LOCK-IN AMPLIFIER MODULE

LI5501 / LI5502

INSTRUCTION MANUAL

NF Corporation

DA00098273-003

LOCK-IN AMPLIFIER MODULE

LI5501 / LI5502

INSTRUCTION MANUAL

Registered Trademarks

National Instruments and LabVIEW are registered trademarks of National Instruments Corporation in the United States.
Other company names and product names used in this instruction manual may be trademarks or registered trademarks of their respective companies.

Preface

Thank you for purchasing the **"LI5501 / LI5502 LOCK-IN AMPLIFIER MODULE"**.
For safe and correct use of this instrument, please read the **"Safety Precautions"** section that follows before attempting to use the instrument.

- **Marks and Symbols**

  For safe operation by the user and to prevent damage to the instrument, please give attention to the following marks and symbols that are used in this manual.

⚠ WARNING

This mark indicates information for preventing the possibility of death or serious personal injury from electrical shock or other hazards in the use or handling of this instrument.

⚠ CAUTION

This mark indicates information for preventing the possibility of injury to the user or damage to the instrument in the use or handling of this instrument.

● **The chapters of this manual are described below.**

If you are using this instrument for the first time, begin reading from Chapter 1.

1. Introduction

This chapter describes a general description of the instrument, including its features, applications, functions, and basic operating principles.

2. Preparation before use

This chapter describes important preparation that must be done before operating the instrument.

3. Names of each part

This chapter describes names and functions of each part.

4. Basic settings

This chapter describes basic settings of the **"LI5501 / LI5502"**.

5. Remote control

This chapter describes remote control commands of the **"LI5501 / LI5502"**.

6. Advanced settings

This chapter describes advanced settings of the **"LI5501 / LI5502"**.

7. Troubleshooting

This chapter describes how to deal with error messages and cases in which you think the instrument is malfunctioning.

8. Maintenance

This chapter describes storage, repacking, transportation, and performance testing methods.

9. Specifications

This chapter describes the instruments specifications (functions and performance).

—— Safety Precautions ——

For safe use of this product, give full attention to the following warnings and cautions. The NF Corporation shall not be held liable for damages that arise from failure to observe these warnings and cautions.

- **Be sure to observe the contents of instruction manual.**

  This instruction manual contains information for the safe operation and use of this instrument.
  Be sure to read this instruction before using this instrument.
  All of the warning items contained in this instruction are intended to avoid risks that may lead to serious accidents. Follow the warnings and instructions carefully.

- **Check the power supply voltage.**

  This instrument operates on the power source voltage described in **"2.3 Grounding and power connections"**.
  Before supplying power to this instrument, confirm that the supply voltage conforms to the rated power supply of this instrument.

- **If you think something is wrong, …**

  If smoke or an unusual odor or sound comes from this instrument, immediately remove the power cord of the power supply from the outlet and cease use of this instrument.
  If any such abnormality occurs, take measures to prevent the use of this instrument until repairs have been completed and promptly contact the NF Corporation or its authorized agent.

- **Do not use this instrument in explosive atmosphere.**

  An explosion or other hazards may occur.

- **Do not open the instrument cover.**

  Because there are precision electronic components inside this instrument, never remove the instrument cover.
  Only technicians certified by the NF Corporation are authorized to inspect and touch anything inside the instrument cover.

- **Do not modify this instrument.**

  Never modify this instrument in any way. Modification might create new risks. The NF Corporation may refuse to service an instrument that has an unauthorized modification.

- **Do not expose this product to water.**

  Use of this instrument when it is wet may result in malfunction. If this instrument becomes wet, immediately unplug the power cord of the power supply and contact the NF Corporation or its authorized agent.

- **If lightning occurs nearby, unplug the power cord.**

  A lightning strike may cause electrical shock, fire, or malfunction.
  Immediately turn off the power supply and unplug the power cord of it.

- **Safety-related symbols**

  The marks and symbols defined below are used in this manual or on the instrument itself to indicate safety information or instructions.

Instruction Manual Reference Symbol

This symbol notifies the user of a potential hazard and indicates that the user must refer to the instruction manual.

⚠ WARNING **Warning Symbol**

This mark indicates information for preventing the possibility of death or serious personal injury from electrical shock or other hazards in the use or handling of this instrument.

⚠ CAUTION **Caution Symbol**

This mark indicates information for preventing the possibility of injury to the user or damage to the instrument in the use or handling of this instrument.

- **Other Symbols**

This symbol indicates that connected to the instrument case.

This symbol indicates that the outer conductor of the connector is isolated from the instrument enclosure.
However, safe operation of the instrument requires that the potential difference from the grounding potential is restricted to 42 Vpk or less.
This instrument must be grounded when in use, so the power supply must be grounded.

● **Electromagnetic compatibility**

Applied EMC standard: EN 61326-1, EN 61326-2-1

Intended electromagnetic environment: Industrial

Emissions, which exceed the levels required by that standard, can occur when this product is connected to a test object.

This product is a CISPR 11 Group 1 Class A equipment.

This product may cause interference if used in residential areas. Such use must be avoided unless the user takes special measures to reduce electromagnetic emissions to prevent interference to the reception of radio broadcasts.

⚠ CAUTION

This product is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments.

● **Disposal of this instrument**

To protect the environment, follow the guidelines described below for the disposal of this instrument.

a) This instrument does not use batteries.

b) Use the services of an industrial waste disposal contractor for disposal of this instrument.

Table of contents

Figures and Tables

Page

(Blank)

1. Introduction

1.1 Features

The **"LI5501 / LI5502 LOCK-IN AMPLIFIER MODULE"** is a dual-phase lock-in amplifier module with a frequency range of 10 mHz to 1 MHz.
They can be widely used to measure amplitude and a phase of small AC signal buried in noise taking advantage of the following features. The **LI5502** can measure amplitude ratio and phase difference between two channels.

- **Wideband**
  A signal from 10 mHz to 1 MHz can be measured.
- **Dual-phase lock-in amplifier**
  Because phase detection and subsequent processing are performed digitally, an output zero drift and orthogonal error are much smaller than an analog method.
  By mounting two of these phase detectors, amplitude ($R = \sqrt{(X^2+Y^2)}$) and a phase ($\theta = \tan^{-1}(Y / X)$) of a signal can be measured.
  The two-channel model **LI5502** is equipped with the two dual-phase detectors (same reference frequency), so amplitude ratio and phase difference between two channels can be measured.
- **Fractional harmonic measurement**
  In addition to harmonic measurement, a frequency of submultiple of fundamental wave (x 1 / 1 to 63 / 64) can be used as reference frequency.
- **Variety of filters**
  This instrument is equipped with the time constant filter and moving average filter.
  a) Time constant filter
     The attenuation slope of the filter can be set to 6, 12, 18, or 24 dB/oct.
     The minimum time constant of 1 µs enables fast response.
  b) Moving average filter
     This instrument is equipped with the moving average filter after the time constant filter. This filter can be set the averaging time from 1 µs to 100 s.
     Fast response can be obtained in low frequency measurement when this filter is combined with the time constant filter in appropriate setting.
- **Smooth output response**
  The maximum update rate is approximately 300 k Samples/s, and the amplitude resolution is 16 bits.
- **External synchronization**
  This instrument can be synchronized with reference frequency of another instrument by using the 10 MHz IN terminal.

- **Remote control**
  Setting changes and measurement data reception are performed via USB or LAN communication. The maximum transfer rate of measurement value is 300k words/s.
- **Small size**
  200 mm (W) × 25 mm (H) × 150 mm (D), approximately A5 size
  It is easy to mount the instrument on equipment by using the attached metal fittings.

1.2 Applications

The **LI5501 / LI5502** can be used in the following fields, taking advantage of its features.

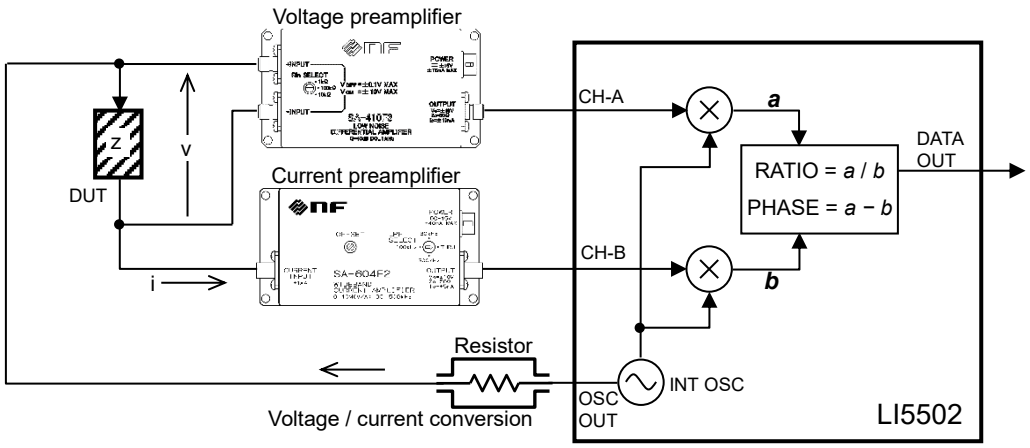
- Signal detection in scanning probe microscope
- Thermal diffusivity measurement of thin film materials
- Spectroscopic analysis
  (material science using Auger electron spectroscopy and Raman spectroscopy)
- Analyses of mechanical vibration
- Noise measurement of electronic components

■ Application example using the LI5502

The following measurement can be performed using functions of the **LI5502**.

● Low-impedance measurement

In impedance measurement of samples whose characteristics change or that are damaged by several mA current, a method of increasing an applied voltage cannot be used because the current value increases with the voltage.
Alternatively, a small current is applied to the sample, and the voltage and current applied to the sample are amplified by a low-noise voltage amplifier and current amplifier, respectively.
The impedance equivalent value can be obtained by measuring the respective output voltages of the amplifiers and calculating with the **LI5502**.



1.3 Operating principle

1.3.1 Basic principle of Lock-in Amplifier

A lock-in amplifier is a device that uses difference of frequencies to separate an signal and noise and amplify the signal. It works equivalently as a tuned amplifier or narrow band pass filter where the center frequency follows the signal.

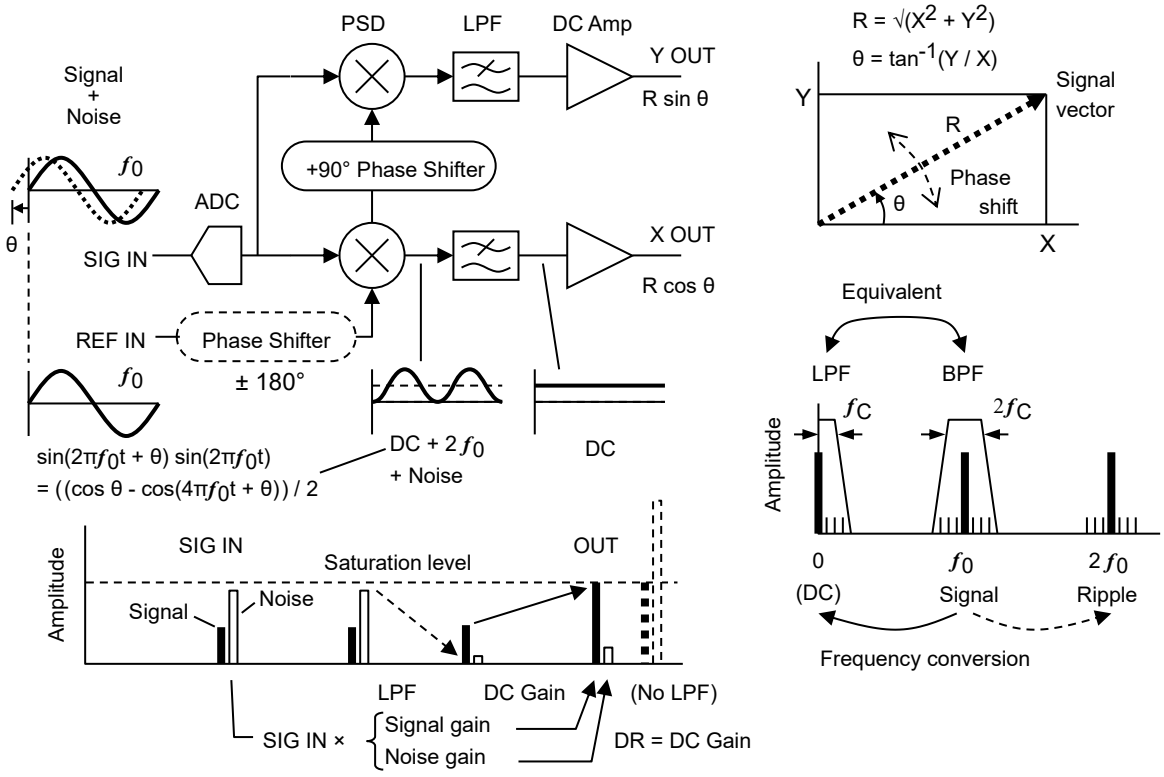


Figure 1-1 Basic principle of Lock-in Amplifier

Firstly, a signal including noise is converted to a DC voltage using a Phase Sensitive Detector (PSD). At this point, noise in the vicinity of the signal frequency is also converted to the vicinity of DC. Then, the noise and ripples caused by the detection are removed using a low pass filter (LPF) to obtain the DC component. When this is returned to the original frequency, the equivalent bandwidth is equal to the band pass filter that is double the cutoff frequency of the LPF. Increasing the time constant (response time) and attenuation slope of the LPF decreases the cutoff frequency, so more noise can be removed. After the noise is removed using the LPF, the DC signal can be amplified without being saturated by the noise. In short, the original signal can be measured even though the noise is greater than the signal. DC gain after the PSD are determined by the sensitivity (full-scale of signal voltage) and dynamic reserve (DR) setting.
(DR value = Allowable maximum noise level / Voltage sensitivity)

A lock-in amplifier needs a reference signal as reference of frequency and phase. The PSD is a multiplier of a measured signal and reference signal (both are sine waves and the same frequency). The PSD output is dependent on the amplitude of the measured value (R) and the phase (θ) difference from the reference signal. The amplitude of the reference signal applied to the PSD is constant, and the phase of it can be shifted.
A dual-phase lock-in amplifier is equipped with the two PSDs, and works as a vector voltmeter that can obtain two orthogonal components X and Y (in other words, R and θ) simultaneously.
The **LI5502** is equipped with two dual-phase PSDs, so two signals can be measured simultaneously using a single reference signal.
The internal oscillator is usually synchronized with an external reference signal by PLL and supplies a reference signal to the PSD. Its frequency can be set numerically and it can supply its harmonic to the PSD as a reference signal.

1.3.2 Block diagram

The block diagram of the **LI5501 / LI5502** is presented and its main functions are explained.

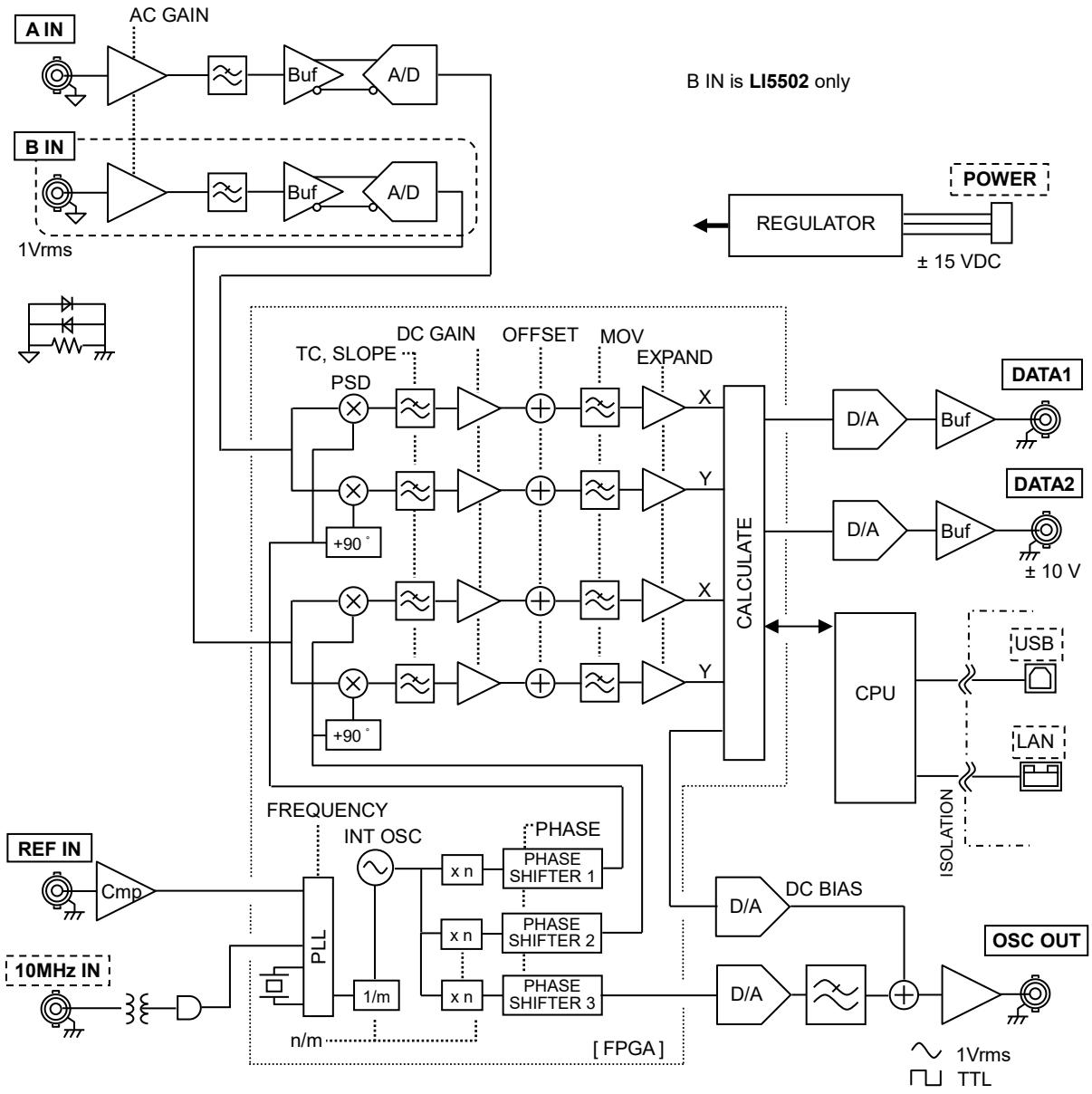


Figure 1-2 Block diagram of the LI5501 / LI5502

a) Signal input section

Input connector selection (A IN, B IN*)

Two input signal channels are provided*. Two input signals can be detected to same reference signal.

***LI5502** only

Signal amplification (AC GAIN)

A signal with noise is amplified in the frequency band. The dynamic reserve affects AC GAIN and DC GAIN.

This instrument can be used in combination with our low-noise amplifiers, etc.

Sampling (A/D)

An input signal is converted to a 16-bit digital signal at a sampling rate of 2.5 M Samples/s.

b) Detector (DETECTOR CKT)

Phase sensitive detection (PSD)

A frequency of signal is converted to a DC voltage using a Phase Sensitive Detector (PSD).

The amplitude and phase of a signal can be obtained by detecting it using two orthogonal phases. Phase sensitive detection is accomplished by multiplexing an input signal and internal reference signal. Since a reference signal applied to the PSD is a sine wave, there is no influence of harmonics of input signal, which becomes a problem when a simple square wave is used as reference signal. A ripple doubling a signal frequency occurs in the product of a measured signal and reference signal, and another ripple that equals to signal frequency occurs in the product of an input DC offset and reference signal, but they are removed by the time constant filter in the next stage. A lock-in amplifier only measures AC signals so it has the advantage that it is not affected by the thermal electromotive force that is a DC signal.

Time constant filter (TC, SLOPE)

A time constant filter removes noise and ripples caused by the detection. Normally, the time constant filter consists of a 1st order low pass filter (LPF) and 1 to 4 of it are cascade-connected (equivalent to 6 / 12 / 18 / 24 dB/oct attenuation slope). Increasing the time constant (TC) and attenuation slope (SLOPE) narrows the bandwidth and removes more noise, but slows an output response.

Amplification (DC GAIN)

It is equivalent to sensitivity of this instrument.

After noise is removed by the time constant filter, a signal can be amplified without being saturated by noise. The phase sensitive detector, time constant filter, and DC signal amplification are performed in digital operations, so there is no limit to dynamic reserve caused by DC drift, which becomes a problem in analog method.

Moving average filter (MOV)

This filter removes noise by moving average of averaging time. It can be used as a synchronous filter by setting an averaging time to a reference signal period. A ripple of detection output can be significantly reduced, so it is easy to obtain a fast response by setting a small time constant.

Amplification (EXPAND)

The EXPAND function can amplify an output signal of the moving average filter. This function is equivalent to **EXPAND** function of our conventional lock-in amplifiers.

c) Calculate section (CALCULATE)

Measured values X and Y of a lock-in amplifier are an RMS value of orthogonal phase components.

By operating X and Y, an RMS value and phase of signal can be obtained.

Amplitude ratio and phase difference between two channels can also be obtained*.

***LI5502** only

d)Reference signal system (REFERENCE CKT)

An internal reference signal that is a sine wave and constant amplitude used by the PSD is supplied by the internal oscillator.

External reference signal

In principle, a lock-in amplifier performs measurement using an external reference signal as the reference of the frequency and phase. If the reference signal source is external reference, the internal oscillator generates the sine wave synchronized with the external reference signal using a Phase Locked Loop (PLL).

Internal oscillator

If the reference signal source is internal reference, the internal oscillator oscillates a signal at a designated frequency. The internal oscillator uses a direct digital synthesis method so the frequency is stabilized immediately. A signal of the internal oscillator is output as a sine wave or TTL-level square wave.

Also, a signal synchronized with external reference signal can be output.

If the amplitude of the internal oscillator is set to zero, interference from reference signal to measured signal can be reduced, which is often a problem in especially at high frequencies.

The internal oscillator has a function to generate a harmonic (harmonic, subharmonic, and fractional harmonic) signal. For example, this function can generate reference signals of two different frequencies, which enables measurement of a fundamental and a harmonic wave.

External 10 MHz synchronization

If a reference frequency for frequency synthesis is applied to the 10MHz IN terminal from an external source, the internal oscillator generates the reference signal synchronized with that external 10 MHz frequency. Therefore, measurement can be performed without applying an external reference signal. Not only the reference signal frequency but also the signal sampling rate, output update rate, and rate for recording to the data memory by the internal timer are also synchronized with the external 10MHz frequency.

(Blank)

2. Preparation before use

2.1 Inspection

■ Safety check

Before using the **LI5501 / LI5502**, read the **"Safety Precautions"** section at the beginning of this manual and perform the safety checks described there.
Before connecting the instrument to a power supply, read **"2.3 Grounding and power connections"** and perform all safety checks fully.

■ Unpacking

Firstly, check for any damage that may have occurred during transportation.
After unpacking, make sure that the contents listed in "**Table 2-1 Packing list"** are supplied.

Table 2-1 Packing list

Main unit (including the metal fittings) ····· 1

⚠ WARNING

Precision electronic components are mounted in this instrument. Do not remove the cover.
The interior of this instrument should not be inspected by anyone other than service technicians who are trained to avoid hazards.

■ Related documents

The following documents are available on our web site (https://www.nfcorp.co.jp/index.html).

- **LI5501 / LI5502 Instruction manual**
  This instruction manual
- **Sample programs**
  Programs written in LabVIEW that can control the **LI5501 / LI5502**

2.2 Installation

2.2.1 General cautions

⚠ CAUTION

Attention should be given to the following item to reduce the possibility of damage to the **LI5501 / LI5502**.

- Because the instrument is small and lightweight, if it is moved while connected to other devices by cables, it may fall.
  It must be placed on a flat and wide table or the like, being careful of the connections.

2.2.2 Installation environment

- Place the instrument in a location that satisfies the following conditions.

Operation:	0 to +50 °C, 5 to 85 %RH
	(absolute humidity is 1 to 25g/m^3, non-condensing)
	Altitude of 2000 m or less
Storage:	−10 to +60 °C, 5 to 95 %RH
	(absolute humidity is 1 to 29g/m^3, non-condensing)
	Altitude of 2000 m or less

- Avoid using the instrument in environments where there is strong radio-frequency electromagnetic radiation. Using the instrument in such environments may result in temporary fluctuations in measured values.

⚠ CAUTION

Avoid installation in the following locations.

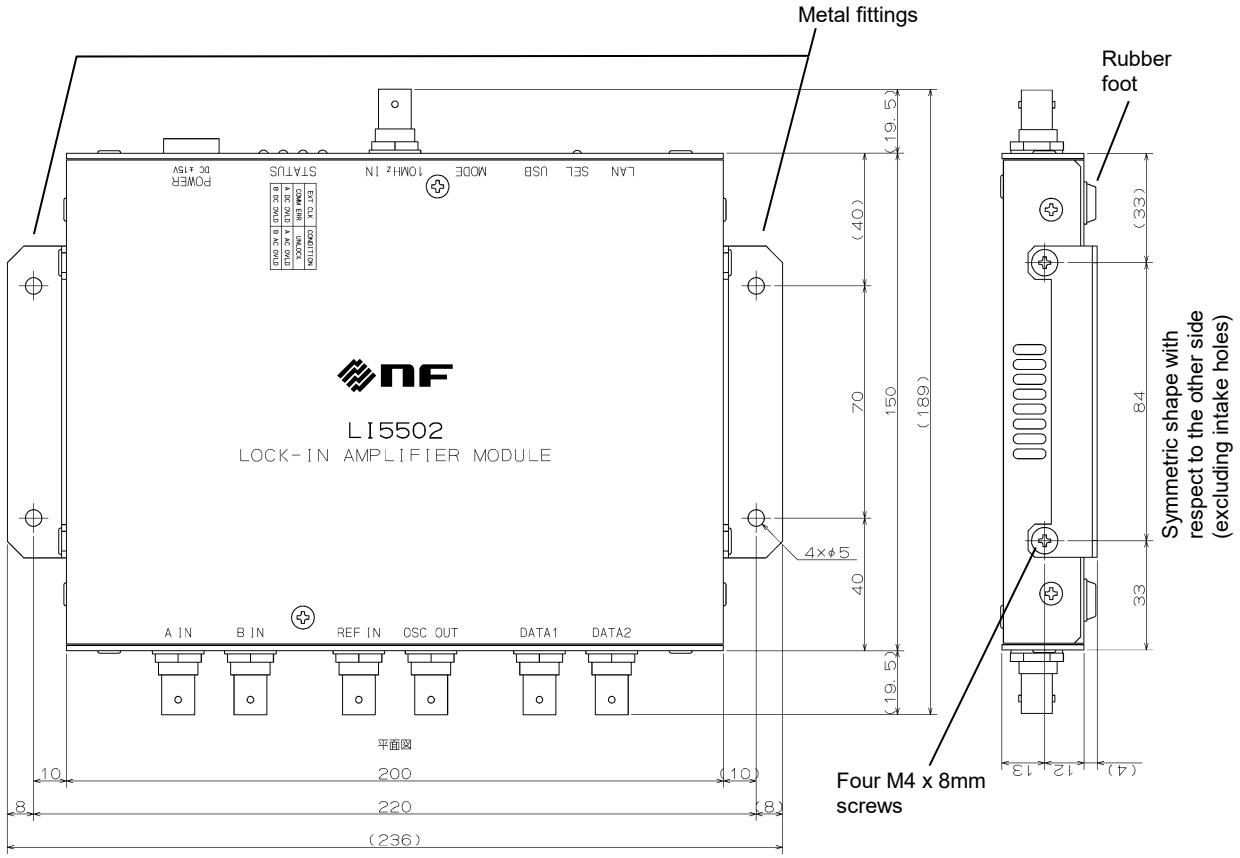
- Where there is flammable gases
  There is a risk of explosioin. Never install or use it in such a location.
- Outdoors, where exposed to direct sunlight, or near fire or a heat source
  The performance may not be satisfied, or a failure may occur.
- Where there are corrosive gases and vapor, a lot of dust and particles, salty air and oily smoke, and metal powder, etc.
  Corrosion, a malfunction or failure may occur.
- Where there is a lot of vibration
  A malfunction or failiure may occur.
- Near an electromagnetic field source, high-voltage equipment, power line, or pulse noise source
  A malfunction may occur.

Signal cables should be placed away from power cords of other equipment that may produce inductive noise. Failure to do so may result in instrument malfunction or a measurement error.

Warm up the instrument for at least 20 minutes before use for accurate measurement.

2.2.3 Mounting

Removable metal fittings are provided for this instrument.
When the fittings are removed, rubber feet on the bottom are available.
When installing this instrument in your equipment, it is recommended to screw the fittings to it.
For instrument dimensions → Refer to **"9.7 External dimensions"**



⚠ CAUTION

- Use 8 mm long screws to attach the metal fittings to the instrument.
  The internal structure may be damaged if screws longer than 8 mm are used.
- The equipment to be installed in this instrument should have sufficient ventilation holes or be air-cooled with cooling fans.
  If the ambient temperature exceeds the specification or the intake and exhaust holes are blocked when the equipped FAN is used, the performance of the instrument may decrease or it may be damaged.

