Amplifiers : Specifications and Characteristics

Ch. 11 of Allan R. Hambley's Book

Brief Summary

In this lecture we will

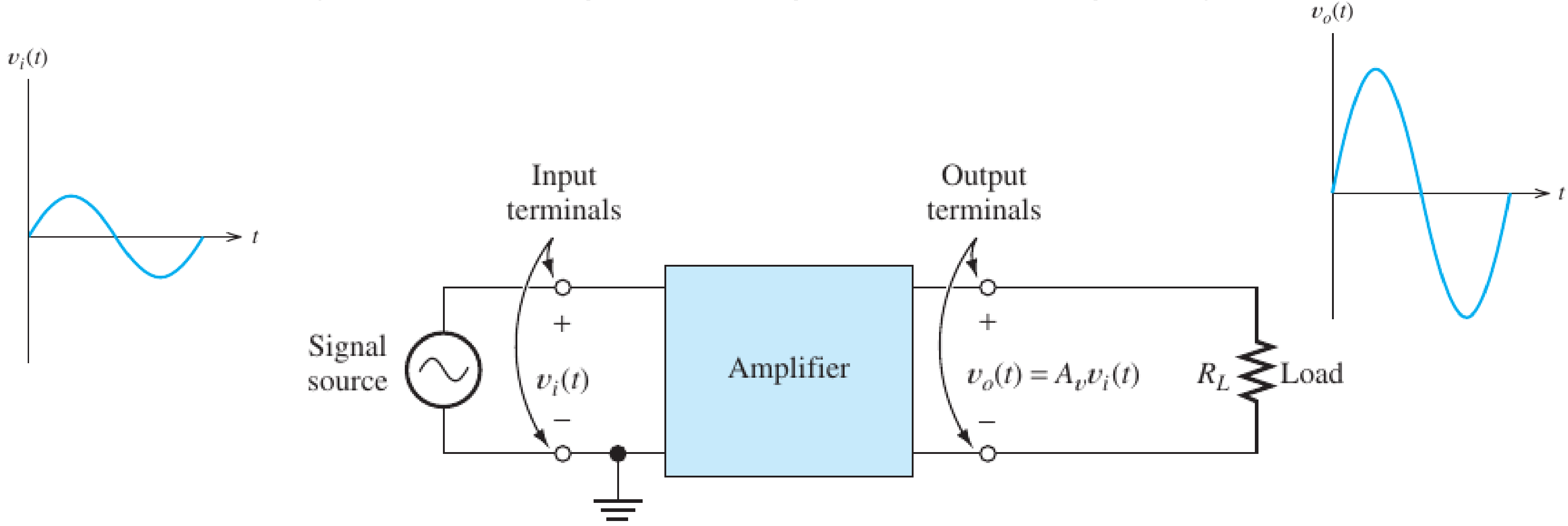
- **Understand the operation of voltage and current amplifiers.**
- **Understand the importance of input and output impedances of amplifiers.**
- **Understand the working principles of various types of amplifiers.**

Basic Amplifier Concepts

Ideally an amplifier produces an output signal with identical wave shape as the input signal with larger amplitude. So the input output relationship of an voltage amplifier would be

