Technical Information

Noise Interference on Recorder Operation, and Anti-Noise Measures
- Measures Against New Noise Sources -

CONTENTS

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1. Introduction

In a wide variety of industrial activities such as energy savings, temperature is one of the most important items to measure. Recorders are used in a wide range of applications centering on temperature measurement. On the othr hand, with the spread of thyristor choppers and transistor inverters, new noise sources are becoming popular. Since noise sources are composed of conventional commercial power supply and new noise sources, it is becoming difficult to take anti-noise measures.

It has been said that “measurement” means to pick “signals” (required data) out of “noise.”

Going back to the above-mentioned basis of measurement, this technical information introduces the basics of anti-noise measures and the means to cope with new noise sources.

If you need to take anti-noise measures urgently, simply reading section 4, “Anti-noise Measures: Applications” may be helpful. If you want to review the basics of anti-noise measures, refer to section 2, “Noise” and section 3, “Anti-noise Measures: Basics.”

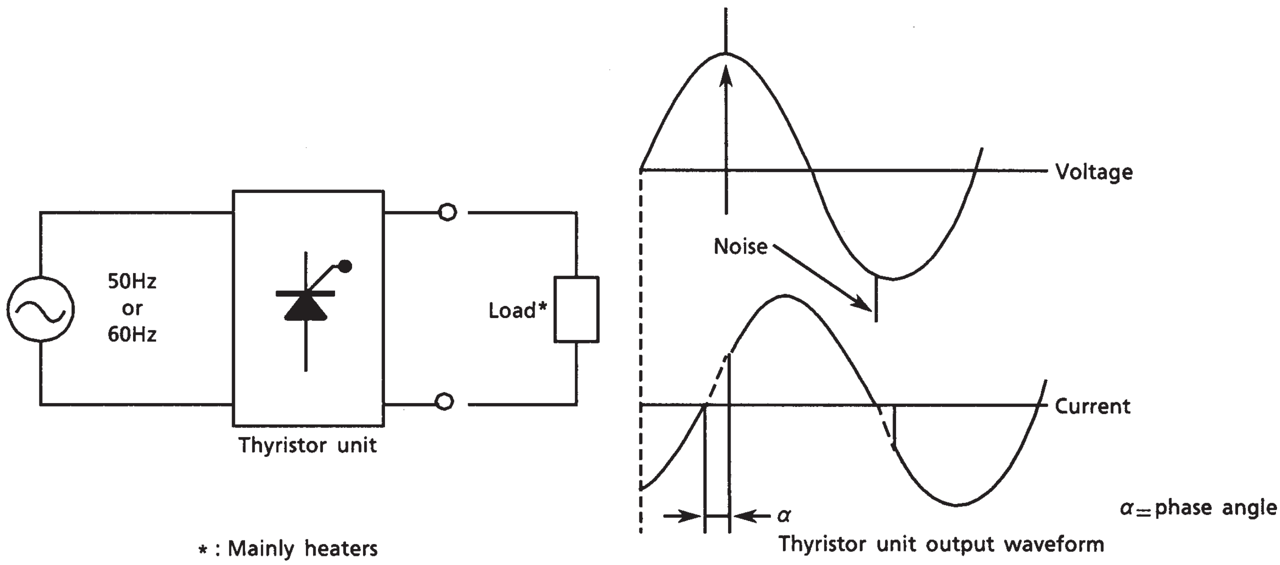
Use this information as a handbook for solutions to noise problems.

2. Noise

2.1 Types and Features of Noise Sources

① **Commercial power supply**
Commercial power is supplied at a fixed frequency of 50 or 60Hz depending on the district and country. Also, since the manufacturers of household electrical products use power at both 50 and 60Hz to inspect their products for various districts and countries, it is necessary to consider both 50 and 60Hz as noise components. It is important to note that a power supply line in which a thyristor or inverter is incorporated functions not only as an "energy supply line," but also as a "noise supply line."

② **Thyristor (SCR)**
A thyristor is used to control power through on / off modulation of commercial power by controlling the phase angle.



When the thyristor turns on or off, a pulse noise is superimposed on commercial power supply, and its pulse width is approximately 1μs. Thus, thyristor noise can be defined as follows:

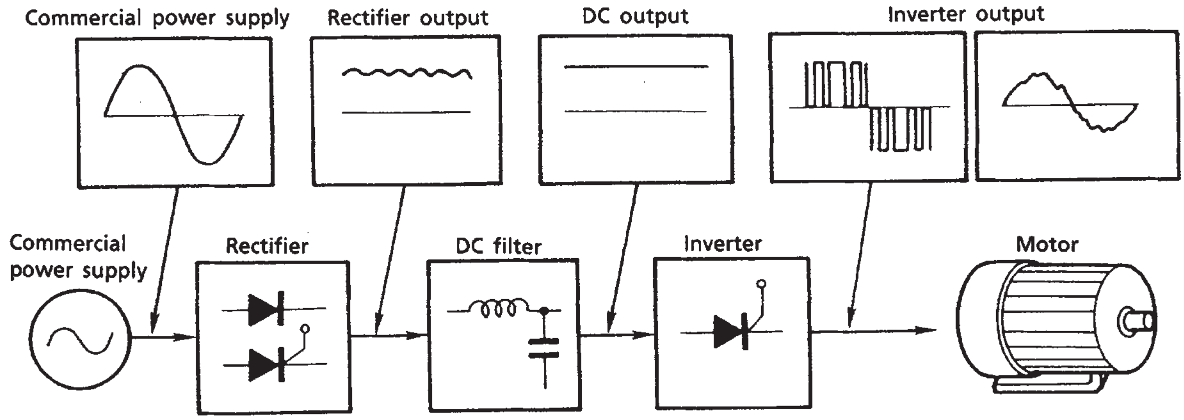
Thyristor noise = commercial power supply + pulse noise

③ Inverter

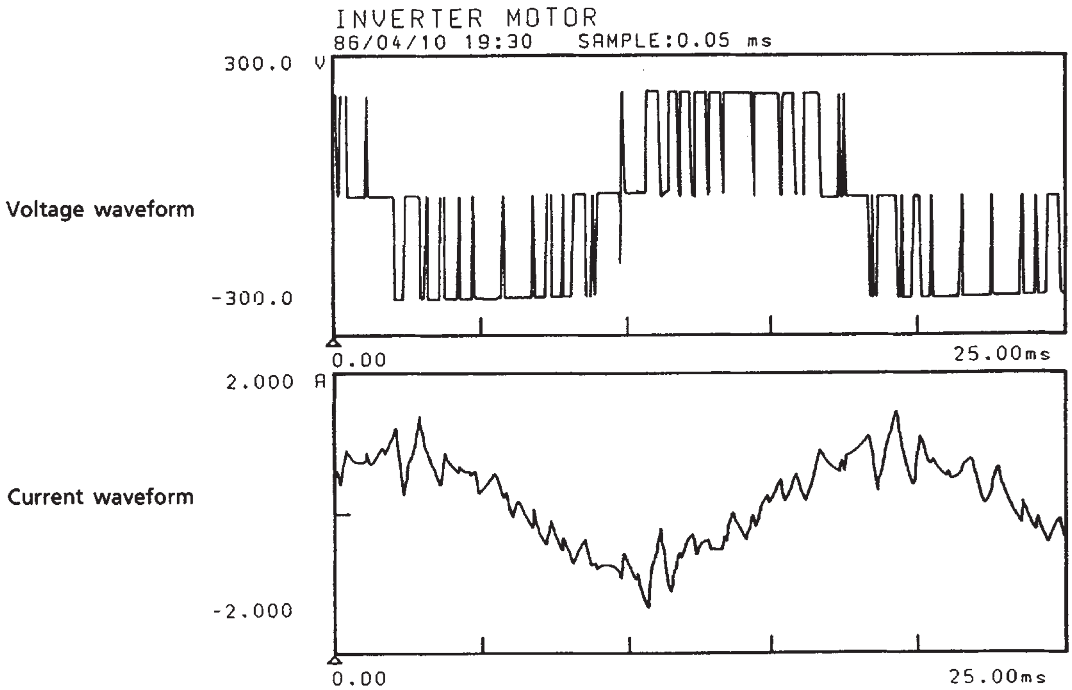
Commercial power supply is converted to direct current by a rectifier (sometimes the thyristor is used as the rectifier to stabilize direct current) and then modulated by a switching transistor and finally converted into alternating current at the desired frequency (from tens to hundreds of Hz) to drive a motor, for example. If the load to be driven is a fluorescent lamp, the frequency is tens of kHz. Thus, inverter noise can be expressed by the following equation:

Inverter noise = commercial power supply + pulse noise (high density) + Variable low frequency noise

Since the density of pulse noise is high compared to that of a thyristor and in addition, there is variable frequency noise, it is difficult to consider a countermeasure for inverter noise.



