EMC and Noise Regulations

1. Electronic Devices and Noise Issues

There are a great deal of electronic devices used in our lives, such as mobile phones, AV devices, personal computers, copy machines, and fax machines. These devices are seldom free from electric noise generation. Devices that insufficiently control noise can at times cause trouble or large social problems.

Cases of noise issues

In a pulp factory in Yamanashi prefecture, a malfunction occurred in the control module of the numeric control panel, and a worker died by getting caught in the rotating main shaft.

In a private railway station in Sakai City, Osaka Prefecture, train radio system contact was disabled by noise. The noises were generated by the electromagnetic waves emitted from game machines in a video game arcade located about 20m away.

When a patient with an implanted cardiac pacemaker used an electric thermal medical device, the pacemaker operation was halted.

When a mobile phone was used in a hospital, a malfunction occurred in the syringe pump in use for a patient.

Along with the rapid spread of devices using radio waves and digital devices, the necessity of noise regulations has rapidly been increasing. And now, there are various regulations for electronic devices around the world. Both suppressing noises generated from electronic devices and implementing countermeasures against the influence of noises emitted from other devices are necessary.

We can thus say that an operating situation where both conditions are satisfied can be called a status where “EMC conditions are kept”.

2. EMC = EMI + EMS

Figure 1: Concept of EMC

Over 100 years has passed since the beginning of the wireless communication innovation by Marconi. During this period, various and versatile electronic devices have been developed. Along with that, however, problems of noise emission from devices and its influence (causing malfunction, etc..) on other devices, have increased.

Therefore, in designing electronic devices, both the suppression of noise generation (EMI) and self-prevention from incoming noises (EMS) have become more important. Parts used for these purposes are generally called “EMC (Electromagnetic Compatibility) control parts”.

TDK developed pioneering products for these purposes in the 1960s. Since then, TDK has been developing and supplying EMC control parts and EMC control technologies to meet the demands of the times as the leader in this field.
3. EMC Standards in the World

Various countries in the world have their own respective EMC-related standards for development of products which are not influenced by incoming noises or do not have noise-related influence on other devices. In most countries, EMC standards are established conforming to the standards of the International Special Committee on Radio Interference (CISPR), realizing a comfortable life where mobile phones, personal computers, home electric appliances, and other devices work properly.

Figure 2: EMC standards in the world

Have you noticed one or more of these marks on electric products or electronic devices on their back or other locations? The CE mark is from Europe, the FCC mark is from the U.S.A., and the VCCI mark is from Japan. These marks guarantee comfortable use of the product.

4. About Noises

“Noise” is defined as below in the fields of electronics / communication / information.

“Noise” is defined as a factor that prevents proper conveyance of intended signals (information).

The definition above is simple but abstract. Actually, noises differ widely in their phenomena and characteristics, etc., and it is not easy to pinpoint the true figure of a noise. In conveyance of signals (information), there exists a “source point”, “reception point”, and “transfer pathway”.

The degree of influence of noise differs depending on the various conditions in which it is found.

For example, if outgoing signals sent from a source are strong, some noise intrusion may not have any influence on the conveyance of signals. If outgoing signals are weak, however, noise may have some influence on the conveyance of signals, and the signals may not be properly received at the reception point. Or, if a reception point is too sensitive, the reception point may catch unintended signals along with the intended signals, resulting in the occurrence of noise.

Thus, be aware that noise problems are not isolated matters but relative matters. There are three factors as shown below in every noise issue. All of them definitely exist where trouble from noise occurs. Such an issue cannot occur if even only one of them is lacking.

Source point → Transfer pathway → Reception point

Further, the degree of trouble differs depending on the “strength of generated energy” from the source point, “conveyability” in the transfer pathway, and “susceptibility to noise” at the reception point. Accordingly, noise control involves countermeasures against noise in these three areas. The basics are as follows.

