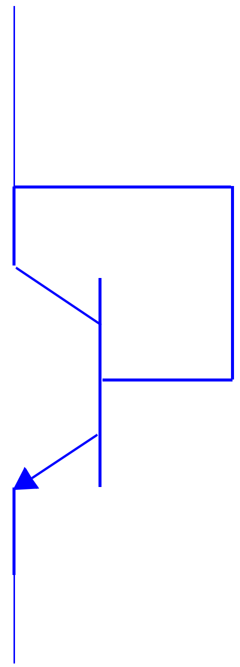
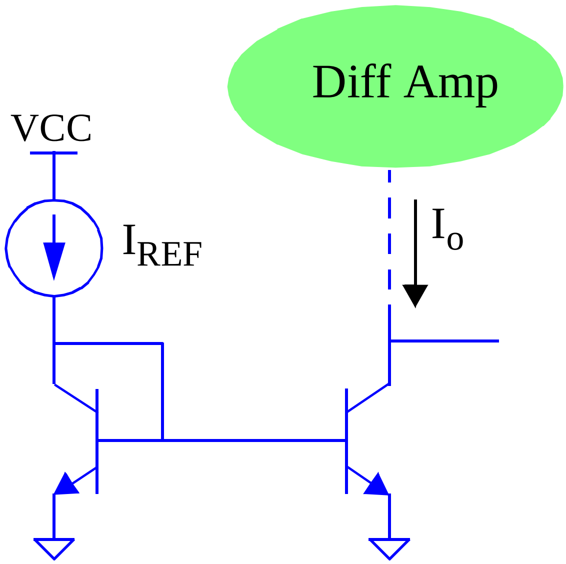
Diode-connected BJT



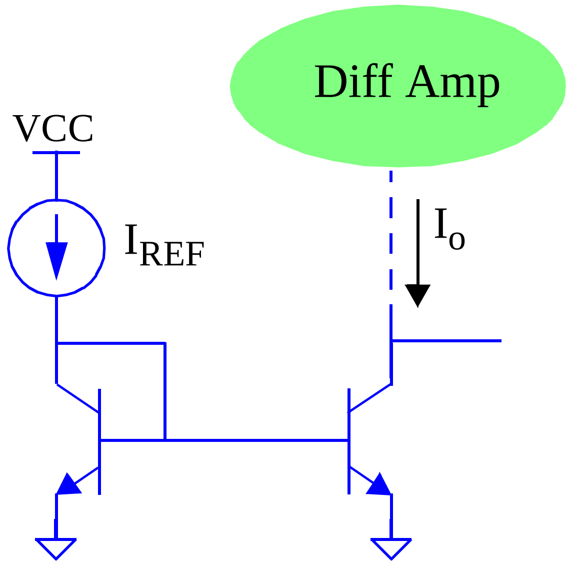
Current Mirrors

- Current sources are created by mirroring currents
- Example: with infinite β, $I_o = I_{REF}$



Current Mirrors

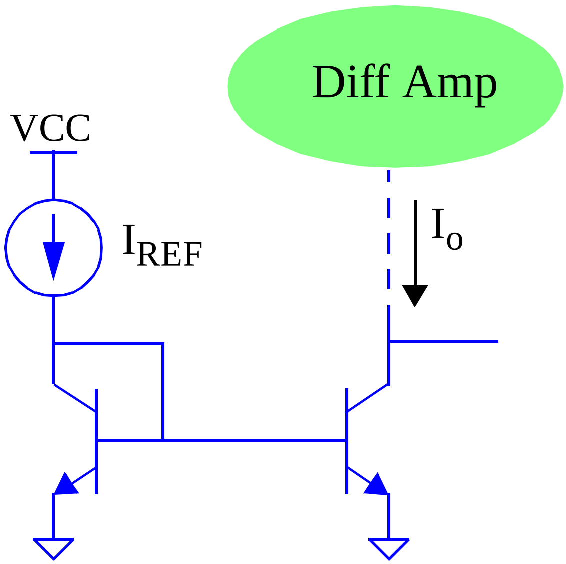
- Example: with finite β



- What is the other reason for I_{REF} ¦ I_o?

