SIEMENS

STEP 2000

Control Circuits

Toggle Full Screen Close REV FWD

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Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Basics of Control Components** and related products.

Upon completion of **Basics of Control Components** you will be able to:

- State the purpose and general principles of control components and circuits
- State the difference between manual and automatic control operation
- Identify various symbols which represent control components
- Read a basic line diagram
- Describe the construction and operating principles of manual starters
- Describe the construction and operating principles of magnetic contactors and magnetic motor starters
- Identify various Siemens and Furnas manual starters and magnetic motor starters, and describe their operation in a control circuit
- Explain the need for motor overload protection
- State the need for reduced-voltage motor starting
- Describe typical motor starting methods

- Describe the difference between normally open and normally pilot devices
- Describe the operating principles of control relays

This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** before attempting **Basics of Control Components**. An understanding of many of the concepts covered in **Basics of Electricity** is required for **Basics of Control Components**. In addition, you may want to complete the STEP 2000 course **Sensors** after completing **Basics of Control Components**.

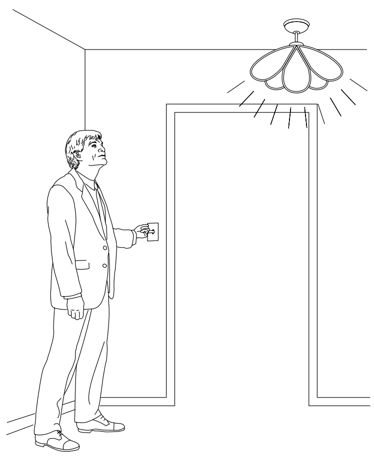
If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

Control Circuits

The National Electrical Code® (NEC®) defines a controller as *a device or group of devices that serves to govern, in some predetermined manner, the electrical power delivered to the apparatus to which it is connected* (Article 100-definitions).

Control

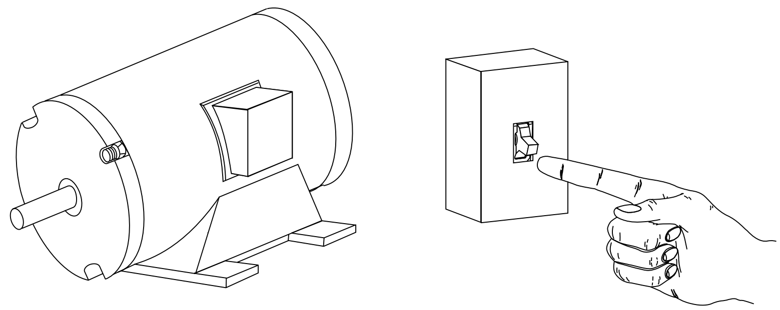
Control, as applied to control circuits, is a broad term that means anything from a simple toggle switch to a complex system of components which may include relays, contactors, timers, switches, and indicating lights. Every electrical circuit for light or power has control elements. One example of a simple control circuit is a light switch used to turn lights on and off.



Of course there are many other devices and equipment systems in industrial applications. Motor control, for example, can be used to start and stop a motor and protect the motor, associated machinery, and personnel. In addition, motor controllers might also be used for reversing, changing speed, jogging, sequencing, and pilot-light indication. Control circuits can be complex: accomplishing high degrees of automatic and precise machine operation.

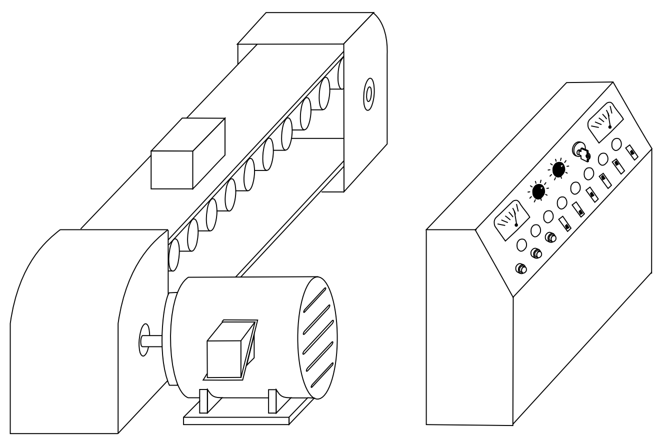
Manual Control

Control is considered to be manually operated when someone must initiate an action for the circuit to operate. For example, someone might have to flip the switch of a manual starter to start and stop a motor.



Automatic Operation

While manual operation of machines is still common practice, many machines are started and stopped automatically. Frequently there is a combination of manual and automatic control. A process may have to be started manually, but may be stopped automatically.



Control Elements

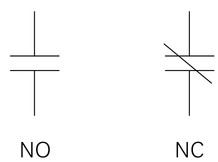
The elements of a control circuit include all of the equipment and devices concerned with the circuit function. This includes enclosures, conductors, relays, contactors, pilot devices, and overcurrent-protection devices. The selection of control equipment for a specific application requires a thorough understanding of controller operating characteristics and wiring layout. The proper control devices must be selected and integrated into the overall plan.

Electrical Symbols

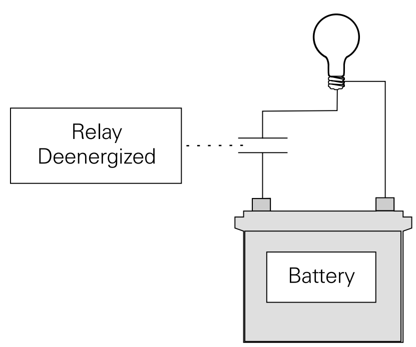
Language has been developed in order to transfer ideas and information. In order to understand the ideas and information being communicated, an understanding of the language is necessary. The language of controls consists of a commonly used set of symbols which represents control components.

Contact Symbols

Contact symbols are used to indicate an open or closed path of current flow. Contacts are shown as normally open (NO) or normally closed (NC). Contacts shown by this symbol require another device to actuate them.

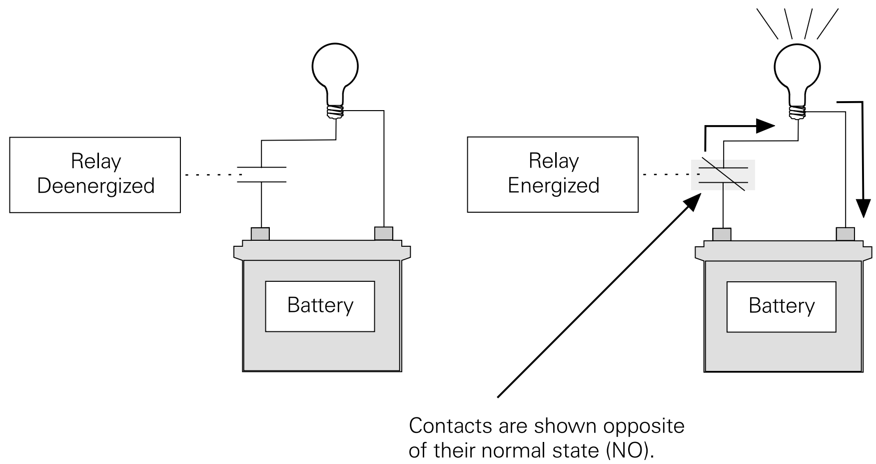


The standard method of showing a contact is by indicating the circuit condition it produces when the actuating device is in the deenergized or nonoperated state. For example, in the following illustration a relay is used as the actuating device. The contacts are shown as normally open, meaning the contacts are open when the relay is deenergized. A complete path of current does not exist and the light is off.



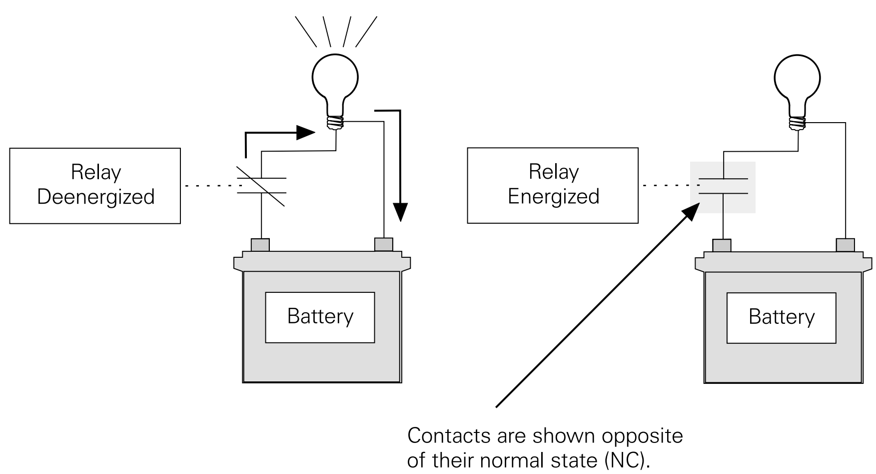
Normally Open Contact Example

In a control diagram or schematic, symbols are usually not shown in the energized or operated state. For the purposes of explanation in this text, a contact or device shown in a state opposite of its normal state will be highlighted. For example, in the following illustration the circuit is first shown in the deenergized state. The contacts are shown in their normally open (NO) state. When the relay is energized, the contacts close completing the path of current and illuminating the light. The contacts have been highlighted to indicate they are now closed. This is not a legitimate symbol. It is used here for illustrative purposes only.



Normally Closed Contact Example

In the following illustration the contacts are shown as normally closed (NC), meaning the contacts are closed when the relay is deenergized. A complete path of current exists and the light is on. When the relay is energized, the contacts open turning the light off.

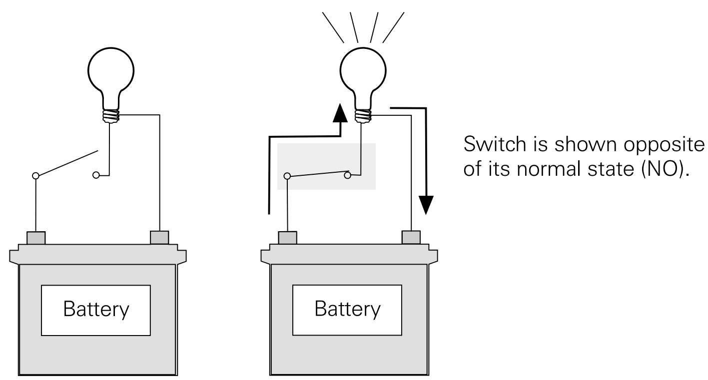


Switch Symbols

Switch symbols are also used to indicate an open or closed path of current flow. Variations of this symbol are used to represent limit switches, foot switches, pressure switches, level switches, temperature-actuated switches, flow switches, and selector switches. Switches, like contacts, require another device or action to change their state. In the case of a manual switch someone must manually change the position of the switch.

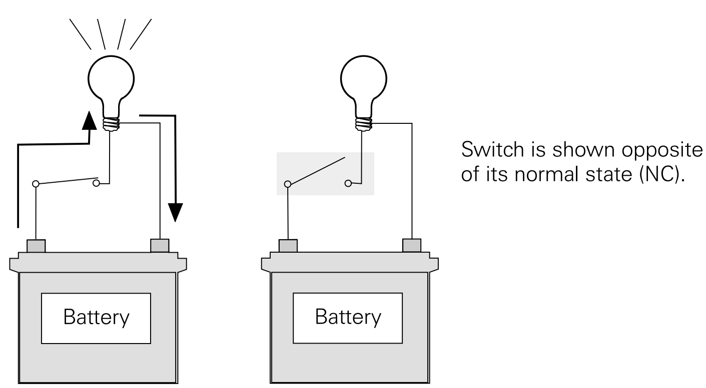
Normally Open Switch Example

In the following illustration a battery is connected to one side of a normally open switch and a light to the other. Current is prevented from flowing to the light when the switch is open. When someone closes the switch, the path of current flow is completed and the light illuminates.



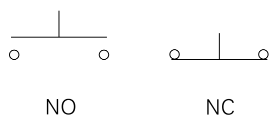
Normally Closed Switch Example

In the following illustration a battery is connected to one side of a normally closed switch and a light to the other. Current is flowing to the light when the switch is closed. When someone opens the switch, the path of current flow is interrupted and the light turns off.



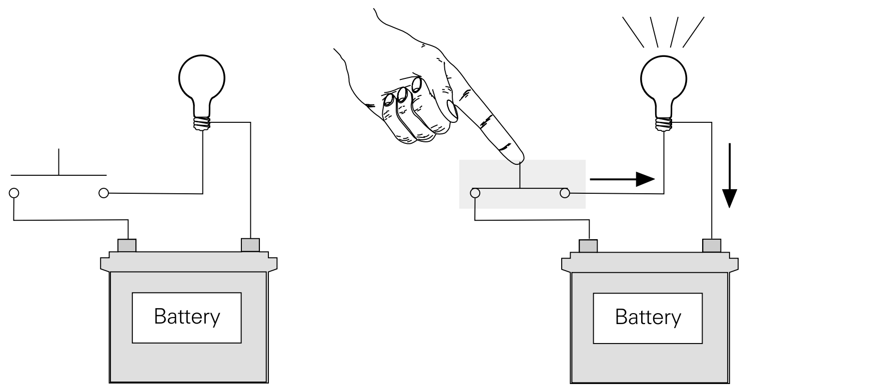
Pushbutton Symbols

There are two basic types of pushbuttons: momentary and maintained. A normally open momentary pushbutton closes as long as the button is held down. A normally closed momentary pushbutton opens as long as the button is held down. A maintained pushbutton latches in place when the button is pressed.



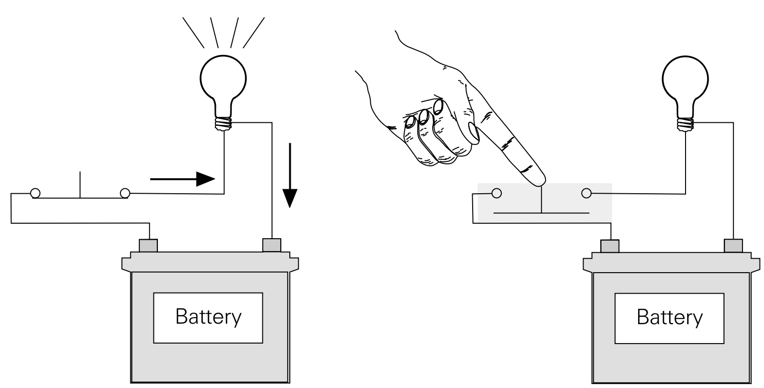
Normally Open Pushbutton Example

In the following illustration a battery is connected to one side of a normally open pushbutton and a light is connected to the other side. When the pushbutton is depressed, a complete path of current flow exists through the pushbutton and the light is illuminated.



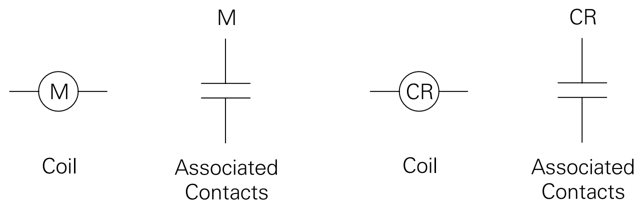
Normally Closed Pushbutton Example

In the following example current will flow to the light as long as the pushbutton is not depressed. When the pushbutton is depressed, current flow is interrupted and the light turns off.



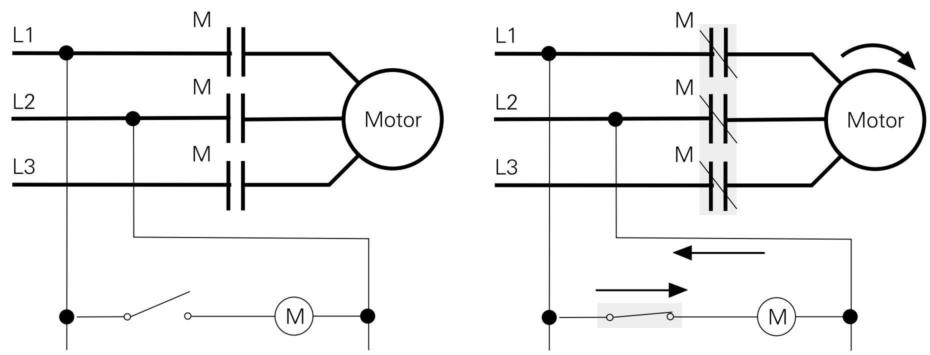
Coil Symbols

Coils are used in electromagnetic starters, contactors, and relays. The purpose of contactors and relays is to open and close associated contacts. A letter is used to designate the coil; for example, " M " frequently indicates a motor starter and " CR " indicates a control relay. The associated contacts have the same identifying letter. Contactors and relays use an electromagnetic action which will be described later to open and close these contacts. The associated contacts can be either normally open or normally closed.



Coil Example Using Normally Open Contacts

In the following example, the " M " contacts in series with the motor are controlled by the " M " contactor coil. When someone closes the switch, a complete path of current flow exists through the switch and " M " contactor coil. The " M " contactor coil actuates the " M " contacts which provide power to the motor.



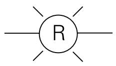
Overload Relay Symbols

Overload relays are used to protect motors from overheating due to an overload on the driven machinery, low-line voltage, or an open phase in a three-phase system. When excessive current is drawn for a predetermined amount of time, the relay opens and the motor is disconnected from its source of power.

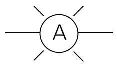
Thermal Overload

Pilot Light Symbols

A pilot light is a small electric light used to indicate a specific condition of a circuit. For example, a red light might be used to indicate a motor is running. The letter in the center of the pilot light symbol indicates the color of the light.



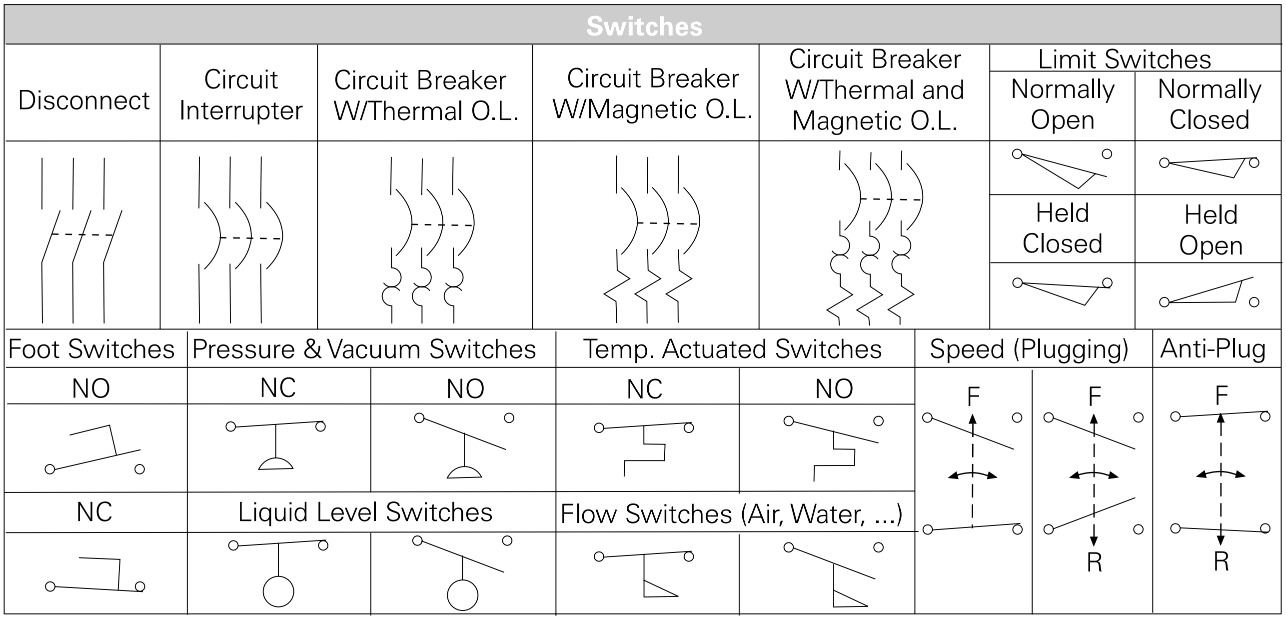
Red Pilot Light

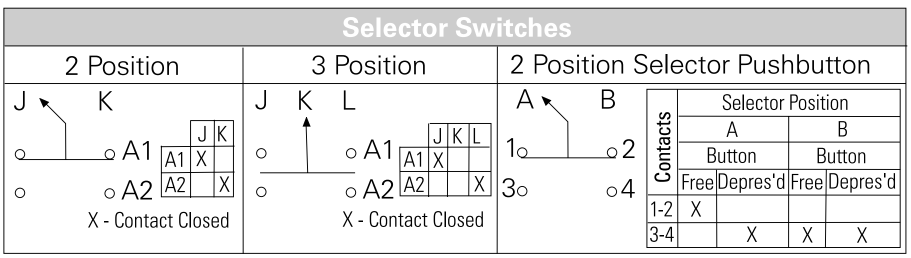


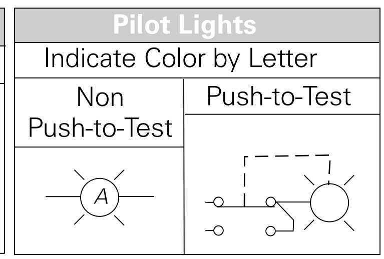
Amber Pilot Light

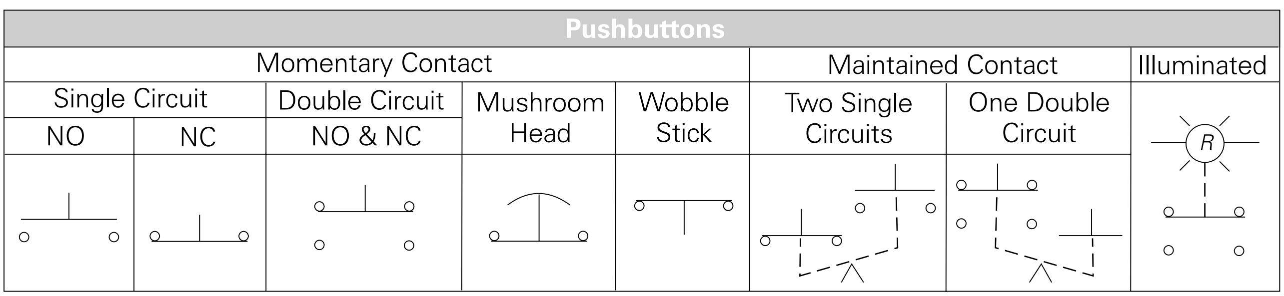
Other Symbols

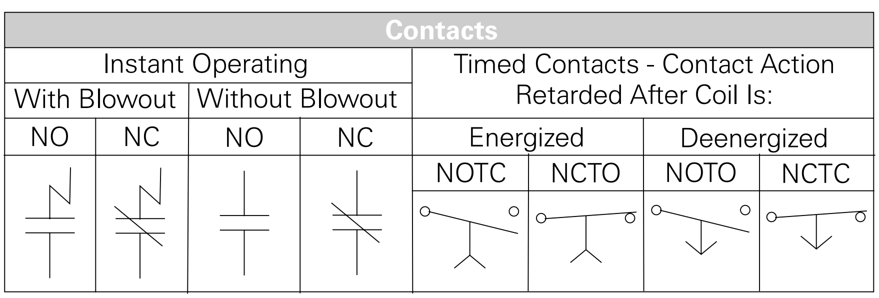
In addition to the symbols discussed here, there are many other symbols used in control circuits. The following chart shows many of the commonly used symbols.