Source point → → → Weakening generated energy
Transfer pathway → → Reducing conveyability
Reception point → → Reducing susceptibility to noise
5. Noises in our surroundings

There are two types of noise sources. One is noise sources that occur naturally. And the other is noise sources from artificial systems. Naturally occurring noise sources are literally generated by natural phenomenon, such as lightning and static electricity. Noise sources from artificial systems are generated by various artificial sources.

Major noise sources from artificial systems are as follows: “glow discharge” produced by fluorescent lights and neon lights, transmitting signals and airwaves from fixed stations and mobile stations in wireless communications, mobile phones, “electronic switches” by semiconductors in switching power supply units and inverters, pulse generation by digital devices, “corona discharge” produced by electric power cables, “spark discharge” produced by cars, electric discharge machines, electric trains, and internal combustion engines, etc.

Figure 3: Noise types

6. Conduction Noises and Radiation Noises

There are two noise transfer pathways. One is cables and printed patterns of electronic devices. The other is the air. Noises transferred via the former are called “conduction noises”, and noises transferred via the latter are called “radiation noises”.

Note that noises being transferred on cables or printed patterns can be radiated into the air along the way, and change into radiation noises. Or, radiated noises can intrude into cables and signal lines, and change into conduction noises.

Noise transfer pathways are dominated by a combination of various conditions including set composition, parts and printed pattern design. They are complexly intertwined with one another.

There can be a limitless number of noise transfer pathways, and so it is very important to implement countermeasures for these in locations close to noise sources.
7. Two Conveyance routes of Conduction Noises and Countermeasure Basics

As mentioned above, there are two types of noises, conduction noises and radiation noises. Conduction noises can be classified into differential mode noises and common mode noises.

**Differential mode noises** are generated in power lines and flow in the same direction as the power current and signals. As their outward and return directions are different, they are called differential mode noises.

Differential mode noises reside in a frequency range higher than the signal frequency. Therefore, LPF-type noise control parts, which reduce higher frequency components, are used. However, note that if the noise frequency range overlaps the signal frequency range to be passed, signals will be removed along with the noise.

Especially, note that removing overshoot or ringing with noise control parts inserted in transfer pathways of square waves can make the rise time of the square waves longer, resulting in a reduction of IC operating margins. It is important to recognize the frequency characteristics of the noise control parts and the frequency range of the signals to be passed.

Recently, operating speeds of circuits have become faster, and the frequency ranges of signals and noises have become closer. Therefore, it is not easy to control noises without lowering signal quality.

**Common mode noises** flow to SG in the same direction as signal patterns, pass through metal frames or metal cases and stray capacitors, etc., and return to signal sources. As their flow direction is common, they are called common mode noises.

**Figure 5: Differential mode noises and Common mode noises**

**Differential mode**

**Common mode**

Differential mode noises are components that flow within relatively narrow circuits, and their outward and return directions are opposite. Therefore, noise components cancel each other out and become reduced, and radiation noises become smaller.

Common mode noises pass through metal frames or metal cases, etc., away from signal lines, and return. Therefore, common mode noises form large current loops.
and even small noise currents radiate large noises. In controlling radiation noises, controlling common mode noises is more important.

8. Countermeasure Basics for Conduction Noises

Conduction noises are transferred through signal lines such as printed patterns and cables, along with signals. Therefore, noise control parts should be set in a location as close to the noise source as possible along the same path as signal lines to remove only noise components.

Figure 6 shows the four methods of noise reduction. They are called “four countermeasure factors against noise”.

1. Shielding of the device
2. Reflection to return only noise components to the noise source side
3. Absorption to convert noise components into heat by noise control parts
4. Bypassing to direct noises to the ground

Basic policy common to these methods is to transfer only the necessary signals to the load sides. Conduction noises are not only transferred through signal patterns but also can be radiated into the air along the way, causing noises to be received in an unexpected location, resulting in noise related problems.