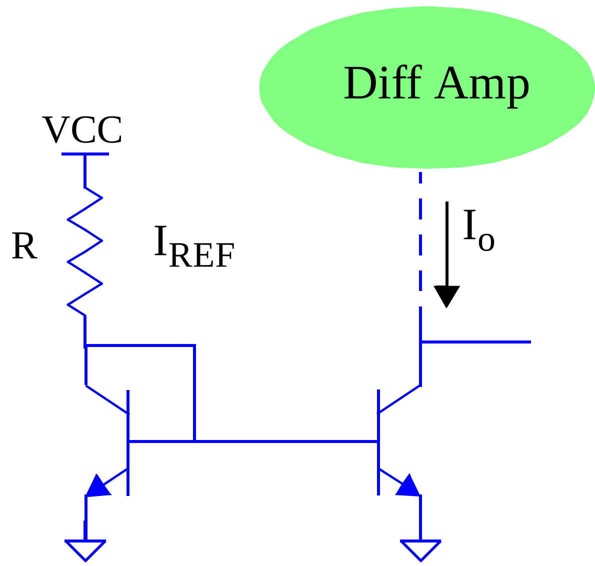
Output Resistance of Current Source, R

- What is the small signal output resistance of this current source, and why do we care?



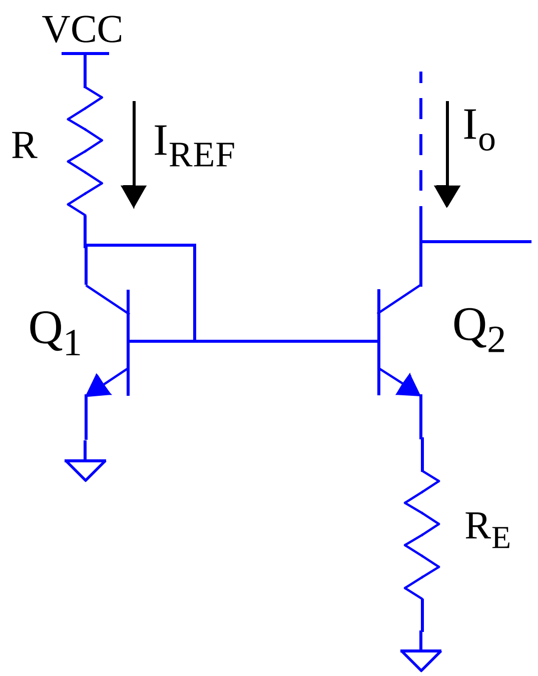
Simple I_{REF} Model

- Select R to establish the required reference current



Widlar current source

- For a given Vcc, you need large resistor R values to obtain small current!
- Lagre resistors are expensive, Widlar current source uses smaller resistor in emitter to reduce achive the same current?



$$I_oR_E = V_{BE1} - V_{BE2}$$

$$V_{BE1} = V_T \ln(I_{REF}/I_s)$$

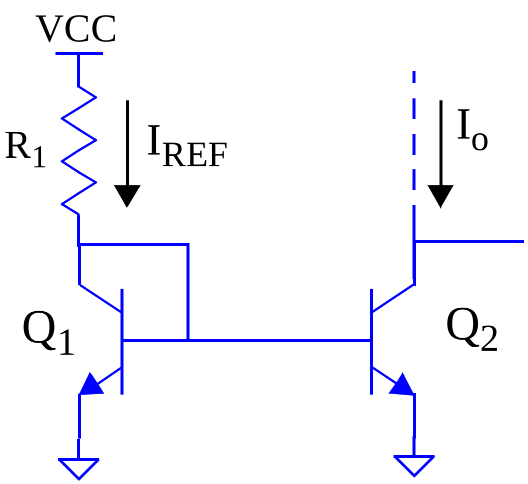
$$V_{BE2} = V_T \ln(I_o/I_s)$$

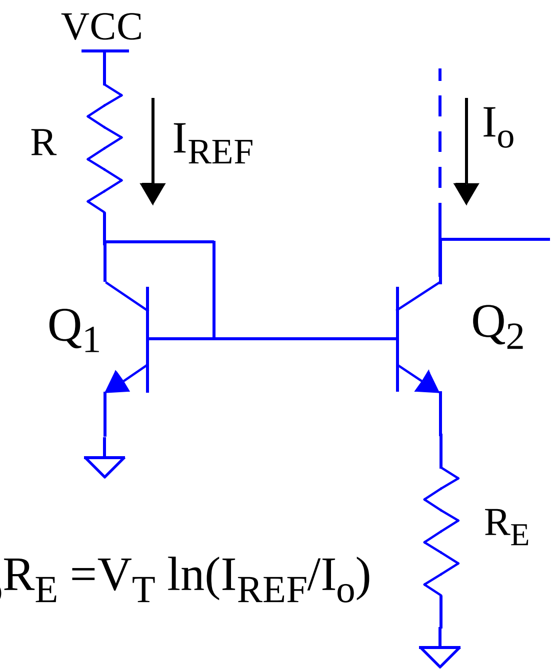
$$V_{BE1} - V_{BE2} = V_T \ln(I_{REF}/I_o)$$