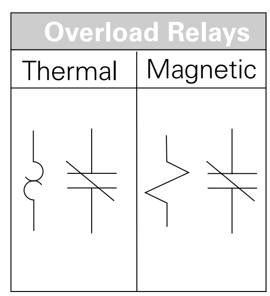

Switches
Disconnect
Circuit Interrupter
Circuit Breaker W/Thermal O.L.
Circuit Breaker W/Magnetic O.L.
Circuit Breaker W/Thermal and Magnetic O.L.
Limit Switches
Normally Open
Normally Closed
Held Closed
Held Open
Foot Switches
NO
NC
Pressure & Vacuum Switches
NC
NO
Liquid Level Switches
Temp. Actuated Switches
NC
NO
Flow Switches (Air, Water, ...)
Speed (Plugging)
F
F
R
Anti-Plug
F
R

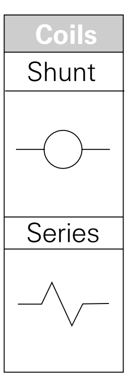

Selector Switches
2 Position
J K
A1
A2
J K
A1 X
A2 X
X - Contact Closed
3 Position
J K L
A1
A2
J K L
A1 X
A2 X
X - Contact Closed
2 Position Selector Pushbutton
A B
1 2
3 4
Selector Position
Contacts
A
B
Button
Button
Free Depres'd Free Depres'd
1-2 X
3-4 X X X

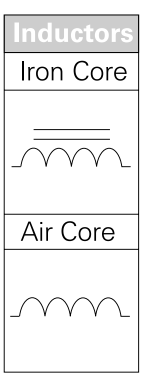

Pilot Lights
Indicate Color by Letter
Non Push-to-Test
Push-to-Test
A

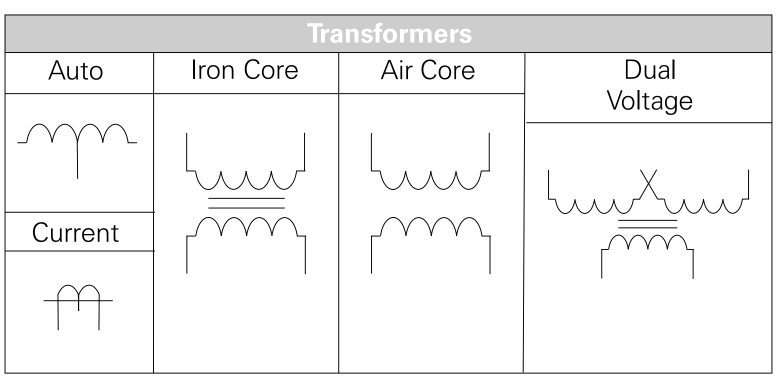

Pushbuttons
Momentary Contact
Single Circuit
NO
NC
Double Circuit
NO & NC
Mushroom Head
Wobble Stick
Maintained Contact
Two Single Circuits
One Double Circuit
Illuminated
R

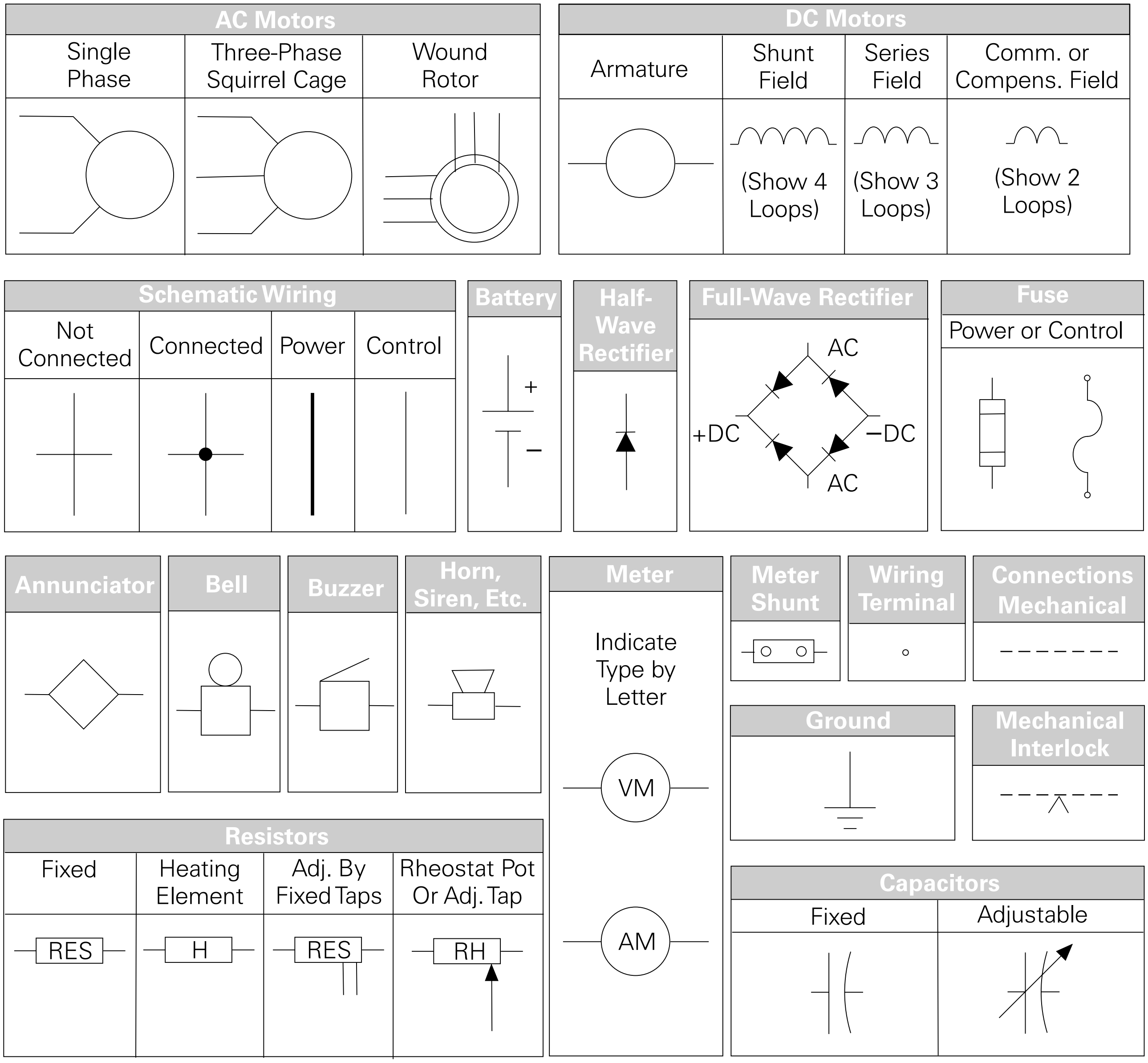

Contacts
Instant Operating
With Blowout
Without Blowout
NO
NC
NO
NC
Timed Contacts - Contact Action Retarded After Coil Is:
Energized
Deenergized
NOTC
NCTO
NOTO
NCTC

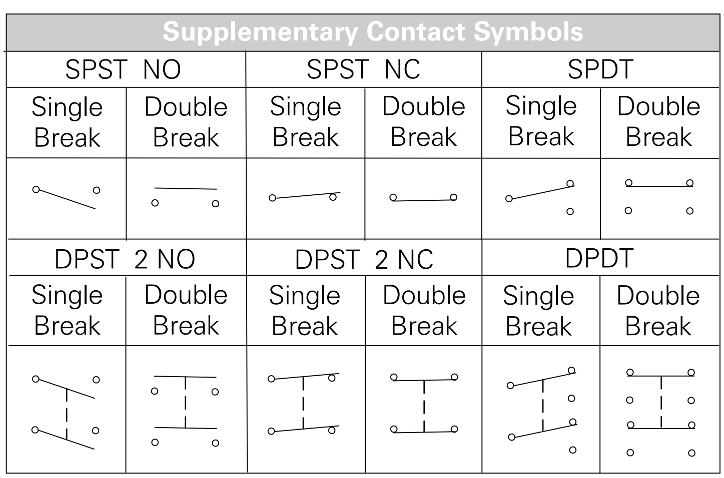

Overload Relays
Thermal
Magnetic


Coils
Shunt
Series


Inductors
Iron Core
Air Core


Transformers
Auto
Current
Iron Core
Air Core
Dual Voltage





Terms

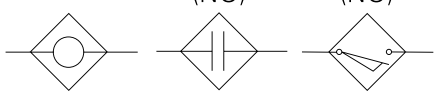
SPST	Single-Pole Single-Throw
SPDT	Single-Pole Double-Throw
DPST	Double-Pole Single-Throw
DPDT	Double-Pole Double-Throw
NO	Normally Open
NC	Normally Closed

Symbols For Static Switching Control Devices

Static switching control is a method of switching electrical circuits without the use of contacts. Primarily by solid-state devices. Use the symbols shown in the table on the previous page except enclosed in a diamond.

Examples:

Input "Coil" | Output (NO) | Limit Switch (NO)



Control and Power Connections - 600 Volts or Less - Across-the-Line Starters (From NEMA Standard ICS 2-321A.60)

		1 Phase	2 Phase 4 Wire	3 Phase
Line Markings		L1,L2	L1,L3-Phase 1 L2,L4-Phase 2	L1,L2,L3
Ground When Used		L1 is always Ungrounded	—	L2
Motor Running Overcurrent Units In	1 Element	L1	—	—
	2 Element	—	L1,L4	—
	3 Element	—	—	L1,L2,L3
Control Circuit Connected To		L1,L2	L1,L3	L1,L2
For Reversing Interchange Lines		—	L1,L3	L1,L3

Abbreviations

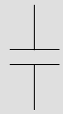
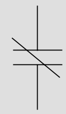
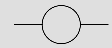
Abbreviations are frequently used in control circuits. The following list identifies a few commonly used abbreviations.

AC	Alternating Current	MTR	Motor
ALM	Alarm	MN	Manual
AM	Ammeter	NEG	Negative
ARM	Armature	NEUT	Neutral
AU	Automatic	NC	Normally Closed
BAT	Battery	NO	Normally Open
BR	Brake Relay	OHM	Ohmmeter
CAP	Capacitor	OL	Overload
CB	Circuit Breaker	PB	Pushbutton
CKT	Circuit	PH	Phase
CONT	Control	POS	Positive
CR	Control Relay	PRI	Primary
CT	Current Transformer	PS	Pressure Switch
D	Down	R	Reverse
DC	Direct Current	REC	Rectifier
DISC	Disconnect Switch	RES	Resistor
DP	Double-Pole	RH	Rheostat
DPDT	Double-Pole, Double-Throw	S	Switch
DPST	Double-Pole, Single-Throw	SEC	Secondary
DT	Double Throw	SOL	Solenoid
F	Forward	SP	Single-Pole
FREQ	Frequency	SPDT	Single-Pole, Double Throw
FTS	Foot Switch	SPST	Single-Pole, Single Throw
FU	Fuse	SS	Selector Switch
GEN	Generator	SSW	Safety Switch
GRD	Ground	T	Transformer
HOA	Hand/Off/Auto Selector Switch	TB	Terminal Board
IC	Integrated Circuit	TD	Time Delay
INTLK	Interlock	THS	Thermostat Switch
IOL	Instanstaneous Overload	TR	Time Delay Relay
JB	Junction Box	U	Up
LS	Limit Switch	UV	Under Voltage
LT	Lamp	VFD	Variable Frequency Drive
M	Motor Starter	XFR	Transformer

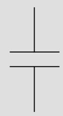
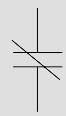
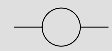
Review 1

1. A control is ____________ operated when someone must initiate an action for the circuit to operate.

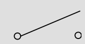
2. Which of the following symbols represents a normally open contact?

   a.  b.  c. 

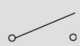
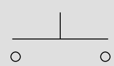
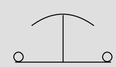
3. Which of the following symbols represents a normally closed contact?

   a.  b.  c. 

4. Which of the following symbols indicates a normally open pushbutton?

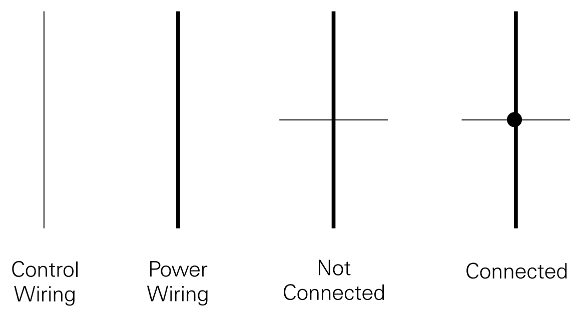
   a.  b.  c. 

5. Which of the following symbols indicates a mushroom head pushbutton?

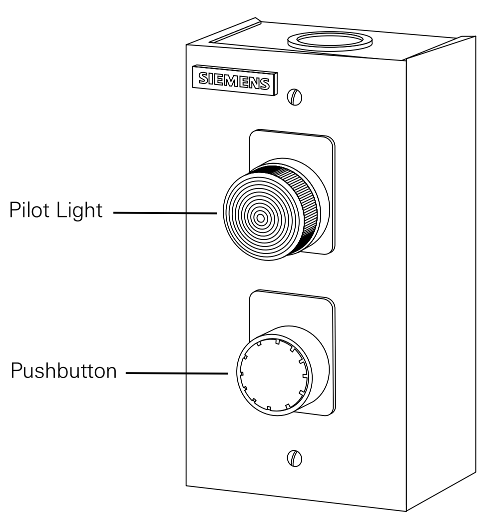
   a.  b.  c. 

Line Diagrams

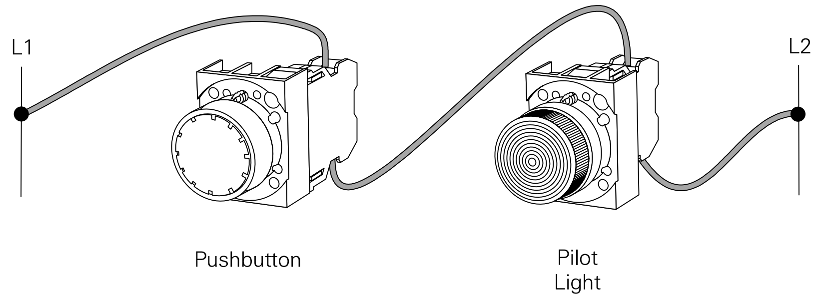
The method of expressing the language of control symbols is a line diagram, also referred to as a ladder diagram. Line diagrams are made up of two circuits, the control circuit and the power circuit. Electrical wires in a line diagram are represented by lines. Control-circuit wiring is represented by a lighter-weight line and power-circuit wiring is represented by a heavier-weight line. A small dot or node at the intersection of two or more wires indicates an electrical connection.



Line diagrams show the functional relationship of components and devices in an electrical circuit, not the physical relationship. For example, the following illustration shows the physical relationship of a pilot light and a pushbutton.

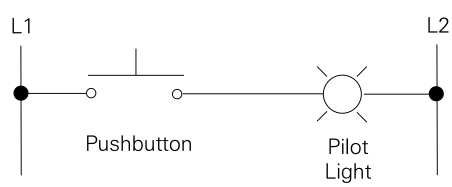


The functional relationship can be shown pictorially with the following illustration.



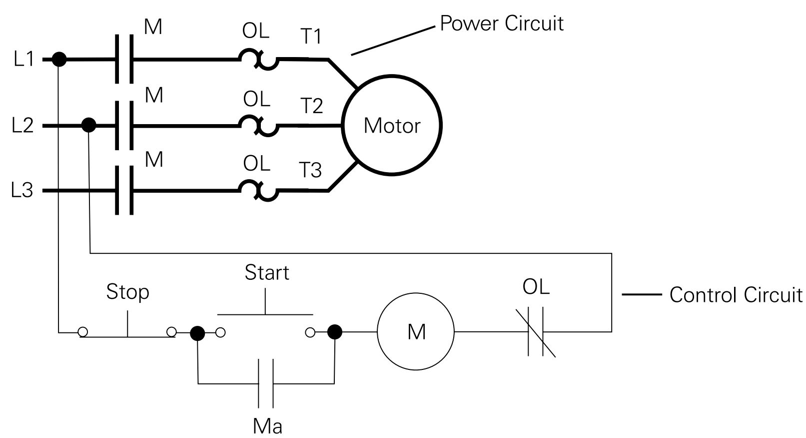
Reading a Line Diagram

This functional relationship is shown symbolically with a line diagram. Line diagrams are read from left to right. Depressing the pushbutton would allow current to flow from L1 through the pushbutton, illuminating the pilot light, to L2. Releasing the pushbutton stops current flow turning the pilot light off.



Power Circuit and Control Circuit

The power circuit, indicated by the heavier-weight line, is what actually distributes power from the source to the connected load (motor). The control circuit, indicated by the lighter-weight line, is used to “control” the distribution of power.



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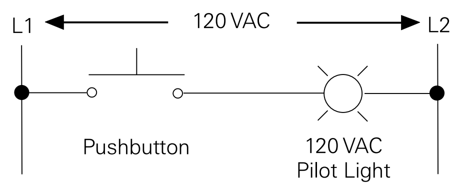
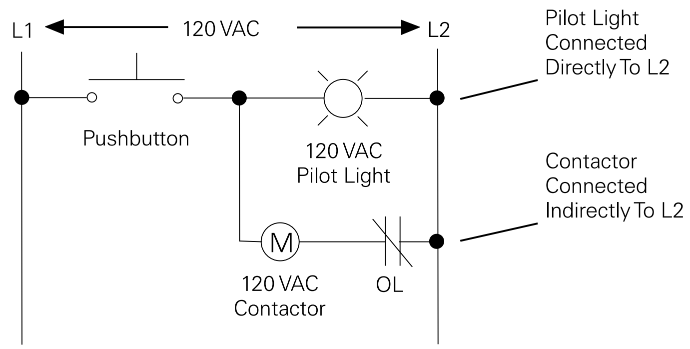
Connecting Loads and Control Devices

Control circuits are made up of control loads and control devices. The control load is an electrical device that uses electrical power. Pilot lights, relays, and contactors are examples of control loads. Control devices are used to activate the control load. Pushbuttons and switches are examples of control devices. The following illustration shows the proper connection of a pilot light (load) with a pushbutton (control device). The power lines are drawn vertically and marked L1 and L2. In this example the voltage potential between L1 and L2 is 120 VAC. The pilot light selected must be rated for 120 VAC. When the pushbutton is depressed, the full 120 volt potential is applied to the pilot light.



Connecting the Load to L2

Only one control load should be placed in any one circuit line between L1 and L2. One side of the control load is connected to L2 either directly or, in some instances, through overload relay contacts. In the following example a pilot light is directly connected to L2 on one circuit line. A contactor coil is indirectly connected through a set of overload contacts (OL) to L2 on a second circuit line. This is a parallel connection. Depressing the pushbutton would apply 120 VAC to the pilot light and the “ M ” contactor.



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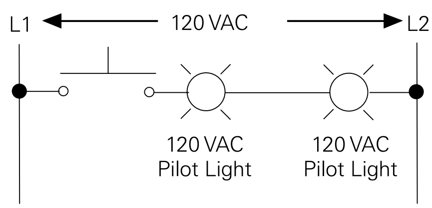
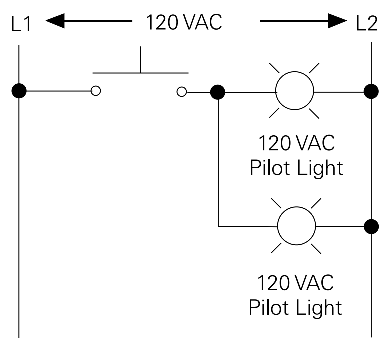
Control loads are generally not connected in series. The following illustration shows two ways to connect a control load. In one instance the control loads are improperly connected in series. When the pushbutton is depressed, the voltage across L1 and L2 is divided across both loads, the result being that neither load will receive the full 120 volts necessary for proper operation. If one load fails in this configuration, the entire circuit is rendered useless.

In the other instance the loads are properly connected in parallel. In this circuit there is only one load for each line between L1 and L2. The full 120 volts will appear across each load when the pushbutton is depressed. If one load fails in this configuration, the other load will continue to operate normally.

Improper Series Connection

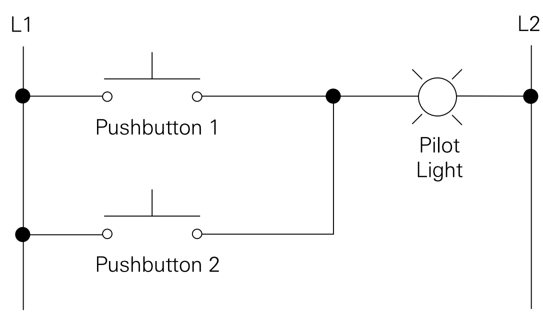


Proper Parallel Connection

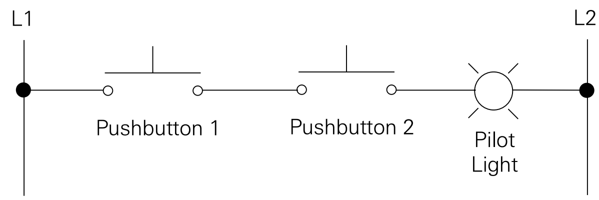


Connecting Control Devices

Control devices are connected between L1 and the load. The control device can be connected in series or parallel, depending on the desired results. In the following illustration, the pushbuttons are connected in parallel. Depressing either pushbutton will allow current to flow from L1, through the depressed pushbutton, through the pilot light, to L2.

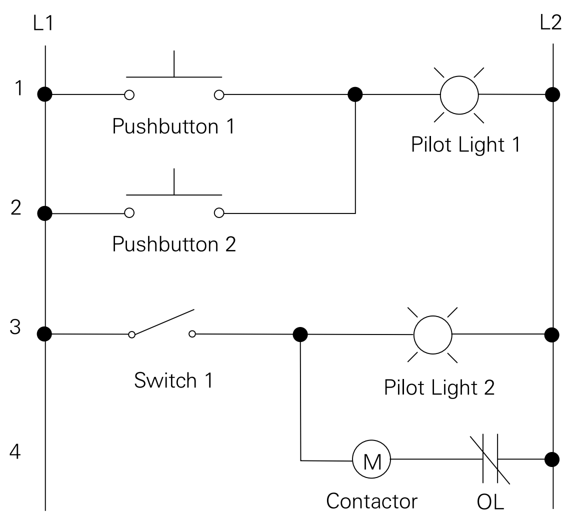


In the following illustration, two pushbuttons are connected in series. Both pushbuttons must be depressed in order to allow current to flow from L1 through the load to L2.



Line Numbering

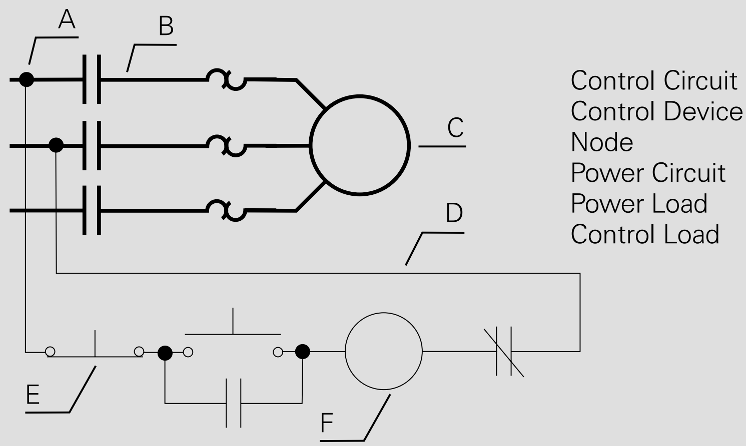
Numbering each line makes it easier to understand more complex line diagrams. In the following illustration, line 1 connects pushbutton 1 to pilot light 1. Line 2 connects pushbutton 2 to pilot light 1. Line 3 connects switch 1 to pilot light 2 and the "M" contactor on line 4.



Review 2

1. Line diagrams are read from ____________ to ____________ , or L1 to L2.

2. Match the items on the line diagram with the associated list.



A ____________

B ____________

C ____________

D ____________

E ____________

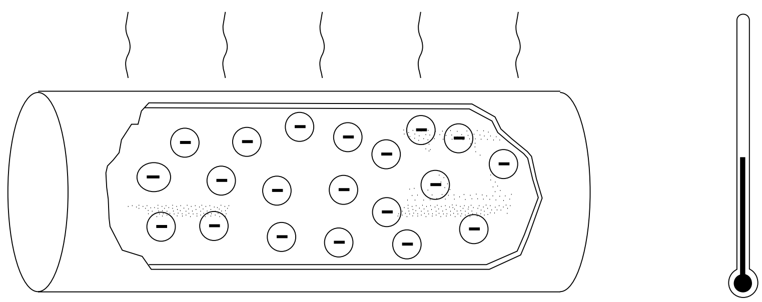
F ____________

Overload Protection

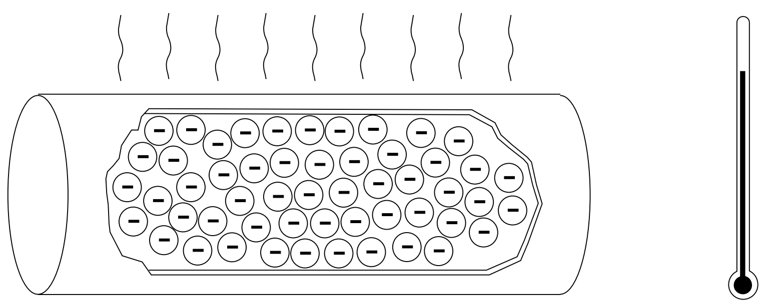
Before discussing specific control components, it is necessary to review what an overload is and what steps can be taken to limit the damage an overload can cause.

Current and Temperature

Current flow in a conductor always generates heat due to resistance. The greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Overcurrent protection devices are used to protect conductors from excessive current flow. Thermal overload relays are designed to protect the conductors (windings) in a motor. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating.



Normal Current Flow



Excessive Current Flow

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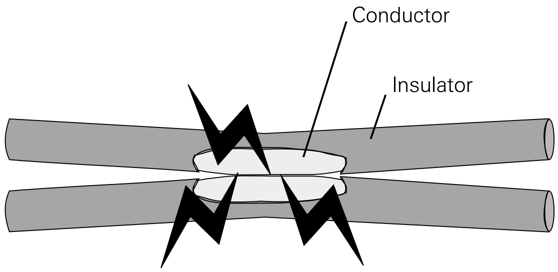
Excessive current is referred to as overcurrent. The *National Electrical Code®* defines overcurrent as *any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault* (Article 100-definitions).

Short Circuits

When two bare conductors touch, a short circuit occurs. When a short circuit occurs, resistance drops to almost zero. Short-circuit current can be thousands of times higher than normal operating current.



Ohm's Law demonstrates the relationship of current, voltage, and resistance. For example, a 240 volt motor with 24 ohms of resistance would normally draw 10 amps of current.

$$I = \frac{E}{R}$$

$$I = \frac{240}{24}$$

$$I = 10 \text{ amps}$$

When a short circuit develops, resistance drops. If resistance drops to 24 milliohms, current will be 10,000 amps.

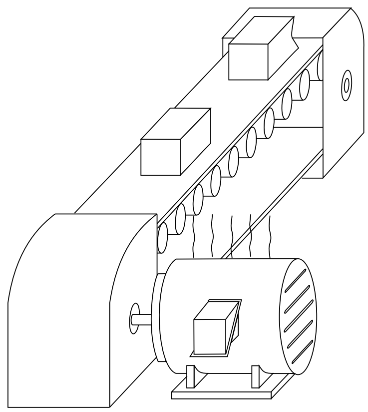
$$I = \frac{240}{0.24}$$

$$I = 10{,}000 \text{ amps}$$

The heat generated by this current will cause extensive damage to connected equipment and conductors. This dangerous current must be interrupted immediately when a short circuit occurs.

