EEE 51: Second Semester 2017 - 2018

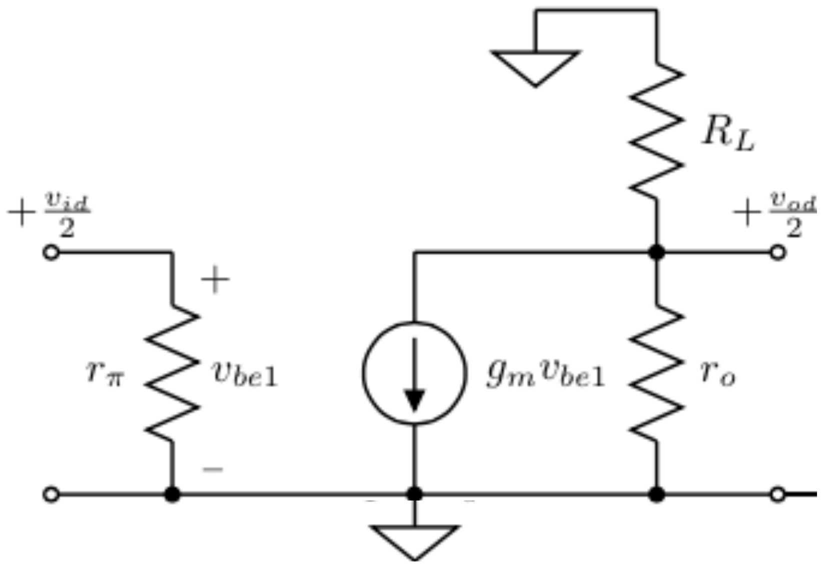
Lecture 12

Differential to Single-Ended Conversion

Today

- Small signal analysis of differential circuits
- Differential to single-ended conversion

The Differential Half Circuit



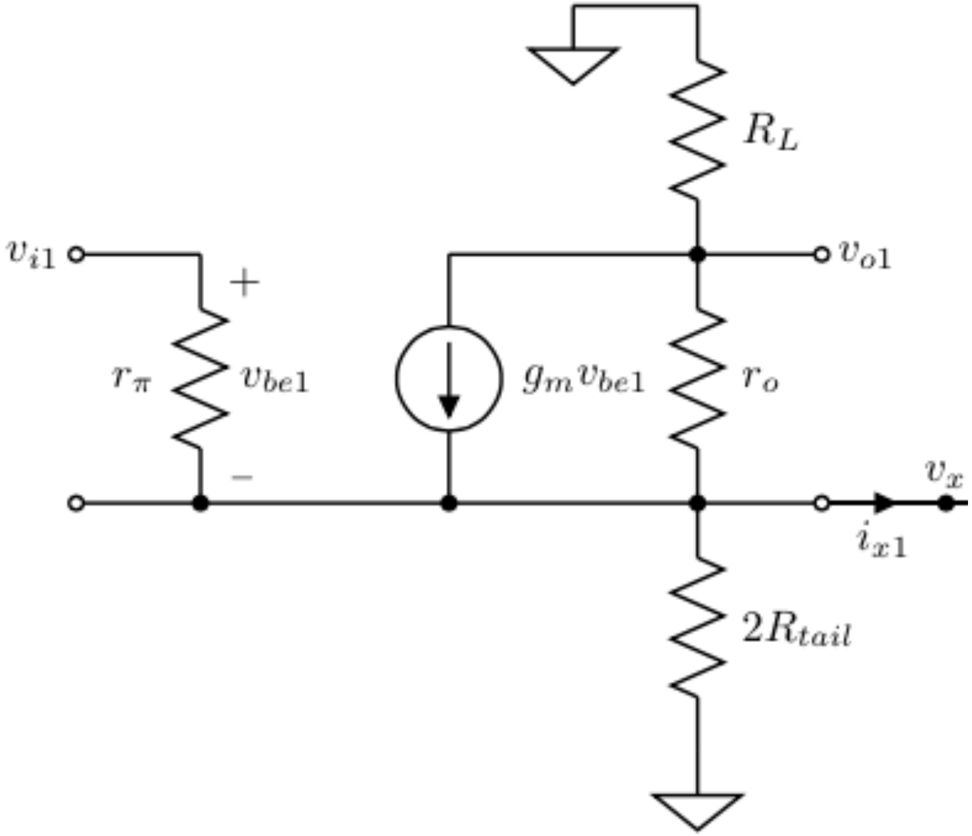
$$A_{dm} = \frac{+\frac{v_{od}}{2}}{+\frac{v_{id}}{2}} = \frac{v_{od}}{v_{id}} = -g_m \cdot (r_o \parallel R_L)$$

