

Operating Manual Supplement

Rev. 1.3

**Integrated Drives HFI
equipped with STO-Module**

SAFE TORQUE OFF

Document History

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Table of Contents



DOCUMENT HISTORY	2
TABLE OF CONTENTS	3
1 INTRODUCTION	4
2 SYMBOLS USED IN THIS DOCUMENT	4
3 LIST OF AVAILABLE INTEGRATED DRIVES WITH STO FUNCTION	4
4 ABBREVIATIONS USED IN THIS DOCUMENT	5
5 SAFETY INFORMATION	5
5.1 General safety information	5
5.2 Intended use	5
5.3 Non-intended use.....	6
5.4 Achievable safety level.....	6
5.5 Requirements for safe operation	6
5.6 Qualified personnel.....	7
6 FUNCTIONAL DESCRIPTION	8
6.1 Inputs of the STO channels	8
6.2 STO status signal	10
6.2.1 Functionality of the status signal and the status output	10
6.2.2 Diagnostic test.....	11
6.2.3 Switch-off time of the safety function	12
6.2.4 Firmware	13
6.3 Error messages	14
7 TECHNICAL DATA	15
7.1 System data.....	15
7.2 Safety parameters	16
7.3 Certification	16
7.4 Maintenance	16
8 PIN ASSIGNMENT / INSTALLATION / COMMISSIONING	17
8.1 X3 – STO signal plug	17
8.2 STO connection cable	17
8.3 Installation diagrams	18
8.3.1 Examples for dual-channel STO connection	18
8.3.2 Examples for single-channel STO connection	19
8.4 Commissioning information	20

1 Introduction

This document is intended solely for the description and intended use of the Safe Torque Off (STO) safety function in accordance with EN 61800-5-2, which is available via an optional "STO module" in the integrated drives of the HFI series.

The separately available operating manual for the HFI series of integrated drives further describes their complete features and functionalities.

2 Symbols used in this document

Symbol	Signal Word	Meaning
	Attention!	This symbol highlights safety and warning notices. Non-observance can result in personal injury and/or damage to property.
	Note!	This symbol highlights notes to be observed.

3 List of available integrated drives with STO function

The Safe Torque Off (STO) safety function is certified and available for the integrated drives of the HFI series from ENGEL Elektroantriebe GmbH. The STO models are equipped with an additional hardware module for this purpose and bear the „S“ in their type designation.

The following basic devices, optionally expandable with fieldbus interfaces, gearboxes and parking brakes, are available with the STO safety function:

Basic Device	Part Number*1)	Description
HFI2230-S200	8822312xxx	Basic Device HFI2230, 24V Version
HFI2230-S400	8822314xxx	Basic Device HFI2230, 48V Version
HFI2260-S200	8822612xxx	Basic Device HFI2260, 24V Version
HFI2260-S400	8822614xxx	Basic Device HFI2260, 48V Version
HFI2630-S200	8826312xxx	Basic Device HFI2630, 24V Version
HFI2630-S400	8826314xxx	Basic Device HFI2630, 48V Version
HFI2660-S200	8826612xxx	Basic Device HFI2660, 24V Version
HFI2660-S400	8826614xxx	Basic Device HFI2660, 48V Version
HFI3260-S200	8832612xxx	Basic Device HFI3260, 24V Version
HFI3260-S400	8832614xxx	Basic Device HFI3260, 48V Version
HFI3290-S400	8832914xxx	Basic Device HFI3290, 48V Version
HFI3760-S400	8837614xxx	Basic Device HFI3760, 48V Version
HFI3790-S400	8837914xxx	Basic Device HFI3790, 48V Version

*1) "xxx" is a placeholder for the expansion options that a basic device is equipped with.

4 Abbreviations used in this document

Abbreviation	Meaning
DCavg	Average D iagnostics C overage
HFT	H ardware F ault T olerance
MTTFd	M ean T ime T o D angerous F ailure
OSSD	O utput S ignal S witching D evice
PELV	P rotected E xtra L ow V oltage
PFD	P robability of dangerous F ailure on D emand
PFH	P robability of dangerous F ailure per H our
PL	P erformance L evel
SELV	S afety E xtra L ow V oltage
SFF	S afe F ailure F raction
SIL (SC)	S afety I ntegrity L evel (S ystematic C apability)
STO	S afe T orque O ff

5 Safety information

5.1 General safety information

Always observe the safety information in the operating manual of the drive used.



Attention!

Potential danger of the safety function becoming ineffective:

- Observe the ambient and installation conditions! (see chapter 7.1 System data)
- Never bypass the safety function!
- Do not open the housing!
- Never carry out unauthorised repairs on the device!

5.2 Intended use

The drives of the HFI series with integrated STO module may only be used under the following conditions:

- The drive is in technically perfect condition.
- The drive is in its original condition without any unauthorised modifications.
- The limit values listed in the *Technical Data* chapters of the operating manual and in this STO document (see chapter 7 Technical data) are complied with.
- Use in the industrial sector.



Attention!

In the event of damage resulting from unauthorised modification or non-intended use, the warranty and liability claim against the manufacturer shall expire.

5.3 Non-intended use

The non-intended use of the HFI integrated drives includes, among other things:

- Use outdoors.
- Use in non-industrial areas (residential areas).
- Use in applications where switching off can lead to dangerous movements or conditions.



