Electrical Level 2

Control Systems and Fundamental Concepts 26211-14

Objectives

When trainees have completed this lesson, they should be able to do the following:

1. Describe the operating principles of contactors and relays.
2. Select contactors and relays for use in specific electrical systems.
3. Explain how mechanical contactors operate.
4. Explain how solid-state contactors operate.
5. Install contactors and relays according to the *NEC*® requirements.

Objectives and Performance Task

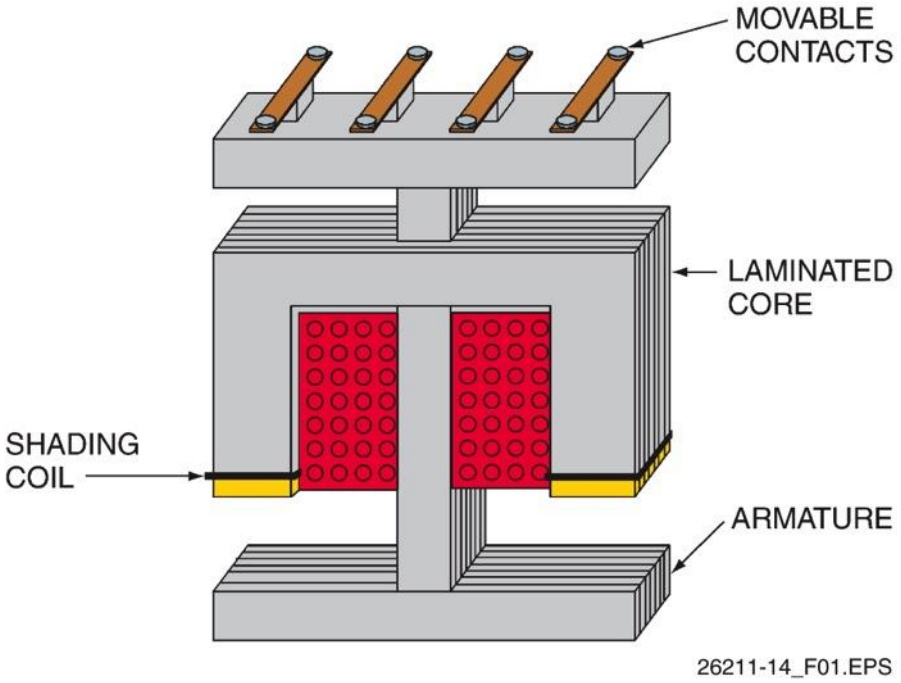
6. Select and install contactors and relays for lighting control.
7. Read wiring diagrams involving contactors and relays.
8. Describe how overload relays operate.
9. Connect a simple control circuit.
10. Test control circuits.

Performance Task

1. Mount and connect a 120V lighting contactor with a three-wire pushbutton control.

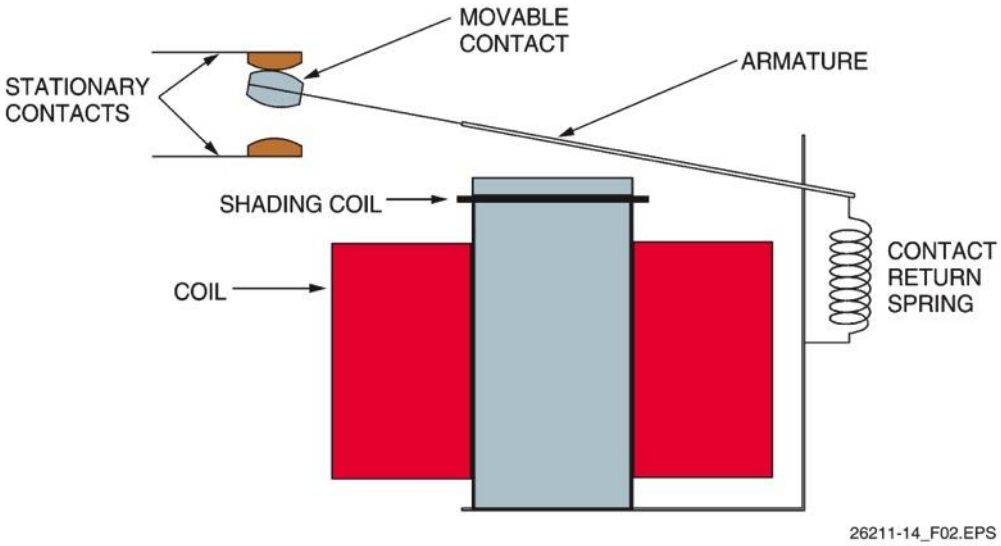
Introduction; Magnetic Contactors

- Contactors are used to make or break a circuit, but do not provide motor protection.
- Relays are used to amplify the contact capability or multiply the switching functions of a pilot device.
- A magnetic contactor picks up the armature when current is applied, pushing the movable contacts up against the stationary contacts and completing the circuit.



Contactor Operating on the Solenoid Principle

- Shading coils are used with AC relays to prevent contact chatter and hum.
- A simple relay operates on the solenoid principle, meaning that electrical energy is converted into linear motion.
- A normally open contact closes when the circuit is energized, while a normally closed contact opens when the circuit is energized.



Electrical Ratings for AC Magnetic Contactors and Starters

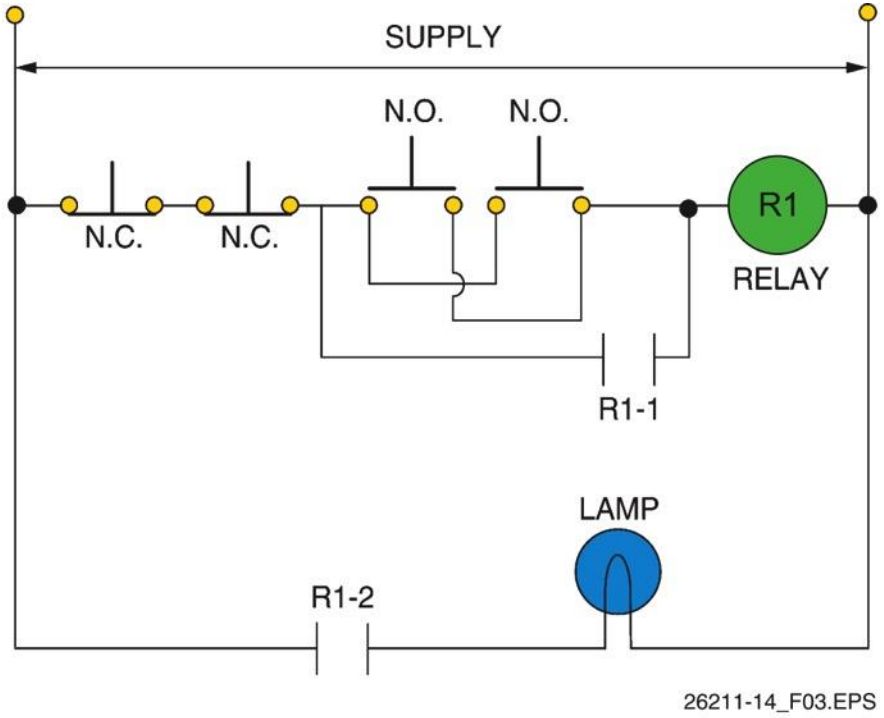
NEMA Size	Volts	Maximum Horsepower Rating—Nonplugging and Nonjogging Duty		Maximum Horsepower Rating—Plugging and Jogging Duty		Continuous Current Rating, Amperes—600 Volt Max.	Service-Limit Current Rating, Amperes	Tungsten and Infrared Lamp Load, Amperes—250 Volts Max.	Resistance Heating Loads, kW—other than Infrared Lamp Loads		KVA Rating for Switching Transformer Primaries at 50 to 60 Cycles		3-Phase Rating for Switching Capacitors
		Single Phase	Poly-Phase	Single Phase	Poly-Phase				Single Phase	Poly-Phase	Single Phase	Poly-Phase	Kvar
	115	⅓	–	–	–	9	11	5	–	–	–	–	–
	200	–	1½	–	–	9	11	5	–	–	–	–	–
	230	1	1½	–	–	9	11	5	–	–	–	–	–
00	380	–	1½	–	–	9	11	–	–	–	–	–	–
	460	–	2	–	–	9	11	–	–	–	–	–	–
	575	–	2	–	–	9	11	–	–	–	–	–	–
	115	1	–	½	–	18	21	10	–	–	0.9	1.2	–
	200	–	3	–	1½	18	21	10	–	–	–	1.4	–
	230	2	3	1	1½	18	21	10	–	–	1.4	1.7	–
0	380	–	5	–	1½	18	21	–	–	–	–	2	–
	460	–	5	–	2	18	21	–	–	–	1.9	2.5	–
	575	–	5	–	2	18	21	–	–	–	1.9	2.5	–
	115	2	–	1	–	27	32	15	3	5	1.4	1.7	–
	200	–	7½	–	3	27	32	15	–	9.1	–	3.5	–
	230	3	7½	2	3	27	32	15	6	10	1.9	4.1	–
1	380	–	10	–	5	27	32	–	–	16.5	–	4.3	–
	460	–	10	–	5	27	32	–	12	20	3	5.3	–
	575	–	10	–	5	27	32	–	15	25	3	5.3	–
	115	3	–	1½	–	36	42	24	–	–	–	–	–
	230	5	–	3	–	36	42	24	–	–	–	–	–
	115	3	–	2	–	45	52	30	5	8.5	1	4.1	–
	200	–	10	–	7½	45	52	30	–	15.4	–	6.6	11.3
2	230	7½	15	5	10	45	52	30	10	17	4.6	7.6	13
	380	–	25	–	15	45	52	–	–	28	–	9.9	21
	460	–	25	–	15	45	52	–	20	34	5.7	12	26
	575	–	25	–	15	45	52	–	25	43	5.7	12	33

