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Identifying Ld, Lq for Permanent Magnet Synchronous Motors (PMSMs)

Measurement & Setup Guide

- ✓ This document provides the procedure for identifying Ld and Lq of the permanent magnet synchronous motor (PMSM) in the operating state using Hioki's Power Analyzer PW8001 / PW4001 and the Motor Ld,Lq Analyzer.
- ✓ For detailed instructions and specifications for each device or software, please read the instruction manual for each.
- ✓ Separately, detailed technical documents and application notes on Ld, Lq are available.

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1 Introduction

This document presents the procedure for identifying Ld and Lq for a permanent magnet synchronous motor (PMSM) in the operating state using Hioki's Power Analyzer PW8001 / PW4001 and Motor Ld,Lq Analyzer. By following the steps in this measurement and configuration guide, you can measure, graph, and store Ld and Lq values in real-time while running the PMSM.

1.1 Necessary Equipment

This guided measurement requires the following instruments and software:

Hioki Power Analyzer PW8001-1x (Motor analysis option specification; x varies from 1 to 6 depending on the installed options.) Hioki Power Analyzer PW4001-03, PW4001-05 (Motor analysis option specification.)
Hioki high-accuracy current sensor × 3
Hioki Motor Ld,Lq Analyzer (You can download the software from Hioki's website.)
Hioki Resistance Meter RM3548, or equivalent

In addition, the required specifications for the computer using the "Motor Ld, Lq Analyzer" are as follows.

Supported OS	Windows 10 (64-bit), Windows 11
Software environment	LabVIEW Runtime 2019 or later and NI VISA Driver installed
CPU	1.0 GHz or higher
Memory	2.0 GB or more
Hard disk	128 MB or more free space
Display	1280 × 1080 dots or more
Communication interface	Ethernet (TCP/IP)

Note

- National Instruments, NI, ni.com, and LabVIEW are trademarks of National Instruments Corporation.
- Windows is a registered trademark or trademark of Microsoft Corporation located in the United States.

1.2 Applicable Test Systems

This guide can be applied to test systems that meet the following conditions.

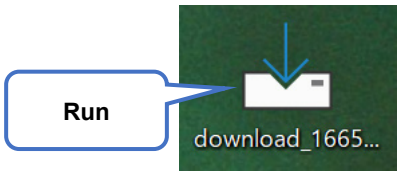
The system must be equipped with a pulse encoder whose output signal yields an integer number of pulses per mechanical revolution (hereinafter referred to as a Z-phase pulse), and the value obtained by dividing the number of pole pairs by the number of pulses per mechanical revolution must be an integer. ○ Applicable example: 26-pole motor with Z-phase pulse (13 pole pairs) 13 ÷ 1 = 13 is an integer, so it can be applied. ● Unapplicable example: 26-pole motor with a 2-pulse signal per revolution (13 pole pairs) 13 ÷ 2 = 6.5 is not an integer, so it cannot be applied.
The PMSM can be disconnected from the drive inverter and the winding resistance can be measured.
The PMSM can be disconnected from the drive inverter and turned from the load side.

2 Preparation

2.1 Installing the Motor Ld,Lq Analyzer

① On Hioki's software download page, search for "PW8001" or "PW4001", select Motor Ld,Lq Analyzer, and download the software and instruction manual.

② Run [Setup_MotorLdLqAnalyzer_1.20.exe] and follow the installer's instructions to proceed with installation. (The extension may not be displayed depending on your computer's settings.)



Note

- Please install with administrator privileges (Administrator).
- You may not be able to install if other applications are running. Before installation, close all applications as much as possible. Anti-virus software may prohibit installation. In that case, configure your anti-virus software to allow the installation to proceed.

2.2 Installing the LabVIEW Runtime and the NI VISA Driver

To install this software, you must have LabVIEW Runtime 2019 or later and the NI VISA Driver installed. The only compatible bit version is the 64-bit version.

Please download the LabVIEW Runtime and NI VISA Driver from the National Instruments website.

3 Measuring Winding Resistance

The PMSM is disconnected from the drive inverter and the winding resistance is measured.

3.1 Measurement Procedure

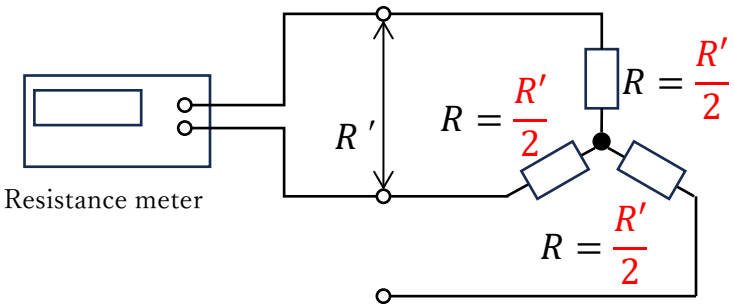
① Use a Multi-tester or voltage detector to verify that the connection terminals of the motor are not live.

② Disconnect the motor from the inverter.

③ Measure the winding resistance between the respective terminals.

④ Obtain the winding resistance R.

Calculation of phase armature resistance R.



