

CONSTRUCTION ELECTRICIAN APPRENTICESHIP PROGRAM

Level 1

Line I: Install Control Circuits and Devices



I-2

LEARNING GUIDE I-2

INSTALL MAGNETIC MOTOR CONTROLS



THE RIGHT SKILLS ► A PROVEN ADVANTAGE



Foreword

The Industry Training Authority (ITA) is pleased to release this major update of learning resources to support the delivery of the BC Electrician Apprenticeship Program. It was made possible by the dedicated efforts of the Electrical Articulation Committee of BC (EAC).

The EAC is a working group of electrical instructors from institutions across the province and is one of the key stakeholder groups that supports and strengthens industry training in BC. It was the driving force behind the update of the Electrician Apprenticeship Program Learning Guides, supplying the specialized expertise required to incorporate technological, procedural and industry-driven changes. The EAC plays an important role in the province's post-secondary public institutions. As discipline specialists the committee's members share information and engage in discussions of curriculum matters, particularly those affecting student mobility.

ITA would also like to acknowledge the Construction Industry Training Organization (CITO) which provides direction for improving industry training in the construction sector. CITO is responsible for organizing industry and instructor representatives within BC to consult and provide changes related to the BC Construction Electrician Training Program.

We are grateful to EAC for their contributions to the ongoing development of BC Construction Electrician Training Program Learning Guides (materials whose ownership and copyright are maintained by the Province of British Columbia through ITA).

Industry Training Authority

January 2011

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INSTALL MAGNETIC MOTOR CONTROLS

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Learning Objectives

- The learner will be able to describe the operating principles of magnetic motor control circuits.
- The learner will be able to connect and maintain magnetic motor control circuits.

Activities

- Read and study the topics of Learning Guide I-2: Install Magnetic Motor Controls.
- Complete Self-Tests 1 through 8. Check your answers with the Answer Key provided at the end of this Learning Guide.

R Resources

- *Canadian Electric Code, Part 1* with Amendments and Bulletins, current editions.
- *Occupational Health & Safety Regulation* – BC Regulation 296/97 by the Workers' Compensation Board of BC.

Also, you are encouraged to obtain the following texts for supplemental information:

- *Electrician's Guide to AC Motor Controls* by Richard A. Cox; Coxco
- *Industrial Motor Control* by Stephen L. Herman; Delmar Cengage Inc.

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We want your feedback! Please go the BC Trades Modules website to enter comments about specific section(s) that require correction or modification. All submissions will be reviewed and considered for inclusion in the next revision.

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January 2011

Learning Task 1:

Describe the features of three-phase, AC magnetic motor starters

The fundamental purpose of any motor starter is to safely start and stop the motor, and to provide running (overload) protection for the motor. They may be simple manual devices, or more complex automatic ones.

A motor starter is a *controller*—a term that implies more operating functions than simply starting and stopping the motor. A controller may also allow for:

- Reversing operation
- Reduced voltage starting
- Speed control
- Sequencing control
- Remote control operation
- Operator safety

One of the most common controllers for three-phase motors is the *across-the-line magnetic* starter. *Magnetic* in this context means that an electromagnet is used to operate a set of contacts for making and breaking the electric circuit to the motor. *Across-the-line* means that the motor is started with full line voltage.

Basic construction

A basic magnetic starter has two fundamental parts: a contactor and an overload relay. The contactor starts and stops the motor and the overload relay provides running protection for the motor.

Contactor

Figure 1 shows the construction of two types of contactor—the clapper type and the vertical lift type.

The stationary contact terminals are connected in series with the line to the motor. By energizing and de-energizing the electromagnetic coil, the start-stop action of the motor is controlled in the following way:

- When it is energized, the coil attracts a movable iron piece called the *armature*.
- The movement of the armature closes a set of normally open contacts (by pushing a set of movable contacts against stationary ones).
- When the coil is de-energized, the armature is released, opening the contacts again.

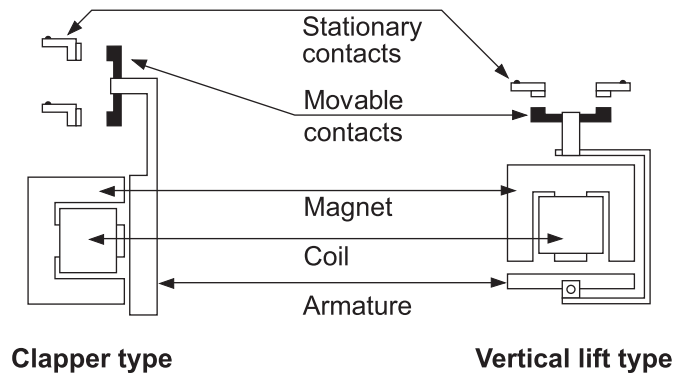


Figure 1—Basic contactor construction

For a three-phase motor starter, the contactor requires three power contacts. A single power contact is connected in series with each line conductor to the motor (Figure 2).

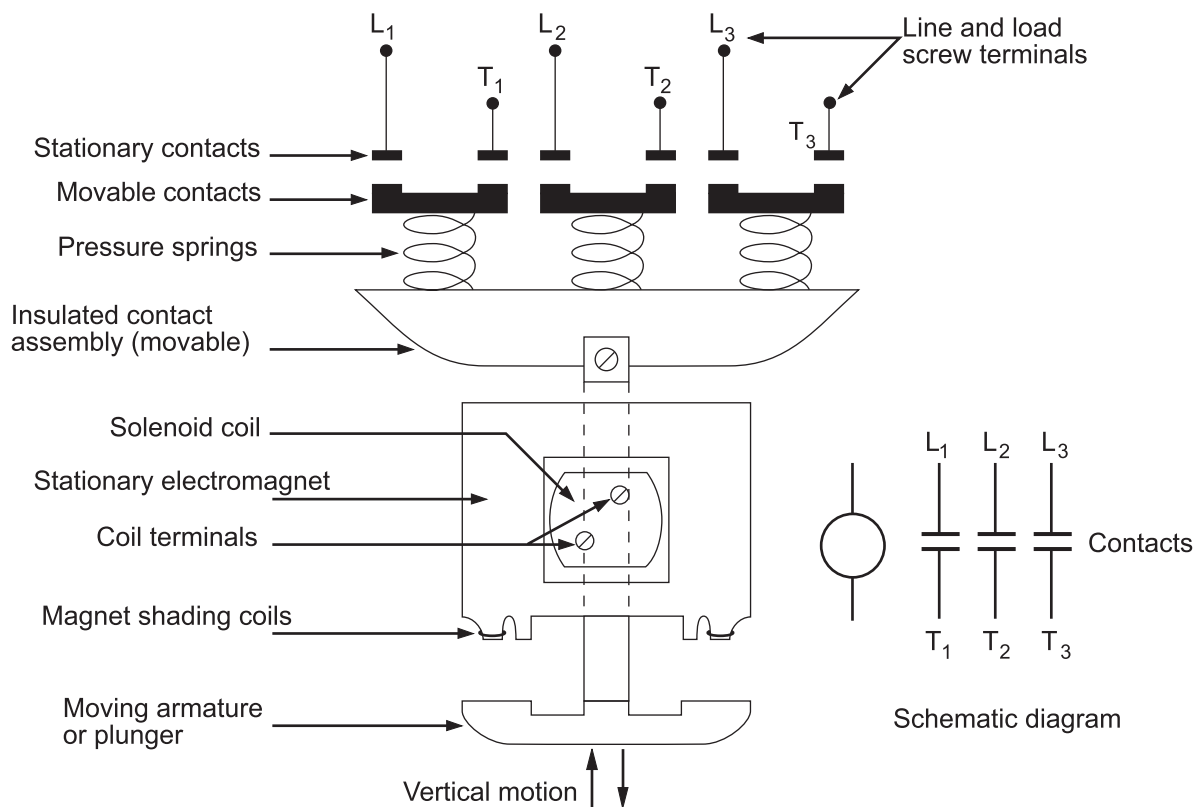


Figure 2—Three-pole, solenoid-operated contactor for a three-phase motor starter

Overload relay (OLR)

You may see overload relay written as OLR, O/L relay, O.L. relay or simply OL. Figure 4 shows an OLR connected into a magnetic starter.

The OLR has two basic parts:

- A heater element, which is connected in series with the line to the motor
- A normally closed, auxiliary contact, which is connected in series with the coil of the magnetic contactor

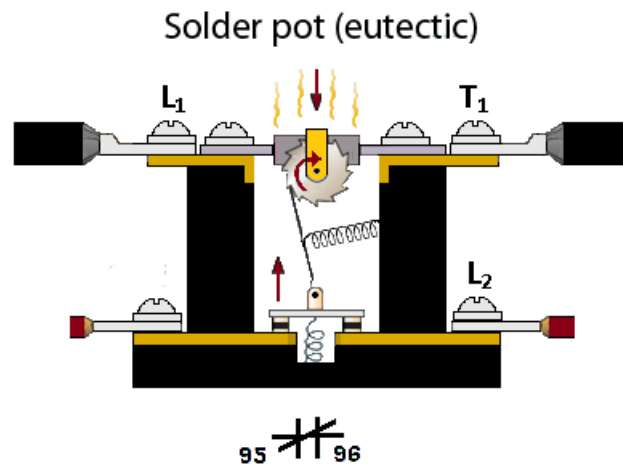


Figure 3—Example of circuit connection for melting alloy overload relay (OLR)

The CEC requires that each line of a three-phase motor have OLR protection by:

- Using three single-pole OLRs, each with a heater and an auxiliary contact, or
- Using a single three-pole OLR, in which a single auxiliary contact is activated by any of three heaters

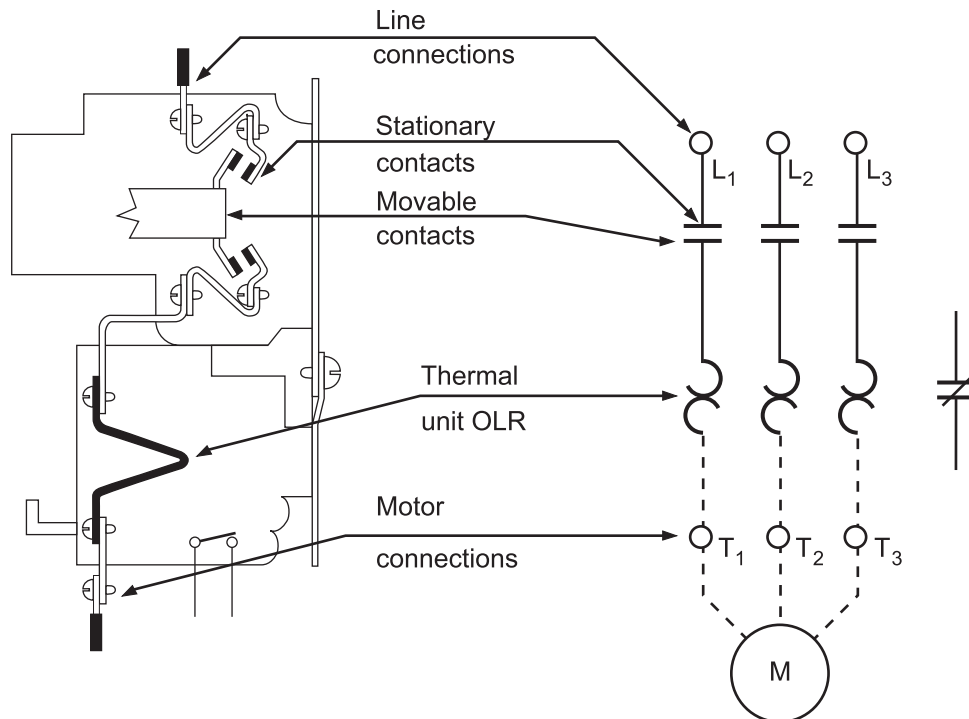


Figure 4—A three-phase motor starter

Heater selection

Manufacturers of motor starters usually provide a *heater table* on the inside of the enclosure door. Be careful to select a heater that corresponds with the nameplate current rating of the motor.

Tripping and resetting

Depending on the manufactured design, a tripped OLR is identified by a protruding plunger, a flag or a coloured disk. If the motor starter has tripped because of overload, you must do the following:

1. Determine the cause of the overload.
2. Wait for the OLR to cool down.
3. Reset the OLR.

You can usually reset the OLR without opening the starter enclosure door.

Contactor and starter ratings

AC magnetic starters are rated by the Electrical Equipment Manufacturers' Association of Canada (EEMAC). Specific starters are rated in standard sizes according to the maximum horsepower motor that they can start directly across-the-line. Low-voltage starters typically range from Size 00 (2 hp maximum) to Size 8 (900 hp maximum).

Table 1 is a chart of contactor and starter ratings.

EEMAC size	Volts	Maximum hp for nonplugging & nonjogging-duty poly-phase	Maximum hp for plugging & jogging-duty poly-phase
00	120	$\frac{3}{4}$	–
	208–240	1- $\frac{1}{2}$	–
	480	2	–
	600	2	–
0	120	2	1
	208–240	3	1- $\frac{1}{2}$
	480	5	2
	600	5	2
1	120	3	2
	208–240	7- $\frac{1}{2}$	3
	480	10	5
	600	10	5
2	120	7- $\frac{1}{2}$	–
	208–240	15	10
	480	25	15
	600	25	15
3	120	15	–
	208–240	30	20
	480	50	30
	600	50	30
4	120	–	–
	208–240	50	30
	480	100	60
	600	100	60
5	120	–	–
	208–240	100	75
	480	200	150
	600	200	150
6	120	–	–
	208–240	200	150
	480	400	300
	600	400	300
7	120	–	–
	208–240	300	–
	480	600	–
	600	600	–
8	120	–	–
	208–240	450	–
	480	900	–
	600	900	–

Table 1: Magnetic starter and contactor hp ratings



Now do Self-Test 1 and check your answers.

Self-Test 1

1. List three functions, other than stopping and starting a motor, that a motor controller can provide.

2. What is the fundamental difference between a magnetic contactor and a magnetic motor starter?

3. What is the difference between the power circuit and the control circuit of a motor starter?

4. What are the two basic parts of a thermal overload relay?

5. A three-phase motor requires an overload _____ in series with each of the line conductors to the motor.

6. Selection of the heater is based on the full-load _____ of the motor, which is easily determined from the _____ of the motor.

7. Before an OLR can be reset, time must be allowed for it to _____ .

8. Sketch the schematic symbol for a thermal OLR, labelling the parts.

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 2:

Describe the operation of across-the-line magnetic motor starters

An across-the-line magnetic motor starter uses full-line voltage to start the motor. As you will learn later, it may sometimes be desirable to start a motor with a reduced value of voltage. Most AC magnetic starters are considered as across-the-line (or full voltage) types.

The three-phase AC magnetic starter consists of two circuits: the power circuit and the control circuit.

Power circuit

The power circuit of a magnetic motor starter usually consists of a disconnect switch, the overcurrent protection, hp-rated contacts and OLR heaters of the magnetic starter, and the motor.

Figure 1 is a schematic diagram of the power circuit of a three-phase, across-the-line, magnetic starter. Note that all devices are normally shown in the de-energized state.

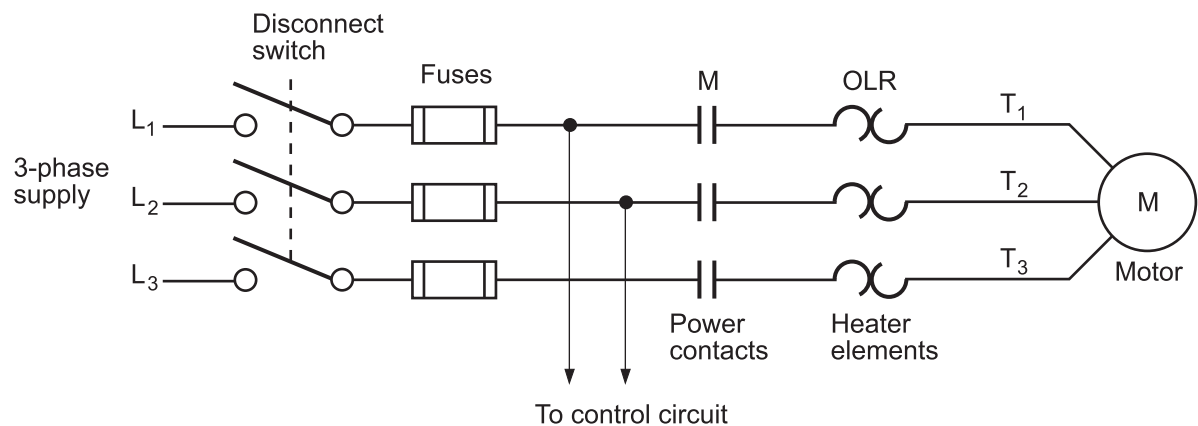


Figure 1—Power circuit schematic for a three-phase motor starter

When the power for the control circuits is derived from the three-phase supply to the motor as shown in Figure 1:

- Two of the three phase line conductors supply single-phase power to the control circuit. These are taken from the *line* side of the motor circuit.
- When the disconnect switch is closed and the control circuit for the magnetic starter is activated, the power circuit to the motor is complete.
- When the disconnect switch is open, both the motor circuit and control circuit are deenergized.

This is typical of most, but not all, motor control circuits.



Power circuits are the same for most three-phase motor starters, so it is usual not to refer to them in schematic drawings. This is why it is *extremely important* to understand their component structure and to be aware of their existence.

Control circuit

The control circuit of a magnetic starter is the interesting part of a motor circuit. It can be very simple or extremely complex, with many devices and interlocking functions. You must be able to recognize common symbols and to read schematic diagrams for motor control circuits. You must also be able to relate the actual devices in the circuit to their symbols in the diagram in order to understand their function.

Two-wire circuits

Figure 2 shows a simple two-wire control circuit for a magnetic motor starter.

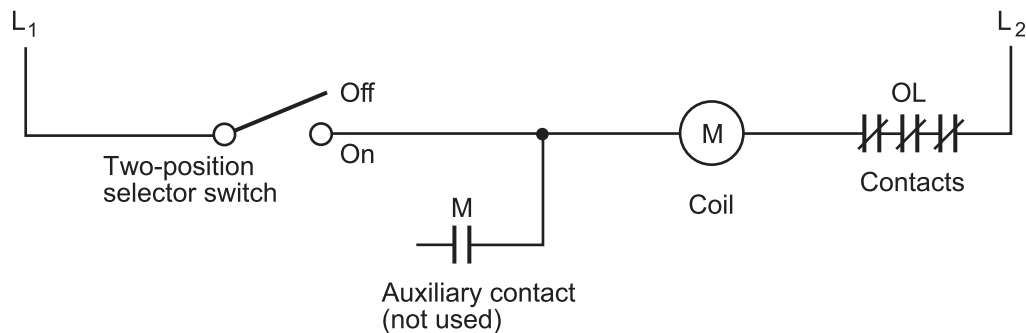


Figure 2—Two-wire control circuit

In Figure 2, a single-pole, maintained-contact, ON/OFF switch is the activating device. When the disconnect switch in the power circuit (Figure 1) is closed, the control circuit becomes functional. Under normal operating conditions, the motor is started or stopped manually with the ON/OFF switch in the control circuit.

