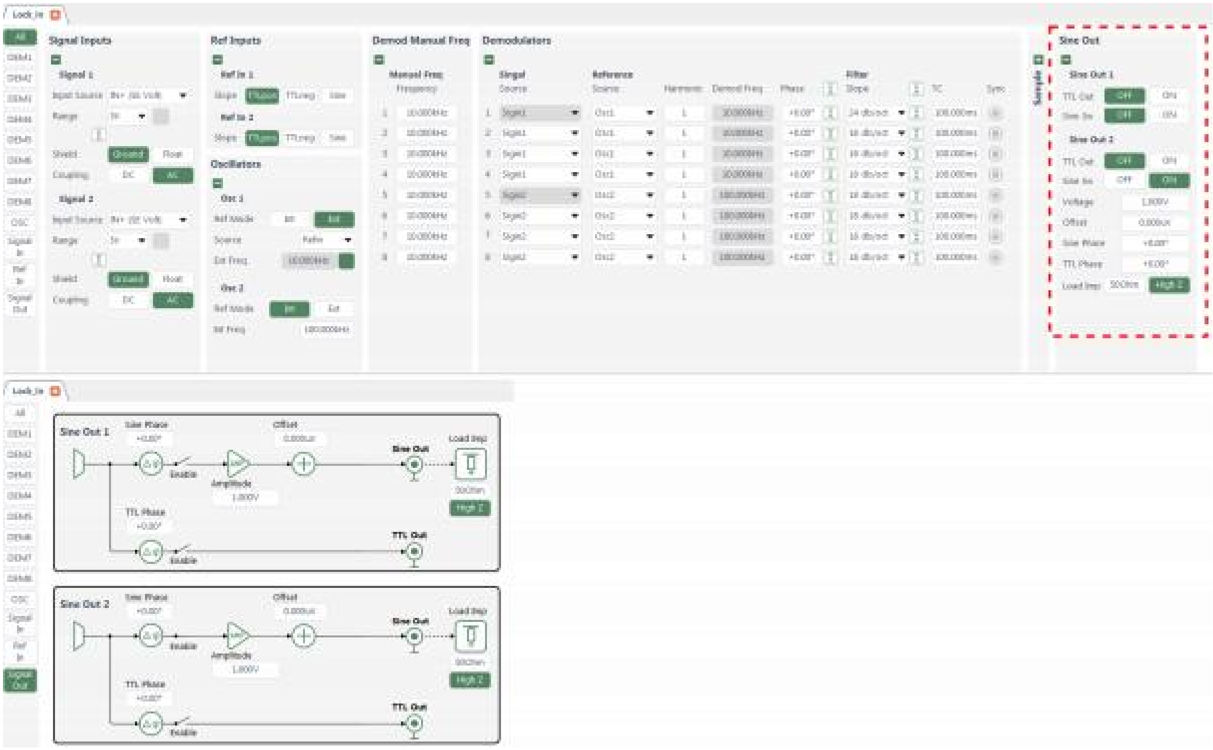
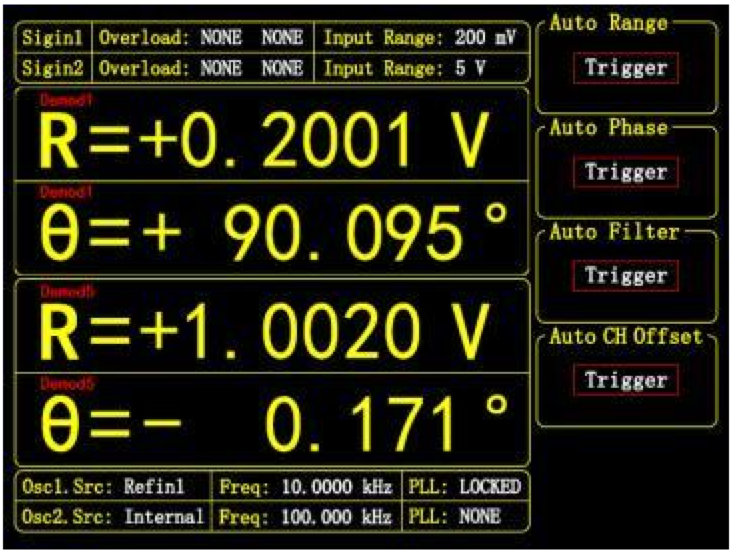


Figure 62. Configuration Area of [SIGNAL OUTPUT

5.7 [AUTO SET] Submenu

5.7.1. Front Panel Interface Configuration

The [AUTO SET] submenu includes four automatic settings in SE2022. As shown in the right sidebar of Figure 63:



```
Sigin1 | Overload: NONE  NONE | Input Range: 200 mV
Sigin2 | Overload: NONE  NONE | Input Range: 5 V
Demod1
R=+0.2001 V
Demod1
θ=+ 90.095 °
Demod5
R=+1.0020 V
Demod5
θ=-   0.171 °
Osc1.Src: Refin1   | Freq: 10.0000 kHz | PLL: LOCKED
Osc2.Src: Internal | Freq: 100.000 kHz | PLL: NONE
```

Figure 63. AUTO SET Submenu

- Auto Range: Automatic range setting function

After pressing the <Auto Range> button, the instrument will automatically adjust the <Input Range> settings for both input channels based on the amplitude of the current input signal.

Automatic range selection starts from the <5 V> range and progressively switches to lower ranges until the selected range can accommodate the maximum signal amplitude without overflow. At this point, the instrument will maintain the current range.

- <Auto Phase>: Automatic phase compensation function

Pressing the <Auto Phase> button automatically adjusts the <Ref. Phase> of all demodulators to set the measured input signal phase to 0°. This process requires a response time (typically under 5 seconds). If the current signal phase value fluctuates significantly, the <Auto Phase> setting may fail. In such cases, switch to the [DEMOD REF] submenu to manually set the <Ref. Phase> value.

- <Auto Filter>: Automatically configure the demodulator's filter function

After pressing the <Auto Filter> button, the instrument automatically calculates the <Time Constant> and <Filter dB/oct> for all demodulators based on their reference frequencies, following this rule:

When the reference frequency exceeds 100 Hz, the Time Constant equals 100 divided by the frequency, and the filter gain is 24 dB/oct.

When the reference frequency is below 100 Hz, Time Constant = 1s, Filter = 24 dB/oct, and Sync Filter = ON.

When the reference frequency is less than 1 Hz, Time Constant = 1 ÷ Frequency, Filter = 24 dB/oct, Sync Filter = ON.

For example: If the reference frequency of Modulator 1 is 10 kHz, pressing <Auto Filter> sets the filter time constant of Modulator 1 to 10 ms and the filter steepness to 24 dB/oct.

- <Auto CH Offset>: Automatically sets the output offset for the CHout interface

When the <Auto CH Offset> button is pressed, the instrument automatically adjusts the <Offset> parameter in the [CH OUT] menu, setting the output formula calculations for the two current CHOUT channels to zero and achieving automatic DC bias compensation.

5.7.2. Upper Computer Configuration

As shown in Figure 64, the configuration area marked in red box on the host computer is designated for [AUTO SET], located on the right side of the corresponding settings interface for users.

Click the corresponding option based on actual needs The icon is automatically configured.

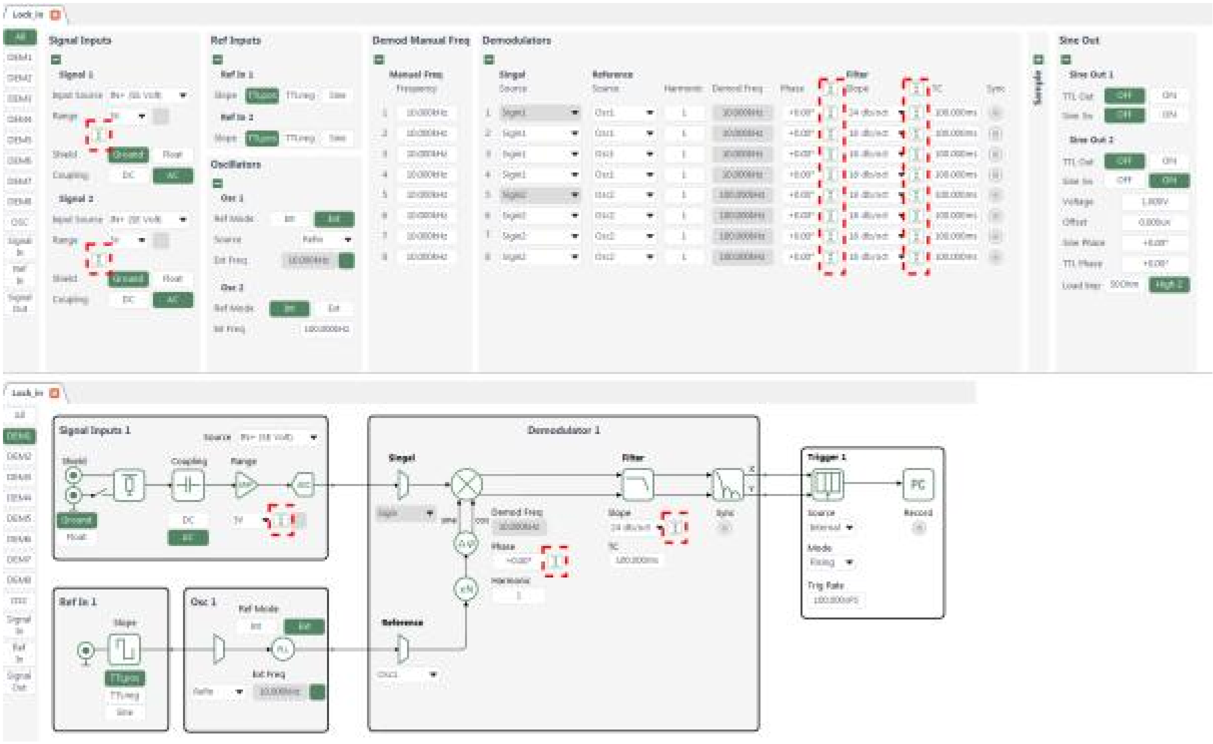
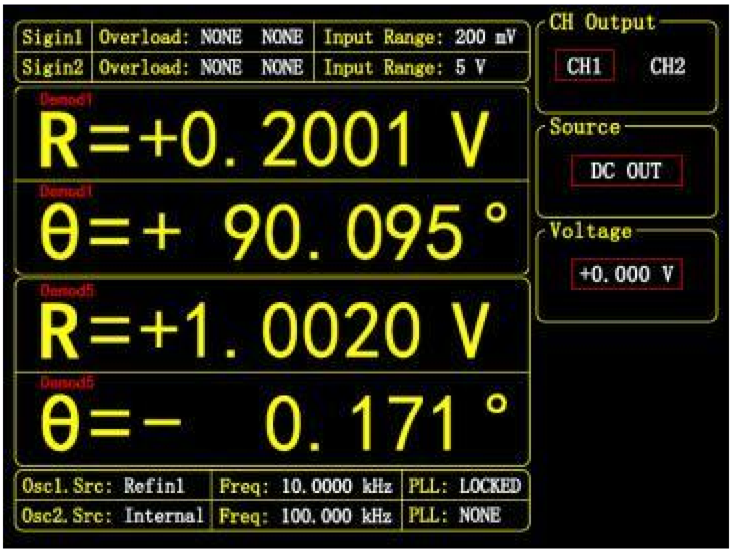


Figure 64. Configuration Area of [AUTO SET]

5.8 [CHANNEL OUTPUT] and [AUX OUTPUT] Submenu

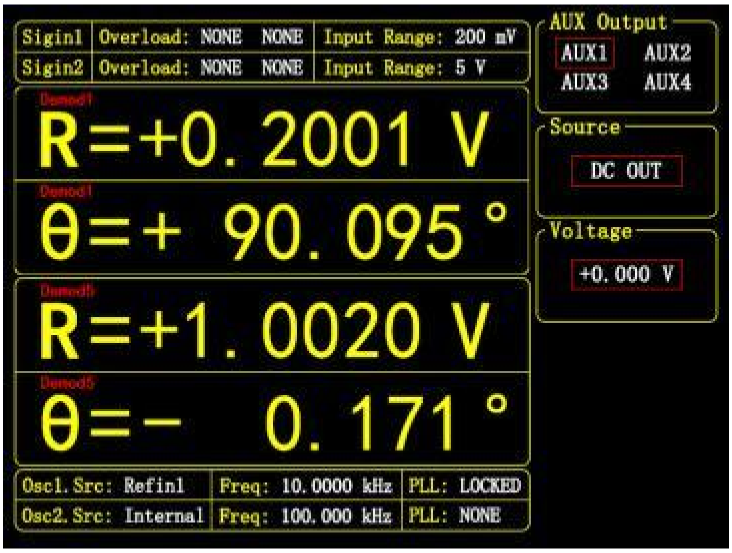
5.8.1. Front Panel Interface Configuration

Select the [CHANNEL OUTPUT] or [AUX OUTPUT] submenu from the MENU menu bar on the front panel to access the menu, as shown in Figure 65 and the sidebar on the right in 66. Since the functional configurations and interface layouts of these two sub menus are identical, this section provides a unified introduction to both.



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V
Demod1
R=+0. 2001 V
Demod1
θ=+ 90. 095 °
Demod5
R=+1. 0020 V
Demod5
θ=− 0. 171 °
Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 65. [CHANNEL OUTPUT] Submenu



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V
Demod1
R=+0. 2001 V
Demod1
θ=+ 90. 095 °
Demod5
R=+1. 0020 V
Demod5
θ=− 0. 171 °
Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 66. [AUX OUTPUT] Sub-Menu

The [CHANNEL OUTPUT] and [AUX OUTPUT] submenus control the six BNC channels on the rear panel of CHOUT/AUXOUT, enabling output of user-defined values, demodulator parameters (R, X, Y, and θ), as well as <Sensitivity> setting proportion coefficients and <Offset&Expand> configuring output bias and gain factors.

The calculation formula for the output signal is as follows

1、 When the Selected Signal Is <R>, <X>, <Y> for Demod1 to Demod8:

$$\text{output}=\left(\frac{\text{Signal(选择信号)}}{\text{Sens}}+\text{Offset}\right)\times\text{Expand}\times 10\text{ V}$$

2、 When the Selected Signal Is <Theta> from Demod1 to Demod8:

$$\text{output}=\left(\frac{Theta}{180^{\circ}}+\text{Offset}\right)\times\text{Expand}\times 10\text{ V}$$

In addition to the two scenarios mentioned above, there are the following options:

a) AUXOUT: Outputs according to the user-defined voltage value, with a range of-10 to 10 V DC and a resolution of 1 mV.

b) AUXIN1 ~ AUXIN4: The output equals the input voltage of the AUXIN interface.

- <CH Output> / <AUX Output>: The CH channel or AUX channel selection settings allow configuration for CH1-CH2 and AUX1-AUX4 respectively. Each channel can be assigned a separate output source.
- <Source>: Channel output source settings

<DC OUT>: The output level set for a channel. Each channel has its own independent <DC OUT> parameter.
<X_Demod1>: Analog level corresponding to the X value of channel output demodulator 1.
<Y_Demod1>: The analog level corresponding to the Y value of channel output demodulator 1.
<R_Demod1>: The analog level corresponding to the R value of channel output demodulator 1. <
θ _Demod1>: The analog level corresponding to the θ value of channel output demodulator 1.
<X_Demod2>: The analog level corresponding to the X value of channel output demodulator 2.
<Y_Demod2>: The analog level corresponding to the Y value of channel output demodulator 2.
<R_Demod2>: The analog level corresponding to the R value of channel output demodulator 2. <
θ _Demod2>: The analog level corresponding to the θ value of channel output demodulator 2.
<X_Demod3>: The analog level corresponding to the X value of channel output demodulator 3.
<Y_Demod3>: The analog level corresponding to the Y value of channel output demodulator 3.
<R_Demod3>: The analog level corresponding to the R value of channel output demodulator 3. <
θ _Demod3>: The analog level corresponding to the θ value of channel output demodulator 3.
<X_Demod4>: Analog level corresponding to the X value of channel output demodulator 4.
<Y_Demod4>: The analog level corresponding to the Y value of channel output demodulator 4.
<R_Demod4>: Analog level corresponding to the R value of channel output demodulator 4.
< θ _Demod4>: The analog level corresponding to the θ value of channel output demodulator 4.
<X_Demod5>: Analog level corresponding to the X value of channel output demodulator 5.
<Y_Demod5>: The analog level corresponding to the Y value of channel output demodulator 5.
<R_Demod5>: Analog level corresponding to the R value of channel output demodulator 5.
< θ _Demod5>: The analog level corresponding to the θ value of channel output demodulator 5.
<X_Demod6>: The analog level corresponding to the X value of channel output demodulator 6.
<Y_Demod6>: The analog level corresponding to the Y value of channel output demodulator 6.
<R_Demod6>: The analog level corresponding to the R value of channel output demodulator 6. <
θ _Demod6>: The analog level corresponding to the θ value of channel output demodulator 6.
<X_Demod7>: Analog level corresponding to the X value of channel output demodulator 7.
<Y_Demod7>: The analog level corresponding to the Y value of channel output demodulator 7.
<R_Demod7>: The analog level corresponding to the R value of channel output demodulator 7. <
θ _Demod7>: The analog level corresponding to the θ value of channel output demodulator 7.
<X_Demod8>: The analog level corresponding to the X value of channel output demodulator 8.

<Y_Demod8>: The analog level corresponding to the Y value of channel output demodulator 8.

<R_Demod8>: The analog level corresponding to the R value of channel output demodulator 8.

< θ _Demod8>: The analog level corresponding to the θ value of channel output demodulator 8.

<AUXIN1>: The level of the AUX_IN1 interface corresponding to channel output.

<AUXIN2>: The voltage level corresponding to the AUX_IN2 channel output interface.

<AUXIN3>: The level of the AUX_IN3 interface corresponding to channel output.

<AUXIN4>: The level corresponding to the AUX_IN4 channel output interface.

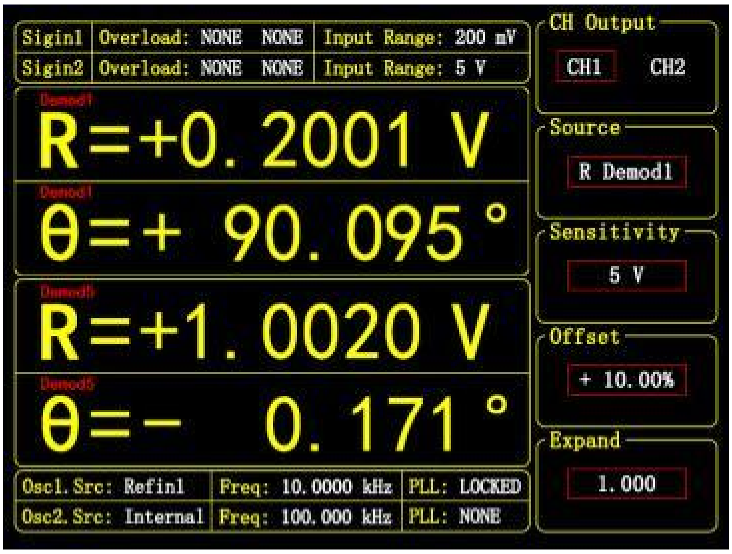
- <Voltage>: Output voltage value in fixed DC output mode

When <Source> is set to <DC OUT>, <Voltage> can be configured as shown in Figures 65 and 66. The voltage value can be entered via the numeric keypad, with a setting range of-10 to 10 V DC and a resolution of 1 mV.

- <Sensitivity>: Sensitivity settings

When <Source> selects an input source other than <AUXOUT> and <AUXIN1 ~ 4>, the option menu interface for <Sensitivity>, <Offset> and <Expand> is shown as shown in Figure 67.

The selectable range of <Sensitivity> sensitivity is shown in Table 3. Note that when <Source> is set to < θ > of Demod1-Demod8, <Sensitivity> is invalid and fixed at 180o.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1
R=+0. 2001 V

Demod1
θ=+ 90. 095 °

Demod5
R=+1. 0020 V

Demod5
θ=− 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

CH Output: CH1 CH2
Source: R Demod1
Sensitivity: 5 V
Offset: + 10. 00%
Expand: 1. 000

Figure 67. <Offset&Expand> Interface

Table 3. Sensitivity Configuration Table

1 nV/pA	500 nV/pA	200 µV/nA	100 mV/µA
2 nV/pA	1 µV/nA	500 µV/nA	200 mV/µA
5 nV/pA	2 µV/nA	1 mV/µA	500 mV/µA
10 nV/pA	5 µV/nA	2 mV/µA	1 V/mA
20 nV/pA	10 µV/nA	5 mV/µA	2 V/mA
50 nV/pA	20 µV/nA	10 mV/µA	5 V/mA
100 nV/pA	50 µV/nA	20 mV/µA	-
200 nV/pA	100 µV/nA	50 mV/µA	-

- Offset: Offset setting:

Using the numeric keypad, the adjustable range is-100% to 100%, with a minimum step of 0.01% and a default value of 0.00%.

- <Expand>: Zoom settings

Using the numeric keypad, you can input real numbers within the range of 0.001 to 10,000, with the default value set to 1. However, if the calculation exceeds ±10 V due to Expand settings, the output value will remain within ±10 V.

I **Note: Each CH / AUX channel has an independent bias value and gain value.** If CH1 is set to have a <Offset> of 50% and a <Expand> of 3, only the CH1 channel output will be affected, while the outputs of other channels remain unchanged.

Note: The settings for <Sensitivity>, <Offset>, and <Expand> do not affect the display within the dynamic area box.

5.8.2. Upper Computer Configuration

As shown in Figure 68, this configuration area corresponds to [CHOUT AUXOUT]. The feature can be accessed via the Aux tab, where configuration settings for <Source>, <Voltage>, <Sensitivity>, <Expand>, and <Offset> can be modified and confirmed.

Aux Input

Aux In 1 0.000uV
Aux In 2 305.185uV
Aux In 3 0.000uV
Aux In 4 0.000uV

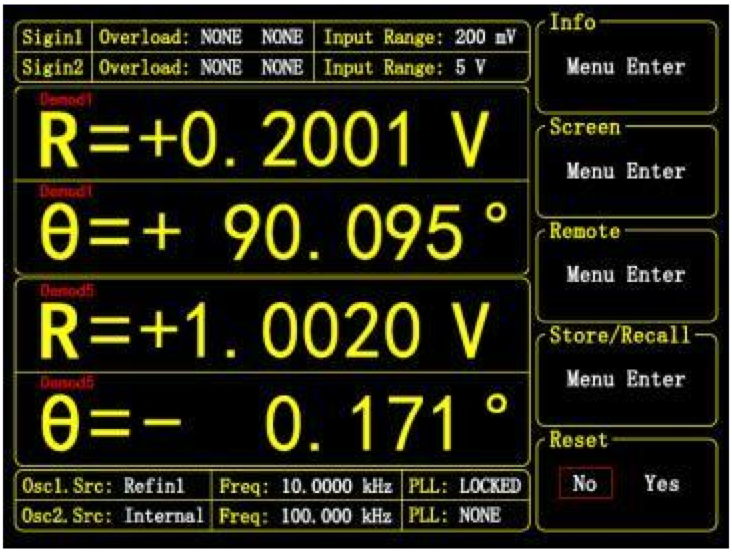
Aux Output	Source/Sensitivity	Offset	Expand	Output
Aux Out 1 =	DC OUT			0.000uV
Aux Out 2 =	(X-Demod2 / 5 V	+ +0.00 %) ×	1.000 ×10V	-819.027uV
Aux Out 3 =	DC OUT			0.000uV
Aux Out 4 =	(Theta-Demo / 180.0°	+ +0.00 %) ×	1.000 ×10V	-9.149V
Channel Output	**Source/Sensitivity**	**Offset**	**Expand**	**Output**
Ch Out 1 =	(R-Demod1 / 5 V	+ +0.00 %) ×	1.000 ×10V	42.688uV
Ch Out 2 =	DC OUT			0.000uV

Figure 68. Configuration Area of [CHOUT AUXOUT]

5.9 [SYSTEM] Submenu

5.9.1. Front Panel Interface Configuration

[SYSTEM] The submenu includes system information and settings in SE2022, such as instrument details, screen brightness, and communication configurations. As shown in the right sidebar of Figure 69:



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=- 0. 171 °

Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Figure 69. [SYSTEM] Submenu

- Secondary submenu

Figure 70 shows that the interface displays information such as the R&D unit details, after-sales contact information, product serial number, and version number. The serial number should match the one on the factory label of the rear panel.

Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

OE2022 DSP Lock-In Amplifier
Designed by SINE SCIENTIFIC INSTRUMENTS
Website: www.ssi-instrument.com
E-mail : support@ssi-instrument.com
Tel : +86-020-84133345
Ver : S26.213.13-L26.203.4-A254
S/N : LD621042518

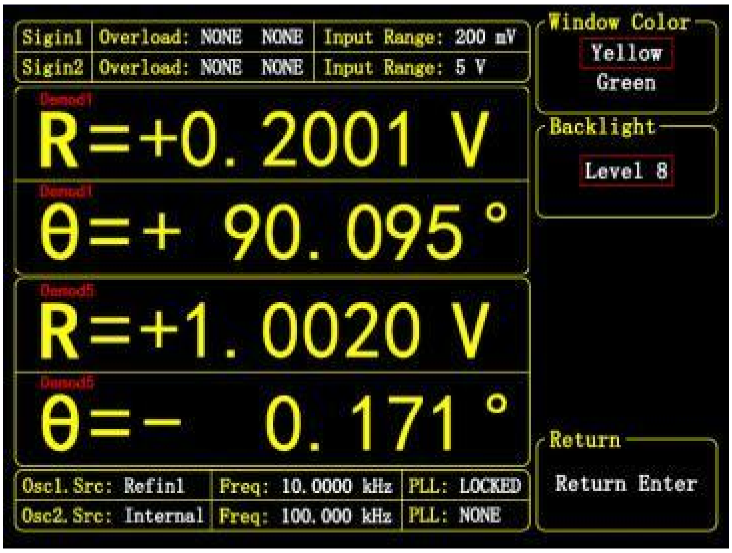
Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Figure 70. <NFO> Instrument Information

- <Screen> Secondary submenu

Select the <Screen> submenu to access the <Window Color> and <Backlight> settings.

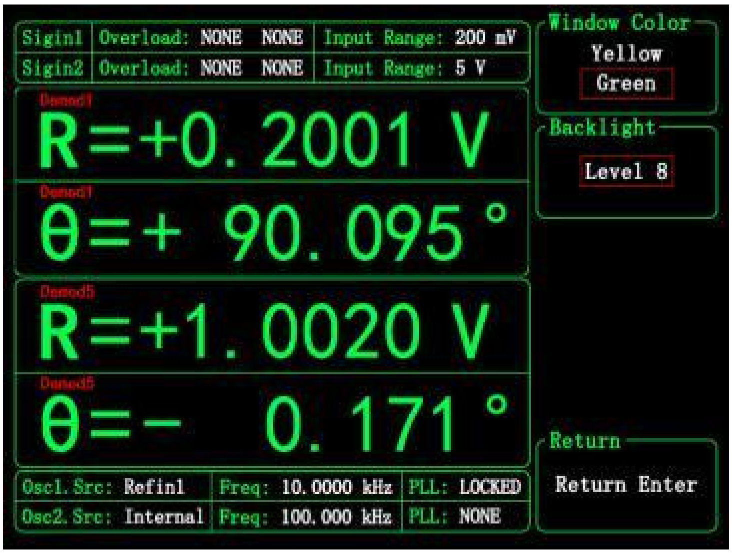
As shown in Figure 71:


Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=- 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 71. <Screen> Submenu <Yellow> Style


Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=- 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Figure 72. <Screen> Sub Menu <Green> Style

<Window Color>: Interface color settings

<Yellow>: The main color scheme of the interface is in a yellow style, as shown in Figure 71.

<Green>: The main color scheme of the interface is green style, as shown in Figure 72.

I **Note: Currently only the yellow style interface is available. For the green style, please wait for the upcoming OTA update.**

<Backlight>: Backlight brightness settings

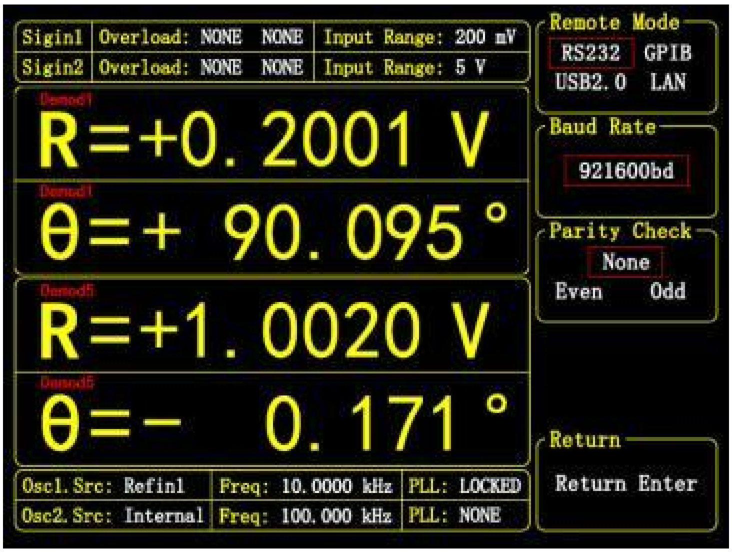
The brightness level can be adjusted from <Level1> to <Level8> by turning the knob, with brightness increasing from low to high. The default is <Level8>.

- <Remote> Level 2 submenu

Select the <Remote> submenu to enter, as shown in Figure 73.

The EO2022 features four remote communication interfaces: RS232 serial port, GPIB interface, USB 2.0 high-speed interface, and Ethernet interface. The corresponding configurations should be set according to the interface selected in <Remote Mode>.

This menu is exclusively for configuring individual remote communication interfaces. Selecting any interface in <Remote Mode> does not affect other interfaces' communication. The instrument supports simultaneous use of multiple communication interfaces.



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Remote Mode: RS232
Baud Rate: 921600bd
Parity Check: None

Figure 73. <Remote> Sub-Menu <RS232> Options

- <Remote Mode>: Select remote interface

<RS232>: RS232 serial communication interface, a DB9 female connector. The configuration interface is shown in Figure 73.

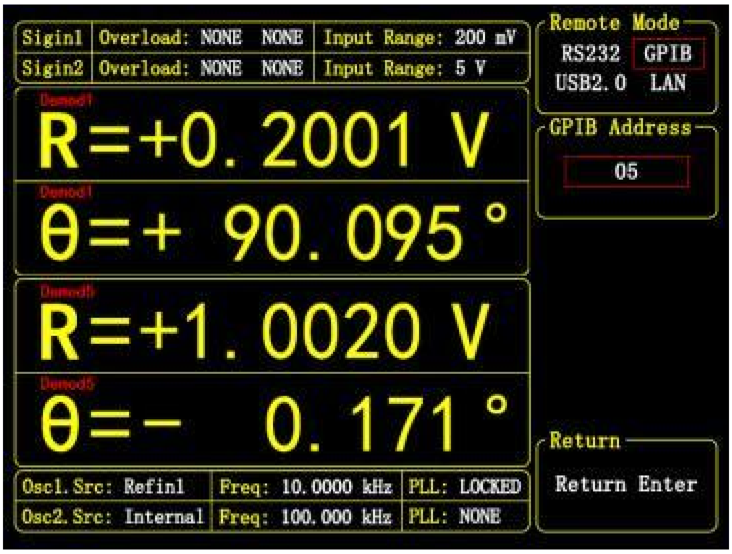
<GPIB>: GPIB mother interface. Its address configuration interface is shown in Figure 74.

<USB2.0>: USB2.0 high-speed communication interface. The configuration interface is shown in Figure 75.

Ethernet: 1000Mbps Ethernet interface. The port number is 10001. Assuming the network IP address obtained by SE2022 is 192.168.1.10, the IP address of the computer connected to SE2022 is 192.168.1.10:10001. The configuration interface diagram 76 is shown as follows:

show 。

The host computer remote control software for the instrument must communicate via USB 2.0 or Ethernet interfaces, and RS232 interface is not supported at present.



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=− 0. 171 °

Osc1. Src: Refin1 | Freq: 10. 0000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 100. 000 kHz | PLL: NONE

Remote Mode: GPIB
GPIB Address: 05

Figure 74. <Remote> Sub-Menu <GPIB> Options

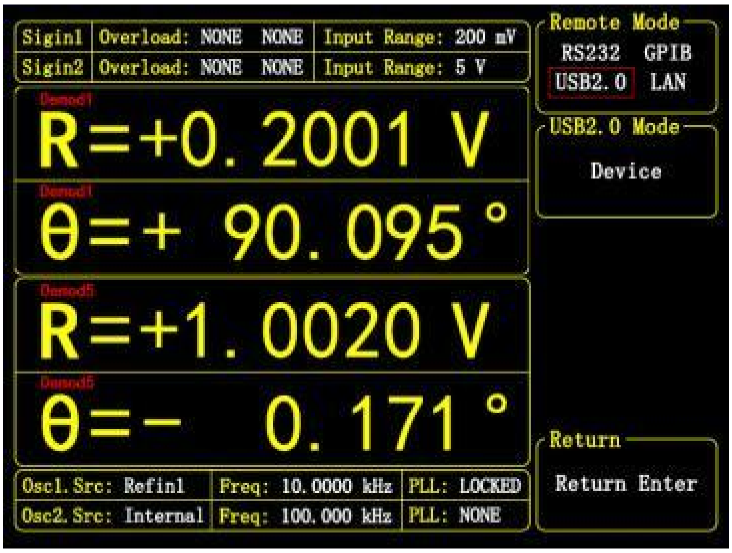

Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V
Demod1 R=+0. 2001 V
Demod1 θ=+ 90. 095 °
Demod5 R=+1. 0020 V
Demod5 θ=− 0. 171 °
Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE
USB2. 0 Mode: Device

Figure 75. <Remote> Sub Menu <USB2.0> Options

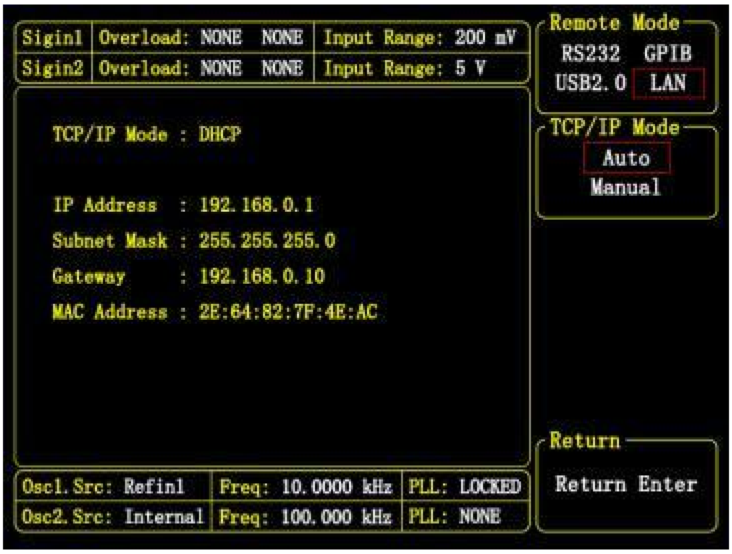

Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V
TCP/IP Mode : DHCP
IP Address : 192. 168. 0. 1
Subnet Mask : 255. 255. 255. 0
Gateway : 192. 168. 0. 10
MAC Address : 2E:64:82:7F:4E:AC
Osc1. Src: Refin1 Freq: 10. 0000 kHz PLL: LOCKED
Osc2. Src: Internal Freq: 100. 000 kHz PLL: NONE

Figure 76. <Remote> Submenu <Ethernet> Options

- <Baud Rate>: Set the baud rate

This configuration item can be enabled in <RS232> mode. The baud rate can be adjusted using the knob and set to: <600>, <1200>, <2400>, <4800>, <9600>, <19200>, <38000>, <43000>, <56000>, <57600>, <115200>, <230400>, <460800>, <921600>. The default value is <921600>.

- <Parity Check>: Parity Check Setting

This configuration item can be enabled in <RS232> mode.

<Even> : even parity check
<ODD> Odd parity check
<NONE> No validation

- <GPIB Address>: GPIB address configuration

This configuration item can be enabled in the GPIB <GPIB> mode. The GPIB address of this device can be adjusted using the knob, with values ranging from <1> to <30>, and the default being <5>.

- <TCP/IP Mode>: Ethernet TCP/IP mode settings

This configuration item can be enabled in <Ethernet> mode. Typically, when the device connects to the router via an Ethernet cable, it automatically connects to the Ethernet network in <Auto> mode.

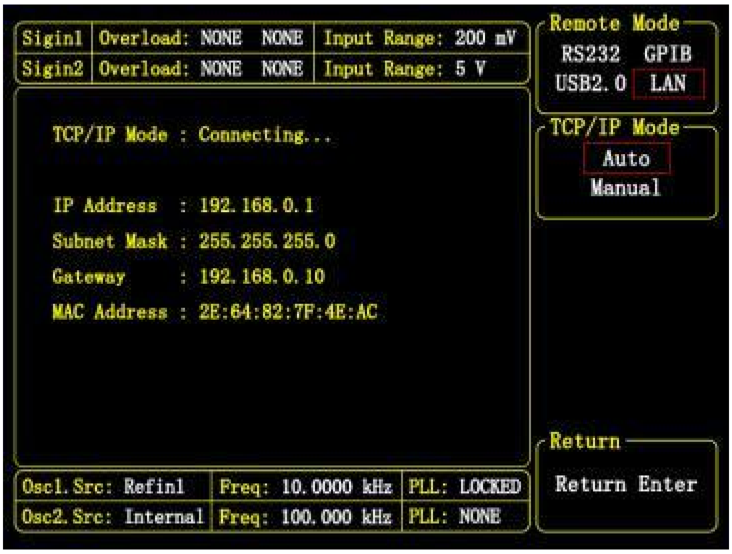
<Auto>: Automatically configure TCP/|P protocols.

Manual: Configure TCP/|P protocol manually.

In <Auto> mode, when network access is detected, the system transitions to the status "Connecting..." in Figure 77, indicating active network connection. Upon successful connection, as shown in Figure 78, the local IP address, subnet mask, gateway, and MAC address of the current network are displayed.

In <Manual> mode, you can manually configure TCP/|P protocol parameters including |P address, subnet mask, and gateway as shown in Figure 79. In the <P Select> window, select the |P, subnet, and gateway to modify, then press the <Excute> key. You can enter configuration parameters using the numeric keypad area as illustrated in Figure 80, and finally press <ENTER> to confirm.

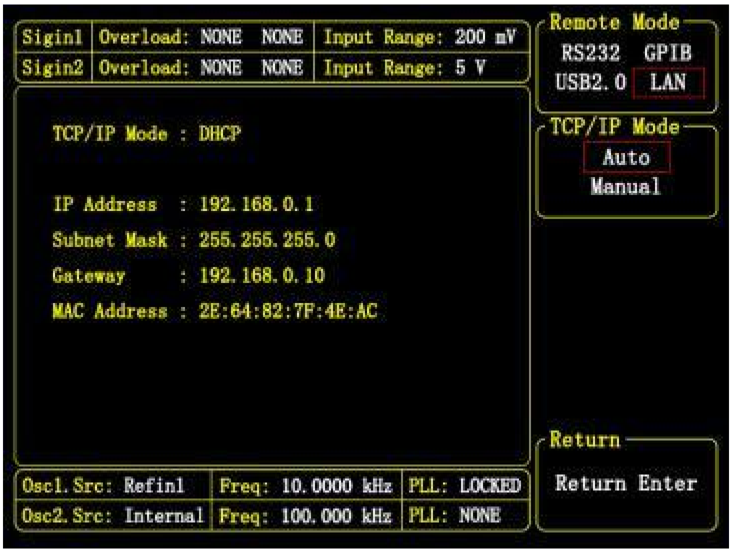
Once the configuration is complete, you can configure and read data from the SE2022 within the local area network.



```
Sigin1 | Overload: NONE  NONE | Input Range: 200 mV     Remote Mode
Sigin2 | Overload: NONE  NONE | Input Range: 5 V        RS232   GPIB
                                                        USB2.0  LAN
  TCP/IP Mode : Connecting...                           TCP/IP Mode
                                                          Auto
  IP Address  : 192.168.0.1                               Manual
  Subnet Mask : 255.255.255.0
  Gateway     : 192.168.0.10
  MAC Address : 2E:64:82:7F:4E:AC

                                                        Return
Osc1.Src: Refin1   | Freq: 10.0000 kHz | PLL: LOCKED    Return Enter
Osc2.Src: Internal | Freq: 100.000 kHz | PLL: NONE
```

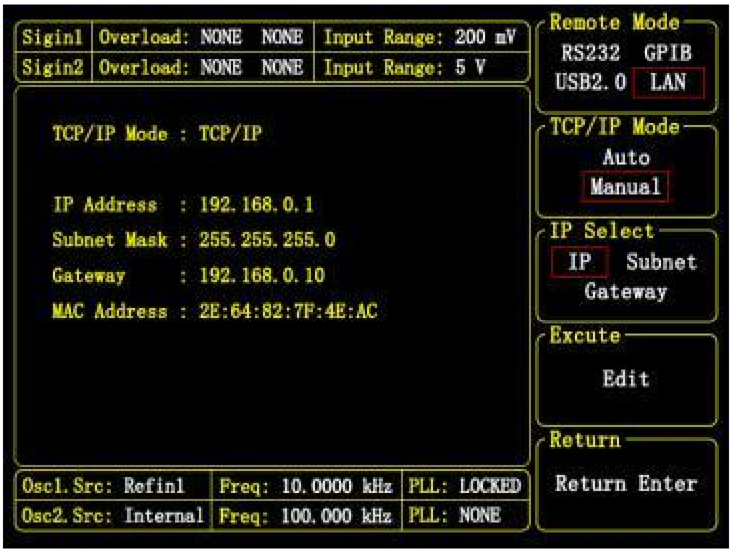
Figure 77. <Auto> Pattern—Connecting



```
Sigin1 | Overload: NONE  NONE | Input Range: 200 mV     Remote Mode
Sigin2 | Overload: NONE  NONE | Input Range: 5 V        RS232   GPIB
                                                        USB2.0  LAN
  TCP/IP Mode : DHCP                                    TCP/IP Mode
                                                          Auto
  IP Address  : 192.168.0.1                               Manual
  Subnet Mask : 255.255.255.0
  Gateway     : 192.168.0.10
  MAC Address : 2E:64:82:7F:4E:AC

                                                        Return
Osc1.Src: Refin1   | Freq: 10.0000 kHz | PLL: LOCKED    Return Enter
Osc2.Src: Internal | Freq: 100.000 kHz | PLL: NONE
```

Figure 78. <Auto> Mode—Connection Successful



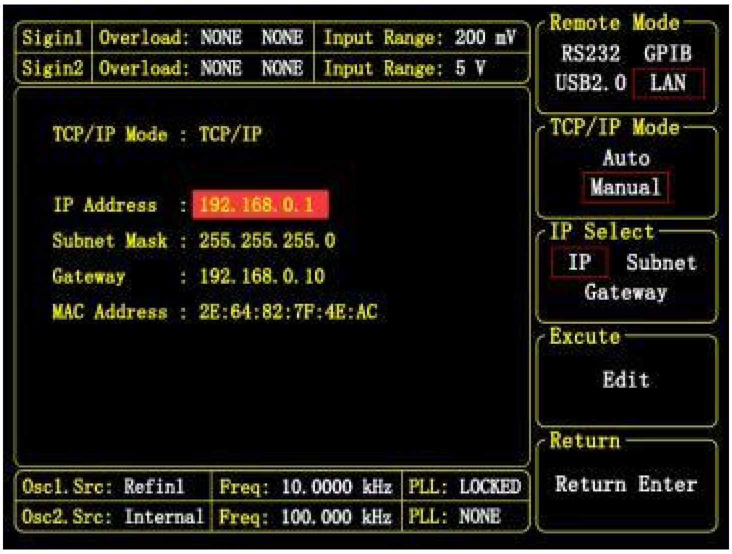
Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

TCP/IP Mode : TCP/IP

IP Address : 192.168.0.1
Subnet Mask : 255.255.255.0
Gateway : 192.168.0.10
MAC Address : 2E:64:82:7F:4E:AC

Osc1.Src: Refin1 | Freq: 10.0000 kHz | PLL: LOCKED
Osc2.Src: Internal | Freq: 100.000 kHz | PLL: NONE

Figure 79. <Manual> Mode



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

TCP/IP Mode : TCP/IP

IP Address : 192.168.0.1
Subnet Mask : 255.255.255.0
Gateway : 192.168.0.10
MAC Address : 2E:64:82:7F:4E:AC

Osc1.Src: Refin1 | Freq: 10.0000 kHz | PLL: LOCKED
Osc2.Src: Internal | Freq: 100.000 kHz | PLL: NONE

Figure 80. <Manual> Mode Modification in Progress

- <Store/Recall>: Secondary submenu

Select the <Store/Recall> submenu as shown in the right sidebar of Figure 81. The <Store/Recall> menu allows saving (Store) or retrieving (Recall) parameter settings and operational status of the current instrument. The device features four dedicated configuration storage zones: <S1>, <S2>, <S3>, and <S4>. Each zone stores complete parameter configurations including demodulator settings, filter parameters, and output configurations. To switch to a saved configuration, simply select the corresponding storage zone and execute the <Recall> command to instantly load the settings, significantly enhancing experimental efficiency and flexibility.

<Store>: After entering the <Store/Recall> menu, select the <Store> mode, specify the target storage area in the <Channel> field (e.g., <S1>), and then select <Store> in the <Execute> field to save all current parameters and state to the selected storage area.

<Recall>: To restore saved configurations, select <Recall> mode and choose the corresponding storage in <Channel>.

Storage area (e.g., <S1>), and execute the <Recall> operation in the <Execute> item. The instrument will load all settings from this storage area.

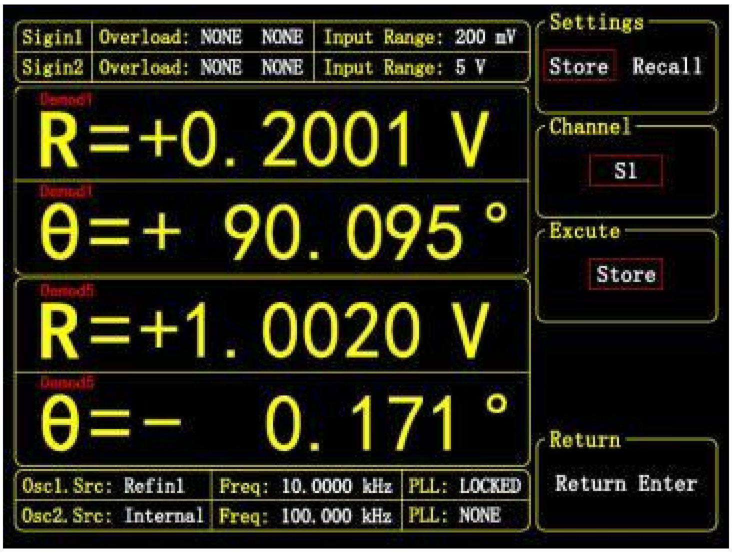


Figure 81. [Store/Recall] Submenu

Restore default settings:

Additionally, in <Recall> mode, <Channel> provides a <Default> option. Selecting this option and executing <Recall> will restore the instrument to its factory default configuration, resetting all parameters to initial states. As shown in Figure 82.

