

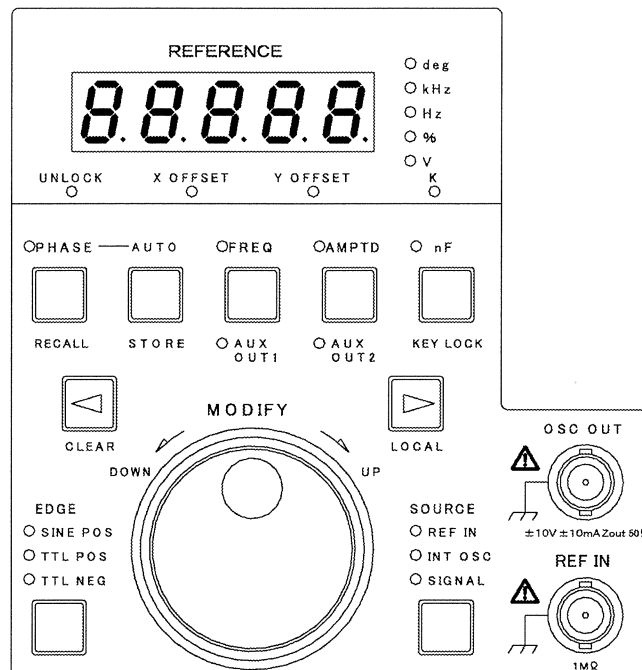
## 4. Detailed Description and Applied Operation

4.1 Operation of reference signal system	4-2
4.2 Operation of measured signal system	4-10
4.3 Operation of power supply frequency noise reduction filter	4-18
4.4 Operation of anti-aliasing filter	4-19
4.5 Operation of dynamic reserve	4-20
4.6 Operation of sensitivity (SENSITIVITY)	4-23
4.7 Operation of time constant and related matters (TIME CONSTANT)	4-25
4.8 Selection of measurement parameters and related operation	4-29
4.9 Ratio indication	4-33
4.10 Measurement of noise density (NOISE)	4-34
4.11 Measurement of DC voltage (auxiliary input AUX IN1/AUX IN2)	4-37
4.12 Output of DC voltage (auxiliary output AUX OUT1/AUX OUT2)	4-38
4.13 Monitor output	4-39
4.14 Operation of setting memory (RECALL/STORE)	4-40
4.15 Disabling panel operation (KEY LOCK)	4-41
4.16 Turning ON/OFF lamps and cooling fan	4-42

## 4.1 Operation of reference signal system

LI5640 requires a reference signal as the datum for frequency and phase.

### 4.1.1 Setting a reference signal (overview)



#### PHASE (- AUTO)

This key displays the phase offset. Shift the reference signal phase so that Y will be zeroed, and the user can read the magnitude of signal at X. It is also possible to do this automatically with the AUTO key.

#### FREQ

This displays the frequency. Select the internal oscillator INT OSC, and the user can set the frequency in the range from 0.5mHz to 105kHz.

#### AMPTD

This shows the amplitude of OSC OUT. The amplitude can be set in the range from 0 to 5Vrms.

#### nF

This shows the order of the harmonics. The order can be set in the range from 1 (fundamental wave) to 19999. However, harmonics must be up to 105kHz.

#### OSC OUT

This function provides a sine wave from the internal oscillator. Set SOURCE to INT OSC. REF OUT on the rear panel provides a TTL-level square wave.

#### REF IN

Supply here the external reference signal. Set SOURCE to REF IN. 0.3 to 30Vp-p sine waves (or square waves) and TTL-level square waves are acceptable here.

## SOURCE

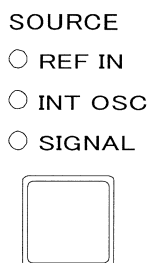
To use external reference signal, select REF IN. To use internal oscillator, select INT OSC. To achieve synchronization with SIGNAL INPUT without supplying a reference signal, select SIGNAL.


## EDGE

Use this function to use REF IN. Select SINE POS when to use a sine wave or a square wave in which the phase reference is the point at which the wave crosses the average value. To use a TTL-level square wave, select TTL POS (rising edge) or TTL NEG (falling edge).

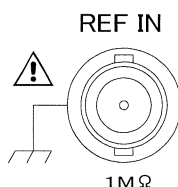
### 4.1.2 Selection of reference signal source (SOURCE)

LI5640 allows the user to use three types of reference signal. Select with the SOURCE key.



- External reference signal (REF IN)  
Supply reference signal from outside.  
 Refer to Section 4.1.3 "External reference signal (REF IN)".
- Internal oscillator (INT OSC)  
LI5640 generates a reference signal having the specified frequency and amplitude.
- Measured signal (SIGNAL)  
A reference signal synchronous with the measured signal is created internally.

### 4.1.3 External reference signal (REF IN)



Supply a reference signal to the REF IN connector from a separately prepared signal generator.

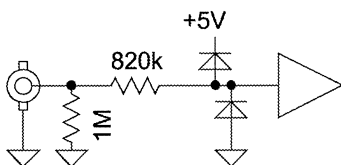
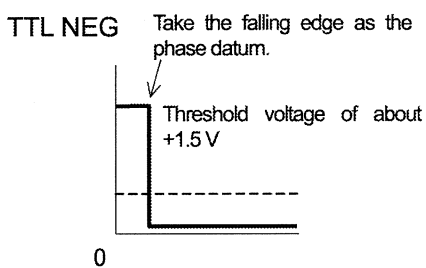
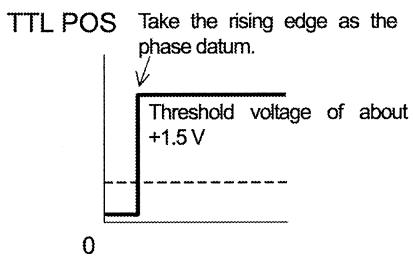
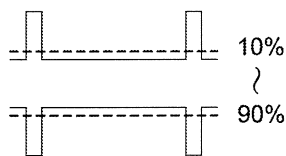
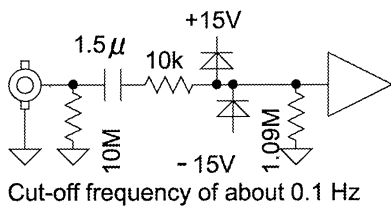
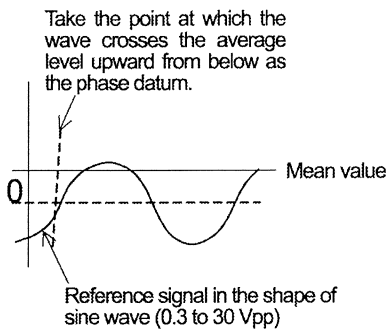
Input impedance	:approx. 1M $\Omega$
Maximum nondestructive input voltage	: $\pm$ 40V
Signal ground	:connected to the chassis



When to use an external reference signal, specify the waveform and phase reference point using the EDGE key.

When the internal oscillator or measured signal is used as the reference signal, the REF IN and EDGE keys are not effective for selection.

In addition, if the reference signal contains noise or time fluctuation, phase noise will increase.



● SINE POS

Use SINE POS for reference signals in which the wave crosses the mean value two times in one period such as sine and square waves.

Input voltage range : 0.3 to 30Vp-p

(Mean value is  $\pm 15V$  for general waveforms)

If this range is exceeded, the protection circuit is activated to lower the input impedance.

If the noise is high, the wave crosses the mean value more than two times, which may hamper proper synchronization.

With SINE POS, the system operates regardless of DC components owing to the AC coupling circuit. However, signal attenuation and phase error becomes conspicuous if the frequency is approximately 1Hz or lower. Therefore, SINE POS should be used for 1Hz or higher frequencies. For lower frequencies, square waves with high amplitude are preferable rather than sine waves.

When using a square wave, keep the duty factor (the proportion of high level in one period) within the range of 10 to 90%. If the amplitude is small or frequency is low, keep the duty factor at approx. 50% to avoid malfunction.

● TTL POS/TTL NEG

Use this function when a TTL-level square wave is used for the reference signal.

For reference signal with the frequency of 0.1Hz or lower, a TTL-level square wave is recommended.

Signal level : 0 to 5V

Pulse width : 20ns or longer

(for both high and low levels)

Keep the transition time between the high and low levels to  $1\mu s$  or lower in order to avoid malfunction by noise. However, in the case of a square wave that transits very quickly, the waveform may be disturbed, causing malfunction. In such cases, add a resistor with  $50\Omega$  or so in series to the reference signal source.

If the range of 0 to 5V is exceeded, the protection circuit is activated to slightly lower the input impedance.

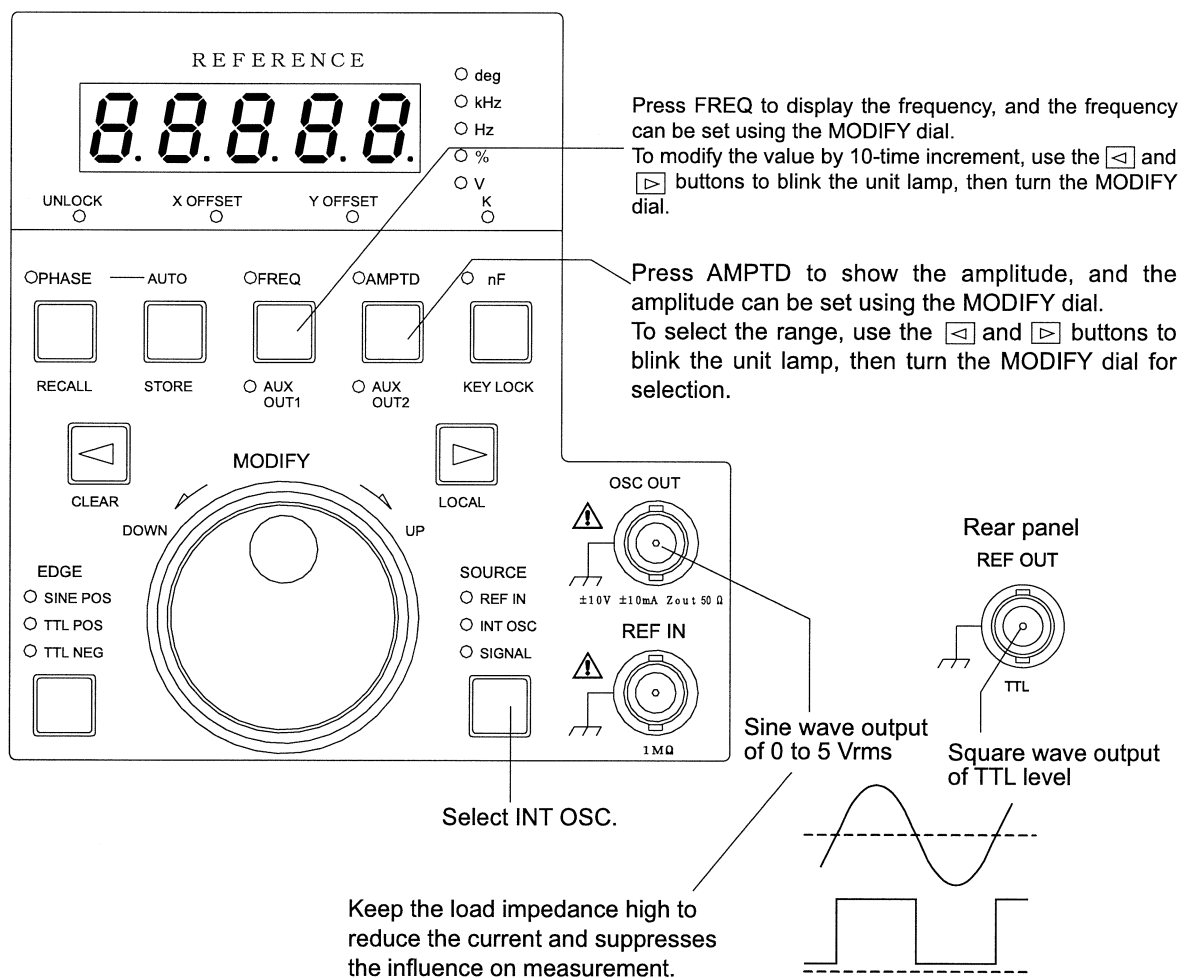
When an external reference signal is used, a synchronous sine wave (i.e., having the same frequency as the reference signal) is available at the OSC OUT connector. The amplitude can be set similarly to the case in which the internal oscillator is used. Also a TTL-level square wave is available at the REFOUT connector on the rear panel.

### 4.1.4 Internal oscillator (INT OSC)

LI5640 can generate a reference signal (sine wave and TTL-level square wave)

#### [Major specifications]

Oscillated frequency:	0.0005Hz to 105.00kHz (max. 19999)
Output voltage:	Three ranges of 0.0500, 0.500, and 5.00Vrms (max. 500)
	Amplitude diminishes drastically when approximately 102kHz is exceeded.
Maximum output current:	$\pm 10\text{mA}$
Output impedance:	$50\ \Omega \pm 3\%$



#### **CAUTION**

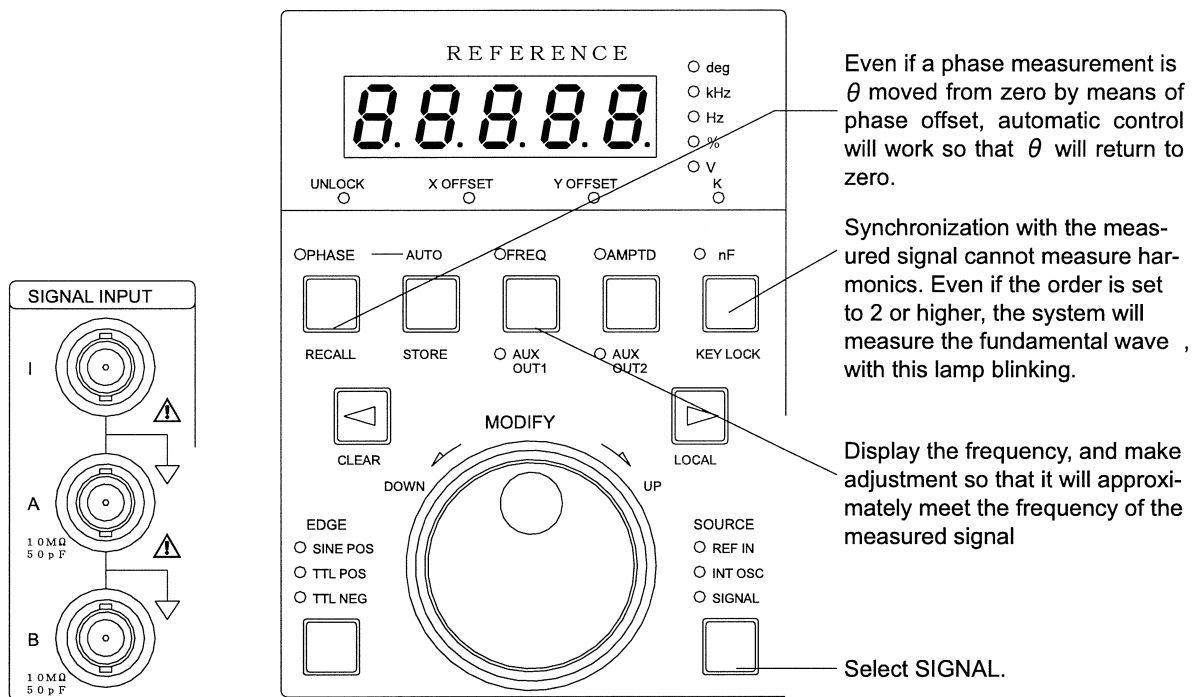
Do not apply external voltage to the output connectors. Doing this will break the internal circuit.

