# EMC Design Guideline for Configuring a System with FA Products

**[Noise Countermeasures for Designing a System Control Cabinet]**

**MITSUBISHI ELECTRIC CORPORATION**

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**Contents**

1. Warnings and Precautions Regarding Safety

Warnings and precautions regarding the products are listed in their instruction manuals and attached documents. Do not attempt to design, install, operate, maintain, or inspect the equipment until you have read through all the documents carefully. Only professional engineers (who have taken proper training or who have licensed to work on electrical equipment) must design, install, operate, maintain, or inspect the equipment. This guideline provides general information about EMC countermeasures. If compliance to standards such as safety standards is required, such standard must precede this guideline.

2. Introduction

This guideline shows recommended methods for designing a control cabinet, laying out of FA products, wiring, and inserting places of countermeasure members to prevent malfunction due to noise superimposed among the products when multiple FA products are placed in a control cabinet. Noise problems may not be solved depending on the products, system scale, grounding environment, and so on even if the countermeasures in this guideline are taken. Use this guideline as reference for countermeasures and designing. Mitsubishi Electric Corporation does not guarantee that all the noise problems are solved by this guideline.

Mitsubishi Electric's FA products alone comply with the EMC standards in each country. Refer to manuals of each product for the complied standards. Be sure to take countermeasures against noise required by each product when configuring a system, and then refer to this guideline. A manufacturer who sells equipment which the FA products are installed in to an end-user must be liable for compliance with the EMC standards. Make sure that the final product complies with the standards.

3. EMC and Regulation

EMC stands for Electromagnetic Compatibility and indicates ability of devices and systems to operate in their electromagnetic environment. EMC includes two elements: emissions/EMI (Electromagnetic Interference) referring to capacity to suppress noise generated from the product, and immunity/EMS (Electromagnetic Susceptibility) referring to ability to tolerate noise from besides the product. Requirements of the EMI must meet the regulation values of the radiated interference, conducted interference, and power supply harmonic currents. Requirements of EMS must meet the immunity standards of the static electricity, radiated noise, conducted noise, electrical fast transient/burst, lightning surge, power supply frequency magnetic field, instantaneous power failure, and voltage dip. EMC is regulated each country and region. The final products which the end-user use must satisfy the requirements of EMI and EMS to be placed on the market.

Mitsubishi Electric's FA products alone comply with the standards required by each product. Refer to instruction manuals and technical documents of each product for information of compliance with the standards in each country and measures to comply with the standards.

[Emission: Electromagnetic Interference (EMI)] [Immunity: Electromagnetic Susceptibility (EMS)]

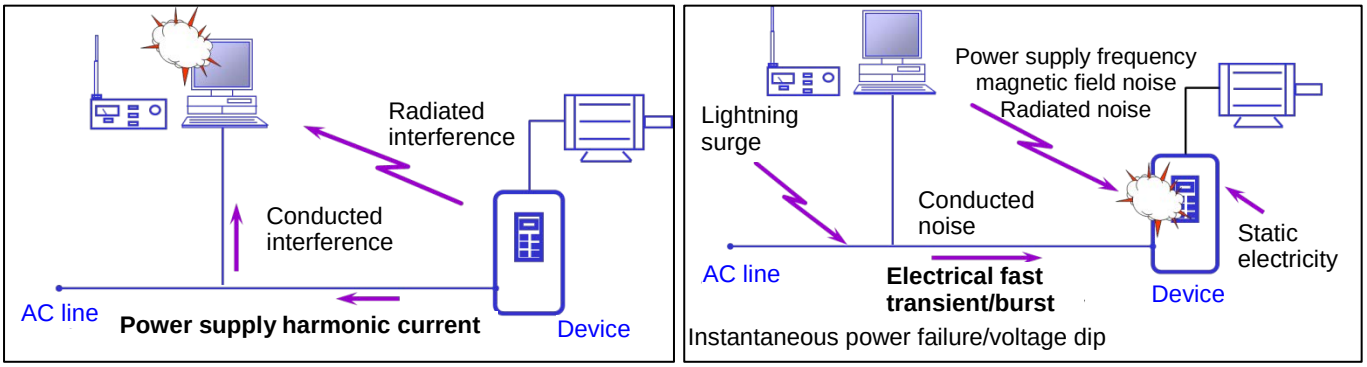



Fig. 1. EMC conceptual diagram

4. Types of Noise and Transmission

4.1. Types of noise

Basically, there are two types of noise: "normal mode noise" and "common mode noise". Figure 2 shows the difference between the normal mode noise and the common mode noise by giving an example of signal line.

"Normal mode noise" is a noise that occurs between signal lines or power lines. The noise current flows in the same path as the signal. "Common mode noise" is a noise that occurs between the ground and signal line or power line. The noise current flows in a different path from the signal and goes back to the noise source through the ground. The common mode noise is generated by induction or unbalanced impedance. Generally, devices are affected more by the common mode noise than by the normal mode noise, and thus it is important to have countermeasures against the common mode noise.

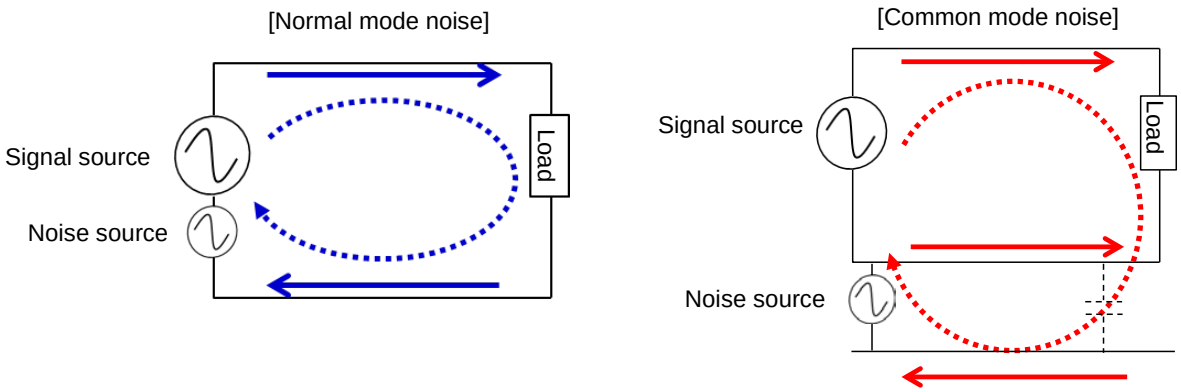



Fig. 2. Normal mode noise and common mode noise

4.2. Noise Transmission paths

4.2.1. General noise transmission paths

There are three paths of noise transmission.

1) Conducted noise: electromagnetic noise propagated along a power, signal, or ground line. The noise is transferred through cables when a power supply is shared or when signals are interconnected.

2) Induction noise: crosstalk noise induced and superimposed on a cable which is laid along a cable with a noise current. When a power input/output line of especially a drive device is laid along with a control signal cable, noise may be superimposed. There are two types of induction noise: "electrostatic induction noise" generated by capacitive coupling and "electromagnetic induction noise" generated by electromagnetic field coupling.

3) Radiated noise: release of noise from a cable through devices in a form of electromagnetic wave. The noise is radiated and received by the cables and the patterns on circuit boards which work as an antenna.

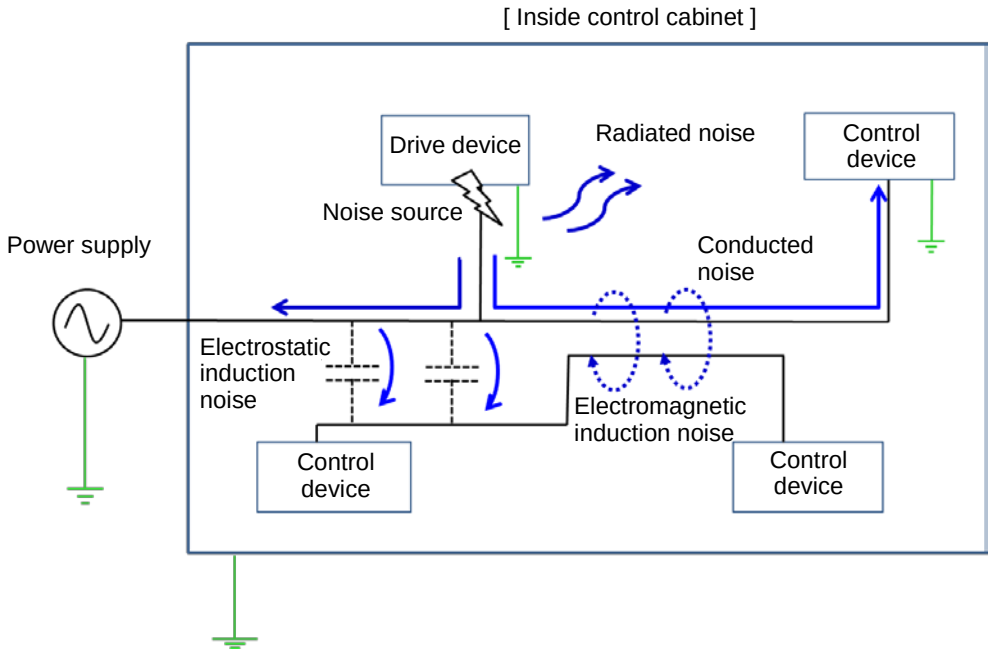



Fig. 3. Noise transmission paths

4.2.2. Noise transmission paths of drive devices

The drive devices generate a large amount of noise because a high voltage and large currents are being switched by switching elements such as IGBT. For reference, noise transmission paths in the inverter system are shown in Figure 4.

Noise flows into the ground through a capacitance between motor windings or through a stray capacitance between the casing and the ground in a drive system having an inverter circuit, creating large loops which generate a large common mode noise.

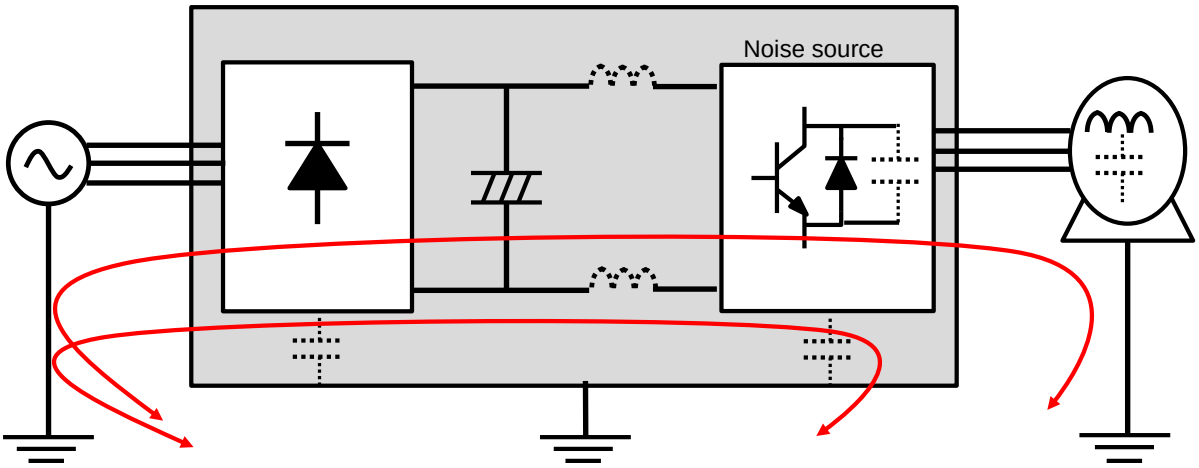



Fig. 4. Noise transmission path in a drive system having an inverter circuit

4.3. Basics of the EMC countermeasures

Main countermeasures are classified as follows:

1) Separating from a noise source and transmission path by laying out of devices and cables

2) Shielding by using a metal cabinet and shielded cables

3) Securing a noise return path by grounding or stabilizing ground by lowering impedance of the common ground

4) Shielding the noise transmission path by using an EMC noise filter or insulation transformer

Table 1 shows the section No. of typical countermeasures, and Table 2 shows the section No. of countermeasure members.