$$I_oR_E = V_T \ln(I_{REF}/I_o)$$

Widlar current source vs. ordinary current mirror

- Let us say we need Io = 10µA
- Assume that for I - 1mA V_{BE} = 0.7

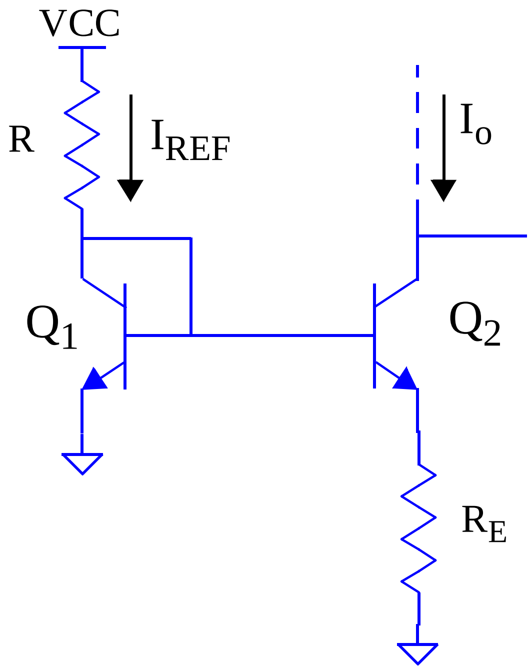


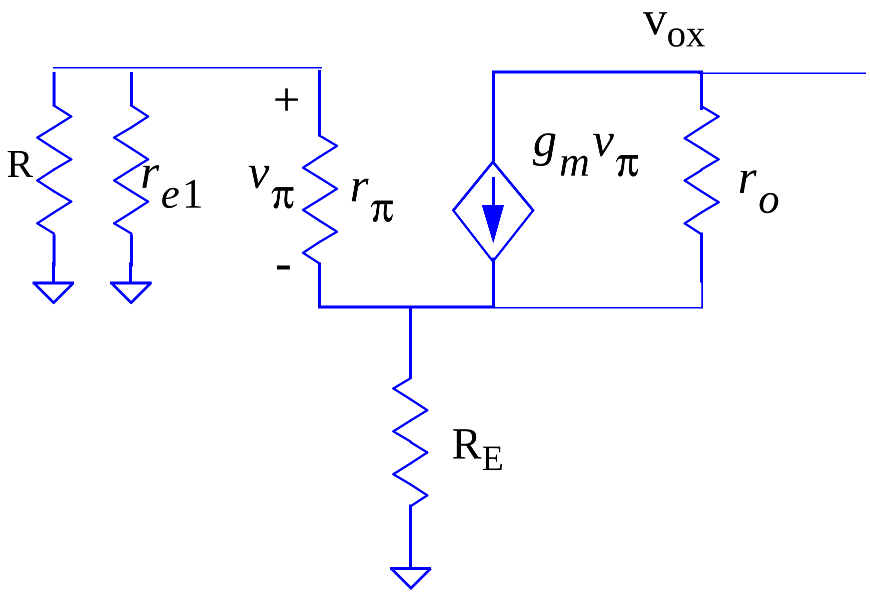


$$I_oR_E = V_T \ln(I_{REF}/I_o)$$

Widlar current source - output resistance

- If we neglect R || r_{e1} , base of Q_2 is on ac ground

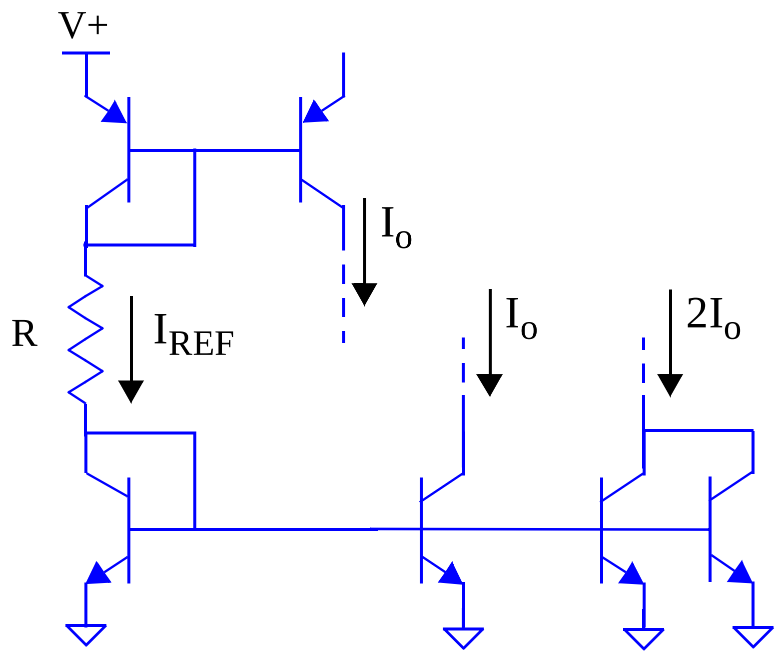




- Presence of R_E is increases output resistance to $(1+g_m R_E||r_\pi)r_o$.
(Read Sec. 6.4 in the textbook!)

