INVERTER
FR-D700-E16

Safety Stop Function Instruction Manual

CONTENTS

Compliance with the EU Machinery Directive – Functional Safety

⚠**WARNING**
● Any misuse of safety function could lead to personal injury or death, property damage, or economic loss. To ensure that the system complies fully with requirement of safety, make a system-level risk assessment. Mitsubishi Electric Co. cannot assume responsibility for any system to comply with safety standards.
● To avoid an electric shock hazard, verify that the voltage on the bus capacitors has discharged before performing any work on the drive. Measure the DC bus voltage at the P(+) and N(-) terminals or test points (refer to your drive's *User Manual* for locations and discharging time). The voltage must be zero.
● The safety stop function do not isolate electrically between drive and motor. To avoid an electric shock hazard, disconnect/isolate power to the drive and verify to ensure that the voltage is zero before performing any work on the motor (refer to your drive's *User Manual* for discharging time).

⚠**CAUTION**
● The information of this manual is merely a guide for proper installation.
● Mitsubishi Electric Co. cannot assume responsibility for the compliance or the noncompliance to any code, national, local or otherwise for the proper installation of this equipment.
● A hazard of personal injury and/or equipment damage exists if codes are ignored during installation.

1. General description

Features

Mitsubishi Electric FR-D700 safety stop function prevents a drive from supplying rotational energy to motors. (In this Instruction Manual, the STO (safe torque off) function specified in IEC 61800-5-2 is referred to as the safety stop function.)

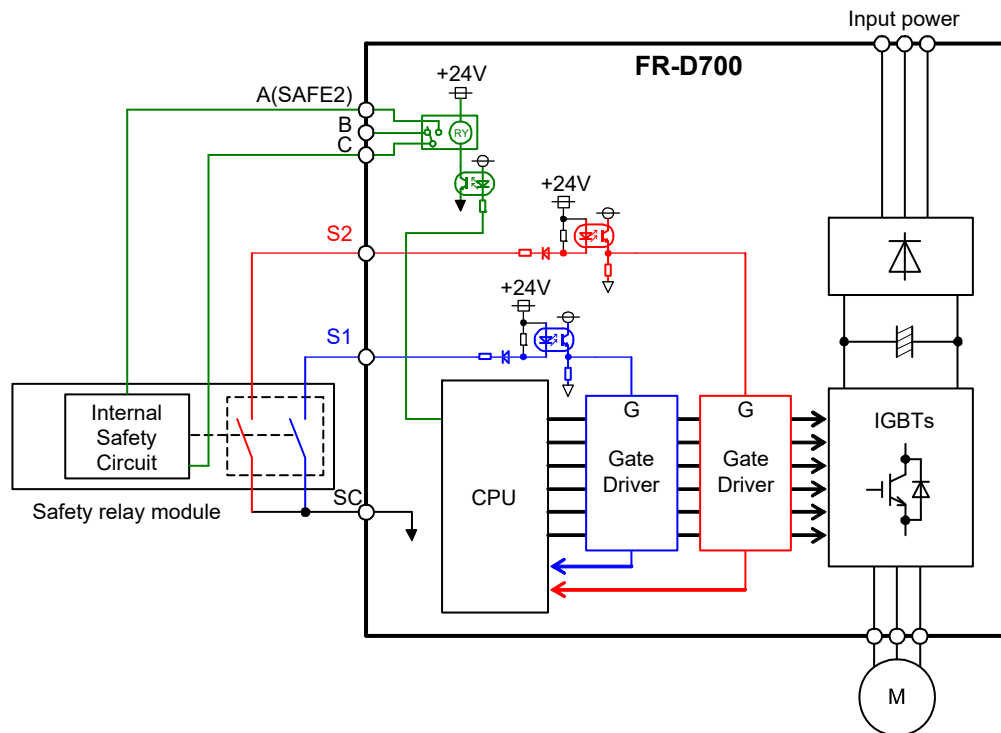Dual safety channels 'S1' and 'S2' cut off the gate-drive power for IGBT to turn off.

Fig.1 FR-D700 safety stop function diagram

⚠WARNING
● The safety stop function doesn't isolate electrically between drive and motor. To avoid an electric shock hazard, disconnect power to the drive and verify that the voltage is zero before performing any work on the motor (refer to your drive's *User Manual* for discharging time).

