Appendix

Contents

Appendix A Trouble-free Use of Inverters (Notes on Electrical Noise)

Excerpt from technical material of
the Japan Electrical Manufacturers' Association (JEMA) (March 1995)

A.1 Effect of inverters on other devices

The applicable fields in which inverters are used have been rapidly expanding. This paper describes the effect that inverters have on electronic devices already installed or on devices installed in the same system as inverters, as well as introducing noise prevention measures. (For details, refer to "A.3.3 Noise prevention examples.")

A.1.1 Effect on AM radios

Phenomenon	If an inverter operates, AM radios may pick up noise radiated from the inverter. (An inverter has almost no effect on FM radios or television sets.)
Probable cause	The noise radiated from the inverter may be received by a radio.
Measures	Inserting a noise filter on the power supply side of the inverter is effective.

A.1.2 Effect on telephones

Phenomenon	If an inverter operates, nearby telephones may pick up noise radiated from the inverter in conversation so that it may be difficult to hear.
Probable cause	A high-frequency leakage current radiated from the inverter and motors enters shielded telephone cables, causing noise.
Measures	It is effective to commonly connect the grounding terminals of the motors and return the common grounding line to the grounding terminal of the inverter.

A.1.3 Effect on pressure sensors

Phenomenon	If an inverter operates, pressure sensors may malfunction.
Probable cause	Noise may penetrate through a grounding wire into the signal line.
Measures	It is effective to install a noise filter on the power supply side of the inverter or to change the wiring.

A.1.4 Effect on position detectors (pulse encoders)

Phenomenon	If an inverter operates, pulse encoders may produce erroneous pulses that shift the stop position of a machine.
Probable cause	Erroneous pulses are liable to occur when the signal lines of the PG and power lines are bundled together.
Measures	The influence of induction noise and radiated noise can be reduced by separating the PG signal lines and power lines. Providing noise filters at the input and output terminals is also an effective measure.

A.1.5 Effect on proximity switches

Phenomenon	If an inverter operates, proximity switches (capacitance-type) may malfunction.
Probable cause	The capacitance-type proximity switches may provide inferior noise immunity.
Measures	It is effective to connect a filter to the input terminals of the inverter or to the 0V side of the power supply of the proximity switches using a condenser. The proximity switches can be replaced with superior noise immunity types such as magnetic types.

A.2 Noise

This section gives a summary of noises generated in inverters and their effects on devices subject to noise.

A.2.1 Inverter operating principles and noise

Fig. A.2-1 shows an Outline of inverter configuration. The inverter converts AC to DC (rectification) in a converter unit and converts DC to AC (inversion) with 3-phase variable voltage and variable frequency. The conversion (inversion) is performed by PWM implemented by switching six transistors (IGBT: Insulated Gate Bipolar Transistor, etc.), and is used for variable speed motor control.

Switching noise is generated by high-speed on/off switching of the six transistors. Noise current (i) is emitted and at each high-speed on/off switching, the noise current flows through stray capacitance (C) of the inverter, cable, and motor to the ground. The amount of the noise current is expressed as follows:

$$i = C \cdot dv/dt$$

It is related to the stray capacitance (C) and dv/dt (switching speed of the transistors). Further, this noise current is related to the carrier frequency since the noise current flows each time the transistors are switched ON or OFF.

Noise is generated by the DC/DC power supply converter for the control circuit during transistor switching.

These noise frequency bands extend across several tens of MHz and may interfere with communication devices such as AM radios, factory wireless networks, and telephones.

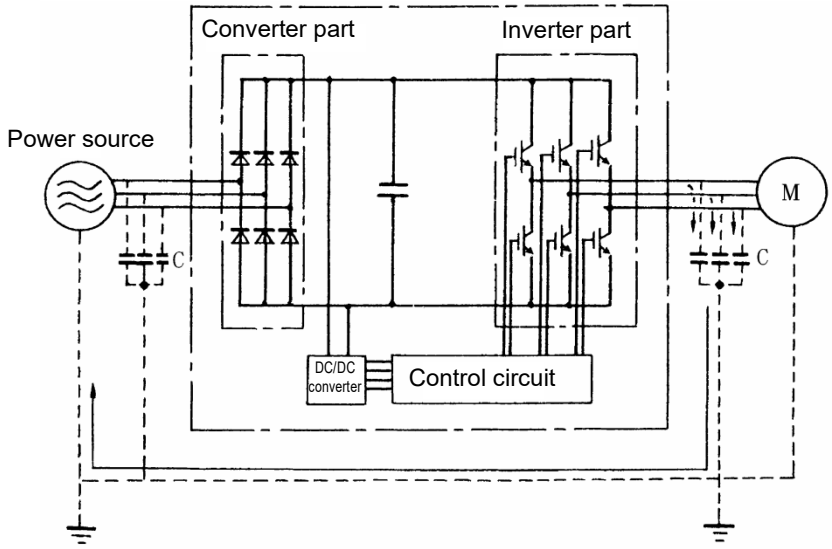


Fig. A.2-1 Outline of inverter configuration

A.2.2 Types of noise

Noise generated in an inverter is propagated through the main circuit wiring to the power supply and the motor so as to affect a wide range of applications from the power supply transformer to the motor. The various propagation routes are shown in Fig. A.2-2. According to those routes, noises are roughly classified into three types:

(1) to (3) are conducted noise, (4) is induction noise, and (5) is radiated noise. Details are given below.

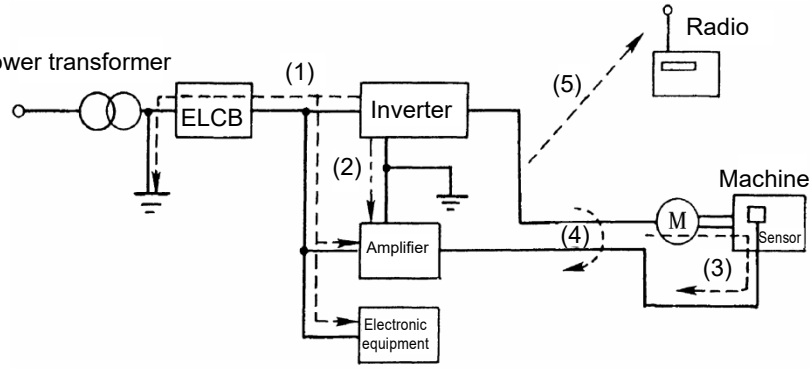


Fig. A.2-2 Noise propagation routes

(1) Conducted noise

The noise that has occurred in the inverter and propagates through a conductor to influence peripheral equipment is called conducted noise. Some conducted noise will propagate through the main circuit (1). If the ground wires are connected to a common ground, conducted noise will propagate through route (2). As shown in route (3), some conducted noise will propagate through signal lines or shielded wires.

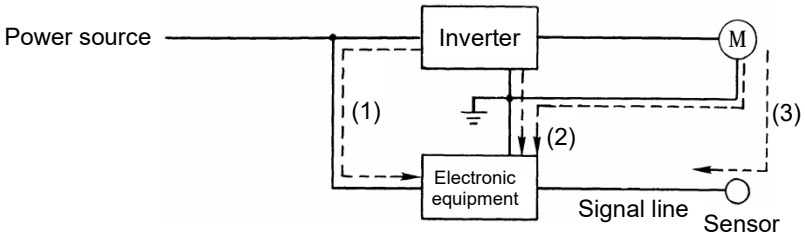


Fig. A.2-3 Conducted noise

(2) Induction noise

When wires or signal lines of peripheral devices are brought close to the wires on the input and output sides of the inverter through which noise current is flowing, noise will be induced into those wires and signal lines of the devices by electromagnetic induction (Fig. A.2-4) or electrostatic induction (Fig. A.2-5). This is called “induction noise” (4).

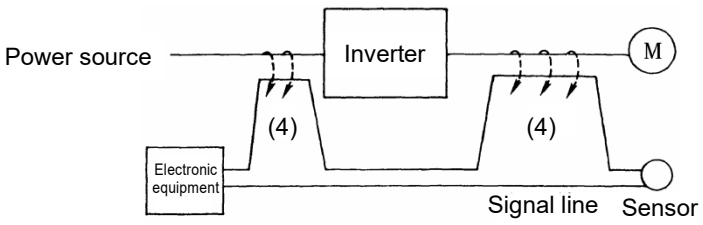


Fig. A.2-4 Electromagnetic induction noise

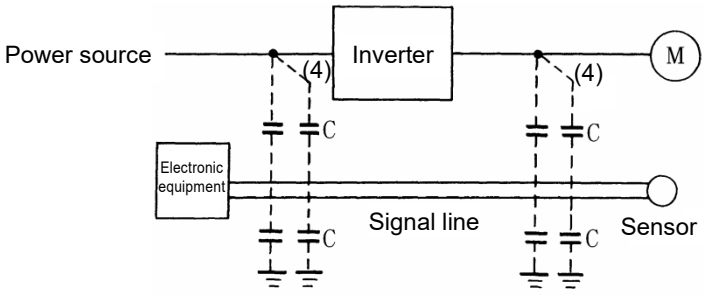


Fig. A.2-5 Electrostatic induction noise

(3) Radiated noise

Noise generated in an inverter radiates through the air with input side and output side main circuit wires, and ground wires acting as antennas; this affects peripheral devices, as well as broadcast and wireless communication. This noise is called “radiated noise,” shown below as (5). Not only wires but motor frames or control system panels containing inverters may also act as antennas.

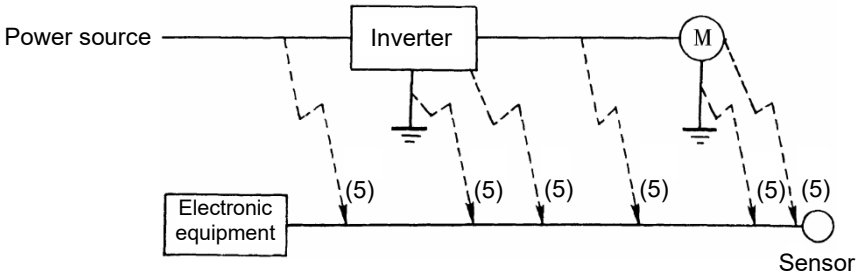


Fig. A.2-6 Radiated noise

A.3 Measures

As the noise prevention is strengthened, the more effective it is. However, with the use of appropriate measures, noise problems may be resolved easily. It is necessary to implement economical noise prevention according to the noise level and the equipment conditions.

A.3.1 Noise prevention prior to installation

Before installing an inverter in your control panel or installing inverter paneling, you need to consider noise prevention. Once noise problems occur, it will cost additional materials and time for solving them.

Noise prevention prior to installation includes:

(1) Separate the main circuit from the control circuit.

(2) Accommodate the main circuit wiring in a metal pipe (conduit pipe).

(3) Use shielded wire or twisted shielded wire in the control circuit.

(4) Perform reliable grounding work and wiring.

These noise prevention measures can avoid most noise problems.

A.3.2 Implementation of noise prevention measures

There are two types of noise prevention measures--one for noise propagation routes and the other for noise receiving sides (that are affected by noise).

The basic measures for reducing the effect of noise at the receiving side include:

(1) Separating the main circuit wiring from the control circuit wiring, avoiding noise effect.
Measures on the noise-affected side are:

(2) Lower the noise level, for example by installing a noise filter.

(3) Suppress the noise level, for example by using a metal wiring pipe or metal control panel.

(4) Block the noise propagation route, for example by using an insulation transformer for power source.

Table A.3-1 lists the Noise prevention measures, their goals, and propagation routes.

Table A.3-1 Noise prevention measures

Noise prevention method		Goal of noise prevention measures				Propagation route		
		Make it more difficult to receive noise	Cutoff noise propagation	Contain noise	Reduce noise level	Conducted noise	Induction noise	Radiated noise
Wiring and installation	Separate main circuit from control circuit	Y					Y	
	Minimize wiring length	Y			Y		Y	Y
	Avoid parallel and bundled wiring	Y					Y	
	Use appropriate grounding	Y			Y		Y	Y
	Use shielded wire and twisted shielded wire	Y					Y	Y
	Use shielded cable in main circuit			Y				Y
	Use metal conduit pipe			Y			Y	Y
Control panel	Appropriate arrangement of devices in panel	Y					Y	Y
	Metal control panel			Y			Y	Y
Anti-noise devices	Line filter	Y			Y	Y		Y
	Insulation transformer		Y			Y		Y
Measures taken on noise-affected side	Use a decoupling capacitor for control circuit	Y					Y	Y
	Use ferrite core for control circuit	Y					Y	Y
	Line filter	Y				Y		
Other IMs	Separate power supply systems	Y	Y			Y		
	Lower the carrier frequency				Y	Y	Y	Y

In the table, a column marked with Y shows a measure expected to produce an effect depending on the conditions. An empty column shows an ineffective measure.

What follows are noise prevention measures for the inverter drive configuration.

(1) Wiring and grounding

As shown in Fig. A.3-1, separate the main circuit wiring from the control circuit wiring as far as possible regardless of whether they are located inside or outside the system control panel containing an inverter. For the control circuit wiring, use shielded wires and twisted shielded wires that will block out extraneous noises, and minimize the wiring distance. Also avoid bundled wiring of the main circuit and control circuit or parallel wiring.

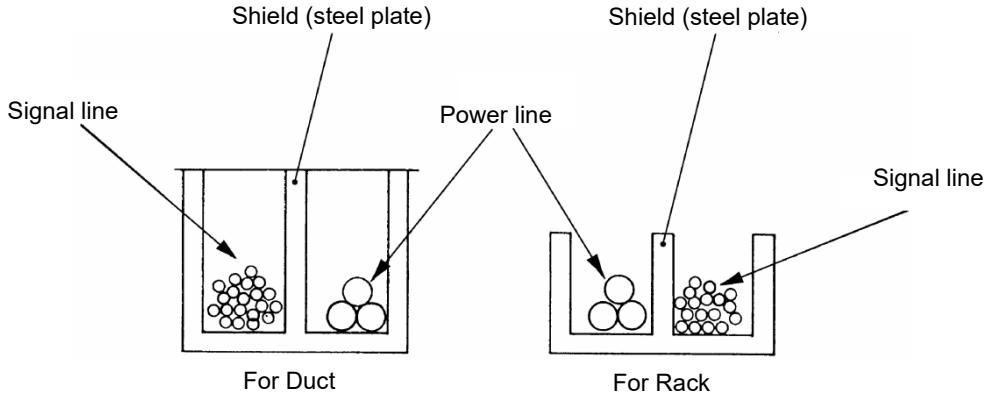


Fig. A.3-1 Separate wiring

For the main circuit wiring, use a metal conduit pipe and connect its wires to the ground to prevent noise propagation (refer to Fig. A.3-2).

The shield (braided wire) of a shielded wire should be securely connected to the base (common) side of the signal line at only one point to avoid the loop formation resulting from a multi-point connection (refer to Fig. A.3-3).

The grounding is effective not only to reduce the risk of electrical shocks due to leakage current, but also to block noise penetration and radiation. Corresponding to the main circuit voltage, the grounding work should be Class D (300 VAC or less) and Class C (300 to 600 VAC). Each ground wire is to be provided with its own ground or separately wired to a grounding point.

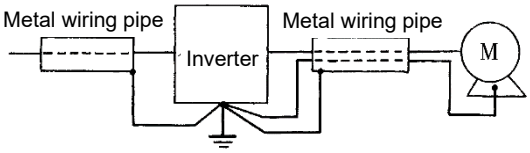


Fig. A.3-2 Grounding of metal conduit pipe

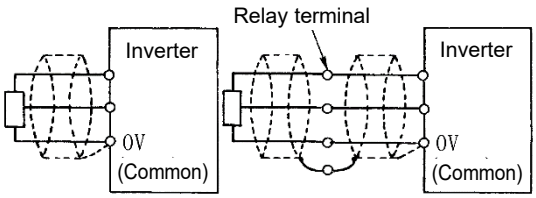


Fig. A.3-3 Treatment of braided wire of shielded wire

(2) Control panel

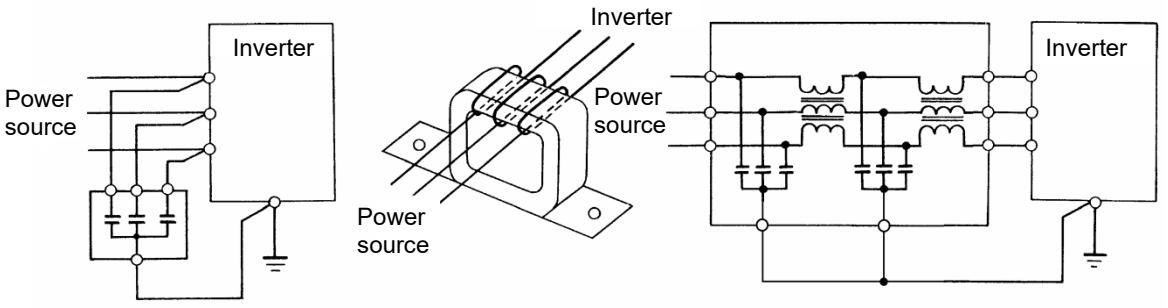
The system control panel containing an inverter is generally made of metal, which can shield noise radiated from the inverter itself.

When installing other electronic devices such as a programmable logic controller in the same control panel, be careful with the layout of each device. If necessary, arrange shield plates between the inverter and peripheral devices.

(3) Anti-noise devices

To reduce the noise propagated through the electrical circuits and the noise radiated from the main circuit wiring to the air, a line filter and power supply transformer should be used (refer to Fig. A.3-4).

Line filters are classified into simple-type filters (including capacitive filters to be connected in parallel to a power line, and inductive filters to be connected in series to a power line) and authentic filters (LC filters) to address radio noise restrictions. They are used selectively to create the target noise reduction effect. Power transformers include general-use insulation transformers, shield transformers and noise-cut transformers, which have different effects to block propagation of noise.



(a) Capacitive filter (b) Inductive filter (zero-phase reactor) (c) LC filter

Fig. A.3-4 Various filters and their connection

(4) Noise prevention measures on the receiving side

It is important to strengthen the noise immunity of those electronic devices installed in the same control panel as the inverter or located near an inverter. Line filters and shielded or twisted shielded wires are used to block the penetration of noise in the signal lines of these devices. The following treatments are also implemented.

1) Lower the circuit impedance by connecting capacitors or resistors to the input and output terminals of the signal circuit in parallel.
2) Increase the circuit impedance for noise by inserting choke coils in series in the signal circuit or passing signal lines through ferrite core beads.

It is also effective to widen the signal base lines (0 V line) or grounding lines.

(5) Other IMs

The level of generating/propagating noise will change with the carrier frequency of the inverter. The higher the carrier frequency, the higher the noise level.

In an inverter whose carrier frequency can be changed, lowering the carrier frequency can reduce the generation of electrical noise and result in a good balance with the audible noise of the motor under driving conditions.

A.3.3 Noise prevention examples

Table A.3-2 lists examples of the measures to prevent noise generated by a running inverter.

Table A.3-2 Examples of noise prevention measures

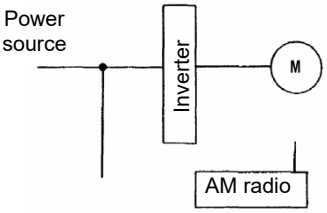
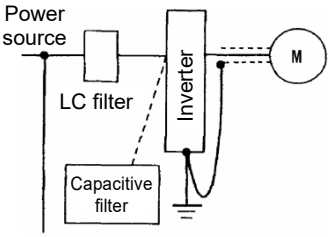
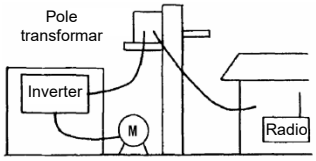
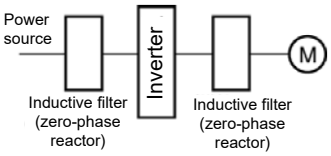
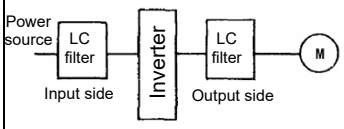
No.	Target device	Phenomenon	Measure	Notes
1	AM radio	Noise enters the AM radio broadcast (500 to 1500 kHz) when the inverter is operated.  <Possible cause> Radiated noise from the power source and output wiring of inverter was received by the AM radio.	1) Install an LC filter on the power supply side of the inverter. (In some cases, a capacitive filter may be used as a simple method.) 2) Install a metal conduit wiring between the motor and inverter. Or use shielded wiring.  Note: Minimize the distance between the LC filter and the inverter (within 1 m).	1) The radiated noise of the wiring can be reduced. 2) Reduce the conducted noise to the power source or apply shielded wiring. Or use shielded wiring. Note: Sufficient improvement may not be expected in narrow regions such as between mountains.
2	AM radio	Noise enters the AM radio broadcast (500 to 1500 kHz) when the inverter is operated.  <Possible cause> Radiated noise from the power line of inverter's power source was received by the AM radio.	1) Install inductive filters at the input and output sides of the inverter.  The number of turns of the zero-phase reactor (or ferrite ring) should be as large as possible. Minimize the distance between the inverter and the inductive filter (within 1 m). 2) When further improvement is necessary, install LC filters. 	1) The radiated noise of the wiring can be reduced.

Table A.3-2 Examples of noise prevention measures (cont'd)

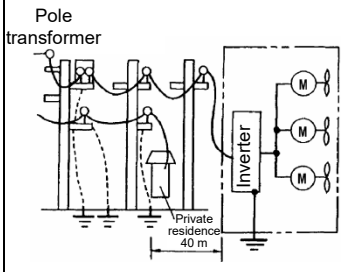
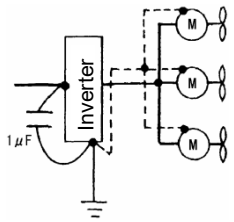
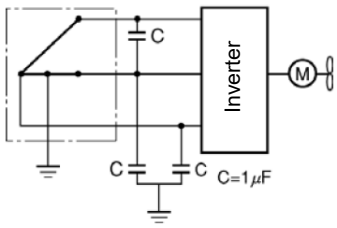
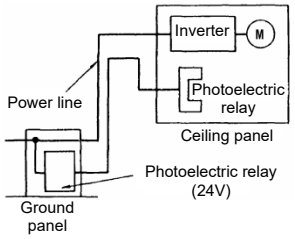
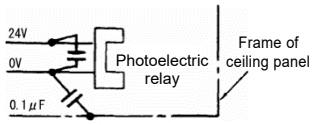
No.	Target device	Phenomenon	Measure	Notes
3	Telephone (in a common private residence at a distance of 40 m)	When driving a ventilation fan with an inverter, noise enters a telephone in a private residence at a distance of 40 m.  <Possible cause> High-frequency leak current of the inverter and motor flows into the shielded ground of the telephone cable on the way back via the ground of the pole transformer to cause noise by electrostatic induction.	1) Connect the ground terminals of the motors in a common connection. Return to the inverter panel and insert a 1 μF capacitor between the input terminal of the inverter and ground.  Power transformer 	1) The effect of the inductive filter and LC filter may not be as expected because of sound frequency components. 2) In the case of a V-connection power supply transformer in a 200 V system, it is necessary to connect capacitors as shown in the following figure, because of different potentials to ground.
4	Photoelectric relay	A photoelectric relay malfunctioned when the inverter runs the motor. (The inverter and motor are installed in the same place (for overhead traveling)).  <Possible cause> Input power line of the inverter and wiring of the photoelectric relay run parallel for 30 to 40 m with a spacing of about 25 mm, which invites induction noise. Due to conditions of the installation, these lines cannot be separated.	1) As a temporary measure, Insert a 0.1 μF capacitor between the 0 V terminal of the power supply circuit in the detection unit of the overhead photoelectric relay and a frame of the overhead panel.  2) As a permanent measure, move the 24 V power supply from the ground to the overhead unit so that signals are sent to the ground side with relay contacts in the ceiling part.	1) Separate the wiring (30 cm or more) 2) When separation is impossible, signals can be received and sent with dry contacts etc. 3) Do not wire low-current signal lines and power lines in parallel.

