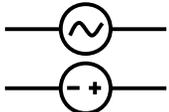
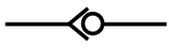


# Electrical Control and Ladder Diagrams

## Analogs Between Electrical and Hydraulic Power

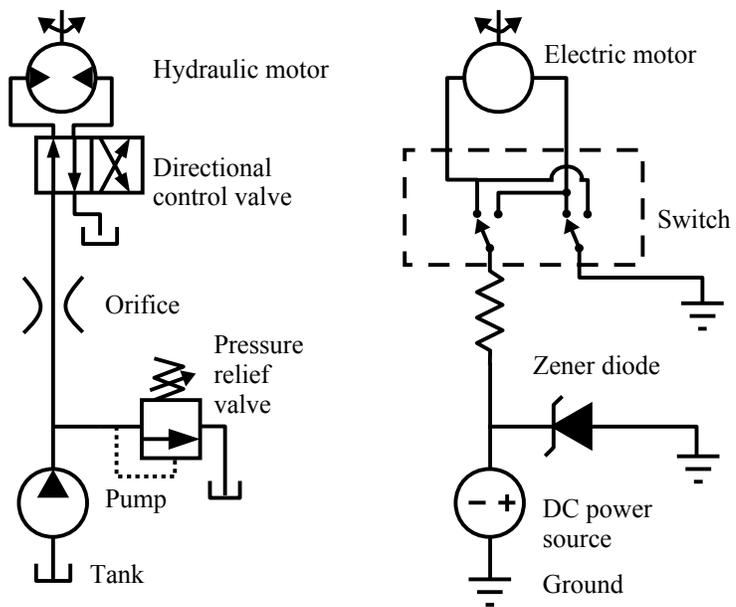
Fluid power systems move molecules of liquid or gas to do useful work. Electrical power systems move electrons to do useful work. There are many parallels between fluid power components and electrical components. For example:

An electrical resistor restricts current flow.			An orifice plate or a flow control valve restricts hydraulic fluid flow.
A generator or power supply creates current and voltage. It does not create electrons...it just gets them moving.			A pump creates fluid flow and pressure. It does not create oil...it just gets it moving.
An electrical ground absorbs the excess current.			A tank absorbs the excess hydraulic fluid.
An electrical switch controls the direction of current flow.			A directional control valve controls the direction of fluid flow.
An electrical diode prevents reverse electrical current.			A check valve prevents reverse fluid flow.

Consider this hydraulic system. An electric motor powers a pump, which moves hydraulic fluid at a certain flow rate and pressure to a hydraulic system. Excess pressure causes the pressure relief valve to dump fluid to the tank. An orifice reduces the pressure downstream. A directional control valve sends fluid to one side of a hydraulic motor, which returns it to the tank.

This is a lot like an electrical system, where a power supply drives electrons through an electrical circuit. The Zener diode regulates the voltage in the circuit, despite fluctuations in voltage from the power supply. A resistor causes a voltage drop. The directional switch sends current to one side of the electric motor; it returns from the other side and goes to ground.

We've seen before that pneumatic and hydraulic directional control valves can be actuated by hand, by mechanical contact (push buttons & rollers), or by solenoids (electromagnets). In this lesson, we'll see how solenoid-actuated valves, various electrical switches, and electrical relays can be used to automate a fluid power system.



## Electrical Components

We'll look at nine electrical components used for controlling fluid power circuits: seven types of electrical switches, solenoids, and timers. Taken together with a power supply and wiring, we can automate a pneumatic or hydraulic circuit. An engineer draws up a fluid power diagram *and* an electrical diagram to depict the automated system. Most of the electrical components only appear on the electrical diagram; one exception is a limit switch, which appears on both

diagrams.

### Electrical Switches

Most electrical switches in fluid power systems have either a normally open (NO) position or a normally closed (NC) position. A mechanical spring returns the switch to its normal position. The exception is a toggle switch...like a household electric light switch, it toggles between two positions, and stays in its most recent setting.

The *push-button switch* is actuated by pushing down, so the NO symbol shows a gap between the electrical contacts and the button above the contacts. The NC symbol develops a gap when the button is pushed down.

