

Read this “Safety function Guide” and keep it handy for future reference.

## Safety function Guide

### HITACHI INVERTER WJ series **C1**

Introduction

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## S.1 Introduction

Thank you for purchasing Hitachi WJ Series C1 Inverter. (Afterward "Hitachi WJ Series C1 Inverter" referred to as WJ-C1.) This is a Safety function Guide that describes the handling and maintenance of Safety function of the WJ-C1.

The information not in the Safety function Guide must be referred to the User's Guide of the WJ-C1.

If there are any inconsistent contents between the User's Guide of the WJ-C1 and this Safety function Guide, the instructions provided in this Safety function Guide always have priority when the Safety function is used.

For the purpose of reduction of paper consumption and provision of the latest information, we enclose the Safety function Guide Caution only, while providing the Safety function Guide (this Guide) for more detailed description through electronic means instead of CD or a printed document.

### ■ Safety function Guide (this document)

The Safety function Guide provides the information necessary for handling the Safe Torque Off (STO) function of the WJ-C1. Be sure to read through this documentation as well as the User's Guide of the WJ-C1 when using the STO function of the WJ-C1.

If future updated descriptions differ from the WJ-C1 Basic Guide and WJ-C1 User's Guide, the description in the Safety function Guide will have higher priority. Always use the WJ-C1 strictly within the range described in the Safety function Guide and perform proper inspection and maintenance to prevent failures or accidents.

Please note that the WJ-C1 User's Guide is basically provided as electronic data (such as PDF). The latest version of the WJ-C1 User's Guide, please contact the supplier where this device was purchased.

## S.2 Precaution

### ■ For a Proper Use

Before using the inverter, carefully read the Safety function Guide / Caution, WJ-C1 Basic Guide, WJ-C1 User's Guide, and the instruction manuals for optional products.

In addition, any personnel handling or performing maintenance of the product must read carefully the inverter's Basic Guide, User's Guide and each optional products instruction manuals.

Before any attempt to install, operate, maintain or inspect this equipment, a complete understanding of the equipment specifications, safety instructions, precautions, handling and operation instructions is required. Follow all the specifications and instructions for a proper use.

Additionally, review the inverter's Basic Guide, User's Guide and each optional product instruction manuals periodically.

### ■ Precautions

It is prohibited to reproduce or reform this document partially or totally in any form without the publisher's permission. The contents of the document are subject to change without prior notice.

Any handling, maintenance or operation method NOT described in the inverter's Basic Guide, User's Guide and each optional product instruction manuals is not covered by the product warranty. DO NOT perform any procedure NOT described in the WJ-C1 and optional product guides since it can be the cause of unexpected failures or accidents.

We are not responsible for any injury or damage due to handling, maintenance or operation of the product in a manner not specified in the inverter's Basic Guide, User's Guide and each optional product instruction manuals. We appreciate your understanding.

If you find any unclear or incorrect description, missing description, or misplaced or missing pages, please inform the distributor of Hitachi.

Note that, in case the inverter's Basic Guide, User's Guide and each optional product instruction manuals are enclosed with the product, they should be delivered to the end user of the inverter. For detailed information, please contact the supplier where this device was purchased.

### S.3 Relevant document

Document name	Document code *1)
WJ series C1 User's Guide	NT361*X
WJ series C1 Basic Guide	NT3611*X
WJ series C1 Safety function Guide (this documentation)	NT3612*X
WJ series C1 Safety function Guide Caution	NTZ3612*X

\*1) The document version ("\*" is alphabet A, B ...) is added to the end of the document code.

### S.4 List of Abbreviation and Technical Terms

#### A

Term / Abbreviation	Description
AWG	American wire gauge Standardized wire gauge used in North America

#### B

Term / Abbreviation	Description
Basic Guide	The documentation that provides basic information to handle the inverter

#### C

Term / Abbreviation	Description
CAT.	Category Structural Classification of the safety-related parts defined in EN ISO13849-1 (B,1,2,3,4)
CCF	Common Cause Failure (EN ISO 13849-1) Failure, which is the result of one or more events, causing concurrent failure of two or more separate channels in a multiple channel system, leading to failure of the safety function
CE marking	A mandatory conformity marking for products sold within the European Economic Area
Charge lamp	The lamp indicates power supply status of the main circuit of the inverter. Even after powered down, the internal voltage remains while the lamp lights.
Control power supply	Internal power supply necessary for powering up the logic board and configuring the inverter using operator keypad. Supplying power to R, S, T terminals (In case of single phase model, please use L1 and N terminals.) or P24, L terminals can power up the internal power supply.

#### D

Term / Abbreviation	Description
Dangerous failure	Failure of a component and/or subsystem and/or system that plays a part in implementing the safety function
DC	Diagnostic coverage (%) (EN ISO 13849-1)
DCavg	Diagnostic coverage average

#### E

Term / Abbreviation	Description
EMC	Electromagnetic compatibility
EUC	Equipment Under Control

#### F

Term / Abbreviation	Description
Functional Safety	Part of the overall safety relating to the EUC and the EUC control system that depends on the correct functioning of the E/E/PE safety-related systems and other risk reduction measures.(IEC61508)

#### H

Term / Abbreviation	Description
HFT	Hardware fault tolerance (IEC61508)

#### I

Term / Abbreviation	Description
I/O	Input / Output
IGBT	Insulated gate bipolar transistor
Inverter model code	The model code written on the specification label of the inverter.

## M

Term / Abbreviation	Description
Machinery Safety Directive	One of the EC Directive which is related to inverters or machines with inverters.
Main power supply	Power supply necessary for operation of inverter
MFG No.	Manufacturing No.
MTTFd	Mean time to dangerous failure. Expectation of the mean time to dangerous failure

## O

Term / Abbreviation	Description
Operator keypad	The keypad mounted on the inverter used for configuration of parameters and monitoring of inverter's state

## P

Term / Abbreviation	Description
PELV	Protected Extra-Low voltage (IEC60204-1)
PFD	Probability of failure on demand (IEC61508)
PFH	Average frequency of a dangerous failure [1/h] (IEC61508)
PL	Performance level (a-e) (EN ISO 13849-1)
PLC	Programmable logic controller
PWM	Pulse width modulation

## R

Term / Abbreviation	Description
Residual risk	Risk remaining after protective measures have been taken
Response time	Delay time inside of the inverter from a request of activation of a function until actual execution of the function
Risk	Probability and severity of hazard

## S

Term / Abbreviation	Description
Safety Function	Safety functions to achieve safe state of system such as STO function defined in IEC61800-5-2.
Safety path	Path of signal to perform the safety function.
Safety-Related System	Whole system including inverter, sensor, switch, and safety relay etc. that achieves safety function(s)
SELV	Safety extra-low voltage (EN/IEC60950)
SFF	Safe failure fraction (%) (IEC61508)
SIL	Safety integrity level (1-3) (IEC61508)
Specification label	The label affixed on the product, on which specification of the inverter is written
STO	Safe torque off (EN/IEC61800-5-2)
Stop category 0	A type of stop category defined in IEC60204-1. Stopping by immediate removal of power to the machine actuator.

## T

Term / Abbreviation	Description
T <sub>M</sub>	Mission time

## U

Term / Abbreviation	Description
User's Guide	The documentation that provides the detailed information to handle the inverter

## V

Term / Abbreviation	Description
Validation	Confirmation by examination and provision of objective that the safety system meets the requirements set by the specification
Verification	Confirmation by examination and provision of objective evidence that the requirements have been fulfilled

\*) Trademark

Some proper nouns such as product name or function names may be registered as trademark or registered trademark. This documentation does not describe ® mark or ™ mark.

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# Chapter 1 Safety Precaution/Risk

## 1.1 What This Chapter Explains

This chapter describes precautions for using the STO function of the WJ-C1 inverter.

Before installation, wiring, operation, maintenance, inspection and running, please make sure to read through **the Safety function Guide, the User's Guide** of the WJ-C1 inverter and all the other documentation enclosed with the product.

## 1.2 Safety Precaution

	General warning indicates a potentially hazardous situation that, if not avoided, can result in serious injury or death, or damage to the equipment.
	This symbol indicates High voltage. It calls to your attention to items or operations that could be dangerous to you and other persons operating this equipment.

### 1.2.1 Planning

The persons who design, install, and perform maintenance of safety-related system must have sufficient knowledge of the functional safety.

It is a responsibility of the manufacturer of safety-related system to perform risk analysis of the overall system and to apply appropriate measures accordingly.

