Introduction to Transistors

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Webster defines electronics as "the science that deals with the behavior and control of electrons …" Specifically, electronics deals with the use of electric fields to control the flow of electric charges.

One of the first known examples of this was observed by Thomas Edison and became known as the Edison effect. In experiments with light bulbs, Edison noted that there was a current between the filament and another conductor in the bulb if that conductor had a positive electric potential relative to the filament but not if that conductor had a relative negative electric potential. Thus, current could be controlled by adjusting an electric field. Years later, this became known as the diode or electric one-way valve. Current conducts in one direction but not the other.

The vacuum diode evolved to have a filament to indirectly heat a cathode to a temperature such that electrons in the cathode literally jumped off the metal and formed an electron cloud balance around a now relatively positive cathode. A plate called the anode was placed a short distance away and would attract the electrons as a current if it were more positive than the cathode. If the plate were more negative then the electron cloud would be squeezed closer to the cathode and there would be no current. The names, cathode and anode, are used to this day in any type of diode.

Flemming discovered that by adding a wire mesh called a control grid between the cathode and anode, that the current due to a positive anode could be controlled by varying the grid voltage relative to the cathode. This was a voltage controlled current source. There were two electric fields at work. One field was between the anode and cathode and the other field was between the grid and the cathode. By proper management of these two fields, amplifiers could be built. Because it had three elements, this device was called a triode. The control grid was biased to a more negative potential than the cathode such that making the control grid more negative reduced the anode current and making the control grid less negative increased anode current. Later, a four element tube known as a tetrode was made by adding a second grid known as the screen grid with a fixed positive bias between the control grid and the anode so that undesirable capacitance between the anode and cathode could be reduced. A further improvement known as the pentode was made by adding another grid known as the suppresser grid between the screen grid and the anode. The suppresser grid was biased at either ground or the potential of the cathode and served to drain away electrons that bounced off of the anode in tetrodes. This grid suppressed the formation of an undesirable electron cloud near the anode. Whether the tube was a triode, tetrode, or pentode, it was a voltage controlled current source. The additional grids enabled better control of the characteristics.

The transistor was developed out of necessity to address the problem that vacuum tubes do wear out and in a large system consisting of hundreds of thousands of vacuum tubes

(such as a phone system) the probability is high that at any given time at least one tube in the system needs to be replaced. A substitute that had considerably longer life was needed. In 1948 the first solid state device which became known as the transistor was developed at Bell Laboratories. The transistor operated at room temperature so a heater was not needed. Also, the transistor was based on solid state physics so a vacuum was not needed for operation. The transistor also operates at very low voltages and is considerably smaller than a vacuum tube. The life span of a transistor is extremely long as there is no wear out mechanism. Once the transistor was perfected, vacuum tube based telephone equipment was replaced with transistor based equipment. The reliability of the phone system was greatly improved.

Because the transistor is small and takes very little power to operate, it began replacing vacuum tubes in a wide variety of equipment over the next three decades. The primary uses for vacuum tubes today are picture tubes for television and computer monitors and transmitting tubes for high power broadcast stations. Miniature vacuum tubes known as nuvistors still find application in electronic equipment because they can survive an overload that would destroy a transistor. A considerable amount of the mathematics developed for analyzing vacuum tube circuits is easily transformed for analyzing transistor circuits.

There is a lot of material to learn when studying transistors. Many students become overwhelmed. The secret to success is to break the problem down into the proper sequence of easily understood small steps. That is what this course attempts to do.