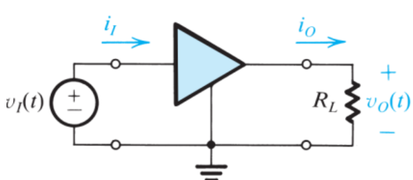
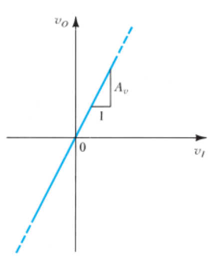
EE112 - Fall 2016
Analog Integrated Circuits I

Prof. Haoyu Wang
wanghy@shanghaitech.edu.cn
5210 Research Bldg.

Amplifier Gain (增益)





- Voltage Gain:

$$A_v = \frac{v_O}{v_I}$$

- Current Gain:

$$A_i = \frac{i_O}{i_I}$$

- Power Gain:

$$A_p = \frac{p_L}{p_I} = \frac{v_O i_O}{v_I i_I}$$

$$A_p = A_v A_i$$

- Note: A_v and A_i can be positive, negative, or even complex numbers. Nagative gain means the output is 180° out of phase with input. However, A_p should always be a positive number.
- Gain is usually expressed in Decibel (dB,分贝)

$$A_v(dB) = 10\log|A_v|^2 = 20\log|A_v|$$

$$A_v(dB) = 10\log|A_i|^2 = 20\log|A_i|$$

$$A_p(dB) = 10\log|A_p|$$

Amplifier Power Supply and Dissipation

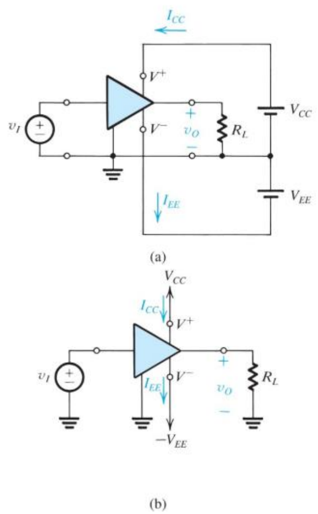


Figure 1.13 An amplifier that requires two dc supplies (shown as batteries) for operation.

- Circuit needs dc power supplies to function
- Typical power supplies are denoted as V_{CC} and $-V_{EE}$
- Total dc power dissipation

$$P_{dc} = V_{CC} I_{CC} + V_{EE} I_{EE}$$

- Power balance

$$P_{dc} + P_I = P_L + P_{diss}$$

  » P_I: power drawn from signal source
  » P_L: power delivered to the load
  » P_{diss}: power dissipated in the amplifier circuit

- Power efficiency

$$\eta = \frac{P_L}{P_{dc}}$$

  » Important for power amplifiers: stereo output, transmitters

Linear Range vs. Saturation(饱和) Range

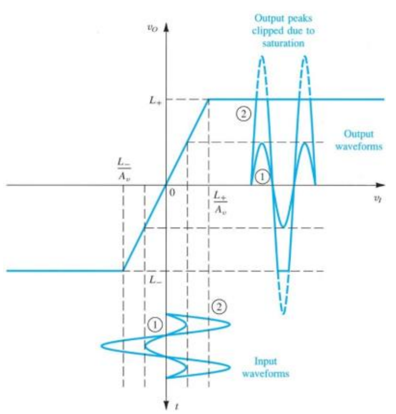


Figure 1.14 An amplifier transfer characteristic that is linear except for output saturation.

- Within linear range, the output voltage (or current) is proportional to the input voltage (or current)
- Beyond linear range, the output voltage (or current) waveforms saturates, resulting in distortions
  » Lose fidelity (失真) in stereo system
  » Cause interference in wireless system

Symbol Notation

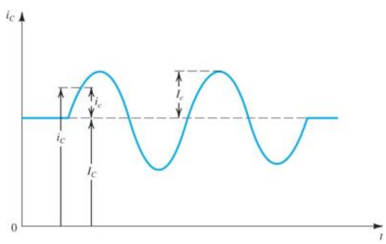


Figure 1.15 Symbol convention employed throughout the book.

$$i_C(\mathrm{t}) = I_C + i_c(\mathrm{t})$$

- where, $i_C(t)$
  - » Lowercase-uppercase-> total current
- I_C
  - » Uppercase-uppercase-> dc current
- $i_c(t)$
  - » Lowercase-lowercase -> small signal ac current

$$i_C = I_c \sin(\omega \mathrm{t})$$

- where, I_c
  - » Uppercase-lowercase-> amplitude of ac current

- We will stick to this notation system throughout this course, including your homework and labs.

