

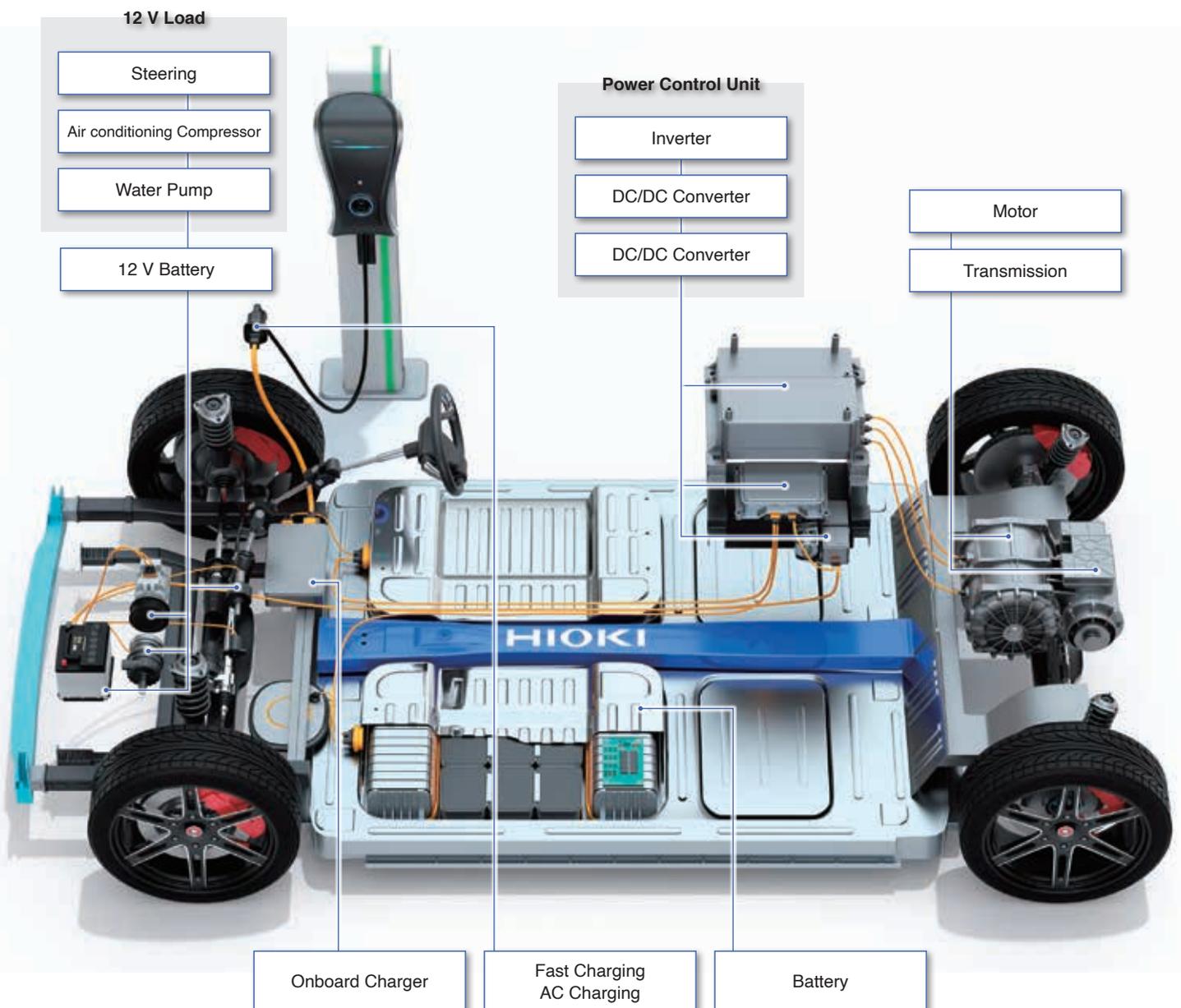
*Motor Measurement,
from Performance Analysis
to Quality Testing*

Measurement Application Profile

Improving Motor Performance and Quality

High-Precision Measurement Solutions

Hioki offers a diverse array of motor measurement solutions that can be used in applications ranging from performance analysis to quality testing. The ability to assess and analyze using high-precision measurement technologies provides valuable assistance to engineers as they work to increase motor performance and quality.



**Design/
Development** **Evaluating Inverter Motor Efficiency and Loss** **Page 4**

Simultaneously measure inverter input and output power, and motor output.
Evaluate inverter, motor, and overall system efficiency and loss in an accurate and highly reproducible manner.

**Design/
Development** **Identifying PMSM Motor Parameters** **Page 5**

Identify more accurate motor control motor control by using motor parameters measured under actual operating conditions in upstream design processes.

**Design/
Development** **Measuring Motor Temperature** **Page 6**

Apply thermocouples to the motor frame and winding to record temperature variations.
Display and record differences in temperature relative to the measurement environment as a waveform in real time.

**Design/
Development** **Measuring Dynamic Motor Characteristics** **Page 7**

Record inverter output voltage and current, torque, and RPM from motor start to stop.
Calculate inverter output power, motor power, and motor efficiency using waveform calculations.

**Design/
Development** **Measuring Motor Torque Vibrations** **Page 8**

Measure torque and vibration, and analyze behavior during motor operation.
Discover resonance phenomena and other unpredicted frequency components by using FFT calculations to perform a frequency analysis.

**Design/
Development** **Measuring Resolver Rotation Angles** **Page 9**

Record the resolver rotor excitation and output signal, and calculate the rotation angle using waveform calculation functionality.
Verify motor control sequences by analyzing the relationship between the resolver rotation angle and other signals.

**Production/
Testing** **Performing Layer Short Testing of Motor Windings** **Page 10**

Detect insulation failures (layer shorts) and deterioration in motor windings.
Generate pass/fail judgments with greater precision than conventional approaches by quantifying response waveforms.

**Production/
Testing** **Performing Motor Winding Maintenance** **Page 11**

Perform impulse testing and use the results in motor winding maintenance and trend management.

**Production/
Testing** **Measuring Motor and Winding Insulation Resistance and Breakdown Voltage** **Page 12**

Carry out insulation resistance and breakdown voltage testing.
Ensure a high level of safety by testing the state of insulation as part of shipping inspections.

**Production/
Testing** **Measuring Winding Resistance** **Page 13**

Check for wire breaks by measuring winding resistance with a high level of precision.
Check for incorrect wire thickness and turn count by using a high-precision resistance meter to make the measurements.

**Production/
Testing** **Measuring Motor Coil Inductance** **Page 14**

Measure winding inductance.
Check phase balance, motor dynamic performance, RPM variations, and compatibility of the driver and motor.

