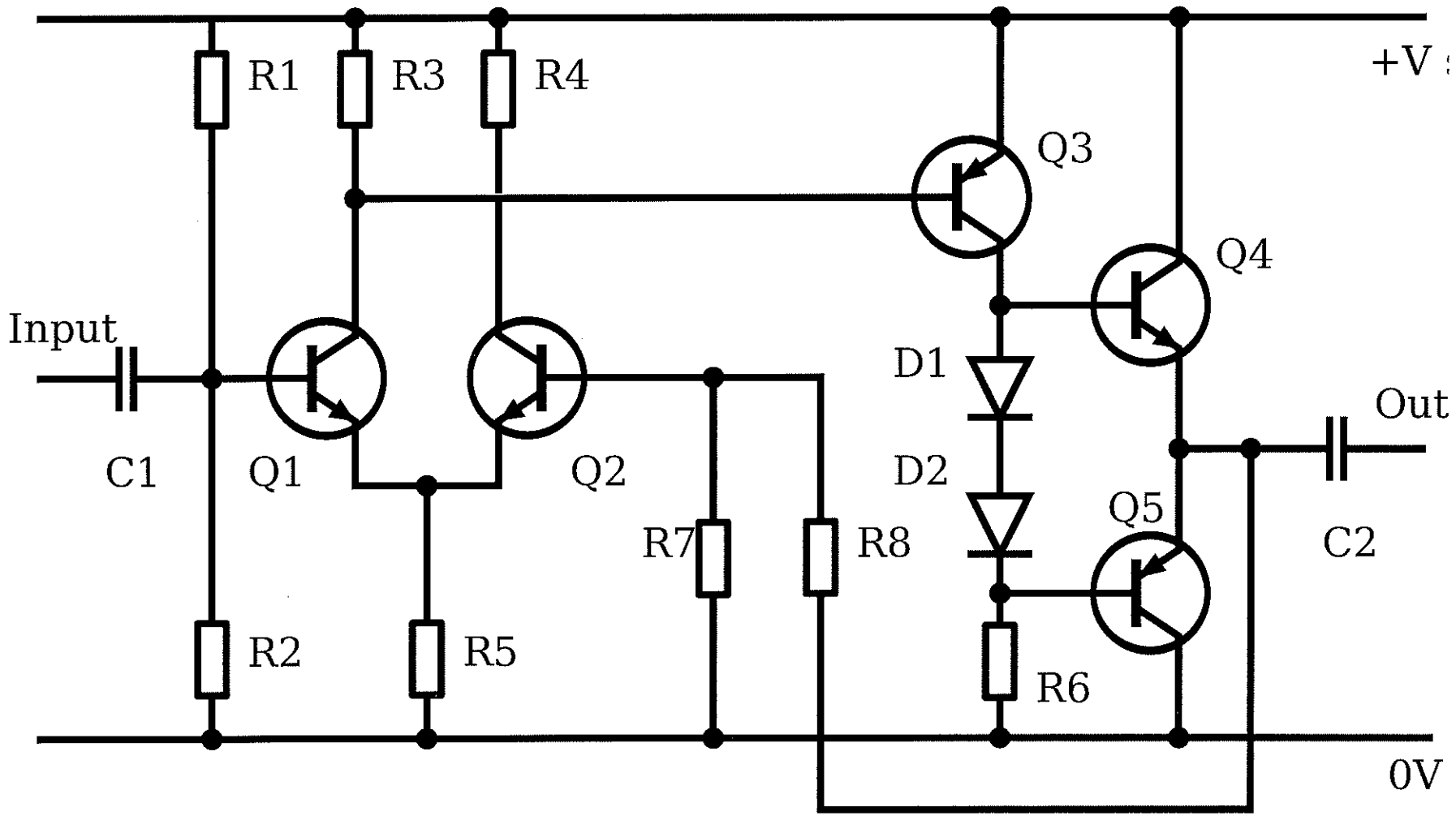
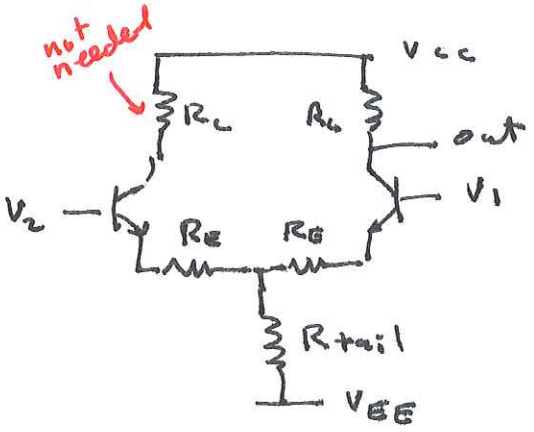

