LI5600 Series

DIGITAL LOCK-IN AMPLIFIER

High-response, wide-band, high-stability

High-speed and high-sensitivity measurements for a wider range of applicable fields

- Scanning probe microscope
- Spintronics
- Ultrasonograph
- Terahertz spectroscopy
- Light transmission measurements
- Light absorption measurements
- Hall coefficient measurements
- Gyroscope
- Ceramic sensors
- Semiconductor lasers

Available in 4 models depends on your usage

0.5Hz～11MHz LI5660

2 phase | 2 Frequency | HF Input | 10V Input

0.5Hz～3MHz LI5655

2 phase | 2 Frequency

1mHz～250kHz LI5650

2 phase | 2 Frequency

1mHz～250kHz LI5645

2 phase | 2 Frequency

NF Corporation

The Lock-in Amplifiers from NF

Simultaneous 2-frequency measurements | **Fractional harmonic measurements** | **External reference 10 MHz synchronization**

Lock-in amplifiers that measure extremely small alternating signals hidden deep within noise are used in a wide range of advanced research fields, including scanning probe microscopes, terahertz spectroscopy and spintronics.
NF's lock-in amplifiers LI5600 series are deliver a high level of stability with post-phase detection digital processing.
They cover all areas of key functionality required for increasing reliability when measuring very small signals, such as an outstanding dynamic reserve up to 100 dB, update rates up to approximately 1.5 M samples/s (for LI5660/LI5655, approx. 780k samples/s for LI5650/LI5645), and smooth, high-speed 16-bit amplitude resolution output response. The maximum measurement frequency of the LI5660 is 11 MHz (with HF input connector), and 3 MHz for the LI5655, which covers a much higher range of frequencies compared to previous models. And LI5650/LI5645 covers low frequency of 1mHz to 250kHz measurement.They are equipped with the latest functions such as simultaneous 2-frequency measurements and fractional harmonic measurements to meet the needs for advance measurements in a wide range of applications and fields.

- **Frequency range**
  LI5660: 0.5 Hz to 11 MHz* *HF input used
  LI5655: 0.5 Hz to 3 MHz
  LI5650/LI5645: 1 mHz to 250 kHz
- **Voltage measurement**
  LI5660: 10 nV to 10 V* F.S. * C input used
  LI5655/LI5650/LI5645: 10 nV to 1 V F.S.
- **Current measurement**
  LI5660/LI5655/LI5650: 10 fA to 1 μA F.S.
- **Minimum time constant**
  LI5660/LI5655: 1 μs
  LI5650/LI5645: 5 μs
- **Analog output update rate**
  LI5660/LI5655: approx. 1.5 M samples/s
  LI5650/LI5645: approx. 780 k samples/s
- **Simultaneous 2-frequency measurements** (LI5660/LI5655/LI5650)
  Comes with dual 2-phase sensitive detectors for simultaneous measurement of two frequency components
- **Fractional harmonic measurements**
  Measurements at fractional times frequencies of the fundamental wave (1 to 63) / (1 to 63)
- **External reference 10 MHz synchronous input**
  Can be synchronized with the reference frequency of other devices by using an external reference frequency
- **Measurement parameters** X, Y, R, θ, DC, NOISE
- **Interfaces** USB, GPIB, RS-232, LAN
- **Thin 2U size (88 mm)**

Line-up

◎ : Equipped – : Not equipped

	LI5660	LI5655	LI5650	LI5645
Frequency Range	0.5 Hz～11 MHz	0.5Hz～3MHz	1mHz～250kHz	1mHz～250kHz
Signal Input	Voltage (A, A-B, C ,HF), Current	Voltage (A, A-B), Current	Voltage (A, A-B), Current	Voltage (A, A-B)
10 Vrms input	◎ (C input , 0.5 Hz～3 MHz)	–	–	–
HF input	◎ (HF input ,10 kHz～11 MHz)	–	–	–
Sensitivity	A, A-B : 10nV～1V F.S. (0.5Hz～3MHz) C : 1mV～10V F.S. (0.5Hz～3MHz) HF : 1mV～1V F.S. (10kHz～11MHz) I : 10fA～1μA F.S.	10nV～1V F.S. (0.5Hz～3MHz) 10fA～1μA F.S.	10nV～1V F.S. (1mHz～250kHz) 10fA～1μA F.S.	10nV～1V F.S. (1mHz～250kHz) –
Input Referred Noise Voltage	4.5nV/√Hz (supplement value)	4.5nV/√Hz (supplement value)	4.5nV/√Hz (supplement value)	4.5nV/√Hz (supplement value)
PSD	2-phase, 2 PSDs	2-phase, 2 PSDs	2-phase, 2 PSDs	2-phase, 1 PSDs
Dynamic Reserve	100 dB	100 dB	100 dB	100dB
Time Constant	1 μs～50 ks	1 μs～50 ks	5 μs～50 ks	5 μs～50 ks
Analog Output Max. Update Rate	Approx. 1.5 M samples/s	Approx. 1.5 M samples/s	Approx. 780 k samples/s	Approx. 780 k samples/s
Fractional Harmonic Measurements	◎ (1 to 63) / (1 to 63) of fundamental wave	◎ (1 to 63) / (1 to 63) of fundamental wave	◎ (1 to 63) / (1 to 63) of fundamental wave	◎ (1 to 63) / (1 to 63) of fundamental wave
Dual Frequency Simultaneous Measurements	◎	◎	◎	–
External 10 MHz Synchronous	◎	◎	◎	◎
Measurement Parameter	X, Y, R, θ, DC, NOISE	X, Y, R, θ, DC, NOISE	X, Y, R, θ, DC, NOISE	X, Y, R, θ, DC, NOISE
Interfaces	USB, GPIB, RS-232, LAN	USB, GPIB, RS-232, LAN	USB, GPIB, RS-232, LAN	USB, GPIB, RS-232, LAN

