d) 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

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

Harmonics are measured under the following conditions.

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 range to external reference signal	Regardless of n, m settings, always operates at n = 1 and m = 1

e) Phase Adjustment

Phase shift amount Range −180.000° to +179.999°

Resolution 0.001°

f) Others

Orthogonality ±0.001° or better (supplementary value)

Phase accuracy ±1° (DC coupling, ≦10 kHz)

±2° (DC coupling, ≦ 100 kHz)

±5° (DC coupling, ≦ 1 MHz)

±10° (DC coupling, ≦ 3 MHz)

Reference signal source = REF IN

Signal input connector A (sensitivity 1 V),

Supplementary value; at Sine wave 1Vrms, both A input and external reference signal input

3.4 Arithmetic Processing

The following calculations are available for measurement values X, Y and R.

For measurement values X, Y and R, ☞ "3.5 Measured Value Output and Display Section"

a) Offset adjustment

Control Enable/Disable

Range X, Y: sensitivity of ± 105% (resolution 0.001%)

Both of primary PSD and secondary PSD can be set

- About Offset Adjustment

  This function enables deduction of a certain amount from the detectors' X and Y outputs. Use it to cancel crosstalk components contained in the input. Also, by setting X and Y near zero, the following expansion capabilities can be used to improve the apparent sensitivity and resolution, enabling measurement of small changes.

b) Expansion

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 F. S.) is 1 / EXPAND magnification

Unusable when normalize or ratio arithmetic processing is running.

c) Normalize

Select from the following

None

% value = (measured value / standard value) x 100

dB value = $20 \times \log_{10}$ | 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 : 1nV to 10V

current : 1fA to 1μA

resolution : 6-digit

Unusable when EXPAND or Ratio arithmetic processing is running.

d) Ratio

Select from the following

- None
- ratio = K × A ÷ B

K: range 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 measured value / 10 V	SINGLE DUAL1 DUAL2
primary PSD output (X, Y, R) / sensitivity	secondary PSD X output / sensitivity	DUAL1 DUAL2
secondary PSD output (X, Y, R) / sensitivity	AUX IN 1 measured value / 10 V	CASCADE

Maximum update rate of B is about 10 k samples/s.

When executing expansion or normalizing or ratio arithmetic procesing cannot be performed.

- About the Ratio

  This is the ratio of measured value A to standard value B. Determining the ratio enables canceling out characteristic variation of the parts common to the measurement and standard systems (signal source, path and sensor).

  For a usage example, ☞ "1.2 Applications" Ex. 2. Light transmission measurements

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3.5 Measured Value Output and Display Section

a) Parameter

Select from the following.

Output/Display	Detection Mode	
	SINGLE	DUAL1 DUAL2, CASCADE
DATA1	X, R, AUX IN 1, NOISE	X_p,R_p,Y_p, θ_p ,X_s, R_s,AUX IN 1, NOISE
DATA2	Y, θ, AUX IN 1, AUX IN 2	Y_p,θ_p,X_s,R_s, Y_s,θ_s,AUX IN 1, AUX IN 2
DATA3	X, R	X_p,R_p,Y_p, θ_p ,X_s, R_s
DATA4	Y, θ	Y_p,θ_p,X_s,R_s, Y_s,θ_s
Remarks: X, Y, R, θ suffix	n: Harmonic (At harmonic value settings, n as a suffix. Ex.: Xn)	p: primary PSD s: secondary PSD n: Harmonic (At harmonic value settings, n as a suffix. Ex.: Xpn)

X	In-phase component (=R cos θ)
Y	Quadrature component (=R sin θ)
R	Signal amplitude
θ	Signal phase
NOISE	Noise density (primary PSD only)
AUX IN 1	DC voltage (rear panel AUX IN 1)
AUX IN 2	DC voltage (rear panel AUX IN 2)

b) Analog output

Front Panel

Output connectors	BNC (DATA OUT 1, DATA OUT2: corresponding to DATA1 and 2)
Maximum update rate	312.5 k samples/s.

Rear Panel

Output connectors	BNC (DATA OUT 3, DATA OUT4: corresponding to DATA3 and 4)
Maximum update rate	1.5625 M samples/s.

Common Specifications

Full-scale voltage	±10 V (bipolar signals), +10 V (unipolar signals)
Output voltage range	±12 V (no-load)
Max output current	±10 mA
Output impedance	470 Ω (nominal value)
Output voltage accuracy	±(0.3 % + 10 mV), versus measured value corresponding voltage Refer to the rightmost column of the table in part "e) Numeric display" for measured values corresponding voltage values.