Circuit Model of Voltage Amplifiers

(Two-Port Model)

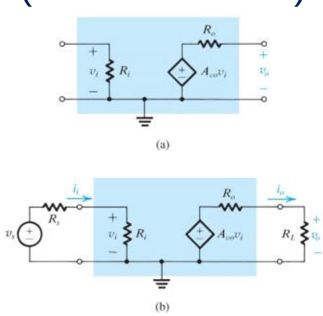


Figure 1.16 (a) Circuit model for the voltage amplifier. **(b)** The voltage amplifier with input signal source and load.

- A_{vo}: open-circuit voltage gain
- R_i: input resistance of the amplifier
- R_o: output resistance of the amplifier
- R_s: source resistance
- R_L: load resistance

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Cascaded Amplifier

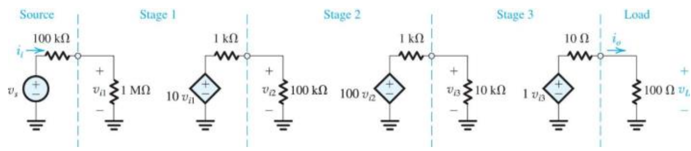


Figure 1.17 Three-stage amplifier for Example 1.3.

For most practical applications, multiple stages of amplifiers are cascaded to

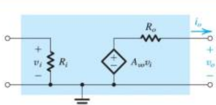
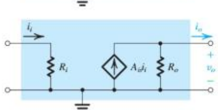
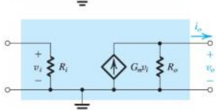
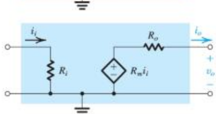
1. Provide sufficient gain
2. Provide adequate input and output resistances/impedances

For example, in a voltage amplifier

- The input stage is designed to have high input impedance
- The output stage is designed to have low output impedance
- Middle stage provides the necessary gain

Amplifier Types

Table 1.1 The Four Amplifier Types

Type	Circuit Model	Gain Parameter	Ideal Characteristics
Voltage Amplifier		Open-Circuit Voltage Gain $A_{vo} \equiv \left.\frac{v_o}{v_i}\right\|_{i_o=0}$ (V/V)	$R_i = \infty$ $R_o = 0$
Current Amplifier		Short-Circuit Current Gain $A_{is} \equiv \left.\frac{i_o}{i_i}\right\|_{v_o=0}$ (A/A)	$R_i = 0$ $R_o = \infty$
Transconductance Amplifier		Short-Circuit Transconductance $G_m \equiv \left.\frac{i_o}{v_i}\right\|_{v_o=0}$ (A/V)	$R_i = \infty$ $R_o = \infty$
Transresistance Amplifier		Open-Circuit Transresistance $R_m \equiv \left.\frac{v_o}{i_i}\right\|_{i_o=0}$ (V/A)	$R_i = 0$ $R_o = 0$

Depending on the nature of the source signals and output loads, different types of amplifiers are needed:

- Voltage amplifier
- Current amplifier
- Transconductance(跨导) amplifier
  - * voltage to current
- Transimpedance (跨阻) amplifier
  - * current to voltage
- 4 models interchangeable via Thevenin equivalent or Norton equivalent

Amplifier Frequency Response

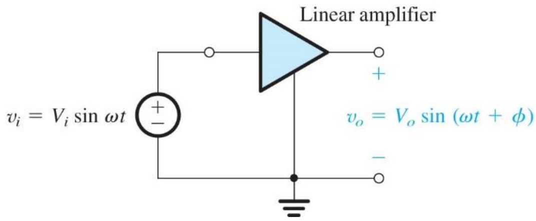


Figure 1.20 Measuring the frequency response of a linear amplifier: At the test frequency, the amplifier gain is characterized by its magnitude (V_o/V_i) and phase ϕ.

When a sinusoidal signal is applied to a linear amplifier, the output is sinusoidal:

- With the same frequency as the input
- But different amplitude (幅度) and phase (相位)

Transfer function (传递函数):

Frequency Response

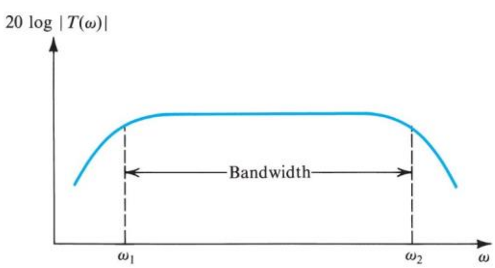


Figure 1.21 Typical magnitude response of an amplifier: $|T(\omega)|$ is the magnitude of the amplifier transfer function—that is, the ratio of the output $V_o(\omega)$ to the input $V_i(\omega)$.

