Application Note
Interfacing AC Drives with Safety Relays

Purpose

- The intent of this document is to provide typical examples of how to interface AC Drives with safety relays. This document will not describe machine guarding safety or risk assessment, which are covered in our safety business documentation.

References

- NFPA79, Electrical Standards for Industrial Machinery

- EN954-1, Safety of Machinery – safety related parts of a control system – Part 1. General Principles for Design

Stop Categories

- Stop Category 0 – Coast. Immediate removal of power to the motor. With immediate removal of power to the motor, the motor will coast to stop. The time required to stop motion is dependent on the load inertia and speed as well as the friction in the mechanical power transmission equipment used in the system.

- Stop Category 1 – Controlled. Controlled Stop then removal of power to the motor. A ramp to stop will be used to control the mechanical power transmission to rest then power is removed from the motor. The time required to bring the mechanical system to rest is dependent upon load inertia and speed as well as the regenerative dissipation capacity of the drive.

Component Descriptions

- Gate Interlock - The Trojan gate interlock uses direct opening contacts. When the gate is opened, the contacts in the interlock are forced open by non-resilient components (e.g., not by springs). A redundant (two) set of double break contacts are designed to ensure that at least one signal is sent to the safety relay, when the gate is opened.

- E-Stop - When the E-Stop button is pressed the safety function is activated (Drive goes to safe state). When a contactor is used it is opened by the E-Stop circuit. The E-stop button must utilize direct-opening contacts. The button must latch to an open state when the contacts open (i.e., you must not be able to tickle the contacts without latching the button). The button must be a red with a yellow background.

- Contactor - Provides electromechanical disconnection of the motor from the drive. Its normally-closed mechanically linked contacts are monitored by the safety relay to help ensure that the contactor has dropped out before the next resetting of the safety relay.

- Start / Stop Pushbuttons - The Start and Stop pushbuttons are used to turn the drive on and off. They are also symbolic of the non-safety related parts of the machine control system. These buttons can be replaced by a programmable control system.

- Generic Drive – Describes a drive that does not contain a Safe-off option
- The PowerFlex Safe-Off Option Board:
    - Is designed to safely remove power from the gate firing circuits of the Drives output power devices (IGBT's). This prevents then from switching in the pattern necessary to generate AC power to the motor.
    - Can be used in combination with other safety devices to meet the Stop and protection against restart requirements of EN954-1.

  IMPORTANT: The option is suitable for performing mechanical work on the drive system or affected area of a machine only. It does not provide electrical safety.
- Safety Relay Reset – The examples in this document use an automatic reset scheme for the safety relay. The use of a manual or automatic reset should be dictated by the application.