When the selector switch is ON, the circuit is completed in the following order:

1. From line 1
2. Through the switch
3. Energizing the coil of the magnetic starter
4. Through the normally closed (n.c.) contacts of the OLR
5. To line 2

The energizing of the coil causes the power contacts of the magnetic starter to close. This starts the motor.

If an overload occurs on the motor, the sequence is:

1. The heater in the power circuit senses a current increase.
2. The n.c. contacts of the OLR in the control circuit open, and the starter coil is de-energized.
3. The power contacts of the starter open, and the motor stops.

If there is a power failure while the switch is ON, the motor automatically restarts when power returns. This is known as *under-voltage release*.

The ON/OFF switch could just as easily be replaced with any other two-wire pilot device, such as a float switch, a pressure switch or a temperature switch.

Three-wire circuits

Figure 3 shows a simple three-wire control circuit. In this, a momentary-contact, STOP/START push-button station is used. The STOP button is normally closed and opens when depressed. The START button is normally open (n.o.) and closes when depressed. When released, both actions revert to their normal state.

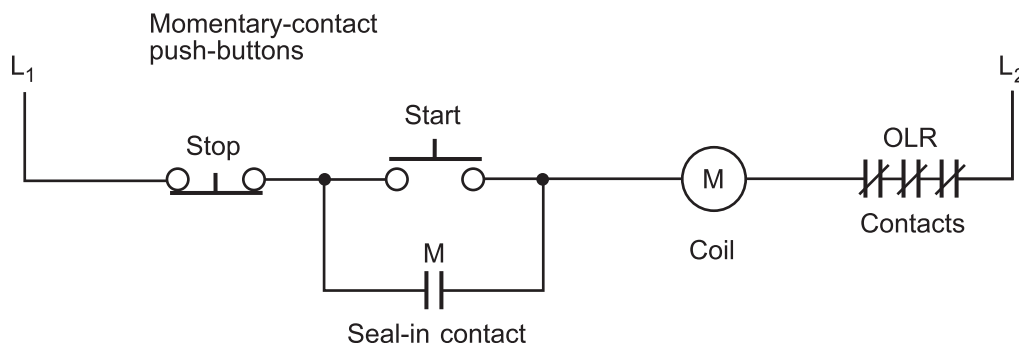


Figure 3—Three-wire control circuit

The fundamental difference between three-wire and two-wire control circuits is the additional normally open contact on the magnetic starter in three-wire circuits. This auxiliary contact is in parallel with the START button and is called the *seal-in contact* (also known as the *holding contact* or *maintaining contact*). Like the power contacts of the magnetic starter, this contact closes and opens with the energizing and de-energizing action of the electromagnetic coil.

- When the START button is pressed, the coil is energized. This closes the main power contacts and the seal-in contact.
- When the START button is released, current to the coil is maintained through the closed seal in contact. The coil stays energized and the motor continues to run.
- If there is an overload on the motor, the opening of the n.c. OLR contacts in the control circuit de-energizes the coil and stops the motor.
- When the STOP button is depressed, a similar action is obtained, with all magnetic starter contacts falling open.
- If there is a power failure during normal running, the magnetic starter coil becomes de-energized and all starter contacts open. When power is restored, the control circuit must be manually restarted. This is called *under-voltage protection*.

Pilot lights

A pilot light is sometimes used to indicate the operating status of a motor in a remote location. Figure 4 shows the electrical connections for an ON light in the control circuit. Note that it is connected in parallel with the coil of the magnetic starter. Whenever the coil of the starter is energized, the pilot light is also energized.

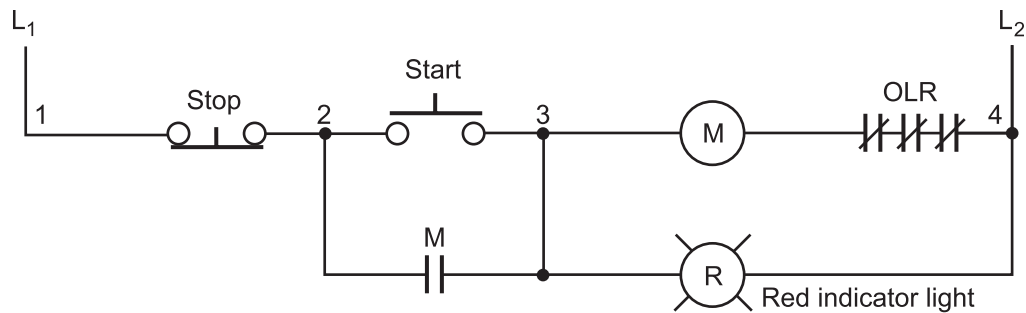


Figure 4—Connection of a motor running light

Operation from remote locations

Sometimes you may need to operate a motor from more than one location. Figure 5 shows the connections for three separate STOP/START push-button stations.

Note that the STOP buttons are electrically connected in series; the START buttons are in parallel with each other.

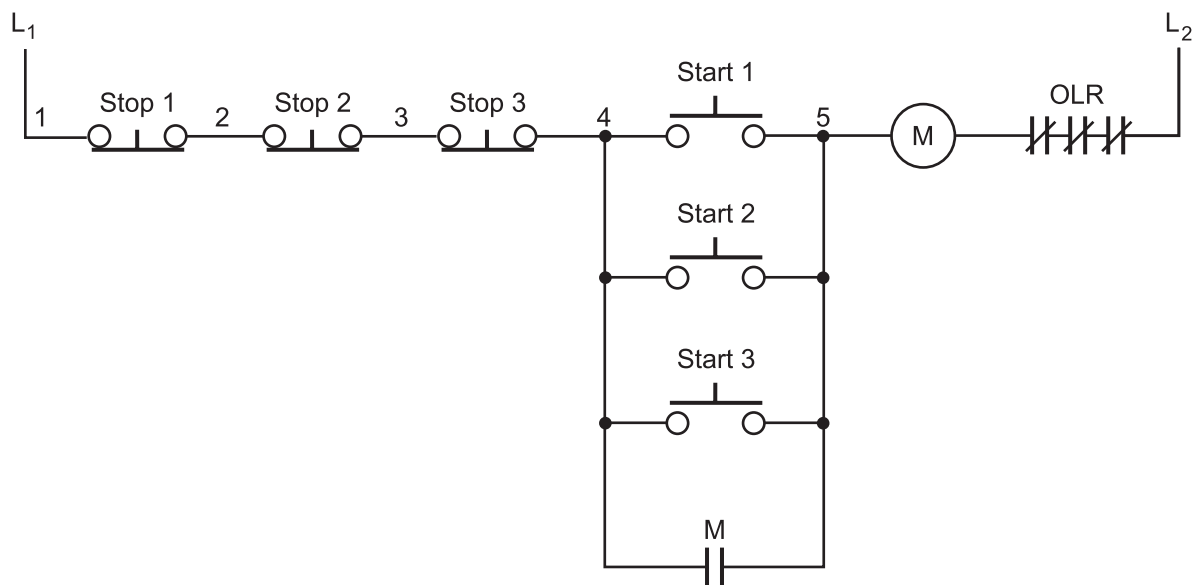


Figure 5—Three-station push-button control for a motor

A three-position selector switch may be used to provide either manual or automatic ON/OFF control. Figure 6 illustrates the use of a float switch for a pump motor to do this. When in the AUTO position, the magnetic starter is controlled by the opening or closing of the float switch contacts.

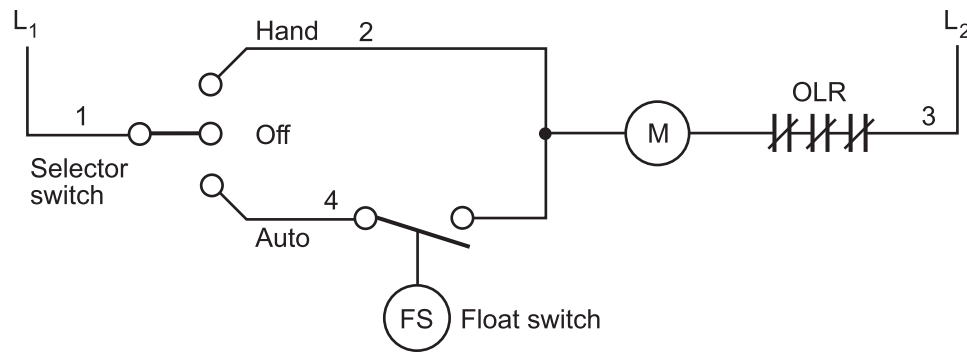


Figure 6—HAND-OFF-AUTO selector switch control

Using a single OLR contact

Note that in Figures 1 to 6, three n.c. OLR contacts are shown. This is because a detector or heater element is required in each line conductor to the motor.

In practice, the three heaters are often mounted in such a way that each heater can operate just one master set of contacts. In a schematic diagram, this is indicated by using just one OLR contact, as shown in Figure 7. Note that the n.c. OLR contact may be located ahead of the STOP button.

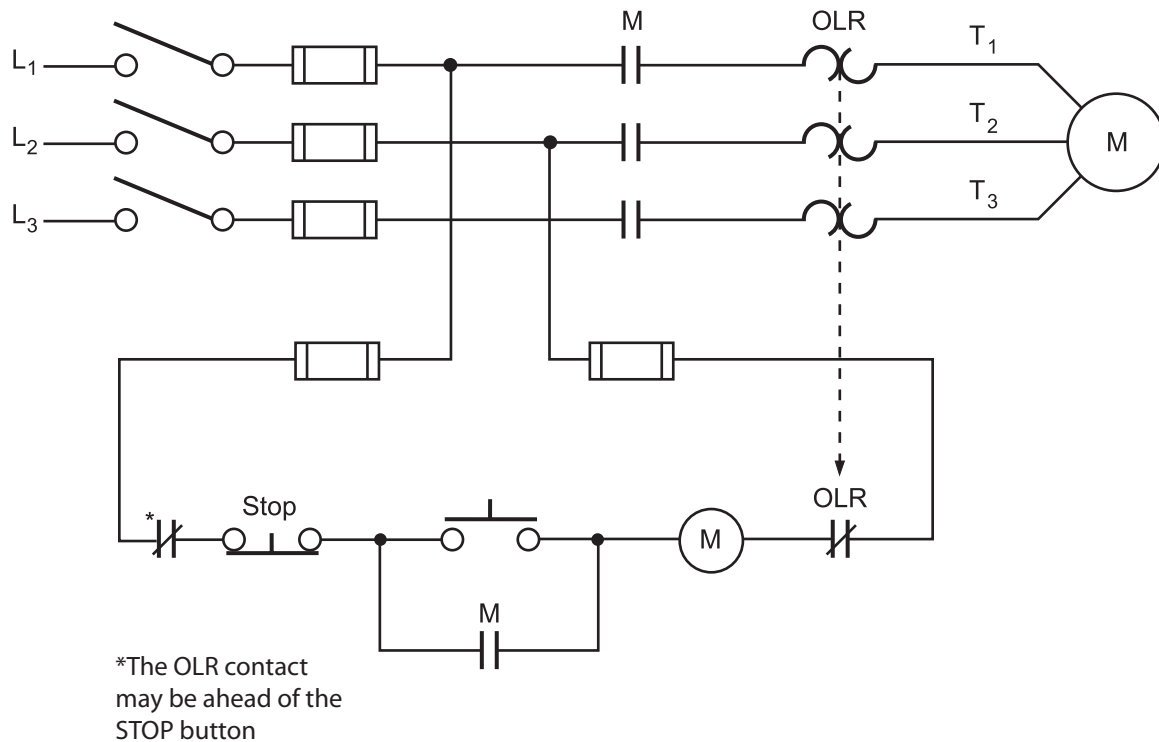


Figure 7—Using a single OLR contact for three heaters

Control circuit voltage

All the preceding circuits utilized full-voltage control. That is, the pilot devices in the control circuit operate at the same voltage as the motor or power circuit. This may be a hazard, so a control transformer is often used to step down the voltage of the control circuit to a lower, safer level.

The schematic in Figure 8 shows a motor that operates at 600 V, but the control transformer steps down the voltage in the control circuit to 120 V. This reduces the shock hazard to the push-button operator. The magnetic starter coil is then rated at 120 V, not at 600 V.

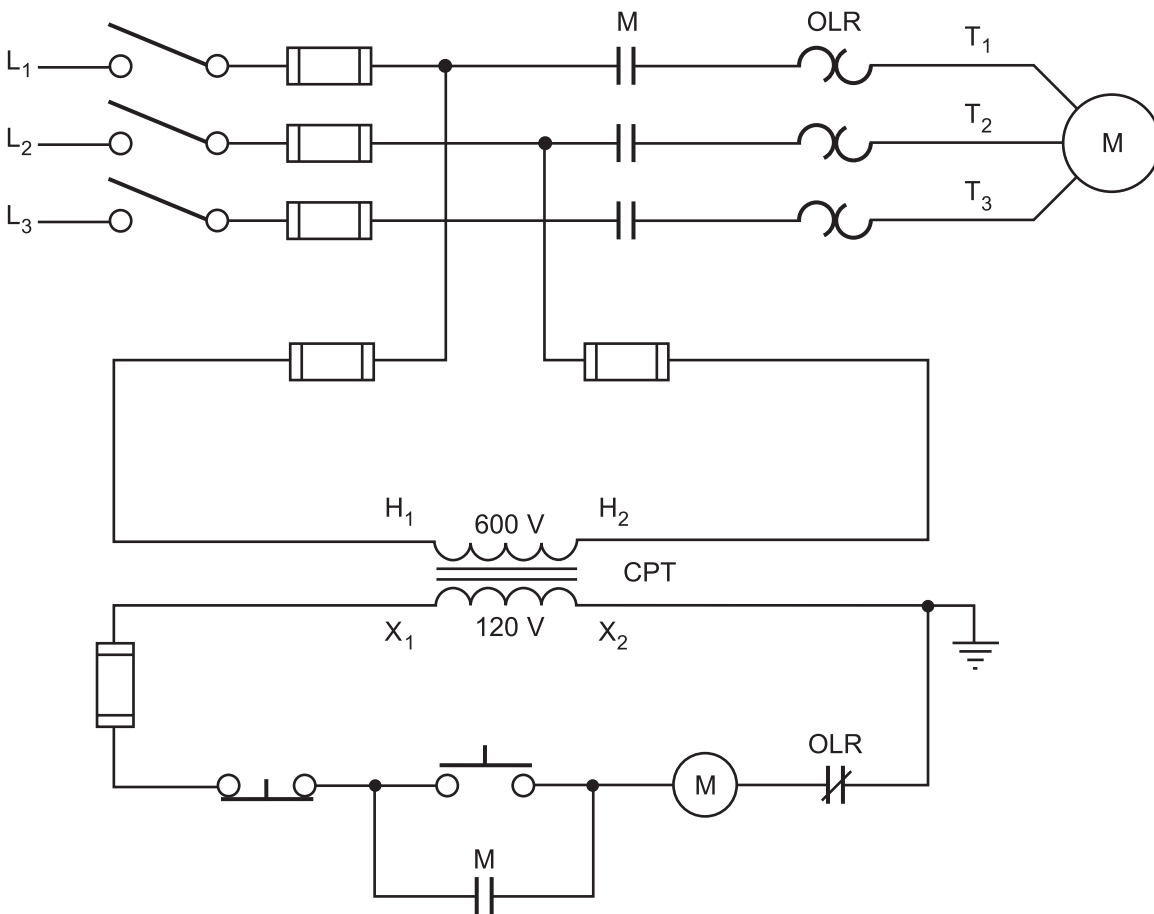


Figure 8—Control power transformer



Now do Self-Test 2 and check your answers.

Self-Test 2

1. List four components found in the power circuit of an across-the-line magnetic starter circuit.

2. List three components found in the control circuit of a magnetic starter.

3. a. A two-wire control circuit provides under-voltage _____ .

- b. A three-wire control circuit provides under-voltage _____ .

4. a. Two-wire control circuits usually include _____-contact initiating devices.

- b. Three-wire control circuits usually include _____-contact devices.

5. What is the purpose of a pilot light?

6. When operating a motor from two or more locations, the STOP buttons are connected in _____ , and the START buttons are connected in _____ .

7. What is meant by *full voltage control*?

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 3:

Develop schematic and wiring diagrams for three-phase magnetic starters

One of the most frequently used diagrams in motor control work is the *schematic diagram*. It uses symbols to identify components and interconnecting lines to display the electrical continuity of a circuit. Schematic diagrams are also called *ladder diagrams* or *elementary diagrams*.

Various symbols are used in schematic diagrams. As you work with motor control circuits, you will have no difficulty identifying many of the symbols. Some of the more common symbols are shown in Table 1.



Study the symbols shown in Table 1.

Wiring diagrams, also called *connection diagrams*, are commonly used in motor control installations. This type of diagram shows the physical relation of all devices in the system and the conductor terminations between these devices.

Comparison of schematic diagrams and wiring diagrams

A wiring diagram simplifies the electrician's task of installing conductors between devices in a circuit.

A wiring diagram shows the relative layout of the components and the wire connections between them. To use this diagram effectively, the electrician must be familiar with the actual components.



Study the Wiring Diagram in Figure 1.