Table 1. Typical countermeasures against noise

| Countermeasure part | | Typical countermeasures | Section No. |
|---|---|---|---|
| Control cabinet | | • Use of a metal cabinet<br>• Joining method of a metal cabinet (top and side panel)<br>• Process of a door and opening<br>• Shielding method of internal cabinet | 6.3 |
| Cable connection port | All cables | Wiring or laying method | 6.1 |
| | Signal, control and I/O cables | Grounding method of shielded cables | 6.2.2 |
| | Grounding | • Connection method of grounding lines<br>• Grounding method of motor | 6.2.1<br>6.2.3 |
| | Power cable | • Usage of shielded cable and metal pipes<br>• Grounding method of shielded cables | 6.1 |

Table 2. Noise countermeasure members

| Countermeasure members | Material name | Section No. |
|---|---|---|
| Countermeasure members (filter, core, etc.) | [Ferrite core and amorphous core]<br>Attachment position, method, characteristics, etc. | 7.1 |
| | [Line noise filter]: FR-BLF/FR-BSF01<br>Connection method and effect | 7.3 |
| | [Radio noise filter]: FR-BIF<br>Connection method and effect | |
| | [EMC noise filter]<br>Installation location and method | |
| | [Insulation transformer]<br>Connection location | 7.4 |
| | [Lightening surge protector] for immunity<br>Connection location | 7.5 |

5. Preparation for Designing a Control Cabinet

FA products affects EMC. To secure the EMC performance effectively, it is important to consider the EMC countermeasures when designing a control cabinet. Earthing (grounding) must conform to the requirements of national and local safety regulations and electrical code.

5.1. Information for designing a control cabinet

Before designing the control cabinet, it is necessary to clarify the usage environment of the cabinet. The principle and criteria of designing the cabinet against EMC must be established based on the information.

Basically, three types of information are necessary.

1) Customer requirements and restrictions: When taking countermeasures against EMC, whether the countermeasure member is available or shielding ground is possible affects the design of the control cabinet. Cabinet dimensions and countermeasures must be taken into consideration.

2) Information on usage environment: The peripheral noise environment and noise tolerance standard can be determined by the usage environment of the control cabinet. Sufficient grounding may not be available depending on the environment, but earthing (grounding) must conform to the requirements of national and local safety regulations and electrical code. When the equipment is used in a situation related to safety or in a highly public facility, higher EMC (Electromagnetic Compatibility) will be required.

3) Information on devices to be used: After selecting devices that satisfy necessary specification for designing the electrical circuit, the electromagnetic compatibility of each device must be clarified. Necessity of additional countermeasures against noise is determined depending on the electromagnetic compatibility of each device. In addition, obtaining information about recommended measures is also important when the additional countermeasures are needed.

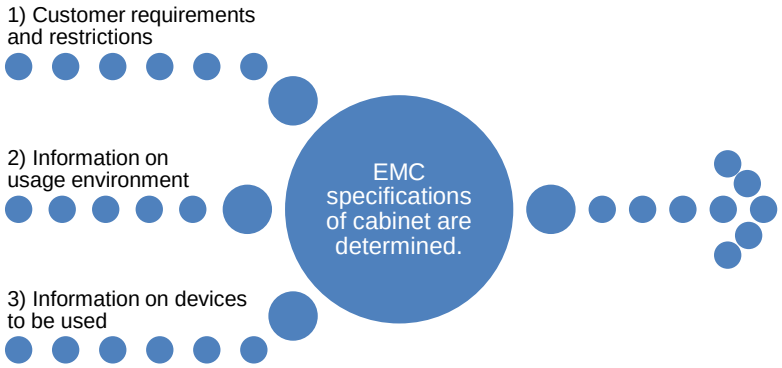



Fig. 5. Information for designing control cabinet

Table 3. List of information necessary before designing control cabinet

| | | |
|---|---|---|
| 1) Customer requirements and restrictions | | |
| Size of control cabinet | Internal dimensions of control cabinet | Affects the device size and selection of the countermeasure members. |
| Cost | Cost of control cabinet and devices | Affects the countermeasure plan such as cost for the countermeasure members. |
| Specifications | Water-proof, heat resistance, etc. | Affects the material of the control cabinet, process of openings, etc. |
| 2) Information on usage environment | | |
| Noise environment | Industrial/commercial /residential environment | Affects the noise control method because EMC requirement level varies depending on the market. Note that the FA products are not suitable for residential environment. |
| Equipment/facility | Machine tools/plant facilities/ships/railways/ construction machineries | Affects the noise control method because grounding and special requirements (emergency radio band regulation) must be fulfilled. |
| Safety consideration | Safety related equipment and highly public facilities | Affects the noise control method because such equipment and facilities require high EMC requirement level. |
| 3) Information on devices to be used | | |
| Device list | List of devices to be used | Confirm the size and electromagnetic compatibility of each device. |
| Electromagnetic compatibility | EMC standard, etc. | Confirm the actual electromagnetic compatibility. |
| Recommended countermeasures | Countermeasures recommended by a manufacturer | Obtain recommended methods against noise when necessary. |

5.2. Flow of designing control cabinet

After the necessary information is obtained, design the control cabinet by following the flow in Figure 6.

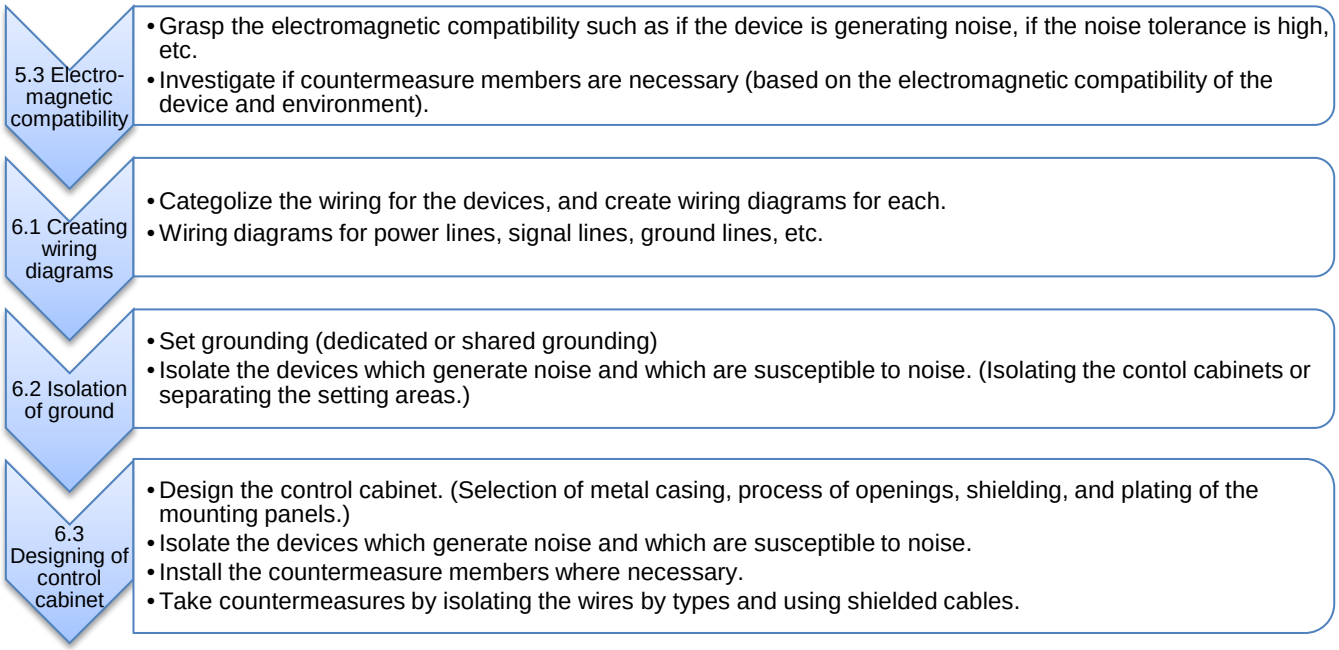



Fig. 6. Flow of designing control cabinet

5.3. Understanding electromagnetic compatibility

The electromagnetic compatibility of the devices to be used in the control cabinet depends on the types of the devices. Generally, power devices and drive devices generate a large noise (noise generating devices), and control devices and sensors are susceptible to noise. To understand the electromagnetic compatibility, refer to the compatible EMC class in each manual.

The manuals also list countermeasure members necessary for compliance with the EMC standard. Refer to the manuals when selecting devices. (Even if costs of the devices with high electromagnetic compatibility are high, when the cost of the noise control is considered, it may be inexpensive in total and save more space.)

The control cabinets for the drive devices generating noise and the control devices susceptible to noise should be isolated.

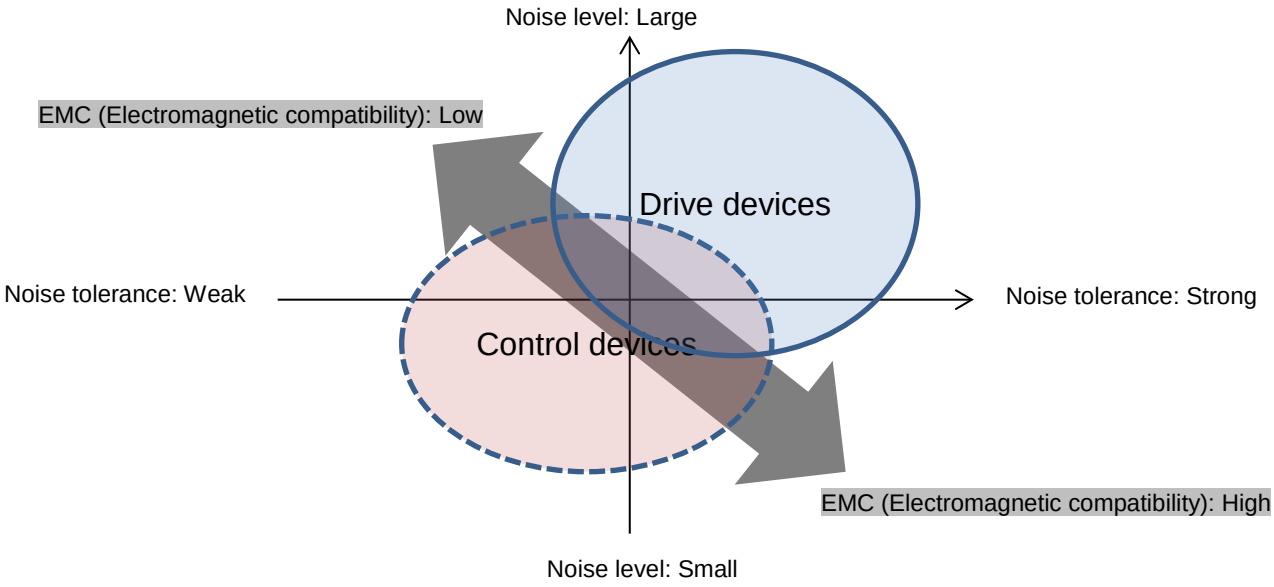



Fig. 7. Electromagnetic compatibility

6. Designing Control Cabinet

6.1. Wiring diagram and wiring route

6.1.1. Wiring diagram for devices

Cables used in the control cabinet will be noise transmission paths. Effective methods for suppressing noise transmitted on the cables are listed in Table 4.