R1
R3
R4
+V
Q3
Q4
Input
D1
Out
C1
Q1
Q2
D2
Q5
C2
R7
R8
R2
R5
R6
0V

Differential Amp - long tail pair



$\Delta V_2 = -V$

Differential gain: $\Delta V_1 = +V$

the current thru tail in this symmetric situation is unchanged so the top of tail is at a fixed voltage — it's just like common emitter amp

$$\frac{\Delta out}{V \rightarrow \Delta V_1} = -\frac{R_c}{r_e + R_E}$$

But for differential mode: $\Delta(V_1 - V_2) = 2V$

so $$\frac{\Delta out}{\Delta(V_1 - V_2)} = \frac{\Delta out}{2V} = -\frac{R_c}{2(r_e + R_E)}$$

Common Mode: $\frac{\Delta V_2}{\Delta V_1} = +V$ - the current thru tail is doubled → seems like $2 \times R_{tail}$ otherwise just like common

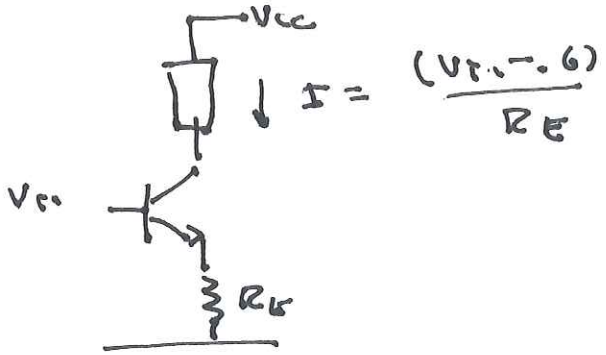
$$\frac{\Delta out}{V} = \frac{-R_c}{2R_{tail} + R_E + r_e}$$

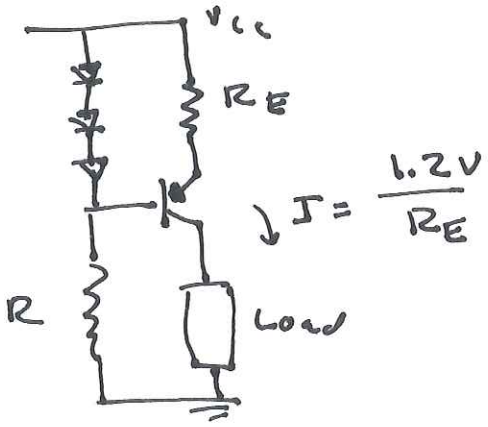
$$CMRR = \frac{\text{diff gain}}{\text{common gain}} = \frac{2R_{tail} + R_E + r_e}{R_E + r_e}$$

Plan: using a current source for R_{tail} will hugely reduce common mode gain

Use a "current mirror" for R_c — has property that for differential signals $R \rightarrow \infty$ but for common mode signals $R \rightarrow 0$

Current Sources





Early Effect ($10^{-4} = h_{re}$) → V_{CE} affects the on voltage of BE diode.

Temp also affects V_{BE}

Compliance? Bias circuit?

Current mirrors ← Rule #3 devices