MODEL OE1022D
DSP Lock-In Amplifier

Revision 1.2

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1. SPECIFICATIONS

1.1 Signal Channel

Voltage Inputs	Single-ended (A) or differential (A-B).
Full Scale Sensitivity	1 nV to 1 V in a 1-2-5 sequence.
Current Input	10^6 or 10^8 V/A.
Input Impedance	
Voltage	10 MΩ//25 pF, AC or DC coupled.
Current	1 kΩ to virtual ground.
CMRR	> 100 dB to 10 kHz, decreasing by 6 dB/oct.
Dynamic Reserve	> 100 dB.
Gain Accuracy	0.2% typ, 1% max.
Noise	
Voltage	6 nV/ √ Hz at 997Hz.
Current	13 fA/ √ Hz at 997 Hz.
	15 fA/ √ Hz at 97 Hz.
Line Filter	50/60 Hz and 100/120 Hz.
Grounding	BNC shields can be grounded or floated via 10 kΩ to ground.
Stability	<5 ppm/°C

1.2 Reference Channel

Input	
Frequency Range	1 mHz to 102 kHz.
Reference Input	TTL or Sine.
Impedance	1 MΩ//25pF.
Phase	
Resolution	0.01°
Absolute Phase Error	< 1°
Relative Phase Error	< 0.01°
Orthogonality	90°±0.001°
Phase Noise	
Internal ref.	Synthesized, < 0.0001°rms at 1kHz.
External ref.	0.005°rms at 1kHz (time constant: 100ms, 12 dB/oct).
Drift	< 0.01°/°C below 10 kHz.
	< 0.1°/°C above 10 kHz.
Harmonic Detection	2F, 3F, ...nF to 120 kHz (n<32,767).
Acquisition Time	
Internal Ref.	Instantaneous acquisition.
External Ref.	(2 cycles + 5 ms) or 40 ms, whichever is greater.

1.3 Demodulator

Stability

Digital Outputs	No zero drift on all settings.
Displays	No zero drift on all settings.
Analog Outputs	< 5 ppm/°C for all dynamic reserves.

Harmonic Rejection	-90 dB
Time Constants	10μs to 3ks (<200Hz); 10μs to 30s (>200Hz)
	(6, 12, 18, 24 dB/oct roll off).
Synchronous Filter	Available below 200 Hz and 18,24 dB/oct.

1.4 Two Internal Oscillator

Frequency

Range	1 mHz to 102 kHz
Accuracy	2 ppm + 10 μHz
Resolution	0.1 mHz

Distortion	-80 dBc (f < 10 kHz), -70 dBc (f > 10 kHz)
Amplitude	0.001 to 5 Vrms with 1 mVrms resolution
Error	1%
Temperature Stability	50 ppm/°C
Outputs	Sine output on rear panel
	TTL sync output on rear panel.

1.5 Displays

Screen	5.6 inch, 640×480 TFT color LCD
Screen Format	Single or dual channel display.
Display Value	X, Y, R, θ.
Display Types	Large numeric readout, bar graph and strip chart.

1.6 Outputs

CH1 and CH2 Outputs

Function	X, Y, R, θ, harmonic
Output Voltage	$\pm$10 V full scale.
	30 mA max output current

AUX Inputs

Function	Four channels for input.
Amplitude	±10V
Impedance	1MΩ

Trigger Input
      Function   TTL external trigger for data storage
Monitor Output
      Function   Analog output of signal amplifiers.

1.7 Interface

USB2.0 and RS232 interfaces

1.8 General

Power Requirements
      Voltage   220/240 V AC
                                  100/120 V AC(optional)
      Frequency   50/60 Hz
      Power   40 W
Weight   28.660 lb. (13kg)
Dimensions
      Width   18.6 ″ (473mm)
      Depth   19.3 ″(490mm)
      Height
            With feet   6.3 ″(160mm)
            Without feet   5.8 ″(147mm)

2. LOCK-IN AMPLIFIER BASICS

2.1 Introduction

The Lock-in amplifier is an instrument used to detect very weak signals, which are always obscured by noise sources many thousands of times lager. The lock-in amplifier can extract these small signals from noises and measure the 'R' values accurately.

The lock-in amplifier employs a weak signal detection method based on the coherence. The key technique is the Phase Sensitive Detection (PSD) that can single out the input signal, which has the same frequency as the reference signal and has a fixed phase difference with the reference signal. Noise at other frequencies are rejected and do not affect the measurement.

The small signals usually need to be amplified. The traditional amplifiers boosts both the noise and the input signals. Without band-pass filter, the amplification will decrease the signal to noise ratio (SNR). Therefore, a filter is needed to purify the signal and increase the SNR in order to measure the weak signal accurately.

PSD can be considered as a band-pass filter with a very narrow bandwidth. The basic modules of PSD include a multiplier and a low-pass filter (LPF), as shown in Fig.1. Sometimes PSD is described as a multiplier module without a LPF.
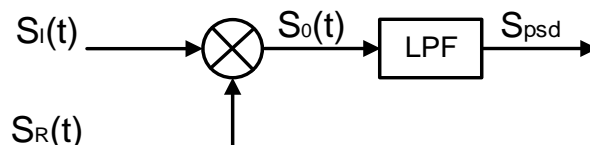
Fig.1 PSD diagram.

In Fig.1, $S_I(t)$ is the input signal including target signal and noise in time domain, $S_R(t)$ is the reference signal, which has the same frequency as the target signal.
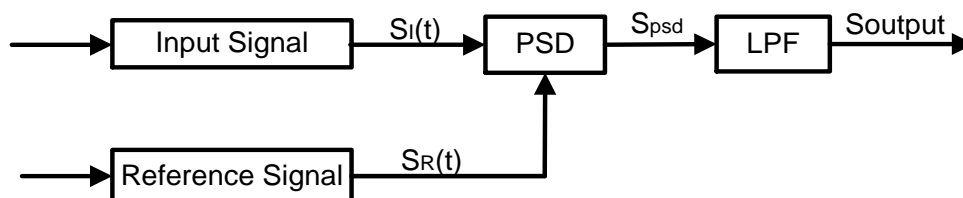
Fig.2 Single-phase amplifier diagram.

In Fig.2, the input signal $S_I(t)$ is defined as: $S_I(t) = A_I \sin(\omega t + \varphi) + B(t)$, where ω is the frequency of the input signal, $A_I \sin(\omega t + \varphi)$ is the signal being

measured, $B(t)$ is the total noise.

The reference signal $S_R(t)$ is defined as: $S_R(t) = A_R \sin(\omega t + \delta)$.

These two signals enter the PSD module for multiplication simultaneously, and the output of the PSD is defined as:

$$S_{psd} = S_I(t)S_R(t) = A_I A_R \sin(\omega t + \varphi) \sin(\omega t + \delta) + B(t)A_R \sin(\omega t + \delta)$$

$$= \frac{1}{2}A_I A_R \cos(\varphi - \delta) - \frac{1}{2}A_I A_R \cos(2\omega t + \varphi + \delta) + B(t)A_R \sin(\omega t + \delta)$$

The output of the PSD consists three parts:

In the first part, if A_I, A_R and the phase difference $(\varphi - \delta)$ between the input signal and the reference signal are constants, this part is a DC signal.

The second part is an AC signal that doubles the frequency of the referencesignal.

The third part is the result of multiplication of the noise and the reference. Because the sine signal is periodic and the noise signal and the reference signal are uncorrelated, The integral of this part is zero.

In the frequency domain, we can re-write these three parts:

The first part is at 0Hz, which is known as the DC component of a signal.

The second part is at $2f_{ref}$ Hz.

The third part is the original random signal whose frequencies are shifted by ω. In this case, white noise is still white noise after it's frequencies are shifted.

Therefore, the LPF output is: $S_{Output} = \frac{1}{2}A_I A_R \cos(\varphi - \delta)$.

Although we can determine the amplitude of the input signal by adjusting the phase difference$(\varphi - \delta)$, the accuracy is not guaranteed. The dual phase lock-in amplifier can solve this problem well. see Fig.3.
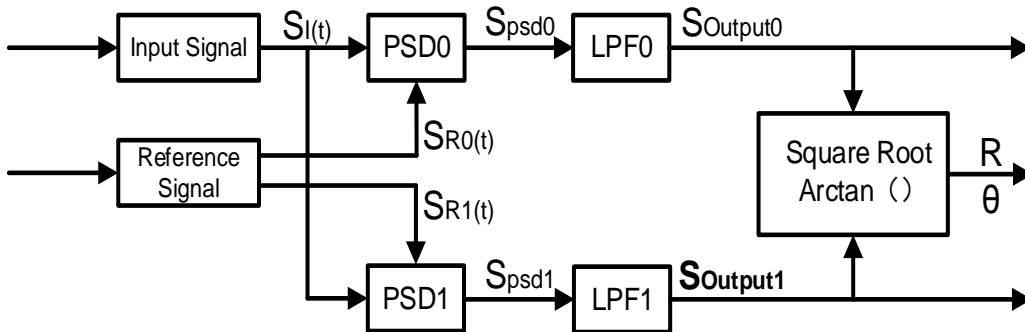
Fig.3 Diagram of Dual Phase Lock-in Amplifier.

Now, we define the phase difference $\theta = \varphi - \delta$, the LPF0 output $X = S_{Output0}$ and the LPF1 output $Y = S_{Output1}$. Then we calculate the amplitude R which is independent of θ:

$$R = \frac{A_I}{\sqrt{2}} = \frac{\sqrt{2(X^2 + Y^2)}}{A_R}$$

The phase difference is derived as: $\theta = \tan^{-1}(Y/X)$.

2.2 Functional Diagram

The functional block diagram of the OE1022D DSP Lock-In Amplifier is shown in Fig.4. In general, the OE1022D consists of signal conditioners, reference signal generators, an algorithm module and a system control module, and so on.
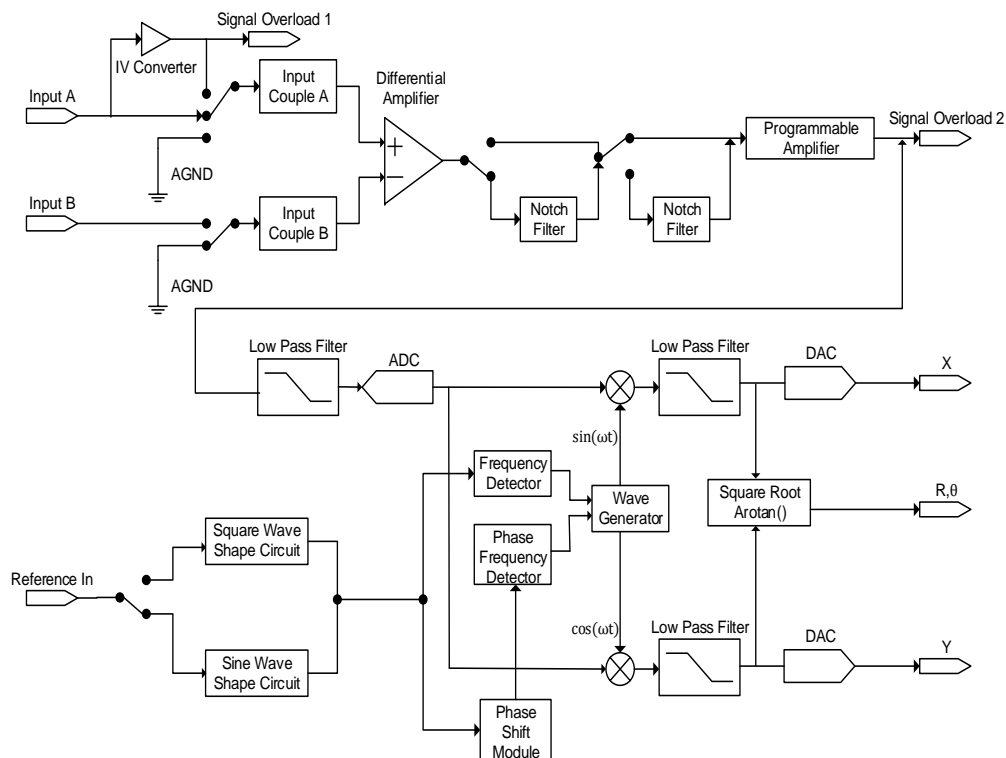
Fig.4 Functional Block Diagram of OE1022D for Each Channel

2.3 Reference Channel

The reference channel is used to provide control signal which is associated with the signal being measured. The OE1022D's reference input has the options of sine wave or TTL logic signal. The input impedance is 1MΩ.

Generally, both the sine wave and the TTL signal can be used as the reference signal. When a TTL signal is used as reference signal, high voltagelevel is defined when the voltage exceeds 2.5V and low voltagelevel is defined when the voltage is lower than 0.4V. When a sine wave signal is used as reference signal, the signal is AC coupled, with signal level greater than 0.4Vpp. Usually a generator's sine wave output has a small variation in amplitude while many function generators provide a stable TTL SYNCD output which can be used as the reference. Therefore, when the frequencies below 1Hz, a TTL reference signal rather than a sine refenrence signal is recommended.

The OE1022D lock-in amplifier has three reference signal modes: internal reference mode ,external reference mode and single reference mode.

In internal reference mode, the internal oscillator generates a digital synthesized sine wave which is then multiplied with the input signal. The phase-locked-loop (PLL) is not necessary since the lock-in reference provides the excitation. The phase noise will not affect the internal reference signal. The phase noise is extremely low. This mode can work normally from 1mHz to 102kHz.

In external reference mode, an external sine wave or TTL logic signalis used as the external reference signal. PLL is used in this mode, but it will generate a little phase jitter which may cause measurement errors.

The phase jitter means that average phase shift is zero but the instantaneous phase shift has a few milli-degrees of noise. The phase jitter causes the reference signal contains noise at different frequencies. According to the coherence principle of PSD, the output is not a single frequency, but a distribution of frequencies around the true reference frequency.

In fact, phase noise in the OE1022D is very low and generally has no effect. In applications that requiring no phase jitter, the internal reference mode should be chose. Since there is no PLL in internal mode. The internal oscillator and the reference sine waves are directly linked and there is no jitter in the measured phase.

Additionally, channel B can be set to single reference mode while channel A is in

either internal or external reference mode, which takes signal of channel A as the reference signal for channel B. In this way, time clock of both channels will be synchronous during the whole process of weak signal measurement.

2.4 Phase Sensitive Detectors

The PSD in the OE1022D is realized by a digital multiplier as shown in Fig.5. The input signal is amplified and filtered, and is converted to digital signal by a 24-bits A/D converter, and then enters the PSD. The reference sine wave is calculated in 24-bit accuracy, and the accuracy of the entire PSD is 48 bit.

The PSD module in lock-in amplifier is mainly used to implement the coherent modulation of the input signal and reference signal. Generally, there are two kinds of phase-sensitive detectors (PSD's): digital PSD's and analog PSD's. Traditional PSD's use an analog multiplier to multiply the input signal with the reference signal. There are many problems associated with these, including harmonic rejection, output offsets, limited dynamic reserve and gain error. It will limit the accuracy of PSD's and introduce various noises.

The digital PSD multiplies the digitized signal with a digital reference sine wave. Because the reference sine wave is computed in 24 bit of accuracy, the harmonics have -90 dB roll off. That is to say, the harmonics do not affect the products of the PSD.

$$S_I(t) \quad\otimes\quad S_{psd}$$

$$S_R(t)$$
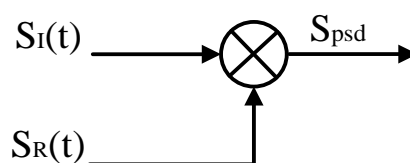
Fig.5 PSD diagram.

Because the PSD based on analog method has the problem of temperature drift, there are always some deviation between the output and actual result . and the error is un-certain. . On the other hand, the PSD based on digital method has a precise amplitude that never change, so it will not generate any system errors. This eliminates a major source of gain error found in the linear analog lock-in. Because the inputs of analog multiplier are analog quantity, the reference signal is also affected by temperature drift, which will cause greater errors in the results of coherent modulation.

The dynamic reserve of an analog PSD's is limited to about 60 dB, because there are always many background noises in the anolog system. When large input noise presents, for example, 1000 times or 60dB greater than the full-scale input signal,

the analog PSD measures the signal with errors. Because the lock-in amplifier is mainly used to detect weak signals, when the amplitude of background noise is similar to or larger than the signal amplitude, the results of coherent modulation will be wrong.

In a digital PSD's, the dynamic reserve is limited by the quality of the A/D convertor. Once the input signal is digitized, no further errors are introduced. Practically, the dynamic reserve of OE1022D can exceed 100dB.

The performance of a lock-in amplifier is largely determined by the performance of its PSD's. Almost in all respects, the digital PSD outperforms the analog one. Besides, the digital PSD is also more convenient to be modified.

2.5 Time Constants and DC Gain

The output signal of the PSD contains many signals of various frequency, such as the sum of or the difference between the input signal frequency and the reference frequency. Only the signal whose frequency is exactly equal to the reference frequency will result in a DC output.

The low pass filter (LPF) at the PSD output removes all the AC signals that are unwanted, including the 2F (sum of the signal and the reference) and the noise signals. This filter is what makes the lock-in amplifier such a narrow band detector.

Time Constants

The bandwidth setting of the low pass filter is the same as the conventional low pass filter. They are both determined by the time constants. The calculation of the time constant is defined as:

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

Here f is the -3dB frequency of the low-pass filter. For example, to a one-order low pass filter of RC type, a 1s time constant means its -3dB point occurs at 0.16Hz.

In fact, where there is an input noise, there is an output noise. By increasing the time constant, the output becomes more stable and measurement becomes more reliable. The time constant reflects not only the stability of the system and the accuracy, but also the respond time of the output.

The time constant also determines the equivalent noise bandwidth (ENBW). The ENBW isn't the filter -3dB pole, it is the effective bandwidth for Gaussian noise.

Digital Filters vs Analog Filters

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Analog filters have many limitations in performance. The temperature drift and non-linearity are two important problems that limit the rolloff performance of an analog filter. A two-stage analog filter provides about a maximum rolloff of 12 dB/oct at high frequency.

Space and expense are also limitations. Each filter needs to have many different time constant settings. These different settings require different components and switches to select. Each setting is costly and space consuming. A large quantity of analog devices also complicates the debugging of the hardwares.

Considering these limitations, we choose a 48 bits digital filter to accomplish narrow band filtering. The DC gain is exactly 0 dB and the equivalent value of Q exceeds 145dB.

Synchronous Filters

Another advantage of digital filtering is to do synchronous filtering. Even if the input signal has no noise, the PSD output always contains a component at 2F (sum frequency of the signal and the reference) whose amplitude may exceed the difference frequency component that we want. At low frequencies, increasing the time constant can attenuate the 2F component.

In OE1022D, synchronous filters are available when the reference frequencies is below 200 Hz. At the higher frequencies, such filters are not required because the 2F component is easily removed without using long time constants. The output of the synchronous filter is followed by two more stages of normal filters. This combination of filters can eliminate the harmonics of the reference signal and attenuate other noise signals.

Long Time Constants

Time constants above 100s are difficult to implement   using analog filters. This is simply because the capacitors required for the RC filters are prohibitively large in value and size. Why would you need such a long time constant? Sometimes you have no choice. If the reference feqquency is below 1 Hz with a lot of noise at low frequency, the PSD output will contain many low frequency components. Nevertheless, the synchronous filter only filters out the harmonic component of the reference frequency, and the followed filters filter out   the noise.

The OE1022D allows the time constants as long as 3000s when the reference frequency is below 200 Hz, which can satisfy most requirements of measurements.

Gain of DC Output

How big is the DC output from the PSD? It depends on the dynamic reserve. With a 60 dB dynamic reserve, a noise signal can be 1000 times (60 dB) greater than a full scale signal. At the PSD, the noise cannot exceed the input range of PSD. For example, in an analog lock-in, the PSD input range might be 5 V. With 60 dB dynamic reserves, the signal will be only 5 mV at the PSD input. The PSD typically has no gain so the DC output from the PSD will only be a few millivolts. Even if the PSD had no DC output errors, amplifying this millivolt signal up to 10 V is error prone. An offset as small as 1 mV will appear as 1 V at the output. This is one of the reasons why analog lock-in does not perform well at high dynamic reserve.

The digital lock-in does not have an analog DC amplifier, and has no DC output offset. Likewise, the digital DC amplifier has no input offset. The output of the digital DC amplifier is simply the product of the input signal and the required gain. This allows the OE1022D to operate with 100 dB of dynamic reserve without any output offset or zero drift.

2.6 DC Outputs and Scaling

The OE1022D has Channel 1 and Channel 2 outputs (CH1 and CH2) on the rear panel.

CH1 and CH2 Outputs and Display

The output voltage range of CH1 and CH2 is from -10V to 10V.
The output signal is proportional to the value of the test signal and the setting scale.
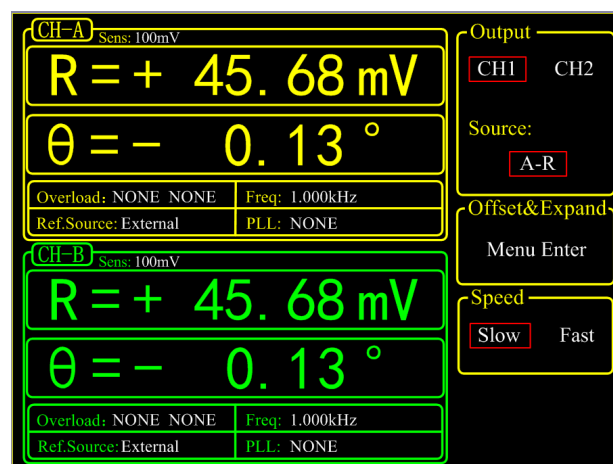
Fig.6 Channel Output Display Interface of OE1022D

The unit and position of decimal point of data displayed on screen can be adjusted manually, or automatically through 'AutoSet' buttons which is very convenient to adjust the accuracy.

X, Y and R Output Offset and Expand

The OE1022D has the function to set the offset value for X, Y and R outputs. It is useful to measure the deviations of the signal around some nominal value. The default offset value for the output is zero. Changes in the output can be read directly from the display or the output port on the back panel. The offset is specified as a percentage of full scale. Offsets can be set up to 100% of full scale. When the sensitivity is changed, the percentage does not change.

The X, Y and R outputs of both channels A and B can be expanded. It's realized by multiplying the output with an expansion factor. Thus, a signal which is only 10% of full scale can be expanded to provide 10 V rather than 1 V. The general purpose for expansion is to increase the measurement resolution around some value which is not zero.

When the output does not exceed the full scale, the OE1022D can expand the output by multiplying with the expansion factor from 1 to 256. The output with offset and expand is:

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

Where <Offset> can be set between ±100% by the digital keyboard and the minimal step is 0.01%. <Expand> can be set from +1 to +256 by the digital keyboard and the minimal step is 1. Related display interface is shown in Fig.7. For example, there is:

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

Fig.7 Output Offset and Expand

2.7 Dynamic Reserve

The definition of dynamic reserve is the ratio of the largest tolerable noise signal to the full scale signal, expressed in dB, which is defined as:

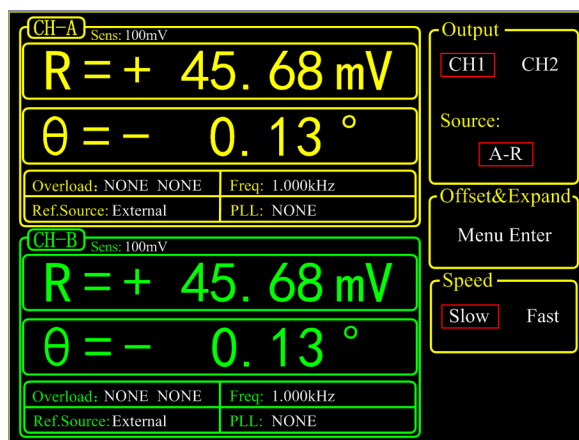$$\text{Dynamic reserve} = 20\text{Lg}(\text{OVL/FS})(\text{dB})$$

Here OVL is the total dynamic range of the input signal. FS is the dynamic range of the output signal. If the dynamic reserve is 100 dB, the tolerable noise can be 10^5 times the input.

The 'tolerable' means that the noise at the dynamic reserve limit should not cause an overload anywhere in the instrument. Overload might appear at the input of the pre-amplifier and the output of DC amplifier. We can adjust the distribution of the gain to achieve high dynamic reserve. This means that the input signal gain at the pre-amplifier should be set very low so the noise is not likely to overload. Then the low pass filter removes the large noise component from the PSD output which allows the remaining DC components to be amplified to reach 10 V full scale.

This gain is distributed between AC gain before the PSD and DC gain following the PSD. The total gain is the product of the AC gain and the DC gain. Suppose the total gain is a constant. If the AC gain increases and the DC gain decreases, the input noise is easy to overload after AC gain. Thus, the dynamic reserve and the DC drifts decrease. In contrast, if the AC gain decreases and the DC gain increases, the dynamic reserve increases. In this case, the output stability will decrease and the accuracy of measurement will be lower.

The noise frequencies and amplitudes affect the accuracy of the DC output signal. Noise at the reference frequency with large amplitude becomes part of the DC signal after the PSD. This enlarges the output error of the lock-in amplifier.

The dynamic reserve is related to noise frequency. The dynamic reserve is 0dB at reference frequency and increases when the noise frequency moves away from the reference frequency. It reaches a maximum value when the frequency is far enough. The dynamic reserve near the reference frequency is important to noise tolerance of the instrument. Providing more low pass filter stages can improve the performance of the filters and then increase the dynamic reserve close to the reference frequency. The dynamic reserve far from the reference frequency is generally high but has little influence.

The dynamic reserve of OE1022D is greater than 100dB. High dynamic reserve will increase output noise and drift. When the dynamic reserve is high, output noise will be increased due to the A/D converter. There is background noise at any signal. When the signal is amplified by PSD, the output signal will contain noises. If

the noise is very high, it will result in large output noise. Otherwise, if the external noise is very low, the output is mainly affected by the noise of OE1022D. Reducing dynamic reserve and DC gain can decrease the error. Therefore, low dynamic reserve should be chosen firstly in actual application.

In fact, the minimum reserve changes with the sensitivity (gain) of the instrument. At high gains, the minimum dynamic reserve increases with the increase of the sensitivity. In analog lock-in amplifiers, low dynamic reserve means low output error and drift. In OE1022D, high dynamic reserve increases output noise, but not increases output error and drift. However, if the gain of analog amplifier is high enough, the amplified intrinsic noise will be greater than the noise generated by the A/D converter. In this case, increasing the analog gain cannot decrease the output noise, but AD quantized error can be reduced.

2.8 Signal Input Amplifier and Filters

A lock-in amplifier can measure signals as small as a few nanovolts. The gain of the low noise signal amplifier should be large enough so that the output signal can be digitized by the A/D converter without degrading the signal to noise ratio (SNR). The analog gain of the OE1022D ranges from roughly 7 to 2000 times. Higher gains do not improve the SNR.

The overall gain (AC plus DC) is determined by the sensitivity and the distribution of the gain is set by the dynamic reserve.

Input Noise

In OE1022D, the input noise is about $10\,\text{nVrm}/\sqrt{Hz}$. If an amplifier has 10 $\text{nVrm}/\sqrt{Hz}$ of input noise and a gain of 1000, the output will have 10 $\mu\text{Vrm}/\sqrt{Hz}$ of noise. Suppose the output of the amplifier is low-pass filtered by a single RC filter (6 dB/oct rolloff) with 100ms time constant.

Input noise of lock-in amplifier and Johnson noise of resistors are both Gaussian in nature. That is to say, the amplitude of noise is proportional to the square root of the noise bandwidth. A single-stage RC filter has an ENBW of 1/4T where T is the time constant (RxC) which means that Gaussian noise is filtered with an effective bandwidth equal to ENBW. In this case, the filter sees 10 $\mu\text{Vrm}/\sqrt{Hz}$ of input noise and has an ENBW of 1/(4x100ms) or 2.5 Hz. The voltage noise at the filter output will be 10 $\mu\text{Vrm}/\sqrt{Hz}$ x $\sqrt{2.5Hz}$ or $15.8\,\mu\text{Vrms}$.

For Gaussian noise, the peak-peak noise is about 5 times the rms noise. Thus, the output noise will be about $79\mu\text{Vrms}$. Input noise works in the same way. For sensitivities below 5μV, the value of input noise determines the output noise.

ENBW depends on the time constant and filter roll off. For example, suppose the OE1022D is set to <5 μV> full scale, <100 ms> time constant and <6dB/oct> roll off. Thus, ENBW is 2.5 Hz. This leads to 7.9nVrms input noise. At the output, this causes about 0.16% of full scale (7.9nV/5μV). The peak to peak noise will be about 0.8% of full scale.

Assume that the signal input is from a low impedance source. The Johnson noise of resistors equals to $0.13\text{x}\sqrt{R}$. Take a 100Ω resistor for example, its noise is almost $1.3\text{nVrm}/\sqrt{Hz}$. When the impedance of the resistor is 2 kΩ, the Johnson noise is greater than the input noise of OE1022D. The overall noise of multiple noise sources is determined by the square root of the sum of the squares of the individual noise figures. For example, if a 1kΩ source impedance is used, the

Johnson noise will be $4.11\,\mathrm{nVrm}/\sqrt{Hz}$.

At low gains (sensitivities above 50μV), the gain is not high enough to amplify the input noise to a level greater than the noise of the A/D converter. In these cases, the output noise is mainly the A/D noise. At these sensitivities, the DC gain is low and the noise at the output is negligible.

Notch Filters

There are two notch filters in the signal amplifier chain in OE1022D. They are pre-tuned at the power line frequency and twice the power line frequency. When the largest noise signals are at the power line frequencies, these filters can remove noise signals at these frequencies. Removing the largest noise before the final gain stage will reduce the dynamic reserve required to perform a measurement.

To prevent such a situation, it is necessary to improve the signal amplifier chain. If the required dynamic reserve without these notch filters is below 60 dB or if the minimum reserve is sufficient, then these filters do not improve the measurement obviously.

Do not use notch filters when making measurement near the notch filter's frequencies. Notch filters have a finite bandwidth of attenuation, generally about 10 Hz. Thus, if the lock-in is measuring at 90Hz, do not use the 80 Hz notch filter. Otherwise, the signal will be attenuated and the measurement will be wrong. Besides, notch filters also have effect on phase shifts measurements.

Anti-aliasing filter

After signal filtering and amplification, there is an anti-aliasing filter, which is required by the signal digitization process. According to the Nyquist criterion, the sampling frequency of signal must be at least twice the highest signal frequency. For example, if the highest signal frequency is 100 kHz, then the sampling frequency of 312.5 kHz can work. However, signals above 156 kHz cannot work with this A/D converter. These signals would violate the Nyquist criterion and be under-sampled. The result of under-sampling is to make the higher frequency signals appear as lower frequency signal in the digital data stream. This would make the measurement wrong.

To avoid under-sampling, the analog signal is filtered to remove signals above 154 kHz. This filter has a flat low-pass bandwidth from DC to 102 kHz so that it would not affect the measurements in the operation range of the lock-in. The filter rolls off from 102 kHz to 154 kHz and achieves an attenuation of at least 100dB above 154

kHz.

Input Impedance

The input impedance of OE1022D is 10 MΩ. If a higher input impedance is desired, low noisepreamplifier of OE series products   can be used so that the OE1022D has the maximum input impedance of 100 MΩ.

2.9 Input Connections

Noises always exist in all circuits. Even if the signal is not very weak, noises exist and decrease the accuracy of measurement. There are many methods to reduce noise. Minimizing the various noise sources can increase the accuracy of the measurement. Besides, the effect of noise sources in the laboratory and the problem of the differential grounds between the detector and the lock-in can be minimized by careful input connection.

There are two basic methods for input connection - the single-ended connection is more convenient while the differential connection eliminates spurious pick-up more effectively.

Single-Ended Connection (A)

In the first method, the lock-in uses the IN+input in a single-ended mode. The lock-in detects the signal as the voltage between the center and outer conductors of the IN+ input only. However, there are two disadvantages of this mode.

Generally, the low level is a constant of 0V. However, grounds of different instruments may be at different potentials. When the shield of the A cable is connected to the lock-in's ground directly, different potentials will result in a high current, that is the ground loop. Thus, connecting via a resistor between them can avoid ground loop problems. In general, float uses 10 kΩ and ground uses 10Ω.

Besides, this mode is not sensitive to noise. The signal cable is just like an antenna. The lock-in lets the shield 'quasi-float' in order to sense the experiment ground and pick up the activities of the electronic in environment. In this case, the noise came up. Unfortunately, the single-ended connection mode cannot distinguish the noise and actual signal.

Differential Connection (A-B)

The second method of connection is the differential mode. This mode has two signals cables which connect the signal source and the lock-in's inputs. There are

two high impendence power amplifiers in the lock-in. The lock-in measures the voltage difference between the center conductors of the A and B inputs, which can avoid common voltage problems since the shields are ignored.

In this mode, take care that the two cables travel the same path between the experiment and the lock-in. There should not be a large loop area enclosed by the two cables. Otherwise, measurement is susceptible to magnetic pickup.

2.10 Intrinsic Noise Sources

Noise is defined as any negative factors which will affect the result of measurement. Noise is random, unpredictable and temporary. Good design of instruments should reduce the noise and improve the stability and accuracy of measurement.

There are various intrinsic noise sources which are present in all electronic signals. Some of them are unavoidable which only can be decreased by signal averaging and a narrower bandwidth. Others can be decreased by filtering and perfecting the circuit's structures and component layout. Meanwhile, amplifier itself also produces noise, which can be solved by low noise component and design techniques.

Johnson Noise

Any resistor generates a noise voltage across its terminals due to thermal fluctuations in the electron density within the resistor itself. This is Johnson noise. The spectrum of the Johnson noise is flat, so the noise power is almost the same in different frequency band (Of course there is an upper limit in frequency).   This noise is usually called white noise. The open-circuit noise voltage can be calculated using this equation

$$V = (4kTRB)^{1/2}$$

Where $k=1.38 \times 10^{-23}$ J/°K is the Boltzmann's constant. T is the temperature in °Kelvin, which can be transformed to °Celsius: °K= °C +273.16. R is the resistance in Ohms, and B is the bandwidth of the measurement   in Hz.

Harry Nyquist's mathematical studies of Johnson noise revealed that the power spectrum function of Johnson noise is:

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

At 300 °K, a resistor of 10 KΩ is connected to the input of the amplifier. The voltmeter is connected to the output of the amplifier. The open-circuit effective voltage of the filter which has a 10 kHz bandwidth is 1.3 μV.

The amplitude of Johnson noise is unpredictable ingeneral, It follows the Gaussian distribution. Johnson noise is the minimum value of the noise voltage of any devices including detectors, signal sources and amplifiers with resistors. Johnson noise is a typical case of wave dissipation.

Shot Noise

Because of the discrete nature of the charge carriers, electric current has noise. Noise is generated in the current since there is always some non-uniformity in the electron flow. This noise is called shot noise. It appears as voltage noise when current is passed through a resistor, or as noise in a current measurement.

If the interaction between carriers is ignored, the shot noise or current noise can be calculated by:

$$I = (2qI_{dc}B)^{1/2}$$

where q is the electron charge of 1.6×10^{-19} Coulomb, I_{dc} is the DC current and B is the measurement bandwidth. If I_{dc} is 1 A and B is 10 kHz, then, I is 57 nA which is about 0.000006% of I_{dc}. The smaller the current, the larger the relative noise ratio. For example, if I_{dc} is 1 µA and B is still 10 kHz, then, I is about 0.006% or -85 dB. If I_{dc} is 1 pA, then, I is about 5.6% or 56 fA.

In fact, shot noise is one kind of the white noise. Its power spectrum density is given by:

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

The equation is based on the assumption that carriers in the current do not interact with each other. This assumption is valid, for example, for the diffusion current in the junction diode. However, for the commonly used metal, this equation cannot be used because the cross effect between carries cannot be ignored.

Flicker Noise (1/f Noise)

In 1925, Johnson first found 1/f noise in the current   of Vacuum tubes. The power spectrum of this noise is proportional to 1/f. The lower the frequency, the more serious the noise. Thus, it is also called low frequency noise. Microscopically, 1/f noise is caused by the random value of contact resistance between two conductors. The current amplitude of 1/f noise follows the Gaussian distribution, and the power spectrum density is proportional to 1/f which is given by:

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

1/f noise is also called flicker noise due to the random fluctuation of the power spectrum density in active devices. It broadens the bandwidth near the center frequency and reduces the value of Q of oscillators. 1/f noise must be considered

near the center frequency.

Total Noise

Johnson noise and shot noise are unreducible. Any resistors with a same resistance have the same Johnson noise. Shot noise relies on the special manufacture of resistors, including its material and package technology and so on. For example, among winding resistor, metal film, carbon resistor and pure carbon, the winding resistor has the minimum resistance. The metal film resistor and carbon resistor have larger resistances. The pure carbon resistor has the maximum resistance of these four. All of these noises are incoherent. The total random noise is the square root of the sum of the squares of all the incoherent noise sources.

2.11 External Noise Sources

In addition to the intrinsic noise sources discussed previously, there are different kinds of external noise sources. Most of these noise sources are asynchronous and not related to the reference. They do not occur at the reference frequency or its harmonics. These noise sources affect the measurement mainly by increasing the requirement of dynamic reserve or lengthening the time constant. However, some external noise sources are related to the reference. If they are picked up in the signal, noise will add or subtract from the actual signal and cause errors in the measurement. Fortunately, external noise sources can be reduced through various ways.

Capacitive Coupling

The mutual capacity between wires is often called stray capacity C_{stray}. An AC voltage from a nearby piece of apparatus can couple to a detector via C_{stray}. Although C_{stray} may be very small, the coupled noise may still be larger than a weak signal and cause severe instability for the detector. The noise current is given by:

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

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

When the noise sources' frequency become larger, the coupling noise will be larger. If the noise source is at the reference frequency, the noise will be quite large. The lock-in rejects noise at other frequencies, but pick-up at the reference

frequency appears as signal.

Cures for capacitive noise coupling include:
1) Remove or turn off the noise source.
2) Design the experiment to measure voltages with low impedance for most of low frequency noise sources.
3) Install capacitive shielding by placing the experiment and detector in one metal box.

Inductive Coupling

An AC current in a nearby piece of apparatus can couple to the experiment via a magnetic field. A changing AC current gives rise to a changing magnetic field which induces voltage. The larger the frequency, the larger the electromotive force, the greater the measurement error.

Cures for inductively coupled noise include:
1) Remove or turn off the interfering noise source.
2) Reduce the area of the pick-up loop by using twisted pairs or coaxial cables.
3) Use magnetic shielding to prevent magnetic field from crossing the area of measurement.

Resistive Coupling or Ground Loops

The ground loop is an interference source which can generate noise voltage between the grounds. If the noise voltage is large enough, it will cause measurement errors. Ground loop is a physic loop, which generates from many ground methods. These grounding methods can act as a big loop wire. They pick up noises from the environment and generate voltages in the grounding system. The 50 Hz magnetic field of the AC power is a normal noise source that the ground loop always pickup. For distributed grounding systems, the ground voltage can cause the ground current flow in the ground loop. Since the ground is with low impedance, noise current is always very high.

Cures for ground loop problems include:
1) Connect all grounds to the same physical point.
2) Use a heavy ground bus to reduce the resistance of ground connections.
3) Remove sources of large ground currents from the ground bus.