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c) Measurement screen display

Select the screen to display measurement values from the following.

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

d) Bar Graphs

On Normal and Large measurement screens, displays measured values as bar graphs as well as numerical values.

e) 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
R	Sensitivity / EXPAND (0 to 120 %)	6 digits, at full-scale sensitivity	Sensitivity /EXPAND
θ	−180.000 to +179.999°	0.001°	± 180 °
NOISE (Noise dencity)	Sensitivity 0 to 120 %	6 digits, at full-scale sensitivity	Sensitivity
AUX IN 1, 2	± 12 V	0.001 V	± 10 V
Ratios	± 2.4	0.00001	± 2
Normalize %	± 240 %	0.001 %	± 200 %
Normalize % of f.s.	± 120 % of FS	0.001 % of FS	± 100 % of FS
Normalize dB	± 120 dB	0.001 dB	± 100 dB

3.6 Monitor Output

Monitor signal Phase sensitive detector input signal

Output connector BNC (front panel MONITOR OUT)

Maximum output voltage ±3 V (no-load)

Output is approximately AC Gain times the input.

For details of AC Gain, ☞ "3.2 Phase Sensitive Detection Section" c) Dynamic Reserve (DR)

Max output current ±20 mA

Output impedance 50 Ω (nominal value)

3.7 Auxiliary Input (DC Voltage Measurement)

Number of channels 2

Input connectors BNC (rear panel AUX IN 1, 2)

Maximum allowable input voltage (linear operating range)

±12 V

Nondestructive maximum input voltage

±42 V

Input impedance 1 MΩ (nominal value), 50 pF in parallel (supplementary value)

When signal ground is at chassis potential.

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 samples/s

Floating characteristics Signal Ground

Maximum voltage to ground (non-destructive)

± 42Vpk max. (DC+AC)

Ground impedance

1MΩ (nominal value)

Signal

Maximum voltage to ground (non-destructive)

± 42Vpk max. (DC+AC)

3.8 Auxiliary Output (DC Voltage Output)

Number of channels 2

Output connectors BNC (rear panel AUX OUT 1, 2)

Output voltage range ±10.500 V (0.001 V resolution)

Maximum output current

±5 mA

Output impedance 1 kΩ (nominal value)

Output voltage accuracy

± (0.3 % + 10 mV), no-load

3.9 Automatic Setting Items

Item	Function
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 θ to a zero.
Offset	Set each offset value, X and Y outputs to a zero.

3.10 Data Memory

Record data — For each sample data, select arbitrary up to five words from the following recorded data

Recording data	Words	Data Resolution
STATUS	1 Word	16 bits
DATA 1	1 Word	16 bits
DATA 2	1 Word	16 bits
DATA 3	1 Word	16 bits
DATA 4	1 Word	16 bits
Reference Signal Frequency	2 Words	32 bits

STATUS detects the following signals.

- UNLOCK (Unsynchronization)
- PROTECT (Input A or B overload)
- INPUT (pre PSD overload)
- OUTPUT (post PSD overload)
- AUX (AUX input overload)

Recording capacity — Buffers 1, 2: 16 to 8192 samples
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 — Internal timer
Range : 1.92µs to 20s, repeated at equal intervals,
Resolution : 640ns, 6 digit max.
External trigger / Remote control commands / Manual trigger
Range : ≥ 2.6µs arbitrary intervals,
Trigger jitter : 640ns (nominal value)

External trigger

Input connector	BNC (rear panel TRIG IN)
Signal level	TTL (High 2.6V or more, LOW 0.8V or less)
Minimum pulse width	500ns (both high and low level)
Effective edge	Falling
Input impedance	10kΩ (nominal value)
Nondestructive maximum input voltage	±15 V

Trigger delay time

Range	0 to 100 s
Resolution	640 ns, 6 digits max

Data is recorded after the delay time has elapsed.

Operation — By remote control.
Can not operate from panel (only manual triggering is possible).

