RELAYS

THEORY OF COMPONENTS USED IN MICROCONTROLLER-BASED PROJECTS

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Introduction

- The term Relay generally refers to a device that provides an electrical connection between two or more points in response to the application of a control signal.
- A relay is a simple electromechanical switch made up of an electromagnet and a set of contacts.
- Hence in brief, a relay is an electrically operated switch.
- Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used.

Introduction contd.

- Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.
- The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations.
- The most common and widely used type of electrical relay is the electromechanical relay or EMR.

Principles of Operation

- As their name implies, electromechanical relays are electro-magnetic devices that convert a magnetic flux generated by the application of a low voltage electrical control signal either AC or DC across the relay terminals, into a pulling mechanical force which operates the electrical contacts within the relay.

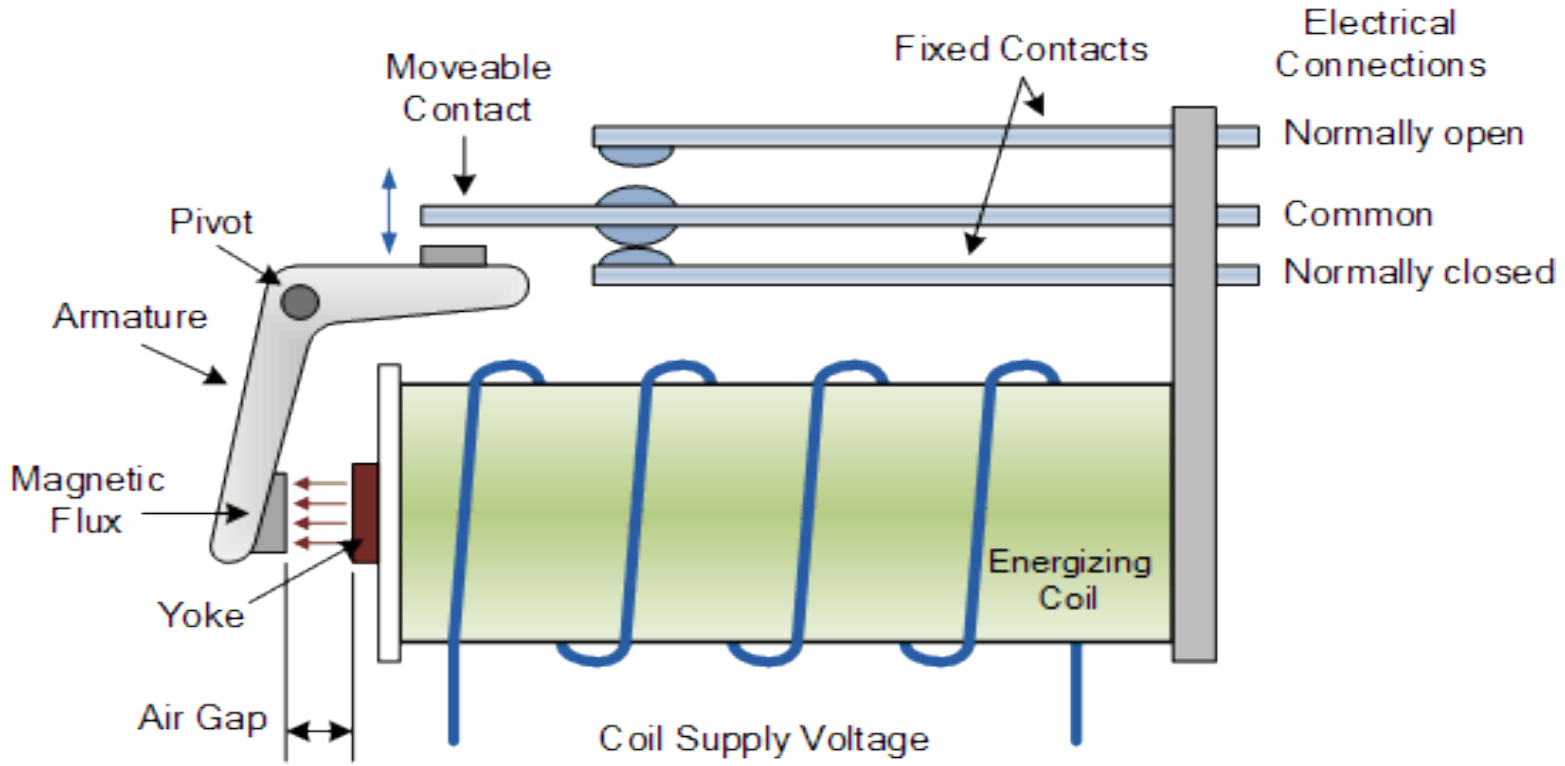

Fig 1: Parts of a simple electromechanical relay

Principles of Operation contd.

