

Noise Countermeasures for AC Power Lines

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As was explained in “EMC Filter for Power Sources to Prevent Noise Intrusion and Emission at the AC Power Supply Part”, noises emitted from equipment will be transmitted via the AC power supply line, intrude into other connected equipment, and can cause malfunctions or a deterioration in their performance, consequently it is very important to reduce noise emission from AC lines. In this article, we will introduce the noise assessment method based on IEC’s noise regulation standard CISPR (Comité international spécial des perturbations radioélectriques), and will explain about methods for noise reduction, and show experimental data.

1 Assessment Methods for Noise Transmitted via AC Power Supply Lines

Measurement Method Specified by EU Standards

EN (European Norm), the noise regulation standard of Europe, is specified based on CISPR.

In IEC’s noise regulation standard CISPR (Comité international spécial des perturbations radioélectriques), the measurement method and limit values for conductive noise emitted from power cords of electronic equipment are specified. The measurement method specified in the standard is shown in Figure 1.

Place the equipment under test on an 80 cm high wooden desk. Connect the power cord to the noise measuring instrument called LISN (Photo 1) placed 80 cm away from the equipment under test. The LISN is to be placed on the surface of a large conductor, in other words, on an earth. The radio interference measuring instrument will detect and display the levels of noise output from LISN.

Figure 1 Measurement Method of AC Power Supply Line’s Conductive Noise Specified by CISPR

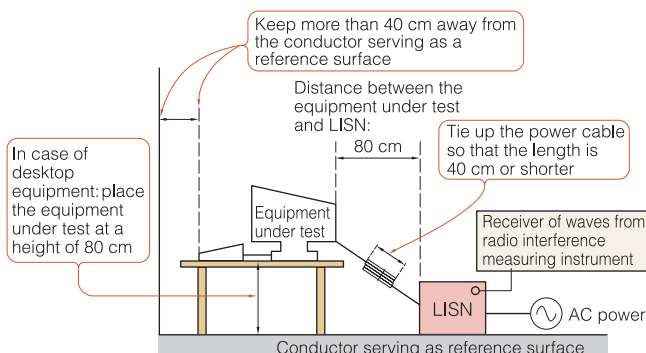
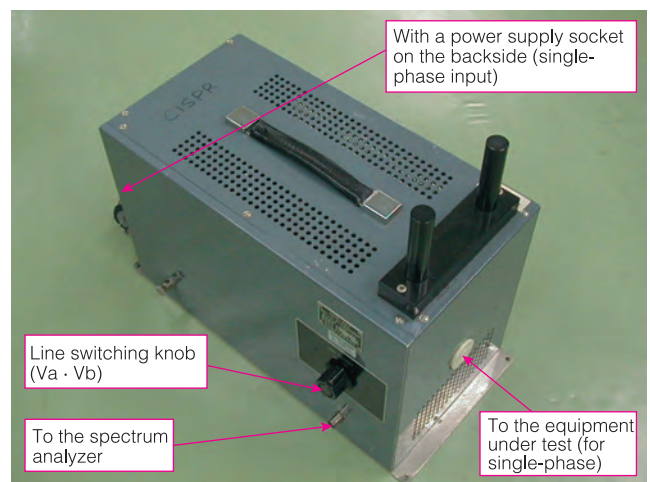


Photo 1 Appearance of LISN (KNW-407, Type V, Kyoritsu Corp.)



Principles of LISN

The LISN (Line Impedance Stabilizing Network) is a sort of jig that enables the quantitative assessment of the level of noises emitted from the power cords of electronic equipment.