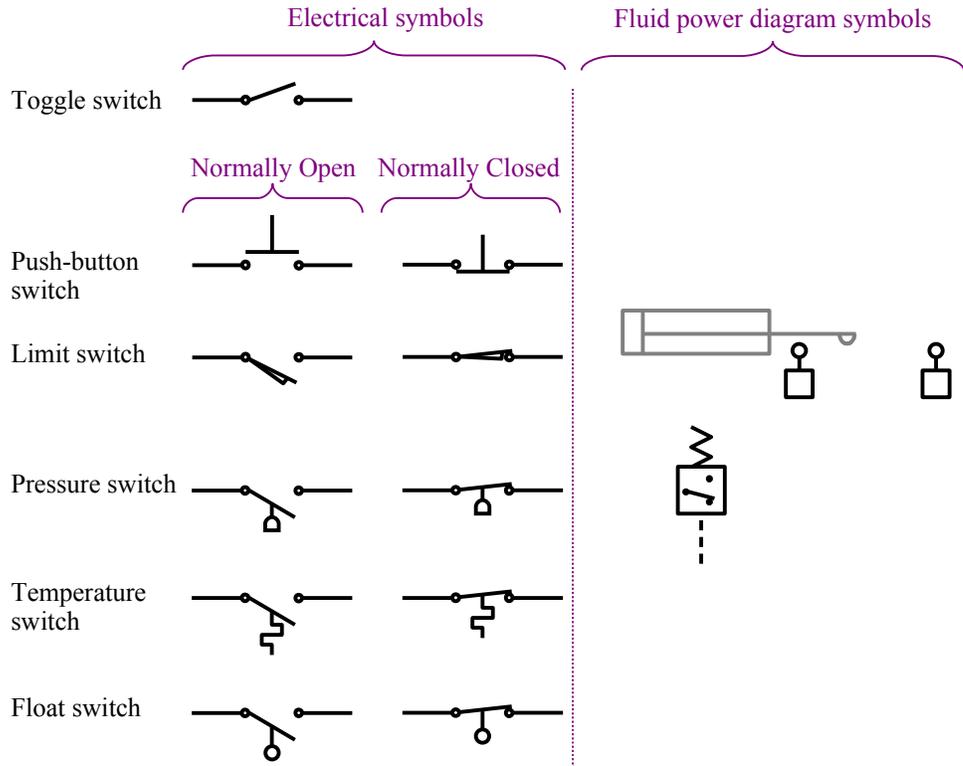
The remaining switches are actuated by lifting up, so the NO symbols show gaps between the electrical

contacts and the switch below the contacts. Consider the left-hand contact point a hinge; the switch rotates counterclockwise up when actuated. The NC symbols develop a gap when the switch lifts.

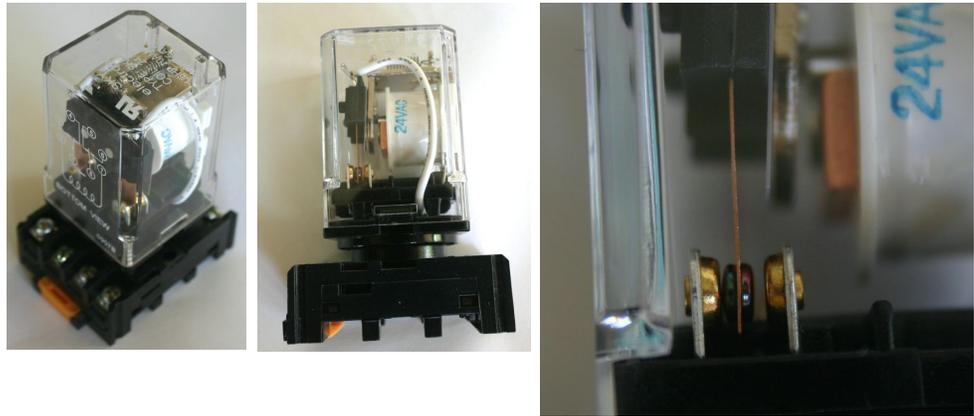
The *limit switch* is drawn on both the electrical and fluid power diagrams, because you have to show which cylinder and which end of the stroke trips the switch. The fluid power symbol looks like a box with a lollipop on top.