Maximum output current of OSC OUT is  $\pm 10\text{mA}$ .  $50\ \Omega$  load cannot be connected.

Keep the load from REF OUT to the ground or to +5 V to a  $500\ \Omega$  or higher value.

### 4.1.5 Synchronization with measured signal (SIGNAL)

LI5640 assures measurement in synchronization with the measured signal itself, which is supplied to the I, A or B connector of SIGNAL INPUT, even when no independent reference signal is supplied. However, the user has to have a broad knowledge of the signal frequency and magnitude and the degree of noise. To keep synchronization with the measured signal, LI5640 controls the internal oscillator so that measurements of phase ( $\theta$ ) will be zeroed. Therefore, the user should make such a system setting beforehand that the unit can start measurement once an independent reference signal is given.



#### a) Operation procedure

- 1) Set the time constant based on the signal frequency and noise level.  
 If they are not clear, specify a value broadly three to ten times the signal period. (For quicker solution, first select a smaller value to look for a synchronization point, and when the synchronization point is detected, increase the value.)  
 Do not use the synchronous filter (SYNC).
- 2) Set the dynamic reserve and sensitivity taking into consideration the magnitude of the signal and noise.  
 If they are not clear, setting should be as follows:  
 Sensitivity : The sensitivity that allows the user to measure the expected maximum signal.  
 Dynamic reserve: MEDIUM; if the OVER lamp tends to light, then select HIGH.

3) Adjust the frequency so that it will be almost equal to the measured signal.

As the frequency approaches the measured signal, the frequency is automatically drawn in, and the phase  $\theta$  continues to near zero until synchronization is attained.

#### b) Setting the time constant

To ensure stable system operation, the time constant must meet the following conditions:

Time constant  $\geq 1/(c \times \text{frequency})$  where c is 1, 2, 3 and 4 for SLOPE of 6, 12, 18 and 24 (dB/oct), respectively.

Time constant  $\geq 100 \mu\text{s}$

If the noise is high, or if the signal is low, then select a time constant that allows sufficient elimination of noise and residual ripples.

Do not use the synchronous filter (SYNC).

#### c) Range of drawing

When the frequency of the subject signal comes in the following range in relation to the present frequency (FREQ), the frequency will be drawn. Keep manual adjustment to this range.

**Table 4-1 Range of Drawing for Measured Signal**

FREQ < 16kHz	FREQ/2
16kHz $\leq$ FREQ < 32kHz	FREQ/4
32kHz $\leq$ FREQ < 64kHz	FREQ/8
64kHz $\leq$ FREQ	FREQ/16

#### d) Restrictions on frequency change rate

Tracking becomes impossible if the frequency of measured signal fluctuates, exceeding the following broad change rate.

$$1 / \{1280 \times (c \times \text{time constant})^2\} \text{ Hz/s}$$

where c is 1, 2, 3 and 4 for SLOPE of 6, 12, 18 and 24 (dB/oct), respectively.

If the time constant is extremely high, the system cannot neglect even the temperature drift of crystal oscillator's frequency.

#### e) Relationship between the time constant and the time for synchronization

If the noise is low, the following expression may be used to determine a broad guideline for the settling time, which is taken from the point of approximate frequency coincidence, then through phase agreement to the time when the signal magnitude R reaches 99% of final value.

$5cT$ ; where T is the time constant and c is 1, 2, 3 and 4 for SLOPE of 6, 12, 18 and 24 (dB/oct), respectively.

#### f) Operation when control is drawn by other frequency than the intended one

It may happen that the system is drawn by other signal and adjustment of frequency is impossible if both of the following conditions are met:

- Time constant is short.
- Another signal(s) is present that has a frequency with which synchronization is possible.

In such cases, try the following steps:

- Move the blinking digit of frequency indication to upper one and swiftly adjust the frequency.
- Increase the time constant.
- First set SOURCE to INT OSC, and adjust the frequency to the intended signal as much as possible, and then switch SOURCE to SIGNAL.

### 4.1.6 Measurement of harmonics (nF)

With LI5640, the user can measure harmonics, or frequency components that are integral multiples of the reference signal frequency. The multiple is called the "Order" of the harmonic.

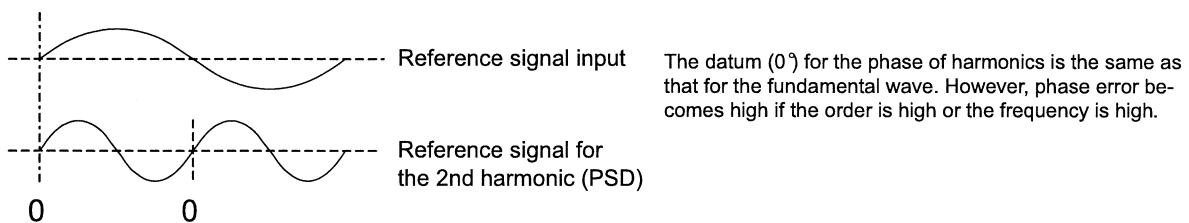
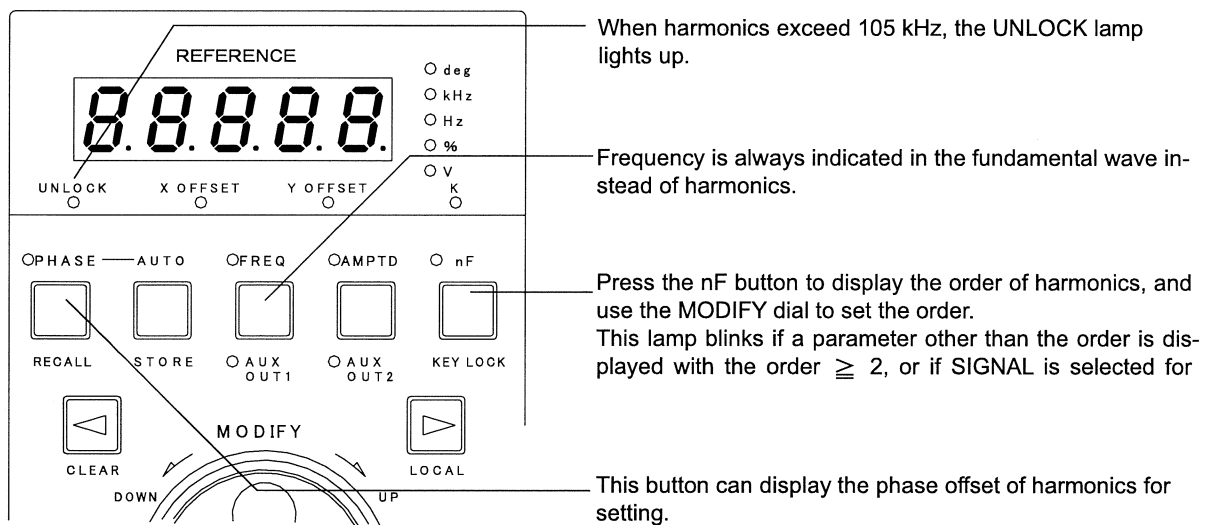
The range of order available: 1 to 19999. However, frequency of harmonics must be  $\leq 105$  kHz.

(Order = 1 means the fundamental wave instead of harmonics.)

Harmonic distortion of A and B inputs: -80dB or lower (10Hz to 5kHz), -70dB or lower (5kHz to 10 kHz)

For dynamic reserve of LOW, sensitivity of 1V and 1Vrms input

If dynamic reserve is high or signal is low, deterioration occurs.



#### [Instructions for harmonics measurement]

When SIGNAL is selected for SOURCE trying to achieve synchronization with the measured signal, harmonics cannot be measured. Even  $n \geq 2$  is specified, the measured wave is the fundamental one.

The fluctuation of reference signal phase appears in by-the-order-multiplied values against harmonics. For high-order harmonics, measurement is impossible unless the reference signal and the measured signal are sufficiently stabilized.

In many cases, the signal level of harmonics is lower than that of the fundamental wave. Also, one-order different harmonics may be present on either side. The time constant must be set to a value high enough to attenuate them.

### 4.1.7 Phase offset (PHASE)

Although lock-in amplifiers take the reference signal as the datum for the phase, LI5640 can give an offset to this standard.

Range of phase adjustment:  $-180.00^\circ$  to  $+179.99^\circ$  with resolution of  $0.01^\circ$

Phase offset has major objectives as follows:

- To adjust the reference phase to an arbitrary point for the convenience of the measurement system.
- To measure the signal magnitude by means of X while adjusting so that  $\theta$  will be 0 ( $Y = 0$ ). Compared with the method of R measurement, this method can reduce the measurement dispersion due to noise to  $1/\sqrt{2}$
- To monitor fine changes in the phase by means of Y while adjusting so that  $\theta$  will be 0 ( $Y = 0$ ). Use the EXPAND key to magnify Y by 10 times or 100 times. Phase can be calculated by the expression:  $\sin^{-1}(Y / R)$

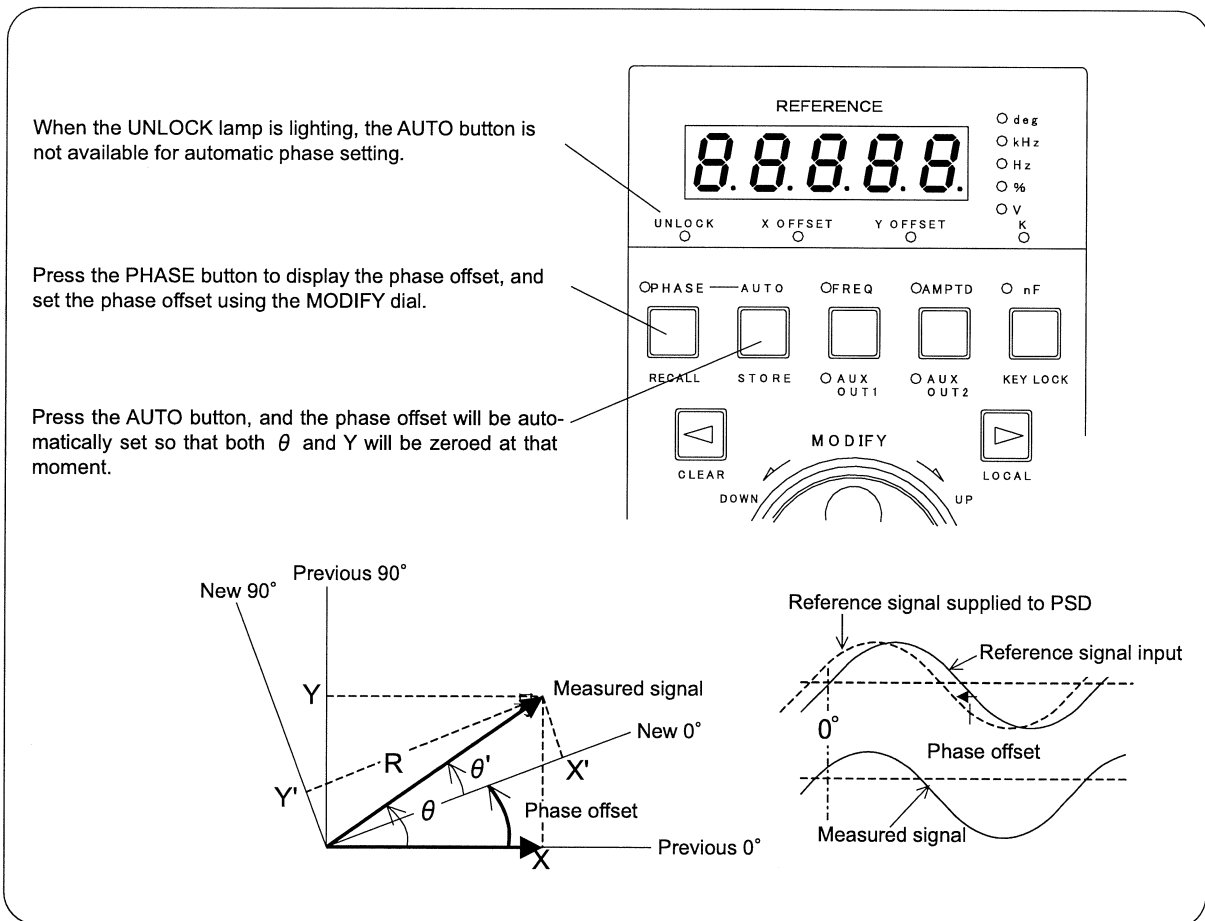
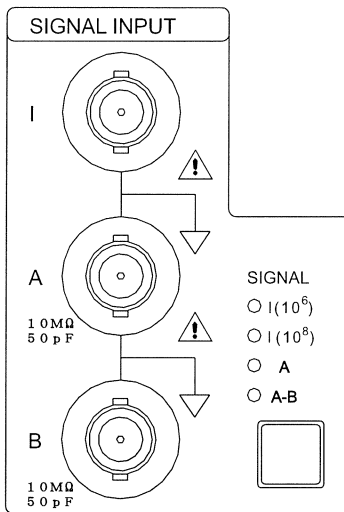


Fig. 4-1 Phase Offset

## 4.2 Operation of measured signal system

### 4.2.1 Connection and setting of measured signal



Connect the signal for measurement to the I, A and B connectors of SIGNAL INPUT.