Attention!

Suspended loads or externally acting load forces must be secured by means of additional measures!

5.4 Achievable safety level

The drives of the HFI series with integrated STO function meet the requirements of the test specifications:

- Category 3 / PL e according to EN ISO 13849-1/-2
- SIL 3 according to EN61508, IEC 61800-5-2, EN62061



Note!

The achievable safety level depends on the other components used to implement a safety function.

5.5 Requirements for safe operation

The requirements for safe operation are:

- The correct integration of the safety function of the device into the overall system. The system/machine manufacturer must always carry out a system/machine-specific risk assessment in accordance with DIN EN 60204-1.
- Compliance with the specifications in this STO document and in the operating manual of the entire drive.
- Consideration of the legal regulations for the place of destination.
- For emergency stop applications, protection against automatic restart must be provided according to the required safety category.



Note!

Depending on the application, measures may be required to prevent the drive from restarting immediately upon deactivation of the STO safety function.



Note!

Depending on the application of the drive and irrespective of its STO safety function, measures in accordance with DIN EN 60204-1 may become necessary to prevent unexpected start-up.

5.6 Qualified personnel

The device may only be commissioned and operated by personnel who are trained in:

- the installation and operation of electrical control systems
- the applicable regulations for the operation of safety-related installations
- the applicable regulations for accident prevention and occupational safety
- the available documentation on the drives with STO functionality



Note!

The design of a system according to safety aspects requires expert knowledge. A safe system can only be achieved after expert, normative assessment.
The mere use of safety components without further assessment is not sufficient!

6 Functional description

The Safe Torque Off (STO) function is ensured by a redundant pulse inhibit. When the STO safety function is engaged, the pulse inhibit disconnects the torque-determining pulse patterns (PWM) generated by the drive's microcontroller from the power stage. Without suitable pulse patterns, the power stage is unable to develop a continuous torque in the motor system, the motor is de-energised and torque-free.



Attention!

Note the following systematic behaviour of the drive:

In the event of a fault, a possible movement of the motor shaft of 60° (mech.) cannot be ruled out, even if the STO safety function is activated!

When the safety function is activated and a defect occurs at the internal power stage on at least two of the three motor phases, i.e. a total of two defects, motor phases can be energised. In this case, a torque and a limited movement of the motor shaft may occur despite the activated safety function, whereby the maximum angle of rotation of the motor shaft is limited to 180° of the electrical period of the motor. For the 6-pole motor systems of the HFI series, this corresponds to a mechanical angle of rotation of 60°.

6.1 Inputs of the STO channels

The safe pulse inhibit of the STO module has a dual-channel redundant design. Each channel has a digital input to control its safety sub-function of the pulse inhibit.

When both STO channels are voltage-free (0 V), e.g. both inputs are open, the pulse inhibit is safely activated.

When both STO channels are supplied with voltage (24 V), the pulse inhibit is deactivated and the drive can be operated.

Activation of the STO function → Channel STO1 = 0 V **AND** Channel STO2 = 0 V

Normal operation of the drive → Channel STO1 = 24 V **AND** Channel STO2 = 24 V

Both STO channels must always be operated simultaneously and consistently, i.e. equivalently.

The STO inputs allow a direct connection to ...

- safe switching contacts such as electromechanical safety relays,
- safe semiconductor outputs such as electronic safety relays,
- passive safety sensors such as position switches with forcibly guided contacts
(see [Figure 6-1: STO function with emergency stop device](#)),
- active safety sensors such as light grids with OSSD signals
(see [Figure 6-2: STO function with OSSD signals](#)).

Test pulses from OSSD switching devices type C with a pulse duration of ≤ 1.0 ms and a period duration ≥ 500 ms do not affect the safety function. This means that the test pulses are safely blanked and that the STO function will not be activated.



Note!

No cross-circuit detection of STO channels 1 and 2 is performed, neither by the STO module nor by the drive.

According to DIN EN 61800-5-2, a cyclical test must be carried out every 3 months at the latest to ensure the specified PFH value (see chapter [6.2.2 Diagnostic test](#)).