Table 1: Chart of common symbols for schematic diagrams

SWITCHES											
Disconnect 	Circuit Breaker 	LIMIT SWITCHES		Motion Switch 	FOOT SWITCHES						
		Normally Open 	Normally Closed 		N.O. 	N.C. 					
		Held Closed 	Held Open 								
PRESSURE & VACUUM SWITCHES		LIQUID LEVEL SWITCH		TEMPERATURE - ACTUATED SWITCH		FLOW SWITCH (AIR, WATER, ETC.)					
N.O. 	N.C. 	N.O. 	N.C. 	N.O. 	N.C. 	N.O. 	N.C. 				
FUSES Power or Control 	2 Position 	2 POSITION		3 POSITION		METER					
	3 Position 					Indicate Type by Letter 					
PUSH-BUTTONS						PILOT LIGHTS					
MOMENTARY CONTACT				MAINTAINED CONTACT		INDICATE COLOUR BY LETTER					
SINGLE CIRCUIT		DOUBLE CIRCUIT		Mushroom Head	Illuminated	Two Single Ckt.	One Double Ckt.	Non Push-to-test	Push-to-test		
N.O. 	N.C. 	N.O. 	N.C. 								
CONTACTS						COIL	OVERLOAD RELAY	CONNECTION			
INSTANT OPERATING		TIME CONTACTS-CONTACT ACTION RETARDED WHEN COIL IS:						Mechanical			
N.O. 	N.C. 	ENERGIZED		DE-ENERGIZED				Mechanical Interlock			
		N.O. 	N.C. 	N.O. 	N.C. 						
TRANSFORMERS				AC MOTORS		WIRING					
Auto 	Iron Core 	Current 	Dual Voltage 	Single Phase 	Three Phase 	Not Connected 	Connected 	Power 	Control 	Wiring Terminal 	
										Ground 	

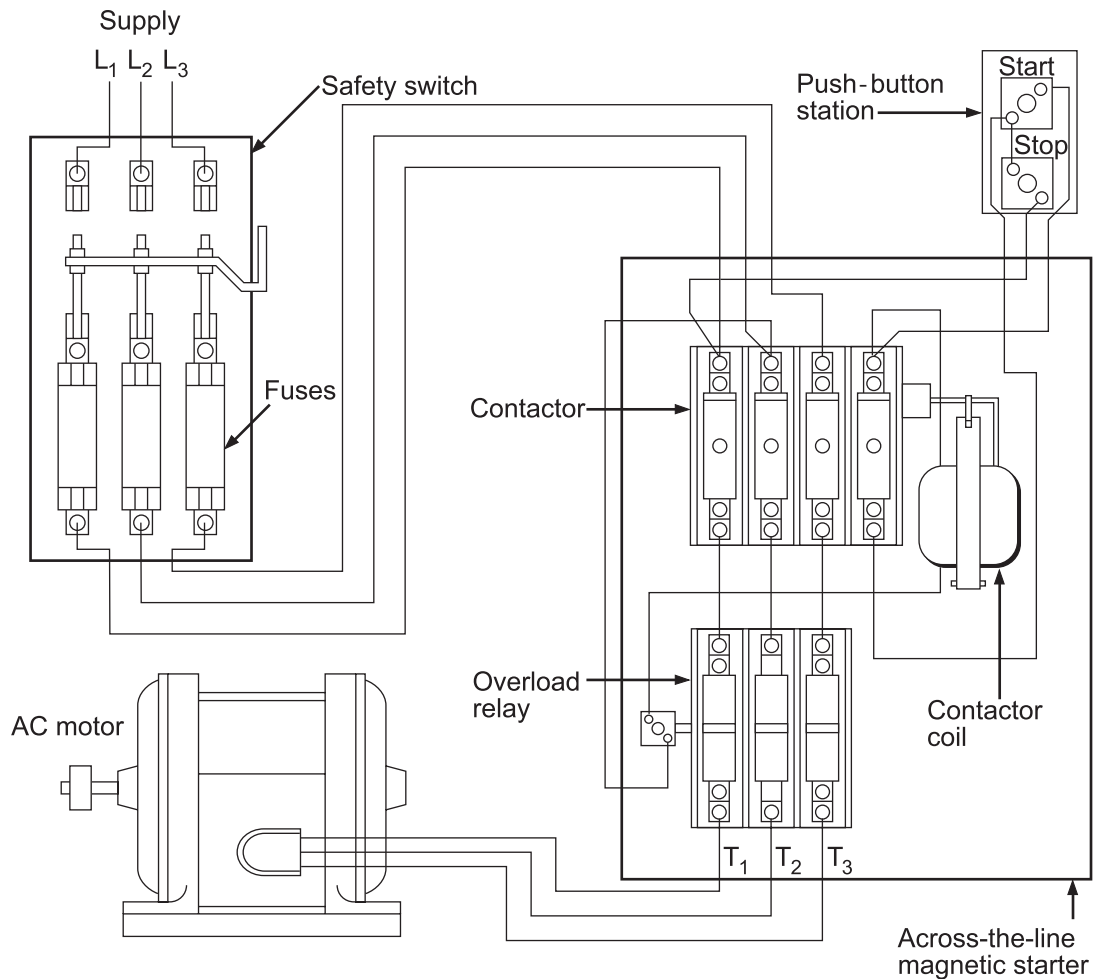


Figure 1—Wiring diagram for an across-the-line magnetic starter

The schematic diagram is useful for quickly identifying the electrical operation of a circuit, but it is usually more time-consuming to wire from a schematic than from a wiring diagram. Also, a wiring diagram is easy to wire from, but more awkward for identifying actual circuit operation. Compare the wiring diagram in Figure 1 with the equivalent schematic diagram in Figure 2.

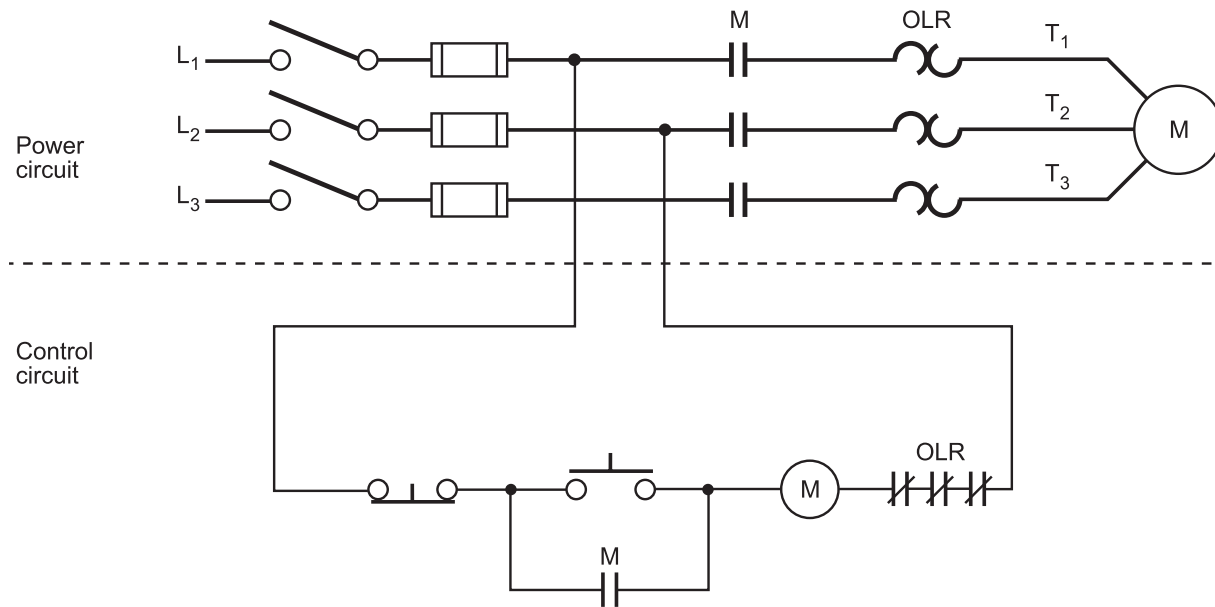


Figure 2—Schematic diagram of an across-the-line magnetic starter

In any electrical installation, it is convenient to have both schematic and wiring diagrams, but this is not always the case. To determine the number of conductors between devices and to simplify wiring procedures, the electrician may need to convert a schematic diagram to a wiring diagram. Also, to facilitate troubleshooting, the electrician may need to develop a schematic from a given wiring diagram.

Converting from schematic diagrams to wiring diagrams

To convert from a schematic to a wiring diagram, a simple numbering system is commonly used. The schematic diagram in Figure 3 represents a basic across-the-line magnetic starter with a single STOP-START push-button control.

- Up to the main contacts, wire numbers for the power circuit are a continuation of the supply line markings: L_1 , L_2 and L_3 .
- From the load side of the main contacts, wire numbers match the motor terminal markings: T_1 , T_2 and T_3 .

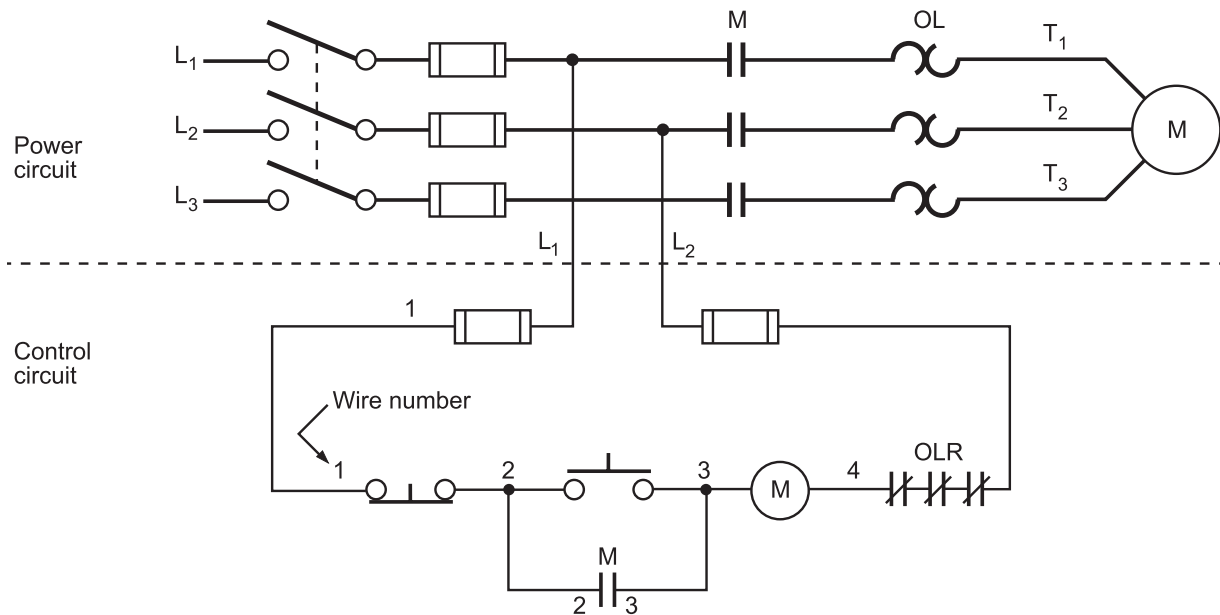


Figure 3—Wire-numbering system for motor control circuits

Control circuit supply is taken from two lines of the power circuit. L_1 and L_2 designate the control circuit power source.

- From this point in Figure 3, number the control circuit independently.
- Assign number 1 to the first wire entering the control circuit. In Figure 3, this is at the left-hand side of the control fuse to the STOP button.
- Trace through a device in the schematic diagram, increasing the numbers given to wires. Except for common terminal strips, each time an operational device or contact is passed, change the number.
- Give the same number to all wires that are spliced or connected to the same terminal.
- Assign number 2 to the wire leaving the right-hand side of the STOP button. This number is common to the left-hand side of the START button and to the seal-in contact. All three of these terminals are numbered 2.
- Continue to trace through the START button and assign number 3 to the next wire you need. This number is common to the right-hand side of the seal-in contact and to the left-hand side of the magnetic coil.
- You could continue numbering the right-hand side of the magnetic coil and so on, but the internal wiring of the starter is usually done by the manufacturer. There is no need to continue the numbering system, since you are usually concerned with the wiring of control devices remote from the starter itself.
- As more lines are encountered, number in succession from left to right and then from top to bottom.

Once you have completed the numbering of the schematic, you can use the information for a wiring diagram. Figure 4 is a partially completed wiring diagram showing the devices used in this schematic. The dotted lines represent the enclosures for different devices. The pushbutton station is separated off to the right.

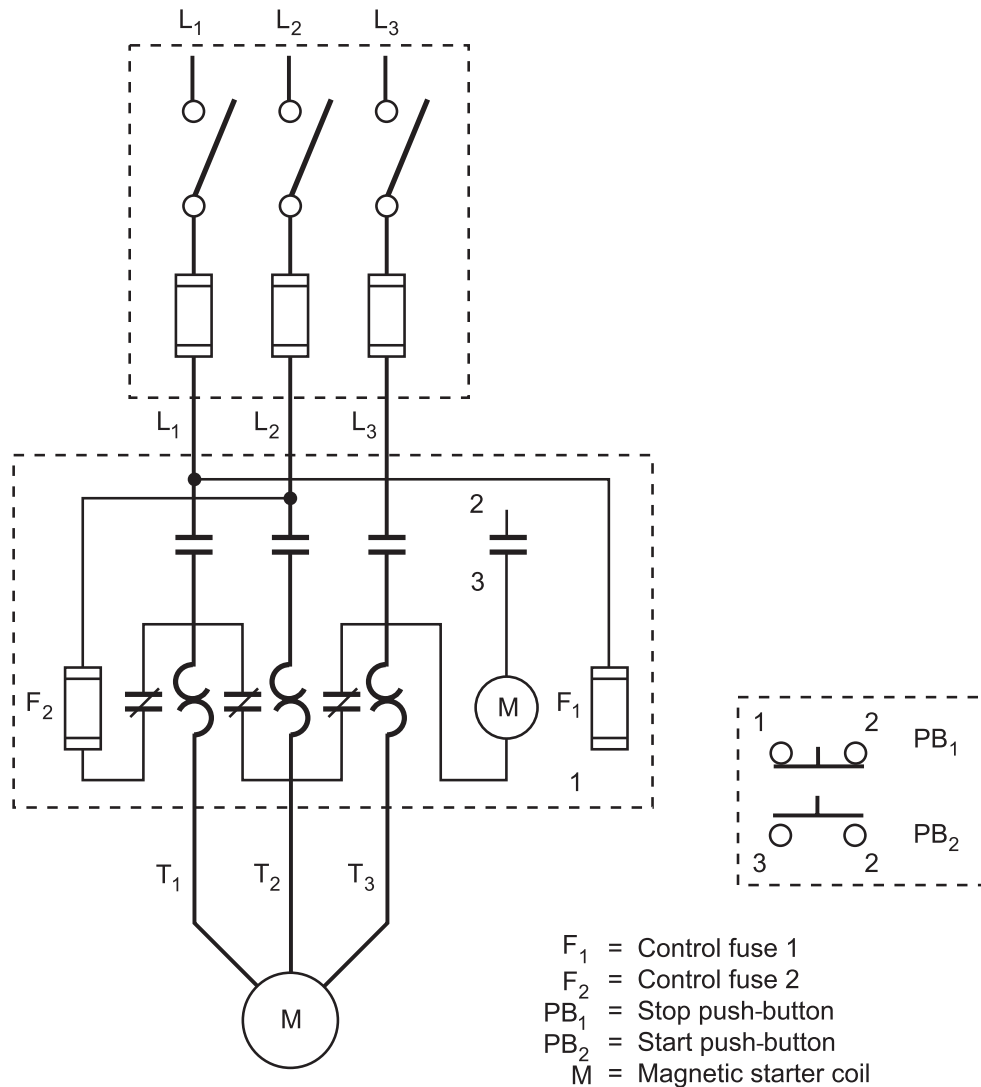


Figure 4—Developing the wiring diagram

To complete your wiring diagram and to determine the number of conductors between devices, you must first identify the numbers assigned to the terminals of each device in the schematic diagram.

- Compare the terminal numbers in Figure 4 with the schematic diagram in Figure 3.
- Once you have identified appropriately numbered terminals, it is easy to interconnect all terminals with the same number.
- This completes the wiring diagram, so that it looks like Figure 5.

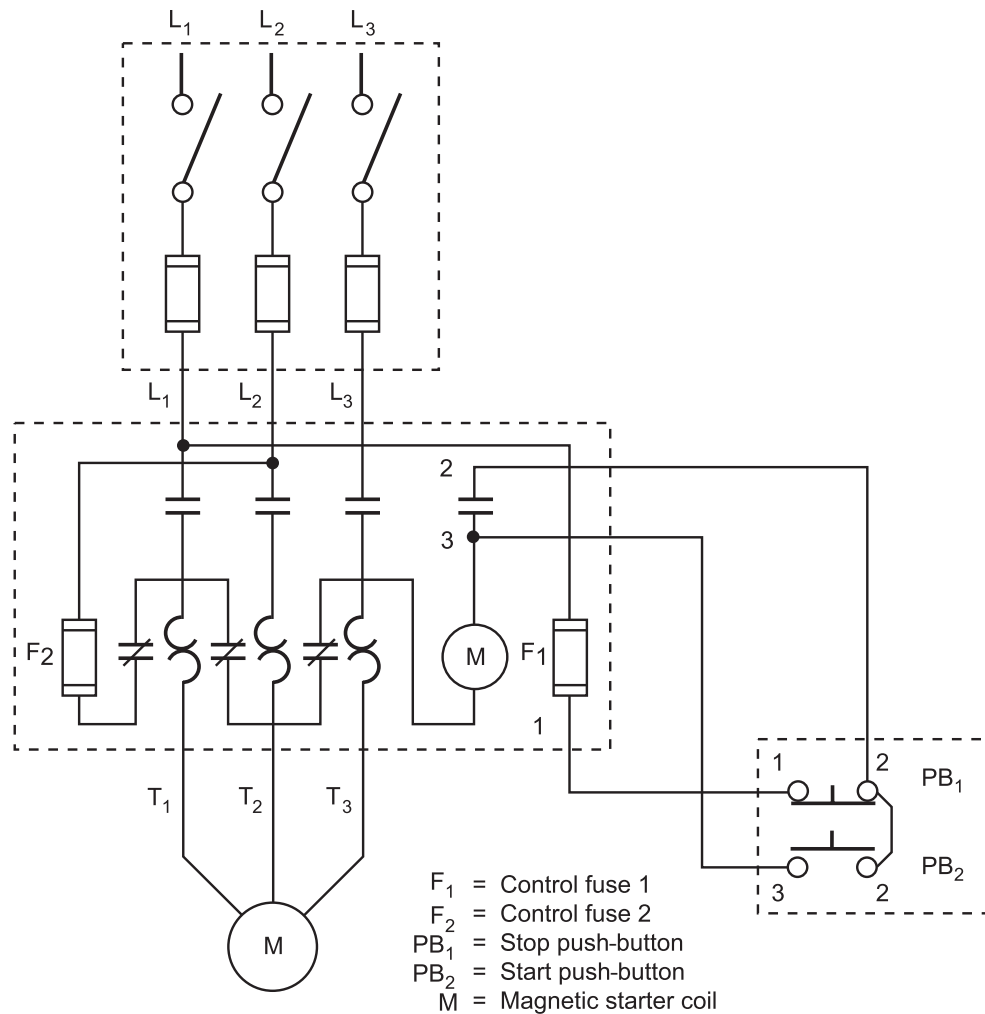


Figure 5—Completed wiring diagram from the schematic in Figure 3

This is a relatively simple example of the procedure to follow in developing a wiring diagram from a schematic using a numbering system. Now you can use the completed wiring diagram to determine the number of conductors required between devices. Refer to the wiring layout in Figure 6.

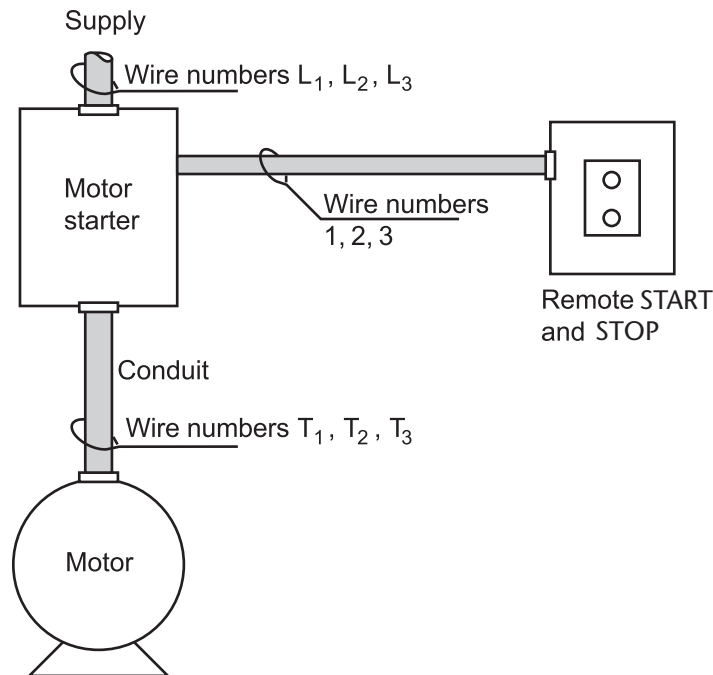


Figure 6—Wiring layout guide

Converting from wiring diagrams to schematic diagrams

The wiring diagram in Figure 7 shows the relative positions of all components in the control circuit and in the power circuit. The power circuit is identified by its somewhat heavier lines and by the fact that the motor load current passes through each of its components. All components are electrically connected in the least complex way possible.