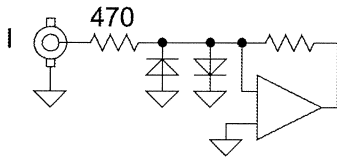
With the SIGNAL keys, select one out of I (10<sup>6</sup>), I (10<sup>8</sup>), A and A-B according to the connection.

- Current  
Connect to the connector I.  
Select I (10<sup>6</sup>) or I (10<sup>8</sup>).
- Voltage  
Connect to the connector A.  
Select A.
- Voltage (differential)  
Connect to the connector A and B.  
Select A-B.

#### CAUTION

Application of a voltage exceeding  $\pm 1V$  between the grounds of I, A and B input signals and the LI5640 chassis will admit high current to flow and break the internal circuit.

## 4.2.2 Current input



Current is measured after conversion to voltage.

When to use current input, specify the current/voltage conversion gain taking into consideration the signal magnitude and the frequency.

- I ( $10^6$ ):  $10^6$  V/A (50fA to  $1\mu\text{A}$ , up to 50kHz)
- I ( $10^8$ ):  $10^8$  V/A (5fA to 10nA, up to 500Hz)

If AC is selected for COUPLING with current input, DC will be eliminated after voltage conversion.

Use a peak value containing DC in the following range:

- $\pm 7\mu\text{A}$  for  $10^6$  V/A
- $\pm 70\text{nA}$  for  $10^8$  V/A

### **CAUTION**

Application of  $\pm 10\text{mA}$  or greater current will break the internal circuit. Do not connect a signal source that has a great current supply capacity. When current input is not used, attach the supplied protection cap to the connector I.

The value of input impedance is as follows (both at 500Hz):

$< 1\text{k}\Omega$  (at  $10^6$  V/A)

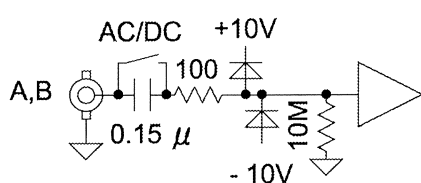
$< 20\text{k}\Omega$  (at  $10^8$  V/A)

In the region of frequency higher than several 100s of Hz, the input impedance increases approximately in proportion to the frequency.

With current input, take into consideration the following points:

- Provide sufficient shield.  
If the electrostatic shield is incomplete, noise current will flow in from the part at which the potential fluctuates.
- For connection, use a low-noise cable, which is unlikely to admit occurrence of noise charge.  
Noise will arise in the cable or inside LI5640 if vibration occurs.
- Keep the connector cable as short as practicable.  
If a long cable is used, frequency characteristics may deteriorate, or operation may become unstable due to the cable's electrostatic capacity.
- If the system is prone to effects of noise, provide a separate current input amplifier (NF's LI-76, for example) in the vicinity of the signal source.

### 4.2.3 Voltage input



Voltage sensitivity

2nV to 1V

(effective value or root-mean-square value (rms) of the signal)

Input impedance

$10\text{M}\Omega \pm 1.5\%$ , approx. 50pF in parallel

Maximum allowable input voltage (malfunction occurs if this range is exceeded)

For DC coupling :  $\pm 7\text{V}$

For AC coupling : 5Vrms (in sine wave) (mean value of  $\pm 7\text{V}$  for general waveforms)

The above values are available in the best condition; becomes smaller depending on the setting.

☞ For details ➡ Refer to Table 4-2 "Practical Values of Dynamic Reserve".

#### **CAUTION**

For AC coupling, application of a voltage exceeding 10Vrms by sine wave, or DC voltage of  $\pm 50\text{V}$  will break the internal circuit. For DC coupling, a voltage exceeding  $\pm 14\text{V}$  will break.

### 4.2.4 Differential input

If differential connection (A-B) is used in a voltage input configuration, unaffected measurement is available regardless of the difference between the grounding potential of the signal source and that of LI5640. In this A-B mode, A is measured in relation to B.

The performance of eliminating noise components applicable commonly to both inputs is as follows:

Common mode reduction ratio (CMRR): 120dB (typical for 1kHz), 100dB (min. for 50Hz to 1kHz)

These values are for the cases of AC coupling, dynamic reserve of LOW, sensitivity setting of 20mV or lower, or dynamic reserve of MEDIUM and sensitivity setting of 2mV or lower. The CMRR varies with the frequency, sensitivity (SENS), dynamic reserve (DR) and input coupling (AC/DC) as broadly shown in Fig. 4-2 "Differential Connection and CMRR".

The potential between the signal ground and A, and between the signal ground and B, is allowed up to  $\pm 7\text{V}$  (for DC coupling) or the mean value of  $\pm 7\text{V}$  (for AC coupling) regardless of the sensitivity and the dynamic reserve.

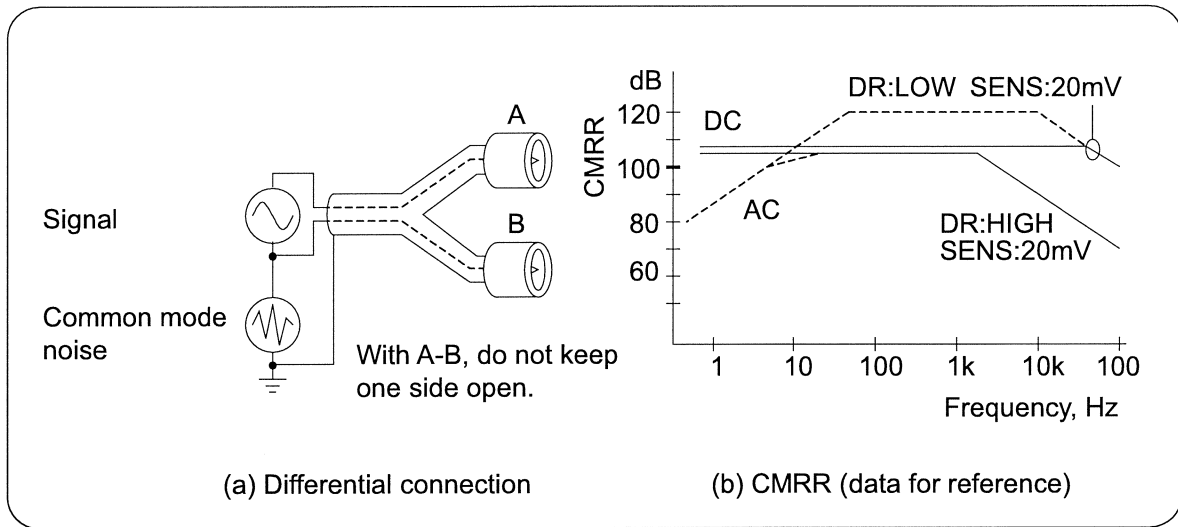
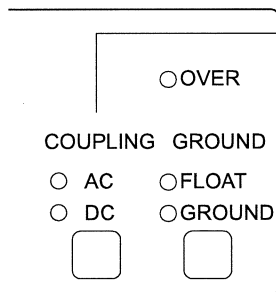


Fig. 4-2 Differential Connection and CMRR

### 4.2.5 Selection of input coupling



Select input coupling by taking into consideration the frequency and the DC components contained in the input. Normally, use AC (AC coupling) for frequencies equal to or higher than approximately 1 Hz and use DC (DC coupling) for frequencies lower than 1 Hz. Input coupling may be left to automatic selection by AUTO SET.

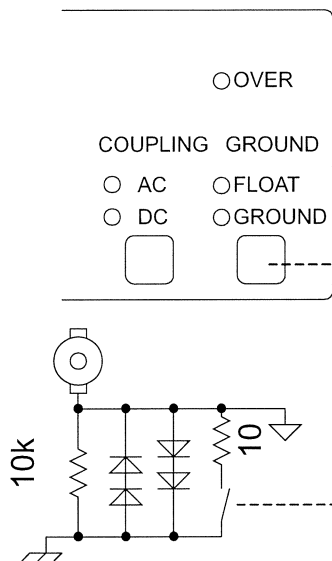
The cutoff frequency of AC (AC coupling) is approx. 0.1Hz, and DC up to  $\pm 50V$  can be eliminated. Although frequency characteristics by AC coupling are compensated up to approx. 0.1Hz, error will become greater with lower frequencies. With 0.1Hz or lower frequencies, error increases sharply. If input contains high DC components, it may be advantageous to use AC even with low frequency. To use AC with 1Hz or lower frequencies, confirm the measurement accuracy beforehand.

	Merits	Demerits
AC	High accuracy is assured because the user can amplify the measured signal greatly even if the input contains high DC components.	If frequency lowers: <ul style="list-style-type: none"> <li>• Measurement error increases.</li> <li>• CMRR decreases.</li> <li>• Takes time until value settles.</li> </ul>
DC	Measurement error of amplitude and phase is small even if the frequency is low. Response is quick because transition response due to AC coupling does not exist when the signal changes.	If input contains high DC components: <ul style="list-style-type: none"> <li>• Measurement error increases because it cannot be amplified.</li> <li>• Signal frequency ripples are likely to remain in output (low by synchronizing filter)</li> </ul>

If AC is selected with current input, DC will be eliminated after voltage conversion. Use a peak value containing DC in the following range:

- $\pm 7\mu A$  for  $10^6 V/A$
- $\pm 70nA$  for  $10^8 V/A$

### 4.2.6 Selection of ground



Normally, select FLOAT if the signal source is grounded and select GROUND if it is not.

Grounding both the signal source and the LI5640 input may create a ground loop, admitting noise current in the system, which in turn affects measurement. If a noise current flows in the ground line, a noise voltage is generated in the ground line.

If the signal source is not grounded, select GROUND and connect the input signal ground to the chassis of LI5640 in order to stabilize the potential. If the both are set to floating, earth impedance will become higher. Therefore, the earth (against the chassis) potential of the signal ground fluctuates because of the electrostatic coupling with noise source in vicinity and for other reasons.

The fluctuation of ground potential affects signal measurement by means of the isolation mode reduction ratio that has similar characteristics to those of the common mode reduction ratio.

When the user is going to ground either the signal source or LI5640 input, fluctuation of potential difference between the both grounds affects the measurement of small signal to a certain degree. Take consideration to minimize the difference of ground potential as much as possible.

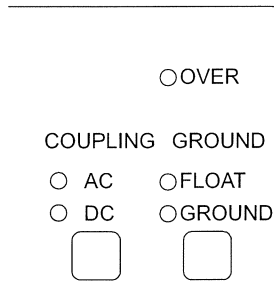
If environmental noise is high, also take the following measures:

- Use differential connection (A-B) for voltage signals.
- If the ground of the reference signal system is common to the ground of the measured signal source, provide an isolation transformer for signal in the reference signal input,

#### **⚠ CAUTION**

Application of a voltage exceeding  $\pm 1V$  between the grounds of I, A and B input signals and the LI5640 chassis will admit high current to flow and break the internal circuit.

### 4.2.7 Measures for OVER lamp lighting



The OVER lamp of SIGNAL INPUT lights up when the first amplifier for voltage input or current/voltage converter for current input is saturated with excessive input.

If the OVER lamp is found lighting, take the following steps to turn off the OVER lamp:

- Increase the dynamic reserve. (LOW → MEDIUM → HIGH)  
Decrease the gain of the first amplifier.
- Set the sensitivity to a higher value. (1mV → 2mV →)  
If the sensitivity has been set to 2mV or higher value, the user may increase the maximum allowable input voltage.  
If current input has been selected for measurement, decrease the current/voltage conversion gain ( $10^8 \rightarrow 10^6$ ) in addition to increasing the sensitivity setting.  
When the measurement lowers to 1/10 or less of the sensitivity full scale, the user may still use the EXPAND key for enlarging.
- Select AC coupling for signal input (DC → AC on COUPLING).  
This prevents DC components in the input from being amplified to an excessive level.  
Signal looks almost zero when full DC saturation occurs.

If the OVER lamp of SIGNAL INPUT lights up although both sensitivity and dynamic reserve are set to the maximum level (1V or  $1\mu\text{A}$  and HIGH), it is because the input signal (or noise) is too high. LI5640 is not available for measurement in this situation; decrease the input signal.

## 4.2.8 Connection of preamplifier

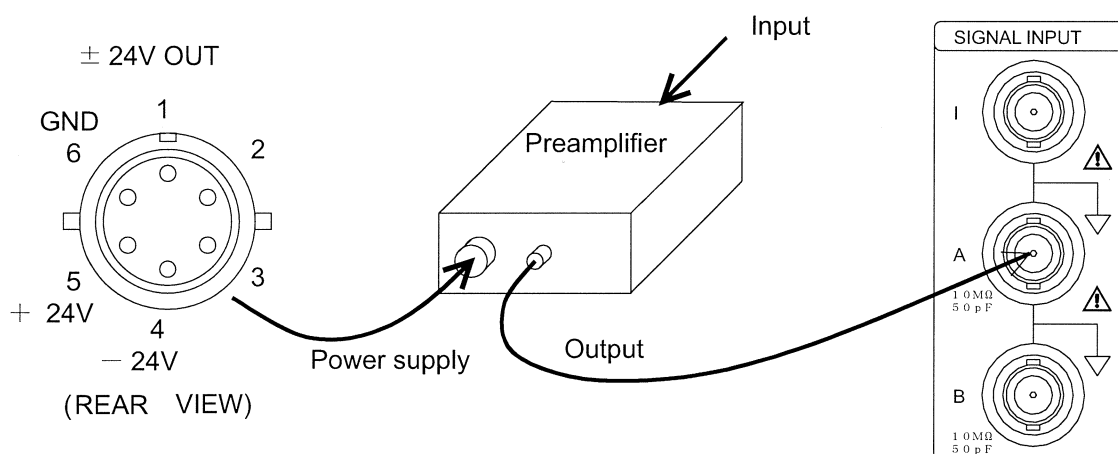
When the noise from LI5640 itself is considered troublesome, use a preamplifier with less noise.