Microphonics

Not all noise sources are electrical in origin. According to microphonic effects,

mechanical noise can be transformed into electrical noise. Physical changes in the device or cables (due to vibrations for example) will cause electrical noise over the whole bandwidth of the lock-in.

Solutions to minimize microphonic signals:
1) Eliminate mechanical vibrations near the experiment.
2) Tie down cables carrying sensitive signals.
3) Use a low noise cable that is designed to reduce microphonic effects.

Thermocouple effects

When two dissimilar metals contact, there will be potential difference between them. The reason for potential difference includes: (1) different electronic work function of two metals. (2) different electron concentration of two metals.
Suppose that metal A and metal B have work functions V_a and V_b respectively. The electromotive force (emf) between A and B is:

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

Where k= 1.38x10-23J/K is Boltzmann's constant. T is the temperature in °Kelvin; q is the elementary charge of 1.60x10-19 Coulomb. It's found that from the formula, the contact potential depends on the nature of the metal and the temperature of the contact surface.

If two dissimilar metals contact, the electromotive force at the contact point will add a slowly changing millivolt level. This kind of noise is sensitive to temperature. The frequency of this noise is typically low because the temperature of the detector usually changes slowly. This effect is large on the scale of many detector outputs and can be a problem for low frequency measurements, especially in the mHz range.

Solutions to minimize thermocouple effects:
1) Hold the temperature of the detector or experiment constant.
2) Use a compensation junction.

2.12 Aux In

There are four 16-bit high-precision AUX-ADC input channels in OE1022D. The input voltage ranges from - 10 V to + 10 V and the minimum resolution is 0.3 mV. These 4 ADC channels can clamp the input signal and amplify the internal differential signal. The input impedance is 1 MΩ. At the same time, they can pick up signals to measure slow analog signals or DC signals (the signals come from temperature sensor and pressure sensor). This is useful for proportional operation

and transferring data to computer.

Because of the internal special structure of the 4 AUX-ADC channels, the measurement result is about 2.048V when the input is floating.

2.13 Sweep Frequency and Amplitude of Signal Generator

The OE1022D adds some new functions, such as frequency and amplitude scanning. Signal generator can scan the output amplitude and frequency. Users can sweep the frequency they are interested in and analyze the characteristics of the signal. This function greatly improved the scope of pplications

The basic method of frequency and amplitude scanning is setting the value of the starting and ending point, and the increasing step . See more details in the sections related to frequency and amplitude scanning.

2.14 Multi-harmonic Detection

Harmonics represent waves at multiple frequencies. Periodic function can be described as the linear combination of one constant and many sine or cosine functions with the base frequency and the multiples of the base frequency. The constant is the DC component. The base frequency component is the base wave. The multiple frequencies are harmonics.

Currently many other lock-in amplifiers can only measure one base wave or one component of harmonics at one time. But in many practical applications, it is necessary to measure and record multiple harmonics simultaneously. In order to solve this problem, OE1022D implemented multi-harmonic detection. Up to 3-channel harmonic components can be measured by one OE1022D at the same time.
Configuration of multi-harmonic detection can be edit through the following approach: [REF/PHASE]->[Harmonic].For more details, see [REF/PHASE] submenu.

3.   INTERFACES

3.1 Front Panel

The front panel of OE1022D is shown in Fig.9.

Fig.9 Front Panel of OE1022D

3.1.1 Display   The OE1022D uses a 5.6-inch TFT-LCD display and interactive control. Display resolution is 640*480. 8 levels of background brightness are available, which is set in the [SYSTEM] sub-menu. The measurement results are displayed at the left of the screen. It can provide single or double area for display. Otherwise, each area can display number, XY coordinates and polar coordinates. The right of the screen is used to choose and modify control conditions of measurement.

3.1.2 Soft Keys   There are 5 soft keys on the right side of the display screen. The soft keys' functions change with the current menu. In general, these soft keys have two main functions, one is to choose different setting options, and another is to highlight some parameters and then use the knob or keyboard to input. For all functions, soft key only work with parameters that are adjacent to it.

3.1.3 Spin Knob   The knob is used to adjust parameters which are highlighted. Most parameters can be adjusted by the spin knob.

3.1.4 Keyboard   The keyboard consists of 3 groups of buttons. The [ENTRY] area is used to input the highlighted parameters by data forms. The [MENU] area is used to change the parameter list at the right side of the screen. It provides 10 different function menus. The [CONTROL] area provides ancillary functions for measurement, like [CURSOR].

3.1.5 BNC Connectors

REF IN   The reference input can be a sine wave or a TTL pulse. When input is a sine wave, the input impedance is 1MΩ AC coupled. For low frequencies (<1Hz), it is necessary to use a TTL reference signal.

SIGNAL IN   There are three signal input modes, single-ended mode (A), differential mode (A-B) and current signal mode(I).The lock-in uses the IN+ input in single-ended mode. In differential mode, the differential signal between input IN+ and IN- is measured. When measuring voltage, the input impedance of A and B are both 10 MΩ//25pF. When measuring current, the IN+ input is connected to the ground via a 1kΩ resistor.

3.2 Rear Panel

The rear panel of OE1022D is shown in Fig.10. It includes a cooling fan, a power connector, a power switch, an USB interface and extended functional interfaces. The extended functional interfaces include SINE OUT, TTL OUT, AUX IN, TRIG IN,CH1&CH2 OUTPUT, and MONITOR.

Fig.10 Rear Panel of OE1022D

SINE SCIENTIFIC INSTRUMENTS

3.2.1 Power Connector   The power connector is used to provide power for the instrument. This power connector with a build-in fuse receives 220 V, 50 Hz AC power. And it can filter high frequency noise.

3.2.2 USB   The OE1022D lock-in amplifier can communicate with PC through USB.In this way, PC can control and read data directly from the OE1022D.

3.2.3 RS-232 Interface   User can also manipulate the OE1022D lock-in amplifier on PC conveniently through the RS-232 data interface.

3.2.4 SINE OUT   Both signal generators can provide programmable output. The maximized amplitude value and output impedance of those signal are 5 Vrms and 50Ω. If the external reference is used, the output signal is in phase-lock with the input reference signal

3.2.5 TTL OUT   The TTL output is synchronous with [SINE OUT]. When the amplitude of [SINE OUT] is so small, [TTL OUT] can be used to make a sync phase lock.

3.2.6 AUX IN   AUX_ADC input 1-4(A/D Inputs). These are auxiliary analog inputs which can be digitized. The range is -10V to +10V.

3.2.7 TRIG IN   TRIG IN receives a TTL input used to trigger data samples and to start data acquisition. The rise edge is effective for TRIG IN. The maximum sample rate is 500 Hz.

3.2.8 CH1&CH2 OUTPUT   CH1&CH2 OUTPUT range from -10V to +10V.Final result of the tested signal is proportional to output. Configurations of range setting will be take into calculation.

3.2.8 MONITOR   Monitor provides an output from the signal amplifiers and filters. This signal will be amplified 5-fold after the A/D converter and PSD. However, because the analog gain will not be too high, very small signals may not be amplified enough to viewed at the monitor output.

SINE SCIENTIFIC INSTRUMENTS

3.3 Main Display

The main display is divided into 3 parts, including data bar, monitoring bar and function bar.
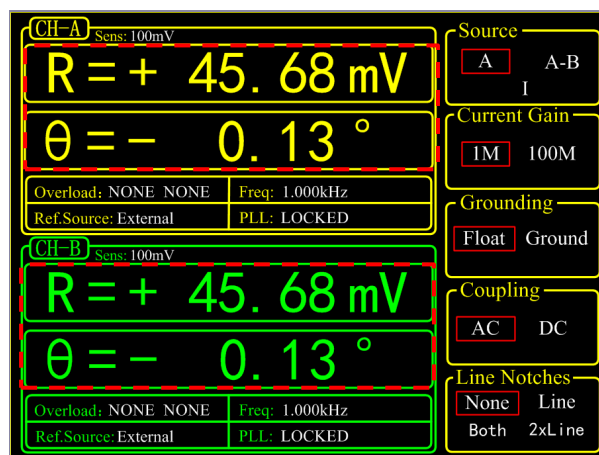
3.3.1 Data Bar

Fig.10 Main Interface: Data Bar

Users can choose which to display among <X>, <Y>, <R>, <θ> in [DISPLAY] submenu, as shown in Fig.10. How to display is also optional, such as number chart, bar chart, XY coordinate graph and pole coordinate graph. More details about settings are in [DISPLAY] submenu.
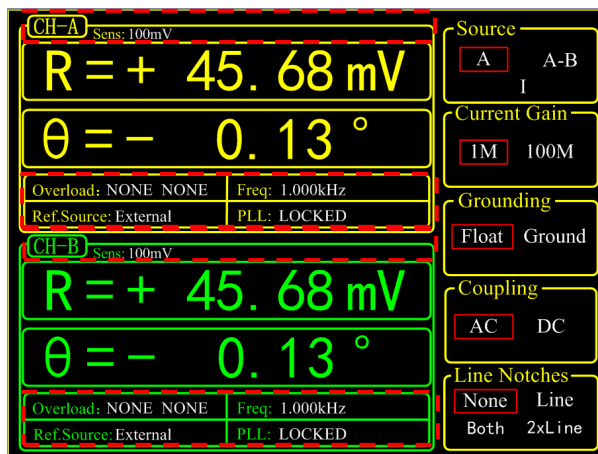
3.3.2 Monitoring Bar

Fig.11 Main Interface: Monitoring Bar

The monitoring bar is at the bottom of the screen as shown in Fig.11:

<Sens>   According to the chosen sensitivity, user can check if the current input signal is too excessive. When the input signal exceeds the sensitivity range, a 'OVLD' alert will appear on the upper-right corner of data bar, prompting user to select another appropriate

range. If the input signal is too excessive, disconnect signal to prevent further damage to device.

<Overload>   To indicate an input overload or amplification overload.
If there is no overload, it shows <Overload: NONE NONE>;
If an input overload, it shows <Overload: INPUT NONE>;
If an amplification overload, it shows <Overload: NONE GAIN>;
If there are both an input overload and amplification overload, it shows <Overload: INPUT GAIN>. In this case, reduce the input as soon as possible to prevent over-voltage damage to the instrument.

<Freq>   Display the frequency of input signal.

<Ref. Source>   The mode of the reference signal: Internal or External.

<PLL>   The status of PLL.
If the internal reference is used, it shows <PLL: UNLOCK>.
If the external reference is used, it shows <PLL: LOCKED>.

3.3.3 Function Bar
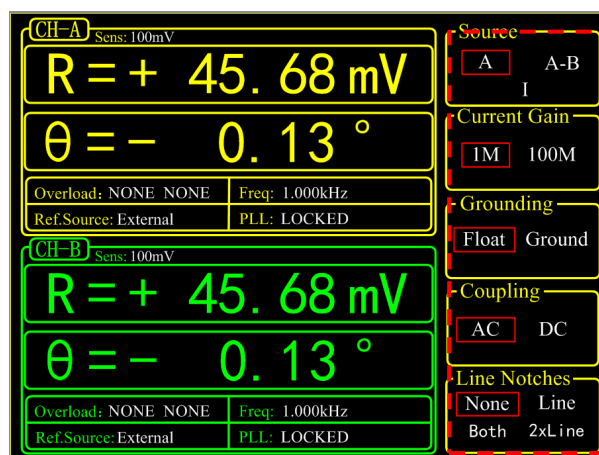
Fig.12 Main Interface: Function Bar

As shown in Fig.12, users can choose different functions in the function bar. Functions can be selected by five soft keys which represent different submenu. This is the basic way to control the system.

4.   MENUS

The MENUs consists of nine parts: [INPUT/FILTERS], [REF/PHASE], [GAIN/TC], [DISPLAY], [SAVE/LOAD], [CHANNEL OUTPUT], [SAMPLE], [AUTO SET] and [SYSTEM], see the front panel of OE1022D in Fig 9. Each button has an independent corresponding submenu. In each submenu, use soft keys such as[CH A/B SWITCH]、[START CONT]、[PAUSE CLEAR]、[CURSOR]、[ACTIVE CHART]to set parameters.

4.1 [INPUT/FILTERS]

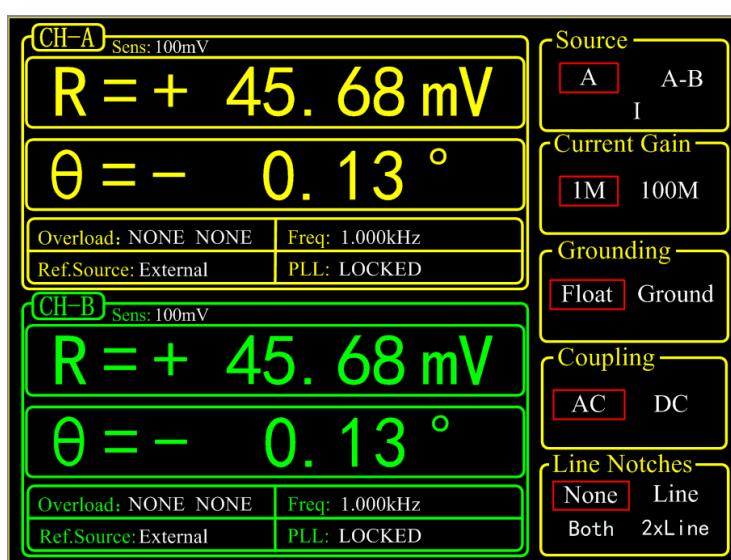When press the [INPUT/FILTERS] button, you will enter this following submenu, as shown in Fig.13.

Fig13. [INPUT/ FILTERS] submenu

There are 5 function settings in this submenu: <Source>, <Current Gain>, <Grounding>, <Coupling> and <Line Notches>. Soft key [CH A/B SWITCH] is provided for switching between two channels. Users can also switch between two channels through knob.

4.1.1 <Source>: Setting the Input Signal Mode

<A>	Single-ended voltage input mode. Receive Signal from IN+ terminal.
<A-B>	Differential voltage input mode. Input Signals through IN+ and IN- terminals.
<I>	Current input mode. Receive current signal from IN+ terminal.

Note that when choose mode <A> and mode <A-B>, the amplitude of the input signal must be less than 1Vrms.In mode <I>, the input current must be less than 1uA

4.1.2 <Current Gain>: Setting the Current Gain

<1M>   The input current is amplified by the gain of 10^6 V/A.

<100M>   The input current is amplified by the gain of 10^8 V/A.

4.1.3 <Grounding>: Setting the Ground Mode

<Float>   The connector shields are isolated from the chassis ground by 10kΩ.

<Ground>   The connector shields are isolated from the chassis ground by 10Ω and chassis ground is connected to the earth directly.

Generally, choose <Ground> when the current of the input signal is not large. It prevent signal drift caused by floating. Choose <Float> when there is a large potential difference between the signal ground and chassis ground and a strong current injection. This can limit the current and protect the system circuit.

4.1.4 <Coupling>: Setting the Coupling Input Mode

<AC>   AC coupling input mode. In this mode, the DC component of the input signal would be eliminated. If the signal frequency is greater than 200 Hz, <AC> should be selected.

<DC>   DC coupling input mode. In this mode, the AC component of the input signal would be eliminated. If the signal frequency is less than 200 Hz, <DC> should be chosen.

4.1.5 <Line Notches>: Setting the Status of the Notch Filters

<None>   Turn off all notch filters.

<Line>   Turn on the 50\60 Hz notch filter to suppress the power line interference.

<2xLine>   Turn on the 100\120 Hz notch filter to suppress the second harmonic interference of power.

<Both>   Turn on the 50\60 Hz and the 100\120 Hz notch filter.

Generally, if the signal frequency is greater than 200Hz, choose <Both>, <Line> or <2xLine>. Otherwise, choose <None> to avoid the amplitude damage due to small slope of the notch filter.

4.2 [REF/PHASE]

Press [REF/PHASE] and enter its submenu. There are 7 function settings in the submenu, including <Ref.phase>, <Ref.source>, <Ref.slope>, <Ref.frequency>, <Sweep>, <Harmonic> and <Sine Output>. Soft key [CH A/B SWITCH] is provided for switching between two channels. Users can also switch between two channels through knob. When different <Ref.source> are selected, there will be different submenus as shown in Fig.14, Fig.15 and Fig.16.
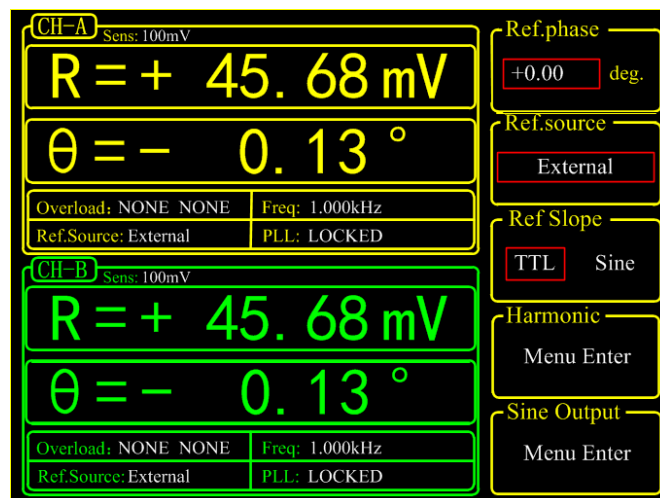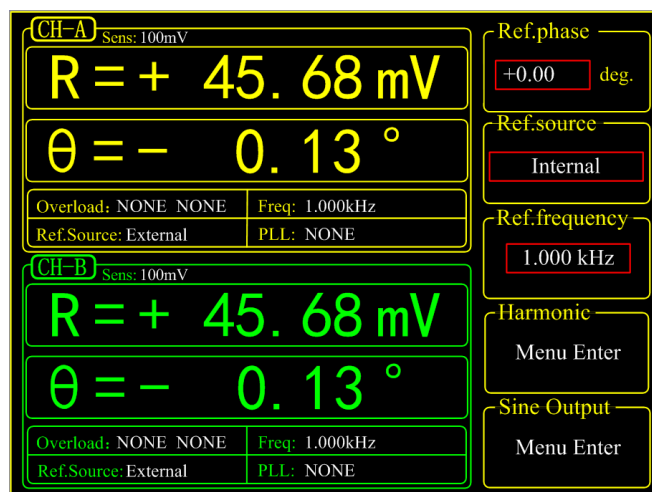

Fig.14 [REF/PHASE] Submenu-<External>.

Fig.15 [REF/PHASE] Submenu-<Internal>
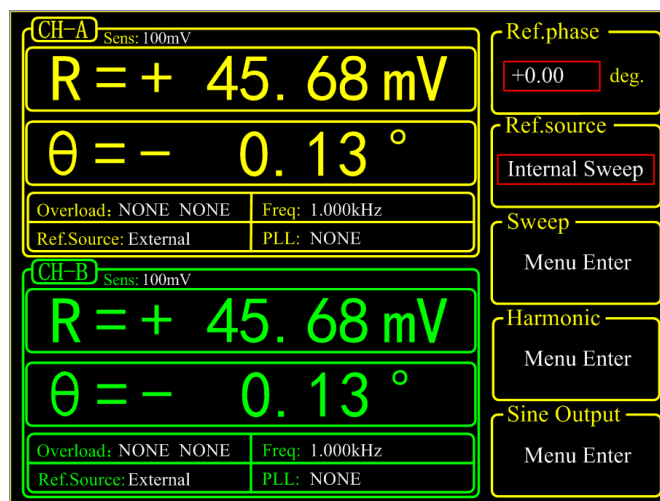
Fig.16 [REF/PHASE] Submenu-<Internal Sweep>

4.2.1 <Ref. phase>: Setting the Reference Phase

Users can set the phase shift between two orthogonal reference signals through the keyboard. The accuracy of phase is 0.01°and the range is from -180° to +180°.

For phase, it is meaningful only when there is a reference. In the system, the default reference phase is the phase of REF IN after locked by a high precision PLL. Other phases are relative to this reference phase.

4.2.2 <Ref. source>: Setting the Reference Source

<External>	The external reference signal. <Ref.slope> can be set here.
<Internal>	The internal reference signal. In this mode, the reference signal is from the internal oscillator. The [REF IN] signal is useless. As shown in Fig.15, <Ref.frequency> can be set.
<Internal Sweep>	The internal reference signal sweep. In this mode, the signal generator will conduct internal sweep according to the parameters set by users. As shown in Fig.16, <Sweep> can be set.

4.2.3 <Ref. slope>: Setting the External Signal Mode

When <External> is chosen in <Ref. source>, this setting can access. Choose the corresponding signal type according to the actual external reference signal.

<TTL>	Choose TTL when the external reference signal is a square wave. Low level threshold range from 0V to 1.5V, High level threshold range from 4V to 5V.
<Sine>	Choose Sine when the external reference signal is a sine wave.

AC coupled input signals are valid only when amplitude is larger than 0.2Vp. The maximum amplitude of the input signals is 5Vp.

If the external reference signal is TTL logic, choose <TTL>. Pay attention that, even if the REFIN is a square wave, it may still obtain an unsteady trigger because the level does not satisfy the threshold condition of the TTL logic. Thus, it is beneficial to choose <Sine> to trigger. Moreover, choose TTL signal if the signal frequency is very low (<1Hz).

If the input reference signal is sine wave, choose SINE to trigger. In this mode, the instrument will do precision truing for the REF IN input and then detect the frequency and phase information.

Otherwise, the system has no requirement on the signal duty cycle no matter what the trigger way is. It is kind to use common 50% duty cycle.

4.2.4 <Ref. frequency>: Setting the Internal Reference Frequency

When <Internal> is chosen in <Ref. source>, this setting can access. The frequency range is from 1mHz to 102 kHz and the default frequency is 1.000 kHz. Users can set frequency through keyboard. The minimum resolution of frequency is 1mHz.

4.2.5 <Sweep>: Setting the Internal Reference Signal Sweep

When <Internal Sweep> is chosen in <Ref. source>, this setting can access. Press the <Sweep> button to access the secondary submenu. In the submenu, users can set <Sweep Type>, <Sweep Set> and <Sweep Run>, as shown in Fig.17.
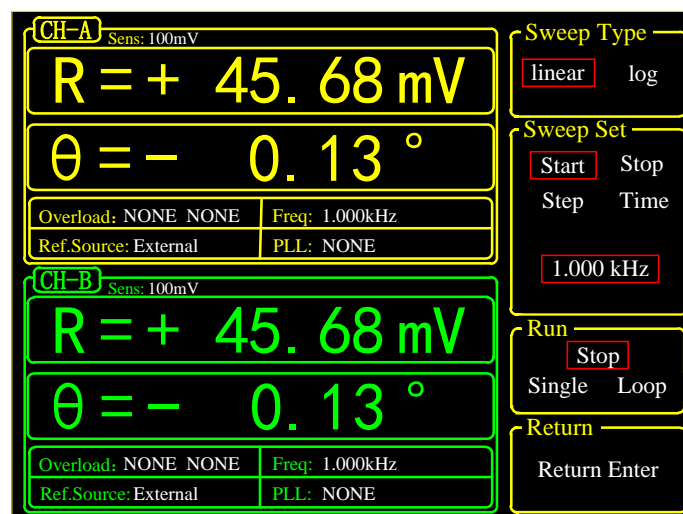
Fig.17 <Sweep> Secondary Submenu

<Sweep Type>   Setting frequency sweep type.
   <Linear>   linear sweep type

               `<Log>`   logarithm sweep type

In the `<Linear>` mode, the step type is frequency by adding the frequency with the setting step frequency. In the `<Log>` mode, the step type is the percentage of frequency.

For example, in the `<Log>` sweep mode, the sweep step is 10% of the frequency, the start frequency is 1 kHz and the cutoff frequency is 2kHz. The process of frequency sweep is:

                      1000.000 Hz
                      1100.000 Hz
                      1210.000 Hz
                      1331.000 Hz
                      1464.000 Hz
                      1610.510 Hz
                      1771.561 Hz
                      1948.717 Hz
                      2000.000 Hz

`<Sweep Set>`   Setting frequency sweep parameters.

   `<Start>`   The start frequency of sweep
   `<Stop>`   The cutoff frequency of sweep
   `<Step>`   In the `<Linear>` mode, the `<Step>` is the step frequency; in the `<Log>` mode, the `<Step>` is the percentage of frequency.

   `<Time>`   The step time interval of sweep.

Setting the start frequency, cutoff frequency, step frequency and time through keyboard and soft keys. The range of start frequency and cutoff frequency is from 1mHz to 102kHz. `<Start>` frequency is 1.000kHz in default and `<Stop>` frequency is 5.000kHz in default. The minimum resolution of the frequency is 1mHz. In the `<Log>` mode, the minimum resolution of the step is 0.001% of the frequency, and the minimum/maximum resolution of the step time is 1mS/100S.

`<Sweep Run>`   Setting frequency sweep running mode

   `<Stop>`   stop sweep
   `<Single>`   single sweep
   `<Loop>`   loop sweep

When start from `<Single>` sweep, OE1022D does an internal frequency sweep according to settings. After that, the status jumps back to `<Stop>` automatically.

When start from `<Loop >` sweep, OE1022D does constant loop sweep until users switch the status to `<Stop>` manually.

4.2.6 <Harmonic>: Setting the Harmonic Detection

The OE1022D allows simultaneous measurement of two harmonics. The harmonic setting interface is shown in Fig.18.

Fig.18 <Harmonic> Secondary Submenu

<Harmonic 1>   Setting harmonic 1. The minimum value is 1 and the maximum value is 32767.

<Harmonic 2>   Setting harmonic 2. The minimum value is 1 and the maximum value is 32767.

Enter the order of harmonic through keyboard. The default order is '1' which means detecting 1st order harmonic (fundamental wave). The limitation of the harmonic settings (Harmonic * Freq) is 102kHz, where 'Freq' means the reference frequency. Once beyond the limit, system will reduce the order of harmonic automatically to meet the conditions. At the same time, when the order is set 0, the system will set the order to 1 automatically

For example, the input signal is 1kHz square wave. Suppose that the signal's amplitude is A. Set <Harmonic>as 1, 2, 3, 4, 5, 6…, the R will be 0.45A, 0，0.15A, 0.09A, 0…respectively. This sequence is A times higher the coefficient sequence of the square wave Fourier Series.

It is necessary to set <List> in the <Full> option of the <Display> submenu during detecting double harmonic.

4.2.7 <Sine Output>: Setting the Sine Output

OE1022D can output sine wave whose amplitude range is from 0V to 5V through the 'Sine Out' BNC connector on front panel. In its secondary submenu, users can set <Sweep Type>,

<Voltage>, <Sweep Set> and <Sweep Run>. Besides, there are 3 modes to choose in <Sweep Type>, including <Fixed> - fix the output amplitude, <Linear> linear sweep output and <Log> logarithm sweep output. When choosing different <Sweep Type>, the submenu is different as shown in Fig.19 and Fig.20.

When using the <External> reference, <Sine Output> provides a sine signal which is in phase-lock with l with the external reference signal. When using the <Internal> reference, the reference signal is generated by the oscillator in OE1022D. The 'TTL OUT' BNC connector on rear panel will output TTL signal which is synchronous with the <Sine Output>.
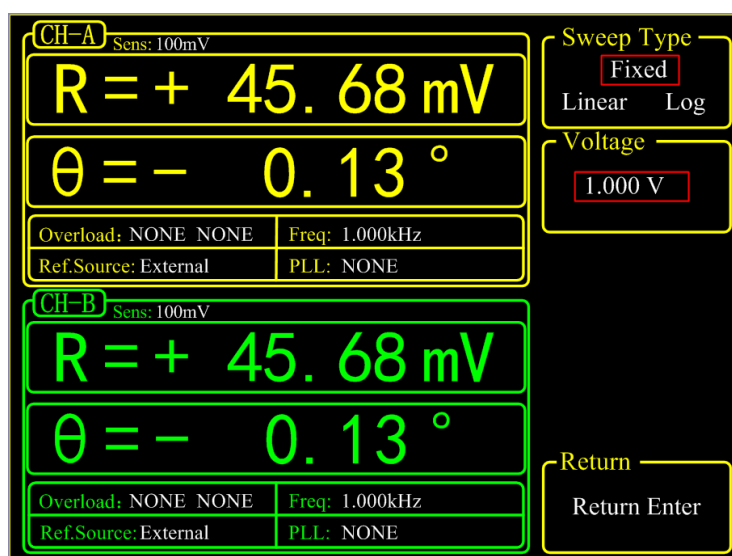
Fig.19 <Sine Output> Secondary Submenu-<Fixed>
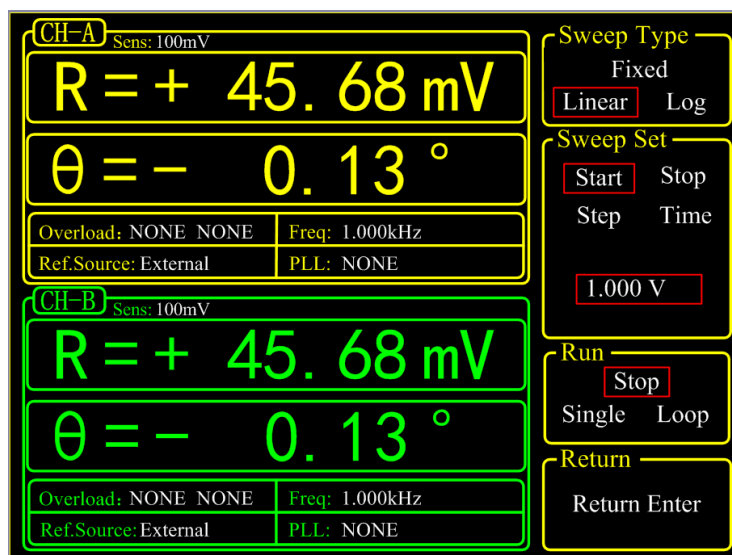
Fig.20 <Sine Output> Secondary Submenu-<Linear & Log>

<Sweep Type> Setting amplitude sweep type.

<Fixed>	fixed amplitude sweep type(default)
<Linear>	linear amplitude sweep type
<Log>	logarithm amplitude sweep type

In <Fixed> mode, the amplitude of <Sine Output> is set by users. In <Linear> or <Log> mode, settings are configured in <Sweep Set> and <Sweep Run>.

<Voltage>   Setting the amplitude of sine output

In <Fixed> mode, users can set the amplitude of sine out through keyboard. The range is from 0.001 Vrms to 5 Vrms and the minimum resolution is 0.001Vrms.

<Sweep Set>   Setting the parameters of amplitude sweep.
   <Start>   The start amplitude of sweep
   <Stop>   The cutoff amplitude of sweep
   <Step>   In <Linear> mode, the <Step> is the step amplitude of sweep; in the <Log> mode, the <Step> is the percentage of amplitude.
   <Time>   The step time interval of sweep.

Users can set the start amplitude, cutoff amplitude, step and time through keyboard and soft keys. The range of amplitude is from 0.001 Vrms to 5 Vrms. The default start amplitude is 1.0 Vrms and cutoff amplitude is 5.000 Vrms. The minimum resolution of amplitude is 0.001Vrms.
In <Log> mode, the minimum resolution of step is 0.001% and the minimum/maximum resolution of the step time is 1ms/100,000ms.

<Sweep Run>   Setting amplitude sweep run mode
   <Stop>   stop sweep
   <Single>   single sweep
   <Loop>   loop sweep

When start from <Single> sweep, OE1022D does an internal amplitude sweep according to the settings of users. After that, the status jumps back to <Stop> automatically.

When start from <Loop > sweep, OE1022D does constant loop sweep until users switch the status to <Stop> manually.

SINE SCIENTIFIC INSTRUMENTS
SSI

4.3 [GAIN/TC]

Press [GAIN/TC] button, then enter the submenu as shown in Fig.21.
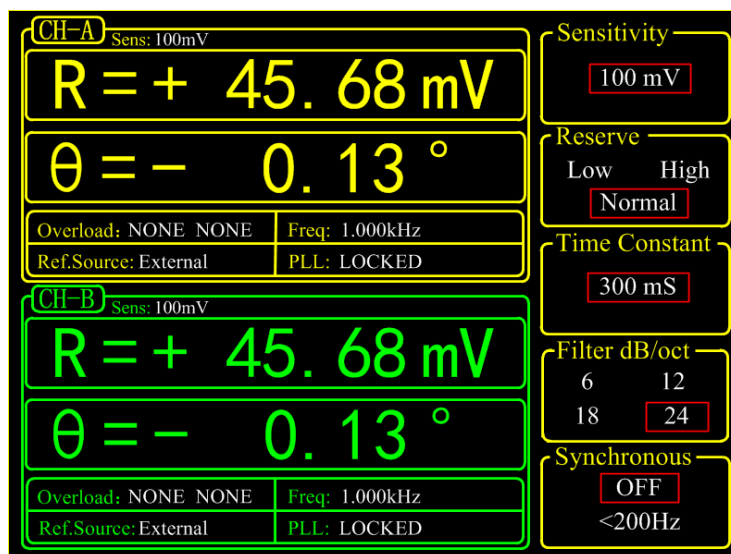
Fig.21 [GAIN/TC] Submenu

There are 5 function settings in the submenu, including <Sensitivity>, <Reserve>, <Time Constant>, <Filter dB/oct> and <Synchronous>. Soft key [CH A/B SWITCH] is provided for switching between two channels. Users can also switch between two channels through knob.

4.3.1 <Sensitivity>: Setting the Full Scale Sensitivity

Choose an appropriate full-scale sensitivity according to the amplitude of the input signal. Adjust the value through the soft keys or spin knob.

Table 1. Full Scale Sensitivity

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

The change of <Sensitivity> will change the dynamic range of the system. Besides, it will interfere the output of CH1&CH2. If the measure signal is current, the full scale acts as the corresponding current unit, <100mV/nA> in default.

When choose <AUTO GAIN>, the system will automatically adjust the sensitivity according to 'R' value of input signal. Note that if the time constant is very large, the system will need a long time to adjust.

4.3.2 <Reserve>: Setting the Dynamic Reserve Mode

<Low>   Low dynamic reserve mode
<High>   High dynamic reserve mode.
<Normal>   Normal dynamic reserve mode. Generally, this mode is recommended.

When choose <AUTO RESERVE>, the system will automatically adjust the minimum dynamic range required according to the 'R' value of input signal.

4.3.3 <Time Constant>: Setting the Time Constants

The range of time constant is from 10 us to 3000 s. Adjust the value through soft keys and spin knob.

Table 2. Time Constants

10 µs	3 ms	1 s	300 s
30 µs	10 ms	3 s	1000 s
100 µs	30 ms	10 s	3000 s
300 µs	100 ms	30 s	
1 ms	300 ms	100 s	

The greater the time constant, the smaller the ENBW, the longer the system response and the higher the measurement accuracy.

4.3.4 <Filter dB/oct>: Setting the Roll off Slope of the Low Pass Filter

<6dB/oct>   The roll off slope is 6 dB/oct.
<12dB/oct>   The roll off slope is 12 dB/oct.
<18dB/oct>   The roll off slope is 18 dB/oct.
<24dB/oct>   The roll off slope is 24 dB/oct.

At the same measurement accuracy, a greater roll off slope can reduce the time constant, making a faster response.

4.3.5 <Synchronous>: Setting the Status of the Synchronous Filter
<OFF>   Close the synchronous filter.
<200Hz>   Open the synchronous filter. It is useful when reference frequency is low (< 200 Hz). When the input signal frequency is very low, the low pass filter require more significant current slump and takes longer to do that. In such circumstances, synchronous filter helps.

Note that if the synchronous filter is open, <Filter dB/oct> must be <18 dB/oct> or <24 dB/oct >!

SINE SCIENTIFIC INSTRUMENTS

4.4 [DISPLAY]

Press [DISPLAY] button to enter the submenu as shown in Fig.22.
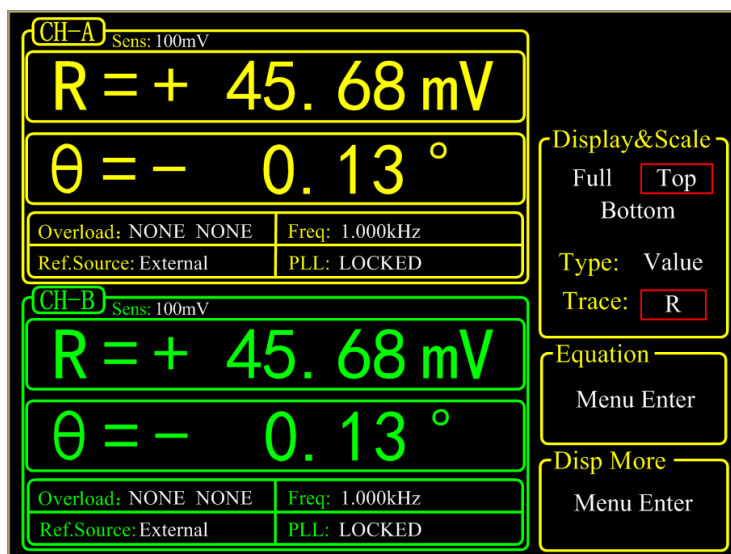
Fig.22 [DISPLAY] Submenu

In this submenu, there are 3 function settings: <Display & Scale> <Equation> and <Disp More>. They can be chosen and set by the soft keys beside the submenu. Soft key [CH A/B SWITCH] is provided for switching between two channels. Users can also switch between two channels through knob.

4.4.1 < Display & Scale >: Setting the Dynamic Area Display

<Display & Scale> is provided for setting the display area and type of measurement results. <Display & Scale> includes two submenus: <Area> and <Type/Trace>.<Area> is provided for displaying area, <Type/Trace> for type of measurement results

4.4.1.1<Area>: Area Display Configuration

<Full>: Full display mode displays in the whole dynamic area. It has 3 display types, including <Bar>, <Chart>and <List>.All are shown in the dynamic displaying area.

1)   <Bar>: Bar chart

The length of Bar is expressed as the percentage of the <R> value to the full scale, as shown in Fig.23. It is very convenient and intuitive in indicating the <R> value.
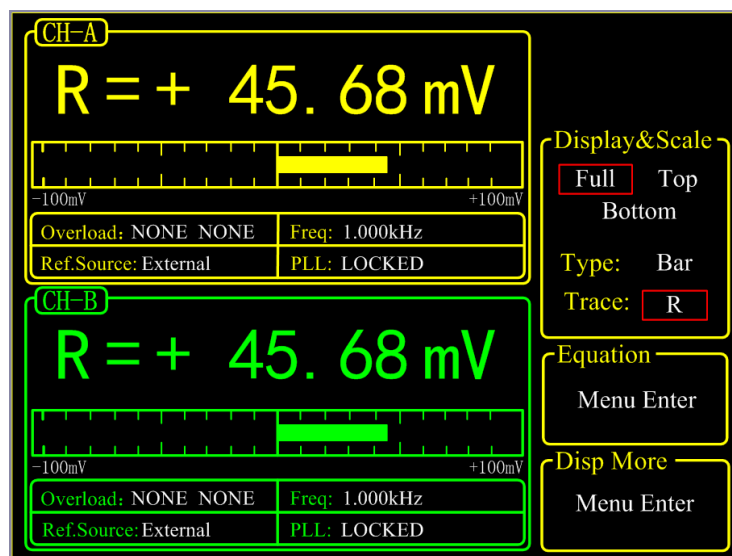
Fig.23 <Full>-<Polar> Display

2)   <Chart>: XY coordinates chart.

