EMERSON
Industrial Automation

User Guide

SM-Safety

- Unidrive SP
- Digitax ST

Part: 0471-0146-01
Issue: 1

CONTROL TECHNIQUES

www.controltechniques.com

General Information

The manufacturer accepts no liability for any consequences resulting from inappropriate, negligent or incorrect installation or adjustment of the optional parameters of the equipment or from mismatching the variable speed drive with the motor.

The contents of this guide are believed to be correct at the time of printing. In the interests of commitment to a policy of continuous development and improvement, the manufacturer reserves the right to change the specification of the product or its performance, or the content of the guide without notice.

Environmental Statement

Control Techniques is committed to minimising the environmental impacts of its manufacturing operations and of its products throughout their life cycle. To this end, we operate an Environmental Management System (EMS) which is certified to the International Standard ISO 14001. Further information on the EMS, our Environment Policy and other relevant information is available on request, or can be found at www.greendrives.com.

The electronic variable speed drives manufactured by Control Techniques have the potential to save energy and (through increased machine/process efficiency) reduce raw material consumption and scrap throughout their long working lifetime. In typical applications, these positive environmental effects far outweigh the negative impacts of product manufacture and end-of-life disposal.

Nevertheless, when the products eventually reach the end of their useful life, they must not be discarded but should instead be recycled by a specialist recycler of electronic equipment. Recyclers will find the products easy to dismantle into their major component parts for efficient recycling. Many parts snap together and can be separated without the use of tools, while other parts are secured with conventional fasteners. Virtually all parts of the product are suitable for recycling.

Product packaging is of good quality and can be re-used. Large products are packed in wooden crates, while smaller products come in strong cardboard cartons which themselves have a high-recycled fibre content. If not re-used, these containers can be recycled. Polythene, used on the protective film and bags from wrapping product, can be recycled in the same way. Control Techniques' packaging strategy prefers easily recyclable materials of low environmental impact, and regular reviews identify opportunities for improvement.

When preparing to recycle or dispose of any product or packaging, please observe local legislation and best practice.

REACH legislation

EC Regulation 1907/2006 on the Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) requires the supplier of an article to inform the recipient if it contains more than a specified proportion of any substance which is considered by the European Chemicals Agency (ECHA) to be a Substance of Very High Concern (SVHC) and is therefore listed by them as a candidate for compulsory authorisation.

For current information on how this requirement applies in relation to specific Control Techniques products, please approach your usual contact in the first instance. Control Techniques position statement can be viewed at:

http://www.controltechniques.com/REACH

Issue Number : 1

Contents

1 Safety information

1.1 Warnings, cautions and notes

A **Warning** contains information, which is essential for avoiding a safety hazard.

A **Caution** contains information, which is necessary for avoiding a risk of damage to the equipment and motor.

NOTE A **Note** contains information, which helps to ensure correct operation of the product.

1.2 Electrical safety - general warning

The voltages used in the drive can cause severe electrical shock and/or burns, and could be lethal. Extreme care is necessary at all times when working with or adjacent to the drive.

Specific warnings are given at the relevant places in this User Guide.

1.3 System design and safety of personnel

Only functions which are explicitly described as safety functions may be used to ensure the safety of personnel, i.e. no other functions of the drive or its option modules must be used for safety-related functions.

The only safety function provided in the drive is Safe Torque Off.

The safety functions provided in the SM-Safety Solutions Module are described in this user guide together with their safety specifications. They have been assessed and approved by independent safety authorities, as meeting the technical standards and safety performance levels stated in the user guide.

The design of safety-related systems requires specialist knowledge. To ensure that a complete control system is safe it is necessary for the whole system to be designed according to recognized safety principles. The use of individual sub-systems such as drives and option modules with safety functions, which are intended for safety-related applications, does not in itself ensure that the complete system is safe. It is the responsibility of the designer of the end product or application to ensure that it is safe and in compliance with the relevant regulations. Any application examples given in this guide are for illustration only and do not purport to represent complete solutions.

1.4 Environmental limits

Instructions in this User Guide regarding transport, storage, installation and use of the drive must be complied with, including the specified environmental limits. Drives must not be subjected to excessive physical force.

1.5 Compliance with regulations

The installer is responsible for complying with all relevant regulations, such as national wiring regulations, accident prevention regulations and electromagnetic compatibility (EMC) regulations. Particular attention must be given to the cross-sectional areas of conductors, the selection of fuses or other protection, and protective earth (ground) connections.

This User Guide contains instruction for achieving compliance with specific EMC standards.

Within the European Union, all machinery in which this product is used must comply with the following directives:

2006/42/EC: Safety of machinery.
2004/108/EC Electromagnetic Compatibility.

1.6 Motor

Ensure the motor is installed in accordance with the manufacturer's recommendations. Ensure the motor shaft is not exposed.

Standard squirrel cage induction motors are designed for single speed operation. If it is intended to use the capability of the drive to run a motor at speeds above its designed maximum, it is strongly recommended that the manufacturer is consulted first.

Low speeds may cause the motor to overheat because the cooling fan becomes less effective. The motor should be installed with a protection thermistor. If necessary, an electric forced vent fan should be used.

The values of the motor parameters set in the drive affect the protection of the motor. The default values in the drive should not be relied upon.

It is essential that the correct value is entered in Pr **0.46** motor rated current. This affects the thermal protection of the motor.

1.7 Adjusting parameters

Some parameters have a profound effect on the operation of the drive. They must not be altered without careful consideration of the impact on the controlled system. Measures must be taken to prevent unwanted changes due to error or tampering.

1.8 Transport/Storage

Information on transport, storage and appropriate handling must be observed.
The environmental requirements are contained in Section 8 *Technical data* on page 51.

1.9 Terms and abbreviations

The term *safe* refers to the classification for use up to PL e in compliance with EN ISO 13849-1 and/or SIL3 in compliance with EN 61800-5-2.

Table 1-1 List of abbreviations used

Abbreviation	Description
AC	Alternating current
AWL	Instruction set
BGIA	German government safety organization
CCF	Common-caused failures recognition
CLK	Cycle (clock)
CPU	Central Processing Unit
DC_{avg}	Diagnostic cover level on demand
DO	Digital Output
ELC	Emergency Limit Control
EMC	Electromagnetic Compatibility
EMU	Emergency Monitoring Unit
EN	European standard
IP20	Protection class for enclosures
ISO	International Organisation for Standardization
LED	Light Emitting Diode
$MTTF_d$	Mean Time To Failure in the dangerous direction
OSSD	Output Signal Switch Device
PAA	Process diagram for outputs
PAE	Process diagram for inputs
P1,P2	Pulse outputs 1, 2
PLC	Programmable Logic Control
SBC	Safe Brake Control
SCA	Safe Cam
SDI	Safe Direction
SEL	Safe Emergency Limit
SELV	Safety Extra Low Voltage
SLA	Safe Limited Acceleration
SLI	Safe Limited Increment
SLP	Safe Limited Position
SLS	Safe Limited Speed
SM	Solutions Module
SMF11 to SMF42, DI5S	Digital input
SOS	Safe Operating Stop
SS1	Safe Stop 1
SS2	Safe Stop 2
SSI	Synchronous Serial Interface
STO	Safe Torque Off
TUV	German Technical Inspections Organization

1.10 General specification

The principle task of the SM-Safety Solutions Module is the provision of safety-related functions for the Unidrive SP and Digitax ST product family.

Key features of the module are:

- Connections for two encoders which monitor safe speed and position. Depending upon the type of speed transmitter and its electrical/mechanical features, safety functions with safety classes SIL2 or SIL 3 or PL e can be achieved.
- Safety inputs which can be grouped and dynamically monitored using pulses, in order to obtain the higher SIL3 and PLe safety classes.
- Safety outputs which can be used for safe control of the drive, brakes, contactors etc.
- Activation and execution of safety functions can be controlled by safety inputs and their logic operations. The outputs from these functions control the process outputs.
- Safety outputs for fast reaction, directly controlled by the logic operations.
- Graphic PC development environment which controls the configuration of the speed encoder interface, limiting of safe motion functionalities and logic operations.

NOTE Compliance with the documentation is a precondition for trouble-free operation and fulfilment of any warranty claims.

NOTE Read the manual carefully before installing or commissioning/start-up of the SM-Safety Solutions Module.

2 Safety principles

Moving machinery represents a potential risk to operators and other personnel.

Controls or components which provide functional safety are therefore required to monitor operation of the machine and prevent unsafe modes of working.

2.1 Design of safe machinery, risk assessment and safety standards

The safety features of a machine should be designed at the same time as its intended functions. An initial risk assessment should be carried out, which should be in accordance with the ISO 14121 (EN ISO 14121) standards (previously EN 1050). The risk assessment identifies whether safety-related control functions are needed in addition to the inherent safety features of the machine.

The standards currently available for the safety of machinery control systems are ISO 13849-1 and IEC 62061 (EN ISO 13849-1 and EN 62061). ISO 13849-1 measures the degree of safety integrity by a "Performance level" with values from a (lowest) to e, while IEC 62061 uses the principles of IEC 61508 to give a SIL (Safety Integrity Level) from 1 (lowest) to 4. Both of these standards allow for the use of complex hardware and software in safety-related control systems.

2.2 Functional safety of electrical power drive systems

Some types of safety-related control functions can usefully be carried out in the drive. Standard IEC 61800-5-2 (EN 61800-5-2) defines specific functions for implementation within a drive. The activation of these functions is carried out through safety features on the machine such as door switches and light curtains, which can be connected directly to the SM-Safety Solutions Module. Alternatively more complex functions can be carried out in a separate safety controller, which can then be connected to the safe interface of the SM-Safety Solutions Module.

2.3 Responsibilities

It is the responsibility of the machine/equipment designer to ensure the safety of the machine/equipment, including the correct configuration and integration of the SM-Safety Solutions Module which is required to achieve the necessary safe operation. It is also the responsibility of the machine/equipment designer to ensure that the SM-Safety Solutions Module meets the requirements of the application, i.e. that the function specified is the correct one for the application and that the integrity data is adequate.

Control Techniques is not responsible for:

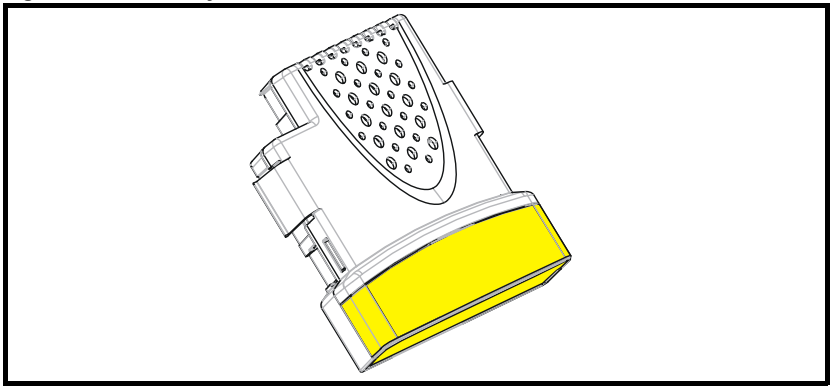
- The correct incorporation/configuration of the SM-Safety Solutions Module into a complete safety-related control system.
- The correct application of the SM-Safety Solutions Module or a safety-related control system in a machine.

3 Product information

3.1 Features

The SM-Safety Solutions Module is an optional Solutions Module for Unidrive SP and Digitax ST, which can be plugged into one of the drive's expansion slots. The SM-Safety Solutions Module is used for safety related functions in compliance with: *EN61800-5-2: Electrical power drive systems safety: Functional Safety.* Refer to Section 3.6 on page 12 for details of supported safety related functions.