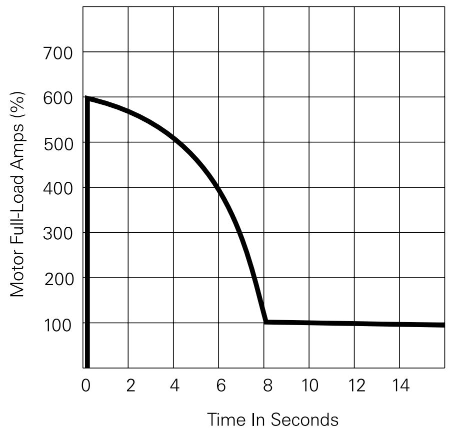
Overload Conditions

An overload occurs when too many devices are operated on a single circuit or a piece of electrical equipment is made to work harder than it is designed for. For example, a motor rated for 10 amperes may draw 20, 30, or more amperes in an overload condition. In the following illustration a package has become jammed on a conveyor causing the motor to work harder and draw more current. Because the motor is drawing more current it heats up. Damage will occur to the motor in a short time if the problem is not corrected or the circuit is not shut down by the overload relay.



Temporary Overload Due to Starting Current

Electric motors are rated according to the amount of current they will draw at full load. When most motors start, they draw current in excess of the motor's full-load current rating. Motors are designed to tolerate this overload current for a short period of time. Many motors require 6 times (600%) the full-load current rating to start. Some newer, high-efficiency motors may require higher starting currents. As the motor accelerates to operating speed, the current drops off quickly. The time it takes for a motor to accelerate to operating speed depends on the operating characteristics of the motor and the driven load. A motor, for example, might require 600% of full-load current and take 8 seconds to reach operating speed.



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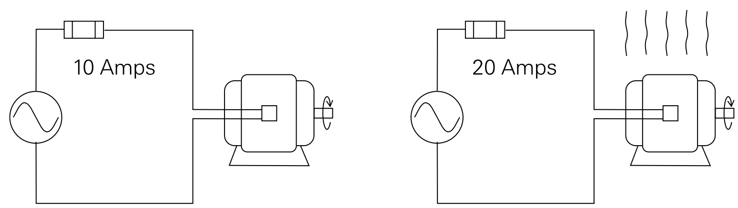
Overload Protection

Fuses and circuit breakers are protective devices used to protect circuits against short circuits, ground faults, and overloads. In the event of a short circuit, a properly sized fuse or circuit breaker will immediately open the circuit.

There is, however, a dilemma that occurs when applying fuses and circuit breakers in motor control circuits. The protective device must be capable of allowing the motor to exceed its full-load rating for a short time. Otherwise, the motor will trip each time it is started. In this situation it is possible for a motor to encounter an overload condition which does not draw enough current to open the fuse or trip the circuit breaker. This overload condition could easily cause enough heat to damage the motor. In the next section we will see how overload relays are used to solve this problem.



Normal Current **Overload Current**

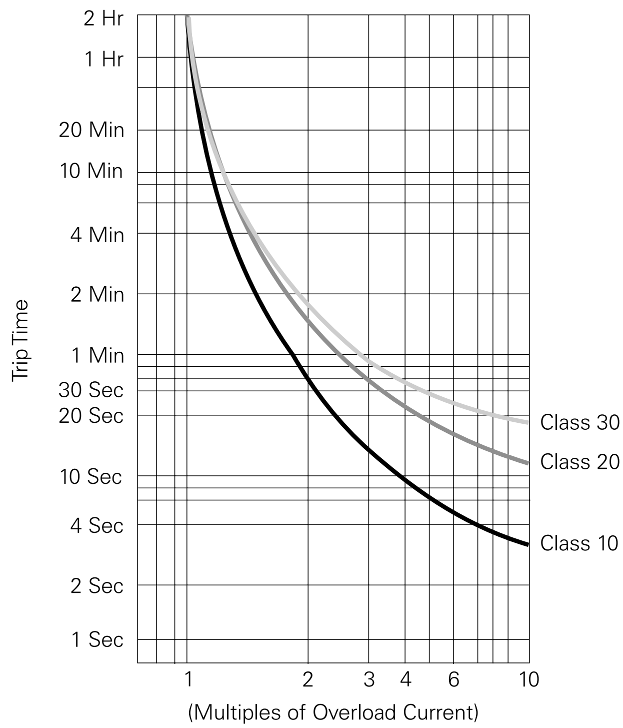
Overload Relays

Overload relays are designed to meet the special protective needs of motor control circuits. Overload relays:

- allow harmless temporary overloads, such as motor starting, without disrupting the circuit
- will trip and open a circuit if current is high enough to cause motor damage over a period of time
- can be reset once the overload is removed

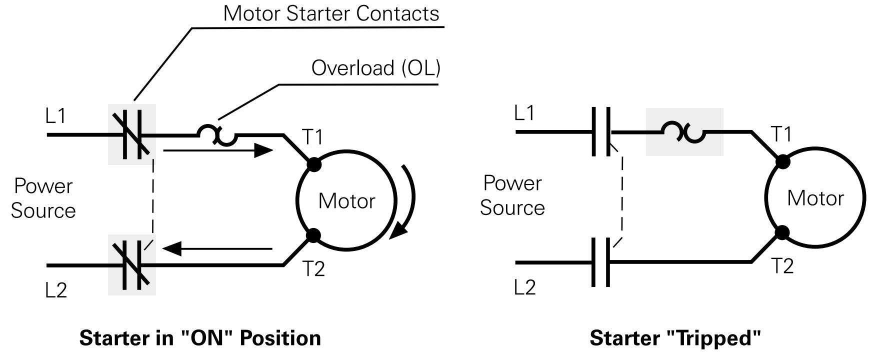
Trip Class

Overload relays are rated by a trip class, which defines the length of time it will take for the relay to trip in an overload condition. The most common trip classes are Class 10, Class 20 and Class 30. Class 10, for example, has to trip the motor off line in 10 seconds or less at 600% of the full load amps. This is usually sufficient time for the motor to reach full speed. Many industrial loads, particularly high inertia loads, use Class 30. Siemens standard overload relays are Class 10 or Class 20 with Class 30 available with some starters.



Overload Relay in a Motor Circuit

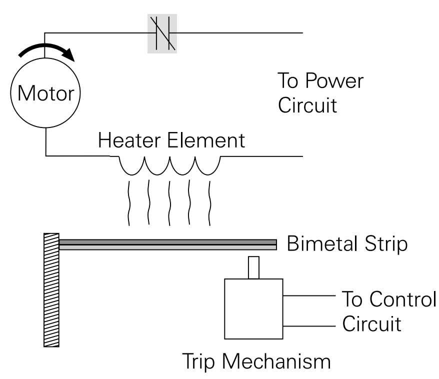
The following illustration shows a motor circuit with a manual starter and overloads. Current flows through the overloads while the motor is running. Excess current will cause the overload to trip at a predetermined level, opening the circuit between the power source and the motor. After a predetermined amount of time the starter can be reset. When the cause of the overload has been identified and corrected the motor can be restarted.



Bimetal Overloads

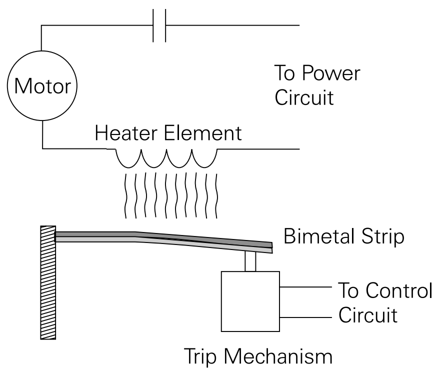
Overload protection is accomplished with the use of a bimetal strip. This component consists of a small heater element wired in series with the motor and a bimetal strip that can be used as a trip lever. A bimetal strip is made of two dissimilar metals bonded together. The two metals have different thermal expansion characteristics, so the bimetal bends at a given rate when heated.

Under normal operating conditions the heat generated by the heater element will be insufficient to cause the bimetal strip to bend enough to trip the overload relay.



Normal Current Flow

As current rises, heat also rises. The hotter the bimetal becomes, the more it bends. In an overload condition the heat generated from the heater will cause the bimetal strip to bend until the mechanism is tripped, stopping the motor.



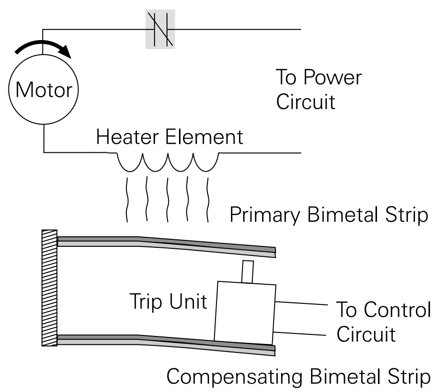
Overload Condition

Some overload relays that are equipped with a bimetal strip are designed to automatically reset the circuit when the bimetal strip has cooled and reshaped itself, restarting the motor. If the cause of the overload still exists, the motor will trip again and reset at given intervals. Care must be exercised in the selection of this type of overload as repeated cycling will eventually damage the motor.

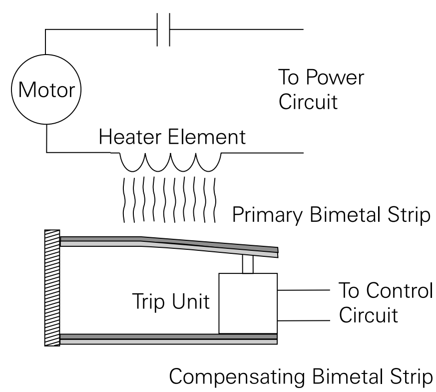
Ambient Compensated Overload Relay

In certain applications, such as a submersible pump, the motor may be installed in a location having a constant ambient temperature. The motor control, along with the overload relay, may be installed in a location with a varying ambient temperature. The trip point of the overload relay will vary with the temperature of the surrounding air as well as current flowing through the motor. This can lead to premature and nuisance tripping.

Ambient compensated overload relays are designed to overcome this problem. A compensated bimetal strip is used along with a primary bimetal strip. As the ambient temperature changes, both bimetal strips will bend equally and the overload relay will not trip the motor. However, current flow through the motor and the heater element will affect the primary bimetal strip. In the event of an overload condition the primary bimetal strip will engage the trip unit.



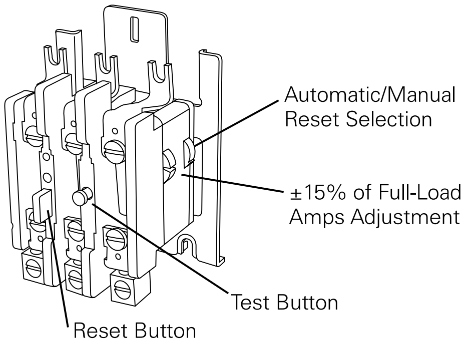
Ambient Compensated Overload Relay Affected By Ambient Temperature



Ambient Compensated Overload Relay Affected By Motor Temperature

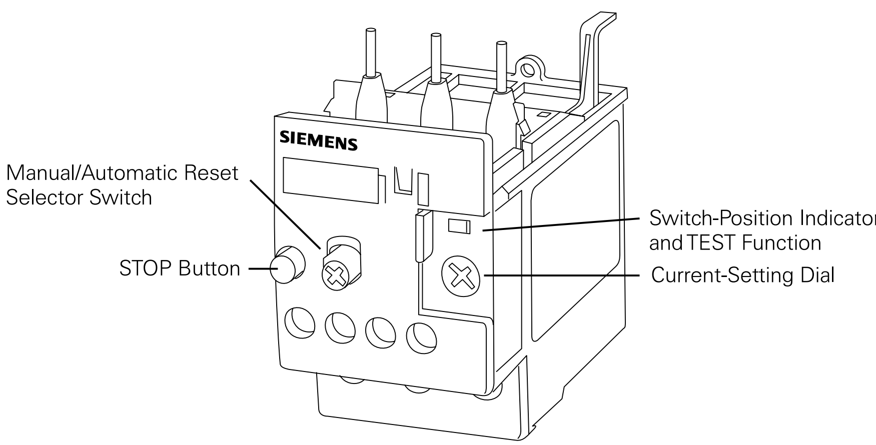
Class 48 Bimetal Ambient Compensated Overload Relay

The Class 48 bimetal ambient compensated overload relay is available in single-pole or three-pole designs. Unlike the melting alloy overload relay, the bimetal ambient compensated overload relay can be set for manual or self-resetting operation. An adjustment dial located on the unit allows the ampere trip setting to be adjusted by ±15%. The bimetal ambient compensated overload relay heater elements are available in Class 20 or Class 10 ratings. A normally open or normally closed auxiliary contact is available as an option.



SIRIUS 3RU11 Overload Relay

The Siemens SIRIUS 3RU11 is a bimetal type of overload relay with the heater elements as an integral part of the design. The unit comes with a Class 10 trip as standard. The SIRIUS 3RU11 features manual or automatic reset, adjustable current settings, and ambient compensation. A switch-position indicator also incorporates a test function which is used to simulate a tripped overload relay. A normally open and a normally closed auxiliary contact are included.

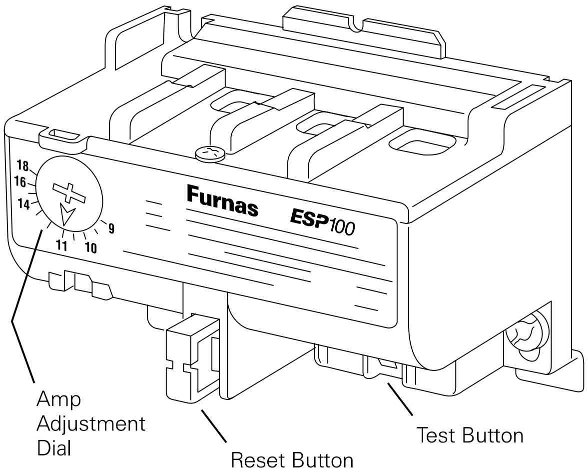


Electronic Overload Relays

Electronic overload relays are another option for motor protection. The features and benefits of electronic overload relays vary but there are a few common traits. One advantage offered by electronic overload relays is a heaterless design. This reduces installation cost and the need to stock a variety of heaters to match motor ratings. Electronic relays offer phase loss protection. If a power phase is lost, motor windings can burn out very quickly. Electronic overload relays can detect a phase loss and disconnect the motor from the power source. This feature is not available on mechanical types of overload relays.

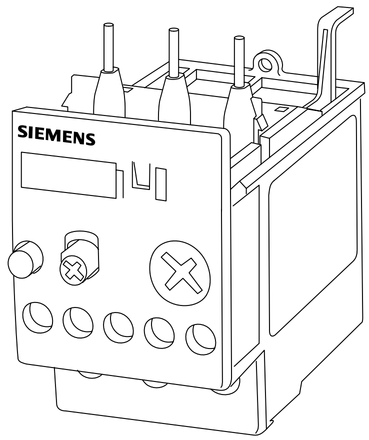
Furnas ESP 100 Electronic Overload Relay

A single ESP100 overload relay replaces at least six size ranges of heaters. Instead of installing heaters the full-load amperes (FLA) of the motor is set with a dial. The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amperes. NEMA Class 10, 20, and 30 trip curves are available for a variety of applications. The relay comes in either a manual or self-resetting version. Auxiliary contacts are available as an option.



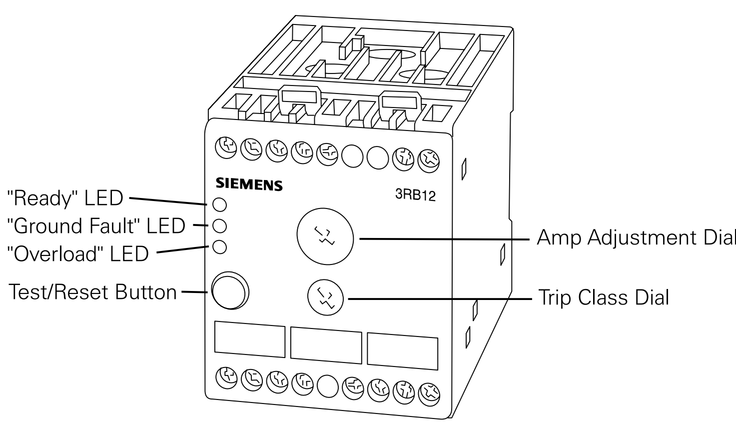
Siemens 3RB10 Electronic Overload Relay

The Siemens SIRIUS 3RB10 is an electronic overload relay with a design very similar to the ESP 100. The unit comes with a Class 10 or Class 20 trip. The 3RB10 features manual or automatic reset, adjustable current settings, and ambient compensation. A switch-position indicator also incorporates a test function which is used to simulate a tripped overload relay. A normally open and a normally closed auxiliary contact are included.



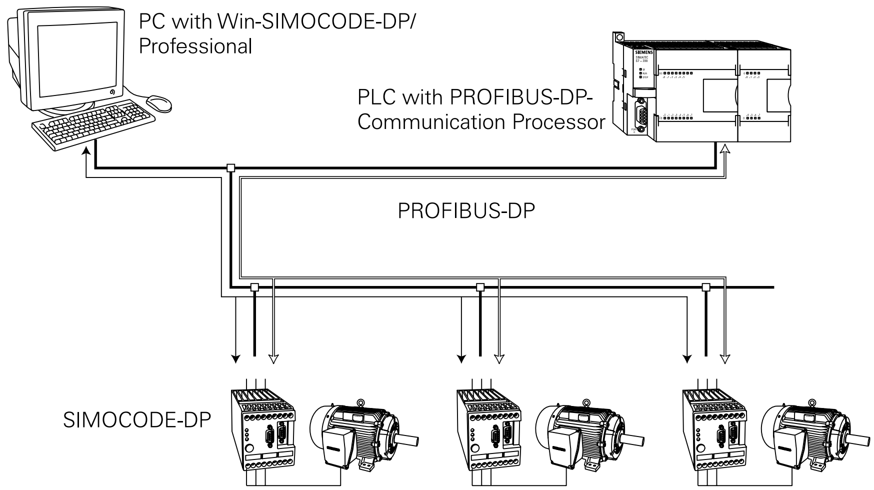
Siemens 3RB12 Electronic Overload Relay

In addition to heaterless construction and phase loss protection, the 3RB12 offers ground fault protection, phase unbalance, LED displays (ready, ground fault, and overload), automatic reset with remote capability, and selectable trip classes (5, 10, 15, 20, 25, or 30). The 3RB12 is self-monitoring and is provided with 2 normally open and 2 normally closed isolated auxiliary contacts.



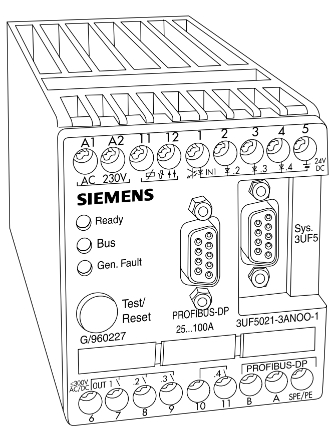
PROFIBUS DP

In any complex process the need for rapid information flow is critcal. PROFIBUS DP is an open communication system based upon international standards developed through industry associations. PROFIBUS DP allows the connection of several field devices, such as SIMOCODE-DP, on a single bus for communication to a PLC or computer. PROFIBUS DP is suitable as a replacement for costly parallel wiring.



3UF5 SIMOCODE-DP

The 3UF5 SIMOCODE-DP overload relay integrates with PROFIBUS-DP. SIMOCODE-DP protects the load against overload, phase failure, ground fault, and current imbalance. SIMOCODE-DP can be parametrized, controlled, observed, and tested from a central source such as a PC with Win-SIMOCODE-DP/Professional installed, or a PLC with a PROFIBUS-DP communication processor. The 3UF50 basic unit can also be used as an autonomous solid-state overload relay for motor protection. A trip class in six steps from Class 5 to Class 30 can be selected. The basic unit (shown) is supplied with four inputs and four outputs. An available expansion unit provides eight additional inputs and four additional outputs.



Review 3

1. With an increase in current, heat will ___________ .

   a. increase
   b. decrease
   c. remain the same

2. The *National Electrical Code®* defines overcurrent as *any current in* ___________ *of the rated current of equipment or the ampacity of a conductor*.

3. An ___________ occurs when electrical equipment is required to work harder than it is rated.

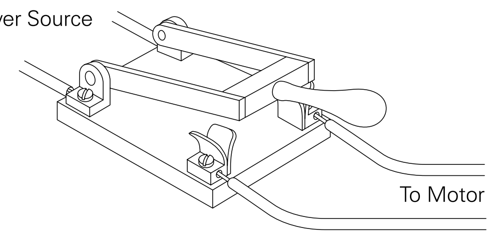
4. A Class _________ overload relay will trip an overloaded motor offline within 10 seconds at six times full-load amps.

   a. 10
   b. 20
   c. 30

5. A ___________ strip uses two dissimilar metals bonded together.

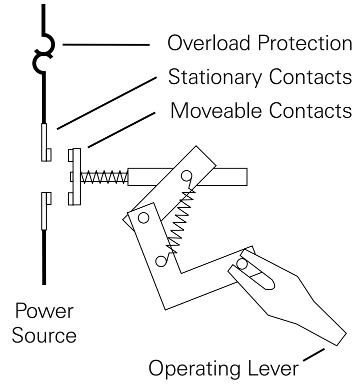
Manual Control

Manual control, as the name implies, are devices operated by hand. A simple knife switch, like the one shown in the following illustration, was the first manual-control device used to start and stop motors. The knife switch was eventually replaced with improved control designs, such as manual and magnetic starters.

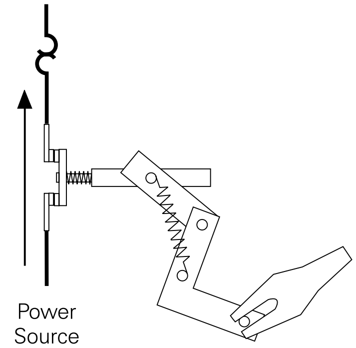


Basic Operation

The *National Electrical Code® requires* that a motor control device must also protect the motor from destroying itself under overload conditions. Manual starters, therefore, consist of a manual contactor, such as a simple switch mechanism, and a device for overload protection. The following diagram illustrates a single-pole manual motor starter. Each set of contacts is called a pole. A starter with two sets of contacts would be called a two-pole starter.



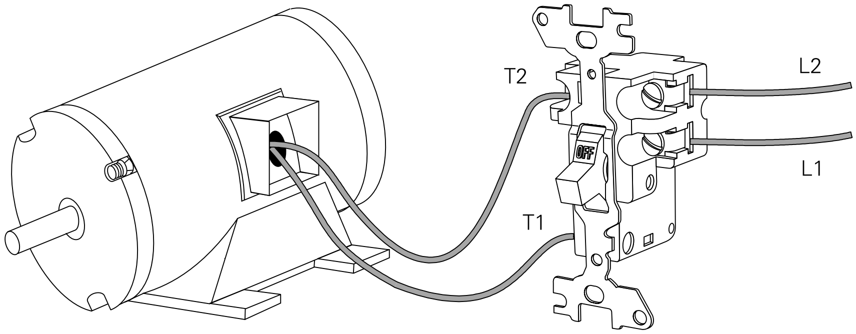
Switch in "OFF" Position



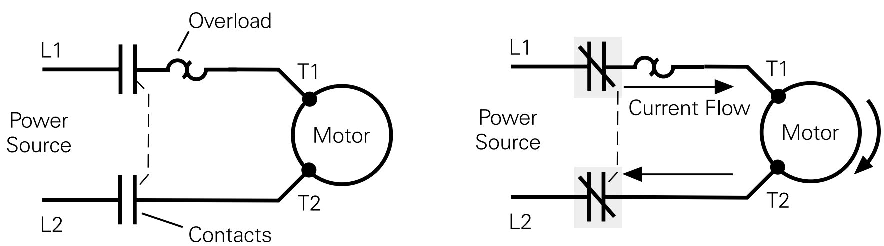
Switch in "ON" Position

Two-Pole Manual Starter

Starters are connected between the power source and the load. For example, a two-pole or single-phase motor starter is connected to a motor. When the switch is in the “OFF” position, the contacts are open preventing current flow to the motor from the power source. When the switch is in the “ON” position, the contacts are closed and current flows from the power source (L1), through the motor, returning to the power source (L2).



This is represented with a line drawing and symbols as illustrated in the following drawing.



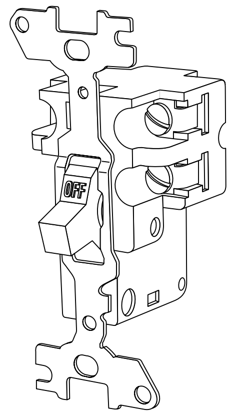
Starter in "OFF" Position **Starter in "ON" Position**

Low Voltage Protection

Some manual motor starters offer low-voltage protection (LVP) as an option. LVP will automatically remove power from the motor when incoming power drops or is interrupted. The starter must be manually reset when power is restored. This protects personnel from potential injury caused by machinery that may otherwise automatically restart when power is restored.

SMF Fractional-Horsepower Manual Starters

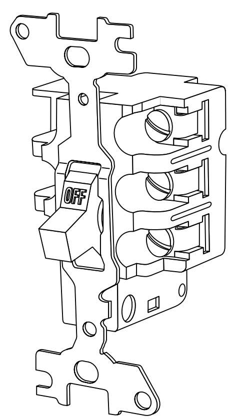
Siemens SMF fractional-horsepower starters provide overload protection and manual “ON/OFF” control for small motors. SMF starters are available in one- or two-pole versions suitable for AC motors up to 1 HP and 277 VAC. The two-pole version is suitable for DC motors up to 3/4 HP and 230 VDC. SMF manual starters are available in a variety of enclosures. A two-speed version is available.



