AC Analysis of BJT and MOSFET Non-inverting Amplifiers

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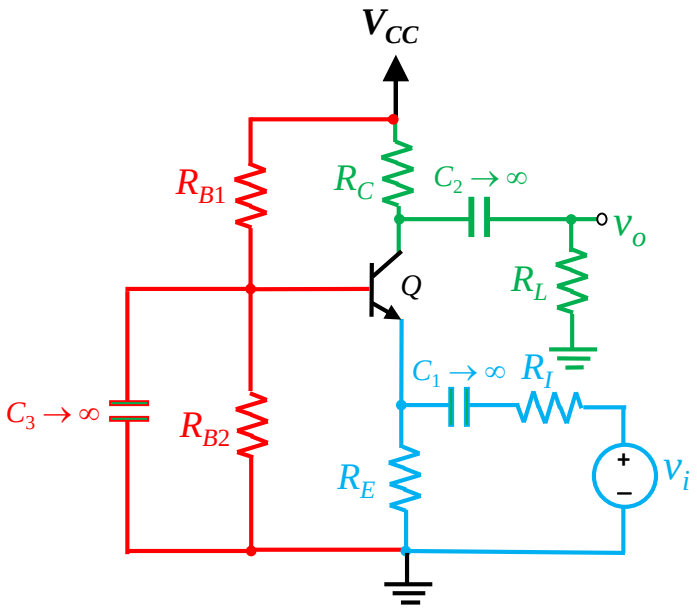
EE2002 Analog Electronics

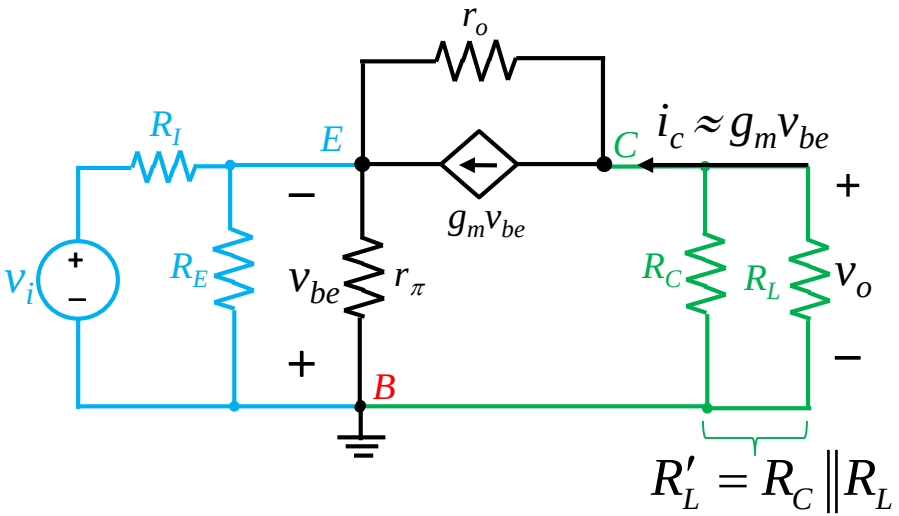
Lesson Objectives

At the end of this lesson, you should be able to:

- Recognise BJT and MOSFET non-inverting amplifiers
- Draw small-signal AC equivalent circuits of C-B and C-G amplifiers
- Calculate the following performance characteristics of C-B and C-G amplifiers
  - Voltage gain
  - Input resistance
  - Output resistance