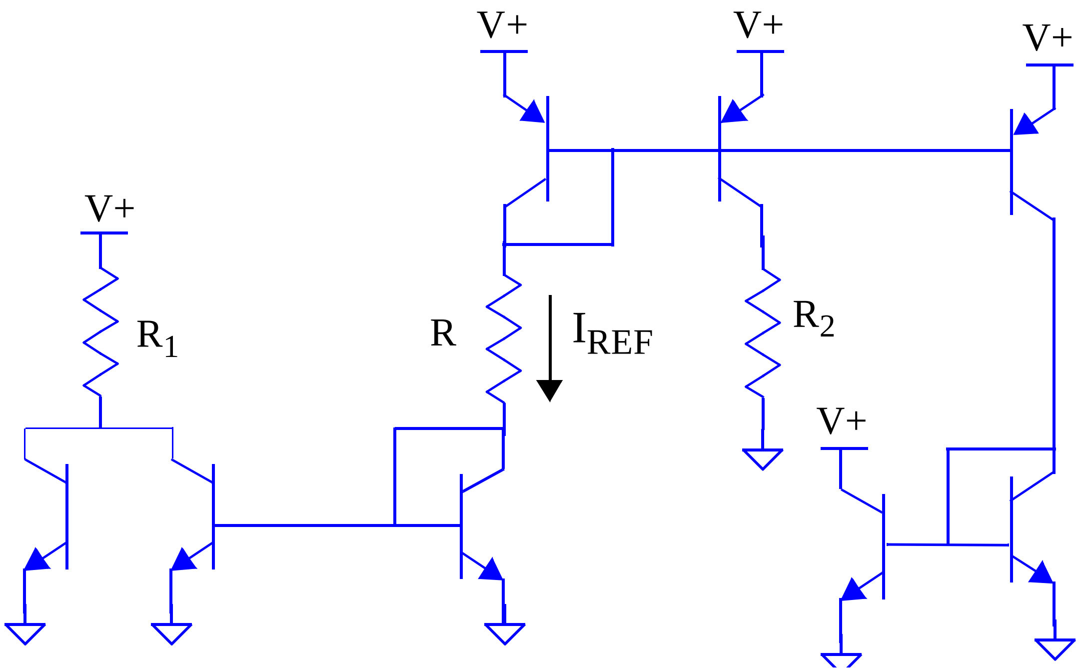
Current Steering

- With an I_{REF} established, steer and/or scale the reference value



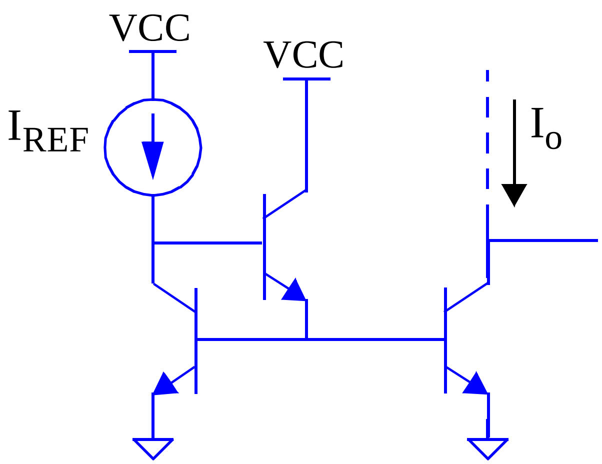
Reading IC circuit schematics

- Find a path between + power supply and - power supply which sets the reference current (very often there is only one even in a large circuit): Only V_{BE} and resistors are in this path.
- Type of transistor will tell you the expected direction of current: npn - current sink, pnp - current source.
- Identify current mirror configurations (Widlar, Wilson, etc.) and respective emitter areas.
- Proceed from the reference current branch an calculate subsequent currents independently