Electrical Ratings for AC Magnetic Contactors and Starters

	115	7½	–	–	–	90	104	60	10	17	4.6	7.6	–
	200	–	25	–	15	90	104	60	–	31	–	13	23.4
	230	15	30	–	20	90	104	60	20	34	8.6	15	27
3	380	–	50	–	30	90	104	–	–	56	–	19	43.7
	460	–	50	–	30	90	104	–	40	68	14	23	53
	575	–	50	–	30	90	104	–	50	86	14	23	67
	200	–	40	–	25	135	156	120	–	45	–	20	34
	230	–	50	–	30	135	156	120	30	52	11	23	40
4	380	–	75	–	50	135	156	–	–	86.7	–	38	66
	460	–	100	–	60	135	156	–	60	105	22	46	80
	575	–	100	–	60	135	156	–	75	130	22	46	100
	200	–	75	–	60	270	311	240	–	91	–	40	69
	230	–	100	–	75	270	311	240	60	105	28	46	80
5	380	–	150	–	125	270	311	–	–	173	–	75	132
	460	–	200	–	150	270	311	–	120	210	40	91	160
	575	–	200	–	150	270	311	–	150	260	40	91	200
	200	–	150	–	125	540	621	480	–	182	–	79	139
	230	–	200	–	150	540	621	480	120	210	57	91	160
6	380	–	300	–	250	540	621	–	–	342	–	148	264
	460	–	400	–	300	540	621	–	240	415	86	180	320
	575	–	400	–	300	540	621	–	300	515	86	180	400
	230	–	300	–	–	810	932	720	180	315	–	–	240
7	460	–	600	–	–	810	932	–	360	625	–	–	480
	575	–	600	–	–	810	932	–	450	775	–	–	600
	230	–	450	–	–	1215	1400	1080	–	–	–	–	360
8	460	–	900	–	–	1215	1400	–	–	–	–	–	720
	575	–	900	–	–	1215	1400	–	–	–	–	–	900

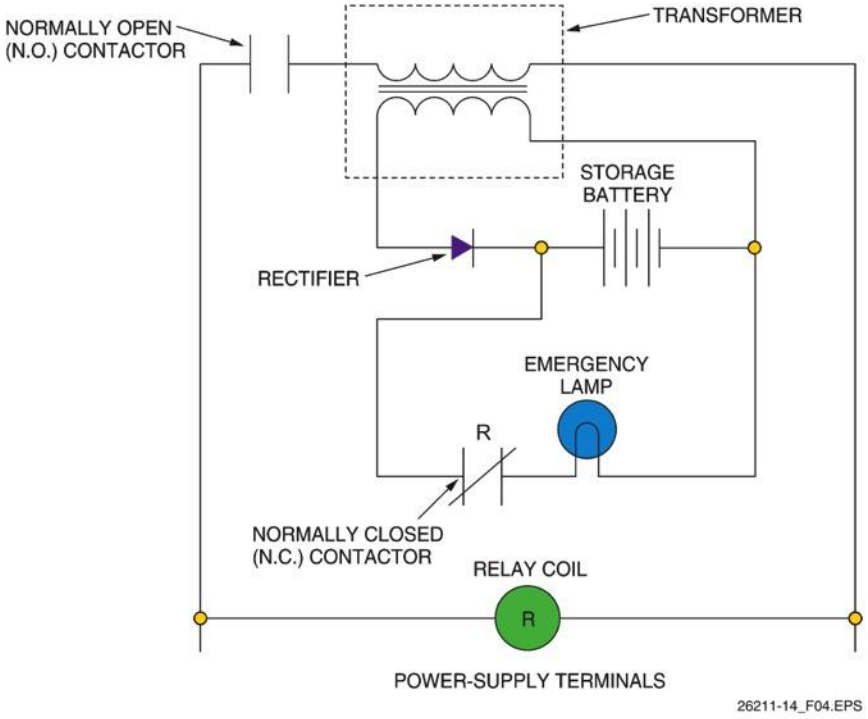
Pushbutton Control Circuit With a Magnetic Relay

- This circuit controls a lamp from two locations.
- Closing one of the N.O. pushbuttons energizes R1 and lights the lamp; opening one of the N.C. pushbuttons de-energizes R1 and turns the lamp off.



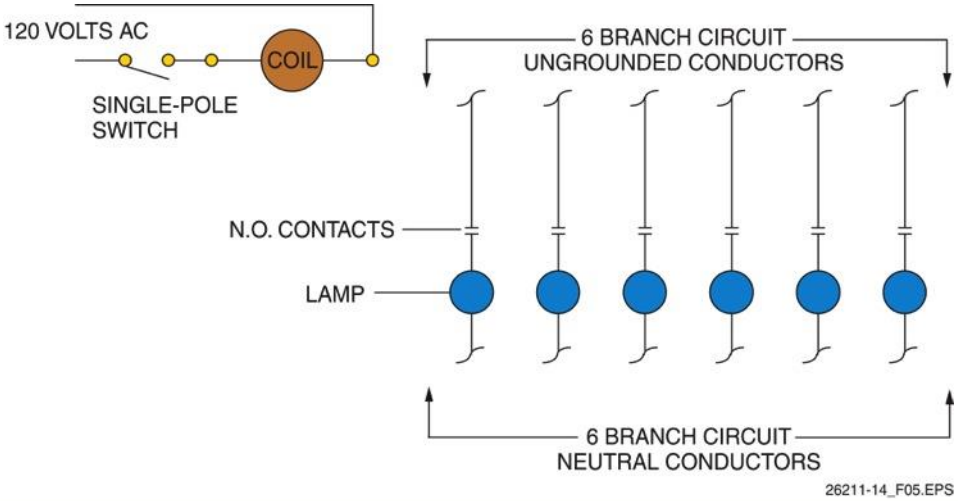
Emergency Lighting Circuit Using a Relay for Operation

- As long as the main power is available, it energizes the relay coil, which keeps the N.O. contacts closed and the N.C. contacts open.
- In the event of a power failure, the N.O. contacts open and the N.C. contacts close, connecting the lamp to the battery to provide emergency lighting.



Several Lighting Circuits Controlled by One Contactor

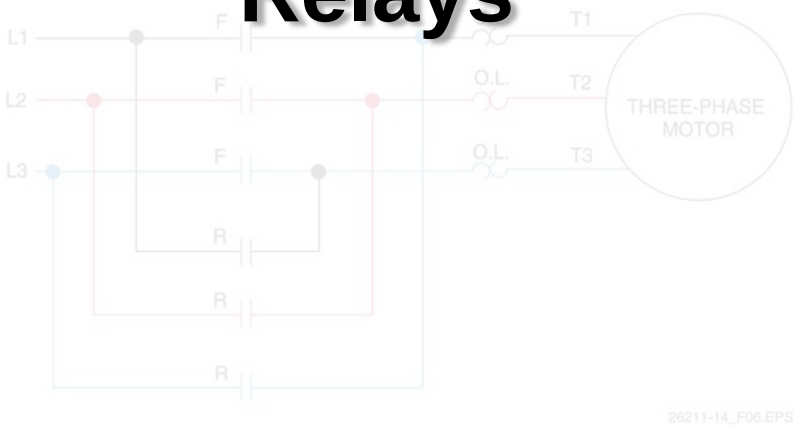
- This relay provides switching to six lamps using one toggle switch, which can be useful for a large area such as a cafeteria or warehouse.
- When the contacts are closed, this relay closes all of the N.O. contacts, energizing all six of the lamp circuits simultaneously.



Next Session…

- Reversing a motor's rotation can be accomplished by switching any two of the three line connections to a motor using forward and reverse contactors on a motor starter.
- Electrical and mechanical interlocks prevent both coils from being energized at the same time.