High-response and high-stability

- **Time Constant**
The minimum time constant is 1μs for LI5660/LI5655 (5μs for LI5650/LI5645).
- **Synchronous filter**
This is an integer-period moving-average filter. Ripple caused by detection is greatly reduced, and the output is nearly settled in the averaging interval (integer period), so the time constant can be reduced (to obtain faster response).
However, at higher signal frequencies, ripple suppression may be insufficient.
- **High-speed Locking Even at Low Frequencies**
It takes just about two cycles to lock on to the reference signal even at low frequencies.

Time Constant

- **Superior Dynamic Reserve**
Phase detection and subsequent processing are performed digitally. Output zero drift at high gains is smaller than the analog system, and up to 100 dB dynamic reserve can be obtained (measurement can be performed with a noise 100,000 times larger than the sensitivity, namely the signal full scale)

Up to 11 MHz with the wide-band, high-frequency input terminal (LI5660)

Voltage measurements can be made with a single end (A) or differential (A-B) input, as well as 10 Vrms input (C) and high-frequency input (HF) terminals with the LI5660.
The HF input terminals can be used to measure up to 11 MHz.

LI5660
Signal Input

Diverse range of reference signal sources and detection modes

Fractional harmonic measurement

Measurements can be made at fractional times frequencies of the fundamental wave (1 to 63) / (1 to 63)

Fractions of the fundamental wave can be measured. With the LI5660/LI5655/LI5650 2-frequency mode it is possible to measure the reference signal frequency given to the primary detector at n/m times the primary frequency, and the reference signal frequency given to the secondary detector at n times or a different value to primary frequency.

Fractional Harmonic

Simultaneous 2-frequency measurements

2-phase (Rcosθ, Rsinθ), Dual PSD (primary PSD, secondary PSD)

- Simultaneous measurements of 2 frequency components
- Ratio calculation
- Phase detectors connected in cascade

This equipment comes with two 2-phase sensitive detectors (PSD), allowing simultaneous measurement of two frequency components that are included in a input signal. Measurements that previously required two lock-in amplifiers using the dual beam method can now be made with a single equipment.
Ratio calculations can be made by determining the ratio between the measured value and reference value, and an secondary PSD can be connected in cascade to the primary PSD, to run detection using the secondary PSD after detecting the signal with the primary PSD.

Detection Mode (Dual 1)

External reference 10 MHz synchronization

Can be synchronized with the reference frequency of other devices by using an external reference frequency

Synchronizing operation of other devices such as a signal generator allows synchronization to any frequency (can be configured) without having to use an external reference signal (REF IN).

External 10 MHz Reference Input

Multi functions in a compact body

Signal input connector

A: Max. 1 Vrms, 10 MΩ, Single ended
A-B: Max. 1 Vrms, 10 MΩ, Differential
C: Max. 1 Vrms, 1 MΩ

HF: Max. 1 Vrms, 10 kHz to 11 MHz, 1 MΩ/50 Ω
I: Max.1μArms, I-V Conversion Gain 1 M/100 M V/A

Front

LI5660

Soft key and
Easy Operation Key

Selection key

Reference Signal
REF IN **External Refernece Signal Input Connector**
OSC OUT **Internal Oscillator Output Connector**

Monitor Output Connector
(Phase sensitive detector input signal)

DATA1, DATA2 Output Connector

LI5655/LI5650

Not equipped C input and HF input.

LI5645

Not equipped C input, HF input, and I input.

Measurement Screen Display

Large

Fine

Normal

REF OUT
Refernece Signal Output Connector

DATA3, DATA4 Output Connector

AUX OUT1, AUX OUT2
(DC Voltage Output Connector)

AUX IN1, AUX IN2
(DC Voltage Input Connector)

Input Voltage Selector
AC100V/120V/230V

Preamp Power Supply Output
±15 V, 100 mA max.

LI5660

10MHz Input Connector

External Trigger Input Connector

Remote Control Interfaces
RS-232, GPIB, LAN, USB

Rear

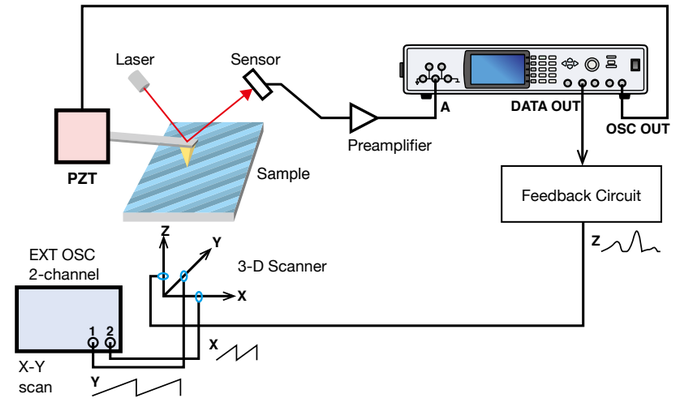
* Rear panel of LI5655/LI5650/LI5645 looks same but there are difference in specifications.

