Experiment (1)
Principles of Switching

Introduction

When you use microcontrollers, sometimes you need to control devices that requires more electrical current than a microcontroller can supply; for this, electrical relays and transistors are used. In this experiment, we will investigate two types of switching; electromechanical switching and solid state switching.

Objectives

This experiment aims to:

1- Understand the basic principles of switching devices.
2- Introduction to electromechanical switching as well as solid state switching.
3- Understand the advantages and disadvantages of each type.
4- Study the relative speed of different type of switches.

Theory

Electromechanically Relays

Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position. The relay is a switch that is controlled by a small electric current. It can be used to control motors, heaters or lamps circuits which themselves can draw a lot more electrical power. Figure 1 shows the circuit symbol for a relay.

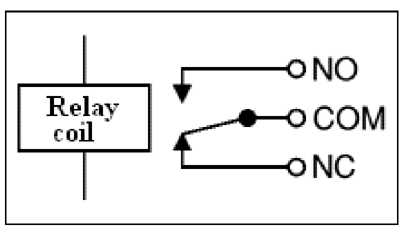

Figure 1: Circuit symbol for a relay

In figure 2, the relay's coil is energized by the low-voltage (12 VDC) source, while the single-pole, single-throw (SPST) contact interrupts the high-voltage (480 VAC) circuit. It is quite likely that the current required to energize the relay coil will be hundreds of times less than the current rating of the contact. Typical relay coil currents are well below 1 amp, while typical contact ratings for industrial relays are at least 10 amps.

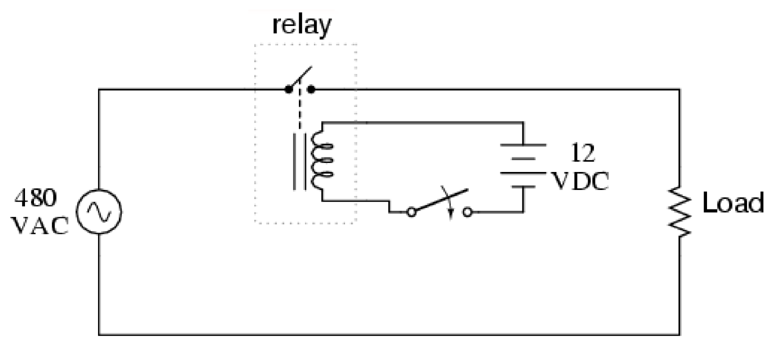

Figure 2: Relay drive an AC load

One relay coil/armature assembly may be used to actuate more than one set of contacts. Those contacts may be normally-open, normally-closed, or any combination of the two. As with switches, the "normal" state of a relay's contacts is that state when the coil is de-energized and not connected to any circuit. Figure 3 shows different relay's contacts arrangement.

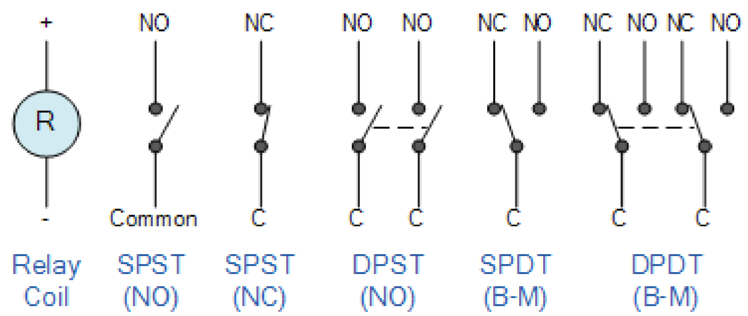

Figure 3: Different Relay's Contacts Arrangement

Relay contacts may be open-air pads of metal alloy, mercury tubes, or even magnetic reeds. Consider these factors when choosing a relay for use in industrial controls:

1. **Voltages driving loads** are the first concern. The voltage rating of a relay must be greater than or equal to the voltage driving the load. The frequency of the switched voltage is also critical. Because ac current fluctuates from positive to negative crossing through zero, the switched voltage will vary between the maximum voltage and zero. Dc voltage, on the other hand, is always at the maximum value, causing maximum wear on the contacts with every switch.
2. **The current required** depends on the type of load. Most loads don't draw a constant current. In fact, the current demand of most loads varies somewhat predictably.

It is also important to avoid switching currents that are too small for the relay to operate reliably. Proper operation of a switch relies, to some extent, on the switching of some minimum current. This current is often referred to as a wiping current because it will burn off traces of contaminants that may build up on the relay contacts. The lower limit of current that can be reliably switched is a function of several factors such as contact material, contact geometry, and mechanical sliding of the contact surfaces.

Open-air contacts are the best for high-current applications, but their tendency to corrode and spark may cause problems in some industrial environments. Mercury and reed contacts are spark-less and will not corrode, but they tend to be limited in current-carrying capacity.