If the signal source is located at a distant position from LI5640, first amplify the signal near the signal source and then send the signal to LI5640 in order to reduce the surrounding noise influence.

NF Corporation provides a range of preamplifiers including Low-noise Preamplifier LI-75A and Current-Input Preamplifier LI-76. LI5640 can supply power to our product preamplifiers although special DC Power Supply PS-70A is available. Connection should be made with the cable supplied with the preamplifier.

Output voltage :  $\pm 24\text{V}$  (DC)

Output current :  $\pm 50\text{mA}$  (max)



### **CAUTION**

The ground of  $\pm 24$  OUT power supply is connected to the grounds of I, A, and B input signals. Application of a voltage exceeding  $\pm 1\text{V}$  between these grounds and the LI5640 chassis will admit high current to flow and break the internal circuit.

Do not apply external voltage to the  $\pm 24\text{V}$  power supply terminals.

### 4.2.9 Use of input transformer

If noise is troublesome, also consider use of an input transformer.

An input transformer is effective in the following cases:

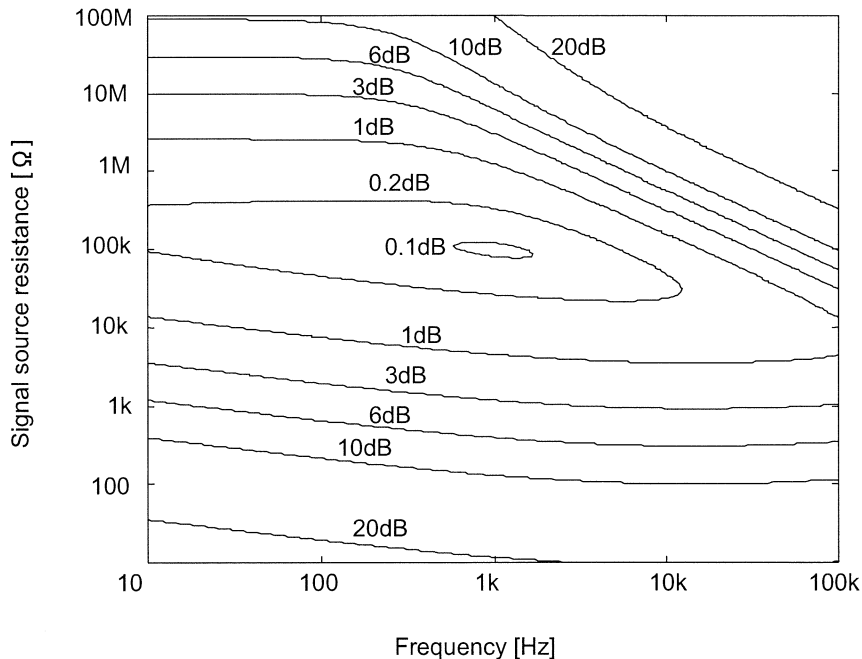
- To improve noise figure when signal source resistance is low.
- To isolate the ground of signal source from the signal grounds of the lock-in amplifier.

For the input transformer, NF Corporation recommends LI-771/772, which is specially designed for lock-in amplifiers.

If the signal source resistance is low, in general, noise figure becomes larger. In such cases, use an adequate input transformer to increase the voltage. This will increase the signal source resistance viewed from the lock-in amplifier and decrease the noise figure. In other words, this method can improve the signal to noise ratio (S/N).

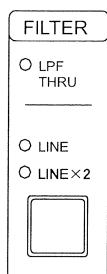
#### [Noise figure]

Use of amplifiers or measuring instruments always deteriorates the S/N ratio because they generate noise internally. Noise figure (NF) indicates the degree of S/N deterioration. A small or almost zero NF value means excellent noise characteristics, and NF varies with the frequencies and signal source resistance. The noise figure of LI5640 is shown below.



**Fig. 4-3 Noise Figure (for reference)**

## 4.3 Operation of power supply frequency noise reduction filter

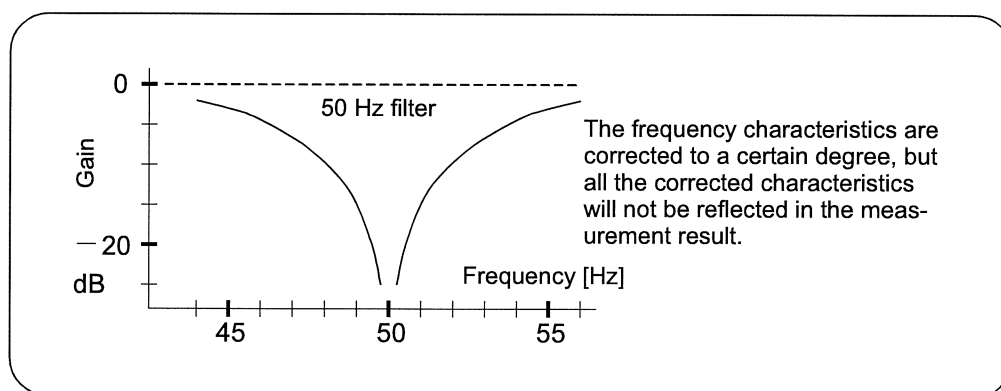


When measurement is carried out in practice, it sometimes happens that signal contains interfering noise (or so-called hum) that has the frequency of commercial power supply or integral multiples of that frequency. The noise of which frequency is equal to that of or twice that of the power supply can be attenuated down to one tenth or lower level if the user adopts a power supply frequency noise reduction filter.

Press the FILTER key to light up the LINE or LINE $\times$ 2 lamp. This will enable notch filters whose center frequency is the power supply frequency or twice that frequency respectively. It is also possible to use both LINE and LINE $\times$ 2.

If the measured frequency is sufficiently far from the power supply frequency and integral multiples of that frequency, the band-limiting filter can eliminate the hum after phase sensitive detector. However, if noise other than hum is little, the dynamic reserve for that portion is required accordingly. If a power supply frequency noise reduction filter is used to attenuate hum, the user can select lower values for the time constant (TIME CONSTANT) of the band-limiting filter and attenuation slope (SLOPE), which can reduce the measurement time in turn. Also, sufficient amplification can be achieved, and the effects of input referred noise become small, assuring retained accuracy.

If the frequency of measured signal is too near to the center frequency of the notch filter, measurement error in amplitude and phase becomes greater on the contrary. In such cases, increase the time constant instead of using the power supply frequency noise reduction filter. The filter characteristics can be corrected to a certain degree in the region outside the center frequency  $\pm 10\%$ , but further approach to the center frequency will suddenly increase the error.

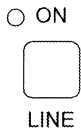


**Fig. 4-4 Characteristics of Power Supply Frequency Noise Reduction Filter (for reference)**

Although the product is applicable to either of 50 and 60Hz power supply frequency, the user has to specify the value. On the following occasions, be sure to specify the actual power supply frequency for setting:

- Just after product delivery
- When the instrument is moved to a location of a different power supply frequency
- When the instrument is reset to the factory default setting

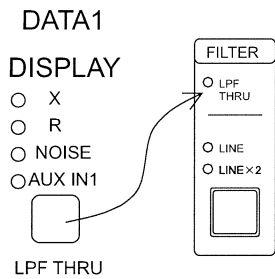
**DATA1 OFFSET**



Press the SHIFT + LINE keys to display the power supply frequency, the user can select 50 (Hz) or 60 (Hz) using the MODIFY dial. Press the SHIFT + EXIT key to return to the previous indication.

DATA1	DATA2	REFERENCE
	Lin	50

### 4.4 Operation of anti-aliasing filter



LI5640 allows the user to disable the anti-aliasing filter provided before the A/D converter, and this measure exerts the following two effects:

- To facilitate capture of signal that quickly changes
- To halve the temperature drift of phase at high frequencies

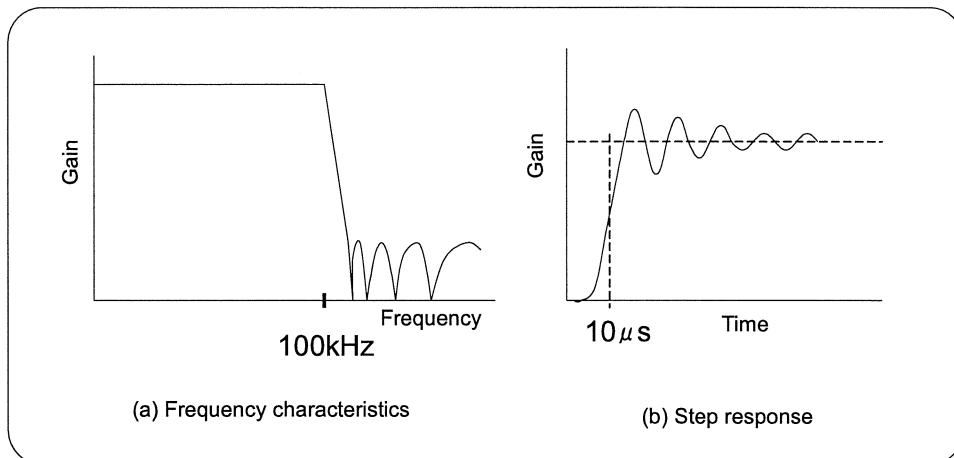
Press the SHIFT + LPF THRU keys to light the LPF THROU lamp, and the anti-aliasing filter will be disabled.

LI5640 converts measured signals into digital data, when all frequency components that have 1/2 of sampling frequency and higher are folded back into the band. These folded components cannot be eliminated later. To avoid this problem, the anti-aliasing filter with steep cutoff characteristics is provided before the A/D converter. However, the delay time and settling time of this filter are long, and therefore it is difficult to capture quickly changing the signals.

If the noise is low enough, the user can observe up to 100 μs response by specifying a shorter time constant. Then disabling the anti-aliasing filter will help somewhat quicken the response.

If the anti-aliasing filter is not used, however, noise becomes greater because those noises having high frequencies are folded back into the signal band. Measurement without using the anti-aliasing filter is effective only when noise is sufficiently low.

Be sure to turn off the LPF THRU lamp unless it is particularly needed.

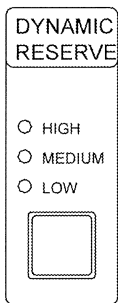


**Fig. 4-5 Anti-aliasing Filter**

## 4.5 Operation of dynamic reserve

Dynamic reserve indicates the value of margin for noise. It means the upper limit of the noise level in relation to the sensitivity full scale in which noise saturation does not occur.

LI5640 provides 100dB or greater dynamic reserve. Since all processing after phase sensitive detector is executed via digital calculation, dynamic reserve is not restrained by the DC offset and its drift like in analog systems.



LI5640 allows the user to select dynamic reserve out of three levels of LOW, MEDIUM and HIGH. When the user has specified the sensitivity, select the minimum dynamic reserve so that the OVER lamp will not light up with that sensitivity. Selection of too high dynamic reserve would cause higher measurement error. Also, the AUTO key of SENSITIVITY may be used for automatic setting of dynamic reserve at the same time.

EXPAND  
  $\times 10$   
  $\times 100$



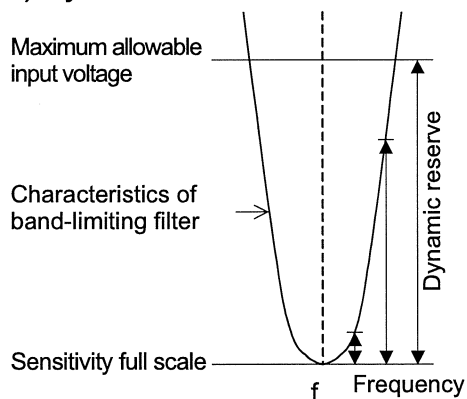
Use of the EXPAND key for magnified indication will produce the same result as increasing the dynamic reserve by enhancing the sensitivity. In effect, " $\times 10$ " increases the apparent dynamic reserve by 20dB, and " $\times 100$ " by 40dB.

If a sufficiently long time constant is selected, actually obtained dynamic reserve depends on the setting of DYNAMIC RESERVE and SENSITIVITY.

☞ Refer to Table 4-2 "Practical Values of Dynamic Reserve".

For specific noise, the value varies with the frequency distribution and the setting of time constant and attenuation slope. For further information, read the description below.

### a) Dynamic reserve for noise having specific frequencies

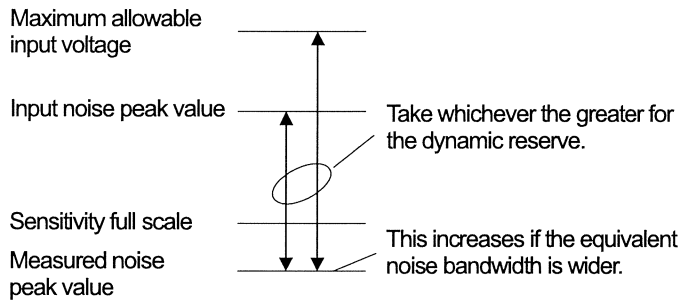


LI5640 equivalently works as a narrow band-pass filter. Therefore, the dynamic reserve that is actually secured depends on the frequency difference between the measured signal and noise.

For noise that has the same frequency as the signal, dynamic reserve becomes 0dB.

If the signal frequency and the noise frequency are sufficiently far away from each other in comparison with the bandwidth of the band-limiting filter, the dynamic reserve will be the ratio of the sensitivity against the maximum allowable input voltage (the effective value of sine wave). This value is shown in Table 4-2 "Practical Values of Dynamic Reserve".

**b) Dynamic reserve for wide band noise**



The effective value of noise contained in measurement is:

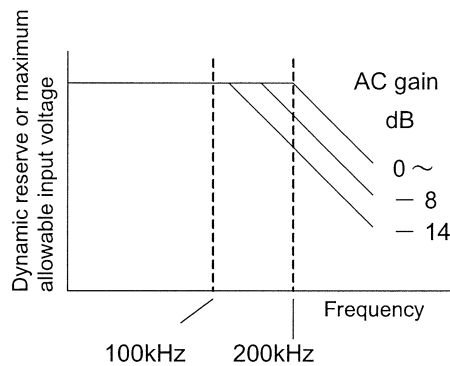
$$\text{Noise density} \times \sqrt{\text{equivalent noise bandwidth}}$$

The peak value will be approx. several times to ten times the above value. The dynamic reserve is the ratio of peak value

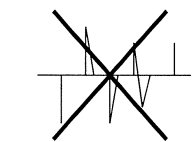
of input noise to the sensitivity when the peak value of noise contained in the measurement equals the sensitivity full scale. In general, frequency distribution of noise contained in input is various, and thus determination of dynamic reserve is not simple.