Functional description

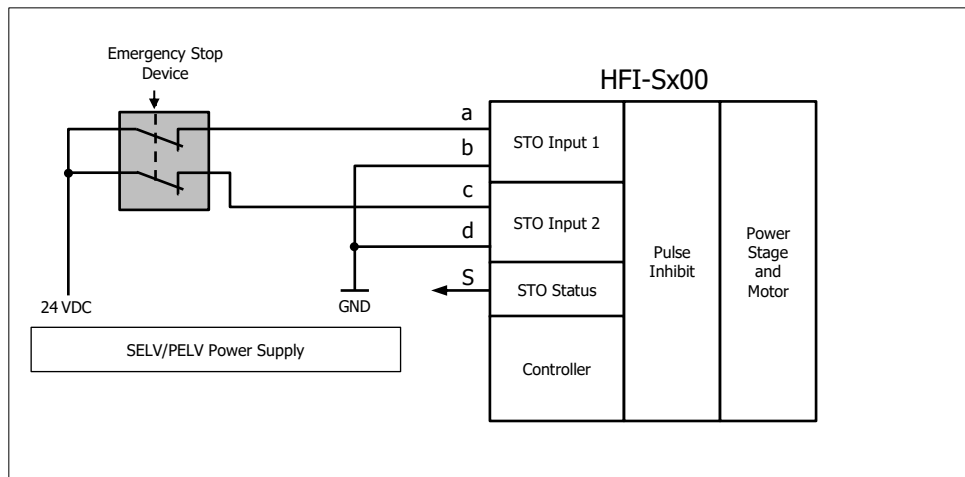


Figure 6-1: STO function with emergency stop device

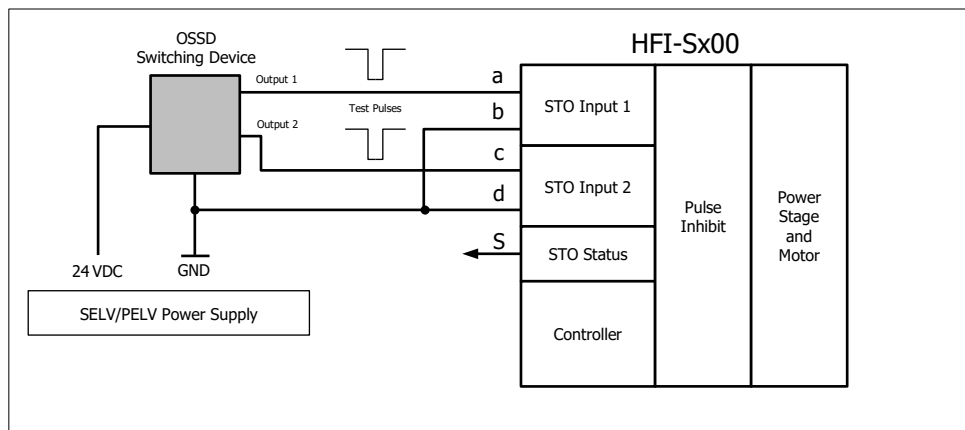


Figure 6-2: STO function with OSSD signals

The integrated drive can be supplied by either a PELV or SELV power source.

The safety circuit, i.e. the STO channels, can as well be supplied by either a PELV or SELV power source.

For drives with a supply voltage of 24 V, it is permissible to supply the STO channels from the 24 V power supply of the integrated drive.

Each STO input and the status output are galvanically isolated from each other and from the control electronics of the integrated drive.



Note!

An incorrect wiring of the STO inputs can result in a lower safety level. By connecting input „a“ to „c“, for example, the external dual-channel structure of the system is lost.

Functional description

6.2 STO status signal

6.2.1 Functionality of the status signal and the status output

The status of the STO safety function is signalled via a potential-free semiconductor output. Only when the safety function is activated the semiconductor output is closed, i.e. conductive.

The status output can be used to signal the status of the safety function to a higher-level control unit.

The status output has reverse polarity protection and is protected against overload and short circuit by a resettable fuse.

Channel1 V_{STO1}	Channel2 V_{STO2}	Status Output	Note
0 ... 5 V (OFF)	0 ... 5 V (OFF)	closed / conductive	Both STO channels voltage-free, unpowered: STO active = safe state
24 V (ON)	0 ... 5 V (OFF)	open / non-conductive	Invalid state: STO channels inconsistently driven
0 ... 5 V (OFF)	24 V (ON)	open / non-conductive	Invalid state: STO channels inconsistently driven
24 V (ON)	24 V (ON)	open / non-conductive	Both STO channels supplied with voltage: Safety function deactivated, normal operation of the drive available

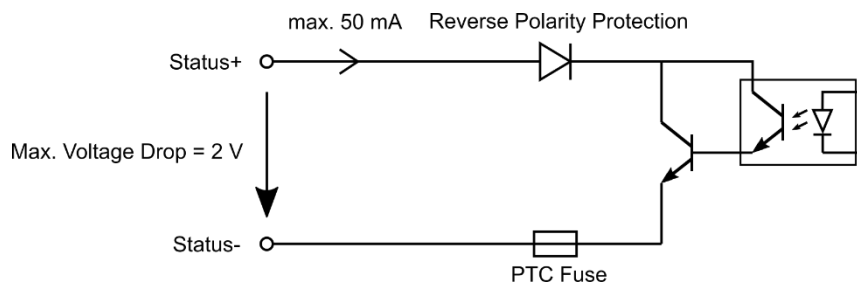


Figure 6-3: Circuit diagram of the status output

Functional description

6.2.2 Diagnostic test

According to DIN EN 61800-5-2, a cyclical test of the proper function of the status output must be carried out at least every 3 months to ensure the specified PFH value.

For this purpose, the two STO channels are stimulated in a test sequence with different input states (test steps 1 – 6). In each test step, the state of the status output is compared to its target state specified in the table below. The correct function of the status output is only fulfilled, when the status output reacts according to the target states in all 6 test steps in succession.

The test sequence can be carried out manually or automatically by means of a control unit.

