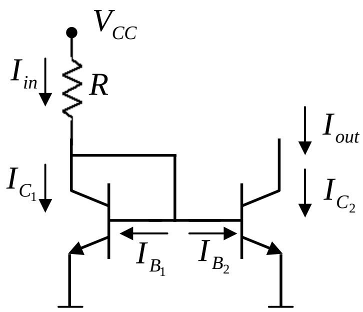
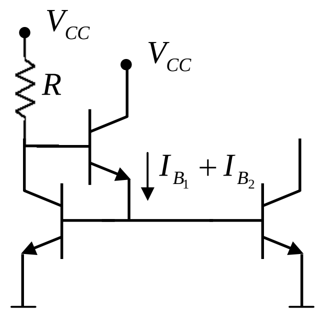
Bipolar transistor Current Source



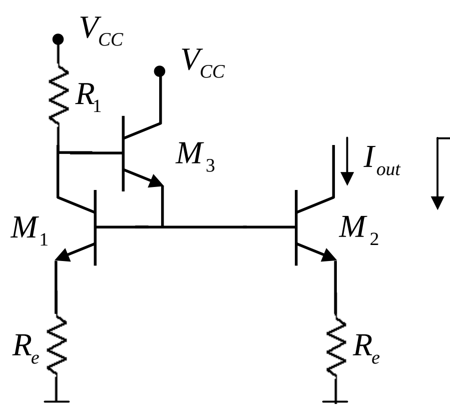
Simple current mirror



Current mirror with less current error (not a function of β)

In order to increase the output resistance:

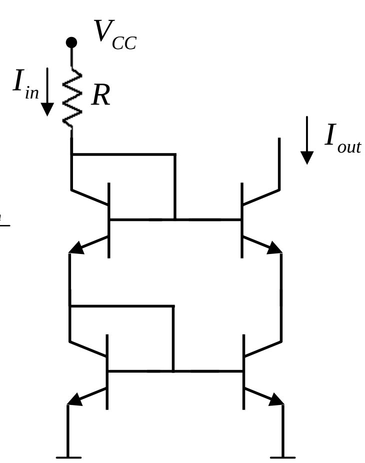
Current mirrors with emitter degeneration



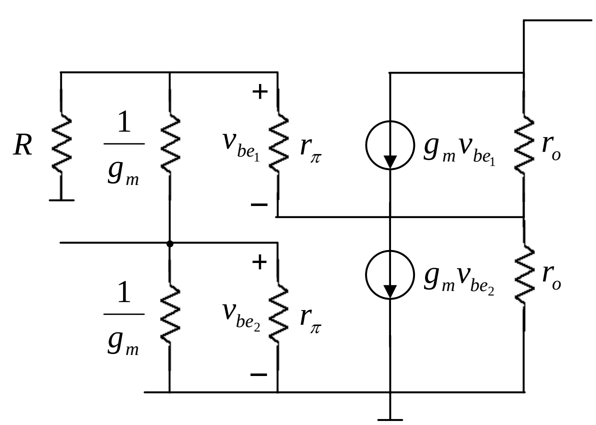
$$R_{out} = r_{o_2}(1 + g_{m_2} R_e)$$

Cascode Current Source

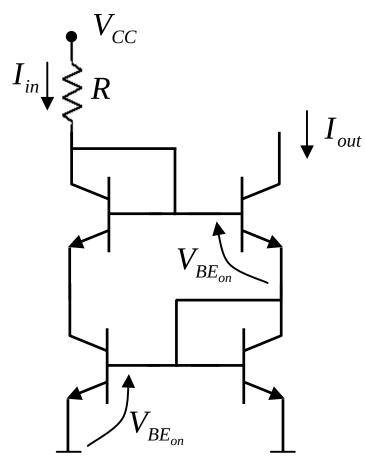
$$I_{in} = \frac{V_{CC} - 2V_{BE_{on}}}{R}$$