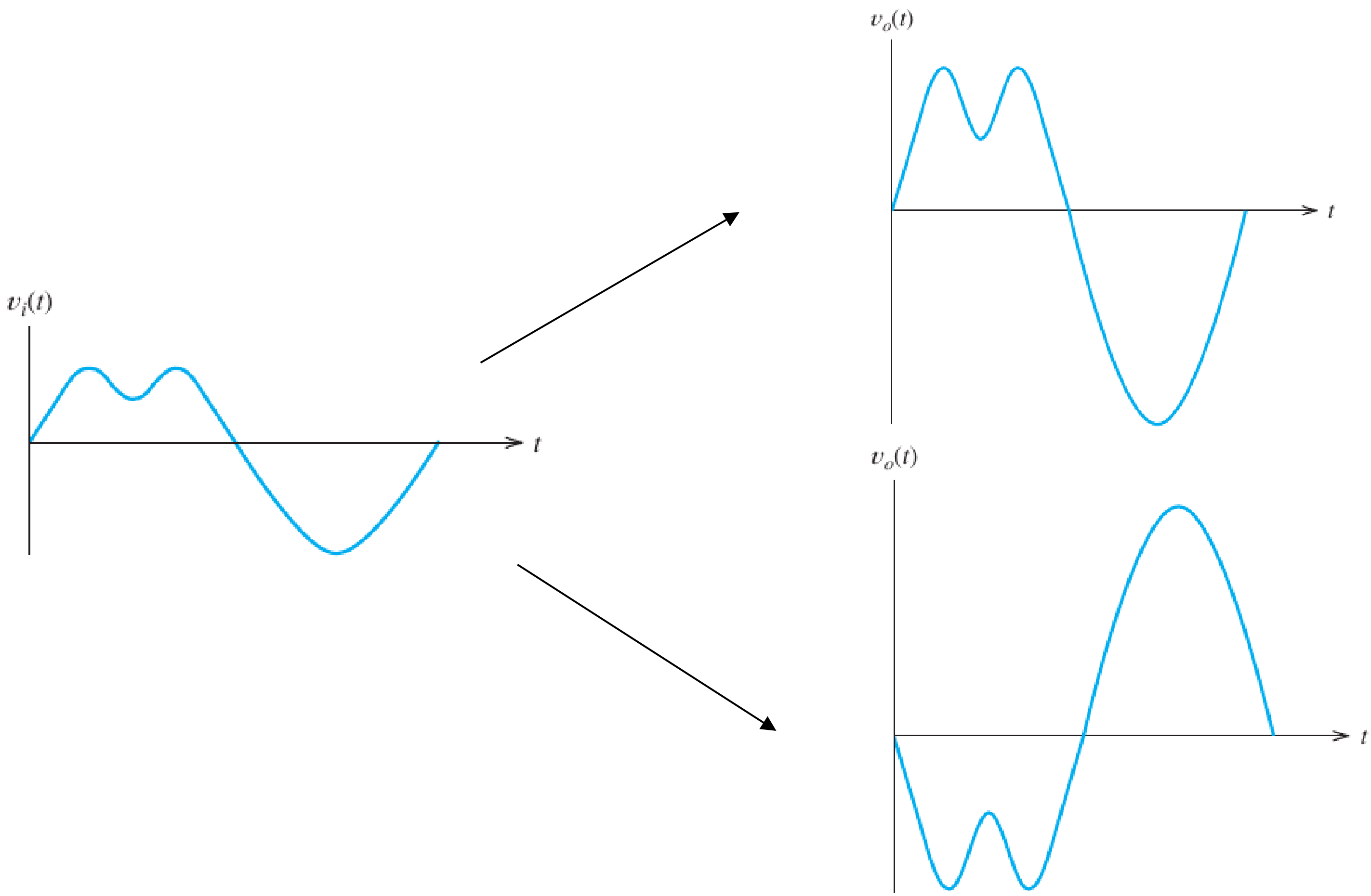
$$v_o(t) = A_v v_i(t)$$

For a signal applied to the input terminals of an amplifier the generated output would be the gain of the amplifier multiplied with the input signal.



Inverting and Non-Inverting Amplifiers

When the amplifier gain, A_v , is negative, the output is an inverted version of the input. This type of amplifier is called **inverting amplifier.** On the other hand if the amplifier gain is positive number we have a **non-inverting amplifier**

