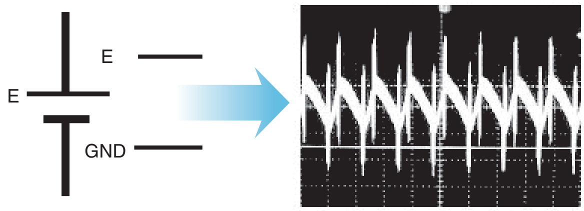
EMI Filter

1 What Is Noise?

Noises refers to unwanted variations or fluctuations in voltage, current, signals, etc.



What a designer expects (an ideal steady voltage source)

In reality, noises are included.

Figure 1.1.1 What Is Noise?

2 Noise Sources

Noise comes in two types: natural noise and manmade noise. While natural noises are generated by a lightning strike or static electricity, manmade noises are generated by familiar devices such as industrial equipment, fluorescent bulbs, or communication equipment.

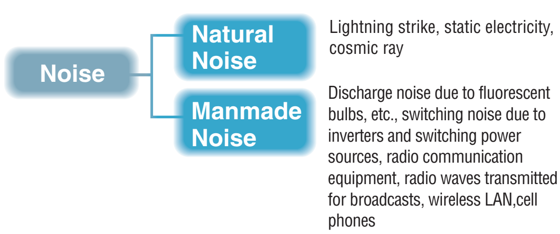


Figure 1.2.1 Noise Sources

Typical devices that generate noise are switching power sources and general-purpose inverters.
Such devices include switching elements such as FETs and IGBTs, and are major noise sources due to high-frequency switching of those elements.

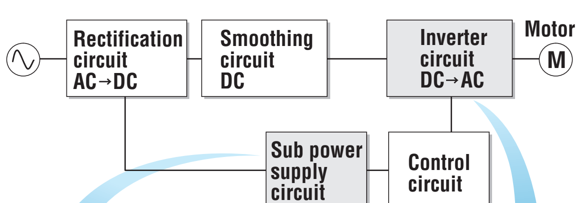


Figure 1.2.2 Inverter block diagram

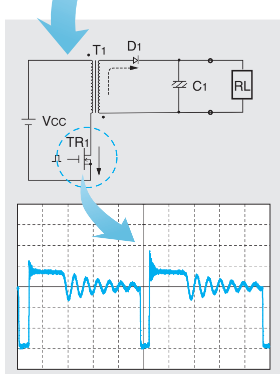


Figure 1.2.3 Sub power supply inverter operation waveform

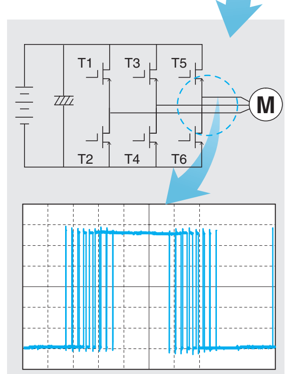


Figure 1.2.4 Inverter PWM output waveform

3 What Is EMC?

EMC stands for electromagnetic compatibility, and refers to the ability of electrical equipment to have both EMI and EMS at once; the former indicates the ability to suppress noise radiated from the equipment itself and the latter means the ability to endure noise from other equipment.

What are EMC compliant products?
The EMC compliant products refer to those that meet standards required by EMI and EMS.
They provide various types of parts that can deal with noise from the viewpoint of EMI and/or EMS.
Our noise filters (hereinafter, "EMI filters") are parts that mainly deal with conducted interference in terms of EMI.

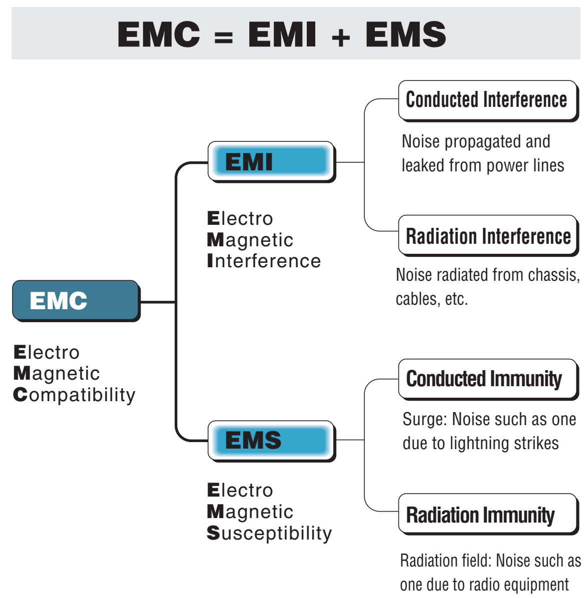


Figure 1.3.1 Concept of EMC

4 Propagation Paths of Noise

a. Conductive noise
Refers to noise that propagates through a power line or PCB tracing.

b. Inductive noise
Refers to noise that is induced due to electromagnetic or electrostatic induction caused by a power line or a signal line of a peripheral device when it is placed near a line or pattern in which noise current flows and propagates through the line.

c. Radiated noise
Noise radiated by an antenna (or a line be having as an antenna) that propagates to other devices through the air.

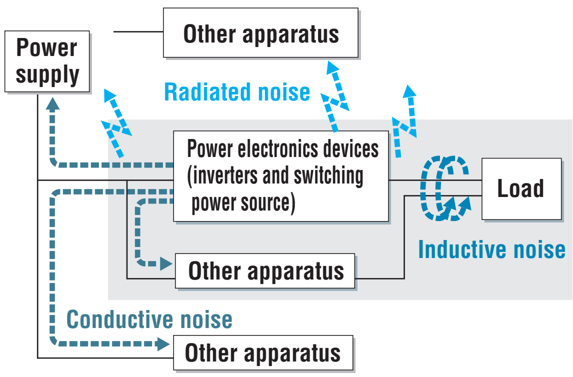


Figure 1.4.1 Propagation Paths of Noise

5 Basics of Noise Reduction

The propagation of noise consists of a noise source, an entity that is affected by the noise, and propagation path that connects both. To reduce noise:

◎**Reduce the noise level of a noise source**
◎**Make it more difficult for noise to propagate**
◎**Make equipment less vulnerable to noise**

In addition to the abore, designs must consider standards, quality and cost of noise reduction methods.

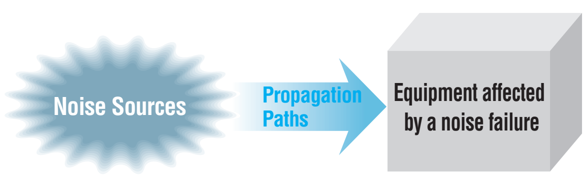


Figure 1.5.1 Overview of Noise Generation and Propagation Path

6 Types of Conductive Noise

Noise is divided into two types based on its generation mode: normal mode noise and common mode noise. Normal mode noise is also called differential mode noise, and refers to noise generated between power lines. Common mode noise refers to noise generated between a power line and ground line.

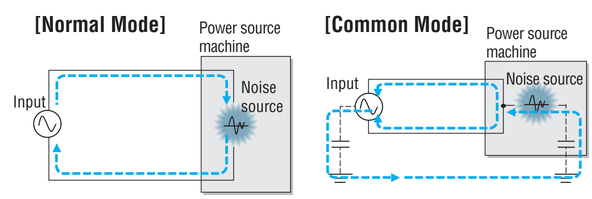
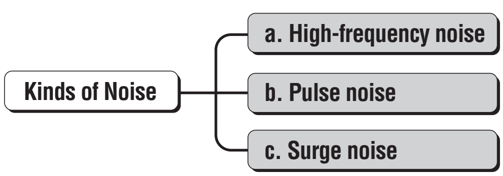


Figure 1.6.1 Noise Generation Paths
(Example in which a noise source is within power equipment)

7 Types of and Countermeasures for Noise



a. High-frequency noise
Also called EMI noise or power supply noise and refers to high-frequency components such as the clock frequency of a computer and switching frequency of power sources. As an antinoise measure, an EMI filter should be installed on the input side. An appropriate filter should be selected based on requirements such as attenuation, mechanical design and cost.

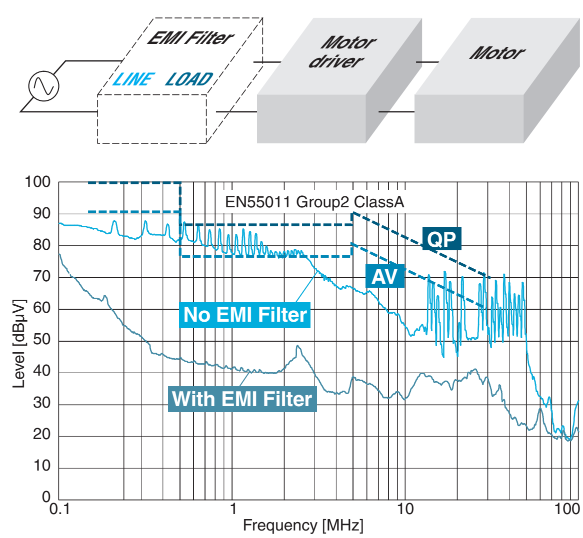


Figure 1.7.1 Example of Noise Reduction by an EMI Filter

Output ripple noise from a switching power source is also a type of high-frequency noise.