Test Step	Channel1 V_{STO1}	Channel2 V_{STO2}	Status Output Target State	Note
1	0 ... 5 V (OFF)	0 ... 5 V (OFF)	closed conductive	Both STO channels voltage-free, unsupplied: STO active = safe state
2	24 V (ON)	0 ... 5 V (OFF)	open non-conductive	Invalid state: STO channels inconsistently driven
3	0 ... 5 V (OFF)	0 ... 5 V (OFF)	closed conductive	Both STO channels voltage-free, unsupplied: STO active = safe state
4	0 ... 5 V (OFF)	24 V (ON)	open non-conductive	Invalid state: STO channels inconsistently driven
5	0 ... 5 V (OFF)	0 ... 5 V (OFF)	closed conductive	Both STO channels voltage-free, unsupplied: STO active = safe state
6	24 V (ON)	24 V (ON)	open non-conductive	Both STO channels supplied with voltage: Safety function deactivated, normal operation of the drive available

**Note!**

The status signal / status output is for diagnostic purposes only and has no safety relevance. It must not be used in the safety circuit!

**Note!**

Measuring and contact points should be provided (in the control cabinet, for example) to make a manual diagnostic test possible and practicable.

A software aided diagnostic test is permissible.

**Note!**

The values listed under [Safety parameters](#) are valid on condition that the specifications of this diagnostic test are observed. Therefore, the diagnostic test must be carried out for dual-channel systems as well as for single-channel systems.

Functional description

6.2.3 Switch-off time of the safety function

After both STO channels are de-energised (0 V ... $V_{STO1/2}$... 5.0 V), the safety function (disconnection of the PWM pulse patterns) is guaranteed after a switch-off time of 20 ms max.

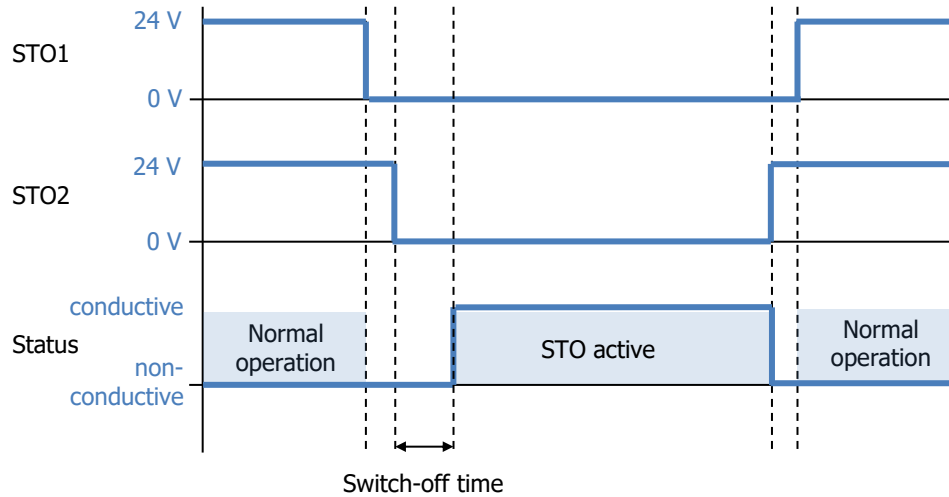


Figure 6-4: STO function switch-off time



Note!

There is no discrepancy time monitoring between the signals STO1 and STO2! This means that there is no defined time interval within which both STO input signals must have reached the same switching state.

Functional description

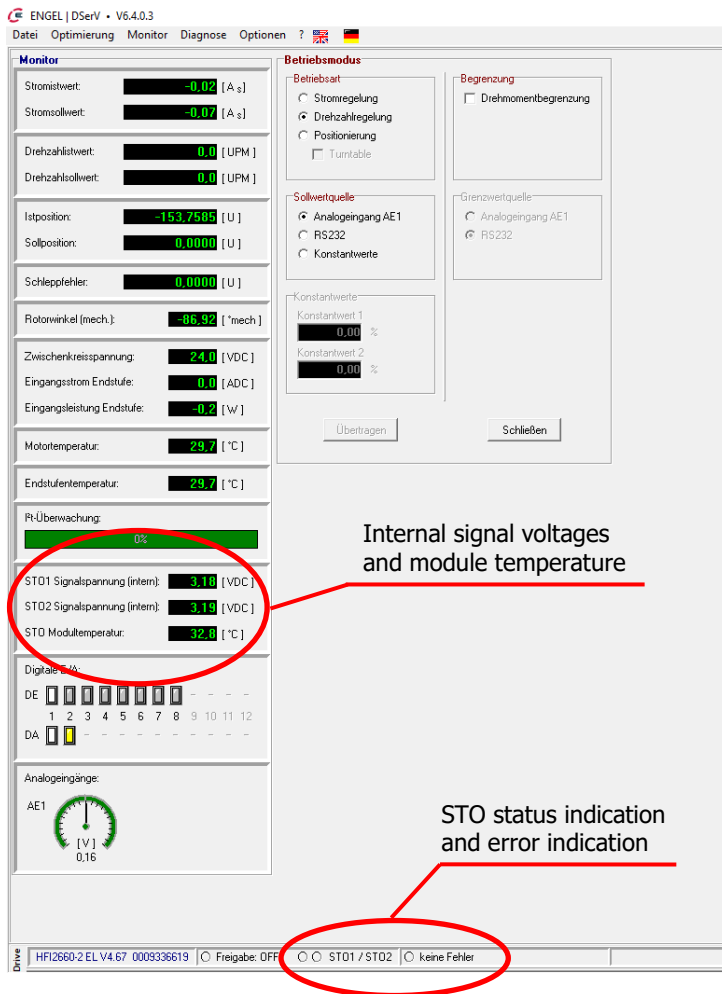
6.2.4 Firmware

The STO functionality is supported from firmware version V4.00 of the HFI series of integrated drives. The pulse inhibit of the STO is hardware-based, i.e. the firmware of the integrated drives has no influence on the STO safety function. The firmware is **not** safety-relevant.

