

Safety Instructions and Precautions for AC Servos (Safety Sub-Function)

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Specifications are subject to change without notice. Compliance with the indicated global standards and regulations is current as of the release date of this installation guide. The original instructions for Europe are in English.

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Contents of the package

Item	Packed articles	Quantity
Servo amplifier		1
MR-JET Safety Instructions and Precautions for AC Servos		1
MR-JET Safety Instructions and Precautions for AC Servos (Safety Sub-Function) (this guide)		1

1. About the manuals

To use the MELSERVO-JET series safely, read MR-JET User's Manuals carefully.

1.1 Purpose of this guide



This guide is subject to engineers of machine manufacturers and operators of machines, and explains functional safety of the MR-JET servo amplifier (hereafter "MR-JET"). For detailed information of the products, refer to MR-JET User's Manual. This guide does not explain how to operate equipment that incorporates an MR-JET.

1.2 Terms related to safety

Item	Detailed explanation
STO (Safe torque off)	Shuts off servo motor drive energy electronically based on an input signal from an external device (secondary-side output shut-off). This corresponds to stop category 0 of IEC/EN 60204-1.
SS1 (Safe stop 1)	Starts deceleration based on an input signal from an external device (EM2). After a specified time to confirm that the motor has stopped, the STO function will be activated (SS1-1). Alternatively, the SS1 function monitors whether the servo motor decelerates according to the deceleration time constant (SS1-r). This corresponds to stop category 1 of IEC/EN 60204-1.
SLS (Safely-limited speed)	This is a function to observe whether the speed is within a regulated speed limit value. When the speed is over a specified speed, energy will be shut off by STO.
SSM (Safe speed monitor)	Outputs a safety output signal when the servo motor speed is within a regulated speed.
SBC (Safe brake control)	Outputs a safety output signal for an external brake control.
SDI (Safe direction)	Monitors whether the travel direction of the servo motor is as specified. The STO function shuts off the energy if the direction is different from the specified direction.
SLT (Safely-limited torque)	Monitors whether the torque exceeds the specified torque. The STO function shuts off the energy if the torque exceeds the specified torque.
Status monitor (SM)	Outputs a signal that indicates the status of the safety sub-function. This is an original function of the MR-JET and is not defined in IEC/EN 61008-5-2.

2. About safety

This chapter explains safety of users and machine operators. Please read the chapter carefully before mounting the equipment. In this guide, the specific warnings and caution levels are classified as follows.

	Indicates that incorrect handling may cause hazardous conditions, resulting in death or severe injury.
	Indicates that incorrect handling may cause hazardous conditions, resulting in medium or slight injury.

2.1 Professional engineer

Only professional engineers should mount this to MR-JET.

Here, professional engineers should meet all the conditions below.

- Persons who took a proper training of related work of electrical equipment or persons who can avoid risk based on past experience.
- Persons who have read and familiarized himself/herself with this installation guide and operating manuals for the protective devices (e.g. light curtain) connected to the safety control system.

2.2 Conditions of use for the product

- MR-JET complies with a safety standard, but this fact does not guarantee that MR-JET will be free from any malfunction or failure. The user of this product shall comply with any and all applicable safety standard, regulation or law and take appropriate safety measures for the system in which the product is installed or used and shall take the second or third safety measures other than the product. Our company is not liable for damages that could have been prevented by compliance with any applicable safety standard, regulation or law.
- Our company prohibits the use of Products with or in any application involving, and we shall not be liable for a default, a liability for defect warranty, a quality assurance, negligence or other tort and a product liability in these applications.

- Power plants
- Trains, railway systems, airplanes, airline operations, and other transportation systems
- Hospitals, medical care, dialysis and life support facilities or equipment
- Amusement equipment
- Incineration and fuel devices
- Handling of nuclear or hazardous materials or chemicals
- Mining and drilling
- Other applications where the level of risk to human life, health or property are elevated.

2.3 Correct use

- If you need to get close to the moving parts of the machine for inspection or other purposes, ensure safety by confirming the power off, etc. Otherwise, it may cause an accident.

Point

- The safety sub-function complies with the immunity-related basic specifications required for functional safety, and fulfills requirements for industrial uses. The safety sub-function is not for general use.
- Functional safety is not available for MR-JET-G4-HS(N1) in a default state. To use functional safety, set the functional safety parameters according to the MR-JET user's manual.