It displays the curve of the measurement results. Users can watch the value of sample points by controlling <Cursor> through spin knob. <Chart> always picks up the measured data cooperating with [SAMPLE] submenu and [CONTROL] area, as shown in Fig.24.
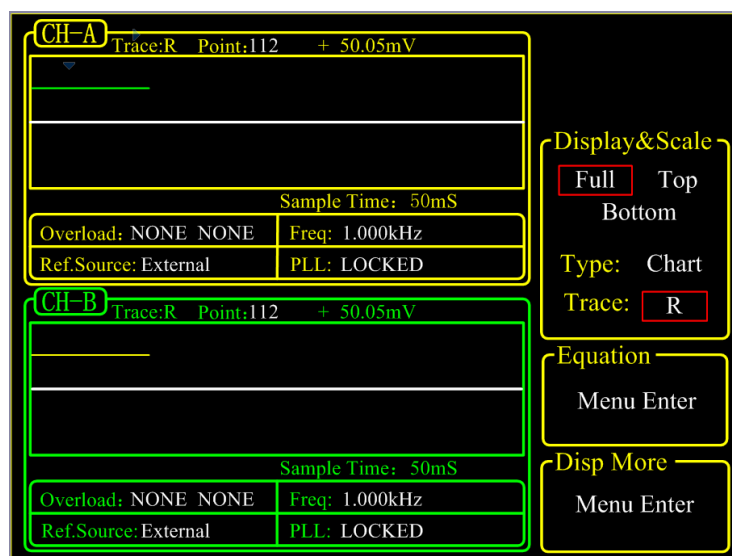
Fig.24 <Full>-<Chart> Display

3)   <List>:

Display the value of the fundamental wave and two harmonics of the input signal at the same time. The interface is shown in Fig.25.

Fig.25 <Full>-<List> Display

4) <TOP>:
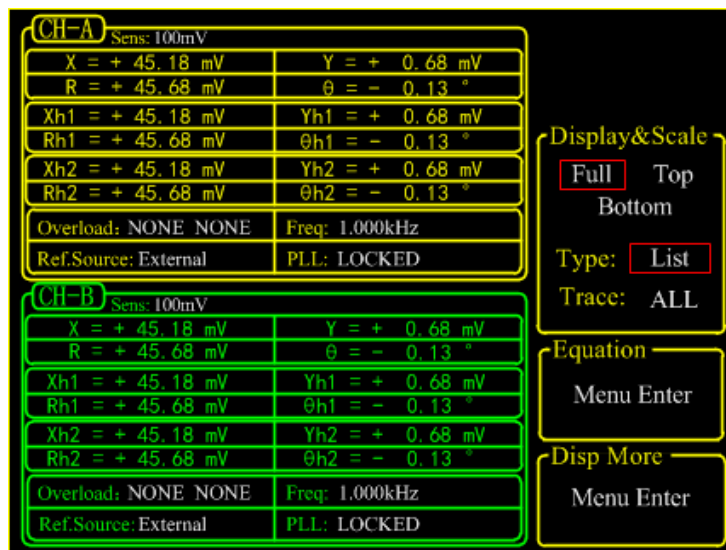
This can be set only by selecting the top area. When <Type> or <Trace> is changed, the display way of top area will change, as shown in Fig.26 and Fig.27. There are two choices in <Type>, including <Value> and <List>.

If <Type> is <Value>, <Trace> provides options, including fundamental wave, harmonic, and Equation.

If <Type> is <List>, <Trace> provides 4 options: <Basic> (Fundamental wave), < Harm1> (Harmonic wave 1), < Harm2> (Harmonic wave 2) and <ADC> (AUX IN).
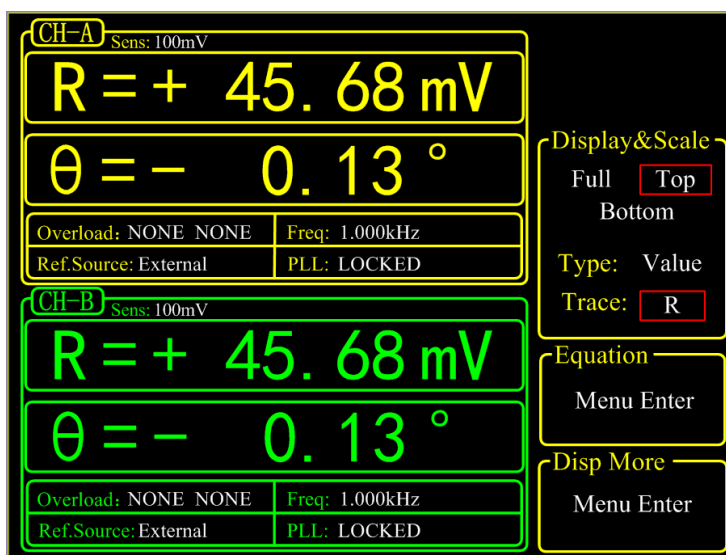
Fig.26 <Top>-<Bar> Display
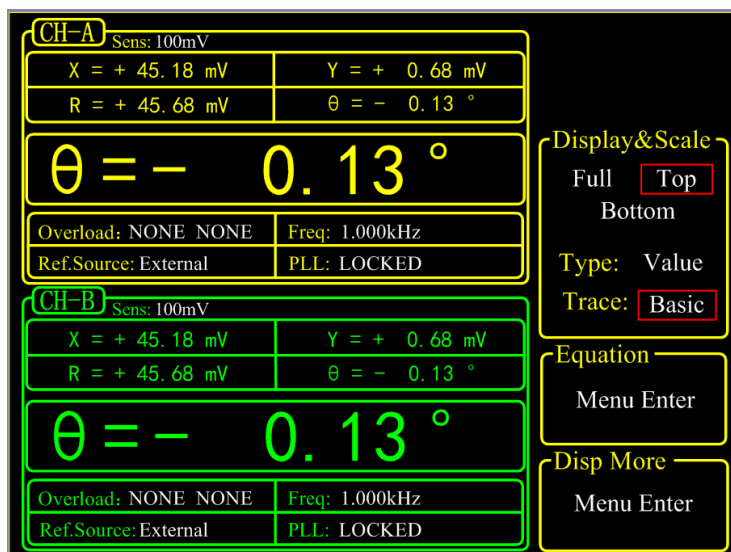
Fig.27 <Top>-<List> Display

<Bottom>

Only choose the bottom area to set. When <Type> or <Trace> is changed, the display way of bottom area will change, just like the <Top> mode.

4.4.1.2 <Type/Trace>：Display Mode and Type Configuration

<Type/Trace>	Setting the way of display
	Switch <Type> or <Trace> to set by soft keys. The chosen one will be highlighted and then switch the wanted mode through knob.

<Type>	How to display. Users can choose <Value> and <List>. Besides, <Bar> (percentage of value) and <Chart> (XY coordinates) are optional in the <Full> mode.

<Trace>	What to display. Users can choose the values to display as the following.
<X>	The X value of fundamental wave of the input signal.
<Y>	The Y value of fundamental wave of the input signal.
<R>	The 'R' value of fundamental wave of the input signal.
<θ>	The θ value of fundamental wave of the input signal.
<Xh1>	The X value of 1th channel harmonic of the input signal.
<Yh1>	The Y value of 1th channel harmonic of the input signal.
<Rh1>	The 'R' value of 1th channel harmonic of the input signal.
<θh1>	The θ value of 1th channel harmonic of the input signal.
<Xh2>	The X value of 2th channel harmonic of the input signal.
<Yh2>	The Y value of 2th channel harmonic of the input signal.
<Rh2>	The 'R' value of 2th channel harmonic of the input signal.
<θh2>	The θ value of 2th channel harmonic of the input signal.

<Noise>	Noise value of input signal.
<E1>	The 1th Equation value.
<E2>	The 2th Equation value.
<E3>	The 3th Equation value.
<E4>	The 4th Equation value.

4.4.2 < Equation >: Setting the Equation.

The function of <Equations> is to do basic proportional calculation with the measurement values. The results output through CH1/CH2 BNCs on front panel. The equation is fixed：

$$\text{Equation} = \frac{A \times B}{C}$$

A, B and C is set in the secondary submenu of <Equation> can there are 4 equations can be set in this menu, as shown in Fig.28
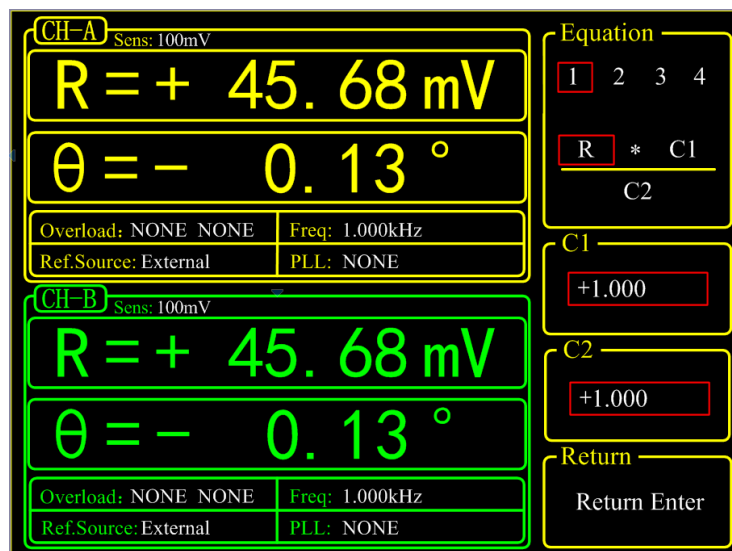
Fig.28 <Equation> Secondary Submenu

4.4.2.1   Setting equation parameters.

<Equation>

The value of A, B and C in equation1~4=A*B/C can be changed through soft keys. The optional values of A, B and C include fundamental wave, harmonic wave, ADC, frequency and constant parameters.
For example, when A is R=50mV, B is θ=130°, C is Freq=1 kHz, then

$$\text{Equation} = \frac{A \times B}{C} = \frac{0.05 \times 130}{1000} = 0.0065$$

When <Trace> in [DISPLY] submenu choose <E1>, the result of Equation 1 will be displayed. In <Bar> display mode, the display range is from 0.000001 to 9999999 without unit and progress bar.

When <Source> in [CHANNEL OUPUT] submenu choose <E1>, the result of Equation 1 will output. More details are in [CHANNEL OUPUT] submenu.

4.4.2.2 <C1>   Setting constant parameter 1.

Constant parameter <C1> setting, range: -10~+10.

4.4.2.3 <C2>   Setting constant parameter 2.

Constant parameter <C2> setting, range: -10~+10.

4.4.3 < Disp More >: More Display Settings

<Disp More> secondary submenu adds two settings, <Range> and <Curve Point>, as shown in Fig.29.
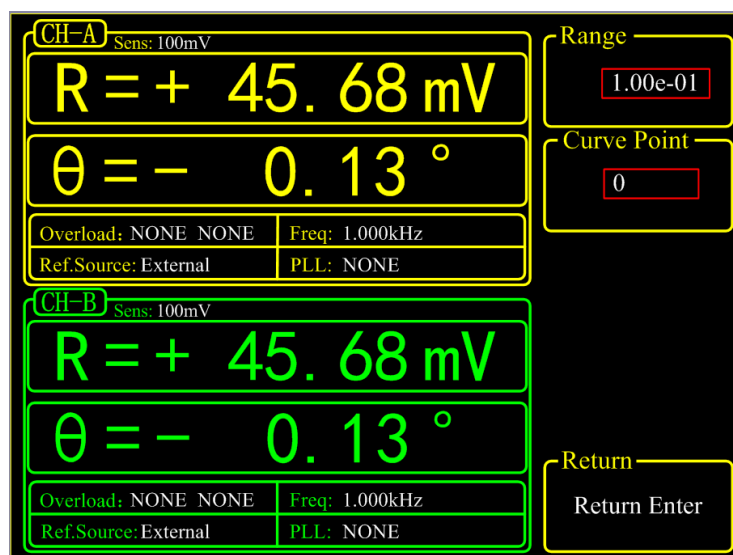
Fig.29 <Disp More> Secondary Submenu

4.4.3.1 <Range>   Setting display range

<Range> is used to set the largest scale of <Bar>, <Chart> and <Polar> chart.

The input range of <Range> is 1 nV to 1 V. This range will change with the change of <Sensitivity>. Besides, it can be set numerically through the keyboard. For example, 1.00e-01 means 1.00×10^{-1}V that is 100mV.

Keep <Sensitivity> unchanged and then change the value of <Range>. Set <Range> 1.00e-03=1mV, then the display range is -1mV to +1mV.

4.4.3.2   Setting the position of sampling curve
<Curve Point>

In <Curve Point> mode, the <Cursor> in <Chart> can rapidly locate position and watch the value of this point. The setting range of <Curve Point> is 1~16384.

When <Chart> is in reset mode (no store data), the <Curve Point> makes no sense and keeps 0. When sampling data, this option is hidden. It would appear after pause.

Before using <Curve Point>, users should callout <Cursor> by pressing the [CURSOR] button in CONTROL area.

4.5 [SAVE/RECALL]

Press [SAVE/RECALL] button and enter the submenu as shown in Fig.30

CH–A Sens: 100mV

R = + 45. 68 mV

θ = − 0. 13 °

Overload：NONE NONE   Freq: 1.000kHz
Ref.Source: External   PLL: NONE

CH–B Sens: 100mV

R = + 45. 68 mV

θ = − 0. 13 °

Overload：NONE NONE   Freq: 1.000kHz
Ref.Source: External   PLL: NONE

Save&Recall

Save   Recall

Channel:
S1

Execute:
NO   YES
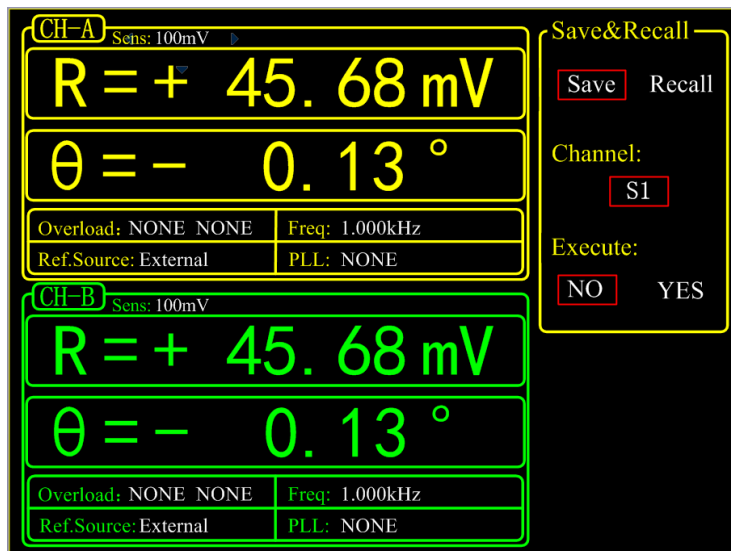
Fig.30 [SAVE/RECALL] Submenu

[SAVE/RECALL] menu is mainly used to save and recall the setting parameters and status. Users can save in <S1>, <S2>, <S3> and <S4> according to their individual favorites. As shown in Fig.30, <Save & Recall> choose <Save>, <Channel> chooses <S1>, <Execute> choose <YES>, and then the current setting parameters and status will be saved in <S1>. In this case, the current parameters and status can be save in <S1>. <Save & Recall> choose <Recall>, <Channel> chooses <S1> and <Execute> choose <YES> to recall the archive. In this case, the data in <S1> can be recalled.

User can recall default settings by following steps: Select <Recall> in 'Save&Recall' side box→ Select <Default> in 'Channel'→Select <Yes> in 'Execute'.

4.6 [CHANNEL OUTPUT]

Press [CHANNEL OUTPUT] button and enter the submenu as shown in Fig.31.
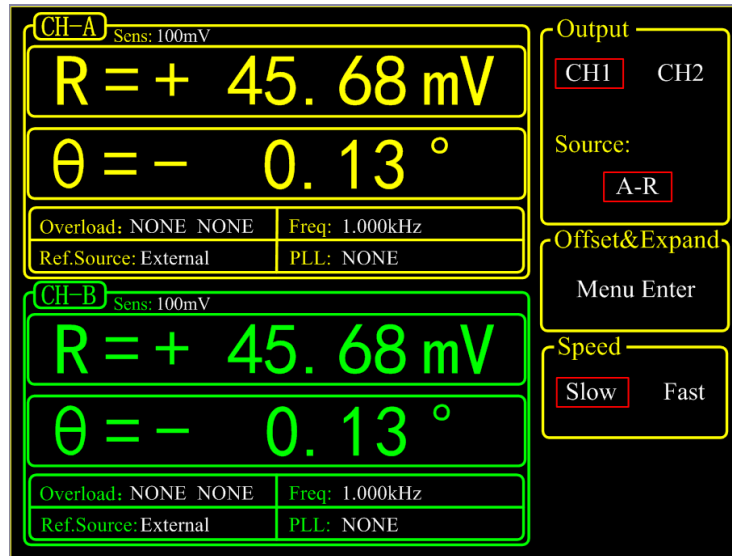
Fig.31 [CHANNEL OUTPUT] Submenu

The two BNCs CH1 and CH2 can output R, X, Y and θ that users wanted by setting in the [CHANNEL OUTPUT] submenu. The output offset and expand is set in <Offset & Expand>. In <Speed>, users can set the output rate of channel.

The calculation equation of output signal is:

1. When source is <R>, <X>, <Y>, <Rh1>, <Xh1>, <Yh1>, <Rh2>, <Xh2>, <Yh2> or <Noise>:

$$\text{output} = (\frac{Signal(source)}{Sens} + offset) \times Expand \times 10V$$

2. When source is <θ>, <θh1>, <θh2>

$$\text{ouput} = \frac{Signal(source)}{180°} \times 10V$$

3. When source is <E1>~<E4>(Equation), in addition to the two equations above, there are other options as below:

   a) AUX_IN1~AUX_IN4: output = the input voltage.

   b) Constant coefficient: directly correspond. Such as 10 corresponds to 10V, -5 corresponds to -5V.

   c): frequency:

   Every stage of the frequency ranges from 5V to 10V. For example,

   1000Hz = 5 V
   1200Hz = 6 V
   1600Hz = 8 V
   1800Hz = 9 V
   1990Hz = 9.95 V
   2000Hz = 5 V (next stage)

The frequency is divided into following stages:

  62.5 Hz – 125 Hz
  125 Hz – 200 Hz
  250 Hz – 500 Hz
  500 Hz – 1000 Hz
  1 kHz – 2 kHz
  4 kHz – 8 kHz
  8 kHz – 16 kHz

  …

Result is calculated according to the Equation formula. The range of result is from -10 V to +10 V.

4.6.1 < Output Source >: Setting Output Source

<X>:	the corresponding analog level of the channel output X
<Y>:	the corresponding analog level of the channel output Y
<R>:	the corresponding analog level of the channel output R
<θ>:	the corresponding analog level of the channel output θ
<Xh1>:	the corresponding analog level of the channel output Xh1
<Yh1>:	the corresponding analog level of the channel output Yh1
<Rh1>:	the corresponding analog level of the channel output Rh1
<θh1>:	the corresponding analog level of the channel output θh1
<Xh2>:	the corresponding analog level of the channel output Xh2
<Yh2>:	the corresponding analog level of the channel output Yh2
<Rh2>:	the corresponding analog level of the channel output Rh2
<θh2>:	the corresponding analog level of the channel output θh2
<E1>:	the corresponding analog level of the channel output E1
<E2>:	the corresponding analog level of the channel output E2
<E3>:	the corresponding analog level of the channel output E3
<E4>:	the corresponding analog level of the channel output E4
<Noise>:	the corresponding analog level of the channel output Noise

4.6.2 < Offset & Expand >: Setting the Offset and Expand

Choose the <Offset & Expand> and enter the secondary submenu, as shown in Fig.32.

Fig.32 <Offset & Expand> Submenu

<Offset> setting: It is set through keyboard. The adjustable range is -100%~+100%. The minimal step is 0.01% and 0.00% is default.

<Expand> setting: It is set through keyboard. The adjustable range is 1~256 and 1 is default. If the 'Expand' value makes the absolute value of calculation result exceeds 10V, the output will be seriously affected.

The settings of <Offset> and <Expand> will not affect the data display in dynamic area.

4.6.3 < Speed >: Setting the Output Speed

<Slow>	the data output speed of channel CH1 & CH2 is 10 Hz
<Fast>	the data output speed of channel CH1 & CH2 is 312.5 kHz

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4.7 [SAMPLE]

[SAMPLE] submenu is used to control the sampling and storage. There are 5 settings in this submenu, including <Step Time>, <Length>, <Select>, <Trigger Mode> and <Sample Mode>, as shown in Fig.33. Soft key [CH A/B SWITCH] is provided for switching between two channels. Users can also switch between two channels through knob.
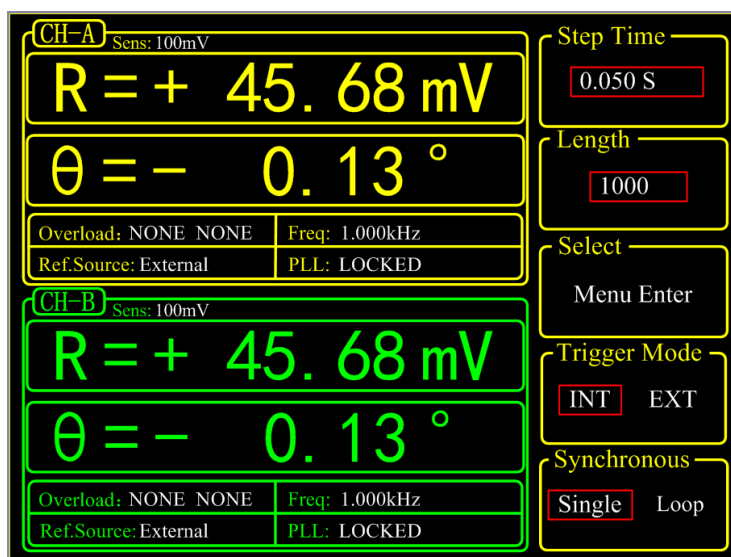
Fig.33 [SAMPLE] Secondary Submenu

The setting of [SAMPLE] menu should cooperate with the keys in CONTROL area. In this case, [SAMPLE] can control the sample to start, pause and reset.

4.7.1 < Step Time >: Setting the Step Time

Setting the step time, range: 1ms~ 100,000ms, collect one data at every step time.

4.7.2 < Length >: Setting the Sample Length

Setting the sample data length, range: 1~16384
When the data sampling is being performed, if the <Length> value is set smaller than the length of the current sampling, sampling will stop immediately in single sample mode. In the loop sample mode, sampling will start again from the first point.

4.7.3 < Select >: Setting the Sampling Object

The <Select> secondary menu is shown in Fig.34.
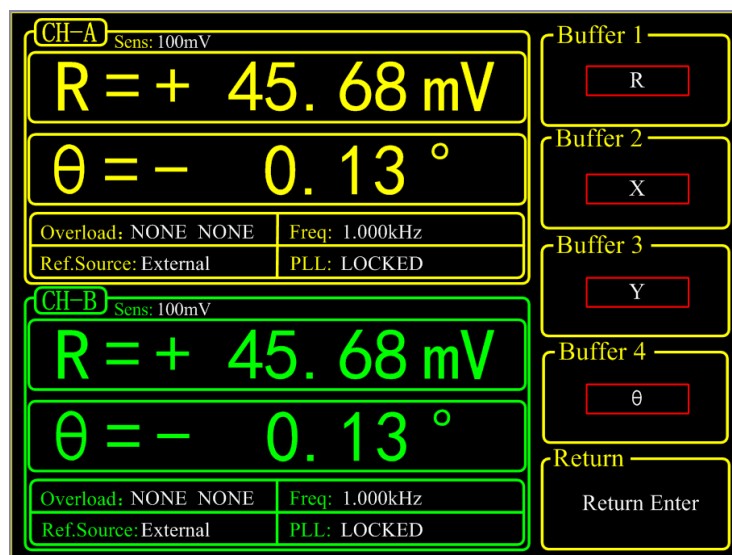
Fig.34 <Select> Secondary Submenu

<Buffer1~4>   Setting the 4 sampling buffers

There are 8 internal <Buffer> in OE1022D. Each buffer can store 16384 32-bits-data. Each buffer can store any one of the following parameter, including <R>, <X>, <Y>, <θ>, <R>, <X>, <Y>, <θ>, <R>, <X>, <Y>, <θ>, <Noise>, <E1>, <E2>, <E3>, <E4>, <A1>, <A2>, <A3>, <A4> and <Freq>.

Only when the sampling restart, the setting of <buffer> is effective. The choice of <buffer> will affect the <Trace> options in <Chart> display mode. In <Chart> display mode, <Trace> can only choose what is already chosen in <Buffer>.

4.7.4 < Trigger Mode >: Setting Trigger Mode

<INT>   internal trigger mode
<EXT>   external trigger mode

In the <INT> mode, the time interval of the sampling process is set by OE1022 itself. Time interval can be set in submenu <Sampling Time>.

In the <EXT> mode, the sampling pulse is received from BNC TRIG_IN on rear panel. Collect data at each sampling pulse and the sampling rate should not be over 500 Hz.

Internal trigger mode and external trigger mode can start, stop or reset the sampling process through buttons in CONTROL area.

4.7.5 < Sample Mode >: Setting Sample Mode

          <Single>   single sample mode
          <Loop>   loop sample mode

In <Single> mode, the system will automatically stop after completing one data collection
In <Loop> mode, the system will loop the sampling process automatically and cover original
    sampling results.
Single and loop sample mode can start, stop or reset the sampling process through buttons in
    CONTROL area.

4.8 [SYSTEM]

[SYSTEM] submenu includes the system information and settings of OE1022D, like instrument information, screen brightness and the remote settings of communications, as shown in Fig.35.
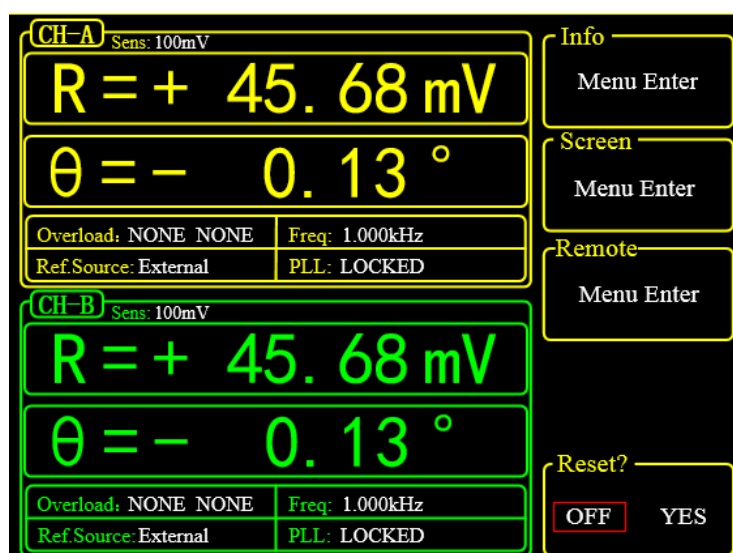
Fig.35 [SYSTEM] Submenu

4.8.1 < Info >: Secondary Submenu

Choose <Info> to enter a secondary submenu shown in Fig.36. This submenu displays related information about the R & D unit of the instrument.
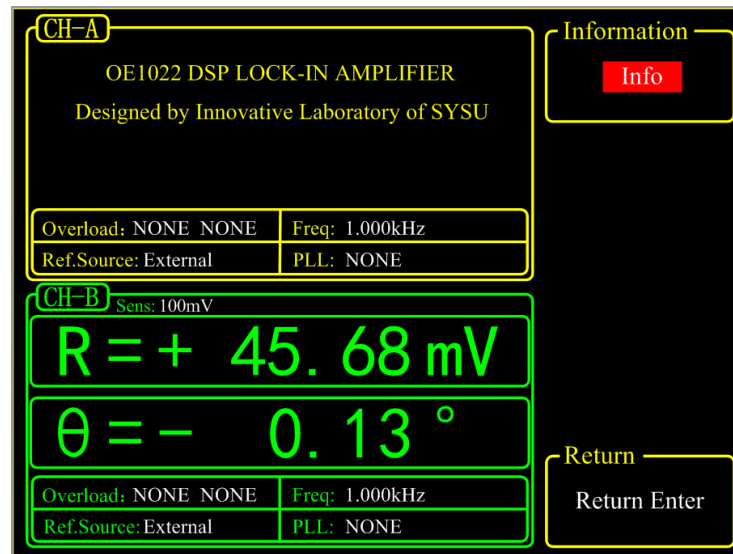
Fig.36 <INFO>Information of R&D Institution

Choose <Version> and the interface displays the version of 0E1022, as shown in Fig.37.
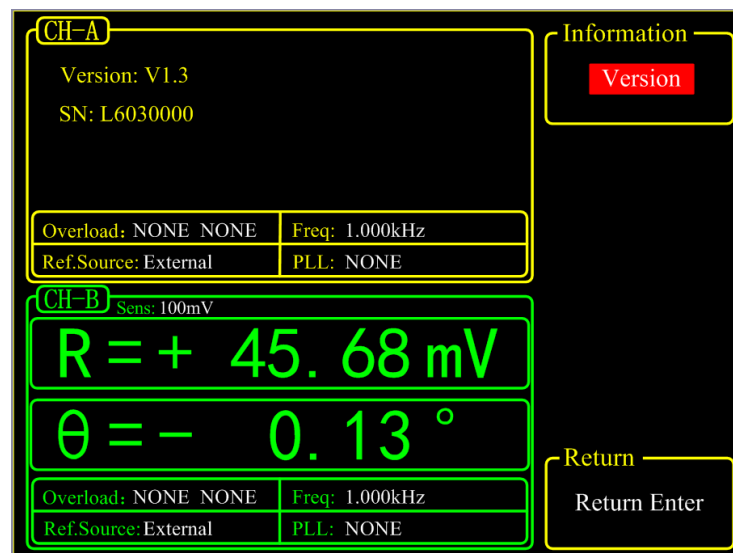
Fig.37 <INFO>-Version

Choose <Contact> and the interface displays contact information as shown in Fig.38.

Fig.38 <INFO>-Contact Information

4.8.2 < Screen > Secondary Submenu

Choose <Screen> to enter this interface, as shown in Fig.39 and Fig.40.

Fig.39 <Screen> Submenu-<Style 1>
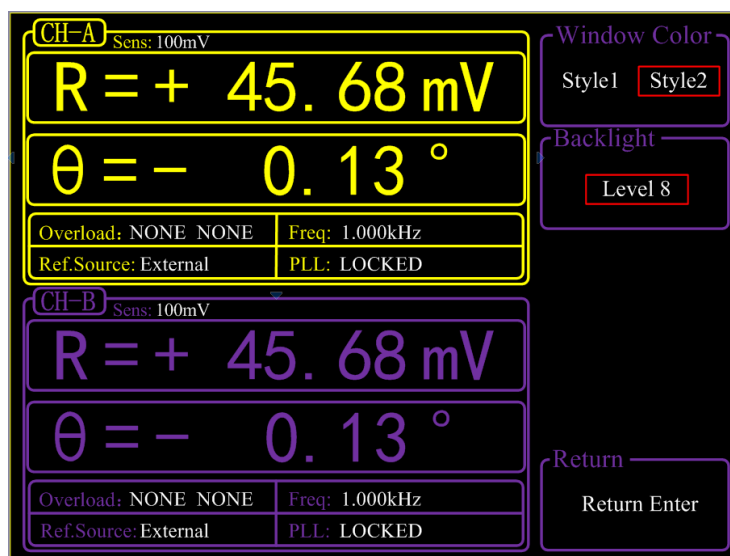
Fig.40 <Screen> Submenu-<Style 2>

This submenu includes two function settings, <Window Color> and <Backlight>.

<Window Color>	setting the window color
<Style 1>	the window main color is yellow
<Style 2>	the window main color is green
<Backlight>	setting the brightness of backlight
	the bright levels can vary from <Level 1> to <Level 8> through Spinning the knob

4.8.3 < Remote >: Setting the RS232 Mode

Choose the <Remote> secondary submenu to enter Fig.41.
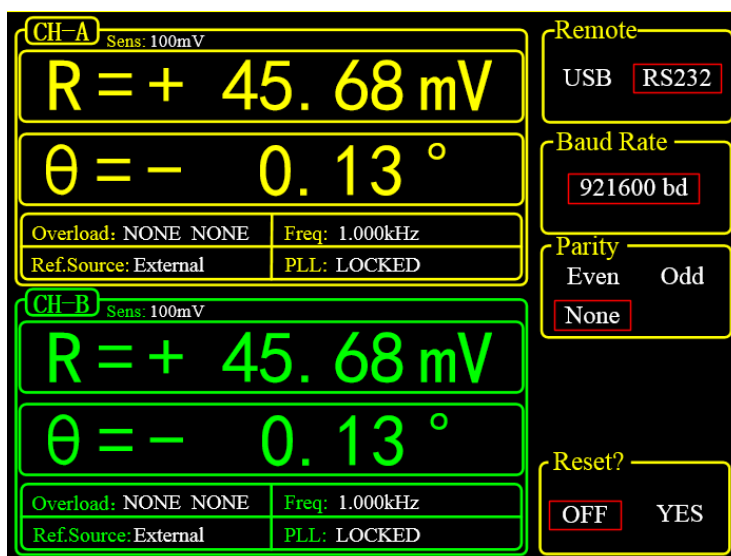
Fig.41 <Remote> Submenu

There are 3 function settings in the submenu, including <Remote>,<Baud Rate>, and <Parity>.

<Remote> :	Setting the communication port
<USB>	Use common USB as communication port.
<RS232>	Use common 9-pin RS-232 connector as communication port.

<Baud Rate>:	Setting the baud rate
	Press the corresponding soft keys and knob to adjust the baud rate. The value can be set as <600>, <1200>, <2400>, <9600>, <19200>, <38000>, <43000>, <56000>, <57600>, <115200>, <230400>, <380400>, <460800> and <921600>.

<Parity>:	Setting the parity
<Even>	Even
<ODD>	Odd
<NONE>	Nothing

Attention: When using USB as the communication port, there is no need to set <Baud Rate> or <Parity>.<Baud Rate> and <Parity> are only use for setting parameters of serial port communication.

4.8.4 <Reset? >: The Lock-in Reset

Press the corresponding soft key and the system will be restarted.

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4.9 [AUTO SET]

There are 4 settings in [AUTO SET] submenu, including <Auto Reserve>, < Auto Gain>, < Auto Phase > and < Auto Scale >, as shown in Fig.42. Soft key [CH A/B SWITCH] is provided for switching between two channels. Users can also switch between two channels through knob.
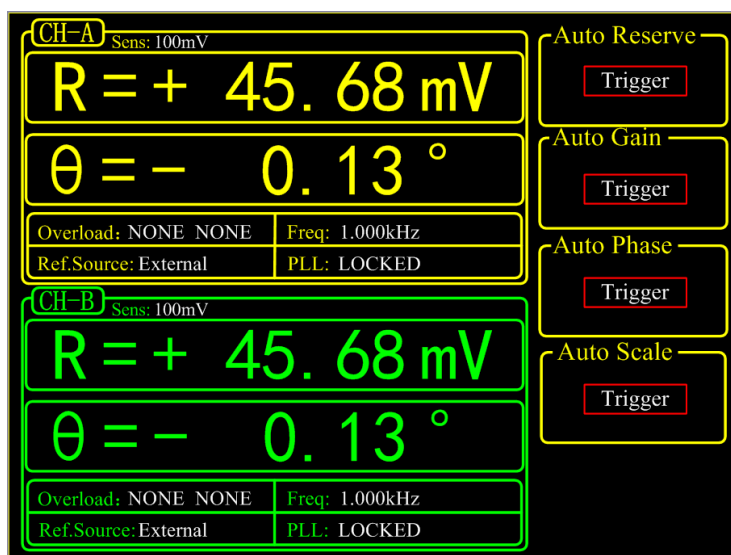
Fig.42 [AUTO SET] Submenu

4.9.1 < Auto Reserve >: Setting the Dynamic Reserve Automatically

Press the < Auto Reserve > button, the system will automatically change the settings of <Reserve> according to the current signal. The principle is to select the minimum dynamic reserve of the current measurement signal.

4.9.2 < Auto Gain >: Setting the Sensitivity Automatically

Press the < Auto Gain> button, the system will automatically change the setting of <Sensitivity> according to the current R. The principle is that the system should choose an appropriate <Sensitivity> but no more than the maximum sensitivity. The < Auto Gain > function in OE1022D needs some response time (generally less than 5s). If the current R fluctuates a lot, the setting for < Auto Gain > might be fail. In this case, users should switch current menu to the [GAIN/TC] submenu and set the R manually.

4.9.3 < Auto Phase >: Setting Phase Shift Automatically

Press the < Auto Phase > button and the system will adjust the phase shift of the reference signal to make the phase of the input signal 0. This < Auto Phase> function needs some response time (generally less than 10s). If the current θ fluctuates a lot, the setting for < Auto Phase > might be fail. In this case, users should switch the current menu to [REF/PHASE] submenu and set θ manually.

4.9.4 < Auto Scale >: Setting Scale Automatically

Press the <Auto Scale> button and the system will adjust the scale according to R to make the displayed value large enough within the range. This < Auto Scale > function only has effect on display. The input and output will not be affected. The scale can also be set through <Range> in the [DISPLAY] submenu.

4.10 [OTHERS]

4.10.1 [CH A/B SWITCH]
Soft key [CH A/B SWITCH] is provided for switching between two channels. Press this soft key to switch from current channel to the other one and configure settings for the other channel.

4.10.2 [CONTROL]
There are 4 buttons in [CONTROL] area, including [START CONT], [PAUSE CLEAR], [CURSOR] and [ACTIVE CHART]. The [CONTROL] menu, alone with [SAMPLE] menu and <CHART>, controls the data sampling to start, pause, reset and also chooses the [CURSOR] and <Chart> to display or not.

4.10.2.1 < START/CONT >: Start or Continue Data Sampling

The [START/CONT] button has two functions. One is to start a new sampling [START], another is to continue the paused sampling [CONTINUE].
Sampling is start and the measured data will be stored in internal buffer as the sampling rate set in [SAMPLE] menu. If in the <Chart> mode, the sampled data will be displayed on <Chart> simultaneously. Otherwise, data will be stored.
In single sampling mode, the sampling will stop automatically when the number of sampling points reaches the sampling length. When sampling process stops, press the [START] button and the system will start sampling again from the beginning until the ending point stops.
If press the [PAUSE] button when the sampling is executing. Sampling will be paused. In this case, press the [START/CONT] button and the sampling process will continue.

4.10.2.2 < PAUSE/CLEAR >: Pause Sampling or Clear Sampling Data

The [PAUSE/CLEAR] button has two functions. One is to pause sampling. Another is to clear the sampling data.

Press this button to pause data sampling when the sampling is executing. The <Chart> will also pause at the same time. Then if press this button one more time, sampling will be stopped and data will be cleared. Besides, the chart will be cleared when in the <Chart> status.

4.10.2.3 < CURSOR >: The Display and Occultation of Cursor in <Chart>

The [CURSOR] button has two functions. One is to display or hide the <Cursor> in <Chart> status. Another is to choose <Cursor> again in other status.