Applications

Comprehensive support for measuring very small signals in advanced research

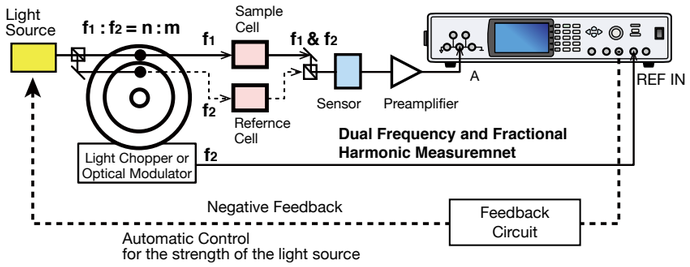
SPM (scanning probe microscope) signal processing

Scanning probe microscopes such as STM (scanning tunnel microscope) and AFM (atomic force microscope) use a nanoscale probe at the tip to scan the surface of a sample. The signal between the probe and the sample is detected to observe the electronic state and structure of the sample surface, as well as its physical and chemical properties.
Lock-in amplifiers are used to control the distance between the sample and probe.
The LI5660/LI5655 can also be used with high resonance frequency cantilever movement in the MHz range, and setting a smaller time constant (from 1 μs) allows high-speed scanning to generate images in a shorter time.
The synchronization filter can drastically reduce phase detection output ripples, resulting in much higher quality images, generated at a faster speed.
Lock-in amplifiers are also used for signal processing such as modulation signal demodulation with KFM (kelvin force microscope) as well as STM and ATM.



Optical transmission level measurement (illuminant fluctuation cancellation)

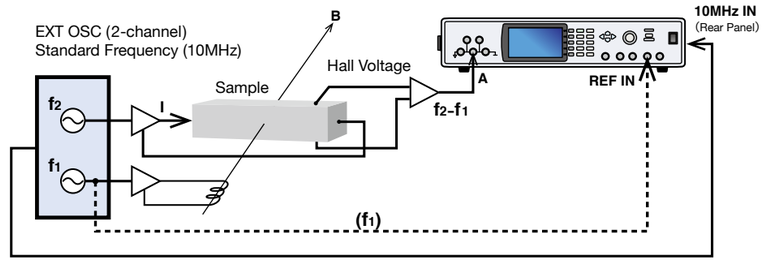
Using both the simultaneous 2-frequency measurement and fractional harmonic measurement functions allows fluctuation corrections of light sources and other sources using the dual beam method (ratio measurement) with a single LI5660 or LI5655.
Applying negative feedback to the reference cell signal also stabilizes the strength of the light source.
The integral multiple (n), integral inverse (1/m) and fraction (n/m) of the reference signal frequency can be configured, allowing it to be used easily with light chopper frequency ratios. When integral ratios are used, signals cannot be distinguished from harmonic components generated by distortion in the signal, however there is no impact on the harmonics if fraction ratios are used.
The reference 10 MHz synchronization function can also be used to synchronize operation with external signal generators, allowing detection of any two frequencies.



Hall coefficient measurement (difference frequency measurement)

The hall voltage is proportional to the product of two signals (current and magnetic field), and its frequency is the difference frequency (and sum) of the two signals. Synchronizing an external signal source, which generates a current and magnetic field, with the LI5660/LI5655 at an external 10 MHz allows measurement of the difference frequency signal of any two frequencies without having to arrange an external reference signal (difference frequency). (when used with a signal generator with a 2-channel output and frequency reference output)
If the original frequency is a integral* ratio, the fractional harmonic measurement function can also be used to measure the difference frequency signal. Either method avoids crosstalk interference from the external reference signal.

* Except for LI5645



Specifications

Nominal, Typical, Supplement and Approximate values show the supplemental data of this product and these do not guarantee the performance.

Measured signal system

Input coupling	A, A-B: AC/DC switching AC coupling with two-stage cascaded 1st order HPF, HPF fc: 0.1Hz (nominal value) I: AC/DC switching, after converting the voltage C (LI5660 only) : DC (Always automatically cancel DC component) HF (LI5660 only): AC fc: 1 kHz (nominal value), when input impedance is 50 Ω, the AC-couple stage is positioned after the 50 Ω termination one.
Input ground	Float/Connect (to chassis) switching Withstand voltage : ± 1 Vpk max. (DC+AC) Impedance to chassis: 10 kΩ (float), 11 Ω (connected to the chassis)
Line filter	Through (disabled), fundamental wave rejection (50 Hz or 60 Hz), 2nd order harmonic rejection (100 Hz or 120 Hz), rejection of both fundamental and 2nd order harmonic Attenuation: 20 dB or more (at f_0) * When using the input C and HF, Line filter is disable regardless of Line filter settings.