Only professional engineers can use control systems related to the safety sub-function that are configured with an MR-JET. Additionally, only when a professional engineer installed, performed test operations, and adjusted a machine following the MR-JET user's Manuals, an operator can use the machine.

2.4 Safety sub-function compatible unit

The safety sub-function is executed by writing parameters and programs to systems configured with the MR-JET and the safety programmable controllers in the following table. Set the safety sub-function parameters of the MR-JET correctly for proper operation of the safety sub-function. Protective functions such as the safety sub-function may not work due to an incorrect setting. Refer to the MR-JET User's Manuals for the parameter setting details.

(1) List of safety sub-function compatible unit

Product name	Model
Servo amplifier	MR-JET-G4-HS(N1)
Programmable controller ¹⁾	R-SFCPU

¹⁾ For using the safety sub-function via CC-Link IE TSN

(2) List of safety sub-function compatible units

Servo amplifier	Function achieving method (wiring direction)	Servo motor type ²⁾	Safety sub-function (IEC/EN 61008-5-2) ¹⁾								
			STO	SS1 ¹⁾	SS1-r ¹⁾	SBC	SLS ¹⁾	SSM ¹⁾	SDI ¹⁾	SLT	
MR-JET-G4-HS(N1)	DIO connection ²⁾ (CN3)	ROLI	Cat. 4 PL e, SIL 3	Cat. 4 PL e, SIL 3	Cat. 3 PL d, SIL 2	Cat. 4 PL e, SIL 3	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2
	Network connection ³⁾ (CN1A/CN1B)	ROLI	Cat. 4 PL e, SIL 3	Cat. 4 PL e, SIL 3	Cat. 3 PL d, SIL 2	Cat. 4 PL e, SIL 3	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2	Cat. 3 PL d, SIL 2

- Combine the MR-JET with a programmable controller R-SFCPU with a firmware version 20 or later.
- The safety levels in the table apply if the safety sub-function control is performed by a programmable controller, a safety CPU or a safety controller that complies with Category 4 PL e, SIL 3.
- If the MR-JET are directly connected with emergency stop switches, safety switches, enabling switches, or other similar devices, the safety level Category 3 PL d, SIL 2 applies.
- Fully closed loop control systems do not support SS1-r, SLS, SSM, and SDI.
- The safety sub-function via a network connection with CC-Link IE Field Network Basic cannot be used.
- For DIO connection (CN3), a diagnosis using test pulses is required to satisfy Category 4 PL e, SIL 3, e.g., Category 4 if the SBC output test pulse is valid, Category 3 if it is not.
- For information on the firmware versions of the MR-JET with which the safety sub-function can be used, refer to the User's Manual (Introduction).
- R.O. Rotary servo motor, L.I. Linear servo motor

2.5 General cautions for safety protection and protective measures

Point

- Observe the cautions for safety protection and protective measures.
- Observe the items in this section for proper use of the safety sub-function.

- When mounting, installing, and using the safety sub-function, always observe the standards and directives applicable in the respective countries.
- The manufacturer and owner of machines for which the safety sub-function of MR-JET is used should be familiarized with all the applicable laws and regulations and should be responsible to observe them. For Declaration of Conformity (DoC), our company declares that the MR-JET is in compliance with the necessary requirements and standards (2006/42/EC, 2014/30/EU, 2014/35/EU, 2011/65/EU, and (EU)2015/863). For the copy of Declaration of Conformity, contact your local sales office.
- The contents of the MR-JET User's Manuals must be observed. When using an encoder manufactured by another company that complies with Mitsubishi Electric Serial ENC communication or ABZ-pulse (TTI), also according to the manual for that encoder, estimate the PFH for the whole safety system according to the diagnostic coverage (DC) of the encoder given in specifications under the responsibility of the customer. All the encoder for PDS should comply IEC/EN 61008-5-1 and 5-2 including environmental and EMC. When there is no PFH value of encoder, it should be calculated from based MTBF (acceptable range of failure rate of encoder $\lambda_d = 50\%$, $\lambda_{du} = (1-DC) \cdot \lambda_d$). And at least PFH < 9E-7 (for SIL2), PFH < 9E-8 (for SIL3) or less.
- Tests should be performed by professional engineers, especially qualified and responsible personnel, and should be recorded/documentated for a third party to rebuild and confirm the tests.
- An external power supply of equipment should have resistance to instantaneous power failure for 20 ms according to the specifications of IEC/EN 60204-1.