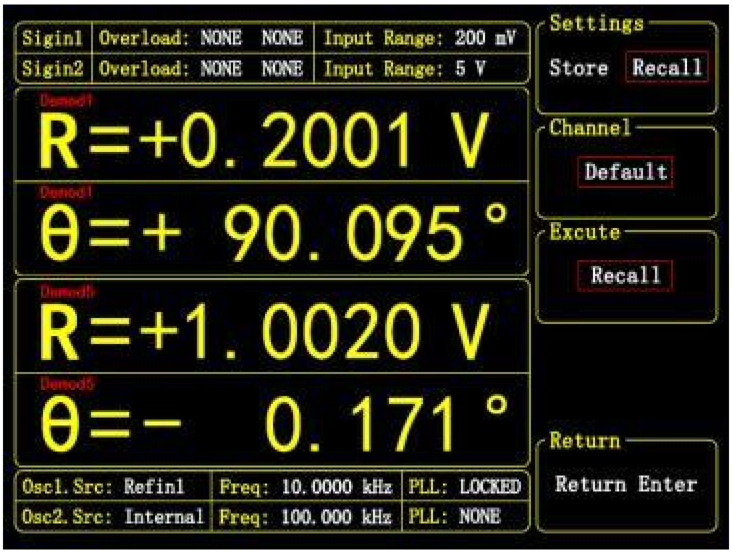


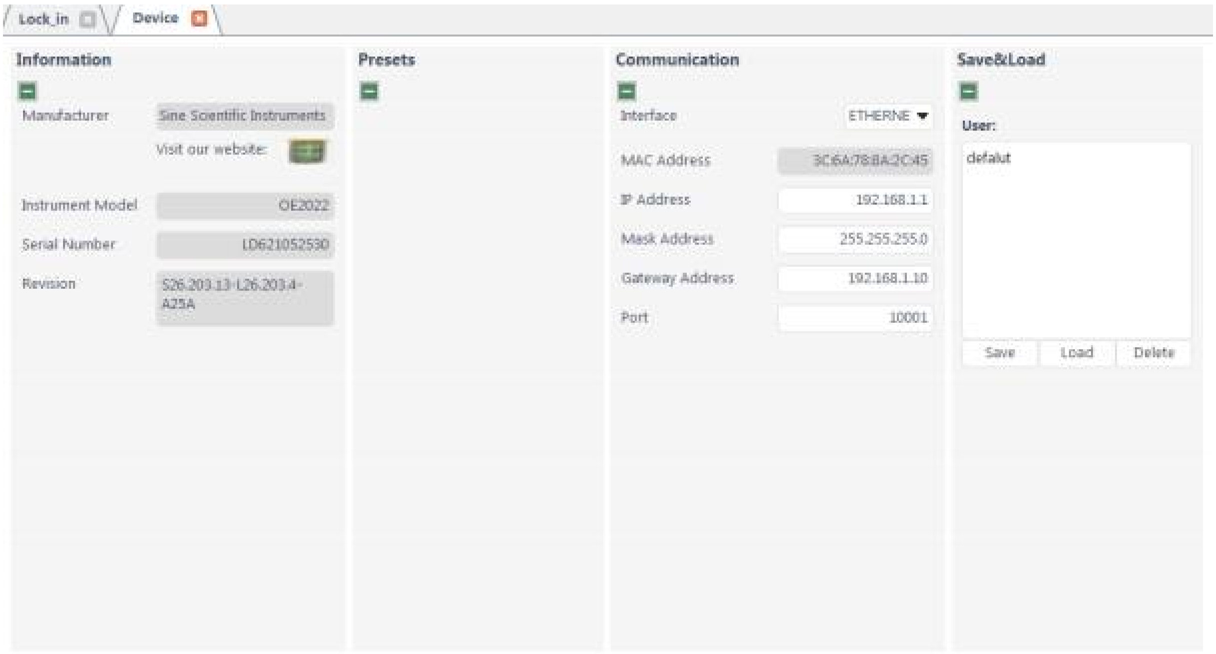
Figure 82. Restore Default Settings Options

- <Reset>: Soft reset of phase-locked amplifier

After pressing the corresponding button, the system will perform a soft reset. The current settings remain unchanged after the reset and restart.

5.9.2. Upper Computer Configuration

As shown in Figure 83, the configuration area is the [SYSTEM] configuration area. You can enable this function through the Device tab, where you can view the instrument's <Info>, configure Ethernet addresses, and perform <Store/Recall> operations.



Manufacturer: Sine Scientific Instruments

Instrument Model: OE2022

Serial Number: LD621052530

Revision: S26.203.13-L26.203.4-A25A

Interface: ETHERNE

MAC Address: 3C:6A:78:8A:2C:45

IP Address: 192.168.1.1

Mask Address: 255.255.255.0

Gateway Address: 192.168.1.10

Port: 10001

User: defalut

Figure 83. Configuration Area of [SYSTEM]

5.10 Upper Computer Data Storage

The host software of SE2022 supports data recording and saving functions, allowing users to select and save measurement data over a specified period as needed.

5.10.1. Global Data Saving

Global data storage includes the following:

- The measured values R, X, Y, and θ for demodulators 1 to 8;
- X and Y noise values for demodulators 1 and 5;
- The measurement frequency of two oscillators;
- Signal values from 4 auxiliary input AUXIN ports.

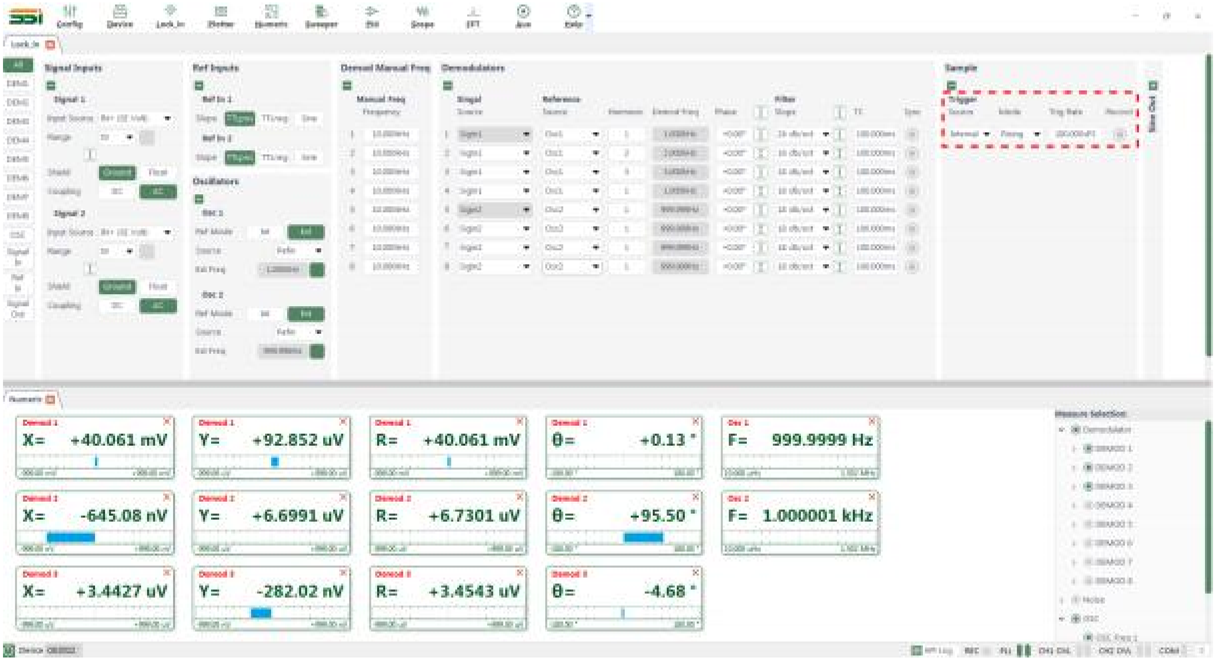
The steps for saving global data are as follows:

1、When the software is running, click the "Record" button in the red box in Figure 84. When the button is selected, it indicates that the system has started recording the current collected data.

2、The data is stored in Excel sheets with the file name "data_lock_in_XXXXXXXX_XXXXXX.csv ", where "XXXXXXXX_XXXXXX" represents the date and timestamp to ensure unique file names. Files are stored in the program directory by default, with data formatting examples shown in Figure 85.

3、Press the "Record" button again. The button will return to the unselected state, indicating that the data acquisition process has stopped.

4、Users can access  The system allows modification of the current sampling rate for data display and storage, with a configurable range from 0.1 to 100 kSa/s.



X= +40.061 mV
Y= +92.852 uV
R= +40.061 mV
θ= +0.13 °
F= 999.9999 Hz
X= -645.08 nV
Y= +6.6991 uV
R= +6.7301 uV
θ= +95.50 °
F= 1.000001 kHz
X= +3.4427 uV
Y= -282.02 nV
R= +3.4543 uV
θ= -4.68 °

Figure 84. Data Storage Configuration Area Diagram

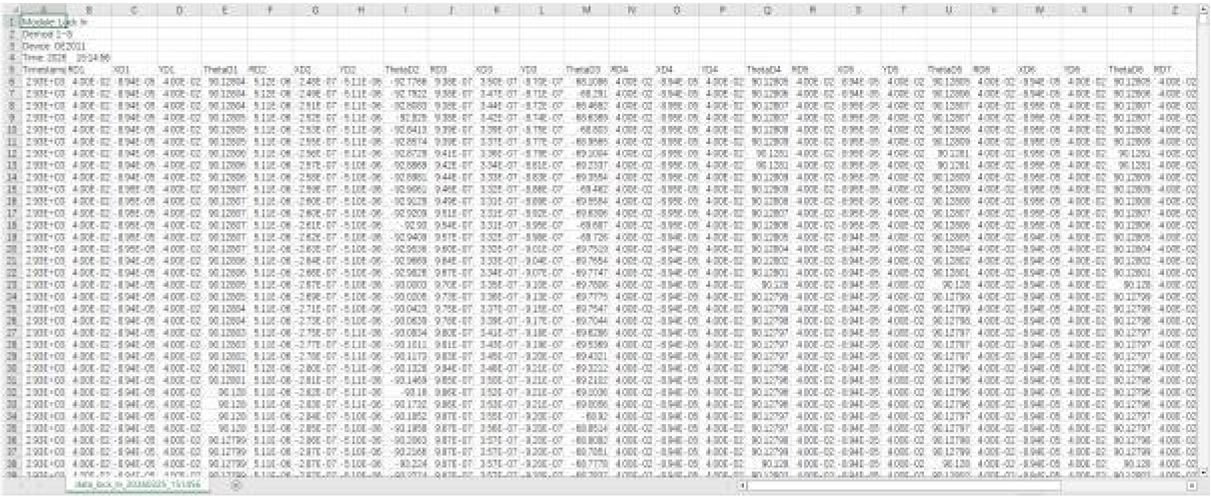


Figure 85. Data_lock_in_XXXXXXXX_XXXXXX.csv File Format

5.10.2. Plotter Waveform Data Save

In the Plotter tab, click the Save button area shown in the red box in Figure 86, and then click the Save Data button to save the data corresponding to the current waveform diagram to the local hard disk.

The data is saved in Excel sheet format with the file name "data_plotter_XXXXXXXX_XXXXXX.csv ", where "XXXXXXXX_XXXXXX" represents the date and timestamp. Ensure each file name is unique. Files are stored by default in the program directory, with the data format example shown in Figure 87.

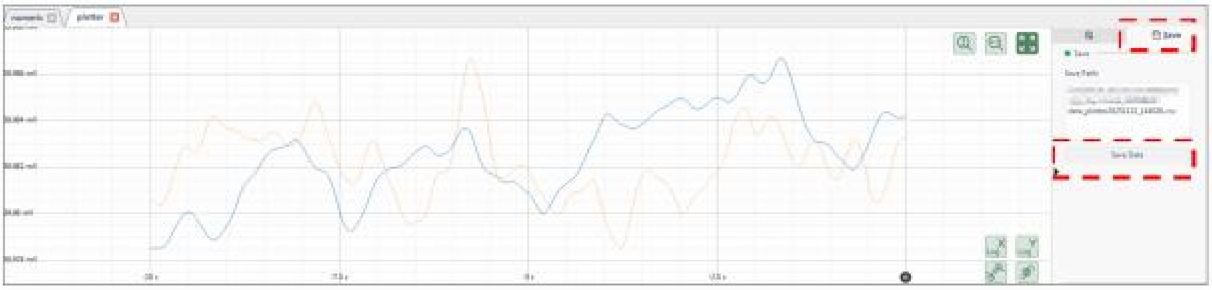
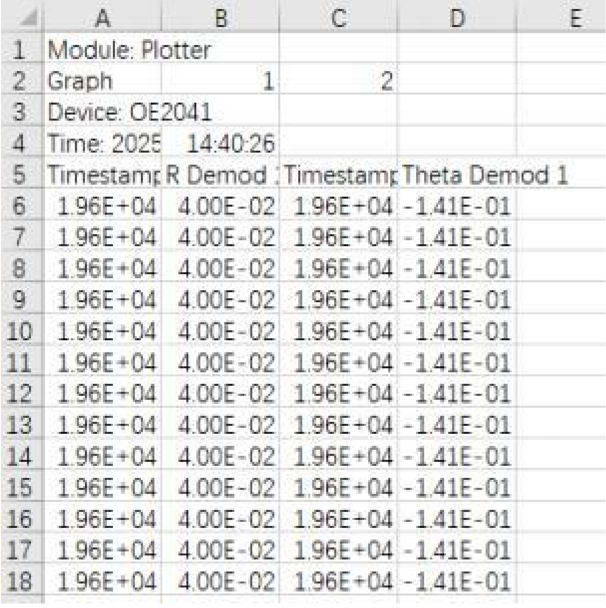


Figure 86. Plotter Waveform Data Saving Configuration Diagram



	A	B	C	D	E
1	Module: Plotter				
2	Graph	1	2		
3	Device: OE2041				
4	Time: 2025	14:40:26			
5	Timestamp	R Demod :	Timestamp	Theta Demod 1	
6	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
7	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
8	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
9	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
10	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
11	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
12	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
13	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
14	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
15	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
16	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
17	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	
18	1.96E+04	4.00E-02	1.96E+04	-1.41E-01	

Figure 87. Plotter Waveform Data File Format

5.10.3. Scope Waveform Diagram Data Save

In the Scope tab, click the Save button area shown in the red box in Figure 88, then click the Save Data button to save the data corresponding to the current waveform diagram to the local hard disk.

The data is stored in Excel sheets with the file name "data_oscilloscope_XXXXXXXX_XXXXXX.csv", where "XXXXXXXX_XXXXXX" represents the date and timestamp to ensure unique file names. Files are stored in the program directory by default, with the data format example shown in Figure 89.

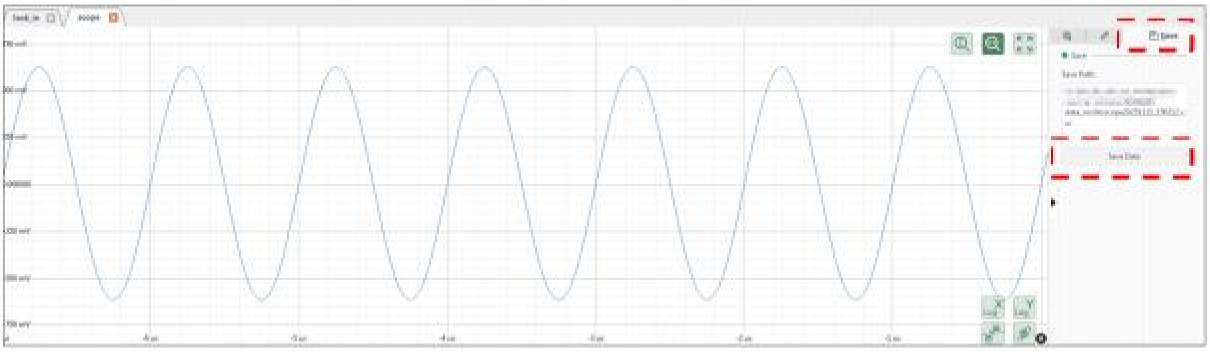
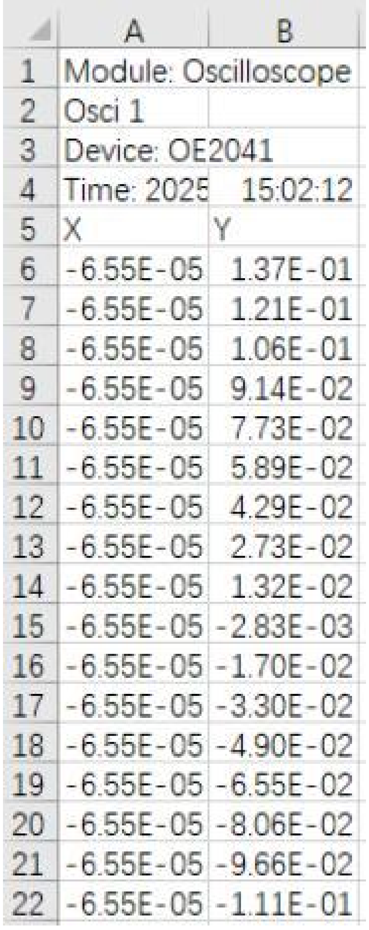


Figure 88. Scope Waveform Data Save Configuration Diagram



	A	B
1	Module: Oscilloscope	
2	Osci 1	
3	Device: OE2041	
4	Time: 2025	15:02:12
5	X	Y
6	-6.55E-05	1.37E-01
7	-6.55E-05	1.21E-01
8	-6.55E-05	1.06E-01
9	-6.55E-05	9.14E-02
10	-6.55E-05	7.73E-02
11	-6.55E-05	5.89E-02
12	-6.55E-05	4.29E-02
13	-6.55E-05	2.73E-02
14	-6.55E-05	1.32E-02
15	-6.55E-05	-2.83E-03
16	-6.55E-05	-1.70E-02
17	-6.55E-05	-3.30E-02
18	-6.55E-05	-4.90E-02
19	-6.55E-05	-6.55E-02
20	-6.55E-05	-8.06E-02
21	-6.55E-05	-9.66E-02
22	-6.55E-05	-1.11E-01

Figure 89. Scope Waveform Diagram Data File Format

5.10.4. Save Sweeper Waveform Data

In the Sweeper tab, click the "Save" button area highlighted in red in Figure 90, then click the "Save Data" button to save the data corresponding to the current waveform diagram to the local hard drive.

The data is saved as an Excel sheet with the file name "data_sweep_XXXXXXXX_XXXXXX.csv," where "XXXXXXXX_XXXXXX" represents the date and time戳. Ensure each file name is unique. The files are stored by default in the program directory, and the data format example is shown in Figure 91.

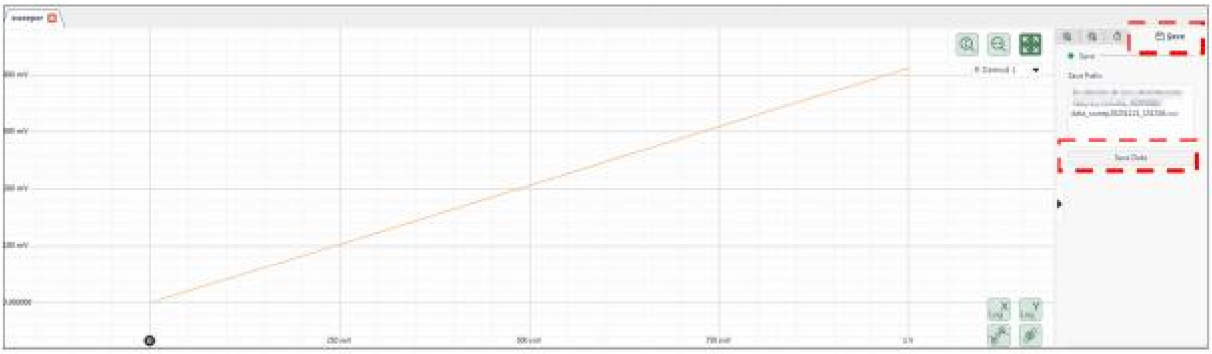


Figure 90. Sweeper Parameter Scanner Data Storage Configuration Area

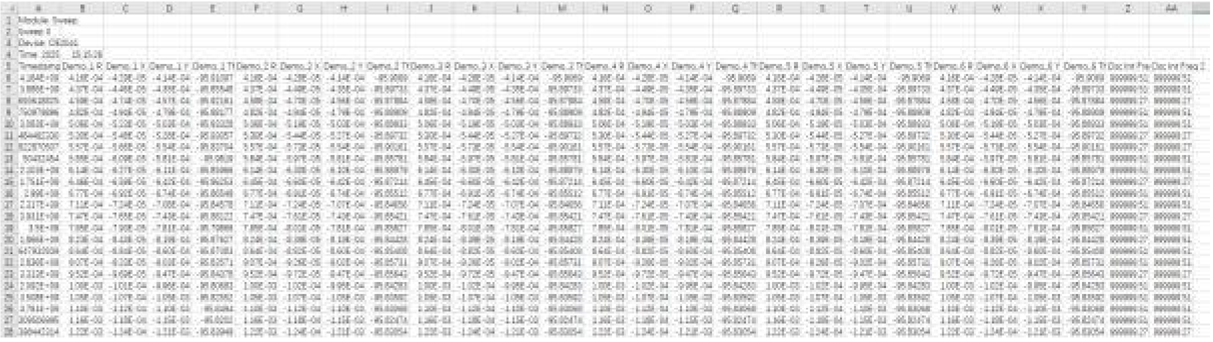


Figure 91. Sweeper Parameter Scanner Data File Format

Chapter 6 Remote Programming

6.1 SE2022 Command Syntax

Communication between the host computer and SE2022 utilizes ASCII characters. Command terms are written in uppercase letters, with each command consisting of four command characters (including optional parameters) and a command terminator. When communicating via RS232, USB2.0, or Ethernet interfaces, the terminator must be either an semicolon <;> or a carriage return <cr>. SE2022 executes user commands only upon receiving the command terminator. Commands may contain one or multiple parameters, separated by commas (,).

Multiple commands can be sent on the same command line, but semicolons <;> must be added between commands. Executing multiple commands on the same command line improves response speed.

SE2022 features an input buffer with a capacity of 1024 characters and processes commands in the order they are received. When the buffer is full, the latest command replaces the oldest executed command. It is recommended not to exceed 1024 characters when entering multiple commands.

SE2022 enables users to query current parameter values configured internally through command queries. The query format consists of the current command followed by a question mark "?" and omits one or more parameters required by the original command. SE2022 returns queried parameters as ASCII character strings. When multiple queries are sent in a command line (separated by semicolons), responses are returned sequentially, with each command's output ending in an end-of-line carriage return <cr>.

For parameters with multiple channels (e.g., demodulators or oscillators), additional channel number parameters are required for identification. Channel numbers start from 1. For instance, "FREQ?1" queries the frequency value of the internal oscillator OSC1, while "FREQ1, 1000" sets the reference signal frequency of OSC1 to 1 kHz. Parameters with a single channel (e.g., clock configurations) do not require channel number parameters. For example, "OCLK?" queries the enable status of the clock output interface.

Additionally, non-channel-number parameters default to starting from 0. For example, "OCLK0" turns off the clock output interface, while "OCLK1" turns it on.

