Basics of Control Components

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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 able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** before attempting **Basics of Control Components**. An understanding of many of the concepts covered in **Basics of Electricity** is required for **Basics of Control Components**.

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.

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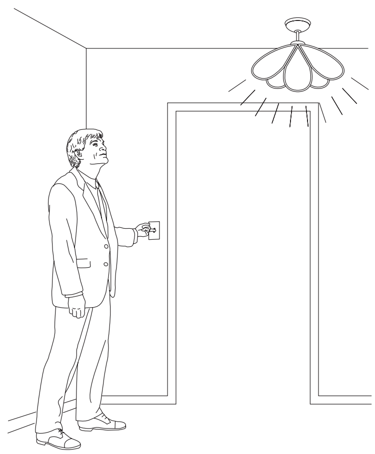
Control Circuits

Control

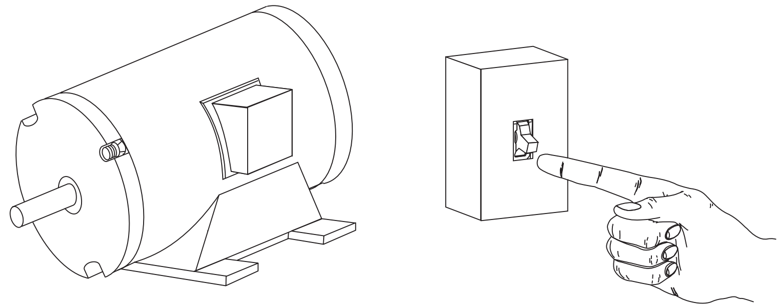
Control, as applied to control circuits, is a broad term that means anything from a simple toggle switch to a complex system of components (which may include relays, contactors, timers, switches, and indicating lights). Every electrical circuit for light or power has control elements. One example of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



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

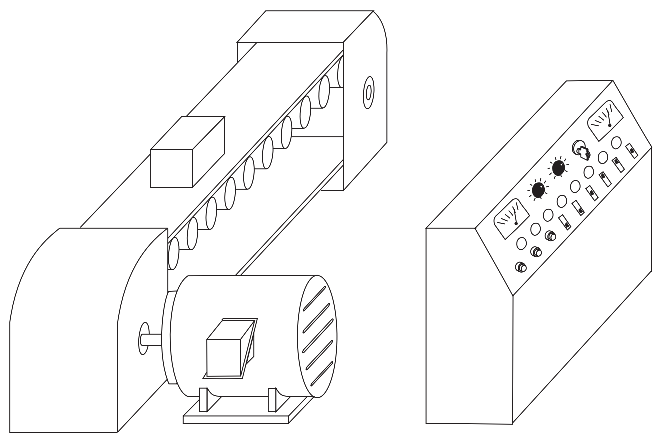
Manual Control

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



Automatic Operation

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



Control Elements

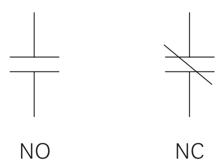
The elements of a control circuit include all of the equipment and devices concerned with the circuit function: enclosures, conductors, relays, contactors, pilot devices, and overcurrent-protection devices. The selection of control equipment for a specific application requires a thorough understanding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

Electrical Symbols

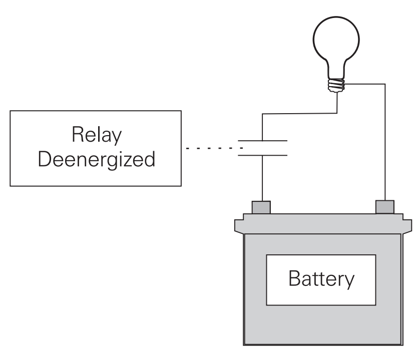
Language has been developed in order to transfer ideas and information. In order to understand the ideas and information being communicated, an understanding of the language is necessary. The language of controls consists of a commonly used set of symbols which represent control components.

Contact Symbols

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

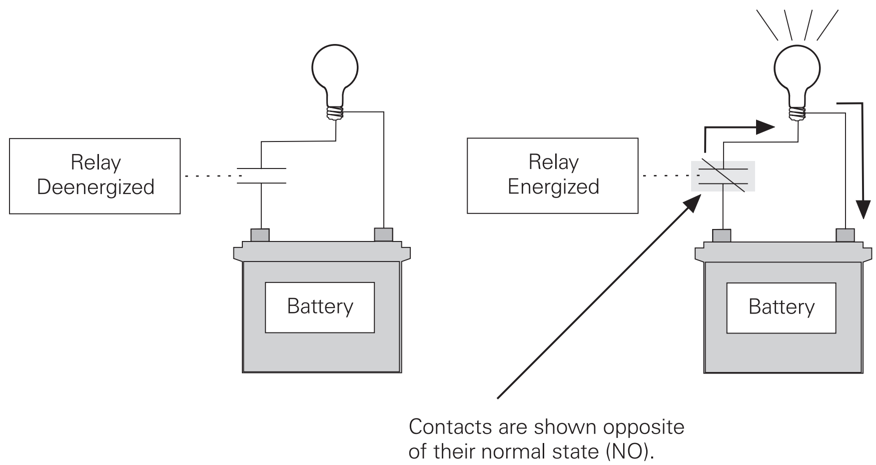


The standard method of showing a contact is to indicate the circuit condition produced when the actuating device is in the de-energized state. For example, in the following illustration a relay is used as the actuating device. The contacts are shown as normally open, meaning the contacts are open when the relay is de-energized. A complete path of current does not exist and the light is off.



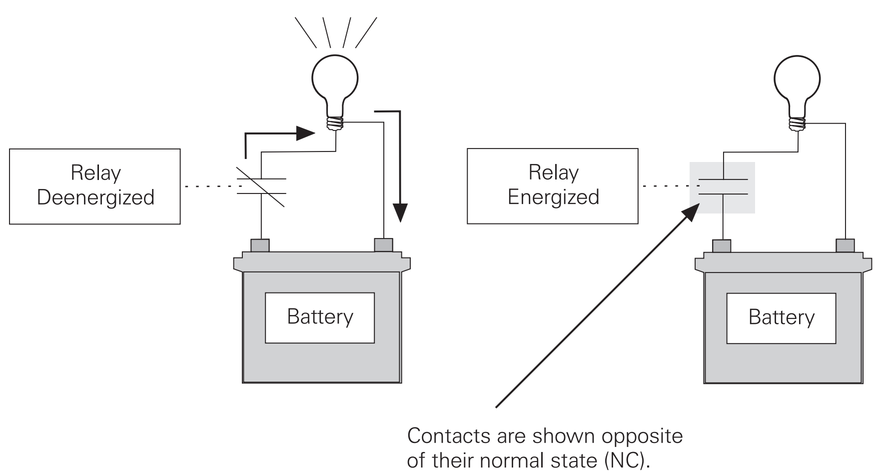
Normally Open Contact Example

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



Normally Closed Contact Example

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

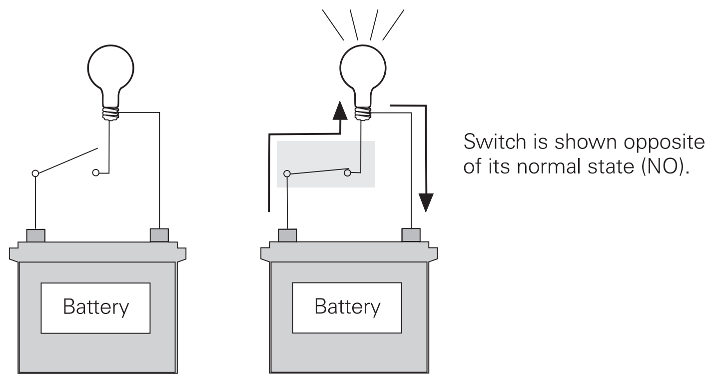


Switch Symbols

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

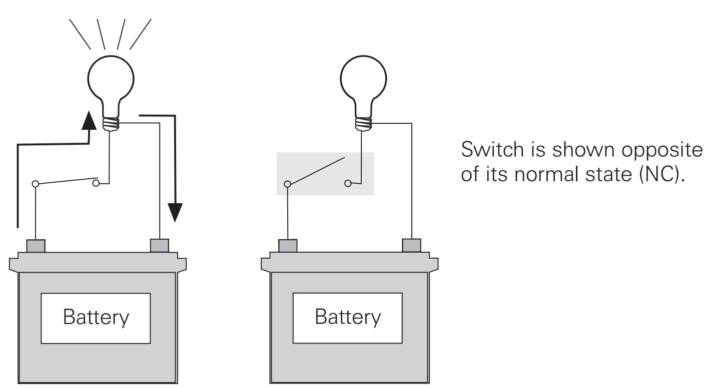
Normally Open Switch Example

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



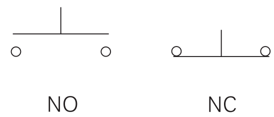
Normally Closed Switch Example

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



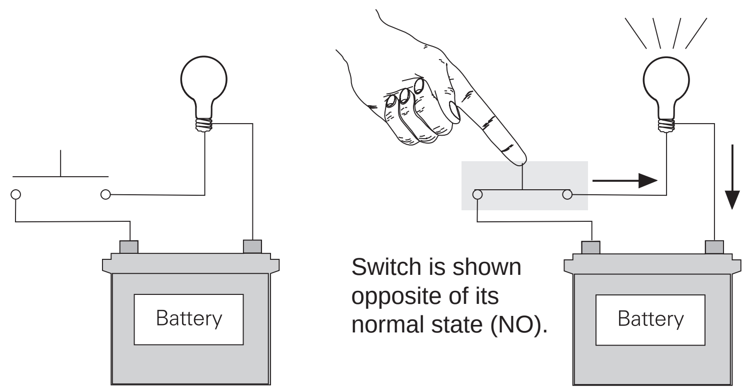
Pushbutton Symbols

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



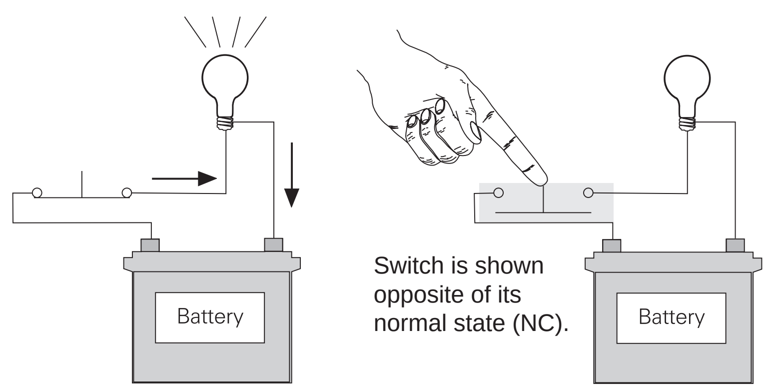
Normally Open Pushbutton Example

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



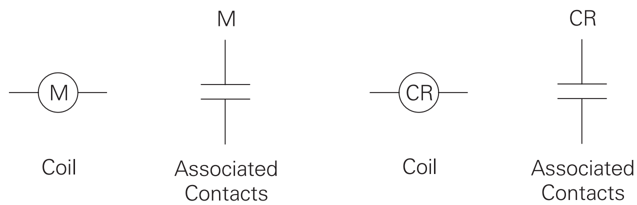
Normally Closed Pushbutton Example

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



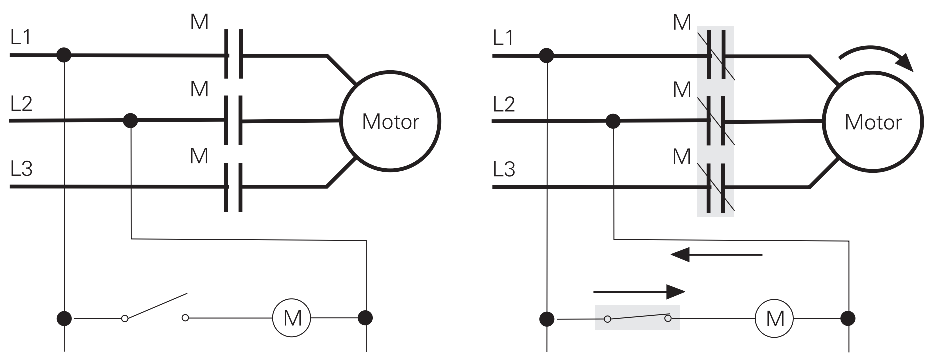
Coil Symbols

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



Coil Example Using Normally Open Contacts

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



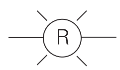
Overload Relay Symbols

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

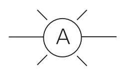
Thermal
Overload

Indicator Light Symbols

An **indicator light** (sometimes 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 a motor is running. The letter in the center of the indicator light symbol indicates the color of the light.



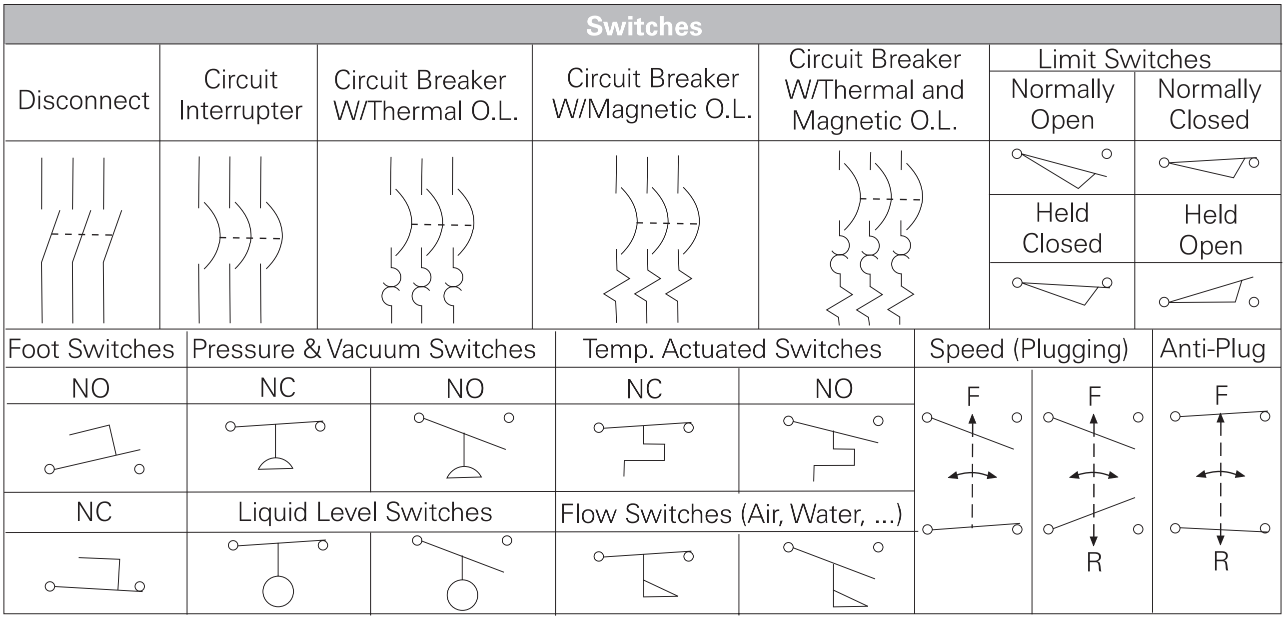
Red
Indicator Light

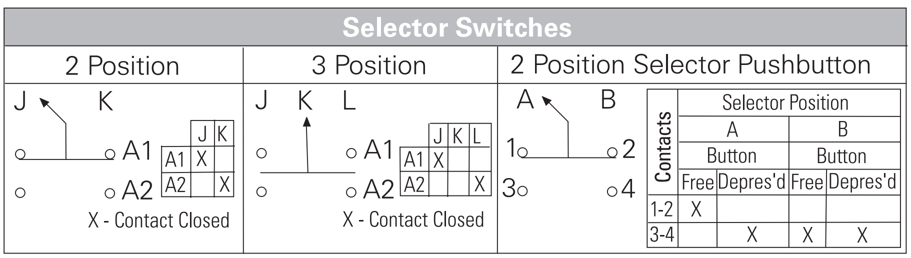


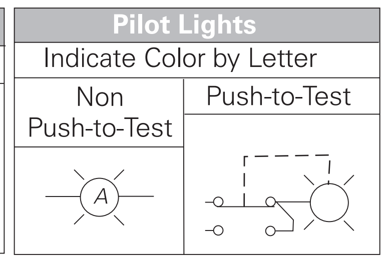
Amber
Indicator Light

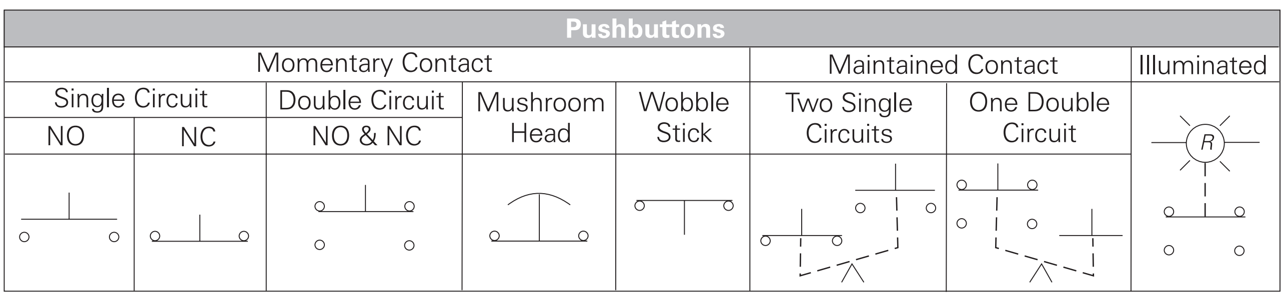
Other Symbols

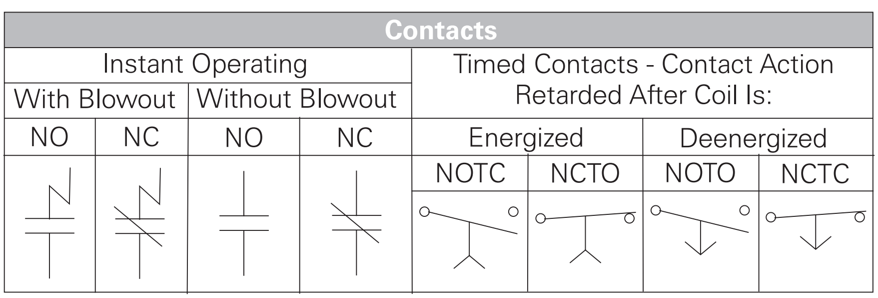
In addition to the symbols discussed here, there are many other symbols used in control circuits. The following chart shows many of the commonly used symbols.

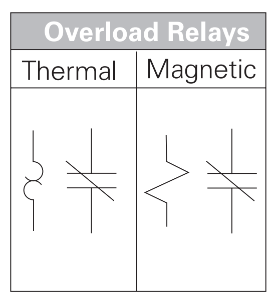

Switches
Disconnect
Circuit Interrupter
Circuit Breaker W/Thermal O.L.
Circuit Breaker W/Magnetic O.L.
Circuit Breaker W/Thermal and Magnetic O.L.
Limit Switches
Normally Open
Normally Closed
Held Closed
Held Open
Foot Switches
NO
NC
Pressure & Vacuum Switches
NC
NO
Liquid Level Switches
Temp. Actuated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

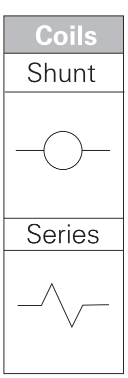

Selector Switches
2 Position
J K
A1
A2
J K
A1 X
A2 X
X - Contact Closed
3 Position
J K L
A1
A2
J K L
A1 X
A2 X
X - Contact Closed
2 Position Selector Pushbutton
A B
1 2
3 4
Selector Position
Contacts
A B
Button Button
Free Depres'd Free Depres'd
1-2 X
3-4 X X X

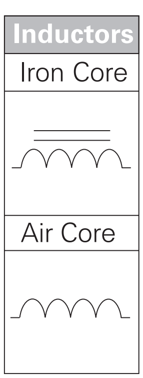

Pilot Lights
Indicate Color by Letter
Non Push-to-Test
Push-to-Test
A

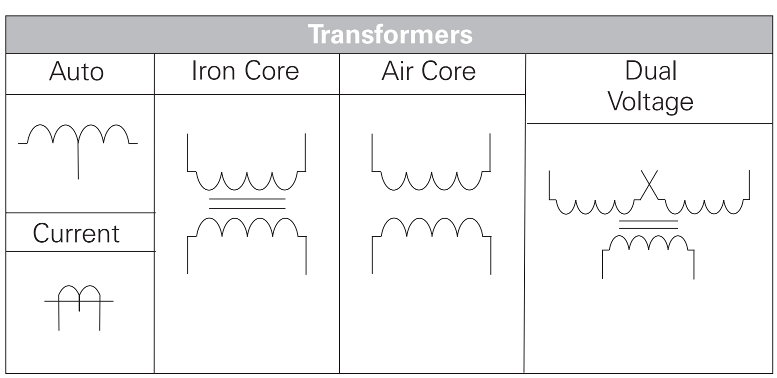

Pushbuttons
Momentary Contact
Single Circuit
NO
NC
Double Circuit
NO & NC
Mushroom Head
Wobble Stick
Maintained Contact
Two Single Circuits
One Double Circuit
Illuminated
R