Conduction noises can often be converted into radiation noises in locations where cables or other parts, which function as antennas, exist. Any countermeasures for conduction noises have the effect of serving as a countermeasure for radiation noises at the same time.

9. Classification of Noise Control Parts

There are two types of noise control methods using electronic parts.

One is to reduce the amount of noise generated in the parts themselves. The other is to suppress noises that have already been emitted by using noise control parts.

The important thing is to be aware that the noise control parts that should be used differ depending on the noise type, i.e., common mode noise or differential mode noise, as shown in Figure 7.

Failure to detect the noise conduction mode or failure to select appropriate noise control parts can cause conditions where “noises have increased opposite to expectation after adding a noise control part”.

Figure 6: Noise transfer and countermeasure basics
10. Noise Control Procedures and EMC Cost

EMC measures tend to be neglected in the development of a device. It is often the case that EMC problems are recognized for the first time in an EMC test during the last stage of development. However, available options for EMC measures will always decrease as the development stage of a device proceeds, beginning with design, and then proceeding to prototype, and finally going to mass production.

If EMC measures are completely neglected in the development of a device, EMC problems will occur in almost every case.

EMC measures during later stages of development can take a lot of time, as well as additional parts and costs, resulting in an increase of size and weight of the device, and an increase of power loss.

Available options for EMC measures decrease and the cost increases as the development stage of a device proceeds. In general, the earlier EMC measures are taken, the better the results are, and the lower the cost is.
1. About Power Supply Line Noises

Electric devices operated by an AC power supply are connected to a common power supply line. Under these conditions, a device can be affected by noises generated by other devices and malfunctions can occur. On the other hand, noises generated by the device itself can affect other devices, causing them to malfunction.

The AC power supply units of devices are inlets of incoming noise energy, and as well as outlets of outgoing noises generated by the respective devices. By attaching power supply EMC filters to these inlets/outlets, incoming noises from the outside and outgoing noises from the power supply lines can be reduced.

Many countries in the world have their own respective regulations about immunity levels for incoming noises and allowable level of outgoing noises. A power supply EMC filter is also used to meet these regulations.

Figure 9: Types of noise control parts and their usage

Noises generated by each device are transferred via AC power supply lines.

2. Noise Types

In AC power supply lines various types of noises are superimposed. Noises can be classified into three types, by the voltage level and the rise time, as shown in Figure 10.

Figure 10: Types of power supply line noises

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>Rise time</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-frequency noise</td>
<td>- several V</td>
<td>- several kV</td>
</tr>
<tr>
<td>Pulse noise</td>
<td>1ms or less</td>
<td>several 100mJ</td>
</tr>
<tr>
<td>Surge noise</td>
<td>0.5µs or less</td>
<td>several J - several kJ</td>
</tr>
</tbody>
</table>

(1) High-frequency noises
Mainly due to harmonic components in the switching frequency in computers and switching power supply units. Generally, EMI noise indicates this type of noise, and common filters are designed for high-frequency noises. Voltage levels are relatively low, i.e., several mV to several 10mV.

(2) Pulse noises
Noises generated during switching of relays and induction motors. They are high in voltage, with peak voltage reaching several thousand V.
They carry a larger amount of energy compared to high-frequency noises, and can cause filter cores to be saturated. For this reason, an amorphous magnetic core or other core materials with a high saturation magnetic flux density are used (refer to “High-voltage pulse attenuation characteristic”).

(3) Surge noises
Noises generated in power supply lines due to induced lightning, etc. They carry a large amount of energy with very high voltage and large current. Peak voltage can reach several 10kV.
As their energy levels are very high, surge-countermeasure components such as varistors and arresters are used.
3. Safety Standards that EMC Filters for Power Supply Lines should Meet

Power supply EMC filters are connected to the primary side of an electronic device. Therefore, the highest level of safety against accidental electric shock, smoking, and firing is required. Many countries in the world have their own safety standards as shown in Table 1. Filters should be selected based on what is approved by the safety standards of the countries to which the device will be exported.