Before we attempt to convert the control-circuit part of the wiring diagram to a schematic, you must be aware of a few basic principles:

- STOP buttons are connected in series.
- START buttons are connected in parallel.
- Maintaining contacts are in parallel with START buttons.
- Main coil, indicating lights and other control coils are all connected in parallel.
- OLR contacts are in series with the stop circuit. Traditionally, OLR contacts were placed on the Line 2 side of the coil. New CEC regulations allow OLR contacts to be placed within the stop circuit on the Line 1 side of the control circuit.

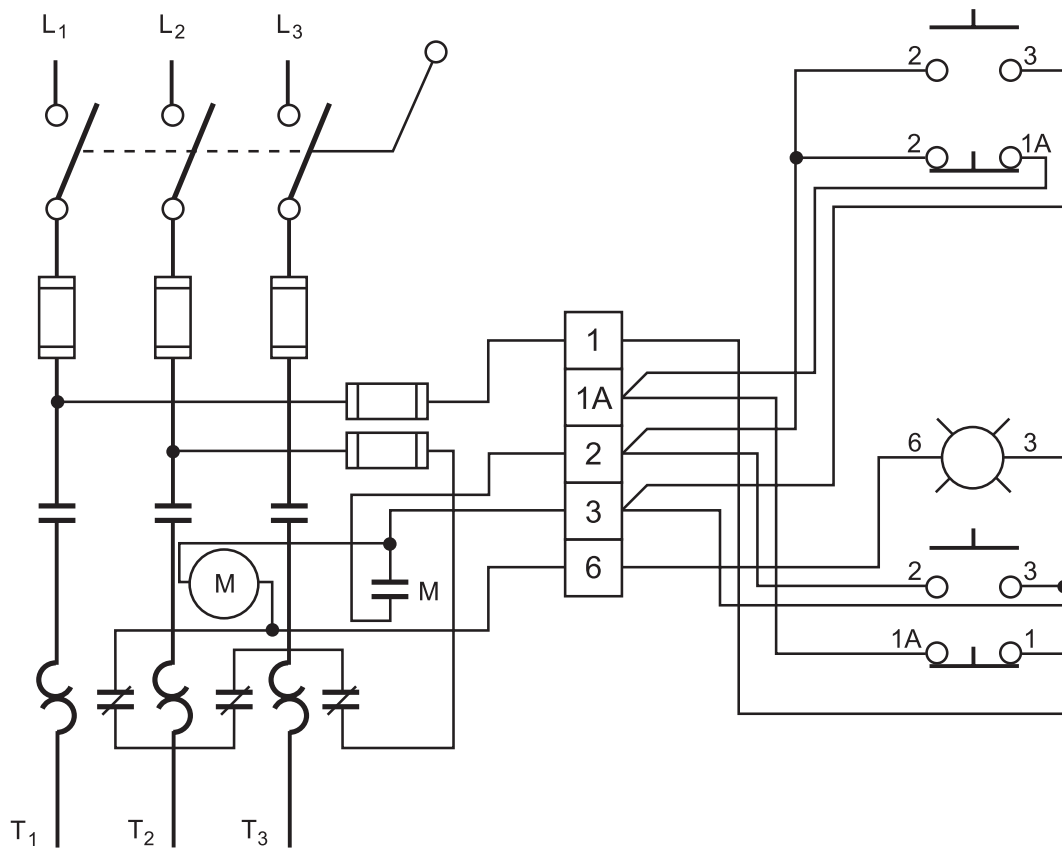


Figure 7—Wiring diagram for a motor control and motor power circuit

Figure 8 shows the structure of a typical motor control schematic. Pilot devices are placed into the circuit so that they can perform their required function. The basic sections of a motor control circuit are as follows:

Stop circuit

Any device that stops the motor or prevents it from starting.

Start circuit

Any device that starts the motor.

Load circuit

Any device that is energized when the motor starts. Examples are M coil, CR relay and indicating light.

Protection portion

Usually, these are OLR contacts that stop the motor when it is overloaded for a predetermined amount of time.

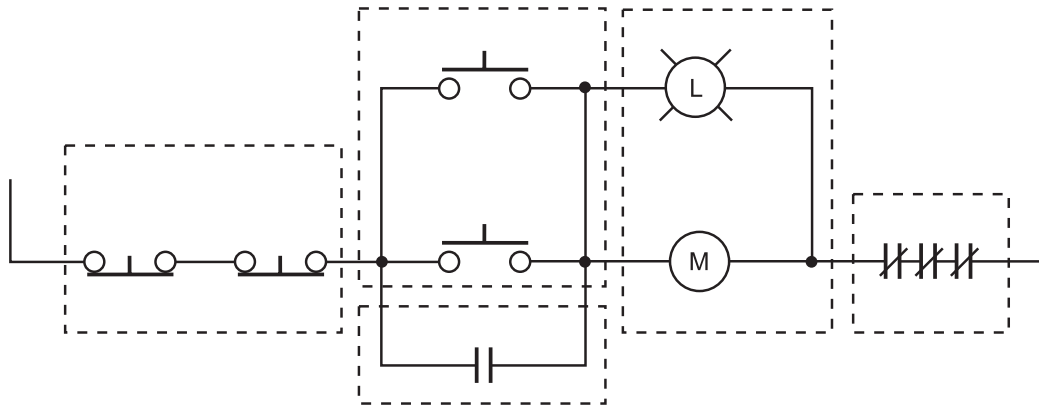


Figure 8—A typical motor control schematic

To convert the wiring diagram in Figure 7 to a schematic diagram, follow these basic rules:

1. Count the number of control components such as STOP buttons, START buttons and operating devices.
2. Organize these pilot devices into appropriate positions, as shown in Figure 9.

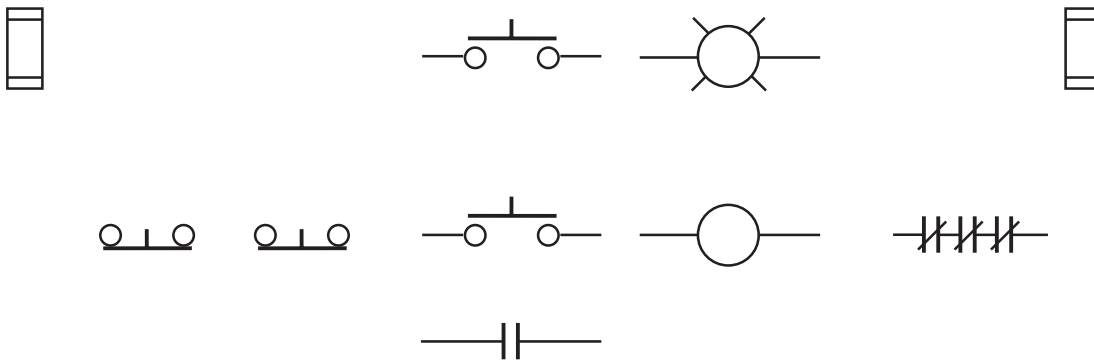


Figure 9—Placement of control components

3. Place the identifying wire numbers used in the wiring diagram of Figure 7 on each component, as shown in Figure 10.
4. Trace from Line 1 through the wiring diagram to Line 2, connecting the like numbers. This ensures that the conventionally drawn schematic is correct.
5. It is helpful to highlight each control conductor simultaneously in the wiring diagram and in the schematic diagram. This will confirm that the wires are correct in your schematic diagram.

The completed schematic diagram is shown in Figure 11.

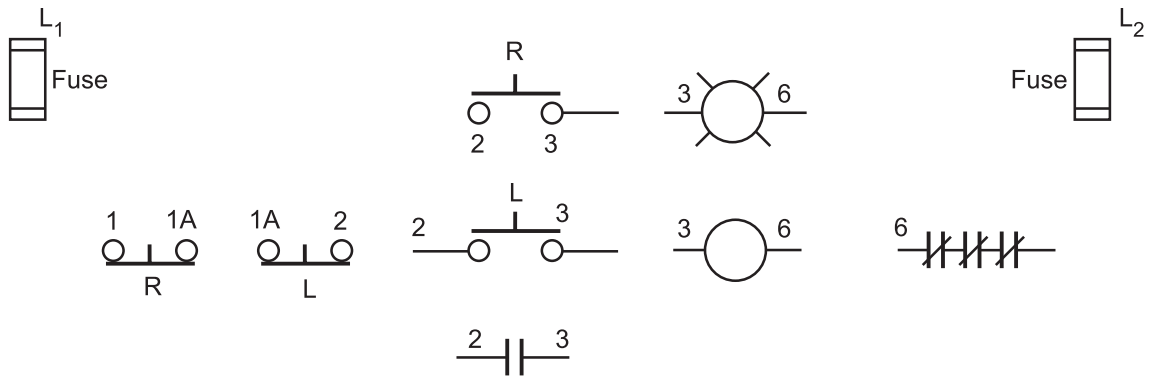


Figure 10—Labelling control components

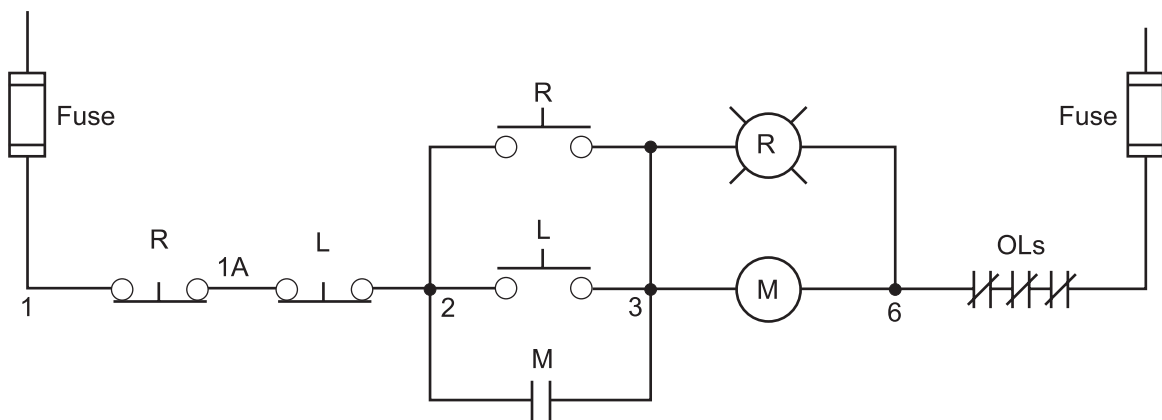


Figure 11—Completed schematic diagram



Now do Self-Test 3 and check your answers.

Self-Test 3

1. Draw a simple schematic diagram for a control circuit that uses a HAND–OFF–AUTO selector switch. An n.c. pressure switch governs the operation of the starter in the AUTO position.

2. Draw a simple schematic diagram for a control circuit that uses two separate STOP-START push-button stations.

3. How does a wiring diagram differ from a schematic diagram?

4. What is meant by a *wire numbering system*?

5. How does a numbering system help in the development of a wiring diagram?

6. Develop a schematic diagram for the control circuit in the wiring diagram in Figure 1.

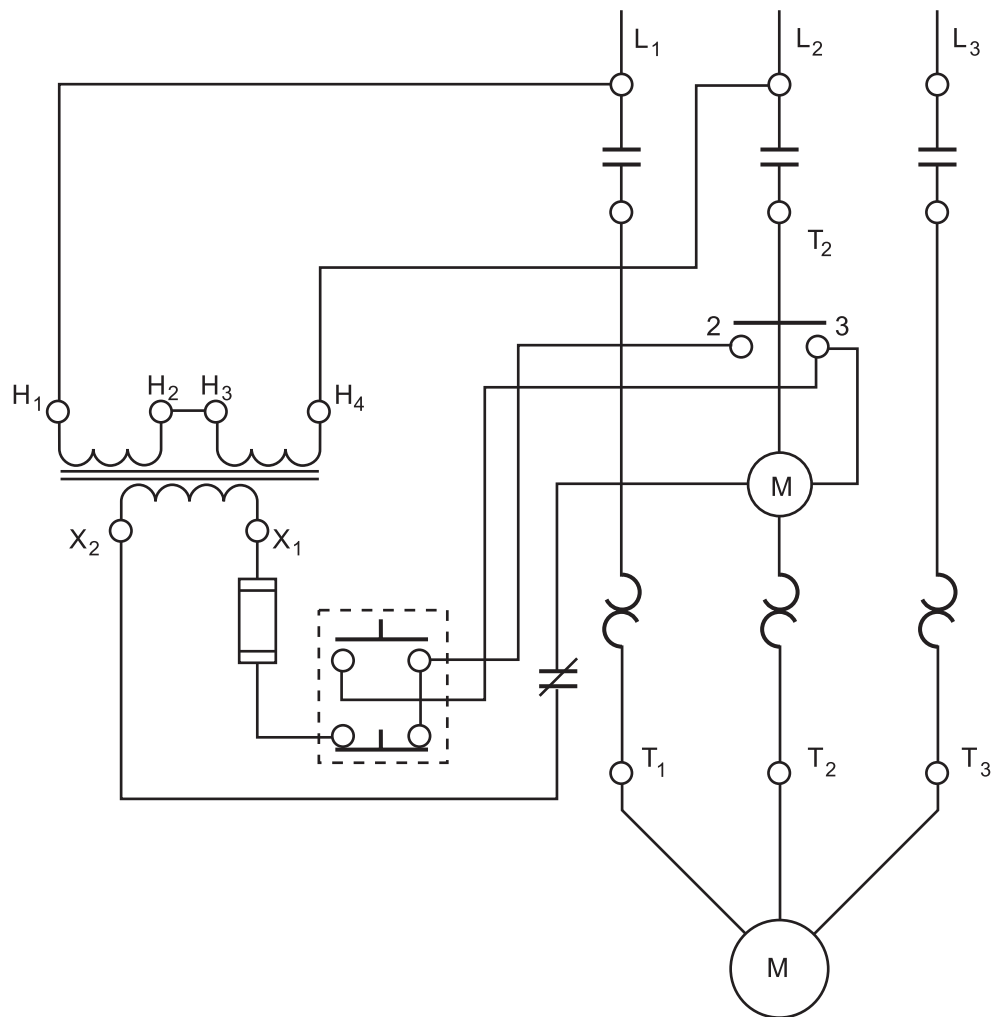


Figure 1—Wiring diagram for Question 6

7. Develop a schematic diagram for the control of a motor from either a local or a remote STOP-START push-button station. The motor starter has a red motor-running indicator light and a green motor-stopped indicator light.
8. Using the schematic diagram from Question 7 as a guide, complete the wiring diagram in Figure 2. Use the minimum number of conductors between devices.

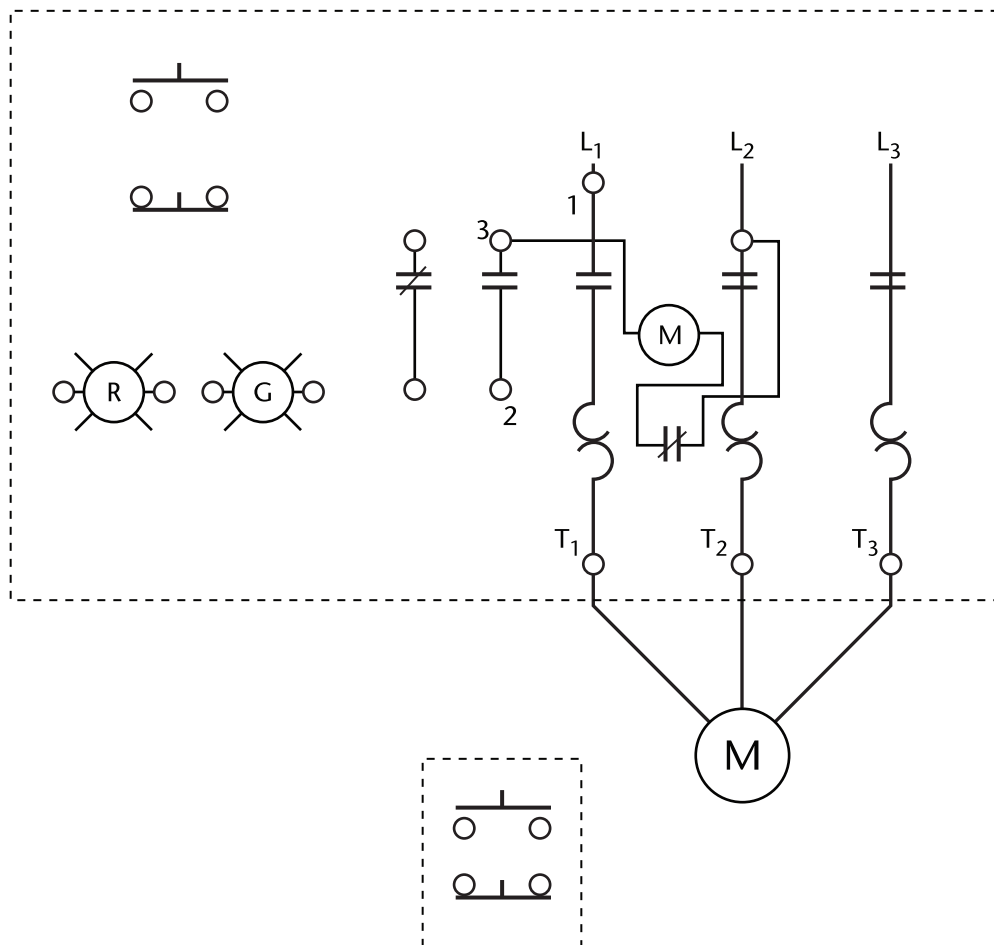


Figure 2—Base for wiring diagram in Question 8

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 4:

Describe features of control and latching relays

Various types of relays are used in motor-control applications. *Simple relays* are magnetic devices used remotely to switch loads and circuits. *Magnetic contactors* are basically relays that have large heavy-duty, hp-rated contacts, as well as one or two small auxiliary seal-in contacts. Some motor-control circuits require the sequencing of several starters, as well as signal or alarm indication. Since magnetic starters do not normally have sufficient electrical contacts to accomplish this, control relays are used.

Control relays

Control relays are used as auxiliary devices in motor-control circuits to switch low-level currents. Examples are the currents in the coils of magnetic starters, in indicating lights, audible alarms, and even sometimes in small motors and electric heaters.