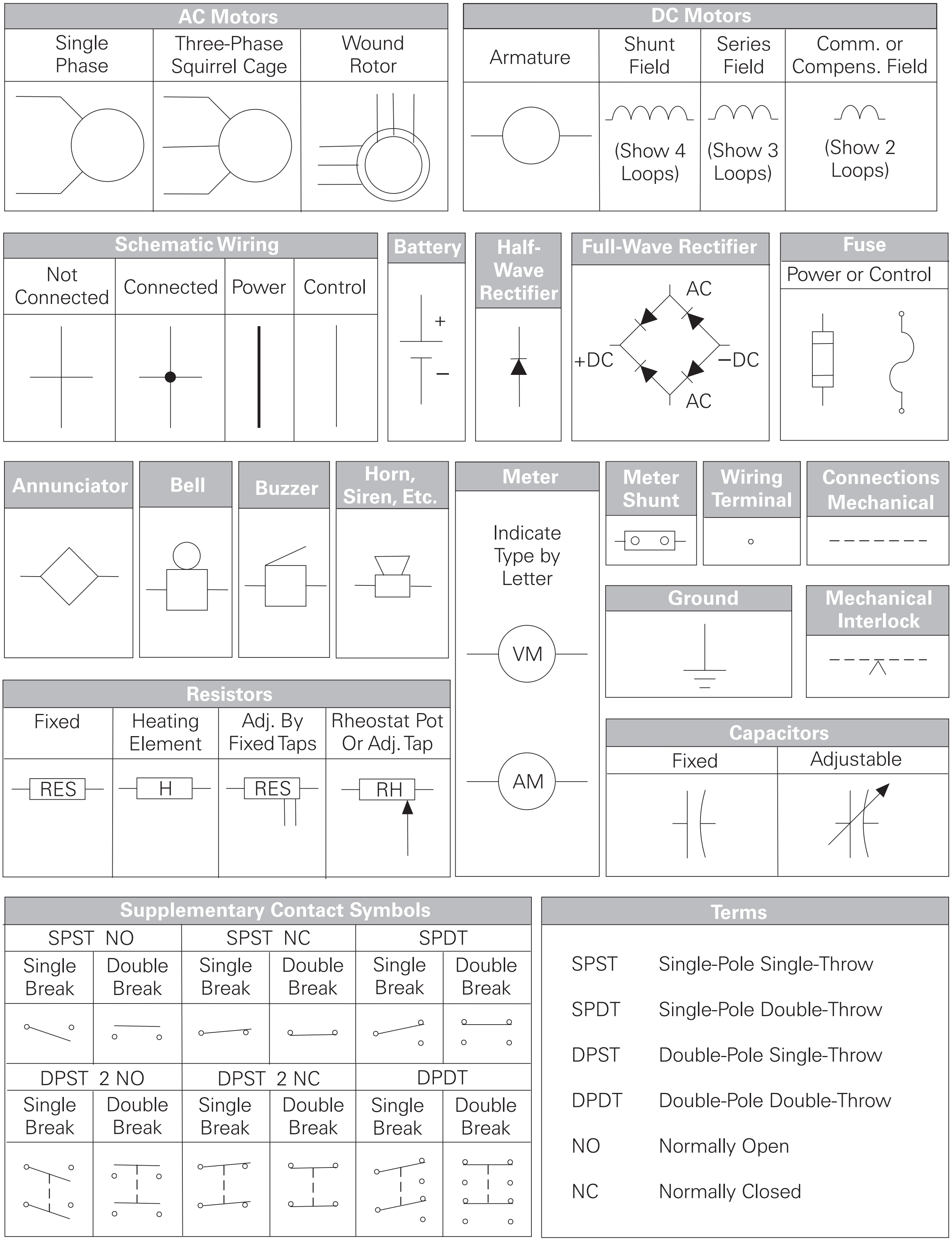

Contacts
Instant Operating
With Blowout
Without Blowout
NO
NC
NO
NC
Timed Contacts - Contact Action Retarded After Coil Is:
Energized
NOTC
NCTO
Deenergized
NOTO
NCTC


Overload Relays
Thermal
Magnetic


Coils
Shunt
Series


Inductors
Iron Core
Air Core


Transformers
Auto
Current
Iron Core
Air Core
Dual Voltage



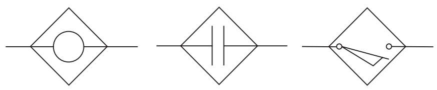
AC Motors
Single Phase
Three-Phase Squirrel Cage
Wound Rotor
DC Motors
Armature
Shunt Field
(Show 4 Loops)
Series Field
(Show 3 Loops)
Comm. or Compens. Field
(Show 2 Loops)
Schematic Wiring
Not Connected
Connected
Power
Control
Battery
+
−
Half-Wave Rectifier
Full-Wave Rectifier
AC
+DC
−DC
AC
Fuse
Power or Control
Annunciator
Bell
Buzzer
Horn, Siren, Etc.
Meter
Indicate Type by Letter
VM
AM
Meter Shunt
Wiring Terminal
Connections Mechanical
Ground
Mechanical Interlock
Resistors
Fixed
RES
Heating Element
H
Adj. By Fixed Taps
RES
Rheostat Pot Or Adj. Tap
RH
Capacitors
Fixed
Adjustable
Supplementary Contact Symbols
SPST NO
Single Break
Double Break
SPST NC
Single Break
Double Break
SPDT
Single Break
Double Break
DPST 2 NO
Single Break
Double Break
DPST 2 NC
Single Break
Double Break
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 is a method of switching electrical circuits without the use of contacts. Primarily by solid-state devices. Use the symbols shown in the table on the previous page except enclosed in a diamond.

Examples:

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



Control and Power Connections - 600 Volts or Less - Across-the-Line Starters (From NEMA Standard ICS 2-321A.60)		1 Phase	2 Phase 4 Wire	3 Phase
Line Markings		L1,L2	L1,L3-Phase 1 L2,L4-Phase 2	L1,L2,L3
Ground When Used		L1 is always Ungrounded	——	L2
Motor Running Overcurrent Units In	1 Element	L1	——	——
	2 Element	——	L1,L4	——
	3 Element	——	——	L1,L2,L3
Control Circuit Connected To		L1,L2	L1,L3	L1,L2
For Reversing Interchange Lines		——	L1,L3	L1,L3

Abbreviations

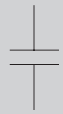
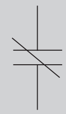
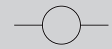
Abbreviations are frequently used in control circuits. The following list identifies a few commonly used abbreviations.

AC	**Alternating Current**
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**

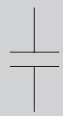
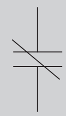
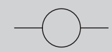
Review 1

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

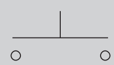
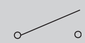
2. Which of the following symbols represents a normally open contact?

   a.  b.  c. 

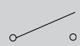
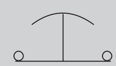
3. Which of the following symbols represents a normally closed contact?

   a.  b.  c. 

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

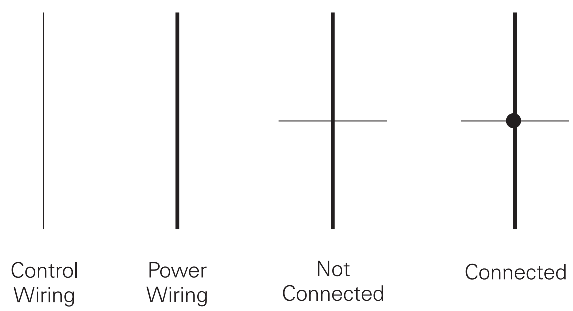
   a.  b.  c. 

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

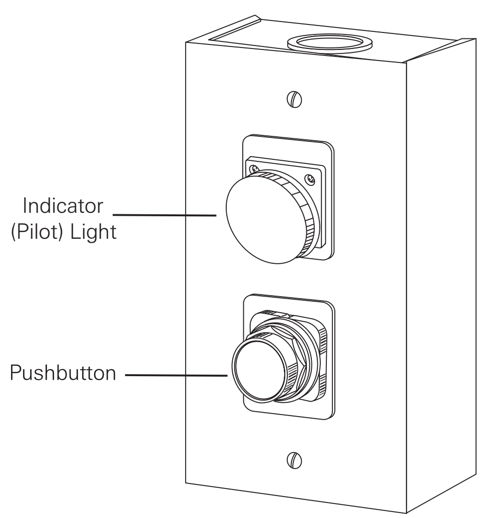
   a.  b.  c. 

Line Diagrams

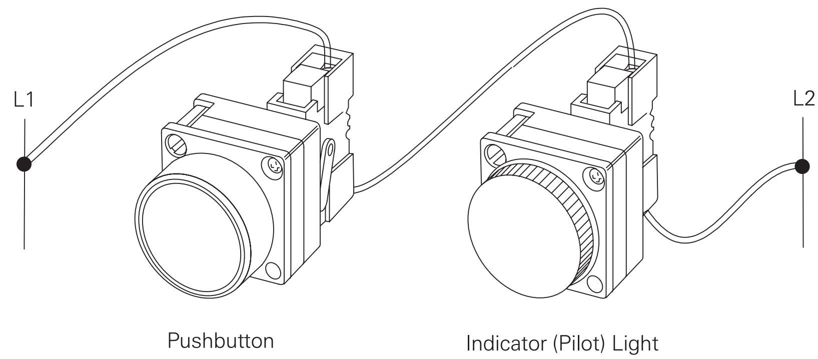
The method of expressing the language of control symbols is a **line diagram**, also referred to as a ladder diagram. Line diagrams are made up of two circuits, the control circuit and the power circuit. Electrical wires in a line diagram are represented by lines. Control-circuit wiring is represented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



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

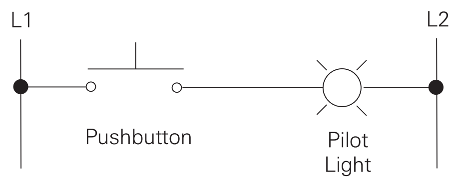


The functional relationship can be shown pictorially with the following illustration.



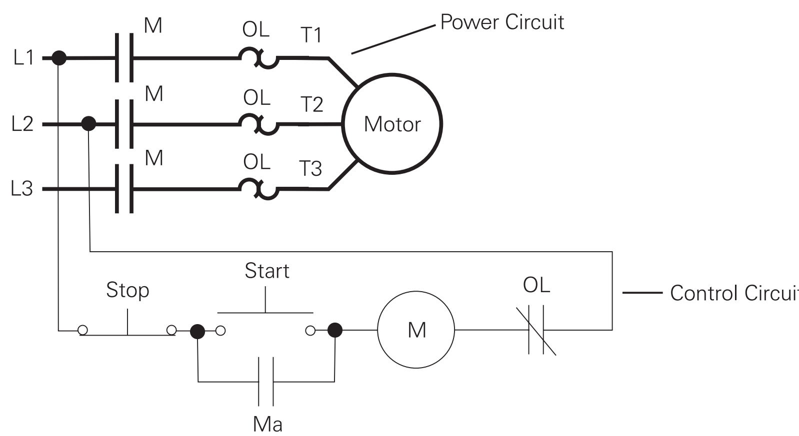
Reading a Line Diagram

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



Power Circuit and Control Circuit

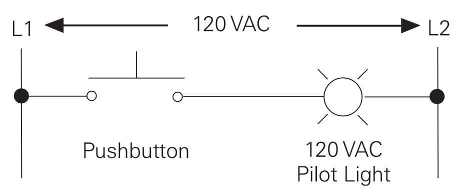
The **power circuit** (indicated by the heavier-weight line) is what actually distributes power from the source to the connected load (motor). The **control circuit** (indicated by the lighter-weight line) is used to “control” the distribution of power.



Connecting Loads and Control Devices

Control circuits are made up of control loads and control devices. **Control loads** are electrical devices that use electrical power; for example, indicator lights, relays, and contactors. **Control devices** (such as pushbuttons and switches) are used to activate the control load.

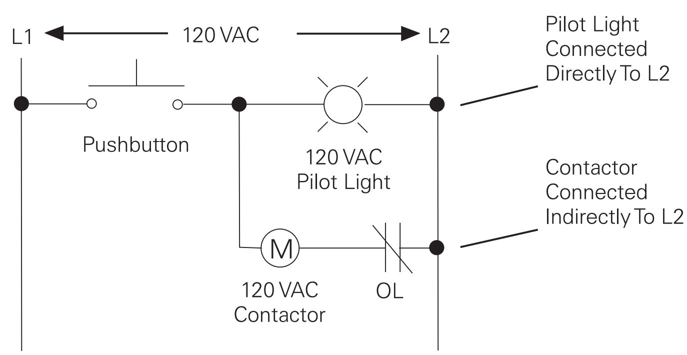
The following illustration shows the proper connection of an indicator light (load) with a pushbutton (control device). The power lines are drawn vertically and marked L1 and L2. In this example, the voltage potential between L1 and L2 is 120 VAC. The indicator light selected must be rated for 120 VAC. When the pushbutton is depressed, the full 120 volt potential is applied to the indicator light.



Connecting the Load to L2

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

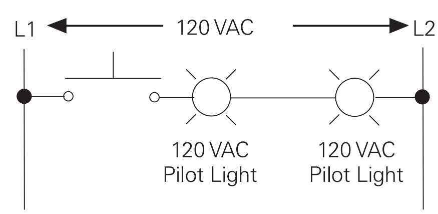


Control loads are generally not connected in series. The following illustration shows why.

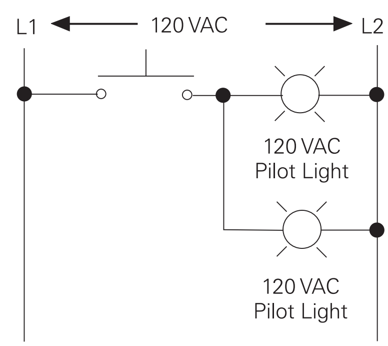
In the first instance, the control loads are improperly connected in series. When the pushbutton is depressed, the voltage across L1 and L2 is divided across both loads with neither load receiving the full 120 volts necessary for proper operation. If one load fails in this configuration, the entire circuit is rendered useless.

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

Improper Series Connection



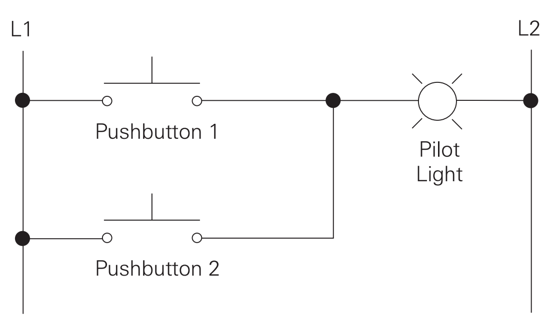
Proper Parallel Connection



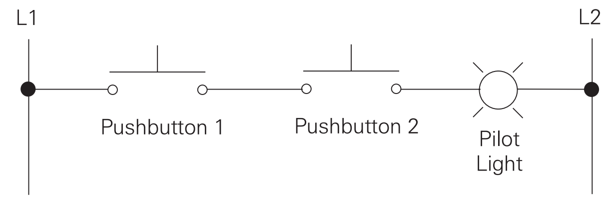
Connecting Control Devices

Control devices are connected between L1 and the load. The control device can be connected in series or parallel, depending on the desired operation of the circuit.

In the following illustration, the pushbuttons are connected in parallel. Depressing either pushbutton will allow current to flow from L1, through the depressed pushbutton, through the indicator light, to L2.

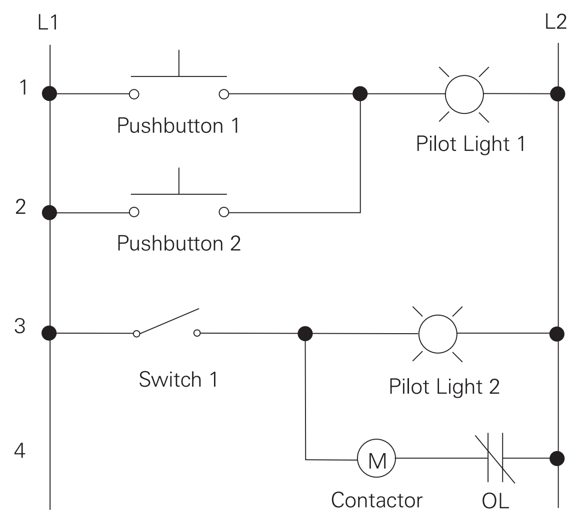


In this second illustration, two pushbuttons are connected in series. Both pushbuttons must be depressed in order to allow current to flow from L1 through the load to L2.



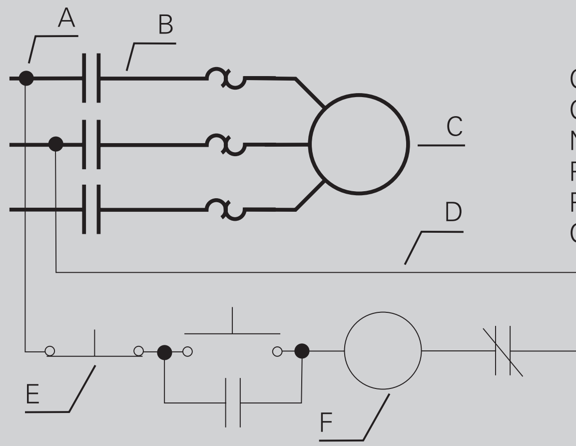
Line Numbering

Numbering each line makes it easier to understand more complex line diagrams. In the illustration below, line 1 connects pushbutton 1 to indicator light 1; line 2 connects pushbutton 2 to indicator light 1; and line 3 connects switch 1 to indicator light 2 and to the “M” contactor on line 4.



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

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



Control Circuit
Control Device
Node
Power Circuit
Power Load
Control Load

A ____________

B ____________

C ____________

D ____________

E ____________

F ____________

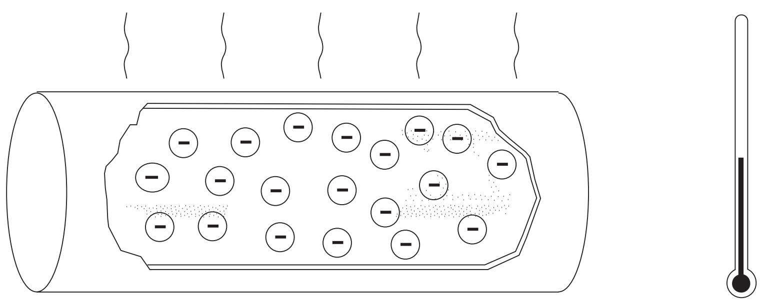
Overload Protection

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

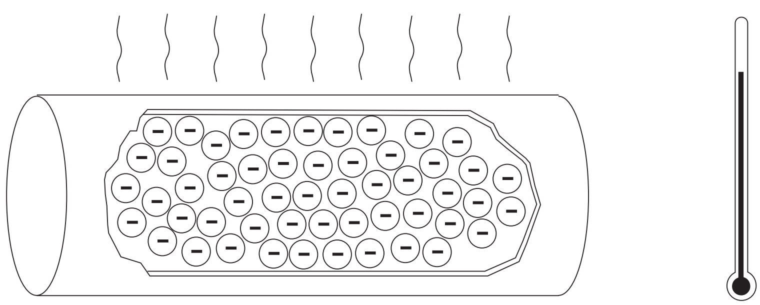
Current and Temperature

Current flow in a conductor always generates heat due to resistance; the greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or **ampacity**.

Overcurrent protection devices are used to protect conductors from excessive current flow. Overload relays are designed to protect the conductors (windings) in a motor. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the conductors from overheating.



Normal Current Flow

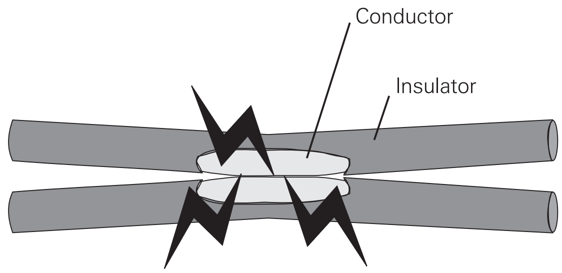


Excessive Current Flow

Excessive current is referred to as **overcurrent**. An overcurrent may result from a short circuit, overload, or ground fault.

Short Circuits

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



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

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

where **I** represents **Current**,
E represents **Voltage**, and
R represents **Resistance**

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

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

As noted above, resistance drops in the event of a short circuit. If resistance drops to 24 milliohms, current will be 10,000 amps.

$$I = \frac{240}{0.024}$$

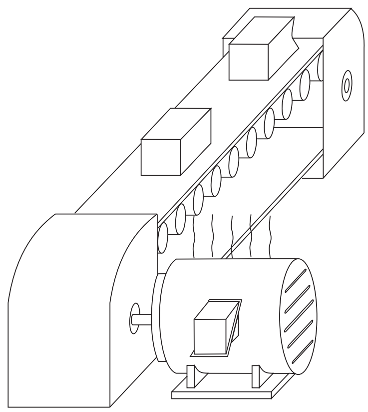
$$I = 10{,}000 \text{ amps}$$

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

Overload Conditions

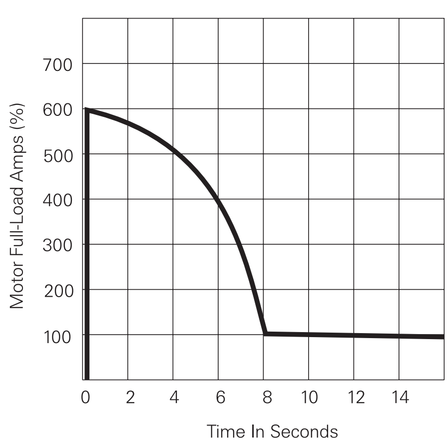
An overload occurs when too many devices are operated on a single circuit, or a piece of electrical equipment is made to work harder than it is designed for. For example, a motor rated for 10 amperes may draw 20, 30, or more amperes in an overload condition.

In the illustration below, a package has become jammed on a conveyor causing the motor to work harder and draw more current. Because the motor is drawing more current, it heats up and will be damaged within a short time if the problem is not corrected or the circuit is not shut down by the overload relay.



Temporary Overload Due to Starting Current

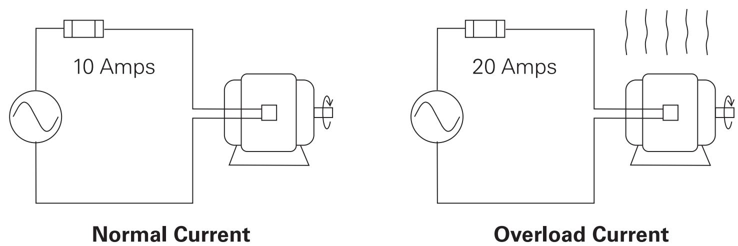
Electric motors are rated according to the amount of current they will draw at full load. When most motors start, they draw current in excess of the motor's full-load current rating. Motors are designed to tolerate this overload current for a short period of time. Many motors require 6 times (600%) the full-load current rating to start. High-efficiency motors may require up to 12 times (1200%) starting current. As the motor accelerates to operating speed, the current drops off quickly. The time it takes for a motor to accelerate to operating speed depends on the operating characteristics of the motor and the driven load. For example, a particular motor might require 600% of full-load current and take 8 seconds to reach operating speed.



