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Introduction

Welcome to another course in the STEP 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 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 construction and operating principles of lighting and heating contactors
- Describe the operating principles of control relays

This knowledge will help you better understand customer applications. In addition, you will be better prepared to discuss electrical products and systems with customers. You should complete **Basics of Electricity** before attempting **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

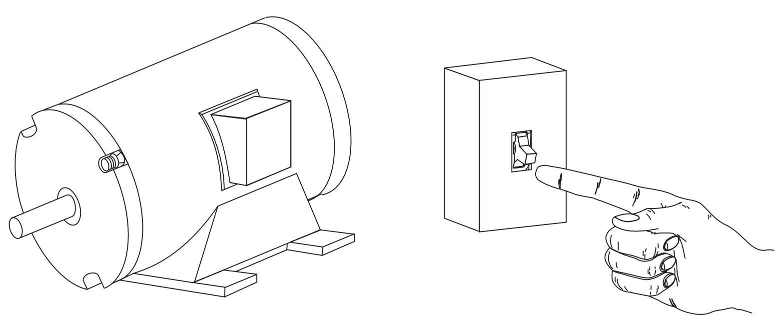
Control

Control components are used in a wide variety of applications with varying degrees of complexity. One example of a simple control circuit is a circuit that turns a light on and off. In this circuit, the control component is often a single-pole switch.

Control circuits used in commercial and industrial applications tend to be more complex than this simple circuit and employ a broader variety of components. However, the function of these circuits is often the same, to turn something on and off. In some cases, manual control is used. More often, automatic control circuits or circuits that combine manual and automatic control are used.

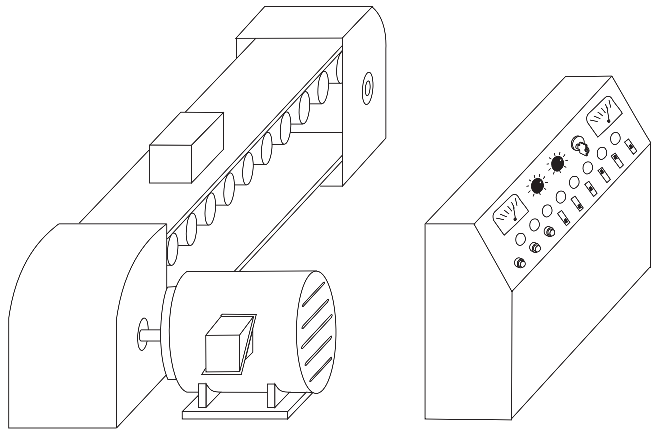
Manual Control

A simple on-off lighting control circuit illustrates an example of **manual control**. Manual control requires someone to use a switch to turn something on or off. The device being turned on or off may be a light, as in the previous example. However, many other devices are also controlled manually. For example, a manual starter can be used to start and stop a motor.



Automatic Operation

While manual control of machines is still common practice, many machines are started and stopped automatically or by some combination of manual and automatic control. **Automatic control** occurs when circuits can turn something on and off without human interaction.



Control Components

A wide variety of components are used in control circuits. This includes components that vary in complexity from indicator lights to advanced systems that monitor, protect, and control AC motors.

In some cases, the interaction of these components is dependent only on how they are wired to each other. This is sometimes referred to as **hard-wired logic**. Increasingly, however, these components are wired to a control system, such as a programmable logic controller or variable speed drive. In such cases, the interaction of the circuit components is dependent both on wiring and the software stored in the controller.

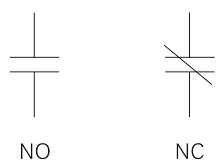
The complete range of Siemens control components is too extensive to be fully addressed in this course. However, this course will give you a good start. For additional information, refer to the Siemens Energy & Automation web site.

Electrical Symbols

Control circuits can be represented pictorially in various ways. One of the more common approaches is to use control logic diagrams which use common symbols to represent control components. Although control symbols vary throughout the world, the symbols used in this course are common in the United States and many other countries.

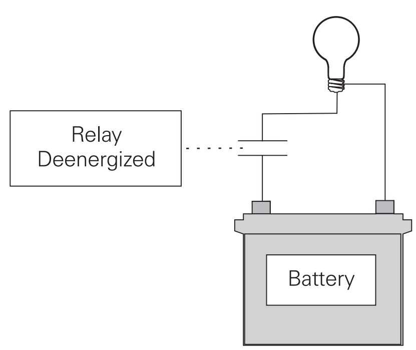
Contact Symbols

Various devices incorporate contacts to control the flow of current to other control components. When in operation, a contact my be either **open**, a condition which blocks current flow, or **closed**, a condition which allows current flow. Control logic diagrams, however, cannot show the dynamic operation of contacts. Instead, these diagrams show contacts as either **normally open (NO)** or **normally closed (NC)**.



The standard method of showing contacts is to indicate the circuit condition produced when the actuating device is in the **de-energized (off) state**.

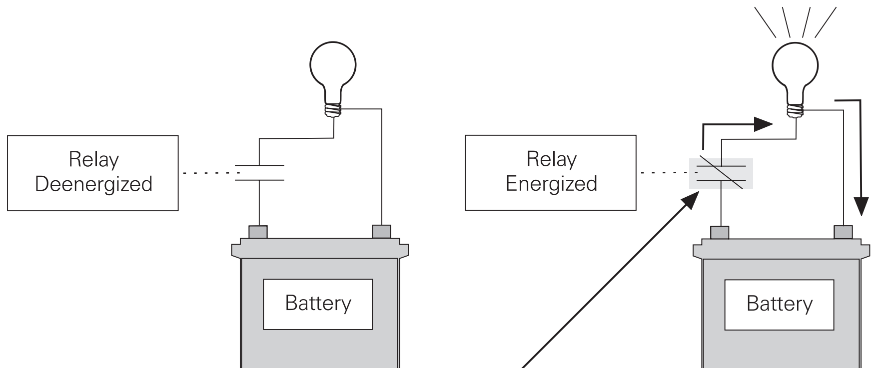
For example, in the following illustration, the contacts are part of a relay. The contacts are shown as normally open to indicate that, when there is no power applied to the relay's coil, the contacts are open. With the contacts open, there is no current flow to light.



Symbols on a control logic diagram are usually not shown in their energized (on) state. However, in this course, contacts and switches are sometimes shown in their energized state for explanation purposes. In such cases, the symbol is highlighted.

Normally Open Contact Example

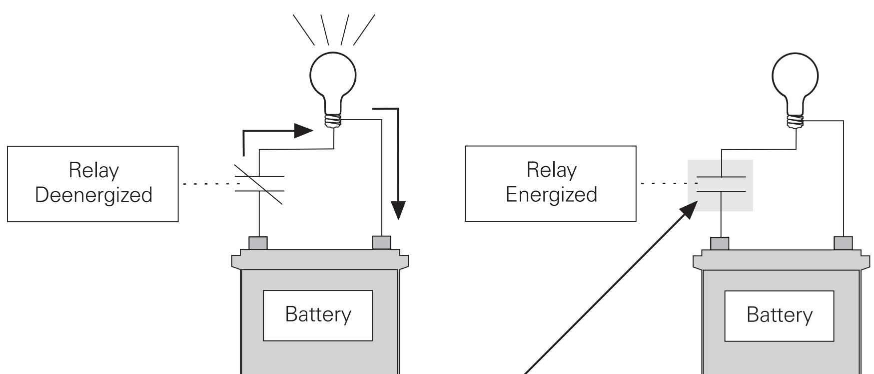
For example, in the following illustration, the circuit is first shown in the de-energized state, and the normally open contacts are not highlighted. When the relay energizes, the contacts close, completing the path for current and illuminating the light. The contacts are then shown as highlighted to indicate that they are not not their **normal** state. *Note: This is not a standard symbol.*



Contacts are shown opposite of their normal state (NO).

Normally Closed Contact Example

In the following illustration, when the relay is de-energized, the normally closed contacts are shown as closed and are not highlighted. A complete path of current exists at this time, and the light is on. When the relay is energized, the contacts open, turning the light off.



Contacts are shown opposite of their normal state (NC).

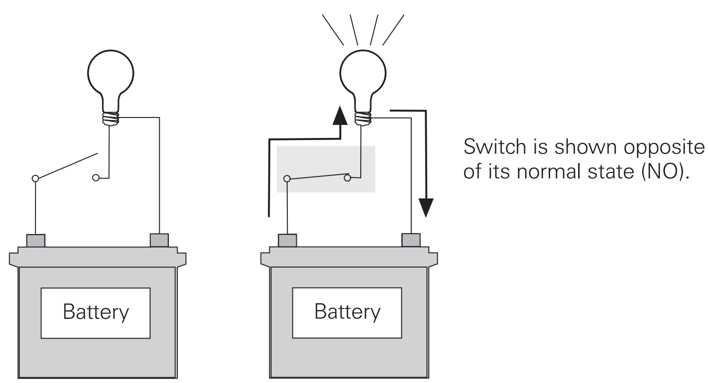
Switch Symbols

Various types of **switches** are also used in control circuits. Like the contacts just discussed, switches can also be normally open or normally closed and require another device or action to change their state. In the case of a manual switch, someone must change the position of the switch. A switch is considered to be in its normal state when it has not been acted upon.

Switch symbols, like the ones shown in the following illustration, are also used to indicate an open or closed path of current flow. Variations of these symbols are used to represent a number of different switch types.

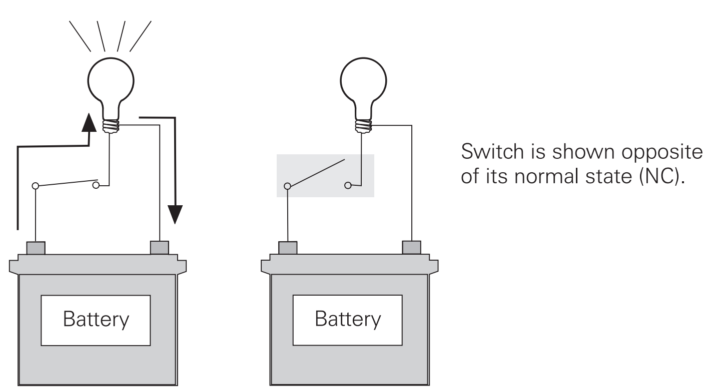
Normally Open Switch Example

In the following illustration, a battery is connected to one side of a normally open switch, and a light is connected to the other side. When the switch is open, current cannot flow through the light. When someone closes the switch, it completes the path for current flow, and the light illuminates.



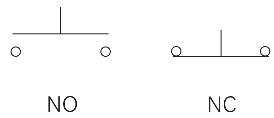
Normally Closed Switch Example

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



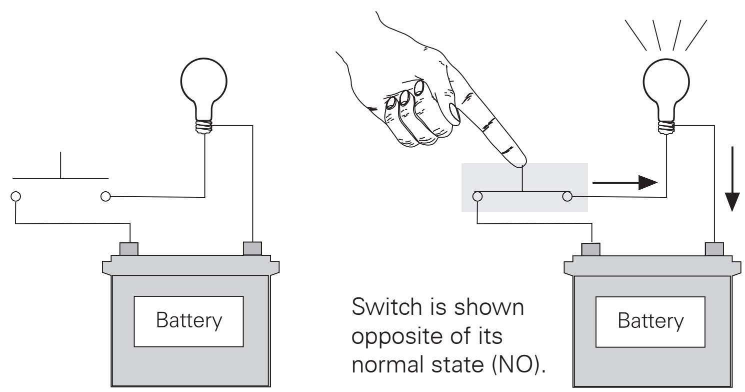
Pushbutton Symbols

There are two basic types of **pushbuttons**, **momentary** and **maintained**. The contacts of a momentary pushbutton change state, open to closed or vice versa, when the button is pressed. They return to their normal state as soon as the button is released. In contrast, a maintained pushbutton latches in place when pressed. It must be unlatched to allow it to return to its normal state.



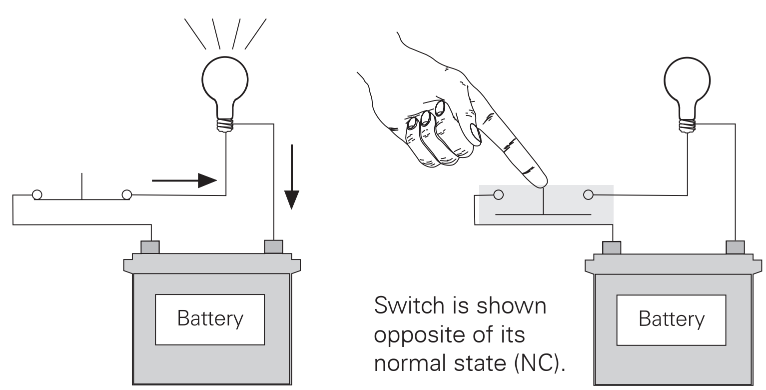
Normally Open Pushbutton Example

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 pressed, current flows through the pushbutton, and the light turns on.



Normally Closed Pushbutton Example

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

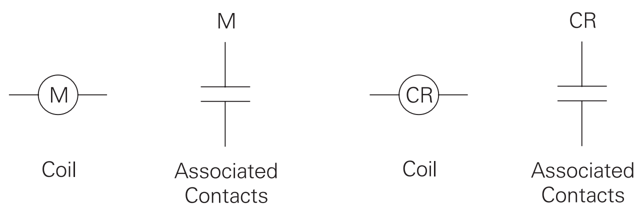


Coil Symbols

Motor starters, contactors, and relays are examples of devices that open and close contacts electromagnetically. The electromagnet in these devices is called a **coil.**

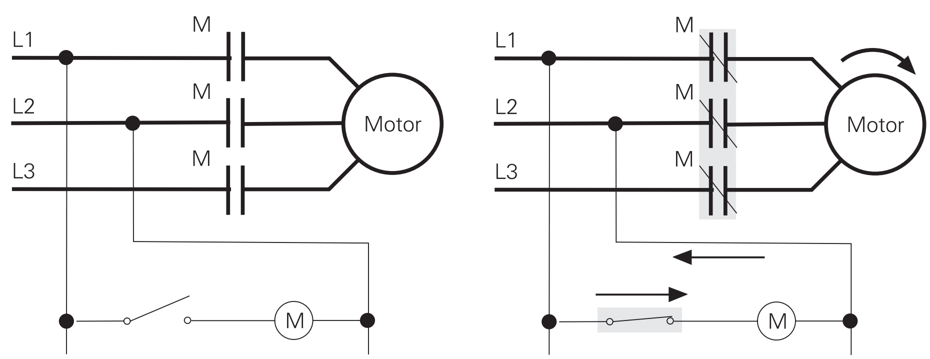
A coil is commonly symbolized as a circle with letters and number inside. The letters often represent the type of device, such as M for motor starter or CR for control relay. A number is often added to the letter to differentiate one device from another.

The contacts controlled by a coil are labeled with the same letter (and number) as the coil so that it is easy to tell which contacts are controlled by each coil. A coil often controls multiple contacts and each contact may be 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, current flows through the switch and "M" contactor coil. The "M" contactor coil closes the "M" contacts and current flows to the motor.



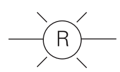
Overload Relay Symbols

Overload relays are used to protect motors from overheating. When excessive current is drawn for a predetermined amount of time, the overload relay's contacts open, removing power from the motor. The following symbol is for contacts associated with a thermal overload relay. An overload relay used with a three-phase motor has three such contacts, one for each phase.

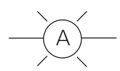
Thermal
Overload

Indicator Light Symbols

An **indicator light**, often referred to as 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 that a motor is running. The letter in the center of the indicator light symbol indicates the color of the light.



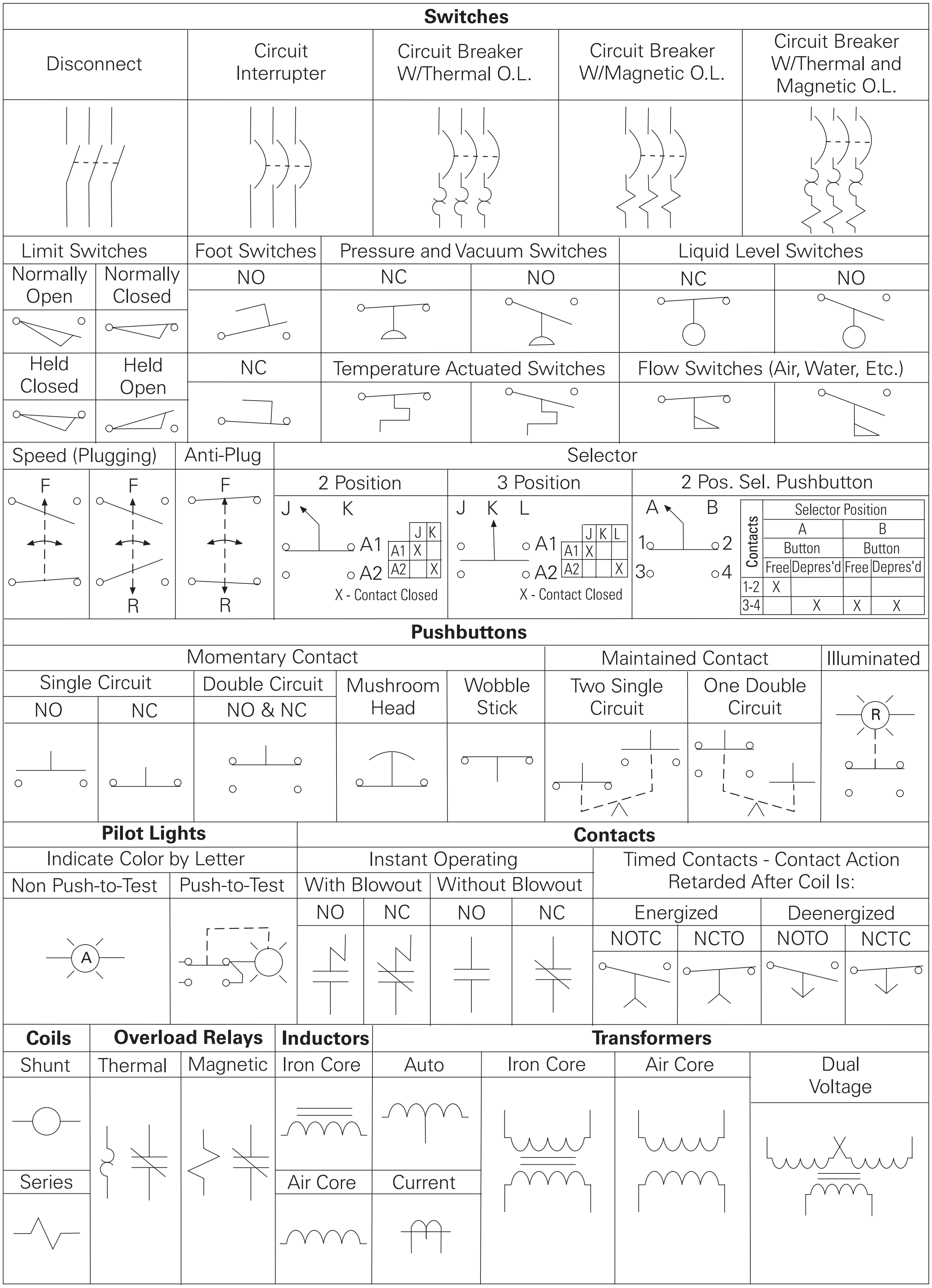
Red
Indicator Light

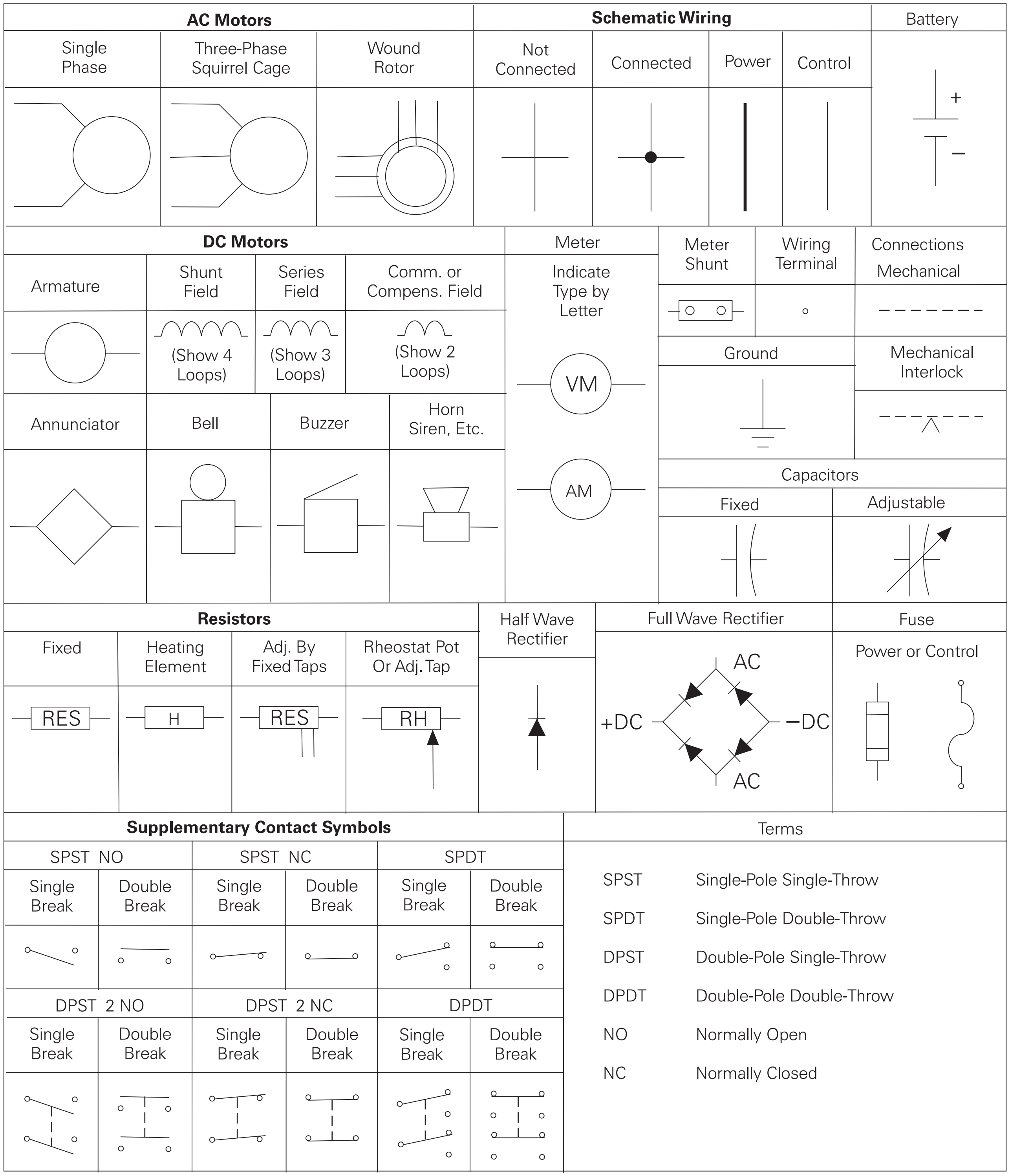


Amber
Indicator Light

Other Symbols

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

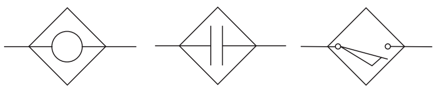

Switches
Disconnect
Circuit Interrupter
Circuit Breaker W/Thermal O.L.
Circuit Breaker W/Magnetic O.L.
Circuit Breaker W/Thermal and Magnetic O.L.
Limit Switches
Normally Open
Normally Closed
Held Closed
Held Open
Foot Switches
NO
NC
Pressure and Vacuum Switches
NC
NO
Liquid Level Switches
NC
NO
Temperature Actuated Switches
Flow Switches (Air, Water, Etc.)
Speed (Plugging)
F
F
R
Anti-Plug
F
R
Selector
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 Pos. Sel. Pushbutton
A B
1 2
3 4
Contacts
Selector Position
A
B
Button
Button
Free
Depres'd
Free
Depres'd
1-2 X
3-4 X X X
Pushbuttons
Momentary Contact
Single Circuit
NO
NC
Double Circuit
NO & NC
Mushroom Head
Wobble Stick
Maintained Contact
Two Single Circuit
One Double Circuit
Illuminated
R
Pilot Lights
Indicate Color by Letter
Non Push-to-Test
Push-to-Test
A
Contacts
Instant Operating
With Blowout
NO
NC
Without Blowout
NO
NC
Timed Contacts - Contact Action Retarded After Coil Is:
Energized
NOTC
NCTO
Deenergized
NOTO
NCTC
Coils
Shunt
Series
Overload Relays
Thermal
Magnetic
Inductors
Iron Core
Air Core
Transformers
Auto
Current
Iron Core
Air Core
Dual Voltage