### 1.2.2 Consideration in Designing safety-related system



The WJ-C1 does not support a retention function of STO state after release of STO inputs. Therefore, after STO inputs to the WJ-C1 inverter are released, the WJ-C1 inverter becomes available to restart the motor operation. (A function of WJ-C1 to hold Shut off state without STO inputs is not safety function.)

Please ensure to design the safety-related system so that the above-mentioned behavior does not lead to any unsafe situation.

Please note that WJ-C1 inverters are delivered with the STO function being disabled by a jumper wire to allow initial drive commissioning without the need of configuring the STO function first.

### 1.2.3 Installation

Installation must be performed by the competent electricians who have sufficient knowledge of the functional safety. Ensure to use the WJ-C1 inverter within the specified environmental condition including EMS environment.

### 1.2.4 Commissioning



The safety-related system must always need to properly carry out the commissioning and be verified/validated before it is considered safe.

### 1.2.5 Maintenance



The STO function does not cut the power supply to the inverter and the peripheral circuits, and does not provide any electrical isolation. Before maintenance, please ensure to separate the system/machine from main power supply lines and from the other devices which may supply any voltage (e.g. permanent magnetic motor, device including capacitors). Additionally, wait more than 10 minutes and check the charge lamp of the inverter disappears, and then confirm that the voltage between P(+) and N(-) terminals is lower than 45 VDC before performing maintenance.

A function test must be conducted at least once in a year.

**1.2.6** Others

Never modify the inverter. Any modification immediately invalidates the conformities to all the applicable norms, and the product guarantee.

The precaution items provided in User's Guide of the WJ-C1 inverter are not always described in this chapter. Please ensure to read through and understand the precaution in the User's Guide before using the WJ-C1.



# Chapter 2 Introduction to the Safety function Guide

# 2

## 2.1 What This Chapter Explains

This chapter describes the applicable product, required knowledge, target audience, purpose and general information of this documentation.

## 2.2 Applicable product

**This documentation is only applicable to the WJ-C1 inverter having the model code listed in EC declaration of conformity (see the appendix of this documentation).**

## 2.3 Target audience

The Safety function Guide is intended for qualified persons who design the safety application, plan the installation, install, carry out the test run and maintenance. Read through this documentation as well as the User's Guide of the WJ-C1 inverter before starting operation on a safety-related application. The persons must have sufficient knowledge of functional safety.

## 2.4 Purpose of the Safety function Guide

The purpose of this document is to provide necessary information to use the STO function of the WJ-C1 inverter.

## 2.5 Recommended readings

The Safety function Guide is based on the following standards. It is recommended you to read and familiarize with these standards before implementing safety-related systems.

- IEC 61508 part 1-2: 2010 *Functional safety of electrical/electronic/programmable electronic safety-related system – Part 1-7*
- IEC 61800-5-2: 2016, *Adjustable speed electrical power drive system – Part 5-2: Safety requirements – Functional.*
- EN ISO 13849-1: 2015, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design.*
- IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirement.*

Additionally, before implementing safety-related systems, it is highly recommended to read and understand the documentation listed in section S.3.

For the standards with which the WJ-C1 complies, please refer to Chapter 4.

# Chapter 3 Safety-related information and consideration

# 3

## 3.1 What This Chapter Explains

This chapter describes safety-related information and considerations.

## 3.2 Requirement of Machinery Directive

In order to fulfill the requirements of the Machinery Directive, all requirements in the applicable standards must be satisfied and WJ-C1 inverters must be used in accordance with the instructions provided in this Safety function Guide and the User's Guide of the WJ-C1.

Before using the inverter, the risk assessment of whole system must be conducted and appropriate measures must be taken. Potential risks and predictable misuse should be mentioned in a manual of machine.

## 3.3 Intentional misuse

The WJ-C1 is not designed to protect against intentional misuse/interference for STO function.

## 3.4 Safety consideration

### **3.4.1** Safety function

The WJ-C1 inverter supports the STO function which is equivalent to STO (Safe Torque Off) function defined in EN/IEC61800-5-2 as well as Stop Category 0 defined in IEC60204-1.

The WJ-C1 inverter shuts off power to a motor when STO inputs are given.

### **3.4.2** Response time

The response time is defined as a time from input of Safety request to actual activation of safety function.

In case of STO function, it is a time from input of STO signals until power to a motor is shut off.

The response time of the STO function of the WJ-C1 is 20 ms or less.

A safety-related system must be designed in consideration of the above mentioned response time so that this delay time may not lead to any hazardous situation.

### **3.4.3** Self-Diagnosis of internal path

The WJ-C1 is equipped with the self-diagnosis function which detects a fault in the internal safety paths.

When an internal fault has been detected, the safety paths maintains shut-off regardless of the states of the STO inputs to the WJ-C1.

### **3.4.4** STO Input

The STO inputs of the WJ-C1 are redundant and the both input signals must be input. The two STO inputs must be appropriately separated from each other. If only one of the inputs is used, the conformities to the applicable norms become invalid.



The WJ-C1 inverter is not equipped with a diagnosis function of STO input signal from an external device. A system must be designed so that both of the STO inputs are always given properly and simultaneously. As needed, please use the EDM signal for failure detection of STO input lines to configure a system which is able to detect a fault in STO input lines.

**3.4.5** STO Status Retention Function

(Not supported as Safety related function)



The retention function that retains the STO status of internal safety path even if STO input is canceled is not implemented as a safety circuit.

Please consider it when designing a system and, if needed, prepare an external mechanism to avoid an unintentional restart of the system. For more detailed information, please refer to Chapter 4.

**3.4.6** STO state monitor output (EDM signal)

Please use EDM signal when it is required to monitor state of the STO inputs to WJ-C1 and state of internal safety paths (failure detection state) by external devices.

Please refer to Chapter 4 for the behavior and function (signal matrix) of EDM signal.



EDM signal output is NOT a safety-related signal, but a reference signal. This signal is not capable of being used to activate another safety function.

**3.4.7** Functional test (Proof test)

A periodical functional test (proof test) to check proper functioning of the STO function must be performed at least once a year in order to maintain the intended SIL / PL.

Please refer to Chapter 10 for the details of the functional test (proof test).

**3.4.8** Caution for using the STO function

The STO function does not cut the power supply to the inverter and the peripheral circuits and does not provide any electrical isolation. Before maintenance, please ensure to separate the system/machine from main power supply lines and from the other devices which may supply any voltage (e.g. permanent magnetic motor, device including capacitors). Additionally, wait more than 10 minutes and check the charge lamp of the inverter disappears, and then confirm that the voltage between P and N terminals is lower than 45 VDC before performing maintenance.



The STO functionality is achieved only through the ST1 and ST2 connector of the inverter.

When permanent magnet motor or synchronous reluctance motor is driven, in case multiple IGBT power semiconductors fail, the inverter system can produce an alignment torque which maximally rotates the motor shaft as below regardless of the activation of the STO function.

- $180/(p/2)$  degrees (with permanent magnet motors)
- $180/p$  degrees (with synchronous reluctance motors)

$p$  denotes the number of poles.

## 4

# Chapter 4 Safety function

## 4.1 What This Chapter Explains

This chapter describes the information about the safety function of the WJ-C1.

## 4.2 Safety function (STO)

The WJ-C1 is equipped with the STO (Safe Torque Off) function defined in IEC61800-5-2. This function is equivalent to stop category 0 defined in IEC60204-1.

## 4.3 Conformity standards

The conformity standards are listed in the table below.