Overload Protection

Fuses and circuit breakers are designed to protect circuit conductors in the event of a short circuit or overload condition. If a short circuit or overload condition occurs, these devices will open the path for current flow before damage to conductors occurs.

When fuses or circuit breakers are used in a circuit providing power to a motor, the protective devices and the circuit 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. In the next section, you will learn about overload relays.

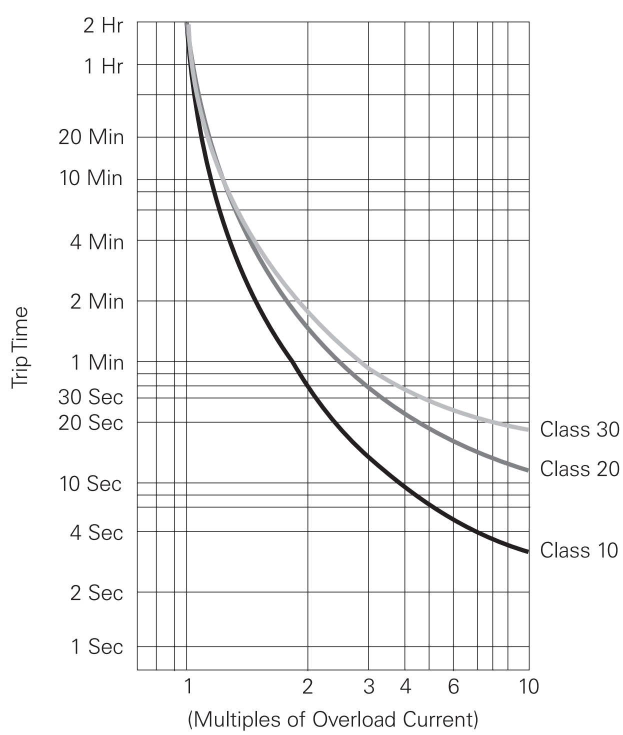


Overload relays are designed to meet the special protective needs of motor control circuits. Overload relays:

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

Trip Class

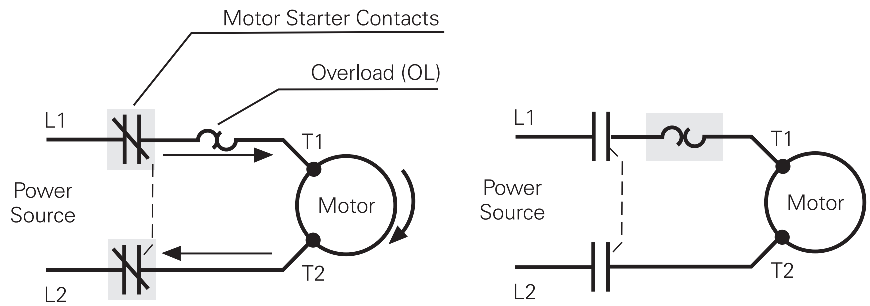
Overload relays are rated by a trip class which defines the length of time it will take for the relay to trip in an overload condition. The most common trip classes are Class 10, Class 20, and Class 30. A Class 10 overload relay, for example, has to trip the motor off line in 10 seconds or less at 600%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



Overload Relay in a Motor Circuit

The following illustration shows a motor circuit with a manual starter and an overload relay.

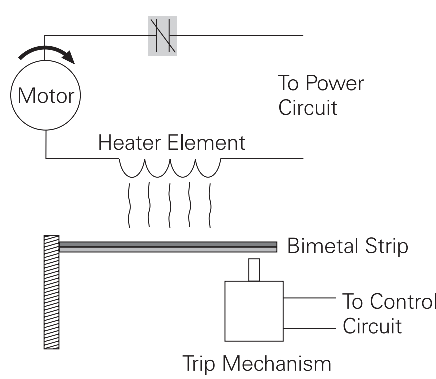
Current flows through the overload relay while the motor is running. Excess current will cause the overload relay to trip at a predetermined level, opening the circuit between the power source and the motor. After a predetermined amount of time, the overload relay can be reset. When the cause of the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



Bimetal Overload Relays

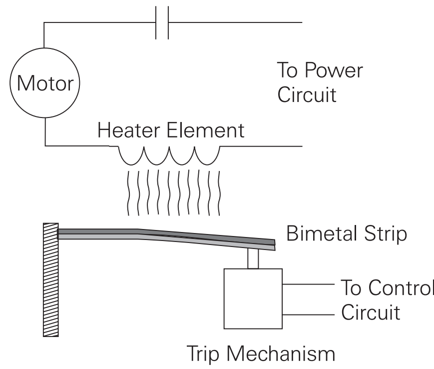
Overload protection can be accomplished with the use of a bimetal overload relay. This component consists of a small heater element wired in series with the motor and a bimetal strip that can be used as a trip lever. The bimetal strip is made of two dissimilar metals bonded together. The two metals have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

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



Normal Current Flow

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



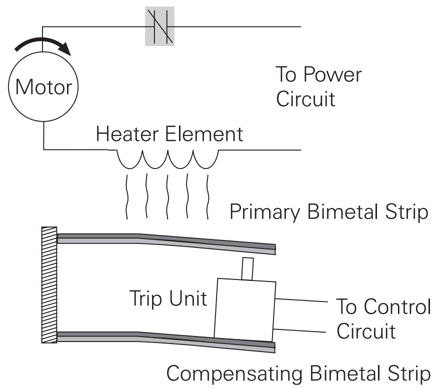
Overload Condition

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

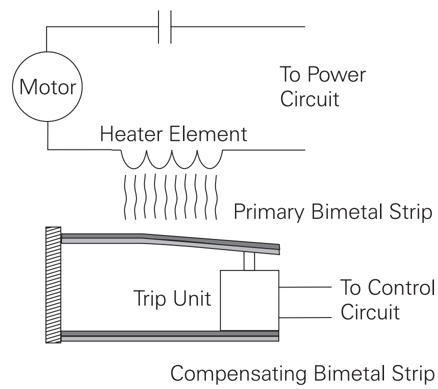
Ambient Compensated Bimetal Overload Relay

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

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



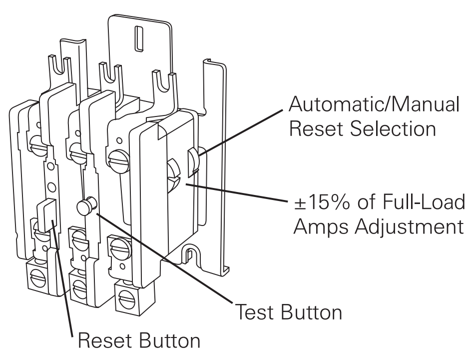
Ambient Compensated Overload Relay Affected By Ambient Temperature



Ambient Compensated Overload Relay Affected By Motor Temperature

Class 48 Ambient Compensated Bimetal Overload Relay

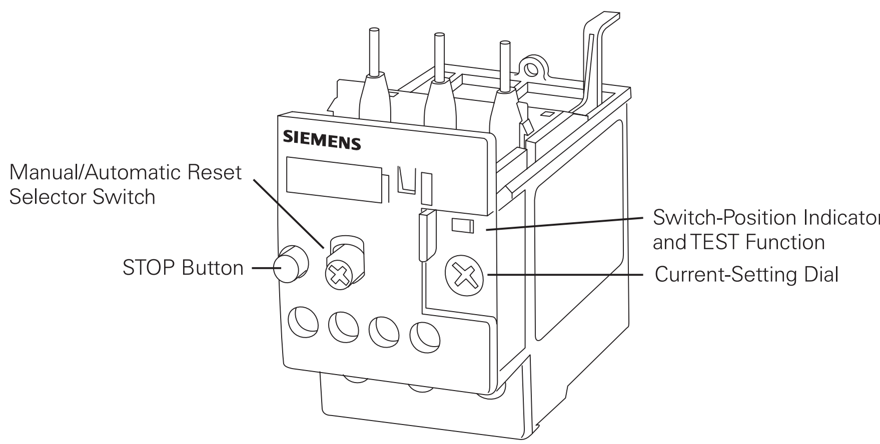
Siemens Class 48 ambient compensated bimetal overload relays are available in single-pole or three-pole designs and can be set for manual or self-resetting operation. An adjustment dial located on the unit allows the ampere trip setting to be adjusted by ±15%. A manual test button is provided to test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



SIRIUS 3RU11 Bimetal Overload Relay

The Siemens SIRIUS 3RU11 is a bimetal overload relay with the heater elements as an integral part of the 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.

The 3RU11 includes 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.



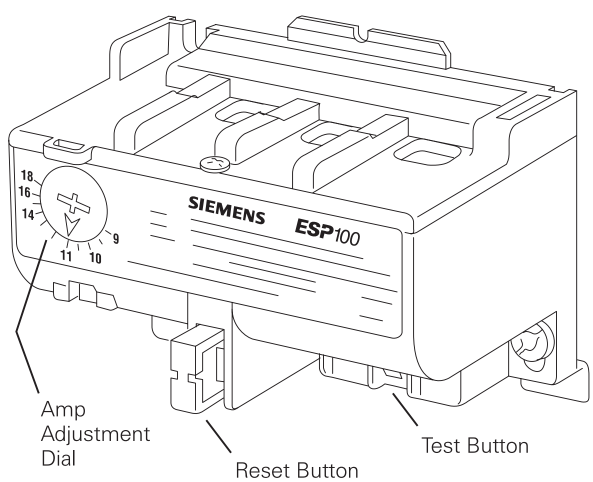
Electronic Overload Relays

Electronic overload relays are another option for motor protection. The features and benefits of electronic overload relays vary, but there are a few common traits. One advantage offered by electronic overload relays is a heaterless design, reducing installation cost and the need to stock a variety of heaters to match motor ratings. Heaterless design also allows the electronic relay to be insensitive to the ambient temperature, minimizing nuisance tripping.

Electronic relays also offer phase loss protection. If a power phase is lost, motor windings can burn out very quickly. Electronic overload relays can detect a phase loss and disconnect the motor from the power source. Phase loss protection is not available on mechanical types of overload relays.

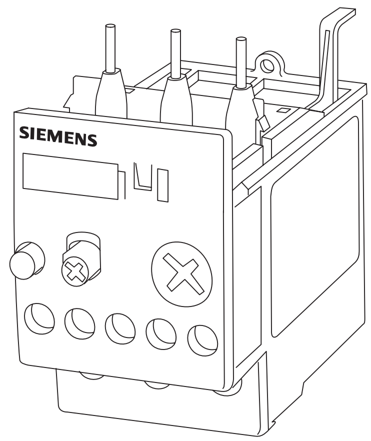
Class 48 ESP100 Electronic Overload Relay

A single ESP100 electronic overload relay replaces at least six size ranges of heaters. Instead of installing heaters, the full-load amperes (FLA) rating of the motor is set with a dial. The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amperes. NEMA Class 10, 20, and 30 trip curves are available for a variety of applications, 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.



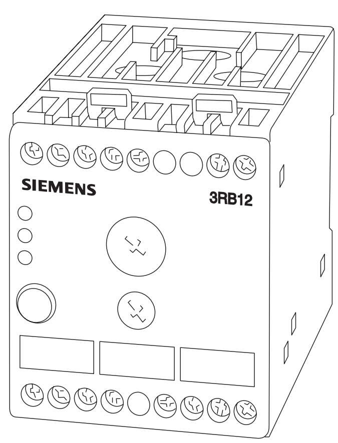
Siemens 3RB10/20 Electronic Overload Relay

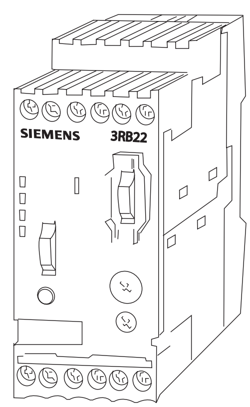
SIRIUS 3RB10/20 electronic overload relays come with a Class 10 or Class 20 trip and feature manual or automatic reset, adjustable current settings, and ambient compensation. A normally closed auxiliary contact for de-energizing the contactor and a normally open auxiliary contact for signaling an overload 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

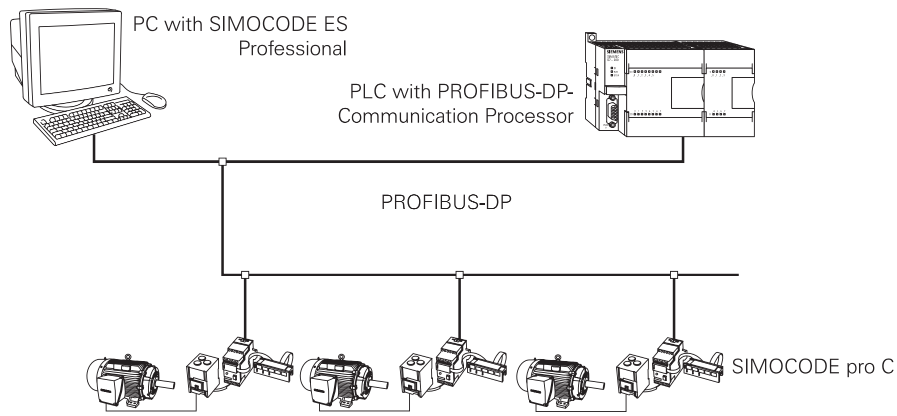
SIRIUS 3RB12/22 electronic overload relays provide trip class adjustments from Class 5 to Class 30 and ground fault, phase imbalance, and phase loss protection. Motor current is continuously monitored in each phase. Two auxiliary contacts, one normally open and one normally closed, are switched in the 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.





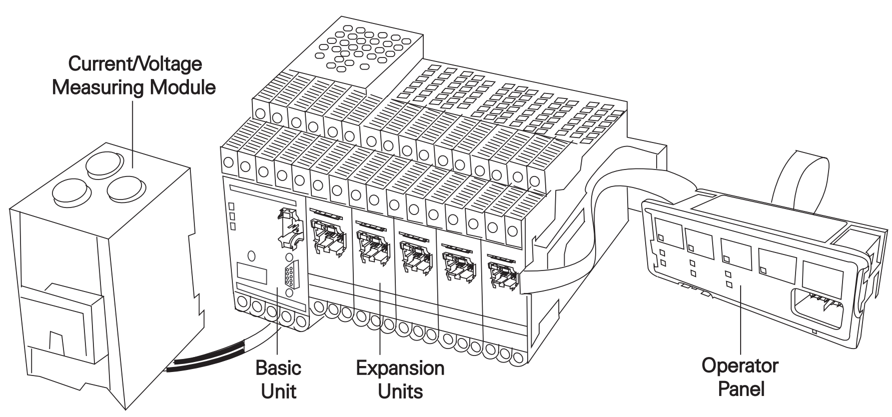
PROFIBUS DP

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.



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

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 an overloaded motor offline within 10 seconds at six times full-load amps.
   a. 10
   b. 20
   c. 30

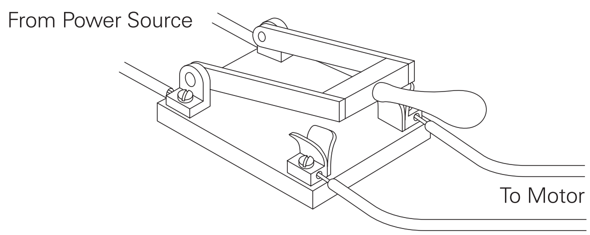
5. A _____________ strip uses two dissimilar metals bonded together.

6. An overload relay can be ______________ once the overload is removed.

7. Advantages common to most electronic overload relays include:
   1. They do not require the use of ___________________ _____________________.
   2. In addition to overload protection, they also provide ____________ ___________ protection.
   3. They are _______________to the ambient temperature.

Manual Control

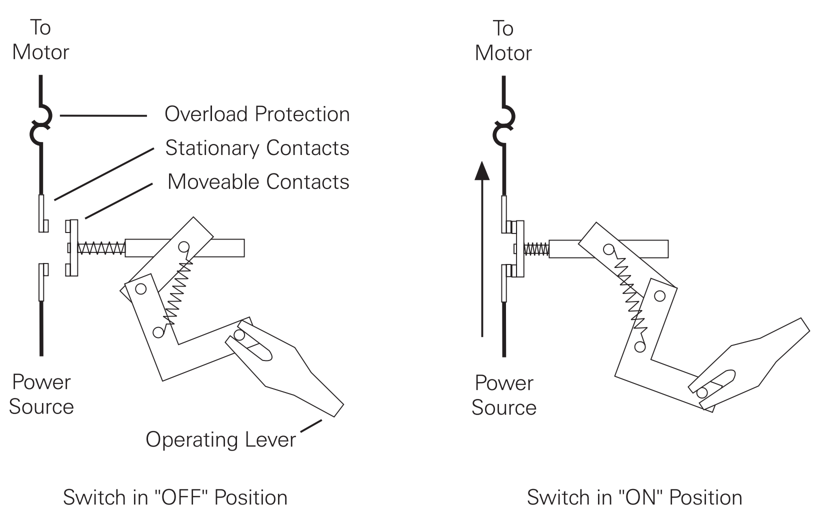
As the name implies, **manual controls** are devices operated by hand. A simple knife switch, like the one shown in the following illustration, was the first manual-control device used to start and stop motors. The knife switch was eventually replaced with improved control designs such as manual and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



Basic Operation

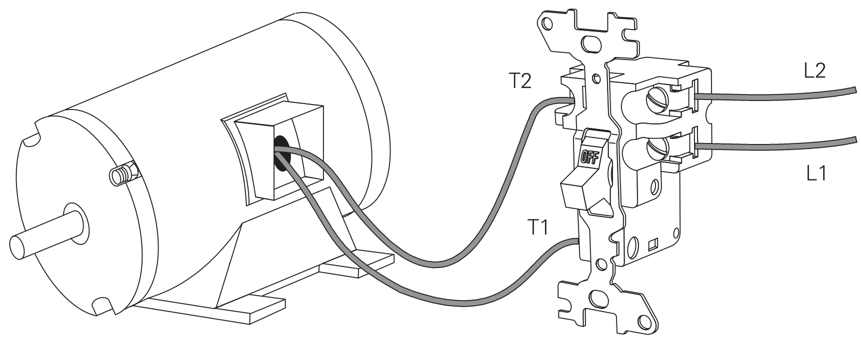
A motor control device must protect the motor from destroying itself under overload conditions. To accomplish this, manual starters consist of a manual contactor (such as a simple switch mechanism) and a device for overload protection.

The following diagram illustrates a single-pole manual motor starter. Each set of contacts is called a **pole**. A starter with two sets of contacts would be called a two-pole starter.

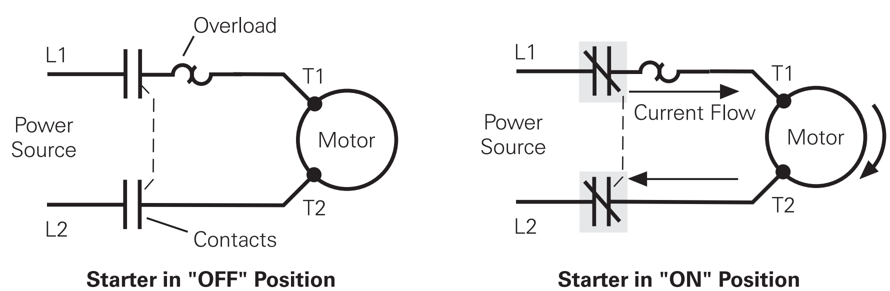


Two-Pole Manual Starter

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.



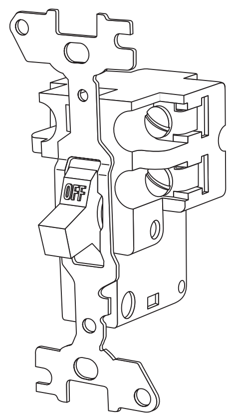
Low Voltage Protection

Some manual motor starters offer low-voltage protection (LVP) as an option. LVP will automatically remove 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

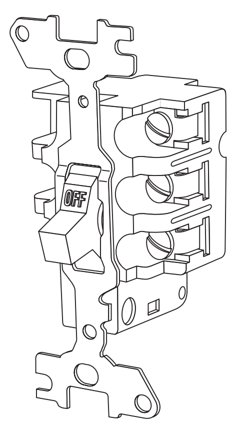
Siemens SMF fractional-horsepower starters provide overload protection and manual "ON/OFF" control for small motors. SMF starters are available in one- or two-pole versions suitable for AC motors up to 1 HP and 277 VAC. The two-pole version is suitable for DC motors up to 3/4 HP and 230 VDC. A melting-alloy 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 Manual Switches

Siemens MMS and MRS manual switches are similar to SMF starters but do not provide overload protection. MMS and MRS switches only provide manual "ON/OFF" control of 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.

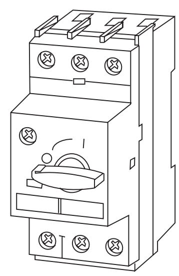


Three-Pole Manual Switch

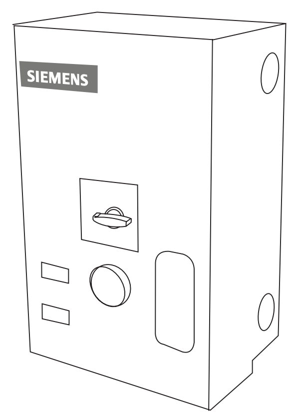
Class 11 - 3RV Manual Starters and Switches

Class 11 - 3RV manual starters and switches provide control for machinery that does not require remote start-stop control. Class 11 - 3RV switches provide control for motors where overload protection is not required or is provided separately. Class 11 - 3RV manual starters are used for single and three-phase motors up to 15HP at 460 VAC. These starters have bimetal heater elements to provide Class 10 overcurrent protection. These manual controllers are available with low-voltage protection which will automatically open the power poles when the voltage drops or the power is interrupted.

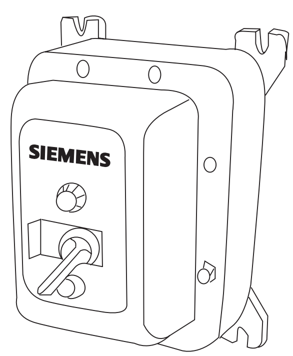
Class 11 - 3RV manual controllers are available in an open style (without enclosure), in NEMA 1 general purpose enclosures, and in NEMA 7 & 9 or NEMA 3 & 4/NEMA 7 & 9 enclosures (for hazardous locations).