3.11 Remote Control Interface

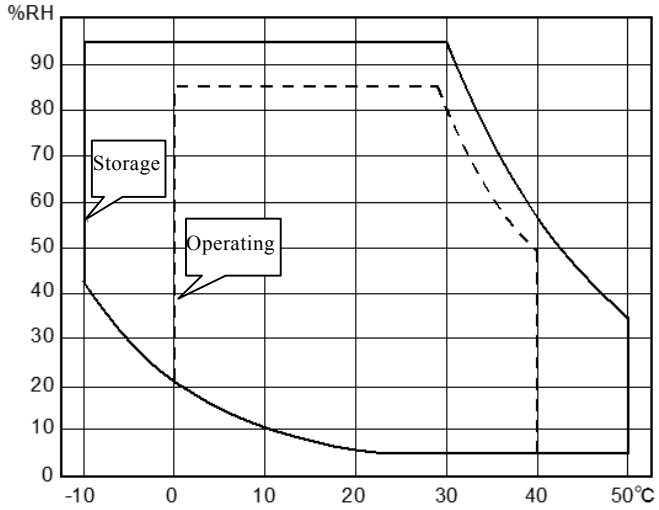
USB	USBTMC, USB 2.0 HiSpeed
RS-232	Baud rate
	4800, 9600, 19200, 38400, 57600, 115200, 230400 bps
	Cable and controller characteristics can inhibit communication speeds over 19200 bps.
	Flow control
	None, Software (X-ON/X-OFF), Hardware (RTS/CTS)
GPIB	Compliance standards IEEE 488.1, IEEE 488.2
LAN	10BASE-T and 100BASE-TX, TCP/IP

3.12 General Specifications

- 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
  Overvoltage category Ⅱ

• Environmental conditions

Operating	Temperature	0 to +40°C
	Humidity range	5 to 85% RH, absolute humidity 1 to 25g/m^3, non-condensing
	Altitude	2000 m or less
Storage	Temperature	–10 to +50°C
	Humidity	5 to 95% RH, absolute humidity 1 to 29g/m^3, non-condensing



- Pollution degree 2 (indoor use)
- Warm-up time 30 miniutes
- 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)
- Key-Lock Present (On, Off)
- Lamp control Present (On, Off)
  Remarks: Cooling fan is always on. It cannot be turned off.
- RoHS Directive 2011/65/EU
- Safety and EMC EN 61010-1:2010, EN61010-2-030:2010,
  EN 61326-1:2013, EN 61326-2-1:2013
  Remarks: Applies to products with CE marking displayed on the rear panel.
- External dimensions 430(W) × 88(H) × 400(D) mm, excluding protrusions
- Weight Approx. 7.5 kg, except for accessories

4. Operating Principles and Block Diagram

A lock-in amplifier is a device that uses the difference of the frequencies to separate signal and noise and amplify the signal. In this way, it works as a narrow-band filter and tuned amplifier in which the center frequency follows the signal.