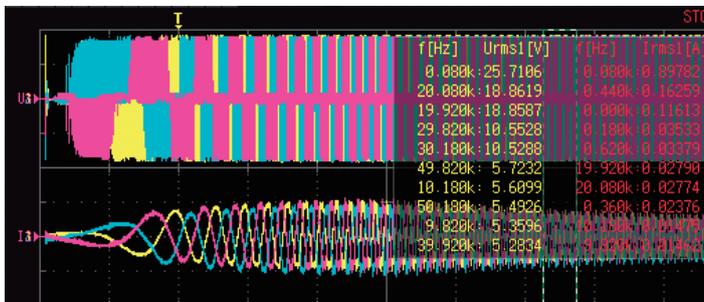
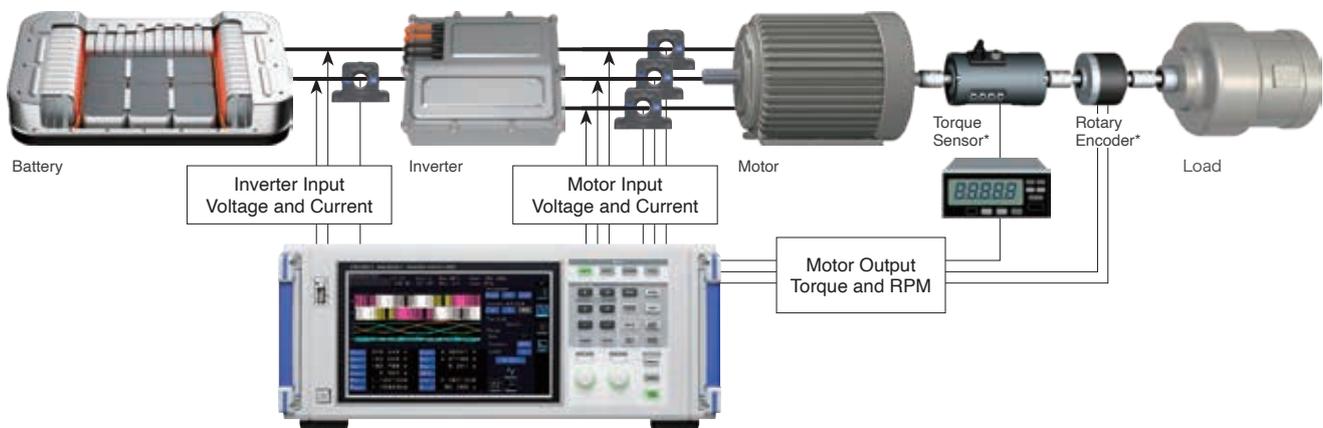
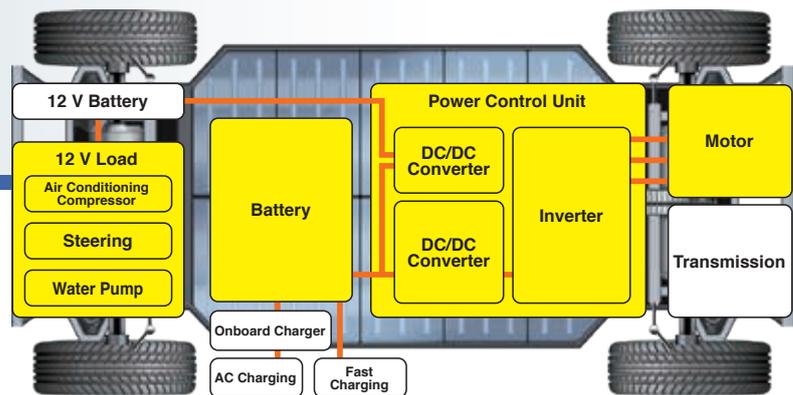
**Production/
Testing** **Measuring Motor Weld Resistance** **Page 15**

Test weld quality (check for weld defects) in rectangular wire stators using a DC resistance meter with high resolution and measurement accuracy.

Design/Development

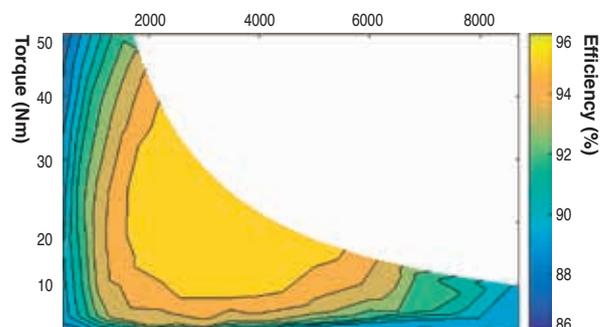
Evaluating Inverter Motor Efficiency and Loss

Simultaneously measure inverter input and output power, and motor output. Evaluate inverter, motor, and overall system efficiency and loss in an accurate and highly reproducible manner.



Analyzing Waveforms at Motor Start

Reliably capture and analyze instantaneous waveforms at the start of motor operation.



Efficiency/Loss Map

Created using measurement data and MATLAB. (MATLAB is a registered trademark of MathWorks.)

Equipment Used



POWER ANALYZER
PW6001



AC/DC CURRENT SENSOR
CT6875, CT6876

PW6001

- Power measurement (6 channels with 1 instrument or up to 12 channels by connecting 2 instruments)
- Basic accuracy (power) of $\pm 0.05\%$
- Waveform analysis without an oscilloscope; triggers specifically designed for motor analysis

CT6875, CT6876

- 500 A AC/DC, DC to 2 MHz (CT6875)
- 1000 A AC/DC, DC to 1.5 MHz (CT6876)
- Basic accuracy (power) of $\pm 0.048\%$

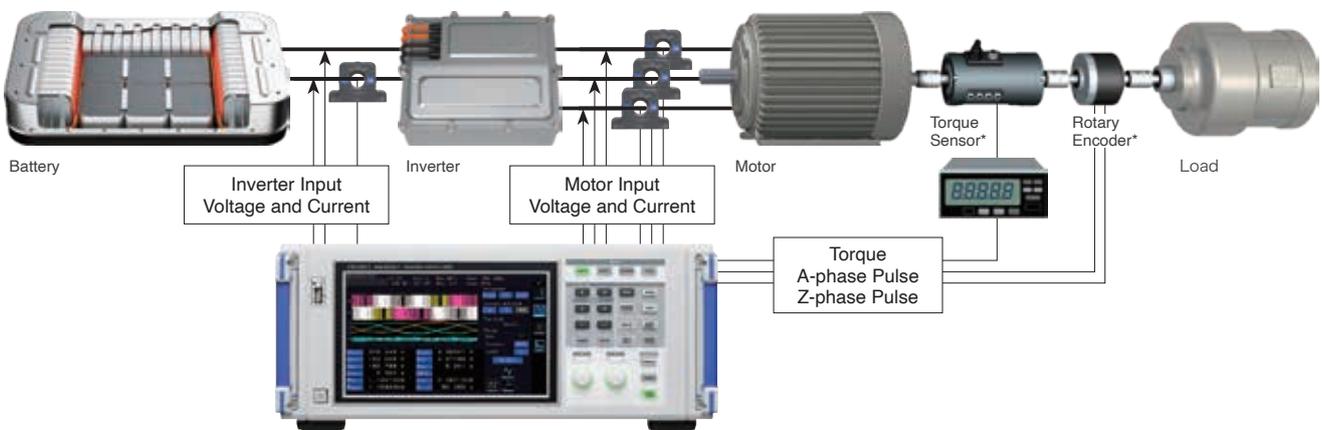
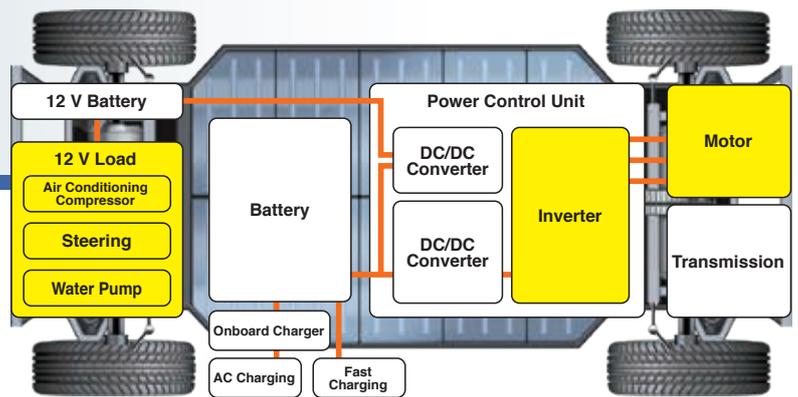
* Please prepare the torque sensor and rotary encoder separately.