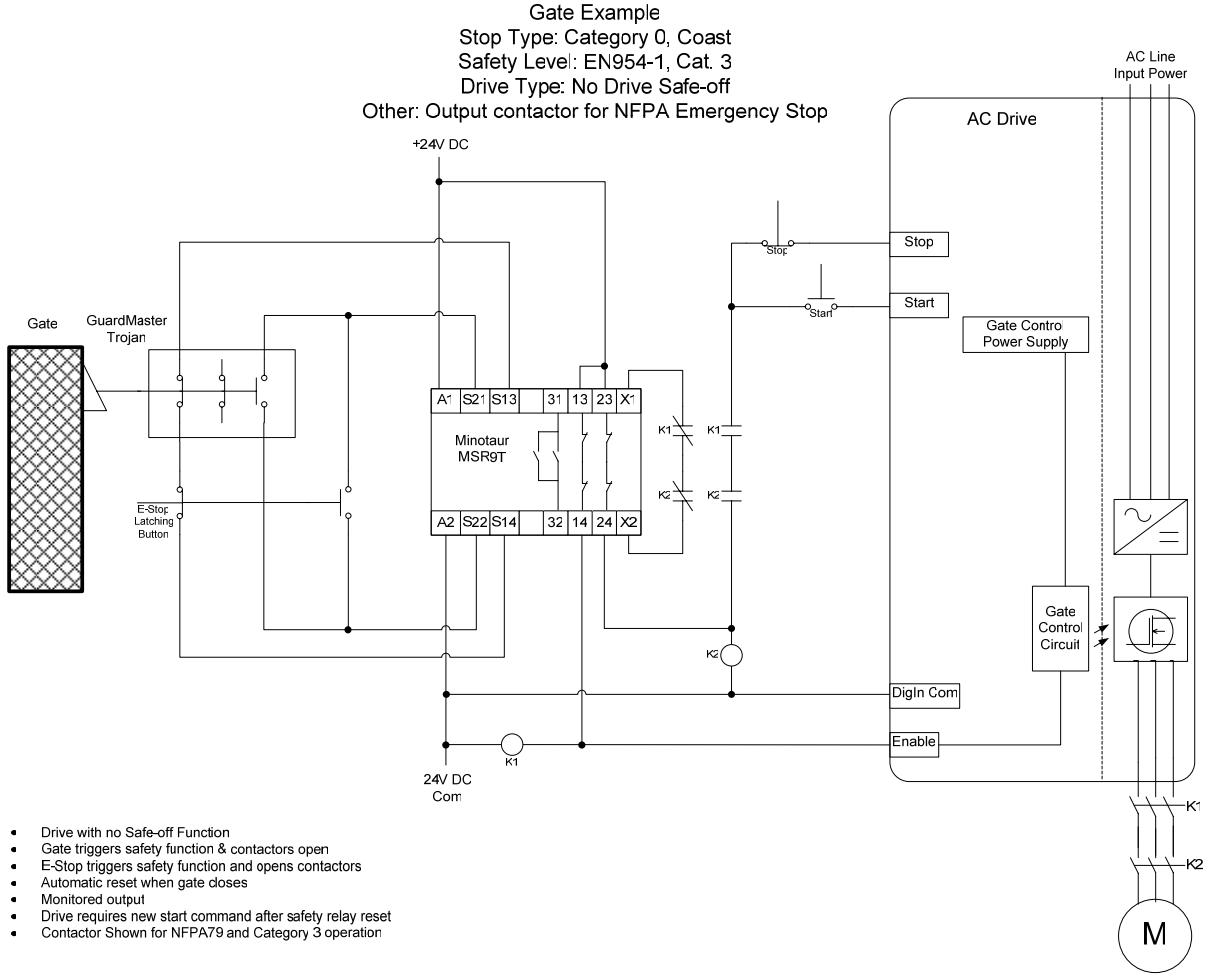
Related Publications

- DriveGuard™ User Manual for the Safe-Off Option

Application Note
Interfacing AC Drives with Safety Relays

Stop Type: Category 0, Coast
Safety Level: EN954-1, Category 3
Drive Type: Drive without Safe-off option
Other: Output contactor for NFPA79 Emergency Stop operation

Overview:
This example shows how to provide Stop and protection against restart (Category 3 per EN954-1) on a drive without a safe-off feature. The contactors can also satisfy the NFPA79 Emergency Stop requirements.



Circuit Operation:
The gate will trigger the safety function. When triggered the safety relay outputs (Terminals 13 to 14 and 23 to 24) open. This immediately removes +24vdc from the drive Enable, the drive Start/Stop inputs and both contactor coils K1 & K2. The result is the drive is disabled, a stop signal is asserted the contactors open, and the motor will coast to stop. The N.O. auxiliary contact of K1 and K2 open to prevent a drive Start before the contactors close. The N.C. auxiliary contacts are monitored by the safety relay at terminals X1 & X2.

When the gate is restored and satisfies the safety relay inputs, the safety relay is reset. The safety relay outputs are energized restoring +24vdc to the drive Enable input, the coils of the contactors and the Drive Not Stop. A start command must be issued to the drive to restart.

When the E-Stop is activated, the safety function is triggered and performs the same as the gate triggered function. Restoration of the E-Stop also recovers in the same manner as the gate restoration.

