EEE 51: Second Semester 2017 - 2018

Lecture 11

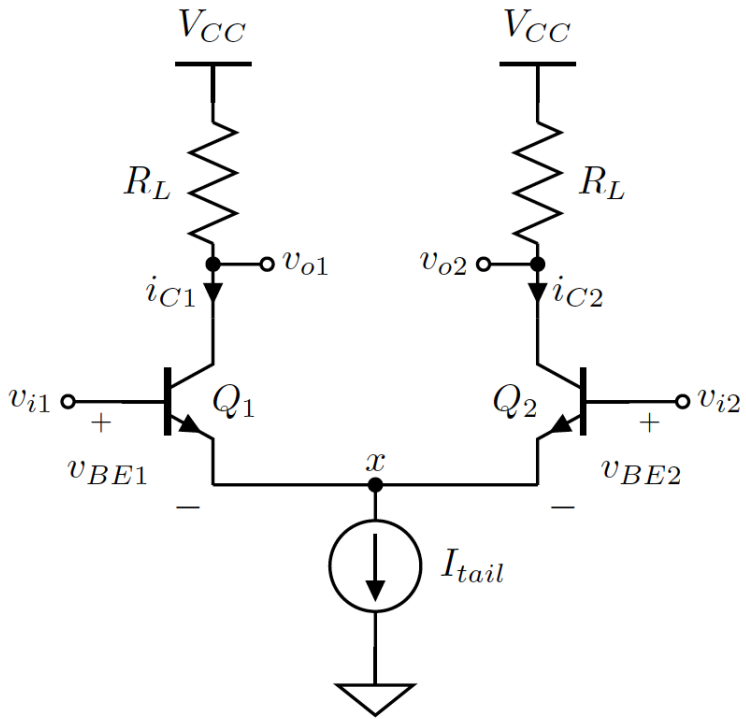
Differential Circuits

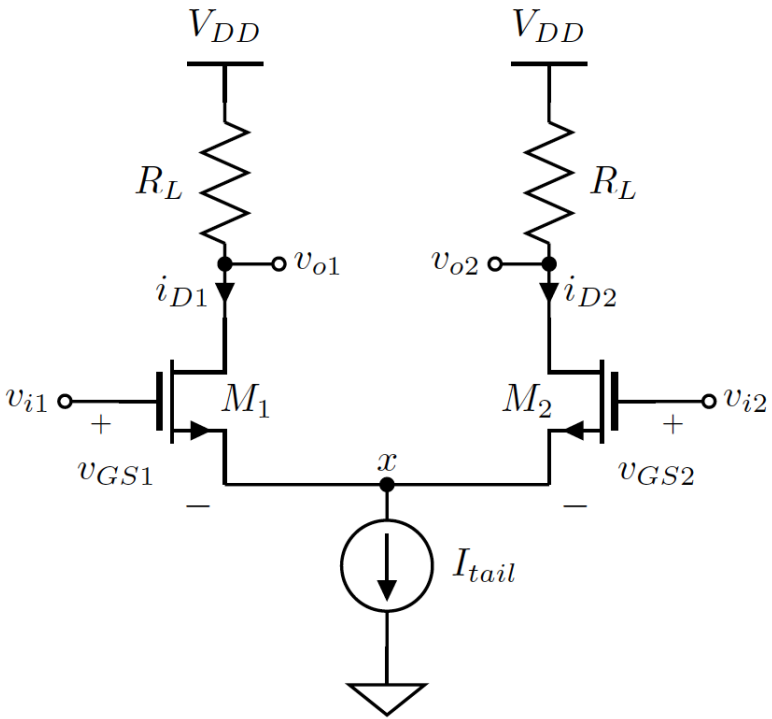
Today

- Small signal analysis of differential circuits

Differential Amplifiers

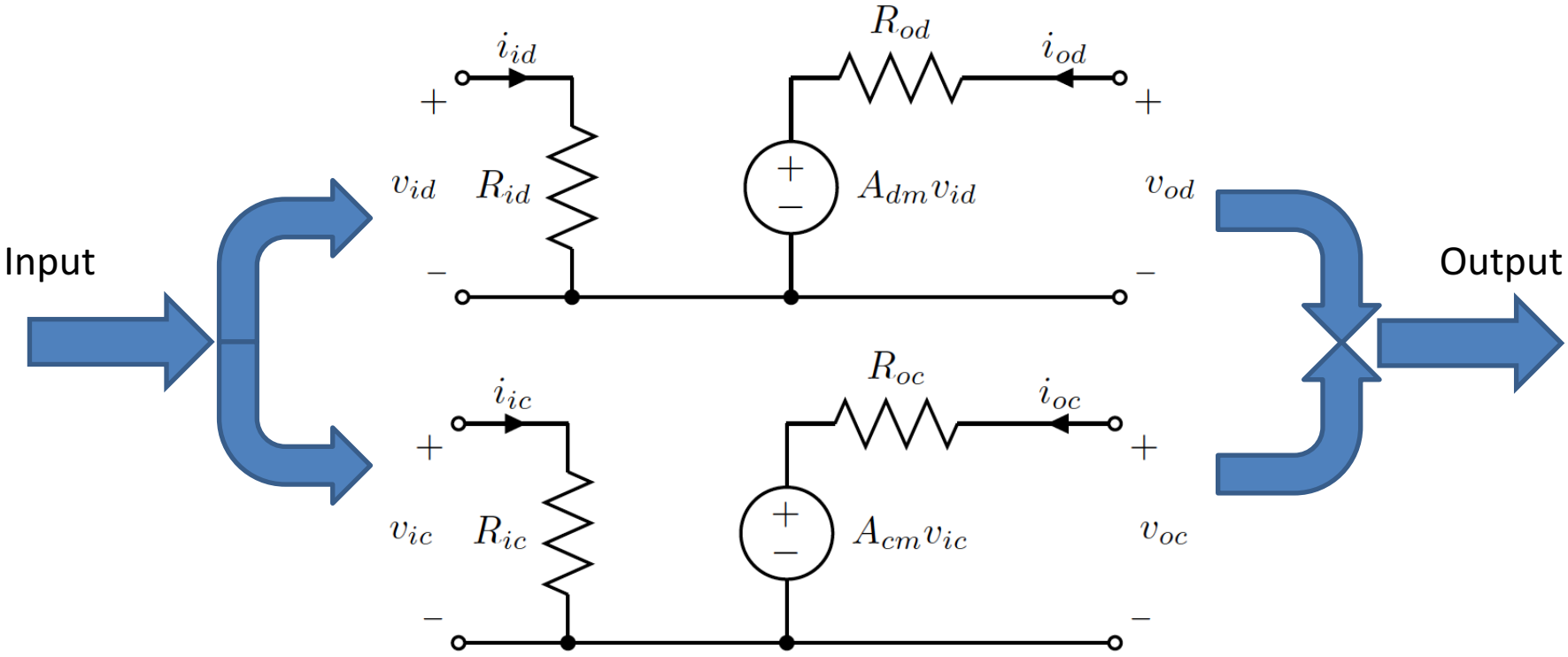
- After DC analysis → same small signal model



