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Common Circuit Examples

Section 1 – Listing by Product Name

Section 2 – Listing by Product Type

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Notes on Circuit Examples

Note 1

In the following circuits the type of device is shown as an example to illustrate the circuit principle. For specific applications the choice of device type should be based on the suitability of its characteristics for its intended use.

Note 2

In most of the following examples showing dual channel applications, one interlock switch, is shown switching both channels (one contact set per channel). If it is foreseeable that damage to the guard (i.e. at the actuator mounting point) could allow it to be opened without operating the switch, then two separate switches may be required. The electrical principle of the circuit will remain the same as shown.

Note 3

In most cases the circuits are shown with the guard door closed and ready for motor starting by operating the normal start control.

It must be possible to start the machine only by voluntary actuation of the control provided for the purpose (see ISO 12100 and IEC 60204-1). For the purposes of these examples, the use of a conventional contactor latching circuit has been assumed. If this is not the case, then a restart interlock will be required to prevent an automatic or unintended starting of the motor when the guard is closed. A safety monitoring relay with a momentary action push button installed in the output monitoring circuit can be used to achieve this.

If the guard is designated as a Control Guard (see ISO 12100, 5.3.2.5), these requirements do not apply. The use of Control Guards is only allowed under certain conditions including:

- A Control Guard can only be used where there is no possibility of an operator or part of his body staying in or reaching into the danger zone while the guard is closed.
- The Control Guard must be the only access to the hazard area.
- The interlocking system must have the highest possible reliability. It is often advisable to use a solenoid locking switch such as the D4JL, D4GL, D4NL, TL4024 or TL4019.

Note 4

This note applies to all monitoring devices which use the technique of comparing the signal at the change of state of dual channels, safety monitoring relay units used in dual channel circuits with infrequent operation, or with more than one switching device connected.

Certain faults are only detected at a change of state of the input switching device (interlock switch or E-stop switch). If there are long periods (i.e. months as opposed to days) between switching actions, it may be possible for multiple faults to accumulate which could lead to a dangerous situation. Therefore, a regular check should be performed on the system in order to detect single faults before an accumulation occurs. This check may be manual or initiated by part of the machine's control system.

If, for example, three interlock switches are connected to the monitoring unit, certain faults will only be detected at the switch on the first guard to be opened and the switch on the last guard to be closed. This is because any switching between the first opening/last closing will not change the state of the monitoring unit input circuits. Therefore, in some applications, it may be necessary to use one monitoring device per switch.

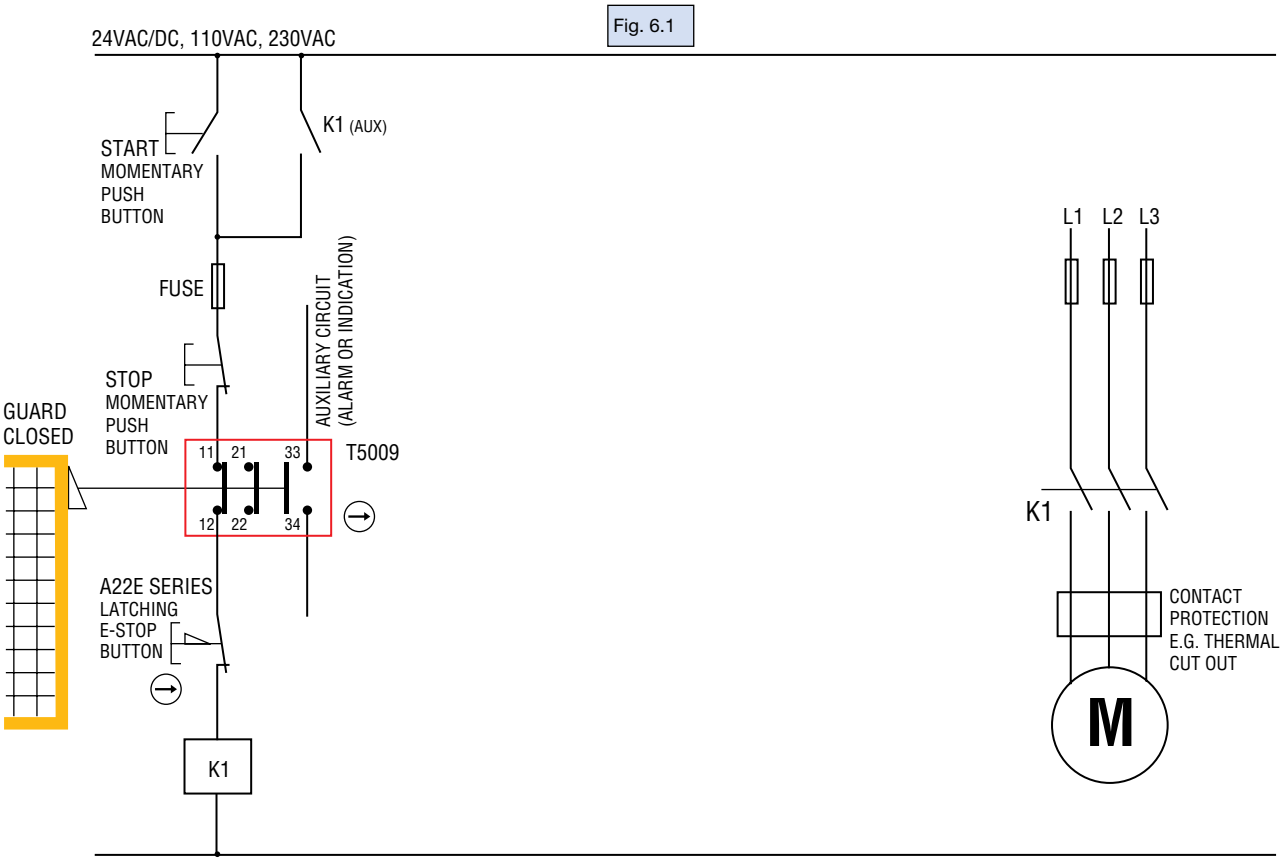
Most of the following examples show an interlock switch and an emergency stop switch combined in the circuit. When a safety monitoring relay is used for fault detection, it is important to note the following:

- All safety critical single faults, except for certain faults over the contact sets at the E-Stop, will be detected at the next opening of the guard.
- All safety critical single faults, except for certain faults over the contact sets at the interlock switch, will be detected at the next operation of the E-Stop.
- Because the E-Stop device is not likely to be operated frequently, it is recommended that its function is checked (with the guard closed) on a regular basis (start of shift or daily) to enable the safety monitoring relay to detect single faults. If the guard is rarely opened, the interlock switch should be checked in a similar manner.

Note 5

Where this symbol is used in the following example circuits, it indicates that the component or device indicated operates in the positive mode. (i.e. where two or more components are intended to move together, they are connected by direct contact or rigid links). Typical examples of this are mechanical guard interlock switches and force guided relays.

Fig. 6.1



Guard Door Interlock and E-Stop

- **Single Channel**
- **Non Monitored**

Circuit status

Circuit shown with guard door closed and ready for motor starting.

Operating principle

Opening the guard or operating the E-Stop device will cause the contactor to isolate the motor power.

Fault behavior

The integrity of the circuit depends on the suitability of the components (conformity with standards, tried and tested principles, etc.) and the nature of the wiring installation (use of protective conduit, short wiring runs, no movement of wiring, etc.).

Comments

This type of arrangement is widely used in applications which have low risk and where the wiring can be properly protected.

Refer to notes starting on page A32.

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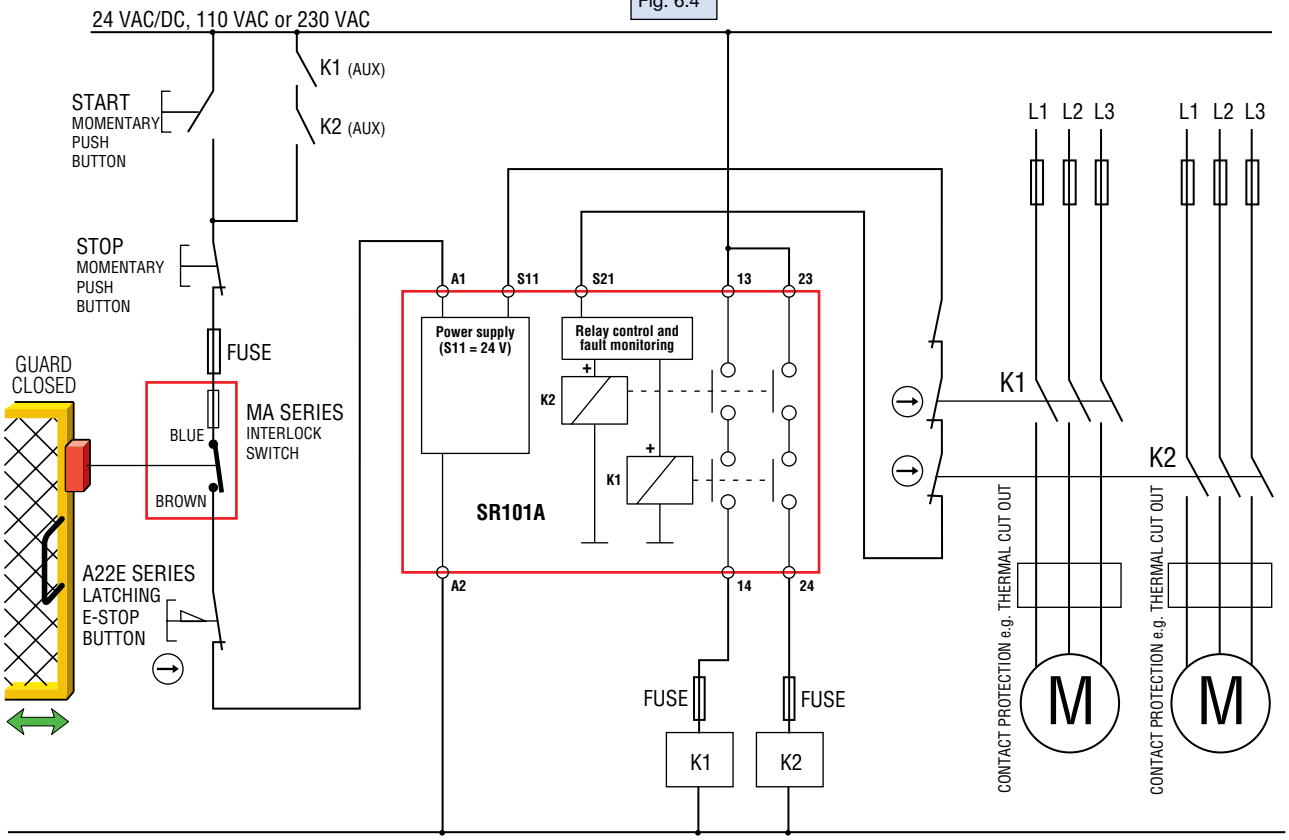
Fig. 6.4



Guard Door Interlock and E-Stop

- **Single Channel**
- **Monitored Output**
- **Auto Reset**

Circuit status

Circuit shown with guard door closed and ready for motor starting.