• Voltage measurement

	LI5660	LI5655	LI5650	LI5645
Input connector	BNC (front panel A, B, C, HF)	BNC (front panel A, B)		
Input type	A, C, HF (single-end), A-B (differential)	A (single-end), A-B (differential)		
Frequency range	A, A-B, C: 0.5 Hz to 3 MHz HF: 10 kHz to 11 MHz	A, A-B: 0.5 Hz to 3 MHz	A, A-B: 1 mHz to 250 kHz	
Sensitivity	A, A-B: 10 nV to 1 V F. S. (1-2-5 sequence)			
	C: 1 mV to 10 V F. S. (1-2-5 sequence)	—		
	HF: 1 mV to 1 V F. S. (1-2-5 sequence)	—		

Voltage accuracy

	LI5660	LI5655
A, A-B	±0.5 % (1 kHz, signal level ≥ 1 mV, at 23 ±5°C)*1 ±2 % (1 kHz, signal level ≥ 1 μV)*1 ±0.5 % (≤ 20 kHz, sensitivity 100 mV to 1 V, at 23 ±5°C)*2 ±1 % (≤ 50 kHz, sensitivity 100 mV to 1 V)*2 ±2 % (≤ 100 kHz, sensitivity 100 mV to 1 V)*2 ±3 % (≤ 1 MHz, sensitivity 100 mV to 1 V)*2 ±5 % (≤ 3 MHz, sensitivity 100 mV to 1 V)*2 *1 at least 30 % full-scale signal (sensitivity), dynamic reserve LOW *2 DC coupling, dynamic reserve LOW and full-scale signal	
C	±0.5 % (≤ 20 kHz) ±1 % (≤ 50 kHz) ±2 % (≤ 100 kHz) ±3 % (≤ 1 MHz) ±5 % (≤ 3 MHz) 1 V to 10 V sensitivity, with full-scale signal, dynamic reserve LOW	—
HF	±3 % (≤ 1 MHz, input impedance 1 MΩ) ±5 % (≤ 3 MHz, input impedance 1 MΩ) ±7 % (≤ 10 MHz, input impedance 50 Ω) ±14 % (≤ 11 MHz, input impedance 50 Ω) Dynamic reserve LOW, sensitivity 100 mV to 1 V, full-scale signal	—

	LI5650 / LI5645
A, A-B	±0.5 % (1 kHz, signal level ≥ 1 mV, at 23 ±5°C)*1 ±2 % (1 kHz, signal level ≥ 1 μV)*1 ±0.5 % (≤ 20 kHz, sensitivity 100 mV to 1 V at 23 ±5°C)*2 ±1 % (≤ 50 kHz, sensitivity 100 mV to 1 V)*2 ±2 % (≤ 100 kHz, sensitivity 100 mV to 1 V)*2 ±3 % (≤ 250 kHz, sensitivity 100 mV to 1 V)*2 *1 at least 30 % full-scale signal (sensitivity), dynamic reserve LOW *2 DC coupling, dynamic reserve LOW and full-scale signal

Voltage accuracy temperature drift	
A, A-B	± 100 ppm / °C (supplementary value) 1 kHz, dynamic reserve LOW, A input, sensitivity 1 V, signal level 100% of F. S.

Input impedance

	LI5660	LI5655 / LI5650 / LI5645
A, B	10 MΩ (nominal value), 50 pF in parallel (supplementary value)	
C	1 MΩ (nominal value), 50 pF in parallel (supplementary value)	—
HF	1 MΩ (nominal value), 50 pF in parallel (supplementary value) | 50 Ω (nominal value)	—

Input referred noise	
A, A-B	4.5 nV/√Hz (supplementary value) Dynamic reserve LOW, sensitivity 1 mV or less, 1 kHz, input short

Common-mode rejection ratio (CMRR)	
A-B	at least 100 dB AC coupling, 50 Hz to 1 kHz, signal source impedance 0 Ω, dynamic reserve LOW and sensitivity 20 mV or less (or MED and 2 mV or less)

Harmonic distortion	
A, A-B	−80 dBc or less (10 Hz to 5 kHz, 2-3rd order harmonics, each order) Dynamic reserve LOW, sensitivity 1 V, signal level 30% of F.S.

Maximum input voltage (linear operating range)

	LI5660	LI5655 / LI5650 / LI5645
A, B, A-B	± 3 V (Each terminal voltage and differential voltage at DC coupling) Dynamic reserve HIGH, sensitivity 1 V	
C	± 30 V Dynamic reserve HIGH, sensitivity 10 V	—
HF	± 3 V Dynamic reserve HIGH, sensitivity 1 V	—

Non-destructive maximum input voltage

	LI5660	LI5655 / LI5650 / LI5645
A, B	AC coupling: 10 Vrms (sine), DC±42 V DC coupling: ±14 V	
C	± 42 V	—
HF	± 5 V	—

• Current measurement (not equipped with LI5645)

Input connector	BNC (Front panel I)
Input type	Single-end
Frequency range	**LI5660** / **LI5655**

0.5 Hz to maximum values shown in the table below (nominal values, 3 dB reduction frequency)

Cs Signal source capacitance + connected cable capacitance	Conversion gain	
	1 M (10^6) [V/A]	100 M (10^8) [V/A]
None	1 MHz	10 kHz
150 pF	1 MHz	10 kHz
1000 pF	150 kHz	1.5 kHz

LI5650

1 mHz to maximum values shown in the table below (nominal values, 3 dB reduction frequency)

Cs Signal source capacitance + connected cable capacitance	Conversion gain	
	1 M (10^6) [V/A]	100 M (10^8) [V/A]
None	250 kHz	10 kHz
150 pF	250 kHz	10 kHz
1000 pF	150 kHz	1.5 kHz