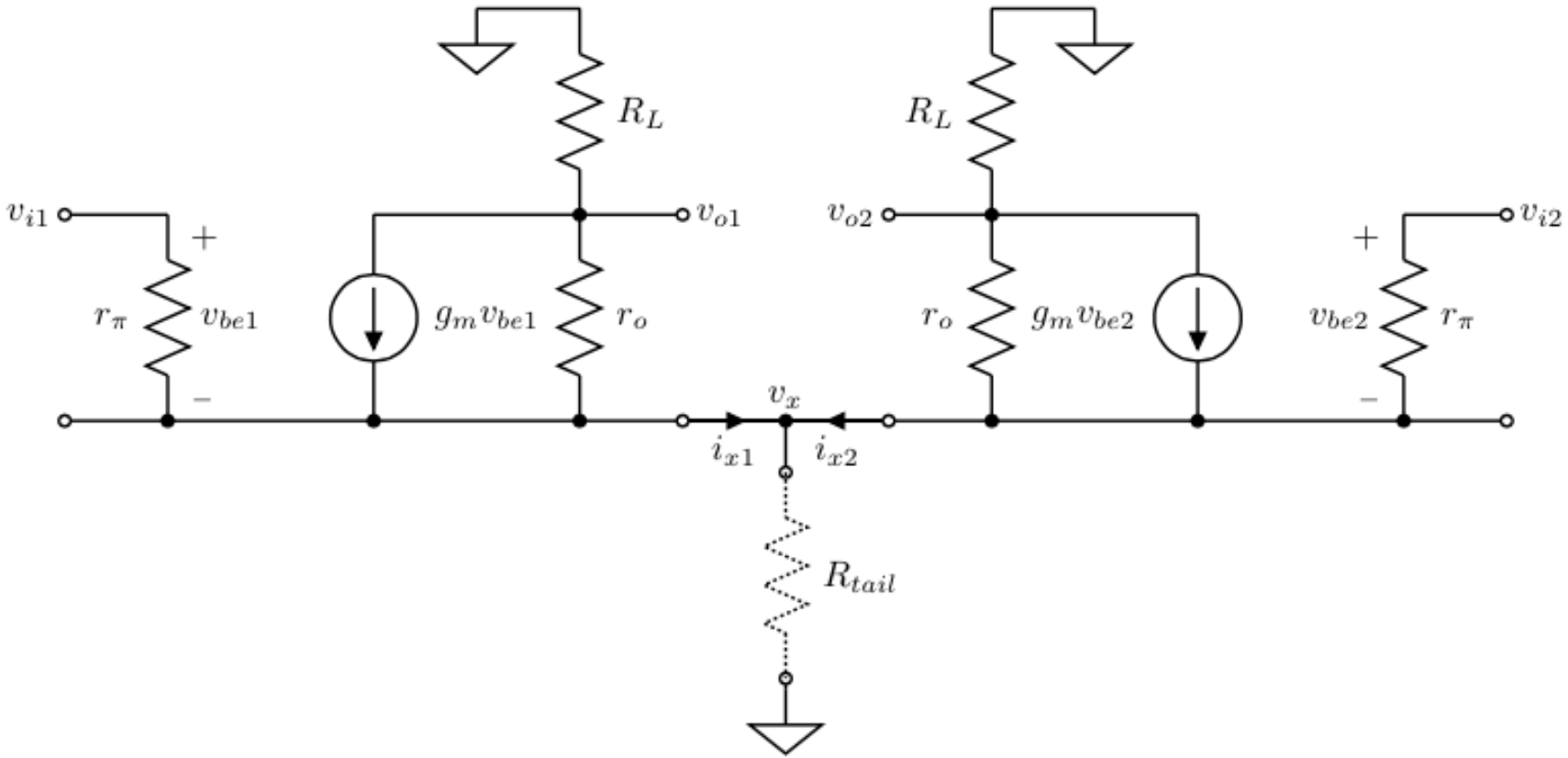


Differential vs. Common-Mode

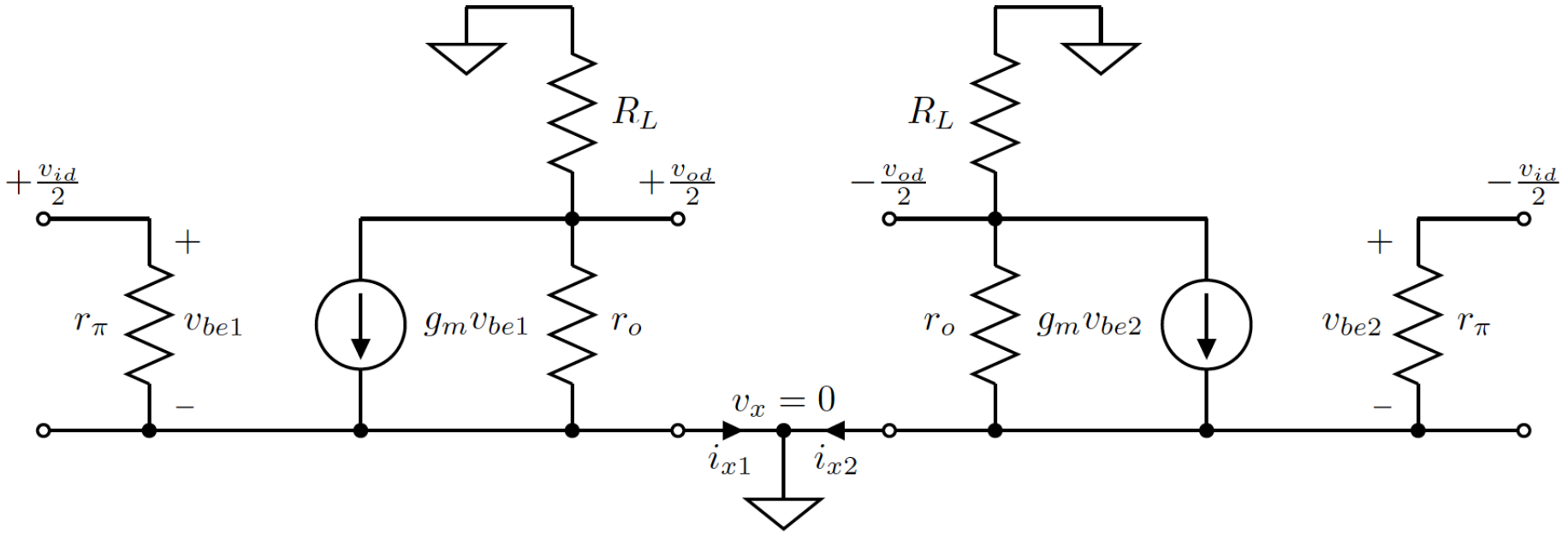
- The amplifier processes the two signals differently!