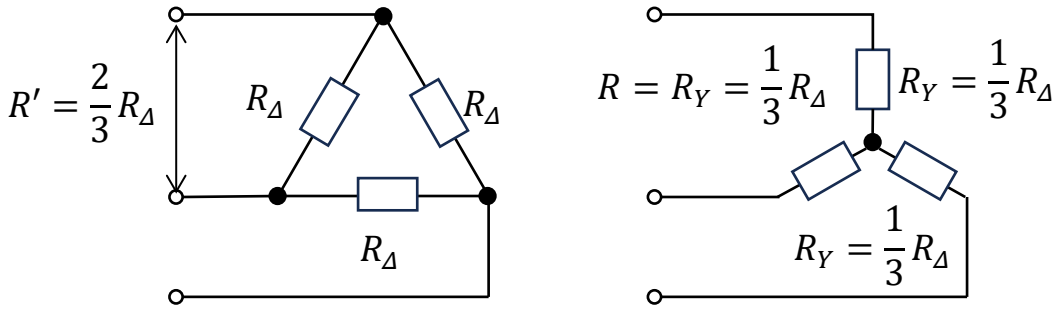
Connect the resistance meter to the motor as shown and measure the DC resistance R' [Ω].

The phase armature resistor R is calculated using the following formula.

$$R = \frac{R'}{2} \ [\Omega]$$

In the case of delta wiring

Even in the case of delta wiring, the resistance value per phase of the stator (Δ-Y conversion) is 1/2 of the measured resistance value.



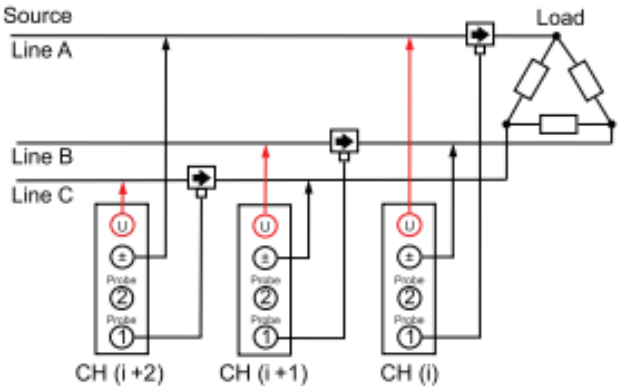
Δ-Y Conversion

$$R = \frac{R'}{2} \ [\Omega]$$

4 PW8001/ PW4001 Wiring

4.1 Measurement Line, Pulse Signal Connection

① The U, V, and W phases of the 3-phase motor are connected with a 3-phase 3-wire (3P3W3M) connection.

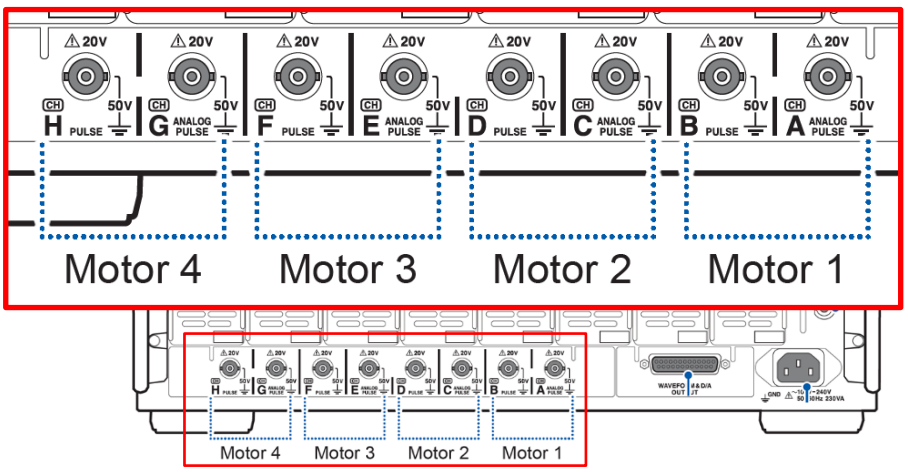


Connection diagram

② Connect the pulse signal from the motor to the [Motor 1] terminal.

Connect the Z-phase pulse signal from the pulse encoder to CH B. When measuring additional torque, connect the torque signal output from the torque sensor to CH A.

- ***The Motor Ld,Lq Analyzer does not use A-phase or B-phase pulses from the pulse encoder, but uses the Z-phase pulse signal as a reference. Please note that this differs from the wiring used for typical motor analysis.***