Current accuracy	±1% (nominal value) At 23 ±5°C, dynamic reserve LOW, sensitivity 1 μA (1 M V/A at 1 kHz) as well as sensitivity 10 nA (100 M V/A at 125 Hz), 30 % or more of full-scale sensitivity signal Both typical value.
Sensitivity	100 fA to 1μA full-scale (with 1M [V/A]) 10 fA to 10 nA full-scale (with 100 M [V/A]) Both 1-2-5 sequence
Current accuracy temperature drift	± 150 ppm / °C Dynamic reserve LOW, supplementary value for (1 M [V/A], 1 kHz) and (100 M [V/A], 125 Hz)
Input referred noise	150 fA/√Hz (1M [V/A], 1kHz) 15 fA/√Hz (100M [V/A], 125Hz) Both supplementary value
Input impedance	1 kΩ (1M [V/A]) 100 kΩ (100M [V/A]) Both supplementary value
Maximum input current (linear operating range)	±3 μA DC coupling, dynamic reserve HIGH, conversion gain 1 M [V/A] sensitivity 1 μA

• Noise density measurement

Sensitivity	**LI5660 / LI5655 / LI5650**
	Voltage: 20 nV/√Hz to 1 V/√Hz (A, A-B) 1 mV/√Hz to 10 V/√Hz (C*) 1 mV/√Hz to 1 V/√Hz (HF*) Current: 1 pA/√Hz to 1 μA/√Hz (with 1 M [V/A]) 100 fA/√Hz to 10 nA/√Hz (with 100 M [V/A]) All in 1-2-5 sequence * LI5660 only
	LI5645
	Voltage: 20 nV/√Hz to 1 V/√Hz (1-2-5 sequence)

Phase sensitive detector section

Phase sensitive detector (PSD)	**LI5660 / LI5655 / LI5650**
	2 phase (Rcos θ, Rsin θ), Dual PSD (primary PSD secondary PSD).
	LI5645
	2 phase (Rcos θ, Rsin θ), 1 PSD (primary PSD).
PSD settings items	Sensitivity, time constant, phase, XY offset, dynamic reserve

Detection mode

Detection mode	Measurement frequency	
	Primary PSD	Secondary PSD*1
SINGLE*2	Fundamental/ Fraction Harmonic	None
DUAL1*1 *3	Fundamental/ Fraction Harmonic	Fundamental/ Harmonic
DUAL2*1 *4	Primary frequency	Secondary frequency
CASCADE*1 *5	Primary frequency	Secondary frequency

*1 Not equipped with LI5645
*2 2-phase detection is at one frequency.
*3 The fundamental and a harmonic component of one input signal are measured simultaneously.
*4 Two independent frequency components (primary and secondary) of one input signal are measured simultaneously.
*5 The secondary PSD is connected in cascade with the primary PSD, so after a signal is detected by the primary PSD, it is further detected by the secondary PSD.

Dynamic reserve	At least 100 dB (supplementary value) LOW/MEDIUM/HIGH 3-point switching (common in primary PSD and secondary PSD)
Time constant filter	**LI5660 / LI5655**
	Time constant: 1 μs to 50 ks (1-2-5 sequence) Attenuation slope: 6, 12, 18. 24 dB/oct
	LI5650 / LI5645
	Time constant: 5 μs to 50 ks (1-2-5 sequence) Attenuation slope: 6, 12, 18. 24 dB/oct
Synchronous filter	On/Off
Phase noise	**LI5660 / LI5655**
	0.001° rms (at 1 kHz, attenuation slope : 18 dB/oct or more) 0.003° rms(at 100 kHz, attenuation slope : 12 dB/oct or more) 0.01° rms (at 3 MHz, attenuation slope : 12 dB/oct or more) Supplementary value; reference signal is external sine wave 1 Vrms, time constant 100 ms, synchronization filter off
	LI5650 / LI5645
	0.001° rms (at 1 kHz, attenuation slope : 18 dB/oct or more) 0.003° rms(at 100 kHz, attenuation slope : 12 dB/oct or more) 0.01° rms (at 250 kHz, attenuation slope : 12 dB/oct or more) Supplementary value; reference signal is external sine wave 1 Vrms, time constant 100 ms, synchronization filter off
Phase temperature drift	**LI5660 / LI5655**
	± 0.01°/ °C (100 Hz ≤ frequency ≤ 10 kHz) ± 0.03°/ °C (10 kHz < frequency ≤ 100 kHz) ± 0.2°/ °C (100 kHz < frequency ≤ 3 MHz) Supplementary value when input signal (A connector) and external reference signal (REF IN connector) are both Sine wave 1Vrms.
	LI5650 / LI5645
	± 0.01°/ °C (100 Hz ≤ frequency ≤ 10 kHz) ± 0.03°/ °C (10 kHz < frequency ≤ 100 kHz) ± 0.2°/ °C (100 kHz < frequency ≤ 250 kHz) Supplementary value when input signal (A connector) and external reference signal (REF IN connector) are both Sine wave 1Vrms.