The internal circuit of LISN is shown in Figure 2. It is a simple filter circuit consisting of resistance, inductor and capacitor. Voltages of interfering waves can be measured under the same conditions, even if the impedance on the side of the power supplier varies. Within the frequency band to be measured (0.15 to 30 MHz), the impedance seen from the side of the equipment under test will also be stabilized at 50 Ω. The two major purposes of LISN are as follows:

- (1) To stabilize the impedance between the voltage line conductor and the grounding wire and the impedance between the neutral line conductor and the grounding wire at 50 Ω.
- (2) To block conductive noises transmitted from the power source

Figure 2 Example of LISN’s Internal Circuit

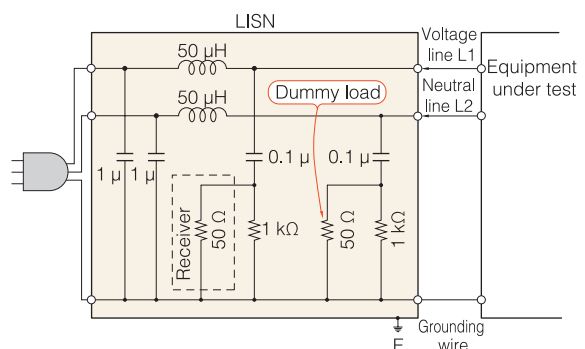
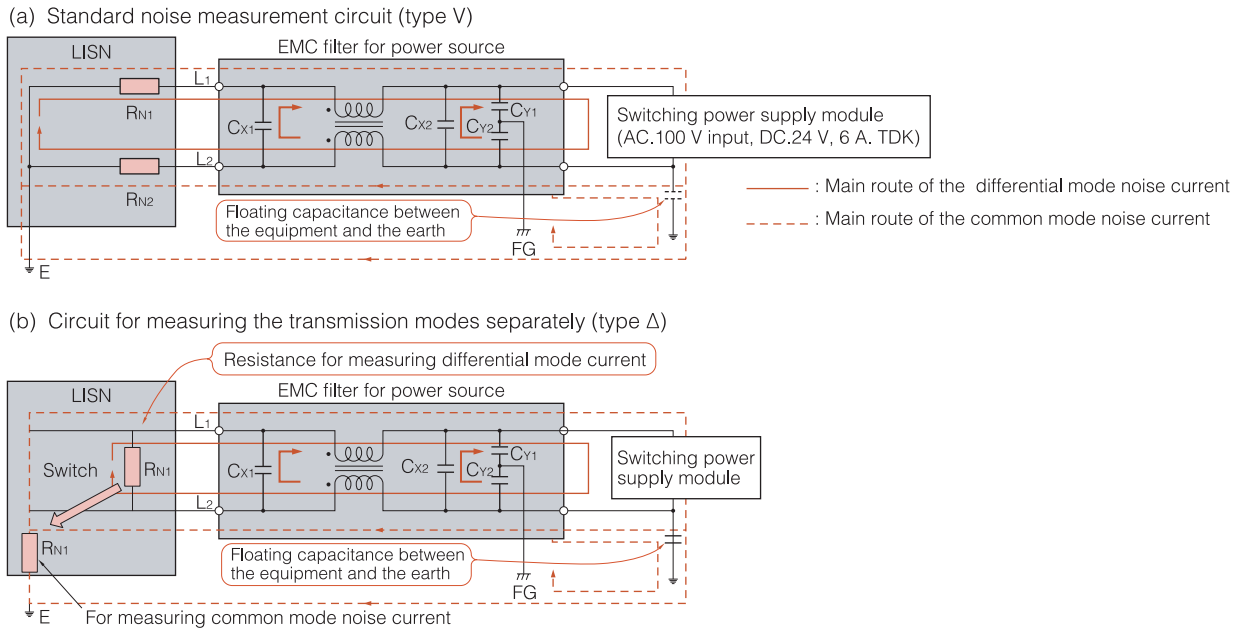


Figure 3 Conductive Noise Measurement Methods Using Standard Type LISN (Type V) and LISN for Separating Transmission Modes (Type Δ), and the Noise Flow



As is shown in Figure 3 (a), in order to measure noise the level of conductive noise is obtained by measuring voltage drops on both ends of the LISN resistances set. The drop in the voltage indicates the noise voltage between the power supply line and the ground (called line-ground voltage), whose value is the sum of common mode noise and differential mode noise. The level of the conductive noise is generally called noise terminal voltage (dB μ V)

■ Measuring Method of Actual Noise Levels

If the frequency components of the noise are not understood, first connect the LISN spectrum analyzer, and check the noise spectrum. The values to be displayed by the spectrum analyzer are peak values. Set a short sweep time and establish the frequency exceeding the regulated value.