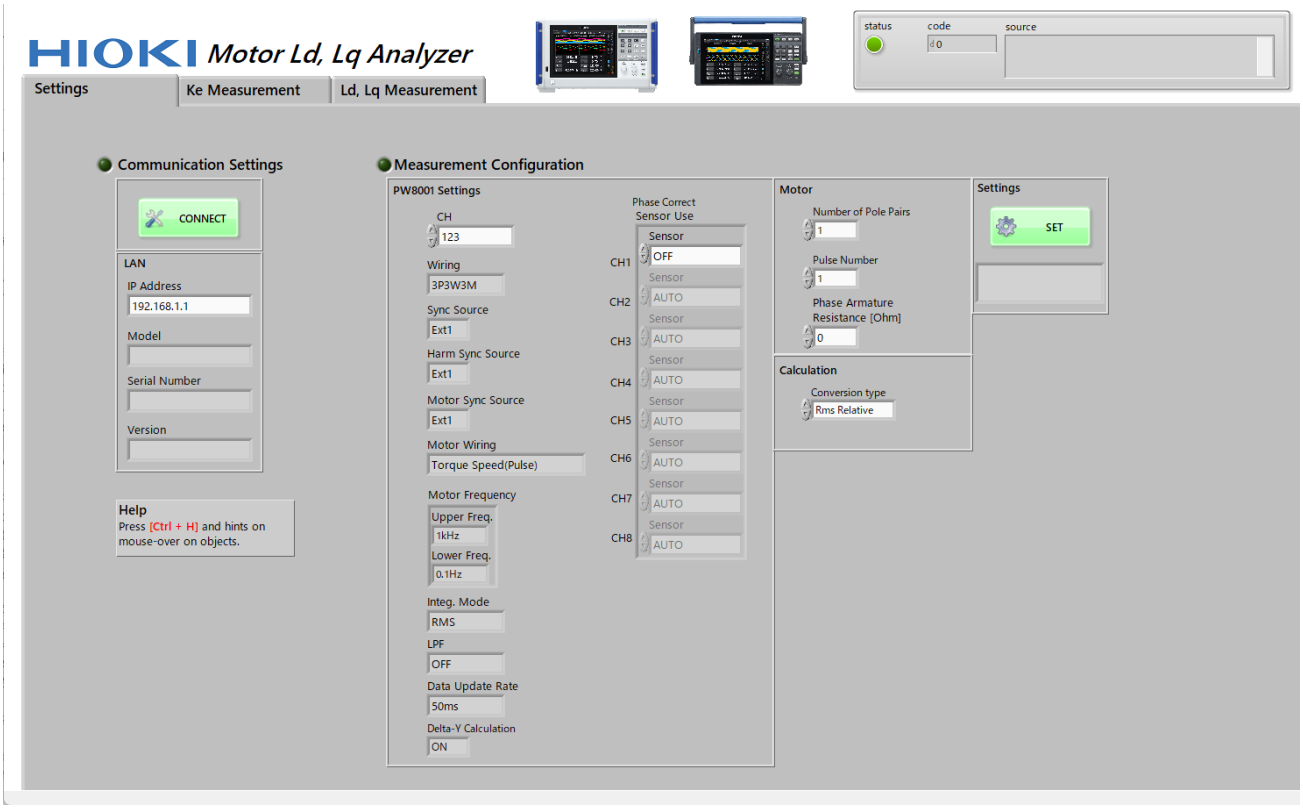


Pulse signal input

5 Motor Ld,Lq Analyzer Configuration

5.1 Startup

When you launch the application, you will be taken to the settings screen.



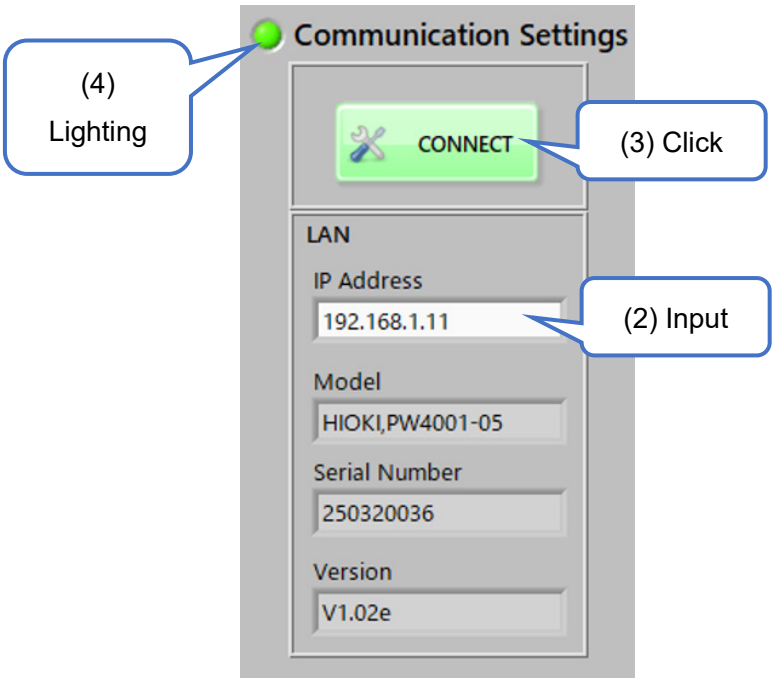
Settings screen

5.2 Connection Settings with the PW8001 / PW4001

First, set up the communication between the PW8001 / PW4001 and the computer.

① Connect the PW8001 / PW4001 and the computer with a LAN cable.
② In the **[IP Address]** field, enter the IP address of the PW8001 / PW4001 to which you want to connect.
③ Press the **[CONNECT]** button to start communication with the specified connection target.
④ If the communication is successful, the **[Model]**, **[Serial Number]**, and **[Version]** fields display the connected PW8001 / PW4001 information, and the green light icon illuminates.

For information on how to check the IP address of the unit, refer to its instruction manual.