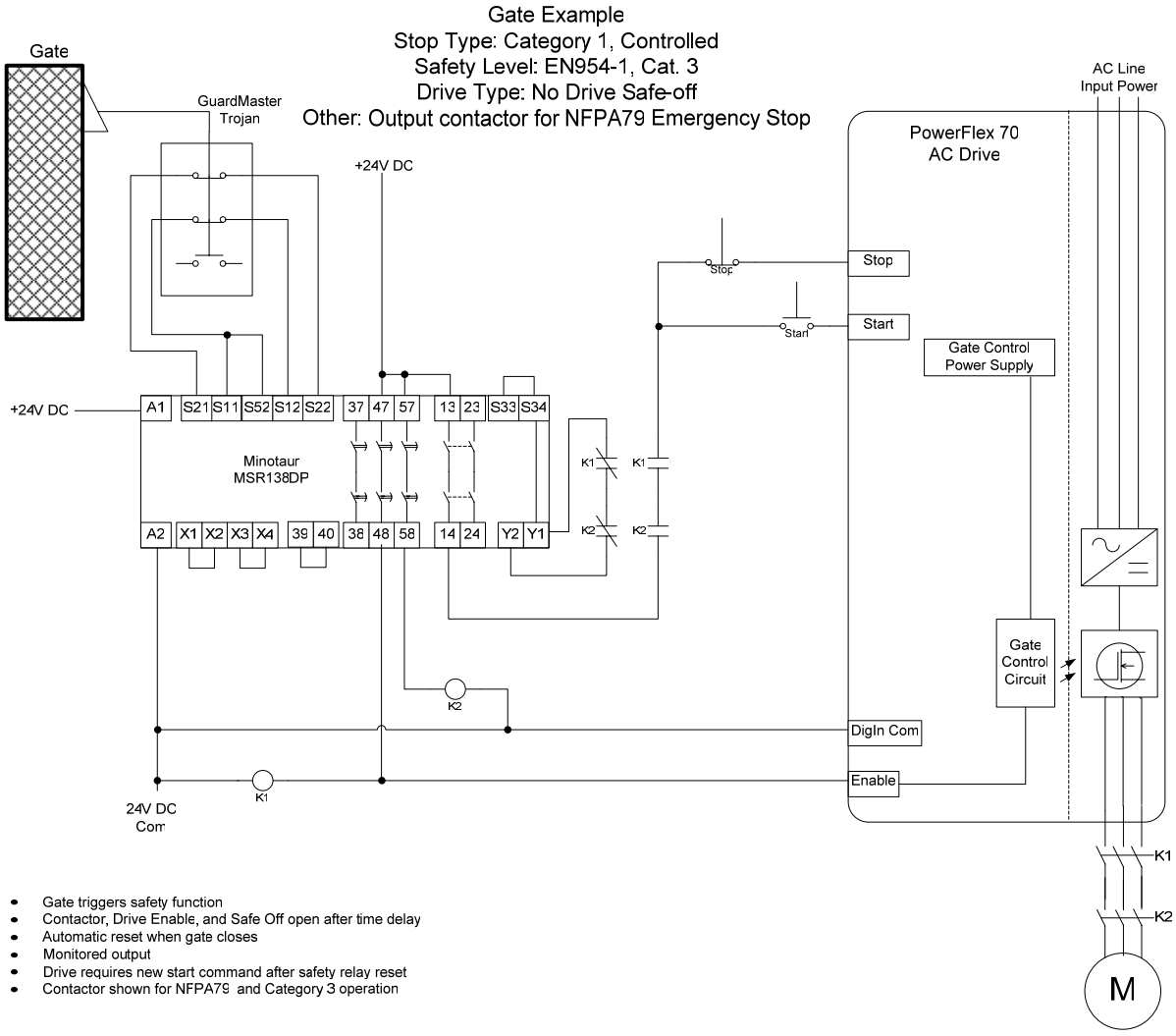
If the contactors N.C. auxiliary contacts are in an abnormal state, as monitored by the safety relay (X1 & X2) the safety relay will prevent operation at the next cycling of the “safety” circuit.

Other Considerations:
The safe-off jumper in the drive must be installed when the Safe-Off Option is not present. Drives with hardware enable feature – Use of hardware enable is not required for this example but in general is recommended when the drive is interfaced with a safety relay.

Application Note
Interfacing AC Drives with Safety Relays

Stop Type: Category 1, Controlled
Safety Level: EN954-1, Category 3
Drive Type: Drive without Safe-off option
Other: Output contactor for NFPA79 Emergency Stop operation

Overview:
This example shows how to provide Controlled Stop and protection against restart (Category 3 per EN954-1) on a drive without a safe-off feature. The contactors can also satisfy the NFPA79 Emergency Stop requirements.



Circuit Operation:
The gate will trigger the safety function. When triggered the safety relay outputs (Terminals 13 to 14 and 23 to 24) open. This immediately removes +24vdc from the drive Start/Stop input. The result is the drive stop signal is asserted and a ramp to stop is issued.

Once the time delay in the safety relay expires, the safety relay time delay contacts (Terminals 47 to 48 & 57 to 58) open. The +24vdc is then removed from the drive enable as well as both contactor coils K1 & K2. The N.O. auxiliary contact of K1 and K2 open to prevent a drive Start before the contactors close. The N.C. auxiliary contacts are monitored by the safety relay at terminals Y1 & Y2.