Small-signal equivalent circuit



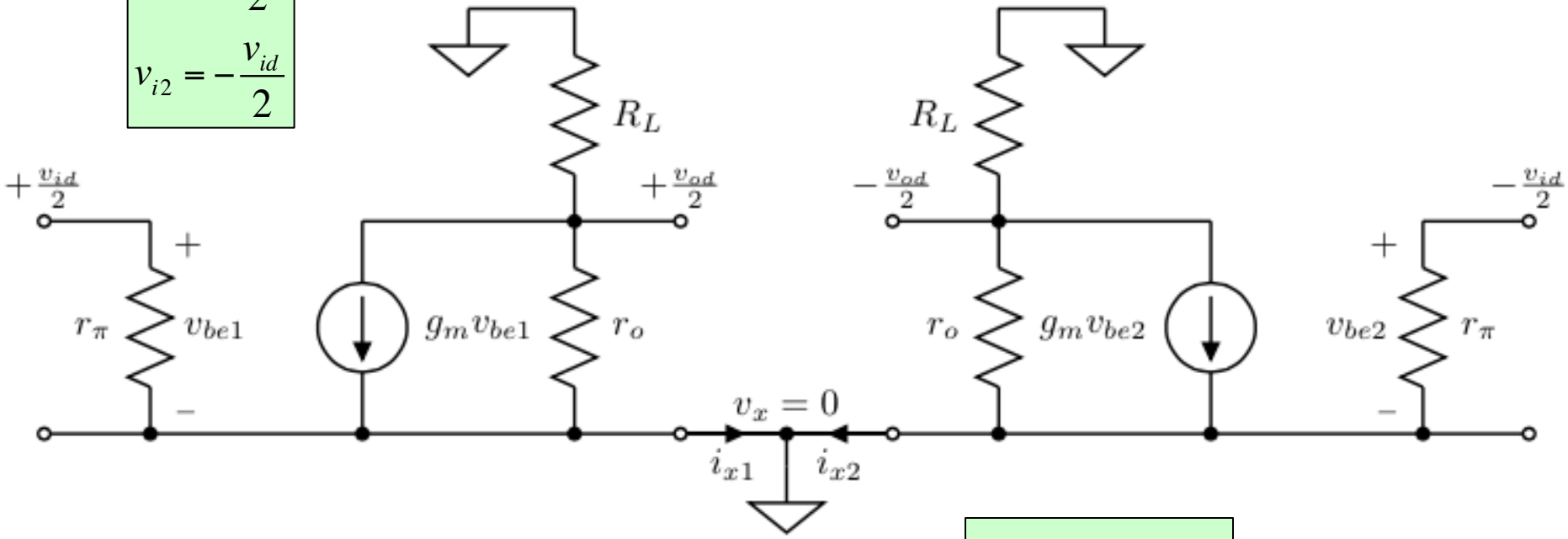
The Differential Mode Half Circuit



Half-circuit analysis (DM)

$$v_{i1} = +\frac{v_{id}}{2}$$

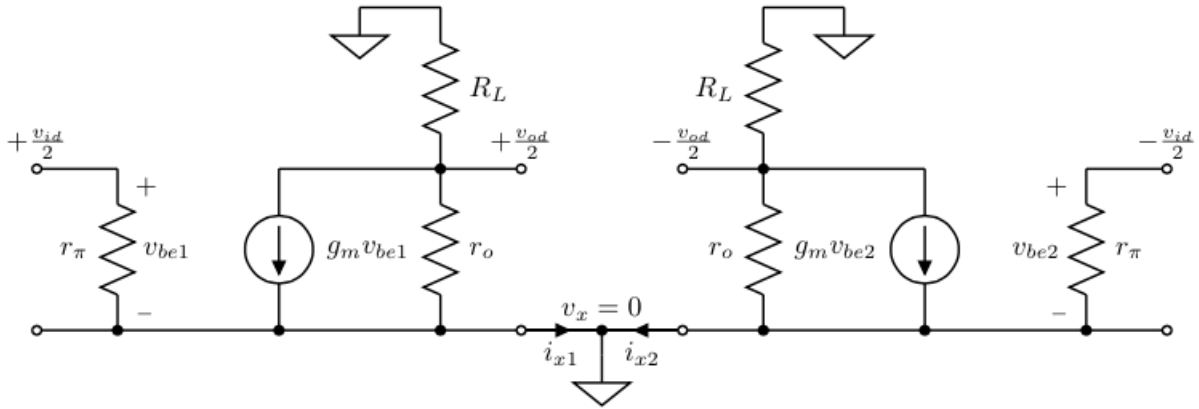
$$v_{i2} = -\frac{v_{id}}{2}$$



$$v_{id} = v_{i1} - v_{i2}$$

$$v_{ic} = \frac{v_{i1} + v_{i2}}{2} = 0$$

Half-circuit analysis (DM)