Table A.3-2 Examples of noise prevention measures (continued)

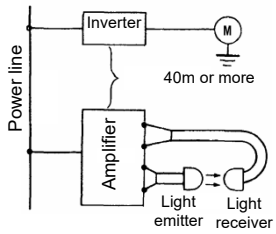
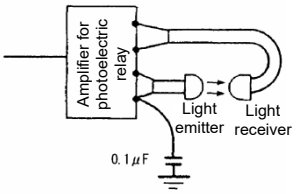
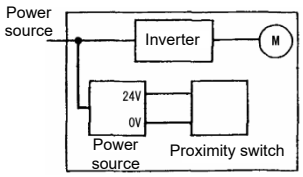
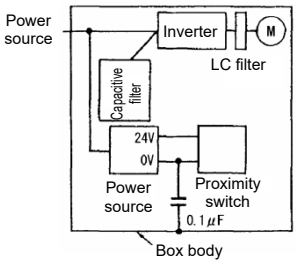
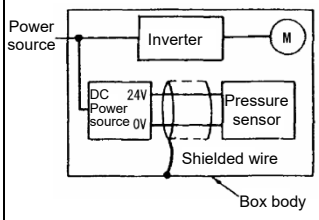
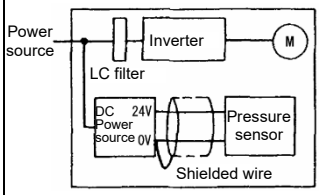
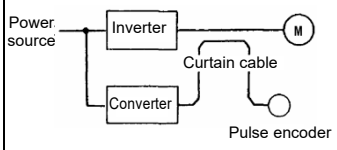
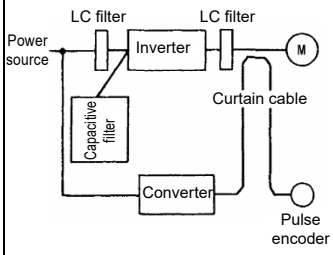
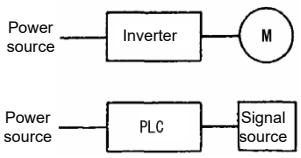
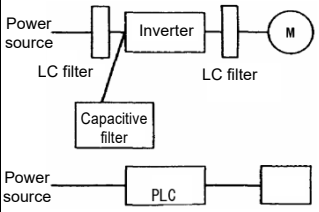
No.	Target device	Phenomenon	Measure	Notes
5	Photoelectric relay	A photoelectric relay malfunctioned when the inverter runs the motor.  <Possible cause> While the inverter is sufficiently away from the photoelectric relay, the power source is connected in common. Conducted noise has entered from the power source line.	1) Insert a 0.1 μF capacitor between the output common terminal of the amplifier of the photoelectric relay and the frame. 	1) If a low-current circuit at the malfunctioning side is observed, the measures may be simple and economical.
6	Proximity switch (capacitance type)	A proximity switch malfunctioned.  <Possible cause> The electrostatic capacitive proximity switch has a low noise immunity, and is vulnerable to circuit conducted noise and radiated noise.	1) Install an LC filter at the output side of the inverter. 2) Install a capacitive filter at the input side of the inverter. 3) Ground the 0 V (common) line of the DC power supply of the proximity switch through a capacitor to the box body of the machine. 	1) Noise generated in the inverter can be reduced. 2) The switch is superseded by a proximity switch of superior noise immunity (such as a magnetic type).
7	Pressure sensor	A pressure sensor malfunctioned.  <Possible cause> Noise enters from the box body via the shielded wire to cause malfunctioning of the pressure sensor.	1) Install an LC filter on the input side of the inverter. 2) Connect the shield of the shielded wire of the pressure sensor to the 0 V line (common) of the pressure sensor, changing the original connection. 	1) The shielded parts of shield wires for sensor signals are connected to a common point in the system. 2) Conductive noise from the inverter can be reduced.

Table A.3-2 Examples of noise prevention measures (cont'd)

No.	Target device	Phenomenon	Measure	Notes
8	Position detector (pulse encoder)	Erroneous-pulse outputs from a pulse converter caused a shift in the stop position of a crane.  <Possible cause> The motor power line and the signal line for the encoder are wired together in a bundle. This produces mis-pulses due to induction noise.	1) Install an LC filter and a capacitive filter on the input side of the inverter. 2) Install an LC filter on the output side of the inverter. 	1) This is an example of a measure where the power line and signal line cannot be separated. 2) Induction noise and radiated noise on the output side of the inverter can be reduced.
9	Programmable logic controller (PLC)	The PLC program sometimes malfunctions.  <Possible cause> Power sources of the inverter and PLC are in the same system so that noise enters PLC via the power source.	1) Install a capacitive filter and an LC filter on the input side of the inverter. 2) Install an LC filter on the output side of the inverter. 3) Lower the carrier frequency of the inverter. 	1) Total conducted noise and induction noise in the electric line can be reduced.

Appendix B Effect on Insulation of General-purpose Motors Driven with 400 V Class Inverters

Excerpt from technical material of
the Japan Electrical Manufacturers' Association (JEMA) (March 1995)

Preface

When an inverter drives a motor, surge voltages generated by switching the inverter elements are superimposed on the inverter output voltage and applied to the motor terminals. If the surge voltages are too high, they may have an effect on the motor insulation and some cases have resulted in damage.

For preventing such cases this document describes the generating mechanism of the surge voltages and countermeasures against them.

For details of the principles of inverter operation, refer to "A.2.1 Inverter operating principles and noise."

B.1 Generating mechanism of surge voltages

As the inverter rectifies a commercial power source voltage and smoothes into a DC voltage, the magnitude E of the DC voltage becomes about √2 times that of the source voltage (about 620 V in case of an input voltage of 440 VAC). The peak value of the output voltage is usually close to this DC voltage value.

However, as there exists inductance (L) and stray capacitance (C) in wiring between the inverter and the motor, the voltage variation due to switching the inverter elements causes a surge voltage originating in LC resonance and results in the addition of high voltage to the motor terminals. (Refer to Fig. B.1-1)

This voltage sometimes reaches up to about twice that of the inverter DC voltage (620 V x 2 = approximately 1,200 V) depending on a switching speed of the inverter elements and wiring conditions.

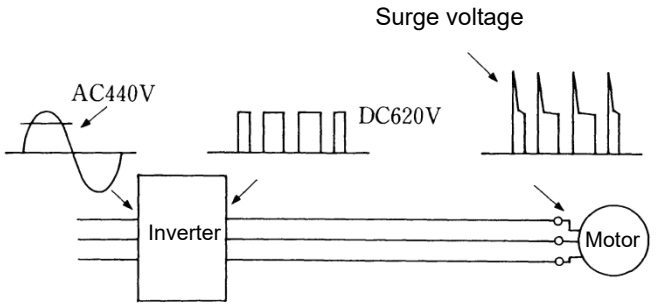
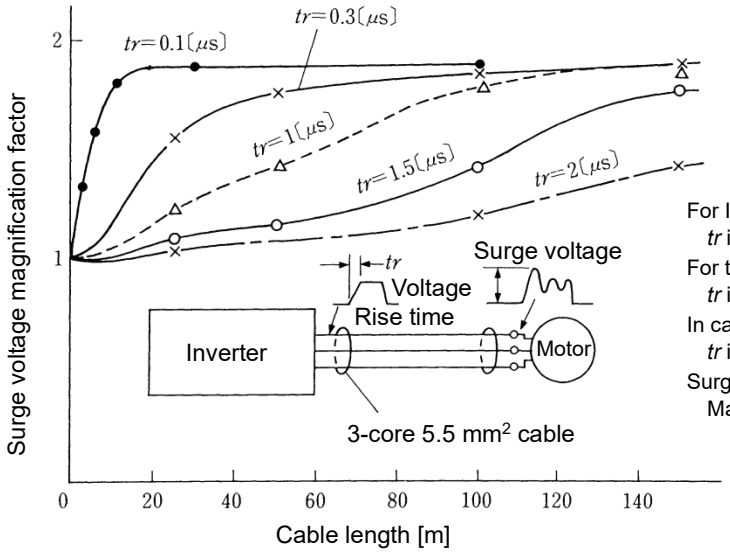


Fig. B.1-1 Voltage waveform of individual portions

A measured example in Fig. B.1-2 illustrates the relation of the peak value of the motor terminal voltage with the wiring length between the inverter and the motor.

From this it can be confirmed that the peak value of the motor terminal voltage ascends as the wiring length increases and becomes saturated at about twice the inverter DC voltage.

The shorter a pulse rise time becomes, the higher the motor terminal surge voltage rises even in the case of a short wiring length.



For IGBT,
tr is equivalent to 0.1 to 0.3 μs.
For the bipolar transistor,
tr is equivalent to 0.3 to1 μs.
In case an output reactor or a filter is inserted,
tr is equivalent to 1 μs or more.
Surge voltage magnification factor:
Magnification factor for DC voltage (E)

Excerpt from Journal of IEEJ, No. 7, vol. 107, 1987

Fig. B.1-2 Measured example of wiring length and peak value of motor terminal voltage

B.2 Effect of surge voltages

The surge voltages originated in LC resonance of wiring may be applied to the motor terminals, and, depending on their magnitude, sometimes cause damage to the motor insulation.

When the motor is driven with a 200 V-series inverter, the dielectric strength of the insulation is no problem even when the peak value of the motor terminal voltage doubles due to the surge voltages (the DC voltage is only about 300 V).

But in case of a 400 V-series inverter, the DC voltage is approximately 600 V, and, depending on the wiring length, the surge voltages may greatly increase and sometimes result in damage to the insulation.

B.3 Countermeasures against surge voltages

When driving a motor with a 400 V-series inverter, the following are countermeasures against damage to the motor insulation by the surge voltages.

B.3.1 Suppressing surge voltages

To suppress surge voltage, a method is employed which involves suppressing voltage rise and peak value.

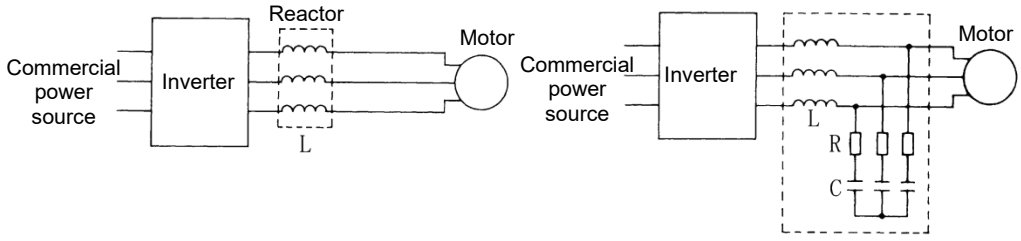
(1) Output reactor

If wiring length is relatively short, the surge voltages can be suppressed by reducing the voltage rise time (dv/dt) with the installation of an AC reactor on the output side of the inverter. (Refer to Fig. B.3-1 (1).)

However, if the wiring length becomes long, suppressing the peak voltage due to surge voltage may be difficult.

(2) Output filter

Installing a filter on the output side of the inverter allows the peak value of the motor terminal voltage to be reduced. (Refer to Fig. B.3-1 (2).)



(1) Output reactor (2) Output filter

Fig. B.3-1 Method to suppress surge voltage

B.3.2 Using motors with enhanced insulation

Enhanced insulation of a motor's winding allows its surge withstanding to be improved.

B.4 Regarding existing equipment

B.4.1 In case of a motor being driven with 400 V-series inverter

A survey over the last five years on motor insulation damage due to the surge voltages originating from switching of inverter elements shows that the damage incidence is 0.013% under the surge voltage condition of over 1,100 V, and most of the damage occurs within several months after commissioning the inverter. Therefore, there seems to be little probability of occurrence of motor insulation damage after a lapse of several months after commissioning.

B.4.2 In case of an existing motor driven using a newly-installed 400 V-series inverter

We recommend suppressing the surge voltages with the methods shown in "B.3 "

Appendix C Inverter Generating Loss

The table below lists the inverter generating loss.

Table D-1

Power system	Inverter type	Carrier frequency (Function code: F26)					
		ND specification	HD specification	HND specification		HHD specification	
		Factory default	Factory default	Factory default	Maximum set value	Factory default	Maximum set value
Three-phase 200 V	FRN0001E3■-2G	-	-	19	22	17	20
	FRN0002E3■-2G	-	-	29	34	23	27
	FRN0004E3■-2G	-	-	47	51	35	39
	FRN0006E3■-2G	-	-	66	71	54	58
	FRN0010E3■-2G	-	-	94	115	74	95
	FRN0012E3■-2G	-	-	115(*1)	145(*1)	98	125
	FRN0020E3■-2G	-	-	210	285	165	230
	FRN0030E3▲-2G	-	-	280	360	170	230
	FRN0040E3▲-2G	-	-	440	540	280	360
	FRN0056E3▲-2G	-	-	520	700	440	540
	FRN0069E3▲-2G	-	-	640	810	520	700
	FRN0088E3▲-2G	-	-	770	970	660	860
	FRN0115E3▲-2G	-	-	1120	1250	790	1040
Three-phase 400 V	FRN0002E3□-4G	33	32	32	56	30	52
	FRN0004E3□-4G	57	50	50	93	40	72
	FRN0006E3□-4G	73	69	69	120	57	100
	FRN0007E3□-4G	98	95	95	170	79	145
	FRN0012E3□-4G	155	150	150	265	130	215
	FRN0022E3△-4G	260	190	190	370	170	320
	FRN0029E3△-4G	380	290	290	510	220	390
	FRN0037E3△-4G	460	390	390	630	300	490
	FRN0044E3△-4G	470	410	410	750	340	600
	FRN0059E3△-4G	710	510	510	870	440	770
	FRN0072E3△-4G	900	710	710	1000	510	900
Single-phase 200 V	FRN0001E3□-7G	-	-	19	21	17	20
	FRN0002E3□-7G	-	-	29	31	23	27
	FRN0004E3■-7G FRN0003E3E-7G	-	-	47	50	36	40
	FRN0006E3■-7G FRN0005E3E-7G	-	-	66	69	55	59
	FRN0010E3■-7G FRN0008E3E-7G	-	-	94	110	78	100
	FRN0012E3■-7G FRN0011E3E-7G	-	-	115	140	100	130

Note 1) The maximum set value (max. carrier) differs depending on specifications. For details, refer to Chapter 5 “5.3.1 F codes (Fundamental functions)/FUNCTION CODE F26.”

Note 2: When HD/ND specification units are operated at maximum carrier, perform derating of the output current while referring to Chapter 10 “Guidelines for selecting inverter drive mode and capacity.”
At that setting, generated losses will be at same level as the factory shipment value.

Note 3) A box (□) in the above table replaces S (Basic type) or T (Finless type) or N (Ethernet built-in type) or E (EMC filter built-in type) depending on the enclosure.

A box (△) in the above table replaces S (Basic type) or N (Ethernet built-in type) or E (EMC filter built-in type)depending on the enclosure.

A box (■) in the above table replaces S (Basic type) or T (Finless type) or N (Ethernet built-in type) depending on the enclosure.

A box (▲) in the above table replaces S (Basic type) or N (Ethernet built-in type) depending on the enclosure.

(*1) ND spec.

(*2)FRN____E3E-7G is only HHD spec.

Appendix D Conversion to Non-SI Units

All expressions given in Chapter 10 “SELECTING OPTIMAL MOTOR AND INVERTER CAPACITIES” are based on SI units (The International System of Units). This section explains how to convert expressions to other units.

D.1 Conversion of units

(1) Force

- 1 [kgf] ≈ 9.8 [N]
- 1 [N] ≈ 0.102 [kgf]

(2) Torque

- 1 [kgf·m] ≈ 9.8 [N•m]
- 1 [N•m] ≈ 0.102 [kgf•m]

(3) Power (energy)

- 1 [kgf•m] ≈ 9.8 [N•m] = 9.8 [J] = 9.8 [W•s]

(4) Power

- 1 [kgf•m/s] ≈ 9.8 [N•m/s] = 9.8 [J/s] = 9.8 [W]
- 1 [N•m/s] ≈ 1 [J/s] = 1 [W] ≈ 0.102 [kgf•m/s]

(5) Motor speed

- 1 [min^{-1}] = $\frac{2\pi}{60}$ [rad/s] ≈ 0.1047 [rad/s]
- 1 [rad/s] = $\frac{60}{2\pi}$ [min^{-1}] ≈ 9.549 [min^{-1}]

(6) Inertia constant

J [kg•m^2]: moment of inertia

GD^2 [kg·m^2]: flywheel effect

- $GD^2 = 4J$
- $J = \frac{GD^2}{4}$

(7) Pressure, stress

- 1 [mmAq] ≈ 9.8 [Pa] ≈ 9.8 [N/m^2]
- 1 [Pa] ≈ 1 [N/m^2] ≈ 0.102 [mmAq]
- 1 [bar] ≈ 100000 [Pa] ≈ 1.02 [kg•cm^2]
- 1 [kg•cm^2] ≈ 98000 [Pa] ≈ 980 [mbar]
- 1 barometric pressure
  = 1013 [mbar] = 760 [mmHg]
  = 101300 [Pa] ≈ 1.033 [kg/cm^2]

D.2 Calculation formulas

(1) Torque, power, rotation speed

- $P[W] \approx \frac{2\pi}{60} \cdot N[min^{-1}] \cdot \tau [N \cdot m]$
- $P [W] \approx 1.026 \cdot N [min^{-1}] \cdot T [kgf \cdot m]$
- $\tau [N \cdot m] \approx 9.55 \cdot \frac{P [W]}{N [min^{-1}]}$
- $T [kgf \cdot m] \approx 0.974 \cdot \frac{P [W]}{N [min^{-1}]}$

(2) Kinetic energy

- $E [J] \approx \frac{1}{182.4} \cdot J [kg \cdot m^2] \cdot N^2 [(min^{-1})^2]$
- $E [J] \approx \frac{1}{730} \cdot GD^2 [kg \cdot m^2] \cdot N^2 [(min^{-1})^2]$

(3) Linear motion load torque

[Driving mode]

- $\tau [N \cdot m] \approx 0.159 \frac{V [m/min]}{N_M [min^{-1}] \cdot \eta_G} \cdot F [N]$
- $T [kgf \cdot m] \approx 0.159 \frac{V [m/min]}{N_M [min^{-1}] \cdot \eta_G} \cdot F [kgf]$

[Braking mode]

- $\tau [N \cdot m] \approx 0.159 \frac{V [m/min]}{N_M [min^{-1}] / \eta_G} \cdot F [N]$
- $T [kgf \cdot m] \approx 0.159 \frac{V [m/min]}{N_M [min^{-1}] / \eta_G} \cdot F [kgf]$

(4) Acceleration torque

[Driving mode]

- $\tau [N \cdot m] \approx \frac{J [kg \cdot m^2]}{9.55} \cdot \frac{\Delta N [min^{-1}]}{\Delta t [s] \cdot \eta_G}$
- $T [kgf \cdot m] \approx \frac{GD^2 [kg \cdot m^2]}{375} \cdot \frac{\Delta N [min^{-1}]}{\Delta t [s] \cdot \eta_G}$

[Braking mode]

- $\tau [N \cdot m] \approx \frac{J [kg \cdot m^2]}{9.55} \cdot \frac{\Delta N [min^{-1}] \cdot \eta_G}{\Delta t [s]}$
- $T [kgf \cdot m] \approx \frac{GD^2 [kg \cdot m^2]}{375} \cdot \frac{\Delta N [min^{-1}] \cdot \eta_G}{\Delta t [s]}$

(5) Acceleration time

- $t_{ACC} [s] \approx \frac{J_1 + J_2 / \eta_G [kg \cdot m^2]}{\tau_M - \tau_L / \eta_G [N \cdot m]} \cdot \frac{\Delta N [min^{-1}]}{9.55}$
- $t_{ACC} [s] \approx \frac{GD_1^2 + GD_2^2 / \eta_G [kg \cdot m^2]}{T_M - T_L / \eta_G [kgf \cdot m]} \cdot \frac{\Delta N [min^{-1}]}{375}$

(6) Deceleration time

- $t_{DEC}[s] \fallingdotseq \frac{J_1 + J_2 \cdot \eta_G [kg \cdot m^2]}{\tau_M - \tau_L \cdot \eta_G [N \cdot m]} \cdot \frac{\Delta N [min^{-1}]}{9.55}$
- $t_{DEC}[s] \fallingdotseq \frac{GD_1^2 + GD_2^2 \cdot \eta_G [kg \cdot m^2]}{T_M - T_L \cdot \eta_G [kgf \cdot m]} \cdot \frac{\Delta N [min^{-1}]}{375}$

Appendix E Permissible Current of Insulated Wires

The tables below list the permissible current of IV wires, HIV wires, and 600 V cross-linked polyethylene insulated wires.

■ IV wire (maximum permissible temperature: 60°C (140°F))

Table F-1 (a) Permissible current of insulated wires

Wire size (mm^2)	Permissible current Threshold value (30°C or less) Io (A)	Aerial wiring					Wire duct wiring (3 wires or less in same duct)			
		35°C (95°F) (Io×0.91) (A)	40°C (104°F) (Io×0.82) (A)	45°C (113°F) (Io×0.71) (A)	50°C (122°F) (Io×0.58) (A)	55°C (131°F) (Io×0.41) (A)	35°C (95°F) (Io×0.64) (A)	40°C (104°F) (Io×0.57) (A)	45°C (113°F) (Io×0.49) (A)	50°C (122°F) (Io×0.40) (A)
2.0	27	24	22	19	15	11	17	15	13	10
3.5	37	33	30	26	21	15	23	21	18	14
5.5	49	44	40	34	28	20	31	28	24	19
8.0	61	55	49	43	35	24	38	34	30	24
14	88	80	71	62	50	35	56	50	43	35
22	115	104	93	81	66	46	73	65	56	46
38	162	147	132	114	93	66	103	92	80	65
60	217	198	177	153	125	88	138	124	107	87
100	298	272	243	210	172	121	190	170	147	120
150	395	360	322	279	228	161	252	225	195	159
200	469	428	382	331	270	191	299	268	232	189
250	556	507	453	393	321	226	355	317	275	224
325	650	593	530	459	375	265	415	371	321	262
400	745	680	608	526	430	304	476	425	368	301
500	842	768	687	595	486	343	538	481	416	340
2 x 100	497	453	405	351	286	202	317	284	246	200
2 x 150	658	600	537	465	379	268	420	376	325	265
2 x 200	782	713	638	552	451	319	499	446	387	316
2 x 250	927	846	756	655	535	378	592	529	458	374
2 x 325	1083	988	884	765	625	442	692	618	536	437
2 x 400	1242	1133	1014	878	717	507	793	709	614	501
2 x 500	1403	1280	1145	992	810	572	896	801	694	567

■ HIV wire (maximum permissible temperature: 75°C (167°F))

Table F-1 (b) Permissible current of insulated wires

Wire size (mm^2)	Permissible current Threshold value (30°C or less) Io (A)	Aerial wiring					Wire duct wiring (3 wires or less in same duct)			
		35°C (95°F) (Io×0.94) (A)	40°C (104°F) (Io×0.88) (A)	45°C (113°F) (Io×0.81) (A)	50°C (122°F) (Io×0.74) (A)	55°C (131°F) (Io×0.66) (A)	35°C (95°F) (Io×0.65) (A)	40°C (104°F) (Io×0.61) (A)	45°C (113°F) (Io×0.57) (A)	50°C (122°F) (Io×0.52) (A)
2.0	33	31	29	26	24	21	21	20	18	17
3.5	45	42	39	36	33	29	29	27	25	23
5.5	60	56	52	48	44	39	39	36	34	31
8.0	74	69	65	59	54	48	48	45	42	38
14	107	100	94	86	79	70	69	65	60	55
22	140	131	123	113	103	92	91	85	79	72
38	198	186	174	160	146	130	128	120	112	102
60	265	249	233	214	196	174	172	161	151	137
100	364	342	320	294	269	240	236	222	207	189
150	483	454	425	391	357	318	313	294	275	251
200	574	539	505	464	424	378	373	350	327	298
250	680	639	598	550	503	448	442	414	387	353
325	796	748	700	644	589	525	517	485	453	413
400	912	857	802	738	674	601	592	556	519	474
500	1,031	969	907	835	762	680	670	628	587	536
2 x 100	608	571	535	492	449	401	395	370	346	316
2 x 150	805	756	708	652	595	531	523	491	458	418
2 x 200	957	899	842	775	708	631	622	583	545	497
2 x 250	1,135	1066	998	919	839	749	737	692	646	590
2 x 325	1,326	1246	1,166	1,074	981	875	861	808	755	689
2 x 400	1,521	1429	1,338	1,232	1,125	1,003	988	927	866	790
2 x 500	1,718	1614	1,511	1,391	1,271	1,133	1,116	1,047	979	893

■ 600 V crosslinked polyethylene insulated wire (maximum permissible temperature: 90°C (194°F))

Table F-3 (c) Permissible current of insulated wires

Wire size	Permissible current	Aerial wiring					Wire duct wiring (3 wires or less in same duct)			
	Threshold value (30°C or less)	35°C (95°F)	40°C (104°F)	45°C (113°F)	50°C (122°F)	55°C (131°F)	35°C (95°F)	40°C (104°F)	45°C (113°F)	50°C (122°F)
(mm^2)	Io (A)	(Io×0.95) (A)	(Io×0.91) (A)	(Io×0.86) (A)	(Io×0.81) (A)	(Io×0.76) (A)	(Io×0.67) (A)	(Io×0.63) (A)	(Io×0.60) (A)	(Io×0.57) (A)
2.0	38	36	34	32	30	28	25	23	22	21
3.5	52	49	47	44	42	39	34	32	31	29
5.5	69	65	62	59	55	52	46	43	41	39
8.0	86	81	78	73	69	65	57	54	51	49
14	124	117	112	106	100	94	83	78	74	70
22	162	153	147	139	131	123	108	102	97	92
38	229	217	208	196	185	174	153	144	137	130
60	306	290	278	263	247	232	205	192	183	174
100	421	399	383	362	341	319	282	265	252	239
150	558	530	507	479	451	424	373	351	334	318
200	663	629	603	570	537	503	444	417	397	377
250	786	746	715	675	636	597	526	495	471	448
325	919	873	836	790	744	698	615	578	551	523
400	1,053	1,000	958	905	852	800	705	663	631	600
500	1,190	1,130	1,082	1,023	963	904	797	749	714	678
2 x 100	702	666	638	603	568	533	470	442	421	400
2 x 150	930	883	846	799	753	706	623	585	558	530
2 x 200	1,105	1,049	1,005	950	895	839	740	696	663	629
2 x 250	1,310	1,244	1,192	1,126	1,061	995	877	825	786	746
2 x 325	1,531	1,454	1,393	1,316	1,240	1,163	1,025	964	918	872
2 x 400	1,756	1,668	1,597	1,510	1,422	1,334	1,176	1,106	1,053	1,000
2 x 500	1,984	1,884	1,805	1,706	1,607	1,507	1,329	1,249	1,190	1,130

Appendix F Conformity with Standards

F.1 Compliance with European standards (CE)

The CE marking on Fuji products indicates that they comply with the essential requirements of the Electromagnetic Compatibility (EMC) Directive, Low Voltage Directive, and Machinery Directive issued by the Council of the European Communities.