Once you have narrowed down the noise frequency to be dealt with, set the measurement frequency of the radio interference measuring instrument to the same frequency. Display the values while switching between quasi-peak detection mode and average detection mode, and consider countermeasures by comparing them with the standard value.

■ Measuring Common Mode and Differential Mode Separately

Conductive noise transmission modes can be classified into two modes, the common mode and the differential mode. We have learned that it is effective to apply a common mode filter for common mode noises. Noise emitted to AC power sources can also be classified into common mode and differential mode, the countermeasures also vary according to each mode.

Although it is not possible to separate the two modes when using a standard LISN, it is possible if you use the type shown in Figure 3 (b). Its structure enables switching the resistance for measurement between the common mode and the differential mode. LISN of the type shown in Figure 3 (a) are called type V, the standard LISN specified by CISPR and FCC (Federal Communications Commission). This is the general type of LISN.

LISN of the type shown in Figure 3 (b) are called type Δ. This type used to be applied when measuring conductive noise in TV bands, but since CISPR and FCC specified type V as the standard LISN, it has almost completely ceased to be used. However, this is the only LISN capable of measuring both the common mode and differential mode separately, and is also a useful tool for noise assessment.

■ Example of Measuring a Power Source Terminal Separating the Transmission Modes

Examples of measuring the power source terminal voltage of a switching power supply module using LISNs of type V and type Δ are shown in Figure 4 and Figure 5.

As is shown in Figure 5, measurement can be carried out by separating the common mode noise and the differential mode noise, when using type Δ LISN. It can be identified from Figure 5 that the main component of the conductive noise is in common mode, indicating that in the first place countermeasures against common mode noise will be needed.

Figure 4 Conductive Noise Spectrum of Switching Power Supply Module Measured Using Type V LISN

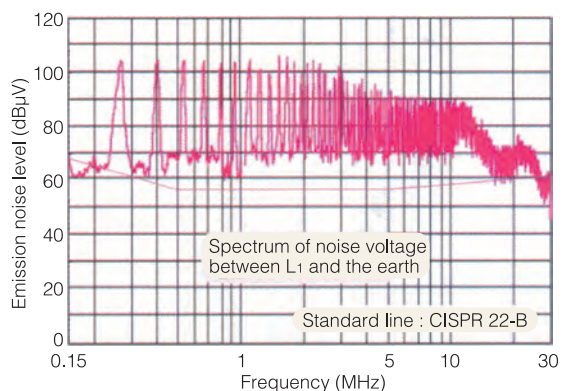
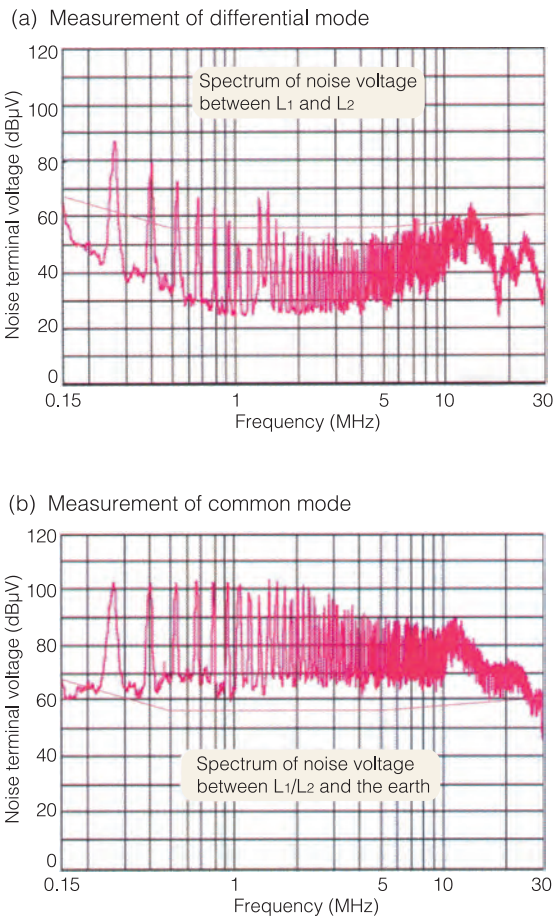