$$R_{id} = \frac{v_{id}}{i_{id}} = 2 \cdot r_\pi$$

$$R_{od} = \frac{v_{od}}{i_{od}} = 2 \cdot (r_o \parallel R_L)$$

$$G_{md} = \frac{i_{od}}{v_{id}} = \frac{g_m}{2}$$

The Common-Mode Half Circuit



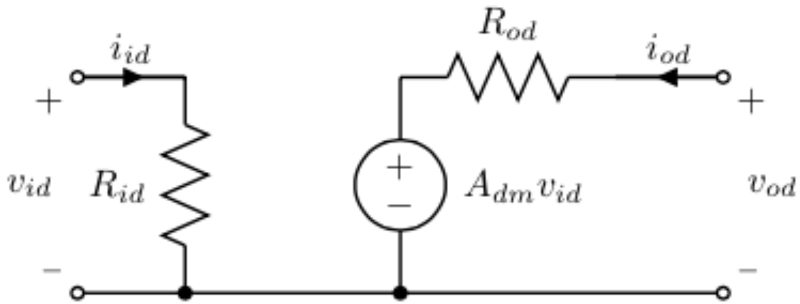
$$A_{cm} = \frac{v_{oc}}{v_{ic}} = -\frac{g_m R_L}{1 + 2 \cdot g_m R_{tail}}$$

$$R_{ic} = \frac{v_{ic}}{2i_{ic}} = \frac{r_\pi \left(1 + 2 \cdot g_m R_{tail}\right)}{2}$$

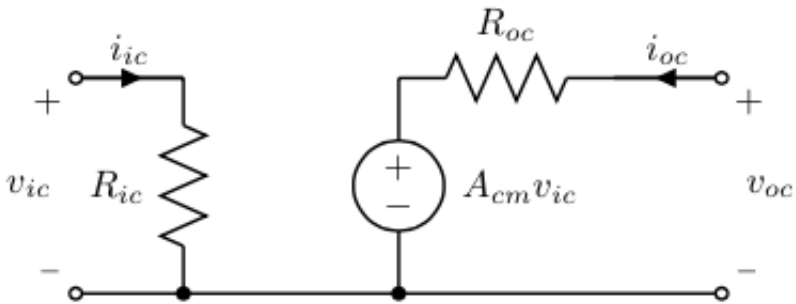
$$R_{oc} = \frac{v_{oc}}{2i_{oc}} = \frac{r_o \left(1 + 2 \cdot g_m R_{tail}\right) \parallel R_L}{2}$$

$$G_{mc} = \frac{2i_{oc}}{v_{ic}} = \frac{2g_m}{\left(1 + 2 \cdot g_m R_{tail}\right)}$$