Operating principle

This is a single channel system with monitoring of the contactors. It uses an SR101A monitored safety relay to distribute the signal from the interlock and E-Stop switches to two contactors.

Opening the guard or operating the E-Stop device will open the input circuits (A1-A2) to the SR101A. The output circuits (13-14 & 23-24) will open and cause the contactors to isolate power to the respective motors.

The SR101A requires a 24 V AC/DC supply.

Fault behavior and detection

The integrity of the circuit depends on the suitability of the components (conformity with standards, tried and tested principles etc.) and the nature of the wiring installation (use of protective conduit, short wiring runs, no movement of wiring etc.).

The SR101A provides an ensured switching action. Contactor monitoring is provided via terminals S11-S21. When more than one contactor is used, if one of the contacts stick ON, the restarting of the other two will be prevented by the safety monitoring relay.

The SR101A can be configured with two contactors in series to control one motor and if either contactor sticks ON, the motor will stop on command due to the other contactor but the SR101A will not reset.

All safety critical single faults within the SR101A itself will be detected. **It does not detect some faults at its input circuit and therefore it is possible for a single fault to cause a loss of safety function.**

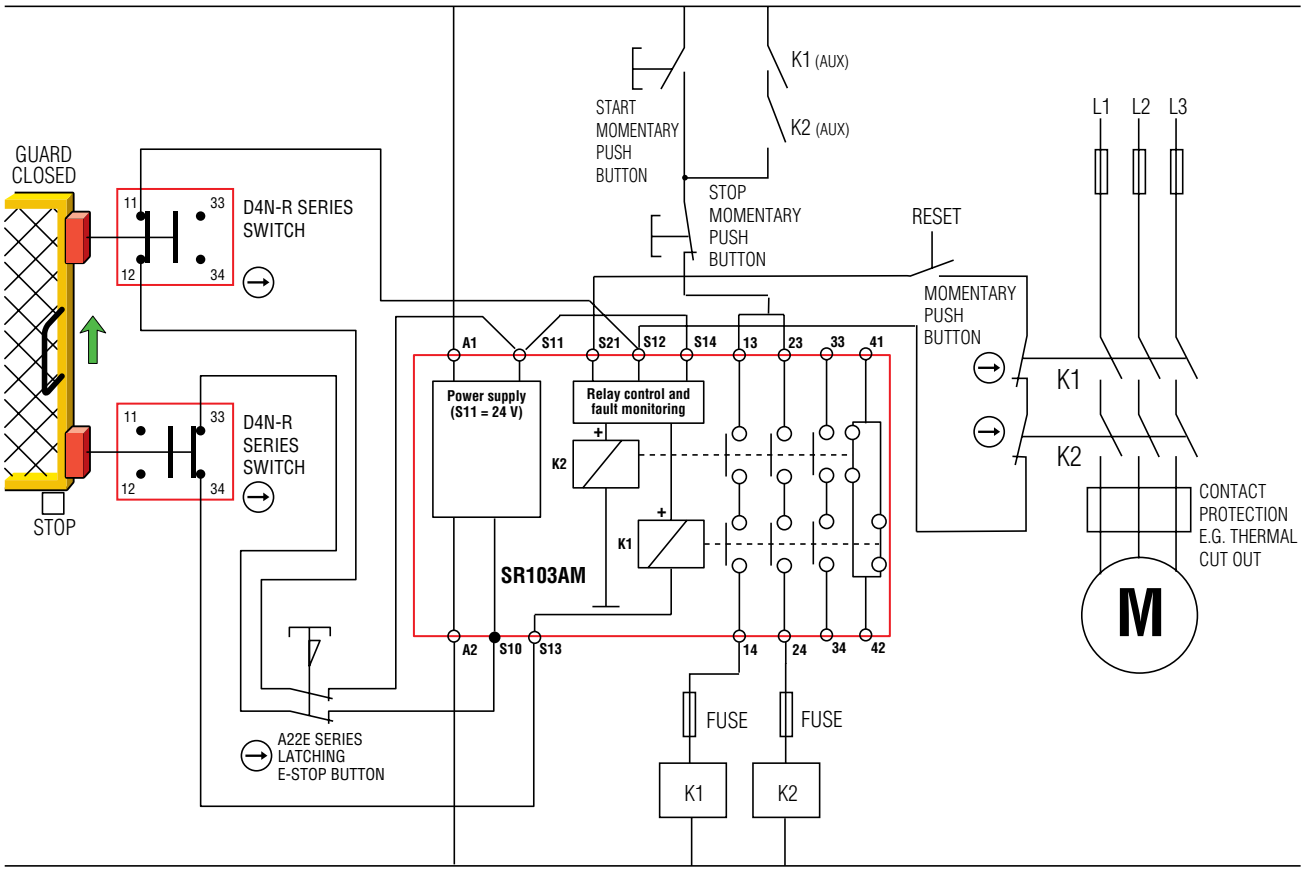
Comments

This type of system is widely used where an intermediate relay is required between the Interlock switch or E-Stop device and the contactor(s). An ordinary relay would not be suitable for this purpose because of its failure modes. This is typically the case where multiple motors are being switched or a higher current switching capacity is required. It is suitable in applications which have low to medium risk and where the wiring can be properly protected.

Refer to notes starting on page A32.

24VAC/DC, 110VAC, 230VAC

Fig. 6.5



Guard Door Interlock and E-Stop

- **Dual Channel**
- **Single Fault Monitored**
- **Manual Auto Reset**

Circuit status

Circuit shown with guard door closed and ready for motor starting after closing Reset.

Operating principle

Opening the guard or operating the E-Stop device will switch the input circuits (S11-S12 & S10-S13) to the safety monitoring relay unit. The SR103AM output circuits (13-14 & 23-24) will open and cause the contactor to isolate the motor power.