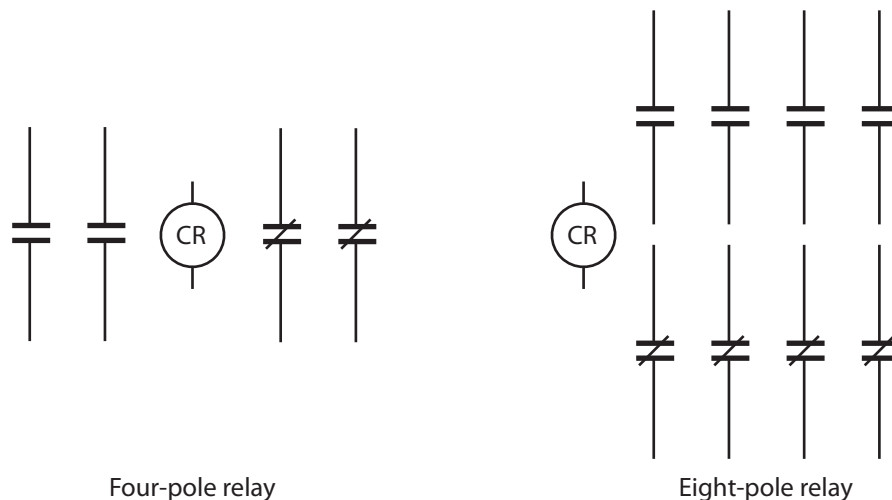


Figure 1—Control relays

A control relay consists of an electromagnetic coil with one or more sets of contacts. The contacts are available as either normally open (n.o.) or normally closed (n.c.) types. In some cases they are convertible from n.o. to n.c. and from n.c. to n.o. Each contact of the relay is called a *pole*. Most control relays are available in standard multiples of poles such as two-pole, four-pole, six-pole, eight-pole and ten-pole. The symbols for four- and eight-pole relays are shown in Figure 1.

Relay contacts are usually silver-plated to improve their conductivity. Although single-break contacts are used, most industrial quality relays use double-break contacts to improve their interrupting capability. See Figure 2.

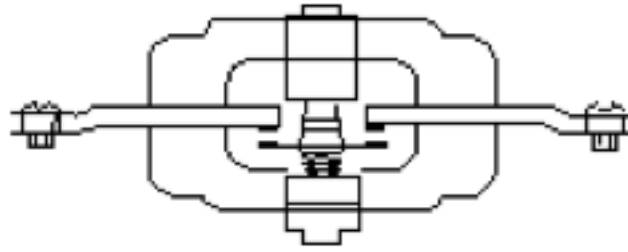


Figure 2—Double-break contact

Contacts are usually rated at 10 amperes and as high as 600 volts AC; however, contact ratings can be misleading. Usually, three different current ratings are published:

- Inrush or *make contact* rating
- Normal or *continuous* rating
- Opening or *break contact* rating

These ratings are sometimes significant when switching inductive rather than resistive types of loads. Table 1 lists some typical current ratings for auxiliary contacts.

Table 1: Contact ratings

AC ratings – EEMAC A600, Inductive power factor = 0.35					
	Make		Break		Continuous
Volts	Amps	VA	Amps	VA	Amps
120	60	7200	6	720	10
240	30	7200	3	720	10
480	15	7200	1.5	720	10
600	12	7200	1.2	720	10

Relay coils are usually constructed in a moulded-epoxy casing to reduce moisture absorption and improve mechanical protection. Coils are generally available in standard AC or DC voltage ratings from 24 V to 600 V. Although the rated voltage is marked on the coil, a relay is designed to activate or *pick up* at approximately 85% of its rated voltage. Similarly, it will not deactivate or *drop out* until the voltage falls below 85% of the rated value. Usually, relay coils can operate at an over-voltage of 10% without damage to the coil.

Most relays are designed for mounting in a vertical position, so that the line conductors are brought into the top, and the load conductors leave from the bottom of the unit.

Latching-type control relays

Some special control relays are the *latching type* (see Figure 3). In these it is necessary to energize the coil only momentarily to pick up the relay. After energizing the coil, the relay remains mechanically latched in the closed position even after power is removed from the coil. To open the relay contacts, you must momentarily energize a second coil to trip the mechanical

latch. The advantage of this type of relay is that it is not necessary to keep the coil continuously energized, which results in quieter operation.

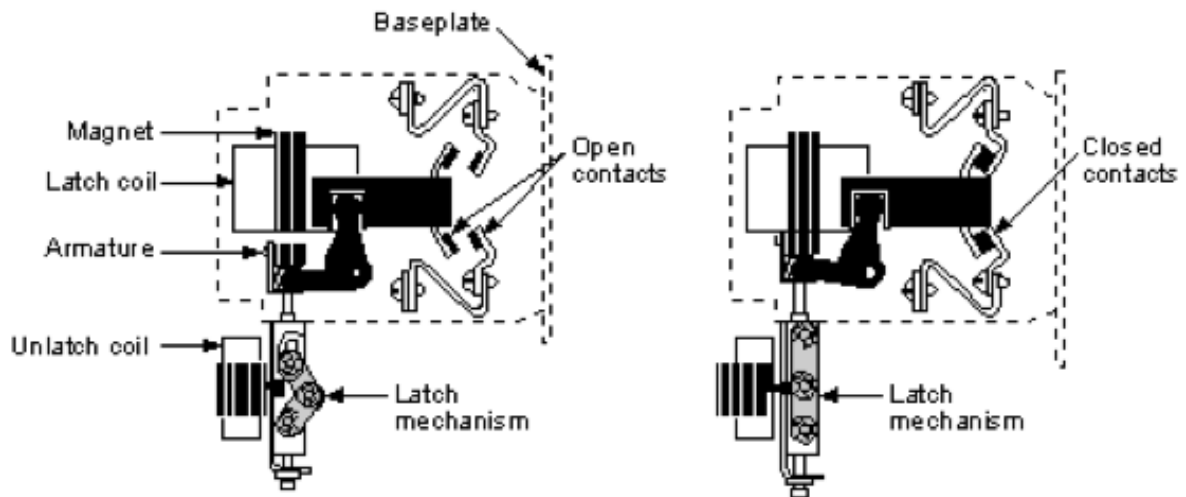


Figure 3—Latching-type control relay



Now do Self-Test 4 and check your answers.

Self-Test 4

1. Why is it sometimes necessary to use control relays in conjunction with magnetic motor starters?

2. When a normally open contact on a control relay is rated at 10 amperes AC, does this mean that it can make and break all values of current up to and including 10 A? Explain your answer.

3. What is a latching relay?

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 5:

Describe operation of jogging circuits

Jogging and *inching* are control terms that mean momentarily operating a motor to allow small movements of the driven machine. Various control schemes can be used to jog or inch a motor drive.

Many texts show a double-block, jog push-button circuit like the one in Figure 1, but this circuit is dangerous. If the jog button is released so that its n.c. contact is made before the magnetic coil's seal-in contact breaks, then the circuit remains energized and the motor continues to run.

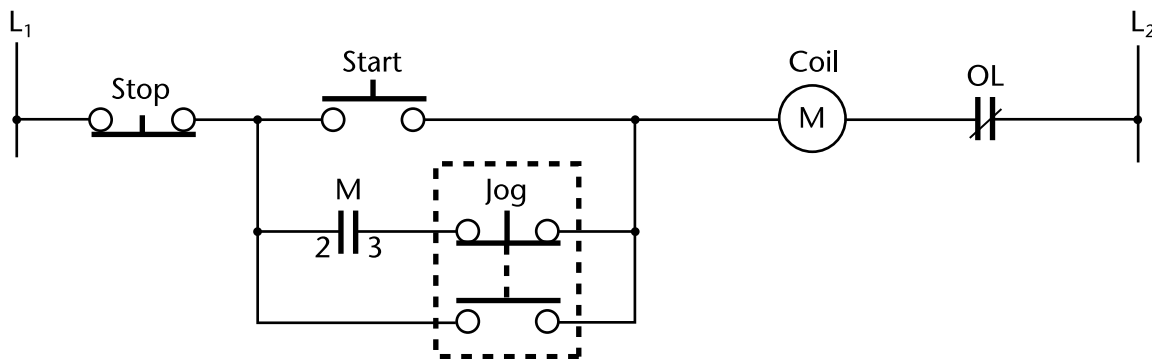


Figure 1—Dangerous jog push-button circuit

To eliminate this problem, use one of several possible *definite break circuits* that include selector switches or control relays.

Jog-run selector circuit

A two-position, jog-run selector switch can be added to a conventional three-wire control circuit, as shown in Figure 2.

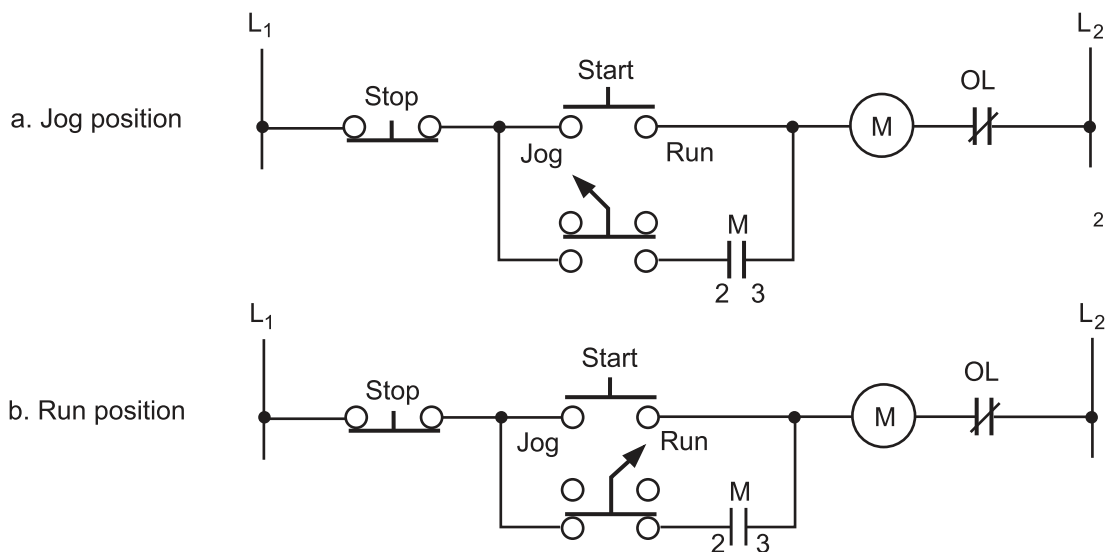


Figure 2—Jog-run selector circuit

- When the switch is placed in the jog position, the START button acts as the JOG button. In this position, the selector switch opens the seal-in contact circuit so that the magnetic starter coil is energized only while the START button is held down.
- When the switch is in the run position, the selector switch closes the seal-in contact circuit, so that the magnetic starter coil is energized when the START button is pressed and stays energized until the STOP button is pressed.

Jogging circuit with control relay

A more sophisticated jogging circuit uses a control relay as shown in Figure 3.

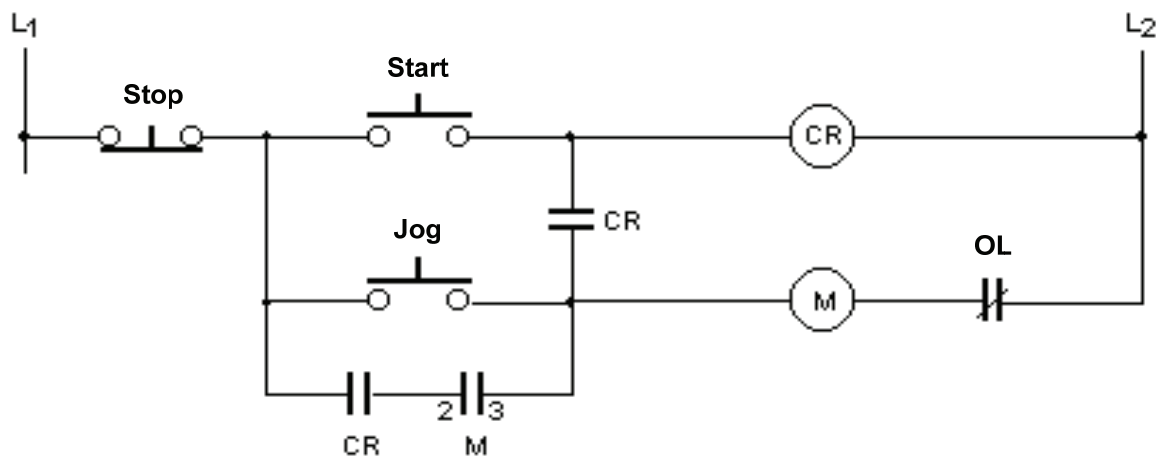


Figure 3—Jogging circuit with control relay

In this circuit, pressing the START button energizes a control relay. The control relay contacts energize the magnetic starter coil. This completes the seal-in circuit of the magnetic starter.

Study Figure 3 carefully. When using the JOG button, the starter coil is energized directly and the seal-in circuit is prevented from being completed because of the control relay contacts.

Note that continuous jogging causes the motor to draw repetitive inrush currents. Therefore, the power contacts of the motor starter must be rated for this more severe operating condition. Usually, this means the motor starter must be rated for horsepower higher than the motor it serves.



Now do Self-Test 5 and check your answers.

Self-Test 5

1. What is meant by the term *jogging*?

2. What hazard can occur when using only a simple JOG button with a STOP-START control circuit?

3. How is the hazard in Question 2 overcome?

4. Using the wiring diagram in Figure 1, develop a schematic diagram for the control circuit.

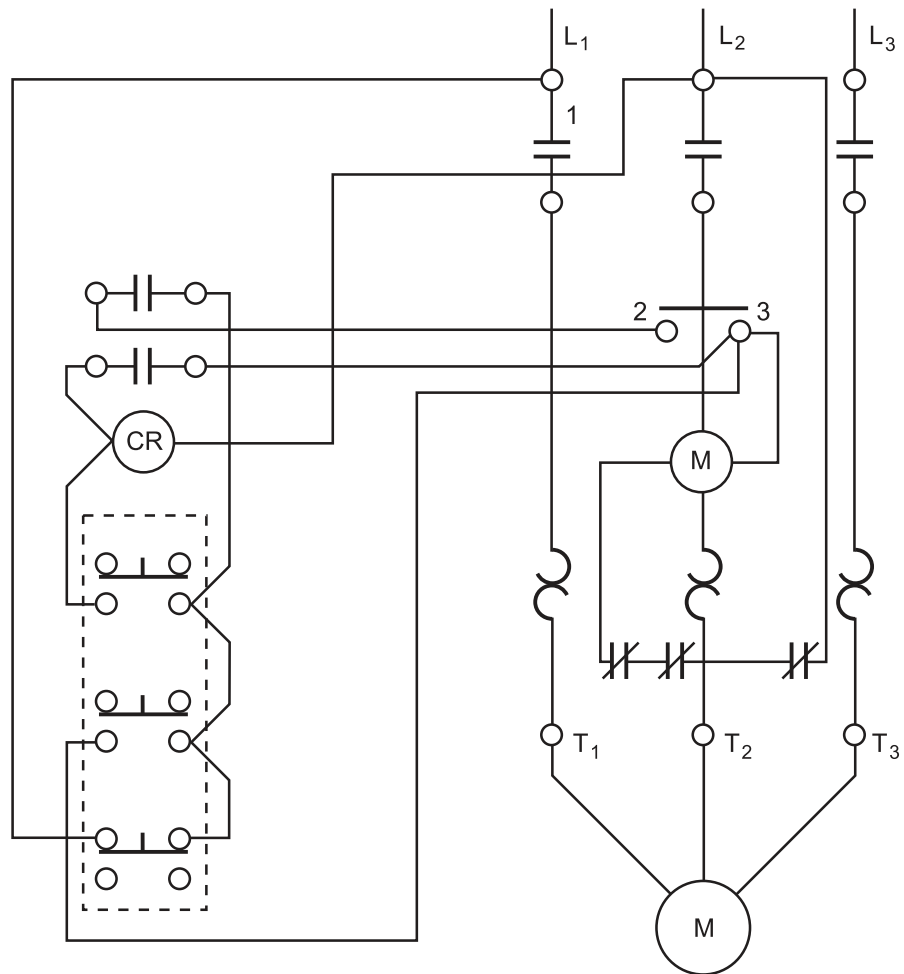


Figure 1—Circuit for Question 4

5. Using the wiring diagram in Figure 2, develop a schematic diagram for the control circuit.

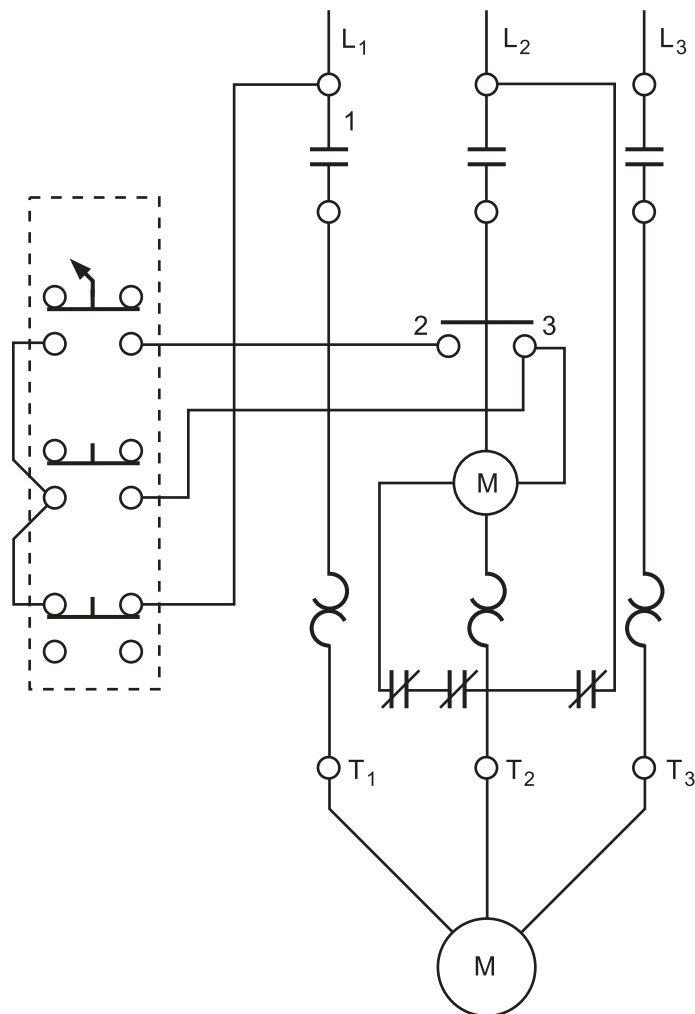


Figure 2—Circuit for Question 5

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 6:

Describe the operation of reversing magnetic starters

If a three-phase motor is energized from an AC supply and its rotation is opposite to what is desired, it is simple to reverse its direction of rotation. All that is needed is to interchange any *two* of the three line leads feeding the motor. This is called *reversing the phase sequence*.