Table 1: Safety standards in countries of the world

<table>
<thead>
<tr>
<th>Name of country</th>
<th>Name of authorizing organization(s)</th>
<th>Name of standard(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A.</td>
<td>UL</td>
<td>UL1283</td>
</tr>
<tr>
<td>Canada</td>
<td>CSA</td>
<td>CSA C22.2 No.8</td>
</tr>
<tr>
<td>Germany</td>
<td>VDE/TÜV</td>
<td>EN60939</td>
</tr>
<tr>
<td>Norway</td>
<td>NEMKO</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>SEMKO</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>FIMKO</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>DEMKO</td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>SEV</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Japan Electrical Safety &amp; Environment Technology Laboratories</td>
<td>Electrical Appliance and Material Safety Law</td>
</tr>
</tbody>
</table>

4. Conduction Noise Assessment Method

As explained above, outgoing noises from devices are transferred via AC power supply lines, and intrude into other devices, causing malfunctions or a decrease in performance.

It is very important to reduce these noises transferred via AC lines. An AC line noise assessment method based on IEC noise regulations CISPR and a noise reduction method will be explained below.

(1) Measurement method regulated by European standards

European noise regulations EN is established based on CISPR.

IEC noise regulations CISPR (Comite International Special des Perturbations Radioelectriques) designates the method for measuring conduction noises being output via power cables for electronic devices, as well as their allowable levels. Figure 11 shows the measurement method designated in these regulations.

The device being measured is set on a wooden desk. A power cable is connected to a device for noise measurement called a LISN (Photo 1), which is located 80cm away from the device being measured. The LISN is placed on a large conductor side (ground). A disturbing wave measurement device checks the noise output from the LISN and indicates its level.

Figure 11: Conduction noise measurement method

(2) Structure of LISN

A LISN (Line Impedance Stabilizing Network) is a tool enabling a quantitative assessment of noise levels being output via power cables for electronic devices.

Figure 12 shows the internal circuitry of a LISN. The internal circuitry of the LISN is a filter circuit composed of resistors, inductors, and capacitors. The LISN maintains a constant impedance of 50Ω for devices being measured in a measurement frequency range (0.15 to 30MHz), in order to measure the disturbing wave voltages under the same conditions even if the impedance of the power supply side differs. The two essential functions of the LISN will be explained below.
(1) Maintaining a constant impedance of 50Ω between the voltage line conductor and grounding cable, and between the neutral line conductor and grounding cable

(2) Preventing the intrusion of conductive noises outside from the power supply

As shown in Figure 13 (a), the conduction noise level can be found by measuring the voltage drop at both ends of the resistor for noise measurement. This amount of voltage drop equals the noise voltage between the power supply lines and the ground (called the voltage between one line and ground), and this is the resulting value of combining common mode noises and differential mode noises. This conduction noise level is generally called the mains terminal voltage, and the unit used is “dBµV”.

Figure 13: Conduction noise measurement methods using standard type (type V) and conduction-mode separation type (type ⊿) LISNs, and noise flow

(a) Standard noise measurement circuit (type V)

(b) Conduction-mode separated measurement circuit (type ⊿)

(3) Separate measurement of common mode and differential mode

Noises being output via power supplies can be classified into differential mode noises and common mode noises. And their noise control methods differ respectively.

A standard LISN cannot separate these two modes. However, a LISN type such as in Figure 13 (b) can do so.

The LISN type in Figure 13 (a) is called a “type V”, and it is the standard LISN designated by CISPR and FCC (Federal Communications Commission). Generally the term LISN indicates this type.

The LISN type in Figure 13 (b) is called a “type ⊿”. In the past, this type was used for measurement of conduction noises from TV sets, etc. However, nowadays this has rarely been used since CISPR and FCC, etc. designated “type V” as the standard LISN. Still, “type ⊿” is the only LISN that can measure common mode and differential mode noises separately, and it is a very convenient tool for noise control.

