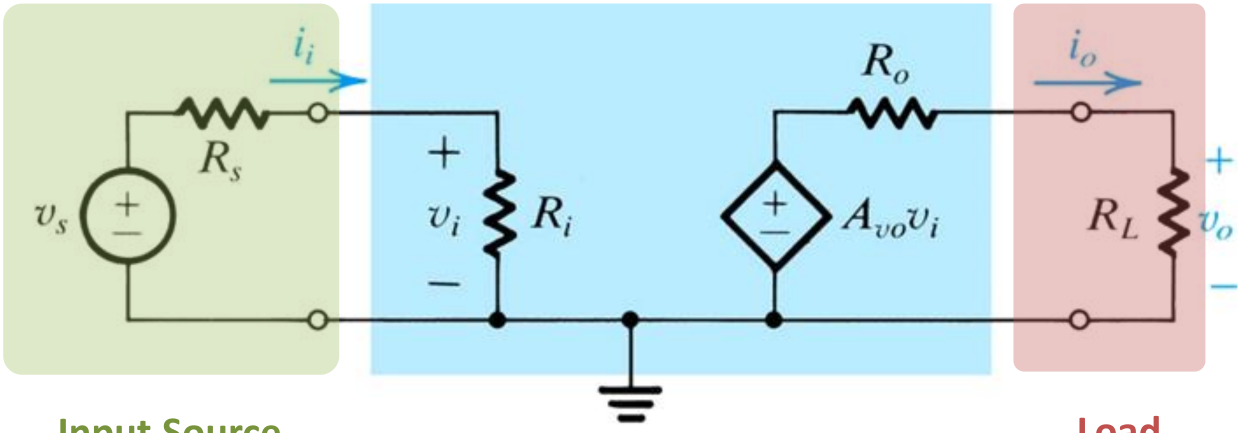
Last Lecture → Amplifier Circuit Model

… is the description of the amplifier's terminal behavior, neglecting internal operation / transistor design

$$v_o = \underbrace{A_{vo} v_s \overset{\text{Amp. Loading}}{\frac{R_i}{R_i + R_s}} \overset{\text{Loading}}{\frac{R_L}{R_L + R_o}}}_{\text{non-ideal model}} = \underbrace{A_{vo} v_s}_{\text{ideal model}}$$

Amplifier Circuit Model



Input Source

Load

Ideal Assumptions…

- $R_i = \infty$ or $R_i >> R_s$
- $R_o = 0$ or $R_o << R_L$

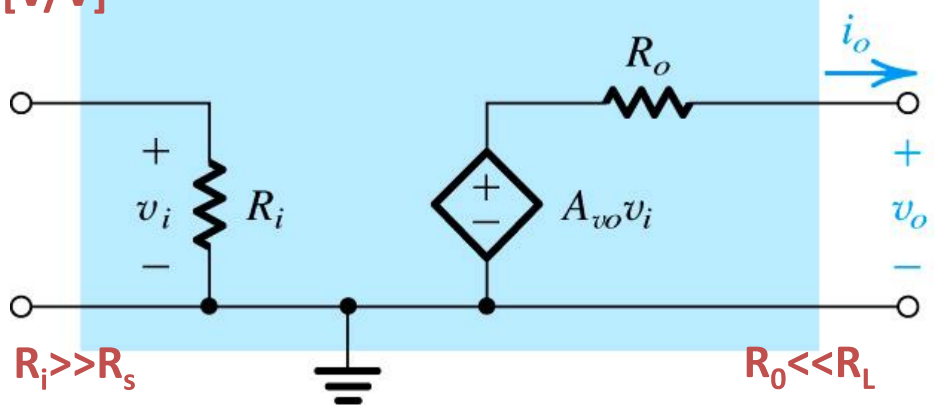
Last Lecture → Types of Amplifiers

Voltage Amplifier

Gain → A_v [V/V]