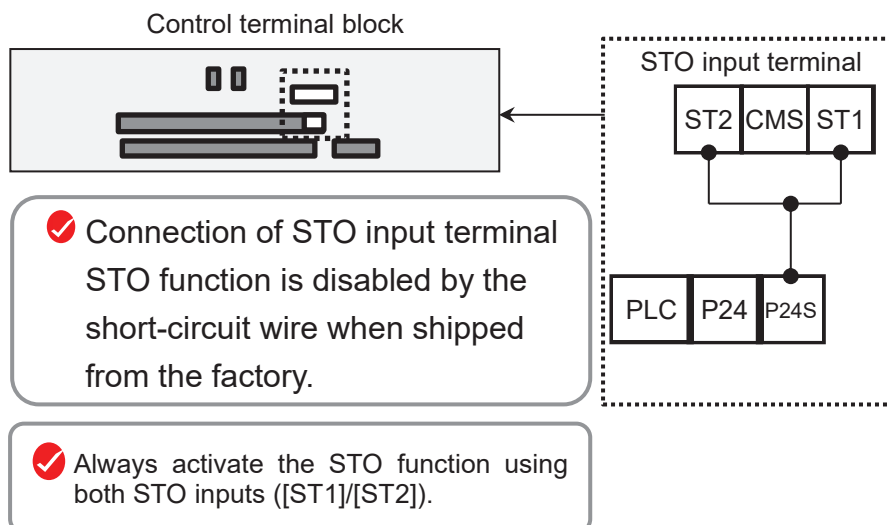
### Conformity standards

Standard	Remark
EN ISO 13849-1:2015	CAT.3 PL e
IEC 61800-5-2:2016, EN61800-5-2:2017	SIL 3
UL1998	Diagnostic software class 1
IEC60204-1:2016	Stop category 0

## 4.4 Operation Procedure of Safety Function

### 4.4.1 STO input terminal

- Input of STO signal is performed by redundant input of STO terminals [ST1] and [ST2].
- When voltage is applied to each input terminal and current flows, operation of safety path is enabled.  
(When shipped from the factory, operation is always enabled. See the figure below.)
- STO function is enabled and the output to the motor is shut off by turning OFF either of the external switches for STO signal input as shown in the wiring diagram on the next page.



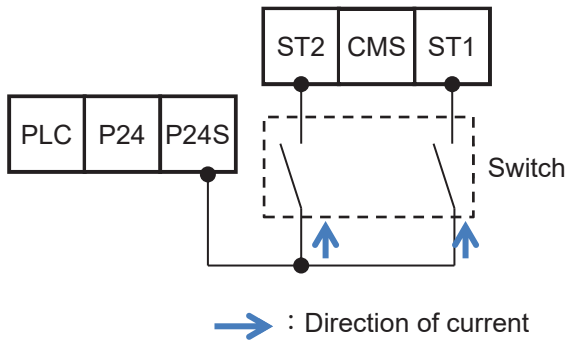
### 4.4.2 Input Method of STO Signal

Input voltage for the STO signal can be chosen from the internal power supply of inverter (P24S terminal) or an external 24 VDC power supply.

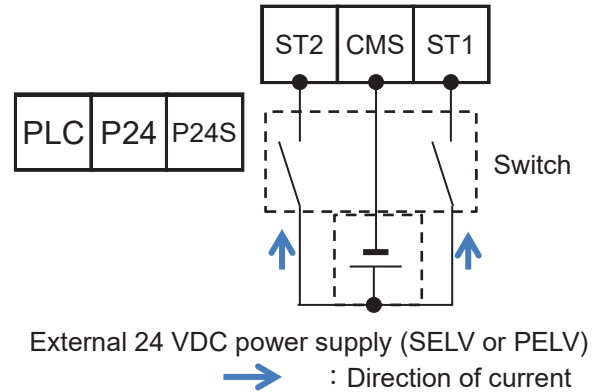
The external 24 VDC power supply must be SELV (EN/IE60950) or PELV (IEC60204).

#### ■ Wiring Example

##### ■ Internal power supply



##### ■ External power supply



See Chapter 11 for the specification of the STO terminal

By turning off the external switch (contact point) for STO input shown in the wiring example above, STO function is enabled, and output to the motor is shut off.

Refer to the User's Guide of WJ-C1 for the detailed information for wiring on the control terminal.

### 4.4.3 STO Status Retention Function (not supported as the safety function)

The retention function that retains the STO status of internal safety path even if STO input is canceled is not implemented as a safety circuit. Therefore, if a RUN command is given after cancellation of STO input or STO input is canceled while the command is given, the inverter starts output to the motor.

Hence, to satisfy the requirements about cancellation of emergency stop specified in IEC60204-1, either of the following measures has to be taken.

- (1) At the same time as STO input, set the RUN command to the inverter to stopped status.
- (2) Configure the system so that STO input to WJ-C1 is canceled when system reboot is required by the user.



By parameter settings, you can select the following operations. (see section 4.7)

- (1) Trip the inverter by STO input. In this case, the inverter is tripped and output is stopped until power is shut off or the error reset signal for the inverter is input.
- (2) If two STO input systems to the inverter are not input at the same time, the inverter is shut off and enters standby mode until STO input for the two systems is input.

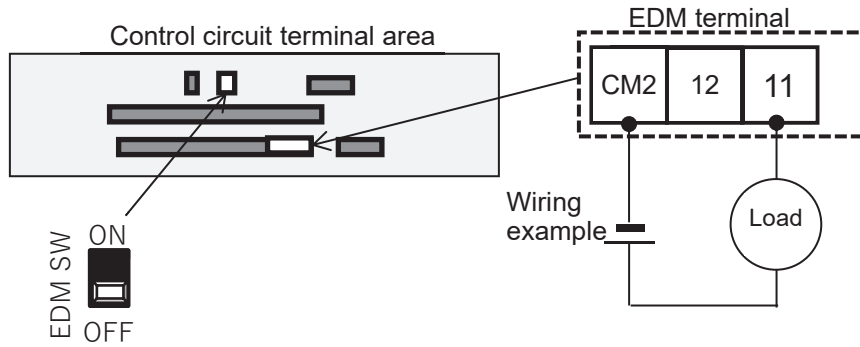
## 4.5 STO State Monitor Output (EDM Signal)

The STO state monitor output (EDM signal) is the output signal for monitoring the input status of STO signal and failure detection status on the internal safety path. When using STO state monitor output (EDM signal), turn ON EDM function selector switch on the control circuit terminal. "Output terminal [11] function [C021]" is automatically changed to "STO state monitor output (62)". At the same time, "Output terminal [11] active state [C031]" becomes "NO: Normally Open (00)" automatically.

When EDM function selector switch is turned OFF from ON, "Output terminal [11] function [C021]" is automatically changed to "No assignment (no)".

When the EDM selector switch is enabled, the monitors at input terminals 3/4 indicate the status of ST1/ST2. However, when input terminals 3/4 are turned on, the input terminal functions set to [C003]/[C004] operate. When the EDM selector switch is disabled, the monitors at input terminals 3/4 indicate the status of input terminals 3/4.

EDM terminal (11 / CM2) and wiring example




For operation of ST1/ST2 and output of EDM signal against failure detection status, see the matrix below. EDM signal turns ON only when both STO inputs are correctly input, and internal failure is not detected.

Signal matrix

Signal	Status 1	Status 2	Status 3	Status 4	Status 5
ST1*1)	STO	Operation permitted	STO	Operation permitted	*2)
ST2*1)	STO	STO	Operation permitted	Operation permitted	*2)
Failure detection	None	None	None	None	Detected
EDM	ON	OFF	OFF	OFF	OFF
Output to the motor	Off	Off	Off	Output permitted	Off

Input status	Contact point
STO	OFF
Operation permitted	ON

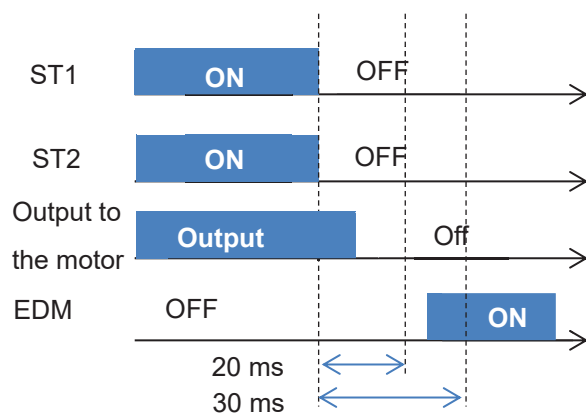
- \*1) Correspondence between the input status of [ST1]/[ST2] and the contact status.
- \*2) STO or Operation permitted

 Refer to the User's Guide of the WJ-C1 for the detailed information for wiring on I/O terminal. See Chapter 11 for the specification of STO terminal.

4.6 STO Timing Chart

The timing chart of the output to the motor and EDM signal for STO input [ST1]/[ST2] is shown below. The output to the motor is shut off within 20 ms after [ST1] and [ST2] are turned off.

Timing Chart



### 4.7 States Indication Function

By setting parameters described in the table below, the status of STO input is displayed on the control panel.