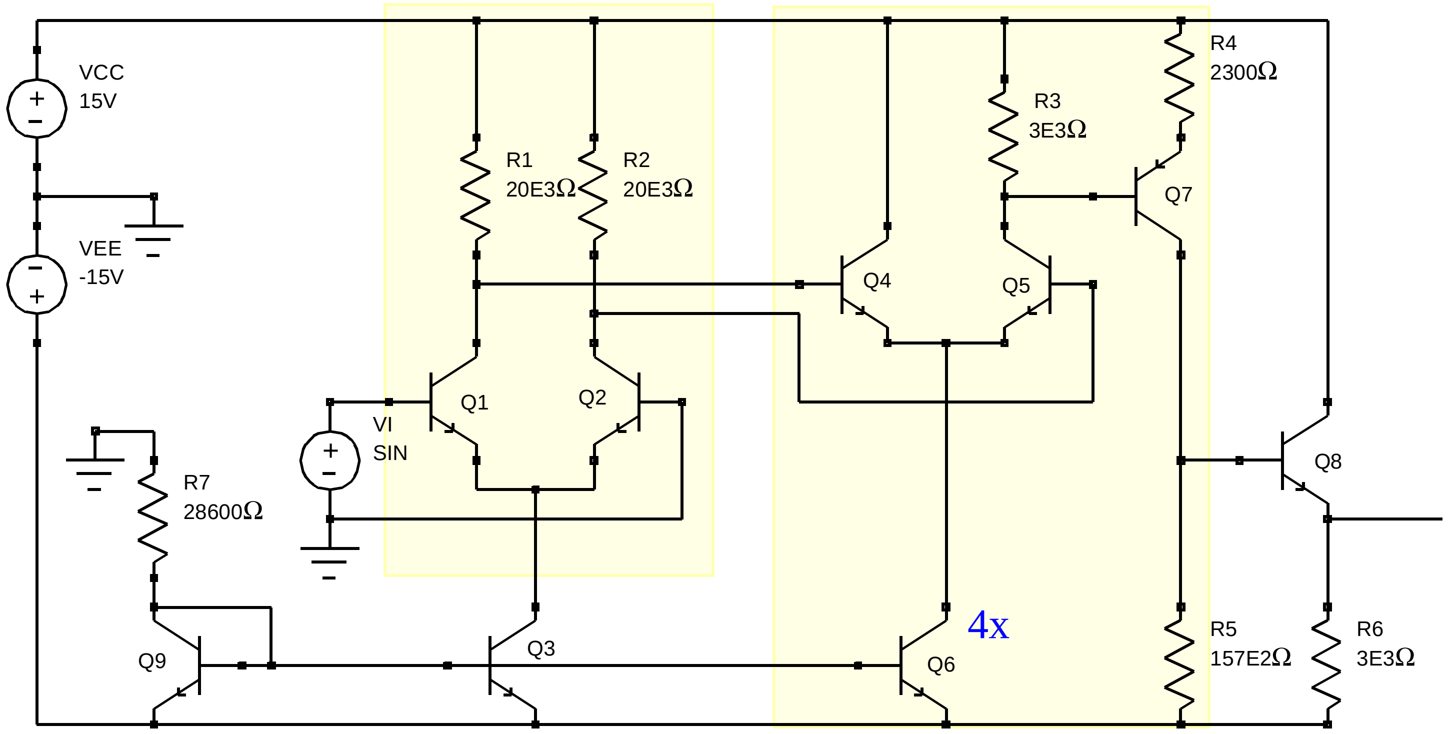
Beta Dependence

- When "steered" to several points, the I_o dependence on β can be a problem



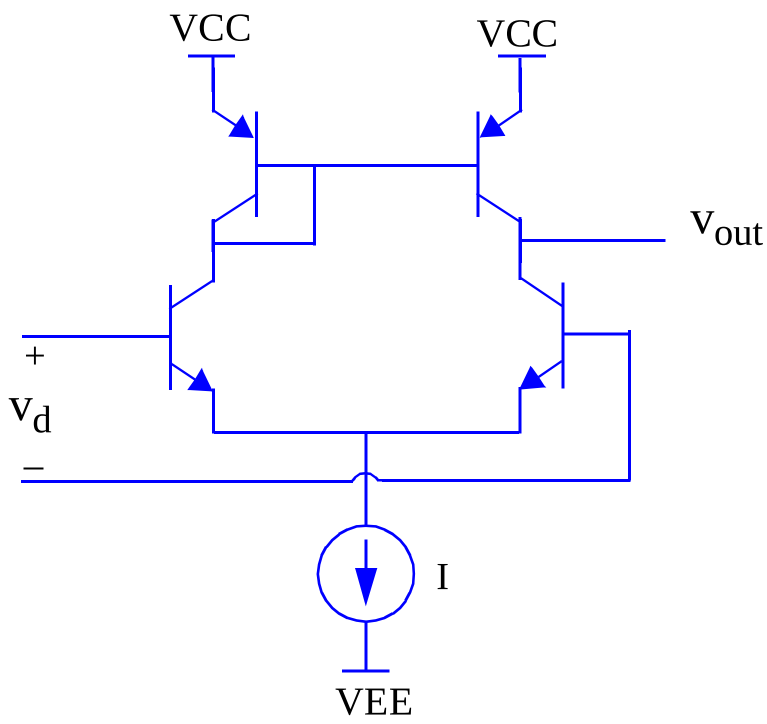
Simple Opamp Example

- First stage is used to reject common mode voltages
- The 2nd diff amp and level shifting stage provide the gain
- The input diff amp also provides the large input resistance
- Why is Q6 designed to be 4x larger than Q3?