Relays

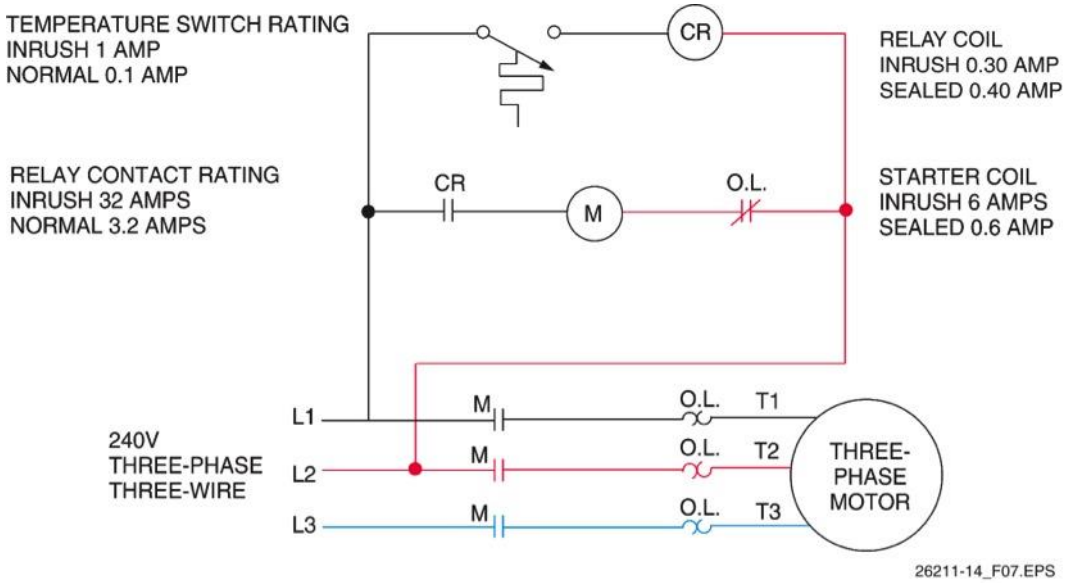


Performance Task

This session concludes with trainees mounting and connecting a 120V lighting contactor with a three-wire pushbutton control.

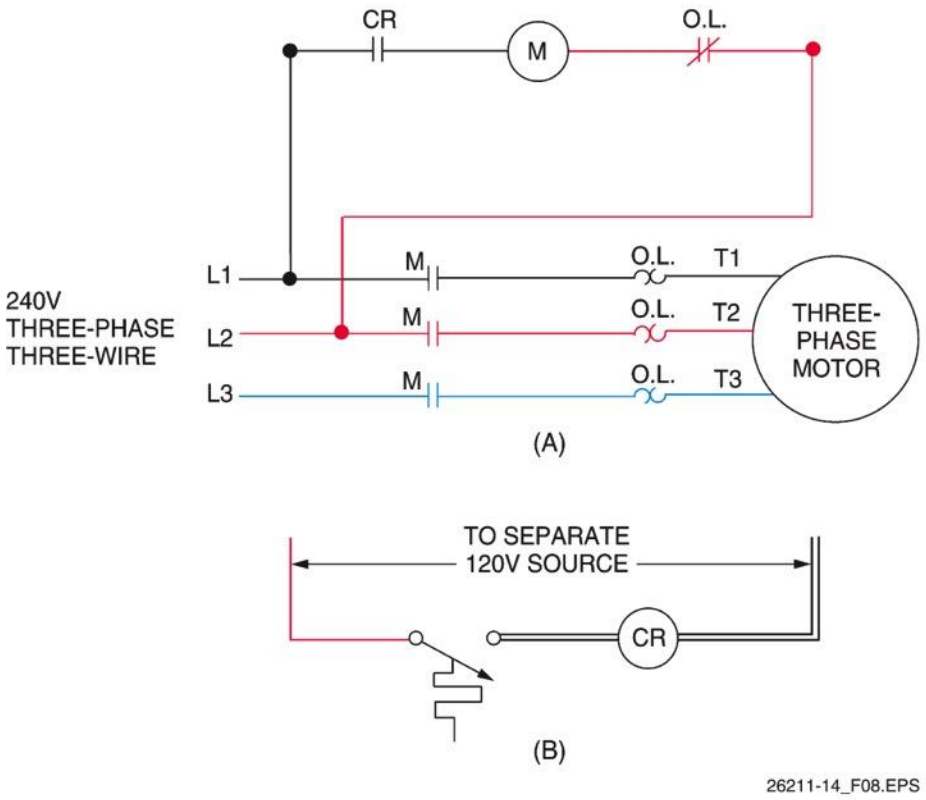
Relays

- While a contactor is generally used to switch power circuits or high current loads, relays are used to amplify the contact capability in low-voltage control circuits.
- The relay shown here amplifies the current capability of the temperature switch to match the amperage draw of the starter coil.



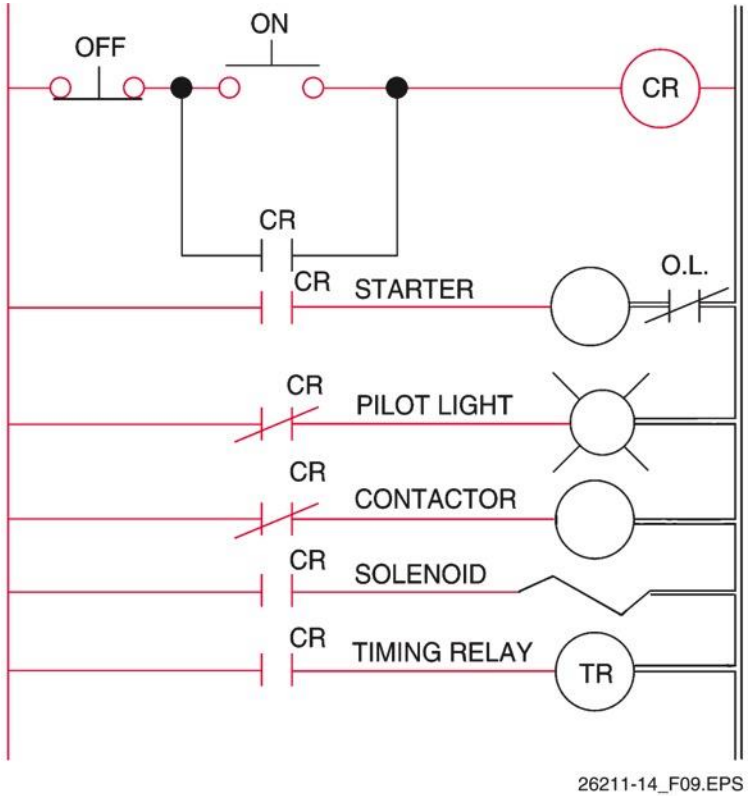
Relay Used for Voltage Amplification

- In addition to current amplification, relays can also be used for voltage amplification.
- The coil of the relay shown here is wired to a low-voltage source of power, while the contact has a higher voltage rating that is then used to operate the starter.



Relay Used to Multiply the Switching Functions of a Pilot Device

- Relays can also be used to multiply the switching functions.
- In this circuit, a single-pole pushbutton can control the operation of several devices using a six-pole relay.



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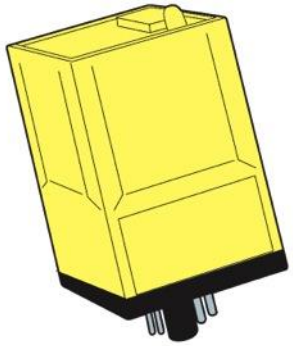
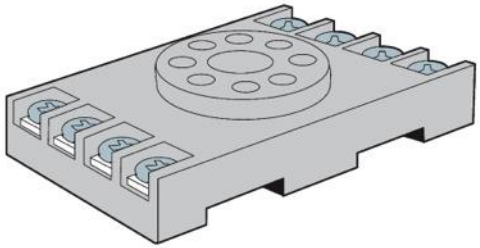
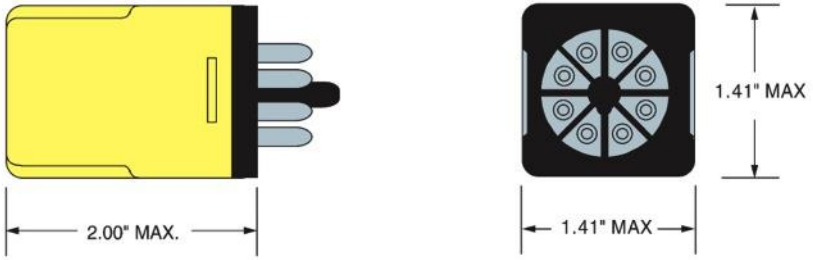
Plug-In Relays



PLUG-IN, 8-PIN RELAY



BASE FOR PLUG-IN, 8-PIN RELAY



(A)

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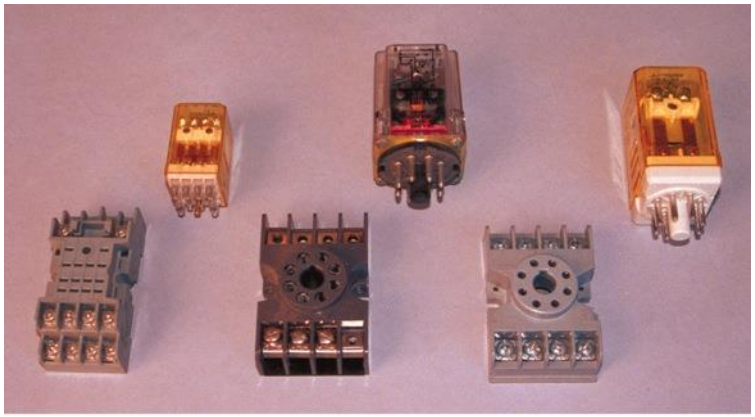

(B)

