OE2031
DSP Lock-In Amplifier
User Manual

SSI SINE SCIENTIFIC INSTRUMENTS

Revision 1.3.1, 2026-06-17

Contents

Revision History

Version Revision 1.3.1 Update, 2026-06-17

1. Corrected part of technical parameters, including the number of demodulators and the minimum resolution of the AUX IN and AUX OUT channels;
2. Added the description of the TTL OUT interface;
3. Corrected the command descriptions for AMSR/FMSR/PMSR and *PLL?, with the corresponding command parameters unchanged;
4. Refined part of wording and descriptions.

Revision 1.3.0, 2026-02-28

Adjusted part of the document formatting and refined the terminology explanation in the noise measurement section.

Revision 1.2.1, 2025-12-18

Added the description of the MARF command.

Revision 1.2.0, 2025-11-23

The user manual has been revised to accommodate the new user interface and the LIA_Liuxi_Console host-computer software. This revision covers a broad range of updates; users are advised to read the manual again in full.

Parameter upgrades: the bandwidth has been extended to 80 MHz; the input range and output amplitude have been extended to 2 V_{rms}; the REFIN interface now supports a selectable 50 Ω impedance; the number of oscillators has been increased to two; and the number of demodulators has been increased to six.

Revision 1.1.1, 2023-06-26

Added descriptions of oscillator clock parameters; added data-rate descriptions for AUX IN and AUX OUT; and added parameter descriptions for auxiliary interfaces such as Clock Input.

Chapter 1 Technical Specifications

1.1 Signal Channel

- Input mode — Single-ended (IN+) or differential (DIFF) voltage input
- Sensitivity — 1 nV to 2 V_{rms}
- Input impedance — 50 Ω || 10 pF or 10 MΩ || 10 pF
- Input coupling
  - 50 Ω input impedance — AC coupling, cutoff frequency 160 Hz; DC coupling
  - 10 MΩ input impedance — AC coupling, cutoff frequency 0.16 Hz; DC coupling
- Shield grounding — Ground or float (1 kΩ)
- CMRR — >80 dB (< 100 kHz)
  >70 dB (@ 1 MHz)
  >50 dB (@ 10 MHz)
- Dynamic reserve — 120 dB
- Gain accuracy — 0.5% (typ.) (< 1 MHz), 3% (max.)
- Voltage noise
  - 10 kHz — 4 nV/$\sqrt{\text{Hz}}$ (typ.)
  - 100 kHz — 3.5nV/$\sqrt{\text{Hz}}$ (typ.)
  - 1 MHz — 3 nV/$\sqrt{\text{Hz}}$ (typ.)
  - 10 MHz — 3 nV/$\sqrt{\text{Hz}}$ (typ.)

1.2 Reference Channel

- Input
  - Frequency range — 10 µHz to 10 MHz
  - Supported waveforms — Square wave or sine wave
  - Input impedance — 50 Ω or 1 MΩ
  - Square ref. levels — $-0.1\,V < V_L < 0.5\,V$, $3\,V < V_H < 5\,V$
  - Sine ref. signal — Frequency > 1 Hz
    100 mV < VPP < 10 V
- Phase
  - Resolution — 1 µ°
  - Phase error — 1° (typ.) (< 1 MHz), 5° (max.)
  - Temperature coefficient — < 200 ppm/°C
- Harmonic detection — 1~10 000 (nF < 10 MHz)
- Acquisition time
  - Internal reference — Immediate
  - External reference — 100 cycles (> 1 kHz); 10 cycles (< 1 kHz)

1.3 Demodulator

• Number of demodulators	6
• Demodulator resolution	64 bit
• Stability	
Digital output	No zero drift
Display	No zero drift
Analog output	<200 ppm/°C
• Filter bandwidth	50 µHz to 1.6 MHz
• Filter time constant	100 ns to 3 ks
• Filter roll-off	6, 12, 18, 24, 30, 36, 42, and 48 dB/oct selectable
• Synchronous filter	Available below 1 MHz and roll-off above 18 dB/oct

1.4 Internal Oscillator and Output

• Internal oscillator	
Number	2
Accuracy	0.3 ppm
Temperature stability	0.5 ppm/°C
Aging rate	< 1 ppm/year
Phase noise	−145 dBc/Hz (@ 1 kHz)
• Output frequency	
Range	DC to 10 MHz
Accuracy	2 ppm + 1 µHz
Resolution	1 nHz
• Harmonic distortion	−75 dBFS (f = 100 kHz); −60 dBFS (f = 1 MHz)
• Sine output	
Amplitude	1 μV_{rms} to 2 V_{rms}
Accuracy	0.5% (typ.) (f < 1 MHz), 3% (max.) ± 50 μV_{rms}
Resolution	0.1 μV_{rms}
Drive capability	± 70 mA (max.)
Temperature stability	< 200 ppm/°C
Output impedance	50 Ω
• Internal DC offset	−3 V to 3 V DC
• External offset interface	Accepts voltage signals from −10 V to 10 V
• Sync output	3.3 V TTL/CMOS (50 Ω)
• Additional functions	AM/FM/PM signal modulation output

1.5 Display

- Screen

Screen size	5.6-inch, 640×480 TFT-LCD
Screen format	Dual-column graph / full-data display
Display values	X, Y, R, and θ
Display type	Data display formats, bar graphs
Color style	Yellow / green

1.6 Auxiliary Inputs and Outputs

- AUX Inputs

Function	4-channel input
Amplitude	± 10 V, 0.3 mV resolution, 0.5% + 10 mV accuracy
Impedance	1 MΩ
Sampling rate	312.5 kSa/s

- AUX Outputs

Function	4-channel output
Amplitude	± 10 V, 0.3 mV resolution, 0.5% + 10 mV accuracy
Drive current	± 30 mA max
Output rate	1 MSa/s

- Clock Input

Function	External 10 MHz clock input port
Level	3.3 V TTL/CMOS

- Clock Output

Function	10 MHz clock output port
Level	3.3 V TTL/CMOS

- Trigger Input

Function	Trigger signal input port for the lock-in amplifier
Level	3.3 V TTL/CMOS

- Trigger Output

Function	Trigger signal output port for other devices
Level	3.3 V TTL/CMOS

- Monitor Output

Function	Mirror signal output before the ADC in the analog chain
Drive current	± 40 mA max

1.7 Communication Interfaces

• RS-232	9-pin female connector
• USB2.0	USB2.0 high-speed
• Ethernet	RJ45,1000Mbps

1.8 Others

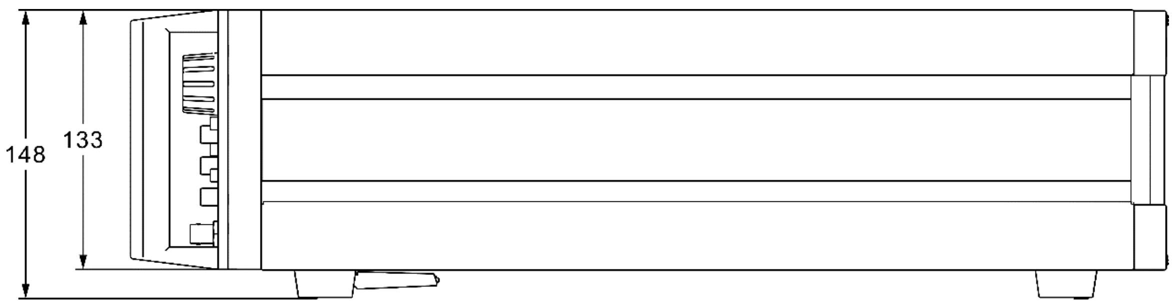
- Power requirements

Voltage	100~240 V AC
Frequency	50 Hz / 60 Hz
Power	50 W (typ.), max. ≤ 70 W

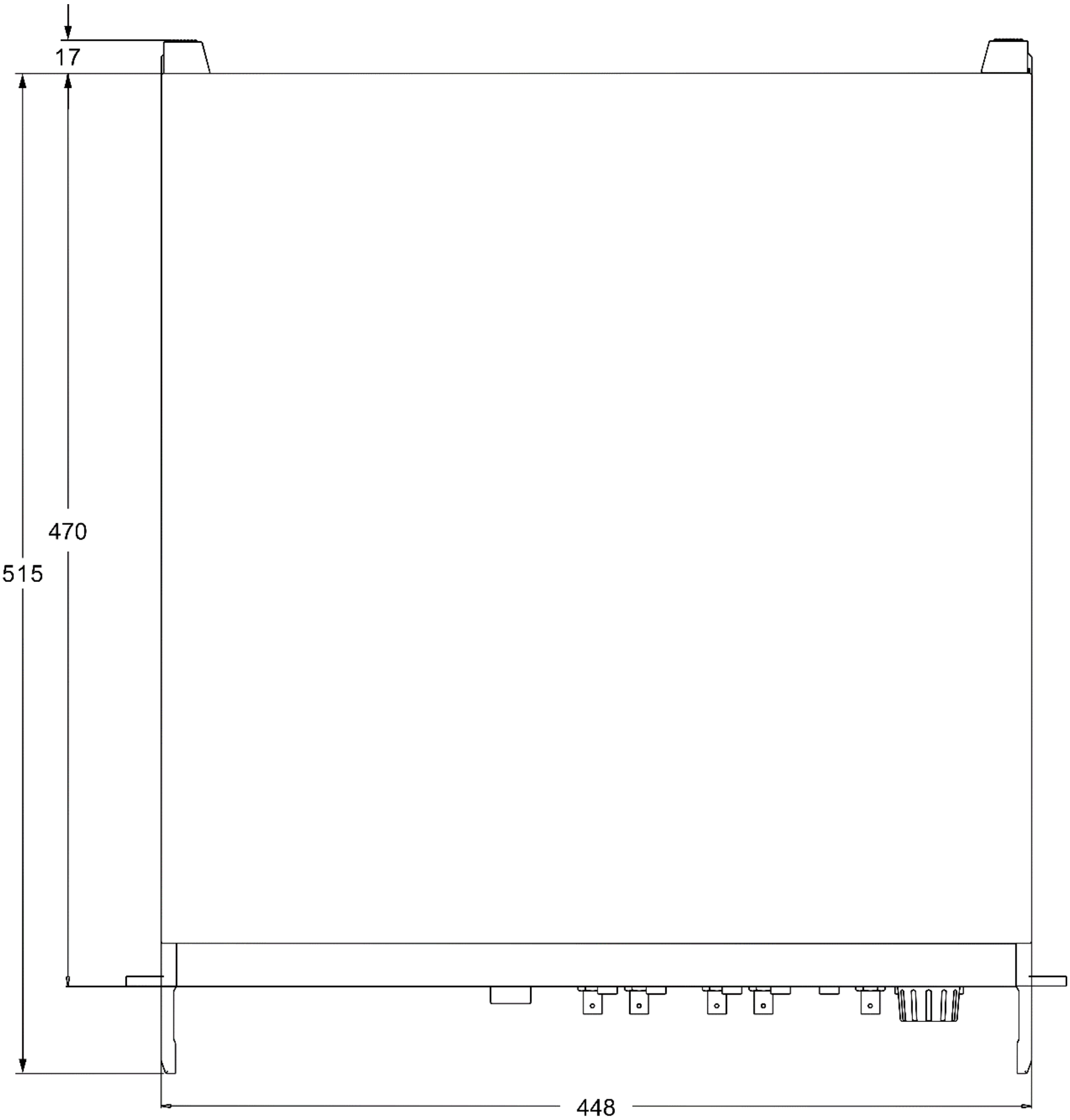
- Power noise rejection — 70 dB @ 1 MHz
- Grounding terminal — Banana jack / M6 threaded stud
- Weight — 8 kg
- Dimensions

Width	448 mm
Depth	
Including handle	532 mm
Excluding handle	470 mm
Height	
Including feet	148 mm
Excluding feet	133 mm

- Product dimension drawing, side view



- Product dimension drawing, top view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Chapter 2 Lock-in Amplifier Fundamentals

2.1 Introduction to Lock-in Amplifiers

A lock-in amplifier is an instrument used for weak-signal detection. Weak signals are often buried in various types of noise. A lock-in amplifier can extract a weak signal from the noise and measure it accurately, as shown in Figure 1. Lock-in detection is a coherent, phase-sensitive technique for recovering weak periodic signals from noise. Its core technique is phase-sensitive detection (PSD), which uses a reference signal with the same frequency as, and a fixed phase relationship to, the signal under test as the basis for detection. The instrument extracts the signal component that is correlated with the reference signal and rejects noise components outside the reference frequency.

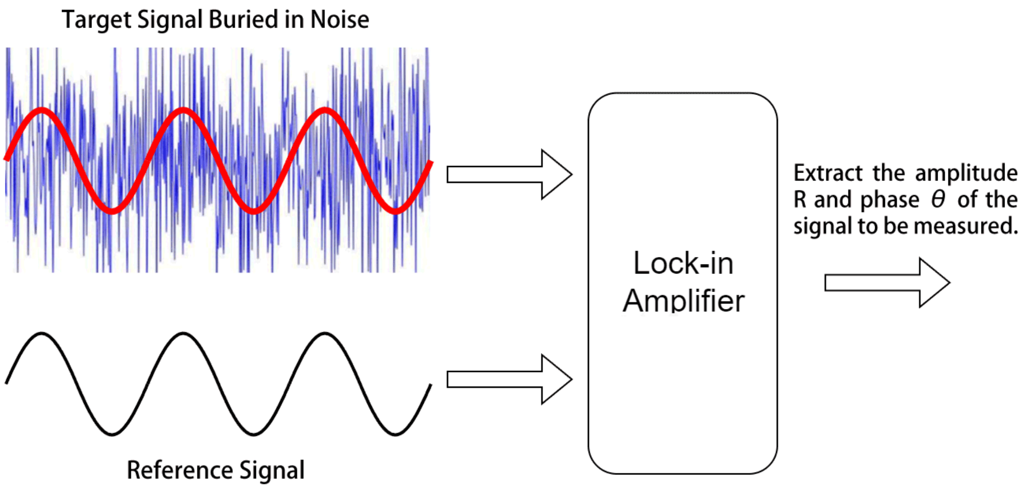


Figure 1. Schematic diagram of a lock-in amplifier

The most basic processing method for a weak signal is amplification. Conventional amplification amplifies the noise together with the signal. In addition, without bandwidth limiting or filtering, any amplification operation will reduce the signal-to-noise ratio. Therefore, filtering must be used to purify the signal and improve the signal-to-noise ratio so that weak signals can be measured accurately. The best choice among filters is a band-pass filter. However, it is often very difficult to implement a band-pass filter with an adjustable center frequency, high stability, and a high Q factor.

A phase-sensitive detector (PSD) can replace a high-Q band-pass filter. Its basic structure includes a multiplier module that multiplies the input signal by the reference signal, and a filter module that low-pass filters the multiplier output. In some contexts, PSD specifically refers to the multiplier module only, excluding the filter module, as shown in Figure 2.

$S_I(t)$ is the time-domain input signal mixed with noise, and $S_R(t)$ is the reference signal that has the same frequency as the signal under test. A PSD combines the measured signal channel and the reference signal channel to form a complete lock-in amplifier architecture, which is referred to as a single-phase lock-in amplifier. Its structural block diagram is shown in Figure 3.

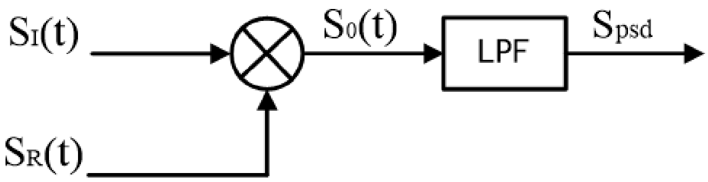


Figure 2. Schematic diagram of phase-sensitive detection

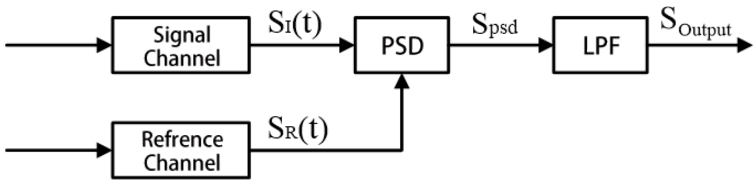


Figure 3. Structure of a single-phase lock-in amplifier

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

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

where ω is the frequency of the signal under test, $A_I \sin(\omega t + \varphi)$ is the signal under test, and $B(t)$ is the mixed noise.

The standard reference signal generated by the reference signal channel can be defined as:

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

The two signals are simultaneously input to the PSD module and multiplied. The output is:

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

The result contains three terms. The first term contains the signal amplitude A_I, the reference signal amplitude A_R, and the cosine of the phase difference $(\varphi - \delta)$ between the input signal and the reference signal. When both the useful part of the input signal and the reference signal are stable, this term can be regarded as a constant, namely a DC signal. Similarly, the second term is an AC signal at twice the original reference frequency. The third term is the product of the noise signal and the reference signal. According to the orthogonality of sinusoidal signals, a random signal is not correlated with the reference signal, and its integral result is zero.

From the frequency-domain perspective, the first term is located at DC, the second term is located at twice the reference frequency, and the third term is the original random signal shifted in frequency by ω. Taking white noise as an example, the shifted result is still white noise. Therefore, by feeding the result into a low-pass filter, the DC component can be obtained as follows:

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

The frequency-domain spectral shifting process of a lock-in amplifier is shown below:

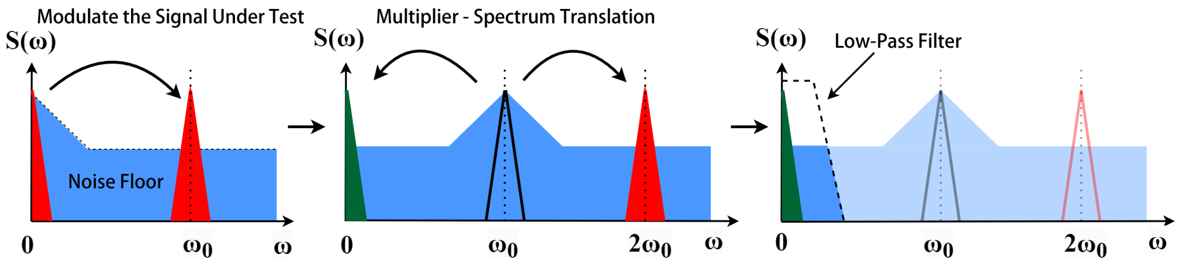


Figure 4. Spectral shifting process in a lock-in amplifier

The amplitude of the signal under test can be determined by adjusting the phase difference $(\varphi - \delta)$ between the measured signal and the reference signal. However, the accuracy of this adjustment is difficult to guarantee. The dual-phase lock-in amplifier provides an effective solution to this problem. Figure 5 shows the operating architecture of a dual-phase lock-in amplifier.

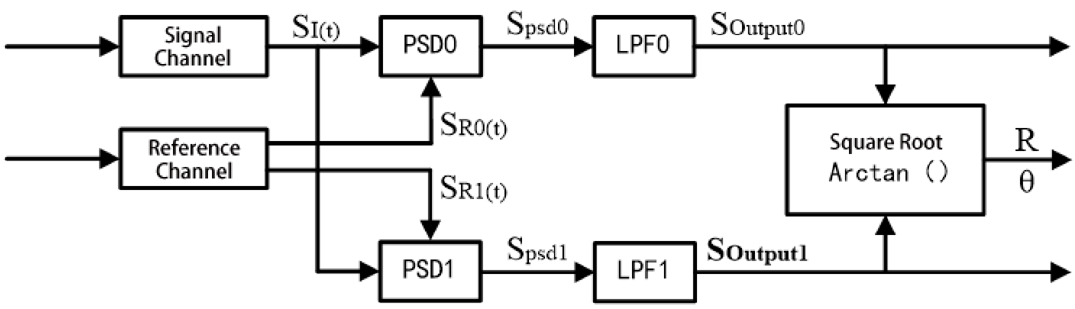


Figure 5. Structure of a dual-phase lock-in amplifier

Let the phase difference be $\theta = \varphi - \delta$. The reference channel generates two sinusoidal signals with a phase difference of 90°:

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

The calculated output results are $S_{Output0} = \frac{1}{2} A_I A_R \cos\theta$ and $S_{Output1} = \frac{1}{2} A_I A_R \sin\theta$.

Define $X = A_I \cos\theta$ and $Y = A_I \sin\theta$. The output amplitude that is independent of the phase difference can therefore be calculated as:

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

The phase difference between the reference signal and the measured signal can be obtained by:

$$\theta = \tan^{-1}(Y/X)$$

2.2 Functional Block Diagram of OE2031

The functional block diagram of the OE2031 digital lock-in amplifier is shown below:

As illustrated in the functional block diagram, the functional modules of OE2031 include

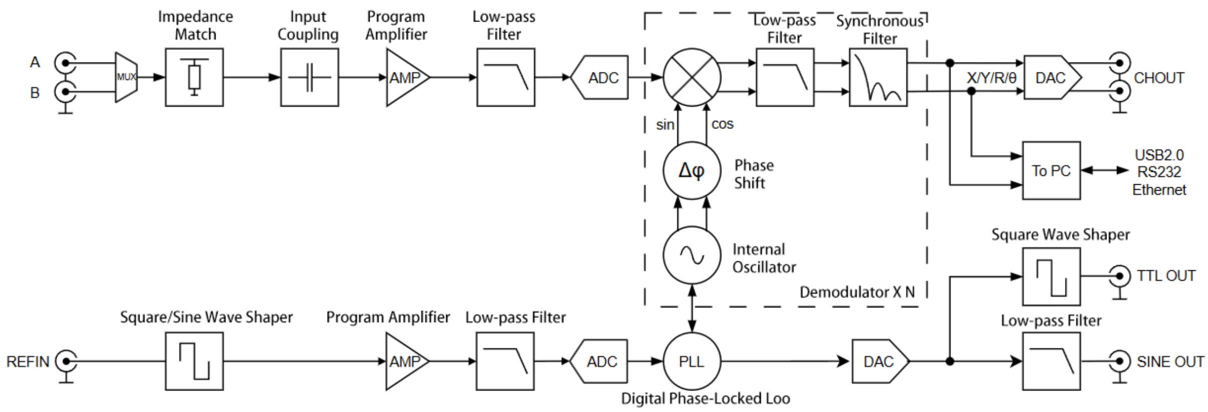


Figure 6. Functional block diagram of OE2031

the signal conditioning channel, reference signal processing channel, demodulator module, system controller, and other sections. The interfaces on the left are input interfaces, and the interfaces on the right are output interfaces.

When the signal under test is connected to the voltage input of the lock-in amplifier, it is amplified to an appropriate range and then digitized by an analog-to-digital converter (ADC), becoming a digital signal. The digitized measured signal is sent to six demodulator channels for demodulation processing. The demodulation results are output to the CHOUT interface, where users can observe them with an oscilloscope or other instruments. The results can also be output to a PC software through the communication interface and viewed with the SSI Lucid Suite software supplied with the instrument.

OE2031 has two digital phase-locked loops that can lock to two reference/synchronization signals simultaneously. The phase-locked loop results can be routed to the Sineout and TTLout interfaces to control other instruments and devices conveniently.

2.3 Reference Channel

The function of the reference channel is to provide a control signal coherent with the detected signal for the phase-sensitive detector. The reference signal of OE2031 can be selected as either a sine wave or a square wave according to the actual application, and its input impedance can be selected as 50 Ω or 1 MΩ. OE2031 provides one dedicated REF IN reference signal input channel.

In general, both reference waveforms can be used. For a TTL reference, the high level must be greater than 3 V, and the low level must be less than 0.5 V. A sine-wave reference is AC-coupled and is valid when its peak-to-peak amplitude is greater than 0.1 V_{pp}. **However, when the frequency is lower than 1 Hz, TTL-level signal mode must be used.** Because a sine-wave signal has a lower signal-to-noise ratio and more amplitude jitter when its output amplitude is small, and because most function generators can generate stable TTL synchronization signals, a square-wave signal is recommended as the reference signal.

The OE2031 lock-in amplifier has two reference source modes: internal reference mode and external input mode.

When internal reference mode is selected, the high-precision oscillator and synthesis algorithm inside the instrument generate the sine-wave signal used for multiplication with the input signal. In this case, no phase-locked loop is required, and the internal reference signal is almost unaffected by phase noise. The internal reference mode can operate normally over the frequency range from 10 µHz to 10 MHz. Because there is a certain frequency deviation between the internal oscillator and the oscillator of the external signal source, and because no phase-locked loop is used for tracking and locking, there will be a certain frequency difference between the internally generated sine-wave signal and the signal under test, and phase stability between the two signals cannot be guaranteed.

OE2031 can also use external reference signal mode. Sine signals and TTL logic levels can be used as external reference signals. When external reference signal mode is used, the internal oscillator automatically tracks the external reference signal to maintain the same frequency and phase. In actual operation, the phase-locked loop introduces a certain amount of phase jitter, which may cause measurement error. Phase jitter introduces noise at different frequencies into the reference signal. According to the coherence principle of PSD, the output signal contains not only the measured signal at the same frequency as the reference signal, but also noise components at other frequencies present in the reference signal. In practice, phase jitter is usually small and does not cause measurement problems. For jitter-free measurement, internal reference mode can be selected. Since the reference signal is derived directly from the internal oscillator, without PLL tracking, no additional phase jitter interference is introduced.

2.4 Phase-Sensitive Detector

The phase-sensitive detector (PSD) of OE2031 is implemented by a digital multiplier. After the input signal is amplified and filtered, it is converted into a digital signal by a 14 bit A/D converter and then input to the phase-sensitive detector. The phase-sensitive detector module of this product has a resolution of 64 bit.

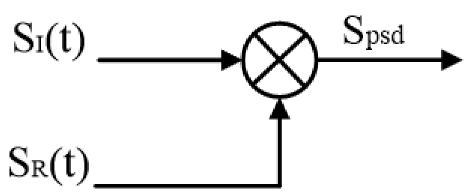


Figure 7. Core part of coherent detection

The phase-sensitive detector module of a lock-in amplifier mainly performs coherent modulation of the input signal and the reference signal. Traditional lock-in amplifiers implement this function with an analog multiplier. However, coherent modulation implemented using analog technology has many drawbacks. It greatly limits the accuracy of the phase-sensitive detector and introduces substantial background noise, both of which are highly unfavorable for weak-signal measurement.

Based on these considerations, this product uses digital technology to implement coherent modulation. Because the reference signal generated by the internal signal generator is a 24 bit digital signal, it can greatly reduce the influence of harmonic components on coherent modulation. In practice, harmonic suppression can reach −120 dB, which means that harmonic components have almost no influence during coherent modulation.

In addition, analog phase-sensitive detectors have temperature drift and DC offset, so their output often deviates from the actual result. This deviation is a systematic error and is often uncertain. A phase-sensitive detector implemented with digital technology avoids this issue. Under normal system operation, almost no corresponding systematic error is generated. Since the inputs of an analog multiplier are analog quantities, its reference signal is also affected by temperature drift, which causes reference-signal deviation and further increases the systematic error in coherent modulation.

The dynamic reserve of a phase-sensitive detector implemented with analog technology is generally limited to below 60 dB, because analog systems usually contain a large amount of background noise. Since lock-in amplifiers are mainly used for weak-signal detection, if the amplitude of the background noise is close to or greater than that of the signal, the coherent modulation result may become incorrect. A phase-sensitive detector implemented with digital technology does not suffer from such problems. Its dynamic reserve is mainly limited by the quality of A/D conversion. Once the input signal has been digitized, no additional error is introduced during coherent modulation. In practice, the dynamic reserve of OE2031 can reach more than 120 dB.

In summary, a phase-sensitive detector implemented with digital technology outperforms one implemented with analog technology in many aspects. It also provides advantages such as easier debugging, making it the best choice for this product.

2.5 Filters, Time Constants, and DC Output Gain

The output of the phase-sensitive detector contains signal components at multiple frequencies, including the sum-frequency component and the difference-frequency component of the input and reference signals, as well as noise. Only when the input signal and the reference signal have the same frequency does the difference-frequency signal become a DC signal. The low-pass filter behind the phase-sensitive detector, as shown in Figure 8, removes the sum-frequency component and noise components, leaving the DC/baseband component and thus allows the lock-in amplifier to function as a high-quality band-pass filter.

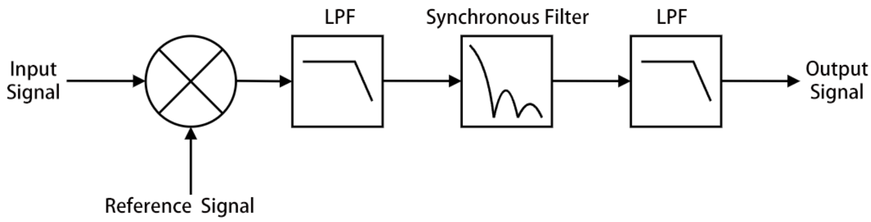


Figure 8. Filter structure of the phase-sensitive detector

Time Constant

The bandwidth of the low-pass filter behind the phase-sensitive detector is set in the same way as that of a conventional low-pass filter, namely by setting the time constant. The time constant TC is calculated as:

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

where f is the cutoff frequency at −3 dB. For example, for a first-order RC low-pass filter, a time constant of 1 second means that its −3 dB cutoff frequency is 0.16 Hz.

In general, when noise is present at the system input, noise will also appear at the output. Increasing the time constant can make the system output more stable and reduce the influence of input noise on the output. In addition to affecting system stability and accuracy, the time constant also affects the response time. For a first-order RC low-pass filter, the output must be allowed to settle for more than five time constants before the result becomes stable. The step responses of low-pass filters with different orders are shown in Figure 9.

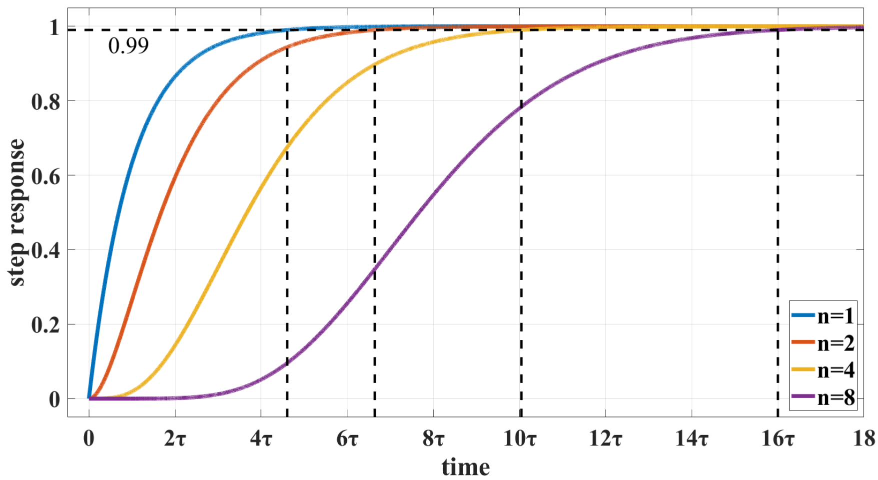


Figure 9. Step response of low-pass filters

The time constant also determines the equivalent noise bandwidth (ENBW) for noise measurements. It should be noted that the equivalent noise bandwidth is not the −3 dB bandwidth of the filter. Instead, it refers to the effective bandwidth for Gaussian noise.

The equivalent noise bandwidth and response settling time of RC low-pass filters of different orders are listed in Table 1.

Table 1. ENBW and response settling time of RC low-pass filters of different orders

Filter order	Roll-off	ENBW	Time required for the output to reach 99% settling
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 and Analog Filters

To maximize the performance of the lock-in amplifier, this product uses digital filters to implement low-pass filtering of the coherent modulation result. As in most comparisons between analog and digital systems, digital systems offer many advantages that analog systems do not. First, the inherent temperature drift and nonlinearity of analog devices greatly limit the roll-off performance of the filter. Second, building a low-pass filter with a large time constant and high quality using analog components requires a considerable amount of PCB area. This not only increases the instrument cost, but also makes future debugging more difficult due to the large number of analog components.

The low-pass filter implemented digitally in this product is a narrowband filter with a 64 bit data width, a DC gain of 0 dB, and whose equivalent Q value yields a dynamic range exceeding 145 dB.

Synchronous Filter

Another advantage of digital filters is that a synchronous filter can be implemented easily. Even if the input signal contains no noise, the output of the phase-sensitive detector still includes the sum-frequency component of the input and reference signals, namely the second-harmonic component. The amplitude of this sum-frequency component may be larger than that of the desired difference-frequency component. At low frequencies, a very large time constant is required to filter out the second-harmonic component. For example, if the input signal has a frequency of 1 Hz, the second-harmonic component is 2 Hz. Even with a second-order RC filter with a 10-second time constant, the attenuation at 2 Hz is only slightly over 40 dB.

The synchronous filter averages all data over one complete period of the reference frequency. It can effectively reject all harmonic components of the reference frequency and is equivalent to a sinc filter with zeros at the reference frequency and its harmonics. In the example above, if a synchronous filter is used, only 1 second of waiting time is required to achieve better performance than a 10-second-time-constant RC filter.

In OE2031, the synchronous filter setting is effective only when the detection frequency is lower than 1 MHz. At higher frequencies, the sum-frequency component can be removed with a smaller time constant, so long waiting times are not required and the synchronous filter is unnecessary. A multi-order filter is also designed after the synchronous filter. This filter combination can remove both harmonic components of the reference signal and other noise signals.

Large Time Constants

It is difficult for analog filters to achieve time constants greater than 100 s, because the required capacitance and physical capacitor size become impractically large. Why are such large time constants needed? In some cases, there is no alternative. For example, when the reference signal frequency is below 1 Hz and substantial low-frequency noise interference is present, the output of the phase-sensitive detector contains many low-frequency interference components. The synchronous filter can remove only the harmonic components of the reference signal, while the remaining noise signals must be removed by the subsequent filter.

Using digital technology, OE2031 can provide a time constant of up to 3000 s, satisfying the requirements of most measurements.

Selection of Time Constant and Filter Slope

Whether the goal is fast signal measurement or a more stable signal display, the desired result can be achieved by adjusting the combination of time constant and filter roll-off. Under the same measurement accuracy requirement, choosing a higher filter roll-off and reducing the time constant accordingly can significantly improve the measurement response speed. Conversely, when the stability of the measurement result needs to be further improved, both the time constant and the filter roll-off can be increased.

For a specific application, the time constant and filter roll-off should be configured flexibly according to the actual conditions. A practical rule is that if the stability of the measurement result is satisfactory, there is no need to excessively increase the time constant or the filter roll-off, as this will only extend the waiting time unnecessarily. If a smoother measurement result is desired, the time constant and filter roll-off can be increased appropriately.

DC Output Gain

How large can the DC output of a phase-sensitive detector be? It depends on the dynamic reserve. When the dynamic reserve is 60 dB, the noise signal may be 1000 times larger than the full-scale signal. In a phase-sensitive detector, the noise signal must not exceed the input range of the phase-sensitive detector. In an analog lock-in amplifier, suppose that the maximum input amplitude of the phase-sensitive detector is 5 V. When the dynamic reserve is 60 dB, the signal at the input of the phase-sensitive detector is only 5 mV. Since the phase-sensitive detector itself does not amplify the signal, its output is only a few millivolts. Even if the DC output of the phase-sensitive detector has no error, the following amplifier can easily distort the signal when it directly amplifies the signal 1000 times to 5 V. If the PSD has an offset of 1 mV, this offset becomes 1 V at the output. This is why analog phase-sensitive detectors cannot achieve very high dynamic reserve.

Because a digital lock-in amplifier does not use an analog DC amplifier, it does not have DC output offset. A digital DC amplifier also has no input offset. The digital DC amplifier simply multiplies the received data by a preset gain and outputs the result. This is why OE2031 can remain unaffected by offset even when its dynamic reserve reaches 120 dB.

2.6 Dynamic Reserve

Dynamic reserve is defined as the ratio between the maximum tolerable noise signal and the full-scale signal. It indicates the lock-in amplifier's tolerance to noise and is usually expressed in dB.

$$\text{Dynamic reserve} = 20\,\lg\frac{\text{OVL}}{\text{FS}}\ (\text{dB})$$

where OVL denotes the total input dynamic range, and FS denotes the selected full-scale signal level, namely the output dynamic range. If the dynamic reserve is 100 dB, the system can tolerate noise that is 10^5 times larger than the useful signal.

In practice, the dynamic reserve setting should ensure that overload does not occur throughout the experiment. Overload may occur at the input of the preamplifier or at the signal output of the DC amplifier. The system input gain is inversely related to the dynamic reserve, because noise is also amplified with the input gain. Therefore, **high dynamic re-**

serve can be achieved by reducing the input gain. The preamplifier gain should be set to a reasonable range to prevent noise overload. After the PSD and low-pass filter remove most of the noise, the DC output gain is set to a larger value to amplify the signal to full scale.

Before PSD processing, the input signal of the lock-in amplifier requires AC amplification. After PSD processing, only DC amplification is required. When the total gain remains unchanged, increasing the AC gain and reducing the DC output gain makes it easier for input noise to overload the PSD, thereby reducing the dynamic reserve, while also reducing the DC drift at the output. Conversely, increasing the DC output gain and reducing the AC gain improves the dynamic reserve and gives the lock-in amplifier better interference immunity, but this comes at the cost of output stability and reduced measurement accuracy.

The accuracy of the DC amplified output is affected by the frequency and amplitude of the noise. Noise with a large amplitude and the same frequency as the signal is also converted into a DC signal after the PSD. When it passes through the low-pass filter, it is directly superimposed on the output and affects the output result.

Dynamic reserve is related to noise frequency. At the reference frequency, the dynamic reserve is 0 dB. As the noise frequency moves away from the reference frequency, the dynamic reserve increases. When the noise frequency is sufficiently far from the reference frequency, the dynamic reserve can reach its maximum value. The dynamic reserve near the reference frequency is extremely important to the instrument's noise tolerance. Increasing the order of the low-pass filter can improve filtering performance and thereby increase the dynamic reserve near the reference frequency. The dynamic reserve far away from the reference frequency is generally larger, but it usually has little effect on the measurement.

The dynamic reserve of OE2031 can exceed 120 dB. A high dynamic reserve may increase output noise and drift. When the dynamic reserve is high, output error increases due to noise in the analog-to-digital converter. All signal sources have a noise floor, so noise is mixed into the signal extraction process of the PSD. If the noise is large, a high-dynamic-reserve measurement may produce a large output error. If the external noise is small, the output is mainly affected by the intrinsic noise of OE2031. In this case, the output error can be reduced by lowering the dynamic reserve and DC output gain. Therefore, in practical applications, a lower dynamic reserve, namely a higher input gain, should be used whenever possible.

2.7 Signal Input Amplification and Filtering

A lock-in amplifier can measure weak signals down to the nanovolt level. An analog-to-digital converter can digitize analog signals, but the signal must be strong enough to be identified. Therefore, the low-noise signal amplifier must provide sufficient gain to amplify the signal to a level that can be directly converted by the analog-to-digital converter while preserving the input signal-to-noise ratio as much as possible. The analog amplification gain of OE2031 is approximately 0.25 to 500. However, no matter how large the gain setting is, it does not improve the signal-to-noise ratio of the input signal.

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

Input Noise

Assume that the amplifier input noise is 10 $nV_{rms}/\sqrt{Hz}$ and the gain is 1000. The amplifier will then output 10 $\mu V_{rms}/\sqrt{Hz}$ of noise. Suppose the amplifier output is followed by a first-order RC low-pass filter with a roll-off of 6 dB/oct and a time constant of 100 ms. The input noise of the amplifier and the Johnson noise of the resistor have Gaussian noise characteristics, and the amount of noise is proportional to the square root of the noise bandwidth. The equivalent noise bandwidth (ENBW) of a single-pole RC filter is $1/(4 \times TC)$. This means that when Gaussian noise at the filter input is filtered, its effective bandwidth is equal to the ENBW. In this example, the filter input has 10 $\mu V_{rms}/\sqrt{Hz}$ of noise, and the equivalent noise bandwidth is 2.5 Hz. The output voltage noise of the filter is $10\,\mu V_{rms}/\sqrt{Hz} \times \sqrt{2.5\,Hz} = 15.8\,\mu V_{rms}$. For Gaussian noise, the peak-to-peak value is approximately 6.6 times the RMS value. Therefore, the output has about 104 µV peak-to-peak noise.

The input noise of a lock-in amplifier follows the same principle. When the gain is set to 1000, the input gain reaches its maximum, and the input noise determines the output noise. The equivalent noise bandwidth of the low-pass filter also affects the amount of output noise.

The equivalent noise bandwidth depends on the time constant and filter roll-off, as described in Section 2.5. For example, when OE2031 is set to the 1 mV range, whose gain is 500, and the time constant is set to 100 ms with a roll-off of 6 dB/oct, the equivalent noise bandwidth is 2.5 Hz. The input noise of OE2031 is about 3 $nV_{rms}/\sqrt{Hz}$. Under this setting, the total noise at the filter output is 2.4 μV_{rms}, and the equivalent input-referred noise is 4.7 nV_{rms}. The noise-to-full-scale ratio is 4.7 ppm, namely 4.7 nV/1 mV.

Assume that the signal is generated by a low-impedance source. The Johnson noise of a resistor is approximately $0.13 \times \sqrt{R}$. Taking a 100 Ω resistor as an example, its Johnson noise at room temperature is 1.3 $nV_{rms}/\sqrt{Hz}$. The Johnson noise of a 10 kΩ source is 13 $nV_{rms}/\sqrt{Hz}$, which is already greater than the intrinsic input noise of OE2031. The total system noise is calculated by taking the square root of the sum of the squares of all noise sources. For example, when a 10 kΩ source is connected to the lock-in amplifier, the Johnson noise of the source and the input noise of OE2031 combine to give a total noise of $\sqrt{3^2 + 13^2} = 13.3\,nV_{rms}/\sqrt{Hz}$. It can be seen that when the input noise is large, more than one order of magnitude greater than the instrument's own input noise, the effect of the input noise of OE2031 on the total system noise can be ignored.

At low gain, the amplified noise signal remains below the intrinsic noise of the analog-to-digital converter. In this case, the system output noise is mainly ADC noise. However, since the DC gain after the filter is very low under this condition, the output noise is negligible relative to the useful signal.

Anti-aliasing Filter

After passing through the notch filter and amplifier circuit, the input signal passes through an anti-aliasing filter. This must be completed before the signal is digitized. According to the Nyquist theorem, the sampling frequency must be at least twice the signal frequency. For example, if the signal frequency is 100 kHz, a sampling frequency of at least 200 kHz is required. The sampling frequency of the A/D converter in OE2031 is 250 MHz. The A/D converter cannot convert signals with frequencies higher than 125 MHz. Signals above 125 MHz violate the Nyquist theorem and cause undersampling. The result of undersampling is that high-frequency signals appear in the low-frequency part of the digital stream output by the A/D converter, causing aliasing and measurement errors.

