Skillplex

Wiring Fundamentals

Table of Contents

Chapter 1: Course Overview

1.1 Course Goal

This course is intended for high school students enrolled in CTE pathway programs to learn the fundamentals of wiring motor contactors, relay circuits, and using a PLC to interface with discrete field devices.

This course is structured to provide students hands-on experience wiring and troubleshooting industrial control circuits. The student will explore different methods of controlling a motor contactor using an operator push button station, control relay, and PLC.

Skillplex is not an expert in safety systems or equipment and does not represent itself as an authority on safety practices in either educational or workplace environments.

1.2 Course Objectives

Upon successful completion of this course, the student will be able to perform the following:

- Use a multimeter to verify the correct voltages are present at power distribution terminal banks.
- Use a multimeter to diagnose open and short circuits.
- Use a relay logic ladder diagram to wire a motor contactor.
- Control a motor contactor using 2-wire and 3-wire motor control circuits.
- Use a control relay to change the operation of a motor control circuit.
- Covert a relay logic ladder diagram to a PLC program.
- Establish communications with a PLC using a programming laptop.
- Use RSLogix500 to create a ladder logic program.
- Download a ladder logic program to a PLC and monitor its operation.
- Detect, diagnose, and repair electrical faults in a PLC system.

Chapter 3: Relay Circuits

3.1 Chapter Objectives

After completing this chapter, you will be able to:

- Interpret basic ladder logic diagrams and symbols.
- Explain the difference between NO and NC contact types.
- Wire relay circuits using ladder diagrams.
- Use a multimeter to analyze the operation of relay circuits.

3.2 Push Buttons and Contact Types

Electrical switches like the ones you use to turn the lights on and off inside your home are a simple mechanism which allow an electric circuit to close or open. When the switch is **open**, there is no continuity and current cannot flow through the circuit. When the switch is **closed**, there is continuity and current is allowed to flow through the circuit.

In industrial control circuits**, hand switches** are often used by operators to turn different devices (such as control relays and motor starters) on and off. A common type of hand switch is a **push button**, which is operated by pressing down on a button to activate a set of contacts to close or open a circuit.

A **contact** is a switching mechanism used with push buttons and other discrete devices used for on/off control. A contact can be one of two types: **normally open (NO)** or **normally closed (NC)**. Here the word “normally” refers to the contact’s “normal” at-rest state when it is not being activated by an operator. The diagram symbols for a push button with each style of contacts is shown below in figure 3.4a.

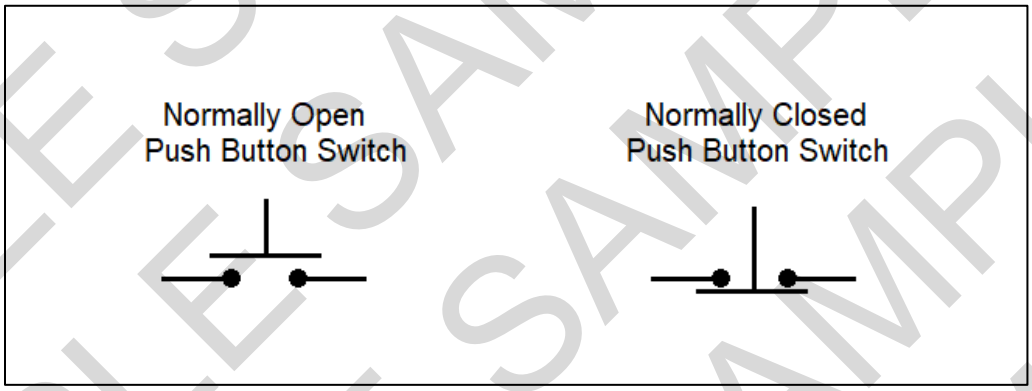

Figure 3.2a

If a push button has a set of NO contacts, this means that when the button is not being pressed by an operator, the contacts will be in an open state and current will not be allowed to flow to the load device(s). When the operator presses the push button, the NO contacts will close, allowing current to flow to the load device(s). When the operator releases the push button, a spring returns the contacts to their normal (open) position

