

## Active Electronic Devices

1. **Vacuum Tubes** (valves in England) use electrons that are “boiled” off the surface of the cathode to allow the flow of current through a vacuum. The current flow is controlled by a negative voltage on a “grid” which lowers the number of electrons that are available to be accelerated to the Anode (AKA plate). They behave as voltage controlled current sources.
2. **Transistors** are solid state devices built out of semiconductor crystals and come in two different forms
  1. **Bipolar Transistors** (NPN and PNP - two polarities) - are effectively two PN junction diodes in series (in opposite directions) so that they have a common central region called the base. When there is a voltage across the two ends (Collector to Emitter) no current flows as the collector base diode is reverse biased. Since the base is very thin, current flowing in the forward biased base emitter junction injects some carriers (electrons in the NPN case) into the depletion region of the reverse biased collector base junction causing current to flow from collector to emitter. Bipolar transistors behave as a current controlled current source.
  2. **Field Effect Transistors** (FET) come in two major variants with each having sub variants. All of them act as either voltage controlled resistors or, in saturation mode, voltage controlled current sources.
    1. **Junction FETs** use a reverse biased PN junction as the gate. As the reverse bias on the gate increases its depletion region (no carriers so no current) the depletion region narrows the channel (conduction path between the “source” and “drain” terminals. There are two flavors P-channel where the gate material is type N or excess electron carriers or N-channel, where the gate material is P-type (and excess of “holes”).
    2. **Insulated Gate FETs** (AKA Metal Oxide Silicon FET or **MOSFET**) where the gate is a metal layer separated from the channel by a layer of Silicon Dioxide (AK glass). When there is a voltage across the capacitor formed (gate to channel), The electric field interacts with the channel which changes the channel depth. In addition to the the two polarities (N-channel and P-channel) there are “depletion mode” (channel decreases in depth with increased gate bias) and “enhancement mode (channel increases in depth with increased bias in each polarity.