Figure 3-1 SM-Safety Solutions Module



The SM-Safety Solutions Module includes the following features:

- Safety switch with two channel micro processor system
- Logic processing up to PL e in compliance with EN ISO 13849-1 and SIL 3 in compliance with EN 61508
- Programmable small controller for up to 500 instructions
- Function block graphical programming
- Pulse outputs for cross-circuit monitoring of connected switching devices
- Safety function external contact monitoring of connected devices
- Monitored 24V outputs for safety functions
- Serial port for program development and diagnostics
- Safety software for speed, position and acceleration monitoring and logistics functions
- Activation and execution of safety functions controlled by safety inputs and their logic operations. The outputs from these functions control the process output.
- Safety outputs for fast reaction, directly controlled by the logic operations
- Speed and/or position monitoring, execution of logic functions and formation of the process outputs are evaluated once per cycle.
- The configuration is saved and protected against mains power failure on the module or activating the safety functions.

The interfaces available with the SM-Safety Solutions Module are summarised in the table below:

Interface	Quantity
Sensor interfaces (for encoders)	2
Grouped safe digital inputs	4 pairs
Safe digital input	1
Pulse outputs (for cross checking safe inputs)	2
Safe digital outputs	3
Auxiliary outputs (non safety)	2
Diagnostic and configuration interface	1

Group inputs may be dynamically monitored using pulses in order to obtain the higher SIL3 and PL e safety classes. The three safety outputs may be used for safe control of the drive, brakes and contactors.

NOTE The drive only provides power to the SM-Safety Solutions Module, there are no interface signals between the module and the drive. The drive will not detect that the module is installed and there will be no parameters displayed in Menus 15, 16 and 17.

NOTE When the SM-Safety Solutions Module is used with a Unidrive SP, the date code for the drive must be P04 or later.

3.2 Configuration

A graphical PC tool, CTSafePro, allows configuration of the speed encoder interface, definition of the safe motion functionality and logic operations. It also provides testing and advanced diagnostic tools.

The configuration is saved and protected against mains power failure within the module.

Refer to the SM-Safety Programming Guide for details of how to configure the SM-Safety Solutions Module.

CTSafeLite enables locally developed software to be tested.

Users may chose between one of two safety logic configurations during normal operation:

- Fixed
- User specific

3.2.1 Fixed configuration

In Fixed mode, pre-programmed logic functions are employed which are pre-loaded. Using this mode of operation, the customer only needs to configure the speed, acceleration and position limit values for the required application.

These parameters may be entered using the complimentary CTSafeLite software tool module. Following entry of the basic user parameters, all values are saved and logged.

3.2.2 User specific configuration

When configured for the User Specific mode of operation, customers have the ability to create their own logic functions, using the CTSafePro software tool available as an optional extra. This licensed software tool allows users to customize the logic structure in accordance with their own specifications. The user specific configuration therefore permits fine adjustment of the operating parameters.

3.2.3 Downloading the configuration to the SM-Safety Solutions Module

The configuration is downloaded to the SM-Safety Solutions Module via a serial cable connected between the PC and the SM-Safety Solutions Module RJ45 port. Refer to SM-Safety Solutions Module Programming Guide for details of downloading the configuration.

An isolated serial communications must be used to connect the SM-Safety Solutions Module to IT equipment (such as lap-top computers). Suitable cables are available from Control Techniques.

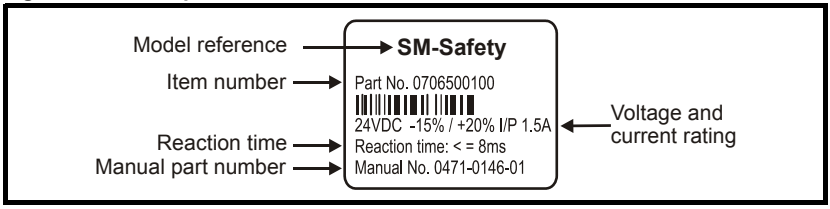
3.3 Product Conformance Certificate

Development of the SM-Safety Solutions Module was carried out in close co-operation with TUV Rheinland. A safety component test certificate is available upon request from the supplier of the drive.

3.4 Rating label

The rating label is located on the rear of the SM-Safety Solutions Module as shown in Figure 3-2.

Figure 3-2 Model plate



3.5 Items supplied

The SM-Safety Solutions Module includes:

SM-Safety Solutions Module with connector for digital inputs (without encoder connection).

Items not included but available from the supplier of the drive:

- Encoder adapter
- CTSafeLite
- CTSafePro and licence key dongle (USB)
- CTSafePro programming guide
- HDMI cable

3.6 Safety functions

The SM-Safety Solutions Module enables the drive to offer a range of safety features and functions. The labelling of the safety functions is in compliance with IEC 61800-5-2 as listed in Table 3-1.

Table 3-1 Safety functions

Abbreviation	Function	Detail
SS1	Safe Stop 1	Monitor deceleration ramp and switch motor off (STO) after idling. Corresponds to stop category 1 in compliance with EN 60204-1
SS2	Safe Stop 2	Monitor deceleration ramp and idling (SOS). Corresponds to stop category 2 in compliance with EN 60204-1
SOS	Safe Operating Stop	Monitor speed of the active motor
SLS	Safe Limited Speed	Safe limiting of motor speed
SLA	Safe Limited Acceleration	Safe limiting of the acceleration value
SLP	Safe Limited Position	Safe limiting of the position value
SLI	Safe Limited Increment	Safe limiting of the incremental value
SDI	Safe Direction	Monitors correct direction of motor rotation
SCA	Safe CAM	Safe output signal is generated when the motor is within a predetermined area
SSM	Safe Speed Monitor	Safe output signal is generated when the motor speed is below a specified limit

Table 3-2 Safety outputs

Output	Abbreviation	Detail
STO	Safe Torque Off	Safe Torque Off is only available with Unidrive SP and Digitax ST drives. Corresponds to stop category 0 in compliance with EN 60204-1
SBC	Safe Brake Control	Safe control and monitoring of an external braking system

In order to provide the various safety functions listed above, the use of specific motor position encoders is required, and may also include the use of external position encoders depending on the actual configuration required.

The total number of safety functions available is dependent on the maximum number of inputs/outputs available on the SM-Safety Solutions Module itself, and consequently this restriction should be considered during the installation process.

3.7 Action in the event of a module fault

If a problem is identified during the regular scanning of the digital I/O ports, or in the event of a processor system fault, all digital outputs are switched to 0V.

3.8 Required encoder technology

3.8.1 General instructions

The SM-Safety Solutions Module features two encoder interfaces for connecting industry standard incremental and absolute encoders. The encoder interfaces can be configured for incremental (A, -A, B, -B), SINE/COSINE or for absolute SSI encoders.

If only one encoder is used in the application, the signals must be wired to the encoder input 1 (process encoder).

It is also possible to connect sensors i.e. proximity switches, which are capable of generating incremental signals (A, -A or HTL level) to the SM-Safety Solutions Module counting input.

Compatible encoder types:

- SINE/COSINE encoder with 1Vss signal
- Incremental encoder (A, -A, B, -B) RS422 signals
- SSI absolute position encoders
- Proximity Switch

Monitoring and wiring

The encoder supply voltage is monitored by an internal diagnostic process. Should the voltage of the power supply exceed the upper or lower operating limits of the encoder system, the SM-Safety Solutions Module will initiate an alarm.

3.8.2 Encoder supply

Encoder 1 supply voltage is always provided from the drive encoder port. Encoder 2 may be supplied from an encoder solutions module or from an external supply connected directly to the SM-Safety Solutions Module. The SM-Safety Solutions Module monitors the supply voltage for both encoders.

SSI encoders can be configured to operate in master or slave mode. In master mode, the clock is generated from the SM-Safety Solutions Module. In slave mode, the clock is generated from the drive or from an encoder Solutions Module.

External encoders or proximity switches must be independent to each other, both electrically and mechanically.

Where external devices are not mounted in close proximity to the device to be monitored, the coupling must be rigid and not comprise any components liable to wear i.e. chains, drive belts etc. If this condition cannot be satisfied, then alternative monitoring devices for the mechanical connection of the sensors will be required where monitoring of a drive belt is required for example.

A minimum of one absolute encoder must be used for active position processing.
The following also applies for an SSI interface:

In slave mode, the SSI clock signal is generated by the drive. The SM-Safety Solutions Module reads this clock signal together with the data signal from the encoder. Since the update rates of the drive and the SM-Safety Solutions Module are different, then an error can occur. This error is calculated as follows:

$$\mathbf{F} = \frac{\textbf{encoder scan time through external system [ms]}}{\textbf{8 [ms]}} \times \textbf{100\%}$$

The scale of the resulting scanning error F must be accounted for when determining the threshold in the SafePLC program's monitoring functions used, as this condition cannot be compensated for.

Twisted pair cable must be used for signal transfer (complying with RS 422 standards) for the data and clock signals, and the A and B signals.

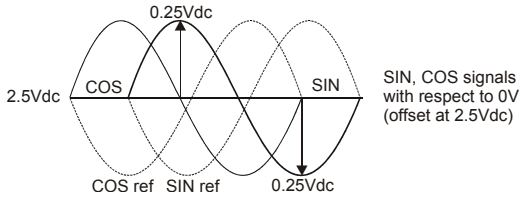
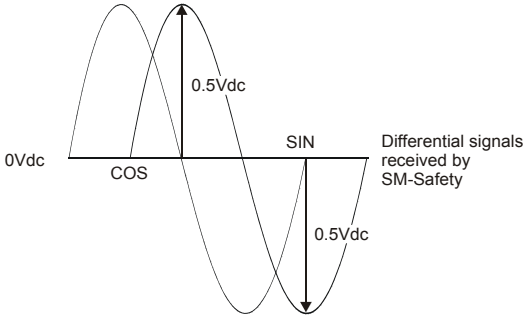
When selecting the twisted pair cable, the power consumption of the encoder and the cable lengths of the installation need to be accounted for individually. In addition the cross-sectional area of the cable used must be selected in the light of the above considerations.

EMC - Please refer to the relevant drives' User Guide or Installation Guide for information regarding shielding and EMC requirements.

3.8.3 Using SINE/COSINE encoders

SINE/COSINE encoders with the following specifications must be used in conjunction with the SM-Safety Solutions Module.

Figure 3-3 Using SINE/COSINE encoders

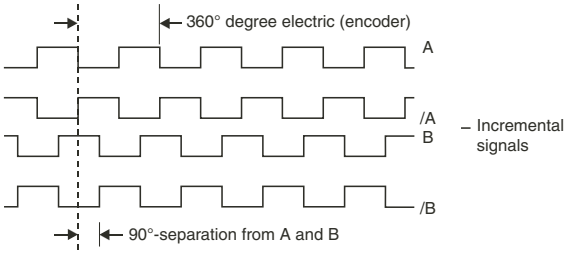
Data	Detail
Incremental SINE/ COSINE signal (SC)	The following SINE/COSINE signals are authorized for operation: **1Vss (1V peak to peak+sine and -sine, +cosine and -cosine)**  **1Vss (1V peak to peak sine and REFSINE, COSINE and REFCOSINE)** 
Measuring signal	A/B trace with 90° phase offset
Maximum input frequency	200kHz
SM-Safety Connection	HDMI - connector

NOTE The signals from a SINE/COSINE encoder are not interpolated, so the available resolution will be equal to the number of sine waves per revolution multiplied by four.

3.8.4 Using incremental encoders

Incremental encoders with the following specifications must be used in conjunction with the SM-Safety Solutions Module.