Aside from the ability to allow a relatively small electric signal to switch a relatively large electric signal, relays also offer electrical isolation between coil and contact circuits. This means that the coil circuit and contact circuit(s) are electrically insulated from one another. One circuit may be DC and the other AC (such as in the example circuit shown earlier in figure 2), and/or they may be at completely different voltage levels, across the connections or from connections to ground.

While relays are essentially binary devices, either being completely on or completely off, there are operating conditions where their state may be indeterminate, just as with semiconductor logic gates. In order for a relay to positively "pull in" the armature to actuate the contact(s), there must be a certain minimum amount of current through the coil. This minimum amount is called the *pull-in* current, and it is analogous to the minimum input voltage that a logic gate requires to guarantee a "high" state (typically 2 Volts for TTL, 3.5 Volts for CMOS). Once the armature is pulled closer to the coil's center, however, it takes less magnetic field flux (less coil current) to hold it there. Therefore, the coil current must drop below a value significantly lower than the pull-in current before the armature "drops out" to its spring-loaded position and the contacts resume their normal state. This current level is called the *drop-out* current, and it is analogous to the maximum input voltage that a logic gate input will allow to guarantee a "low" state (typically 0.8 Volts for TTL, 1.5 Volts for CMOS).

The hysteresis, or difference between pull-in and drop-out currents, results in operation that is similar to a Schmitt trigger logic gate. Pull-in and drop-out currents (and voltages) vary widely from relay to relay, and are specified by the manufacturer.

Solid State Relays

While the electromechanical relay is inexpensive, easy to use and allow the switching of a load circuit controlled by a low power, electrically isolated input signal, one of the main disadvantages of an electromechanical relay is that it is a "mechanical device", that is it has moving parts so their switching speed (response time) due to physically movement of the metal contacts using a magnetic field is slow.

Over a period of time these moving parts will wear out and fail, or that the contact resistance through the constant arcing and erosion may make the relay unusable and shortens its life. Also, they are electrically noisy with the contacts suffering from contact bounce which may affect any electronic circuits to which they are connected.

To overcome these disadvantages of the electrical relay, another type of relay called a Solid State Relay was developed which is a solid state contactless, pure electronic relay.

The solid state relay being a purely electronic device has no moving parts within its design as the mechanical contacts have been replaced by power transistors, thyristors or triac's. The electrical separation between the input control signal and the output load voltage is accomplished with the aid of an opto-coupler type Light Sensor.

The Solid State Relay provides a high degree of reliability, long life and reduced electromagnetic interference, (no arcing contacts or magnetic fields), together with a much faster almost instant response time, as compared to the conventional electromechanical relay.

Also the input control power requirements of the solid state relay are generally low enough to make them compatible with most IC logic families without the need for additional buffers, drivers or amplifiers. However, being a semiconductor device they must be mounted onto suitable heatsinks to prevent the output switching semiconductor device from overheating.

Figure 4 shows an AC type Solid State Relay. It turns “ON” at the zero crossing point of the AC sinusoidal waveform, prevents high inrush currents when switching inductive or capacitive loads while the inherent turn “OFF” feature of Thyristors and Triacs provides an improvement over the arcing contacts of the electromechanical relays.

A Resistor-Capacitor (RC) snubber network is generally required across the output terminals of the solid state relay to protect the semiconductor output switching device from noise and voltage transient spikes when used to switch highly inductive or capacitive loads. In most modern solid state relays this RC snubber network is built as standard into the relay itself reducing the need for additional external components.

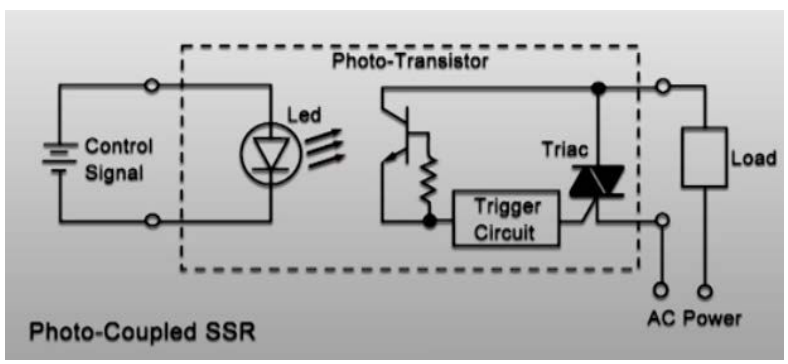

Figure 4: Solid State Relay

Non-zero crossing detection switching (instant “ON”) type solid state relays are also available for phase controlled applications such as the dimming or fading of lights at concerts and shows for motor speed control type applications.

As the output switching device of a solid state relay is a semiconductor device (Transistor for DC switching applications, or a Triac/Thyristor combination for AC switching), the voltage-drop across the output terminals of a solid state relay when “ON” is much higher than that of the electromechanical relay, typically 1.5 – 2.0 volts. If switching large currents for long periods of time an additional heat sink will be required.

The main disadvantages of solid state relays compared to that of an equivalent wattage electromechanical relay is their higher costs, the fact that only single pole single throw (SPST)