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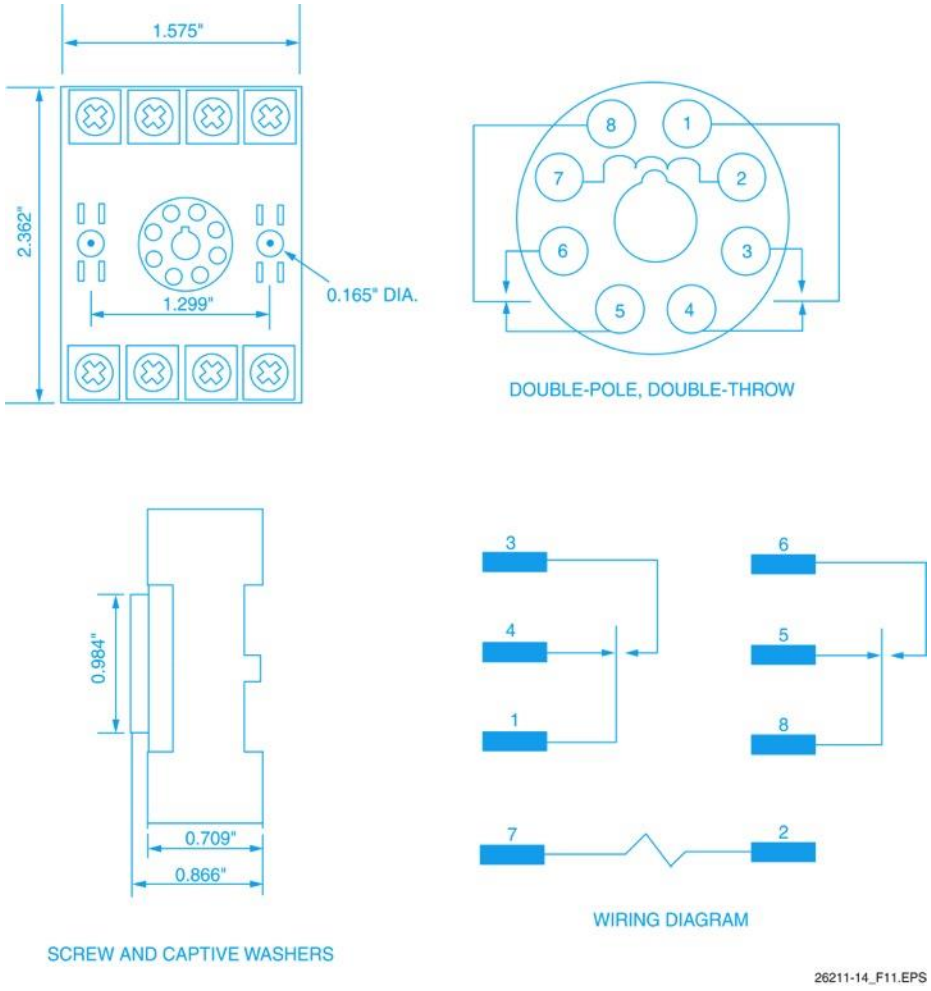
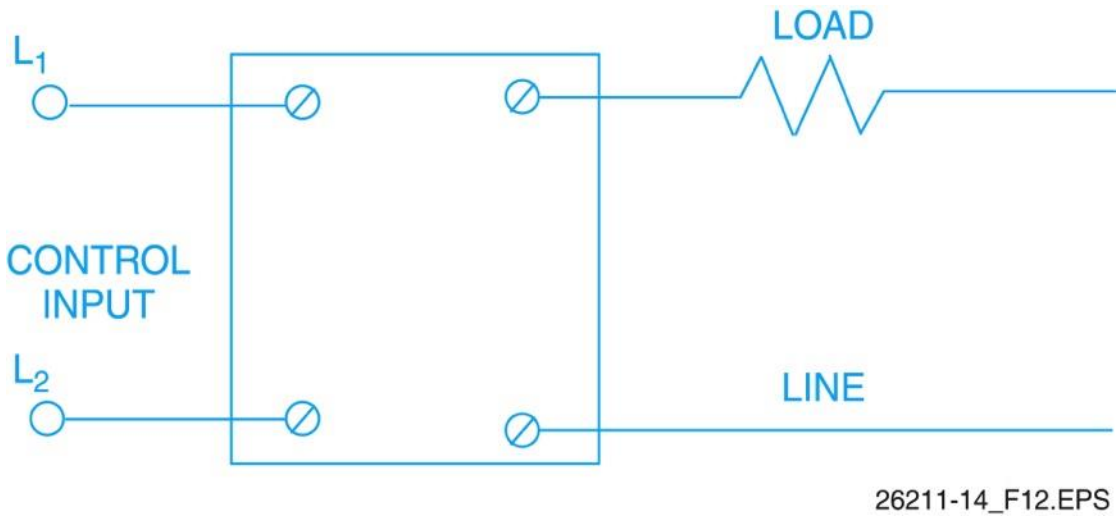
Wiring Diagram for a Plug-In Relay



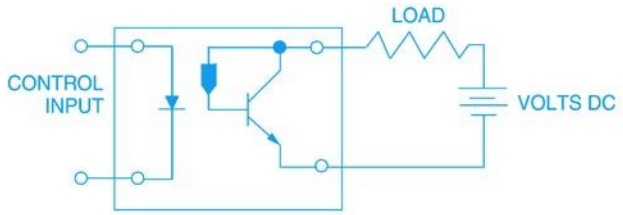
Solid-State Relays

- Solid-state relays are also used in switching applications, such as in programmable controllers.
- Solid-state relays have no moving parts, are sealed, and resist shock and vibration.

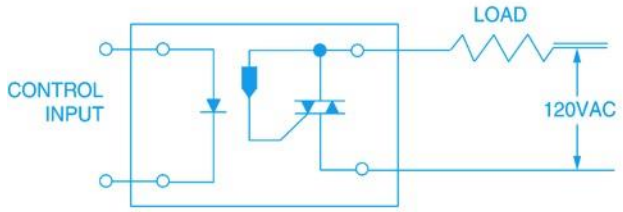


Solid-State Relay Circuits

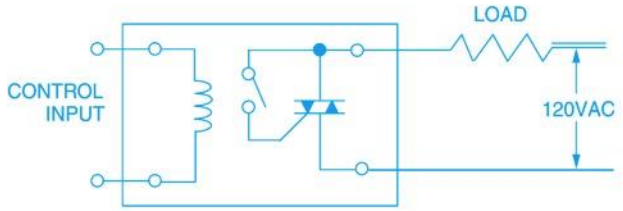
- Solid-state relays normally have control voltages from 3V to 32V.
- Triac-controlled relays commonly have load voltage ratings of 120VAC to 240VAC.
- Zero switching is used to continue conducting until the AC voltage returns to zero if the relay turns off when the voltage is in the middle of a cycle.



(A) POWER TRANSISTOR USED TO CONTROL A DC LOAD



(B) TRIAC USED TO CONTROL AN AC LOAD



(C) REED RELAY CONTROLS THE OUTPUT

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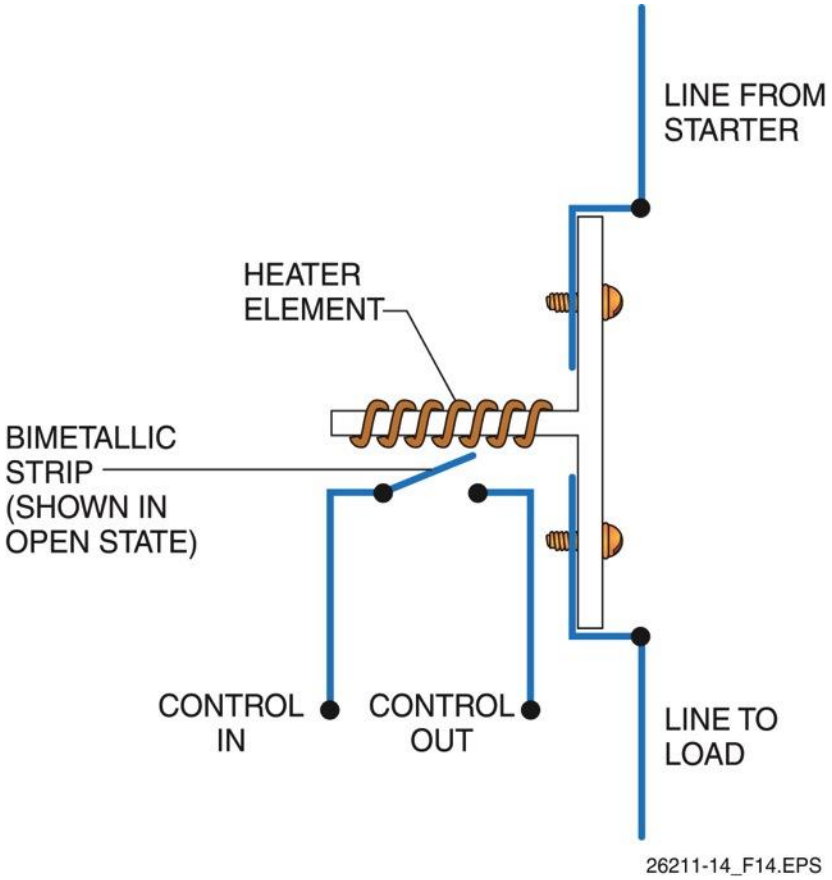
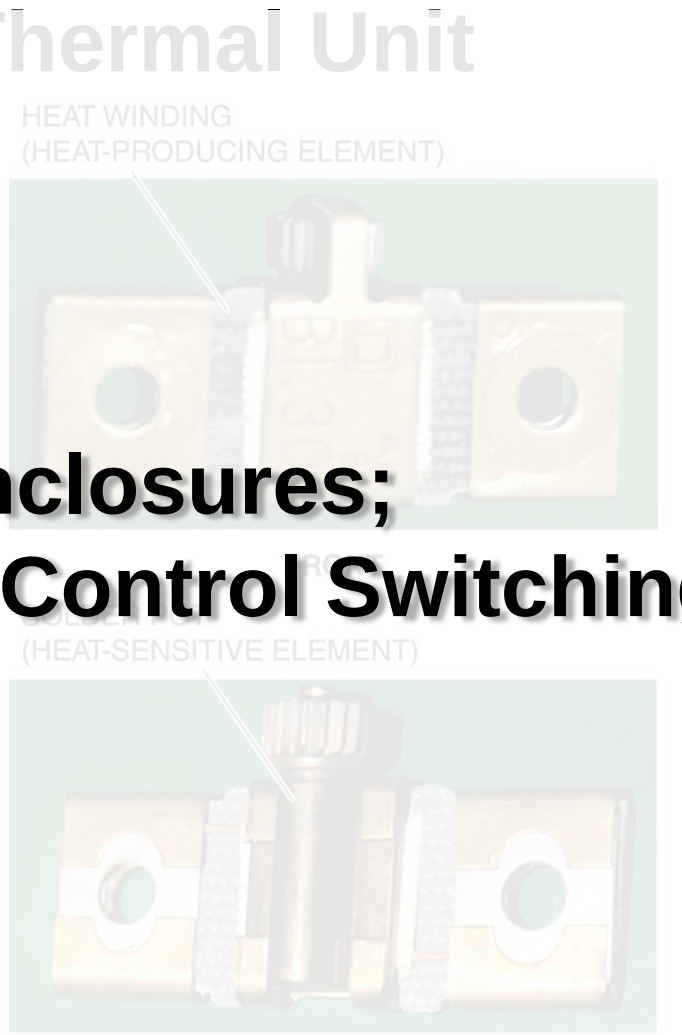
Overload Relays