Figure 3-4 Using incremental encoders

Data	Detail
Incremental signals (AB)	
Measuring signal + hardware	A/B trace with 90 degree phase offset, RS422-compatible
Max. Input frequency	200kHz
SM-Safety connection	HDMI connector

3.8.5 Using absolute value SSI encoders

Absolute value encoders with the following specifications must be used in conjunction with the SM-Safety Solutions Module.

Table 3-3 Using absolute value SSI encoders

Data	Detail
Data interface	Synchronous serial interface (SSI) with variable data lengths from 10 to 28bit
Data format	Binary - / Graycode or SSI - WCS (Weg-Coder-System, Pepperl + Fuchs)
Measuring signal + hardware	Data and cycle, RS422 - compatible Minimum cycle pause time 30µs Maximum cycle pause time 2ms
SSI - Master operation	Clock rate 150kHz
SSI - Listener - operation (Slave)	Max. External clock speed 200kHz*
SM-Safety connection	HDMI connector

* Pr **3.37** on the drive or Pr **x.14** must be set to 200(1) or lower when used as the SSI master.

3.8.6 Using proximity switches

Only proximity switches having the following specifications may be used in conjunction with the SM-Safety Solutions Module.

Table 3-4 Using proximity switches

Data	Detail
Measuring signal + hardware	24V / 0V signal levels Switch logic debouncing
Max. Line count frequency	10kHz
SM-Safety connection	I/O INTERFACE on the digital DI5S input

3.8.7 Combining and configuring encoder types

Combining different encoder types

Where two encoders having the same value are connected to the SM-Safety Solutions Module, ensure that the sensor with the highest resolution is configured as encoder 1 (process sensor), and the sensor having the lower resolution is configured as encoder 2 (reference sensor).

The SM-Safety Solutions Module does not stipulate any particular requirements regarding the internal design of the encoder electronics for applications with different encoder systems.

In practice standard encoders can be employed, however the following limitations must be observed.

- SINE/COSINE encoders. The internal design of the sensor system must ensure independent generation of output signals from both tracers, in order that common faults can be eliminated. The mechanical design must also be suitable. Encoders with the appropriate certificates and test records are commercially available.
- Compact encoder with 2 x SSI or SSI + incremental output. Again, there must be no reaction between both internal encoder units, as well as the internal mechanical construction.
- When using only one encoder (e.g. using a compact encoder) the elimination of shaft break / errors must be accommodated in the mechanical connections to the encoder. The use of a rigid encoder coupling is required, e.g. by means of a slot wedge or locking pin.

The SM-Safety Solutions Module identifies the following faults with the external encoder systems:

1. Short circuit between the safety signal wires
2. Failure on the safety signal wires
3. Static level 0 or 1 on one or all of the safety signal wires

Configuring encoder types

The most important inputs for the SM-Safety Solutions Module are:

- safe position
- safe speed
- safe acceleration

plus the two-channel generation from the connected sensor systems.

For PL e in compliance with EN 13849-1 an architecture based on category 4, i.e. continuous two-channel capture with continuous high coverage is required. For any one-channel portions (e.g. mechanical connections of sensors / encoders with only one shaft/fixture) fault exclusions complying with EN ISO 13849-2 can be employed.

Reduced diagnostic monitoring can be used for PL d in compliance with EN 13849-1. Using the permitted fault exclusion in compliance with EN ISO 13849-2, integrated sensor systems may suffice (speed monitoring only).

For additional information regarding configuration, please refer to the *SM-Safety Programming Manual*.

3.9 SIL and PL Level corresponding to encoder types

The following tables will assist in the selection of suitable encoder technology, as well as the quantity required.

It should be understood that depending on the type of encoder selected, different SIL (Safety Integrity Level) and PL (Performance Levels) will be achieved.

NOTE The use of an absolute encoder is mandatory if the position-related safety function is required.

Table 3-5 SIL and PL corresponding to encoder types

Encoder 1 (Process encoder)	Encoder 2 (Reference encoder)	Comment	SIL	PL	Characteristics
Incremental	-	Mechanical error elimination. Shaft brake, rigid encoder coupling mandatory.	2	d	Speed[1)]
Sine Cosine	-	Mechanical error elimination. Shaft brake, rigid encoder coupling mandatory.	2	d	Speed[1)]
Incremental	Incremental		3	e	Speed[1)]
Incremental	Sine Cosine		3	e	Speed[1)]
Sine Cosine	Sine Cosine		3	e	Speed[1)]
Incremental	1 counter input (Proxi Switch)		3	e	Speed[1)]
Sine Cosine	1 counter input (Proxi Switch)		3	e	Speed[1)]
Incremental	SSI		3	e	Position[2)]
Sine Cosine	SSI		3	e	Position[2)]
SSI	SSI		3	e	Position[2)]

NOTE 1) - SIL or PL level only achievable when evaluating speed.
2) - SIL or PL level only achievable when evaluating absolute position.

Table 3-6 Safety functions based on encoder types

Encoder 1 (Process encoder)	Encoder 2 (Reference encoder)	Safety functions and quantity						
		SS1 SS2	SOS	SLS SLA	SDI	SLI	SCA	SLP
Incremental	-	✓	✓	✓	✓	✓	✓1)	
Sine Cosine	-	✓	✓	✓	✓	✓	✓1)	
Incremental	Incremental	✓	✓	✓	✓	✓	✓1)	
Incremental	Sine Cosine	✓	✓	✓	✓	✓	✓1)	
Sine Cosine	Sine Cosine	✓	✓	✓	✓	✓	✓1)	
Incremental	1 counter input (Proxi Switch)	✓	✓	✓	✓	✓	✓1)	
Sine Cosine	1 counter input (Proxi Switch)	✓	✓	✓	✓	✓	✓1)	
Incremental	SSI	✓	✓	✓	✓	✓	✓2)	✓
Sine Cosine	SSI	✓	✓	✓	✓	✓	✓2)	✓
SSI	SSI	✓	✓	✓	✓	✓	✓2)	✓

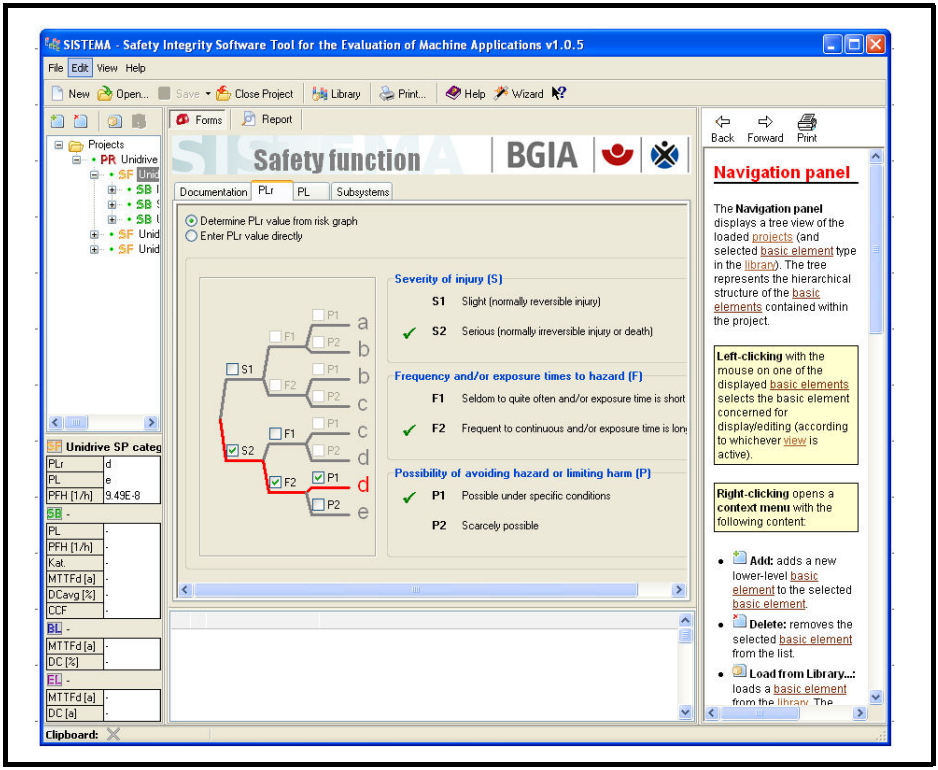
NOTE 1) - SIL or PL level only achievable when evaluating speed.
2) - SIL or PL level only achievable when evaluating absolute position.

3.10 Safety functions within the SISTEMA software

After determining the Performance Level (PL) for safety related applications, it must be established that the selected safety control meets the required Performance Level.

In order to do this, the BGIA provides a complimentary and independent software tool know as Sistema. This enables systematic calculation and documentation of the safety category of the developed safety controllers.

The SISTEMA Software Assistant (machine control safety) evaluates controller safety in the context of EN ISO 13849-1. This Windows based tool forms the basis of the safety-related control components (SRP/CS, Safety-Related Parts of a Control System) based on what is known as the intended architecture. In addition it also calculates reliability values at differing levels of detail, including the achieved Performance Level (PL).



The software provides the following features:

- Determination of required Performance Level (PLr)
- Determination of EN 13849-1 category
- Calculation of Mean Time To Failure (MTTFd)
- Estimation of Diagnostic Coverage average (DCavg) of components and/or blocks step by step measurement.

The impact of each parameter change on the system as a whole is displayed directly and may be sent to a printer as a report.

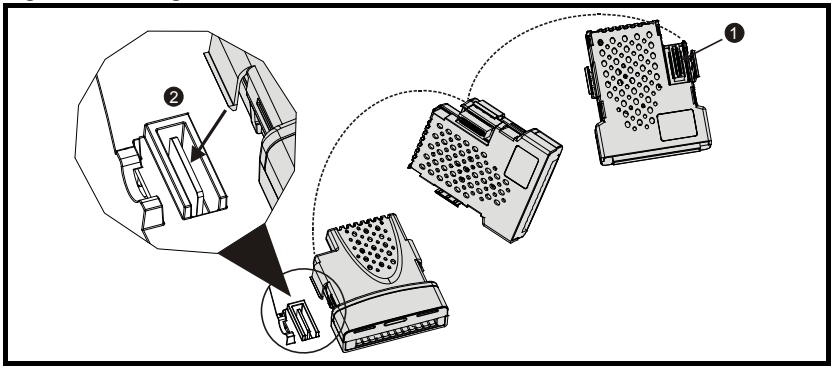
The required indicators may be saved or alternatively downloaded from a library.

4 Mechanical installation

Before installing or removing a Solutions Module in any drive, ensure the AC line power supply has been disconnected for at least 10 minutes and refer to *Safety information* on page 5. If using a DC bus supply, ensure this is fully discharged before working on any drive or Solutions Module.

The installation of a Solutions Module is illustrated in Figure 4-1.

Figure 4-1 Fitting a Solutions Module



The Solutions Module connector is located on the underside of the module (1). Push this into the Solutions Module slot located on the drive until it clicks into place (2). Note that some drives require a protective tab to be removed from the Solutions Module slot. For further information, refer to the appropriate drive manual.

5 Electrical installation

5.1 General

Installation, commissioning/start-up and servicing of the device must only be carried out by qualified personnel.

Before commissioning/start-up, ensure that the relevant EMC guidelines are followed for the place of use. Refer to the EMC data sheet for the drive. Maintain segregation of line power and signal wiring.

Cable lengths for digital inputs and outputs must not exceed 30m (98ft).

The safety regulations and safety plan must be adhered to. The configuration of the safety functions must be recorded in the commissioning/start-up report.