Principle of an Inverter



Voltage and Current Waveforms of an Inverter

④ **Relay**

A relay is frequently used to amplify alarm and temperture controller outputs. However, since a counter-electromotive force (counter e.m.f) is produced by coil inductance when the relay is turned off and the e.m.f. becomes noise, care must be taken. Due to chattering at the relay contact, tens to hundreds of kHz noise occurs mainly in bursts. Thus, the noise energy often becomes high.

⑤ **Transceiver**

In large-scale plants, transceivers are very often used for communications between the field and the control room. Although W / G of the Japanese Electric Measuring Instruments Manufacturers Association recommends to use transceivers covering a wave band of 27MHz, smaller-sized transceivers for the 140 or 470MHz wave band are often used.

⑥ **Noise simulator**

To test the immunity to pulse noise (mainly thyristor noise), a noise simulator is often used. A test noise of approximately 1kV for 0.8μs is used synchronously with the power supply frequency. Since recorders are often used for measurements of equipment subjected to the pulse noise test, the influence of noise must be considered.

2.2 Propagation of Noise

Noise is propagated in the following three ways.

① Conduction : noise is conducted through a power line, input wiring, etc.
② Electrostatic induction : noise leaks through capacitances between wires and instruments.
③ Electromagnetic induction : a loop in the input line, etc. induces a AC voltage by detecting the AC magnetic field.

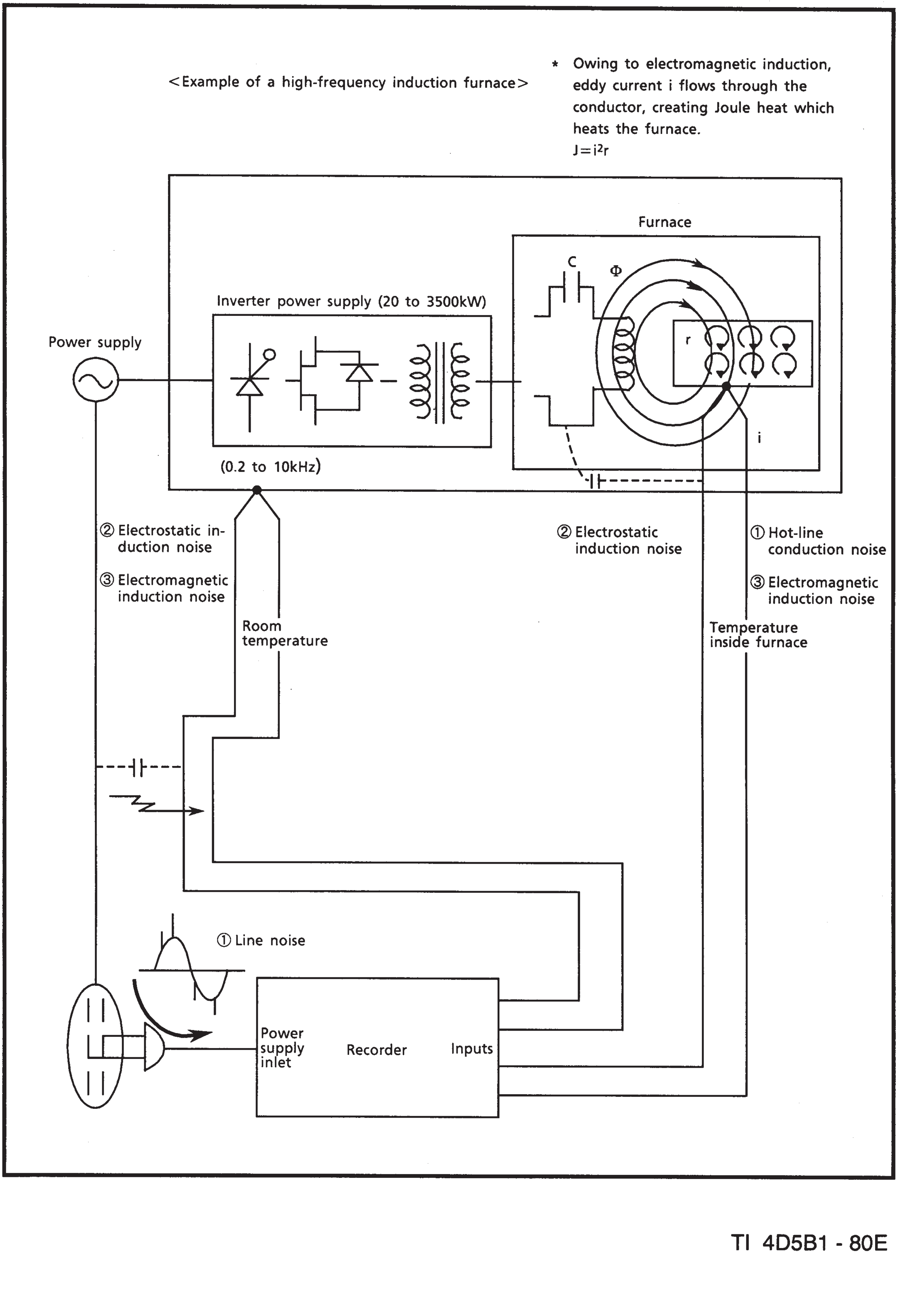
In real applications, the above three propagation paths are not independent of each other. Their combination propagates noise to the recorder and causes problems.

Examples of noise propagated through each of these paths are given below.

① Conduction : inverter noise, relay noise, thyristor noise, and noise caused by surface temperature measurement of a power transistor, etc.
② Electrostatic induction : commercial power supply noise such as the hum of audio equipment, relay noise, etc.
③ Electromagnetic induction : magnetic leakage flux from a power transformer or motor, magnetic field from a high-frequency induction furnace, the rotating magnetic field of a power generator (Cu10Ω), etc.

The figure on the next page shows the propagation paths using practical examples.

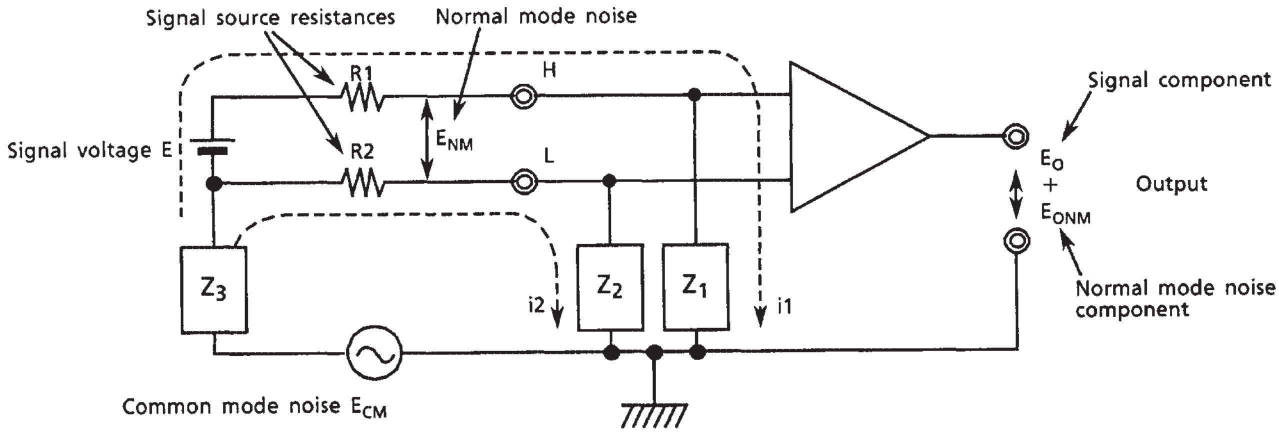
Propagation paths of Noise



3. Anti-noise Measures: Basics

3.1 Basics of Anti-noise Measures (1)

- Common Mode Noise and Normal Mode Noise -



- Common mode noise (E_{CM})
  Noise generates between the signal source and the ground of a measuring instrument. Since it is applied to both the H and L input terminals in phase with one another, it is also called in-phase voltage.

- Normal mode noise (E_{NM})
  This is an unfavorable noise that is superimposed on a signal voltage. Since it is a voltage between the H and L input terminals, it is also called the line voltage, or since it is a voltage in series with the signal voltage, it is sometimes called the series mode voltage.

In the above figure, owing to common mode voltage E_{CM}, noise currents i_1 and i_2 flow through the impedance to grounds Z_1 and Z_2 and coupling impedance Z_3, resulting in the genertion of normal mode noise E_{NM} between input terminals H and L. Like this, common mode noise is converted to normal mode noise, therefore the rate of conversion into normal mode noise is very important as a characteristic value representing the resistance-to-noise characteristics of the measuring instrument. This rate of conversion is called the common mode rejection ratio and expressed using the following equation.

- Common mode rejection ratio (CMRR) $= 20\mathrm{Log}\dfrac{E_{NM}}{E_{CM}}$ (dB)
  Since the actual CMRR is expressed using the ratio of an error component output caused by common mode noise to common mode noise, it contains the normal mode rejection ratio (NMRR) expressed by the following equation.