1) Function category of cables

Table 4. Function category of cables

| Function category | Features | Measures against noise |
|---|---|---|
| Power input cable<br>Motor output cable<br>(Drive device) | Switching noises are superimposed, spreading a band of a few kHz to dozens of MHz. | • EMC noise filter is effective for the input side. Shielded cables are effective for the output side.<br>• For the input/output cables of the drive devices, separating them from the power, signal, and control cables of the control devices are effective. |
| Power input cable<br>(Control device) | Power noises are superimposed for the power cables of the control devices. | • Using a filter, ferrite core, or amorphous core is effective.<br>• For the DC power supply, a twisted pair cable cancels the normal mode noise. |
| Control, signal,<br>I/O cable | Cables for connecting devices.<br>Sensors and analog signals are affected by the noise through the cables. | A twisted pair cable cancels the normal mode noise. Using differential signals and optical cables improve noise resistance.<br>Shielded cables are effective. |
| Communication cable | Clock frequency and harmonic of the communication are superimposed. | Shielded cables are effective against radiated noise. Ferrite cores are effective. |
| Grounding line | Grounding lines mean the cables connecting the ground of the devices and a ground bar, or the cables connecting the grounding points of the control cabinet and the facility/factory. Common mode noise flows on the grounding lines. | Dedicated grounding is recommended. (dedicated grounding > shared grounding)<br>Do not have a common grounding.<br>Separate the noise generating devices form the grounding bar and cables. |

2) Create wiring diagrams for each function category of the cables. When connecting the devices generating noise and susceptible to noise, connect filters, and/or isolate cables and grounding.

6.1.2. Wiring route

Please note the following when considering the wring routes.

- Band by wiring systems (power input/output system, or signal/control system) and keep the wiring as short as possible. (Do not fold the cable.)
- Extra length of the cable can be a path for the noise and transmits the noise to other cables and devices. Adjust the cable as short as necessary.

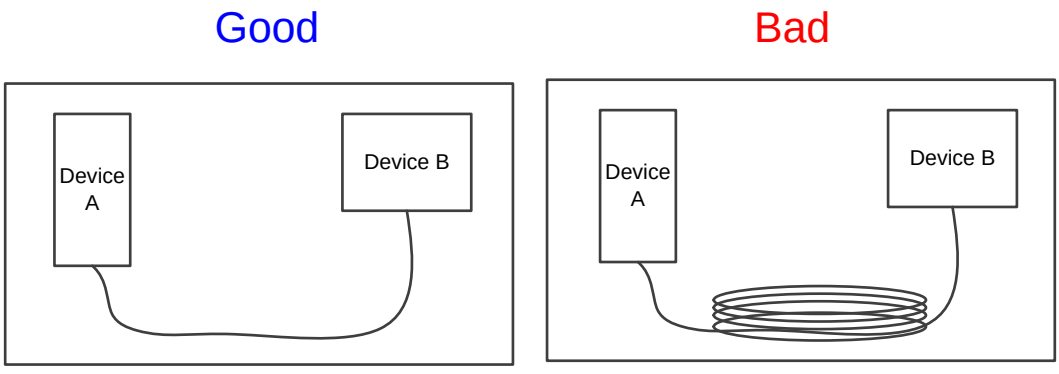
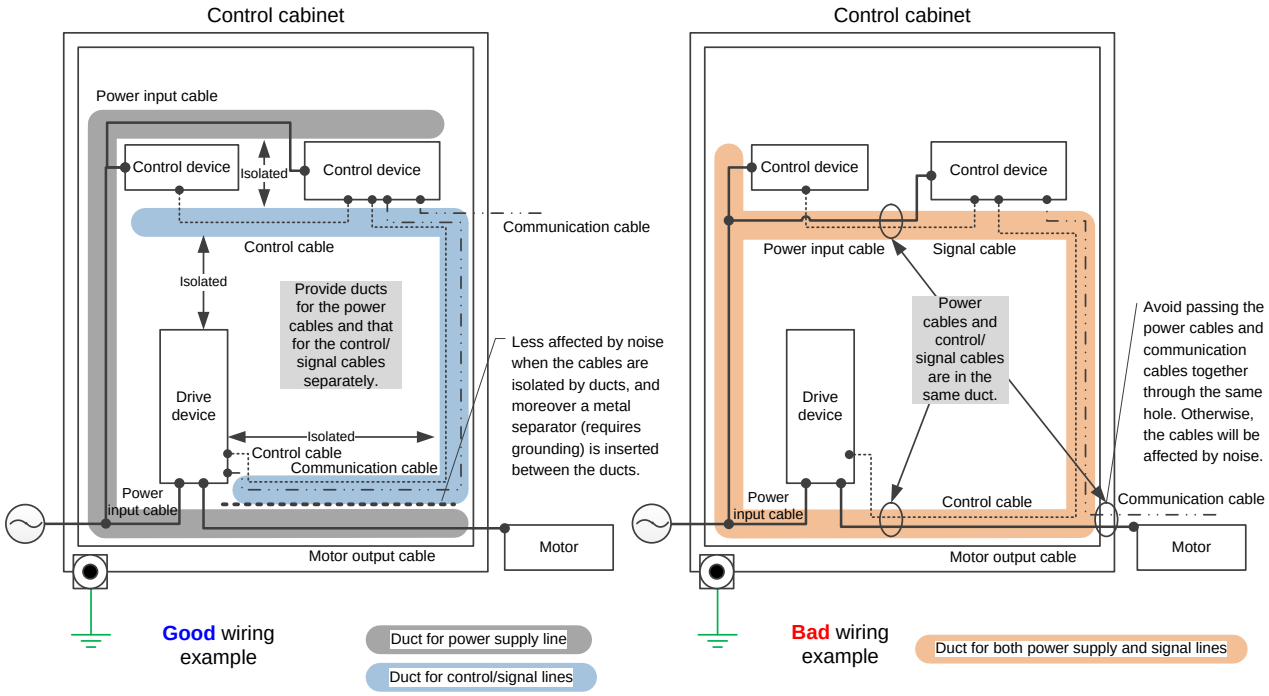



Fig. 8. Processing of extra length of cable

- The power input/output system cables for the drive devices generate a large amount of noise. Keep them away from the power input cables, control lines, and signal lines of the control devices, and do not lay those cables along each other. The noise will cut in from the power input/output cables of the drive devices due to capacitive coupling and magnetic coupling. If unavoidable, isolate the cables of the different systems by using a duct, and cross the cables perpendicularly to limit the superimposition of the induction noise caused by crosstalk.
- Use shielded wires for the control and signal lines when the wires are laid outside the control cabinet.
- Refer to section 6.2.2 for the shield termination of the control and signal lines.




It is recommended that you keep a distance of 300 mm or longer between the power cables and the communication/signal/control cables. For some reason, if the cables are laid along close to each other, isolate the ducts and insert a metal separator to suppress the noise influence. Be sure to ground the separator to the cabinet.

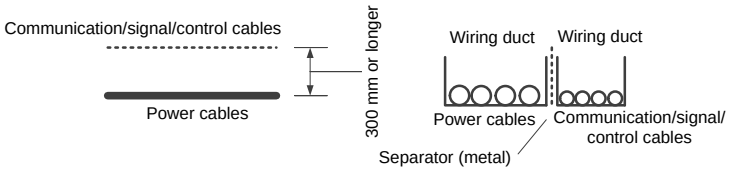



Fig. 9 Example of cabling

## 6.2. Separating and grounding of control cabinet

Install the control devices and the drive devices in isolated control cabinets. The most effective method of noise control is to isolate the control cabinets.

When space is limited and it is unavoidable to install the control devices and the drive devices together in the same control cabinet, be sure to ground referring to section 6.2.1 2) to suppress the mutual interference noise.

Grounding is the most important countermeasure against noise. Be sure to ground as recommended as possible.

6.2.1. Grounding of devices

1) Between cabinets

- Prepare isolated control cabinets for the control devices and for the drive devices, and each cabinet must have a dedicated grounding. If it is difficult to have a dedicated grounding, have a shared grounding.

  Do not use a common grounding because the devices affect each other by the common impedance. For example, if an inverter and a PLC have a common grounding, the noise current flows from the inverter to the common impedance, and the ground potential of the PLC changes, causing malfunction.

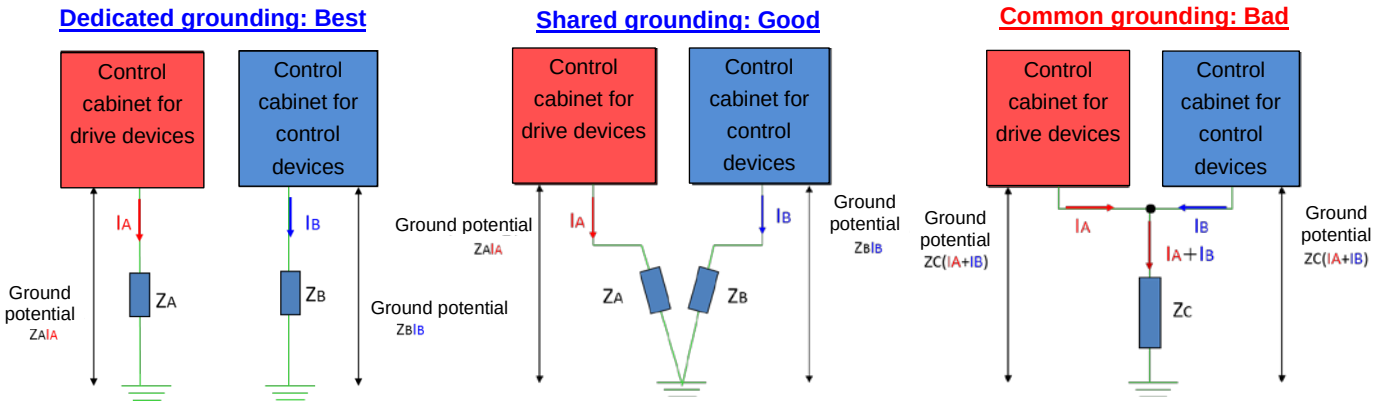



Fig. 10. Grounding

2) Grounding inside the control cabinet when the control devices and the drive devices are in the same cabinet

(Refer to Figure 11.)