Figure 5 Conductive Noise Spectrum of Switching Power Supply Module Measured Using Type Δ LISN



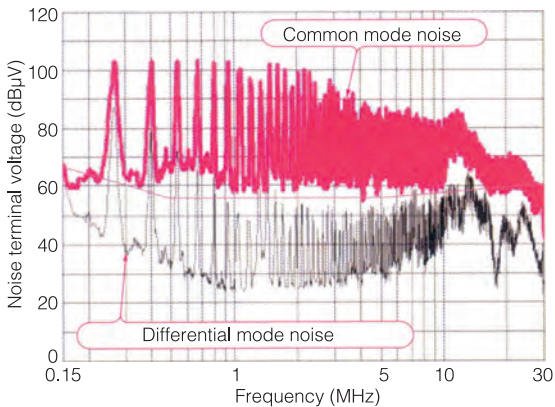
2 Countermeasure Examples against the Noise Terminal Voltage of a Switching Power Supply Module

Countermeasures and Noise Reduction Effects

(1) Countermeasures against common mode noise

As is shown in Figure 6, common mode noises were high reaching around 100 dB μ V and before countermeasures were taken they exceeded the standard limit value by more than 40 dB μ V.

Figure 6 Conductive Noise Spectrum of Switching Power Supply Module without Noise Countermeasures



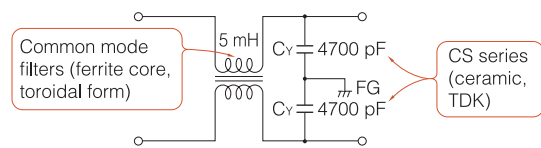
Therefore, we inserted common mode filters in the AC lines as is shown in Figure 7, and inserted 4700 pF capacitors to the lines leading to the frame ground (FG). These capacitors are called Y capacitors. As a result, common mode noise was reduced enough to fall below the regulation value, as is shown in Figure 7 (b).

(2) Countermeasure against differential mode noise

As is shown in Figure 7 (b), differential noise at bandwidth 150 kHz to 2 MHz exceeded the standard regulation value. Therefore, we inserted capacitors of 0.47 μ F between the AC lines, as is shown in Figure 8 (a). These capacitors are called X capacitors. As a result, the noise level fell below the standard regulation value, as is shown in Figure 8 (b).

Figure 7 Common Mode Noise Countermeasures and Their Effects

(a) Add two common mode filters and Y capacitors



(b) Vector of noise terminal voltage

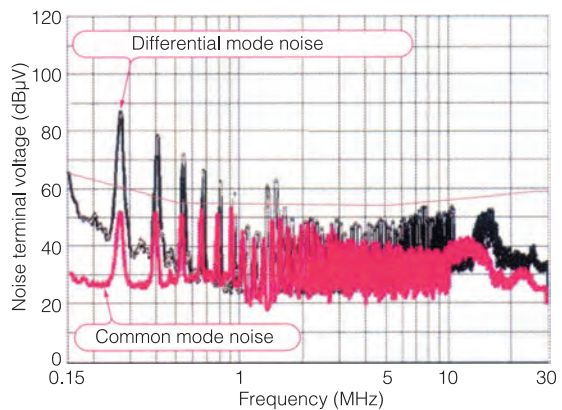
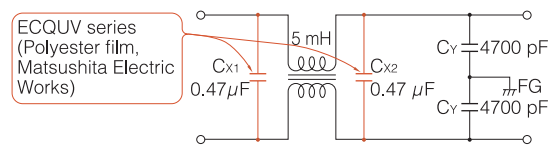
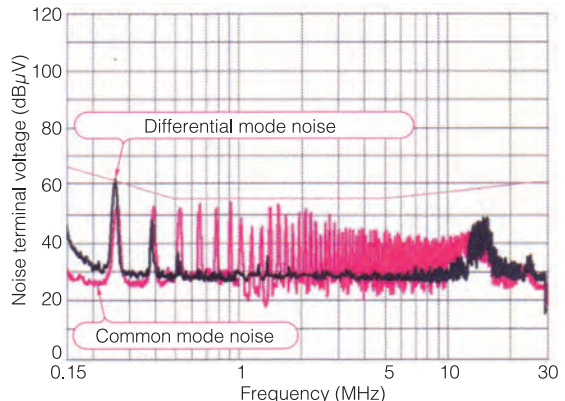


