User Manual

Allen-Bradley

PowerFlex 700H AC Drive Safe Torque Off Option

Catalog Number 20C-DG01

Allen-Bradley • Rockwell Software

Rockwell Automation

Important User Information

Solid-state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (publication SGI-1.1 available from your local Rockwell Automation sales office or online at http://www.rockwellautomation.com/literature/) describes some important differences between solid-state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid-state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

	**WARNING:** Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
	**ATTENTION:** Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence
	**SHOCK HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
	**BURN HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

This manual contains new and updated information.

New and Updated Information

This table contains the changes made to this revision.

Topic	Page
All instances of the term “Safe-Off” are changed to the term “Safe Torque Off”	Throughout manual
Added applicable machinery safety standards to Safety and Machinery Standards.	8
Removed Safety Certificate Examples and provided new link to online certificates.	8
Added new Important Safety Considerations section.	9
Added new PL d/Category 3 Performance Definition section.	10
Added new Stop Category Definitions section.	10
Added new System Performance Level and Safety Integrity Level (SIL) section.	11
Added new PFD and PFH Definitions section.	11
Added new PFD and PFH Data section.	12
Added an Index.	25

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Overview

The PowerFlex 700H control board, 24V DC Digital Input with Analog I/O (20C-DA1-A) board, and the Safe Torque Off option board (20C-DG01), when used with other safety components, helps provide a hardware-based safe torque off to prevent torque on the motor shaft.

The Safe Torque Off option is just one component in a safety control system. Components in the system must be chosen and applied appropriately to achieve the desired level of operator safeguarding.

What is the Safe Torque Off Option?

The Safe Torque Off option is designed to safely remove power from the gate firing circuits of the drive's output power devices (IGBT's). This helps prevent the drive's output power devices from switching in the sequence necessary to generate torque in the motor.

IMPORTANT	This option is suitable for performing mechanical work on the drive system or affected area of a machine only. It does not provide electrical safety. This option should not be used as a control for starting and/or stopping the drive.

ATTENTION: Electrical Shock Hazard. Verify that all sources of AC and DC power are de-energized and locked out or tagged out in accordance with the requirements of ANSI/NFPA 70E, Part II.

ATTENTION: To avoid an electric shock hazard, verify that the voltage on the bus capacitors has discharged completely before servicing. Check the DC bus voltage at the Power Terminal Block by measuring between the +DC and -DC terminals, between the +DC terminal and the chassis, and between the -DC terminal and the chassis. The voltage must be zero for all three measurements.

ATTENTION: In Safe Torque Off mode, hazardous voltages may still be present at the motor. To avoid an electric shock hazard, disconnect power to the motor and verify that the voltage is zero before performing any work on the motor.

Safety of Machinery Standards

The Safe Torque Off option is compliant with the following safety standards:

- EN 60204-1:2006 Safety of Machinery – Electrical equipment of machines – Part 1: General Requirements
- EN ISO 13849-1:2008 Safety of Machinery – Safety-related parts of control systems - Part 1: General Principles for Design
- EN ISO 13849-2:2003 Safety of Machinery – Safety-related parts of control systems – Part 2: Validation
- EN 61800-5-2:2007 Adjustable Speed Electrical Power Drives Systems – Part 5-2 Safety Requirements: Functional
- EN 62061:2005 Safety of Machinery, Functional safety of safety-related electrical, electronic and programmable electronic control systems
- IEC 61508 Parts 1...7: 1998 and 2000 Functional Safety of electrical/ electronic/programmable electronic control systems

Certified Equipment

The Safe Torque Off option for the following PowerFlex 700H AC drives has been evaluated to meet the safety parameters for SIL 2 according to IEC 61508 and PL d/category 3 according to EN ISO 13849-1.

- 400/480V Frames 9-14
- 600/690V Frames 9-14

Note: The TUV certification stamp is only included on the drive data nameplate label when the Safe Torque Off option board is factory installed.

Certifications Online

See the Product Certifications link at http://ab.com for Declarations of Conformity, Certificates, and other certifications details.

Important Safety Considerations

The system user is responsible for:

- the set-up, safety rating, and validation of any sensors or actuators connected to the system.
- completing a system-level risk assessment and reassessing the system any time a change is made.
- certification of the system to the desired safety performance level.
- project management and proof testing.
- programming the application software and the safety option configurations in accordance with the information in this manual.
- access control to the system, including password handling.
- analyzing all configuration settings and choosing the proper setting to achieve the required safety rating.