- The noise of the drive devices cut in the control devices, and therefore, install countermeasure member such as an EMC noise filter on the power supply side of the drive devices. Installing the EMC noise filter suppresses the noise from cutting in the control devices.
- Ground the drive devices and the control devices to each dedicated grounding bar in a way that the grounding bar is shared by the same system devices. Ground the grounding bars by sharing the grounding terminal of the control cabinet.
- When it is difficult to install dedicated grounding bars, separate the installation areas for the drive devices and the control devices on the installation panel, and connect the grounding lines of the devices to the installation panel with the shortest possible cables. The installation area for the drive devices must be close to the grounding terminal of the control cabinet.

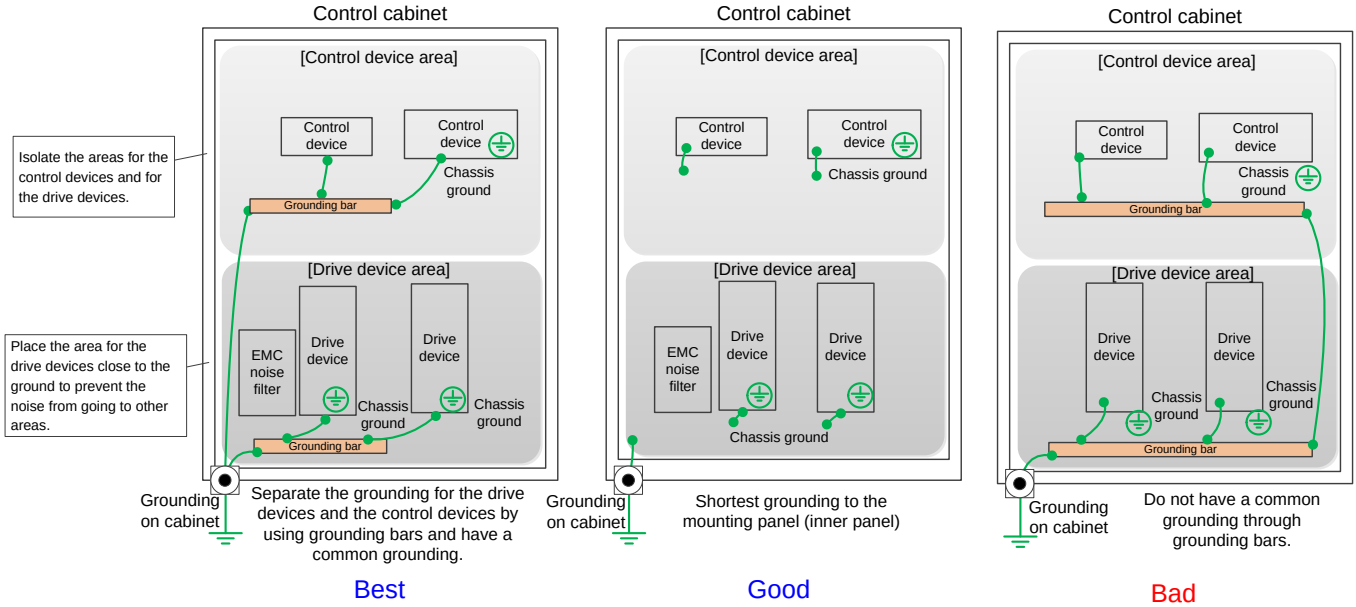



Fig. 11. Example of installing drive devices and control devices in the same control cabinet

3) Grounding lines

- Thick wiring lowers impedance and drops the noise easily to the cabinet.
- Short wiring suppresses unnecessary radiation from the grounding lines themselves and crosstalk from other cables. Refer to manuals of each product for selecting thickness and length of the grounding lines.

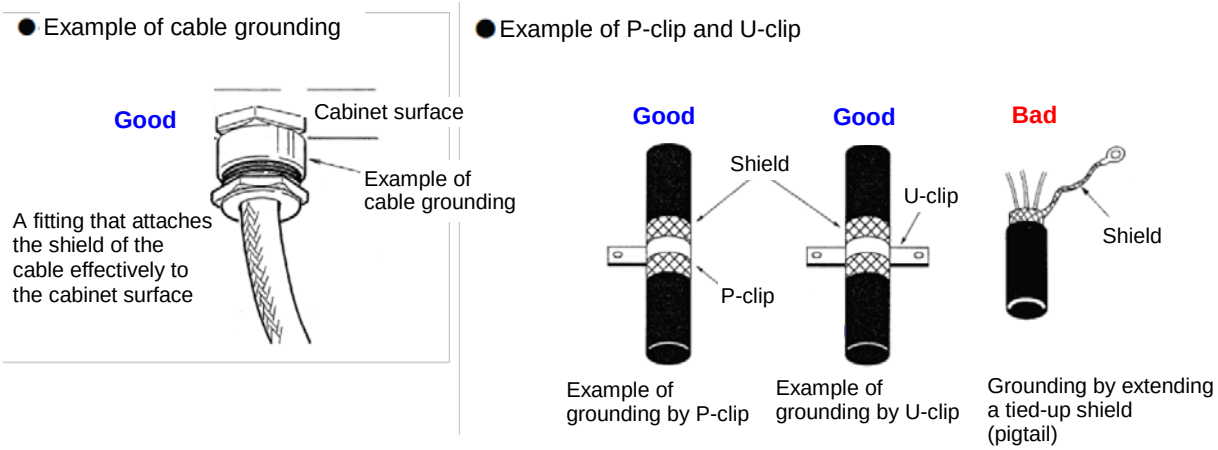
6.2.2. Grounding of shielded cables

Shielded cables are effective for suppressing the radiated noise. The common mode current inside the shield flows in the opposite direction from the common mode current flows in the core, and the common mode currents will be canceled. Thus, the common mode current leaking out of the shield will be suppressed.

However, using the shielded cables increases the stray capacitance and may increase the conduction noise. Set a filter on the power supply side of the drive devices to return the conduction noise back to the drive device side.

1) Attachment of a clamp on the shielded cable

- Use a P-clip, U-clip, or clamp fitting to make a contact with a wide surface when grounding the shielded cable.
  The clamp fitting which can be grounded with a wide surface is effective for high frequency noise because this type of noise flows on surfaces due to the skin effect.
- The high frequency noise does not flow easily with pigtail grounding because the pigtail has a smaller surface than the clip and clamp fitting. If pigtail is used to connect to the terminal, it is recommended that a clamp fitting also be used.




A cable clamp fitting is composed of a ground plate and a cable clamp.

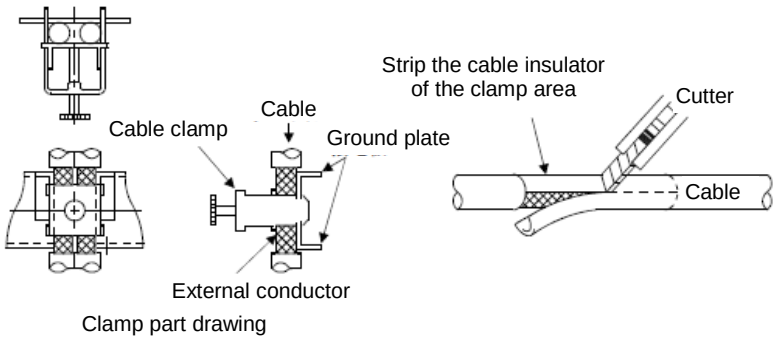



Fig. 12. Termination process of shielded cable

2) Grounding of signal, control, I/O, and communication cables

- Refer to manuals of each product for connecting the signal, control, I/O, and communication cables to the connectors and terminal blocks.

- When connecting the cables between the cabinets, be sure to use shielded cables and ground at the end of both cabinets for the control devices and the drive devices. If a potential difference is generated between the cabinets because of the difference in grounding resistance, ground the cable shields with the clamp fittings close to the control devices only in the cabinet for the control devices to prevent the noise current from cutting in the control signal and communication lines due to the potential difference.
- When grounding the shielded cable in the same control cabinet, ground the both ends of the cables with the clips or clamp fittings close to the control device and the drive device. When it is difficult to ground the both ends, ground only on the control device side. If grounding is executed on the drive device side only, the effect of grounding the shielded cable cannot be expected, and the noise from the drive device may cut in the control device.
- Do not ground the shielded cables of the control lines connected to the common terminals (SD, SE, and 5) of the inverter with clamp fittings.

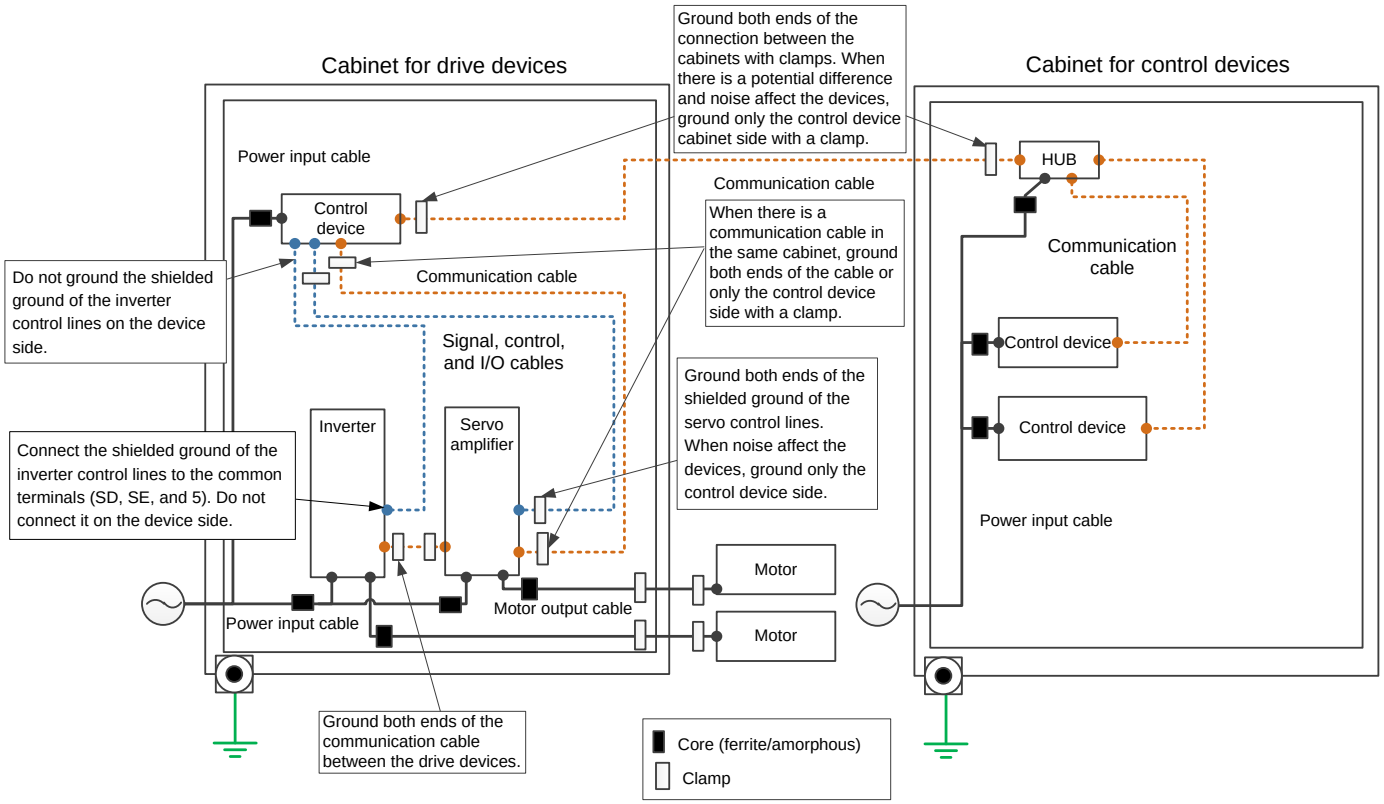



Fig. 13 Grounding of signal, control, and I/O shielded cables and communication cables

- Generation and transmission of the common mode noise due to the potential difference in grounding between the control devices and drive devices

  It is recommended that the signal, control, and I/O shielded cables be grounded on the control device side.