To avoid undersampling, the analog signal is first low-pass filtered to remove high-frequency components above 10 MHz. The low-pass filter has a flat passband from 0~10 MHz, and signals in this frequency range are not affected. High-frequency signal components above 10 MHz are gradually attenuated. The range from 10 MHz to 125 MHz is the transition band, and signals and noise above 125 MHz are attenuated by more than 100 dB.

Input Impedance

The input impedance of OE2031 can be selected as 50 Ω or 10 MΩ. If a higher input impedance is required, the OE400X series preamplifier supplied for use with OE2031 can be used. The OE400X series preamplifier provides an input impedance of 100 MΩ or higher, meeting the requirements of various application scenarios.

Current Input

For signal-integrity considerations, the high-frequency lock-in amplifier OE2031 does not include an internal current amplifier module. If users need to measure current signals, they can use an OE410X series current preamplifier to preprocess the current signal, convert it into a voltage signal, and then connect it to OE2031.

2.8 Input Connection

Noise exists in all circuits. Even when the signal amplitude is large, noise reduces measurement accuracy. To obtain the best measurement accuracy, attention must be paid to reducing avoidable noise sources in the experimental environment. In addition to intrinsic system noise, the effects of other noise sources, such as mains noise, signal generator noise, and spatially distributed electromagnetic fields, as well as ground-potential differences and ground loops between instruments, can be reduced through proper input wiring.

The instrument provides two input connection methods: single-ended connection and differential connection. Single-ended connection is very convenient, while differential connection can effectively reduce the influence of noise.

Single-Ended Connection Mode (IN+)

In single-ended connection mode, the IN+ input is used. The lock-in amplifier measures the voltage difference between the center conductor and the shield conductor of the IN+ input connector.

Ground potential is generally considered to be a constant of 0 V; however, the ground potentials of different instruments may differ slightly. When the ground of the signal source is directly connected to the ground of the measuring instrument, the difference in ground potential can cause a large current, namely a ground loop. In this case, the current of the instrument at the higher ground potential returns to earth through the instrument at the lower ground potential. This causes two serious problems. First, the noise of the instrument at the higher ground potential is directly introduced into the instrument at the lower ground potential. Second, the instrument at the lower ground potential may be damaged by excessive current. This problem can be solved by connecting a resistor between the grounds at different potentials. In OE2031, two shield-grounding modes are available: Float and Ground. Float uses a 1 kΩ resistor, while Ground uses a 0 Ω resistor short. In addition, single-ended connection has relatively weak noise immunity. A single signal cable behaves like an antenna and is affected by electromagnetic noise in the environment. The shield absorbs this noise. Since single-ended connection measures the voltage difference between the center conductor and the shield, this noise is introduced into the lock-in amplifier.

Differential Connection Mode (DIFF)

In differential connection mode, two signal cables are connected to the signal source, and each cable is connected to the corresponding input terminal, IN+ or IN-. In this mode, the voltage difference between the center conductors of the IN+ and IN- connectors is measured. Noise absorbed by the outer shield layers of the two connectors is not acquired by the lock-in amplifier.

One point should be noted when using differential connection mode: the cables of the two input terminals should be tightly twisted and should not form a loop, in order to avoid electromagnetic induction and measurement errors.

AC Coupling and DC Coupling Modes

OE2031 provides two input coupling modes: AC coupling and DC coupling. In AC-coupled mode, a first-order RC high-pass network with a −3 dB cutoff frequency of 0.16 Hz is inserted to attenuate DC and very low-frequency components. AC coupling should be used when the signal frequency is greater than 10 Hz, so that passband flatness is ensured. For signals below 10 Hz, DC coupling mode should be used. DC coupling mode has no effect on the input signal.

If the input signal contains a DC component and it is not removed, several problems may occur. In the amplifier circuit, the DC component is also amplified. If it is amplified beyond the input range of the A/D converter, the measurement result will contain errors, and the A/D converter may even be damaged. In addition, after the DC component is quantized into a digital value by the A/D converter, it is multiplied by the reference sine signal in the PSD. A more powerful low-pass filter is then required to remove it, resulting in a longer measurement time.

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

2.9 Intrinsic Noise

Noise

From a subjective point of view, any input or influence that is undesired or that interferes with accurate measurement can be regarded as noise. Noise is transient, random, and unpredictable. In almost all measurement fields, the ultimate limiting factor in detecting weak signals is noise. Even when the signal to be measured is not very weak, the presence of noise reduces measurement accuracy. Some forms of noise are unavoidable, such as jitter in the signal under test, and can only be overcome by techniques such as signal averaging and bandwidth reduction. Other forms of noise, such as RF interference and ground loops, can be eliminated or reduced by many techniques, including filtering, proper wiring structure, and appropriate component layout. The amplifier itself also generates noise during operation, which can be reduced by low-noise amplifier design techniques.

Electronic systems contain many types of intrinsic noise sources, each with its own physical meaning.

Johnson Noise (Thermal Noise)

In any passive component, the electrons in the conductor are always in random motion, producing a noise voltage across its terminals. This is Johnson noise, also known as white noise or thermal noise. It exists in all electronic components and transmission media. It is affected by temperature, but not by frequency. In the frequency domain, thermal noise has a uniform power spectral density over the entire frequency range, similar to a white spectrum. It cannot be eliminated and is therefore one of the factors that determines the upper limit of electronic system performance. At temperature T, the actual noise voltage generated by a resistor R is calculated as:

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

where k is Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J/K; T is the thermodynamic temperature in kelvin, with the conversion relation $K =^{\circ} C + 273.15$; and B is the bandwidth in hertz.

Nyquist later used thermodynamic reasoning to mathematically describe the statistical characteristics of thermal noise and proved that the power spectral function of thermal noise is:

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

For example, at room temperature, if a 10 kΩ resistor is connected to the input of a high-fidelity amplifier and a voltmeter is connected to the output, using a filter with a bandwidth of 10 kHz to measure its open-circuit RMS voltage gives a result of 1.3 µV.

The instantaneous amplitude of thermal noise voltage is generally unpredictable under any condition, but it follows a Gaussian distribution. Its significance is that it represents the lower limit of the noise voltage of any detector, signal source, or amplifier. The impedance part of the source resistance generates thermal noise, as do the bias and load resistors of the amplifier.

Shot Noise

Electric current is actually a flow of discrete charges, not a true continuous fluid. The finite nature of charge causes statistical fluctuations in current. If the charges do not interact with each other, the current fluctuation is given by:

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

where q is the electron charge (1.6×10^{-19} C), I is the average current in the circuit, and B is the measurement bandwidth. For example, a stable 1 A current measured over a 10 kHz bandwidth has an RMS fluctuation of 57 nA, corresponding to a fluctuation of about 0.000006%. For smaller currents, the relative fluctuation is larger: a stable 1 µA current measured over 10 kHz has an RMS current noise of 57 pA, corresponding to a 0.006% fluctuation. For a 1 pA current, the RMS current noise is 56 fA over the same bandwidth, corresponding to a 5.6% fluctuation.

It has also been proven that shot noise current is a type of white noise, and its power spectral density function is:

$$S_{sl}(f) = 2qI(A^2/Hz)$$

The shot-noise formula above assumes that the charge carriers in the current do not interact with each other. This assumption is valid when charge passes through a potential barrier, such as current diffusion through a point-contact diode. However, it is not valid for the most common metal conductors, in which the charge carriers are closely correlated.

1/f Noise (Flicker Noise)

In 1925, Johnson first discovered 1/f noise in the current of vacuum tubes. Its distinguishing feature is that its power spectral function is proportional to 1/f. The lower the frequency, the more severe the noise, so it is also called low-frequency noise. Its microscopic mechanism is that when the contact between two conductors is imperfect, the contact resistance fluctuates randomly and causes noise.

Although 1/f noise has been studied for decades, its applicable situations vary and many descriptive models exist. Its current amplitude follows a Gaussian distribution, and its power spectral density is inversely proportional to the operating frequency. Its power spectral density function is expressed as:

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

1/f noise, also called flicker noise, is generated by random fluctuations in the carrier density of active devices. It modulates the center-frequency signal and forms two sidebands around the center frequency, reducing the Q factor of the oscillator. Since 1/f noise is the dominant noise near the center frequency, its influence must be considered when designing device models.

Shot noise and thermal noise are unavoidable noises caused by physical characteristics. For resistors of the same resistance value, a well-made resistor and an inexpensive carbon resistor generate exactly the same thermal noise. In addition, practical devices have various excess noise sources. Actual resistors have resistance fluctuations, which generate an additional noise voltage that is superimposed on the ever-present thermal noise and is proportional to the DC current flowing through the resistor. This noise is related to many factors associated with resistor construction, including the resistor material and especially the packaging technology. Taking solid carbon resistors, carbon-film resistors, metal-film resistors, and wire-wound resistors as examples, wire-wound resistors have the lowest noise, followed by metal-film resistors, then carbon-film resistors, and solid carbon resistors have the highest noise.

2.10 External Noise Sources

Intrinsic noise is difficult to avoid and can only be minimized as much as possible. Compared with intrinsic noise, external noise appears in many forms, and most external noise sources are asynchronous. External noise sources mainly affect measurement time by increasing the requirements for dynamic reserve and time constant. A small number of noise sources are closely related to the reference signal and can add to or subtract from the actual measured signal, causing incorrect measurement results. Fortunately, external noise sources can be minimized through various methods.

Capacitive Coupling

Mutual capacitance always exists between conductors. Because this mutual capacitance behaves like a parasitic element between conductors, it is called parasitic capacitance or stray capacitance. Capacitance also exists between electrodes and surrounding objects, including various components and even the human body. AC voltage signals near the lock-in amplifier can be coupled into the equipment through these parasitic capacitances. Although the parasitic capacitance may be very small, the coupled voltage signal may still be larger than the weak signal under test.

The influence of parasitic capacitance can be calculated as:

$$I = \omega C_{stray} V_{noise}$$

where ω is 2π times the noise frequency, C_{stray} is the stray capacitance, and V_{noise} is the noise amplitude.

As the frequency of the noise source increases, the coupled noise also increases. If the noise source has the same frequency as the reference frequency, it will have a large influence on the measurement result. This is because the lock-in amplifier rejects noise at other frequencies, but treats noise at the same frequency as the reference as a measured signal.

Methods for reducing capacitive coupling include:

- Remove the noise source, or keep the noise source as far away as possible from the instrument and signal cables.
- Use a low-impedance experimental setup so that the coupled noise current produces only a small noise voltage.
- Use capacitive shielding, for example by placing the entire experimental setup inside a metal enclosure.

Inductive Coupling

A magnetic field is induced near an AC current. If a device is placed near an AC current, the induced magnetic field can couple into the circuit and affect it. A changing AC current produces a changing magnetic field, and the changing magnetic field induces an electromotive force. The induced electromotive force affects the current and voltage of the circuit, causing measurement deviation. The magnitude of the electromotive force is related to the frequency of the magnetic field variation. The faster the frequency, the larger the electromotive force and the greater the influence on the measurement.

Methods for reducing inductive coupling include:

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

Resistive Coupling and Ground Loops

A ground loop can also become an interference source. It can generate a noise voltage between the grounds at the two ends of a transmission path. If the noise voltage is large enough, measurement errors will occur. A ground loop is a physical loop in the system grounding scheme that arises from multiple ground paths between circuits. These ground paths can act as a large loop antenna, capturing environmental noise and thereby generating voltage in the grounding system. The 50 Hz magnetic field from the AC mains is a common noise source captured by ground loops. Similarly, in a distributed grounding system, a ground voltage originating from one location can cause ground current to flow through the ground loop. Since ground is a low-impedance path, the noise current is often quite large. Noise of several hundred millivolts may cause several amperes of current to flow through a ground loop.

Methods for eliminating ground-loop current include:

- Connect all grounds to the same point.
- Make the ground bus as thick as possible to reduce the impedance of the ground connection.
- Avoid sharing the small-signal ground path with high-current ground return paths.

Microphonic Noise Effect

Most noise sources affect circuits electrically. However, mechanical vibration can also be converted into electrical noise through the microphonic effect. Micro-vibrations of transmission cables or the signal under test can produce electrical noise with varying frequency.

Methods for eliminating the microphonic effect include:

- Reduce mechanical vibration as much as possible during measurement.
- Tie down and fix transmission lines carrying weak signals to reduce their vibration.
- Replace ordinary cables with low-noise cables to reduce the microphonic effect.

Thermocouple Effect

The thermocouple effect refers to the potential difference generated between two different metals when they are in contact with each other. The contact potential difference is caused by: (1) different work functions of the two metals; (2) different electron concentrations in the two metals. If the work functions of metals A and B are V_a and V_b, and their electron concentrations are N_a and N_b, the contact potential difference between them is:

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

where k is Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J/K. T is the thermodynamic temperature in kelvin, with the conversion relation $K = ^{\circ}C + 273.15$, and q is the electron charge (1.60×10^{-19} C). The above equation shows that the contact potential is determined by the properties of the metals and the temperature of the contact surface. It is generated because different metals have different work functions, meaning different amounts of work are required for electrons to escape from the metal surface.

When two different metals are in contact, the electromotive force generated at the contact point adds a slowly varying millivolt-level voltage to the original level. This noise is closely related to temperature. Since temperature changes slowly, the frequency of this noise is also very low. The thermocouple effect can be large as the detector output increases, and it has a greater influence at low frequencies, especially in mHz-level measurements.

Methods for eliminating the thermocouple effect include:

- Keep the measuring instrument at a constant temperature as much as possible.
- Use junctions with compensation characteristics.

2.11 Noise Measurement

OE2031 provides a noise measurement function, which can measure the noise of the input signal at the reference frequency. Some noise sources are frequency-dependent, and the lock-in amplifier can measure such noise sources.

According to the bandwidth of the RC filter set by the user, the lock-in amplifier can be regarded as a band-pass filter whose center frequency is the reference frequency and whose passband bandwidth is twice the RC filter bandwidth. Therefore, noise near the reference frequency remains at the output. When the input signal itself is a noise source, the lock-in amplifier can measure its noise value at the set frequency. If the frequency is swept, the noise power spectrum of the noise source can also be obtained. The PC software of OE2031 includes a Sweeper parameter-sweep function, which can be used to measure noise spectra.

OE2031 measures noise near the reference frequency using total in-band noise integration. First, the X-component data from the demodulator output is acquired over a specified time and its root mean square (RMS) value is calculated. This value represents the total noise amplitude within a specific bandwidth near the reference frequency. The total noise value must then be normalized to eliminate the influence of the digital filter bandwidth. Specifically, the RMS value calculated above is divided by the square root of the equivalent noise bandwidth (ENBW) of the digital filter, namely $\sqrt{ENBW}$. The resulting value is the noise spectral density, with the unit $V/\sqrt{\text{Hz}}$. For details on calculating equivalent noise bandwidth and selecting parameters, refer to Table 1 in Section 2.5 of this manual.

2.12 Channel Output and Gain (AUX OUT)

OE2031 has four AUXOUT1 to AUXOUT4 output channels on the rear panel.

Output and Display of AUXOUT1 to AUXOUT4

The output range of AUXOUT1 to AUXOUT4 is −10 V to 10 V, the update rate is 1 MSa/s, and the digital-to-analog converter resolution is 16 bit. The output can be scaled proportionally according to the ratio between the current signal measurement result and the currently selected measurement range. In addition, OE2031 can display the data sources of AUXOUT1 to AUXOUT4 on the front-panel screen, including the X, Y, R, and θ values of the measured signal.

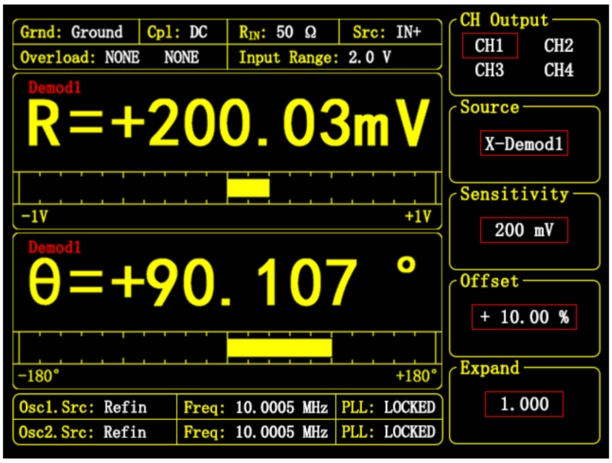


Figure 10. Output setting interface of OE2031

Output Offset and Gain of X, Y, and R

OE2031 can compensate for measurement errors by setting an offset. This is extremely useful when the measured value has an error around a nominal value. Since the offset can be set arbitrarily within the range, the offset can be used to null the output around a nominal value, making small changes easier to observe. Output changes can be read directly from the display screen or from the output terminals on the panel. The offset is expressed as a percentage of the full-scale output, and this ratio does not change with sensitivity. The offset can be set up to ±100% of full-scale output.

The system can also amplify the output values of X, Y, and R. This feature is implemented by multiplying the output data by a specified gain factor. As a result, even if the signal is only one-tenth of full scale, its output can be increased from 1 V to 10 V after amplification. The main function of output signal gain is to significantly improve measurement accuracy and resolution around a specific nonzero value.

As long as the full-scale output is not exceeded, OE2031 can provide multiple output gain settings from +0.001~+10 000. The output is calculated as:

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

<Offset> can be set between −100~100 %. It can be entered directly using the numeric keypad, with a minimum step of 0.01%. <Expand> can be set between +0.001~+10 000. It can be entered directly using the numeric keypad, with a minimum step of 0.001. For example:

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

2.13 Auxiliary Analog Inputs (AUX IN)

OE2031 includes four 16-bit high-precision AUX IN channels. The input voltage range is ±10 V, the minimum resolution is 0.3 mV, and the sampling rate is 312.5 kSa/s. These four ADC channels provide input signal clamp protection and internal differential amplification. With an input impedance of 1 MΩ, they can acquire signals simultaneously and are used to measure low-speed analog signals or DC signals obtained from an experiment, such as signals from temperature or pressure sensors, for PID calculation and transmission to the control computer.

The AUX IN interface uses standard BNC connectors and is integrated on the rear panel of OE2031. AUX IN value display is configured in the [DISPLAY] submenu.

2.14 Signal Generator

OE2031 can select the internal oscillator OSC1 or OSC2 as the signal source to output a sine-wave signal with an arbitrary amplitude. The amplitude range is 1 µV to 2 V_{rms}, the output impedance is 50 Ω, and the drive current capability reaches 70 mA. The phase of the output signal remains synchronized with the internal oscillator of the instrument, and an independent phase offset can be set.

For external devices that require a bias voltage, such as electro-optic modulators, OE2031 can directly drive the device without an additional level-shifting amplifier due to its excellent drive capability. A DC bias voltage in the range of ±3 V can be superimposed internally by OE2031. In addition, the ADD IN interface on the front panel allows an additional voltage signal in the range of ±10 V to be superimposed.

The signal generator of OE2031 supports AM/FM/PM modulation, making it convenient for users to perform modulation control of the system.

2.15 Multi-harmonic Measurement

Harmonics are components of a periodic function or periodic waveform that can be expressed as a linear combination of constants and sine and cosine functions having the same fundamental period as the original function. According to Fourier series theory, a periodic function can be expanded into a constant plus a set of sine and cosine functions with a common period. In the expansion, the constant term is called the DC component; the component whose minimum positive period is equal to the period of the original function is called the fundamental or first harmonic. Higher-order harmonics have frequencies that are integer multiples of the fundamental frequency; equivalently, their periods are integer fractions of the fundamental period.

In traditional lock-in amplifiers, only the fundamental signal or one harmonic component can be measured at a time. In many practical applications, multiple harmonics often need to be measured and recorded simultaneously. In such cases, conventional lock-in amplifiers are often unable to meet the requirement.

OE2031 provides an innovative multi-harmonic simultaneous measurement function. Its six independent demodulator channels can measure up to six harmonic components simultaneously. Tasks that previously required six lock-in amplifiers can now be completed by a single OE2031.

Multi-harmonic measurement is configured in the [DEMOD REF] menu.

In addition to multi-harmonic measurement, OE2031 also provides arbitrary-frequency demodulation and combined-frequency demodulation functions.

Chapter 3 Interface Overview

3.1 Front Panel

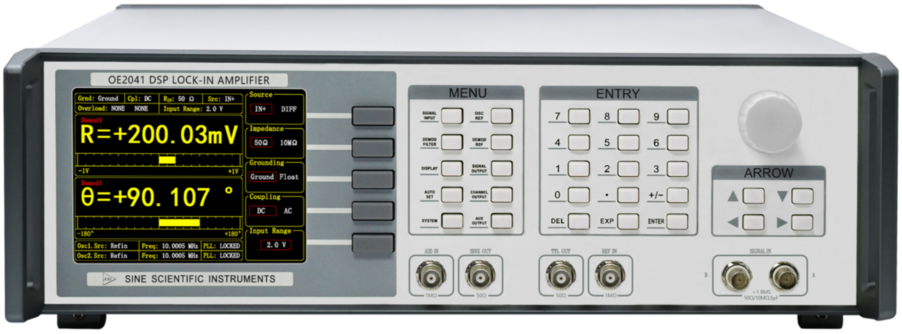


Figure 11. OE2031Front Panel

3.1.1. Display

OE2031 uses a 5.6-inch TFT display for data visualization and user interaction. The display resolution is 640×480, and eight levels of backlight brightness are available for user selection. The brightness can be configured in the [SYSTEM] submenu.

The large area on the left side of the screen is used to display the measurement results of the input signal. It supports dual-column dynamic plots and full-data display. In addition, the dual-column dynamic-plot mode supports numerical and bar-graph display formats, while the full-data display mode supports the display of all measurement parameters. These options can be configured under <Display Mode> in the [DISPLAY] menu.

The area on the right side of the screen is used for selecting and modifying measurement control parameters.

3.1.2. Soft Keys

There are five soft keys located to the right of the display. The functions of the soft keys vary depending on the current menu context. In general, the soft keys serve two main purposes: selecting among different setting options, and highlighting specific parameters for adjustment using the rotary knob or keypad. Regardless of the specific function, each soft key acts only on the parameter adjacent to it on the right side of the screen.

3.1.3. Rotary Knob

The rotary knob is used to adjust parameters highlighted and selected by the soft keys. Most parameters can be adjusted using the rotary knob. Rotating the knob clockwise increases the parameter value, while rotating it counterclockwise decreases the parameter value.

3.1.4. Keypad

The keypad consists of three key groups. The ENTRY area is mainly used for numerical input of parameters highlighted by the soft keys. The MENU area changes the parameter list displayed on the right side of the screen and provides access to ten different function menus. The ARROW area is used for selecting certain highlighted parameters, such as setting the Input Range, or modifying an individual digit of a frequency value.

3.1.5. BNC Connectors

The front panel features six BNC connectors, from left to right: ADD IN, SINE OUT, TTL OUT, REF IN, SIGNAL IN-, and SIGNAL IN+.

ADD IN

The ADD IN input range is from −10 V to 10 V. The signal applied to this connector can be configured to be superimposed on the SINE OUT signal and then output through the SINE OUT connector.

SINE OUT

The signal generator provides a programmable sine-wave output with a maximum amplitude of 2 V_{rms}. The output impedance is 50 Ω. When an external reference signal is used, the signal source of the signal generator is phase-locked to the reference signal through the phase-locked loop.

TTL OUT

The TTL OUT connector outputs a 3.3 V TTL square-wave signal synchronized with the SINE OUT signal. This signal is used as a reference source for the SINE OUT signal.

REF IN

The reference signal input can be driven by either a sine wave or a TTL square wave. The input impedance can be selected as 50 Ω or 1 MΩ. The sine-wave input is AC-coupled and supports signals with reference frequencies above 1 Hz. For low-frequency applications below 1 Hz, a TTL square-wave reference signal is recommended.

SIGNAL IN-/ IN+

The signal input can be configured as single-ended voltage input through IN+, or as differential voltage input DIFF, corresponding to the voltage difference between IN+ and IN-. The input impedance of both connectors can be selected as 50 Ω or 10 MΩ||10 pF.

3.2 Rear Panel

Figure 12. OE2031Rear Panel

The rear panel of OE2031 is shown in Fig. 12. It includes the cooling fan, power inlet, grounding terminal, USB2.0 interface, RS-232 female connector, Ethernet interface, Digital-IO interface, and extended auxiliary-function interfaces. The extended auxiliary-function interfaces include AUX IN, AUX OUT, CLK IN, CLK OUT, TRIGGER IN, TRIGGER OUT, and MONITOR OUT.

3.2.1. Power Inlet

The power inlet provides AC mains input for the entire instrument. It accepts 100~240 V, 50 Hz/60 Hz AC mains power. It includes a built-in fuse and also provides filtering for high-frequency noise interference.

3.2.2. USB2.0

The USB2.0 high-speed interface enables communication between the OE2031 lock-in amplifier and a PC. The PC can be used to control OE2031 and read measurement data.

3.2.3. RS232

The RS232 interface is a standard 9-pin RS-232 female connector, allowing OE2031 to communicate with other host systems.

3.2.4. Ethernet Interface

The Ethernet interface supports communication data rates up to 1000 Mbit/s, enabling high-speed communication with a PC.

3.2.5. AUX IN

The instrument provides four auxiliary AUX-IN input channels, with an input range of ±10 V and a minimum resolution of 0.3 mV.

3.2.6. AUX OUT/CH OUT

The instrument provides four auxiliary AUX-OUT output channels, with an output range of ±10 V and a minimum resolution of 0.3 mV.

3.2.7. CLK IN

CLK IN is an external clock input interface. It accepts a 10 MHz, 3.3 V TTL/CMOS-level clock signal for clock synchronization with external instruments.

⋆ Note: If the external clock source has poor stability, the performance of OE2031 may be degraded.

3.2.8. CLK OUT

CLK OUT provides a 10 MHz clock output interface operating at 3.3 V TTL/CMOS logic level.

3.2.9. TRIG IN & OUT

The trigger input and output interfaces are used for acquiring the signal under test based on an external trigger signal. They can also be used for synchronization among multiple OE2031 instruments.

3.2.10. MONITOR OUT

The MONITOR outputs a copy of the signal after analog amplification and filtering, which is the mirror of the signal sampled by the ADC. Since analog amplification also amplifies noise, the MONITOR output is not intended for viewing very small raw input signals.

3.3 Main Interface

The main interface of OE2031 consists of four areas.

3.3.1. Status Bar

The status bar is located in the red boxed areas shown in Fig. 13 and Fig. 14. It indicates the current system settings and measured values, and its displayed items can be switched in the [DISPLAY] submenu. This bar displays the following information:

<Grnd>: Grounding configuration of the outer shield conductors of the IN+ and IN- connectors.

<Cpl>: Input coupling mode.

<RIN>: Input impedance.

<Src>: Input interface mode.

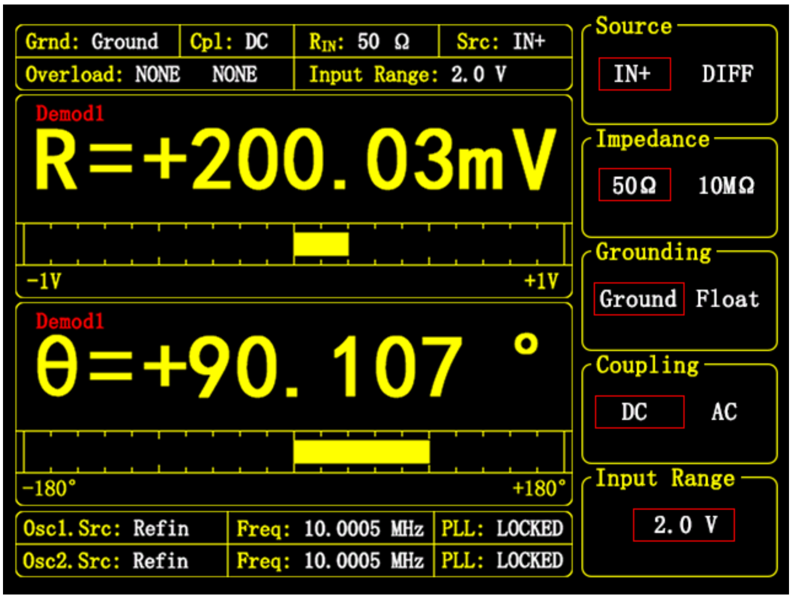


Figure 13. Main Interface–Status Bar 1

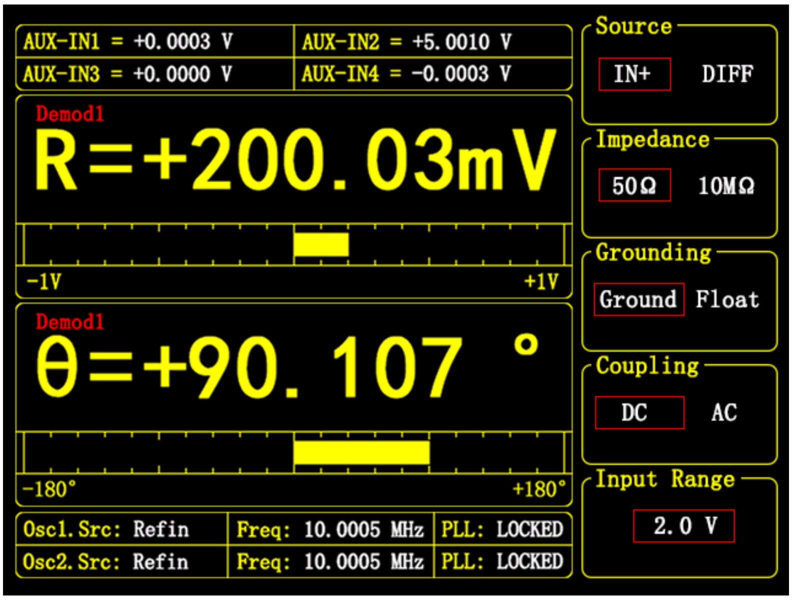


Figure 14. Main Interface–Status Bar 2

<Overload>: Status indicator for input overload or overflow. It indicates whether the front-end input or gain stage has overflowed. If no overflow occurs, Overload: NONE NONE is displayed. If the front-end input overflows, with the judgment threshold set to ±7 V, meaning that the input voltage is higher than 7 V or lower than −7 V, Overload: INPUT NONE is displayed. If the gain stage overflows, Overload: NONE GAIN is displayed. If both overflow conditions occur simultaneously, Overload: INPUT GAIN is displayed. In any overload condition, the input signal level and gain should be reduced as soon as possible to prevent overvoltage damage to the instrument.

<Input Range>: Input range. The input signal must not exceed this range.

<AUX-IN1>: Input amplitude at the AUX-IN1 connector.

<AUX-IN2>: Input amplitude at the AUX-IN2 connector.

<AUX-IN3>: Input amplitude at the AUX-IN3 connector.

<AUX-IN4>: Input amplitude at the AUX-IN4 connector.

3.3.2. Data Bar

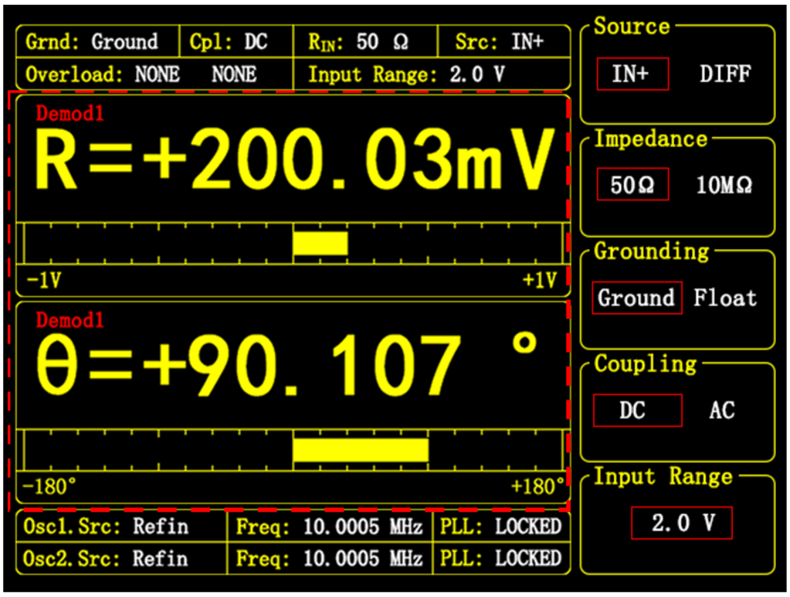


Figure 15. Main Interface–Data Bar

The data bar is located in the red boxed area shown in Fig. 15. In the [DISPLAY] submenu, the displayed values can be selected from <X>, <Y>, <R>, and <θ>. The display mode can be selected as dual-column dynamic plots or full-data display. For details on the setting method, see the [DISPLAY] submenu.

3.3.3. Monitor Bar

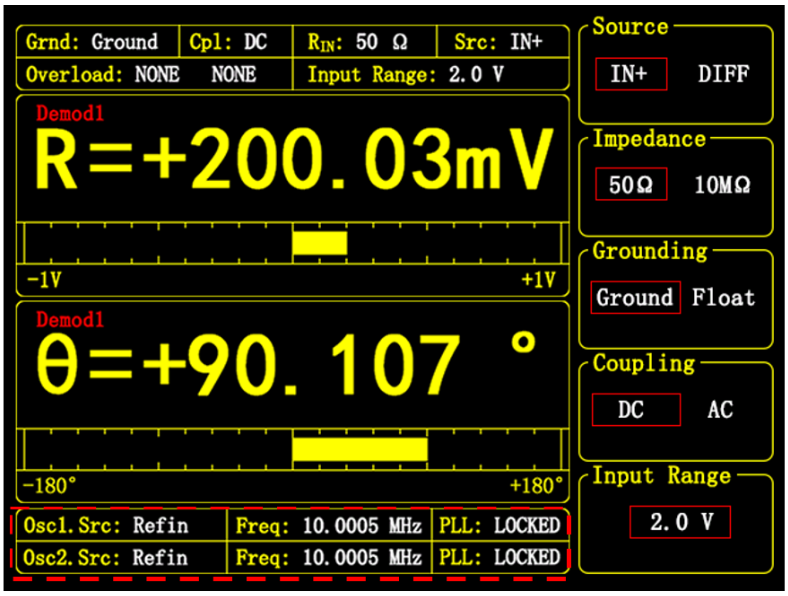


Figure 16. Main Interface–Monitor Bar

The monitor bar, located in the red boxed area shown in Fig. 16, displays three items:

<Osc.Src>: Input source of the oscillator. It indicates whether the selected reference source is internal or external.

<Freq>: Input signal frequency. It displays the frequency of the input signal.

<PLL>: Phase-locked loop lock-status indicator, showing whether the phase is locked. When the phase-locked loop is locked, PLL: LOCKED is displayed. When no reference signal is present or the phase-locked loop is not locked, PLL: UNLOCK is displayed. When the internal reference is used, PLL: NONE is always displayed.

3.3.4. Function Bar

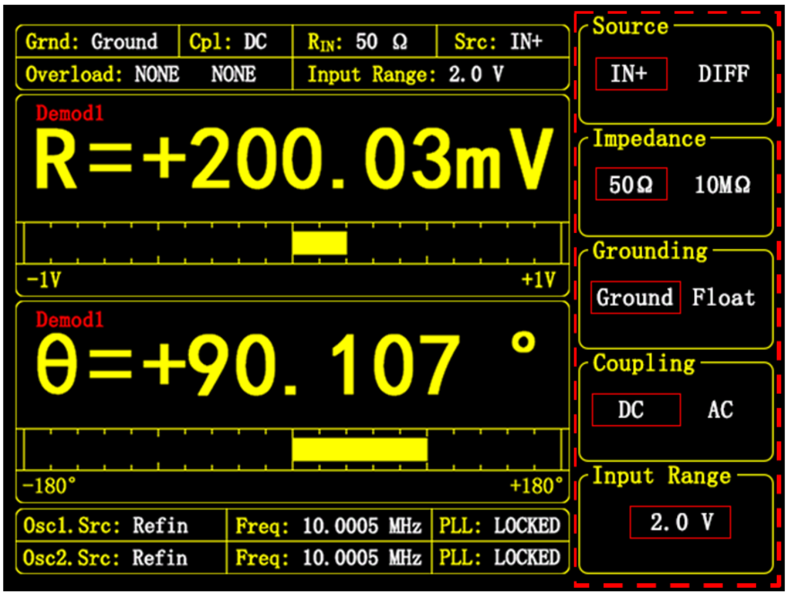


Figure 17. Main Interface–Function Bar

The function bar is located in the red boxed area shown in Fig. 17. The function setting box contains multiple function selections corresponding to the five dark-gray soft keys on the front panel. These keys perform different operations in different submenus and constitute the primary means of controlling the system.

Chapter 4 PC Software Introduction

4.1 PC Software Overview

The OE2031 is supplied with the SSI Lucid Suite PC software. SSI Lucid Suite is a new-generation graphical user interface developed on the QT platform. It visualizes the lock-in signal path and functional configuration as a flow diagram. Compared with the on-screen instrument interface, SSI Lucid Suite is easier to use and understand. In addition, SSI Lucid Suite supports high-speed data transfer and local data storage, making it convenient for users to perform post-processing and analysis. The SSI Lucid Suite interface is shown in Figure 18.

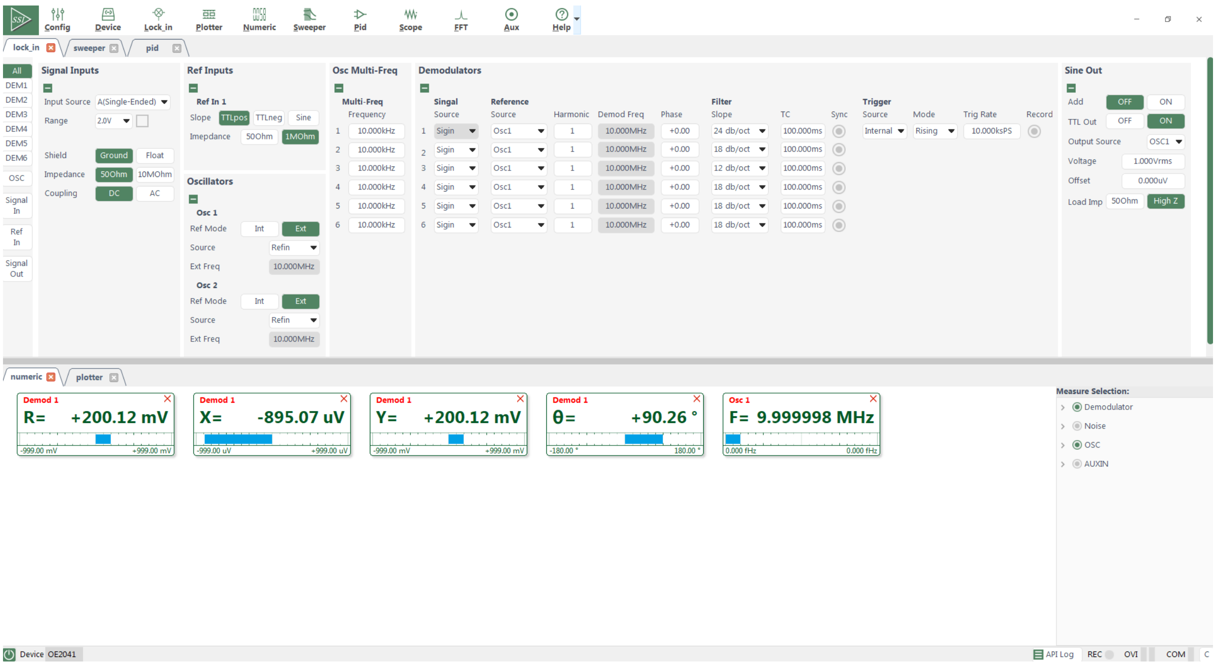


Figure 18. SSI Lucid Suite Software Interface

SSI Lucid Suite is mainly divided into four tab areas: the function menu area, the upper configuration area, the lower configuration area, and the status bar area. The functions of each area are as follows:

Function menu area: This area is used to select different instrument functions. When a function is selected, the corresponding tab is opened in the configuration area.

Upper and lower configuration areas: The configuration area is divided into upper and lower sections. Each configuration section can contain tab interfaces for different functions, and their positions can be swapped freely. By default, the upper configuration area displays the Lock_in function interface, which is used to configure the core functions of the lock-in amplifier demodulators. The lower configuration area displays the Numeric function interface, which presents measurement results in numerical form.

Status bar area: This area displays the basic status of the lock-in amplifier, including the command-setting history log, data recording status, overload status, and communication status.

The locations of these areas are shown in Figure 19.

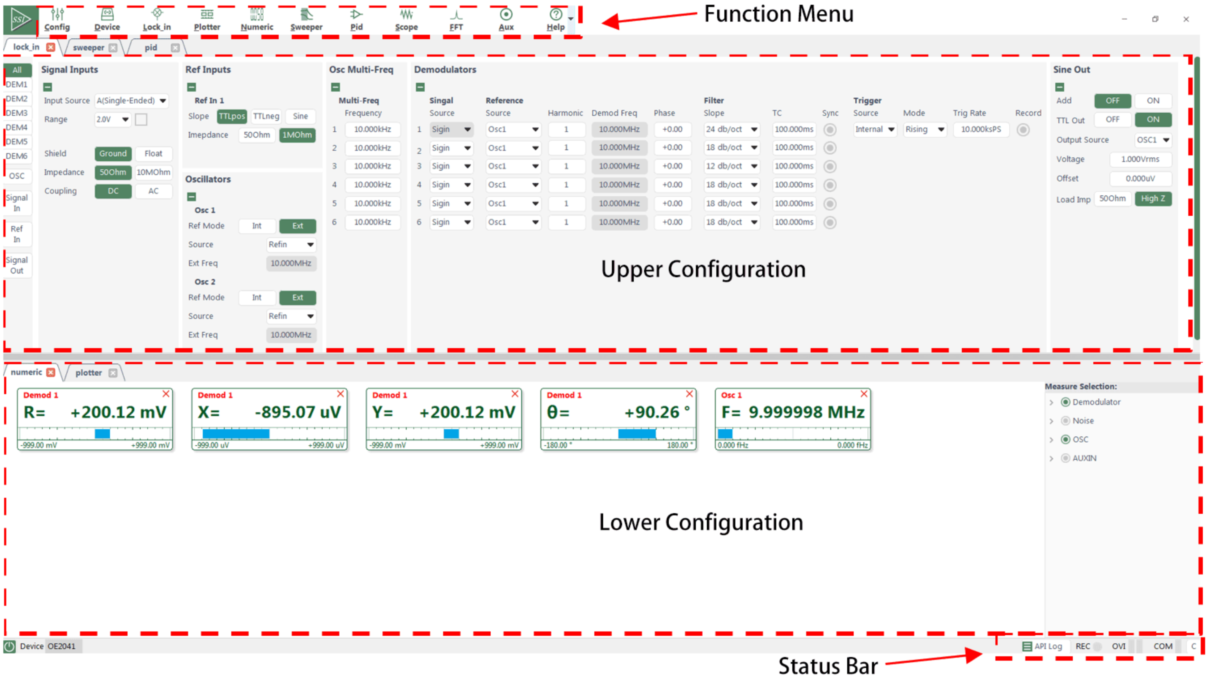


Figure 19. SSI Lucid Suite Area Layout

4.2 Connecting to the PC Software

The OE2031 is supplied with a USB flash drive. The SSI Lucid Suite installer is provided on the supplied USB flash drive. After connecting the PC and the OE2031 using a USB cable or an Ethernet cable, run the “SSI Lucid Suite.exe” file. After the software starts, wait for a few seconds; the software will automatically identify the instrument connected to the PC, as shown in Figure 20.