The reset switch must be closed before the motor can be restarted. Auto reset may be implemented by removing the reset switch.

Fault detection

Any single fault will not cause a loss of safety function.

If either contactor K1 or K2 sticks ON - The motor will stop on command due to the other contactor, but the safety monitoring relay cannot be reset.

Any single fault detected on the safety monitoring relay input circuits will result in the lock-out of the system to a safe state (OFF) at the next operation of the respective input device (see Note 4 on page A32).

Comments

This type of system will also detect simultaneous short circuit faults over both contact sets of the switches. The SR103AM is therefore suitable for applications where short circuit or earth faults are more likely to occur than open circuit faults (this may be due to hot surfaces, chafing, etc.).

Because this circuit uses two opposite actuation modes it ensures that excessive wear at the guard cam or switch is detected.

It is suitable for some medium to high risk applications and where the wiring cannot be fully protected against all potential damage.

Note – It should not be possible to remove or lift the guard otherwise the switches can be easily defeated.

Refer to notes starting on page A32.

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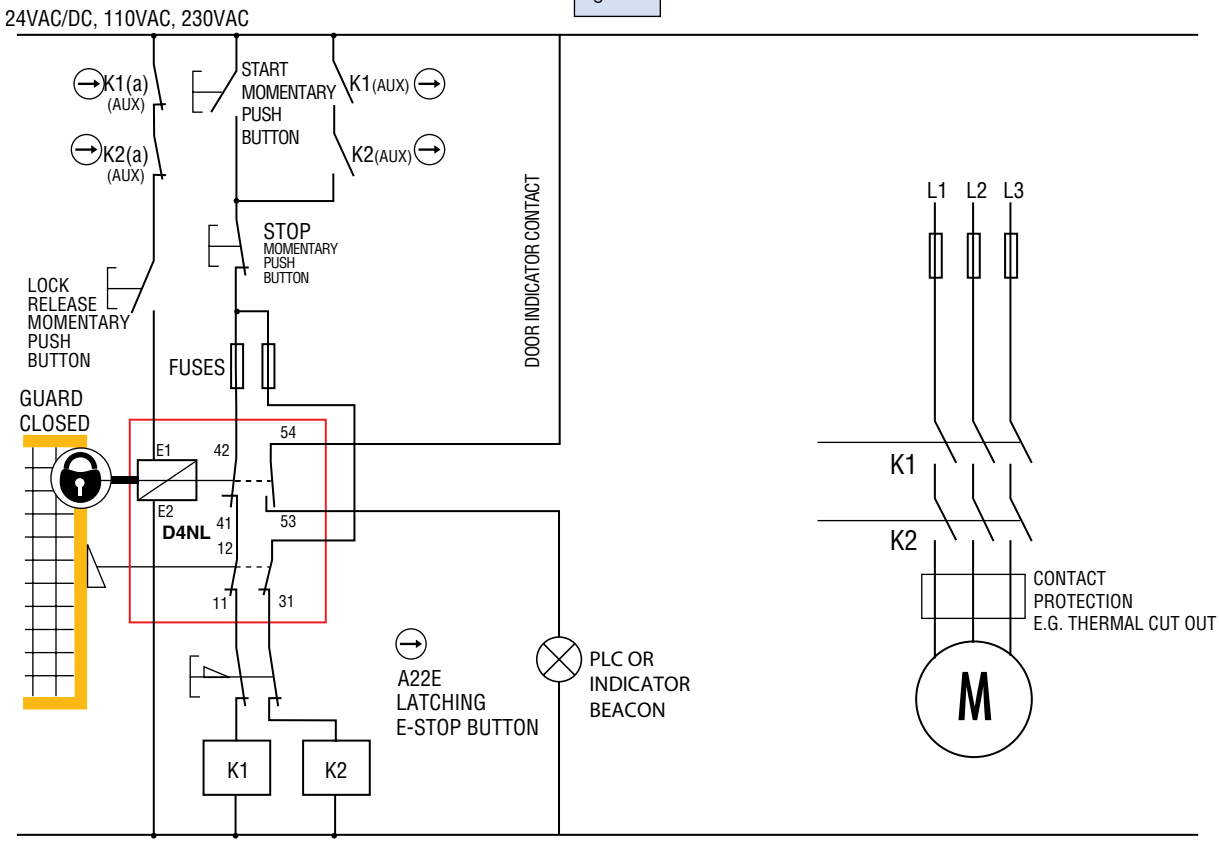
Fig. 6.6



D4NL (Solenoid Locking Switch) and E-Stop

- **Dual Channel (two contactors in series)**
- **Push Button Lock Release**

Circuit status

Circuit shown with guard door closed and locked (solenoid not energized), ready for motor starting (push start button) or lock release (push lock release button).

Operating principle

In this system the guard is locked closed until the solenoid is energized. The solenoid can only be energized when the auxiliary contacts at K1(a) and K2(a) are closed. Therefore power contacts at K1 & K2 are open and the lock release button is pushed. When the locking mechanism is released, monitoring contacts 41-42 are opened. These contacts are in series with the contactor (K1) control circuit and will therefore prevent restart while the D4NL is in the unlocked mode. If the guard is opened, contacts 11-12 and 31, 32 are opened and will prevent restart while the guard is open regardless of the lock status.

Fault detection

If either contactor K1 or K2 sticks ON - The motor will stop but the guard cannot be opened (thus the fault is revealed to the operator).