Note: The time delay of the safety relay must be greater than the deceleration ramp time of the drive otherwise a coast stop will occur when the timer expires.

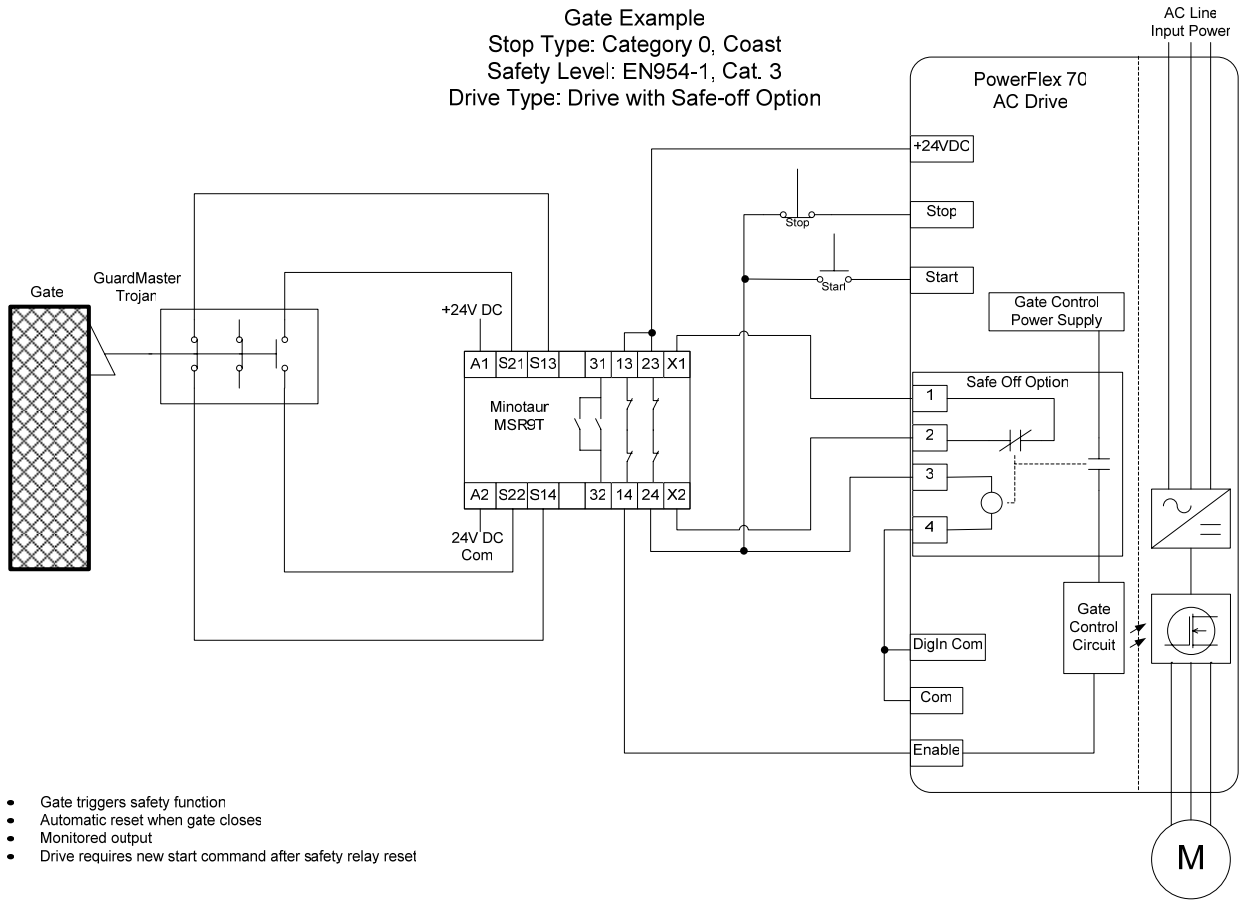
When the gate is restored and satisfies the safety relay inputs, the safety relay is reset (terminals 39 & 40 are N.C.). The safety relay outputs are energized restoring +24vdc to the drive Enable input, the coils of the contactors and the Drive Start/Stop. A start command must be issued to the drive to restart.

Other Considerations:
The safe-off jumper in the drive must be installed when the Safe-Off Option is not present. Drives with hardware enable feature – Use of hardware enable is not required for this example but in general is recommended when the drive is interfaced with a safety relay.