Figure 20. SSI Lucid Suite Startup Interface

Click the button to connect to the instrument. After the connection is established, the SSI Lucid Suite interface changes to the interface shown in Figure 21.

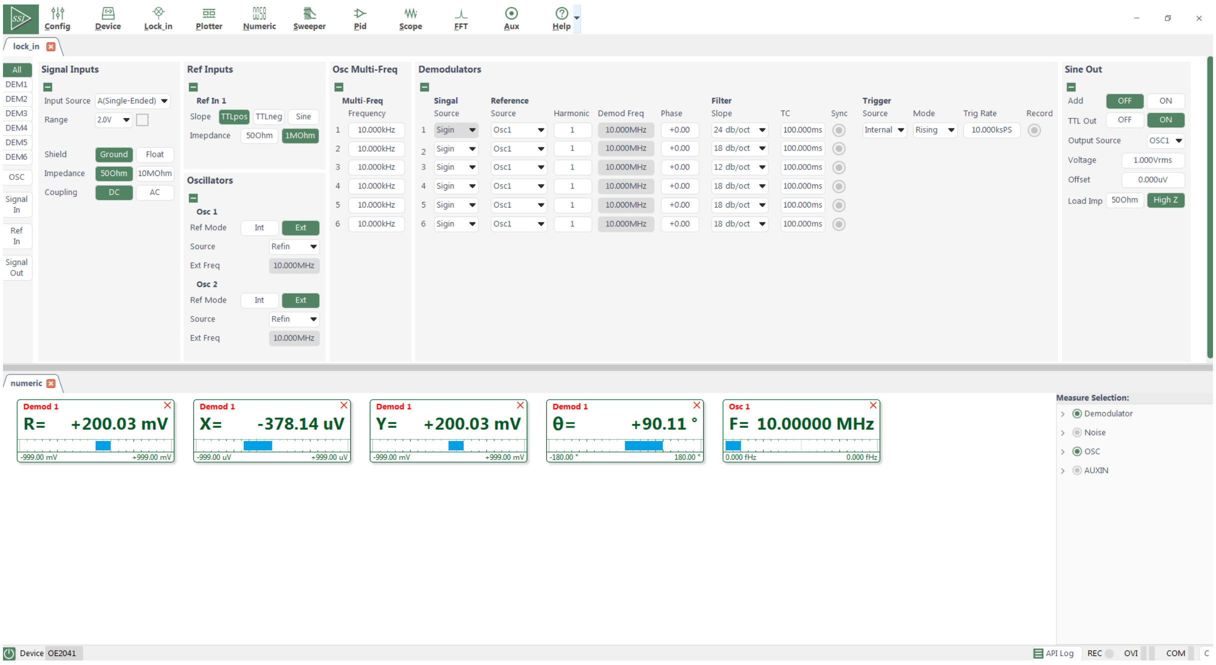


Figure 21. SSI Lucid Suite Interface

4.3 PC Software Function Overview

4.3.1. Function Menu

Figure 22 shows the function menu area of the SSI Lucid Suite PC software. The functions from left to right are as follows:

Config: Instrument connection menu, used to disconnect or reconnect the instrument.

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

Lock_in: Sets and queries the configuration related to the core functions of the lock-in amplifier.

Plotter: Displays curves of the demodulator measurement results.

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

Sweeper: Internal sweep function of the instrument. It supports frequency or amplitude sweep modes. The Sweeper can sweep instrument parameters over a specified range, making it convenient for users to measure system response curves.

PID: Built-in PID module of the instrument. The OE2031 has four PID modules and can control multiple parameters of the lock-in amplifier.

Scope: Oscilloscope function. A virtual oscilloscope is implemented using the high-speed ADC inside the instrument, helping users observe the waveform of the signal under test.

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

Aux: Queries the measured values of the instrument AUX IN channels and sets the output formulas of the AUX OUT channels.

Help: Displays company information and provides functions such as instrument firmware upgrade.

Figure 22. Function Menu Area

4.3.2. Lock_in Tab

The Lock_in configuration tab, shown in Figure 23, contains detailed configuration items for the core functions of the lock-in amplifier, including the demodulators and phase-locked loop. Various variables can be configured in this area. In the left sidebar, the ALL, DEM 1 ~ 6, Osc, Signal In, and other tabs can be selected to switch between the parameter-table view and the flow-diagram view. The parameter-table view displays detailed parameter information, while the flow-diagram view illustrates the instrument's internal hardware and algorithmic architecture, as shown in Figure 24, helping users understand the function of each parameter.

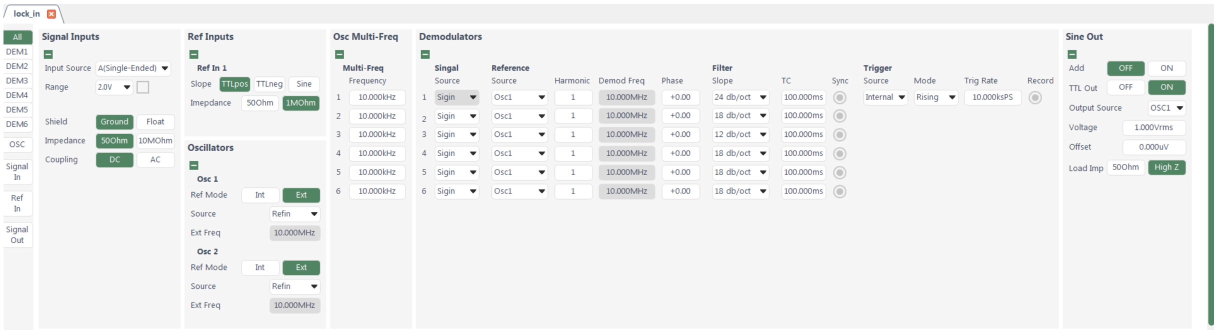


Figure 23. Lock_in Configuration Tab, Parameter-Table View

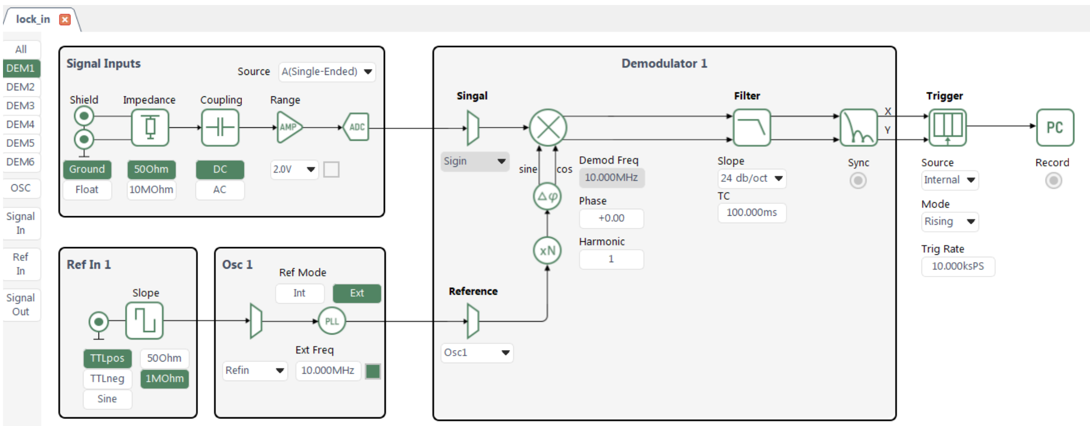


Figure 24. Lock_in Configuration Tab, Flow-Diagram View

4.3.3. Plotter Tab

The Plotter tab, shown in Figure 25, can display and scroll time-domain data traces. It supports flexible scaling of the horizontal and vertical axes, adding different measured values for display, switching between linear and logarithmic coordinates, and displaying the maximum and minimum values of the current waveform. It also allows the current trace data to be saved separately for subsequent analysis and processing.

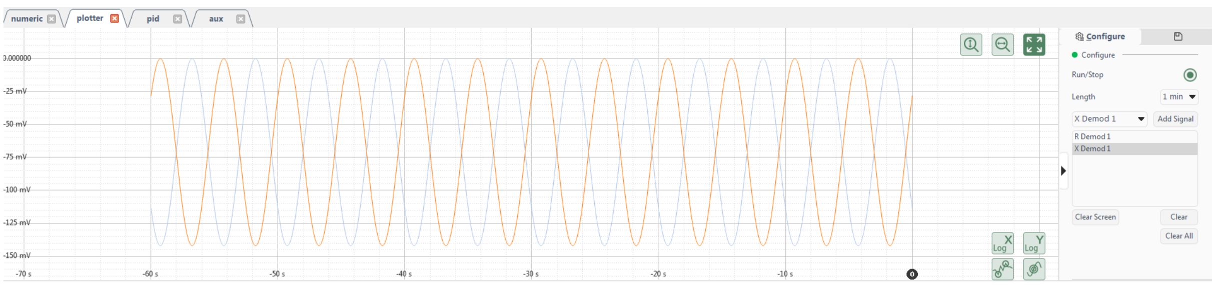


Figure 25. Plotter Tab

4.3.4. Scope Tab

The Scope tab, shown in Figure 26, implements a virtual oscilloscope using the high-speed ADC inside the instrument and can display the waveform of the current measured signal in real time. It supports flexible scaling of the horizontal and vertical axes and provides common oscilloscope functions such as waveform measurement statistics, cursor, and trigger. The current waveform data can also be saved separately for subsequent analysis and processing.

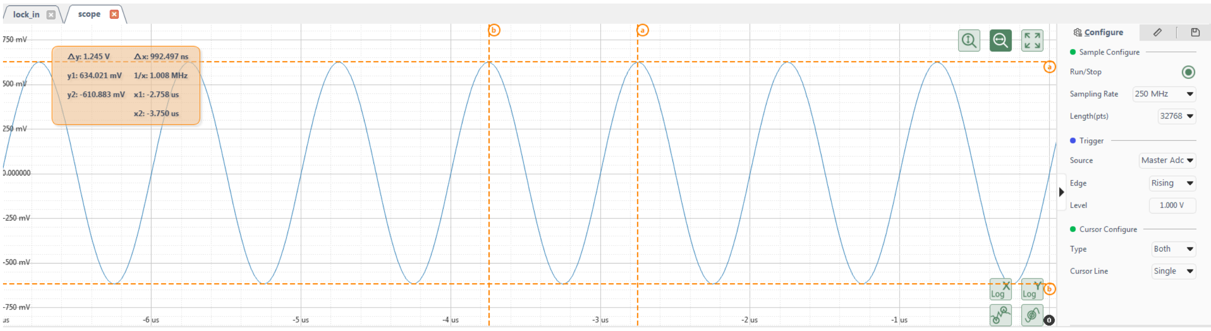


Figure 26. Scope Tab

4.3.5. FFT Tab

The FFT tab, shown in Figure 27, performs a fast Fourier transform on oscilloscope data and converts it into a frequency-domain plot. This helps users analyze the spectral components of the input signal and identify harmonic and interference components.

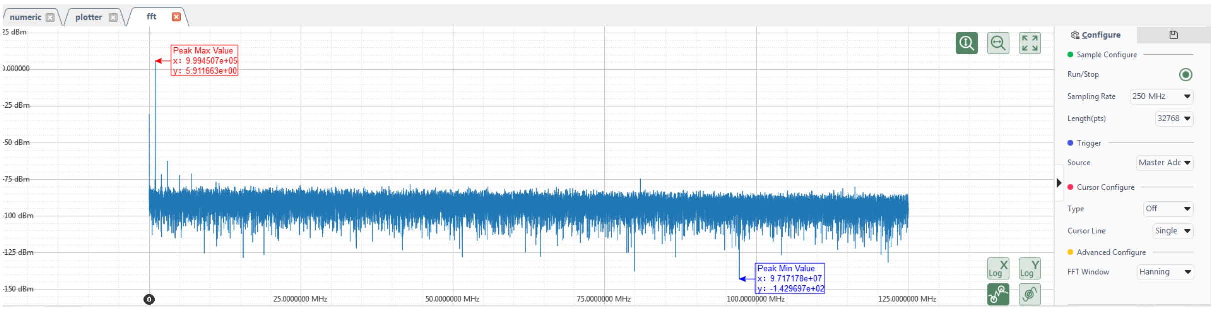


Figure 27. FFT Tab

4.3.6. Sweeper Tab

The Sweeper tab, shown in Figure 28, sweeps instrument parameters within a defined range to measure system frequency response. It facilitates measurement of the system response curve, as well as testing of the amplitude-frequency characteristic curve, phase-frequency characteristic curve, noise spectrum curve, amplitude linearity, and more of the system under test. The Sweeper can select frequency or amplitude sweep modes and supports linear and ratio-based step sweeps. Each sweep captures all measurement data of the OE2031, allowing the results to be analyzed from multiple dimensions.

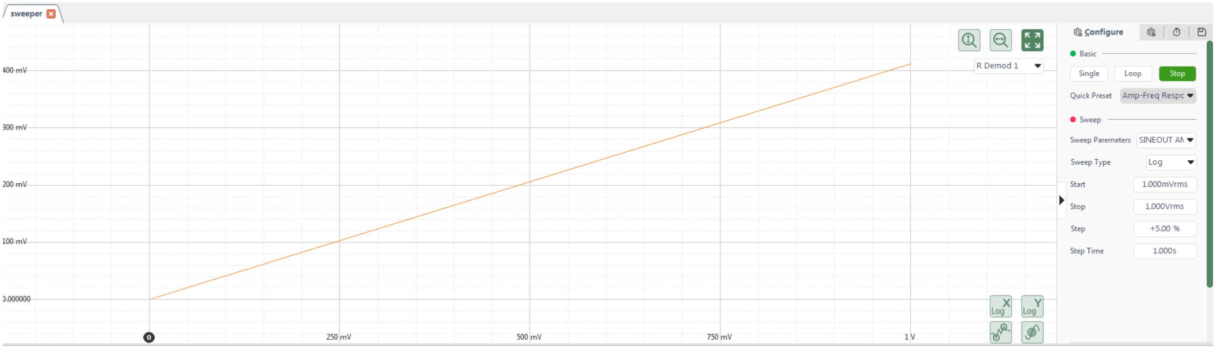


Figure 28. Sweeper Tab

4.3.7. PID Tab

The OE2031 has a built-in four-channel PID controller, as shown in Figure 29. The PID controller supports a maximum sampling rate of 3.9 MHz. The PID input and output signals can be selected from multiple instrument parameters, making the controller suitable for a wide range of applications, such as laser synchronization frequency locking or high-speed scanning probe microscopy (SPM). All available input and output sources are shown in Figure 30.

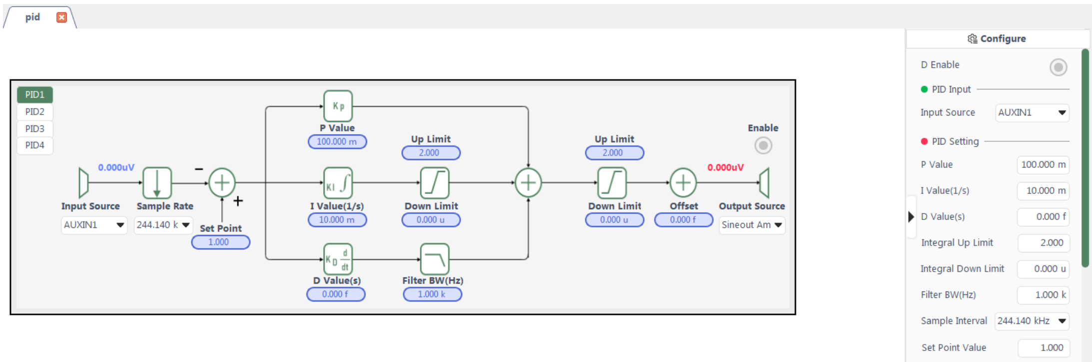


Figure 29. PID Tab

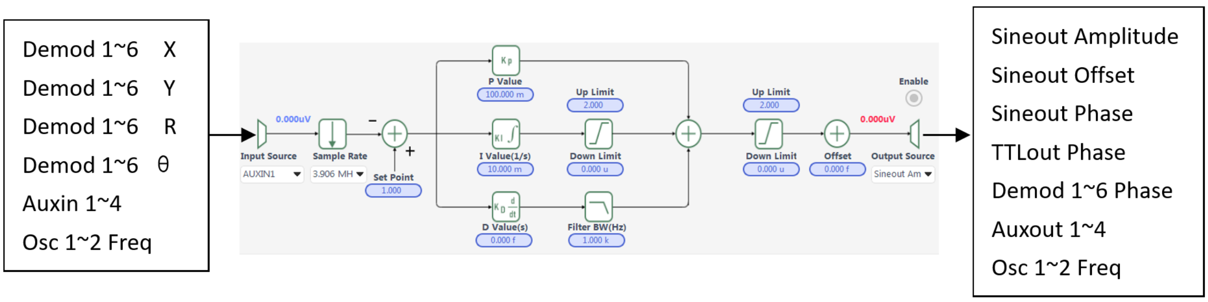


Figure 30. PID Controller Input and Output Source Selection

Some settings in the PID tab are shared with settings that can be accessed from other tabs. If the PID output controls a variable, such as Sineout Amplitude, that variable will be displayed as read-only in the corresponding tab, in this example the Lock-in tab, and the PID output value will override the original parameter configuration.

4.4 Software Usage Example

This example briefly demonstrates how to use the OE2031 PC software to configure lock-in amplifier parameters and observe and record R, X, Y, and θ values.

First, connect the OE2031 to the PC successfully according to the instructions in Section 4.2. After the connection is established, configuration can begin.

Assume that the user needs to perform the following lock-in amplifier settings and save the data:

Table 2. Example Configuration Table

Input signal type	Single-ended voltage input
Input signal amplitude	40 mV
Input coupling	AC
Input gain	100 mV
Reference signal input	External reference, 1000 Hz
Reference trigger mode	TTL rising-edge trigger
Demodulator phase shift	0°
Low-pass filter time constant	100 ms
Filter roll-off	24 dB/oct
Data sampling rate	100 Sa/s

To complete the settings above, perform the following steps:

1. According to the configuration in Table 2, modify the input signal type, input coupling, and input range in the input signal configuration area. Keep the other options at their default values. As shown in Figure 31 and Figure 32, select either method to make the changes.

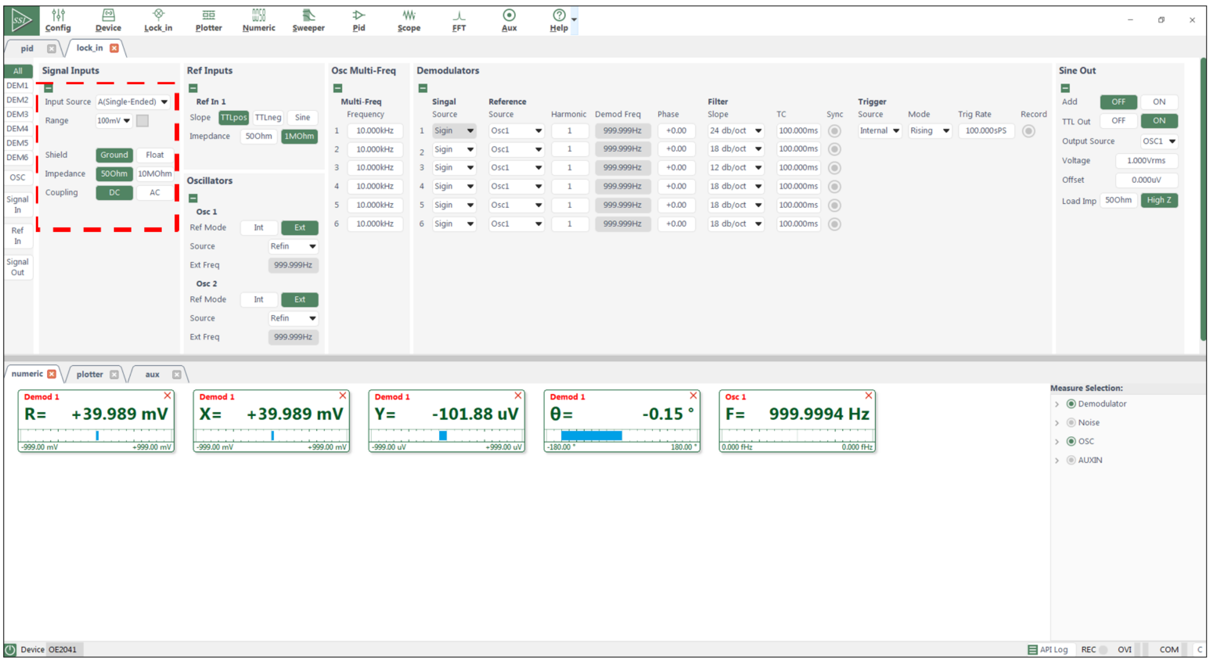


Figure 31. Input Signal Configuration Area

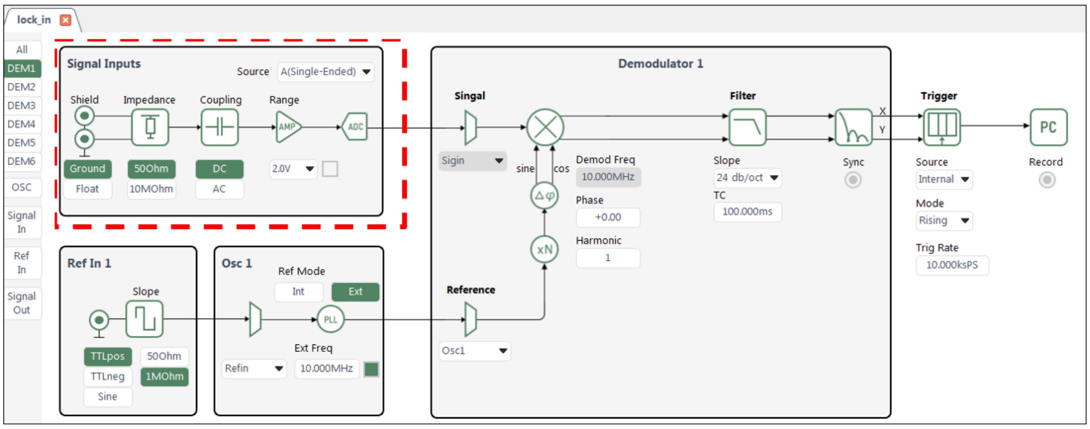


Figure 32. Input Signal Configuration Area in the Flow Diagram

2. According to the configuration in Table 2, set the reference signal source type to external reference in the reference signal configuration area. Keep the other options at their default values. As shown in Figure 33 and Figure 34, select either method to make the changes.

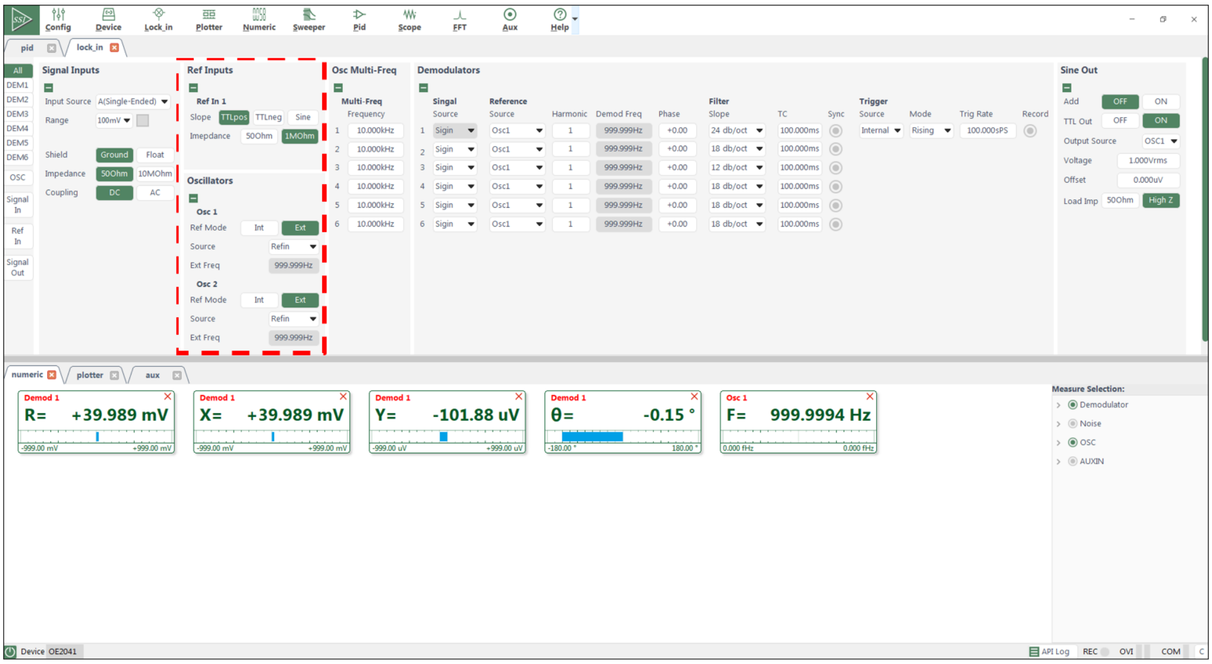


Figure 33. Reference Signal Configuration

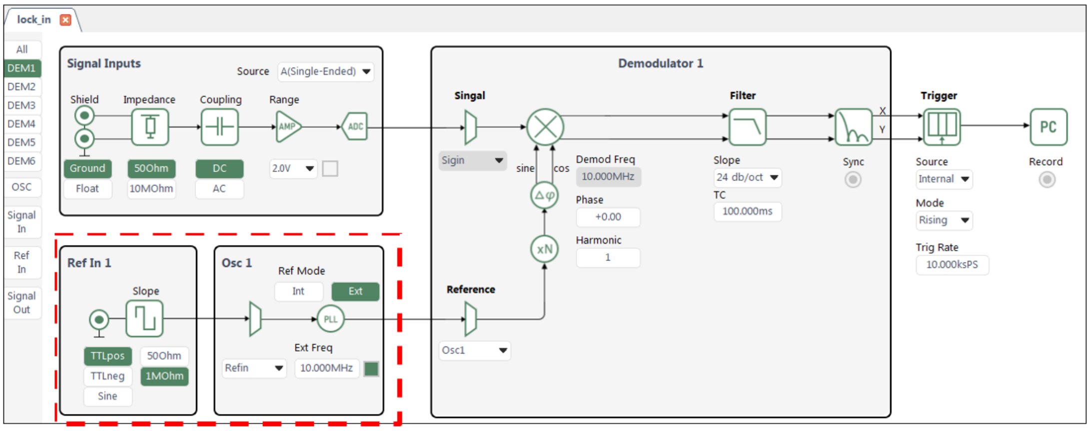


Figure 34. Reference Signal Configuration Area in the Flow Diagram

3. According to Table 2, select the demodulator time constant, filter roll-off, and phase adjustment value in the filter configuration area. Keep the other options at their default values. As shown in Figure 35 and Figure 36, select either method to make the changes and complete the configuration.

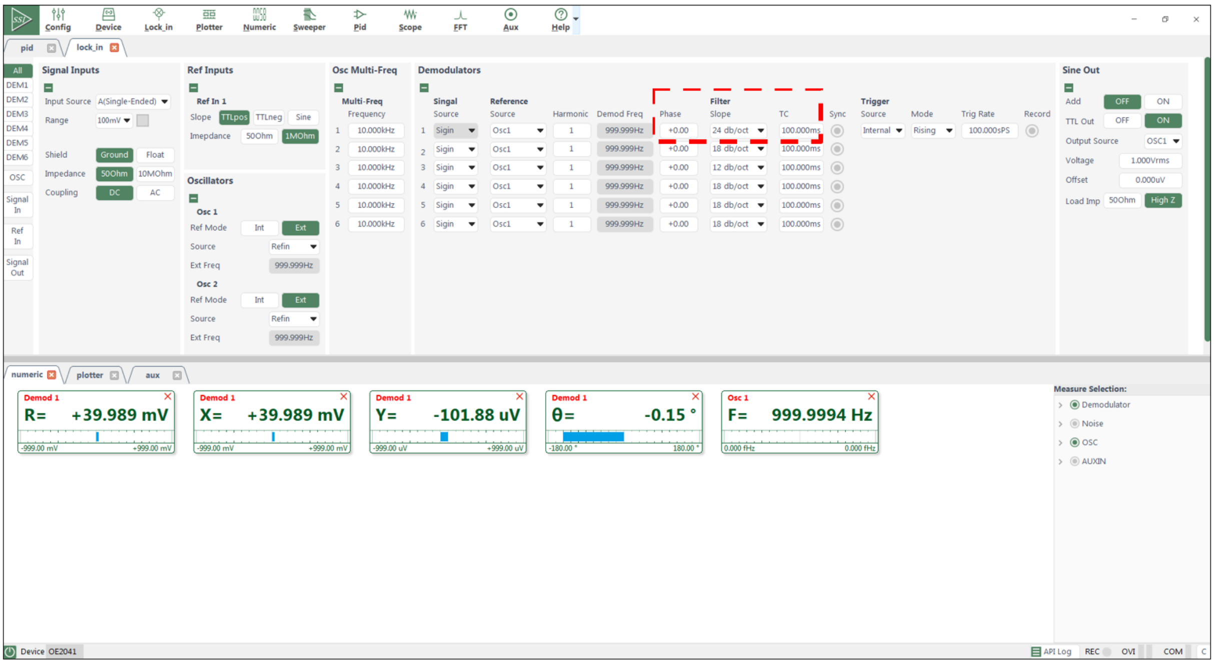


Figure 35. Filter Configuration

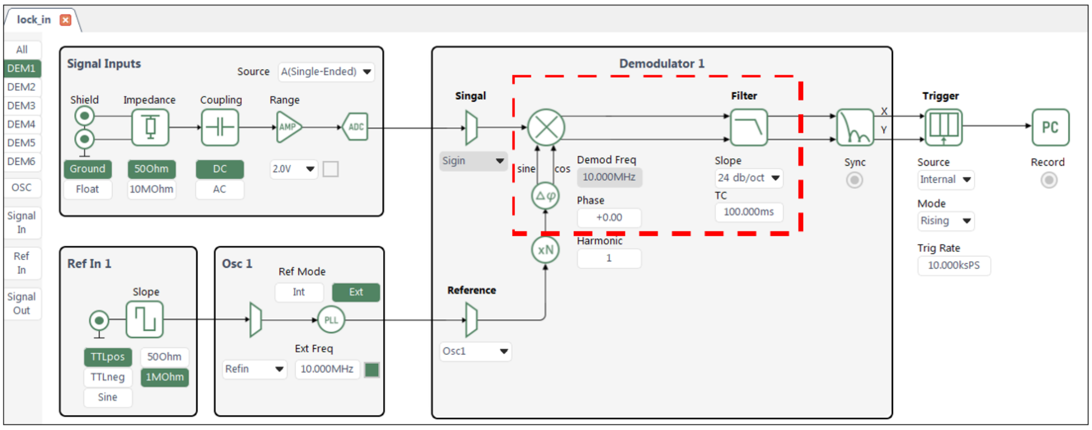


Figure 36. Filter Configuration Area in the Flow Diagram

4. To configure another demodulator, use the red boxed area shown in Figure 37 to set the harmonic order of Demodulator 2 to 3 and enable the display of the Demodulator 2 measurement result. In this way, the fundamental component and the third harmonic component of the input signal can be measured at the same time.

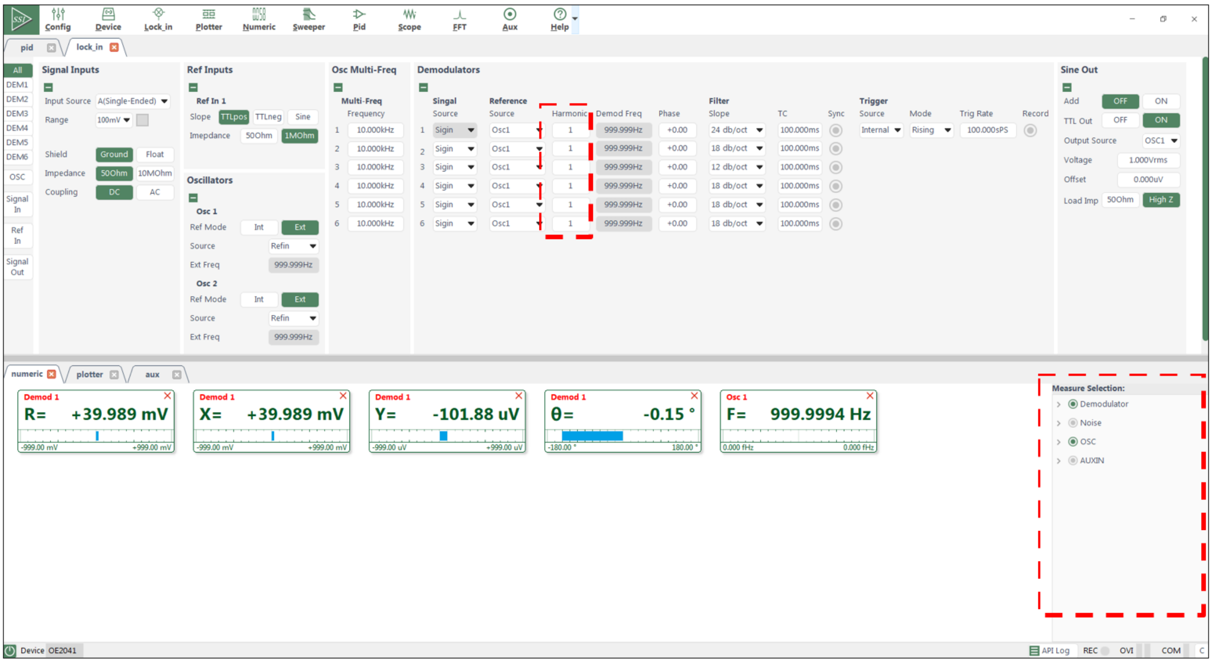


Figure 37. Additional Demodulator Configuration

5. After completing Steps 1–4, the OE2031 has been configured as required. Keep the other options at their default values. Data acquisition and saving can now begin.

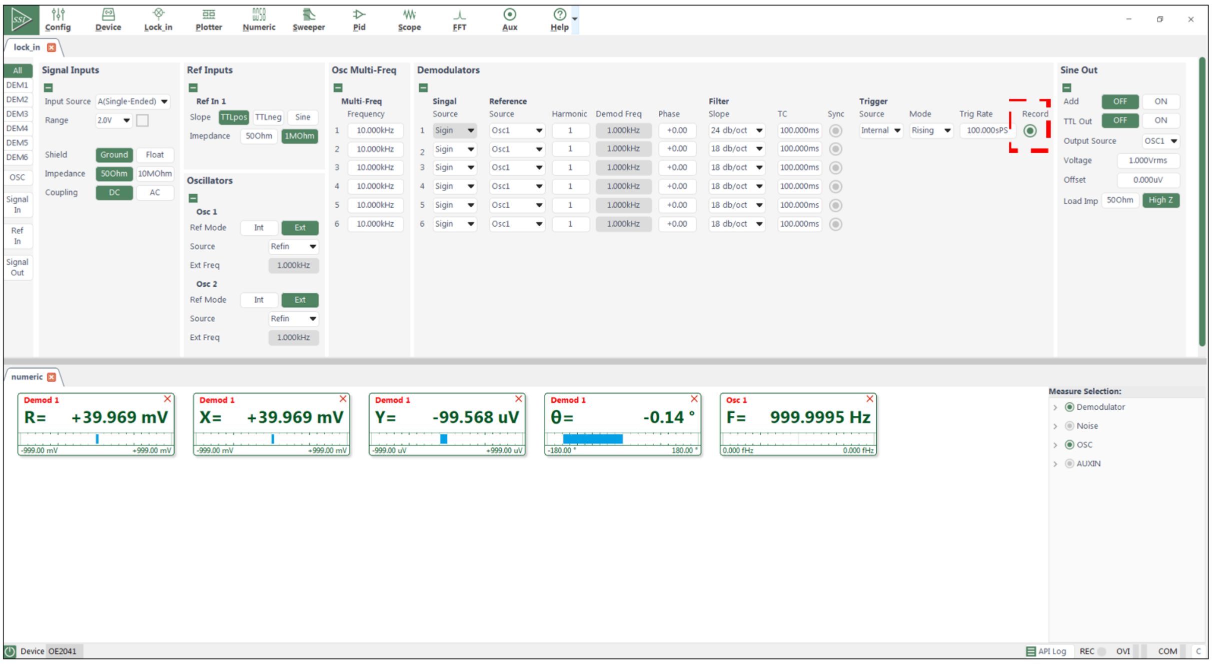


Figure 38. Data Recording in Progress

As shown in Figure 38, click the “Record” button inside the red box. When the button is selected, it indicates that the currently acquired data is being saved.

The data is saved as an Excel-compatible table in the program directory. The file name is “data_lock_in_xxxxx.csv”. The file stores the data from six demodulators.

Chapter 5 Interface and PC Software Functions

The main menu of the OE2031 is located in the MENU key area on the front panel. The MENU main menu contains ten submenus: [SIGNAL INPUT], [OSC REF], [DEMOD FILTER], [DEMOD REF], [DISPLAY], [SIGNAL OUTPUT], [AUTO SET], [CHANNEL OUTPUT], [SYSTEM], and [SAVE RECALL]. Pressing each key switches the instrument to the corresponding submenu interface.

The OE2031 can also be controlled from the PC software, and measurement data can be read through the PC software.

5.1 [SIGNAL INPUT] Submenu

5.1.1. Front-Panel Configuration

Select [SIGNAL INPUT] from the front-panel menu bar to enter this submenu. This menu is used to configure the hardware settings of the signal input channel, as shown in the right-side panel of Figure 39.

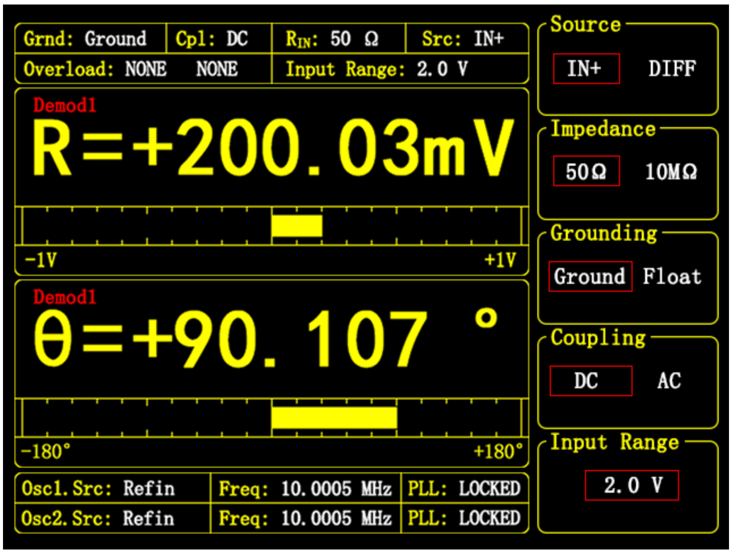


Figure 39. [INPUT/FILTERS] submenu

This submenu includes five function settings: <Source>, <Impedance>, <Grounding>, <Coupling>, and <Input Range>.

- <Source>: input source setting

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

<DIFF> : Differential voltage signal input mode. In this mode, connect one side of the differential signal to the IN+ connector and the other side to the IN- connector. The measured signal is the differential voltage between IN+ and IN-.

☆ **The amplitude of the maximum input signal must not exceed the <Input Range> setting.**

- <Impedance>: input impedance setting

  50 Ω : The input impedance of the IN+ / IN- connectors is set to 50 Ω.

  10 MΩ : The input impedance of the IN+ / IN- connectors is set to 10 MΩ.

  ☆ **At higher frequencies (>1 MHz), using the 50 Ω input impedance setting is recommended to reduce interference caused by impedance reflections.**

- <Grounding>: input shield grounding setting

  <Float> : Shield of the IN+/IN− input connectors are isolated from instrument ground through a 1 kΩ resistor.

  <Ground> : Shield of the IN+/IN− input connectors is connected to the instrument ground via a 0 Ω resistor (Note: the instrument ground is inherently tied to the AC mains Earth ground).

  In general, if the signal source is not capable of injecting a large current into the instrument (so it will not damage the instrument input interface chip), or if it is confirmed that the signal ground and instrument ground are at the same ground potential, <Ground> can be selected to short the signal ground and system ground together. This prevents signal drift caused by a floating signal ground. If the absolute potential difference between the signal ground and instrument ground is large and the signal ground is capable of injecting a large current, use <Float> to float the signal ground and provide current-limiting protection.

  ☆ **When measuring weak signals (<1 mV), <Ground> mode is recommended, provided that the signal ground and instrument ground are at the same ground potential.**

- <Coupling>: input coupling setting

  <AC> : AC-coupled input. The cutoff frequency of AC coupling is 0.16 Hz. It is used to block the DC component in the input signal. If the signal frequency is above 10 Hz, <AC> coupling is recommended.

  <DC> : DC-coupled input. DC coupling does not block any input signal component. If the signal frequency is below 10 Hz, <DC> coupling is recommended. Note that the offset component of the input signal may cause signal overflow.

- <Input Range>: input range setting

  The available <Input Range> settings are as follows:

  2 V : The maximum allowed RMS input voltage is 2 V_{rms}.

  500 mV : The maximum allowed RMS input voltage is 500 mV_{rms}.

  100 mV : The maximum allowed RMS input voltage is 100 mV_{rms}.

  20 mV : The maximum allowed RMS input voltage is 20 mV_{rms}.

  5 mV : The maximum allowed RMS input voltage is 5 mV_{rms}.

  1 mV : The maximum allowed RMS input voltage is 1 mV_{rms}.

For general measurements, the gain should be selected based on the absence of overload indication in the monitor bar. As long as no overload occurs, selecting a range closer to the signal amplitude improves the stability and accuracy of the measurement result.

When the automatic gain setting function <Auto Range> is used, the system automatically adjusts the input range to the closest appropriate range according to the maximum amplitude of the input signal, ensuring measurement accuracy.

5.1.2. PC Software Configuration

As shown in the red box in Figure 40, the highlighted area in the PC software is the [SIGNAL INPUT] configuration area. The user can configure the signal input channel either in the parameter table or in the flowchart area. The configuration information for <Source>, <Impedance>, <Grounding>, <Coupling>, and <Input Range> can all be modified and confirmed in the red-boxed area.