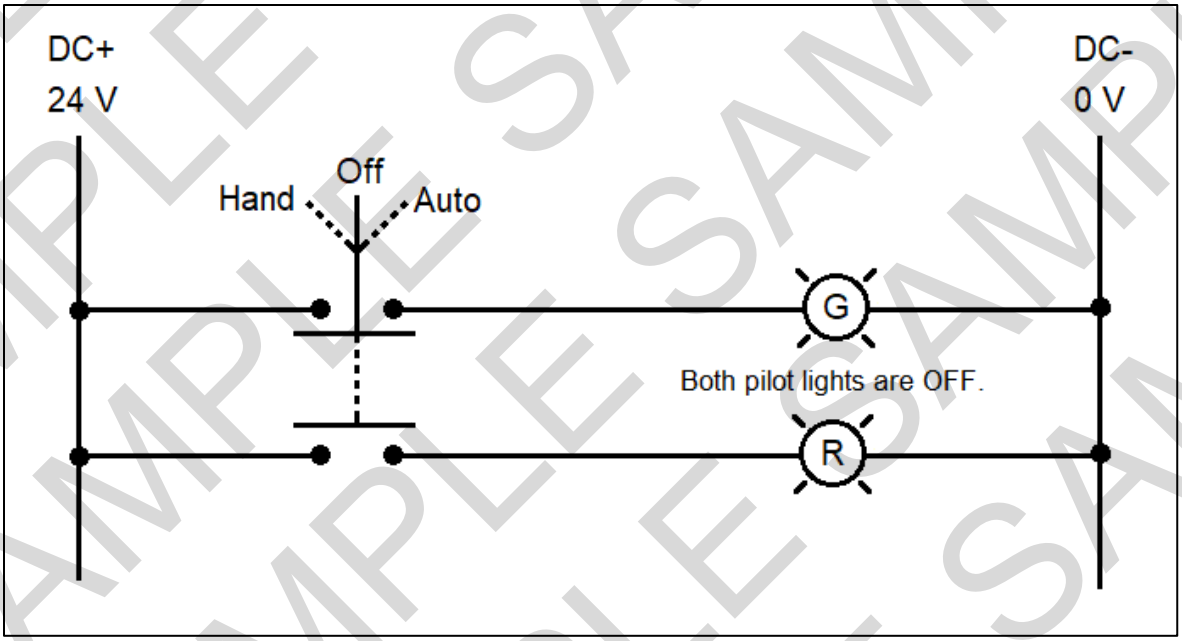

Figure 3.2f

The main difference between how a selector switch operates compared to a pushbutton, is that a selector switch allows the selected contact state to be **maintained** without having to hold the switch in that position. The selector switch will actually “click” into one of the three positions and remain in that position until adjusted by the operator. The pushbuttons we have discussed in this chapter, on the other hand, only allow for **momentary** contact closure, and must be held down by an operator to keep the contacts in their activated state.

3.3 Electromagnetic Relays

A relay is a discrete control device that is used to switch power on and off to other circuits connected to it. The word **discrete** means “individual” or “distinct” and indicates that the device only has two possible states: on or off. An electromagnetic relay is made up of an electromagnetic coil and one or more sets of contacts which can be used to turn different load circuits on or off.

An **electromagnetic coil** is an electrically-operated magnet in which a copper wire is wound around an iron core; when energized with the proper voltage, the coil generates a magnetic field which attracts or “pulls in” an iron armature that is mechanically linked to a set of contacts that switch open or closed depending on the contact type (NO or NC). Relays can have a single NO contact, a single NC contact, one NO and one NC contact, or two NO and two NC contacts.

The electrical schematic symbol for a single-pole, single-throw (SPST) relay with a normally open contact is shown below in figure 3.3a. The **pole** or **common** of the relay contact is the side of the contact set that performs the switching action. The term **throw** refers to how many contacts there are for the pole to connect to (only one in this case). The effect of the coil’s magnetic field which causes the relay contacts to actuate (operate) is represented by a dashed line.