Command format example:

FMOD 1,1 <cr>	Set the reference source of the internal oscillator OSC1 to internal mode
FREQ 1,10E3 <cr>	Set the reference signal frequency of the internal oscillator OSC1 to 10 kHz.
OUTP? 1 <cr>	Query the output value of Y from demodulator 1
ISRC? 1 <cr>	Query single-ended or differential mode for input channel 1
IGND 1 <cr>	Set the grounding method for the input interface shielding layer to GND mode.
OCLK? <cr>	Check the startup status of the clock output interface

6.2 Detailed Command List

Command syntax description:

- The parameters specified in the command must be written in the prescribed order, separated by English commas ".
- Parameters in curly braces {} are optional. You can fill them in as needed without completing all fields.
- A command is executed as a query only when it contains the question mark (?) mnemonic. Without the?, it is treated as a configuration command and does not return measurement or status data.
- Typically, when sending a setup command, you must include the required parameters within curly braces {}. However, optional parameters within {} are not required when executing a query command.
- Do not insert spaces between the command name, mnemonic, and parameters. The spaces in the example below are for readability only and should be omitted during actual communication.
- Note: When sending commands in practice, round brackets () and curly braces {} must not be included in the command string. They are used solely for explaining and labeling command structures in this document.

Variables are defined as follows:

i,j,k,l,m,n,o,p,q,r,s,t,u	Integer
x, y, z	Real
f	Frequency value

All of the above numerical variables can be represented in integer, floating-point, or exponential formats (for example, the number 5 can be represented as 5, 5.0, or 0.5E1). Strings, on the other hand, are sent as sequences of ASCII characters.

6.2.1. Input Channel Configuration Command

The SE2022 features two signal input channels: Signal in 1 and Signal in 2. All input channel-related instructions require an additional input channel selection parameter. The signal input channel parameter is denoted by i, where i=1 selects Input Channel Signal in 1 and i=2 selects Input Channel Signal in 2.

<table>
<tr><td>ISRC (?) i {,j}</td><td>The SRC command is used to configure or query the interface connection method of input signals.
Parameter i must be set when sending this command. Parameter i indicates the number of signal input channels: i=1 selects Signal in 1, and i=2 selects Signal in 2.
Select <N+> (single-ended voltage signal input) when parameter j=0;
For j=1, select <D|FF> (differential voltage input).
Select <(current input) when j=2.</td></tr>
<tr><td>IGND (?) i {,j}</td><td>The GND instruction is used to configure or query the grounding method of the input interface shielding layer. Parameter i must be set: i=1 selects Channel 1, and i=2 selects Channel 2.
Select the <Float> mode when parameter j=0 (the input connector housing is isolated from the instrument ground through a 10 kΩ resistor);
Select the <Ground> mode when j=1 (short-circuit the input connector housing to the instrument ground).</td></tr>
<tr><td>ICPL (?) i {,j}</td><td>The CPL command is used to set or query the input coupling method.
Parameter i must be set. Select channel 1 when i=1, and channel 2 when i=2. Select <AC> (AC coupled input) when j=0;
Select <DC> (AC coupled input) when j=1.</td></tr>
<tr><td>IRNG (?) i {,j}</td><td>The RNG instruction sets or queries the range of an input channel. Parameter i selects different ranges.
The parameter i must be set. Select channel 1 when i=1, and channel 2 when i=2.
Details are as follows:
<table>
<tr><th>i</th><th>Input Range</th></tr>
<tr><td>0</td><td>5 V / 5 mA</td></tr>
<tr><td>1</td><td>1 V / 500 μA</td></tr>
<tr><td>2</td><td>200 mV / 50 μA</td></tr>
<tr><td>3</td><td>50 mV / 5 μA</td></tr>
<tr><td>4</td><td>10 mV / 500 nA</td></tr>
<tr><td>5</td><td>2 mV / 50 nA</td></tr>
<tr><td>6</td><td>1 mV / 5 nA</td></tr>
</table></td></tr>
<tr><td>RMOD ? i</td><td>The RMOD command queries the system's dynamic reserve and returns integer-type data as the result. The meaning is:
The parameter i must be set: select channel 1 when i=1, and select channel 2 when i=2.
<table>
<tr><th>Return parameters</th><th>Dynamic Reserve</th></tr>
<tr><td>0</td><td>High</td></tr>
<tr><td>1</td><td>Normal</td></tr>
<tr><td>2</td><td>Low</td></tr>
</table></td></tr>
</table>

6.2.2. Oscillator Configuration Command

The SE2022 features two oscillators, OSC1 and OSC2. All oscillator-related instructions require the inclusion of an oscillator channel selection parameter. The oscillator channel parameter is denoted by i, where i=1 selects oscillator OSC1 and i=2 selects oscillator OSC2.

<table>
<tr><td>FMOD (?) i {,j}</td><td>The FMOD instruction is used to configure or query the internal and external modes of an oscillator.

When sending this command, parameter i must be set. Parameter i indicates the oscillator channel number: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

Select external reference mode when parameter j=0;
Select internal reference mode when j=1.</td></tr>
<tr><td>RSRC (?) i {,j}</td><td>The RSRC instruction is used to configure or query the reference signal source for the oscillator's external reference mode.

When sending this command, parameter i must be set. Parameter i indicates the oscillator channel number: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

Parameter j is used to select different reference signal sources, as detailed below:
<table>
<tr><th>j</th><th>Reference Signal Source Interface</th></tr>
<tr><td>0</td><td>Ref In</td></tr>
<tr><td>1</td><td>SignaI In 1</td></tr>
<tr><td>2</td><td>SignaI In 2</td></tr>
<tr><td>3</td><td>Aux In 1</td></tr>
<tr><td>4</td><td>Aux In 2</td></tr>
<tr><td>5</td><td>Aux In 3</td></tr>
<tr><td>6</td><td>Aux In 4</td></tr>
<tr><td>7</td><td>Trig In</td></tr>
</table></td></tr>
<tr><td>FREQ (?) i {,f}</td><td>The FREQ command is used to set or query the signal frequency of the oscillator's internal reference mode.

When sending this command, parameter i must be set. Parameter i indicates the oscillator channel number: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

The parameter f value can be set in the range of 1E^{-5} to 1.5E ^{6}, with a minimum resolution of 1E^{-9}.

The command FREQ?i returns the current reference signal frequency. When oscillator i is in internal mode, it returns the signal frequency of the internal reference mode. When oscillator i is in external mode, it returns the frequency of the external reference source.</td></tr>
<tr><td>FEXT ? i</td><td>The FEXT instruction is used to query the frequency of a reference source in the oscillator's external mode.

When sending this command, parameter i must be set. Parameter i indicates the oscillator channel number: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

The return parameter type is a floating-point number, with a range from 1E^{-5} to 1.5E ^{6}.</td></tr>
<tr><td>FINT (?) i {,f}</td><td>The F|NT instruction is used to set or query the reference signal frequency of the oscillator's internal mode.

When sending this command, parameter i must be set. Parameter i indicates the oscillator channel number: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

The parameter f value can be set within the range of 1E^{-5} to 1.5E ^{6}, with a minimum resolution of 1E^{-9}. The command F|NT?i returns the set frequency of the current oscillator's internal mode.</td></tr>
<tr><td>RSLP (?) i {,f}</td><td>The RSLP command is used to configure or query the edge trigger method for the REF |N interface.

When sending this command, parameter i must be set. Parameter i indicates the oscillator channel number: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

Set TTL level rising edge triggering when parameter i=0.
Set TTL level falling edge triggering for i=1;
Enable sine wave zero-crossing detection when i=2;

When the signal frequency is below 1 Hz, it is recommended to use either of the two TTL triggering methods.</td></tr>
</table>

6.2.3. Modem Configuration Command

The EO2022 features eight demodulators (Demod1 to Demod8). For all demodulator-related instructions, the selection parameter for the demodulator channel must be specified. In the following instructions, the demodulator channel parameter is denoted by i: i=1 selects Demod1, i=2 selects Demod2, and i=3 selects Demod3.... … Select Modulator 8 when i=8.

<table>
<tr>
<td>DSRC (?) i {,j}</td>
<td>
The DSRC command is used to configure or query the input signal source of a modem.

Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.

Parameter j is used to select different input signal sources, as detailed below:
<table>
<tr><th>j</th><th>Input signal source</th></tr>
<tr><td>0</td><td>Signal In 1</td></tr>
<tr><td>1</td><td>Signal In 2</td></tr>
<tr><td>2</td><td>Aux In 1</td></tr>
<tr><td>3</td><td>Aux In 2</td></tr>
<tr><td>4</td><td>Aux In 3</td></tr>
<tr><td>5</td><td>Aux In 4</td></tr>
<tr><td>6</td><td>Demod1 X</td></tr>
<tr><td>7</td><td>Demod1 Y</td></tr>
<tr><td>8</td><td>Demod1 R</td></tr>
<tr><td>9</td><td>Demod1 θ</td></tr>
<tr><td>10</td><td>Demod5 X</td></tr>
<tr><td>11</td><td>Demod5 Y</td></tr>
<tr><td>12</td><td>Demod5 R</td></tr>
<tr><td>13</td><td>Demod5 θ</td></tr>
</table>
Note: Modulator channels 1 and 5 cannot modify the input signal sources. Regardless of configuration, the input source for Demodulator Demod1 remains the Signal In 1 interface, while that for Demodulator Demod5 remains the Signal In 2 interface.
</td>
</tr>
<tr>
<td>OFLT (?) i {,x}</td>
<td>
The OFLT command is used to set or query the time constant of a demodulator's filter.

Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.

The parameter x value can be set within the range of $1E^{-7}$ to 3000, with a minimum resolution of $1E^{-7}$.
</td>
</tr>
<tr>
<td>OFSL (?) i {,j}</td>
<td>
The OFSL command is used to configure or query the steepness of the low-pass filter in a modem.

Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.

The parameter j is used to select different steepness levels, as follows:
<table>
<tr><th>j</th><th>Filter dB/oct</th></tr>
<tr><td>1</td><td>6 dB/oct</td></tr>
<tr><td>2</td><td>12 dB/oct</td></tr>
<tr><td>3</td><td>18 dB/oct</td></tr>
<tr><td>4</td><td>24 dB/oct</td></tr>
<tr><td>5</td><td>30 dB/oct</td></tr>
<tr><td>6</td><td>36 dB/oct</td></tr>
<tr><td>7</td><td>42 dB/oct</td></tr>
<tr><td>8</td><td>48 dB/oct</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><td>SYNC (?) i {,j}</td><td>The SYNC command is used to set or query the switch state of the modem's synchronization filter. The synchronization filter only becomes active when the reference frequency is below 1 MHz.
Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.
Disable the synchronous filter when parameter j=0.
Enable the synchronous filter when j=1.</td></tr>
<tr><td>DMOD (?) i {,j}</td><td>The DMOD command is used to configure or query the reference source mode of a modem.
Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.
Parameter j is used to select different reference sources for the demodulator, as detailed below:
<table>
<tr><th>j</th><th>Reference source</th></tr>
<tr><td>0</td><td>Oscillator OSC1</td></tr>
<tr><td>1</td><td>Oscillator OSC2</td></tr>
<tr><td>2</td><td>Free-Frequency Demodulation</td></tr>
<tr><td>3</td><td>Frequency Synthesis FreqComb1</td></tr>
<tr><td>4</td><td>Frequency Synthesis FreqComb2</td></tr>
<tr><td>5</td><td>Frequency Synthesis FreqComb3</td></tr>
<tr><td>6</td><td>Frequency Synthesis FreqComb4</td></tr>
</table></td></tr>
<tr><td>DMFR (?) i {, f}</td><td>The DMFR command is used to set or query the reference frequency for any frequency demodulation mode of the modem.
Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.
The parameter f value can be set in the range of $1E^{-5}$ to $1.5E^{6}$, with a minimum resolution of $1E^{-9}$.</td></tr>
<tr><td>HARM (?) i {,j}</td><td>The HARM instruction is used to set or query the harmonic order of the modem reference signal.
Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.
The parameter j can be set to an integer between 1 and 10000, representing the harmonic order.
The HARM i,j instruction sets the signal for the j-th harmonic of the detection reference frequency for the i-th demodulator. The parameter j must satisfy j*f ≤ 1.5 MHz. If the j-th harmonic value exceeds 1.5 MHz, the demodulator output will be erroneous.</td></tr>
<tr><td>PHAS (?) i ,{x}</td><td>The PHAS instruction is used to set or query the reference phase shift.
Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.
The parameter x represents the phase value (a real number, unit: radians, no unit input required). The input range is-180.000 to 180.000, with a resolution of 0.001.
For instance, sending the command PHAS 1,179.0 sets the phase shift value of demodulator 1 to-179.000°. The command PHAS?1, on the other hand, queries the phase shift value of demodulator 1.</td></tr>
<tr><td>DREF ? i</td><td>The DREF command is used to query the final reference frequency of the modem.
Parameter i must be set when sending this command. Parameter i corresponds to the demodulator channel number parameter, with a range of 1 to 8.
The return parameter type is a floating-point number, with a range from $1E^{-5}$ to 1.5E6. The returned frequency value = reference frequency * harmonic order.</td></tr>
</table>

It should be noted that the FreqComb frequency synthesis channel consists of four independent channels, each operating separately from the demodulator channels. The parameter configuration instructions for FCMB (Formula Parameter Setting Command) involve complex settings, as detailed in the table below:

<table>
<tr>
<td>FCMB (?) i {,x,j,y,k}</td>
<td>
The FCMB command is used to set or query formula parameters for the formula-based composite frequency demodulation mode of a modem.
Parameter i must be set when sending this command. Parameter i corresponds to the frequency synthesis channel count, with a range of 1 to 4.
Parameters x, j, y, k correspond to the four parameters A,F_1, B,F_2 of the formula FreqComb = A × F_1+ B × F_2;
x and y can be set as real numbers within the range of-10,000 to 10,000, with a minimum resolution of 0.001.
j and k can be set to different frequency sources, as detailed below:
<table>
<tr><th>j、k</th><th>Frequency source selection</th></tr>
<tr><td>0</td><td>Oscillator OSC1</td></tr>
<tr><td>1</td><td>Oscillator OSC2</td></tr>
<tr><td>2</td><td>Demod1 internal arbitrary frequency</td></tr>
<tr><td>3</td><td>Demod2 internal arbitrary frequency</td></tr>
<tr><td>4</td><td>Demod3 internal arbitrary frequency</td></tr>
<tr><td>5</td><td>Demod4 internal arbitrary frequency</td></tr>
<tr><td>6</td><td>The arbitrary internal frequency of Demod5</td></tr>
<tr><td>7</td><td>Demod6 internal arbitrary frequency</td></tr>
<tr><td>8</td><td>Demod7 internal arbitrary frequency</td></tr>
<tr><td>9</td><td>Demod8 internal arbitrary frequency</td></tr>
</table>
</td>
</tr>
</table>

6.2.4. Signal Output Channel Configuration Command

Since the SE2022 has two signal output channels, all instruction parameters related to signal output channels require the inclusion of a channel selection parameter. The signal output channel parameter for the following instructions is denoted as i, where i=1 selects Signal Out 1 and i=2 selects Signal Out 2.

STTL (?) i {,j}	The STTL instruction is used to set or query the output status of the <TTL Out> interface. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Select to disable TTLout output when parameter j=0. Enable TTLout output when j=1.
SIGO (?) i {,j}	The SIGO command is used to set or query the output status of the <Sineout> interface. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Select to disable Sineout output when parameter j=0; Enable Sineout output when j=1.
SLVL (?) i {,x}	The SLVL command is used to set or query the sine wave voltage amplitude of the output <Sineout>. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Parameter x indicates the amplitude voltage (real number, unit: Vrms, no unit input required). Parameter x must satisfy 0.1 μ $V_{rms} \leq x \leq 5$ V_{rms}, with a minimum resolution of 0.1 μ V_{rms}.
SOFF (?) i {,x}	The SOFF instruction is used to set or query the DC bias voltage of the output <Sineout>. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Parameter x represents the bias voltage value (real number, unit: V; no unit specified for input). Parameter x ranges from-5 to 5, with a minimum resolution of 0.001.
SPHS (?) i {,x}	The SPHS instruction is used to set or query the phase shift of the <Sineout> sine wave relative to the oscillator reference. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. The parameter x represents the phase value (a real number, with units not required). The input range is-180 to 180, and the minimum resolution is 0.001.
TPHS (?) i {,x}	The TPHS command is used to set or query the phase shift of the <TTLout> waveform relative to the oscillator reference. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. The parameter x represents the phase value (a real number, unit: rad; no unit input required). The input range is-180 to 180, with a minimum resolution of 0.001.
SMFR (?) i {,f}	The SMFR command is used to set or query the internal frequency of the <Sineout> modulation mode. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. The parameter f value can be set within the range of $1E^{-5}$ to $1.5E^{6}$, with a minimum resolution of $1E^{-9}$.

SMOD (?) i {,j}	The SMOD command is used to set or query the output mode of<Sineout>. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Select sine wave output mode when parameter j=0; Select AM modulation mode when j=1; Select FM modulation mode when j=2; Select the PM modulation mode when j=3. When selecting AM/FM/PM debugging mode, the carrier amplitude and frequency information remain consistent with those in sine wave mode, while the modulation wave depth and frequency are controlled by other commands.
AMSR (?) i {,j}	The AMSR instruction is used to set or query the frequency source of the AM modulated signal. The parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Select the frequency value of oscillator OSC1 when parameter j=0; Select the frequency value of oscillator OSC2 for j=1; When j=2, the internal frequency for selecting modulation mode is determined, which corresponds to the frequency value set by SMFR.
AMDP (?) i {,x}	The AMDP command is used to set or query the modulation depth of AM modulation signals. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. The parameter x takes real numbers between 0 and 1 as input, representing the percentage ratio of the modulation signal amplitude to the carrier signal amplitude. For example, setting AMDP1 indicates that the modulation signal amplitude equals that of the carrier signal.
FMSR (?) i {,j}	The FMSR instruction is used to set or query the frequency source of the FM modulated signal. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Select the frequency value of oscillator OSC1 when parameter j=0; Select the frequency of oscillator OSC2 when j=1; When j=2, the internal frequency for selecting modulation mode is determined, which corresponds to the frequency value set by SMFR.
FMDV (?) i {,f}	The FMDV command is used to set or query the peak frequency deviation ofFM modulation signals. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. The parameter f value can be set in the range of $1E^{-5}$ to $1.5E^{6}$, with a minimum resolution of $1E^{-9}$.
PMSR (?) i {,j}	The PMSR command is used to configure or query the frequency source of the AM modulation signal. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. Select the frequency value of oscillator OSC1 when parameter j=0; Select the frequency value of oscillator OSC2 for j=1; When j=2, the internal frequency for selecting modulation mode is determined, which corresponds to the frequency value set by SMFR.
PMDV (?) i {,x}	The PMDV command is used to set or query the phase deviation value of the PM modulation signal. Parameter i indicates the number of signal output channels: i=1 selects Signal Out 1, and i=2 selects Signal Out 2. The parameter x represents the phase value (a real number, unit: rad; no unit input required). The input range is 0-360, with a minimum resolution of 0.001.

6.2.5. Channel Output Instruction

The SE2022 features two auxiliary channel CHOUT interfaces and four auxiliary channel AUXOUT interfaces. For all channel outputs, the corresponding commands must include the CH/AUX channel selection parameter.

First, we introduce the relevant instructions of CHOUT. The parameters of the CH channel for the following instructions are denoted by i, where i=1 selects channel 1 and i=2 selects channel 2.

<table>
<tr><td>CHDC(?) i {, x}</td><td>The CHDC command is used to set or query the voltage value of the DC OUT DC mode for the CHOUT channel.
Parameter i corresponds to the channel of CH. CH1 is selected when i=1, and CH2 is selected when i=2.
The parameter x sets the output voltage value (real number in V, no unit required).
The range is-10.000 ≤ x ≤ 10.000, with a minimum resolution of 0.001.
For example, sending the command CHDC1,5.00 sets the DC OUT output value of <CHOUT1> to 5.00 V in DC mode.</td></tr>
<tr><td>SENS (?) i {,j}</td><td>The SENS command is used to set or query the sensitivity of the CHOUT channel.
Parameter i corresponds to the channel of CH, with CH1 selected when i=1 and CH2 selected when i=2. Parameter j is used to select different ranges.
Details are as follows：
<table>
<tr><th>j/sensitivity</th><th>j/sensitivity</th></tr>
<tr><td>0: 1 nV/pA</td><td>15: 100 μV/nA</td></tr>
<tr><td>1: 2 nV/pA</td><td>16: 200 μV/nA</td></tr>
<tr><td>2: 5 nV/pA</td><td>17: 500 μV/nA</td></tr>
<tr><td>3: 10 nV/pA</td><td>18: 1 mV/μA</td></tr>
<tr><td>4: 20 nV/pA</td><td>19: 2 mV/μA</td></tr>
<tr><td>5: 50 nV/pA</td><td>20: 5 mV/μA</td></tr>
<tr><td>6: 100 nV/pA</td><td>21: 10 mV/μA</td></tr>
<tr><td>7: 200 nV/pA</td><td>22: 20 mV/μA</td></tr>
<tr><td>8: 500 nV/pA</td><td>23: 50 mV/μA</td></tr>
<tr><td>9: 1 μV/nA</td><td>24: 100 mV/μA</td></tr>
<tr><td>10: 2 μV/nA</td><td>25: 200 mV/μA</td></tr>
<tr><td>11: 5 μV/nA</td><td>26: 500 mV/μA</td></tr>
<tr><td>12: 10 μV/nA</td><td>27: 1 V/mA</td></tr>
<tr><td>13: 20 μV/nA</td><td>28: 2 V/mA</td></tr>
<tr><td>14: 50 μV/nA</td><td>29: 5 V/mA</td></tr>
</table></td></tr>
<tr><td>COFP (?) i {, x}</td><td>The COFP instruction is used to set or query the bias value of the CHOUT channel output. Parameter i corresponds to the channel of CH: CH1 for i=1 and CH2 for i=2.
The parameter x sets the bias value (in%), with a range of-100.00 ≤ x ≤ 100.00 and a minimum resolution of 0.01.</td></tr>
<tr><td>CEXP (?) i {,x}
OEXP (?) i {,x}</td><td>The CEXP command is used to set or query the amplification factor of the CHOUT channel output. CEXP and OEXP commands have identical functionality and are mutually compatible.
Parameter i corresponds to the channel of CH. CH1 is selected when i=1, and CH2 is selected when i=2.
The parameter x sets the output gain, ranging from 0.001 to 10,000 as a real number, with a minimum resolution of 0.001.</td></tr>
</table>

COUT (?) i {, j}
FOUT (?) i {, j}

The COUT command is used to configure or query the signal source of the CHOUT output channel on the rear panel of the SE2022.

The COUT and FOUT instructions have identical functionality and are mutually compatible.

When sending this command, parameter i must be set: CH1 for i=1 and CH2 for i=2.

The parameter j is used to select the type of output value, as follows:

i	CH channel source
0	DC OUT
1	X-Demod1
2	Y-Demod1
3	R-Demod1
4	θ-Demod1
5	X-Demod2
6	Y-Demod2
7	R-Demod2
8	θ-Demod2
9	X-Demod3
10	Y-Demod3
11	R-Demod3
12	θ-Demod3
13	X-Demod4
14	Y-Demod4
15	R-Demod4
16	θ-Demod4
17	X-Demod5
18	Y-Demod5
19	R-Demod5
20	θ-Demod5
21	X-Demod6
22	Y-Demod6
23	R-Demod6
24	θ-Demod6
25	X-Demod7
26	Y-Demod7
27	R-Demod7
28	θ-Demod7
29	X-Demod8
30	Y-Demod8
31	R-Demod8
32	θ-Demod8
33	AUXIN1
34	AUXIN2
35	AUXIN3
36	AUXIN4

Next, the relevant AUXOUT instructions are introduced. The AUX channel parameters for the following instructions are denoted by i: i= 1 selects channel 1, i=2 selects channel 2, i=3 selects channel 3, and i=4 selects channel 4.