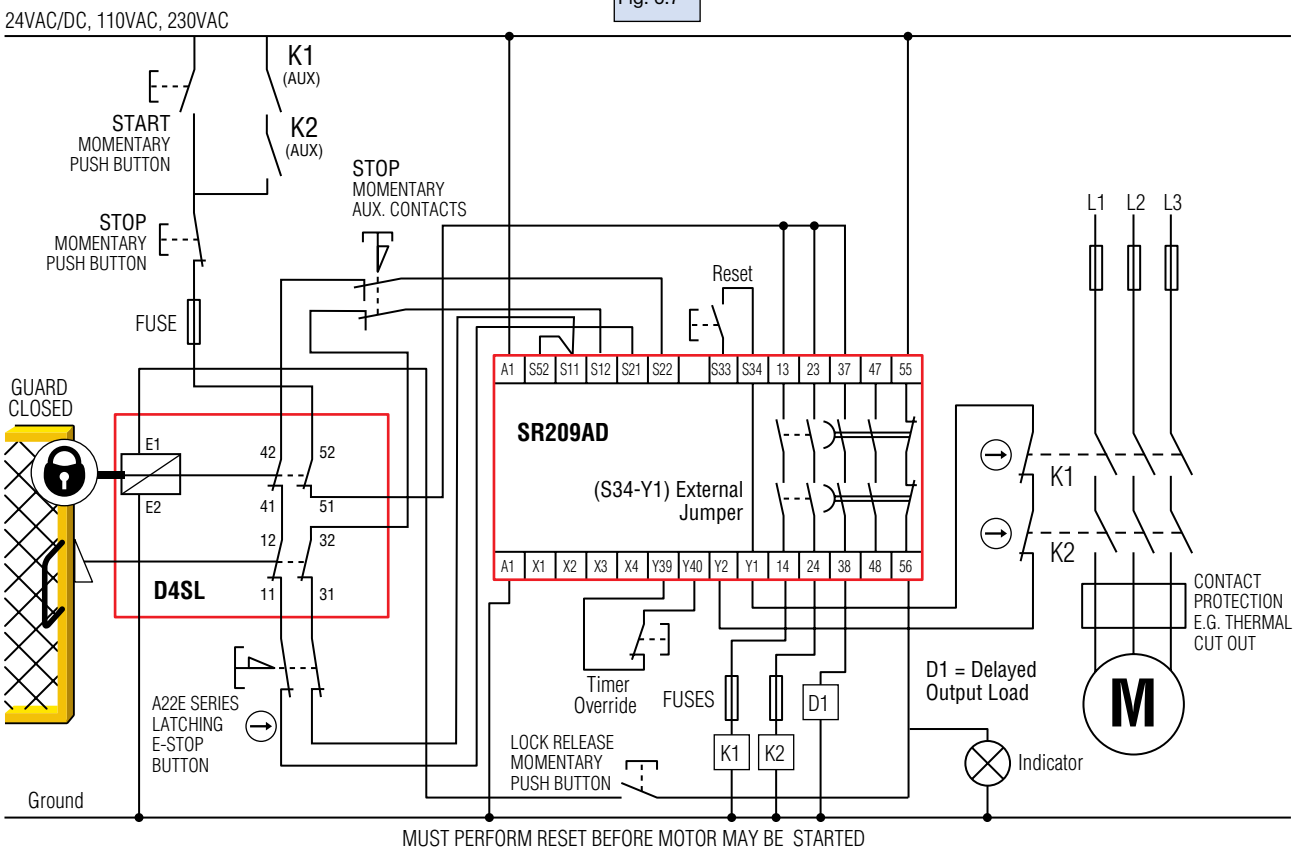
A short circuit fault on the solenoid energization circuit will initiate a STOP via contacts 41-42. A short circuit fault across either terminals 11-42 or terminals 31, 32 will not be detected, but the motor cannot be started while the guard is open. A single short circuit fault across the E-Stop device will not be detected but will not prevent emergency stopping. An open circuit fault on the solenoid energization circuit will prevent guard opening (other than by the emergency release points on the D4NL).

Comments

This system is a practical and effective method of providing an interlock function of enhanced integrity. **The inclusion of the lock release push button means that the solenoid is only energized when guard opening is required.** This prevents guard doors from swinging open whenever the control stop button is pressed. It also means that the solenoid is not left energized for long periods which can cause efficiency loss. The solenoids used in the D4NL is continuously rated but, as with any solenoid, their action will be more positive when they are working at maximum possible efficiency.

Refer to notes starting on page A32.

Fig. 6.7



D4SL (Solenoid Locking Switch) and E-Stop Switch

- **SR209AD Dual Channel (single fault monitored)**
- **Push Button Lock Release**
- **Manual Auto Reset**

Circuit status

Circuit shown with guard door closed and locked (solenoid not energized), ready for motor starting (push start button) after closing Reset or lock release (momentary push button).

Operating principle

In this system the guard is locked closed until the solenoid is energized.

The solenoid can only be energized when the normally closed Delayed Outputs 55, 56 are closed. This time delay would be set to allow sufficient time for the load to come to a stop. Therefore power contacts at K1 & K2 are open and the lock release button may be pressed. When the solenoid goes to the unlocking mode and the guard is opened which opens the input circuit to terminals S11-S12 & S21-S22 at the SR209AD which isolates the contactor control circuits between its open terminals 13-14 and 23-24. When the guard is opened, the guard operated contact sets at 11, 12 and 31, 32 are opened, thus ensuring that the safety monitoring relay outputs remain in the OFF state while the guard is open. After the guard has been closed the Reset button must then be pressed to close the output circuit to the contactors which can then be started by the control start button.

Fault detection

If either contactor K1 or K2 sticks ON - the motor will stop on command but the guard cannot be opened (thus the fault is revealed to the operator).

Any single fault within the SR209AD will prevent the closing of its outputs.