Log-log plot of the transfer function vs. angular frequency, ω

- Vertical axis: $20\log|T(\omega)|$
- Horizontal axis: $10\log\omega$

This is called Bode Plot(波特图)

Bandwidth(带宽)

- Band of frequencies over which the gain response falls by 3dB

Frequency Response of Low-Pass Filters

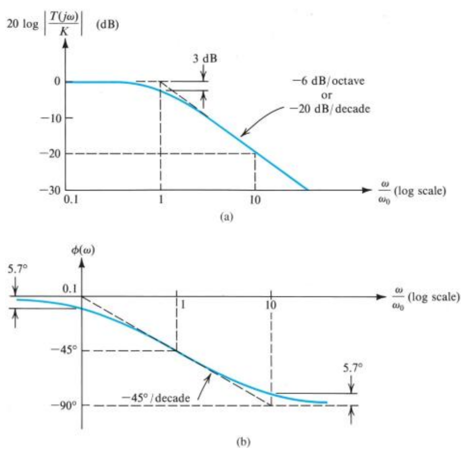


Figure 1.23 (a) Magnitude and **(b)** phase response of STC networks of the low-pass type.

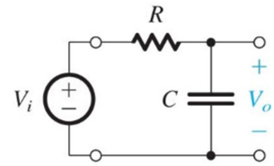


Figure 1.22 (a) a low-pass network.

Transfer function:

Frequency Response of High-Pass Filters

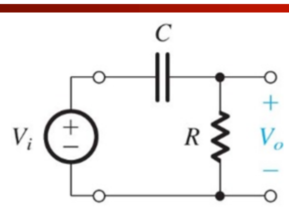


Figure 1.22 (a) a high-pass network.

Transfer function:

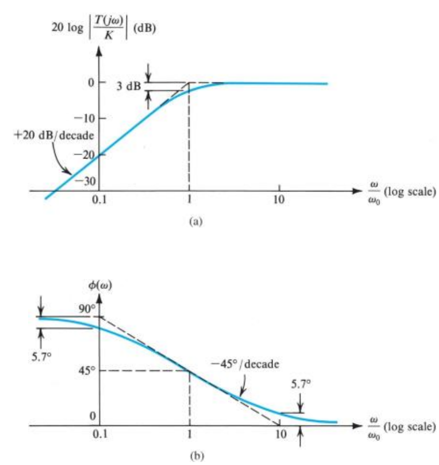


Figure 1.24 (a) Magnitude and **(b)** phase response of STC networks of the high-pass type.

Example: Amplifier Frequency Response

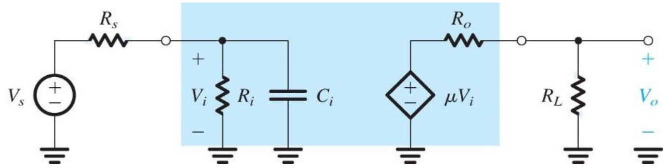


Figure 1.25 Circuit for Example 1.5.

Typical Frequency Responses

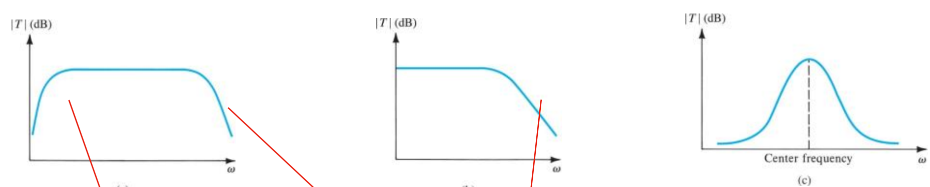


Figure 1.26 Frequency response for **(a)** a capacitively coupled amplifier, **(b)** a direct-coupled amplifier, and **(c)** a tuned or bandpass amplifier.

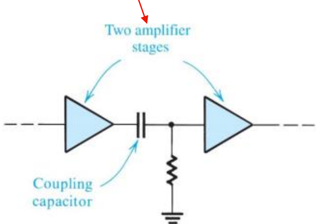


Figure 1.27 Use of a capacitor to couple amplifier stages.

High frequency cut-off due to intrinsic capacitors of the transistors

Low frequency roll-off due to coupling capacitor