Wiring and connection instructions

The following measures ensure compliance with the regulations when operating the SM-Safety Solutions Module:

- The power converter's signal wires and line power cables must be run in separate cable ducts. The distance between ducts should be a minimum of 10mm (0.39in).
- Shielded cable is not required for the SM-Safety digital inputs and outputs.
- Shielded cable must be employed when connecting position and speed sensors. The cable for transmitting the signal must comply with standard RS-485 (twisted pair wires).
- Ensure correct connection of the cable shielding for the 19 way HDMI connector and the position and speed sensors. Use only metallic or metalized connectors.
- Shielding of the sensors must be carried out in compliance with current best practise.
- Ensure EMC compliance of the power converter within the SM-Safety environment. Particular attention should be paid to cable placement and shielding for both the motor wiring and the braking resistor. For more information refer to the manufacturers installation guidelines.

When the Safe Torque Off output is connected to a drive, the guidelines detailed in the relevant drive *User Guide* and *Installation Guide* must be adhered to.

5.2 Input / output connection detail

The SM-Safety Solutions Module provides a range of inputs and outputs as described in Table 5-1 below.

Figure 5-1 SM-Safety Solutions Module

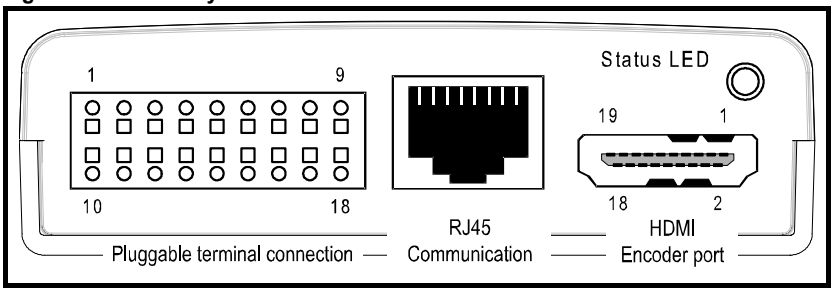


Table 5-1 Terminal plug connection and allocation of function

Terminal	Name	Function
1	SMF11	Digital input SMF11
2	SMF12	Digital input SMF12
3	SMF21	Digital input SMF21
4	SMF22	Digital input SMF22
5	SMF31	Digital input SMF31
6	SMF32	Digital input SMF32
7	SMF41	Digital input SMF41
8	SMF42	Digital input SMF42
9	DI5S	Digital input D5S
10	P1	Pulse output P1
11	P2	Pulse output P2
12	STO	STO output
13	SBC1	SBC1 output
14	SBC2	SBC2 output
15	DO1NS	Auxiliary output DO1NS (Non safety)
16	DO2NS	Auxiliary output DO2NS (Non safety)
17	L- ENC 2	Ext. encoder power supply for Encoder 2, 0 V (GND) ENC 2
18	L+ ENC 2	Ext. encoder power supply for Encoder 2, +Ub ENC 2

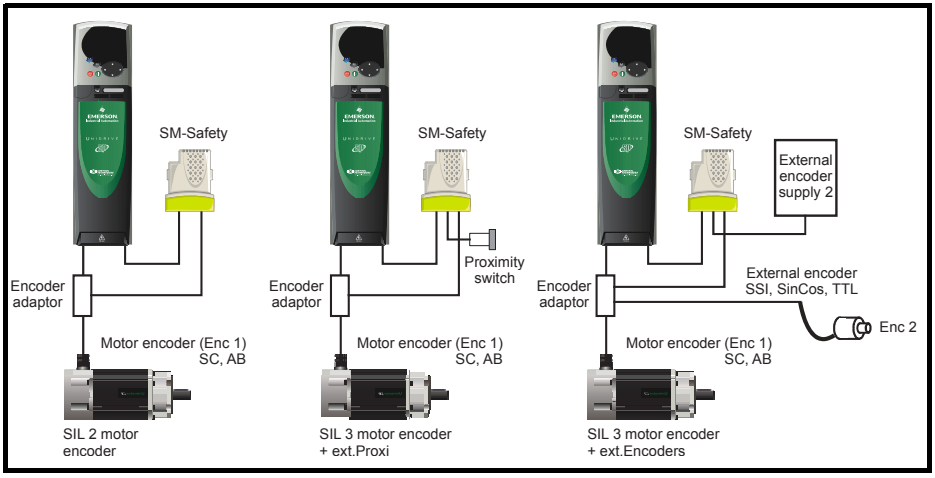
Table 5-2 Encoder port connections

Pin	Name	Encoder	Function
1	A+, DATA+, COS+	1	Incremental channel (TTL or Cos) or data signal
2	Shield		
3	A-, DATA-, COS-	1	Incremental channel (TTL or Cos) or data signal
4	B+, CLK+, SIN+	1	Incremental channel (TTL or sine) or clock signal
5	Shield		
6	B-, CLK-, SIN-	1	Incremental channel (TTL or sine) or clock signal
7	A+, DATA+, COS+	2	Incremental channel (TTL or Cos) or data signal
8	Shield		
9	A-, DATA-, COS-	2	Incremental channel (TTL or Cos) or data signal
10	B+, CLK+, SIN+	2	Incremental channel (TTL or sine) or clock signal
11	Shield		
12	B-, CLK-, SIN-	2	Incremental channel (TTL or sine) or clock signal
13	L+ ENC 1	1	Encoder supply voltage Encoder 1, Ub+
14	L+ ENC 1	1	Encoder supply voltage Encoder 1, Ub+
15	L- ENC 1 / 2	1 and 2	Encoder power supply for Encoder, 0 V (GND) ENC 1 / 2
16	L- ENC 1 / 2	1 and 2	Encoder power supply for Encoder, 0 V (GND) ENC 1 / 2
17	L- ENC 2	2	Encoder supply voltage Encoder 2, Ub-
18	L- ENC 2	2	Encoder supply voltage Encoder 2, Ub-
19	not used		Not used

5.3 Connecting the SM-Safety Solutions Module

Figure 5-2 shows the connections between the drive motor and the SM-Safety Solutions Module.

Figure 5-2 Typical connection between SM-Safety Solutions Module and drive (Unidrive SP illustrated)



5.3.1 SM-Safety Solutions Module control connections

The SM-Safety Solutions Module provides a total of seven outputs. Outputs SBC1 and SBC2 may be connected as a group.

The pulse outputs P1 and P2, can be used to monitor external safety switching devices e.g. E-Stop, end switches or auxiliary contacts, all of which are application dependent. Three outputs are also available which provide safe outputs (SBC1, SBC2 and STO) when used with the appropriate wiring. A further two non-safe digital outputs are also provided.

Output	Quantity	Description
SBC1 SBC2 STO	3	Outputs comprising a full power down channel based on category four architecture in compliance with EN ISO 13849-1
P1, P2	2	Pulse outputs
DO1NS DO2NS	2	Auxiliary output

Wiring must be carried out in compliance with the information contained in the relevant Safe Torque Off section in the drive *User Guide* and *Installation Guide.*

5.4 Digital input connection and architecture

The SM-Safety Solutions Module features four SMF inputs plus a DI5S input. These are suitable for connection to one or two channel signals with or without pulse, and with or without cross circuit monitoring.

The SM-Safety Solutions Module features two pulse outputs P1 and P2, which are in addition to the signal inputs exclusively reserved for monitoring the digital inputs (SMF and DI5S) which have no other function within the application.

The pulse outputs provide 24Vdc switching outputs.

If the appropriate procedures are followed during commissioning/start-up with particular regard to the provision of suitable cable ducts, a short circuit or fault between different inputs or between inputs and the supply voltage can be avoided.

Each SM-Safety Solutions Module input may be individually configured for the following signal sources (CTSafePro):

- Input Pulse P1
- Input Pulse P2
- Input 24Vdc continuous operating voltage
- Proximity input DI5S (single input)

The examples shown on the following pages and their individual configuration are principally responsible for the allocation in a category in compliance with EN ISO 13849-1.

The examples assume the following:

- The switch elements used have a safety approval based on the target PL in compliance with EN ISO 13849-1 and/or SIL in compliance with EN 61508.
- Current safety regulations and EMC guidelines must be observed.
- With regard to error conditions, reference should be made to the relevant tables under appendix D in EN 13849-2.

Classification in Performance Levels (PL) in compliance with EN 13849-1

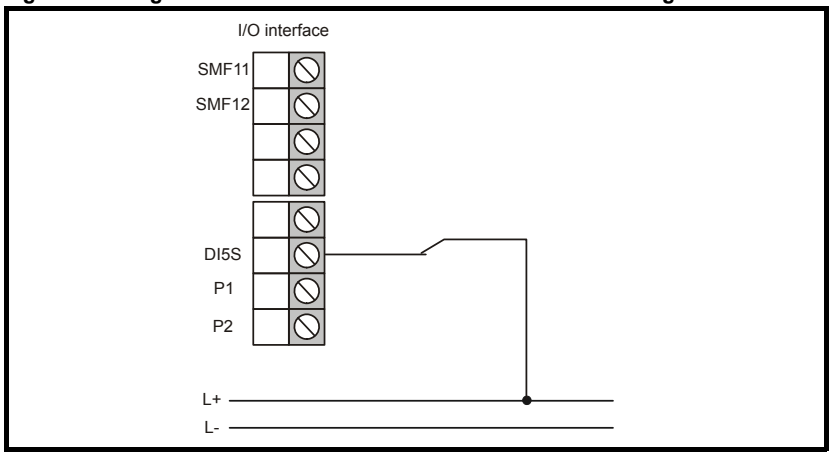
The resulting maximum possible Performance Levels in compliance with EN 13849 are dependent on the following factors of the externally-used components:

- Structure (single or redundant)
- Commonly Caused Failures recognition (CCF)
- Diagnostic Cover level on demand (DC_{avg})
- Mean Time To Failure of a channel ($MTTF_d$)

5.4.1 Single channel sensor without cross circuit monitoring

The single channel sensor is connected without pulsing and/or without cross-circuit monitoring to the SM-Safety Solutions Module, and therefore it is not recommended for use in safety related applications. Maximum PL b in compliance with EN ISO 13849-1 can be achieved as shown in Figure 5-3.

Figure 5-3 Single channel sensor without cross circuit monitoring

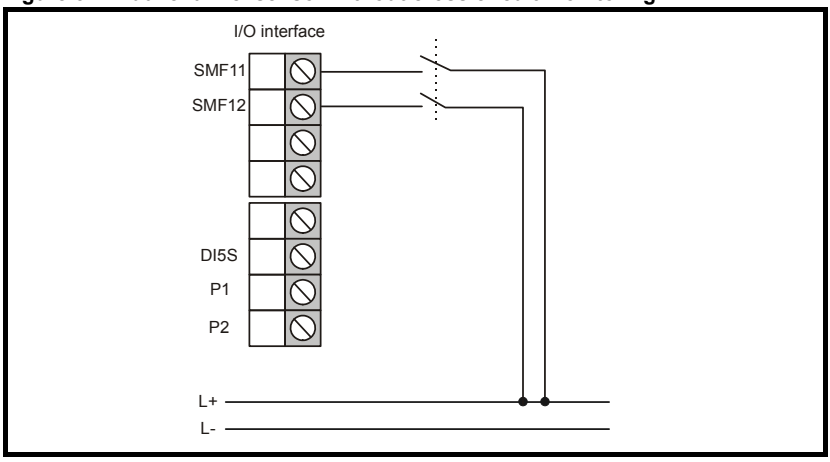


5.4.2 Dual channel sensor without cross circuit monitoring

The use of dual channel sensors without pulsing, and/or without cross circuit monitoring can lead to problems under certain conditions. Should a short circuit develop in the signal cable of the two channel sensor for example, this would not be detected. To ensure the best possible operating environment therefore, separate cable ducts should be used for the line power and signal cable runs. This type of connection is not recommended for use with safety applications except the switch cabinet.