The *pressure switch* is also drawn on both diagrams, because you have to show where the pressure is being measured on the fluid power diagram. The fluid power symbol shows a pilot line running to a spring-returned switch; when the pressure builds up enough to overcome the spring force, the switch trips. You can buy adjustable pressure switches, with an arrow through the spring.

*Temperature* and *float* switches are triggered by a change in environmental conditions. You might use a temperature switch to shut down a fluid power system if the fluid temperature gets too hot. The symbol for a float switch looks like the float in a toilet tank.

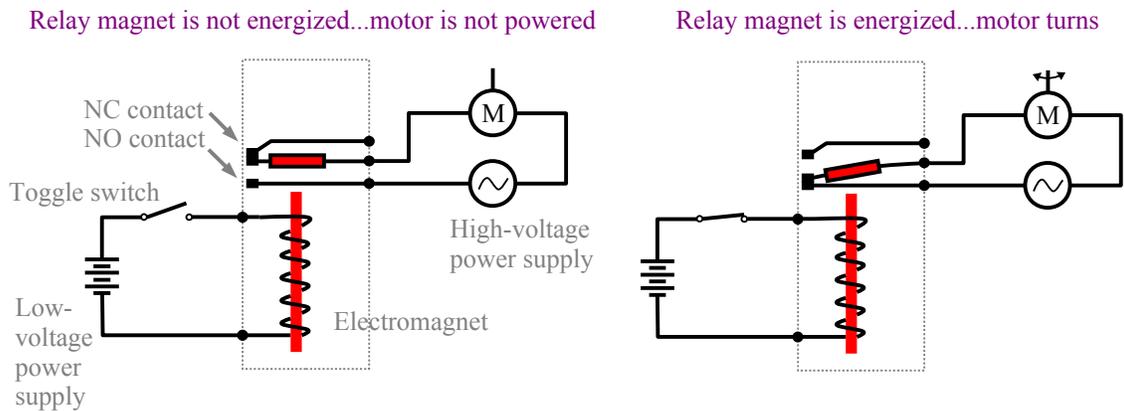


The switches described above are controlled by physical contact with a solid or liquid, or by a change in the environment. A *relay*, shown at the right, is a switch controlled by an electromagnet. When current flows through the magnet, it pulls a reed switch, opening NC contacts and closing NO contacts. Relays are used in applications where an electrical signal needs to turn several switches on or off.

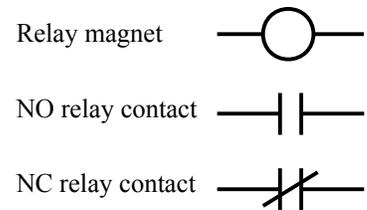


The high-magnification photo at the far right shows the contacts on this relay. The lefthand contact is NC; the righthand contact is NO. The magnet is wrapped in white tape, marked 24VAC in blue lettering. Eight screws in the black base are used for electrical contacts (2 to power the magnet, 2 for the higher voltage power supply, and 4 for the NO and NC contacts). If the relay burns out, simply unplug it from the base and install a new relay.

Relays are also used in high voltage applications; the operator uses a switch on a low-voltage circuit to control a high-voltage circuit, like the motor below. This is a safety application...the operator never touches a high-voltage switch.

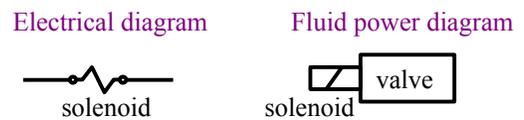


The electrical symbol for a relay magnet is a circle. The electrical symbol for a NO relay contact (the switch) is a pair of parallel lines. A diagonal line indicates a NC relay contact. If a control circuit has more than one relay, then the relay number is written next to the appropriate magnet and contacts.



**Solenoids**

A solenoid is an electromagnet that operates a pneumatic or hydraulic directional control valve. When the magnet is energized, it pushes on the valve spool, shifting the valve. The electrical symbol is a squiggly line; the fluid power symbol is a rectangle with a diagonal line attached to the end of the directional control valve. If the control circuit has more than one solenoid, then the solenoid number (or letter) is written on both diagrams.