IMPORTANT When applying Functional Safety, restrict access to qualified, authorized personnel who are trained and experienced.

ATTENTION: When designing your system, consider how personnel will exit the machine if the door locks while they are in the machine. Additional safeguarding devices may be required for your specific application.

PL d/Category 3 Performance Definition

To achieve PL d/category 3 according to EN ISO 13849-1, the safety-related parts have to be designed such that:

- the safety-related parts of machine control systems and/or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled, and combined in accordance with relevant standards so that they can withstand expected conditions.
- well tried safety principles shall be applied.
- a single fault in any of its parts does not lead to a loss of safety function.
- some but not all faults will be detected.
- the accumulation of undetected faults can lead to loss of safety function.
- short circuits in the external wiring of the safety inputs is not one of the faults that can be detected by the system, therefore, according to EN ISO 13849-2, these cables must be installed so as to be protected against external damage by cable ducting or armor.
- whenever reasonably practical a single fault shall be detected at or before the next demand of the safety function.
- the average diagnostic coverage of the safety-related parts of the control system shall be low to medium.
- the mean time to dangerous failure of each of the redundant channels shall be medium to high.

Stop Category Definitions

The selection of a stop category for each stop function must be determined by a risk assessment.

- Stop Category 0 is achieved with immediate removal of power to the actuator, resulting in an uncontrolled coast to stop. See "Description of Operation" Example 1 on page 17.
- Stop Category 1 is achieved with power available to the machine actuators to achieve the stop. Power is removed from the actuators when the stop is achieved. See "Description of Operation" Example 2 on page 18.

IMPORTANT When designing the machine application, timing and distance should be considered for a coast to stop (Stop Category 0 or Safe Torque Off). For more information regarding stop categories, refer to EN 60204-1.

System Performance Level and Safety Integrity Level (SIL)

For safety-related control systems, Performance Level (PL), according to EN ISO 13849-1, and SIL levels, according to IEC 61508 and EN 62061, include a rating of the system's ability to perform its safety functions. All of the safety-related components of the control system must be included in both a risk assessment and the determination of the achieved levels.

Refer to the EN ISO 13849-1, IEC 61508, and EN 62061 standards for complete information on requirements for PL and SIL determination.

PFD and PFH Definitions

Safety-related systems can be classified as operating in either a Low Demand mode, or in a High Demand/Continuous mode.

- Low Demand mode: where the frequency of demands for operation made on a safety-related system is no greater than one per year or no greater than twice the proof-test frequency.

- High Demand/Continuous mode: where the frequency of demands for operation made on a safety-related system is greater than once per year or greater than twice the proof test interval.

The SIL value for a low demand safety-related system is directly related to order-of-magnitude ranges of its average probability of failure to satisfactorily perform its safety function on demand or, simply, average probability of failure on demand (PFD). The SIL value for a High Demand/Continuous mode safety-related system is directly related to the probability of a dangerous failure occurring per hour (PFH).

PFD and PFH Data

PFD and PFH calculations are based on the equations from Part 6 of IEC 61508 and show worst-case values. This table provides data for a 20-year proof test interval and demonstrates the worst-case effect of various configuration changes on the data.

Table 1 - PFD and PFH for 20-year Proof Test Interval

Attribute	Test Result
PFD_{av}	1.52×10^{-3}
PFH	1.7×10^{-8} 1/h (calculated according to IEC 61508)
$MTTF_D$	High (2172 years)
DC_{av}	low (66%)

Functional Proof Tests

The functional safety standards require that functional proof tests be performed on the equipment used in the system. Proof tests are performed at user-defined intervals and are dependent upon PFD and PFH values.

IMPORTANT Your specific application determines the time frame for the proof test interval for the overall safety system.

Contact Information if Safety Option Failure Occurs

If you experience a failure with any safety-certified device, contact your local Rockwell Automation distributor. With this contact, you can:

- return the device to Rockwell Automation so the failure is appropriately logged for the catalog number affected and a record is made of the failure.
- request a failure analysis (if necessary) to determine the probable cause of the failure.

Installation and Wiring

Installation must be in accordance with the following steps and must be carried out by suitably competent personnel. The Safe Torque Off option board (device) is intended to be part of the safety related control system of a machine. Before installation, a risk assessment should be performed to determine whether the specifications of this device are suitable for all foreseeable operational and environmental characteristics of the machine to which it is to be fitted.

At regular intervals during the life of the machine check the safety function for proper operation. How frequently the safety function is checked is dependent on the safety analysis of the machine section controlled by the drive.

