Fuji Electric

Innovating Energy Technology

High Performance Inverter

FRENIC-Ace

User's Manual

Functional Safety Supplementary materials

ENGLISH

G.4 Compliance with Functional Safety Standard

G.4.1 General

In FRENIC-Ace series of inverters, opening the hardware circuit between terminals [EN1]-[PLC] or between terminals [EN2]-[PLC] stops the output transistor, coasting the motor to a stop. (EN1: Enable input 1, EN2: Enable input 2) This is the Safe Torque Off (STO) function prescribed in EN60204-1, Category 0 (Uncontrolled stop) and compliant with Functional Safety Standard.

Using the Safe Torque Off (STO) function eliminates the need of external safety circuit breakers while conventional inverters need those breakers to configure the Functional Safety Standard compliant safety system.

EN ISO 13849-1	
Category	3
Perfomance level	e
Diagnostic Coverage	More than 90%(DCave medium)
Response time	50ms or less
Mean time to dangerous random hardware failure	More than 62years(MTTFd)
EN 61508-1 to -7 EN 61800-5-2	
Functional safety	Safety Torque Off(STO)
Safety Integrity Level	SIL3
Hardware failure tolerance	1(HFT)
Safe failure fraction	More than 90%
Probability of Failuer on Demand	Less than 0.15E-03(PFDave)
Probability of dangerous failure per hour[h^{-1}]	Less than 0,15-07(PFH)

⚠ WARNING ⚠

- The output shutdown function of this inverter uses the Safe Torque Off (STO) function prescribed in IEC61800-5-2 so that it does not completely shut off the power supply to the motor electrically. Depending upon applications, therefore, additional measures are necessary for safety of end-users, e.g., brake function that locks the machinery and motor terminal protection that prevents possible electrical hazard(s).

- The output shutdown function does not completely shut off the power supply to the motor electrically. Therefore, before starting wiring or maintenance jobs, be sure to disconnect the input power to the inverter and wait at least five minutes.

- The synchronous motors generate a voltage at the terminal during coast to a stop with the output cutoff function. For maintenance, inspection and wiring, confirm that the synchronous motor has stopped securely before performing.

  Risk of electrical shock.

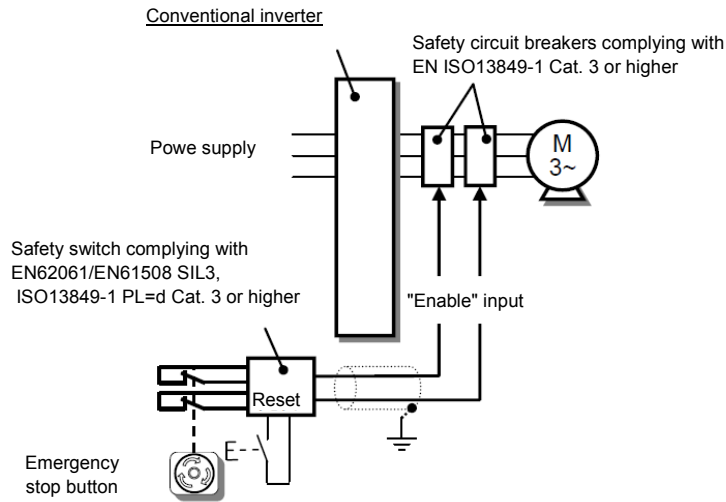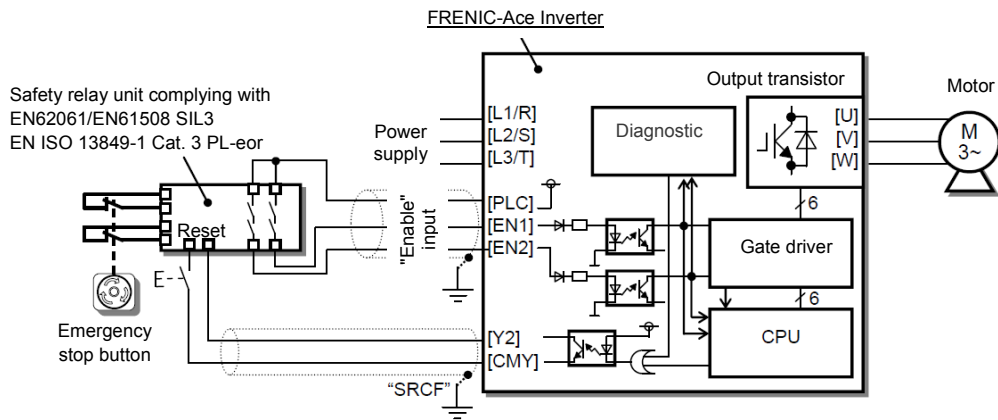Enable terminals and peripheral circuit, and internal circuit configuration