  As illustrated in Figure 14, when there are grounding points for both the drive devices and the control devices, the common mode noise is being transmitted to the grounding points of the drive devices, and therefore the potential will be high against the ground reference point.

  If the signal, control, I/O, and communication shielded cables are grounded on the drive device side, the grounding potential will be high. The potential difference from the control device side causes the noise to transmit to the control device side.

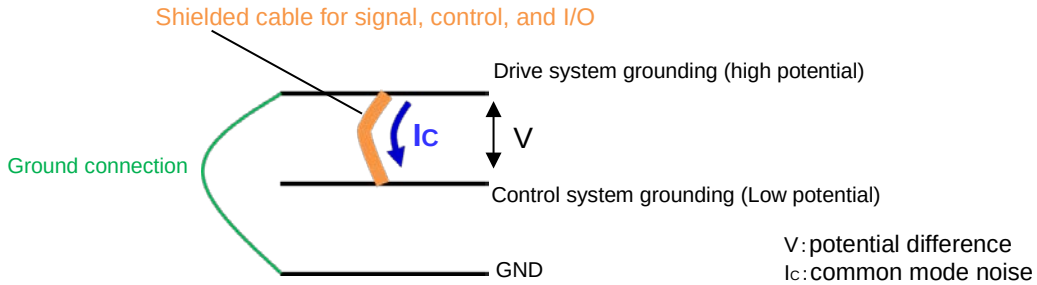


Fig. 14 Noise transmission mechanism of grounding lines of shielded cable

3) Grounding of shielded cable of motor output cable

- Use a shielded cable, shielding cover, or metal pipe (conduit pipe) for the motor output cable.
- Connect the shield of the shielded cable to the ground on both ends (drive unit side: control cabinet, and motor side: motor terminal box or grounding terminal).
- If the shield is connected by pigtail (shield wires are tied up and extended), it is less effective than the grounding by the clips or clamp fittings.
- Use a shielded cable with four cores for the motor output, and connect one to the ground terminal on the motor side and to the ground terminal on the drive unit.
- Be sure to ground the motor side because it is effective to suppress the noise.

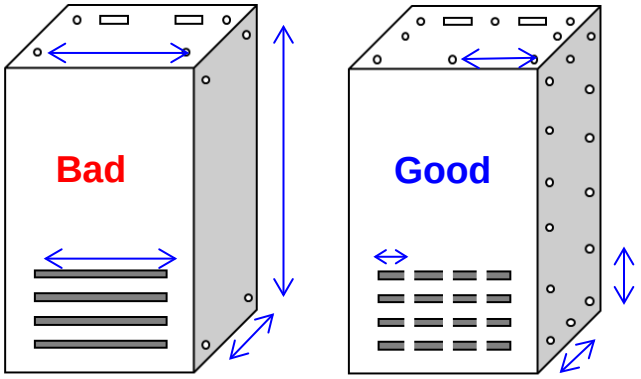
4) Termination process of shielded cable of encoder cable

- Note that the grounding method of the encoder cable connecting the drive unit and the motor varies for vector inverters and servos.
- For the vector inverter, ground one side on the drive unit side to the control cabinet with a crimp fitting.
- For servo, ground both drive unit side and motor side with crimp fittings.

## 6.3. Designing of control cabinet

### 6.3.1. Type of control cabinet

- Use a metal control cabinet. The radiated noise will be suppressed and the grounding will be stabilized.
- Weld or screw the cabinet's top plate and side plate without any space on the joining sections. Keep the intervals between the welding or screws to 100 mm or less. (To have 20 dB or higher shielding effect, keep the opening length to 1/20 or less of the wave length of the shielding frequency. Refer to Figure 15. When the opening length L is 100 mm (0.1 m), the shielding frequency of 20 dB or higher is 150 MHz or less.)
- The installation panels (inner panels) of the cabinet must be plated to have sufficient grounding for the devices, and be sure to connect the installation panel to the grounding terminal of the cabinet.
- Open holes for leading cables from the control cabinet. Separate holes must be provided for the cables of each system and have enough distance from each other.
- There are general and EMC-dedicated control cabinets. The EMC-dedicated control cabinet has following features. It is effective to use the EMC-dedicated control cabinet especially when enhancing the noise control. (Refer to Figure 16.)
  1) Shield characteristics of casing: It has a sealing structure by being welded without any space. A rectangular wire for grounding and shielding gaskets are provided.
  2) Process of opening: The opening is shielded with a punched metal to prevent leakage of noise.
  3) The inside the cabinet is plated so that the noise from the devices can be released easily.




Calculation of shielding frequency f [MHz] and opening length L [m] with shielding effect of 20 [dB].

・Opening length L [m]

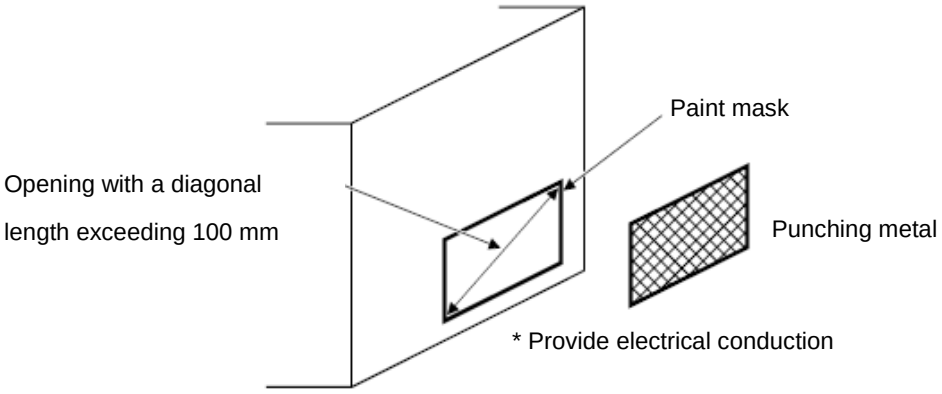
$$L = \frac{150}{10 * f}$$

・Shielding frequency [MHz]

$$f = \frac{150}{10 * L}$$

When the long side (indicated by ↔) of the opening is welded or screwed with an interval of 100 mm or shorter, noise of 150 kHz or less is shielded by 20 dB or more.

Fig. 15. Measures for openings



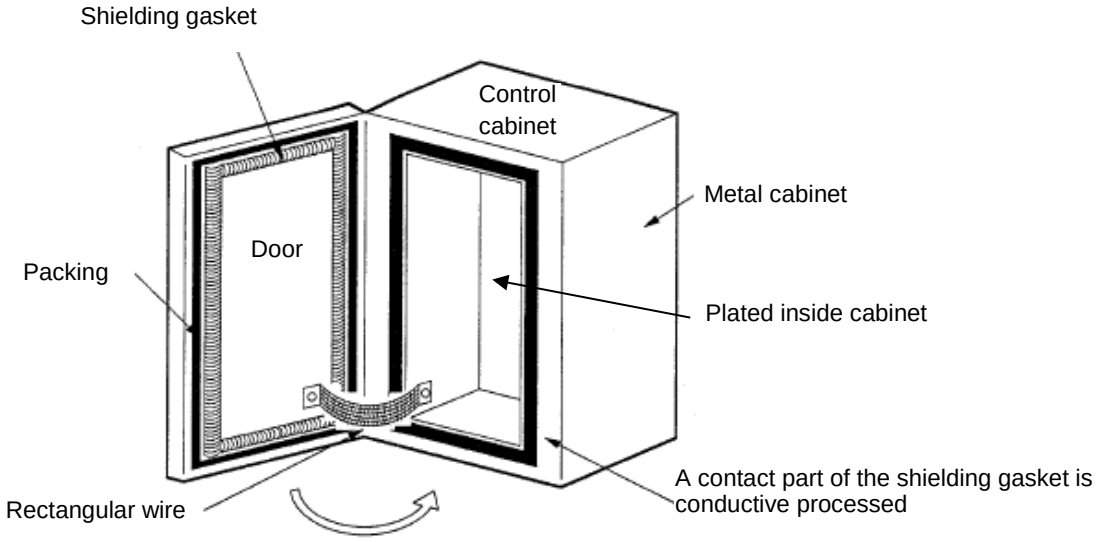




Fig. 16 Example of control cabinet with EMC countermeasures

6.3.2. Layout of devices in the control cabinet

Please note the following when laying out the devices in the control cabinet.

- Consider the electromagnetic compatibility of the devices and the wiring route.
- Lay out the devices to make the wiring as short as possible and not to connect different types of cables.
- Secure the positions for the EMC noise filter, clips, clamp fittings, ferrite cores, and amorphous cores.
- Install the EMC filter on a bare metal or a plated metal to release the noise from the filter. (Refer to Figure 17.)
- Isolate the control devices and the drive devices with a metal shielding plate, etc.
- Ground the control cabinet with a thick short cable (4.2 $mm^2$ or thicker is recommended).

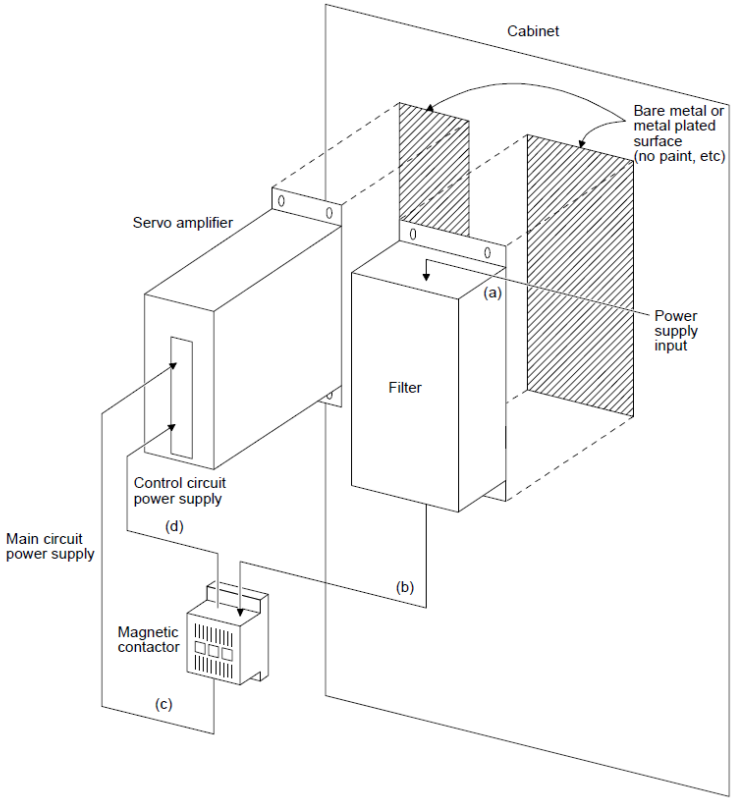



Fig. 17. Mounting devices on the control cabinet

7. Countermeasure Member

Methods of using the general noise countermeasure members are listed. (not in recommended order)

Please also refer to appendix for the recommended countermeasure members.