With regard to cross circuit error elimination, PL d in compliance with EN ISO 13849-1 is achievable as shown in Figure 5-5.

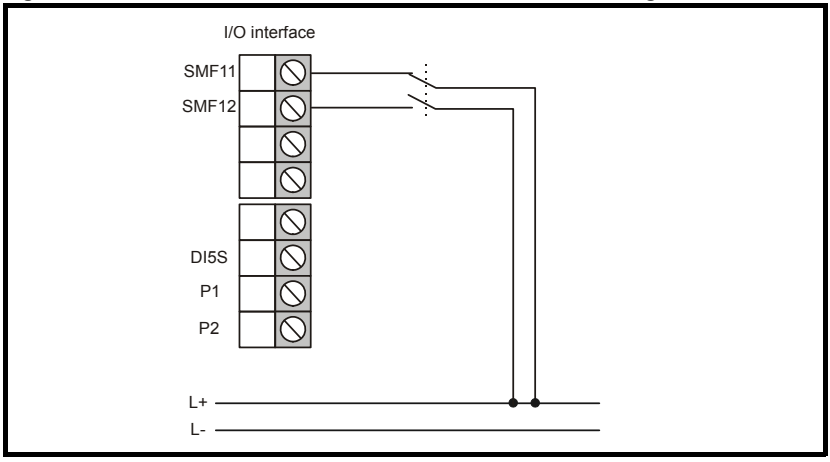
Figure 5-4 Dual channel sensor without cross circuit monitoring



5.4.3 Dual channel sensor without cross circuit monitoring (complementary)

The use of dual channel complementary sensors without pulsing, and/or without cross circuit monitoring can be processed safely by the SM-Safety Solutions Module. With regard to the cross circuit error elimination, PL e in compliance with EN ISO 13849-1 is achievable as shown in Figure 5-5.

Figure 5-5 Dual channel sensor without cross-circuit monitoring



5.4.4 Single channel sensor with pulsing

When using a single channel sensor with pulsing, connection is made using the pulse outputs P1 or P2.

Using a single channel sensor with pulsing will detect:

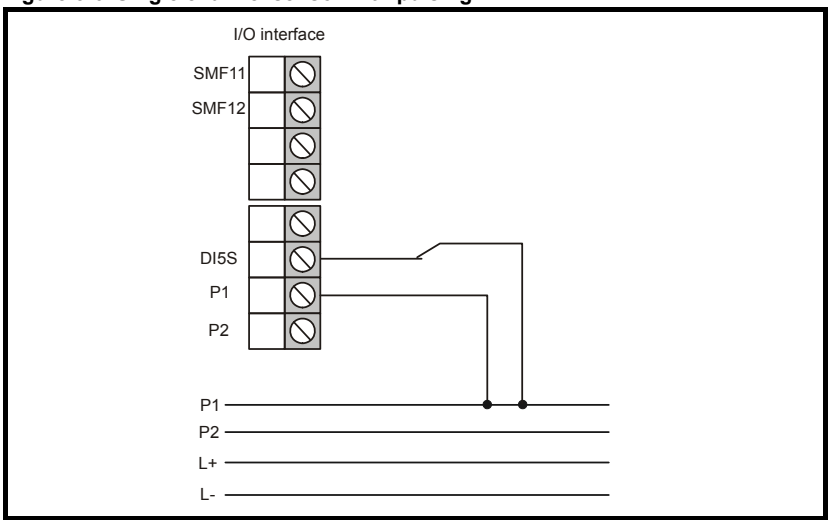
- Suspected power supply short circuit 24Vdc and on 0Vdc
- Disconnected or broken cable connection

Steps should be taken to avoid any possibility of a short circuit between the two sensor cables, or between P1 and DI5S, as these conditions are not detected. When using a suitable switching element and with adequate sensor cabling, PL d in compliance with EN ISO 13849-1 can be achieved as shown in Figure 5-6.

NOTE

PL e in compliance with EN ISO 13849-1 can be achieved if the short circuit between DI5S and P1 and the short circuit between the sensor connections can be eliminated. Ensure that the switch is spring biased in the event of an error. The sensor must also be triggered at regular intervals and the safety function requested. Error eliminations based on EN ISO 13849-2 Table D8 can be achieved.

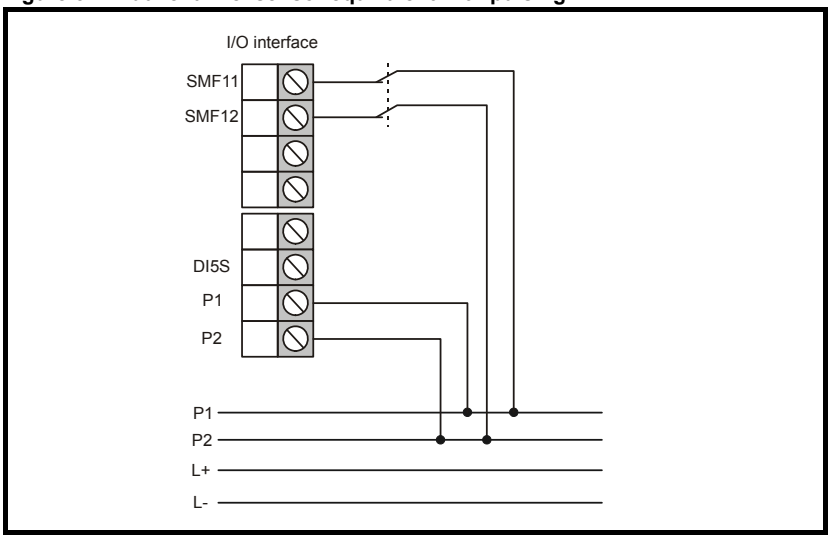
Figure 5-6 Single channel sensor with pulsing



5.4.5 Dual channel sensor with cross circuit monitoring

By using two independent pulsing signals on the homogenous sensor, all cross connections, including connections in compliance with 24Vdc and 0Vdc are detected as shown in Figure 5-7. Use only normally open contact switches with safety related applications.

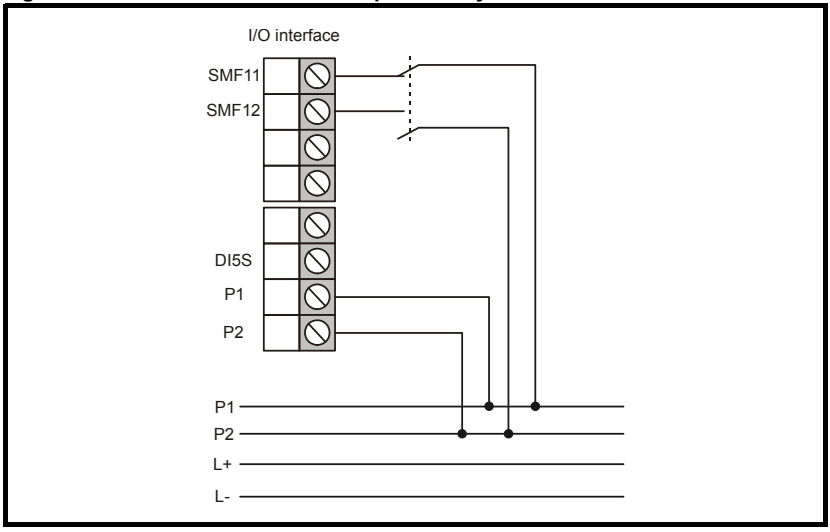
Figure 5-7 Dual channel sensor equivalent with pulsing



5.4.6 Dual channel sensor complementary

When connecting a complementary sensor, ensure that only the open contact with pulsing is continuously tested. All error types are detected in the feed line as with homogenous sensors. When using approved spring loaded switching elements, PL e in compliance with EN ISO 13849-1 can be achieved in both cases as shown in Figure 5-8.

Figure 5-8 Dual channel sensor complementary



5.5 Digital outputs connection and architecture

5.5.1 Single-pole switching 24V output without cross-circuit monitoring

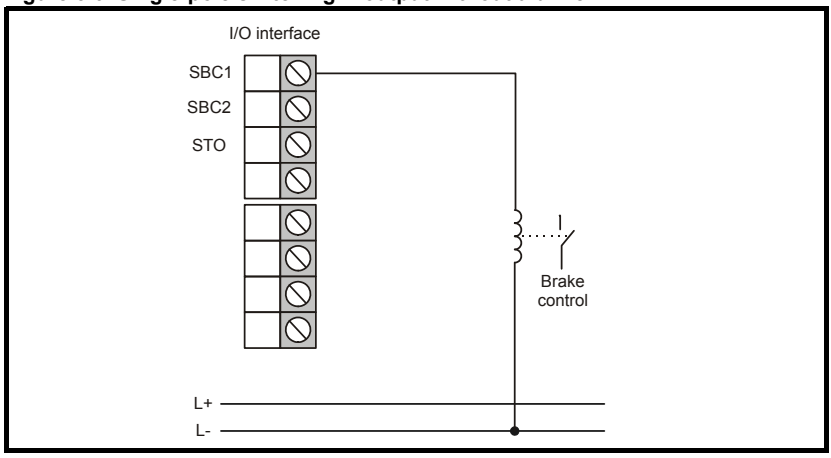
For switching in multiple applications and/or for high power requirements, external contactors should be used. For a single pole switch without external monitoring, ensure there is no jamming of one or more external contacts of the SM-Safety Solutions Module as shown in Figure 5-9.

The output is safe for external monitoring using a drive, as shown in Figure 5-10.

WARNING

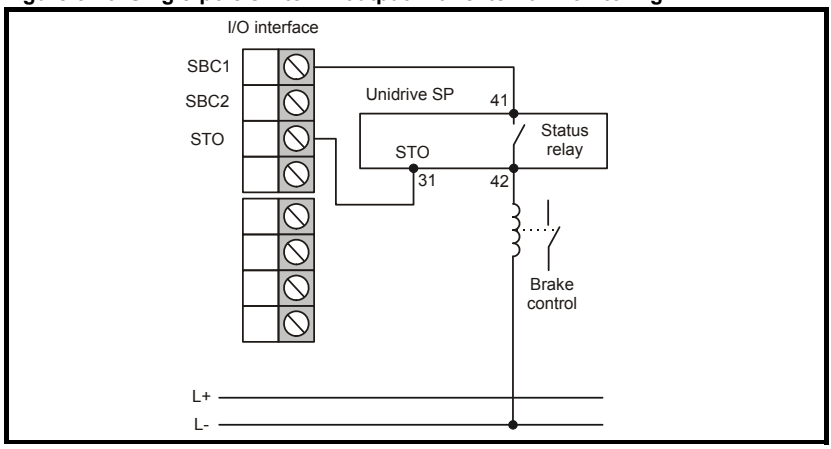
Safety applications up to PL e (in accordance with EN ISO 13849-1) and SIL 3 (in accordance with EN 61508) can be achieved with a direct connection between the Safe Torque Off output of the SM Safety module and the drive Safe Torque Off terminal, as long as protected wiring is used for this connection. Protected wiring is required to reduce the risk of a short circuit from the enable input to 24 volts which would cause the drive STO function to be overridden.
The wire can be protected by physically segregating it from all other circuits so that there is no possibility of a short circuit causing it to be forced to a logic high potential (+24V nominal). If this is not practical then a second disable channel must be created by using another safe digital output in SM-Safety to control a contactor or other means for removing power, in the event of a fault in the STO circuit.