The pulse inhibit is available at all times and works independently of other settings and operating modes of the integrated drives.

The firmware monitors the internal signal voltages of the STO channels as well as the temperature of the STO module. In the event of impermissible operating conditions, error messages are triggered that switch off the drive via its standard functionality.

From version V6.403, the parameterisation software DSeV supports the STO functionality.



Internal signal voltages and module temperature

STO status indication and error indication

STO input signals

STO status indication

STO1= 24 V / STO2= 24 V
 STO1= 0 V / STO2= 24 V
 STO1= 24 V / STO2= 0 V
 STO1= 0 V / STO2= 0 V

STO1 / STO2
 STO1 / STO2
 STO1 / STO2
 STO1 / STO2

Figure 6-5: DSeV with STO visualisation



Note!

The parameterisation software **DSeV** is described in the operating manual of the HFI series.

Functional description

6.3 Error messages

The firmware of the integrated drive monitors various variables and conditions and triggers error messages (including STO error messages) as soon as defined limit values or tolerance ranges are exceeded. In this case, the drive is deactivated, but solely via its normal, non-safe function.



Note!

For a safe deactivation of the drive, it is always required that the STO function is activated! This also applies if the drive has already been deactivated due to an error message.

Some of the STO error messages are only triggered when the controller enable of the integrated drive is active, i.e. without controller enable only the temperature monitoring of the STO module is active and no other STO error messages are triggered. The following table lists the error messages resulting from the non-safety-relevant monitoring of the STO module.

Error Code (Fieldbus)	Error Code (DSerV)	Error Description	Cause / Measure for error rectification
F080 _h	13.00000	Generic STO error	Internal error / No action
F081 _h	13.00002	Signal voltage STO1 ≤ min	STO channel 1 voltage too low / Operate STO channel with the specified voltage
F082 _h	13.00003	Signal voltage STO1 ≥ max	Internal error / No action
F083 _h	13.00257	Temperature of STO > 115 °C	Overheat / Check operating conditions
F084 _h	13.00512	Signal voltage STO2 ≤ min	STO channel 2 voltage too low / Operate STO channel with the specified voltage
F085 _h	13.00514	Signal voltage STO1 ≤ min and Signal voltage STO2 ≤ min	STO channel 1+2 voltages too low / Operate STO channels with the specified voltage
F086 _h	13.00515	Signal voltage STO1 ≥ max and Signal voltage STO2 ≤ min	Internal error / No action
F087 _h	13.00768	Signal voltage STO2 ≥ max	Internal error / No action
F088 _h	13.00770	Signal voltage STO1 ≤ min and Signal voltage STO2 ≥ max	Internal error / No action
F089 _h	13.00771	Signal voltage STO1 ≥ max and Signal voltage STO2 ≥ max	Internal error / No action



Note!

If internal errors occur, the unit must be replaced!
Repairs and interventions by the user are not permitted!

7 Technical data

7.1 System data

Designation	Unit	Value			Additional information
		min	typ	max	
Permissible input voltage STO channel 1/2 (V_{STO1}/V_{STO2})	VDC	0		28.8	SELV/PELV Overvoltage protection up to 60 V
Input voltage for deactivation of STO channel 1/2	VDC	20.4		28.8	24 V -15% / $+20\%$ ($\leq 5\%$ AC) V_{STO1} / V_{STO2}
Input voltage for activation of STO channel 1/2	VDC	0		5.0	
Current consumption STO channel 1/2	mA			12	at $V_{STO1/2} = 24$ V
Status output reverse voltage	VDC		24	30	Load current max. 50 mA Voltage drop at 50 mA: $\Delta U \leq 2$ V
STO switch-off time	ms			20	Time between activation of the STO function and the safe deacti- vation of the power stage
Ambient temperature	°C	0		40	No condensation permissible
Storage temperature	°C	-25		75	No condensation permissible
Permissible altitude	m			2000	[m above sea level]
Max. cable length	m			20	Permissible max. cable length of the STO inputs (M12 con- nector)
OSSD pulse duration	ms			1.0	
OSSD period duration	ms	500			
Working life	years			20	due to design
Electromagnetic compatibility					
Emission ^{*1)}	DIN EN 61800-3: 2019-04			According to category C2	
Immunity	DIN EN 61800-3: 2019-04 DIN EN 61800-5-2: 2017-11 ^{*2)}			According to category C3 / second environment	
Insulation strength					
Overvoltage Category III Surge Voltage 800 V between each STO channel, status output and control unit					

*1) Conducted emissions towards the AC mains must be suppressed in the power supply unit of the device.

*2) Concerning the functional safety.