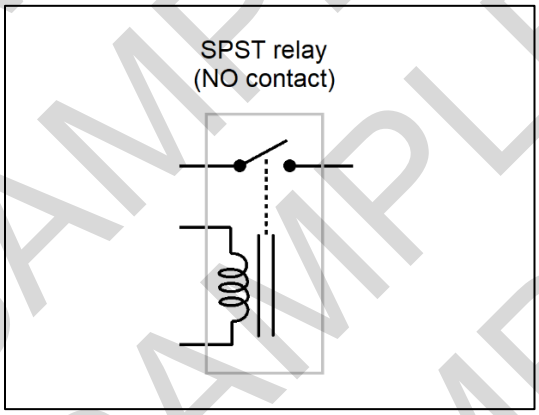

Figure 3.3a

The electrical schematic symbol for an SPST relay with a normally closed contact is shown below.

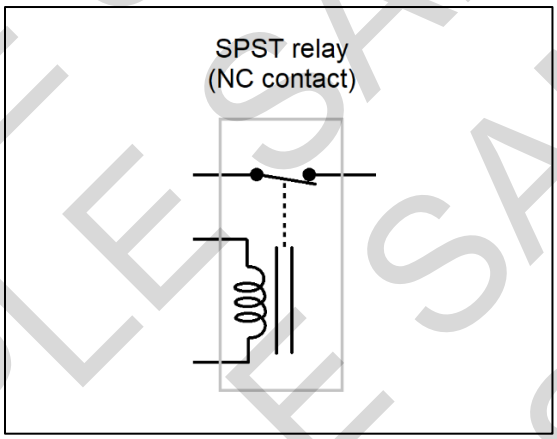

Figure 3.3b

In figure 3.3g below, you can see the internal parts of an electromagnetic relay. An electromagnetic coil is positioned below an iron armature. The armature is resting on a pivot point (like a seesaw) and is held in its normal position by a spring. While the relay coil is **de-energized** (does not have voltage applied to it), the tension from the spring keeps the armature tilted up and away from the coil. There are two contacts positioned above and below the end of the armature. The upper contact is normally closed, since the armature is already touching it while the coil is de-energized. The lower contact is normally open, since the armature is not touching it while the coil is de-energized.

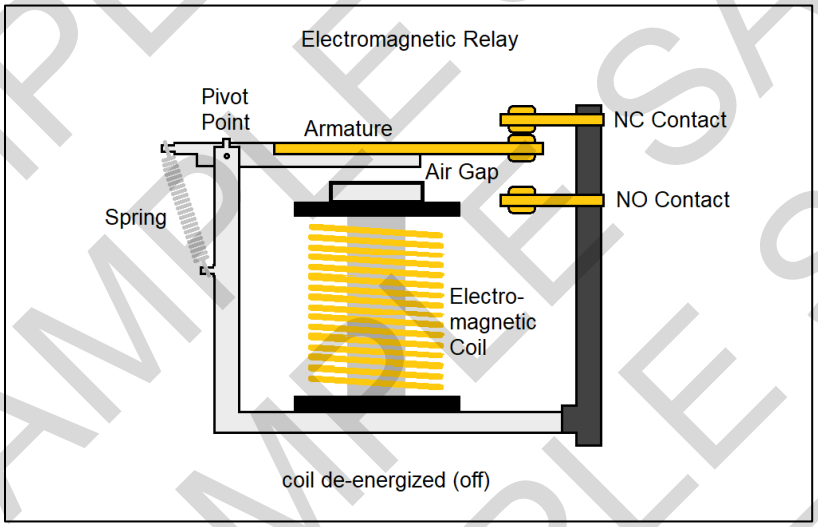

Figure 3.3g

In figure 3.3h below, the same relay is shown with the coil **energized** (has voltage applied to it). When current flows through the coil, it causes a magnetic field to be generated which attracts the iron armature towards the coil. This pulls the armature down, causing the normally closed contact to open, and causing the normally open contact to close. The magnetic field is now overcoming the force of tension from the spring. When the coil becomes de-energized again, the spring will return the armature back to its normal position, tilted up and away from the coil.