Ripple noise can be reduced with a DC filter designed fot it.

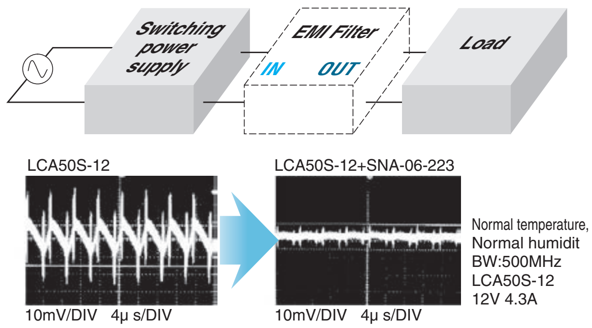
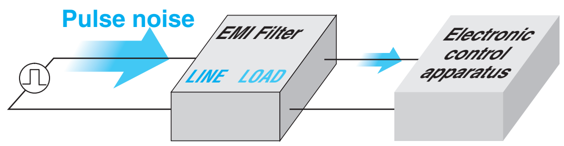


Figure 1.7.2 Example of Effectivemess of Ripple Noise Filter

b. Pulse noise

This noise is generated when a relay or motor is driven. As peak voltage may reach as high as a few thousand volts, generic filters may not be able to sufficiently attenuate noise because its choke coil gets saturated. As an antinoise measure, one could select a filter that uses an amorphous core for its superior pulse attenuation characteristic.



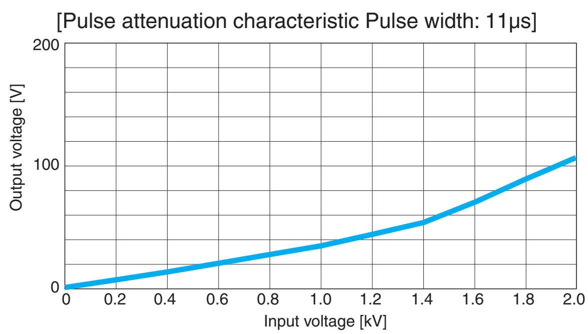


Figure 1.7.3 Example of Pulse Attenuation Characteristic(NAP-16-472)

c. Surge noise

This noise occurs when a natural discharge (such as lightning) affects a power line. As the generated voltage reaches as extremely high as a few kilovolts or more, EMI filters cannot suppress surge noise. As an antinoise measure, one could use a part such as a varistor to control surge voltage between power lines or between a power line and ground. EMI filters can withstand approximately 2 kV between power lines and approximately 4 kV between a power line and ground (these values are not guaranteed).

If surges are a concern, surge countermeasures should be selected and installed to handle the EMI filter's capabilities.

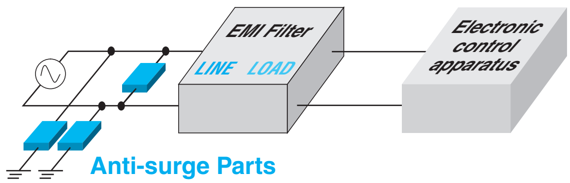


Figure 1.7.4 Proper Installation Location of surge Countermeasvres

1 Rated Voltage

The rated voltage is the maximum line voltage (nominal value) allowable to be used.
As the rated voltages for some parts used within an EMI filter are high in reality, however, voltages higher than the rated voltage of the EMI filter may be used without causing any trouble.
In fact, the rated voltages of filter components are often higher, in which case the filter can handle actual voltages that exceed its ratins.
In the case of some EMI filters, the maximum operation voltages are defined by specifications for them, separately from rated voltages.
Note that using EMI filters at voltages lower than their rated voltages do not pose any problems. For example, an EMI filter with a rated voltage of AC 250 V can be used for power lines of AC 100V.

As for line frequency, EMI filters for AC power supply lines have been basically designed to be used with the commercial frequency (50 Hz/60 Hz).
Higher frequencies such as 400Hz can cause problems such as excessive capacitor heating.
Note that EMI filters for AC power lines can also be used for DC power supply lines.

2 Rated Current

The rated current is the maximum load current (nominal value) that can be continuously carried. If the ambient temperature is high, however, the load current needs to be derated.

Figure 2.2.1 shows an example of a derating characteristic.

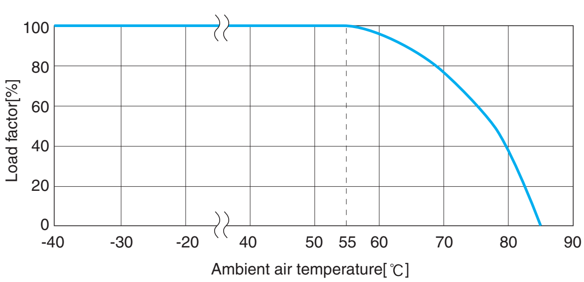


Figure 2.2.1 Derating Curve

This example indicates that when the maximum ambient temperature reaches 75 , the EMI filter should be used with a load factor of approximately 60% (approximately 60% of the rated current) or lower.
Current higher than the rated current would be allowed to flow in EMI filters for a short period of time only. Inrush current (Up to 40A or 10 times the rated current, single shots with a length of a few milliseconds) from devices such as a general switching power source does not cause any problems, but relatively long and / or repetitive peak current draws can result in the average current exceeding the filter's raring.

3 Test Voltage (Withstand Voltage)

The test voltage is a voltage value that is applied at the time of withstand voltage test. The withstand voltage test is to verify that the part does not break when applying a high voltage in a short period of time between a terminal (line) and the mounting plate (ground) of an EMI filter.
In the case of EMI filters for AC power lines, the test voltage is generally AC 2000 V or AC 2500 V.

In withstand voltage tests, the high voltage applied between a line and ground, results in abnormally high leakage current flow. When carrying out a withstand voltage test in an acceptance inspection, please set the cutoff current of withstand voltage test equipment to an appropriate value (the cutoff current defined in the specifications for the EMI filter).
For some EMI filters that have ground capacitors with extremely large capacity, DC voltages may be used for test voltages because the leakage current becomes too high when AC voltages are applied.

4 Insulation Resistance (Isolation Resistance)

Insulation resistance is a resistance value when applying a specified DC voltage (normally 500 V) between isolated conductors such as a terminal (line) and the mounting plate (ground), and regarded as one indicator of degree of insulation.
The insulation resistance is found by measuring the very small current that flows in an insulating material such as a resin case and capacitor when DC voltage is applied.

5 Leakage Current

The leakage current is an electric current that flows from the ground terminal of an EMI filter when the filter is connected to an AC power line.
Generally, as one sets the capacitance of a ground capacitor to a higher value, the reduction effect on common mode noise will be heightened and at the same time, the leakage current will increase.
Care must be taken, because large leakage current could cause a circuit breaker to trip or electric shock to occur when the EMI filter is not properly grounded.

Current (I) that flows from each power line to ground is represented with the following expression; it forms the basis of leakage current calculation.

$$I = 2\pi f C E$$

f : Power frequency
C : Capacitance between line and ground
E : Power supply voltage between line and ground

6 DC Resistance

DC resistance is a resistance value between the input and output of an EMI filter (the sum of resistance values for both directions).
It is mostly accounted for with the coil resistances but also includes connections between the coils and terminals.
The voltage drop caused by an EMI filter is represented with the following expression:

Voltage drop = DC resistance x Load current

Note that specifications for some products define voltage drops when rated current is carried, instead of resistance values.

7 Temperature/Humidity

a. Operating temperature

This is the range of ambient temperatures for which the product's usage is guaranteed.
If an ambient temperature is high, the load current needs to be derated.

b. Operating humidity

This is the range of ambient humidities for which the product's usage is guaranteed.
It assumes no condensation.

c. Storage temperature and humidity

The specified ranges of ambient temperatures and humidities that EMI filters in an unenergized state can be stored without deteriorating performance. No condensation is assumed for the storage humidity.