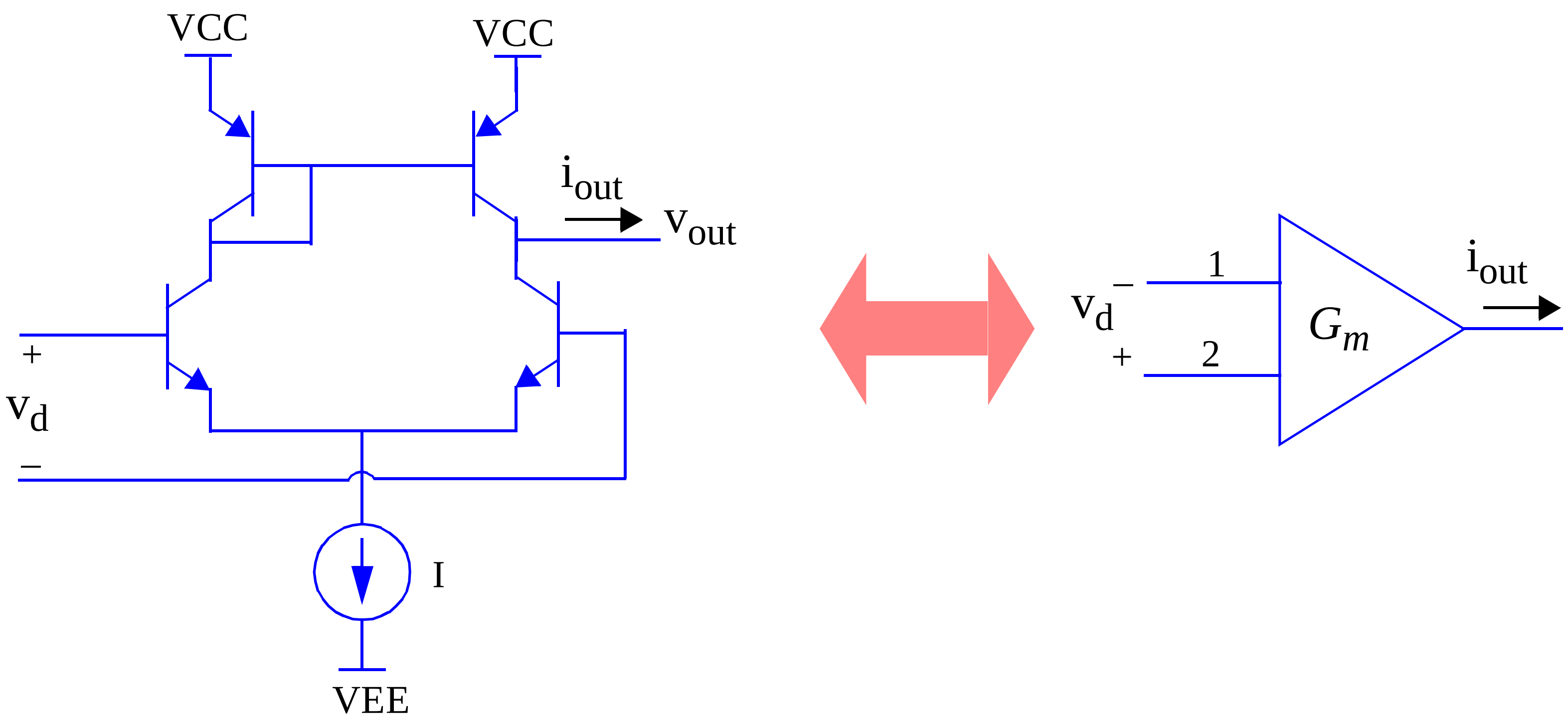
Differential Amplifiers: Active Loads

- IC resistors are impractical
- Active loads provide current-source-like loads, hence large small signal gains



Differential Amplifiers: Active Loads

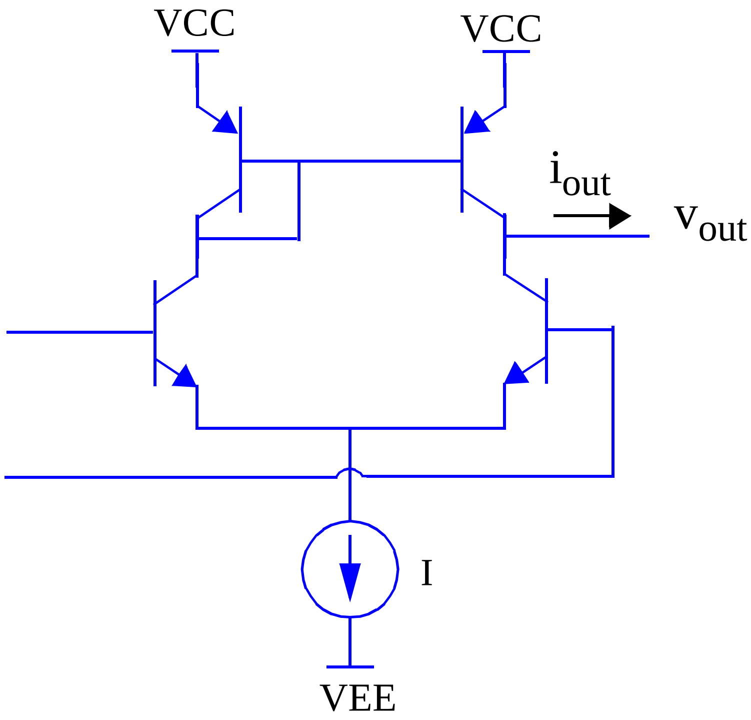
- The output in this example is single-sided, but behaves sort of differentially