$R_i = \propto$

$R_0 = 0$



$R_i >> R_s$

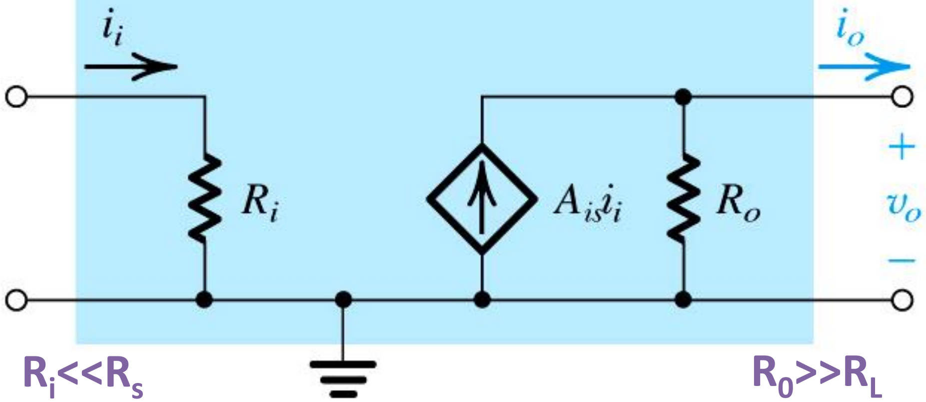
$R_0 << R_L$

Current Amplifier

Gain → A_i [A/A]

$R_i = 0$

$R_0 = \propto$



$R_i << R_s$

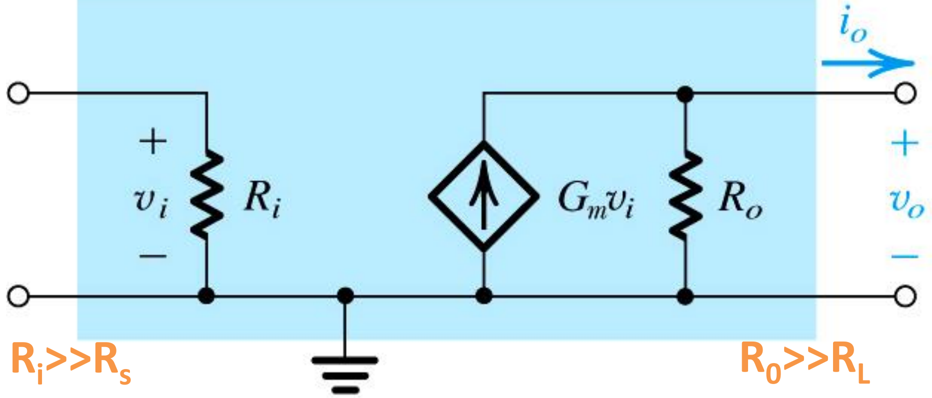
$R_0 >> R_L$

Trans-conductance Amplifier

Gain → A_v [A/V]

$R_i = \propto$

$R_0 = \propto$



$R_i >> R_s$

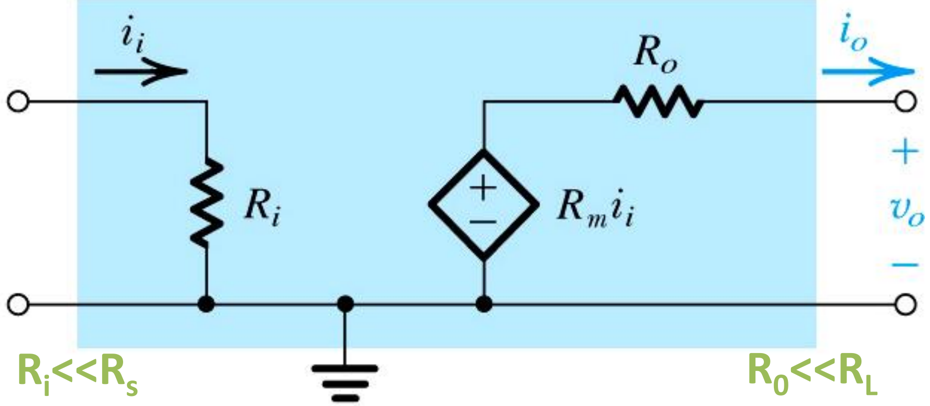
$R_0 >> R_L$

Trans-resistance Amplifier

Gain → A_v [V/A]