If the equivalent noise bandwidth can be sufficiently narrowed, dynamic reserve is the ratio of sensitivity to maximum allowable input voltage (peak value). If the equivalent noise bandwidth cannot be sufficiently narrowed, the dynamic reserve becomes smaller.

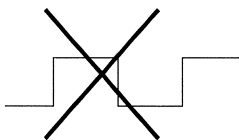
**c) Dynamic reserve for noise having high frequencies**



When the frequency goes beyond approximately 100kHz to 200kHz, the maximum allowable input voltage (RMS value of sine wave) lowers in inverse proportion to the frequency. In such a frequency area, dynamic reserve also decreases.



Pulsed noise contains a number of high frequency components. Therefore, the dynamic reserve for pulsed noise is low. Do not supply steep and high pulsed noise because this may cause distortion and measurement error.



Also a square wave signal contains high frequency components. If the edge change is steep, the signal must be passed an appropriate low-pass filter before connected to the measured signal input of LI5640.

**Table 4-2 Practical Values of Dynamic Reserve (for reference)**

DR stands for dynamic reserve

Dynamic reserve			LOW		MEDIUM		HIGH	
Sensitivity			AC gain	Actual DR	AC gain	Actual DR	AC gain	Actual DR
I(10 <sup>6</sup> )	I(10 <sup>8</sup> )	A,A-B	dB	dB	dB	dB	dB	dB
1μA	10nA	1V	0	0	-8	8	-14	14
500nA	5nA	500mV	6	0	-8	14	-8	14
200nA	2nA	200mV	12	2	0	14	0	14
100nA	1nA	100mV	18	2	6	14	0	20
50nA	500pA	50mV	24	2	6	20	0	26
20nA	200pA	20mV	30	4	12	22	0	34
10nA	100pA	10mV	36	4	12	28	0	40
5nA	50pA	5mV	42	4	18	28	0	46
2nA	20pA	2mV	48	6	22	32	0	54
1nA	10pA	1mV	48	12	22	38	0	60
500pA	5pA	500μV	48	18	22	44	0	66
200pA	2pA	200μV	48	26	22	52	0	74
100pA	1pA	100μV	48	32	22	58	0	80
50pA	500fA	50μV	48	38	22	64	0	86
20pA	200fA	20μV	48	46	22	72	0	94
10pA	100fA	10μV	48	52	22	78	0	100
5pA	50fA	5μV	48	58	22	84	0	106
2pA	20fA	2μV	48	66	22	92	0	114
1pA	10fA	1μV	48	72	22	98	0	120
500fA	5fA	500nV	48	78	22	104	0	126
200fA	—	200nV	48	86	22	112	0	134
100fA	—	100nV	48	92	22	118	0	140
50fA	—	50nV	48	98	22	124	0	146
—	—	20nV	48	106	22	132	0	154
—	—	10nV	48	112	22	138	0	160
—	—	5nV	48	118	22	144	0	166
—	—	2nV	48	126	22	152	0	174

AC gain : The gain before phase sensitive detector PSD.

Actual DR : The value of dynamic reserve. Equal to the DC gain after PSD.

Relation between dB and linear magnification:

0dB → 1 time, 6dB → 2 times, 10dB → 3 times, 12dB → 4 times, 14dB → 5 times, 18dB → 8 times, and 20dB → 10 times

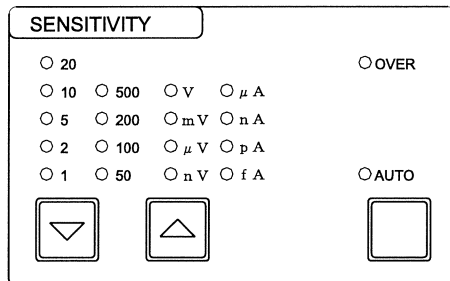
The values of dynamic reserve shown in this table are the ratio of the sensitivity and the maximum allowable input voltage (or current). In other words, they are the value obtainable under the best conditions.

The actual maximum allowable input voltage (or current) when a sine wave is assumed is the sensitivity full scale multiplied by the actual DR (= DC gain) shown in the above table.

If the user wants to perform measurement while securing 120dB or higher dynamic reserve, an extremely long time constant is required. Very high dynamic reserve cannot be secured if signal contains noise that has frequency components near to the frequency of measured signal.

## 4.6 Operation of sensitivity (SENSITIVITY)

### a) Range of sensitivity



The magnitude of signals displayed on LI5640 is expressed in an RMS value (rms). The sensitivity of LI5640 can be set in the following range using the  $\nabla$  and  $\triangle$  keys.

Voltage sensitivity	: 2nV to 1 V (e.g., 1mV, 2mV, 5mV, 10mV, ...)
Current sensitivity	: 50fA to 1 $\mu$ A (at conversion gain of 10 <sup>6</sup> V/A) 5fA to 10nA (at conversion gain of 10 <sup>8</sup> V/A)
Voltage noise density sensitivity	: 20nV/ $\sqrt{\text{Hz}}$ to 1V/ $\sqrt{\text{Hz}}$
Current noise density sensitivity	: 1pA/ $\sqrt{\text{Hz}}$ to 1 $\mu$ A/ $\sqrt{\text{Hz}}$ (at conversion gain of 10 <sup>6</sup> V/A) 100fA/ $\sqrt{\text{Hz}}$ to 10nA/ $\sqrt{\text{Hz}}$ (at conversion gain of 10 <sup>8</sup> V/A)

When reading a noise density (NOISE), add  $1/\sqrt{\text{Hz}}$  to the unit shown on the panel.

### b) Automatic setting of sensitivity by AUTO key

Press the AUTO key, and an optimal sensitivity will be automatically set according to the signal magnitude. This automatic setting is the same operation as the automatic sensitivity setting conducted when the AUTO SET key is pressed. The AUTO lamp keeps lighting during the automatic setting process. When a proper sensitivity has been identified, the automatic setting is complete.

Simultaneously, the dynamic reserve is adjusted to the optimal value (necessary lowest value). Only the sensitivity and dynamic reserve are modified.

In the following cases, adequate sensitivity may not be obtained because automatic setting is forced to end after sensitivity going up and down several times:

- Signal changes drastically.
- Noise is high.
- Signal is low.

If signal changes drastically, first broadly set the sensitivity via automatic sensitivity setting, and then fix it to a little larger range. If fluctuation by noise is high, increase the time constant and the attenuation slope in order to suppress the fluctuation due to noise, and then automatic setting will be available. When signal is low, manually set the sensitivity and the dynamic reserve.

### [Abortion of automatic sensitivity setting operation]

Press the AUTO key, or any other key during automatic sensitivity setting, and the automatic setting will be aborted. If other key is used than AUTO of SENSITIVITY, the original function of that key is also effective.

### c) OVER lamp

Lighting of the OVER lamp of SENSITIVITY indicates an over-level state of amplifiers except the first one, the phase sensitive detectors, the subsequent band-limiting filters due to signal or noise.

Use the following operation to turn off the OVER lamp:

- Increase the dynamic reserve. (LOW → MEDIUM → HIGH)  
Decrease the gain before the phase sensitive detector to prevent noise saturation.
- Set the sensitivity to a higher value. (1mV → 2mV →)  
If the sensitivity has been set to 2mV or higher value, the user may increase the maximum allowable input voltage.  
When the measurement lowers to 1/10 or less of the sensitivity full scale, the user may still use the EXPAND key for enlarging.
- Increase the time constant and the attenuation slope (10ms and 12dB/oct → 100ms and 24dB/oct)  
This attenuates the noise.
- Use the power supply frequency noise reduction filter (i.e., turn on the LINE and LINEx2 lamps).  
This attenuates the hum noise caused by power supply.
- Select AC coupling for signal input (DC → AC on COUPLING).  
This prevents DC components in the input from being amplified to an excessive level.  
Signal looks almost zero when full DC saturation occurs.

If it is suspected that noise is causing an over-level condition while signal magnitude R does not reach the sensitivity full scale, then preferably try the above items other than the sensitivity.

Once noise has been attenuated satisfactorily, the user can decrease the sensitivity setting, or lower the dynamic reserve as far as the OVER lamp will not light up.

Further, if the OVER lamp of SIGNAL INPUT lights up although both sensitivity and dynamic reserve are set to the maximum level, it is because the input signal (or noise) is too high. LI5640 is not available for the measurement in this situation.

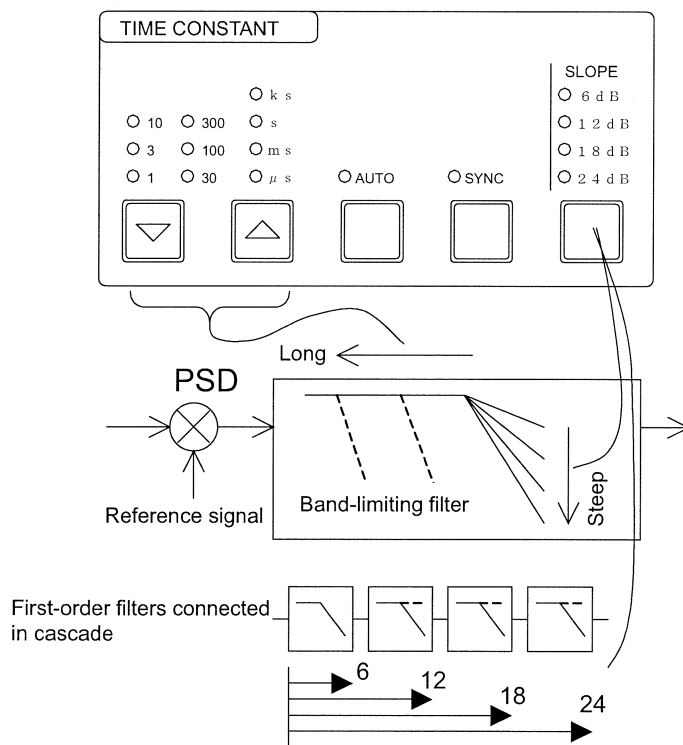
## 4.7 Operation of time constant and related matters (TIME CONSTANT)

### 4.7.1 Setting the time constant and the attenuation slope

The low-pass filter located downstream of the phase sensitive detector has the following functions:

- To remove noise (band-limiting filter).
- To remove ripples of two times the reference signal frequency, which are caused by phase sensitive detector of signals.
- To remove ripples of the reference signal frequency, which are caused by phase sensitive detector of DC offset.

The time constant of the filter can be set in the range from  $10\mu\text{s}$  to  $30\text{ks}$  using the  and  keys. The higher time constant can remove the more noise although response becomes the slower. Depending on the situation, select a value around three times the signal period but 30 ms or longer and monitor the situation for a while before taking further steps.



If a too short value is specified for the filter time constant, ripples will be conspicuous for the measurements. To measure a small signal or a signal of low frequency, select longer value to attenuate noise and ripples. If the signal is low or the dynamic reserve is high, ripples due to DC offset cannot be ignored. Therefore, a longer time constant is required.

To effectively reduce ripples that appear in the measurement, increase the attenuation slope, or use the synchronous filter.

For synchronous filter → Refer to Section 4.7.5 "Synchronous filter (SYNC)".

Attenuation slope can be selected with the SLOPE key out of 6, 12, 18 and 24 (dB/oct).

In the attenuation region, every time the frequency is doubled and the gain will be halved as  $1/2$ ,  $1/4$ ,  $1/8$  and  $1/16$ .

Compared with the same equivalent noise bandwidth, it will take a shorter time until the final value is reached by selecting a bigger attenuation slope and a higher time constant. The value of 6dB/oct is prepared to prevent the system from getting unstable when LI5640 is put in a control loop. To read just values, 24dB/oct will be better to choose.

### 4.7.2 Automatic setting of time constant

Press the AUTO key, and the time constant and the attenuation slope will be automatically set from the frequency of the measured signal at the moment of key pressing. The steps of automatic time constant setting can be described broadly as follows:

- Set the SLOPE to 24dB/oct.
- Turn off SYNC if the frequency  $\geq 200\text{Hz}$ , and turn on if  $< 200\text{Hz}$ .
- Set the time constant to approx. three times the signal period ( $= 1 / \text{frequency of measured signal}$ ). However, value will be limited within 30ms to 30s.

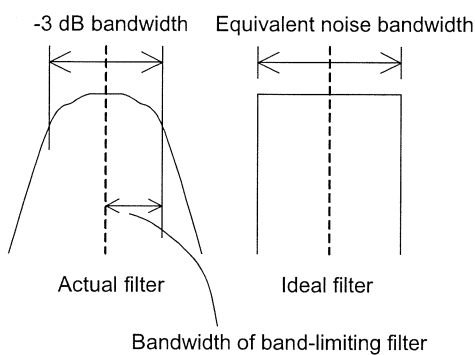
The above steps are the same as the operation associated to time constant in automatic setting by the AUTO SET key.

This automatic setting is disabled when the UNLOCK lamp is lighting.

In harmonics measurement (i.e., the nF key has been pressed to select 2 or higher), automatic setting will be made according to the frequency of harmonics.

In automatic setting, dispersion is conspicuous when noise is high or signal is low because the time constant is rather small. If noise is almost none, the user may select much smaller time constant to get quicker response. In such cases, manually adjust the time constant to an adequate value while monitoring the dispersion of measurements.

### 4.7.3 Equivalent noise bandwidth



The sensitivity to the broadband noise or, noise suppression performance in an opposite phrasing, is expressed by the equivalent noise bandwidth. The bandwidth of the ideal filter whose sensitivity to noise is equal to the actual filter is called the equivalent noise bandwidth of the filter.

Equivalent noise bandwidth  $B_N$  of LI5640 is twice the band-limiting filter (low-pass filter) defined by the time constant  $T$  and the attenuation slope and calculated by the following expressions:

$$B_{N6} = \frac{1}{2T}, B_{N12} = \frac{1}{4T}, B_{N18} = \frac{3}{16T}, B_{N24} = \frac{5}{32T} \quad (6, 12, 18 \text{ and } 24\text{dB/oct, respectively})$$

However, the above is the characteristics of an analog filter. Since a digital filter is used in LI5640, actual values slightly shift from the above expressions if the time constant is 1 ms or less.