Conventional inverter

Figure G. 4-1 Conventional Inverters

FRENIC-Ace Inverter

*Select SRCF on Y2 terminal : set SW8 to SRCF side

Figure G. 4-2 FRENIC-Ace

Table G. 4-2 List of STO functions

Digital Input		*ECF* Alarm	Digital Output 【Y2】 (*SRCF*)	Inverter State
EN1	EN2			
Short	Short	No alarm	ON	Operation Ready
		Alarm issued	OFF	Safety Torque Off
Open	Open	No alarm	ON	Safety Torque Off
		Alarm issued	OFF	Safety Torque Off
Short	Open	Alarm issued	OFF	Safety Torque Off
Open	Short	Alarm issued	OFF	Safety Torque Off

G.4.2 Notes for compliance to Functional Safety Standard

(1) Wiring for terminals [EN1] (Enable input 1) and [EN2] (Enable input 2)
  - [EN1]/[EN2] and [PLC] are terminals prepared for connection of safety related wires; therefore, careful wiring should be performed to ensure that no short-circuit(s) can occur to these terminals.
  - For opening and closing the hardware circuit between terminals [EN1]/[EN2] and [PLC], use safety approved components such as safety relays that comply with EN ISO13849-1 PL=e Cat. 3 or higher to ensure a complete shutoff.
  - It is the responsibility of the machinery manufacturer to guarantee that a short-circuiting or other fault does not occur in wiring of external safety components between terminals [EN1]/[EN2] and [PLC].
    Fault examples:
    • Terminals [EN1]/[EN2] and [PLC] are short-circuited due to the wiring being caught in the door of the control panel so that a current continues to flow in terminal [EN1]/[EN2] although the safety component is OFF and therefore the safety function may NOT operate
    • The wiring is in contact with any other wire so that a current continues to flow in terminal [EN1]/[EN2] and therefore the safety function may NOT operate

(2) Note for Safe Torque Off (STO)
  - When configuring the product safety system with this Safe Torque Off (STO) function, make a risk assessment of not only the external equipment and wiring connected to terminals [EN1] and [EN2] (Enable input 1 and Enable input 2) but also the whole system including other equipment, devices and wiring against the product safety system required by the machinery manufacturer under the manufacturer's responsibility in order to confirm that the whole system conforms to the product safety system required by the machinery manufacturer.

    In addition, as preventive maintenance, the machinery manufacturer must perform periodical inspections to check that the product safety system properly functions.
  - To bring the inverter into compliance with Functional Safety Standard, it is necessary to install the inverter on a control panel with the enclosure rating of IP54 or above.
  - To bring the inverter into compliance with Functional Safety Standard, it is necessary to bring it into compliance with European Standards EN61800-5-1 and EN61800-3.
  - This Safe Torque Off (STO) function coasts the motor to a stop.
    Set SW8 to the SRCF side to satisfy the functional safety standard that uses STO. Then, connect the output of the Y2 terminal to reset of the safety relay (ISO13839-1 5.2.2 manual reset function). For further details of the connections, refer to "figure G. 4-2 FRENIC-Ace".
    However, in case of this setting, the output of Y2 terminal cannot be used as an input signal of safety command to other devices (such as safety brake etc.). (Conforms to functional safety standards)
    - When SW8 is set to the Y2 side, the terminal [Y2] is a general-purpose output compliant with the function code E21. In this setting, it is a non-safety signal. Terminal [Y1] and terminal [30A / B / C] are alike.
  - When inputting a minute pulse to the EN1 and EN2 terminals in the safety PLC diagnosis, set it to less than 1 ms.
  - Make sure that the safety shut-off circuits of the [EN1] and [EN2] input section and the inverter output block section are doubled (redundant circuit) so that a single failure will not damage the safety stop function (STO).