Standards

Mitsubishi Electric FR-D700 safety stop function meets the following standards and categories.
   ISO13849-1:2015 Category 3/PLd
   IEC62061:2021 / IEC61800-5-2:2016 / IEC61508:2010 SIL2
   IEC61800-5-2:2016 Stop category 0

⚠WARNING
● The misuse of safety function leads to personal injury or death, property damage, or economic loss. To ensure that the system complies fully with requirement of safety, make a system-level risk assessment. Mitsubishi Electric Co. cannot assume responsibility for any system to comply with safety standards.

2. Installation and wiring

⚠CAUTION
● The following information is merely a guide for proper installation. Mitsubishi Electric Co. cannot assume responsibility for the compliance or the noncompliance to any code, national, local or otherwise for the proper installation of this equipment. A hazard of personal injury and/or equipment damage exists if codes are ignored during installation. ● Ensure the safety relay unit and the FR-D700 unit is mounted closely in enclosure meeting IP54 and all interconnection wiring is short and protected against open and short circuit faults. Refer EN/ISO13849-2.

Installation

Mitsubishi Electric FR-D700 safety stop function should be used under following condition and environment.

Table.1 The condition and environment for using safety stop function

Item		Condition
Temperature range	Operation	-10°C to +50°C (non-freezing)
	Storage	-20°C to +65°C
Ambient humidity		90%RH maximum (non-condensing)
Vibration		5.9m/s^2 or less
Altitude		maximum 1000m
Atmosphere		Indoors (without corrosive gas, flammable gas, oil mist, dust and dirt etc.)
Over voltage category		II or less
Pollution degree		II or less
Mounting		wall mounting / vertical orientation

⚠WARNING
● To avoid an electric shock hazard, insert the magnetic contactor (MC) between power source and drive. ● Open the contact of MC and keep away from drive for discharging time (refer to your drive's *User Manual* for information) before performing any work on the drive. And verify that the voltage on the bus capacitors has discharged before Measure the DC bus voltage at the P(+) and N(-) terminals or test points (refer to your drive's *User Manual* for locations). The voltage must be zero.

⚠CAUTION
● In order to meet safety stop, an approved safety relay unit to ISO13849-1/EN954-1 safety category 3 or better shall be used in conjunction with FR-D700 as shown in example1, 2. In addition, all other components with in the safety stop loop shall be 'safety approved' types. ● To avoid systematic faults, a test even for faulty demands of the safety function has to be performed in order to check the correct function of the monitor signal. This test shall be carried out at system installation, any software changes, parameterization changes, and/or at least once per year. Refer to '4. Test and checking failure'.

Wiring

The safety related terminals are described in Table.2 and Table.3

Table.2 The safety related terminals

Terminal Symbol	Description	Rating
S1	For input of safety stop channel1. 　　S1-SC is 　　　　Open: In safety stop mode. 　　　　Short: Non safety stop mode.	Input resistance: 4.7kΩ Current: 4 to 6mA 　　(In case of shorted to SC) Voltage: 21 to 26V 　　(In case of open from SC)
S2	For input of safety stop channel2. 　　S2-SC is 　　　　Open: In safety stop mode. 　　　　Short: Non safety stop mode.	
SO (SAFE)	As output for safety stop condition. SO terminal type is 'Open collector output'. 　　SO-SC is 　　　　OFF (Open): Drive enabled, or drive shutoff (with internal circuit fault) 　　　　ON (Close): Drive shutoff (no internal circuit fault) **Important:** SO terminal should be used for monitoring safety stop condition only. SO terminal cannot be used for safety function.	Load: 24VDC/0.1A max. Voltage drop: 3.4V max. 　　(In case of 'ON' state)
SC	Common terminal for S1, S2, SO terminals. *SC is connected terminal SD internally.	
RUN (SAFE2)	As output for failure detection and alarm. RUN terminal type is 'Open collector output'. 　　RUN-SE is 　　　　OFF (Open): Detect failure or Alarm. 　　　　ON (Close): No failure detected. **Attention:** To use RUN terminal for monitor output of failure detection, **Pr. 190 should be set "81" (Safety monitor 2).** **Note:** This terminal can be used for alarm or to prevent restart only, no other safety function.	Load: 24VDC/0.1A max. Voltage drop: 3.4V max. 　　(In case of 'ON' state)
SE	Common terminal for safety RUN terminal.	
A,C (SAFE2)	As output for failure detection. A, C terminal type is 'Relay output'. 　　A-C is 　　　　OFF (Open): Detect failure or Alarm. 　　　　ON (Close): No failure detected. **Attention:** To use A, C terminal for monitor output of failure detection, **Pr. 192 should be set "81" (Safety monitor 2).** **Note:** This terminal can be used for alarm or to prevent restart only, no other safety function.	Load: 30VDC/0.3A max.
SD	Signal ground	