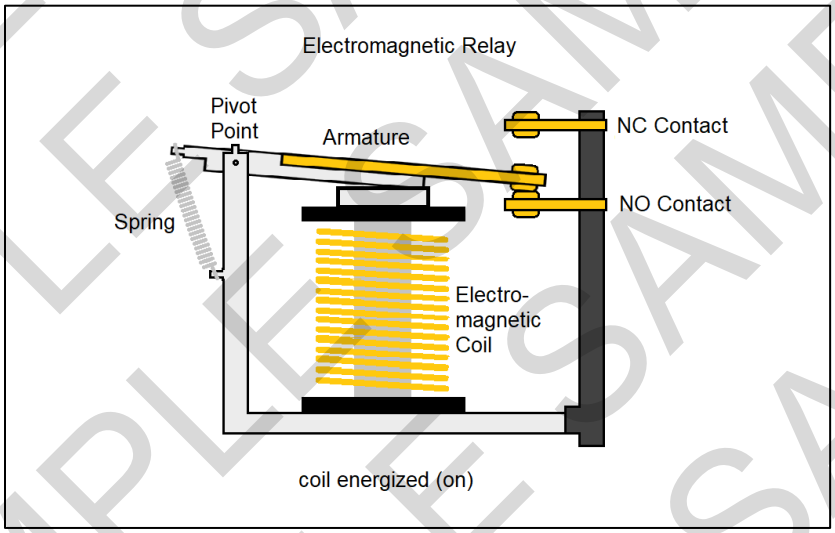

Figure 3.3h

Electromagnetic relays consist of two parts: the **relay** or “ice cube” and the **terminal base** which the relay is plugged into. The relay terminal base brings the connections from the external pins or blades of the relay to the wiring terminals at the top and bottom of the terminal base. The wiring terminals are used to wire the control circuit and load circuits to the relay. In figure 3.3h below, you can see the **pinout diagram** for a DPDT relay and its terminal base. A pinout diagram shows which internal component of a device each pin or wiring terminal is connected to.