7.1. Ferrite core and amorphous core

- When the ferrite core or amorphous core is attached, its magnetic loss effect converts the noise to heat or the inductance component increases the impedance to lower the noise.
- The impedance is proportional to the square of windings on the ferrite core or the amorphous core. Pass through multiple times (three or four passes) if possible. However, note that winding too much lowers the high frequency impedance of the ferrite core or amorphous core because of the stray capacitance between the cables, and cancels the effect.

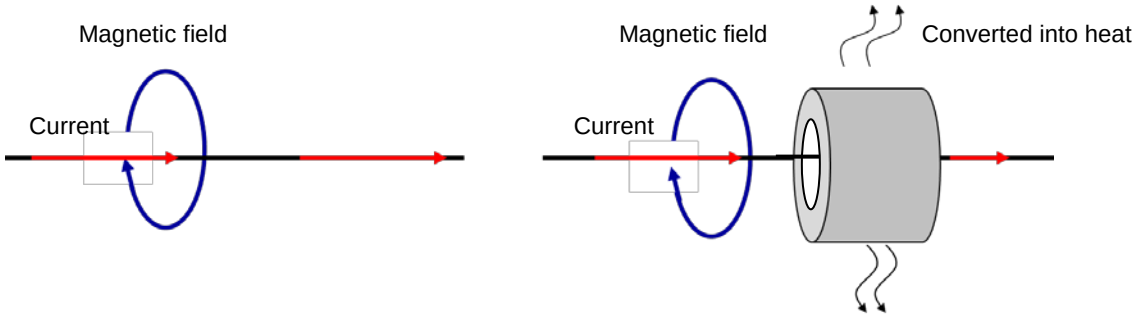


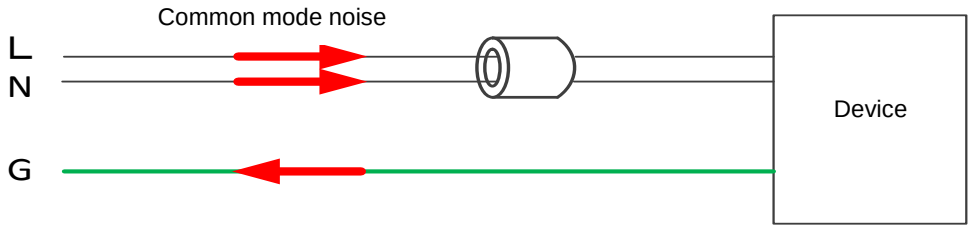

Fig. 18. Characteristics of ferrite core and amorphous core

7.1.1. Cautions when attaching the ferrite core and amorphous core

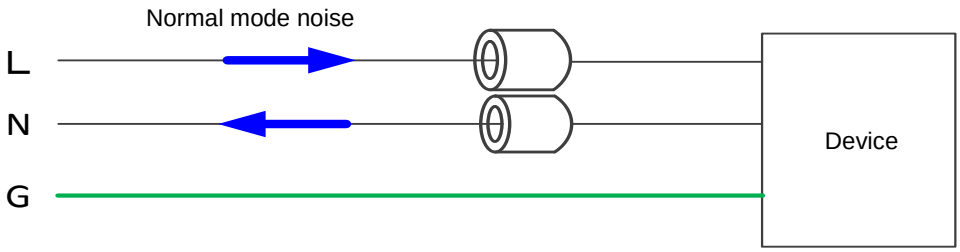
The attachment method of the ferrite core and amorphous core varies depending on the noise types (common mode noise or normal mode noise). (Refer to Figure 19.)

The common mode noise is the dominant source. Therefore, attaching the ferrite core or amorphous core on L and N together (three phases together for 3-phase power supply) is effective for suppressing the noise.

For the normal mode noise, attach the ferrite cores or amorphous cores on each L and N wire separately. When the core is attached on each wire, the currents may generate magnetic saturation, causing lower impedance, heat generation, or noise due to magnetostriction. When the magnetic saturation occurs, reduce the number of passes, replace with a larger ferrite core, or replace with an amorphous core in which the magnetic saturation hardly occurs.




Attaching a core for common mode noise




Attaching cores for normal mode noise

Fig. 19. Effective attachment of ferrite core or amorphous core

7.1.2. Attachment position of ferrite core or amorphous core

1) Power input cables of the control devices: Lowers the noise flows on the cable

2) Motor output cables: Lowers the noise flows on the cable.

Lowering the noise from the motor output cable with the ferrite core or amorphous core lowers the noise induced to the other cables such as for signal, control, and I/O.

3) Signal, control, and I/O cables: Lowers the noise.

It is recommended that the cores be attached on the both sides of the cables. If only one side is available, attach the core as close to the control device as possible. Note that attachment of the ferrite core or amorphous core may deteriorate the signals, depending on the cable type and length. In addition, for the communication cables, preventing the communication speed to be more than necessary can be a countermeasure against the noise.

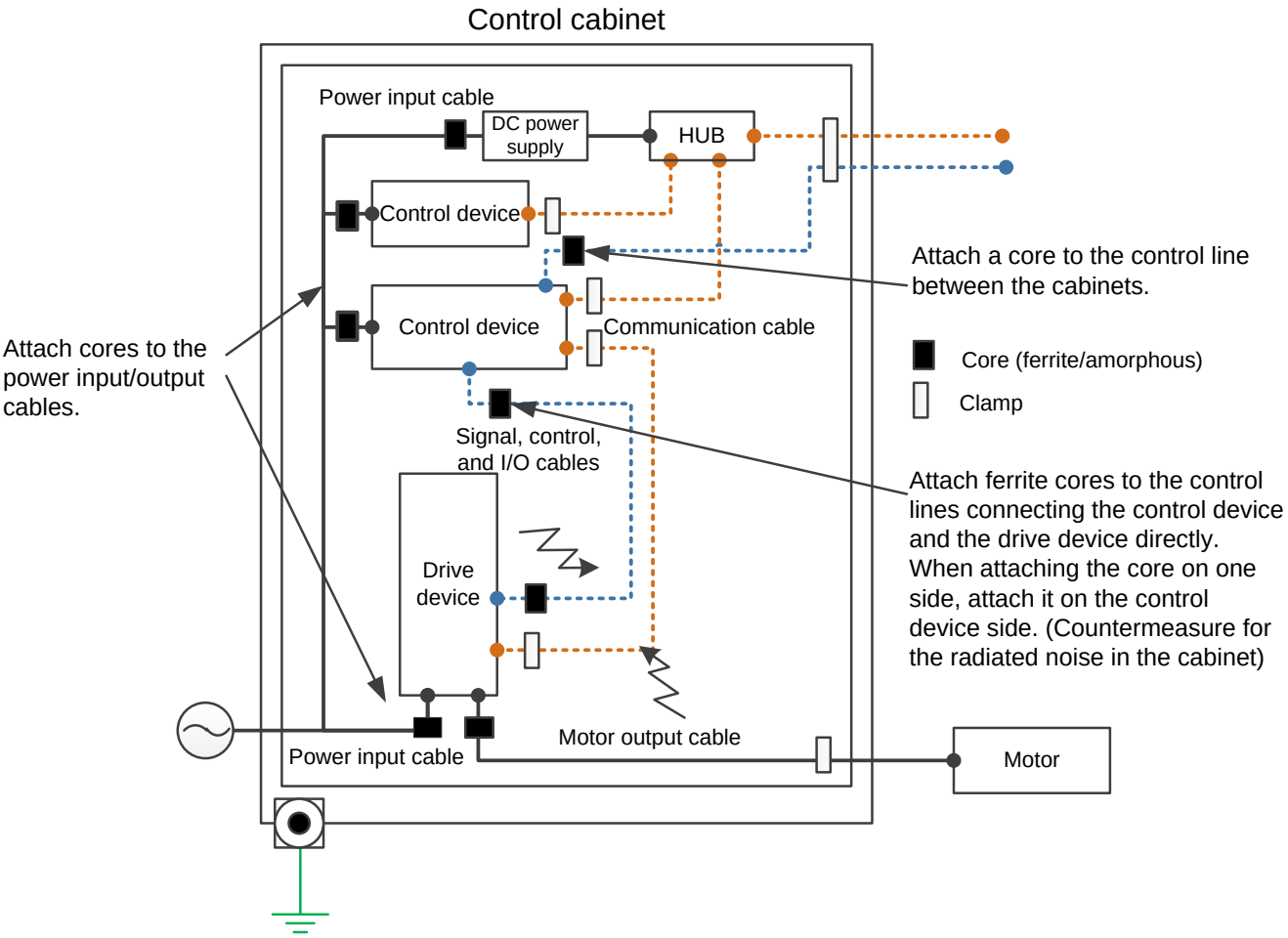



Fig. 20. Attachment position of ferrite core and amorphous core

4) Line noise filter: FR-BSF01, FR-BLF

Mitsubishi Electric has optional ferrite cores available as line noise filters. Please use these filters effective for the noise by attaching on the power input cables and the motor cables.

7.2. Shielded cable

A shielded cable is an electrical cable enclosed by a metal shield. The shield is composed of braided strands of metal or a layer of metal foil, and is useful for shielding the radiated noise and for returning the common mode currents.

Use a double-shielded cable for higher effect.

Termination process is important for the shielded cable. Refer to section 6.2.2 for the termination.

7.3. EMC noise filter

- This filter is often used for the power input lines, and is composed of a capacitor, common mode choke coils, and resistors.
- Effect of EMC noise filter: Generally, this filter is effective in a band width of 0.1 MHz to ten-odd MHz. It is especially recommended that the EMC noise filter be installed in the input side of the control devices. In this way, the filter lowers the noise of the drive devices and decreases the noise transmission to the control devices.
- Selecting EMC noise filter: When installing the EMC noise filter on the power input lines of the control cabinet at one place, consider the total power supply capacity of the whole control cabinet, and select the EMC noise filter with a margin. If the power supply capacity of the EMC noise filter is small, the core built in the filter generates magnetic saturation, eliminating the noise reduction effects.
- Mitsubishi Electric has capacitor-type optional filters available as radio noise filters FR-BIF. Please use these filters effective for the radio band width (medium-wave broadcasting band) by connecting to the power supply lines.
- The effects of the EMC noise filter vary by wiring and grounding methods. Connect the filter as follows:

  When the EMC noise filter is installed, leakage current becomes larger. Refer to manuals of each product.