Any single fault on the SR209AD input and output circuits will be detected and will result in the lock-out of the system to a safe state (OFF) at the next operation of the respective input device.

An open circuit fault across the solenoid energization circuit will prevent guard opening (other than by the emergency release points on the D4GL).

Comments

This system provides an interlock function of high integrity and is suitable for many high risk applications.

The solenoid is only energized when guard opening is required.

Refer to notes starting on page A32.

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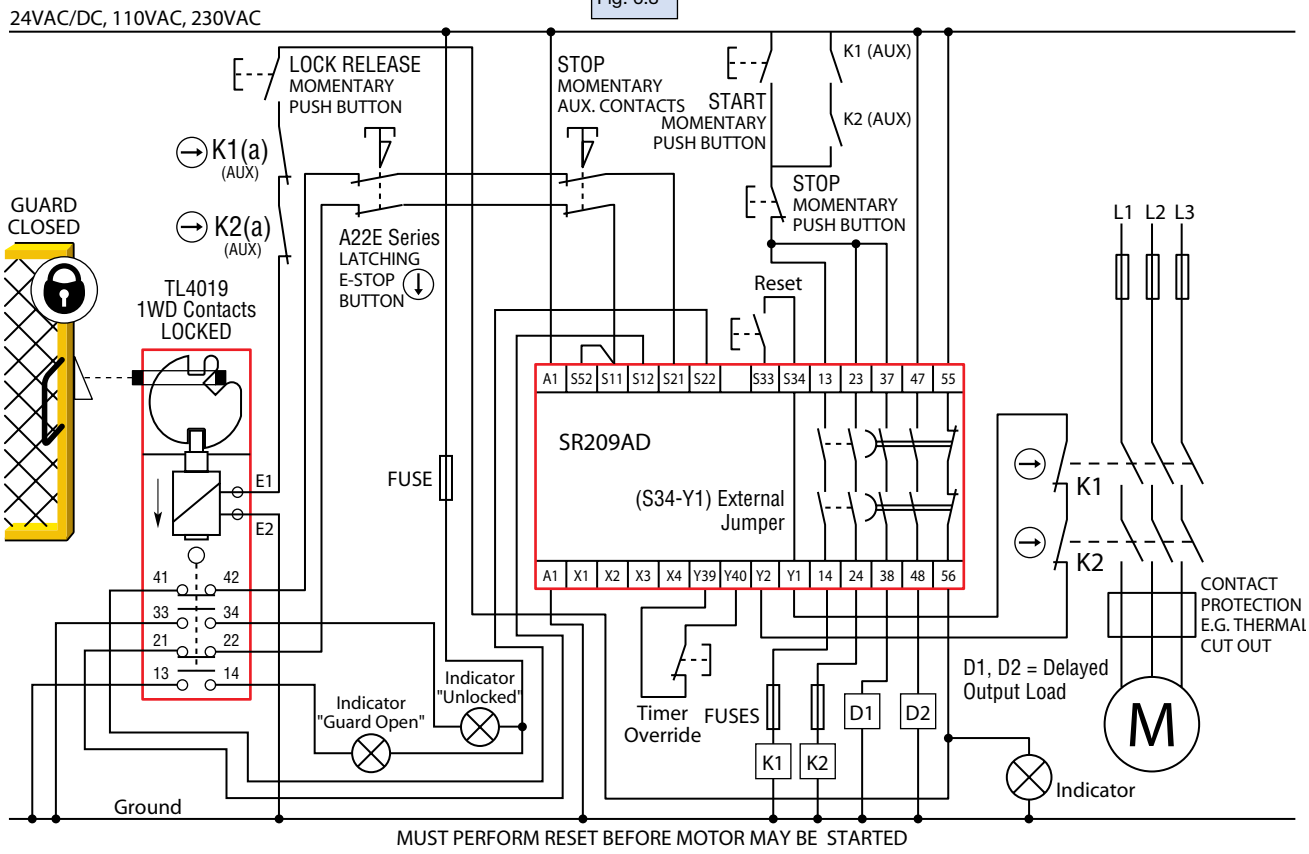
Fig. 6.8



TL4019 (Solenoid Locking Switch)

- **SR209AD (timed delayed unit)**
- **Dual Channel**
  (single fault monitored)
- **2 Contactors**
- **Push Button Lock Release**
- **Manual Auto Reset**

Circuit status

Circuit shown with guard door closed and locked (solenoid not energized), ready for Reset Input Signal (push reset switch) and Motor Start (push start button), or Lock Release (push lock release button).

Operating principle

In this system the guard is locked closed until the solenoid is energized. The solenoid can only be energized when:

• the auxiliary contacts at K(a)1 and K2(a) are closed. Therefore power contacts at K1 & K2 are open.

• the SR209AD control unit has timed out for a pre-set period. At this stage the Delayed Output Indicator Light will show that the guard can now be opened by operating the lock release push button. When the locking mechanism is released, the guard door may be opened. Unlocking the guard door opens contacts 21-22 & 41-42 of the TL4019 Interlock Switch, thus opening the monitoring circuit of the SR209AD. This assures that the motor power circuit is disabled while the guard door is open. In order for the motor circuit to be started, the guard door must be shut and the TL4019 must be locked. The SR209AD must be manually reset just prior to sending the start signal.