Figure 5-9 Single-pole switching P-output without a drive



NOTE This configuration is not suitable for safety related applications

Figure 5-10 Single-pole switch P-output with external monitoring

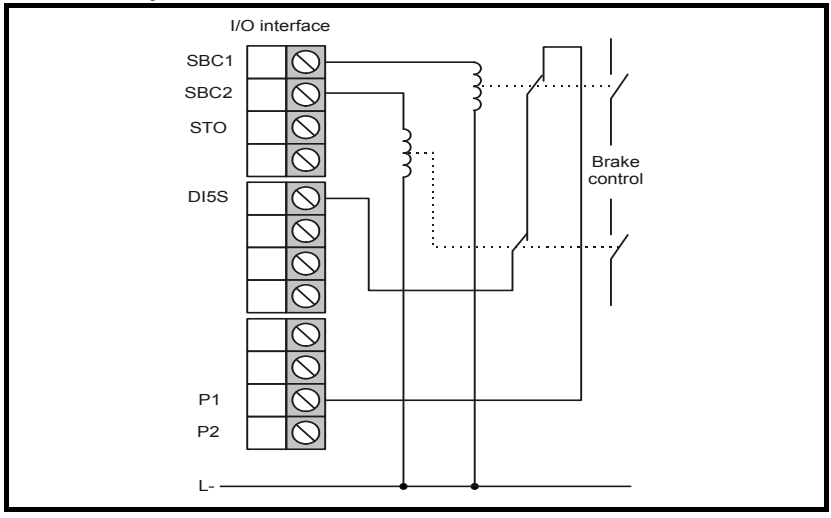


5.5.2 Dual channel switching output D0 with external monitoring

For safety applications to PL d in compliance with EN ISO 13849-1, it is recommended that two complementary outputs are connected as a group and used to control two external power contactors.

Both external monitoring contacts are switched in series, supplied by pulsing signal P1 and read by input DI5S. Input DIS5 is used as back read input, but another input can employed if required. For installations with high demand, ensure that at least one switching operation takes place every 24 hours to test the switching function of external power contactors as shown in Figure 5-11.

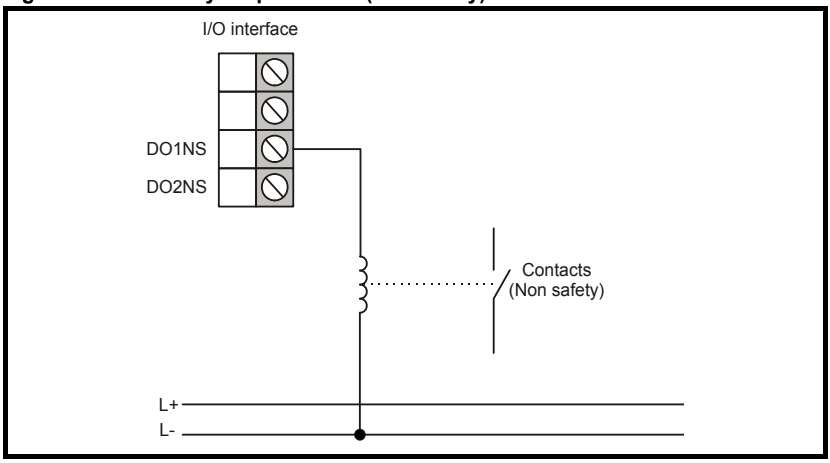
Figure 5-11 Dual channel switching outputs with external monitoring to an input as joint feedback



5.5.3 Auxiliary output circuit

Both semiconductor outputs provided on the SM-Safety Solutions Module can be wired for functional applications as shown in Figure 5-12. The outputs are not pulsed.

Figure 5-12 Auxiliary output circuit (non safety)

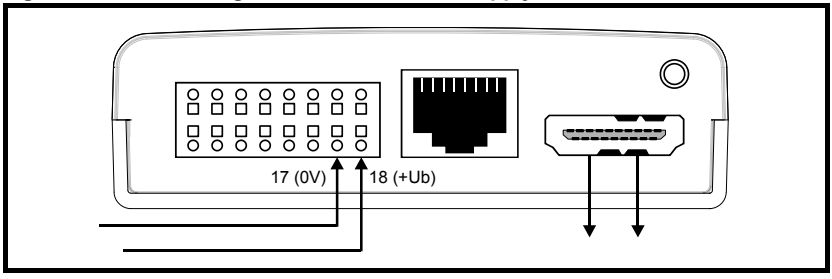


Applications with auxiliary outputs are not authorized for safety applications.

5.6 Encoder connection to the SM-Safety Solutions Module

The monitoring of speed, position and acceleration data is essential to ensure compliance with the relevant safety functions. Data monitoring is accepted from motors, encoders, proximity switches or absolute value encoders connected to the SM-Safety Solutions Module HDMI encoder port. The SM-Safety Solutions Module can support up to two different encoders while monitoring the encoder power supply. If an external absolute value encoder is connected this may be powered directly by the module.

Figure 5-13 Connecting the external encoder supply



The SM-Safety Solutions Module supports encoder supplies of 5V, 8V, 10V, 15V and 24V all of which are internally monitored depending on which user configuration mode is selected. Where an encoder system is not supplied with power by the SM-Safety Solutions Module, an encoder supply voltage must be connected to the HDMI encoder port. The maximum encoder supply current is 2A maximum.

The encoder supply voltage is monitored in accordance with the selected nominal voltage between the following levels:

Nominal voltage Vdc	Minimum voltage Vdc	Maximum voltage Vdc
5	4.4	5.6
8	7	9
10	8	12
15	12	18
24	20	29

NOTE To minimize the encoder wiring an encoder adapter can be used. This way, correct wiring between the drive and the SM-Safety Solutions Module can be ensured.

Refer to the *Encoder Adaptor Installation Sheet* for details of connections and switch settings.

NOTE For SERVO operation, it is recommended that no SSI encoder is used for speed feedback. The data monitoring does not include a CRC test, and customers should note that the use of an SSI encoder could lead to unstable operation.

5.7 Connecting external safety components

Connection to external safety components e.g. E-Stop brakes, must be carried out in accordance with PL or SIL with a pre-defined architecture. Direct connection can be made with the relevant SM-Safety Solutions Module terminals, and then configured using the CTSafePro tool. The following components can be selected.

Safety components

- Enabling button
- Emergency stop (E-Stop)
- Door control
- Limit switches
- Light grid
- General sensors
- Start / Reset Element

6 commissioning/start-up and maintenance

6.1 commissioning/start-up

6.1.1 Configuration

commissioning/start-up must only be carried out by suitably qualified personnel. Please observe all relevant safety regulations during commissioning/start-up.

6.1.2 LED display

Following a system restart, the module status is displayed on the front panel LED. Refer to *Diagnostics* on page 36 for details of the LED status.

6.1.3 Function inspection

In order to ensure continued safety, an annual safety inspection is required. The modules which are used to configure the system (inputs, outputs, monitoring functions and logic modules), should all be tested for functionality and switching ability. See Section 6 for more information.

To verify the safety related functions, the user must inspect and document parameters and connections after successful commissioning. This is supported by the validation assistant in the programming interface (refer to Section 6.1.4).

6.1.4 Safety-related inspection

To ensure implemented safety-related functions, the user must inspect and document parameters and connections after successful commissioning. This is supported by the CTSafePro configuring software (refer to Programming the SM-Safety options module).

Basic data can be entered via the first two pages. The last page of the validation report lists the items contained within the safety-related inspection.

The following two entries are mandatory:

- Serial number (same as serial number on the name plate)
- Component identification

During inspection, the safety components confirm that the displayed CRC in the programming interface is identical with the one stored in the SM-Safety Modules.

After all header data has been entered, the validation report is generated using the Save button. The configuration tool then creates a text file (.TXT) using the file names of the program dataset.

The resultant text file contains the following information:

- Three pages of the edited header data
- The encoder configuration
- The parameters of the current monitoring functions
- PLC program as instruction set

After transferring configuration and program data to the SM-Safety Module, the status LED flashes orange. This indicates that the configuration data has not been validated as yet. By confirming with “BLOCK CONFIGURATION” at the end of the validation dialogue, the data is marked as having been validated and the status LED flashes green.

6.2 Maintenance

6.2.1 Modification / modifying the device

Repairs

The device can only be repaired in the factory.

Warranty

The warranty becomes null and void in the event of unauthorized opening of the module.

Note:

Modifying the components voids the safety authorization.

NOTE The SM-Safety Solutions Module must never be connected or disconnected with the power on. With regard to position or speed sensors, there is a high risk of destroying the sensor if they are disconnected with the power applied.

6.2.2 Maintenance intervals

Components exchange	Refer to *Technical data* on page 51
Function inspection	Refer to *commissioning/start-up and maintenance* on page 34

7 Diagnostics

7.1 Overview

The SM-Safety Solutions Module features a number of diagnostic options:

- LED indication
- Error displays and diagnostics in CTSafePro
- Diagnostic parameters

7.2 LED status

The SM-Safety Solutions Module incorporates an LED on the front panel which displays the current system status. The following status and error conditions are indicated as shown in Table 7-1 below.

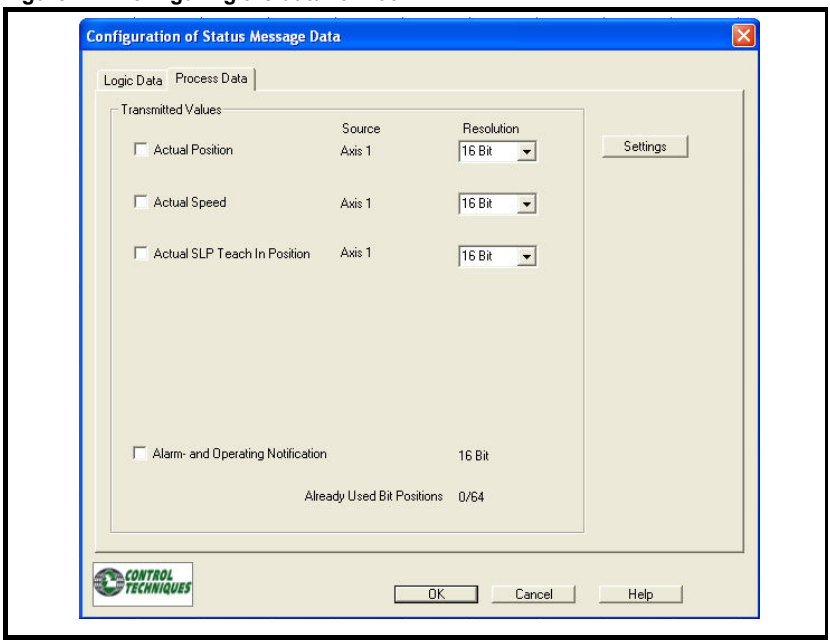
Table 7-1 Detailed description during operation

Mode	Attribute	LED display
STARTUP	Synchronization between both process systems and inspection of configuration / firmware data.	Off
RUN	System operating normally. All outputs are connected based on current logic status.	Flashing green, 1Hz
STOP	In Stop mode, parameter and program data can be loaded externally.	Flashing red/ green, 1Hz
ALARM	Alarm can be reset by a configured digital input.	Flashing red, 1Hz
ERROR	Error can only be reset through switching components ON/OFF.	Continuous red
SYSTEM OK	System healthy but not yet configured	Continues green
CONFIGURATION	Configuration active, not yet complete	Flashing orange

7.3 Diagnostic parameters

The SM-Safety Solutions Module is designed to accept pre-defined data during operation. A fully-assigned patch cable for connecting the SM-Safety Solutions Module (RJ45) and the Unidrive SP or Digitax ST (RJ45) is required. The data to be transferred are defined in CTSafePro. The configuration of the signal channel data is defined as shown in Table 7-1 below.

Figure 7-1 Configuring the data format



The user may define all aspects of the data including speed, position and logic data, plus switching conditions of logic elements on the terminal interface. Processed data is subsequently displayed in registers in menu 18 on the drive.