5. Examples of Noise Countermeasures in Separated Conduction Modes

(1) Example of power supply terminal measurement in separated conduction modes

Figure 14 and figure 15 show examples of measuring the power supply terminal voltage of a switching power supply module, by using “type V” and “type ⊿” LISNs.

As shown in Figure 15, the “type ⊿” LISN can measure common mode and differential mode noises separately. Figure 15 indicates that common mode noises make up the major proportion of noises, and countermeasures against common mode noises should be taken first.

Figure 14: Switching power supply module conduction noise spectrum measured by the “type V” LISN

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**Figure 12 Example of the internal circuitry of a LISN**

![Diagram of LISN circuitry](image)
(2) Countermeasures and noise reduction effects

(a) Countermeasures against common mode noises

Figure 16 shows the conditions before countermeasures are taken. The level of common mode noises is high, approximately 100dBμV, exceeding the allowable regulated level by over 40dBμV.

As a countermeasure, as shown in Figure 17 (a), a common mode filter was inserted in the AC line, and 4700pF capacitors were inserted between each line and the frame ground (FG). The latter capacitor is called “Y” capacitor.

Consequently, common mode noises have been reduced to a level meeting regulations.

(b) Countermeasures against differential mode noises

Figure 17 (b) shows the conditions before countermeasures are taken. The 150kHz to 2MHz range differential mode noise levels exceed the allowable regulated level.

As a countermeasure, as shown in Figure 18 (a), 0.47μF capacitors were inserted between AC lines. This capacitor is called “X” capacitor.

Consequently, noises have been reduced to a level meeting regulations.
Figure 18: Countermeasures against differential mode noises and their effects

(a) Inserting two “Y” capacitors between lines

“X” capacitor

(b) Mains terminal voltage spectrum

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Differential mode noises</th>
<th>Common mode noises</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>120</td>
</tr>
</tbody>
</table>

As the capacity of a “Y” capacitor grows, leak current also increases. This can cause electric shock. Therefore, UL and other safety standards restrict the capacity so that the amount of leak current does not exceed a certain level.

Usually, two “Y” capacitors are used, as shown in Figure 17 and Figure 18. As AC lines are connected with capacitors, they are effective in reducing differential mode noises. In particular, they are effective for high frequency ranges of 8 to 10MHz or so.

(2) “X” capacitor

An “X” capacitor to be connected between AC lines is only effective in reducing differential mode noises. It is often called a differential mode capacitor, and one with a relatively high capacity of 1µF or so is used.

An “X” capacitor is connected between lines. As it is not connected between lines and the ground, there is no risk of electric shock, etc., even if it is damaged.

An “X” capacitor is particularly effective for a frequency range between 150kHz to 1MHz, lower than that for the “Y” capacitor.

6. Selection of Noise Control Parts

Figure 19 shows a typical filter structure. A common mode choke coil has several to several 10µH of leakage inductance. When this component is overly used, the core easily becomes saturated. However, this component has an effect of reducing differential mode noises. Thus saturation control and control of differential mode noises are in a “trade-off” relationship.

Figure 19: Typical structure of power supply EMC filters

As the capacity of a “Y” capacitor grows, leak current also increases. This can cause electric shock. Therefore, UL and other safety standards restrict the capacity so that the amount of leak current does not exceed a certain level.

Figure 20: Equivalent circuit for noise filter

(a) Equivalent circuit for differential mode signals

(b) Equivalent circuit for common mode signals

(1) “Y” capacitor

A “Y” capacitor to be connected between AC lines and the FG has an effect of emitting common mode current to the FG.