Connection settings

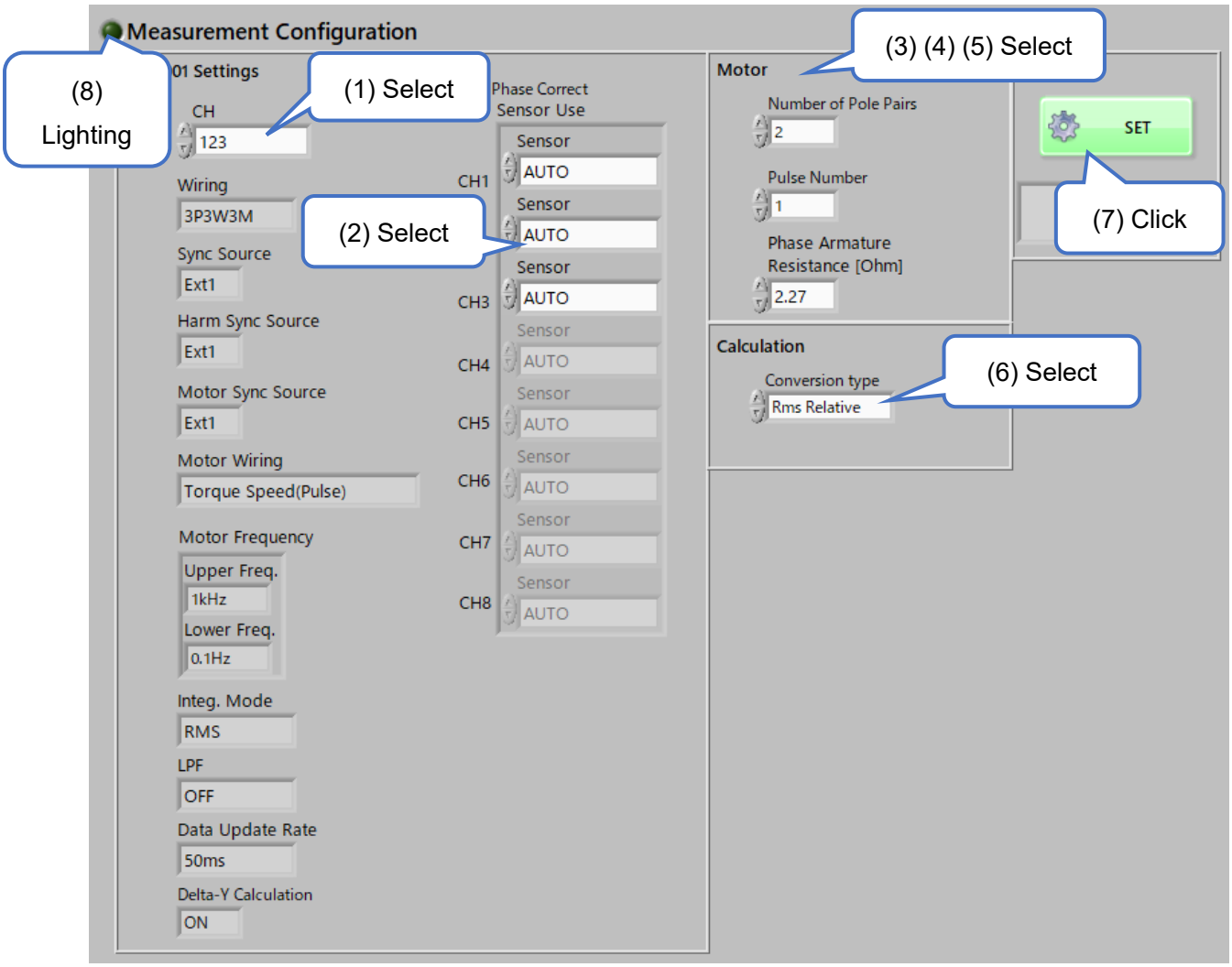
Note

If the connection fails, refer to the instruction manual and check the following:

- *Check the cable connection and the IP address settings of the PC and the PW8001 / PW4001.*
- *Make sure that the NI-VISA Driver is installed on your PC.*

5.3 Measurement Settings

Configure the settings for motor parameter measurement.



Measurement Settings

① In the **[CH]** field, select the channel for which you want to make the measurement. Combinations containing channels with no unit installed are unavailable.

② In the **[Sensor Use]** field, click the current sensor model you will use in the 3 channels selected in (1) and set the phase correction settings.

If you want to use a current sensor that has automatic phase correction functionality, select AUTO.

If you are using a current sensor model that does not have automatic phase correction, select the model name from the drop-down list.

Use the same current sensor model for each of the 3 channels selected in the **[CH]** field.

If you send a setting other than OFF to a channel that does not have a current sensor connected, an error will occur.

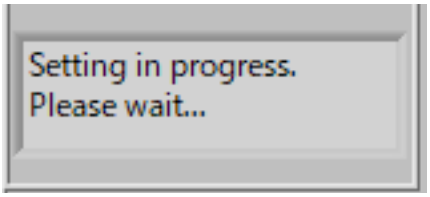
③ Enter the number of motor pole pairs in the **[Number of Pole Pairs]** field.
The input range of the motor pole pairs is 1 to 60,000.

④ In the **[Pulse Number]** field, enter the number of pulses output per motor revolution.
The input range of pulse numbers is 1 to 60,000.
Example 1: if you want to use the Z-phase pulse of an incremental rotary encoder, enter "1."
Example 2: if you want to use the output of a torque sensor that outputs 4 pulses in one revolution, enter "4."

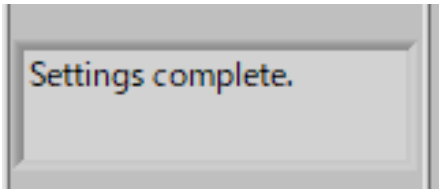
⑤ In the **[Phase Armature Resistance]** field, enter the phase armature resistance value measured using a resistance meter or similar device.

⑥ Set one of the following conversion types in the **[Calculation]** field.
Rms Relative: a conversion method which the RMS value before the Clarke transformation equals the peak value after transformation.
Relative: a conversion method in which peak values are stored before and after the Clarke transformation
Absolute: a conversion method in which power is conserved before and after the Clarke conversion

⑦ Press the **[SET]** button to send the settings to the PW8001 / PW4001. This step will take some time because it performs zero adjustment.