- Overload protection must be provided to protect motors from accidental or prolonged overloads.
- A simple bimetallic overload relay has a bimetallic strip that reacts to a temperature increase and opens the circuit.



Next Session…

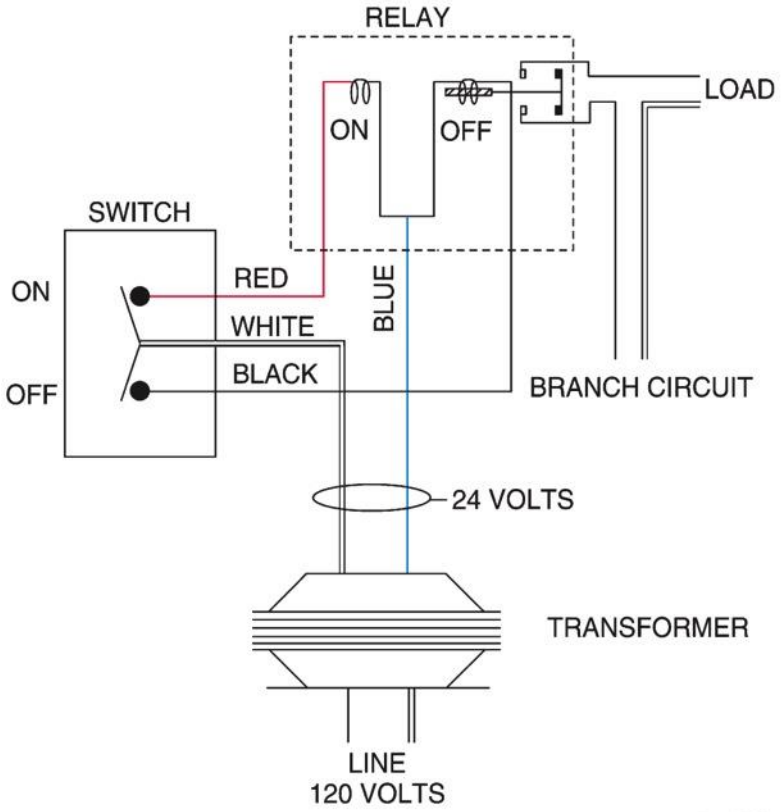
- Overload relays can be thermal or magnetic.
- Magnetic overload relays react to excess current and are not affected by temperature.
- Thermal overload relays react to excess temperature generated by the overload current.



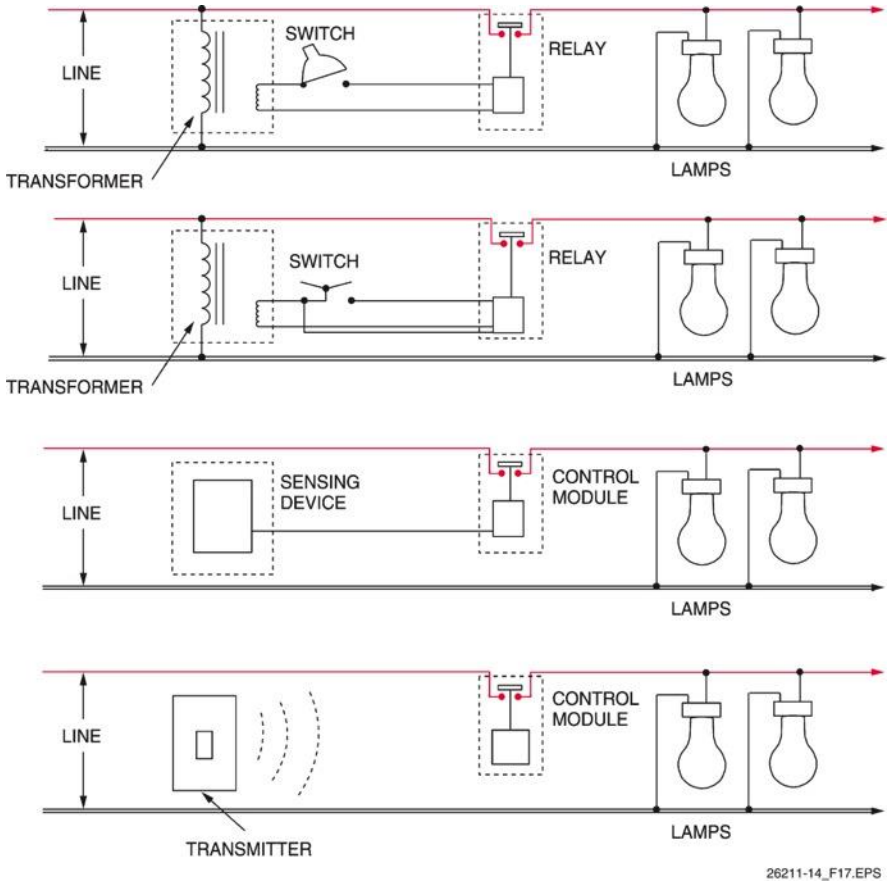
Protective Enclosures; Low-Voltage Remote Control Switching

Protective Enclosures; Low-Voltage Remote Control Switching

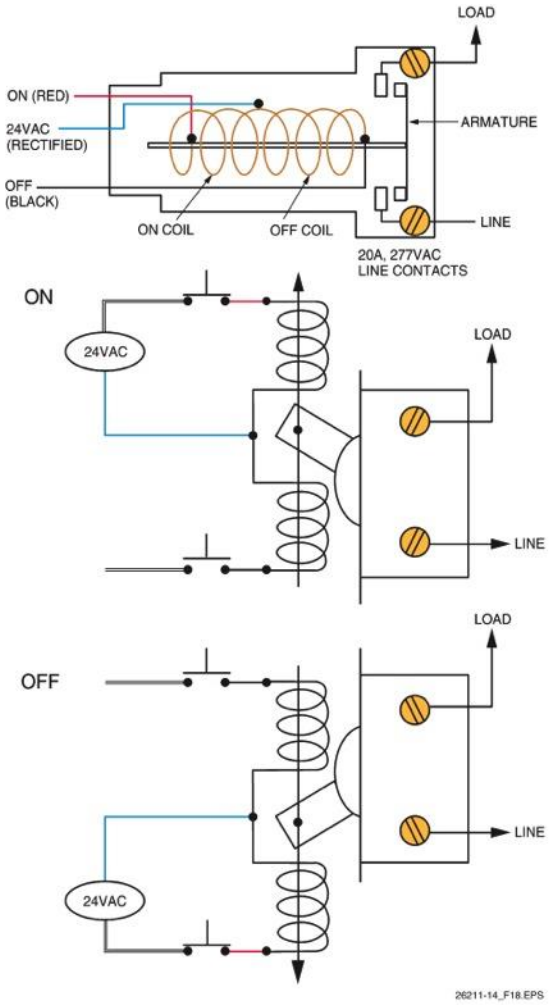
- All control apparatuses must be protected from the effects of dust and moisture using an appropriate enclosure.
- Low-voltage remote control switching can be used to isolate control circuits from power circuits. The remote control switch shown here can be located near the load or at a great distance.