Assume that the line connections shown in Figure 1 result in wrong rotation of the motor. You can reverse the phase sequence by doing the following:

1. De-energize the motor.
2. Swap any two line leads to the motor, making connections as shown in Figure 2.
3. Re-energize the motor and confirm rotation in the opposite direction.

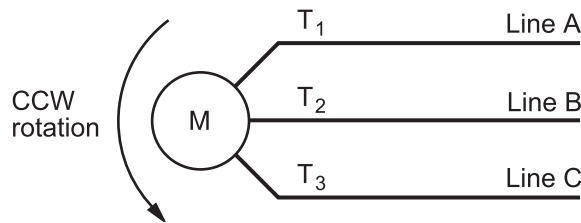


Figure 1—Normal line connections to a three-phase motor

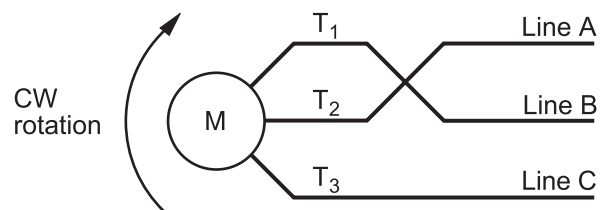


Figure 2—Reversed line connections, giving opposite rotation of a three-phase motor

A reversing magnetic starter uses this same process. The reversing starter has *two* three-pole contactors rather than just one as in the conventional starter. The power circuit for a reversing starter is shown in Figure 3.

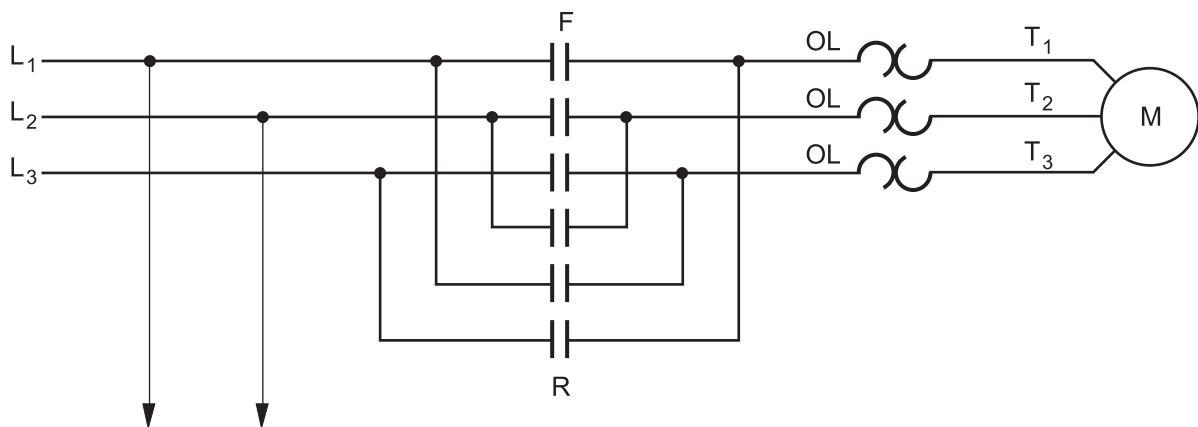


Figure 3—Reversing magnetic starter power circuit

Referring to Figure 3:

- When the forward contactor F is energized, power contacts connect line L_1 to T_1 , line L_2 to T_2 , and line L_3 to T_3 at the motor.
- When F is de-energized and the reverse contactor R is energized, the power contacts connect line L_1 to T_3 , line L_2 to T_2 , and line L_3 to T_1 at the motor. Two of the line leads to the motor have been interchanged so that the rotation of the motor is reversed.



Note that the two contactors must be electrically and mechanically interlocked so that they cannot be energized simultaneously. This prevents all the power contacts from being closed together, which would result in a short circuit across the incoming power supply.

In the power circuit of a reversing magnetic motor starter, only one set of OLR heaters is needed.

The schematic diagram of a push-button control circuit can be developed in three easy steps, as shown in Figure 4 and described as follows:

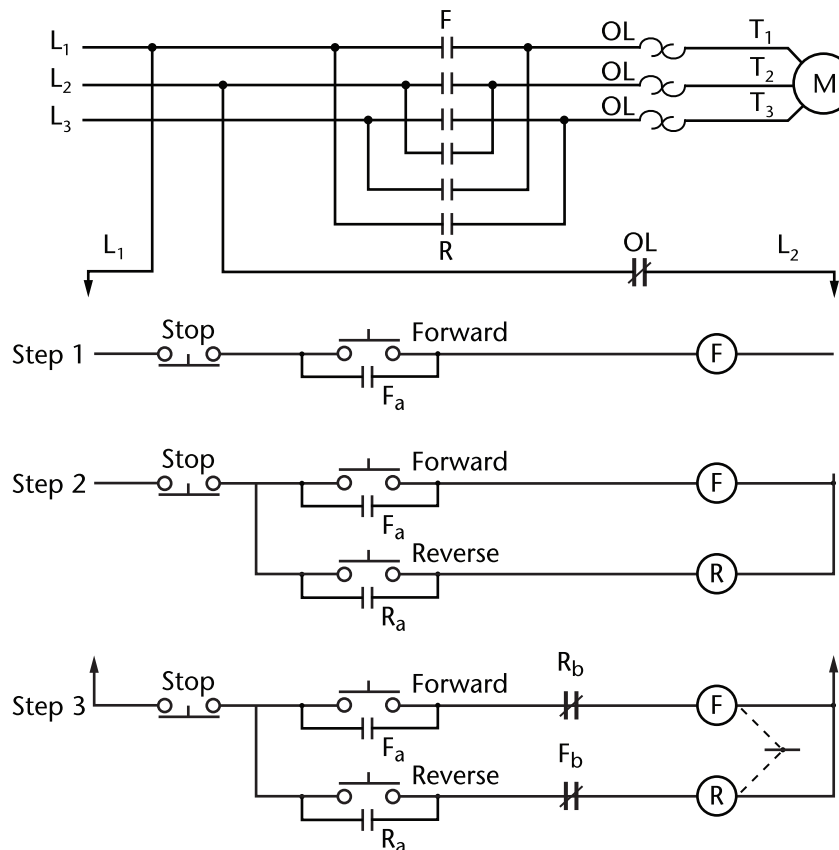


Figure 4—Developing a control schematic for a reversing magnetic motor starter

Step 1: This step shows a STOP-START control of one contactor, in this case the forward coil F. The START button is labelled FORWARD and is connected with its seal-in contact F_a .

Step 2: This step allows the energizing of a second contactor, in this case the reverse coil R. The START button for this coil is labelled REVERSE and is connected with its own seal-in contact R_a .

A second STOP button is not needed since this function is common to both coil paths. The second branch R connects after the STOP button (to the right in the diagram).

Step 3: One more feature is needed: electrical interlocking to prevent the power lines from short-circuiting.

An n.c. auxiliary contact F_b from the forward contactor is connected in series with the reversing coil R. When the forward coil F is energized, contact F_b opens, preventing the reverse coil R from being energized.

Similarly, an n.c. auxiliary contact R_b is connected in series with the forward coil F. When the reverse coil R is energized, contact R_b opens, preventing the forward coil F from being energized.

As an additional safety feature, a mechanical interlock is also provided. This shows as a dotted line between the F and R coils in Figure 4, Step 3.

Figure 5 is a complete schematic diagram for push-button control of a reversing magnetic motor starter.

The circuit also has forward and reverse running-indicator lights.

Notice that an overload condition in either forward or reverse operation de-energizes the control circuit.

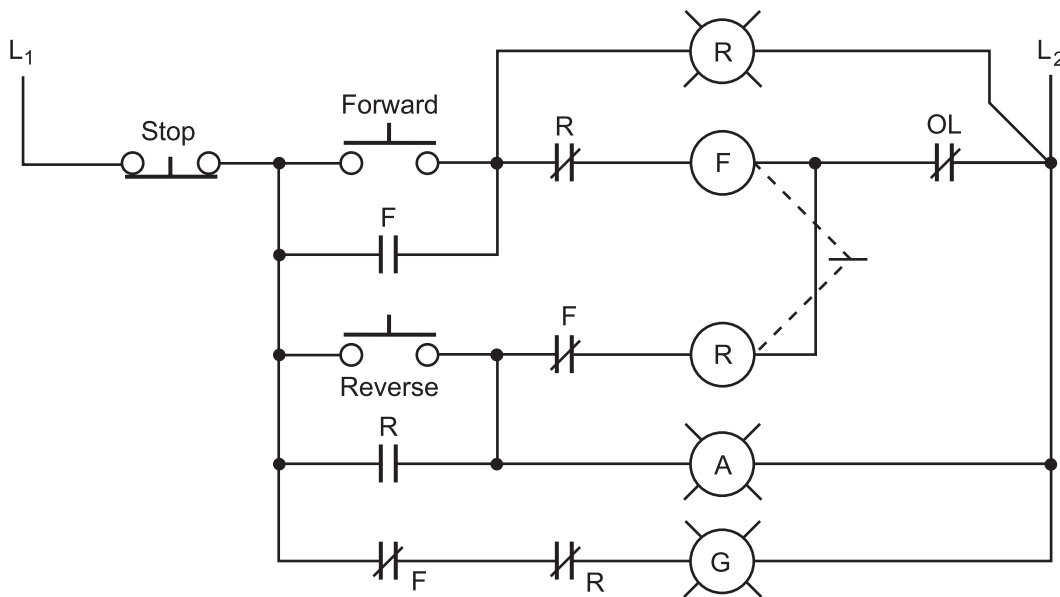


Figure 5—Forward/reverse, push-button control with indicating lights



Now do Self-Test 6 and check your answers.

Self-Test 6

1. What are the constructional differences between a three-phase, reversing magnetic starter and a non-reversing one?

2. How does a reversing starter reverse the rotation of a three-phase induction motor?

3. Why is it necessary to prevent the forward and reverse contactors from being energized simultaneously?

4. What is *electrical interlocking* on a reversing starter?

5. Why is there only one set of OLR contacts in a three-phase reversing starter?

6. If an electrical interlock is provided in a reversing starter, is it also necessary to provide a mechanical interlock?

7. Develop a control schematic illustrating push-button interlocking for a reversing magnetic motor starter.

8. Develop a control schematic from the wiring diagram shown in Figure 1.

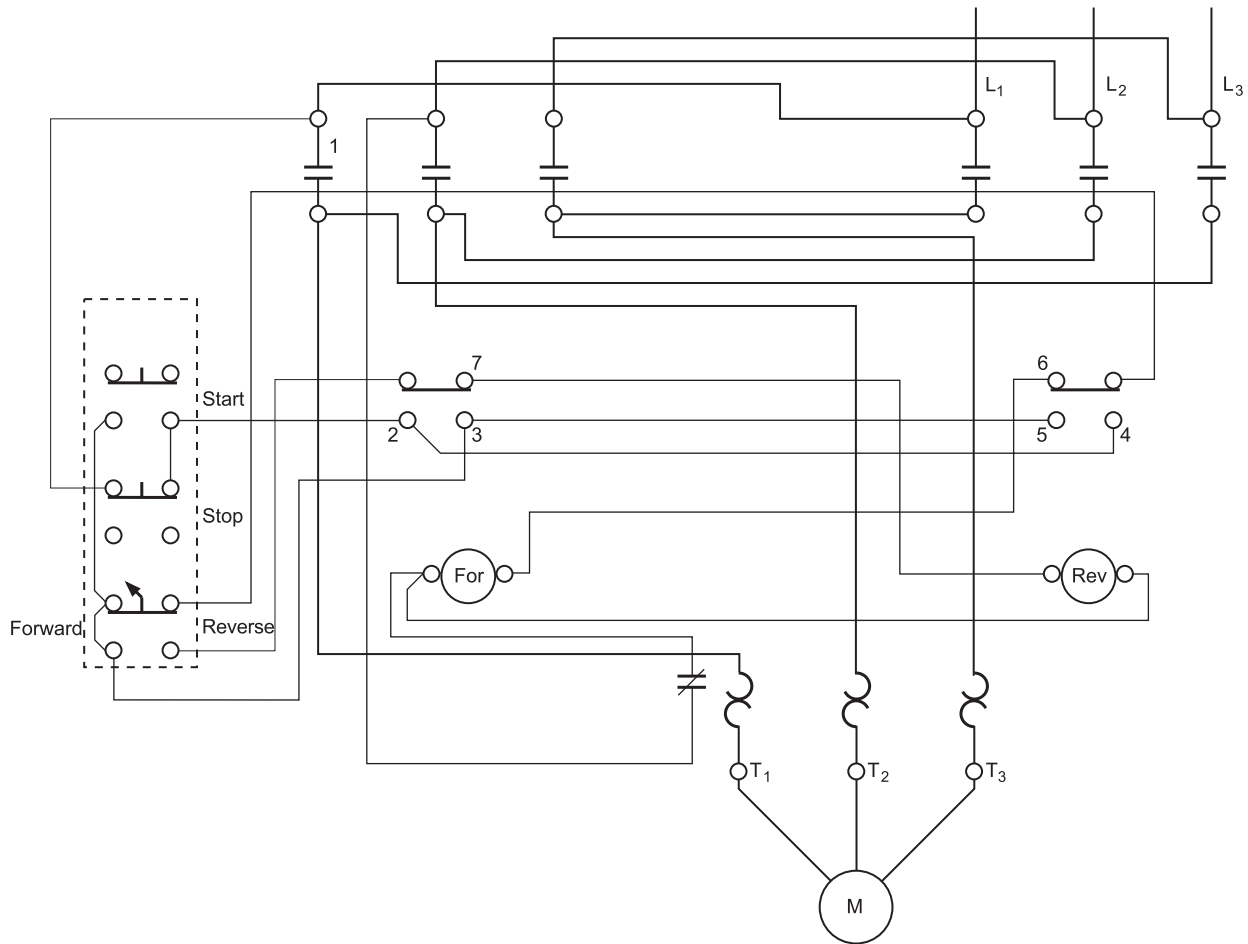


Figure 1—Wiring diagram for Question 8

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 7:

Describe safety lockout procedures

Safety isolation requirements

Before you work on a piece of equipment or machinery with moving parts, you must take certain precautions to ensure everyone's safety. This means following the proper lockout procedure to safely isolate equipment from all sources of hazardous energy.

To be safe:

- It is not enough to simply throw a switch and start work.
- It is not enough to hang a *do not use* sign on a machine.
- It is not enough to *tell* everyone not to turn on the power.
- It is not enough to have everyone *assure* you that no one will activate the power.

As the name implies, a *lockout* procedure uses locks to completely secure devices that control or represent hazards. It also ensures that equipment is de-energized before being maintained or repaired.



To be safe when working on de-energized machinery, *you must*:

- Follow correct lockout procedures.
- Do the lockout yourself.
- Ensure that the circuit is dead before work is started.

WCB rules and regulations

The Workers' Compensation Board (WCB) Occupational Health and Safety (OHS) Regulation contributes to the safety of all workers. For your own safety and the safety of your co-workers, you must become familiar with the regulation.

De-energization and lockout procedures are described in Part 10 of the OHS Regulation.

Note that:

1. You must use your own locks and keys.
2. You must not borrow another person's lock. If necessary, get extra locks from your supervisor.
3. You must remove your own locks.
4. You must not remove someone else's lock.
5. If you apply the first lock, you must ensure that the machinery cannot be operated.
6. In an emergency, a senior shift supervisor may remove someone else's lock, but only after every effort has been made to contact the person who put on the lock. The supervisor must ensure that the equipment will operate safely.



Read OHS Regulation Part 10 concerning de-energization and lockout procedures.

Removing the lockout

You must treat the removal of the last lock from a locked-out control seriously.

Carelessness at this point can cause major injuries to fellow workers, and it can damage equipment.

Before removing the last lock:

1. Make sure that the equipment can be operated safely. If not, provide an appropriate warning tag according to the OHS Regulation.
2. Make sure that all workers are clear.



Now do Self-Test 7 and check your answers.

Self-Test 7

1. With regard to a worker's safety, the term *isolate*, means to:

- a. remove to a remote location
 - b. turn off the switch
 - c. disconnect from all energy sources
 - d. leave the worker alone
-

2. With regard to a worker's safety, what does the term *lockout* mean?

3. What types of work require lockout procedures?

4. Whose responsibility are the lockout procedures for a job?

- a. Supervisor
 - b. Person doing the job
 - c. The apprentice or assistant on the job
-

5. What type of lock is used for a lockout procedure?

6. How does the OHS Regulation of WCB specify that your lock be identified?

7. Which locks are workers authorized to remove?

Go to the Answer Key at the end of the Learning Guide to check your answers.

Learning Task 8:

Describe basic troubleshooting procedures

Efficient troubleshooting of problems in motor controls requires thorough knowledge of the system and equipment, ability to interpret drawings and instructions, and logical reasoning. Most manufacturers provide literature to assist in troubleshooting their equipment.

Usually, the two fundamental steps in troubleshooting are:

- Visual inspection and testing without tools
- Analyzing with diagrams and meter measurements

Visual inspection sometimes quickly locates a fault or identifies situations requiring maintenance. For example you can see:

- A tripped indicator on a circuit breaker, switch or overload relay
- Burnt or heat-discoloured components
- Loose wires in terminal blocks
- Mechanical parts that bind together or cause excessive friction

When there is no obvious cause for the problem(s), it is often necessary to analyze circuit diagrams and take measurements of voltage, current and resistance at key points of the circuit.

Checking for incoming power

Whenever equipment or circuits are not working, first check for *incoming power*.

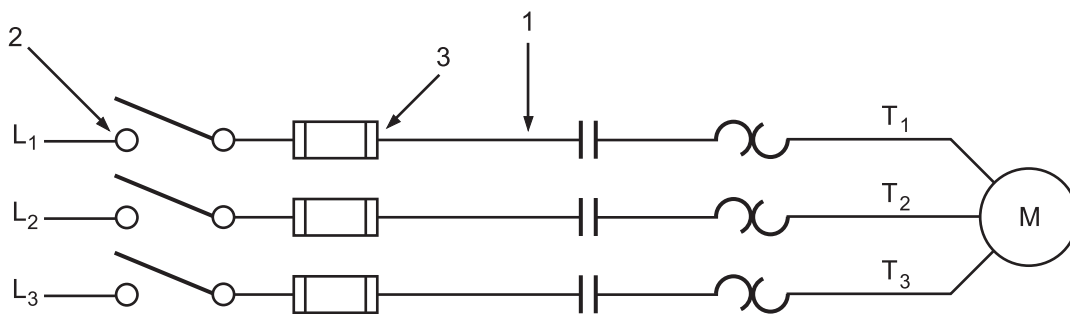


Figure 1—Voltage testing for motor controls

To check incoming power for motor controls, you do three sets of measurements: at the line terminals, on the line side of the disconnect and across the fuses.

Referring to the circuit in Figure 1:

1. Make sure that voltage is available at the line terminals of the starter. To do this, measure across each pair of line terminals (L₁–L₂; L₂–L₃; L₃–L₁). If all is well, the system voltage of 230 V should be read for each of these measurements.

