EEE105 - Electronic Devices
Lecture 20

Common Emitter Amplifier

(CAL: Bjt(e))

The common emitter amplifier circuit is much more common that the common base configuration. It will be seen that it can give both current and voltage gain.

It is shown here for a npn device.

In the device the base-emitter voltage, V_{be} will (assuming a Si transitor) be close to 0.7 V as the base-emitter junction is forward biased.

Changing the forward bias on this junction may dramatically change the value of the current flow, but due to the exponential nature of the diode equation:

The value of the base emitter voltage will always remain close to 0.7 V.

We can now calculate the value of the base current as the current through the resistor, R_i : $I_B =$

Now let us make a small change to I_B, equal to ΔI_B.

Let us also define the term: $\boxed{\beta = \frac{\Delta I_C}{\Delta I_B}}$, called the ***"common emitter current gain".***

Aside: there is a related parameter $h_{FE} = \frac{I_C}{I_B}$.

Now β is closely related to the common base current gain, α_B.

Let us show that this is the case:

From Kirchoff's laws (conventional current): $I_E = I_C + I_B$, and similarly $\Delta I_E = \Delta I_C + \Delta I_B$

Now using $\alpha_B = \frac{\Delta I_C}{\Delta I_E}$ and rearranging we get $\Delta I_B = \frac{\Delta I_C}{\alpha_B} - \Delta I_C$

And hence $\Delta I_B = \Delta I_C \left(\frac{1 - \alpha_B}{\alpha_B} \right)$ *Prove Yourself for Homework*

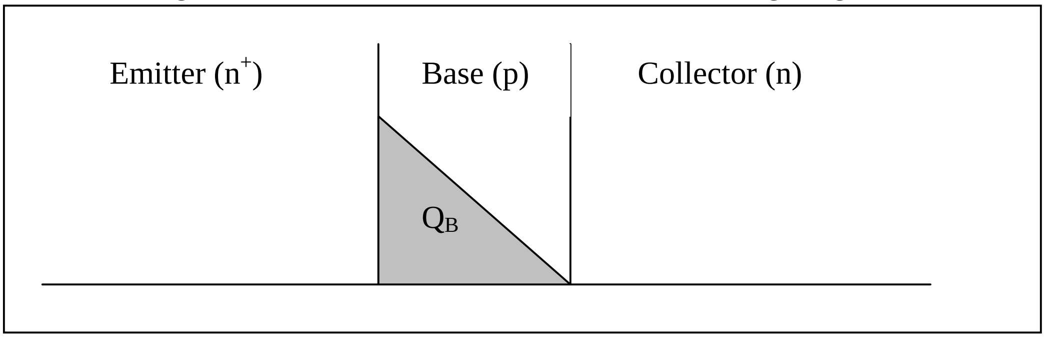
Now $\beta = \frac{\Delta I_C}{\Delta I_B} = \left(\frac{\alpha_B}{1 - \alpha_B} \right)$

Note that from the common base example we said that α_B should be close to 1. This means that β must be large. For example if $\alpha_B = 0.99$ then $\beta = 99$.

How Does Gain Occur?

(CAL: Bjt(f))

To understand how gain occurs in the transistor let us consider the following charge control model:



Consider the electron concentration in the base:

Let us also introduce the characteristic time τ_B which is the average time it takes for an electron to travel across the base from emitter to collector. We call it the ***base transit time.***

Now the base charge Q_B is changed every base transit time, τ_B as the electrons reach the collector end of the base and are swept into the collector by the reverse biased base-collector junction. Hence we can say:

$$I_C = \frac{Q_B}{\tau_B}$$

However, a proportion of the charge will recombine with holes in the base and will appear as the base current (as electrons from the emitter recombine with holes in the base which are then replaced). We can write this as:

$I_B = \dfrac{Q_B}{\tau_e}$, where τ_e is

Now let us assume for simplicity that $\beta = {\Delta I_C}/{\Delta I_B} \approx {I_C}/{I_B} = \dfrac{\tau_e}{\tau_B}$, the last step coming from the equations we have just found. As we said before for high gain (large β) we want low recombination in the base. This means we $\tau_e >> \tau_B$ (That is the carriers must transit the base in a much shorter time than the minority carrier lifetime)

BJT Operating Characteristics

(CAL: Bjt(g))

The Transistor Output Characteristic can be split into two regions:

Region (1) is the so-called saturation region where both junctions are forward biased and the device conducts electricity freely.

[NOTE: Do not confuse this with the saturation current in a Field Effect Transistor or in a reverse biased p-n junction!]

The device in region (1) can be used as the on-state of an electronic switch. (there is a large current flow and small voltage drop)

We can achieve an off-state with V_{be} set such that the base current is negligibly small (eg $V_{be} \approx 0\mathrm{V}$). In this region the base-emitter junction is unbiased and therefore does not conduct and the collector base junction is reverse biased. The collector current will be small, even when V_{ce} is large.

Region (2) is the normal operating regime. The emitter-base junction is forward biased and the base-collector junction reverse biased. The collector current is *controlled* by the base current and this is the AMPLIFICATION region.

Small Signal Equivalent Circuit

(CAL: Bjt(h))

As we did for the field effect transistor we can develop a small signal equivalent circuit for the BJT operating as an amplifier

The base-emitter junction is a forward biased diode, hence $I =$

Therefore $\dfrac{dI}{dV} = \dfrac{q}{kT} I$

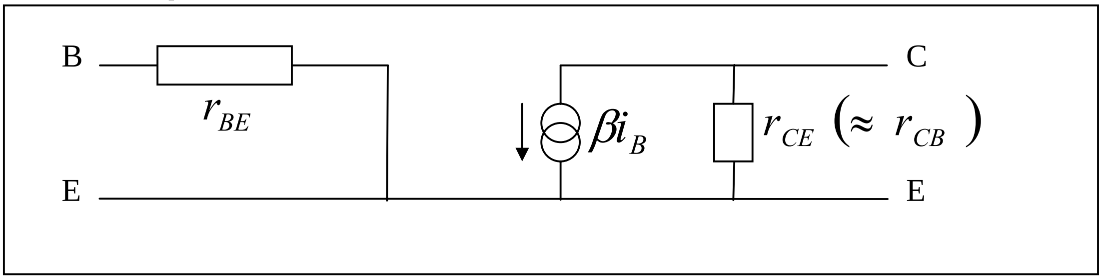
Hence (the differential or dynamic resistance) $r_{BE} = \dfrac{kT}{qI}$

r_{BE} is the reciprocal of the slope of the current against voltage curve of the forward biased diode.

From this we can see that r is dependent on I. Normally r_{BE} is small.

For the collector-base junction we have a reverse biased diode. This means that we will expect r_{CB} to be high, dominating the output resistance between collector and emitter.

We can draw the equivalent circuit as:



Where βi_B - is the current generator giving gain in the device.

Key Points to Remember:

1. Both voltage and current gain can be obtained from a common emitter amplifier circuit.
2. The common emitter current gain is defined as the ratio of the change in collector current to change in base current.
3. We normally want this value to be high.
4. The common emitter current gain can be related to the common base current gain.
5. We can define the source of the gain in terms of the average time it takes for a minority carrier to cross the base against the average time it takes for it to recombine in the base.
6. The BJT can be shown to operate as a switch or amplifier, as could the FET.
7. We can create a small signal current equivalent circuit for the BJT operating as an amplifier.