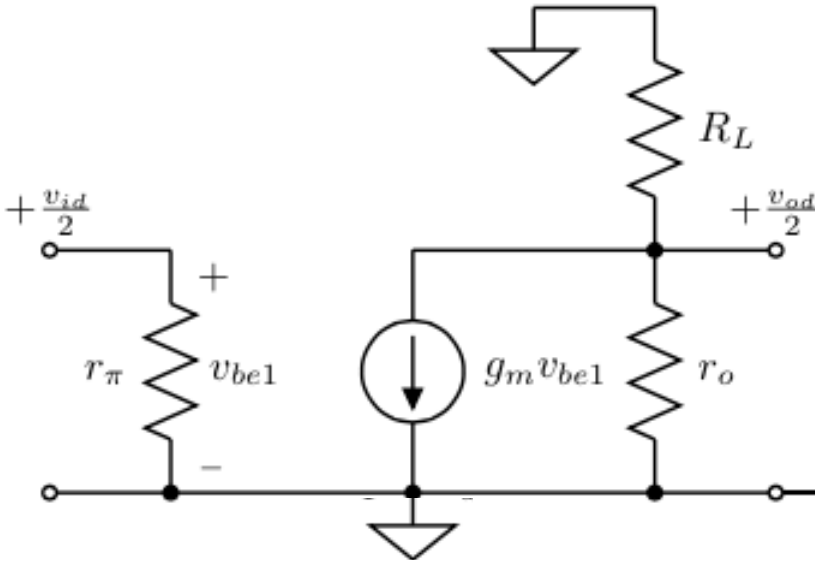


$$v_{i1} - v_{be1} + v_{be2} - v_{i2} = \left(+\frac{v_{id}}{2}\right) - v_{be1} + v_{be2} - \left(-\frac{v_{id}}{2}\right) = 0$$

$$v_{id} = v_{i1} - v_{i2} = v_{be1} - v_{be2}$$

$$i_{x1} = -i_{x2}$$

Half-circuit analysis (DM)

