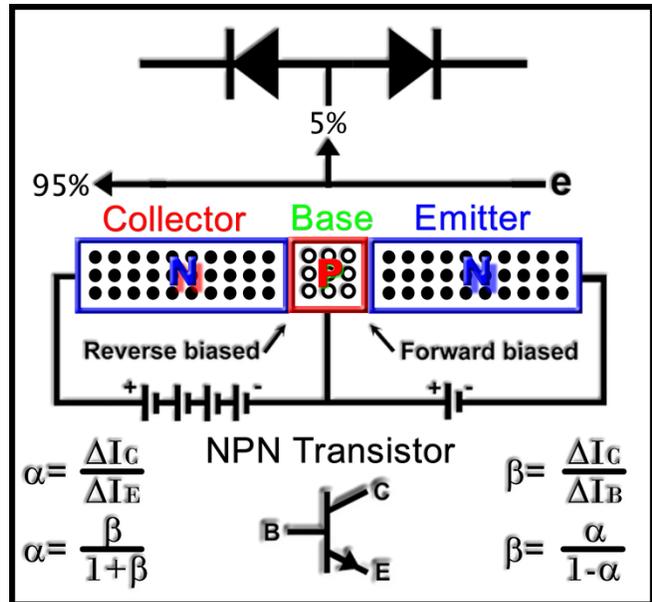


## Chapter 8 : Bipolar Transistors

### 8.1 NPN basics

By taking the PN junction we discussed in chapter 2 and adding another N crystal we form the first type of **Bipolar Transistor**. This is called an **NPN transistor** and has a very small P-type crystal sandwiched between two much larger N-type crystals, hence the name NPN. In the drawing to the right the P-type crystal is made much larger than it is in reality for purposes of the drawing. The connections made to the three crystals are named **Collector, Base, and Emitter**. Note that the two junctions can also be seen as two diodes that share the same P-type crystal.



The “diode” made of emitter and base is forward biased, so electrons will flow from emitter into the base. *It might help to think of the Emitter in an NPN transistor as emitting electrons into the rest of the transistor.* Remember that the P-type crystal is much smaller than the N-type crystals. Because of this, there are far more electrons coming into the P-type crystal than it has holes for the electrons to fill.

We then make the collector N-type crystal much more positive than the base. This means that the electrons that don’t have a hole in the base are pulled into the collector. *The collector “collects” most of the electrons emitted by the Emitter.* Even though the base-collector junction is reverse biased, the collector is so much more positive and the base P-type crystal is so small that electrons still flow into the collector. It turns out that approximately 5% of the electrons end up at the base while 95% end up at the collector. This means that there is a ratio of electrons (or current) of 5 to 95 (or 1 to 19) between Base and Collector.

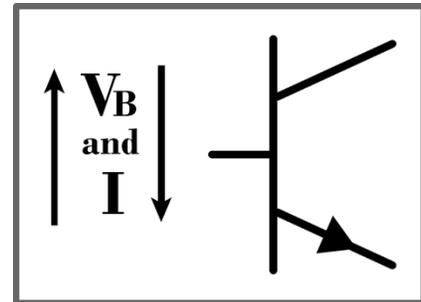
This relationship remains constant for any transistor but varies from transistor to transistor. However, in all cases **an increase in current flow at any point in the transistor will mean an increase in current at the other two points in the transistor.** This is also true of decreases in current flow.

Emitter I	Base I	Collector I
↑	↑	↑
↓	↓	↓

Note the schematic representation of the NPN transistor. The direction of the arrow on the emitter determines whether the transistor is NPN or PNP. It follows the direction of the arrow in the diode drawing of the transistor. Remember that in a diode current flows through the arrow, while electrons flow against the arrow. The same is true with transistors.

With the transistor properly biased (emitter most negative, collector most positive, and base in the middle) what would happen if we put a small current into the base? We would end up with a larger current at the collector. Suppose we put a signal of varying current into the base, such as a sine wave? We would end up with a larger current sine wave. We have just made a simple transistor amplifier!