Leak current corresponding in frequency and voltage to the AC power supply flows in the “Y” capacitor.
7. Filter Specifications / Characteristics

(1) Rated voltage
This is the maximum AC line voltage (actual value) allowable within a designated operating temperature range. Rated voltage of AC 250V is common recently, but sometimes a rated voltage of AC 400V is also used. As for transmission and distribution wiring systems, the major systems in use are single-phase systems and three-phase systems.

(2) Rated current
This is the maximum load current amount (actual value) allowable within a designated operating temperature range. This differs depending on the heat resistance properties of the internal components. Also, when used in a high ambient temperature, the allowable load current amount should be derated accordingly, as shown in Figure 21.
In this example, when used in an ambient temperature of 70°C, the amount of allowable load current should be derated to approximately 70% of the rated current.

(3) Power supply frequency
Power supply voltage frequency is generally 50Hz/60Hz. However, a larger value is sometimes used for special use products. For example, it is 400Hz in the aviation-related field. Power supply EMC filters are designed for use in 50Hz/60Hz commercial power supplies.

(4) Test voltage (withstanding voltage)
In order to simulate possible accidents including grounding faults, tests are executed by applying several times higher voltage than the rated voltage between lines, or between the line and case (ground), and checking if any failure occurs or not. This is called the withstanding voltage test. The test voltage is that applied in the tests. It is usually AC 1500V, AC 2000V or AC 2500V for commercial products.

(5) Insulation resistance
This is a resistance value representing insulation strength. This resistance value is found by applying DC voltage between lines or between the line and case (ground), and measuring a very small amount of current flowing in the dielectric body of a capacitor or insulating materials (especially in plastic cases). Applied voltage is usually DC 500V.

(6) Leak current
Leak current is the current leaking from power supply lines to cases (ground), when noise filters are inserted in power supply lines and a rated voltage is applied. This value is mainly dominated by electrostatic capacitance (C), power supply voltage (E), and power supply voltage frequency (f), and found in the expression below.

Leak voltage = 2 \pi f CE

If this value is large and noise filters or ground terminals are ungrounded, electric shock can occur.

(7) DC resistance
DC resistance is the summation of resistance in a noise filter. Almost all of this is the wire wound resistance of the coil, but also includes resistance from the connection to the terminal. The value calculated by multiplying DC resistance by the load current corresponds to the voltage drop value generated in the noise filter.

(8) Temperature rise
This is the temperature rise of a case surface when a rated current is passed through a noise filter. In general, this value is the one measured in a condition where a product is directly exposed to the air. When the product is attached to a metal board or forcibly cooled by fans, etc., the value will be lowered.
(9) Attenuation characteristics (static characteristics)
This is reference to assess the attenuation characteristics of noise filters. Data is plotted on a graph with frequency on the horizontal axis and attenuation amount on the vertical axis. Figure 23 shows the measurement method, and Figure 24 shows an example of the characteristics.

Figure 23: Method of measuring attenuation characteristics (static characteristics)

* Balun is for stabilizing impedance in a specific frequency range.
* e₁ and e₂ are values measured in S.A.

\[
\text{Attenuation} = 20 \log_{10} \left( \frac{e_1}{e_2} \right) \text{ (dB)}
\]

Here, a 20dB attenuation indicates that the noise level is reduced to 1/10, a 40dB attenuation indicates that the noise level is reduced to 1/100, and a 60dB attenuation indicates that the noise level is reduced to 1/1000.

(10) High-voltage pulse attenuation characteristics
A several kV voltage surge can occur in a power supply line, and it can intrude into devices in the form of common mode noises, causing them to malfunction. For this reason pulse energy durability is assessed by pulse-applying tests, etc., for robots and other machines. Noise filters are used as countermeasure parts. For countermeasures against pulse noises there is a need to be careful of a reduced effect due to a saturation of the magnetic materials.