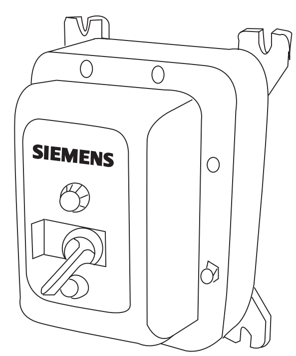
OPEN TYPE
Starter



NEMA 1
General Purpose



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



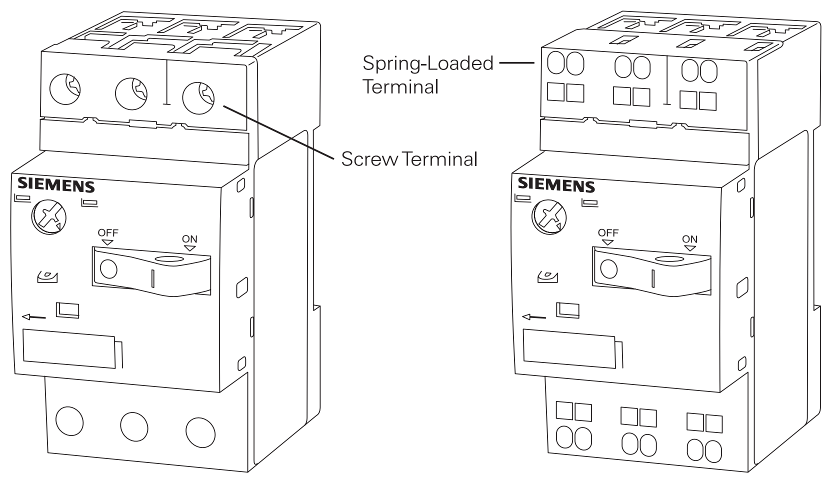
NEMA 3 & 4, NEMA 7 & 9
Class I Group C & D
Class II Group E, F & G

3RV10 Motor Starter Protectors

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

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

The 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

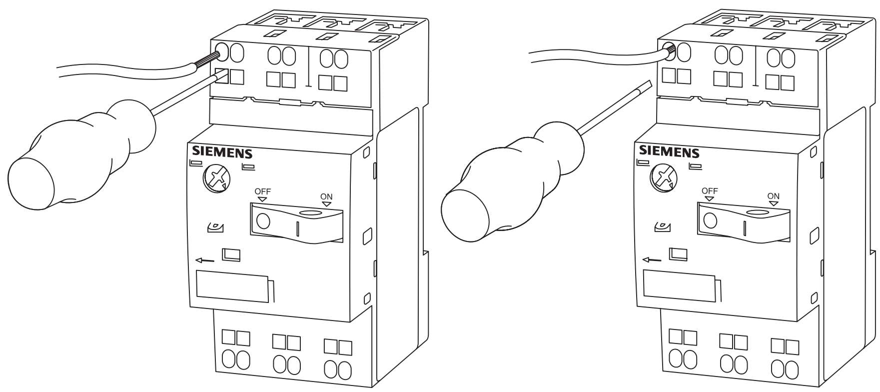
3RV101 with Spring-LoadedTerminals

SIRIUS 3RV10 MSPs are UL listed as Manual Motor Controllers per UL508, making them appropriate for manual starting and stopping applications if upstream short-circuit protection is provided in the form of an appropriately-sized circuit breaker or fuses.

SIRIUS 3RV10 MSPs can also be used as a component in group installation where one MSP is used to provide group short circuit protection for multiple motor controllers.

Spring-Loaded Terminals

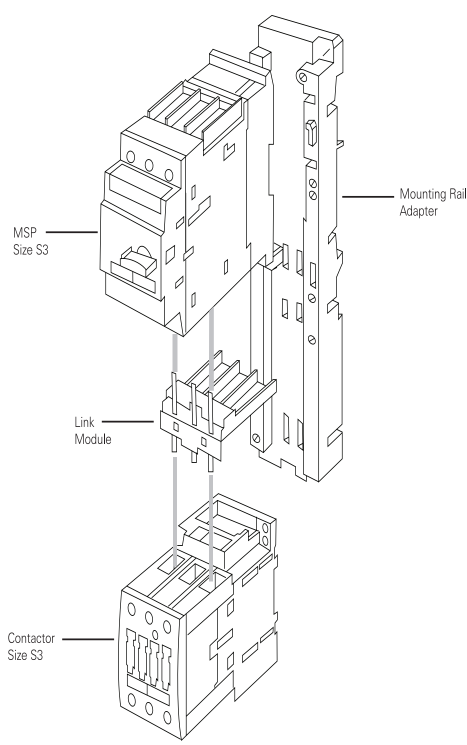
Spring-loaded terminals are available on many Siemens SIRIUS 3R products including the MSPs. To connect a wire simply push an electrician's blade screwdriver into the appropriate portal, and insert the stripped end of the wire into the portal directly above the blade. Remove the screwdriver, and the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



Enclosures and Options

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

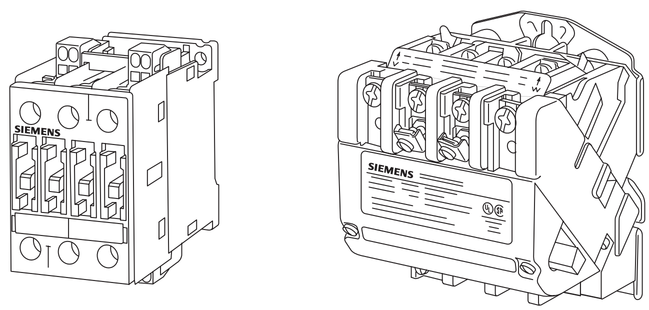
Additionally, most 3RV10 MSPs have been listed as UL508 Type E, Self-protected Manual Combination Starters. This UL listing allows the MSP to be operated in a machine without having to add separate short-circuit protection upstream.



Size S3 Combination Starter

Magnetic Contactors and Starters

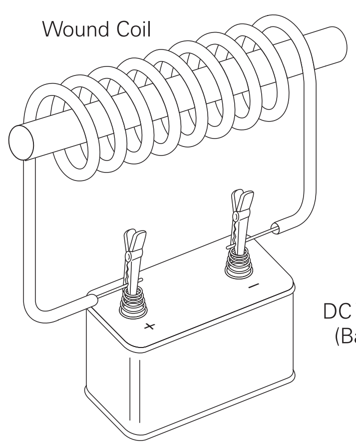
Most motor applications require the use of remote control devices to start and stop the motor. **Magnetic contactors** (similar to the ones shown below) are commonly used to provide this function. Contactors are also used to control distribution of power in lighting and heating circuits.



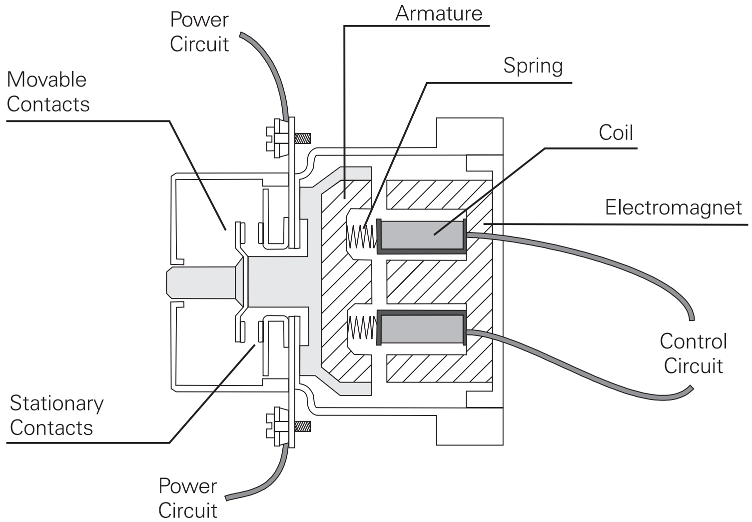
SIRIUS 3R IEC Contactor   Class 40 NEMA Contactor

Basic Contactor Operation

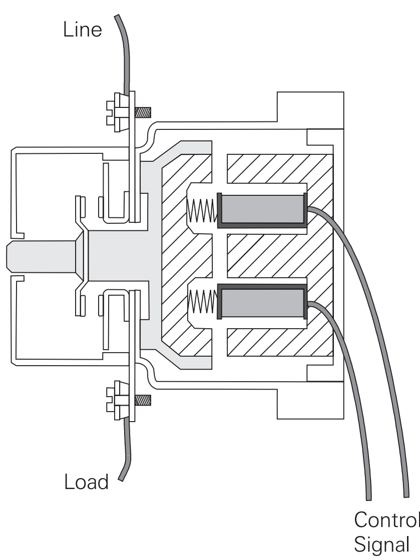
Magnetic contactors operate by utilizing electromagnetic principles. A simple electromagnet can be fashioned by winding a wire around a soft iron core. When a DC voltage is applied to the wire, the iron becomes magnetic. When the DC voltage is removed from the wire, the iron returns to its nonmagnetic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



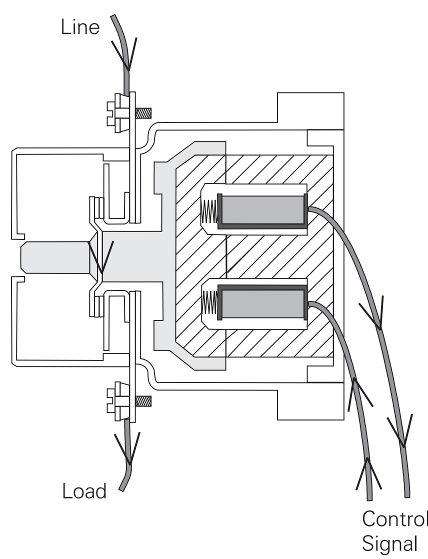
The following illustration shows the interior of a basic contactor. There are two circuits involved in the operation of a contactor: the control circuit and the power circuit. The control circuit is connected to the coil of an electromagnet, and the power circuit is connected to the stationary contacts.



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 power circuit, the electromagnet's coil is de-energized, the magnetic field collapses and the movable contacts open under spring pressure.



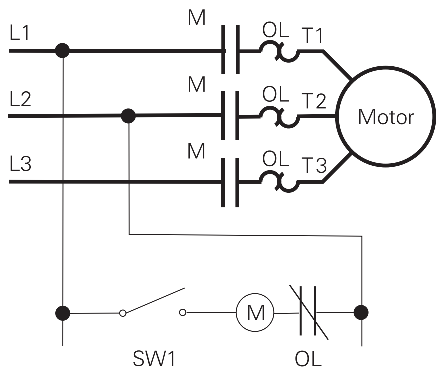
Contactor Deenergized

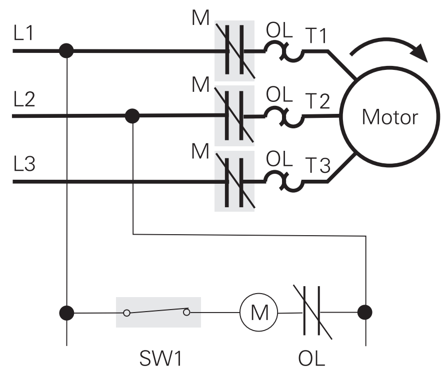


Contactor Energized

The following schematic shows the electromagnetic coil of a contactor connected to the control circuit through a switch (SW1). The contacts of the contactor are connected in the power circuit to the AC line and a three-phase motor.

When SW1 is closed the electromagnetic coil is energized, closing the “M” contacts and applying power to the motor. Opening SW1 de-energizes the coil, opening the “M” contacts and removing power from the motor.

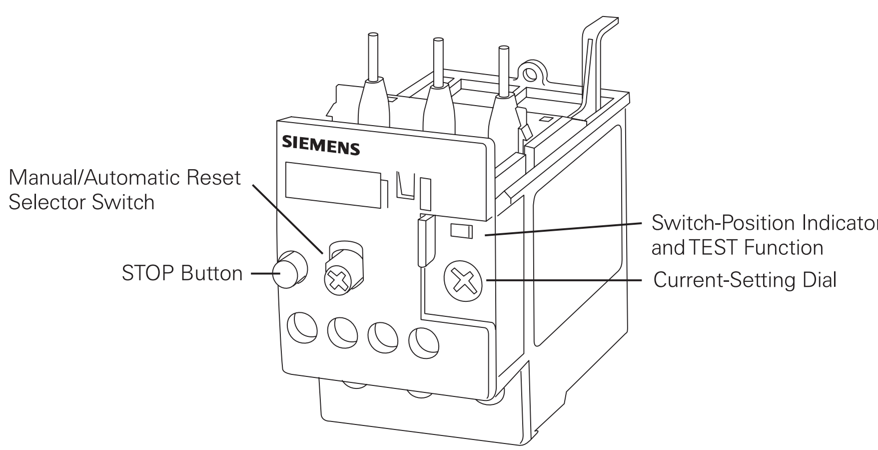




Contactors vs. Overload Relays

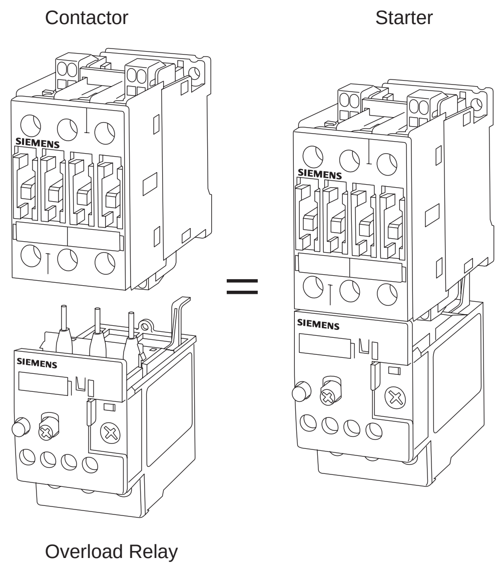
Contactors are used to control power in a variety of applications. When used in motor-control applications, contactors can only start and stop motors. Contactors cannot sense when the motor is being loaded beyond its rated conditions, and provide no overload protection.

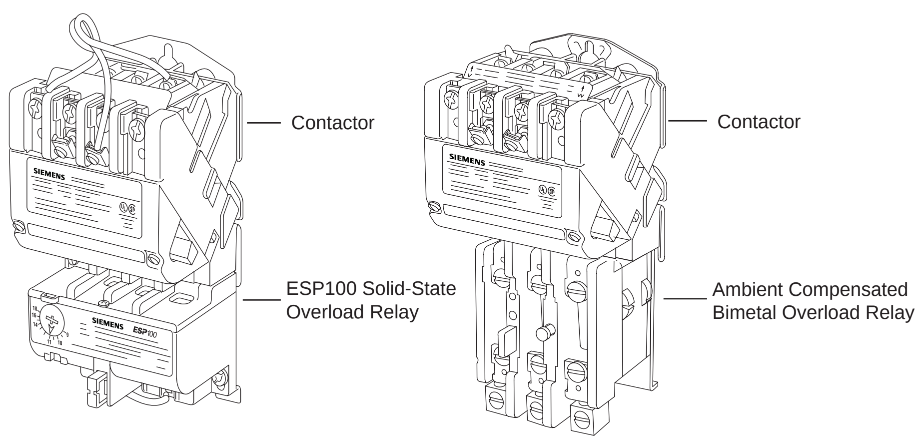
Most motor applications require overload protection, although some smaller-rated motors (such as household garbage disposals) have overload protection built into the motor. Where overload protection is required, overload relays (discussed previously, similar to the one shown below) provide such protection.



Motor Starter

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

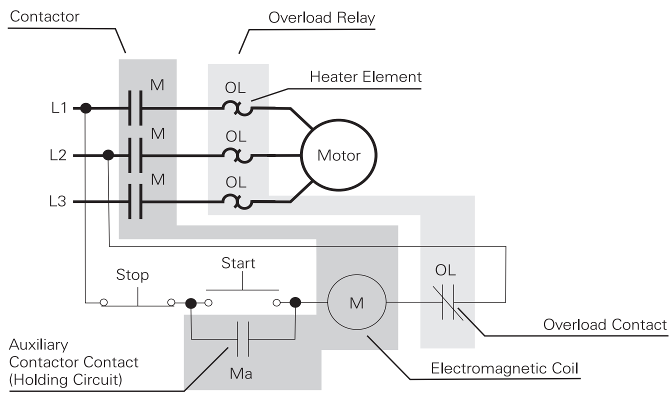




Motor Starter in a Control Circuit

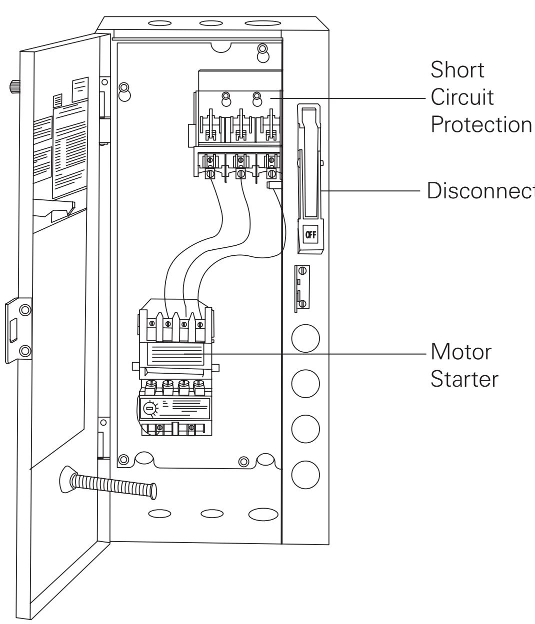
The following diagram shows the electrical relationship of the contactor and overload relay. The contactor (highlighted with the darker grey) includes the electromagnetic coil, the main motor contacts, and the auxiliary contacts. The overload relay, highlighted by the lighter grey, includes the “OL” heaters and overload contacts. The contactor and the overload relay have additional contacts (known as **auxiliary contacts**) for use in the control circuit.

In this circuit, a normally closed “OL” contact has been placed in series with the “M” contactor coil and L2. A normally open “M” auxiliary contact (“Ma”) has been placed in parallel with the “Start” pushbutton.



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 would be called a ____________ -pole starter.

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

3. The Class 11 - 3RV manual starter protects motors up to ____________ HP at 460 VAC.

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

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

6. A ______________ _____________ incorporates a motor starter, short circuit, 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 rate 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 National Electrical Manufacturers Association 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, one needs only 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 by the International Electrotechnical Commission in publication IEC 158-1. IEC does not specify sizes. Utilization categories are used with IEC devices to define the typical duty cycle of an IEC device. AC-3 and AC-4 are the categories of most interest for general motor-starting applications.

Utilization Category	IEC Category Description
AC1	Non-inductive or slightly inductive 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, noninductive amps (resisitive load), number of power poles, duty cycle, and the total number of expected operations.

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

DP contactors are well suited for loads found in the following 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

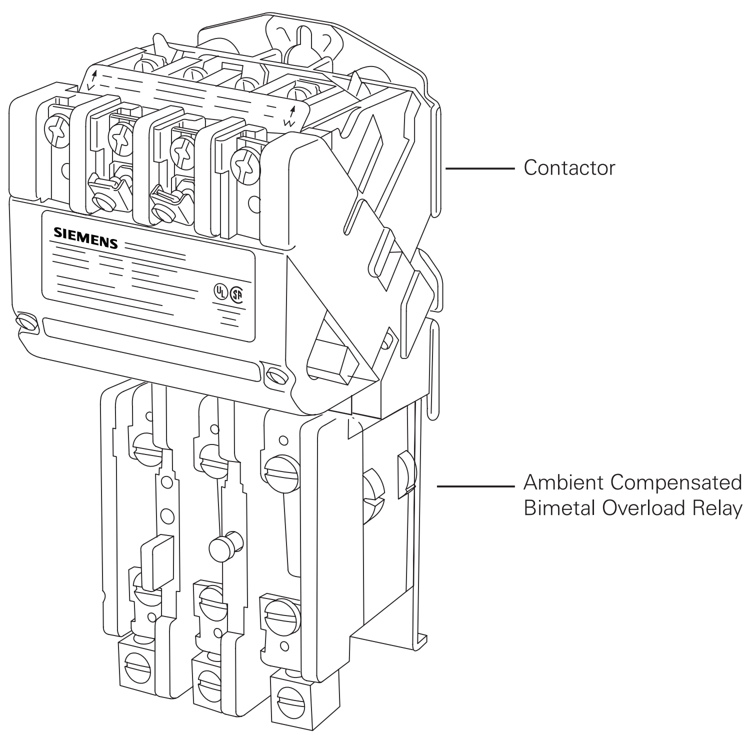
Other Organizations

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 at least one of the previous organizations' test procedures. 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.

Class 14 NEMA Starters with Bimetal Overload Relays

NEMA starters are available in NEMA sizes 00 through 4. In addition to whole sizes, this range includes 1¾, 2½, and 3½ sizes, and are available up to 100 HP. These starters are available with Class 10 or 20 ambient-compensated bimetal overload relays.

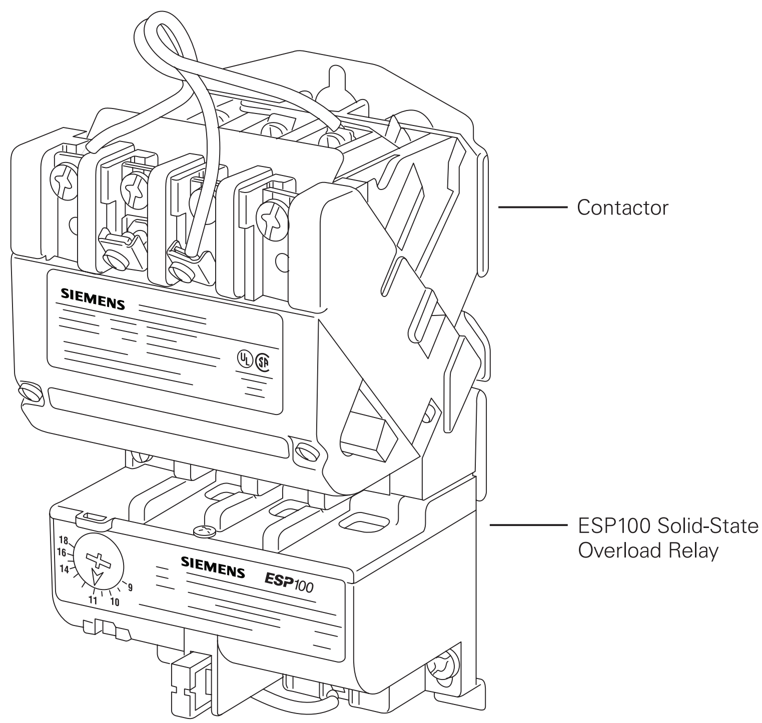


Class 14 ESP100 Starters

Class 14 ESP100 starters use the same contactors as Class 14 NEMA starters equipped with bimetal 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 3Ø motors with FLA of ¼ ampere through 1220 amperes, and 1Ø motors with FLA of ¾ ampere through 16 amperes. All ESP100 overload relays have an adjustable overload ampere range.