Small-signal model of differential amplifier

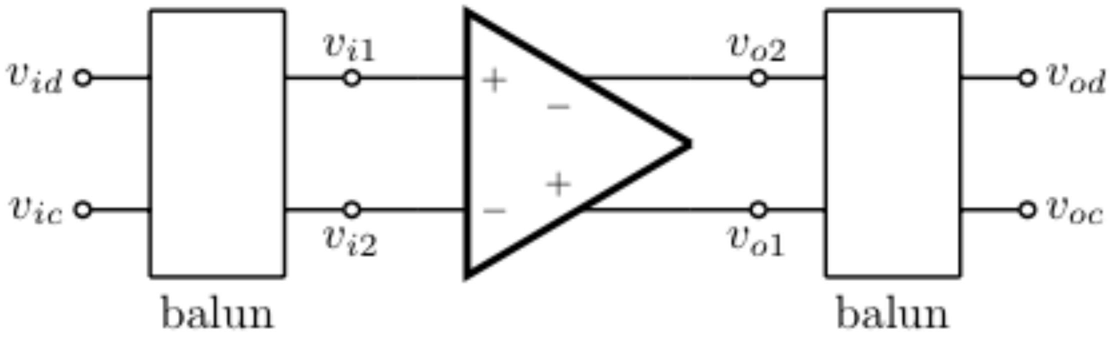


(a) Differential-mode

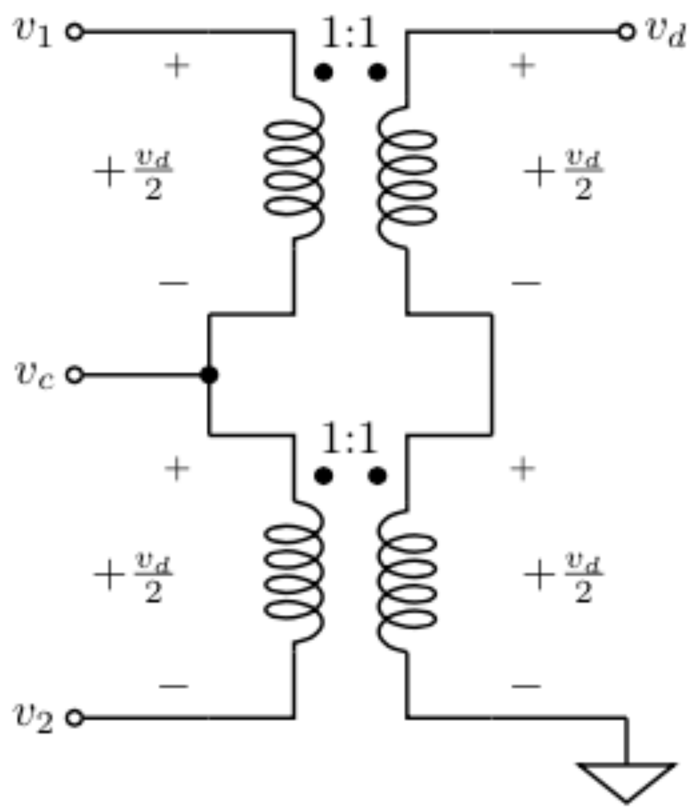


(b) Common-mode