Note Keep the ambient temperature to 50°C (122°F) or less to comply with European standards.
Products with no standards indicated do not comply with European Standards.

Table F.1-1 Compliance standards

EMC Directive	EN61800-3 Immunity : Second environment (Industrial) Emission : Category C2(Applicable only when an optional EMC-compliant filter is attached.) Type of FRN0012E3E-4☐ or below : Category C2 Type of FRN0011E3E-7☐ or below : Category C2 Type of FRN0022E3E-4☐ or above : Category C3 (Applicable only to the EMC filter built-in type of inverters)
Low Voltage Directive	Adjustable speed electrical power drive systems. Part 5-1: Safety requirements. Electrical, thermal and energy EN61800-5-1
Machine Directives	EN ISO 13849-1 : Cat.3 / PL:e EN 60204-1 : Stop Category 0 EN 61800-5-2 : SIL3 (Functional Safety: STO) EN 62061 : SIL3

* A basic type inverter that does not have a built-in EMC filter complies with the EMC Directive by combining it with an dedicated Fuji external filter.

Warning

Category C2: In a domestic environment this product may cause radio interference in which case supplementary mitigation measures may be required.

Category C3: This product is not intended to be used on a low-voltage public network which supplies domestic premises; radio frequency interference is expected if used on such a network.

Category C2 and C3:

It has a risk about other equipment malfunction or breakdown by radiated electric field strength out of frequency range that is defined in EN 61800-3: 2004 + A1: 2012 2nd Environment and EN/IEC 61800-3: 2018 2nd Environment.

F.1.1 Compliance with EMC standards

The CE marking on inverters does not ensure that the entire equipment including our CE-marked products is compliant with the EMC Directive. Therefore, CE marking for the equipment shall be the responsibility of the equipment manufacturer. The reason for this is that Fuji's CE mark is indicated under the condition that the product shall be used in a way that meets all requirements for the relevant Directives.

Generally, machinery or equipment includes not only our products but other devices as well. Manufacturers, therefore, shall design the whole system to be compliant with the relevant Directives.

■ List of EMC-compliant filters

To comply with standards, either use an inverter with built-in EMC filter, or use an inverter with no built-in EMC filter in combination with a dedicated Fuji external filter (option). No matter what the application, please install noise filters using the following recommended installation method. It is recommended that noise filters be installed inside metal cabinets to ensure more reliable compliance with standards.

Tip Our EMC compliance test is performed under the following conditions. Wiring length (of the shielded cable) between the inverter (EMC filter built-in type) and motor: 10 m.

Note To use Fuji inverters in combination with a PWM converter, the basic type of inverters having no built-in EMC filter should be used. Use of an EMC filter built-in type may increase the heat of the capacitors in the inverter, resulting in damage. In addition, the effect of the EMC filter will be lost.

Table F.1-2 EMC-compliant filters

Power system	Inverter type	Filter type			
		ND mode	HD mode	HND mode	HHD mode
Three-phase 200 V	FRN0001E3□-2■	-	-	B84243A8008W000	B84243A8008W000
	FRN0002E3□-2■	-	-		
	FRN0004E3□-2■	-	-		
	FRN0006E3□-2■	-	-		
	FRN0010E3□-2■	-	-	B84243A8033W000	B84243A8033W000
	FRN0012E3□-2■	-	-		
	FRN0020E3□-2■	-	-		
	FRN0030E3□-2■	-	-	FN3258T-75-34	FN3258T-75-34
	FRN0040E3□-2■	-	-	FN3258T-100-35	FN3258T-75-34
	FRN0056E3□-2■	-	-		FN3258T-100-35
	FRN0069E3□-2■	-	-		
	FRN0088E3□-2■	-	-	EFL-22SP-2 (*1) FS5536-180-40	EFL-22SP-2 (*1)
	FRN0115E3□-2■	-	-		
Three-phase 400 V	FRN0002E3□-4■	B84243A8017W221	B84243A8017W221	B84243A8017W221	B84243A8017W221
	FRN0004E3□-4■				
	FRN0006E3□-4■				
	FRN0007E3□-4■				
	FRN0012E3□-4■				
	FRN0022E3□-4■	FS21312-44-07	FS21559-24-07-1	FS21559-24-07-1	FS21559-24-07-1
	FRN0029E3□-4■		FS21312-44-07	FS21312-44-07	
	FRN0037E3□-4■	FS5536-72-07			FS21312-44-07
	FRN0044E3□-4■		FS5536-72-07	FS5536-72-07	
	FRN0059E3□-4■	FS21312-78-07			FS5536-72-07
	FRN0072E3□-4■	FS5536-100-35 (*1)	FS21312-78-07	FS21312-78-07	
Single-phase 200 V	FRN0001E3□-7■	-	-	FS34916-10-07	FS34916-10-07
	FRN0002E3□-7■	-	-		
	FRN0004E3□-7■	-	-		
	FRN0006E3□-7■	-	-	FS34916-17-07	
	FRN0010E3□-7■	-	-	FS34916-25-07	FS34916-17-07
	FRN0012E3□-7■	-	-	FN2410-60-34	FS34916-25-07

*1) If a ferrite core (ACL-40C or ACL-74C) is added for input power wires and grounding wire (1 turns), conforms category C3 for radiated emission of IEC61800-3.

Note: A box (□) in the above table replaces S (Basic type) or T (Finless type) or N (Ethernet built-in type) depending on the enclosure. A box (■) in the above table replaces G, C or K depending on the model.

■ Recommended installation method

To make the machinery or equipment fully compliant with the EMC Directive, certified technicians should install and wire the motor and inverter in strict accordance with the procedure described below.

EMC-compliant filter (option) installation method

1) Mount the inverter and the filter on a grounded panel or metal plate. Use shielded wires for the motor cable and route the cable as short as possible. Firmly clamp the shields to the metal plate to ground them. Furthermore, connect shields and motor grounding terminals electrically. Use a wiring guide, etc., and try as best as possible to keep input wires and output wires separate from one another.
2) For connection to inverter's control terminals and for connection of the RS-485 communication signal cable, use shielded wires. As with the motor connections, clamp the shields firmly to a grounded panel.
3) If noise from the inverter exceeds the permissible level, enclose the inverter and its peripherals within a metal panel as shown in Fig. F.1-1.

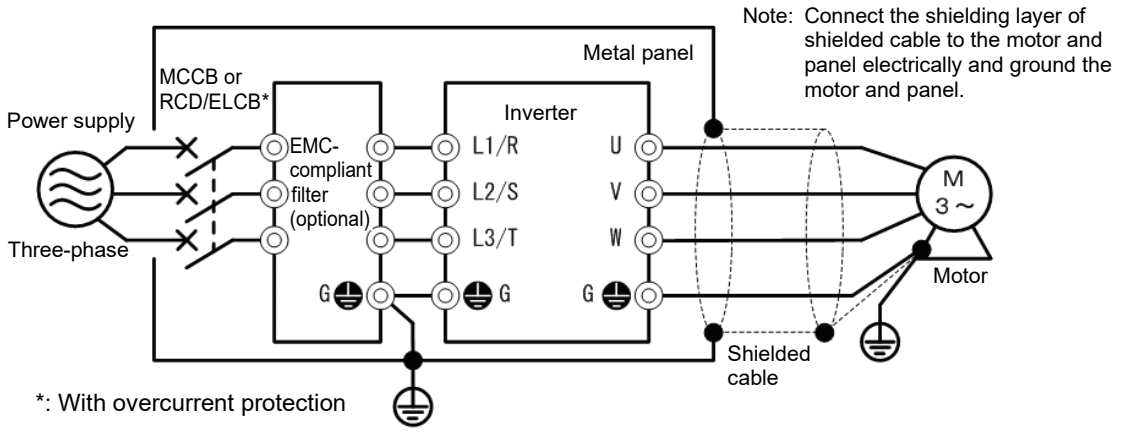


Fig. F.1-1 EMC-compliant filter (option) installation method

In case of EMC filter built-in type inverter

1) Mount the inverter on a grounded panel or metal plate. Use shielded wires for the motor cable and route the cable as short as possible. Firmly clamp the shields to the metal plate to ground them. Further, connect the shielding layers electrically to the grounding terminal of the motor. Use a wiring guide, etc., and try as best as possible to keep input wires and output wires separate from one another.
2) For connection to inverter's control terminals and for connection of the RS-485 communication signal cable, use shielded wires. As with the motor connections, clamp the shields firmly to a grounded panel.
3) If noise from the inverter exceeds the permissible level, enclose the inverter and its peripherals within a metal panel as shown in Fig. F.1-2.

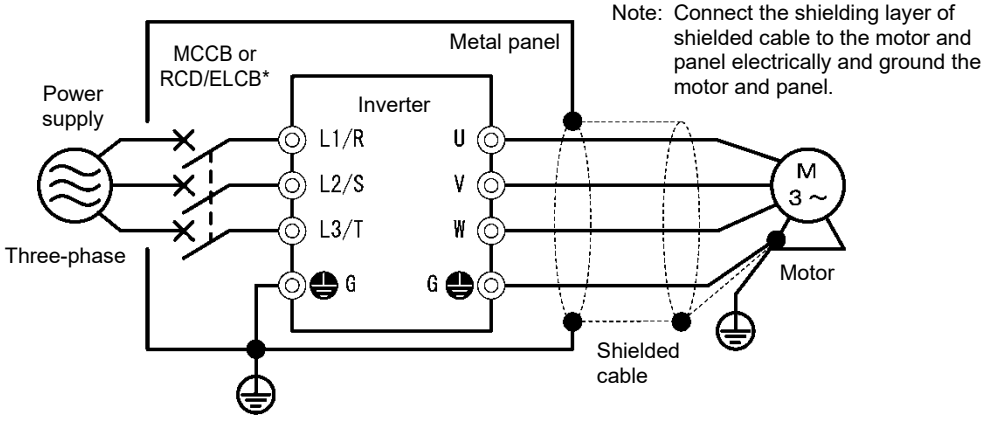


Fig. F.1-2 Installation method for built-in type EMC-compliant filter

For inverters with a capacity of FRN0059E3E-4 to FRN0072E3E-4 with carrier frequency above 8 kHz, add a core ACL-74C 2 turns at input cable

■ Leakage current of EMC-filter built-in type inverters

An EMC filter uses grounding capacitors for noise suppression. The use of grounding capacitors leads to an increase in leakage current, and therefore a check should be carried out to ensure that the power supply system has not been affected.

⚠CAUTION⚠

As the touch current (leakage current) of EMC filter built-in type inverters is relatively high, it is of essential importance to always assure a reliable connection to Protective Earth (PE). In Table G.1-3, for the inverter types whose leakage currents are equal to or exceed the critical value of 3.5 mA AC or 10 mA DC (IEC 61800-5-1), the minimum cross-sectional area of the PE-conductor should be:

- 10 mm^2 (Cu-conductors)
- 16 mm^2 (Al-conductors)

Failure to observe this could result in electric shock.

Table F.1-3 Leakage Current of EMC Filter Built-in Type of Inverters

Power supply voltage	Inverter type	Leakage current (mA)
Three-phase 400V *1)	FRN0002E3E-4G	2.3
	FRN0004E3E-4G	
	FRN0006E3E-4G	5.5
	FRN0007E3E-4G	
	FRN0012E3E-4G	
	FRN0022E3E-4G	11.7
	FRN0029E3E-4G	
	FRN0037E3E-4G	22.3
	FRN0044E3E-4G	
	FRN0059E3E-4G	5
	FRN0072E3E-4G	

Power supply voltage	Inverter type	Leakage current (mA)
Single-phase 200V *2)	FRN0001E3E-7G	8.7
	FRN0002E3E-7G	
	FRN0003E3E-7G	
	FRN0005E3E-7G	
	FRN0008E3E-7G	7.8
	FRN0011E3E-7G	

*1) Calculated based on these measuring conditions: 480 V/ 60 Hz, neutral grounding in Y-connection, interphase voltage unbalance ratio 2%.

*2) Calculated based on these measuring conditions: 240 V/ 60 Hz.

F.1.2 Compliance with European Low Voltage Directive

General-purpose inverters are subject to compliance with the European Low Voltage Directive. The CE marking on inverters represents a self-declaration that the product complies with the Low Voltage Directive.

■ Note

If using as a European Low Voltage Directive-compatible product, compatibility with Low Voltage Directive 2014/35/EU is achieved by installing the product as follows.

Compliance with European standards

Adjustable speed electrical power drive systems.

Part 5-1: Safety requirements. Electrical, thermal and energy EN61800-5-1

Compliance with European Low Voltage Directive

⚠WARNING⚠

1. Always ground the grounding terminal ⏚G, and do not attempt to provide electric shock protection simply with an earth leakage circuit breaker* (RCD (Residual-current-operated protective) or ELCB (Earth Leakage Circuit Breaker). Be sure to use ground wires whose size is greater than power lines.
   *With overcurrent protection function
2. This offers protection against the risk of high voltage or accidents that may result in inverter damage, and therefore a fuse of the specifications indicated in the following table must be installed on the power supply side.
   •Breaking capacity of 10 kA or higher, rated voltage of 500 V or lower

Power system	Standard applicable motor (kW)	Inverter type	Specification	Fuse rating (A)
Three-phase 200 V	0.1	FRN0001E3☐-2G	HHD	50(IEC 60269-4)
	0.2		HND	
		FRN0002E3☐-2G	HHD	50(IEC 60269-4)
	0.4		HND	
		FRN0004E3☐-2G	HHD	50(IEC 60269-4)
	0.75		HND	
		FRN0006E3☐-2G	HHD	50(IEC 60269-4)
	1.1		HND	
	1.5	FRN0010E3☐-2G	HHD	80(IEC 60269-4)
	2.2		HND	
		FRN0012E3☐-2G	HHD	125(IEC 60269-4)
	3.0		HND	
	3.7	FRN0020E3☐-2G	HHD	125(IEC 60269-4)
	5.5		HND	
		FRN0030E3△-2G	HHD	160(IEC 60269-4)
	7.5		HND	
		FRN0040E3△-2G	HHD	200(IEC 60269-4)
	11		HND	
		FRN0056E3△-2G	HHD	200(IEC 60269-4)
	15		HND	
		FRN0069E3△-2G	HHD	250(IEC 60269-4)
	18.5		HND	
		FRN0088E3△-2G	HHD	250(IEC 60269-4)
	22		HND	
		FRN0115E3△-2G	HHD	315(IEC 60269-4)
	30		HND	

Note) The ☐ in the inverter type is replaced by a letter of the alphabet (S, T, N) indicating the type.

Note) The △ in the inverter type is replaced by a letter of the alphabet (S, N) indicating the type.

(cont.)

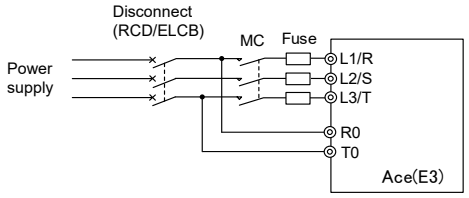
Compliance with European Low Voltage Directive (cont'd)

⚠WARNING⚠

Power system	Standard applicable motor (kW)	Inverter type	Specification	Fuse rating (A)
Three-phase 400 V	0.4	FRN0002E3□-4G	HHD	50(IEC 60269-4)
	0.75		HND	
			HD	
			ND	
	1.1	FRN0004E3□-4G	HHD	50(IEC 60269-4)
			HND	
	1.5		HD	
			ND	
	2.2	FRN0006E3□-4G	HHD	50(IEC 60269-4)
			HND	
			HD	
			ND	
	3.0	FRN0007E3□-4G	HHD	63(IEC 60269-4)
			HND	
			HD	
			ND	
	3.7	FRN0012E3□-4G	HHD	63(IEC 60269-4)
	5.5		HND	
			HD	
			ND	
	7.5	FRN0022E3△-4G	HHD	100(IEC 60269-4)
			HND	
			HD	
		FRN0029E3△-4G	HHD	125(IEC 60269-4)
	11	FRN0022E3△-4G	ND	100(IEC 60269-4)
		FRN0029E3△-4G	HND	125(IEC 60269-4)
			HD	
		FRN0037E3△-4G	HHD	125(IEC 60269-4)
	15	FRN0029E3△-4G	ND	125(IEC 60269-4)
		FRN0037E3△-4G	HND	160(IEC 60269-4)
			HD	
		FRN0044E3△-4G	HHD	160(IEC 60269-4)
	18.5	FRN0037E3△-4G	ND	125(IEC 60269-4)
		FRN0044E3△-4G	HND	160(IEC 60269-4)
			HD	
		FRN0059E3△-4G	HHD	160(IEC 60269-4)
	22	FRN0044E3△-4G	ND	160(IEC 60269-4)
		FRN0059E3△-4G	HND	160(IEC 60269-4) 160(IEC 60269-4)
			HD	
		FRN0072E3△-4G	HHD	200(IEC 60269-4)
	30	FRN0059E3△-4G	ND	160(IEC 60269-4)
		FRN0072E3△-4G	HND	200(IEC 60269-4)
			HD	
	37		ND	
Single-phase 200 V	0.1	FRN0001E3□-7G	HHD	50(IEC 60269-4)
	0.2	FRN0001E3■-7G	HND	
		FRN0002E3□-7G	HHD	50(IEC 60269-4)
	0.4	FRN0002E3■-7G	HND	
		FRN0004E3■-7G FRN0003E3E-7G	HHD	50(IEC 60269-4)
	0.55	FRN0004E3■-7G	HND	
	0.75	FRN0006E3■-7G FRN0005E3E-7G	HHD	80(IEC 60269-4)
	1.1	FRN0006E3■-7G	HND	
	1.5	FRN0010E3□-7G FRN0008E3E-7G	HHD	125(IEC 60269-4)
	2.2	FRN0010E3■-7G	HND	
		FRN0012E3■-7G FRN0011E3E-7G	HHD	125(IEC 60269-4)
	3.0	FRN0012E3■-7G	HND	

⚠WARNING⚠

Note) The ☐ in the inverter type is replaced by a letter of the alphabet (S, E, T, N) indicating the type.
Note) The △ in the inverter type is replaced by a letter of the alphabet (S, E, N) indicating the type.
Note) The ■ in the inverter type is replaced by a letter of the alphabet (S, T, N) indicating the type.



(cont.)

Compliance with European Low Voltage Directive (cont'd)

⚠WARNING⚠

3. When used with the inverter, a molded case circuit breaker (MCCB), residual-current-operated protective device (RCD)/earth leakage circuit breaker (ELCB) or magnetic contactor (MC) should conform to the EN or IEC standards.
4. When you use a residual-current-operated protective device (RCD)/earth leakage circuit breaker (ELCB) for protection from electric shock in direct or indirect contact power lines or nodes, be sure to install type B of RCD/ELCB on the input (primary) of the inverter.

Power system	Standard applicable motors	Inverter type	Specification	Molded case circuit breaker (MCCB) *1		Residual-current-operated device/earth leakage circuit breaker (RCD / ELCB) *1			
				Rated current		Rated current		Sensitivity current *2	Maximum fault loop impedance
				With DC reactor	Without DC reactor	With DC reactor	Without DC reactor		
Three-phase 200 V	0.1	FRN0001E3☐-2G	HHD	5	5	5	5	30mA	200Ω
	0.2		HND						
		FRN0002E3☐-2G	HHD						
	0.4		HND						
		FRN0004E3☐-2G	HHD						
	0.75		HND		10		10		
		FRN0006E3☐-2G	HHD						
	1.1		HND	10		10			
	1.5	FRN0010E3☐-2G	HHD		15		15		
	2.2		HND		20		20		
		FRN0012E3☐-2G	HHD						
	3.0		HND	20	30	20	30		
	3.7	FRN0020E3☐-2G	HHD						
			HND	30	40	30	40		
	5.5	FRN0030E3△-2G	HHD		50		50		
			HND	40	75	40	75		
	7.5	FRN0040E3△-2G	HHD						
			HND	50.	100	50	100		
	11	FRN0056E3△-2G	HHD						
			HND	75	125	75	125		
	15	FRN0069E3△-2G	HHD						
			HND	100	150	100	150		
	18.5	FRN0088E3△-2G	HHD						
			HND		175		175		
	22	FRN0115E3△-2G	HHD						
	30		HND	150	200	150	200		

Note) The ☐ in the inverter type is replaced by a letter of the alphabet (S, T, N) indicating the type.

Note) The △ in the inverter type is replaced by a letter of the alphabet (S, N) indicating the type.

*1 The frame size and model of the MCCB or RCD/ELCB (with overcurrent protection) will vary, depending on the power transformer capacity. Refer to the related technical documentation for details.

*2 Sensitivity current settings in the TT-system vary by country, so follow the instructions of the authorities.

(cont.)