- Normal mode rejection ratio (NMRR) $= 20\mathrm{Log}\dfrac{E_{ONM}}{E_{NM}}$ (dB)
  The NMRR is a value that shows the aility to reject the output error (normal mode noise component: E_{ONM}) by normal mode noise can be rejected. Thus, this is also a very important value which shows the resistance-to-noise characteristics of the measuring instrument.

3.2 Basics of Anti-noise Measures (2)

- Decreasing and Increasing Impedance -

As described in the previous section, conversion of common mode noise into normal mode noise causes an error in the measured output. In other words, prevention of such a conversion is the key to anti-noise measures. According to the figure in the previous section, normal mode noise (E_{NM}) can be obtained as follows:

$$E_{NM} = E_{CM} \times \left(\frac{Z_1}{R_1 + Z_1} - \frac{Z_2}{R_2 + Z_2} \right) \frac{R'}{Z_3 + R'}$$

Thus, $R' = \frac{(R_1 + Z_1)\ (R_2 + Z_2)}{(R_1 + Z_1) + (R_2 + Z_2)}$

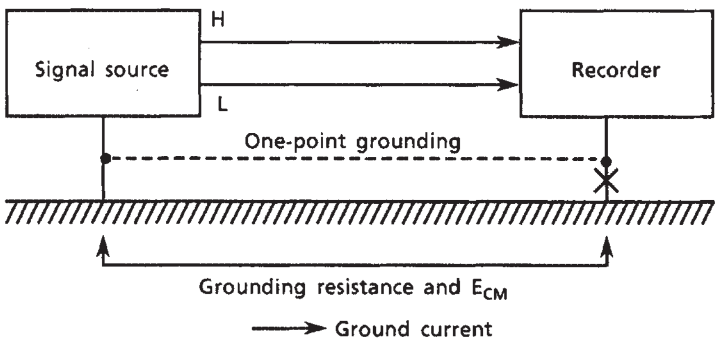
where $E = 0V$

Supposing that common mode noise has already been given, it is important to take the following measures to reduce normal mode noise.

① Decrease impedance to grounds Z_1 and Z_2 as much as possible
② Increase coupling impedance Z_3 as much as possible

These are called the decrease and increase of impedance as basics of anti-noise measures.

In the above discussions, anti-noise measures have been described on the assumption that common mode noise has already been given. In real applications, common mode noise often occurs owing to grounding resistance as shown in the figure below.



In such a case, perform one-point grounding as indicated by the dotted line, as an extreme example of decreasing impedance, to equalize the potentials of the signal source and the recorder. Rejecting common mode noise in this way is the basics of anti-noise measures.

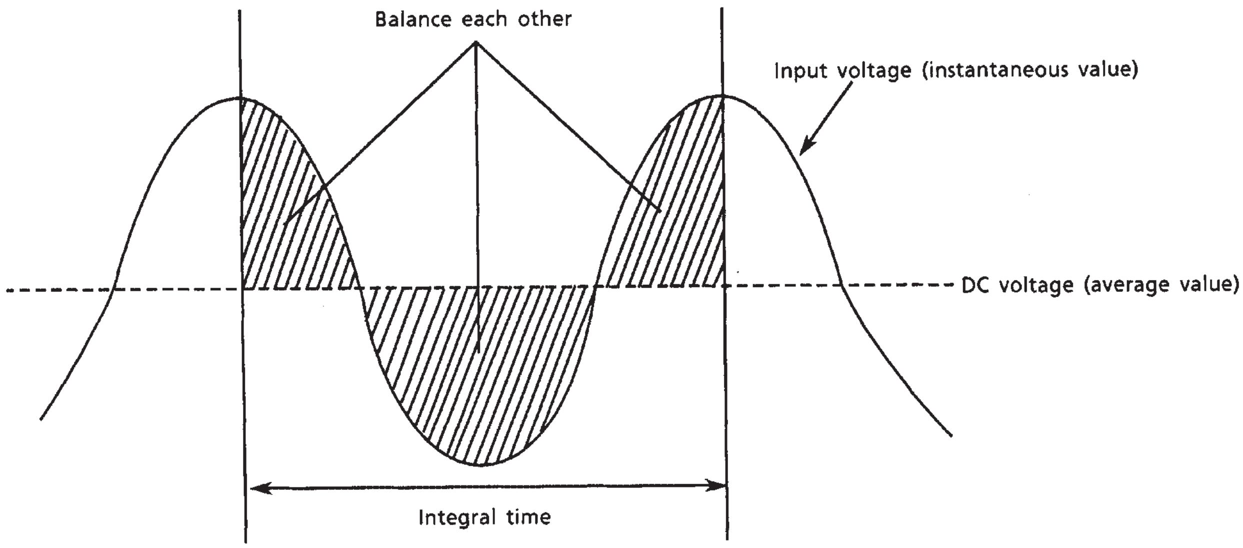
Section 4, "Anti-noise Measures: Applications" introduces how to practice the decrease and increase of impedance and potential equalization, and case examples.

3.3 Anti-noise Measures by the Recorder Itself

① **Pulse-width modulation (PWM) A / D converter**
Among our recorders, the μR1000 / 1800, the earlier μR models, the μR-T series, the μR-F, the HR1300 / 2300 / 2400, and the HR2500E employ our original feedback PWM A / D converter. The main features of the converter are as follows:

- Superior linearity and stability achieved by the feedback effect
- Excellent noise rejection because of the integral A / D converter

If the integral time and noise cycle are equal, the shaded portions on the plus and minus sides balance each other and the average value becomes zero.



Normally, an integral time of 20ms (50Hz) or 16.7ms (60Hz) is selected depending on the commercial power supply frequencies. However, a 100-ms integral mode is added to the μR1000 / 1800 (dot printing model only) and the HR1300 / 2300 / 2400 to achieve superior noise rejection. The integral effect enables the PWM A / D converter to perform the following two functions:

① Rejection of frequency determined by the reciprocal of the integral time and frequencies which are whole multiples of that frequency
② First-order lag filter provided with cut-off frequency proportional to the reciprocal of the integral time

The following table compares the integral times of 16.7ms, 20ms, and 100ms.

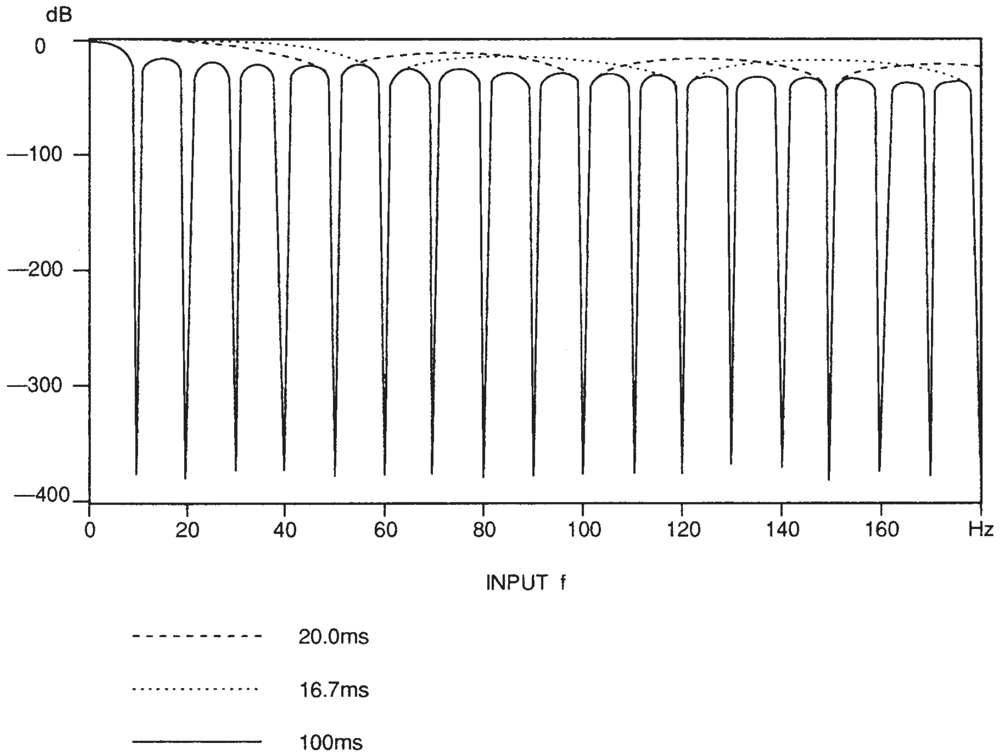
Integral time	Rejection frequency	Cut-off frequency	Remarks
16.7ms	n×60Hz	≃19Hz	For 60Hz only
20.0ms	n×50Hz	≃16Hz	For 50Hz only
100.0ms	n×10Hz	≃3.2Hz	For both 50 and 60Hz

