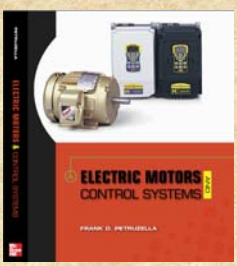


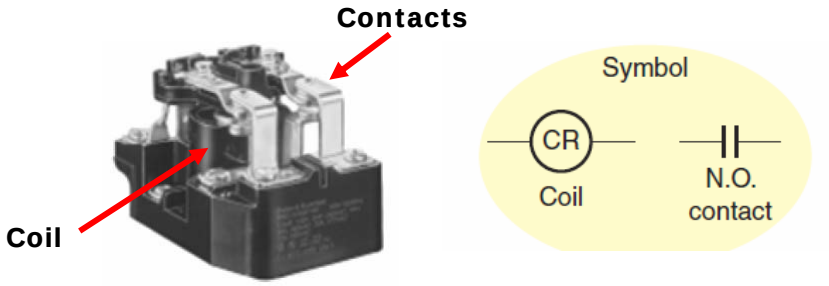
Chapter 4

Motor Control Devices

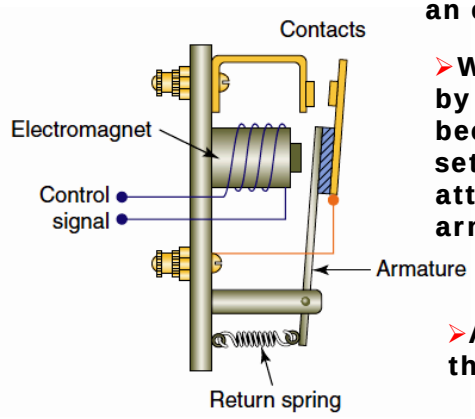
PART 4 Actuators

RELAYS

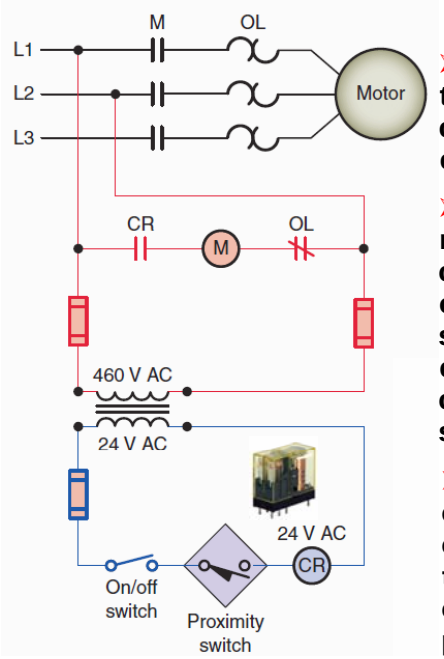
An *actuator*, in the electrical sense, is any device that converts an electrical signal into mechanical movement. An *electromechanical relay* is a type of actuator that mechanically switches electric circuits.



Electromechanical Relay Operation



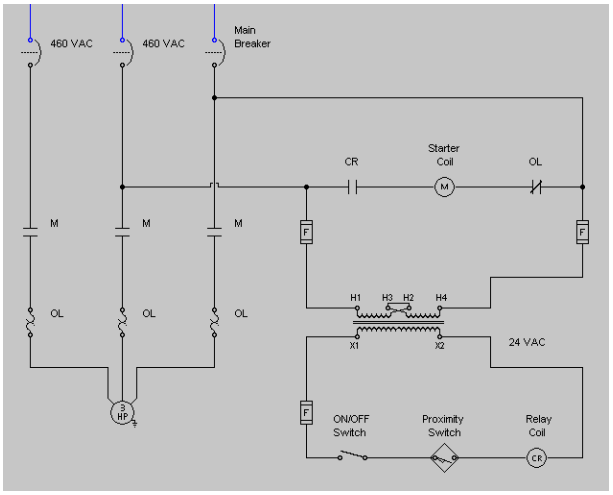
- The relay consists of a coil, wound on an iron core, to form an electromagnet.
- When the coil is energized by a control signal the core becomes magnetized and sets up a magnetic field that attracts the iron arm of the armature to it.
- As a result, the contacts on the armature close.
- When the current to the coil is switched off, the armature is spring returned to its normal de-energized position and the contacts on the armature open.