Compliance with European Low Voltage Directive (cont'd)

⚠WARNING⚠

Power system	Standard applicable motors	Inverter type	Specification	Molded case circuit breaker (MCCB) *1		Residual-current-operated device/earth leakage circuit breaker (RCD / ELCB) *1			
				Rated current		Rated current		Sensitivity current *2	Maximum fault loop impedance
				With DC reactor	Without DC reactor	With DC reactor	Without DC reactor		
Three-phase 400 V	0.4	FRN0002E3□-4G	HHD	5	5	5	5	30mA	20Ω
	0.75		HND						
			HD						
			ND						
		FRN0004E3□-4G	HHD						
	1.1		HND						
			HD						
	1.5		ND						
		FRN0006E3□-4G	HHD		10		10		
	2.2		HND						
			HD						
			ND						
		FRN0007E3□-4G	HHD	10	15	10	15		
	3.0		HND						
			HD						
			ND						
	3.7	FRN0012E3□-4G	HHD		20		20		
	5.5		HND	15	30	15	30		
			HD						
			ND						
		FRN0022E3△-4G	HHD						
	7.5		HND	20	40	20	40		
			HD						
		FRN0029E3△-4G	HHD						
		FRN0022E3△-4G	ND						
	11	FRN0029E3△-4G	HND	30	50	30	50		
			HD						
		FRN0037E3△-4G	HHD						
		FRN0029E3△-4G	ND						
	15	FRN0037E3△-4G	HND	40	60	40	60		
			HD						
		FRN0044E3△-4G	HHD						
		FRN0037E3△-4G	ND						
	18.5	FRN0044E3△-4G	HND	40	75	40	75		
			HD						
		FRN0059E3△-4G	HHD						
		FRN0044E3△-4G	ND					100mA	
	22	FRN0059E3△-4G	HND	50	100	50	100		
			HD						
		FRN0072E3△-4G	HHD						
		FRN0059E3△-4G	ND						
	30	FRN0072E3△-4G	HND	75	125	75	125		
			HD						
	37		ND	100		100			
Single-phase 200 V	0.1	FRN0001E3□-7G	HHD	5	5	5	5	30mA	200Ω
	0.2	FRN0001E3■-7G	HND						
		FRN0002E3□-7G	HHD						
	0.4	FRN0002E3■-7G	HND		10		10		
		FRN0004E3■-7G FRN0003E3E-7G	HHD						
	0.55	FRN0004E3■-7G	HND	10		10			
	0.75	FRN0006E3■-7G FRN0005E3E-7G	HHD		15		15		
	1.1	FRN0006E3■-7G	HND	15	20	15	20		
	1.5	FRN0010E3■-7G FRN0008E3E-7G	HHD						
	2.2	FRN0010E3■-7G	HND	30	30	30	30		
		FRN0012E3■-7G FRN0011E3E-7G	HHD	20		20			
	3.0	FRN0012E3■-7G	HND	30	40	30	40		

⚠WARNING⚠

Note) The ☐ in the inverter type is replaced by a letter of the alphabet (S, E, T, N) indicating the type.

Note) The △ in the inverter type is replaced by a letter of the alphabet (S, E, N) indicating the type.

Note) The ■ in the inverter type is replaced by a letter of the alphabet (S, T, N) indicating the type.

*1 The frame size and model of the MCCB or RCD/ELCB (with overcurrent protection) will vary, depending on the power transformer capacity. Refer to the related technical documentation for details.

*2 Sensitivity current settings in the TT-system vary by country, so follow the instructions of the authorities.

(cont.)

Compliance with European Low Voltage Directive (cont'd)

⚠WARNING⚠

5. The inverter should be used in an environment that does not exceed Pollution Degree 2 requirements. If the environment has a Pollution Degree of 3 or 4, install the inverter in an enclosure of IP54 or higher.
6. Install the inverter, AC or DC reactor, input or output filter in an enclosure with a minimum degree of protection of IP2X, to prevent the human body from directly touching live parts of the equipment. The top surface of the enclosure shall be minimum IP4X if it can be easily touched.
7. Do not connect any copper wire directly to grounding terminals. Use crimp terminals with tin or equivalent plating to connect them.
8. When you use an inverter at an altitude of more than 2000 m, you should apply basic insulation for the control circuits of the inverter. The inverter cannot be used at altitudes of more than 3000 m.
9. Use the wiring shown in IEC60364-5-52.

Power system	Standard applicable motors	Inverter type	Specification	Molded-case circuit-breaker (MCCB) or earth leakage circuit breaker (RCD/ELCB) *1 Rated current		Recommended wire size (mm^2)					
						Main terminal				Control circuit	Control power auxiliary supply R0, T0
						Main power supply input [L1/R, L2/S, L3/T] Grounding for inverter [⏚] *3		Inverter output [U, V, W] *2	DC reactor connection [P1, P(+)] *2	Braking resistor connection [P(+), DB] *2	
				With DC reactor	Without DC reactor	With DC reactor	Without DC reactor				
Three-phase 200 V	0.1	FRN0001E3☐-2G	HHD	5	5	2.5	2.5	2.5	2.5	2.5	—
	0.2		HND								
	0.2	FRN0002E3☐-2G	HHD								
	0.4		HND								
	0.4	FRN0004E3☐-2G	HHD								
	0.75		HND		10						
	0.75	FRN0006E3☐-2G	HHD								
	1.1		HND		10						
	1.5	FRN0010E3☐-2G	HHD		15						
	2.2		HND		20						
	2.2	FRN0012E3☐-2G	HHD								
	3.7		HND	20	30		4				
	3.7	FRN0020E3☐-2G	HHD								
	5.5		HND	30	40		6		4	2.5	0.75
	5.5	FRN0030E3△-2G	HHD		50	4		4			
	7.5		HND	40	75	6	10	6	10		
	7.5	FRN0040E3△-2G	HHD								
	11		HND	50	100	10	16	10	16		
	11	FRN0056E3△-2G	HHD								
	15		HND	75	125	16	25	16	25		
	15	FRN0069E3△-2G	HHD								
	18.5		HND	100	150	25 (16)	35 (16)	25	35		2.5
	18.5	FRN0088E3△-2G	HHD								
	22		HND		175	35 (16)	50 (16)	35			
	22	FRN0115E3△-2G	HHD								
	30		HND	150	200	50 (25)	70 (35)	50	70		

Note) The ☐ in the inverter type is replaced by a letter of the alphabet (S, E, T, N) indicating the type.

Note) The △ in the inverter type is replaced by a letter of the alphabet (S, E, N) indicating the type.

*1 The frame size and type of a MCCB or RCD/ELCB (with overcurrent protection) vary with the capacity of the power supply transformer. Refer to the related technical documents for detailed selection.

*2 The recommended wire sizes for the main circuit terminals are shown for an ambient temperature of 40°C (104°F) using 70°C (158°F), 600 V PVC wire.

*3 Only one wire with a recommended size can be connected to a ground terminal.
The wire size in parentheses indicates the ground wire.

(cont.)

Compliance with European Low Voltage Directive (cont'd)

⚠WARNING⚠

Power system	Standard applicable motors	Inverter type	Specification	Molded-case circuit-breaker (MCCB) or earth leakage circuit breaker (RCD/ELCB) *1 Rated current		Recommended wire size (mm^2)						
						Main terminal				Control circuit	Control power auxiliary supply R0, T0
						Main power supply input [L1/R, L2/S, L3/T] Grounding for inverter [⏚] *3		Inverter output [U, V, W] *2	DC reactor connection [P1, P(+)] *2	Braking resistor connection [P(+), DB] *2	
				With DC reactor	Without DC reactor	With DC reactor	Without DC reactor				
Three-phase 400 V	0.4	FRN0002E3☐-4G	HHD	5	5	2.5	2.5	2.5	2.5	2.5	0.75	–
	0.75		HND									
			HD									
			ND									
	1.1	FRN0004E3☐-4G	HHD									
			HND									
			HD									
	1.5		ND									
	2.2	FRN0006E3☐-4G	HHD		10							
			HND									
			HD									
			ND									
	3.0	FRN0007E3☐-4G	HHD	10	15							
			HND									
			HD									
			ND									
	3.7	FRN0012E3☐-4G	HHD		20							
	5.5		HND	15	30							
			HD									
			ND									
	7.5	FRN0022E3△-4G	HHD	20	40		4					
			HND									
			HD									
	11		ND	30	50	4	6	4	4			
	7.5	FRN0029E3△-4G	HHD	20	40	2.5	4	2.5	2.5			
	11		HND	30	50	4	6	4	4			
			HD									
	15		ND	40	60	6	10	6	10			
		FRN0029E3E-4G					:6					
	11	FRN0037E3△-4G	HHD	30	50	4		4	4			
	15		HND	40	60	6	10	6	10			
			HD									
	18.5		ND		75	10	16	10				
		FRN0037E3E-4G					10					
	15	FRN0044E3△-4G	HHD		60	6	10	6				
	18.5		HND		75	10	16	10				
		FRN0044E3E-4G					10					
		FRN0044E3△-4G	HD				16					
		FRN0044E3E-4G					10					
	22	FRN0044E3△-4G	ND	50	100	10	16	10	16			
		FRN0044E3E-4G										
	18.5	FRN0059E3△-4G	HHD	40	75	16		16	10			2.5
	22		HND	50	100	10		10	16			
			HD									
	30		ND	75	125	16	25 (16)	16	25			
	22	FRN0072E3△-4G	HHD	50	100	10	16	10	16			
	30		HND	75	125	16	25 (16)	16	25			
			HD									
	37		ND	100		25 (16)	35	25				
Single-phase 200 V	0.1	FRN0001E3☐-7G	HHD	5	5	2.5	2.5	2.5	2.5	2.5	0.75	-
	0.2	FRN0001E3■-7G	HND									
		FRN0002E3☐-7G	HHD									
	0.4	FRN0002E3■-7G	HND		10							
		FRN0004E3☐-7G FRN0003E3E-7G	HHD									

⚠WARNING⚠

	0.55	FRN0004E3■-7G	HND	10	15							
	0.75	FRN0006E3□-7G FRN0005E3E-7G	HHD									
	1.1	FRN0006E3■-7G	HND	15	20							
	1.5	FRN0010E3□-7G FRN0008E3E-7G	HHD									
	2.2	FRN0010E3■-7G	HND	30	30		4		4			
		FRN0012E3□-7G FRN0011E3E-7G	HHD	20								
	3	FRN0012E3■-7G	HND	30	40	4			6			

Note) The □ in the inverter type is replaced by a letter of the alphabet (S, E, T, N) indicating the type.

Note) The △ in the inverter type is replaced by a letter of the alphabet (S, E, N) indicating the type.

Note) The ■ in the inverter type is replaced by a letter of the alphabet (S, T, N) indicating the type.

*1 The frame size and type of a MCCB or RCD/ELCB (with overcurrent protection) vary with the capacity of the power supply transformer. Refer to the related technical documents for detailed selection.

*2 The recommended wire sizes for the main circuit terminals are shown for an ambient temperature of 40°C (104°F) using 70°C (158°F), 600 V PVC wire.

*3 Only one wire with a recommended size can be connected to a ground terminal.
The wire size in parentheses indicates the ground wire.

(cont.)

Compliance with European Low Voltage Directive (cont'd)

⚠WARNING⚠

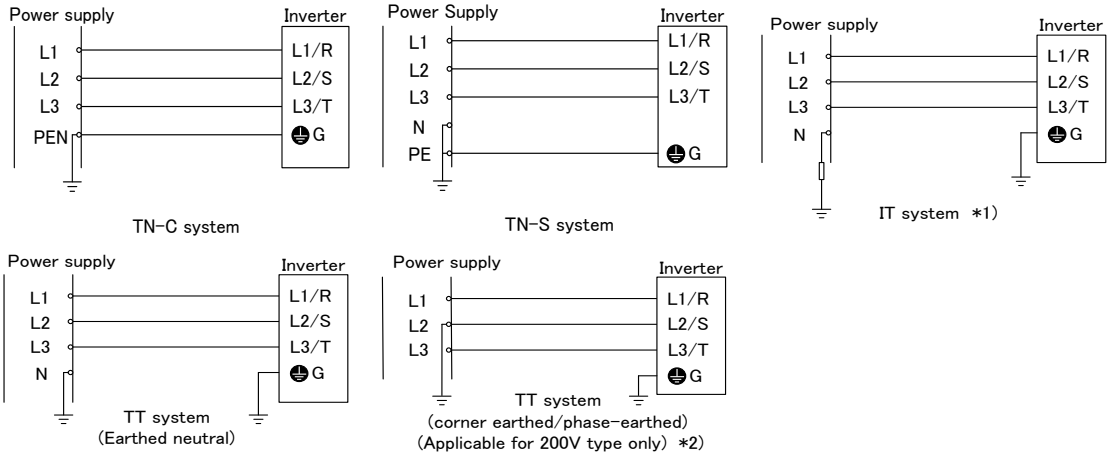
10. An IEC61800-5-1 5.2.3.6.3 Short-circuit Current Test has been carried out on this inverter under the following conditions.

    Current when shorted: 10,000 A

    240 V or less (200V series)

    480 V or less (400V series)

11. Use this inverter with the following power supply systems.



*1 Use this inverter with the following IT systems.

Non-earthed (isolated from earth) IT system	Can be used. In this case the insulation between the control interface and the main circuit of the inverter is basic insulation. Thus, do not connect SELV circuit from external controller directly. (Make connection using supplementary insulation.) Use an earth fault detector able to disconnect the power within 5s after the earth fault occurs.
IT system which earthed neutral by an impedance	
Corner earthed / Phase-earthed IT system by an impedance	Cannot be used.

*2 Cannot apply to Corner earthed / Phase-earthed TT system of 400V type

12. Motor overload protection (electronic thermal overload relay) is provided in each model. Use function codes F10 to F12 to set the protection level.

(Finished)

■ Compatibility with revised EMC and Low Voltage Directives

In the revised EMC Directive (2014/30/EU) and Low Voltage Directive (2014/35/EU), it is necessary to clearly state the name and the address of manufacturers and importers to enhance traceability. Importers shall be indicated as follows when exporting products from Fuji Electric to Europe.

(Manufacturer)
Fuji Electric Co., Ltd.
5520, Minami Tamagaki-cho, Suzuka-city, Mie 513-8633, Japan

(Importer in Europe)
Fuji Electric Europe GmbH
Goethering 58, 63067 Offenbach / Main, Germany

<Precaution when exporting to Europe>

- Not all Fuji Electric products in Europe are necessarily imported by the above importer. If any Fuji Electric products are exported to Europe via another importer, please ensure that the importer is clearly stated by the customer.

F.2 Harmonic component regulations in EU

F.2.1 General comments

When you use general-purpose industrial inverters in the EU, the harmonics emitted from the inverter to power lines are strictly regulated as stated below.

If an inverter whose rated input is 1 kW or less is connected to a public low-voltage power supply, it is regulated by the harmonics emission regulations from inverters to power lines (with the exception of industrial low-voltage power lines). (For details, refer to Fig. F.2-1.)

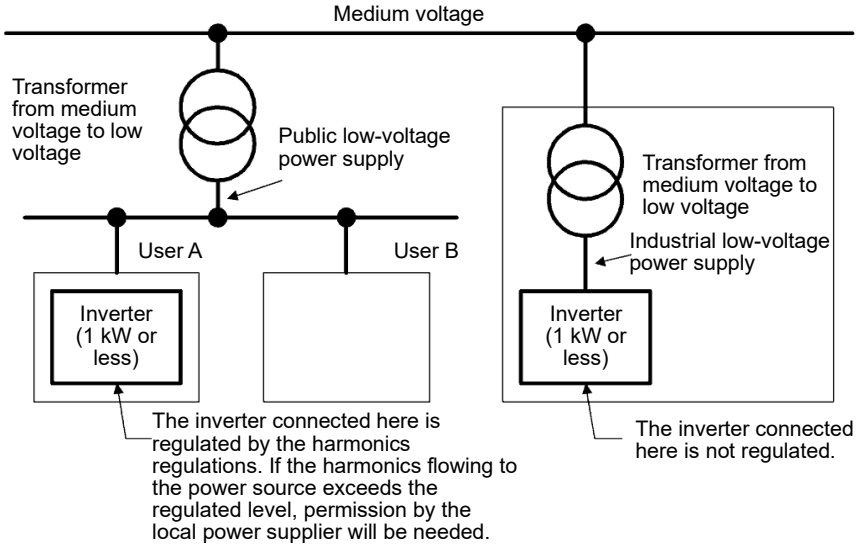


Fig. F.2-1 Power supply system

F.2.2 Compliance with harmonic component regulations

Table F.2-1 Compliance with harmonic component regulations

Power supply voltage	Inverter type	Applicable motor [kW]	ND/HD/HND/ HHD	w/o DCR	w/ DCR	Applicable DC reactor type
Three-phase 200 V	FRN0001E3☐-2G	0.1	HHD	Y *1	Y *1	DCR2-0.2
		0.2	HND	Y *1	Y *1	DCR2-0.2
	FRN0002E3☐-2G	0.2	HHD	Y *1	Y *1	DCR2-0.2
		0.4	HND	Y *1	Y *1	DCR2-0.4
	FRN0004E3☐-2G	0.4	HHD	Y *1	Y *1	DCR2-0.4
		0.75	HND	Y *1	Y *1	DCR2-0.75
	FRN0006E3☐-2G	0.75	HHD	Y *1	Y *1	DCR2-0.75
Three-phase 400 V	FRN0002E3☐-4G	0.4	HHD	x	Y	DCR4-0.4
		0.75	HND/HD/ND	x	Y	DCR4-0.75
	FRN0004E3□-4G	0.75	HHD	x	Y	DCR4-0.75
Single-phase 200 V(*1)	FRN0001E3☐-7G	0.1	HHD	x	x	DCR2-0.2
		0.2	HND	x	x	DCR2-0.4
	FRN0002E3☐-7G	0.2	HHD	x	x	DCR2-0.4
		0.4	HND	x	x	DCR2-0.75
	FRN0004E3△-7G FRN0003E3E-7G	0.4	HHD	x	x	DCR2-0.75
		0.55	HND	x	x	DCR2-0.75
	FRN0006E3△-7G FRN0005E3E-7G	0.75	HHD	x	x	DCR2-1.5

Note 1) Evaluated by the level of harmonics flow to the 400 VAC line when three-phase 200 VAC power is supplied from the three-phase 400 VAC power supply via a step-down transformer.

Note 2) A box (□) in the above table replaces S (Basic type) or T (Fin-less type) or N (Ethernet type) or E (EMC filter built-in type) depending on the enclosure.

A box (△) in the above table replaces S (Basic type) or T (Fin-less type) or N (Ethernet type) depending on the enclosure.

*1 FRN_____E3E-7G is only HHD specification.

F.3 Compliance with UL standards and Canadian standards (cUL certification)

F.3.1 General comments

UL standards (Underwriters Laboratories Inc. standards) are North American safety standards used to prevent fire and other such accidents, and offer protection to users, service technicians, and the general public.

cUL indicates that products which comply with CSA standards are certified by UL. cUL certified products are as valid as those certified as complying with CSA standards.

F.3.2 UL standards and Canadian standards (cUL certification) compatibility

Compatibility with UL standards (UL61800-5-10) and Canadian standards (cUL certification C22.2 No.274-17) is ensured by installing inverters with UL/cUL marking in accordance with the items in the following table.

UL standards and Canadian standards (cUL certification) compatibility

⚠WARNING⚠
High available fault current – damage warning: The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of fire or electric shock, current-carrying parts and other components of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced.

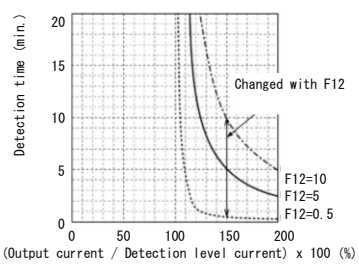
(cont.)

UL standards and Canadian standards (cUL certification) compatibility (cont'd)

⚠CAUTION

1. Motor overload protection (electronic thermal overload relay) is provided in each model.
   Use function codes F10 to F12 to set the protection level, referring to the descriptions below.

F10	Electronic thermal overload protection for motor 1 (Select motor characteristics)	Electronic thermal 1 (Motor protection) (Select motor characteristics)
	1: Enable (For a general-purpose motor with self-cooling fan) 2: Enable (For an inverter-driven motor with separately powered cooling fan)	1: Enable (For a general-purpose motor with self-cooling fan) 2: Enable (For an inverter-driven motor with separately powered cooling fan)
F11	(Overload detection level)	(Overload detection level)
	0.00 (disable), current value of 1 to 135% of inverter rated current (Inverter rated current dependent on F80)	0.00 (disable), current value of 1 to 135% of inverter rated current (Inverter rated current dependent on F80)
F12	(Thermal time constant)	(Thermal time constant)
	0.5 to 75.0 min, Refer to the graph below.	0.5 to 75.0 min



2. No terminal end treatment is required for connection.

3. Use Cu wire only.

4. Use R/C Appliance Wiring Material (AVLV2/8), rated min. 105˚C (221°F)/600V for control circuit if the control circuit wiring can touch the main circuit part.

5. Short circuit rating

   Suitable for use on a circuit delivering not more than 100,000 A, 240 Volts maximum for 200 V-series input when protected by semiconductor protection fuses having an interrupting rating not less than 100,000 A, 240 Volts maximum. Suitable for use on a circuit delivering not more than 100,000 A, 480 Volts maximum when protected by semiconductor protection fuses having an interrupting rating not less than 100,000 A, 480 Volts maximum."

   Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes.

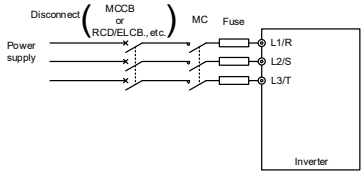
(cont.)

UL standards and Canadian standards (cUL certification) compatibility (cont'd)

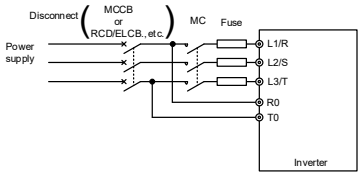
⚠CAUTION

6. Field wiring connections must be made by a UL Listed and CSA Certified closed-loop terminal connector sized for the wire gauge involved. Connector must be fixed using the crimp tool specified by the connector manufacturer.

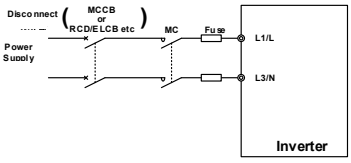
7. All circuits with terminals L1/R, L2/S, L3/T, L1/L, L2/N, R0, T0 must have a common disconnect and be connected to the same pole of the disconnect if the terminals are connected to the power supply.



FRN0069E3☐-2 or below
FRN0044E3☐-4 or below



FRN0088E3☐-2 or above
FRN0059E3☐-4 or above



Connection diagram of the single-phase input type.

8. Environmental Requirements

The table below applies to FRN△△△E3☐ -○.

(△ indicates inverter capacity, ☐: Indicates type※ ○: Indicates the series 2, 4, or 7.)

※☐ : S,T,N, or E △ : S,N, or E ■ : S,N, or T ▲ : S, or N

Type	Open type		Enclosed type	
	HHD °C (°F)	HND °C (°F)	HHD °C (°F)	HND °C (°F)
FRN0001E3■-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0002E3■-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0004E3■-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0006E3■-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0010E3■-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0012E3■-2	50 (122)	40 (104)	40 (104)	30 (86)
FRN0020E3■-2	50 (122)	40 (104)	40 (104)	30 (86)
FRN0030E3▲-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0040E3▲-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0056E3▲-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0069E3▲-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0088E3▲-2	50 (122)	50 (122)	40 (104)	40 (104)
FRN0115E3▲-2	50 (122)	50 (122)	40 (104)	40 (104)

Type	Open type				Enclosed type*			
	HHD °C (°F)	HND °C (°F)	HD °C (°F)	ND °C (°F)	HHD °C (°F)	HND °C (°F)	HD °C (°F)	ND °C (°F)
FRN0002E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0004E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0006E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0007E3☐-4	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)	30 (86)
FRN0012E3☐-4	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)	30 (86)
FRN0022E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0029E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0037E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0044E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0059E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)
FRN0072E3☐-4	50 (122)	50 (122)	40 (104)	40 (104)	40 (104)	40 (104)	30 (86)	30 (86)

	Open type		Enclosed type	
Type	HHD °C (°F)	HND °C (°F)	HHD °C (°F)	HND °C (°F)
FRN0001E3■-7	50 (122)	50 (122)	40 (104)	40 (104)
FRN0001E3E-7	50 (122)	-	-	-
FRN0002E3■-7	50 (122)	50 (122)	40 (104)	40 (104)
FRN0002E3E-7	50 (122)	-	-	-
FRN0004E3■-7	50 (122)	40 (104)	40 (104)	30 (86)
FRN0003E3E-7	50 (122)	-	-	-
FRN0006E3■-7	50 (122)	40 (104)	40 (104)	30 (86)
FRN0005E3E-7	50 (122)	-	-	-
FRN0010E3■-7	50 (122)	40 (104)	40 (104)	30 (86)
FRN0008E3E-7	50 (122)	-	-	-
FRN0012E3■-7	50 (122)	40 (104)	40 (104)	30 (86)
FRN0011E3E-7	50 (122)	-	-	-

・ Atmosphere: For use in pollution degree 2 environments. (for Open-type models)

* There is no Enclosed type for FRN△△△E3E-○.