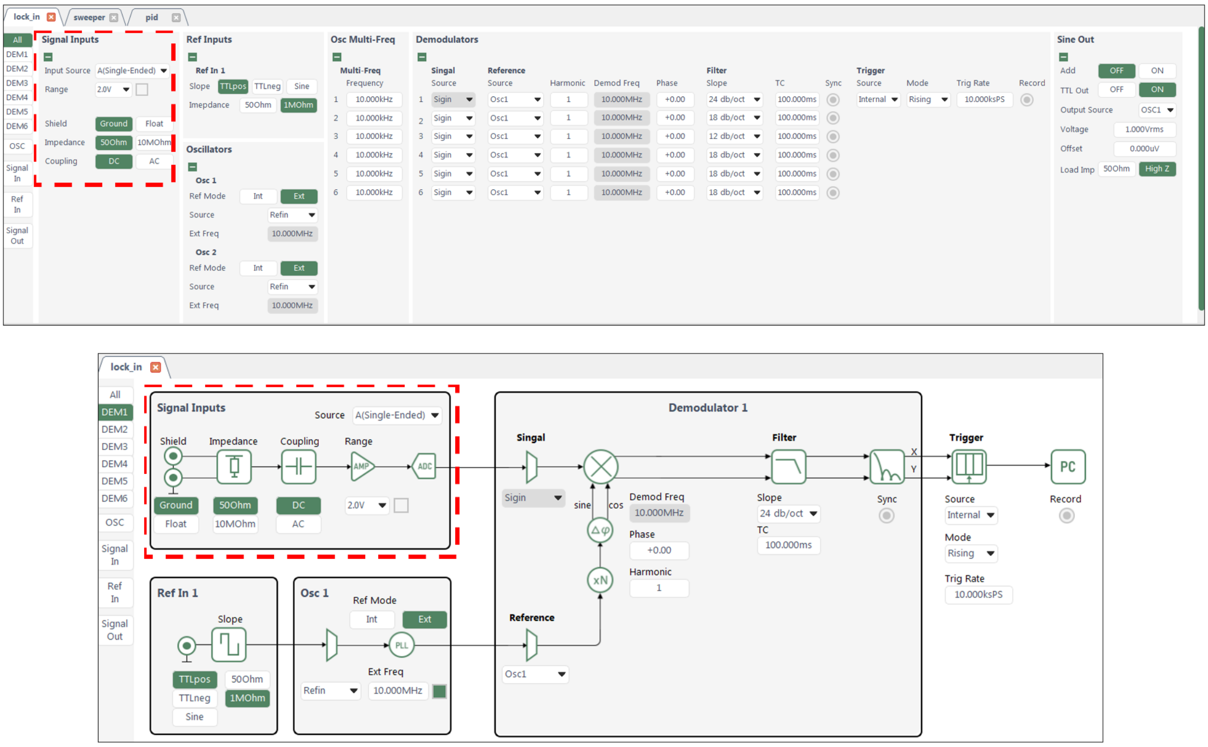


Figure 40. [SIGNAL INPUT] configuration area

5.2 [OSC REF] Submenu

5.2.1. Front-Panel Configuration

Select [OSC REF] from the front-panel menu bar to enter this submenu. This menu is used to configure the hardware settings of the reference input channel and the mode settings of the two oscillators, OSC1 and OSC2. Different configuration modes switch to different interfaces, as shown in Figure 41 and Figure 42.

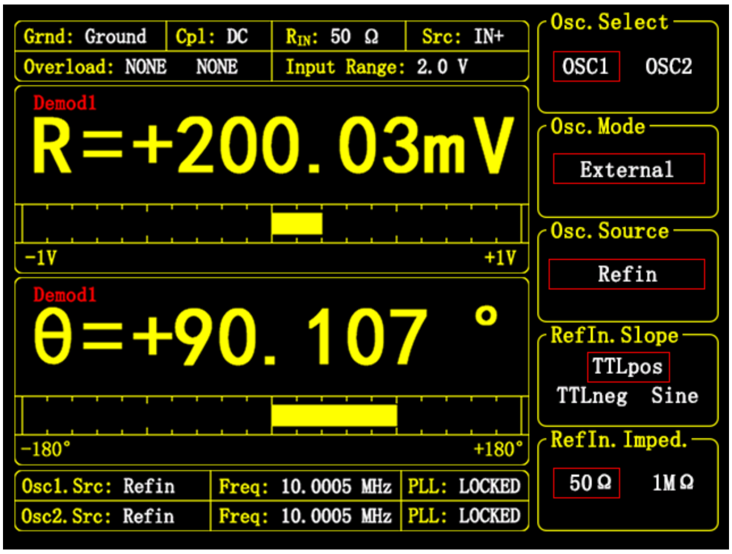


Figure 41. [OSC REF] submenu—<External>

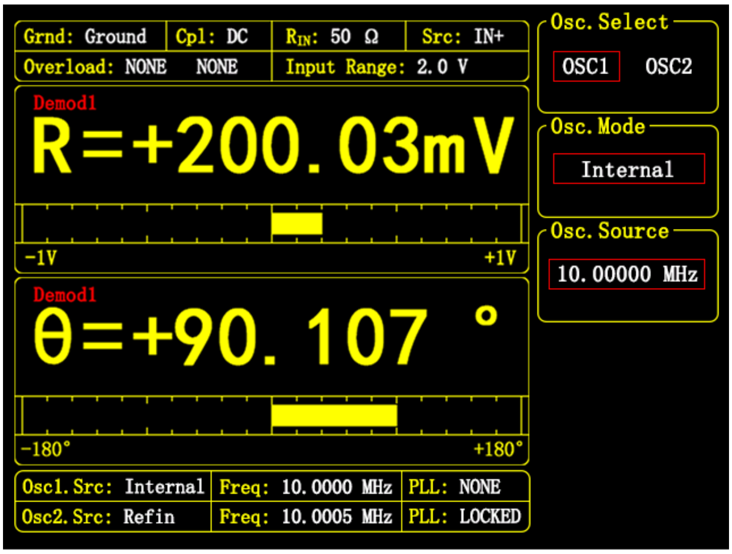


Figure 42. [OSC REF] submenu—<Internal>

This submenu includes six function settings: <Osc.Select>, <Osc.Mode>, <Osc.Source>, <Osc.Frequency>, <RefIn.Slope>, and <RefIn.Imped.>.

- <Osc.Select>: OSC channel selection

Press the corresponding key to switch the parameter display and configuration between the two oscillators, <OSC1> and <OSC2>. For example, when <OSC1> is selected, the settings of <Osc.Mode>, <Osc.Source>, and <Osc.Frequency> all correspond to the current configuration of <OSC1>. Changing these settings at this time does not affect the configuration of <OSC2>. Since the Refin interface has only one channel, <RefIn.Slope> and <RefIn.Imped.> are shared by <OSC1> and <OSC2>. Modifying either oscillator changes the configuration of the Refin interface.

- <Osc.Mode>: oscillator mode setting

<External>: External mode. The OE2031 sets the current oscillator to external mode. In this mode, the reference signal input from the REFIN-BNC connector is connected to the

oscillator and phase-locked inside the instrument. Due to the phase-locked loop, the oscillator output signal tracks the external reference signal in real time. The interface is shown in Figure 41, where <Osc.Source> can be set.

<Internal> : Internal mode. The OE2031 sets the current oscillator to internal mode. In this setting, the oscillator is connected to the instrument's internal crystal oscillator, and the reference signal is generated by the instrument itself. The REF IN input signal is not used. The interface is shown in Figure 42, where <Osc.Frequency> can be set.

- <Osc.Source>: reference signal source setting

<Refin> : Sets the reference input source of the oscillator in external mode to REF IN. The waveform type of the REF IN signal can then be set using <Ref.Slope>. Note that <Refin> is the shared reference interface for <OSC1> and <OSC2>.

<Sigin> : Sets the reference input source of the oscillator in external mode to the SIGNAL IN interface.

<Auxin1> : Sets the reference input source of the oscillator in external mode to the AUX IN 1 interface.

<Auxin2> : Sets the reference input source of the oscillator in external mode to the AUX IN 2 interface.

<Auxin3> : Sets the reference input source of the oscillator in external mode to the AUX IN 3 interface.

<Auxin4> : Sets the reference input source of the oscillator in external mode to the AUX IN 4 interface.

<Trigin> : Sets the reference input source of the oscillator in external mode to the TRIGGER IN interface.

- <RefIn.Slope>: reference signal type setting for the REFIN interface

This item can be set when <Osc.Mode> is set to <External> and <Osc.Source> is set to <Refin>. Select the corresponding signal type according to the type of the external reference signal.

<TTLpos> : Select this item when the external input signal is a square wave. The reference signal is phase-locked to the rising edge.

<TTLneg> : Select this item when the external input signal is a square wave. The reference signal is phase-locked to the falling edge.

<Sine> : Select this item when the external input signal is a sine wave. The reference signal is phase-locked to the rising zero crossing.

When the input reference signal is at TTL logic levels, TTL triggering is recommended. Note that if the reference signal input to REF IN is a square wave but its voltage levels do not meet the TTL logic high/low threshold requirements ($3\,V < V_{IH} < 5\,V$, $-0.1\,V < V_{IL} < 0.5\,V$), stable triggering may not be obtained, and the expected measurement result may not be achieved. In this case, SINE triggering is recommended. In addition, for very low frequencies (<1 Hz), a TTL reference signal is required.

When the REF IN reference signal is a sine signal, SINE triggering is recommended. SINE triggering precisely shapes the REF IN input inside the system before detecting frequency and phase information.

In addition, neither <TTL> triggering nor <SINE> triggering imposes a requirement on the duty cycle of the signal, but a conventional 50% duty cycle is recommended. A smaller duty cycle results in more severe high-order harmonics and stronger radiated interference.

- <RefIn.Imped.>: input impedance setting for the REFIN interface
  <50 Ω> : The input impedance of the REF IN interface is set to 50 Ω.
  <1 MΩ> : The input impedance of the REF IN interface is set to 1 MΩ.
- <Osc.Frequency>: internal reference signal frequency setting

This item can be set when <Osc.Mode> is set to <Internal>. The frequency range is from 10 μHz to 10 MHz, and the default value is 10.000 kHz. The frequency can be entered from the keypad, and the minimum frequency resolution is 1 nHz. When <Osc.Frequency> is selected, one digit can also be changed independently using the up, down, left, and right keys in the [ARROW] area. For example, to quickly change 1000 Hz to 1100 Hz, first select the <Osc.Frequency> key, then move the cursor to the hundreds digit using the [→] and [←] keys, change that digit to 1 using the [↑] and [↓] keys, and finally press <Enter> to confirm, as shown in Figure 43.

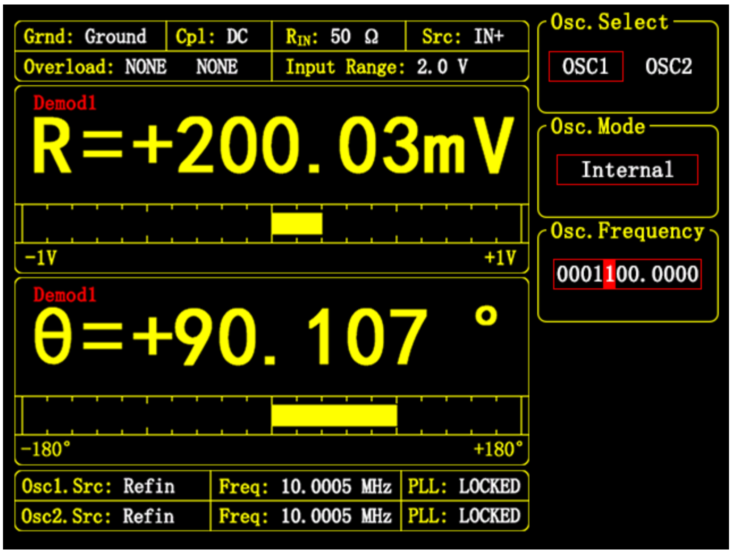


Figure 43. Frequency adjustment using [ARROW]

5.2.2. PC Software Configuration

As shown in the red box in Figure 44, the highlighted area in the PC software is the [OSC REF] configuration area. The user can configure the hardware settings of the reference input channel and the internal oscillator settings either in the parameter table or in the flowchart area. The configuration information for <Osc.Select>, <Osc.Mode>, <Osc.Source>, <Osc.Frequency>, <RefIn.Slope>, and <RefIn.Imped.> can all be modified and confirmed in the red-boxed area.

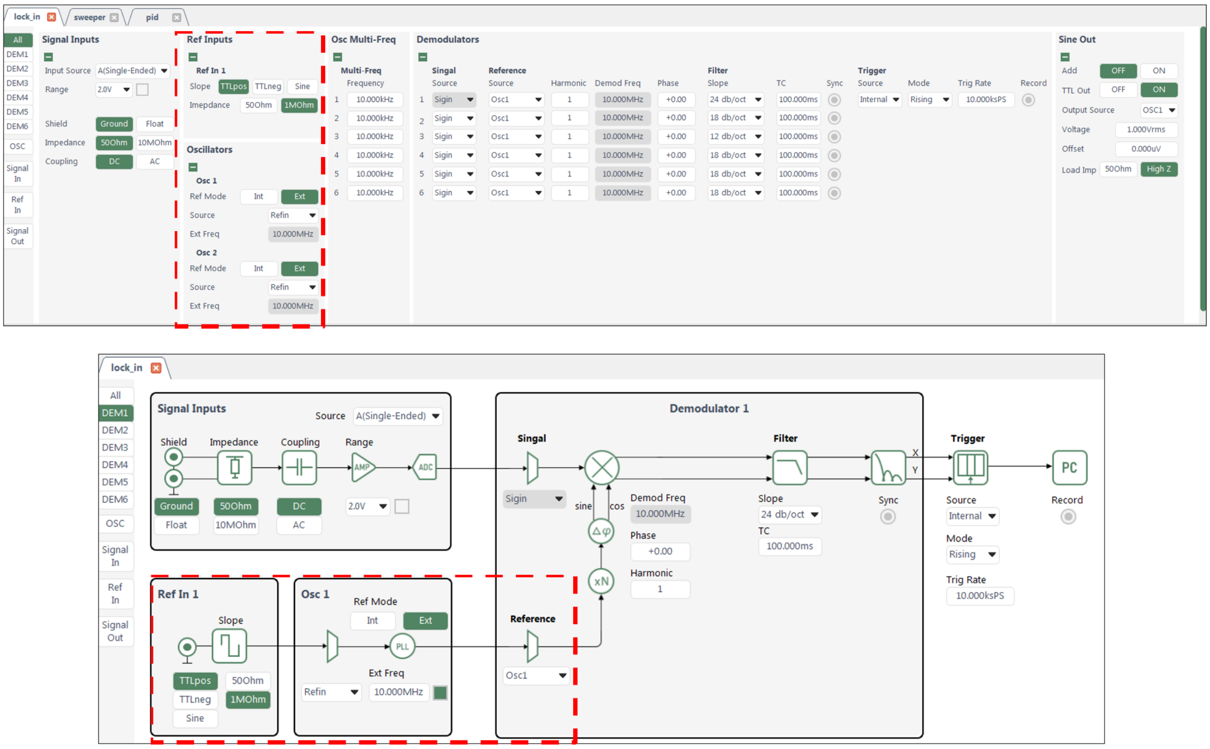


Figure 44. [OSC REF] configuration area

5.3 [DEMOD FILTER] Submenu

5.3.1. Front-Panel Configuration

Select [DEMOD FILTER] from the front-panel menu bar to enter this submenu. This menu configures the demodulator input source and low-pass filter settings, as shown in the right-side panel of Figure 45.

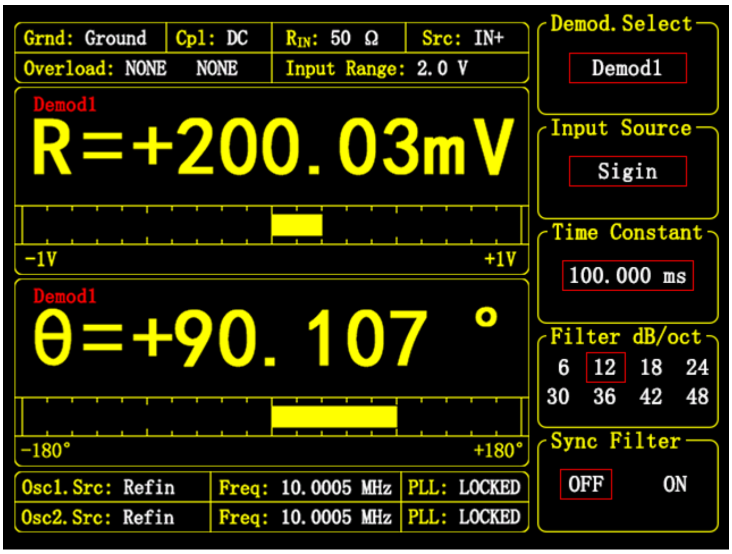


Figure 45. [DEMOD FILTER] submenu

This submenu includes five function settings: <Demod.Select>, <Input Source>, <Time

Constant>, <Filter dB/oct>, and <Sync Filter>.

- <Demod.Select>: demodulator channel selection setting

  The knob and the keys in the ARROW area can be used to switch the parameter display and configuration among the six demodulators, <Demod1> through <Demod6>. For example, when <Demod1> is selected, the settings of <Input Source>, <Time Constant>, <Filter dB/oct>, and <Sync Filter> all correspond to the current configuration of <Demod1>. Changing these settings at this time does not affect the related configurations of other demodulators.

- <Input Source>: demodulator signal input source selection setting

  <Sigin> : Sets the signal input source of the current demodulator to the SIGNAL IN interface.

  <Auxin1> : Sets the signal input source of the current demodulator to the AUX IN 1 interface.

  <Auxin2> : Sets the signal input source of the current demodulator to the AUX IN 2 interface.

  <Auxin3> : Sets the signal input source of the current demodulator to the AUX IN 3 interface.

  <Auxin4> : Sets the signal input source of the current demodulator to the AUX IN 4 interface.

  <X-Demod1> : Sets the signal input source of the current demodulator to the X output value of Demodulator 1.

  <Y-Demod1> : Sets the signal input source of the current demodulator to the Y output value of Demodulator 1.

  <R-Demod1> : Sets the signal input source of the current demodulator to the R output value of Demodulator 1.

  <Theta-Demod1> : Sets the signal input source of the current demodulator to the Theta output value of Demodulator 1.

  When the signal input source of a demodulator is set from <X-Demod1> to <Theta-Demod1>, the OE2031 enters cascaded demodulation mode for applications such as secondary demodulation of modulated signals, recovery of the carrier signal, as well as recovery of the modulating wave signal.

  ☆ **Note: Demod1 is fixed to use Sigin as its input source.**

- <Time Constant>: time constant setting

  The time constant setting range is from 100 ns to 3 ks. The value can be entered from the keypad or modified using the ARROW area.

  A longer time constant gives a smaller equivalent noise bandwidth, a longer measurement response time, and higher measurement accuracy.

- <Filter dB/oct>: low-pass filter roll-off setting

  <6 dB/oct> : First-order low-pass filter, with a 6 dB/oct roll-off.
  <12 dB/oct> : Second-order low-pass filter, with a 12 dB/oct roll-off.
  <18 dB/oct> : Third-order low-pass filter, with an 18 dB/oct roll-off.
  <24 dB/oct> : Fourth-order low-pass filter, with a 24 dB/oct roll-off.
  <30 dB/oct> : Fifth-order low-pass filter, with a 30 dB/oct roll-off.
  <36 dB/oct> : Sixth-order low-pass filter, with a 36 dB/oct roll-off.
  <42 dB/oct> : Seventh-order low-pass filter, with a 42 dB/oct roll-off.

<48 dB/oct> : Eighth-order low-pass filter, with a 48 dB/oct roll-off.

For the same measurement accuracy, using a steeper filter roll-off can reduce the time constant and make the measurement response faster. The specific combination of time constant and filter roll-off must be selected according to the actual situation. One criterion is that as long as the stability of the measurement result is satisfactory, the time constant and filter roll-off do not need to be set too large, so as to avoid excessive waiting time. Of course, if a smoother result is desired, the time constant and filter roll-off may be increased appropriately.

- <Sync Filter>: synchronous filter setting

  <OFF> : Disables the synchronous filter.

  <ON> : Enables the synchronous filter.

The synchronous filter can effectively remove signals at the reference frequency and its harmonics, reducing the requirements on the low-pass filter. The synchronous filter can be enabled or disabled in any state, but it is effective only when the signal frequency is below 1 MHz.

When the input signal frequency is low, the low-pass filter may be unable to obtain a stable result, or may require a long time to do so. In this case, enabling the synchronous filter can improve the result. The effect is shown in Figure 46.

☆ **Note: When the synchronous filter is enabled, it takes effect only when <Filter dB/oct> is <18 dB/oct> or higher and <Demod Frequency> is below 1 MHz!**

Figure 46. Effect of enabling the synchronous filter

5.3.2. PC Software Configuration

As shown in the red box in Figure 47, the highlighted area in the PC software is the [DEMOD FILTER] configuration area. The user can configure the demodulator-related settings either in the parameter table or in the flowchart area. The configuration information for <Input Source>, <Time Constant>, <Filter dB/oct>, and <Sync Filter> can all be modified and confirmed in the red-boxed area.

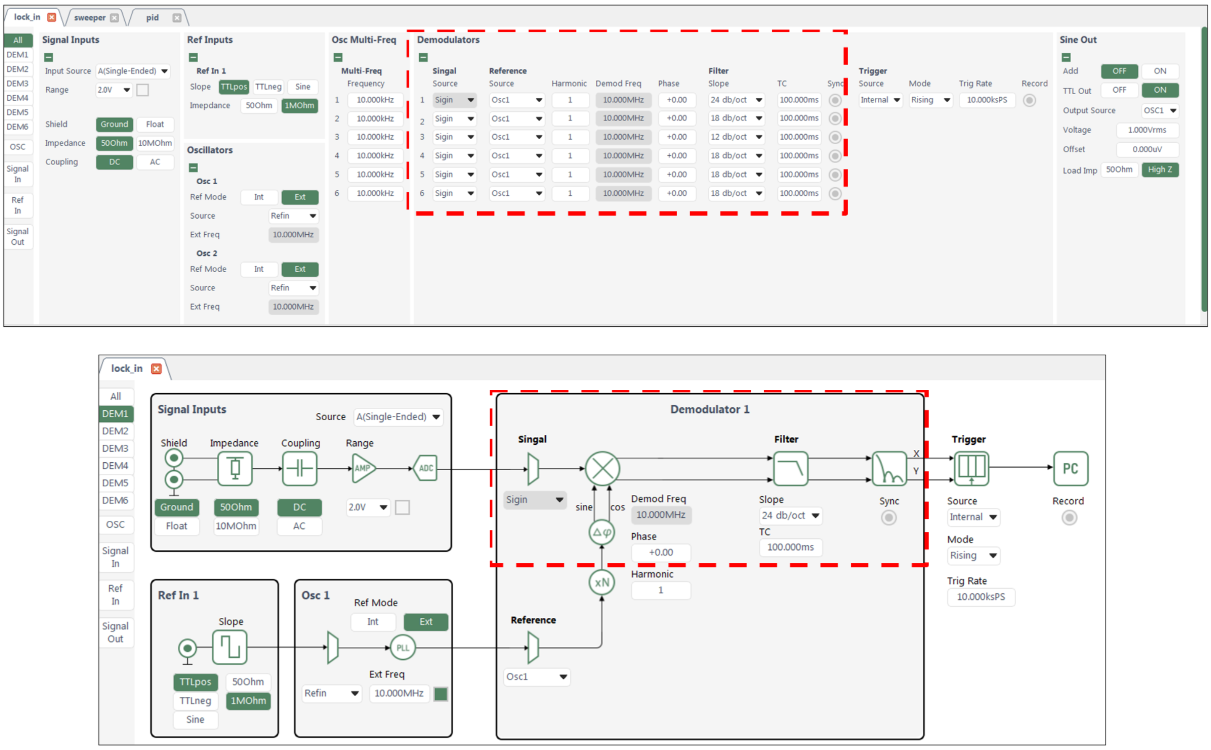


Figure 47. [DEMOD FILTER] configuration area

5.4 [DEMOD REF] Submenu

5.4.1. Front-Panel Configuration

Select [DEMOD REF] from the front-panel menu bar to enter this submenu. This menu is used to configure the reference source of the demodulators, as shown in the right-side panel of Figure 48.

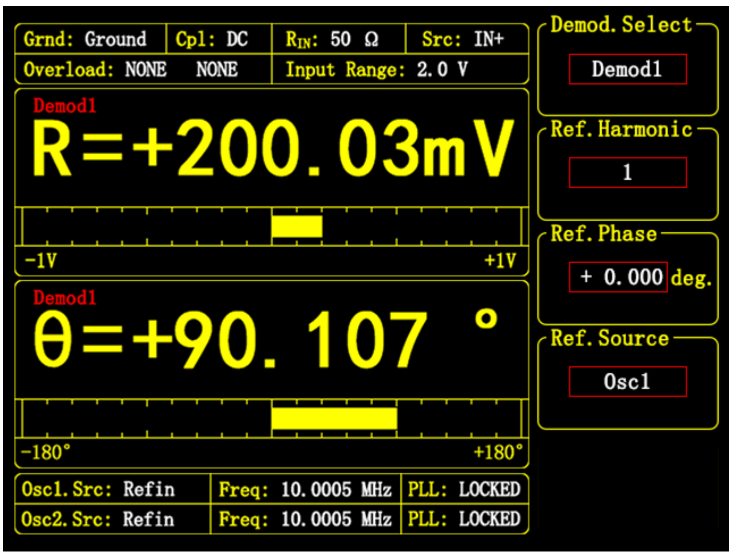


Figure 48. [DEMOD REF] submenu

This submenu includes function settings such as <Demod.Select>, <Ref.Harmonic>, <Ref.Phase>, <Ref.Source>, <Frequency Set>, and <Equation Set>.

- <Demod.Select>: demodulator channel selection setting

The knob and the keys in the ARROW area can be used to switch the parameter display and configuration among the six demodulators, <Demod1> through <Demod6>. For example, when <Demod1> is selected, the settings of <Ref.Harmonic>, <Ref.Phase>, <Ref.Source>, and <Frequency Set> all correspond to the current configuration of <Demod1>. Changing these settings at this time does not affect the related configurations of other demodulators.

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

The setting range is an integer from 1~10 000. Enter the harmonic order to be measured using the numeric keypad. The default display is 1, indicating measurement of the 1st harmonic (the fundamental). The condition for a valid <Ref.Harmonic> setting is (Harmonic * reference signal frequency ≤ 10 MHz). When the product exceeds the upper frequency limit, the instrument does not forcibly limit the input; however, this will result in abnormal measurement results. Users must ensure that the set harmonic frequency remains within the valid range.

For example, when the input signal is a square wave with a frequency of 1 kHz and an assumed peak-to-peak value of A, setting <Ref.Harmonic> to 1, 2, 3, 4, 5, 6…… is expected to give R values of 0.45 A, 0, 0.15 A, 0, 0.09 A, 0……. This sequence is the Fourier-series coefficient sequence of the square wave multiplied by A.

☆ **Note: To display measurement results from multiple demodulators at the same time, select <Full> for <Display Mode> in the [DISPLAY] submenu. See the [DISPLAY] submenu section for details.**

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

The phase-shift angle of the two quadrature reference signals used in the PSD algorithm can be set using the numeric keypad. The phase-shift resolution is 0.001°, and the input range is from −180° to 180°.

A phase value is meaningful only when there is a base reference. In the system, the rising zero crossing of the internal oscillator is used by default as the phase reference, and all other phase values are based on this reference. When the signal source of the internal oscillator is set to REF IN, the internal oscillator locks its phase through a high-precision phase-locked loop. In this case, the system phase reference tracks the REF-IN signal to meet the phase-locking requirement. The phase offset affects the phase deviation of the demodulator reference relative to the internal oscillator, as shown in Figure 49. If no phase offset is required, keep <Ref.Phase> at 0°; the demodulator reference then remains in phase with the internal oscillator.

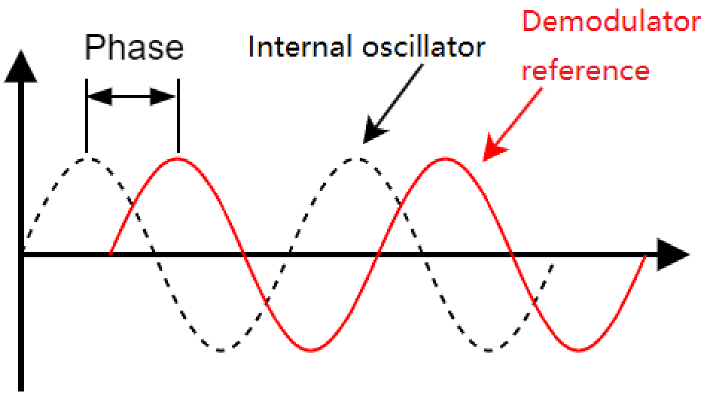


Figure 49. Effect of phase offset on the reference

- <Ref.Source>: demodulator reference source setting

<Osc1> : Sets the reference source of the current demodulator to internal oscillator OSC1.

<Osc2> : Sets the reference source of the current demodulator to internal oscillator OSC2.

<Frequency> : Sets the reference source of the current demodulator to an arbitrary frequency. The interface for this mode is shown in Figure 50.

<Equation> : Sets the reference source of the current demodulator to equation-combination demodulation. The interface for this mode is shown in Figure 51. In this mode, press <Menu Enter> to enter the secondary menu and set the equation combination.

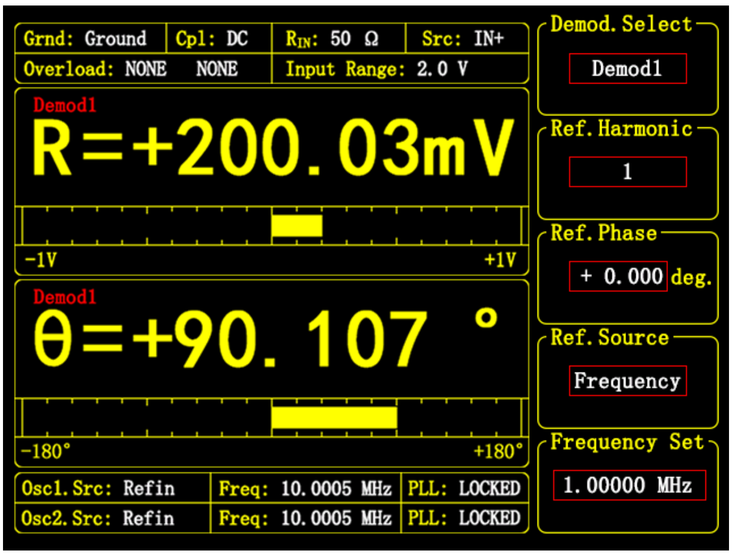


Figure 50. <Frequency> mode interface

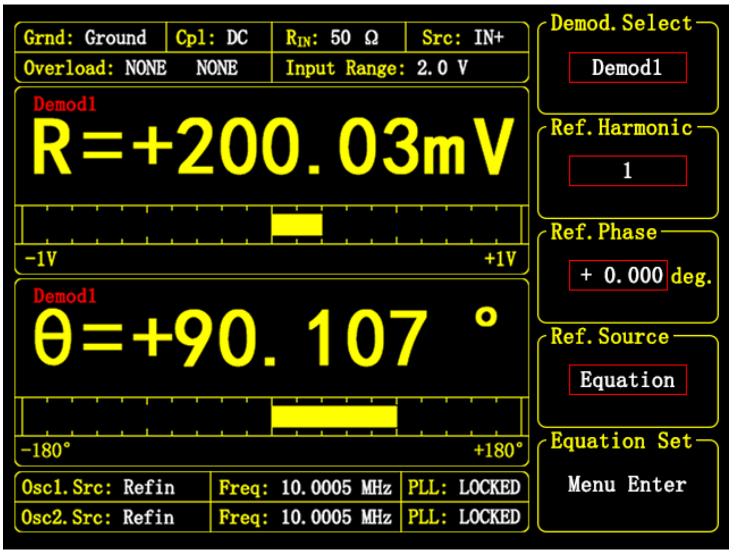


Figure 51. <Equation> mode interface

- <Frequency Set>: demodulator reference frequency setting

This item is enabled when <Ref.Source> is set to <Frequency>. Its setting rules are the same as those for <Osc.Frequency> in [OSC REF]. When <Frequency> is set to a certain frequency, the demodulator uses that frequency as the reference frequency to demodulate the signal.

This mode is especially useful when the input signal contains multiple frequency components and the user needs to extract them separately. The six demodulators can be set to different demodulation frequencies to demodulate six frequency components at the same time.

- <Equation Set>: equation-combination reference setting

This item is enabled when <Ref.Source> is set to <Equation>. Press <Menu Enter> to enter the secondary menu and set the equation combination, as shown in Figure 52. The calculation formula for <Equation> is:

$$Equation = A \times F_{OSC} + B \times F$$

where:

A and B are signed real numbers with a range from -10000 to +10000;

F_{OSC} can be selected as the frequency output result of OSC1 or OSC2;

F can be selected as the frequency output result of OSC1 or OSC2, or set to an arbitrary frequency.

If the calculated result of Equation is 1500 Hz, then the demodulator uses 1500 Hz as the reference frequency for the phase-sensitive detection algorithm. This mode works well in AM and FM signal demodulation scenarios, such as sum-frequency and difference-frequency signal demodulation.

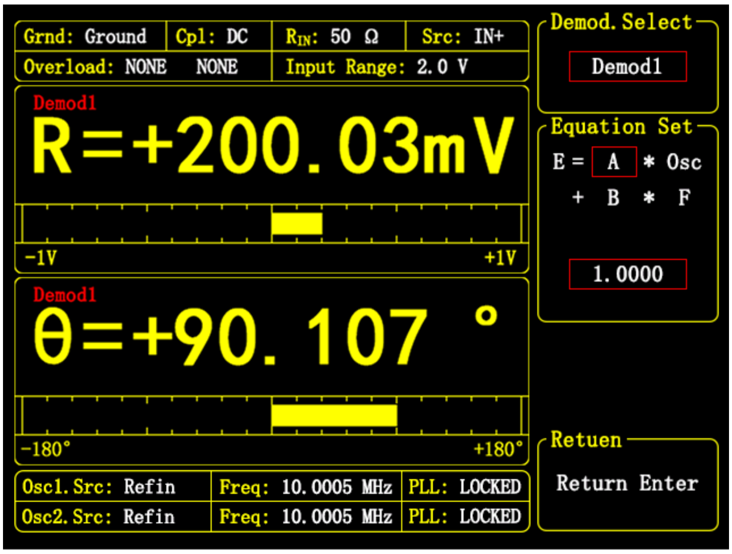


Figure 52. <Equation> secondary-menu setting interface

5.4.2. PC Software Configuration

As shown in the red box in Figure 53, the highlighted area in the PC software is the [DEMOD REF] configuration area. The user can configure the reference-source settings of the demodulators either in the parameter table or in the flowchart area. The configuration information for <Ref.Harmonic>, <Ref.Phase>, <Ref.Source>, <Frequency Set>, and <Equation Set> can all be modified and confirmed in the red-boxed area.

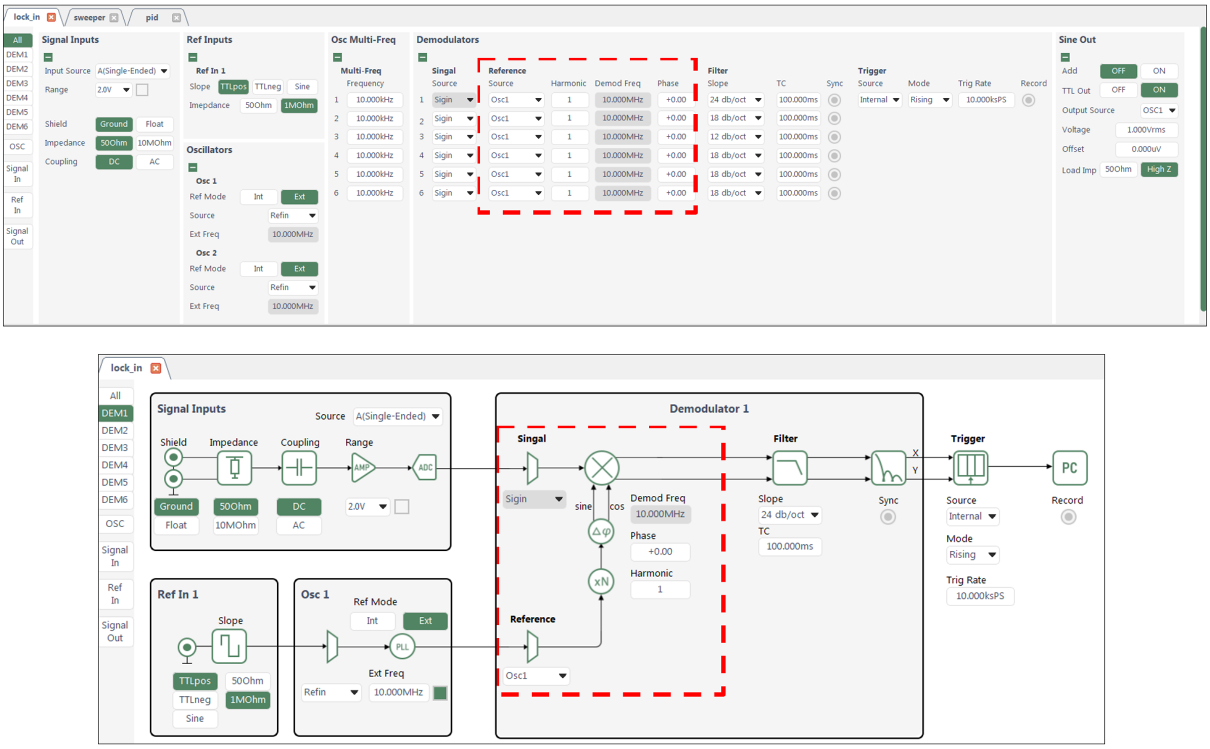


Figure 53. [DEMOD REF] configuration area

5.5 [DISPLAY] Submenu

5.5.1. Front-Panel Configuration

Select [DISPLAY] from the MENU bar on the front panel to enter this submenu, as shown in the right-side panel of Figure 54.

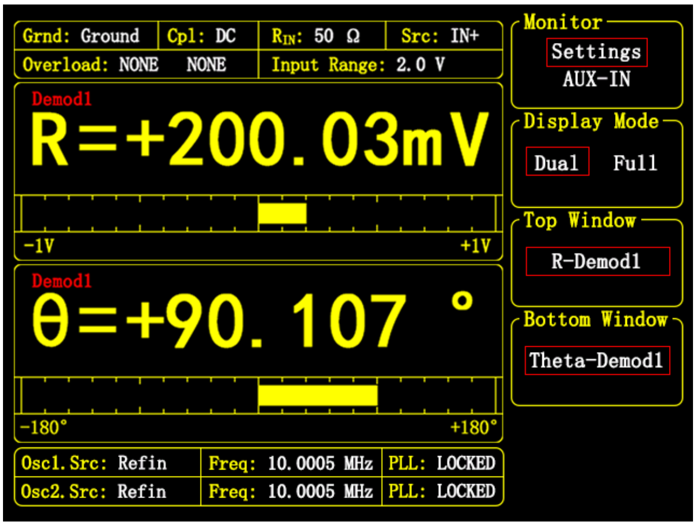


Figure 54. [DISPLAY] submenu

The [DISPLAY] submenu mainly includes five function settings: <Monitor>, <Display Mode>, <Top Window >, <Bottom Window>, and <Full Window>. These can be selected and set using the corresponding soft keys next to the submenu.

- <Monitor>: status-bar display setting

<Settings> : Displays current settings and status information such as <Input Source> and <Overload> in the status bar at the top of the LCD screen.

<AUX-IN> : Displays the real-time input voltage amplitudes of the four rear-panel AUX-IN BNC connectors in the status bar at the top of the LCD screen. The interface is shown in Figure 55:

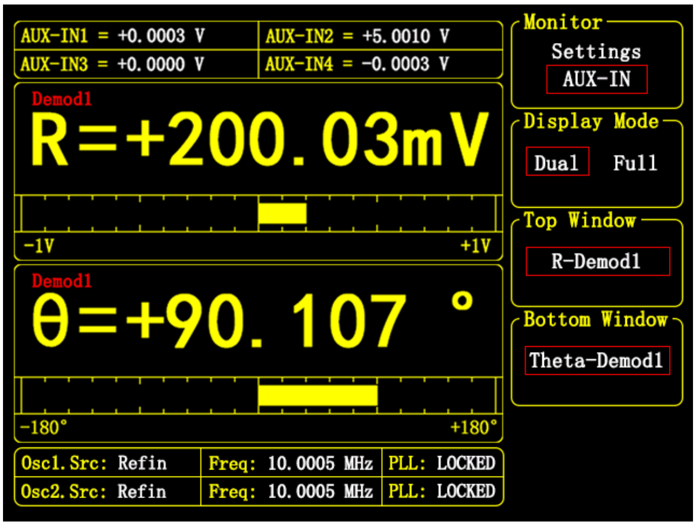


Figure 55. <AUX-IN> interface

- <Display Mode>: dynamic-area display mode setting

The <Display Mode> option is mainly used to set the display type of the data area. Two types are available:

<Dual> : Dual-window dynamic display mode, displaying two measurement values at the same time. This mode is shown in Figure 54.

<Full> : Full-data display mode, displaying the measurement data of all six demodulators at the same time. This mode is shown in Figure 56.

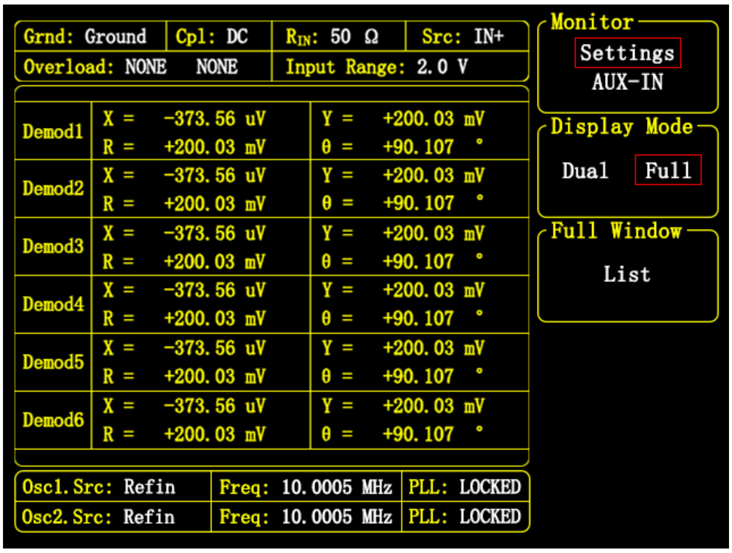


Figure 56. <Full> display mode

- <Top Window>&<Bottom Window>: display-content settings for the two split windows

These two configuration items are enabled when <Display Mode> is set to <Dual>. <Top Window> sets the measurement data displayed in the upper split window, and <Bottom Window> sets the measurement data displayed in the lower split window. The selectable measurement data are:

<X-demod1> : X value of the demodulation result of Demodulator 1.
<Y-demod1> : Y value of the demodulation result of Demodulator 1.
<R-demod1> : R value of the demodulation result of Demodulator 1.
<θ-demod1> : θ value of the demodulation result of Demodulator 1.
<X-demod2> : X value of the demodulation result of Demodulator 2.
<Y-demod2> : Y value of the demodulation result of Demodulator 2.
<R-demod2> : R value of the demodulation result of Demodulator 2.
<θ-demod2> : θ value of the demodulation result of Demodulator 2.
<X-demod3> : X value of the demodulation result of Demodulator 3.
<Y-demod3> : Y value of the demodulation result of Demodulator 3.
<R-demod3> : R value of the demodulation result of Demodulator 3.
<θ-demod3> : θ value of the demodulation result of Demodulator 3.
<X-demod4> : X value of the demodulation result of Demodulator 4.
<Y-demod4> : Y value of the demodulation result of Demodulator 4.
<R-demod4> : R value of the demodulation result of Demodulator 4.
<θ-demod4> : θ value of the demodulation result of Demodulator 4.
<X-demod5> : X value of the demodulation result of Demodulator 5.