2.6 Disposal
Disposal of unusable or irreparable devices should always occur in accordance with the applicable country-specific waste disposal regulations.

2.7 Risk assessment

To ensure safety, users should decide all the risk assessments and residual risks in the entire machine equipment. A company and/or individual who constructs the safety related system must take full responsibility for installation and commissioning of the system. Additionally, when complying with a European machinery directive, the system must acquire safety standards certification as a whole. Perform all risk assessments and safe level certification to the machine or the system as a whole. It is recommended that a Certification Body final safety certification of the system be used. The following shows residual risks concerning the safety sub-function of this product.

2.7.1 Common residual risks in each function

- At the shipment to end-users, check the settings of safety related components with programming tools and monitor/displayed contents on display and record and save the setting data concerning the safety sub-function and the programming tools you used. Perform them using a check sheet, etc.
- The safety will not be ensured such as in assembling machine until installing, wiring, and adjustment are completed properly. Install, wire, and adjust your system referring to installation guide for each unit.
- Only qualified personnel are authorized to install, startup, repair or adjust the machines in which the components are installed. Only trained engineers should install and operate the equipment. (ISO 13849-1:2015 Table F.1 No. 5)
- Separate the wiring for the safety sub-function from other signal wirings. (ISO 13849-1:2015 Table F.1 No. 1)
- Protect the cables with appropriate ways (routing them in a cabinet, using a cable guard, etc.).
- We recommend using a switch, relay, sensor, etc. which comply with safety standards. When using a switch, relay, sensor, etc. which do not comply with safety standards, perform a safety confirmation.
- Keep the required clearance/creepage distance depending on voltage you use.
- The time to detect a safety observation error depends on the parameter setting.

2.7.2 Residual risks specific to each function

- Speed monitoring (SLS)
 - Speed monitoring function guarantees the servo motor speed, but it does not guarantee the actual machine speed. Set parameters so that the safe speed of the machine is the same as the safety speed of the specified motor.
 - Check if the speed of the monitored servo axis is the same as the actual speed by using a tachometer, etc. considering the speed includes an error caused by the command and encoder resolution.
 - The defect of the mechanical section such as slippage of shaft and wanting of a timing belt, etc. is not covered. Be sure to eliminate the risk of mechanical section before operation.
 - Speed monitoring error detection time is set to 1 ms. Errors in shorter than this time are not detected.
 - After speed is over the limit, a safety observation error (shut-off signal off) does not occur during the speed error detection time set by parameters. Make sure that safety can be ensured during this period.
- Safe speed monitor (SSM)
- Safe brake control (SBC)
 - This function guarantees only that power to mechanic break is properly supplied and abrasion of the brake cannot be detected. Check this function regularly that the mechanic brake can operate.
- Safe rotation direction limit (SDI)
 - If the shaft of the servo motor (or a coil, if a linear servo motor is used) remains at a stop for a long time after the motor has traveled as specified, switch the function to the SBC function.

3. Using safety sub-functions and block diagram

3.1 Using safety sub-functions

The safety sub-functions can be used on the MR-JET-G4-HS(N1). Refer to the MR-JET User's Manuals for applications and setting methods of the functions.

(1) Using safety sub-functions by MR-JET itself

The safety sub-functions can be used by assigning them (STO, SLS, etc.) to CN3 without depending on controllers, etc.

(2) Using safety sub-functions by combining with safety programmable controllers

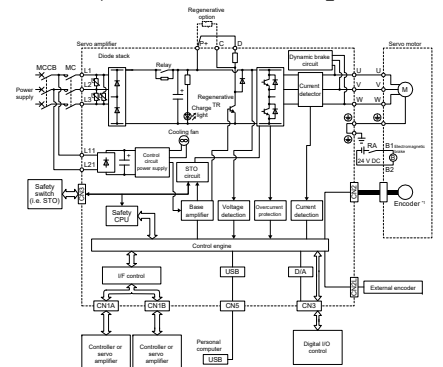
The MR-JET-G4-HS are used to establish a safe communication with safety programmable controllers via CC-Link IE TSN. This enables the electrical wirings (for example STO) to the MR-JET to be omitted.

(3) Using safety sub-functions by combining with FSoE Master

The MR-JET-G4-HS(N1) are used to establish safe communication with the FSoE Master via FSoE. This enables the electrical wirings (for example STO) to the MR-JET to be omitted.

3.2 Function block diagrams

This is an example of a combination with the MR-JET-G4-HS.