- The output is a current, proportional to v_d --- transconductance amplifier



- Assuming infinite β, what is the output current when $v_d = 0$?

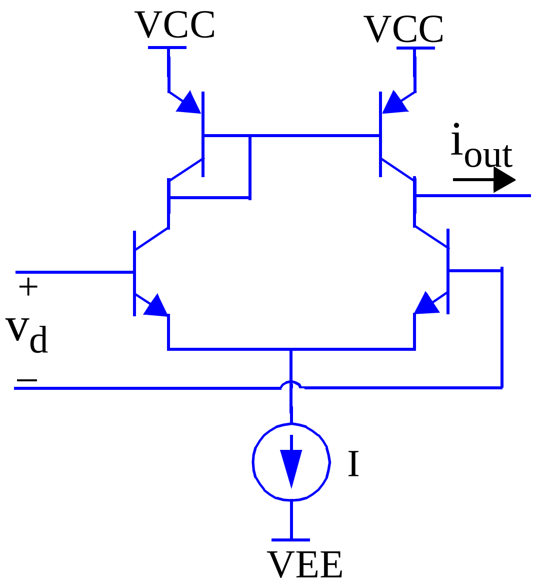
Common Mode Gain

- If all of the parameter values are exactly matched to one another, and β=100, will there be any common mode gain?