Isolate the input and output of the EMC noise filter. When they are banded together, even if the noise is attenuated by the filter, the noise of the input side will be conducted to the output side.

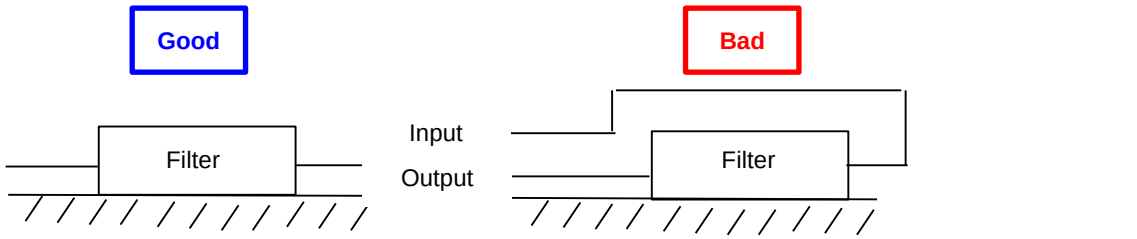
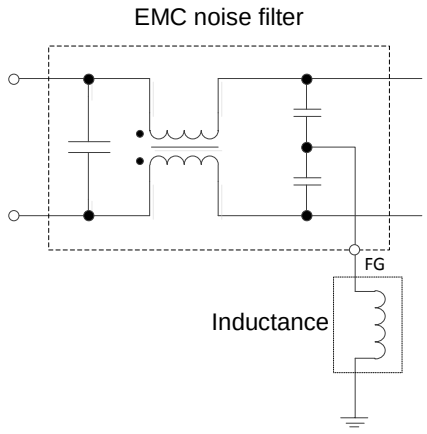



Fig. 21. Caution for handling EMC noise filter (1)

Ground the EMC noise filter with low impedance. The ground line will be inductance in the high frequency band. When the cable is long, the impedance will be large, lowering the noise attenuation effect of the EMC noise filter.
The filter is more effective when it is grounded by surface.



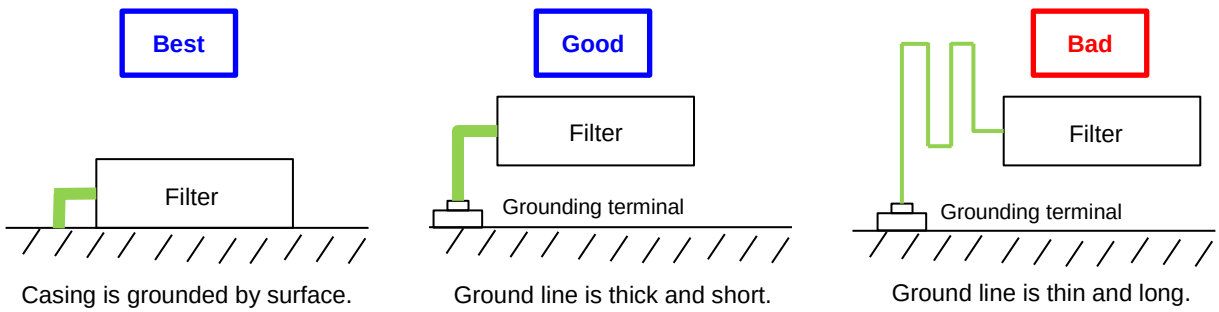




Fig. 22. Caution for installing EMC noise filter (2)

7.4. Insulation transformer and Noisecuttrans™ (Noisecuttrans is a trademark of Denkenseiki Research Institute Co., Ltd.)

- Separate the power supplies for the control devices and for the drive devices, and connect an insulation transformer or the Noisecuttrans.
- The insulation transformer is effective for suppressing the common mode noise, and the Noisecuttrans is effective for suppressing both the common mode noise and normal mode noise.
- Connecting the insulation transformer or the Noisecuttrans to the power supply of the control devices requires a smaller capacity and therefore cost-effective than connecting to the power supply of the drive devices.
- However, if the noise from the drive devices is large and has a large influence on the peripheral equipment, shield the noise from the noise source by connecting the power supply of the drive devices.

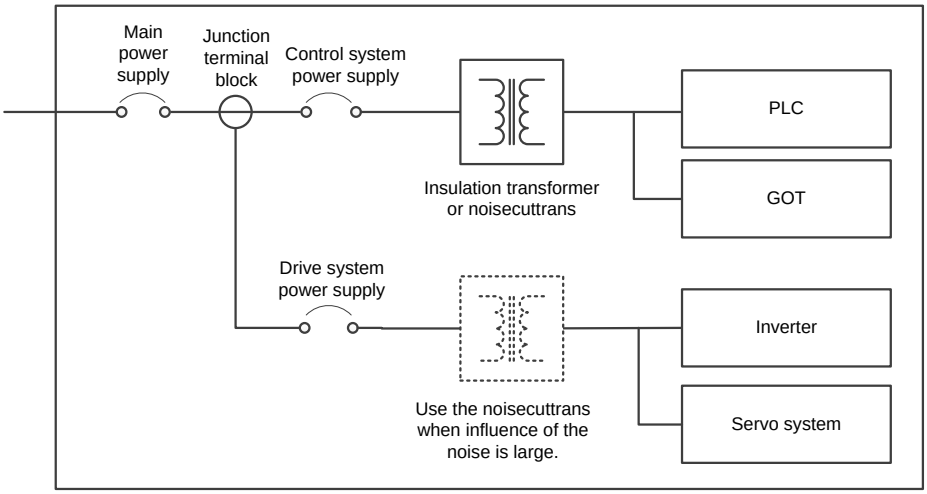



Fig. 23. Connection of insulation transformer or Noisecuttrans

7.5. Lightening surge protector (reference: immunity measures)

- Connect a lightening surge protector (surge absorber) to the power supply for countermeasures against the lightening surge.
- Separate the grounding for the devices and the lightening surge absorber.
- If not separated, the lightning surge traveling to the ground may flow into the devices.

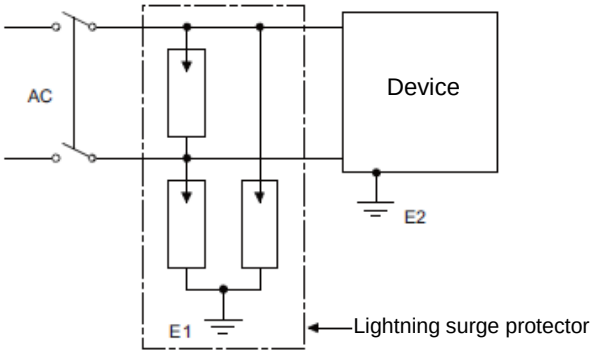



Fig. 24. Connecting a lightning surge protector

8. Summary of EMC Countermeasures

EMC countermeasures and effects explained in section 6 and 7 are listed in Table 6.

Table 6 EMC countermeasures and effects

| Countermeasure part | Method | Effect | | | Principal |
|---|---|---|---|---|---|
| | | Conduction noise | Radiated noise | Induction noise | |
| Control cabinet | Use a metal casing.<br>Space of 100 mm or shorter is recommended for the joining area (top and side plates) of the metal casing.<br>Use shielding gaskets for the door.<br>Keep the openings as small as possible (ϕ100 mm or smaller is recommended.)<br>Insulate devices in the cabinet by using a metal shielding plate. | A little effective | Very effective | Effective | Shielding the electromagnetic interference waves by a metal shielding effect.<br>When the shielding effect of 20 dB or larger is required, keep the openings and the space of the joining area to 1/20 or less of the frequency wave length to be shielded.<br>For ϕ100 mm, it is effective up to 150 MHz. |
| Grounding | Have dedicated grounding for each of the drive devices and the control devices. If not possible, have a shared grounding. | Effective | Effective | Effective | Separating the grounding for the control devices and for the drive devices by having different grounding points. |
| All cables | Do not lay along the power cables and control/signal cables close to each other, or do not fold the cables together. (Keep at least 100 mm away from each other. Keeping 300 mm is recommended.) | Very effective | Very effective | Very effective | Preventing the induction noise due to crosstalk between the cables. |
| | Use P-clips, U-clips, or clamp fittings for grounding the shielded cable. | Very effective | Very effective | Effective | Effective for the skin effect of the current. (Frequency of 1 MHz or higher flows only on the surface of conductor.) |
| | Install the clips or clamp fittings as close to the opening of the control cabinet as possible. (Distance of 100 mm is recommended.) | Effective | Effective | A little effective | Preventing superimposition of exogenous noise caused by the second radiation from the wires in the control cabinet. |
| Power input port | Shield by using the shielded cables, shielding covers, or metal pipes. | Effective *1 | Very effective | Effective | • Shielding by the shield effect.<br>• Reducing the ground loop area by returning the common mode noise. |
| | Separate the power supply systems. | Very effective | Not effective | Not effective | Effect from separating the noise transmission paths. |
| | Insulation transformer or the Noisecuttrans:<br>Connect to the power input lines to shield the noise. | Effective | A little effective | Not effective | Cutting the ground loop by the insulation of the transformer, and shielding the noise. |
| | EMC noise filter:<br>Install to the power input lines.<br>Select the recommended filters for each product. | Very effective | A little effective | Not effective | Reducing the noise by the heat of the LCR filter or returning the noise from the power supply line to the product. |
| | Radio noise filter: FR-BIF<br>Connect a capacitor to the power input lines and ground line. | Effective | Effective | Not effective | Resolving the unbalance between the lines with the capacitor, or returning the noise to the devices with a small ground loop. |
| Power input/output port | Ferrite core and amorphous core<br>Attach the cores to the input/output cables as close to the product as possible. Be careful with the magnetic saturation when the cores are attached for the normal mode noise. | Effective | Effective | A little effective | Attenuating the noise by converting it into heat by the magnetic loss effect with the core.<br>Attenuating the noise inflow by increasing the impedance in the high frequency band. |
| | Line noise filter: FR-BLF/FR-BSF01<br>Install the filter on the input side and output side of the drive device. Multiple number of passes is highly effective. (Four passes are recommended.) | Effective | Effective | A little effective | |
| Signal, control, I/O cable | Wire the control lines in the cabinet. When wiring outside the cabinet, use the shielded twisted pair cable, and connect the shielded ground wire to a specified place (SG, LG, etc.). | Effective | Effective | Effective | • Shielding by the shield effect.<br>• Reducing the ground loop area by returning the common mode noise. |
| | Ferrite core and amorphous core:<br>Attach the cores to the control and signal lines.<br>Attach the cores as close to the product as possible.<br>For the cables between the control device and drive device, it will more effective when the cores are attached on the both ends.<br>When attaching the core to only one side, it is more effective to attach to the control device side. | Effective | Effective | A little effective | Attenuating the noise by converting it into heat by the resistance component with the core in the high frequency band. |
| Other immunity countermeasure | Lightning surge protector:<br>Attach the protector for countermeasure against the lightning surge from the power input cable or a circuit breaker. | Not effective | Not effective | Not effective | Attenuating the lightning surge noise level by intentionally discharging electricity with a varistor (*2) or gas arrester (*3). |

*1. Only when the EMC noise filter is used.
*2. A varistor is an electronic component with two electrodes. When a certain voltage is applied, the electric resistance suddenly drops. The varistor is used as a bypass to protect from the lightening surge.
*3. A gas arrestor (also called as a gas-encapsulated discharge tube) discharges electricity to protect the devices when a certain voltage is applied such as lightning surge.