Application Note
Interfacing AC Drives with Safety Relays

Stop Type: Category 0, Coast
Safety Level: EN954-1, Category 3
Drive Type: Drive with Safe-Off Option
Other:

Overview:
This example shows how to provide Stop and protection against restart (Category 3 per EN954-1) on a drive with a safe-off feature.



Circuit Operation:
The gate will trigger the safety function. When triggered the safety relay outputs (Terminals 13 to 14 and 23 to 24) open. This immediately removes +24vdc from the drive Enable, the Safe-Off Option relay and the drive Start/Stop input. The result is the drive is disabled, a stop signal is asserted, the Safe-Off Option goes to a safe state (off), and the motor will coast to stop.

When the gate is restored and satisfies the safety relay inputs, the safety relay is reset. The safety relay outputs are energized restoring +24vdc to the drive Enable input, the Safe-Off Option relay and the Drive Start/Stop. A start command must be issued to the drive to restart.

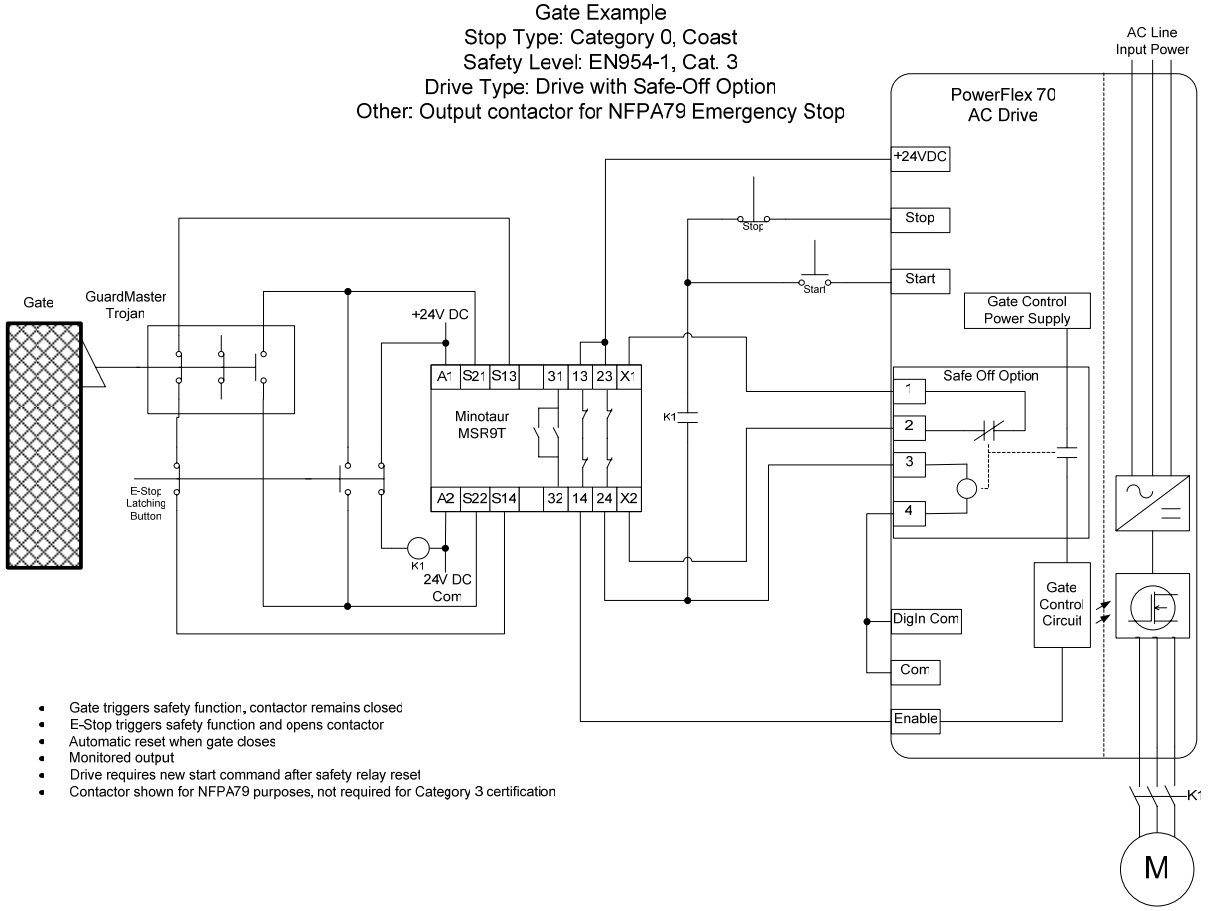
If the Safe-off monitor contact is in an abnormal state, as monitored by the safety relay (X1 & X2) the safety relay will prevent operation at the next cycling of the “safety” circuit.