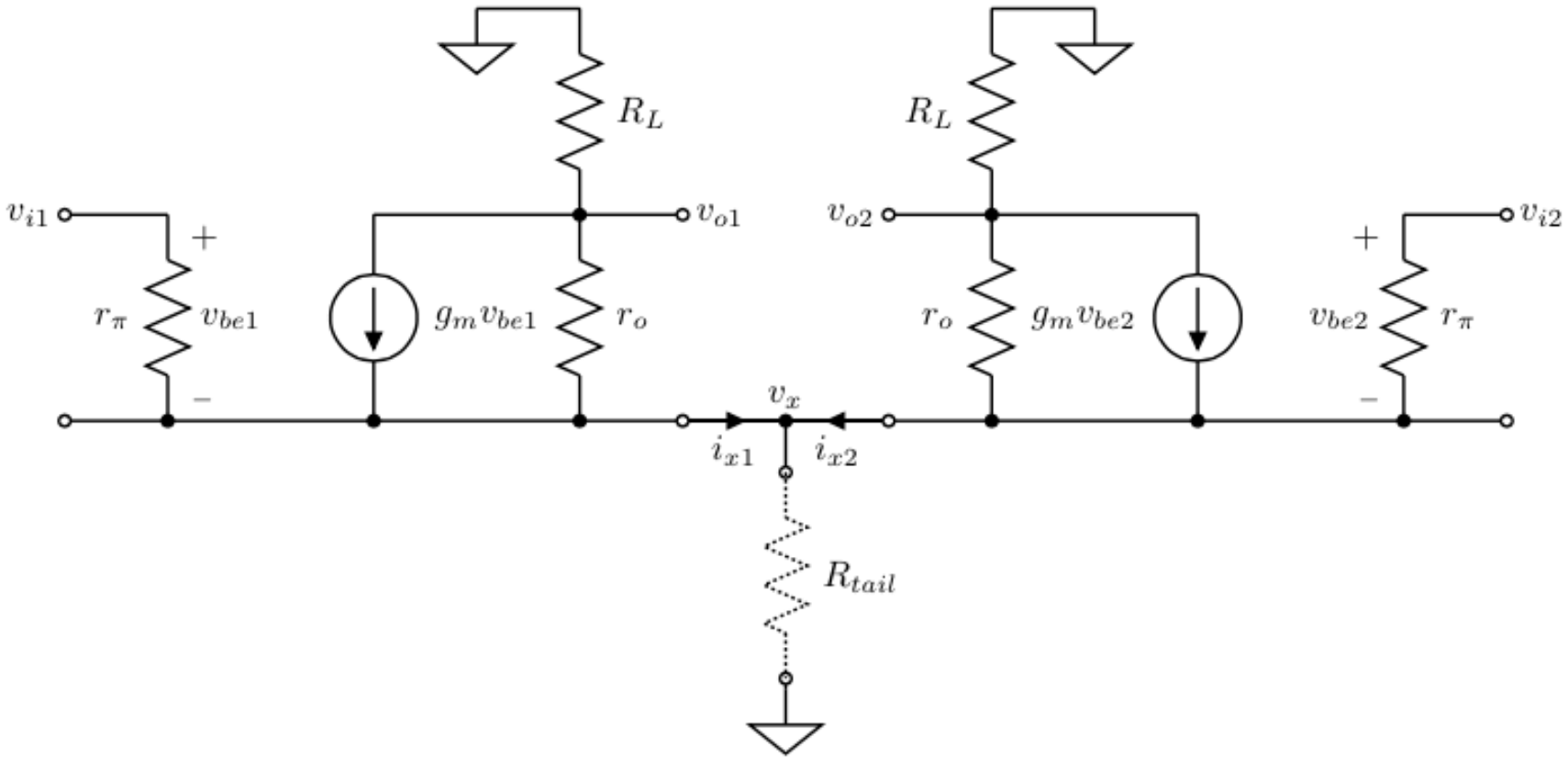


$$A_{dm} = \frac{+\frac{v_{od}}{2}}{+\frac{v_{id}}{2}} = \frac{v_{od}}{v_{id}} = -g_m \cdot (r_o \parallel R_L)$$

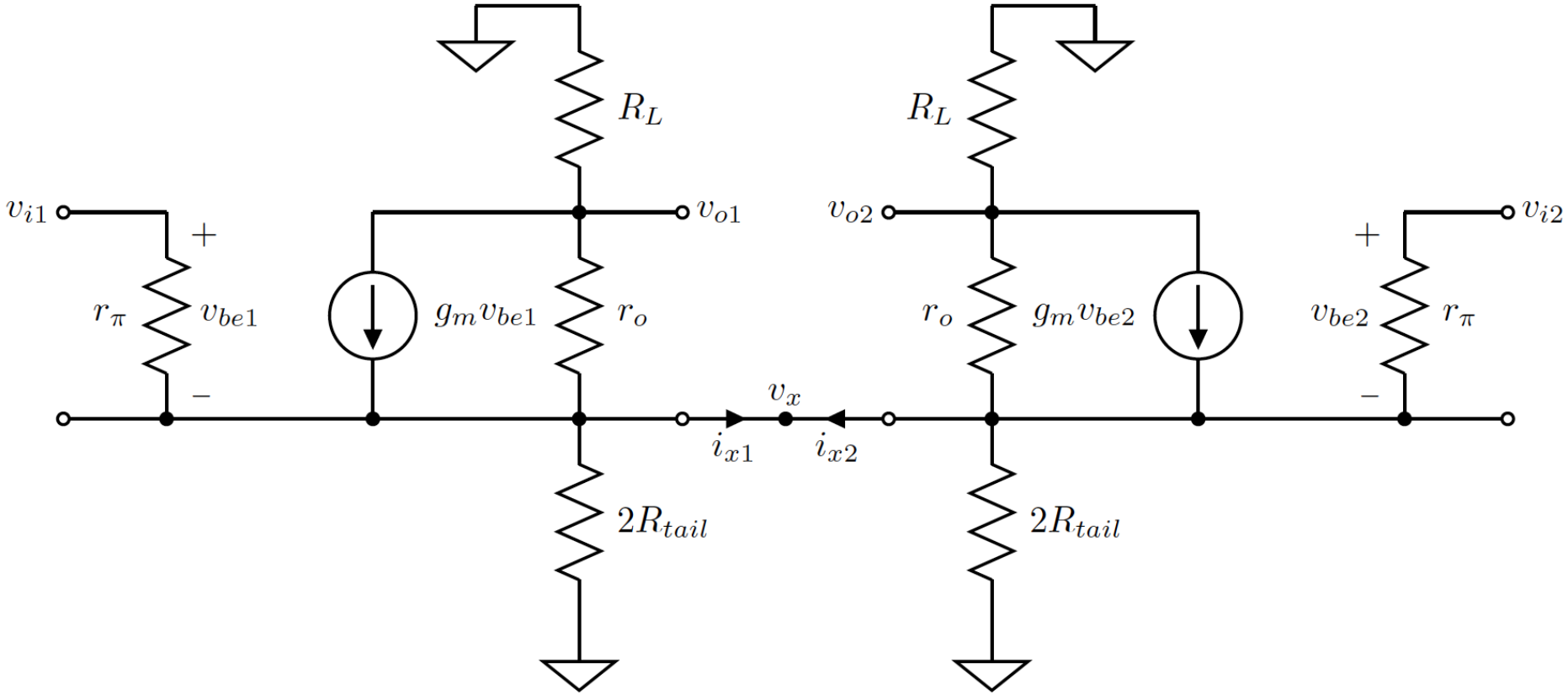
$$R_{id} = \frac{v_{id}}{i_{id}} = 2 \cdot r_\pi$$