Several Types of Remote Control Circuits and Related Components

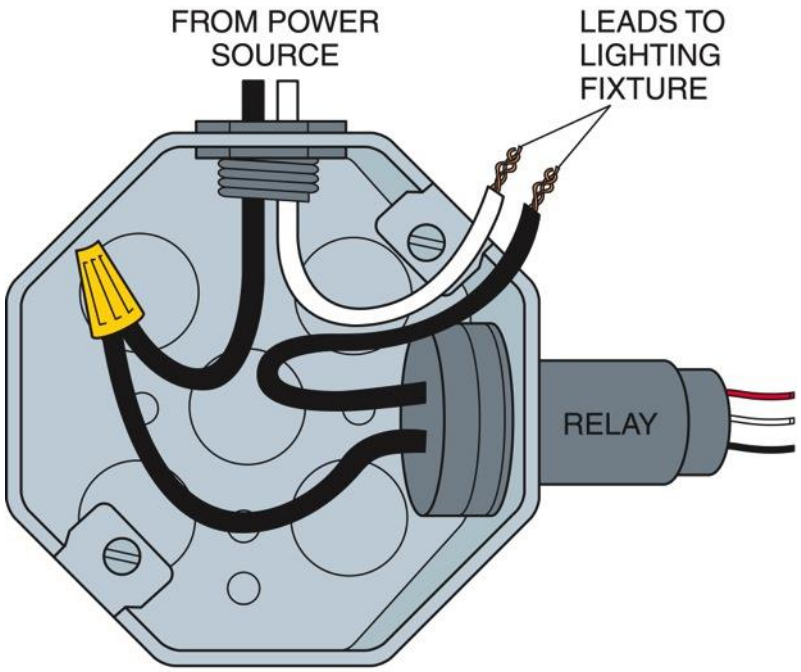


Relay Operation

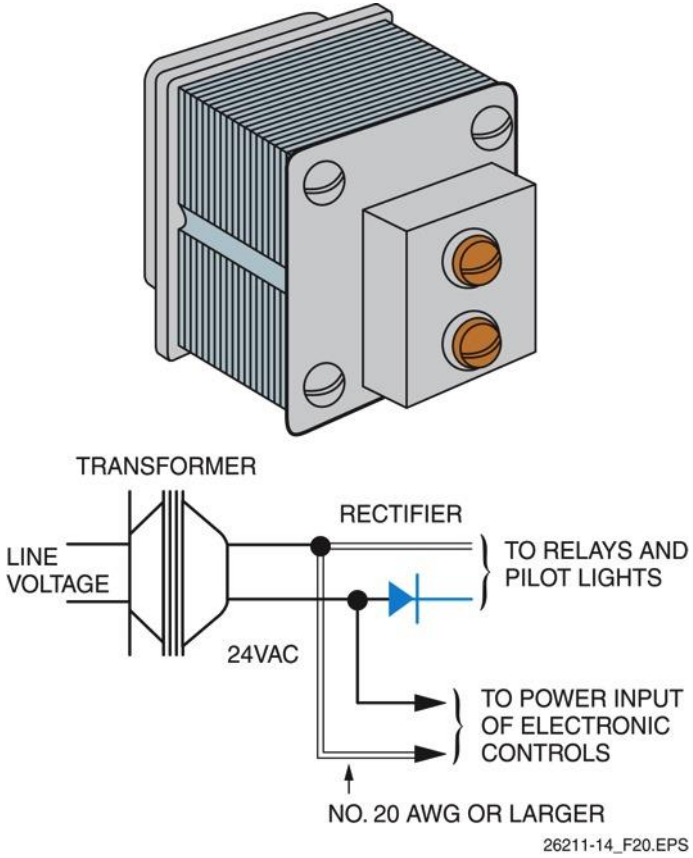


Relay Installed in an Outlet Box

Some low-voltage relays can be installed in a standard outlet box.



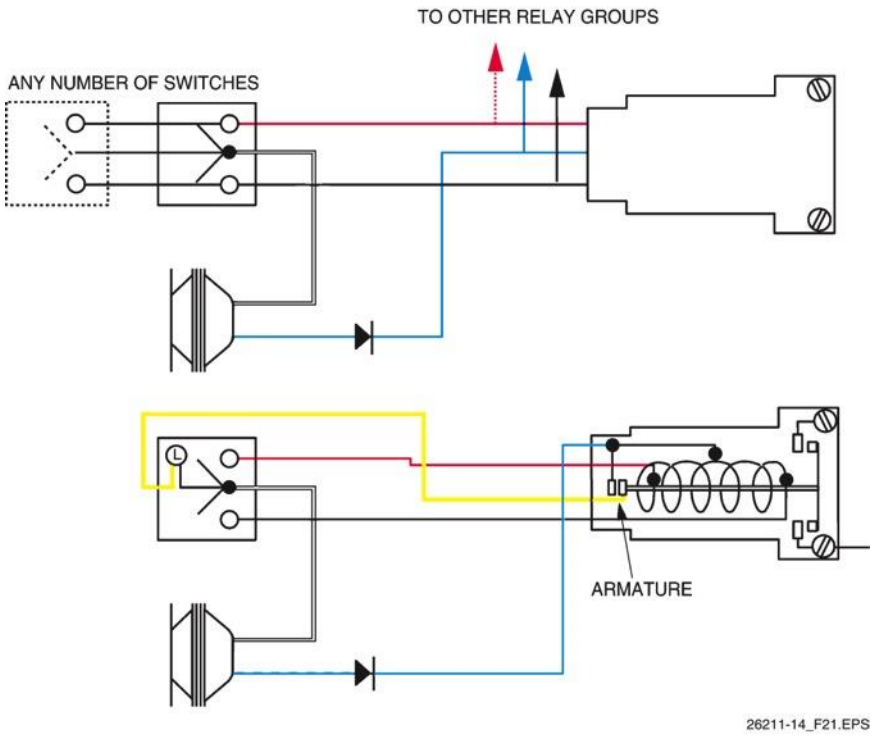
Control Transformer with Power-Supply Wiring Diagram



- The transformers used with remote control switching systems supply 24VAC.
- The AC input voltage to the power supply varies by manufacturer, but common voltages include 120V, 208V, 240V, and 277V.

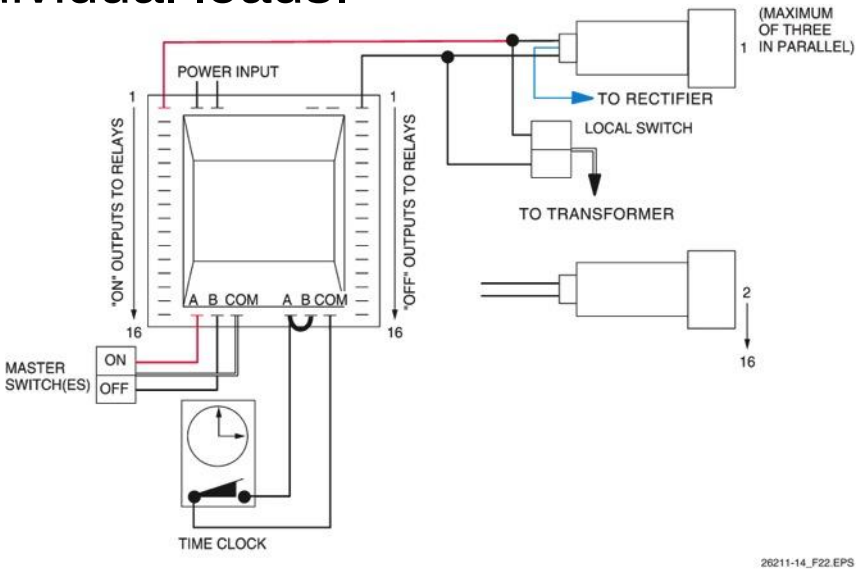
Switch Operation

- A standard low-voltage switch is a single-pole, double-throw type: pushing the On button completes the circuit, shifting the armature to the corresponding position.
- The pulse operation allows any number of switches to be wired in parallel, as shown here. In addition, other relay groups can be added by paralleling their control leads.