AC Motors
Single Phase
Three-Phase Squirrel Cage
Wound Rotor
Schematic Wiring
Not Connected
Connected
Power
Control
Battery
+
−
DC Motors
Armature
Shunt Field
(Show 4 Loops)
Series Field
(Show 3 Loops)
Comm. or Compens. Field
(Show 2 Loops)
Meter
Indicate Type by Letter
VM
AM
Meter Shunt
Wiring Terminal
Connections Mechanical
Ground
Mechanical Interlock
Annunciator
Bell
Buzzer
Horn Siren, Etc.
Capacitors
Fixed
Adjustable
Resistors
Fixed
RES
Heating Element
H
Adj. By Fixed Taps
RES
Rheostat Pot Or Adj. Tap
RH
Half Wave Rectifier
Full Wave Rectifier
AC
+DC
−DC
AC
Fuse
Power or Control
Supplementary Contact Symbols
SPST NO
SPST NC
SPDT
Single Break
Double Break
DPST 2 NO
DPST 2 NC
DPDT
Single Break
Double Break
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 uses solid-state devices instead of electromechanical devices. Many of the symbols used with this type of control are the same as those shown on the previous page, but enclosed in a square as shown in the following examples.

Coil	Contact (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

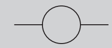
Abbreviations are frequently used in control circuits. The following list identifies commonly used abbreviations.

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

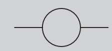
Review 1

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. 

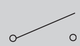
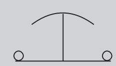
3. Which of the following symbols represents a normally closed contact?

   a.  b.  c. 

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

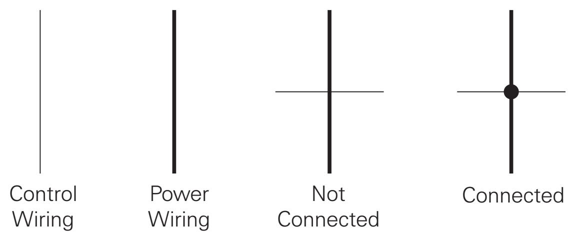
   a.  b.  c. 

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

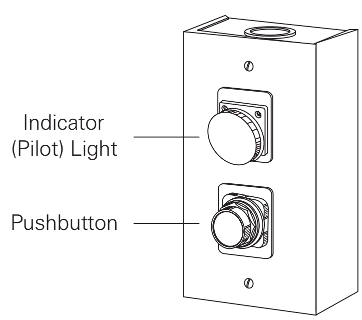
   a.  b.  c. 

Line Diagrams

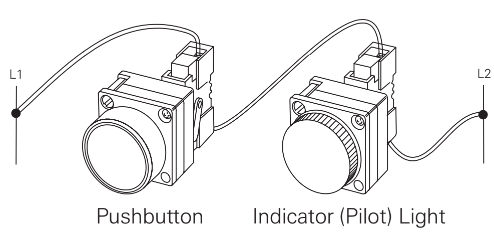
Control symbols are used in line diagrams, also referred to as ladder diagrams. Line diagrams are made up of two types of circuits, control circuits and power circuits. Within a line diagram, control circuit wiring is represented by a light line, and power-circuit wiring is represented by a heavy line. 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 in an electrical circuit, not the physical relationship. For example, the following illustration shows the physical relationship of an indicator light and a pushbutton.

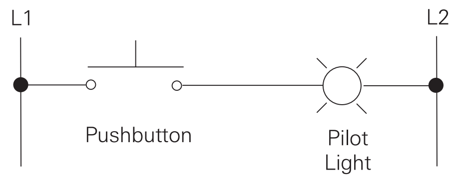


The functional relationship can be shown pictorially with the following illustration.



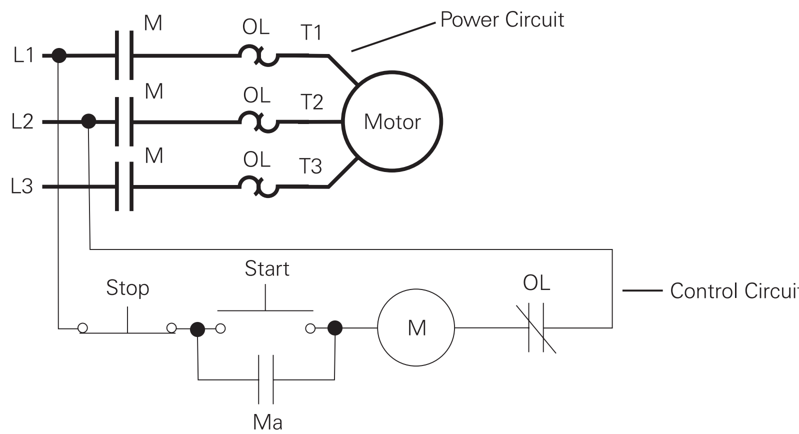
Reading a Line Diagram

The following line diagram symbolically displays the functional relationship of these same components. In order to properly interpret this diagram, you must read it starting at L1 from left to right to L2. With that in mind, note that pressing the pushbutton allows current to flow from L1 to L2 through the pushbutton and the indicator light. Releasing the pushbutton stops current flow, turning the indicator light off.



Power and Control Circuits

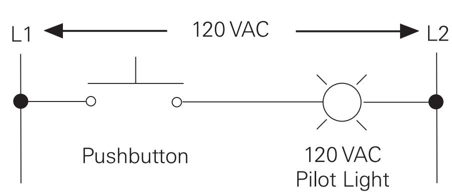
The following line diagram includes both power and control circuits. The **power circuit**, drawn with a heavy line, is the circuit that supplies power to the motor. The **control circuit,** drawn with a light line, controls the the distribution of power.



Control Circuits

A typical control circuit includes a control load and one or more components that determine when the control load will be energized. Some control loads, such as relays and contactors, activate other devices. Other control loads, such as indicator lights, do not.

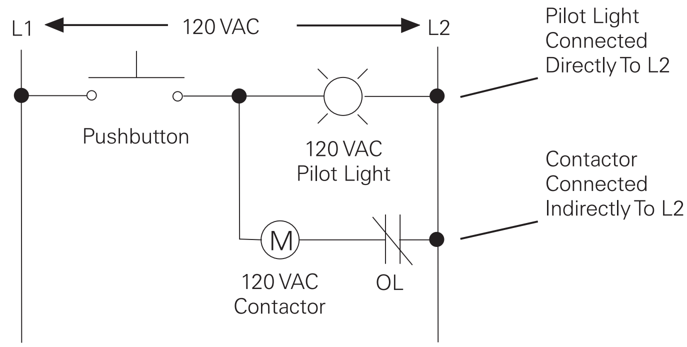
The following illustration shows the connection of an indicator light and a pushbutton. The power lines are drawn vertically and marked L1 and L2. In this example, the voltage between L1 and L2 is 120 VAC. This means that the indicator light must be rated for 120 VAC, because, when the pushbutton is pressed, 120 VAC is applied to the indicator light.



Connecting the Load to L2

Only one control load can be placed in any one circuit line between L1 and L2. One side of the control load is connected to L2 either directly or through overload relay contacts.

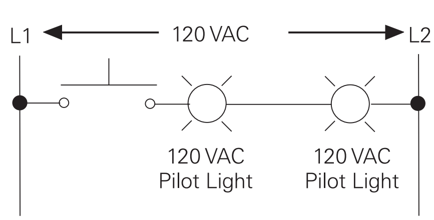
In the following example, an indicator light is directly connected to L2 on one circuit line. A contactor coil is indirectly connected through a set of overload contacts (OL) to L2 on a second, parallel circuit line. Depressing the pushbutton would apply 120 VAC to the indicator light and to the "M" contactor.



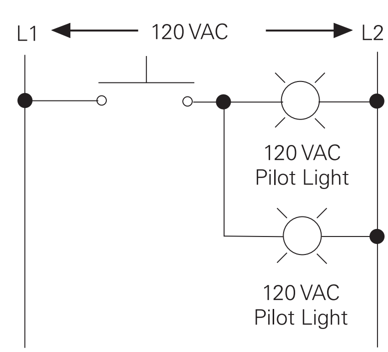
Control loads are generally not connected in series. The following illustration shows why. In the circuit on the left, the control loads are improperly connected in series. When the pushbutton is pressed, the voltage across L1 and L2 is divided across both loads with neither load receiving the full 120 volts necessary for proper operation.

In the circuit on the right, the loads are properly connected in parallel, and, when the pushbutton is pressed, the full 120 volts is applied to both loads. In addition, if one load fails in this configuration, the other load will continue to operate normally.

Improper Series Connection



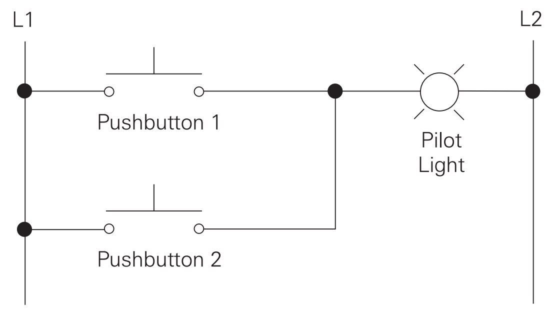
Proper Parallel Connection



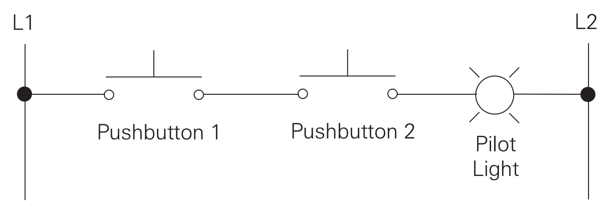
Connecting Control Devices

In the previous example, only one control device is used to control the load. Usually more than one control device is needed. These control devices may be connected in series, parallel, or in a combination series-parallel circuit, depending on the logic required to control the load.

In the following illustration, the pushbuttons are connected in parallel. Pressing either pushbutton, or both pushbuttons, allows current to flow from L1, through the indicator light, to L2.

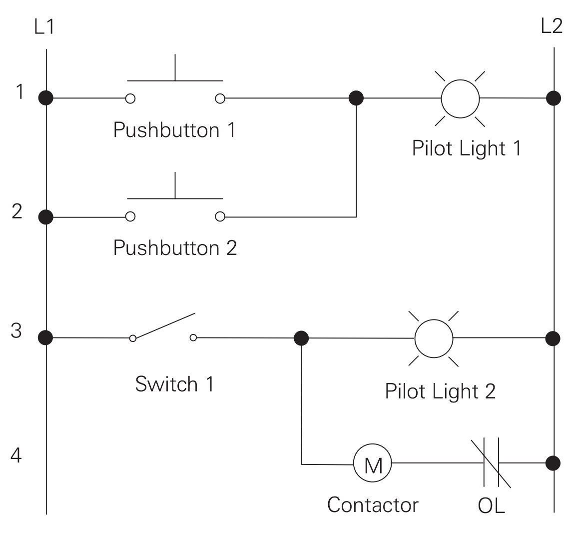


The next illustration shows two pushbuttons connected in series. Both pushbuttons must be pressed at the same time to allow current to flow from L1 through the load to L2.



Line Numbering

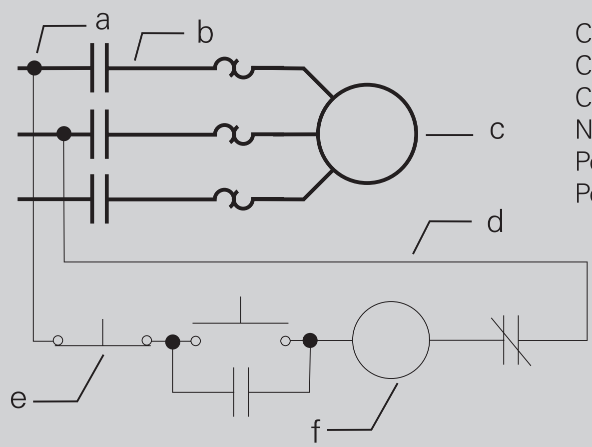
Because line diagrams often have multiple lines, the lines are numbered to simplify describing the logic. For example, in the illustration, line 1 connects pushbutton 1 to pilot light 1, line 2 connects pushbutton 2 to pilot light 1, and line 3 connects switch 1 to pilot light 2 and to the "M" contactor on line 4.



Review 2

1. Line diagrams are read starting at L1 from _______ to _______ to L2.

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



Control Circuit
Control Device
Control Load
Node
Power Circuit
Power Load

a. _______ b. _______ c. _______

d. _______ e. _______ f. _______

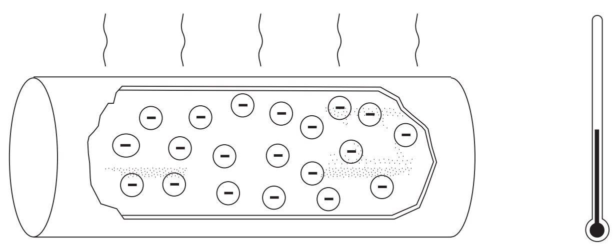
Overload Protection

Some of the control components covered in this course are designed to protect motors from overloads. In order to understand these control components, you must have a clear understanding of what an overload is and how it differs from a short circuit, another type of overcurrent condition.

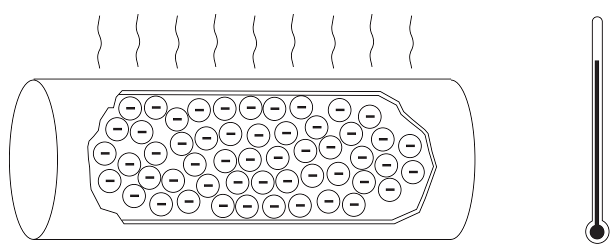
Current and Temperature

To begin with, current flow always generates heat. The amount of heat generated is proportional to both the amount of current flow and the resistance of conductive path. Keep in mind that conductors can be damaged by excess heat. For that reason, each conductor has a rated continuous current capacity, referred to as the **ampacity** of the conductor.

Excessive current is referred to as **overcurrent**. An overcurrent may result from a short circuit, overload, or ground fault. The first two types of overcurrent conditions are pertinent to this discussion.



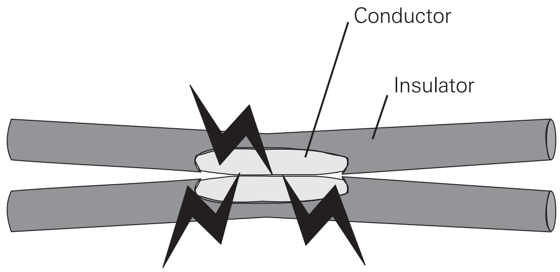
Normal Current Flow



Excessive Current Flow

Short Circuit

Normally, the insulation used to separate conductors prevents current from flowing between the conductors. When the insulation is damaged; however, a short circuit can result. A **short circuit** occurs when bare conductors touch and the resistance between the conductors drops to almost zero. This reduction in resistance causes current to rise rapidly, usually to many times the normal circuit current.



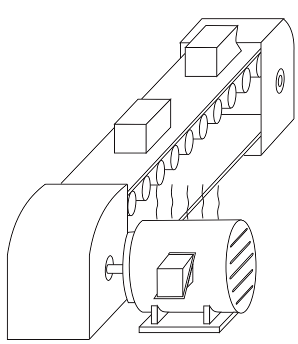
To understand this better, consider the relationship between current and resistance described by **Ohm's Law**. For example, if the voltage in a circuit is 240 volts and the resistance is 24 ohms, the current is 10 amps. When a short circuit occurs, the resistance between conductors drops to a very low value, 0.024 ohms in this example. Note that this causes the current to rise proportionally.

	Before Short Circuit	After Short Circuit
Ohm's Law $I = \frac{E}{R}$	$I = \frac{240\ V}{24\ \Omega} = 10\ A$	$I = \frac{240\ V}{0.024\ \Omega} = 10{,}000\ A$

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

Overload

In contrast, an **overload** is a much lower current than a short circuit. An overload may result when too many devices are connected to a circuit or when electrical equipment is made to work too hard. For example, if a conveyor jams, its motor may draw two or more times its rated current.

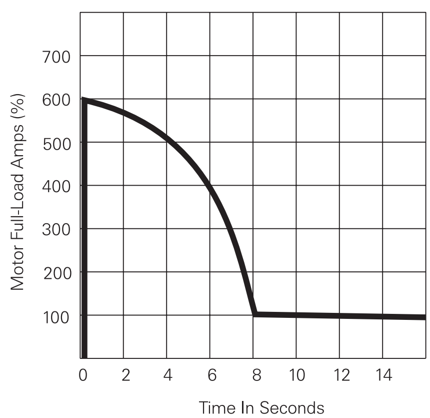


In the previous example, the overload resulted when a circuit exceeded its rated capacity for an extended time. In such a situation, an overcurrent protection device should shut down the circuit.

Temporary Overload Due to Starting Current

A different response is required for a short-duration overload. In such a situation, it may be undesirable to disable the circuit immediately. For example, consider what happens when an electric motor is started.

When most motors start, they draw current in excess of their full-load current rating. For example, a NEMA design B AC motor typically has a **starting current** that is about six times its **full-load current**. For some high-efficiency motors, the starting current is even higher. Motors are designed to tolerate a high starting current for a short time. As a motor accelerates to operating speed, its current drops off quickly. In the following example, the motor's starting current is 600% of full load current, but after eight seconds, current has dropped to the rated value.



Overload Protection

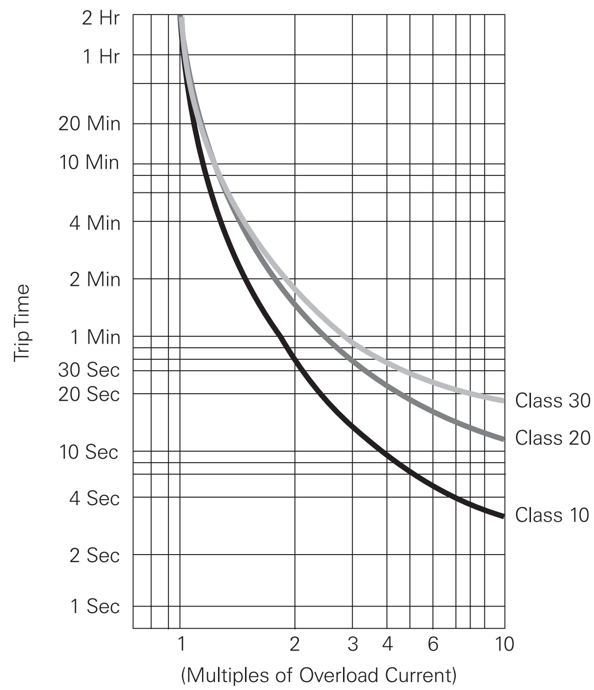
Fuses and circuit breakers are designed to protect circuit conductors in the event of a short circuit or overload. Under such conditions, these devices open the path for current flow before damage to conductors occurs. In a motor circuit, circuit conductors and the fuse or circuit breaker designed to protect the conductors must be sized to allow for the high starting current of the motor. Because of this, overload protection for the motor must be provided by a separate device known as an **overload relay**.