⑧ Once the setting is complete, the green light icon will turn on.



PW8001 / PW4001 Configuration Items

The **[SET]** button sends the following settings to the PW8001 / PW4001:

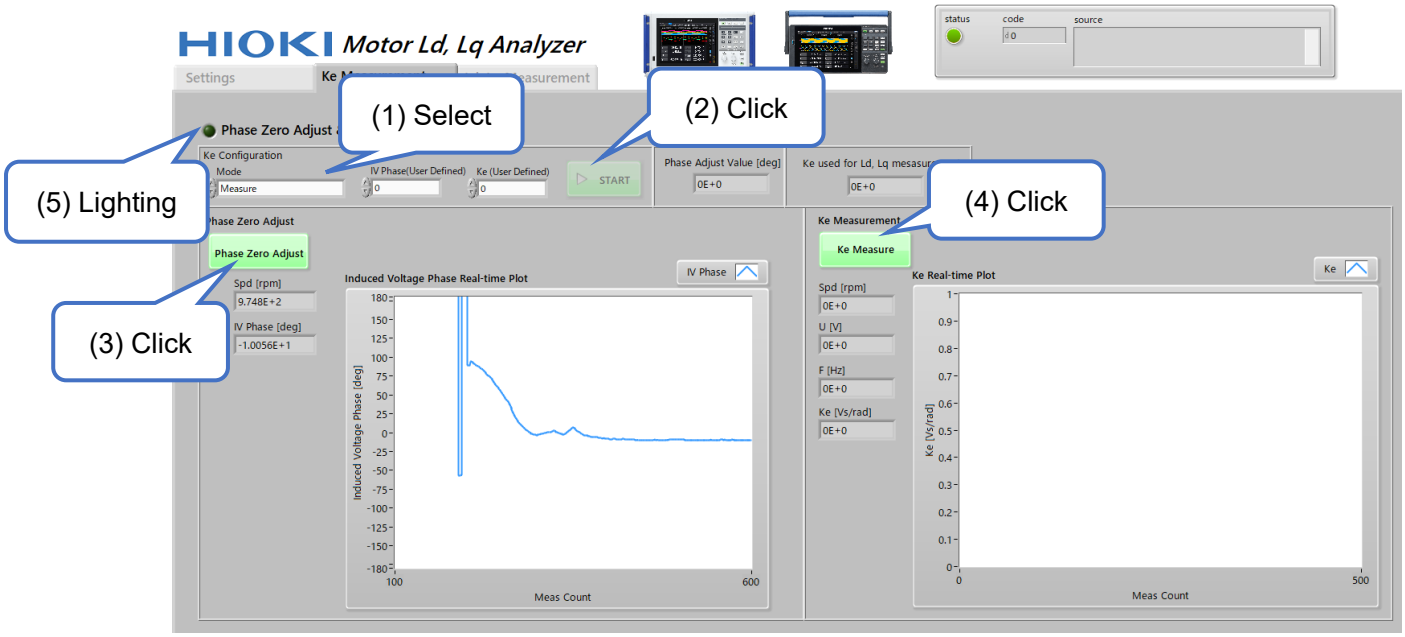
Setting item type	Setting sent to PW8001 / PW4001
Wiring	3P3W3M
Sync. source, harmonic synchronization source, motor synchronization source	Ext1
Motor measurement items	Torque, speed (pulse)
Motor input upper frequency	1 kHz
Motor input lower frequency	0.1 Hz
Simple configuration mode (PWM)	Frequency upper limit 1 kHz, lower limit 1 Hz Integration mode RMS U/I rectification method MEAN/RMS LPF OFF
Voltage/current range	AUTO
Number of motor poles	2
Number of pulses	Based on user input
Δ-Y conversion	ON
Current sensor phase correction	AUTO, representative value (when a model name is input)
Data refresh rate	50 ms
Averaging mode	When measuring induced voltage constants: Exp MID When measuring Ld, Lq: based on user selection at the start of the measurement
Efficiency and loss formulas	For η1 (efficiency 1) and LOSS1: Input: active power of the selected channel (CH) Output: Pm (motor power)
Zero adjustment	Activates upon settings submission

5.4 Measurement and User Input of Induced Voltage Constants

Select the Ke Measurement tab to perform phase zero adjustment, induced voltage constant measurement, and user input.

When Using the Induced Voltage Constant Measurement Mode

Measure the phase angle of the induced voltage, the phase zero adjustment, and the induced voltage constant.



Induced voltage constant measurement mode.

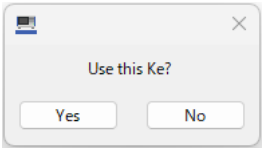
① Rotate the motor from the load side.

② Select Measure in the **[Mode]** field and press the START button.

③ The real-time plotting of the induced voltage phase starts. When the graph stabilizes, press the **[Phase Zero Adjust]** to start phase zero adjustment. The value is then recorded in the **[Phase Adjust Value [deg]]** field.