Simplified equivalent circuit for cascode



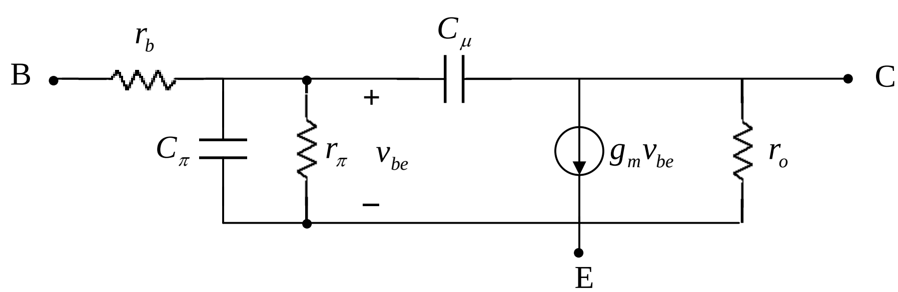
Wilson Current Source



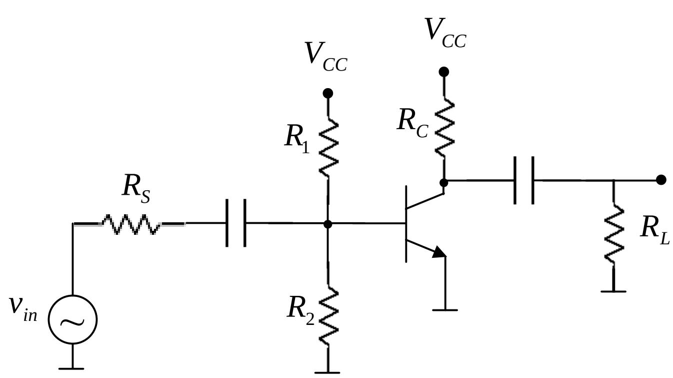
$$I_{in} = \frac{V_{CC} - 2V_{BE_{on}}}{R}$$

$R_{out} = \beta \frac{r_o}{2}$ for both Cascode and Wilson → HW 5 problem.

Bipolar Single-stage Amplifiers

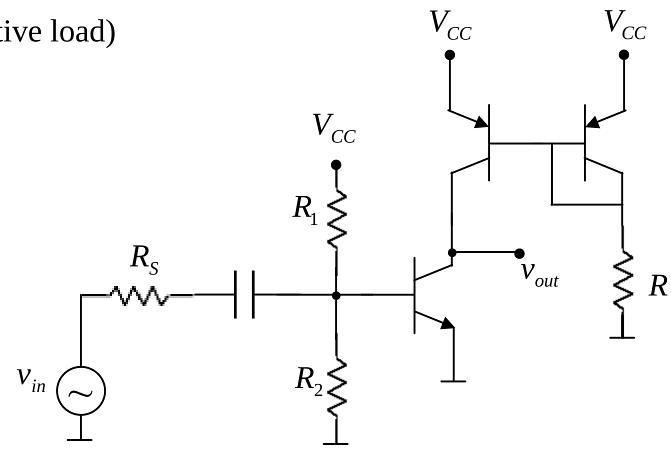


Common-Emitters

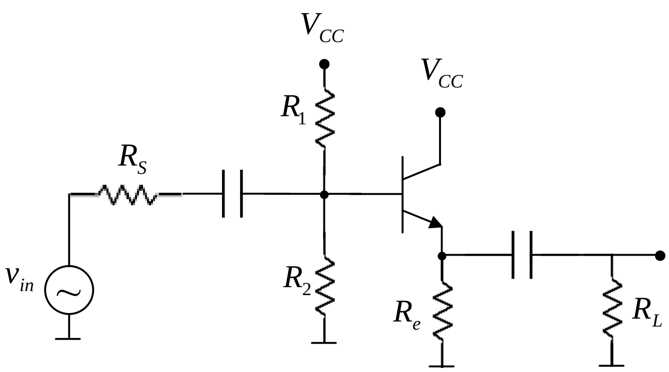


Non-integrated version.