Overload Relays

Overload relays are designed to meet the special protective needs of motors. First, they allow short-duration overloads without disabling the circuit. Second, they trip and open a circuit to protect a motor if current remains above the rated value long enough. And third, they can be reset to allow the motor to be restarted after the overload has been cleared.

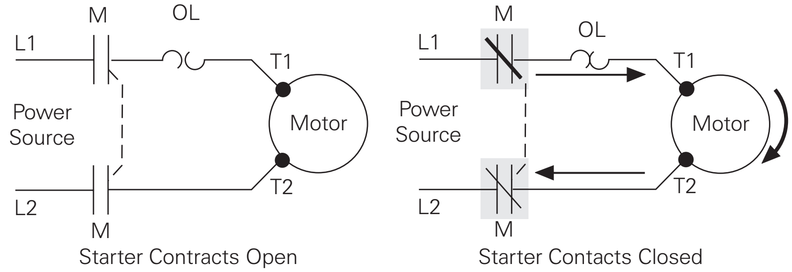
Trip Class

An overload relay has a **trip class rating** which identifies the maximum time (in seconds) it takes for the overload relay to trip at a specific current, typically six times its continuous current rating. The most common trip classes are **classes 10**, **20**, and **30**. Siemens offers overload relays in all three trip classes.



Overload Relay in a Motor Circuit

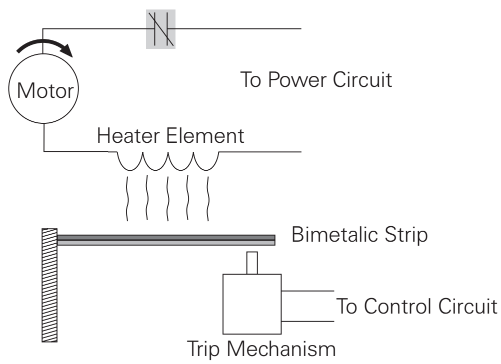
The following illustration shows a circuit with a manual motor starter (M) and an overload relay (OL). When the starter contacts close, current flows through the overload relay and motor. If the motor is overloaded, excess current will cause the overload relay to trip, opening the circuit between the power source and the motor. After the overload relay cools, it can be reset. This allows the motor to be restarted, preferably after the cause of the overload has been corrected.



Bimetallic Overload Relays

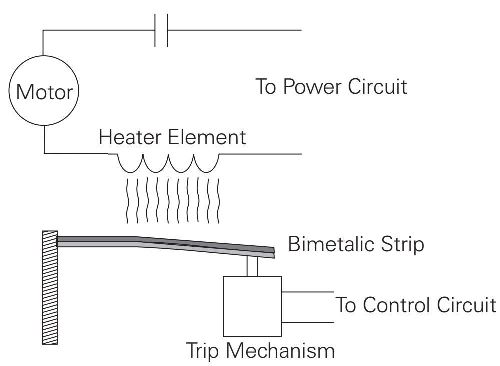
Some overload relays use a **bimetallic strip** to sense an overload condition. A bimetallic overload relay incorporates a small **heater element** wired in series with the motor and a bimetallic strip that functions as a trip lever. The bimetallic strip is made of two dissimilar metals bonded together. These metals have different thermal expansion characteristics, causing the bimetallic strip to bend when heated.

Under normal operating conditions, the heat generated by the heater element causes the bimetallic strip to bend only slightly, not enough to trip the overload relay.



Normal Current Flow

If an overload condition occurs and persists long enough, the bimetallic strip bends until the overload relay's trip mechanism is tripped. This causes the overload relay's contacts to open, removing power from the motor.



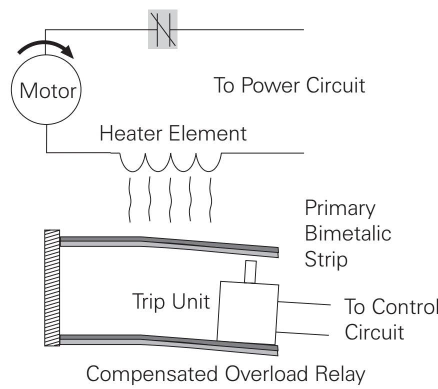
Overload Condition

Some bimetallic overload relays are designed to reset automatically after the bimetallic strip has cooled. Depending on the circuit, the motor may then restart automatically. In some applications, this is desirable. However, if the cause of the overload still exists, the overload relay will trip and reset repeatedly. Proper circuit design can prevent this condition, which can damage the motor.

Ambient Compensated Bimetallic Overload Relay

In some applications, a motor is installed in a location with a relatively constant ambient temperature, and the motor control components are installed in a location with a varying ambient temperature. In such cases, a typical thermal overload relay may trip too soon or too late because its bimetallic strip is bent both by heat from motor current and the surrounding air.

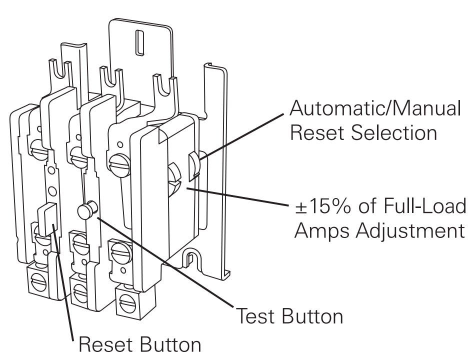
Ambient compensated bimetallic overload relays are designed to overcome this problem. These overload relays use a compensated bimetallic strip along with a primary bimetallic strip. As the ambient temperature changes, both bimetallic strips bend equally and the overload relay does not trip. However, because current flow through the motor and the heater element affects only the primary bimetallic strip, the primary bimetallic strip will bend sufficiently to trip the overload relay if an overload occurs.



The compensating bimetalic strip bends as ambient temperature i.ncreases. This preventis a nuisance overload trip.

Class 48 Ambient Compensated Bimetallic Overload Relay

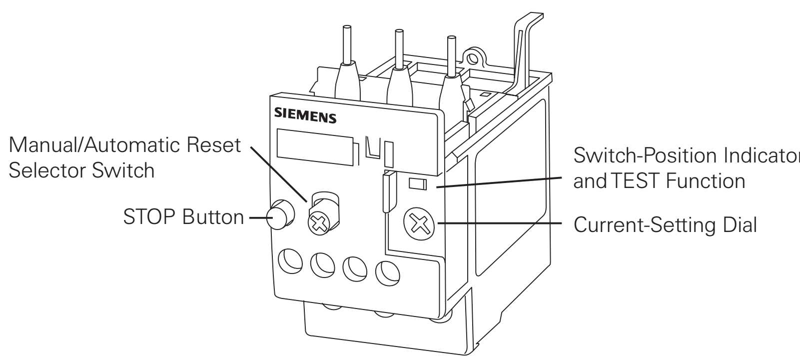
Siemens Class 48 ambient compensated bimetallic overload relays are available in single or three-pole designs and can be set for manual or self-resetting operation. An adjustment dial allows the ampere trip setting to be adjusted by ±15%. A manual test button is provided to test the operation of the overload relay control contacts. The ambient compensated bimetallic overload relay heater elements are available with either class 10 or 20 ratings. A normally open or normally closed auxiliary contact is available as an option.



SIRIUS 3RU11 Bimetallic Overload Relay

Siemens SIRIUS 3RU11 bimetallic overload relay has heater elements as an integral part its design. The unit comes with a Class 10 trip as standard. SIRIUS 3RU11 overload relays feature manual or automatic reset, adjustable current settings, ambient compensation, and a differential trip bar that causes the unit to trip faster in the event of a phase loss.

SIRIUS 3RU11 overload relays include a normally closed auxiliary contact for de-energizing the contactor, and a normally open auxiliary contact for signaling an overload trip. Pressing the STOP button momentarily opens the normally closed contact without affecting the normally open contact. The switch-position indicator incorporates a TEST function which, when activated, simulates a tripped overload relay by actuating both auxiliary contacts and displaying the switch position.



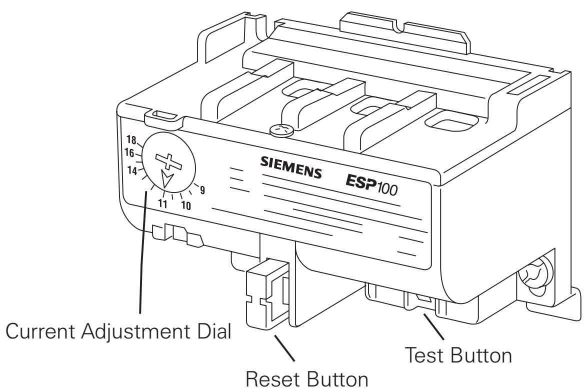
Electronic Overload Relays

Electronic overload relays are another option for motor protection. The features of electronic overload relays vary, but there are a few common advantages. One advantage of electronic overload relays is that they do not require heaters. This eliminates the need to stock multiple heaters to match motor ratings. This heaterless design also allows electronic relays to be insensitive to the ambient temperature, minimizing nuisance tripping.

In addition, electronic overload relays can detect a power phase loss and disconnect the motor from the power source. This is an important advantage because, without phase lose protection, loss of a power phase can quickly result in damaged motor windings.

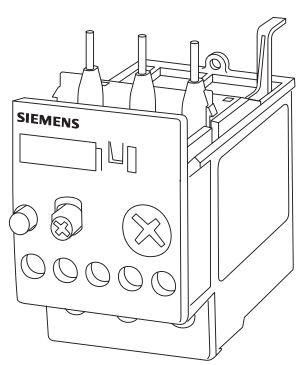
Class 48 ESP100 Electronic Overload Relay

Use of **class 48 ESP100 electronic overload relays** eliminates the need for at least six size ranges of heaters. Instead of installing a heater, a dial on the overload relay is set to the motor's full-load current rating. The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amps. NEMA class 10, 20, and 30 trip curves are available for a variety of applications, in either manual or self-resetting versions. A manual test button is provided to test the operation of the overload relay contacts. One normally closed auxiliary contact is included as a standard feature.



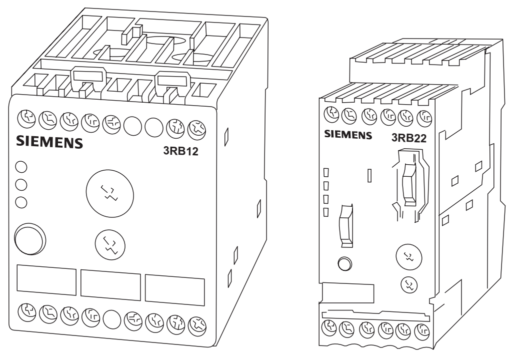
Siemens 3RB10/20 Electronic Overload Relay

SIRIUS 3RB10/20 electronic overload relays come with a class 10 or 20 trip and feature manual or automatic reset, adjustable current settings, and ambient compensation. A normally closed auxiliary contact for de-energizing the contactor and a normally open auxiliary contact for signaling an overload trip are included. Pressing the STOP button momentarily opens the normally closed contact without affecting the normally open contact. The switch-position indicator incorporates a test function which, when activated, simulates a tripped overload relay by actuating both auxiliary contacts and displaying the switch position.



Siemens 3RB12/22 Electronic Overload Relay

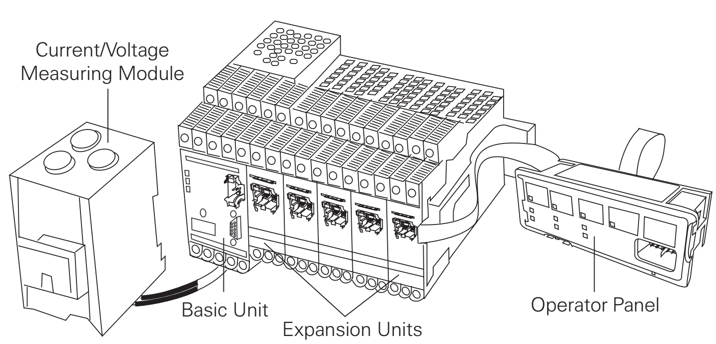
SIRIUS 3RB12/22 electronic overload relays provide trip class adjustments from class 5 to 30 and ground fault, phase imbalance, and phase loss protection. Motor current is continuously monitored in each phase. Two auxiliary contacts, one normally open and one normally closed, are switched in the event of an overload, phase imbalance, or phase loss. One additional set of auxiliary contacts, one normally open and one normally closed, are switched without time delay in the event of a ground fault. In addition to sensing current, SIRIUS 3RB22 overload relays directly sense motor winding temperature via a thermistor sensor.



SIMOCODE pro

SIMOCODE pro is a flexible, modular motor management system that provides multifunctional, solid-state protection for constant speed motors. SIMOCODE pro implements all motor protection and control functions; provides for tracking of operational, diagnostic, and statistical data; and communicates with the automation system via **PROFIBUS DP**.

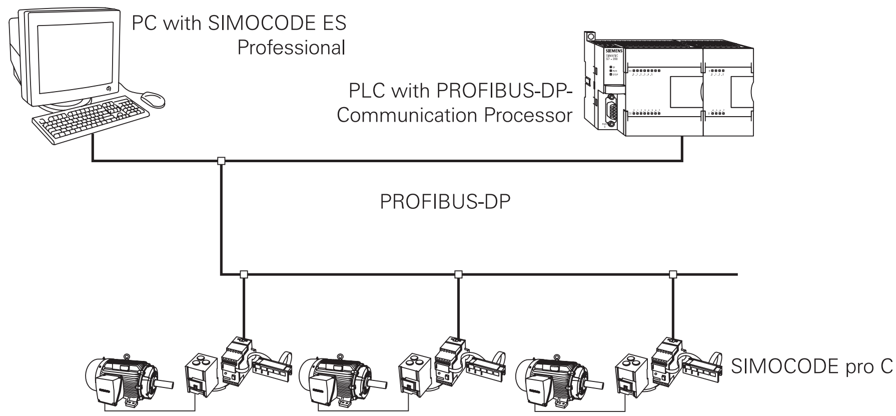
SIMOCODE pro C includes a Basic Unit, a Current Measuring Module, and an Operator Panel. **SIMOCODE pro V** includes a Basic Unit, a Current/Voltage Measuring Module, and Operator Panel, but can accommodate up to five expansion modules. Expansion modules are available for digital inputs, analog inputs, ground fault detection, and temperature sensing.



SIMOCODE pro V

PROFIBUS DP

In any complex process, the need for rapid communication is critical. PROFIBUS DP is an open communication system based upon international standards developed through industry associations. PROFIBUS DP allows multiple field devices, including SIMOCODE pro Basic Units, to communicate with a PLC or computer.



Review 3

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

   a. increase b. decrease c. remain the same

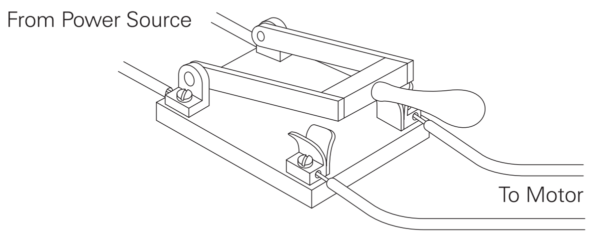
2. Excessive current is referred to as _______.
3. An _______ occurs when electrical equipment is required to work harder than it is rated.
4. A class _______ overload relay will trip and remove power from an overloaded motor within 10 seconds at six times full-load current.

   a. 10 b. 20 c. 30

5. A _______ strip is made of two dissimilar metals bonded together.
6. If an overload relay trips, it can be _______ after the overload has been removed.
7. Electronic overload relays do not require _______ and also provide _______ protection.

Manual Control

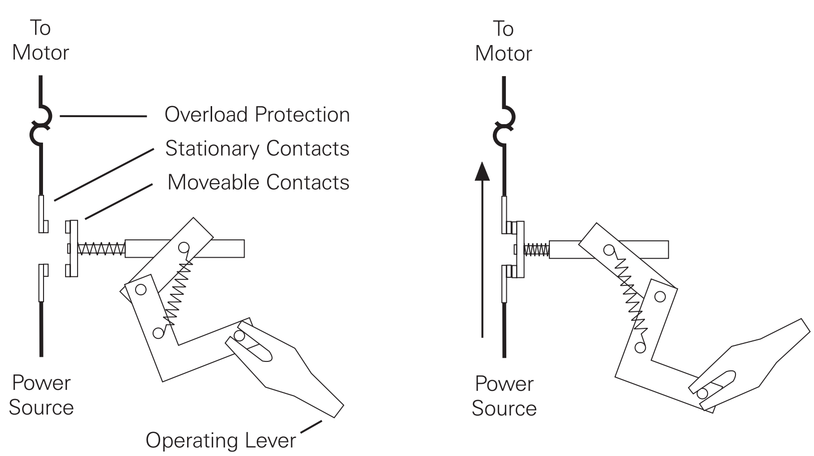
As the name implies, manual controls are devices operated by hand. A simple knife switch, like the one shown in the following illustration, was the first manual-control device used to start and stop motors. The knife switch was eventually replaced with improved control designs such as manual and magnetic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



Basic Operation

In addition to turning a motor on and off, a motor control device must also provide overload protection for the motor. To accomplish these tasks, **manual starters** combine a manual contactor or switch mechanism and an overload protection device.

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.

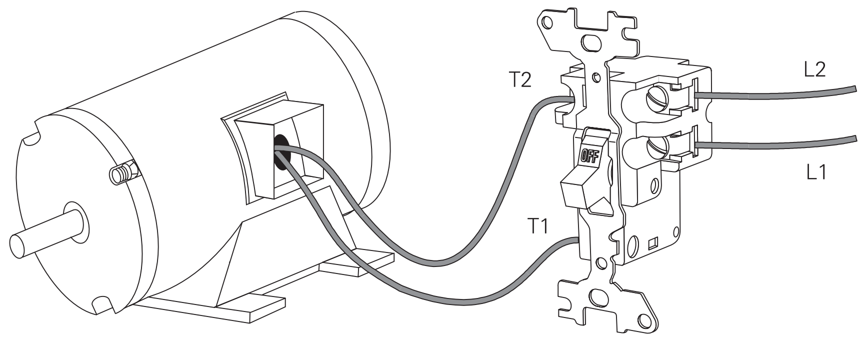


Switch in "OFF" Position

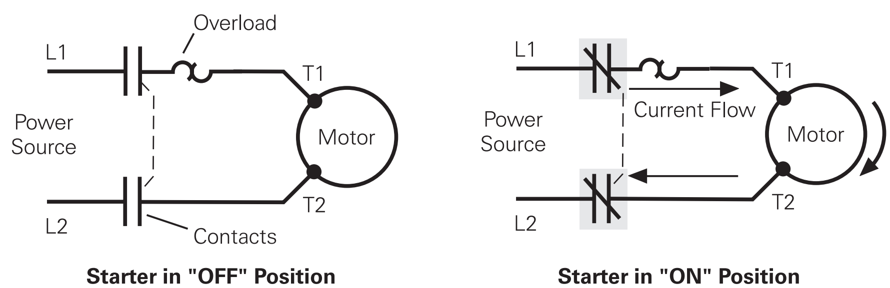
Switch in "ON" Position

Two-Pole Manual Starter

Starters are connected between the power source and the load. In the following 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, then returning to the power source (L2).



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



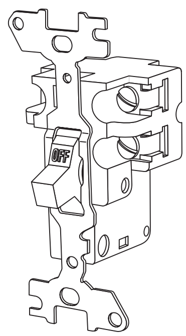
Low Voltage Protection

Some manual motor starters offer **low-voltage protection (LVP**) as an option. LVP automatically removes power from the motor when incoming power drops or is interrupted.

An LVP starter must be manually reset when power is restored. This protects personnel from potential injury caused by machinery that would otherwise automatically restart when power is restored.

SMF Fractional-Horsepower Manual Starters

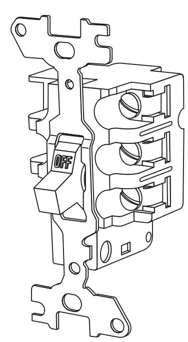
Siemens **SMF fractional-horsepower starters** provide overload protection and manual “ON/OFF” control for small motors. SMF starters are available in one- or two-pole versions suitable for AC motors up to 1 HP and 277 VAC. The two-pole version is suitable for DC motors up to 3/4 HP and 230 VDC. A melting-alloy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



Two-Pole Manual Starter

MMS and MRS Switches

Siemens **MMS and MRS switches** are similar to SMF starters but do not provide overload protection. MMS and MRS switches only provide manual “ON/OFF” control of DC and 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 also available.



Three-Pole Manual Switch

Class 11 - 3RV Manual Starters and Switches

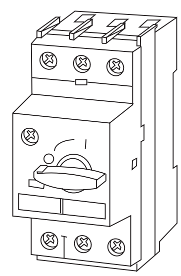
Class 11 across the line manual starters and switches provide control for machinery where remote start and stop control is not required.

Siemens class 11- 3RV manual starters are used for single and three-phase motors up to 15 HP at 460 VAC and have bimetalliclic heater elements to provide class 10 overload protection.