Figure 8 Differential Mode Noise Countermeasures and Their Effects

(a) Add two common mode filters and Y capacitors



(b) Spectrum of noise terminal voltage

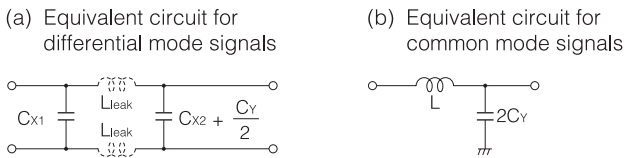


■ Key Points in Choosing Countermeasure Components

(1) Common mode filter

Equivalent circuits are shown in Figure 9. The common mode filter has a leak inductance of several to several dozen μH . Although the core reaches saturation easier when this component is high, it also helps to reduce differential mode noise. A two-mode filter is a part that positively utilizes this component. Countermeasures against saturation and against differential mode noise are in a trade-off relationship.

Figure 9 Equivalent Circuits of Common Mode Filters



► Y capacitor

Y capacitors connected between the AC lines and the FG work to let out the common mode noise current to the FG.

These are also called “common mode capacitors”.

Leakage current according to the frequency and voltage of the AC power source will flow into the Y capacitor. The leakage current increases when the capacitance of Y capacitors become larger and there is a risk of electric shock; restrictions are placed on the capacity by safety standards such as UL (Underwriters Laboratories Incorporated), in order to prevent the leakage current amount from exceeding a certain value.

Normally, two Y capacitors will be used as in Figure 7 and Figure 8. As the AC lines will be connected by capacitances, it will also prove effective against differential mode noise. The effect will be especially high at high frequencies around 8 to 10 MHz.

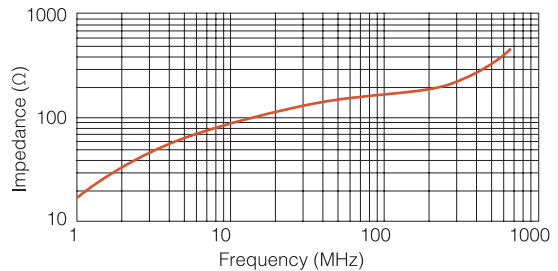
► X capacitor

X capacitors to be connected between the AC lines are effective only against differential mode noise. They are also called differential mode capacitors, and those with comparatively large capacities around $1 \mu\text{F}$ are used. As X capacitors are connected between the lines and are not connected between the line and the earth, even if they break there will be no danger such as the risk of electric shock. Frequency bands where X capacitors prove effective are lower than those of Y capacitors, being around 150 kHz to 1 MHz