## Timers

Timers can activate a set time after the timer is powered on; or activate a set time after the timer is powered off. In either case, timers can be connected as NO or NC switches.

NO, timed to close a set time after timer is energized



NC, timed to open a set time after timer is energized



NO, timed to close a set time after timer is turned off



NC, timed to open a set time after timer is turned off



## Ladder Diagrams

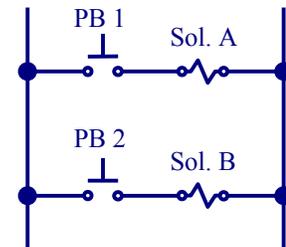
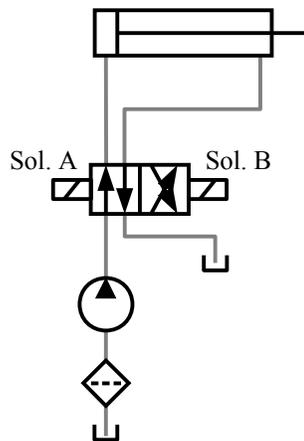
Now we'll put these pieces together and design electrically-controlled fluid power systems. On the left is a fluid power circuit. This hydraulic circuit has a solenoid-activated directional control valve. The solenoids are labeled A and B.

When solenoid A is energized, it moves the spool in the directional control valve to the right (its current position). The cylinder extends.

When solenoid B is energized, it moves the spool in the directional control valve to the left, and the cylinder retracts.

When neither solenoid is activated, the spool stays in whatever position it was most recently moved into. So you only have to energize a solenoid for a short amount of time, then you can turn off the power.

Where is the spool if neither solenoid is energized? It depends on which solenoid was energized most recently.



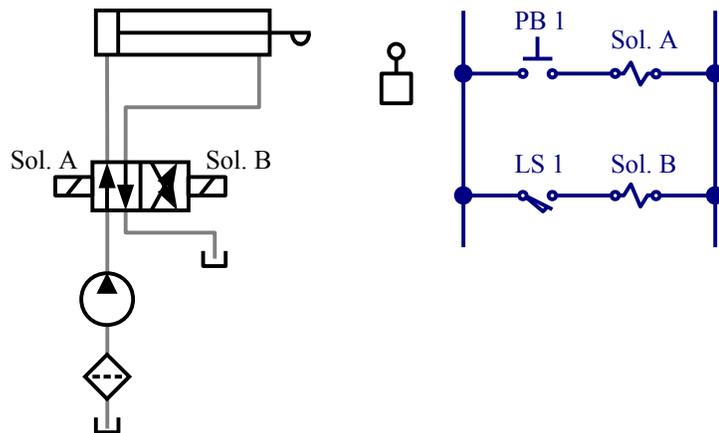
The electrical circuit at the right is drawn in the form of a ladder. Each rung in the ladder has two parts: on the left is a switch or some other control device. On the right is an actuator that responds to the switch. Electricity wants to flow from the left leg of the ladder to the right leg of the ladder, and it will take whatever path is open to it. You can think of one leg as powered, the other as the ground.

In this ladder diagram, we have two rungs. Each rung has a push-button switch that activates a solenoid. If you depress push button #1, Solenoid A will be energized, and the cylinder extends. If you depress push button #2, Solenoid B will be energized, and the cylinder retracts.

Here's a similar circuit. When the cylinder extends fully, it trips a limit switch.

On the ladder diagram, if you depress push button #1, Solenoid A is energized, pushing the spool to the right. The cylinder extends.

When the cylinder is fully extended, it trips limit switch #1, closing the second rung of the ladder diagram. Solenoid B is energized, pushing the spool to the left. The cylinder retracts.



In this circuit we have one solenoid on the directional control valve, and a return spring. When the solenoid is energized, it pushes the valve spool to the right, and the cylinder extends.

When the solenoid is de-energized, the spring pushes the spool to the left, and the cylinder retracts.