2.3 Grounding and power connections

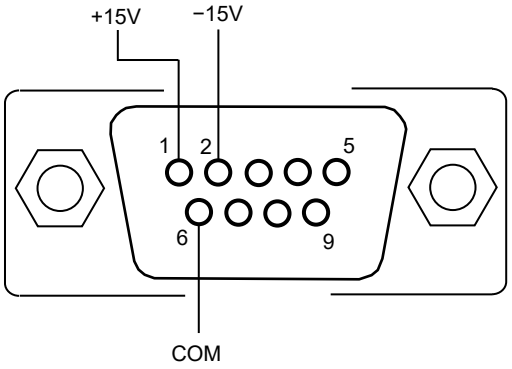
■ Grounding

⚠ WARNING

The USB and LAN connector shells are connected to the instrument enclosure. Applying a voltage of 42 Vpk (DC + ACpeak) or more to the terminals may damage the instrument.
When using the instrument, ground a power supply and take your own precautions against electric shock.

■ Power supply specifications

Power supply voltage range:	± 14 to 16 VDC
Current consumption:	+400 mA / −110 mA (**LI5501**)
	+480 mA / −120 mA (**LI5502**)
	initial settings, no input siganls, and no loads
	It is recommended to use a power supply with about twice the current capacity considering at power-on and overload conditions.
Power connector:	Equivalent to DELC-J9PAF-20L9 (JAE)
Pin assignment:	See below.



⚠ CAUTION

- Connect to a power supply paying attention to the voltage range and polarity of it.
- The positive and negative power supplies must start up at approximately the same time. It is recommended to use a dual tracking power supply.
- The instrument does not work with a single power supply (+30 V / GND). Be sure to use a dual power supply (+15 V / GND / −15 V).
- Do not supply power to any pins other than the power supply pins.

■ **Recommended power supply**

Fluctuations in power supply voltage may affect measured values.
For accurate measurement of minute signals, use a DC power supply with excellent stability and noise performance.
The recommended DC power supplies are shown below.

- NND30-1515 (TDK Lambda)
- TC-15 (Japan Stabilizer Industry)

2.4 Firmware update

How to check the firmware version → Refer to **"8.4 Checking the version number"**.

For the latest firmware version and firmware update procedure, please contact the NF Corporation or its authorized agent or visit our web site (https://www.nfcorp.co.jp/index.html).

Please check the contents of the update and if necessary, update the firmware version.

2.5 Calibration

This instrument is designed to be installed in equipment. It is recmmended to calibrate the instrument while it is installed in the equipment.
However, perform the unit test described in "**8.6 Calibration**" at least once a year although the appropriate calibration interval depends on how often the instrument is used and the conditions under which it is used.
Also, when the instrument is used for important measurement or tests, it is recommended that the same performance test be performed immediately before the measurement or tests.

If the instrument fails to satisfy the specifications in the performance test, the NF Corporation will make adjustments or calibrate the instrument to restore performance.
If an adjustment or calibration is required, please contact the NF Corporation or its authorized agent. This adjustment and calibration is available for a fee.

(Blank)

3. Names of each part

3.1 Names and functions of each part

This section describes the names and functions of each part of the **LI5502**.

3.1.1 Top side

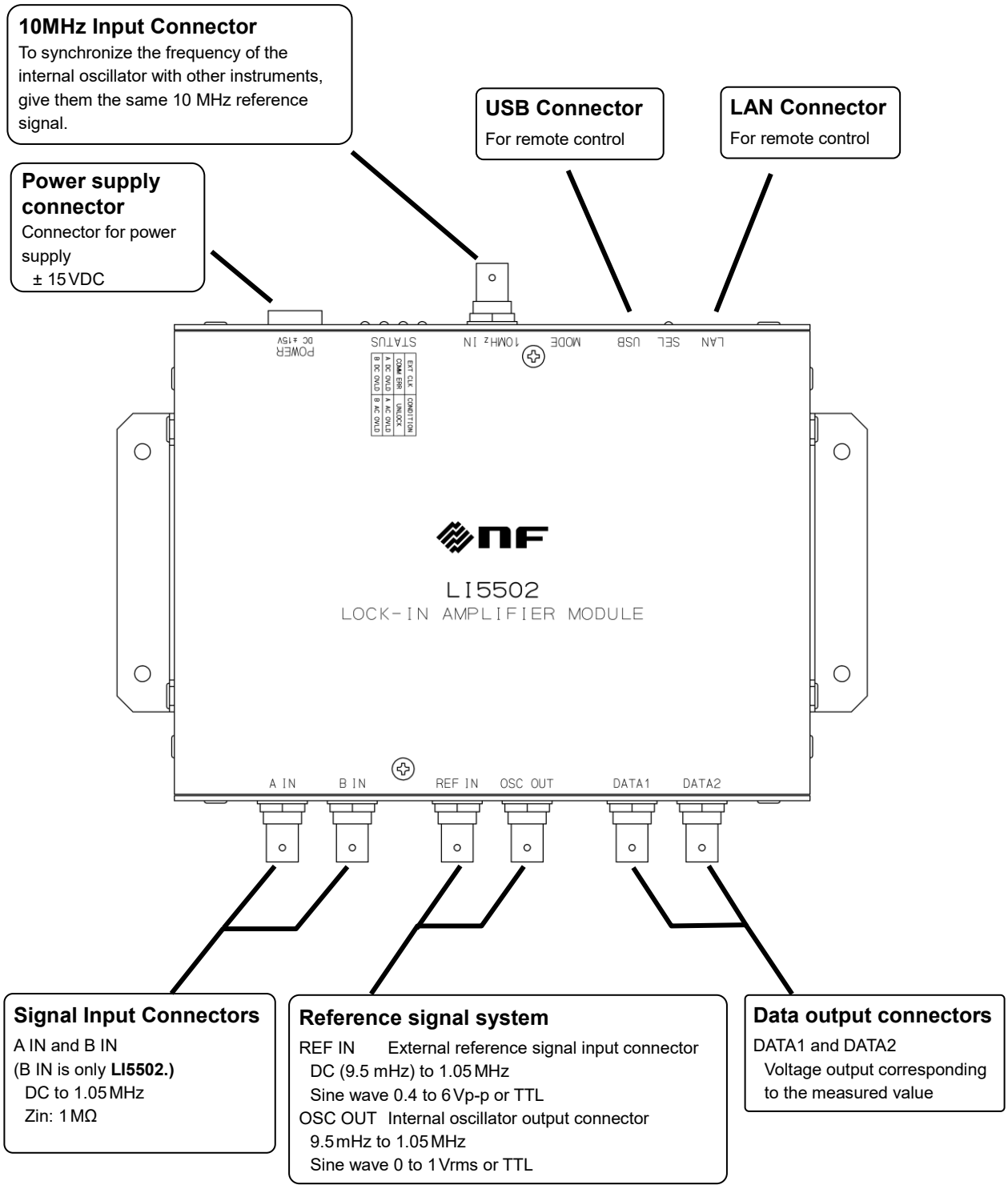


Figure 3-1 Top side

3.1.2 Rear side

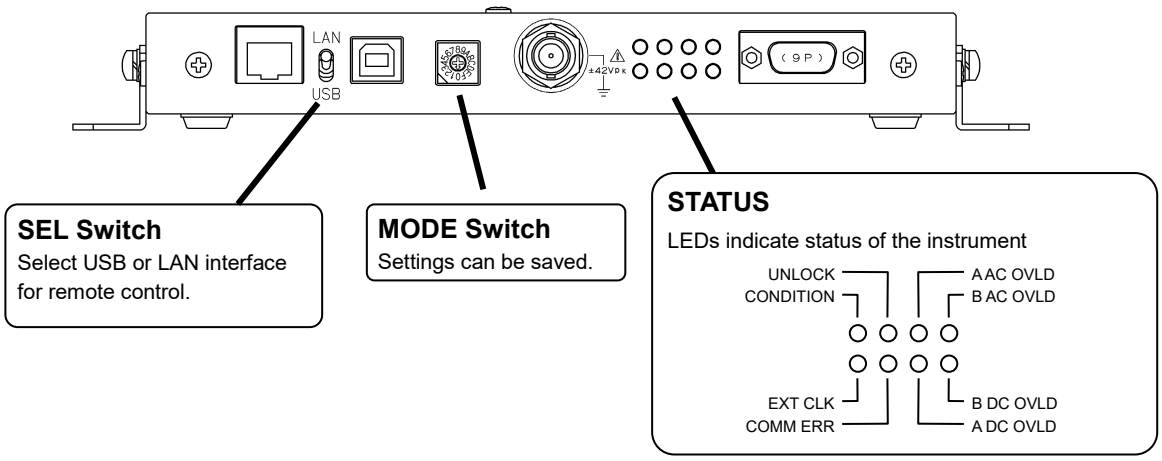


Figure 3-2 Rear side

■ **Status indication**

The table below describes the contents of the status LEDs.

Status LED	Color	Description
CONDITION	Green	Lights up when normal operation Blinks when the calibration information is lost and the specifications cannot be maintained due to some trouble When it blinks, please contact the NF Corporation or its authorized agent as it is malfunction.
EXT-CLK	Green	The followings applies only when the external 10 MHz synchronization is enabled. Lights up when synchronized with an external reference signal Blinks when not synchronized with an external reference signal
UNLOCK	Orange	Out of synchronization There are possibilities that a reference signal is not input, the reference signal settings are not appropriate, the signal level is low, or the frequency of it is out of range.
COMM ERR	Orange	A communication error Overflowed the FIFO buffer when transmitting data
A AC OVLD	Orange	Saturates a signal on A IN side before the PSD Confirm the input signal amplitude.
A DC OVLD	Orange	Saturates a signal on A IN side after the PSD Adjusts the time constant filter settings and voltage sensitivity.
B AC OVLD (only **LI5502**)	Orange	Saturates a signal on B IN side before the PSD Confirms the input signal amplitude.
B DC OVLD (only **LI5502**)	Orange	Saturates a signal on B IN side after the PSD Adjusts the time constant filter settings and voltage sensitivity.

3.2 I/O connectors

⚠ WARNING

To avoid an electric shock, ensure that a voltage exceeding 42 Vpk (DC + AC peak) must not be applied between the outer or inner conductor of the BNC connectors and the enclosure.
Similarly, a voltage exceeding 42 Vpk (DC + AC peak) must not be applied between the 10 MHz input connector and other BNC connectors.
If doing so, the internal voltage limiters will become active and try to limit that voltage. However, if that voltage is too large, there is a risk of electrical shock.

⚠ CAUTION

Do not apply a voltage exceeding the maximum input range to the input connectors. Doing so may damage the instrument.

⚠ CAUTION

Do not apply a voltage to the output connectors. Doing so may damage the instrument.

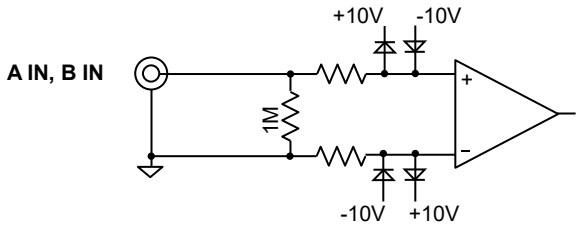
3.2.1 Signal input connectors

1) Signal input (A IN and B IN*)

The signal input connectors **A IN** and **B IN*** are described below.

***LI5502** only

- Input impedance 1 MΩ (nominal value)
  20 pF in parallel (supplementary value)
- Maximum input voltage (linear operating range)
  ± 5 V
- Non-destructive maximum input voltage
  ± 10 V

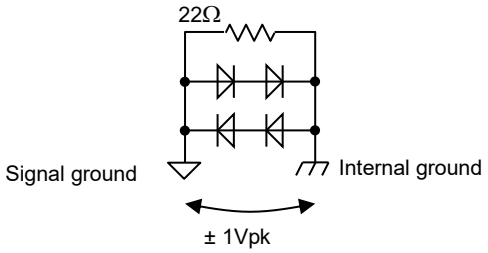


2) Signal ground

The resistor is inserted between the signal ground and the internal ground (reference signal input ground, etc.).

The voltage between them is limited to ±1 V.

- Floating voltage (allowable voltage to enclosure)
  ± 1 Vpk (DC＋AC)
- Impedance between signal ground and enclosure
  22 Ω (nominal value)



⚠ CAUTION

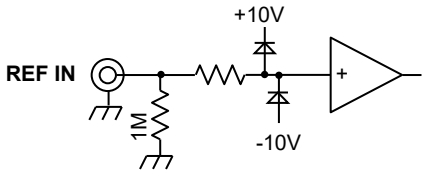
If a voltage exceeding 1.0 V is applied between the signal ground and the internal ground, a large current will flow and damage an internal circuit.

3.2.2 Reference signal I/O connectors

1) Reference signal input (REF IN)

The reference signal input connectors **REF IN** are described below.

- Input impedance 1 MΩ (nominal value)
  20 pF in parallel (supplementary value)
- Input voltage range SINE 0.4 V to 6 Vp-p
  TTL 0 to 5 V (low level 0.8 V or less, high level 2.6 V or more)
- Non-destructive maximum input voltage
  ± 10 V

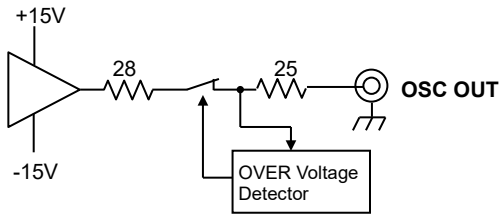


2) Oscillator output (OSC OUT)

A sine wave or a TTL-level square wave synchronized with the internal oscillator is output from the **OSC OUT** connector.

When the reference signal source is external, the output signal is synchronized with the external reference signal.

- Output voltage range SINE 1 Vrms ± 5 VDC
  TTL 0 to 3 V (nominal value)
- Maximum output current
  ± 15 mA
- Output impedance 53 Ω (nominal value)



⚠ CAUTION

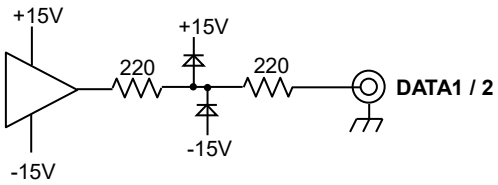
Do not apply a voltage exceeding the maximum input voltage range to REF IN.
There is a limit of output current at the OSC OUT terminal.
If an exceeding voltage is applied to the OSC OUT terminal, an overvoltage will be detected and an internal circuit will be disconnected.
After the overvoltage is removed, the disconnection will be restored automatically.
The non-destructive maximum input voltage of the OSC OUT terminal is ± 15 V (noiminal value).

3.2.3 Analog data output connectors

1) Measured value output (DATA1 and DATA2)

The voltage proportional to the measured value such as R, X, and Y is output.

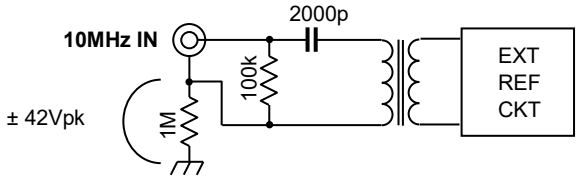
- Output voltage range ± 12 V (no load)
- Maximum output current
  ± 10 mA
- Output impedance 440 Ω (nominal value)



3.2.4 The other input connector

1) External 10MHz synchronization (10MHz IN)

- Input impedance Approximately 500 Ω, AC-coupling
- Signal level 0.5 to 5 Vp-p
- Non-destructive maximum input voltage
  10 Vp-p
- Withstand voltage (allowable voltage to enclosure)
  ± 42 Vpk (DC + ACpeak)

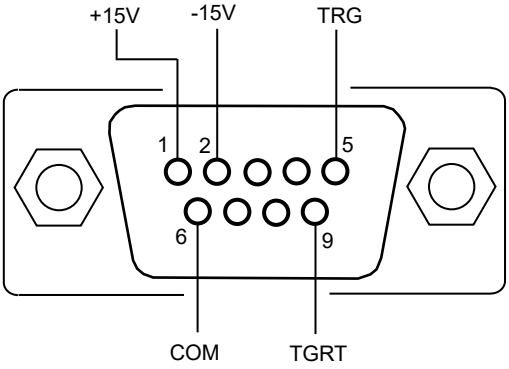


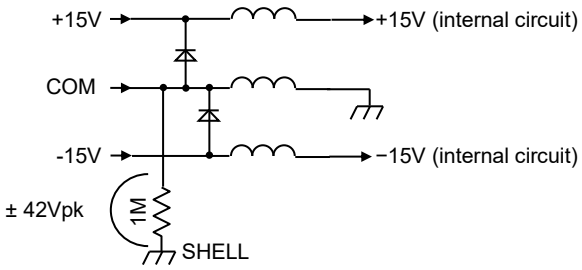
3.2.5 Power supply connector

1) Power supply input (POWER)

The power supply connector is equivalent to DELC-J9PAF-20L9 (JAE).
It is recommended to use a power supply with about twice the current capacity considering at power-on and overload conditions.

- Voltage range ± 14 to 16 VDC
- Current consumption Approximately +400 mA / −110 mA (**LI5501**)
  Approximately +480 mA / −120 mA (**LI5502**)
  initial settings, no input signals, and no loads

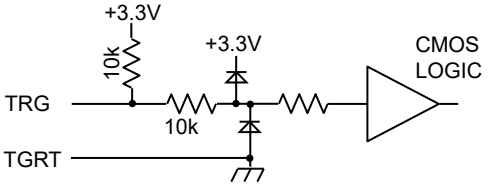




2) External trigger input

This input is to start recording measurement data to the internal data buffer.

- Input impedance 10 kΩ (nominal value)
- Signal level TTL (low level 0.8 V or less, high level 2.6 V or more)
- Non-destructive maximum input voltage
  ± 15 V



⚠ CAUTION

Applying a voltage exceeding the specified voltage range, incorrect polarity of the power supply, or wrong connection to terminals may result in failure.

3.3 Power-on

3.3.1 Confirmation before power-on

Check the power supply voltage and the pin assignments of the power connector before power-on.

Refer to **"2.3 Grounding and power connections"**.

3.3.2 Power-on

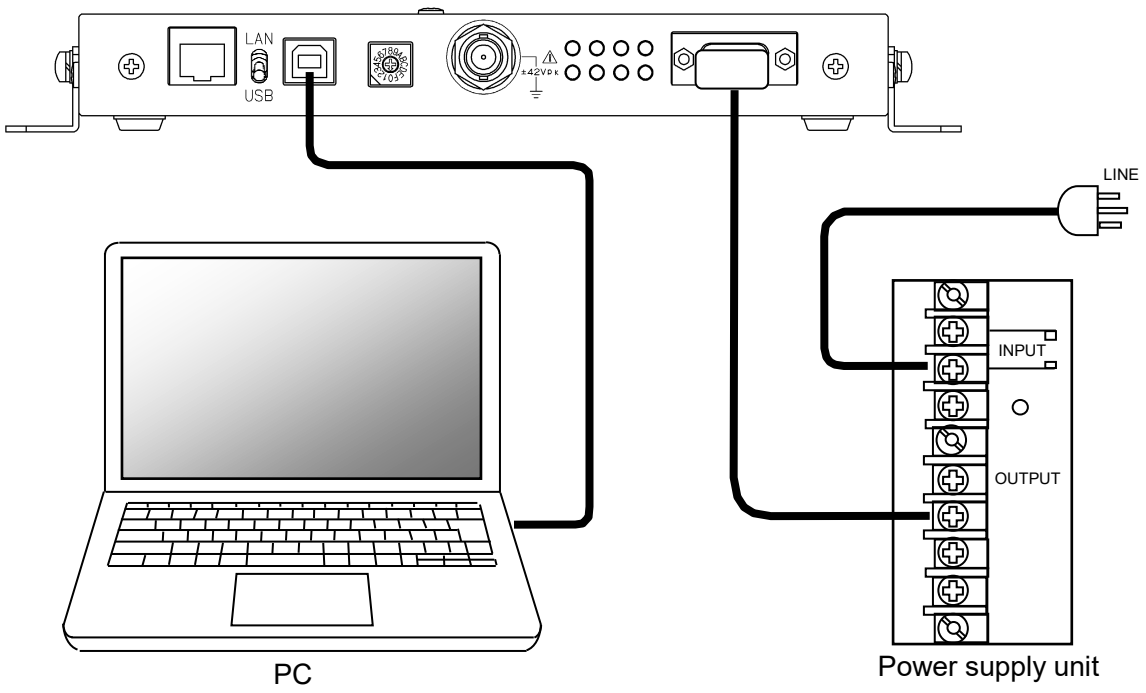
The **LI5501 / LI5502** have no power switch.

Supply power to the instrument from an external power supply.

A typical connection diagram is shown below.

When the power is turned on, the settings of the configuration memory number corresponding to the MODE switch number are recalled.

For details → Refer to "6.2 Configuration memory".



Typical connection diagram

(Blank)

4. Basic settings

4.1 Setting items

This section describes setting items of the **LI5501 / LI5502**.

4.1.1 Reference signal settings

A reference signal serves as frequency and phase reference.
This section describes how to select reference signal settings.

1) Reference signal source

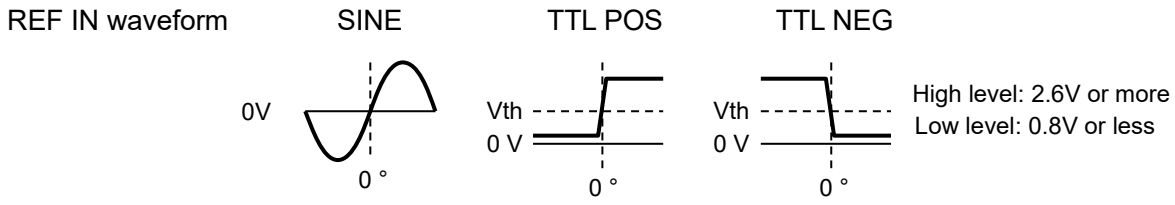
Select a reference signal source from below to synchronize with the instrument.

- Reference signal source: RINP (External reference signal)
  Input a reference signal to the REF IN terminal.
  IOSC (Internal oscillator)
  The internal oscillator generates a designated frequency.

2) Waveform of external reference signal

When using an external reference signal, select a edge from below according to the input waveform.

- Edge: SIN (sine wave, 0.4 to 6 Vp-p,
  point where signal crosses 0 V from below to above)
  TPOS (square wave, rising edge of TTL-level)
  TNEG (square wave, falling edge of TTL-level)



■ **UNLOCK state**

When the reference signal source is set for the external reference signal (RINP) and the reference signal is not synchronized with the instrument, the LED on the rear panel will light up and a flag is set in the status register.
In the UNLOCK state, a measured frequency and values do not correspond to those of the actual signal and fluctuate.
When the instrument cannot synchronize with a reference signal, the frequency, amplitude, or waveform of the signal may be different from the reference signal settings. Also, if a reference signal contains a lot of noise or frequency/amplitude variations, the instrument may be the UNLOCK state.

3) Internal oscillator

The internal oscillator frequency can be set.

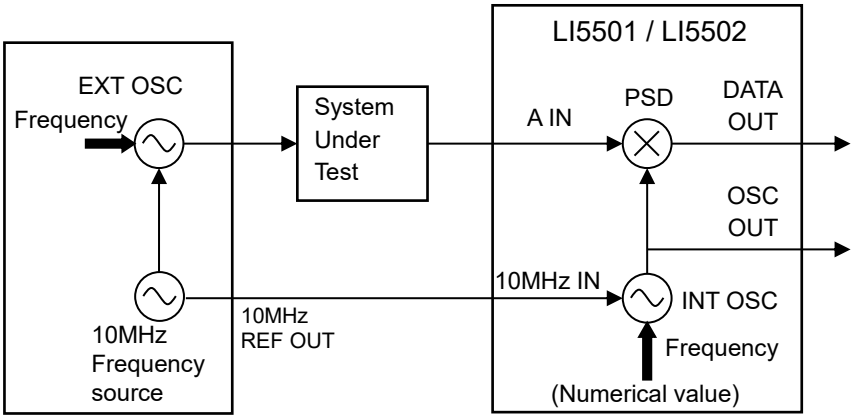
This is available when the reference signal source is IOSC (internal oscillator).

- Frequency: 9.5 mHz to 1.05 MHz, 0.1 mHz resolution

4) 10MHz IN

The frequency reference source of the instrument can be synchronized with other instruments (such as function generators) that operate with a 10 MHz frequency reference source.

However, since the phase do not match, the phase adjustment is required every time the internal oscillator frequency is changed. Generally, once a signal (oscillation) stops, the phase is shifted, so the phase adjustment is required again.



As a result, by matching the frequency setting of other devices with the internal oscillator frequency of the instrument, it can be synchronized with other devices even without inputting a reference signal to the REF IN terminal.

- 10MHz IN: ON (enabled), OFF (disabled)

■ EXT CLK LED

The table below shows the status of the LED corresponding to the 10 MHz IN setting and a signal to 10 MHz IN terminal.

10MHz IN setting	Signal to 10MHz IN terminal	LED (EXT CLK)
ON	10MHz signal	ON
ON	Signal other than 10MHz or no signal	Blinking
OFF	——	OFF

■ **φSYNC function**

When the instrument is connected to the 10 MHz REF OUT terminal of our function generators (**WF1973 / 74, WF1947 / 48, WF1967 / 68**), the reference phase of the internal oscillator can be initialized by the φSYNC function of the function generators. For detials, refer to the instruction manual of the function generators.

4.1.2 Phase shift and harmonics measurement

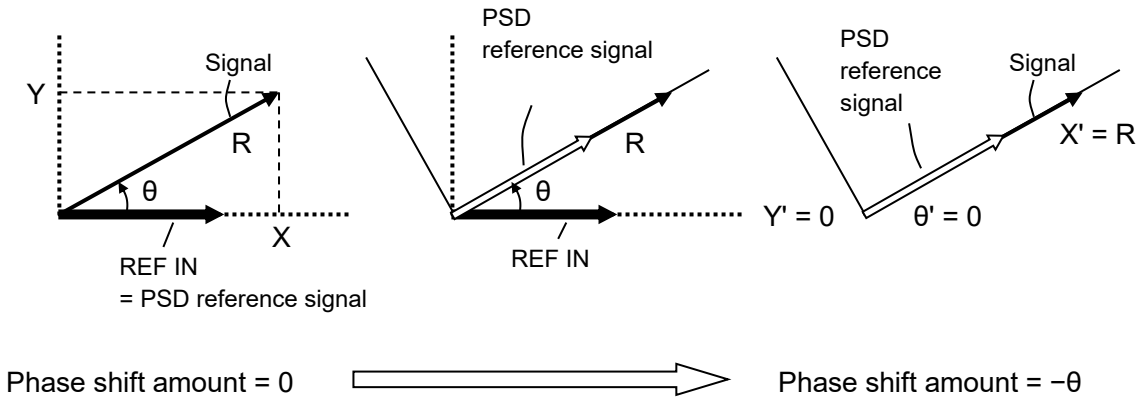
The phase can be shifted with respect to the reference signal.
A fundamental wave (F), harmonic (n × F), subharmonic (F / m), and fractional harmonic (n × F / m) can be measured with a reference signal frequency "F" as the reference.

1) Phase shift

The phase shift amounts of A/B IN can be set with respect to the reference signal.

- Phase shift amount: −180.000° to +179.999°, 1m° resolution

Basic usage of a lock-in amplifier is to adjust the phase of the reference signal to be applied to the PSD so that Y output is equal to zero (θ = 0), and then measure the amplitude of the signal at the X output and the phase shift of the signal at the Y output.



■ **Automatic phase shift adjustment**

By executing this adjustment, the reference signal phase shift amount is set so that the Y and θ outputs are equal to zero. However, it cannot be executed during the UNLOCK state.

2) Harmonic

The reference signal frequencies of A IN and B IN can be multiplied by “n”.

- Harmonic: 1 to 63 or 0 (integer)

Set “n” to 1 when measuring a fundamental wave. When measuring a fractional harmonic, the “n” is the numerator.

When the “n” is set to zero, the input signal passes through the PSD.

3) Subharmonic

When the reference signal source is the external reference signal (RINP), the external reference signal can be divided by “m”.

- Subharmonic: 1 to 64 (integer)

When measuring a fractional harmonic, the “m” is the denominator. This “m” is common to each PSD and the oscillator output.

The response to the frequency query command (:FREQ?) is the frequency input to the REF IN terminal diveded by the “m”.

4) Multiplication and phase shift of oscillator output

The output frequency of the OSC OUT terminal can be multiplied by that of the reference signal source. The phase can also be shifted with respect to the reference signal source.

- Multiplication: 1 to 63 (integer)
- Phase: −180.000° to +179.999°, 1m° resolution

■ Note

The frequency range of harmonic, subharmonic, fractional harmonic, and multiplier oscillation output need to be within the synchronizable frequency range.

4.1.3 Oscillator output

The frequency synchronized with the reference signal can be output to the OSC OUT terminal.