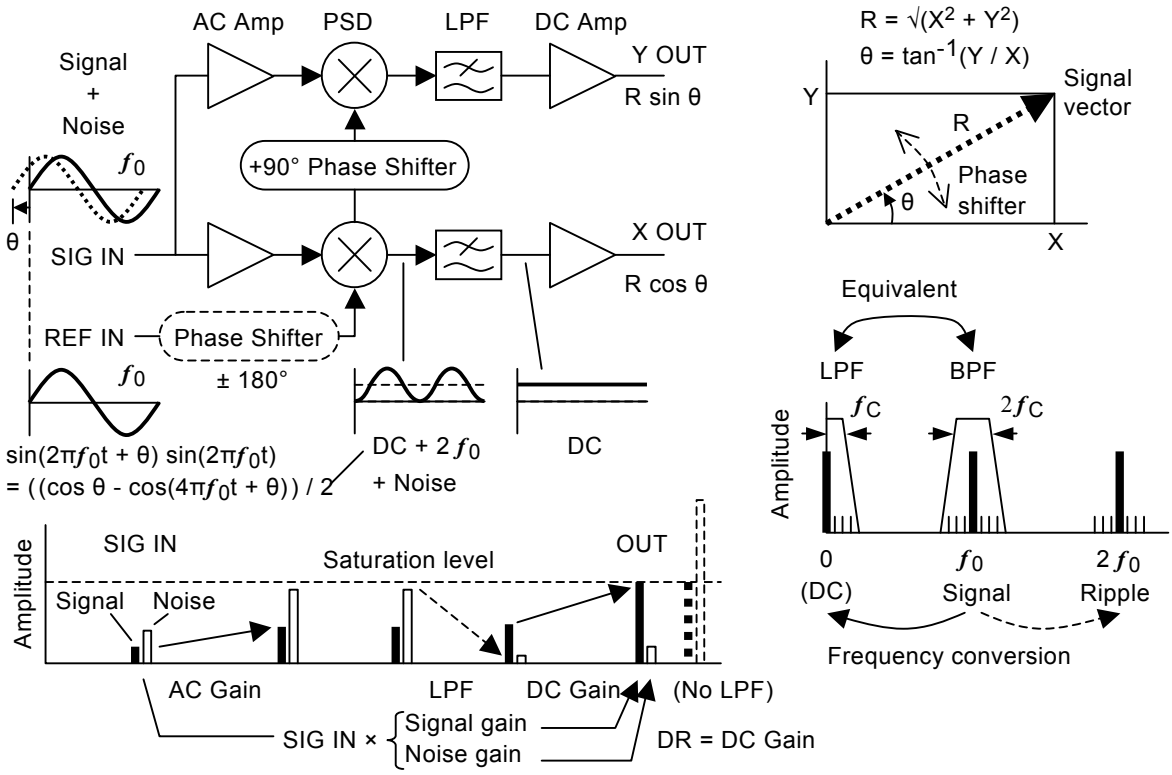


Figure 4-1 Lock-In Amplifier Basic Principles

First, the signal containing noise is frequency-converted to DC using the phase-sensitive detector (PSD). Noise in the vicinity of the signal frequency is also converted into nearby DC. Then, noise and ripple caused by the detection are removed by the low-pass filter (LPF) to obtain DC components. When this is returned to the original frequency, the equivalent bandwidth is equal to the band pass filter (BPF) that is double the cutoff frequency (f_C) of the LPF. Increasing the filter time constant (response time) and attenuation slope (number of stages), lowers *fc* and removes the noise. After the LPF removes the noise, the signal can be amplified without being saturated by the noise. In other words, measurement becomes possible in environments where the noise is larger than the signal. AC gain before phase detection and DC gain after phase detection are determined by the sensitivity (signal full-scale) and dynamic reserve (DR) settings. (DR value = maximum acceptable noise level/sensitivity).

A lock-in amplifier needs a reference signal (REF IN) as the reference of the frequency and phase.

The PSD is a multiplier of the signal to be measured and the reference signal (both being sine waves at the same frequency), and its output (DC) depends on measured signal size R and phase difference θ with the reference signal (it's "phase sensitive"). The amplitude of a reference signal applied to the PSD is constant, and the phase can be shifted.

The two-phase lock-in amplifier contains two PSDs and works as a vector voltmeter that can obtain two orthogonal components X and Y (in other words, R and θ) at the same time.

As the LI5655 / LI5660 are dual systems equipped with two PSDs, two frequency components in one input signal can be measured at the same time. The two PSDs can be connected in cascade configuration.

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The internal oscillator (INT OSC) is normally synchronized with the external reference signal (REF IN) by a PLL (phase-locked loop) to supply the reference signal to the PSD. A function is also provided to set the frequency as a numerical value, and to supply its harmonic to the PSD as a reference signal.