n=1, 2, 3 ···

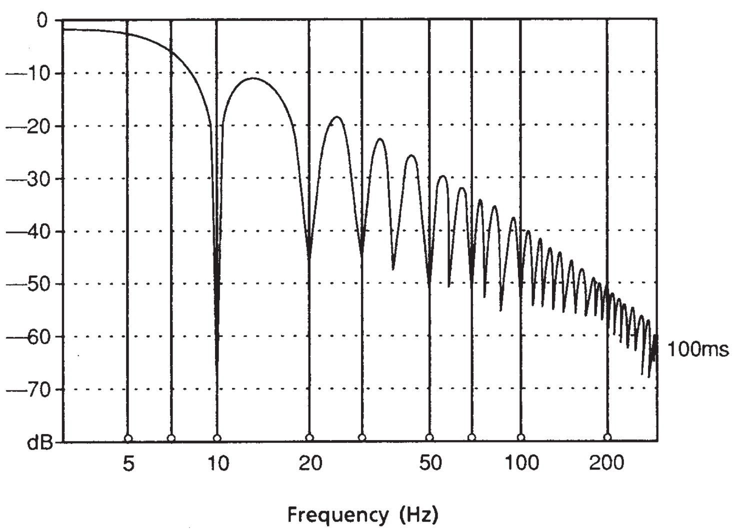
As shown in the table, the merit of 100.0-ms integration is not only that it applies to both 50 and 60Hz, but also that it provides a low cut-off frequency as the first-order lag filter and improves the noise rejection ability.

The following figure shows the calculation values of the NMRR for three integration times and an example of actual measurement of the NMRR for a 100-ms integral time.

- Calculated values of NMRR



- Example of actual measurement of NMRR (100ms)

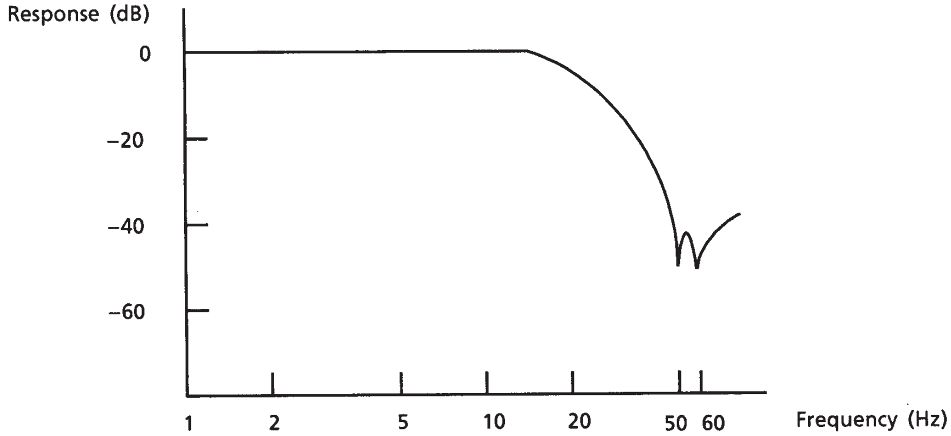


② **Noise filter**

While the PWM A / D converter has the excellent effect of rejecting normal mode noise, it has a fault in that its conversion speed is low because it needs to match the integral time and commercial frequency. With conventional recorders not incorporating a microprocessor, the PWM A / D converter cannot be used. Thus, the LR series of recorders that need a high-speed response and the conventional X-Y recorders (3023 / 3024 / 3025) are provided with a noise filter for normal mode noise rejection.

Model	LR series	X-Y recorders
Filter type	Fourth-order digital filter	Double twin-T filter
Cut-off frequency	OFF (10Hz), 1Hz, 0.1Hz	15Hz
NMRR*	50dB or more	50dB or more
Filter characteristics	−24dB / octave	See the figure below.

*: at 50 / 60Hz



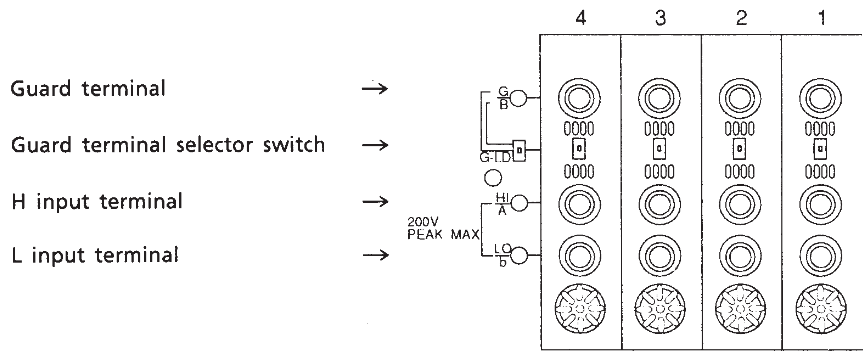
The HR1300 / 2300 / 2400 and μR1000 / 1800 recorders enable the noise filter function through digital computation. For details, refer to their respective instruction manuals.

	HR series	μR1000 / 1800
Dot printing model	Moving average (n=8)	Moving average (n=2 to 16)
Pen model		Time constant=2, 5, 10s

③ Guard

In addition to the noise filter, the LR series and X-Y recorders (3023 / 3024 / 3025) are provided with guard (shielding) terminals to improve the CMRR without degrading the response.

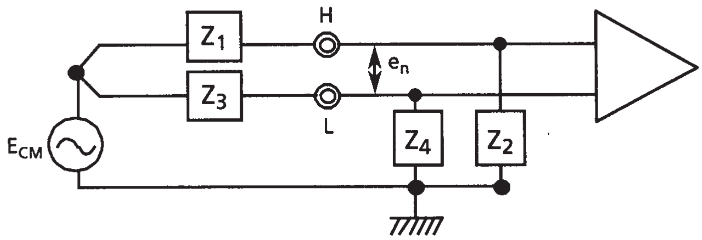
- Input terminals of LR series (example)



The guard terminal is normally connected to the L input terminal when used. If there is a significant error due to common mode noise, the noise can be reduced by connecting the shielding wire to the guard terminal as an independent terminal.

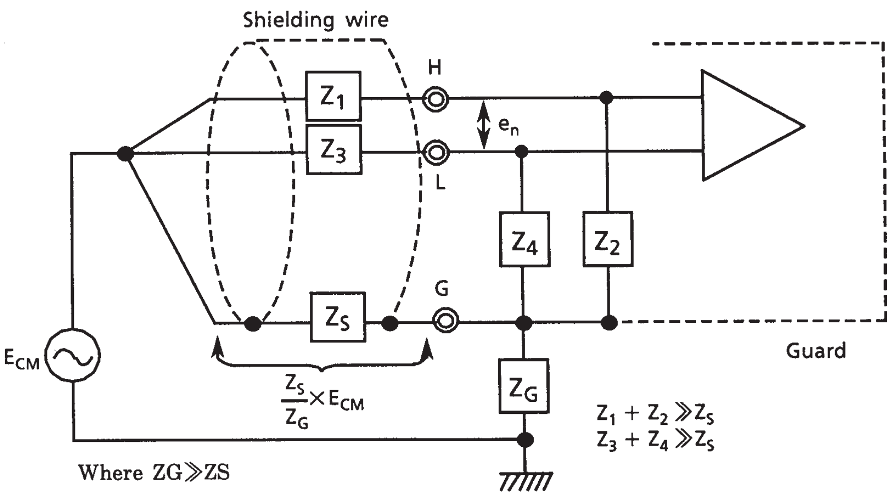
- When no guard terminal is provided

$$e_n \simeq \left(\frac{Z_2}{Z_1+Z_2} - \frac{Z_4}{Z_3+Z_4}\right) \times \underline{\underline{E_{CM}}}$$



- When the shielding wire is connected to the guard terminal

E_{CM} is divided by Z_S and Z_G and it appears that the common mode noise is low.



$$e_n \simeq \left(\frac{Z_2}{Z_1+Z_2} - \frac{Z_4}{Z_3+Z_4}\right) \times \underline{\underline{\frac{Z_S}{Z_G} \times E_{CM}}}$$

It is important that shielding wire impedance Z_S be sufficiently low.

4. Anti-noise Measures: Applications

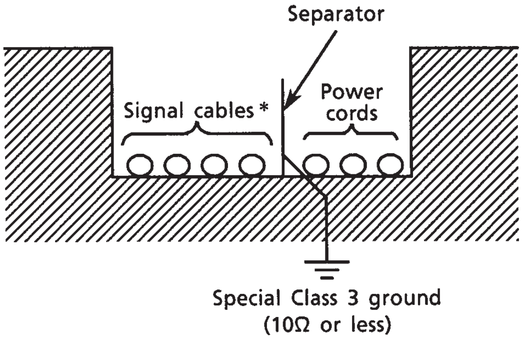
4.1 Practical Measures

① **Reducing noise itself**

The basics of the practical measures dictates using the recorder in conditions where noise is suppressed as much as possible.