Item	Parameter	Data	Description
STO input mode selection	b145	00	No special indication. No trip (only shut down by hardware)
		01	No special indication. "STO shut-off error [E37]" occurs.
		02	Display [-S-]. "ST1, ST2 mismatch error [E98]" occurs.
		03 (04)	Display [-S-]. (03 and 04 are the same in terms of function.)
		05	Display [-S-]/[-F**]. Detect a delay of [ST1]/[ST2]. (*1)
		06	Display [-S-]/[-F**]. Detect a delay of ST1/ST2.
STO input release permissible time	b146	0.00 to 2.00(s)	Allowed time from when only one of [ST1]/[ST2] is in operation enable status (contact ON) to when both are in operation enable status (contact ON) when returning from STO status to operation enable status when (05) is set in [b145].
STO special indication cancel selection	b147	00	If a special display such as [-S-] is displayed, the indication continues.
		01	Cancellation of STO special indication is valid.
STO special indication re-display time	b148	1 to 30(s)	When the special display is canceled, the special display is re-displayed after this set time has elapsed.

\*1) When b145=05 and only one of ST1 or ST2 is operation enabled status (contact ON) for more than the "STO input release permissible time[b146]", recovery is not possible unless both of [ST1]/[ST2] are set to STO (contact OFF) status.

- b147 can temporarily cancel the STO special indications by pressing any key when the STO special indication (-S- or -F\*\*) is displayed.  
b147 = 00: Key operations are not accepted, and the STO special indication is displayed continuously. (E37/E98/E99 are error and not STO special indication. Key operations are accepted during the error.)  
b147 = 01: The STO special indication is canceled by pressing the key and the control panel becomes a normal display.
- After cancellation of the STO special indication, if there is not key operation for a certain period of time, the STO special indication will be displayed again. Also, the STO special indication is immediately displayed again when there is a change in the STO special indication.  
b148 can adjust the time from when the STO special indication is canceled to when the STO special indication is displayed again.

#### List of STO special indication and error indication

Display of control panel	Description
-S-	STO
-F01	Delay of [ST1] is detected during operation restoration from STO.
-F02	Delay of [ST2] is detected during operation restoration from STO.
-F10	Delay of [ST1] is detected during transition to STO.
-F20	Delay of [ST2] is detected during transition to STO.
E37	At least either [ST1] or [ST2] is OFF. Release trip by inputting [RS], STOP/RESET key, or turning the power off and then on again.
E98	Status of [ST1] and [ST2] are inconsistent. Release trip by inputting [RS], STOP/RESET key, or turning the power off and then on again.
E99	An error is detected in the internal circuit. The trip cannot be cancelled by inputting [RS] and STOP/RESET key. Trip can be canceled only by turning the power off and then on again.

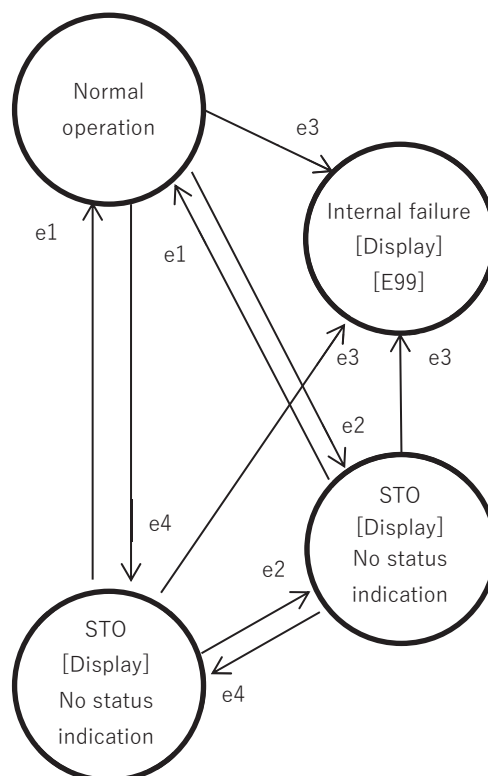
Condition table of terminal status / STO special indication / error indication

Input status	①	②	③	④	⑤	
[ST1]	Close	Open	Close	Open	Open or Close	
[ST2]	Close	Close	Open	Open	Open or Close	
Failure detection	None				Detected	
[b145]	00	–	–	–	–	E99
	01	–	E37	E37	E37	E99
	02	–	E98	E98	-S--	E99
	03	–	–	–	-S--	E99
	04	–	–	–	-S--	E99
	05	–	-F01 or -F20	-F02 or -F10	-S--	E99
	06	–	-F01 or -F20	-F02 or -F10	-S--	E99

Definition of event

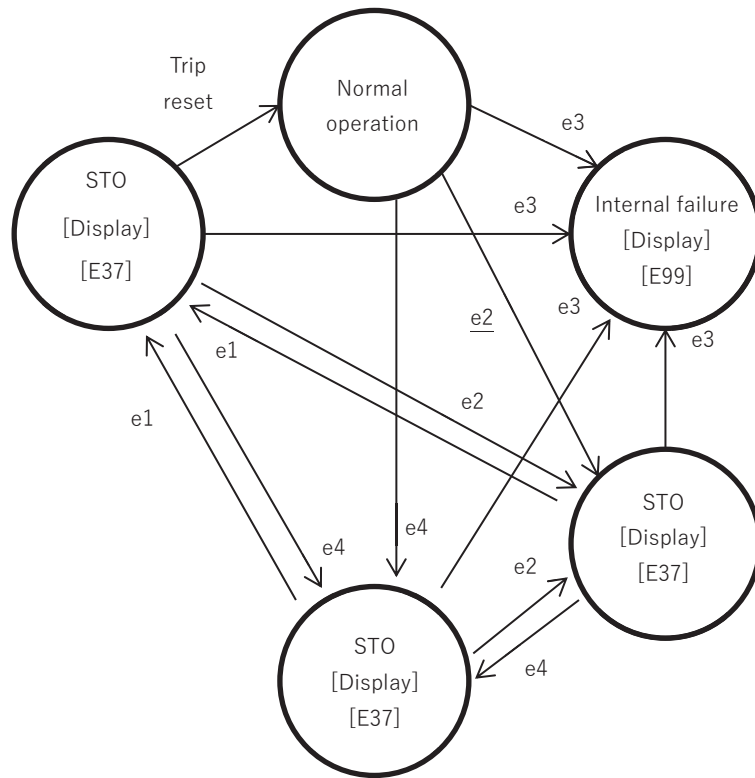
Event	Description
e1	Input status becomes ①
e2	Input status becomes ② or ③
e3	Input status becomes ⑤
e4	Input status becomes ④
e5	Input status is held more than the time set in “STO input release permissible time [b146].” This event does not exist except for b145=05.

■ State transition diagram (b145:00)

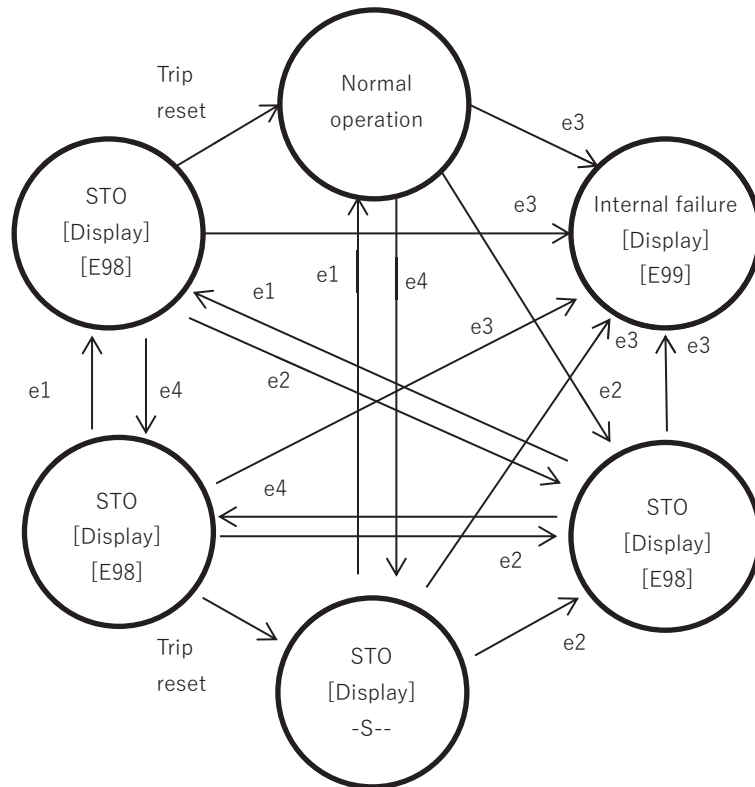




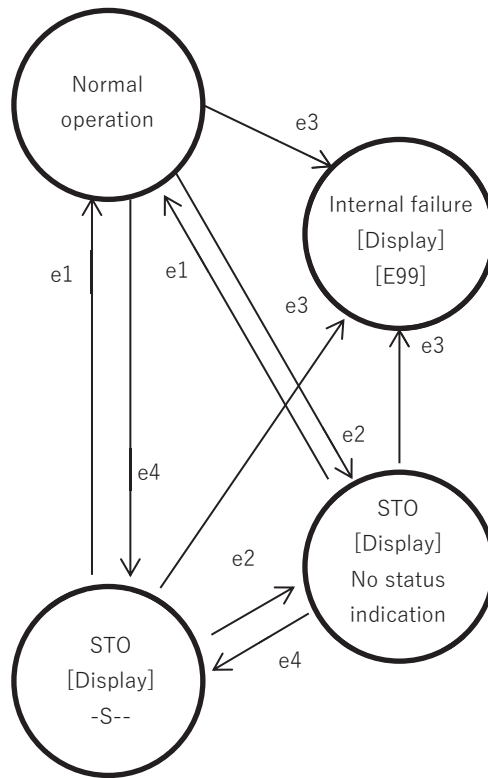
State transition diagram (b145:01)