Reference signal system

Reference signal source	• REF IN: the external reference signal is used as the primary PSD's reference frequency at SINGLE, DUAL1*, and DUAL2*, and is used as the secondary one at CASCADE* • INT OSC: internal oscillator • SIGNAL: measurement signal (cannot be used when input HF is selected) * Except for LI5645

• External reference signal

Waveform	SIN POS, TTL POS, TTL NEG
Input connector	BNC (Front panel REF IN)
Input impedance	1 MΩ (nominal value), 100 pF in parallel (supplementary value)
Input voltage range	SIN: 0.3 to 20 Vp-p (sine), TTL: 0 to 5 V, High 2.6 V or more, Low 0.8 V or less (square)
Pulse width (square wave)	40 ns or more (both High level and Low level)
Non-destructive maximum input voltage	±15 V

Synchronization frequency range

LI5660

Signal input	Detection mode	External reference signal	Synchronization frequency range
A A-B C I	SINGLE DUAL1 DUAL2 CASCADE	SIN POS TTL POS TTL NEG	0.3 Hz to 3.2 MHz
HF	SINGLE DUAL1 DUAL2	TTL POS TTL NEG	8 kHz to 11.5 MHz
	CASCADE	SIN POS TTL POS TTL NEG	0.3 Hz to 3.2 MHz

LI5655

Signal input	Detection mode	External reference signal	Synchronization frequency range
A A-B I	SINGLE DUAL1 DUAL2 CASCADE	SIN POS TTL POS TTL NEG	0.3 Hz to 3.2 MHz

LI5650

Signal input	Detection mode	External reference signal	Synchronization frequency range
A A-B I	SINGLE DUAL1 DUAL2 CASCADE	SIN POS	0.3 Hz to 260 kHz
		TTL POS TTL NEG	0.5 mHz to 260 kHz

LI5645

Signal input	Detection mode	External reference signal	Synchronization frequency range
A A-B	SINGLE	SIN POS	0.3 Hz to 260 kHz
		TTL POS TTL NEG	0.5 mHz to 260 kHz

Synchronization time	2 periods + 50 ms (supplementary value)
Frequency display resolution	6 digits (0.1 mHz at less than 100 Hz)
Frequency measure-ment accuracy	± (40 ppm + 1 count)

• Internal Oscillator

Frequency (primary and secondary)	Oscillates two independent frequencies (primary frequency and secondary frequency) (detection mode DUAL2*1, CASCADE*1) • Setting range: LI5660 / LI5655 0.3 Hz to 3.2 MHz (A, A-B, C*2,I) 8 kHz to 11.5 MHz (HF*2) LI5650 / LI5645 0.5 mHz to 260 kHz • Resolution: 6 digits (0.1 m Hz, less than 100 Hz) • Accuracy: ± 40 ppm *1 Except for LI5645 *2 LI5660 only
Reference frequency source	Internal / external switching

Reference frequency source	
Frequency range	10 MHz ± 0.2 %
Waveform	Sine Wave or Square Wave (duty 45 to 55%)
Signal level	0.5 Vp-p to 5 Vp-p
Non-destructive maximum input voltage	10 Vp-p
Input impedance	1 kΩ (nominal value)
Input coupling	AC
Withstand voltage	± 42 Vpk max. (DC+AC) (Allowable voltage to ground)

Sine wave output

Frequency	Primary frequency (with detection mode SINGLE, DUAL1*) Primary frequency/secondary* frequency (With detection mode DUAL2*, CASCADE*, selectable) * Except for LI5645	
Amplitude	0 to 10.00 mVrms / 0 to 100.0 mVrms / 0 to 1.000 Vrms When > 3.2 MHz, 0 Vrms regardless of the setting (LI5660/LI5655 only)	
Amplitude accuracy	**LI5660 / LI5655** ±(2% of setting + 1 mV) ≤ 20 kHz ±(3% of setting + 1 mV) ≤ 100 kHz ±(4% of setting + 2 mV) ≤ 1 MHz ±(7% of setting + 5 mV) ≤ 3.2 MHz	**LI5650 / LI5645** ±(2% of setting + 1 mV) ≤ 20 kHz ±(3% of setting + 1 mV) ≤ 100 kHz ±(4% of setting + 2 mV) ≤ 260 kHz
Maximum output current	± 15 mA	
Output impedance	50 Ω (nominal value)	
Harmonic distortion (Output voltage setting 1 Vrms, supplementary value)	**LI5660 / LI5655** -80 dBc or less (20 Hz ≤ frequency ≤ 5 kHz, no load, 2nd to 5th order) -70 dBc or less (5 kHz < frequency ≤ 100 kHz, no load, 2nd to 5th order) -60 dBc or less (100 kHz < frequency ≤ 1 MHz, 50 Ω, 2nd to 3rd order) -50 dBc or less (1 MHz < frequency ≤ 3 MHz, 50 Ω, 2nd to 3rd order)	
	LI5650 / LI5645 -80 dBc or less (20 Hz ≤ frequency ≤ 5 kHz, no load, 2nd to 5th order) -70 dBc or less (5 kHz < frequency ≤ 100 kHz, no load, 2nd to 5th order) -60 dBc or less (100 kHz < frequency ≤ 250 kHz, 50 Ω, 2nd to 3rd order)	

Square wave output

Frequency	Primary frequency (with detection mode SINGLE, DUAL1*) Primary frequency/secondary frequency (With detection mode DUAL2*, CASCADE*, selectable) * Except for LI5645
Signal level	TTL (0 to 3.3 V, nominal value at no load), ±8 mA max. (supplementary value) Less than 3.2 MHz, Output level fixed in High or Low (LI5660/LI5655 only)