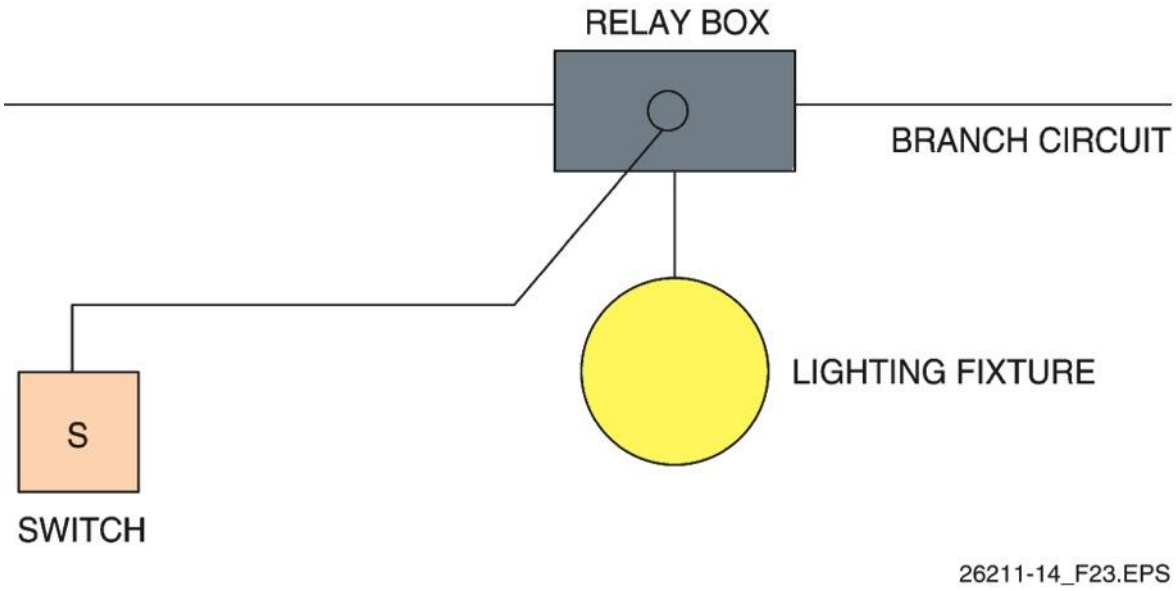
Master Sequencer Connections

- A master sequencer allows relays to be controlled as a group while still maintaining individual control using local switches.
- This system allows the use of other control elements including time clocks, building automation system outputs, photocells, and other contact devices to provide automation with local override of individual loads.



Single-Switch Control

- A single-switch relay control for a light or group of lights is similar to that of a single-pole conventional circuit.
- A time clock and/or photocell can be added to control multiple lights at prescribed intervals.



Schematic Wiring Diagram of Single Switches Controlling Each Circuit

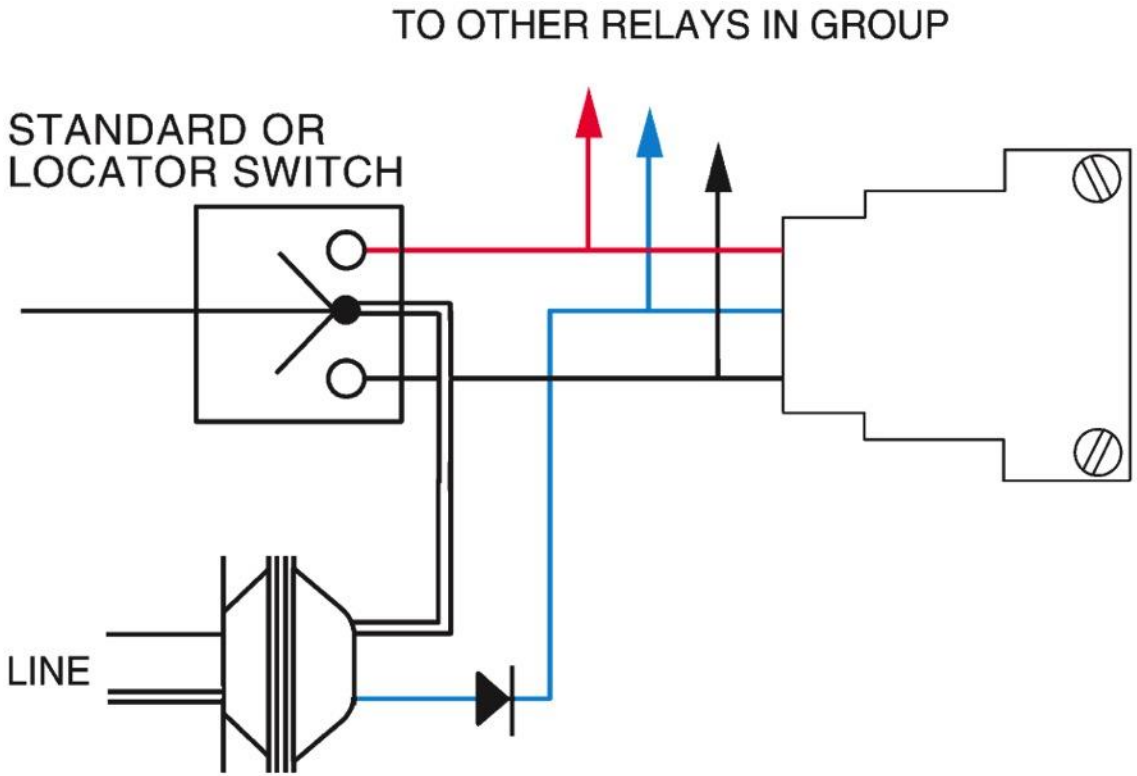
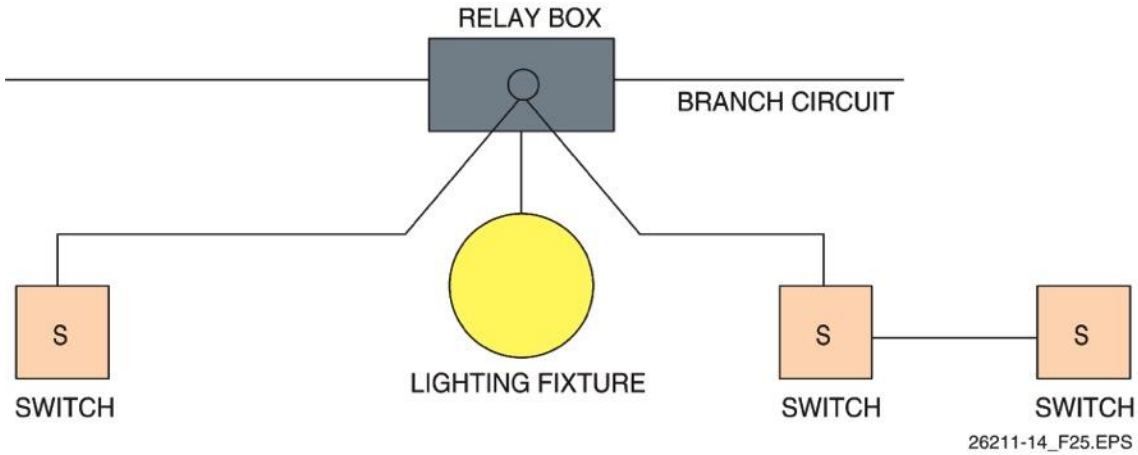
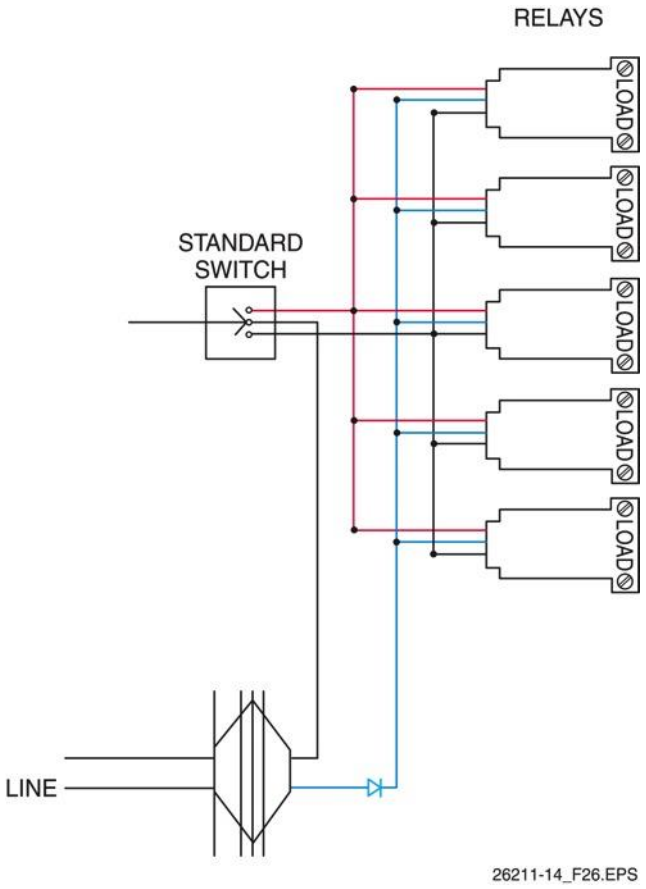


Diagram of Multipoint Switching of a Single Circuit



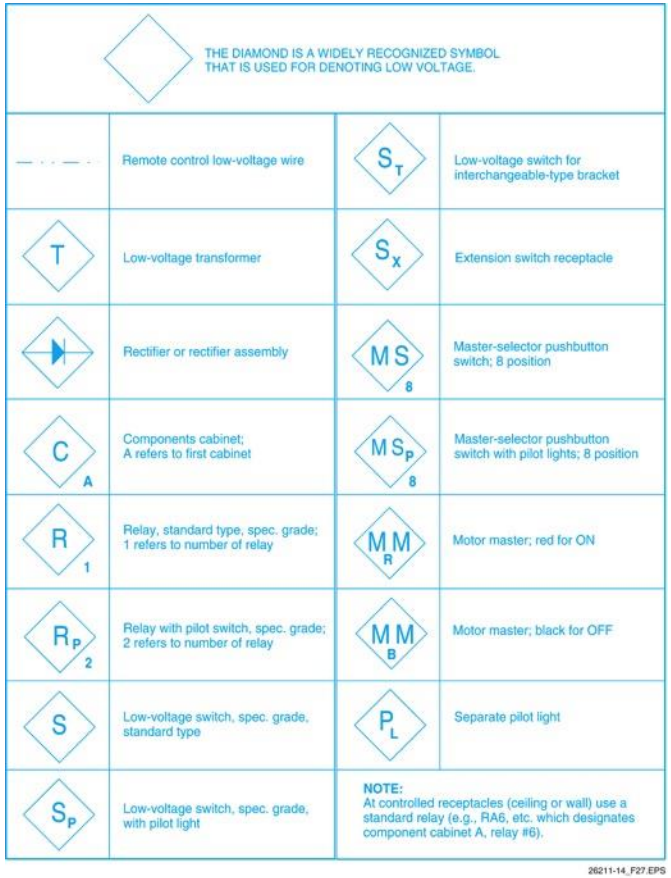
- With conventional multipoint switching, expensive three-way and four-way switches are required, along with traveler wires through all of the switches.
- Relay switching offers the advantage of adding low-cost control points.