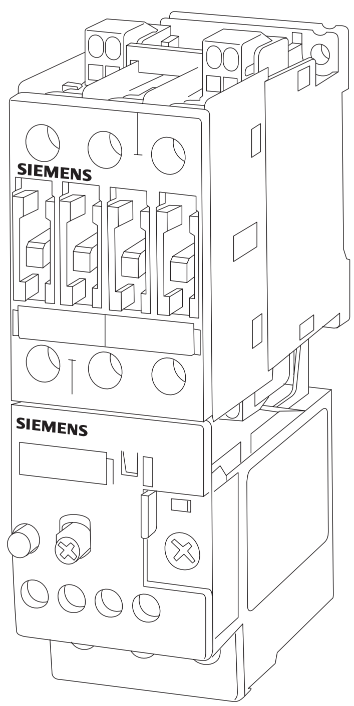
The ESP100 also protects the motor by tripping within three seconds if any of the three power phases is lost.



SIRIUS Type 3R Starters

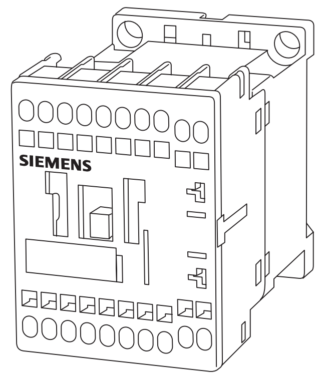
SIRIUS 3R is a complete modular, building-block system. The system includes a variety of components including a structured range of contactors and overload relays in seven frame sizes. These frame sizes are referred to as S00, S0, S2, S6, S10, and S12.

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.

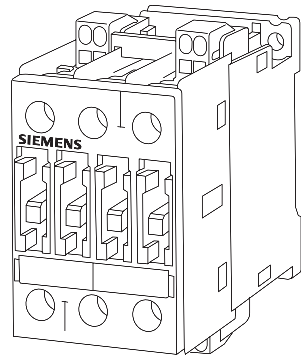


Spring-Loaded Terminals

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.



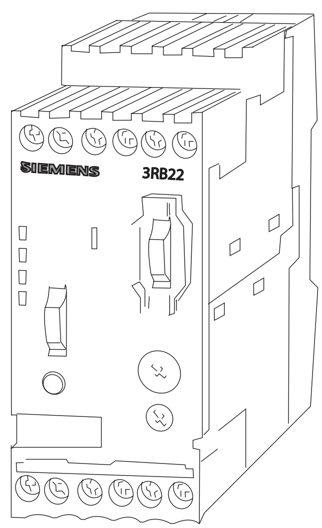
Contactor with Spring-Loaded Terminals



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. ____________ is an organization primarily associated with rating equipment used in North America and ____ ________ is associated with rating equipment used in many countries worldwide including the U.S.

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

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

4. Siemens Class 14 NEMA starters are available in NEMA sizes 00 through ____________, including sizes 1¾, 2½, and _____________.

5. The ESP100 trips within ____________ seconds of 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 (based on motor construction). The speed of a constant-speed motor is a function of the supply frequency and the number of poles, and is determined using the following formula:

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

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

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

(In contrast, a two-pole induction motor on a 60 hertz AC line would run at twice that speed.)

When motors are required to run at different speeds, the motor's torque or horsepower characteristics will change with a change in speed. The proper motor must be selected and correctly connected for the application.There are three categories of such multi-speed applications: constant torque, variable torque, and constant horsepower.

Constant Torque (CT) motors maintain constant torque at all speeds. Horsepower varies directly with speed. This type of motor is used for conveyors, mills, and similar applications.

Variable Torque (VT) motors produce a torque characteristic which varies with the square of the speed. This type of motor is applicable to fans, blowers, and centrifugal pumps.

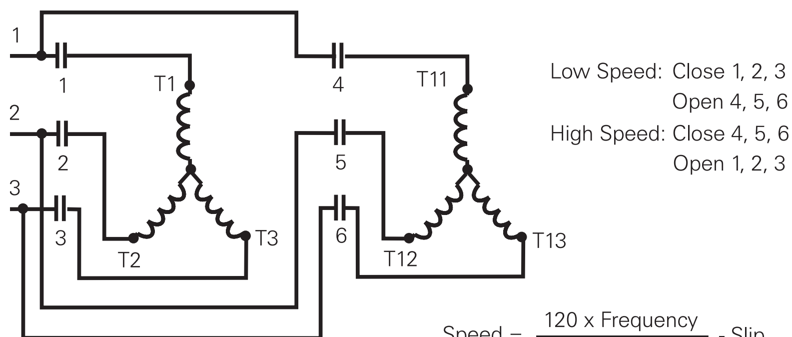
Constant Horsepower (CHP) motors
maintain constant horsepower at all speeds, with torque varying inversely with speed. This type of motor is applicable to metal-working machines such as drills, lathes, mills, bending machines, punch presses, and power wrenches.

Separate-Winding

There are two basic methods of providing multi-speed control using magnetic starters: separate-winding motors and consequent-pole motors.

Separate-winding motors have a separate winding for each speed, 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.

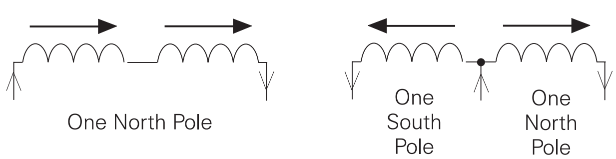


$$\text{Speed} = \frac{120 \times \text{Frequency}}{\text{Number of Poles}} - \text{Slip}$$

Consequent-Pole Motors

Consequent-pole motors have a single winding for two speeds. Taps can be brought from the winding for reconnection for a different number of poles.

Two-speed, consequent-pole motors have one reconnectable winding. Low speed of a two-speed consequent-pole motor is one half the speed of high speed. Three-speed motors have one reconnectable winding and one fixed winding. Four-speed motors have two reconnectable windings.



Speed Selection

There are three control schemes of speed selection for multi-speed motors: selective control, compelling control, and progressive control.

Selective control permits motor starting at any speed; 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

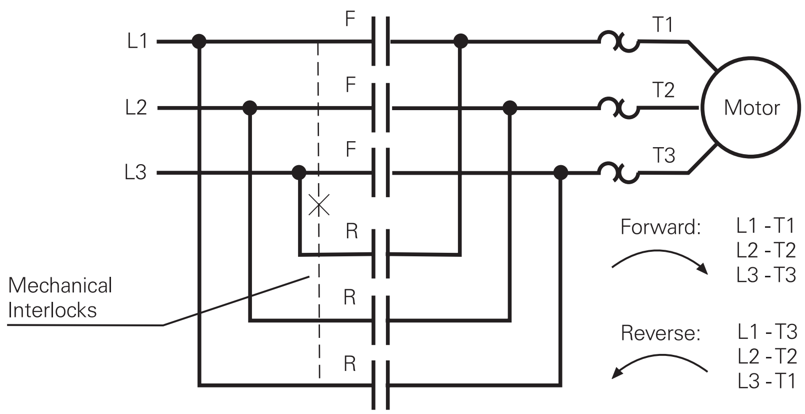
Siemens offers Class 30 two-speed starters for both separate-winding and consequent-pole motors for constant torque, variable torque, and constant horsepower applications.

Starters are available in NEMA sizes 0 through 4, including Siemens half-sizes. Overload protection is furnished with both ESP100 solid-state and ambient-compensated bimetal overload relays.

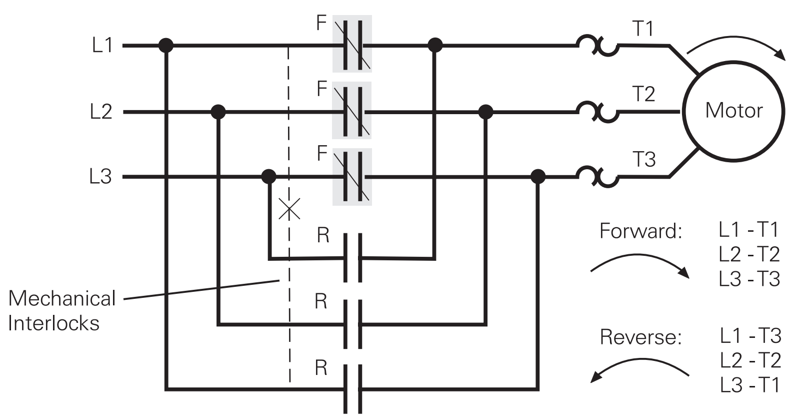
Reversing Starters

Many applications require a motor to run in both directions. In order to change the direction of motor rotation, the direction of current flow through the windings must be changed. This is done on a three-phase motor by reversing any two of the three motor leads. Traditionally T1 and T3 are reversed.

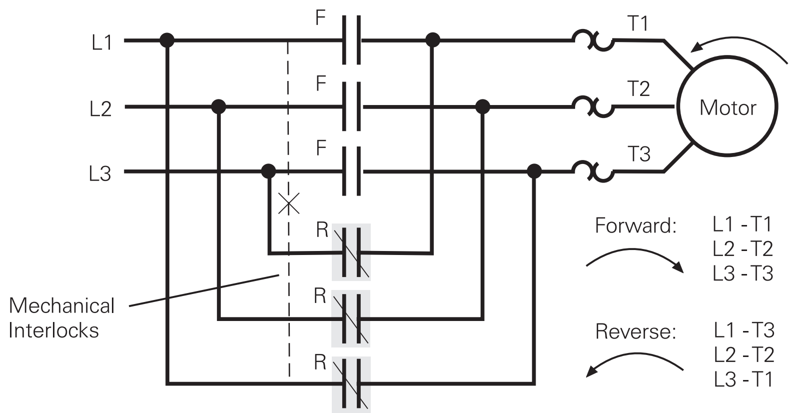
The following illustration shows a three-phase reversing motor circuit. It has one set of forward (F) contacts controlled by the "F" contactor, and one set of reverse (R) contacts controlled by the "R" contactor.



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



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



Class 22 Reversing Starters

Siemens offers Class 22 reversing starters in NEMA sizes 00 through 8 including Siemens half-sizes. Overload protection is furnished with both ESP100 solid-state and ambient compensated bimetal overload relays.

Class 43 Reversing Contactors

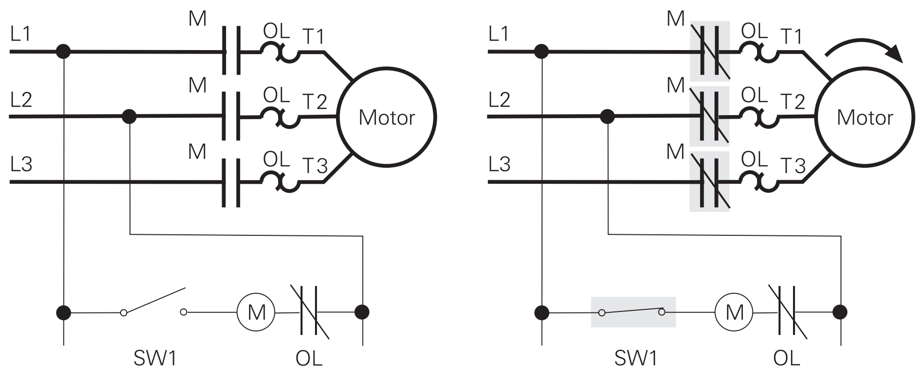
Siemens offers Class 43 reversing contactors in NEMA sizes 00 through 8, including Siemens half-sizes.

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.

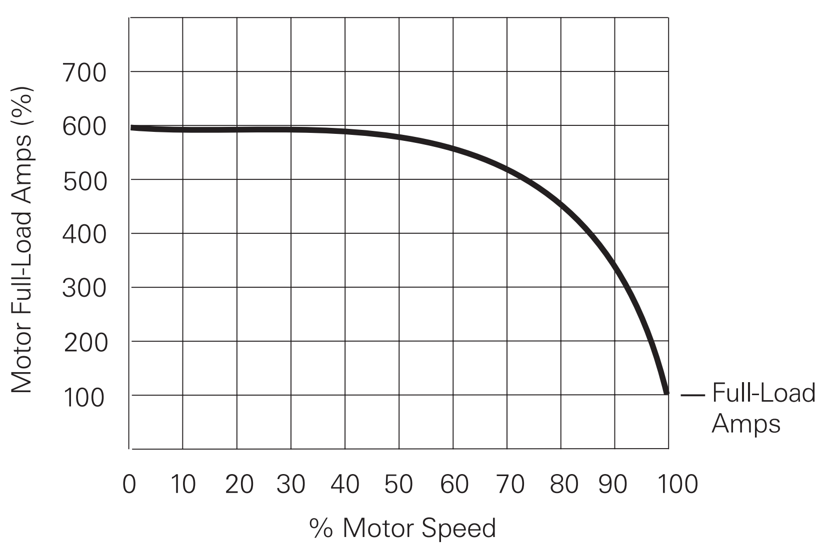
Full-Voltage Starting

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

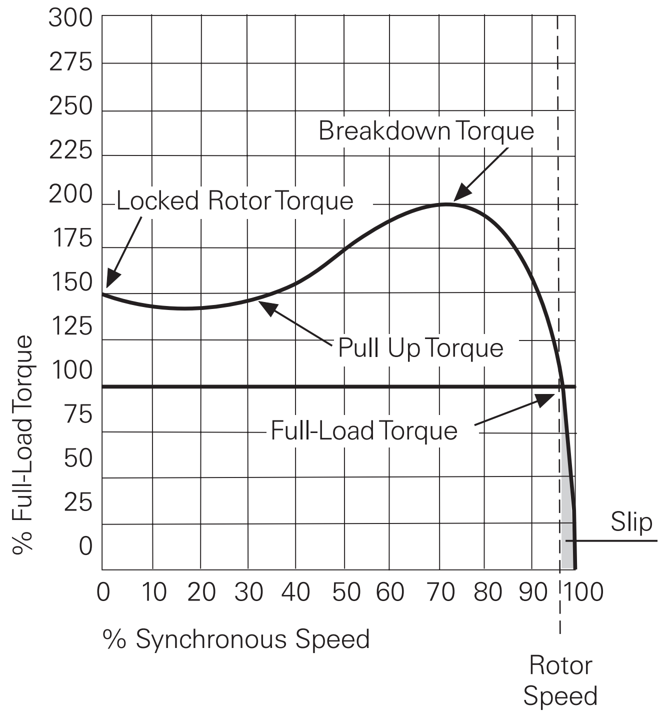


With this type of starter, the motor receives the full-line voltage immediately upon being energized. When a motor is started with full voltage, starting current can be as high as 600% of full-load current on standard squirrel cage motors. It can be as high as 1200% of full-load current for high efficiency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

There are situations where this method of starting is not acceptable. On large motors, the high starting current is reflected back into the power lines of the electric utility, causing lights to flicker and (in more serious situations) computers to malfunction. Many power companies in the U.S. require reduced-voltage starting on large-horsepower motors.



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



Reduced-Voltage Starting

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

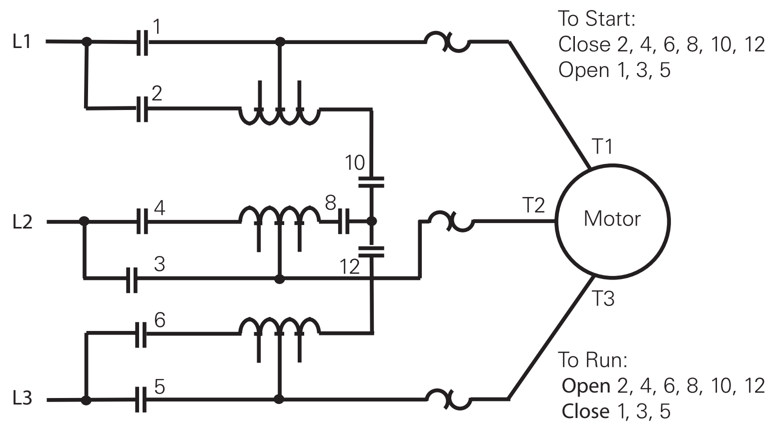
Reduced-voltage starting reduces the starting voltage of an induction motor in order to confine the rate of change of the starting current to predetermined limits. When the voltage is reduced to start a motor, It is important to remember that current is also reduced, reducing the amount of starting torque a motor can deliver. In addition to reducing inrush current and starting current, reduced-voltage starting also reduces the stress on mechanical linkage.

Several methods are available for reduced-voltage starting, usually selected based on the application or the type of motor. A few of the methods offered by Siemens are described below.

Autotransformer Reduced-Voltage Starters

Autotransformer reduced-voltage starters provide 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.

Applications: Crushers, Fans, Conveyors, Compressors, Mixers

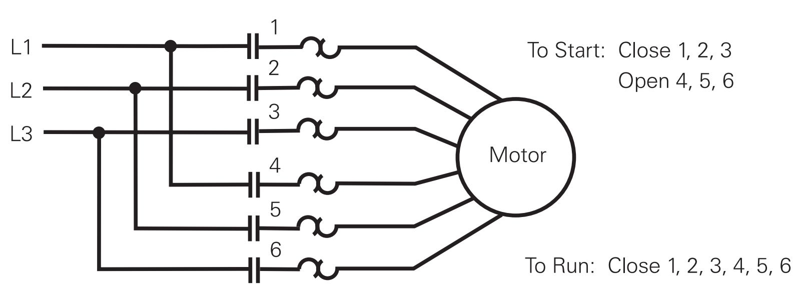


Part-Winding Starters

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

Part-winding, reduced-voltage starters are the least expensive type of reduced-voltage starters, and use a very simplified control circuit. However, they require special motor design, and are not suitable for high-inertia loads. There is no adjustment of current or torque.

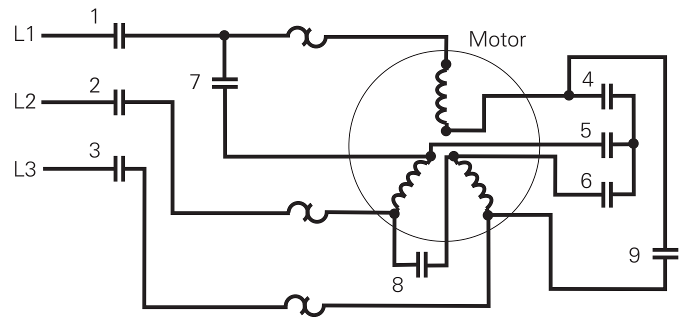
Applications: Low-inertia Fans & Blowers, Low-Inertia Pumps, Refrigeration, Compressors



Wye-Delta Starters

Wye-delta, reduced-voltage starters are applicable only with motors having stator windings not connected internally and all six motor leads available. Connected in a wye configuration, the motor starts with reduced starting line current, and is reconfigured to a delta connection for run. 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 other methods of reduced-voltage starters.

Applications: Central Air Conditioning Equipment, Compressors, Conveyors



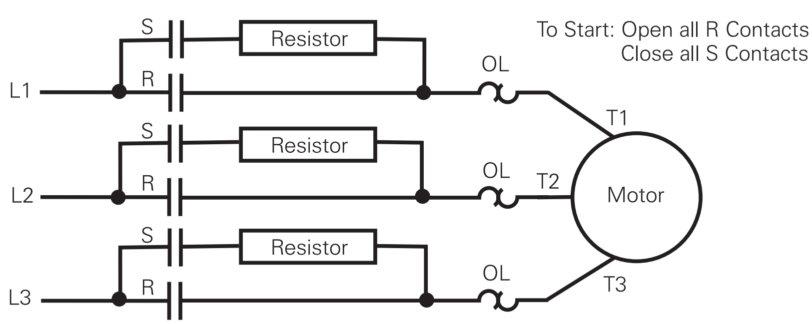
To Start: Close 1, 2, 3, 4, 5, 6
Open 7, 8, 9

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

Primary Resistance Starter

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: Conveyors, Belt-Driven and Gear Drive Equipment



To Run: Close all R Contacts

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.

Review 6

1. A _____________ - _____________ _____________ provides multi-speed control by utilizing taps brought out from a reconnectable winding.

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

3. Starting methods which deviate from full-voltage starting by providing a lower starting voltage are referred to as ____________ ____________ ____________ .

4. A reduced-voltage starter reduces all of the following during startup:
    1. ________________________________
    2. ________________________________
    3. ________________________________

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

SIRIUS Soft Starters

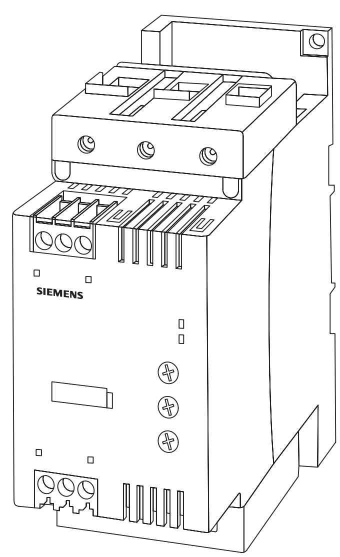
Solid-state, reduced-voltage controllers or **soft starters** limit motor starting current and torque by ramping up the voltage applied to the motor during the selectable starting time.

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.