Rockwell Automation, Inc. cannot accept responsibility for a failure of this device if the procedures given in this publication are not implemented or if it is used outside the recommended specifications in this publication.

ATTENTION: The following information is merely a guide for proper installation. Rockwell Automation, Inc. cannot assume responsibility for the compliance or the noncompliance to any code, national, local or otherwise for the proper installation of this equipment. A hazard of personal injury and/or equipment damage exists if codes are ignored during installation.

Safe Torque Off Option Board Installation

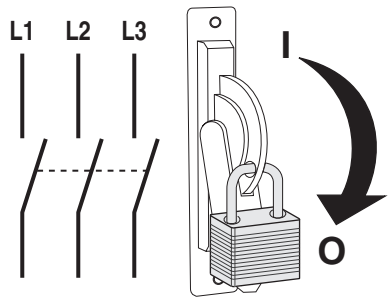
ATTENTION: To avoid an electric shock hazard, verify that the voltage on the bus capacitors has discharged completely before servicing. Check the DC bus voltage at the Power Terminal Block by measuring between the +DC and -DC terminals, between the +DC terminal and the chassis, and between the -DC terminal and the chassis. The voltage must be zero for all three measurements.

Remove power before making or breaking cable connections. When you remove or insert a cable connector with power applied, an electrical arc may occur. An electrical arc can cause personal injury or property damage by:

- sending an erroneous signal to your system's field devices, causing unintended machine motion
- causing an explosion in a hazardous environment

Electrical arcing causes excessive wear to contacts on both the module and its mating connector. Worn contacts may create electrical resistance.

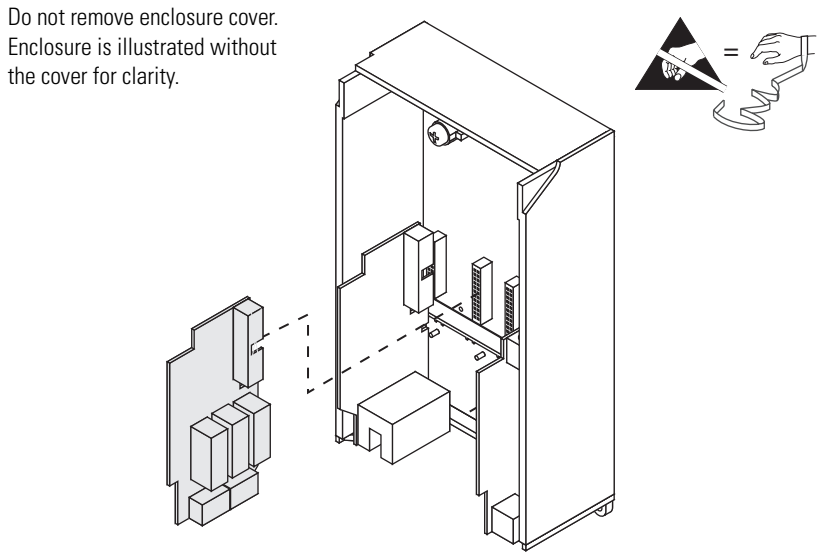
1. Turn off and lock out input power. Wait five minutes.
2. Verify that there is no voltage at the drive's input power terminals.
3. Measure the DC bus voltage at the DC+ & DC- terminals on the Power Terminal Block. The voltage must be zero.



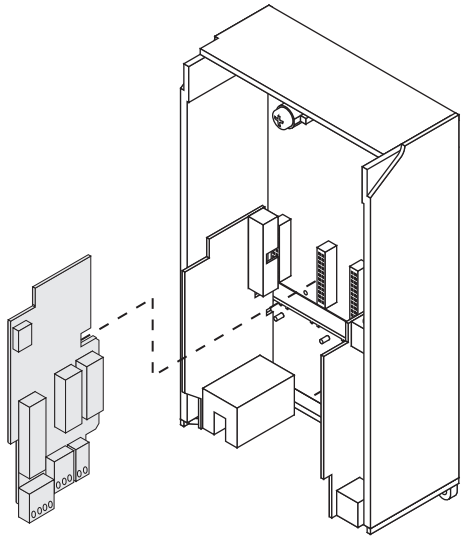
IMPORTANT Before removing connections and wires, mark the connections and wires to avoid incorrect wiring during assembly.

4. Open the door of the enclosure that contains the control and I/O circuit boards and unplug any I/O cables from the I/O board in Slot B.