When there is no cursor in <Chart>, this button can call out <Cursor>. Move <Cursor> through spinning the knob and then read the measurement value. If the <Cursor> has been paged out but not chosen (for example, when <Sensitivity> is highlighted and then the knob is only used to set parameters on <Sensitivity>), the <CURSOR> button can pick on <Cursor> again. Press the [CURSOR] again when the <Cursor> is already selected, the <Cursor> will be hidden afterwards. Spin the knob to move <Cursor>. If the <Cursor> exceeds the edge of <Chart>, the <Chart> will change to the next page. <Cursor> can also be positioned directly through <Curve Point> in <Disp More> menu. [CURSOR] makes sense when the data sampling is executing or pausing.

4.10.2.4 < ACTIVE CHART >: Choose <Chart> as the Active Area

The [ACTIVE CHART] is used to choose the <Top> or <Bottom> area of <Chart> as the current active area. <Cursor> only makes sense in active area. The chosen active area will be highlighted at the top-left corner of the <Chart>. The <Chart> in <Full> area is always active. Therefore, the [ACTIVE CHART] button makes no sense to <Full> area.

5. REMOTE PROGRAMMING

5.1 OE1022D Command Syntax

Computers use ASCII characters to communicate with OE1022D. Commands must be in upper case. A command consists of a four-character command mnemonic, arguments if necessary, and a command terminator. The terminator must be a linefeed <lf> or carriage return <cr> on RS232 to USB. No command processing occurs until a command terminator is received. Commands may require one or more parameters. Multiple parameters are separated by commas (,).

Multiple commands may be sent in one command line by separating them with semicolons (;). The difference between sending several commands in the same line and sending several independent commands is that no other commands can be executed before every commands in previous line of commands are executed.

The OE1022D has a 256-character input buffer and processes commands in the order received. If the buffer fills up, the new commands will cover the oldest and processed commands.

OE1022D allows users to query the current value of internal parameters through commands. A query is formed by appending a question mark '?' to the command mnemonic and omitting the desired parameter(s) from the command. Values returned by the OE1022D are sent as a string of ASCII characters terminated by a corresponding terminator. If multiply queries are sent in one command line (separated by semicolons), results will return one by one with a terminator.

Examples of Command Formats

FMOD1<cr>	Set reference source to internal
FREQ10E3<cr>	Set the internal reference frequency to 10kHz
OUTP?1<cr>	Queries the output value of CH1

5.2 Detailed Command List

The parameters in each command sequence specify the command. Different parameters are separated by commas. Parameters shown in {} are optional. Commands that may be queries have a question mark in parentheses (?) after the mnemonic. Do not send () or {} as part of the command.

The variables are defined as follows.

i, j, k, l, m, n, o, p, q, r, s, t, u	integers
x	real numbers
f	frequency

Note that all numeric variables can be expressed in integer, floating point or exponential formats (i.e., the number five can be 5, 5.0, or .5E1). Strings are sent as a sequence of ASCII characters.

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In addition, parameter i represents which channel is selected. 'i=1' indicates that channel A (CH-A) is selected. 'i=2' indicates that channel B (CH-B) is selected

5.2.1 Reference and Phase Commands

PHASD(?) i {,x}   The PHASD command sets or queries the reference phase shift. The parameter i represents the selected channel (A or B). The parameter x refers to the phase (real number, unit: °). The PHASD i x command will set the current phase shift of channel A (i=1) or B (i=2) to x°.
The value of x is rounded to 0.01°. The value of phase shift can be set from -180° to +180°. For example, send command 'PHASD 1 -179.0' and the phase shift of channel A will be set to -179°. The PHASD? 1 command queries the phase shift of channel A.

FMODD(?)i {,j}   The FMOSD command sets or queries the reference source. The parameter i represents the selected channel (A or B).The parameter j selects external reference (j=0), internal reference (j=1) or internal sweep reference (j=2).

FREQD(?) i {,f}   The FREQD command sets or queries the reference signal. The parameter i represents the selected channel (A or B). The parameter f represents frequency (unit:Hz).The FREQD? 1 command will return the current reference frequency of signal from channel A (internal or external).

RSLPD(?) i {,j}   The RSLPD command sets or queries the trigger way of reference signal when in external reference mode.
The parameter i represents the selected channel (A or B). The parameter j selects <TTL> rising edge (j=0) or <Sine> zero crossing (j=1). When the frequency is less than 1 Hz, User must use the <TTL> reference.

SWPTD(?) i {,j}   The SWPTD command sets or queries the mode of internal frequency sweep. The parameter i represents the selected channel (A or B). The parameter j selects <Linear> (j=0) or <Log> (j=1).

SLLMD(?) i {,f}   The SLLMD command sets or queries the <Start> frequency in internal frequency sweep mode. The parameter i represents the selected channel (A or B). The parameter f indicates the start frequency(unit:Hz). The SLLMD? 1 command will return the start frequency of channel A. The range of f is 0-100kHz and the minimum resolution is 1mHz.

SULMD(?) i {,f}   The SULMD command sets or queries the <Stop> cutoff frequency in internal frequency sweep mode. The parameter i represents the selected channel (A or B). The parameter f indicates the stop frequency(unit:Hz).The

SULMD? 1 command will return the cutoff frequency of channel A. The range of f is 0-102kHz and the minimum resolution is 1mHz.

SSLLD(?) i {,f}　　　The SSLLD command sets or queries the step frequency in <Linear> internal frequency sweep mode. The parameter i represents the selected channel (A or B). The parameter f indicates the step frequency(unit:Hz).The SSLLD? 1 command will return the step frequency of channel A. The range of f is 0-102kHz and the minimum resolution is 1mHz.

SSLGD(?) i {,x}　　　The SSLGD command sets or queries the percentage in <Log> internal sweep mode. The parameter i represents the selected channel (A or B). The parameter x indicates the percentage(unit:%). The SSLGD? 1 command will return the percentage of channel A in <Log> frequency sweep mode. The range of x is 0-100 and the minimum resolution is 0.001. x=50 means that the percentage is 50%.

STLMD(?)i {,j}　　　The STLMD command sets or queries the step time in internal frequency sweep mode. The parameter i represents the selected channel (A or B). The parameter j indicates the step time (unit:ms).The STLMD? 1 command will return the step time of internal sweep mode. The range of j is 1ms-100,000ms and the minimum resolution is 1ms.

SWRMD(?)i {,j}　　　The SWRMD command sets or queries the running mode in internal frequency sweep mode. The parameter i represents the selected channel (A or B). The parameter j indicates the running mode. The parameter j selects <STOP> (j=0) , <Single> (j=1) or <Loop> j=2).

HARMD(?) i,j {,k}　　　The HARMD command sets or queries harmonic detection. Parameter i and j are necessary for transmitting this command. The parameter i represents the selected channel (A or B). The parameter j selects harmonic 1(j=1) or harmonic 2 (j=2). The parameter k is an integer from 1 to 32767. The HARMD i,j,k command will set the OE1022D to detect at the kth harmonic of reference frequency. The value of k is limited by k*f≤102kHz. If the frequencyof k^{th} harmonic exceeds102kHz, then j will be set automatically to the maximum value that meets this condition.

SLVLD(?)i {,x}　　　The SLVLD command sets or queries the amplitude of the output synchronous sine wave. The parameter i represents the selected channel (A or B). The parameter x determines the amplitude of voltage (real number, unit: V). The range of x is 0.000Vrms≤x≤5.000Vrms and x is rounded to 0.001Vrms.

SWVTD(?)i {,j}	The SWVTD command sets or queries the output type of \<Sine Output>. The parameter i represents the selected channel (A or B). The parameter j selects fixed amplitude output (j=0), linear amplitude sweeping output (j=1) or logarithm amplitude sweeping output (j=2).
SVLLD(?)i {,x}	The SVLLD command sets or queries \<Start> amplitude in \<Sine Output> sweep mode. The parameter i represents the selected channel (A or B). The parameter x indicates the start amplitude (unit:V).The SVLLD? 1 command will return the start amplitude of sweeping amplitude of channel A. The range of x is 0.001Vrms≤x≤5.000Vrms and the minimum resolution is 0.001Vrms.
SVULD(?)i {,x}	The SVULD command sets or queries \<Stop> cutoff amplitude in \<Sine Output> sweep mode. The parameter i represents the selected channel (A or B). The parameter x indicates the cutoff amplitude (unit:V). The SVULD? 1 command will return the cutoff amplitude of sweeping amplitude of channel A. The range of x is 0.000Vrms≤x≤5.000Vrms and the minimum resolution is 0.001Vrms.
SVSLD(?)i {,x}	The SVSLD command sets or queries \<Step> amplitude in \<Linear> \<Sine Output> sweep mode. The parameter i represents the selected channel (A or B). The parameter x indicates the step amplitude (unit:V).The SVSLD? 1 command will return the step amplitude of linear sweeping amplitude mode of channel A. The range of x is 0.000 Vrms≤x≤5.000Vrms and the minimum resolution is 0.001Vrms.
SVSGD(?)i {,x}	The SVSGD command sets or queries the percentage in \<Log> \<Sine Output> sweep mode. The parameter i represents the selected channel (A or B). The parameter x indicates the percentage (unit:%).The SVSGD? 1command will return the percentage in \<Log> sweep amplitude mode of channel A. The range of x is 0-100 and the minimum resolution is 0.001. x=50 means that the percentage is 50%.
SVTMD(?)i {,x}	The SVTMD command sets or queries step \<Time> in \<Sine Output> sweep mode. The parameter i represents the selected channel (A or B). The parameter x indicates the step time (unit:ms).The SVTMD? 1 command will return the step \<Time> of logarithm amplitude sweeping of channel A. The range of x is 1ms-100,000ms and the minimum resolution is 1ms.
SVRMD(?)i {,j}	The SVRMD command sets and queries the executing mode in \<Sine Output> sweep mode. The parameter i represents the selected channel (A or B). The parameter j indicates the selected mode. The parameter i selects \<Stop> (j=0), \<Single> (j=1) or \<Loop> (j=2).

5.2.2 Equation Commands

EQCDD(?)i{,j,k,l}   The EQCDD command sets or queries the 'R' value of A, B and C in four <Equation>. Parameter i and j are necessary for transmitting this command. The parameter i represents the selected channel (A or B). The parameter j indicates the selected equation. The parameter i selects Equation1(j=1), Equation2(j=2), Equation3(j=3) or Equation4(j=4).

The parameter k, l, m are corresponding to A, B, C in <Equation> and selects the numbers below.

k，l，m	Parameter
0	R
1	X
2	Y
3	θ
4	Rh1
5	Xh1
6	Yh1
7	θh1
8	Rh2
9	Xh2
10	Yh2
11	θh2
12	Noise
13	A1
14	A2
15	A3
16	A4
17	Freq
18	C1
19	C2

For example, send command 'EQCDD 1,2,0,18,17' and then the Equation 2 of channel A will be set as follows: E2=R*C1/Freq.

The EQCDD? i,j command queries the corresponding channel for the configuration parameters of Equation j. Values are returned as the serial number corresponding to A, B, C with the values separated by commas. For example, send command 'EQCDD? 1,2' and return string '0,18,17'. In this case, for the Equation2 of channel A, A is the value of <R>, B is the value of <C1>, C is the value of <Freq>.

EQCSD(?)i{,x}   The EQCSD command sets or queries two coefficients <C1>, <C2>. Parameter i and j are necessary for transmitting this command. The parameter i represents the selected channel (A or B). The parameter j

indicates the selected coefficient. The parameter i selects to set <C1> (j=1) or <C2> (j=2) and is required when sending this command.

The parameter x is used to set the value of coefficients and the range is -10.000≤x≤10.000.

For example, send command 'EQCSD 1,2,5.00' and this will set the <C2> value of channel A to 5.00.

5.2.3 Input and Filter Commands

ISRCD(?)i{,j}   The ISRCD command sets or queries the input configuration. The parameter i represents the selected channel (A or B). The parameter j indicates the input configuration. The parameter j selects A (single input mode) (j=0), A-B (differential voltage input mode) (j=1), I (1 MΩ) (current input, the amplitude is $10^6 V/A$) (j=2) or I (100 MΩ) (current input, the amplitude is $10^8 V/A$) (j=3).

IGNDD(?)i{,j}   The IGNDD command sets or queries the input shield grounding. The parameter i represents the selected channel (A or B). The parameter j indicates the input shield grounding. The parameter j selects Float (j=0) when the input ground is connected to the instrument ground with a 10 kΩ resistor or Ground (j=1) when the input ground is connected to the instrument ground with a 10 Ω resistor.

ICPLD(?)i{,j}   The ICPLD command sets and queries the input coupling. The parameter i represents the selected channel (A or B). The parameter j indicates the input coupling. The parameter i selects AC (j=0) or DC (j=1).

ILIND(?)i{,j}   The ILIND command sets and queries the notch filter status. The parameter i represents the selected channel (A or B). The parameter j indicates the notch filter status. The parameter j selects to close notch filters (j=0), open the 50Hz notch filter (j=1), open the 50Hz and 100Hz notch filter at the same time (I=2) or open the 100Hz notch filter (j=3).

5.2.4 Sensitivity and Time Constants Commands

SENSD(?)i{,j}   The SENSD command sets or queries the sensitivity. The parameter i represents the selected channel (A or B). The parameter j indicates the sensitivity. The parameter i is used to select a different range.

j sensitivity	j sensitivity
0: 1 nV/fA	14: 50 uV/pA
1: 2 nV/fA	15: 100 uV/pA
2: 5 nV/fA	16: 200 uV/pA
3: 10 nV/fA	17: 500 uV/pA

4:	20 nV/fA	18:	1 mV/nA
5:	50 nV/fA	19:	2 mV/nA
6:	100 nV/fA	20:	5 mV/nA
7:	200 nV/fA	21:	10 mV/nA
8:	500 nV/fA	22:	20 mV/nA
9:	1 uV/pA	23:	50 mV/nA
10:	2 uV/pA	24:	100 mV/nA
11:	5 uV/pA	25:	200 mV/nA
12:	10 uV/pA	26:	500 mV/nA
13:	20 uV/pA	27:	1 V/uA

RMODD(?)i{,j}   The RMODD command sets or queries the mode of dynamic reserve. The parameter i represents the selected channel (A or B). The parameter j indicates the mode of dynamic reserve. The parameter i selects <Low Noise> (j=0), <Normal> (j=1) or <High Reserve> (j=2).

OFLTD(?)i{,j}   The OFLTD command sets or queries the time constant of filters. The parameter i represents the selected channel (A or B). The parameter j indicates the time constant of filters. The parameter i selects a time constant below.

i	time constant	i	time constant
1:	10 us	10:	300 ms
2:	30 us	11:	1 s
3:	100 us	12:	3 s
4:	300 us	13:	10 s
5:	1 ms	14:	30 s
6:	3 ms	15:	100 s
7:	10 ms	16:	300 s
8:	30 ms	17:	1000 s
9:	100 ms	18:	3000 s

OFSLD(?)i{,j}   The OFSLD command sets or queries the low pass filter slope. The parameter i represents the selected channel (A or B). The parameter j indicates the low pass filter slope. The parameter i selects <6dB/oct> (j=0), <12dB/oct> (j=1), <18dB/oct> (j=2) or <24dB/oct> (j=3).

SYNCD(?)i{,j}   The SYNCD command sets or queries the status of synchronous filter. The parameter i represents the selected channel (A or B). The parameter j indicates the status of synchronous filter. The parameter i selects Off (j=0) or On (j=1). It is recommended to turn on the synchronous filtering when the reference frequency is less than 200 Hz.

5.2.5 Display and Output Commands

FPOPD(?)j{,k}   The FPOPD i command sets and queries the output channel on the front panel of OE1022D. The parameter j must be set when sending this command. The parameter j selects CH1 (j=1) or CH2 (j=2) as the output channel. The parameter k is used to select the type of output source. More details are as follow.

k	Parameter
0	A-R
1	A-X
2	A-Y
3	A-θ
4	A-Rh1
5	A-Xh1
6	A-Yh1
7	A-θ h1
8	A-Rh2
9	A-Xh2
10	A-Yh2
11	A-θ h2
12	A-Noise
13	A-E1
14	A-E2
15	A-E3
16	A-E4
17	B-R
18	B-X
19	B-Y
20	B-θ
21	B-Rh1
22	B-Xh1
23	B-Yh1
24	B-θ h1
25	B-Rh2
26	B-Xh2
27	B-Yh2
28	B-θ h2
29	B-Noise
30	B-E1
31	B-E2
32	B-E3

33	B-E4

OEXPD(?)j,k {,x,k}

The OEXPD i command sets or queries the output offsets and expands. The parameter j and k must be set when sending this command. The parameter j selects CH1 (j=1) or CH2 (j=2) as the output channel. The parameter k selects the type of parameters below.

k	Parameter
0	A-R
1	A-X
2	A-Y
3	A-Rh1
4	A-Xh1
5	A-Yh1
6	A-Rh2
7	A-Xh2
8	A-Yh2
9	A-Noise
10	B-R
11	**B**-X
12	B-Y
13	B-Rh1
14	B-Xh1
15	B-Yh1
16	B-Rh2
17	B-Xh2
18	B-Yh2
19	B-Noise

The parameter x is used to set the offset and the range is -100.00≤x≤100.00. The parameter l is used to set expand and the range is 1≤l≤256. For example, send command 'OEXPD 1,2,50.00,2' and then the offset of parameter <Y> of channel A is 50%; the output expand is 2. Parameter x and l are required to send this command.

The OEXPD? 1,k command queries channel A for the offset and expand of the corresponding parameter of k. The returned string contains both the offset and expand separated by a comma. For example, if the OEXPD? 1, 2 command returns '50.00,10', then the offset of Y from channel A is 50.00% and the amplification is 10.

SPEDD(?)j{,k}

The SPEDD command sets or queries the executing mode of <Channel Output>. The parameter j selects CH1 (j=1) or CH2 (j=2) as the output channel.

The parameter i selects <Slow> (k=0) or <Fast> (k=1).

In the <Fast> mode, the output can only choose <R>, <X> and <Y>. If in <Slow> mode and the current choice is not <R>, <X> or <Y>, then when switching to <Fast> mode, the output will choose <R> automatically.

5.2.6 Save and Read Settings Commands

SSETD i   The SSETD i command saves the current setup in setting buffer i (1≤i≤4). The parameter i selects S1 (i=1), S2 (i=2), S3 (i=3) or S4 (i=4). OE1022D can store settings even after the power is turned off

RSETD i   The RSETD i command recalls the saved setup information from buffer i (1≤i≤5). After delivering the RSETD i command, the internal parameters will be set as corresponding parameters in the setting buffer i. The parameter i indicates S1 (i=1), S2 (i=2), S3 (i=3), S4 (i=4) and Default (i=5).Please note that S1,S2,S3,S4 are user-defined settings,S5 is the default setting. For example, command 'RSETD 5' will restore the factory configuration.

5.2.7 Auto Set Commands

AGAND i   The AGAND command performs the Auto Gain function. It is the same as pressing the [Auto Gain] key. Auto Gain may take some time if the time constant is long. The parameter i represents the selected channel (A or B).

ARSVD i   The ARSVD command performs the Auto Reserve function. It is the same as pressing the [Auto Reserve] key. Auto Reserve may take some time. The parameter i represents the selected channel (A or B).

APHSD i   The APHSD command performs the Auto Phase function. It is the same as pressing the [Auto Phase] key. The parameter i represents the selected channel (A or B).The outputs will take some time to reach their new values. Do not send a new APHSD command without waiting the appropriate amount time. If the phase is unstable, then APHSD will do nothing.

Use PHAS? Command to query the new value of the phase shift and see if APHSD changed the phase shift.

ASCLD i   The ASCLD command performs the Auto Scale function. It is the same as pressing the [Auto Scale] key. The parameter i represents the selected channel (A or B).

5.2.8 Data Store Commands

SRATD(?)i{,x}   The SRATD command sets or queries the step time of data sampling. The

parameter i represents the selected channel (A or B). SRATD? 1 command will queries channel A for the value of step time in sampling. The setting range of i is 1ms-100,000ms. The minimum resolution is 1ms.

SLEND(?)i{,j}   The SLEND command sets or queries the length of data sampling. The parameter i represents the selected channel (A or B). The parameter j indicates the length of data sampling. The maximum length is 16384.

SSLED(?)i,j{,k}   The SSLED command sets or queries the chosen parameters in four buffers. The parameter i represents the selected channel (A or B). The parameter j indicates the chosen parameters. The parameter i must be set when sending this command. The parameter i selects <Buffer 1> (k=1), <Buffer 2> (k=2), <Buffer 3> (k=3) or <Buffer 4> (k=4). The parameter j means the recorded measurement value in buffers.

The parameter k selects the parameters as the following.

k	Parameter
0	R
1	X
2	Y
3	θ
4	Rh1
5	Xh1
6	Yh1
7	θh1
8	Rh2
9	Xh2
10	Yh2
11	θh2
12	Noise
13	A1
14	A2
15	A3
16	A4
17	E1
18	E2
19	E3
20	E4
21	Freq

STRGD(?)i{,j}   The STRGD command sets or queries the trigger way of data sampling. The parameter i represents the selected channel (A or B). The parameter j indicates the trigger way of data sampling. The parameter j selects inner trigger mode

<INT> (j=0) or outer trigger mode <EXT> (j=1).

SPRMD(?)i{,j}   The SPRMD command sets or queries the mode of data sampling. The parameter i represents the selected channel (A or B). The parameter j indicates the mode of data sampling. The parameter j selects <Single> mode (j=0) or <Loop> mode (j=1).

STRDD i   The STRDD command starts or continues data sampling. The parameter i represents the selected channel (A or B). The parameter i demands channel A (i=1), channel B (i=2) or both channels (i=3) to starts or continues data sampling.

PAUSD i   The PAUSD command pauses data sampling. The parameter i represents the selected channel (A or B). The parameter i indicates the mode of data sampling. The parameter i demands channel A (i=1), channel B (i=2) or both channels (i=3) to pauses data sampling.

RESTD i   The RESTD command resets the data buffers. This command will empty the four data buffers, including Buffer1 ~ Buffer4. The parameter i represents the selected channel (A or B). The parameter i indicates the mode of data sampling. The parameter i demands channel A (i=1), channel B (i=2) or both channels (i=3) to resets the data buffers.

5.2.9 Data Read Commands

OUTPD? i,j   The OUTPD? i,j command is used to read a single parameter 'R' value. The parameter i represents the channel to be selected ('i=1' means channel A , 'i=2' represents channel B). The parameter j selects the parameters as the following.

j	Parameter
0	X
1	Y
2	R
3	θ
4	Xh1
5	Yh1
6	Rh1
7	θ h1
8	Xh2
9	Yh2
10	Rh2
11	θ h2

12	Noise
13	A1
14	A2
15	A3
16	A4
17	Freq

Values are returned as ASCII floating point numbers with units of Volts, degrees or Hz. This command is a query only command.

SNAPD?i,j,k{l, m,n }

The SNAPD? i,j,k command records the values of no more than 5 parameters at a single instant. The parameter i represents the channel to be selected (i=1 means channel A , i=2 represents channel B).

For example, SNAPD? 1 is a way to query channel A for 'R' values of <X>, <Y>, (or <R>, <θ> , <F>) which are taken at the same time. This is convenient when the time constant is very short. Using the OUTPD? command will result in time delays, which may be greater than the time constant, between reading two different parameters.

The SNAPD? command requires at least three parameters and at most five parameters. The parameters j, k, l, m, n select the parameters below.

j, k, l, m, n	Parameter
0	X
1	Y
2	R
3	θ
4	Frequency
5	Xh1
6	Yh1
7	Rh1
8	θh1
9	Xh2
10	Yh2
11	Rh2
12	θh2
13	Noise
14	A1
15	A2
16	A3
17	A4
18	E1
19	E2

20	E3
21	E4

The requested values return in a single string with the values separated by commas. For example, the SNAPD?1,1,2,5,4 will query channel A for the values of <X>, <Y>, <Frequency> and <θ>. These values returns in a single string such as '0.951359,0.0253297,1000.00,1.234'. The first value is <X>, the second is <Y>, the third is <Frequency> and the fourth is <θ>.

The SNAPD? command is only used for recording various parameters simultaneously.

SPTSD? i   The SPTSD? i command queries the number of points stored in the buffer. The parameter i represents the channel to be selected (i=1 means channel A , i=2 represents channel B). This command can be sent at any time. If the data buffer is reset, then 0 is returned. This command is a query only command.

TRCAD?i,j,k,l   The TRCAD? i,j,k,l command queries the data (Buffer1~Buffer 4) in the channel j Buffer.

The values return in ASCII floating-point format with the units of the trace. Multiple points are separated by commas (,) and the final point is followed by a terminator. For example, the response of two points might be '-1.234567e-009, +7.654321e-009'.

All parameter (i,j,k,l) are necessary for transmitting this command. The parameter i represents the channel to be selected (i=1 means channel A , i=2 represents channel B).The parameter j selects the display buffer (j=1,2,3,4) and is required to send with this command. Points are read from the buffer starting at bin k (k≥0); A total of l bins are read (l≥1); To read a single point, set l=1. Both k and l are required. If k+l exceeds the number of stored points (as returned by the SPTSD? query), then an error occurs. Therefore, the value of k+l should be no more than 16384 which is the maximum number of data stored in the buffer.

The INOVD? i command check whether the current input signal is too excessive, which would lead to preamplifier overload. The parameter i represents the channel to be selected (i=1 means channel A , i=2 represents channel B).This command returns 0 if the current input signal meets the usage conditions. In case of overload, return value is integer '1'.

This command is a query only command.

The GNOVD? i command check whether the sensitivity or reserve are too low, which would lead to amplification overload. The parameter i represents the

channel to be selected (i=1 means channel A , i=2 represents channel B).This command returns 0 if the current input signal meets the usage conditions. In case of overload, return value is integer '1'.

This command is a query only command.

The *PLLD? i command check whether the internal PLL locks on to reference signal. The parameter i represents the channel to be selected (i=1 means channel A , i=2 represents channel B).This command always returns 0 in internal reference mode. In external reference mode, frequency of PLL varies with frequency of external reference signal, If frequency of PLL coincides with frequency of external reference signal, return value is integer '1'. Otherwise, return value is 0.

This command is a query only command.

5.2.10 Reset and IDN Commands

*RSTD   The *RSTD command is used to reset OE1022D to its default configurations. All internal status and parameters are set to their default conditions and values. Data stored in the buffers will be lost.

*IDND?   The *IDND? command returns the OE1022D's device identification string. This string is in the format 'SSL LIA-OE1022D, SNXXXXXX, VerXXX'. In this example, the model name is OE1022D; the serial number is SN0001; the firmware version is Ver1.00.

6. COMPUTER OPERATION

6.1 Install Software

The CD we provide contains computer control software and drivers.contents of disc file are shown below in Fig 43.

Name	Date modified	Type	Size
OE1022D Software Driver	7/30/2019 5:37 PM	File folder	
OE1022D_Console_UART_CN	7/30/2019 5:37 PM	File folder	
OE1022D_Console_USB	7/30/2019 5:37 PM	File folder	
Uart Assistant	5/8/2019 5:31 PM	File folder	
UART Driver	7/30/2019 5:37 PM	File folder	
USB Driver	7/30/2019 5:38 PM	File folder	
OE1022D_User_Manual_CN.pdf	9/19/2017 7:23 PM	Foxit Reader PDF ...	6,123 KB
Readme.txt	5/8/2019 7:46 PM	Text Document	2 KB

Fig.43 CD disc files.

Step 1:Install Labview and VISA

1. Software NI LabView 2011 or higher version is required. This software can be downloaded easily from the NI official website.

2. After the installation of Labview, install Visual Instrument Software Architecture(VISA), which is provided in the CD folder as shown in Fig.43.

名称	修改日期	类型	大小
bin	7/10/2018 5:44 ...	文件夹	
license	7/10/2018 5:44 ...	文件夹	
supportfiles	7/10/2018 5:44 ...	文件夹	
nidist.id	3/14/2014 11:23...	ID 文件	1 KB
setup	1/20/2012 12:29...	应用程序	1,382 KB
setup	3/14/2014 11:23...	配置设置	27 KB

Fig.44 "OE1022D VISA" files.

To install VISA, double click the 'setup.exe' file. Generally, selecting the default installation option would be enough to install VISA successfully.

Attention:

1. LabView requires a restart of PC to finish installing.

2. If there already exists NI LabView 2011 or higher version, and the VISA of the according version is already installed. Skip step 1 and begin from step 2 as follows.

Step 2:Install Serial Port Driver

There are two types of interface drivers for OE1022D. User can select any one of them according to requirements.

Detail instructions for Installation of RS232 serial port driver:

Open file 'Uart Driver' in Fig 43, as shown in Fig.45.

Name	Date modified	Type
📁 Inf installation file	8/14/2017 3:50 PM	File folder
FT232_drive.exe	3/8/2017 2:36 PM	Application
📄 readme.txt	9/22/2014 3:01 PM	Text Document

Fig.45 'Uart Driver' files

Double-click 'FT232_driver.exe', a popup window would display as shown in Fig 46, which means RS232 Serial Port Driver is under installation. Installation may take a few minutes. Please wait.
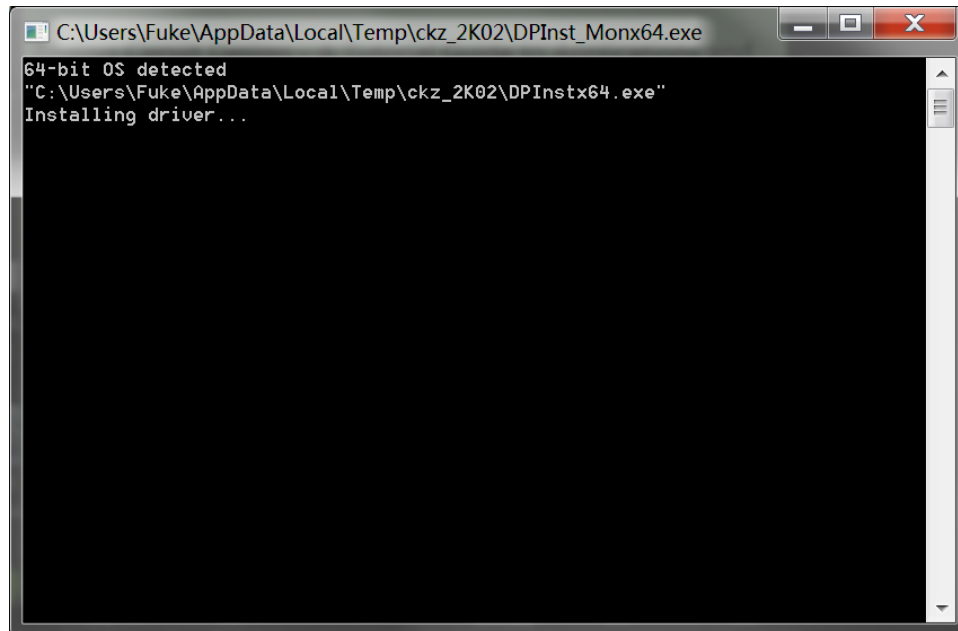
Fig.46 installation widow of FT232 driver

After the successful installation of the serial port driver, a message would show in the installation window, as shown in Fig 47. Press "Enter" to finish the installation process.
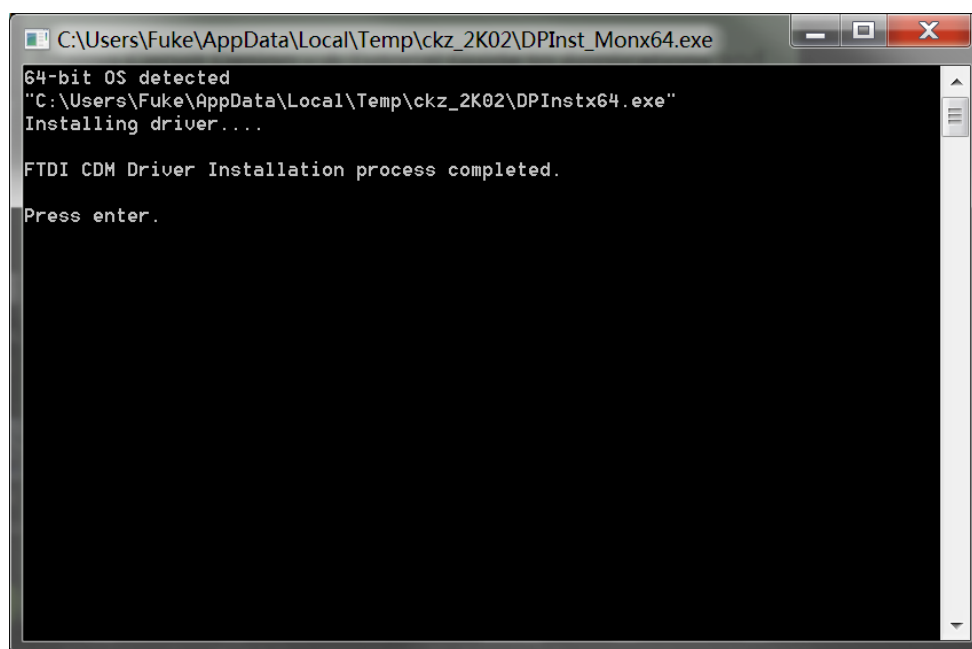
<p align="center">Fig.47 Sucessful installation of FT232</p>

After the installation, connect PC and OE1022D through a serial port line. PC should be able to detect OE1022D automatically.

Attention:

1. When the PC is connected to OE1022D with a USB line, and if the computer is already connected to the Internet, PC would search for the proper driver online and install it automatically.

2. If the computer has already installed the driver to convert serial port to USB, there is no need to install the FT232 driver.

3. If installation failed, user could use the 'inf installation file' in Fig.45 to install. For more details, please read the 'readme.txt' file.

Detail instructions for Installation of USB driver:

Open the fourth file 'USB Driver' in Fig.43, as shown in Fig.48:

<p align="center">Fig.48 'USB Driver' file</p>

There are many versions of USB2.0 driver. User can select different version according to their PC system. Double click the specific version of file to begin the installation process. Generally, selecting the default installation option would be enough to install the USB driver successfully.

Attention: There is no need to install USB2.0 driver on win10 system. For win10 system, simply plug in USB line, Labview software on PC would automatically connect to OE1022D.

Step 3: Run OE1022D_Console_EN.

After the installation of Labview, VISA, and drivers, users can use a communication interface of their choice to connect the computer with OE1022D. To use USB2.0, open folder 'OE1022D_console_USB'. To use RS232 serial port, open folder 'OE1022D_console_RS232'. Both folders contain the following file:

Name	Date modified	Type	Size
SSI OE1022D_Console_EN.exe	17/02/2019 16:31	Application	1,588 KB

Fig.49 "OE1022D_Console"file

Double click the file 'OE1022D_Console_EN.exe' in Fig 49, if previews installation is correct, following window would display on the screen. Now, user can configure parameters of OE1022D lock-in amplifier on PC.
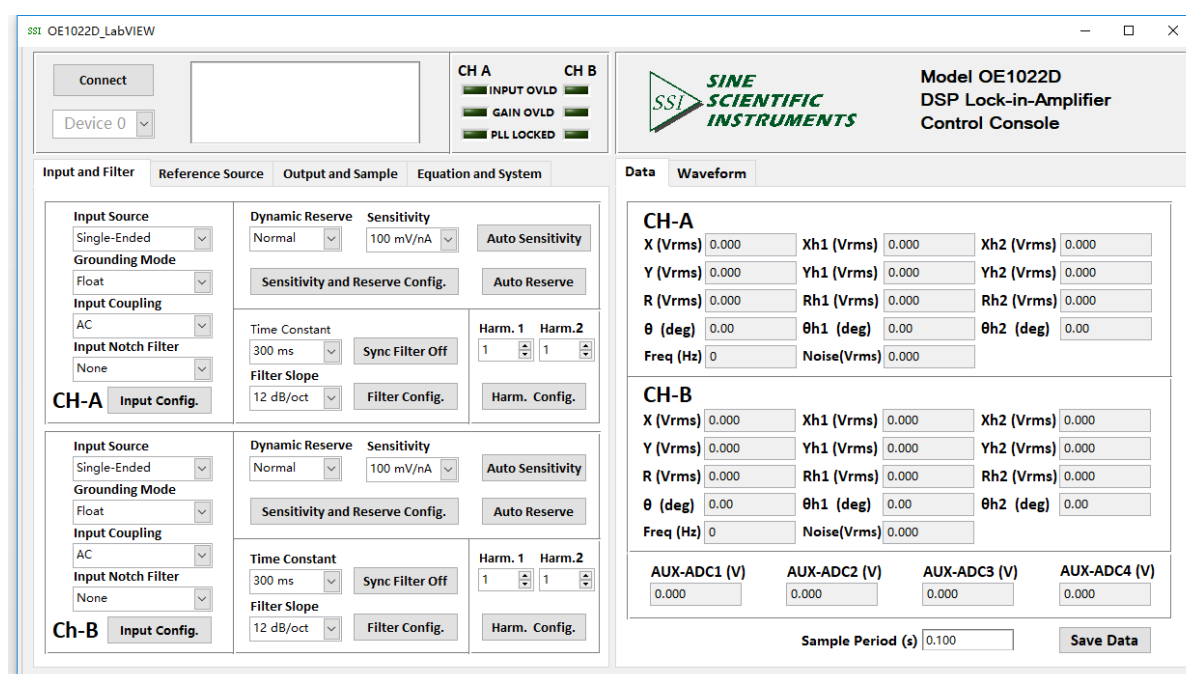
Fig.50 OE1022D Software Interface

6.2 How to Use the Software

6.2.1 Run 'OE1022D_LabVIEW.exe'

This part shows you how to connect the PC and the OE1022D.
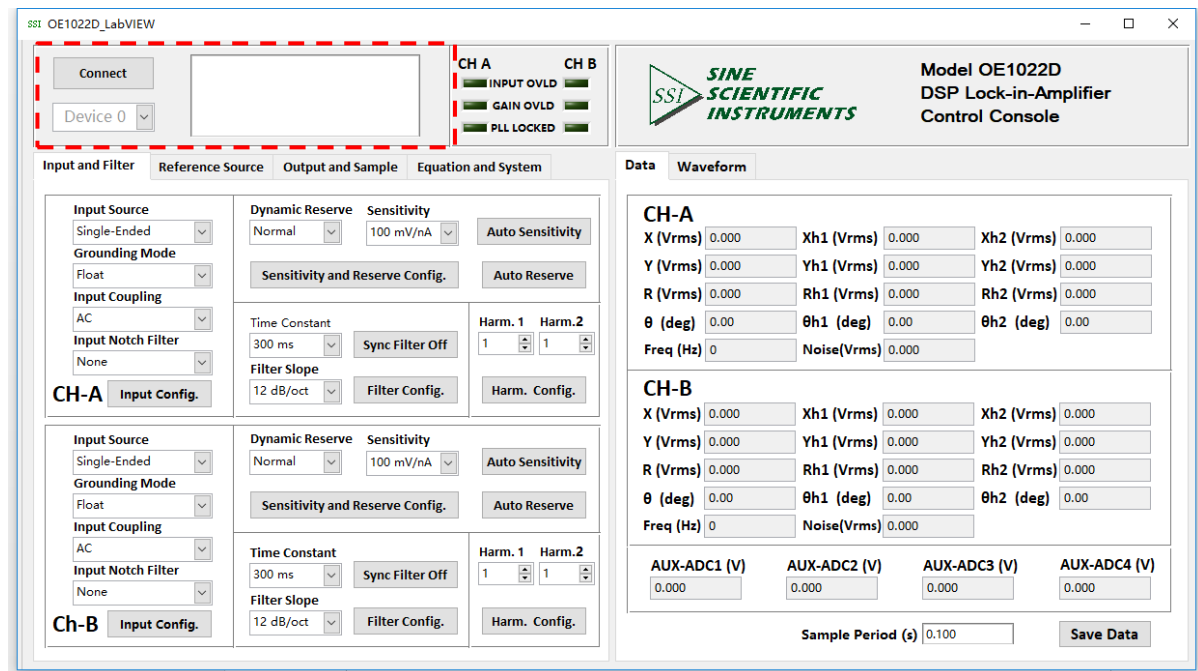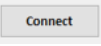
Fig.53 OE1022D Interface

As shown in Fig 51, click the button Connect .