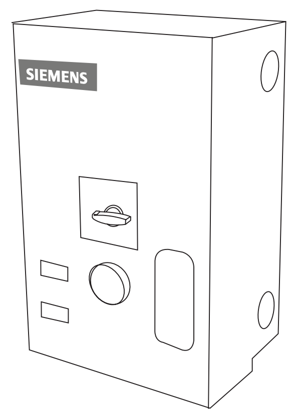
These starters have ambient temperature compensation. A built-in differential trip bar reduces tripping time in the event of a phase loss condition.

Class 11 - 3RV switches provide control where overload protection is not required or is provided separately.

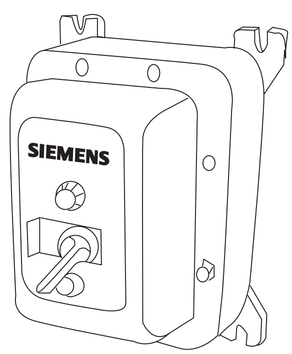
Class 11 - 3RV controllers are available with low voltage protection which automatically opens the power poles when the voltage drops or power is interrupted. They are available in an open style (without enclosure), in NEMA 1 general purpose enclosures, and in NEMA 7 & 9 or NEMA 3 & 4/NEMA 7 & 9 enclosures (for hazardous locations).



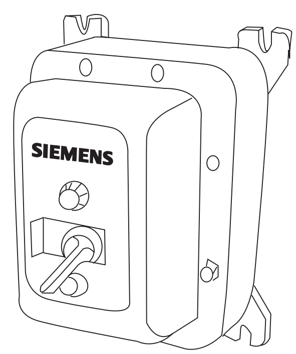
OPEN TYPE
Starter



NEMA 1
General Purpose



NEMA 7 & 9
Class I Group C & D
Class II Group E, F & G



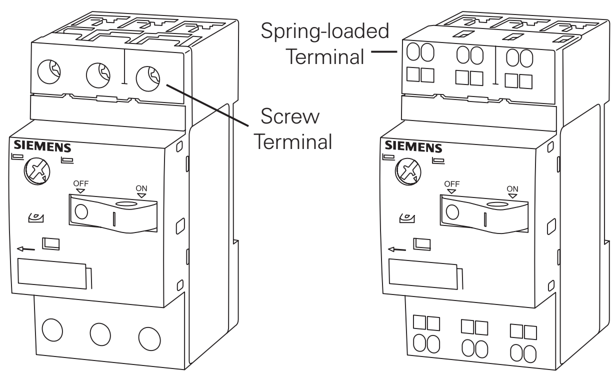
NEMA 3 & 4, NEMA 7 & 9
Class I Group C & D
Class II Group E, F & G

3RV1 Motor Starter Protectors

3RV1 motor starter protectors (MSPs) are part of our **SIRIUS** product line. They incorporate a class 10 adjustable bimetallic overload relay (class 20 is available in the two largest frame sizes), and magnetic trip elements for short circuit protection. 3RV1 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

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



3RV101 with Screw Terminals

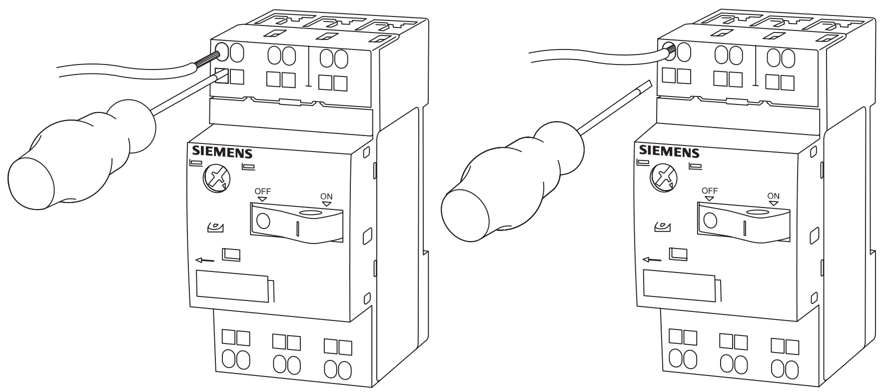
3RV101 with Spring-loaded Terminals

3RV1 MSPs are UL listed as manual motor controllers per UL508, making them appropriate for manual starting and stopping applications where upstream short-circuit protection is provided. SIRIUS 3RV102, 3RV103, and 3RV104 MSPs can be used as Type E self-protected manual combination starters per UL508. (3RV102 and 3RV104 require additional terminal adapters.) Type E controllers do not require upstream short-circuit protection.

SIRIUS 3RV1 MSPs can also be used as a component in group installation where one circuit breaker is used to provide group short circuit protection for multiple motor controllers.

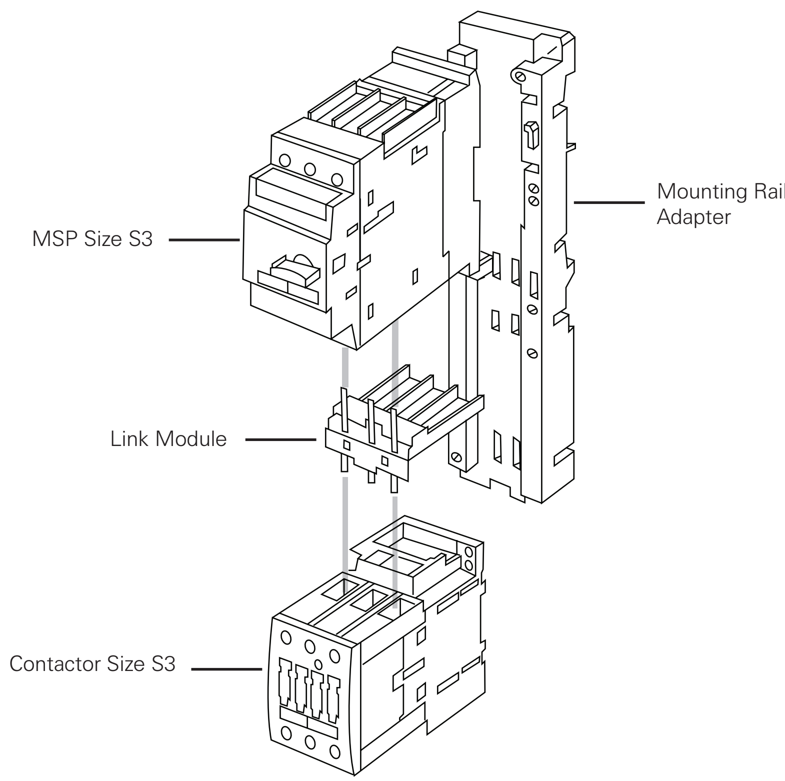
Spring-loaded Terminals

Spring-loaded terminals are available on many Siemens SIRIUS 3R products including the MSPs. To connect a wire simply push an electrician's blade screwdriver into the appropriate portal, and insert the stripped end of the wire into the portal directly above the blade. Remove the screwdriver, and the wire is securely connected. Devices equipped with spring-loaded terminals are especially beneficial in installations that are subject to vibration.



Enclosures and Options

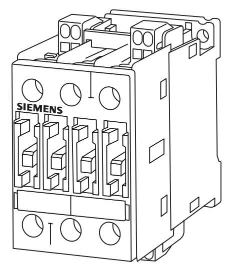
Siemens 3RV1 MSPs are available in a variety of enclosures. Several options, such as indicator lights, are also available.



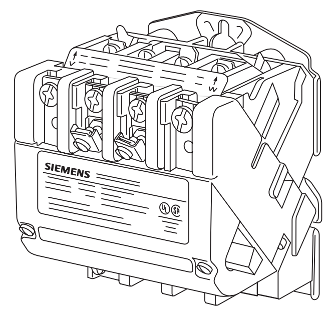
Size S3 Combination Starter

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. Magnetic contactors are also used to control distribution of power in lighting and heating circuits.



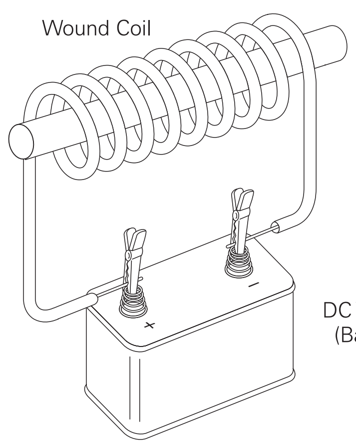
SIRIUS 3R IEC Contactor



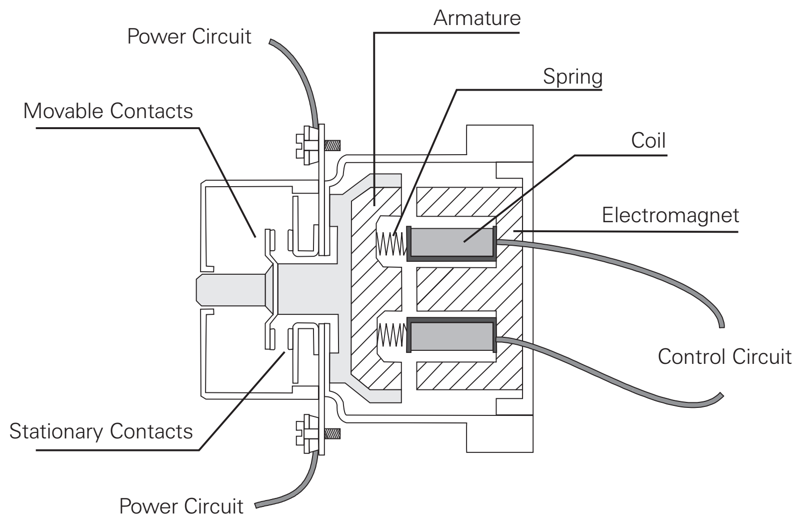
Class 40 NEMA Contactor

Basic Contactor Operation

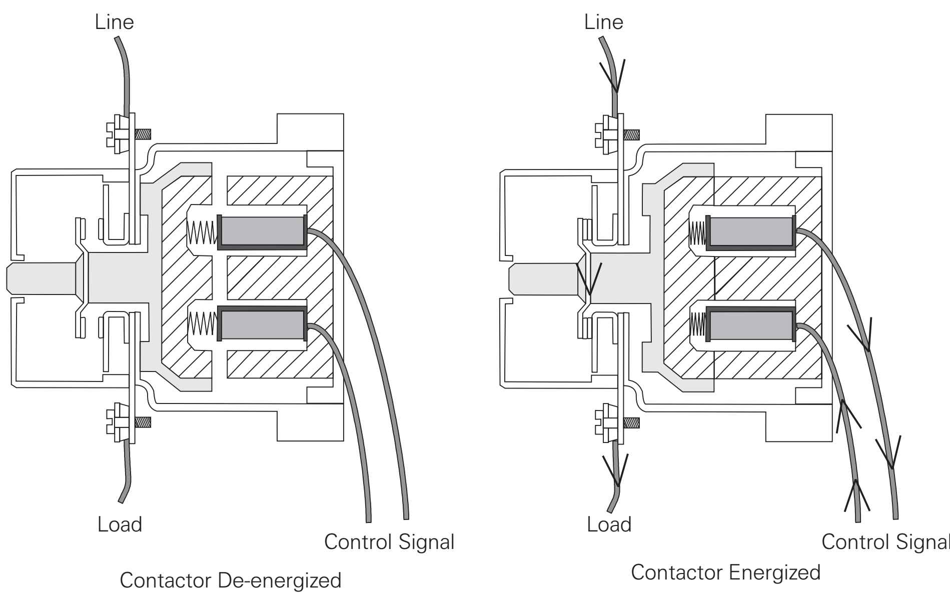
Magnetic contactors operate by utilizing electromagnetic principles. A simple **electromagnet** can be fashioned by winding a wire around a soft iron core. When a DC voltage is applied to the wire, the iron becomes magnetic. When the DC voltage is removed from the wire, the iron returns to its nonmagnetic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



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.

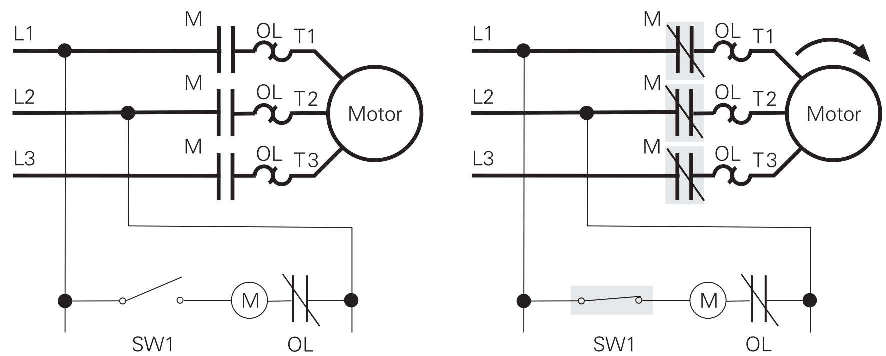


The operation of this electromagnet is similar to the operation of the electromagnet we made by wrapping wire around a soft iron core. When power is supplied to the coil from the control circuit, a magnetic field is produced, magnetizing the electromagnet. The magnetic field attracts the armature to 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 current no longer flows through the control circuit, the electromagnet's coil is de-energized, the magnetic field collapses, and the movable contacts open under spring pressure.



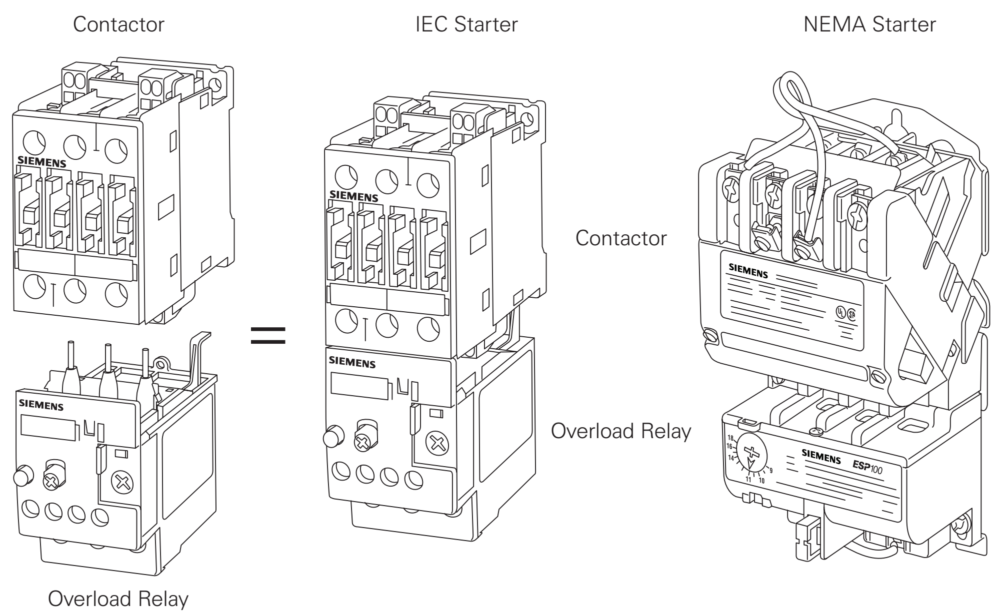
The following line diagram shows a contactor that provides on-off control for a three-phase motor. Note that the power to the electromagnetic coil of this contactor is controlled by SW1.

When SW1 closes, the electromagnetic coil energizes, closing the “M” contacts and applying power to the motor. When SW1 opens, the coil de-energizes, opening the “M” contacts and removing power from the motor.



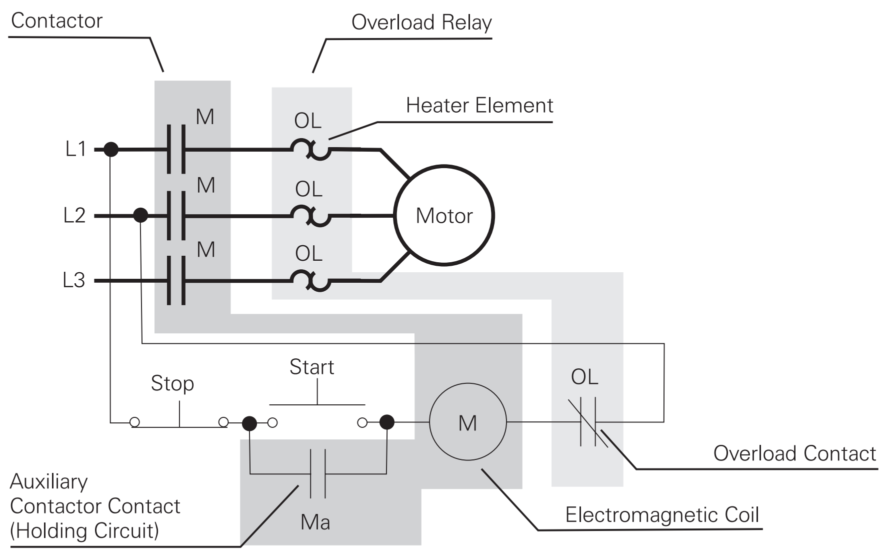
Motor Starter

Contactors provide on-off control in a variety of circuits. When used for motor control, overload protection is usually also required. 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 a contactor and an overload relay in a typical motor control circuit. The contactor (highlighted with the darker grey) includes an electromagnetic coil (M) and auxiliary contacts (Ma) in the control circuit and three main contacts (M) in the power circuit. The overload relay, highlighted by the lighter grey, includes three heaters contacts (OL) in the power circuit and auxilliary contacts (OL) in the control circuit.



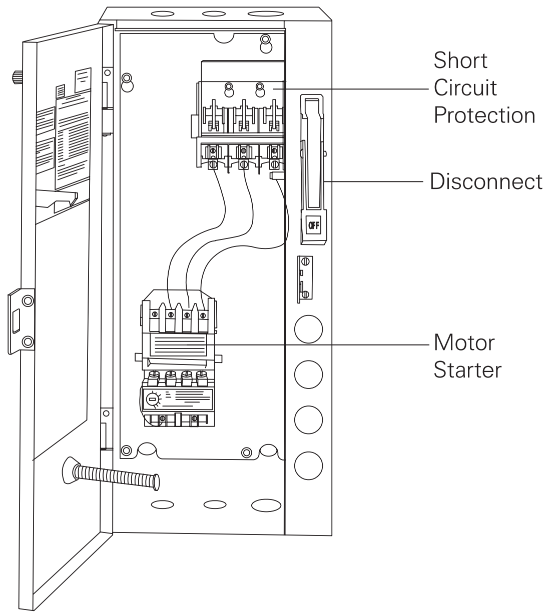
In this circuit, when the Start pushbutton is pressed, power is provided to the coil, and the M contacts close. This provides power to the motor through the OL heater contacts. At the same time, Ma contacts close so that, when the Start pusbutton is released, power is still provided to the coil.

The motor will continue to run until the Stop pushbutton is pressed, unless an overload occurs. If an overload occurs, the OL heater contacts open, removing power from the motor, and OL auxiliary contacts open, removing power from the coil. Removing power from the coil is necessary to prevent the motor from automatically restarting when the overload relay cools.

This is an example of a **full-voltage starter**, also called an **across-the-line starter**. This type of circuit starts the motor by providing the full line voltage to the motor.

Combination Starters

Combination starters are devices that incorporate a motor starter, short circuit protection, and a means of safely disconnecting power. In addition to combination starters formed using IEC components as described earlier, Siemens offers a full selection of combination starters incorporating NEMA components.



Review 4

1. A starter with two sets of contacts is called a ____ -pole starter.

2. A starter with _______ automatically disconnects power from the motor when incoming power is too low.

3. Siemens Class 11- 3RV manual starters are used for single and three-phase motors up to ___ HP at 460 VAC and have bimetalliclic heater elements to provide class ___ overload protection.

4. The 3RV102 motor starter protector can be used with motors up to _______ HP at 460 VAC.

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

6. A _______ incorporates a motor starter, short circuit protection, and a means of safely disconnecting power.

Contactor and Starter Ratings

Contactors and motor starters are rated according to size and type of load they are designed to handle.

The **National Electrical Manufacturers Association (NEMA)** and the **International Electrotechnical Commission (IEC**) are two organizations that provide ratings for contactors and motor starters. NEMA is primarily associated with equipment used in North America. IEC is associated with equipment sold in countries worldwide (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 based on maximum horsepower ratings as specified in the NEMA ICS2 standards. NEMA starters and contactors are selected according to their NEMA size, 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	5	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, you only need to know the horsepower and voltage of the motor. However, if there is considerable plugging and jogging duty involved, 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, allowing the user to more closely match the motor control to the actual application. Motor Matched sizes are beneficial because they cost less than larger NEMA size starters. 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	30
3½	115	40	75

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 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 rows
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 are designed for specific applications where the operating conditions are clearly defined. Operating conditions that must be considered include full load amps, locked rotor amps, non-inductive amps (resistive 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 application 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

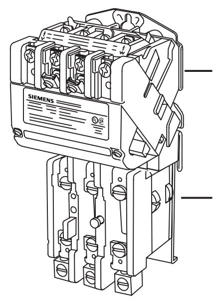
Other Organizations

There are several other organizations that have developed standards and tests for electrical equipment. For example, contactors are tested by Underwriters Laboratory (UL) using test procedure UL508, which specifies a maximum horsepower rating for which a contactor can be used.

All Siemens contactors are rated in accordance with test procedures of at least one of the previous organizations. Some carry multiple ratings. For example, Siemens NEMA starters meet or exceed NEMA, CSA, and UL standards, while Siemens SIRIUS starters meet or exceed IEC, CSA, and UL standards. Some SIRIUS starters also carry NEMA labeling.

NEMA Starters with Bimetalliclic Overload Relays

Class 14 NEMA starters with ambient-compensated bimetallic overload relays are available up to 100 HP at 460 VAC (NEMA sizes 00 through 4). In addition to whole sizes, this range includes 1¾, 2½, and 3½ sizes. These starters are available with Class 10 or 20 ambient-compensated bimetallic overload relays.