5. Remove the I/O board in Slot B (if present).



6. Install the new Safe Torque Off option board (20C-DG1) in Slot B.



Wire the Safe Torque Off Option

The Safe Torque Off option disables the drive's output IGBT's by disconnecting the gate control power supply (see Figure 1 on page 17). The system satisfies the requirements of EN ISO 13849-1 PL d/Category 3 for Safe Torque Off and protection against restart.

Under normal drive operation, the Safe Torque Off inputs (SD1 and SD2) are energized and gate control power is available to the gate control circuit. If either or both of these inputs is/are de-energized, the gate control circuit is disabled and the drive will stop as programmed (coast or controlled). The drive can be configured to display a "Gate Disable" fault or alarm (F59) on the HIM when the gate control circuit is disabled.

Both Safe Torque Off inputs must be used to meet EN ISO 13849-1 PL d/ Category 3 operation and must be energized in order to run the drive. Refer to the wiring examples on the following pages for details.

The Safe Torque Off activation delay time is less than 20 ms. When the drive is enabled, there is a delay time of 1 second before a valid start command can be issued.

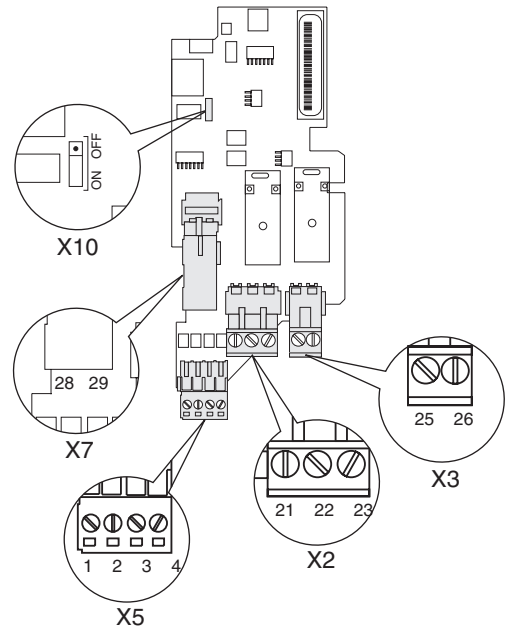
PowerFlex 700H drives containing the Safe Torque Off option board will only accept an edge sensitive start command when the drive is in a "ready" state.

IMPORTANT By itself, the Safe Torque Off option initiates a coast-to-stop action. If coasting to a stop is not desired, additional protective measures must be taken. See Figure 3 on page 20 for a controlled stop wiring example.

Important points to remember about wiring:

- Always use copper wire.
- 0.5 mm^2 (20 AWG), 3 conductor, shielded cable is required.
- Wire with an insulation rating of 600V or greater is recommended.
- Control and signal wires should be separated from power wires by at least 0.3 m (1 ft).
- According to EN 60204-1, part 13.5: The voltage drop from the supply point to the load should not exceed 5%.
- Due to electromagnetic disturbances, the cable length should be limited to 200 m (656 ft) maximum. In a noisy environment, the length of the cable should be less than 200 m (656 ft).

Table 2 - Safe Torque Off Option Board Terminal Descriptions



Term. Blk.	No.	Signal	Description
X5	1	SD1+	Isolated Disable input 1 +24V +/-20% 10... 15 mA
	2	SD1–	Virtual GND 1
	3	SD2+	Isolated Disable input 2 +24V +/-20% 10... 15 mA
	4	SD2–	Virtual GND 2
X2 (1)	21	Digital Out 1 - N.C.	Max. Resistive Load: 240V AC / 30V DC - 1200 VA, 150 W Max. Current: 5A, Min. Load: 10 mA Max. Inductive Load: 240V AC / 30V DC - 8400 VA, 105 W Max. Current: 3.5 A, Min. Load: 10 mA
	22	Digital Out 1 Common	
	23	Digital Out 1 - N.O.	
X3 (1)	25	Digital Out 2 Common	
	26	Digital Out 2 N.O.	
X7 (1)	28	TI1+	Thermistor input: $R_{trip} \geq 4.0\ k\Omega$(PTC)
	29	TI1–	

(1) This terminal block is not used as part of the Safe Torque Off function.

IMPORTANT The drive will not run unless a wire is installed in the hardware thermistor input (X7-28 and X7-29) and the thermistor short circuit supervisor jumper X10 is installed in the OFF position.