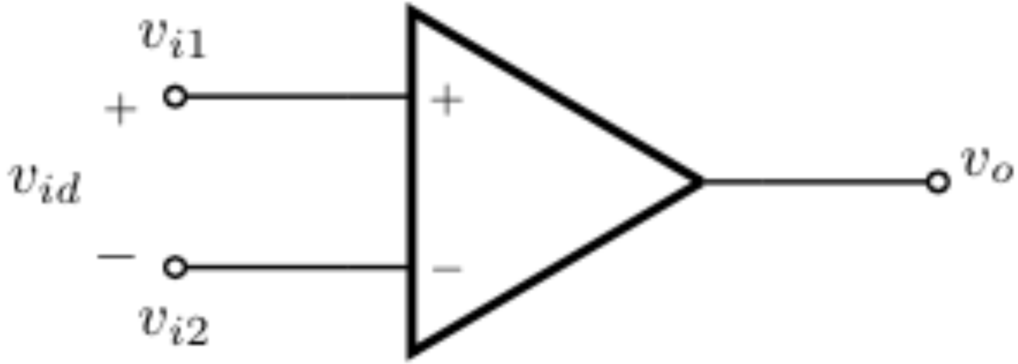
The Balun



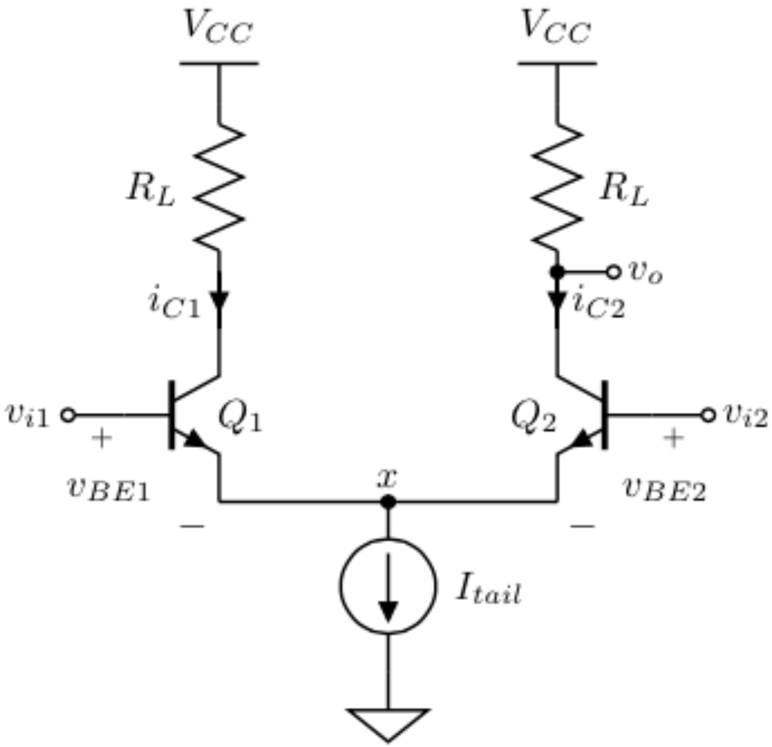
The Balun



Differential to Single-Ended Conversion



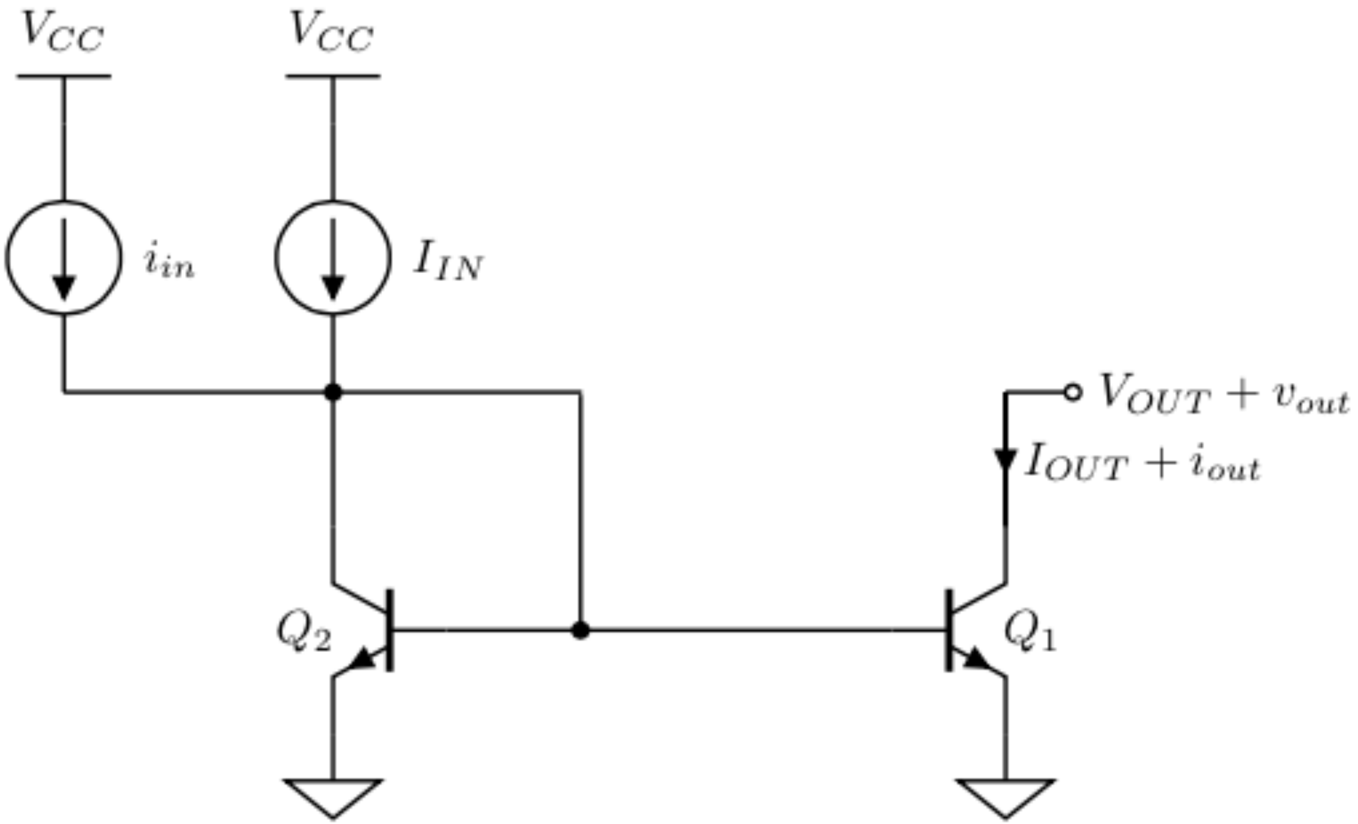