- Will there be any dc offset?

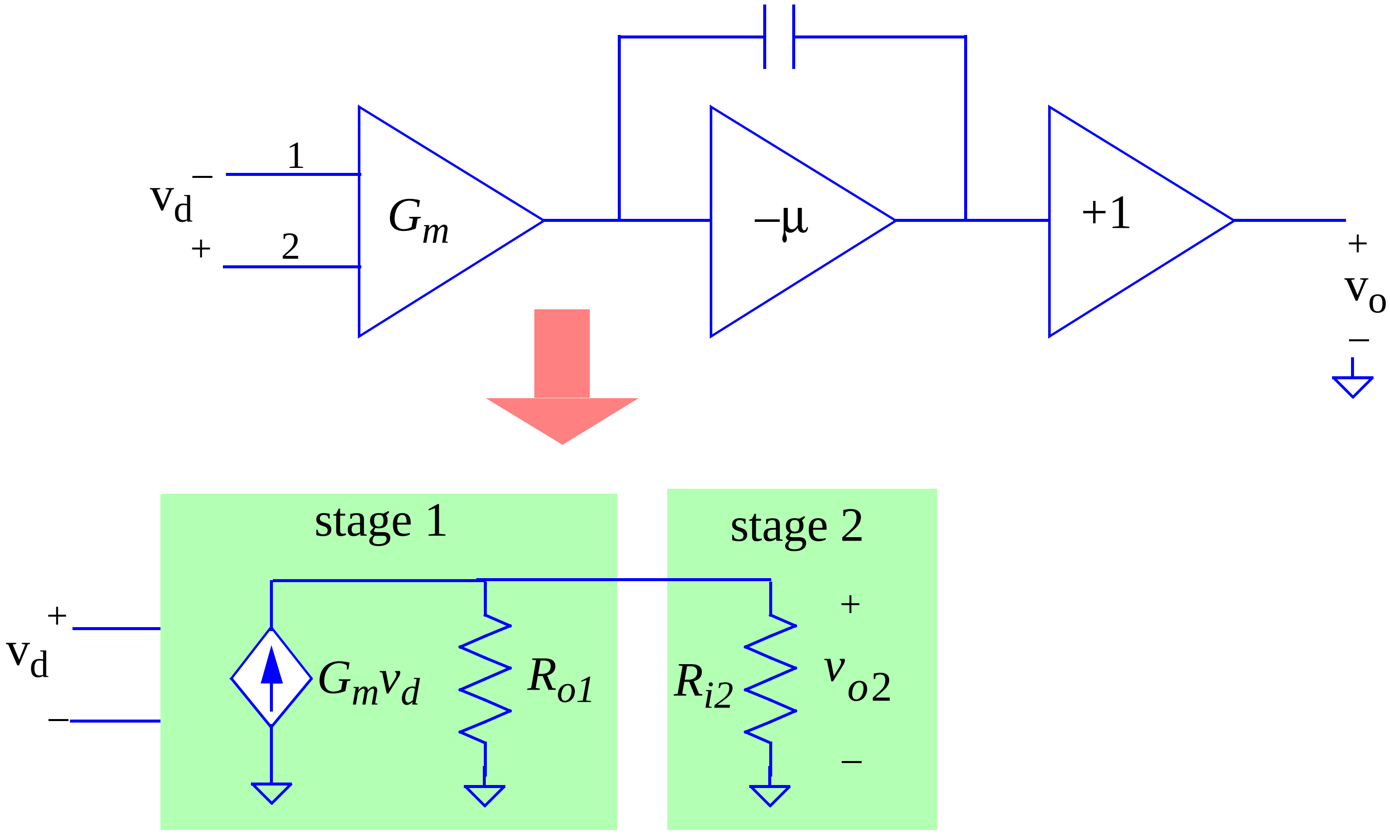
Small Signal Gain, G_m



Small Signal Gain, G_m

Transconductance Stage of Opamp Model

- The voltage gain of stage 1 depends on the output impedance of stage 1 and the input impedance of stage 2



Transconductance Amplifier Voltage Gain

- Active loads are often designed to maximize R_o