7 Transistors

Transistors are active non-linear devices that facilitate signal amplification. In the hydrodynamic model of electrical current, transistors are equivalent to a dam with a variable gate that controls the amount of water flow shown in *Figure 7.1.* Just as in a real dam, a small amount of energy is required to operate the gate. Amplification is achieved in the sense that a small amount of energy can be used to control the flow of a large amount of current.

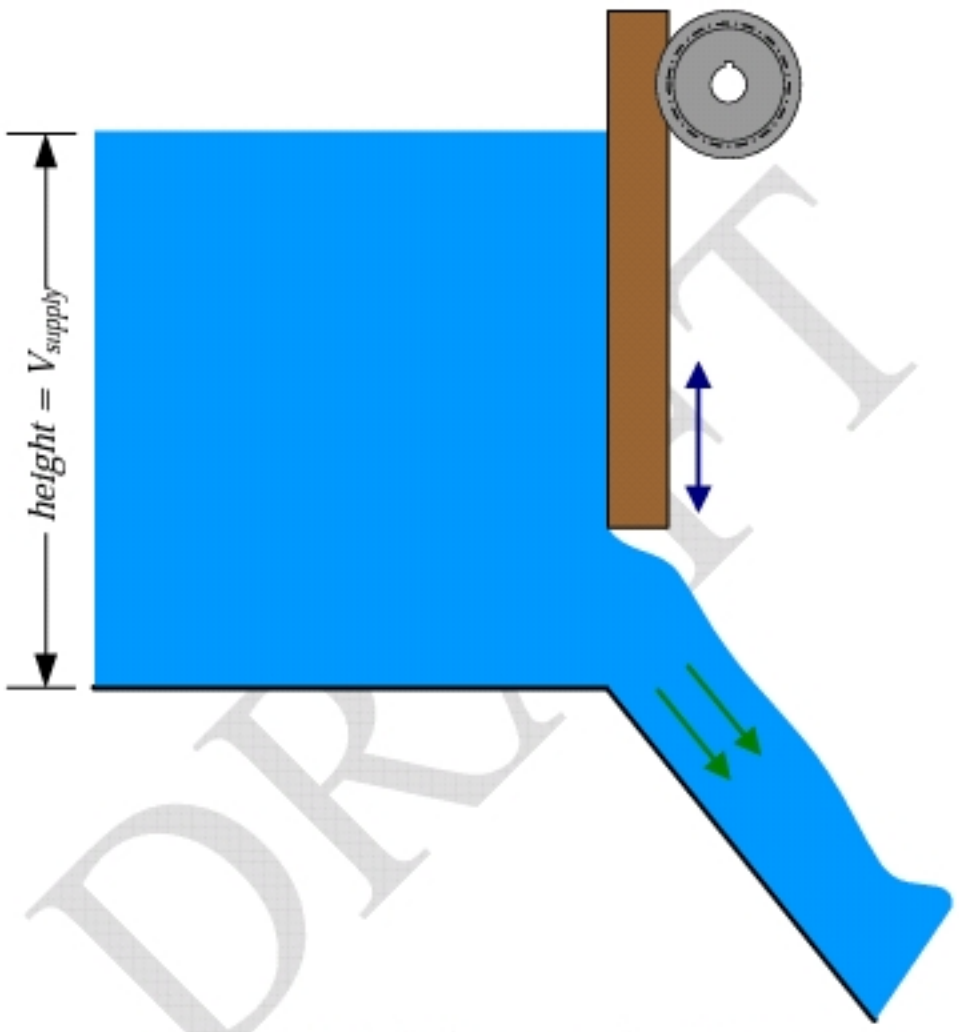

Figure 7.1: The hydrodynamic analogy of a transistor

There are two main classes of transistors: bipolar-junction transistors and field-effect transistors.

7.1 Bipolar-Junction Transistors (BJT)

A BJT has three terminals: emitter, base, and collector. In the hydrodynamic analogy, the emitter and collector correspond to the river above and below the dam. The base terminal corresponds to the control input that varies the flow through the dam.

There are two varieties of BJT's: NPN devices that use electrons as the primary charge carrier and PNP devices that use holes as the primary charge carrier. The circuit symbols for NPN and PNP BJT's are shown in *Figure 7.2.* From this point on, the

discussions of BJT behavior will use NPN devices as examples. The discussion for PNP devices is exactly complementary to that of NPN devices except electrons and holes are interchanged and as a result, all the characteristic device voltages are reversed.

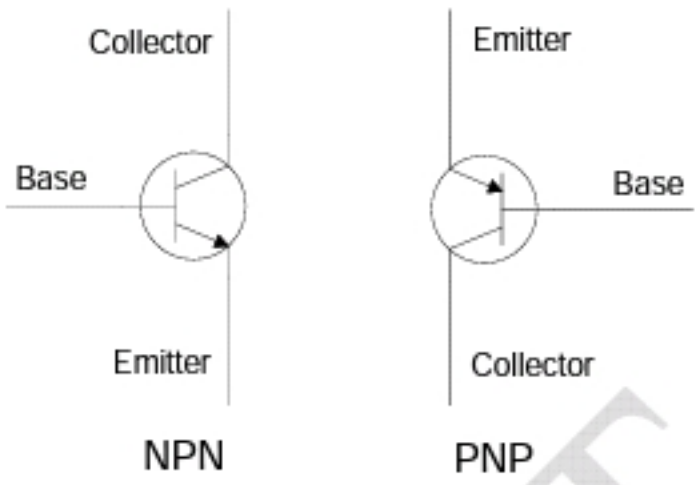

Figure 7.2: Circuit symbols for the NPN and PNP transistor

The structure of an NPN BJT, shown in Figure ###, consists of three layers of materials: an N-type layer, a thin P-type layer, and another N-type layer, which corresponds to the emitter, base, and collector. The emitter-base and collector-base PN-junction form diodes with opposing directions of conduction as shown in *Figure 7.3.* Typically, the collector is connected to a higher voltage than the emitter, while the base is connected to a voltage between the two. The collector-to-emitter voltage is equivalent to the height of the water in the dam model. The base voltage is equivalent to the position of the control gate. When the voltage at the base is not enough to turn-on the base-emitter diode, there is no conduction from collector to emitter. When the voltage at the base is high enough to turn-on the base-emitter diode, a conduction path from collector to emitter is opened.