Other Considerations:
Note: The hardware enable jumper in the drive must be removed if the Safe-Off Option is installed. If not, the drive will fault (F111) when a start command is issued.

Application Note
Interfacing AC Drives with Safety Relays

Stop Type: Category 0, Coast
Safety Level: EN954-1, Category 3
Drive Type: Drive with Safe-Off Option
Other: Output contactor for NFPA79 Emergency Stop operation

Overview:
This example shows how to provide Stop and protection against restart (Category 3 per EN954-1) on a drive with a safe-off feature. The contactors can also satisfy the NFPA79 Emergency Stop requirements.



Circuit Operation:
The gate will trigger the safety function. When triggered the safety relay outputs (Terminals 13 to 14 and 23 to 24) open. This immediately removes +24vdc from the drive Enable, the Safe-Off Option relay and the drive Start/Stop input. The result is the drive is disabled, a stop signal is asserted, the Safe-Off Option goes to a safe state (off), and the motor will coast to stop. The contactor K1 stays energized.

When the gate is restored and satisfies the safety relay inputs, the safety relay is reset. The safety relay outputs are energized restoring +24vdc to the drive Enable input, the Safe-Off Option relay and the Drive Not Stop. A start command must be issued to the drive to restart.

When the E-Stop is activated, the safety function is triggered and performs the same as the gate. The E-Stop also removes power from the contactor coil which opens the contactor and disconnects the motor from the drive. The auxiliary contacts open the circuit to the drive Start/Stop to prevent a drive Start before the contactor closes.

Upon restoring the E-Stop (and gate is in normal condition) the safety relay resets and the contactor is energized closing the main poles and auxiliary contacts. A start command will now restart the drive.

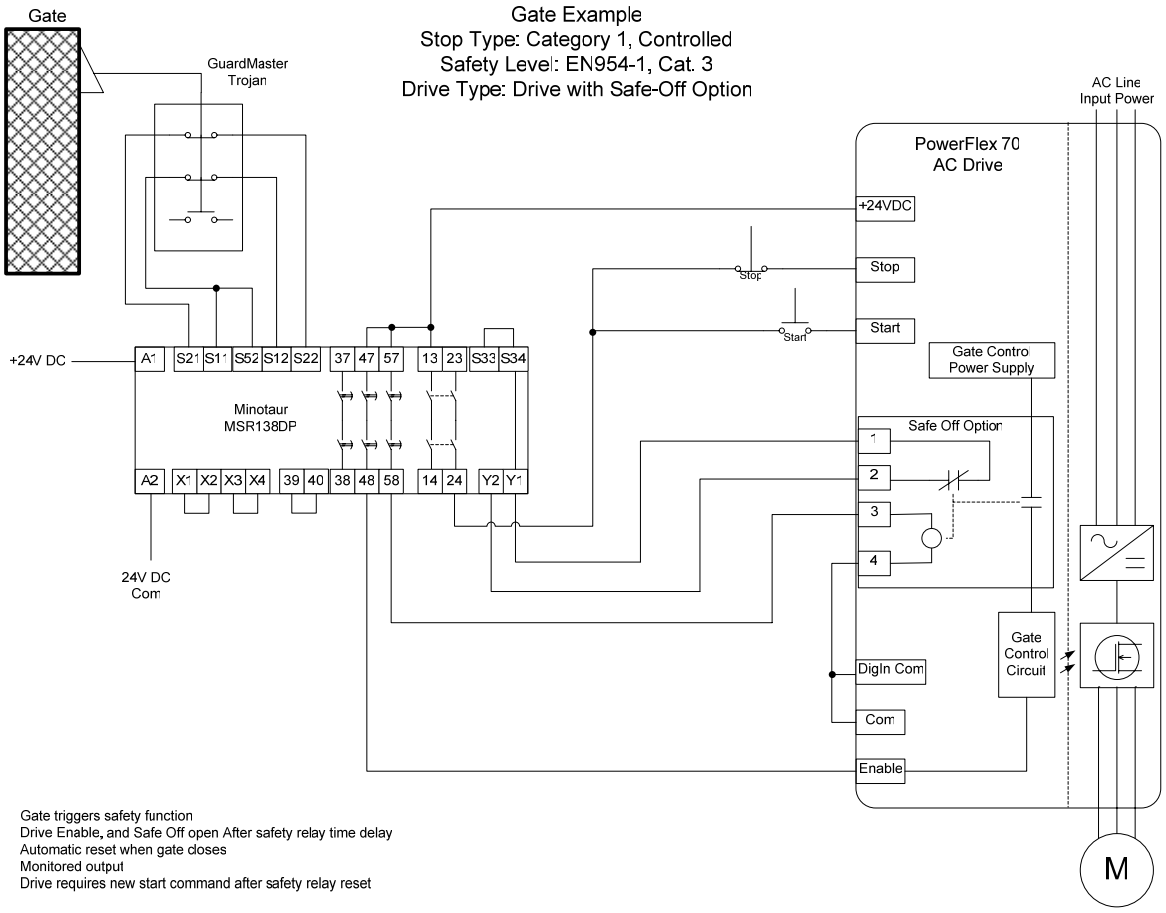
If the Safe-off monitor contact is in an abnormal state, as monitored by the safety relay (X1 & X2) the safety relay will prevent operation at the next cycling of the “safety” circuit.