Table.3 Truth table of Safety related signals

| Input power | Input signal | | Internal safety circuit *1 | Output signal | | Inverter operation state |
	S1-SC	S2-SC		SO-SC (SAFE)	RUN-SE or A-C (SAFE2) *2 *3	
OFF	-	-	-	OFF (Open)	OFF (Open)	Output shutoff (Safe state)
ON	Short	Short	No failure	OFF (Open)	ON (Close)	Drive enable
			Failure	OFF (Open)	OFF (Open)	Output shutoff (Safe state)
	Open	Open	No failure	ON (Close)	ON (Close)	Output shutoff (Safe state)
			Failure	OFF (Open)	OFF (Open)	Output shutoff (Safe state)
	Short	Open	N/A	OFF (Open)	OFF (Open)	Output shutoff (Safe state)
	Open	Short	N/A	OFF (Open)	OFF (Open)	Output shutoff (Safe state)

" N/A " denotes a condition where circuit fault does not apply.

*1   At an internal safety circuit fault, E.SAF or E.CPU is displayed on the operation panel. SA is displayed on the operation panel while S1 and S2 signals are both open and the safety function operates (without internal safety circuit fault).

*2   To use RUN terminal for monitor output of failure detection, Pr. 190 should be set "81" (Safety monitor 2).

*3   To use A, C terminal for monitor output of failure detection, Pr. 192 should be set "81" (Safety monitor 2).

Wire and ferrule specification

Table.4 wire and ferrule specification

Wire size (mm^2)	Ferrule with insulation sleeve *	Crimping tool name *
0.3	AI 0,34-10TQ	CRIMPFOX 6
0.5	AI 0,5-10WH	
0.75	AI 0,75-10GY	
1	AI 1-10RD	
1.25, 1.5	AI 1,5-10BK	
0.75 (for two cables)	AI-TWIN 2 X 0,75-10GY	

*Ferrules and tools are distributed by Phoenix Contact Co., Ltd.

Jumper cable

The jumper cable between S1, S2 and SC terminal has been installed in the factory as shown in Fig.2.
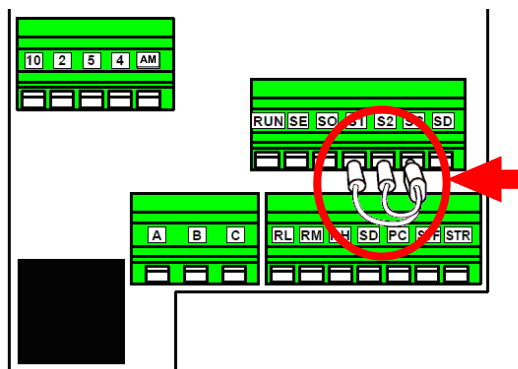

Fig.2. Short wire

Before connecting safety input wire to S1, S2 and SC terminal, remove this jumper cable.