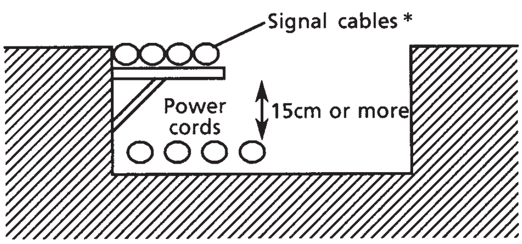
- For power lines : an increase of impedance
  Separate the power lines for noise source equipment (inverter, thyristor, etc.) from those for the measuring instrument.
- For input lines : an increase of impedance
  Always separate the input line from the noise source lines (power and alarm lines).

(1) Install the separator.



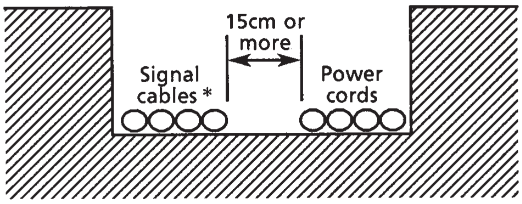
(2) Keep the signal cables at least 15cm above the power cords using a cable bracket.

If the power cords are not shielded, the operating voltage is 220V or less, and the operating current is 10A or more, the distance between the signal cables and power cords must be 60cm or more.



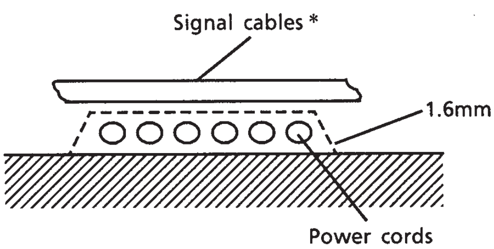
(3) Leave a clearance of 15cm or more between the signal cables and power supply cords.

If the power cords are not shielded, the operating voltage is 220V or less, and the operating current is 10A or more, the distance between the signal cables and power cords must be 60cm or more.



(4) Lay the cables at right angles to the cords.

If the power cords are not shielded, separate the signal cables and power cords where they cross using steel sheeting at least 1.6mm thick.

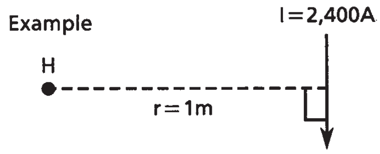


* : Separate analog signal cables and communication cables in the same manner as from power cords.

- When there is influence from a magnetic or electrical field : an increase of impedance

1. Keep the noise source as far from the recorder as possible.

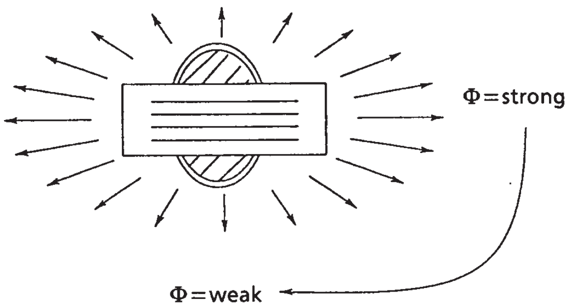
   - Magnetic field strength $H=\frac{I}{2\pi r}\doteqdot\frac{2,400}{6}=400$ [A / m]



   - The influence of the external magnetic field on the recorder : 400A / m or less

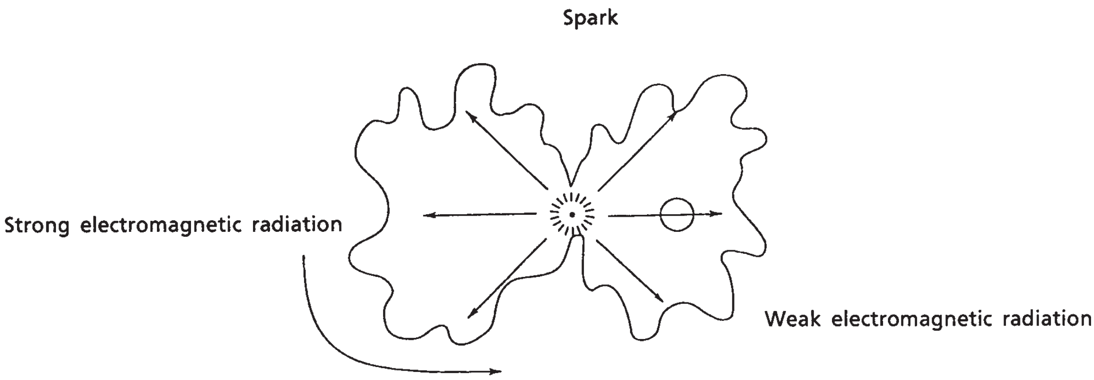
2. Change the recorder position.

   (A) Leakage magnetic flux of transformer : Φ



Move the recorder to a location where the influence from magnetic flux is weak.

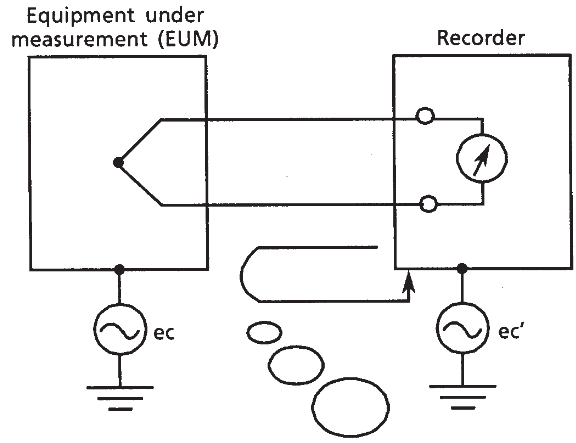
   (B) Sparks



Move the recorder to a location where the influence from electromagnetic radiation is slight.

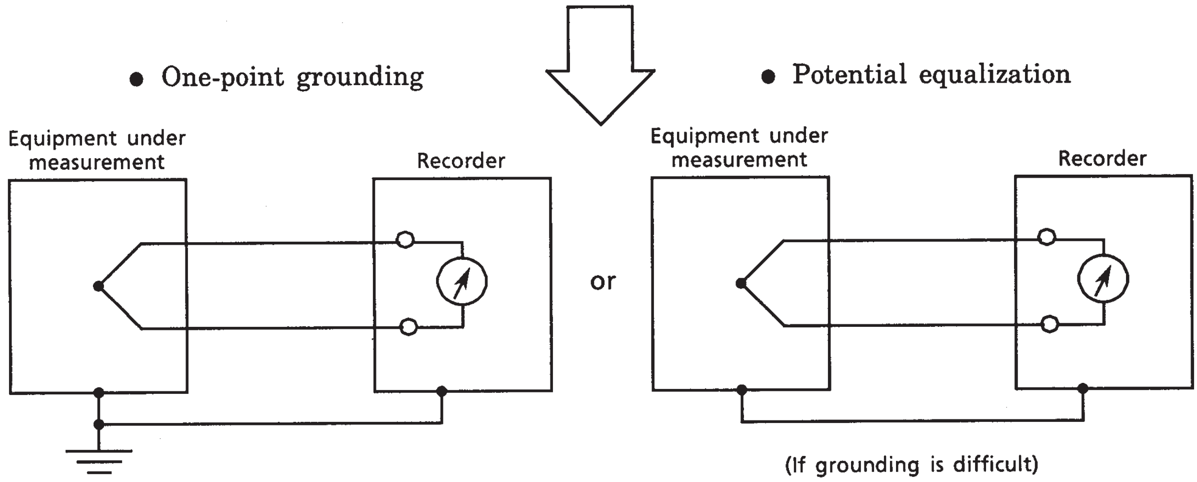
② Grounding (an earth): a decrease of impedance

The grounding method is the point of common mode noise suppression.



The difference in the potential to the ground between EUM and the recorder may cause a ground current, resulting in noise.

Equalize the potentials to the ground so that the common mode noise becomes zero.



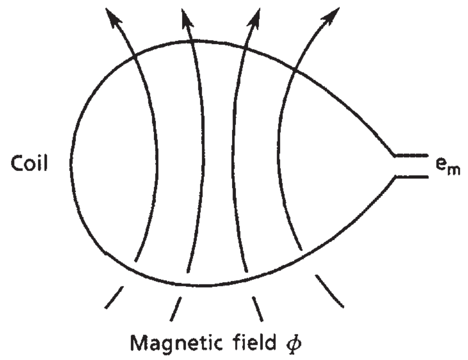
The basic means to obtain stable measurement is to set the circuit potential with proper grounding. Thus, potential equalization is the means to be adopted only when grounding is impossible.

⑨ Shielding and twisted pair (prevention of electromagnetic coupling) : an increase of impedance

If it is difficult to keep the noise source away from the measuring instrument owing to limited space, the use of a shielded twisted pair is effective.

- Electrostatic coupling can be completely cut off by shielding.
- For a magnetic field, shielding with a magnetic material (iron, permalloy, etc.) can be employed. However, there are many restrictions on this use and perfect shielding is impossible.

