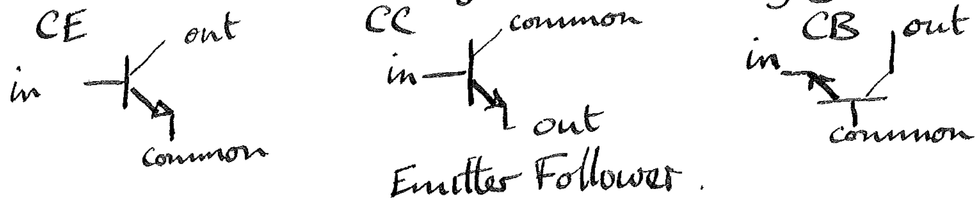
Other BJT Applications

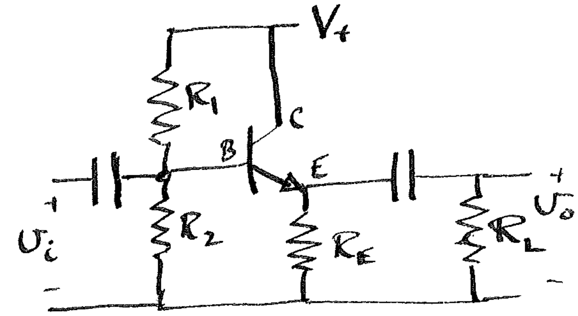
Use a designation common-emitter, common-collector, common-base to refer to 3 configs

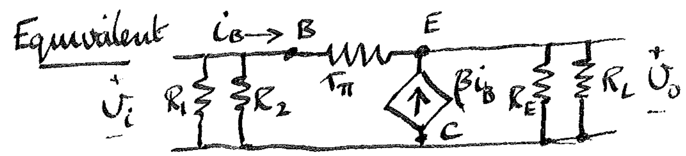


Common Collector (=) Emitter Follower

We already used this configuration as a switch.
Its advantage was ability to supply big current/power.

Now we calculate its response to small-signals, assuming bias puts it in middle of active region.





Voltage Gain

$$v_o = i_B(1+\beta)\, R_E /\!/ R_L$$

$$v_i = i_B r_\pi + v_o$$

So $$\frac{v_o}{v_i} = \frac{1}{1 + \frac{r_\pi}{(1+\beta) R_E /\!/ R_L}} \quad \underline{\simeq 1} \text{ if } r_\pi \ll (1+\beta) R_E /\!/ R_L.$$

Since $r_\pi = \dfrac{V_T \beta}{I_{CQ}}$, condition is $V_T \ll I_{CQ}(R_E /\!/ R_L)$.

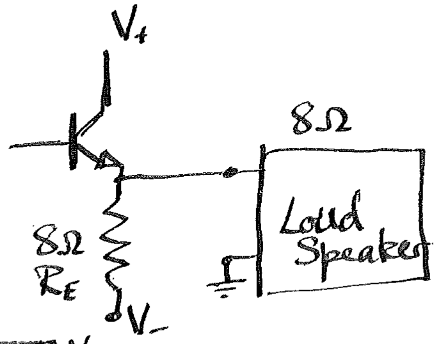
Output Impedance (seen by R_L)

Calculated in previous lecture $\sim \dfrac{r_\pi}{\beta} \simeq \dfrac{V_T}{I_{CQ}}$. Low.

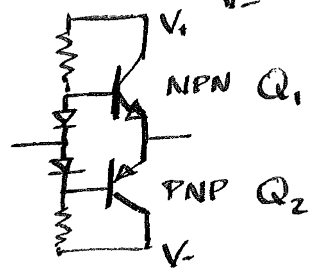
Input Impedance

In parallel with R_1, R_2, the transistor presents impedance $r_\pi + (1+\beta)(R_E /\!/ R_L)$ fairly High.

<u>Push-Pull</u> The problem with an emitter follower as amplifier is large quiescent dissipation.
To drive substantial negative current requires small R_E, large I_{EQ}.

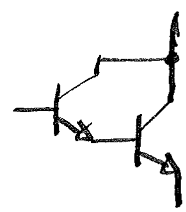


A good way round this is to use two transistors of opposite type
When npn (Q_1) is sourcing +ve current, Q_2 (pnp) is off. When Q_2 sources -ve i, Q_1 is off.



We could just connect bases together. But then we would get cross-over distortion. So we use 2 diode drops to bias the transistors just turning on.
This configuration is sometimes called a class-B amplifier.

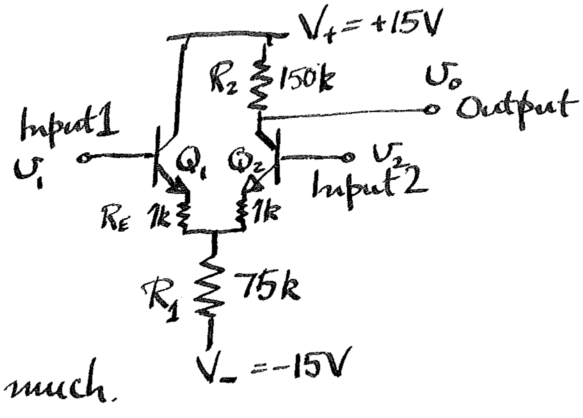
<u>Darlington Connection</u>



While on the subject of sourcing big currents, the Darlington-connected pair works like a single transistor with <u>product</u> of betas. Useful for high current. [Has 2×0.6V BE drop.].
TIP31 is actually a Darlington.