<table>
<tr>
<td>AXDC(?) i {, x}</td>
<td>The AXDC command is used to set or query the voltage value of the DC OUT mode for the AUXOUT channel.
Parameter i corresponds to the AUX channel parameter, with a range of 1 to 4.
The parameter x sets the output voltage value (real number in V, no unit required). The range is-10.000 ≤ x ≤ 10.000, with a minimum resolution of 0.001.
For example, sending the command AXDC1,5.00 sets the DC OUT output value of<AXOUT1> to 5.00 V in DC mode.</td>
</tr>
<tr>
<td>AXSN (?) i {j}</td>
<td>The AXSN command is used to set or query the sensitivity of the AUXOUT channel <sensitivity>.
Parameter i corresponds to the AUX channel parameter, with a range of 1 to 4.
Parameter j is used to select different ranges.
Details are as follows：
<table>
<tr><th>j/sensitivity</th><th>j/sensitivity</th></tr>
<tr><td>0: 1 nV/pA</td><td>15: 100 μV/nA</td></tr>
<tr><td>1: 2 nV/pA</td><td>16: 200 μV/nA</td></tr>
<tr><td>2: 5 nV/pA</td><td>17: 500 μV/nA</td></tr>
<tr><td>3: 10 nV/pA</td><td>18: 1 mV/μA</td></tr>
<tr><td>4: 20 nV/pA</td><td>19: 2 mV/μA</td></tr>
<tr><td>5: 50 nV/pA</td><td>20: 5 mV/μA</td></tr>
<tr><td>6: 100 nV/pA</td><td>21: 10 mV/μA</td></tr>
<tr><td>7: 200 nV/pA</td><td>22: 20 mV/μA</td></tr>
<tr><td>8: 500 nV/pA</td><td>23: 50 mV/μA</td></tr>
<tr><td>9: 1 μV/nA</td><td>24: 100 mV/μA</td></tr>
<tr><td>10: 2 μV/nA</td><td>25: 200 mV/μA</td></tr>
<tr><td>11: 5 μV/nA</td><td>26: 500 mV/μA</td></tr>
<tr><td>12: 10 μV/nA</td><td>27: 1 V/mA</td></tr>
<tr><td>13: 20 μV/nA</td><td>28: 2 V/mA</td></tr>
<tr><td>14: 50 μV/nA</td><td>29: 5 V/mA</td></tr>
</table>
</td>
</tr>
<tr>
<td>AXOF (?) i {, x}</td>
<td>The AXOF command is used to set or query the bias value of the AUXOUT channel output. Parameter i corresponds to the AUX channel parameter, with a setting range of 1 to 4.
The parameter x sets the bias value (in%), with a range of-100.00 ≤ x ≤ 100.00 and a minimum resolution of 0.01.</td>
</tr>
<tr>
<td>AXEX (?) i {,x}</td>
<td>The AXEX command is used to set or query the amplification factor of the AUXOUT channel output.
Parameter i corresponds to the AUX channel parameter, with a range of 1 to 4.
The parameter x sets the output gain, ranging from 0.001 to 10,000 as a real number, with a minimum resolution of 0.001.</td>
</tr>
</table>

<table>
<tr>
<td>AXOS (?) i {,j}</td>
<td>
<p>The AXOS command is used to configure or query the signal source of the AUXOUT output channel on the rear panel of the SE2022.</p>
<p>Parameter i corresponds to the AUX channel parameter, with a range of 1 to 4.</p>
<p>The parameter j is used to select the type of output value, as follows:</p>
<table>
<tr><th>i</th><th>AUX channel source</th></tr>
<tr><td>0</td><td>DC OUT</td></tr>
<tr><td>1</td><td>X-Demod1</td></tr>
<tr><td>2</td><td>Y-Demod1</td></tr>
<tr><td>3</td><td>R-Demod1</td></tr>
<tr><td>4</td><td>θ-Demod1</td></tr>
<tr><td>5</td><td>X-Demod2</td></tr>
<tr><td>6</td><td>Y-Demod2</td></tr>
<tr><td>7</td><td>R-Demod2</td></tr>
<tr><td>8</td><td>θ-Demod2</td></tr>
<tr><td>9</td><td>X-Demod3</td></tr>
<tr><td>10</td><td>Y-Demod3</td></tr>
<tr><td>11</td><td>R-Demod3</td></tr>
<tr><td>12</td><td>θ-Demod3</td></tr>
<tr><td>13</td><td>X-Demod4</td></tr>
<tr><td>14</td><td>Y-Demod4</td></tr>
<tr><td>15</td><td>R-Demod4</td></tr>
<tr><td>16</td><td>θ-Demod4</td></tr>
<tr><td>17</td><td>X-Demod5</td></tr>
<tr><td>18</td><td>Y-Demod5</td></tr>
<tr><td>19</td><td>R-Demod5</td></tr>
<tr><td>20</td><td>θ-Demod5</td></tr>
<tr><td>21</td><td>X-Demod6</td></tr>
<tr><td>22</td><td>Y-Demod6</td></tr>
<tr><td>23</td><td>R-Demod6</td></tr>
<tr><td>24</td><td>θ-Demod6</td></tr>
<tr><td>25</td><td>X-Demod7</td></tr>
<tr><td>26</td><td>Y-Demod7</td></tr>
<tr><td>27</td><td>R-Demod7</td></tr>
<tr><td>28</td><td>θ-Demod7</td></tr>
<tr><td>29</td><td>X-Demod8</td></tr>
<tr><td>30</td><td>Y-Demod8</td></tr>
<tr><td>31</td><td>R-Demod8</td></tr>
<tr><td>32</td><td>θ-Demod8</td></tr>
<tr><td>33</td><td>AUXIN1</td></tr>
<tr><td>34</td><td>AUXIN2</td></tr>
<tr><td>35</td><td>AUXIN3</td></tr>
<tr><td>36</td><td>AUXIN4</td></tr>
</table>
</td>
</tr>
</table>

6.2.6. Auto Setup Command

ARNG i	The ARNG command activates the automatic range function for the input channel. It functions similarly to pressing <Auto Range> in the menu. Parameter i corresponds to input channels. When i=0, both input channels are selected; when i=1, Signal in 1 is selected; and when i=2, Signal in 2 is selected.
APHS i	The APHS command activates the modem's automatic phase compensation function. Its effect is identical to pressing <Auto Phase> in the menu. Parameter i corresponds to a demodulator channel. When i=0, all 8 demodulators are selected; when i=1, Demod1 is selected; when i=2, Demod2 is selected.… …Select Modulator 8 when i=8. For instance, when APHS 2 is sent, the instruction automatically resets the current phase value of demodulator 2 to 0, with the phase value being set to the Ref. Phase of demodulator 2. Automatic phase setting may take some time. Do not resend the APHS command before the process completes. Additionally, if the phase is unstable, the command will be invalid.
AFLT i	The AFLT command activates the filter function for automatically configured demodulators. It functions similarly to pressing <Auto Filter> in the menu. Parameter i corresponds to a demodulator channel. When i=0, all 8 demodulators are selected; when i=1, Demod1 is selected; when i=2, Demod2 is selected.… …Select Modulator 8 when i=8.
AOFP i	The AOFP instruction enables the output bias value for the automatically configured CHOUT channel. Its function is identical to pressing <Auto CH Offset> in the menu. Parameter i corresponds to the CHOUT channel. When i=0, both CHOUT channels are selected; when i=1, CH1 is selected; when i=2, CH2 is selected.

6.2.7. Save Read Settings Command

SSET i	The SSET i instruction saves the current settings of SE2022 into the configuration storage area, specifically the Setting buffer i (1≤i≤4). The configuration data stored in the setting buffer remains intact after a power outage in SE2022.
RSET i	The RSET i instruction reads settings from Setting buffer i (0≤i≤4). Here, i=0 indicates the <Default> default setting, and i=1~4 represent the <S1> to <S4> settings. Upon successful readout, the internal parameters ofSE2022 will be set to match those in Setting buffer i.

6.2.8. Reduction and IDN Command

*RST	*The RST instruction is used for soft reset of SE2022. All internal states and parameters of the instrument remain unchanged, but the data in the data buffer will be lost. The number is used to pad 4 command characters.
*IDN?	*IDN? The command is used to query the ID ofSE2022, with the format "Scientific Instruments, SE2022, SN: XXXXXX, Ver: XXXXX". The first part represents the company name, the second part indicates the model (e.g., OE 2022), the third part is the serial number (e.g., SN: 00001), and the fourth part is the version number (e.g., Ver: 1.00_1.10). * The number is used to supplement the four-digit command characters.

6.2.9. Data and Status Reading Instructions

<table>
<tr>
<td>OUTP? i</td>
<td>
<p>The OUTP? i instruction is used to read a single measurement value. Parameter i corresponds to the table below. The selection of parameter i is specified as follows:</p>
<table>
<tr><th>i</th><th>Parameter</th><th>i</th><th>Parameter</th></tr>
<tr><td>0</td><td>X-Demod1</td><td>22</td><td>R-Demod6</td></tr>
<tr><td>1</td><td>Y-Demod1</td><td>23</td><td>θ-Demod6</td></tr>
<tr><td>2</td><td>R-Demod1</td><td>24</td><td>X-Demod7</td></tr>
<tr><td>3</td><td>θ-Demod1</td><td>25</td><td>Y-Demod7</td></tr>
<tr><td>4</td><td>X-Demod2</td><td>26</td><td>R-Demod7</td></tr>
<tr><td>5</td><td>Y-Demod2</td><td>27</td><td>θ-Demod7</td></tr>
<tr><td>6</td><td>R-Demod2</td><td>28</td><td>X-Demod8</td></tr>
<tr><td>7</td><td>θ-Demod2</td><td>29</td><td>Y-Demod8</td></tr>
<tr><td>8</td><td>X-Demod3</td><td>30</td><td>R-Demod8</td></tr>
<tr><td>9</td><td>Y-Demod3</td><td>31</td><td>θ-Demod8</td></tr>
<tr><td>10</td><td>R-Demod3</td><td>32</td><td>Xnoise-Demod1</td></tr>
<tr><td>11</td><td>θ-Demod3</td><td>33</td><td>Ynoise-Demod1</td></tr>
<tr><td>12</td><td>X-Demod4</td><td>34</td><td>Xnoise-Demod5</td></tr>
<tr><td>13</td><td>Y-Demod4</td><td>35</td><td>Ynoise-Demod5</td></tr>
<tr><td>14</td><td>R-Demod4</td><td>36</td><td>Frequency-OSC1</td></tr>
<tr><td>15</td><td>θ-Demod4</td><td>37</td><td>Frequency-OSC2</td></tr>
<tr><td>16</td><td>X-Demod5</td><td>38</td><td>AUXIN1</td></tr>
<tr><td>17</td><td>Y-Demod5</td><td>39</td><td>AUXIN2</td></tr>
<tr><td>18</td><td>R-Demod5</td><td>40</td><td>AUXIN3</td></tr>
<tr><td>19</td><td>θ-Demod5</td><td>41</td><td>AUXIN4</td></tr>
<tr><td>20</td><td>X-Demod6</td><td>42</td><td>Time stamp</td></tr>
<tr><td>21</td><td>Y-Demod6</td><td></td><td></td></tr>
</table>
<p>The values of the selected parameters are returned in ASCII floating-point format, in volts (V), degrees (°), or hertz (Hz), but the units are not output. This command is used only for queries.</p>
</td>
</tr>
<tr>
<td>SNAP? i {,j,k,l,m,n,o,p……}</td>
<td>
<p>The SNAP? instruction is used to read up to 20 different measurements from the SE2022 at the same time.</p>
<p>The SNAP instruction enables simultaneous measurement of instantaneous values such as <X>, <Y>, <R>, and < θ >, which proves particularly crucial in scenarios with short time constants or rapidly changing signals. The OUTP instruction sequentially queries multiple parameters, resulting in delays between parameter returns that lead to non-strictly synchronized data acquisition. Such temporal discrepancies may introduce significant errors in dynamic signal measurements. The SNAP instruction ensures all specified parameters are calculated and output based on a unified internal sampling point, thereby guaranteeing temporal consistency in data acquisition.</p>
<p>The SNAP?i command requires at least one parameter and can read up to 20 parameters simultaneously. Parameter selection is as follows:</p>
</td>
</tr>
</table>

<table>
<tr>
<td>SNAP? i {,j,k,l,m,n,o,p……}</td>
<td>
<table>
<tr><th>i,j,k,l,m,n,o,p… …</th><th>Parameter</th></tr>
<tr><td>0</td><td>X-Demod1</td></tr>
<tr><td>1</td><td>Y-Demod1</td></tr>
<tr><td>2</td><td>R-Demod1</td></tr>
<tr><td>3</td><td>θ-Demod1</td></tr>
<tr><td>4</td><td>X-Demod2</td></tr>
<tr><td>5</td><td>Y-Demod2</td></tr>
<tr><td>6</td><td>R-Demod2</td></tr>
<tr><td>7</td><td>θ-Demod2</td></tr>
<tr><td>8</td><td>X-Demod3</td></tr>
<tr><td>9</td><td>Y-Demod3</td></tr>
<tr><td>10</td><td>R-Demod3</td></tr>
<tr><td>11</td><td>θ-Demod3</td></tr>
<tr><td>12</td><td>X-Demod4</td></tr>
<tr><td>13</td><td>Y-Demod4</td></tr>
<tr><td>14</td><td>R-Demod4</td></tr>
<tr><td>15</td><td>θ-Demod4</td></tr>
<tr><td>16</td><td>X-Demod5</td></tr>
<tr><td>17</td><td>Y-Demod5</td></tr>
<tr><td>18</td><td>R-Demod5</td></tr>
<tr><td>19</td><td>θ-Demod5</td></tr>
<tr><td>20</td><td>X-Demod6</td></tr>
<tr><td>21</td><td>Y-Demod6</td></tr>
<tr><td>22</td><td>R-Demod6</td></tr>
<tr><td>23</td><td>θ-Demod6</td></tr>
<tr><td>24</td><td>X-Demod7</td></tr>
<tr><td>25</td><td>Y-Demod7</td></tr>
<tr><td>26</td><td>R-Demod7</td></tr>
<tr><td>27</td><td>θ-Demod7</td></tr>
<tr><td>28</td><td>X-Demod8</td></tr>
<tr><td>29</td><td>Y-Demod8</td></tr>
<tr><td>30</td><td>R-Demod8</td></tr>
<tr><td>31</td><td>θ-Demod8</td></tr>
<tr><td>32</td><td>Xnoise-Demod1</td></tr>
<tr><td>33</td><td>Ynoise-Demod1</td></tr>
<tr><td>34</td><td>Xnoise-Demod5</td></tr>
<tr><td>35</td><td>Ynoise-Demod5</td></tr>
<tr><td>36</td><td>Frequency-OSC1</td></tr>
<tr><td>37</td><td>Frequency-OSC2</td></tr>
<tr><td>38</td><td>AUXIN1</td></tr>
<tr><td>39</td><td>AUXIN2</td></tr>
<tr><td>40</td><td>AUXIN3</td></tr>
<tr><td>41</td><td>AUXIN4</td></tr>
<tr><td>42</td><td>Time stamp</td></tr>
</table>
</td>
</tr>
</table>

	The returned value is a string separated by commas (,) between different values, with parameters ordered in the i, j, k, l, m sequence when the command is sent. For example, sending SNAP?0,1,36,3 will sequentially return the values of <X>, <Y>, <Frequency>, and < θ >. All values are enclosed within a single string, such as: "0.951359,0.0253297,1000.00,1.234". The first is the <X> value, the second is the <Y> value, the third is the frequency value, and the fourth is the < θ > value.
OAUX? i	The OAUX command is used to query the input voltage value of the AUX_|N interface on the rear panel. The parameter i must be set. When i=1, read AUX_|N1; when i=2, read AUX_|N2; when i=3, read AUX_|N3; when i=4, read AUX_|N4. The query returns a real number in volts (V), but the unit is not displayed.
INOV? i	The NOV? command queries the overload status of the input channel's nput. The result returns 0 or 1: 0 indicates no overload in the input channel's preamplifier, while 1 indicates overload requiring signal attenuation to prevent instrument damage. The parameter i must be set. When i=1, query Signal in 1; when i=2, query Signal in 2.
GNOV? i	The GNOV? command queries the Gain Overload status of an input channel. The query returns either 0 or 1. A value of 0 indicates that the input channel ADC is not currently overflowing, while 1 signifies that the ADC is experiencing overflow. In this case, the input signal should be reduced or the input range expanded to prevent instrument damage. The parameter i must be set. When i=1, query Signal in 1; when i=2, query Signal in 2.
*PLL? i	*The PLL command is used to check the status of the oscillator phase-locked loop. Parameter i must be set. When i=0, the phase-locked loop status of OSC1 is read; when i=1, the same status is read. The query returns either 0 or 1, where 0 indicates the phase-locked loop is not locked or in internal reference mode, and 1 signifies the phase-locked loop is locked.

6.2.10. Clock and Trigger Signal Configuration Instructions

<table>
<tr><td>TMOD (?) {i}</td><td>The TMOD instruction is used to set or query the instrument's clock source. When sending the instruction, parameter i specifies the clock mode:
i=0 indicates use of internal clock;
i=1 indicates the use of an external 10 MHz clock.</td></tr>
<tr><td>TSTA?</td><td>TSTA? This command queries the instrument's clock PLL status. The returned parameter is of integer type:
0 Indicates that all clock PLLs are malfunctioning;
2 indicates normal internal clock PLL operation;
7 Indicates that the external clock PLL is normal.</td></tr>
<tr><td>OCLK (?) {i}</td><td>The OCLK command is used to configure or check the enable status of the instrument's 10 MHz clock output interface.
Parameter i=0 turns off the Clock out interface, keeping its output at low level.
Parameter i=1 indicates the activation of the Clock out interface, which outputs a square wave clock signal at 10 MHz/3.3 V.</td></tr>
<tr><td>TRIG (?) {i}</td><td>The TRIG command is used to set or query the trigger source type of the instrument.
Parameter i=0 indicates the use of the instrument's internal trigger source, where all data sampling is governed by the internal clock.
Parameter i=1 indicates the use of an external trigger source Trigger in.</td></tr>
<tr><td>TRIM (?) {i}</td><td>The TRIM command is used to set or query the external trigger mode of the instrument. The external trigger mode corresponding to parameter i is as follows:
<table>
<tr><th>i</th><th>External Trigger Mode</th></tr>
<tr><td>0</td><td>Rising edge</td></tr>
<tr><td>1</td><td>Trailing edge</td></tr>
<tr><td>2</td><td>Edge trigging</td></tr>
<tr><td>3</td><td>High level triggering</td></tr>
<tr><td>4</td><td>Low level triggering</td></tr>
</table>
When selecting the rising edge, falling edge, or edge triggering mode, the instrument will output instantaneous data upon detecting the trigger signal edge.
When selecting the high/low level trigger mode, the instrument continuously outputs data at the user-defined sampling rate during the period when the trigger signal remains at the corresponding level, effectively applying a window function to define the data output range.</td></tr>
<tr><td>TRIO (?) {i}</td><td>The TRIO instruction is used to set or query the enable status of the instrument's Trigger Out interface.
Parameter i=0 indicates that the Trigger out interface is in the off state, with the output maintained at a low level.
Parameter i=1 enables the Trigger out interface, which outputs trigger signals based on the instrument's current trigger mode.</td></tr>
<tr><td>TRIF (?) {f}</td><td>The TRIF command is used to set or query the sampling rate during the instrument's internal trigger mode.
The parameter f represents the data sampling rate, with a configurable range of 0.01 to 100,000 Hz.</td></tr>
</table>

Chapter 7 Performance Testing

brief introduction

This chapter provides users with a series of performance tests to verify the measurement accuracy of the device, thereby enhancing confidence in its reliability. All test results can be recorded in the Performance Test Record Form attached at the end of this chapter for subsequent performance evaluation.

serial number

To contact our technical support, please provide the device serial number for quick issue resolution.

The serial number is clearly marked on the back of the device and the outer packaging box. Additionally, after powering on the device, you can view this information by entering the <INFO> interface.

Firmware version

After enabling the device, you can view the firmware version number by accessing the <INFO> interface.

preheat

Due to the temperature drift characteristics of internal components in the device, thorough preheating is recommended before formal testing to ensure accurate measurement results. The recommended preheating duration is 30 to 60 minutes to allow the system to reach thermal stability, thereby effectively reducing measurement errors.

test record

A performance test record sheet is attached at the end of this chapter for documenting various system test data. It is recommended to back up the record sheet prior to formal completion.

Upon completion of all tests, comprehensively evaluate whether the equipment performance meets the expected specifications based on the measured data recorded in the report. Please retain this report properly as a critical reference for future communication with our engineers.

Test failed

If a test fails, follow these steps to troubleshoot:

1、 Verification settings: Carefully check whether the configuration of this device and all external connected devices is correct.

2、 Reheat: After confirming the settings are correct, fully preheat the device and repeat the test.

3、 Replace peripherals: If conditions permit, try using other known high-quality external devices to eliminate peripheral interference.

If the test still fails after the above measures, please:

1、 Record the device serial number and firmware version number;

2、 Organize and complete the performance testing record form;

3、 Contact our technical support team promptly for further assistance with diagnosis and resolution.

Test the necessary equipment

1. function signal generator

Freq Range: 1 Hz to 100 MHz
Freq Accuracy : Better than 2 ppm
Amplitude Accuracy: 0.2dB from 1 Hz to 100 MHz
Spurious: ≤-55 dBc
TTL SYNC: Available
Output Setup: 50 Ω or High Z
Recommend: AGILENT 33600B series

2. digital multimeter

Voltage Range ≥20 V， 4 1/2 digits
Accuracy ≤0.005%
Recommend KEITHLEY 2100

3. DC voltage regulator

Voltage Range ≥10 V
Accuracy <10 mV_{pp}
Recommend RIGOL DP831A

4. Connector

BNC resistance 50 Ω

BNC_T type connector

5. connecting line

BN-C BNC cable	0.5 There are several strands of rice noodles.
BNC_BNC Connector	1 There are several strands of rice noodles.

Front panel LCD test

Please follow these steps to operate the device: First, turn on the power switch on the back to start the device; then, carefully check whether the LCD screen has been successfully lit; finally, on the screen interface, carefully inspect for any damaged spots on the display.

Keyboard test

After powering on the device, try tapping any button. You should hear a clear 'beep' sound as feedback.

Next, test each button individually and carefully observe the screen display to ensure every button press correctly triggers the corresponding setting change.

Finally, select the <Demod.Select> setting item from the [DEMOD FILTER] menu, rotate the knob to verify its proper functioning, and make necessary adjustments accordingly.

7.1 Start Test

Before conducting other performance tests, it is essential to first perform startup tests to comprehensi - vely inspect the hardware functionality of the phase-locked amplifier, ensuring it operates in a normal state.

equipment

No external devices are required for this test.

step

1） Turn on the Rear Power Switch to Activate the Phase-Locked Amplifier;
2） Check Whether the Device Screen, Keyboard Functionality, and Rear Cooling Fan Are Operating Normally.
3） The Test Pass/fail Status Is Recorded in the Test Record Sheet at the End of This Chapter.

7.2 DC Bias

The purpose of this test is to evaluate the DC bias at the input terminal.

equipment

Apply a 50 Ω BNC resistor load to short-circuit the |N+ interfaces of Signal |n 1 and Signal |n 2. After short-circuiting the input terminals, the phase-locked amplifier can measure its own DC bias.

