EEE105 - Electronic Devices
Lecture 19

b. Thin Base Transistor

In the last lecture we saw that if the base is thick essentially all the carriers injected into the base will

This will lead to the situation where the base current I_B will be much

than the collector current, I_C.

Let us now consider the opposite situation where the base is thin. For the base to be thin we need its thickness, $W_B << L_e$

Where in this relationship L_e is the

If the base is sufficiently thin the most of the electrons injected into our npn transistor will diffuse right the way across the base with out recombining with the holes there.

When they reach the base-collector junction the reverse biased field will sweep the minority carrier electrons from the base into the collector.

In the collector the electrons are majority carriers and will appear as a collector current from the device.

There are a number of points to note about the figure of the transistor drawn above.

First as any electrons reaching the edge of the collector-base junction depletion region are immediately swept into the collector, the density of electrons at this point must be very very small. We normally assume it to be zero.

Second the concentration profile of the excess electrons across the base is a nearly linear decay with distance across the base, this means that the diffusion current across the base is nearly constant (as diffusion current is proportional to the rate of change of concentration of the charge carriers). The reason it is not totally linear is due to the fact that there will always be some, hopefully small, amount of electron-hole recombination in the base, no matter how thin the device is.

Now the key point to note in the above device is that the current flowing in the collector does not depend on the bias on the collector base junction. The current flowing into the base, across and then into the collector depends on the bias applied to the base-emitter junction. The more forward biased the base-emitter junction is made, the more current flows into the transistor to the collector.

The key point is that ***small changes in*** V_{be} ***induce large changes in the emitter current*** I_E ***and hence,*** as most of the emitter current flowing into the base reaches the collector, ***induce large changes in the collector current,*** I_C. (Remember that a forward biased diode has an exponentially rising current with bias voltage.)

In the device there will always be some recombination in the base. This gives rise to a small base current, I_B, which depends on the base width and the minority carrier diffusion length in the base. Both these parameters can only be adjusted by our initial design of the transistor.

We can use the transistor to have current gain, which is defined by the ration of the collector and base currents.

To get good gain, (where I_C/I_B is large) we need

1. The current emitted into the base to be as high as possible. For an npn transistor, this means

2. Most of the electrons injected into the base to reach the collector. This means

BJT Current Components.

In order to analyse the BJT more thoroughly we need to look at the different possible currents flowing in the device:

In the structure above we have five different kinds of current that can flow:

❶ Electrons flowing from the emitter recombine with holes in the base.

❷ Electrons flowing from the emitter diffuse across the base and are swept into the collector.

❸ Holes from the base are injected into the emitter and recombine with electrons.

❹ Holes to replace those lost by recombination with the electrons.

❺ Reverse leakage current across the collector base junction.

Now normally ❺ is very small and we will ignore it.

Note that in essence ❶ are ❹ the same current. Allowing for the signs of the current we can say ❶ = -❹.

Let us look how currents ❶,❷,❸,❹ contribute to the Base, Collector and Emitter currents: I_B, I_C, I_E, and also to the electron and hole currents flowing across the base-emitter junction: I_e, I_h

❶

❷

❸

❹

Allowing for the signs we can hence write that:

I_E

I_C

I_B

BJTs as amplifiers.

We shall discuss two ways of using a BJT in a simple amplifier circuit. These will allow us to flesh out the description of the BJT further, giving important parameters that are used to characterise the device.

Common Base Amplifier

(CAL: Bjt(d))

The common base amplifier circuit is shown schematically for a npn device.

In the device a small change in the input voltage, V_{be}, will cause a large change in I_E, and I_C will follow it.

Now let us assume that $I_E \approx I_e$ (True if $N_d >> N_a$) then I_E is due to the electron current injected into the base.

As the base is narrow, virtually all the electrons can cross from emitter to collector so: $I_C \approx \acute{I}_E (\approx I_e)$. Of course I_C can never quite be equal to I_E because

Let us now consider the situation for *changes* to the currents and voltages across the transistor due to the application of *small input signals*.

If I_E changes by ΔI_E then there is a corresponding change in I_C of ΔI_C in the collector. We can define the following relationship:

$$\frac{\Delta I_C}{\Delta I_E} = \alpha_B$$

where α_B is the "***common base current gain***" which will have a value close to, *but just below*, one.

Note that in this circuit no current amplification is possible as $I_C \approx \acute{I}_E$ but since I_C is almost independent of V_{BC} we can get good voltage amplification at the output of the circuit above.

α_B is the fraction of ***extra*** emitter current that reaches the collector $(\Delta I_C / \Delta I_E)$. However for simplicity only let us assume that $\alpha_B = {}^{I_C}\!/\!_{I_E}$

$\alpha_B =$	fraction of extra emitter current due to electrons	x	fraction of electron current that reaches the collector
	$\dfrac{I_e}{I_e + I_h}$	x	$\dfrac{I_C}{I_e}$
	-❶-❷/-❶-❷+❸	x	-❷/-❶-❷
	γ_E		α
	Emitter Injection Efficiency		***Base Transport Factor***

For a "good" transistor we:

use asymmetric doping: $N_d(\text{emitter}) >> N_a(\text{base})$	choose $W_B << L_e$
so $I_e >> I_h$	so electrons mainly cross the base without recombining with a hole.
Hence $\gamma_E \approx 1$	Hence $\alpha \approx 1$

Key Points to Remember:

1. For a transistor we want the collector current and emitter current to be nearly equal
   a. This means the base current must be small
   b. Achievable if the base is much thinner than the minority carrier diffusion length.
2. In a BJT small changes in V_{be} give large changes in the emitter, and hence collector current.
3. The collector current is ideally independent of the reverse bias on the collector base junction.
4. The ratio of collector to base current is controlled by the transistor design
   a. We usually want this ratio to be as high as possible.
5. In the common base amplifier we can get good voltage gain, but not current gain.
6. The ***common base current gain*** can be defined as the product of the ***emitter injection efficiency*** and ***base transport factor***.