Design/Development

Identifying PMSM Motor Parameters

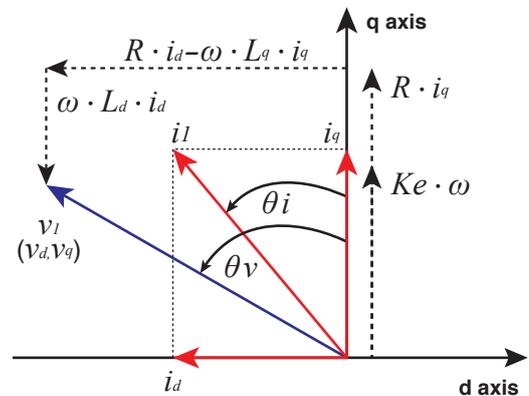
Identify more accurate motor control motor control by using motor parameters measured under actual operating conditions in upstream design processes.

PMSM
Permanent magnet synchronous motors (PMSMs) have been attracting attention in recent years as a type of 3-phase AC motor that can deliver low energy loss and significantly reduced power consumption.



Identifying Advanced Motor Control

In order to identify advanced motor control, it is necessary to take into account the current dependence of the d-axis and q-axis inductance L_d and L_q , which in the past were treated as constants. The PW6001 can carry out d-axis and q-axis vector analysis of voltage and current during motor operation. Since that data can be used to calculate L_d and L_q in real time, it is possible to measure the current saturation characteristics of motor parameters.



$$L_d = \frac{v_q - K_e \cdot \omega - R \cdot i_q}{\omega \cdot i_d} \quad L_q = \frac{R \cdot i_d - v_d}{\omega \cdot i_q}$$

Equipment Used



POWER ANALYZER
PW6001



AC/DC CURRENT SENSOR
CT6875, CT6876

PW6001

- Provides electrical angle measurement functionality that is needed to analyze vector control.
- Can display voltage and current vectors based on the d- and q-axes.
- Provides user-defined numerical calculation functionality that is useful when measuring motor parameters.

CT6875, CT6876

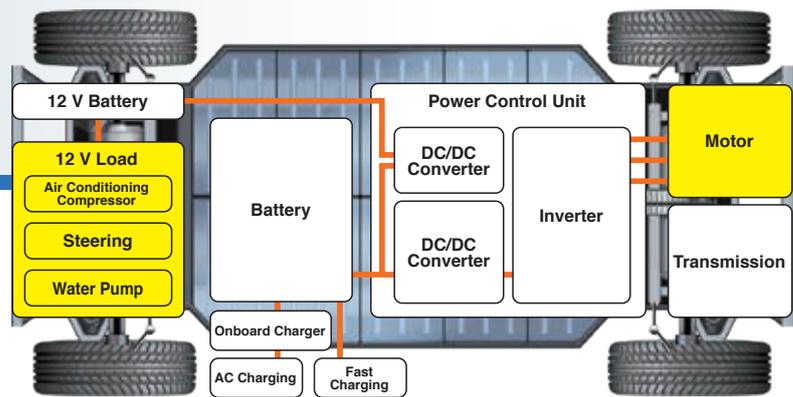
- 500 A AC/DC, DC to 2 MHz (CT6875)
- 1000A AC/DC, DC to 1.5MHz (CT6876)
- Basic accuracy (power) of $\pm 0.048\%$

*Please prepare the torque sensor and rotary encoder separately.

Design/Development

Measuring Motor Temperature

Apply thermocouples to the motor frame and winding to record temperature variations. Display and record differences in temperature relative to the measurement environment as a waveform in real time.



Accommodates up to four units

- Voltage: from 1 ms sampling
- Temperature: from 10 ms sampling
- Strain: from 1 ms sampling
- Humidity: from 10 ms sampling
- Resistance: from 10 ms sampling



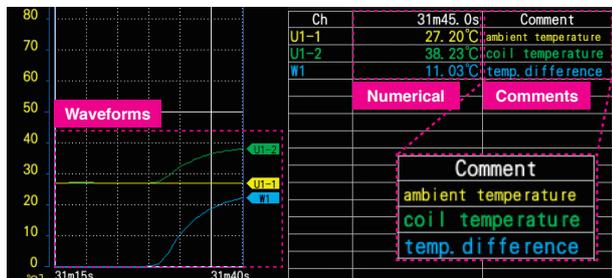
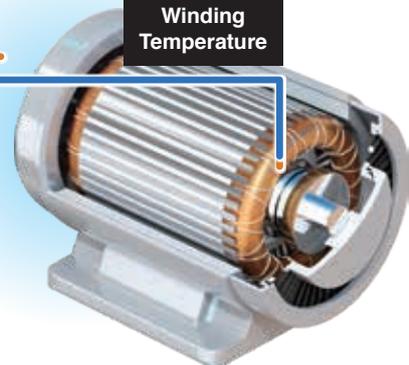
U8550



Ambient Temperature

Winding Temperature

LR8450



Channel	Formula
#1	=(I[M]B-2) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#2	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#3	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#4	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#5	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#6	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#7	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#8	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#9	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#10	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#11	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#12	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)
#13	=(I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1) + (I[M]B-1)

Display Waveforms, Values, and Comments on The Screen

The instrument can simultaneously display waveforms and numerical values. Recorded data can be identified easily since user-entered comments can be displayed along with the data.

Record The Differences Between The Ambient Temperature and The Winding Temperature

By configuring calculation formulas with the waveform calculation function, you can record the differences between temperature measurements along with the measurement results.

Equipment Used



MEMORY HILOGGER LR8450



VOLTAGE/TEMP UNIT U8550

LR8450

The instrument accommodates various measurement units. These units can measure not only temperature, but also voltage and strain at a 1 ms sampling period.