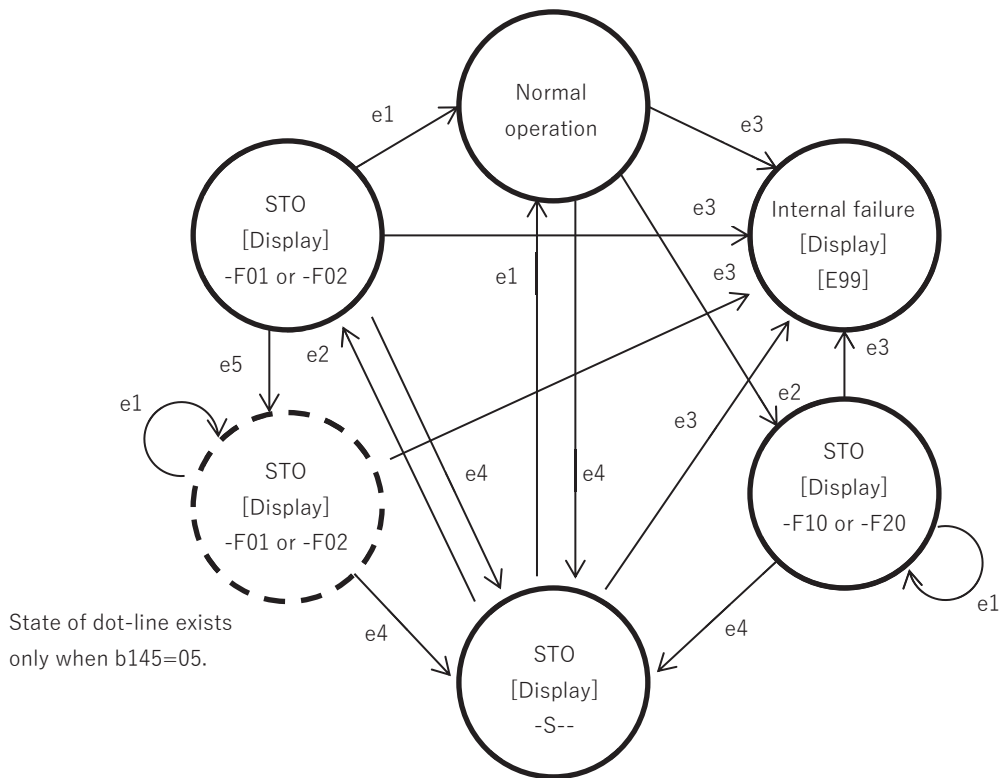
State transition diagram (b145:02)



■ State transition diagram (b145:03/04)



■ State transition diagram (b145:05/06)



## 4.8 Activation method of STO function

After completing wiring on STO terminals (See section 4.4), the STO function is automatically activated when WJ-C1 is energized and established. Any special key operation is not required.



The instructions in the User's Guide are to be followed and "verification & validation" of a system is to be completed. Otherwise, the system cannot be regarded as safe.

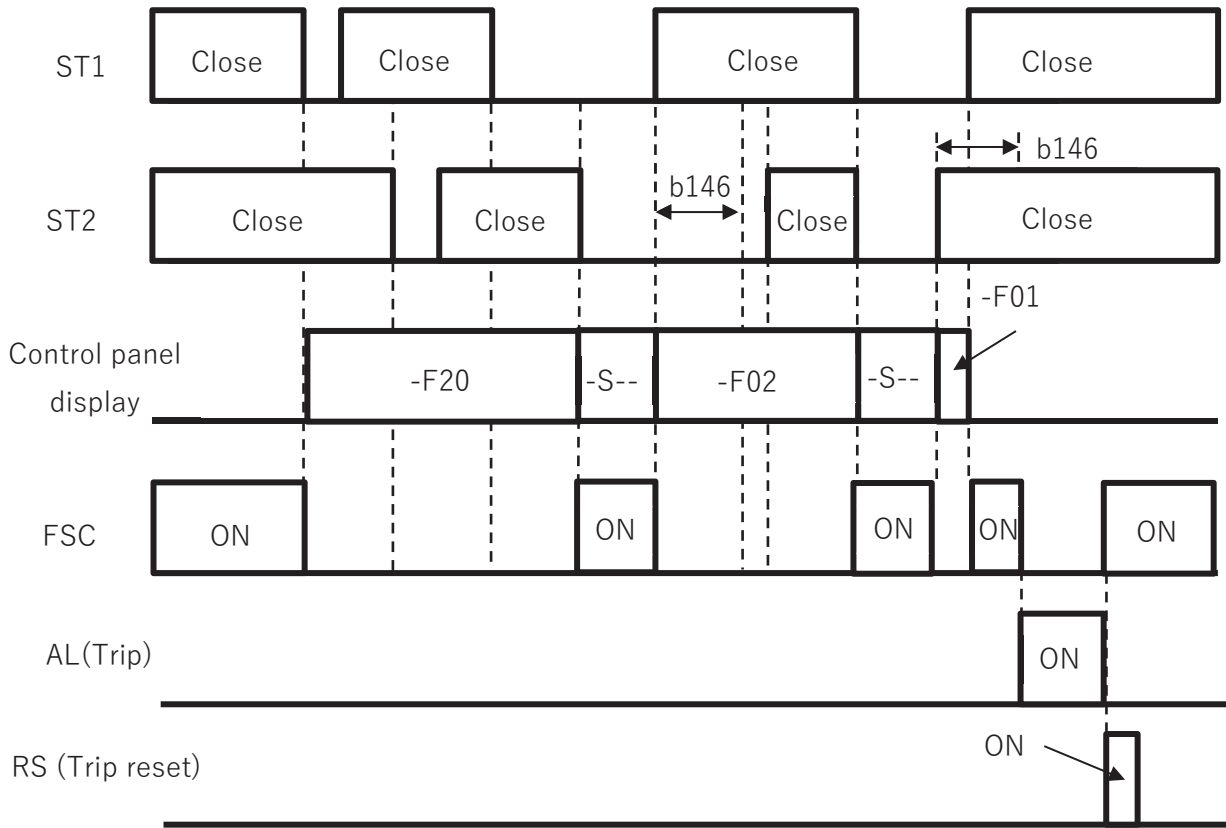
## 4.9 FSC (STO input discrepancy) output signal

The [FSC] signal is deactivated (OFF) when the inverter is in trip or a delay is detected (-F\*\* is displayed) in ON/OFF switching of [ST1]/[ST2]. The [FSC] signal outputs the status of STO signal (ST1/ST2) only when [b145] is set to 05 or 06. If [b145] is not 05 or 06, the [FSC] signal is always activated (ON).