8 Circuitry

The following represents examples of EMI filter circuit structures.

a. Single-phase 1-stage filter

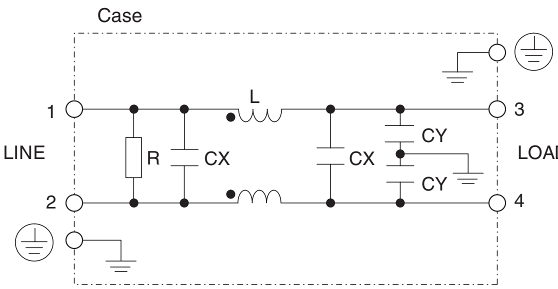


Figure 2.8.1 Circuit Structure Example of a Single-phase 1-stage EMI Filter

This figure shows a standard circuit structure for single-phase EMI filters.
L and CYs reduce the common mode noise; CXs and leakage inductance from L reduce the normal mode noise.
R indicates a discharge resistance for capacitors.

b. Single-phase 2-stage EMI filter

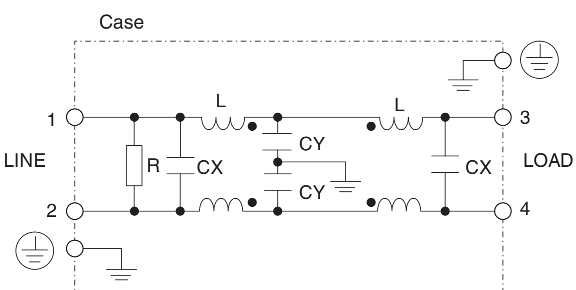


Figure 2.8.2 Circuit Structure Example of a Single-phase 2-stage EMI filter

The above figure represents a circuit structure example of placing choke coils in two stages to improve the attenuation characteristic.
The following graph shows an example comparison of attenuation characteristics for a 1-stage and 2-stage EMI filter.

[Common Mode]

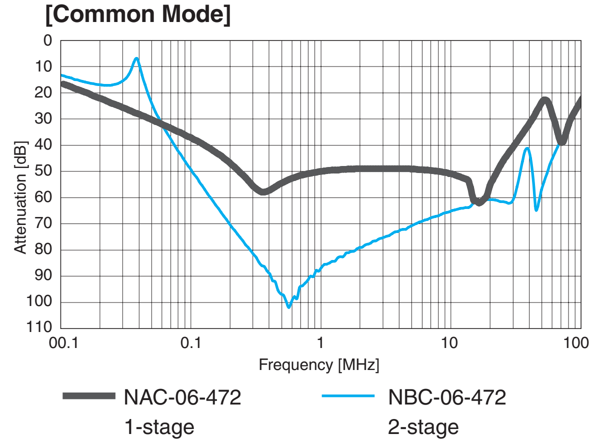


Figure 2.8.3 Example of Comparing Attenuation Characteristics between 1-stage and 2-stage EMI filters.

9 Safety Standards

a. General description of safety standards

The international standards consist of IEC standards which concern the electrical fields, and ISO standards which concern the non-electrical fields.

IEC

(International Electrotechnical Commission)

Standardization organization for standards related to the electrical fields; its headquarters is located in Switzerland.

It releases technical standards for electricity based on the latest sciences and technologies, and each country develops its own specific safety standards based on the corresponding IEC standards.

CISPR

(Comite International Special des Perturbations Radioelectriques =International Special Committee on Radio Interference)

One of IEC's special committees; it was established with the aim to integrate standards such as allowable values and measurement methods for interfering waves causing radio communication failures, and includes a standardization committee for EMC (Electro Magnetic Compatibility).

European Standard / EN Standard

(Europaische Norm=European Standard)

The EN Standard was created based on the IEC and CISPR standards, and consists of items almost similar to those in both standards.

A unique number is assigned to each standard.
(Exampla:IEC939 EN60939)

[An example of Certification Authorities in Europe based on EN Standard]

VDE	Germany	
TUV	Germany	
DEMKO	Denmark	
SEMKO	Sweden	

EN Standard: EN 55 □□□

Europe standard sign (EN)
Standard classification number (55)
Sequence number (□□□)

Standard classification number	Reference standards
EN50000 series	General European standards
EN55000 series	CISPR standards
EN60000 series	IEC standards

ENEC

(European Norm Electrical Certification)

The safety approval mark in Europe that enables products to smoothly be delivered among all the EU signatories, EFTA (European Free Trade Area), and East European countries.

Electronic products that are authorized to bear the ENEC mark do not need to be subjected to application procedures among the signatories. It provides a benefit of eliminating the need to obtain approval from each signatory to which they are distributed.

The ENEC mark is intended to apply to products such as lighting equipment, transformers, information processing equipment, switches and EMI filters.

★EU signatories···Germany, UK, Italy, Denmark, and 24 other countries
★EFTA········· Iceland, Norway, Switzerland, and Lichtenstein
★East European countries···Ukraine, Estonia, Belorussia, Moldova, Latvia, and Lithuania

North America

UL (Underwriters Laboratories Inc.)

A test organization established in 1894 by the Electrical Bureau of the National Board of Fire Underwriters. Since then, it has been performing compliance tests on various electric products.

CSA (Canadian Standard Association)

A non-profit standardization organization established in Canada in 1919. Each state law in Canada requires that electric equipment that needs to be connected to a public power source conforms to the CSA standards.

UL	USA	
CSA	Canada	

As the US and Canada have signed MRA (Mutual Recognition Agreement), mutual approval can be obtained. If UL verifies that a certain electric product conforms to the CSA standard, or to the UL and CAS standards, the product is authorized to bear the following approval marks:

CSA	
UL,CSA	

b. Safety standards for EMI filters

Different products may conform to different safety standards and bear different approval marks (for use in different countries). Check the approved safety standards when considering purchasing them.

IEC939	International standard	IEC
EN60939	EU	EN
UL1283	USA	UL
C22.2 No.8	Canada	CSA

c. CCC approval from China

EMI filters do not fall within the scope of CCC.
(as of November 2011)

10 Attenuation Characteristic (Static Characteristic)

Attenuation characteristic provides a rough indication of noise reduction effect. The graph is derived from plotting an attenuation characteristic when connecting a EMI filter to a specified measurement circuit with frequency on the horizontal axis and with attenuation on the vertical axis.
The measurement methods are shown in Figure 2.10.1 and Figure 2.10.2. The attenuation is given as the ratio of U01 to U02, where U01 is output when EMI filters are not in the measured circuit and U02 is when an EMI filter is in the circuit, and normally expressed with the logarithm of that ratio in [dB].

$$\text{Attenuation} = 20\text{Log}_{10}\,(U_{01}/U_{02})\ [\text{dB}]$$

U_{01}:Generated voltage when a EMI filter is not inserted [V]
U_{02}:Generated voltage when a EMI filter is inserted [V]

*An attenuation of 20 [dB] means that the noise level reduces to 1/10 of the one without an EMI filter. Similarly, 40 [dB] and 60 [dB] mean a 1/100 and 1/1000 reduction of the noise level, respectively.

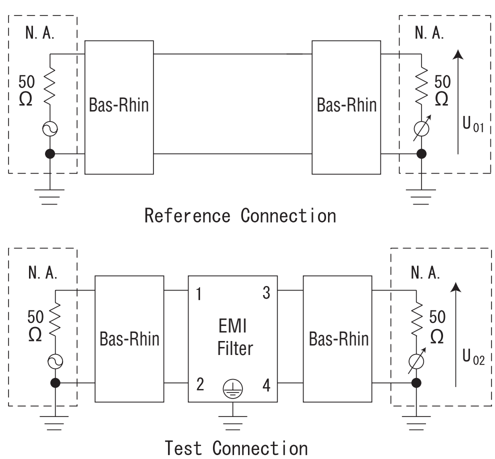


Figure 2.10.1 Attenuation Characteristic Measurement Method (Single-phase Normal Mode)

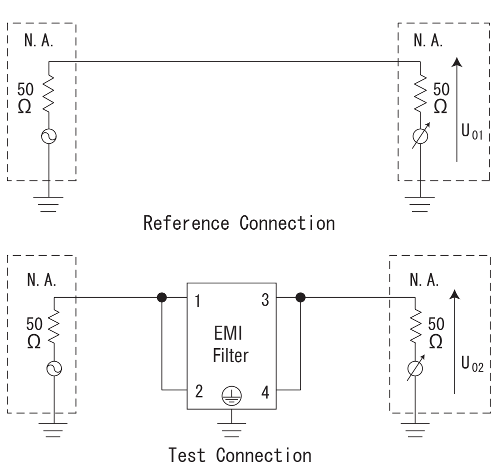


Figure 2.10.2 Attenuation Characteristic Measurement Method (Single-phase Common Mode)

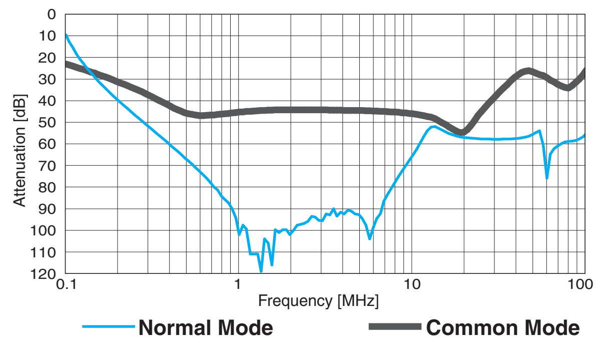


Figure 2.10.3 Example of Attenuation Characteristic (NAC-16-472)

The attenuation characteristic of EMI filters is affected by the input and output impedances of a measured circuit.
This attenuation characteristic (static characteristic) is measured under the constant condition of input and output impedances of 50Ω regardless of measurement frequencies. This enables the attenuation characteristics of different filters to be compared under the same conditions.
However, actual electronic devices have different power line impedances, and impedance itself has its own frequency characteristic and does not take a constant value.
For these reasons, the attenuation characteristics (static characteristics) that are specified in the catalogs for EMI filters do not necessarily coincide with those when they are attached to actual electronic devices.
One must also be careful that when connecting EMI filters in series, the static characteristic of the resultant series is not derived from simply adding the static characteristics [dB] of the individual filters.