9. Recommended Configurations

1) A recommended wiring diagram is shown in Figure 25 for when the control cabinets are installed separately for the control devices and for the drive devices.

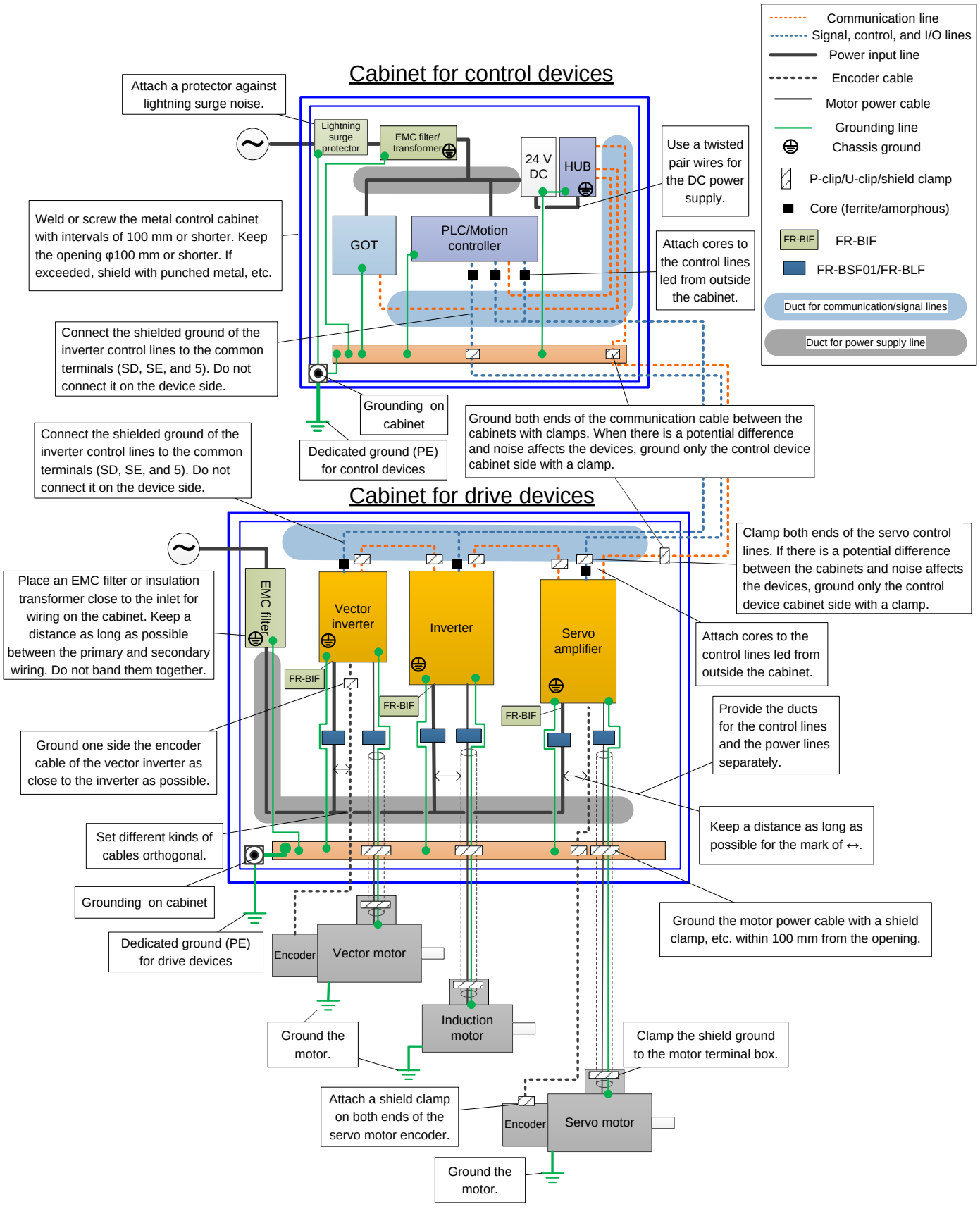



Fig. 25. Recommended wiring diagram inside cabinet (separation by dedicated cabinet)

2) Figure 26 shows a recommended wiring diagram inside cabinet including the layout, wiring, countermeasure member, and grounding for when there are the control devices and drive devices together in the same cabinet. (having difficulty of separating cabinets)

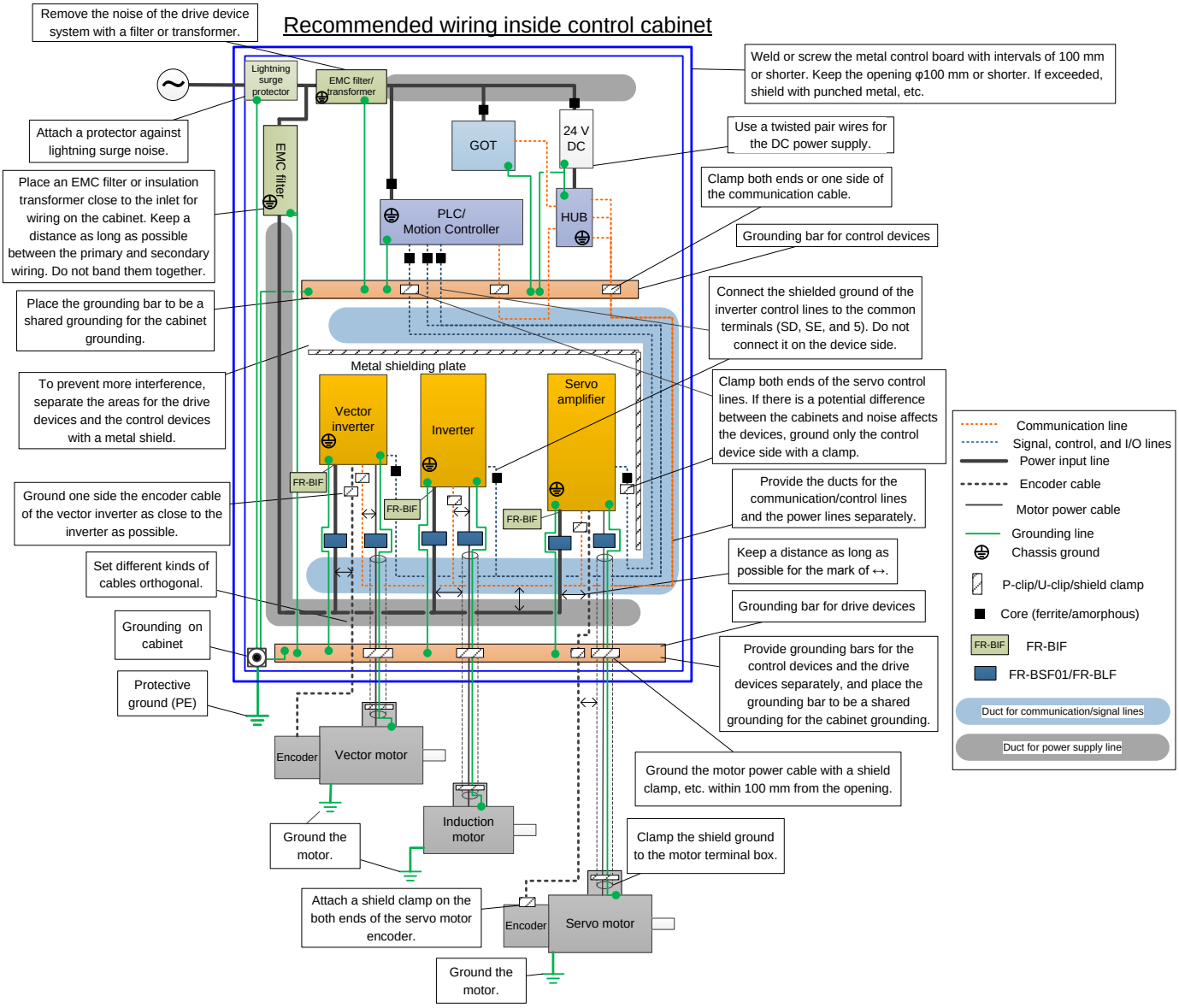



Fig. 26. Recommended wiring diagram inside cabinet (control devices and drive devices in one cabinet)

10. Reference (*: Available at Mitsubishi Electric’s Factory Automation Website)

- Mitsubishi Electric Inverter EMC Installation Guidelines *
- Mitsubishi Electric General-Purpose AC Servo EMC Installation Guidelines *
- Mitsubishi Electric Motion Controller User’s Manual (Q series) *
- Mitsubishi Electric MELSEC iQ-R Module Configuration Manual *
- GOT2000 Series User's Manual (Hardware) *
- Electromagnetic Compatibility Engineering by Henry W. Ott

Appendix: List of Countermeasure Members

1. Lines of Noise Countermeasure Members for FA Products of Mitsubishi Electric

App.-Table 1. List of noise countermeasure members (Official options by Mitsubishi Electric)

| Model* | Product name | Type | Application | Note |
|---|---|---|---|---|
| FR-BIF(-H) | Radio noise filter | Capacitor type | Inverter and servo | (-H) is for 400 V AC. |
| FR-BSF01 | Line noise filter | Ferrite core | Inverter, servo, and robot | For 200 V AC and 400 V AC |
| FR-BLF | Line noise filter | Ferrite core | Inverter, servo, and robot | For 200 V AC and 400 V AC |
| SF series | Noise filter | Noise filter | Inverter and servo | Filter for power supply |
| FR-E5NF series | Noise filter | Noise filter | Inverter | |
| FR-S5NFSA series | Noise filter | Noise filter | Inverter | Filter for 1-phase power supply |
| FR-BFP2 | Noise filter | Filterpack | Inverter | A filter pack including a DC reactor, zero-phase reactor, and capacitive filter. |
| FR-ASF | Surge voltage suppression filter | EMC noise filter | Inverter | Surge voltage suppression filter for output side of 400 V class inverter |
| FR-BMF | Surge voltage suppression filter | EMC noise filter | Inverter | Surge voltage suppression filter for output side of 400 V class inverter |
| MT-BSL | Sine wave filter | EMC noise filter | Inverter | Connecting the filter on the output side of the inverter makes the voltage and current of the motor almost sine waves. |
| MT-BSC | Sine wave filter | EMC noise filter | Inverter | |
| AD75CK | Cable clamp | Clamp fitting | PLC, GOT, and Motion controller | For clamping the shielded cable |
| AERSBAN-DSET | Cable clamp | Clamp fitting | Servo and PLC | For clamping the shielded cable |
| AERSBAN-ESET | Cable clamp | Clamp fitting | Servo and PLC | For clamping the shielded cable |

* Models available at Mitsubishi Electric Corporation.

Refer to catalogs and instruction manuals of each product for details.

As of January 30, 2017