Two-Pole Manual Starter

MMS and MRS Manual Switches

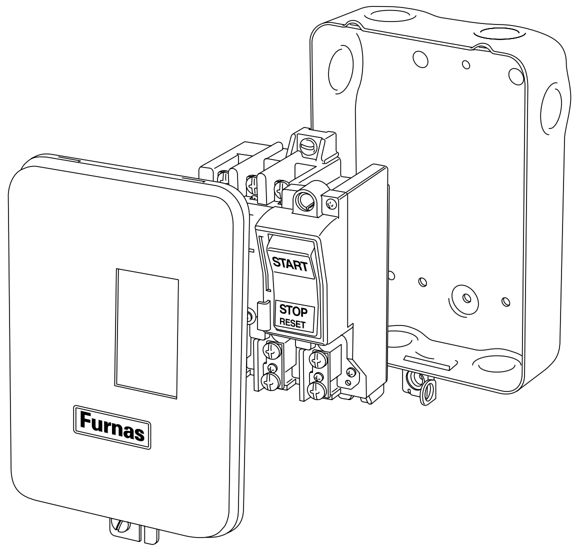
Siemens MMS and MRS manual switches are similar to SMF starters but do not provide overload protection. MMS and MRS switches only provide manual “ON/OFF” control of single- or three-phase AC motors where overload protection is provided separately. These devices are suitable for use with three-phase AC motors up to 10 HP and 600 VAC and up to 1-1/2 HP and 230 VDC. The MMS and MRS manual switches are available in various enclosures. Two-speed and reversing versions are available.



Three-Pole Manual Switch

Furnas Class 11 Manual Starter and Manual Contactor

Furnas Class 11 manual starters use a melting-alloy overload relay with interchangeable heater elements and a manual reset. It has a maximum rating of 10 HP at 460 VAC (3Ø) and 5 HP at 230 VAC (1Ø). Class 11 manual starters are available in a complete line of general-purpose and industrial-duty enclosures. Class 11 manual starters may also be furnished with a low-voltage protection circuit. Class 11 manual contactors provide no overload protection.



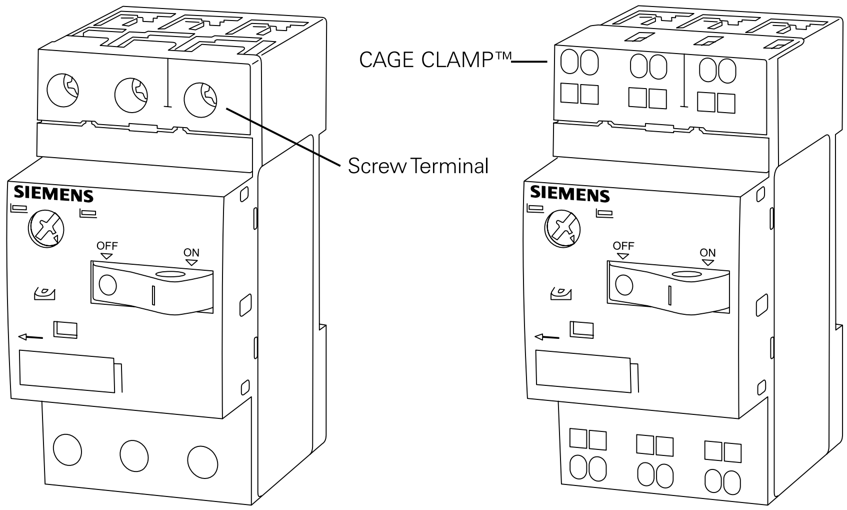
3RV10 Motor Starter Protectors

3RV10 motor starter protectors (MSPs) are part of the Siemens SIRIUS 3R motor control product line. A thermal overload with a bimetal strip is used to provide overload protection with the 3RV10 motor starter protector. 3RV10 MSPs come in four frame sizes: 3RV101, 3RV102, 3RV103, and 3RV104.

Frame	Max Current at 460 VAC	Max HP at 460 VAC
3RV101	12 Amps	7.5
3RV102	25 Amps	20
3RV103	50 Amps	40
3RV104	100 Amps	75

Toggle Full Screen Close REV FWD

The 3RV101 is available in both screw-terminal and CAGE CLAMP™ versions. The 3RV102, 3RV103, and 3RV104 are available with screw terminals.

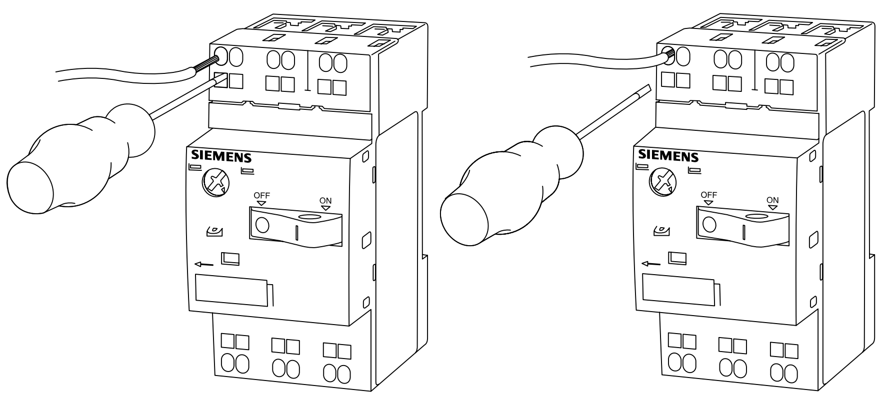


3RV101 with Screw Terminal

3RV101 with Cage Clamp

CAGE CLAMP™

The CAGE CLAMP™ is available on many Siemens SIRIUS 3R products including the MSPs. To connect a wire, simply push an electrician blade screwdriver into the appropriate portal, insert the stripped end of the wire into the portal directly above, remove the screwdriver, and the wire is securely connected. CAGE CLAMP™ devices are especially beneficial in installations that are subject to vibration.

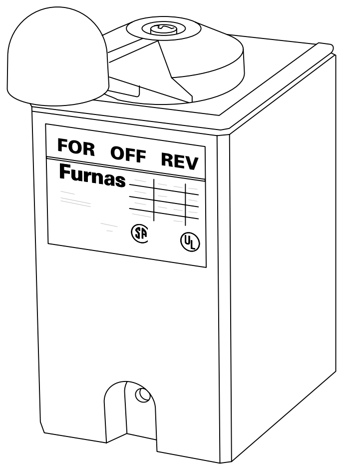


Enclosures and Options

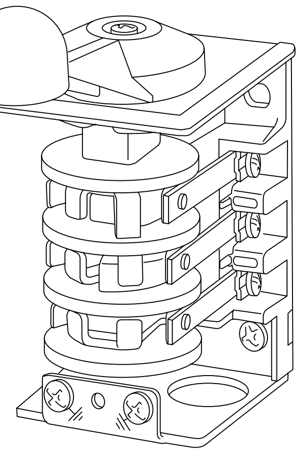
Siemens 3RV10 MSPs are available in a variety of enclosures. Several options, such as indicator lights, are also available.

Reversing Drum Controller

Manually operated drum controllers, like the Furnas Class 58 reversing drum controller, stop and change direction of reversible AC motors. Overload protection is not provided by the reversing drum controller and must be supplied by an external means. The Furnas Class 58 reversing drum controller is rated for 10 HP at 460 VAC. Another style of drum switch is used to change speed of multi-speed motors.



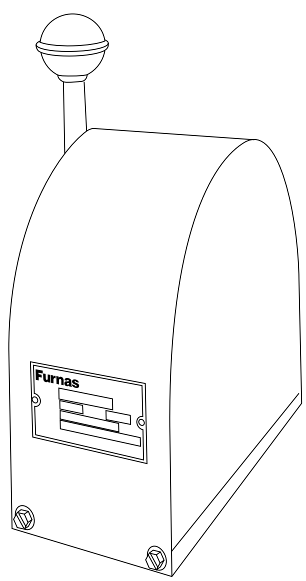
Reversing Drum Controller



Reversing Drum Controller
With Cover Removed

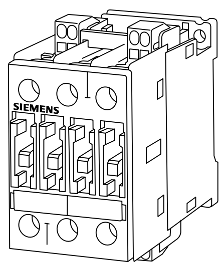
Master Switch

The Furnas Class 53 master switches provide single-handle control of hoists, cranes, oven pushers, and other equipment requiring speed steps of wound rotor or direct-current motors. Master switches are available with momentary or maintained contacts and up to five speed settings.

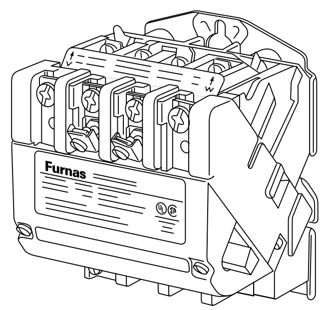


Magnetic Contactors and Starters

Most motor applications require the use of remote control devices to start and stop the motor. Magnetic contactors, similar to the ones shown below, are commonly used to provide this function. Contactors are also used to control distribution of power in lighting and heating circuits.



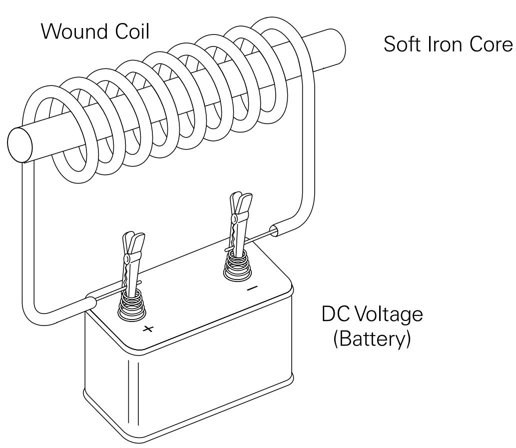
Sirius 3R



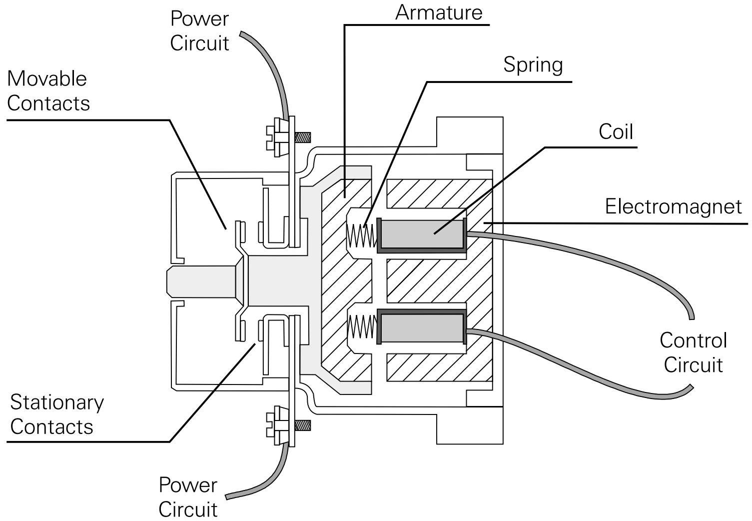
INNOVA Series

Basic Contactor Operation

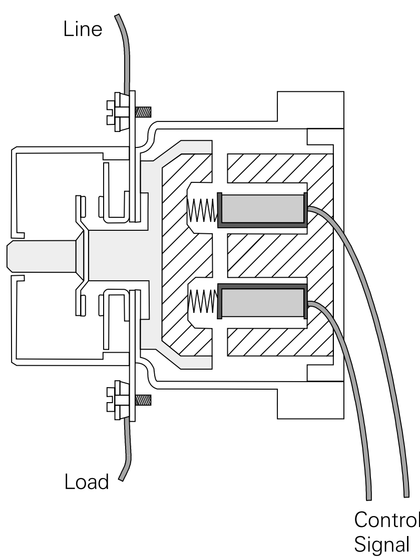
Magnetic contactors operate utilizing electromagnetic principles. A simple electromagnet can be fashioned by winding a wire around a soft iron core. When a DC voltage is applied to the wire, the iron becomes magnetic. When the DC voltage is removed from the wire, the iron returns to its nonmagnetic state. This principle is used to operate magnetic contactors.



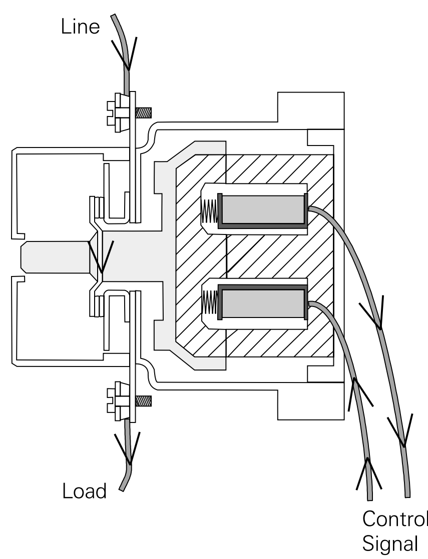
The following illustration shows the interior of a basic contactor. There are two circuits involved in the operation of a contactor: the control circuit and the power circuit. The control circuit is connected to the coil of an electromagnet, and the power circuit is connected to the stationary contacts.



The operation of this electromagnet is similar to the operation of the electromagnet we made by wrapping wire around a soft iron core. When power is supplied to the coil from the control circuit, a magnetic field is produced magnetizing the electromagnet. The magnetic field attracts the armature to the magnet, which in turn closes the contacts. With the contacts closed, current flows through the power circuit from the line to the load. When the electromagnet's coil is deenergized, the magnetic field collapses and the movable contacts open under spring pressure. Current no longer flows through the power circuit.

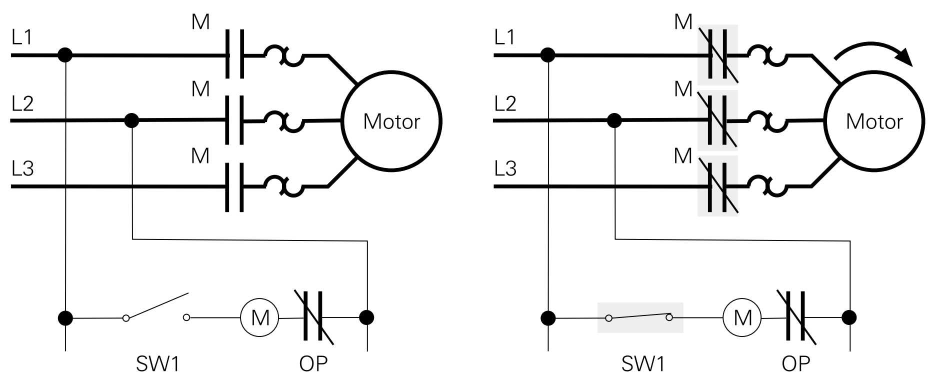


Contactor Deenergized



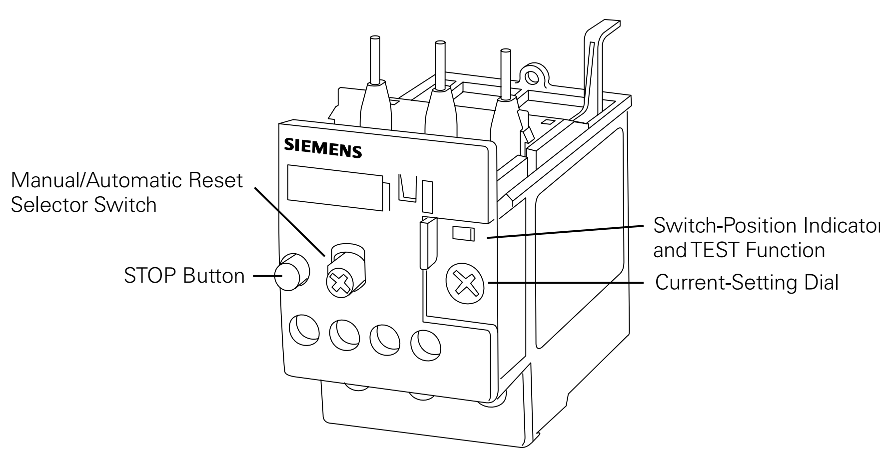
Contactor Energized

The following schematic shows the electromagnetic coil of a contactor connected to the control circuit through a switch (SW1). The contacts of the contactor are connected in the power circuit to the AC line and a three-phase motor. When SW1 is closed, the electromagnetic coil is energized, closing the "M" contacts and applying power to the motor. Opening SW1 deenergizes the coil and the "M" contacts open, removing power from the motor.



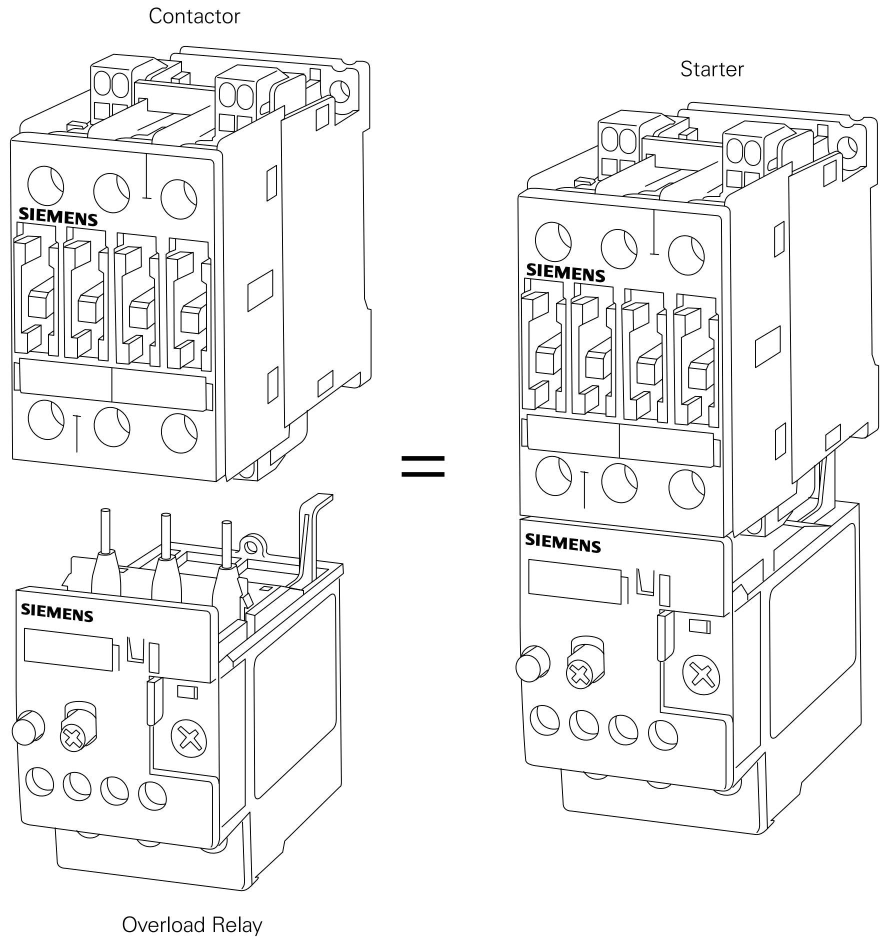
Overload Relay

Contactors are used to control power in a variety of applications. When applied in motor-control applications, contactors can only start and stop motors. Contactors cannot sense when the motor is being loaded beyond its rated conditions. They provide no overload protection. Most motor applications require overload protection. However, some smaller-rated motors have overload protection built into the motor (such as a household garbage disposal). Overload relays, similar to the one shown below, provide this protection. The operating principle, using heaters and bimetal strips, is similar to the overloads discussed previously.



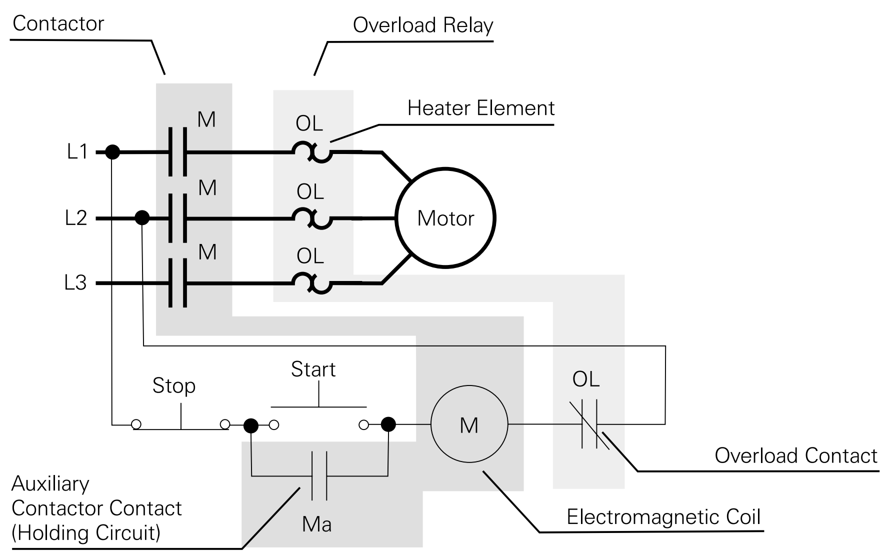
Motor Starter

Contactors and overload relays are separate control devices. When a contactor is combined with an overload relay, it is called a motor starter.



Motor Starter in a Control Circuit

The following diagram shows the electrical relationship of the contactor and overload relay. The contactor, highlighted with the darker grey, includes the electromagnetic coil, the main motor contacts, and the auxiliary contacts. The overload relay, highlighted by the lighter grey, includes the "OL" heaters and overload contacts. The contactor and the overload relay have additional contacts, referred to as auxiliary contacts, for use in the control circuit. In this circuit a normally closed "OL" contact has been placed in series with the "M" contactor coil and L2. A normally open "M" auxiliary contact ("Ma") has been placed in parallel with the "Start" pushbutton.



Review 4

1. A starter with two sets of contacts would be called a ___________ -pole starter.

2. ___________ will automatically disconnect power from the motor when incoming power drops or is interrupted.

3. The Furnas Class 11 motor starter protects motors up to ___________ HP at 460 VAC and ___________ HP at 230 VAC.

4. The 3RV102 motor starter protector protects motors up to ___________ HP at 460 VAC.

5. When a contactor is combined with an overload relay, it is called a ___________ ___________ .

Toggle Full Screen | Close | REV | FWD

Starter Ratings

Starter contactors are rated according to size and type of load they handle. The National Electrical Manufacturers Association (NEMA) and the International Electrotechnical Commission (IEC) are two organizations that rate contactors and motor starters. NEMA is primarily associated with equipment used in North America. IEC, on the other hand, is associated with equipment sold in many countries including the United States. International trade agreements, market globalization, and domestic and foreign competition have made it important for controls manufacturers to be increasingly aware of international standards.

NEMA

NEMA ratings are maximum horsepower ratings, according to the National Electrical Manufacturers Association ICS2 standards. NEMA starters and contactors are selected according to their NEMA size. These sizes range from size 00 to size 9.

NEMA Size	Continuous Amp Rating	HP 230 VAC	HP 460 VAC
00	9	1	2
0	18	3	5
1	27	7	10
2	45	15	25
3	90	30	50
4	135	50	100
5	270	100	200
6	540	200	400
7	810	300	600
8	1215	450	900
9	2250	800	1600

NEMA motor-control devices have generally become known for their very rugged, heavy-duty construction. Because of their rugged design NEMA devices are physically larger than IEC devices. NEMA motor starters and contactors can be used in virtually any application at their stated rating, from simple "ON" and "OFF" applications to more-demanding applications that include plugging and jogging. To select a NEMA motor starter for a particular motor one need only know the horsepower and voltage of the motor. If there is considerable plugging and jogging duty involved, however, even a NEMA-rated device will require some derating.

Motor Matched Sizes

Siemens also has what are called Motor Matched sizes available on some Siemens motor starters. The ratings for these devices fall in between the ratings of normal NEMA sizes. This allows the user to more closely match the motor control to the actual application. The following table shows Motor Matched sizes available.

MM Size	Continuous AMP Rating	HP 230 VAC	HP 460 VAC
1¾	40	10	15
2½	60	20	31
3½	115	40	75
4½	210	75	150

IEC

Not all applications require a heavy-duty industrial starter. In applications where space is more limited and the duty cycle is not severe, IEC devices represent a cost-effective solution. IEC devices are rated for maximum operational current as specified by the International Electrotechnical Commission in publication IEC 158-1. IEC does not specify sizes. Utilization categories are used with IEC devices to define the typical duty cycle of an IEC device. AC-3 and AC-4 are the categories of most interest for general motor-starting applications.

Utilization Category	IEC Category Description
AC1	Non-inductive or slightly inductive loads.
AC2	Starting of slip-ring motors
AC3	Starting of squirrel-cage motors and switching off only after the motor is up to speed. (Make LRA, Break FLA)
AC4	Starting of squirrel-cage motors with inching and plugging duty. Rapid Start/Stop. (Make and break LRA)
AC11	Auxiliary (control) circuits.

Definite Purpose

Definite Purpose (DP) contactors have certain characteristics which must be taken into consideration. DP contactors were designed for specific applications where the operating conditions are clearly defined. These operating conditions include full load amps, locked rotor amps, noninductive amps (resisitive load), number of power poles, duty cycle, and the total number of expected operations.