11 Pulse Attenuation Characteristic

Figure 2.11.2 represents how much the EMI filter can attenuate pulse common mode noises, which may cause malfunctions of electronic equipment, connected to a power line. Figure 2.11.1 illustrates the measurement method.
When terminating the input and output of the EMI filter with 50Ω, and applying a specified pulse waveform on the input, pulse voltages appearing on the output are measured and plotted with the horizontal axis representing input pulse voltage and with the vertical axis representing output pulse voltage.

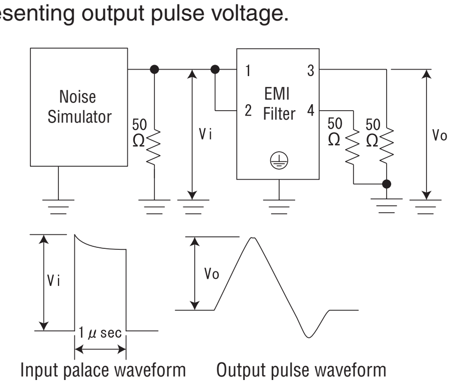


Figure 2.11.1 Measurement Method for Pulse Attenuation Characteristic (Single Phase)

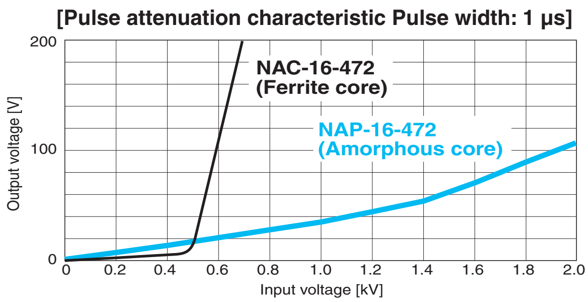


Figure 2.11.2 Example of Comparing Pulse Attenuation Characteristics

Figure 2.11.2 gives an example of comparing pulse attenuation characteristics for an EMI filter using a general ferrite core and one using an amorphous core.
The graph suggests that the amorphous core prevents the voltage of output pulses from increasing quickly in relation to rising input pulse voltage (a good pulse attenuation characteristic).
Beyond a given volt-time product the choke coil of an EMI filter will saturate, resulting in significantly reduced noise suppression. The volt-time product (V·T) that causes the core to reach magnetic saturation is found with the following calculation expression:

$$V \cdot T = \Delta B \cdot N \cdot Ae$$

V : Pulse voltage [V]
T : Pulse width [sec]
⊿B : Change of core's magnetic flux density = Bm – Br [T]
(Bm: Saturation magnetic flux density
Br : Residual magnetic flux density)
N : Number of turns in a coil [turns]
Ae: Effective cross section [m²]

According to the expression, an EMI filter using a core that has larger ⊿B (for example, an amorphous core) is less vulnerable to magnetic saturation, assuming that the numbers of turns and the sizes of cores are the same.

12 Ground Capacitor Codes

Many EMI filters can support various capacities of ground capacitors by specifying an appropriate code. The selectable ground capacitor codes depend on the types of EMI filters; the following table lists an example of ground capacitor codes and attenuation characteristics.

Table 2.12.1 Example of Ground Capacitor Codes (EAP series)

Code	Leak Current (input 125/250V 60Hz)	Line to ground capacitor (nominal value)
000	5 μA / 10 μA max	Not Provided
101	12.5 μA / 25 μA max	100pF
221	25 μA / 50 μA max	220pF
331	37.5 μA / 75 μA max	330pF
471	50 μA / 100 μA max	470pF
681	75.5 μA / 150 μA max	680pF
102	0.13 mA / 0.25 mA max	1000pF
222	0.25 mA / 0.5 mA max	2200pF
332	0.38 mA / 0.75 mA max	3300pF
472	0.5 mA / 1.0 mA max	4700pF

EAP -10 -472 -□

Model Name — Rated Current — Ground Capacitor Codes — Option

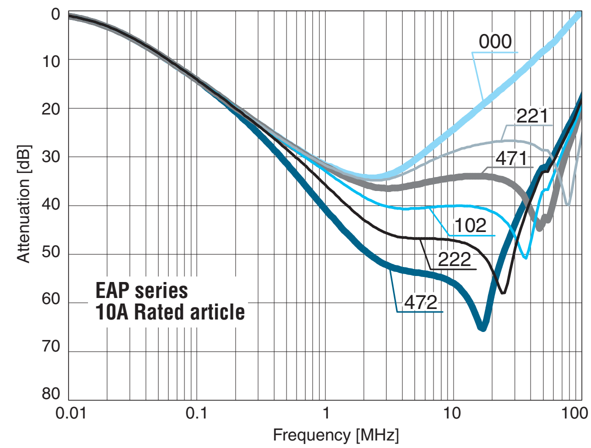


Figure 2.12.1 Example of Ground Capacitor Codes and Common Attenuation Characteristics

Generally, the larger capacity one sets a ground capacitor to, the better the common mode attenuation characteristic. But, the leakage current will also become larger, which means that there is a tradeoff.
The abundant selections of ground capacitor capacities make it possible for one to develop the best balance between attenuation characteristic and leakage current.

13 Options

Our EMI filters can be customized by specifying an option code.
As the types of set options depend on filter products, please refer to our catalog.
The following describes the outline of each option:

a. DIN rail installation type: D

This type of EMI filter can be installed to a DIN rail often used for control consoles, etc.

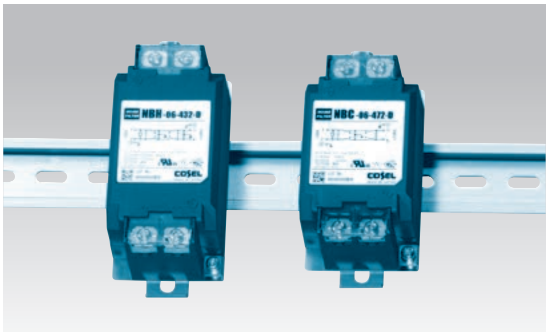


Figure 2.13.1 Examples of DIN Rail Installation Type EMI Filters

Note that as this type of EMI filter may not produce proper noise attenuation with grounding through a DIN rail, one must connect the ground to the protective earth terminal (PE) of the EMI filter. For EMI filters that have two protective earth terminals, it can connect the ground to either one only.

b. Terminal block type: T

These types of EMI filters use a terminal block as their interface (if the standard product uses a connector).

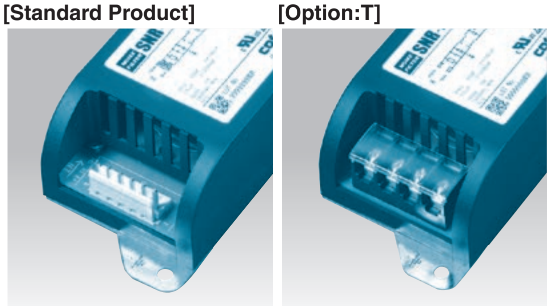


Figure 2.13.2 Comparison between Standard Product and T-option Product

c. High permeability choke coil type (ultra low-frequency and ultra high attenuation): H

These types of EMI filters the choke coil core with a high permeability core.

These types improve the common mode attenuation characteristic for low frequencies compared to their standard products.

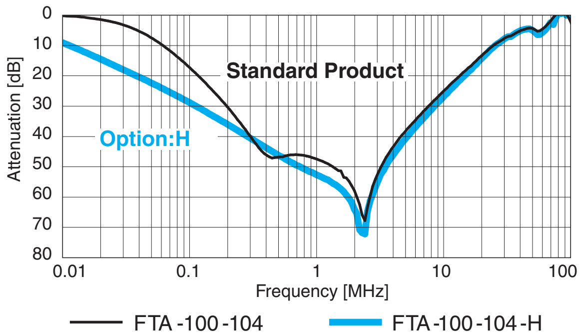


Figure 2.13.3 Example of Comparing Common Mode Attenuation Characteristics between Standard Product and H-option Product

d. Hexagon socket head cap bolt type: S

These types of EMI filters have a hexagon socket head cap (Allen) bolt in their terminal block in instead of the standard bolt (cross recessed (Philips) hexagon head bolt).