Harmonic measurement

Detection mode SINGLE	The primary frequency to the PSD is n/m times of reference signal frequency n range (harmonic) 1 to 63 m range (sub harmonic) 1 to 63
Detection mode DUAL1 (Except for LI5645)	The primary frequency to the primary PSD is n/m times of the reference signal frequency. The secondary frequency to the secondary PSD is n times of the reference signal frequency. n PRI range (harmonics number of primary PSD) 1 to 63 m PRI range (sub harmonics number of primary PSD) 1 to 63 n SEC range (harmonics number of secondary PSD) 1 to 63

Allowable frequency range of Harmonic measurement

Reference signal source	Fundamental frequency range	Harmonic frequency range
REF IN	Synchronization frequency range to external reference signal	Same as at left
INT OSC	Internal oscillator frequency setting range	Same as at left
SIGNAL	Synchronization frequency to external reference signal	Regardless of n, m settings, always operates at n = 1 and m = 1

Phase adjustment range	−180.000° to +179.999° (resolution 0.001°)	
Orthogonality	± 0.001° or better (supplementary value)	
Phase accuracy	**LI5660 / LI5655** ±1° (DC coupling, ≤ 10 kHz) ±2° (DC coupling, ≤ 100 kHz) ±5° (DC coupling, ≤ 1 MHz) ±10° (DC coupling, ≤ 3 MHz)	**LI5650 / LI5645** ±1° (DC coupling, ≤ 10 kHz) ±2° (DC coupling, ≤ 100 kHz) ±5° (DC coupling, ≤ 250 kHz)
	Supplementary value; at Sine wave 1 Vms, both A input (sensitivity 1 V) and external reference signal input	

Arithmetic processing

Offset adjustment	X, Y: sensitivity of ± 105% (resolution 0.001%) Both of primary PSD and secondary PSD* can be set * Except for LI5645
EXPAND	X, R:1, 10, 100 (Ratio of X and R is common) Y:1, 10, 100 • Primary PSD and secondary PSD* can be set individual • Apparent sensitivity (signal full-scale) is 1 / EXPAND magnification • Unusable when normalize or ratio calculation is running. * Except for LI5645
Normalize (normalize calculation not available or select from right)	% value = (measured value / standard value) x 100 dB value = 20 × $\log_{10}$ | Measurement values / standard values | % FS value = (measured value / sensitivity) × 100 • When detection mode is SINGLE, DUAL1*, DUAL2*, the above measurement value = primary PSD output (X or R) • When detection mode is CASCADE*, the above measurement value = secondary PSD output (X or R) Standard value range: voltage 1 nV to 10 V, current 1 fA to 1 μA*, resolution 6-digit • Unusable when EXPAND or Ratio calculation is running. * Except for LI5645

Ratio	Ratio of measured value A and standard value B ratio = K × A ÷ B K: 0.1 to 10 (resolution 0.00001) A, B: Select from a combination of the below

A (measured value)	B (standard value)	Detection mode
Primary PSD output (X, Y, R) / Sensitivity	AUX IN 1 Measurement value / 10 V	SINGLE
Primary PSD output (X, Y, R) / Sensitivity	Secondary PSD X output / Sensitivity	DUAL1* DUAL2*
Secondary PSD output (X, Y, R) / Sensitivity	AUX IN 1 Measurement value / 10 V	CASCADE*

* Maximum update rate of B is 10 k sample/s * Except for LI5645
• When executing expansion or normalizing or ratio arithmetic processing it cannot be performed.

Measured value output and display

Parameter

Output/ Display	Detection mode	
	SINGLE	DUAL1*, DUAL2*, CASCADE*
DATA1	X, R, AUX IN 1, NOISE	Xp, Rp, Yp, θp, Xs, Rs, AUX IN 1, NOISE
DATA2	Y, θ, AUX IN 1, AUX IN 2	Yp, θp, Xs, Rs, Ys, θs, AUX IN 1, AUX IN 2
DATA3	X, R	Xp, Rp, Yp, θp, Xs, Rs
DATA4	Y, θ	Yp, θp, Xs, Rs, Ys, θs
Remarks X, Y, R, θ suffix	n: harmonic (At harmonic value settings, n as a suffix. Ex.: Xn)	p: primary ditector s: secondary ditector n: harmonic (At harmonic value settings, n as a suffix. Ex.: Xpn)

* Except for LI5645

Analog output

Full scale voltage	± 10 V (bipolar signal) , +10 V (unipolar signal)
Output voltage range	± 12 V (no-load)
Maximum output current	± 10 mA
Output impedance	470 Ω (nominal value)
Output voltage accuracy	± (0.3% + 10 mV) to measurement value
Maximum update rate	**LI5660 / LI5655**
	DATA OUT 1/DATA OUT2 (Front panel) 312.5 k sample/s. DATA OUT 3/DATA OUT4 (Rear panel) 1.5625 M sample/s.
	LI5650 / LI5645
	DATA OUT 1/DATA OUT2 (Front panel) 156.25 k sample/s. DATA OUT 3/DATA OUT4 (Rear panel) 781.25 k sample/s.
Measurement screen display	Normal: show the measured values (DATA1, DATA2) and key settings Large: enlarged display the measured values (DATA1, DATA2) Fine: Show the measured values (DATA1, DATA2, DATA3, DATA4) and advanced settings On Normal and Large measurement screens, displays measured values as bar graphs as well as numerical values.