DP contactors are sized by the motor full-load amps (FLA) and locked rotor amps (LRA). FLA is the amount of current the motor draws at full speed, under full mechanical load, at rated voltage. LRA is the maximum current the motor will draw at the instant full-line voltage is applied to the motor. DP contactors are well suited for loads found in the following areas:

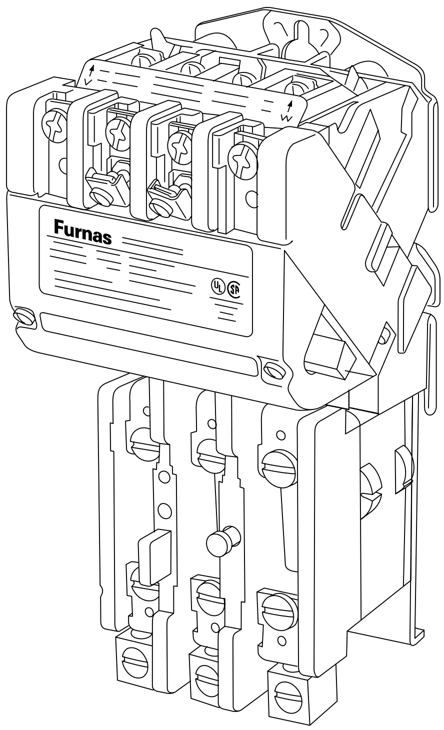
- Heating, Ventilating, and Air Conditioning (HVAC)
- Farm Equipment and Irrigation
- Environmental Control Systems
- Office Equipment
- Pool and Spa Controls
- Welding Equipment
- Medical Equipment
- Food-Service Equipment

Other Organizations

There are several other organizations that have developed standards and tests for electrical equipment. Underwriters Laboratory (UL), for example, specifies a maximum horsepower rating for which a contactor can be used. The contactor is tested by Underwriters Laboratory using test procedure U.L. 508. All Siemens contactors are rated in accordance with at least one of the previous organizations' test procedures. Some carry multiple ratings. For example, Furnas INNOVA starters meet or exceed NEMA and UL standards. Siemens SIRIUS starters meet or exceed NEMA, IEC, and UL standards.

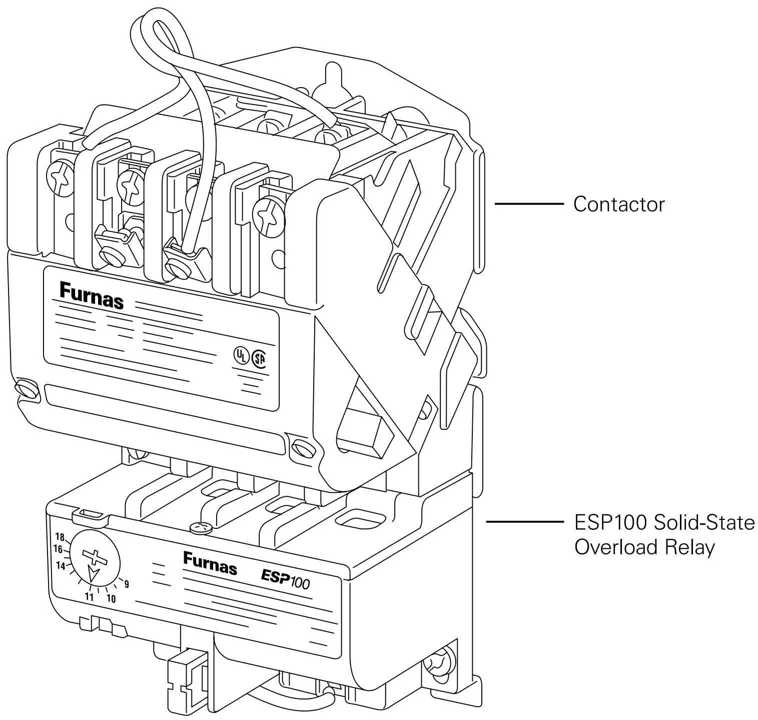
Furnas INNOVA PLUS Starters

Furnas INNOVA PLUS™ starters are available in NEMA sizes 0 through 4. They are available up to 100 HP. Furnas INNOVA PLUS starters are available with Class 10 or 20 ambient-compensated bimetal overload relays.



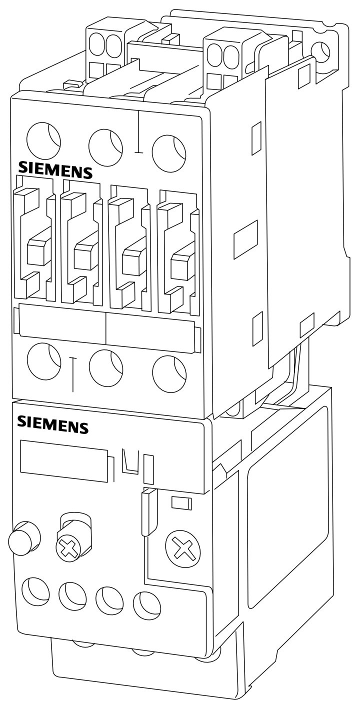
ESP100 Starters

The Furnas ESP100™ starters use the same contactor as the INNOVA PLUS™ starters. The ESP100 starters are supplied with a Class 10, 20, or 30 ESP100 solid-state overload relay. The ESP100 overload relay protects 3Ø motors with FLA of ¼ ampere through 135 amperes. From ¼ ampere to 10 amperes the overload has a 4:1 FLA range, i.e.; 2½ - 10 amperes. Above 10 amperes the range is 2:1 The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amperes. The ESP100 also protects the motor against phase loss. The ESP100 trips within three seconds of loss of one of the power-supply phases.



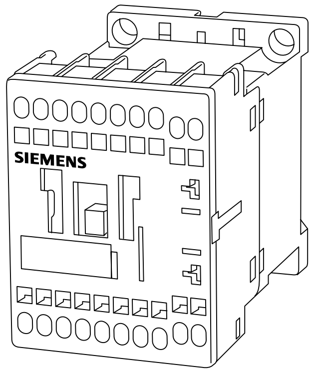
SIRIUS Type 3R Starters

SIRIUS 3R is a complete modular, building-block system. The system includes a structured range of contactors and overload relays covering loads up to 95 amps in four frame sizes. These four frame sizes are referred to as S00 (12A), S0 (25A), S2 (50A), and S3 (95A). A feature of the SIRIUS product line is a narrow mounting width. An S3 contactor rated at 75 HP, for example, is only 70mm (2.75”). SIRIUS 3R contactors and overload relays can operate in ambient temperatures up to 140°F (60°C). This, along with the smaller size, allows more units to be packed into a panel without overheating the components.

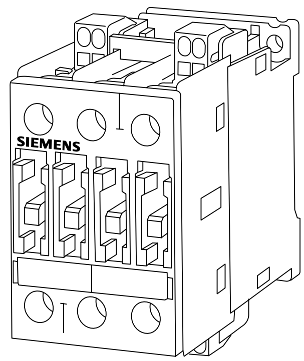


CAGE CLAMP™

Size S00 contactors and overload relays are available with CAGE CLAMP™ connections on power and control-circuit terminals. Size S0, S2, and S3 contactors and overload relays have CAGE CLAMP™ connections on the control-circuit terminals only.



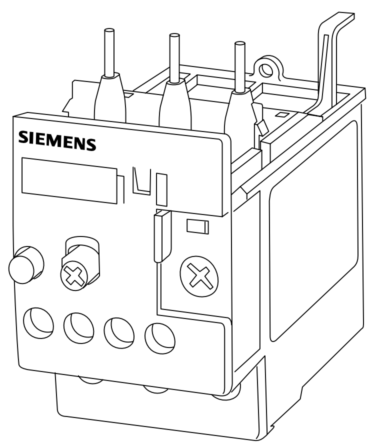
Contactor with
CAGE CLAMP™



Contactor with
Screw Terminals

Overload Relays

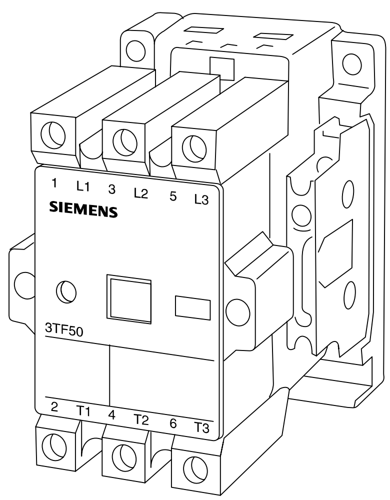
SIRIUS 3R overload relays provide Class 10 overcurrent protection for both AC and DC motors. Ambient-compensated bimetal strips prevent the overload relay from nuisance tripping when the panel temperature is higher than the ambient temperature of the motor. The design of the overload relay also includes a differential trip bar that causes the unit to trip faster in the event of a phase-loss condition. An optional remote-reset module (not shown) is available.



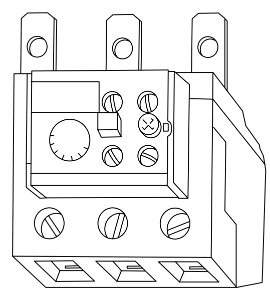
World Series Type 3TF Starters

The World Series starters are supplied with a type 3TF contactor and overload relay. World Series starters are available in horsepower ratings from 100 to 500 HP at 460 VAC. Auxiliary contacts are provided for use in the control circuit. World Series type 3TF contactors are available with various enclosures. Additional auxiliary contacts can be added. Coil voltages for the electromagnetic coil range from 24 to 600 VAC.

The overload relay is a Class 10 relay that uses a bimetal strip unit and heater element to detect overloads. Each phase monitors current. The unit has a full-load amps adjustment, test button, and reset button. The full-load amps adjustment corresponds to the range of the motor full-load ampere rating. The test button is to ensure the overload relay is functioning properly. The reset button is used to reset a trip. It can be either automatic or manual reset. There is also a trip indicator.



3TF50 Contactor



3UA Overload Relay

Overload Relay Selection

The following chart is useful in selecting the correct contactor and overload-relay combination. The chart reflects the maximum horsepower rating using Underwriters Laboratory test procedure U.L. 508 and the appropriate overload relay.

Contactor	Max HP (at 460 VAC)	Overload Relay
3TF50	100	3UA60
3TF51	100	3UA61
3TF52	125	3UA62
3TF53	150	3UA62
3TF54	200	3UA66
3TF55	250	3UA66
3TF56	300	3UA66
3TF57	400	3UA68
3TF68	500	3UA68

Review 5

1. ___________ is an organization primarily associated with rating equipment used in North America and ___________ is associated with rating equipment used in many countries including the U.S.

2. A NEMA Size ___________ starter is rated for 200 HP at 460 volts .

3. IEC utilization category ___________ applications are described as the starting of squirrel-cage motors and switching off only after a motor is up to speed.

4. Furnas INNOVA PLUS™ starters are available in NEMA sizes 0 through ___________ .

5. The ESP100 trips within ___________ seconds of loss of one of the power-supply phases.

6. The maximum load current of a size S2 SIRIUS 3R starter is ___________ amps.

7. The correct overload relay for a 3TF54 contactor is ___________ .

Multi-Speed and Reversing Starters

Full-voltage AC magnetic multi-speed controllers are designed to control squirrel-cage induction motors for operation at two, three, or four different constant speeds, depending on motor construction. The speed of a constant-speed motor is a function of the supply frequency and the number of poles and is given in the following formula:

$$\text{Synchronous Speed in RPM} = \frac{120 \times \text{Frequency}}{\text{Number of Poles}}$$

The speed in RPM is the synchronous speed or the speed of the rotating magnetic field in the motor stator. Actual rotor speed is always less due to slip. The design of the motor and the amount of load applied determine the percentage of slip. This value is not the same for all motors. A motor with four poles on a 60 hertz AC line has a synchronous speed of 1800 RPM. This means that, after allowing for slip, the motor is likely to run at 1650 to 1750 RPM when loaded.

$$1800 = \frac{120 \times 60}{4}$$

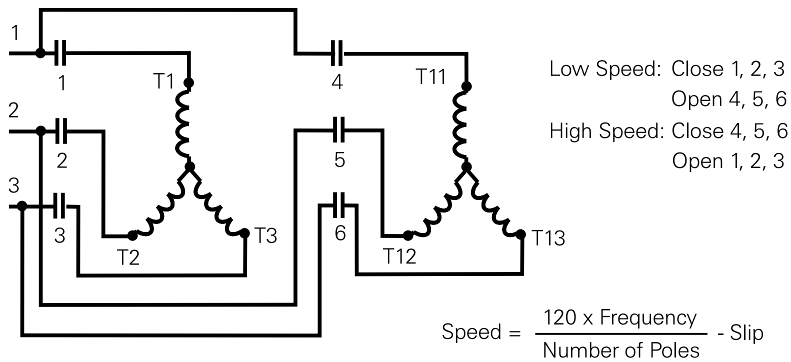
An induction motor with two poles on a 60 hertz AC line, however, would run at twice that speed.

When motors are required to run at different speeds, the motor's torque or horsepower characteristics will change with a change in speed. The proper motor must be selected and correctly connected for the application. In these applications, there are three categories.

Constant Torque (CT)
Variable Torque (VT)
Constant Horsepower (CHP)

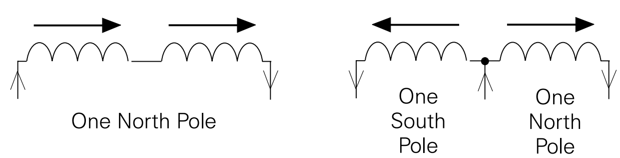
Separate-Winding

There are two basic methods of providing multi-speed control using magnetic starters: separate-winding motors and consequent-pole motors. Separate-winding motors have a separate winding for each speed. The speed of each winding depends on the number of poles. The low-speed winding is wound for more poles than the high-speed winding. The motor cost is higher than consequent pole, but the control is simpler. There are many ways multi-speed motors can be connected depending on speed, torque, and horsepower requirements. The following schematic shows one possible connection of a two-speed, two-winding, wye-connected motor.



Consequent-Pole Motors

Consequent-pole motors have a single winding for two speeds. Taps can be brought from the winding for reconnection for a different number of poles. Two-speed, consequent-pole motors have one reconnectable winding. Low speed of a two-speed, consequent-pole motor is one half the speed of high speed. Three-speed motors have one reconnectable winding and one fixed winding. Four-speed motors have two reconnectable windings.

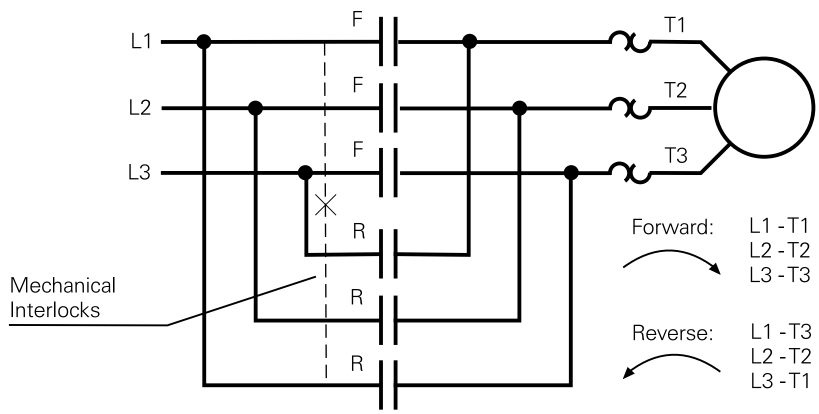


Speed Selection

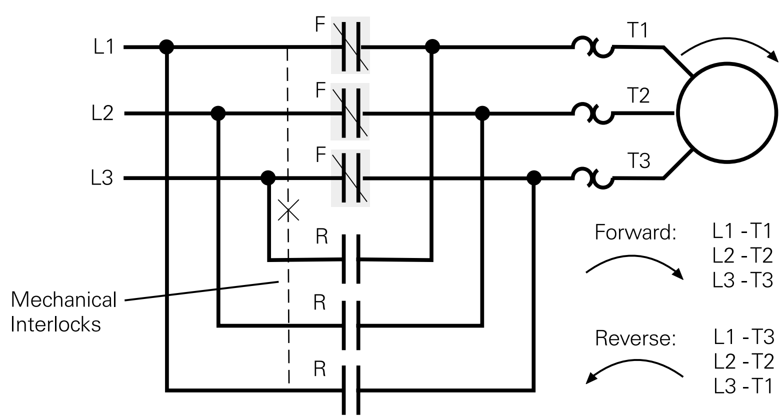
There are three control schemes of speed selection for multi-speed motors: selective control, compelling control, and progressive control. Selective control permits motor starting at any speed and to move to a higher speed the operator depresses the desired speed pushbutton. Compelling control requires the motor to be started at the lowest speed, then the operator must manually increment through each speed step to the desired speed. With progressive control the motor is started at the lowest speed and automatically increments to the selected speed.

Reversing

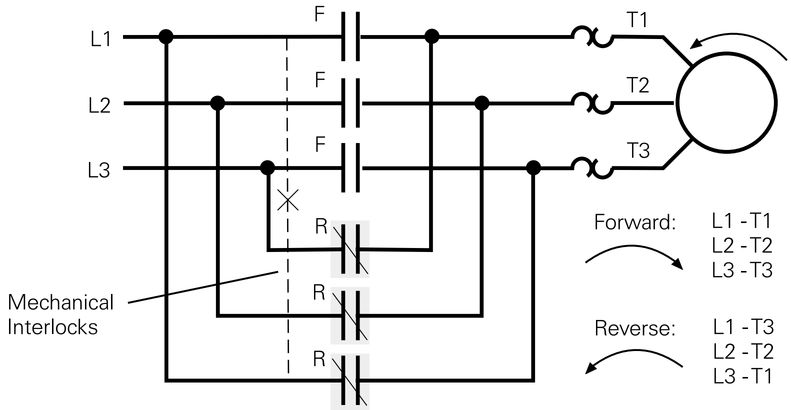
Many applications require a motor to run in both directions. In order to change the direction of motor rotation, the direction of current flow through the windings must be changed. This is done on a three-phase motor by reversing any two of the three motor leads. Traditionally T1 and T3 are reversed. The following illustration shows a three-phase reversing motor circuit. It has one set of forward (F) contacts controlled by the "F" contactor, and one set of reverse (R) contacts controlled by the "R" contactor.



When the "F" contacts are closed, current flows through the motor causing it to turn in a clockwise direction.

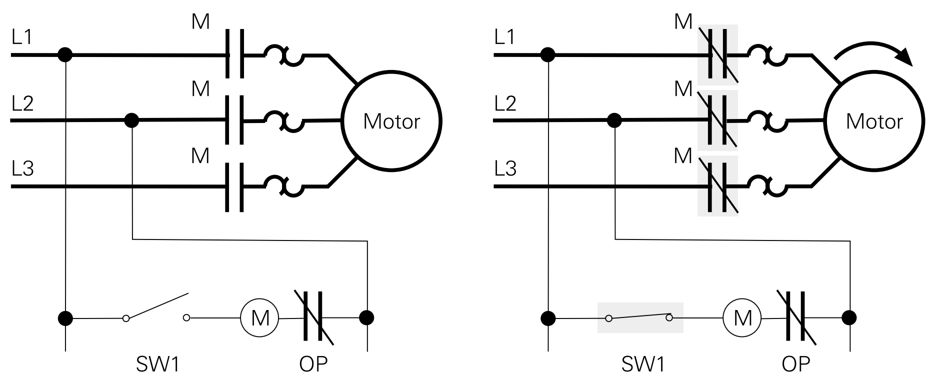


When the “R” contacts are closed, current flows through the motor in the opposite direction causing it to rotate in a counterclockwise direction. Mechanical interlocks prevent both forward and reverse circuits from being energized at the same time.

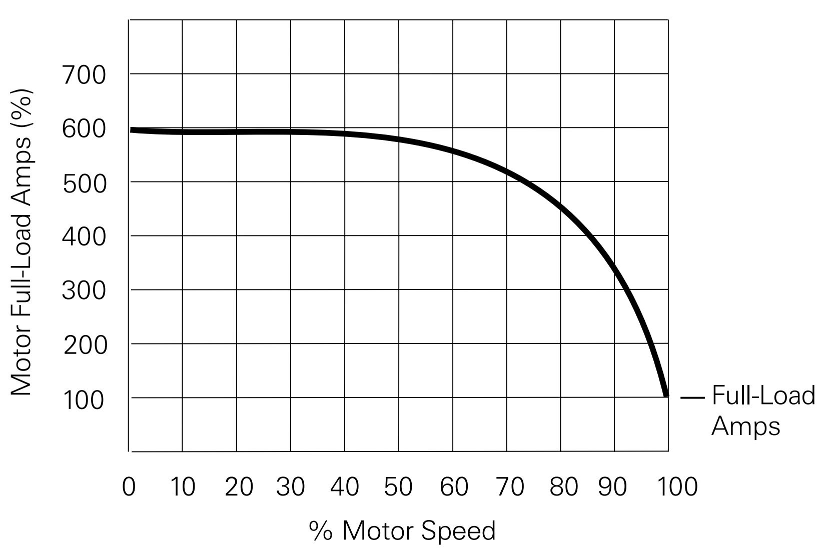


Full-Voltage Starting

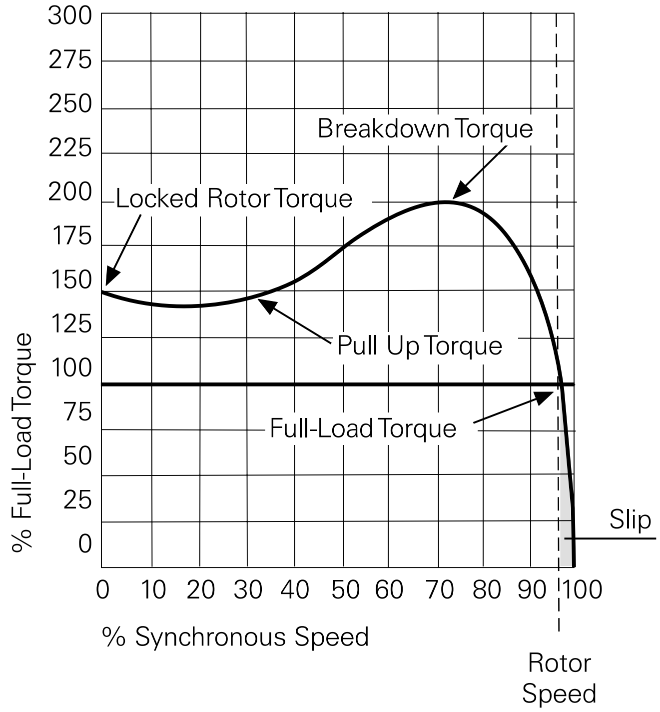
The most common type of motor starting is full-voltage starting. The motor is placed directly across the line with this method.



With this type of starter the motor receives the full-line voltage. When a motor is started with full voltage, starting current can be as high as 600% of full-load current on standard squirrel cage motors. It can be even higher on high efficiency motors. There are situations where this method of starting is not acceptable. On large motors the high starting current is reflected back into the power lines of the electric utility, causing lights to flicker and in more serious situations can cause computers to malfunction. Many power companies in the U.S. require reduced-voltage starting on large-horsepower motors.



Another potential problem with applying full-voltage starts is the high torque developed when power is first applied to the motor. This can be as high as 175% to 200% of full-load torque on a standard NEMA B type motor. Many applications require the starting torque to be applied gradually. A conveyor belt, for example, requires the starting torque to be applied gradually to prevent belt slipping or bunching.



Reduced-Voltage Starting

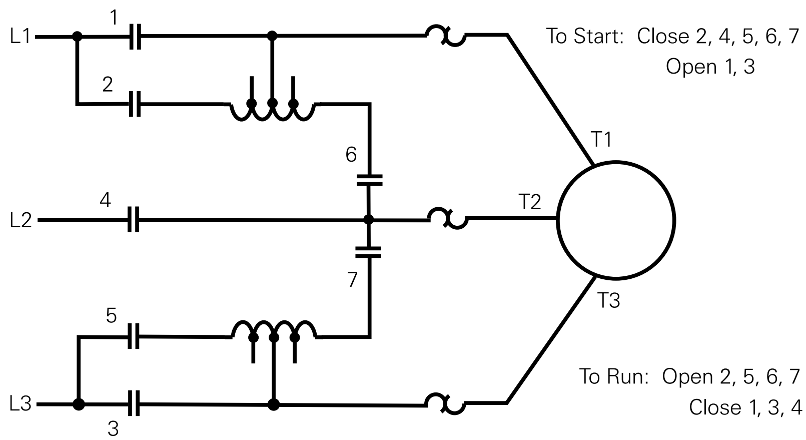
In general, starting methods which deviate from full-voltage starting by providing a lower starting voltage are referred to as reduced-voltage starting. Reduced-voltage starting should be used when it is necessary to limit the initial inrush of current or it is desired to reduce the starting torque of a motor.

Reduced-voltage starting reduces the starting voltage of an induction motor with the purpose of confining the rate of change of the starting current to predetermined limits. It is important to remember that when the voltage is reduced to start a motor, current is also reduced, which also reduces the amount of starting torque a motor can deliver. Several methods are available for reduced-voltage starting. The application or the type of motor generally dictates the method to use. A few of the methods offered by Siemens are described in the following paragraphs.

Autotransformer Reduced-Voltage Starters

Autotransformer reduced-voltage starters provide the highest starting torque per ampere of line current and is one of the most effective means of starting a motor for an application in which starting current must be reduced with a minimum sacrifice of starting torque. Autotransformers have adjustable taps to reduce starting voltage to 50%, 65%, or 80% of full-line voltage.

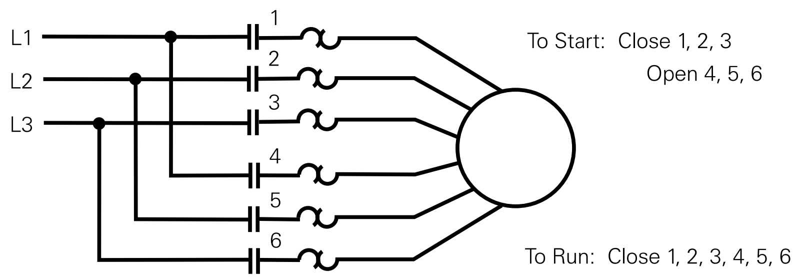
Applications: Blowers, Pumps, Compressors



Part-Winding Starters

Part-winding, reduced-voltage starters are used on motors with two separate parallel windings on the stator. The windings used during start draw about 65 - 80% of rated locked rotor current. During run each winding carries approximately 50% of the load current. Part-winding, reduced-voltage starters are the least-expensive type of reduced-voltage starters and use a very simplified control circuit. However, they require special motor design and are not suitable for high inertia loads. There is no adjustment of current or torque.