<Y-demod5> : Y value of the demodulation result of Demodulator 5.
<R-demod5> : R value of the demodulation result of Demodulator 5.
<θ-demod5> : θ value of the demodulation result of Demodulator 5.
<X-demod6> : X value of the demodulation result of Demodulator 6.
<Y-demod6> : Y value of the demodulation result of Demodulator 6.
<R-demod6> : R value of the demodulation result of Demodulator 6.
<θ-demod6> : θ value of the demodulation result of Demodulator 6.
<XNoise-Demod1> : X-Noise value of the demodulation result of Demodulator 1.
<YNoise-Demod1> : Y-Noise value of the demodulation result of Demodulator 1.

The upper and lower split-window display contents can be selected flexibly. By default, the <R> and <θ> values of Demodulator 1 are displayed.

5.5.2. PC Software Configuration

The [DISPLAY] submenu only sets the display result on the front-panel interface and does not affect the configuration information in the PC software. The data measurement results in the PC software can be configured separately for display. As shown in Figure 57, the Numeric tab can be used to select measurement results from any demodulator for display. Compared with the front-panel interface, the PC software configuration is more flexible and convenient.

The PC software also provides a waveform display mode. Select the Plotter tab to choose one or more output results for waveform observation.

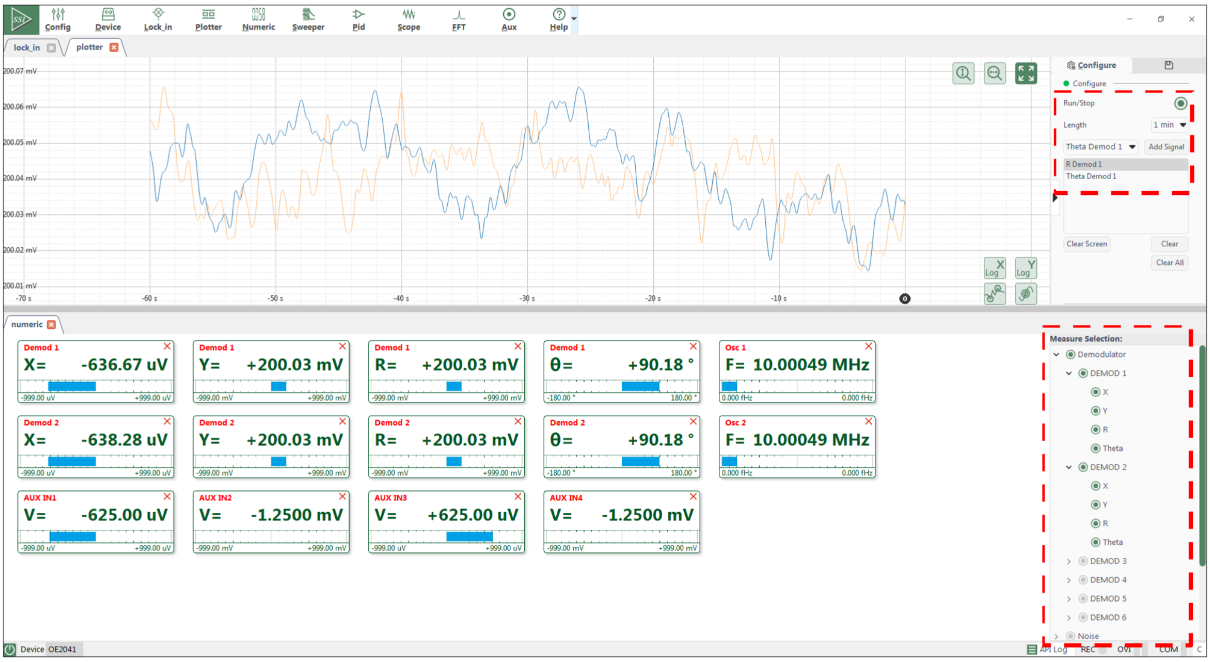


Figure 57. PC Software [DISPLAY] setting

5.6 [SIGNAL OUTPUT] Submenu

5.6.1. Front-Panel Configuration

Select [SIGNAL OUTPUT] from the MENU bar on the front panel to enter this submenu. This menu is used to configure the parameters of the Sine Out and TTL out interfaces, as shown in the right-side panel of Figure 58.

This submenu includes five function settings: <Add In Mode>, <Output Source>, <TTLout SW>, <Amplitude>, and <Offset>.

The OE2031 can output a sine-wave signal with an amplitude from 1 μV_{rms} to 2 V_{rms} through the “Sine Out” BNC connector on the front panel. Its reference source follows the internal oscillator, equivalent to an adjustable-amplitude output of the internal oscillator.

When <Osc.Mode> uses the <External> external reference, “Sine Out” outputs a sine signal with the same frequency and phase as the external reference. When the <Internal> internal reference is used, the signal is generated by the instrument’s own oscillator.

The “TTL OUT” BNC connector on the front panel outputs a TTL signal with the same frequency and phase as “Sine Out”.

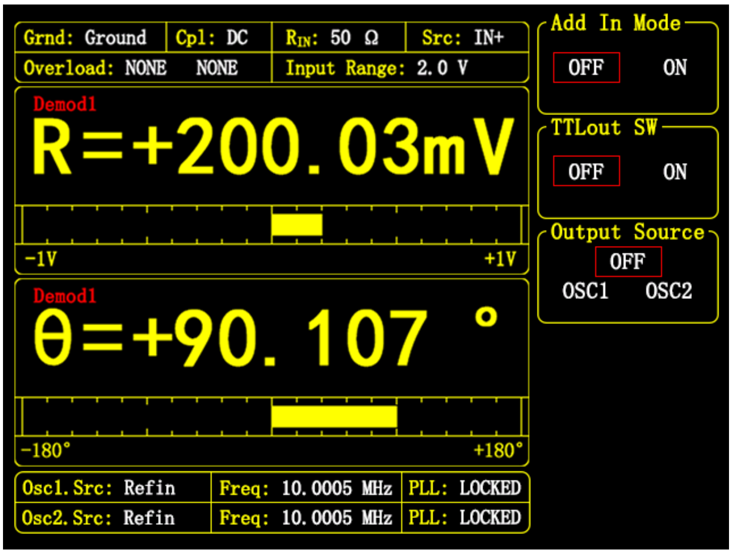


Figure 58. [SIGNAL OUTPUT] submenu

- <Add In Mode>: ADD IN interface enable-mode setting

  <OFF> : Disables the ADD IN interface function.

  <ON> : Enables the ADD IN interface function.

When this function is enabled, the “SINE OUT” signal and the input signal from the “ADD IN” BNC connector are summed and then output from the “SINE OUT” BNC connector. For example, if Sineout is set to a 100 mV sine wave and the ADD IN interface receives an external 1 V DC signal, the final Sineout signal becomes a sine wave with a 1 V DC offset and an AC amplitude of 100 mV.

- <TTLout SW>: output-mode setting of the TTL OUT interface

  <OFF> : Disables TTLout output. TTLout outputs a constant 0 V.

<ON> : Enables TTLout output. TTLout outputs a 3.3 V TTL square-wave signal.

- <Output Source>: output-mode setting of the SINE OUT interface

<OFF> : Disables Sineout output. Sineout outputs a constant 0 V.

<OSC1> : Enables Sineout output. The frequency reference source of Sineout follows internal oscillator OSC1.

<OSC2> : Enables Sineout output. The frequency reference source of Sineout follows internal oscillator OSC2.

After Sineout output is enabled, the amplitude and offset of the output sine wave can be set using <Amplitude> and <Offset>, as shown in Figure 59.

For extremely weak-signal measurements, such as resistor thermal-noise measurement and small-impedance measurement, it is recommended to turn off Sineout and TTLout output to reduce internal same-frequency interference in the system.

- <Amplitude>: Sineout output amplitude setting

The Sineout amplitude can be entered using the numeric keypad and the knob. The RMS range is 0.000 001~2 V_{rms}, and the minimum resolution is $0.1\,\mu V_{rms}$.

- <Offset>: Sineout output offset setting

The Sineout offset can be entered using the numeric keypad and the knob. The DC range is −3~3 V, and the minimum resolution is 0.001 V DC.

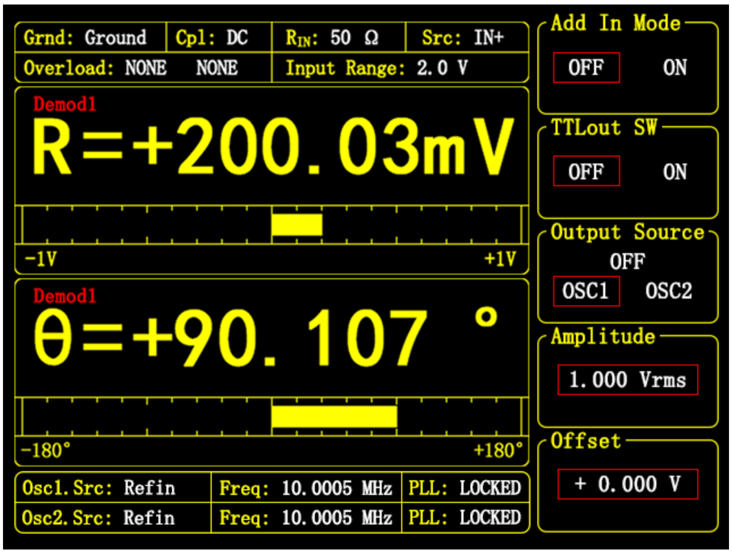


Figure 59. Menu when <Output Source> is enabled

5.6.2. PC Software Configuration

As shown in the red box in Figure 60, the highlighted area in the PC software is the [SIGNAL OUTPUT] configuration area. The user can configure the signal output channel settings either in the parameter table or in the flowchart area. The configuration information for <Add In Mode>, <Output Source>, <TTLout SW>, <Amplitude>, and <Offset> can all be modified and confirmed in the red-boxed area.

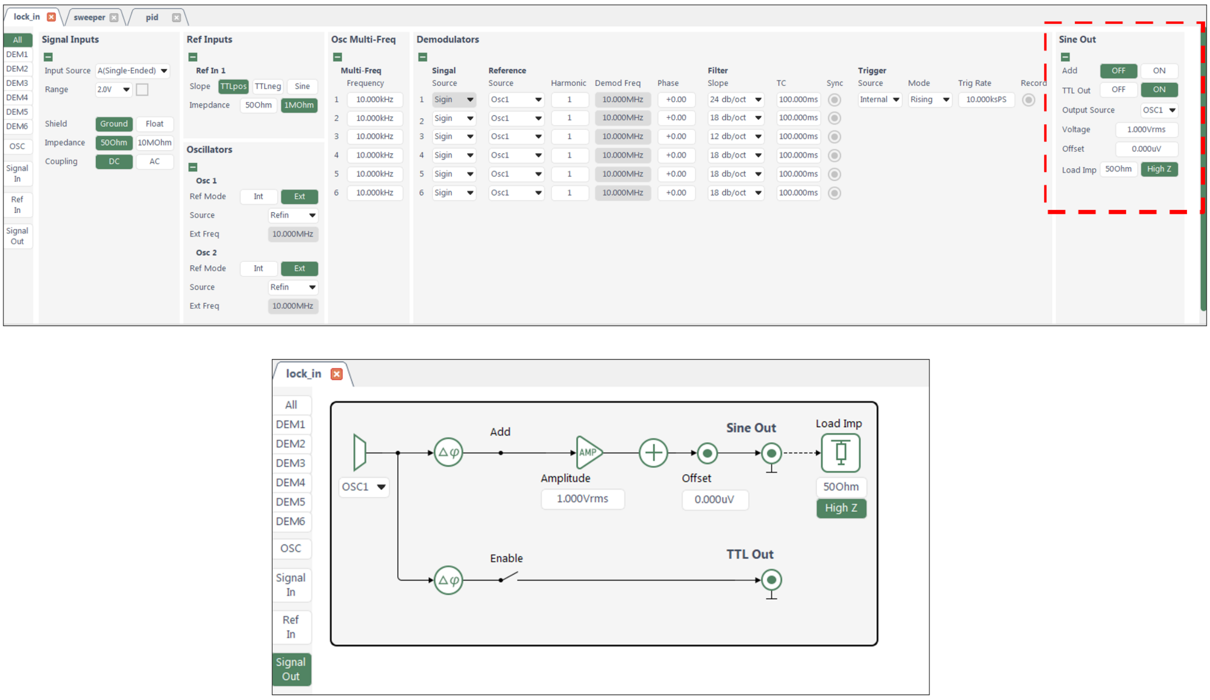


Figure 60. [SIGNAL OUTPUT] configuration area

5.7 [AUTO SET] Submenu

5.7.1. Front-Panel Configuration

The [AUTO SET] submenu includes four automatic setting functions in the OE2031, as shown in the right-side panel of Figure 61.

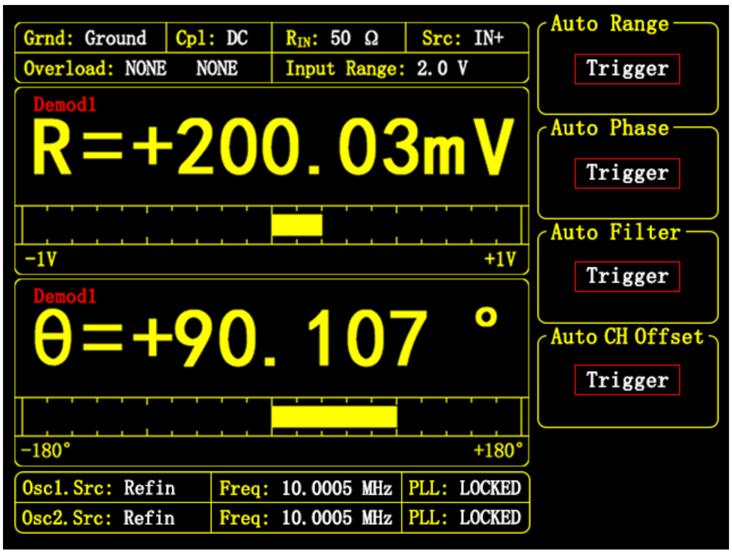


Figure 61. AUTO SET submenu

- <Auto Range>: automatic range setting function

After the <Auto Range> button is pressed, the instrument automatically adjusts the <Input Range> setting according to the amplitude of the current input signal.

Automatic range selection starts from the <2 V> range and switches step by step to lower ranges until the selected range can accommodate the maximum amplitude of the signal without overload. The instrument then keeps the current range.

- <Auto Phase>: automatic phase compensation function

After the <Auto Phase> button is pressed, the instrument automatically adjusts the <Ref.Phase> of all demodulators so that the measured phase of the input signal is 0°. The operation takes time to settle, typically less than 5 s. If the current signal phase fluctuates greatly, the <Auto Phase> setting may fail. In this case, switch to the [DEMOD REF] submenu and manually set <Ref.Phase>.

- <Auto Filter>: automatic demodulator filter setting function

After the <Auto Filter> button is pressed, the instrument automatically calculates the <Time Constant> and <Filter dB/oct> for all demodulators according to their reference frequencies. The rules are:

When the reference frequency is greater than 100 Hz, Time Constant = 100 ÷ Frequency, and Filter = 24 dB/oct.

When the reference frequency is less than 100 Hz, Time Constant = 1 s, 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, and Sync Filter = ON.

For example, if the reference frequency of Demodulator 1 is 10 kHz, after <Auto Filter> is pressed, the filter time constant of Demodulator 1 becomes 10 ms, and the filter roll-off slope is set to 24 dB/oct.

- <Auto CH Offset>: automatic CHout output-offset setting function

When the <Auto CH Offset> button is pressed, the instrument automatically adjusts the <Offset> parameter in the [AUX OUT] menu so that the calculation results of the output formulas for the current four AUXOUT/CHOUT channels return to zero, thereby implementing automatic DC-offset compensation.

5.7.2. PC Software Configuration

PC software configuration for this submenu is not available at this time.

5.8 [CHOUT AUXOUT] Submenu

5.8.1. Front-Panel Configuration

Select [CHOUT AUXOUT] from the MENU bar on the front panel to enter this submenu, as shown in the right-side panel of Figure 62.

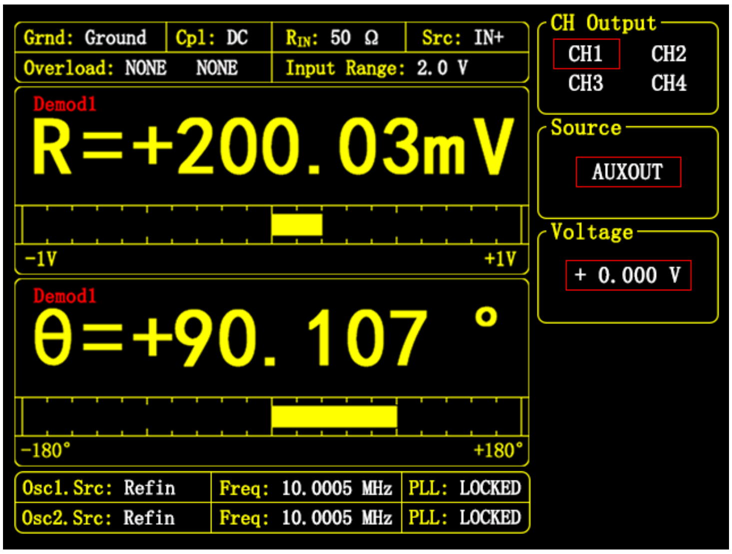


Figure 62. [CHANNEL OUTPUT] submenu

The [CHOUT AUXOUT] submenu controls the four AUXOUT/CHOUT BNC channels on the rear panel. These channels can output user-defined arbitrary values, the R, X, Y, and θ values of the demodulators, and so on. <Sensitivity> sets the scale factor, while <Offset&Expand> sets the output offset and magnification factor.

The output signal is calculated as follows.

1. When the selected signal is <R>, <X>, or <Y> of Demod1 ~ Demod6:

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

2. When the selected signal is <Theta> of Demod1 ~ Demod6:

$$\text{Output} = \left(\frac{\text{Theta}}{180°} + \text{Offset}\right) \times \text{Expand} \times 10\,\text{V}$$

In addition to the two cases above, the following options are available:

a) AUXOUT: Outputs the voltage value set by the user. The range is −10~10 V, with a resolution of 1 mV.

b) AUXIN1 ~ AUXIN4: The output is equal to the input voltage of the corresponding AUXIN interface.

- <CH Output>: CH channel selection setting

Select the channel configuration from CH1 to CH4. Each channel can independently select one output source.

- <Source>: channel output source setting

<AUXOUT> : The channel outputs the set voltage level. Each CH channel has an independent <AUXOUT> parameter.

<X-Demod1> : The channel outputs the analog level corresponding to the X value of Demodulator 1.

<Y-Demod1> : The channel outputs the analog level corresponding to the Y value of

Demodulator 1.

<R-Demod1> : The channel outputs the analog level corresponding to the R value of Demodulator 1.

<θ-Demod1> : The channel outputs the analog level corresponding to the θ value of Demodulator 1.

<X-Demod2> : The channel outputs the analog level corresponding to the X value of Demodulator 2.

<Y-Demod2> : The channel outputs the analog level corresponding to the Y value of Demodulator 2.

<R-Demod2> : The channel outputs the analog level corresponding to the R value of Demodulator 2.

<θ-Demod2> : The channel outputs the analog level corresponding to the θ value of Demodulator 2.

<X-Demod3> : The channel outputs the analog level corresponding to the X value of Demodulator 3.

<Y-Demod3> : The channel outputs the analog level corresponding to the Y value of Demodulator 3.

<R-Demod3> : The channel outputs the analog level corresponding to the R value of Demodulator 3.

<θ-Demod3> : The channel outputs the analog level corresponding to the θ value of Demodulator 3.

<X-Demod4> : The channel outputs the analog level corresponding to the X value of Demodulator 4.

<Y-Demod4> : The channel outputs the analog level corresponding to the Y value of Demodulator 4.

<R-Demod4> : The channel outputs the analog level corresponding to the R value of Demodulator 4.

<θ-Demod4> : The channel outputs the analog level corresponding to the θ value of Demodulator 4.

<X-Demod5> : The channel outputs the analog level corresponding to the X value of Demodulator 5.

<Y-Demod5> : The channel outputs the analog level corresponding to the Y value of Demodulator 5.

<R-Demod5> : The channel outputs the analog level corresponding to the R value of Demodulator 5.

<θ-Demod5> : The channel outputs the analog level corresponding to the θ value of Demodulator 5.

<X-Demod6> : The channel outputs the analog level corresponding to the X value of Demodulator 6.

<Y-Demod6> : The channel outputs the analog level corresponding to the Y value of Demodulator 6.

<R-Demod6> : The channel outputs the analog level corresponding to the R value of Demodulator 6.

<θ-Demod6> : The channel outputs the analog level corresponding to the θ value of Demodulator 6.

<AUXIN1> : The channel outputs the voltage level corresponding to the AUX-IN1

interface.

<AUXIN2> : The channel outputs the voltage level corresponding to the AUX-IN2 interface.

<AUXIN3> : The channel outputs the voltage level corresponding to the AUX-IN3 interface.

<AUXIN4> : The channel outputs the voltage level corresponding to the AUX-IN4 interface.

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

When <Source> is set to <AUXOUT>, <Voltage> can be set, as shown in Figure 62. The voltage value can be entered using the numeric keypad. The setting range is −10~10 V, with a resolution of 1 mV.

- <Sensitivity>: sensitivity setting

When <Source> is set to any input source other than <AUXOUT> and <AUXIN1 ~ 4>, the <Sensitivity>, <Offset>, and <Expand> options appear, as shown in Figure 63.

The available <Sensitivity> settings are shown in Table 3. Note that when <Source> is set to <Theta> of Demod1 through Demod6, the <Sensitivity> setting is invalid and is fixed at 180°.

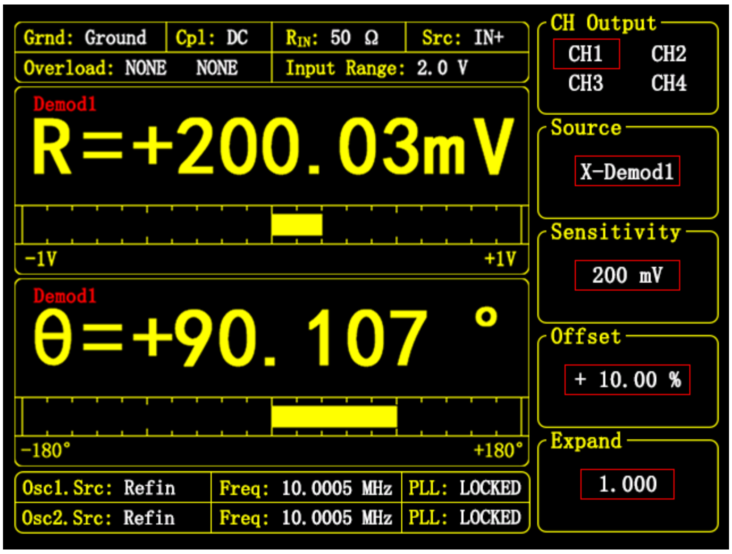


Figure 63. <Offset&Expand> interface

Table 3. Available sensitivity settings

1 nV	500 nV	200 μV	100 mV
2 nV	1 μV	500 μV	200 mV
5 nV	2 μV	1 mV	500 mV
10 nV	5 μV	2 mV	1 V
20 nV	10 μV	5 mV	2 V
50 nV	20 μV	10 mV	-
100 nV	50 μV	20 mV	-
200 nV	100 μV	50 mV	-

- <Offset>: offset setting

  The adjustable range is −100~100 %, entered using the numeric keypad. The minimum step is 0.01%, and the default value is 0.00%.

- <Expand>: magnification setting

  The value can be entered using the numeric keypad. The adjustable range is a real number from 0.001~10 000, and the default value is 1. If the <Expand> setting makes the calculated value exceed ±10 V, the output value is limited to ±10 V.

☆ **Note: Each CH channel has an independent offset value and magnification value.** For example, if the <Offset> of CH1 is set to 50% and <Expand> is set to 3, only the output of CH1 is affected; the outputs of CH2 ~ 4 remain unchanged.

☆ Note: The <Sensitivity>, <Offset>, and <Expand> settings do not affect the data displayed in the dynamic-area data boxes.

5.8.2. PC Software Configuration

The configuration area shown in Figure 64 is the [CHOUT AUXOUT] configuration area. This function can be opened through the Aux tab. The configuration information for <CH Output>, <Source>, <Voltage>, <Sensitivity>, <Expand>, and <Offset> can all be modified and confirmed in this configuration area.

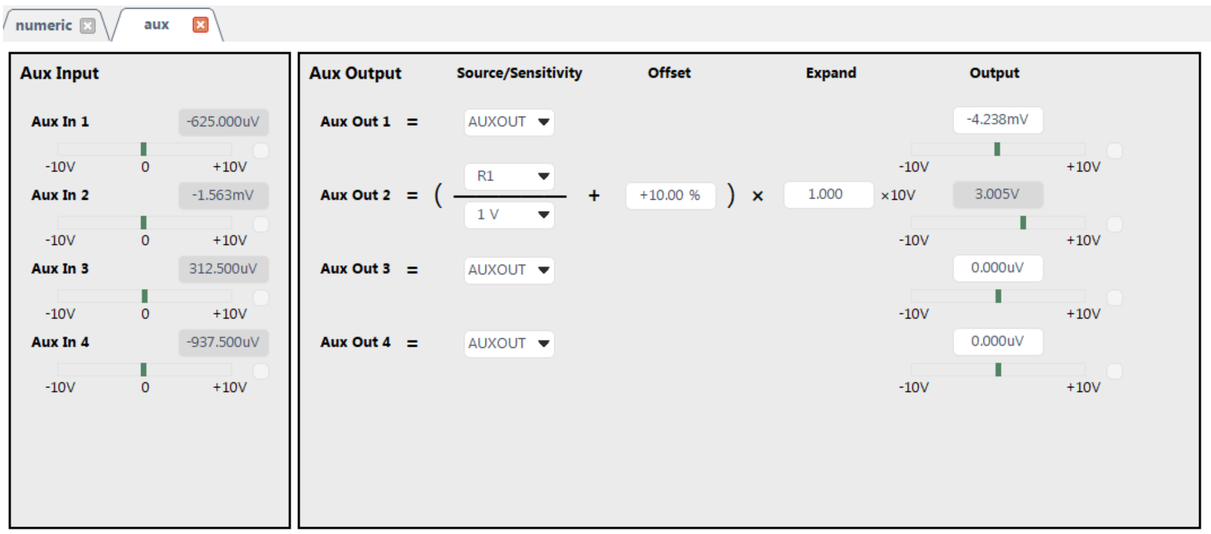


Figure 64. [CHOUT AUXOUT] configuration area

5.9 [SYSTEM] Submenu

5.9.1. Front-Panel Configuration

The [SYSTEM] submenu includes system information and system settings of the OE2031, such as instrument information, screen brightness, and communication settings, as shown in the right-side panel of Figure 65.

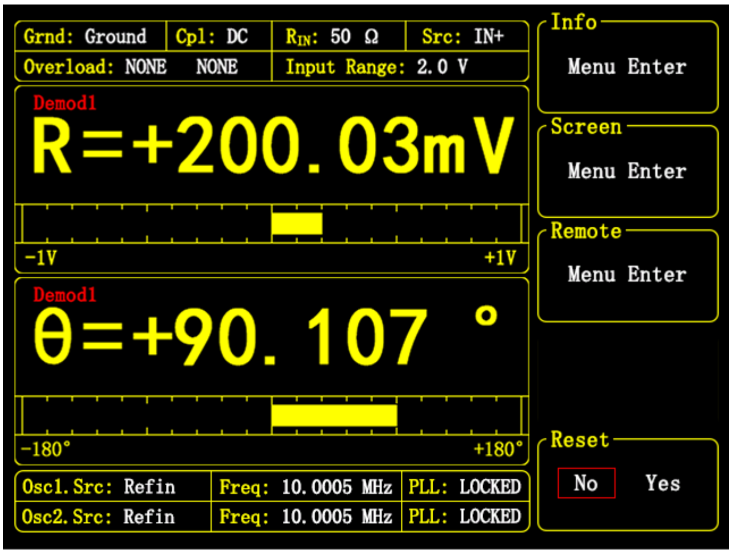


Figure 65. [SYSTEM] submenu

- <Info> secondary submenu

Select the <Info> secondary submenu to enter it. The interface displays information such as the R&D organization, after-sales contact information, product serial number, and version number, as shown in Figure 66. The serial number should be consistent with the factory label on the rear panel.

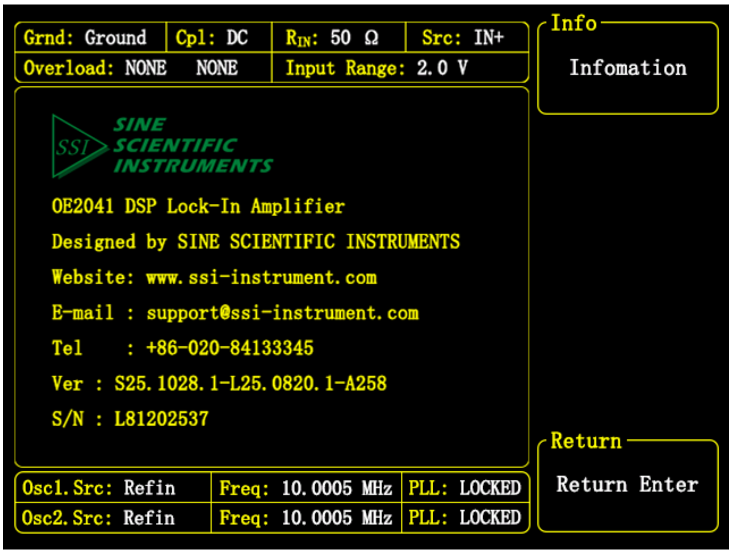


Figure 66. <INFO>—instrument information

- <Screen> secondary submenu

Select the <Screen> submenu to enter it. This submenu includes two function settings: <Window Color> and <Backlight>.

The interfaces are shown in Figure 67:

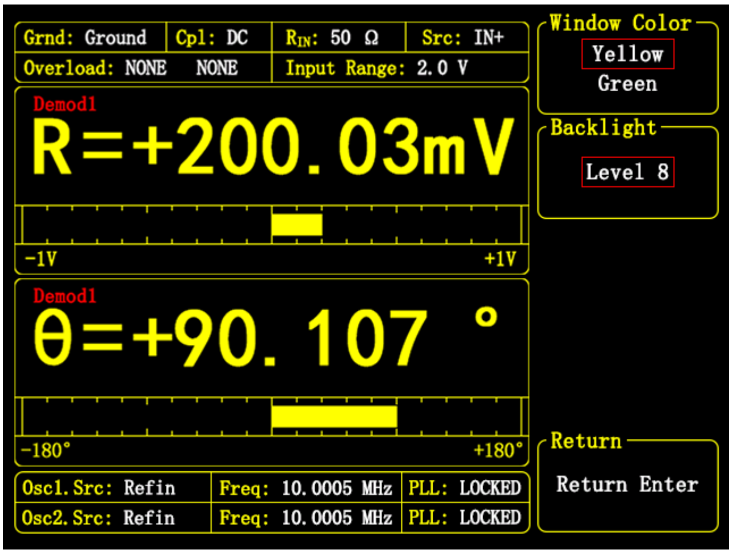


Figure 67. <Screen> submenu—<Yellow> style

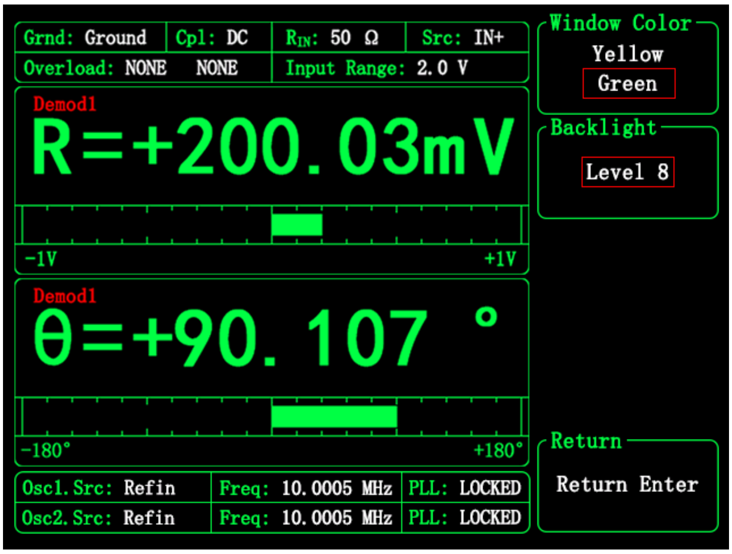


Figure 68. <Screen> submenu—<Green> style

<Window Color>: interface color-tone setting

<Yellow> : The main interface color tone is the yellow style, as shown in Figure 67.

<Green> : The main interface color tone is the green style, as shown in Figure 68.

☆ **Note: Currently, only the yellow-style interface is provided. The green style will be available after a future OTA upgrade.**

<Backlight> : backlight brightness setting

Adjusted using the knob. The brightness level can be adjusted from <Level1> to <Level8>, corresponding to brightness from low to high. The default value is <Level8>.

- <Remote> secondary submenu

Select the <Remote> secondary submenu to enter it, as shown in Figure 69.

The OE2031 has three remote communication interfaces: RS232 serial port, USB2.0 high-speed interface, and Ethernet interface. The corresponding configuration is set according to the interface selected in <Remote Mode>.

This menu is used only to modify the configurations of the remote communication interfaces. Selecting a communication interface in <Remote Mode> does not affect the communication of other interfaces. The instrument supports simultaneous use of multiple communication interfaces.

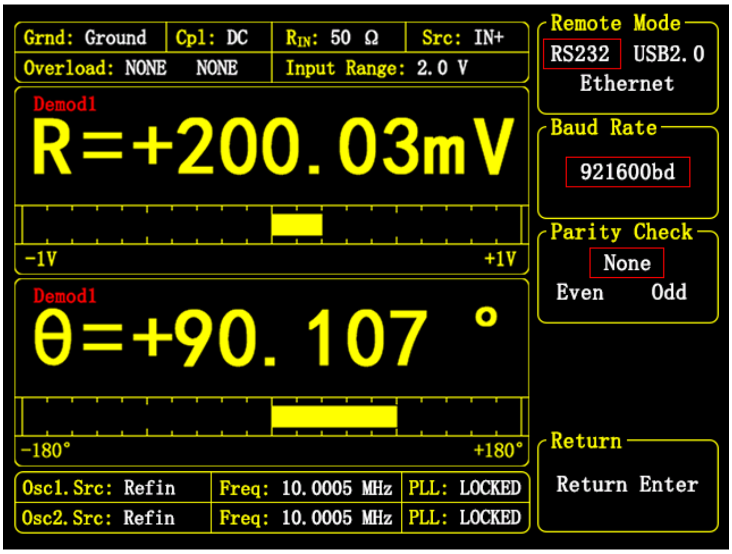


Figure 69. <Remote> submenu—<RS232> option

- <Remote Mode>: remote interface selection

<RS232> : RS232 serial communication interface, using a female DB9 connector. The configuration interface is shown in Figure 69.

<USB2.0> : USB2.0 high-speed communication interface. The configuration interface is shown in Figure 70.

<Ethernet>: 1000Mbps Ethernet interface. The port number is 10001. For example, if the network IP address obtained by the OE2031 is 192.168.1.10, then the IP address used by the computer to connect to the OE2031 is 192.168.1.10:10001. The configuration interface is shown in Figure 71.

The PC remote-control software supplied with the instrument must communicate through the USB2.0 or Ethernet interface. The RS232 interface is not currently supported.

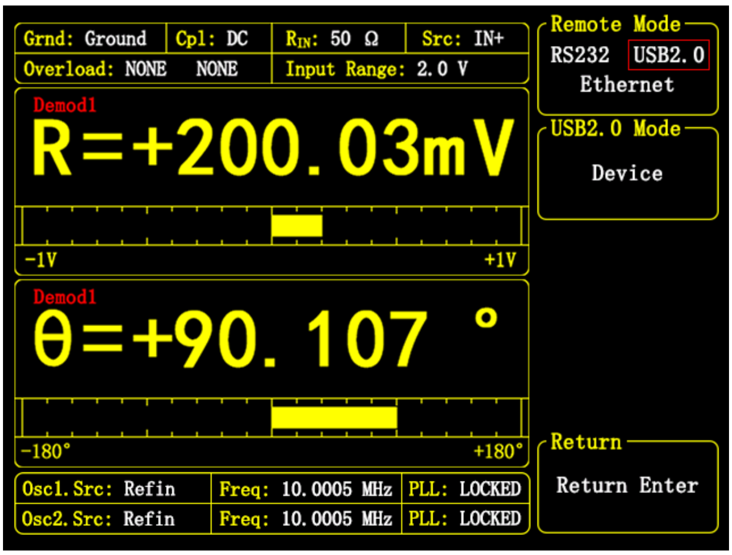


Figure 70. <Remote> submenu—<USB2.0> option

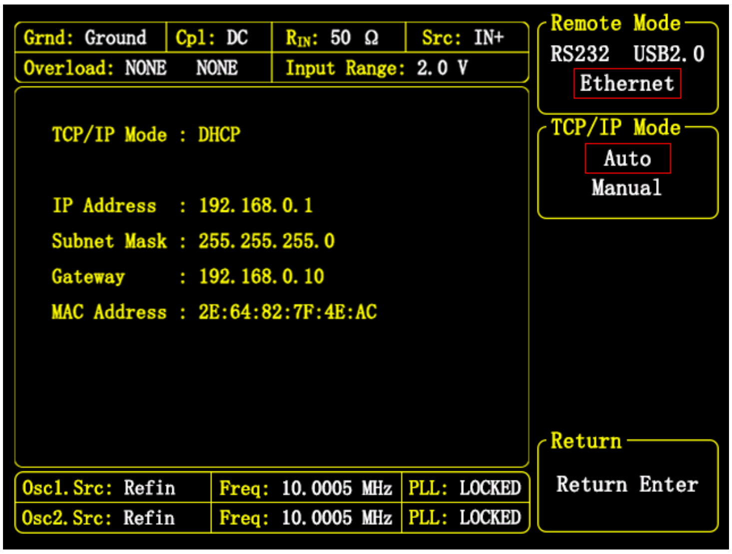


Figure 71. <Remote> submenu—<Ethernet> option

- <Baud Rate>: baud-rate setting

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

- <Parity Check>: parity-check setting

This configuration item is enabled in <RS232> mode.

<Even> : Even parity

<ODD> : Odd parity

<NONE> : No parity

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

This configuration item is enabled in <Ethernet> mode. In general, after the instrument is connected to a router using a network cable, <Auto> mode can automatically connect it to Ethernet.

<Auto> : Automatically configures the TCP/IP protocol.

<Manual> : Manually configures the TCP/IP protocol.

In <Auto> mode, when a network connection is detected, the status changes to “Connecting…”, as shown in Figure 72, indicating that the instrument is connecting to the current network. When the network connection succeeds, the local IP address, subnet mask, gateway, and local MAC address of the current network are displayed, as shown in Figure 73.

In <Manual> mode, the IP address, subnet mask, and gateway of the TCP/IP protocol can be configured manually, as shown in Figure 74. In the <IP Select> window, select the IP, subnet, or Gateway item to be modified, and then press <Execute>. The parameter to be configured can then be entered in the numeric keypad area, as shown in Figure 75. Finally, press <ENTER> to confirm.

After configuration is complete, the OE2031 can be configured and read within the local area network.