- The most common form of electromechanical relay consists of an energizing coil called the "primary circuit" wound around a permeable iron core.
- This iron core has both a fixed portion called the yoke, and a moveable spring loaded part called the armature, that completes the magnetic field circuit by closing the air gap between the fixed electrical coil and the moveable armature.
- The armature is hinged or pivoted allowing it to freely move within the generated magnetic field closing the electrical contacts that are attached to it.
- Connected between the yoke and armature is normally a spring (or springs) for the return stroke to "reset" the contacts back to their initial rest position when the relay coil is in the "de-energized" condition, ie. turned "OFF".

Principles of Operation contd.

- In the simple relay shown in fig 1, we have two sets of electrically conductive contacts.
- Relays may be "Normally Open", or "Normally Closed". One pair of contacts are classed as Normally Open, (NO) or make contacts and another set are classed as Normally Closed, (NC) or break contacts.
- In the normally open position, the contacts are closed only when the field current is "ON" and the switch contacts are pulled towards the inductive coil.
- In the normally closed position, the contacts are permanently closed when the field current is "OFF" as the switch contacts return to their normal position.
- These terms Normally Open, Normally Closed or Make and Break Contacts refer to the state of the electrical contacts when the relay coil is "de-energized", i.e, no supply voltage connected to the inductive coil.

Principles of Operation contd.

- The relays contacts are electrically conductive pieces of metal which touch together completing a circuit and allow the circuit current to flow, just like a switch.
- When the contacts are open the resistance between the contacts is very high in the Mega-Ohms, producing an open circuit condition and no circuit current flows. When the contacts are closed the contact resistance should be zero, a short circuit, but this is not always the case.
- All relay contacts have a certain amount of "contact resistance" when they are closed and this is called the "On-Resistance", similar to FET's.
- With a new relay and contacts this ON-resistance will be very small, generally less than 0.2Ω's because the tips are new and clean, but over time the tip resistance will increase.

Principles of Operation contd.

- Change-over (CO), or double-throw (DT), contacts control two circuits, one normally-open contact and one normally-closed contact with a common terminal.
- It is also called a Form C contact or "transfer" contact ("break before make").
- If this type of contact utilizes a "make before break" functionality, then it is called a Form D contact.

Terminologies - Pole and throw

The following designations are commonly encountered:

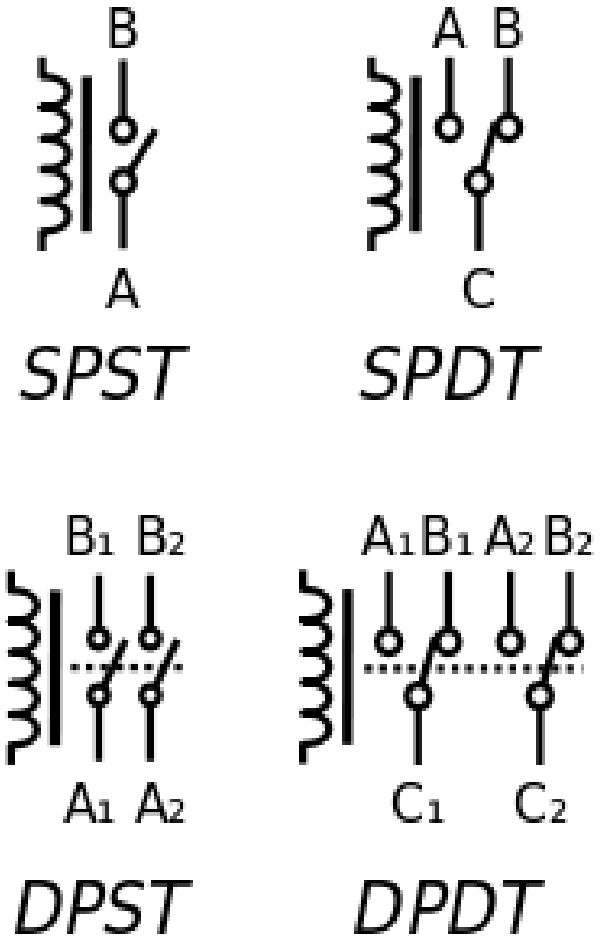

Fig 2: Circuit symbols of relays. (C denotes the common terminal in SPDT and DPDT types.)

Terminologies - Pole and throw contd.

- **SPST – Single Pole Single Throw.** These have two terminals which can be connected or disconnected. Including two for the coil, such a relay has four terminals in total. It is ambiguous whether the pole is normally open or normally closed. The terminology "SPNO" and "SPNC" is sometimes used to resolve the ambiguity.
- **SPDT – Single Pole Double Throw**. A common terminal connects to either of two others. Including two for the coil, such a relay has five terminals in total.
- **DPST – Double Pole Single Throw**. These have two pairs of terminals. Equivalent to two SPST switches or relays actuated by a single coil. Including two for the coil, such a relay has six terminals in total. The poles may be Form A or Form B (or one of each).
- **DPDT – Double Pole Double Throw**. These have two rows of change-over terminals. Equivalent to two SPDT switches or relays actuated by a single coil. Such a relay has eight terminals, including the coil.

The "S" or "D" may be replaced with a number, indicating multiple switches connected to a single actuator. For example 4PDT indicates a four pole double throw relay (with 12 terminals).

Usage Considerations

- As the current flows through the coil a self induced magnetic field is generated around it. When the current in the coil is turned "OFF", a large back emf (electromotive force) voltage is produced as the magnetic flux collapses within the coil (transformer theory). This induced reverse voltage value may be very high in comparison to the switching voltage, and may damage any semiconductor device such as a transistor, FET or microcontroller used to operate the relay coil.

Usage Considerations contd.