C-B Amplifier (Non-inverting Amplifier): Terminal Voltage Gain

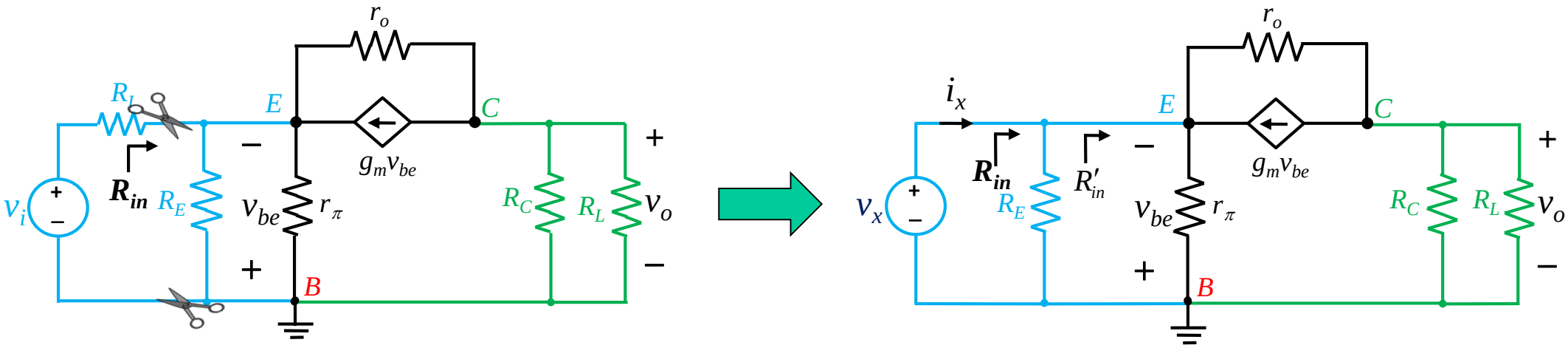




$$\because\ i_{r_o} \ll g_m v_{be}, i_c \approx g_m v_{be}$$

$$A_{vt} = \frac{v_c}{v_e} = \frac{-i_c R'_L}{-v_{be}} \approx \frac{-g_m v_{be} R'_L}{-v_{be}} = g_m R'_L$$

C-B Amplifier (Non-inverting Amplifier): Input Resistance



$$i_x = -\frac{v_{be}}{r_\pi} - g_m v_{be} + \frac{v_{ec}}{r_o}$$

This current is small because of large r_o

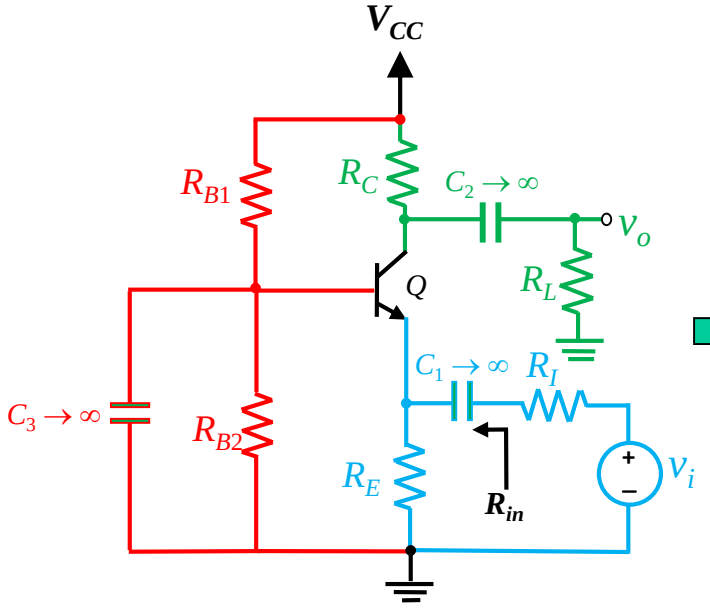
$$\because\ v_{be} = -v_x,\ i_x = \frac{v_x}{r_\pi} + g_m v_x$$