$R_i = 0$

$R_0 = 0$



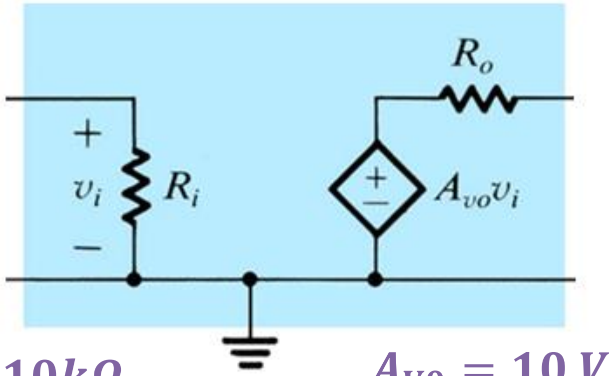
$R_i << R_s$

$R_0 << R_L$

Problem D1.49

A designer has available voltage amplifiers with an input resistance of 10kΩ, an output resistance of 2kΩ, and an open-circuit voltage gain of 10V/V. The signal source has a 10kΩ resistance and provides a 10-mV$_{rms}$ signal, and it is required to provide a signal of at least 2V$_{rms}$ to a 2kΩ load. How many amplifier stages are required? What is the output voltage actually obtained?

$R_0 = 2k\Omega$

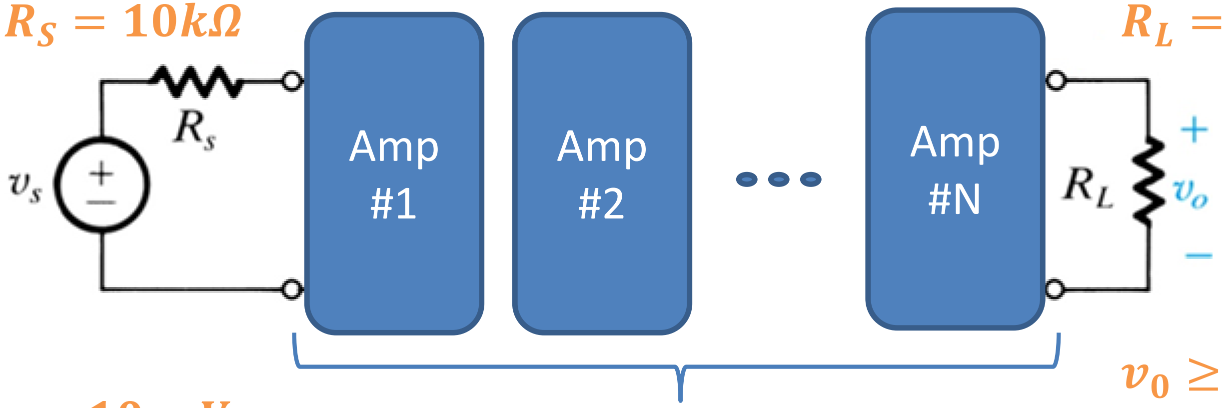


$R_i = 10k\Omega$

$A_{V0} = 10\ V/V$

$R_S = 10k\Omega$

$R_L = 2k\Omega$



$v_S = 10\ mV_{rms}$

$v_0 \geq 2\ V_{rms}$

$$A_v = \frac{v_0}{v_S} \geq 200\ V/V$$

- $N = 3$

$$A_v = \left[\frac{R_i}{R_i + R_S}\right]\left[A_{V0}\frac{R_i}{R_i + R_0}\right]^2\left[A_{V0}\frac{R_L}{R_L + R_0}\right]$$