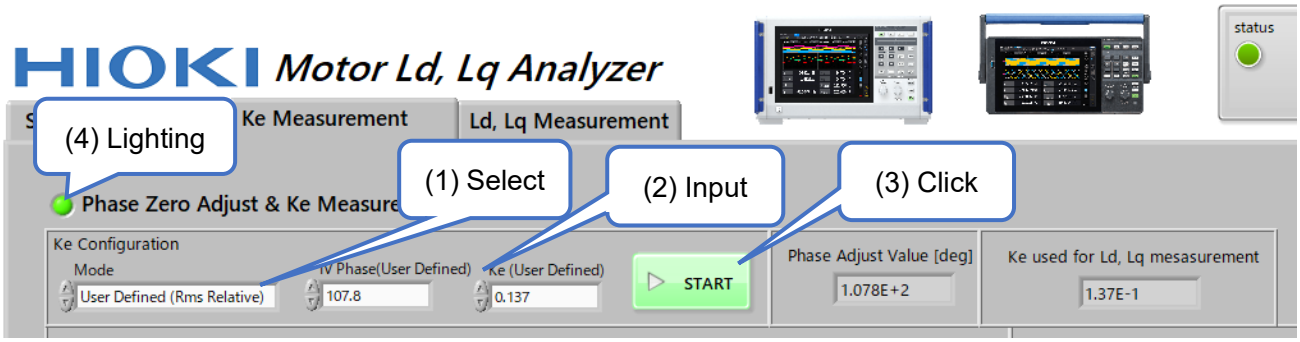
④ The real-time plotting of the induced voltage constant starts. When the graph stabilizes, press the **[Ke Measure]** button. The Ke values used for Ld, Lq measurement field will be recorded in the **[Ke used for Ld, Lq Measurement]** field.

⑤ A message box will appear. Press **[Yes]** to complete the phase zero adjustment and induced voltage constant measurements. The green light icon will illuminate.
(If you want to start over from ②, select **[No]**.)



When Inputting Induced Voltage Constant

If the user has already measured the induced voltage phase angle and the induced voltage constant, the value can be manually input to perform phase zero adjustment.



User input of induced voltage constant.

① In the **[Mode]** field, select the type of induced voltage constant that matches the input Ke value (**[User Defined (Rms Relative)]**, **[User Defined (Relative)]**, or **[User Defined (Absolute)]**).
The entered Ke value is converted to the value of the Conversion type set in the [Calculation] field of the Measurement Configuration screen.
For details, please refer to "7.1 Measurement of Induced Voltage Constant".

② Enter the induced voltage phase angle in the **[IV Phase (User Defined)]** field and the induced voltage constant in the **[Ke (User Defined)]** field.
The input range of the induced voltage phase angle is −180° to 180°.

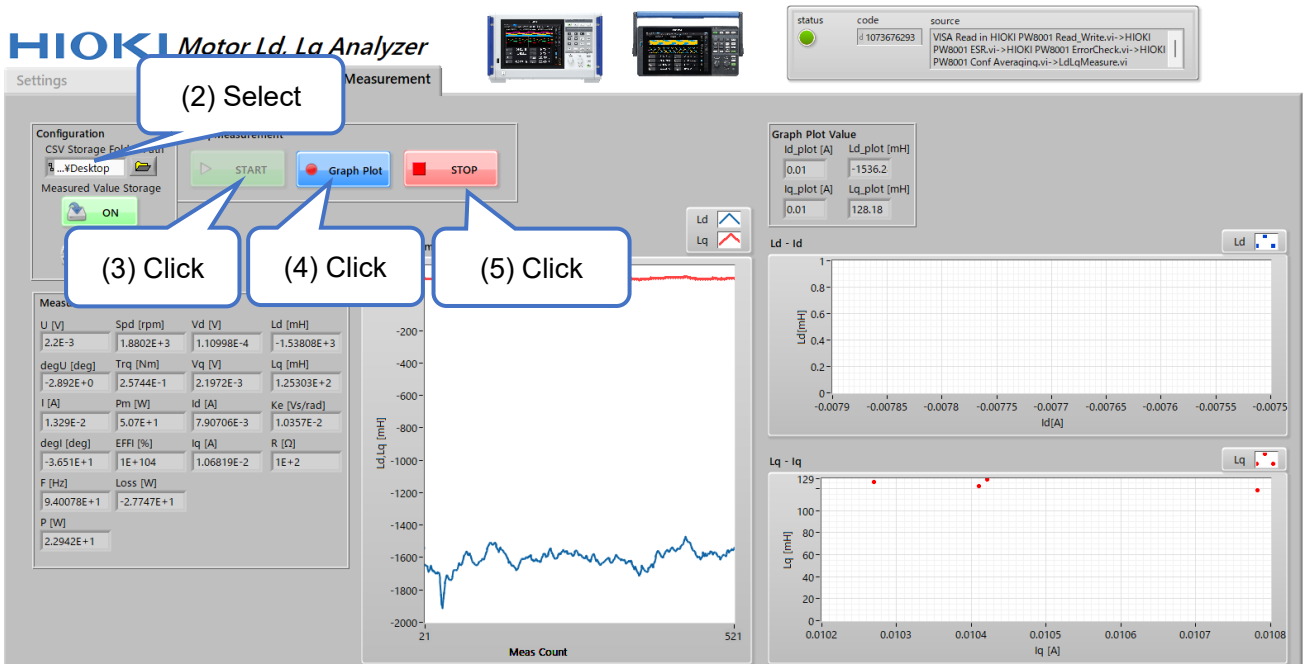
③ Press the START button. A phase zero adjust command based on the input induced voltage phase angle is sent to the PW8001 / PW4001.