1) Oscillator output state

When the oscillator output is turned on, the AC voltage is output from the OSC OUT terminal.

When the oscillator output is turned off, the D/A converter for the oscillator output is stopped and the output amplitude is set to zero.

However, DC offset is always output.

- Output state: ON (enabled), OFF (disabled)

■ **Crosstalk reduction**

Crosstalk from the reference signal to the measured signal can be reduced by disabling the oscillator output.

2) Output waveform selection

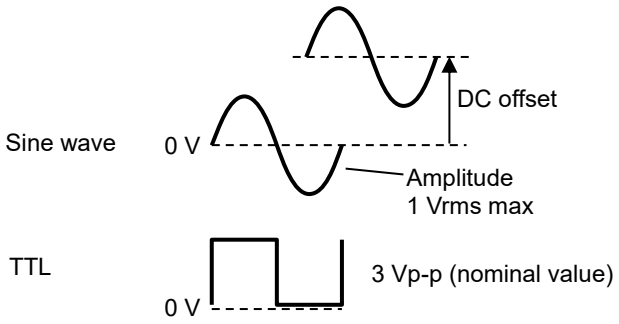
The output waveform can be selected from a sine wave or TTL-level square wave.

- Output wave form: SIN (sine wave), TTL

3) Output amplitude and DC offset

The output amplitude and DC offset can be set only when the output waveform is SIN (sine wave).

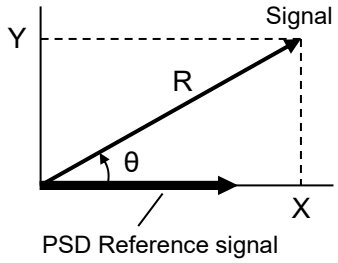
- Amplitude: 0 to 1 Vrms, 1 mVrms resolution
- DC offset: 0 to ± 5 V, 5 mV resolution



4.1.4 Analog data outputs

Parameters shown in the table below can be obtained.

Parameter	Description
X	In-phase component (= R cos θ)
Y	Quadrature component (= R sin θ)
R	Signal amplitude (= $\sqrt{X^2 + Y^2}$)
θ	Signal phase (= $\tan^{-1} Y/X$)



The voltage corresponding to the measured value of designated parameter can be output to the DATA1 or DATA2 terminal.

- DATA1: See the below table.
- DATA2: See the below table.

Parameter	Description
X_A	X value on A IN side (Rcosθ)
Y_A	Y value on A IN side (Rsinθ)
R_A	R value on A IN side (RMS amplitude)
θ_A	θ value on A IN side (phase value)
X_B	X value on B IN side (Rcosθ)
Y_B	Y value on B IN side (Rsinθ)
R_B	R value on B IN side (RMS amplitude)
θ_B	θ value on B IN side (phase value)
RATIO	Amplitude ratio (R_A / R_B)
PHASE	Phase difference ($\theta_A - \theta_B$)

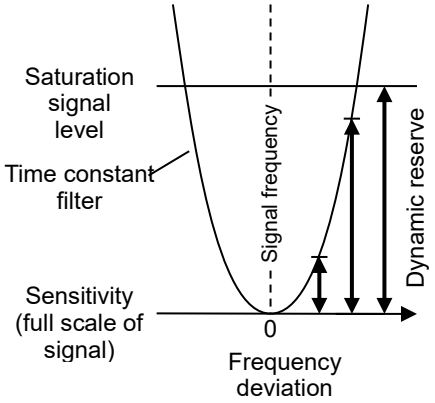
Parameters related to B IN are available only for the **LI5502**.

■ Disabling analog data outputs

The DATA1 and DATA2 output terminals can be disabled. Doing so stops the clock signal to the D/A converter, which reduces noise and is resistant to interference when measuring minute signals.

4.1.5 Sensitivity and dynamic reserve

The dynamic reserve value depends on saturation signal level inside the instrument at a specific sensitivity (full scale of signal) and noise rejection characteristics of the time constant filter. In other words, it depends on frequency.
Set the value to the minimum. The higher the DR setting (lower AC GAIN) is set, the larger the input-referred noise and the drift of measured value will be.



■ Dynamic reserve for random noise

Random noise (wideband noise) is acceptable until its peak value reaches the saturation signal level inside the instrument. Even if the RMS values of sine wave and random noise are equal, the peak value of noise is several times larger than that of sine wave. Set the dynamic reserve considering that peak value.

1) Dynamic reserve setting

The DR setting corresponds to the gain of the analog circuit before the PSD. This setting restricts the range of the voltage sensitivity.

- DR setting: LOW1, LOW2, MED, HIGH

2) Voltage sensitivity

The voltage sensitivity is the DC gain after the time constant filter.

- Voltage sensitivity: See below (1-2-5 sequence).

DR	AC GAIN	Range
LOW1	100x	10 nVrms to 10 mVrms
LOW2	10x	100 nVrms to 100 mVrms
MED	1x	1 µVrms to 1 Vrms
HIGH	0.2x	5 µVrms to 1 Vrms

■ Note

If the DR setting is changed and the voltage sensitivity is out of range, the sensitivity may be changed corresponding to the DR setting after the change.

■ **Dynamic reserve**

The actual dynamic reserve value depends on dynamic reserve setting, voltage sensitivity, frequency difference between signal and noise, and settings of the time constant filter.

The values in the table below are nominal values when noise is sufficiently removed by the time constant filter.

Setting a dynamic reserve greater than 100 dB requires a large time constant setting and may result in large error in measured value.

DR setting	LOW1		LOW2		MED		HIGH	
Voltage sensitivity (A/B IN)	AC gain dB	DR dB	AC gain dB	DR dB	AC gain dB	DR dB	AC gain dB	DR dB
1 V	——	——	——	——	0	6	−14	20
500 mV	——	——	——	——	0	12	−14	26
200 mV	——	——	——	——	0	20	−14	32
100 mV	——	——	20	6	0	26	−14	40
50 mV	——	——	20	12	0	32	−14	46
20 mV	——	——	20	20	0	40	−14	52
10 mV	40	6	20	26	0	46	−14	60
5 mV	40	12	20	32	0	52	−14	66
2 mV	40	20	20	40	0	60	−14	72
1 mV	40	26	20	46	0	66	−14	80
500 µV	40	32	20	52	0	72	−14	86
200 µV	40	40	20	60	0	80	−14	92
100 µV	40	46	20	66	0	86	−14	100
50 µV	40	52	20	72	0	92	−14	106
20 µV	40	60	20	80	0	100	−14	112
10 µV	40	66	20	86	0	106	−14	120
5 µV	40	72	20	92	0	112	−14	126
2 µV	40	80	20	100	0	120	——	——
1 µV	40	86	20	106	0	126	——	——
500 nV	40	92	20	112	——	——	——	——
200 nV	40	100	20	120	——	——	——	——
100 nV	40	106	20	126	——	——	——	——
50 nV	40	112	——	——	——	——	——	——
20 nV	40	120	——	——	——	——	——	——
10 nV	40	126	——	——	——	——	——	——

4.1.6 Filters

This section describes the time constant filter, DC offset, moving average filter, and EXPAND function.

1) Time constant filter

The time constant of the time constant filter can be set.

- Time constant: 1 μs to 1 ks, 1-2-5 sequence

2) Attenuation slope

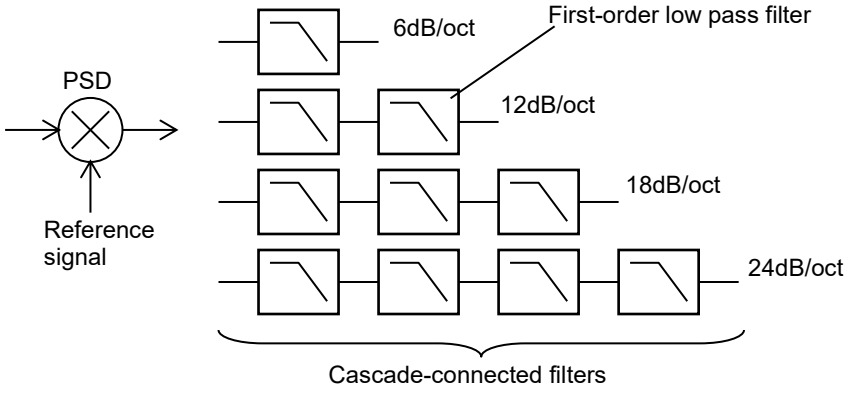
The attenuation slope of the time constant filter can be set.

- Attenuation slope: 6 / 12 / 18 / 24 dB/oct

■ Time constant filter

The characteristics of the time constant filter (TC) are those of cascade-connected first-order lowpass filter (cutoff frequency: fc). The attenuation slope per stage is 6 dB/oct (20 dB/dec). This means that in the transition band, doubling the frequency results in half attenuation (a ten-fold increase in frequency results in one-tenth attenuation).

By cascade-connecting 1 to 4 stages of this filter, the attenuation slope of 6 to 24 dB/oct (20 to 80 dB/dec) can be obtained.



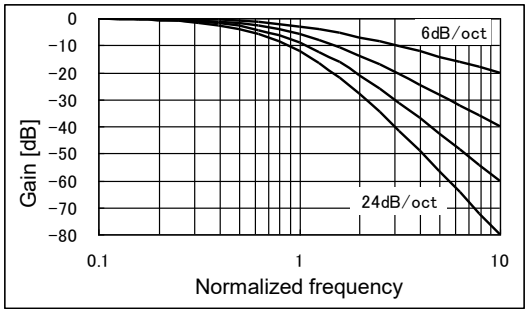
a) Frequency response

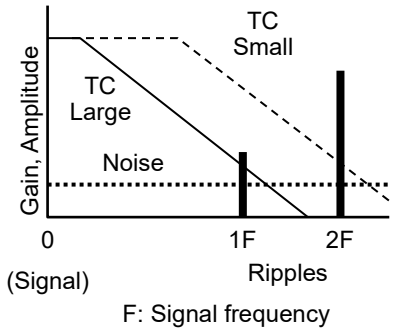
Normalized frequency =

|Frequency difference from reference signal| / cutoff frequency (fc)

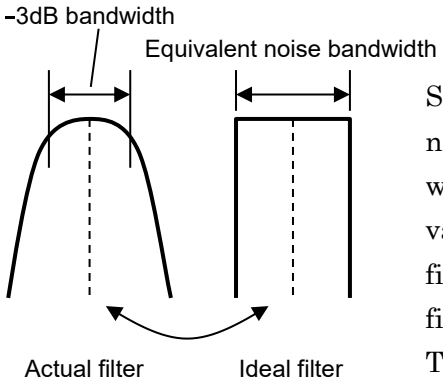
fc = 1 / (2πT)

Here, T indicates a time constant.





b) Equivalent noise bandwidth B_N



Sensitivity to white noise is represented by equivalent noise bandwidth. The bandwidth of an ideal filter where sensitivity to noise (in other words, an RMS value of output noise) is equal to that of an actual filter is called the equivalent noise bandwidth of that filter.

The equivalent noise bandwidth of this instrument B_N is twice that of a low pass filter determined by the time constant T and attenuation slope. B_N is represented by the following expression.

$$B_{N6} = \frac{1}{2T}, \quad B_{N12} = \frac{1}{4T}, \quad B_{N18} = \frac{3}{16T}, \quad B_{N24} = \frac{5}{32T}$$

corresponding to 6, 12, 18, and 24 dB/oct respectively

The RMS noise value Vm included in the output (measured value) can be obtained using the following expression.

$$Vm = Vn \times \sqrt{B_N}$$

Here, Vn indicates the noise density of the input and B_N indicates the equivalent noise bandwidth.

c) –3dB bandwidth B_{3dB}

$$B_{3\mathrm{dB}} = \sqrt{\sqrt[m]{2} - 1} \Big/ (\pi T)$$

Here, T indicates the time constant, and m is equal to 1, 2, 3, or 4 (corresponding to 6, 12, 18, or 24 dB/oct respectively).

d) Step response time

A response y(t) to applying a step signal to low pass filter after phase sensitive detection is represented by the following expression.

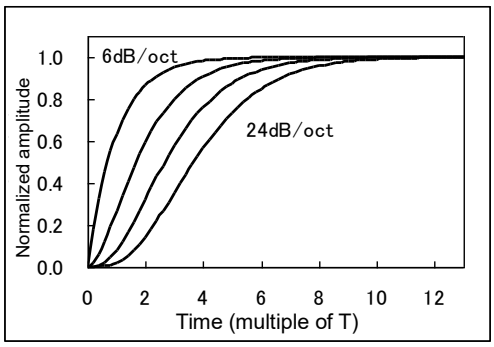
$$y(0) = 0,\ y(t) = 1 - \left\{ \sum_{n=1}^{m} \frac{t^{n-1}}{T^{n-1}(n-1)!} \right\} e^{-\frac{t}{T}}$$ However, t is greater than 0.

Here, T indicates the time constant, and m is equal to 1, 2, 3, or 4 (corresponding to 6, 12, 18, or 24 dB/oct respectively).

Step response time

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

Step response waveform



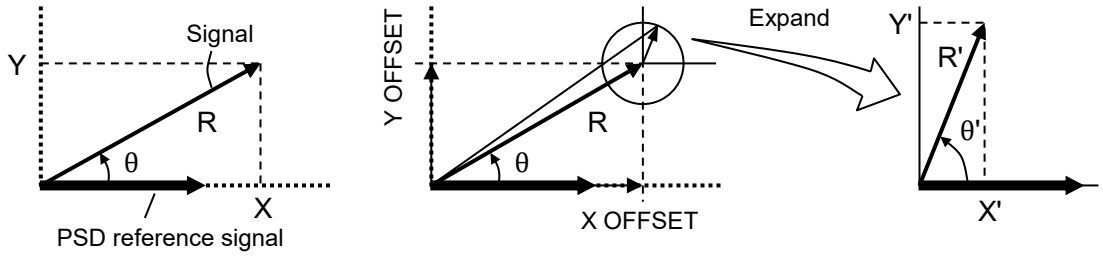
This is the case of analog filter. Since the instrument realizes this filter by digital processing, the filter characteristics when the time constant is small differ slightly from the above.

3) Offset function

An offset can be set in the X-axis and Y-axis for signal amplified by the voltage sensitivity (DC GAIN).

By moving a measured value near zero using the offset function, changes in the value can be magnified and small changes of it can be read.

- X-axis offset: ± 120 % (relative to full scale)
- Y-axis offset: ± 120 % (relative to full scale)



4) Moving average filter

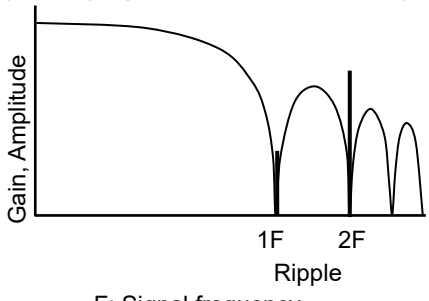
The averaging time of the moving average filter can be set.

- Averaging time: 1 µs to 100 s, 1-2-5 sequence
  AUTO (Inverse of reference signal frequency is set.)
  OFF (Disabled)

When the time constant is reduced in the TC filter, integer multiple ripples of the reference signal frequency are difficult to attenuate. In this case, the output response will slow at low frequency because the time constant must be large even if noise is small. In such case, if the moving average filter is enabled, the ripple generated at integer multiples of the reference signal frequency can be attenuated.

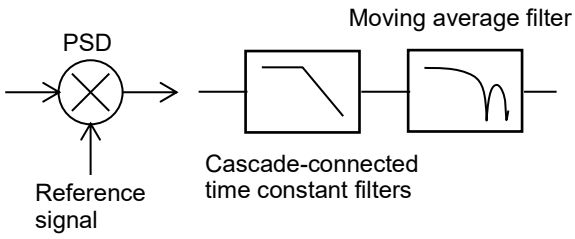
The moving average filter is connected after the TC filter.

Frequency response of moving average filter
(Averaging interval equals to 1 cycle)



F: Signal frequency

Diagram of filters



5) EXPAND function

The EXPAND value can be set to expand a signal after the MOV filter.

X, Y, and R values are commonly expanded. θ value is not affected.

- EXPAND: 1 to 1000 [times], 1-2-5 sequence recommended

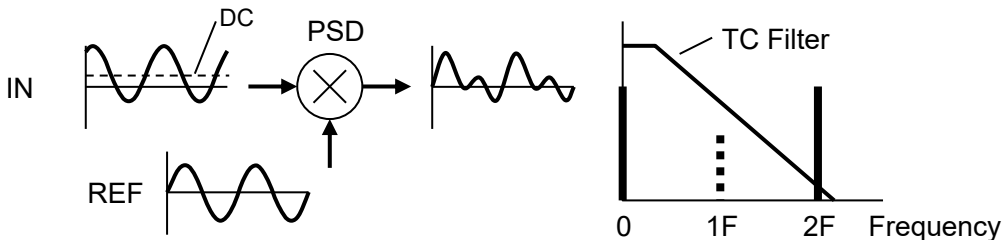
4.1.7 PSD input offset adjustment

The instrument has a function to cancel a DC offset of the PSD input.

If a DC component is included in the PSD input, a 1F ripple that is equal to the measurement frequency F occurs in the PSD output. A large time constant is required to remove the 1F ripple and an output response slows.

If a fast response is needed at high frequencies, it is recommended to perform the PSD input offset adjustment.

At low frequencies, it is effective to use the MOV filter simultaneously.



Before the adjustment, short-circuit input terminals (A/B IN).

Execute the PSD input offset adjustment command to start the adjustment.

The adjustment takes about 10 seconds. After adjustment, release short-circuit on the input terminals.

Executing the command to initialize the PSD input offset will return it to the factory default settings.

■ Preparation

The following preparation is needed to execute the PSD input offset adjustment.

- Set the actual operating conditions. When measurement parameters such as the dynamic reserve are changed after this adjustment, a re-adjustment is required.
- Set input signals to zero.
- Warm up the instrument sufficiently so that a temperature drift after the adjustment can be reduced.
- Keep the power supply voltage and ambient temperature as constant as possible.

4.2 Initial settings

The **LI5501 / LI5502** will be initialized at the following conditions below.

- When shipped from a factory and the MODE switch is set to "F"
  All of the settings are the factory default settings.
- When the system initialization is executed
  Settings other than the LAN interface are initialized.
  Use the ":SYSTem:RST" command.
- When the initialization is executed
  Contents of the resume memory are initialized.
  Use the "*RST" command.
- When there is an abnormality in the resume memory
  When the power is on, if there is an abnormality in the resume memory, abnormal parts will be initialized.

The details of the setting items and initial values are shown in **"Table 4-1 Setting items and initial values"**.

Table 4-1 Setting items and initial values

Setting item	Parameter range	Initial value	:SYST:RST	*RST	Configuration memory	Resume
<Reference signal>						
Reference signal source	REF IN, INT OSC	REF IN	←	←	Y	Y
Waveform (EDGE)	SIN+, TTL+, TTL-	SIN+	←	←	Y	Y
<Internal oscillator>						
Frequency	9.5 mHz to 1.05000 MHz	1.00000 kHz	←	←	Y	Y
10MHz IN	OFF, ON	OFF	←	←	Y	Y
<Harmonics>						
Common subharmonic	1 to 64	1	←	←	Y	Y
A IN harmonic	1 to 63	1	←	←	Y	Y
B IN harmonic	1 to 63	1	←	←	Y	Y
Oscillator multiplication	1 to 63	1	←	←	Y	Y
<Phase adjustment>						
A IN phase shift	−180.000° to +179.999°	0°	←	←	Y	Y
B IN phase shift	−180.000° to +179.999°	0°	←	←	Y	Y
Oscillator phase shift	−180° to +179.999°	0°	←	←	Y	Y
<Oscillator output>						
Output state	OFF, ON	OFF	←	←	Y	Y
Waveform	SINE, TTL	SINE	←	←	Y	Y
Amplitude	0.0 to 1.000 Vrms	0.000 Vrms	←	←	Y	Y
DC offset	0 to ± 5.000 V	0 mV	←	←	Y	Y

Table 4-1 Setting items and initial values

Setting item	Parameter range	Initial value	:SYST:RST	*RST	Configuration memory	Resume
<Analog data output>						
DATA1	X_A, Y_A, R_A, θ_A, X_B, Y_B, R_B, θ_B, G, P	R_A	←	←	Y	Y
DATA2	X_A, Y_A, R_A, θ_A, X_B, Y_B, R_B, θ_B, G, P	θ_A	←	←	Y	Y
<Dynamic reserve>						
A IN DR	LOW1 / LOW2 / MED / HIGH	MED	←	←	Y	Y
B IN DR	LOW1 / LOW2 / MED / HIGH	MED	←	←	Y	Y
<Voltage sensitivity>						
A IN sensitivity	10 nV to 1 V	1 V	←	←	Y	Y
B IN sensitivity	10 nV to 1 V	1 V	←	←	Y	Y
<Time constant filter>						
A IN time constant	1 µs to 10 ks (1-2-5)	100 ms	←	←	Y	Y
B IN time constant	1 µs to 10 ks (1-2-5)	100 ms	←	←	Y	Y
A IN attenuation slope	6 / 12 / 18 / 24 dB/oct	24 dB/oct	←	←	Y	Y
B IN attenuation slope	6 / 12 / 18 / 24 dB/oct	24 dB/oct	←	←	Y	Y
<DC offset>						
A IN X offset range	± 120.000 %	0 %	←	←	Y	Y
A IN Y offset range	± 120.000 %	0 %	←	←	Y	Y
B IN X offset range	± 120.000 %	0 %	←	←	Y	Y
B IN Y offset range	± 120.000 %	0 %	←	←	Y	Y
<Moving average filter>						
A IN averaging time	1 µs to 100 s (1-2-5), AUTO, OFF	OFF	←	←	Y	Y
B IN averaging time	1 µs to 100 s (1-2-5), AUTO, OFF	OFF	←	←	Y	Y
<EXPAND multiplier>						
A IN EXPAND multiplier	1 to 1000	1	←	←	Y	Y
B IN EXPAND multiplier	1 to 1000	1	←	←	Y	Y
<PSD input offset >						
Offset amount	Default, Automatic adjustment	Default	←	←	Y	Y
<Communication>						
Measurement data parameters	STATUS, FREQ-H, FREQ-L, X_A, Y_A, R_A, θ_A, X_B, Y_B, R_B, θ_B, RATIO, PHASE up to 7 words from above	R_A, θ_A	←	←	Y	Y

Table 4-1 Setting items and initial values

Setting item	Parameter range	Initial value	:SYST:RST	*RST	Configuration memory	Resume
<Measurement data buffer>						
Sampling interval	0.4 µs to 26.2 ms	0.8 µs	←	←	Y	Y
Buffer size	1 to 65536	65536	←	←	Y	Y
Trigger source	BUS, EXT	BUS	←	←	Y	Y
Trigger delay time	0 to 1.67 s	104 ms	←	←	Y	Y
<Interface>						
LAN IP address	0.0.0.0 to 255.255.255.255	192.168.0.2	N	N	Y	Y
LAN subnet mask	0.0.0.0 to 255.255.255.255	255.255.255.0	N	N	Y	Y
LAN default gateway	0.0.0.0 to 255.255.255.255	0.0.0.0	N	N	Y	Y
<FAN control>						
FAN control	ON, OFF, AUTO	AUTO	←	←	Y	Y
<Configuration memory>						
Contents	—	Initial values	←	N	—	—

■ **Notes**

Initial values	Factory default settings
:SYST:RST	When the :SYSTem:RST command is executed
*RST	When the *RST command is executed
←	Same as left (initial value)
N	Has no function (not changed)
Y	Has a function (setting stored)
—	Not applicable

The followings are not stored in the resume memory.

・Measurement data stored in the measurement data buffer

・Latest measurement data

The commands with respect to B IN and the measurement data parameters (X_B, Y_B, R_B, θ_B, RATIO, and PHASE) are only applicable to the **LI5502**.

(Blank)

5. Remote control

5.1 Preparation before use

The **LI5501 / LI5502** can be controlled remotely via USB or LAN interface.
By sending messages from a controller (personal computer for control), it is possible to change settings, check current settings, and obtain measurement data.

5.1.1 Selection of the remote control interface

Select the USB or LAN interface by flipping the SEL switch on the rear panel.
The interface connectors are located on the rear panel of the **LI5501 / LI5502**.
It is not possible to use both of the two interfaces at the same time.

5.1.2 USB overview

5.1.2.1 Preparation of controller

To use the USB interface, prepare a controller equipped with a USB interface.
Install the USBCDC (Universal Serial Bus Communication Device Class) driver on the controller.

■ USBCDC driver

The USBCDC driver is required before Windows10.
It is available on our web site (https://www.nfcorp.co.jp).

5.1.2.2 Connections and cautions

The **LI5501 / LI5502** should be connected directly to the USB connector of the computer by a commercial USB cable. The instrument may not operate correctly if the connection is made via a USB hub.

5.1.2.3 Confirmation of connection

If the instrument-specific information can be obtained, the connection has been made correctly.
Vendor ID = 0D4A (hexadecimal notation): The number indicates the NF Corporation.
Product ID = 0078 (hexadecimal notation): The number indicates the product number for **LI5501**.
Product ID = 0079 (hexadecimal notation): The number indicates the product number for **LI5502**.
Serial Number = 1234567 (example): A 7-digit serial number is specific to the instrument.

■ **Message terminator**

A set of commands and responses must end with a terminator that indicates the end of the message.

The response message terminator sent by the **LI5501 / LI5502** is always LF.

The program message terminator received by the **LI5501 / LI5502** is always LF.

5.1.3 LAN overview

5.1.3.1 Preparation of controller

To use the LAN interface, prepare a controller equipped with a LAN interface (a personal computer for control). The **LI5501 / LI5502** can communicate by using the TCP/IP protocol.

5.1.3.2 Connections

The **LI5501 / LI5502** can distinguish a straight and a crossover cable, so either type of cable can be used.

5.1.3.3 Settings of the LI5501 / LI5502

Configure the following settings when the instrument is connected via the USB interface.

■ **IP address**

In the IP (Internet Protocol), an address that identifies an instrument is set (logical address). The range of addresses from 192.168.0.0 to 192.168.255.255 is for private IP addresses that can be used freely within a small-scale local network (class C).

■ **Subnet mask**

A subnet mask is set to separate the IP addresses of a higher-level network and those of lower-level network.

■ **Default gateway**

When an instrument accesses an external network, the IP address of the gateway (repeater) to be used will be set implicitly.

■ **Port number**

The specific port number is used when the **LI5501 / LI5502** communicates using the TCP protocol.

The number is 5025 (decimal notation) and cannot be changed.

■ **MAC address**

This indicates an instrument-specific address (physical address). It cannot be changed.

For example, when a serial number is 1234567, the MAC address is ”00:14:CE:12:D6:87”.

”00:14:CE” is fixed.

1234567 (decimal notation) → 12D687 (hexadecimal notation)

■ **Message terminator**

A set of commands and responses must end with a terminator that indicates the end of the message.

The response message terminator sent by the **LI5501 / LI5502** is always LF.

The program message terminator received by the **LI5501 / LI5502** is always LF.

5.1.4 Precautions of communication

■ **Input buffer**

- Commands that have been sent are temporarily stored in the input buffer and then they are interpreted and executed in sequence. The input buffer capacity is 1024 bytes. Even if program messages exceed that size, these messages will be interpreted and executed in sequence.
- If an invalid command is encountered during interpretation and execution, an error will occur and none of the subsequent commands up to the program message terminator will be executed.

■ **Output buffer**

- The output buffer capacity is 1024 bytes.
- If the maximum capacity is exceeded, the output buffer will be cleared and the query error bit of the standard event status register is set to “1”. Subsequently, command interpretation and execution proceeds in the normal manner, but all generated response messages are discarded up to the program message terminator.

■ **Error queue**

- The queue can hold up to 16 error messages.
- If there are more than 17 error messages, the 16th message will return “Queue overflow” and subsequent error messages will be discarded. The error messages up to the 15th message will be retained.

■ **Program message terminator**

- When commands are sent from the controller, be sure to append the program message terminator, which is either LF (Line Feed, 0x0A hex) or CRLF (Carriage Return, 0x0D hex + Line Feed, 0x0A hex) to the end of the message.

5.2 List of commands and command tree

5.2.1 List of commands

The remote control commands and subsystem commands for the **LI5501 / LI5502** are listed in the **"Table 5-1 Common commands"** and **"Table 5-2 Subsystem commands"**.
The descriptions here are in short-form format, which omits all optional keywords. For the long-form format and the parameter format of the commands, refer to pages listed in the column of "Details".

Supplement: Commands that perform a query end with a question mark (?). In these tables, the queries are omitted for commands that can both set and query a parameter.
The rows of "R/W" in the tables indicate whether there are functions for querying (R) and setting (W). The rows of "*RST" indicate whether the function can be initialized by the "*RST" command.