Relay Motor Control Circuit

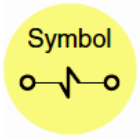
- With the switch "on", anytime the proximity switch contacts close, relay coil CR will become energized.
- This in turn will cause the normally open CR contacts to close and complete the path of current to the M motor starter. The M motor starter energizes and closes the M contacts in the power circuit, starting the motor.
- When the proximity switch opens CR coil de-energizes opening CR contacts which in turn de-energizers coil M and opens the M contacts in the power circuit to stop the motor

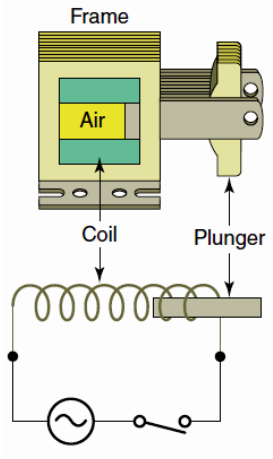
Simulated Relay Motor Control Circuit



SOLENOIDS

An *electromechanical solenoid* is a device that uses electrical energy to magnetically cause mechanical control applications.





- **The coil and frame form the fixed part**
- **When the coil is ener-gized it produces a magnetic field that attracts the plunger, pulling it into the frame and thus creating mechanical motion.**
- **When the coil is de-energized the plunger returns to its normal position through gravity or assistance from spring assemblies within the solenoid.**

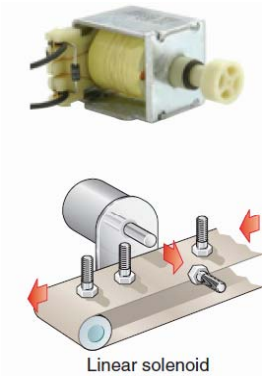
AC solenoid

The frame and plunger of an AC operated solenoid are constructed with laminated pieces instead of a solid piece of iron to limit eddy currents induced by the magnetic field.

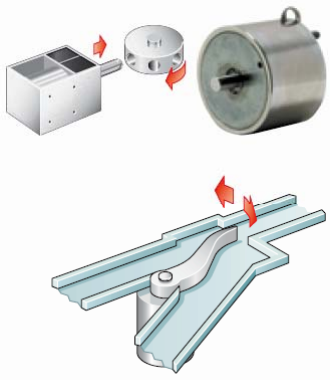
DC solenoid

- AC solenoids tend to be more powerful in the fully open position than DC.
- AC solenoids must close completely so that the inrush current falls to its normal value.
- AC operated solenoids are usually faster than DC.

- DC solenoids take the same current throughout their stroke and cannot overheat through incomplete closing.
- A DC solenoid is naturally quiet.
- DC repeat their closing times accurately against a given load.



Linear solenoid



Rotary solenoid

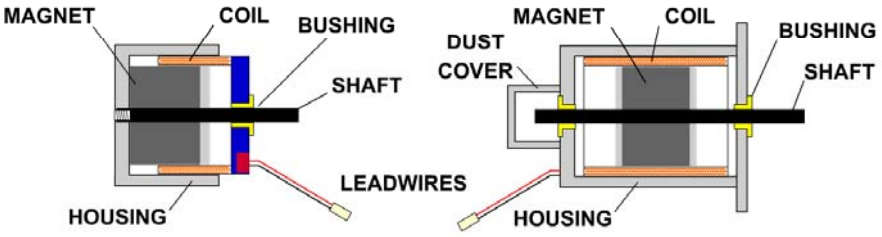
Linear solenoids are usually classified as pull (the electromagnetic path pulls a plunger into the solenoid body) or a push type where the plunger shaft is pushed out of the frame case.

Rotary solenoids incorporate a mechanical design that converts linear motion to rotary motion.