¹⁾ Support encoder type are OSBA/OBSA/CBW/CSW, another company encoder that complies with Mitsubishi Electric Serial ENC communication and ABZ-pulse.

4. Technical specifications

4.1 Servo amplifier specifications

Model	MR-JET-G4-HS(N1)
Satisfied standards ¹⁾	EN ISO 13849-1:2015 Category 4 PL e, IEC 61508 SIL 3, EN IEC 62061:2021 maximum SIL 3, EN 61008-5-2
Mean time to dangerous failure (MTTFd)	MTTFd ≥ 100 [years] (300a)
Diagnostic coverage (DC)	DC = Medium, 96.5 [%]
Probability of dangerous Failure per Hour (PFH)	PFH = 7.7 × 10 ⁻⁹ [1/h]
Mission time (Tu) ²⁾	Tu = 20 [year]

- For DIO connection (CN3), a diagnosis using test pulses is required to satisfy Category 4 PL e, SIL 3.
- The performance of special proof tests within the mission time of the product is regarded as not necessary. For example, on IEC 61008-5-2:2016, the diagnostic interval is suggested as at least one test per three months for Category 3 PL e, SIL 3.

4.2 Function specifications

Model	MR-JET-G4-HS(N1)
STO	Shut-off response time (STO input off → energy shut off) 8 ms or less (when an input device is used) 60 ms or less (with CC-Link IE TSN) ¹⁾ 7) 7) 7)
SS1	Deceleration delay time 0 ms to 60000 ms (set by functional safety parameters)
SBC	Shut-off response time 8 ms or less (when an input device is used) 60 ms or less (with EtherCAT) ¹⁾ 7) 7) 7)
SLS1/2/3/4	Observation speed 0 r/min (mm/s) to 10000 r/min (mm/s) (set by functional safety parameters) ¹⁾
SSM	Observation speed 0 r/min (mm/s) to 10000 r/min (mm/s) (set by functional safety parameters)
SDI	Direction monitor delay time 0 ms to 60000 ms (set by functional safety parameters)
SLT	Observation torque -1000.0 % to 1000.0 % (set by functional safety parameters)
Input device	Number of input points (double wiring) 3 point
	Mismatched permissible time of redundant input mismatch detection 0 ms to 60000 ms (set by functional safety parameters)
	Noise eliminating filter 1.000 ms to 32.000 ms (set by functional safety parameters)
	Test pulse off time ²⁾ Within 1 ms
	Test pulse interval 250 ms to 1000 ms
Output device	Number of output points (double wiring) 3 point
	Test pulse off time 0.500 ms to 2.000 ms (set by functional safety parameters)
Safe communication function	Response time 250 ms (Transmission interval monitor time within 84 ms) (with CC-Link IE TSN)
	Transmission interval monitor time 16.0 ms to 1000.0 ms (set by functional safety parameters) (with EtherCAT)
	FSoE Watchdog Time 16.0 ms to 65534.0 ms (set by objects) (with EtherCAT) ¹⁾
	Safe communication delay time 60 ms or less (with CC-Link IE TSN) ¹⁾ 7) 7) 7)

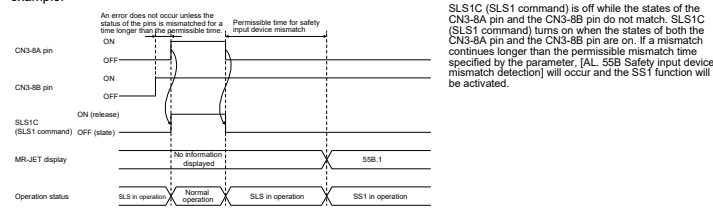
- For DIO connection (CN3), a diagnosis using test pulses is required to satisfy Category 4 PL e, SIL 3.
- This value is applicable when the transmission interval monitor time is ≤ 32.0 ms or less.
- For the MR-JET-G4-HS, connect to a network with a communication cycle of 125 μs or longer. For the MR-JET-G4-HS(N1), connect to a network with a communication cycle of 250 μs or longer.
- The safety observation speed can be set separately.
- A test pulse is a signal which instantaneously turns off a signal to the MR-JET at a constant period for external circuits to perform self-diagnosis.
- The specifications are for using the safety sub-functions via a network connection.
- This value is applicable when FSoE Watchdog Time is 30.0 ms or less.