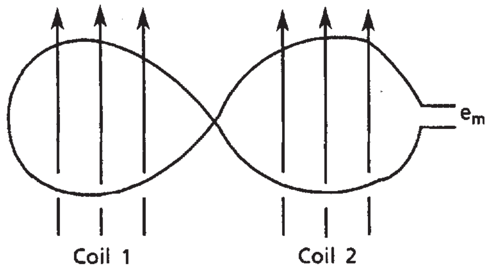
  ⇒ Therefore, use of a twisted pair is preferable.



Voltage e_m induced by the coil is proportional to the area of the coil.

↓

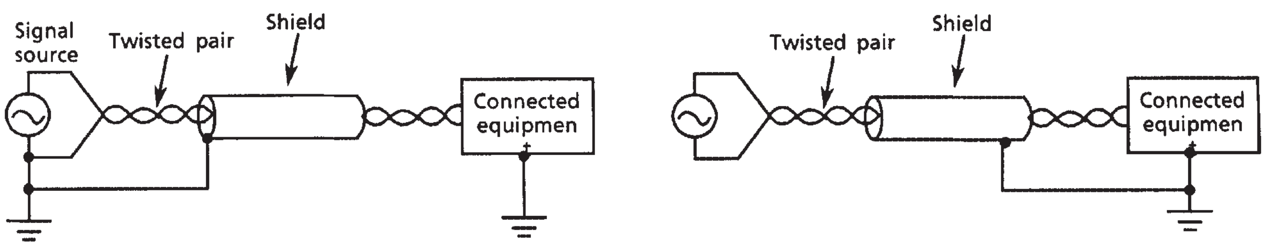
The smaller the area of the coil becomes, the smaller the noise becomes.



If the directions of coils 1 and 2 are reversed by twisting, as shown, if the areas of the two coils are equal, the induced voltages of the coils offset each other and total induced voltage e_m becomes zero.

The above two principles are combined as a twisted pair.
Even though a shielded twisted pair is used, a proper grounding method is still important.

- If the signal source is grounded
- If the signal source is not grounded

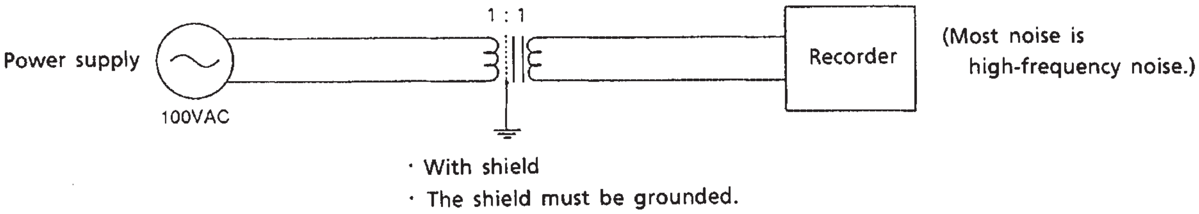


Ground the signal cable shields collectively but separately from the power line ground. If the separation of grounds is impossible, use the guard terminal (LR series recorders, X-Y recorders).

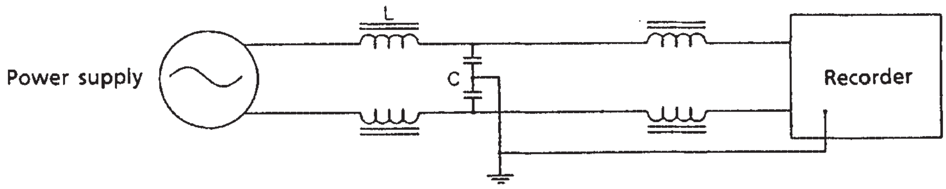
④ **Insertion of noise filter and noise killer**

If the influence from noise cannot be eliminated by the methods described in ① to ③, use noise filter or noise killer.

- Power line noise rejection
  1. Insert an isolation transformer into the power line.
     - Increasing impedance to high frequency



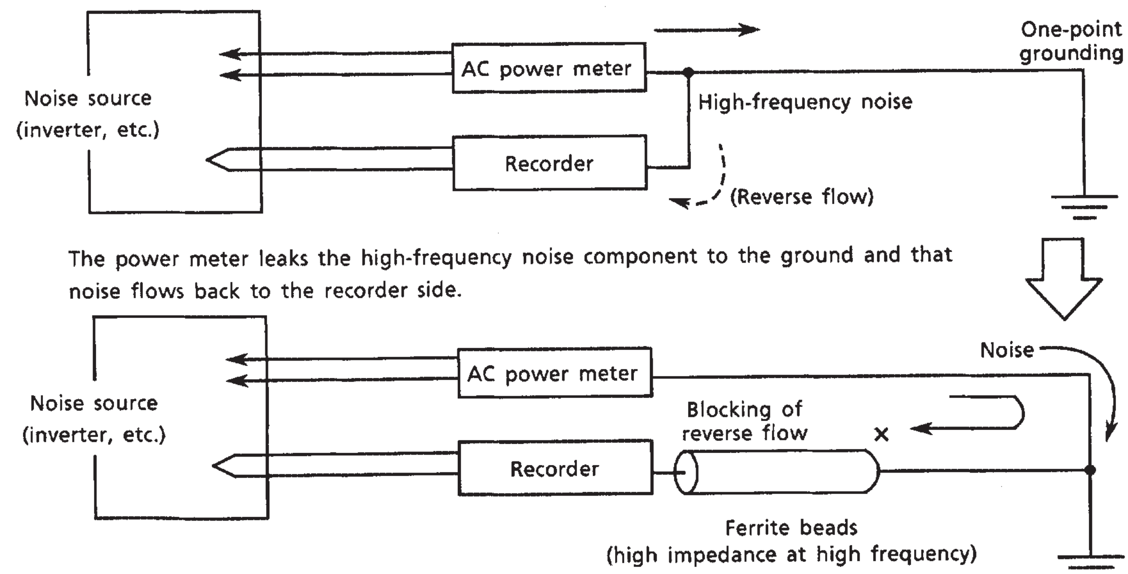
  2. Insert a power line noise filter (available on the market).
     - High frequency noise is divided by decreasing impedance to ground through C and increasing impedance through L.



- Note 1: Ground the noise filter and recorder in common.
- Note 2: Since insertion of a power line noise filter increases the by-pass current (regarded as leakage current), make sure that the leakage current is within the specified value.

- When the noise contains wide frequency range components.
  While one-point grounding is effective at a low frequency, it sometimes forms a loop and has an adverse effect on a high frequency.

Example: Connecting a power meter and recorder grounded at one point to an inverter

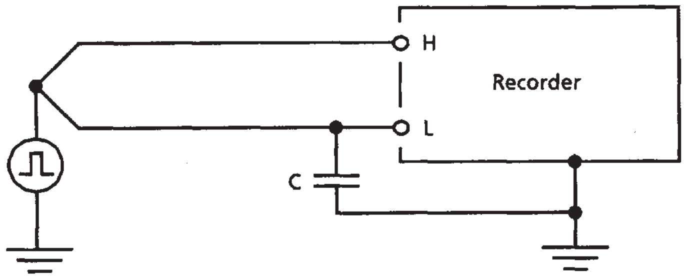


Reverse flow of high-frequency noise to the recorder is thus suppressed.

- Input noise rejection

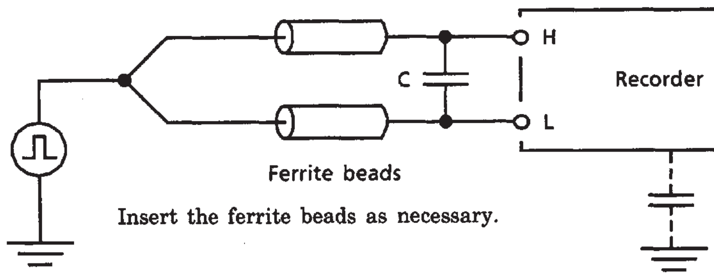
  If input noise cannot be rejected by means of one-point grounding or 100-ms integration, insert capacitor or ferrite beads as they are effective in rejecting pulse noise.

  1. Connect a capacitor between the L input and ground.



Use a capacitor from a hundred to thousands of pF which can withstand high voltages and must be grounded.

  2. Rejection of pulse noise when grounding is impossible

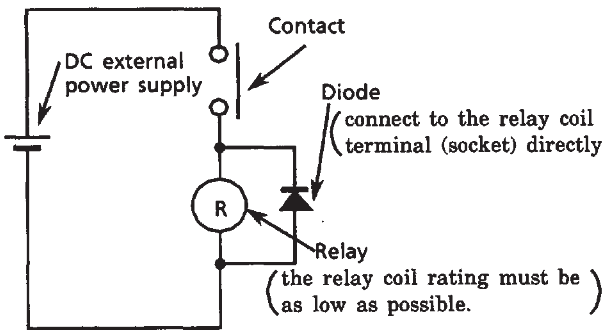


Use a capacitor from a hundred to thousands of pF.