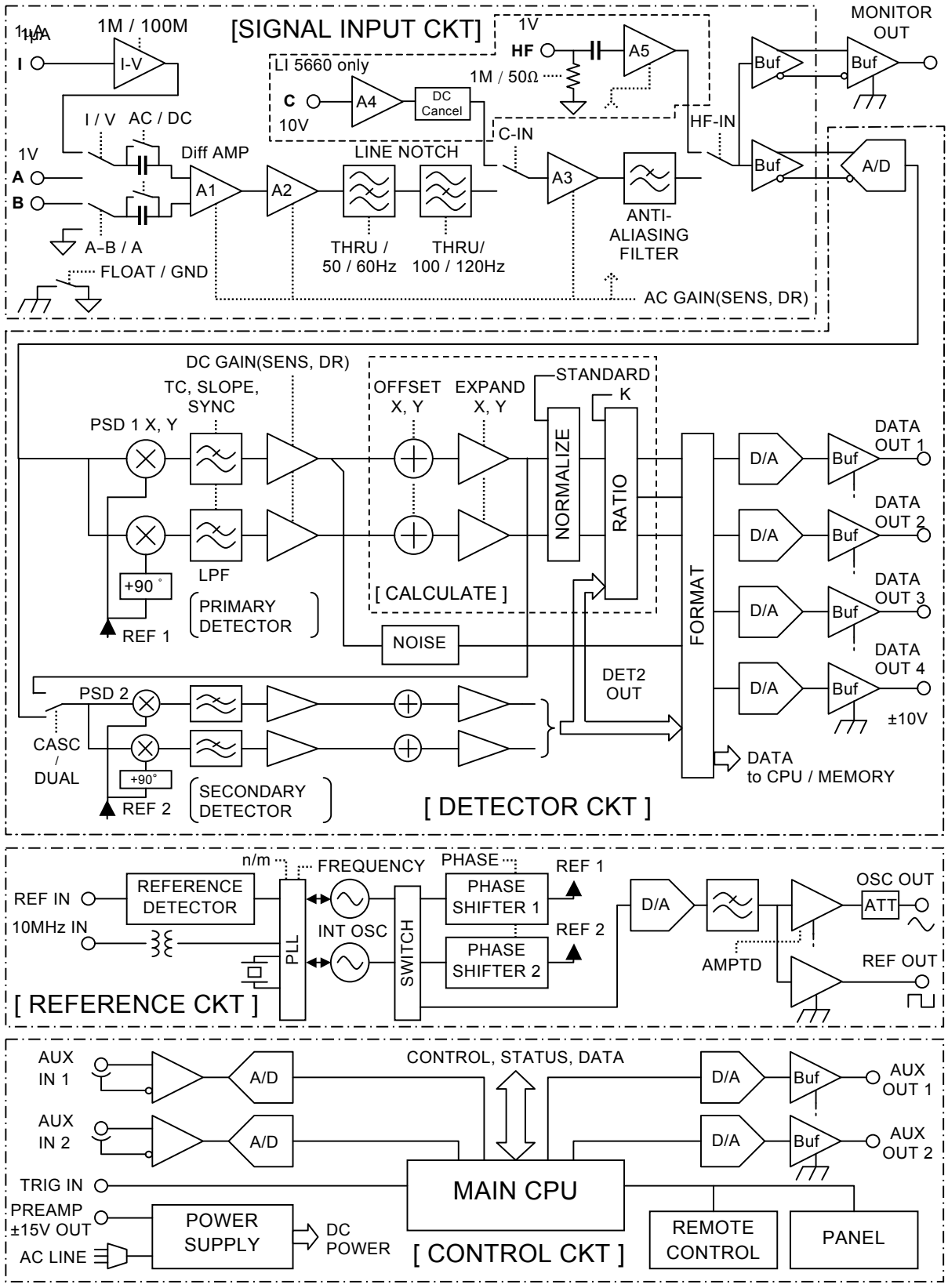

Figure 4-2 LI5655 / LI5660 Block Diagram

5. External dimensions diagram

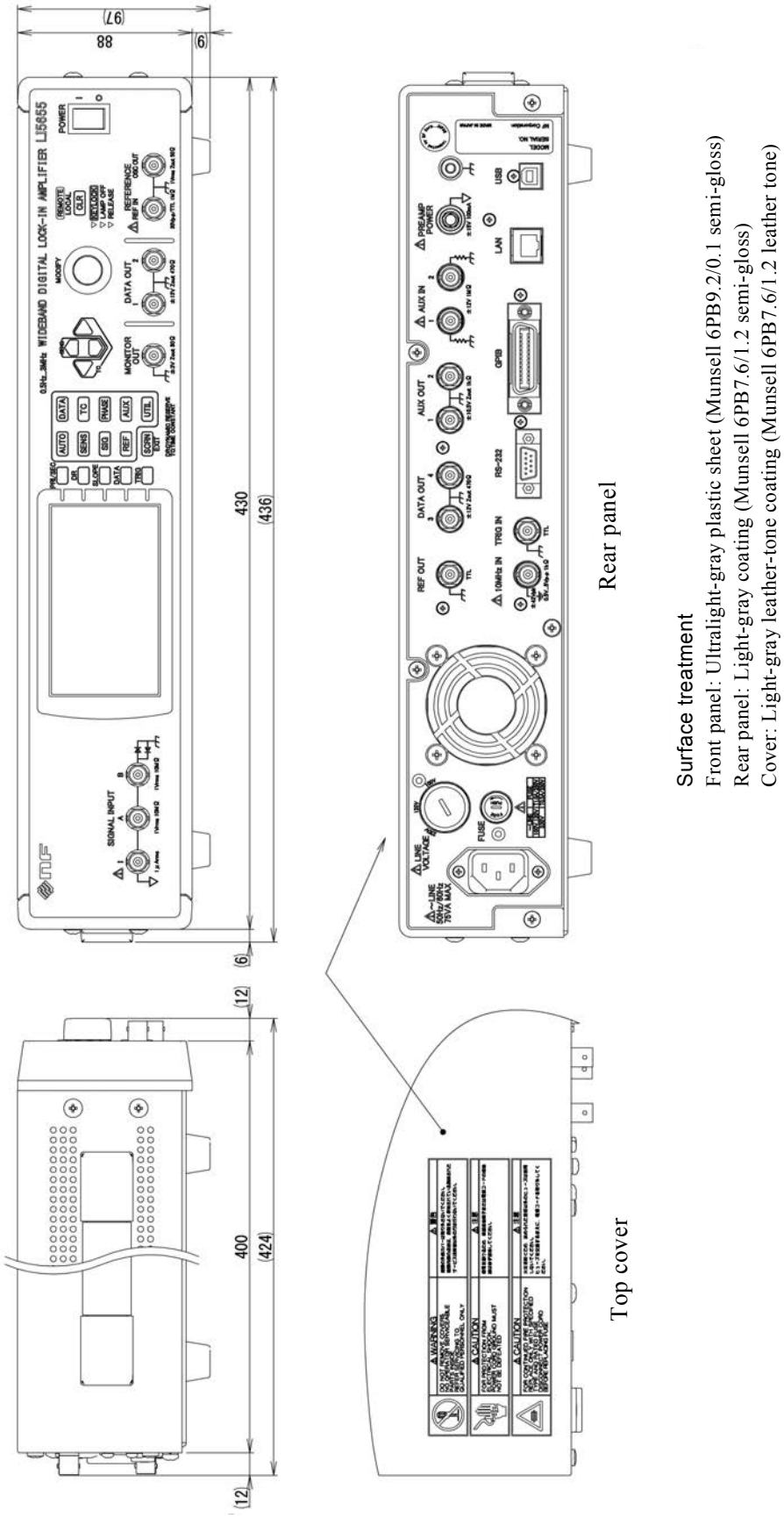