Table 5-1 Common commands

Command	Function	R/W	*RST	Details
*CLS	Clears status register and error queue	W	—	P5-21
*ESE	Standard event status enable register	R/W	—	P5-21
*ESR?	Queries standard event status register	R	—	P5-21
*IDN?	Queries instrument-specific information	R	—	P5-21
*OPC	Notification that all previous commands have ended	R/W	—	P5-21
*RCL	Reads from the configuration memory	W	—	P5-22
*RST	Initializes configuration	W	—	P5-22
*SAV	Saves to the configuration memory	W	—	P5-22
*SRE	Service request enable register	R/W	—	P5-22
*STB?	Queries status byte register	R	—	P5-22
*TST?	Queries results of the self-diagnostic test	R	—	P5-22
*WAI	Waits for execution of commands and queries	W	—	P5-22

Table 5-2 Subsystem commands

Command	Function	R/W	*RST	Details
ABORt subsystem				
:ABORt	Aborts recording of measurement data	W	—	P5-23
CALCulate subsystem				
:CALC:FORM	Sets DATA1 output parameter	R/W	✓	P5-23
:CALC:MULT	Sets A IN EXPAND multiplier	R/W	✓	P5-23
:CALC:OFFS	Sets A IN offset value for X output	R/W	✓	P5-23
CALCulate2 subsystem				
:CALC2:FORM	Sets DATA2 output parameter	R/W	✓	P5-24
:CALC2:OFFS	Sets A IN offset value for Y output	R/W	✓	P5-24
CALCulate3 subsystem				
:CALC3:MULT	Sets B IN EXPAND multiplier	R/W	✓	P5-24
:CALC3:OFFS	Sets B IN offset value for X output	R/W	✓	P5-24
CALCulate4 subsystem				
:CALC4:OFFS	Sets B IN offset value for Y output	R/W	✓	P5-25

Command	Function	R/W	*RST	Details
DATA subsystem				
:DATA:COUN?	Queries the number of data sampling points	R	✓	P5-25
:DATA:DATA?	Queries measurement values	R	✓	P5-25
:DATA:DEL	Clears measurement data buffer	W	✓	P5-25
:DATA:FEED	Sets data parameters to record	R/W	✓	P5-26
:DATA:FEED:CONT	Whether to record measurement data	R/W	✓	P5-26
:DATA:POIN	Sets measurement data buffer size	R/W	✓	P5-26
:DATA:PER	Sets recording interval	R/W	✓	P5-27
FETCh subsystem				
:FETC?	Queries latest measurement data	R	✓	P5-27
INITiate subsystem				
:INIT	Starts triggering system	W	✓	P5-27
INPut1 subsystem				
:INP:OFFS:AUTO:ONCE	Executes PSD input offset adjustment (A IN)	W	✓	P5-27
:INP:OFFS:RST	Disables PSD input offset adjustment (A IN)	W	✓	P5-27
INPut2 subsystem				
:INP2:OFFS:AUTO:ONCE	Executes PSD input offset adjustment (B IN)	W	✓	P5-27
:INP2:OFFS:RST	Disables PSD input offset adjustment (B IN)	W	✓	P5-27
INPut3 subsystem				
:INP3:TYPE	Selects reference signal waveform	R/W	✓	P5-28
MEMory subsystem				
:MEM:STAT:DEL	Clears contents of designated memory	W	—	P5-28
OUTPut subsystem				
:OUTP	Sets output state of DATA1 terminal	R/W	✓	P5-28
OUTPut2 subsystem				
:OUTP2	Sets output state of DATA2 terminal	R/W	✓	P5-28
ROUTe subsystem				
:ROUT	Selects reference signal source	R/W	✓	P5-28
SENSe subsystem				
:DRES	Sets A IN dynamic reserve	R/W	✓	P5-29
:DRES2	Sets B IN dynamic reserve	R/W	✓	P5-29
:FREQ?	Queries frequency	R	—	P5-30
:FREQ:MULT	Sets harmonic order “n” (A IN)	R/W	✓	P5-31
:FREQ:SMUL	Sets subharmonic order “m” (A/B IN)	R/W	✓	P5-31
:FREQ2:MULT	Sets harmonic order “n” (B IN)	R/W	✓	P5-31
:FILT:SLOP	Sets attenuation slope of TC filter (A IN)	R/W	✓	P5-29
:FILT:TCON	Sets time constant of TC filter (A IN)	R/W	✓	P5-30
:FILT:MOV	Sets averaging time of MOV filter (A IN)	R/W	✓	P5-29
:FILT2:SLOP	Sets attenuation slope of TC filter (B IN)	R/W	✓	P5-30
:FILT2:TCON	Sets time constant of TC filter (B IN)	R/W	✓	P5-30
:FILT2:MOV	Sets averaging time of MOV filter (B IN)	R/W	✓	P5-30
:PHAS	Sets phase shift amount (A IN)	R/W	✓	P5-31
:PHAS:AUTO:ONCE	Automatic phase adjustment (A IN)	W	✓	P5-31
:PHAS2	Sets phase shift amount (B IN)	R/W	✓	P5-32
:PHAS2:AUTO:ONCE	Automatic phase adjustment (B IN)	W	✓	P5-32
:ROSC:SOUR	Selects reference frequency source	R/W	✓	P5-32
:VOLT:AC:RANG	Sets voltage sensitivity (A IN)	R/W	✓	P5-32
:VOLT2:AC:RANG	Sets voltage sensitivity (B IN)	R/W	✓	P5-33

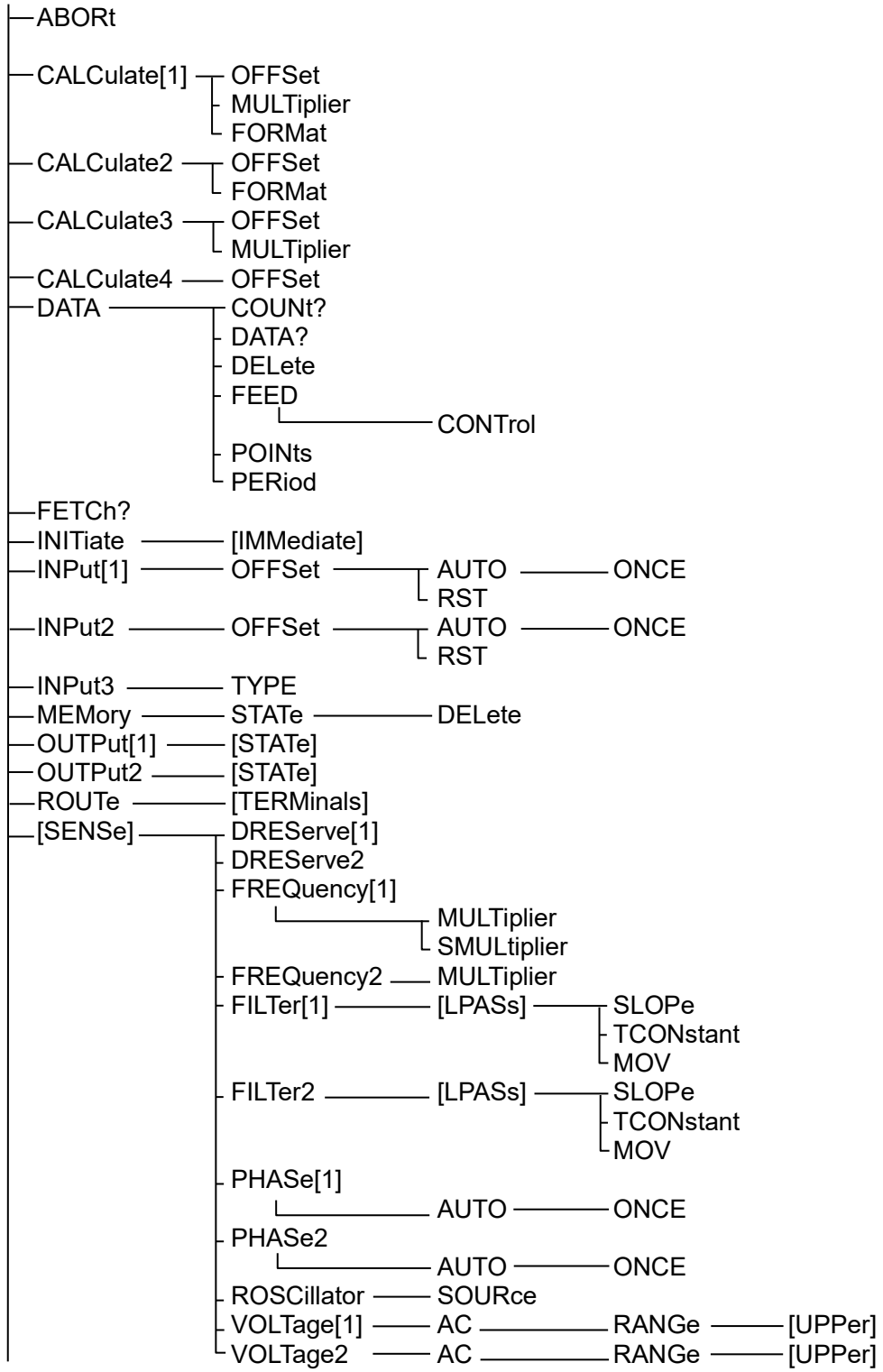
Command	Function	R/W	*RST	Details
SOURce subsystem				
:SOUR:FREQ	Sets internal oscillator frequency	R/W	✓	P5-33
:SOUR:FREQ:MULT	Sets harmonic order “n” of oscillator output	R/W	✓	P5-33
:SOUR:VOLT	Sets amplitude of internal oscillator	R/W	✓	P5-34
:SOUR:VOLT:OFFS	Sets DC offset of internal oscillator	R/W	✓	P5-34
:SOUR:OUTP	Sets output state of internal oscillator	R/W	✓	P5-33
:SOUR:PHAS:	Sets phase shift amount of internal oscillator	R/W	✓	P5-34
:SOUR:PHAS:INIT	Initializes phase reference of internal oscillator	W	—	P5-34
:SOUR:TYPE	Selects internal oscillator waveform	R/W	✓	P5-34
STATus subsystem				
:STAT:OPER?	Queries operation status event register	R	—	P5-35
:STAT:OPER:COND?	Queries operation status condition register	R	—	P5-35
:STAT:OPER:ENAB	Operation status event enable register	R/W	—	P5-35
:STAT:OPER:NTR	Negative operation status transition filter	R/W	—	P5-35
:STAT:OPER:PTR	Positive operation status transition filter	R/W	—	P5-35
:STAT:QUES?	Queries questionable event register	R	—	P5-36
:STAT:QUES:COND?	Queries questionable condition register	R	—	P5-36
:STAT:QUES:ENAB	Questionable event enable register	R/W	—	P5-36
:STAT:QUES:NTR	Questionable status negative transition filter	R/W	—	P5-36
:STAT:QUES:PTR	Questionable status positive transition filter	R/W	—	P5-36
SYSTem subsystem				
:SYST:ERR?	Queries error messages	R	—	P5-37
:SYST:FAN:CONT	FAN control	R/W	—	P5-37
:SYST:REM:LAN:IPAD	Sets IP address	R/W	—	P5-37
:SYST:REM:LAN:MASK	Sets subnet mask	R/W	—	P5-37
:SYST:REM:LAN:GATE	Sets default gateway	R/W	—	P5-38
:SYST:RST	Initialize settings and the configuration memory	W	—	P5-38
TRIGger subsystem				
:TRIG:DEL	Sets trigger delay time	R/W	—	P5-38
:TRIG	Executes trigger (starts recording)	W	—	P5-38
:TRIG:SOUR	Sets trigger source	R/W	—	P5-38

Note: The commands with respect to B IN are only applicable to the **LI5502**.

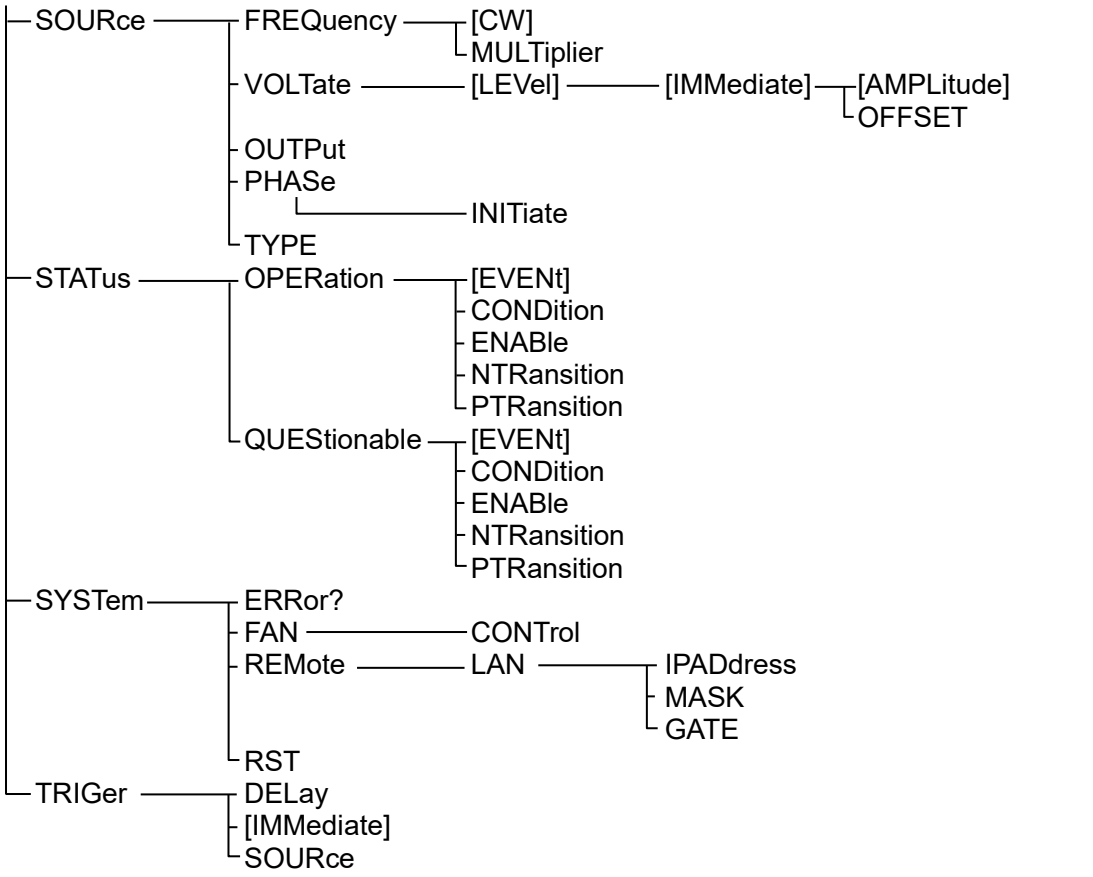
5.2.2 Command tree

The subsystem command tree for the **LI5501 / LI5502** is shown below.
Brackets ([ ]) in the tree indicate optional keywords.

<Root> Command tree 1/2



Command tree 2/2



5.3 Commands

5.3.1 Overview

Commands of the **LI5501 / LI5502** are classified into common commands compliant with the IEEE488.2 standard and subsystem commands corresponding to device-specific functions.

5.3.1.1 Notation

For convenience, the following notations are used in this manual.

< > Parameters or parameter formats are enclosed in angle brackets (< >).

[ ] Brackets ([ ]) are used to enclose options, which can be omitted.

{abc | xyz}

A vertical bar (|) indicates that either “abc” or “xyz” can be used.

[abc | xyz]

Square brackets indicate that either “abc” or “xyz” can be used, which can be omitted.

Uppercase and lowercase letters

Keywords written in uppercase and lowercase letters are long-form expressions; keywords written in uppercase letters only are short-form expressions.

5.3.1.2 SCPI commands

The program messages of the **LI5501 / LI5502** consist of the common commands and subsystem commands. Here, these command formats and the subsystem command tree are explained.

■ **Common commands**

The common commands are for control of the general instrument functions.
The command syntax is illustrated in **“Figure 5-1”**.

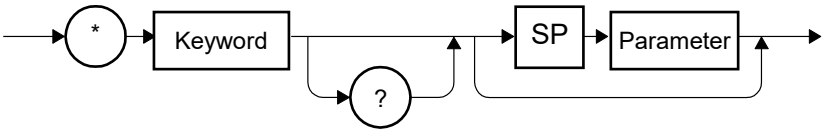


Figure 5-1 Common command syntax

The keyword in **"Figure 5-1"** are composed of three alphabetic characters. In this figure, SP represents a space (ASCII code 32).

■ Subsystem commands

The subsystem commands are for executing specific instrument functions. They consist of a root keyword, one or more lower-level keywords, a parameter, and a suffix. Examples of a command and query are shown below.

:OUTPut:STATe ON
:OUTPut:STATe?

"OUTPut" is a root-level keyword that is concatenated with a second-level keyword and "ON" is a parameter.

■ Subsystem command syntax

The subsystem command syntax is illustrated in **"Figure 5-2"**.

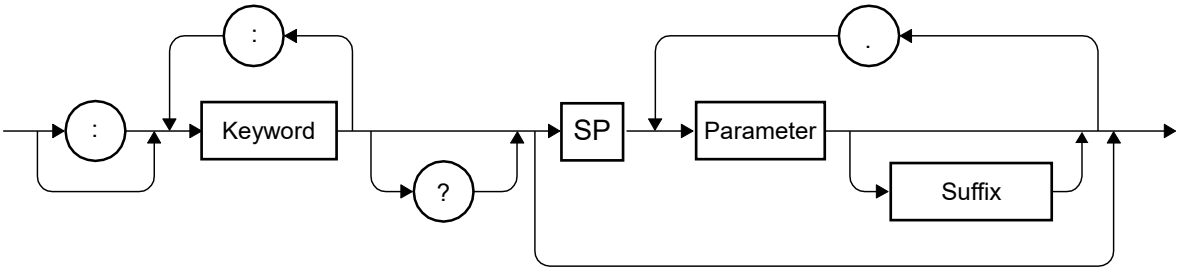


Figure 5-2 Subsystem command syntax

[Keywords]

The keyword in **"Figure 5-2"** is a text strings of up to 12 characters that begins with a letter of the alphabet. The remaining characters are uppercase or lowercase alphabetic characters, underscore characters, or numerals.

Most of the keywords shown in **"5.3.3 Commands description"** are composed of a mixture of uppercase and lowercase characters. Here, uppercase characters indicate short-form expressions and the mixture of uppercase and lowercase characters indicates long-form keywords. For convenience and explanation, uppercase and lowercase characters are used in keywords, but actual commands are case insensitive. The **"Table 5-3"** shows an example for the keyword "OUTPut".

Table 5-3 Keywords that can be interpreted or not

Keyword	Description
OUTPUT	Can be used as the long form
OUTP	Can be used as the short form
OutpUt	Keywords are case insensitive. This can be used as the long form.
oUTP	Keywords are case insensitive. This can be used as the short form.
OUTPU	This cannot be used, because it does not correspond to either the long form or short form.
OU	This cannot be used, because it does not correspond to either the long form or short form.

[Keyword separators]

The colons that appear in **"Figure 5-2"** are interpreted as keyword separators. The keyword separator serves to separate upper-level keyword and lower-level keyword in the command tree.

The colon that appears at the beginning of the subsystem commands is interpreted as a root specifier. The root specifier sets the current path as the root.

[Keyword omission]

For the commands shown in **"5.3.3 Commands description"**, a keyword enclosed in square brackets ([ ]) can be omitted. When the keyword is omitted, the instrument assumes that it has been received and analyzed.

Taking the ":OUTPut[:STATe]" command for example, either the following commands can be used.

:OUTPut:STATe

:OUTPut

[Parameters]

The parameter formats are described below.

(1) Numerical parameters (<NRf>, <NR1>, <NR2>, and <NR3>)

The numerical parameter formats include integer (<NR1>), real number (floating-point) (<NR2>), and real umber (exponent) (<NR3>). <NRf> is a generic expression that includes <NR1>, <NR2>, and <NR3>. The syntax for numerical parameters is illustrated below.

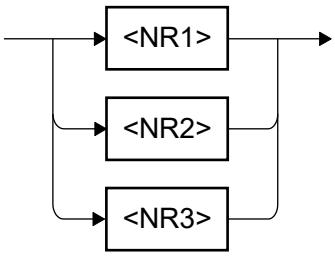


Figure 5-3 Numerical parameter syntax (<NRf>)

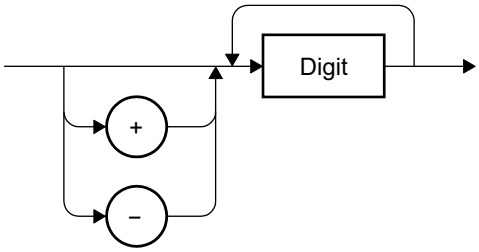


Figure 5-4 Numerical parameter syntax (<NR1>)

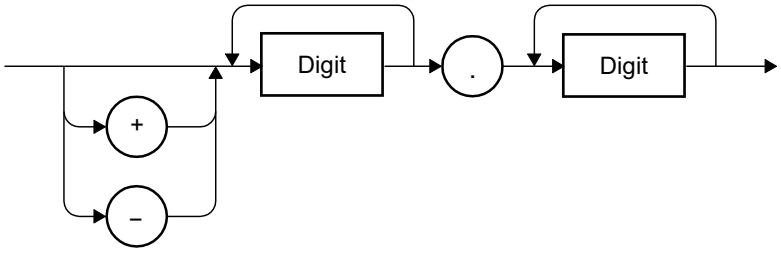


Figure 5-5 Numerical parameter syntax (<NR2>)

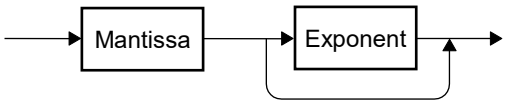


Figure 5-6 Numerical parameter syntax (<NR3>)

Here, the syntax for the mantissa and the exponent of **"Figure 5-6"** is illustrated below.

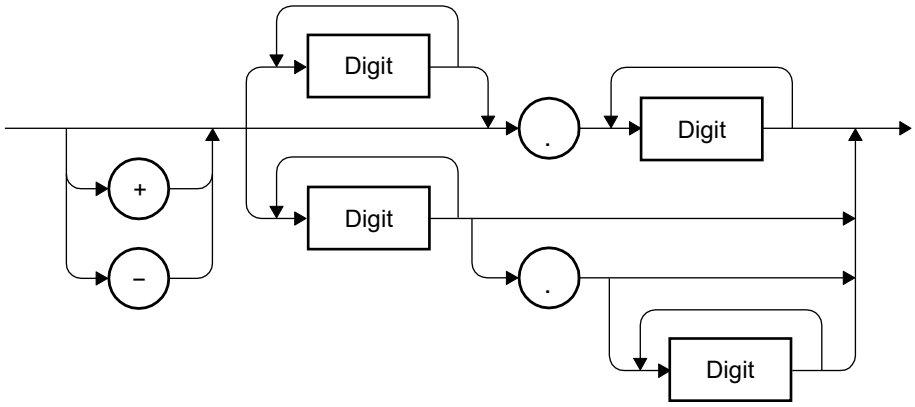


Figure 5-7 Mantissa syntax

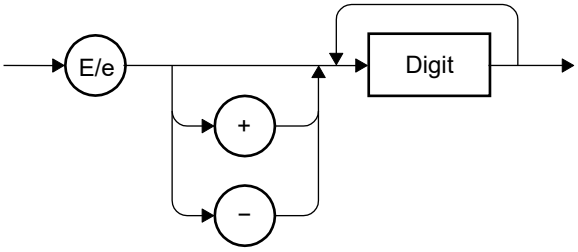


Figure 5-8 Exponent syntax

(2) Discrete parameters (<DISC>)

The syntax for discrete parameters is illustrated below.

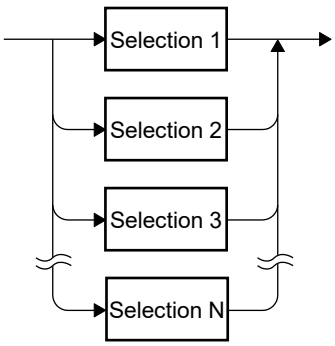


Figure 5-9 Discrete parameter syntax (<DISC>)

(3) Boolean parameters (<BOL>)

The syntax for Boolean parameters is illustrated below.

The Boolean parameter value of "0" is interpreted as "false" (OFF) and all the other values are interpreted as "true" (ON).

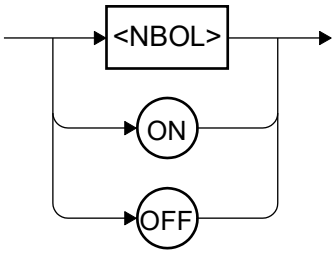


Figure 5-10 Boolean parameter syntax (<BOL>)

(4) Text string parameters (<STR>)

The syntax for text string parameters is illustrated below.

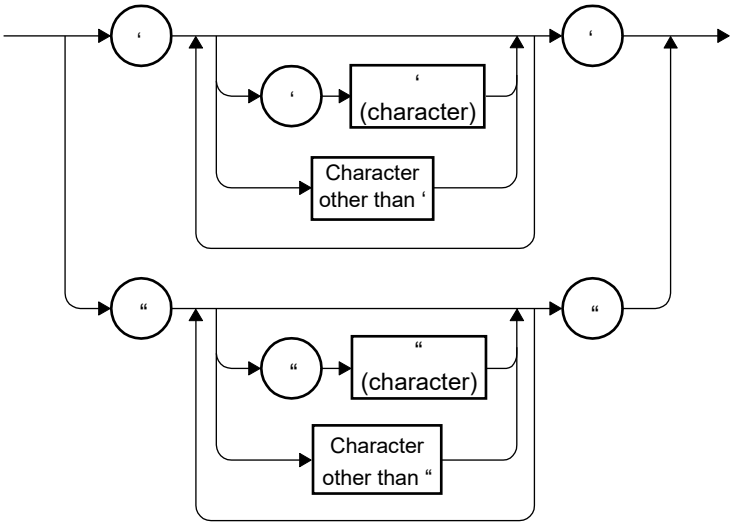


Figure 5-11 Text string parameters (<STR>)

[Parameter separators]

The parameter separator will be used between two parameters when two or more parameters are used in command.

[Query parameters]

Query parameters are specified after the “?” of a query.

[Suffixes]

In some commands, it is possible to set a value by specifying an SI suffix and unit. The syntax for suffixes is illustrated below.

Figure 5-12 Suffix syntax

■ **Program message syntax**

The controller can send a combination of two or more common commands and subsystem commands to the instrument in a single program message. The program message syntax is illustrated below.

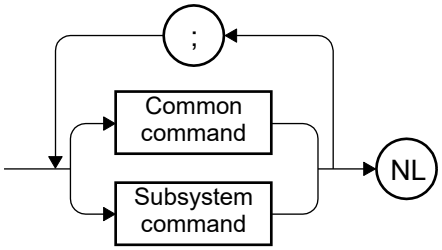


Figure 5-13 Program message syntax

Commands are separated by a semicolon.

■ **Response message syntax**

Response messages are used by the instrument to send data in response to a query.

[Response message syntax]

The syntax for response messages is illustrated below.

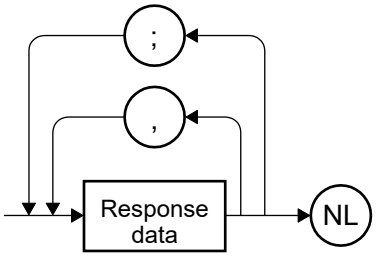


Figure 5-14 Response message syntax

In response messages, commas and semicolons are used as separators. When multiple values are returned by a single command, a response message will be delineated by commas. When a single program message contains multiple queries, a response message will be delineated semicolons.

[Response message data]

The response message data types are described below.

(1) Numerical response data (<NR1>, <NR2>, and <NR3>)

The syntax for numerical response data is illustrated below.

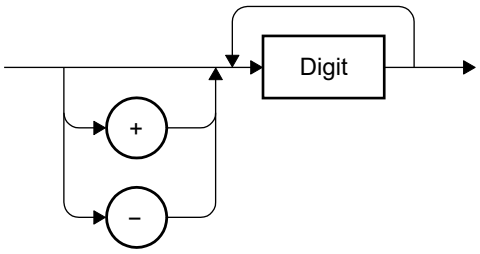


Figure 5-15 Integer response data syntax (<NR1>)

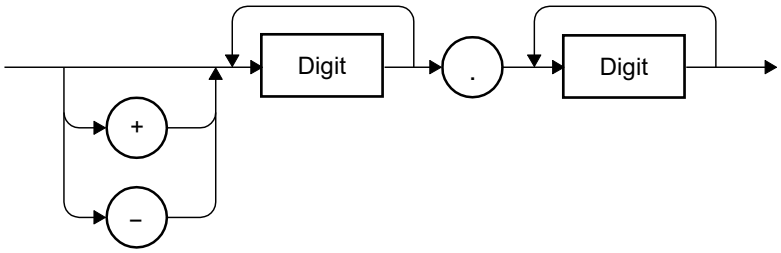


Figure 5-16 NR2 numerical response data syntax (<NR2>)

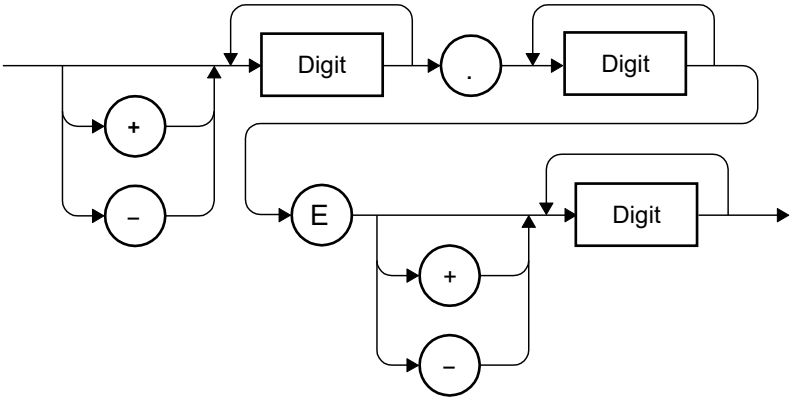


Figure 5-17 NR3 numerical response data syntax (<NR3>)

(2) Discrete response data (<DISC>)

The syntax for discrete response data is illustrated below.