- Relay noise suppression

<DC relay>

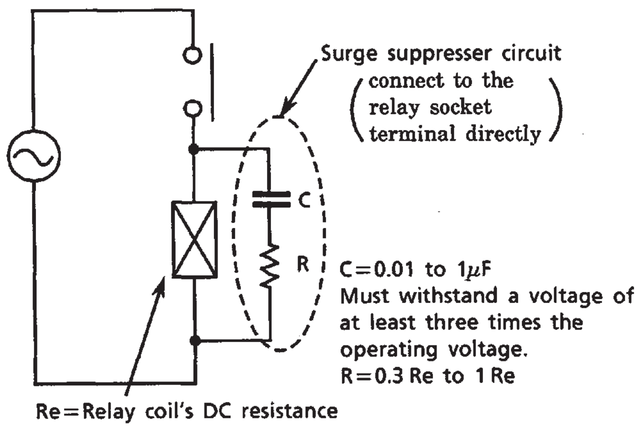
- To prevent noise and protect the contact, connect the diode to the relay coil terminal directly.
- In addition to the above measure, reduce the rated voltage of the relay circuit as much as possible for higher reliability.
- It is necessary to choose a diode that matches the relay. Generally, a diode whose rated rectifying current is at least three times the current flowing through the relay coil must be used. And the rated reverse voltage must be at least three time the operating voltage.



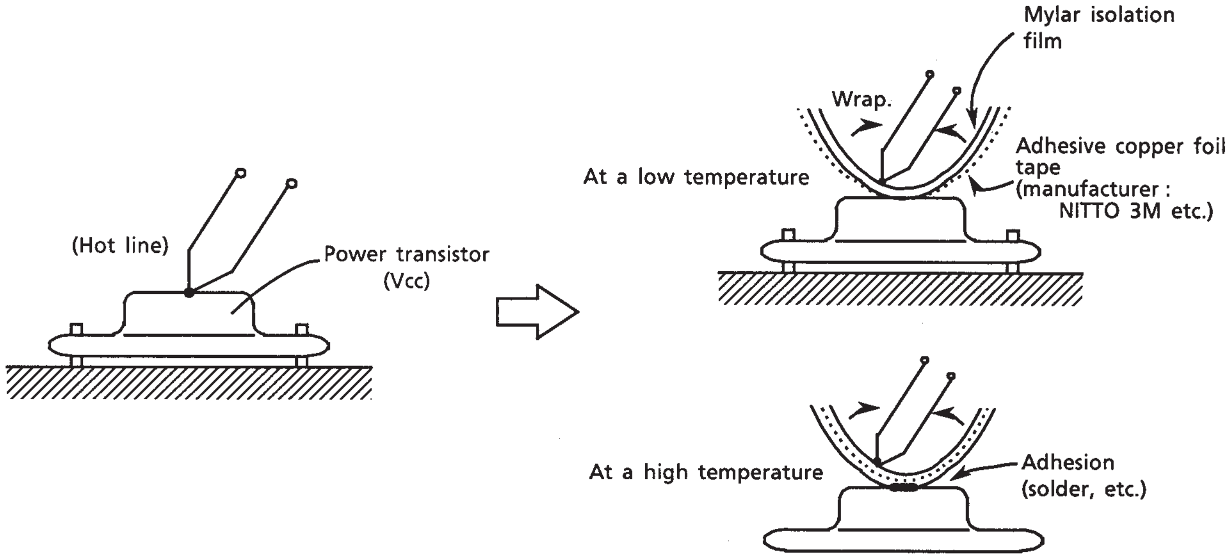
(Note) Across the relay or solenoid coil, a counter-electromotive force is produced by an inductive load. This phenomenon may damage the contact or, as the noise source, cause a malfunctioning of the equipment, and have an unfavorable effect on the entire system.

<AC relay>

- If a relay contact is connectd to the input of the system components, apply the measure shown in the figure at the right to the relay coil. Otherwise, a counter-electromotive force produced across the coil may be induced on the contact side through the relay's internal coupling or coupling between the lines, and may cause a malfunctioning of the equipment.



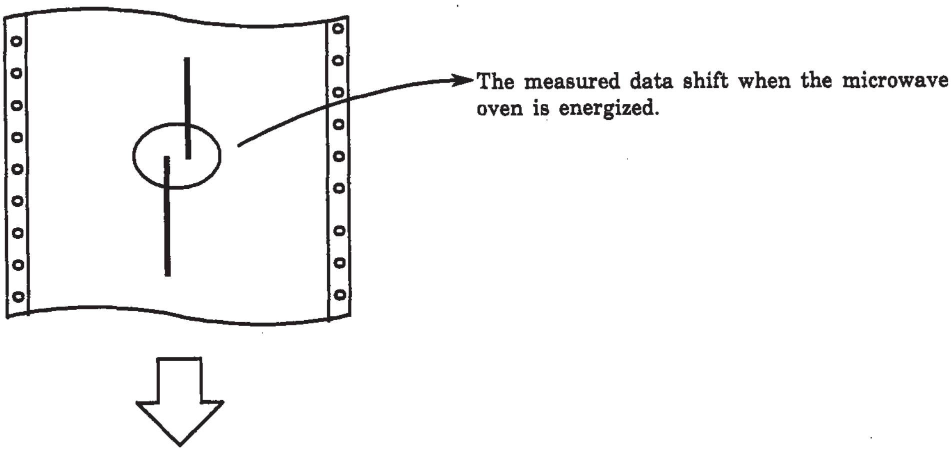
⑤ Others (isolation from noise source: for hot line measurement)
Example of isolation using copper foil tape and mylar film



4.2 Examples of Practical Measures

① Measurement of a magnetron temperature in a microwave oven

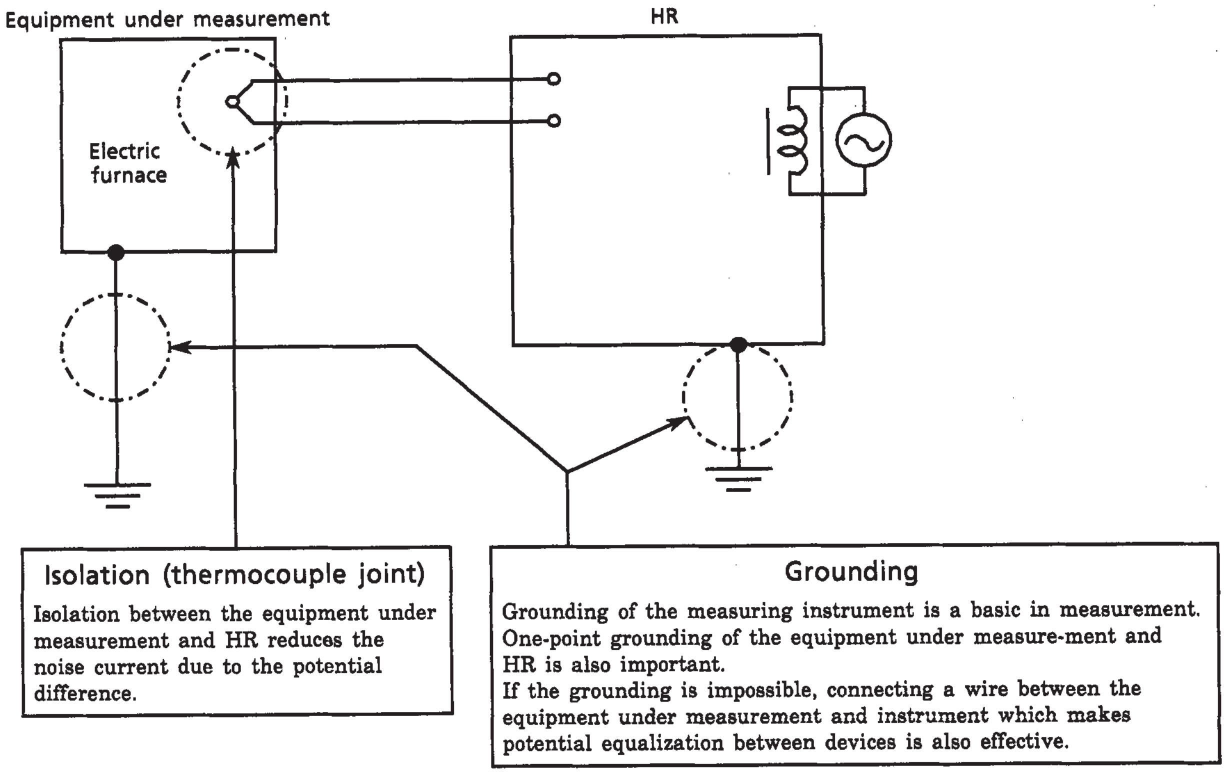
If a microwave is leaked to the temperatue sensor, there may be no random error but the whole measured data may uniformly shift.