DC Amplifiers

If we want DC operation we can't use coupling cap. Instead, combinations of transistors are used to make differential amplifiers



Consider this example called "Long tailed pair".

If v_1, v_2 are close to 0, then the current in 75k Resistor is $\sim \frac{V_-}{R_1} \sim 200\mu A$. It doesn't change much.

If v_1 goes +ve (w.r.t v_2) more current flows in Q_1, less in Q_2. Consequently v_o rises. v_1 is the +ve input. v_2 is the -ve input.

Gain is $\frac{v_o}{v_1 - v_2} \simeq \frac{R_2}{2R_E}$ Differential

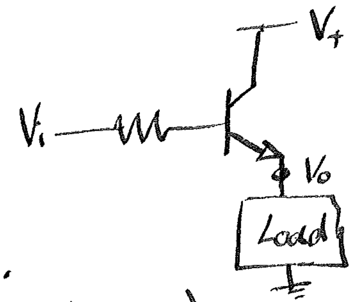
Common Mode $\frac{v_o}{(v_1+v_2)/2} \simeq \frac{R_2}{2R_1 + R_E}$ CMRR $\sim \frac{R_1}{R_E}$.

This is a very rudimentary form of the basis for an op-amp input stage.

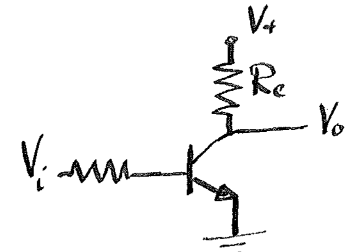
Op Amps incorporate numerous other tricks to minimize thermal drifts and input currents, offsets etc. Also need output stages capable of driving currents etc.

We don't need to reinvent these "wheels". We use Op Amps! [But its nice (and sometimes useful) to know a bit about what's inside].

Transistor Switches

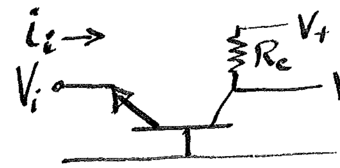


We saw that emitter follower can be used as a switch.
It is non-inverting (high in → high out).
Useful for large currents (low output impedance)
But only unity gain.



Common emitter can be inverting switch
$V_i \lesssim 0.6V$ cut-off $\Rightarrow V_o$ high $(\sim V_+)$
$V_i \gtrsim 0.6V + ?$ saturated $\Rightarrow V_o$ low $(\sim 0.2V)$.
Generally R_c chosen to make gain large, hence saturation.
But then output impedance $\sim R_c$ (cut-off) can't give very large currents. CE switch suitable for turning moderate size (voltage) signal $(\approx 1V)$ into on-off level.

Common Base



Configuration is a transimpedance amplifier: turns input current at approximately constant voltage into voltage output.
Current gain $\simeq 1$. Voltage output $V_o \simeq V_+ + R_c i_i$.
Sometimes transducers produce a current signal.
Sometimes this is less subject to interference.
Can be a small-signal amplifier or switch.
[In the above config $V_i \simeq -0.6$ at active region.]

BJT Summary

npn, pnp transistor carriers: polarity of emitter (n, p)

Emitter Current controlled by V_{BE} : $I_E = I_S \left[\exp \frac{V_{BE}}{V_T} - 1\right]$
diode characteristic $I_E \simeq I_C$.

In Active Region $I_c = \beta \; I_B$ $[\beta \gg 1]$
substantially independent of V_{CE} (dI_c/dV_{CE} small, +ve).

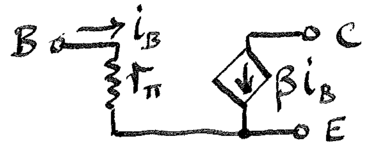
Saturation (reduction of I_c) occurs for $V_{CE} \lesssim 0.3V$.

Cut-Off means $I_c \simeq 0$; occurs for $V_{BE} \lesssim 0.6V$.

Large Signal or Bias calculation assumes one of three regions (active, saturation, cut-off) and demonstrates self-consistent solution.

Small-Signal response in active region linearizes.

$$i_B = \frac{v_{BE}}{r_\pi} \qquad r_\pi = \frac{V_T}{I_{BQ}} = \frac{\beta V_T}{I_{CQ}}$$

equivalent circuit 

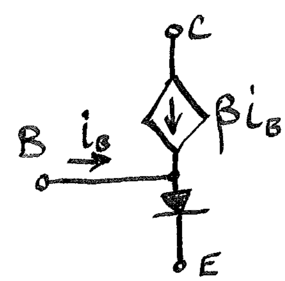
npn

Common Emitter $Z_{in} \simeq r_\pi$, $Z_{out} = R_c$, $\text{Gain} = -\frac{R_c I_{cQ}}{V_T}$.

Emitter Follower $Z_{in} \simeq r_\pi + \beta R_E$, $Z_{out} \simeq \frac{r_\pi}{\beta}$, $\text{Gain} \simeq 1$.

Large Signal Equivalent Circuit

Valid away from saturation, i.e. when $V_{CE} \gtrsim 0.3V$, and $i_B \geq 0$.



npn