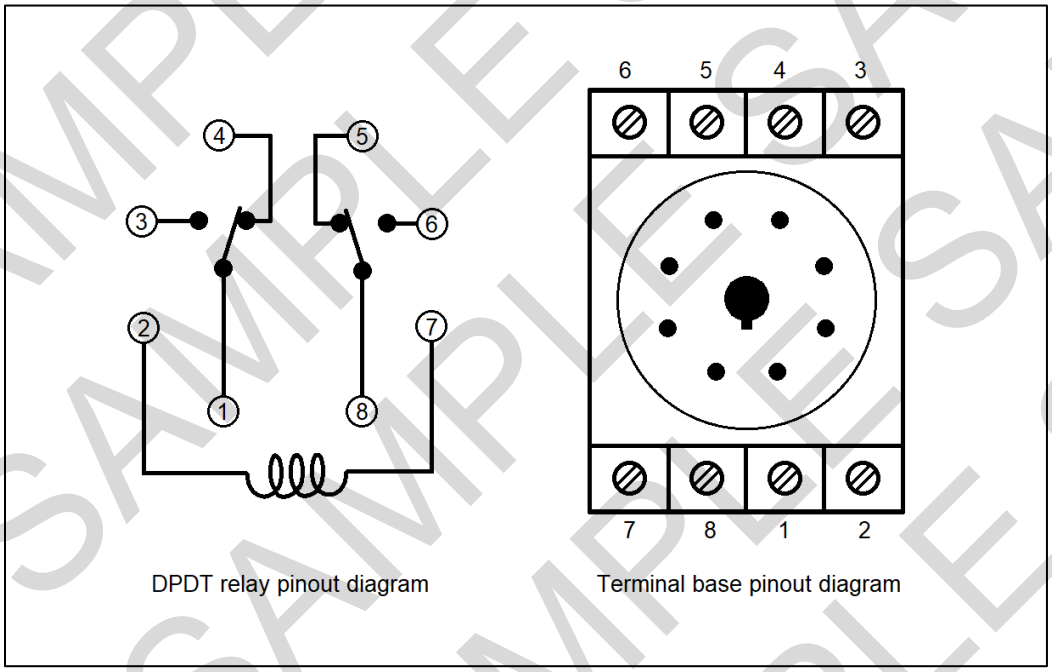

Figure 3.3h

You can see in the relay pinout diagram in figure 3.3h that the relay coil is connected to pins 2 and 7. The poles (also called “commons” or abbreviated to COM) of the relay are connected to pins 1 and 8. The poles are what you connect the voltage you will be using in the load circuits (e.g. +24 VDC). The normally closed contacts are connected to pins 4 and 5, and the normally open contacts are connected to pins 3 and 6. On the terminal base pinout on the right side of the picture above, you can see that once the relay is plugged into the base, the pins labeled on the relay pinout will correspond to the wiring terminals labeled on the terminal base pinout. For example, if you were going to wire power to the relay coil, you would connect +V and -V to terminals 2 and 7 on the terminal base.

The ladder logic diagram symbols for NO and NC relay contacts are different from those used to represent NO and NC push buttons. NO relay contacts are represented by two vertical lines with a space in between (showing there is no continuity across the contacts in their normal state). NC relay contacts are represented by a two vertical lines with a diagonal line through them (showing there is continuity across the contacts in their normal state). The relay coil symbol is an empty circle. These symbols are shown below in figure 3.3j.

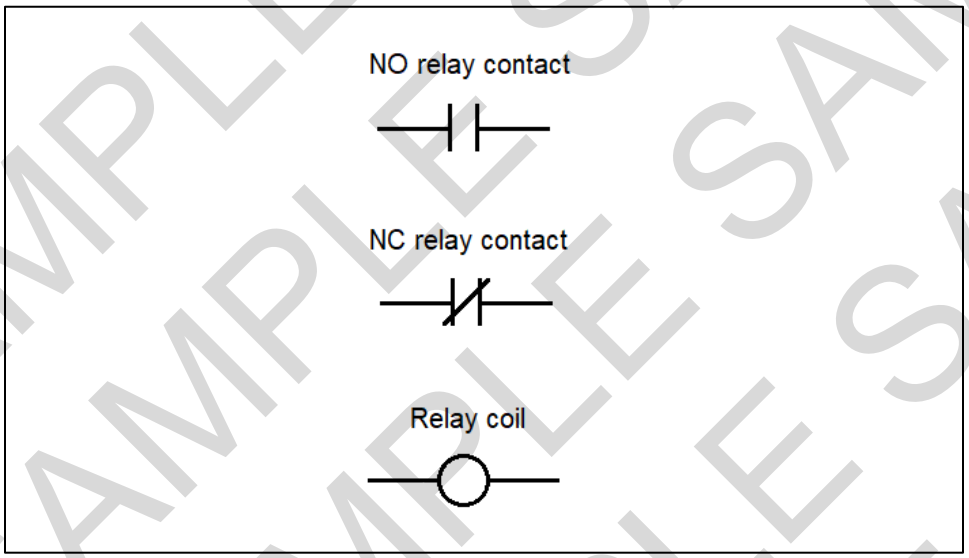

Figure 3.3j

Ladder diagrams do not show the connections between the coil and contacts of a relay the way an electrical schematic does (such as figures 3.3e or 3.3f). Instead, ladder diagrams show the corresponding coil and contacts of the same relay using **labels**. You will either see the relay contacts have the exact same name as the coil (i.e. coil labeled CR2 and all contacts also labeled CR2), or you will see the relay contacts labeled with the name of the coil along with a unique number to separate it from the other contacts in the same relay (i.e. coil labeled CR2 and contacts labeled CR2-1, CR2-2, CR2-3, CR2-4).

The ladder diagram in figure 3.3k shows a relay circuit that controls two pilot lights using one SPDT relay. On rung 001, a NO push button is used to control the relay coil labeled CR1. On rung 002, the NO relay contact labeled CR1-1 controls a green pilot light. On rung 003, the NC relay contact labeled CR1-2 controls a red pilot light. When the push button is not pressed, the red light is on and the green light is off, and when the push button is pressed the red light turns off and the green light turns on.