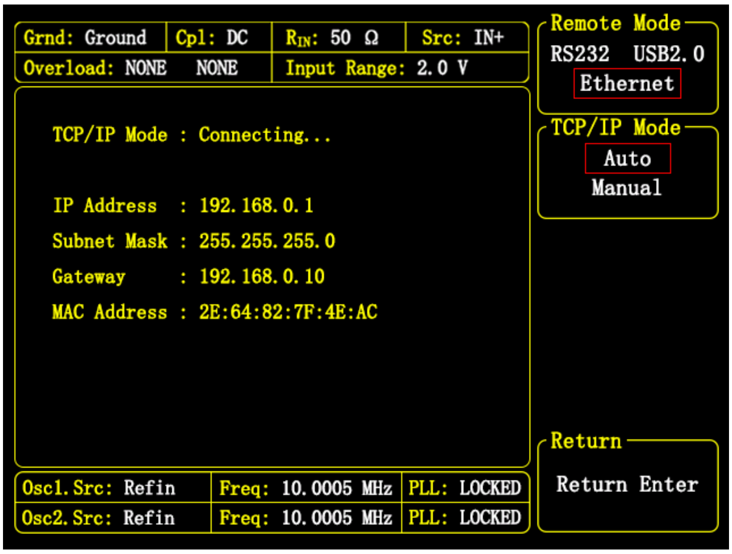


Figure 72. <Auto> mode—Connecting

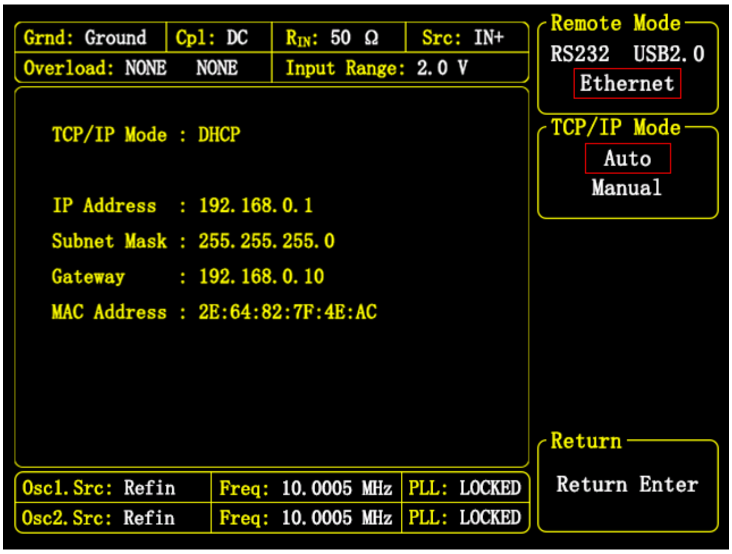


Figure 73. <Auto> mode—connection successful

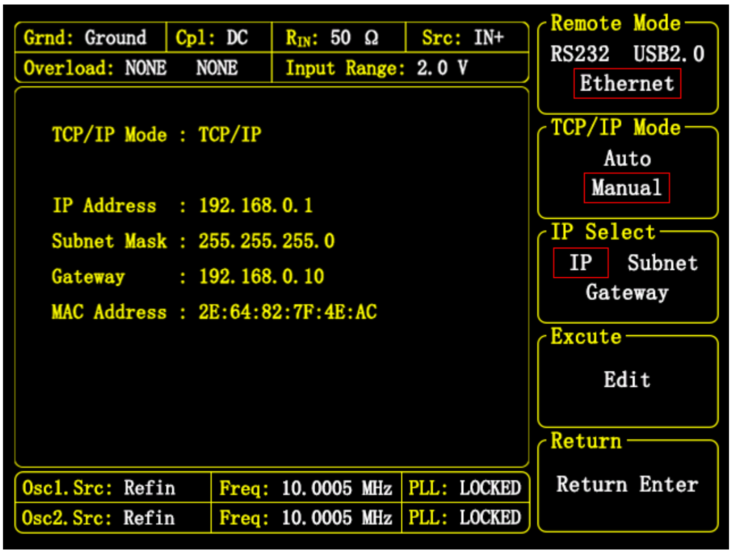


Figure 74. <Manual> mode

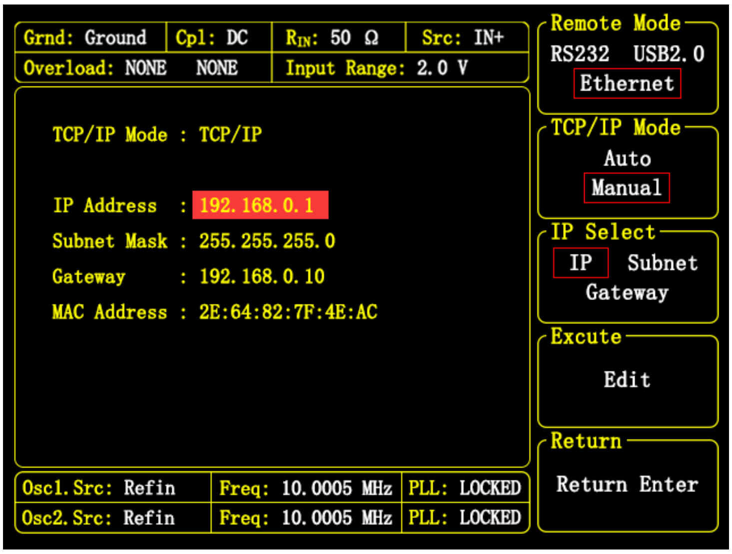


Figure 75. <Manual> mode during modification

- <Reset>: lock-in amplifier soft reset

After the corresponding button is pressed, the system performs a soft reset. The current settings are not changed after reset and restart.

5.9.2. PC Software Configuration

PC software configuration for this submenu is not available at this time.

5.10 [SAVE RECALL] Submenu

5.10.1. Front-Panel Configuration

Select [SAVE RECALL] from the MENU bar on the front panel to enter this submenu, as shown in the right-side panel of Figure 76.

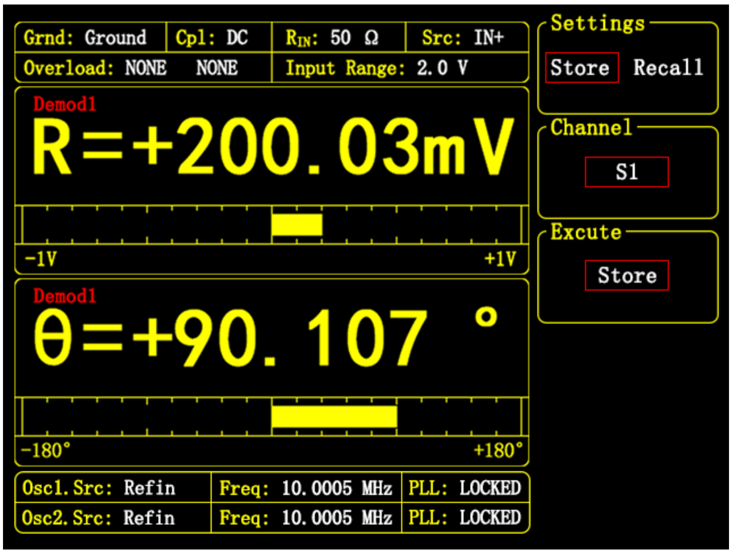


Figure 76. [SAVE RECALL] submenu

The <Store/Recall> menu is used to store or recall the current instrument parameter settings and operating status. The instrument has four built-in independent configuration storage areas: <S1>, <S2>, <S3>, and <S4>.

- Store configuration:

As shown in Figure 76, after entering the <Store/Recall> menu, select <Store> mode, specify the target storage area (for example, <S1>) in <Channel>, and then select <Store> in <Execute>. The current parameters and status are then stored in the selected storage area.

- Recall configuration:

To restore a stored configuration, select <Recall> mode, select the corresponding storage area (such as <S1>) in <Channel>, and execute <Recall> in <Execute>. The instrument then loads all settings from that storage area.

- Restore default configuration:

In <Recall> mode, <Channel> also provides the <Default> option. After this option is selected and <Recall> is executed, the instrument restores the factory default configuration, and all parameters are reset to their initial states, as shown in Figure 77.

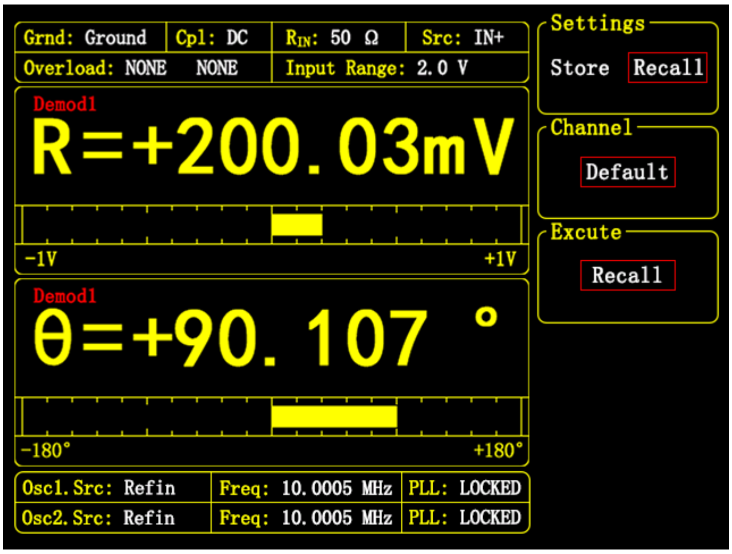


Figure 77. Restore-default setting option

5.10.2. PC Software Configuration

PC software configuration for this submenu is not available at this time.

5.11 PC Software Data Saving

The PC software of the OE2031 supports data logging and saving functions, allowing the user to select and save measurement data over a period of time as needed.

5.11.1. Global Data Saving

Global data saving includes the following contents:

- Measurement values R, X, Y, and θ of Demod1 ~ 6;
- X and Y noise values of Demod1;
- Measured frequencies of the two oscillators;
- Signal values of the four auxiliary input AUXIN interfaces.

The steps for global data saving are as follows:

1. When the software is running, click the "Record" button in the red box in Figure 78. When the button is selected, the system has started recording the currently acquired data.

2. The data is saved in Excel-compatible CSV format. The file name is "data_lock_in_XXXXXXXX_XXXXXX.csv", where "XXXXXXXX_XXXXXX" represents the date and timestamp, ensuring that each file name is unique. The file is stored in the program directory by default. An example data format is shown in Figure 79.

3. Press the "Record" button again. When the button returns to the unselected state, the data acquisition process has stopped.

4. The current display and saved-data sampling rate can be modified in " 

". The setting range is 0.1~100 kSa/s.

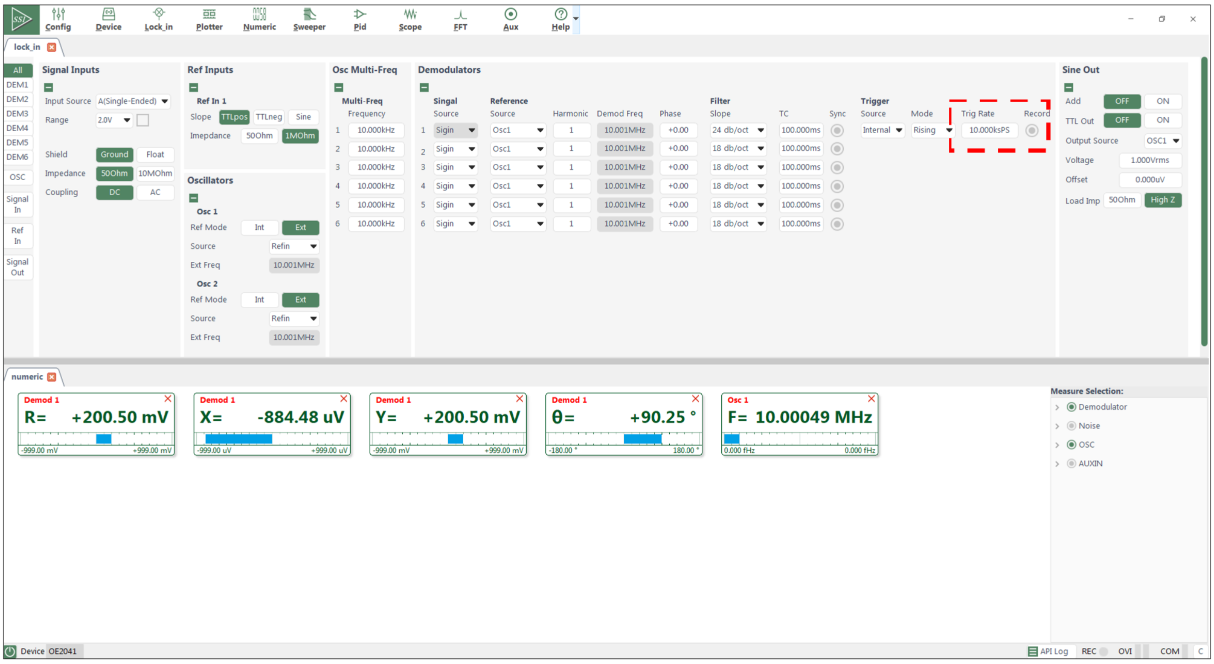
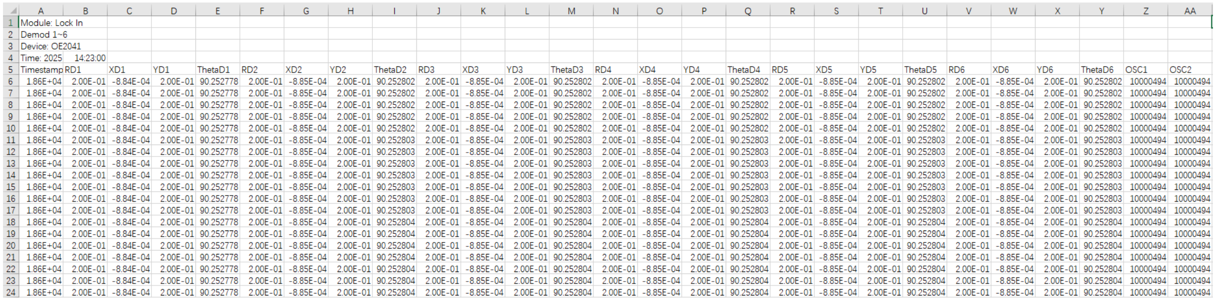


Figure 78. Data saving configuration area



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	Module: Lock In																										
2	Demod 1~6																										
3	Device: OE2041																										
4	Time: 2025	14:23:00																									
5	Timestamp	RD1	XD1	YD1	ThetaD1	RD2	XD2	YD2	ThetaD2	RD3	XD3	YD3	ThetaD3	RD4	XD4	YD4	ThetaD4	RD5	XD5	YD5	ThetaD5	RD6	XD6	YD6	ThetaD6	OSC1	OSC2
6	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	10000494	10000494
7	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	10000494	10000494
8	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	10000494	10000494
9	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	10000494	10000494
10	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	2.00E-01	-8.85E-04	2.00E-01	90.252802	10000494	10000494
11	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
12	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
13	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
14	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
15	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
16	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
17	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	2.00E-01	-8.85E-04	2.00E-01	90.252803	10000494	10000494
18	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494
19	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494
20	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494
21	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494
22	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494
23	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494
24	1.86E+04	2.00E-01	-8.84E-04	2.00E-01	90.252778	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	2.00E-01	-8.85E-04	2.00E-01	90.252804	10000494	10000494

Figure 79. Format of the data_lock_in_XXXXXXXX_XXXXXX.csv file

5.11.2. Plotter Waveform Data Saving

In the Plotter tab, click the "Save" button area shown in the red box in Figure 80, and then click the "Save Data" button to save the data corresponding to the current trace plot to the local hard disk.

The data is saved in Excel-compatible CSV format. The file name is "data_plotter_XXXXXXXX_XXXXXX.csv", where "XXXXXXXX_XXXXXX" represents the date and timestamp, ensuring that each file name is unique. The file is stored in the program directory by default. An example data format is shown in Figure 81.

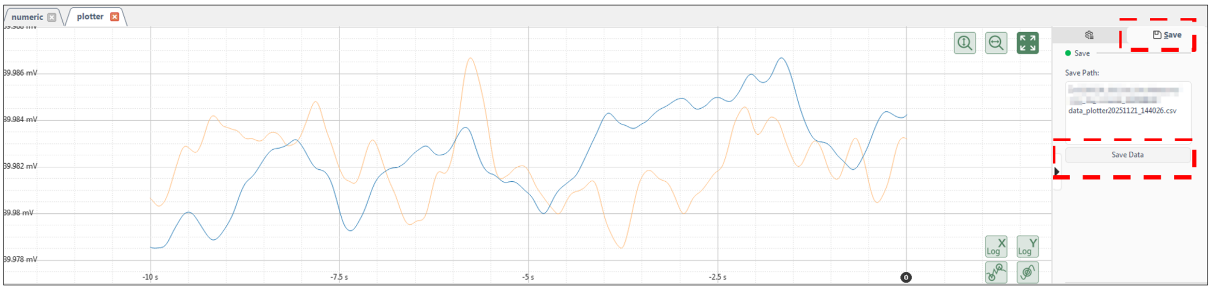


Figure 80. Plotter waveform data saving configuration

	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 81. Plotter waveform data file format

5.11.3. Scope Waveform Data Saving

In the Scope tab, click the "Save" button area shown in the red box in Figure 82, and then click the "Save Data" button to save the data corresponding to the current trace plot to the local hard disk.

The data is saved in Excel-compatible CSV format. The file name is "data_oscilloscope_XXXXXXXX_XXXXXX.csv", where "XXXXXXXX_XXXXXX" represents the date and timestamp, ensuring that each file name is unique. The file is stored in the program directory by default. An example data format is shown in Figure 83.

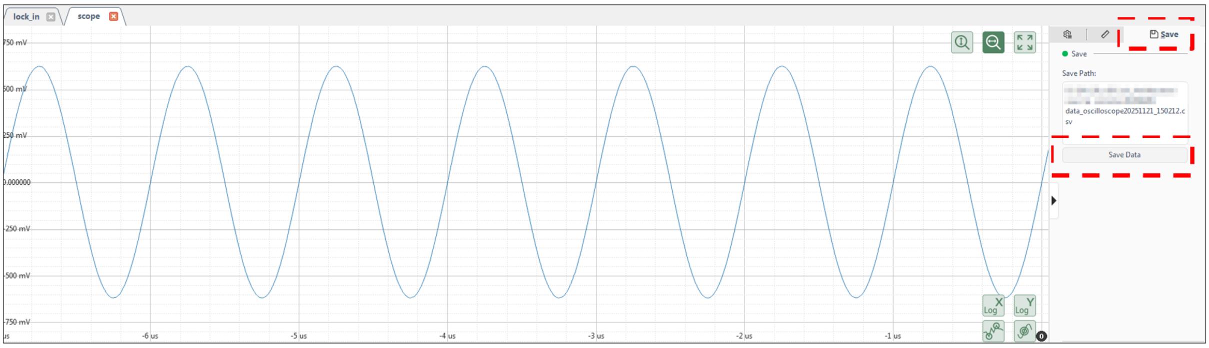


Figure 82. Scope waveform data saving configuration

	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 83. Scope waveform data file format

5.11.4. Sweeper Waveform Data Saving

In the Sweeper tab, click the “Save” button area shown in the red box in Figure 84, and then click the “Save Data” button to save the data corresponding to the current trace plot to the local hard disk.

The data is saved in Excel-compatible CSV format. The file name is “data_sweep_XXXXXXXX_XXXXXX.csv”, where “XXXXXXXX_XXXXXX” represents the date and timestamp, ensuring that each file name is unique. The file is stored in the program directory by default. An example data format is shown in Figure 85.

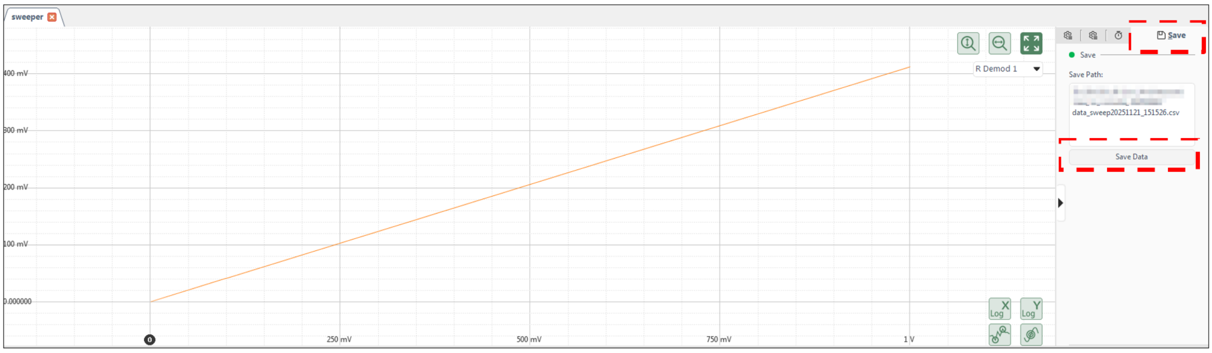


Figure 84. Sweeper parameter-scan data saving configuration area

	A	B	C	D	E	F	G	H	I
1	Module: Sweep								
2	Sweep 0								
3	Device: OE2041								
4	Time: 2025 15:15:26								
5	Timestamp	Demo_1 R	Demo_1 X	Demo_1 Y	Demo_1 Th	Demo_2 R	Demo_2 X	Demo_2 Y	Demo_2 Th
6	4.164E+09	4.16E-04	-4.29E-05	-4.14E-04	-95.91097	4.16E-04	-4.28E-05	-4.14E-04	-95.9069
7	3.886E+09	4.37E-04	-4.46E-05	-4.35E-04	-95.85548	4.37E-04	-4.49E-05	-4.35E-04	-95.89733
8	693618825	4.59E-04	-4.74E-05	-4.57E-04	-95.92161	4.58E-04	-4.70E-05	-4.56E-04	-95.87884
9	750979896	4.82E-04	-4.94E-05	-4.79E-04	-95.88177	4.82E-04	-4.94E-05	-4.79E-04	-95.88909
10	3.083E+09	5.06E-04	-5.23E-05	-5.03E-04	-95.93328	5.06E-04	-5.19E-05	-5.03E-04	-95.88933
11	484492330	5.30E-04	-5.48E-05	-5.28E-04	-95.93057	5.30E-04	-5.44E-05	-5.27E-04	-95.89732
12	822870507	5.57E-04	-5.66E-05	-5.54E-04	-95.83704	5.57E-04	-5.73E-05	-5.54E-04	-95.90161
13	50432454	5.85E-04	-6.09E-05	-5.81E-04	-95.9819	5.84E-04	-5.97E-05	-5.81E-04	-95.85781
14	2.103E+09	6.14E-04	-6.27E-05	-6.11E-04	-95.85966	6.14E-04	-6.30E-05	-6.10E-04	-95.88979
15	1.751E+09	6.46E-04	-6.59E-05	-6.42E-04	-95.86253	6.45E-04	-6.60E-05	-6.42E-04	-95.87214
16	2.99E+09	6.77E-04	-6.92E-05	-6.74E-04	-95.86549	6.77E-04	-6.91E-05	-6.74E-04	-95.85512
17	2.317E+09	7.11E-04	-7.24E-05	-7.08E-04	-95.84578	7.11E-04	-7.24E-05	-7.07E-04	-95.84656
18	3.931E+09	7.47E-04	-7.65E-05	-7.43E-04	-95.88122	7.47E-04	-7.61E-05	-7.43E-04	-95.85421
19	3.5E+09	7.85E-04	-7.93E-05	-7.81E-04	-95.79868	7.85E-04	-8.01E-05	-7.81E-04	-95.85827
20	1.866E+09	8.23E-04	-8.43E-05	-8.19E-04	-95.87627	8.24E-04	-8.39E-05	-8.19E-04	-95.84428
21	647932839	8.64E-04	-8.84E-05	-8.60E-04	-95.87083	8.64E-04	-8.82E-05	-8.60E-04	-95.85408
22	2.836E+09	9.07E-04	-9.23E-05	-9.03E-04	-95.83571	9.07E-04	-9.26E-05	-9.02E-04	-95.85731
23	3.313E+09	9.52E-04	-9.69E-05	-9.47E-04	-95.84378	9.52E-04	-9.72E-05	-9.47E-04	-95.85643
24	2.092E+09	1.00E-03	-1.01E-04	-9.96E-04	-95.80683	1.00E-03	-1.02E-04	-9.95E-04	-95.84283
25	3.508E+09	1.05E-03	-1.07E-04	-1.05E-03	-95.82552	1.05E-03	-1.07E-04	-1.05E-03	-95.83592
26	3.781E+09	1.10E-03	-1.12E-04	-1.10E-03	-95.8494	1.10E-03	-1.12E-04	-1.10E-03	-95.83068
27	309506995	1.16E-03	-1.18E-04	-1.15E-03	-95.8202	1.16E-03	-1.18E-04	-1.15E-03	-95.82474
28	398442314	1.22E-03	-1.24E-04	-1.21E-03	-95.83949	1.22E-03	-1.24E-04	-1.21E-03	-95.83054

	J	K	L	M	N	O	P	Q	R
5	Demo_3 R	Demo_3 X	Demo_3 Y	Demo_3 Th	Demo_4 R	Demo_4 X	Demo_4 Y	Demo_4 Th	Demo_5 R
6	4.16E-04	-4.28E-05	-4.14E-04	-95.9069	4.16E-04	-4.28E-05	-4.14E-04	-95.9069	4.16E-04
7	4.37E-04	-4.49E-05	-4.35E-04	-95.89733	4.37E-04	-4.49E-05	-4.35E-04	-95.89733	4.37E-04
8	4.58E-04	-4.70E-05	-4.56E-04	-95.87884	4.58E-04	-4.70E-05	-4.56E-04	-95.87884	4.58E-04
9	4.82E-04	-4.94E-05	-4.79E-04	-95.88909	4.82E-04	-4.94E-05	-4.79E-04	-95.88909	4.82E-04
10	5.06E-04	-5.19E-05	-5.03E-04	-95.88933	5.06E-04	-5.19E-05	-5.03E-04	-95.88933	5.06E-04
11	5.30E-04	-5.44E-05	-5.27E-04	-95.89732	5.30E-04	-5.44E-05	-5.27E-04	-95.89732	5.30E-04
12	5.57E-04	-5.73E-05	-5.54E-04	-95.90161	5.57E-04	-5.73E-05	-5.54E-04	-95.90161	5.57E-04
13	5.84E-04	-5.97E-05	-5.81E-04	-95.85781	5.84E-04	-5.97E-05	-5.81E-04	-95.85781	5.84E-04
14	6.14E-04	-6.30E-05	-6.10E-04	-95.88979	6.14E-04	-6.30E-05	-6.10E-04	-95.88979	6.14E-04
15	6.45E-04	-6.60E-05	-6.42E-04	-95.87214	6.45E-04	-6.60E-05	-6.42E-04	-95.87214	6.45E-04
16	6.77E-04	-6.91E-05	-6.74E-04	-95.85512	6.77E-04	-6.91E-05	-6.74E-04	-95.85512	6.77E-04
17	7.11E-04	-7.24E-05	-7.07E-04	-95.84656	7.11E-04	-7.24E-05	-7.07E-04	-95.84656	7.11E-04
18	7.47E-04	-7.61E-05	-7.43E-04	-95.85421	7.47E-04	-7.61E-05	-7.43E-04	-95.85421	7.47E-04
19	7.85E-04	-8.01E-05	-7.81E-04	-95.85827	7.85E-04	-8.01E-05	-7.81E-04	-95.85827	7.85E-04
20	8.24E-04	-8.39E-05	-8.19E-04	-95.84428	8.24E-04	-8.39E-05	-8.19E-04	-95.84428	8.24E-04
21	8.64E-04	-8.82E-05	-8.60E-04	-95.85408	8.64E-04	-8.82E-05	-8.60E-04	-95.85408	8.64E-04
22	9.07E-04	-9.26E-05	-9.02E-04	-95.85731	9.07E-04	-9.26E-05	-9.02E-04	-95.85731	9.07E-04
23	9.52E-04	-9.72E-05	-9.47E-04	-95.85643	9.52E-04	-9.72E-05	-9.47E-04	-95.85643	9.52E-04
24	1.00E-03	-1.02E-04	-9.95E-04	-95.84283	1.00E-03	-1.02E-04	-9.95E-04	-95.84283	1.00E-03
25	1.05E-03	-1.07E-04	-1.05E-03	-95.83592	1.05E-03	-1.07E-04	-1.05E-03	-95.83592	1.05E-03
26	1.10E-03	-1.12E-04	-1.10E-03	-95.83068	1.10E-03	-1.12E-04	-1.10E-03	-95.83068	1.10E-03
27	1.16E-03	-1.18E-04	-1.15E-03	-95.82474	1.16E-03	-1.18E-04	-1.15E-03	-95.82474	1.16E-03
28	1.22E-03	-1.24E-04	-1.21E-03	-95.83054	1.22E-03	-1.24E-04	-1.21E-03	-95.83054	1.22E-03

	S	T	U	V	W	X	Y	Z	AA
5	Demo_5 X	Demo_5 Y	Demo_5 Th	Demo_6 R	Demo_6 X	Demo_6 Y	Demo_6 Th	Osc Int Fre	Osc Int Freq 2
6	-4.28E-05	-4.14E-04	-95.9069	4.16E-04	-4.28E-05	-4.14E-04	-95.9069	999999.51	999999.51
7	-4.49E-05	-4.35E-04	-95.89733	4.37E-04	-4.49E-05	-4.35E-04	-95.89733	999999.51	999999.51
8	-4.70E-05	-4.56E-04	-95.87884	4.58E-04	-4.70E-05	-4.56E-04	-95.87884	999999.27	999999.27
9	-4.94E-05	-4.79E-04	-95.88909	4.82E-04	-4.94E-05	-4.79E-04	-95.88909	999999.51	999999.51
10	-5.19E-05	-5.03E-04	-95.88933	5.06E-04	-5.19E-05	-5.03E-04	-95.88933	999999.51	999999.51
11	-5.44E-05	-5.27E-04	-95.89732	5.30E-04	-5.44E-05	-5.27E-04	-95.89732	999999.27	999999.27
12	-5.73E-05	-5.54E-04	-95.90161	5.57E-04	-5.73E-05	-5.54E-04	-95.90161	999999.27	999999.27
13	-5.97E-05	-5.81E-04	-95.85781	5.84E-04	-5.97E-05	-5.81E-04	-95.85781	999999.51	999999.51
14	-6.30E-05	-6.10E-04	-95.88979	6.14E-04	-6.30E-05	-6.10E-04	-95.88979	999999.51	999999.51
15	-6.60E-05	-6.42E-04	-95.87214	6.45E-04	-6.60E-05	-6.42E-04	-95.87214	999999.27	999999.27
16	-6.91E-05	-6.74E-04	-95.85512	6.77E-04	-6.91E-05	-6.74E-04	-95.85512	999999.51	999999.51
17	-7.24E-05	-7.07E-04	-95.84656	7.11E-04	-7.24E-05	-7.07E-04	-95.84656	999999.51	999999.51
18	-7.61E-05	-7.43E-04	-95.85421	7.47E-04	-7.61E-05	-7.43E-04	-95.85421	999999.27	999999.27
19	-8.01E-05	-7.81E-04	-95.85827	7.85E-04	-8.01E-05	-7.81E-04	-95.85827	999999.51	999999.51
20	-8.39E-05	-8.19E-04	-95.84428	8.24E-04	-8.39E-05	-8.19E-04	-95.84428	999999.27	999999.51
21	-8.82E-05	-8.60E-04	-95.85408	8.64E-04	-8.82E-05	-8.60E-04	-95.85408	999999.51	999999.51
22	-9.26E-05	-9.02E-04	-95.85731	9.07E-04	-9.26E-05	-9.02E-04	-95.85731	999999.51	999999.51
23	-9.72E-05	-9.47E-04	-95.85643	9.52E-04	-9.72E-05	-9.47E-04	-95.85643	999999.27	999999.27
24	-1.02E-04	-9.95E-04	-95.84283	1.00E-03	-1.02E-04	-9.95E-04	-95.84283	999999.51	999999.51
25	-1.07E-04	-1.05E-03	-95.83592	1.05E-03	-1.07E-04	-1.05E-03	-95.83592	999999.51	999999.51
26	-1.12E-04	-1.10E-03	-95.83068	1.10E-03	-1.12E-04	-1.10E-03	-95.83068	999999.51	999999.51
27	-1.18E-04	-1.15E-03	-95.82474	1.16E-03	-1.18E-04	-1.15E-03	-95.82474	999999.51	999999.51
28	-1.24E-04	-1.21E-03	-95.83054	1.22E-03	-1.24E-04	-1.21E-03	-95.83054	999999.27	999999.27

Figure 85. Sweeper parameter-scan data file format

Chapter 6 Remote Programming

6.1 OE2031 Command Syntax

The PC software communicates with the OE2031 by using ASCII characters. Command mnemonics must be uppercase. Each command contains four command characters, optional parameters when required, and a command terminator. For RS232, USB2.0, or Ethernet communication, the terminator must be a semicolon <;> or a carriage return <cr>. The OE2031 executes a command only after the command terminator is received. A command may contain one or more parameters, and multiple parameters are separated by commas (,).

Multiple commands can be sent in the same command line. A semicolon <;> must be inserted between commands. Sending multiple commands in one command line provides a faster command response.

The OE2031 has an input buffer with a capacity of 1024 characters and processes commands in the order in which they are received. When the buffer is full, the newest command overwrites the oldest executed command. When entering multiple commands, it is recommended that the total length not exceed 1024 characters.

The OE2031 allows users to query the current values of internal settings through commands. A query command is formed by appending a question mark "?" to the command and omitting one or more parameters required by the original command. The OE2031 returns the queried parameters as ASCII strings. If multiple queries separated by semicolons are sent in one command line, the responses are returned in sequence. The return value of each command is terminated by a carriage return <cr>.

For parameter settings with multiple channels, such as demodulators and oscillators, a channel parameter must be added for identification. Channel numbers start from 1. For example, "FREQ?1" queries the frequency value of internal oscillator OSC1, and "FREQ1,1000" sets the reference signal frequency of internal oscillator OSC1 to 1 kHz. For parameters with only one channel, such as the input channel, no channel parameter is required. For example, "ISRC?" queries the single-ended or differential mode of the input channel.

In addition, non-channel parameters are indexed from 0 by default. For example, "ISRC0" sets the input channel to single-ended mode, and "ISRC1" sets the input channel to differential mode.

Command format examples:

FMOD 1,1 <cr>	Set the reference source of internal oscillator OSC1 to internal mode
FREQ 1,10E3 <cr>	Set the reference signal frequency of internal oscillator OSC1 to 10 kHz
OUTP? 1 <cr>	Query the Y output value of Demodulator 1
ISRC? <cr>	Query the single-ended or differential mode of the input channel
IGND 1 <cr>	Set the input shield grounding mode to GND mode

6.2 Detailed Command List

Command syntax notes:

- Parameters specified in a command must be written strictly in the specified order and separated by English commas ", ".
- Parameters enclosed in braces { } are optional. Fill them in as needed; not all optional parameters need to be entered.
- A command is executed as a query only when it includes the question mark "?" mnemonic. Without "?", it is treated as a setting command and does not return measurement or status data.
- In general, setting commands must include the required parameters shown in braces { }. Query commands do not need to include the optional parameters in { }.
- Do not insert spaces between the command name, mnemonic, and parameters. Spaces shown in the examples below are only for readability and should be omitted during actual communication.
- Note: When sending an actual command, parentheses ( ) and braces { } must not be included in the command string. They are used only in this document to explain and mark the command structure.

The variables are defined as follows:

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

All numeric variables above can be expressed as integers, floating-point numbers, or exponential notation. For example, the number 5 can be written as 5, 5.0, or 0.5E1. Strings are sent as ASCII character sequences.

6.2.1. Input Channel Configuration Commands

<table>
<tr><td>ISRC (?) {i}</td><td>ISRC command is used to set or query the input signal connection mode.
When i=0, select <IN+> (single-ended voltage signal input);
when i=1, select <DIFF> (differential voltage input).</td></tr>
<tr><td>INHZ (?) {i}</td><td>INHZ command is used to set or query the input impedance setting.
When i=0, select 50 Ω;
when i=1, select 10 MΩ.</td></tr>
<tr><td>IGND (?) {i}</td><td>IGND command is used to set or query the input shield grounding mode.
When i=0, select <Float> mode (the input connector shell is isolated from instrument ground through a 1 kΩ resistor);
when i=1, select <Ground> mode (the input connector shell is shorted to instrument ground).</td></tr>
<tr><td>ICPL (?) {i}</td><td>ICPL command is used to set or query the input coupling mode.
When i=0, select <AC> (AC-coupled input);
when i=1, select <DC> (DC-coupled input).</td></tr>
<tr><td>IRNG (?) {i}</td><td>IRNG command is used to set or query the input channel range. Parameter i is used to select different ranges.
The selections are as follows:
<table>
<tr><th>i</th><th>Input Range</th></tr>
<tr><td>0</td><td>2 V</td></tr>
<tr><td>1</td><td>500 mV</td></tr>
<tr><td>2</td><td>100 mV</td></tr>
<tr><td>3</td><td>20 mV</td></tr>
<tr><td>4</td><td>5 mV</td></tr>
<tr><td>5</td><td>1 mV</td></tr>
</table></td></tr>
<tr><td>RMOD?</td><td>RMOD command is used to query the system dynamic reserve. The returned parameter is integer data with the following meaning:
<table>
<tr><th>Returned parameter</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 Commands

The OE2031 has two oscillators, OSC1 and OSC2. All oscillator-related commands require an oscillator channel selection parameter. The oscillator channel parameter is represented by i: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.

FMOD (?) i {,j}	FMOD command is used to set or query the internal/external mode of an oscillator. Parameter i must be specified with this command. It identifies the oscillator channel: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2. When j=0, select external reference mode; when j=1, select internal reference mode.

RSRC (?) i {,j}	RSRC command is used to set or query the reference signal source in oscillator external reference mode.
	Parameter i must be specified with this command. It identifies the oscillator channel: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2.
	When j=0, select the Ref In interface;
	when j=1, select the Signal In interface;
	when j=2, select the Aux In 1 interface;
	when j=3, select the Aux In 2 interface;
	when j=4, select the Aux In 3 interface;
	when j=5, select the Aux In 4 interface;
	when j=6, select the Trig In interface.

FREQ (?) i {,f}	FREQ command is used to set or query the signal frequency in oscillator internal reference mode. Parameter i must be specified with this command. It identifies the oscillator channel: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2. Parameter f can be set in the range $1E^{-5}$ ~$1E^{7}$, with a minimum resolution of $1E^{-9}$. Command FREQ?i returns the current reference signal frequency. When oscillator i is in internal mode, it returns the signal frequency in internal reference mode; when oscillator i is in external mode, it returns the frequency of the external reference source.
FEXT ? i	FEXT command is used to query the frequency of the reference source in oscillator external mode. Parameter i must be specified with this command. It identifies the oscillator channel: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2. The returned parameter type is floating point, and the parameter range is $1E^{-5}$ ~$1E^{7}$.

FINT (?) i {,f}	FINT command is used to set or query the reference signal frequency in oscillator internal mode. Parameter i must be specified with this command. It identifies the oscillator channel: i=1 selects oscillator OSC1, and i=2 selects oscillator OSC2. Parameter f can be set in the range $1E^{-5}$ ~$1E^{7}$, with a minimum resolution of $1E^{-9}$. Command FINT?i returns the current set frequency of oscillator i in internal mode.

RSLP (?) {i}	RSLP command is used to set or query the edge trigger mode of the REF IN interface.
	When i=0, set TTL rising-edge trigger;
	when i=1, set TTL falling-edge trigger;
	when i=2, set sine-wave zero-crossing detection;
	when the input signal frequency is lower than 1 Hz, it is recommended to use either TTL trigger mode.

REFZ (?) {i}	REFZ command is used to set or query the input impedance setting of the REF IN interface. When i=0, select 50 Ω; when i=1, select 1 MΩ.

6.2.3. Demodulator Configuration Commands

The OE2031 has six demodulators, Demod1–Demod6. All demodulator-related commands require a demodulator channel selection parameter. The demodulator channel parameter in the following commands is represented by i: i=1 selects demodulator Demod1, i=2 selects demodulator Demod2, i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6.

DSRC (?) i {,j}	DSRC command is used to set or query the input signal source of a demodulator.
	Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6.
	When j=0, select the Signal In interface;
	when j=1, select the Aux In 1 interface;
	when j=2, select the Aux In 2 interface;
	when j=3, select the Aux In 3 interface;
	when j=4, select the Aux In 4 interface;
	when j=5, select X data of demodulator Demod1;
	when j=6, select Y data of demodulator Demod1;
	when j=7, select R data of demodulator Demod1;
	when j=8, select θ data of demodulator Demod1.
	Note that the input signal source of Demodulator channel 1 cannot be modified. Regardless of the configuration, the input source of demodulator Demod1 remains the Signal In interface.

OFLT (?) i {,x}	OFLT command is used to set or query the time constant of the demodulator filter. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. Parameter x can be set in the range $1E^{-7}$ ~3000, with a minimum resolution of $1E^{-7}$.
OFSL (?) i {,j}	OFSL command is used to set or query the roll-off of the demodulator low-pass filter. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. Parameter j is used to select different roll-off values. The selections are as follows:

<table>
<tr><td>OFSL (?) i {,j}</td><td>
<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>
<tr><td>SYNC (?) i {,j}</td><td>SYNC command is used to set or query the on/off status of the demodulator synchronous filter. The synchronous filter is effective only when the reference frequency is lower than 1 MHz.
Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6.
When j=0, turn off the synchronous filter;
when j=1, turn on the synchronous filter.</td></tr>
<tr><td>DMOD (?) i {,j}</td><td>DMOD command is used to set or query the reference source mode of a demodulator.
Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6.
When j=0, select oscillator OSC1 as the reference mode;
when j=1, select oscillator OSC2 as the reference mode;
when j=2, select arbitrary-frequency demodulation mode;
when j=3, select formula-combined-frequency demodulation mode.</td></tr>
<tr><td>DARF (?) i {, f}</td><td>DARF command is used to set or query the reference frequency used in arbitrary-frequency demodulation mode.
Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6.
Parameter f can be set in the range $1E^{-5}$ ~$1E^{7}$, with a minimum resolution of $1E^{-9}$.</td></tr>
</table>

DEQU (?) i {,x,j,y,k}	DEQU command is used to set or query the formula parameters used in formula-combined-frequency demodulation mode. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. Parameters x, j, y, and k correspond to the four parameters A, FOSC, B, and F in the formula E=A*FOSC+B*F. x and y can be set as floating-point numbers in the range −10 000~10 000. When j=0, select the frequency value of oscillator OSC1; when j=1, select the frequency value of oscillator OSC2. When k=0, select the frequency value of oscillator OSC1; when k=1, select the frequency value of oscillator OSC2; when k=2, select the arbitrary set frequency.
DEAF (?) i {, f}	DEAF command is used to set or query the value of the arbitrary set frequency F in the formula used in formula-combined-frequency demodulation mode. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. Parameter f can be set in the range $1E^{-5}$ ~$1E^{7}$, with a minimum resolution of $1E^{-9}$.
HARM (?) i {, j}	HARM command is used to set or query the harmonic order of the demodulator reference signal. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. Parameter j can be set to an integer from 1 to 10000, indicating the harmonic order. Command HARM i,j sets the signal at the j-th harmonic of the detection reference frequency for the i-th demodulator. Parameter j must satisfy j*f ≤ 10 MHz. If the value of the j-th harmonic is greater than 10 MHz, the demodulator output result will be incorrect.

PHAS (?) i ,{x}	PHAS command is used to set or query the reference phase shift. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. Parameter x is the phase value (real number, in °; the unit does not need to be entered). The input range is −180.000~180.000, and the resolution is 0.001. For example, sending command PHAS 1,-179.0 sets the phase-shift value of Demodulator 1 to −179.000°. Command PHAS?1 queries the phase-shift value of Demodulator 1.
DREF? i	DREF command is used to query the final reference frequency of a demodulator. Parameter i must be specified when sending this command. When i=1, select demodulator Demod1; i=2 selects demodulator Demod2; i=3 selects demodulator Demod3, ……, and i=6 selects Demodulator 6. The returned parameter type is floating point, and the parameter range is $1E^{-5}$ ~$1E^{7}$. The returned frequency value equals reference frequency * harmonic order.