Differential to Single-Ended Conversion



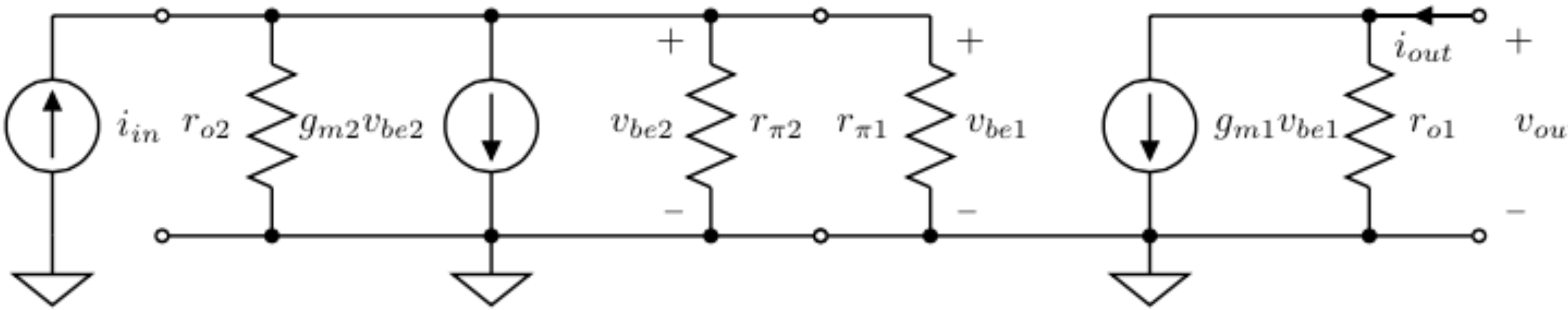
$$v_o = -g_m\left(r_o \parallel R_L\right)\cdot\left(-\frac{v_{id}}{2}\right)$$