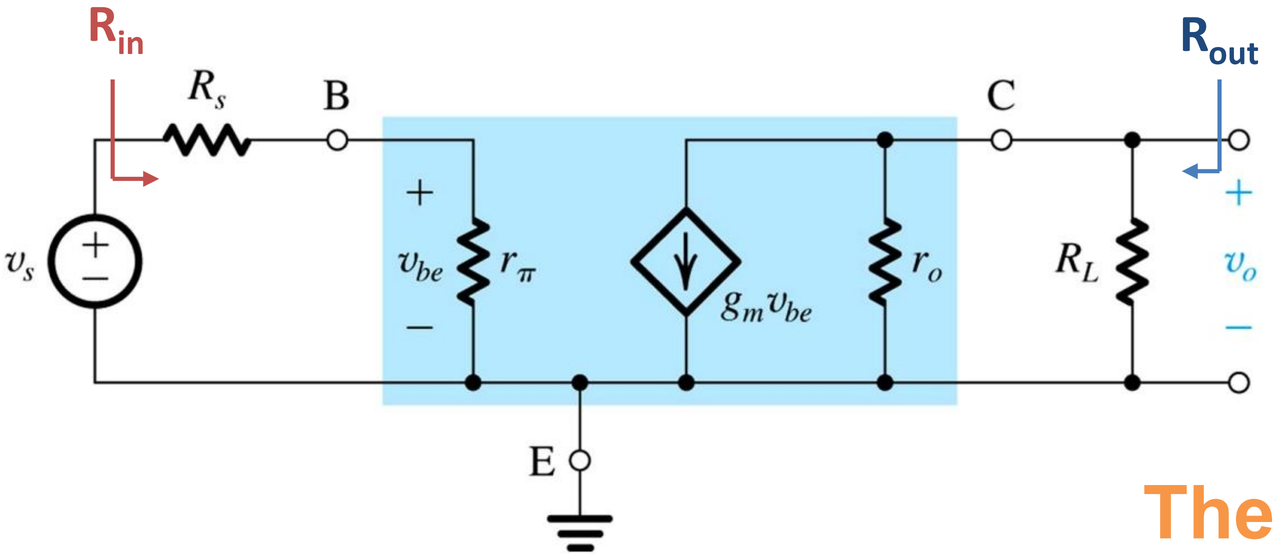
$$A_v = 172\ V/V$$

- $N = 4$

$$A_v = \left[\frac{R_i}{R_i + R_S}\right]\left[A_{V0}\frac{R_i}{R_i + R_0}\right]^3\left[A_{V0}\frac{R_L}{R_L + R_0}\right]$$