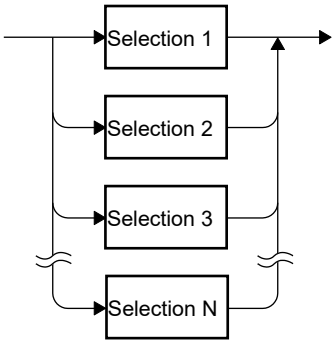


Figure 5-18 Discrete response data syntax (<DISC>)

(3) Numerical Boolean response data (<NBOL>)

The syntax for numerical Boolean response data is illustrated below.

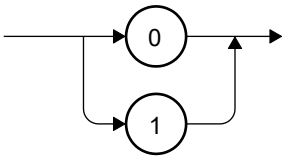


Figure 5-19 Numerical Boolean response data syntax (<NBOL>)

(4) Text string response data (<STR>)

The syntax for text string response data is illustrated below.

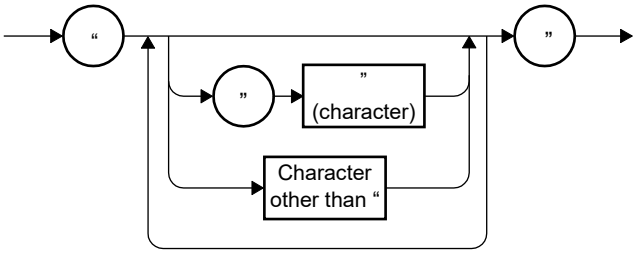


Figure 5-20 Text string response data syntax (<STR>)

(5) Defined-length arbitrary block response data (<DBLK>)

The syntax for defined-length arbitrary block response data is illustrated below.

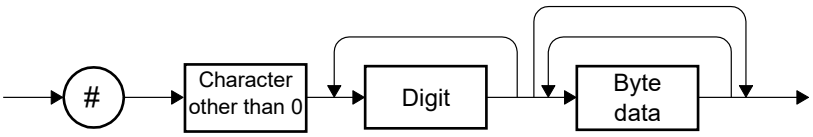


Figure 5-21 Defined-length arbitrary block response data syntax (<DBLK>)

5.3.2 Sequential commands

The commands of the **LI5501 / LI5502** are all sequential commands. After execution of a command is completed, the next command will be executed. There are no overlapping commands.

5.3.3 Commands description

This section describes the commands in detail.

Supplement: "4 digits (1 p (10^{-12}) when <10 n (10^{-9}))" in the resolution of the tables means that the resolution is usually 4 digits, but 1 p (10^{-12}) when a setting value is less than 10 n (10^{-9}).

5.3.3.1 *CLS

Explanation	Clears the event register and error queue
Comments	Targets for the clear operation: • Status byte register • Standard event status register • Operation status event register • Error queue

5.3.3.2 *ESE <value>

*ESE?

Explanation	Sets and queries the standard event status enable register		
Parameter	<value>	<NRf>	Standard event status enable register Range: 0 to 255 Resolution: 1 Default: 0
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the "*RST" command		

5.3.3.3 *ESR?

Explanation	Queries the standard event status register
Response format	<NR1>
Comments	The standard event status register will be cleared when the *ESR? query or the *CLS command is received.

5.3.3.4 *IDN?

Explanation	Queries the instrument-specific information		
Response format	<corporation>,<model>,<serial>,<ver>		
	<corporation>	<STR>	Company name (NF Corporation)
	<model>	<STR>	Model name (LI5501 / LI5502)
	<serial>	<STR>	Serial number
	<ver>	<STR>	Firmware version
Comments	The response is returned without including double quotation marks. NF Corporation,LI5501 / LI5502,1234567,Ver1.00		

5.3.3.5 *OPC

*OPC?

Explanation	*OPC: Sets the OPC bit to "1" when all previous commands have ended *OPC?: Sets "1" to the output buffer when all previous commands have ended
Response format	<NR1>
Comments	—

5.3.3.6 *RCL <value>

Explanation	Executes a read from the configuration memory (internal memory)		
Parameter	<value>	<NRf>	Configuration memory number Range: 0 to 15 Resolution: 1
Comments	The No.0 memory is resume memory and settings are not changed. Contents of the No.15 memory is the factory default setting.		

5.3.3.7 *RST

Explanation	Initializes settings
Comments	Refer to **"Table 4-1 Setting items and initial values"** what contents to be initialized.

5.3.3.8 *SAV <value>

Explanation	Executes a save to the configuration memory (internal memory)		
Parameter	<value>	<NRf>	Configuration memory number Range: 1 to 14 Resolution: 1
Comments	Refer to **"Table 4-1 Setting items and initial values"** what contents to be saved.		

5.3.3.9 *SRE <value>
*SRE?

Explanation	Sets and queries the service request enable register		
Parameter	<value>	<NRf>	Service request enable register Range: 0 to 255 Resolution: 1 Default: 0
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the "*RST" command		

5.3.3.10 *STB?

Explanation	Queries the status byte register
Response format	<NR1>
Comments	Refer to **"5.4.2 Status byte"** about status bytes.

5.3.3.11 *TST?

Explanation	Executes the self-diagnostic test and queries its results
Response format	<NR1>
Comments	It is the SCPI command. "0" is always returned.

5.3.3.12 *WAI

Explanation	Standby for end of overlapping command execution
Comments	There are no overlapping commands for the **LI5501 / LI5502**.

5.3.3.13 :ABORt

Explanation	Stops recording to the measurement data buffer and makes the triggering system idle
Comments	—

5.3.3.14 :CALCulate1:FORMat <value>

:CALCulate1:FORMat?

Explanation	Sets and queries the measurement parameter to be output to the DATA1		
Parameter	<value>	<DISC>	Measurement parameters REAL: X_A ($= R_A \cos \theta_A$) MLINear: R_A ($= \sqrt{X_A^2 + Y_A^2}$) IMAGinary: Y_A ($= R_A \sin \theta_A$) PHASe: θ_A REAL2: X_B ($= R_B \cos \theta_B$) MLINear2: R_B ($= \sqrt{X_B^2 + Y_B^2}$) IMAGinary2: Y_B ($= R_B \sin \theta_B$) PHASe2: θ_B MLINear3: R_A / R_B (amplitude ratio of A IN to B IN) PHASe3: $\theta_A - \theta_B$ (phase difference between A IN and B IN)
Response format	<DISC>		
Comments	Example) When setting parameter to X_A, enter ":CALCulate1:FORMat REAL".		

5.3.3.15 :CALCulate1:MULTiplier <value>

:CALCulate1:MULTiplier?

Explanation	Sets and queries EXPAND multiplier on the A IN side		
Parameter	<value>	<NRf>	Multiplier [times] Range: 1 to 1000 Resolution: 1
Response format	<NR1>		
Comments	The EXPAND multiplier only affects X, Y, and R parameters. It does not affect the other parameters. 1-2-5 sequence is recommended.		

5.3.3.16 :CALCulate1:OFFSet <value>

:CALCulate1:OFFSet?

Explanation	Sets and queries the offset value for the X output on the A IN side		
Parameter	<value>	<NRf>	Offset [%] Range: –120.00 to +120.00 Resolution: 0.01
Response format	<NR2>		
Comments	—		

5.3.3.17 :CALCulate2:FORMat <value>

:CALCulate2:FORMat?

Explanation	Sets and queries the measurement parameter to be output to the DATA2		
Parameter	<value>	<DISC>	Measurement parameters REAL: X_A (= $R_A \cos \theta_A$) MLINear: R_A (= $\sqrt{X_A^2 + Y_A^2}$) IMAGinary: Y_A (= $R_A \sin \theta_A$) PHASe: θ_A REAL2: X_B (= $R_B \cos \theta_B$) MLINear2: R_B (= $\sqrt{X_B^2 + Y_B^2}$) IMAGinary2: Y_B (= $R_B \sin \theta_B$) PHASe2: θ_B MLINear3: R_A / R_B (amplitude ratio of A IN to B IN) PHASe3: $\theta_A - \theta_B$ (phase difference between A IN and B IN)
Response format	<DISC>		
Comments	—		

5.3.3.18 :CALCulate2:OFFSet <value>

:CALCulate2:OFFSet?

Explanation	Sets and queries the offset value for the Y output on the A IN side		
Parameter	<value>	<NRf>	Offset [%] Range: –120.00 to +120.00 Resolution: 0.01
Response format	<NR2>		
Comments	—		

5.3.3.19 :CALCulate3:MULTiplier <value>

:CALCulate3:MULTiplier?

Explanation	Sets and queries EXPAND multiplier on the B IN side		
Parameter	<value>	<NRf>	Multiplier [times] Range: 1 to 1000 Resolution: 1
Response format	<NR1>		
Comments	The EXPAND multiplier only affects X, Y, and R parameters. It does not affect the other parameters. 1-2-5 sequence is recommended.		

5.3.3.20 :CALCulate3:OFFSet <value>

:CALCulate3:OFFSet?

Explanation	Sets and queries the offset value for the X output on the B IN side		
Parameter	<value>	<NRf>	Offset [%] Range: –120.00 to +120.00 Resolution: 0.01
Response format	<NR2>		
Comments	—		

5.3.3.21 :CALCulate4:OFFSet <value>
:CALCulate4:OFFSet?

Explanation	Sets and queries the offset value for the Y output on the B IN side		
Parameter	<value>	<NRf>	Offset [%] Range: –120.00 to +120.00 Resolution: 0.01
Response format	<NR2>		
Comments	—		

5.3.3.22 :DATA:COUNt?

Explanation	Queries the number of data sampling points recorded in the measurement data buffer
Response format	<NR1>
Comments	—

5.3.3.23 :DATA:DATA? <value>

Explanation	Queries the contents of the measurement data buffer (measurement values)		
Parameter	<value>	<DISC>	Size [points] Range: 1 to 65536
Response format	<NR1> | <DISC>		
Comments			

5.3.3.24 :DATA:DELete

Explanation	Clears the measurement data buffer
Comments	—

5.3.3.25 :DATA:FEED <value>

:DATA:FEED?

Explanation	Sets and queries measurement data parameters recorded in the measurement data buffer		
Parameter	<value>	<NRf>	Measurement data parameters Weight: 1: STATUS 2: FREQ-H (upper bits of reference signal frequency) 4: FREQ-L (lower bits of reference signal frequency) 8: X_A (X value on A IN side) 16: Y_A (Y value on A IN side) 32: R_A (R value on A IN side) 64: θ_A (θ value on A IN side) 128: X_B (X value on B IN side) 256: Y_B (Y value on B IN side) 512: R_B (R value on B IN side) 1024: θ_B (θ value on B IN side) 2048: RATIO (amplitude ratio of A IN to B IN) 4096: PHASE (phase difference between A IN and B IN)
Response format	<NR1>		
Comments	Example) When selecting R_A and θ_A, enter ":DATA:FEED 96". Refer to **"6.1.1 Setting of measurement data parameters"** about STATUS.		

5.3.3.26 :DATA:FEED:CONTrol <value>

:DATA:FEED:CONTrol?

Explanation	Sets and queries whether or not to be recorded in the measurement data buffer		
Parameter	<value>	<DISC>	Whether recording or not ALWays: Records measurement data NEVer: Does not record measurement data
Response format	<DISC>		
Comments	—		

5.3.3.27 :DATA:POINts <value>

:DATA:POINts?

Explanation	Sets and queries the measurement data buffer size		
Parameter	<value>	<DISC>	Size [points] Range: 1 to 65536 or INFinity
Response format	<NR1> or <DISC>		
Comments	"INFinity" indicates that recording continues until the measurement buffer is full.		

5.3.3.28 :DATA:PERiod <value>

:DATA:PERiod?

Explanation	Sets and queries recording interval to the measurement data buffer		
Parameter	<value>	<NRf>	Recording interval [s] Range: 0.4 µs to 26.2 ms Resolution: 0.4 µs Suffix “U” (10^{-6}) and “M” (10^{-3}) and unit “S” are available.
Response format	<NR2>		
Comments	It takes 0.4 µs per measured data parameter.		

5.3.3.29 :FETCh?

Explanation	Queries the latest measurement data
Response format	<NR1>
Comments	Query the measurement data set by the “:DATA:FEED” command.

5.3.3.30 :INITiate[:IMMediate]

Explanation	When recording to the measurement data buffer is enabled and the triggering system is idle, the system transitions to the awaiting trigger state.
Comments	If the measurement data buffer is full during recording, the system becomes the idle state. It cannot become the awaiting trigger state, while the measurement data if full. Clear the buffer if necessary.

5.3.3.31 :INPut[1]:OFFSet:AUTO:ONCE

Explanation	Automatically adjusts the PSD input offset on the A IN side only once
Comments	—

5.3.3.32 :INPut[1]:OFFSet:RST

Explanation	The PSD input offset amount on the A IN side is restored to the factory default setting.
Comments	—

5.3.3.33 :INPut2:OFFSet:AUTO:ONCE

Explanation	Automatically adjusts the PSD input offset on the B IN side only once
Comments	—

5.3.3.34 :INPut2:OFFSet:RST

Explanation	The PSD input offset amount on the B IN side is restored to the factory default setting.
Comments	—

5.3.3.35 :INPut3:TYPE <value>

:INPut3:TYPE?

Explanation	Sets and queries the reference signal waveform		
Parameter	<value>	<DISC>	Edge
			SINusoid: Sine wave (edge: rising slope intersects 0 V)
			TPOS: TTL level rising edge
			TNEG: TTL level falling edge
Response format	<DISC>		
Comments	—		

5.3.3.36 :MEMory:STATe:DELete <value>

Explanation	Clears contents of designated configuration memory		
Parameter	<value>	<NRf>	Memory number
			Range: 1 to 14
Response format	<NR1>		
Comments	—		

5.3.3.37 :OUTPut[1][:STATe] <value>

:OUTPut[1][:STATe]?

Explanation	Sets and queries the output state of the DATA1 terminal		
Parameter	<value>	<BOL>	Output state
			ON｜1: Enables output of the DATA1 terminal
			OFF｜0: Disables output of the DATA1 terminal
Response format	<NBOL>		
Comments	—		

5.3.3.38 :OUTPut2[:STATe] <value>

:OUTPut2[:STATe]?

Explanation	Sets and queries the output state of the DATA2 terminal		
Parameter	<value>	<BOL>	Output state
			ON｜1: Enables output of the DATA2 terminal
			OFF｜0: Disables output of the DATA2 terminal
Response format	<NBOL>		
Comments	—		

5.3.3.39 :ROUTe[:TERMinals] <value>

:ROUTe[:TERMinals]?

Explanation	Sets and queries the reference signal source		
Parameter	<value>	<DISC>	Reference signal source
			RINPut: Input signal to the REF IN terminal
			IOSC: Internal oscillator
Response format	<DISC>		
Comments	—		

5.3.3.40 [:SENSe]:DREServe[1] <value>
[:SENSe]:DREServe[1]?

Explanation	Sets and queries the dynamic reserve on the A IN side		
Parameter	<value>	<DISC>	Dynamic reserve
			HIGH: High dynamic reserve (when noise level is high) MEDium: Medium dynamic reserve LOW2: Low dynamic reserve LOW1: Lower dynamic reserve (when noise level is low)
Response format	<DISC>		
Comments	—		

5.3.3.41 [:SENSe]:DREServe2 <value>
[:SENSe]:DREServe2?

Explanation	Sets and queries the dynamic reserve on the B IN side		
Parameter	<value>	<DISC>	Dynamic reserve
			HIGH: High dynamic reserve (when noise level is high) MEDium: Medium dynamic reserve LOW2: Low dynamic reserve LOW1: Lower dynamic reserve (when noise level is low)
Response format	<DISC>		
Comments	—		

5.3.3.42 [:SENSe]:FILTer[1][:LPASs]:MOV <value>
[:SENSe]:Filter[1][:LPASs]:MOV?

Explanation	Sets and queries the averaging time of the moving average filter on the A IN side		
Parameter	<value>	<NRf> <DISC>	Averaging time [s]
			Range: OFF, AUTO, or| 1E−6 to 100 (1-2-5 sequence) Suffix “U” (10^{-6}) and “M” (10^{-3}) and unit “S” are available.
Response format	<DISC>		
Comments	If an arbitrary number is entered, it will be rounded to the nearest value.		

5.3.3.43 [:SENSe]:FILTer[1][:LPASs]:SLOPe <value>
[:SENSe]:Filter[1][:LPASs]:SLOPe?

Explanation	Sets and queries the attenuation slope of the time constant filter on the A IN side		
Parameter	<value>	<NRf>	Attenuation slope [dB/oct]
			Range: 6 | 12 | 18 | 24
Response format	<NR1>		
Comments	—		

5.3.3.44 [:SENSe]:FILTer[1][:LPASs]:TCONstant <value>
[:SENSe]:Filter[1][:LPASs]:TCONstant?

Explanation	Sets and queries the time constant of the time constant filter on the A IN side		
Parameter	<value>	<NRf>	Time constant [s] Range: 1E−6 to 10E+3 (1-2-5 sequence)
Response format	<NR3>		
Comments	—		

5.3.3.45 [:SENSe]:FILTer2[:LPASs]:MOV <value>
[:SENSe]:Filter2[:LPASs]:MOV?

Explanation	Sets and queries the averaging time of the moving average filter on the B IN side		
Parameter	<value>	<NRf> <DISC>	Averaging time [s] Range: OFF, AUTO, or 1E−6 to 100 (1-2-5 sequence) Suffix “U” (10^{-6}) and “M” (10^{-3}) and unit “S” are available.
Response format	<DISC>		
Comments	If an arbitrary number is entered, it will be rounded to the nearest value.		

5.3.3.46 [:SENSe]:FILTer2[:LPASs]:SLOPe <value>
[:SENSe]:Filter2[:LPASs]:SLOPe?

Explanation	Sets and queries the attenuation slope of the time constant filter on the B IN side		
Parameter	<value>	<NRf>	Attenuation slope [dB/oct] Range: 6 | 12 | 18 | 24
Response format	<NR1>		
Comments	—		

5.3.3.47 [:SENSe]:FILTer2[:LPASs]:TCONstant <value>
[:SENSe]:Filter2[:LPASs]:TCONstant?

Explanation	Sets and queries the time constant of the time constant filter on the B IN side		
Parameter	<value>	<NRf>	Time constant [s] Range: 1E−6 to 10E+3 (1-2-5 sequence)
Response format	<NR3>		
Comments	—		

5.3.3.48 [:SENSe]:FREQuency[1]?

Explanation	Queries the frequency
Response format	<NR2> value Range: 9.5E−3 to 1.05E+6, Resolution: 7digits, Unit: Hz
Comments	—

5.3.3.49 [:SENSe]:FREQuency[1]:MULTiplier <value>
[:SENSe]:FREQuency[1]:MULTiplier?

Explanation	Sets and queries the harmonic order “n” when measuring a harmonic on the A IN side		
Parameter	<value>	<NRf>	Harmonic order “n” Range: 1 to 63
Response format	<NR1>		
Comments	—		

5.3.3.50 [:SENSe]:FREQuency[1]:SMULtiplier <value>
[:SENSe]:FREQuency[1]:SMULtiplier?

Explanation	Sets and queries the subharmonic order “m” common to the A IN and B in side when measuring subharmonics		
Parameter	<value>	<NR1>	Subharmonic order “m” Range: 1 to 64
Response format	<NR1>		
Comments	—		

5.3.3.51 [:SENSe]:FREQuency2:MULTiplier <value>
[:SENSe]:FREQuency2:MULTiplier?

Explanation	Sets and queries the harmonic order “n” measuring a harmonic on the B IN side		
Parameter	<value>	<NR1>	Harmonic order “n” Range: 1 to 63
Response format	<NR1>		
Comments	—		

5.3.3.52 [:SENSe]:PHASe[1] <value>
[:SENSe]:PHASe[1]?

Explanation	Sets and queries the phase shift amount on the A IN side		
Parameter	<value>	<NRf>	Phase shift amount [°] Range: −180.000 to +179.999 Resolution: 0.001
Response format	<NR2>		
Comments	—		

5.3.3.53 [:SENSe]:PHASe[1]:AUTO:ONCE

Explanation	Automatically adjusts the phase shift amount so that the A IN side θ becomes zero
Comments	When this adjustment is done, signal amplitude can be determined from the parameter “X” and phase change can be determined from the parameter “Y”.

5.3.3.54 [:SENSe]:PHASe2 <value>
[:SENSe]:PHASe2?

Explanation	Sets and queries the phase shift amount on the B IN side		
Parameter	<value>	<NRf>	Phase shift amount [°] Range: –180.000 to +179.999 Resolution: 0.001
Response format	<NR2>		
Comments	—		

5.3.3.55 [:SENSe]:PHASe2:AUTO:ONCE

Explanation	Automatically adjusts the phase shift amount so that the B IN side θ becomes zero
Comments	When this adjustment is done, signal amplitude can be determined from the parameter “X” and phase change can be determined from the parameter “Y”.

5.3.3.56 [:SENSe]:ROSCillator:SOURce <value>
[:SENSe]:ROSCillator:SOURce?

Explanation	Sets and queries the reference frequency source for frequency synthesis		
Parameter	<value>	<DISC>	Reference frequency source INTernal: Internal EXTernal: External (10 MHz IN terminal)
Response format	<DISC>		
Comments	—		

5.3.3.57 [:SENSe]:VOLTage[1]:AC:RANGe[:UPPer] <value>
[:SENSe]:VOLTage[1]:AC:RANGe[:UPPer]?

Explanation	Sets and queries the voltage sensitivity on the A IN side		
Parameter	<value>	<NRf>	Voltage sensitivity [V] When the dynamic reserve is HIGH Range: 5E-6 to 1 (1-2-5 sequence) When the dynamic reserve is MED Range: 1E-6 to 1 (1-2-5 sequence) When the dynamic reserve is LOW2 Range: 100E-9 to 100E-3 (1-2-5 sequence) When the dynamic reserve is LOW1 Range: 10E-9 to 10E-3 (1-2-5 sequence) Suffix “N” (10^{-9}), “U” (10^{-6}), and “M” (10^{-3}) and unit “V”, “MAX”, and “MIN” are available.
Response format	<NR2>		
Comments	If the voltage sensitivity is out of range due to changing the dynamic reserve, it is automatically set to the nearest value within the range.		

5.3.3.58 [:SENSe]:VOLTage2:AC:RANGe[:UPPer] <value>
[:SENSe]:VOLTage2:AC:RANGe[:UPPer]?

Explanation	Sets and queries the voltage sensitivity on the B IN side		
Parameter	<value>	<NRf>	Voltage sensitivity [V] When the dynamic reserve is HIGH Range: 5E-6 to 1 (1-2-5 sequence) When the dynamic reserve is MED Range: 1E-6 to 1 (1-2-5 sequence) When the dynamic reserve is LOW2 Range: 100E-9 to 100E-3 (1-2-5 sequence) When the dynamic reserve is LOW1 Range: 10E-9 to 10E-3 (1-2-5 sequence) Suffix “N” (10^{-9}), “U” (10^{-6}), and “M” (10^{-3}) and unit “V”, “MAX”, and “MIN” are available.
Response format	<NR2>		
Comments	If the voltage sensitivity is out of range due to changing the dynamic reserve, it is automatically set to the nearest value within the range.		

5.3.3.59 :SOURce:FREQuency[:CW] <value>
:SOURce:FREQuency[:CW]?

Explanation	Sets and queries the internal oscillator frequency		
Parameter	<value>	<NRf>	Frequency [Hz] Range: 9.5E-3 to 1.05E+6 Resolution: 6 digits Suffix “M” (10^{-3}), “K” (10^{3}), and “MA” (10^{6}) and unit “HZ”, “MAX”, and “MIN” are available.
Response format	<NR2>		
Comments	—		

5.3.3.60 :SOURce:FREQuency:MULTiplier <value>
:SOURce:FREQuency:MULTiplier?

Explanation	Sets the oscillator output frequency to “n” times the internal oscillator frequency and queries the harmonic order “n”		
Parameter	<value>	<NRf>	Harmonic order “n” Range: 1 to 63
Response format	<NR1>		
Comments	—		

5.3.3.61 :SOURce:OUTPut <value>
:SOURce:OUTPut?

Explanation	Sets and queries the output state of the OSC OUT terminal		
Parameter	<value>	<BOL>	Output state ON | OFF
Response format	<NBOL>		
Comments	Only AC waveforms can be turned on and off. The DC offset is not affected.		

5.3.3.62 :SOURce:PHASe <value>

:SOURce:PHASe?

Explanation	Sets and queries the phase of the internal oscillator		
Parameter	<value>	<NRf>	Phase [°] Range: −180.000 to +179.999 Resolution: 0.001
Response format	<NR2>		
Comments	—		

5.3.3.63 :SOURce:PHASe:INITiate <value>

Explanation	Executes phase synchronization of the internal oscillator
Comments	—

5.3.3.64 :SOURce:TYPE <value>

:SOURce:TYPE?

Explanation	Sets and queries the wave form of the internal oscillator		
Parameter	<value>	<DISC>	Waveform SINusoid: Sine wave TTL: TTL-level square wave
Response format	<DISC>		
Comments	—		

5.3.3.65 :SOURce:VOLTage[:LEVel][:IMMediate][:AMPLitude] <value>

:SOURce:VOLTage[:LEVel][:IMMediate][:AMPLitude]?

Explanation	Sets and queries the output amplitude of the internal oscillator		
Parameter	<value>	<NRf>	Amplitude [Vrms] Range: 0.000 to 1.000 Resolution: 0.001
Response format	<NR2>		
Comments	—		

5.3.3.66 :SOURce:VOLTage[:LEVel][:IMMediate]:OFFSet <value>

:SOURce:VOLTage[:LEVel][:IMMediate]:OFFSet?

Explanation	Sets and queries the DC offset voltage of the internal oscillator		
Parameter	<value>	<NRf>	Offset voltage [VDC] Range: –5.000 to +5.000 Resolution: 0.005
Response format	<NR2>		
Comments	—		

5.3.3.67 :STATus:OPERation:CONDition?

Explanation	Queries the operation status condition register
Response format	<NR1>
Comments	—

5.3.3.68 :STATus:OPERation:ENABle <value>

:STATus:OPERation:ENABle?

Explanation	Sets and queries the operation status event enable register		
Parameter	<value>	<NRf>	Operation status event enable register Range: 0 to 65535 Resolution: 1 Default: 0
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the “*RST” command		

5.3.3.69 :STATus:OPERation[:EVENt]?

Explanation	Queries the operation status event register
Response format	<NR1>
Comments	It will be cleared if the event register is queried or the “*CLS” command is received.

5.3.3.70 :STATus:OPERation:NTRansition <value>

:STATus:OPERation:NTRansition?

Explanation	Sets and queries the negative operation status transition filter		
Parameter	<value>	<NRf>	Negative operation status transition filter Range: 0 to 65535 Resolution: 1 Default: 0
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the “*RST” command		

5.3.3.71 :STATus:OPERation:PTRansition <value>

:STATus:OPERation:PTRansition?

Explanation	Sets and queries the positive operation status transition filter		
Parameter	<value>	<NRf>	Positive operation status transition filter Range: 0 to 65535 Resolution: 1 Default: 5296 (LI5501) 5552 (LI5502)
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the “*RST” command		

5.3.3.72 :STATus:QUEStionable:CONDition?

Explanation	Queries the questionable condition register
Response format	<NR1>
Comments	—

5.3.3.73 :STATus:QUEStionable:ENABle <value>

:STATus:QUEStionable:ENABle?

Explanation	Sets and queries the questionable event enable register		
Parameter	<value>	<NRf>	Questionable event enable register Range: 0 to 65535 Resolution: 1 Initial value: 0
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the "*RST" command		

5.3.3.74 :STATus:QUEStionable[:EVENt]?

Explanation	Queries the questionable event register
Response format	<NR1>
Comments	It is cleared when querying the event register or the "*CLS" command is received.

5.3.3.75 :STATus:QUEStionable:NTRansition <value>

:STATus:QUEStionable:NTRansition?