Other Considerations:
Note: The hardware enable jumper in the drive must be removed if the Safe-Off Option is installed. If not, the drive will fault (F111) when a start command is issued.

Application Note
Interfacing AC Drives with Safety Relays

Stop Type: Category 1, Controlled
Safety Level: EN954-1, Category 3
Drive Type: Drive with Safe-Off Option
Other:

Overview:
This example shows how to provide Controlled Stop and protection against restart (Category 3 per EN954-1) on a drive with a safe-off feature.



Circuit Operation:
The gate will trigger the safety function. When triggered the safety relay outputs (Terminals 13 to 14 and 23 to 24) open. This immediately removes +24vdc from the drive Start/Stop input. The result is the drive stop signal is asserted and a ramp to stop is issued.

Once the time delay in the safety relay expires, the safety relay time delayed contacts (Terminals 37 to 38, 47 to 48 & 57 to 58) open. The +24vdc is then removed from the drive Enable input as well as the Safe-Off Option. The Safe-Off Option goes to a safe state (off).

Note: The time delay of the safety relay must be greater than the deceleration ramp time of the drive otherwise a coast stop will occur when the timer expires.

When the gate is restored and satisfies the safety relay inputs, the safety relay is reset (terminals 39 & 40 are N.C.). The safety relay outputs are energized restoring +24vdc to the drive Enable input, the Safe-Off Option and the Drive Start/Stop. A start command must be issued to the drive to restart.

If the Safe-off monitor contact is in an abnormal state, as monitored by the safety relay (X1 & X2) the safety relay will prevent operation at the next cycling of the “safety” circuit.