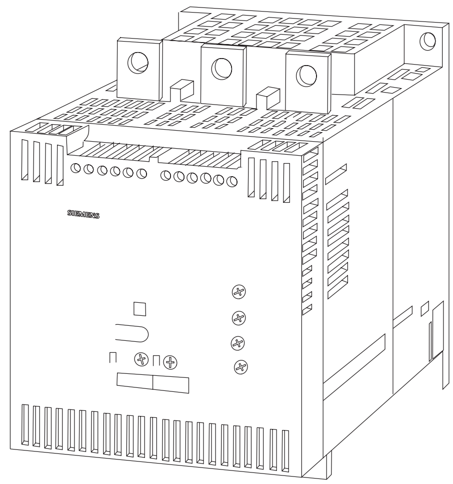
SIRIUS 3RW30/31 Soft Starters

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 40º C. Potentiometers on the front of the unit provide settings for starting time, starting voltage, and stopping time.



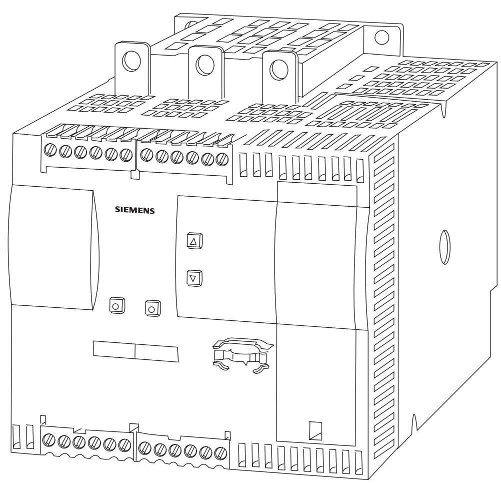
SIRIUS 3RW40 Soft Starters

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 40º 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 40º C, and can be equipped with a Profibus DP communication option.

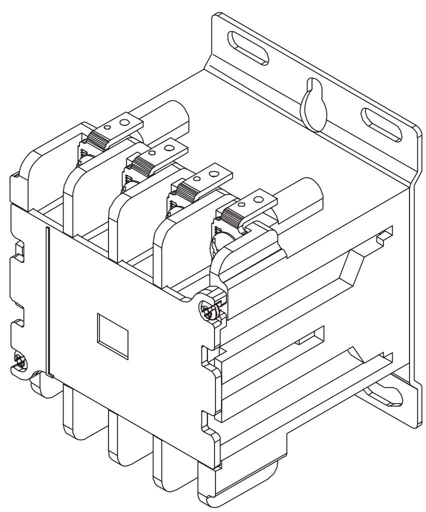


Lighting and Heating Contactors

Electrically Held Contactors

Most lighting and heating applications require the use of 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, the lighting/heating contactor is designed for lighting and resistive heating loads rather than motor loads.

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



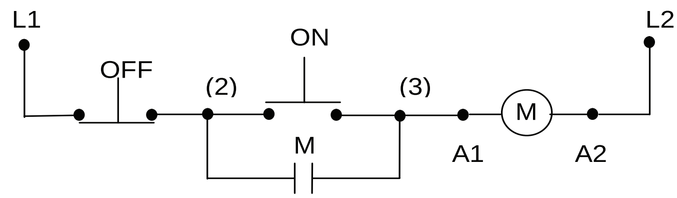
Basic Contactor Operation

Electrically held lighting contactors utilize the same operating principles as the magnetic contactors and starters that you learned about previously. This style of contactor will open when control power is lost.

Some Typical Applications

Electrically held contactors are typically used in applications where noise is not an issue. These contactors have an inherent hum due to the electromagnetic coil and the constant supply of voltage to it. This type of contactor is not recommended for locations where this humming can be heard, such as libraries, hospitals, and some commercial buildings.

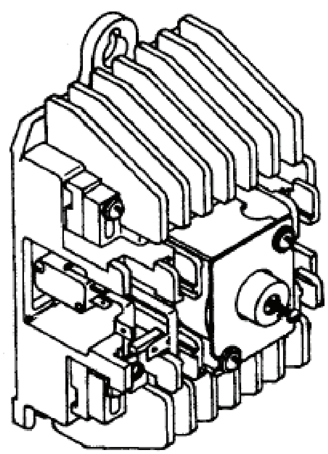
Here is a typical wiring schematic for an electrically held lighting/heating contactor with ON/OFF pushbuttons.



Magnetically Held and Mechanically Latched Contactors

Mechanically held and **mechanically latched contactors** are also used for lighting and heating applications and are designed for lighting and resistive heating loads.

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



Basic Contactor Operation (Magnetically Held)

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, DC voltage is applied to produce 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.

To open the contactor, it is necessary to create a field through the OFF coil in reverse direction to the permanent magnet. This momentarily cancels the magnetic attraction, and the contactor drops out.

Basic Contactor Operation (Mechanically Latched)

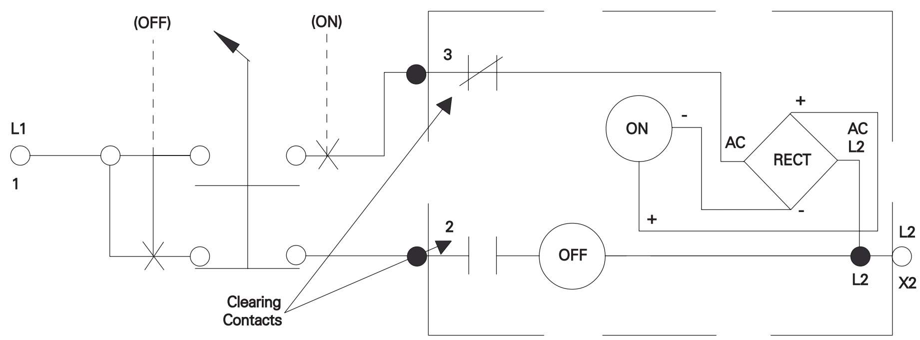
These contactors are latched mechanically and released electrically by means of an AC trip solenoid and clearing contact. It is similar to the magnetically held contactor in that it will remain in the closed state indefinitely. The contactor opens only when the trip solenoid receives a signal to release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

Some Typical Applications

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

These types of contactors are also used in parking lots and stadium lighting, since the contactor is not affected by loss of power. If power is lost, the contactor remains in the ON or closed state. When power is restored, the lights stay on without requiring someone to turn them on.

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 device offerings include devices with a variety of features and mounting dimensions, with selections appropriate for a broad range of applications, including:

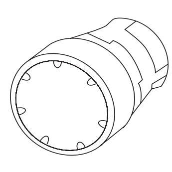
- 3SB2 devices with 16 mm mounting diameters
- SIGNUM 3SB3 devices with 22 mm mounting diameters, and
- Class 51/52 devices with 30.5 mm mounting diameters.

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

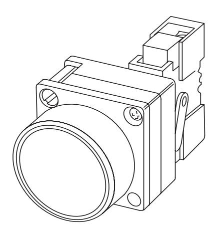
Class 51 devices are rated for hazardous locations such as Class I, Groups C and D and Class II, Groups E, F, and G. Class 52 devices are heavy duty products designed for harsh, industrial environments.

Pushbuttons

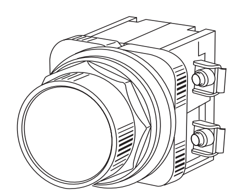
A **pushbutton** is a control device used to manually open and close a set of contacts. Pushbuttons may be illuminated or non-illuminated, and are available in a variety of configurations and actuator colors.



16 mm 3SB2 Pushbutton



22 mm SIGNUM 3SB3 Pushbutton

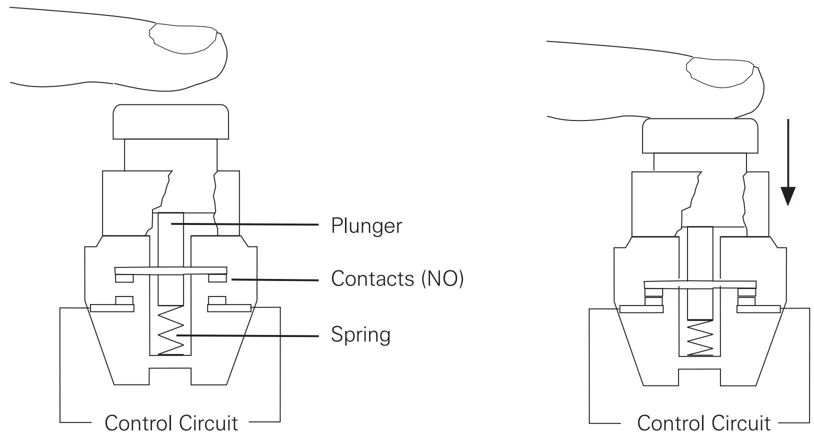


30 mm Class 52 Pushbutton

Normally Open Pushbuttons

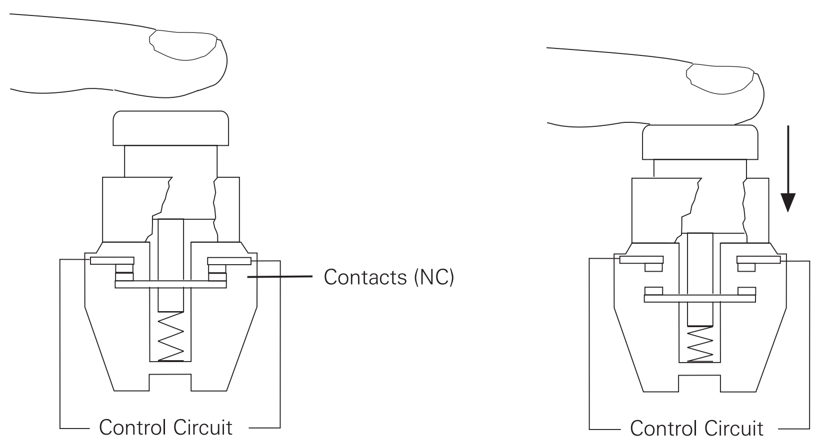
Pushbuttons are used in control circuits to perform various functions; for example, starting and stopping a motor. A typical pushbutton uses an operating plunger, a return spring, and one set of contacts.

The following drawing illustrates a normally open (NO) pushbutton. Normally the contacts are open and no current flows through them. Depressing the button causes the contacts to close. When the button is released, the spring returns the plunger to the open position.



Normally Closed Pushbuttons

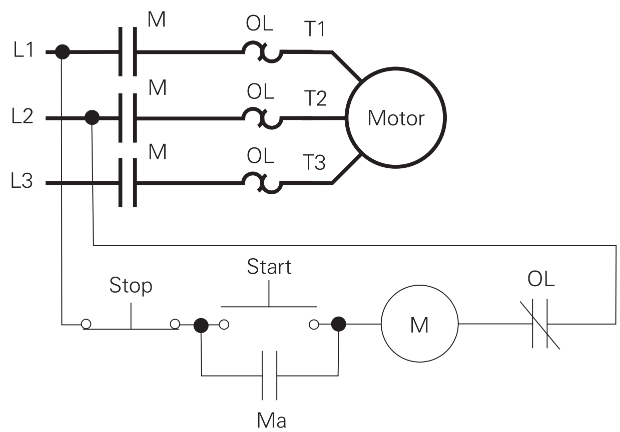
Normally closed (NC) pushbuttons, such as the one shown below, are also used to open and close a circuit. In this pushbutton's normal position, the contacts are closed to allow current flow through the control circuit. Depressing the button opens the contacts, preventing current flow through the circuit.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



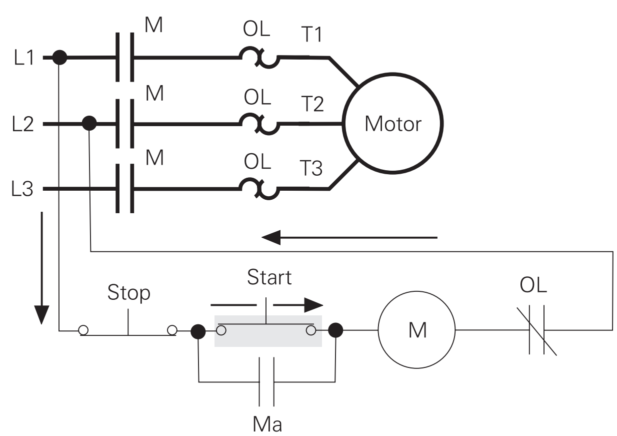
Pushbuttons are available with variations of the contact configuration. For example, a pushbutton may have one set of normally open and one set of normally closed contacts so that when the button is depressed, one set of contacts is open and the other set is closed. By connecting to the proper set of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

Using Pushbuttons in a Control Circuit

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



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

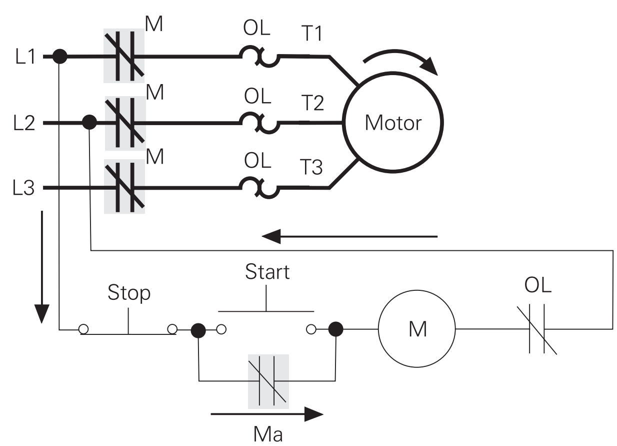


Holding Circuit Three-Wire Control

Depressing the “Start” pushbutton closes the associated normally open “M” and “Ma” contacts. When the “Start” pushbutton is released, a **holding circuit** exists to the “M” electromagnetic coil through the auxiliary contacts “Ma”. The motor will run until the normally closed “Stop” pushbutton is depressed, breaking the path of current flow to the “M” electromagnetic coil and opening the associated “M” and “Ma” contacts.

This is referred to as **three-wire control** because there are three wires or three connection points required to connect the “Start” and “Stop” pushbuttons and the holding circuit (“Ma”).

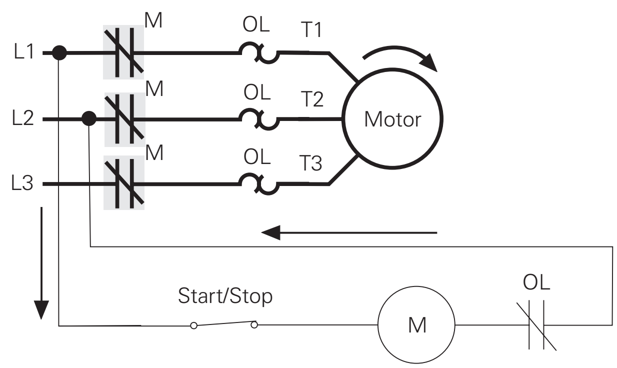
An advantage to three-wire control is **low-voltage protection**. If an overload causes the “OL” contacts in the control circuit to open, the “M” coil is de-energized and the motor shut down. When the overload is cleared, the motor will not suddenly restart on its own. An operator must depress the “Start” button to restart the motor.



Two-Wire Control

A **two-wire control** circuit provides low-voltage release, but not low-voltage protection. Low-voltage release means that in the event of a power loss, the contactor will de-energize, stopping the motor. When the contacts of the control device open, the power is removed from the motor and it stops. However, when power is restored, the motor will restart without warning if the control device is still closed.

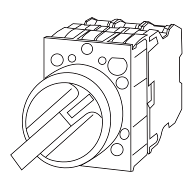
This type of control scheme is used for remote or inaccessible installations such as water-treatment plants or pumping stations. In these applications it is desirable to have an immediate return to service when power is restored.

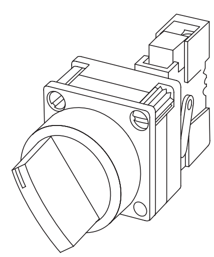


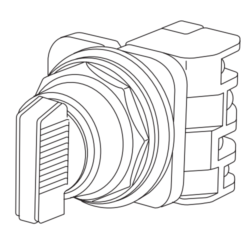
Selector Switches

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

The basic difference between a push button and a selector switch is the operator mechanism. With a selector switch, the operator is rotated to open and close contacts. Contact blocks used on pushbuttons are interchangeable with those on used on selector switches. Selector switches are used to select one of several circuit possibilities such as manual or automatic operation, low or high speed, up or down, right or left, and stop or run.

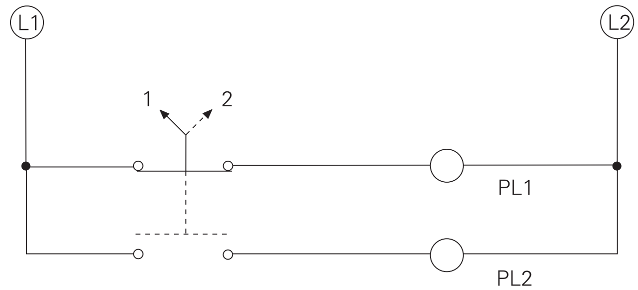

16 mm 3SB2
Selector Switch


22 mm SIGNUM
3SB3 Selector Switch


30.5 mm Class 52
Selector Switch

Two Position Selector Switch

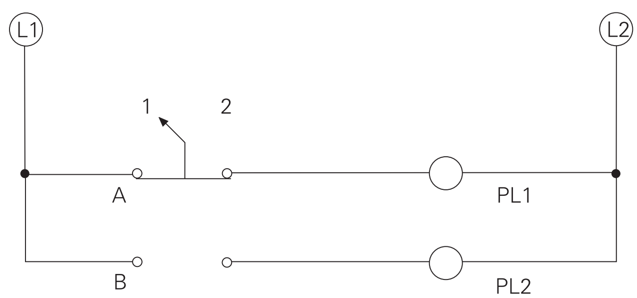
In the example below, PL1 is connected to the power source when the switch is in position 1, and PL2 is connected to the power source when the switch is in position 2. In this circuit, either PL1 or PL2 would be on at all times. If there was only one load, the selector switch could be used as an On/Off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



Contact Truth Tables

There are two accepted methods of indicating contact position of a selector switch in a circuit. The first method uses solid and dashed lines to denote contact position (as shown in the previous example).

The second method uses **truth tables** (also known as target tables), where each contact is marked with a letter. An “X” in the truth table indicates which contacts are closed for a given switch position. In the example below, contact A is closed (connecting PL1 to the power source) when the switch is in position 1. Contact B is closed (connecting PL2 to the power source) when the switch is in position 2.



Contacts

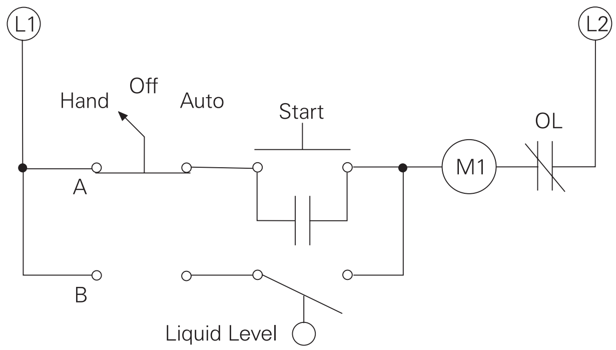
Position	A	B
1	X	
2		X

2 Position
Selector Switch

Three-Position Selector Switch

A three-position selector switch can be used to select either of two sets of contacts or to disconnect both sets of contacts.

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



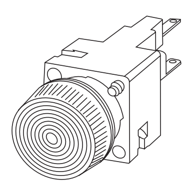
Contacts

Position	A	B
1	X	
2		
3		X

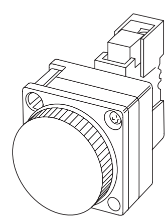
3 Position Selector Switch

Indicator Lights

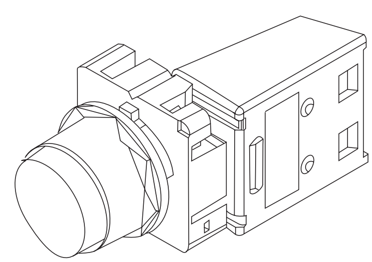
Indicator lights (sometimes referred to as pilot lights) provide visual information of the circuit’s operating condition at a glance. Indicator lights are normally used for “ON/OFF” indication, caution, changing conditions, and alarm signaling.



16 mm 3SB2 Indicator Light

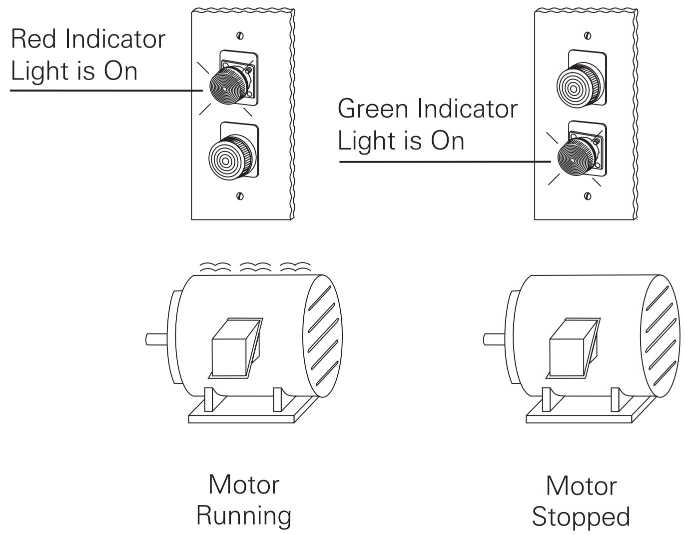


22 mm SIGNUM 3SB3 Indicator Light



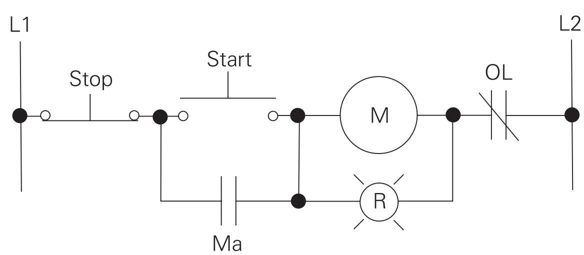
30.5 mm Class 52 Indicator Light

Indicator lights come with a color lens (typically red, green, amber, blue, white, or clear). A red indicator light normally indicates that a system is running. A green indicator light normally indicates that the system is off or de-energized. For example, a red indicator light located on a control panel would give visual indication that a motor was running, while a green indicator light would indicate that the motor was stopped.