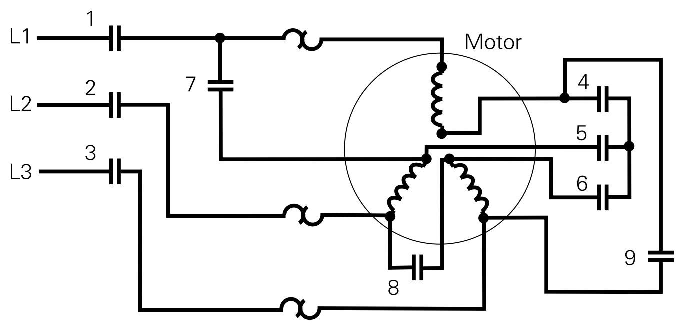
Applications: Pumps, Fans, Refrigeration, Compressors



Wye-Delta Starters

Wye-delta, reduced-voltage starters are applicable only with motors having stator windings not connected internally and all six motor leads available. Connected in a wye configuration, the motor starts with reduced starting line current. The motor is reconfigured to a delta connection for run. This type of starter is a good method for applications requiring frequent starts. The starting torque is lower compared to other methods of reduced voltage starters.

Applications: Central Air Conditioning Equipment, Compressors



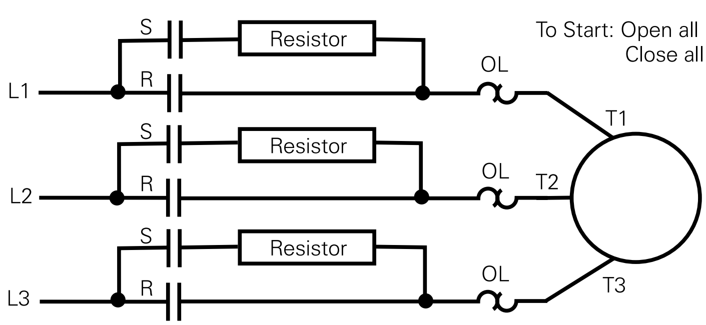
To Start: Close 1, 2, 3, 4, 5, 6
Open 7, 8, 9

To Run: Open 4, 5, 6
Close 7, 8, 9

Primary Resistance Starter

This is a simple and effective starting method. The motor is initially energized through a resistor in each of the three incoming lines. Part of the voltage is dropped through the resistors. The motor receives 70% to 80% of the full-line voltage. As the motor picks up speed, the motor sees more of the line voltage. At a preset time a time-delay relay closes a separate set of contacts, shorting out the resistors and applying full voltage to the motor. This type of reduced voltage starting is limited by the amount of heat the resistors can dissipate.

Applications: Conveyors, Belt-Driven and Gear Drive Equipment



To Start: Open all R Contacts
Close all S Contacts

To Run: Close all R Contacts

Review 6

1. ___________ - ___________ ___________ is a method of providing multi-speed control that utilize taps brought out from a reconnectable winding.

2. With ___________ ___________ the motor is started at the lowest speed and automatically increments to the selected speed.

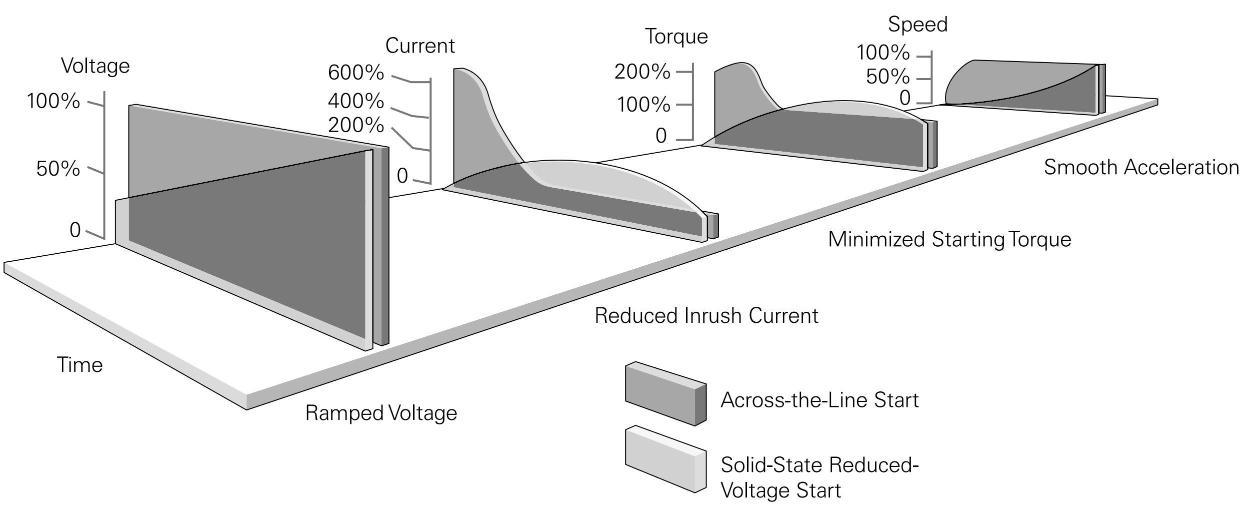
3. In general, starting methods which deviate from full-voltage starting by providing a lower starting voltage are referred to as __________ __________ __________ .

4. ___________ reduced-voltage starters have adjustable taps to reduce starting voltage to 50%, 65%, or 80% of full line voltage.

Solid-State Reduced-Voltage Controllers

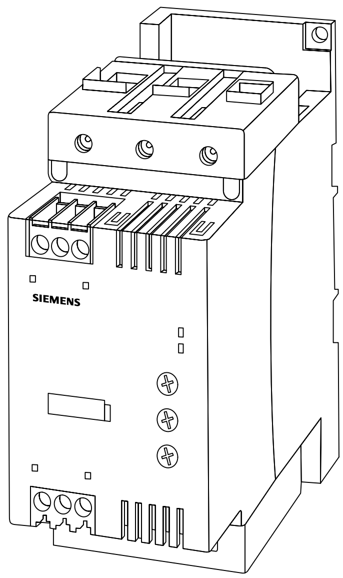
Solid-state or soft-start controllers also use reduced voltage starting. These controllers are more advanced and allow greater control of the starting, running, and stopping of an AC motor than the electromechanical starters discussed in the previous section. Reduced-voltage electromechanical starters start a motor in steps by first applying a reduced voltage followed by full voltage.

Solid-state reduced-voltage controllers, however, can apply voltage gradually from some low intial volatge to 100% voltage. The following graph compares a solid-state reduced-voltage controller to a full- voltage (across-the-line) starter. By applying voltage gradually, the motor experiences reduced inrush current and speed is accelerated smoothly. In addition, just enough torque can be applied to start and accelerate the motor. This is beneficial for loads that have problems with the initial jerk and rapid acceleration of across-the-line starting.



SIRIUS 3R Soft-Start Controls

SIRIUS 3R controllers provide gradual voltage starting and stopping.SIRIUS 3R soft-start controls are compact and compliment the rest of the SIRIUS line. The compact design allows the controls to be DIN rail mounted and integrated with any combination of other controls, such as, overloads, contactors, and motor starter protectors. SIRIUS 3R soft-start controls are available for motors up 75HP at 575 volts. A cost saving advantage of the SIRIUS 3R controller is the ability of one model to handle voltages from 200 to 460 volts.

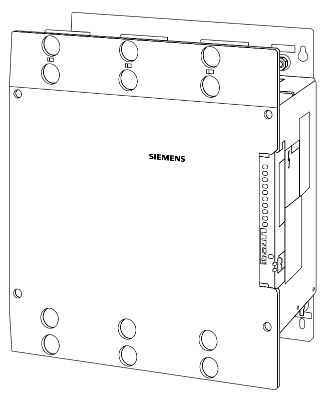


Three-Phase Models for Motors up to:

25HP @ 200V
30HP @ 230V
60HP @ 460V
75HP @ 575V

SIKOSTART

SIKOSTART controllers are used in applications of up to 1000 horsepower. Like the SIRIUS 3R, SIKOSTART provides gradual voltage starting and stopping.

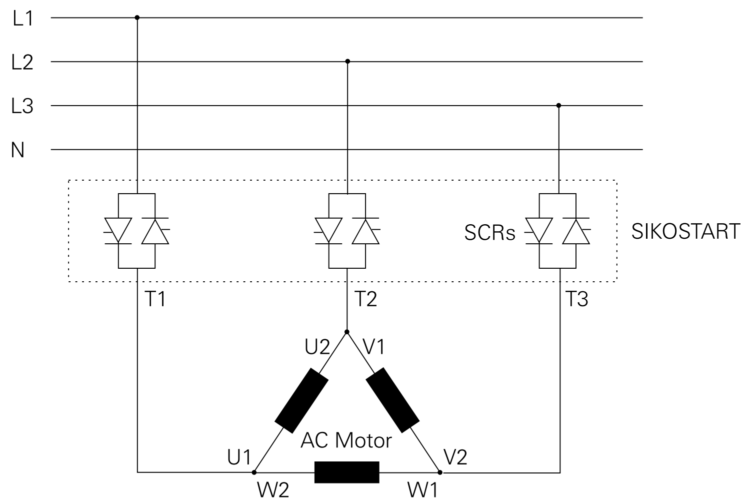


Three-Phase Models for Motors up to:

350HP @ 200V
400HP @ 230V
800HP @ 460V
1000HP @ 575V

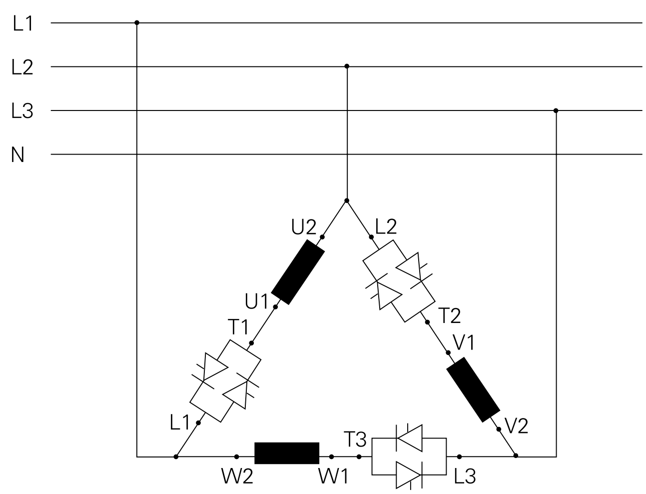
SIKOSTART Wired Inline

SIKOSTART can easily be wired conventionally in line with the motor windings. In this configuration the controller sees full motor current.



SIKOSTART Wired Inside the Delta

On motors that have all leads available, the SIKOSTART controller can also be wired inside the delta connection of the motor. This offers a significant cost advantage. Current inside the delta of an AC motor is approximately 57% of nominal motor current. With this configuration a smaller SIKOSTART controller can be selected.

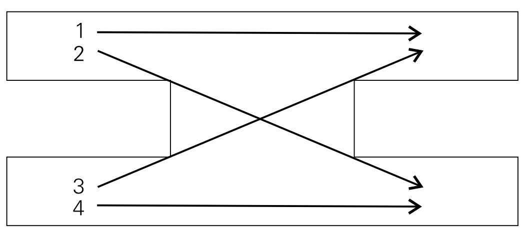


Pilot Devices

A pilot device directs the operation of another device (pushbuttons and selector switches) or indicates the status of the operating system (pilot lights). This section discusses Siemens 3SB and Furnas Class 51/52 pushbuttons, selector switches, and pilot lights. 3SB devices are available in 22 mm diameters. Class 51/52 pilot devices are available in 30 mm diameter. The diameter refers to the size of the knockout hole required to mount the devices. Class 51 devices are rated for hazardous locations environments such as Class I, Groups C and D and Class II, Groups E, F, and G. Class 52 devices are heavy duty for harsh, industrial environments.

Bifurcated Contacts

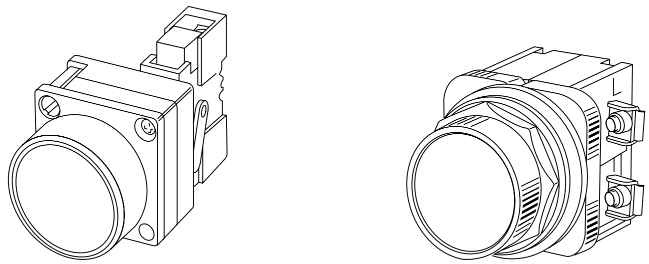
Whether one chooses the 3SB or the Class 51/52 pilot devices, the fine silver contacts have a 10 A/600 V continuous-current rating and can be used on solid state equipment. The 3SB and the Class 51/52 devices use bifurcated movable contacts. The design of the bifurcated contacts provides four different pathways for current to flow, thus improving contact reliability.



Bifurcated Contact
Four Paths of Current Flow

Pushbuttons

A pushbutton is a control device used to manually open and close a set of contacts. Pushbuttons are available in a flush mount, extended mount, with a mushroom head, illuminated or nonilluminated. Pushbuttons come with either normally open, normally closed, or combination contact blocks. The Siemens 22 mm pushbuttons can handle up to a maximum of 6 circuits. The Furnas 30 mm pushbutton can handle up to a maximum fo 16 circuits.

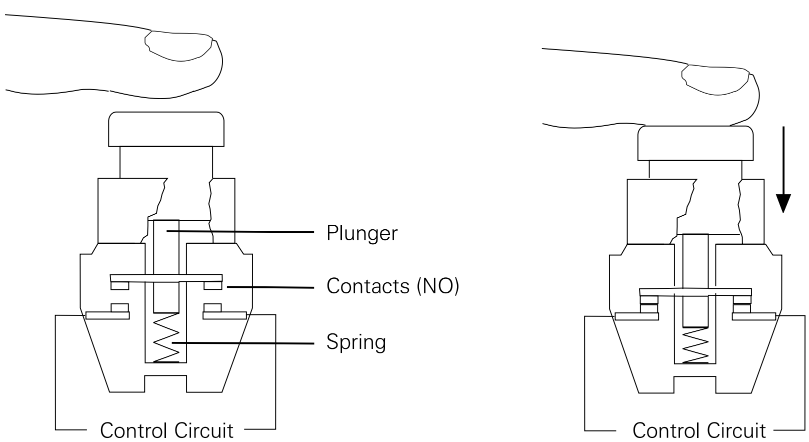


Siemens
22 mm Diameter
Pushbutton

Furnas
30 mm Class 52
Pushbutton

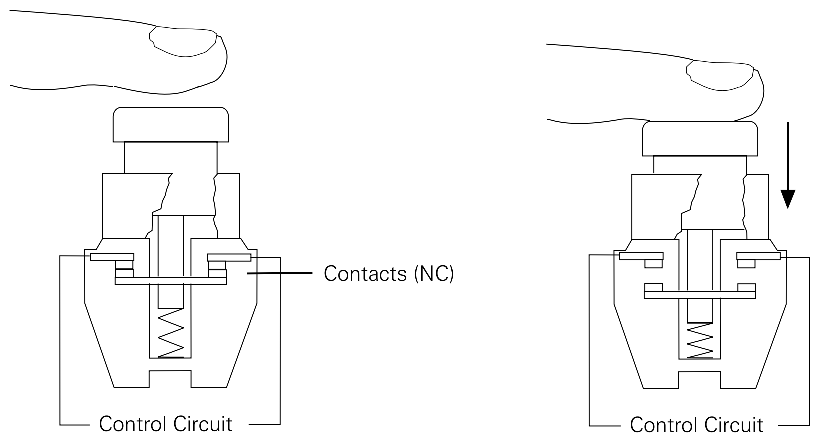
Normally Open Pushbuttons

Pushbuttons are used in control circuits to perform various functions. For example, pushbuttons can be used when starting and stopping a motor. A typical pushbutton uses an operating plunger, a return spring, and one set of contacts. The following drawing illustrates a normally open (NO) pushbutton. Normally the contacts are open and no current flows through them. Depressing the button causes the contacts to close. When the button is released, the spring returns the plunger to the open position.



Normally Closed Pushbuttons

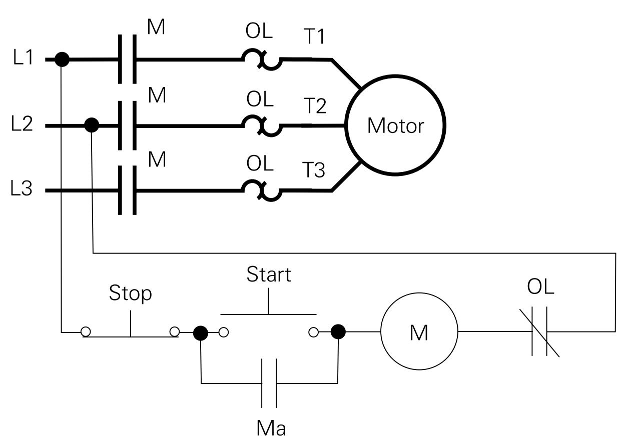
Normally closed (NC) pushbuttons, such as the one shown below, are also used to open and close a circuit. In the pushbutton's normal position the contacts are closed to allow current flow through the control circuit. Depressing the button opens the contacts preventing current flow through the circuit. These types of pushbuttons are momentary contact pushbuttons because the contacts remain in their activated position only as long as the plunger is held depressed.



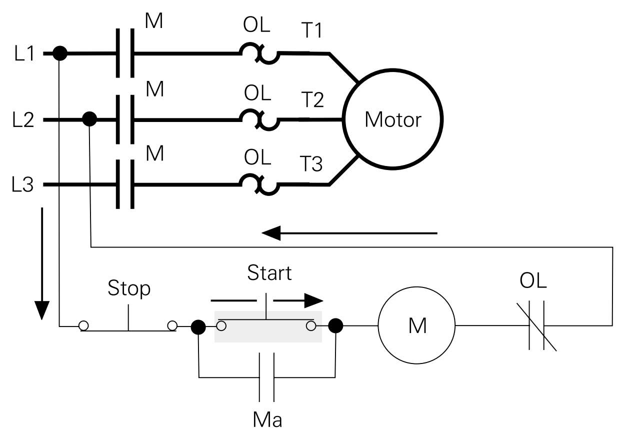
Pushbuttons are available with variations of the contact configuration. For example, a pushbutton may have one set of normally open and one set of normally closed contacts so that when the button is depressed, one set of contacts is open and the other set is closed. By connecting to the proper set of contacts, either a normally open or normally closed situation exists.

Using Pushbuttons in a Control Circuit

The following line diagram shows an example of how a normally open and a normally closed pushbutton might be used in a control circuit.

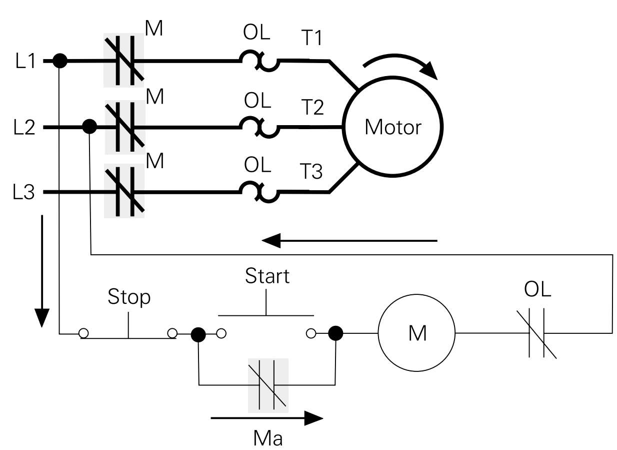


Momentarily depressing the "Start" pushbutton completes the path of current flow and energizes the "M" contactor's electromagnetic coil.



Holding Circuit Three-Wire Control

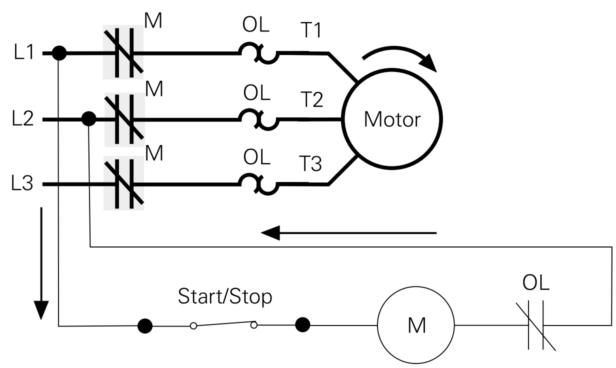
This closes the associated normally open "M" and "Ma" contacts. When the "Start" pushbutton is released a holding circuit exists to the "M" electromagnetic coil through the auxiliary contacts "Ma." The motor will run until the normally closed "Stop" pushbutton is depressed, breaking the path of current flow to the "M" electromagnetic coil and opening the associated "M" and "Ma" contacts. This is referred to as three-wire control because there are three wires or three connection points required to connect the "Start" and "Stop" pushbuttons and the holding circuit ("Ma"). An advantage to three-wire control is low-voltage protection. If an overload causes the "OL" contacts in the control circuit to open, the "M" coil is deenergized and the motor shut down. When the overload is cleared, the motor will not suddenly restart on its own. An operator must depress the "Start" button to restart the motor.



Two-Wire Control

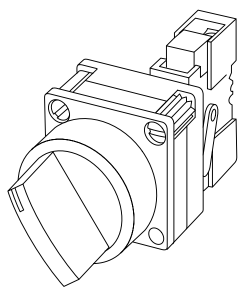
In comparison, a two-wire control has only two connection points for the "Start/Stop" circuit. When the contacts of the control device close, they complete the coil circuit of the contactor, causing it to be energized and connect the load to the line through the power contacts. When the contacts of the control device open, the power is removed from the motor and it stops.

A two-wire control circuit provides low-voltage release but not low-voltage protection. This means that in the event of a power loss the contactor will deenergize, stopping the motor. This is low-voltage release. However, when power is restored, the motor will restart without warning if the control device is still closed. This type of control scheme is used for remote or inaccessible installations such as water-treatment plants or pumping stations. In these applications it is desireable to have an immediate return to service when power is restored.

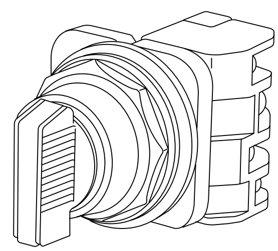


Selector Switches

Selector switches are also used to manually open and close contacts. Selector switches can be maintained, spring return or key operated. Selector switches are available in two-, three-, and four-position types. The basic difference between a push button and a selector switch is the operator mechanism. With a selector switch the operator is rotated to open and close contacts. Contact blocks used on pushbuttons are interchangeable with those on used on selector switches. Selector switches are used to select one of several circuit possibilities such as manual or automatic operation, low or high speed, up or down, right or left, and stop or run. The Siemens 22 mm selector switches can handle up to a maximum of 6 circuits. The Furnas 30 mm selector switch can handle up to a maximum of 16 circuits.



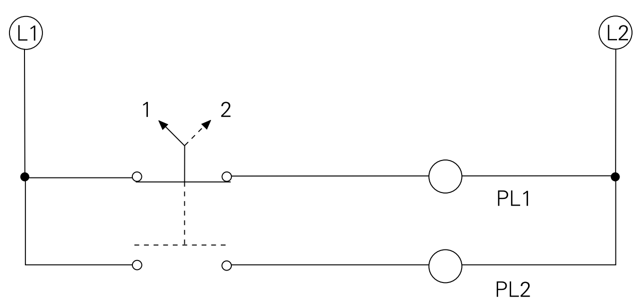
Siemens
22 mm Diameter
Selector Switch



Furnas
30 mm Class 52
Selector Switch

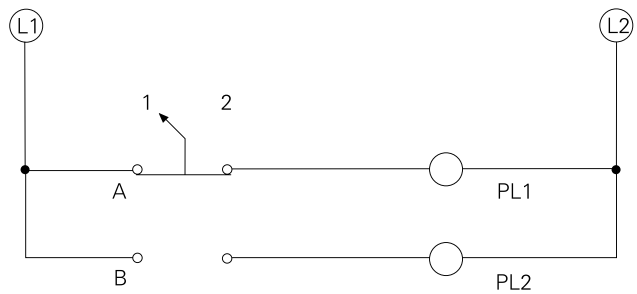
Two Position Selector Switch

In the following example PL1 is connected to the power source when the switch is in position 1. PL2 is connected to the power source when the switch is in position 2. In this circuit either PL1 or PL2 would be on at all times. If there were only one load, then the selector switch could be used as an On/Off switch.



Contact Truth Tables

There are two accepted methods of indicating contact position of a selector switch in a circuit. The first method uses solid and dashed lines to denote contact position as shown in the previous example. In the second method truth tables, also known as target tables, are used. Each contact is marked with a letter. An “X” in the truth table indicates which contacts are closed for a given switch position. In this example contact A is closed, connecting PL1 to the power source, when the switch is in position 1. Contact B is closed, connecting PL2 to the power source, when the switch is in position 2.



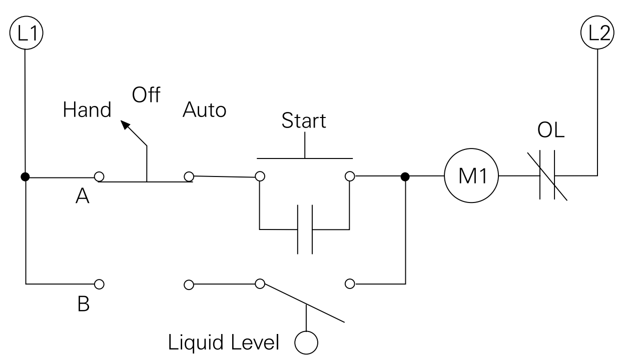
Contacts

Position	A	B
1	X	
2		X

2 Position Selector Switch

Three-Position

A three-position selector switch can be used to select either of two sets of contacts or to disconnect both sets of contacts. Hand/Off/Auto is a typical application for a three-position selector switch used for controlling a pump. In the Hand (manual) position the pump will start when the Start pushbutton is pressed. The pump can be stopped by switching the switch to the Off position. The liquid level switch has no effect in either the Hand or Off position. When the selector switch is set to Auto, the pump will be controlled by the liquid-level switch. At a predetermined level the liquid level switch closes, starting the pump. At a predetermined level the liquid level switch opens, stopping the pump.