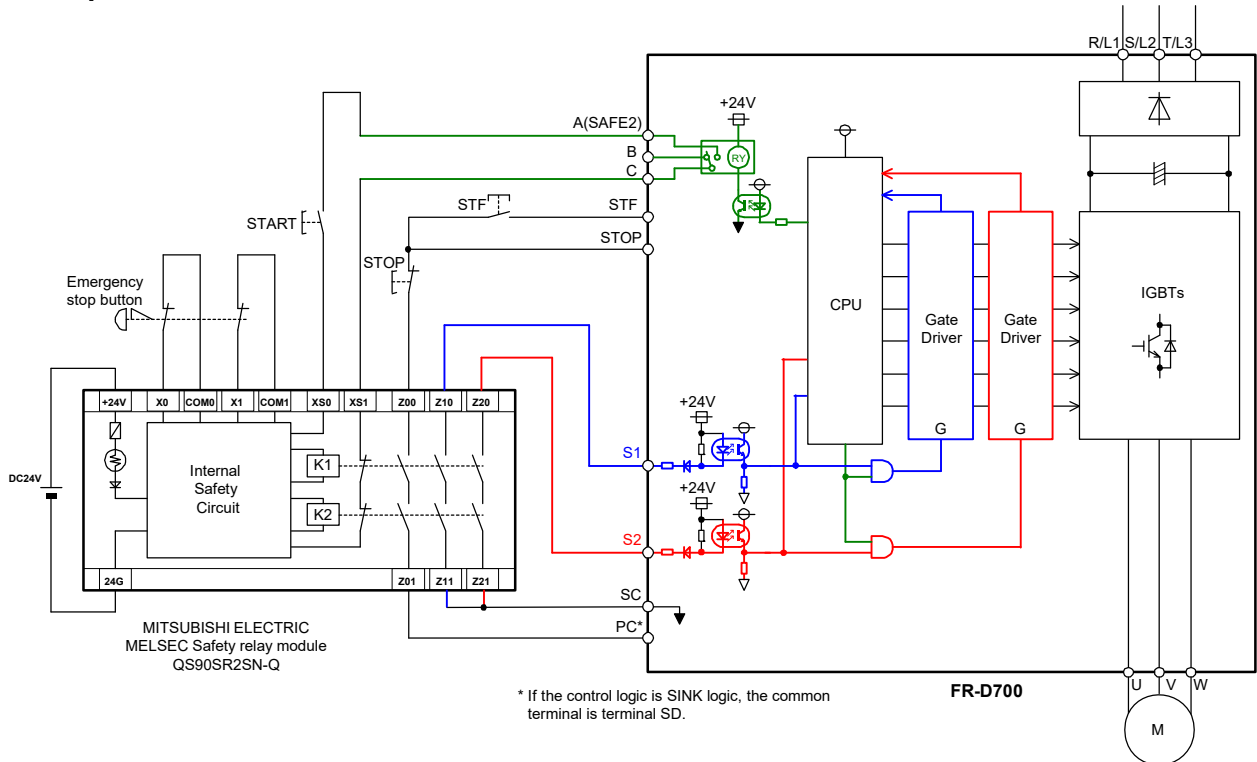## 3. Example of safety system configuration

Example 1

Fig.3 Safety system example 1 – STOP asynchronous with emergency stop button and fault detection through A-C output.

NOTE
- Pr. 192 (A, B, C terminal function selection) must be set to "81". This setting makes the A-C output to open in case of failure.
- The above wiring is configured to prevent restart in case of a fault.
- When starting up the system's operation, press the START switch to reset the safety stop function first, then turn ON the STF switch to run the motor.
- In the above configuration, after reset of emergency stop button, drive will be in safe-state until START switch is pressed.