Figure 5-1 LI5655 External Dimensions Diagram

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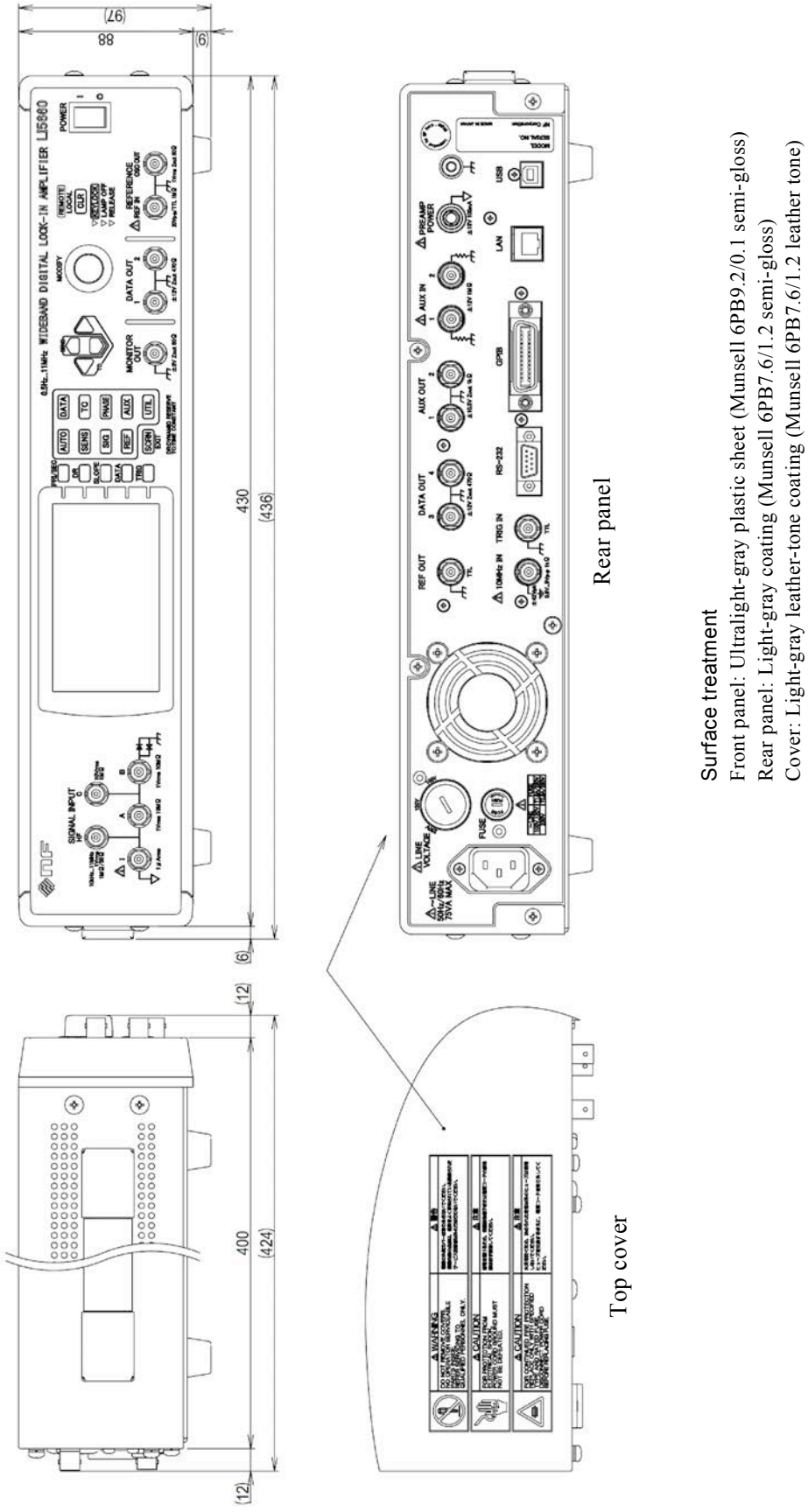