7.2 Safety parameters

Designation	Unit	Standard			Additional information
		62061	61508	13849	
HFT		1	1		Hardware fault tolerance
PFH	1/h	$4.73 \cdot 10^{-11}$	$9.12 \cdot 10^{-11}$		Probability of dangerous failure per hour
PDF		$1.04 \cdot 10^{-7}$	$7.89 \cdot 10^{-6}$		Probability of dangerous failure on demand
SFF	%	99.92	99.92		Safe failure fraction (Percentage of failures that do not affect the safety function)
SIL (SC)		3	3		Safety integrity level
DCavg	%			0.00	Average diagnostic coverage
MTTFd	years			25974	Mean time to dangerous failure
PL				e	Performance level
Cat				3	Category

7.3 Certification

Designation	
Type examination	The functional safety technology of the product has been tested and certified as a safety component to Annex IV of the European Machinery Directive 2006/42/EG. Safety function „Safe Torque Off“ (STO) according to DIN EN 61800-5-2 2017 Safety of machinery.
Certificate-issuing authority	TÜV Rheinland Industrie Service GmbH, Köln



7.4 Maintenance

The integrated drives from ENGEL Elektroantriebe GmbH do not require any special maintenance measures. A defective drive must be completely replaced. Repairs are not permitted.

8 Pin assignment / Installation / Commissioning

8.1 X3 – STO signal plug

Connector on the device: 8-pin M12 circular connector (male, A-coded)
 Mating plug: 8-pin M12 circular connector (female, A-coded)

Pin-No.	Wire ¹	Name	Description
1	WH	Status+	Potential-free status output (positive potential, collector)
2	BN	Status-	Potential-free status output (negative potential, emitter)
3	GN	STO1-	STO channel 1 supply, reference potential, 0 V
4	YE	STO1+	STO channel 1 supply, positive potential, 24 V
5	GY	n.c.	
6	PK	STO2+	STO channel 2 supply, positive potential, 24 V
7	BU	STO2-	STO channel 2 supply, reference potential, 0 V
8	RD	n.c.	

¹ Wire colours and cross-sections apply to assembled STO connection cables from ENGEL Elektroantriebe GmbH (see chapter [8.2 STO connection cable](#)).

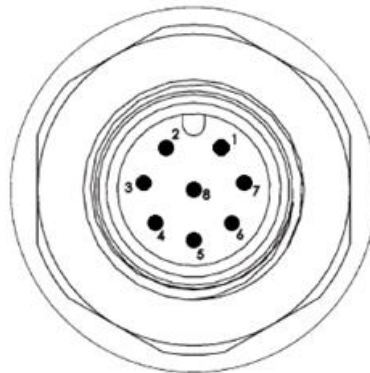


Figure 8-1: Pin layout of the STO signal plug
 View on the mating side of the receptacle on the drive

8.2 STO connection cable

Recommendations for the properties of the STO connection cable:

- recommended wire cross-section: 0.25 mm²
- overall shield
- suitable for drag chains, operating temperature min. +80 °C
- cable length max. 20 m

ENGEL original accessories:

Item-No.: **9900000650** SK_STO_M12_NC_5 signal cable STO | M12 | NC length 5 m
 Item-No.: **9900000651** SK_STO_M12_NC_15 signal cable STO | M12 | NC length 15 m

Cable assembly with M12 connection plug, open on one end,
 8 x 0.25 mm², overall shield, PUR, -30 °C ... +90 °C, suitable for drag chains.
 (For wire colours, see chapter [8.1 X3 – STO signal plug](#).)

