ECE 342
Electronic Circuits

Lecture 2
Large and Small Signal Circuits

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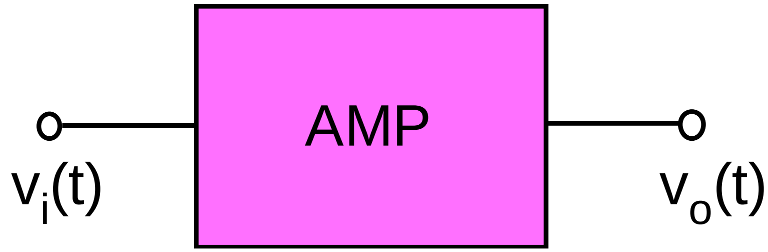
Amplifiers

- **Definitions**
  - Used to increase the amplitude of an input signal to a desired level
  - This is a fundamental signal processing function
  - Must be linear (free of distortion) – Shape of signal preserved



$$v_o(t) = Av_i(t), \text{ where } A \text{ is the voltage gain}$$

$$Voltage\ Gain: A_v = \frac{v_o}{v_i}$$

$$Power\ Gain: A_p = \frac{Load\ Power\ (P_L)}{Input\ Power\ (P_I)}$$

Amplifiers

$$A_p = \frac{v_o i_o}{v_I i_I}$$

$$Current\ Gain: A_i = \frac{i_o}{i_i}$$

$$Note: A_p = A_v A_i$$

Expressing gain in dB (decibels)

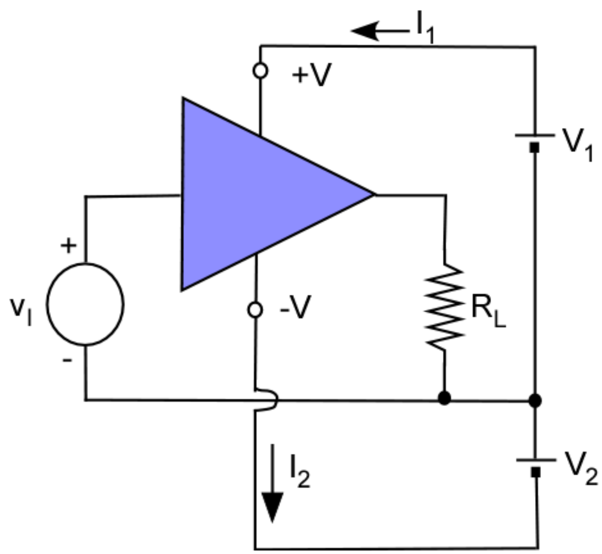
$$Voltage\ gain\ in\ dB = 20\log\left|A_V\right|$$

$$Current\ gain\ in\ dB = 20\log\left|A_I\right|$$

$$Power\ gain\ in\ dB = 10\log\left|A_P\right|$$

Amplifiers

Since output associated with the signal is larger than the input signal, power must come from DC supply



$$P_{DC} = V_1 I_1 + V_2 I_2$$

$$P_{DC} + P_I = P_L + P_{dissipated}$$

$$\eta = \frac{P_L}{P_{DC}} \times 100 = Power\ Efficiency$$

Problem

An amplifier has ±10 V power supplies and an input current of 0.1 mA (sine wave) input voltage 1 V peak-to-peak and an output voltage with a peak of 9V. The load impedance is 1 kΩ and the amp draws 9.5 mA from each power supply. Determine:

- the voltage gain
- the current gain
- the power gain
- the power drawn from supplies
- the power dissipated and η

$$A_v = \frac{V_o}{V_i} = \frac{9}{1} = 9$$

$$A_{v-dB} = 20\log\left|A_v\right| = 20\log\left|9\right| = 19.1\,dB$$

$$\hat{I}_o = \frac{9}{1k\Omega} = 9\,mA$$

The current gain is

$$A_i = \frac{\hat{I}_o}{\hat{I}_i} = \frac{9}{0.1} = 90$$

Problem

$$A_{i-dB} = 20\log 90 = 39.1\,dB$$

$$Power\ at\ Load = P_L = V_{o-rms} I_{o-rms} = \frac{9}{\sqrt{2}}\frac{9}{\sqrt{2}} = 40.5\,mW$$