The processed data is displayed in the row below and is limited to a total of 64 bits with the current position of axis 1 appearing in Pr **18.20**. If the current speed of axis 1 is also required, this value is displayed in Pr **18.21**.

Communication with the drive is performed automatically after the data cable is connected to the unit. The peripheral devices are activated through Baud rate and serial addresses in the CTSafePro with the data being sent in cyclic format.

With the RJ45 data cable connected between the SM-Safety Solutions Module and the drive, the following diagnostic parameters are displayed. The transmitted register in menu 18 is allocated in the following table:

Parameters	Status
Pr **18.11** - Pr **18.13**	**Information data**
Pr **18.11**	Module identification number (16 Bit)
Pr **18.12**	Version number application software (8 Bit)
Pr **18.13**	Identifier of application software (8 Bit)
Pr **18.14** - Pr **18.19**	**Logic data**
Pr **18.14**	Logic data (8 Bit)
Pr **18.15**	Logic data (8 Bit)
Pr **18.16**	Logic data (8 Bit)
Pr **18.17**	Logic data (8 Bit)
Pr **18.18**	Logic data (16 Bit)
Pr **18.19**	Logic data (16 Bit)
Pr 1**8.20** - Pr **18.23**	**Process data**
Pr **18.20**	Process data (16 Bit)
Pr **18.21**	Process data (16 Bit)
Pr **18.22**	Process data (16 Bit)
Pr **18.23**	Process data (16 Bit)

Expanded description of individual parameters

18.11	Module identification number	
Explanation	Pr **18.11** is a permanently assigned module code and specially defined for SM-Safety Solutions Module. The option module is therefore labelled in its hardware and also identifiable in connected status.	
Operating mode	OL, CL, Servo	
Range	0 to +32767	
Default	801	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	16 Bit	
18.12	**Application software version number**	
Explanation	The version number of the loaded application software is displayed here. The display is numerical only and should show no more than three figures. A total of 255 versions of a program can be created. For version 1.00, “100” is displayed.	
Operating mode	OL, CL, Servo	
Range	0 to 255	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	8 Bit	
18.13	**Application software identification**	
Explanation	The loaded application software displays a counter, which counts from 0 up to 255. The display is numerical only and indicates to the user that the module is connected to the right drive controller via the serial port and is running correctly.	
Operating mode	OL, CL, Servo	
Range	0 to 255	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	8 Bit	

18.14 - 18.19	**Logic data**	
Explanation	Here, the defined logic data is displayed as configured in CTSafePro.	
18.14	**Operating mode**	
Explanation	Display Bit 64 to Bit 57 of logic data Here, the different operating modes are displayed. 1 Startup 2 SendConfig 3 StartupBus 4 Run 5 Stop 6 Error 7 Alarm	
Operating mode	OL, CL, Servo	
Range	0 to 7	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	8 Bit	
18.15	**Diagnostic expansion 2**	
Explanation	Display Bit 56 to Bit 49 of logic data	
Operating mode	OL, CL, Servo	
Range	0 to 255	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	8 Bit	

18.16	Diagnostic expansion 1	
Explanation	Display Bit 48 to Bit 41 of logic data	
Operating mode	OL, CL, Servo	
Range	0 to 255	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	8 Bit	
18.17	**Diagnostic expansion 0**	
Explanation	Display Bit 40 to Bit 33 of logic data	
Operating mode	OL, CL, Servo	
Range	0 to 255	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	8 Bit	
18.18	**Diagnostic 0**	
Explanation	Display Bit 16 to Bit 1 of logic data	
Operating mode	OL, CL, Servo	
Range	0 to +32767	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	16 Bit	
18.19	**Diagnostic 1 or error / alarm code**	
Explanation	Display Bit 31 - Bit 17 of logic data Either diagnostic data, error or alarm codes are displayed depending upon the operating mode shown in Pr **18.14**. In the event of an alarm and then an error occurring, the following priority applies: Priority 1 - error display Priority 2 - alarm display Priority 3 - encoder alarm display	
Operating mode	OL, CL, Servo	
Range	0 to +32767	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	16 Bit	

18.20 - 18.23	Process data	
Explanation	Here, the defined logic data is displayed via the CTSafePro software.	
Operating mode	OL, CL, Servo	
Range	-32768 to 0 to +32767	
Default	0	
Update	1.2, 2.4, 4.8, 9.6, **19.2**, 38.4, 57.6, 115.2 kb/s	
Format	16 Bit	

7.4 Input / output status indication

The input/output status can be displayed in the CTSafePro or via configuration of the logic data in the Pr **18.15** Pr **18.19**.

7.5 SM-Safety error / alarm codes

Table 7-2 Error / alarm status

State	Attribute	Impact on system	Reset condition
Fatal Error	Fatal program error in SM-Safety Cyclical program procedure is no longer possible for safety reasons. System B is in stop mode	All outputs are switched off	Reset by switching the module on and off
Alarm	Functional error, caused by external process. Both systems continue running cyclically and serve all communication interfaces requirements. Sampling of external processes is also maintained	All outputs are switched off	Reset by configurable input
ECS Alarm	When using the ECS function in the programming interface, the encoder alarm messages are labelled with “E” instead of “A”	ECS function block delivers a “0” result	Reset by configurable input

Identifying errors from system A and system B

- System A: Odd numbers
- System B: Even numbers

NOTE If a fatal error occurs, contact the supplier of the drive.

7.5.1 SM-Safety alarm list

The error code display (numerical only) is shown in Pr **18.19** and grouped in the following sections:

- Alarm / error codes for the terminal block digital inputs/outputs
- Alarm / error codes for the encoder
- Alarm / error codes for safety functions

Table 7-3 Alarm codes

Alarm Code	Alarm Description
A 3101	Pulse 1 monitoring error on input SMF 11: **Cause:** The configured Pulse 1 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3117	Pulse 2 monitoring error on input SMF 11: **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3159	24V signal error on input SMF 11 cause: **Cause:** There is no steady 24V voltage at this input **Error rectification:** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 3102	Pulse 1 monitoring error on input SMF 12: **Cause:** The configured Pulse 1 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3118	Pulse 2 monitoring error on input SMF 12: **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3160	24V signal error on digital input SMF12 **Cause:** There is no steady 24V voltage at this input **Error rectification:** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 3103	Pulse 1 monitoring error on digital input SMF21 **Cause:** The configured Pulse 1 voltage is not connected to the input. **Error rectification:** Check configuration of the digital input based on project and circuit diagram Check wiring
A 3119	Pulse 2 monitoring error on expansion input SMF 21: **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring

Alarm Code	Alarm Description
A 3161	24V signal error on digital input SMF21 **Cause:** There is no steady 24V voltage at this input **Error rectification:** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 3104	Pulse 1 monitoring error on digital input SMF22 **Cause:** The configured Pulse 1 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3120	Pulse 2 monitoring error on digital input SMF22 **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3162	24V signal error on digital input SMF22 **Cause:** There is no steady 24V voltage at this input **Error rectification:** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 3105	Pulse 1 monitoring error on digital input SMF31 **Cause:** The configured Pulse 1 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3121	Pulse 2 monitoring error on digital input SMF31 **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3163	24V signal error on digital input SMF31 **Cause:** There is no steady 24V voltage at this input **Error rectification:** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 3106	Pulse 1 monitoring error on digital input SMF32 **Cause:** The configured Pulse 1 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring

Alarm Code	Alarm Description
A 3122	Pulse 2 monitoring error on digital input SMF32 **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3164	24V signal error on digital input SMF32 **Cause:** There is no 24V supply. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3107	Pulse 1 monitoring error on digital input SMF41 **Cause:** The configured Pulse 1 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3123	Pulse 2 monitoring error on digital input SMF41 **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3165	24V signal error on digital input SMF41 **Cause:** There is no steady 24V supply at this input **Error rectification:** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 3108	Pulse 1 monitoring error on digital input SMF42 **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3124	Pulse 2 monitoring error on digital input SMF42 **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3166	24V signal error on digital input SMF42 **Cause:** There is no steady 24V voltage at this input **Error rectification** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected

Alarm Code	Alarm Description
A 3109/ 3110	Pulse 1 monitoring error on digital input DI5S **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3125/ 3126	Pulse 2 monitoring error on digital input DI5S **Cause:** The configured Pulse 2 voltage is not connected at this input. **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 3167/ 3168	24V signal error on digital input DI5S **Cause:** There is no steady 24V voltage at this input **Error rectification** • Check voltage at the digital input • Check wiring • Check if Pulse 1 or Pulse 2 is connected
A 5003/ A 5004	Error on grouped input SMF1: **Cause:** monitoring inspection of grouped input has failed **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5005/ A 5006	Error on grouped input SMF2 **Cause:** monitoring inspection of grouped input has failed **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5007/ A 5008	Error on grouped input SMF3 **Cause:** monitoring inspection of grouped input has failed **Error rectification** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5009/ A 5010	Error on grouped input SMF4 **Cause:** monitoring inspection of grouped input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5013	Monitoring error on single input SMF11 **Cause:** monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring

Alarm Code	Alarm Description
A 5014	Monitoring error on single input SMF12 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5015	Monitoring error on single input SMF21 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5016	Monitoring error on single input SMF22 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5017	Monitoring error on single input SMF31 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5018	Monitoring error on single input SMF32 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5019	Monitoring error on single input SMF41 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring
A 5020	Monitoring error on single input SMF42 **Cause:** Monitoring inspection of single input has failed **Error rectification:** • Check configuration of the digital input based on project and circuit diagram • Check wiring

Alarm Code	Alarm Description
A 3209/ A 3210	Encoder supply voltage Encoder 1 has failed. **Cause:** • encoder supply voltage does not correspond to the configured threshold • Component error on equipment **Error rectification:** • Check configuration • Check encoder supply voltage • Turn appliance on/off.
A 3213/ A 3214	Encoder supply voltage Encoder 2 has failed. **Cause:** • encoder supply voltage does not correspond to the configured threshold • Component error on equipment **Error rectification:** • Check configuration • Check encoder supply voltage • Turn appliance on/off.
A 3229/ A 3230	Monitoring test encoder voltage error **Cause:** encoder voltage value **Error rectification:** • Check encoder voltage supply • Check encoder voltage supply cabling
A 3301/ A 3302	Monitoring error speed capture **Cause:** The difference between both speed sensors is higher than the configured turn-off threshold **Error rectification:** • Check distance theory again with data set in the configuration of the encoder • Check speed sensor
A 3303/ A 3304	Monitoring error position capture **Cause:** The difference between both position signals is higher than the configured turn-off threshold increments **Error rectification:** • Check distance theory with configured data of the encoder setting • Check position signal • Are all signal encoder connectors properly connected? • Check encoder connector circuit.
A 3307/ A 3308	Monitoring error failed position range **Cause:** The current position lies outside the configured measurement length **Error rectification:** • Check distance theory with configured data of the encoder setting • Check position signal if required. • Check encoder offset.