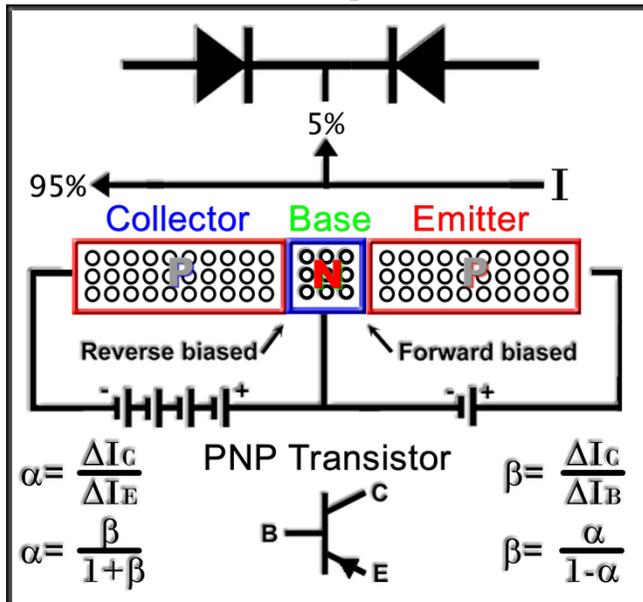
In chapter 1 we learned that modern electronics rely on **Voltage Transfer**. So far we have only talked about how transistors affect current. Transistors are current devices; increase current at the Base and current at the Emitter and Collector will both increase. So we need a method and thought process for thinking about transistors and voltage. To start, let's think about the base emitter junction. This is like a forward biased diode. If we want more current to flow through a forward biased diode, we increase the voltage difference between the Emitter and Base. At the same time we are moving the Base close to the Collector in voltage. You can think of the transistor as a potentiometer. The closer you "move" the base to the collector, the more current that flows through the transistor. The closer you "move" the base to the emitter, the less current that flows through the transistor. Thinking in this way will make the PNP transistors we are about to discuss as well as circuits with negative voltages a lot easier to understand.



### 8.2 PNP basics

The other type of Bi-polar transistor is the PNP transistor. It is the opposite in almost every way of the NPN transistor. The charges for the emitter, and collector are reversed. The emitter must be more positive than the collector. Instead of electrons flowing from the emitter to the base and collector, you can think of current flowing in that direction. In this case you might think of the emitter as emitting current (or holes) into the rest of the transistor. The only way that the PNP is not opposite of the NPN is that the emitter-base junction is still forward biased and the collector-base junction is reverse biased, exactly as it is with an NPN transistor.

The schematic symbol for the PNP transistor looks identical to the NPN except that the arrow on the emitter points toward the base. One way to remember is that an NPN transistor “Never Points iN” while a PNP is “Perpetually iN Pointing”.



Once again you can represent the transistor with two diodes indicating the two PN junctions. Note that the arrow on the schematic symbol and the arrow of the diode points in the same direction.

Thinking of the transistor as two diodes can be of use when testing transistors. Most Volt-Ohm-Meters have a setting to test a PN junction (usually a diode symbol) and this is used to test the emitter-base and collector-base junctions.

### 8.3 Current Gain

There are a couple of formulas to describe how well a transistor amplifies. The first is  $\alpha$  (alpha) which shows the relationship of collector current to emitter current. The formula for alpha is  $\alpha = \Delta I_C / \Delta I_E$ . Alpha is often given as a percentage, simply multiply the given formula by 100 for this value. The second is  $\beta$  (beta) which shows the relationship of collector current to base current, or the current gain of the transistor. The formula for beta is  $\beta = \Delta I_C / \Delta I_B$ . They are also related by the following formulas:  $\alpha = \beta / (1 + \beta)$  and  $\beta = \alpha / (1 - \alpha)$ .

#### Input and Output IMPEDANCE

When we talk about input or output impedance, we are talking about what another device “sees” when connected to the input or output of the device we are interested in.

**Input impedance** is a measurement of the path from the + input to ground through the circuit to which the signal is being sent. This would include any components that are part of that path.

**Output impedance** is a measurement of the path from the + output of the device from which signal is being sent. This would include any components that are part of that path.