Figure 1 - Safe Torque Off Drive Circuitry

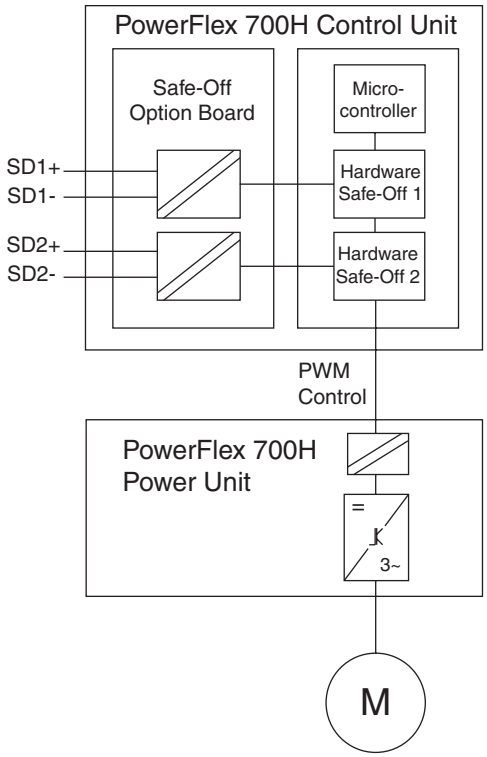
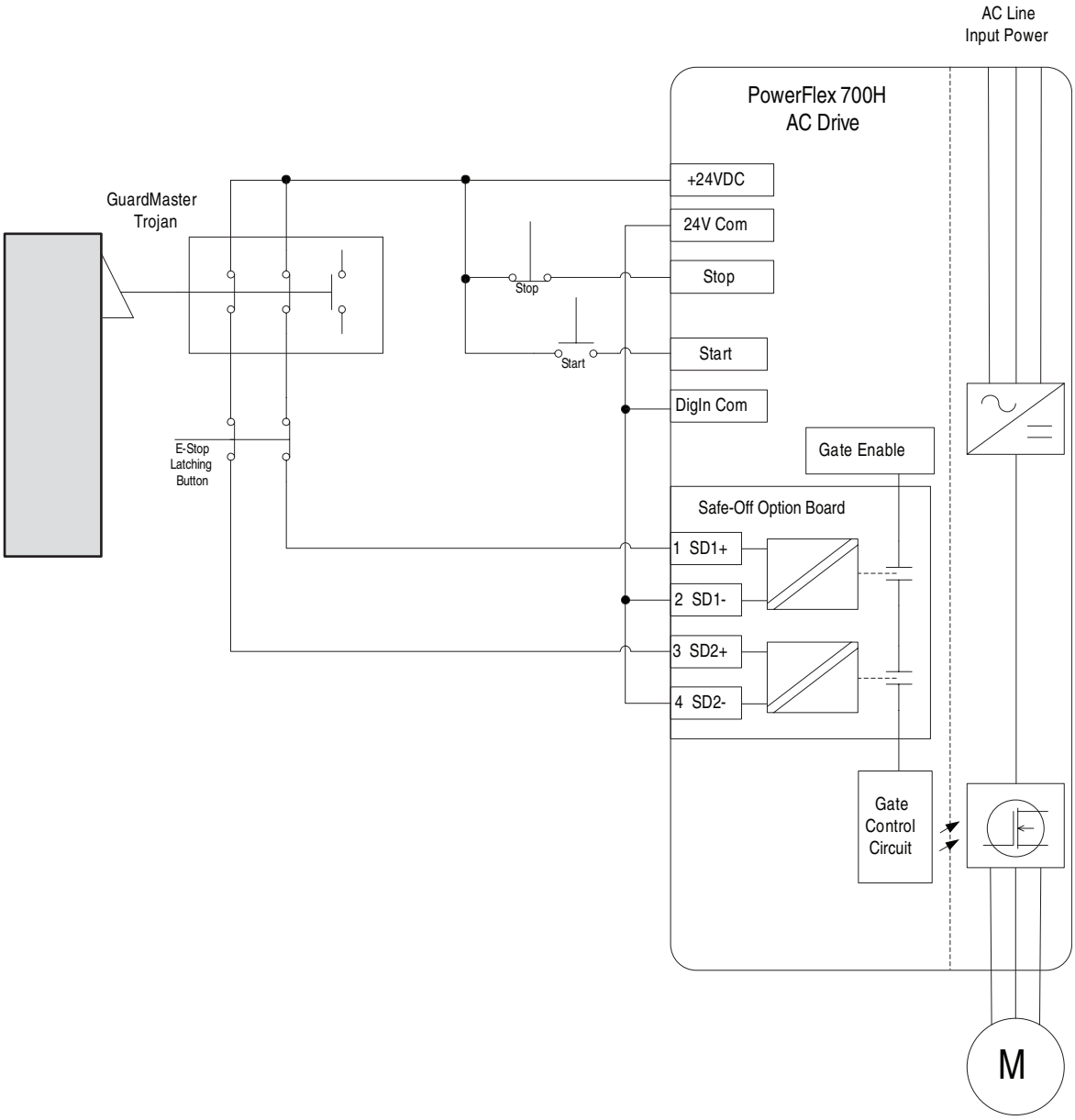