$$A_v = 1430\ V/V$$

Input / Output Impedance



R_{in} → input impedance

R_{out} → output impedance

Thevenin's Resistance

- No dependent Source

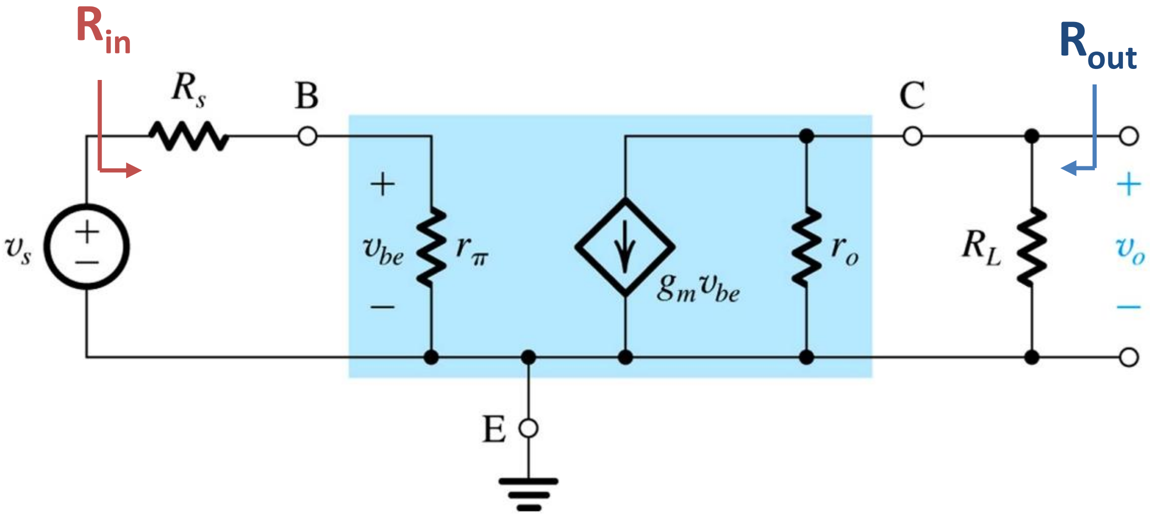
  R_{th} → series / parallel combination
- Dependent Source

  Place test source V_x=1V at terminals

  $$R_{th} = \frac{V_x}{I_x} = \frac{1}{I_x}$$
- For R_{out} turn "off" input source!

Example 1.4

For the following circuit derive an expression for the voltage gain v_o/v_s, and evaluate its magnitude for the case R_s=5kΩ, r_π=2.5kΩ, g_m=40mA/V, r_o=100kΩ, and R_L=5kΩ. What would be the gain value if the effect of r_o were neglected? Calculate the value for the impedance seen by the source and at the output terminals.



$$A_v = \frac{v_0}{v_s} = \left[\frac{v_0}{v_{be}}\right]\left[\frac{v_{be}}{v_s}\right] = \left[\frac{r_\pi}{r_\pi + R_s}\right][-g_m r_0 \| R_L]$$

$$= [0.33][190] = \text{-63 V/V}$$

for $r_0 \gg R_L \rightarrow$

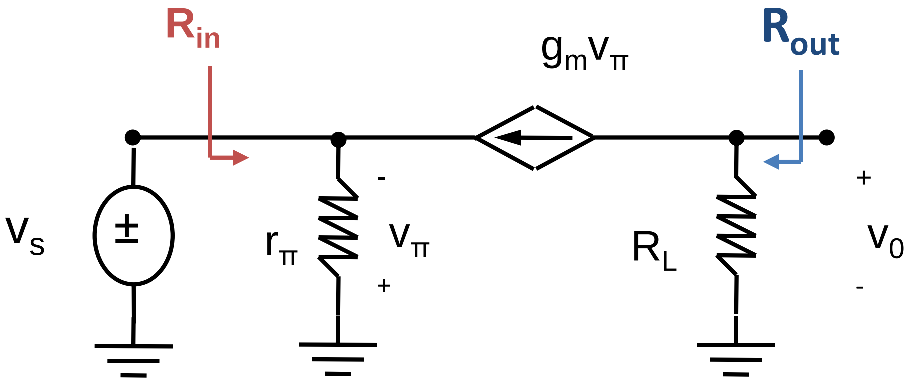
$$A_v = [0.33][200] = \text{-66 V/V}$$

$$R_{in} = R_s + r_\pi = 7.5\ \text{k}\Omega$$

$$R_{out} = r_0 \| R_L = 4.76\ \text{k}\Omega$$

Input / Output Impedance

For the circuit provided find the expression for the input and output resistances, R_{in} and R_{out} respectively.



$$R_{out} = \frac{1}{I_y} = R_L$$

$$R_{in} = \frac{1}{I_x} = \frac{1}{g_m}\left[\frac{1}{1 + \frac{1}{g_m r_\pi}}\right]$$

for $g_m r_\pi \gg 1 \;\rightarrow\; R_{in} \approx \frac{1}{g_m}$