$$A_v = \frac{v_o}{v_{id}} = \frac{g_m\left(r_o \parallel R_L\right)}{2}$$

The Current Mirror Revisited



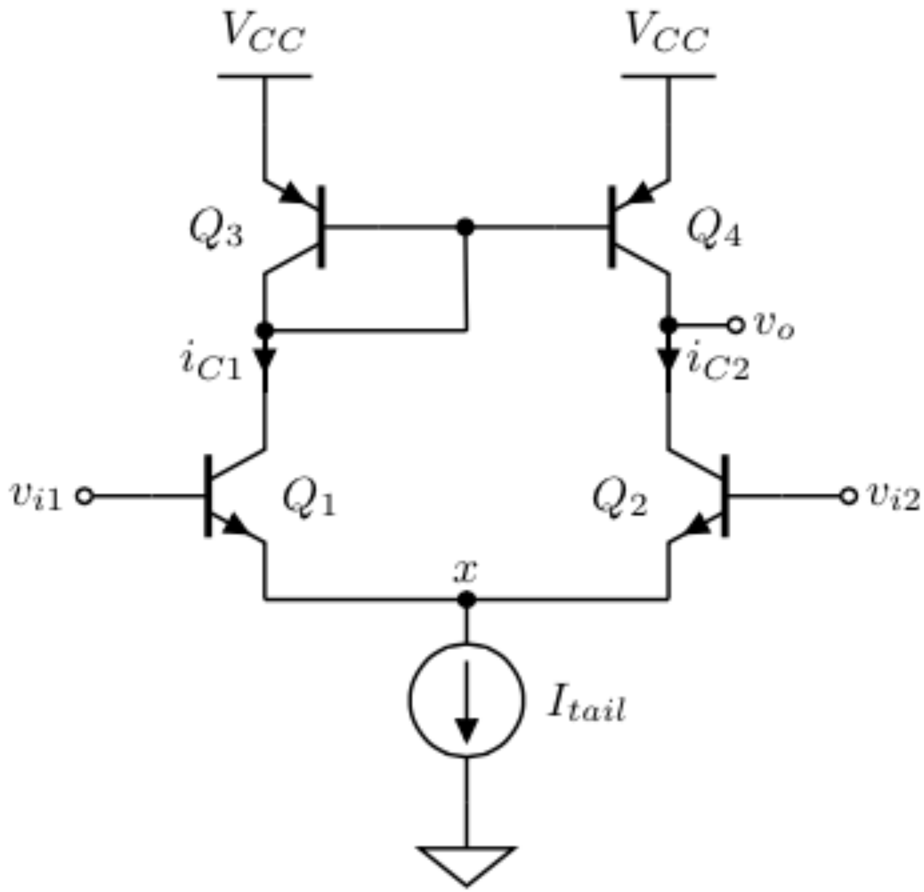
The Current Mirror Revisited