This phenomenon can be eliminated by proper grounding.

- Equalization and stabilization of potential
- One-point grounding

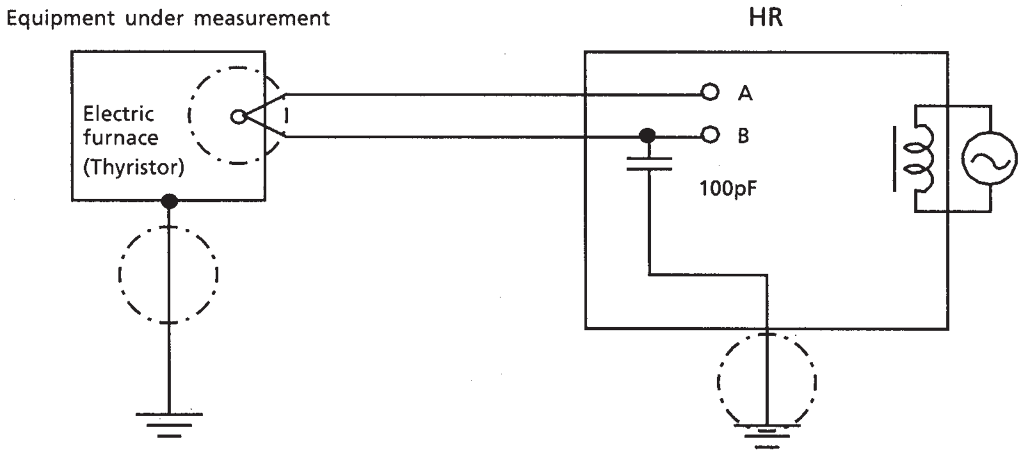
② Measurement of the inside temperature of an electric furnace (1st of 2 examples)



③ Measurement of the inside temperature of an electric furnace (2nd of 2 examples)

In application to an electric furnace, even though a 100-ms integration, thermocouple isolation and grounding were performed, the noise could not be reduced to a negligible level.

As a countermeasure, as shown below, a scanner with a 100-pF capacitor between input channel line B and the ground is applied, and as a result, the noise can be reduced.

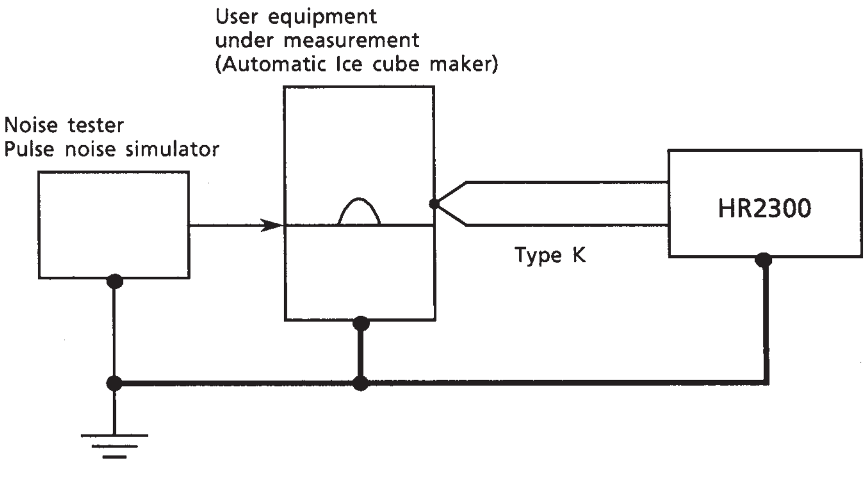


* When using an HR recorder with a capacitor-incorporated scanner, do not fail to ground it.
(If the HR is used without grounding, the capacitor cannot work as a filter and measurement is influenced by common mode noise.)

④ Pulse noise simulator

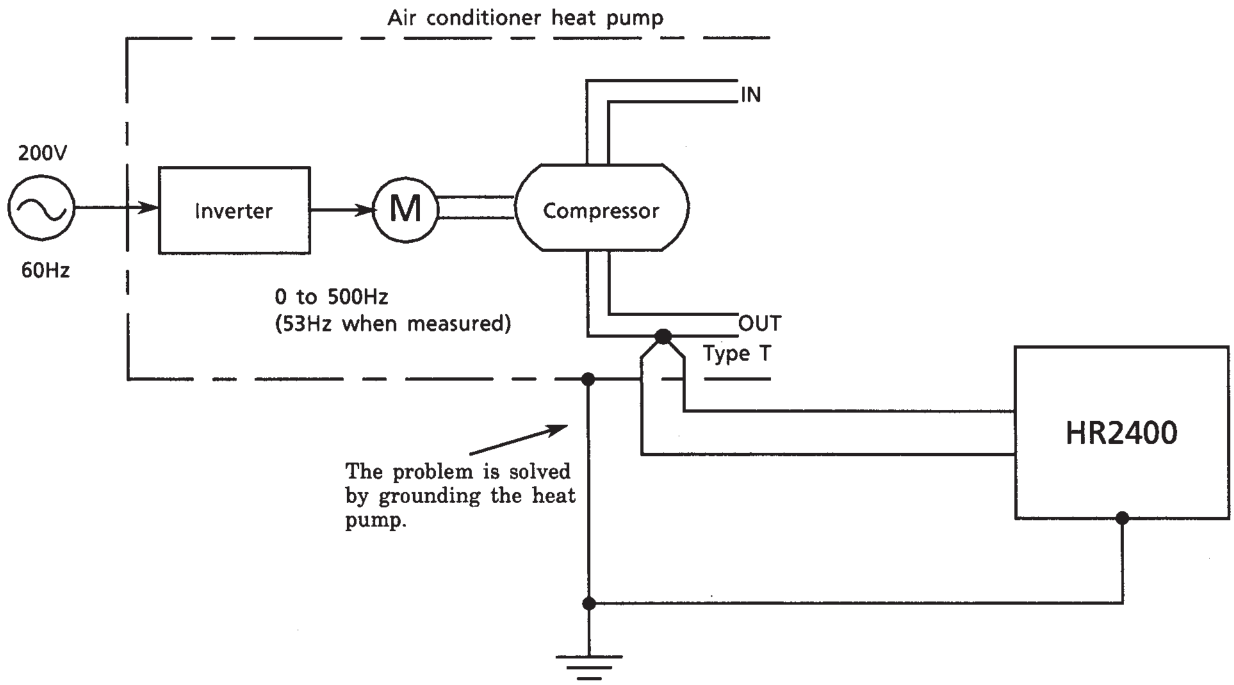
An HR recorder is rarely used for monitoring the equipment under a pulse noise test, an HR recorder is rarely used for monitoring. This is a very severe operating environment for the recorder, which is as if the recorder itself is undergoing a noise test using a pulse noise simulator.

As an anti-noise measure, equalize the potentials of the equipment under measurement, HR, and noise tester, and ground them. However, since connection with thin or long ground wiring is not very effective, use sufficiently thick wiring and keep it as short as possible. The use of metal sheeting instead of ground wiring is more effective.



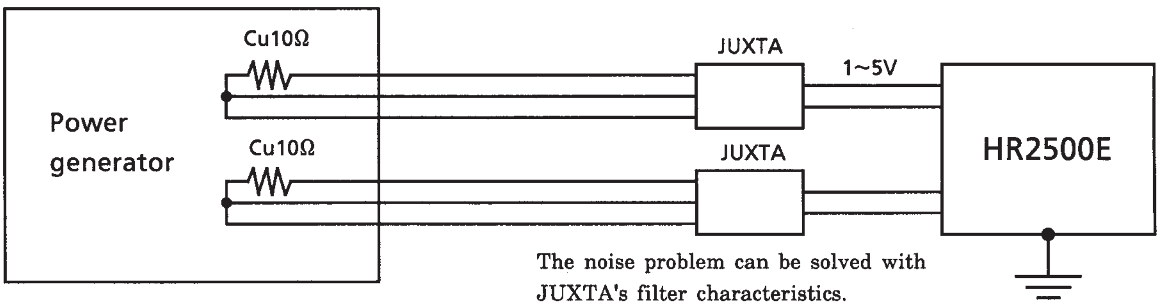
⑤ Measuring the temperature of an inverter heat pump

In some cases, noise cannot be rejected by a PWM A / D converter because the inverter output is not always 50Hz of 60Hz. This problem is solved by making one-point grounding.



⑥ Measuring the temperature of a power generator

If the rotating speed of a turbine is varying, such as when a power generator starts up or stops, the noise frequency changes to other frequencies than 50 or 60Hz. Therefore a PWMA'D converter can not reject the noise. In a case with the HR2500E, this problem is solved by connecting JUXTA converters between the generator and HR.



The noise problem can be solved with JUXTA's filter characteristics.
Since the HR does high-speed scanning, the equivalent filter cannot be built in.
(Because such a filter would make the response of the HR slower.)

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