Customers can select the desired type of bolt for tools they are using.

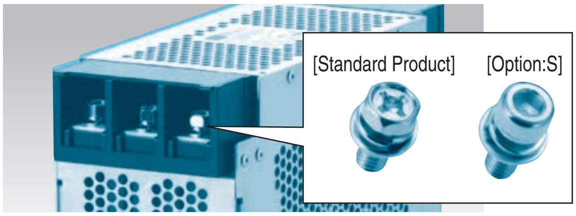


Figure 2.13.4 Comparison between Standard Product and S-option Product

e: With switch of line to ground capacitor type : G

These types of Ultra high attenuation type for EU, With switch of line to ground capacitor.

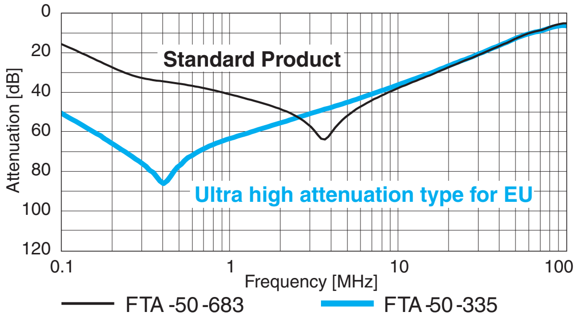


Figure 2.13.5 Example of Comparing Common Mode Attenuation Characteristics between Standard Product and Ultra high attenuation type for EU Product

Figure 2.13.6 With switch of line to ground capacitor type (Customers use when Test Voltage)

f. Improve differential mode attenuation type : U

These types of change the rated voltage 250V.

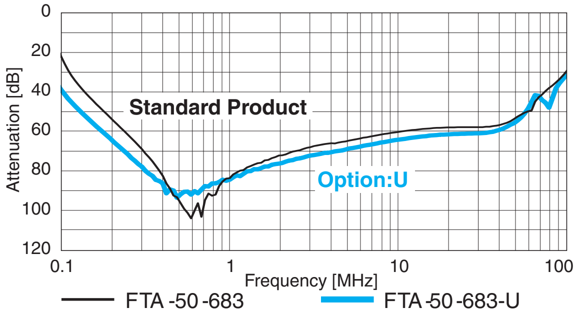


Figure 2.13.7 Example of Comparing differential Mode Attenuation Characteristics between Standard Product and U-option Product

g. Ultra high attenuation type for EU : L

These types of Ultra high attenuation type for EU.

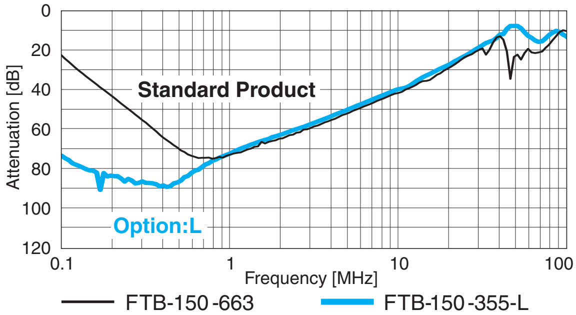


Figure 2.13.8 Example of Comparing Common Mode Attenuation Characteristics between Standard Product and L-option Product

h. High input voltage : F

These types of change the rated voltage 500VAC/600VDC.

Option code is possible combination.
Please contact us for more information.

1 Ground Wiring

When wiring an EMI filter with a ground wire, use a wire as thick and short as possible.
A long ground wire will deteriorate attenuation of high frequencies due to inductance in the wire.

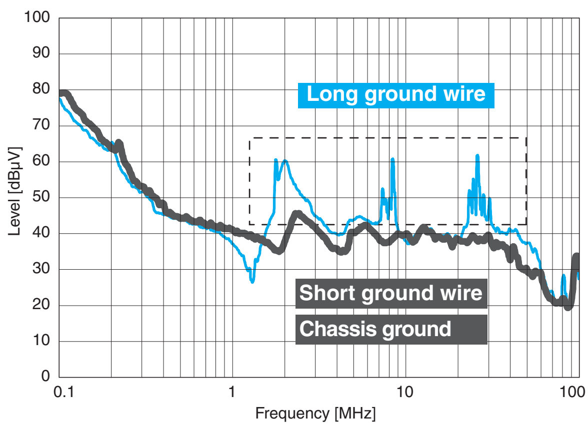


Figure 3.1.1 Example of Ground wiring Effed on Noise

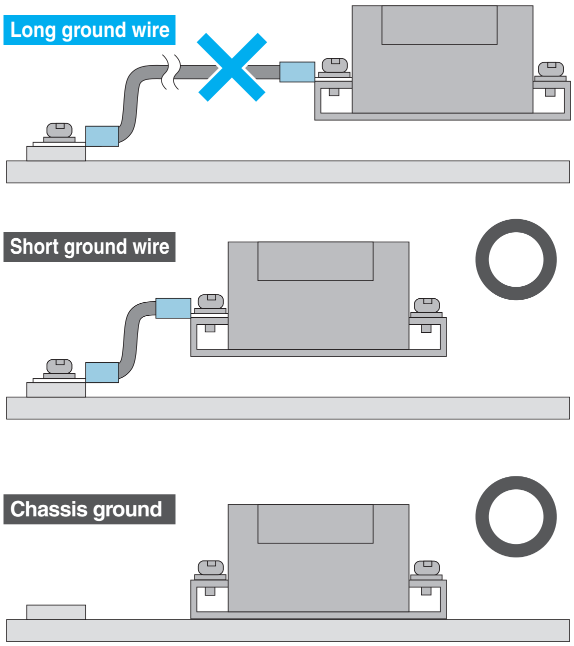


Figure 3.1.2 Proper grounding

If customers connect the metal chassis of their EMI filter, they can obtain an effect similar to a short ground wire.

2 Input and Output Wiring

Separate input wires from output wires.
If one binds input and output wires of EMI filters, or lays them close to each other, the filters may lose their proper attenuation effect because the high-frequency noise component may bypass them.
Twisting input (and / or output) wires in pairs can redvce noise.

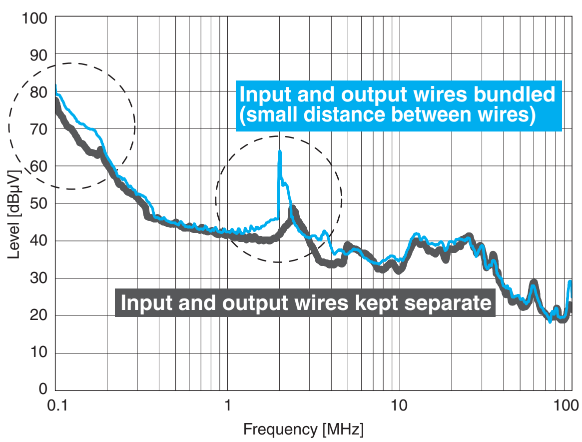


Figure 3.2.1 Example of Effect of wiring on Noise

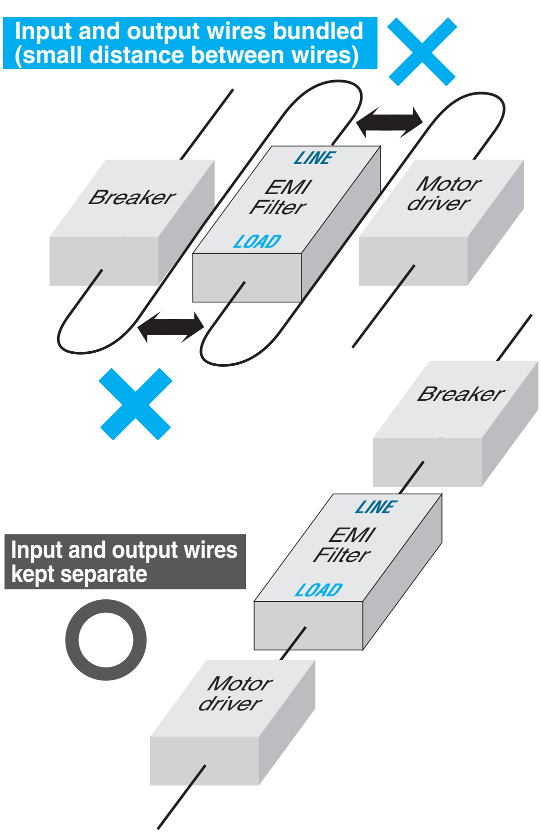
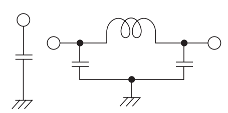
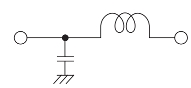
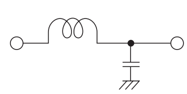
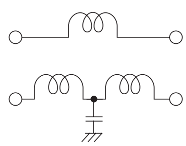


Figure 3.2.2 Input and output wires

1 Input and Output Impedance and Filter Circuit

The input/output impedances of a noise source and a load will have various optimal filter circuits.
General EMI filters take a configuration of a low pass filter that combines L and C. If the expected attenuation effect can not be obtained, impedances of noise source and load may be the reasons.