The RMS value  $V_m$  of noise contained in the signal measurement is calculated from the input noise density  $V_n$  (assumed to be constant regardless of the frequency) and equivalent noise bandwidth  $B_N$  by the following expression:

$$V_m = V_n \times \sqrt{B_N}$$

To minimize the noise contained in measurement by 1/10, the time constant must be magnified by 100.

Further, the -3dB bandwidth is determined by the following expression:

$$B_{3dB} = \sqrt{m/2-1} / \pi T$$

where T is the time constant and m = 1, 2, 3 and 4 (corresponding to attenuation slope of 6, 12, 18 and 24dB/oct).

#### 4.7.4 Response time

The response when a step signal is supplied to the band-limiting filter downstream of phase sensitive detector is given by the following expression:

$$y(t) = 1 - \left\{ \sum_{n=1}^m \frac{t^{n-1}}{T^{n-1} (n-1)!} \right\} e^{-t/T}$$

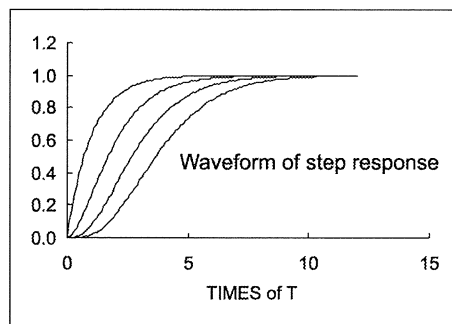
where T is the time constant and m = 1, 2, 3 and 4 (corresponding to attenuation slope of 6, 12, 18 and 24dB/oct).

However, the above is response of an analog filter. Since digital filter is used in LI5640, response varies a little if the time constant becomes smaller. In addition, this is joined by the fixed delay time of the power supply frequency noise reduction filter, anti-aliasing filter, data transfer and others on the input side. Therefore, use experimentation for confirmation if an exact response time is required.

**Table 4-3 Step Response Time**

(multiples of time constant T)

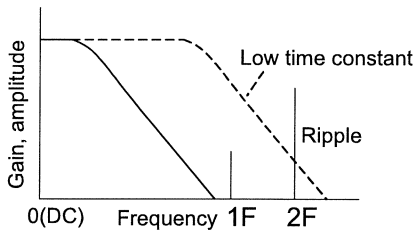
Response	SLOPE(dB/oct)			
	6	12	18	24
90%	2.3	3.9	5.3	6.7
99%	4.6	6.6	8.4	10.0
99.9%	6.9	9.2	11.2	13.1



**Fig. 4-6 Waveform of Step Response**

### 4.7.5 Synchronous filter (SYNC)

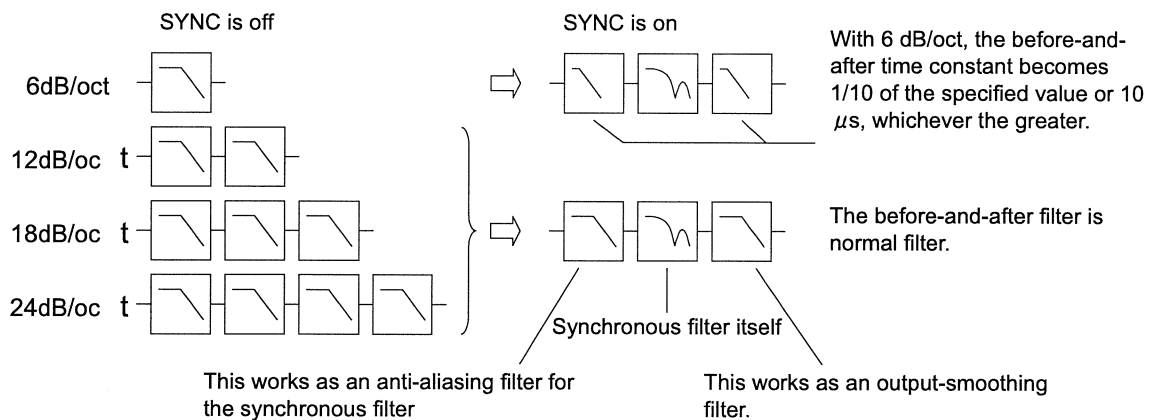
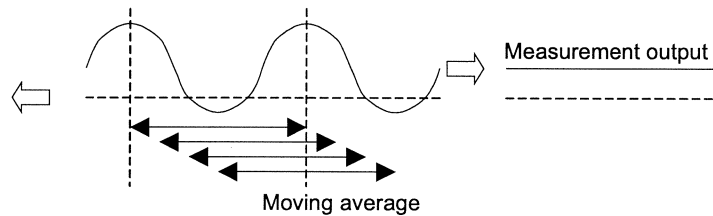
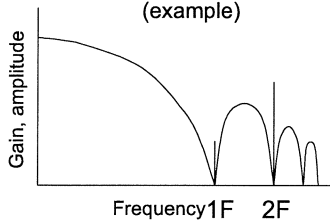
Frequency characteristics of normal filter



When noise is low, it is possible to suppress the noise to a sufficiently low level without increasing the time constant. However, the ripples generated in phase sensitive detector will appear in the measurement output if the time constant is kept low with a normal filter.

In such cases, use of a synchronous filter can keep ripples low. A synchronous filter is a moving-average filter of which the averaging section is equal to an integral multiple of signal period.

Frequency characteristics of synchronous filter (example)



- SYNC To use the synchronous filter, press the SYNC key, turning on the lamp.
- Although the synchronous filter operates independent of frequencies, ripple-removing performance drops as the frequency goes higher if the frequency is 200Hz or higher.

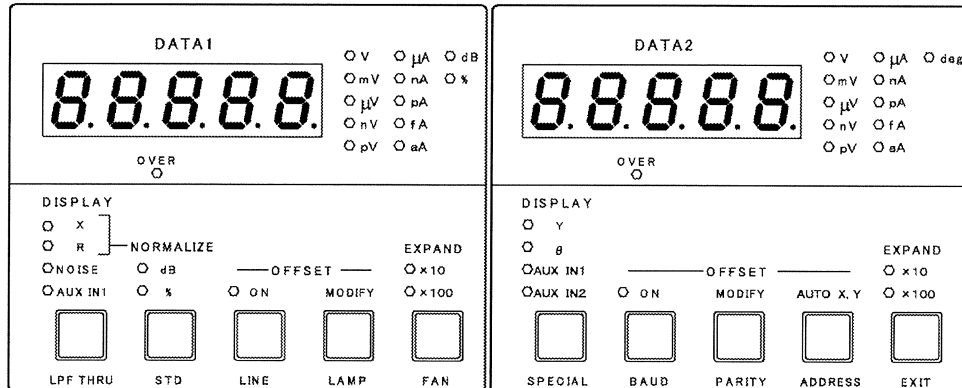
The band-limiting filter when SYNC is on is structured such that a normal primary filter is provided each before and after the synchronous filter.

If 6dB/oct is selected for SLOPE, the time constant of the before-and-after filters decreases. In this structure, output will be settled within approx. one period at shortest. This is useful when the frequency is low. However, the change looks stepwise because the average output is supplied at time intervals into which the averaging section is divided by approximately 100 to 200.

If synchronization is made with the external reference signal (REF IN), measurement may slightly vary due to frequency fluctuation.

## 4.8 Selection of measurement parameters and related operation

### 4.8.1 Selection of measurement parameters (overview)



#### OVER (DATA1 and DATA2)

These lamps light up when the display range is exceeded or an over-level state is detected during data processing.

#### DATA1 DISPLAY

##### X

The signal component  $R \cos \theta$  with the same phase as the reference signal

##### R

The magnitude of R

##### NOISE

The noise density

##### AUX IN1

DC voltage at AUX IN1 (rear),  $\pm 12$ V

#### DATA2 DISPLAY

##### Y

The signal component  $R \sin \theta$  orthogonal to the reference signal

##### $\theta$

The phase of signal in relation to the reference signal

##### AUX IN1

DC voltage at AUX IN1 (rear),  $\pm 12$ V

##### AUX IN2

DC voltage at AUX IN2 (rear),  $\pm 12$ V

#### NORMALIZE

The ratio of signal (X, R) to the standard value

##### dB

$20 \log_{10} |X \text{ or R measurement} / \text{standard value}|$

##### %

$(X \text{ or R measurement} / \text{standard value}) \times 100$

#### DATA1 OFFSET

##### ON

Subtract the offset from X.

##### MODIFY

Set the X offset (% value of sensitivity full scale) using the MODIFY dial

#### DATA2 OFFSET

##### ON

Subtract the offset from Y.

##### MODIFY

Set the Y offset (% value of sensitivity full scale) using the MODIFY dial

##### AUTO X, Y

Turn on the offset to automatically set the offset so that both X and Y will be zero.

#### DATA1 EXPAND



Expand the measurement of X.

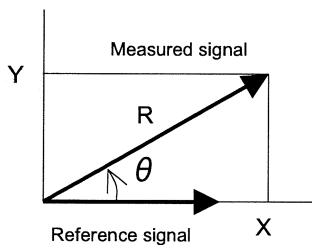
#### DATA2 EXPAND

Expand the measurement of Y.

### 4.8.2 Selection of measurement parameters

LI5640 allows the user to view two measurement parameters at the same time.

- |  |   |
|--|---|
| <p>DISPLAY</p> <p><input type="radio"/> X</p> <p><input type="radio"/> R</p> <p><input type="radio"/> NOISE</p> <p><input type="radio"/> AUX IN1</p>                      | <p>• DATA1</p> <p>X :The signal component of the same phase as the reference signal (<math>R \cos \theta</math>)</p> <p>R :The magnitude of signal (<math>=\sqrt{X^2+Y^2}</math>)</p> <p>NOISE :The noise density (this item is AUX IN1 for DATA2)</p> <p>AUX IN1 :The DC voltage at rear panel AUX IN1 (up to <math>\pm 12V</math>)</p>                                  |
| <p>DISPLAY</p> <p><input type="radio"/> Y</p> <p><input type="radio"/> <math>\theta</math></p> <p><input type="radio"/> AUX IN1</p> <p><input type="radio"/> AUX IN2</p>  | <p>• DATA2</p> <p>Y : The signal component orthogonal to the reference signal (<math>R \sin \theta</math>)</p> <p><math>\theta</math> : The phase of signal in relation to the reference signal</p> <p>AUX IN1 : The DC voltage at rear panel AUX IN1 (up to <math>\pm 12V</math>)</p> <p>AUX IN2 : The DC voltage at rear panel AUX IN2 (up to <math>\pm 12V</math>)</p> |



When R is selected, the user can measure the magnitude of the signal regardless of the phase  $\theta$ . If the phase is stable, however, adjust Y to zero and determine the signal magnitude by X, which can minimize the effect of noise.

The user can shift the phase ( $0^\circ$ ) of datum from the reference signal. Press the PHASE key of REFERENCE and set the phase offset. Press the AUTO key of PHASE, and Y and  $\theta$  will be automatically set to zero.


DATA1 and DATA2 measurements are indicated or supplied in the following three expressions:

- Numerical indication
- Analog meter indication
- Analog voltage (DATA1 OUT and DATA2 out in 16 bits, at maximum 256k samples/s)

The measurement values that correspond to the meter full scale (analog output  $\pm 10V$ ) are as follows:

- |                     |  |
|---------------------|--|
| X, Y and R          | : The set sensitivity/EXPAND magnification |
| NOISE               | : The set sensitivity                      |
| AUX IN1 and AUX IN2 | : $\pm 10V$                                |
| $\theta$            | : $\pm 180^\circ$                          |
| Ratio               | : $\pm 2$                                  |
| % indication        | : $\pm 200\%$                              |
| dB indication       | : $\pm 100dB$                              |

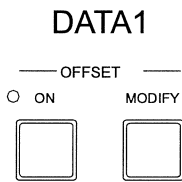
 For details of NOISE  $\Rightarrow$  Refer to Section 4.10 "Measurement of noise density".

 For details of AUX IN1 and AUX IN2  $\Rightarrow$  Refer to Section 4.11 "Measurement of DC voltage (auxiliary input AUX IN1/AUX IN2)".

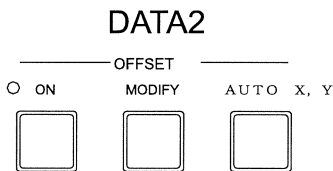
### 4.8.3 X and Y offset

The user can display the value of X and Y subtracted by the offset. This expression may be used for the following purposes:

- To eliminate fixed noise.
- To monitor the change in relation to a certain value.

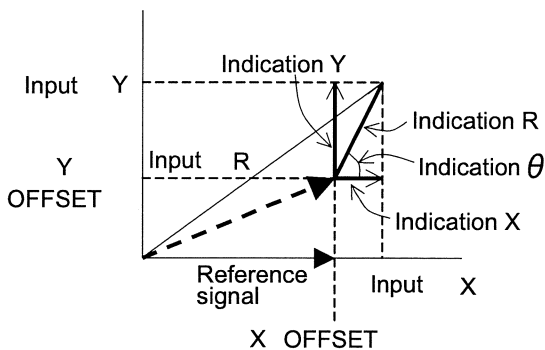


Press the OFFSET ON key of DATA1 to turn on the lamp, and the offset will be subtracted from X. Press the MODIFY key, and the REFERENCE digital display will show the offset of X. The offset is expressed in percentage to the sensitivity. If the user changes the offset using the MODIFY dial, the X indication value will be changed according to the offset.



DATA2 allows the user to operate the Y offset in the same way as X.

To stop the offset indication of REFERENCE, press the SHIFT + EXIT keys, or otherwise specify other parameter with the FREQ or other keys.



To monitor the change in relation to the current X and Y, press the AUTO X and Y keys. This will automatically set the X and Y offset values and turns on the offset so that X, Y and R indication will be zeroed.

When the UNLOCK lamp is lighting, automatic offset setting by the AUTO X and Y keys is not available because correct measurement cannot be obtained.

The value of R and  $\theta$  can be determined from X and Y after offset subtraction. Direct R offset cannot be set. NOISE, AUX IN1 or AUX IN2 offset cannot be set either.