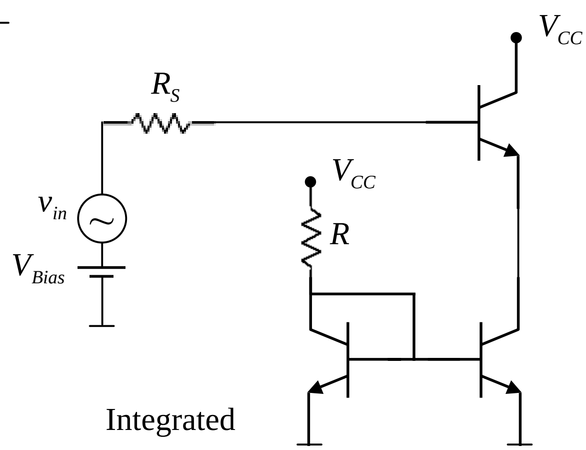
Integrated version (active load)



Emitter followers

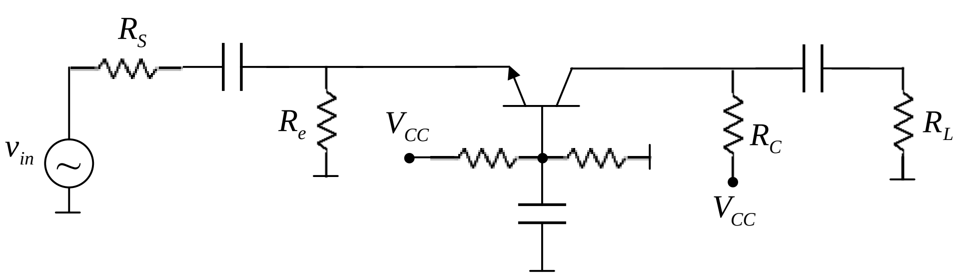


Non-integrated

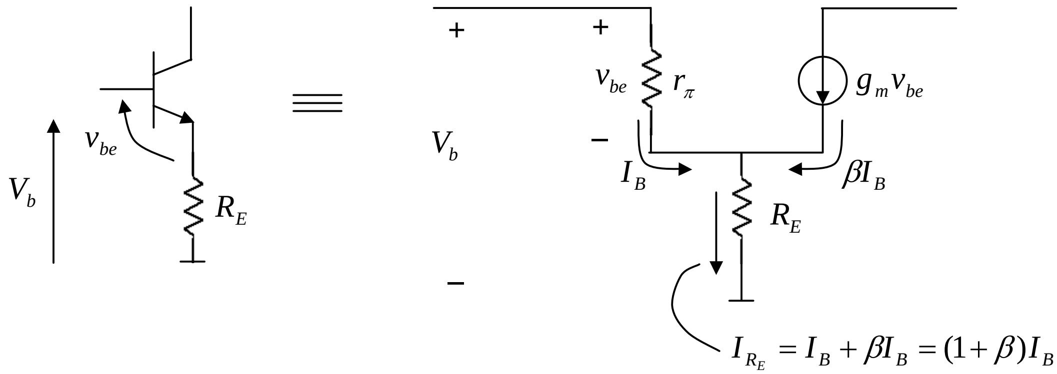


Integrated

Common base



Simple trick when you analyze bipolar transistors:

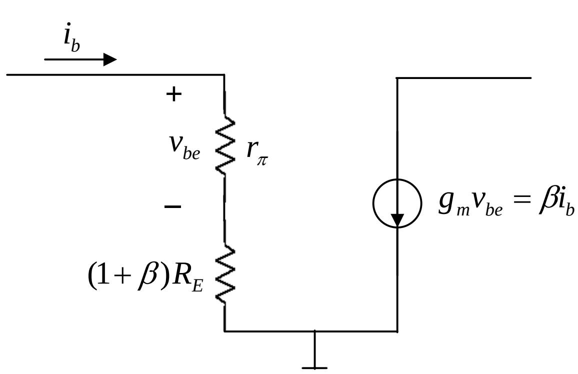


$V_{be} = r_\pi . i_b$

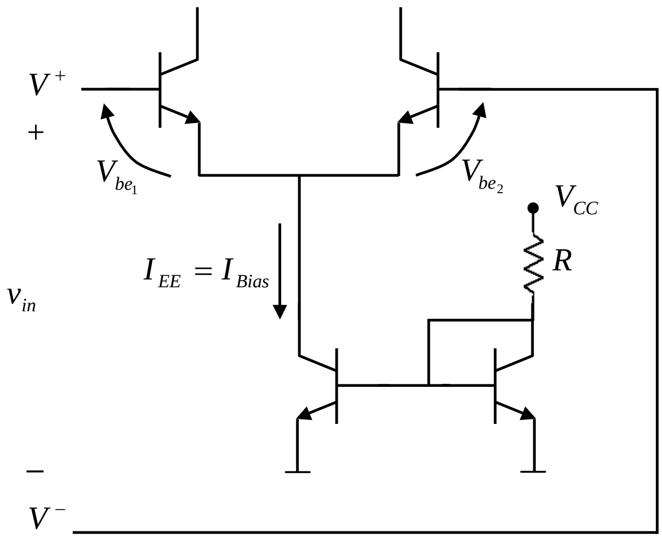
$$V_b = V_{be} + V_{R_E} = v_{be} + I_{R_E} . R_E = V_{be} + I_B (1+\beta) . R_E$$

$$V_b = r_\pi . i_b + i_e . R_E = r_\pi . i_b + (1+\beta) . R_E . i_b = . i_b (r_\pi + (1+\beta) . R_E)$$

At the input you have the following circuit:



Bipolar Differential Pairs

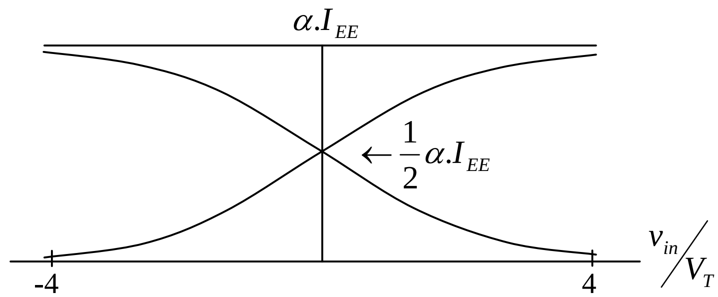


$$\left.\begin{aligned} V_{be_1} &= V_T \ln\left(\frac{I_{C_1}}{I_{S_1}}\right) \\ V_{be_2} &= V_T \ln\left(\frac{I_{C_2}}{I_{S_2}}\right) \\ V^+ - V_{be_1} &+ V_{be_2} - V^- = 0 \end{aligned}\right\} \rightarrow \frac{I_{C_1}}{I_{C_2}} = e^{\frac{V^+ - V^-}{V_T}} = e^{\frac{v_{in}}{V_T}}$$

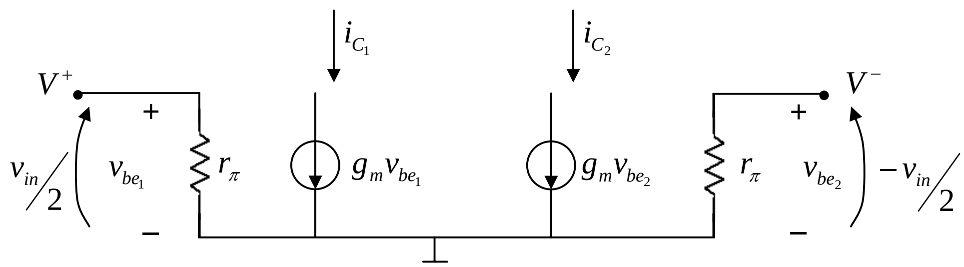
$$I_{C_1} + I_{C_2} = (I_{Bias} = I_{EE}).\alpha \quad \rightarrow \quad \alpha = \frac{\beta}{1+\beta}$$

$$\Rightarrow \quad I_{C_1} = \frac{\alpha I_{EE}}{1 + e^{-\frac{v_{in}}{V_T}}}$$

$$I_{C_2} = \frac{\alpha I_{EE}}{1 + e^{+\frac{v_{in}}{V_T}}}$$



Small-signal Analysis



$$i_{C_1} = g_m \frac{v_{in}}{2}$$

$$i_{C_2} = -g_m \frac{v_{in}}{2}$$