Table 4.1.1 Combinations of I/O Impedances and Optimal Filters

		Output impedance (Zo)	
		High	Low
Input impedance (Zi)	High		
	Low		

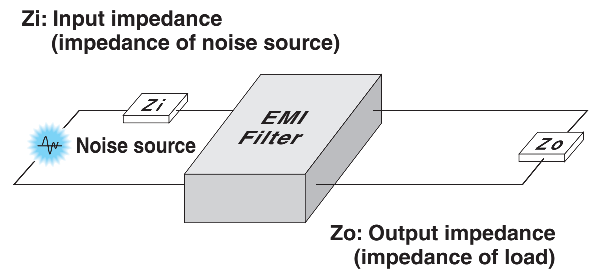


Figure 4.1.1 Input/output Impedances of an EMI Filter Circuit

2 EMI Filter Installation and Orientation

Generally, an EMI filter is placed in a way that the LINE terminal is connected to the input side, but it can also be used in a reverse configuration.
However, it may end up producing a different attenuation effect.

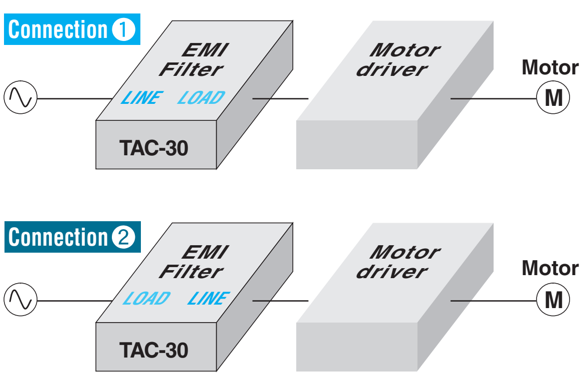


Figure 4.2.1 Direction in which an EMI Filter Is Attached and Connected

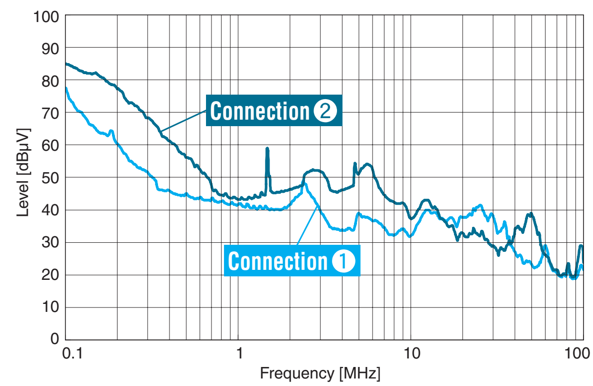


Figure 4.2.2 Example of Effed of Filter Orientation on Noise

If the internal circuit consists of a symmetric EMI filter (one of the NBC series or TBC series), the direction in which the filter is connected will not cause any difference in noise attenuation. But in the case of asymmetric ones, it may cause difference in the attenuation.

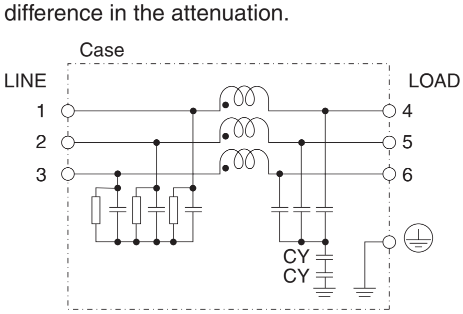


Figure 4.2.3 TAC Series Circuit Diagram
(Circuit Is Asymmetric)

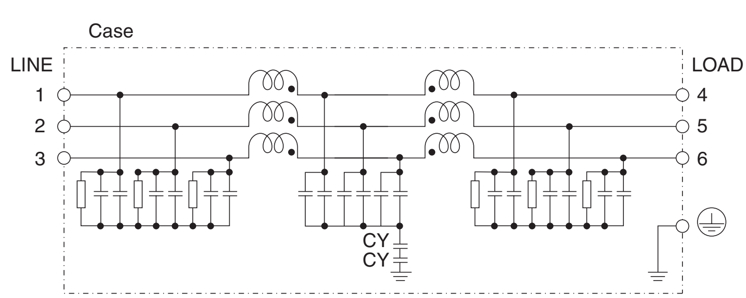


Figure 4.2.4 TBC Series Circuit Diagram
(Circuit Is Symmetric)

CY: Line to ground capacitor
⏚: Mounting Plate

3 Combining Multiple EMI Filters

If one EMI filter cannot provide sufficient attenuation, the attenuation effect can be improved by connecting two filters in series. However, one must pay attention to the fact that it will result in combining the leakage current and voltage drop of two EMI filters.

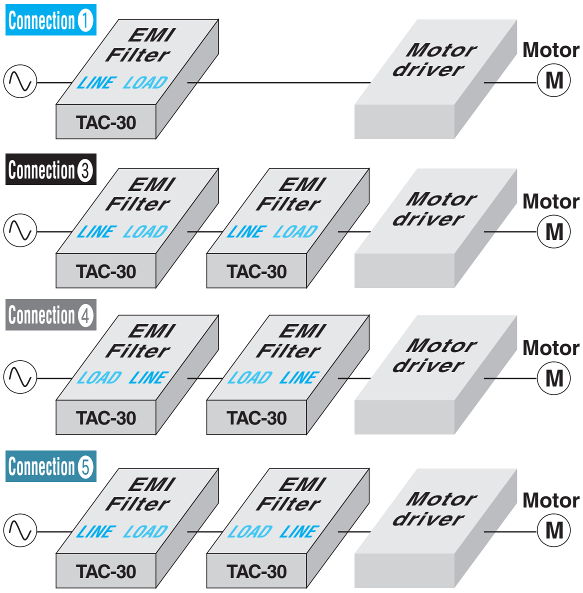


Figure 4.3.1 Example of EMI Filter Connection Directions

When connecting two EMI filters, the direction in which they are connected may also cause difference in the attenuation characteristic. Figure 4.3.3 shows the results of comparing the attenuation characteristics (static characteristics) due to different directions in which two EMI filters are connected.

Figure 4.3.4 shows the actual sample noise characteristics caused by the connection directions.

Unlike the static characteristic data, connection ❹ does not improve the attenuation in this case. This phenomenon occurred because the input and output impedances of the EMI filters were different from the conditions of static characteristics.

When trying to optimize the way EMI filters are connected, one must evaluate by checking actual noise levels.

4 External Ferrite Core

If one EMI filter cannot provide sufficient attenuation, the effect can be improved by inserting an external core.

Whether a core is inserted on the LINE side or on the LOAD side of an EMI filter may cause difference in the attenuation characteristic.

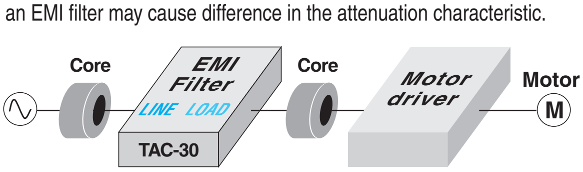


Figure 4.4.1 Example of Placing an External Core

When adding a core on the LINE side, one needs a core that can generate sufficiently large inductance for the choke coil within the EMI filter.

Just inserting on the LINE side a core whose performance is equal to or less than that of the internal choke coil does not contribute to reducing noise.

When inserting it on the LOAD side, it will produce a large attenuation effect because the circuit takes a configuration of a T-type EMI filter circuit.