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

Small-signal equivalent circuit



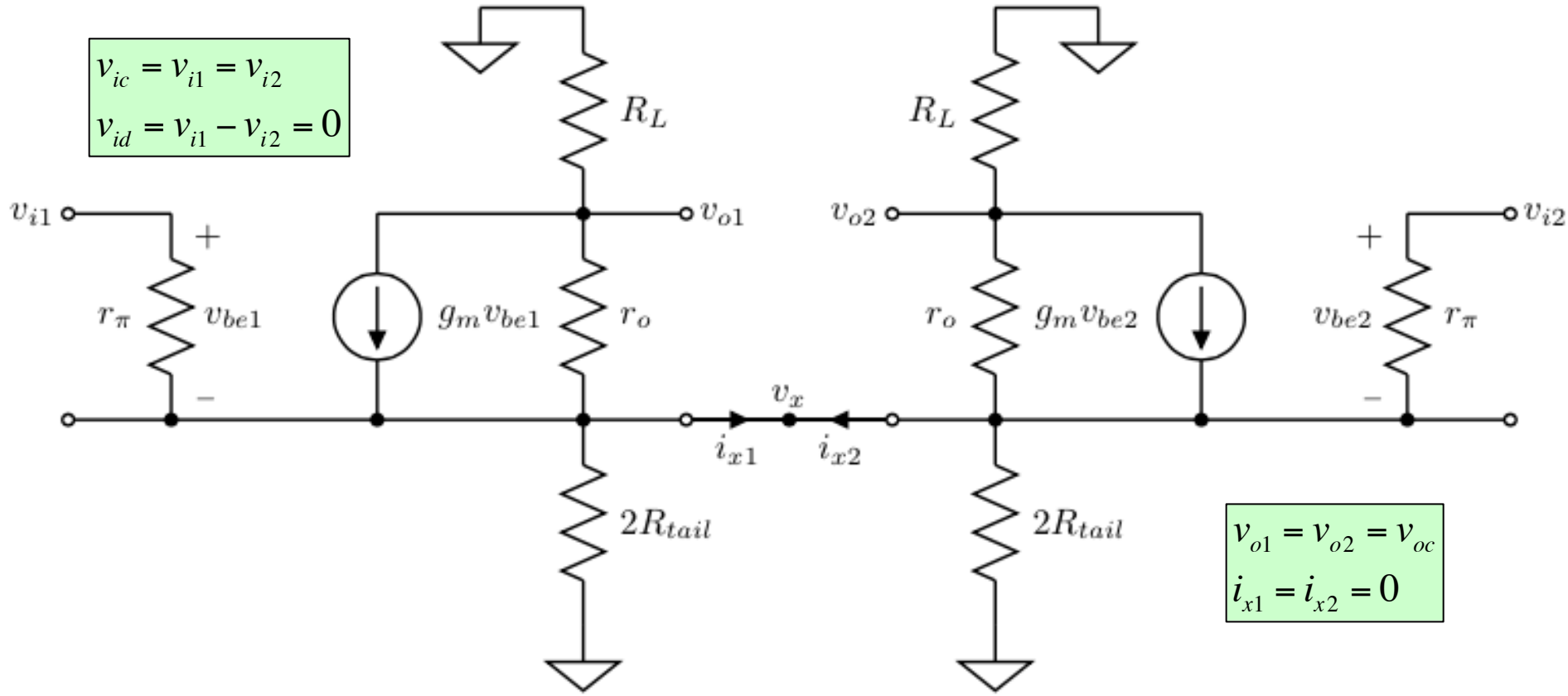
The Common-Mode Half Circuit



Half-circuit analysis (CM)