Explanation	Sets and queries the questionable status negative transition filter		
Parameter	<value>	<NRf>	Negative transition filter Range: 0 to 65535 Resolution: 1 Initial value: 0
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the "*RST" command		

5.3.3.76 :STATus:QUEStionable:PTRansition <value>

:STATus:QUEStionable:PTRansition?

Explanation	Sets and queries the questionable status positive transition filter		
Parameter	<value>	<NRf>	Positive transition filter Range: 0 to 65535 Resolution: 1 Initial value: 339 (LI5501) 351 (LI5502)
Response format	<NR1>		
Comments	It is initialized when the power is turned on. Not initialized by the "*RST" command		

5.3.3.77 :SYSTem:FAN:CONTrol <value>

:SYSTem:FAN:CONTrol?

Explanation	Sets and queries the internal fan setting		
Parameter	<value>	<DISC>	Fan control ON: Always on OFF: Always off AUTO: When the CPU temp. exceeds about 60 °C, it is turned on and when the CPU temp. falls below about 55 °C, it is turned off.
Response format	<DISC>		
Comments	—		

5.3.3.78 :SYSTem:ERRor?

Explanation	Queries remote errors		
Response format	<code>,<message>		
	<code>	<NR1>	Error code
	<message>	<STR>	Error message
Comments	• <message> includes double quotation marks. • The error queue can hold up to 16 error messages and the message can be read one by one in order of oldest first. • If there are more than 16 error messages, the last message in the error queue will be replaced by “Queue overflow” and a new error will not be added until there is a room in the error queue. • The error queue will be cleared when the “*CLS” command is received.		

5.3.3.79 :SYSTem:REMote:LAN:IPADdress <value>

:SYSTem:REMote:LAN:IPADdress?

Explanation	Sets and queries the IP address		
Parameter	<value>	<STR>	IP address Range: 0 to 255 XXX. XXX. XXX. XXX Example) 192. 168. 0. 2
Response format	<STR>		
Comments	—		

5.3.3.80 :SYSTem:REMote:LAN:MASK <value>

:SYSTem:REMote:LAN:MASK?

Explanation	Sets and queries the subnet mask		
Parameter	<value>	<STR>	Subnet mask Range: 0 to 255 XXX. XXX. XXX. XXX Example) 255. 255. 255. 0
Response format	<STR>		
Comments	—		

5.3.3.81 :SYSTem:REMote:LAN:GATE <value>

:SYSTem:REMote:LAN:GATE?

Explanation	Sets and queries the default gateway		
Parameter	<value>	<STR>	Default gateway Range: 0 to 255 XXX. XXX. XXX. XXX Example) 192. 168. 0. 1
Response format	<STR>		
Comments	—		

5.3.3.82 :SYSTem:RST

Explanation	Initializes settings Unlike the "*RST" command, this command also clears contents of the configuration memories from No.1 to 14.
Comments	—

5.3.3.83 :TRIGger:DELay <value>

:TRIGer:DELay?

Explanation	Sets and queries the trigger delay time		
Parameter	<value>	<NRf>	Delay time [s] Range: 0 to 1.67 s (1.6777212 s)
Response format	<NR2>		
Comments	—		

5.3.3.84 :TRIGger[:IMMediate]

Explanation	When the measurement data buffer is enabled, measurement data is recorded in the buffer by a trigger.
Comments	—

5.3.3.85 :TRIGger:SOURce <value>

:TRIGer:SOURce?

Explanation	Sets and queries the trigger source		
Parameter	<value>	<DISC>	Trigger source EXTernal: By external signal BUS: By communication Use the ":TRIGger[:IMMediate]" command.
Response format	<DISC>		
Comments	—		

5.4 Status system

5.4.1 Overview of status system

The status system of the **LI5501 / LI5502** is illustrated in **"Figure 5-22"**.

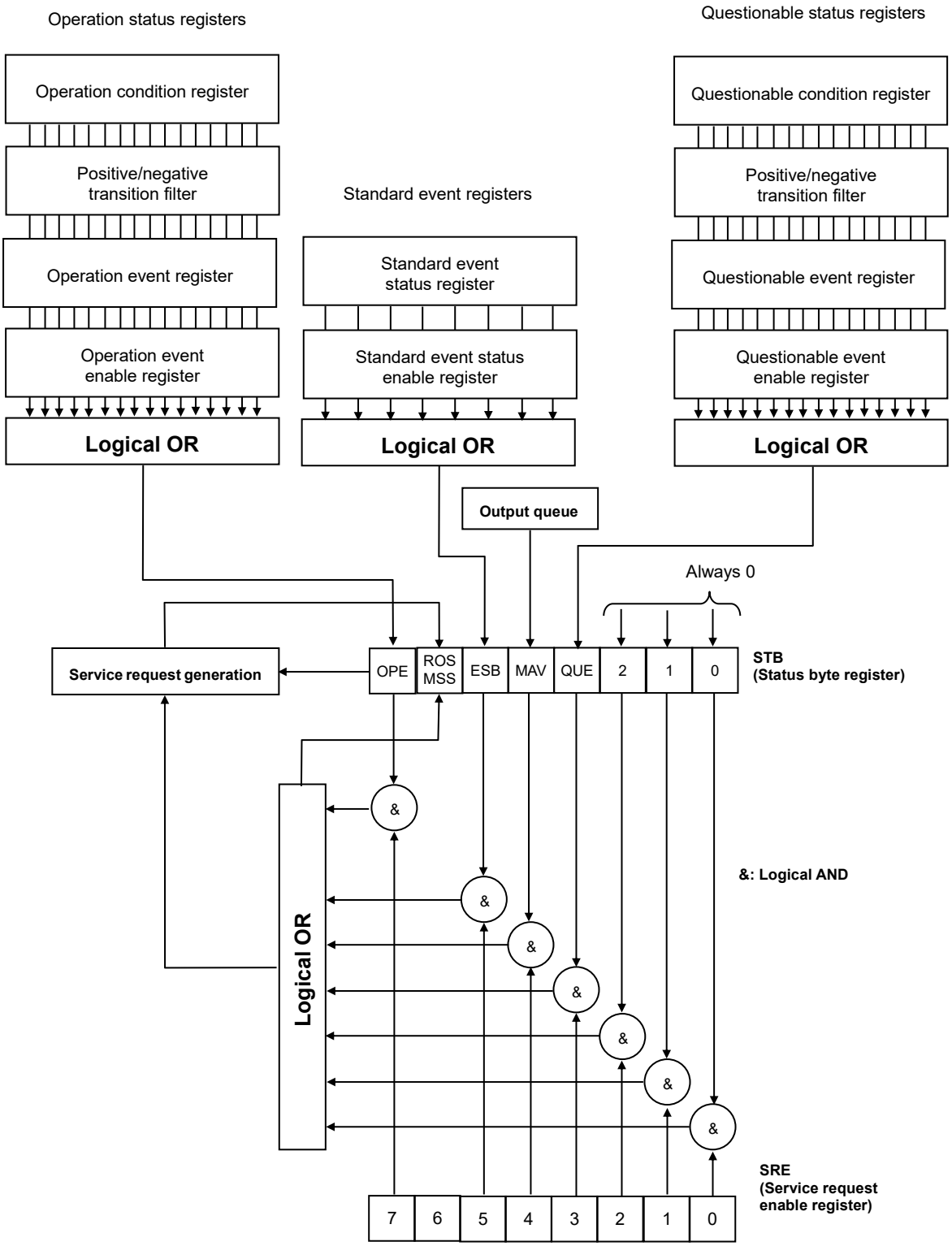


Figure 5-22 Status system

5.4.2 Status byte

The definition of the status byte register is described in **"Table 5-4"**. The status byte can be read by serial polling. In this case, bit "6" is RQS (Request service).

Table5-4 Definitions of the status byte register

Bit		Weight	Condition for setting to "1"	Condition for setting to "0"
OPE	7	128	When any of the effective bits of the operation status event register is set to "1"	When all of the effective bits of the operation status event register are set to "0"
RQS/ MSS	6	64	When SRQ is sent	· When the device clear is received · When RQS reads the status byte by serial polling
ESB	5	32	When one of the effective bits of the standard event status register becomes "1"	When all of the effective bits of the standard event status register become "0"
MAV	4	16	When a response to the query has been prepared and can be output	When all of responses have been output and there are no more responses to be output
QUE	3	8	−	Always "0" (not used)
−	2	4	−	Always "0" (not used)
−	1	2	−	Always "0" (not used)
−	0	1	−	Always "0" (not used)

■ **Relevant commands and queries**

***STB?**

This command can query contents of the status byte register.
Bit "6" is MSS (Master Summary Status).

***SRE, *SRE?**

These commands can set and query the service request enable register.
Immediately after the power is turned on, the register will have been cleared to zero.
The status byte register bits will become effective when the corresponding bits in the service request enable register are set to "1". The service request will be issued when any one of the effective bits is set to "1".

Parameters for setting and response messages to each register are the sums of all the weights of the bits that have the value of "1".

■ **Checking status when making a query**

Normally, a correct response message can be received after a query has been sent, and it is not necessary to check the MAV bit of the status byte. If it is necessary to proceed with processes while the MAV bit is being checked, first check that the MAV bit of the status byte is "1" by serial polling after the query is sent and then read the response message. Then confirm that the MAV bit has changed to "0" and proceed with the next operation.

5.4.3 Standard event status

The structure of the standard event status is illustrated in **"Figure 5-23"**, and the details of the status are described in **"Table 5-5"**. If the bits of the standard event status enable register are set to "1", the corresponding bits of the standard event status register will be enabled, and if any of the enabled bits become the value "1", the ESB bit of the status byte register will be set to "1".

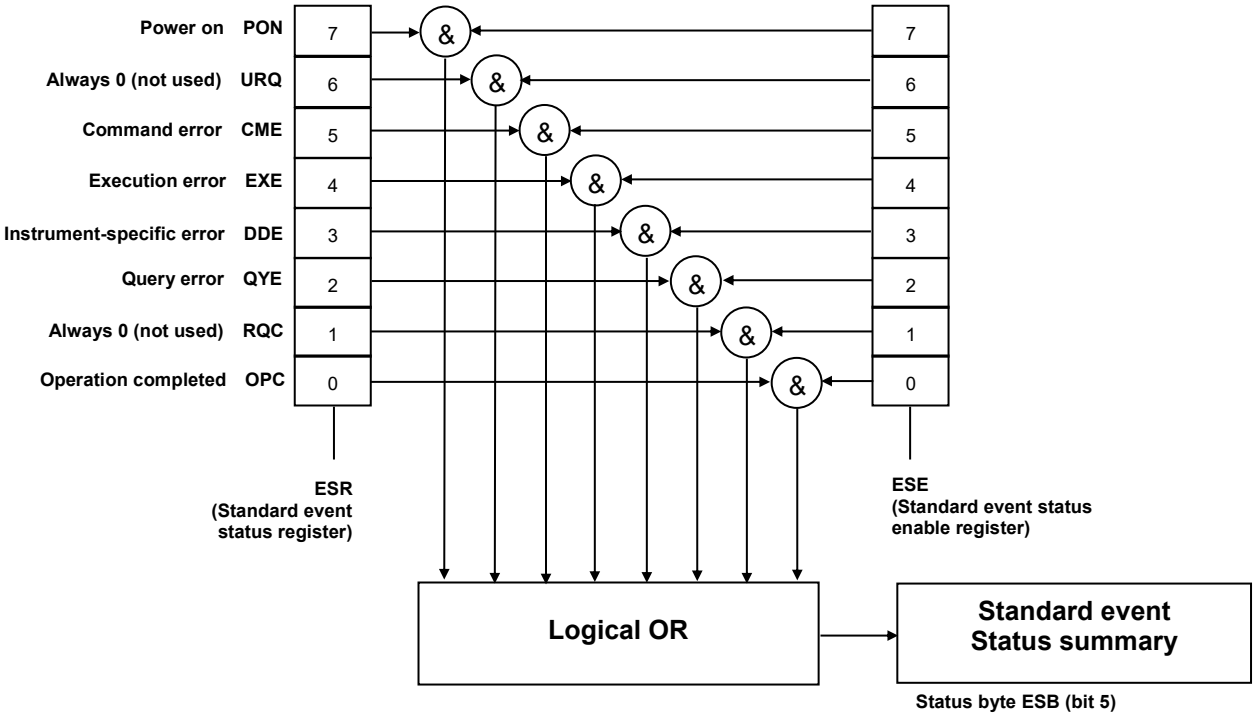


Figure 5-23 Structure of the standard event status

Table5-5 Contents of the standard event status register

Bit		Weight	Content
PON	7	128	Power-on This bit will be set to “1” when the power is turned on. It will remain “0” until the power is turned on again when this register is read and the value is cleared to “0”.
URQ	6	64	User’s request Always “0” (not used)
CME	5	32	Command error This bit will be set to “1” if there is a syntax error in a remote command.
EXE	4	16	Execution error This bit will be set to “1” if a parameter is out of range or there is a conflict in setting.
DDE	3	8	Instrument-specific error This bit will be set to “1” if the error queue is overflowed.
QYE	2	4	Query error This bit will be set to “1” if a read attempt is made when there is no data in the output buffer or if the data in the output buffer has been lost.
RQC	1	2	Request control Always “0” (not used)
OPC	0	1	Operation completed This bit will be set to “1” when processing for all commands up to the *OPC command has been completed.

■ **Relevant commands and queries**

***ESR?**

This command can query contents of the standard event status register.

The register will be cleared to “0” if it is queried. The “*CLS” command also can clear the register.

The register will have been cleared to “0” immediately after the power is turned on, but the PON bit will have been set to “1”.

***ESE, *ESE?**

These commands can set and query the standard event status enable register.

Set the value “0” to clear the register to “0”.

There are no other clear commands.

The register will have been cleared to “0” immediately after the power is turned on.

Parameters for setting and response messages to each register are the sums of all the weights of the bits that have the value of “1”.

5.4.4 Operation status

The structure of the operation status is illustrated in **"Figure 5-24"**.
The operation condition register (OPCR) indicates a status of the **LI5501 / LI5502** as shown in **"Table 5-6"**. The transition filter can detect changes in the conditions and generates events. Generating an event requires settings of the transition filter. The operation status event register can store generated events. If the operation status event enable register bits are set to "1", the corresponding bits of the operation status event register will be enabled. If the value of any of the enabled bits is set to "1", the OPE bit of the status byte will be set to "1".

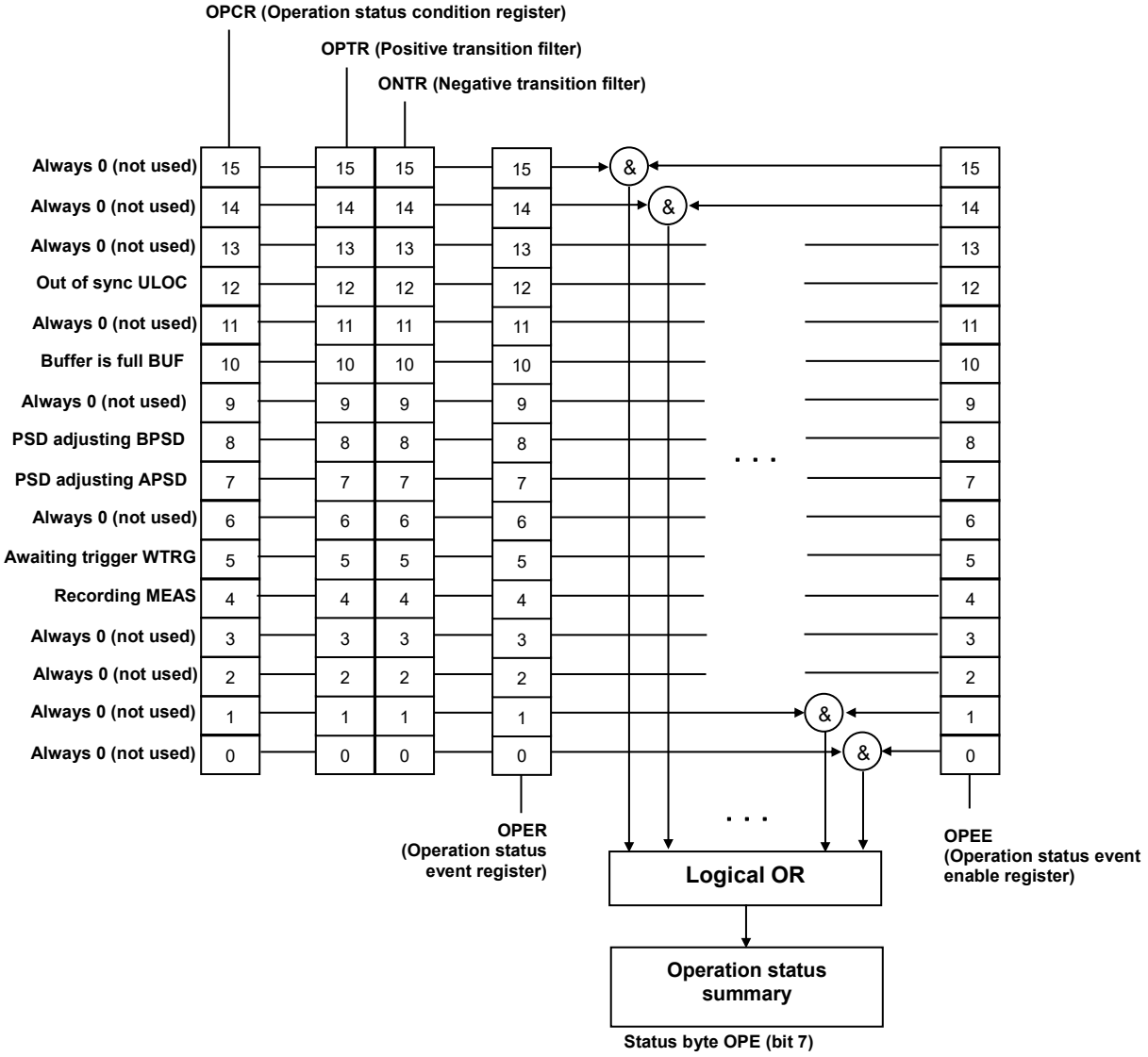


Figure 5-24 Structure of the operation status

Table5-6 Contents of the operation status condition register

Bit		Weight	Content
—	15	32768	Always “0” (not used)
—	14	16384	Always “0” (not used)
—	13	8192	Always “0” (not used)
ULOC	12	4096	Not synchronized with external reference frequency (10 MHz)
—	11	2048	Always “0” (not used)
BUF	10	1024	The buffer is full.
—	9	512	Always “0” (not used)
BPSD	8	256	Adjusting DC offset to zero on the B in side
APSD	7	128	Adjusting DC offset to zero on the A in side
—	6	64	Always “0” (not used)
WTRG	5	32	Awaiting trigger
MEAS	4	16	Recording
—	3	8	Always “0” (not used)
—	2	4	Always “0” (not used)
—	1	2	Always “0” (not used)
—	0	1	Always “0” (not used)

Note: When an external trigger is used, the MEAS bit is always “0”.

■ **Relevant commands and queries**

:STATus:OPERation:CONDition?

This command can query contents of the operation status condition register.

The register will not be cleared to “0” if it is queried

The status of the instrument is always indicated.

:STATus:OPERation[:EVENt]?

This command can query the operation status event register.

The register will be cleared to “0” if it is queried.

The register can also be cleared by the “*CLS” command.

The register will have been cleared to “0” immediately after the power is turned on.

:STATus:OPERation:ENABle , STATus:OPERation:ENABle?

This command can set and query the operation status event enable register.

Set the value "0" to clear the register to "0".

There are no other clear commands.

The register will have been cleared to "0" immediately after the power is turned on.

:STATus:OPERation:NTRansition, STATus:OPERation:NTRansition?

:STATus:OPERation:PTRansition, STATus:OPERation:PTRansition?

These commands can set and query the operation status transition filters.

The relationships between a transition filter setting and event register transition are shown in **"Table 5-7"**.

Table5-7 Transition filter settings and the event register transitions

Positive transition filter bit	Negative transition filter bit	Condition register transition for changing the event register to "1"
"1"	"0"	"0" → "1"
"0"	"1"	"1" → "0"
"1"	"1"	"0" → "1" or "1" → "0"
"0"	"0"	Event register cannot be changed to "1".

Parameters for setting and response messages to each register are the sums of all the weights of the bits that have the value of "1".

5.4.5 Questionable status

The structure of the questionable status is illustrated in **"Figure 5-25"**.
The questionable condition register indicates an abnormal staus of the **LI5501 / LI5502** as shown in **"Table 5-7"**. The transition filter can detect changes in the conditions and generates events. Generating an event requires settings of the transition filter. The questionable event register can store generated events. If the event enable register bits are set to "1", the corresponding bits of the event register will be enabled. If the value of any of the enabled bits is set to "1", the QUE bit of the status byte will be set to "1".

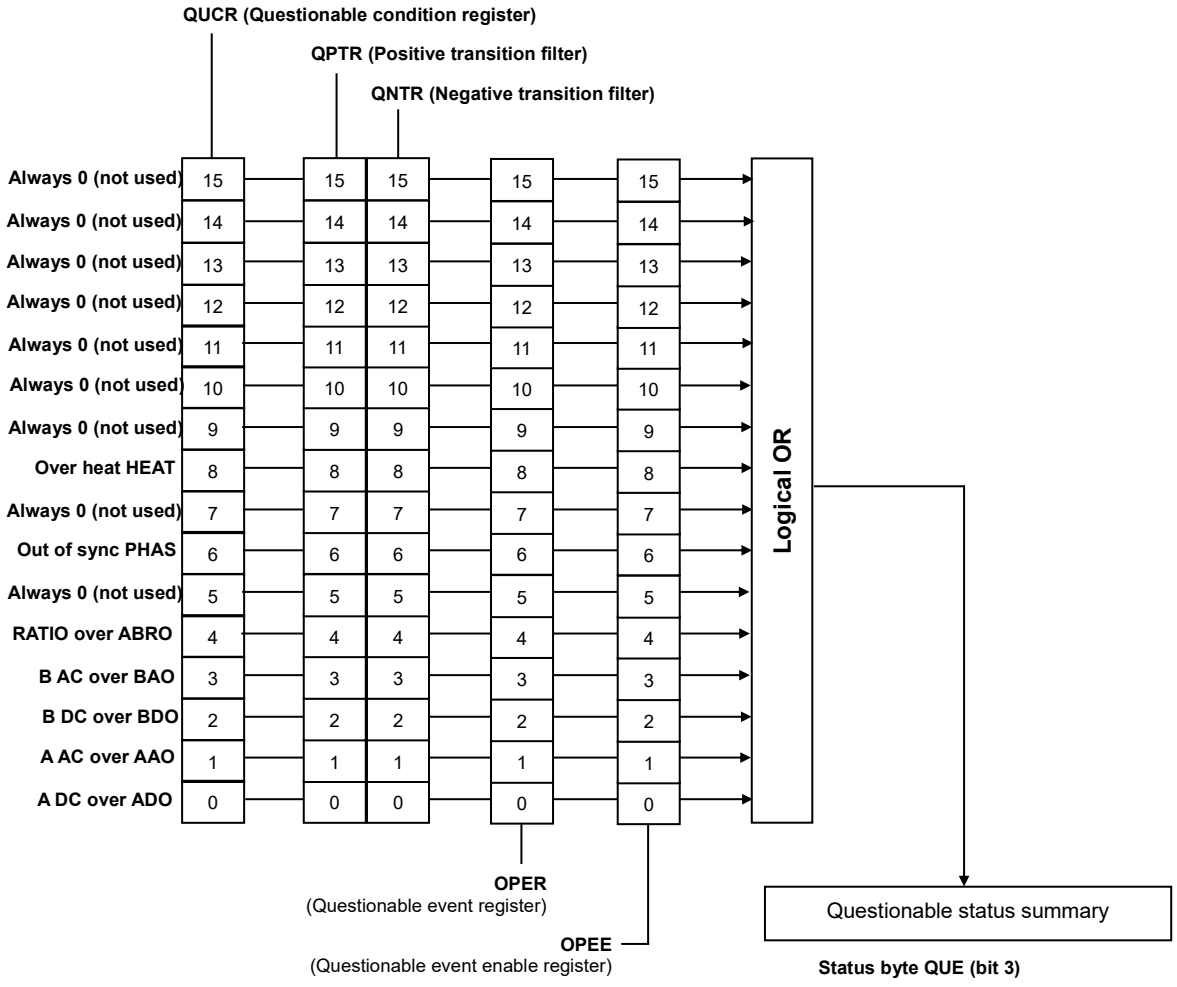


Figure 5-25 Structure of the questionable status

Table5-8 Contents of the questionable condition register

Bit		Weight	Content
—	15	32768	Always “0” (not used)
—	14	16384	Always “0” (not used)
—	13	8192	Always “0” (not used)
—	12	4096	Always “0” (not used)
—	11	2048	Always “0” (not used)
—	10	1024	Always “0” (not used)
—	9	512	Always “0” (not used)
HEAT	8	256	Overheated state
—	7	128	Always “0” (not used)
PHAS	6	64	Not synchronized with external reference signal
—	5	32	Always “0” (not used)
ABRO	4	16	Saturation in ratio operation
BAO	3	8	Saturation in the previous PSD stage on the B IN side
BDO	2	4	Saturation after PSD stage on the B in side*
AAO	1	2	Saturation in the previous PSD stage on the A IN side
ADO	0	1	Saturation after PSD stage on the A in side*

*Saturation in the time constant filter, DC GAIN, moving average filter, EXPAND, or operational parts

■ **Relevant commands and queries**

:STATus:QUEStionable:CONDition?

This command can query contents of the questionable condition register.

The register will not be cleared to “0” if it is queried.

The status of the instrument is always indicated.

:STATus:QUEStionable[:EVENt]?

This command can query the questionable event register.

The register will be cleared to “0” if it is queried.

The register can also be cleared by the “*CLS” command.

The register will have been cleared to “0” immediately after the power is turned on.

:STATus:QUEStionable:ENABle, STATus:QUEStionable:ENABle?

This command can set and query the questionable event enable register.

Set the value “0” to clear the register to “0”.

There are no other clear commands.

The register will have been cleared to “0” immediately after the power is turned on.

:STATus:QUEStionable:NTRansition, STATus:QUEStionable:NTRansition?

:STATus:QUEStionable:PTRansition, STATus:QUEStionable:PTRansition?

This command can set and query the questionable transition filter.

The relationships between a transition filter setting and event register transition are shown in **"Table 5-9"**.

Table5-9 Transition filter settings and the event register transitions

Positive transition filter bit	Negative transition filter bit	Condition register transition for changing the event register to "1"
"1"	"0"	"0" → "1"
"0"	"1"	"1" → "0"
"1"	"1"	"0" → "1" or "1" → "0"
"0"	"0"	Event register cannot be changed to "1".

Parameters for setting and response messages to each register are the sums of all the weights of the bits that have the value of "1".

5.5 Error messages

In this section, primary errors that occur in the remote control are described.

Table5-10 Error messages 1/2

Error number	Error message	Description
0	No error	No abnormality
-100	Command error	There is an abnormality in the command (no detailed classification).
-101	Invalid character	There is an abnormality in the text data.
-102	Syntax error	The command or data that cannot be recognized has been received.
-103	Invalid separator	There is an abnormality in the command separators.
-104	Data type error	The parameter format is inappropriate.
-108	Parameter not allowed	There are too many parameters or there are parameters where it cannot be used.
-109	Missing parameter	Not enough parameters
-110	Command header error	There is an abnormality in the command header (no detailed classification).
-113	Undefined header	The command header is undefined.
-115	Unexpected number of parameters	There is an abnormality in the number of parameters.
-120	Numeric data error	There is an abnormality in the numerical data (no detailed classification).
-123	Exponent too large	The exponent is too large (greater than 32000).
-124	Too many digits	A number has too many digits (more than 255-digit).
-130	Suffix error	There is an abnormality in the SI prefix or unit (no detailed classification).
-134	Suffix too long	The SI prefix or unit is too long (more than 7 characters).
-140	Character data error	There is an abnormality in the text data (no detailed classification).
-144	Character data too long	The text data is too long.
-150	String data error	There is an abnormality in the string data (no detailed classification).
-200	Execution error	The command could not be executed (no detailed classification).
-221	Settings conflict	The command cannot be executed because of constraint conflicts among multiple settings.
-222	Data out of range	The data is outside of the valid range.
-224	Illegal parameter value	The parameters are incorrect (inappropriate other than “Data type error”).

Table5-10 Error message 2/2

Error number	Error message	Description
-310	System error	An instrument-specific internal error has occurred. (memory contents were lost, etc.)
-350	Queue overflow	The error queue has overflowed and cannot accommodate new errors. (more than 16 error queues)
-363	Input buffer overrun	The input buffer has been overflowed.
-430	Query DEADLOCKED	The buffer was full and the processing cannot proceed. The output buffer will be cleared.
-440	Query UNTERMINATED after indefinite response	There was a query following "*IDN?" in the text string ("*IDN?" must be the last query in received text string.).