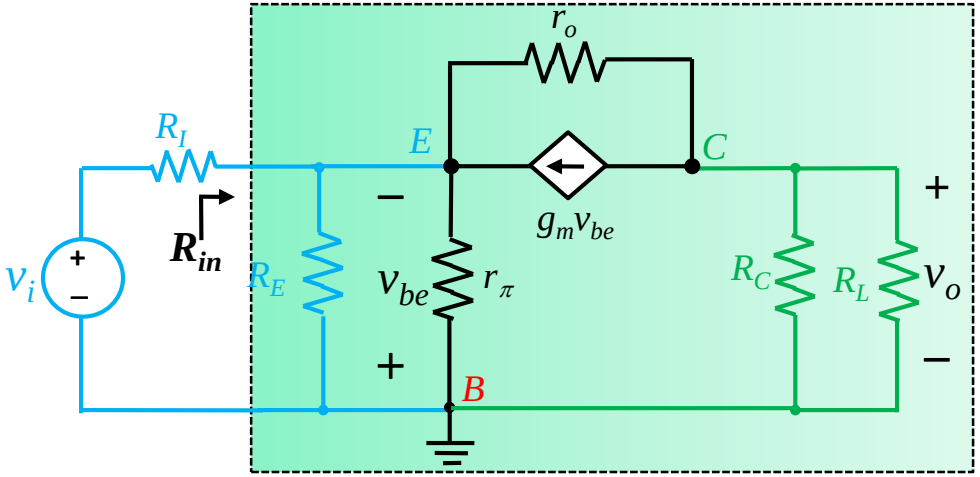
$$i_x = \left(\frac{1+g_m r_\pi}{r_\pi}\right) v_x = \left(\frac{1+\beta}{r_\pi}\right) v_x$$

$$R'_{in} = \frac{v_x}{i_x} = \left(\frac{r_\pi}{\beta+1}\right) \approx \frac{r_\pi}{\beta} = \frac{1}{g_m}$$