⚠CAUTION

● To prevent restart in case of recovering from input power loss of drive, 3-wired connection for STF/STOP control is recommended. In case of 2-wire connection and using latching type switch to short between STF and SD/PC for starting, ensure the compliance with safety requirement for the restarting when the drive recover from input power loss.
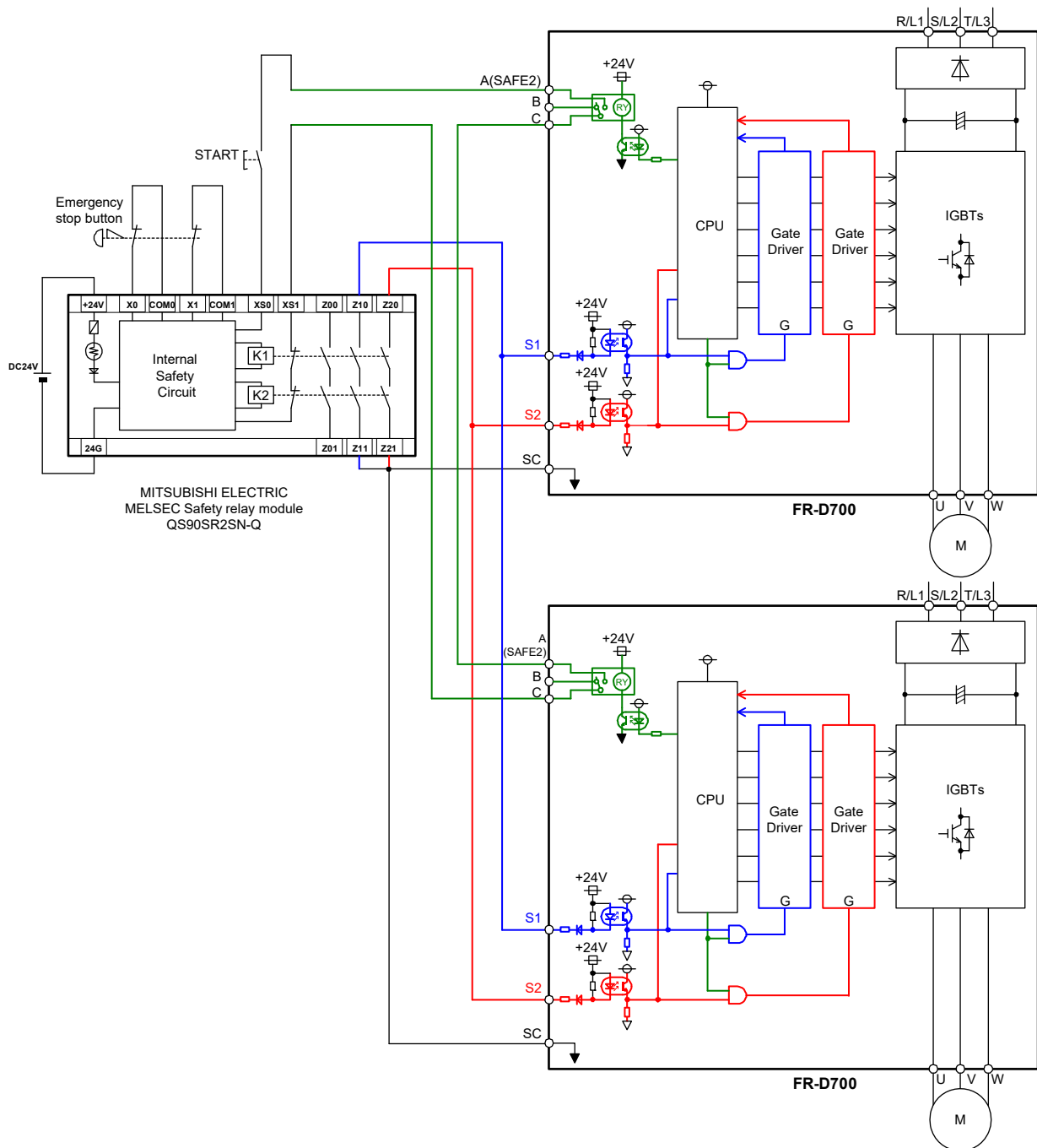
Fig.4 Example when using multiple FR-D700 inverters for the safety stop function