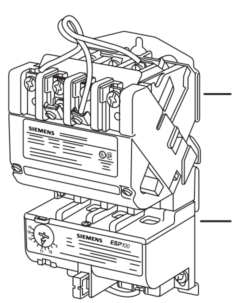


NEMA Starters with ESP100 Overload Relays

Class 14 ESP100 starters use the same contactors as Class 14 NEMA starters equipped with bimetallic overload relays (for NEMA sizes 00 through 4), but are supplied with a Class 10, 20, or 30 ESP100 solid-state overload relay. In addition, these starters are available with contactors up to and including NEMA size 8.

The ESP100 overload relay protects three-phase motors with FLA of ¼ amp through 1220 amps, and single-phase motors with FLA of ¾ through 16 amps. All ESP100 overload relays have an adjustable overload current range.

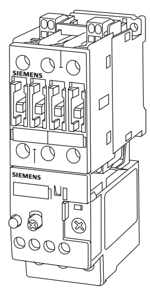
The ESP100 also protects the motor by tripping within three seconds if any of the three power phases is lost.



SIRIUS Type 3R Starters

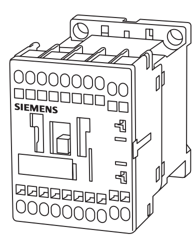
SIRIUS 3R is a complete modular, building-block system. The system includes a variety of components including a structured range of contactors and overload relays in seven frame sizes. These frame sizes are referred to as S00, S0, S2, S3, S6, S10, and S12.

A feature of the SIRIUS product line is a narrow mounting width. Along with the ability of SIRIUS components to operate at ambient temperatures up to 140º F (60º C), this allows more units to be packed into a panel without overheating the components.

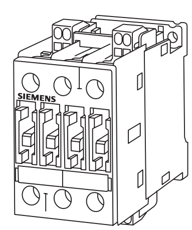


Spring-Loaded Terminals

Size S00 contactors and overload relays are equipped with spring-loaded power and control circuit terminals. Size S0 through size S12 contactors and overload relays have spring-loaded terminals on control-circuits only.



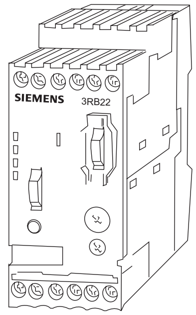
Contactor with
Spring-loaded Terminals



Contactor with
Screw Terminals

Overload Relays

As previously described, the SIRIUS 3R system incorporates a broad range of thermal and electronic overload relays.



Review 5

1. _______ and _______ are organizations that provide ratings for contactors and starters.

2. A NEMA size __ starter is rated for 200 HP at 460 VAC.

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. Siemens Class 14 NEMA starters with ambient compensated bimetalic overload relays are available in NEMA sizes 00 through _______ including sizes 1¾, 2½, and _______.

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

6. SIRIUS Type 3R starters are available in seven frame sizes: _______ S0, S2, S3, _______ S10, and S12.

7. SIRIUS 3R contactors and overload relays are designed to operate in ambient temperatures up to _______.

Multi-Speed 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 the motor's construction. In order to understand these controllers, you must first understand what factors determine the speed of a single-speed, three-phase induction motor.

The **synchronous speed** of a three-phase induction motor is the speed of the rotating magnetic field created by the motor's stator. As the following formula shows, this speed is a function of the power supply frequency and the number of motor poles.

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

For example, a motor with four poles on a 60 hertz AC line has a synchronous speed of 1800 RPM.

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

For a three-phase induction motor, actual rotor speed is always less than synchronous speed due to **slip**. The design of the motor and the amount of load applied determine the percentage of slip. For example, a NEMA B motor with a synchronous speed of 1800 RPM will typically have a full-load speed of 1650 to 1750 RPM.

When motors are required to run at different speeds, the motor's characteristics vary with speed. Therefore, proper motor selection and application is critical. There are three categories of multi-speed applications: constant torque, variable torque, and constant horsepower.

Constant Torque (CT) applications require constant torque at all speeds. Horsepower varies directly with speed. For example, many conveyor applications require constant torque.

Variable Torque (VT) applications often have load torques proportional to the square of the speed. Fans, blowers, and centrifugal pumps are examples of variable torque applications.

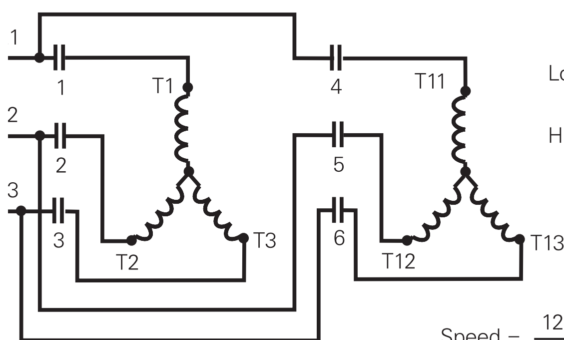
Constant Horsepower (CHP) applications maintain constant horsepower at all speeds, with torque varying inversely with speed. Many metal-working machines such as drills, lathes, mills, bending machines, punch presses, and power wrenches are examples of constant horsepower applications.

Separate-Winding Motors

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, with the speed of each winding depending 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 for a two-speed, two-winding, wye-connected motor.

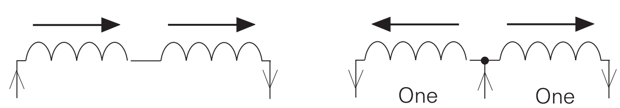


Low Speed: Close 1, 2, 3
Open 4, 5, 6
High Speed: Close 4, 5, 6
Open 1, 2, 3

$$\text{Speed} = \frac{120 \times \text{Frequency}}{\text{Number of Poles}} - \text{Slip}$$

Consequent-Pole Motors

Consequent-pole motors have windings with a tap for re-connection to vary the number of poles. Two-speed, consequent-pole motors have one re-connectable winding. The low speed of a two-speed consequent-pole motor is one half the speed of high speed. Three-speed motors have one re-connectable winding and one fixed winding. Four-speed motors have two re-connectable 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; 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, requiring the operator to 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.

Class 30 Two-Speed Starters

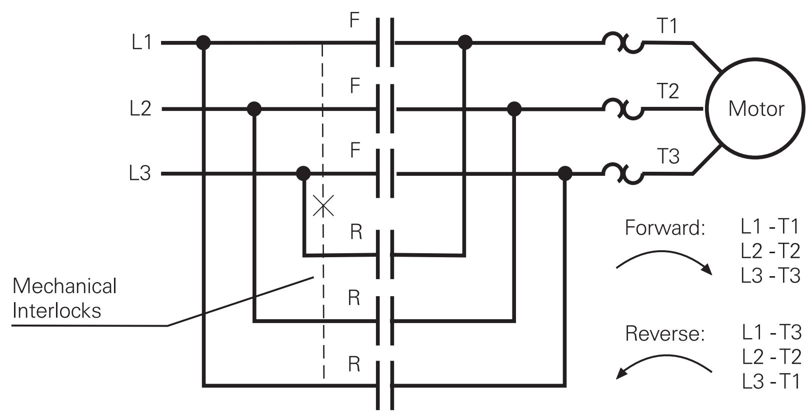
Siemens offers **class 30 two-speed starters** for both separate-winding and consequent-pole motors for constant torque, variable torque, and constant horsepower applications.

Starters are available in NEMA sizes 0 through 4, including Siemens half-sizes. Both ESP100 solid-state and ambient-compensated bimetallic overload relays are available.

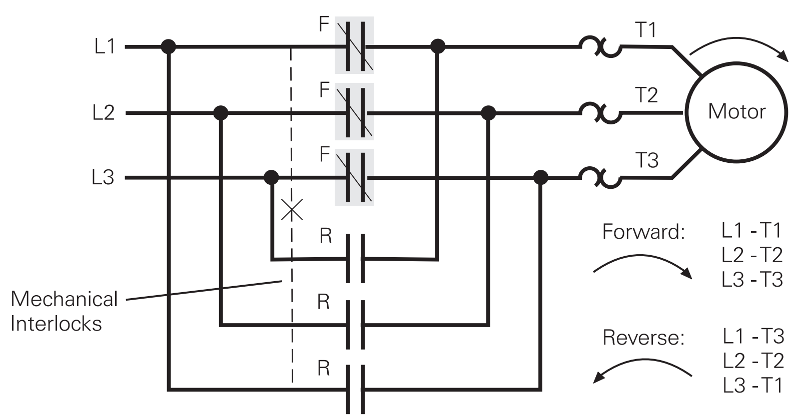
Reversing Starters

Many applications require a motor to run in either forward or reverse. The direction of motor rotation is changed by changing the direction of current flow through the windings. This is done for a three-phase motor by reversing any two of the three motor leads. Most often, T1 and T3 are reversed.

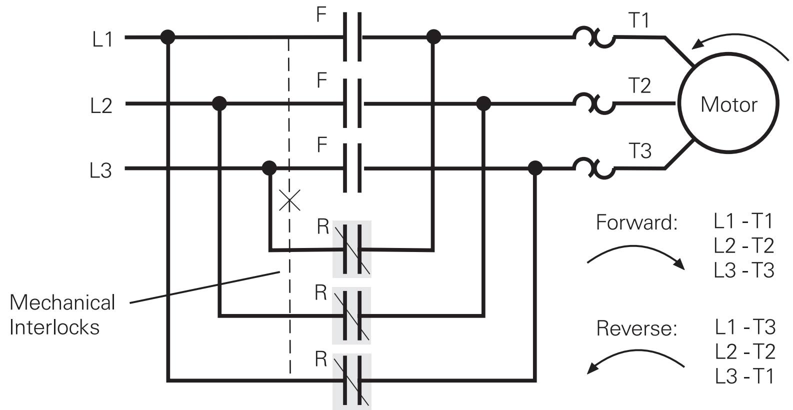
The following illustration shows a three-phase motor **reversing circuit** with one set of forward (F) contacts controlled by the "F" contactor and one set of reverse (R) contacts controlled by the "R" contactor.



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



When the “F” contacts open and the “R” contacts are close, 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.



Class 22 Reversing Starters

Siemens offers **class 22 reversing starters** in NEMA sizes 00 through 8 including Siemens half-sizes. Both ESP100 solid-state and ambient-compensated bimetallic overload relays are available.

Class 43 Reversing Contactors

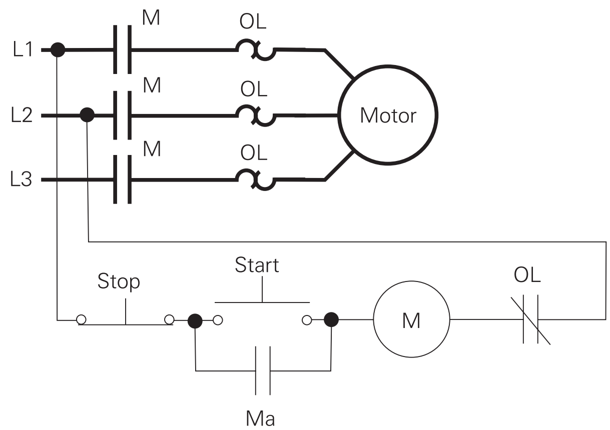
Siemens offers **class 43 reversing contactors** in NEMA sizes 00 through 8, including Siemens half-sizes.

3RA13 Reversing Contactors

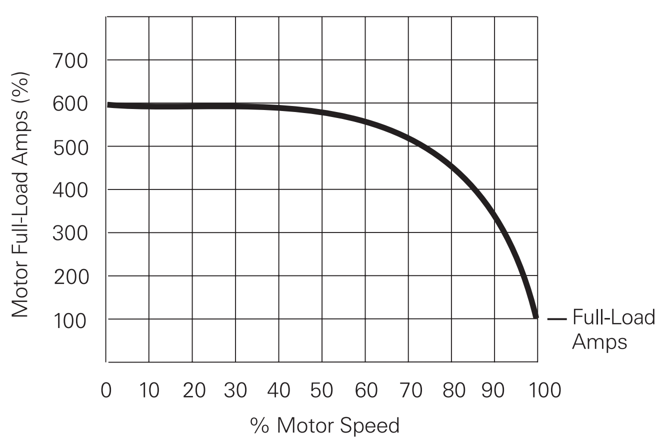
Siemens offers **3RA13 factory-assembled reversing contactors** for SIRIUS frame sizes S00 through S3. Kits are available for field assembly of reversing contactors in SIRIUS frame sizes S6 through S12.

Full-Voltage Starting

The most common type of motor starting is **full-voltage starting**, where the motor is placed directly across the line.

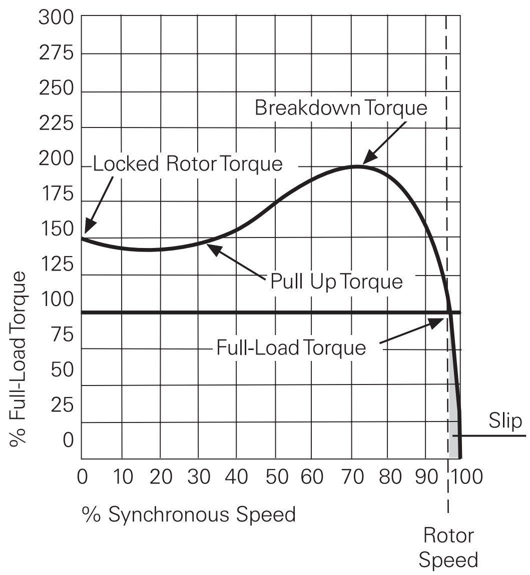


With this type of starter, the motor receives the full-line voltage immediately upon being energized. When a motor is started with full voltage, starting current is typically 600 to 650% of full-load current for standard squirrel cage motors and can be as high as 1200% of full-load current for high efficiency motors.



There are situations where this method of starting is not acceptable. For example, when a large motor starts at full voltage, the high starting current is reflected back onto the power lines, causing lights to flicker and potentially damaging sensitive equipment. As a result, many power companies require reduced-voltage starting for large-motors.

Another potential problem with full-voltage starts is the high torque developed when power is first applied to the motor. For a standard NEMA B type motor, the starting torque is typically 150% of full-load torque and the breakdown torque is typically 200% of full-load torque. Many applications require torque to be applied gradually to reduce the stress on mechanical components or to accelerate the load more gradually. For example, a conveyor belt often requires the starting torque to be applied gradually to prevent belt slipping or bunching.



Reduced-Voltage Starting

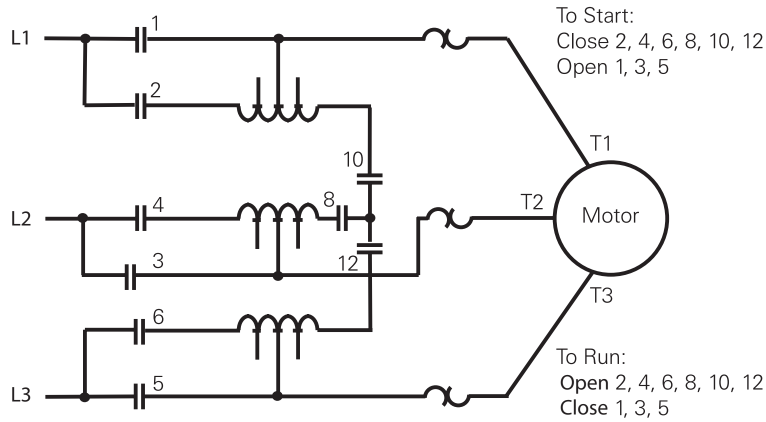
As the name implies, **reduced-voltage starting** involves starting a motor at less than its full voltage rating and then increasing the voltage as the motor comes up to speed. Reduced-voltage starting is used when it is necessary to limit the starting current and/or starting torque of a motor.

Several methods are available for reduced-voltage starting. The following paragraphs describe the more common methods.

Autotransformer Starters

Autotransformer reduced-voltage starters have the highest starting torque per ampere of line current and are typically used for applications where starting current must be reduced while retaining maximum starting torque. Autotransformers have adjustable taps to reduce starting voltage to 50%, 65%, or 80% of full-line voltage.

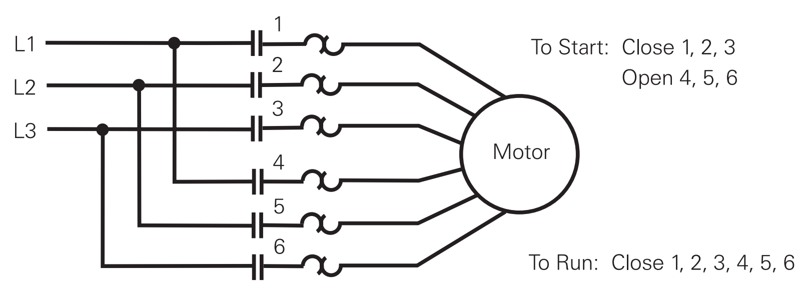
Common applications for autotransformer reduced-voltage starters include: crushers, fans, conveyors, compressors, and mixers



Part-Winding Starters

Part-winding, reduced-voltage starters are used on motors with two separate parallel windings on the stator. The start windings draw about 65 to 80% of rated locked rotor current. When running, each set of windings carries approximately 50% of the load current.

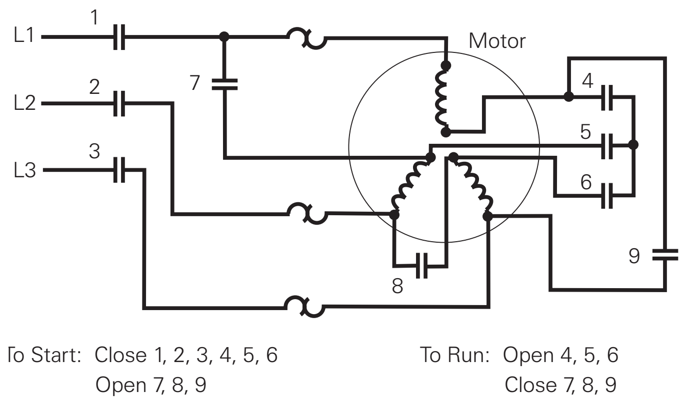
Part-winding, reduced-voltage starters are the least expensive type of reduced-voltage starters and use a very simplified control circuit. However, they require special motor design, and are not suitable for high-inertia loads. This type of starter has no adjustment for current or torque. Common applications for part-winding reduced-voltage starters include: low-inertia fans and blowers, low-inertia pumps, refrigeration, and compressors.



Wye-Delta Starters

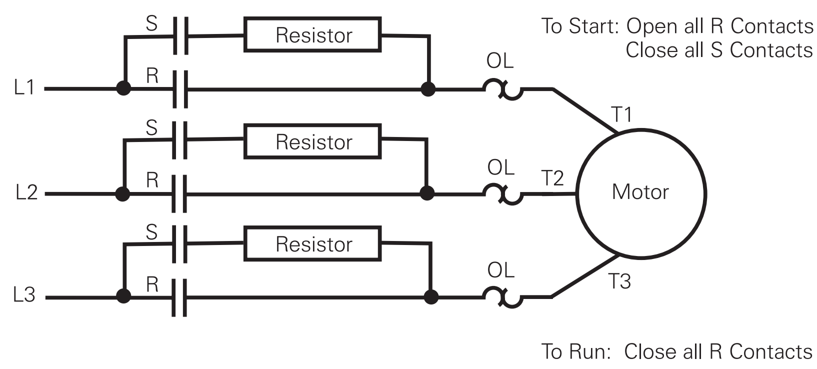
Wye-delta, reduced-voltage starters are applicable only for motors with stator windings that are not connected internally and have all six motor leads available. The motor starts with its windings connected in a wye configuration and then converted to a delta connection for running.

This type of starter is a good choice for applications requiring frequent starts, high-inertia loads, or long accelerating times. The starting torque is lower compared to methods of reduced-voltage starters previously discussed. Applications for wye-delta, reduced-voltage starters include: central air conditioning equipment, compressors, and conveyors.



Primary Resistance Starter

Primary Resistance starters provide simple and effective starting. The motor is initially energized through a resistor in each of the three incoming lines, dropping part of the voltage through the resistors and providing the motor with 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 for primary resistance starters include: conveyors and belt-driven and gear drive equipment.



Class 36 and 37 Reduced-Voltage Starters

Siemens offers **class 36 and 37 reduced-voltage starters** in NEMA sizes 0 through 6 including Siemens half-sizes. The ESP100 solid-state overload relay is furnished as standard for overload protection.

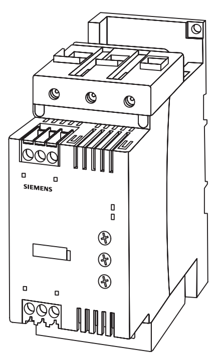
SIRIUS Soft Starters

Solid-state, reduced-voltage controllers, often called **soft starters**, limit motor starting current and torque by ramping up the voltage applied to the motor during the selectable starting time. Soft starters accomplish this by gradually increasing the portion of the power supply cycle applied to the motor windings, a process sometimes referred to as **phase control**. Soft starters also allow this phase control process to be applied in reverse when the motor is being stopped. This controlled starting and stopping significantly reduces stress on connected devices and minimizes line voltage fluctuations.

The SIRIUS 3R modular system of components incorporates a broad range of soft starters that includes SIRIUS 3RW30/31 and 3RW40 soft starters for standard applications, and SIRIUS 3RW44 soft starters for high feature applications.