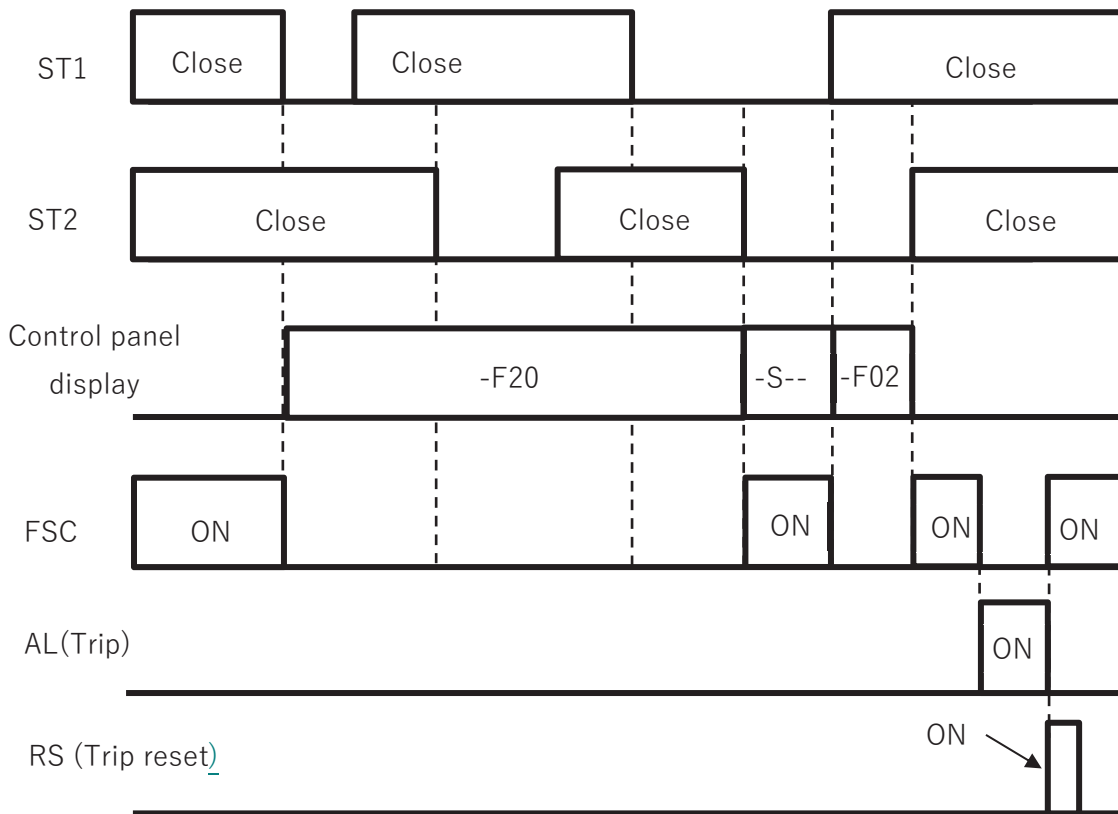
When [b145] is not 05 or 06, the [FSC] signal is deactivated (OFF) in trip. The [FSC] signal maintains deactivated (OFF) even if [b147] is set to 01 and "-Fxx" is canceled.

The judgement cycle of the [FSC] signal is 10 ms. (If [b145] is not 05/06 and the inverter is not in trip, the [FSC] signal is ON.)

Item	Parameter	Data/ Data rang	Description
Selection of output terminal [11] (EDM is assigned automatically when EDM SW is ON)	C021	00 to 64, no	64: STO input discrepancy [FSC]
Selection of output terminal [12]	C022		
Selection of output terminal [AL]	C026		



a) Timing chart of FSC output signal with b145=05



b) Timing chart of FSC output signal with b145=06

## 5

# Chapter 5 Installation Planning

## 5.1 What This Chapter Explains

This chapter describes the items which must be taken into consideration for planning installation of WJ-C1 and safety-related system.

## 5.2 Requirement for designer and installer (installation supervisor)

Designers and installers (installation supervisor) who design and install safety-related system must have been trained to have the specialist knowledge of the essential principles for designing and installing safety-related systems.

Designers and those who maintain safety-related system must have been trained to understand the cause and consequences of the common cause failure (CCF).

## 5.3 Installation environment

The product must be installed in a place where environmental condition such as temperature, humidity, corrosive gas, dust, vibration, is within the specification of the product without external environmental controls. Please refer to the User's Guide of WJ-C1 for the requirements and specification for installation as well as the environmental specification provided in chapter 11 in this documentation.

The WJ-C1 must be installed in an enclosure (cabinet) having a protection rating of IP54 or higher for protection against conductive dust and contamination.

## 5.4 Electrical installation

### 5.4.1 General Requirements

Please follow the instruction provided in the User's Guide of WJ-C1 for electrical installation. If there is any conflict or different description in the User's Guide of WJ-C1 and this documentation, the description in this documentation shall be considered to have priority.

All the cables and signal lines must be protected, routed, and fixed appropriately.

### 5.4.2 STO input

The two STO inputs (ST1 and ST2) must be appropriately separated and protected from each other to avoid mutual interference. (E.g. separated cables, protection, double-shield cable)

The length of the cablings connected to STO terminals (ST1, ST2, P24S, and STC) must be twenty (20) meters or shorter.

Please refer to the wiring examples in Chapter 4 for wirings on STO terminals.

At least one of the measures 1 to 3 below must be adapted to STO input wirings for the protection against grounding fault:

1. Grounding STO signal power line (CMS)
  - ◆ In case of use of the internal power supply  
Ground CMS terminal
  - ◆ In case of use of an external power supply  
Use a power supply (PELV) which is grounded on CMS terminal side.
2. A fail-safe cable routing (The requirements of ISO13849-2 table D.4 to be met. One of the following measures needs to be adopted)
  - ◆ Permanently connected (fixed) and protected against external damage, e.g. by cable ducting or
  - ◆ Use of separate multicore cable
  - ◆ Within an electrical enclosure, with both conductor and enclosure meeting the requirement of IEC 60204-1
  - ◆ Individually shielded with earth connection
3. Using an external device for grounding fault detection.

In case of connecting a device that generates diagnostic test pulses on STO input lines, the width of the test pulse (width of OFF pulse) must be 500  $\mu$ s or shorter.

### 5.4.3 STO status monitor (EDM signal)

The EDM signal which indicates state of STO inputs and internal fault detection is a reference signal, non-safety signal. This signal may not be used to activate another safety function.

The length of the cabling connected to 11 and CM2 terminals must be twenty (20) meters or shorter.

### 5.4.4 EMC

The system must only be used in the EMC environment that it is designed for, or necessary mitigations must be applied. WJ-C1 must only be used within the EMC environment specified in IEC61800-5-2:2016, 2<sup>nd</sup> environment.

### 5.4.5 Routing the cables

Cabling of input and output of the safety function must be physically and appropriately separated from the other signal cablings.

## 6

# Chapter 6 Installation

## 6.1 What This Chapter Explains

This chapter describes the items to be taken into consideration for installation of WJ-C1 and safety-related system.

## 6.2 Installation

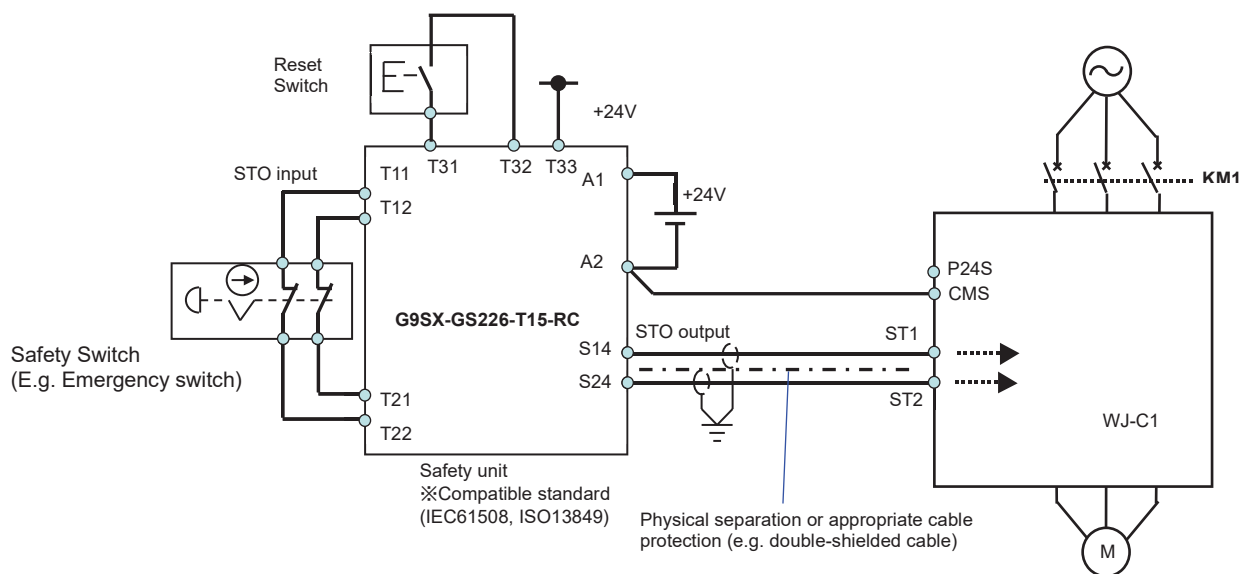
The product must be installed according to the instructions provided in the User's Guide of WJ-C1 and this documentation. In case of using any optional devices such as a fieldbus module, please read through the guides of each optional device before working on the product.