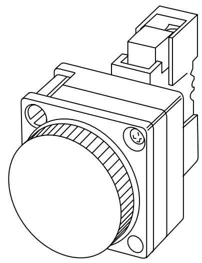
Contacts

Position	A	B
1	X	
2		
3		X

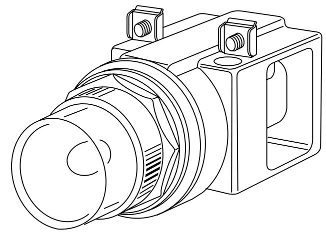
3 Position Selector Switch

Pilot Lights

Pilot lights provide visual information at a glance of the circuit's operating condition. Pilot lights are normally used for "ON/OFF" indication, caution, changing conditions, and alarm signaling.

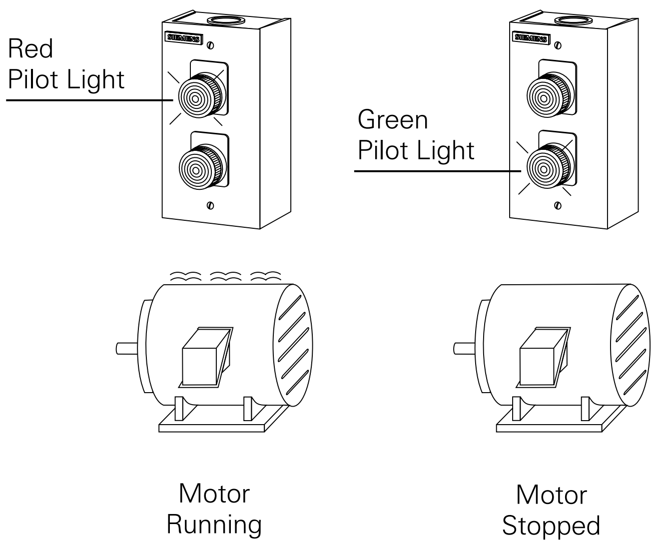


Siemens 22 mm Diameter Pilot Light



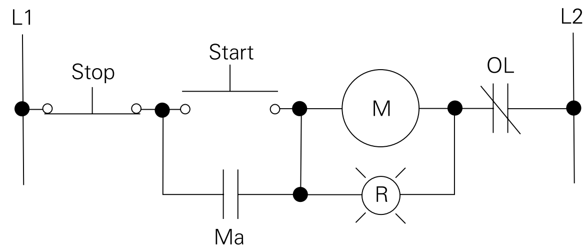
Furnas 30 mm Class 52 Pilot Light

Pilot lights come with a color lens, such as red, green, amber, blue, white, or clear. A red pilot light normally indicates that a system is running. A green pilot light normally indicates that the system is off or deenergized. For example, a red pilot light located on a control panel would give visual indication that a motor was running. A green pilot light would give visual indication that a motor was stopped.

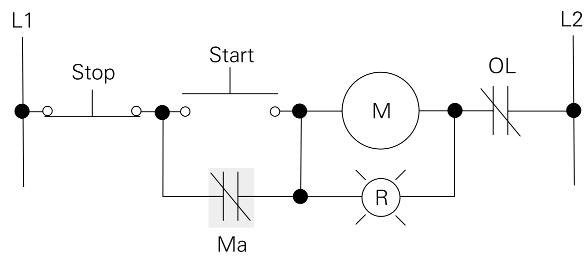


Using a Pilot Light in a Control Circuit

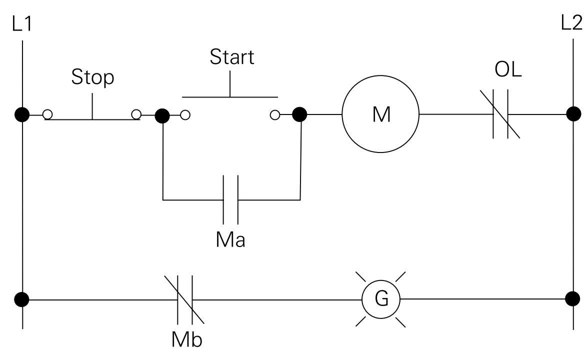
In the following line diagram, a red pilot light is connected in parallel with the "M" electromagnetic coil.



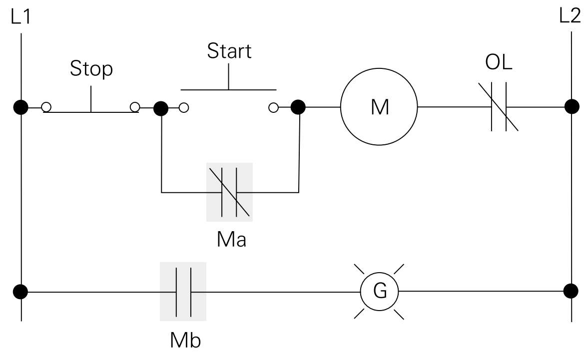
When the coil is energized, the light will illuminate to indicate the motor is running. In the event the pilot light burns out the motor will continue to run.



In the following line diagram a green pilot light is connected through a normally closed "M" auxiliary contact (Mb). When the coil is deenergized, the pilot light is on to indicate the motor is not running.

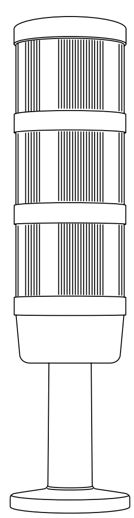


Depressing the "Start" pushbutton and energizing the "M" contactor opens the normally closed "Mb" contacts, turning the light off.

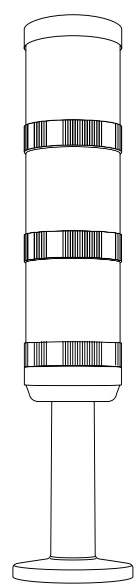


Signalling Columns

Signalling columns can be mounted locally on individual machines, making it possible for the operating personnel to monitor production stations from a distance. Individual modules, or elements, are connected together. Various visual elements are available, including strobe lights, steady or flashing lights, and incandescent or LED lights. Lenses for the light elements are available in red, yellow, green, blue, and clear. Audible elements for the 8WD43 include a siren and a buzzer. Audible elements for the 8WD42 include a buzzer. In addition, a communication element is available allowing the signalling column to communicate with PLCs or computers through the Actuator Sensor Interface (ASI) network. Up to 10 elements can be used on a signalling column.



8WD43 (70 mm)



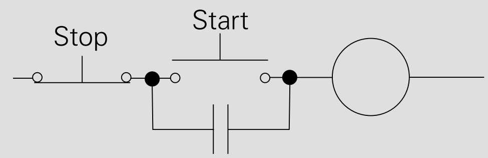
8WD42 (50 mm)

Review 7

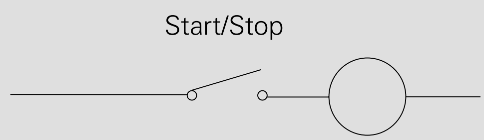
1. A ____________ ____________ directs the operation of another device.

2. Which of the following circuits represents a two-wire control and which represents a three-wire control?

____ - Wire Control



____ - Wire Control

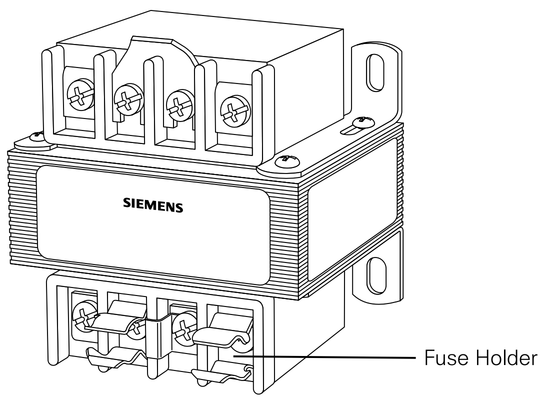


3. Pilot lights provide ____________ information of the circuit’s operating condition.

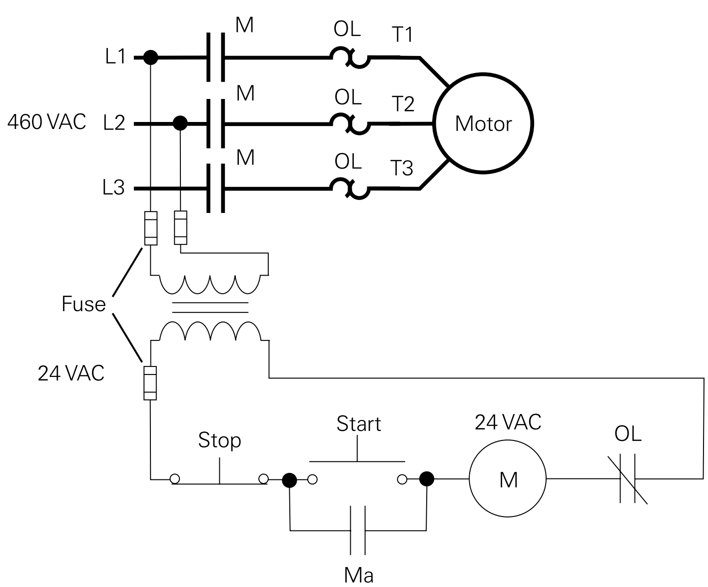
4. A ____________ pilot light normally indicates a motor is running and a ____________ pilot light normally indicates a motor is stopped.

Control Transformers

It is often desirable to operate the control circuit at a lower voltage than the power circuit. Control transformers are used to step a voltage down to a lower level. Siemens control transformers are available in various primary and secondary voltages from 50 to 5000 VA.

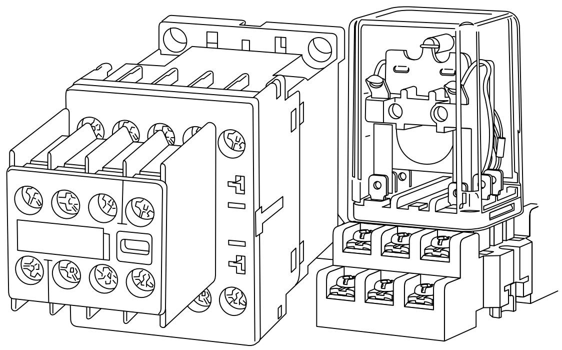


In the following example, the power circuit is 460 VAC. A control transformer is used to step the voltage down to 24 VAC for use in the control circuit. The electromagnetic coil voltage must be rated for 24 VAC. Fuses on the primary and secondary windings of the transformer provide overcurrent protection.



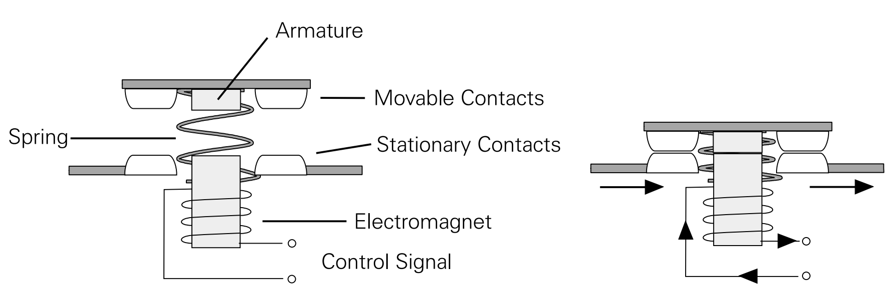
Control Relays

Relays are widely used in control circuits. They are used for switching multiple control circuits and for controlling light loads such as starting coils, pilot lights, and audible alarms.



Relay Operation

The operation of a control relay is similar to a contactor. In the following example a relay with a set of normally open (NO) contacts is used. When power is applied from the control circuit, an electromagnetic coil is energized. The resultant electromagnetic field pulls the armature and movable contacts toward the electromagnet closing the contacts. When power is removed, spring tension pushes the armature and movable contacts away from the electromagnet opening the contacts.

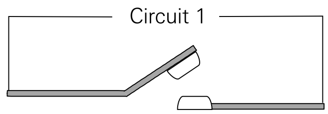


Contact Arrangement

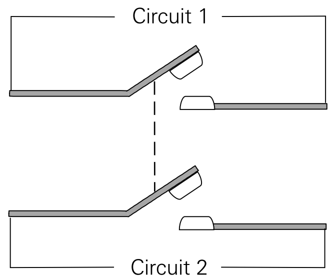
A relay can contain normally open, normally closed, or both types of contacts. The main difference between a control relay and a contactor is the size and number of contacts. The contacts in a control relay are relatively small because they need to handle only the small currents used in control circuits. There are no power contacts. Also, unlike a contactor, each contact in a control relay controls a different circuit. In a contactor, they all control the starting and stopping of the motor. Some relays have a greater number of contacts than are found in the typical contactor. The use of contacts in relays can be complex. There are three words which must be understood when dealing with relays.

Pole

Pole describes the number of isolated circuits that can pass through the relay at one time. A single-pole circuit can carry current through one circuit. A double-pole circuit can carry current through two circuits simultaneously. The two circuits are mechanically connected so that they open or close at the same time.



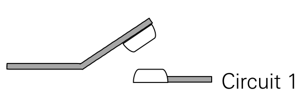
Single Pole



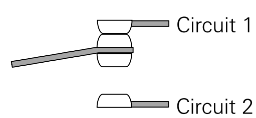
Double Pole

Throw

Throw is the number of different closed-contact positions per pole. This is the total number of different circuits each pole controls.



Single-Throw



Double-Throw

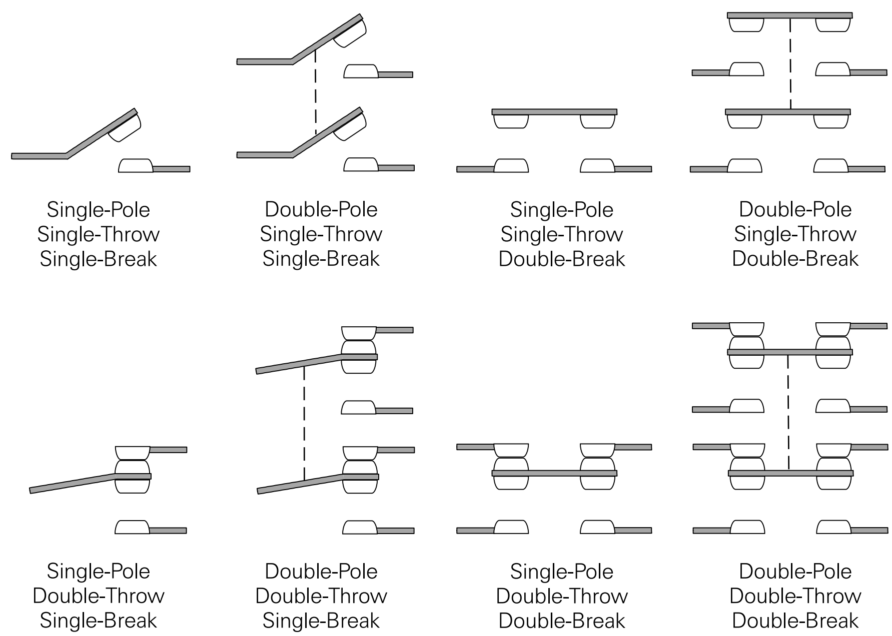
The following abbreviations are frequently used to indicate contact configurations:

SPST Single-Pole, Single-Throw
SPDT Single-Pole, Double-Throw
DPST Double-Pole, Single-Throw
DPDT Double-Pole, Double-Throw

Break

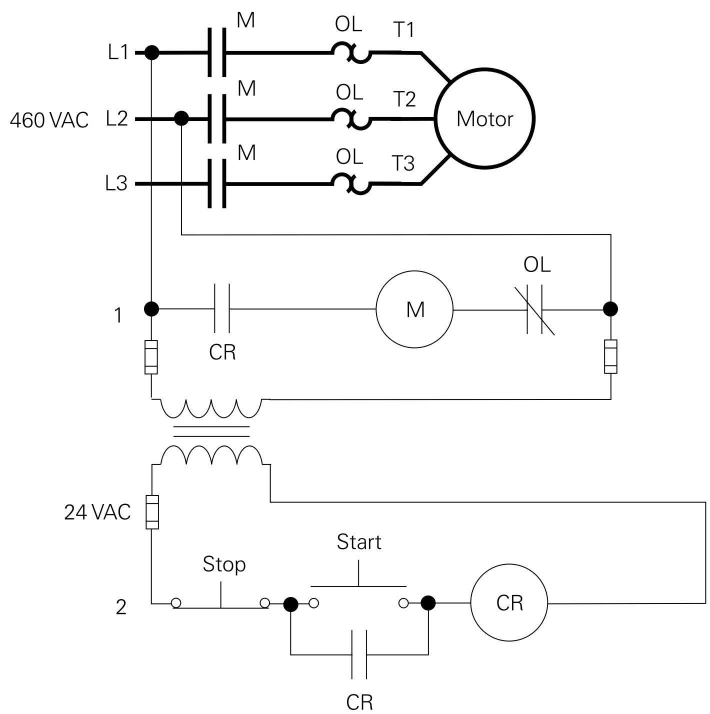
Break is the number of separate contacts the switch contacts use to open or close individual circuits. If the switch breaks the circuit in one place, it is a single-break. If the relay breaks the circuit in two places, it is a double-break.

The following illustrates various contact arrangements.

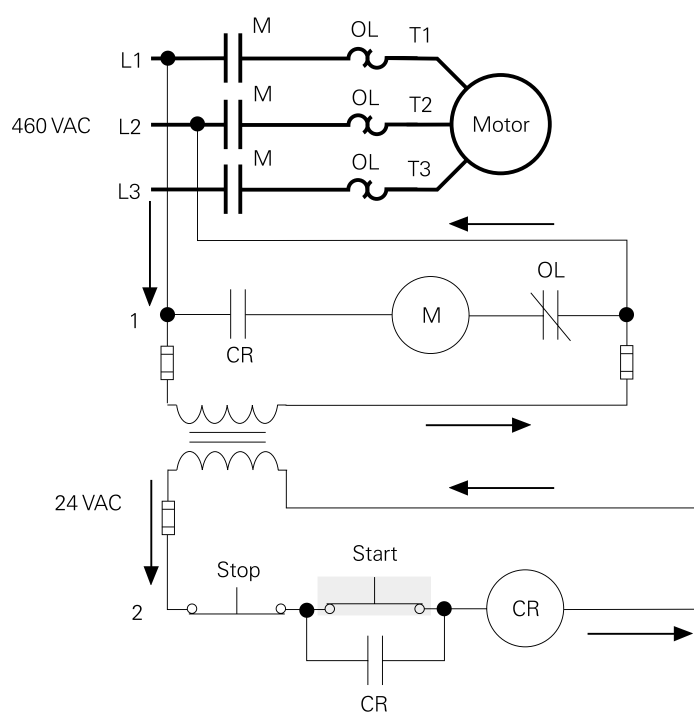


Interposing a Relay

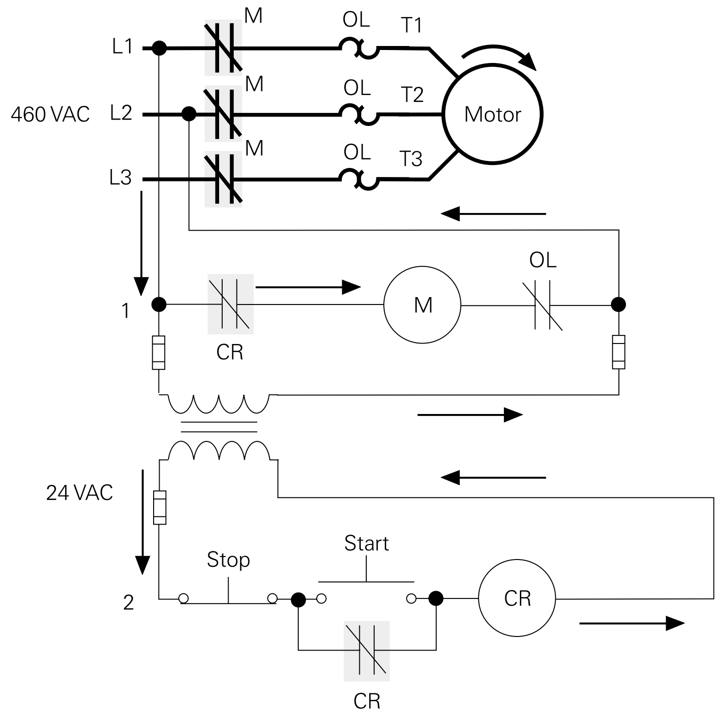
The following line diagram illustrates one way a control relay might be used in a circuit. A 24 VAC coil may not be strong enough to operate a large starter. In this example the electromagnetic coil of the "M" contactor selected is rated for 460 VAC. The electromagnetic coil of the control relay (CR) selected is 24 VAC. This is known as interposing a relay.



When the "Start" pushbutton in line 2 is momentarily depressed, power is supplied to the control relay (CR).

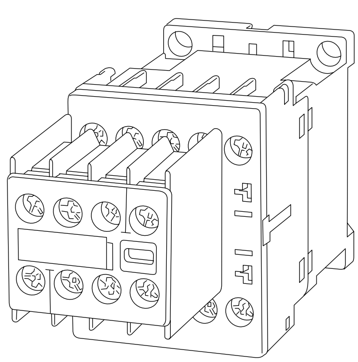


The “CR” contacts in lines 1and 2 close. The “CR” contacts in line 2 maintain the start circuit. The “CR” contacts in line 1 complete the path of current to the “M” motor starter. The “M” motor starter energizes and closes the “M” contacts in the power circuit, starting the motor. Depressing the “Stop” pushbutton deenergizes the “CR” relay and “M” motor starter.



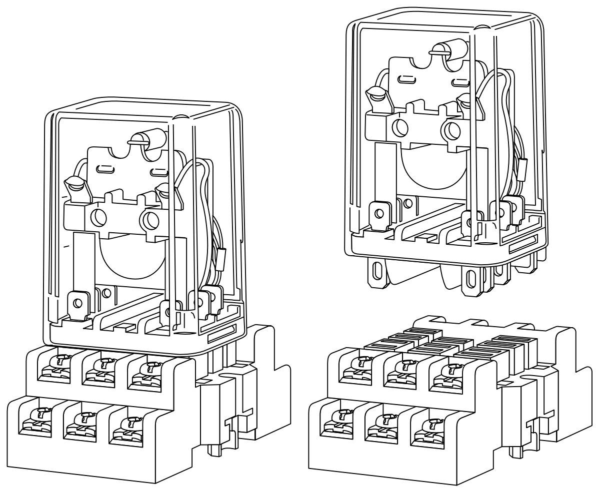
SIRIUS 3RH11 Control Relays

Siemens has a complete line of industrial-control relays. SIRIUS 3RH11 relays are available with screw terminal or Cage Clamp. The screw terminal version is shown in the following illustration. Four contacts are available in the basic device. Four additional contacts in the form of a snap-on device can be added to the front of the relay. Some SIRIUS 3RH11 relays are specifically designed to interface directly with PLCs and other solid-state control devices. SIRIUS 3RH11 relays are rated for switching both AC and DC circuits. Coil voltages range from 12 VDC to 230 VDC and 24 VAC to 600 VAC.



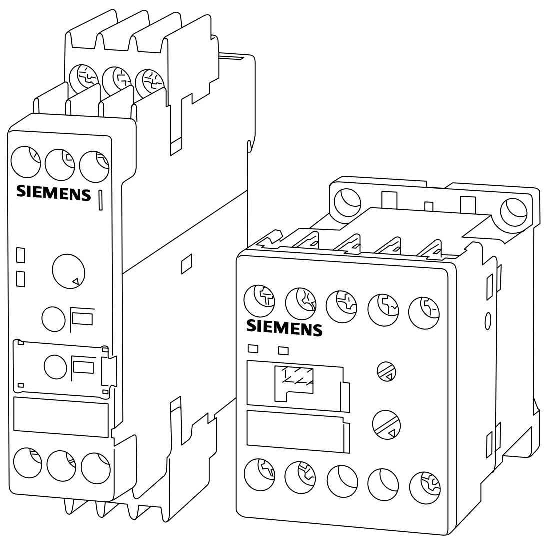
General-Purpose Relays (Plug-In Relays)

Siemens also manufactures a variety of general-purpose relays for socket and flange mounting. Coil voltages are available in 24 VAC, 120 VAC or 24 VDC. The biggest benefit of this type of relay is all the wiring stays in place with the socket if the relay needs to replaced with a new one.



Timing Relays

Timing relays, such as the SIRIUS 3RP timing relays, are used in control switching operations involving time delay. SIRIUS 3RP1 timing relays have timing ranges available from .05 seconds to 10 hours. SIRIUS 3RP15 have timing ranges from .05 seconds to 100 hours.



3RP15 3RP1

Time Delay

A timing relay has two major functions: On-delay and Off-delay timing. An arrow is used to denote the function of the timer. An arrow pointing up indicates an On-delay timing action. An arrow pointing down indicates an Off-delay timing action.