Solenoid Operation

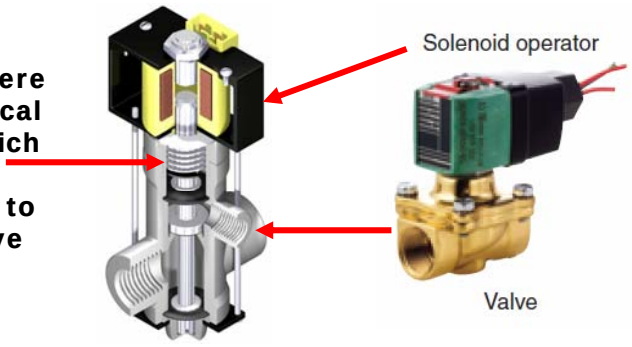
MOVING-COIL ACTUATOR

MOVING-MAGNET ACTUATOR

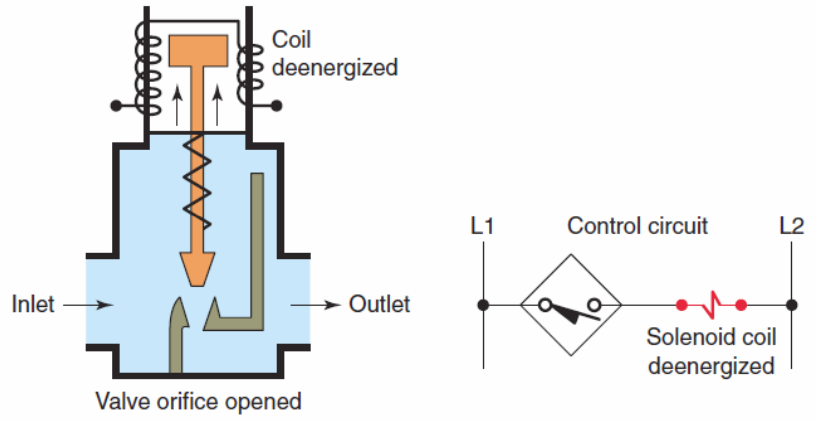


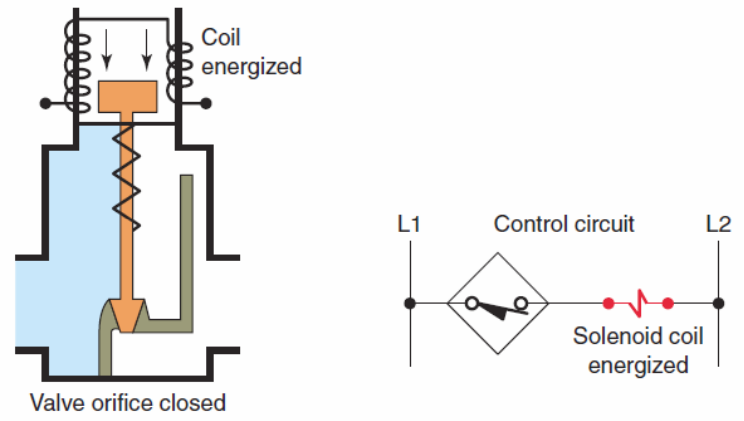
Solenoid valves **are electromechanical devices which work by passing an electrical current through a solenoid, thereby changing the state of the valve.**

Normally, there is a mechanical element, which is often a spring, used to hold the valve in its default position.



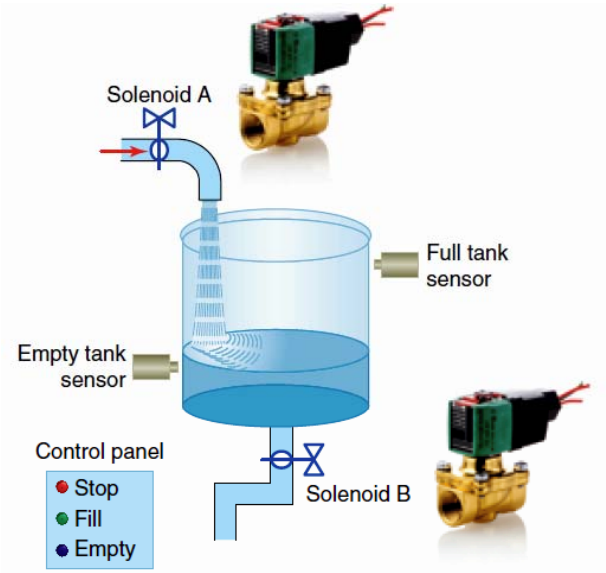
The valve body contains an orifice in which a disc or plug is positioned to restrict or allow flow. Flow through an orifice is *off or allowed* by the movement of the core and depends on whether the solenoid coil is energized or de-energized.