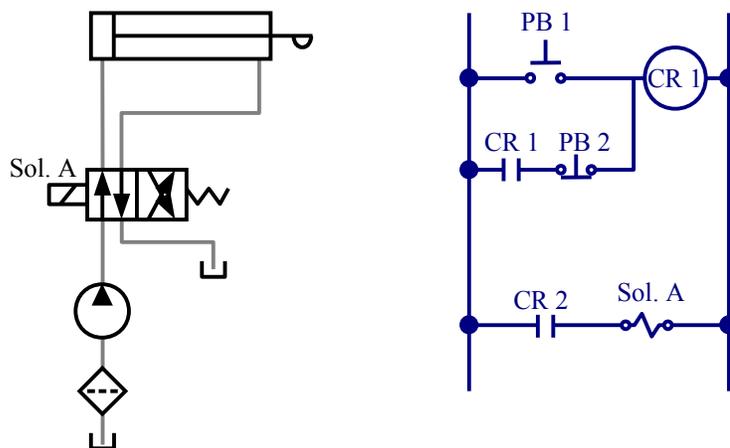
The electrical circuit uses a relay and two push-button switches. The relay has at least two NO contacts; we'll use one to power the relay magnet, and the other to control power to the solenoid.

Push-button switch #1 is NO. We have to depress the switch to *close* a circuit.

Push-button switch #2 is NC. We have to depress the switch to *break* a circuit.

Depress push-button switch #1. This energizes control relay #1. When this relay is energized, we get a path through the relay contact on the left...so electricity goes from the left leg through CR 1 and PB 2, and on to the right leg. The relay switch CR 1 on the lower rung sends electricity through solenoid A, and the cylinder extends.

Depress push-button switch #2, and it breaks the circuit to our control relay. This breaks the circuit in the lower rung, and solenoid A is de-energized. The spring returns the valve spool to the left, and the cylinder retracts.



Now we're going to automate the cylinder so it extends and retracts continuously.

There's a pressure switch on each line going to the cap and rod ends of the cylinder. When the cylinder is fully extended, the pressure at the cap end rises, tripping pressure switch PS 1. When the cylinder is fully retracted, the pressure at the rod end rises, tripping pressure switch PS 2.

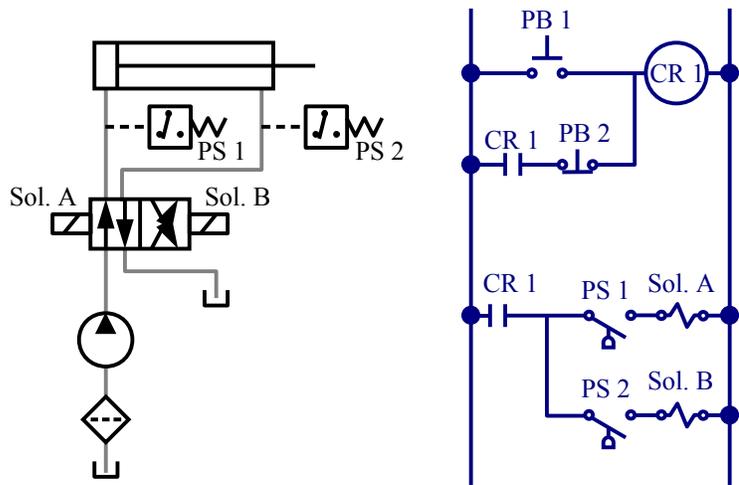
We can use the relay rung from the previous circuit to turn the electrical system on and off. PB 1 turns the system on, while PB 2 kills the circuit. Once the cylinder has fully extended, PS 1 is tripped, which energizes solenoid B, and the cylinder retracts.

Once the cylinder has fully retracted, PS 2 is tripped, which energizes solenoid A, and the cylinder extends.

This circuit could be automated in other ways. For example, you could use limit switches in place of pressure switches, or you could use timers.

### Creating Ladder Diagrams

In all of these examples, the switches (inputs) are on the left side of each rung; the relays and solenoids are on the right side of each rung (outputs). Some of the examples in the textbook are drawn incorrectly, which makes them hard to read. If you follow the standard format, it will be easier for a technician to build your circuit, and it will be easier for you to debug it.



*Dr. Barry Dupen, Indiana University-Purdue University Fort Wayne. Revised May 2014. This document was created with Apache Software Foundation's OpenOffice software v.4.1.0.*

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