$$Power\ at\ input = P_I = V_{I-rms} I_{I-rms} = \frac{1}{\sqrt{2}}\frac{0.1}{\sqrt{2}} = 0.05\,mW$$

$$A_p = \frac{P_d}{P_I} = \frac{40.5}{0.05} = 810$$

$$A_{p-dB} = 10\log 810 = 29.1\,dB$$

$$P_{dc} = 10\times 9.5 + 10\times 9.5 = 190\,mW$$

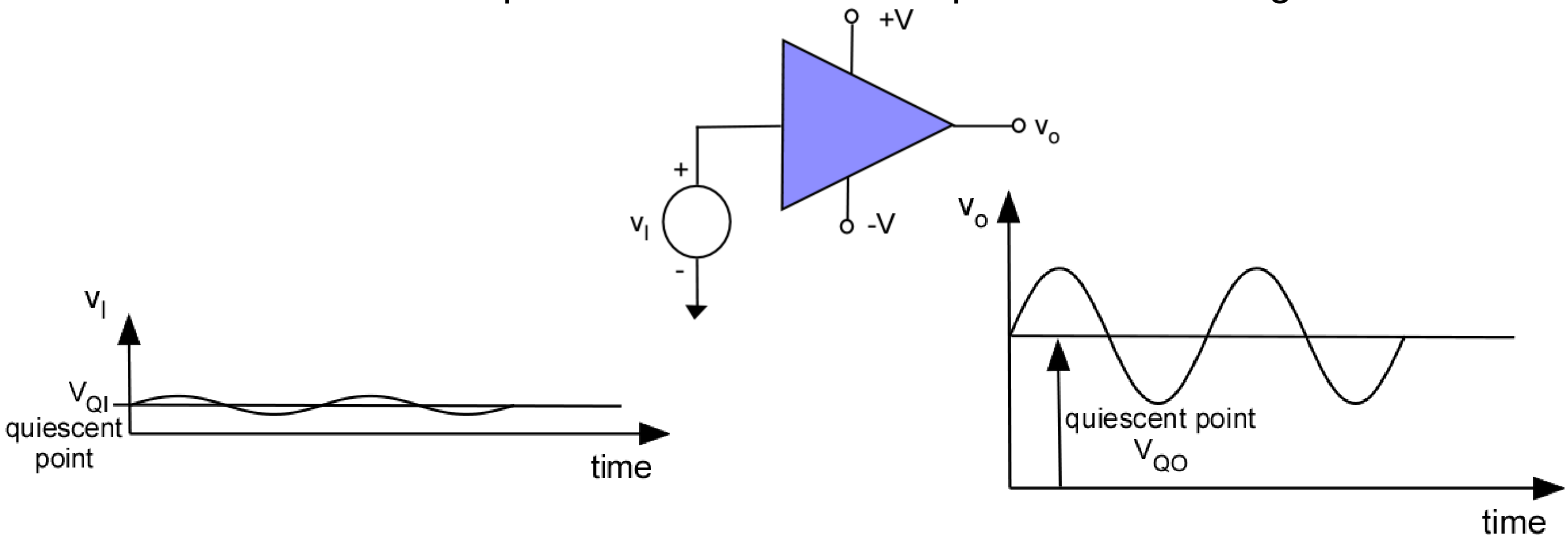
$$P_{dissipated} = P_{dc} + P_I - P_L$$

$$P_{dissipated} = 190 - 0.05 - 4.05 = 149.6\,mW$$

$$\eta = \frac{P_L}{P_{dc}}\times 100 = 21.3\%$$

Biasing of Amp

Bias will provide quiescent points for input and output about which variations will take place. Bias maintain amplifier in active region.