    If a single failure is detected by the safety shutoff circuit, an alarm is output to the external device even if [EN1]-[PLC] and [EN2]-[PLC] are ON, and the inverter coasts the motor to a stop (The alarm output function does not guarantee that all single failures will be output, but it can conform to EN ISO 13849-1 PL = e Cat. 3)
  - The Safe Torque Off (STO) function does not completely shut off the power supply to the motor electrically. Before starting wiring or maintenance jobs, be sure to disconnect the input power to the inverter and wait at least 5 minutes.

(3) A test of Safe Torque Off (STO)
  - Check at least once a day that the Safe Torque Off (STO) function works correctly.

G.4.3 Inverter output state when Safe Torque Off (STO) is activated

Turning the emergency stop button ON turns EN1 and EN2 OFF, bringing the inverter into the Safe Torque Off (STO) state.

Figure G.4-3 shows the timing scheme to apply when the emergency stop button is turned OFF with the inverter being stopped. Inputs of the EN1 and EN2 are turned ON, makes the inverter ready to run.

Please note that diagnosis of the EN terminal circuit are sometimes performed while the inverter stops. When the operation command is turned on at the time of this diagnosis execution, the operation start might be delayed by up to 1 second.

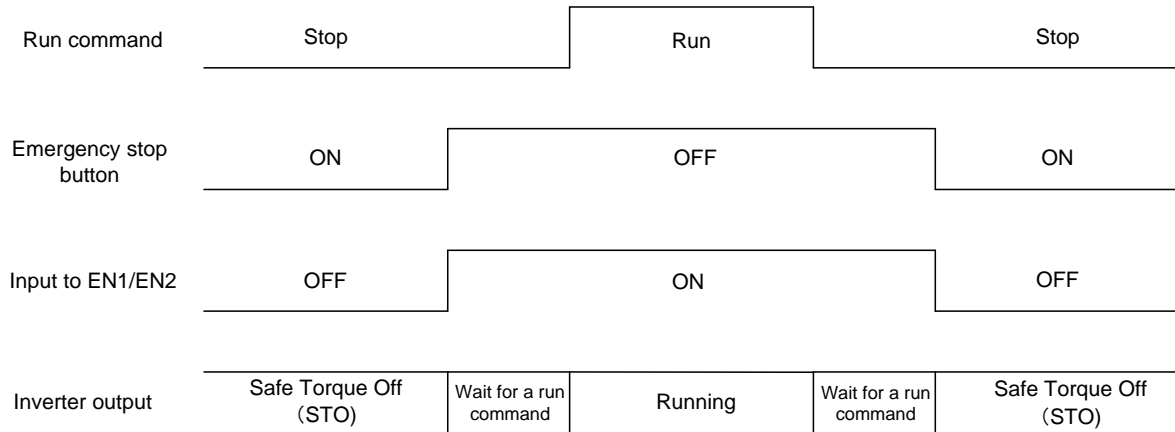| Run command	Stop		Run		Stop
Emergency stop button	ON		OFF		ON
Input to EN1/EN2	OFF		ON		OFF
Inverter output	Safe Torque Off (STO)	Wait for a run command	Running	Wait for a run command	Safe Torque Off (STO)

Figure G.4-3 Inverter Output State when the Emergency Stop Button is Turned OFF with the Inverter being Stopped

Figure G.4-4 shows the timing scheme to apply when the emergency stop button is turned ON with the inverter running. Input to the EN1 and EN2 goes OFF, bringing the inverter into the Safe Torque Off (STO) state and coasting the motor to a stop.
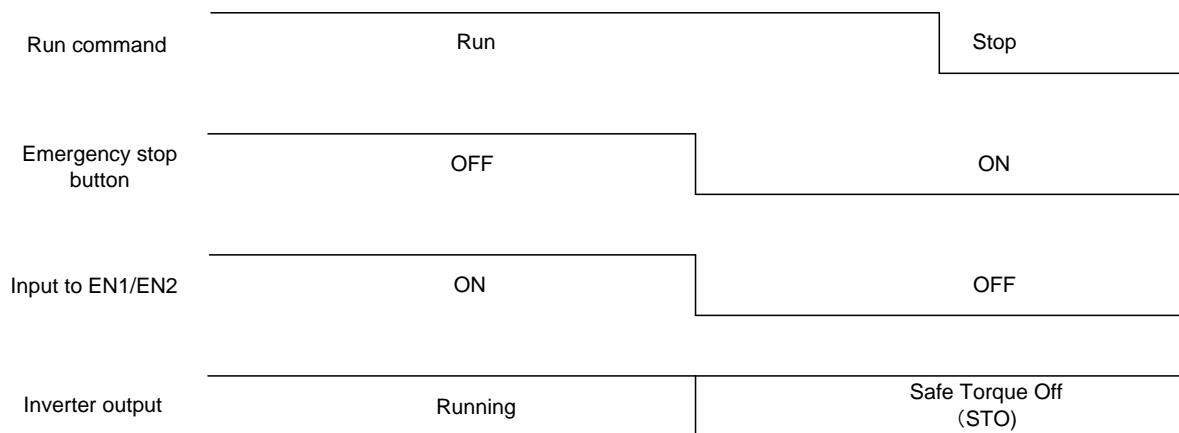
Run command	Run	Stop
Emergency stop button	OFF	ON
Input to EN1/EN2	ON	OFF
Inverter output	Running	Safe Torque Off (STO)