## 6.3 Wiring example

The figure below is a wiring example under the following conditions.

- ◆ Use of an external power supply for STO inputs
- ◆ STO input logic : "Source" logic
- Note:** In case of using the internal power supply, please refer to Chapter 4 to perform wiring appropriately.
- ◆ No use of EDM signal output
- ◆ Reset/Release of STO input to WJ-C1 is controlled using the reset function of a safety unit.

### Wiring Example



### Operation sequence of wiring example

1. When the safety switch is pressed, S14 and S24 become OFF, the current flowing in ST1 and ST2 terminals are shut off, and the STO function is activated. (The output of the inverter is shut off).
2. Even after the safety switch has been released, the STO inputs to ST1/ST2 on WJ-C1 maintain shut off by the safety unit.
3. After the operator of the system has confirmed the safety of human and the system, and then presses the reset switch, STO inputs to ST1/ST2 on WJ-C1 are released and the inverter becomes available to restart motor operation. In case of b145=01, a release of trip on WJ-C1 is needed to become available to restart motor operation.

## 6.4 External device

All power supply connected to control circuit terminal block must comply with SELV or PELV.

The signal lines to ST1 and ST2 terminals must be physically separated or appropriately protected.

All devices used to deliver STO signals must comply with the functional safety such as ISO13849-1, IEC61508.

WJ-C1 does not diagnose external devices.

The followings are the examples of the safety devices to be combined with WJ-C1.

### Example of Safety devices

Series	Model	Manufacturer	Conformity standards
G9SA	301	OMRON	ISO13849-1 cat4, SIL3
G9SX	GS226-T15-RC	OMRON	IEC61508 SIL1-3
NE1A	SCPU01-V1	OMRON	IEC61508 SIL3

The configuration of all components used in any circuit other than an appropriately pre-approved safety module that interfaces with the WJ-C1 STO terminals MUST be at least equivalent to Cat.3 PLe/SIL3 under ISO13849-1 in order to be able to claim PLe/SIL3 for the combination of WJ-C1 and external circuits.

The width of test pulse (OFF pulse) applied to ST1/ST2 terminals must be 500  $\mu$ s or shorter.

Stop category 0 (IEC60204-1) is realized when used in combination with external devices complying with the standards and installed following the instructions of the manual, in particular the safety related instructions.



## 7

# Chapter 7 Test Run

## 7.1 What This Chapter Explains

This chapter describes the items to be considered for a test run.

## 7.2 Considerations

After completion of installation, the test run of whole system must be conducted.

The test run of the system must be conducted by only competent electricians who have sufficient knowledge on functional, machine and process safety.



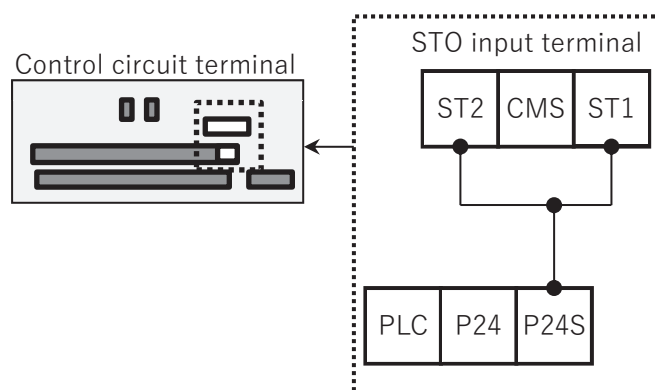
The system must not be considered safe until all the safety functionality is verified and validated.

## 7.3 Enabling STO function

The STO function is automatically activated when WJ-C1 is energized and established according to this Safety function Guide and the User's Guide of the WJ-C1 inverter.

## 7.4 Disabling STO function

To disable the STO function, please connect the short-wiring as shown in the figure below. (The same wiring condition as the factory default)



## 7.5 Validation test

- (1) Start operation of the motor by giving RUN and frequency command.
- (2) Open ST1 and ST2 and check if the inverter displays the status and the power to the motor is shut off (free-run).
- (3) WJ-C1 without failure is confirmed by completing the test procedure above.

# Chapter 8 Verification and Validation

# 8

## 8.1 What This Chapter Explains

This chapter describes information related to verification and validation of system.

## 8.2 Verification

It is to be verified that the system has achieved the required safety level and function.

## 8.3 Validation

It is the responsibility of machine manufacturer who uses safety devices and configure safety-related system to ensure that the required safety functions have been achieved in the system.

A test plan for validation test must be prepared and validation test must be conducted in accordance with the test plan. The result of the validation test is to be documented in a report.

Validation test must be conducted in the following timing.

- (1) Start-up of the safety-related system (test run)
- (2) When a change which may affect the safety function has been applied
- (3) After maintenance
- (4) In case that a periodical test is required by the applicable EU directive/standard or local standard.

In the validation test, it is to be confirmed that the STO function of WJ-C1 works as intended with the same procedure as the functional test (proof test).

**Note:** In order to maintain the intended functionality of the STO function, it is necessary to conduct a functional test (proof test) at least once in a year. For the details of the functional test, please refer to Chapter 10.

## 8.4 Requirement for Validator

Validation of the system must be conducted by only competent electricians who have essential knowledge of the functional safety as well as the safety function realized in the system.

The report of the validation must be completed by the above-mentioned competent electricians.

## 8.5 Residual Risk

The safety functions are applied to reduce the recognized risk and hazardous conditions in the system.

It may not be always possible to eliminate all potential risks and hazards.

Therefore, warning for the residual risks must be given to the operators.

# Chapter 9 Error and Troubleshooting

# 9

## 9.1 What This Chapter Explains

This chapter describes the errors related to the STO function and their troubleshooting.

## 9.2 Error events

An error is generated when the internal diagnosis function detects a failure in the internal safety paths or when configured by related parameters. Please refer to the sections below for the error contents and their troubleshooting.

### 9.2.1 [E37] STO shut-off error

When "STO input mode selection [b145]" is set to "[E37] trip (01)" and either of the [ST1]/[ST2] input terminals is off, the inverter trips.

#### **What to do**

- If this error is not released even after releasing STO inputs to WJ-C1 and then cycling power, please check wiring and signals of the STO inputs.
- If this error is generated in an unintentional condition, please perform the functional test of the STO function of WJ-C1 to check proper functionality of the STO function.
- If the generation of this error is not desired in the system, it can be disabled by setting [b145] to other than "01".

### 9.2.2 [E99] STO internal failure error

When a failure is detected in the safety path inside WJ-C1, the inverter trips regardless of [b145] setting. After this error occurs, the internal safety paths hold on STO state until powered down.

#### **What to do**

- When this error is generated, it is likely that a fault exists in the internal safety paths of the WJ-C1.
- Please ensure to stop the operation of the system and shut off the power supply, and then conduct the functional test.

### 9.2.3 [E98] ST1/ST2 mismatch error

When "STO input mode selection [b145]" is 02 and there is a mismatch in the [ST1]/[ST2] input signal status, the inverter trips.

#### **What to do**

- Check the wiring and signal on STO input.
- If this error is not desired, it can be disabled by setting the parameter [b145] to other than "02".

## 9.3 Warning display

In case that a warning (one of -F10/-F20/-F01/-F02) is displayed on the control panel, there is a possibility that input status of ST1 and ST2 is inconsistent. Please check that the two STO inputs are given properly.

In case the inconsistent state of ST1/ST2 during state transition is inevitable because of system configuration, please adjust the parameter [b146] suitable for the system.

## 9.4 When fault found in safety path

Please contact the nearest Hitachi distributor when there is a fault in the safety path of WJ-C1.

- [E99] occurs.
- STO or any warning is displayed on the operator keypad even if the power is turned on with the wiring set to the factory default.

# Chapter 10 Maintenance

## 10.1 What This Chapter Explains

This chapter describes the items related to maintenance.

## 10.2 Planning of maintenance

The maintenance on a safety system is critical importance for safety reasons.

You must plan and perform maintenance accordingly.

The WJ-C1 requires conducting the functional test (proof test) at least once in a year. When planning maintenance of the system, this functional test must be considered.