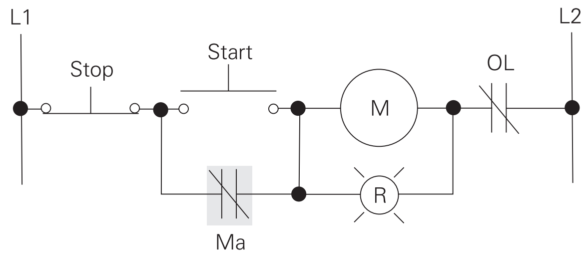


Using an Indicator Light in a Control Circuit

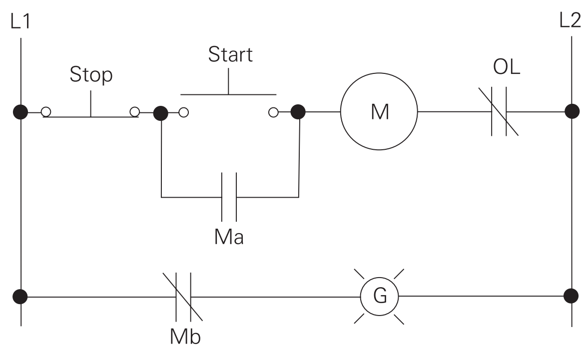
In the following line diagram, a red indicator light is connected in parallel with the “M” electromagnetic coil.



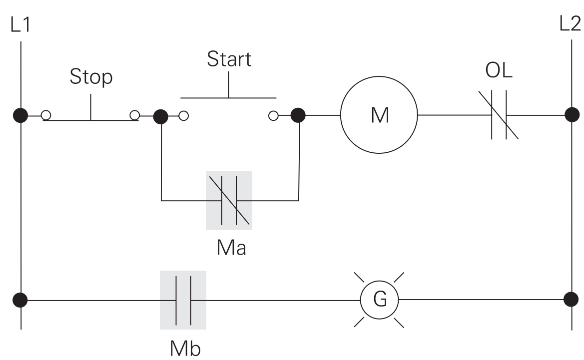
When the coil is energized, the light will illuminate to indicate that the motor is running. Even if the indicator light burns out, the motor will continue to run.



In the line diagram below, a green indicator light is connected through a normally closed "M" auxiliary contact (Mb). When the coil is de-energized, the indicator light is on to indicate the motor is <u>not</u> running.



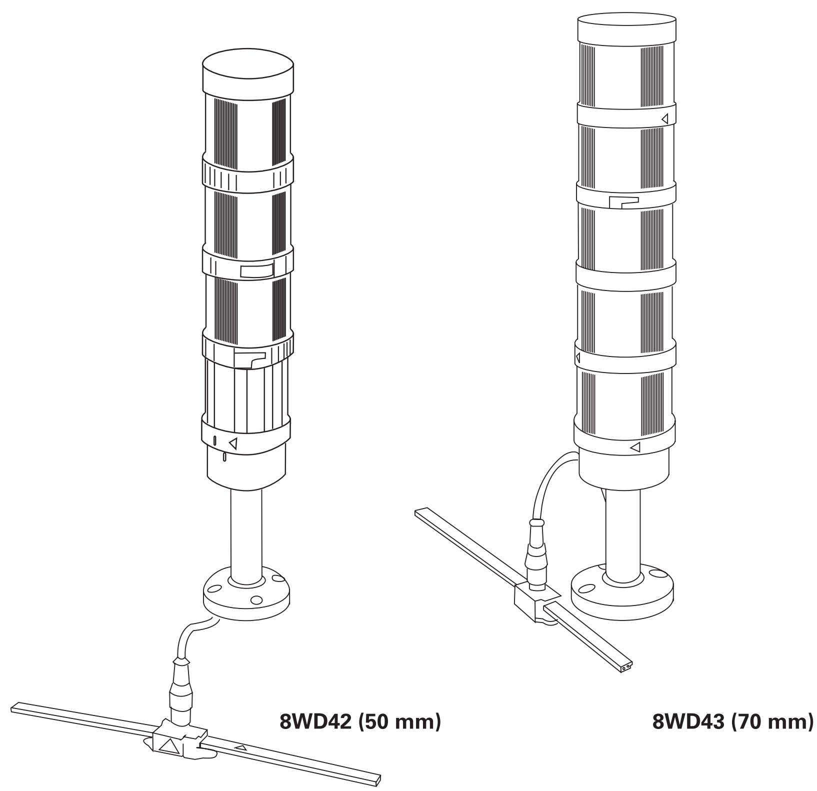
Depressing the "Start" pushbutton and energizing the "M" contactor opens the normally closed "Mb" contacts, turning the light off.



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.



Review 7

1. Soft starters limit motor starting current and torque by gradually increasing the portion of the
   ____________ ____________ ____________ applied to the motor windings

2. Potentiometers on the front of SIRIUS 3RW40 soft starters provide settings for:
   1. ______________________________
   2. ______________________________
   3. ______________________________

3. A (an) ____________ ____________ lighting and heating contactor is best used in applications where noise is not an issue.

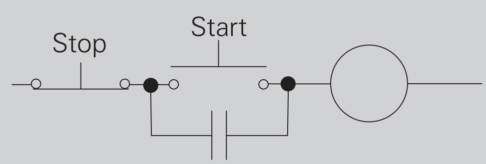
4. Lighting and heating contactors are rated by:
   a. Horsepower
   b. Amperes

5. ____________ ____________ and ____________ ____________ lighting and heating contactors are not affected by a loss of control power.

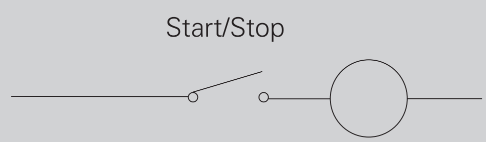
6. A ____________ ____________ directs the operation of another device, or indicates the status of the operating system.

7. Label each of the circuits below as representing either two-wire control or three-wire control.

____ - Wire Control



____ - Wire Control

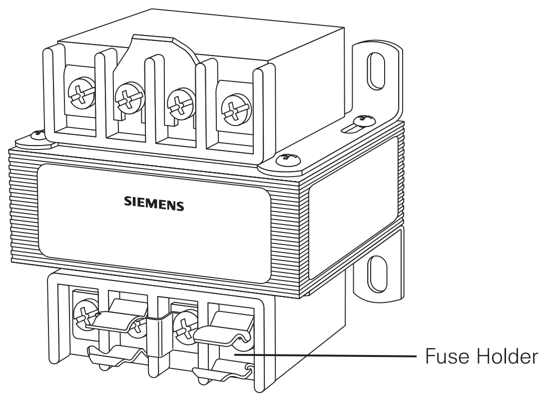


8. Indicator lights provide ____________ information of the circuit's operating condition.

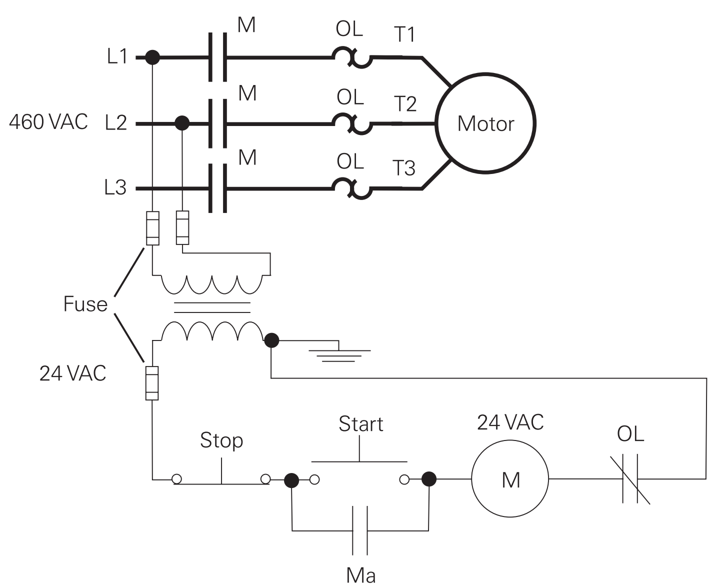
9. A ____________ indicator light normally indicates a motor is running, while a ____________ indicator light normally indicates that the motor is stopped.

Control Transformers

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

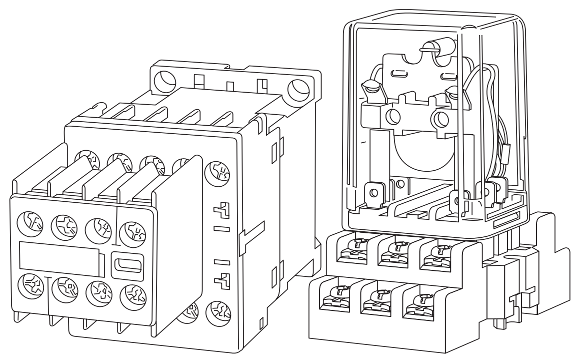


In the following example, the power circuit is 460 VAC. A control transformer is used to step the voltage down to 24 VAC for use in the control circuit. The electromagnetic coil voltage must be rated for 24 VAC. Fuses on the primary and secondary windings of the transformer provide overcurrent protection.



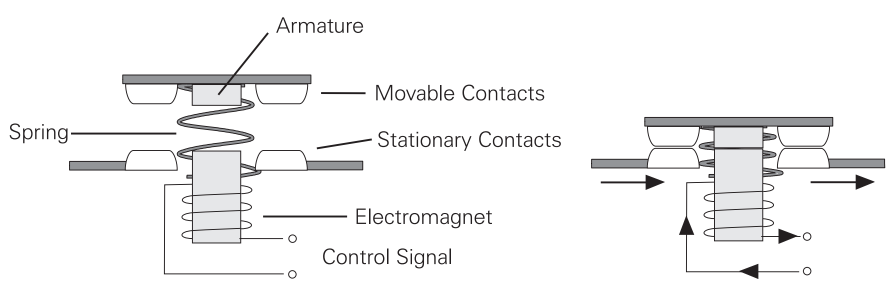
Control Relays

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



Relay Operation

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



Contact Arrangement

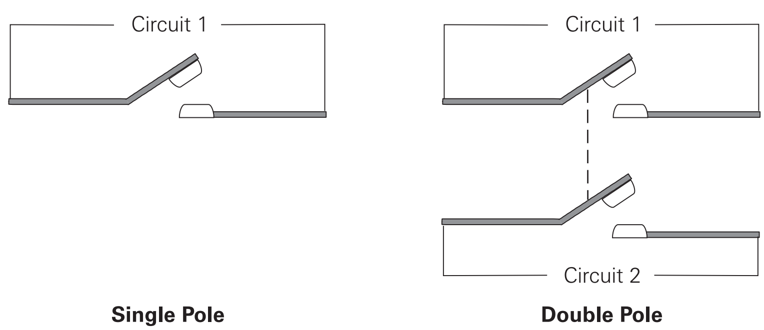
A relay can contain normally open, normally closed, or both types of contacts.

The main difference between a control relay and a contactor is the size and number of contacts. The contacts in a control relay are relatively small because they need to handle only the small currents used in control circuits. There are no power contacts. Also, unlike a contactor, each contact in a control relay controls a different circuit. In a contactor, they all control the starting and stopping of the motor. Some relays have a greater number of contacts than are found in the typical contactor.

The use of contacts in relays can be complex. There are three key terms you will need to understand in dealing with relays.

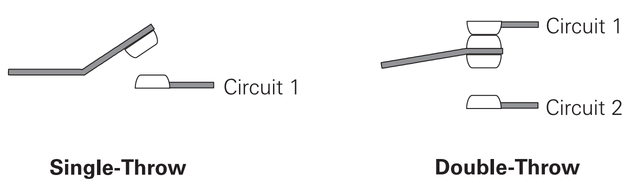
Pole

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



Throw

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



The following abbreviations are frequently used to indicate contact configurations:

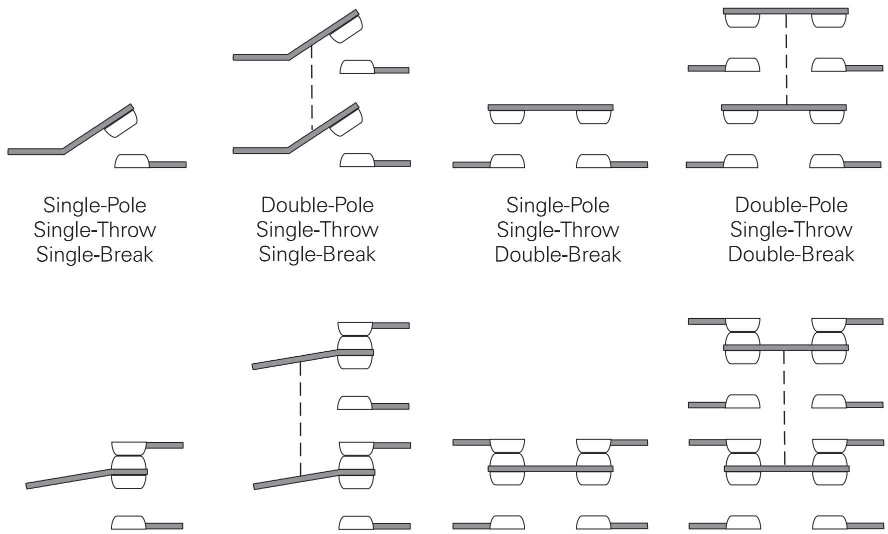
SPST Single-Pole, Single-Throw
SPDT Single-Pole, Double-Throw
DPST Double-Pole, Single-Throw
DPDT Double-Pole, Double-Throw

Break

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

Single-Break **Double-Break**

The diagram below illustrates various contact arrangements.

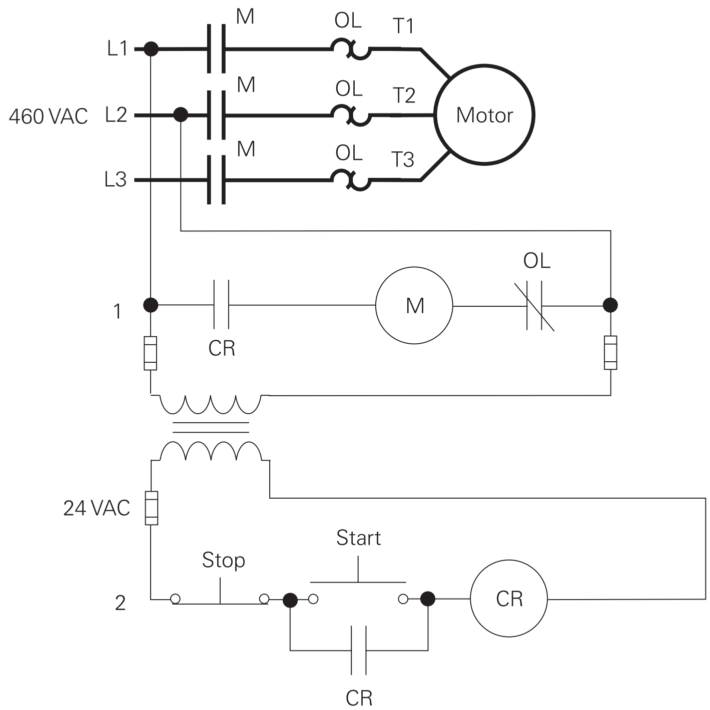


Single-Pole Single-Throw Single-Break | Double-Pole Single-Throw Single-Break | Single-Pole Single-Throw Double-Break | Double-Pole Single-Throw Double-Break

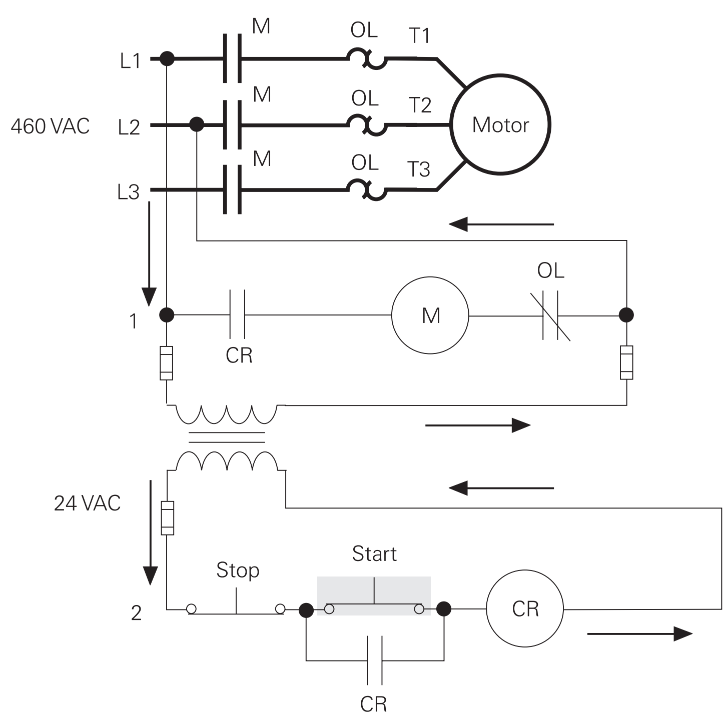
Single-Pole Double-Throw Single-Break | Double-Pole Double-Throw Single-Break | Single-Pole Double-Throw Double-Break | Double-Pole Double-Throw Double-Break

Interposing a Relay

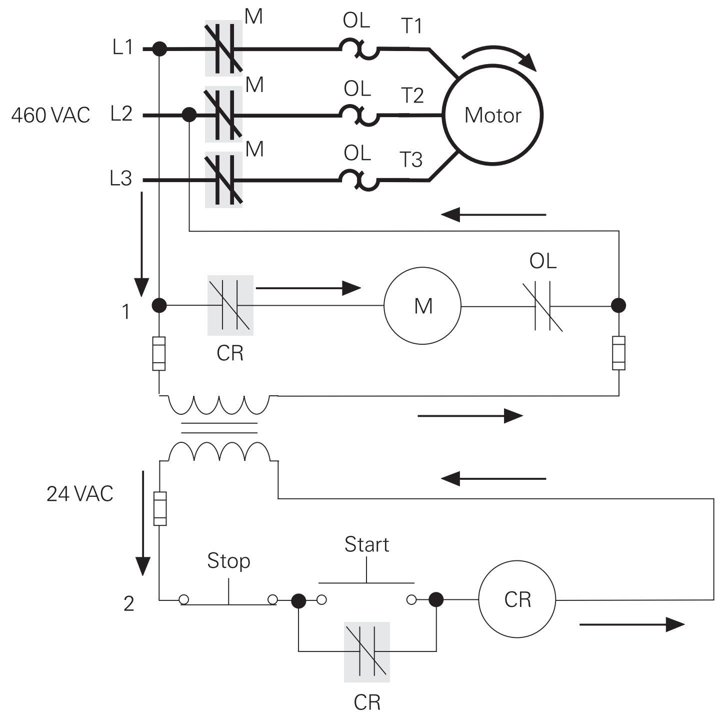
The following line diagram illustrates one way that a control relay might be used, in a circuit where a 24 VAC coil may not be strong enough to operate a large starter. In this example the electromagnetic coil of the "M" contactor selected is rated for 460 VAC. The electromagnetic coil of the control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



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

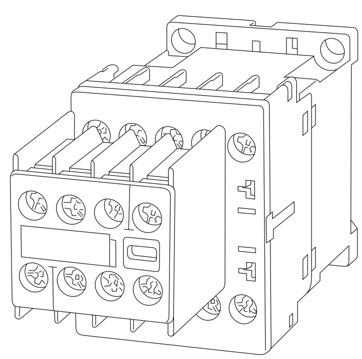


This causes the “CR” contacts in lines 1 and 2 to close. The “CR” contacts in line 2 maintain the start circuit, while the “CR” contacts in line 1 complete the path of current to the “M” motor starter. The “M” motor starter energizes and closes the “M” contacts in the power circuit, starting the motor.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



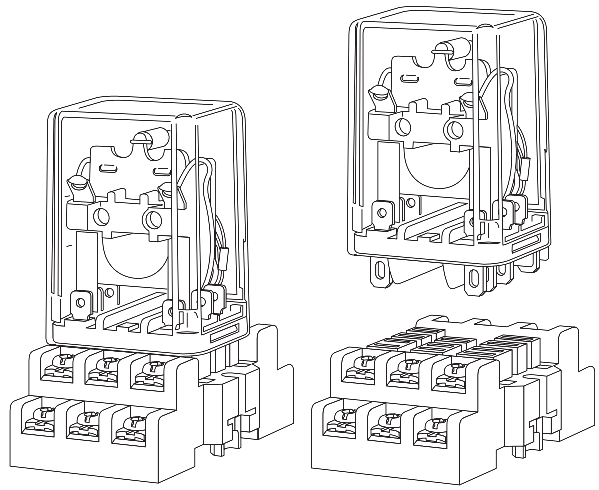
SIRIUS 3RH Control Relays

Siemens SIRIUS 3R 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.



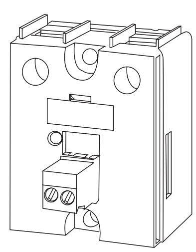
Solid-State Switching Devices

Conventional electromechanical switching devices are unsuitable for applications requiring high switching frequencies due to the wear on mechanical components. Electromechanical switching devices are also inherently noisy and, as a result, undesirable for use in noise-sensitive areas.

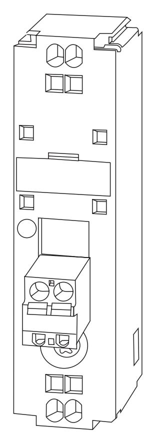
As a result, Siemens has developed three categories of SIRIUS SC solid-state switching devices, relays, contactors, and function modules. SIRIUS SC solid-state relays and contactors are intended for switching resistive loads, but some units are capable of switching slightly inductive loads.

SIRIUS SC Solid-State Relays

SIRIUS SC **solid-state relays** can be mounted on existing cooling surfaces. 3RF20 solid-state relays have a 45 mm assembly width, and 3RF21 solid-state relays have a 22.5 mm assembly width.