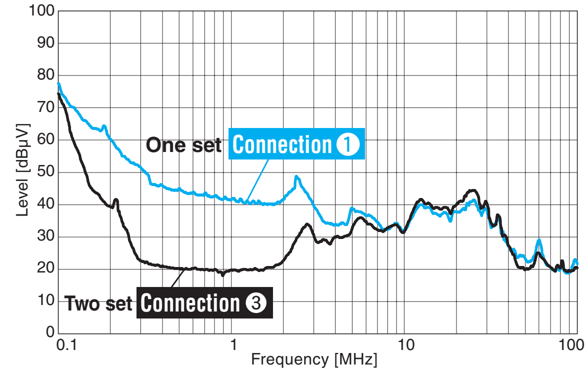


Figure 4.3.2 Example of Effect of Combining Multiple Filters

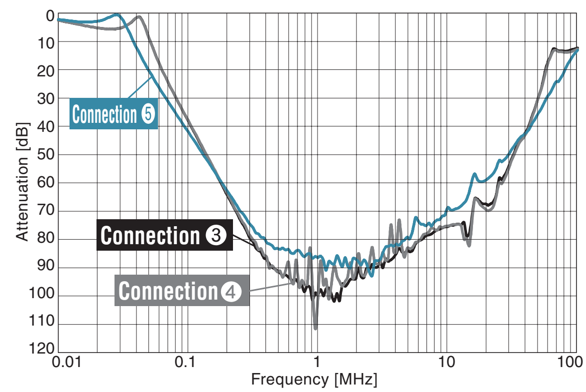


Figure 4.3.3 Comparing Static Characteristics of Different 2-filter cofigurations

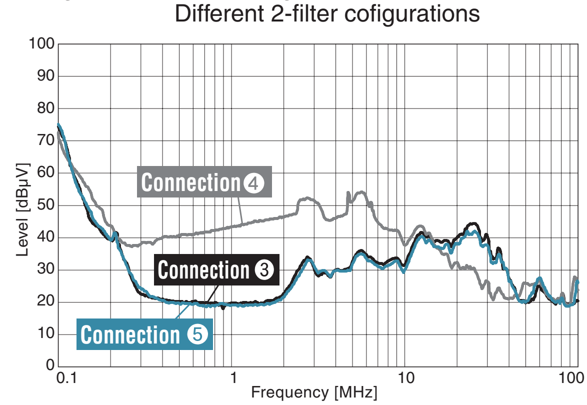


Figure 4.3.4 Comparing Effects of Different 2-filter Configurations

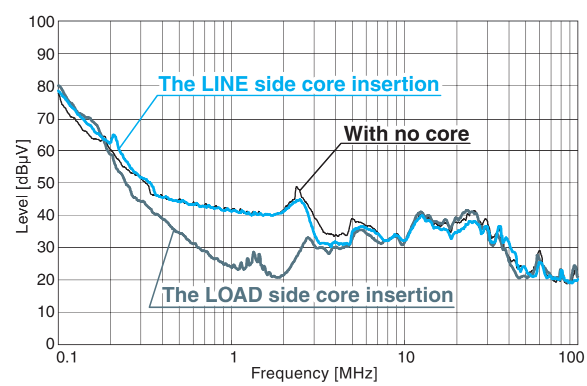


Figure 4.4.2 Example of Effect of Adding an External Ferrite Core

1 CE Marking

For machines and electric products to be sold in the EU area, manufacturers are required to bear a CE mark to prove they are in compliance with safety requirements, quality control, and ecocide prevention. To be allowed to do so, they must meet appropriate EC directives.
The following describes the EC directives that are applied to general machinery products:

a. Machinery directive

This directive covers products that are an assembly of parts and have a driving section
(with the central focus on industrial equipment).

b. EMC directive

This directive is intended to apply to electric parts which can be sources of radio disturbance or are affected by electromagnetic interference. It requires that two items, emission (EMI) and immunity (EMS), be met.

c. Low voltage directive

This directive is intended to apply to products that operate with a rated voltage in the range of 50 to 1000 V AC or 75 to 1500 V DC.

As there are no appropriate EC directives (including the ones described above) which apply to EMI filters, EMI filter products cannot bear a CE mark.

However, EMI filters can obtain an ENEC mark, which has a similar effect on bypassing application procedures of its signatories.

2 Conducted Emission EN61000-6-4

The voltages of interfering waves propagated through a power cable from equipment to the outside are measured with LISN★ in an open site★ or anechoic chamber★.

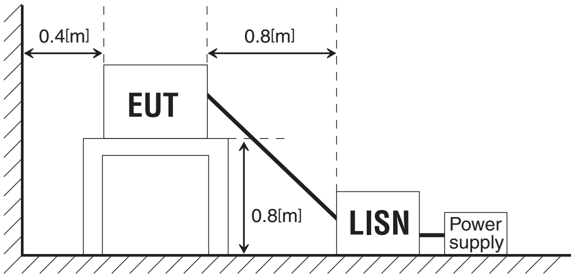


Figure 5.2.1 Example of Conducted Emissions Measurement Configuration

★ : Refer to the description in "Terminology related to EMC Test" in this document.

3 Radiated Emission EN61000-6-4

When operating equipment, the strength of electromagnetic waves is measured in a range of specified frequencies at a location 3 or 10 m away from the equipment

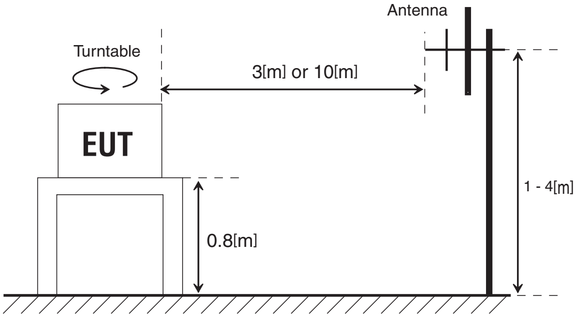


Figure 5.3.1 Example of Radiated Emission Measurement Configuration

4 Power Supply Harmonic Current EN61000-3-2

One analyzes the frequencies of input currents and checks the value of the harmonic current for each order.

5 Electrostatic Discharge EN61000-4-2

This test simulates effects of electrostatic discharge (malfunctions or destruction of semiconductor elements) and includes contact discharge and aerial discharge in its scope.

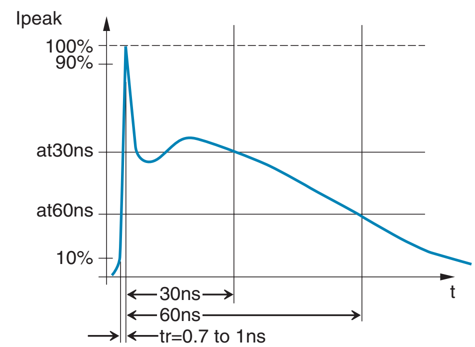


Figure 5.5.1 Discharge current waveform

Table 5.5.1 Application Level

Level	Specified voltage	First peak discharge current (±10%) Ip	Rise time	Current value at 30 ns (±30%)	Current value at 60 ns (±30%)
1	2kV	7.5A	0.7 - 1ns	4A	2A
2	4kV	15A	0.7 - 1ns	8A	4A
3	6kV	22.5A	0.7 - 1ns	12A	6A
4	8kV	30A	0.7 - 1ns	16A	8A

6 Radio frequency electromagnetic field EN61000-4-3

This test checks immunities of equipment to effects of electromagnetic waves.

7 Fast Transient/Burst EN61000-4-4

This test checks immunities to burst waves by from injecting via cable pulses that resemble the results of a discharge.

8 Surge EN61000-4-5

This test checks immunities to surges by applying a specified surge waveform.

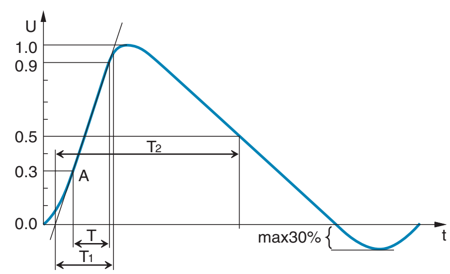


Figure 5.8.1 Example of a Surge Waveform in Voltage

Table 5.8.1 Level

Level	Open circuit test voltage±10% [kV]
1	0.5
2	1.0
3	2.0
4	4.0
X	special

9 Conducted Radio-frequency Interference EN61000-4-6

This test checks immunities to conducted disturbances when electromagnetic waves pass into equipment through a cable.

10 Power Frequency Magnetic Field EN61000-4-8

This test checks immunities to magnetic fields generated by power frequency currents flowing through an input line or a power wiring.

11 Voltage Dip/Momentary Power Interruption EN61000-4-11

These tests check if equipment functions normally after momentary voltage drop, or power failure that decreases voltage to 0.

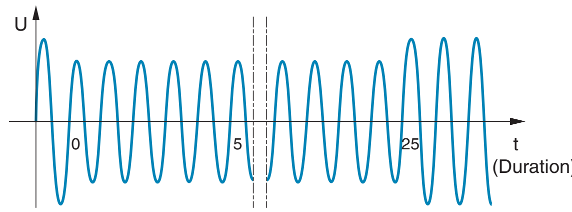


Figure 5.11.1 Example of a Waveform of Voltage Dips

12 Unit of Noise

Noise is represented with 1 [μV] as its reference in [dB].
It is assumed that 1 [μV] equals 0 [dBμV].
For example, 1 [V] is represented as follows:

$$20\mathrm{Log}_{10}\frac{1}{1\times10^{-6}} = 120\ [\mathrm{dB\mu V}]$$

10 [V]⇒140 [dBμV]
100 [V]⇒160 [dBμV]
1000 [V]⇒180 [dBμV]

13 Detection Method

a. Peak detection (PK)

It detects the heights of peaks of an output waveform.

b. Quasi-peak detection (QP)

It detects quasi-peaks through a circuit that has time constants at the time of charge and discharge.
Quasi-peak detection value equals an intermediate value between peak and average ones.
This detection has high measurement results when noise has a long duration or occurs frequently.

c. Average detection (AV)

It detects an average of values of an output waveform.