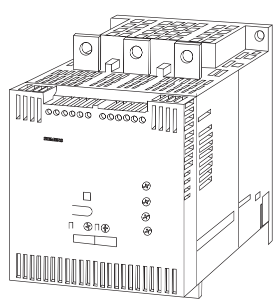
SIRIUS 3RW30/31 Soft Starters

SIRIUS 3RW30/31 soft starters have an especially compact design that saves space and easily integrates with other SIRIUS 3R components. SIRIUS 3RW30/31 soft starters are available for supply voltages up to 575 VAC and for operating current up to 100 amps at 40° C. Potentiometers on the front of the unit provide settings for starting time, starting voltage, and stopping time.



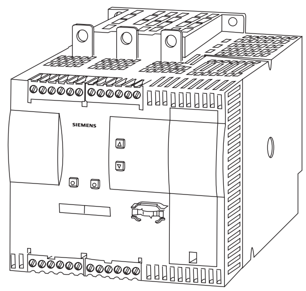
SIRIUS 3RW40 Soft Starters

SIRIUS 3RW40 soft starters have all the advantages of 3RW30/31 soft starters, but have more features and are available for operating current up to 432 amps at 40° C. Potentiometers on the front of the unit provide settings for current limit, starting voltage, and starting and stopping times of the voltage ramp.



SIRIUS 3RW44 Soft Starters

SIRIUS 3RW44 soft starters make soft starting and stopping attractive for difficult starting applications and combine a high degree of functionality, simplified operational settings, and extensive diagnostics. SIRIUS 3RW44 soft starters are available for operating current up to 1214 amps at 40° C, and can be equipped with a Profibus DP communication option.



Review 6

1. Siemens offers class 30 two-speed starters for ______ and _______ motors.

2. A _______ starter changes the direction of rotation for a three-phase motor by switching two of the three motor leads.

3. A reduced-voltage starter reduces starting voltage. This also reduces starting _______ and _______.

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

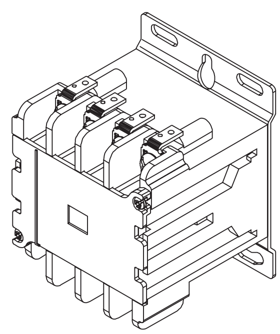
5. _______, reduced voltage starters are also called soft starters.

6. The SIRIUS 3R modular system of components includes _______ and _______ soft starters for standard applications and _______ soft starters for high feature applications.

Electrically Held Contactors

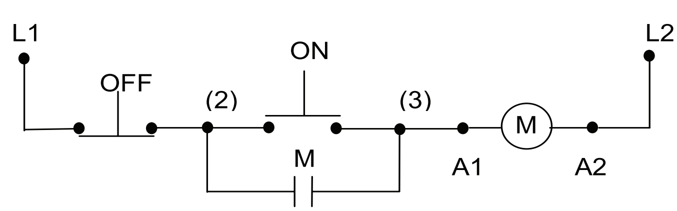
Most lighting and heating applications require a contactor to control the loads. One type of contactor is an **electrically held contactor**, which is similar to a magnetic starter. Unlike a magnetic starter, however, a **lighting and heating contactor** is designed for lighting and resistive heating loads rather than motor loads.

Siemens **class LE lighting and heating contactors** are available with 2 to 12 poles rated from 20 to 400 amps. They can be used on 480 VAC tungsten and 600 VAC ballast-type lighting loads as well as 600 VAC resistive loads. Enclosures are also available.



Electrically held lighting contactors are similar to the magnetic contactors and starters discussed previously. When current is applied to the coil, all normally open contacts close. If power is lost, these contacts open, removing the supply of current to connected loads. Because the constant current flow needed to keep the contactor energized causes a humming noise, these contactors should not be used for applications such as libraries, hospitals, and some commercial buildings where this noise will be a problem.

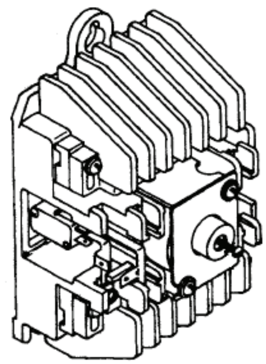
The following diagram shows a typical on/off control circuit for an electrically held lighting/heating contactor.



Magnetically Held and Mechanically Latched Contactors

Magnetically held and **mechanically latched contactors** are also designed for lighting and resistive heating loads.

Siemens **class CLM lighting and heating contactors** are available with 2 to 12 poles, rated from 20 to 400 amps. They can be used on 480 VAC tungsten, 600 VAC ballast, and general type lighting and resistive heating loads.



Magnetically Held Contactor Operation

Each magnetically held contactor contains a permanent magnet that will maintain the contactor in its energized state indefinitely, without using control power.

When the contactor is energized, current flow causes a magnetic field that reinforces the polarity of the permanent magnet and closes the contactor. Current to the coil is then immediately disconnected by the coil clearing auxiliary contact.

The contactor contacts are opened by energizing the OFF coil, which creates a magnetic field that opposes the permanent magnet. This momentarily cancels the magnetic attraction of the permanent magnet, and the contacts open.

Mechanically Latched Contactor Operation

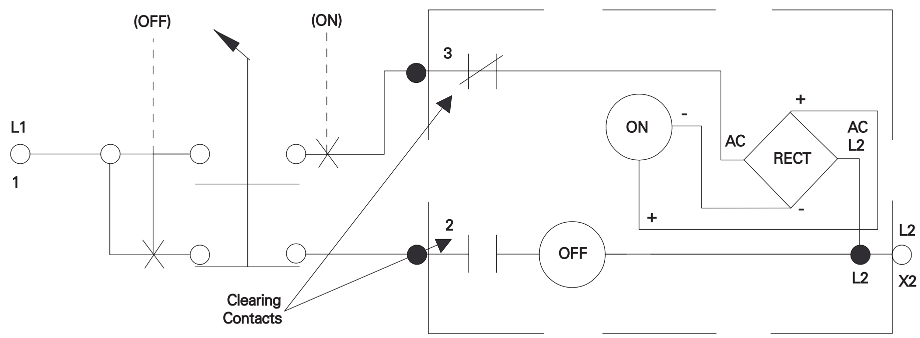
Mechanically latched contactors are latched mechanically and released electrically by means of an AC trip solenoid and clearing contact. This is similar to the magnetically held contactor in that it will remain in the closed state indefinitely. The contacts open only when the trip solenoid receives a signal to release the mechanical latch.

Typical Applications

Magnetically held and mechanically latched contactors are typically used in locations such as libraries, hospitals, or stores where noise is a concern. These contactors are well-suited to these sites because they do not require a constant supply of current through the coil, thus eliminating the inherent humming noise typical of electrically held contactors.

Because these contactors, once energized, keep their contacts closed if power is lost, they are also used to control parking lot and stadium lighting in situations where it is desirable to have lights automatically come on when power is restored.

Here is a typical wiring schematic for a magnetically held and mechanically latched lighting contactor with ON/OFF selector switch.



Pilot Devices

A **pilot device** directs the operation of another device (pushbuttons or selector switches) or indicates the status of an operating machine or system (indicator lights).

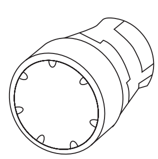
Siemens pilot devices are available with a variety of features and mounting dimensions and include product selections appropriate for a broad range of applications. The following product families are available.

- **3SB2 devices** with 16 mm mounting diameters
- **3SB3 devices** with 22 mm mounting diameters
- **Class 52 devices** with 30 mm mounting diameters are heavy duty products designed for harsh, industrial environments
- **Class 51 devices** for hazardous locations such as Class I, Groups C and D and Class II, Groups E, F, and G

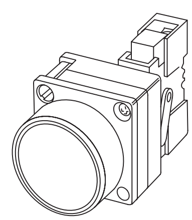
The mounting diameter refers to the size of the knockout hole (in millimeters) required to mount the devices.

Pushbuttons

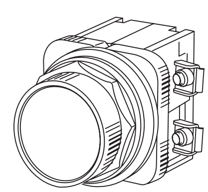
A **pushbutton** is a control device used to manually open and close a set of contacts. Pushbuttons may be illuminated or non-illuminated, and are available in a variety of configurations and actuator colors.



16 mm 3SB2 Pushbutton



22 mm 3SB3 Pushbutton

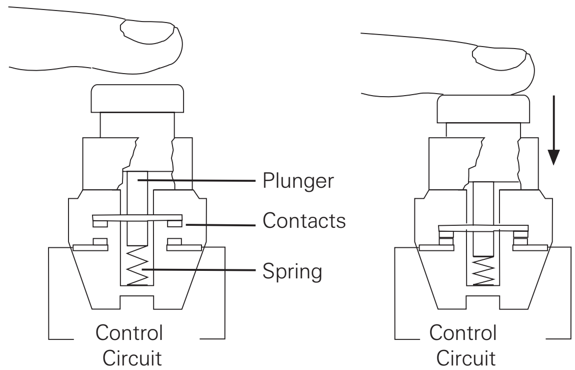


30 mm Class 52 Pushbutton

Normally Open Pushbuttons

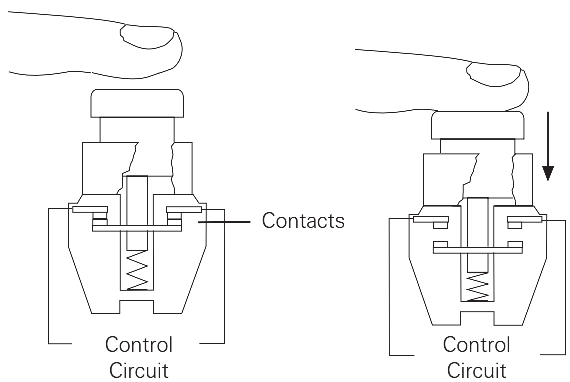
Pushbuttons are used in control circuits to perform various functions, for example, starting and stopping a motor. A typical pushbutton uses an operating plunger, a return spring, and one set of contacts.

The following drawing illustrates a normally open (NO) pushbutton, so called because the contacts are open unless the button is pressed. Pressing 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 in the following illustration, are also used to open and close a circuit. In the normal position, the contacts are closed and current can flow through them. Pressing the button opens the contacts, preventing current flow through the circuit.

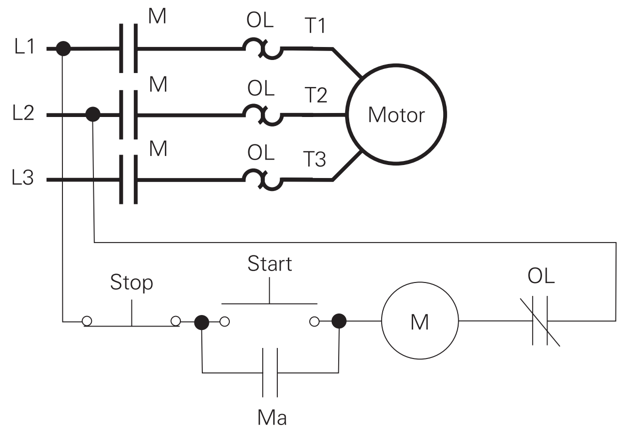


The pushbuttons just described are **momentary contact** pushbuttons because their contacts remain in their activated state only as long as the button is pressed. Pushbuttons with contacts that remain in their activated state after the button is released are called **maintained contact** pushbuttons.

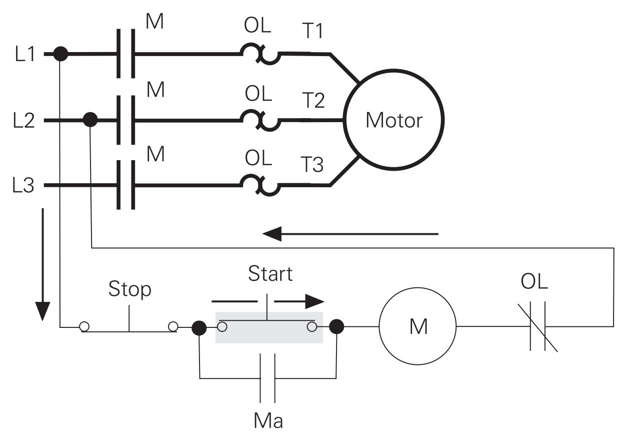
Pushbuttons are available with various contact configurations. For example, a pushbutton may have one set of normally open and one set of normally closed contacts so that, when the button is pressed, one set of contacts open and the other set is closed. In this example, the pusbutton can be wired to function as either a normally open or normally closed pushbutton.

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

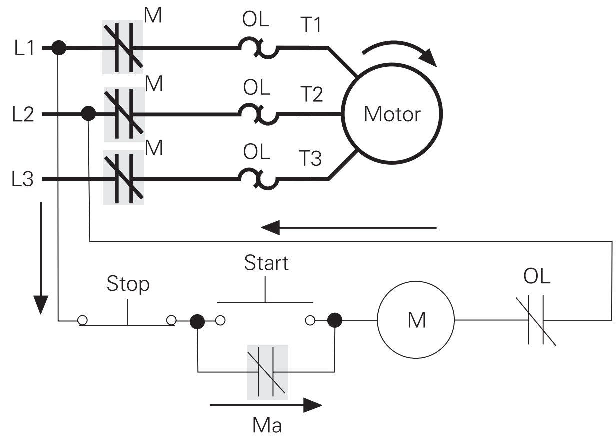


Three-Wire Control

Pressing the "Start" pushbutton closes the "M" and "Ma" contacts. When the "Start" pushbutton is released, auxiliary contacts "Ma" function as a **holding circuit** supplying power to the "M" electromagnetic coil. The motor will run until the normally closed "Stop" pushbutton is pressed, breaking the path of current flow to the "M" electromagnetic coil and opening the "M" and "Ma" contacts.

This is referred to as **three-wire control** because three wires are required to connect the "Start" and "Stop" pushbuttons and the holding circuit ("Ma").

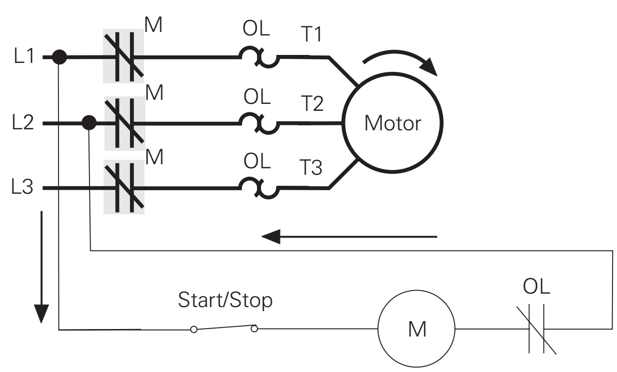
An advantage to three-wire control that the motor will not automatically restart after an overload. When an overload causes the "OL" contacts in the control circuit to open, the "M" coil de-energizes and the motor shuts down. When the overload is cleared, an operator must depress the "Start" button to restart the motor.



This circuit also has **low voltage protection** because if control power is lost, it will shut down the motor and will not automatically restart the motor when control power is regained.

Two-Wire Control

Contrast this operation with that of a **two-wire control** circuit, so called because the "Start/Stop" switch requires only two wires to connect it into the circuit. This circuit provides **low-voltage release**, but not low-voltage protection. Low-voltage release means that in the event of a loss of control power, the contactor de-energizes, stopping the motor. However, when control power is restored, the motor will restart immediately if the control device is still closed.



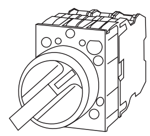
This type of control scheme is used for remote or inaccessible installations such as water-treatment plants or pumping stations. In these applications, it is often desirable to have an immediate return to service when power is restored.

Selector Switches

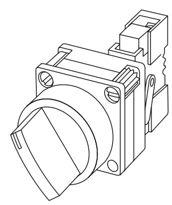
Selector switches are also used to manually open and close contacts. Selector switches can be **maintained**, **spring return**, or **key operated** and are available in two, three, and four-position types.

The basic difference between a pushbutton 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 used on selector switches.

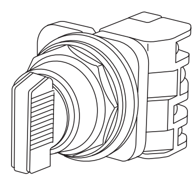
Selector switches are used to select one of two or more circuit possibilities, for example, stop and run or stop, low speed, and high speed.



16 mm 3SB2 Selector Switch



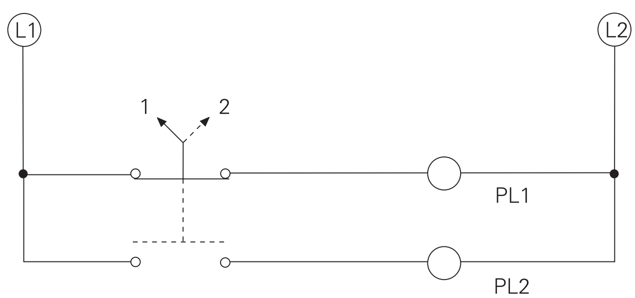
22 mm 3SB3 Selector Switch



30 mm Class 52 Selector Switch

Two-Position Selector Switch

In the following example, pilot light PL1 is turned on when the switch is in position 1, and pilot light PL2 is turned on when the switch is in position 2. This is only part of a control circuit for a machine and the status of the pilot lights could be used to indicate either of two machine conditions, for example, stop and run.

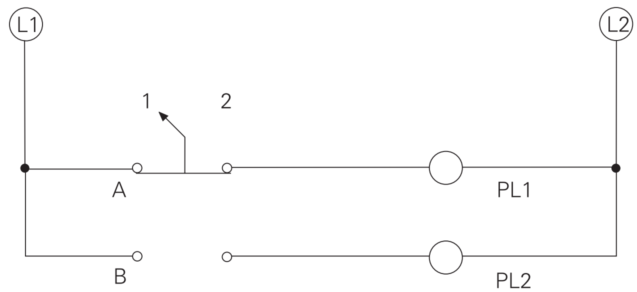


Contact Truth Tables

There are two accepted methods for indicating contact positions of a selector switch. The first method, shown in the previous example, uses solid and dashed lines to show contact positions.

The second method uses a **truth table,** also known as a **target table**, which uses a letter to represent each contact position. An "X" in the truth table indicates which contacts are closed for a given switch position.

In the example below, the switch is in position 1, contact A is closed and pilot light PL1 is on. When the switch is in position 2, contact B is closed and pilot light PL2 is on.



Contacts

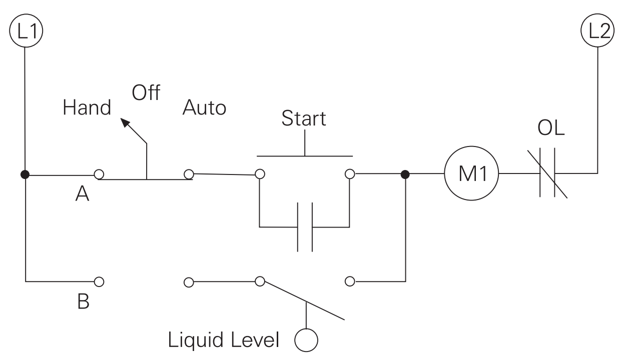
Position	A	B
1	X	
2		X

2 Position
Selector Switch

Three-Position Selector Switch

A three-position selector switch is used to select any of three contact positions. For example, the following diagram shows a Hand/Off/Auto control circuit for a pump motor.

In the "Hand" (manual) position, the pump starts when the Start pushbutton is pressed. The pump is stopped by switching to the "Off" position. The liquid level switch has no effect until the selector switch is set to "Auto." Then, the pump is controlled by the liquid-level switch. The liquid level switch closes when the fluid rises to a preset level, starting the pump. When the fluid drops to a lower preset level, the liquid level switch opens, stopping the pump.



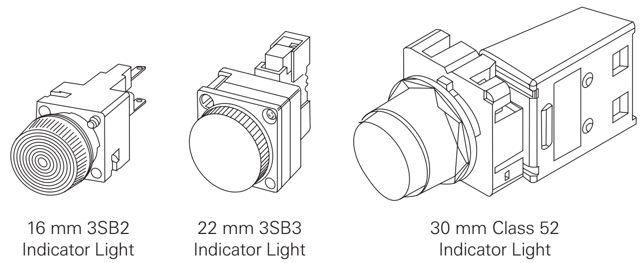
Contacts

Position	A	B
1	X	
2		
3		X

3 Position
Selector Switch

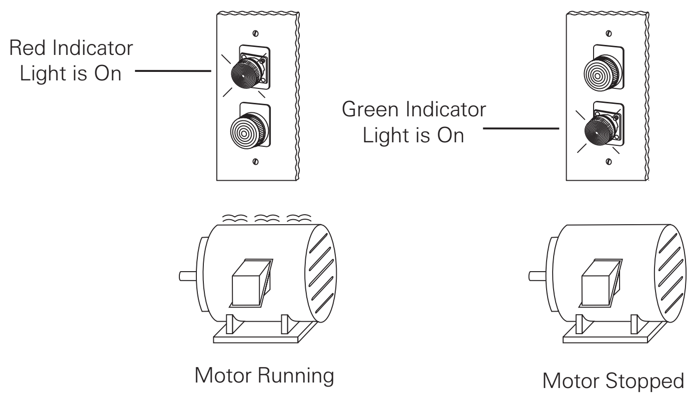
Indicator Lights

Indicator lights, also referred to as **pilot lights**, provide a visual indication of a circuit's operating condition, for example, on, off, or alarm.



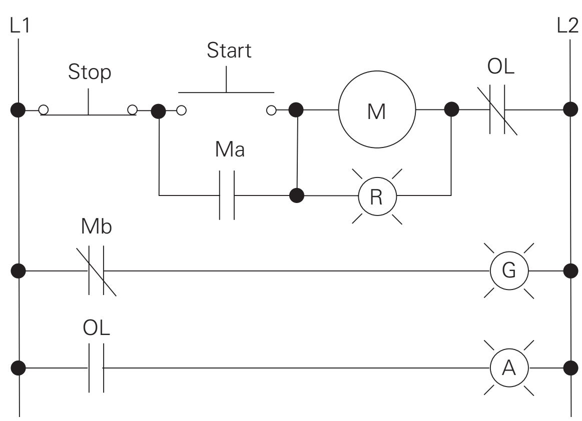
Indicator lights are available with a variety of lens colors to allow for a quick visual indication of machine or process status. Siemens indicator lights are available with a red, green, amber, blue, white, or clear lens.