Figure 2 - Example 1 - Drive Safe Torque Off Connections with Coast-to-Stop Action and Emergency Stop Operation, Dual Channel, without External Relay



Circuit Status – Circuit shown with guard door and E-stop closed and system ready for normal operation.

Operating Principle – Opening the guard door or pressing the E-stop button will disable the drive gate firing circuit, the motor will coast to stop. The drive can be configured to display a "Gate Disable" fault or alarm (F59) on the HIM when the gate control circuit is disabled.

When the guard door or the E-stop button is closed, the drive remains in a faulted state. Once the drive fault is cleared a valid start command will restart the drive.

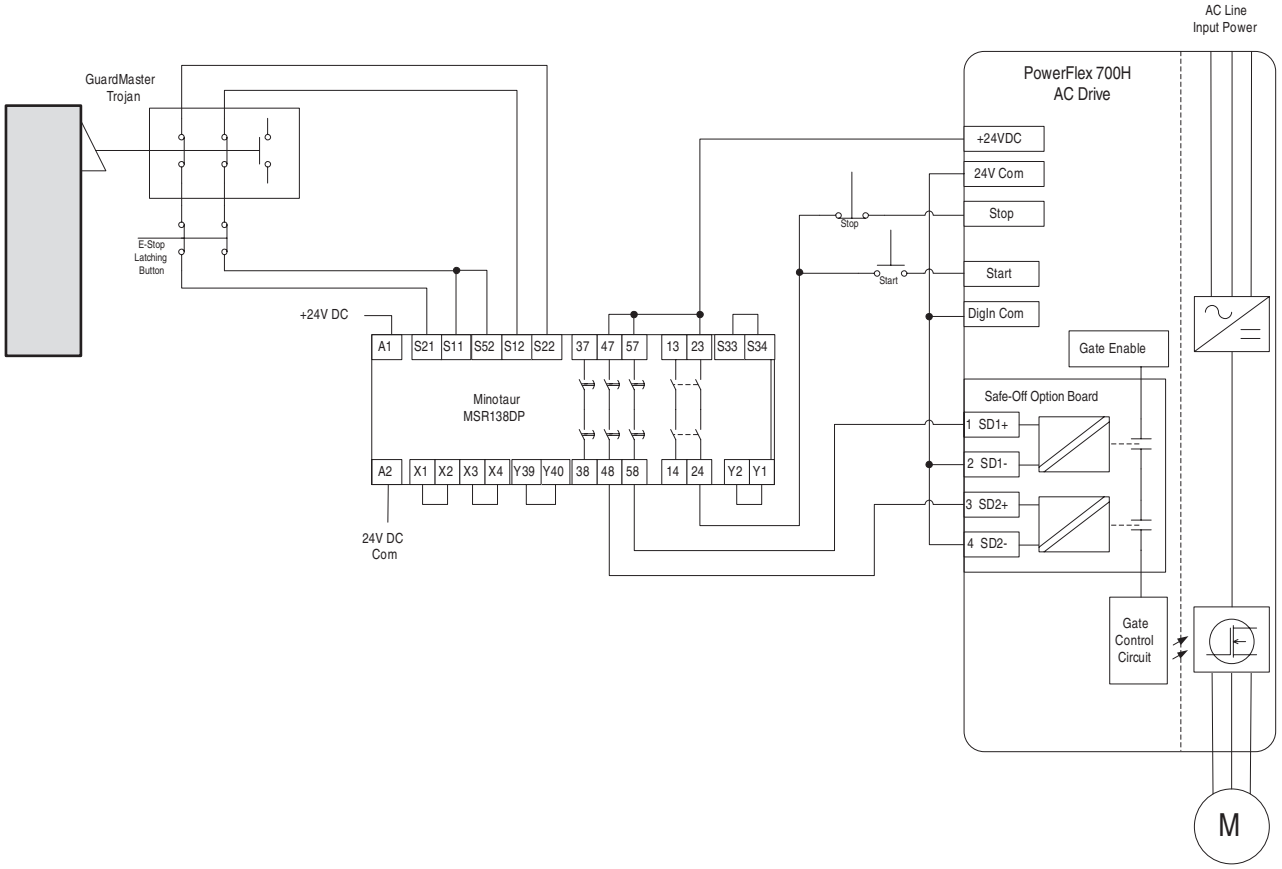
Application Considerations – When the hazard analysis for the overall machine determines the need for external mechanical brakes or other stopping means, the external means shall be activated after the removal of power for Stop Category 0.