## 10.3 Daily and periodical inspection

The WJ-C1 requires daily and periodical inspection in addition to the functional test (proof test) of the STO function. Please perform inspections as instructed in the User's Guide of WJ-C1.

## 10.4 Functional test (proof test)

A periodical STO functional test (proof test) must be performed at least once in a year in order to maintain the intended safety performance level of the STO function.

This periodical STO function test (proof test) is one of the conditions for the STO function of WJ-C1 to meet PLe of EN ISO13849-1 and SIL 3 of IEC61800-5-2.

In the functional test (proof test), it is to be verified that output to the motor is appropriately shut off and EDM signal is output as intended (see the signal matrix in the following page)

The procedure of the functional test (proof test) is as below:

- (1) Check if the EDM terminal (11 and CM2) is OFF (open) when power to WJ-C1 is not supplied.  
**(State 1)**
- (2) Power up WJ-C1 and set both ST1/ST2 to ON (Allow operation: short), and then start motor operation.  
**(State 5)**
- (3) Set both ST1 and ST2 to OFF (STO: open), and check if the output to the motor is shut off and EDM signal (11 and CM2) is ON (Conducted).  
**(State 2)**
- (4) Set both ST1 and ST2 to ON (Allow operation) and then restart the motor operation.  
**(State 5)**
- (5) Set only ST1 to OFF (STO: open) and check if the output to the motor is shut off and EDM signal (11 and CM2) is OFF.  
**(State 3)**
- (6) Set both ST1 and ST2 to ON (Allow operation) and then restart motor operation. **(State 5)**
- (7) Set only ST2 to OFF (STO: open) and check if the output to the motor is shut off and EDM signal (11 and CM2) is OFF.  
**(State 4)**

When finding any state not following the signal matrix below, there may be a fault in the safety path of the WJ-C1. In that case, stop using the inverter immediately and contact Hitachi distributor.

**Signal Matrix for functional test (proof test)**

	<b>Status</b>				
	Status 1	Status 2	Status 3	Status 4	Status 5
Power	OFF	ON	ON	ON	ON
ST1	-	OFF (Open circuit)	OFF (Open circuit)	ON (Short circuit)	ON (Short circuit)
ST2	-	OFF (Open circuit)	ON (Short circuit)	OFF (Open circuit)	ON (Short circuit)
Output to the motor	Shut-off	Shut-off	Shut-off	Shut-off	Output permitted
EDM	OFF (Open)	ON (Closed)	OFF (Open)	OFF (Open)	OFF (Open)

# Chapter 11 Specifications and Technical data

# 11

## 11.1 What This Chapter Explains

This chapter describes the specifications related to the STO function and its technical data.

## 11.2 Electrical Specifications

Refer to the table below for the specifications of the terminals related to the STO function.

### ■ STO Terminal Specifications

Terminal Symbol	Terminal Name	Description	Electrical Characteristics
ST1/ST2	STO input terminal	Input terminals for STO signal	Voltage between ST1/ST2 and CMS <ul style="list-style-type: none"> <li>• ON voltage Min.15 VDC</li> <li>• OFF voltage Max.5 VDC</li> <li>• Max. allowable voltage 27 VDC</li> <li>• Load current 5.8 mA (at 27 VDC)</li> </ul> (Note 1)
P24S	24 VDC output power terminal (STO dedicated terminal)	24 VDC power supply dedicated for ST1/ST2 input Not used when the STO input voltage is supplied from an external power supply.	24 VDC, 100 mA output at maximum
CMS	Common for 24 VDC output power terminal (STO dedicated terminal)	Common terminal for P24S	
11	Output terminal [11]	Terminal 11 outputs EDM signal when EDM SW is turned ON.	Open collector output Between 11 terminal and CM2 <ul style="list-style-type: none"> <li>• Voltage drop when turned on: 4 VDC or less</li> <li>• Max. allowable voltage: 27 VDC</li> <li>• Max. allowable current: 50 mA</li> </ul>
CM2	Common for output terminal	Common terminal for output terminal [11].	

**Note 1:** Corresponding to "Digital input type 1" defined in IEC61131-2

Please refer to the User's Guide of WJ-C1 for the specifications of the other terminals of I/O terminal block and main terminals.

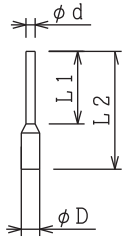
Length of cabling connected to the terminals above must be twenty (20) meters or shorter.

## 11.3 Recommended terminals for wiring

For the control circuit terminal block, a spring clamp type terminal block is employed.

For the convenience of wiring and improvement of connection reliability, it is recommended to use ferrules terminals with the following specifications.

\* Ferrule with sleeve

Wire size mm <sup>2</sup> (AWG)	Rod terminal model *2	L1 [mm]	L2 [mm]	φd [mm]	φD [mm]	
0.25 (24)	AI 0,25-8YE	8	12.5	0.8	2.0	
0.34 (22)	AI 0,34-8TQ	8	12.5	0.8	2.0	
0.5 (20)	AI 0,5-8WH	8	14	1.1	2.5	
0.75 (18)	AI 0,75-8GY	8	14	1.3	2.8	

**Note 2:** Manufacturer: Phoenix Contact GmbH & Co. KG, Crimping tool: CRIPMFOX 6

### 11.4 Safety function

Function	Standard
STO (Safe Torque Off)	IEC61800-5-2:2016 EN61800-5-2:2017
Stop category 0	IEC60204-1:2016

### 11.5 Response time

Item	Time
Response time of STO	20 ms max.
Response time of EDM signal (reference)	30 ms max.

### 11.6 Safety-related parameters

Parameter	Value	Standard
PL	e	EN ISO 13849-1:2015
CAT.	3	
MTTFd	100 years	
DCavg	> 99%	
SIL	3	IEC61508: 2010
HFT	1	IEC61800-5-2:2016
SFF	> 90%	EN61800-5-2:2017
PFH	$< 2 \times 10^{-8}$	
PFD	$< 2 \times 10^{-4}$	
T <sub>M</sub>	20 years	

### 11.7 Operating environment

Ambient temperature	ND (normal duty): -10 to 50 °C LD (Low duty): -10 to 40 °C
Storage temperature	-20 to 65 °C
Level of humidity	20 to 90 %RH (No condensation allowed)
Vibration tolerance	5.9 m/s <sup>2</sup> (0.6G), 10 to 55 Hz
Installation place	1,000 m altitude or lower (location free from corrosive gas, oil mist, and dust)

# Appendix

## EC Declaration of Conformity (Copy)



### <Remarks>

- Purpose of this chapter is to provide necessary information related to EC declaration of conformity.
- The original version is available separately. Please contact Hitachi distributor for the original.

## EC-DECLARATION OF CONFORMITY (Sample)

We, Hitachi Industrial Equipment Systems Co., Ltd.

1-1 Higashinarashino 7-chome, Narashino-shi, Chiba 275-8611, Japan, declare in our sole responsibility that the following products conform to all the relevant provisions.

Product name: **AC Inverter, WJ series C1**

Single-phase, 200-240VAC, 50/60Hz

Three-phase, 200-240VAC, 50/60Hz

Three-phase, 380-480VAC, 50/60Hz

### Models Covered:

Model C1, may be followed by -, followed by 001, 002, 004, 007, 015, 022 may be followed by S, maybe followed by B or F, maybe followed by C, E or U, maybe followed by F, maybe followed by any letters or numbers.

Model C1, may be followed by -, followed by 001, 002, 004, 007, 015, 022, 037, 055, 075, 110, 150 may be followed by L, maybe followed by B or F, maybe followed by C, E or U, maybe followed by F, maybe followed by any letters or numbers.

Model C1, may be followed by -, followed by 004, 007, 015, 022, 030, 040, 055, 075, 110, 150 may be followed by H, maybe followed by B or F, maybe followed by C, E or U, maybe followed by F, maybe followed by any letters or numbers.

Authorized Representative: Hitachi Europe GmbH

Niederkasseler Lohweg 191, 40547 Dusseldorf, Germany

Council Directives: MD: 2006/42/EC (MD: Machinery Directive)  
EMC: 2014/30/EU

Harmonized Standards: MD: EN 61800-5-2:2017 / IEC 61800-5-2:2016  
EN ISO 13849-1:2015 / ISO13849-1:2015  
EMC: EN61800-3:2018

Relevant Standard: IEC61508 Parts 1-7:2010  
EN/IEC 61800-5-1:2021  
IEC 60204-1:2016 (Stop Category 0)  
(To apply the EMC EN61800-3, use a filter designed for above models.)



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