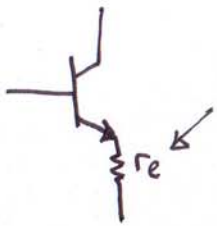
Effective emitter resistance

Ebers-Moll $\Rightarrow V_{BE} \cong V_T \ln \frac{I_C}{I_S} = V_T [\ln I_C - \ln I_S]$

$\Rightarrow r_e \equiv \frac{dV_{BE}}{dI_C} = \frac{V_T}{I_C}$

$V_T \cong 25\,mV$ at RT

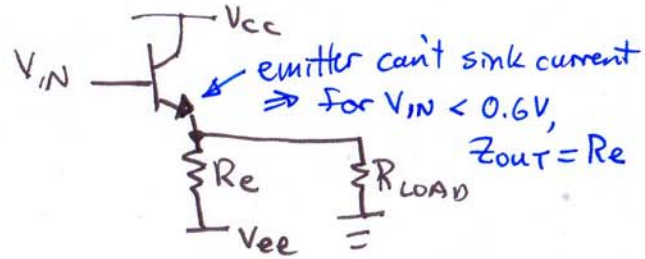


resistance built into the transistor:

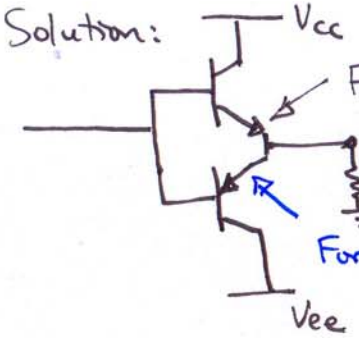
$$r_e = \frac{25}{I_C}\ (I_C \text{ in mA})$$

Push-Pull Buffer

NPN-based emitter follower doesn't work well for $V_{IN} < 0.6V$:

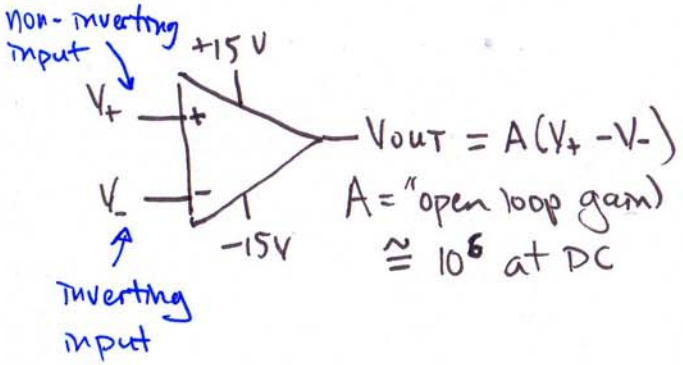


Solution:



One problem: for $-0.6 < V_{IN} < 0.6$, neither transistor is active ⇒ $V_{OUT} = 0$. ☹

Op amps



Golden Rules

** 1) No current flows into inputs **

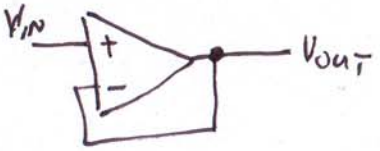
(Z_{IN} typically >100 MΩ at DC)

V_{OUT} is between ±15V

$\Rightarrow (V_+ - V_-)$ is between $\pm 15\mu V \approx 0$

$\Rightarrow$ 2) ** $V_+ \cong V_-$ **

Example: buffer



By 2), $V_- = V_{IN}$

because of the wire from V_{OUT} to V_-,

$V_{OUT} = V_-$

$\Rightarrow V_{OUT} = V_{IN}$, as desired for a buffer

Why is Z_{OUT} of the buffer so low? feedback!

low $Z_{OUT} \Rightarrow V_{OUT}$ should be constant

If $V_{OUT} \downarrow$, $V_- \downarrow$, Then, since $V_{OUT} = A(V_+ - V_-)$,

the op amp brings V_{OUT} back up!