When used, the E-stop button must utilize direct-opening contacts. The button must latch to an open state when the contacts open. The button must be red with a yellow background.

Fault Detection – A redundant (two) set of double break contacts on the Trojan gate interlock are designed to ensure that at least one signal is sent to the Safe Torque Off option board when the gate is opened. A single fault detected on the safety input circuits will result in the lock-out of the system to a safe state (off) at the next operation and will not cause loss of the safety function.

Each of the inputs on the Safe Torque Off option board independently monitors the status of the safety circuit and the status of the other input on the board.

Figure 3 - Example 2 - Drive Safe Torque Off Connections with Controlled Stop Action and Emergency Stop Operation, Dual Channel, with External Relay



Circuit Status – Circuit shown with guard door and E-stop closed and system ready for normal operation.

Operating Principle – Opening the guard door or pressing the E-stop button will switch the input circuits (S11-S12 & S21-S22) to the Minotaur monitoring safety relay unit. The immediate output circuits (23-24) will issue a Stop command and the drive will follow the programmed stop configuration. After the programmed delay, the timed output circuits (47-48 & 57-58) will cause the Safe Torque Off option to go to a safe state (off). If the motor has not stopped rotating, it will coast to stop. The drive can be configured to display a "Gate Disable" fault or alarm (F59) on the HIM when the gate control circuit is disabled. To restart the drive, the Minotaur safety relay inputs (S11-S12, S21-S22) must first be ready for normal drive operation, the drive fault must be cleared and a valid start command must be issued to the drive.

Application Considerations – When used, the E-stop button must utilize direct-opening contacts. The button must latch to an open state when the contacts open. The button must be red with a yellow background.

Fault Detection – A redundant (two) set of double break contacts on the Trojan gate interlock are designed to ensure that at least one signal is sent to the Safe

Torque Off option board when the gate is opened. A single fault detected on the Minotaur safety input circuits will result in the lock-out of the system to a safe state (off) at the next operation and will not cause loss of the safety function.

Each of the inputs on the Safe Torque Off option board independently monitors the status of the safety circuit and the status of the other input on the board.

Fault/Alarm Configuration

The drive's fault or alarm response to a gate circuit disable can be configured in one of four ways when using the 20C-DG1 option board, each resulting in the drive being put into a gate disabled state when digital inputs (SD1 and SD2) are de-energized.

1. Gate Disable Fault (59):

   Configured by setting bit 10 "Gate Disable" of parameter 238 [Fault Config1].

   If either or both digital inputs open, the drive output will be disabled and the motor will stop as programmed. The drive HIM will display fault 59 "Gate Disable".

   When the condition is cleared, the fault can be reset and the drive can be restarted. Refer to Table 3 on page 23 for a description of drive conditions and actions.

2. Gate Disable Alarm (59):

   Configured by setting bit 15 "Gate Disable" of parameter 259 [Alarm Config1].

   If either or both digital inputs open, the drive output will be disabled and the motor will stop as programmed. The drive HIM will display alarm 59 "Gate Disable".

   When the condition is cleared, the alarm will automatically clear in 10 seconds and the drive can be restarted. Refer to Table 3 on page 23 for a description of drive conditions and actions.

3. Neither of the "Gate Disable" bits, 10 in parameter 238 [Fault Config1] or 15 in parameter 259 [Alarm Config1], are set.

   If either or both digital inputs open, the drive output will be disabled and the motor will stop as programmed. No fault or alarm will be displayed on the HIM, but the Gate Disable status can be seen in bit 0 "Gate Disable" of parameter 359 [20C-DG1 Status].

   When the condition is cleared, the drive can be restarted after 3 seconds. Refer to Table 3 on page 23 for a description of drive conditions and actions.

4. Both "Gate Disable" bits, 10 in [Fault Config1] and 15 in [Alarm Config1], are set:

   The Gate Disable fault takes precedence.

Installation Checklist

The following items must be completed when installing and configuring the Safe Torque Off option for PowerFlex 700H drives.