NOTE

- **For Europe model:**
  When using the safety stop function, do not connect the FR-D700 series manufactured in July 2010 or before together with the one manufactured in August 2010 or later. If connected together, the safety stop function may not work properly.
  When the FR-D700 series manufactured in July 2010 or before must be used together, connect an electronic component (diode) to the inverter output shutoff signals (terminal S1 and S2).
- **For Japan model:**
  When using the safety stop function, do not connect the FR-D700 series manufactured in December 2010 or before together with the one manufactured in January 2011 or later. If connected together, the safety stop function may not work properly.
  When the FR-D700 series manufactured in December 2010 or before must be used together, connect an electronic component (diode) to the inverter output shutoff signals (terminal S1 and S2).
  Refer to page 7 for the specification of the diode.
- **Do not connect the FR-E700-SC/NF/NC (source logic) or the FR-D700-SC (source logic) together with the FR-D700 (sink logic). If connected together, the safety stop function does not work properly. (Refer to page 8.)**
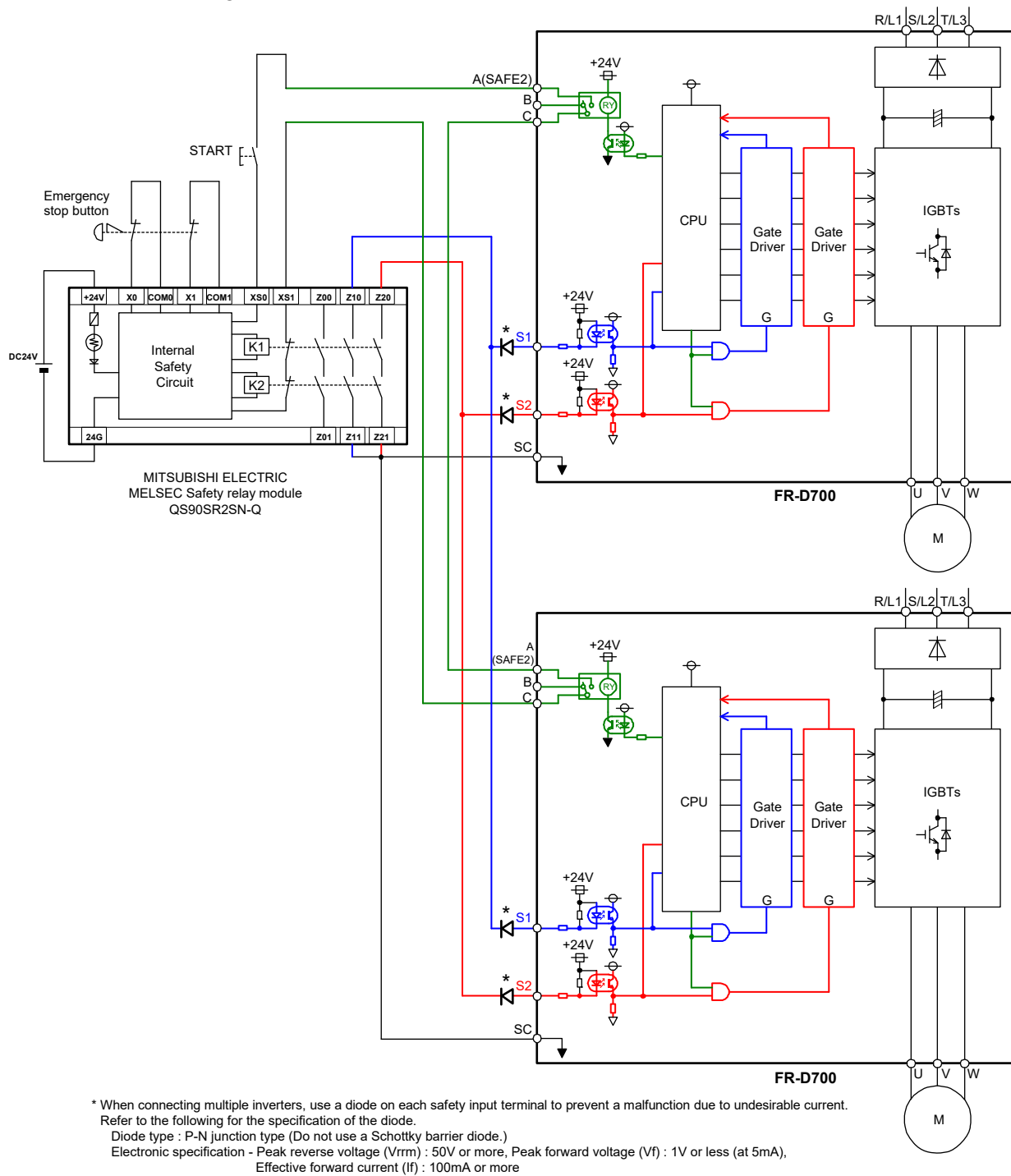
• Example when using multiple FR-D700 inverters

* When connecting multiple inverters, use a diode on each safety input terminal to prevent a malfunction due to undesirable current.
  Refer to the following for the specification of the diode.
    Diode type : P-N junction type (Do not use a Schottky barrier diode.)
    Electronic specification - Peak reverse voltage (Vrrm) : 50V or more, Peak forward voltage (Vf) : 1V or less (at 5mA),
        Effective forward current (If) : 100mA or more