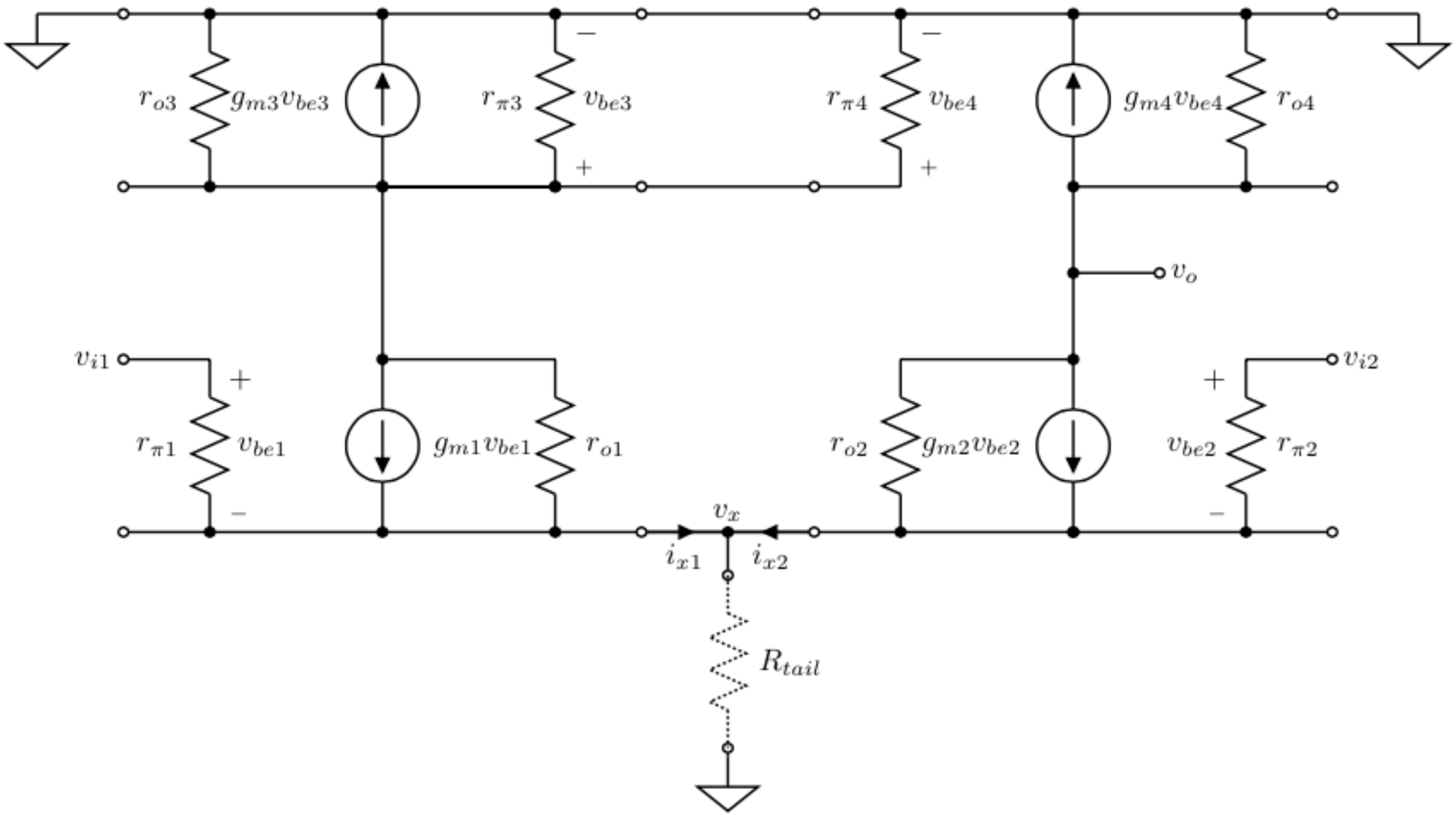
$$v_{be1} = v_{be_2} = i_{in} \cdot \left(\frac{1}{g_{m2}} \parallel r_{o2} \parallel r_{\pi 1} \parallel r_{\pi 2} \right) \approx \frac{i_{in}}{g_{m2}}$$