3 Clamp Filters should be Used to Block the Intrusion of a Sharp Noise Pulse

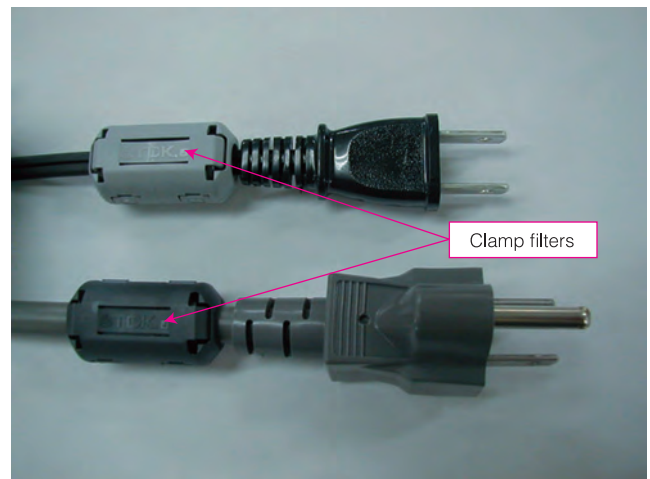
As is shown in Figure 10, a clamp filter is a part capable of maintaining impedance up to the high frequencies. Just by attaching it to the cable, it is very effective as a countermeasure against pulse noise with high frequency components and noises of external origin such as static electricity.

Figure 10 High Impedance Characteristic is Maintained up to High Frequency Band when Using a Clamp Filter



AC power cords with clamp filters (ZCAT2035-0930A) attached are shown in Photo 2.

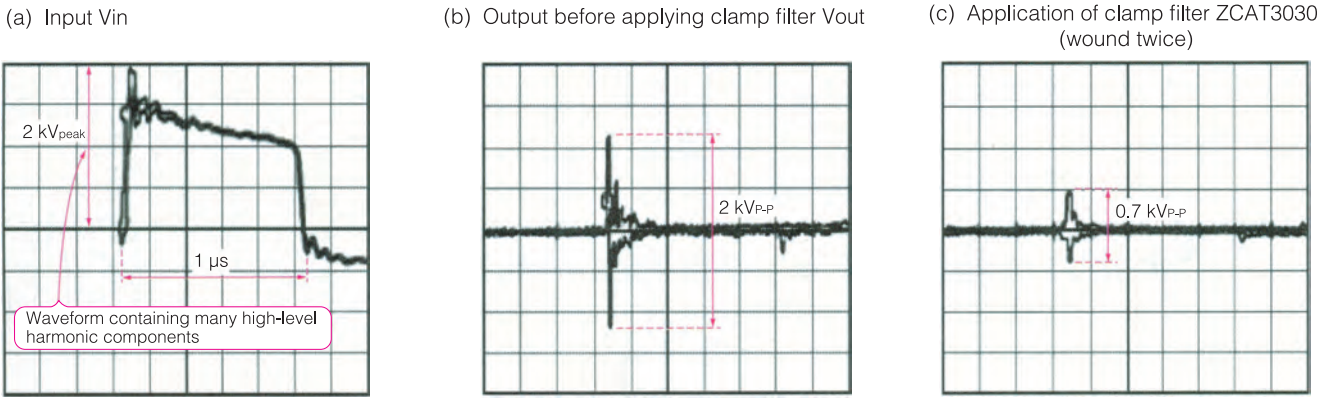
Photo 2 Clamp Filters Attached to AC Power Cords



The reduction effect of pulse noise before and after attaching the clamp filter is shown in Figure 11. We applied a pulse voltage with peak voltage of 2 kV and a pulse width of $1 \mu\text{s}$ to the primary side of the switching power supply module, and observed the voltage waveform appearing on the secondary side. When a clamp filter is applied, the peak value of the waveform of the noise leaking out to the primary side will be reduced from 2.0 kVp-p to 0.7 kVp-p.

When using a general EMC filter on a power line, no effect could be expected against high frequency components above 30 MHz. Even if you use an EMC filter on a power line compatible with high-voltage pulses, if the pulse noise shows a sharp rise, it is possible that pulse noises with high peak values would be output to the secondary side. In that respect, it will be possible to obtain a stable reduction effect even at the high frequency band, if you use a clamp filter.