6.2.4. Signal Output Channel Configuration Commands

SADD (?) {i}	SADD command is used to set or query the enable status of the ADD IN interface. When i=0, disable ADD IN input; when i=1, enable ADD IN input. In this state, the signal at the ADD IN interface is added to the Sineout signal.
STTL (?) {i}	STTL command is used to set or query the output status of the TTL OUT interface. When i=0, disable TTLout output; when i=1, enable TTLout output.
SSRC (?) {i}	SSRC command is used to set or query the output status of the SINE OUT interface. When i=0, disable Sineout output; when i=1, enable Sineout output with the frequency reference source from oscillator OSC1; when i=2, enable Sineout output with the frequency reference source from oscillator OSC2.
SLVL (?) {x}	SLVL command is used to set or query the sine-wave voltage amplitude output from <Sineout>. Parameter x indicates the amplitude voltage (real number, unit: Vrms; the unit does not need to be entered). Parameter x must satisfy $1\,\mu V_{rms} \le x \le 2\,V_{rms}$, with a minimum resolution of $0.1\,\mu V_{rms}$.
SOFF (?) {x}	SOFF command is used to set or query the DC offset voltage output from <Sineout>. Parameter x indicates the offset voltage value (real number, unit: V; the unit does not need to be entered). The range of parameter x is −3~3 V, with a minimum resolution of 0.001 V.
SPHS (?) {x}	SPHS command is used to set or query the phase shift of the <Sineout> sine wave relative to the oscillator reference. Parameter x is the phase value (real number, in °; the unit does not need to be entered). The input range is −180~180, and the resolution is 0.001.
TPHS (?) {x}	TPHS command is used to set or query the phase shift of the <TTLout> waveform relative to the oscillator reference. Parameter x is the phase value (real number, in °; the unit does not need to be entered). The input range is −180~180, and the resolution is 0.001.

SMOD (?) {i}	SMOD command is used to set or query the output mode of <Sineout>.
	When i=0, select sine-wave output mode;
	when i=1, select AM modulation mode;
	when i=2, select FM modulation mode;

SMOD (?) {i}	when i=3, select PM modulation mode. When AM/FM/PM modulation mode is selected, the carrier amplitude and frequency information remain the same as in sine-wave mode, while the modulation-wave depth and frequency are controlled by other commands.
MARF (?) {f}	MARF command is used to set or query the internal frequency of <Sineout> modulation mode. Parameter f can be set in the range $1E^{-5}$ ~$1E^{7}$, with a minimum resolution of $1E^{-9}$.
AMSR (?) {i}	AMSR command is used to set or query the frequency source of the AM modulation signal. When i=0, select the frequency value of oscillator OSC1; when i=1, select the frequency value of oscillator OSC2; when i=2, select the internal frequency of modulation mode, namely the frequency set by MARF.
AMDP (?) {x}	AMDP command is used to set or query the modulation depth of the AM modulation signal. The input range of parameter x is a real number from 0~1, indicating the amplitude percentage ratio between the modulation signal and the carrier signal. For example, setting AMDP1 indicates that the modulation signal amplitude is the same as the carrier signal amplitude.
FMSR (?) {i}	FMSR command is used to set or query the frequency source of the FM modulation signal. When i=0, select the frequency value of oscillator OSC1; when i=1, select the frequency of oscillator OSC2; when i=2, select the internal frequency of modulation mode, namely the frequency set by MARF.
FMDV (?) {f}	FMDV command is used to set or query the peak frequency deviation of the FM modulation signal. Parameter f can be set in the range $1E^{-5}$ ~$1E^{7}$, with a minimum resolution of $1E^{-9}$.
PMSR (?) {i}	PMSR command is used to set or query the frequency source of the PM modulation signal. When i=0, select the frequency value of oscillator OSC1; when i=1, select the frequency value of oscillator OSC2; when i=2, select the internal frequency of modulation mode, namely the frequency set by MARF.
PMDV (?) {x}	PMDV command is used to set or query the phase deviation of the PM modulation signal. Parameter x is the phase value (real number, in °; the unit does not need to be entered). The input range is 0~360, and the resolution is 0.001.

6.2.5. Channel Output Commands

The OE2031 has four AUXOUT/CHOUT channel interfaces. All channel-output-related commands require a CH channel selection parameter. The CH channel parameter in the following commands is represented 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>COUT (?) i {, j}
FOUT (?) i {, j}</td>
<td>COUT command is used to set or query the signal source of the AUXOUT/CHOUT output channels on the rear panel of the OE2031.
COUT and FOUT commands have the same function and are provided for compatibility with earlier versions.
Parameter i must be specified when sending this command: i=1 selects CH1; i=2 selects CH2; i=3 selects CH3; and i=4 selects CH4.
Parameter j is used to select the output value type, as follows:
<table>
<tr><th>j</th><th>CH Channel Source</th><th>j</th><th>CH Channel Source</th></tr>
<tr><td>0</td><td>AUXOUT</td><td>15</td><td>R-Demod4</td></tr>
<tr><td>1</td><td>X-Demod1</td><td>16</td><td>θ-Demod4</td></tr>
<tr><td>2</td><td>Y-Demod1</td><td>17</td><td>X-Demod5</td></tr>
<tr><td>3</td><td>R-Demod1</td><td>18</td><td>Y-Demod5</td></tr>
<tr><td>4</td><td>θ-Demod1</td><td>19</td><td>R-Demod5</td></tr>
<tr><td>5</td><td>X-Demod2</td><td>20</td><td>θ-Demod5</td></tr>
<tr><td>6</td><td>Y-Demod2</td><td>21</td><td>X-Demod6</td></tr>
<tr><td>7</td><td>R-Demod2</td><td>22</td><td>Y-Demod6</td></tr>
<tr><td>8</td><td>θ-Demod2</td><td>23</td><td>R-Demod6</td></tr>
<tr><td>9</td><td>X-Demod3</td><td>24</td><td>θ-Demod6</td></tr>
<tr><td>10</td><td>Y-Demod3</td><td>25</td><td>AUXIN1</td></tr>
<tr><td>11</td><td>R-Demod3</td><td>26</td><td>AUXIN2</td></tr>
<tr><td>12</td><td>θ-Demod3</td><td>27</td><td>AUXIN3</td></tr>
<tr><td>13</td><td>X-Demod4</td><td>28</td><td>AUXIN4</td></tr>
<tr><td>14</td><td>Y-Demod4</td><td></td><td></td></tr>
</table>
</td>
</tr>
<tr>
<td>CAUX(?) i {, x}</td>
<td>CAUX command is used to set or query the voltage value of the AUXOUT DC mode for an AUXOUT/CHOUT channel.
Parameter i corresponds to the CH channel: i=1 selects CH1; i=2 selects CH2; i=3 selects CH3; and i=4 selects CH4.
Parameter x is used to set the output voltage value (real number, unit: V; the unit does not need to be entered). The range is -10.000 ≤ x ≤ 10.000, with a minimum resolution of 0.001.
For example, sending command CAUX1,5.00 sets the output value of <CHOUT1> in AUXOUT DC mode to 5.00 V.</td>
</tr>
</table>

<table>
<tr>
<td>SENS (?) i {,j}</td>
<td>SENS command is used to set or query the sensitivity of an AUX-OUT/CHOUT channel.
Parameter i corresponds to the CH channel: i=1 selects CH1; i=2 selects CH2; i=3 selects CH3; and i=4 selects CH4.
Parameter j is used to select different ranges.
The selections are as follows:
<table>
<tr><th>j</th><th>sensitivity</th><th>j</th><th>sensitivity</th></tr>
<tr><td>0</td><td>1 nV</td><td>15</td><td>100 μV</td></tr>
<tr><td>1</td><td>2 nV</td><td>16</td><td>200 μV</td></tr>
<tr><td>2</td><td>5 nV</td><td>17</td><td>500 μV</td></tr>
<tr><td>3</td><td>10 nV</td><td>18</td><td>1 mV</td></tr>
<tr><td>4</td><td>20 nV</td><td>19</td><td>2 mV</td></tr>
<tr><td>5</td><td>50 nV</td><td>20</td><td>5 mV</td></tr>
<tr><td>6</td><td>100 nV</td><td>21</td><td>10 mV</td></tr>
<tr><td>7</td><td>200 nV</td><td>22</td><td>20 mV</td></tr>
<tr><td>8</td><td>500 nV</td><td>23</td><td>50 mV</td></tr>
<tr><td>9</td><td>1 μV</td><td>24</td><td>100 mV</td></tr>
<tr><td>10</td><td>2 μV</td><td>25</td><td>200 mV</td></tr>
<tr><td>11</td><td>5 μV</td><td>26</td><td>500 mV</td></tr>
<tr><td>12</td><td>10 μV</td><td>27</td><td>1 V</td></tr>
<tr><td>13</td><td>20 μV</td><td>28</td><td>2 V</td></tr>
<tr><td>14</td><td>50 μV</td><td></td><td></td></tr>
</table>
</td>
</tr>
<tr>
<td>COFP (?) i {, x}</td>
<td>COFP command is used to set or query the offset value output from an AUXOUT/CHOUT channel.
Parameter i corresponds to the CH channel: i=1 selects CH1; i=2 selects CH2; i=3 selects CH3; and i=4 selects CH4.
Parameter x is used to set the offset value (unit: %), with a range of $-100.00 \le x \le 100.00$ and a minimum resolution of 0.01.</td>
</tr>
<tr>
<td>CEXP (?) i {,x}
OEXP (?) i {,x}</td>
<td>CEXP command is used to set or query the gain value output from an AUXOUT/CHOUT channel. CEXP and OEXP commands have the same function and are provided for compatibility with earlier versions.
Parameter i corresponds to the CH channel: i=1 selects CH1; i=2 selects CH2; i=3 selects CH3; and i=4 selects CH4.
Parameter x is used to set the output gain, a real number in the range $0.001 \le x \le 10000$, with a minimum resolution of 0.001.</td>
</tr>
</table>

6.2.6. Auto-Setup Commands

ARNG 1	ARNG 1 command is used to enable the auto range function of the input channel. This command has the same effect as pressing <Auto Range> in the menu.
APHS i	APHS command is used to enable the auto phase compensation function of a demodulator. This command has the same effect as pressing <Auto Phase> in the menu. Parameter i corresponds to the demodulator channel. When i=0, all six demodulators are selected for configuration; i=1 selects demodulator Demod1; i=2 selects demodulator Demod2, ……, and i=6 selects Demodulator 6. For example, sending command APHS 2; automatically adjusts the current phase value of Demodulator 2 to 0, and the phase value is set in Ref.Phase. Auto phase setting takes some time. Do not send the APHS command again before auto setup is complete. In addition, if the phase is unstable, this command will be invalid.
AFLT i	AFLT command is used to enable the function for automatically setting the demodulator filter. This command has the same effect as pressing <Auto Filter> in the menu. Parameter i corresponds to the demodulator channel. When i=0, all six demodulators are selected; i=1 selects demodulator Demod1; i=2 selects demodulator Demod2, ……, and i=6 selects Demodulator 6.
AOFP i	AOFP command is used to enable the function for automatically setting the output offset value of a CHOUT channel. This command has the same effect as pressing <Auto CH Offset> in the menu. Parameter i is optional. When i=0, all four CHOUT channels are selected; i=1 selects CH1; i=2 selects CH2; i=3 selects CH3; and i=4 selects CH4.

6.2.7. Save and Recall Setting Commands

SSET i	SSET i command is used to save the current settings of the OE2031 into configuration storage, namely Setting buffer i (1≤i≤4). The configuration information in the Setting buffer is retained after the OE2031 is powered off.
RSET i	RSET i command is used to recall the settings in Setting buffer i (0≤i≤4). Here, i=0 indicates the <Default> default settings, and i=1~4 indicates the settings of <S1> ~ <S4>. After a successful recall, the internal parameters of the OE2031 are set to the same parameters as those in Setting buffer i.

6.2.8. Reset and IDN Commands

*RST	*RST command performs a soft reset of the OE2031. All internal states and parameters of the instrument remain unchanged. However, the measured data, including data stored in the buffer, will be reset or lost. The asterisk is included so that the command mnemonic has four characters.
*IDN?	*IDN? command is used to query the OE2031 ID, with the format "Sine Scientific Instruments, OE2031, SN:XXXXXX, Ver:XXXXX". The first field is the company name, the second is the model, for example OE2031; the third is the serial number, for example SN:00001; and the fourth is the version number, for example Ver:1.00-1.10. The asterisk is included so that the command mnemonic has four characters.

6.2.9. Data and Status Read Commands

<table>
<tr>
<td>OUTP? i</td>
<td>OUTP? i command is used to read a single measured value. Parameter i corresponds to the table below. The parameter selections are as follows:
<table>
<tr><td>i</td><td>Parameter</td><td>i</td><td>Parameter</td></tr>
<tr><td>0</td><td>X-Demod1</td><td>17</td><td>Y-Demod5</td></tr>
<tr><td>1</td><td>Y-Demod1</td><td>18</td><td>R-Demod5</td></tr>
<tr><td>2</td><td>R-Demod1</td><td>19</td><td>θ-Demod5</td></tr>
<tr><td>3</td><td>θ-Demod1</td><td>20</td><td>X-Demod6</td></tr>
<tr><td>4</td><td>X-Demod2</td><td>21</td><td>Y-Demod6</td></tr>
<tr><td>5</td><td>Y-Demod2</td><td>22</td><td>R-Demod6</td></tr>
<tr><td>6</td><td>R-Demod2</td><td>23</td><td>θ-Demod6</td></tr>
<tr><td>7</td><td>θ-Demod2</td><td>24</td><td>Xnoise-Demod1</td></tr>
<tr><td>8</td><td>X-Demod3</td><td>25</td><td>Ynoise-Demod1</td></tr>
<tr><td>9</td><td>Y-Demod3</td><td>26</td><td>Frequency-OSC1</td></tr>
<tr><td>10</td><td>R-Demod3</td><td>27</td><td>Frequency-OSC2</td></tr>
<tr><td>11</td><td>θ-Demod3</td><td>28</td><td>AUXIN1</td></tr>
<tr><td>12</td><td>X-Demod4</td><td>29</td><td>AUXIN2</td></tr>
<tr><td>13</td><td>Y-Demod4</td><td>30</td><td>AUXIN3</td></tr>
<tr><td>14</td><td>R-Demod4</td><td>31</td><td>AUXIN4</td></tr>
<tr><td>15</td><td>θ-Demod4</td><td>32</td><td>Timestamp</td></tr>
<tr><td>16</td><td>X-Demod5</td><td></td><td></td></tr>
</table>
The selected parameter value is returned in ASCII floating-point format, in volts (V), degrees (°), or hertz (Hz), but the unit is not output. This command is query-only.</td>
</tr>
<tr>
<td>SNAP? i {,j,k,l,m,n,o,p……}</td>
<td>SNAP? command is used to read up to 20 different measured values from the OE2031 at the same time.
SNAP? command is used to query instantaneous values such as <X>, <Y>, <R>, <θ>, or <F> at the same moment. This function is especially important in scenarios with short time constants or rapidly changing signals. If the OUTP? command is used to query multiple parameters sequentially, a certain delay occurs between the returned values of each parameter, so the acquired data are not strictly synchronous. In dynamic signal measurement, this timing deviation may introduce significant error. The SNAP? command ensures that all specified parameters are calculated and output based on the same internal sampling point, thereby ensuring time consistency of the data.
The SNAP?i command requires at least one parameter and can read up to 20 parameters simultaneously. The parameter selections are as follows:</td>
</tr>
</table>

<table>
<tr><td>SNAP? i {,j,k,l,m,n,o,p……}</td><td>
<table>
<tr><th>i</th><th>Parameter</th><th>i</th><th>Parameter</th></tr>
<tr><td>0</td><td>X-Demod1</td><td>17</td><td>Y-Demod5</td></tr>
<tr><td>1</td><td>Y-Demod1</td><td>18</td><td>R-Demod5</td></tr>
<tr><td>2</td><td>R-Demod1</td><td>19</td><td>θ-Demod5</td></tr>
<tr><td>3</td><td>θ-Demod1</td><td>20</td><td>X-Demod6</td></tr>
<tr><td>4</td><td>X-Demod2</td><td>21</td><td>Y-Demod6</td></tr>
<tr><td>5</td><td>Y-Demod2</td><td>22</td><td>R-Demod6</td></tr>
<tr><td>6</td><td>R-Demod2</td><td>23</td><td>θ-Demod6</td></tr>
<tr><td>7</td><td>θ-Demod2</td><td>24</td><td>Xnoise-Demod1</td></tr>
<tr><td>8</td><td>X-Demod3</td><td>25</td><td>Ynoise-Demod1</td></tr>
<tr><td>9</td><td>Y-Demod3</td><td>26</td><td>Frequency-OSC1</td></tr>
<tr><td>10</td><td>R-Demod3</td><td>27</td><td>Frequency-OSC2</td></tr>
<tr><td>11</td><td>θ-Demod3</td><td>28</td><td>AUXIN1</td></tr>
<tr><td>12</td><td>X-Demod4</td><td>29</td><td>AUXIN2</td></tr>
<tr><td>13</td><td>Y-Demod4</td><td>30</td><td>AUXIN3</td></tr>
<tr><td>14</td><td>R-Demod4</td><td>31</td><td>AUXIN4</td></tr>
<tr><td>15</td><td>θ-Demod4</td><td>32</td><td>Timestamp</td></tr>
<tr><td>16</td><td>X-Demod5</td><td></td><td></td></tr>
</table>
The returned value is a string. Different values in the string are separated by commas (,), and the values are returned in the order of the i, j, k, l, and m parameters in the sent command. For example, sending SNAP?0,1,26,3; returns <X>, <Y>, <Frequency>, and <θ> values in sequence. These values are placed in the same string, for example:
"0.951359,0.0253297,1000.00,1.234". The first value is <X>, the second is <Y>, the third is the frequency value, and the fourth is the <θ> value.</td></tr>
<tr><td>OAUX? i</td><td>OAUX command is used to query the input voltage value of the rear-panel AUX-IN interface.
Parameter i must be specified. When i=1, read AUX-IN1; i=2 reads AUX-IN2; i=3 reads AUX-IN3; and i=4 reads AUX-IN4.
The query result is a real number in volts (V), but the unit is not output.</td></tr>
<tr><td>INOV?</td><td>INOV? command is used to query the Input Overload status. The query returns 0 or 1. Here, 0 indicates that the input-channel preamplifier is not currently overloaded; 1 indicates that the input-channel preamplifier is overloaded, in which case the input signal must be reduced to protect the instrument from damage.</td></tr>
<tr><td>GNOV?</td><td>GNOV? command is used to query the Gain Overload status. The query returns 0 or 1. Here, 0 indicates that the input-channel ADC is not currently overloaded; 1 indicates that the input-channel ADC is overloaded, in which case the input signal must be reduced or the input range increased to protect the instrument from damage.</td></tr>
</table>

*PLL? i	*PLL? command is used to query the status of the oscillator phase-locked loop. Parameter i must be specified. When i=1, read the PLL status of OSC1; when i=2, read the PLL status of OSC2. The query returns 0 or 1, where 0 indicates that the PLL is not locked or is in internal reference mode, and 1 indicates that the PLL is locked.

6.2.10. Clock and Trigger Signal Configuration Commands

TMOD (?) {i}	TMOD command is used to set or query the instrument clock source. Parameter i indicates the clock mode to select when sending the command: i=0 indicates use of the internal clock; i=1 indicates use of an external 10 MHz clock.
TSTA?	TSTA? command is used to query the clock PLL status of the instrument. The returned parameter type is integer: 0 indicates that all clock PLLs are abnormal; 2 indicates that the internal clock PLL is normal; 7 indicates that the external clock PLL is normal.
OCLK (?) {i}	OCLK command is used to set or query the enable status of the instrument 10 MHz clock output interface. Parameter i=0 disables the CLOCK OUT interface, and the interface output remains low; parameter i=1 enables the CLOCK OUT interface, and the interface outputs a 10 MHz/3.3 V square-wave clock.
TRIG (?) {i}	TRIG command is used to set or query the trigger source type of the instrument. Parameter i=0 indicates use of the instrument internal trigger source, and all data sampling depends on the instrument internal clock; parameter i=1 indicates use of the external trigger source Trigger in.
TRIM (?) {i}	TRIM command is used to set or query the external trigger mode of the instrument. The external trigger modes corresponding to parameter i are as follows:

<table>
<tr><td>TRIM (?) {i}</td><td>
<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>Falling edge</td></tr>
<tr><td>2</td><td>Edge trigger</td></tr>
<tr><td>3</td><td>High-level trigger</td></tr>
<tr><td>4</td><td>Low-level trigger</td></tr>
</table>
When rising-edge, falling-edge, or edge-trigger mode is selected, the instrument outputs data at the instant when the trigger signal edge is detected.
When high-/low-level trigger mode is selected, the instrument continuously outputs data at the user-set sampling rate while the trigger signal is in the corresponding level state. This is equivalent to applying a window function to limit the data output range.</td></tr>
<tr><td>TRIO (?) {i}</td><td>TRIO command is used to set or query the enable status of the instrument TRIGGER OUT interface.
Parameter i=0 indicates that the TRIGGER OUT interface is disabled, and the interface output remains low;
parameter i=1 enables the TRIGGER OUT interface, and the interface outputs a trigger signal according to the current trigger mode of the instrument.</td></tr>
<tr><td>TRIF (?) {f}</td><td>TRIF command is used to set or query the sampling rate in instrument internal trigger mode.
Parameter f indicates the data sampling rate, which can be set in the range 0.01~100 000 Hz.</td></tr>
</table>

Chapter 7 Performance Tests

Introduction

This chapter provides a series of performance tests to help users verify the measurement accuracy of the instrument and gain confidence in its reliability. All test results can be recorded in the performance test record table attached at the end of this chapter for subsequent performance evaluation.

Serial Number

When contacting our technical support team, be sure to provide the instrument serial number so that we can process the issue quickly.

The serial number is clearly marked on the rear panel of the instrument and on the outer packaging box. After the instrument is powered on, this information can also be viewed on the <INFO> interface.

Firmware Version

After the instrument is powered on, the firmware version can be viewed on the <INFO> interface.

Warm-up

Because the internal components of the instrument exhibit temperature drift, allow the instrument to warm up sufficiently before formal testing to ensure accurate test results. A warm-up time of 30 to 60 minutes is recommended so that the system reaches thermal stability and measurement error is effectively reduced.

Test Records

A performance test record table is provided at the end of this chapter for recording system test data. It is recommended to make a backup copy of the record table before filling it in.

After all tests are completed, evaluate whether the instrument performance meets the expected specifications based on the measured data in the record table. Keep the record table properly; it can serve as an important reference when communicating with our engineers in the future.

Test Failure

If any test fails, troubleshoot according to the following steps:

1. Check the settings: carefully verify that the configuration of this instrument and all externally connected devices is correct;

2. Warm up again: after confirming that the settings are correct, fully warm up the instrument and repeat the test;

3. Replace external devices: if possible, use other known-good external devices to elim-

inate peripheral interference factors.

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

1. Record the instrument serial number and firmware version;
2. Prepare the complete performance test record table;
3. Contact our technical support team promptly for further assistance with diagnosis and handling.

Required Test 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
Recommended	AGILENT 33600B series

2. Digital multimeter

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

3. DC power supply

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

4. Connectors

BNC resistor	50 Ω
BNC T-connector	

5. Cables

BNC-BNC cable	several 0.5 m cables
BNC-BNC cable	several 1 m cables

Front-panel LCD Test

Operate the instrument as follows: first, turn on the rear-panel power switch to start the instrument; then carefully observe whether the LCD screen lights successfully; finally, carefully check whether there are any dead pixels on the screen.

Keypad Test

After the instrument starts, gently press any key. You should hear a clear beep from the instrument as feedback.

Next, test all keys one by one and carefully observe the screen display to confirm that each key operation correctly triggers the corresponding setting change.

Finally, select the <Demod.Select> setting item in the [DEMOD FILTER] menu and rotate the knob to verify that the knob operates normally and responds with the corresponding adjustment.

7.1 Startup Test

Before performing other performance tests, the startup test must first be performed to comprehensively check the hardware functions of the lock-in amplifier and ensure that it is operating normally.

Equipment

No external equipment is required for this test.

Procedure

1) Turn on the rear-panel power switch to start the lock-in amplifier;

2) Observe whether the instrument screen, keypad functions, and rear cooling fan are operating normally;

3) Record whether the check passes in the test record table at the end of this chapter.

7.2 DC Offset

The purpose of this test is to test the DC offset at the input.

Equipment

Use a 50 Ω BNC resistor load to short the IN+ connector. After the input is shorted, the lock-in amplifier can measure its own DC offset.

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;

2) Modify the settings in the following order:

<Osc.Mode>:	Set to <Internal>
<Osc.Frequency>:	Set to 1 Hz
<Input Range>:	Set with the knob to <1 mV>

<Demod1> <Time Constant>:	Set to 1 s
<Demod1> <Filter dB/oct>:	Set to 24 dB/oct

3) After waiting for 10 seconds, record the <R-Demod1> value;
4) Modify the settings:

<Coupling>:	Set to <DC>

5) After waiting for 10 seconds, record the <R-Demod1> value;
6) This completes the DC offset test. Fill in the data in the test record table at the end of this chapter.

7.3 Common-mode Rejection

The purpose of this test is to test the common-mode rejection ratio of the lock-in amplifier.

Equipment

Use the sine wave generated by this instrument as the output signal.

Connect the SINE OUT output connector of the lock-in amplifier to the IN+ and IN- input connectors. Attach a BNC T-connector to the SINE OUT connector, and use two signal cables of equal length (BNC male-to-male) to connect the T-connector to the IN+ and IN- connectors respectively.

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;
2) Modify the settings in the following order:

<Input Range>:	Set with the knob to <2 V>
<Coupling>:	Set to <DC>
<Impedance>:	Set to <10 MΩ>
<Osc1> <Osc.Mode>:	Set to <Internal>
<Osc1> <Osc.Frequency>:	Set to 100 Hz
<Output Source>:	Set to <OSC1>
<Amplitude>:	Set to 1 V_{rms}

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

<Input Port>:	Set to <DIFF>
<Input Range>:	Set with the knob to <5 mV>

5) After waiting for 10 seconds, record the <R-Demod1> value;
6) This completes the common-mode rejection test. Calculate the common-mode rejection ratio CMRR = 20lg(1.0/R). Fill in the data in the test record table at the end of this chapter.

7.4 Amplitude Accuracy and Flatness

The purpose of this test is to test the accuracy of each range and the frequency response of the lock-in amplifier.

Equipment

Use a function signal generator to provide accurate frequency and sine wave signals.

Use one signal cable (BNC male-to-male) to connect the output connector of the function signal generator to the IN+ connector of the lock-in amplifier, and use another signal cable to connect the sync signal connector of the function signal generator to the REF IN connector of the lock-in amplifier.

Set the function signal generator as follows:

Function:	Sine wave
Frequency:	10 kHz
Amplitude:	1 V_{rms}
Offset:	0 V
Output:	50 Ω
Sweep:	off
Modulation:	none

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;

2) Modify the settings:

<Filter dB/oct>:	Set to 24 dB/oct.
<Impedance>:	Set to 50 Ω.
<Coupling>:	Set to <DC>.
<Osc1> <Osc.Mode>:	Set to <External>.

3) For the amplitude accuracy test, keep the function signal generator frequency at 10 kHz, and modify the lock-in amplifier <Input Range> and the function generator <Amplitude> in the following order:

Input Range	Amplitude
2 V	1.000 V_{rms}
500 mV	250.00 mV_{rms}
100 mV	50.000 mV_{rms}
20 mV	10.000 mV_{rms}
5 mV	2.500 mV_{rms}
1 mV	1.000 mV_{rms}

a) Set the amplitude of the function signal generator;

b) After waiting for 10 seconds, record the <R> value, and then test the next data point;

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

4) The frequency response test is performed at frequencies above 1 kHz. Modify the function generator frequency in the following order:

Test Frequency
2.4 kHz
24 kHz
240 kHz
2.4 MHz

a) Set the function signal generator amplitude to 200.00 mV_{rms};
b) Set the lock-in amplifier <Input Range> to <500 mV>;
c) Set the function signal generator frequency in sequence;
d) After waiting for 10 seconds, record the <R-Demod1> value, and then test the next data point;
e) Repeat steps 4c to 4d until the frequency response test is completed.

5) This completes the amplitude accuracy and frequency response tests. Fill in the data in the test record table at the end of this chapter.

7.5 Amplitude Linearity

The purpose of this test is to test the amplitude linearity of the lock-in amplifier and verify its measurement capability when the signal is below full scale.

Equipment

Use a function signal generator to provide accurate frequency and sine wave signals.

Use one signal cable (BNC male-to-male) to connect the output connector of the function signal generator to the IN+ connector of the lock-in amplifier, and use another signal cable to connect the sync signal connector of the function signal generator to the REF IN connector of the lock-in amplifier.

Set the function signal generator as follows:

Function:	Sine wave
Frequency:	1 kHz
Amplitude:	1 V_{rms}
Offset:	0 V
Output:	50 Ω
Sweep:	off
Modulation:	none

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;

2) Modify the settings:

<Filter dB/oct>:	Set to <24 dB/oct>.
<Impedance>:	Set to 50 Ω.
<Input Range>:	Set with the knob to <2 V>.
<Osc1> <Osc.Mode>:	Set to <External>.

3) Keep the function signal generator frequency 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 for 10 seconds, record the <R-Demod1> value, and then test the next data point;
c) Repeat steps 3a to 3b until all data measurements are completed.

4) This completes the amplitude linearity test. Fill in the data in the test record table at the end of this chapter.

7.6 Frequency Accuracy

The purpose of this test is to test the frequency accuracy of the lock-in amplifier.

Equipment

Use a function signal generator to provide the reference signal.

Use one signal cable (BNC male-to-male) to connect the reference signal connector of the function signal generator to the REF IN connector of the lock-in amplifier.

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;
2) Set the function signal generator frequency to 1 MHz;
3) Set <Osc.Mode> of <Osc1> on the lock-in amplifier to <External>.
4) After <PLL> in the lower-right corner of the lock-in amplifier screen changes from <UNLOCK> to <LOCKED>, connect the host computer program and record the <Freq> value of Osc1;
5) This completes the frequency accuracy test. Fill in the data in the test record table at the end of this chapter.

7.7 Sine Out Amplitude/Phase Accuracy and Flatness

The purpose of this test is to test the amplitude/phase accuracy and frequency response of the sine wave (Sine Out) generated by the signal generator.

Equipment

Use one 1 m signal cable (BNC male-to-male) to connect the SINE OUT connector to the IN+ connector.

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;
2) Modify the settings:

<Input Range>:	Set with the knob to <2 V>.
<Impedance>:	Set to 50 Ω.
<Osc.Mode>:	Set to <Internal>.
<Osc.Frequency>:	Set to 10 kHz.
<Output Source>:	Set to <OSC1>.

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

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

a) Set the <Sineout> amplitude <Amplitude>;
b) Set the lock-in amplifier <Input Range>;
c) After waiting for 10 seconds, record the <R-Demod1> value and the <θ-Demod1> value, and then test the next data point;
d) Repeat steps 3a to 3c until the amplitude accuracy test is completed.

4) The frequency response test is performed at frequencies above 1 kHz. Modify <Osc. Frequency> in the following order:

Test Frequency
2.4 kHz
24 kHz
240 kHz
2.4 MHz

a) Set the lock-in amplifier <Input Range> to 100 mV;
b) Set the <Sineout> amplitude <Amplitude> to 0.160 V_{rms};
c) Set the <Osc.Frequency> values in sequence;
d) After waiting for 10 seconds, record the <R-Demod1> value and the <θ-Demod1> value, and then test the next data point;
e) Repeat steps 4c to 4d until the frequency response test is completed.

5) This completes the Sine Out amplitude and phase accuracy and frequency response tests. Fill in the data in the test record table at the end of this chapter.

7.8 DC Output and Input

This test mainly tests the accuracy of the DC output and input of the lock-in amplifier.

Equipment

Use a linear DC regulated power supply as the DC input. Use a digital multimeter to measure the DC output of the lock-in amplifier.

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;

2) Modify the settings:

<CH Source>: Set the sources of the four CH channels to <AUXOUT>

3) Perform the following steps:

a) Use a signal cable to connect connector 1 of AUXOUT/CHOUT on the rear panel to the digital multimeter, and set the digital multimeter range to 19.999 V;

b) Modify the value in <AUXOUT> according to the following list:

AUXOUT (V)
10.000
5.000
0.000
-5.000
-10.000

c) After waiting for 10 seconds, record the digital multimeter reading, and then test the next data point;

d) Repeat steps 3b to 3c until the AUXOUT/CHOUT 1 test is completed. Then connect connectors 2~4 of AUXOUT/CHOUT to the digital multimeter in sequence to continue and complete the test.

4) Perform the following steps:

a) Modify the setting: in the [DISPLAY] submenu, set <Monitor> to <AUX-IN>;

b) Use a signal cable to connect the voltage output connector of the DC regulated power supply to AUX-IN connector 1 on the rear panel;

c) Set the output voltage of the DC regulated power supply 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-IN1> reading at the top of the screen, and then test the next data point;

e) Repeat steps 4c to 4d until the AUX-IN1 test is completed. Then connect the output connector of the DC regulated power supply to AUX-IN2, AUX-IN3, and AUX-IN4 in sequence to complete the AUX-IN2, AUX-IN3, and AUX-IN4 tests.

5) This completes the DC output and input test. Fill in the data in the test record table at the end of this chapter.

7.9 Input Noise

This test mainly tests the input noise of the lock-in amplifier.

Equipment

After the system is grounded, the lock-in amplifier can measure its own input noise.

Procedure

1) Power off and then power on the rear-panel power switch, and then recall the <Default> settings in <Recall>;

2) Modify the settings in the following order:

<Osc1> <Osc.Mode>:	Set to <Internal>.
<Osc1> <Osc.Frequency>:	Set to 10 kHz.
<Input Range>:	Set with the knob to <1 mV>.
<Impedance>:	Set to 50 Ω.
<Time Constant>:	Set to <1 ms>
<Filter dB/oct>:	Set to <24 dB/oct>.
<Window Display>:	Set to <X-Noise>.

3) After the reading becomes relatively stable (about 2 min), record the X-Noise value (average value);

4) Modify the following parameters in sequence:

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

5) This completes the input noise test. Fill in the data in the test record table at the end of this chapter.

7.10 Performance Test Record Table

OE2031Performance Test Record Table (1/4)

Serial Number: ____________ Tested by: ____________

Firmware Version: ____________ Date: ____________

Instrument Use: ____________________________

____

1.Startup Test

Pass ____ Fail ____

2.DC Offset

Input Coupling	Reading	Upper Limit
AC	______	0.500 mV
DC	______	0.500 mV

3.Common-mode Rejection

Frequency	Reading	Upper Limit
100 Hz	______	1 mV

4.Amplitude Accuracy and Flatness

Input Range	Amplitude	Lower	Reading	Upper
2 V	1.000 V_{rms}	0.9700 V	______	1.0300 V
500 mV	250.00 mV_{rms}	242.50 mV	______	257.50 mV
100 mV	50.000 mV_{rms}	48.50 mV	______	51.50 mV
20 mV	10.000 mV_{rms}	9.700 mV	______	10.30 mV
5 mV	2.5000 mV_{rms}	2.425 mV	______	2.575 mV
1 mV	1.0000 mV_{rms}	0.970 mV	______	1.030 mV

Input Range	Frequency	Lower	Reading	Upper
500 mV	2.4 kHz	194 mV	______	206 mV
Amplitude	24 kHz	194 mV	______	206 mV
200.00 mV_{rms}	240 kHz	194 mV	______	206 mV
	2.4 MHz	194 mV	______	206 mV

5.Amplitude Linearity

Input Range	Amplitude	Lower	Reading	Upper
2 V	1.0000 V_{rms}	0.9700 V	______	1.0300 V
	100.00 mV_{rms}	97.00 mV	______	103.0 mV
	10.000 mV_{rms}	9.700 mV	______	10.30 mV
	1.0000 mV_{rms}	0.970 mV	______	1.030 mV

OE2031Performance Test Record Table (2/4)				
6.Frequency Accuracy				
	Frequency	Lower	Reading	Upper
REF IN	1 MHz	0.999 99 MHz	______	1.000 01 MHz
7.Sine Out Amplitude/Phase Accuracy and Flatness				
Range	SineOut Ampl.	Lower	Reading	Upper
2 V	1.600 V_{rms}	776.0 mV	R:______	824.0 mV
		−2.000°	θ:______	2.000°
100 mV	160 mV_{rms}	77.60 mV	R:______	82.40 mV
		−2.000°	θ:______	2.000°
20 mV	16 mV_{rms}	7.760 mV	R:______	8.240 mV
		−2.000°	θ:______	2.000°
5 mV	1.6 mV_{rms}	0.776 mV	R:______	0.824 mV
		−2.000°	θ:______	2.000°
SineOut Ampl.	Frequency	Lower	Reading	Upper
160.0 mV_{rms}	2.4 kHz	776.0 mV	R:______	824.0 mV
		−2.000°	θ:______	2.000°
	24 kHz	776.0 mV	R:______	824.0 mV
		−2.000°	θ:______	2.000°
	240 kHz	776.0 mV	R:______	824.0 mV
		−2.000°	θ:______	2.000°
	2.4 MHz	776.0 mV	R:______	824.0 mV
		−2.000°	θ:______	2.000°
8.DC Output and Input				
Output	Voltage	Lower	Reading	Upper
AUXOUT/	10.000 V	9.940 V	______	10.060 V
CHOUT 1	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
AUXOUT/	10.000 V	9.940 V	______	10.060 V
CHOUT 2	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

OE2031Performance Test Record Table (3/4)

8.DC Output and Input (continued)

Output	Voltage	Lower	Reading	Upper
AUXOUT/	10.000 V	9.940 V	________	10.060 V
CHOUT 3	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
AUXOUT/	10.000 V	9.940 V	________	10.060 V
CHOUT 4	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
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

OE2031Performance Test Record Table (4/4)

9.Input Noise

Osc.Frequency	Input Range	Reading	Upper Limit
10 kHz	1 mV	________	$7\,nV/\sqrt{Hz}$
100 kHz		________	$5\,nV/\sqrt{Hz}$
1 MHz		________	$4\,nV/\sqrt{Hz}$
10 MHz		________	$4\,nV/\sqrt{Hz}$

Chapter 8 Operation Examples

8.1 Basic Signal Measurement

This operation example briefly demonstrates how to use the OE2031 to measure the R, θ, X, and Y values of a signal. Prepare two signal cables with BNC connectors, one for the input signal under test and the other for the reference signal. In this example, a function generator is used to generate a sine wave with an amplitude of 100 mV_{rms} and a frequency of 1 MHz, and the OE2031 is used for measurement. The procedure is as follows:

1. Disconnect all signal cables from the instrument chassis, connect the power cord, and turn on the power switch. The system is now in the default state.
2. Use a signal cable with BNC connectors to connect the output connector of the function generator to the IN+ connector of SIGNAL IN on the front panel of the OE2031. Use another BNC signal cable to connect the synchronous reference signal connector of the function generator to the REF IN connector on the front panel of the OE2031, as shown in Figure 86.

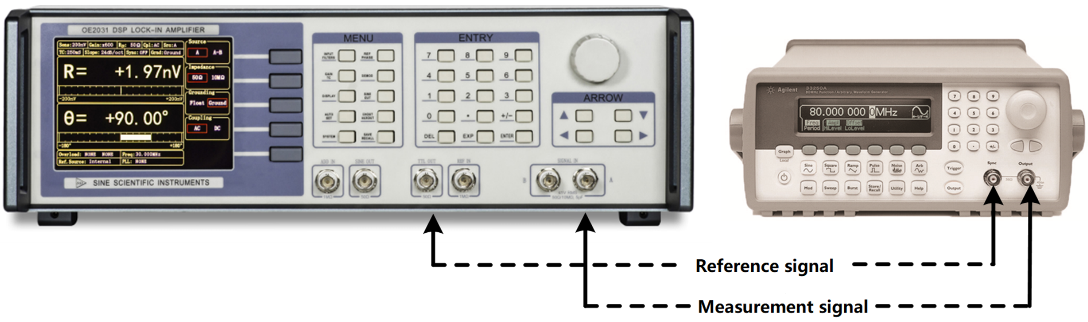


Figure 86. Signal Cable Connection Diagram

3. Turn on the function generator and set the parameters to “Waveform: sine wave”, “Amplitude: 100 mV_{rms}”, “Frequency: 1 MHz”, “Output impedance: high impedance”, and “Sync output: on”. The waveforms of the signal under test and the synchronization signal are shown in Figure 87.

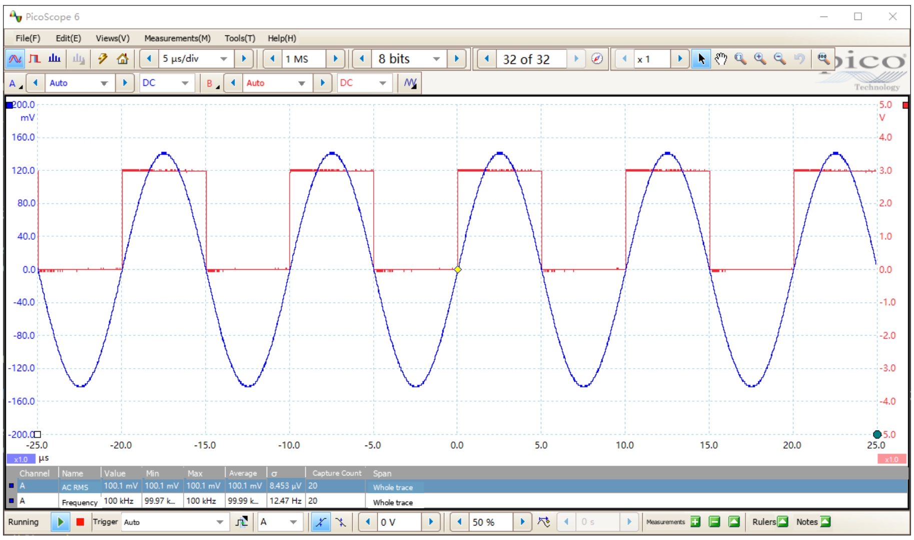


Figure 87. Waveform of the Signal Under Test

4. Enable the output of the function generator and observe whether the <Overload> item in the status bar of the main interface indicates an overflow condition:

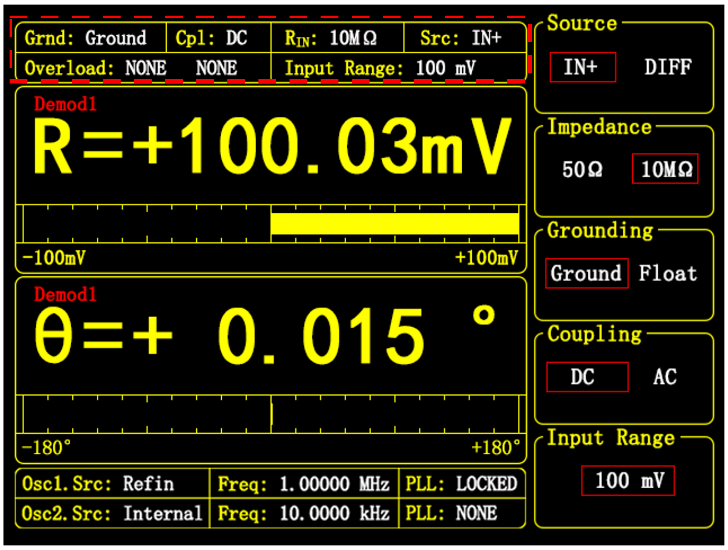


Figure 88. Status Bar on the Main Interface

If the front-end input overflows, Overload: INPUT NONE is displayed. If the gain stage overflows, Overload: NONE GAIN is displayed. If both overflow conditions occur, Overload: INPUT GAIN is displayed.
When front-end overflow occurs, immediately reduce the output amplitude of the function generator. When gain overflow occurs, immediately adjust the gain value. Front-end overflow occurs when the peak value at the OE2031 input is higher than 3 V or the valley value is lower than −3 V. Therefore, in this example, a sine-wave output amplitude of 100 mV_{rms} from the function generator will not cause overflow. However, pay attention to overflow conditions when measuring other signals. The method for adjusting the sensitivity is described below.