Fault detection

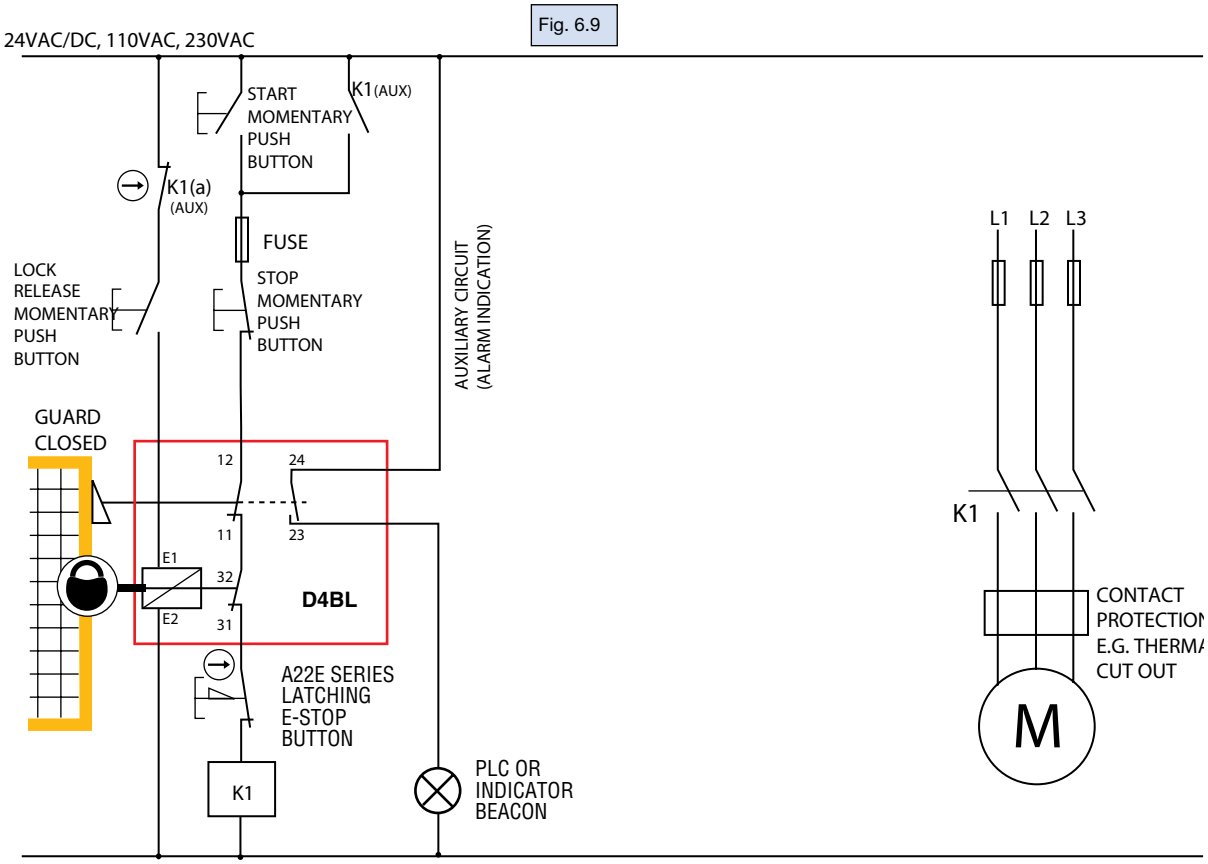
If either contactor K1 or K2 sticks ON - the motor will stop and the guard may be opened, but the SR209AD will not reset. The External Device Monitoring circuit Y1-Y2 of the SR209AD must detect the proper contact state before the reset signal will be accepted. Any single fault within the SR209AD will prevent the closing of its outputs.

Comments

This system is a practical and effective method of providing an interlock function of increased integrity. It is suitable for applications where motion overruns after the stop command and the time taken to run down to a stop is predictable, consistent and less than approximately 30 minutes. The inclusion of the lock release push button means that the solenoid is only energized when guard opening is required. This prevents guard doors from swinging open whenever the control stop button is pressed. It also means that the solenoid is not left energized for long periods which can cause efficiency loss. The solenoids used in the TL4019, TL4024, TL5019, TL8012-S, and TL8018-5 are continuously rated but, as with any solenoid, their action will be more positive when they are working at maximum possible efficiency.

Refer to notes starting on page A32.

Fig. 6.9



D4BL (Solenoid Locking Switch) and E-Stop

- **Single Channel**
- **Push Button Lock Release**

Circuit status

Circuit shown with guard door closed and locked (solenoid not energized), ready for motor starting (push start button) or lock release (push lock release button).

Operating principle

In this system the guard is locked closed until the solenoid is energized. The solenoid can only be energized when the auxiliary contacts at K1(a) are closed. Therefore power contacts at K1 are open and the lock release button is pushed. When the locking mechanism is released, monitoring contacts D4BL are opened. These contacts are in series with the contactor (K1) control circuit and will therefore prevent restart while the D4BL is in the unlocked mode. If the guard is opened, contacts 11, 12 are opened and will also prevent restart while the guard is open regardless of the lock status.

Fault detection

If contactor K1 sticks ON the motor will continue to run but the guard cannot be opened (thus the fault is revealed to the operator). A short circuit fault on the solenoid energization circuit will initiate a STOP via contacts 31, 12.

A short circuit fault across terminals 31,12 will not be detected. A short circuit fault across the E-Stop device will not be detected.

An open circuit fault on the solenoid energization circuit will prevent guard opening (other than by the emergency release points on the D4BL).

Comments

This system is a practical and effective method of providing an interlock function of enhanced integrity. **The inclusion of the lock release push button means that the solenoid is only energized when guard opening is required.** This prevents guard doors from swinging open whenever the control stop button is pressed. It also means that the solenoid is not left energized for long periods which can cause efficiency loss. The solenoids used in the D4BL is continuously rated but, as with any solenoid, their action will be more positive when they are working at maximum possible efficiency.

Refer to notes starting on page A32.