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;
2) Modify settings in the following order:

<OSC 1&2> 's <Osc. Mode>: Change to <internal>
<OSC 1&2> 's <Osc. Frequency>: Modified to 1 Hz
<Signal |n 1&2> 's <ninput Range>: Modify to <1 mV> using the knob
<Demod 1&5> 's <Time Constant>: Changed to 1s
<Demod 1&5>'s <Filter dB/oct>: Modified to <24 dB/oct>

3) After waiting for 10 seconds, record the <R_Demod1> and <R_Demod5> values;
4) Change Settings:

<Signal |n 1&2> 's <Coupling>: Modified to <DC>

5) After waiting for 10 seconds, record the values of<R_Demod1> and <R_Demod5>;
6) This completes the DC bias test; enter the data in the test record form at the end of this chapter.

7.3 Common-Mode Suppression

The purpose of this test is to measure the common-mode rejection ratio of the phase-locking amplifier.

equipment

The device generates a sine wave as output to provide the signal.

Connect the S|NE OUT output terminal of the phase-locking amplifier to the |N+ and |N_ input terminals. Insert the BNC T-type connector into S|NE OUT 1.

For interface configuration, use two equal-length signal lines (BNC male-to-male connectors) to connect the T-type connector to the |N+ and |N_ interfaces of S|GNAL |N1, then repeat the same connection method for S|NE OUT 2 to the |N+ and |N_ interfaces of S|GNAL |N 2.

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;
2) Modify settings in the following order:

<Signal |n 1&2> 's <ninput Range>: Modify with the knob to <5 V>
<Signal |n 1&2> 's <Coupling>: be revised as <DC>
<Osc 1&2> 's <Osc. Mode>: Change to <internal>
<Osc 1&2> 's <Osc. Frequency>: Change to 100 Hz
<Signal Out 1&2> Amplitude: Modify to 1 V_{rms}

3) Wait for the <R> value to stabilize, and the <R> value should be 1.000 V_{rms}(within 1% error);
4) Modify settings in the following order:

<Source> of <Signal |n 1&2>: Change to <D|FF>
<Signal |n 1&2> 's <ninput Source>: Modify with knob to <5 mV>

5) After waiting for 10 seconds, record the values of<R_Demod1> and <R_Demod5>;

6) The common-mode rejection test has been successfully completed, with the common-mode rejection ratio (CMRR) calculated as 20lg(1.0/R). The data should be recorded in the test log sheet at the end of this chapter.

7.4 Amplitude Accuracy and Flatness

The purpose of this test is to evaluate the accuracy across various ranges and the frequency response of the phase-locking amplifier.

equipment

Use a function signal generator to provide precise frequencies and sine waves.

First, connect the output interface of the function signal generator to the Signal |n1 |N+ interface of the phase-locked amplifier using a BNC male-to-male signal cable. Then, use another signal cable to link the synchronization signal interface of the function signal generator to the REF |N1 interface of the phase-locked amplifier. Next, connect the function generator to the Signal |n2 |N+ interface and REF |N2 interface of the phase-locked amplifier in the same manner.

Set function signal generator:

function: sinusoidal wave
frequency: 1 kHz
amplitude: 1 V_{rms}
bias in affine function: 0 V
output: High-Z
sweep frequency: off
modulate: none

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;
2) First, test Channel 1 and modify the settings in the following order:

<Demod 1&5> 's <Filter dB/oct>: Change to <24 dB/oct>
<Demod 1&5> 's <Time Constant>: Change to 300 ms

<Signal |n 1&2> 's <Coupling>: Modified to <DC>
<Osc 1&2> 's <Osc. Mode>: Change to <External>

3) To test amplitude accuracy, maintain the function signal generator at 10 kHz frequency and adjust the phase-locked amplifier's <nput Range> and the function generator's <Amplitude> in the following sequence:

nput Range
5 V
1V
200 mV
50 mV
10 mV
2 mV
1 mV

Amplitude
2.000 V_{rms}
0.500 V_{rms}
100.00 mV_{rms}
25.000 mV_{rms}
5.000 mV_{rms}
1.000 mV_{rms}
1.000 mV_{rms}

a) Set the amplitude of the function signal generator;
b) After waiting for 10 seconds, record the <R_Demod1> value and then test another set of data;
c) Repeat steps 3a to 3b until the amplitude accuracy test is completed.

4) The frequency response test is performed at frequencies greater than 1 kHz. Adjust the frequency of the function generator in the following order:Test Frequency

1.2 kHz
12 kHz
120 kHz
1.2 MHz

a) Set the amplitude of the function signal generator to 100.00 mV_{rms};
b) Set the input range of the phase-locking amplifier to <200 mV>.
c) Set the frequency of the function signal generator in sequence;
d) After waiting for 10 seconds, record the <R_Demod1> value and then test another set of data;
e) Repeat steps 4c to 4d until the frequency response test is complete.

5) Connect the cable to Channel 2, then repeat the above steps to complete the test of Channel 2, during which the <R_Demod5> value should be recorded.

6) The testing of amplitude accuracy and frequency response has been completed, and the data should be recorded in the test log sheet at the end of this chapter.

7.5 Amplitude Linearity

This test aims to evaluate the amplitude linearity of the phase-locked amplifier and verify its measurement capability when the signal is below the full-scale range.

equipment

Use a function signal generator to provide precise frequencies and sine waves.

First, connect the output interface of the function signal generator to the Signal |n1 |N+ interface of the phase-locked amplifier using a BNC male-to-male signal cable. Then, use another signal cable to link the synchronization signal interface of the function signal generator to the REF |N1 interface of the phase-locked amplifier. Next, connect the function generator to the Signal |n2 |N+ interface and REF |N2 interface of the phase-locked amplifier in the same manner.

Set function signal generator:

function：	sinusoidal wave
frequency：	1 kHz
amplitude：	1 V_{rms}
bias in affine function：	0 V
output：	High-Z
sweep frequency：	off
modulate：	none

Step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;
2) First, test Channel 1 and modify the settings in the following order:

<Demod 1&5>'s <Filter dB/oct>: Modified to <24 dB/oct>
<Demod 1&5> 's <Time Constant>: Modified to 300 ms
<Signal |n 1&2> 's <ninput Range>: Modify with the knob to <1 V>
<Osc 1&2> 's <Osc. Mode>: Change to <External>

3) Keep the frequency of the function signal generator at 10 kHz and modify its amplitude in the following order:Amplitude

1.0000 V_{rms}
100.00 mV_{rms}
10.000 mV_{rms}
1.0000 mV_{rms}

a) Set the amplitude of the function signal generator;
b) Wait 10 seconds, record the <R_Demod1> value, and then test another set of data;
c) Repeat steps 3a to 3b until all data measurements are completed.

4) Connect the Cable to Channel 2, Then Repeat the Above Steps to Complete the Testing of Channel 2. During This Process, Record <R_Demod5> The value.

5) The amplitude linearity test is now complete, and the data should be recorded in the test log sheet at the end of this chapter.

7.6 Frequency Accuracy

The purpose of this test is to evaluate the frequency accuracy of the phase-locked amplifier.

equipment

Use a function signal generator to provide a reference signal.

First, connect the reference signal interface of the function signal generator to the REF |N 1 interface of the phase-locked amplifier using a signal line (BNC male-to-male). Then, connect the function generator to the REF |N 2 interface of the phase-locked amplifier in the same manner.

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;

2) Set the frequency of the function signal generator to 100 kHz.

3) Set the <Osc. Mode> of the phase-lock amplifier to <External>.

4) After the <PLL> in the lower right corner of the PLLA screen changes from <UNLOCK> to <LOCKED>, connect to the host computer program and record the <Freq> value of Osc1;

5) Connect the cable to REF |N 2, then repeat the aforementioned steps to complete channel 2 testing, recording the Osc2 <Freq> value during the process.

6) This completes the frequency accuracy test; enter the data into the test record form at the end of this chapter.

7.7 Accuracy and Flatness of Sine Out Amplitude-Phase

This test aims to evaluate the amplitude-phase accuracy and frequency response of the sine wave (Sine Out) generated by the phase-locked amplifier.

equipment

Connect the S|NE OUT 1 interface to the |N+ interface of Signal |n 1 using a 1-meter signal cable (BNC male-to-male), and follow the same procedure to connect S|NE OUT 2 to the |N+ interface of Signal |n 2.

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;
2) Modify the following settings:

<Signal |n 1&2> 's <ninput Range>: Modify with the knob to <5 V>
<Demod 1&5>'s <Filter dB/oct>: Modified to <24 dB/oct>
<Demod 1&5> 's <Time Constant>: Modified to <300 ms>
<OSC 1&2> 's <Osc. Mode>: Change to <internal>
<OSC 1&2> 's <Osc. Frequency>: Modified to 10 kHz
<Signal Out 1&2> of <Sineout SW>: Modified to <ON>

3) To test amplitude accuracy, maintain the internal reference signal frequency at 10 kHz and modify the <nput Range> and Sine amplitude <Amplitude> in the following order:

Input Range	Sineout Amplitude
5 V	1.6 V_{rms}
200 mV	0.160 V_{rms}
50 mV	0.016 V_{rms}
2 mV	0.0016 V_{rms}

a) Set two <Sineout> amplitude values separately <Amplitude>;

b) Set separate <Signal |n 1&2> <ninput Range>;

c) After waiting for 10 seconds, record the values of <R_Demod1> and < θ _Demod1>, as well as <R_Demod5> and < θ _Demod5>, and then test another set of data;

d) Repeat steps 3a to 3c until the amplitude accuracy test is completed.

4) The frequency response test is performed at frequencies greater than 1 kHz, modifying the <Osc. Frequency> value in the following order:

Test Frequency
1.2 kHz
12 kHz
120 kHz
1.2 MHz

a) Set the <Signal |n 1&2> 's <nput Range> to 200 mV;

b) Set the <Signal Out 1&2> amplitude <Amplitude> to V_{rms};

c) Set the value of <OSC 1&2> <Osc. Frequency> in order;

d) After waiting for 10 seconds, record the values of <R_Demod1> and < θ _Demod1>, as well as <R_Demod5> and < θ _Demod5>, and then test another set of data;

e) Repeat steps 4c to 4d until the frequency response test is complete.

5) The testing of <Sine Out> amplitude, phase accuracy, and frequency response has been completed. The data should be recorded in the test log sheet at the end of this chapter.

7.8 DC Output and Input

This test primarily evaluates the accuracy of the phase-lock amplifier's DC output and input.

equipment

Use a linear DC voltage regulator as the DC input. Employ a digital multimeter to measure the DC output of the phase-locked amplifier.

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;
2) Change Settings:

<CH Source>: The two CH channel sources have been modified to <DC OUT>

3) Follow these steps:
   a) Connect the CHOUT 1 interface on the rear panel to the digital multimeter using signal cables, and set the multimeter's range to 19.999 V.
   b) Modify the values in <DC OUT> in the following list order:DC OUT (V)

      10.000
      5.000
      0.000
      - 5.000
      - 10.000

   c) After waiting for 10 seconds, record the digital multimeter reading, then test the next set of data.
   d) Repeat Steps 3b to 3c Until the CHOUT 1 Test Is Completed, Then Sequentially Replace the CHOUT 2 Interface to Connect to the Digital System.

   Use the multimeter to continue testing.
4) Follow these steps:
   a) Connect the AUXOUT 1 interface on the rear panel to the digital multimeter using a signal cable, and set the multimeter range to 19.999 V.
   b) Modify the values in <DC OUT> in the following list order:DC OUT (V)

      10.000
      5.000
      0.000
      - 5.000
      - 10.000

   c) After a 10-second wait, record the digital multimeter reading and proceed to test the next set of data.
   d) Repeat Steps 4b to 4c Until the AUXOUT 1 Test Is Completed, Then Sequentially Replace the AUXOUT Ports 2-4. After receiving the digital multimeter, continue with the test.
5) Follow these steps:
   a) Modify settings: In the [D|SPLAY] submenu, change <Monitor> to <nput>;
   b) Connect the voltage output interface of the DC voltage regulator via a signal cable to Port 1 of the AUX_|N on the rear panel.
   c) Set the output voltage of the DC voltage regulator in the following order:Voltage (V)

      10.000
      5.000

0.000

-5.000

-10.000

d) After waiting for 10 seconds, record the <AUX_|N1> reading above the screen and test the next set of data;

e) Repeat steps 5c to 5d until the AUX_|N1 test is completed. Then sequentially connect the DC regulated power supply output interface to AUX_|N2, AUX_|N3, and AUX_|N4 to finish testing these three components.

5) The testing of DC output and input is now complete. The data should be recorded in the test record sheet at the end of this chapter.

7.9 Input Noise

This test primarily evaluates the input noise of the phase-locking amplifier.

equipment

After grounding the system itself, the phase-locked amplifier can measure its own input noise. Two 50 Ω BNC resistors are connected in series between the |N+ terminals of Signal |n1 and Signal |n2 to simulate the 50 Ω source impedance scenario where the input terminal is connected to a signal source in actual operation.

step

1) First, turn off the power switch on the back, then read the <Default> settings in <Recall>;

2) Modify settings in the following order:

<Osc 1&2> 's <Osc. Mode>:	Change to <internal>
<Osc 1&2> 's <Osc. Frequency>:	Change to 1 kHz
<Signal |n 1&2> 's <ninput Range>:	Adjust to <1 mV> using the knob
<Demod 1&5> 's <Time Constant>:	Change to 10 ms
<Demod 1&5> 's <Filter dB/oct>:	Change to <24 dB/oct>
<Window Display>：	Change Window <2> to <X_Noise-Demod1> and <4> is <X_Noise-Demod5>

3) After the readings stabilize (approximately 2 minutes), record the X_Noise value (as the average).

4) Modify the following parameters in sequence:

<Osc.Frequency>
1 kHz
10 kHz
100 kHz
1 MHz

5) The input noise test is now complete. Enter the data into the test record sheet at the end of this chapter.

7.10 Performance Test Record Form

SE2022 Performance Test Record Form (1/6)

Serial number: ____________________ tester: ____________________

Firmware version: ____________________ date: ____________________

Instrument Purpose: ____

1. Start test

Pass _____ Fail _____

2. DC Bias

	Input Coupling	Reading	Upper Limit
Signal In 1		______	0.500 mV
		______	0.500 mV
Signal In 2	ACDCACDC	______	0.500 mV
		______	0.500 mV

3. Common-mode suppression

	Frequency	Reading	Upper Limit
Signal In 1	100 Hz	______	1 mV
Signal In 2	100 Hz	______	1 mV

4. Amplitude accuracy and flatness (Signal In 1)

Input Range	Amplitude	Lower	Reading	Upper
5 V	2.000 V_{rms}	1.980 V	______	2.020 V
1V	500.0 mV_{rms}	495.00 mV	______	505.00 mV
200 mV	100.00 mV_{rms}	99.00 mV	______	101.00 mV
50 mV	25.000 mV_{rms}	24.75 mV	______	25.25 mV
10 mV	5.000 mV_{rms}	4.950 mV	______	5.050 mV
2 mV	1.0000 mV_{rms}	0.990 mV	______	1.010 mV
1 mV	1.0000 mV_{rms}	0.990 mV	______	1.010 mV

Input Range	Frequency	Lower	Reading	Upper
200 mV	1.2 kHz	99 mV	______	101 mV
Amplitude	12 kHz	99 mV	______	101 mV
100.00 mV_{rms}	120 kHz	99 mV	______	101 mV
	1.2 MHz	99 mV	______	101 mV

SE2022 Performance Test Record Form (2/6)

4. Amplitude accuracy and flatness (Signal In 2)

Input Range	Amplitude	Lower	Reading	Upper
5 V	2.000 V_{rms}	1.980 V	_________	2.020 V
1 V	500.0 mV_{rms}	495.00 mV	_________	505.00 mV
200 mV	100.00 mV_{rms}	99.00 mV	_________	101.00 mV
50 mV	25.000 mV_{rms}	24.75 mV _____	25.25 mV 10 mV	5.000 mV_{rms}
4.950 mV	_____	5.050 mV		
2 mV	1.0000 mV_{rms}	0.990 mV	_________	1.010 mV
1 mV	1.0000 mV_{rms}	0.990 mV	_________	1.010 mV

Input Range	Frequency	Lower	Reading	Upper
200 mV	1.2 kHz	99 mV	_________	101 mV
Amplitude	12 kHz	99 mV	_________	101 mV
100.00 mV_{rms}	120 kHz	99 mV	_________	101 mV
	1.2 MHz	99 mV	_________	101 mV

5. Amplitude linearity

Signal In 1

Input Range	Amplitude	Lower	Reading	Upper
1V	1.000 V_{rms}	0.990 V		1.010 V
	100.0 mV_{rms}	99.00 mV		101.0 mV
	10.00 mV_{rms}	9.900 mV _____	10.10 mV 1.000 mV_{rms}	
	0.990 mV	1.010 mV		

Signal In 2

Input Range	Amplitude	Lower	Reading	Upper
1 V	1.000 V_{rms}	0.990 V	_________	1.010 V
	100.0 mV_{rms}	99.00 mV	_________	101.0 mV
	10.00 mV_{rms}	9.900 mV _____	10.10 mV 1.000 mV_{rms}	
	0.990 mV	_____ 1.010 mV		

6. Frequency Accuracy

	Frequency	Lower	Reading	Upper
REF IN 1	100 kHz	99.999 kHz	_________	100.001 kHz
REF IN 2	100 kHz	99.999 kHz	_________	100.001 kHz

SE2022 Performance Testing Record Form (3/6)

7. Accuracy and Flatness of Sine Out Amplitude-Phase

Sine Out 1 Range	SineOut Ampl.	Lower	Reading	Upper
5 V	1.600 V_{rms}	1.568 V	R: ________	1.632 V -
		2.000°	θ: ___	2.000°
200 mV	160 mV_{rms}	156.8 mV	R: ________	163.2 mV
		-2.000°	θ: ___	2.000°
50 mV	16 mV_{rms}	15.68 mV	R: ________	16.32 mV
		-2.000°	θ: ___	2.000°
2 mV	1.6 mV_{rms}	1.568 mV	R: ________	1.632 mV
		-2.000°	θ: ___	2.000°

Sine Out 2

Range	SineOut Ampl.	Lower	Reading	Upper
5 V	1.600 V_{rms}	1.568 V	R: ________	1.632 V -
		2.000°	θ: ___	2.000°
200 mV	160 mV_{rms}	156.8 mV	R: ________	163.2 mV
		-2.000°	θ: ___	2.000°
50 mV	16 mV_{rms}	15.68 mV	R: ________	16.32 mV
		-2.000°	θ: ___	2.000°
2 mV	1.6 mV_{rms}	1.568 mV	R: ________	1.632 mV
		-2.000°	θ: ___	2.000°

Sine Out 1

SineOut Ampl.	Frequency	Lower	Reading	Upper
160.0 mV_{rms}	1.2 kHz	1.568 V	R: ________	1.632 V -
			2.000° θ: ___	2.000°
12 kHz	1.568 V	R: ________	1.632 V -2.000° θ: __	2.000°
120 kHz	1.568 V	R: ________	1.632 V -2.000° θ: __	2.000°
1.2 MHz	1.568 V	R: ________	1.632 V -2.000° θ: __	2.000°

SE2022 Performance Testing Record Form (4/6)

7. Accuracy and flatness of Sine Out amplitude-phase relationship (continued from previous table)

Sine Out 2 Range	SineOut Ampl.	Lower	Reading	Upper
5 V	1.600 V_{rms}	1.568 V	R: ________	1.632 V -
		2.000°	θ: ___ 2.000°	
200 mV	160 mV_{rms}	156.8 mV	R: ________	163.2 mV
		-2.000°	θ: ___ 2.000°	
50 mV	16 mV_{rms}	15.68 mV	R: ________	16.32 mV
		-2.000°	θ: ___ 2.000°	
2 mV	1.6 mV_{rms}	1.568 mV	R: ________	1.632 mV
		-2.000°	θ: ___ 2.000°	

8. DC output and input

Output	Voltage	Lower	Reading	Upper
CH OUT 1	10.000 V	9.940 V	________	10.060 V
	5.000 V	4.965 V	________	5.035 V
	0.000 V	-0.010 V	________	0.010 V -
	5.000 V -5.035 V	___	-4. 965 V -10.000 V	-10.060 V
	___ -9.940 V			

Output	Voltage	Lower	Reading	Upper
CH OUT 2	10.000 V	9.940 V	________	10.060 V
	5.000 V	4.965 V	________	5.035 V
	0.000 V	-0.010 V	________	0.010 V -
	5.000 V -5.035 V	___	-4. 965 V -10.000 V	-10.060 V
	___ -9.940 V			

Output	Voltage	Lower	Reading	Upper
AUX OUT 1	10.000 V	9.940 V	________	10.060 V
	5.000 V	4.965 V	________	5.035 V
	0.000 V	-0.010 V	________	0.010 V -
	5.000 V -5.035 V	___	-4. 965 V -10.000 V	-10.060 V
	___ -9.940 V			

SE2022 Performance Testing Record Form (5/6)

8. DC output and input (continued from previous table)

Output	Voltage	Lower	Reading	Upper
AUX OUT 2	10.000 V	9.940 V	_________	10.060 V
	5.000 V	4.965 V	_________	5.035 V
	0.000 V	-0.010 V	_________	0.010 V
	-5.000 V	-5.035 V	_________	-4.965 V
	-10.000 V	-10.060 V	_________	-9.940 V

Output	Voltage	Lower	Reading	Upper
AUX OUT 3	10.000 V	9.940 V	_________	10.060 V
	5.000 V	4.965 V	_________	5.035 V
	0.000 V	-0.010 V	_________	0.010 V
	-5.000 V	-5.035 V	_________	-4.965 V
	-10.000 V	-10.060 V	_________	-9.940 V

Output	Voltage	Lower	Reading	Upper
AUX OUT 4	10.000 V	9.940 V	_________	10.060 V
	5.000 V	4.965 V	_________	5.035 V
	0.000 V	-0.010 V	_________	0.010 V
	-5.000 V	-5.035 V	_________	-4.965 V
	-10.000 V	-10.060 V	_________	-9.940 V

Input	Voltage	Lower	Reading	Upper
AUX IN 1	10.000 V	9.940 V	_________	10.060 V
	5.000 V	4.965 V	_________	5.035 V
	0.000 V	-0.010 V	_________	0.010 V
	-5.000 V	-5.035 V	_________	-4.965 V
	-10.000 V	-10.060 V	_________	-9.940 V

Input	Voltage	Lower	Reading	Upper
AUX IN 2	10.000 V	9.940 V	_________	10.060 V
	5.000 V	4.965 V	_________	5.035 V
	0.000 V	-0.010 V	_________	0.010 V
	-5.000 V	-5.035 V	_________	-4.965 V
	-10.000 V	-10.060 V	_________	-9.940 V

SE2022 Performance Test Record Form (6/6)

8. DC output and input (continued from previous table)

Input	Voltage	Lower	Reading	Upper
AUX IN 3	10.000 V	9.940 V	________	10.060 V
	5.000 V	4.965 V	________	5.035 V
	0.000 V	-0.010 V	________	0.010 V
	-5.000 V	-5.035 V	________	-4.965 V
	-10.000 V	-10.060 V	________	-9.940 V

Input	Voltage	Lower	Reading	Upper
AUX IN 4	10.000 V	9.940 V	________	10.060 V
	5.000 V	4.965 V	________	5.035 V
	0.000 V	-0.010 V	________	0.010 V
	-5.000 V	-5.035 V	________	-4.965 V
	-10.000 V	-10.060 V	________	-9.940 V

9. input noise

	Osc.Frequency	Input Range	Reading	Upper Limit
Signal In 1	1 kHz	1 mV		6 nV/.Hz
	10 kHz		________	4 nV/.$\overline{\text{Hz}}$
	100 kHz		________	4 nV/.$\overline{\text{Hz}}$
	1 MHz		________	4 nV/.$\overline{\text{Hz}}$