Figure 5-2 LI5660 External Dimensions Diagram

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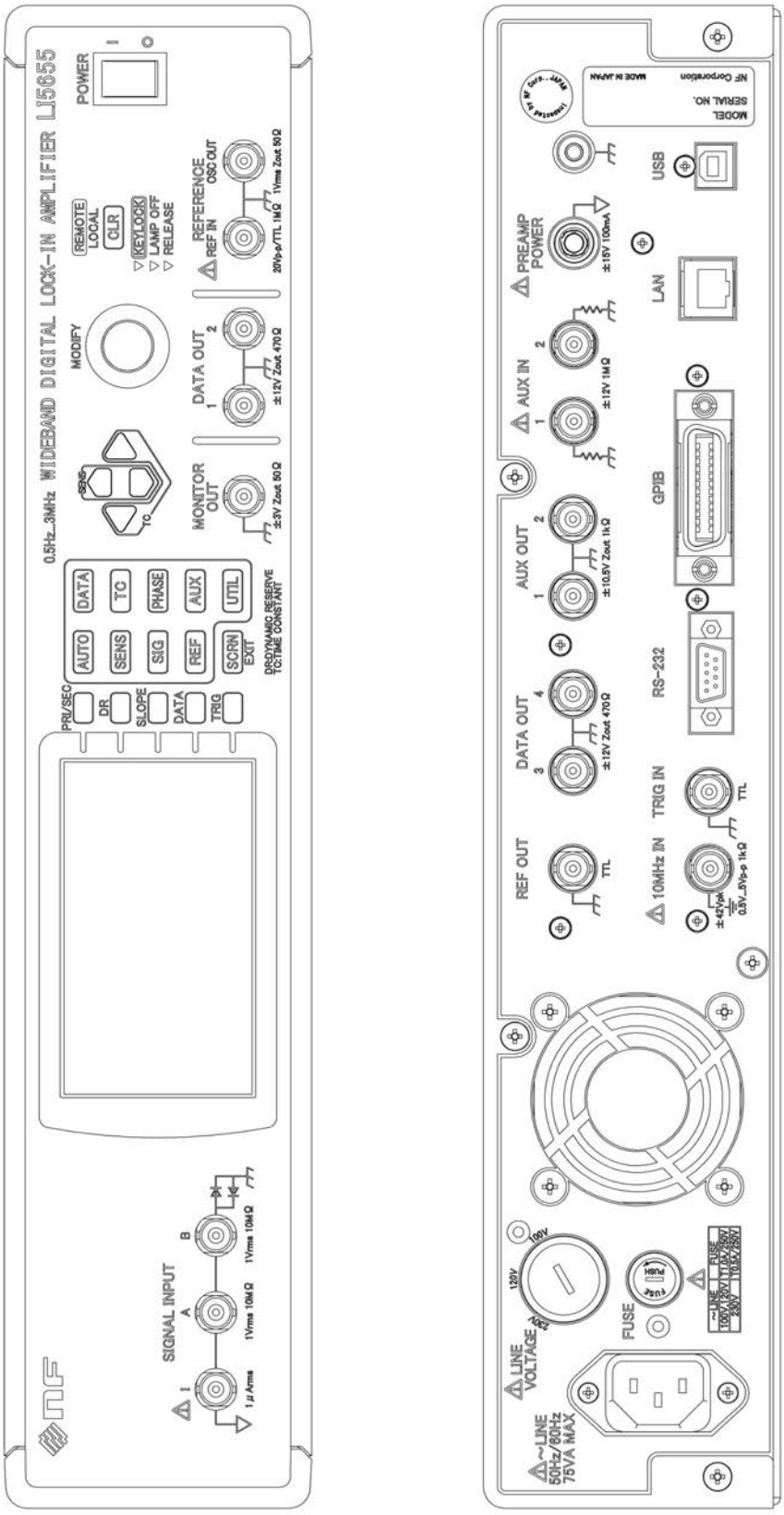