8.3 Installation diagrams

8.3.1 Examples for dual-channel STO connection

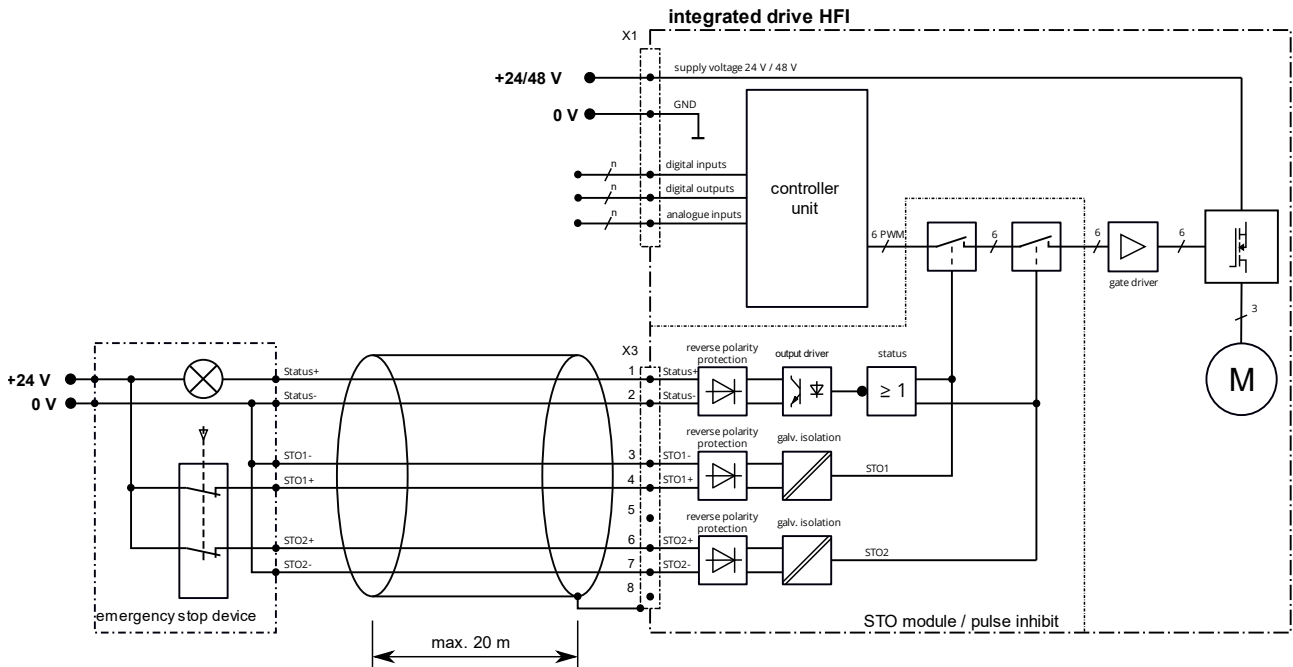


Figure 8-2: Dual-channel STO connection with emergency stop device

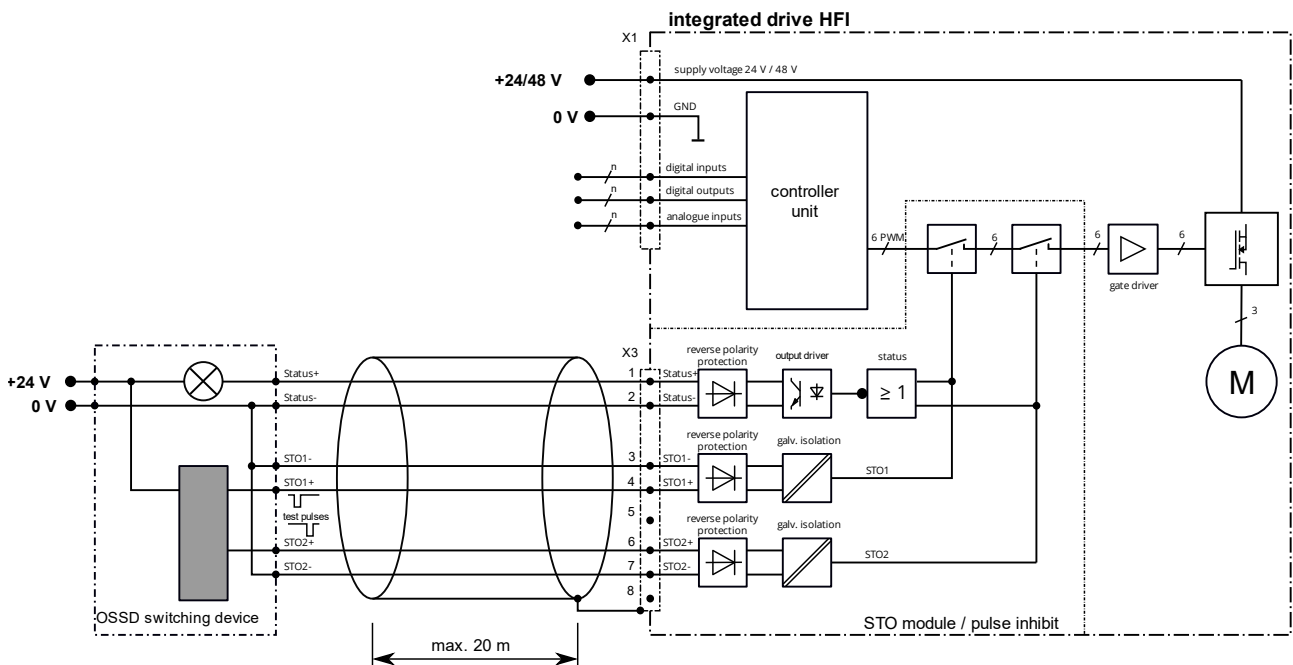


Figure 8-3: Dual-channel STO connection with OSSD switching device

The installation diagrams in the figures above show the dual-channel connection assignment of the STO function.