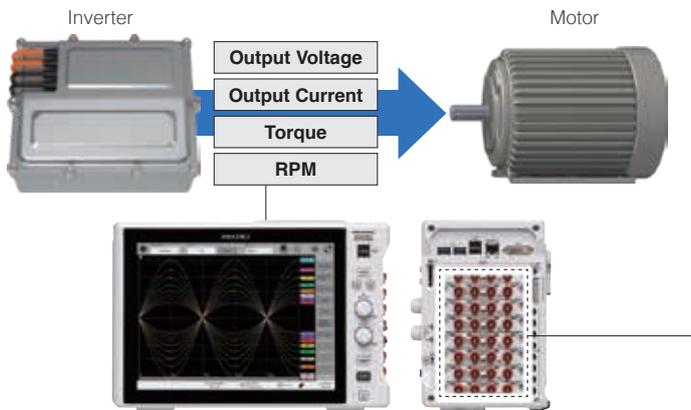
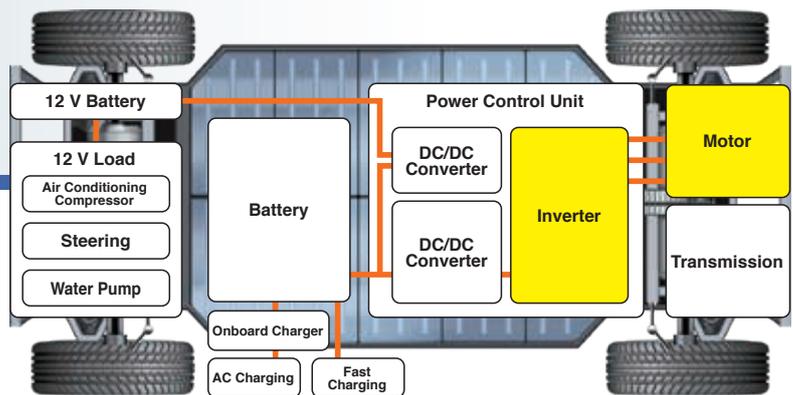
LR8450-01 (wireless LAN model)

The LR8450-01 can accommodate wireless units such as the LR8530 Wireless Voltage/Temp Unit, eliminating the need to wire together the instrument and unit.

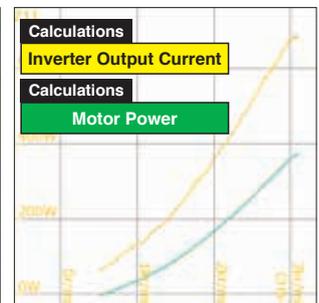
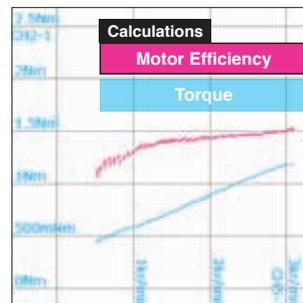
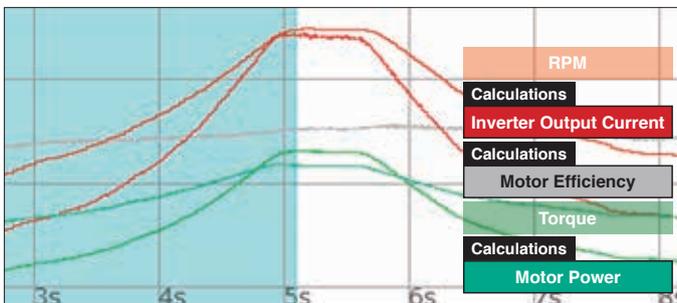
Design/Development

Measuring Dynamic Motor Characteristics

Record inverter output voltage and current, torque, and RPM from motor start to stop. Calculate inverter output power, motor power, and motor efficiency using waveform calculations.



Output Voltage U8978 9322		Output Current U8977 CT6841-05	
Torque U8969		RPM 8970 L9197	



Calculate Inverter Output Power, Motor Power, and Motor Efficiency Using Waveform Calculations

Calculate motor power, motor efficiency, and inverter output power after measurement using high-speed waveform calculations and display the results using the instrument's X-Y display function. The ability to use the X-Y display for waveform calculation results as well as input signals from measurement units means you can perform a broad range of analyses. Additionally, X-Y analysis can be performed at user-specified areas of the recorded fluctuating waveform, since you can choose waveform areas for generating an X-Y display.

Equipment Used



MR6000/MR6000-01



U8978



U8977



8970



U8969



9322



CT6841-05



L9197

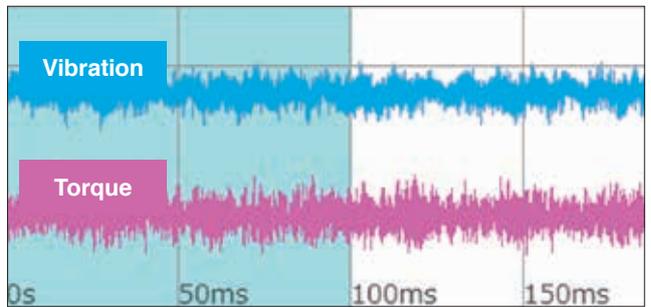
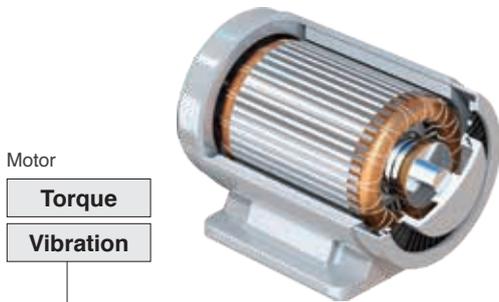
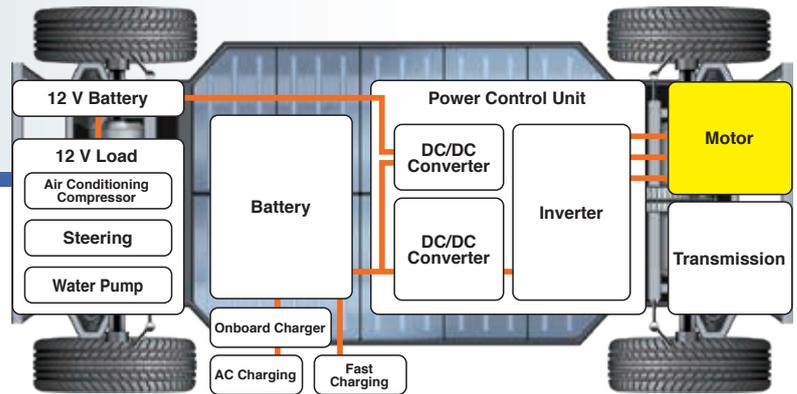
- MEMORY HiCORDER MR6000/MR6000-01
- 4CH ANALOG UNIT U8978
- DIFFERENTIAL PROBE 9322
- 3CH CURRENT UNIT U8977
- AC/DC CURRENT PROBE CT6841-05
- FREQ UNIT 8970
- CONNECTION CORD L9197
- STRAIN UNIT U8969
- Torque sensor^{*1}

*1 Torque sensor (strain gage-type converter) (For more information about the sensor, please contact the sensor manufacturer.)

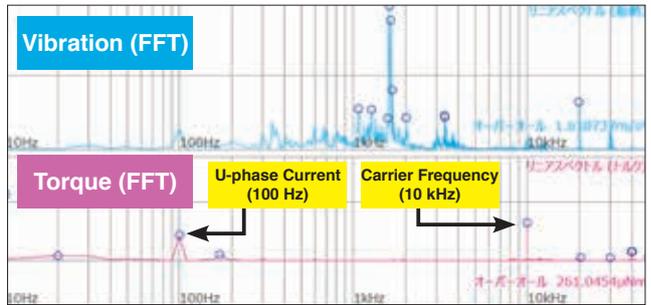
Design/Development

Measuring Motor Torque Vibrations

Measure torque and vibration, and analyze behavior during motor operation. Discover resonance phenomena and other unpredicted frequency components by using FFT calculations to perform a frequency analysis.