4.3 When using the I/O of the CN3 connector of the MR-JET

This I/O function can be used when the safety sub-function control by network is not used.

4.3.1 I/O signal sequence

An operation sequence with the SLS function achieved by the input wiring CN3-8A and CN3-8B pins is shown as an example.



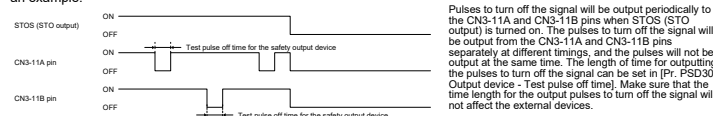
4.3.2 Selecting input devices

The input devices can be assigned to CN3 by functional safety parameters. (Refer to chapter 5)

Input signal
STOC (STO command), SS1C (SS1 command), SLS1C (SLS1 command), SDIPC (SDIP command), SDINC (SDIN command), and SLT1C (SLT1 command)

4.3.3 Output signal sequence

An operation sequence with STOS (STO output) assigned to the input wiring CN3-11A and CN3-11B pins is shown as an example.



4.3.4 Selecting output devices

The output devices can be assigned to CN3 by functional safety parameters. (Refer to chapter 5)

Output signal
STOS (STO output), SS1S (SS1 output), SLS1S (SLS1 output) to SLS4S (SLS4 output), SSMs (SSM output), SBCs (SBC output), SDIPs (SLIP output), SDINs (SDIN output), and SLT1S (SLT1 output) to SLT4S (SLT4 output)

5. Signals

5.1 Connector pin assignment of the safety sub-function I/O signals

The following shows connector pin assignments of the MR-JET-60G4-HS as a typical example. Refer to "MR-JET User's Manual (Hardware)" for precautions for wiring or other operations.

Servo amplifier	CN3			
	Pin No.	Symbol	Symbol	Pin No.
	1A	DOCOM	MBR/DO	1B
	2A	INP	ALM	2B
	3A	DICOM	EM1	3B
	4A	TPR1	TPR2	4B
	5A	LSP	LSN	5B
	6A	DICOM	TPR3	6B
	7A	-	-	7B
	8A	SD1A	SD1B	8B
	9A	SDICOMA	SDICOMB	9B
	10A	SDO24VA	SDO24VB	10B
	11A	SDO1A	SDO1B	11B
	12A	SD2A	SD2B	12B
	13A	SD3A	SD3B	13B
	14A	SDO2A	SDO2B	14B
	15A	SDO3PA	SDO3PB	15B
	16A	SDO3NA	SDO3NB	16B

5.2 Input devices

Assign the input devices to CN3 by functional safety parameters. The devices can be input via network if the safety sub-function is controlled by network.

Devices	Symbol	Connector-pin No.	FUNCTION	Input pin status during operation
STO command	STOC		The STO function operates by the STO command.	Open
SS1 command	SS1C		The SS1 function operates by the SS1 command.	Open
SLS1 command to SLS4 command	SLS1C to SLS4C	CN3-8A CN3-8B CN3-12A CN3-12B	The SLS function 1 to SLS function 4 operates by the SLS1 command to SLS4 command. Four sets of SLS speed and SLS deceleration monitor time can be set with the SLS function.	Open
SDIP command	SDIPC	CN3-15A CN3-15B	The SDIP command activates the SDI function for the address increasing direction.	Open
SDIN command	SDINC	CN3-16A CN3-16B	The SDIN command activates the SDI function for the address decreasing direction.	Open
SLT1 command to SLT4 command	SLT1C to SLT4C		The SLT function 1 to SLT function 4 operates by the SLT1 command to SLT4 command. Four sets of SLT torque upper limit value and SLT torque lower limit value can be set with the SLT function.	Open

5.3 Output devices

The CN3 output status monitor (SM) of the safety sub-function. The output devices can be assigned to CN3 by functional safety parameters. The status monitor can be output via network if the safety sub-function is controlled by network. In that case, the CN3 can also be used at the same time.

Devices	Symbol	Connector-pin No.	FUNCTION	Output pin status during operation
SSM output	SSMS		Indicates that the servo motor speed is equal to or lower than the SSM speed while the speed monitoring by the SSM function is activated.	Close
SBC output	SBCS	CN3-11A	Outputs a control signal of the electromagnetic brake.	Open
STO output	STOS	CN3-11B	This is a monitor output signal meaning that the STO function is operating.	Open
SS1 output	SS1S	CN3-14A	This is a	