$$V_I(t) = V_{QI} + v_I(t)$$

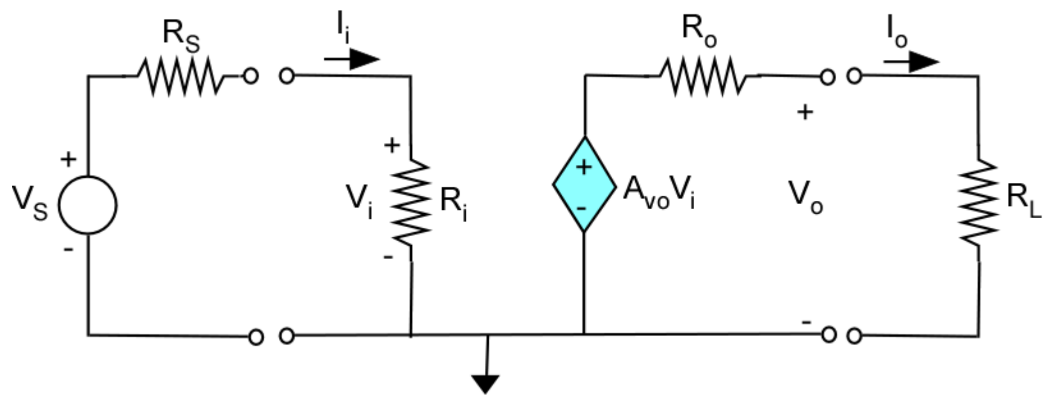
$$V_o(t) = V_{QO} + v_o(t)$$

$$v_o(t) = A_v v_I(t)$$

$$A_v = \left.\frac{dv_o}{dv_I}\right|_{at\ Q}$$

Amplifier characteristics are determined by bias point

Voltage Amplifier



$$Voltage\ gain\ is: \frac{v_o}{v_i} = A_v = \frac{A_{vo} R_L}{R_L + R_o}$$

$$Input\ v_i = v_s \frac{R_i}{R_i + R_S}$$

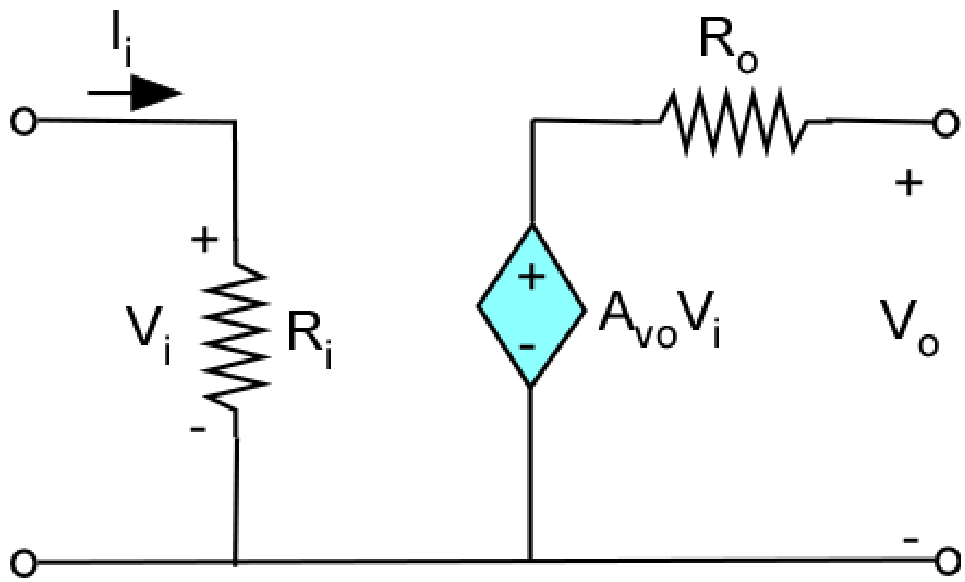
$$v_o = \frac{A_{vo} v_i R_L}{R_L + R_o}$$

Want R_i large (so $v_i \approx v_s$) (actually want $R_i >> R_s$) ideal $R_i = \infty$

<u>Want R_o small</u> (as small as possible) to achieve maximum gain ➔ ideal $R_o=0$

$$Overall\ gain: \frac{v_o}{v_s} = A_{vo} \frac{R_i}{R_i + R_s} \cdot \frac{R_L}{R_L + R_o}$$