Record Torque and Vibration.



Perform Frequency Analysis Using FFT Calculations.

The MR6000/MR6000-01's FFT calculation functionality can be used to perform frequency analysis of torque and vibration signals. The MR6000/MR6000-01's FFT calculation functionality can analyze 8 phenomena simultaneous per measurement. By performing FFT analysis of signals input to different channels, it is possible to analyze frequency components occurring at the same time on different channels.

Torque		Vibration	
	Torque Sensor ¹		Acceleration Sensor ²
U8969		U8979	

Equipment Used



- MEMORY HICORDER MR6000/MR6000-01
- STRAIN UNIT U8969
- Torque sensor¹
- CHARGE UNIT U8979
- Acceleration sensor²

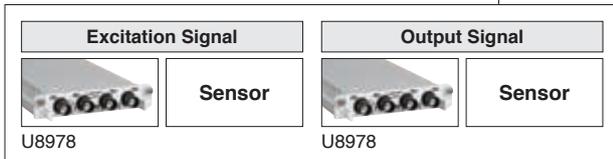
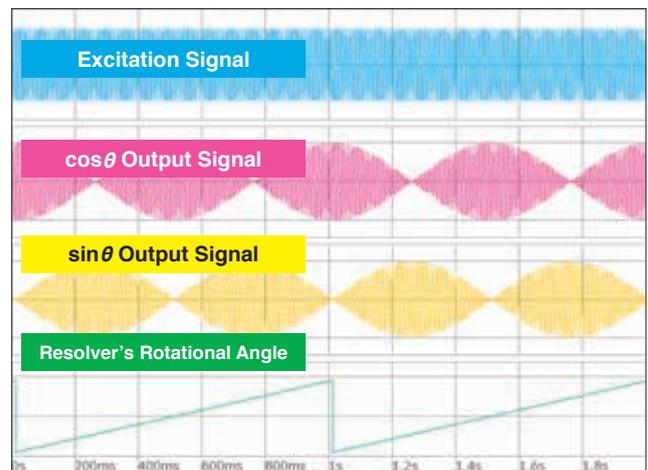
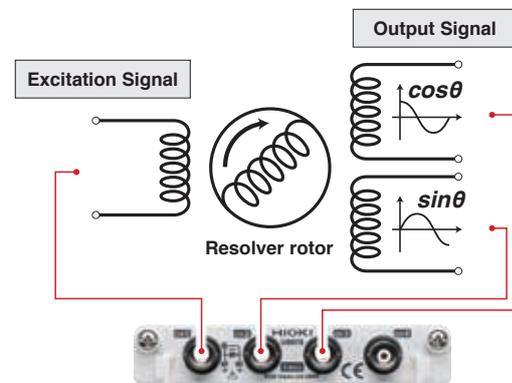
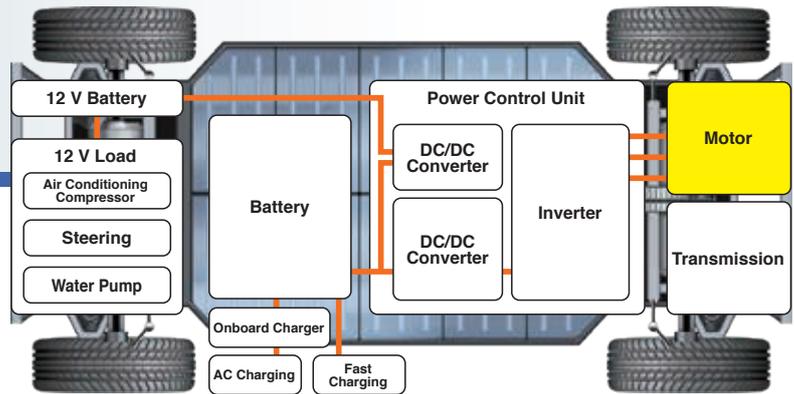
The torque sensor (strain gage-type converter) is connected to the Strain Unit U8969 to measure torque. An acceleration sensor affixed to the chassis, on which the motor is mounted, is connected to the Charge Unit U8979 to measure vibrations being transferred to the chassis.

¹ Torque sensor (strain gage-type converter) (For more information about the sensor, please contact the sensor manufacturer.)
² Charge output type with built-in pre amp (For more information about the sensor, please contact the sensor manufacturer.)

Design/Development

Measuring Resolver Rotation Angles

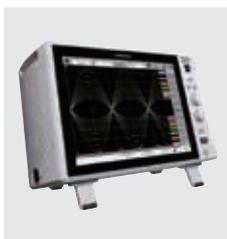
A resolver is used as a sensor to accurately measure the angular position of the motor. Resolvers are used in harsh environments such as industrial motors, servers, and electric vehicles (EVs) because they can operate under demanding conditions for extended period of time. In order to increase EV range, it's necessary to control motors with a high degree of precision so as to boost their energy efficiency.



Calculate The Resolver's Rotational Angle Using Waveform Calculations.

The resolver's excitation signal and output signal are input to the 4ch Analog Unit U8978. Since setups that would have required two slots with previous models can be accommodated with a single slot, there's capacity left over to measure temperature, control signals, torque, and current signals at the same time. The instrument's waveform calculation function is used to calculate the resolver's rotational angle. Motor control sequences can be adjusted by analyzing the relationship between the resolver rotation angle and other signals.

Equipment Used



MR6000/MR6000-01



U8978

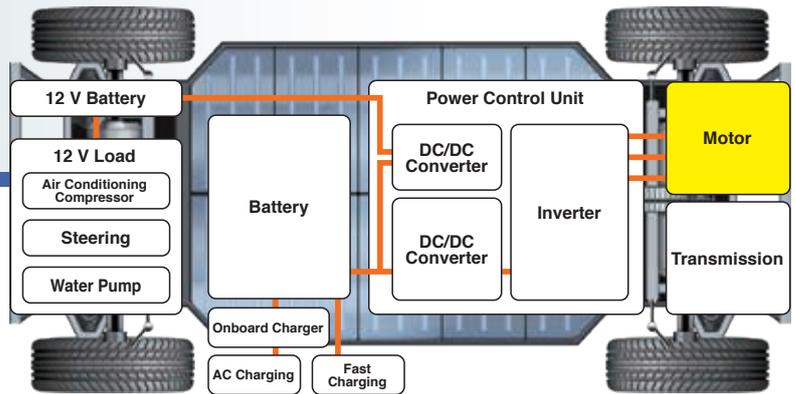
- MEMORY HiCORDER MR6000/MR6000-01
- 4CH ANALOG UNIT U8978

The 4ch Analog Unit U8978 can be used to measure a resolver's excitation signal and output signal ($\sin\theta$ and $\cos\theta$) with a single unit slot. Additionally, the MR6000/MR6000-01's high-speed waveform calculation function can be used to display the rotational angle.