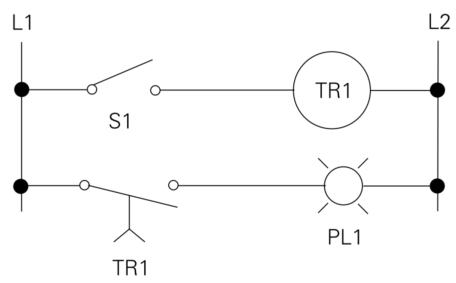
On-Delay
Arrow Points Up

Off-Delay
Arrow Points Down

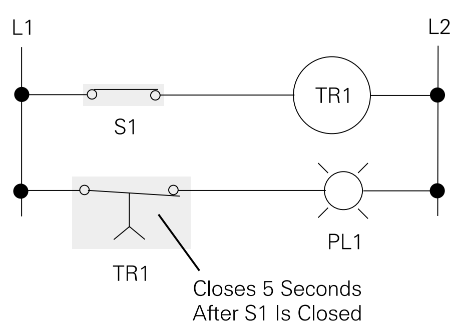
On-delay and Off-delay timers can turn their connected loads on or off, depending on how the timer's output is wired into the circuit. On-delay indicates that once a timer has received a signal to turn on, a predetermined time (set by the timer) must pass before the timer's contacts change state. Off-delay indicates that once a timer has received a signal to turn off, a predetermined time (set by the timer) must pass before the timer's contacts change state.

On-Delay, Time Closed

The following is an example of On-delay, timed closed. For this example a set of normally open (NO) contacts is used. This is also referred to as normally open timed closed (NOTC). The timing relay (TR1) has been set for an On-delay of 5 seconds.



When S1 is closed, TR1 begins timing. When 5 seconds has elapsed, TR1 will close its associated normally open (NO) TR1 contacts, illuminating pilot light PL1. When S1 is open, deenergizing TR1, the TR1 contacts open immediately, extinguishing PL1.



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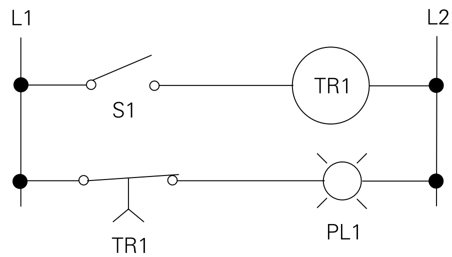
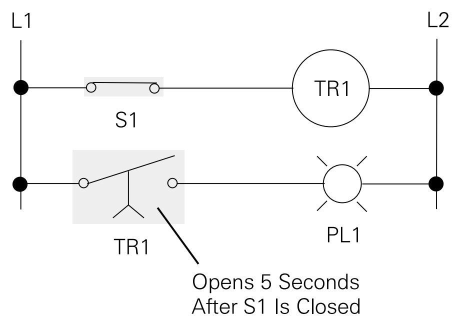
On-Delay, Timed Open

The following is an example of On-delay, timed open. For this example a set of normally closed (NC) contacts is used. This is also referred to as normally closed, timed open (NCTO). PL1 is illuminated as long as S1 remains open. The timing relay (TR1) has been set for an ON delay of 5 seconds.

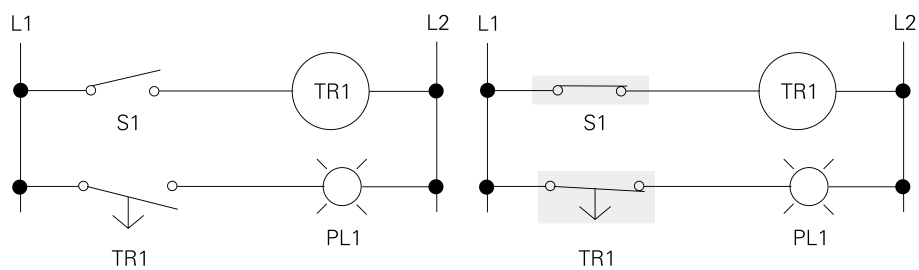


When S1 is closed, timing relay TR1 is energized. After a timed delay of 5 seconds, the associated normally closed TR1 contacts open, extinguishing PL1. When S1 is open, deenergizing TR1, the TR1 contacts close immediately, illuminating PL1.

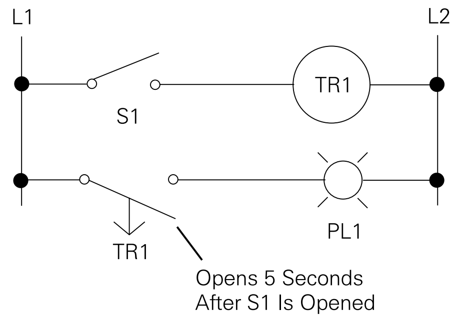


Off-Delay, Timed Open

The following is an example of Off-delay, timed open. For this example a set of normally open contacts (NO) is used. This is also referred to as normally open, timed open (NOTO). The timing relay (TR1) has been set for an off delay of 5 seconds. Closing S1 energizes TR1 causing its associated normally open TR1 contacts to close immediately, illuminating PL1.

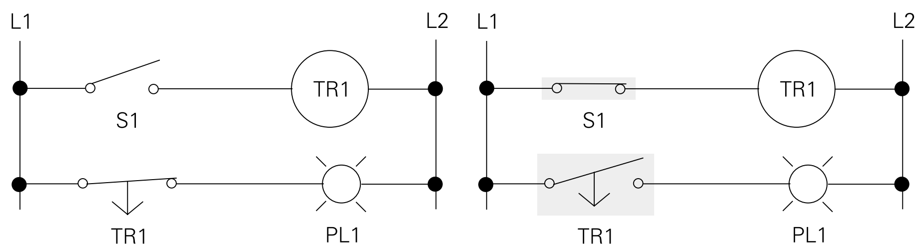


When S1 is opened, TR1 begins timing. When 5 seconds has elapsed, TR1 will open its associated normally open contacts, extinguishing pilot light PL1.

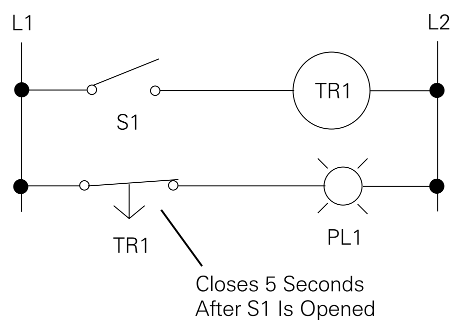


Off-Delay, Timed Closed

The following is an example of Off-delay, timed closed. For this example a set of normally closed (NC) contacts is used. This is also referred to as normally closed, timed closed (NCTC). The timing relay (TR1) has been set for 5 seconds. PL1 is on. Closing S1 energizes TR1 causing its associated contacts to open immediately, extinguishing PL1.

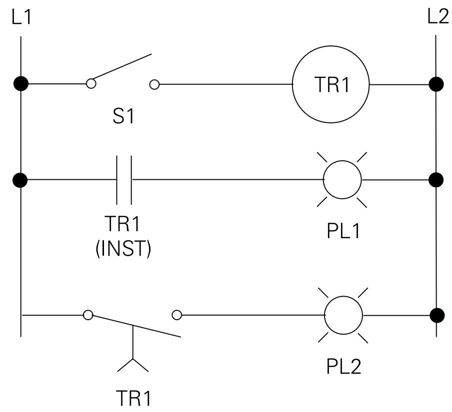


When S1 is opened, timing relay TR1 is deenergized. After 5 seconds, the associated normally closed contacts close, illuminating PL1.



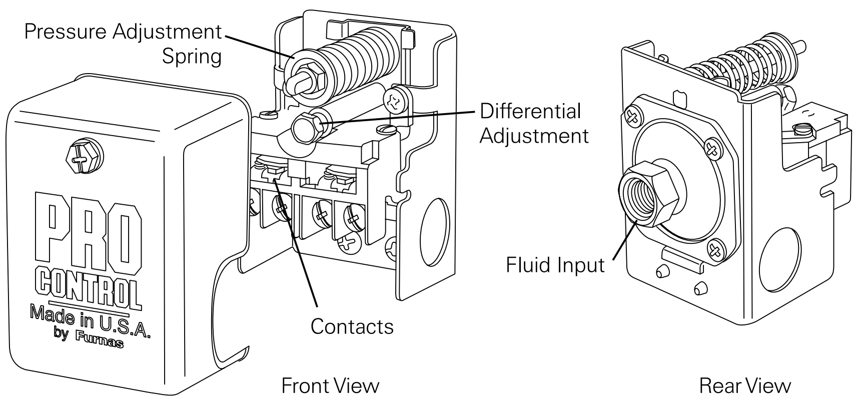
Instantaneous Contacts

Timing relays can also have normally open or normally closed instantaneous contacts. In the following example, when switch S1 is closed, the TR1 instantaneous contacts will close immediately, illuminating PL1. After a preset time delay the TR1 timing contacts will close, illuminating PL2.



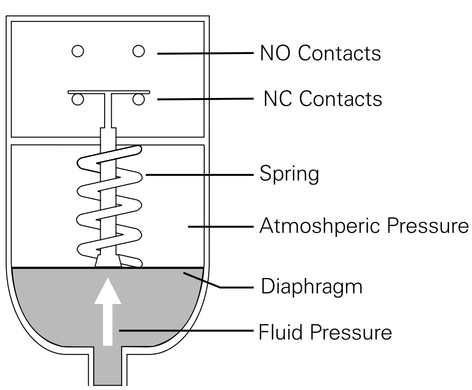
Pressure Switches

Pressure switches are control devices that respond to changes in pressure of liquid or air. The liquid or air is referred to as fluid pressure. They open or close electrical contacts in response to pressure changes by either turning on or off a motor, opening or closing louvers, or signaling a warning light or horn. For loads up to 5 HP the pressure switches may handle the current directly. For larger loads the pressure switch is used to energize relays, contactors, or motor starters, which then energize the load.



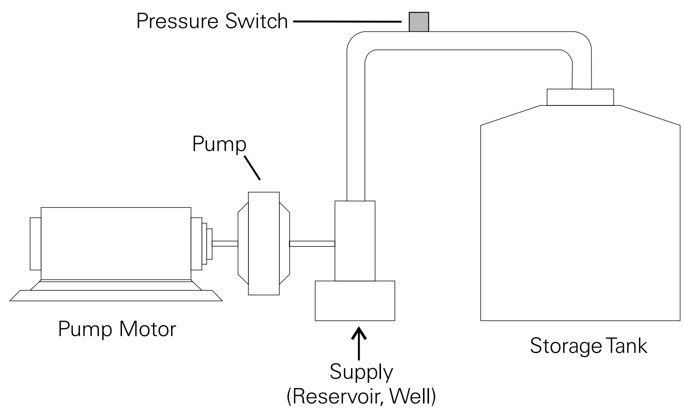
Pressure Switch Components

The basic components of a pressure switch are illustrated below. Electrical contacts are operated by the movement of a diaphragm against the force of a spring. The contacts may be normally open (NO) or normally closed (NC). The spring setting determines how much fluid pressure is required to operate the contacts.



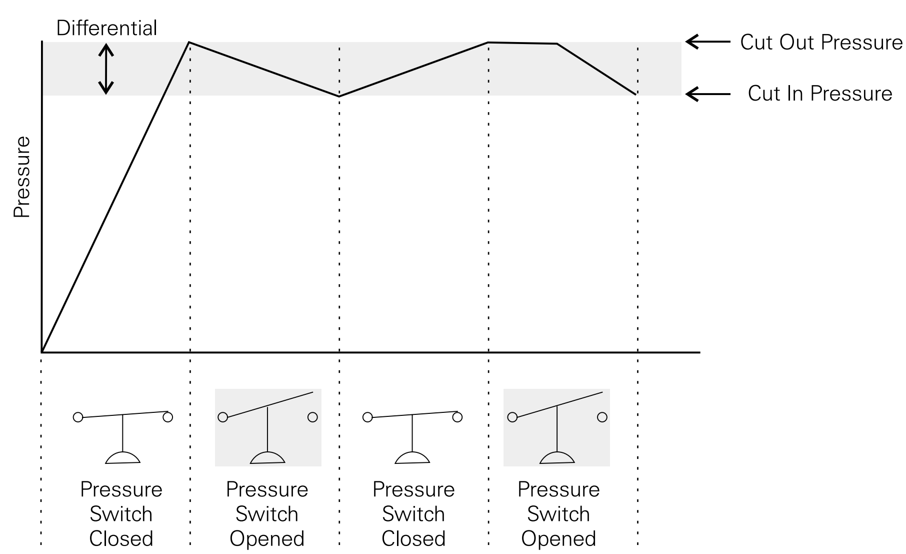
Application

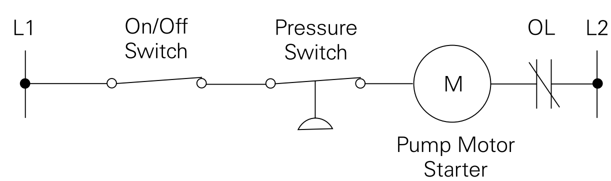
Pressure switches are frequently used to maintain a specified pressure range in a storage tank. Storage tanks can be used to hold a liquid, such as water, or a gas, such as air.



Operation

In this example a normally closed pressure switch is used. The pump starts as soon as power is applied to the circuit. When the pressure in the storage tank has reached a predetermined level, the contacts in the pressure switch open, removing power from the pump motor. As the contents of the storage tank are used, the pressure in the tank decreases. At a predetermined level the pressure switch will close its contacts, applying power to the pump motor.





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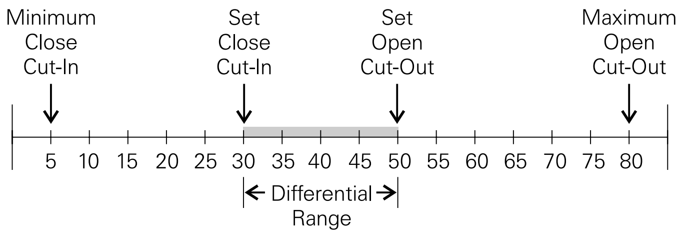
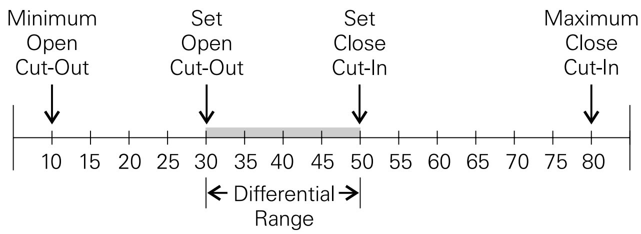
Pressure Range

Pressure switches are designed to operate within a specified pressure range, usually given in pounds per square inch (PSI). In the following example, a Furnas Class 69ES water pressure switch operates within a range of 10 to 80 PSI. The minimum close, or cut-in pressure, is 10 PSI. This is the point at which fluid pressure on the diaphragm causes the contacts to close. The maximum open, or cut-out pressure, is 80 PSI. This is the point at which fluid pressure on the diaphragm causes the contacts to open. Pressure differential is the difference between these two settings. The Furnas Class 69ES pressure switch can have a differential range of 15-25 PSI. In this example the cut-in pressure has been set to 30 PSI. The cut-out pressure has been set to 50 PSI. The pressure differential is 20 PSI. The pressure switch will regulate the pressure between 30 and 50 PSI.



Reverse Action

Reverse action pressure switches cut-in on a rising pressure. They are designed to ground the ignition on gas engine driven pumps and compressors when the maximum pressure has been reached. In the following example a Furnas Class 69WR5 reverse action pressure switch has been selected. The 69WR5 has a minimum open (cut-out) of 10 PSI and a maximum close (cut-in) of 80 PSI. The differential is set so that the switch opens at 30 PSI and closes at 50 PSI.



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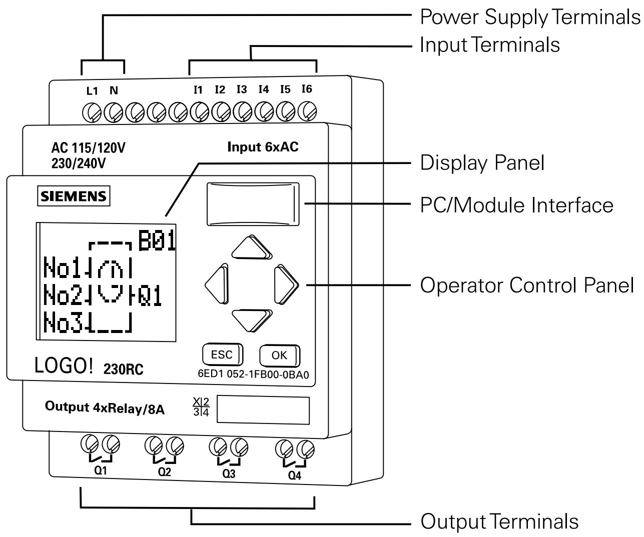
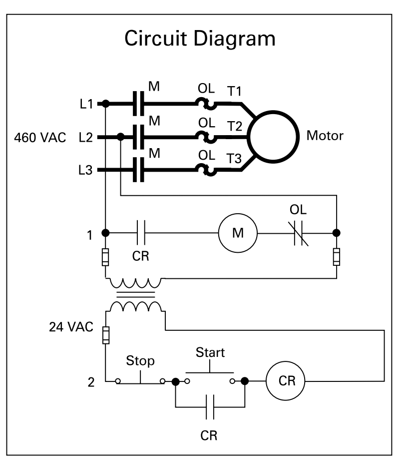
LOGO! Logic Module

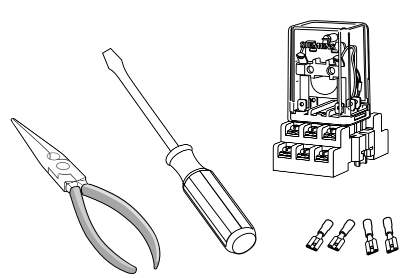
LOGO! is a logic module used to perform control tasks. The module is compact and user friendly, providing a cost-effective solution for the end user.



Hard-Wired Control

In the past, many of these control tasks were solved with contactor or relay controls. This is often referred to as hard-wired control. Circuit diagrams had to be designed and electrical components specified and installed. A change in control function or system expansion could require extensive component changes and rewiring.

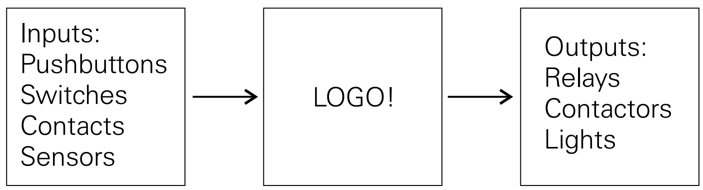




Many of the same tasks can be performed with LOGO!. Initial hard-wiring, though still required, is greatly simplified. Modifying the application is as easy as changing the program via the keypad located on the front of the LOGO!. Likewise, control programs can be created and tested before implementation via a PC software program. Once the program is performing per specification, the transfer to LOGO! is as simple as plugging in a cable.

Basic LOGO! Operation

LOGO! accepts a variety of digital inputs, such as pushbuttons, switches, and contacts. LOGO! makes decisions and executes control instructions based on the user-defined program. The instructions control various outputs. The outputs can be connected to virtually any type of load such as relays, contactors, lights, and small motors.



Design Features

LOGO! is available in many different versions for different supply voltages (12 VDC, 24 VDC, 24 VAC or 115/230 VAC).

All models have:

- Relay outputs with maximum 10 amp output current (not LOGO! 24/24L models)
- Integrated clock (not LOGO! 24/24L models)
- Integrated display
- Integrated keypad
- Integrated basic and special functions
- Integrated EEPROM for storing programs and setpoints
- Optional program module
  - Yellow Module for simple program dupication
  - Red Module for program backup and protection
- Basic AND, OR, NOT, NAND, NOR, and XOR functions
- AND and NAND functions with positive and negative edge detection
- Special ON delay, latching ON delay, OFF delay, pulse relay, latching relay, clock pulse generator, and counter (up/down) functions (total of 21 special functions)

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Basic version features:

- Six digital inputs, four digital outputs for AC models
- Eight digital inputs, four digital outputs for DC models with two inputs capable of accepting analog inputs

Pure version features:

- LOGO! Basic without display

L model features:

- Twelve digital inputs, eight digital outputs
- Four additional inputs and outputs on the AS-i modules

The maximum possible options for every model version are as follows:

- 16 Timers
- 24 Counters
- Eight Time Switches
- Three Operating Hour Counters
- 42 Current Impulse Relays
- 42 Latching Relays
- Four Markers for Program Continuation
- 56 Total Function Blocks

Review 8

1. ___________ is the total number of different circuits each pole controls.

2. ___________ describes the number of isolated circuits that can pass through a relay at one time.

3. An SPDT relay has ___________ pole(s) and ____________ closed contact position(s).

4. A timing relay that has received a signal to turn on, and then delays a predetermined amount of time before an action takes place is referred to as ____________ delay.

Review Answers

Review 1	1) manually; 2) a; 3) b; 4) b; 5) c.
Review 2	1) left to right; 2) A - Node, B - Power Circuit, C - Power Load, D- Control Circuit; E - Control Device; F - Control Load.
Review 3	1) a; 2) excess; 3) overload; 4) a; 5) bimetal.
Review 4	1) 2; 2) LVP; 3) 10, 5; 4) 20; 5) motor starter.
Review 5	1) NEMA, IEC; 2) 5; 3) AC3; 4) 4; 5) 3; 6) 50; 7) 3UA66.
Review 6	1) Consequent-pole motor; 2) progressive control; 3) reduced-voltage starting; 4) Autotransformer.
Review 7	1) pilot device; 2) Three-Wire Control, Two-Wire Control; 3) visual; 4) red, green.
Review 8	1) Throw; 2) Pole; 3) one, two; 4) ON.

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After completing the test, mail in the answer sheet for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

Questions

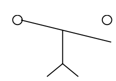
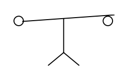
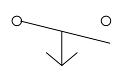
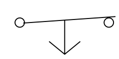
1. The standard method of showing a contact is by indicating the circuit condition it produces when the actuating device is in the ___________ state.

   a. normally closed b. normally open
   c. energized d. deenergized

2. A motor that is running would usually be indicated by a ___________ pilot light.

   a. green b. red
   c. amber d. white

3. Which of the following symbols represents a normally closed, timed open (NCTO) contact?

   a.  b. 
   c.  d. 

4. With an increase of current, temperature will ___________ .

   a. decrease b. increase
   c. remain the same d. increase and decrease

5. The two circuits involved in the operation of a contactor are the ___________ circuits.

   a. power and control
   b. power and armature
   c. control and electromagnetic
   d. control and starter

6. A motor starter is a combination of a/an ___________ .

a. electromagnet and armature
b. contactor and electromagnet
c. contactor and overload relay
d. overload relay and instantaneous contacts

7. Which of the following is not part of a contactor?

a. armature
b. electromagnetic coil
c. overcurrent sensing device
d. stationary contacts

8. One reason reduced-voltage starting may be used to start a motor is to ___________ .

a. apply torque gradually
b. increase starting torque
c. get motor to full speed faster
d. run the motor at a lower speed

9. A type of speed selection control that requires the operator to manually increment through each speed step to get to the desired speed is ___________ control.

a. selective b. compelling
c. progressive d. consequent pole

10. The organization primarily concerned with the rating of contactors and starters used in many countries, including the U.S. is ___________ .

a. NEMA b. UL
c. ICS d. IEC

11. The proper overload relay for a World Series 3TF50 contactor is ___________ .

a. 3UA50 b. 3UA54
c. 3UA58 d. 3UA60

12. A device used to provide visual information of the circuit's operating condition is a ___________ .

a.	pushbutton	b.	selector switch
c.	proximity switch	d.	pilot light

13. A relay that has two isolated circuits and one closed contact position per pole is a ___________ .

a.	DPST	b.	DPDT
c.	SPST	d.	SPDT

14. The point at which fluid pressure on the diaphragm of a pressure switch causes the contacts to open is referred to as ___________ .

a.	cut-out pressure	b.	cut-in pressure
c.	pressure range	d.	pressure differential

15. A NEMA Size 6 starter has a continuous amp rating of ___________ amps.

a.	200	b.	540
c.	810	d.	1600

16. Audible elements for the 8WD42 siganlling column include a ___________ .

a.	siren	b.	buzzer and siren
c.	buzzer	d.	horn

17. Furnas INNOVA PLUS™ starters are available up to ___________ HP.

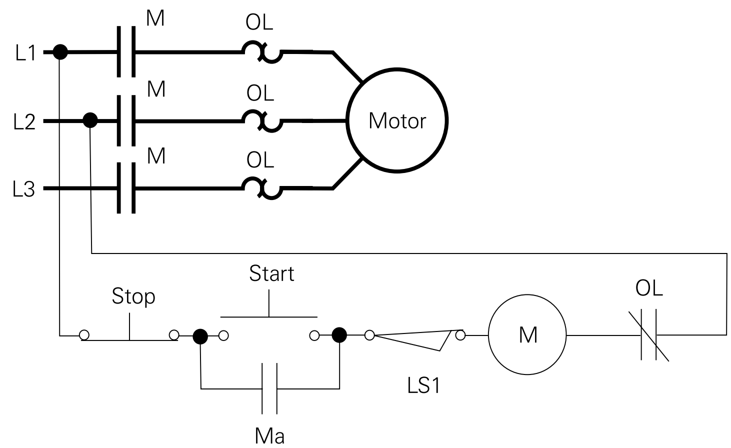
a.	25	b.	50
c.	100	d.	250

18. SIRIUS Type 3R motor starters are available for loads up to __________ amps.

a.	95	b.	135
c.	200	d.	270

19. In the following diagram, the motor will stop when ___________ .

a. the "Stop" button is depressed
b. limit switch "LS1" opens
c. the motor overload contact opens
d. all of the above



20. The _________ overload relay integrates with PROFIBUS-DP.

a. 3RB10
b. ESP 100
c. 3UF5
d. 3RU11