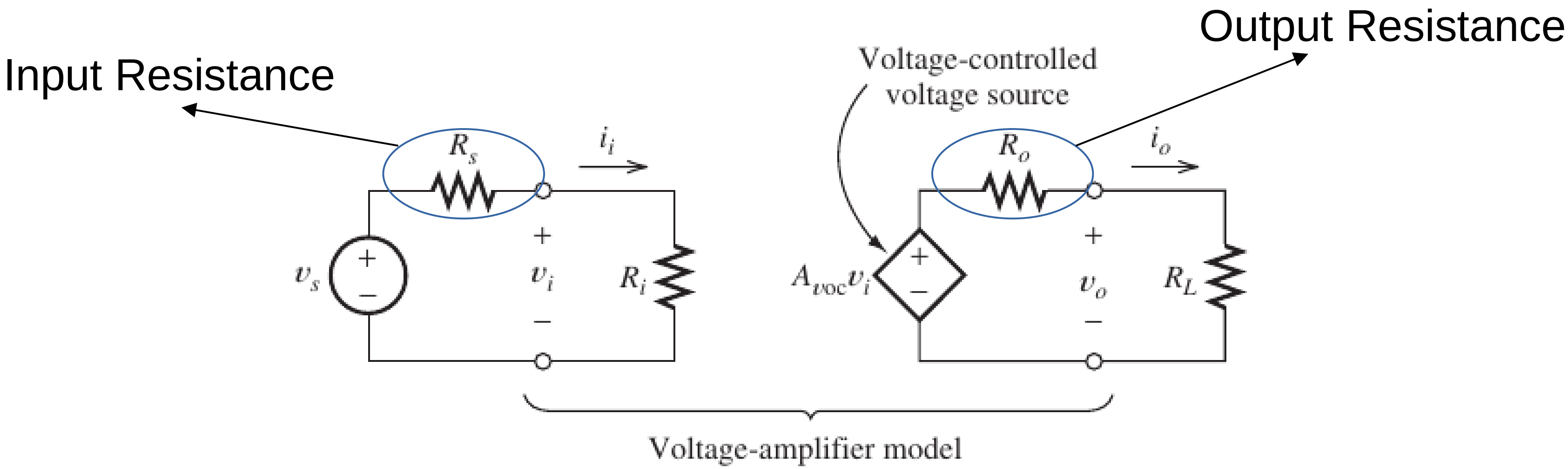


Non-inverting

Inverting

Voltage-Amplifier Model

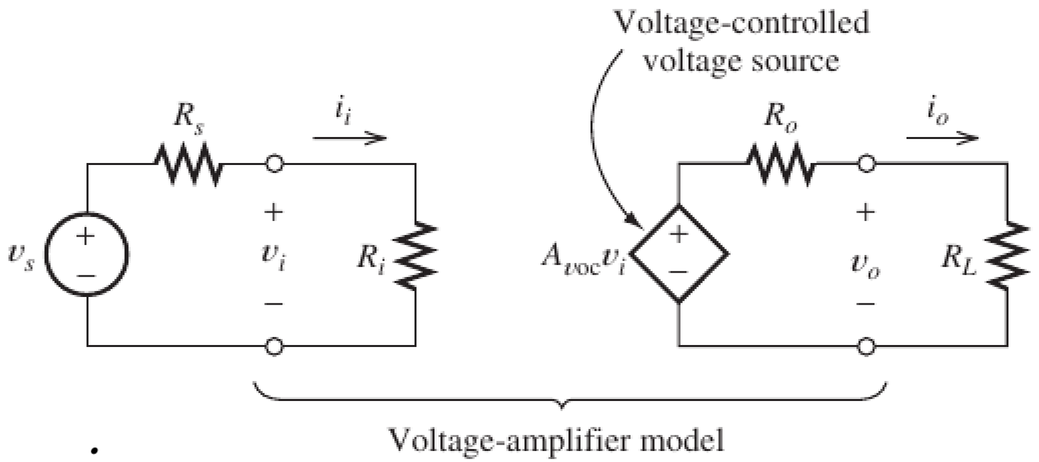
As the real life amplifiers draws some current from the signal source we need to include a input resistance, furthermore in order to account for the fact that the output voltage is reduced when load current flows, we also add an output resistor in series, making the overall model



If the load in an open circuit, there is no drop across the output resistance and

$v_o = A_{voc} v_i$ For this reason, the gain here is called open-circuit voltage gain

Current Gain



The input current i_i is the current delivered to the input terminals of the amplifier and the output current i_o is the current flowing through the load.

The current gain A_i of an amplifier is the ratio of the output current to the input current . That is

$$A_i = \frac{i_o}{i_i}$$

The current gain in terms of the voltage gain can be formulated as

$$A_i = \frac{i_o}{i_i} = \frac{v_o/R_L}{v_i/R_i} = A_v \frac{R_i}{R_L}$$

Power Gain

The power delivered to the input terminals by the input signal (or the signal source) is called the input power, and the power delivered to the load by the amplifier is the output power.