Production/Testing

Performing Layer Short Testing of Motor Windings

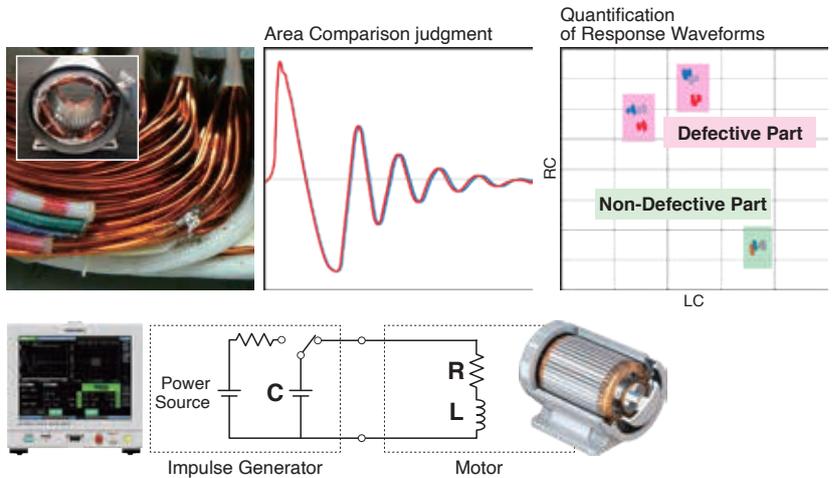
Detect insulation failures (layer shorts) and deterioration in motor windings. Generate pass/fail judgments with greater precision than conventional approaches by quantifying response waveforms.



Capture Minuscule Variations That Do Not Appear in Response Waveforms

Detect minuscule defects that do not appear in response waveforms more effectively than conventional area comparison judgment (AREA, DIFF AREA) by quantifying response waveforms.

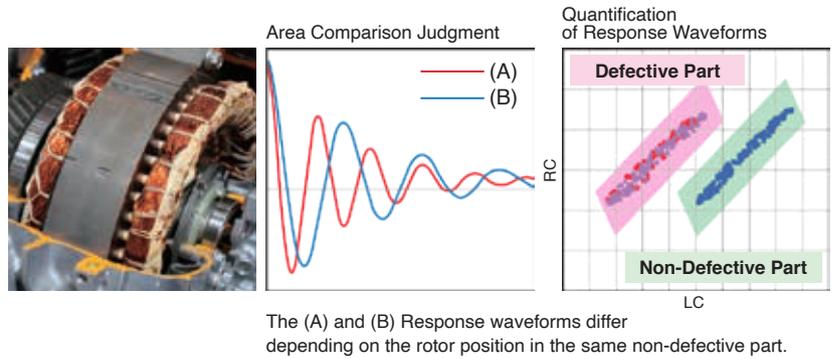
Since minuscule defects such as 1-turn shorts differ only slightly from the response waveform for a non-defective part, it's difficult to detect them using area comparison.



Carry Out Tests with The Rotor Installed

Changes in response waveforms caused by rotor position can also be quantified. Pass/fail judgments can then be generated by configuring non-defective and defective part areas.

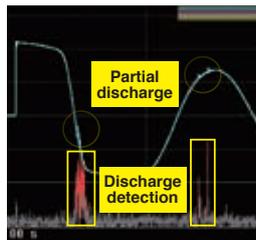
Since the response waveform varies with rotor position in conventional area comparison judgment, it is not possible to make pass/fail judgments for the motor.



Equipment Used



IMPULSE WINDING TESTER ST4030A



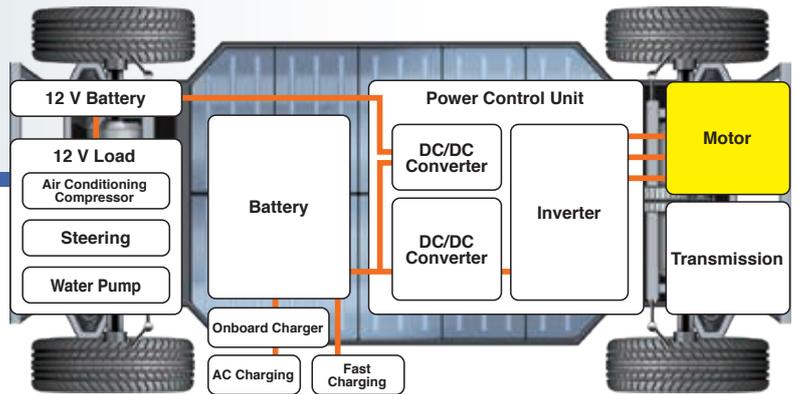
Discharge Detection Function ST9000

- High-precision waveform detection: 200 MHz, 12-bit resolution
- Quantification of response waveforms (using a patent held by Toenec Corporation)
- Detection of discharges obscured by noise (option)

Production/Testing

Performing Motor Winding Maintenance

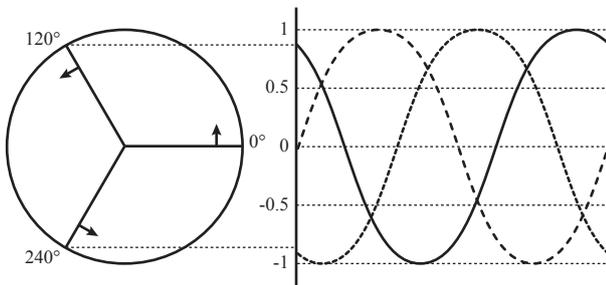
Perform impulse testing and use the results in motor winding maintenance and trend management.



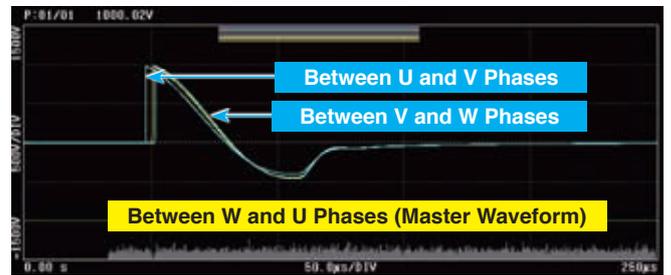
Check for Insulation Defects and Deterioration Even If No Non-Defective Part is Available

On a standard, properly configured 3-phase motor, the phases (U, V, and W) are balanced. Consequently, the response waveforms obtained when an impulse voltage is applied between phases (U-V, V-W, W-U) will be almost identical.

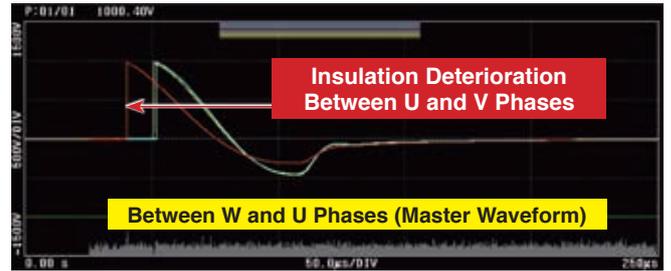
By tentatively identifying the response waveform obtained from one phase as the waveform for a non-defective part and comparing it to the response waveforms from the other phases, you can detect insulation failures and deterioration.



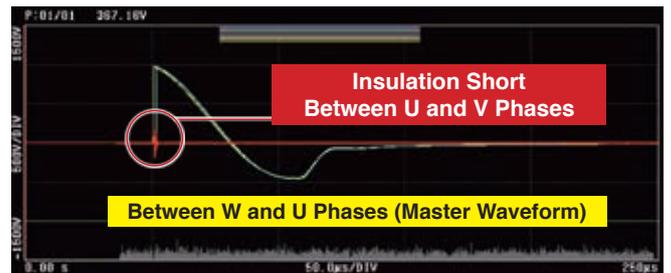
Properly Configured 3-phase Motor Phases (U, V, W) are Balanced.