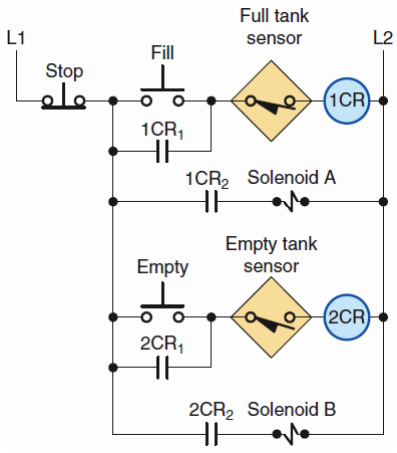




A valve must be installed with direction of flow in accordance with the arrow cast on the side of the valve body.

Solenoid valves are commonly used as part of tank filling and emptying processes.

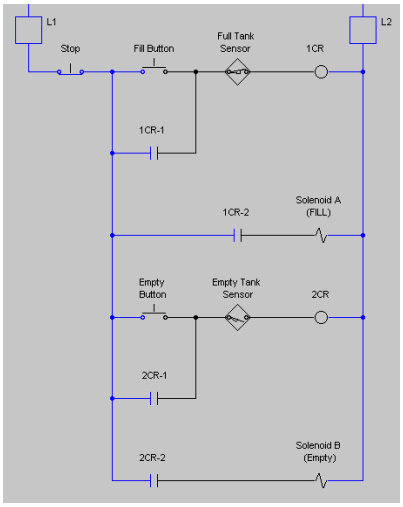




- **Momentarily pressing the FILL pushbutton will energize control relay 1CR.**
- **Solenoid coil A is energized to start filling the tank**
- **As the tank fills, the normally open empty level sensor switch closes.**
- **When liquid reaches the full level the full level sensor opens to de-energized solenoid coil A.**

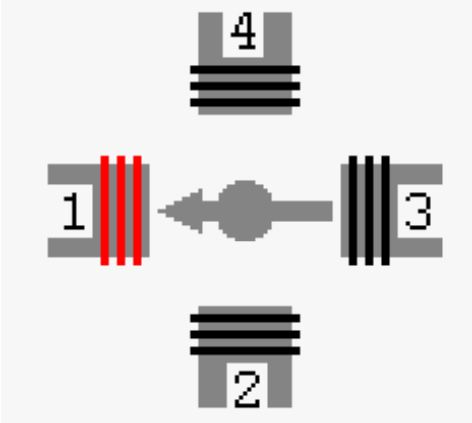
- **Any time the liquid level of the tank is above the empty level mark, momentarily pressing the EMPTY pushbutton will energize solenoid coil B to start emptying the tank.**
- **When the liquid reaches the empty level, the empty level sensor opens to de-energized solenoid coil B.**

Simulated Tank Fill And Empty Operation



STEPPER MOTORS

The shaft of a *stepper motor* rotates in discrete increments when electrical command pulses are applied to it in the proper sequence.

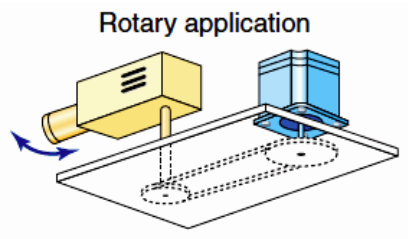


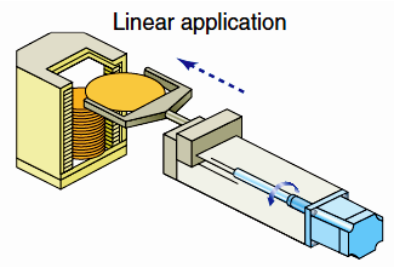
- **Every revolution of the motor is divided into a number of steps and the motor must be sent a single voltage pulse for each step.**
- **The amount of rotation is directly proportional to the number of pulses and the speed of rotation is relative to the frequency of those pulses.**
- **A one-degree-per-step motor will require 360 pulses to move through one revolution and is known as the "resolution".**
- **When stopped a stepper motor inherently holds its position.**
- **Stepper systems are used most often in *open loop* control systems where the controller only tells the motor how many steps to move and how fast to move.**

Stepper motor

Motor drive

The movement created by each pulse is precise and repeatable, which is why stepper motors are so effective for load positioning applications.