Figure 11 Reduction Effect of High-Speed Pulse Noises by a Clamp Filter

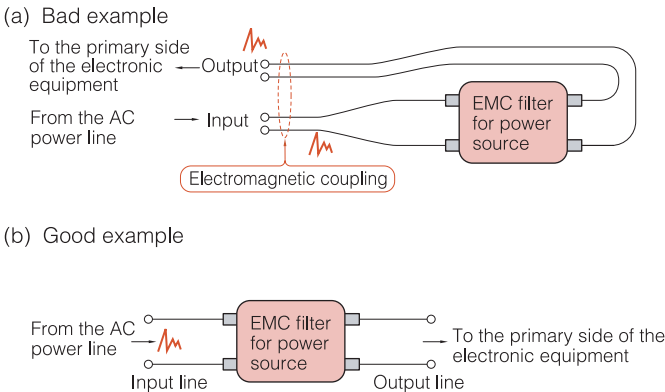


4 | To Increase the Performance of an EMC Filter for Power Line

Do not Arrange Input Wires and Output Wires close together

Please try to keep input wires and output wires away from each other, as shown in Figure 12. If the input/output wires come in contact with each other such as when they are bound together, the noise inhibiting effect will be reduced, since the eliminated noise will be taken up again by floating capacitance and electromagnetic coupling.

Figure 12 Keeping the Distance between the Input / Output Wires of an EMC Filter for Power Line



Keep the Impedance between the EMC Filter and the Earth as low as possible

Keep the impedance between the ground of the EMC filter for the power line and the earth as low as possible.

When the case is made of metal, it is possible to reduce high-frequency noises just by connecting the case and the equipment's FG. When the chassis of the equipment is painted, it will be necessary to realize a low-impedance connection status, by such means as scraping the paint off, as shown in Figure 13. When the case is made of plastic, a lead wire as thick and short as possible should be used for connecting. Transitions of decay characteristics for connecting the case of an EMC filter for power line, RSAN-2010 type (single-phase AC, 250 V, 10 A, TDK-Lambda) with the earth, and for connecting it with the earth using a wire rod as long as 10 cm, are shown in Figure 14.

Figure 13 Connect Earth Terminal of the EMC Filter for Power Line after Scraping Off the Paint from the Chassis

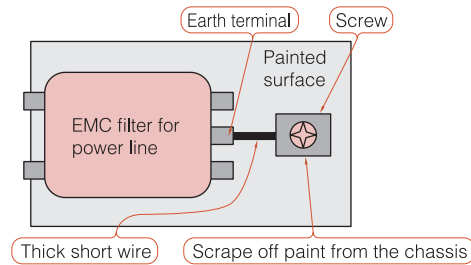
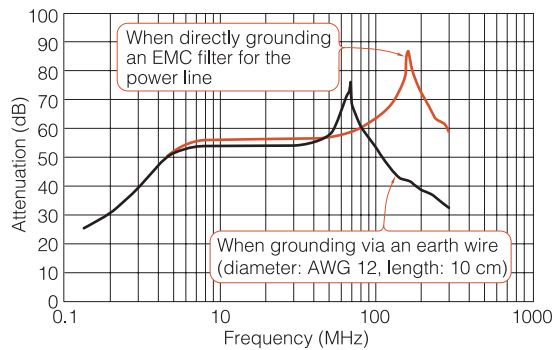


Figure 14 How to Ground an EMC Filter for Power Line, and the Attenuation Change in Conductive Noise



■ Separation of Input/Output by Shielding

As is shown in Figure 15, the EMC filter for the power line should be set as close as possible to the noise source, or at the input/output point of the electronic equipment. If it is placed outside the equipment and wired from there, it may become the cause of noise radiation, or reversely, of malfunction due to noise intrusion into the power supply line.

References

- (1) Toshio Kinoshita; Basics and Practice of EMC, Nikkan Kogyo Shimbun, LTD., 1997)
- (2) Tim Williams; EMC for Product Designers, Newnes, 1992
- (3) Clayton R. Paul; Introduction to EMC, pp.482 to 483, Feb. 1996, mimatsu-data-system
- (4) Yoshio Masuno; Additional Volume of Electronics November, pp. 89 to 90, 1998, Ohmsha, Ltd.

Figure 15 The EMC Filter for the Power Line should be Placed Close to the Noise Source