Generally, the expression in Figure 25 (a) is applicable for pulse voltage in an area where the core is not magnetically saturated. In order to reduce the surge voltage with a large value of multiplication of \( E \) and \( \tau \), the saturation magnetic flux density of the core should be higher, if the core shapes and the number of turns of coil are the same. For this purpose an amorphous magnetic core, which has high saturation magnetic flux density, high permeability, and superior frequency characteristics, is used.

Figure 25: Characteristics of amorphous magnetic core and high-voltage pulse characteristics

(a) Core material characteristics and pulse voltage
\[
\Delta B = \frac{E \cdot \tau}{N \cdot A_e} \times 10^4
\]
\( \Delta B \): Magnetic flux density change of core = \( B_m - B_r \)
\( E \): Pulse voltage
\( \tau \): Pulse width (sec)
\( N \): Number of turns of coil
\( A_e \): Cross-section area of core

(b) B-H characteristics (hysteresis loop)

(c) Measurement circuit
8. Practical Examples of Countermeasures against Noises

(1) Countermeasures against noises in NC machine tools
NC machine tools, which are driven by servomotors, generate a very large amount of noises. Over 100dBμV noises were generated by this machine tool before countermeasures were taken. However, through the use of filters the noises have been reduced to a level meeting regulations.

Figure 26: Countermeasure by using a three-phase noise filter

(2) Improvement of cable layout
Input and output cables of a filter were located close to each other, causing noises from the output side to intrude into the input side of the filter. However, by relocating the breaker to increase the distance between the input and output lines of the filter, noises have been reduced to a level meeting regulations.

Figure 27: Improvement of cable layout
(3) Countermeasure by improving grounding
Since the filters are located away from the EUT main unit, the grounding condition was not good, and the level of high-frequency noises was high.

By improving grounding of the transformer box where filters are set, and by improving grounding of the EUT main unit, the noise levels have been reduced to a level meeting standards (lowering impedance between the transformer box and the EUT main unit by special metal-shielded wiring).

Figure 28: Improving grounding

(4) Countermeasure against saturation by filter with amorphous magnetic core
As a large amount of current flows in a device momentarily, the filter core was saturated and the attenuation characteristics of the filter were weakened. As a result, noise levels exceeded the allowable regulated level. By using an amorphous magnetic core, DC superimposition characteristics have been improved, and noise levels have been reduced to a level meeting standards (Figure 29).

Figure 29: Countermeasure against saturation of core
9. Effective Filter Mounting

Noise filters are widely used for reduction of noises outgoing/incoming to/from power supply lines. However, if they are used incorrectly their characteristics cannot be effective, resulting in wasted countermeasures.

Explained below are the necessary and basic matters to be considered when using noise filters. They are also thoroughly described in catalogs, etc., for every noise filter manufacturer. However, it has been found that these matters do not seem to be observed in actual devices.

This may be due to a lower incidence of noise-related problems. However, if any problems occur after products are released to the market, it is difficult to reproduce the same situation, difficult to find the causes, and difficult to find effective countermeasures.

Therefore, to assure maximum reliability of products, we recommend checking and observing all the points for countermeasures against noises explained below.

Countermeasure 1:
Use noise filters. Shield the device and noise sources.

Countermeasure 2:
Locate units and cables away from noise sources.

Countermeasure 3:
Do not allow noise current to flow in the chassis.

Countermeasure 4:
Make current loops smaller.

Countermeasure 5:
Be sure to locate the input and output lines away from each other.
Countermeasure 6: Supply power from the noise filter output side for every unit.

Countermeasure 7: Ground wire from the noise filter should be as thick and as short as possible.

If the ground wire from the noise filter is long, inductance increases between the noise filter and chassis causing deterioration of the high frequency characteristics of the noise filter. When a noise filter is grounded via a metal case, attach the noise filter directly to the chassis of the device after removing any coating on the contact surfaces for better metal contact.

If a case is made of metal but not grounded, or if it is plastic, use a lead wire as short as possible in length to ground the noise filter via the chassis of the device.