8.3.2 Examples for single-channel STO connection

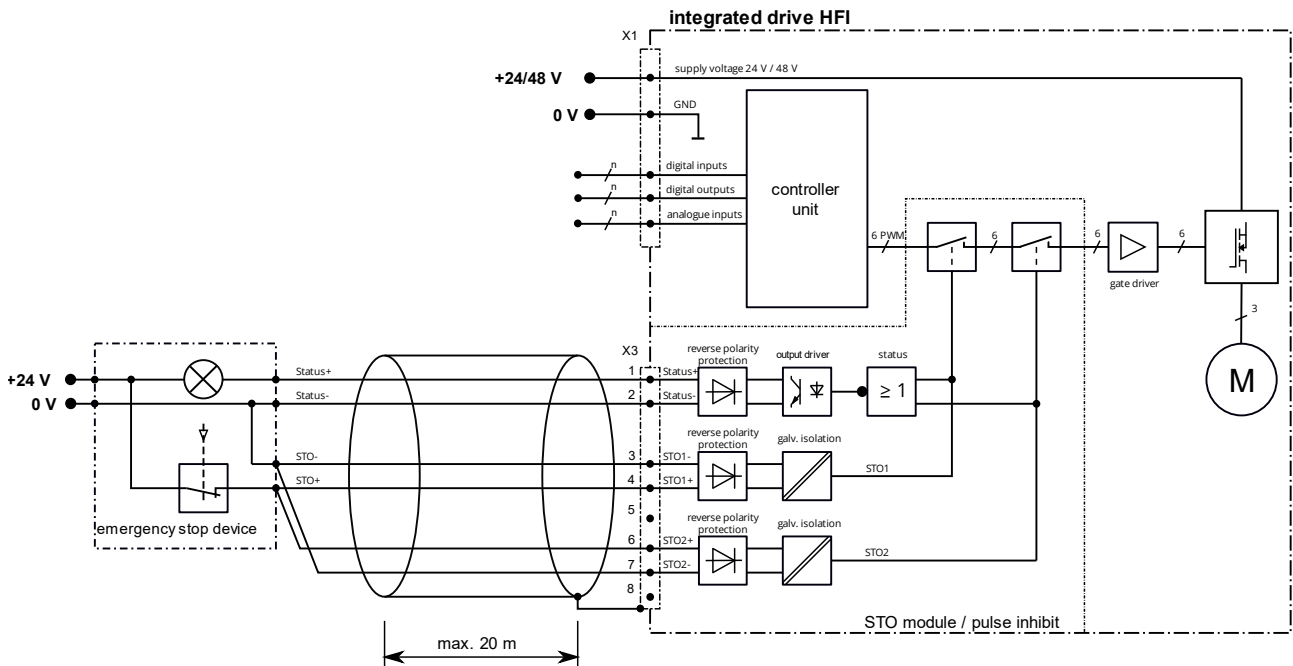


Figure 8-4: Single-channel STO connection with emergency stop device

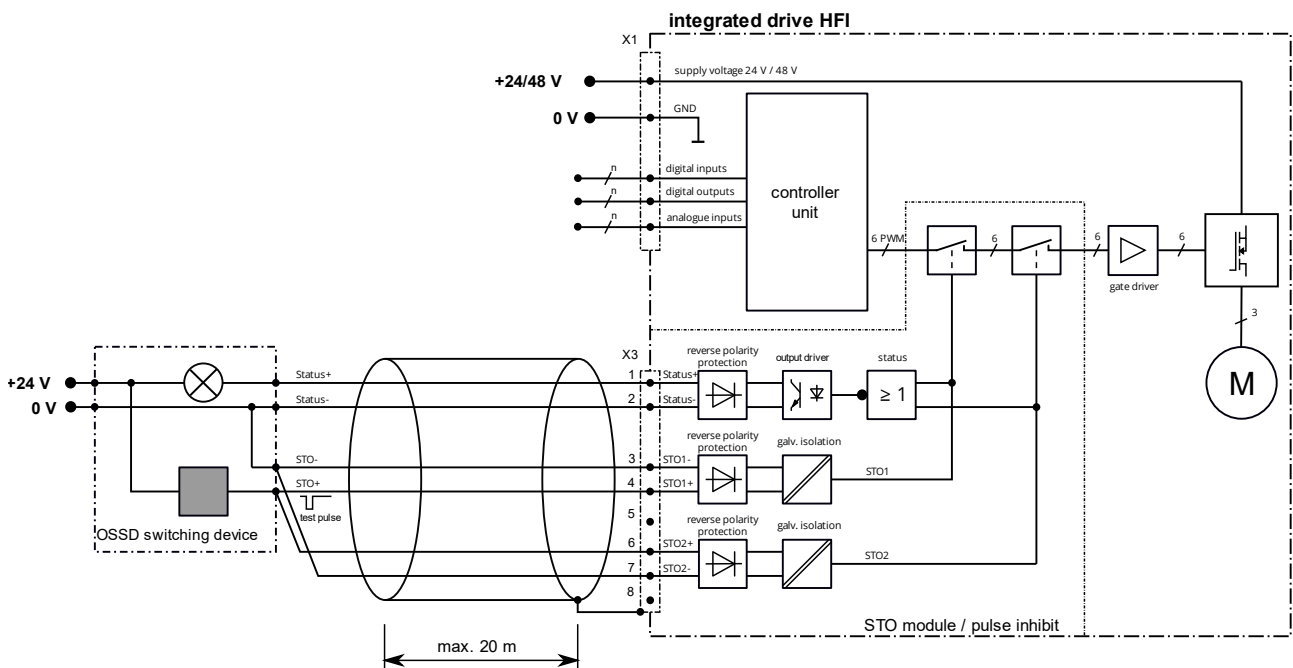


Figure 8-5: Single-channel STO connection with OSSD switching device

The installation diagrams in the figures above show the single-channel connection assignment of the STO function.

8.4 Commissioning information

In addition to the commissioning instructions described in the operating manual of the HFI series, the following steps have to be executed:

- Step 1:** Wire the connections of the STO module properly according to the installation diagram.
- Step 2:** Check the wiring.
- Step 3:** Validate the functionality of the drive and the safety function.
- Step 4:** Perform a diagnostic test according to chapter [6.2.2 Diagnostic test](#).