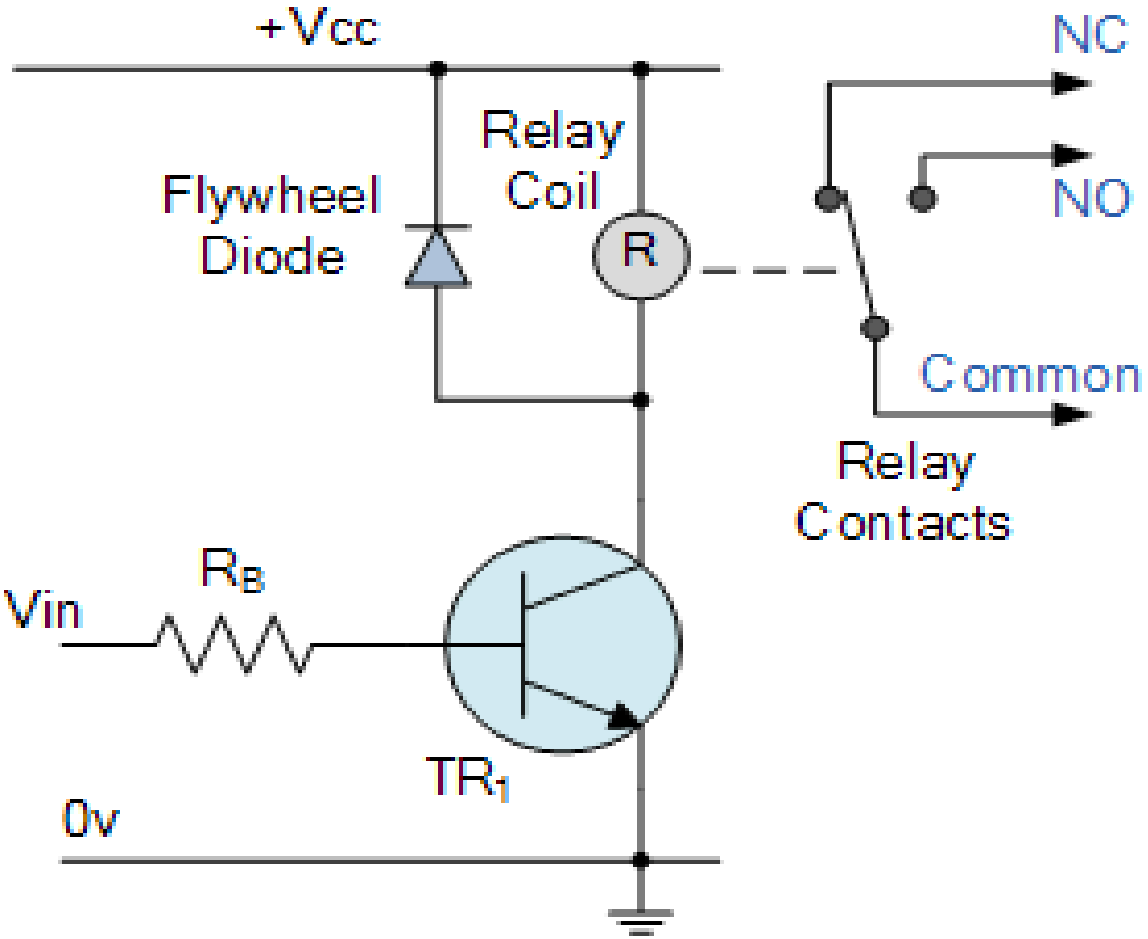

Fig 3: Connecting a flyweel diode across a relay

Usage Considerations contd.

- One way of preventing damage to the transistor or any switching semiconductor device, is to connect a reverse biased diode across the relay coil, see fig 3.
- When the current flowing through the coil is switched "OFF", an induced back emf is generated as the magnetic flux collapses in the coil. This reverse voltage forward biases the diode which conducts and dissipates the stored energy preventing any damage to the semiconductor transistor.
- When used in this type of application the diode is generally known as a Flywheel Diode, Free-wheeling Diode and even Fly-back Diode, but they all mean the same thing.
- Other types of inductive loads which require a flywheel diode for protection are solenoids, motors and inductive coils.
- As well as using flywheel Diodes for protection of semiconductor components, other devices used for protection include RC Snubber Networks, Metal Oxide Varistors or MOV and Zener Diodes.

Applications

Some common uses of relays include:

- Amplifying a digital signal, switching a large amount of power with a small operating power. Some special cases are:
  - A telegraph relay, repeating a weak signal received at the end of a long wire
  - Controlling a high-voltage circuit with a low-voltage signal, as in some types of modems or audio amplifiers,
  - Controlling a high-current circuit with a low-current signal, as in the starter solenoid of an automobile,
- Detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers (protection relays),
- Isolate the controlling circuit from the controlled circuit when the two are at different potentials, for example when controlling a mains-powered device from a low-voltage switch.

Applications contd.

- Logic functions. For example, the boolean AND function is realised by connecting normally open relay contacts in series, the OR function by connecting normally open contacts in parallel. The change-over or Form C contacts perform the XOR (exclusive or) function. Similar functions for NAND and NOR are accomplished using normally closed contacts. The Ladder programming language is often used for designing relay logic networks.
- Early computing. Before vacuum tubes and transistors, relays were used as logical elements in digital computers. See electro-mechanical computers such as ARRA (computer), Harvard Mark II, Zuse Z2, and Zuse Z3.
- Safety-critical logic. Because relays are much more resistant than semiconductors to nuclear radiation, they are widely used in safety-critical logic, such as the control panels of radioactive waste-handling machinery.

Applications contd.

- Time delay functions. Relays can be modified to delay opening or delay closing a set of contacts. A very short (a fraction of a second) delay would use a copper disk between the armature and moving blade assembly. Current flowing in the disk maintains magnetic field for a short time, lengthening release time. For a slightly longer (up to a minute) delay, a dashpot is used. A dashpot is a piston filled with fluid that is allowed to escape slowly. The time period can be varied by increasing or decreasing the flow rate. For longer time periods, a mechanical clockwork timer is installed.
- Vehicle battery isolation. A 12v relay is often used to isolate any second battery in cars, 4WDs, RVs and boats.
- Switching to a standby power supply.