The power gain ***G*** of an amplifier is the ratio of the output power to the input power :

$$G = \frac{P_o}{P_i}$$

Assuming that the input impedance and the load are purely resistive, the average power at either set of terminals is the product of the root-mean-square (rms) current and voltage. Thus

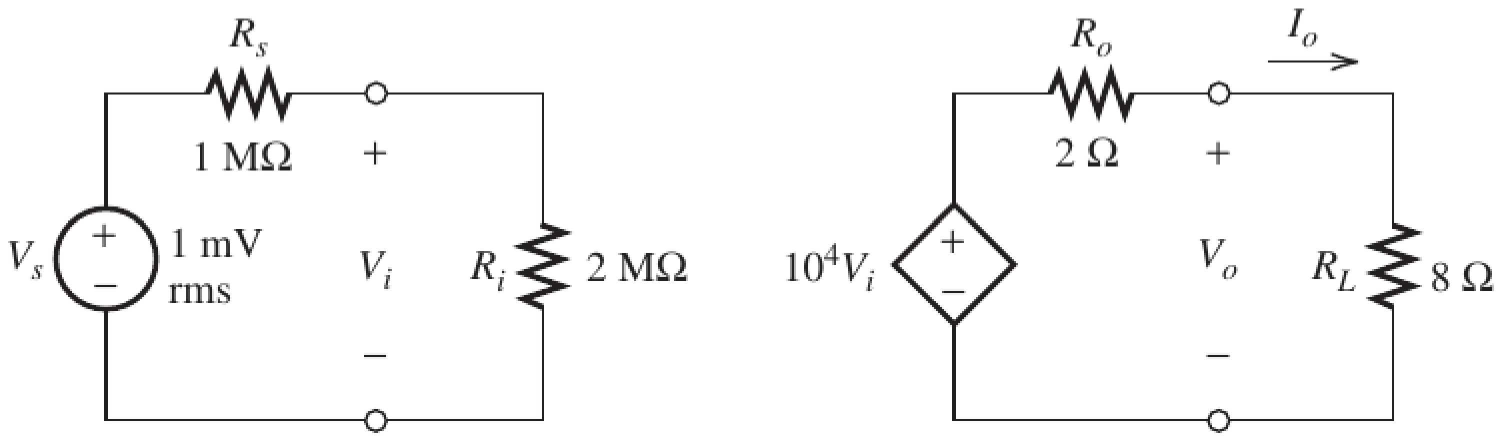
$$G = \frac{P_o}{P_i} = \frac{V_o I_o}{V_i I_i} = A_v A_i = (A_v)^2 \frac{R_i}{R_L}$$

Notice that upper case symbols are used for ***rms*** values of currents and voltages

Example:

Calculating Amplifier Performance

A source with an internal voltage of 1 mv rms and an internal resistance of 1M ohms is connected to the input terminal of an amplifier having an open-circuit voltage gain of 104, an input resistance of 2 Mohms and an output resistance of 2 ohms. The load resistance is 8ohms. Find the voltage gains $A_{vs} = V_o/V_s$ and $A_v = V_o/V_i$
Also find the current gain and power gain



Example:

Solution :

Apply voltage division to calculate V_i

$$V_i = \frac{R_i}{R_i + R_s} V_s = 0.667 \text{ mV rms}$$

the voltage produced by the voltage-controlled source is then

$$A_{voc} V_i = 10^4 V_i = 6.67 \text{ V rms}$$

The output voltage can be found as

$$V_o = A_{voc} V_i \frac{R_L}{R_L + R_o} = 5.33 \text{ V rms}$$

The required voltage gains are then given as

$$A_v = \frac{V_o}{V_i} = A_{voc} \frac{R_L}{R_o + R_L} = 8000$$

$$A_{vs} = \frac{V_o}{V_s} = A_{voc} \frac{R_i}{R_i + R_s} \frac{R_L}{R_o + R_L}$$

Example: (cont.)