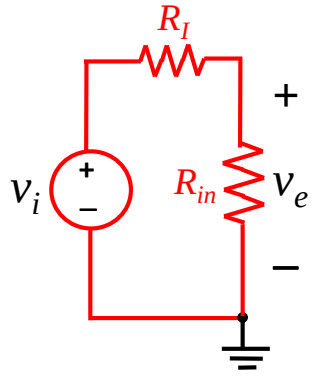
$$R_{in} = R'_{in} \| R_E$$

C-B Amplifier (Non-inverting Amplifier): Overall Voltage Gain

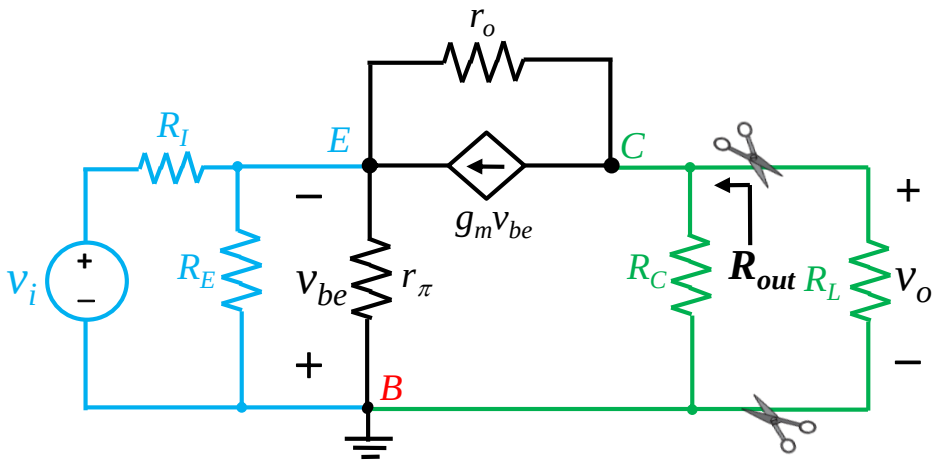


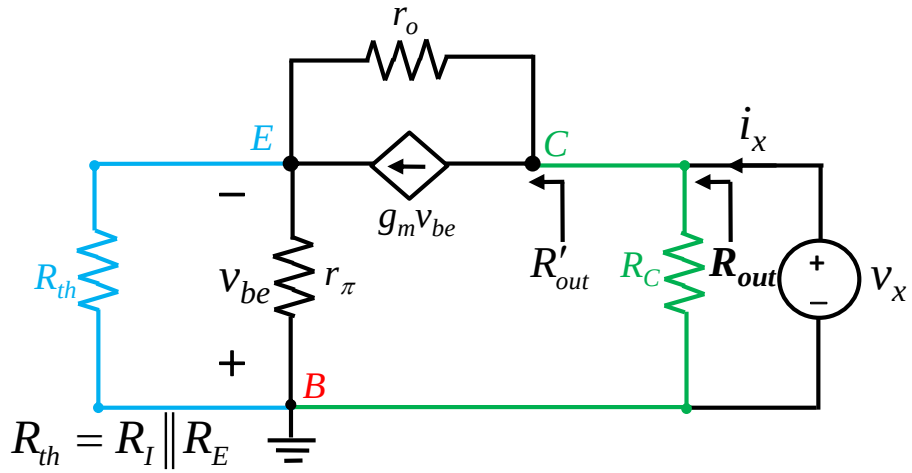


$$A_v = \frac{v_o}{v_i} = \frac{v_o}{v_e} \times \frac{v_e}{v_i} = A_{vt} \times \frac{R_{in}}{R_I + R_{in}}$$



C-B Amplifier (Non-inverting Amplifier): Output Resistance





$$v_x = \underbrace{\left(i_x - g_m v_{be}\right)}_{\text{current through } r_o} r_o + v_e$$

$$v_e = i_x \left(r_\pi \| R_{th}\right)$$

$$v_{be} = -v_e = -i_x \left(r_\pi \| R_{th}\right)$$

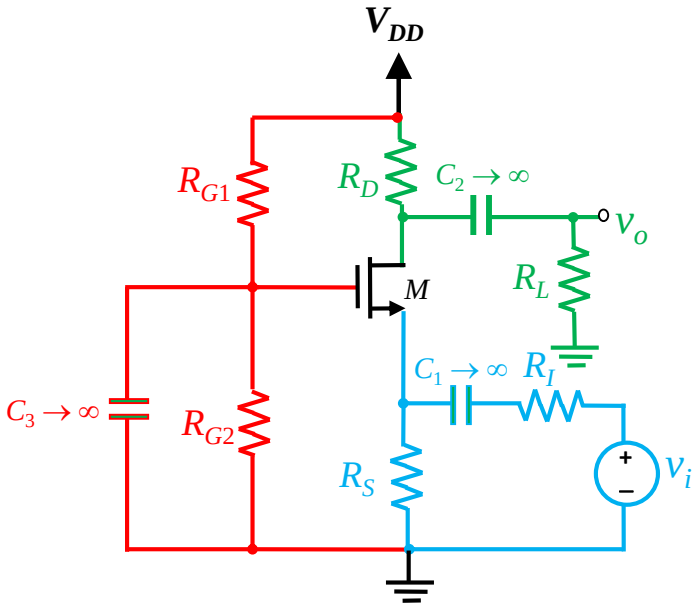
$$v_x = \left[i_x + g_m i_x \left(r_\pi \| R_{th}\right)\right] r_o + i_x \left(r_\pi \| R_{th}\right)$$

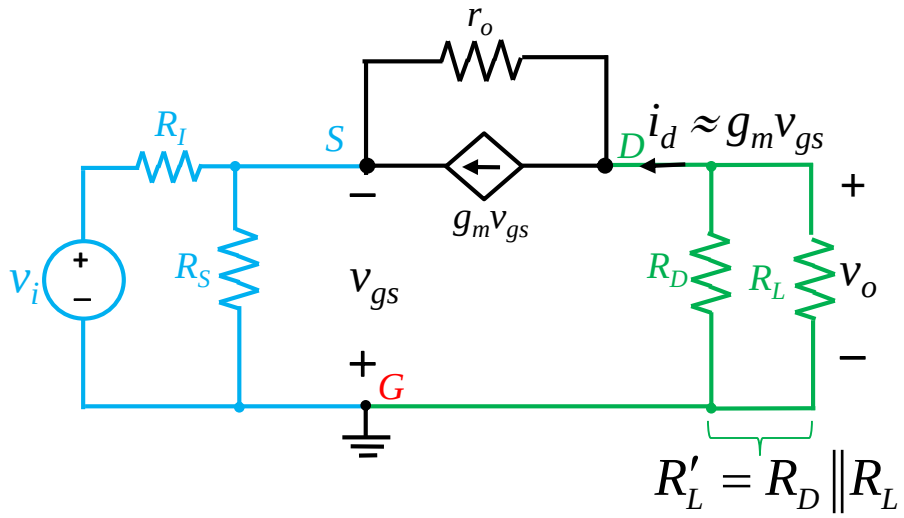
$$R'_{out} = \frac{v_x}{i_x} = \left[1 + g_m \left(r_\pi \| R_{th}\right)\right] r_o + r_\pi \| R_{th}$$