Figure G.4-4 Inverter Output State when the Emergency Stop Button is Turned ON with the Inverter Running

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G.4.4 *ecf* alarm (caused by logic discrepancy) and inverter output state

Figure G.4-5 shows the timing scheme to apply when EN1 and EN2 inputs are not aligned so that an alarm *ecf* occurs.

Turning the emergency stop button ON turns EN1 and EN2 inputs OFF, which usually brings the inverter into the Safe Torque Off (STO) state. If the misalignment of the EN1 and EN2 inputs is within 50 ms, no alarm occurs; if it is more than 50 ms, the inverter interprets it as a logic discrepancy, outputting an alarm *ecf*. The alarm can be cleared by restarting the inverter.

In order to correctly diagnose the EN terminal circuit by turning the EN1 and EN2 terminals ON / OFF, keep EN1 and EN2 terminals ON for at least 200 ms and OFF for at least 1.1 s.
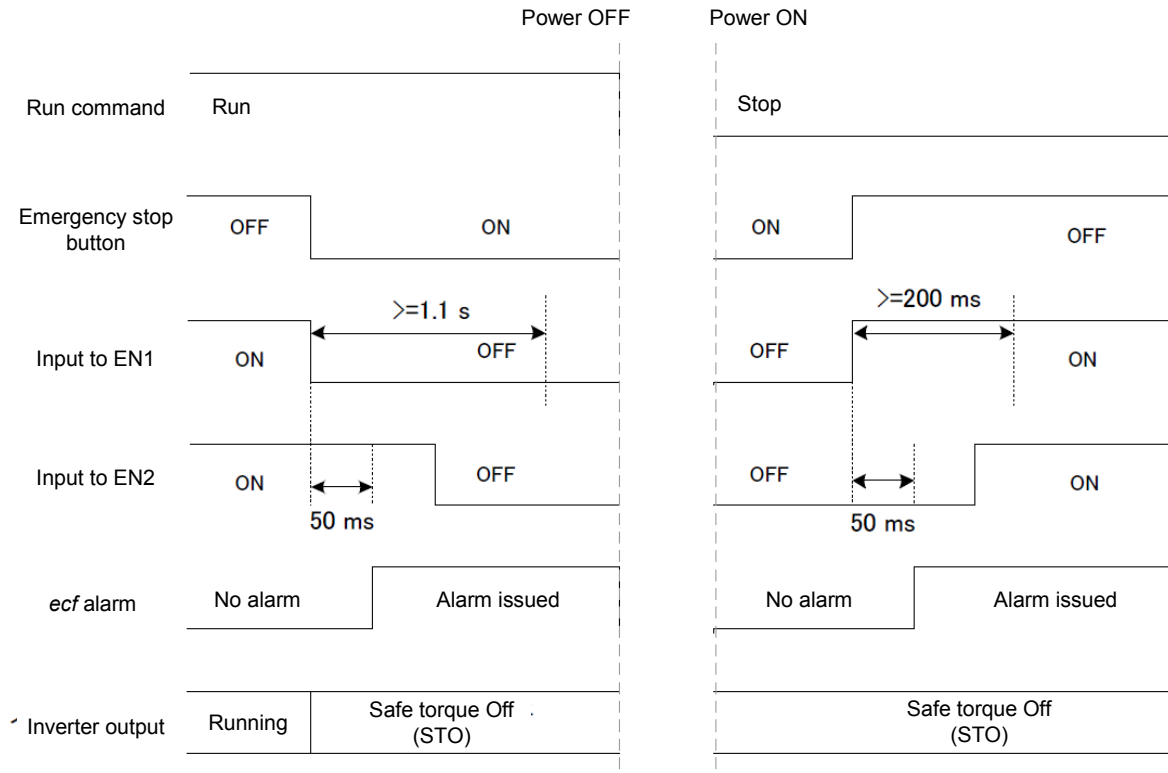