(cont.)

UL standards and Canadian standards (cUL certification) compatibility (cont'd)

⚠CAUTION

9. Storage and Transport Environments

Item	Specifications	
Storage temperature	During transport: -25 to +70°C (-13 to +158°F)	Places not subjected to abrupt temperature changes or condensation or freezing
	During storage: -25 to +65°C (-13 to +153°F)	
Relative humidity	5 to 95% RH *1	
Atmosphere	The inverter must not be exposed to dust, direct sunlight, corrosive or flammable gases, oil mist, vapor, water drops or vibration. The atmosphere must contain only a low level of salt. (0.01 mg/cm^2 or less per year)	
Atmospheric pressure	86 to 106 kPa (during storage)	
	70 to 106 kPa (during transportation)	

*1 Even if the humidity is within the specified requirements, avoid such places where the inverter will be subjected to sudden changes in temperature that will cause condensation or freezing.

(cont.)

UL standards and Canadian standards (cUL certification) compatibility (cont'd)

⚠CAUTION

10. Install UL certified fuses between the power supply and the inverter, referring to the table below.

Power system	Standard applicable motor	Inverter type	HHD/HND mode	Semiconductor Protection Fuse Cat No. Manufacturer: Mersen/Bussmann(Eaton) *4	Required torque lb-in (N・m)			Wire size AWG (mm²)						
								Main terminal Cu Wire						
								L1/R, L2/S, L3/T L1/L, L2/N			U, V, W			
					Main terminal	Grounding	Control power auxiliary input	60°C (140°F) Cu Wire	75°C (167°F) Cu Wire	Remarks	60°C (140°F) Cu Wire	75°C (167°F) Cu Wire	Remarks	Control power auxiliary input
Three-phase 200V	0.1	FRN0001E3□-2	HHD	PC30UD69V50□/170M3458	7.1 (0.8)	10.6 (1.2)	—	14 (2.1)	14 (2.1)	*3	14 (2.1)	14 (2.1)	*3	—
			HND											
	0.2	FRN0002E3□-2	HHD	PC30UD69V50□/170M3458										
			HND											
	0.4	FRN0004E3□-2	HHD	PC30UD69V50□/170M3458										
			HND											
	0.75	FRN0006E3□-2	HHD	PC30UD69V50□/170M3460										
			HND											
	1.1	FRN0010E3□-2	HHD	PC30UD69V80□/170M3462	10.6 (1.2)	15.9 (1.8)								
	1.5		HND											
	2.2	FRN0012E3□-2	HHD	PC30UD69V125□/170M3462										
	3		HND					12 (3.3)	12 (3.3)					
	3.7	FRN0020E3□-2	HHD	PC30UD69V125□/170M3463				10 (5.3)	10 (5.3)		12 (3.3)	12 (3.3)		
			HND											
	5.5	FRN0030E3□-2	HHD	PC30UD69V160□/170M3464	27 (3.0)	27 (3.0)		8 (8.4)	8 (8.4)		10 (5.3)	10 (5.3)		
			HND					6 (13.3)			8 (8.4)	8 (8.4)		
	7.5	FRN0040E3□-2	HHD	PC30UD69V200□/170M3465										
			HND					4 (21.2)	6 (13.3)		6 (13.3)			
	11	FRN0056E3□-2	HHD	PC30UD69V200□/170M3465	51.3 (5.8)	51.3 (5.8)								
			HND					3 (26.7)	4 (21.2)		4 (21.2)	6 (13.3)		
	15	FRN0069E3□-2	HHD	PC30UD69V250□/170M3466										
			HND					1 (42.4)	3 (26.7)		3 (26.7)	4 (21.2)		14 (2.1) *1 *2
	18.5	FRN0088E3□-2	HHD	PC30UD69V250□/170M3466			10.6 (1.2)							
			HND					—	2 (33.6)	*2 *3	2 (33.6)	3 (26.7)		
	22	FRN0115E3□-2	HHD	PC30UD69V315□/170M3467										
	30		HND						2/0 (67.4)		—	2 (33.6)	*2 *3	

Note) Control circuit terminals tightening torque: 6.1 lb-in (0.7 N・m), Recommended wire size: AWG18 (0.8 mm²)

Note) □ is replaced by a letter of the alphabet indicating the inverter type and the fuse type.

*1 No terminal end treatment is required for connection.。

*2 Use 75°C (167°F) Cu wire only.。

*3 The wire size of UL Open Type and Enclosed Type are common. Please contact us if dedicated UL Open Type wire is necessary.

*4 The fuses listed are representative parts. Refer to additional material (INR-SI47-2587) for the alternative parts.

(cont.)

UL standards and Canadian standards (cUL certification) compatibility (cont'd)

⚠CAUTION

Power system	Standard applicable motor	Inverter type	HHD/HND/HD/ND mode	Semiconductor Protection Fuse Cat No. Manufacturer: Mersen/Bussmann(Eaton) *4	Required torque lb-in (N・m)			Wire size AWG (mm^2)						
								Main terminal Cu Wire						
								L1/R, L2/S, L3/T L1/L, L2/N			U, V, W			
					Main terminal	Control power auxiliary input	Grounding	60°C (140°F) Cu Wire	75°C (167°F)Cu Wire	Remarks	60°C (140°F) Cu Wire	75°C (167°F) Cu Wire	Remarks	Control power auxiliary input
Three-phase 400V	0.4	FRN0002E3☐-4	HHD/HND	PC30UD69V50☐ /170M3458	10.6 (1.2)	15.9 (1.8)	–	14(2.1)	14(2.1)	*3	14(2.1)	14(2.1)	*3	–
	0.75		HD/ND											
		FRN0004E3☐-4	HHD	PC30UD69V50☐ /170M3458										
	1.1		HND/HD											
	1.5		ND											
		FRN0006E3☐-4	HHD/HND	PC30UD69V50☐ /170M3459										
	2.2		HD/ND											
		FRN0007E3☐-4	HHD	PC30UD69V63☐ /170M3460										
	3		HND/HD/ND											
	3.7	FRN0012E3☐-4	HHD	PC30UD69V63☐ /170M3461										
	5.5		HND/HD/ND					12(3.3)	12(3.3)					
		FRN0022E3☐-4	HHD	PC30UD69V100☐ /170M3462	27 (3.0)	27 (3.0)								
	7.5		HND/HD					10(5.3)	10(5.3)		12(3.3)	12(3.3)		
	11		ND											
	7.5	FRN0029E3☐-4	HHD	PC30UD69V125☐ /170M3463				8(8.4)	8(8.4)		10(5.3)	10(5.3)		
	11		HND/HD											
	15		ND					6(13.3)						
	11	FRN0037E3☐-4	HHD	PC30UD69V125☐ /170M3464	51.3 (5.8)	51.3 (5.8)		8(8.4)						
	15		HND/HD								8(8.4)	8(8.4)		
	18.5		ND					6(13.3)	6(13.3)		6(13.3)	6(13.3)		
	15	FRN0044E3☐-4	HHD	PC30UD69V160☐ /170M3464					8(8.4)	*3	8(8.4)	8(8.4)	*3	
	18.5		HND/HD											
	22		ND					4(21.2)	6(13.3)		6 (13.3)	6(13.3)		
	18.5	FRN0059E3☐-4	HHD	PC30UD69V160☐ /170M3464			10.6 (1.2)	6(13.3)						14(2.1) *1 *2
	22		HND/HD					4(21.2)						
	30		ND					3(26.7)	4(21.2)		4(21.2)			
	22	FRN0072E3☐-4	HHD	PC30UD69V200☐ /170M3465				4(21.2)	6(13.3)		6(13.3)			
	30		HND/HD					3(26.7)	4(21.2)		4(21.2)			
	37		ND					2(33.6)	3(26.7)		3(26.7)	4(21.2)		
Three-phase 400V	5.5	FRN0022E3E-4	HHD	PC30UD69V100☐ /170M3462	INPUT 10.6 (1.2) Other 27(3.0)	INPUT 35.4 (4.0) Other 27(3.0)	–	12	12	*3	14	14	*3	–
	7.5		HND/HD					10	10		12	12		
	11		ND					8	8		10	10		
	7.5	FRN0029E3E-4	HHD	PC30UD69V125☐ /170M3463				10	10		12	12		
	11		HND/HD					8	8		10	10		
	15		ND					6						
	11	FRN0037E3E-4	HHD	PC30UD69V125☐ /170M3464	INPUT 15.9 (1.8) Other 27(3.0)	INPUT 35.4 (4.0) Other 27(3.0)		8						
	15		HND/HD						6		8	8		
	18.5		ND					6	8					
	15	FRN0044E3E-4	HHD	PC30UD69V160☐ /170M3464										
	18.5		HND/HD						6		6			
	22		ND					4						
Single-phase 200V	0.1	FRN0001E3☐-7 FRN0001E3E-7	HHD	PC30UD69V50☐ /170M3458	7.1 (0.8)	10.6 (1.2)	–	14(2.1)	14(2.1)	*3	14(2.1)	14(2.1)	*3	–
		FRN0001E3☐-7	HND											
	0.2	FRN0002E3☐-7 FRN0002E3E-7	HHD	PC30UD69V50☐ /170M3458										
		FRN0002E3☐-7	HND											
	0.4	FRN0004E3☐-7 FRN0003E3E-7	HHD	PC30UD69V50☐ /170M3459										
	0.55	FRN0004E3☐-7	HND											
	0.75	FRN0006E3☐-7 FRN0005E3E-7	HHD	PC30UD69V80☐ /170M3462										
	1.1	FRN0006E3☐-7	HND											
	1.5	FRN0010E3☐-7 FRN0008E3E-7	HHD	PC30UD69V125☐ /170M3463	10.6 (1.2)	15.9 (1.8)		12(3.3)	12(3.3)					
		FRN0010E3☐-7	HND											
	2.2	FRN0012E3☐-7 FRN0011E3E-7	HHD	PC30UD69V125☐ /170M3463				10(5.3)	10(5.3)					
	3	FRN0012E3☐-7	HND											

Note) Control circuit terminals tightening torque: 6.1 lb-in (0.7 N・m), Recommended wire size: AWG18 (0.8 mm^2)
Note) ☐ is replaced by a letter of the alphabet indicating the inverter type and the fuse type.
*1 No terminal end treatment is required for connection.
*2 Use 75°C (167°F) Cu wire only.
*3 The wire size of UL Open Type and Enclosed Type are common. Please contact us if dedicated UL Open Type wire is necessary.
*4 The fuses listed are representative parts. Refer to additional material (INR-SI47-2587) for the alternative parts.

(Finished)

F.4 Compliance with functional safety standards

F.4.1 General comments

With FRENIC-Ace Series, the motor coasts to a stop by turning OFF (opening) the connection between terminals [EN1] - [PLC] or [EN2] - [PLC]. This is a safe shutdown function (STO) of Cat. 0 (uncontrolled stop) specified in EN 60204-1 and complies with the functional safety standards.

When constructing a safety system, a safety shut-off device was required outside the inverter, but using Safe Torque Off (STO) eliminates the need for an external safety shut-off device.

Table F.4-1 Functional safety performance

EN ISO 13849-1		
	Category	3
	Performance level	e
	Average diagnostic coverage	Medium (DCavg)
	Response time	50 ms or less (Response time)
	Mean dangerous failure time for each channel	>62 years (MTTFd)
EN 61508-1 to -7 EN 61800-5-2		
	Safety function	Safe Torque Off (STO)
	Safety integrity level	SIL3
	Hardware fault tolerance	1 (HFT)
	Safe failure fraction	90 % or more (SFF)
	Average probability of failure of a hazardous function upon request for actuation	1.58E-05 (PFDavg)
	Mean frequency of hazardous failures [h^{-1}]	2.60E-09 (PFH)

⚠ WARNING ⚠

- Although the specified STO is used for IEC61800-5-2 for the output breaker-off function of this inverter, it does not completely shut off the power supply and the motor electrically. Therefore, depending on the application of the inverter, for the safety of the final user, for example, a mechanically locking brake and motor terminal protection to prevent electric shock are required.
- The output breaker-off function of this inverter does not completely shut off the power supply and the motor electrically. Therefore, turn off the power supply of the inverter securely and wait at least 5 minutes before wiring or maintenance work.
- For the PMSM (permanent magnet synchronous motor), voltage is generated at the terminal during coasting with the output shut-off function. Make sure that the PMSM is stopped securely before performing maintenance, inspection, and wiring.

Failure to observe this could result in electric shock.

Enable terminals, peripheral circuits and internal circuit configuration

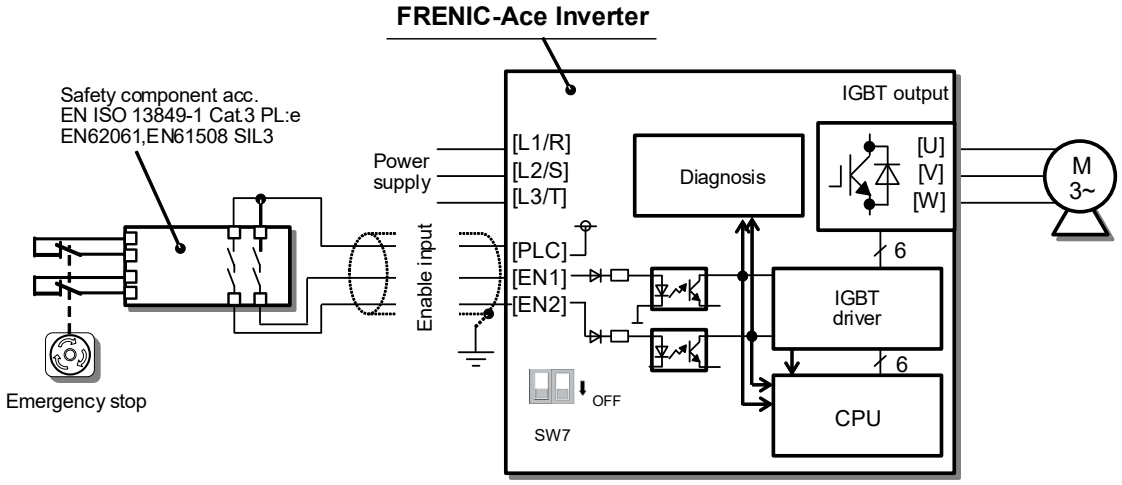


Fig. F.4-1 FRENIC-Ace

Note When the terminals [EN1] and [EN2] are used as functional safety, turn OFF both SW9 switches on the control PCB.

Table F.4-2 Terminals [EN1], [EN2]-[PLC] and inverter status

Digital input signal		ECF alarm*	Inverter status	Remarks
[EN1]	[EN2]			
ON (short circuit)	ON (short circuit)	None	Completion of operation preparation	
		Yes	Output shutdown (STO)	Logical mismatch detection*
OFF (open circuit)	OFF (open circuit)	None	Output shutdown (STO)	
		Yes	Output shutdown (STO)	Logical mismatch detection*
ON (short circuit)	OFF (open circuit)	Yes	Output shutdown (STO)	Logical mismatch detection*
OFF (open circuit)	ON (short circuit)	Yes	Output shutdown (STO)	Logical mismatch detection*

* For details, refer to F.4.4

F.4.2 Notes for compliance with functional safety standards

1) Safety requirements

All of the following requirements must be met in order to comply with functional safety.

1-1) Installation

- Turn off both SW9 switches on the control PCB.
- Install the inverter in a cabinet with a protective enclosure of IP54 or higher.
- Also comply with the European standards EN 61800-5-1 and EN 61800-3 for inverters or mechanical equipment.
- To ensure redundancy, wire the terminals [EN1] and [EN2] separately.
- For ON/OFF of terminals [EN1] and [EN2], use a safety component with EN ISO 13849-1 Cat.3 PL:e or higher.
- When using an external power supply, use a SELV power supply.

1-2) STO test

- Check that STO operates properly once every three months.

2) Notes for using STO

- When constructing a product safety system with STO, the machinery manufacturer is responsible for conducting a risk assessment of all machinery and equipment for the product safety system required by the machinery manufacturer, including other equipment, devices, and wires, as well as the external equipment and wires connected to the terminals [EN1] and [EN2], to ensure that all machinery and equipment conforms to that product safety system. Also, for preventive maintenance, be sure to perform periodic inspections to confirm that the product safety system operates properly.
- Input short pulses to terminal [EN1] and [EN2] for less than 1 ms when performing a diagnosis with the safety PLC.

  If a single fault is detected in the inverter, an alarm is output to the external device and the inverter coasts the motor to a stop even if the terminals [EN1] and [EN2] are ON. (The alarm outputting function is not guaranteed to be outputted with all single faults, but can be adapted to EN ISO 13849-1 Cat.3 PL:e.)
- The logical discrepancy due to the signal delay between the terminals [EN1] and [EN2] should be 50ms or less. Outputs an EtF alarm when it exceeds 50 ms.

3) Wiring for terminal [EN1], [EN2]

- The terminals [EN1] and [EN2] are used to wire the safety circuitry. Since reliability is obtained by connecting each signal independently, be careful not to short-circuit the signal in the middle of wiring. wiring.

F.4.3 Inverter output status when STO is activated

A STO condition occurs in the inverter when terminals [EN1] and [EN2] are turned OFF.

Fig. F.4-2 shows the inverter output status when terminals [EN1] and [EN2] are turned OFF while the inverter is stopped.

The inverter ready status will be complete when the terminal [EN1] and [EN2] inputs turn ON.

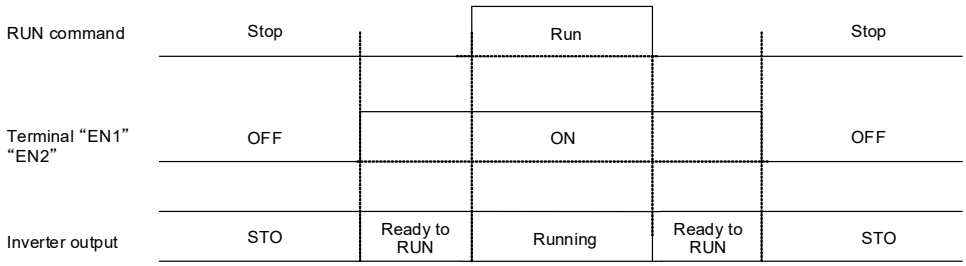


Fig. F.4-2 Inverter output status when terminals [EN1] and [EN2] are turned OFF while the inverter is stopped

Fig. F.4-3 shows the timing chart when terminals [EN1] and [EN2] are turned OFF while the inverter is running.

Input to terminals [EN1] and [EN2] turns OFF, the inverter enters the STO condition, and the motor coasts to a stop.

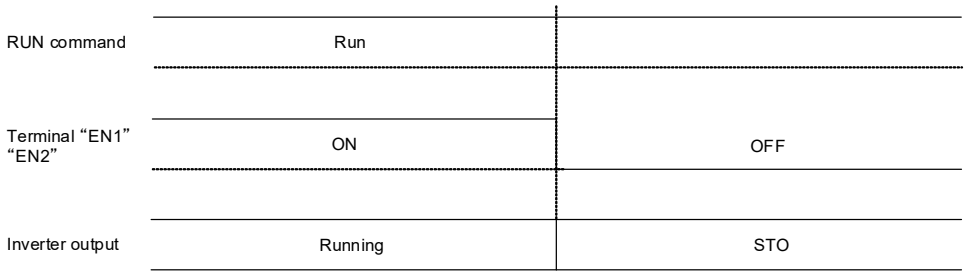


Fig. F.4-3 Inverter output status when terminals [EN1] and [EN2] are turned OFF during inverter operation

F.4.4 ECF alarm and inverter-output status

FRENIC-Ace monitors the logical discrepancy of the signal input to the terminals [EN1] and [EN2], and continuously diagnoses the failure of the safety circuit.

Fig. F.4-4 shows the timing chart for the ECF alarm following a terminal [EN1] or [EN2] input mismatch. A STO condition occurs in the inverter when terminals [EN1] and [EN2] are turned OFF. If the terminal [EN1] and [EN2] input mismatch lasts longer than 50 ms, the inverter will interpret that there is an abnormality with the safely system and output an ECF alarm.

To operate the EN terminal circuit correctly by operating the terminals [EN1] and [EN2], hold ON/OFF of [EN1] and [EN2] for 2 s or more. If they is not held for more than 2 s, an ECF alarm may occur.

In the event of an ECF alarm, it will be necessary to shut OFF the power supply or the alarm reset to cancel the safety status.

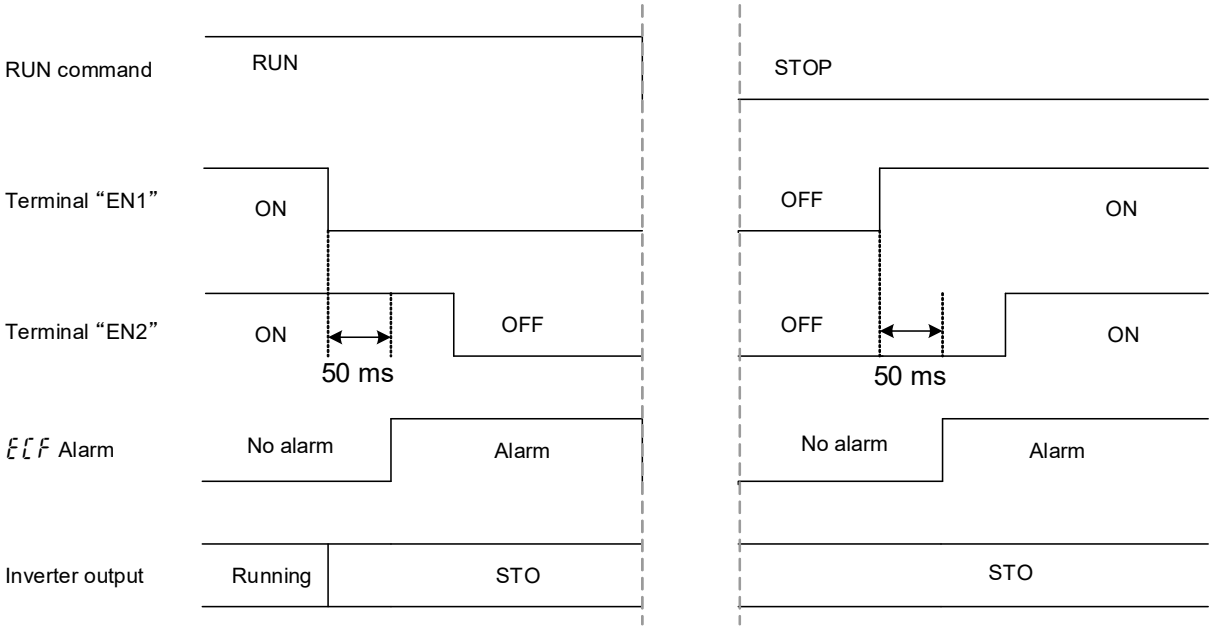


Fig. F.4-4 ECF alarm (logical mismatch) and inverter-output status

F.4.5 Precautions for releasing STO

If the terminals [EN1] and [EN2] are turned OFF during inverter operation, the inverter forcibly coasts to a stop.

After that, if [EN1] and [EN2] are turned ON with the operation command being input, the inverter restarts the output. Be careful when resetting the safety components. (Fig. F.4-5)

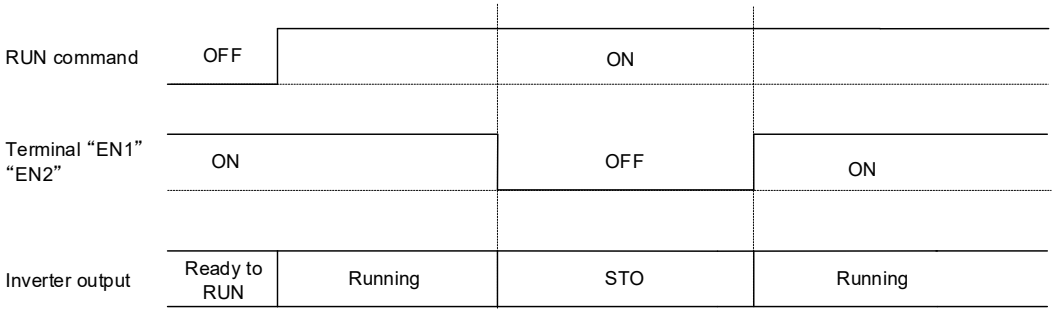


Fig. F.4-5 When STO is released

F.5 Compliance with the Radio Waves Act (South Korea)

한국 전파법 대응

사용자안내문

이 기기는 업무용 환경에서 사용할 목적으로 적합성평가를 받은 기기로서 가정용 환경에서 사용하는 경우 전파간섭의 우려가 있습니다.