Figure 5-3 LI5655 Panel Diagram

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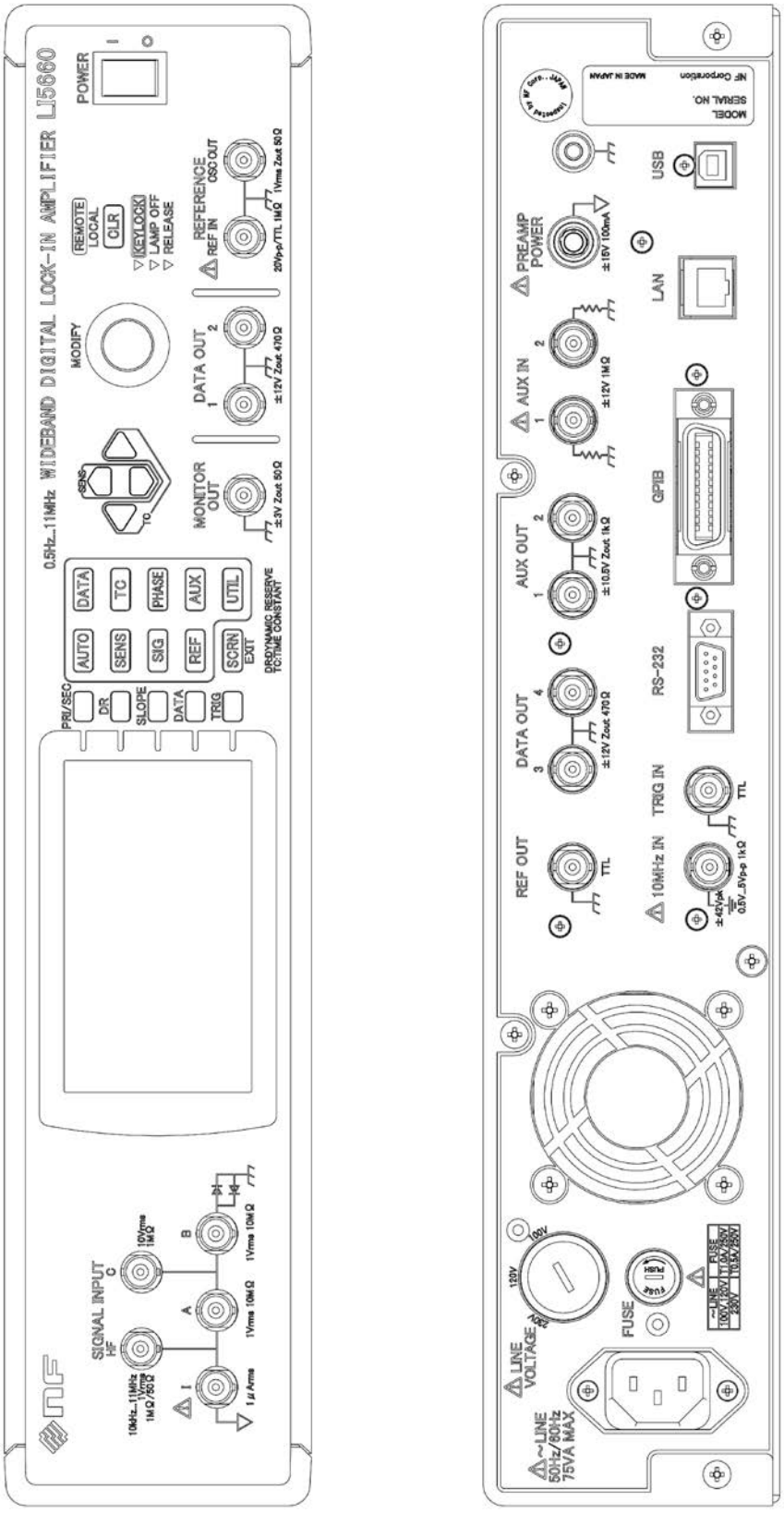

Figure 5-4 LI5660 Panel Diagram

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LI5655 / LI5660 Specifications

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