Non-Defective Product Response Waveform



Example of Response Waveform Exhibiting Insulation Deterioration

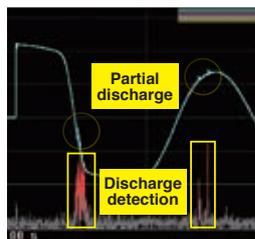


Example of Response Waveform Exhibiting Insulation Short

Equipment Used



IMPULSE WINDING TESTER ST4030A



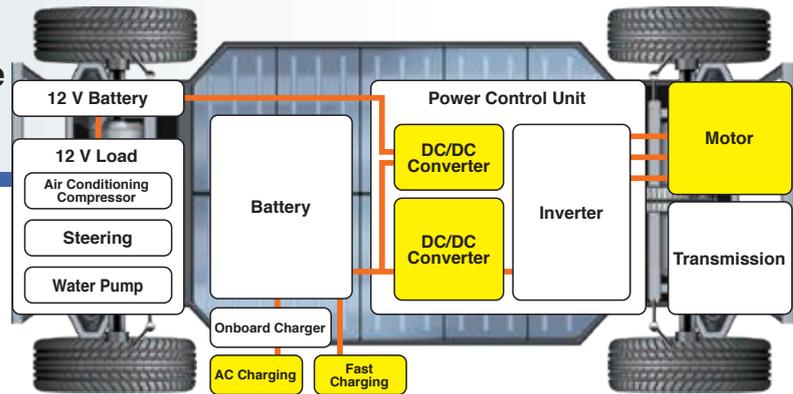
Discharge Detection Function ST9000

- High-precision waveform detection: 200 MHz, 12-bit resolution
- Quantification of response waveforms (using a patent held by Toenec Corporation)
- Detection of discharges obscured by noise (option)

Production/Testing

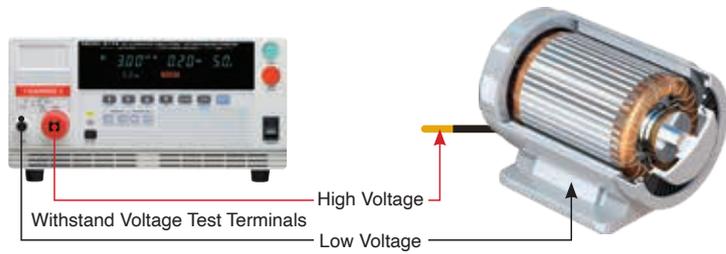
Measuring Motor and Winding Insulation Resistance and Withstand Voltage

Carry out insulation resistance and withstand voltage testing. Ensure a high level of safety by testing the state of insulation as part of shipping inspections.



For Use in Shipping Inspections Measure Insulation Resistance and Withstand Voltage

Insulation deterioration leads to the risk of electric shock and ground faults. The condition of insulation is tested during shipping inspections to ensure product safety.



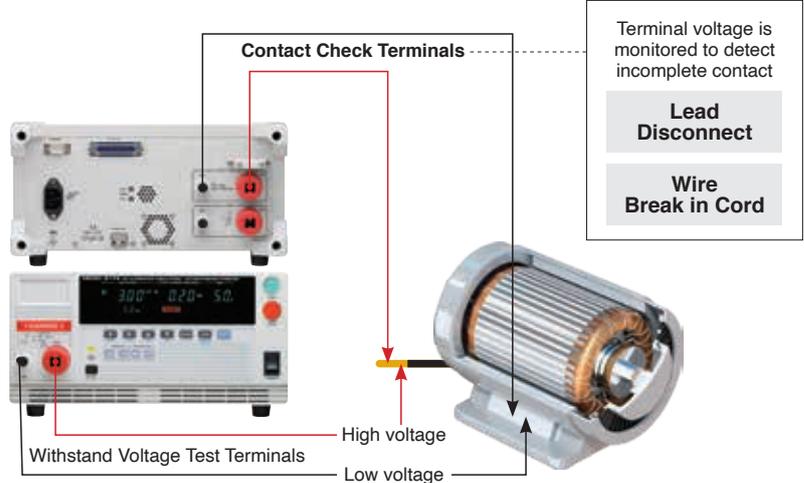
Results of Insulation Deterioration

Risk of Electric Shock

Risk of Ground Faults

Contact Check Function to Ensure Reliable Testing

Incomplete probe contact and wire breaks in cables can prevent proper contact with the device under test. In such cases, defective parts can be misidentified as non-defective. Contact check functionality provides an effective means of ensuring test integrity.



Equipment Used



AC AUTOMATIC INSULATION/
WITHSTANDING HI TESTER
3174



INSULATION TESTER
ST5520

Contact checks can be performed continuously without affecting measured values.

3174

- AC withstand voltage testing: 0.2 kV to 5 kV AC, 20 mA
- Insulation resistance testing: 500 V or 1000 V DC, 0.5 MΩ to 2000 MΩ

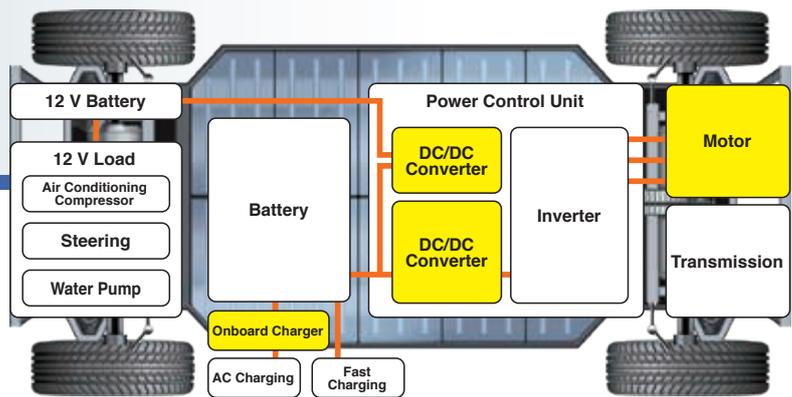
ST5520

- 25 V to 1000 V DC, 0.002 MΩ to 9990 MΩ

Production/Testing

Measuring Winding Resistance

Check for wire breaks by measuring winding resistance with a high level of precision. Check for incorrect wire thickness and turn count by using a high-precision resistance meter to make the measurements.



Testing Winding Quality with Resistance Measurement

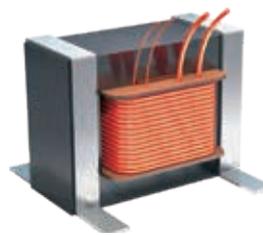
To operate a motor efficiently, it's necessary to apply a large current. To accommodate such currents, thick windings with low resistance are essential.

What can resistance values tell us?

- Incorrect Wire Thickness
- Incorrect Number of Turns
- Winding Shorts



Motor Windings



Transformer Winding



Coil Winding

Performance Required for Resistance Measurement

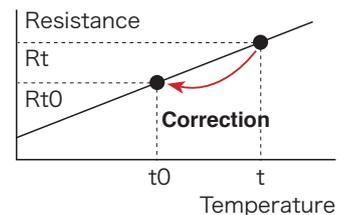
Winding resistance, which is continually falling as technology progresses, can be accurately measured using a resistance meter.