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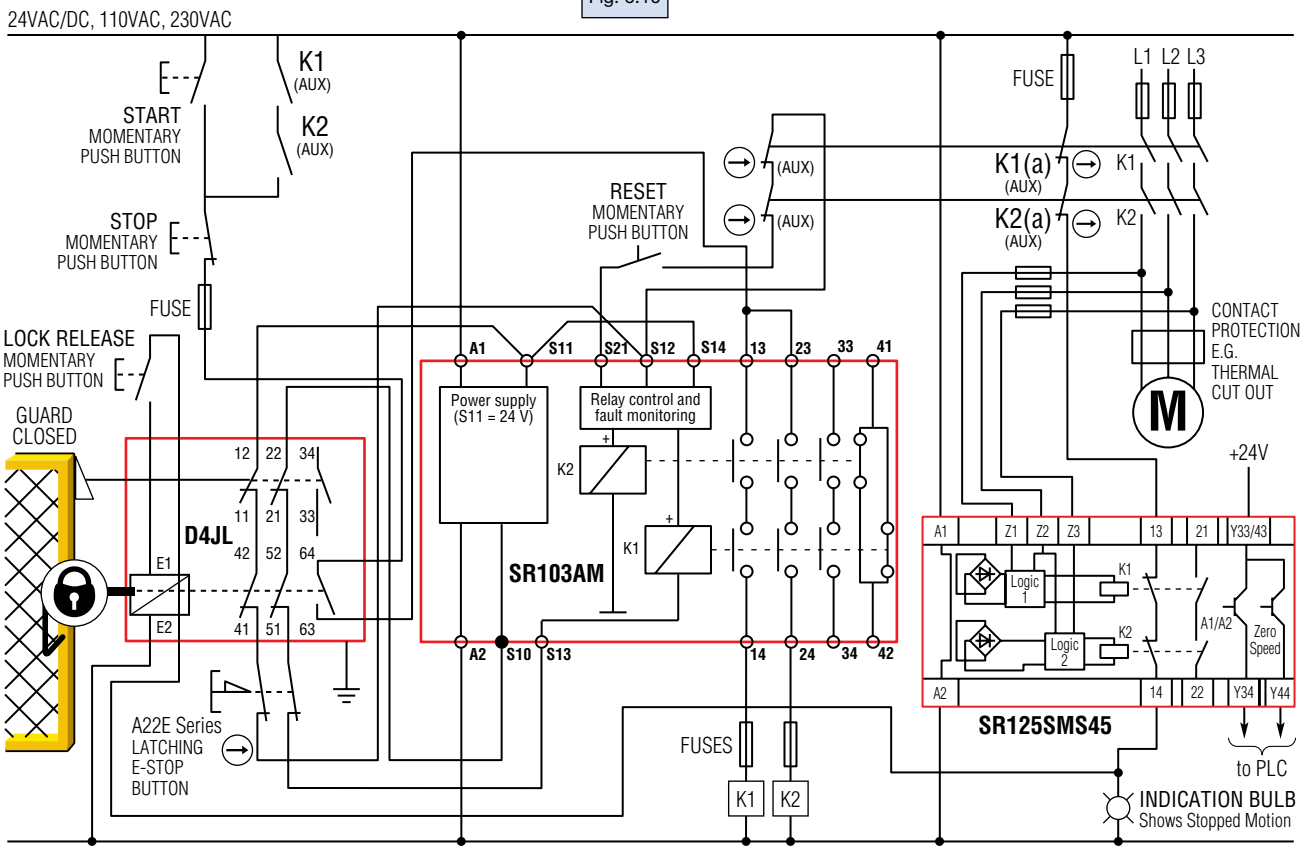
Fig. 6.10



D4JL (Solenoid Locking Switch) and E-Stop Switch

- **SR103AM**
- **SR125SMS45**
  (stopped motion detection system)
- **Dual Channel**
  (single fault monitored)
- **Push Button Lock Release**
- **Manual Auto Reset**

Circuit status

Circuit shown with guard door closed and locked (solenoid not energized) after closing Reset, ready for motor starting (push start button) or lock release (push lock release button).

Operating principle

In this system the guard is locked closed until the solenoid is energized. The solenoid can only be energized when:-

- the auxiliary contacts at K1(a) & K2(a) are closed (therefore power contacts at K1 & K2 are open).
- the SR125SMS45 senses stopped motion and closes its output circuit at terminals 13-14.
- the lock release button is pressed. The monitoring contacts 63, 64 isolate power to the contactor control circuits when the solenoid is in the unlocked mode. The guard operated contact sets at 11,12 and 21, 22 are opened whenever the guard is not fully closed. The output contacts at 13-14 and 23-24 on the SR103AM will only be closed (allowing power to the control circuit) when both input circuits (S10-S13 & S11-S12) are closed. Therefore the motor can only be started when the guard is in the closed and locked position and the reset is closed. Auto reset may be implemented by removing the reset switch.

Fault detection

If either contactor K1or K2 sticks ON - The motor will stop on command but the guard cannot be opened (thus the fault is revealed to the operator). Any single fault which causes solenoid energization will initiate a STOP via contacts 63, 64. Any single fault within the SMD125SMS45 will prevent the closing of its outputs (preventing solenoid energization). Any single fault detected on the SR103AM input and output circuits will result in the lock-out of the system to a safe state (OFF) at the next operation of the respective input device. An open circuit fault across the solenoid energization circuit will prevent guard opening (other than by the manual emergency release points on the D4JL).

Comments

This system provides an interlock function of high integrity and will be suitable for many high risk applications. It is suitable for applications where motion overruns after the stop command and the time taken to run down to a stop is not predictable, consistent or more than approximately 30 minutes.

Refer to notes starting on page A32.