As shown in the following illustration, a red indicator light often indicates that a system is running and a green indicator light often indicates that a system is off.

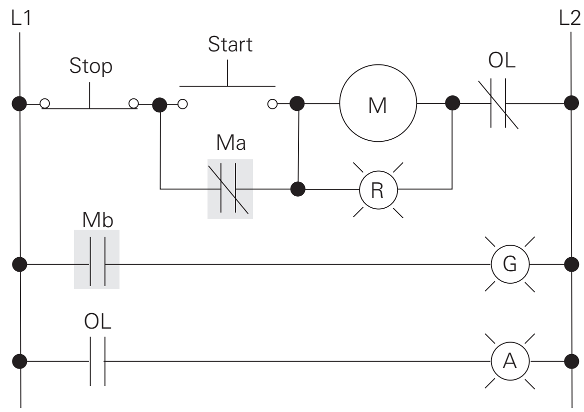


Using an Indicator Light in a Control Circuit

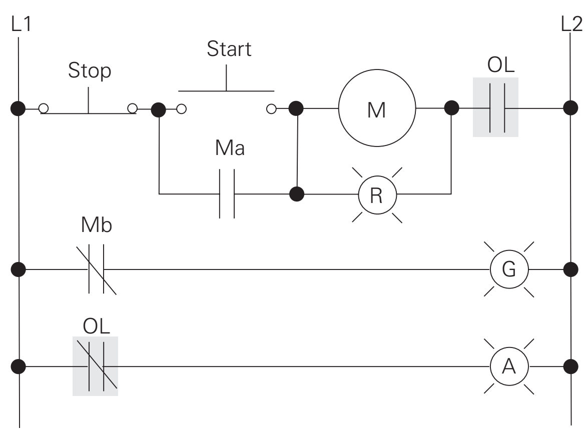
In the following diagram, when the motor is stopped, the normally closed Mb contact is closed, and the green (G) light is on.



When the coil is energized, the red (R) light is on to indicate that the motor is running. Note that the indicator light is wired in parallel with the coil so that the motor will turn on even if the indicator light burns out. In addition, the Mb contact is now open, and the green light is off.

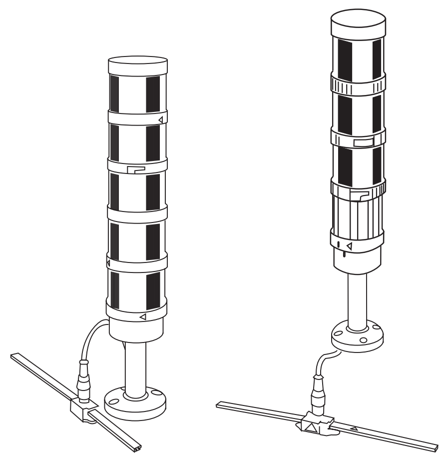


If an overload occurs, the normally closed OL contact opens, stopping the motor and turning off the red light, the Mb contact closes, turning on the green light, and the normally open OL contact closes, turning on the amber (A) light.



Signaling Columns

Signaling columns allow operating personnel to monitor machine or process operation from a distance. Columns are easily assembled by stacking elements to achieve the desired configuration. Various visual elements are available to provide steady, flashing, and rotating beacon indications in five colors: red, yellow, green, white, and blue. Buzzer or siren elements can be added to provide audible indications of machine or process conditions. Siemens **8WD42 and 8WD44 signaling columns** also can be networked to other devices through an optional **AS-Interface adapter**.



8WD42 (50 mm) 8WD44 (70 mm)

Review 7

1. _______ lighting and heating contactors are best used in applications where noise is not an issue.

2. Once their contacts are closed, _______ and _______ lighting and heating contactors keep their contacts closed even if control power is lost.

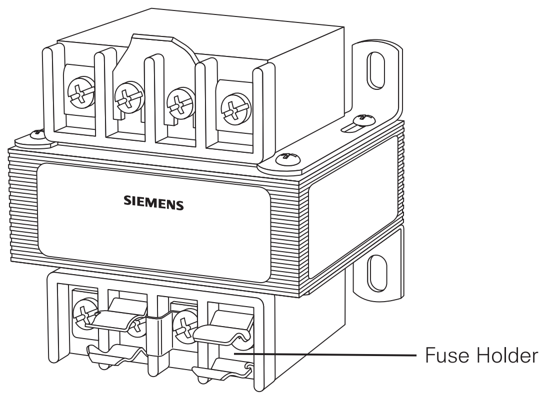
3. A _______ device directs the operation of another device or indicates the status of an operating system.

4. Siemens 3SB3 pushbuttons, selector switches, and indicator lights have a ___ mm mounting diameter.

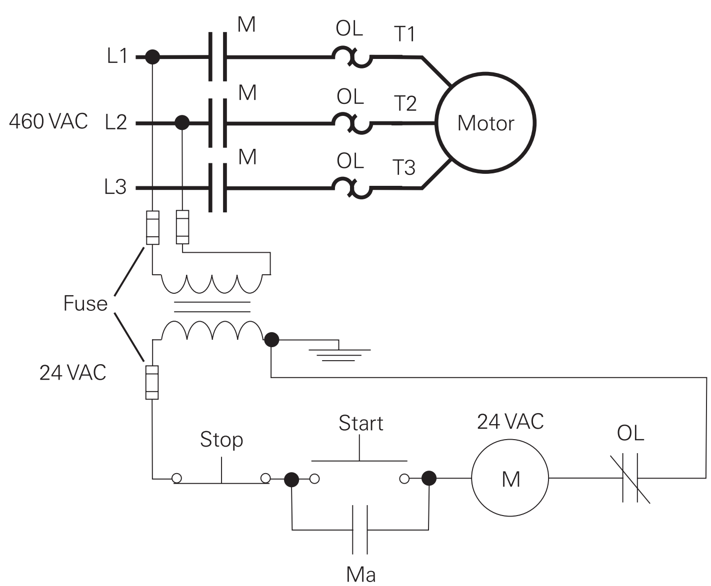
5. Siemens indicator lights are available with the following lenses: red, green, amber, _____, _____, and _____.

Control Transformers

The voltage applied to the main terminals of an industrial motor is frequently higher than the voltage needed by a control circuit. In such cases, a **control power transformer (CPT)** is used to step down the voltage. Siemens **class MT and MTG control power transformers** are available for a variety of primary and secondary voltages with ratings from 25 to 5000 VA.

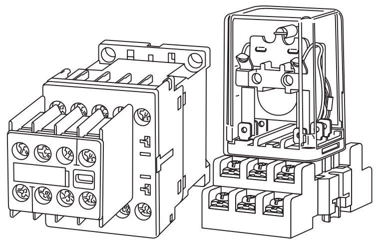


In the following example, the voltage on the primary of the CPT is 460 VAC. This voltage is stepped down to 24 VAC for use in the control circuit. Fuses on the primary and secondary windings of the transformer provide overcurrent protection.



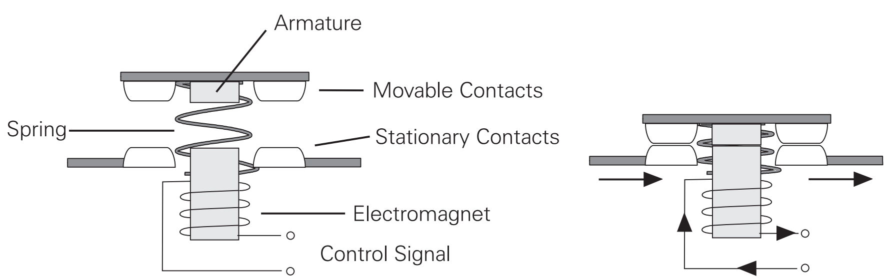
Control Relays

Control relays are widely used in control circuits to switch multiple control circuits and to control light loads such as starting coils, indicator lights, and audible alarms.



Relay Operation

The operation of a control relay is similar to a contactor. Like a contactor, control relay can contain normally open, normally closed, or both types of contacts. In the following illustration, a relay with a set of normally open (NO) contacts is shown. When power is applied to the control circuit, this energizes the relay's coil (electromagnet), which then magnetically pulls the armature and movable contacts to the closed position. When power is removed the magnetic field is lost and spring tension pushes the armature and movable contacts to the open position.



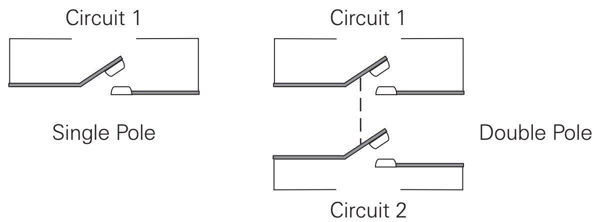
Contact Arrangement

The main difference between a control relay and a contactor is the size and number of contacts. A control relay has relatively small contacts because they need only to conduct the small currents used in control circuits. This allows a control relay to have multiple contacts. Because these contacts are usually not electrically interconnected, they can be used to control multiple circuits.

The use of contacts in relays can be complex. There are three key terms that describe the operation of these contacts, pole, throw, and make.

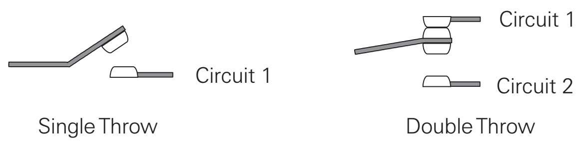
Pole

A control relay's **pole** number is the number of isolated circuits that can pass through the relay. This is the total number of circuits that can be controlled by the relay. Control relays often have multiple poles, but they need not all be used.



Throw

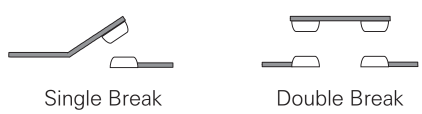
A control relay's **throw** number is the number of closed-contact positions per pole.



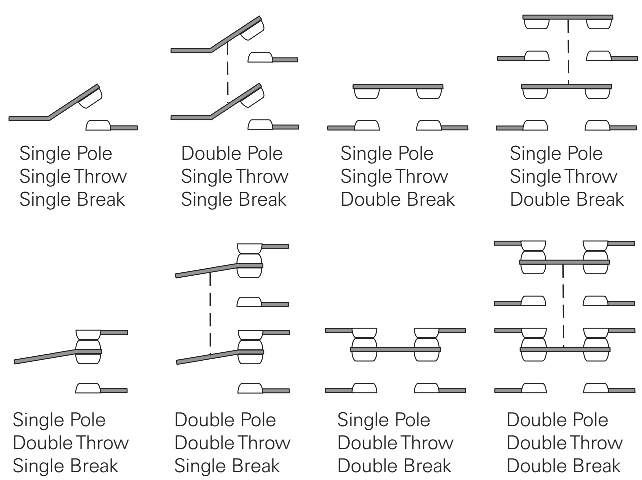
The following abbreviations are frequently used to indicate contact configurations: **SPST** (single pole, single throw), **SPDT** (single pole, double throw), **DPST** (double pole, single throw), and **DPDT** (double pole, double throw).

Break

A control relay contact **break** number is the number of separate contacts that open or close a circuit.

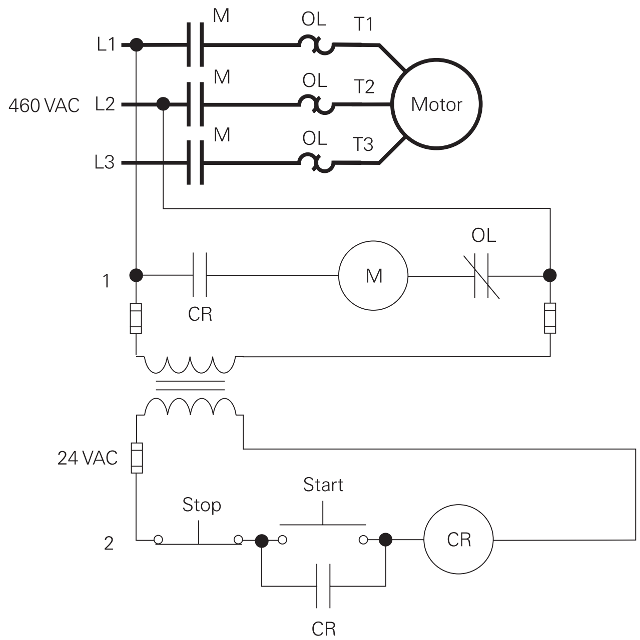


The following diagram illustrates various contact arrangements.

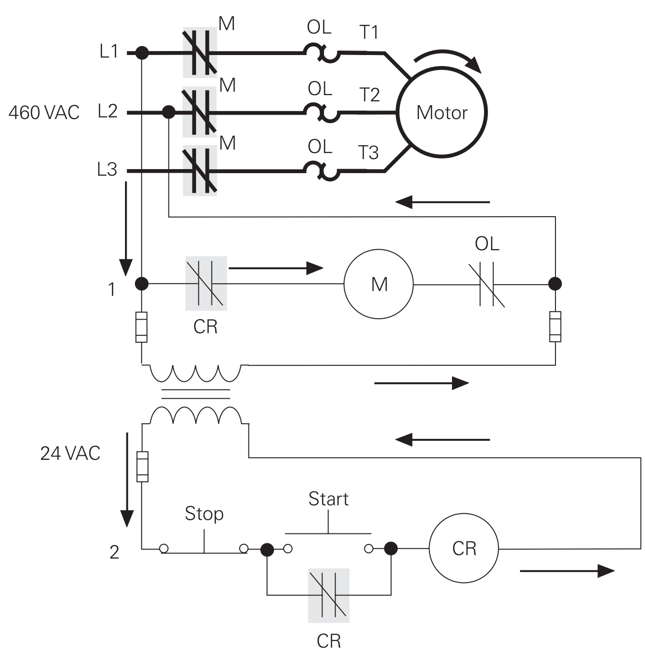


Interposing a Relay

The following line diagram illustrates one way that a control relay can be used in a 24 VAC control circuit. In this example, the 24 VAC coil is not strong enough to operate a large starter (M) that is rated for 460 VAC. This type of arrangement is called **interposing** a relay.

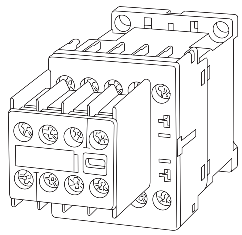


When the Start pushbutton is momentarily pressed, power is supplied to the control relay (CR), and the "CR" contacts in lines 1 and 2 close. The "M" motor starter energizes and closes the "M" contacts in the power circuit, starting the motor. Pressing the "Stop" pushbutton de-energizes the "CR" relay and "M" motor starter.



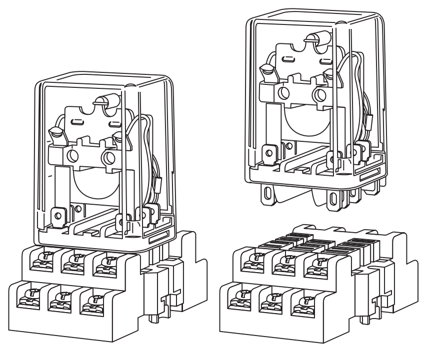
SIRIUS 3RH Control Relays

Siemens SIRIUS modular system includes a complete line of control relays. For example, **SIRIUS 3RH11 control relays** and **3RH14 latching control relays** are available with screw or spring-loaded terminals. Four contacts are available in the basic device. Four additional contacts can be added by attaching auxiliary switch blocks. Units are available for control supply voltages from 12 to 230 VDC and from 24 to 600 VAC. 3RH14 latching control relays have two coils, a relay coil and a release coil, that are rated for continuous duty operation.



3TX71 Plug-in Relays

Siemens offers a variety of **3TX71 plug-in relays** for socket or flange mounting. Units are available for common AC and DC control supply voltages. The biggest benefit of this type of relay is that all the wiring stays in place if the relay needs to be replaced.

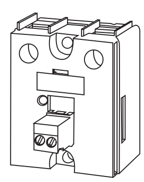


Solid-State Switching Devices

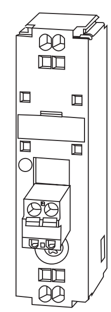
Electromechanical switching devices are unsuitable for applications requiring high switching frequencies or quiet operation. However, SIRIUS SC solid-state relays, contactors, and function modules operate quietly and perform reliably at high switching frequencies.

SIRIUS SC Solid-State Relays

SIRIUS SC solid-state relays can be mounted on existing cooling surfaces. **3RF20 single-phase and 3RF22 three-phase solid-state relays** have a 45 mm assembly width, and **3RF21 single-phase solid-state relays** have a 22.5 mm assembly width. One version of these relays is designed for switching resistive loads such as space heaters. Another version is designed for switching inductive loads such as solenoid valves.



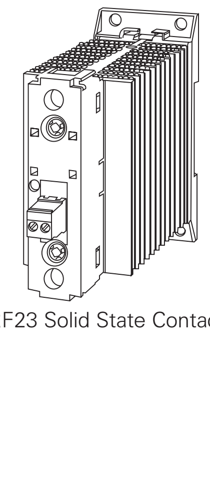
3RF20 Solid-State Relay (45 mm)



3RF21 Solid-State Relay (22.5 mm)

SIRIUS SC Solid-State Contactors

SIRIUS SC 3RF23 single-phase and 3RF24 three-phase solid-state contactors combine a solid-state relay and an optimized heat sink to form a ready-to-use device with defined current ratings. As with the solid-state relays, both resistive load and inductive load versions are available. In addition, versions of 3RF24 contactors and reversing contactors are available for switching low horsepower motor loads.



3RF23 Solid State Contactor

SIRIUS SC Function Modules

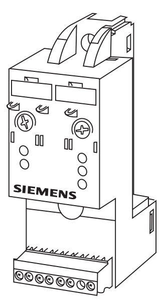
Many applications require extended functionality that can be accommodated by SIRIUS SC **function modules**. The following types of SIRIUS 3RF29 function modules are available.

Converter – The module is for use with 3RF21 relays and 3RF23 or 3RF24 three-phase contactors. This module converts an analog control signal to a pulse-width modulated digital signal. This allows a SIRIUS SC solid-state relay or contactor to use an analog signal from a device such as a temperature sensor to determine how much to adjust power to a load.

Heating current monitoring module – This module is for use with 3RF21 relays and 3RF23 contactors used in heating applications. This module detects a variety of faults, including failure of load elements, and provides a fault indication by LEDs and a normally-closed relay contact.

Load monitoring module – This module is for use with 3RF21 relays and 3RF23 contactors. This module detects a variety of faults, including failure of load elements, and provides an LED fault indication and a PLC-compatible fault signal.

Power controller – This module is for use with 3RF21 relays and 3RF23 contactors for power control of complex heating systems. This module combines load circuit monitoring capability and inrush current limitation with proportional control of the power to the connected loads.



3RF29 Power Controller

Power regulator – This module is for use with 3RF21 relays and 3RF23 contactors for power control of complex heating systems and inductive loads. It combines load circuit monitoring and inrush current limitation with the ability to adjust power to the connected loads.

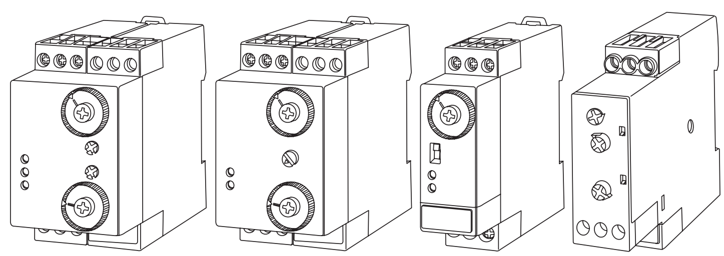
Monitoring Relays

SIRIUS monitoring relays reduce machine and plant downtime by monitoring electrical and mechanical quantities and fault conditions and providing appropriate diagnostic indications.

A variety of monitoring relays are available. Examples of functions performed by various monitoring relays include:

- Line monitoring for phase sequence, phase failure, phase asymmetry, undervoltage, and overvoltage.
- Single-phase current monitoring.
- Single-phase voltage monitoring.
- Power factor monitoring.
- Insulation resistance monitoring.
- Filling level monitoring.
- Motor underspeed monitoring.
- Temperature monitoring.

The following illustration shows a few of the various types of monitoring relays available.

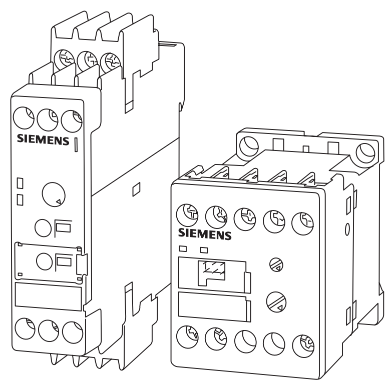


3UG30 Line Monitoring Relay | 3UG30 Underspeed Monitoring Relay | 3UG35 Level Monitoring Relay | 3UG35 Voltage Monitoring Relay

Time Relays

Time relays, such as Siemens **3RP15 and 3RP20 solid-state time relays**, are used in control switching operations involving time delay. 3RP15 time relays have a 22.5 mm assembly width, and 3RP20 time relays have a 45 mm assembly width.

Most of these time relays have multiple time setting ranges. For example, a number of the 3RP15 and 3RP20 time relays have 15 time setting ranges covering the span from 0.05 seconds to 100 hours.



