ENG2210
Electronic Circuits

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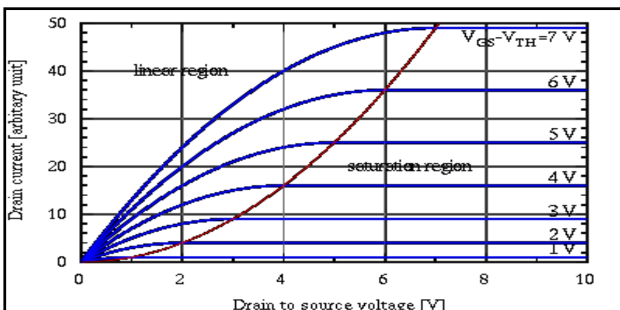
ENGR2210

- Text: Microelectronic Circuits: Sedra and Smith. Oxford publishing.
- LAB
- Marks distribution

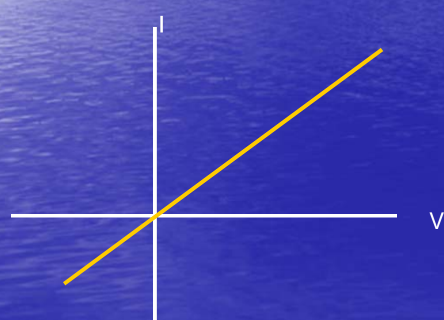
3 quizzes	15%
Midterm	20%
LAB (including a project)	20%
Final	45%

Electronic Circuits

- Electric circuits course deals with passive elements (resistors, capacitors, ...)
- Electronic circuits course deals with active elements (transistors) as will as passive elements
- Generally harder



I_V characteristics of a trtansistor



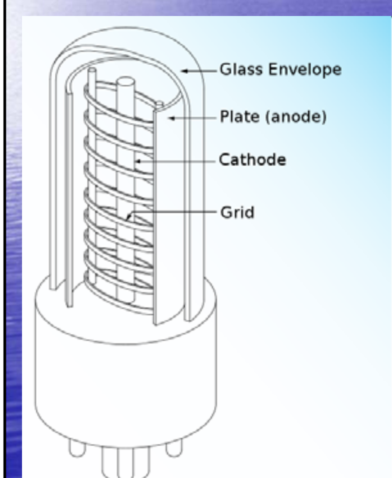
I_V characteristics of a resistor

What we will cover

- Chapter 1: Introduction
- Chapter 2: Operational Amplifiers
- Chapter 4: Diodes
- Chapter 5: MOSFET
- Chapter 6: BJT (MAY BE)

A trip through time

- Triode, AKA vacuum tube Lee De Fortest 1907



A trip through time

- Transisitor was invented at Bell labs in 1947 by Brattain, and Shockley
- In 1956 They were awarded Nobel Prize in Physics

- A few weeks after the invention of the transistor, while the invention was still a secret, co-inventor Walter Brattain attended a meeting of the American Physical Society at which two graduate students from Purdue University, Seymour Benzer and Ralph Bray, were reporting the results of their experiments with germanium..
- Brattain realised how close the two students were to inventing the transistor. He later had a chat with Bray and remembers Bray saying to him: "I think if we would put down another point on the germanium surface, and measure the potential around this point, that we might find out what was going on."
- "And I couldn't resist saying", remembered Brattain, "'Yes Bray, I think that would probably be a good experiment' and walked away."
- Bray had just described to Brattain the exact same experiment which had led Brattain, John Bardeen and William Shockley to the invention of the transistor at Bell Labs a few weeks before

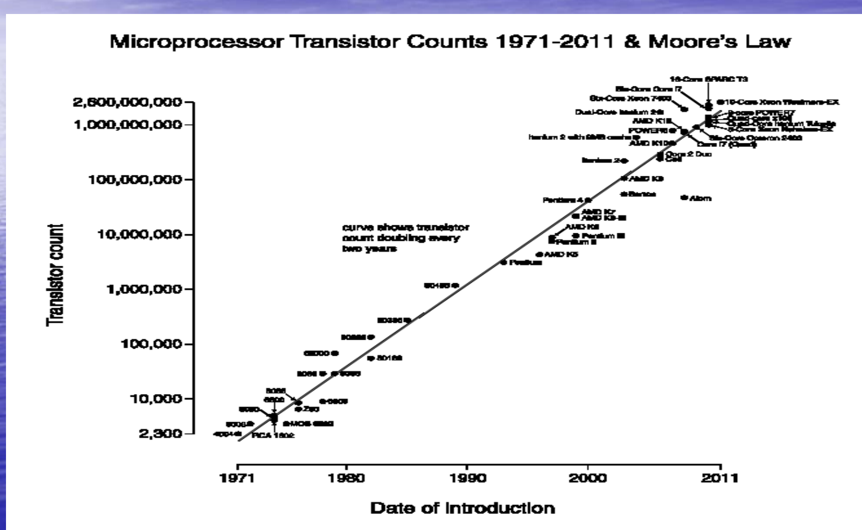
Source: Electronics Weekly blog

David Manners Feb 20, 2009

A trip through time -- IC (microchip)