$$i_{out} \approx g_{m1} v_{be1} = \frac{g_{m1}}{g_{m2}} \cdot i_{in} \approx i_{in}$$

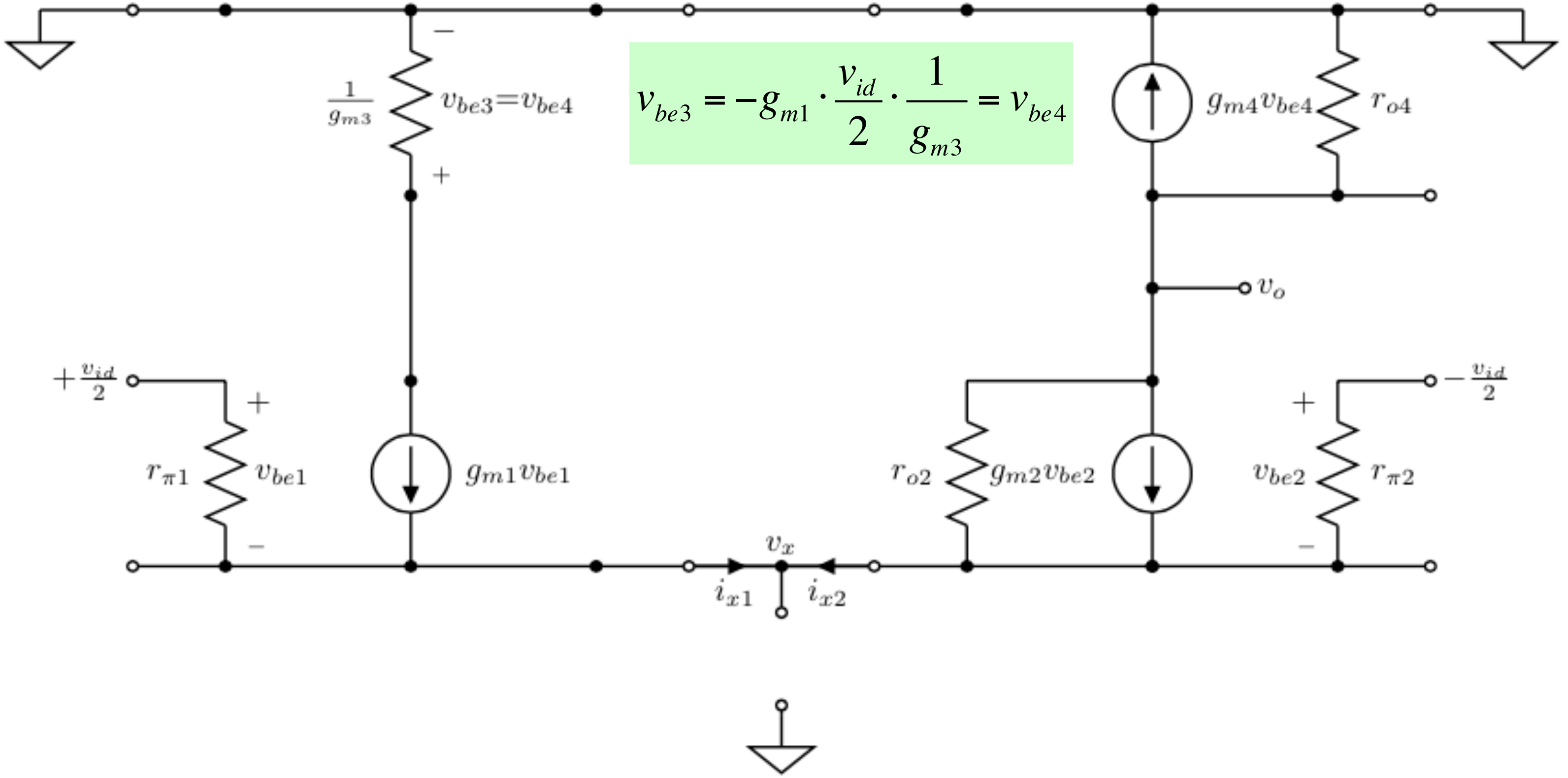
Current Mirror Loads



Current Mirror Loads



Current Mirror Loads



$$v_{be3} = -g_{m1} \cdot \frac{v_{id}}{2} \cdot \frac{1}{g_{m3}} = v_{be4}$$

at no load, $i_o = g_{m4} \cdot v_{be4} + g_{m2} \cdot v_{be2} = -g_{m4} \cdot g_{m1} \cdot \frac{v_{id}}{2} \cdot \frac{1}{g_{m3}} - g_{m2} \cdot \frac{v_{id}}{2}$

Current Mirror Loads

$$i_o = g_{m4} \cdot v_{be4} + g_{m2} \cdot v_{be2} = -g_{m4} \cdot g_{m1} \cdot \frac{v_{id}}{2} \cdot \frac{1}{g_{m3}} - g_{m2} \cdot \frac{v_{id}}{2}$$

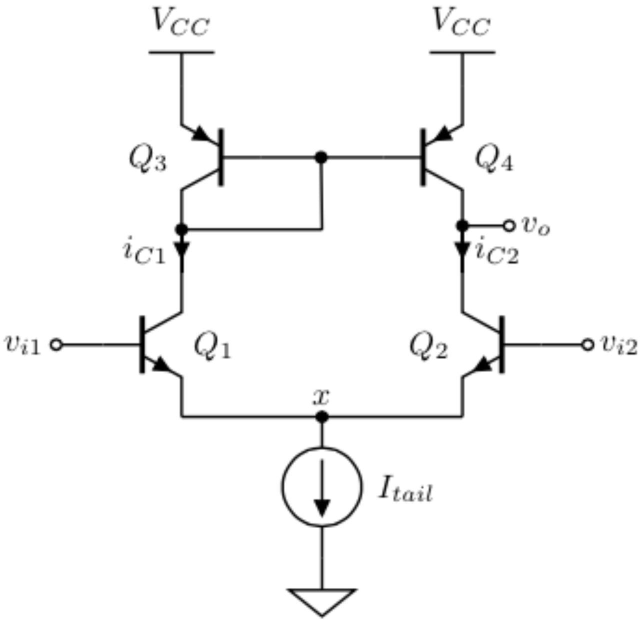
If $g_{m1} = g_{m2} = g_m$ and $g_{m3} = g_{m4}$,

$$i_o = -g_m \cdot v_{id}$$

$$G_m = -g_m$$

$$R_o = \left(r_{o2} \parallel r_{o4}\right)$$

$$A_v = \frac{v_o}{v_{id}} = -G_m R_o = g_{m2}\left(r_{o2} \parallel r_{o4}\right)$$



Next Meeting

- Compound Amplifiers