3RP15 Time Relay   3RP20 Time Relay

Time Delay

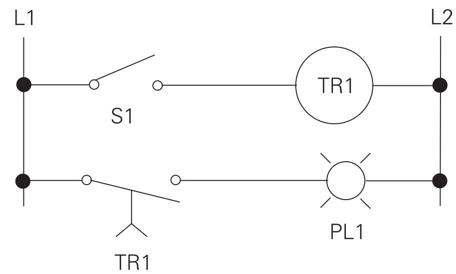
Time relays perform either **on-delay** or **off-delay timing**. An arrow is used to denote the function of the timer. An arrow pointing up indicates an on-delay timing action, while an arrow pointing down indicates an off-delay timing action.

On Delay Arrow Points Up   Off Delay Arrow Points Down

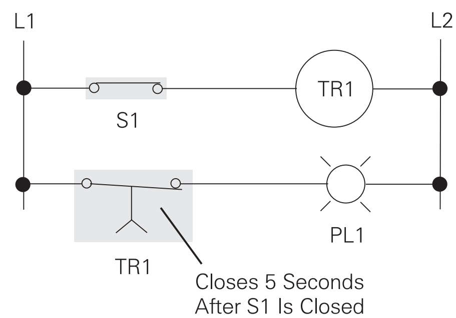
On-delay and off-delay timers can turn their connected loads on or off, depending on how the timer's output is wired into the circuit. The term "on delay" indicates that a preset time must pass after the timer receives a signal to turn on before the timer's contacts change state. The term "off delay" indicates that a preset time must pass after the timer receives a signal to turn off before the timer's contacts change state.

On-Delay, Timed Closed Timer

The following illustration shows an example of an **on-delay, timed closed timer**, also called a **normally open, timed closed (NOTC) timer**. In this example, The timing relay (TR1) has been set for an on delay of 5 seconds.

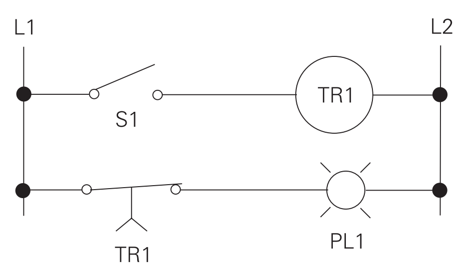


When S1 is closes, timer TR1 begins timing. After 5 seconds, TR1 contacts close, and pilot light PL1 turns on. When S1 opens, timer TR1 de-energizes, and TR1 contacts open immediately, turning off pilot light PL1.

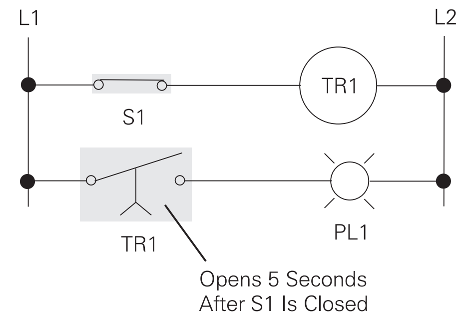


On-Delay, Timed Open Timer

The following illustration shows an example of an **on-delay, timed open timer**, also called a **normally closed, timed open (NCTO) timer**. The timing relay (TR1) has been set for an on delay of 5 seconds.



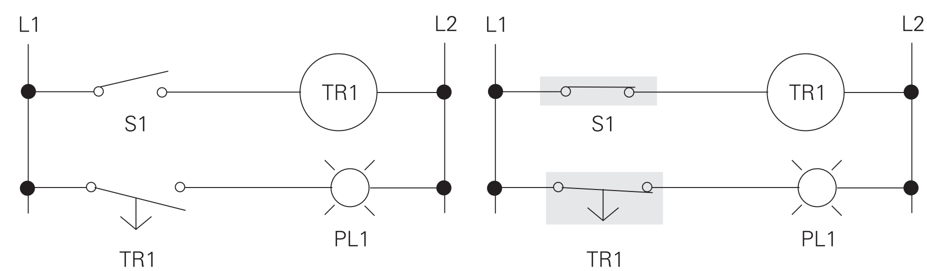
When S1 closes, timer TR1 energizes. After 5 seconds, TR1 contacts open, and pilot light PL1 turns off. When S1 opens, timer TR1 de-energizes, and TR1, contacts close immediately, turning on pilot light PL1.



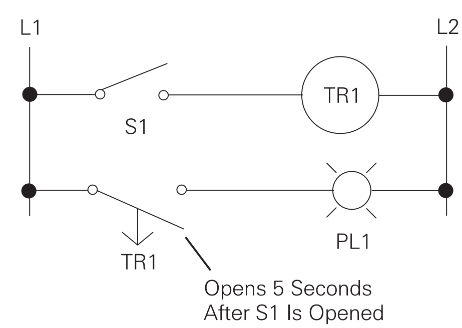
Off-Delay, Timed Open

The following illustrations shows an example of an **off-delay, timed open timer**, also called a **normally open, timed open (NOTO) timer**. The timing relay (TR1) has been set for an off delay of 5 seconds.

When S1 closes, open TR1 contacts open immediately, and pilot light PL1 turns on.



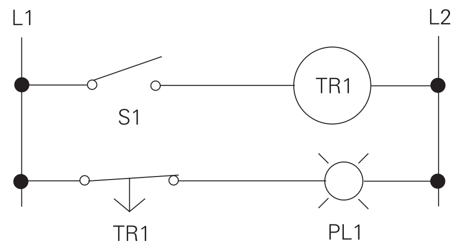
When S1 opens, timer TR1 begins timing. After 5 seconds, TR1 TR1 contacts open, and pilot light PL1 turns off.

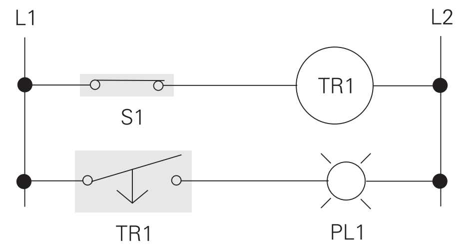


Off-Delay, Timed Closed

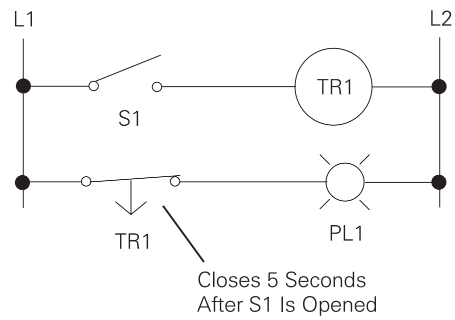
The following illustraton shows an example of an **off-delay, timed closed timer**, also called a **normally closed, timed closed (NCTC) timer**. The timing relay (TR1) has been set for 5 seconds.

When S1 closes, TR1 contacts open immediately, and pilot light PL1 turns off.



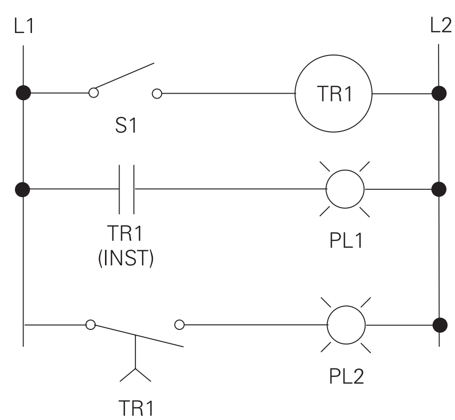


When S1 opens, timer TR1 begins timing. After 5 seconds, timer TR1 contacts close, and pilot light PL1 turns on.



Instantaneous Contacts

Timing relays can also have normally open or normally closed **instantaneous contacts**. In the following example, when switch S1 closes, TR1 instantaneous contacts close immediately, and pilot light PL1 turns on. After a preset time delay, TR1 timing contacts close, and pilot light PL2 turns on.

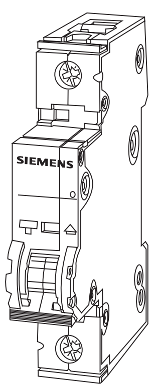


Terminal Blocks and Supplementary Protectors

Supplementary Protectors

Siemens **UL 1077 supplementary protectors** are designed to trip faster than standard UL 489 circuit breakers providing additional protection for more sensitive devices. In addition to providing supplementary branch circuit protection, supplementary protectors may also be used as a local disconnect means inside a panel when a branch circuit protection device is already present.

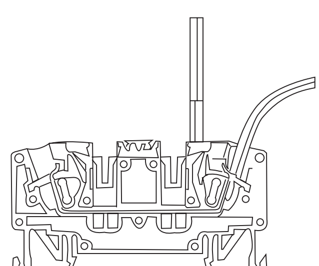
Siemens supplementary protectors are equipped with a thermal bimetallic trip mechanism for low-current overloads and an instantaneous electromagnetic trip for high-current overloads and short circuits. Single-pole and multiple-pole varieties are available with mounting depths of 55 or 70 mm.



5SY4 Supplementary Protector (70 mm)

Terminal Blocks

Siemens offers a broad range of **spring-loaded and screw-type terminal blocks** for space-saving connections.



8WA2 Through-type Terminal

Examples of the types of terminal blocks are listed below.

8WA1 Terminals With Screw Connections

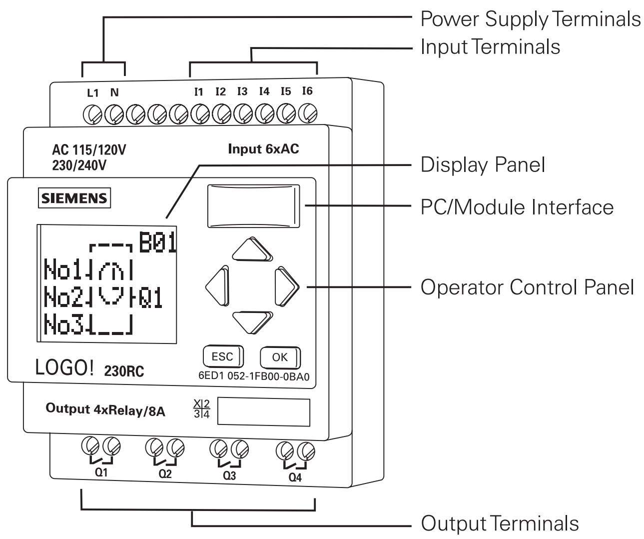
- Through-type terminals
- N isolating and branch terminals
- Ground and ground-neutral terminals
- Two-tier terminals
- Two-tier terminals with solid-state components
- Insta or three-tier terminals
- Flat-type and bolt-type terminals
- Fuse terminals
- Terminal for components
- Diode and isolating terminals
- Fuse terminals
- Sliding-link terminals
- Through-type plug connection
- Measuring transformer terminals
- Circuit breaker terminals for auxiliary circuits

8WA2 Spring-Loaded Terminals

- Through-type terminals
- Two-tier terminals
- Insta or three-tier terminals
- N isolating terminals
- Ground terminals
- Fuse terminals
- Terminal for components
- Diode terminals
- Sliding-link terminals

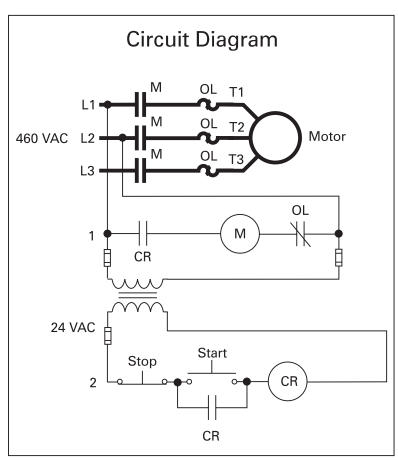
LOGO! Logic Module

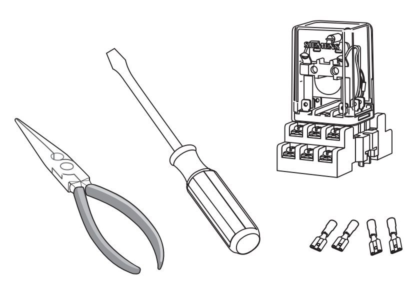
LOGO! is a **logic module** used to perform control tasks. The module is compact and user friendly, providing a cost-effective solution for the end user.



Hard-Wired Control

In the past, many of these control tasks were solved by hard-wiring control relays. This approach required the design of circuits, development of control diagrams, specification and procurement of components, and installation and testing of the control system. In addition, a change in control function or system expansion often required extensive rework.

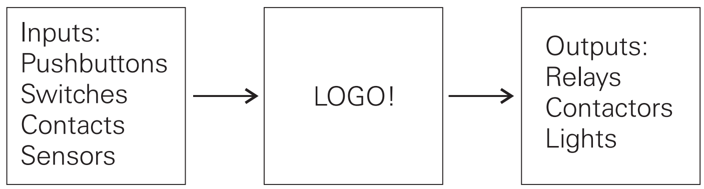




Many of the same tasks can be performed with LOGO!. Initial hard-wiring, although still required, is greatly simplified. Modifying the application is as easy as changing the program via the keypad located on the front of the LOGO!. Likewise, control programs can be created and tested before implementation 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 connected to virtually any type of load such as relays, contactors, lights, and small motors.



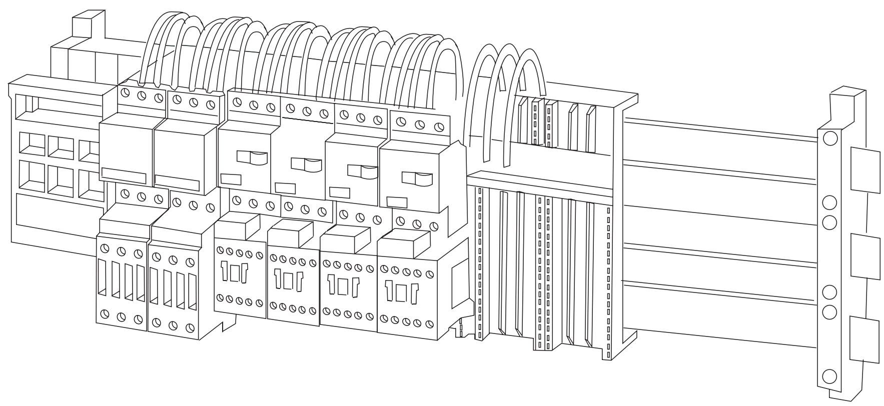
Design Features

LOGO! Basic units are equipped with a display panel. **LOGO! Pure units** do not have a display panel. Versions of LOGO! are available for multiple supply voltages (12/24 VDC, 24 VDC, 24 VAC/DC, or 115/230 VAC/DC). LOGO! units are equipped with 4 to 8 digital inputs and 4 to 8 relay or solid-state outputs. Expansion modules are available to increase the number of digital inputs and outputs and to add analog inputs or outputs. A communication module for connection to the AS-Interface is also available.

Fast Bus Busbar Adapter System

The **Fast Bus Multi-Motor Control system** is a **three-phase, insulated busbar system** that reduces wire connections and hole drilling when building control panels. **SIRIUS 3RV/3RT starter combinations**, built from components, and Siemens circuit breakers use Fast Bus for convenient mounting.

Fast Bus is not new to Siemens, but due to the narrower dimensions of SIRIUS components, more starters will fit on the same run of Fast Bus. Components are available for busbar center-line spacings of 40 or 60 mm.



8US1 Busbar Adapter System

All This and More

In this course, you learned about an extensive range of products, and you might be tempted to think that we have covered everything you need to know about Siemens control components and systems. However, Siemens offers many more components and systems than we can describe in one course.

For example, Siemens sensors, variable speed drives, integrated safety products, and automation systems represent additional categories for further exploration. In addition, many of these products and systems are capable of communicating using a comprehensive networking structure that forms the backbone of Siemens Totally Integrated Automation capability.

Review 8

1. A control relay's _______ number is the number of isolated circuits that can pass through the relay.

2. A control relay's _______ number is the total number of closed contact positions per pole.

3. _______ solid-state relays, contactors, and function modules operate quietly and perform reliably at high switching frequencies.

4. SIRIUS _______ reduce machine and plant downtime by monitoring electrical and mechanical quantities and fault conditions and providing appropriate diagnostic indications.

5. A timing relay that receives a signal to turn on and then begins timing is referred to as an _______ delay timer.

6. Siemens UL 1077 _______ are designed to trip faster than standard UL489 circuit breakers, providing additional protection for more sensitive devices.

7. Siemens terminal blocks are available with either ______ connections or _______ terminals.

8. The _______ Multi-Motor Control system is a three-phase, insulated busbar system that reduces wire connections and hole drilling when bulding control panels.

Review Answers

Review 1 1) manually; 2) a; 3) b; 4) b; 5) c.

Review 2 1) left, right; 2) a - Node, b - Power Circuit, c - F
d- Control Circuit, e - Control Device, f - Contro

Review 3 1) a; 2) overcurrent; 3) overload; 4) a; 5) bimeta
7) heaters, phase loss.

Review 4 1) two; 2) low voltage protection (LVP); 3) 15, 1
5) motor starter; 6) combination starter.

Review 5 1) NEMA, IEC; 2) 5; 3) AC3; 4) 4, 3½; 5) 3; 6) S
7) 140° F (60° C).

Review 6 1) separate-winding, consequent-pole; 2) rever
3) current, torque; 4) Autotransformer; 5) Solid-
6) 3RW30/31, 3RW40, 3RW44.

Review 7 1) Electrically held; 2) magnetically held, mecha
3) pilot; 4) 22; 5) blue, white, clear.

Review 8 1) pole; 2) throw; 3) SIRIUS SC; 4) monitoring r
6) supplementary protectors; 7) screw, spring-
8) Fast Bus.

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.

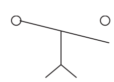
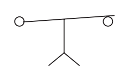
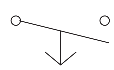
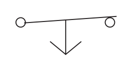
1. The standard method of drawing a contact shows the circuit condition produced when the actuating device is in the _______ state.

   a. normally closed   b. normally open
   c. energized   d. de-energized

2. A motor that is running is usually indicated by a by a _______ indicator 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. fluctuate

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

7. Which of the following items 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. accelerate motor to full speed faster
   d. run the motor at a lower speed

9. A control relay's _______ number is the number of isolated circuits that can pass through the relay.

   a. throw b. pole
   c. break d. make

10. NEMA and _______ are organizations that provide ratings for contactors and starters.

   a. NAED b. NFPA
   c. NEC d. IEC

11. _______ is a flexible, modular motor management system that provides multifunctional, solid-state protection for constant-speed motors.

   a. SINAMICS b. LOGO!
   c. MICROMASTER d. SIMOCODE pro

12. _______ provide a visual indication of a circuit's operating condition.

   a. Pushbuttons b. Selector switches
   c. Proximity switches d. Indicator lights

13. A _______ relay contact configuration has two isolated circuits and one closed contact position per pole.

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

14. A _______ lighting and heating contactor produces a humming sound during normal operation and is not recommended for a quiet area?

a.	electrically held	b.	mechanically latched
c.	magnetically held	d.	both b and c

15. A NEMA size 6 starter has a continuous amp rating of _______ amps.

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

16. Siemens 8WD42 and 8WD44 signaling columns can be networked to other devices through an optional _______ adapter.

a.	PROFIBUS	b.	Ethernet
c.	AS-Interface	d.	PROFINET

17. Siemens class 14 ESP100 starters are available with contactor ratings up to and including NEMA size ___ .

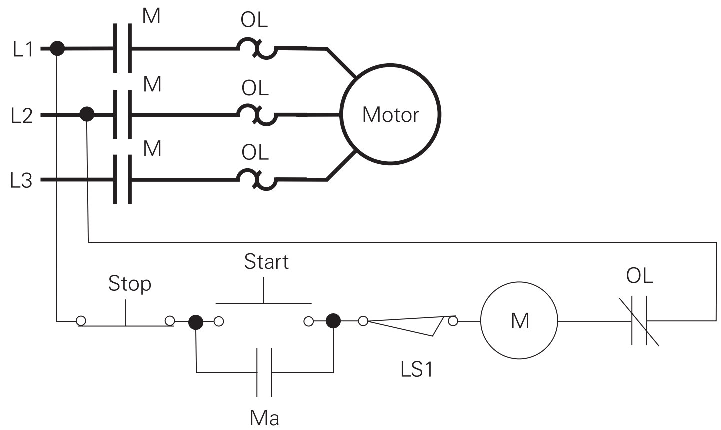
a.	4	b.	6
c.	8	d.	10

18. Another name for a solid-state, reduced voltage starter is a/an ______ starter.

a.	soft	b.	primary resistance
c.	wye-delta	d.	autotransformer

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

a. the “Stop” pushbutton is pressed
b. limit switch “LS1” opens
c. the motor overload contacts open
d. all of the above



20. _______ solid-state contactors are made up of a solid-state relay and an optimized heat sink.

a. SIRIUS 3UG b. SIRIUS 3RH11
c. SIRIUS SC d. SIRIUS 3RW40

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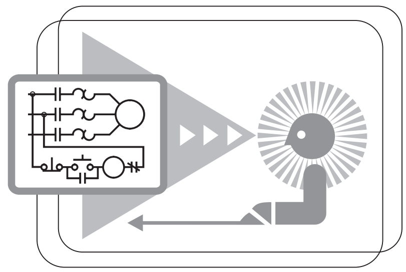

quickSTEP online courses are available at http://www.sea.siemens.com/step.

The quickSTEP training site is divided into three sections: Courses, Downloads, and a Glossary. Online courses include reviews, a final exam, the ability to print a certificate of completion, and the opportunity to register in the Sales & Distributor training database to maintain a record of your accomplishments.

From this site the complete text of all STEP courses can be downloaded in PDF format. These files contain the most recent changes and updates to the STEP courses.

A unique feature of the quickSTEP site is our pictorial glossary. The pictorial glossary can be accessed from anywhere within a quickSTEP course. This enables the student to look up an unfamiliar word without leaving the current work area.