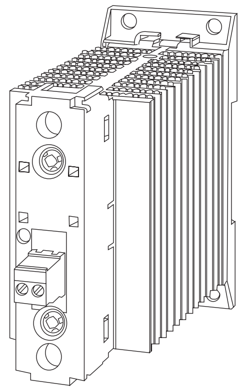
3RF20 Solid-State Relay (45 mm)



3RF21 Solid-State Relay (22.5 mm)

SIRIUS SC
Solid-State Contactors

SIRIUS SC 3RF23 **solid-state contactors** incorporate a solid-state relay in an optimized heat sink to form a ready to use device with defined current ratings.



3RF23 Solid-State Contactor

SIRIUS SC
Function Modules

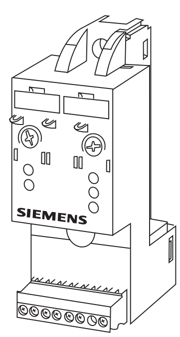
Many applications require extended functionality that can be accommodated by SIRIUS SC **function modules**.

Examples of SIRIUS 3RF29 function modules include:

Converter – Converts an analog control signal to a pulse-width modulated digital signal. This allows a SIRIUS SC solid-state relay or contactor to adjust power to a load based on an analog signal from a device such as a temperature sensor.

Load monitoring module – This module detects a variety of faults, such as a failed load element and provides for an LED fault indication and a PLC-compatible fault signal.

Power controller – This module combines load circuit monitoring capability with the ability to adjust power to the connected load.



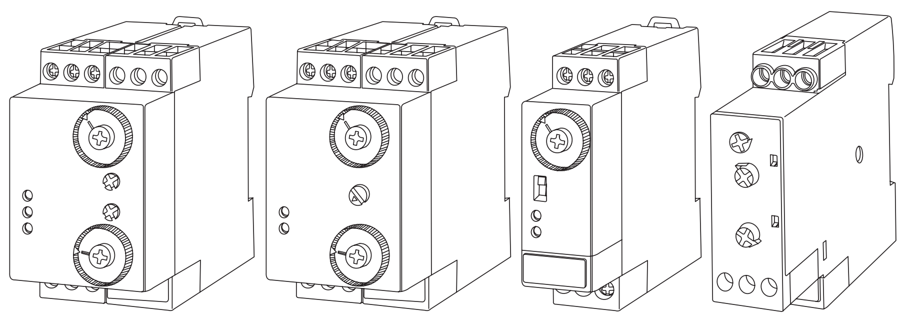
3RF29 Power Controller

Monitoring Relays

SIRIUS 3UG **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.

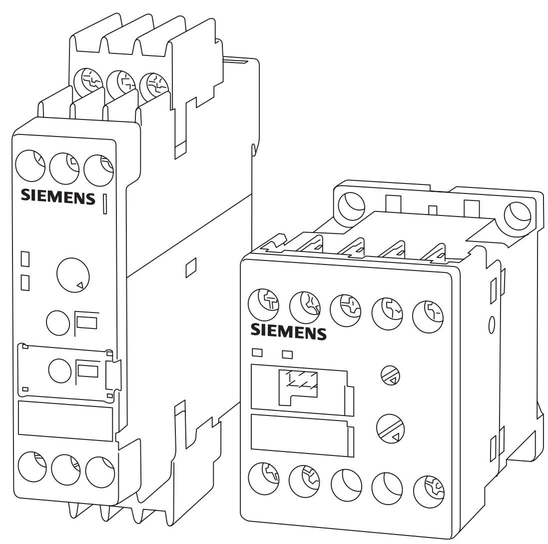


SIRIUS 3UG Monitoring Relays

Time Relays

Time relays, such as Siemens 3RP15 and 3RP20 solid-state time relays, are used in control switching operations involving time delay.

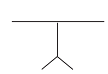
3RP15 time relays have a 22.5 mm assembly width, and 3RP20 time relays have a 45 mm assembly width. Most of these time relays have multiple time setting ranges. For example, a number of the 3RP15 and 3RP20 time relays have 15 time setting ranges covering the span from 0.05 seconds to 100 hours.



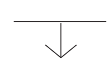
3RP15 3RP20

Time Delay

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



On-Delay
Arrow Points Up

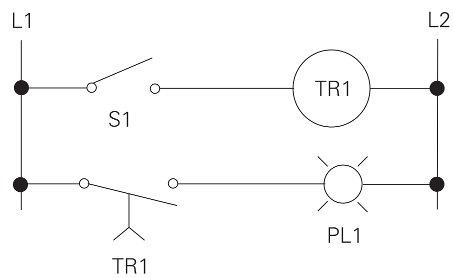


Off-Delay
Arrow Points Down

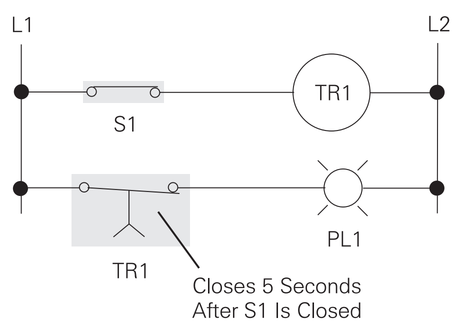
On-delay and Off-delay timers can turn their connected loads on or off, based on how the timer's output is wired into the circuit. **On-delay** indicates that once a timer has received a signal to turn on, a predetermined time (set by the timer) must pass before the timer's contacts change state. **Off-delay**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

On-Delay, Timed Closed

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

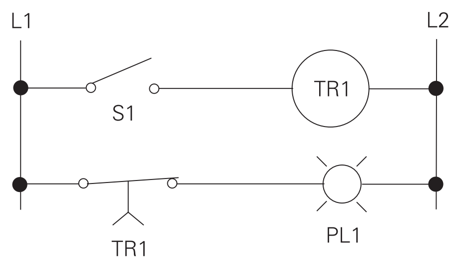


When S1 is closed, TR1 begins timing. When 5 seconds has elapsed, TR1 will close its associated normally open (NO) TR1 contacts, illuminating indicator light PL1. When S1 is open, de-energizing TR1, the TR1 contacts open immediately, extinguishing PL1.

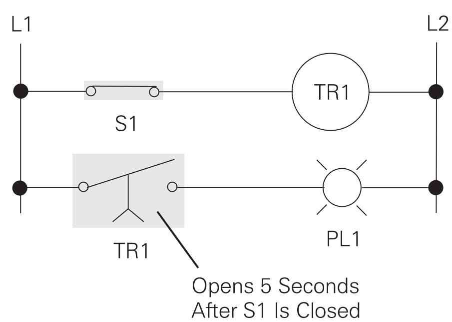


On-Delay, Timed Open

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

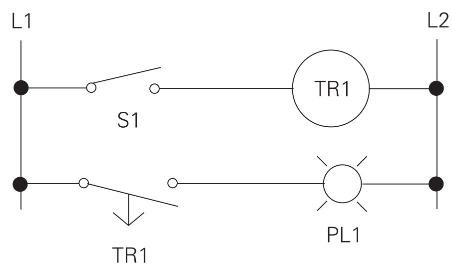


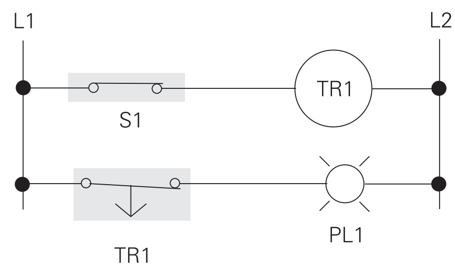
When S1 is closed, timing relay TR1 is energized. After a timed delay of 5 seconds, the associated normally closed TR1 contacts open, extinguishing PL1. When S1 is open, de-energizing TR1, the TR1 contacts close immediately, illuminating PL1.



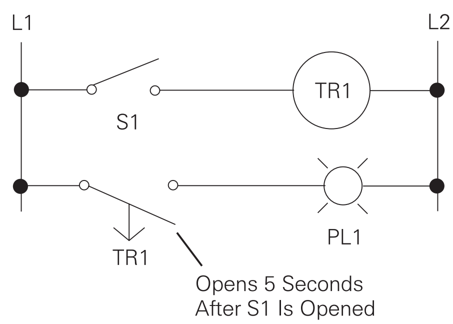
Off-Delay, Timed Open

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



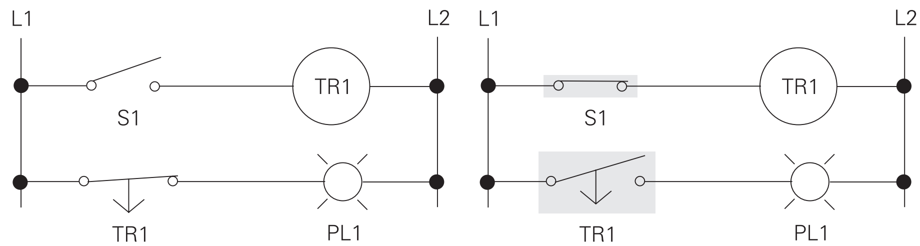


When S1 is opened, TR1 begins timing. When 5 seconds has elapsed, TR1 will open its associated normally open contacts, extinguishing indicator light PL1.

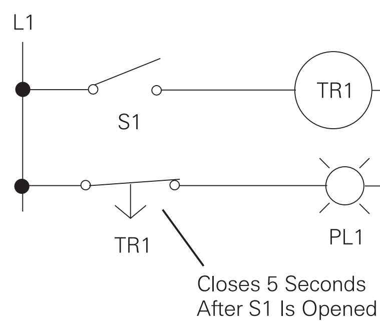


Off-Delay, Timed Closed

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

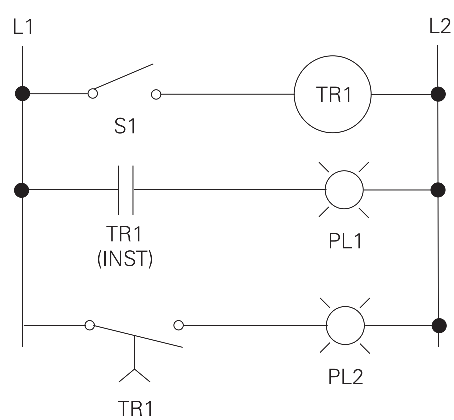


When S1 is opened, timing relay TR1 is de-energized. After 5 seconds, the associated normally closed contacts close, illuminating PL1.



Instantaneous Contacts

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



Terminal Blocks and Supplementary Protectors

Terminal Blocks

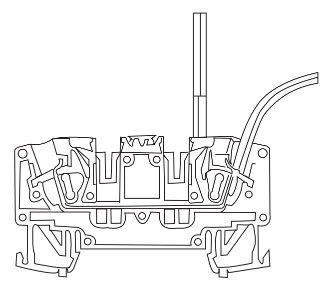
Siemens offers a broad range of spring-loaded and screw-type **terminal blocks** for space-saving connections. Examples of the types of terminal blocks are listed below.

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

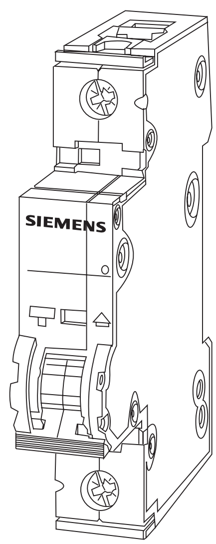


8WA2 Through-Type Terminal

Supplementary Protectors

Siemens UL1077 **supplementary protectors** are designed to trip faster than standard UL489 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.

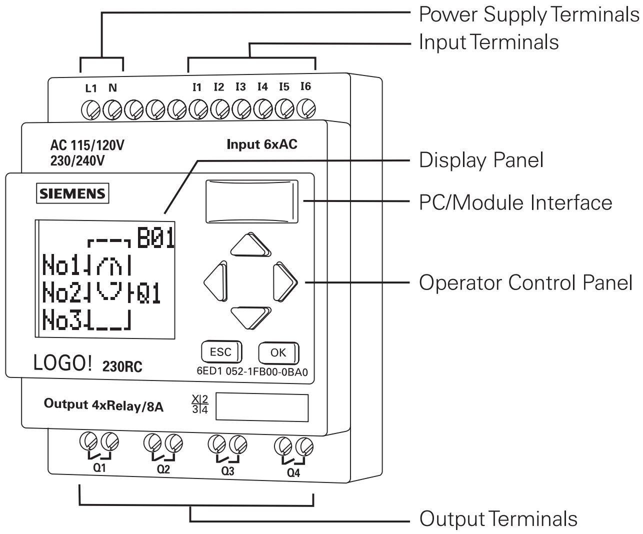
Siemens supplementary protectors are equipped with a thermal bimetal trip mechanism for low-current overloads and an instantaneous electromagnetic trip for high-current overloads and short circuits. Devices are available for single-pole and multiple-pole varieties with mounting depths of 55mm or 70 mm.



5SY4 Supplementary Protector (70 mm)

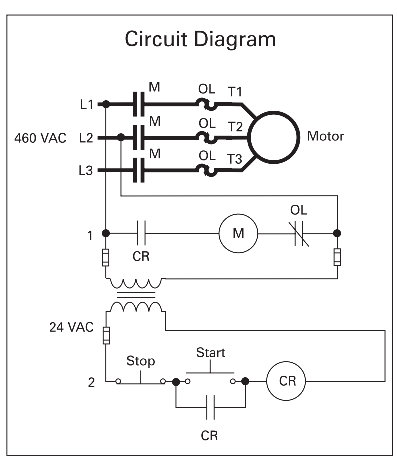
LOGO! Logic Module

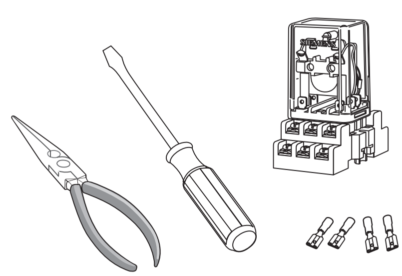
LOGO! is a logic module used to perform control tasks. The module is compact and user friendly, providing a cost-effective solution for the end user.



Hard-Wired Control

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

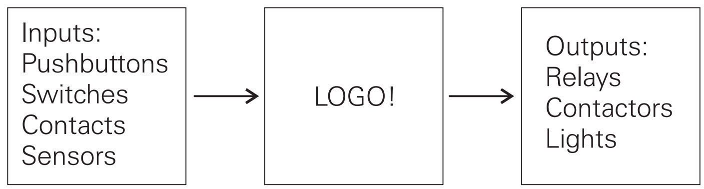




Many of the same tasks can be performed with LOGO!. Initial hard-wiring, although still required, is greatly simplified. Modifying the application is as easy as changing the program via the keypad located on the front of the LOGO!. Likewise, control programs can be created and tested before implementation 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.



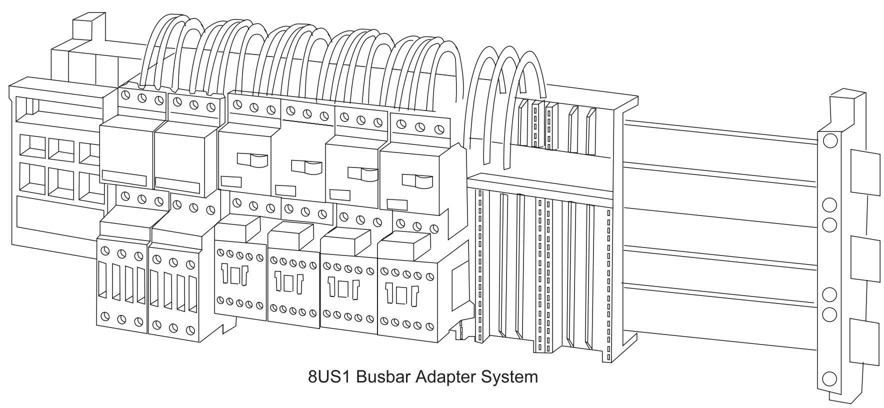
Design Features

Multiple versions of LOGO! are available for different supply voltages (12 VDC, 24 VDC, 24 VAC, or 115/230 VAC). Units are equipped with 8 digital inputs and 4 relay or solid-state outputs. Units are available with or without the display panel and keyboard. Expansion modules are available to increase the number of discrete inputs and outputs and to add analog inputs or outputs. A communication module for connection to the AS-Interface is also available.

Fastbus Busbar Adapter System

The **Fastbus** Multi-Motor Control system is a 3-phase, insulated busbar system used to reduce wire connections and hole drilling when building control panels. SIRIUS 3RV/3RT starter combinations build from components, and Siemens circuit breakers use Fastbus for convenient mounting.

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

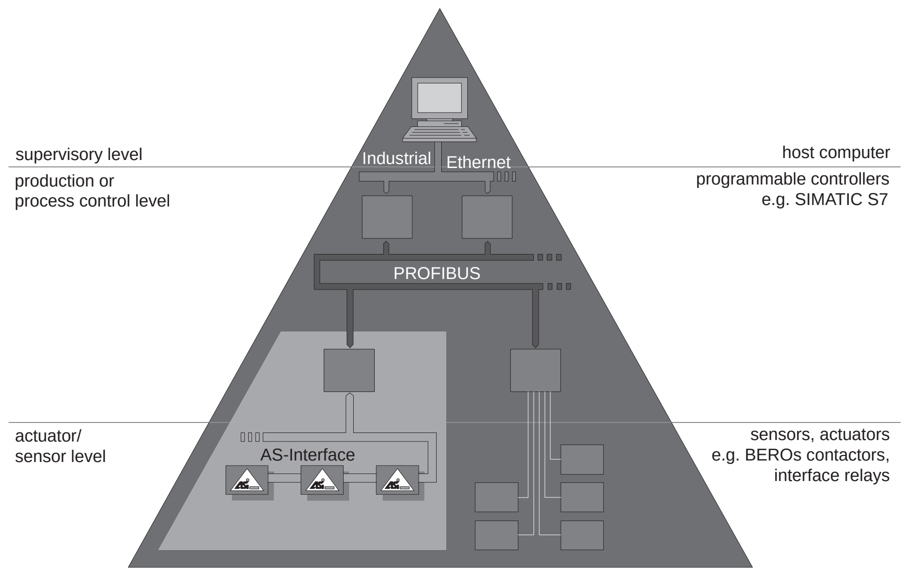


8US1 Busbar Adapter System

All This and More

In this course, you have 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 adequately describe in this 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. ____________ is the total number of different circuits each pole controls.

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

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

4. A timing relay that receives a signal to turn on, and then delays a predetermined amount of time before performing this action, is referred to as _____________ delay.

5. _____________ _____________ relays and contactors eliminate the mechanical wear and noise characteristics of conventional electromechanical switching devices.

6. _____________ _____________ can monitor electrical and mechanical quantities and fault conditions, and provide appropriate diagnostic indications.

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

8. Siemens UL1077 _____________ _____________ are designed to trip faster than standard UL489 circuit breakers, providing additional protection for more sensitive devices.

Review Answers

Review 1	(1) manually; (2) a; (3) b; (4) b; (5) c
Review 2	(1) left to right; (2) A - Node, B - Power Circuit, C - Power Load, D- Control Circuit; E - Control Device; F - Control Load
Review 3	(1) a; (2) overcurrent; (3) overload; (4) a; (5) bimetal; (6) reset; (7-1) heater elements; (7-2) phase loss; (7-3) insensitive
Review 4	(1) two; (2) low voltage protection (LVP); (3) 15; (4) 20; (5) motor starter; (6) combination starter
Review 5	(1) NEMA, IEC; (2) 5; (3) AC3; (4) 4, 3½; (5) three; (6) S00, S6; (7) 140ºF (60ºC)
Review 6	(1) consequent-pole motor; (2) progressive control; (3) reduced-voltage starting; (4-1) inrush current; (4-2) starting torque; (4-3) stress on mechanical linkage; (4) Autotransformer
Review 7	(1) power supply cycle; (2-1) current limit; (2-2) starting voltage; (2-3) starting and stopping times of the voltage ramp; (3) electrically held; (4) b; (5) magnetically held, mechanically latched; (6) Pilot device; (7-top) Three-Wire Control; (7-bottom) Two-Wire Control; (8) visual; (9) red, green
Review 8	(1) Throw; (2) Pole; (3) one, two; (4) ON; (5) Solid-State; (6) Monitoring Relays; (7) screw, spring-loaded; (8) Supplementary Protectors

Final Exam

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

Questions

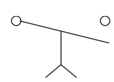
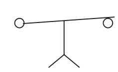
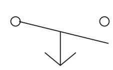
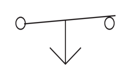
1. The standard method of showing a contact is by indicating the circuit condition it produces when the actuating device is in the _____________ state.

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

2. A motor that is running would usually be indicated 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 _________.

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

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

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

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

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

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

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

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

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

11. ____________ 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. A device used to provide visual information of the circuit's operating condition is a _____________ .

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

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

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

14. Which type of lighting and heating contactor is likely to produce a humming sound during normal operation, and is not recommended for a quiet area?

a.	electrically-held	b.	magnetically-held
c.	mechanically-latched	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.	proprietary network

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

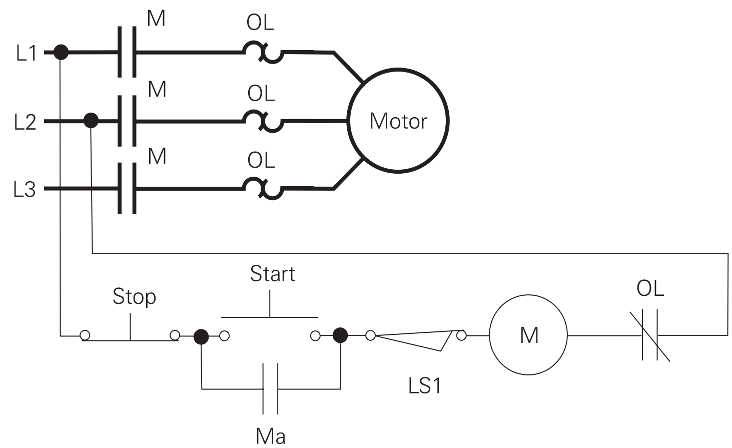
a.	4	b.	6
c.	8	d.	10

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” button is depressed
b. limit switch “LS1” opens
c. the motor overload contact opens
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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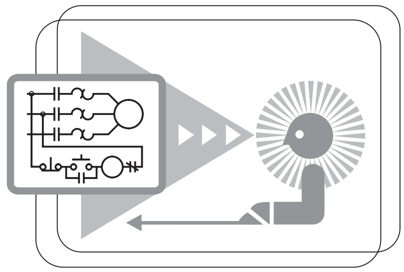

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