Numeric display

Parameter	Numeric display		Measurement value for the full scale voltage of the analog output
	Range	Resolution	
X, Y	Sensitivity / EXPAND (±120%)	6 digits, at full-scale sensitivity	± sensitivity / EXPAND ratio
R	Sensitivity / EXPAND (0 to 120%)	6 digits, at full-scale sensitivity	Sensitivity / EXPAND ratio
θ	-180.000 to +179.999 °	0.001 °	± 180 °
NOISES (Noise density)	Sensitivity 0 to 120 %	6 digits, at sensitivity F. S.	Sensitivity
AUX IN 1, 2	± 12 V	0.001 V	± 10 V
Ratio	± 2.4	0.00001	± 2
Normalize %	± 240 %	0.001 %	± 200 %
Normalize % of full-scale	± 120 % of F.S.	0.001 % of F.S.	± 100 % of F.S.
Normalize dB	± 120 dB	0.001 dB	± 100 dB

Monitor output

Monitor signal	Phase sensitive detector input signal
Maximum output	Maximum output voltage ± 3 V (no-load), maximum output current ± 20 mA
Output impedance	50 Ω (nominal value)

Automatic setting items

Measurement	Perform the following items “time constant”, “sensitivity”, “phase”
Time constant	Set the time constant and attenuation slope corresponding to the frequency of the reference signal.
Sensitivity	Set the sensitivity , and dynamic reserve according to the input signal.
Phase	Set the phase shift value as Y and phase output to a zero
Offset	Set each offset value, X and Y outputs to a zero

Auxiliary input (DC voltage measurement)

Number of channels	2
Maximum allowable input voltage	(linear operating range) ± 12 V
Non-destructive maximum input voltage	± 42 V
Input impedance	1 MΩ (nominal value), 50 pF in parallel (supplementary value)
Voltage measurement accuracy	± (0.3% + 10 mV), when the input ground is equal to the chassis potential
Frequency bandwidth	Highest: 5 kHz (-3 dB) (supplementary value)
Sampling rate	Highest: 125 k sample / s
Floating characteristics	Signal Ground Maximum voltage to ground (non-destructive): ± 42 Vpk max. (DC+AC) Ground impedance: 1 MΩ (nominal value) Signal Maximum voltage to ground: ± 42 Vpk max. (DC+AC)

Auxiliary output (DC voltage output)

Number of channels	2
Output voltage range	± 10.500 V (resolution 0.001 V)
Maximum output current	± 5 mA
Output impedance	1 kΩ (nominal value)
Output voltage accuracy	± (0.3% + 10 mV), at no load

Data Memory

Record data	For each sample data, select arbitrary up to five words from the recorded data
Recording capacity	Buffer 1, 2: 16 to 8192 sample Buffer 3: 16 to 65536 sample (FIFO)
Trigger Signal	Internal timer/External trigger/Remote control commands/Manual trigger 1 sample recorded when trigger signal is received
Sampling interval	**LI5660 / LI5655**
	Internal timer Range: 1.92 µs to 20 s, repeated at equal intervals, resolution: 640 ns, 6 digits max. External trigger/Remote control commands/Manual trigger Range: ≥ 2.6 µs arbitrary intervals, trigger jitter 640 ns (nominal value)
	LI5650 / LI5645
	Internal timer Range: 9.6 µs to 20 s, repeated at equal intervals, resolution: 640 ns, 6 digits max. External trigger/Remote control commands/Manual trigger Range: ≥ 2.6 µs arbitrary intervals, trigger jitter 640 ns (nominal value)
External trigger	Signal level: TTL (0 to 5 V, High 2.6 V or more, Low 0.8 V or less), Minimum pulse width: 500 ns (both high and low level) Effective edge: Falling, input impedance: 10 kΩ (nominal value) Non-destructive maximum input voltage: ± 15 V
Trigger delay time	0 to 100 s (resolution: 640 ns, 6 digits max.)

Remote control interface

USB	USBTMC, USB 2.0 High speed
RS-232	4800 / 9600 / 19200 / 38400 / 57600 / 115200 / 230400 bps
GPIB	Compliance standards IEEE 488.1, IEEE 488.2
LAN	10BASE-T / 100BASE-TX, TCP/IP

General specification

Display	4.3-inch WQVGA, color LCD
Power supply	AC 100 V ± 10% / 120 V ± 10% / 230 V+10%, - 14% However 250 V or less 50 Hz / 60 Hz ± 2 Hz, power consumption 75 VA or less, over voltage category II
Operating temperature / humidity range	0 to +40°C 5 to 85% RH, absolute humidity 1 to 25 g / m^3, no condensation
Warm-up time	30 minutes
Setting memory	9 sets
Resume	Return to the last settings at power-on state
Power output for Preamp	± 15 V (nominal value) 100 mA max. (rear panel PREAMP POWER)
External dimensions (mm)	430 (W) × 88 (H) × 400 (D) Excluding protrusions
Weight	Approx. 7.5 kg Except for accessories

Accessories and options

Accessories	Instruction manual, CD-ROM (remote control driver etc.) power cord set (3-pin, 2 m) fuse (time lag, 1.0 A / 250 V), protective cap* (for current input terminal) * Except for LI5645
Option	PA-001-2779 EIA rack-mount kit PA-001-2780 JIS rack-mount kit

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