5. Adjust the input range. Press the [SIGNAL INPUT] key on the front panel to enter the submenu.

Figure 89. Location of the [SIGNAL INPUT] Menu

The [SIGNAL INPUT] submenu interface is shown below:

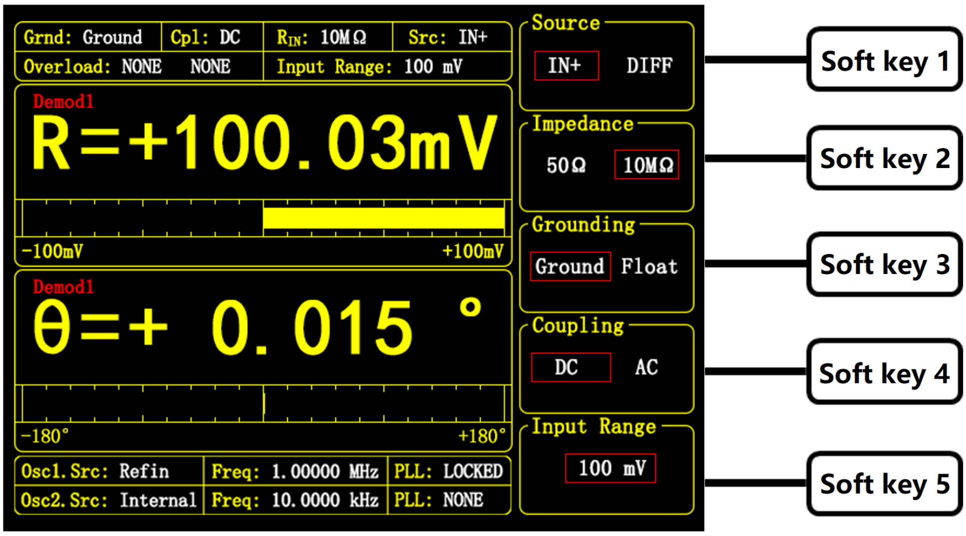


Figure 90. [SIGNAL INPUT] Menu Interface

Press "Soft key 5" to select the <Input Range> function. The selected area is highlighted. Rotate the knob to adjust the <Input Range> value so that the measured signal value is as close as possible to the input range without causing overflow. In this example, set it to <200 mV>. At this point, the sine-wave signal from the function generator has been measured. As shown in Figure 90, the measured data are R = 100.03 mV and θ = 0.015°.

6. Display the <R>, <θ>, <X>, and <Y> values in the data bar of the main interface. Press the [DISPLAY] key on the front panel to enter the submenu.

Figure 91. Location of the [DISPLAY] Menu

The DISPLAY submenu interface is shown below:

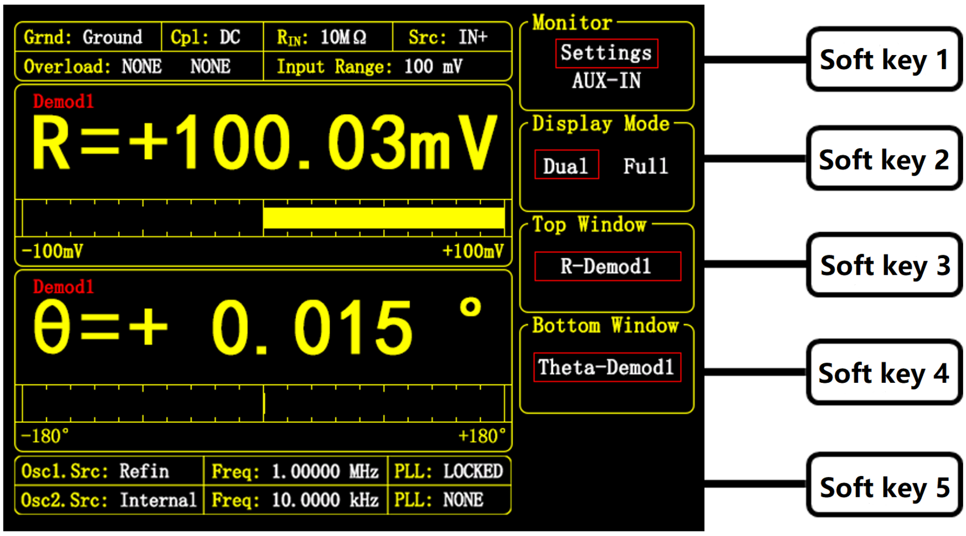


Figure 92. [DISPLAY] Menu Interface

In the default system settings, the upper and lower data fields display the <R> and <θ> values, respectively. The displayed values can be changed using the method described below. In the [Display] submenu, press "Soft key 3" to select the <Top Window> menu, and use the knob to change the displayed value to "X-Demod1". Then press "Soft key 4" to select the <Bottom Window> menu, and use the knob to change the displayed value to "Y-Demod1". After the modification, the result is shown in Figure 93. This method can be used to view the desired measurement result.

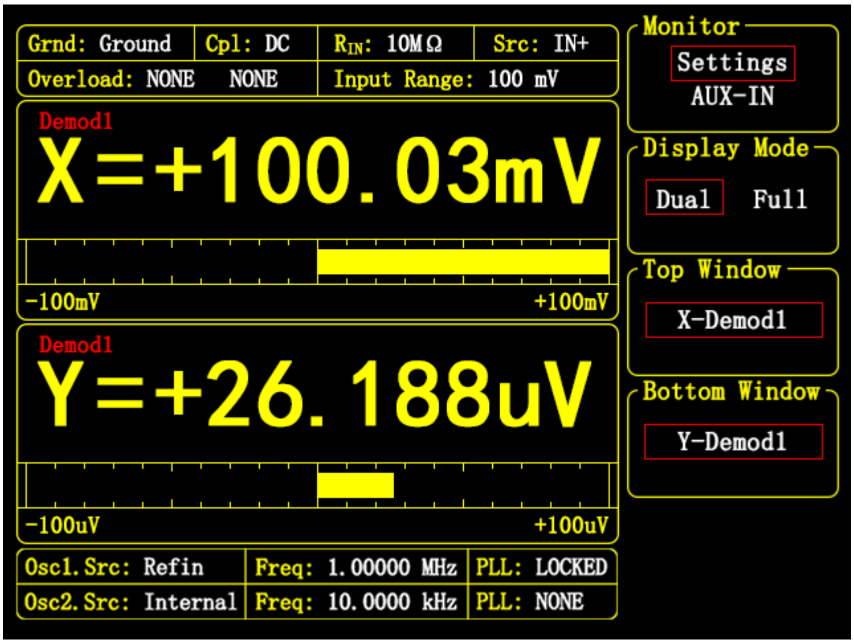


Figure 93. Modified X\Y Display

8.2 Harmonic Measurement

This example demonstrates how to measure the harmonic components of the input signal. Prepare two signal cables with BNC connectors, one for the signal under test and the other for the reference signal. In this example, a function generator is used to generate a square wave with an amplitude of 160 mV_{pp} and a frequency of 1 kHz, and the OE2031 is used to measure its 1st, 2nd, 3rd, 4th, 5th, and 6th harmonics. The procedure is as follows:

1. Disconnect all signal cables from the instrument chassis, connect the power cord, and turn on the power switch. The system is now in the default state.
2. Use a signal cable with BNC connectors to connect the output connector of the function generator to the IN+ connector of SIGNAL IN on the front panel of the OE2031. Use another BNC signal cable to connect the reference signal connector of the function generator to the REF IN connector on the front panel, as shown in Figure 94.

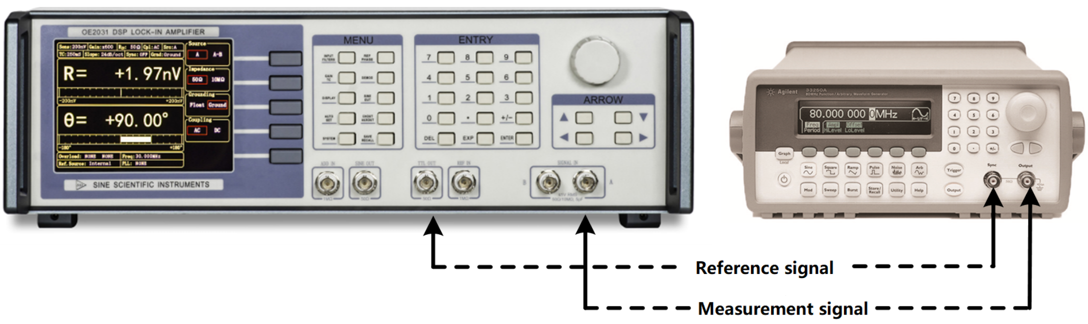


Figure 94. Signal Cable Connection Diagram

3. Turn on the function generator and set the parameters to "Waveform: square wave", "Amplitude: 160 mV_{pp}", and "Frequency: 1 kHz". The waveform of the signal under test is shown in Figure 95.
4. Press the [DEMOD REF] key on the front panel, shown in Figure 96, to enter the submenu.

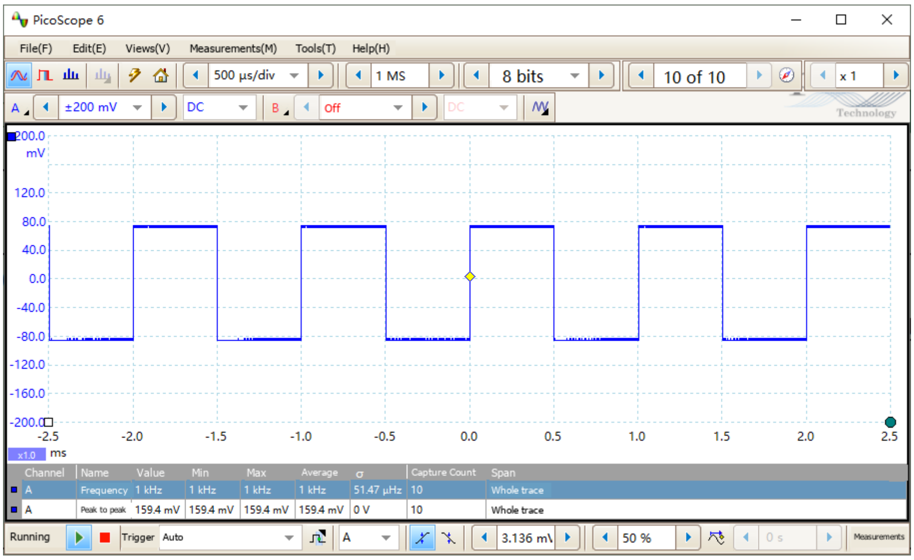


Figure 95. Signal Under Test Parameter Diagram

Figure 96. Location of the [DEMOD] Submenu

The [DEMOD REF] submenu interface is shown in Figure 97.

In the <Ref.Harmonic> menu, set the harmonic order measured by each demodulator.Use the keypad to enter the desired harmonic order.

5. To measure the 1st, 2nd, 3rd, 4th, 5th, and 6th harmonics of the input square wave simultaneously, operate as follows. In the [DEMOD REF] submenu, press "Soft key 1" to switch among the six demodulator channels. Press "Soft key 2" to select the harmonic setting window, where the harmonic order of the current demodulator channel can be modified. For demodulators 1 to 6, set their harmonic orders to 1 to 6 in order.
6. Then, in the [DISPLAY] submenu, press "Soft key 2" to set <Display Mode> to <Full>, as shown in Figure 98, so that all fundamental and harmonic measurement results are displayed.

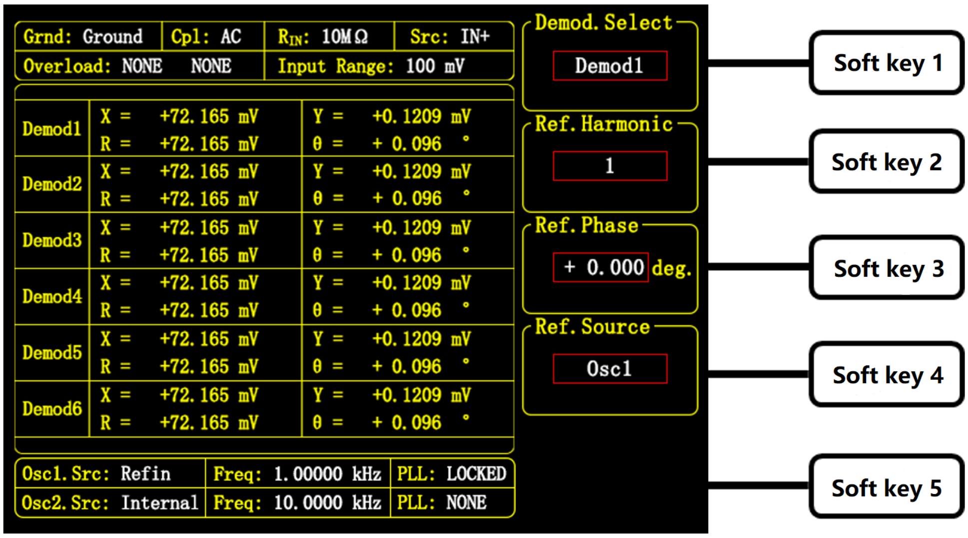


Figure 97. DEMOD REF Submenu

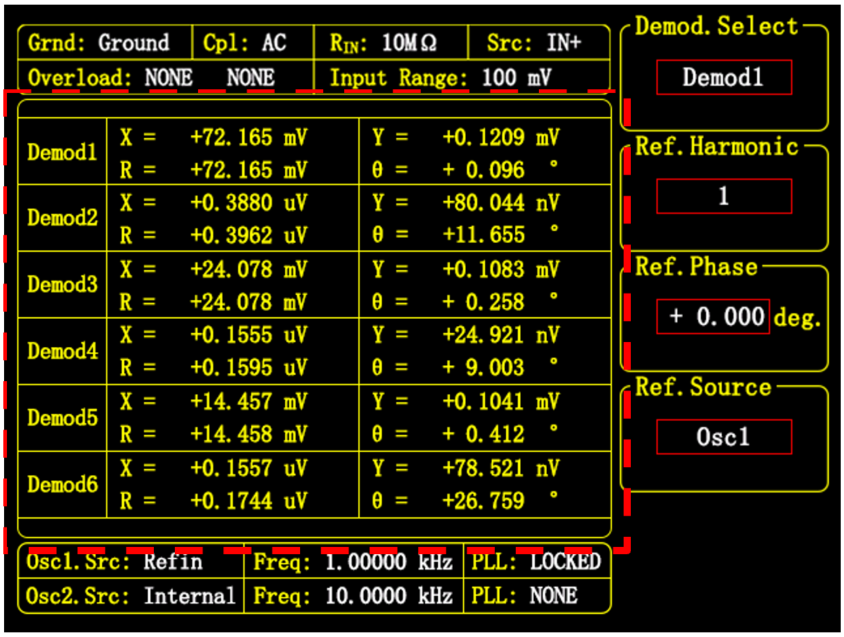


Figure 98. Harmonic Measurement Results of the Square Wave

The theoretical harmonic values of the square wave are calculated as follows. Let the peak-to-peak value of the square wave be E and its angular frequency be ω. After Fourier expansion, the signal is obtained as:

$$f(t) = \frac{2E}{\pi}\left(\sin(\omega t) + \frac{1}{3}\sin(3\omega t) + \frac{1}{5}\sin(5\omega t)\cdots + \frac{1}{n}\sin(n\omega t)\right)$$

The nth harmonic is therefore the sine wave:

$$f(t) = \frac{2E}{n\pi}\sin(n\omega t)$$

Therefore, the RMS value of the nth harmonic is:

$$R = \frac{\sqrt{2}E}{n\pi}$$

In this example, the peak-to-peak value E of the square wave is 160 mV. Therefore:

The calculated value of the 1st harmonic is: $R = \frac{\sqrt{2}\times 160}{1\times\pi}$mV $\approx$ 72.025 mV.

The calculated value of the 3rd harmonic is: $R = \frac{\sqrt{2}\times 160}{3\times\pi}$mV $\approx$ 24.008 mV.

The calculated value of the 5th harmonic is: $R = \frac{\sqrt{2}\times 160}{5\times\pi}$mV $\approx$ 14.405 mV.

The theoretical values of the 2nd, 4th, and 6th harmonics are 0 V.

Using the calculation method described above, the measurement values can be compared with the theoretical calculated values. As shown in the measurement results in Figure 98, the measured values are consistent with the theoretical values.

8.3 AM Demodulation Measurement

Amplitude modulation (AM) is a modulation method in which the amplitude of the carrier varies according to the signal to be transmitted, while the frequency remains unchanged. The modulated signal can propagate over a long distance, but its interference immunity is relatively poor.

Modulating signal: $U_m(t) = A_m * \cos\omega_m t$

Carrier signal: $U_c(t) = A_c * \cos\omega_c t$

The modulated signal is:

$$U(t) = (A_c + A_m \cos\omega_m t) * \cos\omega_c t \quad = A_c * \left(1 + \frac{A_m}{A_c}\cos\omega_m t\right) * \cos\omega_c t$$

where A_c is the carrier amplitude and ω_c is the carrier frequency; A_m is the modulating-signal amplitude and ω_m is the modulating-signal frequency. The modulation depth is defined as $m = \frac{A_m}{A_c}$.

Further conversion gives:

$$\begin{aligned} U(t) &= A_c * (1 + m\cos\omega_m t) * \cos\omega_c t \\ &= A_c * \cos\omega_c t + \frac{mA_c}{2} * \cos(\omega_c - \omega_m)t + \frac{mA_c}{2} * \cos(\omega_c + \omega_m)t \end{aligned}$$

It can be observed that the AM signal contains three frequency components: ω_c, $\omega_c - \omega_m$, and $\omega_c + \omega_m$. By using three demodulators of the lock-in amplifier to demodulate these three frequency components simultaneously, the values of A_c and $\frac{mA_c}{2}$ can be recovered, and thus the amplitude information of the carrier and modulating signal can be obtained.

The actual demodulation procedure is as follows:

1. Set the function generator to AM modulation mode. Set a 100 kHz, 200 mV$_{rms}$ sine wave as the carrier, and set a sine wave with a frequency of 10 kHz and a modulation depth of 100% as the modulating signal. Note that in the AM modulation mode of the function generator, regardless of the modulation depth setting, the carrier amplitude is reduced by half. For example, when the current setting is 200 mV$_{rms}$, the actual amplitude is only 100 mV$_{rms}$. The waveform output from the function generator is shown in Figure 99.
2. Press the [DEMOD REF] key on the front panel of the OE2031 to enter the submenu.
3. Set the following parameters:
   Set <Ref.Source> of Demod1 to <Osc1>;
   Set <Ref.Source> of Demod2 to <Frequency>, and set <Frequency Set> to 90.0000 kHz;
   Set <Ref.Source> of Demod3 to <Frequency>, and set <Frequency Set> to 110.000 kHz;
   At this point, the three demodulators of the OE2031 demodulate the frequency components at 100 kHz, 90 kHz, and 110 kHz, respectively. The results are shown in Figure 100.
4. The results are R-Demod1 = 100.4 mV$_{rms}$, R-Demod2 = 49.985 mV$_{rms}$, and R-Demod3 = 49.957 mV$_{rms}$. The converted carrier amplitude is 100.4 mV$_{rms}$, the modulating-signal amplitude is 99.942 mV$_{rms}$, and the modulation depth is 99.54%, which agrees with the theoretical expectation.

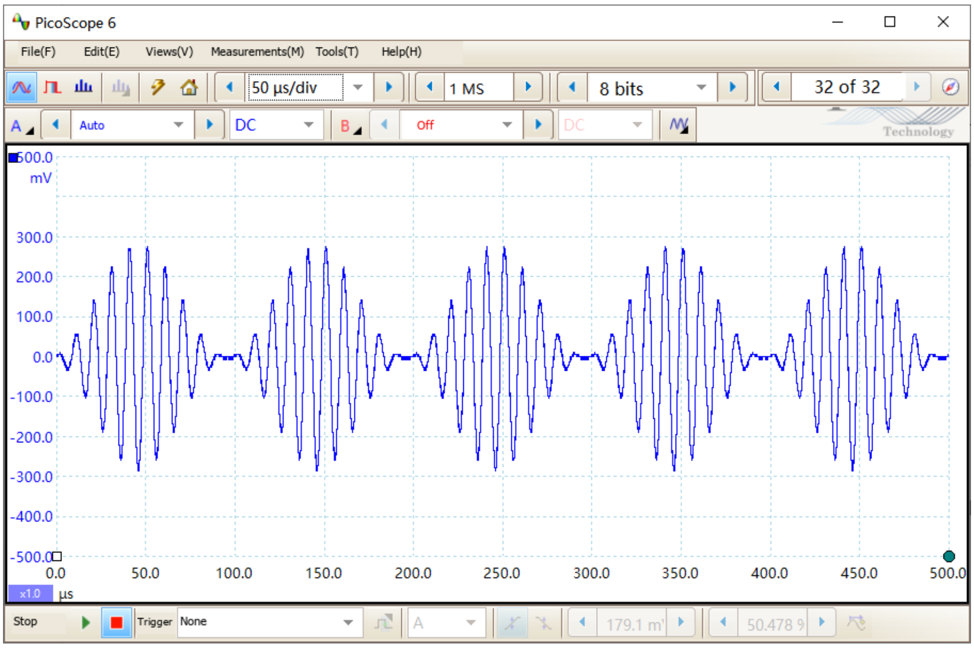


Figure 99. Waveform of the AM Signal

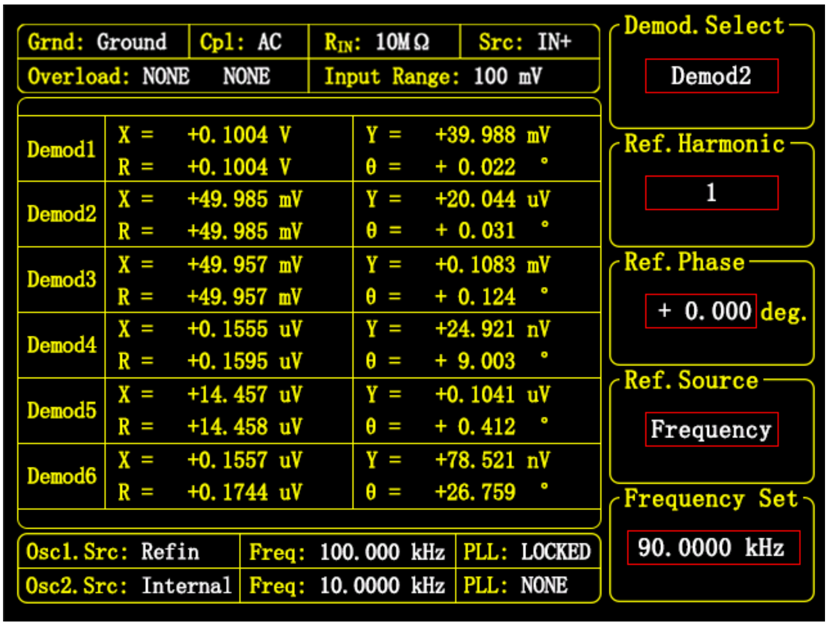


Figure 100. AM Demodulator Measurement Results

8.4 Serial Communication

This example demonstrates how to set up and debug the serial/USB2.0 remote-control environment for the OE2031. Prepare a USB2.0 Type-B cable or a USB-to-RS232 male cable. The procedure is as follows:

1. Use a USB cable to connect the USB connector of the OE2031 to any USB port on the computer.
2. The computer automatically detects the USB device and prompts you to install the driver.
3. Open the Uart_Assistant folder on the USB flash drive and double-click UartAssist.exe.

The software interface appears as shown in Figure 101.

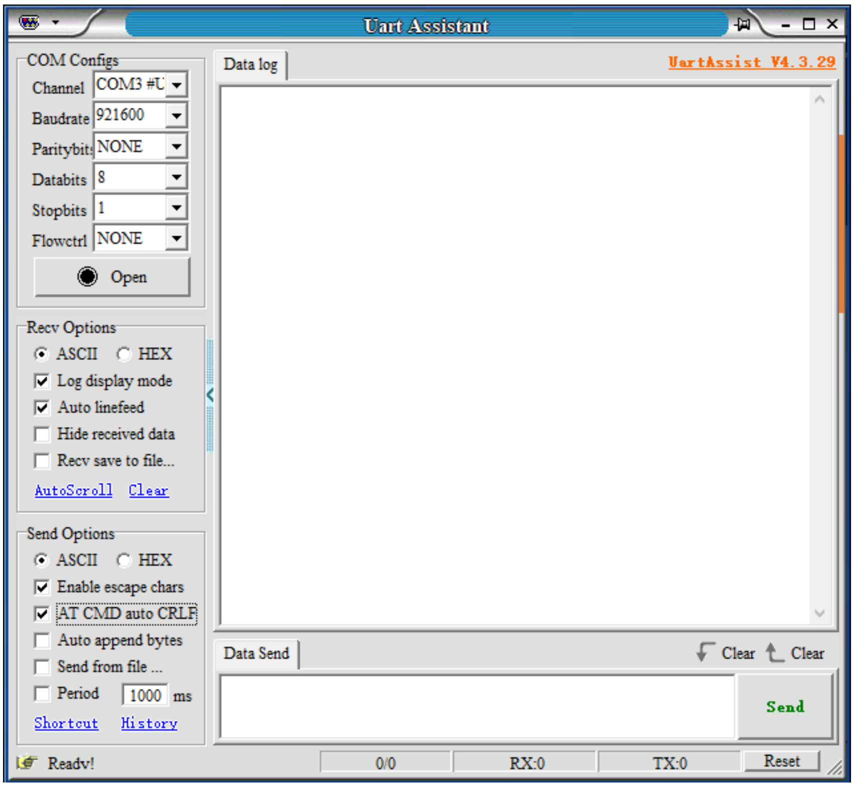
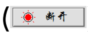


Figure 101. Opened Software Interface

The serial debugging software includes communication settings, receive-area settings, send-area settings, a receive area, and a send area.

The default serial-port settings of the OE2031 are a baud rate of 921600, no parity, 8 data bits, and 1 stop bit. The baud rate, parity, and other serial settings of the OE2031 can be configured through the RS232 menu option in the front-panel submenu.

Because the USB2.0 driver creates a virtual serial port, the USB2.0 interface, like the RS232 serial port, requires selecting the COM port automatically assigned by the computer to the OE2031. The COM port number can be viewed in Device Manager under Ports (COM & LPT): right-click Computer → Properties → Device Manager → Ports, as shown in Figure 102.

After the port number, baud rate, parity, data bits, and stop bits are configured, check the connection button. If the small circle on the left side of the connection button is black and unlit (), click it once to change the button status to a red lit state (). If the button is red and lit, the computer has successfully connected to the device on the selected serial port. If repeated attempts to connect fail, check whether the selected port number is correct and try again. A successful connection is shown in Figure 103.

4. After completing the above steps, commands can be sent to communicate with the OE2031:

The OE2031 command format requires a four-letter uppercase mnemonic followed by option parameters. For example, use the command "ISRC0;" or "*IDN?" followed by a carriage return character (0D). Multiple consecutive commands can be separated by semicolons ";". The command ending must include either a semicolon ";" or a carriage return character (hexadecimal 0D). For more detailed commands, refer to the chapter on remote programming.

When sending a command, first enter the command in the send area, then enter the semicolon ";", and finally click the send button. The command will then be sent, as shown in Figure 104.

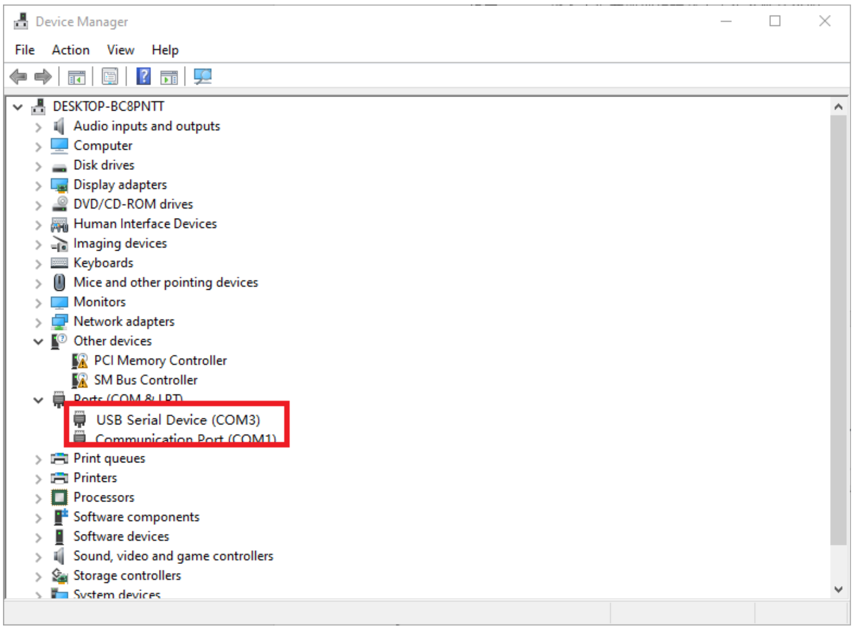


Figure 102. Viewing the Port Number

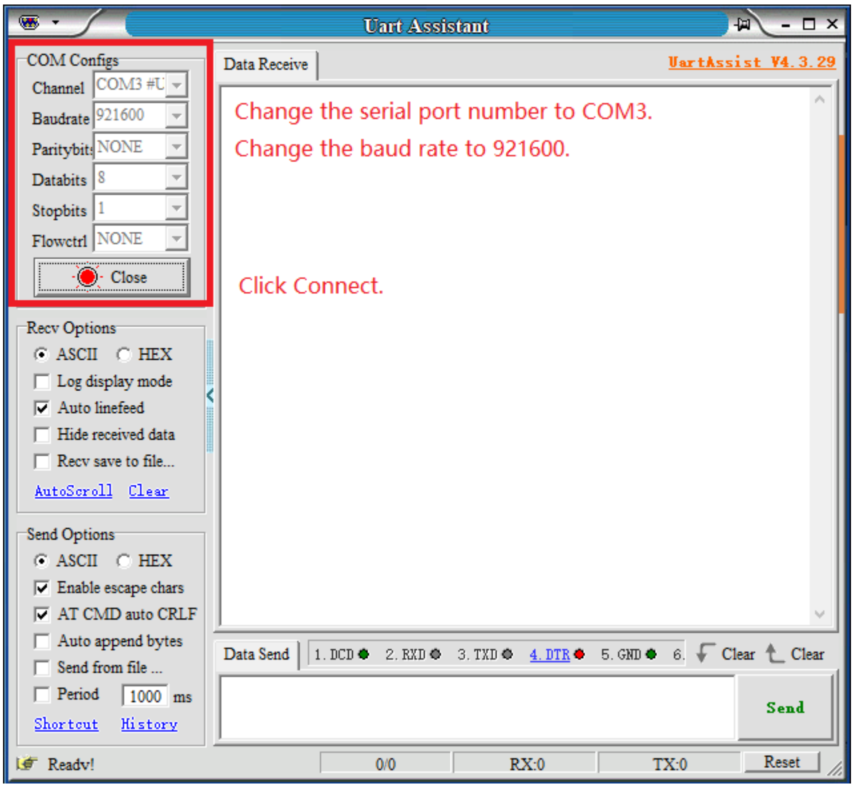


Figure 103. Successful Connection Status

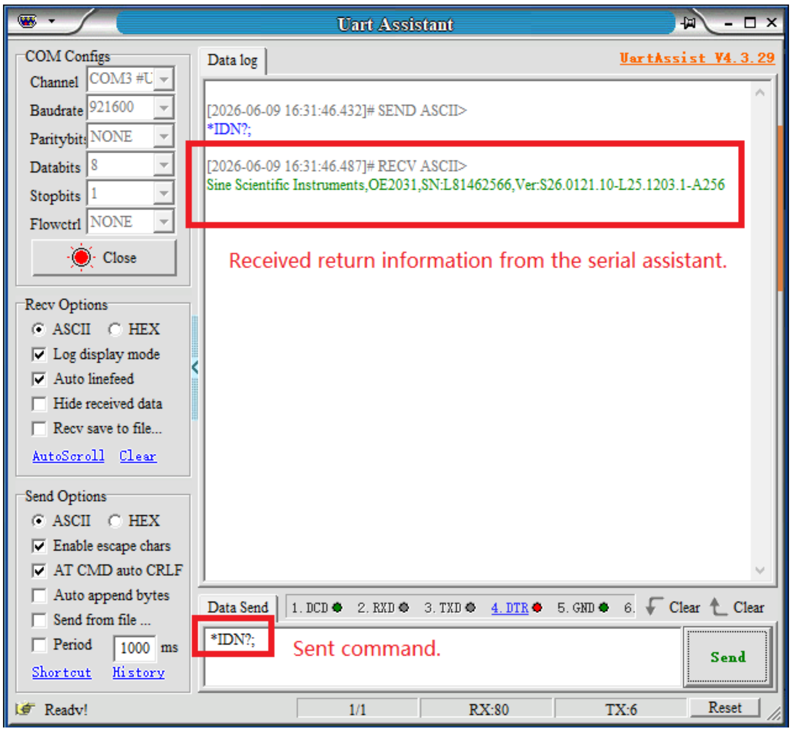


Figure 104. Sending and Receiving Commands in ASCII Format

The serial debugging assistant can also be configured to automatically append the carriage return character 0X0D when sending. Select the "Auto Append" option in the send-area settings, choose the fixed-bit option in the appended-bit settings window that appears, and set the appended value to the hexadecimal value "0D". The configuration is shown in Figure 105.

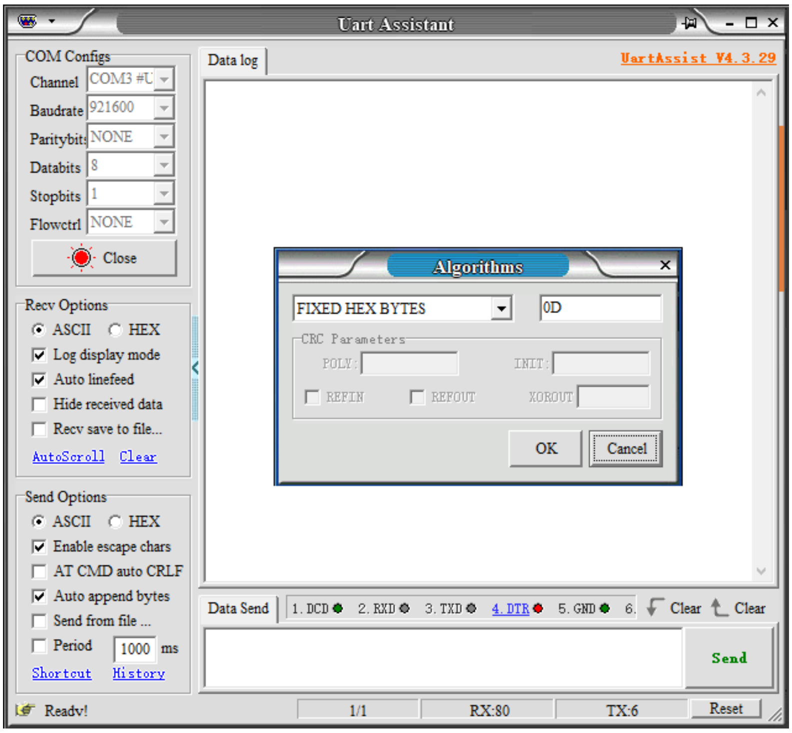


Figure 105. Appended-Bit Setting

When sending multiple commands, semicolons ";" must be used to separate them. For example, sending "IGND1;IGND?; OUTP?2; SENS?0;" produces the result shown in Figure 106.

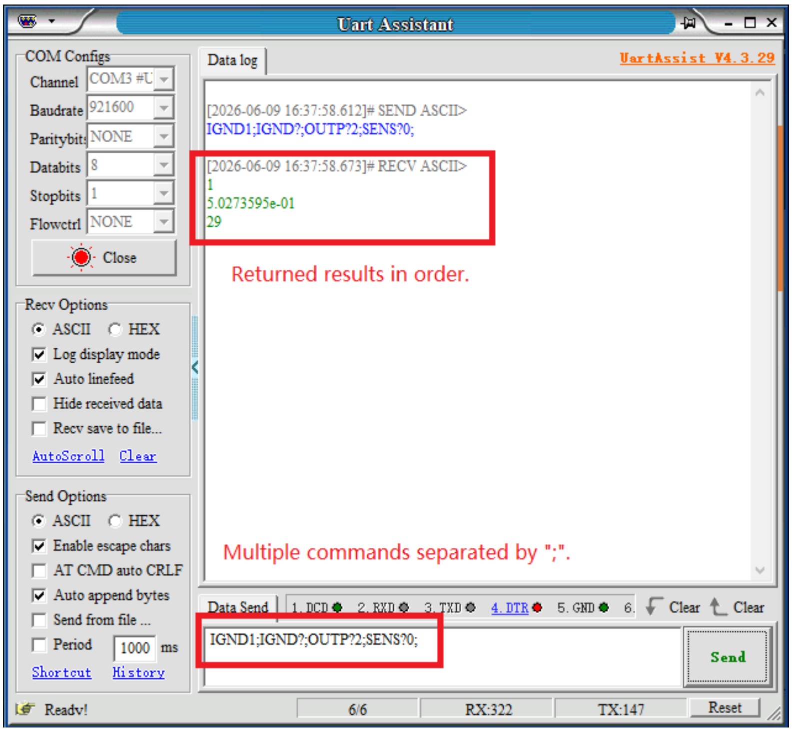


Figure 106. Executing Multiple Commands

To continuously read the X, Y, R, and θ values of the OE2031, configure interval sending in the serial debugging assistant software, as shown in Figure 107 and Figure 108.

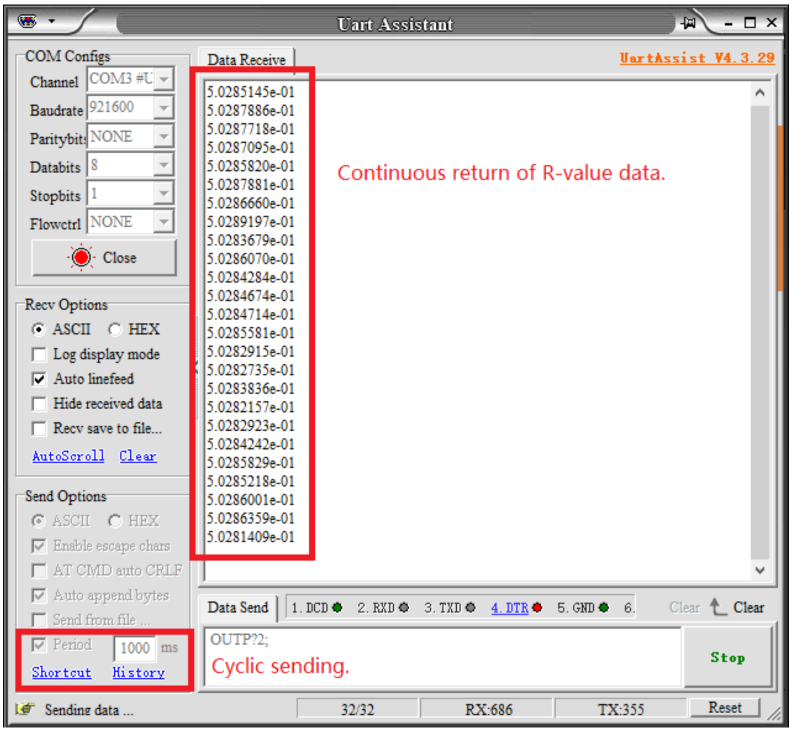


Figure 107. Continuously Reading a Single R Value

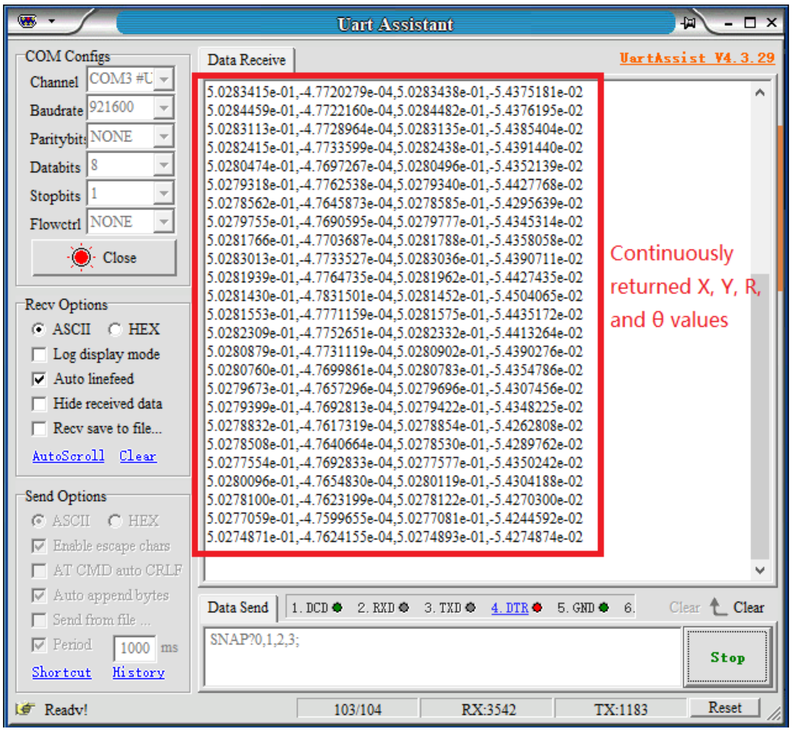


Figure 108. Continuously Reading X, Y, R, and θ Values

When the OE2031 internal parameters are set by sending commands through the serial debugging assistant, the corresponding parameter status on the LCD screen is updated at the same time. For example, if the current <Input Range> value in the status bar of the OE2031 is <2.0 V>, the corresponding command identifier is IRNG0. After sending the command "IRNG1", the <Input Range> value in the status bar of the OE2031 changes to the value corresponding to command identifier 1, <500 mV>.

Other serial debugging tools of the same type can also be used for remote debugging, and the operating steps are similar.