Figure G.4-5 *ecf* Alarm (Caused by Logic Discrepancy) and Inverter Output State

9.6.6 Prevention of restarting

When the emergency stop button is turned on while the inverter is running, the inverter is forced to coasting the motor to a stop.
Even if the emergency stop button is turned OFF, the safety relay turns the EN1 and EN2 OFF and the inverter does not restart operation.
To enable operation, turn on the reset button of the safety relay and turn on the EN1 and EN2. After that, turn off the operation command and then turn it on again to start the operation.
If the EN1 and EN2 terminals and Operation command are turned ON at the same time, operation may not be started. When the terminals is on, OFF the operation command for 10ms or more.
After the terminals is turned off and turned on, the operation cannot be started even if the operation is returned to normal for 25ms. The details are shown in time chart G.4-6.

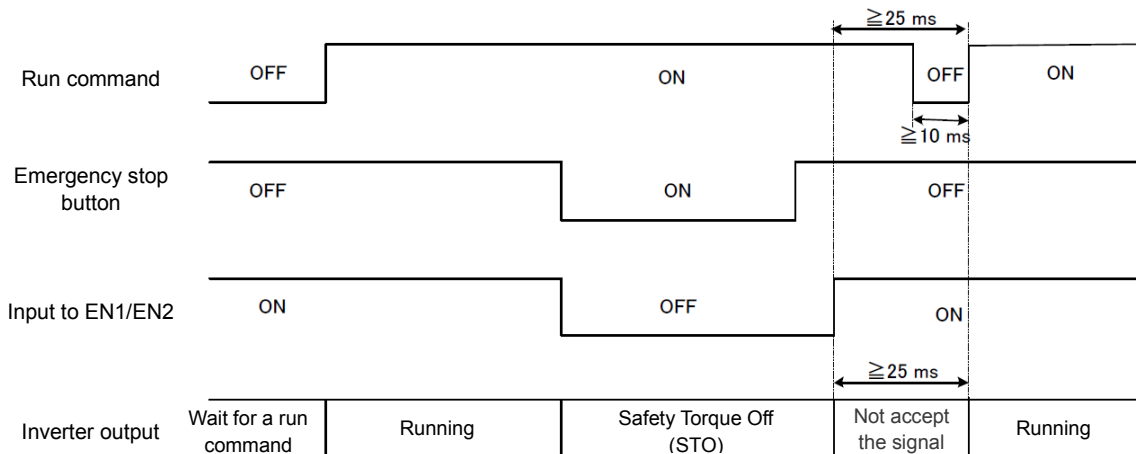|				
Run command	OFF	ON	OFF	ON
Emergency stop button	OFF	ON	OFF	
Input to EN1/EN2	ON	OFF	ON	
Inverter output	Wait for a run command	Running	Safety Torque Off (STO)	Not accept the signal	Running

≧25 ms   ≧10 ms   ≧25 ms

Figure G.4-6 Prevention of

Functional Safety Specifications Change

Regarding functional safety, some specifications of the inverter ROM have been reviewed since version 6100 (~3.7kW)/900 (~5.5kW).
Functional safety performance has not been changed due to the revision of the specifications.
(Performance Level by EN ISO 13849-1 and Safety Level by EN 61508-1 to-7,EN 61800-5-2)
The following shows the differences before and after the review.

Specifiction	ROM Version	
	6000(~3.7kW)/900(~5.5kW) before	6000(~3.7kW)/900(~5.5kW) after
Timing of self-diagnosis of EN circuit	• When the power supply is started • Inverter stop state is accumulated every 50 minutes.	• When the EN1 and EN2 terminals are turned on after the power is started (only when the initial condition is satisfied).
Ready-to-run output "RDY"	The inverter stops for approximately one second every 50 minutes. Also when repeating the Runing/stop, it turns OFF for about 1 second when the cumulative stop time elapses for 50 minutes. Therefore, the operation command is not accepted during the OFF period of about 1 second.	Since the self-diagnosis of the EN circuit is not performed except when the initial condition is satisfied, the stop state of the inverter does not turn OFF even after 50 minutes have elapsed.