- If, at any of these test points, a zero voltage reading is obtained, then check the voltage at each pair of terminals on the line side of the disconnect. If all is well, the system voltage of 230 V should be read for each of these measurements. If this correct line voltage is indicated, you must check the fuses.

Referring to Figure 2:

- Make line-side voltage measurements across pairs of fuses as shown. In this example, all of these should read 230 V.

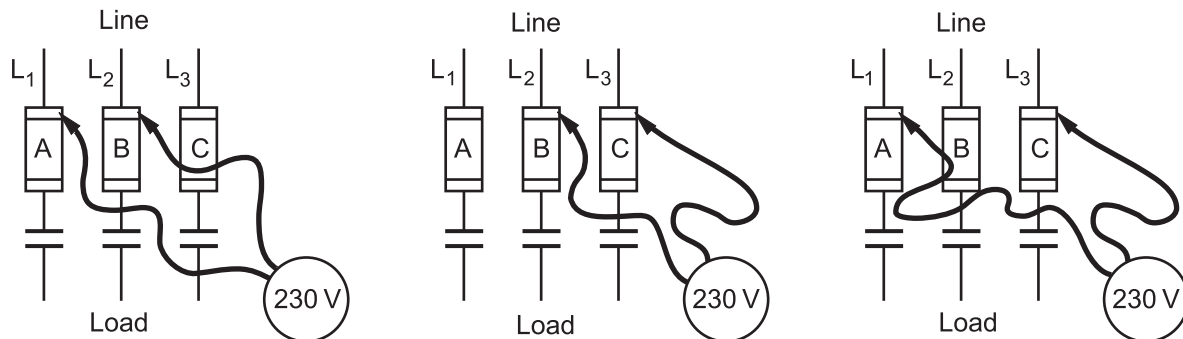


Figure 2—Line-side voltage measurements across pairs of fuses

Referring to Figures 3 and 4:

- Use the *criss-cross method* to measure voltage. This means measure the voltage from the line side of one fuse to the load side of the remaining two fuses. Usually more than one fuse is blown.

Figure 3 shows the voltage readings obtained if only fuse C is blown in this example.

Figure 4 shows the reading you get if fuse C is fine, but fuses A and B are blown.

When making these measurements, you must be aware that a three-phase motor may continue to run when only one fuse is blown. This is called *single-phasing*.

A voltage may still be measured on the load side of the blown fuse.

Voltage can be measured on the load side of a blown fuse only with the power ON. Make sure that the power contacts to the motor are open by pressing the STOP button.

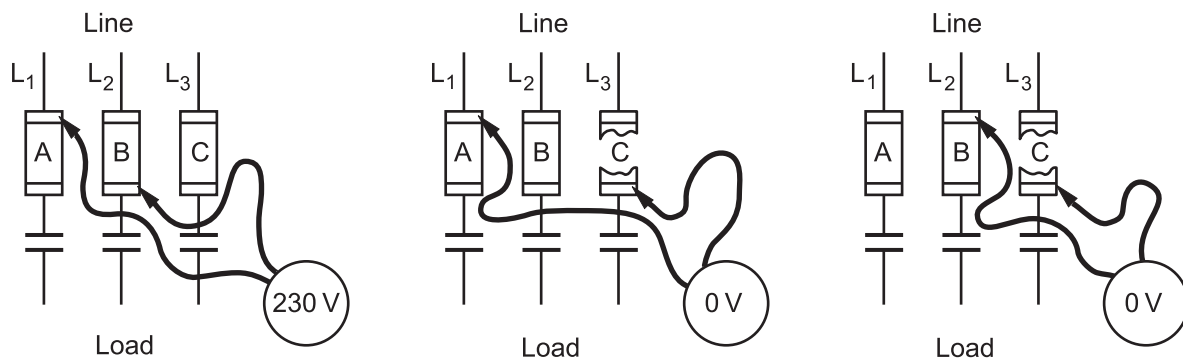


Figure 3—Measurements showing that fuse C is blown

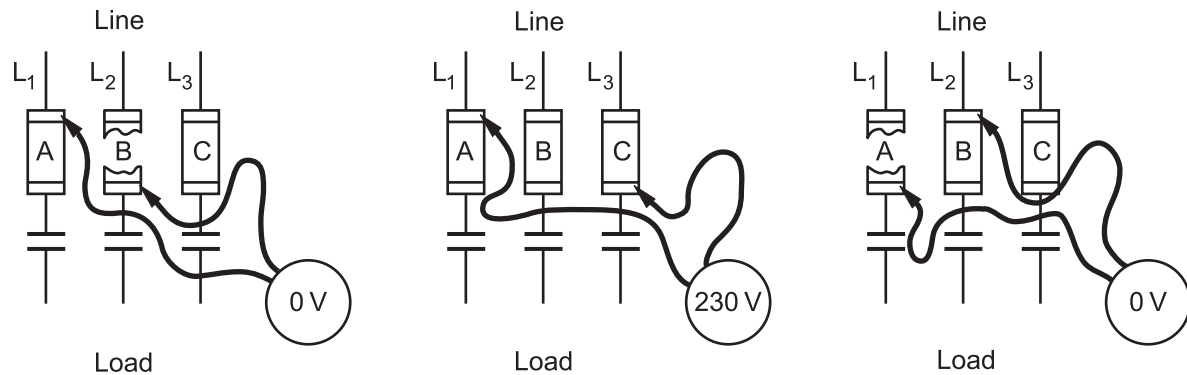


Figure 4—Measurements showing that fuses A and B are blown

Control circuit testing by measurement

To help locate faults that are not easily seen in control circuits, you may use a voltage tester or a voltmeter to take systematic readings.

For example, suppose that when the START button is pressed in the simple control circuit shown in Figure 5, the magnetic starter coil is not energized.

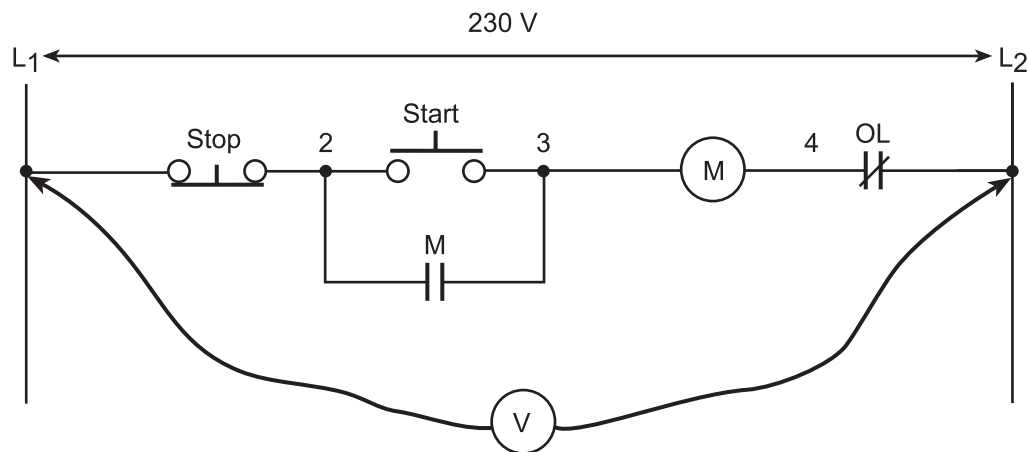


Figure 5—Three-wire control circuit

A typical troubleshooting sequence is described below. Wherever you find the faulty component in this procedure, fix it or replace it.

1. Check the control circuit voltage between L_1 and L_2 , as shown in Figure 5.

If you measure 0 V:

- Either a control fuse is blown
- Or there is a loss of line power into the magnetic starter
- Or there may be a broken wire

If you measure 230 V:

- Proceed with the other measurements

2. Leave one end of the voltmeter at L_1 . Move the other lead to point 4 in the control circuit, as shown in Figure 6.

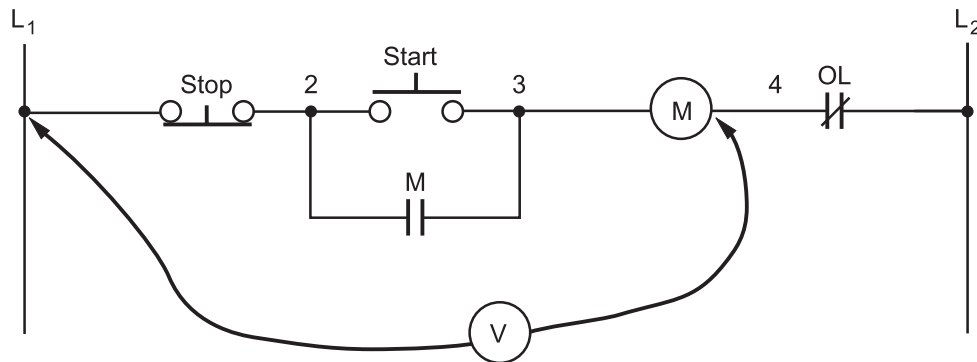


Figure 6—Testing a motor control circuit with a voltmeter

If you measure 0 V:

- Either the OLR contact is open
- Or a wire between L_2 and the OLR contact is loose or broken
- Or a wire between the OLR contact and the magnetic starter coil terminal is loose or broken

If you measure 230 V:

- Proceed with the other measurements

3. Leaving one lead at L_1 , move the other voltmeter lead to point 3 terminal on the starter coil, as shown in Figure 7.

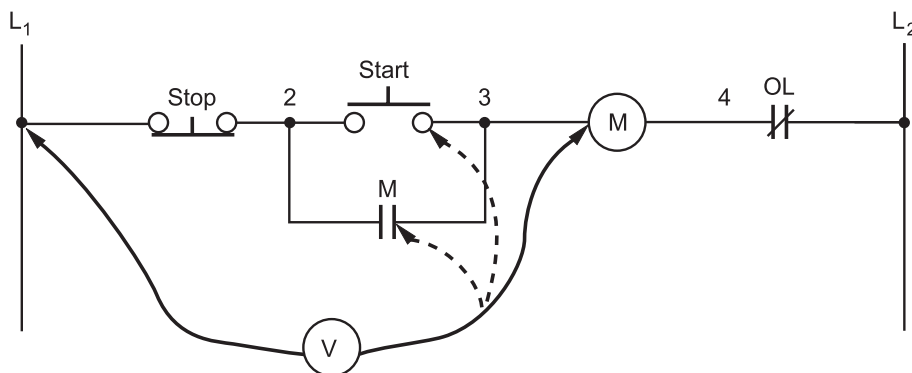


Figure 7—Point-to-point testing with a voltmeter

If you measure 0 V:

- The starter coil is faulty (open)

If you measure 230 V:

- Test each of the remaining terminals at point 3 to ensure that the wires are properly connected. Connect the voltmeter as shown in Figure 7, by the two dotted lines in turn.

4. Leave the right-hand lead of the voltmeter at point 3 and move the left-hand lead to point 2, as shown in Figure 8.

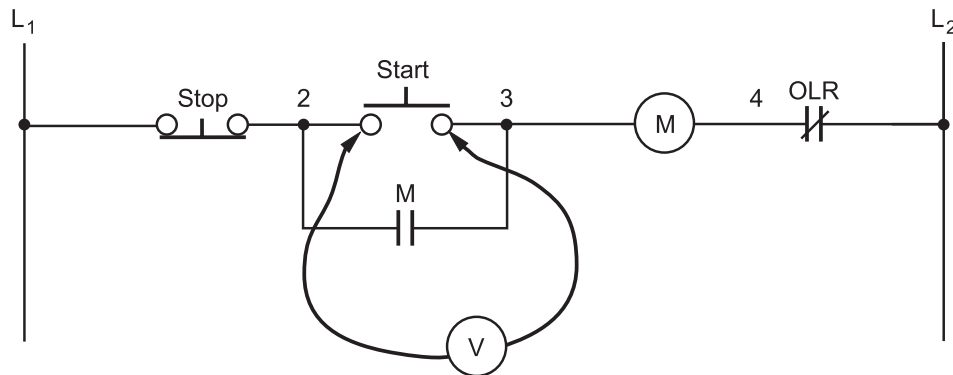


Figure 8—Testing the STOP button with a voltmeter

If you measure 0 V:

- Either there is a faulty wire connection from L_1 to the STOP push-button
- Or the push-button is faulty (open)

If you measure 230 V:

- The STOP button works

5. If your tests bring you to this point, then the problem must be in the START button itself or in the seal-in contact. (You *expect* that the voltage across these open contacts is 230 V when the coil is not energized.)

Press the START button again and release it.

If the starter picks up but drops out again when the START button is released:

- The seal-in contact is faulty.

If the starter does not pick up at all:

- The problem is in the START button.

6. Now test the START button. Inspect the push-button for obstructions. Turn off the power to the circuit. Use an ohmmeter as in Figure 9 to test for continuity of the START button when it is pressed.

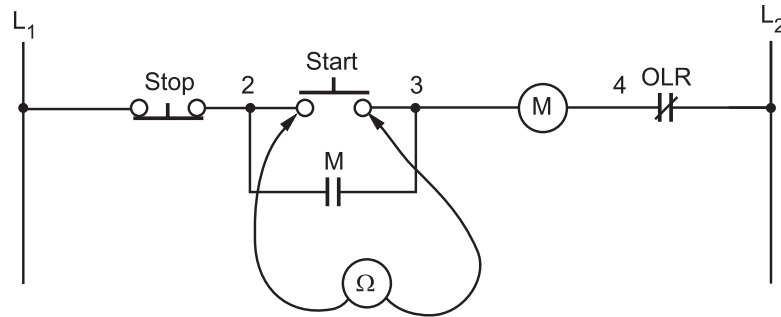


Figure 9—Testing the START button with an ohmmeter

If there is no continuity:

- The START button is faulty

The process just described is a systematic method for testing a simple motor starter control circuit. As you can see, successful troubleshooting requires a thorough working knowledge of the components and normal circuit operation.

Table 1 is a guide for troubleshooting motor controls. It lists troubles that may occur and suggests possible causes and remedies.

Table 1: Troubleshooting guide for motor controls

Trouble	Possible Cause	Remedy
CONTACTS		
Chatter	1. Broken shading coil	1. Replace armature parts.
	2. Poor contact in control circuit	2. Improve contact or use circuit interlock (3-wire control).
	3. Low voltage	3. Correct the voltage; check for momentary voltage dip during starting.
Welding or freezing	1. Abnormal current inrush	1. Use larger contactor or check for grounds, shorts or excessive motor load current.
	2. Rapid jogging	2. Install larger device rated for jogging service or caution the operator.
	3. Insufficient tip pressure	3. Replace contact springs. Check contact carrier for damage.
	4. Low voltage preventing contacts from closing	4. Correct the voltage; check for momentary voltage dip during starting.
	5. Foreign matter preventing contacts from closing	5. Clean contacts with approved solvent.
	6. Short circuit	6. Remove short fault and ensure that fuse or breaker size is correct.
Short contact life or overheating of tips	1. Filing or dressing	1. Do not file silver-faced contacts. Rough spots and discoloration will not harm them.
	2. Interrupting too-high currents	2. Install larger device or check for grounds, shorts or excessive motor currents. Use silver-faced contacts.
	3. Excessive jogging	3. Install larger device rated for jogging service or caution the operator.
	4. Weak contact pressure	4. Adjust or replace contact springs.
	5. Dirt or foreign matter on contact surface	5. Clean contacts with approved solvent.
	6. Short circuit	6. Remove short fault and ensure that fuse or breaker size is correct.
	7. Loose connection	7. Clean and tighten the connection.
	8. Sustained overload	8. Install larger device or check for excessive load current.

Trouble	Possible Cause	Remedy
COIL		
Overheating	1. Over-voltage or high ambient temperature	1. Check application and circuit.
	2. Incorrect coil	2. Check coil rating. If incorrect, replace.
	3. Shorted turns due to mechanical damage or corrosion	3. Replace coil.
	4. Under-voltage, failure of magnet to seal in.	4. Correct system voltage.
	5. Dirt or rust on pole faces increasing the air gap	5. Clean the pole faces.
OVERLOAD RELAYS		
Tripping	1. Sustained overload	1. Check for grounds, shorts or excessive motor currents.
	2. Loose connection on load wires	2. Clean and tighten.
	3. Incorrect heater	3. Replace relay with correct size heater unit.
Failure to trip (causing motor burnout)	1. Mechanical binding, dirt, corrosion, etc.	1. Clean or replace.
	2. Wrong heater, or heater omitted and jumper wires used	2. Check ratings; apply proper heater.
	3. Motor and relay in different temperatures	3. Adjust relay rating accordingly, or make temperature the same for both.
	4. Wrong calibration or improper calibration adjustment	4. Consult factory.
MAGNETIC AND MECHANICAL PARTS		
Noisy magnet (humming)	1. Broken shading coil	1. Replace amature parts.
	2. Magnet facing not mating	2. Replace or realign magnet assembly.
	3. Dirt or rust on magnet faces	3. Clean and realign.
	4. Low voltage	4. Check system voltage and voltage dips during starting.

Trouble	Possible Cause	Remedy
Failure to pick up and seal	1. Low voltage	1. Check system voltage and voltage dips during starting.
	2. Coil open or shorted	2. Replace coil.
	3. Wrong coil	3. Check coil number and replace.
	4. Mechanical obstruction	4. With power off, check for free movement of contact and armature assembly.
Failure to drop out	1. Gummy substance on pole faces	1. Clean with solvent.
	2. Voltage not removed	2. Check coil circuit.
	3. Worn or rusted parts causing binding	3. Replace defective parts.
	4. Residual magnetism due to lack of air gap in magnet path	4. Replace worn electromagnet parts.



Now do Self-Test 8 and check your answers.

Self-Test 8

1. A voltmeter is used to test for a blown fuse in a three-phase disconnect supplying a motor starter. In Figure 1, if fuse C is blown, determine the reading on the voltmeter when connected across the following pairs of points:

- a. 1 and 4 _____
- b. 2 and 3 _____
- c. 4 and 5 _____
- d. 5 and 6 _____
- e. 3 and 5 _____
- f. 2 and 5 _____
- g. 1 and 6 _____
- h. 1 and 2 _____
- i. 3 and 6 _____

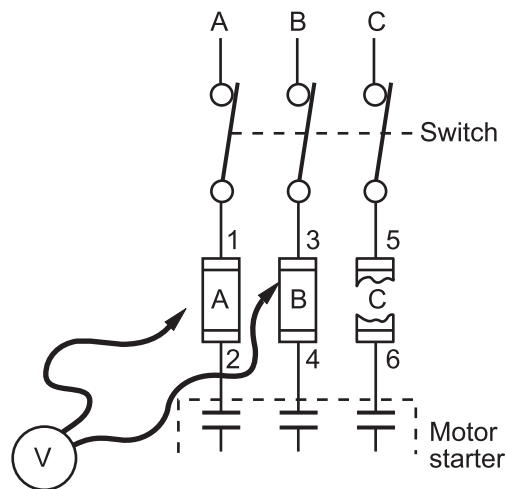


Figure 1—Motor starter circuit for Question 1

2. If voltage is measured across a device such as a lamp or starter coil, but the device is not functioning, what is the problem?