Fig.5 Example of multiple inverters connected to a safety relay unit

NOTE

- **The number of inverters connected to a safety relay unit should be decided under considerations of output terminal rating of a safety relay unit.**
- **Do not connect the FR-E700-SC/NF/NC (source logic) or the FR-D700-SC (source logic) together with the FR-D700 (sink logic). If connected together, the safety stop function does not work properly. (Refer to page 8.)**
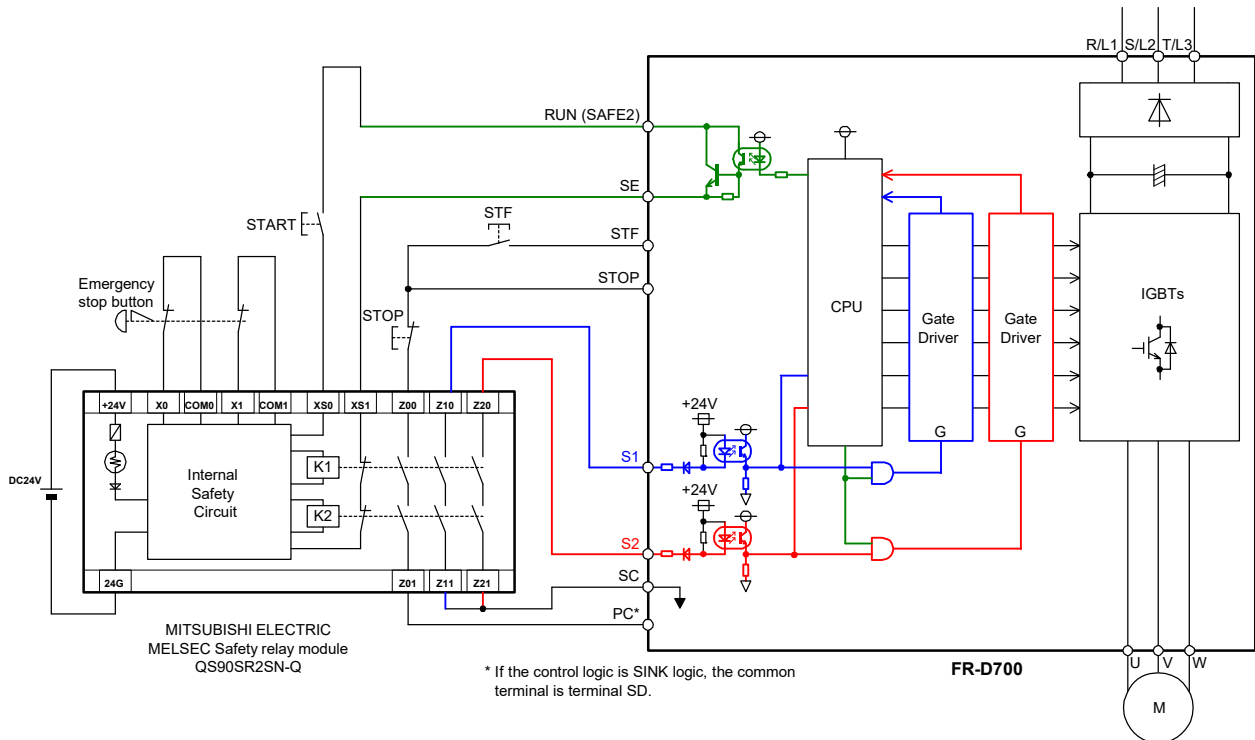
Example 2

Fig.6 Safety system example 2 – STOP synchronous with emergency stop button and fault detection through RUN output.

! NOTE

- **XS0 should be connected to RUN terminal and XS1 should be connected to SE, because polarity of XS0 is positive, XS1 is negative.**
- **Pr. 190 (RUN terminal function selection) must be set to "81". This setting makes the RUN output to turn off in case of failure.**
- **The above wiring is configured to prevent restart in case of a fault.**
- **When starting up the system's operation, press the START switch to reset the safety stop function first, then turn ON the STF switch to run the motor.**
- **In the above Fig.6, wired example 2, in the event of reset of 'safe-condition' the motor rotation will not occur until STF is pressed.**
  (for normal 'non-safety' STF/STOP function, please refer to your drive's *User Manual*)

⚠CAUTION

● To prevent restart in case of recovering from input power loss of drive, 3-wired connection for STF/STOP control is recommended. In case of 2-wire connection and using latching type switch to short between STF and SD/PC for starting, ensure the compliance with safety requirement for the restarting when the drive recover from input power loss.