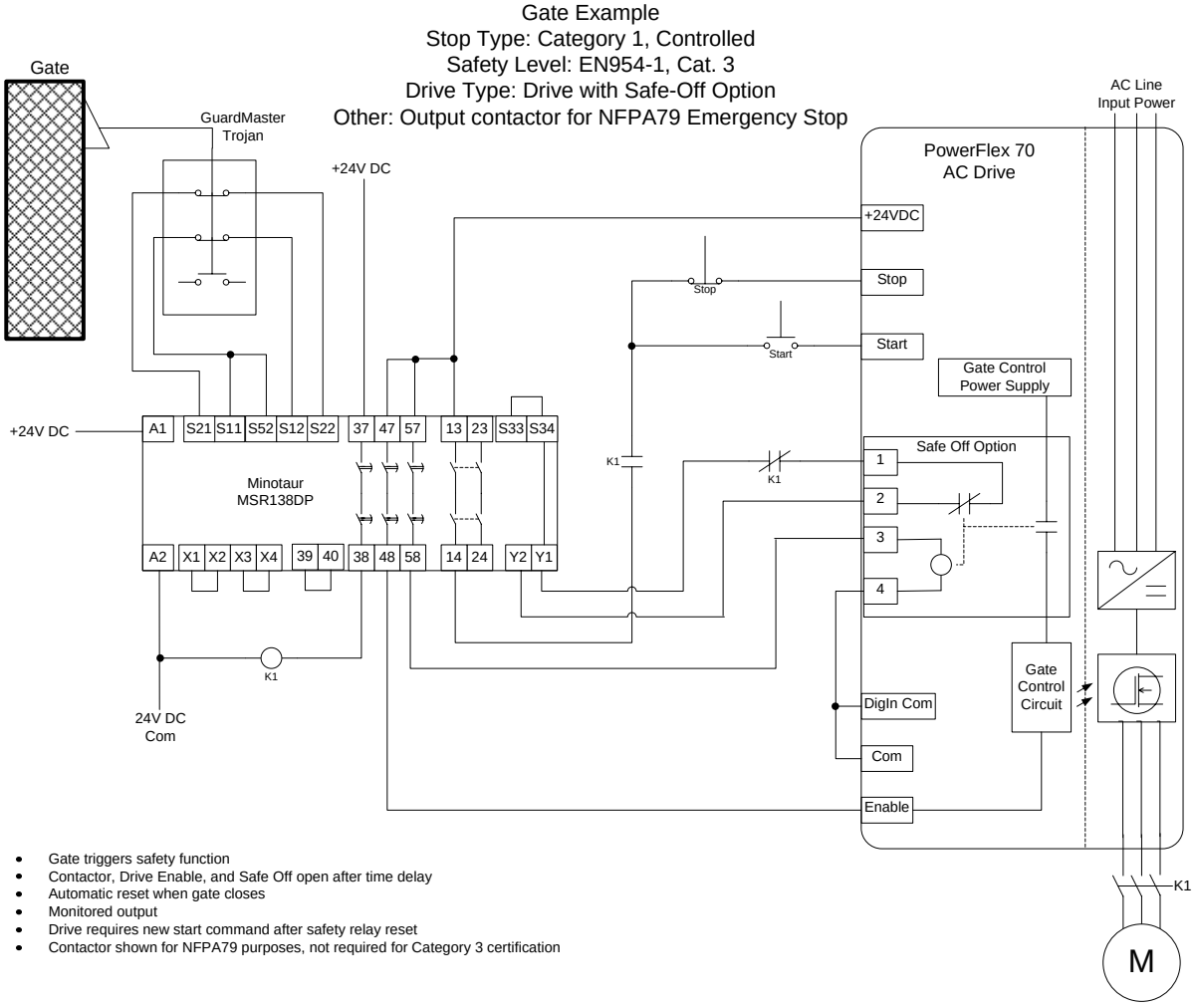
Other Considerations:

Note: The hardware enable jumper in the drive must be removed if the Safe-Off Option is installed. If not, the drive will fault (F111) when a start command is issued.

Application Note
Interfacing AC Drives with Safety Relays

Stop Type: Category 1, Controlled
Safety Level: EN954-1, Category 3
Drive Type: Drive with Safe-Off Option
Other: Output contactor for NFPA79 Emergency Stop operation

Overview:
This example shows how to provide Controlled Stop and protection against restart (Category 3 per EN954-1) on a drive with a safe-off feature. The contactors can also satisfy the NFPA79 Emergency Stop requirements.



- Gate triggers safety function
- Contactor, Drive Enable, and Safe Off open after time delay
- Automatic reset when gate closes
- Monitored output
- Drive requires new start command after safety relay reset
- Contactor shown for NFPA79 purposes, not required for Category 3 certification

Circuit Operation:
The gate will trigger the safety function. When triggered the safety relay outputs (Terminals 13 to 14 and 23 to 24) open. This immediately removes +24vdc from the drive Start/Stop input. The result is the drive stop signal is asserted and a ramp to stop is issued.

Once the time delay in the safety relay expires, the safety relay time delayed contacts (Terminals 37 to 38, 47 to 48 & 57 to 58) open. The +24vdc is then removed from the contactor K1 coil, the drive Enable input as well as the Safe-Off Option. The N.O. auxiliary contact of K1 open to prevent a drive Start before the contactor closes. The N.C. auxiliary contacts of K1 and the Safe-Off Option are monitored by the safety relay at terminals Y1 & Y2.

Note: The time delay of the safety relay must be greater than the deceleration ramp time of the drive otherwise a coast stop will occur when the timer expires.

When the gate is restored and satisfies the safety relay inputs, the safety relay is reset (terminals 39 & 40 are N.C.). The safety relay outputs are energized restoring +24vdc to the drive Enable input, the coil of the contactor K1 and the Drive Start/Stop. A start command must be issued to the drive to restart.

If the Safe-off monitor contact is in an abnormal state, as monitored by the safety relay (X1 & X2) the safety relay will prevent operation at the next cycling of the “safety” circuit.

Other Considerations:
Note: The hardware enable jumper in the drive must be removed if the Safe-Off Option is installed. If not, the drive will fault (F111) when a start command is issued.