Switches and Relays

A perfect switch is a device that can alternate between a perfect short and a perfect open on demand.

Switch

Throughout the years, many different technologies have been employed to make switches. Beyond their fundamental utility in controlling currents, the basic two position switch is one of the fundamental abstractions needed for digital computation. That is, if one considers one state a “1” and the other a “0”, one can quickly build systems that can perform Boolean mathematics if switches can be wired up to switch each other’s states. This is the fundamental assumption underlying digital computation, since the majority of transistors in digital chips act as switches, changing states between 0 and 1.

Relays and mechanical switches

The most basic switch, arguably, is simply a mechanically-driven contact that can be used to either contact or not contact, thereby alternating between open and closed states. Your hand operated light switch is such an example. Even these simple switches are not ideal, since some (usually very small) series resistance must be included in the model. An obvious refinement is a switch that can be opened or closed based on a current or voltage applied to a third terminal (or through a separate wire on the switch. Electromagnetic relays and solid-state relays are examples of this. In an electromagnetic relay, a sufficiently large current flowing an electromagnet forces it to move, closing a contact. When no current flows, the electromagnet does not force the contact closed (and thus, the relay is open). Many relay variants exist, including solid-state relays, reed relays, even relays using liquid mercury to short terminals. There are as many relays as there are mechanisms whereby an electrical phenomenon can mechanically force a contact.

Transistors

One of the seminal discoveries of the 20th century was the observation that non-mechanical, purely solid-state (that is, devices where all the actions happens in the charge carriers of a solid, with no liquid, gases, moving parts, etc.) switches could be built in germanium, silicon and other materials now known as *semiconductors*. These switches are known as **transistors** and continue to be the workhorse of digital computing. Interestingly, beyond the original discovery, a number of physical phenomena were found within semiconductors that could be used to build different types of transistors. This is why the novice is often over-whelmed by the acronym jargon associated with transistors (e.g. MOSFET, JFET, BJT, FinFET, TFET, etc.). As a circuit designer, the key to designing circuits is to have working models which the designer can substitute for the symbols below. In great measure, learning to work with these models, building clever and useful circuits with them and understanding the optimization and ultimate performance limits of these devices is what *integrated circuit (IC)* designers do.