### 4.8.4 Expanding indications (EXPAND)

**EXPAND** If X, Y or R indication is too small to ensure sufficient measurement resolution, the

$\times 10$  EXPAND key will magnify the substantial sensitivity (or resolution) by 10 or 100 times.

$\times 100$  Press the EXPAND key of DATA1, and the apparent sensitivity of X or R will be magnified by 10 or 100 times.



Press the EXPAND key of DATA2, and the apparent sensitivity of Y will be magnified by 10 or 100 times. Turning on the  $\times 10$  or  $\times 100$  lamp of EXPAND cannot expand  $\theta$ , AUX IN1 or AUX IN2.

### 4.8.5 Normalize (dB and %)

NORMALIZE The user can view the ratio of X or R to a standard value expressed in dB or %.

- dB
- %

Press the NORMALIZE key twice to turn on the dB or % lamp.





STD

The indication value of dB =  $20 \text{ LOG}_{10} \left| \frac{\text{X or R measurement}}{\text{Standard value}} \right|$ ; indication range:  $\pm 120.00\text{dB}$

The indication value of % =  $\left( \frac{\text{X or R measurement}}{\text{Standard value}} \right) \times 100$ ; indication range:  $\pm 199.99\%$

#### [Setting the standard value]

Press the SHIFT + STD keys, and the standard value will appear on DATA1. Set the value using the MODIFY dial. Use of the  and  keys to blink the unit lamp allows the user to change the value in ten-times decrement with the MODIFY dial.

DATA1	DATA2	REFERENCE
1.2345 $\mu$	Std	

Selection of SIGNAL allows the user to set the standard value for voltage when voltage is measured, and the standard value for current when current is measured, independently. The range of standard value for setting is as follows:

- Voltage: 1.0000nV to 1.0000V
- Current: 1.0000fA to 1.0000  $\mu$ A

Press the Shift + EXIT keys and the original value will appear in the display.

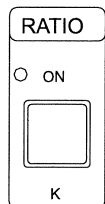
#### [Restrictions]

- Specification of  $\times 10$  or  $\times 100$  of EXPAND cannot expand the value when the value is displayed in dB or %.
- Even if this dB or % lamp is turned on, indication in dB or % will not be available for NOISE or AUX IN1 or IN2.
- When ratio indication (RATIO) is specified, indication in dB or % will not be available, either.
- If X, Y or R exceeds the indication range to a certain degree using offset, the OVER lamp of DATA1 will light up.

## 4.9 Ratio indication

Ratio indication is used to counteract the sensor sensitivity fluctuation.

The sensitivity of sensor varies with temperature and other factors. If LI5640 measures the signal this sensor has captured, resulting measurement will not be correct. If any method can obtain a signal that compensates the fluctuation of sensitivity, ratio indication can correct the sensitivity.



With ratio indication, the user can view the value of X, Y and R in the ratio to the absolute value of the voltage supplied to the AUX IN1 connector on the rear panel. To do this, press the RATIO key, tuning on the ON lamp.

$$\text{Ratio} = K \times \frac{\text{Percentage to the X, Y and R sensitivity}}{|\text{AUX IN1}|[\text{V}] \times 10}$$

Range of ratio indication:  $\pm 2.4$  (0.0000 to  $\pm 1.9999$ , to  $\pm 2.400$ )

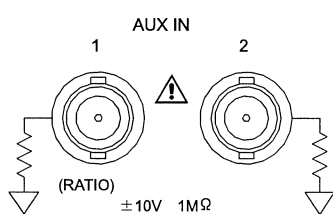
Analog output will be +10V when the ratio is 2.

K is an arbitrary constant ranging from 0.1000 to 1.9999 or from 2.000 to 9.999

Pressing the SHIFT + K keys will display the value of K constant on the REFERENCE digital display, and then use MODIFY dial for setting. Press the SHIFT + EXIT keys to return to the previous indication.

Example: If  $K = 1$ ,  $\text{AUX IN1} = 5\text{V}$ , sensitivity is 10mV and R is 3.5mV, then the value of ratio will be the following:

$$\text{Ratio} = 1 \times \left\{ \left( \frac{3.5}{10} \right) \times 100 \right\} / (5 \times 10) = 0.7$$



Supply the compensation-input signal to the AUX IN1 connector on the rear panel.

The maximum allowable input voltage is  $\pm 12\text{V}$ . Select a voltage of 1V or higher in order to minimize the error.

The auxiliary input AUX IN1 has a frequency bandwidth of approx. 130 Hz, and cannot respond to signals that change too quick. Do not supply sharp-changing signals to AUX IN1 or IN2 because this may affect measurement of I, A or B input.

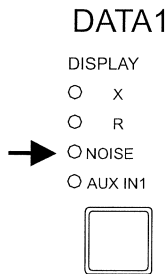
To keep errors low, set the potential difference between the auxiliary input ground and the ground of measured signal input (I, A and B) within  $\pm 1\text{V}$  or so.

### [Restrictions]

- With ratio indication, specifying  $\times 10$  or  $\times 100$  of EXPAND will not work enlargement.
- Specifying ratio indication will not enable ratio calculation for NOISE and AUX IN.
- With ratio indication, turning on the dB or % lamp of NORMALIZE will not enable dB or % indication.

## 4.10 Measurement of noise density (NOISE)

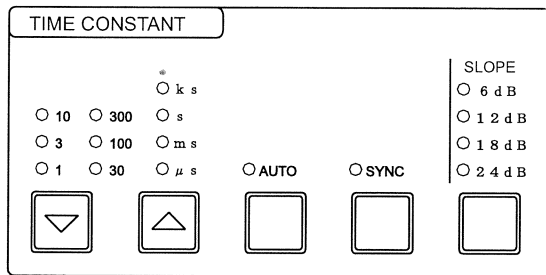
### 4.10.1 Operation of noise density measurement



#### a) Viewing noise density

Noise density is the magnitude of noise per unit frequency width. LI5640 works as a band-pass filter to measure the noise density in the reference signal frequency.

To measure noise density, select NOISE using the DISPLAY key of DATA1. DATA2 will show AUX IN1 regardless of DISPLAY selection. If Y or others have been specified, Y or other lamps will keep blinking during measurement of noise density.



#### b) Setting time constant and attenuation slope

Set the attenuation slope (SLOPE) to 24dB/oct if the user have no inconvenience with it.

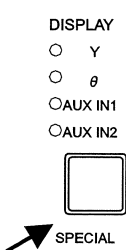
Set the time constant (TIME CONSTANT) to three or more times the signal period (= 1/frequency) and 300 μs or higher as a guideline. For frequency of several tens kHz, select a value of 1 ms or higher taking into

consideration the swell of frequency characteristics.


If conditions allow, the user may shorten the time constant for the purpose of reducing the time for measurement.

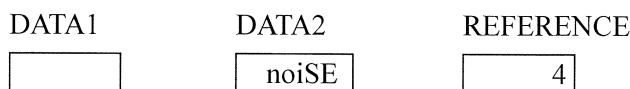
When the time constant or the attenuation slope is too small, the measurements will involve signals and noise of distant frequency as well as ripples that arise in phase sensitive detector. As a result, the noise density may appear high. If noise density decreases with larger time constant or attenuation slope, this indicates that the time constant and the attenuation slope is too low. When automatic setting has been selected with the AUTO key, also check the values manually.

Even if the synchronous filter (SYNC) is specified, the filter remains the normal one, with the SYNC lamp blinking during measurement of noise density.



#### c) Specifying the response time constant for the noise-measurement smoothing filter

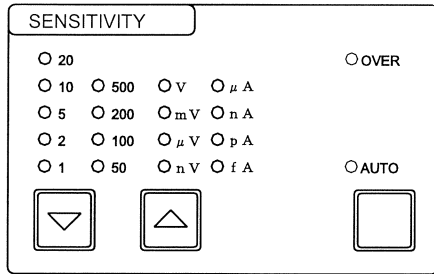
- Press the SHIFT + SPECIAL keys.
- Confirm that noiSE appears on DATA2.
- Using the  key, move the blinking digit to value on the REFERENCE digital display.
- Select one out of 1, 4, 16 and 64 using the MODIFY dial.
- Press the SHIFT + EXIT keys to return to the previous indication.



Every selection of a four times the previous value will approximately halve the measurement dispersion. However, the response time will become longer in proportion to the specified value. Select 1 if the user wants to know a broad value quickly or if the user may read the central value after recording the value in the recorder. Select 4 or higher if direct reading of a stabilized value is desired.

When the attenuation slope is 24dB/oct, the time necessary for settling down to the final value is approximately the following:

$170 \times \text{The time constant} \times \text{The smoothing filter setting (1 to 64)}$

**d) Setting sensitivity**

In measurement of noise density, set the sensitivity (SENSITIVITY) in the full scale of noise density.

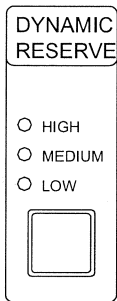
Current I ( $10^6$ ) :  $1\text{pA}/\sqrt{\text{Hz}}$  to  $1\ \mu\text{A}/\sqrt{\text{Hz}}$

Current I ( $10^8$ ) :  $100\text{fA}/\sqrt{\text{Hz}}$  to  $10\text{nA}/\sqrt{\text{Hz}}$

Voltage A, A-B :  $20\text{nV}/\sqrt{\text{Hz}}$  to  $1\text{V}/\sqrt{\text{Hz}}$

Automatic setting with AUTO key is also available.

Sensitivity of an adequate RMS value will be set inside LI5640 from the sensitivity of noise density and the equivalent noise bandwidth. Noise density will be indicated in the converted value of the measured RMS value of noise with limited frequency band.

**e) Setting dynamic reserve**

Since noise is also a kind of measured signal, it involves a problem of dynamic reserve. It may occur that the user has to increase the dynamic reserve if the noise of frequencies that are different from the target frequency is strong.

If the OVER lamp would light up even when the measurement is far smaller than the full scale, then increase the dynamic reserve.

However, increased dynamic reserve will admit more LI5640 input referred noise. For white noise, it is hard to measure the noise smaller than the LI5640 noise because the following relationship holds:

$$\text{Measurement of noise density} = \sqrt{(\text{LI 5640 input-converted noise density})^2 + (\text{input signal noise density})^2}$$

The value of  $6\text{nV}/\sqrt{\text{Hz}}$  (1kHz at the maximum) as indicated in the specifications is a value for LOW dynamic reserve and low sensitivity setting. This phenomenon in current input is not so conspicuous as for voltage one because the noise by current/voltage conversion is dominant.

If the user wants to use the system in the best condition for input referred noise, then select LOW for dynamic reserve and decrease the input level. For voltage noise, set DISPLAY of DATA1 to R and select such an input level that the OVER lamp will not light up when measuring the input signal (noise) with the sensitivity of 2 mV.

**[Complementary explanation]**

The following describes some key points for measurement of noise density:

- Input referred noise varies with the sensitivity, dynamic reserve, time constant and attenuation slope.
- If time constant or attenuation slope is too low, unintended signal may be measured together.

Once sensitivity, time constant and other settings have been specified, check the input referred noise. For voltage, make a short circuit on the input, or for current, open the input, and measure the input referred noise. It would be acceptable to attach a shield cap because current input is likely to pick up surrounding noise. Do not make a short circuit on current input.

When measuring noise density in practice, try to increase the time constant to confirm that noise density changes little.

### 4.10.2 Principle of noise density measurement

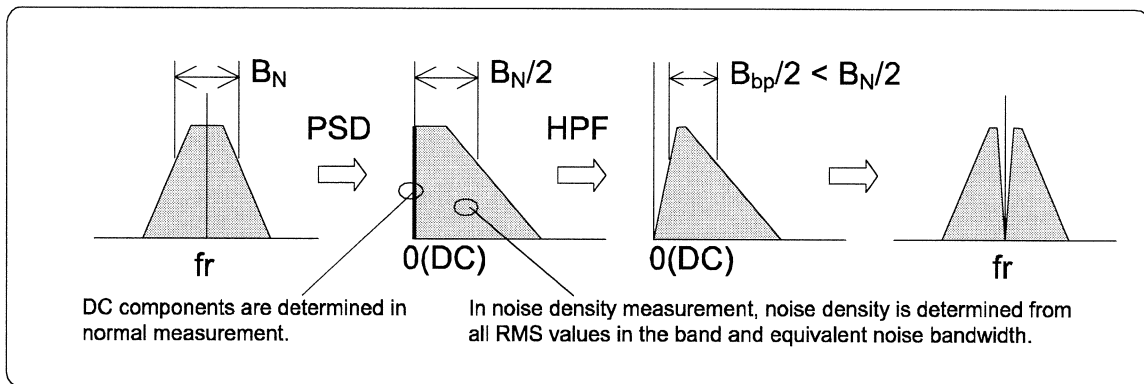
Assuming the RMS value  $V_m$  of a certain noise is measured by passing through a filter with the equivalent noise bandwidth of  $B_N$ , the noise density  $V_n$  can be determined by the following expression:

$$V_n = \frac{V_m}{\sqrt{B_N}}$$

A lock-in amplifier works as a band-pass filter that has a center frequency at the frequency "fr" of reference signal. While normal measurement intends to measure only the center frequency, RMS values of all components are measured in noise measurement.

In practice, a high-pass filter is provided after the band-limiting filter to eliminate the reference signal frequency components (DC components after phase sensitive detection) in order to determine the RMS value. This device can suppress the effects of leak-in of reference signal and staggering of noise measurement.

The equivalent noise bandwidth  $B_{bp}$  when noise is measured is a little narrower than when signal magnitude is measured. Therefore, noise density is calculated by using the equivalent noise bandwidth for noise density.



**Fig. 4-7 Measurement of Noise and Bandwidth**

Incidentally, LI5640 determines the RMS value based on the value from average detection. In random noise, the RMS value can be determined easily from the mean value because the noise density is constant within a narrow band.

## 4.11 Measurement of DC voltage (auxiliary input AUX IN1/AUX IN2)

### DATA 1

DISPLAY  
 X  
 R  
 NOISE  
 AUX IN1



### DATA 2

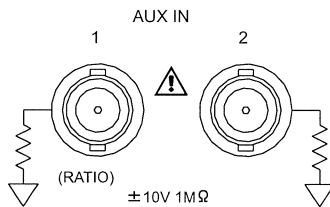
DISPLAY  
 Y  
 θ  
 AUX IN1  
 AUX IN2



LI5640 can measure two DC voltages. To measure DC voltage, use the DISPLAY keys of DATA1 and DATA2 to select auxiliary input AUX IN1 or AUX IN2.