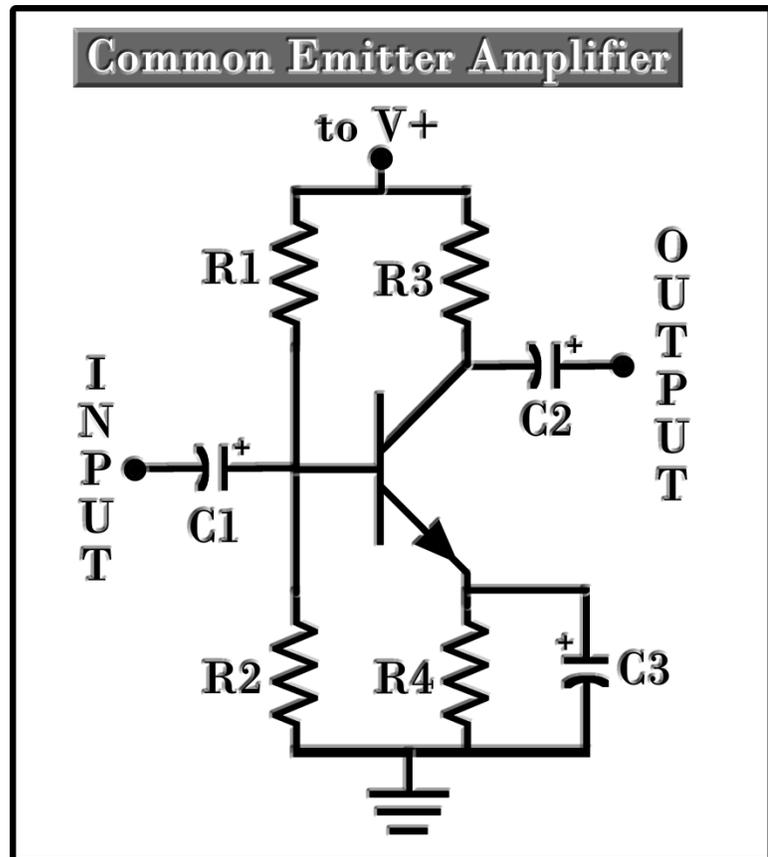
### 8.4 Amplifier Circuits

There are three main types of amplifier circuits for bipolar transistors. They are Common Emitter, Common Collector, and Common Base. **Common Emitter** circuits are seen most often. In most cases the emitter is connected to ground, though this is not always the case. The determining factor in a circuit being common emitter is that the input comes into the base and the output comes from the collector. The common emitter amplifier has moderately high input impedance and high output impedance. The input impedance is made up of the forward biased Base-Emitter junction in series with  $R_4$  and  $C_3$ . The output impedance is made up mostly of the reverse biased Collector-Base junction.

The circuit outputs a signal that is the inverse polarity of the input signal. As more current is put into the base (more positive voltage in the example to the right), the current at the collector increases as well. This means that the voltage drop across  $R_3$  increases, which makes the output farther away from  $V+$ , or lower in voltage. The output then ends up as the opposite polarity compared to the input.

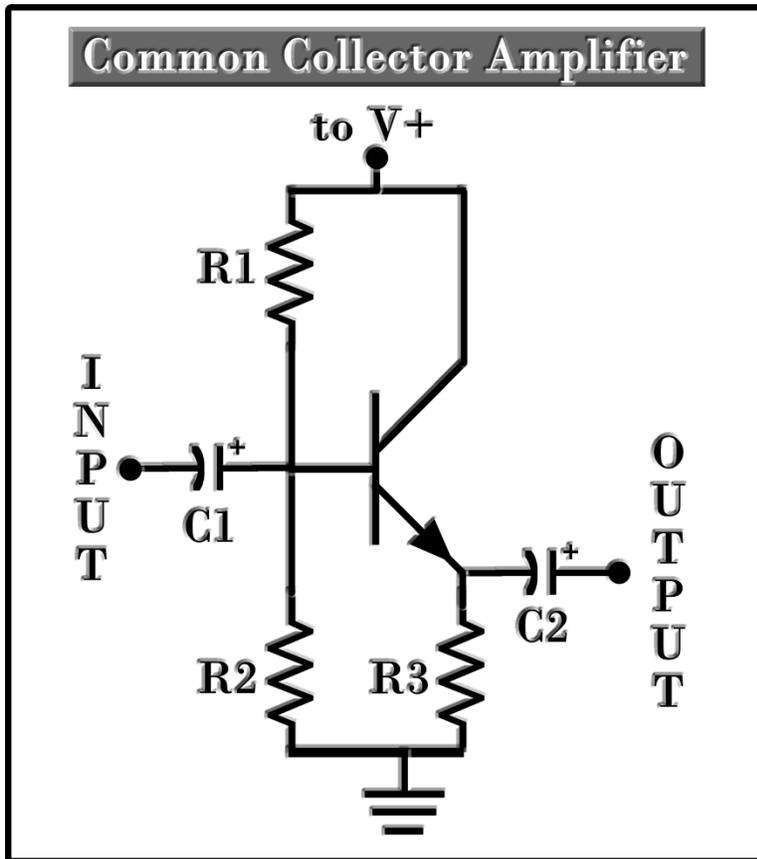
Let's look back at Voltage and Current basics. Current flow is a result of a voltage potential between two points. The larger that potential is, the larger the flow of current. If we apply this to our first transistor circuit we see a very important concept. The larger the voltage between Base and Emitter ( $V_{BE}$ ) is, the larger the current flowing through the transistor (both  $I_B$  and  $I_C$ ).

With the **Common Base** amplifier the base is typically connected to ground, the input goes into the emitter and the output comes from the collector. The common base amplifier has a low input impedance, a high output impedance, and the output is the same polarity as the input. The low input impedance is caused by the forward biased base-emitter junction. The high output impedance is a result of the reverse biased collector-emitter junction.



Common Base amplifiers are often used in RF amplifiers. The input of a common base circuit requires a great deal of power. Remember that all of the current through the emitter is made up of the current from the base and collector. This means that the current gain of a common base amplifier is always less than unity. However, the circuit can still have a large power gain because of voltage gain.

The **Common Collector** amplifier is also called the **Emitter Follower** amplifier. The



collector is often grounded. The

input goes into the base, the output comes from the emitter,

and the output signal is the same polarity as the input signal. The

gain of a Common Collector amplifier is always less than

unity, though greater than the common base circuit. This is

referred to as an emitter follower because the output voltage

follows the emitter voltage. One way to properly bias the

transistor a negative voltage is connected to the emitter.

Capacitor  $C2$  connects the  $R3$  to ground for the AC or varying DC

portion of the current through the emitter. This allows the output to

be taken from  $C3$  and ground.