으로 합니다. 해당제품은 형식FRN△△△E3S-□G, FRN△△△E3N-□G, FRN△△△E3T-□G, FRN△△△E3E-□G 의 제품만 대상이 됩니다.

(△는 인버터 ND 정격전류가 표기됩니다.)

(규격 표시 가 없는 제품은 적합 대상에서 제외됩니다.)

Compliance with the Radio Waves Act (South Korea)

User guidance

This product has undergone a conformity assessment for the purpose of use in a work environment, and is intended for use in areas outside the home.

Only the following types of the products are applicable to this certification.

Type: FRN△△△E3S-□G, FRN△△△E3N-□G, FRN△△△E3T-□G, FRN△△△E3E-□G

(△ indicates inverter capacity and the number 2 or 4 or 7 is placed in □ to indicate the series.)

(Products without standard indication are not applicable.)

Applicant: Fuji Electric Korea
Equipment Name: Inverter
Country of Origin: Described on the nameplate
Date of Manufacture: Described on the nameplate
Manufacturer: Fuji Electric Co., Ltd.

Appendix G Precautions when Using Finless Type Inverters

Note We plan to launch the finless type inverter soon.
This content is subject to change without notice.

This is a finless type inverter that does not use cooling fins, which are the main heat-generating components of the inverter. The inverter can be installed more compactly if the user prepares an external cooling element to replace the cooling fins. However, be sure to install following the precautions in this appendix.
In order to comply with UL standards for machines and equipment incorporating this product, the conditions shown in “Conformity to H.n. UL standards” must be met.

G.1 Installation Environment

Install the finless type inverter in a location that meets the conditions listed in Chapter 1 “1.3.1 Operating environment.”

G.2 Check items when using finless type inverters

⚠CAUTION⚠

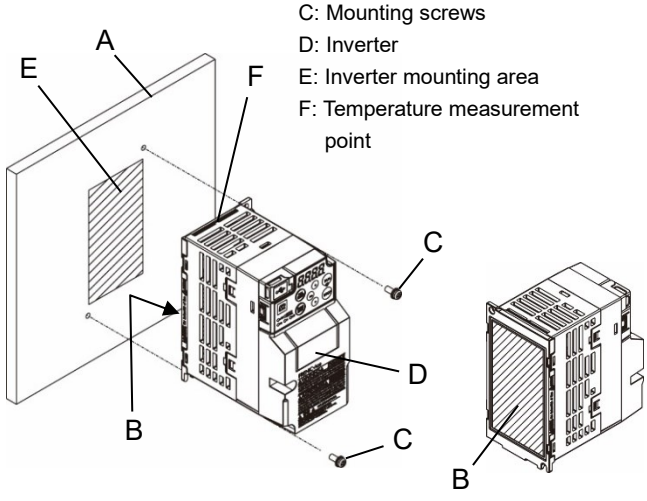
To prevent burns: Do not touch the inverter's heat sink or external cooling element. It is recommended that a high temperature caution mark or warning label be displayed on the external cooling element. The inverter's heat sink and external cooling element become hot, which may cause burns.

G.2.1 Inverter installation method

Step	Check item	Description	Remarks
1	Installation Environment	Ensure that the ambient temperature is below the specifications.	-
2	Inverter mode	Check the rating modes (HHD/HND) to be set.	-
3	Temperature of Part F	Check the allowable temperature of Part F and use the product at or below that temperature. Measure the temperature of Part F with a thermocouple, etc. A simple method to check the temperature without thermocouples is shown in the Remarks section. For the allowable temperature values, refer to Table G.2-1.	1, Keypad 5_03: Part F maximum temperature 5_25: Part F temperature (real-time value)
			2, Analog/pulse output F31 = 18: Part B temperature (10V/200°C(392°F))
4	Apply compound to the rear surface of Part B	Apply the recommended thermal compound. Remove any excess thermal compound.	Recommended manufacturer: Momentive Performance Materials Type: TIG2000 Coating thickness: 100~250μm
5	Surface roughness and flatness of Part E	Machining accuracy should be as indicated in the Remarks section.	Surface roughness: Rz≦25 s（Ra≦6.3 a） Surface flatness: 0.1mm or less per 100mm
6	Tightening torque of Part C	Tighten according to the values in the Remarks section.	Screw size: M4, tightening torque: 1.8±0.2N · m

Table G.2-1 Allowable temperatures

Power system Type		Ambient temperature °C (°F)	Max. temperature °C (°F)	
			HHD	HND
Three-phase 200 V	FRN0001E3T-2G	35 (95)	95(203)	95(203)
	FRN0002E3T-2G		95(203)	94(201)
	FRN0004E3T-2G		95(203)	95(203)
	FRN0006E3T-2G		96(204)	96(204)
	FRN0010E3T-2G		70(158)	71(159)
	FRN0012E3T-2G		78(172)	70(158)
	FRN0020E3T-2G		82(179)	75(167)
Three-phase 400	FRN0002E3T-4G		85(185)	86(186)
	FRN0004E3T-4G		88(190)	90(194)
	FRN0006E3T-4G		98(208)	102(215)
	FRN0007E3T-4G		69(156)	65(149)
	FRN0012E3T-4G		85(185)	80(176)
Single-phase 200 V	FRN0001E3T-7G		94(201)	94(201)
	FRN0002E3T-7G		94(201)	93(199)
	FRN0004E3T-7G		96(204)	90(194)
	FRN0006E3T-7G		96(204)	96(204)
	FRN0010E3T-7G		69(156)	58(136)
	FRN0012E3T-7G		69(156)	57(134)



A: User mounting surface
B: Inverter mounting plate
C: Mounting screws
D: Inverter
E: Inverter mounting area
F: Temperature measurement point

Note *1 Extreme changes in the performance of the inverter's refrigerant (sudden temperature changes) during operation may reduce the life of the inverter.
*2 Do not use in an environment where condensation occurs.
*3 Be sure to confirm that the cooling element is functioning before inputting an operation command to the inverter.

G.2.2 Selecting inverter cooling elements

The finless type does not have a cooling mechanism in the inverter itself, so it is necessary to select a cooling element to cool the inverter. The formulas and parameters required for selection (calculations) are shown below. Please note that this is only basic information for selection of the inverter cooling element and is not a guarantee of performance. Please select an appropriate cooling element for the inverter based on your operating environment and conditions.

Table G.2-2 Calculations

Purpose	Description	Formula
To select an inverter cooling element	Calculate the thermal resistance **R3** of the inverter cooling element and prepare an equivalent cooling element.	**R3 = (T1-T2)/P-R1-R2**
To confirm use of inverter cooling element already installed	Calculate the allowable temperature **T1** and determine if the current inverter cooling element can be used.	**T1 = P · (R1+R2+R3)+T2**
Thermal resistance calculation for thermal compound	Calculate the thermal resistance **R2** of the thermal compound and use in the formula for selecting the inverter cooling element.	**R2 = t/(λ · S)**

Table G.2-3 Parameters for calculations

Parameter		FRN0001-0006E3T-2G FRN0001-0006E3T-7G	FRN0010-0012E3T-2G FRN0002-0007E3T-4G FRN0010E3T-7G	FRN0020E3T-2G FRN0012E3T-4G FRN0012E3T-7G
T1	Allowable temperature [°C]	For details, refer to Table G.2-1.		
T2	Inverter (cooling element) ambient temperature [°C]	User ambient temperature (within product specifications)		
P	Inverter heat generation [W]	For details, refer to Table G.2-4.		
R1	Thermal resistance of inverter mounting plate [K/W]	0.26	0.17	0.13
R2	Thermal resistance of thermal compound [K/W] (*)	0.01		
S	Surface area of inverter mounting plate [m^2]	0.0086	0.0154	0.0196
λ	Thermal conductivity index of thermal compound [W/(m・K)]	2.0		
t	Thickness of thermal compound [m]	0.0001(100μm)		

* Thermal resistance may differ when using thermal compounds other than those recommended by Fuji Electric. Please check the characteristic values of the thermal compound to be used and calculate the thermal resistance R2.

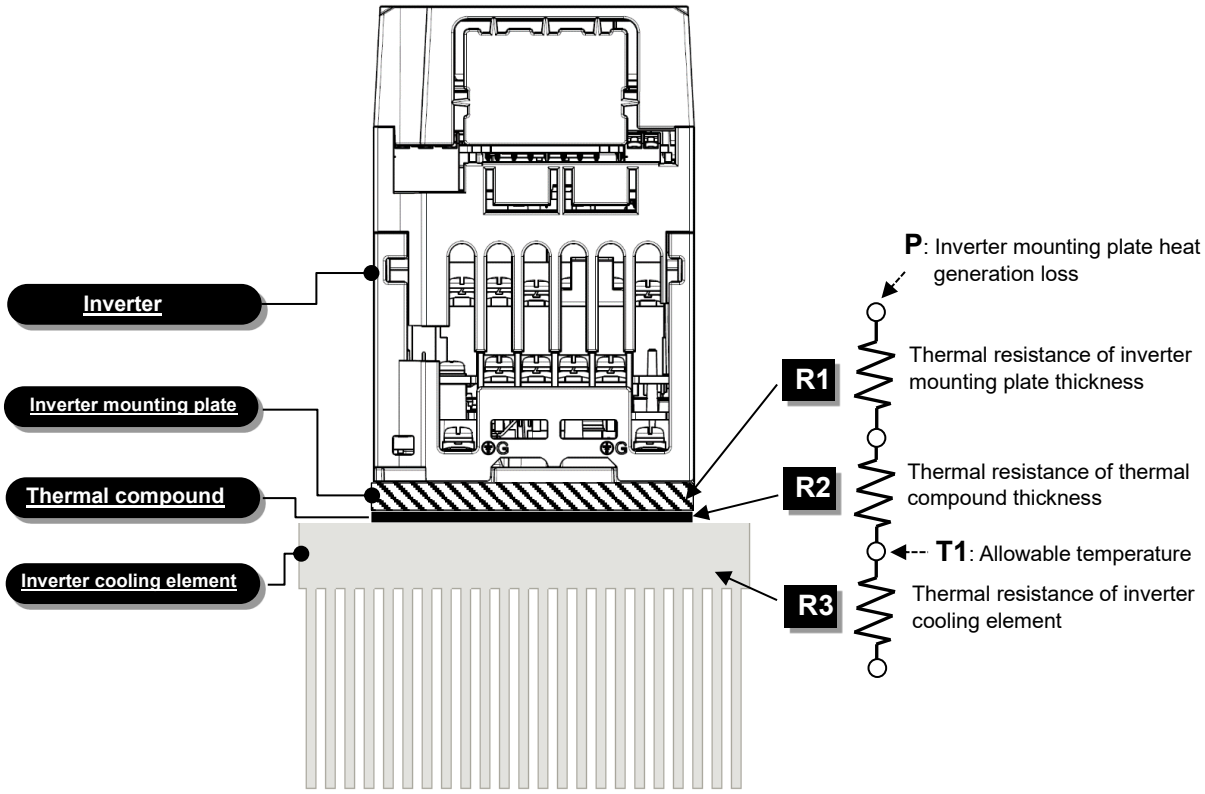


Fig. G.2-1 Names and positions of thermal resistance R1, 2, 3

Table G.2-4 P: Inverter heat generation (heat loss)

Power system	Inverter type	HHD specification							
		During high carrier frequency (Upper limit at which output current reduction is not required)				During low carrier frequency (Factory default value)			
		F26 Setting value [kHz]	Generated loss [W]			F26 Setting value [kHz]	Generated loss [W]		
			Unit interior	Inverter mounting plate	Total loss		Unit interior	Inverter mounting plate	Total loss
Three-phase 200 V	FRN0001E3T-2G	8	13	5	18	2	13	4	17
	FRN0002E3T-2G	8	16	9	25	2	16	7	23
	FRN0004E3T-2G	8	20	18	38	2	20	15	35
	FRN0006E3T-2G	8	30	28	58	2	30	24	54
	FRN0010E3T-2G	8	34	51	84	2	32	42	74
	FRN0012E3T-2G	8	42	68	111	2	41	57	98
	FRN0020E3T-2G	8	47	118	165	2	44	96	139
Three-phase 400 V	FRN0002E3T-4G	8	21	18	39	2	19	11	30
	FRN0004E3T-4G	8	23	30	53	2	21	19	40
	FRN0006E3T-4G	8	27	49	76	2	25	32	57
	FRN0007E3T-4G	8	38	66	103	2	34	45	79
	FRN0012E3T-4G	8	63	101	165	2	59	71	130
Single-phase 200 V	FRN0001E3T-7G	8	12	6	18	2	12	5	17
	FRN0002E3T-7G	8	14	10	25	2	14	9	23
	FRN0004E3T-7G	8	17	22	39	2	17	19	36
	FRN0006E3T-7G	8	22	38	60	2	22	33	55
	FRN0010E3T-7G	8	34	54	88	2	32	46	78
	FRN0012E3T-7G	8	38	79	116	2	35	65	100

Power system	Inverter type	HND specification							
		During high carrier frequency (Upper limit at which output current reduction is not required)				During low carrier frequency(Factory default value)			
		F26 Setting value [kHz]	Generated loss [W]			F26 Setting value [kHz]	Generated loss [W]		
			Unit interior	Inverter mounting plate	Total loss		Unit interior	Inverter mounting plate	Total loss
Three-phase 200 V	FRN0001E3T-2G	4	13	6	19	2	13	6	19
	FRN0002E3T-2G	4	18	11	29	2	18	11	29
	FRN0004E3T-2G	4	28	20	47	2	28	19	47
	FRN0006E3T-2G	4	34	32	67	2	34	32	66
	FRN0010E3T-2G	4	37	59	95	2	36	58	94
	FRN0012E3T-2G	4	43	73	117	2	43	72	115
	FRN0020E3T-2G	4	56	128	183	2	54	125	179
Three-phase 400 V	FRN0002E3T-4G	8	20	22	42	2	18	14	32
	FRN0004E3T-4G	8	27	39	66	2	25	25	50
	FRN0006E3T-4G	8	30	62	91	2	27	42	69
	FRN0007E3T-4G	4	33	66	99	2	32	63	95
	FRN0012E3T-4G	4	47	108	155	2	47	103	150
Single-phase 200 V	FRN0001E3T-7G	4	12	7	19	2	12	7	19
	FRN0002E3T-7G	4	14	15	29	2	14	15	29
	FRN0004E3T-7G	4	21	26	47	2	21	26	47
	FRN0006E3T-7G	4	19	47	67	2	19	47	66
	FRN0010E3T-7G	4	31	64	95	2	31	63	94
	FRN0012E3T-7G	4	35	82	117	2	35	80	115

Appendix H Inverter Replacement Precautions (When Using PWM Converter (RHC Series))

If using the RHC series and replacing the following inverters, it is necessary to change the connection method for the inverter control power auxiliary input terminals (R0, T0). The replaced inverter may not function normally if the connection method is not changed. Be sure to change the connection method.

H.1 Applicable inverters

Table H.1-1

Applicable inverter (before change)	Replacement inverter (after change)
<FRENIC5000G11S series> • FRN30G11S-2, FRN30P11S-2 inverter or higher • FRN30G11S-4, FRN30P11S-4 inverter or higher <FRENIC-VG7S series> • FRN18.5VG7S-2, FRN18.5VG7S-4 inverter or higher <FRENIC-MEGA series> • FRN G1	FRENIC-Ace series (FRENIC-MEGA series) (FRENIC-VG series) (FRENIC-Eco series) (FRENIC-Lift series)

H.2 Changing the connection method (inverter control power auxiliary input terminals (R0, T0))

(1) RHC series: if using ■ RHC7.5-2C to RHC90-2C, ■ RHC7.5-4C to RHC220-4C

Applicable inverter (before change) connection diagram

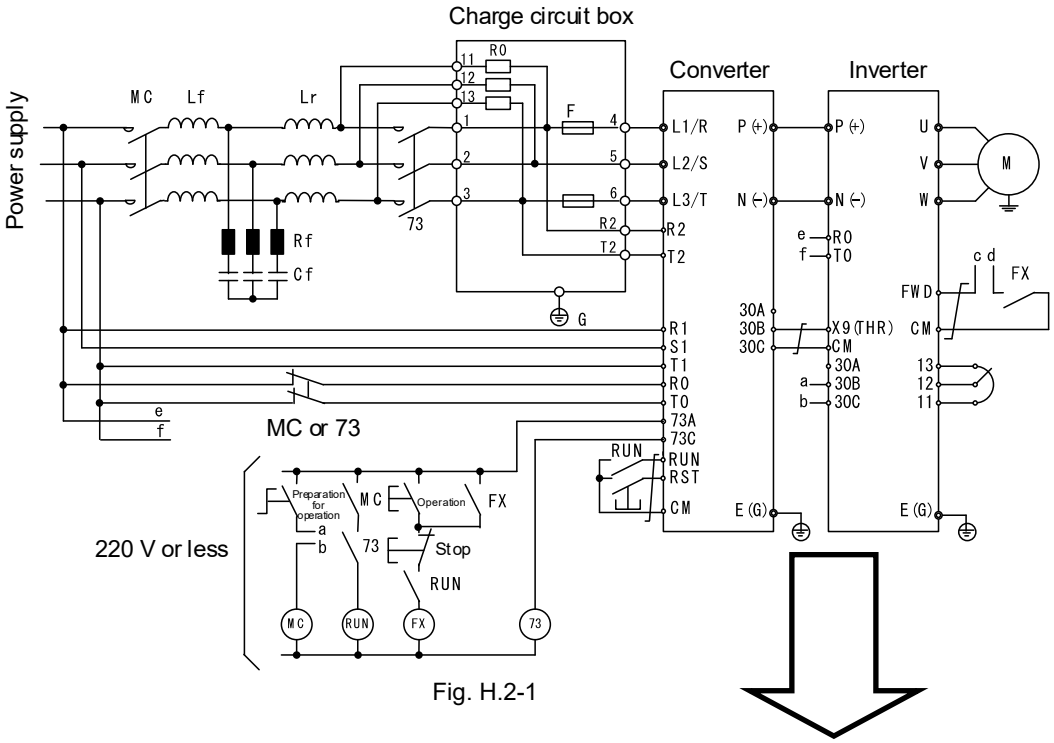


Fig. H.2-1

Replacement inverter (after change) connection diagram

Change the connections of the ⬚ sections.

1) Inverter control power auxiliary input terminals (R0, T0)
   Be sure to connect to the main power supply via contact b on the power supply circuit electromagnetic contactor (73 or MC).
2) Fan power auxiliary input terminals (R1, T1) * Only on models equipped with R1, T1 terminals
   Be sure to connect to the main power supply without going via contact b on the power supply circuit electromagnetic contactor (73 or MC).

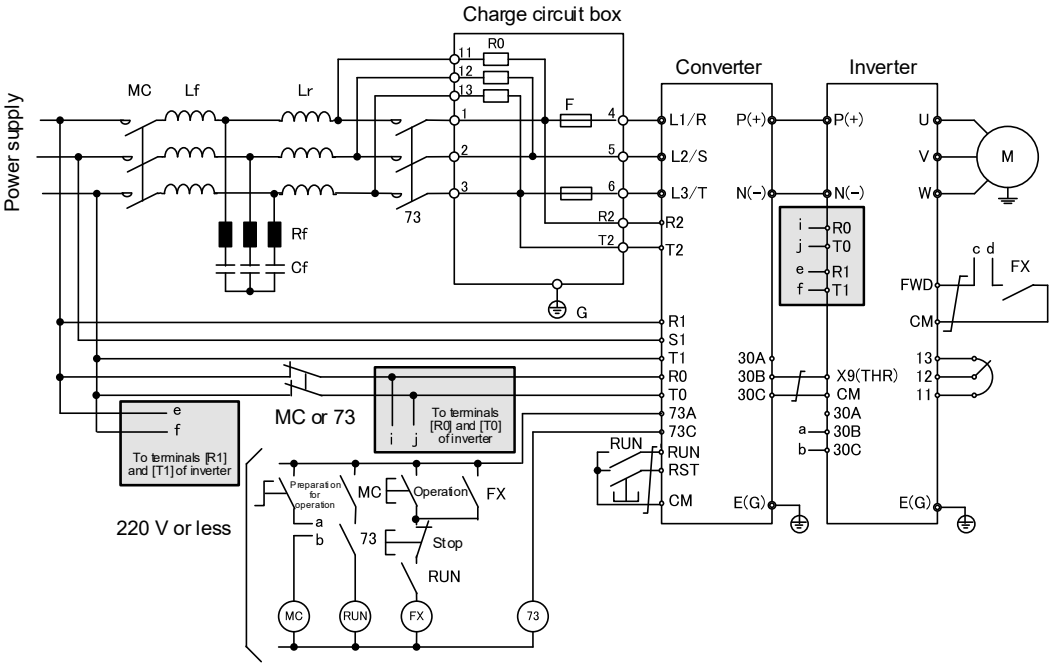


Fig. H.2-2

(2) RHC series: If using when ■ RHC280-4C to RHC630-4C, ■ RHC400-4C VT specifications apply
If using ■ RHC500B to RHC800B-4C

Applicable inverter (before change) connection diagram

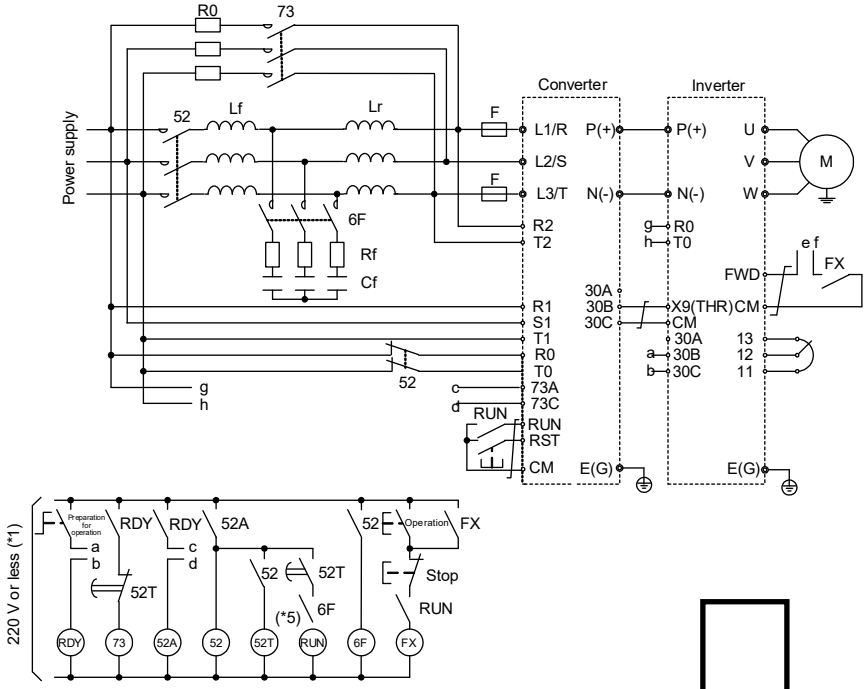


Fig. H.2-3

Replacement inverter (after change) connection diagram

Change the connections of the [ ] sections.

1) Inverter control power auxiliary input terminals (R0, T0)
Be sure to connect to the main power supply via contact b on the power supply circuit electromagnetic contactor (52).
2) Fan power auxiliary input terminals (R1, T1) * Only on models equipped with R1, T1 terminals
Be sure to connect to the main power supply without going via contact b on the power supply circuit electromagnetic contactor (73 or 52).