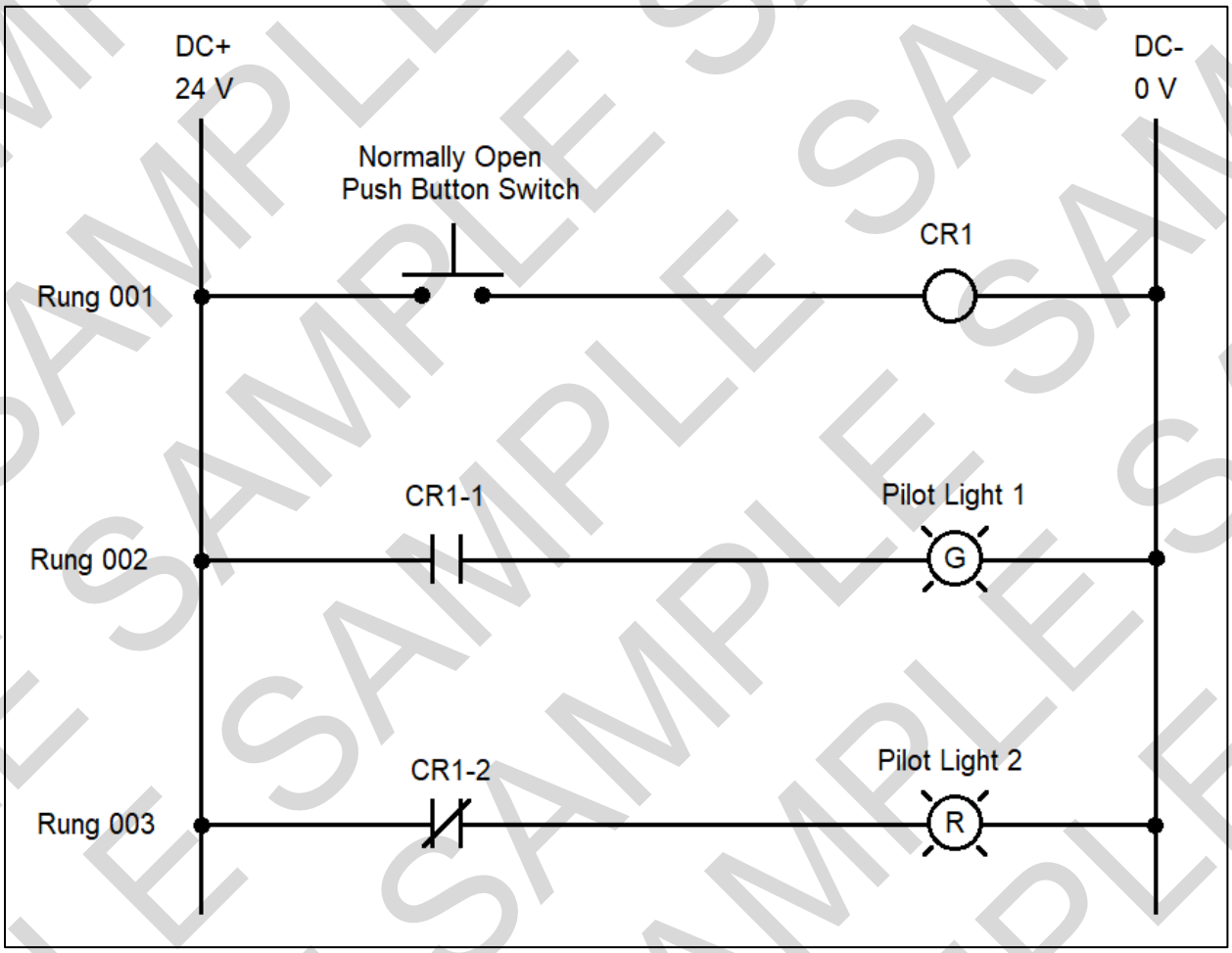

Figure 3.3k