Switching Circuits Being Controlled From One Location

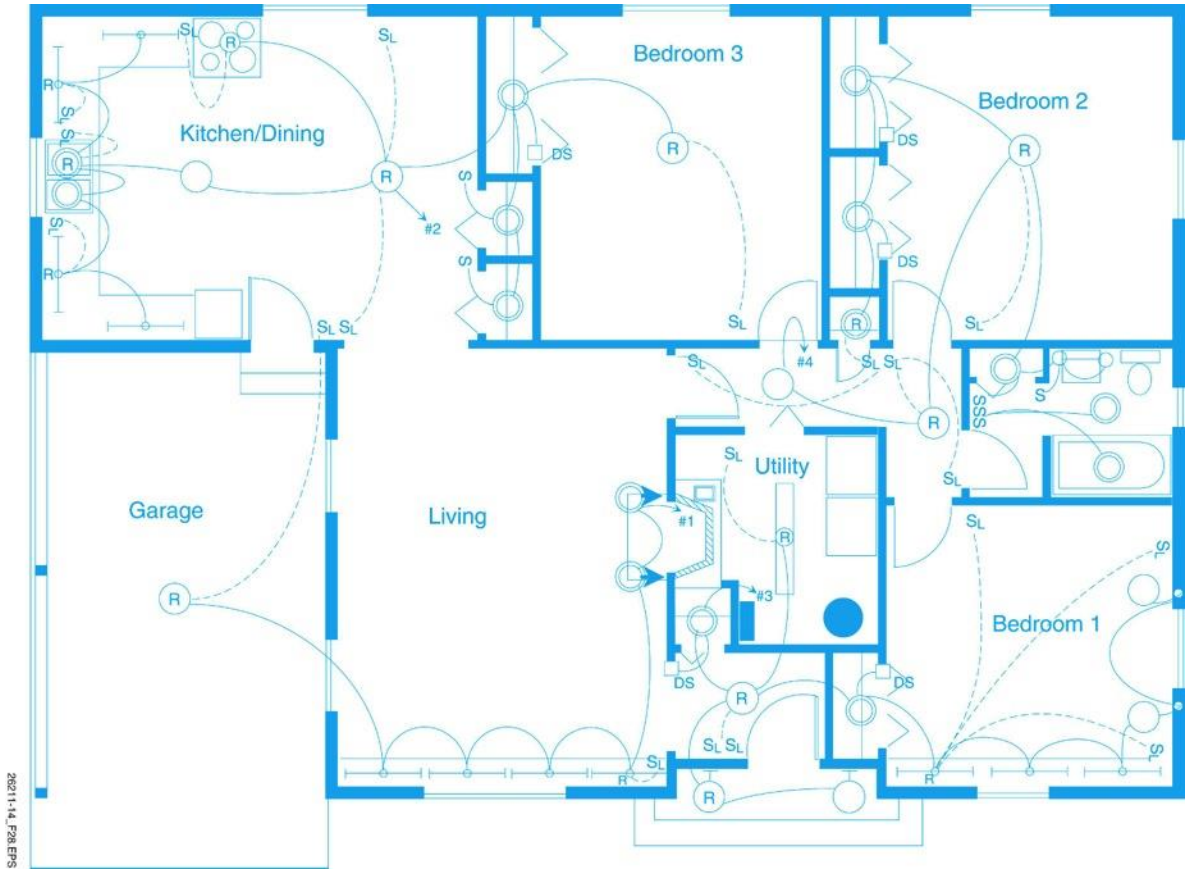


- With conventional circuits, switches are ganged to control many lighting circuits from a single location. Remote control switches can be used to provide a similar form of control.
- Master control units are normally used where more than six switches are required.

Recommended Symbols for Low-Voltage Drawings



Floor Plan of a Residence Using Low-Voltage Switching

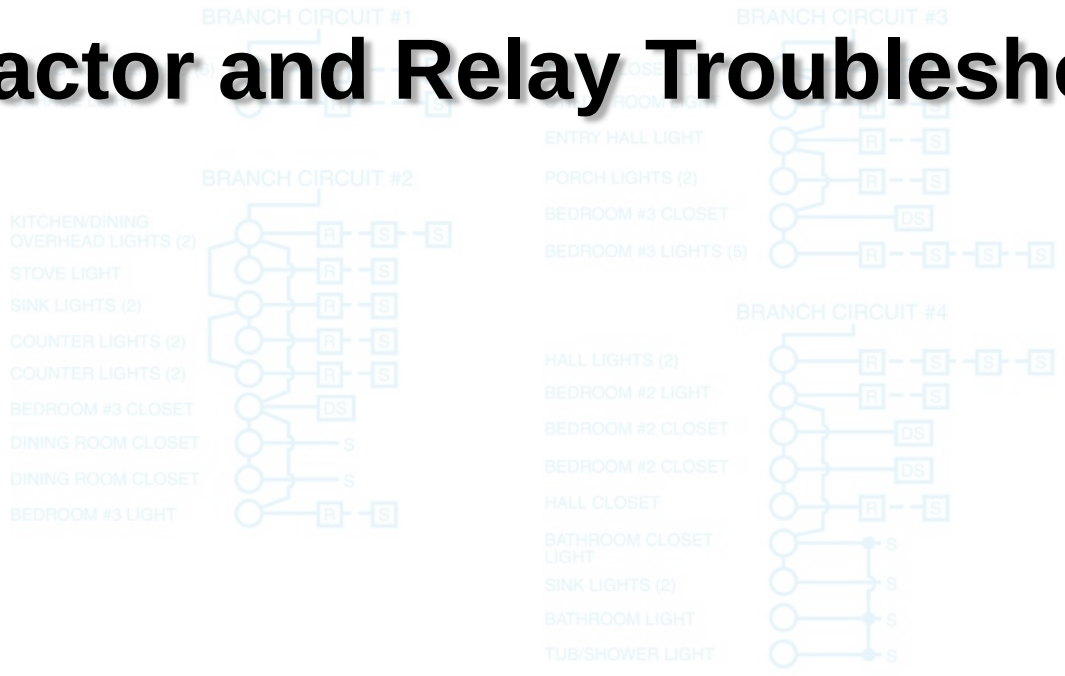


6.0.0 – 7.6.0

Next Session…

Schematic Wiring Diagram of Lighting Circuits

A schematic wiring diagram provides details of the connections in a low-voltage control system.



Contactor and Relay Troubleshooting

Contactor and Relay Troubleshooting

Symptoms	Probable Cause	Action or Items to Check
Failure to pull in	Either no voltage or low voltage at coil terminals	Blown fuse, open line switch, break in wiring Line voltage below normal Overload relay open or set too low Tripping toggle (non-automatic breakers) fouled Control level or start button in off position Pull-in circuit open, shorted, or grounded Contacts in protective or controlling circuit open or one of their pigtail connections broken
	Operating coil open or grounded	Inspect and test coil
	Loose or disconnected coil lead wire	Inspect and correct
	Excessive magnet gap, improper alignment	Inspect and correct
	Armature obstructed or gumming deposits between armature and pole face	Inspect and correct
	Binding caused by deformed or gummy hinge	Replace if bent; degrease if gummed up
	Excessive armature spring force	Lessen spring force
	Normally closed contacts welded together	Replace contacts
Failure of equipment to start with contactor closed	One contact not closing	Replace set of contacts
	Contacts burned	Replace
	Contact pigtail connection broken	Replace
Failure to drop out	Operating coil is energized	Contacts in controlling or protective tripping circuits closed, shorted, or shunted Tripping devices defective, such as overload tripping toggles do not strike release, undervoltage relay plunger stuck or out of adjustment, defective stop button, or defective time-delay escape mechanism (closed air vent) Current supplied over an unintentional path due to grounds, defective insulation, pencil markings, moisture, or lacquer chipped off relay base
	Residual magnetism excessive due to armature closed tightly against pole face	Adjust or replace
	Armature obstructed or gumming deposits between armature and pole face	Clear and clean
	Binding caused by deformed or gummy hinge	Replace or degrease
	Contact pressure spring or armature spring too weak or improperly adjusted	Replace or adjust
	Improper mounting position (upside down)	Mount correctly
	Normally open contacts welded together	Replace contacts

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Next Session...

Wrap Up

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3-2-1

3 – Write 3 important things learned during class

2 – Write 2 questions you have about the material

1 – Write 1 thought you had about the material

Next Session…

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.