The current and power gains can be calculated as

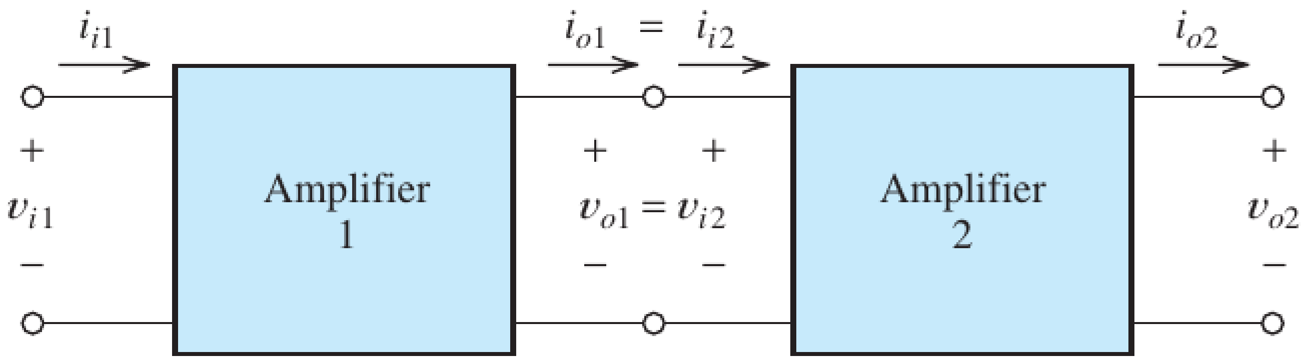
$$A_i = A_v \frac{R_i}{R_L} = 2 \times 10^9$$

$$G = A_v A_i = 16 \times 10^{12}$$

Notice that the current gain is very large, as the high input

Cascaded Amplifiers

When we connect the output of an amplifier to the input terminals of another amplifier, this forms a cascade connection of two amplifiers as in the figure



The overall voltage gain of the cascade amplifier is given by

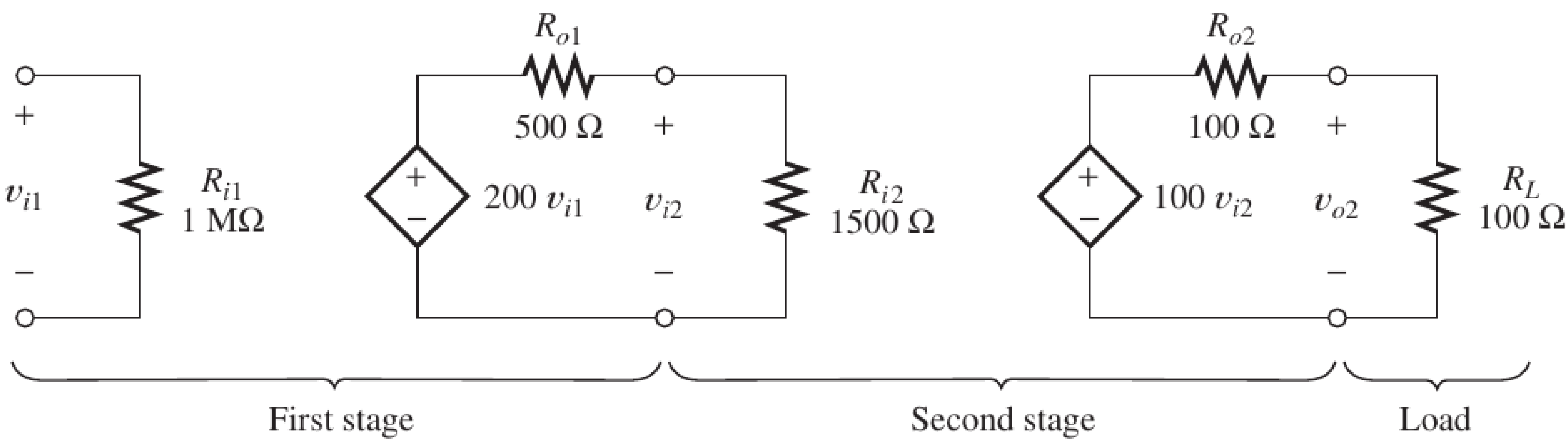
$$A_v = \frac{v_{o2}}{v_{i1}}$$

which then can be written

$$A_v = \frac{v_{o1}}{v_{i1}} \times \frac{v_{o2}}{v_{o1}} = \frac{v_{o1}}{v_{i1}} \times \frac{v_{o2}}{v_{i2}} \Rightarrow \boxed{A_v = A_{v1}A_{v2}}$$