$$\approx \left[1 + g_m \left(r_\pi \| R_{th}\right)\right] r_o$$

$$R_{out} = R'_{out} \| R_C$$

C-G Amplifier (Non-inverting Amplifier): Terminal Voltage Gain



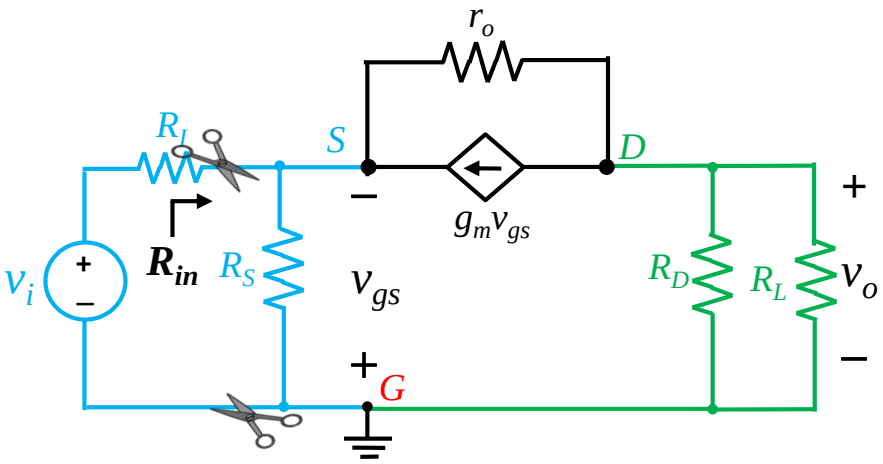


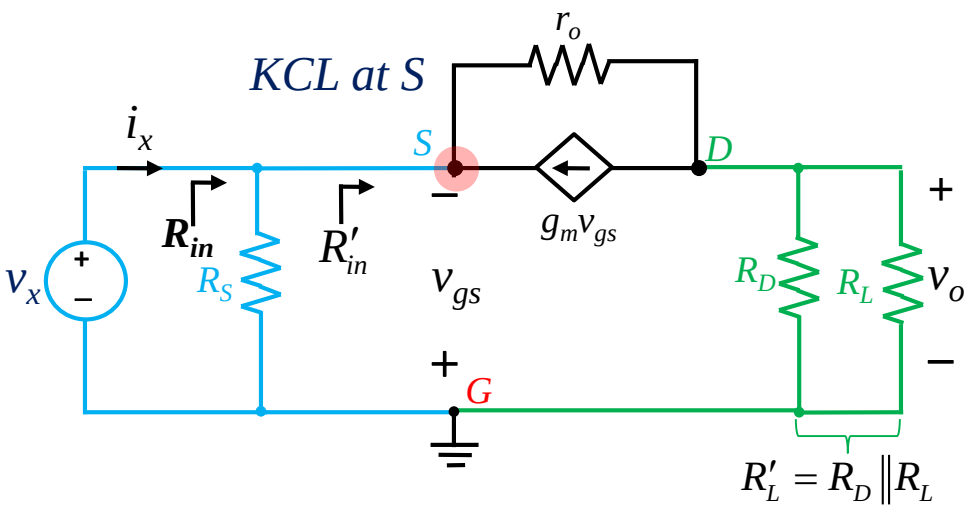
$$\because\ i_{r_o} \ll g_m v_{gs}, i_d \approx g_m v_{gs}$$

$$v_s = -v_{gs}$$

$$A_{vt} = \frac{v_d}{v_s} = \frac{-i_d R'_L}{-v_{gs}} \approx \frac{-g_m v_{gs} R'_L}{-v_{gs}} = g_m R'_L$$