The program begins to run and search for the proper COM automatically. If the connection succeeds, you will see the connection message and version information as shown in Fig.54.
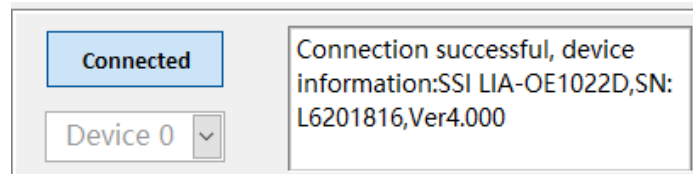
Fig.54 Connection Succeeds

Wait for a few seconds. If the interface displays messages as Fig.55 or Fig.56, it means that the connection between PC and OE1022D fails.
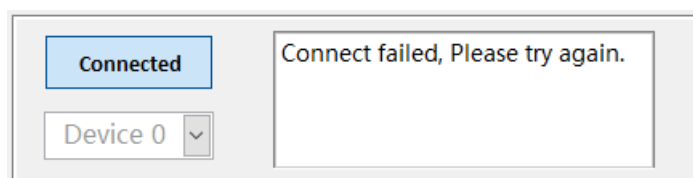
Fig.55 USB device search fails.
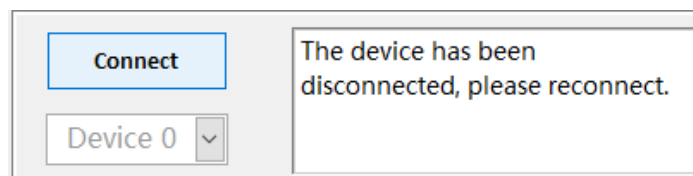
Fig.56 Connection fails

In this case, first step, please check if the USB connection between OE1022D and PC is correct or not. Second step, press the 'system' soft key, and then choose the 'Remote' option, choose 'USB' option in the 'Remote' side box. User can also simply recall the default settings. At last, rerun the OE1022D_LabVIEW.exe.

After connection successes, the data in red box will be empty and it will restart automatically to display parameters in real time, as shown in Fig.57.

The software interface will display the current configuration of the OE1022D. User can set change configuration shown on the GUI.
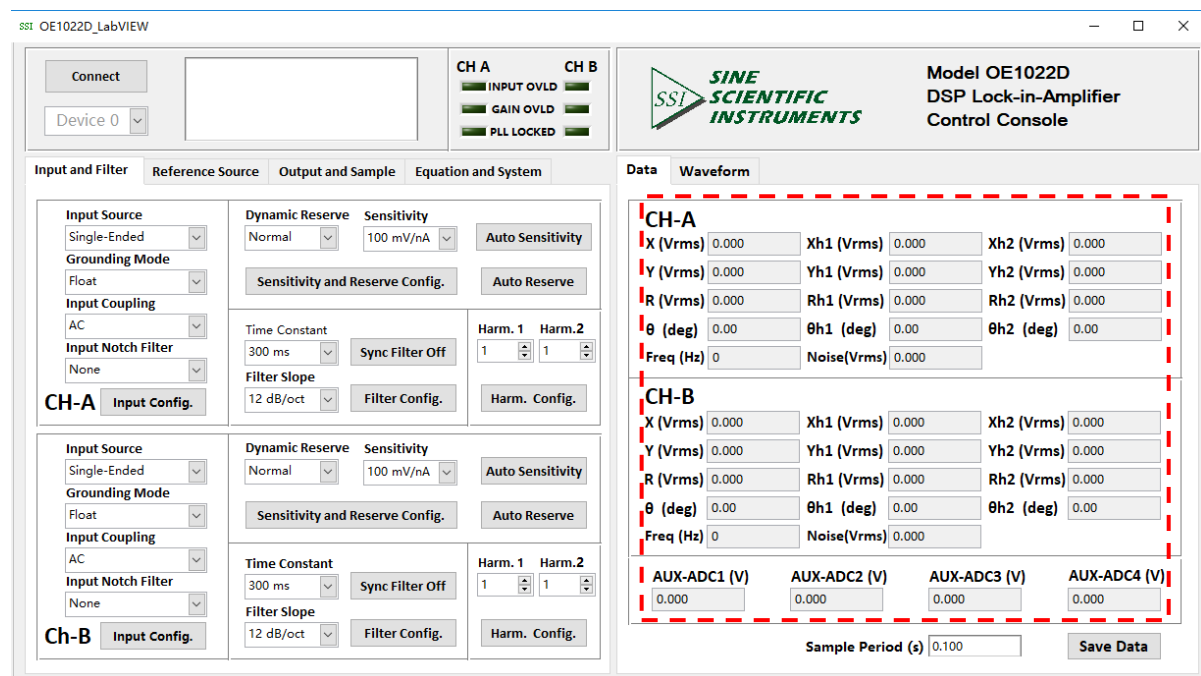
Fig.57 OE1022D Software Connection Succeeds

6.2.3 Input and Filter Configuration

The program configuration area of input signal and filter are shown in the red box in Fig.58

Fig.58 The Configuration Area of Input Signal and Filter

Input mode can be configure according to characteristic of signal-under-test. For example, in order to eliminate power interference, user can turn on the notch filter; In case of large noise, user can select high reserve; If the frequency is under 200Hz, user can turn on Synchronized Filters. User can also specify values of harmonics number. For example, in order to measure the fundamental wave and the 3rd order harmonic, user can set the parameters as follows: harmonic 1 = 1, harmonic 2 = 3.

The following sections provide detailed description of the configuration area.

6.2.3.1 Input Configuration

The program configuration area of input signal is as shown in the red box in Fig.59. The details of the configuration are listed on Table 3.
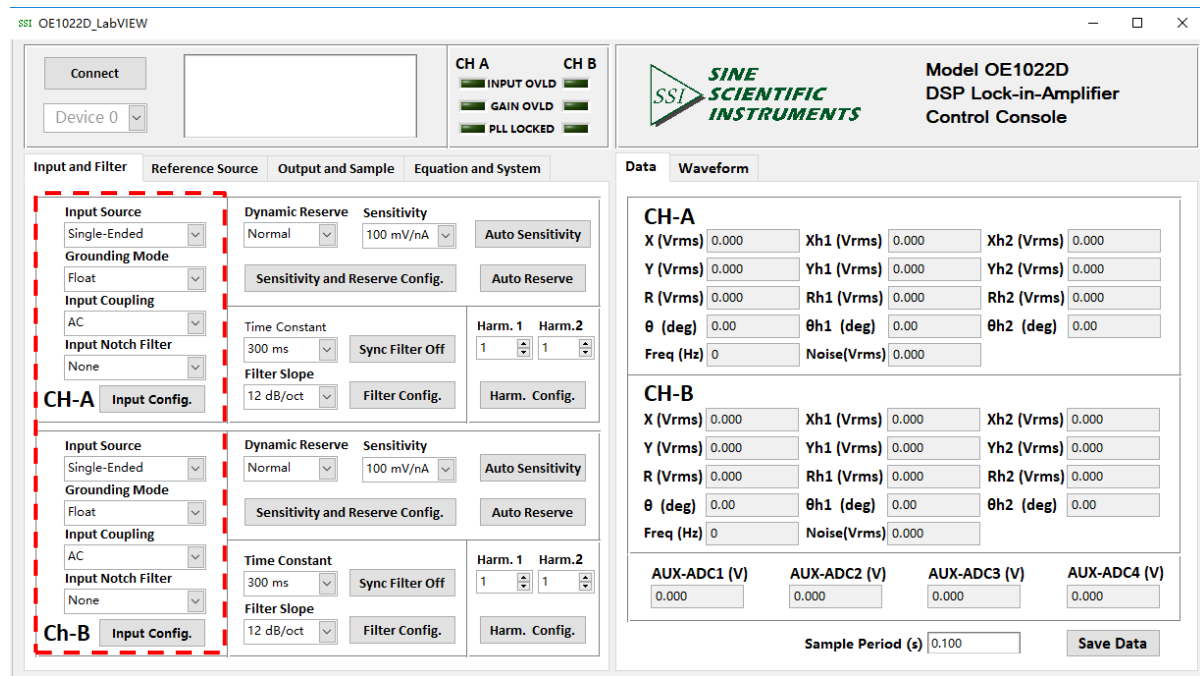
Fig.59 Configuration area of Input Signal

Table 3. Input Configuration

	Single-Ended Voltage
Input Source	Differential Voltage
	1 MOhm Current Gain
	100 MOhm Current Gain
Input Shield Grounding	Float
	Ground
Input Coupling	AC
	DC
	None
Input Notch Filter	Line Notch
	Both Notch Filters
	2x Line Notch

Note that:

1. After setting all the configurations, click [Input Config.] to finish configuration for input signal. All settings can be changed simultaneously and you only need to click this button once.

2. After changing the settings, you need to click [Input Config.] to finish configuration. Otherwise, changes of settings would not be saved.

6.2.3.2 Dynamic Reserve and Sensitivity Configuration

The program configuration area of reserve and sensitivity is shown in the red box in Fig.60. The details of the configuration are listed on Table 4.
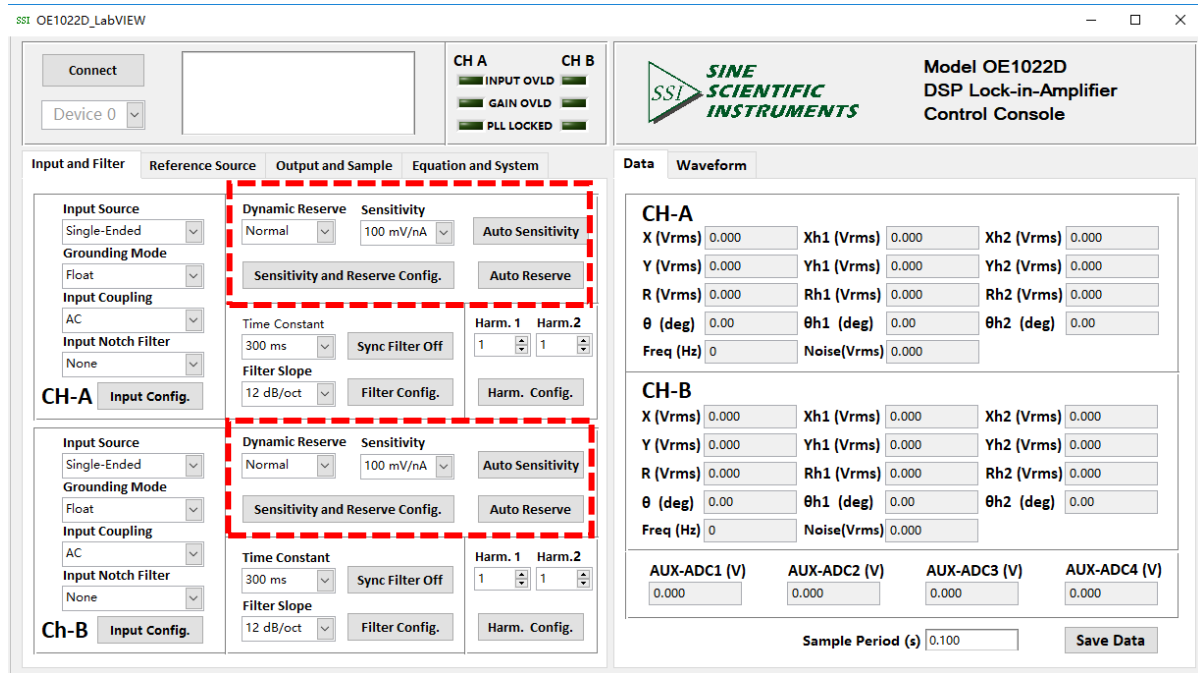
Fig.60 The Configuration area of Reserve and Sensitivity

Table 4. Dynamic Reserve and Sensitivity Configuration

Dynamic Reserve	Low Noise			
	Normal			
	High Reserve			
Sensitivity	1 nV/fA	200 nV/fA	50 uV/pA	10 mV/nA
	2 nV/fA	500 nV/fA	100 uV/pA	20 mV/nA
	5 nV/fA	1 uV/pA	200 uV/pA	50 mV/nA
	10 nV/fA	2 uV/pA	500 uV/pA	100 mV/nA
	20 nV/fA	5 uV/pA	1 mV/nA	200 mV/nA
	50 nV/fA	10 uV/pA	2 mV/nA	500 mV/nA
	100 nV/fA	20 uV/pA	5 mV/nA	1 V/uA
Auto Sensitivity	Disable/Enable			
Auto Reserve	Disable/Enable			

Note that:

1. After finishing all the settings, click the button ![Sensitivity and Reserve Config.] to finish the configuration for input signal. All settings can be changed simultaneously and you just need to click this button once.

2. Once you change the settings, you need to click [Sensitivity and Reserve Config.] to finish this configuration. Otherwise, changes of settings will not be saved.

6.2.3.3 Filter Configuration

The filter configuration is in the red box of the Fig.61. The details of configuration are listed on the Table 5.
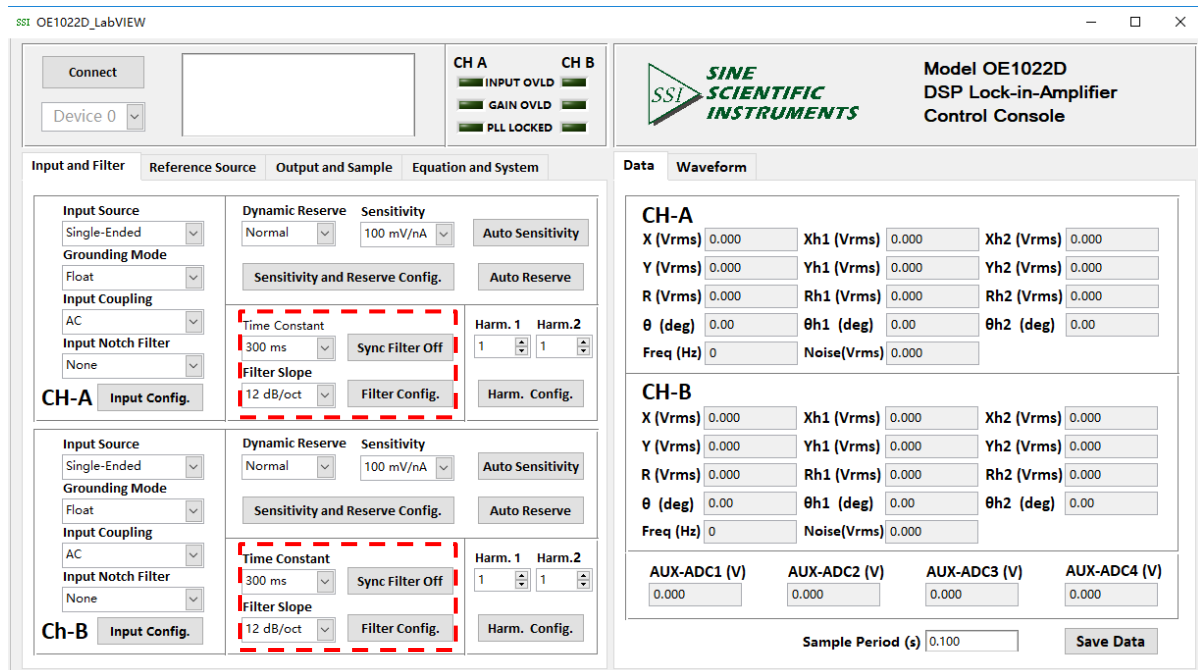
Fig.61 The Configuration Area of Filter

Table 5. Filter Configuration

Time Constant	10 us	3 ms	1 s	300 s
	30 us	10 ms	3 s	1000 s
	100 us	30 ms	10 s	3000 s
	300 us	100 ms	30 s	
	1 ms	300 ms	100 s	
Sync Filter	Disable/Enable			
Filter Slope	6 dB/oct 12 dB/oct 18 dB/oct 24 dB/oct			

Note that:

1. After choosing all the settings, click the button [Filter Config.] to finish the configuration. All settings can be changed simultaneously and you just need to click this button once.

2. Please remember to click the button [Filter Config.] after changing the settings. Otherwise, changes of settings will not be saved.

3. The configurations of 'Sync Filter' is relatively independent. It is recommended to turn the 'Sync Filter' on when the frequency of reference signal is under 200Hz. User can turn 'Sync Filter' on by simply click [Sync Filter Off] once. If you need to close the sync filter, click this button again and it will reset to the start status.

6.2.3.4 Harmonic Configuration

The harmonic configuration is in the red box in the Fig.62. The details of configuration are shown in Table 6.
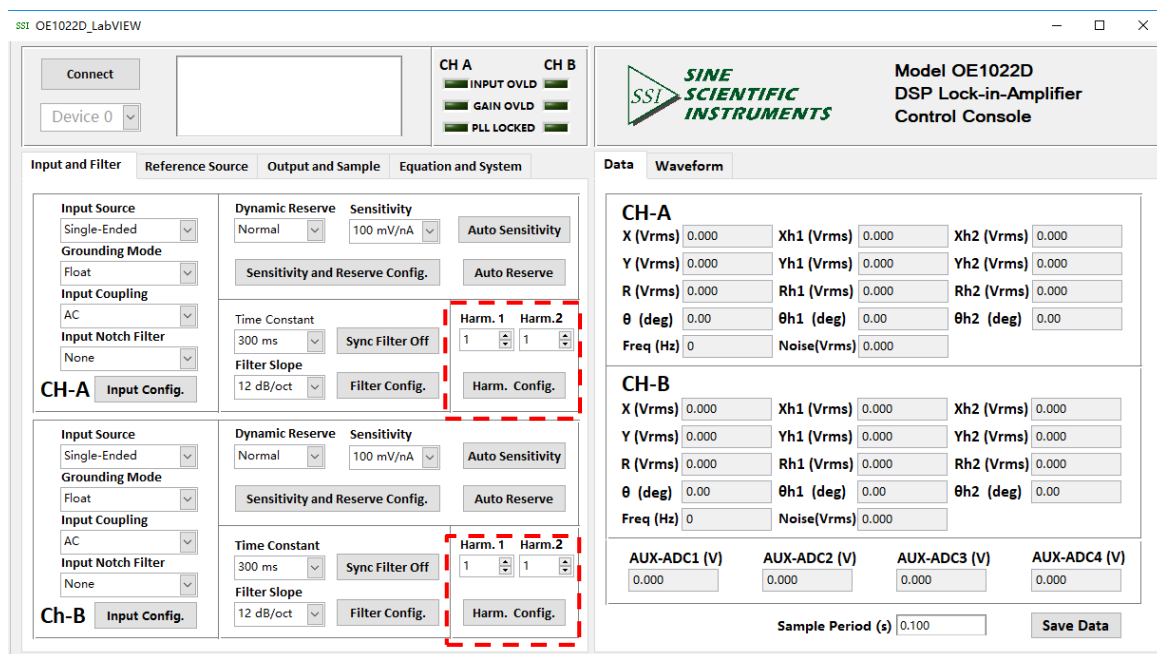
Fig.62 The Configuration Area of Harmonic Settings

Table 6. Harmonic and Auto Setting Configuration Options

Harmonic 1	Manually, the range is 1-32767.
Harmonic 2	Manually, the range is 1-32767.
Auto Scale	Disable / Enable

Note that:

1. After choosing all the settings, click the button [Harm. Config.] to finish the configuration. All settings can be changed simultaneously and you just need to click this button once.

2. The configurations of 'Auto Sensitivity',' Auto Reserve',' Auto Phase' and' Auto Scale' are relatively independent.

6.2.4 Reference Source Configuration

The program configuration area of input signal and filter are shown in the red box in Fig.63
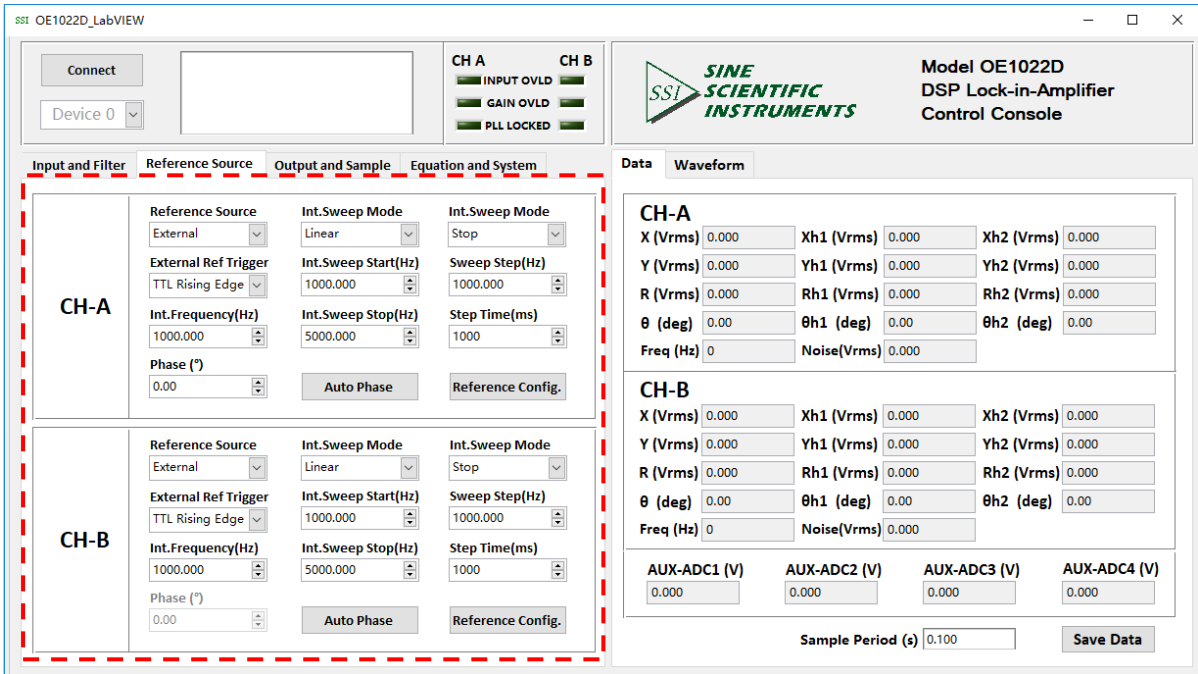
Fig.63 The Configuration Area of Reference Source

The area of output and sample configuration is provided for setting configuration. The following sections provide detailed description of the configuration area.

6.2.4.1 Reference Signal Configuration

The configuration area of reference signal is shown in the red box in Fig.64. The details of configuration are shown in Table 7.
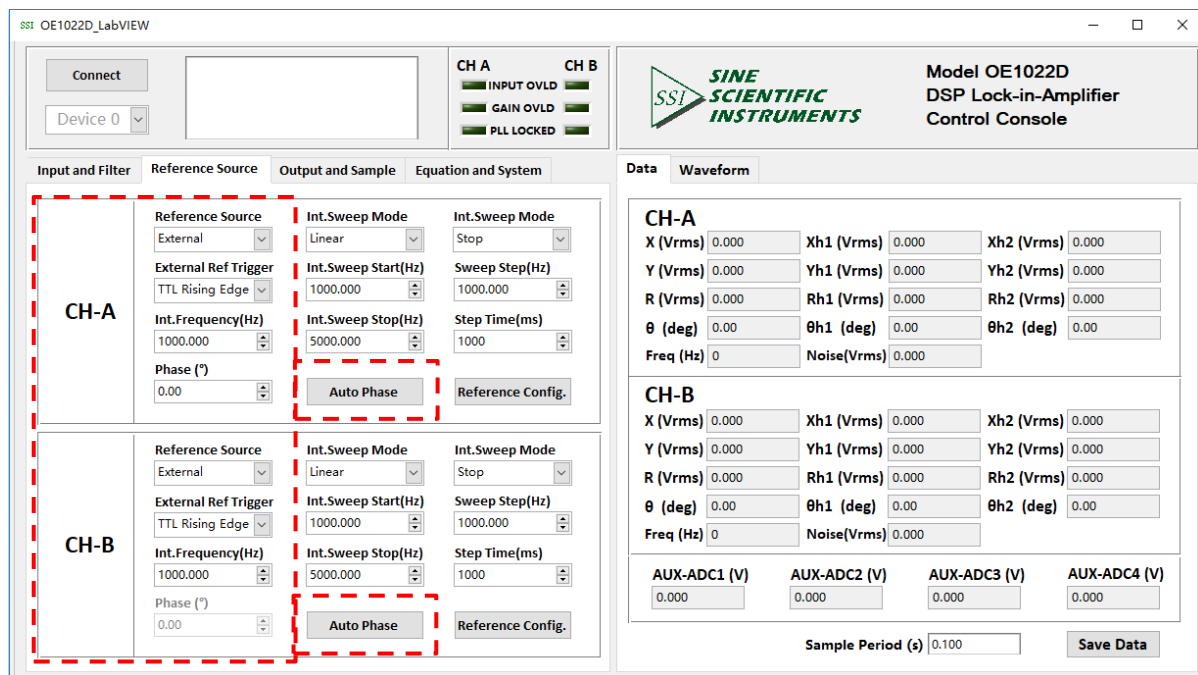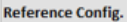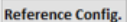
Fig.64 The Configuration Area of Reference Signal

Table 7. Reference Signal Configuration

	External
Reference Source	Internal
	Int. Sweep
External Ref Trigger	TTL Rising Edge
	Sine Zero Crossing
Int.Frequency	User is required to input manually, frequency range from 1mHz to 102kHz, minimum frequency resolution is 1mHz.
Phase(°)	Configure the phase shift of two quadrature reference signals of PSD algorithm. Phase accuracy is 0.01°. Input range from -180° to +180°.
Auto Phase	Disable/Enable

Note that:

1. After finishing all the settings, click the button [Reference Config.] to finish the configuration for input signal. All settings can be changed simultaneously and you just need to click the button once.

2. After changing the settings, you need to click [Reference Config.] to finish this configuration. Otherwise, changes of settings will not be saved.

Frequency Sweep Configuration:

The configuration area of internal frequency sweep as shown in Fig 63. The details of configuration are shown in Table 8.
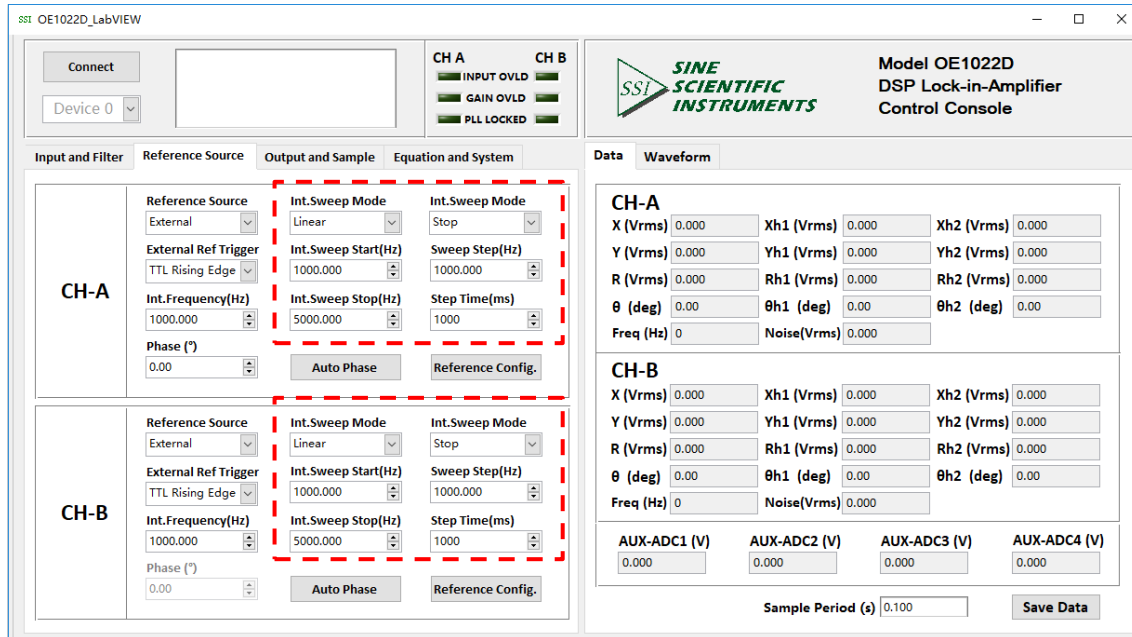
Fig.65 The Configuration Area of Internal Frequency Sweep

Table 8. Internal Sweep frequency Reference Configuration

Int.Sweep Type	Linear
	Log
Int.Sweep Run Mode	Single
	Loop
	Stop
Int.Sweep Start(Hz)	User is required to input the sweep start frequency manually, frequency ranges from 1mHz to 102kHz. Minimum frequency resolution is 1mHz.
Int.Sweep Step(Hz)	User is required to manually input the step value of linear sweep or logarithmic sweep. Linear sweep: frequency ranges from 1mHz to 102kHz. Minimum frequency resolution is 1mHz. Logarithmic sweep: value of step range from 0.001%~100 %
Int.Sweep Stop(Hz)	User is required to input the stop frequency of sweep manually, frequency ranges from 1mHz to 102kHz. Minimum frequency resolution is 1mHz.
Linear Step Time(ms)	User is required to input the step time which ranges from 1 ms to 100 s. Minimum step time is 1ms.

Note that:

After finishing all the settings, click the button [Reference Config.] to finish the configuration for input signal. All settings can be changed simultaneously and you just need to click this button once.

6.2.5 Output and Sample Configuration
The output and sample configuration is in the red box of the Fig.66.
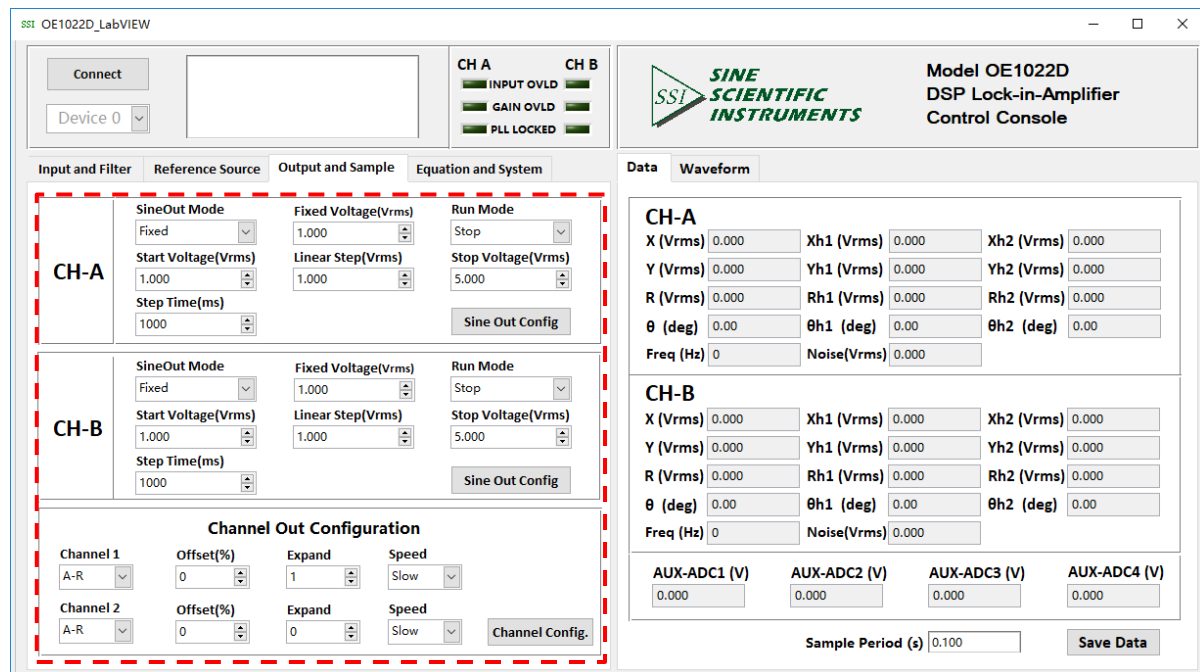
Fig.66 The Configuration Area of Output and Sample

The area of Output and Sample configuration is provided for setting voltage or mode of the sine output signal and Channel Out configuration. The following sections provide detailed description of the configuration area.

6.2.5.1 Sine Output Configuration
The sine output configuration is shown in the red box in Fig.67. The details of configuration are shown in Table 9.
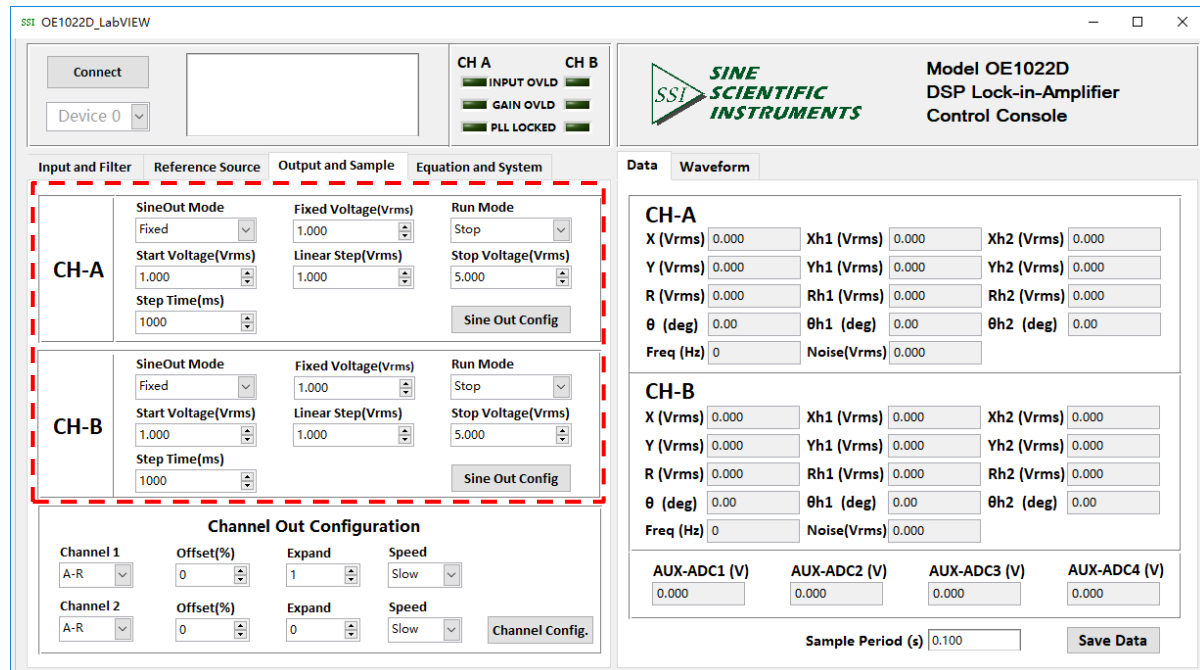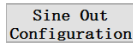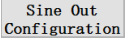
Fig.67 The Configuration Area of SINE OUTPUT

Table 9. Sine Output Configuration Options

	Fixed
Sine Out Mode	Linear
	Log
Sine Out Voltage (Vrms)	Set the amplitude of sine output manually when Sine Out Mode is 'Fixed'. The peak-peak voltage is 1mVrms to 5Vrms, the minimum resolution is 1 mVrms.
Sine Out Start Voltage (Vrms)	Set the start frequency of sweep manually. The frequency range is 1mVrms to 5Vrms, the minimum resolution is 1 mVrms.
Sine Out Stop Voltage (Vrms)	Set the stop frequency of sweep manually. The frequency range is 1mVrms to 5Vrms, the minimum resolution is 1 mVrms.
Step Time (ms)	Set the step time manually. The range is 1ms to 100s, the minimum resolution is 1 ms.
Linear Step (Vrms)	Set the step frequency manually. The range is 1mVrms to 5Vrms, the minimum resolution is 1 mVrms.
Sine Out Run Mode	Single
	Loop
	Stop

Note that:
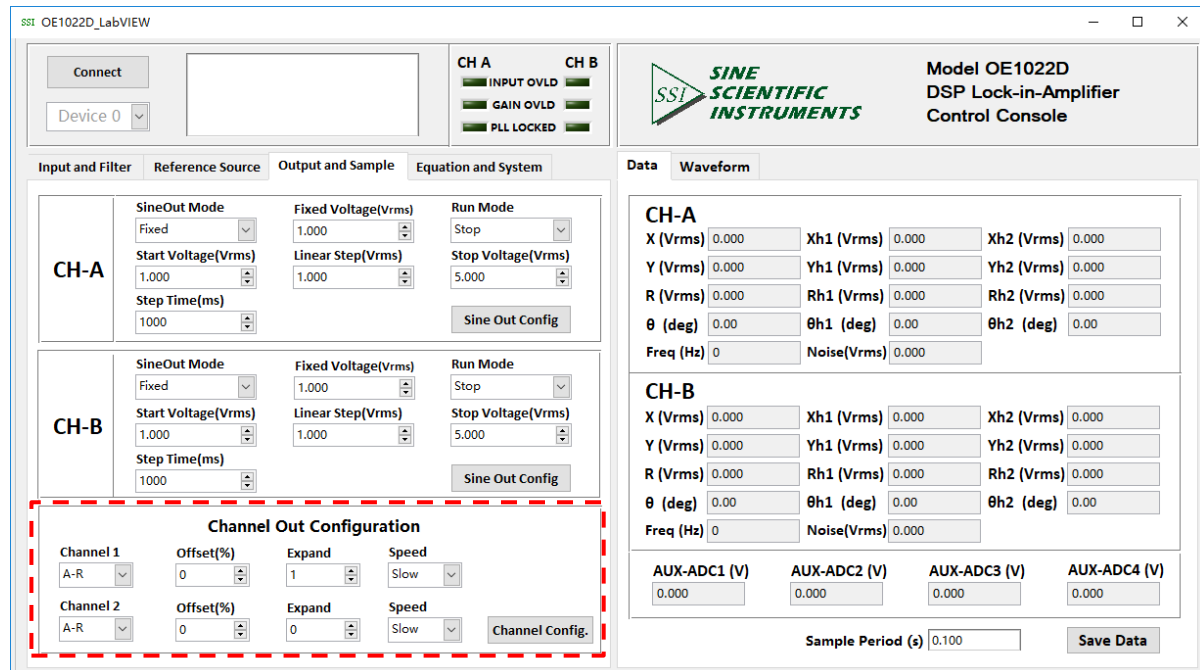
1. After setting the output configuration, click the button Sine Out Configuration to finish the configuration. All settings can be changed simultaneously and you just need to click this button once.

2. After changing the settings, you need to click Sine Out Configuration to finish this configuration. Otherwise, changes of settings will not be saved.

6.2.5.2 Channel Out Configuration

The area of output configuration is in the red box of the Fig.68. The details of the configuration are listed in the Table 10.