Item Description	✓ Complete
A risk assessment has been performed to determine whether the specifications of this device are suitable for all foreseeable operational and environmental characteristics of the machine to which it is to be fitted.	
The safety switch and/or safety relay used is EN ISO 13849-1 PL d/Category 3 and EN60947-5-1:1997 annex K compliant.	
The reset function is edge sensitive.	
In an IGBT fault situation, the safety system has been designed to allow the shaft of the permanent magnet motor to rotate up to 360 degrees / pole of the motor.	
The cabling has been installed to be EMC compliant.	
The safety system has been designed so that enabling the drive through the Safe Torque Off inputs will not lead to an unexpected start of the drive.	
Only an approved PowerFlex 700H drive(s) and safety components have been used in this installation.	
The PowerFlex 700H control board, VB00561, revision H, or newer is installed in the drive (see label on control board).	
Revision 2.001, or higher, of firmware is installed in the drive.	
Regular intervals have been planned to check the safety function for proper operation.	
All information and instructions in this manual have been read, understood and completed.	

Verify Operation

At regular intervals during the life of the machine check the safety function for proper operation. Both safety channels shall be verified. How frequently the safety function is checked is dependent on the safety analysis of the machine section controlled by the drive.

Table 3 - Gate Disable Status and Verification

Protective System Status	Drive In Gate Disable State	Drive In Gate Disable State	Drive In Gate Disable State	Drive Able To Run
Channel Operation				
SD1 - terminals X5-1 & X5-2 Par 359 [20C-DG1 Status], bit 3 "No Enable CH1"	Bit 3 = 1 No Power Applied	Bit 3 = 0 Power Applied	Bit 3 = 1 No Power Applied	Bit 3 = 0 Power Applied
SD2 - terminals X5-3 & X5-4 Par 359 [20C-DG1 Status], bit 4 "No Enable CH2"	Bit 4 = 1 No Power Applied	Bit 4 = 1 No Power Applied	Bit 4 = 0 Power Applied	Bit 4 = 0 Power Applied
Description For Verification				
PowerFlex 700H Drive Status	**Output Disabled**	**Output Disabled**	**Output Disabled**	**Output Enabled**
Par 359 [20C-DG1 Status], Bit 0 "Gate Disable" or Bits 2 "Unexp In Pro" and 15 "Unexp HW Pro"	Bit 0 = 1	Bit 2 = 1 Bit 15 = 1	Bit 2 = 1 Bit 15 = 1	Bit 0 = 0
Fault or Alarm	F59 "Gate Disable" (Fault or Alarm based on drive set up)	F10 "System Fault"	F10 "System Fault"	None

Safe Torque Off Option Board (20C-DG01) Removal

During maintenance or service there may be a need to remove the Safe Torque Off (20C-DG1) option board.

The drive is designed to generate a non-resettable fault F10 "System Fault" if the option board is removed. The operator must manually change parameter 358 [20C-DG1 Remove] to 1- "Remove" and then back to 0 - "Ready" to clear and acknowledge the fault.

Once maintenance or service is completed and the 20C-DG1 option card has been reinstalled, the drive will recognize the option card on power-up.

it is recommended that the safety function be checked for proper operation after any maintenance is performed. Refer to Verify Operation above.

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Rockwell Automation Support

Rockwell Automation provides technical information on the Web to assist you in using its products.
At http://www.rockwellautomation.com/support/, you can find technical manuals, a knowledge base of FAQs, technical and application notes, sample code and links to software service packs, and a MySupport feature that you can customize to make the best use of these tools.

For an additional level of technical phone support for installation, configuration, and troubleshooting, we offer TechConnect support programs. For more information, contact your local distributor or Rockwell Automation representative, or visit http://www.rockwellautomation.com/support/.

Installation Assistance

If you experience a problem within the first 24 hours of installation, review the information that is contained in this manual. You can contact Customer Support for initial help in getting your product up and running.

United States or Canada	1.440.646.3434
Outside United States or Canada	Use the Worldwide Locator at http://www.rockwellautomation.com/support/americas/phone_en.html, or contact your local Rockwell Automation representative.

New Product Satisfaction Return

Rockwell Automation tests all of its products to ensure that they are fully operational when shipped from the manufacturing facility. However, if your product is not functioning and needs to be returned, follow these procedures.

United States	Contact your distributor. You must provide a Customer Support case number (call the phone number above to obtain one) to your distributor to complete the return process.
Outside United States	Please contact your local Rockwell Automation representative for the return procedure.

Documentation Feedback

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