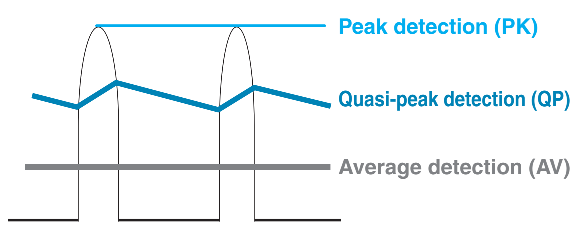


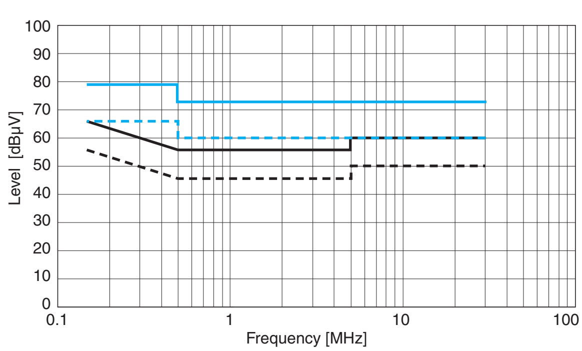
Figure 5.13.1 Relations between Detection Methods and Measurement Levels

14 Conducted and Radiated Emission Limits (Excerpt)

Test item			Standard	EN61000-6-3	EN61000-6-4	EN55011 Group 1 ★			EN55022		EN60601-1-2			EN50370-1	
			Classification	Common standard	Common standard	Standard for product groups			Standard for product groups		Standard for product groups			Standard for product groups	
			Product	–	–	ISM equipment ★ –	ISM equipment ★ 20 kVA or less	ISM equipment ★ Exceeding 20 kVA	Information processing equipment (ITE equipment)		ISM equipment (medical equipment) –	ISM equipment (medical equipment) 20 kVA or less	ISM equipment (medical equipment) Exceeding 20 kVA	Machine tool 16A or less	Machine tool Exceeding 16A
			Operating environment	Class B	Class A	Class B	Class A		Class B	Class A	Class B	Class A		Class A	
															Level:Unit [dBμV]
Conducted emission	Limit	QP	0.1 - 50.5MHz	66 - 56	79	66 - 56	79	100	66 - 56	79	66 - 56	79	100	79	100
			0.5 - 5MHz	56	73	56	73	86	56	73	56	73	86	73	86
			5 - 30MHz	60	73	60	73	90 - 73	60	73	60	73	90 - 73	60	90 - 70
		AV	0.15 - 0.5MHz	56 - 46	66	56 - 46	66	90	56 - 46	66	56 - 46	66	90	66	90
			0.5 - 5MHz	46	60	46	60	76	46	60	46	60	76	60	76
			5 - 30MHz	50	60	50	60	80 - 60	50	60	50	60	80 - 60	60	80 - 60
															Level:Unit [dBμV/m]
Radiated emission	Limit	10m Law	30 - 230MHz	30	40	30	40	50	30	40	30	40	50	40	50
			230MHz - 1GHz	37	47	37	47	50	37	47	37	47	50	47	50
		30m Law	30 - 230MHz	–	30	–	–	–	–	–	–	–	–	–	–
			230MHz - 1GHz	–	37	–	–	–	–	–	–	–	–	–	–

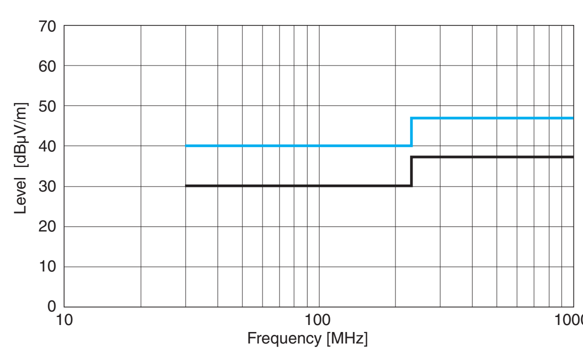
★ : Refer to the description in "Terminology related to EMC Test" in this document.

(As of November 2011)



EN55011 ClassA QP (Group 1)
EN55011 ClassA AV (Group 1)
EN55011 ClassB QP (Group 1)
EN55011 ClassB AV (Group 1)
(the above is also applied to EN55013, EN55014-1, EN55022, and EN60601-1)

Figure 5.14.1 Conducted Emission Limit Graph



ClassB
ClassA

Figure 5.14.2 Radiated Emission Limit Graph

5 EMC Test

15 Terminology related to EMC Test

★ EUT
Stands for Equipment Under Test, and refers to equipment that will be tested or provided for a test.

★ Immunity test
Refers to a test to evaluate the durability of EUT against electromagnetic interference.

★ Emission test
Refers to a test to evaluate whether the strength of electromagnetic interference emitted from EUT exceeds a given limit.

★ Open site
Refers to an experimental facility installed outdoors to be used for activities such as EMC measurement.

★ Anechoic chamber
Refers to a facility to be used to create an electromagnetically isolated environment; the interior surfaces of the chamber absorb radio frequency waves.

★ CISPR
One of IEC's special committees; it was established to integrate standards such as those for allowable values and measurement methods for interfering waves causing radio communication failures and includes a standardization committee for EMC (Electro Magnetic Compatibility).

★ Group 1 and Group 2 in EN55011
Group1 : Equipment for laboratories, healthcare, and sciences (Example: frequency counters, spectrum analyzers, switching power source, and measuring apparatus)
Group2 : Industrial induction heating equipment, induction heating equipment,
industrial microwave heating equipment, household microwave ovens,
medical equipment, spark erosion equipment, and spot welders.

★ ISM equipment
Stands for Industrial, Scientific and Medical radio-frequency equipment and refers to radio-frequency equipment for industry, science, and health care.

★ LISN
Stands for Line Impedance Stabilization Network. It refers to equipment that sends noise components to a measurement device while monitoring impedances, looking at the power source from EUT. It is also called AMN (Artificial Mains Network).

6 Supplement

1 Source Voltages in the World

People's Republic of China	Single phase 2 wire 220V	Three phase 4 wire 380V
Taiwan	Single phase 2 wire 110V, 220V	Three phase 4 wire 380V
India	Single phase 2 wire 230V, 240V	Three phase 4 wire 400V, 415V
Indonesia	Single phase 2 wire 220V	Three phase 4 wire 380V
Japan	Single phase 2 wire 100V, 200V	Three phase 3 wire 200V
Korea	Single phase 2 wire 110V, 220V	Three phase 3 wire 200V Three phase 4 wire 380V
Philippines	Single phase 2 wire 220V, 230V, 240V	Three phase 3 wire 480V
Singapore	Single phase 2 wire 230V	Three phase 4 wire 400V
Thailand	Single phase 2 wire 220V	Three phase 4 wire 380V
Malaysia	Single phase 2 wire 240V	Three phase 4 wire 415V
Egypt	Single phase 2 wire 220V	Three phase 4 wire 380V
Saudi Arabia	Single phase 2 wire 127V, 220V	Three phase 4 wire 380V
Australia	Single phase 2 wire 240V	Three phase 4 wire 415V
New Zealand	Single phase 2 wire 230V, 240V	Three phase 4 wire 400V, 415V
Austria	Single phase 2 wire 230V	Three phase 4 wire 400V
France	Single phase 2 wire 230V	Three phase 4 wire 400V
Germany	Single phase 2 wire 230V	Three phase 4 wire 400V
UK	Single phase 2 wire 240V	Three phase 4 wire 415V
Netherlands	Single phase 2 wire 230V	Three phase 4 wire 400V
Italy	Single phase 2 wire 220V	Three phase 4 wire 380V
Spain	Single phase 2 wire 127V, 220V	Three phase 4 wire 380V
Switzerland	Single phase 2 wire 230V	Three phase 4 wire 400V
Russia (former republics of the Soviet Union)	Single phase 2 wire 127V, 220V	Three phase 4 wire 380V
USA	Single phase 2 wire 120V, 265V, 277V Single phase 3 wire 115/230V, 120/240V, 240/480V	Three phase 4 wire 208V, 460V, 480V
Brazil	Single phase 2 wire 127V	Three phase 4 wire 220V