Inverter connection

Do not connect the FR-E700-SC/NF/NC (source logic) or the FR-D700-SC (source logic) together with the FR-D700 (sink logic). If connected together, the safety stop function does not work properly.

	FR-E700-SC/NF/NC (source logic)	FR-D700-SC (source logic)	FR-D700 (sink logic)
FR-E700-SC/NF/NC (source logic)	○	○	★
FR-D700-SC (source logic)	○	○	★
FR-D700 (sink logic)	★	★	○

○: Enabled, ★: Disabled

4. Test and checking failure

⚠CAUTION
● To avoid systematic faults, a test even for faulty demands of the safety function has to be performed in order to check the correct function of the monitor signal. This test shall be carried out at system installation, any software changes, parameterization changes, and/or at least once per year.

I/O status and failure

FR-D700 safety related I/O status obeys the following truth table.

Table.5 Truth table of Safety related signals

Input power	Input signal		Internal safety circuit *1	Output signal		Inverter operation state
	S1-SC	S2-SC		SO-SC (SAFE)	RUN-SE or A-C (SAFE2) *2 *3	
OFF	-	-	-	OFF(Open)	OFF(Open)	Output shutoff (Safe state)
ON	Short	Short	No failure	OFF(Open)	ON(Close)	Drive enable
			Failure	OFF(Open)	OFF(Open)	Output shutoff (Safe state)
	Open	Open	No failure	ON(Close)	ON(Close)	Output shutoff (Safe state)
			Failure	OFF(Open)	OFF(Open)	Output shutoff (Safe state)
	Short	Open	N/A	OFF(Open)	OFF(Open)	Output shutoff (Safe state)
	Open	Short	N/A	OFF(Open)	OFF(Open)	Output shutoff (Safe state)

" N/A " denotes a condition where circuit fault does not apply.

*1   At an internal safety circuit fault, E.SAF or E.CPU is displayed on the operation panel. SA is displayed on the operation panel while S1 and S2 signals are both open and the safety function operates (without internal safety circuit fault).

*2   To use RUN terminal for monitor output of failure detection, Pr. 190 should be set "81" (Safety monitor 2).

*3   To use A, C terminal for monitor output of failure detection, Pr. 192 should be set "81" (Safety monitor 2).

In case of diagnostic or functionality test, check the I/O state whether it is same or not as Table.5.

Diagnostic

If the failure detected, FR-D700 output alarm signal and indicate 'E.SAF' at the display.

In case of FR-D700 output the alarm, please take following action.

(1) Check the S1-SC and S2-SC input signal logic is the same. If these are different logic, correct the input signal and reset the FR-D700.

(2) Disconnect the wire from S1, S2, SC terminal, then reset or power-off and on, If the 'SA' letter is flashed up at display, there is failure in system except FR-D700. But, still 'E.SAF' is displayed and alarm output, there is malfunction on FR-D700.

Self diagnostic test

FR-D700 does the self-diagnostic test on the power-ON.

If FR-D700 output alarm at power-ON, please take the action described in 'Diagnostic' at above.

Test procedure for functionality

As depicted 'ATTENTION' in above, the test for the functionality is important.

Please do the test following procedure.

(1) Please make each state of S1-SC and S2-SC depicted at Table.5.

(2) If there is any different state from Table.5, FR-D700 has some malfunction.

(3) If there is no different state from Table.5, check the systematic performance, such as, press the Emergency switch, press the start/restart button at the failure detected (RUN-SE opened), and so on.

(4) Finally clear the error record of the FR-D700 (see the user manual how to clear the error record).

5. Safety parameters of FR-D700

FR-D700 safety related I/O status obeys the following truth table.

Table.6 Safety parameters of FR-D700

Parameter	Value
PFD_{AVG}	2.5×10^{-4}
PFH_D	2.5×10^{-9}
PL	d
$MTTF_D$	500 years
DC_{AVG}	60%

REVISIONS

Revision Date	Manual Number	Revision
Aug. 2018	BCN-A211508-008-A	First edition
Dec. 2018	BCN-A211508-008-B	Edited • Compliance with the EU Machinery Directive – Functional Safety
Oct. 2023	BCN-A211508-008-C	Edited • Functional safety standards • Safety parameters

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