Example: Performance of Cascaded Amplifiers

For the cascade connected amplifiers given in the figure, find the current gain, voltage gain and power gain of each stage and for the overall cascade connection



Example:

Solution :

The first stage gain

$$A_{v1} = \frac{v_{o1}}{v_{i1}} = \frac{v_{i2}}{v_{i1}} = A_{voc1}\frac{R_{i2}}{R_{i2} + R_{o1}} = 150$$

The gain for the second stage is then

$$A_{v2} = \frac{v_{o2}}{v_{i2}} = A_{voc2}\frac{R_L}{R_L + R_{o2}} = 50$$

Overall amplifier gain

$$A_v = A_{v1}A_{v2} = 7500$$

Example: cont.

Current gain of the first stage

$$A_{i1} = A_{v1}\frac{R_{i1}}{R_{i2}} = 10^5$$

Similarly the current gain of the second stage

$$A_{i2} = A_{v2}\frac{R_{i2}}{R_L} = 750$$

Overall current gain

$$A_i = A_{i1}A_{i2} = 75 \times 10^6$$

Using these results power gains can be computed as follows

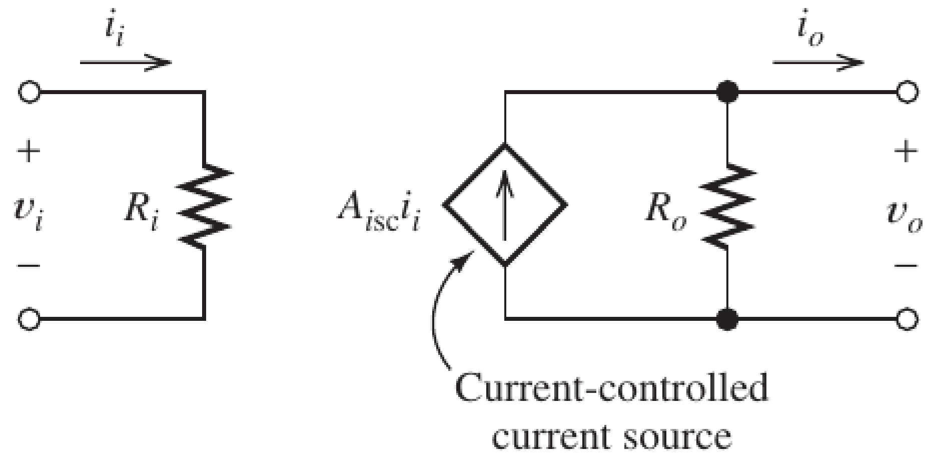
$$G_1 = A_{v1}A_{i1} = 1.5 \times 10^7$$
$$G_2 = A_{v2}A_{i2} = 3.75 \times 10^4$$

$\longrightarrow$

$$G = G_1 G_2 = 5.625 \times 10^{11}$$

Other Amplifier Models

An alternative to the voltage amplifies (represented by a voltage-controlled voltage source) is the current amplifier modeled as



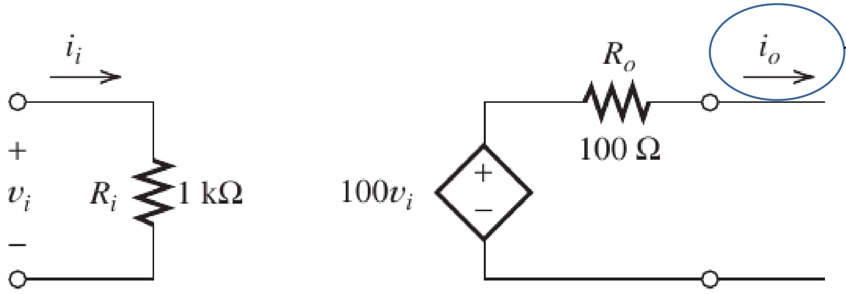
The output resistance on this model is parallel to the load

An amplifier initially modeled as a voltage amplifier can also be modeled as a current amplifier.