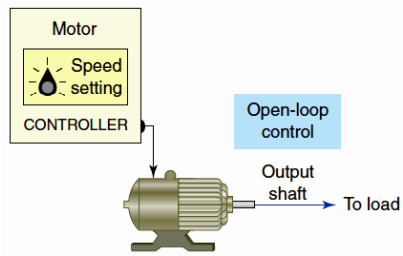


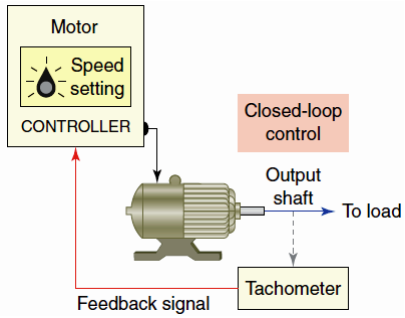


Generally, stepper motors produce less than 1 horsepower and are therefore frequently used in low-power position control applications.

SERVO MOTORS

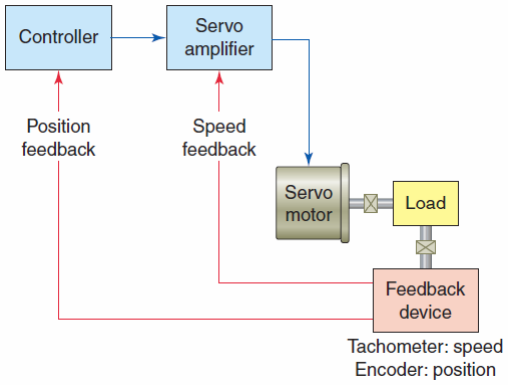
All *servo motors* operate in closed loop whereas most stepper motors operate in open loop.





Open loop **is control without feedback where for example the controller tells the stepper motor how many steps to move and how fast to move, but does not verify where the motor is at.**

Closed loop **control compares speed or position feedback with the commanded speed or position and generates a modified command to make the error smaller.**



- **A feedback device such as an encoder for position and a tachometer for speed are either incorporated within the servo motor or are remotely mounted.**

- **These provide the servo motor's position and speed feedback information that the controller compares to its programmed motion profile and uses to alter its position or speed.**

In a typical closed loop servo motor system the motor controller directs operation of the servo motor by sending speed or position command signals which drives the servo motor.

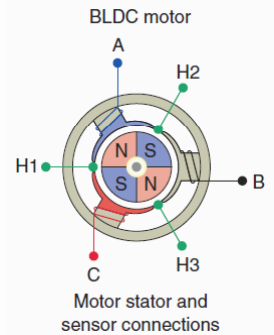
While stepper motors are DC operated a servo motor can be either DC or AC operated. Three basic types of servo motors are used in modern servo systems:

- **AC servo motors, based on induction motor designs**
- **DC servo motors, based on DC motor designs**
- **DC or AC brushless servo motors.**

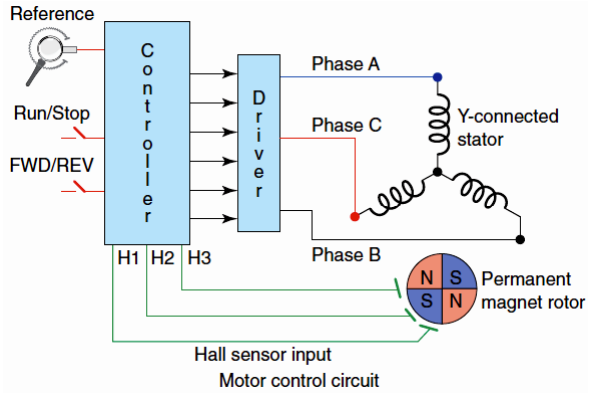
Brushless DC motor with integrated electronic drive

As the name implies, *brushless DC motors (BLDC)* have no brush or commutation mechanism; instead, they are electronically commutated.

The stator is normally a three-phase stator (A-B-C) like that of an induction motor and the rotor has surface-mounted permanent magnets.



Motor stator and sensor connections



- **Three Hall sensors (H1-H2-H3) are used to detect the rotor position and commutation is performed electronically based on signals from the Hall sensor inputs.**
- **The signals from the Hall-Effect sensors are decoded by the controller and used to control the driver circuit, which energizes the stator coils in the proper rotational sequence.**

Servo Motor Applications