	Osc.Frequency	Input Range	Reading	Upper Limit
Signal In 2	1 kHz	1 mV	________	6 nV/.Hz
	10 kHz		________	4 nV/.$\overline{\text{Hz}}$
	100 kHz		________	4 nV/.$\overline{\text{Hz}}$
	1 MHz		________	4 nV/.$\overline{\text{Hz}}$

Chapter 8: Operational Examples

8.1 Basic Signal Measurement

This operational example will simply demonstrate how to measure the R, θ, X, and Y values of a signal using OE 2022. You need to prepare two signal lines with BNC connectors for inputting the signal under test and the reference signal. In this example, we use a function signal generator to produce a sine wave with an amplitude of 100 mV_{rms} and a frequency of 100 kHz, and measure it using SE2022. The steps are as follows:

1. Disconnect all signal cables connected to the chassis, connect the power supply, and turn on the power switch. The system will then return to its default settings.
2. Connect the output interface of the function signal generator to the |N+ interface ofSE2022's front panel S|GNAL |N 1 using a signal line with a BNC connector, and connect the synchronous reference signal interface of the function signal generator to the REF |N 1 interface ofSE2022's front panel using another signal line with a BNC connector, as shown in Figure 92:

Figure 92. Signal Line Connection Diagram

3. Turn on the power supply of the function signal generator, and set the parameters to "Waveform: Sine Wave," "Amplitude: 100 mV_{rms}," and "Frequency:" "100 kHz", "Output Impedance: High Impedance", "Synchronous Interface: Open", the waveform diagrams of the test signal and synchronization signal are shown in Figure 93:

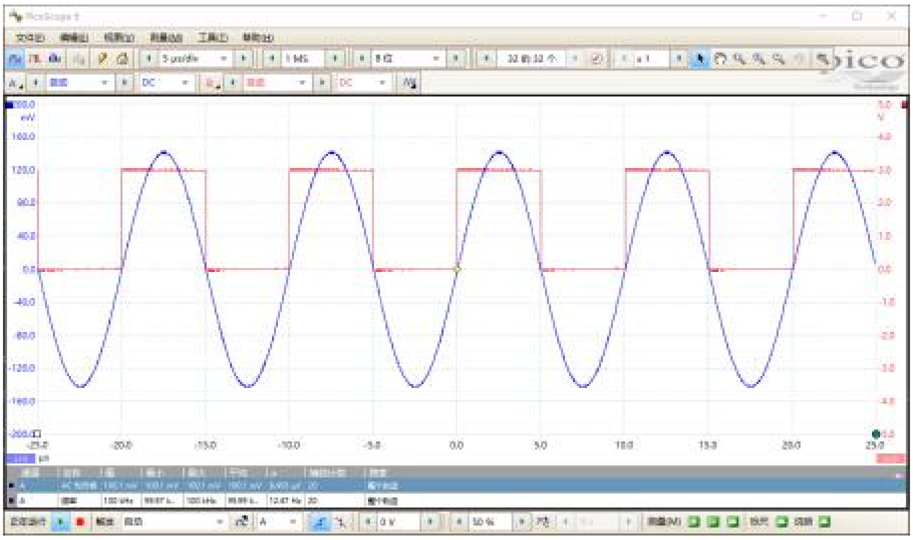
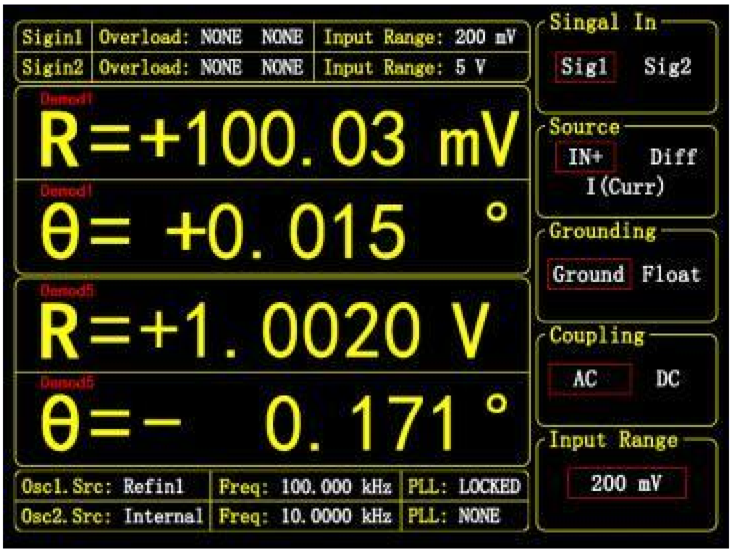


Figure 93. Waveform Diagram of the Signal to Be Measured

4. Enable the function signal generator output and check if the <Overload> status bar in the main interface indicates overflow:

If the upstream input overflows, display Overload:|NPUT NONE; if the amplification overflows, display Overload: NONE GA|N; if both overflow, display Overload:|NPUT GA|N.

When overflow occurs in the前置 stage, immediately reduce the output amplitude of the digital signal generator; for amplification overflow, promptly adjust the gain value (SE2022 input).



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1
R=+100.03 mV

Demod1
θ= +0.015 °

Demod5
R=+1.0020 V

Demod5
θ=- 0.171 °

Osc1.Src: Refin1 Freq: 100.000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 10.0000 kHz PLL: NONE

Figure 94. Main Interface Status Bar

Pre-stage overflow occurs when the peak value exceeds 7 V or the valley value falls below-7 V (the peak-to-valley level corresponding to a maximum range of 5 V_{rms}). Therefore, in this example, the digital signal generator will not experience overflow when outputting a sine wave with an amplitude of 100 mV_{rms}. However, overflow conditions should be carefully monitored when measuring other signals. Methods for adjusting sensitivity values are detailed below.

5. Adjust the input range. Press the [S|GNAL |NPUT] key on the front panel to enter the submenu.

Figure 95. [S|GNAL |NPUT] Kitchen Unit Placement

The [S|GNAL |NPUT] submenu interface is as follows:

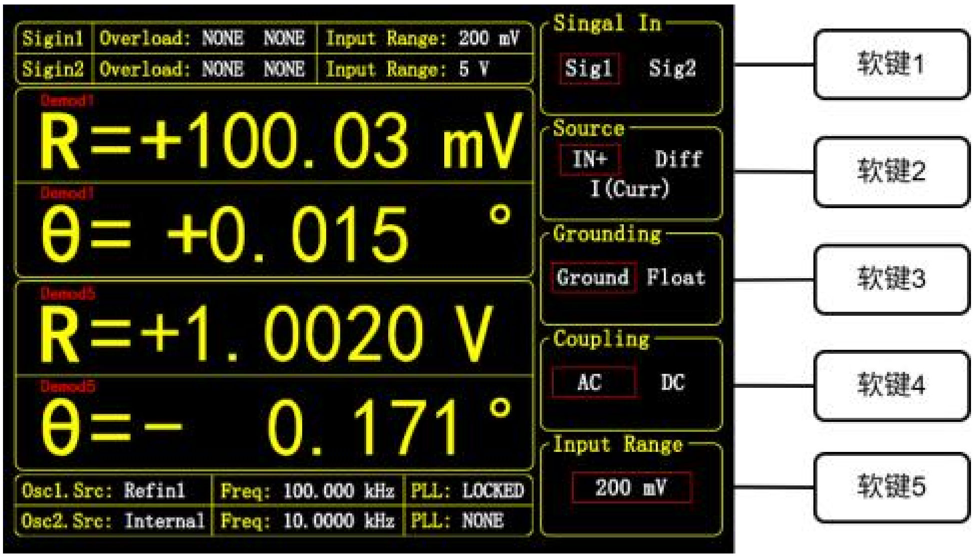

Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V
Demod1
R=+100.03 mV
Demod1
θ= +0.015 °
Demod5
R=+1.0020 V
Demod5
θ=- 0.171 °
Osc1.Src: Refin1 Freq: 100.000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 10.0000 kHz PLL: NONE

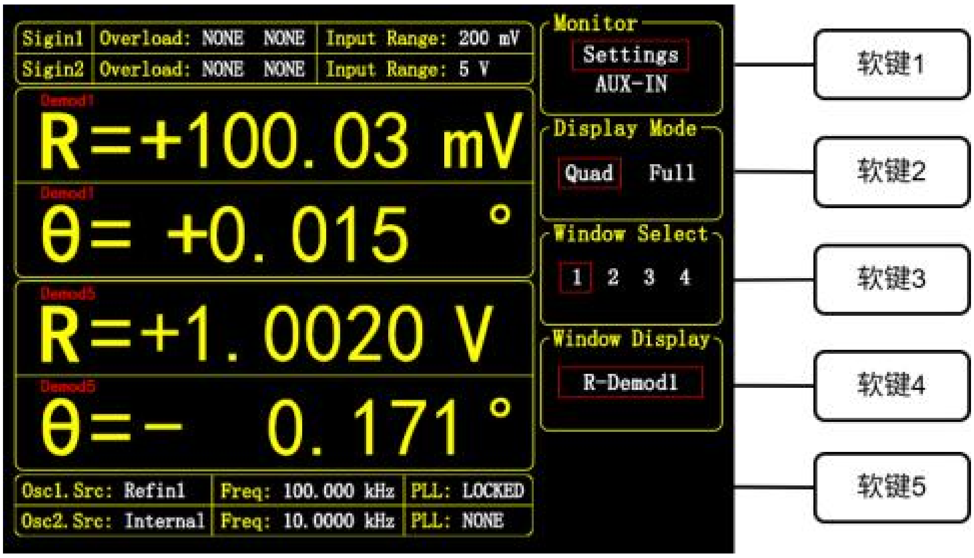
Figure 96. [S|GNAL |NPUT] Menu Interface

Press "Soft Key 5" to activate the <ninput Range> function. The selected area will be highlighted, and adjust the <ninput Range> value by rotating the knob to bring the measured signal value as close as possible to the input range without overflow. Here, we set it to <200 mV>. At this point, we have measured the sine wave signal generated by the function signal generator. As shown in Figure 96, the measured values are: R = 100.03 mV, θ = 0.015°.

6. The main interface data bar displays <R>, < θ >, <X>, and <Y> values. Press the front panel [D|SPLAY] key to enter the submenu.

Figure 97. [D|SPLAY] Dish Unit Position

The [DISPLAY] submenu interface is as follows:



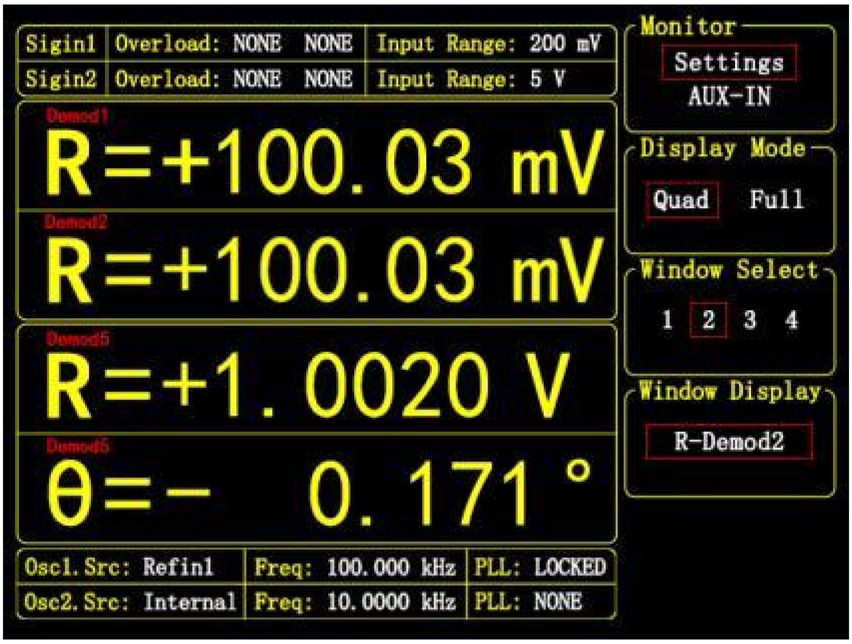
Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1 R=+100.03 mV
Demod1 θ= +0.015 °
Demod5 R=+1.0020 V
Demod5 θ=- 0.171 °

Osc1.Src: Refin1 Freq: 100.000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 10.0000 kHz PLL: NONE

Figure 98. [DISPLAY] Menu Interface

In the system's default settings, the data bar displays four columns showing the <R> and < θ > values of Demod1 and Demod5 respectively. The displayed values can be modified using the following method: Press the "soft key 3" in the [Display] submenu to switch between <Window Select> menu items <1>, <2>, <3>, and <4>. For example, selecting <2> indicates the second sub-column is selected. Then press "soft key 4" to access the <Window Display> menu, where you can adjust the display to show the "R_Demod2" value via the knob. After modification, as shown in Figure 99, this method allows you to view the desired measurement results.



Sigin1 Overload: NONE NONE Input Range: 200 mV
Sigin2 Overload: NONE NONE Input Range: 5 V

Demod1 R=+100.03 mV
Demod2 R=+100.03 mV
Demod5 R=+1.0020 V
Demod5 θ=- 0.171 °

Osc1.Src: Refin1 Freq: 100.000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 10.0000 kHz PLL: NONE

Figure 99. Modify Column Display Results

8.2 Harmonic Measurement

This example demonstrates how to measure the harmonic components of an input signal. Prepare two signal lines with BNC connectors for the test signal and reference signal. For illustration, use a function signal generator to produce a square wave with an amplitude of 160 mVpp and a frequency of 1 kHz, and measure its first through eighth harmonics using the SE2022. The steps are as follows:

1. Disconnect all signal cables connected to the chassis, connect the power supply, and turn on the power switch. The system will then return to its default settings.
2. Connect the output interface of the function signal generator to the |N+ port of SE2022's front panel S|GNAL |N 1 using a signal line with a BNC connector, and connect the reference signal interface of the function signal generator to the REF |N 1 port of the front panel using another signal line with a BNC connector, as shown in Figure 100:

Figure 100. Signal Line Connection Diagram

3. Turn on the power supply of the function signal generator, set the parameters to "Waveform: Square Wave", "Amplitude: 160 mV_{pp}", and "Frequency: 1 kHz". The waveform diagram of the signal under test is shown in Figure 101:

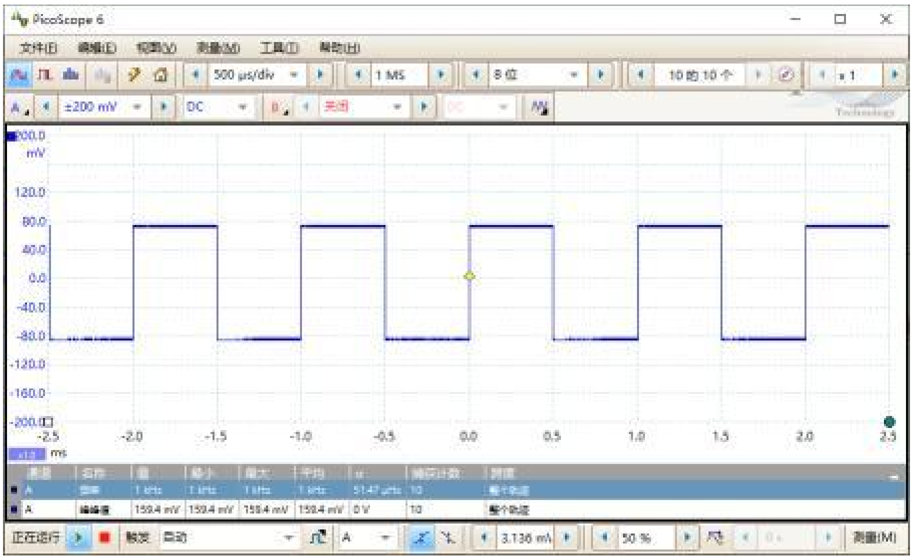


Figure 101. Parameter Diagram of the Signal to Be Measured

4. Press the front panel [DEMOD REF] button (shown in Figure 102) to access the submenu.

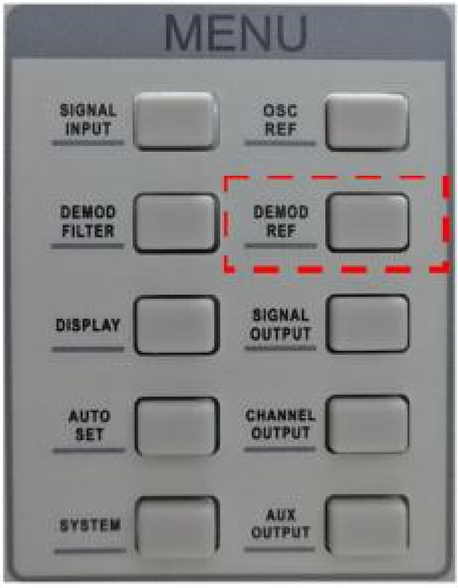
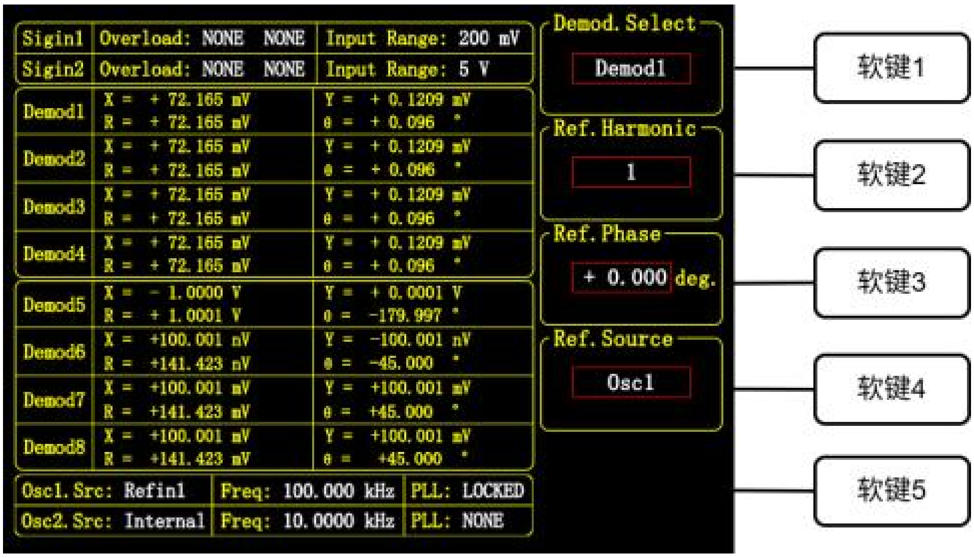


Figure 102. [DEMOD] Subunit Positioning

[DEMOD REF] The submenu interface is shown in Figure 103:



Sigin1	Overload: NONE NONE	Input Range: 200 mV
Sigin2	Overload: NONE NONE	Input Range: 5 V
Demod1	X = + 72.165 mV R = + 72.165 mV	Y = + 0.1209 mV θ = + 0.096 °
Demod2	X = + 72.165 mV R = + 72.165 mV	Y = + 0.1209 mV θ = + 0.096 °
Demod3	X = + 72.165 mV R = + 72.165 mV	Y = + 0.1209 mV θ = + 0.096 °
Demod4	X = + 72.165 mV R = + 72.165 mV	Y = + 0.1209 mV θ = + 0.096 °
Demod5	X = - 1.0000 V R = + 1.0001 V	Y = + 0.0001 V θ = -179.997 °
Demod6	X = +100.001 nV R = +141.423 nV	Y = -100.001 nV θ = -45.000 °
Demod7	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °
Demod8	X = +100.001 mV R = +141.423 mV	Y = +100.001 mV θ = +45.000 °

Osc1.Src: Refin1	Freq: 100.000 kHz	PLL: LOCKED
Osc2.Src: Internal	Freq: 10.0000 kHz	PLL: NONE

Demod.Select: Demod1

Ref.Harmonic: 1

Ref.Phase: + 0.000 deg.

Ref.Source: Osc1

Figure 103. DEMOD REF Submenu

In the <Ref. Harmonic> menu, set the harmonic order measured by each demodulator; select the desired harmonic order using the keyboard.

5. The operation method for simultaneously measuring the 1st to 8th harmonics of the input square wave is as follows: In the [DEMOD REF] submenu, press "Soft Key 1" to select 8 demodulator channels, then press "Soft Key 2" to open the harmonic setting window. You can modify the harmonic order of the current demodulator channel and set the harmonic order of demodulators 1-8 to 1-8 respectively.

6. Then in the [DISPLAY] submenu, press Soft Key 2 to set <Display Mode> to <Full> mode, as shown in Figure 104, to display the measurement results of all fundamental and harmonic waves.

Calculation of harmonic theoretical values for square waves: Given that the peak-to-peak voltage of a square wave is E and its angular frequency is ω, the Fourier expansion yields the following expression:

$$f\,(t) = \frac{2E}{\pi}\left(\sin(\omega t) + \frac{1}{3}\sin(3\omega t) + \frac{1}{5}\sin(5\omega t)\cdots + \frac{1}{n}\sin(n\omega t)\right)$$

Sigin1	Overload: NONE NONE	Input Range: 200 mV
Sigin2	Overload: NONE NONE	Input Range: 5 V

Demod1	X = + 72.165 mV R = + 72.165 mV	Y = + 0.1209 mV θ = + 0.096 °
Demod2	X = + 0.3880 uV R = + 0.3962 uV	Y = + 80.044 nV θ = + 11.655 °
Demod3	X = + 24.078 mV R = + 24.078 mV	Y = + 0.1083 mV θ = + 0.258 °
Demod4	X = + 0.1555 uV R = + 0.1595 mV	Y = + 24.921 nV θ = + 9.003 °
Demod5	X = + 14.457 mV R = + 14.458 mV	Y = + 0.1041 mV θ = + 0.412 °
Demod6	X = + 0.1557 uV R = + 0.1744 uV	Y = + 78.521 nV θ = + 26.759 °
Demod7	X = + 10.332 mV R = + 10.333 mV	Y = + 0.1006 mV θ = + 0.558 °
Demod8	X = + 0.1255 uV R = + 0.1281 uV	Y = + 25.611 nV θ = + 11.537 °

Osc1. Src: RefIn1	Freq: 100.000 kHz	PLL: LOCKED
Osc2. Src: Internal	Freq: 10.0000 kHz	PLL: NONE

Demod. Select: Demod1

Ref. Harmonic: 1

Ref. Phase: + 0.000 deg.

Ref. Source: Osc1

Figure 104. Harmonic Measurement Results of a Square Wave

Its n-th harmonic is the sine wave:

$$f(t) = \frac{2E}{n\pi}\sin(n\omega t)$$

Therefore, the RMS value of the n-th harmonic is obtained as:

$$R = \frac{\sqrt{2}E}{n\pi}$$

In this example, the square wave's peak-to-peak voltage E is 160 mV.

1 The calculated value of the second harmonic is:R $= \frac{\sqrt{2}\times 160}{1\times\pi}$ mV ≈ 72.025 mV

3 The calculated value of the second harmonic is:R $= \frac{\sqrt{2}\times 160}{3\times\pi}$ mV ≈ 24.008 mV

5 The calculated value of the second harmonic is:R $= \frac{\sqrt{2}\times 160}{5\times\pi}$ mV ≈ 14.405 mV

7 The calculated value of the second harmonic is:R $= \frac{\sqrt{2}\times 160}{7\times\pi}$ mV ≈ 10.203 mV

The theoretical values of the 2nd, 4th, 6th, and 8th harmonics are 0 V.

According to the above algorithm, the measured values can be compared with the theoretical calculated values. As shown in the measurement results of Figure 104, the measured values are consistent with the theoretical values.

8.3 AM Demodulation Measurement

AM modulation is a modulation method that varies the amplitude of the carrier wave according to the variation pattern of the desired transmitted signal while maintaining a constant frequency. The modulated signal has a long propagation distance but exhibits poor anti-interference capability.