Errors relevant to the remote control are stored in the error queue and can be read one at a time in order of oldest first with the ":SYSTem:ERRor?" query. If a read operation is executed after all of the errors have been read, "0, "No error"" will be returned. The error queue can be cleared with the "*CLS" command.
If a problem occurs that results in data remaining in the input buffer or output buffer, the buffers can be cleared with the device clear messages (DCL, SDC).

A error other than those described above may occur in some situations. In such case, check the error message for a summary.

6. Advanced settings

6.1 Measurement data buffer

The **LI5501 / LI5502** can acquire measurement data in two ways: Streaming, which uses the internal memory and can acquire a large amount of data, and Querying, which queries the latest measurement data with the ":FETCh?" command.
This section describes setting items for these data acquisition ways.

6.1.1 Setting of measurement data parameters

Up to 7 measurement data (7 words) parameters to be obtained can be selected from the **"Table 6-1"**.

Table6-1 Measurement data parameters

Weight	Parameter	Description	Bit length	
			Streaming	Querying
1	STATUS	Status	16 bits	16 bits
2	FREQ-H	Upper bits of reference signal frequency	16 bits	16 bits
4	FREQ-L	Lower bits of reference signal frequency	16 bits	20 bits
8	X_A	X value on the A IN side	16 bits	18 bits
16	Y_B	Y value on the A IN side	16 bits	18 bits
32	R_A	R value on the A IN side	16 bits	20 bits
64	θ_A	θ value on the A IN side	16 bits	20 bits
128	X_B	X value on the B IN side	16 bits	18 bits
256	Y_B	Y value on the B IN side	16 bits	18 bits
512	R_B	R value on the B IN side	16 bits	20 bits
1024	θ_B	θ value on the B IN side	16 bits	20 bits
2048	RATIO	Amplitude ratio of R_A to R_B	16 bits	20 bits
4096	PHASE	Phase difference between θ_A and θ_B	16 bits	20 bits

The "STATUS" descriptions are shown in below.

Weight	STATUS	Description
1	——	Indefinite
2	——	Indefinite
4	——	Indefinite
8	RATIO over	Saturation in ratio operation
16	MOV over (B)	Saturation in the MOV filter or EXPAND on the B IN side
32	MOV over (A)	Saturation in the MOV filter or EXPAND on the A IN side
64	LPF over (B)	Saturation in the TC filter or DC GAIN on the B IN side
128	LPF over (A)	Saturation in the TC filter or DC GAIN on the A IN side
256	ADC over (B)	Saturation in the previous PSD stage on the B IN side
512	ADC over (A)	Saturation in the previous PSD stage on the A IN side
1024	——	Indefinite
2048	——	Indefinite
4096	——	Indefinite
8192	——	Indefinite
16384	OSC over	Overvoltage at the oscillator output
32768	UNLOCK	No synchronization

6.1.2 Format

1) Streaming

Measured data is read in order of ascending weight of parameters.
The data is sent in blocks of one measurement data without a comma or message terminator.
The measured value can be obtained using the following formula after converting signed 4-digit hexadecimal (16 bits) to signed 16-bit integer format (−32,768 to 32,767).

Measured value = Measured data × 2^{-15} × 1.2 × full-scale of a meter (See below.)

The actual value of parameter received in integer format can be determined by the bit length recorded in the measurement data buffer using the following formula.

Parameter	Formula
R	Measured value = Measured data × 2^{-15} ×1.2 × (Sensitivity / EXPAND)
X Y	Measured value = Meter value × (Sensitivity / EXPAND) Meter value = Measured data × 2^{-15} ×1.2
RATIO	Measured value = Measured data × 2^{-15} × (5 / 3) × 2.4 × Sensitivity ratio Sensitivity ratio = (A IN Sensitivity / B IN Sensitivity) × (A IN EXPAND / B IN EXPAND)
θ PHASE	Measured value = Measured data × 2^{-15} ×180°
Frequency	Frequency = (A × 2^{16} + B) × 2^{-33} × 2.5 MHz Measured frequency data is transferred after divided unsigned 8-digit hexadecimal data (32 bits) into A: FREQ-H and B: FREQ-L. This is converted to an unsigned 16-bit integer format (0 to 65,535) and the measurement value can be calculated from it.

If the sensitivity setting when querying measured data is different from the setting when recording the data, correct measurement results cannot be obtained.

2) Querying

Measured data can be read by the ":FETCh?" command in order of ascending weight of parameters.

Each value is separated by commas.

The actual value of parameter received in integer format can be determined by the bit length recorded in the measurement data buffer using the following formula.

Parameter	Formula
R	Measured value = Measured data × 2^{-19} × 1.2 × (Sensitivity / EXPAND)
X Y	Measured value = Meter value × (Sensitivity / EXPAND) Meter value = Measured data × 2^{-17} × 1.2 If a calculated meter value is greater than or equal to 1.2, subtract 2.4 to obtain a range of −1.2 to 1.2.
RATIO	Measured value = Measured data × 2^{-19} × 2.4 ×Sensitivity ratio Sensitivity ratio = (A IN Sensitivity / B IN Sensitivity) × (A IN EXPAND / B IN EXPAND)
θ PHASE	Measured value = Measured data × 2^{-19} × 180° If a calculated value is greater than or equal to 180, subtract 360 to obtain a range of −180.000 to +179.999.
Frequency	Frequency = (A × 2^{20} + B) × 2^{-37} × 2.5 MHz A measured frequency data is transferred after divided into A: FREQ-H and B: FREQ-L.

If the sensitivity setting when querying measured data is different from the setting when recording the data, correct measurement results cannot be obtained.

6.1.3 Triggering system

This section describes settings for continuous data acquisition using the measurement data buffer.

1) Sampling interval

This is the sampling interval for data acquisition.

- Range: 0.4 µs to 26.2 ms

2) Buffer size

This is the number of samples per trigger.

- Range: 1 to 65536 or INF (continuous)

3) Trigger source

Select the trigger source from the remote control command by computer (BUS) or external signal (EXT) to the trigger pin in the power supply terminal.

When the trigger source is EXT, the instruments is triggered by falling edge of an external signal.

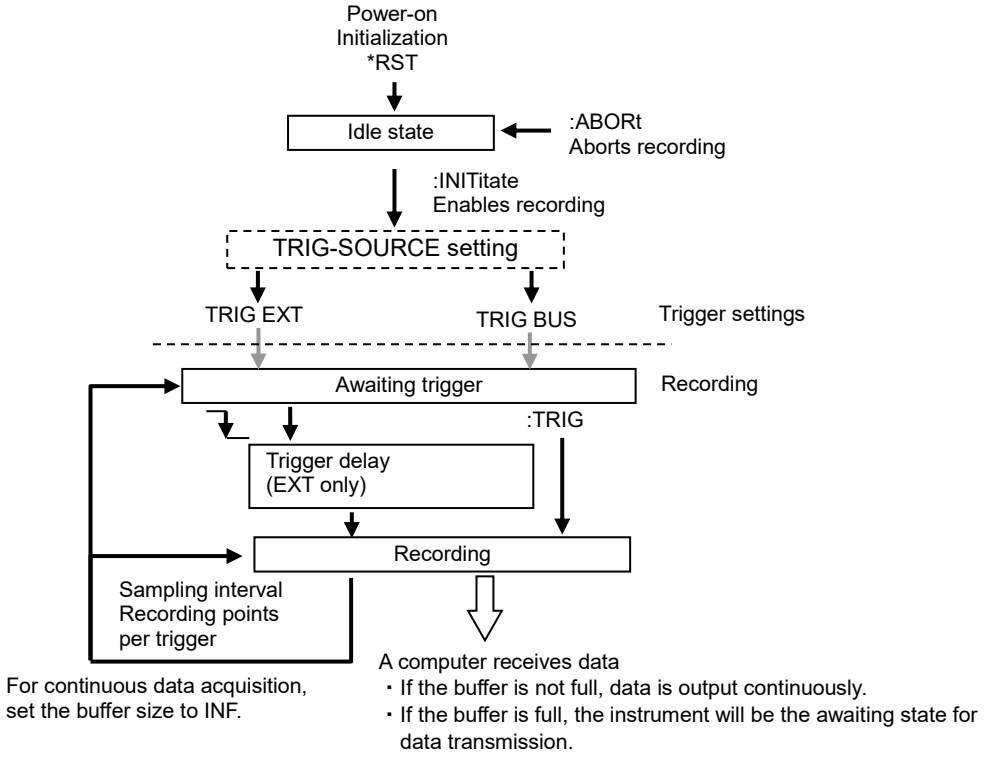
- Trigger source: BUS or EXT

4) Trigger delay

When the trigger source is EXT, set the trigger delay.

When the trigger source is BUS, adjust a timing on a computer side.

- Range: 0 to 1.67 s



6.1.4 Sample programs of data acquisition

Sample programs using the measurement data buffer are shown below.

Example 1) Records measurement data at arbitrary timing and then reads them together

```
Send (":ABOR")
    ' If recording is in progress, it is aborted.
Send (":DATA:FEED 96")
    ' Sets the measurement data set for recording
Send (":DATA:POIN 1")
    ' Sets the number of samples per trigger
Send (":DATA:FEED:CONT ALW")
    ' Enables recording into the measurement data buffer
Send (":TRIG:SOUR BUS")
    ' Sets the trigger source to the remote control command
Send (":INIT")
    ' Transition to the awaiting trigger state

Send (":TRIG")
    ' Applies the trigger to repeatedly record measurement data
    ' If the measurement data buffer becomes full during recording,
      the trigger system enters the idle state and further triggers are not accepted.

Send (":DATA:DATA? X")
    ' X: Number of required data points
    ' Requests sending measurement data
Receive (MLIN_1, PHAS_1, MLIN_2, PHAS_2, MLIN_3, PHAS_3, ...)
    ' Reads out measurement data from the measurement data buffer
```

Example 2) Reads out measurement data while recording it

```
Send (":ABOR")
    ' If recording is in progress, it is aborted.
Send (":DATA:FEED 96")
    ' Sets the measurement data set for recording
Send (":DATA:POIN INF")
    ' Sets the number of samples per trigger
Send (":DATA:FEED:CONT ALW")
    ' Enables recording into the measurement data buffer
Send (":DATA:PER 1E-3")
    ' Sets the recording cycle of measurement data
Send (":TRIG:SOUR BUS")
    ' Sets the trigger source to the remote control command
Send (":INIT")
    ' Transition to the awaiting trigger state
Send (":TRIG")
    ' Applies the trigger to repeatedly record measurement data
    ' If the measurement data buffer becomes full during recording,
      the trigger system enters the idle state and further triggers are not accepted.

Send (":DATA:COUNt?")
    ' Queries the number of data sampling points recorded in the buffer
    ' The number of samples requested by computer is less than or equal to
      recorded number of samples.
Send (":DATA:DATA? X")
    ' X: Number of required data points
    ' Requests sending measurement data
Receive (MLIN_1, PHAS_1, MLIN_2, PHAS_2, MLIN_3, PHAS_3, ... )
    ' Receives data on requested number of samples
    ' If readout is faster than recording, the buffer doesn't become full
      and recording can continue.
    ' If the buffer becomes full, no more data will be recorded.

Send (":DATA:FEED:CONT NEV")
    ' Stops recording after acquiring necessary data
```

6.2 Configuration memory

There are 16 sets of the configuration memory from No.0 to 15.

The No.1 to 14 memories are for user's memory. Frequently used settings can be saved to the memories and recalled when needed.

The No.15 memory is factory default settings memory. The factory default settings can be recalled.

The No.0 memory is the RESUME memory. The current settings are always saved to the memory during power-on and saved even when the power is turned off.

The MODE switch on the rear panel is used to recall settings stored in the configuration memory.

MODE Switch

"0" to "9" and "A" to "F" on the MODE switch correspond to the configuration memory numbers "0" to "9" and "10" to "15" respectively.

The table below summarizes the configuration memory.

Memory number	Function	User operation			
		Save	Recall	*RST	:SYS:RST
0	RESUME	Always	——	Initialized	Initialized
1 to 14	User's memory	By command	By command or switch	Unchanged	Initialized
15	Factory default settings	——	By command or switch	——	——

The RESUME memory can be initialized by the "*RST" command.

The RESUME and user's memory can be initialized by the ":SYS:RST" command.

6.2.1 Recall settings

1) MODE switch

The number set on the MODE switch is recalled at startup.

If the MODE switch is changed during power-on, settings stored in the memory number will be recalled.

If the mode switch is set to "0" when the power is turned on, the settings at the time the power is previously turned off are recalled.

2) Recall settings by remote control

Settings stored in specified memory number can be recalled by remote control.

6.2.2 Save settings

1) Save current settings

Current settings (contents of the RESUME memory) can be saved to a specified user's memory.

6.3 FAN control

This instrument contains electronic components that generate a lot of heat in small enclosure. Ambient temperature above 40 °C will shorten the life of the instrument. Therefore, the cooling fan is equipped with the instrument.
In acoustic or vibration measurement, the cooling fan may affect the measurement system, so turn it off if necessary.

The fan control can be set to always ON, always OFF, or AUTO. For details, refer to **"5.3.3.77 :SYSTem:FAN:CONTrol <value>"**.
In "AUTO" setting, the fan is automatically controlled according to measured temperature of the CPU inside the instrument. The fan will be turned on when the measured temperature exceeds about 60 °C and turned off when the temperature drops below about 55 °C.
The ventilation holes are provided on the sides of the instrument, and the airflow direction is as shown in the figure below.
The life of the fan in continuous operation is about 30,000 hours.
When the fan is turned on, dust or foreign matter may be absorbed into the enclosure, resulting in corrosion and failure. Periodic maintenance (cleaning) is recommended.

⚠ CAUTION

As an internal temperature of the instrument becomes hot, the enclosure and metal parts of the connectors also become hot.

(Blank)

7. Troubleshooting

7.1 Error messages

To check operational status of the instrument, check the LEDs on the rear panel or use the remote command. Refer to **"5.4 Status system"** and **"5.5 Error messages"** about the status system and error messages due to communication.
Main errors that occur during normal measurement are described in this section, along with their causes and how to deal with them.

If the instrument requires repair, please contact the NF Corporation or its authorized agent.
When requesting repair, please provide the error message and symptom.

An error message that are not described in this manual may also appear during unusual operations such as updating the instrument firmware. If other manuals are provided, refer to them as well.

7.2 Abnormalities during measurement

In addition to error detection by remote control, LEDs on the rear panel can be used to detect abnormalities.

LED name and Color	Description and cause	Handling
CONDITION Green	・The LED does not light up. ・The LED blinks during startup. The calibration data was lost and the specified performance cannot be maintained.	・Review the power supply voltage. ・Contact the NF Corporation or its authorized agent and request a repair.
EXT-CLK Green	・The LED blinks. When the external 10 MHz setting is enabled, no external 10 MHz signal is applied.	・Input a specified 10 MHz signal to the 10MHz IN terminal. ・Check if the input 10 MHz input signal can be driven. ・The instrument can work with the internal reference clock even when the LED is blinking.
UNLOCK Orange	・The LED lights up. The instrument is not synchronized with a reference signal	・An external reference signal is not connected. ・The related settings are not appropriate. ・The amplitude of the input signal is too low or out of the frequency range.
COMM ERR Orange	・The LED lights up. Communication failure occurred. The data buffer is full.	・Change data buffer settings.
A AC OVLD Orange	・The LED lights up. Saturation in the previous PSD stage on the A IN side	・Check input signal amplitude on the A IN side. ・Review the dynamic reserve setting on the A IN side.
A DC OVLD Orange	・The LED lights up. Saturation after the PSD on the A IN side	・Review settings of the time constant filter, DC GAIN, OFFSET, and EXPAND on the A IN side.
B AC OVLD* Orange	・The LED lights up. Saturation in the previous PSD stage on the B IN side	・Check input signal amplitude on the B IN side. ・Review the dynamic reserve setting on the B IN side.
B DC OVLD* Orange	・The LED lights up. Saturation after the PSD on the B IN side	・Review settings of the time constant filter, DC GAIN, OFFSET, and EXPAND on the B IN side.

*B AC/DC OVLD are **LI5502** only.

(Blank)

8. Maintenance

8.1 Introduction

The maintenance items required to keep the instrument in good condition for use are listed below.

• Operational inspection	Check whether the instrument is functioning properly.
• Performance test	Check whether the instrument is operating at the rated performance levels.
• Adjustment and calibration	If the instrument does not meet the specifications, the NF Corporation will adjust and calibrate the instrument to restore performance.
• Repair	If adjustment and calibration fail to improve performance, the NF Corporation will investigate the cause, locate the failure, and repair the instrument.

This instruction manual describes how you can easily check for proper operation of the instrument and performance test methods.
For more advanced inspection, adjustment, calibration, and repair, contact the NF Corporation or its authorized agent.

⚠ WARNING

There are high temperature locations and Precision electronic components inside the instrument. Do not remove the cover.
Inspection of the interior of the instrument should not be performed by anyone other than service technicians that have been trained to avoid hazards.

8.2 Daily maintenance

Before use, install the instrument in a location that satisfies the installation conditions.
Installation conditions → Refer to "2.2.2 Installation environment"
Clean the outside of the instrument using a soft cloth as necessary. To remove stubborn soiling, use a cloth that has been dampened with a mild detergent solution and squeezed well to remove excess liquid. Do not use organic solvents such as paint thinner or benzene, or a chemically-treated cloth. Doing so may result in degradation, a cloudy appearance, or peeling of paint.

8.3 Storage, repacking, and transport

The **LI5501 / LI5502** should be stored in a location that satisfies the storage conditions.
Storage conditions → Refer to "2.2.2 Installation environment".
When packing the instrument for transportation, etc., use a box that is sufficiently strong and large enough to provide a surplus of space. Fill the box with packing materials that can withstand the weight of the instrument so that it is fully protected.
Make sure that the package is handled with care to avoid strong shock during transport.

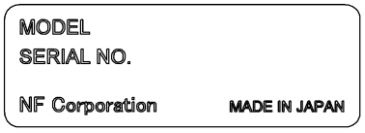
8.4 Checking the version number

Because the instrument continues to be improved, instruments may have the same model name but may have different firmware versions. Instruments that have different firmware versions may differ in operation. When a problem arises, be sure to include the firmware version number with description of the problem.

Use the "*IDN?" command to check the firmware version number.

■ Serial number

If the serial number cannot be checked by the "*IDN?" command, check the nomenclature label on the bottom of the instrument.



Nomenclature label

Label of
passing inspection

8.5 Performance tests

8.5.1 Introduction

The performance tests are a part of preventive maintenance and is performed to prevent degradation of instrument performance. The tests should be done for acceptance inspection, periodic inspections, and whenever it is necessary to check the performance, such as after repair.

The simple performance tests described here can be performed using commercially available standards and measurement instruments. For advanced tests, please contact the NF Corporation or its authorized agent. This is available for a charge.

If the performance tests indicate that the instrument does not satisfy the specifications, calibration or repair is required. In that case, please contact the NF Corporation or its authorized agent.

1) Test environment

The performance tests should be performed under the following conditions.

- Ambient temperature 23 ± 5 °C
- Ambient humidity 20 to 70 %RH, no condensation
- Power supply requirements ± 15 VDC, 1 A or more
- Warm-up time 20 minutes or more

2) Preparation for tests

Before doing the tests, initialize the settings.

To initialize the settings, set the MODE switch to “F” and power-on.

3) Test equipment

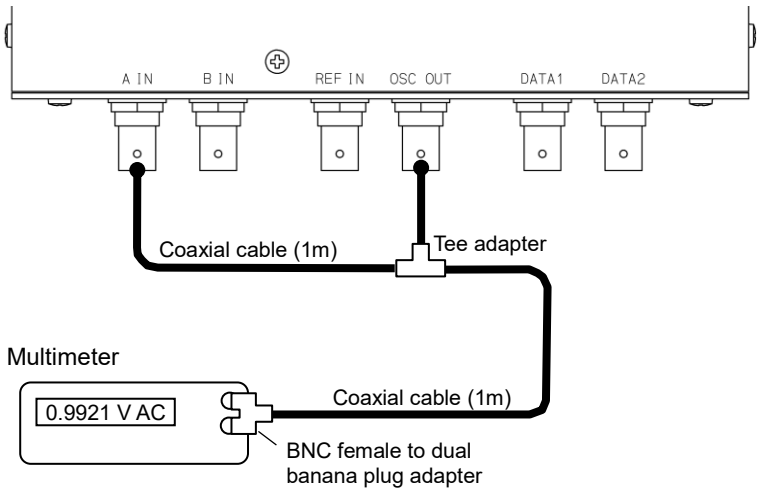
The measurement instruments needed for the tests are listed as below.

Product		Required specifications	Example model
Function generator		Waveform: Sine wave Frequency: 1 mHz to 1.05 MHz Amplitude: 10 mVrms to 7 Vrms TTL output synchronized with sine wave	WF1947 (NF Corp.)
Digital multimeter		AC voltmeter (true rms) (100 mV to 1 V range) Accuracy: ± 0.1 % (10 Hz to 20 kHz) DC voltmeter (100 mV to 100 V range) Accuracy: ± 0.04 %	34401A (Keysight)
Oscilloscope		Bandwidth: 10 MHz or more Time / division: 10 s / division or faster For monitoring	TBS2072B (Tektronix)
Others			
	Coaxial cables	50 Ω, BNC, equivalent to RG58/U	
	Shorted plug	BNC shorted plug or 50 Ω BNC terminator	
	Adapter	BNC, Tee adapter	

8.5.2 Voltage measurement accuracy

In the following descriptions, the **LI5502** is shown in the connection diagrams as a representative.

LI5502 settings:	Set the reference signal source to INT OSC (internal oscillator). Set the frequency to 1 kHz. Set the time constant to 100 ms. Set the attenuation slope to 24 dB/oct. Set the measurement parameter to R. Turn on the oscillator output. The amplitude, dynamic reserve, and sensitivity are shown in the following table. Perform the test for each input.
Measurement Instrument settings:	Set the multimeter to AC voltage measurement mode.
Connections:	Connect a coaxial cable from one side of a tee adapter at the OSC OUT terminal to the A IN terminal. Connect another coaxial cable from the other side of the adapter to the multimeter.
Measurement method:	Set the following specified amplitude, dynamic reserve, and sensitivity and read the measured value and multimeter.
Judgement (passing range):	See the table below.



judgement

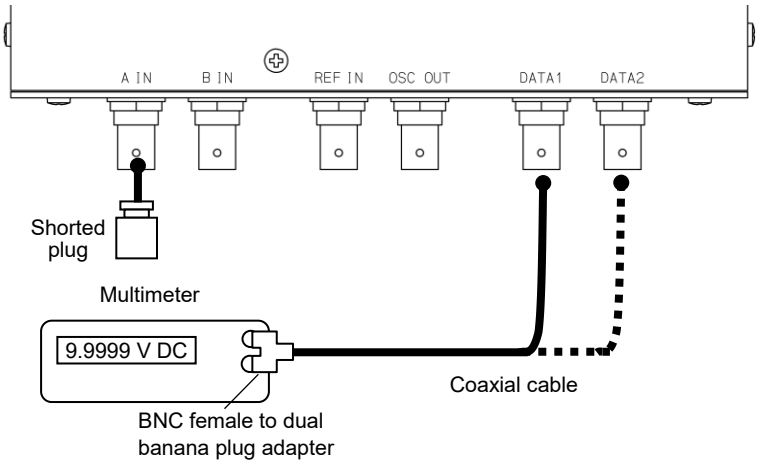
Input	Dynamic reserve	Sensitivity [rms]	Internal oscillator amplitude [rms]	R: Measured value [rms] S: DMM reading [rms] R / S	Passing range (R / S)
A IN	HIGH	1 V	1 V	_._____ V _._____ V _._____	0.995 to 1.005 *
	MED	1 V	1 V	_._____ V _._____ V _._____	0.995 to 1.005
	LOW2	100 mV	100 mV	___._ mV ___._ mV _._____	0.995 to 1.005 *
	LOW1	10 mV	10 mV	__._ __ mV __._ __ mV _._____	0.995 to 1.005 *
B IN	HIGH	1 V	1 V	_._____ V _._____ V _._____	0.995 to 1.005 *
	MED	1 V	1 V	_._____ V _._____ V _._____	0.995 to 1.005
	LOW2	100 mV	100 mV	___._ mV ___._ mV _._____	0.995 to 1.005 *
	LOW1	10 mV	10 mV	__._ __ mV __._ __ mV _._____	0.995 to 1.005 *

*These are supplementary values, not guaranteed values.

These values are generally in this range, but if these are significantly out of range, the instrument may be malfunctioning.

8.5.3 Analog outputs voltage accuracy

LI5502 settings:	Set the reference signal source to INT OSC (internal oscillator). Set the frequency to 1 kHz. Set the internal oscillator amplitude to 0 V. Set the time constant to 100 ms. Set the attenuation slope to 24 dB/oct. Set the measurement parameter of DATA1 to X and that of DATA2 to Y. Set the offset values for both X and Y as shown in the table below.
Measurement Instrument settings:	Set the multimeter to DC voltage measurement mode.
Connections:	Connect a shorted plug or 50Ω terminator to the A IN terminal. Connect the DATA1 or DATA2 terminal to the digital multimeter with a coaxial cable.
Measurement method:	Set the following specified offset value and read the measurement value on the multimeter.
Judgement (passing range):	See the table below.



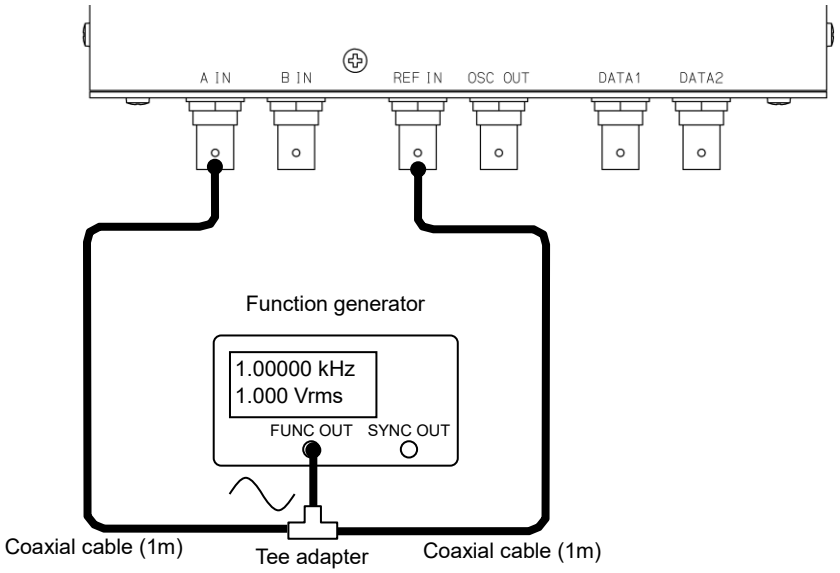
Judgement

Offset values (X and Y)	DMM reading Passing range (± 10 V ± 60 mV at ± 100% and ± 10 mV at 0%)	
	DATA1 (X)	DATA2 (Y)
+100%	+ _ _ . _ _ _ V	+ _ _ . _ _ _ V
0%	_ _ _ . _ _ mV	_ _ _ . _ _ mV
−100%	− _ _ . _ _ _ V	− _ _ . _ _ _ V

8.5.4 Phase accuracy

1) Relative to external reference signal

LI5502 settings:	Set the reference signal source to REF IN (external reference). Set the reference signal waveform to SIN. Set the sensitivity to 1 V and dynamic reserve to MED. Set the measurement parameter to θ. Set the time constant to 100 ms. Set the attenuation slope to 24 dB/oct.
Measurement Instrument settings:	Set the wave form to a sine wave. Set the frequency to 1 kHz and the amplitude to 1 Vrms.
Connections:	Connect a coaxial cable from one side of a tee adapter at the function generator output terminal to the A IN terminal. Connect another coaxial cable from the other side of the adapter to the REF IN terminal.
Measurement method:	Read the measured θ value by remote control.
Judgement (passing range):	See the table below.



Use same length and characteristics cables.
Shorter cables are preferable.

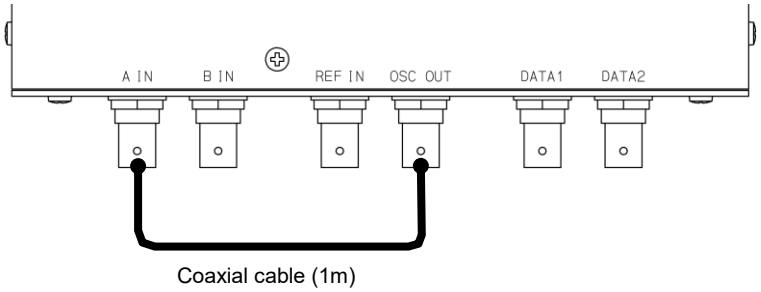
Judgement

Input	Frequency	θ	Passing range *
A IN	1 kHz	_ _ _ . _ _ °	−1 to +1 °
B IN	1 kHz	_ _ _ . _ _ °	−1 to +1 °

*This is a supplementary value, not guaranteed value.