3. If the motor starter shown in Figure 2 is energized and functioning properly, what is the voltage across the:
- n.o. contact M_a
 - n.c. contact M_b

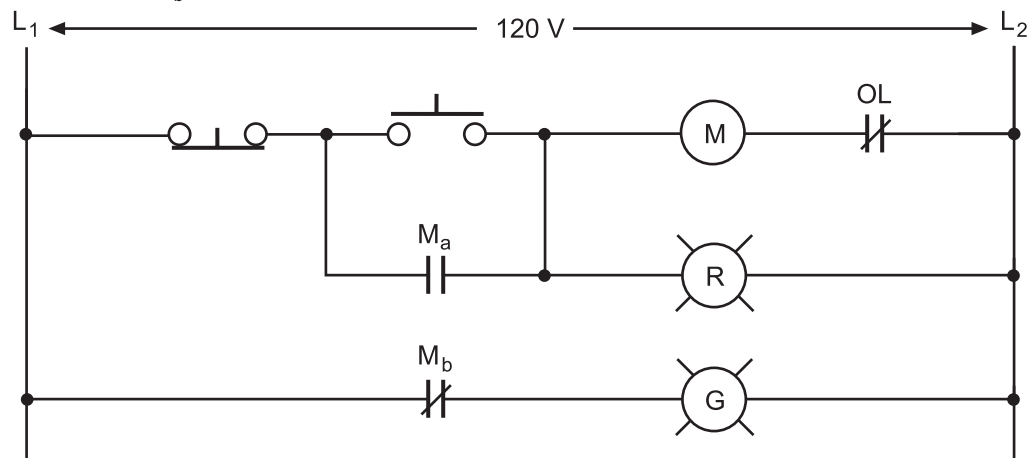


Figure 2—Circuit for Questions 3 and 4

4. If the starter in Figure 2 is de-energized by pressing STOP, what is the voltage measured across the:
- n.o. contact M_a
 - n.c. contact M_b
5. If, when the START button is pressed, the coil of the starter energizes but drops out when the button is released, what is the most likely problem?

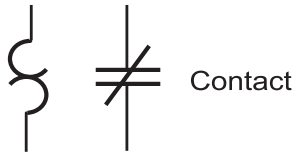
6. If the magnetic starter is properly energized initially but there is a loud chattering noise during operation, what could be wrong?

Go to the Answer Key at the end of the Learning Guide to check your answers.

Answer Key

Self-Test 1

1. Any three of the following:
 - Provides running protection for the motor.
 - Reverses rotation of the motor.
 - Varies the speed of the motor.
 - Provides quick stopping of the motor in an emergency.
 - Varies starting voltage to the motor.
 - Allows sequencing of several motors.
 - Provides automatic and remote control of the motor.
2. A magnetic motor starter consists of a magnetic contactor plus overload relay protection.
3. Power circuit = main line contacts
Control circuit = electromagnetic coil and auxiliary contacts
4. the heater element and the normally closed auxiliary contact
5. heater
6. current, nameplate
7. cool down
8. Thermal OLR schematic: Heater



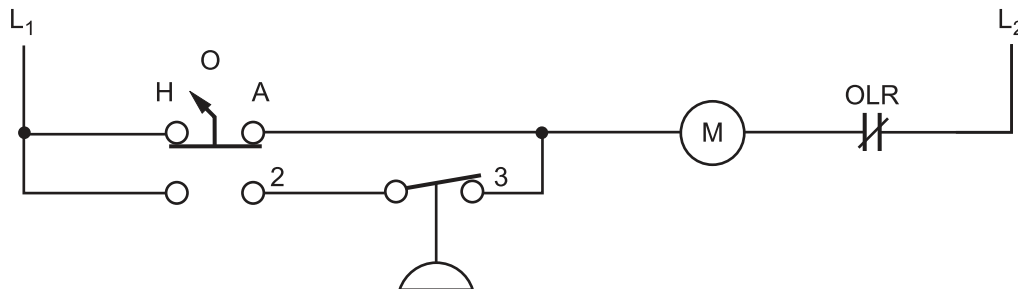
Self-Test 2

1. Any four of the following:
 - Disconnect means
 - Overcurrent protection device
 - Magnetic starter power contacts
 - Overload relay heater
 - Motor and conductors
2. Any three of the following:
 - OLR auxiliary contacts
 - Magnetic starter coil
 - Magnetic starter seal-in contact (if used)
 - Pilot-initiating devices (such as push-buttons)
3. a. release
b. protection
4. a. maintained
b. momentary

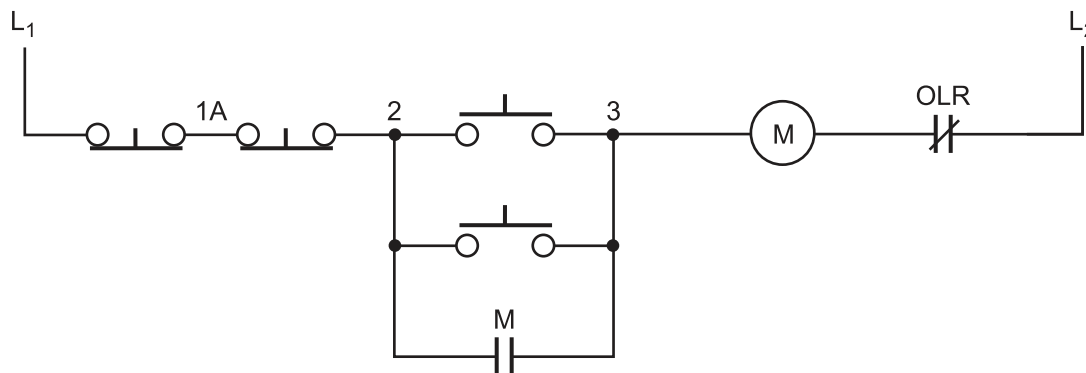
5. to indicate the operating status of a motor in a remote location
6. series, parallel
7. The control circuit is energized with the same value of voltage as the motor (power) circuit.

Self-Test 3

1. Control circuit using a HAND-OFF-AUTO selector switch:

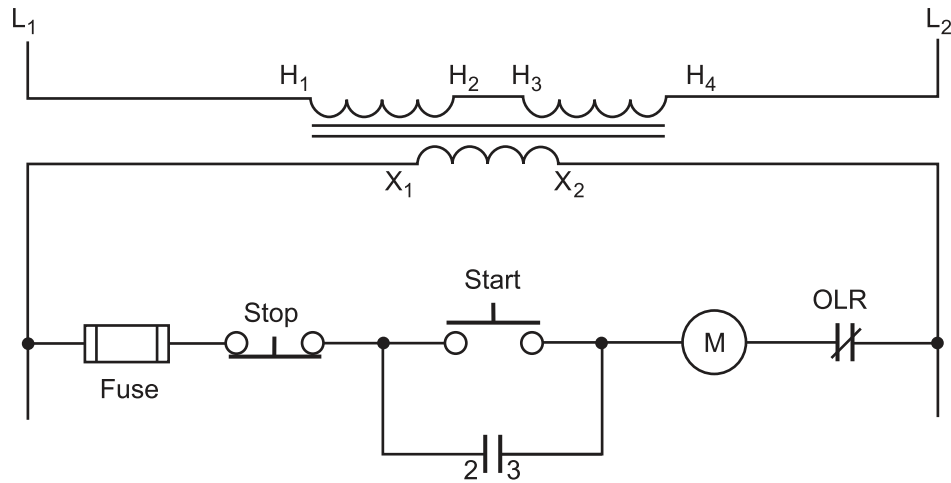


2. Control circuit using two separate STOP-START pushbutton stations:

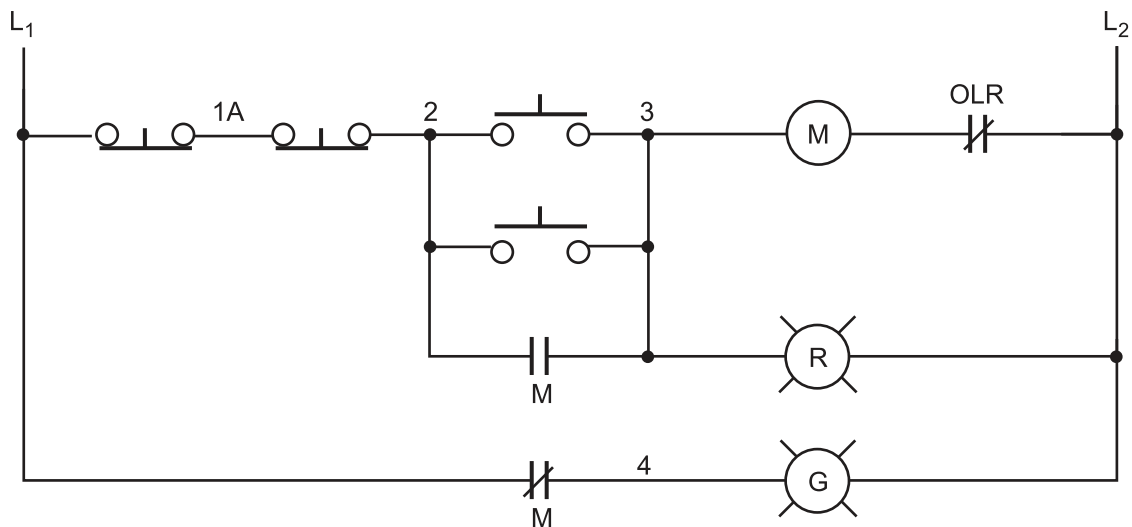


3.
 - A schematic diagram uses symbols and interconnecting lines to display the electrical operation of a circuit.
 - A wiring diagram shows the physical relationships of all the devices and the actual number of conductors and terminations between devices.

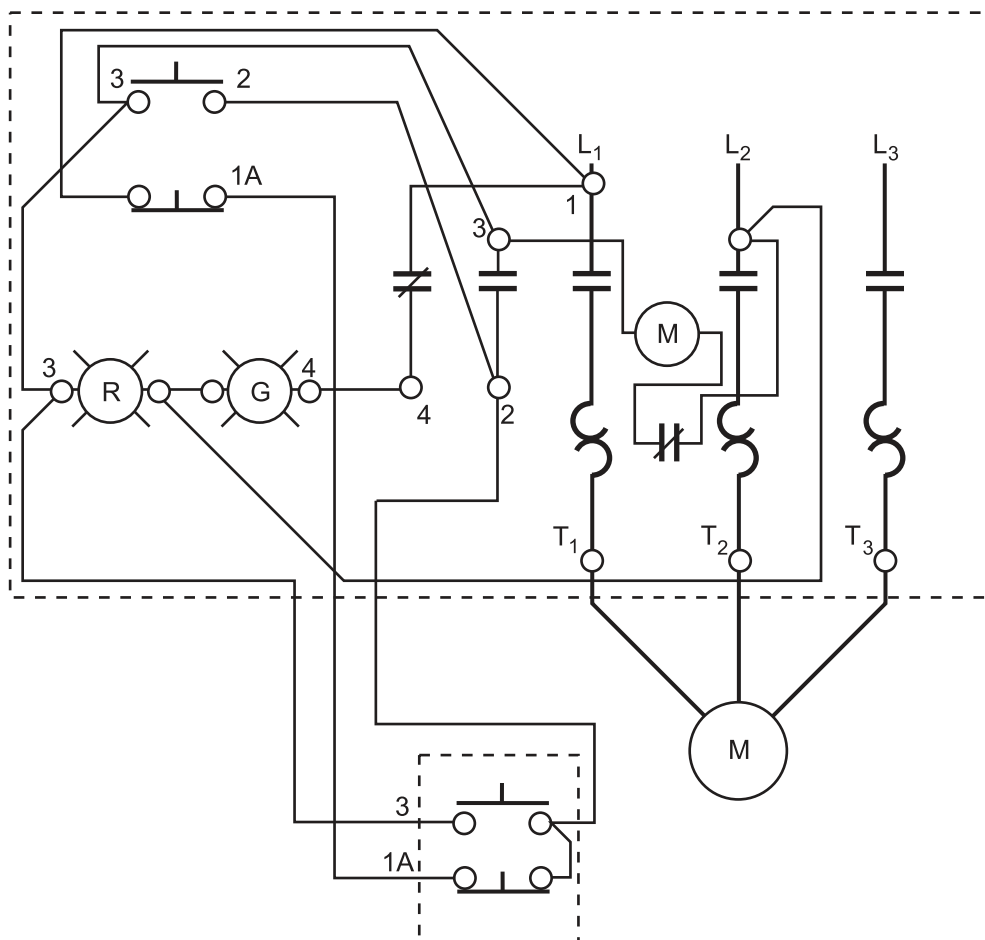
4. The wire numbering system is a numeric marking method applied to a schematic diagram to help identify conductor terminations in a wiring diagram.
5. Like-numbered terminals are simply interconnected with conductors. For example, 2 to 2; 3 to 3; and so on.
6. Schematic diagram:



7. Schematic diagram:



8. Wiring diagram:

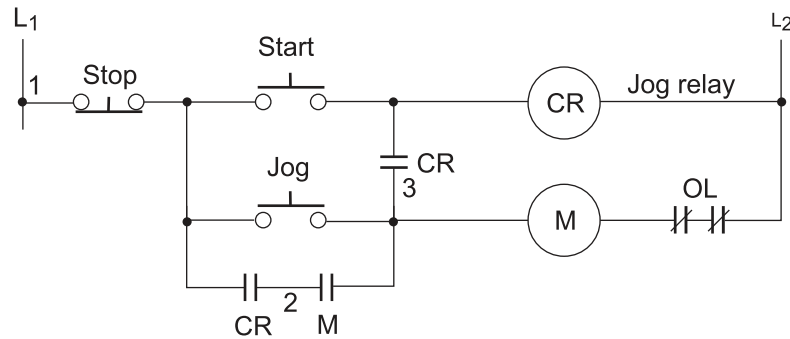


Self-Test 4

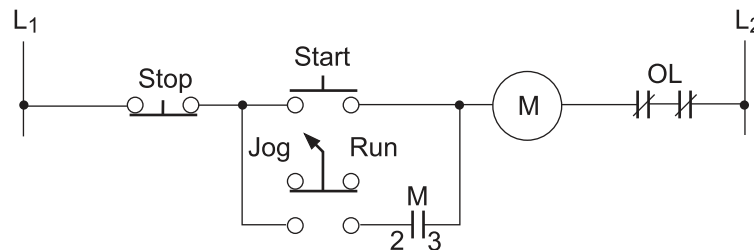
1. Whenever a magnetic starter does not have enough auxiliary contacts for the control circuit operations, then one (or more) control relays is used.
2. No, the value of 10 A is the continuous-current-carrying rating. For making or breaking inductive types of circuits, the continuous current rating must be greatly reduced (see Table 1 in Learning Task 2) or a contactor must be used.
3. A latching relay is a control relay that is activated electrically but held mechanically. The coil needs only to be energized momentarily for picking up (latching) or dropping out the relay.

Self-Test 5

1. Jogging is the quickly repeated closure of a circuit. It starts a motor from rest and causes small movements of the motor-driven machine.
2. The motor may continue to run if the JOG button closes before the seal-in contact has a chance to open.
3. by using a *definite break* device, such as a selector switch or a control relay, in the jog control (seal-in) circuit
4. The schematic for Figure 1 is:

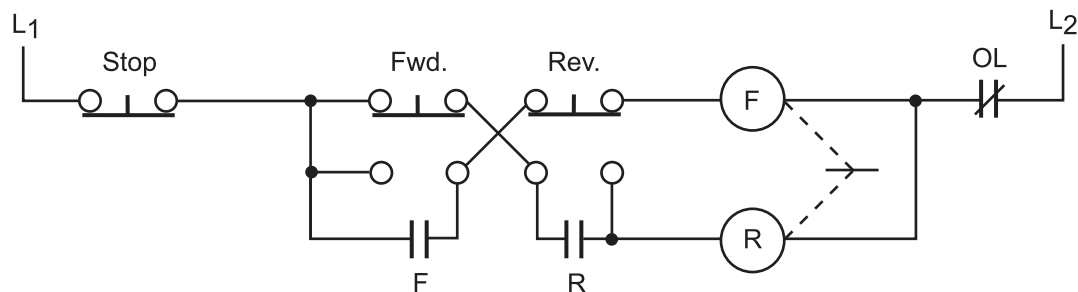


5. The schematic for Figure 2 is:

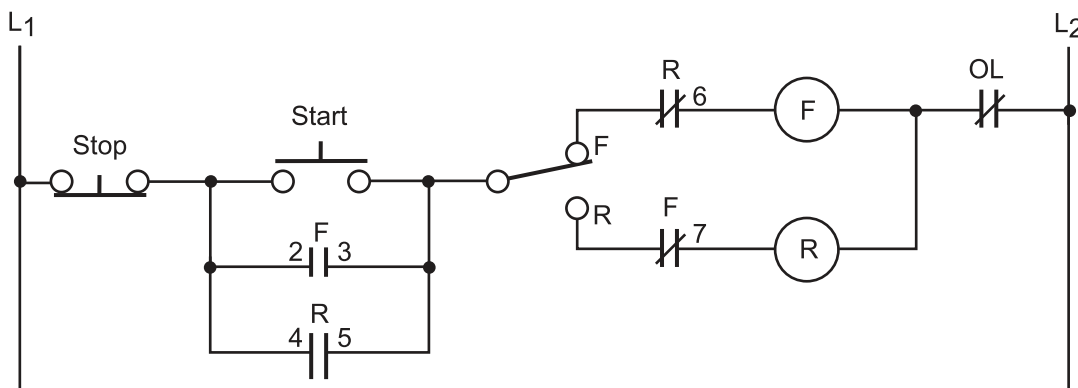


Self-Test 6

1. The reversing starter contains an additional three-pole contactor and a mechanical interlock between the two contactors.
2. When the second reversing contactor is energized, two of the supply lines to the three-phase motor are interchanged.
3. If both contactors are energized simultaneously, a line-to-line short circuit results.
4. The use of auxiliary normally closed contacts to ensure that only one contactor can be energized at one time. These n.c. contacts for one contactor are wired in series with the control circuit of the other contactor, and vice versa.
5. A three-phase motor draws the same current whether running in the forward or reverse direction of rotation, so only one set of overload heaters is needed to protect the lines to the motor.
6. yes
7. Control schematic for push-button interlocking:



8. Control schematic for the given wiring diagram:



Self-Test 7

1. c. disconnect from all energy sources
2. Lock the energy controls in the OFF position.
3. any work that must be done on equipment that can become energized
4. b. person doing the job
5. a keyed padlock
6. marked or tagged with your name
7. only their own locks

Self-Test 8

1. a. 230 V
b. 230 V
c. 230 V
d. 0 V
e. 230 V
f. 230 V
g. 0 V
h. 0 V
i. 0 V
2. The device is open.
3. a. 0 V
b. 120 V
4. a. 120 V
b. 0 V
5. The seal-in circuit is not working. This may be due to a:
 - Loose wire
 - Faulty contact
 - Open connection
6. Possible faults are:
 - Low voltage
 - Broken shading coil
 - Poor contact in the seal-in circuit