Voltage Amplifier

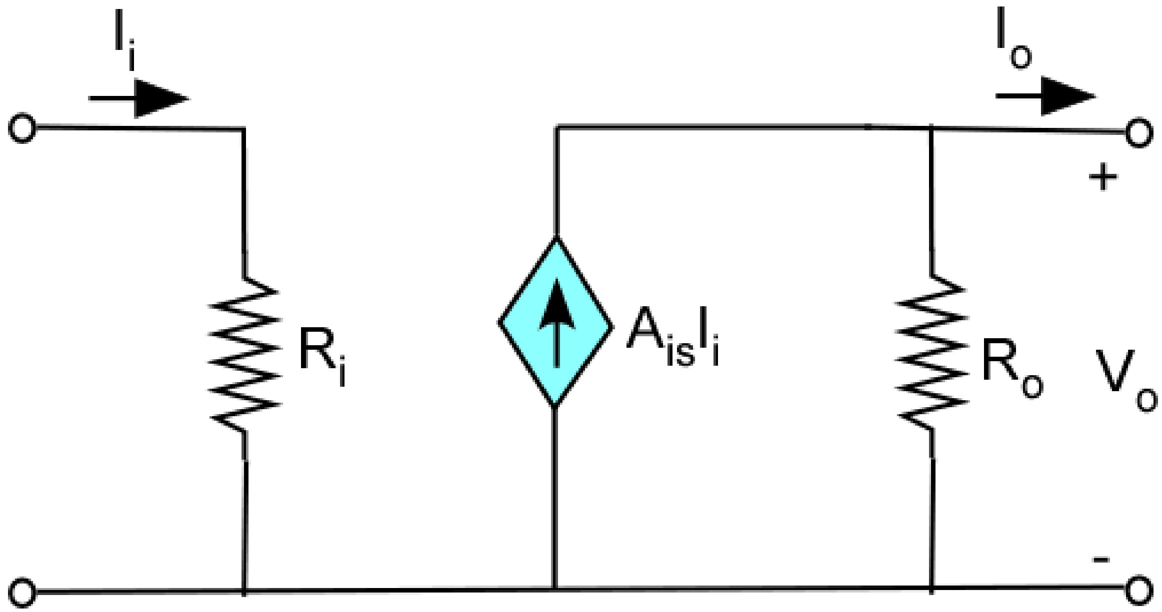


$$Open\ Circuit\ Voltage\ Gain: A_{vo} = \left.\frac{v_o}{v_i}\right|_{i_o=0}$$

$$ideal: R_i = \infty$$

$$R_o = 0$$

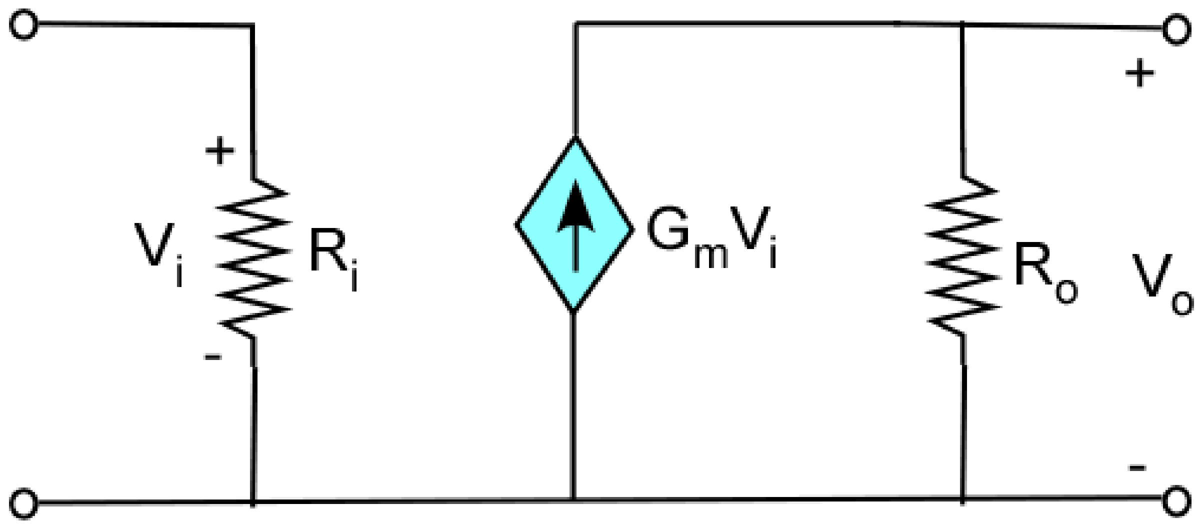
Current Amplifier



$$Short\ Circuit\ Current\ Gain: A_{is} = \left.\frac{i_o}{i_i}\right|_{i_o=0}$$

$$ideal: R_i = 0$$
$$R_o = \infty$$

Transconductance Amplifier

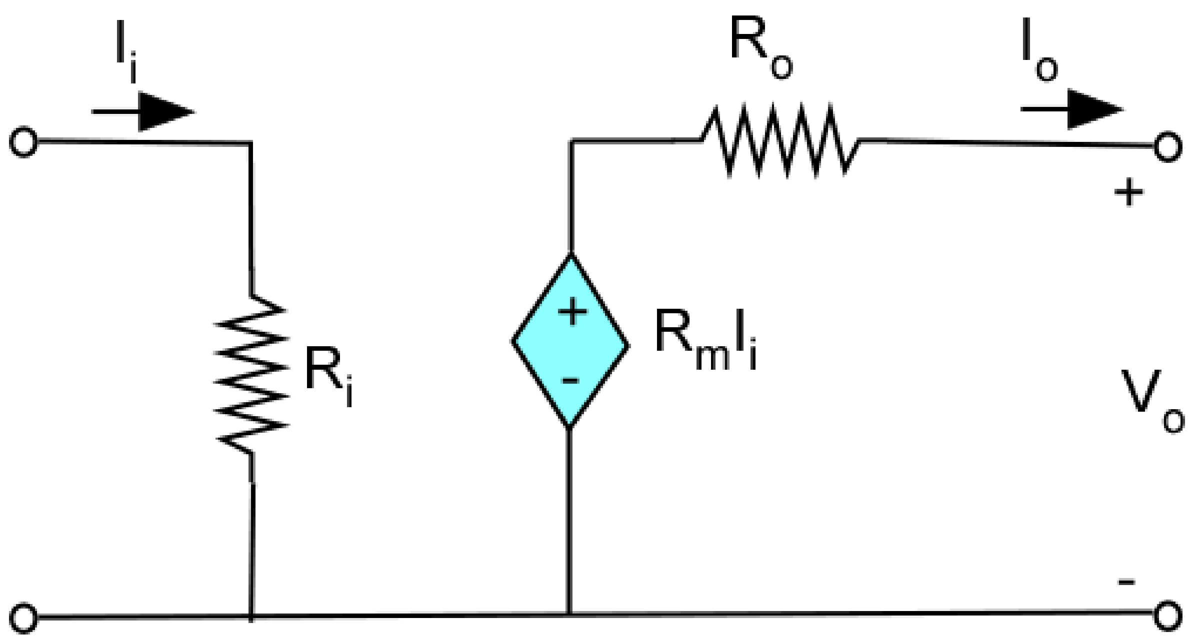


$$\text{Short Circuit Transconductance}: G_m = \frac{i_o}{v_i}$$

$$ideal: R_i = \infty$$

$$R_o = \infty$$

Transresistance Amplifier



$$\text{Open Circuit Transresistance}: R_m = \frac{v_o}{i_i}$$

$$ideal: R_i = 0$$

$$R_o = 0$$

Small-Signal Model

- **What is a small-signal incremental model?**
  - Equivalent circuit that only accounts for signal level fluctuations about the DC bias operating points
  - Fluctuations are assumed to be small enough so as not to drive the devices out of the proper range of operation
  - Assumed to be linear
  - Derives from superposition principle