④ When phase zero adjustment is complete, the green light icon will illuminate.

6 Measurement with the Motor Ld,Lq Analyzer

6.1 Ld, Lq Measurement

Select the **[Ld, Lq Measurement]** tab to display the motor measurement data in real time, plot the Ld-Id, Lq-Iq graph, and save to a CSV file.



Ld, Lq Measurement Screen

① Let the inverter drive the motor.

② You can set the CSV destination path, turn CSV saving on or off, and select the measurement averaging mode. If CSV saving is on, the measurement data is stored in the specified path. If you do not specify a path, the measurement data is not saved.

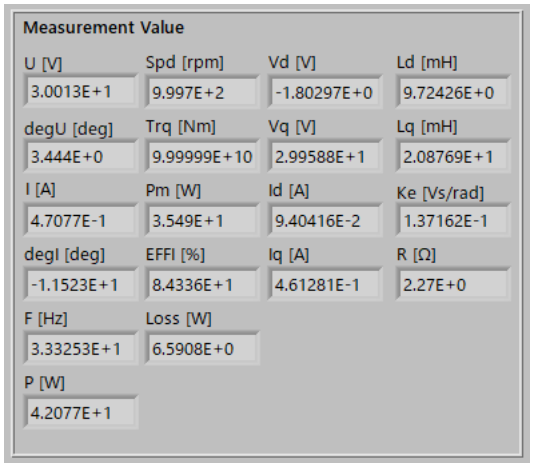
③ Press the START button to start the real-time display of the motor measurement data.

④ When the Graph Plot button is pressed, the measured values when the button is pressed are plotted in the Ld-Id and Lq-Iq graphs.

⑤ Press the STOP button to end the measurement.

Optional Item Measurement

In addition to Ld and Lq measurements, you can select any six items from the Measurement Value to plot.

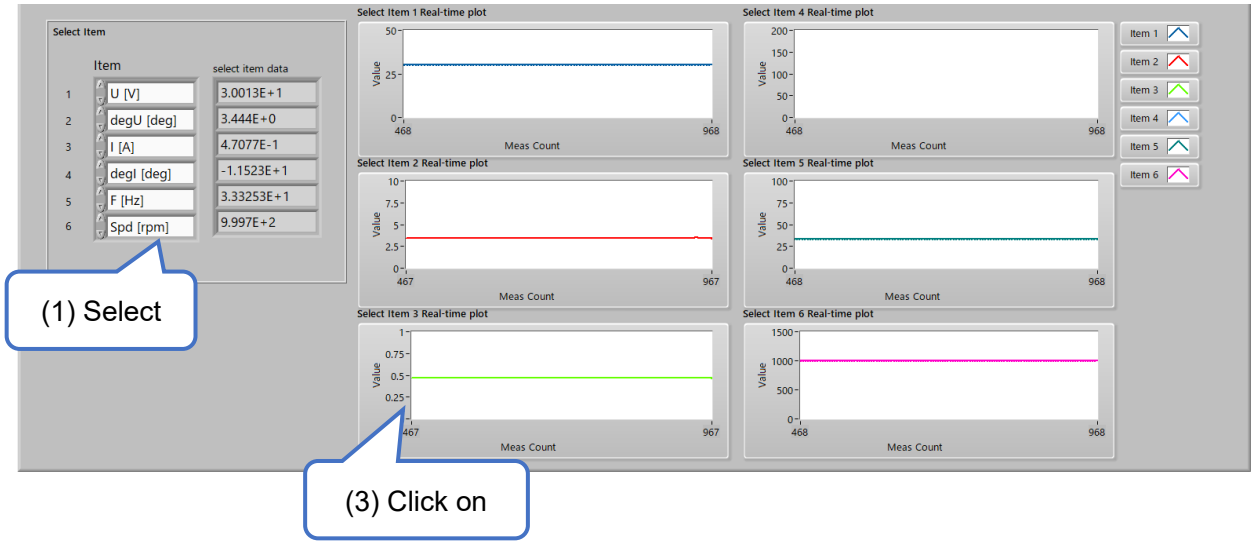


① In the **[Item]** field, select the data you want to plot in the graph.

② Real-time display of these data begins at the same time that the Ld and Lq measurements start.

③ You can click on the vertical axis of the graph to set the upper and lower limits of the display.

④ Press the STOP button to end the measurement.



Optional item measurement screen.

6.2 Measurement Data Storage to CSV File

- If CSV saving is ON, the measurement data is output as a file.
- The timestamp and the date/time in the file name are based on the PC clock.
- Changing the AUTO range of the current sensor or sending commands to the PW8001 / PW4001 may output invalid data (large values such as 7.78E+103).

Measurement Data Files (CSV)

All measurement data from the beginning to the end of the measurement is stored to the CSV.

In the CSV file, the items you chose to plot (by pressing the Graph Plot button) are marked with a “1” in the Plot column.

The file name is saved as follows: “Ld, Lq_meas_ year-month-day hour-minute-second.csv”

Saved parameters

Parameter name	Header
Timestamp	Time
Voltage RMS	U
Voltage phase angle	degU
Current RMS	I
Current phase angle	degI
Frequency	F
Active power	P
Rotation speed	Spd
Torque	Trq
Motor power	Pm
Motor efficiency	EFFI
Motor loss	Loss
d-axis voltage	Vd
q-axis voltage	Vq
d-axis current	Id
q-axis current	Iq
D-axis inductance	Ld
Q-axis inductance	Lq
Induced voltage constant	Ke
Phase electric armature resistor	R
Graph plot	Plot

6.3 If the Measured Value is Not Displayed or Stable

If the measured value is not displayed or stable when using this software, please check the following.