$v_{ic} = v_{i1} = v_{i2}$

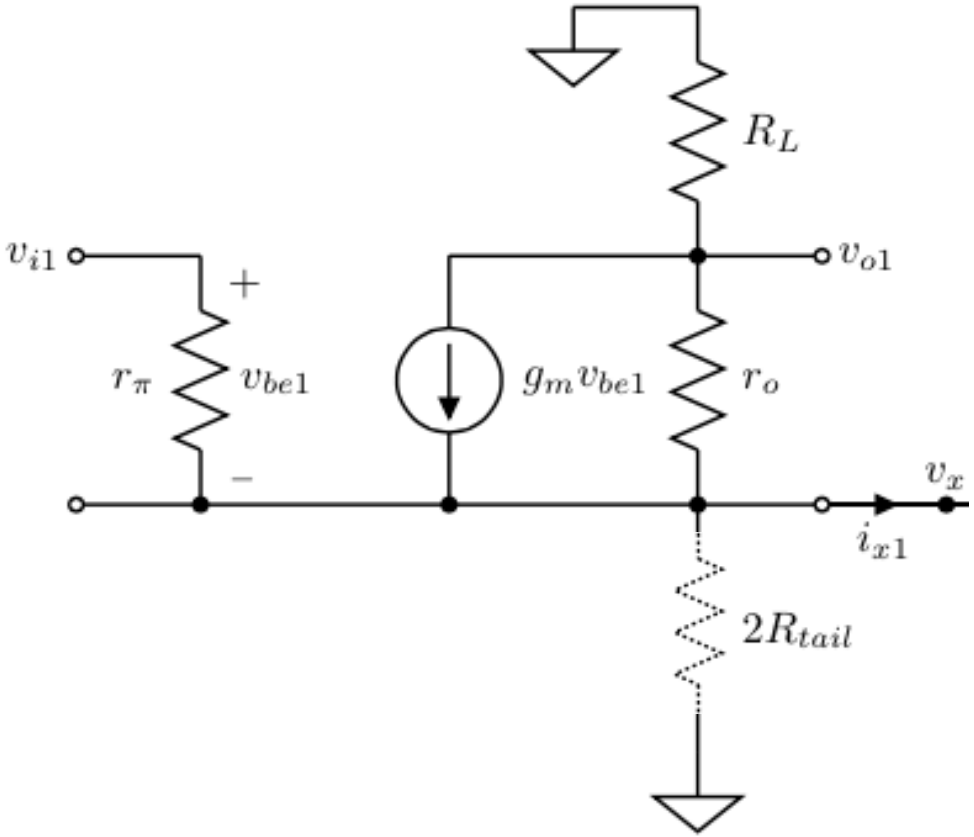
$v_{id} = v_{i1} - v_{i2} = 0$



$v_{o1} = v_{o2} = v_{oc}$

$i_{x1} = i_{x2} = 0$

Half-circuit analysis (CM)

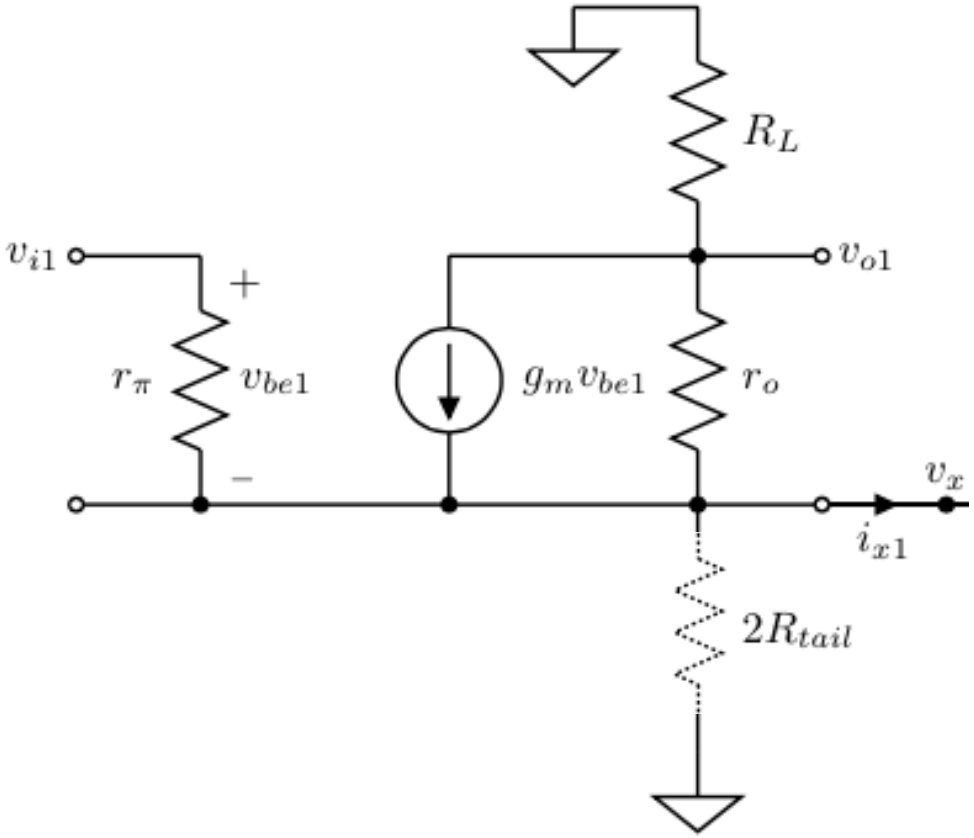


$$\frac{v_x - v_{ic}}{r_\pi} + \frac{v_x - v_{oc}}{r_o} - g_m\left(v_{ic} - v_x\right) = 0$$

$$\frac{v_{oc}}{R_L} = \frac{v_{ic} - v_x}{r_\pi}$$

$$v_{oc} = v_{ic} \cdot \frac{R_L}{R_L + r_o + r_\pi\left(1 + g_m r_o\right)}$$

Half-circuit analysis (CM)



$$A_{cm} = \frac{v_{oc}}{v_{ic}} = \frac{R_L}{R_L + r_o + r_\pi (1 + g_m r_o)}$$

$$A_{cm} \approx \frac{R_L}{r_\pi g_m r_o} \approx \frac{R_L}{\frac{\beta}{g_m} g_m r_o} \approx \frac{R_L}{\beta \cdot r_o} \approx 0$$

If current source is not ideal:

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

Next Meeting

- Finish up discussion of Differential Circuits
- Compound Amplifiers