Alarm Code	Alarm Description
A 3309/ A 3310	Monitoring error failed speed **Cause:** The current speed lies outside the configured maximum speed **Error rectification:** • The drive moves outside the authorized and configured speed range • Check configuration • Analyse speed characteristics with SCOPE
A 3311/ A 3312	Configuration error: Acceleration **Cause:** Current acceleration lies outside the configured acceleration range **Error rectification:** • The drive has exceeded the authorized acceleration range • Check maximum speed configuration • Analyse speed/acceleration characteristics with SCOPE
A 3313/ A 3314	SSI sensor error **Cause:** encoder jump SSI value within a cycle too large **Error rectification:** • Check encoder cabling • Check encoder configuration
A 3333/ A 3334	Monitoring error SinCos encoders **Cause:** Wrong encoder type connected **Error rectification:** • Check configuration • Check encoder assignment
A 3407/ A 3408	Level difference RS485 driver 1 error INC_B or SSI_CLK failed **Cause:** • No encoder connection • Wrong encoder type connected **Error rectification:** • Check encoder connection • Check encoder cabling
A 3409/ A 3410	Level difference RS485 driver 2 error INC_A or SSI_DATA failed **Cause:** • No encoder connection • Wrong encoder type connected **Error rectification:** • Check encoder connection • Check encoder cabling
A 3411/ A 3412	Sine/cosine error monitoring Encoder 1 **Cause:** Monitoring of single traces failed **Error rectification:** • Check encoder cabling • Sine to cosine trace must be linear
A 3413/ A 3414	Sine/cosine error monitoring Encoder 2 **Cause:** Monitoring of single traces failed **Error rectification:** • Check encoder cabling • Sine to cosine trace must be linear

Alarm Code	Alarm Description
A 4001/ A 4002	Run forward or run reverse monitoring SDI.1 were activated at the same time **Cause:** Multiple activation **Error rectification:** When programming, care must be taken to ensure that only one “Enable” is activated
A 4003/ A 4004	Run forward or run reverse monitoring SDI.2 were activated at the same time **Cause:** Multiple activation **Error rectification:** When programming, care must be taken to ensure that only one “Enable” is activated
A 4605/ A 4606	SLP Teach in state error **Cause:** SET and QUIT input have wrong switching sequence **Error rectification:** Check input configuration, check switching sequence
A 4609/ A 4610	SLP Teach in position error **Cause:** Teach in position out of configured range **Error rectification:** Check position tolerance input, check sect. Length in sensor configuration
A 4613/ A 4614	SLP Teach in SOS error **Cause:** During Teach in SOS released **Error rectification:** By using Teach in the supervisioning drive has to be stopped
A 4901/ A 4902	Run forward or run reverse monitoring SLI.1 were activated at the same time **Cause:** Multiple activation **Error rectification:** When programming, care must be taken to ensure that only one “Enable” is activated
A 4903/ A 4904	Run forward or run reverse monitoring SLI.2 were activated at the same time **Cause:** Multiple activation **Error rectification:** When programming, care must be taken to ensure that only one “Enable” is activated

7.6 Software diagnostics

Refer to the *SM-Safety Solutions Module* programming guide.

8 Technical data

8.1 Environmental conditions

Table 8-1

Protection category	IP20
Ambient temperature	0°C (32°F) to 50°C (122°F)
Climate category	3 in compliance with EN 50178
Lifespan	90000h at 50°C (122°F) ambient temperature
Environment category	3C2 in compliance with IEC 60721-3-3
RoHS compliant	Yes

8.2 Safety-related features of SM-Safety Solutions Module

Table 8-2

Max. achievable safety category	• SIL 3 in accordance with EN 61508 • Category 4 accordance with EN 945-1 • Performance-Level e in accordance with EN ISO 13849-1
System structure	Dual channel with diagnostic (1oo2)
Design of operating mode	“high demand” acc. to EN 61508 (high demand rate)
Probability of failure per hour (PFH - value)	SM-Safety Solutions Module <0.651 x 10^{-8}
Proof-Test-Interval (EN 61508)	20 years after which components must be replaced
Construction and architecture	Internal design of SM-Safety Solutions Module corresponds to architecture and function type of category 4 of EN ISO 13849-1.

8.3 Terminal electrical data

Table 8-3 Input connection detail

Attribute	Terminals	Detail
Wiring (Wire length and protection)	All digital inputs/ outputs	The maximum connection length must not exceed 30m (98ft). By using external measures, in particular suitable cable ducts, a short circuit in external wiring between different inputs and against the SM-Safety Solutions Module supply voltage must be prevented.
Signals	SMF11, SMF12 SMF21, SMF22 SMF31, SMF32 SMF41, SMF42 DI5S	Suitable for connection with one or two channel signals with or without pulsing, and/or cross-circuit monitoring +24V level (according to type1 in compliance with EN 61131-2) High - level (+11Vdc to +30Vdc) Low - level (-3Vdc to +5Vdc) The inputs have internal filters
Current draw	SMF11, SMF42 DI5S	max. 15mA max. 25mA
Counting input	DI5S	Maximum input frequency 10kHz, for additional technical data, see chapter *Digital input connection and architecture* on page 25
Diagnostic	All digital inputs	Cyclical monitoring of inputs for correct functionality including filter. A detected error puts SM-Safety Solutions Module in alarm status. All inputs are simultaneously shut down to 0V
Pulsing outputs	P1, P2	The pulsing outputs switch 24Vdc and are only intended for monitoring digital inputs (SMFxx and DI5S). They must not be used for any other function within the application.
Configuration	All digital inputs	Input assigned Pulse P1 Input assigned Pulse P2 Input assigned DC 24V continuous operating voltage Proxy switch - input only on DI5S (single input)
Connection cross section	All digital inputs/ outputs	The maximum connection cross-section is 1mm², AWG18
OSSD	All digital inputs	OSSD compatible outputs can be connected to the inputs
Input impedance	A, -A, B, -B etc.	470Ω between all signal pairs

Table 8-4 Output connection detail

Attributes	Terminals	Current max	Voltage +Ub
Load	STO	20mA	+24V
	SBC1 SBC2	500mA	
	P1 P2 DO1NS DO2NS	100mA	
Architecture	STO SBC1 SBC2	Complete power down channel based on category 4 architecture in compliance with EN ISO 13849-1 with relevant error elimination.	
	P1, P2	Pulsing outputs, switching frequency 125Hz for each pulse output.	
	DO1NS, DO2NS	Auxiliary output.	
Diagnostic	STO SBC1 SBC2	These outputs undergo a diagnostic test in all operating conditions. With power on, all outputs are tested with a cyclical test pulse for proper operation. For this, the output is switched to the inverse value for a maximum test time TT <300µs i.e. a P-output is temporarily switched to 0Vdc. **Comment:** This output test function is carried out on grouped and single controllers. Auxiliary outputs are not tested.	
Switch elements	All	Only external switching elements with a minimum holding current of >1.2mA can be used for safety related applications.	

Table 8-5 Encoder connection detail

Attribute	HDMI Encoder port	Detail Monitored voltage level		
		Supply voltage	**Min voltage**	**Max voltage**
Supply	Pin 13/14 and 17/18	+5.0V	+4.4V	+5.6V
		+8.0V	+7.0V	+9.0V
		+10.0V	+8.0V	+12.0V
		+15.0V	+12.0V	+18.0V
		+24.0V	+20.0V	+29.0V
Signals and max. Input frequency	SinCos 1Vss SSI A, B - TTL	In general, absolute value transmitters, incremental transmitters and SineCosine transmitters are suitable for connection. See *Using SINE/COSINE encoders* on page 15, *Using incremental encoders* on page 16 and *Using absolute value SSI encoders* on page 16.		
External Encoder 2 supply	Pin 17, 18	The encoder supply has a maximum of 2A		
Input impedance	A, -A, B, -B etc.	470Ω between all signal pairs		

8.4 Reaction times

8.4.1 Reaction times in standard operation

The base for calculating reaction times is the cycle time of the SM-Safety Solutions Module. In operation, this is **T_cycle = 8ms**. The supplied reaction times correspond to the maximum running time for specific applications within the SM-Safety Solutions Module. Depending on the application, additional application-dependent reaction times of the sensor system and actuators used need to be added on, to reach the total run time.

Table 8-6

Function	Reaction-time [ms]	Detail
Activation of a monitoring function through ENABLE with subsequent power off via digital output	24*	Activation of a monitoring function through the ENABLE signal.
Reaction of a previously activated monitoring function including PLC processing for position and speed processing via digital output	16*	For a previously activated monitoring function via ENABLE, the components require a cycle to calculate the current speed value. In the next cycle after calculating the monitoring function, the information is processed via the PLC and displayed i.e. after implemented logic, this goes to an input circuit.
Activating digital output via digital input	16	Activating an input and switching off the output
Deactivating digital output via digital input	16	Deactivating an input and so deactivating the output
Mid-value filter (setting see encoder dialogue CTSafePro)	0 - 64	Group running time of mid-value filter. This running time only impacts monitoring functions in cooperation with position / speed / acceleration, but not the logic processing.

NOTE *When using a mid-value filter the reaction time must be added.

8.4.2 Reaction times for FAST_CHANNEL

FAST_CHANNEL is a feature within the SM-Safety Solutions Module which reacts more rapidly to speed requirements than is possible with the processing of a safety program in the normal cycle typically 8ms. The scan time of the FAST_CHANNEL is just 2ms and is selected for individual safety functions using CTSafePro. Typical reaction times are 6ms (worst case scenario).

NOTE When using FAST_CHANNEL, ensure that a power down in the time indicated above for a given speed threshold can only occur if the sensor information is available via an adequate resolution. The smallest resolvable FAST_CHANNEL switching threshold requires at least two side changes on each sensor system selected within a time of 2ms. This function is only possible when using the SBC outputs.

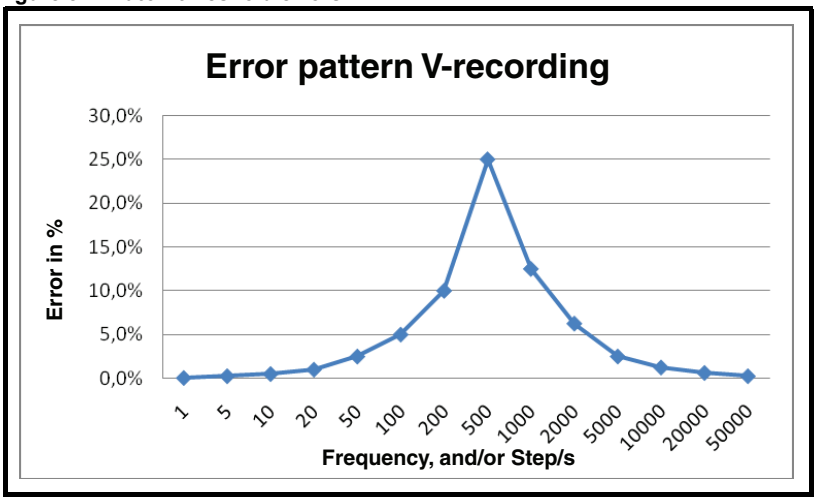
8.5 Safety related cutoff thresholds

As a basic precaution, monitoring tests are performed using current position and speed values derived from the measuring channels A and B of the SM-Safety Solutions Module. These values are then checked against the configurable thresholds.

- The incremental cutoff threshold checks the position deviation between both channels A and B.
- The speed cutoff threshold checks the speed deviation between both channels A and B.
- To define the optimum configuration values for the application, diagnostic functions are available within the SCOPE-diagnostic of the configuration tool.

The speed is measured using a time measuring function up to 500Hz (or 500 steps / second) and a frequency measuring procedure above 500 Hz. This results in the following error:

Figure 8-1 Cutoff threshold errors



NOTE The error can be optimized by proper selection of sensor resolution for each application.

For applications with restricted resolution, and/or time variation of the power off signal, the functionality of the monitoring used can be improved by using a mid-value filter. The mid-value filter attempts to flatten the sensor's digital noise components. This inevitably results in a higher reaction time in the entire system.

The filter time can vary between 0ms and 64ms with changes of 8ms. To determine the reaction time of the whole system, the filter times must be added to the indicated reaction times of the SM-Safety Solutions Module.

9 Documentation revision status

Version	Date	Author	Description of modification
1	xx.09.2009	SW	First edition

0471-0146-01