Fig.68 The Configuration Area of Output Channel

Table 10. Output Channels Configuration Options

Channel 1	Choose CH1 to output the required values. The value types contain the X/Y/R/θ value of signal and signal harmonic, the noise value and the E1/E2/E3/E4 value.
Channel 2	Choose CH2 to output the required values. The value types contain the X/Y/R/θ value of signal and signal harmonic, the noise value and the E1/E2/E3/E4 value.
Offset (%)	The range is -100% to +100%, the minimal step is 0.01%, 0.00% in default. It can only set the R/X/Y value.
Expand	The range is 1~256, 1 in default.
Speed	Choose 'Fast' /' Slow'. When choosing 'Fast', the CH1 and CH2 can only output the R/X/Y value.

Note that:

1. After setting the CH1 or CH2 output configuration, click the button [Channel Config.] to finish the configuration; all settings can be changed simultaneously and you just need to click this button once.

2. After changing the settings, you need to click [Channel Config.] to finish this configuration. Otherwise, changes of settings will not be saved.

6.2.6 Equation and System Configuration

The sine output configuration is shown in the red box in Fig.69.
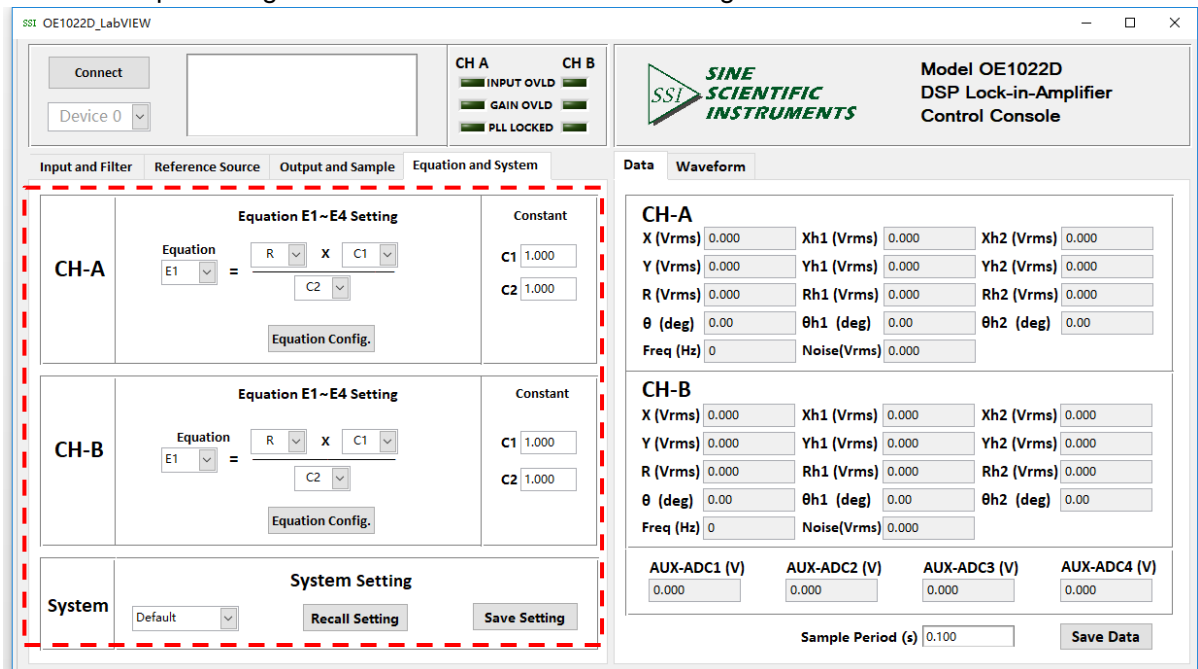
Fig.69 The Configuration Area of Equation and System

The area of equation and system configuration is provided for setting custom equation and system. The following sections provide detailed description of the configuration area.

6.2.6.1 Custom Equation Configuration

The custom equation configuration is shown in the red box in Fig.70. Details of configuration are shown in Table 11.
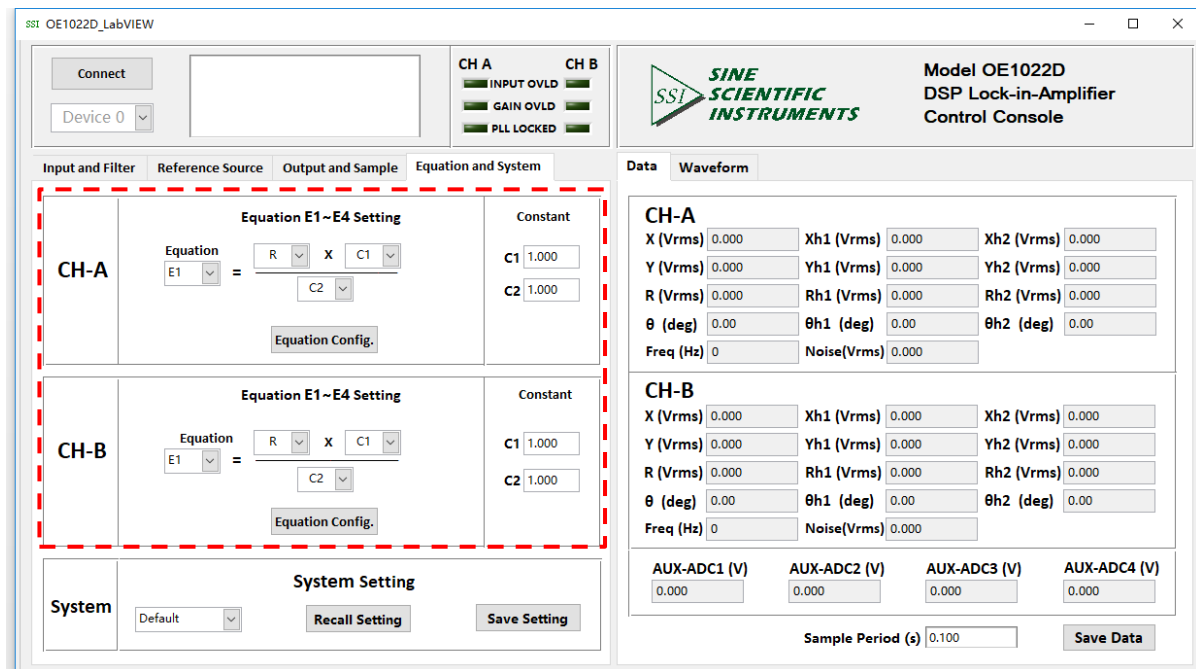
Fig.70 Configuration Area of Equation

Table 11. Equation Configuration Options

Equation	The output of Equation can be E1/E2/E3/E4. The input can be the X/Y/R/θ of signals in two channels or signal harmonic, the ADC1/ADC2/ADC3/ADC4 of AUX_ADC input, noise, frequency and C1/C2.
C1	Set the input of Equation manually. The range is -10~+10, and the minimum resolution is 0.001.
C2	

Note that:

1. After setting the output configuration, click the button [Equation Config.] to finish the configuration. All settings can be changed simultaneously and you only need to click the button [Equation Config.] once.

2. After changing the settings, you need to click this button [Equation Config.] to finish this configuration. Otherwise, changes of settings will not be saved.

6.2.6.2 Setting Storage

The software has the function of setting storage. Users can choose to save current setting or load previously saved setting. The details of configuration are shown in Table 12.
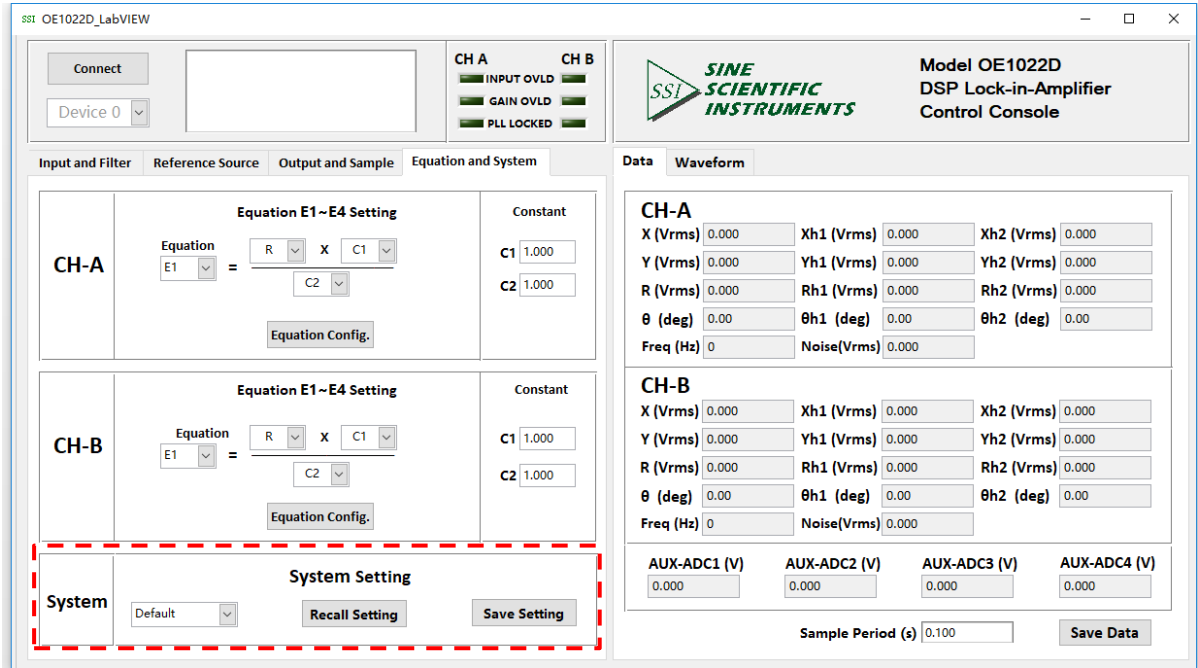
Fig.71 The Configuration Area of Setting Storage

Table 12. Data Buffer Settings Options

System Setting	Users can select default setting or setting 1(S1), setting 2(S2), setting 3(S3), setting 4(S4).
Save Setting	Users can save current setting as default setting or setting 1(S1), setting 2(S2), setting 3(S3), setting 4(S4).
Recall Setting	The option 'Recall Setting' could apply to restore not only the factory configuration(default setting) but also can recall setting 1(S1), setting 2(S2), setting 3(S3), setting 4(S4).

6.2.7 Data Display and Storage

6.2.7.1 Measured values displayed in real time

Default right window is the tab page 'data display', as shown in the red box in Fig.72.
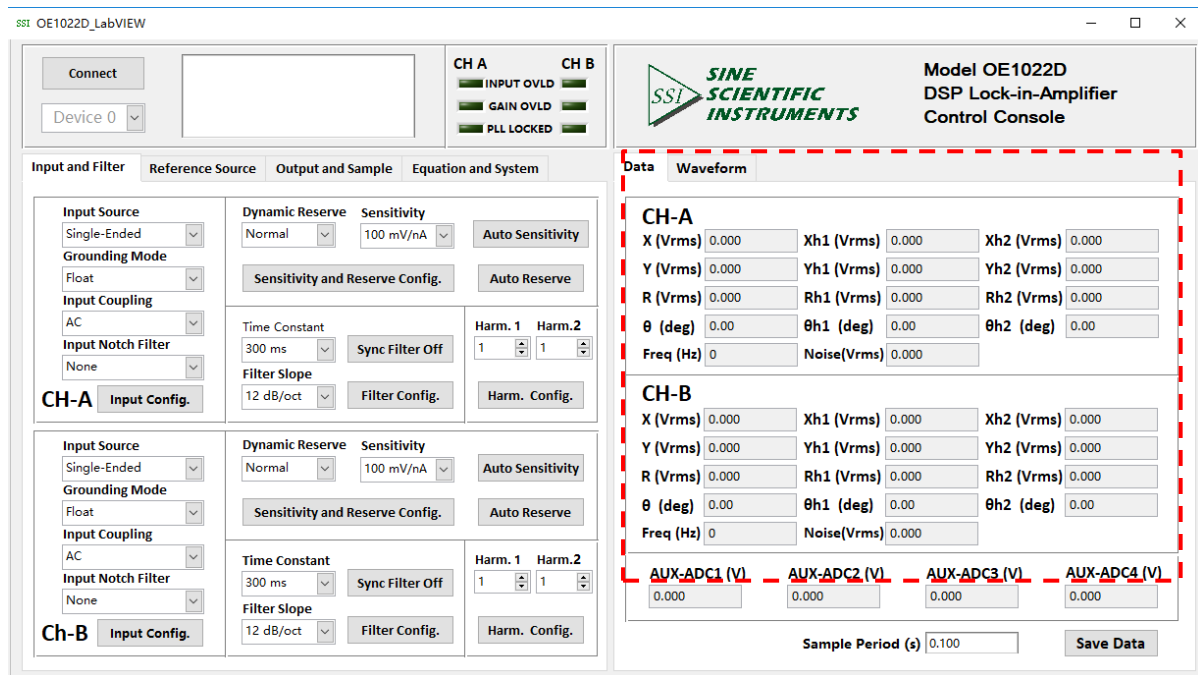
Fig.72 The Harmonic Waveform Display

The measured values of fundamental wave, harmonic 1, harmonic 2.frquency, noise and AUX-ADC1, AUX-ADC2, AUX-ADC3, AUX-ADC4 are displayed in real time during testing. Please note that letters 'm','u','n','f','p' represents $10^{-3}, 10^{-6}, 10^{-9}, 10^{-12}$.

6.2.7.2 Data Storage

The software has the function of data storage. Users can choose to save the data or not that OE1022D collects in a period.

The saved data contains the X/Y/R/θ of measure signal or signal harmonic, frequency, noise and the ADC1/ADC2/ADC3/ADC4 of 4 AUX_ADC inputs.
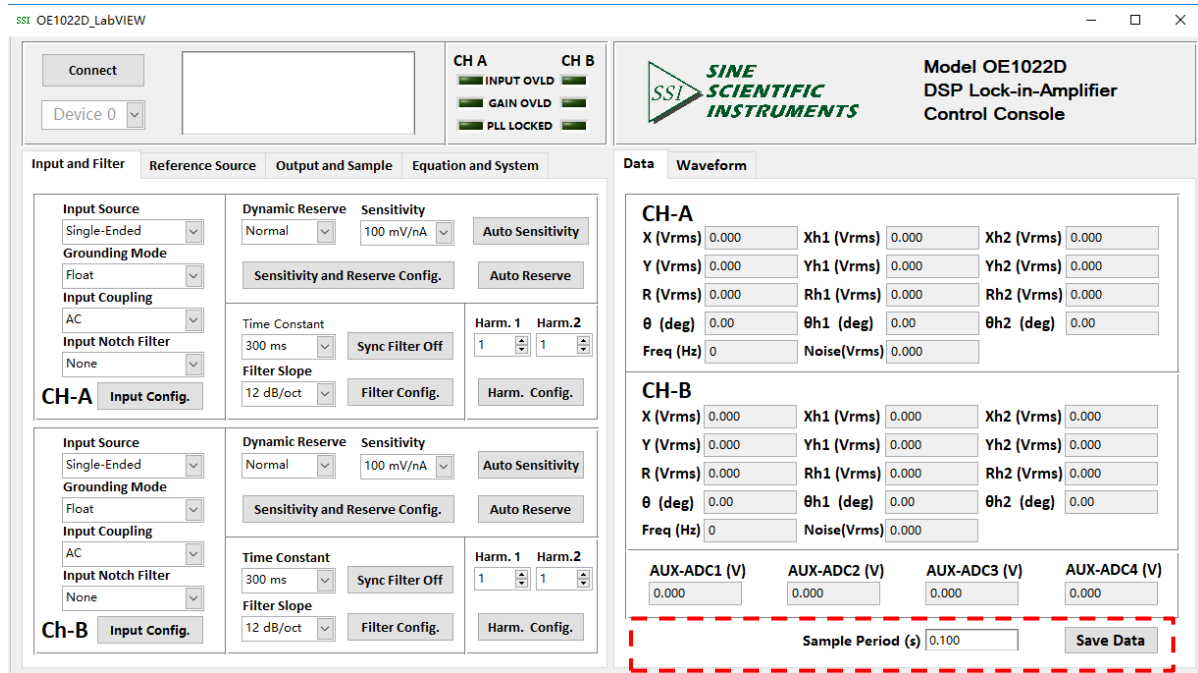
Fig.73 The Configuration Area of Data Storage

The steps for choosing to save data or not:

1. The data is saved in Excel. The file name is 'Data_recorded_excel.xls'. It is saved in the program directory.

2. When the software is executing, click the button Save Data in the red box in Fig.73. After clicking this button and it displays Saving... . The software is saving the current collected data.

3. Click the button Saving... again, and the button status will switch back to Save Data again. This means the software stops saving collected data.

4. In Sample Period (s) 0.100 , you can modify the sampling rate of the current display and data storage. The input range is 0.1s ~ 100s.

6.2.7.3 Display Harmonic Waveform

Choose the 'Harmonic Wave' option in left window of the software. Result is shown in Fig.74.
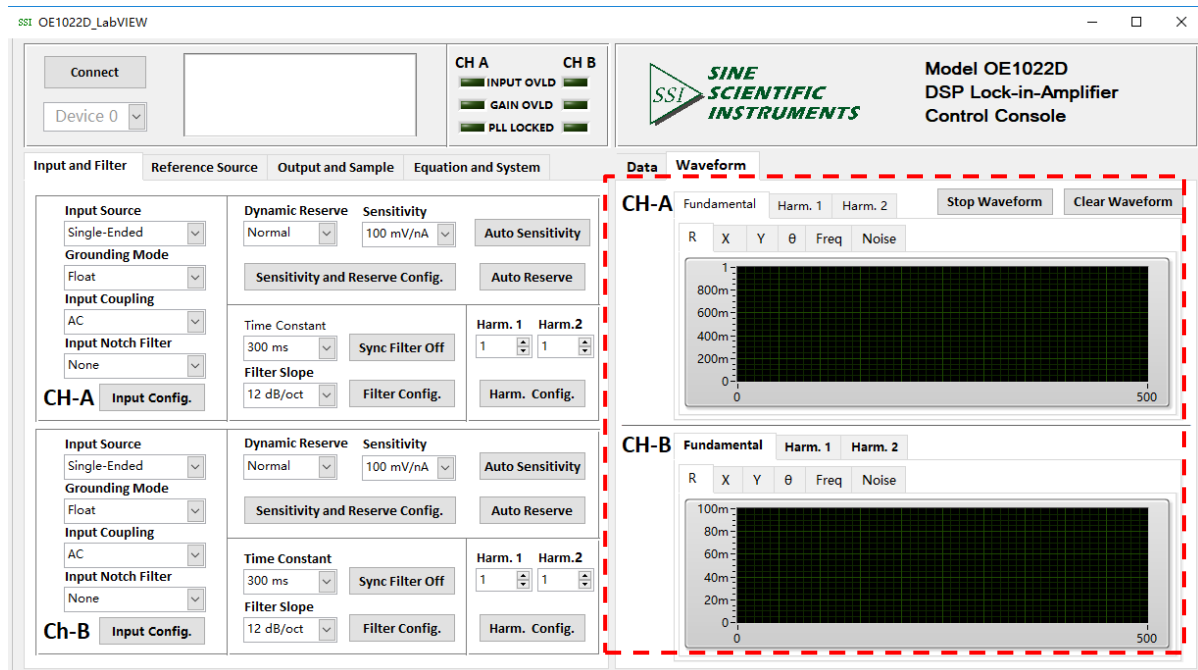
Fig.74 The Harmonic Waveform Display

There are two XY coordinates charts which display fundamental wave, harmonic 1 and harmonic 2. Users can choose to display R/X/Y/θ for each wave.

6.3 Usage Examples

This example will show how to use OE1022D PC software to configure parameters, and observe and record the value of R/X/Y/θ.
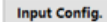
First, connect the OE1022D and PC according to the software usage guidance in 6.2 and then you can start to configure.

Suppose that the lock-in amplifier configurations are as follows:

Table 13. Configuration Instance

Input Source	Single-ended voltage input
Input Amplitude	40mV
Input Coupling	AC
Input Notch Filter	Close
Dynamic Reserve	Low Noise
Sensitivity	Auto Sensitivity
Reference Source	External reference, 1000Hz
Reference Signal Trigger Way	TTL rising edge trigger
Phase Shift Angle	0
Time Constant of Low Pass Filter	300ms
Roll Off	12 dB/oct
Sampling Rate	125Hz
Buffer 1	X
Buffer 2	Y

The steps to finish the configurations in table13 are as follows:

1. According to table 13, select suitable options as required in tab page 'Input and Filter', including 'Input Source', 'Grounding Mode', 'Input Coupling' and 'Input Notch Filter'. Leave other options as initial state for now as shown in Fig.73. Click the button `Input Config.` to finish configurations.

Fig.75 Input Configuration

Fig.76 Filter Configuration

2. As shown in Fig.76, select suitable options for 'Time Constant' and 'Filter Slope' as required. Leave other options as initial state for now. Click the button [Filter Config.] to finish the configurations.

2. Select suitable options as required in tab page 'Reference Source Configuration' such as 'Reference Source', 'External Ref Trigger', 'Phase' with other options in default, as shown

in Fig.76. Click the button [Reference Config.] to finish the configurations.
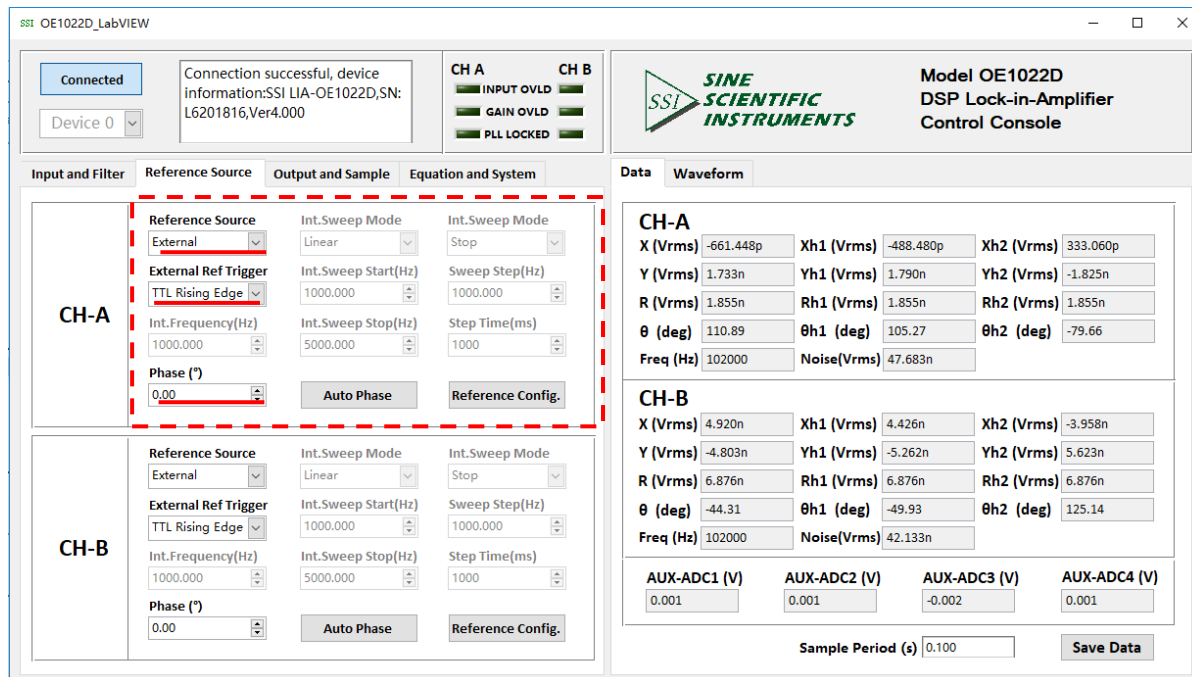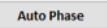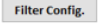
Fig.77 Reference configuration

The button [Auto Phase] is provided for setting phase shift angle automatically, you only need to click this button once to use the 'auto phase' function. User doesn't need to click the button [Filter Config.] afterward.
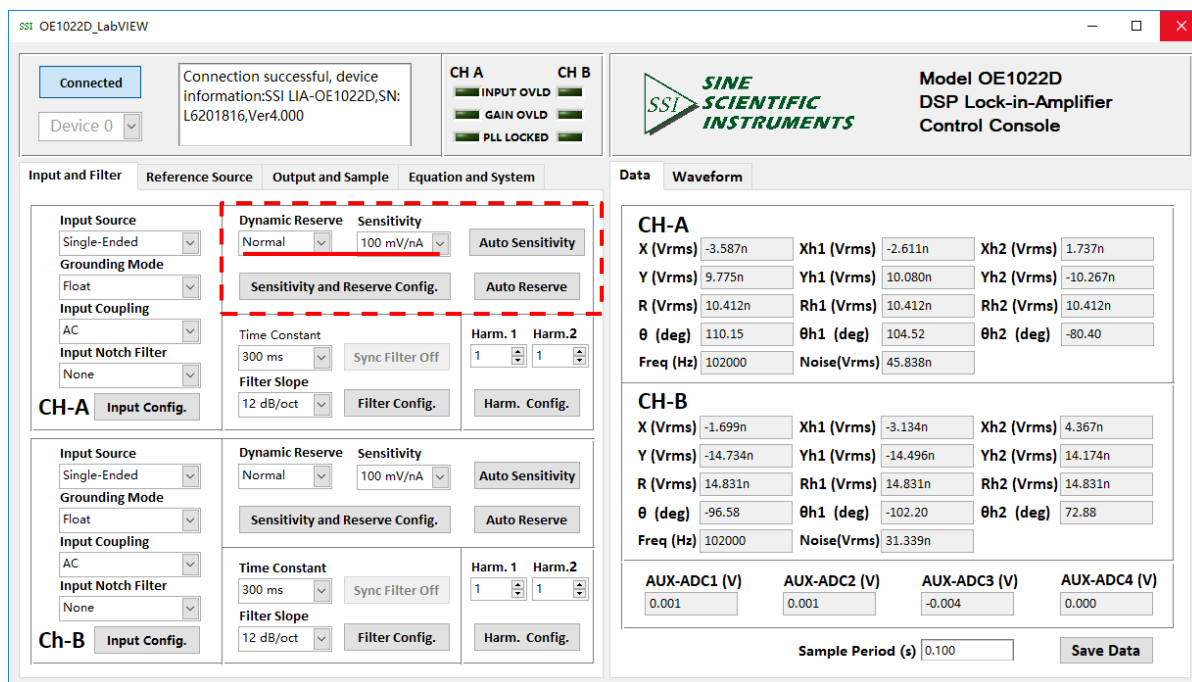
Fig.78 Reserve & Sensitivity Configuration

The button Auto Sensitivity is provided for setting phase shift angle automatically, you only need to click this button once to use the 'auto phase' function. User doesn't need to click the button Filter Config. afterward.
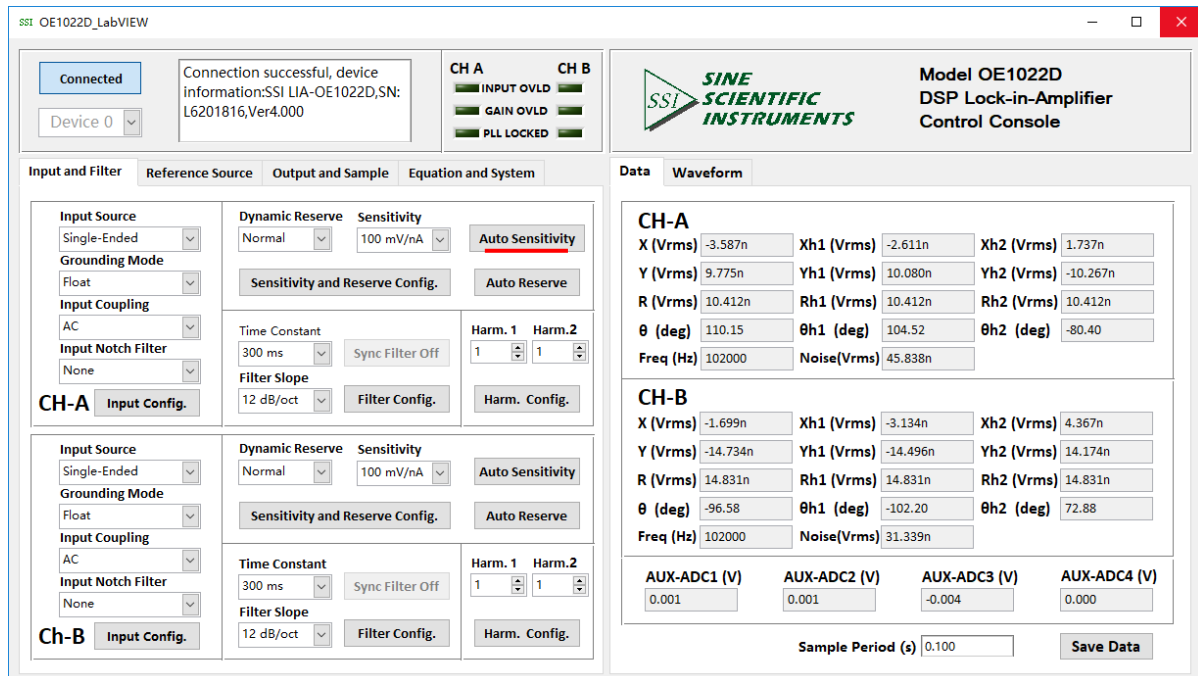
Fig.79 Auto Sensitivity Configuration

Compare the two OE1022D interfaces before and after configuration as shown in Fig.80 and Fig.81, and you will see the configurations are successful.
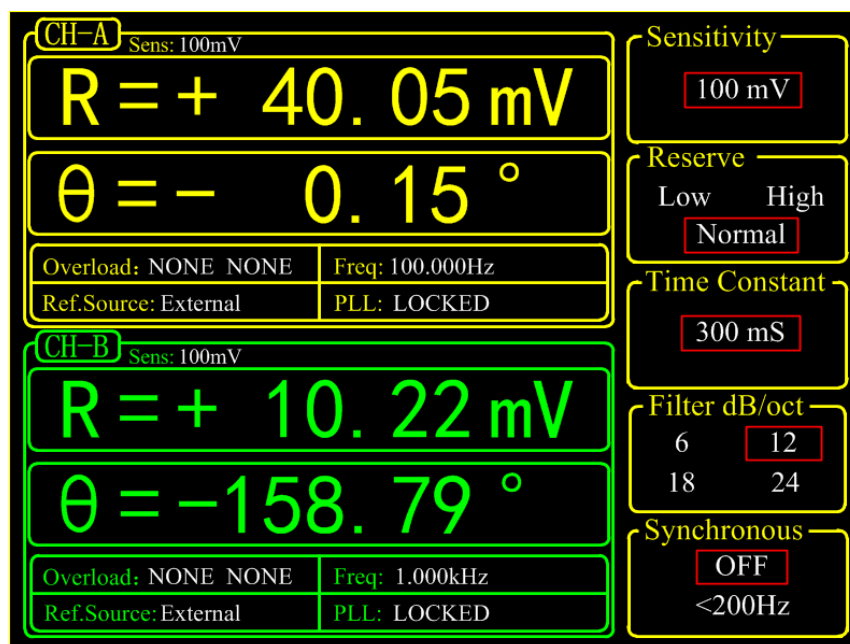
Fig.80 <SENS> is 100 mV before configuration
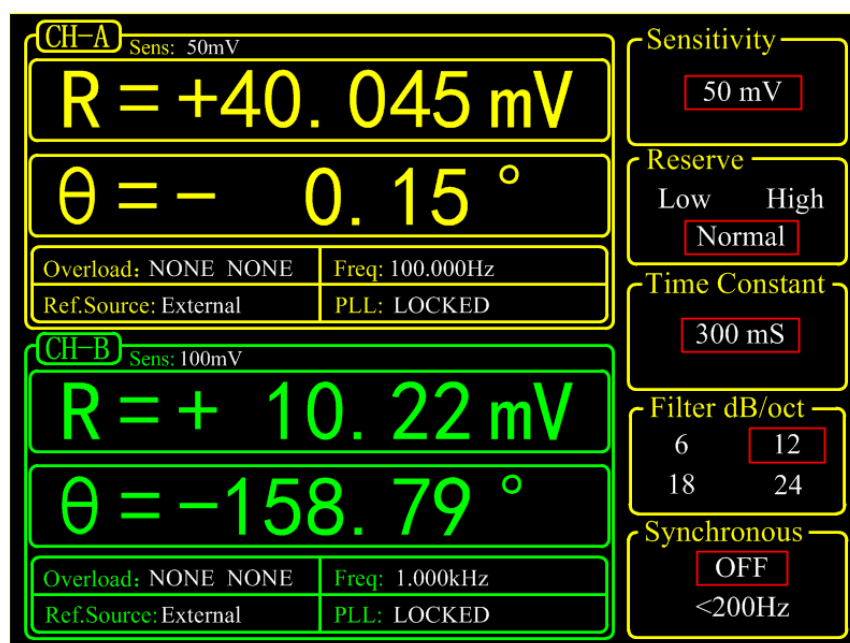
Fig.81 <SENS> is 50 mV after configuration

5. The configurations of OE1022D are finished. Other options are in default. Then users can collect and save data.

Data is saved in the selected directory in the form of an Excel. The file name is 'Data_recorded_excel.xls' and it has 32 columns of data.

Fig.82 The data saving is paused

As shown in Fig.82, click the button Save Data in the red box. After this button is clicked, it

turns to ' Saving... ' which means the OE1022D is saving data, as shown in Fig.83.

Fig.83 Data saving

7. PERFORMANCE TESTS

Introduction   The performance tests are designed for users to prove that the OE1022D can operate normally and enhance users' confidence to our instrument. Each test can be recorded on the Performance Test Record form at the final section of this chapter.

Serial Number   If you have any questions and need to contact us, please offer the serial number of your unit. You can find the serial number on the CD box, the package box or the backside of your unit. You can also check the serial number at <Info> on the screen when the unit is powered on.

Firmware Revision   The firmware revision number is shown at <Info> on the screen when the unit is powered on.

Warm Up   Due to the temperature drift of chips, it is best to warm up the instrument for some time (30~60 minutes) in order to reduce measurement error.

Test Record   At the end of this section, there is a performance test record. It is necessary to make a copy of it before filling in the record. This record will allow you to determine whether the tests pass or fail and preserve a record of the tests.

If a Test Fails   If a test fails, you should check the settings and connections of any external equipment and internal equipment. If possible, verify its operation with a DVM, scope or other pieces of test equipment. After checking the settings, repeat this test from warm up and make sure that the test is performed correctly.

If the test continues to fail, contact us for further instructions. Make sure that you have the unit's serial number and firmware revision code handy. Have the test record on hand as well.

Necessary Equipment   The following equipment is necessary to complete the performance tests. The suggested equipment or its equivalent should be used.

1. Function Signal Generator

Freq Range	1 Hz to 1 MHz
Freq Accuracy	Better than 5 ppm
Amplitude Accuracy	0.2 dB from 1 Hz to 120 kHz
Spurious	≤ -55 dBc
TTL SYNCD	Available
Output Setup	50 Ω or High Z
Recommended	AGILENT 33250A

SINE SCIENTIFIC INSTRUMENTS

2. Digital Voltmeter

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

3. DC Voltage Source

Voltage Range	≥ 10 V
Accuracy	< 10mVpp
Recommended	RIGOL DP831A

4. Feed through Terminations

Impedance	50 Ω

Front Panel Display Test First, turn on the power switch on the rear panel to start the device. Second, check whether the display screen can be turn on. Third, check whether there are bad pixels on the display. End the display test.

Keypad Test After the device is turned on, press any button and you will hear 'Di' sound once. Then, try to press every button to check whether the display change to the corresponding setting. Finally, press <Sensitivity> and spin the knob to check whether the knob is OK.

7.1 Self-Test

The self-test checks the lock-in hardware. This test should be done before any other performance tests.

Device

No external device is required in this test.

Steps

1. Open the power switch on the rear panel to start the lock-in amplifier.
2. Observe the device, and check whether the screen, keyboard and cooling fan is OK.
3. Record the test results in the Performance Test Record.

7.2 DC Offset

This test measures the DC offset of the input.

Device

Connect a 50Ω BNC cable to the A/I input. This shorts the input so the lock-in's own DC offset will be measured.

Steps

1. Turn the lock-in off and on to restart it.
2. Press the buttons in the following sequence:
       <Ref. Source>   Set to <Internal>
       <Ref. Frequency> Set to 1Hz
       <Sensitivity>   Set to <1mV> through the spinning knob
3. Wait 10 seconds, then record the value of R.
4. Change the setting:
       <Coupling>   Set to <DC>
5. Wait 10 seconds, then record the value of R.
6. End the test and fill the result into the performance test form.

7.3 Common Mode Rejection

This test measures the common mode rejection of the lock-in.

Device

Use the internal oscillator sine output to provide the signal.
Connect the [SINE OUT] to both A and B inputs of the lock-in.
Use equal length cables from A and B to a BNC TEE.
Connect the cable from the [SINE OUT] to the TEE. Do not use any termination.

Steps

1. Turn the lock-in off and on to restart it.
2. Press the buttons in the following sequence:
       <Sensitivity>   Set to <1 V> through the spinning knob
       <Ref. Source>   Set to <Internal>
       <Ref. Frequency> Set to 100 Hz
3. Wait until <R> is steady and <R> should be 1Vrms (within 3% error)
4. Press the buttons in the following sequence:

SINE
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INSTRUMENTS

<Coupling>   Set to <DC>
<Source>   Set to <A-B>
<Sensitivity>   Set to <200 µV> through the spinning knob

5. Wait 10 seconds, and then record the value of R.

6. End the test. The common mode rejection equals to 20lg(1/R), where R is in Volts(V). Fill the results in the performance test form.

7.4 Amplitude Accuracy and Flatness

This test measures the amplitude accuracy and frequency response.

Device

Use the function signal generator to provide an accurate frequency and a sine wave. Use one cable with BNC connector to connect the output of the function signal generator to the A input of the lock-in. Use another cable with BNC connector to connect the reference output of the function signal generator to the REF IN of the lock-in.

Set the function signal generator to:

Function   Sine
Frequency   1 kHz
Amplitude   1 Vrms
Offset   0 V
Output   High Z
Sweep   off
Modulation   none

Steps

1. Turn the lock-in off and on to restart it.
2. Set <Filter> to 24 dB/oct.
3. Amplitude accuracy is verified at 1kHz and various sensitivities. Set the sensitivity of the lock-in and the amplitude of the function signal generator in the following sequence:

Sensitivity	Amplitude
1 V	1.0000 Vrms
200 mV	200.00 mVrms
100 mV	100.00 mVrms
20 mV	20.000 mVrms
10 mV	10.000 mVrms

a) Set the function signal generator to the amplitude shown above.

SINE
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b) Set <Sensitivity> of the lock-in.

c) Wait 10 seconds, then record <R>, then test the next group of the sensitivity-amplitude.

d) Repeat the steps from 3)-a) to 3)-c) until the Sensitivity-Amplitude test is completed.