The range of measurement is within  $\pm 12V$  and the indication resolution is 0.001V.

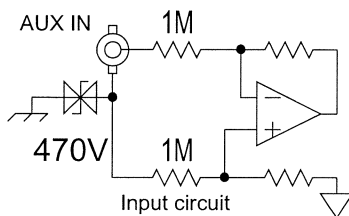
Although the sampling rate is 16k samples/s, the frequency bandwidth is approx. 130Hz (-3dB).



Connect the DC voltage to AUX IN1 and AUX IN2 connectors on the rear panel.

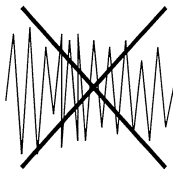
Input impedance : approx.  $1M\Omega$  and 100pF or less in parallel

Maximum nondestructive input voltage :  $\pm 40V$



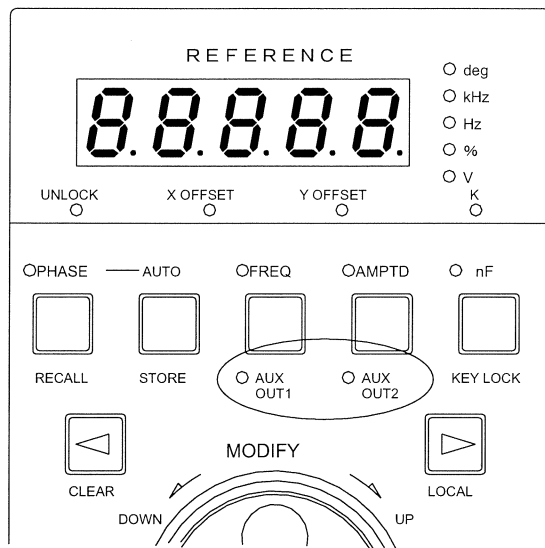
The signal ground of auxiliary input is isolated from the chassis and signal inputs (I, A and B connectors). However, measurement error of the auxiliary input becomes greater if the potential difference with the signal inputs (I, A and B) becomes higher. Keep the potential difference between the both grounds within 1V.

Common with the ground of measured signal inputs (I, A and B)



A steeply changing high-amplitude signal supplied to the auxiliary input may affect the measurement of signal input (I, A and B). If a 1kHz or higher signal, or a steeply changing signal such as a square wave is anticipated to enter the auxiliary input connector, be sure to confirm it will not affect the system badly before starting operation.

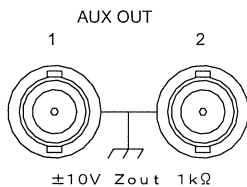
## 4.12 Output of DC voltage (auxiliary output AUX OUT1/AUX OUT2)



LI5640 provides two auxiliary outputs of DC voltage. The auxiliary outputs are available as a signal to control measurement conditions.

To set a DC voltage, press the SHIFT + AUX OUT1 or SHIFT + AUX OUT2 keys first to display a DC voltage on the REFERENCE digital display. Next, use the MODIFY dial for setting. Select the changing digit (or blinking digit) with the ◀ and ▶ keys.

The range of voltage setting is within  $\pm 10\text{V}$  and the resolution is  $0.001\text{V}$ .



DC voltages will be supplied via the AUX OUT1 and AUX OUT2 connectors on the rear panel.

Output impedance: approx.  $1\text{k}\Omega$

The signal ground of DC voltage output is connected to the chassis.

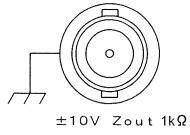
### **CAUTION**

Do not apply external voltage to the output connector. This will break the internal circuit.

Output current is limited. Keep the load impedance to  $1\text{k}\Omega$  or higher.

## 4.13 Monitor output

**MONITOR OUT** The user can check the input signal to the phase sensitive detector (PSD) at the MONITOR OUT connector. If the measurement does not run as the user expects, try to check the monitor output on an oscilloscope or other devices. This will help the user to figure out the situation of signal and noise.



If the monitor output is too small for observation, set the dynamic reserve to LOW, and decrease the sensitivity setting.

The output impedance is approx.  $1\text{k}\Omega$ , and the signal ground is connected to the chassis. It is isolated from the signal input section with a differential amplifier so that it will not affect the measurement.

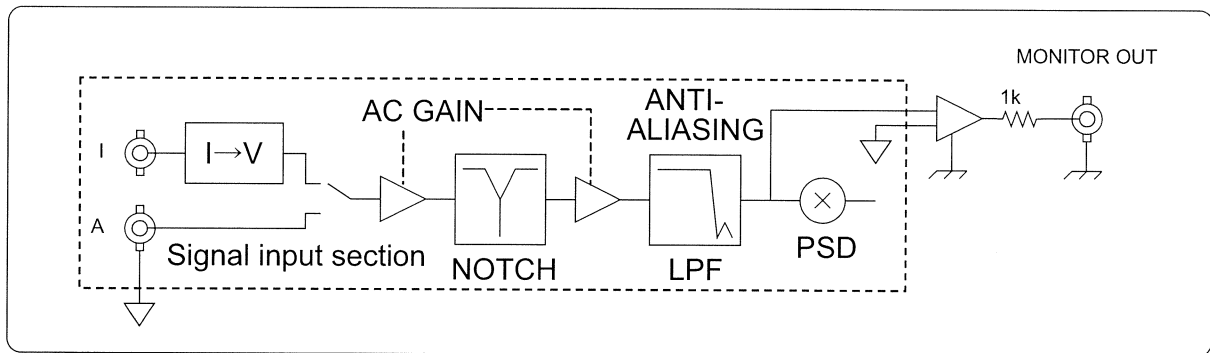


Fig. 4-8 Paths from Input to Monitor Output

### **⚠ CAUTION**

Do not apply external voltage to the output connector. This will break the internal circuit.

Output current is limited. Keep the load impedance to  $1\text{k}\Omega$  or higher.

### **[Gain of monitor output]**

The gain from the signal inputs (I, A and B) to the monitor output is defined by the AC gain. When the AC gain is 0dB, the gain from the signal input (A) to the monitor output is about seven times (approx. 17dB). If the gain is not 0dB, the gain will be multiplied by value of the AC gain. The AC gain is determined by using Table 4-2 "Actual Value of Dynamic Reserve" based on the sensitivity and dynamic reserve.

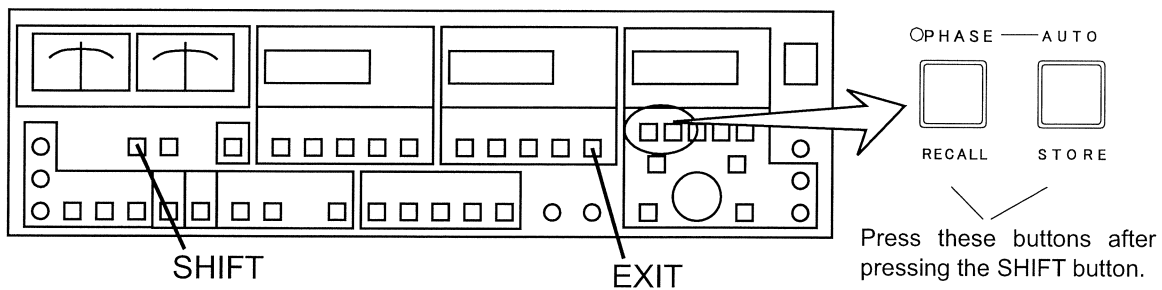
For current input, multiply by the value of the current/voltage conversion gain ( $10^6$ ,  $10^8\text{V/A}$ ) according to the selection of SIGNAL in the signal input section.

Further, do not use the monitor output to confirm the phase because the phase is rotated drastically by the steep anti-aliasing filter.

### **[Phase inversion on current input]**

In the current input connector (I) of LI5640, the direction of flowing-out current is called positive. If the current flowing into the I connector is considered as the positive direction, the phase of measurement value and monitor output is inverted.

## 4.14 Operation of setting memory (RECALL/STORE)



LI5640 can store nine sets of settings.

In addition to the above, LI5640 has another memory to store the settings on the last power off occasion.

☞ For details of settings that can be stored in the setting memory, and the settings that are automatically reset when power is turned on.

➡ Refer to Table 3-2 "List of Initial Values".

Measurement conditions are reset, but settings that relate to external interface are not changed.

### a) Storing settings

To store the current settings into the setting memory, follow the steps below:

- Press the SHIFT + STORE keys. → Setting memory numbers appear.
- Select the desired setting memory number in the range from 1 to 9 using the MODIFY dial.
- Press the SHIFT + STORE keys again. → The set data is restored.

DATA1	DATA2	REFERENCE	
<input type="text"/>	<input type="text" value="Str"/>	<input type="text" value="1"/>	← Memory number

### b) Recalling settings

To read stored settings from the setting memory, follow the steps below:

- Press the SHIFT + RECALL keys. → Setting memory numbers appear.
- Select the desired setting memory number in the range from 1 to 9 using the MODIFY dial.
- Press the SHIFT + RECALL keys again. → Set data is retrieved.

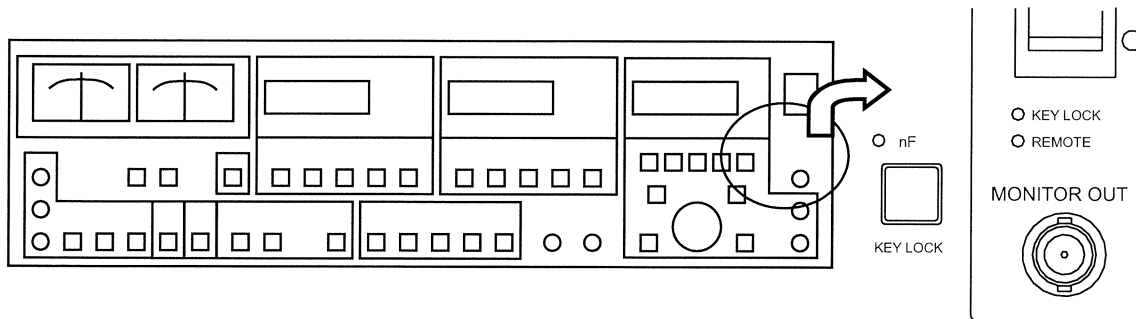
DATA1	DATA2	REFERENCE	
<input type="text"/>	<input type="text" value="rcL"/>	<input type="text" value="1"/>	← Memory number

If zero is specified for the setting memory number, the settings on the last power off can be retrieved. In other words, the user can recall the state of the system when the user turned on the power for the current operation.

### c) Aborting storage and recall

If the user wants to abort the current storing/recalling data into/from the setting memory halfway, press the SHIFT + EXIT keys, or otherwise press the FREQ or any other key to display another parameter.

## 4.15 Disabling panel operation (KEY LOCK)



LI5640 allows the user to set panel keys inoperable. Disabling key operation can prevent settings from being changed accidentally during measurement.

Pressing the SHIFT + KEY LOCK keys toggles the KEY LOCK lamp between ON and OFF.

When the KEY LOCK lamp is lighting, panel operation is disabled except the operation of the SHIFT + KEY LOCK keys and SHIFT + LOCAL keys.

If the user wants to set all panel keys operable, press the SHIFT + KEY LOCK keys, turning off the KEY LOCK lamp.

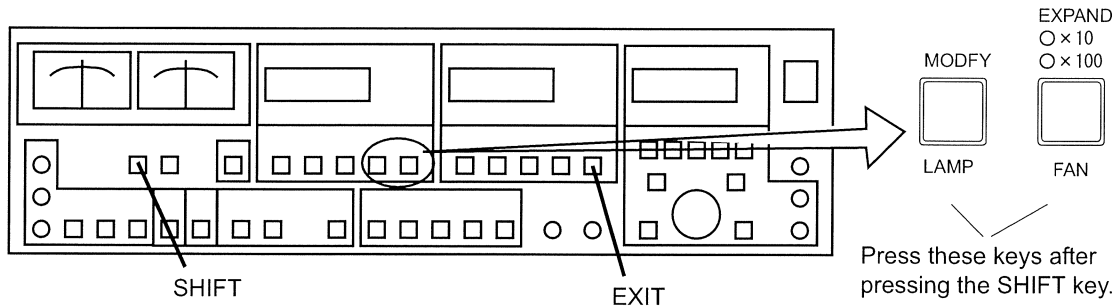
Turning off the power releases panel keys from disabled state.

### [Relation with external interface]

Control via external interface (GPIB or RS-232) is still effective even when the KEY LOCK lamp is lighting.

However, if the user selects remote state for GPIB control (the REMOTE lamp lights up) when the KEY LOCK lamp is lighting, KEY LOCK cannot be released from the panel. Also SHIFT + LOCAL keys are inoperable.

## 4.16 Turning ON/OFF lamps and cooling fan



### 4.16.1 Turning ON/OFF lamps

During optical measurement, the light emitted from LI5640 may affect the measuring system. In such cases, turn off LI5640 lamps. Buttons are operable even when the lamps are turned off.

Pressing the SHIFT + LAMP keys turns off all lamps and digital displays.

Press the SHIFT + LAMP keys when all lamps are off to return to the previous lighting condition.

When the unit is powered, lamps are always turned on.

### 4.16.2 Turning ON/OFF cooling fan

During acoustic measurement, the sound emitted from the LI5640 cooling fan may affect the measuring system. In such cases, turn off the LI5640 cooling fan.

If measurement is conducted in an environment of steeply changing ambient temperature, stop the fan in order to control temperature change inside LI5640 and to improve stable measurement.

To switch fan ON/OFF, operate as shown below:

- Press the SHIFT + FAN keys. → The current ON/OFF state is shown.
- Select on or oFF using the MODIFY dial.
- Press the SHIFT + EXIT keys to return to the previous indication.

DATA1	DATA2	REFERENCE
	FAn	oFF

Stopped fan will permit the internal temperature to rise, shortening the equipment life. Do not keep the fan turned off for an extended time if the ambient temperature is higher than 30°C.

Dissimilar to lamp ON/OFF setting, fan ON/OFF setting will be retained even when the power is turned off. Do not leave the equipment with the cooling fan turned off indiscriminately.