Required Performance

- Low-Resistance Measurement
- Ambient Temperature Correction

When measuring large windings, where low resistance values are increasingly becoming the norm, values must be managed on the order of 10 $\mu\Omega$.

It's essential to perform temperature correction since wire resistance values vary with temperature.



Equipment Used



RESISTANCE METER RM3545



MULTIPLEXER UNIT Z3003



RESISTANCE METER RM3548

RM3545

- High-precision resistance meter with a resolution of 0.01 $\mu\Omega$
- The RM3545-02 features an available internal multiplexer that efficiently measures resistance at multiple points.

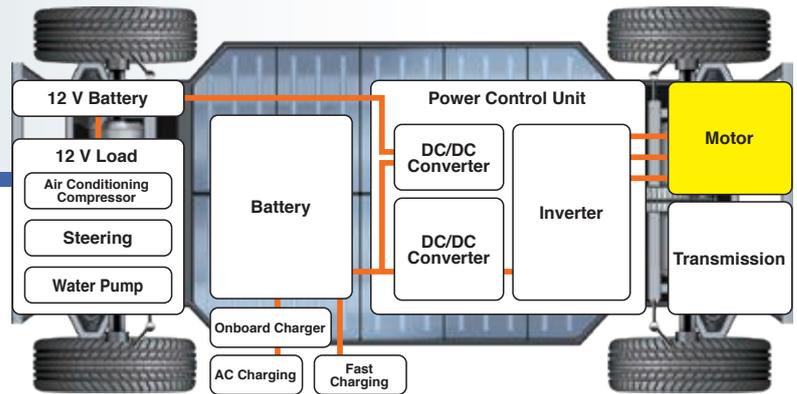
RM3548

- Temperature correction functionality and interval measurement are convenient in temperature rise testing of motors and transformers.
- The portable form factor is ideal for measuring large motors and transformers.

Production/Testing

Measuring Motor Coil Inductance

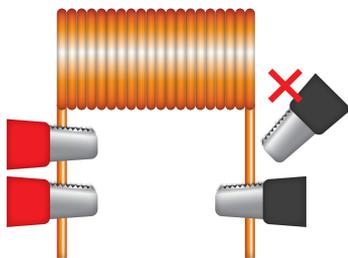
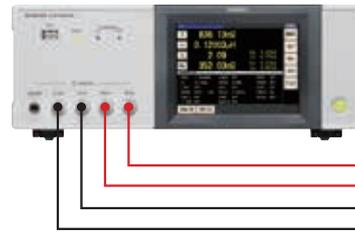
Measure winding inductance. Check phase balance, motor dynamic performance, RPM variations, and compatibility of the driver and motor.



Using Winding Inductance to Test Motor Performance

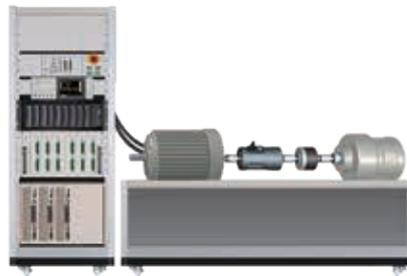
What can inductance tell us?

- Phase Balance
- Motor Operating Performance
- RPM Variations
- Compatibility of Drivers and Motors



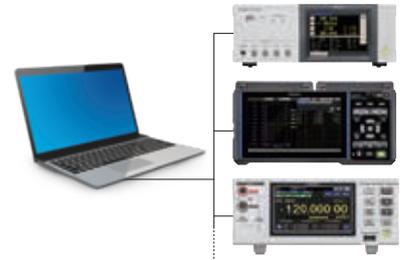
Contact Check

Preventing erroneous measurement to ensure reliable testing



Cable Length: 4 m

Accuracy is guaranteed for measurement cables up to 4 m in length. Compatible with large equipment designed for use with motors



Labview Driver Available

Use in combination with other instruments.

Equipment Used



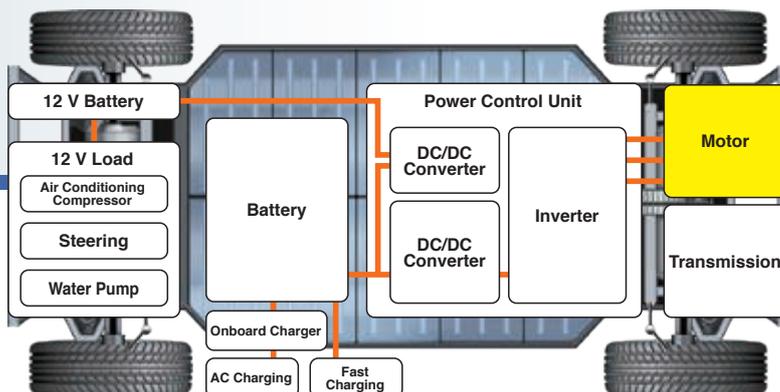
LCR METER
IM3536

- DC and 4Hz to 8MHz (up to 10MHz special order available) measurement frequency
- Manage winding inductance values using the judgment function.

Production/Testing

Measuring Motor Weld Resistance

Test weld quality (check for weld defects) in rectangular wire stators using a DC resistance meter with high resolution and measurement accuracy.



Rectangular Wire Stators

Rectangular copper wire that has been bent is affixed to the stator core, and rectangular wires from the same phase are welded together by a robot. Incomplete bonds can lead to latent defects due to insufficient weld penetration, cracking, and pinhole formation.

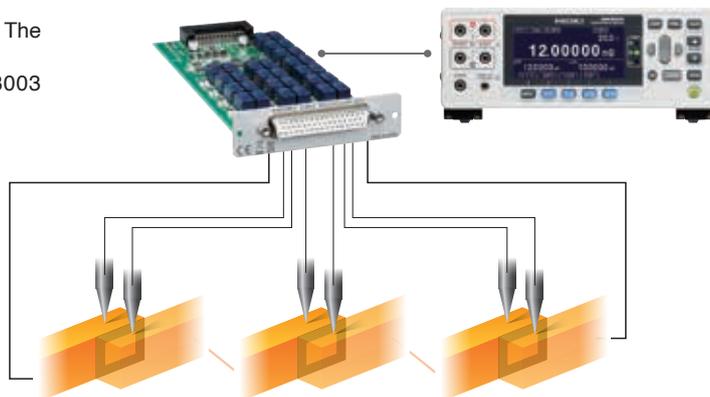


Testing Weld Quality with DC Resistance Measurement

Probes for detecting voltage contact both side of welding point. The RM3545 can measure resistance of welding. You can easily built measurement system by use the Z3003 multiplexer unit with the RM3545.

Since the Resistance Meter RM3545 can measure resistance at a resolution of 10 nΩ in the 10 mΩ range, the weld state can be judged on the basis of DC resistance values.

*Use the Temperature Sensor Z2001 with the RM3545's temperature correction function.



Equipment Used



RESISTANCE METER RM3545-02



MULTIPLEXER UNIT Z3003

- World-class Accuracy and Digit Count
- Measurement basic accuracy of 0.006%
 - Display count of 6 digits

Accurate Measurement of Super-low Resistance Values Allows quantification of the status of rectangular wire welds, playing a positive role when testing in the field.

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