4. Frequency response is checked at frequencies above 1kHz. Set the frequency in the following sequence:

> Test Frequency
> 24 kHz
> 48 kHz
> 72 kHz
> 96 kHz
> 120 kHz

a) Set <Sensitivity> of the lock-in to <200 mV>.

b) Set the frequency of the function signal generator to 1 kHz and the amplitude to 200.00mVrms.

c) Set the frequency of the function signal generator in the upper sequence.

d) Wait 10 seconds, then record <R>, then test the next frequency.

e) Repeat from 4)-c) to 4)-d) until all the frequencies are tested over.

5. End the test and fill the results in the performance test form.

7.5 Amplitude Linearity

This test measures the amplitude linearity. It tests how accurately the lock-in measures a signal smaller than full scale.

Device

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

Use a cable with BNC connector to connect the output of the function signal generator to the A/I input of the lock-in. Use another cable with BNC connector to connect the reference output of the function signal generator to the REF IN of the lock-in.

Set the function signal generator to:

Function	Sine
Frequency	1 kHz
Amplitude	1 Vrms
Offset	0 V
Output	High Z
Sweep	off
Modulation	none

SINE
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INSTRUMENTS
SSI

Steps

1. Turn the lock-in off and on to restart it.
2. Set <Filter> to <24 dB/oct> and <Sensitivity> to <1 V>.
3. The Amplitude of the function signal generator should be 1kHz at various amplitudes. Set the amplitude in the following sequence:

> Amplitude
> 1.0000 Vrms
> 100.00 mVrms
> 10.000 mVrms

   a) Set the output amplitude of the function signal generator.
   b) Wait 10 seconds, then record <R>, then test next amplitude.
   c) Repeat from 3)-a) to 3)-b) until all amplitudes are tested over.
4. End the test and fill the results in the performance test form.

7.6 Frequency Accuracy

This test measures the frequency accuracy of the lock-in.

Device

Use the function signal generator to provide the reference signal.
Use one cable with BNC connector to connect the reference signal of the function signal generator to the REF IN of the lock-in.

Steps

1. Turn the lock-in off and on to restart it.
2. Set the frequency of the function signal generator to 10 kHz.
3. Wait until <PLL: UNLOCK> changes to <PLL: LOCKED>, then record <Freq>.
4. End the test and fill in the performance test form.

7.7 Sine Output Amplitude Accuracy and Flatness

This test measures the amplitude accuracy and frequency response of the internal oscillator SINE OUT.

Device

Use a 1-meter length cable with BNC connector to connect the SINE OUT to the A/I of the lock-in.

Steps

    1. Turn the lock-in off and on to restart it.

    2. Set <Sensitivity> to <1 V> and <Ref. Source> to <Internal>.

    3. The frequency of the internal oscillator should be 1kHz steadily. Set <Sensitivity> and the amplitude of the SINE OUT in the following sequence:

Sensitivity	Sine Output
1 V	0.800 Vrms
500 mV	0.400 Vrms
200 mV	0.160 Vrms

    a) Set the amplitude of <SINE OUT>.

    b) Set <Sensitivity>.

    c) Wait 10 seconds, then record <R>, then test next group of Sensitivity-Sine Output.

    4. Repeat from 3)-a) to 3)-c) until all the Sensitivity-Sine Output are tested over.

Frequency response is checked at frequencies above 1 kHz. Set <Ref. Frequency> in the following sequence:

Test Frequencies
24 kHz
48 kHz
72 kHz
96 kHz

    a) Set <Sensitivity> to <1 V>.

    b) Set the amplitude of the SINE OUT to <1Vrms>.

    c) Set <Ref. Frequency> in the upper sequence.

    d) Wait 10 seconds, then record <R>, then test next frequency.

    e) Repeat from 4)-c) to 4)-d) until all the frequencies are tested over.

    5. End the test and fill results in the performance test form.

7.8 Outputs of Dual Channels and 4 AUX Inputs

    This test measures the DC accuracy of the DC outputs and inputs of the lock-in.

Device

    Use a linear DC regulator to generate a DC input.

    Use a DVM to measure the DC output of the lock-in.

    Connect a 50 Ω BNC termination to the A/I input of the lock-in.

Steps

    1. Turn the lock-in off and on to restart it.

2. Set <Ref.Source> to <Internal>.

3. Follow the steps below:

a) Use a cable to connect CH1 or CH2 of the lock-in to the DVM. Set the DVM to 19.999 V range.

b) Set <Offset> of <Channel Output> in the following sequence:

Offset (%)
100.00
50.00
0.00
-50.00
-100.00

c) Waiting for 10 seconds and record the reading of the DVM. Then, test next group data.

d) Repeat steps 3-b) to 4-c) until finishing the tests for CH1. Then, connect the DVM to CH2 and continue to finish the tests for CH2.

4. Follow the steps below:

a) modify settings: select <TOP> option in submenu [DISPLAY], set the <Type> and <Trace> to <List> and <ADC> respectively.

b) use signal cable to connect the DC regulator source to the Lock-in AUX_OUT 1 on rear panel.

c) set voltage output of the DC regulator source in the following sequence

Voltage (V)
10.000
5.000
0.000
-5.000
-10.000

c) Wait 10 seconds and record the reading of the<A1>. Then, test next group data.

d) Repeat steps 4c to 4d until finishing the tests for A1. Then connect the DC voltage source to A2, A3, A4 to finish the tests for A2, A3, A4.

5. Finish the tests for DC inputs and outputs and fill the results in the Performance Test Record Form.

7.9 Input Noise

This test measures the input noise of the lock-in.

Device

Connect a 50 Ω BNC termination to the A/I input of the lock-in. This grounds the input so the lock-in's own noise is measured.

Steps

1. Turn the lock-in off and on to restart it.
2. Set the parameters in the following sequence:

<Ref. Source>	Set to <Internal>
<Ref. Frequency>	Set to 997 Hz
<Sensitivity>	Set to <100 nV> through the spinning knob
<Reserve>	Set to <Low>
<Filter>	Set to <24 dB/oct>
<Trace>	Set <Trace> in <Display> to <Noise>.

3. Wait until the reading is steady, and then record the maximum value of noise.
4. End the test and fill the result in the performance test form.

7.10 OE1022D Performance Test Record

OE1022 Performance Test Record

Serial Number _____ Tested By _____

Firmware Revision _____ Date _____

Equipment Used _____
_____

---

1. Starting Tests

Pass	Fail
_____	_____

---

2. DC Offset

	Input Coupling	Reading	Upper Limit
Channel A	AC	_____	0.500mV
Channel A	DC	_____	0.500mV
Channel B	AC	_____	0.500mV
Channel B	DC	_____	0.500mV

---

3. Common Mode Rejection

	Frequency	Reading	Upper Limit
Channel A	100Hz	_____	30µV
Channel B	100Hz	_____	30µV

---

4. Amplitude Accuracy and Flatness

Channel A

Sensitivity	Amplitude	Lower Limit	Reading	Upper
1V	1.0000Vrms	0.9800V	_____	1.0200V
200mV	200.00Vrms	198.99mV	_____	202.00mV
100mV	100.00Vrms	98.00mV	_____	102.00mV
20mV	20.000Vrms	19.60mV	_____	20.400mV
10mV	10.000Vrms	9.800mV	_____	10.200mV

Sensitivity	Amplitude	Lower Limit	Reading	Upper
200mV	24kHz	196mV	_____	204mV
200mV	48kHz	196mV	_____	204mV
200mV	72kHz	196mV	_____	204mV
200mV	96kHz	196mV	_____	204mV

SINE SCIENTIFIC INSTRUMENTS

OE1022 Performance Test Record

Channel B

Sensitivity	Amplitude	Lower Limit	Reading	Upper Limit
1V	1.0000Vrms	0.9800V	_____	1.0200V
200mV	200.00Vrms	198.99mV	_____	202.00mV
100mV	100.00Vrms	98.00mV	_____	102.00mV
20mV	20.000Vrms	19.60mV	_____	20.400mV
10mV	10.000Vrms	9.800mV	_____	10.200mV

Sensitivity	Amplitude	Lower Limit	Reading	Upper
200mV	24kHz	196mV	_____	204mV
200mV	48kHz	196mV	_____	204mV
200mV	72kHz	196mV	_____	204mV
200mV	96kHz	196mV	_____	204mV

5. Amplitude Linearity

Channel A

Sensitivity	Amplitude	Lower Limit	Reading	Upper Limit
1V	1.0000Vrms	0.9900V	_____	1.0100V
	100.00Vrms	0.0990V	_____	0.1010V
	10.000Vrms	0.0099V	_____	0.0101V

Channel B

Sensitivity	Amplitude	Lower Limit	Reading	Upper Limit
1V	1.0000Vrms	0.9900V	_____	1.0100V
	100.00Vrms	0.0990V	_____	0.1010V
	10.000Vrms	0.0099V	_____	0.0101V

6. Frequency Accuracy

	Frequency	Lower Limit	Reading	Upper Limit
Channel A	10kHz	9.990kHz	_____	10.010kHz
Channel B	10kHz	9.990kHz	_____	10.010kHz

7. SINE OUT Amplitude and Flatness

Channel A

Sensitivity	SINE OUT Ampl.	Lower Limit	Reading	Upper Limit
1 V	0.800 Vrms	0.776 Vrms	_____	0.824 Vrms
200 mV	0.16 Vrms	155.2 mVrms	_____	164.8 mVrms
50 mV	0.040 Vrms	38.80 mVrms	_____	41.20 mVrms
10 mV	0.008 Vrms	7.760 mVrms	_____	8.240 mVrms

OE1022 Performance Test Record

SINE OUT	Frequency	Lower Limit	Reading	Upper Limit
1.000 Vpp	24 kHz	0.9700V	_____	0.1030 V
	48 kHz	0.9700V	_____	0.1030 V
	72 kHz	0.9700V	_____	0.1030 V
	96 kHz	0.9700V	_____	0.1030 V

Channel B

Sensitivity	SINE OUT Ampl.	Lower Limit	Reading	Upper Limit
1 V	0.800 Vrms	0.776 Vrms	_____	0.824 Vrms
200 mV	0.16 Vrms	155.2 mVrms	_____	164.8 mVrms
50 mV	0.040 Vrms	38.80 mVrms	_____	41.20 mVrms
10 mV	0.008 Vrms	7.760 mVrms	_____	8.240 mVrms

SINE OUT	Frequency	Lower Limit	Reading	Upper Limit
1.000 Vpp	24 kHz	0.9700V	_____	0.1030 V
	48 kHz	0.9700V	_____	0.1030 V
	72 kHz	0.9700V	_____	0.1030 V
	96 kHz	0.9700V	_____	0.1030 V

8. DC Outputs and Inputs

Output	Offset	Lower Limit	Reading	Upper Limit
CH1	100.00	9.960V	_____	10.040V
	50.00	4.960V	_____	5.040V
	0.00	-0.020V	_____	0.020V
	-50.00	-5.040V	_____	-4.960V
	-100.00	-10.040V	_____	-9.960V

Output	Offset	Lower Limit	Reading	Upper Limit
CH1	100.00	9.960V	_____	10.040V
	50.00	4.960V	_____	5.040V
	0.00	-0.020V	_____	0.020V
	-50.00	-5.040V	_____	-4.960V
	-100.00	-10.040V	_____	-9.960V

Input	Voltage	Lower Limit	Reading	Upper Limit
AUX IN 1	100.00	9.960V	_____	10.040V
	50.00	4.960V	_____	5.040V
	0.00	-0.020V	_____	0.020V
	-50.00	-5.040V	_____	-4.960V
	-100.00	-10.040V	_____	-9.960V

SINE
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INSTRUMENTS
SSI

OE1022 Performance Test Record

Input	Voltage	Lower Limit	Reading	Upper Limit
AUX IN 2	100.00	9.960V	_____	10.040V
	50.00	4.960V	_____	5.040V
	0.00	-0.020V	_____	0.020V
	-50.00	-5.040V	_____	-4.960V
	-100.00	-10.040V	_____	-9.960V
Input	Voltage	Lower Limit	Reading	Upper Limit
AUX IN 3	100.00	9.960V	_____	10.040V
	50.00	4.960V	_____	5.040V
	0.00	-0.020V	_____	0.020V
	-50.00	-5.040V	_____	-4.960V
	-100.00	-10.040V	_____	-9.960V
Input	Voltage	Lower Limit	Reading	Upper Limit
AUX IN 4	100.00	9.960V	_____	10.040V
	50.00	4.960V	_____	5.040V
	0.00	-0.020V	_____	0.020V
	-50.00	-5.040V	_____	-4.960V
	-100.00	-10.040V	_____	-9.960V

9.   Input Noise

Channel A

Frequency	Sensitivity	Reading	Upper Limit
1 kHz	100nV	_____	15 $nV/\sqrt{Hz}$

Channel B

Frequency	Sensitivity	Reading	Upper Limit
1 kHz	100nV	_____	15 $nV/\sqrt{Hz}$

8. OPERATION EXAMPLES

8.1 Simple Signal Measurements

This example will show how the OE1022D measure the value of R, X, Y, θ. You need two BNC cables to input the measurement signal and the reference signal. In this case, we use the function signal generator to generate a 80mVrms, 1kHz sine signal and use the OE1022D to measure it. The steps are below:

Measure a Sine Signal

1. Disconnect all cables from the lock-in. Connect the power source and then turn on the power switch. The system is in default now.

2. Use a BNC cable to connect the output of the function signal generator and the A/I input of the OE1022D. Use another BNC cable to connect the reference signal of the function signal generator and the REF IN of the OE1022D, as shown in Fig.84.
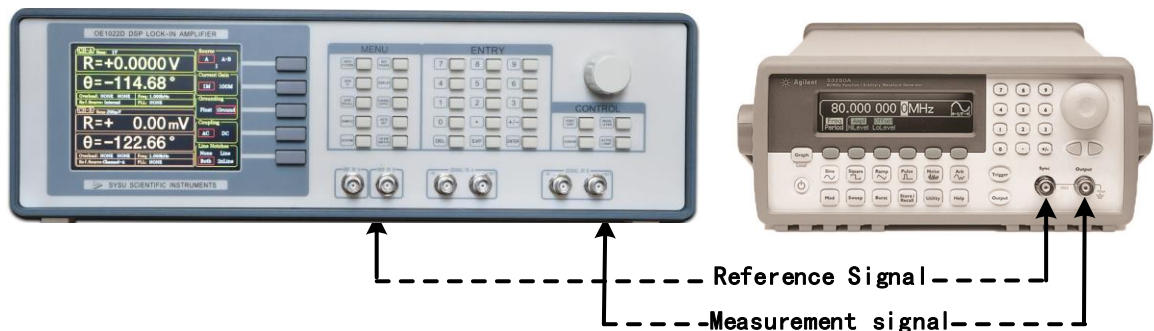
Fig.84 Signal Cable Connection Diagram

3. Turn on the function signal generator and set 'Function: Sine', 'Amplitude: 80mVrms', 'Frequency: 1kHz', 'Output Impedance: High Z', as shown in Fig.85.
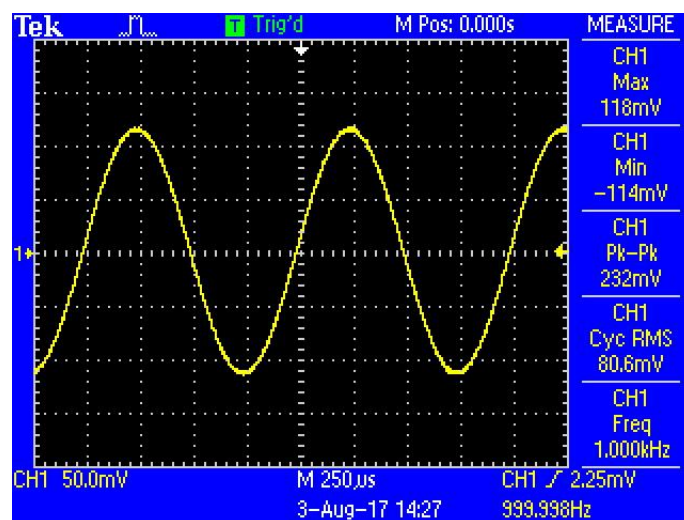
Fig.85 Parameters of Measured Signal

4. Turn on the output of the function signal generator and check whether the scale is overload by watching <Overload>.

Note that if the input of the preamplifier is overload, it shows <Overload: INPUT NONE>. If the output is overload, it shows <Overload: NONE GAIN>. If both the input and the output are overload at the same time, it shows <Overload: INPUT GAIN>.
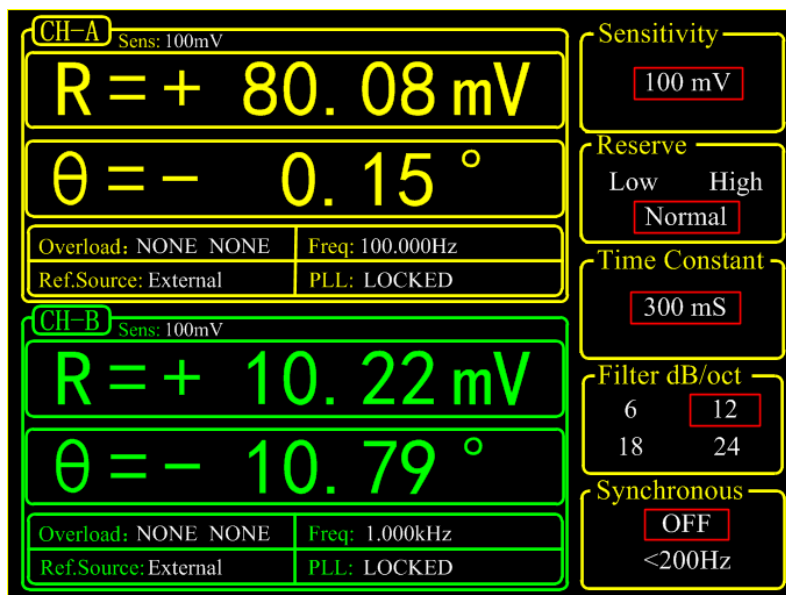
Fig.86 The Monitoring Bar of Main Interface

When the input of the preamplifier is overload, you should decrease the output amplitude of the function signal generator. If the output gain is overload, you should increase the sensitivity of the OE1022D (the input of the preamplifier will be overload when the peak value is larger than 1.7V or the valley value is lower than -1.7V). The default sensitivity is <100mV>. Therefore, in this example, it will not be overload with the output amplitude of 80mVrms. Be careful in other cases. If you need to adjust the sensitivity, the steps are as below.

5. Press [GAIN/TC] in front panel and then enter the submenu as shown in Fig.87.
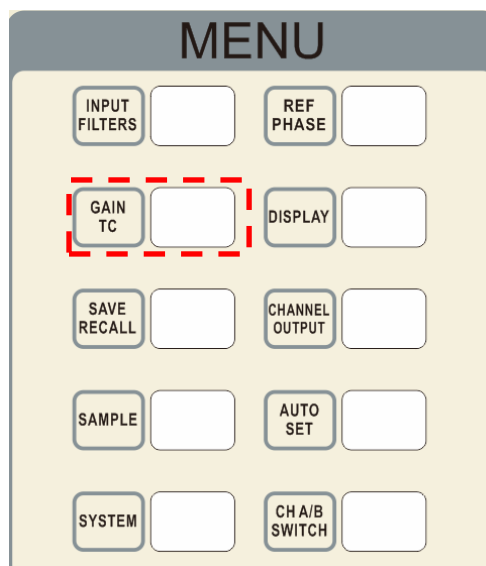
Fig.87 [GAIN/TC] Menu

Press [Soft Key 1] to choose <Sensitivity> and then it will be highlighted. Spin the knob to change the value of sensitivity so that there is no overload and the full scale is the maximum. In this case, we set the parameters as Fig.88. Then OE1022D measures the sine signal and the result is R=80.08 mV, θ=-0.15°.
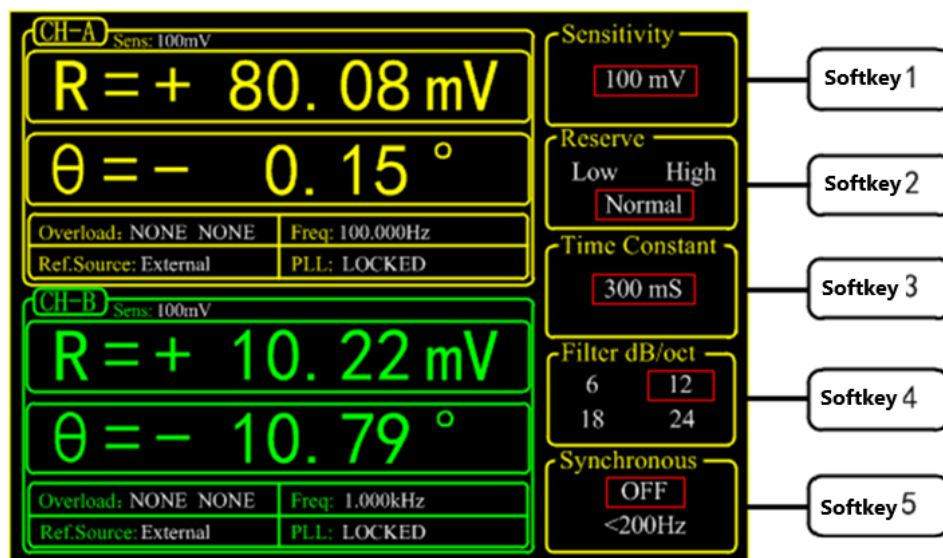
Fig.88 GAIN/TC Submenu

6. The data bar of main interface displays the value of <R>, <X>, <Y> and <θ>. Press [DISPLAY] in front panel to enter the submenu, as shown in Fig 86 and 87.

In default settings, the top area displays <R> and the bottom area displays <θ>.
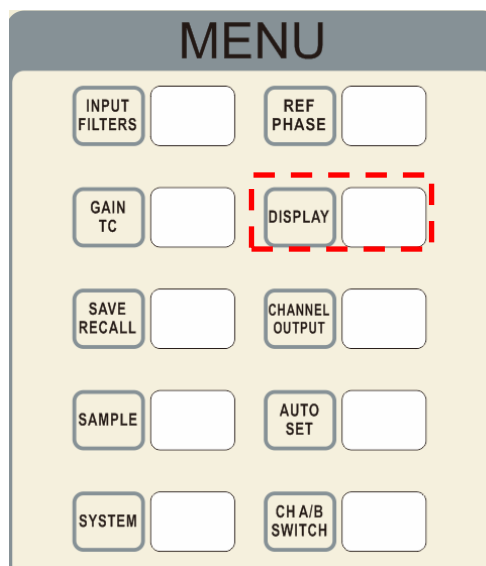
Fig.89 [DISPLAY]
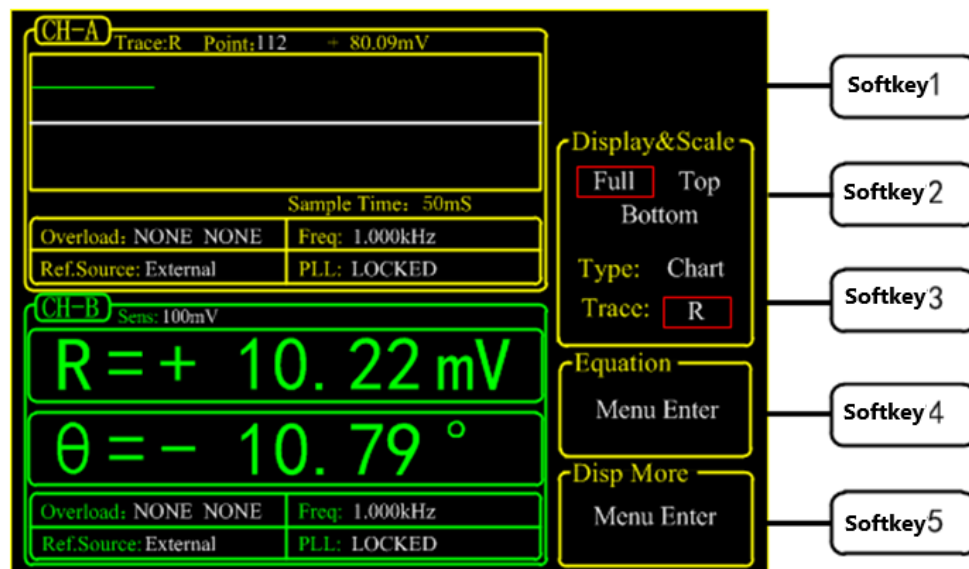
Fig.90 [DISPLAY] Menu Interface

Users can change which value to display as the following steps. For example, how to display <θ> instead of <R> in top area with XY Coordinates Chart.

First, press [soft key 2] and choose <Top>.

Second, press [soft key 3] to highlight [Type] and then choose <Chart> though the knob.

Third, press [soft key 3] to highlight <Trace> and then choose <θ>. After these settings, the result is shown in Fig.91.
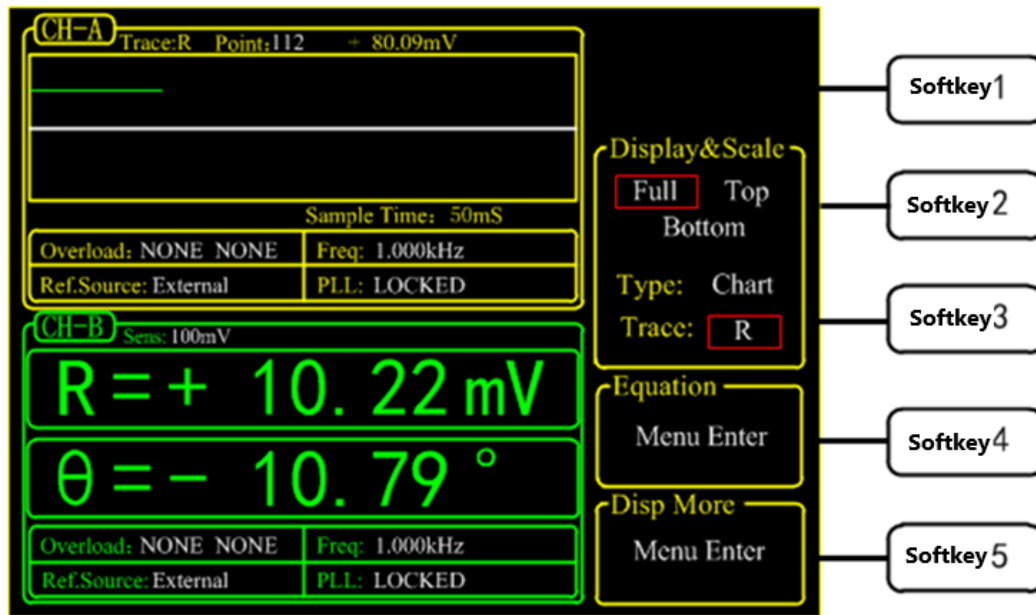
Fig.91 Display <θ> in XY Chart

8.2 Harmonics Measurements

This example will show how to measure harmonic component of the input signal. You need two BNC cables to input the measured signal and the reference signal. Use the function signal generator to provide a 160mVpp, 1 kHz square wave and then measure the first and third harmonic with the OE1022D. The steps are below.

1. Disconnect all cables from the lock-in. Connect the power source and then turn on the power switch. The system is in default.

2. Use a BNC cable to connect the output of the function signal generator and the A/I input of the OE1022D. Use another BNC cable to connect the reference signal of the function signal generator and the REF IN of the OE1022D, as shown in Fig.92.
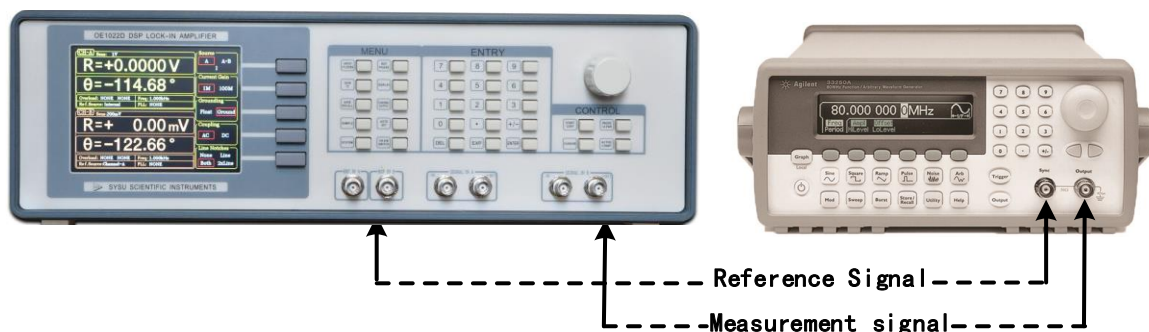
Fig.92 Signal Cable Connect Diagram

3. Turn on the function signal generator and set 'Function: Square', 'Amplitude: 80mVrms',

'Frequency: 1 kHz', as shown in Fig.93.
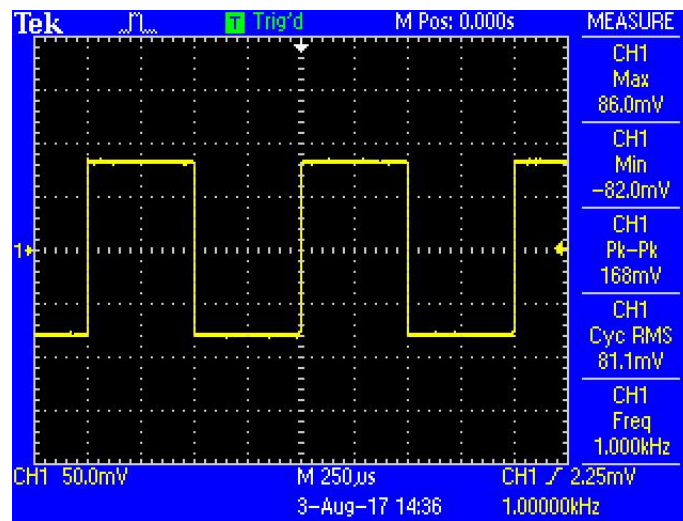
Fig.93 Measured Signal Parameter

4. Press [REF PHASE] in front panel and set <Harmonic> to the required order, as shown below.
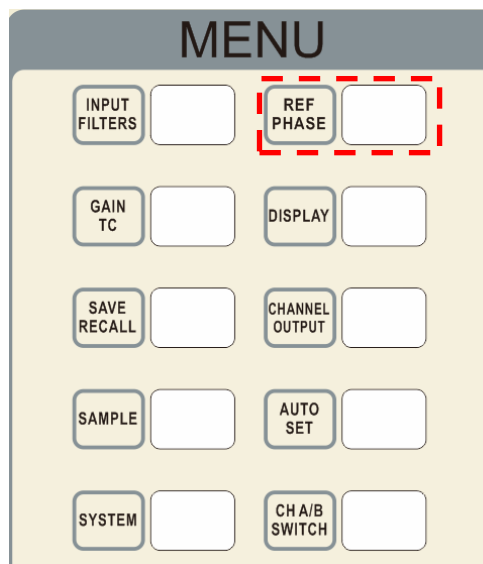
Fig.94 [REF PHASE] Submenu
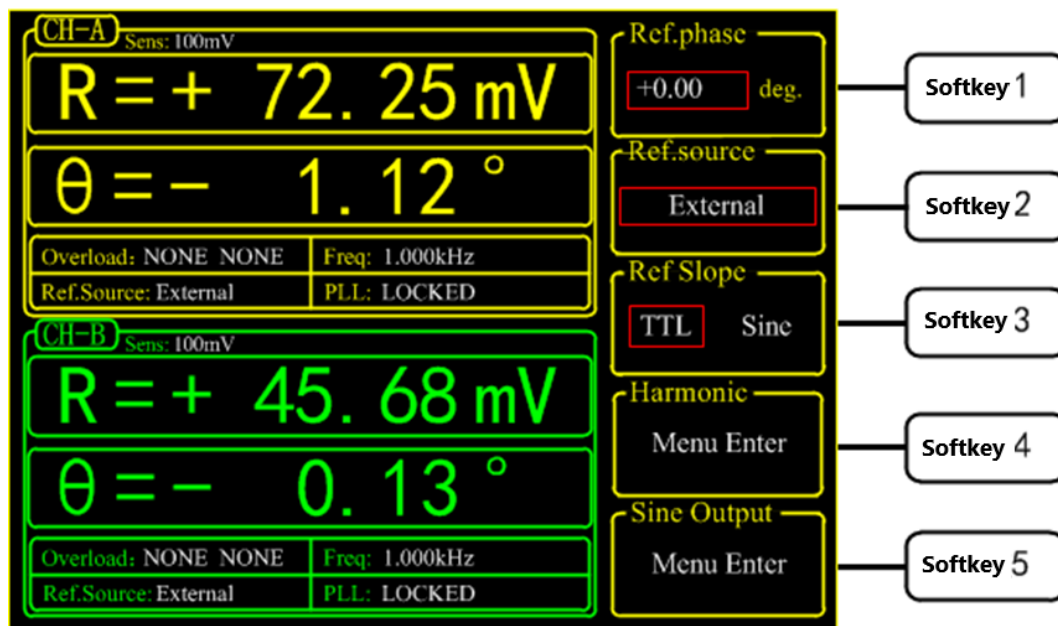
Fig.95 REF PHASE Submenu

Set the harmonic number in <Harmonic> secondary submenu and use the keyboard to input the required order.

The operation steps of measuring the first and third harmonic of the input square wave is below.

First, press the [soft key 4] in [REF PHASE] menu to choose [harmonic] submenu as shown in Fig.96.
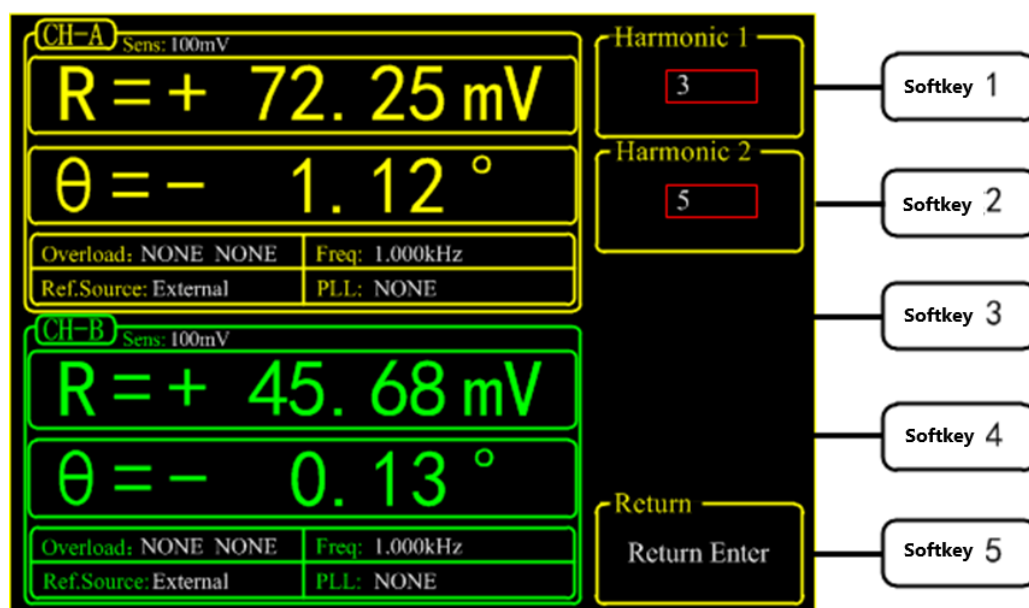
Fig.96 Harmonic Secondary Submenu

Second, press [soft key 1] and then press the number key [1] in numeric keyboard. Then press [ENTER] to confirm. Third, press [soft key 2] and then number key [3]. Now the measure result is the first and third harmonic of the input signal.

Choose [DISPLAY] submenu and choose <Full> in <Display & Scale> option and <List> in <Type> option. Then, you can read the measured harmonic (harmonic 1 is corresponding to <Xh1>, <Yh1>, <Rh1> and <θh1>; harmonic 2 is corresponding to <Xh2>, <Yh2>, <Rh2> and <θh2>). The result is shown in Fig.97.
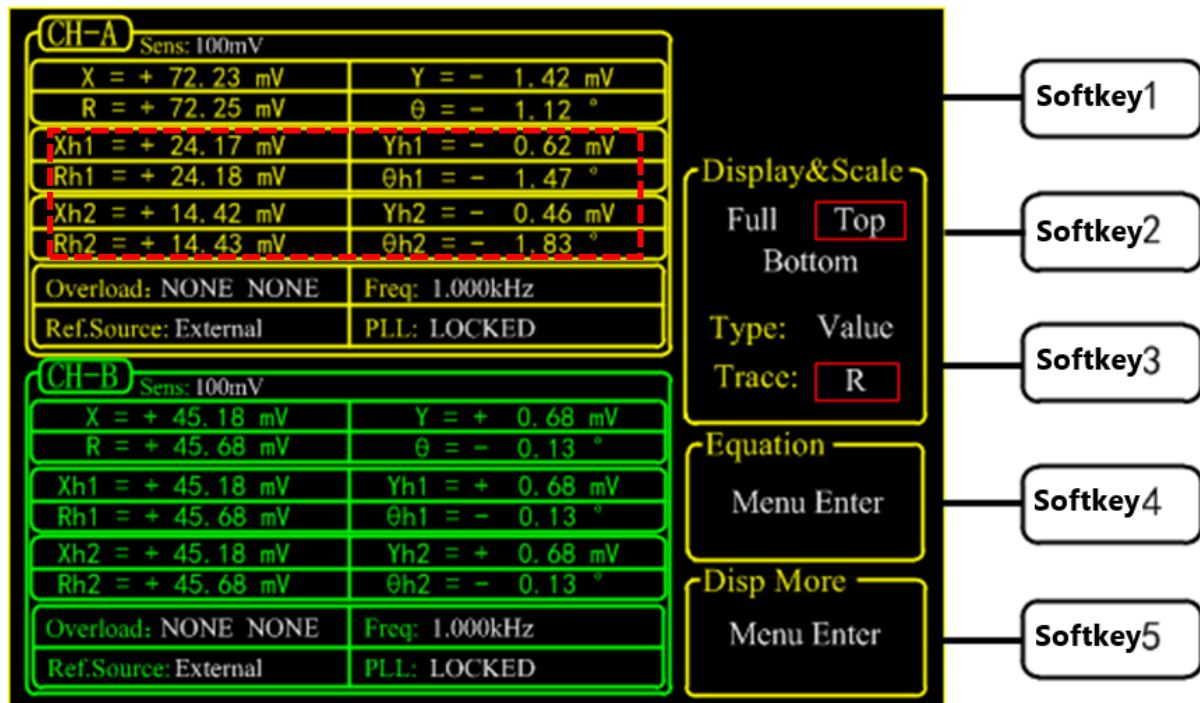
Fig.97 The 3th Harmonic Measurement Result

How to get the amplitude of the nth harmonics

How to calculate the harmonic theoretical value of the square wave: suppose that the peak-peak value of square value is E and the angular frequency is ω. After Fourier expand, the result is:

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

Where the nth harmonic is a sine wave:

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

Therefore, the valid value of the nth harmonic is:

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

We can verify that whether the measured result is close to the theoretical result. In this example, the peak-peak value E is 160mV, and the calculated value of first harmonic is:

$$R = \frac{\sqrt{2} \times 160}{1 \times \pi} mV \approx 72.025 \ mV$$

The calculated value of third harmonic is:

$$R = \frac{\sqrt{2} \times 160}{3 \times \pi} mV \approx 24.008 \ mV$$

The calculated value of fifth harmonic is:

$$R = \frac{\sqrt{2} \times 160}{5 \times \pi} mV \approx 14.410 \ mV$$

Compare the measured result with theoretical result according the above method.