Modulated signal:U_m(t) =A_m cos $_m$ t

Carrier signal:U_c(t) =A_c cos w $_c$ t

The modulated signal is:

$$U\ (t) = (A_c + A_m \cos w_m t) * \cos w_c t \quad = A_c * (1 + \frac{A_m}{A_c} \cos w_m t) * \cos w_c t$$

Where A_c is the amplitude of the carrier wave, w $_c$ is the frequency of the carrier wave;A_m is the amplitude of the modulated wave, w $_m$ is the frequency of the modulated wave; the modulation depth m is defined as $\frac{A_m}{A_c}$.

Further conversion:

$$U\ (t) = A_c * (1 + m \cos wmt) * \cos w_c t$$

$$= A_c * \cos \omega_c t + \frac{mA_c}{2} * \cos(\omega_c - \omega_m)\,t + \frac{mA_c}{2} * \cos(\omega_c + \omega_m)\,t$$

It can be observed that the AM modulated signal contains three frequency information components, namely (1)$_c$, (2)(1)$_{c\_}$ w $_m$, and (1)$_c$+ (1)$_m$. By simultaneously demodulating these three frequency information components using the three demodulators of a phase-locked amplifier, the signals A_c and$\frac{mA_c}{2}$ The result yields the amplitude information of both the carrier wave and the modulated wave.

The actual demodulation operation is as follows:

1. The function generator is configured in AM modulation mode, using a sine wave with 100 kHz frequency and 200 mV $_{rms}$ as the carrier wave, and a sine wave with 10 kHz frequency and 100% modulation depth as the modulating wave. Note that when operating in AM modulation mode, the carrier wave amplitude is halved regardless of the modulation depth settings. For example, if the current setting is 200 mV$_{rms}$, the actual amplitude will be only 100 mV$_{rms}$. The waveform output from the function generator is shown in Figure 105:

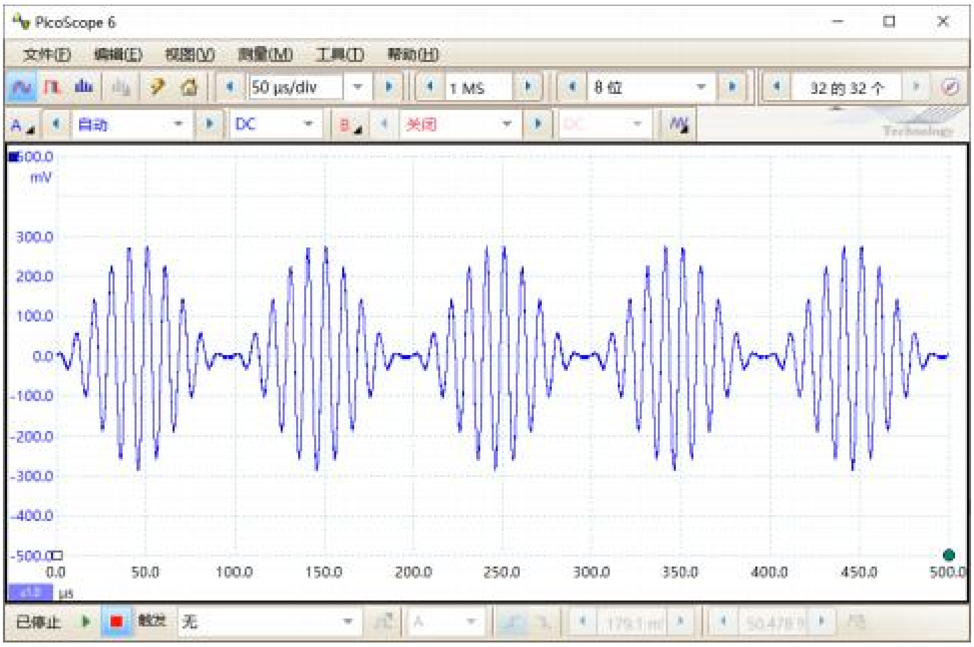


Figure 105. Waveform of AM Modulated Signal

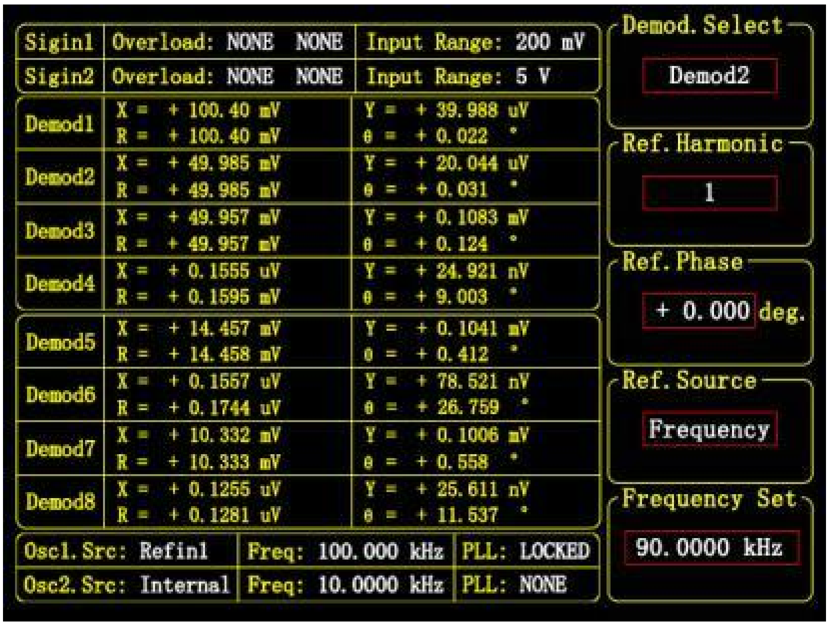
2. In SE2022, press the front panel [DEMOD REF] button to access the submenu.
3. Set separately:

   The demodulator Demod1 is <Osc1>;

   The <Ref.Source> of demodulator Demod2 is <Frequency>, and the <Frequency Set> is 90.0000 kHz;

   The Demod3 demodulator has a <Ref.Source> of <Frequency> and a <Frequency Set> of 110.000 kHz;

At this time, the three demodulators ofSE2022 will demodulate the frequency components of 100 kHz, 90 kHz, and 110 kHz respectively, as shown in Figure 106:



Sigin1 | Overload: NONE NONE | Input Range: 200 mV
Sigin2 | Overload: NONE NONE | Input Range: 5 V

Demod1	X = + 100.40 mV R = + 100.40 mV	Y = + 39.988 uV θ = + 0.022 °
Demod2	X = + 49.985 mV R = + 49.985 mV	Y = + 20.044 uV θ = + 0.031 °
Demod3	X = + 49.957 mV R = + 49.957 mV	Y = + 0.1083 mV θ = + 0.124 °
Demod4	X = + 0.1555 uV R = + 0.1595 mV	Y = + 24.921 nV θ = + 9.003 °
Demod5	X = + 14.457 mV R = + 14.458 mV	Y = + 0.1041 mV θ = + 0.412 °
Demod6	X = + 0.1557 uV R = + 0.1744 uV	Y = + 78.521 nV θ = + 26.759 °
Demod7	X = + 10.332 mV R = + 10.333 mV	Y = + 0.1006 mV θ = + 0.558 °
Demod8	X = + 0.1255 uV R = + 0.1281 uV	Y = + 25.611 nV θ = + 11.537 °

Osc1. Src: Refin1 | Freq: 100.000 kHz | PLL: LOCKED
Osc2. Src: Internal | Freq: 10.0000 kHz | PLL: NONE

Demod. Select: Demod2
Ref. Harmonic: 1
Ref. Phase: + 0.000 deg.
Ref. Source: Frequency
Frequency Set: 90.0000 kHz

Figure 106. AM Demodulator Measurement Results

4. The results are R_Demod1 = 100.4 mV$_{rms}$,R_Demod2 = 49.985 mV$_{rms}$,R_Demod3 = 49.957 mV$_{rms}$. The converted carrier amplitude is 100.4 mV$_{rms}$, the modulated wave amplitude is 99.942 mV$_{rms}$, and the modulation depth is 99.54%, which is consistent with theoretical expectations.

8.4 Serial Communication

This example demonstrates how to set up and debug the SE2022 remote control serial/USB 2.0 environment. You will need a USB 2.0 Type-B cable or a USB-to-RS232 adapter cable. The steps are as follows:

1. Connect the SE2022's USB port to any USB port on your computer using a USB cable.
2. The computer will automatically detect the USB device and prompt you to install the driver.
3. Open the Uart_Assistant folder in the U disk, double-click the UartAssist.exe file, and the software interface will pop up as shown in Figure 107:

This serial port debugging software includes communication settings, receive area settings, send area settings, the receive area, and the send area.

The default baud rate for the SE2022 serial port is 921600, with no parity bit, 8 data bits, and 1 stop bit (the baud rate and parity bit settings for SE2022 can be configured via the RS232 menu option on the front panel menu).

Since the USB 2.0 driver operates as a virtual serial port, similar to RS232 serial ports, you must select the COM port automatically assigned by the SE2022 computer. The COM port numbering can be viewed through the Ports (COM and LPT) option in Device Manager (right-click the computer → Properties → Device Manager → Ports), as shown in Figure 108:

串口号 COM5
波特率 921600
校验位 NONE
数据位 8
停止位 1
发送间隔 1000 毫秒

Figure 107. Software Interface of UartAssist

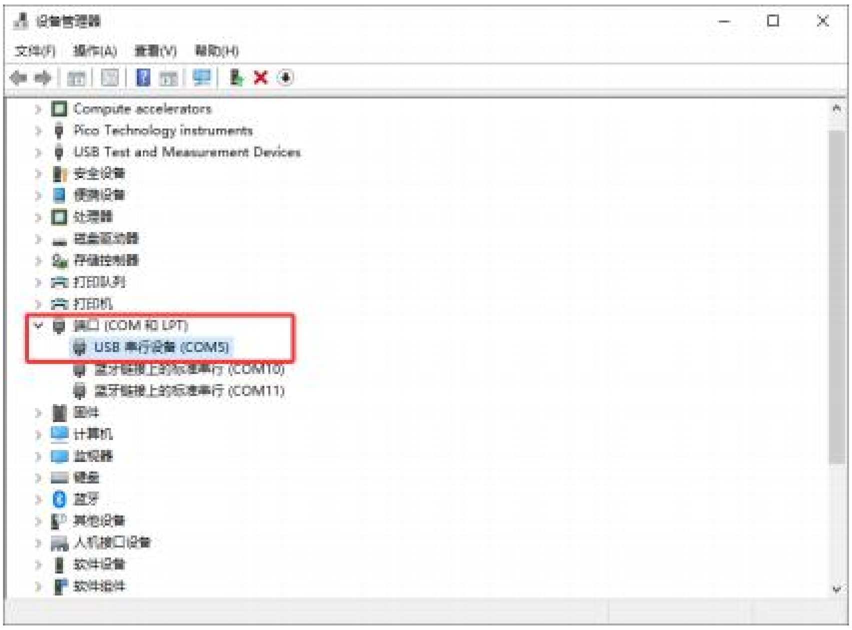


Figure 108. Port Number View

After configuring the port number, baud rate, parity bit, data bits, and stop bit, if the small circle on the left side of the connection button is in a black off state (● 打开), requiring a single click to change the button status to a red illuminated state(● 关闭) If the button lights up red, it indicates that the computer has successfully connected to the current serial port device. If multiple connection attempts fail, please verify that the port number is correctly selected before trying again. The successful connection is shown in Figure 109:

4. After completing the above operations, you can communicate with the SE2022 by sending commands:

串口号 COM5

波特率 921600

校验位 NONE

数据位 8

停止位 1

发送间隔 1000 毫秒

发送 : 0

接收 : 0

串口号修改为COM5

波特率修改为921600

点击连接

Figure 109. Successful Connection Status

The SE2022 instruction format consists of four uppercase letter mnemonics followed by option parameters, such as the instruction "ISRC1,1;" or "*IDN?; + Enter character (0D)". Multiple consecutive instructions can be separated by a semicolon (";"). Each instruction must end with a semicolon (";") or an Enter character (hexadecimal 0D). For detailed instructions, refer to the Remote Programming section.

To send an instruction, first enter the instruction in the sending field, then type the semicolon (;), and finally click the send button to transmit the instruction. As shown in Figure 110:

Meanwhile, the serial port debugging assistant can be configured to automatically add the carriage return character 0X 0D. To enable this feature, check the "Auto Send Additional Bits" option in the transmission area settings. In the pop-up additional bits configuration window, select fixed bits and set the additional value to the hexadecimal value "0D". The configuration is illustrated in Figure 111:

串口号 COM5
波特率 921600
校验位 NONE
数据位 8
停止位 1

☐ 接收转向文件...
☐ 显示接收时间
☐ 十六进制显示
☐ 暂停接收显示

☐ 启用文件数据源...
☑ 自动发送附加位
☐ 发送完自动清空
☐ 按十六进制发送
☐ 数据流循环发送
发送间隔 1000 毫秒

串口数据接收

Sine Scientific Instruments,SE2022,SN:LD621052530,Ver:S26.203.13-126.203.4-A25A

串口助手接收的返回信息

*IDN?;

发送的指令

就绪! 发送:7 接收:80

Figure 110. Sending and Receiving Commands in ASCII Code Format

串口号 COM5
波特率 921600
校验位 NONE
数据位 8
停止位 1

☐ 接收转向文件...
☐ 显示接收时间
☐ 十六进制显示
☐ 暂停接收显示

☐ 启用文件数据源...
☑ 自动发送附加位
☐ 发送完自动清空
☐ 按十六进制发送
☐ 数据流循环发送
发送间隔 1000 毫秒

附加位设置

附加位设置
○ 负校验 （附加位字节的值为其他所有字节和的负数）
○ 正校验 （附加位字节的值为其他所有字节的和）
● 固定位 （附加位字节的值为固定的16进制数：0D H）

就绪! 发送:0 接收:0

Figure 111. Setting of Additional Bits

Multiple commands require the addition of semicolons (";") for separation. For example, sending the command "IGND1,1; IGND?1; OUTP?2; SENS?0;" produces the effect shown in Figure 112:

By continuously reading the X, Y, R, and θ values ofSE2022, you can set the interval transmission for the serial port debugging assistant software. The configuration is shown in Figure 113.

串口号 COM5
波特率 921600
校验位 NONE
数据位 8
停止位 1
☐ 启用文件数据源...
☑ 自动发送附加位
☐ 发送完自动清空
☐ 按十六进制发送
☐ 数据流循环发送
发送间隔 1000 毫秒

串口数据接收

```
1
1.0041468e-01
29
```

依次返回查询的结果

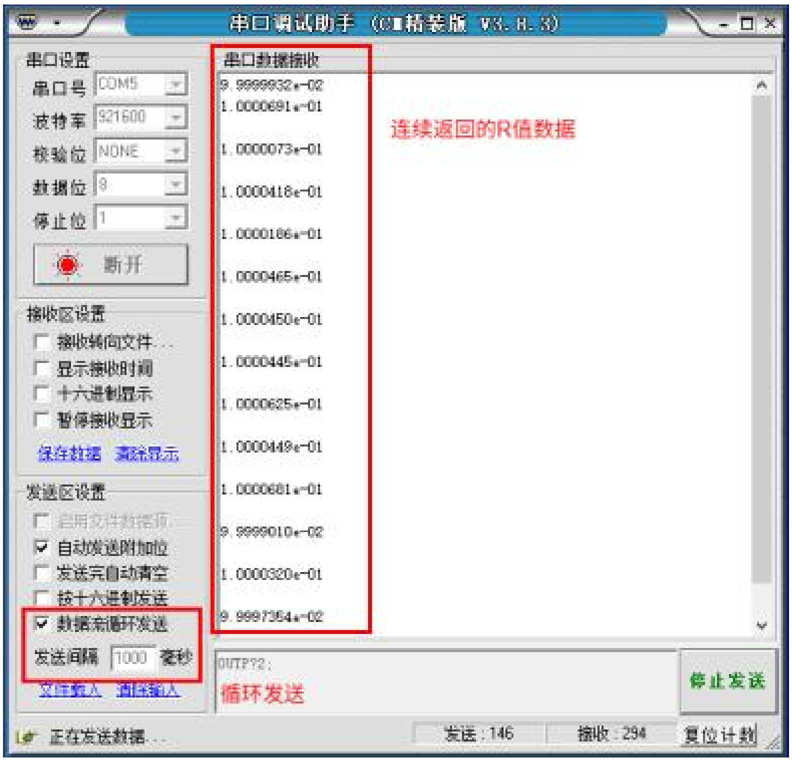
多个指令用 ";" 号隔开

```
IGND1,1;IGND?1;OUTP?2;SENS?0;
```

就绪! 发送：30 接收：19

Figure 112. Execution of Multiple Instructions

As Shown in Figure 114:



串口号 COM5
波特率 921600
校验位 NONE
数据位 8
停止位 1
☐ 启用文件数据源
☑ 自动发送附加位
☐ 发送完自动清空
☐ 按十六进制发送
☑ 数据流循环发送
发送间隔 1000 毫秒

串口数据接收

```
9.9999932e-02
1.0000691e-01

1.0000073e-01

1.0000418e-01

1.0000186e-01

1.0000465e-01

1.0000450e-01

1.0000445e-01

1.0000625e-01

1.0000449e-01

1.0000681e-01

9.9999010e-02

1.0000320e-01

9.9997354e-02
```

连续返回的R值数据

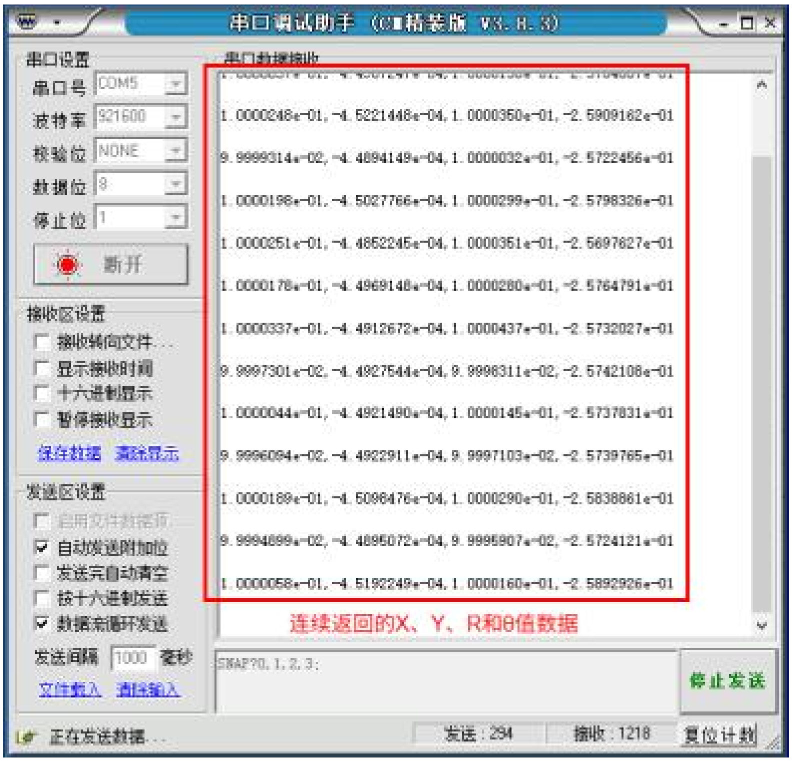
```
OUTP?2;
```

循环发送

正在发送数据... 发送：146 接收：294

Figure 113. Continuous Reading of a Single R Value

When setting internal parameters of the SE2022 through remote command transmission via the serial port debugging assistant, the corresponding parameter status on the LCD display is updated simultaneously. For example, if the current <Input Range> value in the OE 2022 status bar is <5 V> with the corresponding command IRNG, the parameter



串口号 COM5
波特率 921600
校验位 NONE
数据位 8
停止位 1

☐ 接收转向文件...
☐ 显示接收时间
☐ 十六进制显示
☐ 暂停接收显示

☐ 启用文件数据源
☑ 自动发送附加位
☐ 发送完自动清空
☐ 按十六进制发送
☑ 数据流循环发送

发送间隔 1000 毫秒

```
1.0000248e-01,-4.5221448e-04,1.0000350e-01,-2.5909162e-01
9.9999314e-02,-4.4894149e-04,1.0000032e-01,-2.5722456e-01
1.0000198e-01,-4.5027766e-04,1.0000299e-01,-2.5798326e-01
1.0000251e-01,-4.4852245e-04,1.0000351e-01,-2.5697627e-01
1.0000178e-01,-4.4969148e-04,1.0000280e-01,-2.5764791e-01
1.0000337e-01,-4.4912672e-04,1.0000437e-01,-2.5732027e-01
9.9997301e-02,-4.4927544e-04,9.9998311e-02,-2.5742108e-01
1.0000044e-01,-4.4921490e-04,1.0000145e-01,-2.5737831e-01
9.9996094e-02,-4.4922911e-04,9.9997103e-02,-2.5739765e-01
1.0000189e-01,-4.5096476e-04,1.0000290e-01,-2.5838861e-01
9.9994899e-02,-4.4895072e-04,9.9995907e-02,-2.5724121e-01
1.0000058e-01,-4.5192249e-04,1.0000160e-01,-2.5892926e-01
```

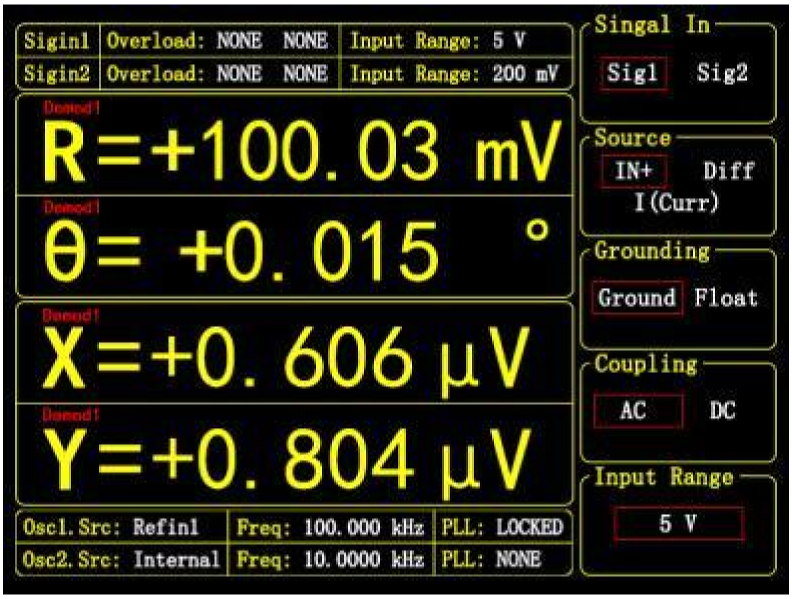
连续返回的X、Y、R和θ值数据

```
SNAP?0,1,2,3;
```

正在发送数据...
发送：294
接收：1218

Figure 114. Continuous Reading of X, Y, R, and Θ Values

Set to 0. After sending the command "IRNG2,2", the <Input Range> value in the SE2022 status bar will change to the corresponding value specified in the command parameter <200 mV>. The screen interface is shown in Figure 115:



Sigin1 Overload: NONE NONE Input Range: 5 V
Sigin2 Overload: NONE NONE Input Range: 200 mV

R=+100.03 mV
θ= +0.015 °
X=+0.606 μV
Y=+0.804 μV

Oscl.Src: Refin1 Freq: 100.000 kHz PLL: LOCKED
Osc2.Src: Internal Freq: 10.0000 kHz PLL: NONE

Figure 115. Interface for Modifying the Input Range Value

Other serial debugging tools of the same type also support remote debugging, with similar operational steps.