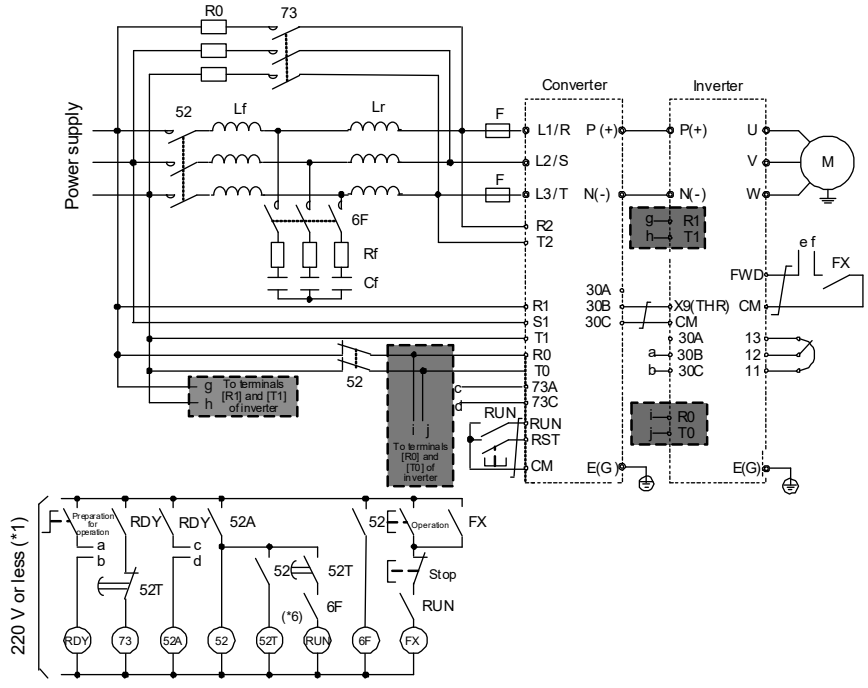


Fig. H.2-4

Appendix I Replacement Precautions (FRENIC-Multi (E1), FRENIC-Ace (E2))

Please refer to this appendix when replacing an existing model (FRENIC-Multi (E1), FRENIC-Ace (E2)) with the FRENIC-Ace (E3).

I.1 Comparison of external dimensions

The FRENIC-Ace (E3) has the same external dimensions as all capacities of the FRENIC-Ace (E2), so this section only compares the FRENIC-Ace (E3) with the FRENIC-Multi (E1).

The following explains how to read the comparison charts beginning on the next page.

- Installation area/Ace (E2) (%) The comparison between FRENIC-Ace (E3) and each model is shown with FRENIC-Ace (E3) as 100%.
  A value greater than 100% indicates that FRENIC-Ace (E3) is smaller.
- Volume/Ace (E2) (%) The comparison between FRENIC-Ace (E3) and each model is shown with FRENIC-Ace (E3) as 100%.
  A value greater than 100% indicates that FRENIC-Ace (E3) is smaller.
- The figures in grey-filled boxes in the FRENIC-Ace (E3) column ( ) indicate dimensions that are smaller than the corresponding dimensions for the FRENIC-Multi (E1).
- Underlined and bolded dimensions indicate that the FRENIC-Ace (E3) is larger.

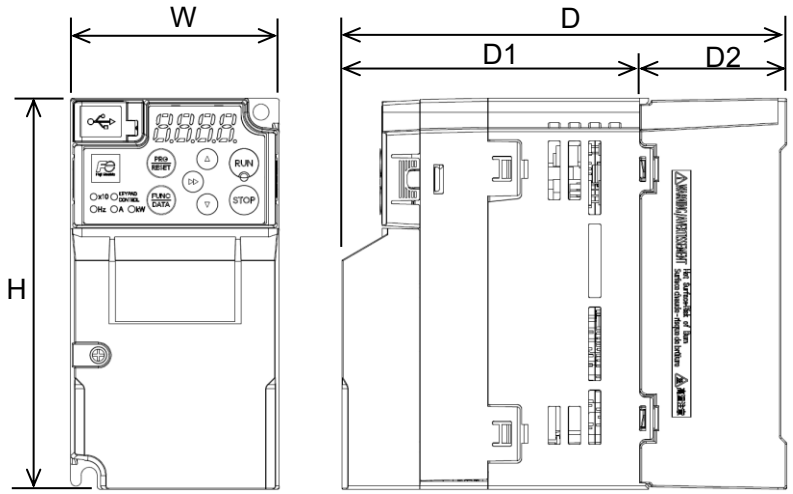


Fig. J-1

I.1.1 Standard specifications

FRENIC-Ace (E3S) HHD mode compared with FRENIC-Multi (E1S)

		FRENIC-Multi (E1S)									FRENIC-Ace (E3S)						
Power system	Standard applicable motor (kW) *1	External dimensions (mm)					Installation area		Volume		External dimensions (mm)					Installation area	Volume
		W	H	D	D1	D2	m^2 ($x10^{-2}$)	/Ace (%)	m^3 ($x10^{-3}$)	/Ace (%)	W	H	D	D1	D2	m^2 ($x10^{-2}$)	m^3 ($x10^{-3}$)
Three-phase 200 V	0.1	80	**120**	**92**	**82**	10	1.0	111%	0.9	80	68	127	98	90	8	0.9	0.8
	0.2	80	**120**	**92**	**82**	10	1.0	111%	0.9	80	68	127	98	90	8	0.9	0.8
	0.4	80	**120**	**107**	**82**	25	1.0	111%	1.0	80	68	127	113	90	23	0.9	1.0
	0.75	80	**120**	**132**	**82**	50	1.0	111%	1.3	80	68	127	145	97	48	0.9	1.3
	1.5	110	130	**150**	**86**	64	1.4	100%	**2.1**	110	110	130	156	98	58	1.4	2.2
	2.2	110	130	**150**	**86**	64	1.4	100%	**2.1**	110	110	130	156	98	58	1.4	2.2
	3.7	140	180	**151**	**87**	64	2.5	138%	3.8	140	140	130	156	98	58	1.8	2.8
	5.5	180	220	**158**	**81**	**77**	4.0	100%	**6.3**	180	180	220	171	83.3	87.7	4.0	6.8
	7.5	180	220	**158**	**81**	**77**	4.0	100%	**6.3**	180	180	220	171	83.3	87.7	4.0	6.8
	11	220	260	**195**	**98.5**	96.5	5.7	100%	**11.2**	220	220	260	203	113	90	5.7	11.6
	15	220	260	**195**	**98.5**	96.5	5.7	100%	**11.2**	220	220	260	203	113	90	5.7	11.6
	18.5	-	-	-	-	-	-	-	-	-	250	400	203	118	90	10.0	20.3
	22	-	-	-	-	-	-	-	-	-	250	400	203	118	90	10.0	20.3
Three-phase 400 V	0.4	110	130	**126**	**86**	40	1.4	100%	**1.8**	110	110	130	132	98	34	1.4	1.9
	0.75	110	130	**150**	**86**	64	1.4	100%	**2.1**	110	110	130	156	98	58	1.4	2.2
	1.5	110	130	**150**	**86**	64	1.4	100%	**2.1**	110	110	130	156	98	58	1.4	2.2
	2.2	110	130	**150**	**86**	64	1.4	100%	**2.1**	110	110	130	156	98	58	1.4	2.2
	3.7	140	180	**151**	**87**	64	2.5	138%	3.8	140	140	130	156	98	58	1.8	2.8
	5.5	180	220	**158**	**81**	**77**	4.0	100%	**6.3**	180	180	220	171	83.3	87.7	4.0	6.8
	7.5	180	220	**158**	**81**	**77**	4.0	100%	**6.3**	180	180	220	171	83.3	87.7	4.0	6.8
	11	220	260	**195**	**98.5**	96.5	5.7	100%	**11.2**	220	220	260	203	113	90	5.7	11.6
	15	220	260	**195**	**98.5**	96.5	5.7	100%	**11.2**	220	220	260	203	113	90	5.7	11.6
	18.5	-	-	-	-	-	-	-	-	-	250	400	203	118	90	10.0	20.3
	22	-	-	-	-	-	-	-	-	-	250	400	203	118	90	10.0	20.3
Single-phase 200 V	0.1	80	**120**	112	102	10	1.0	111%	1.1	80	68	127	98	90	8	0.9	0.8
	0.2	80	**120**	112	102	10	1.0	111%	1.1	80	68	127	98	90	8	0.9	0.8
	0.4	80	**120**	127	102	25	1.0	111%	1.2	80	68	127	120	97	23	0.9	1.0
	0.75	80	**120**	**152**	**102**	50	1.0	111%	1.5	80	68	127	165	117	48	0.9	1.4
	1.5	110	130	**160**	**96**	64	1.4	100%	**2.3**	110	110	130	166	108	58	1.4	2.4
	2.2	140	180	**151**	**87**	64	2.5	138%	3.8	140	140	130	156	98	58	1.8	2.8

*1 Standard applicable motor of FRENIC-Ace(E3S) is HHD mode.

FRENIC-Ace (E3E) HHD mode compared with FRENIC-Multi(E1E)

		FRENIC-Multi (E1E)									FRENIC-Ace (E3E)						
Power system	Standard applicable motor (kW) *1	External dimensions (mm)					Installation area		Volume		External dimensions (mm)					Installation area	Volume
		W	H	D	D1	D2	m^2 ($x10^{-2}$)	/Ace (%)	m^3 ($x10^{-3}$)	/Ace (%)	W	H	D	D1	D2	m^2 ($x10^{-2}$)	m^3 ($x10^{-3}$)
Three-phase 400 V	0.4	110	130	**169**	**129**	**40**	1.5	100%	**2.5**	96%	110	130	175	154	58	1.5	2.6
	0.75	110	130	**193**	**129**	64	1.5	100%	**2.8**	97%	110	130	199	154	58	1.5	2.9
	1.5	140	180	**194**	**130**	64	2.6	137%	4.9	126%	140	130	212	154	58	1.9	3.9
	2.2	140	180	**194**	**130**	64	2.6	137%	4.9	126%	140	130	212	154	58	1.9	3.9
	3.7	140	180	**194**	**130**	64	2.6	137%	4.9	126%	140	130	212	154	58	1.9	3.9
	5.5	181.5	285	**208**	-	**-**	5.2	100%	**10.8**	94%	181.5	285	221	-	50	5.2	11.4
	7.5	181.5	285	**208**	-	**-**	5.2	100%	**10.8**	94%	181.5	285	221	-	50	5.2	11.4
	11	220	332	**250**	-	-	7.4	100%	**18.3**	97%	220	332	258	-	55	7.4	18.9
	15	220	332	**250**	-	-	7.4	100%	**18.3**	97%	220	332	258	-	55	7.4	18.9
	18.5	-	-	-	-	-	-	-	-	-	250	400	203	-	90	10	20.3
	22	-	-	-	-	-	-	-	-	-	250	400	203	-	90	10	20.3
Single-phase 200 V	0.1	80	**120**	**112**	102	10	1.0	111%	1.1	100%	68	127	125	97	8	0.9	1.1
	0.2	80	**120**	**112**	102	10	1.0	111%	1.1	100%	68	127	125	97	8	0.9	1.1
	0.4	80	**120**	**127**	102	25	1.0	111%	1.3	100%	68	127	140	97	23	0.9	1.3
	0.75	110	130	150	110	40	1.5	100%	2.2	105%	110	130	142	108	34	1.5	2.1
	1.5	140	180	**194**	**130**	64	2.6	137%	4.9	126%	140	130	212	154	58	1.9	3.9
	2.2	140	180	**194**	**130**	64	2.6	137%	4.9	126%	140	130	212	154	58	1.9	3.9

*1 Standard applicable motor of FRENIC-Ace(E3E) is HHD mode.

I.1.2 Mounting dimensions

Compared with FRENIC-Multi (E1S)

Power system	Standard applicable motor (kW) *1	FRENIC-Multi (E1S)			FRENIC-Ace (E3S)		
		Mounting dimensions(mm)	Mounting dimensions(mm)	Mounting dimensions(mm)	Mounting dimensions(mm)	Mounting dimensions(mm)	Mounting dimensions(mm)
		W1	H1	Φ	W1	H1	Φ
Three-phase 200 V	0.1	67	110	6	56	118	5.2
	0.2						
	0.4						
	0.75						
	1.5	97	118	7	96.5	118	5.2 x 6.7 (oblong hole)
	2.2						
	3.7	128	168	5	128	118	5.2
	5.5	164	205	6	164	205	6
	7.5						
	11	196	238	10	196	238	10
	15						
	18.5	-	-	-	226	378	10
	22	-	-	-			
Three-phase 400 V	0.4	97	118	7	96.5	118	5.2 x 6.7 (oblong hole)
	0.75						
	1.5						
	2.2						
	3.7	128	168	5	128	118	5.2
	5.5	164	205	6	164	205	6
	7.5						
	11	196	238	10	196	238	10
	15						
	18.5	-	-	-	226	378	10
	22	-	-	-			
Single-phase 200 V	0.1	67	110	6	56	118	5.2
	0.2						
	0.4						
	0.75						
	1.5	97	118	7	96.5	118	5.2 x 6.7 (oblong hole)
	2.2	128	168	5	128	118	5.2

*1 Standard applicable motor of FRENIC-Ace(E3S) is HHD mode.

* Mounting holes are 5.2 x 6.7 mm oblong holes. The mounting pitch is compatible with Multi and Ace E2.

Compared with FRENIC-Multi (E1E)

Note In case of EMC filter built-in type inverter

Power system	Standard applicable motor (kW) *1	FRENIC-Multi(E1E)			FRENIC-Ace(E3E)		
		Installation dimensions(mm)	Installation dimensions(mm)	Installation dimensions(mm)	Installation dimensions(mm)	Installation dimensions(mm)	Installation dimensions(mm)
		W1	H1	Φ	W1	H1	Φ
Three-phase 400 V	0.4	97	118	7	96.5	118	5.2 x 6.7
	0.75						
	1.5	128	168	5	128	118	5.2
	2.2						
	3.7						
	5.5	164	205	6	150	256.5	6.5
	7.5						
	11	196	238	10	180	302.5	8.4
	15						
	18.5	-	-	-	226	378	10
	22	-	-	-			
Single-phase 200 V	0.1	67	110	6	56	118	5.2
	0.2						
	0.4						
	0.75	97	118	7	96.5	118	5.2 x 5.5
	1.5	128	168	5	128	118	5.2
	2.2						

*1 Standard applicable motor of FRENIC-Ace(E3E) is HHD mode.

I.2 Terminal arrangement and terminal symbols

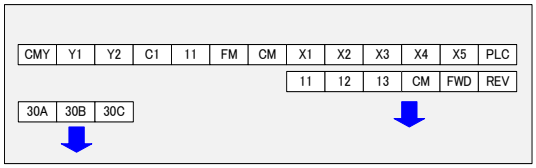
The following table shows the corresponding terminal arrangements and terminal symbols for interchangeable models.

■ Comparison of control circuit terminal block arrangement

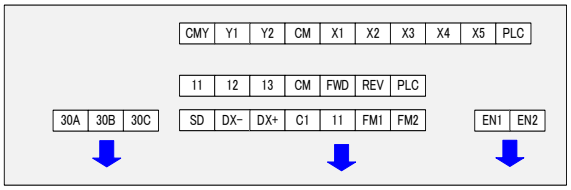
Table I.2-1

Wiring drawer orientation

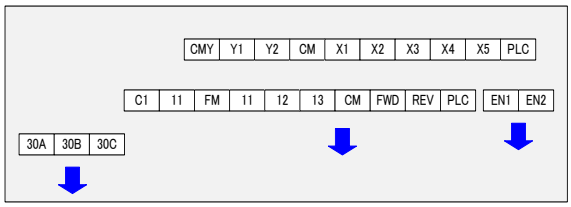
FRENIC-Multi (E1)



FRENIC-Ace (E3)

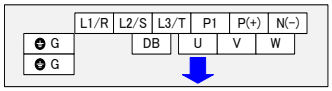
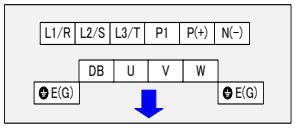
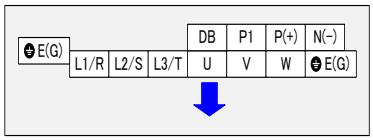
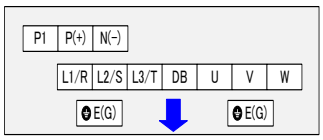
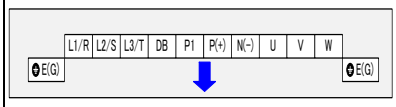
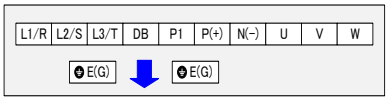
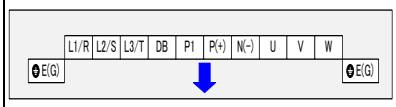
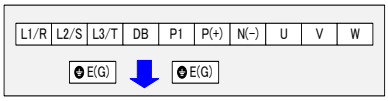
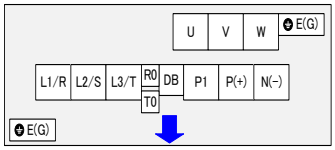
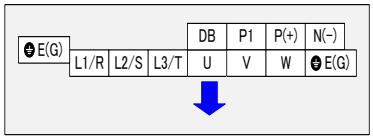
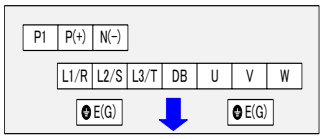
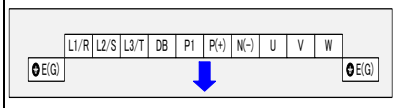
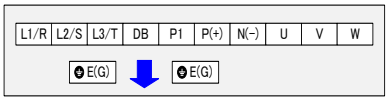
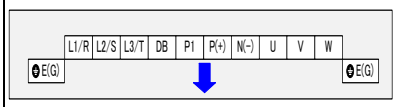
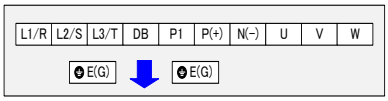
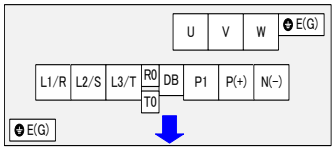
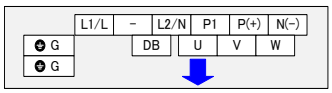
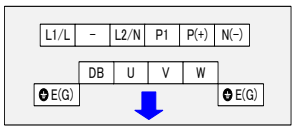
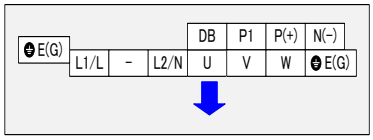
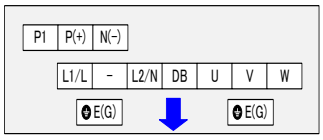


FRENIC-Ace (E2)



■ Comparison of main circuit terminal block screw size and arrangement

Compared with FRENIC-Multi (E1S)

FRENIC-Multi (E1S)					FRENIC-Ace (E3S)			
Voltage	Capacity (kW)	Main circuit	Separate pwr. supply		Capacity (kW)	Main circuit	Separate pwr. supply	
Three-phase 200 V	0.1 0.2 0.4 0.75	M3.5	-		0.1 0.2 0.4 0.75	M3.5	-	
	1.5 2.2 3.7	M4	-		1.5 2.2 3.7	M4	-	
	5.5 7.5	M5	-		5.5 7.5	M5	-	
	11 15	M6	-		11 15	M6	-	
	18.5 22	-	-	-	18.5 22	M6	M3.5	
Three-phase 400 V	0.4 0.75 1.5 2.2 3.7	M4	-		0.4 0.75 1.5 2.2 3.7	M4	-	
	5.5 7.5	M5	-		5.5 7.5	M5	-	
	11 15	M6	-		11 15	M6	-	
	18.5 22	-	-	-	18.5 22	M6	M3.5	
Single-phase 200 V	0.1 0.2 0.4 0.75	M3.5	-		0.1 0.2 0.4 0.75	M3.5	-	
	1.5 2.2	M4	-		1.5 2.2	M4	-	

■ Terminal signal compatibility

Compared with FRENIC-Multi (E1)

Classification	FRENIC-Multi (E1)		FRENIC-Ace (E3)	
	Terminal symbol	Terminal name	Terminal symbol	Terminal name
Main circuit	L1/R, L2/S, L3/T	Main power supply input (three-phase input)	L1/R, L2/S, L3/T	Main power supply input (three-phase input)
	L1/L, L2/N	Main power supply input (single-phase 200V input)	L1/L, L2/N	Main power supply input (single-phase 200V input)
	-	-	R0, T0	Control power auxiliary input
	U, V, W	Inverter output	U, V, W	Inverter output
	P1, P(+)	For DC reactor connection	P1, P(+)	For DC reactor connection
	P(+), N(-)	For DC bus connection	P(+), N(-)	For DC bus connection
	P(+), DB	For external braking resistor connection	P(+), DB	For external braking resistor connection
	⏚G	For inverter and motor grounding	⏚G	For inverter and motor grounding
Analog input	13	Power supply for potentiometer	13	Power supply for potentiometer
	12	Analog setup voltage input	12	Frequency setting voltage input
	C1	Analog setup voltage input (C1 function)	C1	Analog setup voltage input (C1 function)
		Analog setup voltage input (V2 function)		Analog setup voltage input (V2 function)
		PTC thermistor input (PTC function)		PTC thermistor input (PTC function)
	11	Analog common	11	Analog common
Digital input	FWD	Forward rotation/stop command	FWD	Forward rotation/stop command
	REV	Reverse rotation/stop command	REV	Reverse rotation/stop command
	X1	Digital input 1	X1	Digital input 1
	X2	Digital input 2	X2	Digital input 2
	X3	Digital input 3	X3	Digital input 3
	X4	Digital input 4	X4	Digital input 4
	X5	Digital input 5	X5	Digital input 5
	-	-	EN1	Enable input
			EN2	
	CM	Digital input common	CM	Digital input common
	PLC	PLC signal power supply	PLC	PLC signal power supply

Classification	FRENIC-Multi (E1)		FRENIC-Ace (E3)	
	Terminal symbol	Terminal name	Terminal symbol	Terminal name
Analog output/pulse output	FM	Analog monitor (FMA function)	FM1	Analog monitor (FMV function/FMI function)
		Pulse monitor (FMP function)		Pulse monitor (FMP function)
	-	-	FM2	Analog monitor (FMV function/FMI function)
	(11)	(Analog monitor)	(11)	(Analog common)
Transistor output	Y1	Transistor output 1	Y1	Transistor output 1
	Y2	Transistor output 2	Y2	Transistor output 2
	CMY	Transistor output common	CMY	Transistor output common
Contact output	30A, 30B, 30C	Batch alarm output	30A, 30B, 30C	Batch alarm output
Communication	RJ-45 connector for RS-485 communication (for keypad connection)	RJ-45 connector for RS-485 communication (for keypad connection)	RJ-45 connector for keypad connection	RJ-45 connector for keypad connection RS-485 communications port 1
	-	-	DX+, DX-, SD	RS-485 communications port 2
	-	-	For USB communication	USB communications port

I.3 Function codes

With regard to function codes, information on the replacement of previous models (FRENIC-Multi (E1), FRENIC-Ace (E2)) with the FRENIC-Ace (E3) is shown below.

I.3.1 Comparison with FRENIC-Multi (E1)

Function codes not listed in the table below can be replaced directly from FRENIC-Multi (E1). Function codes can also be easily replaced from the previous model Multi (E1) to Ace (E3) by using the copy function of the optional keypad (touch panel) TP-E2.

For details, refer to Chapter 4 “4.9 Function code settings when replacing previous models.”

Note Some function codes may differ between E1 and E3. When copied using the keypad, they are automatically read and copied. If you enter the codes manually, please refer to the function code comparison tables below.
However, the function codes for options (o-codes) are not read from E1 to E3, so refer to the information below to replace the settings.

If the function codes are operated using RS-485 or bus communications, you can set function code y96 (communication compatibility mode) to 6 (E1 compatibility) to use E3 without changing the host program.