- Check the frequency settings for motor measurement. If the upper frequency limit is too high, motor measurement items such as rotation speed will not be displayed.
- Check whether there is noise in the Z-phase pulse input to CH B. Check the cable wiring. Ground the encoder that outputs the pulse signal. Set the Pulse Noise Filter (PNF) (refer to the unit's instruction manual).

7 Specifications (Processing Details)

7.1 Measurement of Induced Voltage Constant

The harmonic measurement data for the N-th order harmonic (where N equals the number of pole pairs entered in the settings) is obtained and displayed.

When the Phase Zero Adjust button is pressed, the induced voltage phase angle at that moment is divided by the order N, and the result is sent to the PW8001 / PW4001 as the fundamental (1st order) induced voltage phase angle to perform phase zero adjustment.

After phase zero adjustment, measurement data is acquired from the PW8001 / PW4001, the induced voltage constant is identified, and the result is displayed.

The value of the induced voltage constant recorded when the Ke Measure button is pressed is used for Ld, Lq measurements.

Measured data obtained
- RMS voltage (Urms) of the harmonic order is set in the [Number of Pole Pairs] field.
- Voltage frequency (FU)

(The harmonic order is automatically calculated from the pole-pairs setting.)

Identification equation for Ke

Rms Relative : $\mathbf{Ke = Urms\ /\ (2\pi FU)}$

Relative : $\mathbf{Ke = \sqrt{2} * Urms/(2\pi FU)}$

Absolute : $\mathbf{Ke = \sqrt{3} * Urms/(2\pi FU)}$

Measurements are obtained with the exponential average mode MID of the PW8001.

The user-defined Ke value entered in the Ke Measurement screen (RMS Relative, Relative, or Absolute) is automatically converted using the formula listed above that corresponds to the Conversion type selected on the Measurement Configuration screen. The converted value is used for all subsequent calculations.

7.2 Ld, Lq measurement

Measurement data is obtained from the PW8001 / PW4001, and Ld and Lq are identified and displayed.

Measurement data that is acquired

Harmonic measurement data of the N-th order (pole pairs):

Voltage RMS Urms, voltage phase angle degU, current RMS Irms, current phase angle degI

Basic measurement data:

Voltage frequency FU

Identification Equations for Vd, Vq, Id, and Iq

Rms Relative:

$$V_d = -U_{rms} \sin degU$$
$$V_q = U_{rms} \cos degU$$
$$I_d = -I_{rms} \sin degI$$
$$I_q = I_{rms} \cos degI$$

Relative:

$$V_d = -\sqrt{2} * U_{rms} \sin degU$$
$$V_q = \sqrt{2} * U_{rms} \cos degU$$
$$I_d = -\sqrt{2} * I_{rms} \sin degI$$
$$I_q = \sqrt{2} * I_{rms} \cos degI$$

Absolute:

$$V_d = -\sqrt{3} * U_{rms} \sin degU$$
$$V_q = \sqrt{3} * U_{rms} \cos degU$$
$$I_d = -\sqrt{3} * I_{rms} \sin degI$$
$$I_q = \sqrt{3} * I_{rms} \cos degI$$

Identification equations for Ld, Lq (using the Ke value obtained through the conversion type as explained in 7.1)

$$L_d = \frac{V_q - 2\pi \cdot FU \cdot K_e - RI_q}{2\pi \cdot FU \cdot I_d}$$

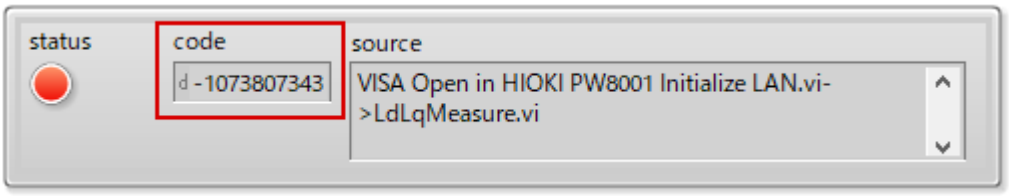
$$L_q = \frac{RI_d - V_d}{2\pi \cdot FU \cdot I_q}$$

8 Error handling

If you encounter an error, fix the error cause first, then restart the application and run again.

Error Code: -1073807343

・Unable to connect to LAN



Make sure that your IP address is correct, that your LAN is connected correctly, and that NI-VISA is installed.

・Measurements cannot be obtained

Check your LAN connection.

Error code: 1300

・PW8001 / PW4001 cannot be configured

Check whether the 3 channels selected in the settings have units installed. Make sure that each of the 3 channels is using the same current sensor. Check the phase correction settings of the current sensor. Sending a setting other than OFF to a channel not connected to a current sensor, or selecting AUTO for a current sensor without the automatic recognition function, will result in an error. Reset the integration state of the power analyzer.

・Phase zero adjustment cannot be performed

Make sure that the phase angle measurement (IV Phase) when pressing the Phase Zero Adjust button is within the range of -180° to 180°

- No motor analysis option installed

No motor analysis option installed Use a PW8001 / PW4001 with the motor analysis option installed.

Error Code: 1

・CSV file cannot be saved

Make sure that the CSV save path is set and that the path is enabled.

HIOKI

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