8.3 Optical Spectral Measurements

This case shows how to measure a spectral diagram of any light source. You need an optical chopper (such as SIGNAL RECOVERY MODEL 197 Light Chopper), a grating monochromator (such as WDG15-Z) and its control system, a photoelectric detector (such as the S286 series photodiode of Japan Hamamatsu Company), a data collection platform (such as NI cDAQ-9172) and a PC. You should control the monochromator to sweep automatically in the spectral measurement range. Then measure the photo current by the OE1022D. The steps are as follows:

1. Disconnect all cables from the lock-in. Connect the power source and then turn on the power switch. The system is in default.

2. Set the corresponding parameters of OE1022D.
   (1) Press [INPUT/FILTERS] and then set the input mode to <I> and <Amplitude: 1M>. Other settings remain the default.
   (2) Press [REF/PHASE] and then set <Ref. Source: External> and <Type: TTL>.
   (3) Press [GAIN/TC] and then set <Sensitivity: 1μA> which can be adjusted in measurement, <Reserve: Normal>, <TC: 300ms> and <Roll off: 12dB/oct>. Finally, turn off the SYNCD filter.
   (4) Press [OUTPDUT/OFFSET] and then set <CH1>, <Source: R> and <Speed: Fast>.

3. Build up the spectral measurement platform.
Use a BNC cable to connect the output of the photoelectric detector and the IN+ input of the OE1022D.
Use a BNC cable to connect the OUTPUT of the optical chopper and the REF IN of the OE1022D.
Use a BNC cable to connect the data collection platform and the CH1 OUT of the OE1022D.
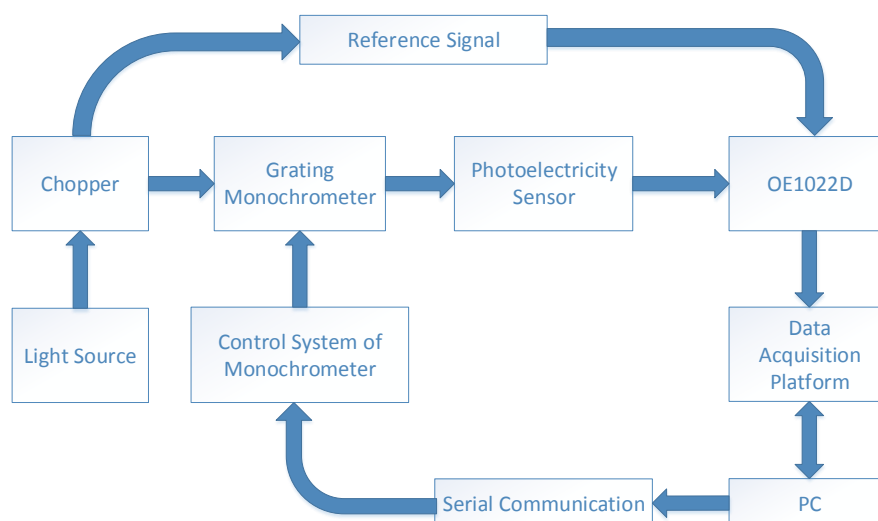The sketch is shown in Fig.98

Fig.98 Spectral Measurement Platform Diagram

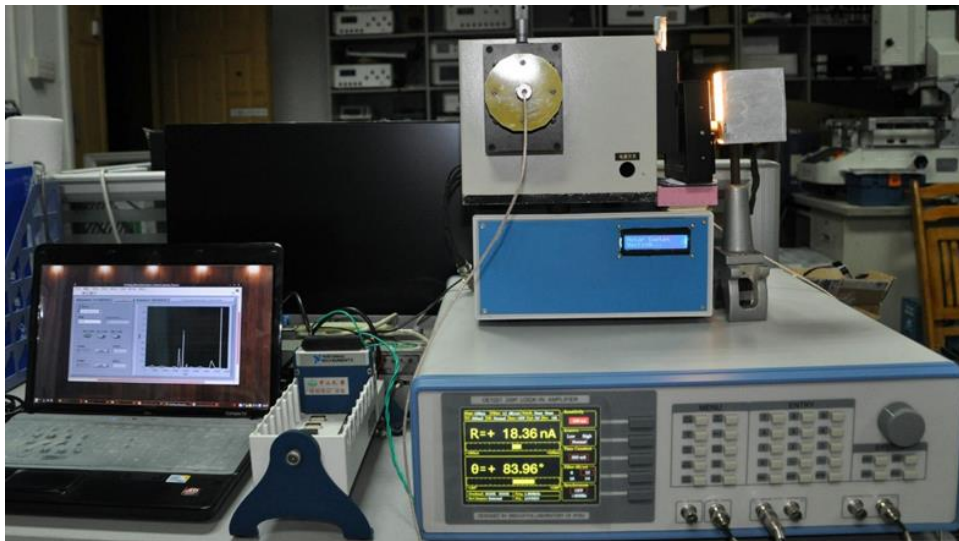The actual connect figure is shown in Fig.101.

Fig.99 Spectral measurement platform physical connection

4. Start the spectral measurement and collect data from the data collection platform. Then, you will get a spectral curve as shown in Fig.100
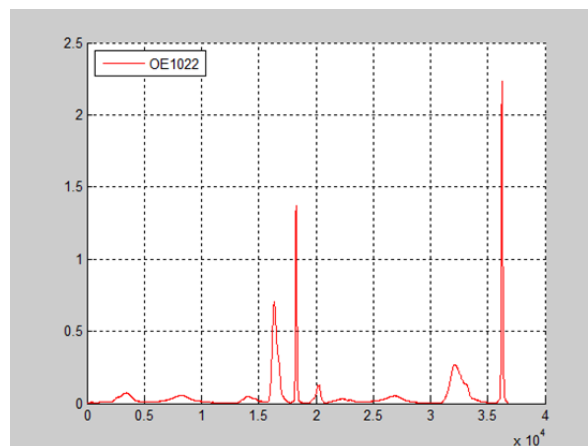

Fig.100 Spectrum Curve measured by OE1022D

5. Use the SR830 instead of the OE1022D to measure. Repeat the steps above to run the same experiment. Then you will get another spectral curve as shown in Fig.101. You can see that these two curves measured by OE1022D and SR830 are almost the same.
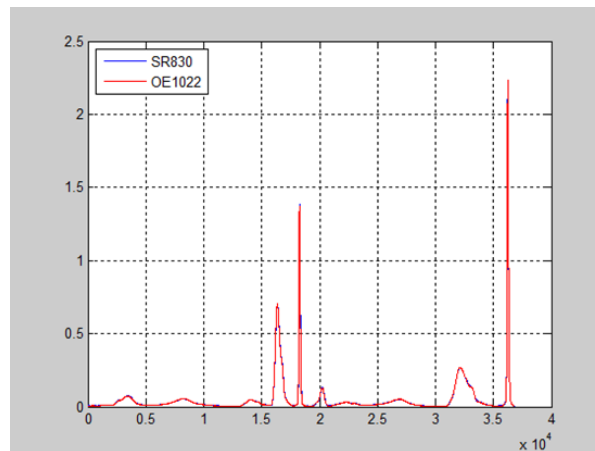
Fig.101 Contrast Spectrum Curve between SR830 and OE1022D

8.4 Serial Communication

This case shows how to run the serial communication remotely. You need an USB cable. The steps are as follows:

1. Use an USB serial converter to connect the serial port of the OE1022D to the USB socket of the PC.

2. The PC will recognize the USB device and remind to install the driver program. If your PC system is WIN 7/8/10, the PC will do these automatically online. You just need to wait for a few minutes. If the installation fails, you need to install the driver manually according to Chapter 6.2.

3. Open the folder 'Uart Driver' in your disk and double click the file UartAssist.exe. It will call out the software interface, as shown in Fig.102.

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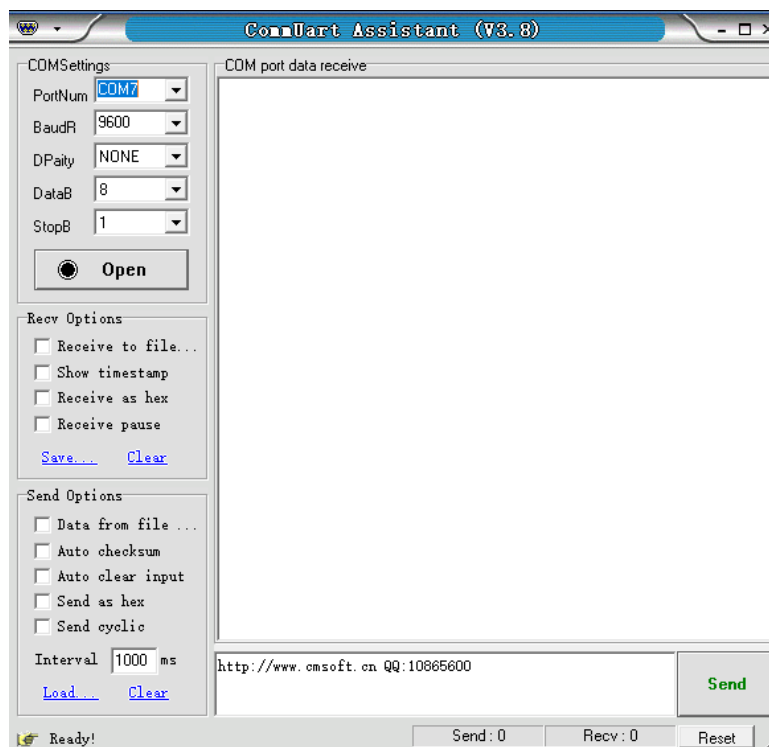
Fig.102 'UartAssist.exe' Software Interface

Note that this software can set the communication mode, the receiver mode, the transfer mode. The default Baud rate of the OE1022D is 9600. The OE1022D has no parity bit, 8 data bits and 1 stop bit. The port number choose the COM number automatically assigned by the PC.

Users can check it at the 'COM and LPT' option in Device Manager of the PC, as shown in Fig.103.
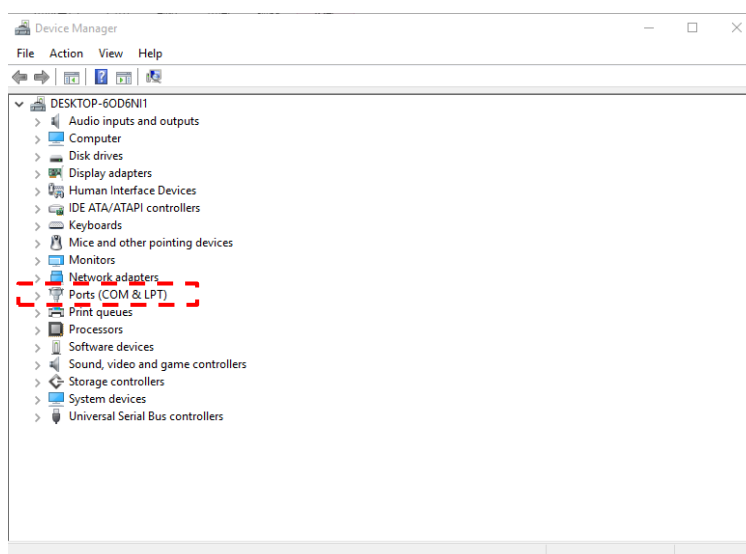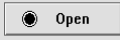

Fig.103 Check the port number at 'Device Manager'

2) After these settings are completed, if you see a black circle like ⬤ Open , you need to click the

button to turn it into ⬤ Close . If you fail in doing so, please check the port number and retry the

connection. Please note that if the baud rate is too high, packet loss might occur in process of

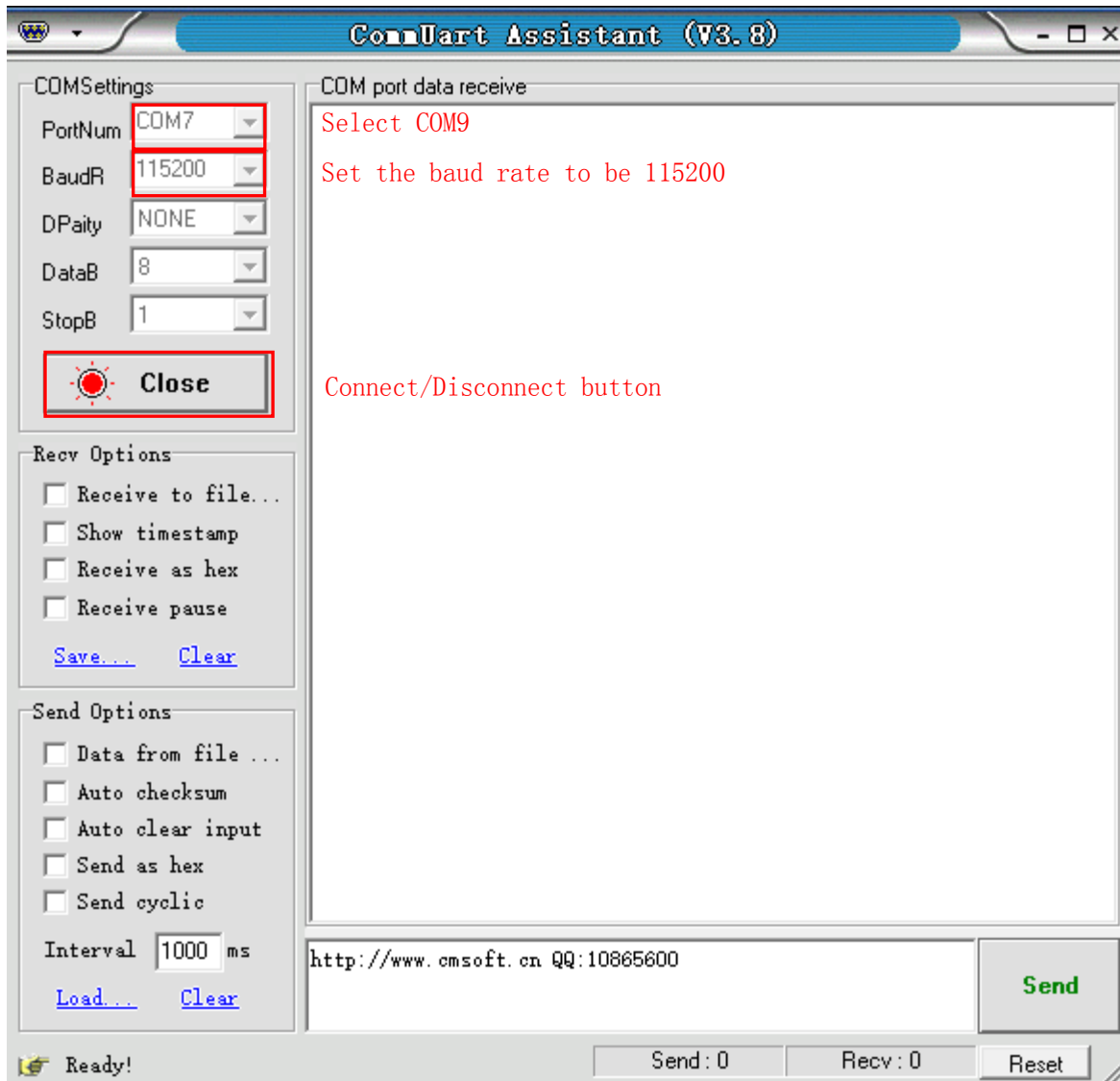data transmission. In our example, we set the baud rate to be 115200 as shown in Fig.104.

Fig.104 USB connection succeeds

4. Transfer commands to communicate with the OE1022D.

1) The command format of OE1022D is defined as follows: upper mnemonics + channel selection
(1/2) + option parameters + semicolon/carriage return sign. For more details, please see Chapter
5 Remote Programming. To send commands, firstly, clear input area. Secondly, input commands
in the sending area, single command can be finished by pressing the 'Enter' key rather than with
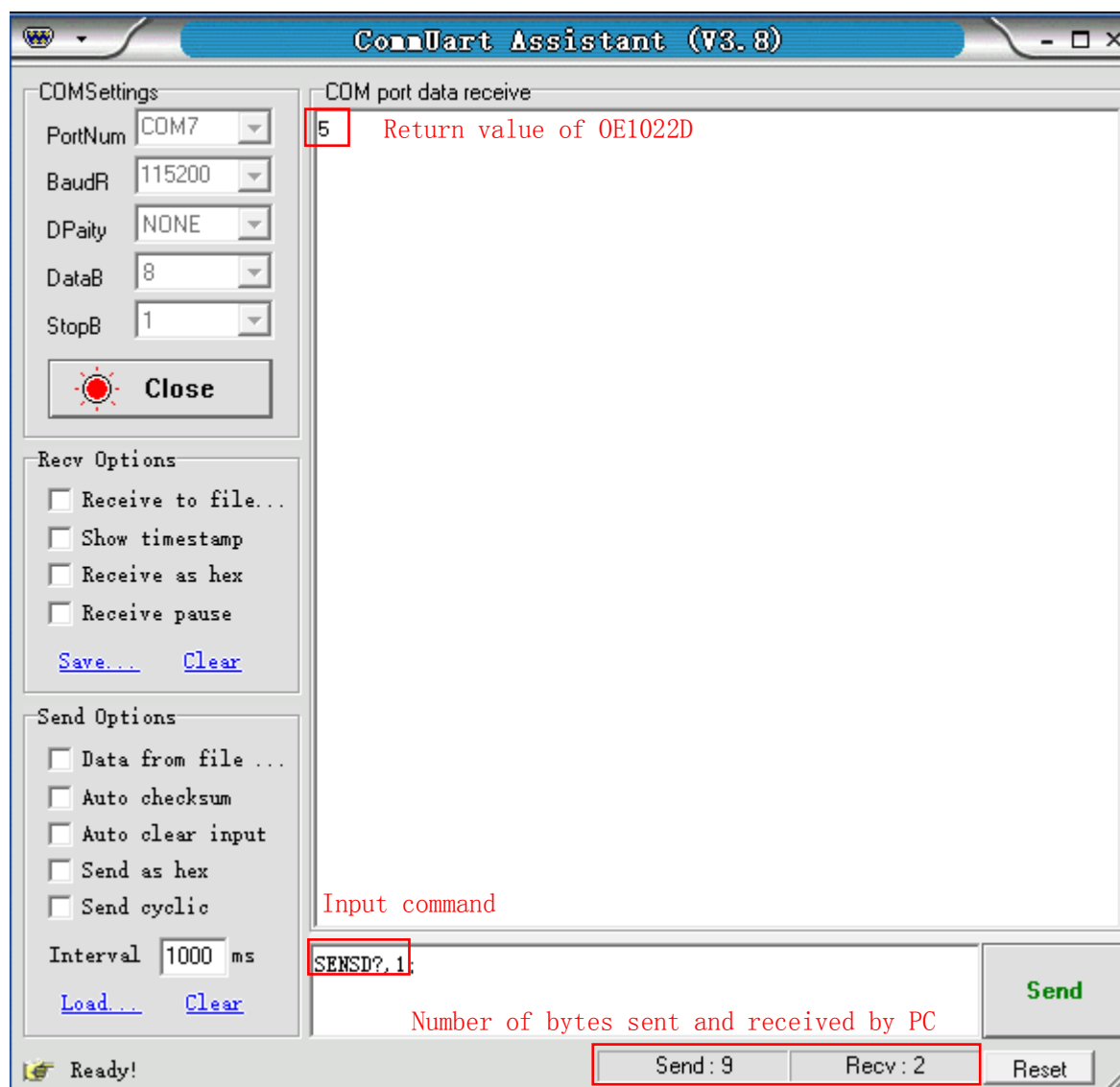a semicolon. Thirdly, click the 'Send' button to send command.
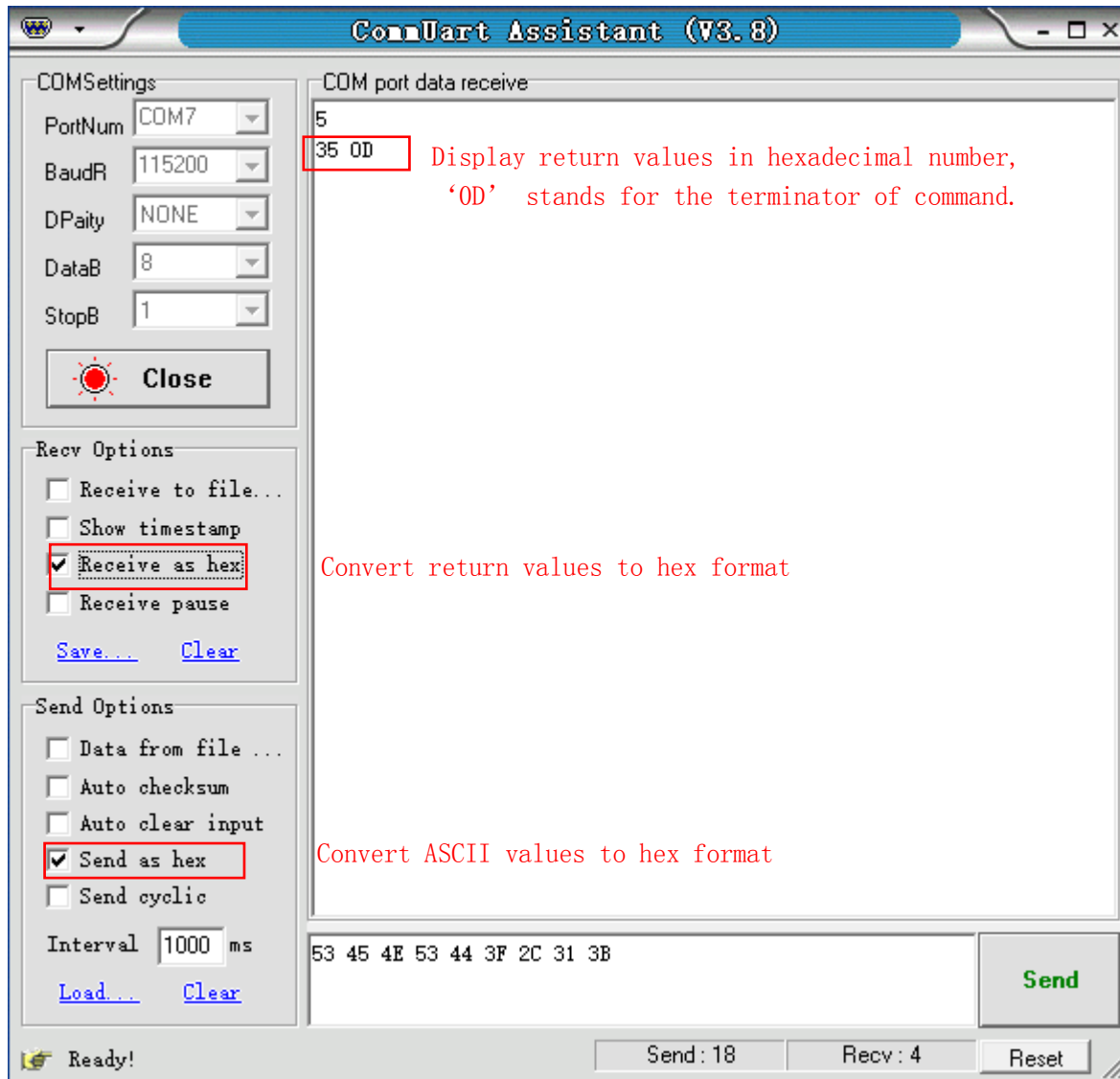
Fig.105 Send and receive commands in ASCII codes

Fig.106 Send and receive commands in HEX

The serial assistant can automatically add carriage return sign 0X0D. You just need to click `Auto checksum` and choose `Fixed Byte Checksum` as shown in Fig.107.
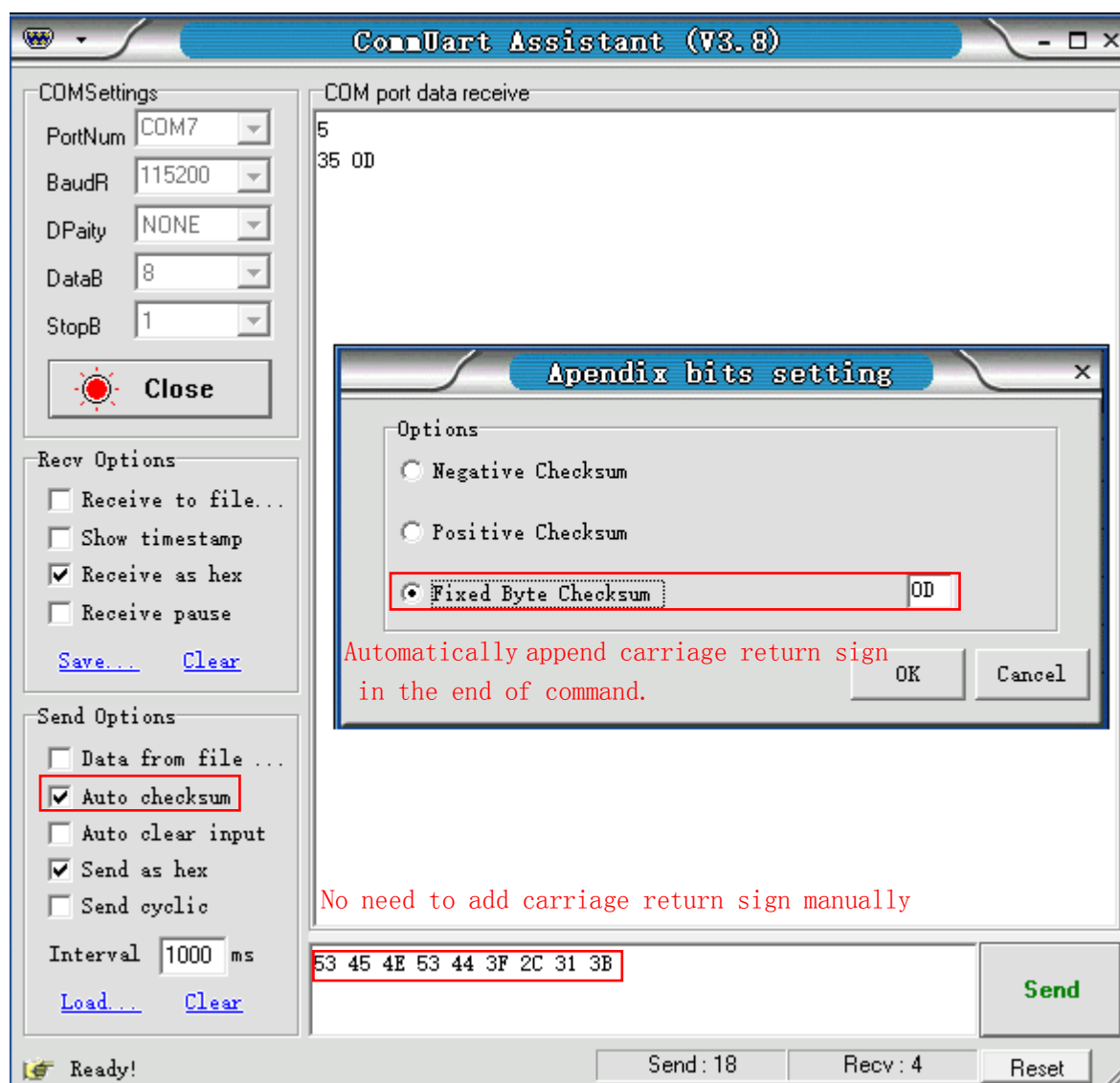
Fig.107 Setting the checksum

Multiple commands are separated by ';', such as 'SENSD 1,25;FMODD 1,1;FREQD ,1,2048;SENSD ?,1; FREQD ?,1' , as shown in Fig.108.
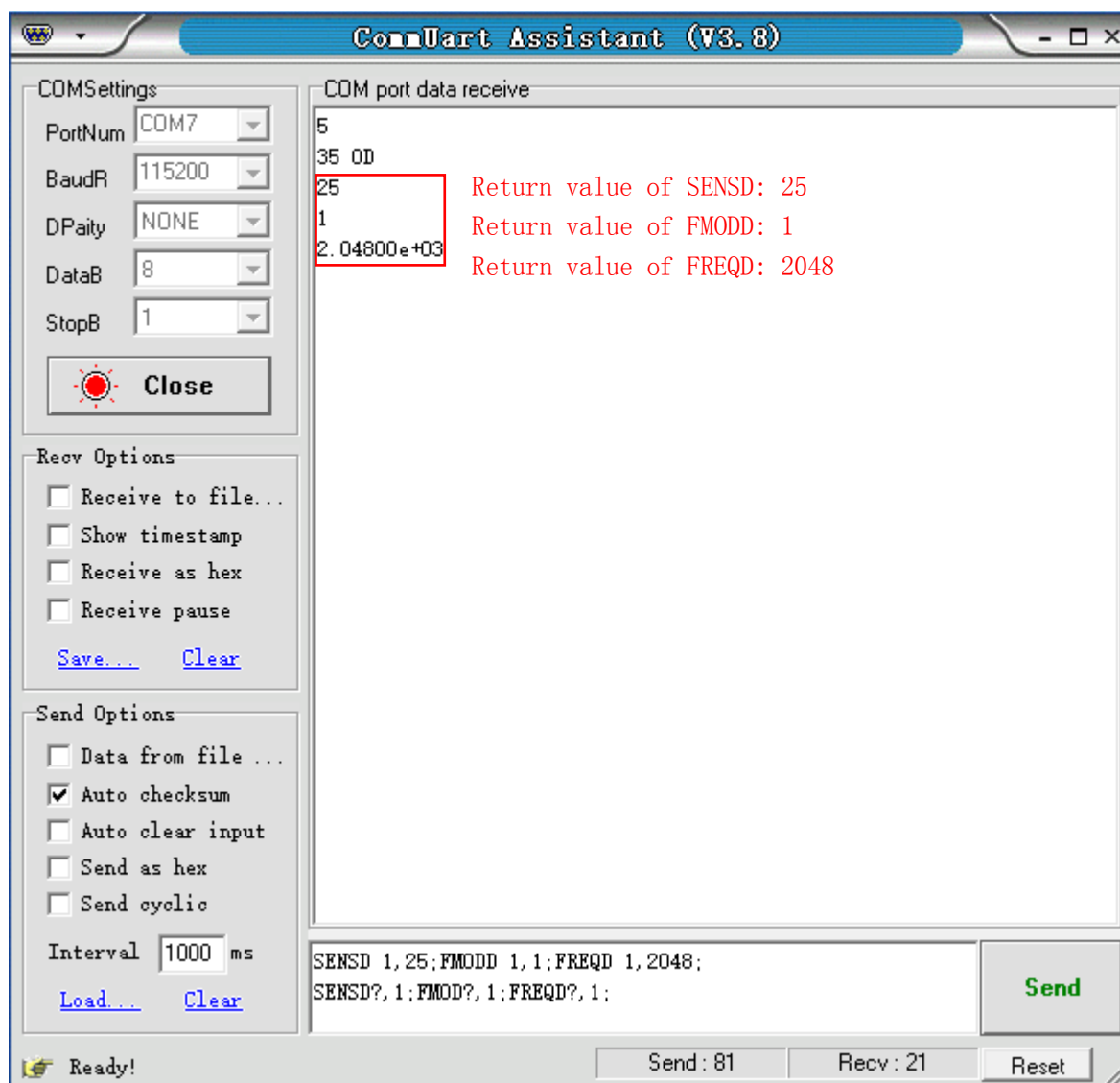
Fig.108 The execution of multiple commands

If you want to read the values of <X>, <Y>, <R>, <θ> and Frequency continuously, you can set the transfer interval time as Fig.106 and Fig.107.
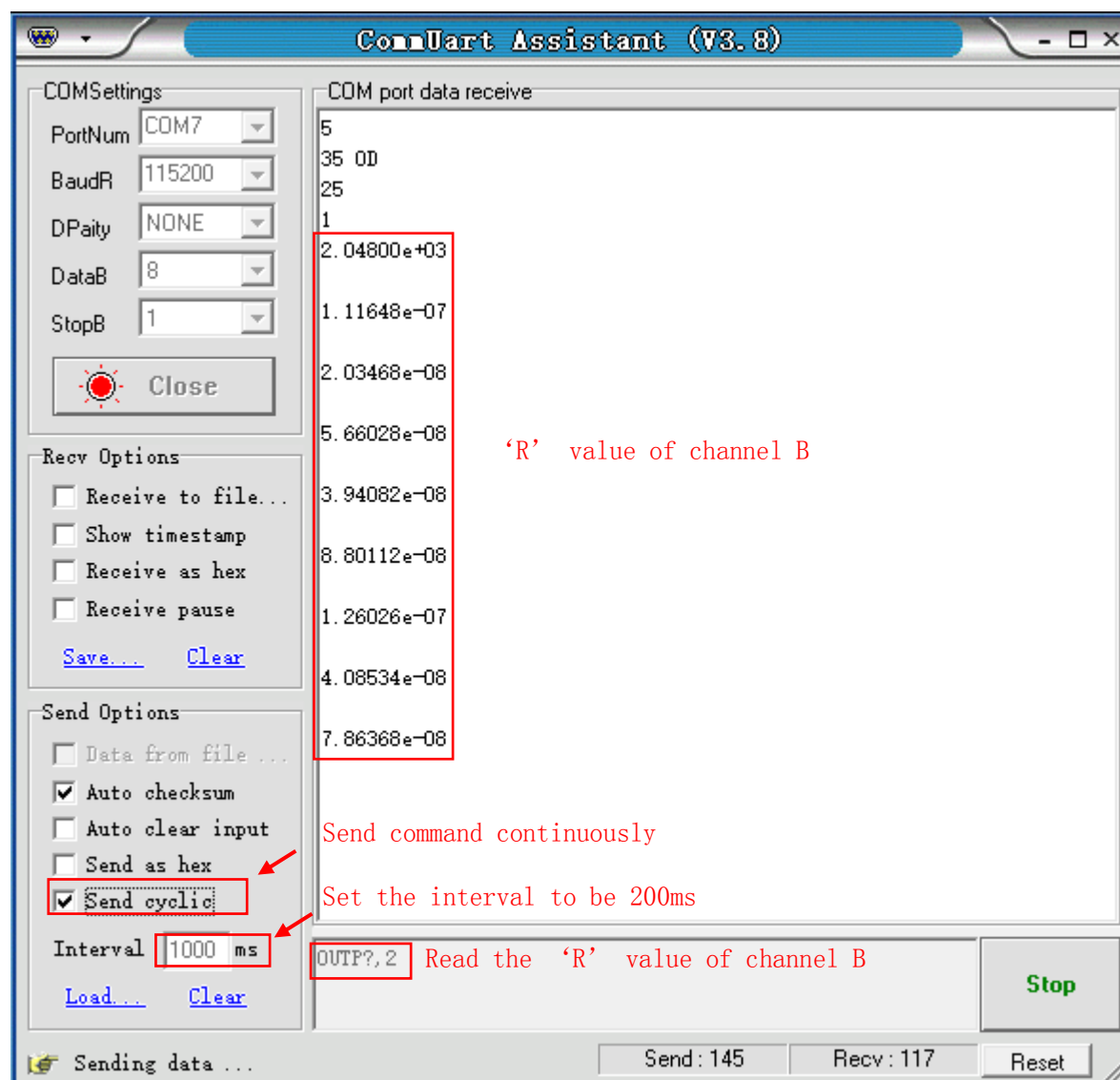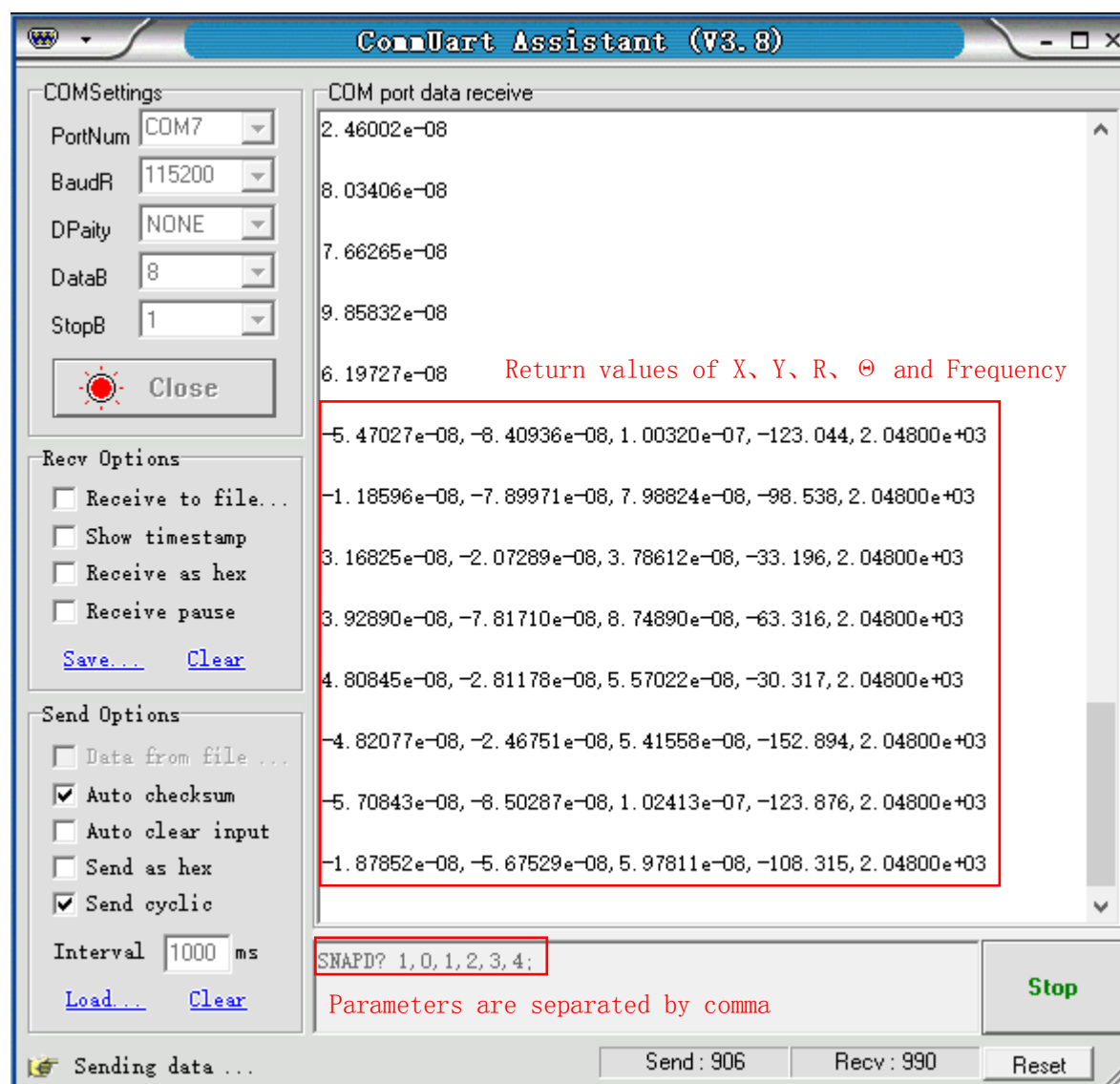
Fig.109 Read the 'R' value continuously

Fig.110 Read the Values of X, Y, R, θ and Freq continuously

Note that when use this software to control the OE1022D, the LCD display will refresh at the same time.

The OE1022D supports many versions of serial debugging assistant. You can use other software to control the OE1022D remotely.