E: Control functions of frequency

FRENIC-Multi (E1)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings
E01	Terminal X1 (Function selection)	27: speed control switching [PG/Hz]	E01	Terminal X1 (Function selection)	12: Select motor 2 [M2]
E02	Terminal X2		E02	Terminal X2	
E03	Terminal X3		E03	Terminal X3	
			E04	Terminal X4	
E04	Terminal X4		E05	Terminal X5	
			F42	Drive control selection 1	0: V/f control: without slip compensation
E05	Terminal X5		A14	Drive control selection 2	3: V/f control with speed sensor 4: Dynamic vector control with speed sensor
			Correctly set motor constants in A codes.		
E40	Display coefficient A	0.00 to 200.0	J106	PID control (Maximum scale)	-999.00 to 9990.00
E41	Display coefficient B	0.00 to 200.0	J107	PID control (Minimum scale)	-999.00 to 9990.00
E45	LCD monitor (Display selection)	0 to 1 0: Operation guide display 1: Bar graph (speed, current, torque)	K15	LCD monitor sub-monitor (display selection)	0 to 1 0: Operation guide display 1: Bar graph display
			K20	Bar graph 1 (display selection)	1, 13, 18 1: Output frequency 1 (before slip compensation) 13: Output current 18: Calculated torque
			K21	Bar graph 2 (display selection)	
			K22	Bar graph 3 (display selection)	
E46	(Language selection)	0 to 5 0: Japanese 1: English 2: German 3: French 4: Spanish 5: Italian	K01	(Language selection)	0 to 5 0: Japanese 1: English 2: German 3: French 4: Spanish 5: Italian
E47	(Contrast adjustment)	0 (low) to 10 (high)	K04	(Contrast adjustment)	0 (low) to 10 (high)
E59	Terminal [C1] function selection (C1 function/V2 function)	0: Analog current input (C1 function) 1: Analog voltage input (V2 function)	—	No applicable function codes. No setting necessary.	

C: Control functions of frequency

FRENIC-Multi (E1)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
C21	Timer operation	0: Disable 1: Enable	C21	Pattern operation/timer operation (mode selection)	0~2: Pattern operation 3: Timer operation (Set the timer time with the ▲/▼ keys on the keypad, in 1s increments from 1~3,600.)
C51	Bias (PID command 1) (Bias value)	-100.00~+100.00%	C55	Analog input adjustment (Terminal [12]) (bias)	-100.00~100.00%
			C61	Analog input adjustment (Terminal [C1] (C1 function)) (bias)	
			C67	Analog input adjustment (Terminal [C1] (V2 function)) (bias)	
C52	(Bias reference point)	0.00~100.00%	C56	Analog input adjustment (Terminal [12]) (bias reference point)	0.00~100.00%
			C62	Analog input adjustment (Terminal [C1] (C1 function)) (bias reference point)	
			C68	Analog input adjustment (Terminal [C1] (V2 function)) (bias reference point)	

P: Motor parameters

FRENIC-Multi(E1)			FRENIC-Ace(E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range
P99	Motor 1 selection	0: Motor characteristics 0 (Fuji standard motors, 8-series) 1: Motor characteristics 1 (Horsepower motors) 3: Motor characteristics 3 (Fuji standard motors, 6-series) 4: Other	P99	Motor 1 selection	0: Motor characteristics 0 (Fuji standard motors, 8-series) 1: Motor characteristics 1 (Representative HP motor model) 4: Other 5: Motor characteristics 5 (Fuji premium efficiency motors) (3: Please inquire about replacement from Motor characteristics 3.)

H: High-performance functions

FRENIC-Multi (E1)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
H27	Thermistor (Operation level)	0.00 to 5.00V $Set\ value = \frac{R_p}{1000 + 5 \times R_p} \times 10[V]$	H27	Thermistor (Operation level)	0.00 to 5.00V $Set\ value = \frac{R_p}{1000 + 5 \times R_p} \times 10.5[V]$
H94	Cumulative motor run time 1	0~65535 (decimal) time 0~FFFF (hexadecimal) time	H94	Cumulative motor run time 1	0~9999(×10) time

A: Alternative motor parameters

FRENIC-Multi(E1)			FRENIC-Ace(E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
A45	Cumulative run time 2	0~65535 (decimal) time 0~FFFF (hexadecimal) time	A51	Cumulative motor run time 2	0~9999 (×10) time
A46	Startup count 2	0~65535 times (decimal) 0~FFFF (hexadecimal) times	A52	Startup count 2	0~65535 times (decimal) 0~FFFF (hexadecimal) times
A39	Motor 2 selection	0: Motor characteristics 0 (Fuji standard motors, 8-series) 1: Motor characteristics 1 (Horsepower motors) 3: Motor characteristics 3 (Fuji standard motors, 6-series) 4: Other	A39	Motor 1 selection	0: Motor characteristics 0 (Fuji standard motors, 8-series) 1: Motor characteristics 1 (Representative HP motor model) 4: Other 5: Motor characteristics 5 (Fuji premium efficiency motors) (3: Please inquire about replacement from Motor characteristics 3)

J: Application functions

FRENIC-Multi (E1)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
J68	Brake symbol (release current)	0 to 200%	J68	Brake symbol (release timer)	0.00 to 300.00%
J70	(release timer)	0.0 to 5.0s	J70	(release timer)	0.000 to 5.000s
J72	(input timer)	0.0 to 5.0s	J72	(input timer)	0.000 to 5.000s

o: Option functions

FRENIC-Multi (E1)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
F42 A14	Drive control selection Drive control selection	3: V/f control with PG 4: Dynamic vector control with PG	F42 A14	Drive control selection 1 Drive control selection 2	3: V/f control with PG 4: Dynamic vector control with PG
o01	Command/feedback (input type selection)	0: Command/feedback input: B-phase pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	0: Pulse string sign/pulse string input
			d59	Command(pulse string input) (pulse input method)	0: Pulse string sign/pulse string input
		1: Command input: forward/reverse pulse, Feedback input: B-phase pulse	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	0: Pulse string sign/pulse string input
			d59	Command(pulse string input) (pulse input method)	1: Forward pulse/reverse pulse
		2: Command input: A, B-phase pulse input, Feedback input: B-phase pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	0: Pulse string sign/pulse string input
			d59	Command(pulse string input) (pulse input method)	2: A, B-phase 90° phase difference (B phase lead)
		10: Command input: B-phase pulse input, Feedback input: forward/reverse pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	1: Forward pulse/reverse pulse
			d59	Command(pulse string input) (pulse input method)	0: Pulse string sign/pulse string input
		11: Command/feedback input: forward/reverse pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	1: Forward pulse/reverse pulse
			d59	Command(pulse string input) (pulse input method)	1: Forward pulse/reverse pulse
		12: Command input: A, B-phase pulse input, Feedback input: forward/reverse pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	1: Forward pulse/reverse pulse
			d59	Command(pulse string input) (pulse input method)	2: A, B-phase 90° phase difference (B phase lead)
		20: Command input: B-phase pulse input, Feedback input: A, B-phase pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	2: A, B-phase 90° phase difference (B phase lead)
			d59	Command(pulse string input) (pulse input method)	0: Pulse string sign/pulse string input
		21: Command input: forward/reverse pulse input, Feedback input: A, B-phase pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	2: A, B-phase 90° phase difference (B phase lead)
			d59	Command(pulse string input) (pulse input method)	1: Forward pulse/Reverse pulse
		22: Command/feedback input: A, B-phase pulse input	F01 C30	Frequency setting 1 Frequency setting 2	12: Pulse string input
			d14	Feedback (feedback input) (pulse input method)	2: A, B-phase 90° phase difference (B phase lead)
			d59	Command (pulse string input) (pulse input method)	2: A, B-phase 90° phase difference (B phase lead)

FRENIC-Multi (E1)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
o02	Speed control (P gain)	0.01 to 200.00 times	d03	Speed control 1P (Gain)	0.1 to 200.0 times
o03	(I integral time)	0.000: Disable integral operation 0.001 to 5.000s	d04	I (Integral time)	0.001 to 9.999 s, 999: Disable integral operation
o04	(Filter time constant)	0.000 to 5.000s	d01	(Speed command filter)	0.000 to 5.000s
o05	Reference pulse (Encoder pulse number)	Same as 0:o09 20 to 3600 (decimal)	d60	Command (Pulse string input) (Encoder pulse number)	20 to 60000 (decimal), 0014 to EA60 (hexadecimal)
o06	(Filter time constant)	0.000 to 5.000s	d61	(Filter time constant)	0.000 to 5.000s
o07	(Pulse correction coefficient 1)	Same as 0:o11 1 to 9999	d62	(Pulse correction coefficient 1)	1 to 32767
o08	(Pulse correction coefficient 2)	Same as 0:o12 1 to 9999	d63	(Pulse correction coefficient 2)	1 to 32767
o09	Trailing pulse (Encoder pulse number)	20 to 3600 (decimal)	d15	Feedback (feedback input) (Encoder pulse number)	20 to 60000 (decimal), 0014 to EA60 (hexadecimal)
o11	(Pulse correction coefficient 1)	1 to 9999	d16	(Pulse correction coefficient 1)	1 to 32767
o12	(Pulse correction coefficient 2)	1 to 9999	d17	(Pulse correction coefficient 2)	1 to 32767
o13	Speed control (Output limiter)	0.00 to 100.00%	d70	Speed control limiter	0.00 to 100.00%
o17	Excessive speed deviation level	0 to 50%	d21	Speed agreement/PG error (Detection range)	0.0 to 50.0%
o18	Excessive speed deviation timer	0.0 to 10.0s	d22	(Detection timer)	0.00 to 10.00s
o19	PG error selection	0: Continue to run 1: Stop running (Alarm mode 1) 2: Stop running (Alarm mode 2)	d23	PG error selection	3: Continue to run 2 4: Alarm stoppage 3 5: Alarm stoppage 4
o60	Master-follower operation	0: Speed master-follower operation 1: Position-synchronized operation (Standby synchronization) 2: Position-synchronized operation (Synchronized start synchronization)	d41	Application control selection	0: Disable (normal control) 3: Master-follower operation (start after synchronization) 4: Immediate synchronization operation (at the start (with Z-phase))
o61	Master-follower operation (Main speed regulator gain)	Fixed at 1.0	d71	Master-follower operation (Main speed regulator gain)	0.00 to 1.50 times
o62	(APR P gain)	0.00 to 200.00	d72	(APR P gain)	0.00 to 200.00 times
o63	(APR output + side limiter)	20 to 200, 999: No limiter	d73	(APR output + side limiter)	20~200%: Limiter level 999: Disable
o64	(APR output - side limiter)	20 to 200, 999: No limiter	d74	(APR output - side limiter)	20~200%: Limiter level 999: Disable
o65	(Z-phase alignment gain)	0.0 to 10.0	d75	(Z-phase alignment gain)	0.00 to 10.00 times
o66	(Synchronous offset angle)	0 to 359 deg	d76	(Synchronous offset angle)	0 to 359 deg
o67	(Synchronous completion detection range)	0 to 100 deg	d77	(Synchronous completion detection range)	0 to 359 deg
o68	(Over-deviation detection range)	0.0 to 6553.5	d78	(Over-deviation detection range)	0 to 65535 (10 pulse/unit)

I.3.2 Comparison with FRENIC-Ace (E2)

Function codes not listed in the table below can be replaced directly from FRENIC-Ace (E2). Function codes can also be easily replaced from the previous model Ace (E2) to Ace (E3) by using the copy function of the optional keypad (touch panel) TP-E2.

For details, refer to Chapter 4 “4.9 Function code settings when replacing previous models.”

Note Some function codes may differ between E2 and E3. When copied using the keypad, they are automatically read and copied. If you enter the codes manually, please refer to the function code comparison tables below.

If the function codes are operated using RS-485 or bus communications, you can set function code y96 (communication compatibility mode) to 7 (E2 compatibility) to use E3 without changing the host program.

E: Control functions of frequency

FRENIC-Ace (E2)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
E59	Terminal [C1] function selection (C1 function/V2 function)	0: Analog current input (C1 function) 1: Analog voltage input (V2 function)	—	No applicable function codes. No setting necessary.	

J: Application functions

FRENIC-Ace (E2)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
J70	(Release timer)	0.00 to 5.00s	J70	(Release timer)	0.000 to 5.000s
J72	(Input timer)	0.00 to 5.00s	J72	(Input timer)	0.000 to 5.000s

d: Application functions 2

FRENIC-Ace (E2)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
d92	Reserved for manufacturer	0.00 to 10.00	d192	For adjustment by manufacturer	0.00 to 10.00

o: Option functions

FRENIC-Ace (E2)			FRENIC-Ace (E3)		
Function code	Name	Permissible setting range	Function code	Name	Permissible setting range (Settings corresponding to FRENIC-Multi settings)
o01	Terminals [O1] to [O8] function selection	Based on the setting range for E20 on the inverter	o121	Terminals [O1] to [O8] (function selection)	Setting values compatible with Ace (E2)
o02			o122		
o03			o123		
o04			o124		
o05			o125		
o06			o126		
o07			o127		
o08			o128		

I.3.3 Motor constants for Fuji standard motors, 6 series

■ Three-phase 200V series

Motor capacity setting range (kW) P02/A16	Applicable motor capacity (kW)	Rated current (A) P03/A17	No-load current (A) P06/A20	%R1 (%) P07/A21	%X (%) P08/A22	Rated slip P12/A26	Iron loss factor 1 P13/A27	Magnetic saturation factor 1 P16/A30	Magnetic saturation factor 2 P17/A31	Magnetic saturation factor 3 P18/A32	Magnetic saturation factor 4 P19/A33	Magnetic saturation factor 5 P20/A34	Magnetic saturation factor a P21/A35	Magnetic saturation factor b P22/A36	Magnetic saturation factor C P23/A37	Torque current under vector control P55/A55	Induced voltage factor under vector control P56/A56	Reserved for manufacturers P57/A57	Starting mode (Auto search delay time 2) H46
0.01 to 0.09	0.06	0.44	0.40	13.79	11.75	1.77	14.00	93.8	87.5	75.0	62.5	50.0	106.3	112.5	118.8	0.20		0.027	
0.10 to 0.19	0.1	0.68	0.55	12.96	12.67	1.77	14.00	93.3	86.1	74.4	63.6	50.7	108.8	118.7	129.6	0.34		0.024	
0.20 to 0.39	0.2	1.30	1.00	12.61	13.63	2.33	12.60	90.0	81.3	67.9	56.6	45.0	112.4	126.6	145.1	0.68		0.026	0.5
0.40 to 0.74	0.4	2.30	1.56	10.20	14.91	2.40	9.88	88.7	81.3	67.0	55.2	43.8	112.1	126.5	144.3	1.36		0.029	
0.75 to 1.49	0.75	3.60	2.35	8.67	10.66	2.33	7.40	88.3	77.7	62.6	51.8	41.1	112.4	129.2	148.4	2.55		0.032	
1.50 to 2.19	1.5	6.10	3.00	6.55	11.26	2.00	5.85	92.1	82.8	71.1	58.1	46.2	111.4	126.1	143.9	5.09		0.061	
2.20 to 3.69	2.2	9.20	4.85	6.48	10.97	1.80	5.91	85.1	74.6	61.7	50.3	39.8	115.7	133.5	150.6	7.47		0.051	0.6
3.70 to 5.49	3.7	15.00	7.70	5.79	11.22	1.93	5.24	86.0	76.9	61.3	49.5	39.1	115.6	133.2	154.1	12.57		0.063	0.8
5.50 to 7.49	5.5	22.00	10.70	5.09	13.66	1.40	4.75	87.2	78.2	65.5	54.2	44.1	111.7	129.1	150.9	18.68		0.088	1.0
7.50 to 10.99	7.5	29.00	12.50	4.50	14.70	1.57	4.03	87.7	80.0	67.1	56.1	45.6	111.7	128.4	149.2	25.47		0.095	1.2
11.00 to 14.99	11	42.00	17.60	3.78	15.12	1.07	3.92	91.3	83.3	69.9	58.0	47.0	114.1	130.2	147.9	37.36		0.132	1.3
15.00 to 18.49	15	55.00	20.00	3.24	16.37	1.13	3.32	90.5	83.5	72.1	60.7	49.5	109.0	121.3	137.8	50.94		0.151	
18.50 to 21.99	18.5	67.00	21.90	2.90	17.00	0.87	3.34	90.7	83.0	70.7	59.9	48.7	112.1	127.9	147.5	62.83	85	0.243	2.0
22.00 to 29.99	22	78.00	25.10	2.70	16.05	0.90	3.28	89.7	81.3	68.9	59.1	48.4	114.1	130.2	151.8	74.72		0.228	
30.00 to 36.99	30	107.0	38.90	2.69	15.00	0.80	3.10	90.2	81.6	68.7	57.2	45.8	114.8	132.3	153.9	101.9		0.202	2.3
37.00 to 44.99	37	130.0	41.50	2.76	16.42	0.80	2.30	88.7	78.9	65.4	54.2	43.4	112.2	126.4	143.6	125.7		0.25	
45.00 to 54.99	45	156.0	47.50	2.53	16.16	0.80	2.18	89.0	79.7	66.8	55.4	44.4	112.3	126.0	141.8	152.8		0.272	2.5
55.00 to 74.99	55	190.0	58.60	2.35	16.20	0.94	2.45	89.2	79.3	64.7	53.6	43.1	117.2	136.2	157.8	186.8		0.267	2.6
75.00 to 89.99	75	260.0	83.20	1.98	16.89	0.80	2.33	88.1	78.0	64.3	54.2	42.9	114.9	129.8	144.6	254.7		0.292	2.8
90.00 to 109.9	90	310.0	99.20	1.73	16.03	0.80	2.31	88.8	79.0	65.0	54.0	44.0	115.0	130.0	145.0	305.7		0.31	3.2
From 110.0	110	376.0	91.20	1.99	20.86	0.66	1.73	90.5	82.6	70.7	58.7	47.8	112.2	126.1	142.4	373.6		0.378	3.5

■ Three-phase 400V series

Motor capacity setting range (kW) P02/A16	Applicable motor capacity (kW)	Rated current (A) P03/A17	No-load current (A) P06/A20	%R1(%) P07/A21	%X (%) P08/A22	Rated slip P12/A26	Iron loss factor 1 P13/A27	Magnetic saturation factor 1 P16/A30	Magnetic saturation factor 2 P17/A31	Magnetic saturation factor 3 P18/A32	Magnetic saturation factor 4 P19/A33	Magnetic saturation factor 5 P20/A34	Magnetic saturation factor a P21/A35	Magnetic saturation factor b P22/A36	Magnetic saturation factor C P23/A37	Torque current under vector control P55/A55	Induced voltage factor under vector control P56/A56	Reserved for manufacturers P57/A57	Starting mode (Auto search delay time 2) H46
0.01 to 0.09	0.06	0.22	0.20	13.79	11.75	1.77	14.00	93.8	87.5	75.0	62.5	50.0	106.3	112.5	118.8	0.10		0.027	
0.10 to 0.19	0.1	0.35	0.27	12.96	12.67	1.77	14.00	93.3	86.1	74.4	63.6	50.7	108.8	118.7	129.6	0.17		0.024	
0.20 to 0.39	0.2	0.65	0.50	12.61	13.63	2.33	12.60	90.0	81.3	67.9	56.6	45.0	112.4	126.6	145.1	0.34		0.026	0.5
0.40 to 0.74	0.4	1.20	0.78	10.20	14.91	2.40	9.88	88.7	81.3	67.0	55.2	43.8	112.1	126.5	144.3	0.68		0.029	
0.75 to 1.49	0.75	1.80	1.18	8.67	10.66	2.33	7.40	88.3	77.7	62.6	51.8	41.1	112.4	129.2	148.4	1.27		0.032	
1.50 to 2.19	1.5	3.10	1.50	6.55	11.26	2.00	5.85	92.1	82.8	71.1	58.1	46.2	111.4	126.1	143.9	2.55		0.061	
2.20 to 3.69	2.2	4.60	2.43	6.48	10.97	1.80	5.91	85.1	74.6	61.7	50.3	39.8	115.7	133.5	150.6	3.74		0.051	0.6
3.70 to 5.49	3.7	7.50	3.85	5.79	11.22	1.93	5.24	86.0	76.9	61.3	49.5	39.1	115.6	133.2	154.1	6.28		0.063	0.8
5.50 to 7.49	5.5	11.00	5.35	5.09	13.66	1.40	4.75	87.2	78.2	65.5	54.2	44.1	111.7	129.1	150.9	9.34		0.088	1.0
7.50 to 10.99	7.5	14.50	6.25	4.50	14.70	1.57	4.03	87.7	80.0	67.1	56.1	45.6	111.7	128.4	149.2	12.74		0.095	1.2
11.00 to 14.99	11	21.00	8.80	3.78	15.12	1.07	3.92	91.3	83.3	69.9	58.0	47.0	114.1	130.2	147.9	18.68	85	0.132	1.3
15.00 to 18.49	15	27.50	10.00	3.24	16.37	1.13	3.32	90.5	83.5	72.1	60.7	49.5	109.0	121.3	137.8	25.47		0.151	
18.50 to 21.99	18.5	34.00	11.00	2.90	17.00	0.87	3.34	90.7	83.0	70.7	59.9	48.7	112.1	127.9	147.5	31.41		0.243	2.0
22.00 to 29.99	22	39.00	12.60	2.70	16.05	0.90	3.28	89.7	81.3	68.9	59.1	48.4	114.1	130.2	151.8	37.36		0.228	
30.00 to 36.99	30	54.00	19.50	2.69	15.00	0.80	3.10	90.2	81.6	68.7	57.2	45.8	114.8	132.3	153.9	50.94		0.202	2.3
37.00 to 44.99	37	65.00	20.80	2.76	16.42	0.80	2.30	88.7	78.9	65.4	54.2	43.4	112.2	126.4	143.6	62.83		0.25	2.5
45.00 to 54.99	45	78.00	23.80	2.53	16.16	0.80	2.18	89.0	79.7	66.8	55.4	44.4	112.3	126.0	141.8	76.41		0.272	
55.00 to 74.99	55	95.00	29.30	2.35	16.20	0.94	2.45	89.2	79.3	64.7	53.6	43.1	117.2	136.2	157.8	93.39		0.267	2.6
75.00 to 89.99	75	130.0	41.60	1.98	16.89	0.80	2.33	88.1	78.0	64.3	54.2	42.9	114.9	129.8	144.6	127.4		0.292	2.8
90.00 to 109.9	90	155.0	49.60	1.73	16.03	0.80	2.31	88.8	79.0	65.0	54.0	44.0	115.0	130.0	145.0	152.8		0.31	3.2
110.0 to 131.9	110	188.0	45.60	1.99	20.86	0.66	1.73	90.5	82.6	70.7	58.7	47.8	112.2	126.1	142.4	186.8		0.378	3.5
132.0 to 159.9	132	224.0	57.60	1.75	18.90	0.66	1.80	90.3	81.9	69.8	57.8	46.6	112.9	127.6	144.8	211.7		0.394	4.1
160.0 to 199.9	160	272.0	64.50	1.68	19.73	0.66	1.50	92.2	84.8	71.1	58.6	46.9	114.6	130.5	148.0	256.6		0.482	4.5
200.0 to 219.9	200	335.0	71.50	1.57	20.02	0.66	1.36	91.9	85.5	72.3	60.0	47.6	109.8	122.7	136.4	320.8		0.534	4.7
220.0 to 249.9	220	365.0	71.80	1.60	20.90	0.58	1.25	93.1	86.1	72.9	60.8	48.6	108.7	118.8	130.9	352.8		0.561	
250.0 to 279.9	250	415.0	87.90	1.39	18.88	0.54	1.33	92.2	84.9	72.7	60.5		109.9	122.2	137.8	400.9		0.571	5.0
280.0 to 314.9	280	462.0	93.70	1.36	19.18	0.54	1.27									449.1		0.589	5.5
315.0 to 354.9	315	520.0	120.0	0.84	16.68	0.45	1.81									505.2		0.862	5.6
355.0 to 399.9	355	580.0	132.0	0.83	16.40	0.43	1.77									569.3	90	0.891	
400.0 to 449.9	400	670.0	200.0	0.62	15.67	0.29	1.58					48.9				641.5		0.683	7.5
450.0 to 499.9	450	770.0		0.48	13.03	0.23	1.84	92.7	85.6	72.9	60.9		109.3	120.2	133.5	721.7		0.694	
500.0 to 559.9	500	835.0	270.0	0.51	12.38	0.18	1.80									801.9		1.393	9.8
560.0 to 629.9	560	940.0		0.57	13.94	0.20	1.61									898.1		1.395	
630.0 to 709.9	630	1050.0	355.0	0.46	11.77	0.17	1.29									1010			10.5
From 710.0	710	1150.0	290.0	0.54	14.62	0.21	0.97									1139		1.560	