C-G Amplifier (Non-inverting Amplifier): Input Resistance





$$i_x = -g_m v_{gs} + \frac{v_{sd}}{r_o}$$

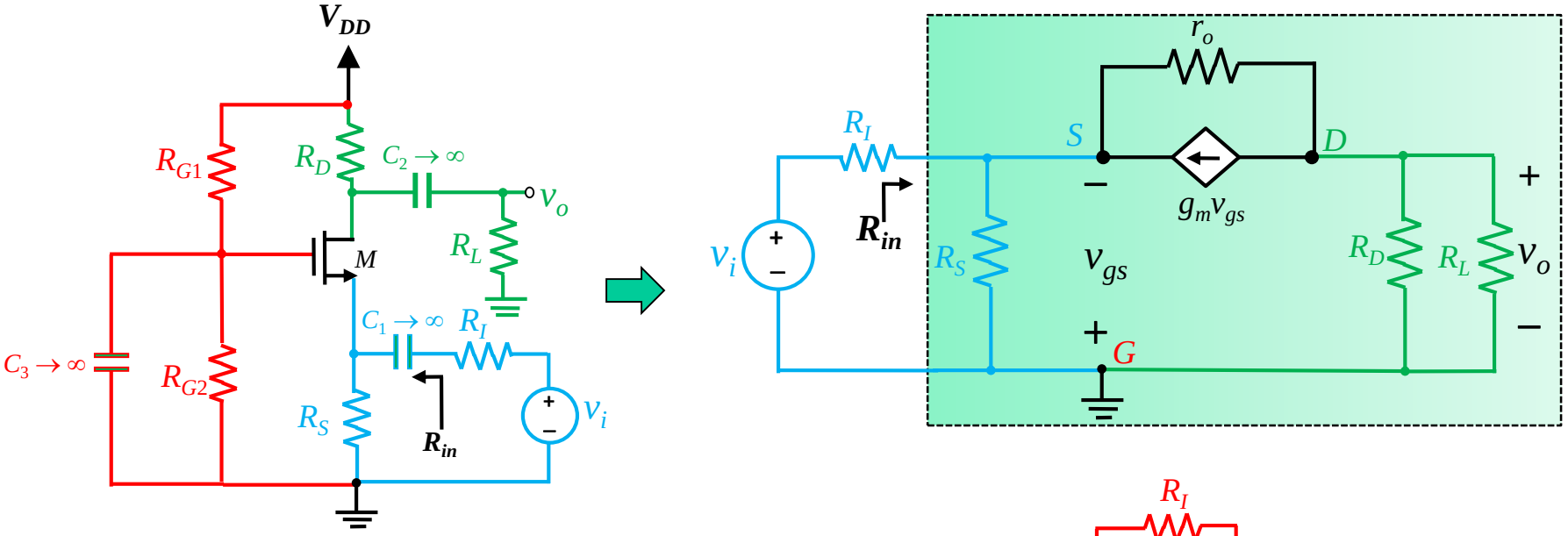
This current can be ignored due to large r_o

$$\because\ v_{gs} = -v_x,\ i_x \approx g_m v_x$$

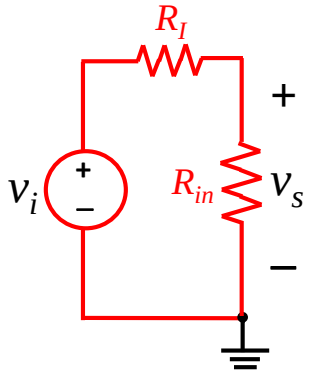
$$R'_{in} = \frac{v_x}{i_x} \approx \frac{1}{g_m}$$