2) Relative to the internal oscillator

LI5502 settings:	Set the reference signal source to INT OSC (internal oscillator). Set the wave form to a sine wave. Set the frequency to 1 kHz. Set the internal oscillator amplitude to 1 Vrms. Turn on the oscillator output. Set the measurement parameter to θ. Set the time constant to 100 ms. Set the attenuation slope to 24 dB/oct.
Measurement Instrument settings:	Only a coaxial cable is used.
Connections:	Connect the A IN terminal and OSC OUT terminal with a coaxial cable.
Measurement method:	Read the measured θ values by remote control.
Judgement (passing range):	See the table below.



Judgement (same as **1) Relative to external reference signal**)

Input	Frequency	θ	Passing range *
A IN	1 kHz	_ _ _ . _ _ °	−1 to +1 °
B IN	1 kHz	_ _ _ . _ _ °	−1 to +1 °

*This is a supplementary value, not guaranteed value.

8.5.5 Amplitude accuracy of the internal oscillator

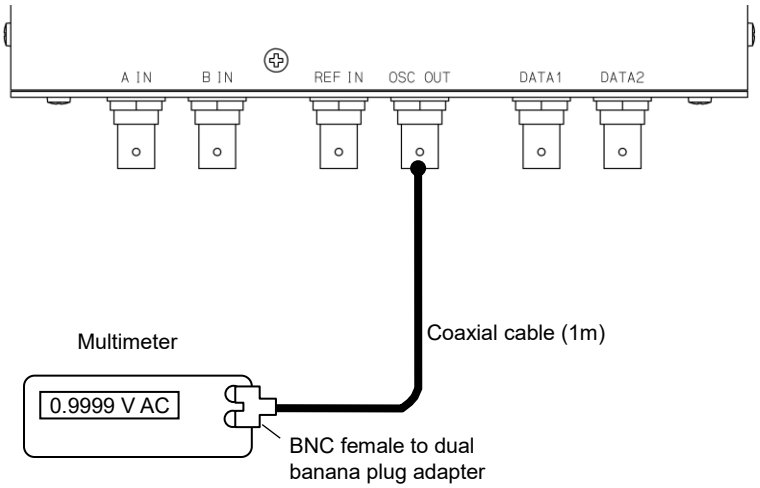
LI5502 settings: Set the reference signal source to INT OSC (internal oscillator).
Set the wave form to a sine wave.
Set the frequency to 1 kHz.
Set the internal oscillator amplitude to 1 Vrms.
Turn on the oscillator output.

Measurement Instrument settings: Set the multimeter to AC voltage measurement mode.

Connections: Connect the OSC OUT terminal to the multimeter with a coaxial cable.

Measurement method: Read the measurement value on the multimeter.

Judgement (passing range): See the table below.



Judgement

Frequency	Oscillator amplitude	DMM reading [rms]	Passing range
1 kHz	1 Vrms	_._____V	0.955 to 1.045 V

8.6 Calibration

If the performance tests reveal that the instrument fails to satisfy the specifications, the NF Corporation will adjust or calibrate the instrument to restore performance.
If calibration is required, please contact the NF Corporation or its authorized agent.
Adjustment or calibration that is performed outside the warranty period is available for a charge.

9. Specifications

Nominal, typical, supplementary and approximate values

These values imply the supplemental data of this instrument and do not guarantee the instrument performance.

9.1 Input section

This section describes specifications of the input terminals such as the signal input terminals and reference signal input terminal.

9.1.1 Signal inputs

Input connector	BNC
No. of channels	LI5501: 1 (Terminal name: A IN)
	LI5502: 2 (Terminal names: A IN, B IN)
Input type	Single-ended
Input impedance	1 MΩ (nominal value), 20 pF in parallel (supplementary value)
Frequency range	DC to 1.05 MHz
Voltage gain	0.2x / 1x / 10x / 100x (AC GAIN)
Voltage gain temperature drift	
	± 250 ppm / °C (supplementary value)
	1 kHz frequency
Input-referred noise	25 nV/√Hz (supplementary value)
	1 kHz frequency, 100x voltage gain, input shorted
Harmonic distortion	−70 dBc or less (supplementary value)
	1 Vrms input siganl, 1x voltage gain, 20 Hz to 100 kHz, second and third harmonics respectively
Maximum input voltage (for linear operation)	
	± 5 V
Non-destructive maximum input voltage	
	± 10 V
Impedance between the signal ground and chassis ground	
	22 Ω (nominal value), ± 1 V

9.1.2 Reference signal input

Input connector	BNC
No. of channels	1 (Terminal name: REF IN)
Imput impedance	1 MΩ (nominal value), 20 pF in parallel (supplementary value)
Frequency range	DC to 1.05 MHz
Input voltage range	Sine wave (SIN): 0.4 to 6 Vp-p
	Square wave (TTL): 0 to 5 V
	high level 2.6 V or more, low level 0.8 V or less
Pulse width (square wave)	100 ns or more (both high and low levels)
Non-destructive maximum input voltage	
	± 10 V

9.1.3 External reference frequency input

Input connector	BNC
No. of channels	1 (Terminal name: 10MHz IN)
Frequency range	10 MHz ± 0.2 %
Waveform	Sine wave or square wave (45 to 55 % duty cycle)
Signal level	0.5 to 5 Vp-p
Non-destructive maximum input voltage	10 Vp-p
Input impedance	500 Ω (approximate value)
Input coupling	AC
Withstand voltage (allowable voltage to enclosure)	± 42 Vpeak max (DC + AC)
Reference frequency source	Internal or external If a reference signal for frequency synthesis is applied to the 10MHz IN terminal from an external source, the internal oscillator generates the reference signal synchronized with that external 10 MHz frequency. Therefore, measurement can be performed without applying an external reference signal.

9.2 Output section

This section describes specifications of the output terminals such as the internal oscillator output terminal and measurement data output terminals.

9.2.1 Oscillator output

Output connector	BNC
No. of channels	1 (Terminal name: OSC OUT)
Output frequency	Synchronization frequency or internal oscillator frequency
Waveform	Sine wave or square wave
Amplitude	Sine wave: 1 Vrms, 1 mVrms resolution
	Square wave: TTL level
Amplitude accuracy	± (4 %+5 mV)
	sine wave, 1 kHz frequency
DC offset voltage	± 5 V (available only with sine wave,
	5 mV resolution, nominal value)
Maximum output current	± 15 mA or more
Recommended load	500 Ω or more (resistor connected to signal ground)
Output impedance	53 Ω (nominal value)
Harmonic distortion	−70 dBc or less (supplementary value)
	20 Hz to 100 kHz, no load, sine wave, 1 Vrms amplitude
	second and third harmonics respectively, 0 V DC offset

9.2.2 Analog data outputs

Output connector	BNC
No. of channels	2 (Terminal names: DATA1, DATA2)
Maximum update rate	312.5 k Samples/s
Frequency range	10 kHz or more
Output voltage range	± 12 V (no load), 16-bit resolution
Maximum output current	± 10 mA or more
Output impedance	440 Ω (nominal value)
Output voltage accuracy	± (0.5 % + 10 mV), relative to measured value

9.3 Analysis function

The instrument works as a dual-phase lock-in amplifier.
The **LI5502** can also measure amplitude ratio and phase difference between two channels.

a) Measurement signal system

Frequency range	9.5 mHz to 1.05 MHz
No. of channels	LI5501: 1 (A IN)
	LI5502: 2 (A IN, B IN)

b) Phase sensitive detector section

Phase sensitive detector	Dual-phase (R cosθ, R sinθ)
Orthgonality	± 0.001 ° (supplementary value)
Dynamic reserve	100 dB or more (supplementary value)

- **Dynamic reserve**
  The dynamic reserve is a value that expresses a margin against noise.
  It indicates how much noise is tolerated relative to the full scale of the voltage sensitivity.
  DR = Allowable maximum noise level / Voltage sensitivity (full scale of signal)
  The actual DR value depends on voltage sensitivity, frequency difference between a signal and noise, and settings of the time constant filter.
  To realize 100 dB or more, 100 ms or more time constant and 24 dB/oct attenuation slope or equivalent filter settings are required.

Time constant filter

Time constant (TC)	1 µs to 10 ks (1-2-5 sequence)

- 1-2-5 sequence is a sequence of numbers repeating as “1, 2, 5, 10, 20, 50, …”.

Attenuation slope (SLOPE)

6 / 12 / 18 / 24 dB/oct

- **Time constant filter**
  It is cascade-connected first-order lowpass filters and eliminates noise and ripples associated with phase detection.
  The filter is realized with a digital filter that demonstrates the same response as an analog filter.
  The time constant corresponds to the response time of the first-order lowpass filter and the attenuation slope corresponds to the number of cascade-connected stages (6 dB/oct per stage) of the filter.
  The greater these settings, the greater the effect of noise rejection and ripple rejection.

Voltage sensitivity — See the table below (1-2-5 sequence).

DR setting — LOW1 / LOW2 / MED / HIGH (linked with AC GAIN)

DR	AC GAIN	Voltage sensitivity
LOW1	100x	10 nVrms to 10 mVrms
LOW2	10x	100 nVrms to 100 mVrms
MED	1x	1 µVrms to 1 Vrms
HIGH	0.2x	5 µVrms to 1 Vrms

- **Voltage sensitivity**
  The DR setting corresponds to the gain of the analog circuit (AC GAIN) and restricts the range of the voltage sensitivity.
  Within this range, the voltage sensitivity (DC GAIN) can be set, which amplifies a digital signal after the PSD.

Voltage measurement accuracy

± 0.5 % (1 kHz and 1 Vrms input siganl, DR MED, 1 Vrms voltage sensitivity)

Moving average filter

Averaging time — OFF (0.4 µs), 1 µs to 100 s (1-2-5 sequence), AUTO (Inverse of reference signal frequency is set as averaging time.)

- **Moving average filter (MOV)**
  This filter removes noise by moving average of averaging time.
  A notch filter can be set with integer multiples of the averaging time as the period.
  When the averaging time is equal to inverse of reference signal frequency, ripples associated with PSD is greatly reduced and the output is almost settled in the averaging time, so it is easy to obtain a fast response by setting a small time constant.
  However, if signal frequency is high, the ripple suppression effect may not be sufficient.
  When the filter is OFF, the minimum averaging time of 0.4 µs is set.

EXPAND — 1x to 1000x

- **EXPAND**
  The EXPAND function amplifies a signal after the moving average filter.
  If this function is used without the moving average filter, lower bits will be missing.
  Therefore, it is recommended to use the filter with an appropriate amount of averaging time when using this function.
  1-2-5 sequence is recommended.

Phase noise
0.001 °rms (1 kHz, 18 dB/oct or more attenuation slope)
Supplementary value; reference signal is external
1 Vrms sine wave, 100 ms time constant, MOV OFF
When a reference signal is noisy or has high jitter or the amplitude is less than 1 Vrms, this specification may not be satisfied.

Phase temperature drift
± 0.02 ° / °C
Supplementary value when input and reference signal are both 1 kHz and 1 Vrms sine waves.

Phase measurement accuracy
± 1 °
Supplementary value when input and reference signal are both 1 kHz and 1 Vrms sine waves.

Phase shift amount
−180.000 ° to +179.999 °, 0.001 ° resolution

PSD offset adjustment
Capable of removing a DC component of ± 25% of full-scale

- **About PSD offset adjustment**
  When the PSD offset adjustment is executed, the average value of the DC component for about 420 ms is measured, and then the correction value is set.
  By the adjustment execution command, the adjustment is ececuted.
  By the adjustment reset command, the correction value returns to the factory default setting.

c) Reference signal system

Signal source REF IN (external reference) / INT OSC (internal oscillator)

- **REF IN**
  When the internal oscillator cannot be synchronized with external reference signal, the instrument will be UNLOCK state.
  When the internal oscillator can be synchronized with external reference signal, the instrument will be LOCK state within the specified synchronization time.
- **INT OSC**
  Immediately synchronized with the internal oscillator

Waveform SINE / TTL POS / TTL NEG

- **SINE (SIN)**
  Frequency-stable waveform that crosses the 0 V only twice per period
  When using a square wave, use it with 10 to 90 % duty factor.
  Point where a signal crosses 0 V from below to above is 0°
- **TTL POS (TPOS)**
  Frequency-stable waveform that crosses the threshold level only twice per period
  The rising edge is 0°.
- **TTL NEG (TNEG)**
  Frequency-stable waveform that crosses the threshold level only twice per period
  The falling edge is 0°.

Frequency range 9.5 mHz to 1.05 MHz

Synchronization time 2 periods + 50 ms or less (supplementary value)

Frequency resolution 0.3 mHz

Frequency measurement accuracy

± 40 ppm (1 Hz or more, waveform: TTL POS / TTL NEG)

Harmonic measurement

A reference frequency given to the detector can be set to n/m times of reference signal frequency.

Range of n (harmonic): 1 to 63

Range of m (sub-harmonic): 1 to 64

Note: n/m times of reference signal frequency needs to be within the synchronization frequency range.

d) Internal oscillator

Frequency range 9.5 mHz to 1.05 MHz

Frequency resolution 0.1 mHz

Frequency accuracy ± 30 ppm (supplementary value)

e) Output section of measurement values

Parameters LI5501: X_A, Y_A, R_A, θ_A

LI5502: X_A, Y_A, R_A, θ_A, X_B, Y_B, R_B, θ_B, RATIO, PHASE

- **Parameters**

  X: In-phase component (= R cosθ)

  Y: Quadrature component (= R sinθ)

  R: Signal amplitude, RMS value(= $\sqrt{(X^2+Y^2)}$)

  θ: Signal phase (= $\tan^{-1}$ (Y / X))

  The subscripts indicate the measured channel (A:CH-A, B:CH-B).

  RATIO: Amplitude ratio between the two channels (R_A / R_B,)

  PHASE: Phase defference between the two channels ($\theta_A - \theta_B$)

- **Example of measuring amplitude ratio**

  When

  measured R_A is 60 mVrms at sensitivity is 0.1 Vrms (60% full-scale) and

  measured R_B is 100 mVrms at sensitivity is 0.2 Vrms (50% ful-scale),

  the measured amplitude ratio (G) is equalt to 1.2 (= 60 %FS / 50 %FS).

  The actual amplitude ratio can be calculated using the above measured value and the ratio of the sensitivity settings.

  Taking the above as an example, since the sensitivity ratio is 0.5 (= 0.1/ 0.2), the actual amplitude ratio is 0.6 (= 1.2 (G) × 0.5).

Measurement range	X, Y	± 0 to 120 % relative to voltage sensitivity
		Resolution: 18 bits
	R	0 to 120 % relative to voltage sensitivity
		Resolution: 19 bits
	RATIO	0 to 200 %
		Resolution: 19 bits
	θ, PHSAE	−180.000 ° to +179.999 °
		Resolution: 0.001 °
Voltage range of analog outputs		
	X, Y	± 10 VDC
		(when ± 100 % relative to voltage sensitivity)
	R	10 VDC
		(when 100 % relative to voltage sensitivity)
	RATIO	10 VDC (when 200 % amplitude ratio)
	θ, PHASE	± 10 VDC
		(when 179.999 ° or −180.000 ° respectively)
Offset	± 120.00 % relative to voltage sensitivity for X and Y, 0.01% resolution	

9.4 Digital data output

Output mode: Querying / Streaming

- **Querying**
  Responds to the command query with ASCII
- **Streaming**
  Outputs binary data continuously
  There are seven 16-bit registers and measured data can be output at a specified sample period.
  The maximum transfer rate is 300k word/s.

Sampling interval: 0.4 µs × (1 to 65536)

Output parameters:

LI5501: X_A, Y_A, R_A, θ_A

LI5502: X_A, Y_A, R_A, θ_A, X_B, Y_B, R_B, θ_B, RATIO, PHASE

LI5501/2: Reference signal frequency, Status

- **Reference signal frequency**
  When the output mode is Streaming, measured frequency data is divided into upper frequency data (16 bits) and lower frequency data (16 bits).
- **Status**
  Not synchronized with reference signal (UNLOCK)
  Saturation in the previous PSD stage (ADC over)
  Saturation in the time constant filter (LPF over)
  Saturation in the moving average filter (MOV over)
  Saturation in the ratio operation (RATIO over)
  Overvoltage at the oscillator output (OSC over)

9.5 Remote control interface

USB	USB 2.0 full speed, device class CDC
LAN	10BASE-T / 100BASE-TX, TCP/IP (socket communication)

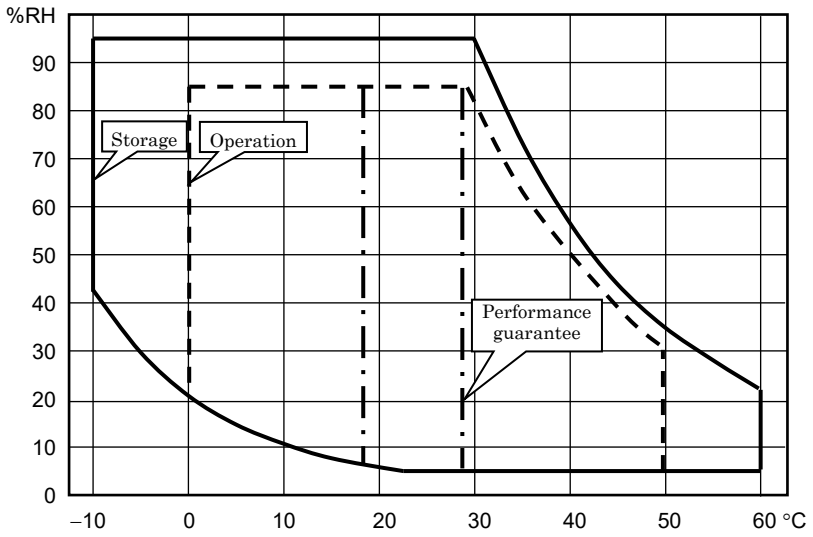
9.6 Miscellaneous specifications

Power supply

Recommended power supply Voltage	± 15 VDC ± 2% linear power supply (with dual tracking) recommended
Operating voltage range	± 14 to 16 VDC
Current consumption	approximately +400 mA / −110 mA (LI5501) approximately +480 mA / −120 mA (LI5502) factory default settings, no input signals, no loads
Connector	D-SUB 9pin (equivalent to DELC-J9PAF-20L9 (JAE))
Configuration memory	16 sets (switchable by MODE switch on the rear panel) One of them is for resume function and another has factory default settings.
Resume function	Last operating settings will be restored when the instrument is restarted.

Environmental conditions

Operation	0 to +50 °C, 5 to 85 %RH (absolute humidity 1 to 25 g/m^3, no condensation) Altitude of 2000 m or less
Performance guarantee	23 ± 5 °C, 5 to 85 %RH (absolute humidity 1 to 25 g/m^3, no condensation) Altitude of 2000 m or less
Storage	−10 to +60 °C, 5 to 95 %RH (absolute humidity 1 to 29 g/m^3, no condensation)



Pollution degree	2 (indoor use)
Warm-up time	20 minutes
RoHS directive	Directive 2011/65/EU
EMC	EN 61326-1, EN 61326-2-1 Applies to instruments that have a CE marking on the bottom
External dimensions	200 mm (W) × 30 mm (H) × 150 mm (D) excluding metal fittings and protruding parts
Weight	Approximately 700 g main unit only, excluding accessories and metal fittings

9.7 External dimensions

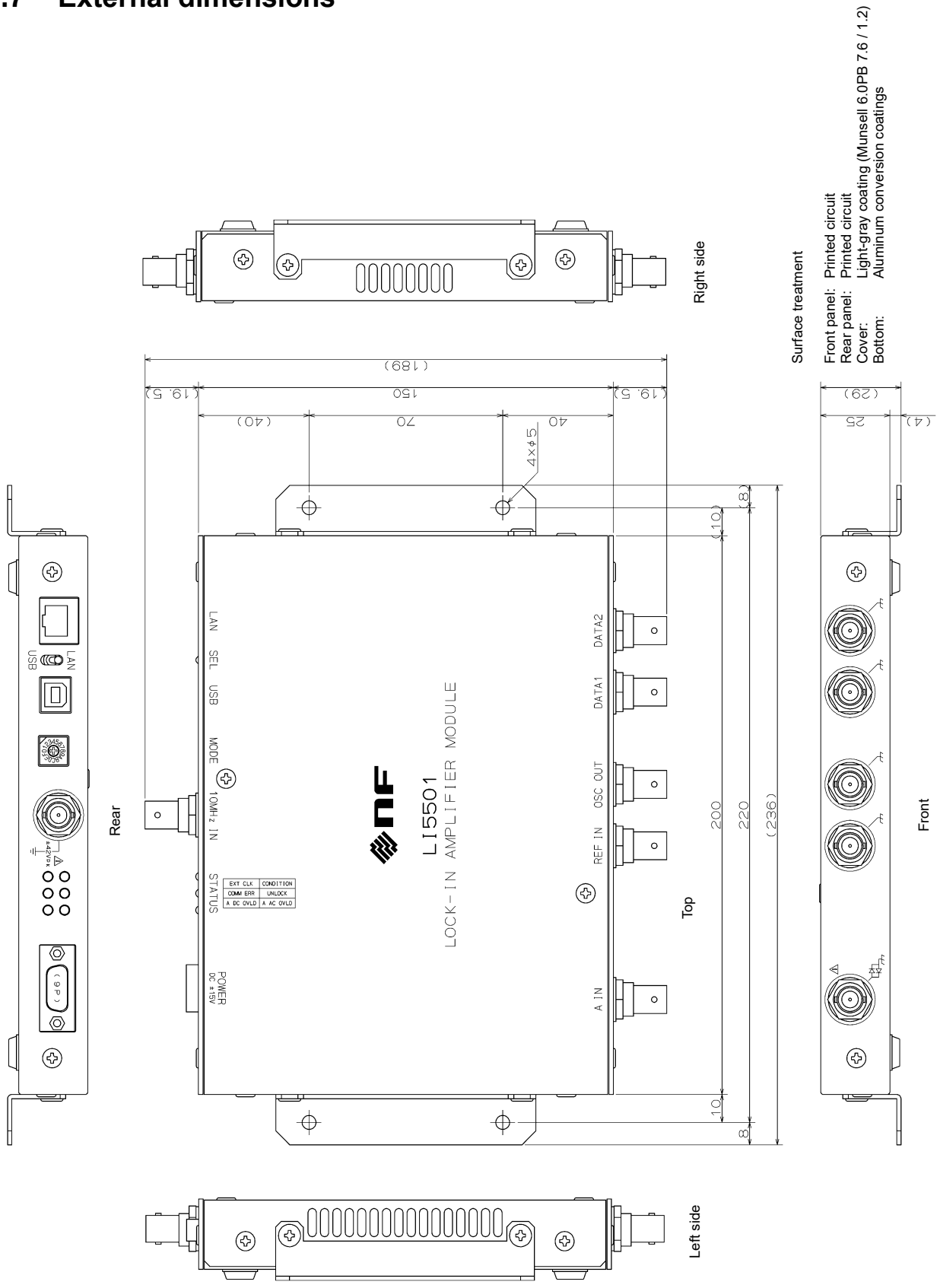


Figure 9-1 External dimensions of the LI5501

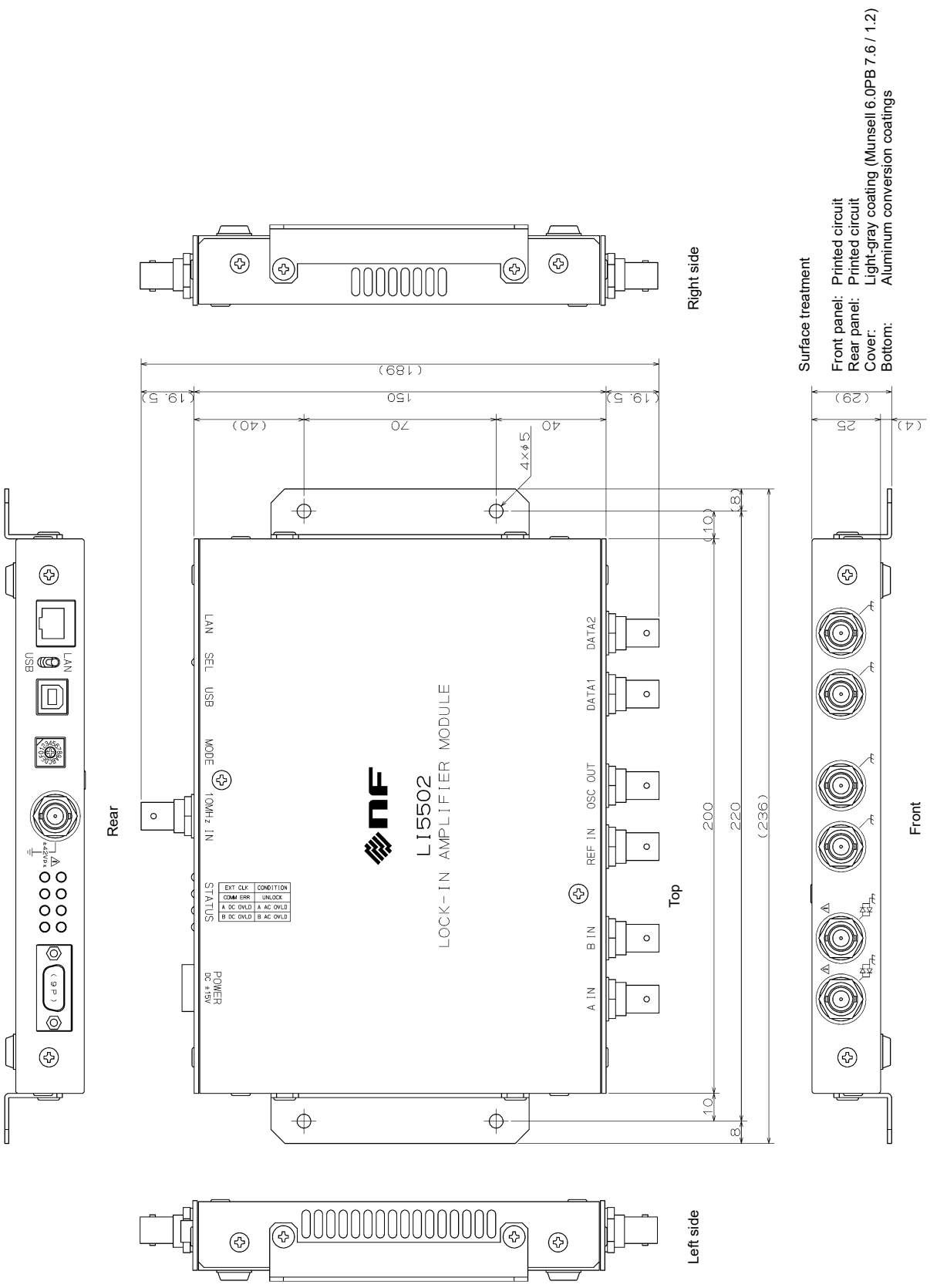


Figure 9-2 External dimensions of the LI5502

———— WARRANTY ————

NF Corporation certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from our factory. In the unlikely event that you experience an issue during use, please contact our company or agency of our company from which you purchased the instrument.
All NF products are warranted against defects in materials and workmanship for a period of one year from the date of shipment. During the warranty period, NF will repair the defective instrument without any charge for the parts and labor.
For repair service under warranty, the instrument must be returned to either NF or an agent designated by NF. The Purchaser shall prepay all shipping cost, duties and taxes for the instrument to NF from another country, and NF shall pay shipping charges to return the instrument to the purchaser.

This warranty shall not apply when corresponding to following particulars.

A) Failure caused by improper handling or use of the instrument in a manner that does not conform with the provisions of the Instruction Manual.
B) Failure or damage caused by transport, dropping, or other handling of the instrument after purchase.
C) Failure caused by repair, adjustment, or modification of the instrument by a company, organization, or individual not approved by NF.
D) Failure caused by abnormal voltage or the influence of equipment connected to this instrument.
E) Failure caused by the influence of supply parts from the customer.
F) Failure caused by such as corrosion that originate in the use of causticity gas, organic solvent, and chemical.
G) Failure caused by the insect or small animal that invaded from the outside.
H) Failure or damage caused by fire, earthquakes, flood damage, lightning, war, or other uncontrollable accident.
I) Failure caused by the reason that was not able to be foreseen by the science and technology level when shipped from our company.
J) Replacement and replenishment of consumables such as batteries.

NF Corporation

WABUN: (DA00096776-003)

If there are any misplaced or missing pages, we will replace the manual. Contact the sales representative.

NOTES

- Reproduction of the contents of this manual is forbidden by applicable laws.
- The contents of this manual may be revised without notice.
- Information provided in this manual is intended to be accurate and reliable. However, we assume no responsibility for any damage regarding the contents of this manual.
- We assume no responsibility for influences resulting from the operations in this manual.

LI5501 / LI5502 INSTRUCTION MANUAL

NF Corporation

6-3-20, Tsunashima Higashi, Kohoku-ku, Yokohama
223-8508 JAPAN
Phone +81-45-545-8128 Fax +81-45-545-8187

https://www.nfcorp.co.jp/

NF Corporation

6-3-20, Tsunashima Higashi, Kohoku-ku, Yokohama 223-8508 JAPAN