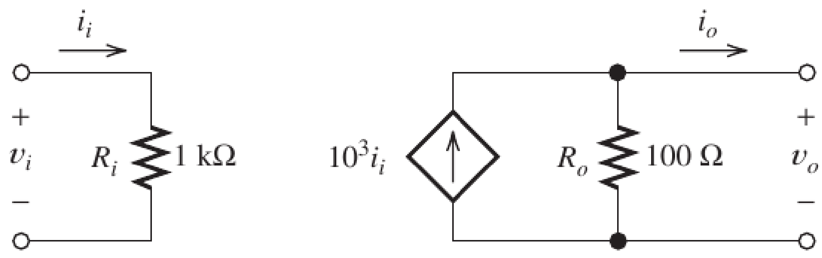
Other Amplifier Models

Figure shows a voltage amplifier and the corresponding current amplifier equivalent

Short Circuit Current



$$i_i = \frac{v_i}{R_i} \quad \text{and} \quad i_{osc} = \frac{A_{voc} v_i}{R_o}$$

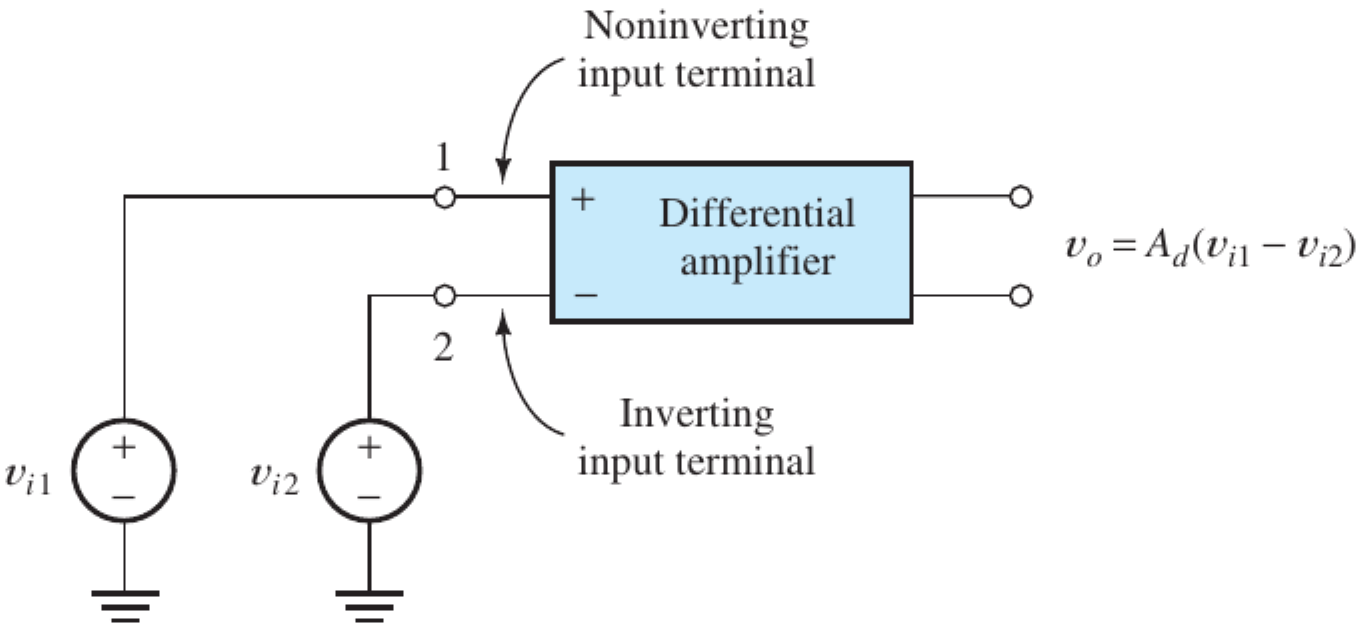


$$A_{isc} = \frac{i_{osc}}{i_i} = A_{voc}\frac{R_i}{R_o} = 10^3$$

Differential Amplifiers

Differential amplifiers have two input sources.

An ideal differential amplifier produces an output proportional to the difference between the input voltages as shown in the figure



Next ???

Next, we will investigate the basic building blocks of amplifiers, transistors