$$R_{in} = R'_{in} \| R_S$$

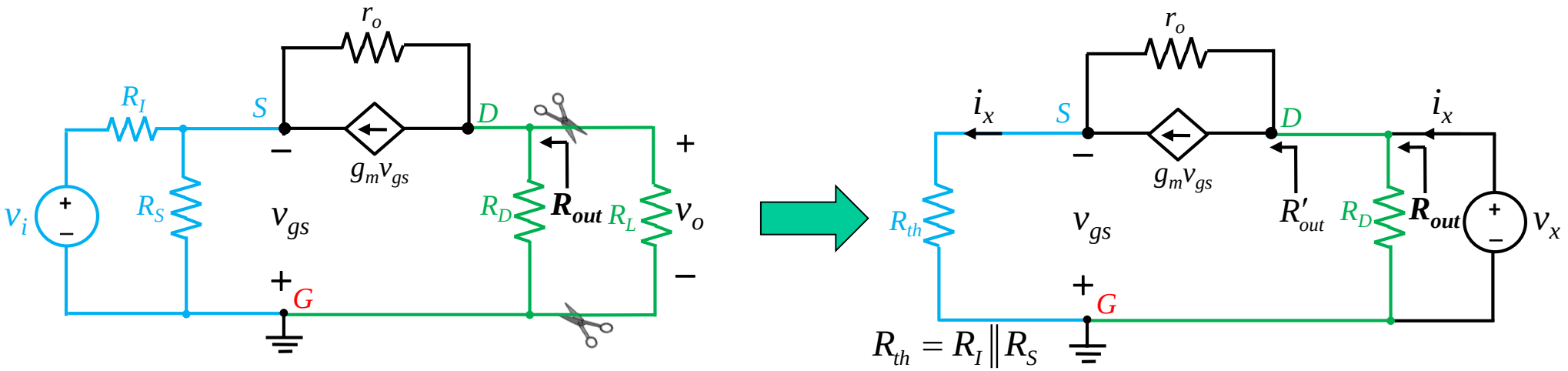
C-G Amplifier (Non-inverting Amplifier): Overall Voltage Gain



$$A_v = \frac{v_o}{v_i} = \frac{v_o}{v_s} \times \frac{v_s}{v_i} = A_{vt} \times \frac{R_{in}}{R_I + R_{in}}$$



C-G Amplifier (Non-inverting Amplifier): Output Resistance



$$v_x = \left(i_x - g_m v_{gs}\right) r_o + v_s$$

$$v_s = i_x R_{th}$$

$$v_{gs} = -v_s = -i_x R_{th}$$

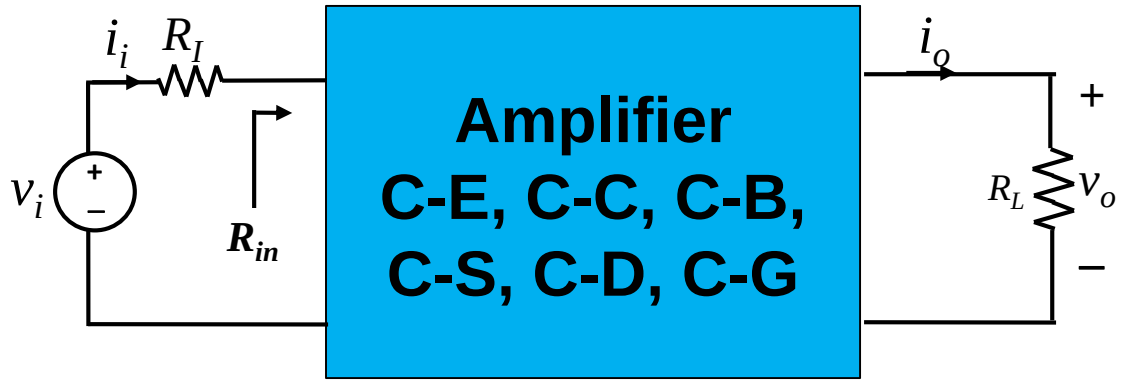
$$v_x = \left(i_x + g_m i_x R_{th}\right) r_o + i_x R_{th}$$

$$R'_{out} = \frac{v_x}{i_x} = \left(1 + g_m R_{th}\right) r_o + R_{th}$$

$$\approx \left(1 + g_m R_{th}\right) r_o$$

$$R_{out} = R'_{out} \| R_D$$

Current Gain



$$A_i = \frac{i_o}{i_i} = \frac{\frac{v_o}{R_L}}{\frac{v_i}{R_I + R_{in}}} = \frac{v_o}{v_i} \times \frac{R_I + R_{in}}{R_L} = A_v \times \frac{R_I + R_{in}}{R_L}$$