- Accredited to Jack Kilby of Texas Instruments 1958.
- Robert Noyce made a similar circuit few months later

Moore's law



Chapter 1 Signals and Amplifiers

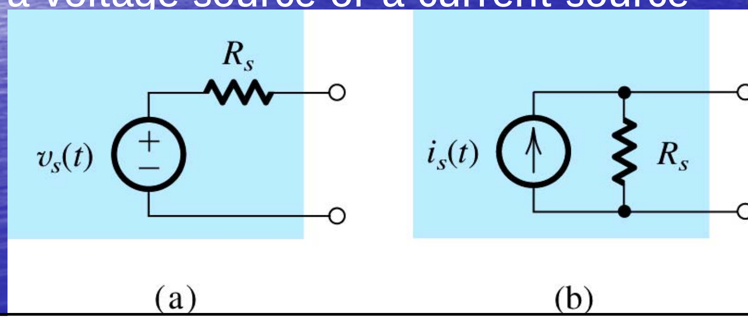
1. Signals
2. Frequency Spectrum of Signals
3. Analog and Digital Signal
4. Amplifiers
5. Circuits Models for Amplifiers
6. Frequency Response of Amplifiers

Chapter 1 Objectives

- Unserstanding electrical signals
- Thevenin and Norton representation of signal sources
- Analog and digital representation of signals
- Amplification and amplifiers
- How amplifiers are characterized
- Frequency amplifiers of amplifiers: how to measure it and calculate it.

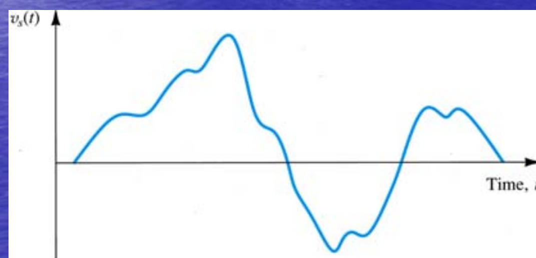
Signals

- Electrical signals, probably generated by a transducer.
- The signal could be represented by either a voltage source or a current source



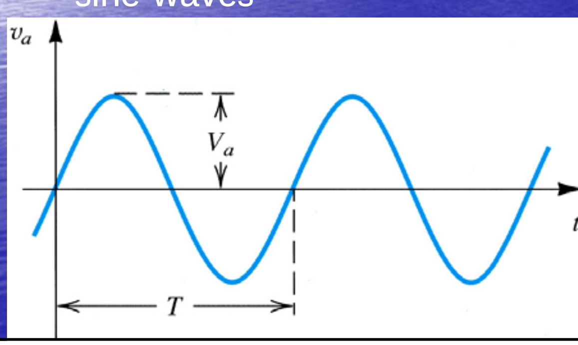
Signals

- Signals varies with time
- Represented as the value changing with time



Signals

- Sine wave is a very important and useful signal
- Using Fourier transform or Fourier series we can represent any signal as (possible infinite) sum of sine waves



$$v_a(t) = V_a \sin \omega t$$

$$\omega = 2\pi f \ , \quad f = 1/T$$

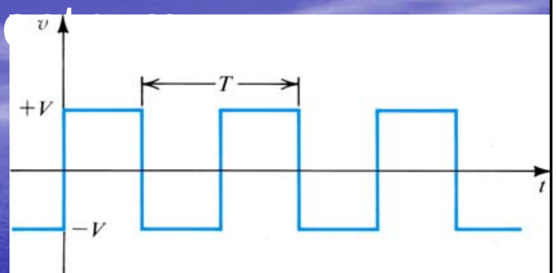
Signals

- Any periodic signal with a period T ($\omega_0 = 2\pi/T$)

$$S = \frac{a_0}{2} + \sum_{n=1}^{\infty} A_n \sin(n\omega_0 + \Phi_n)$$

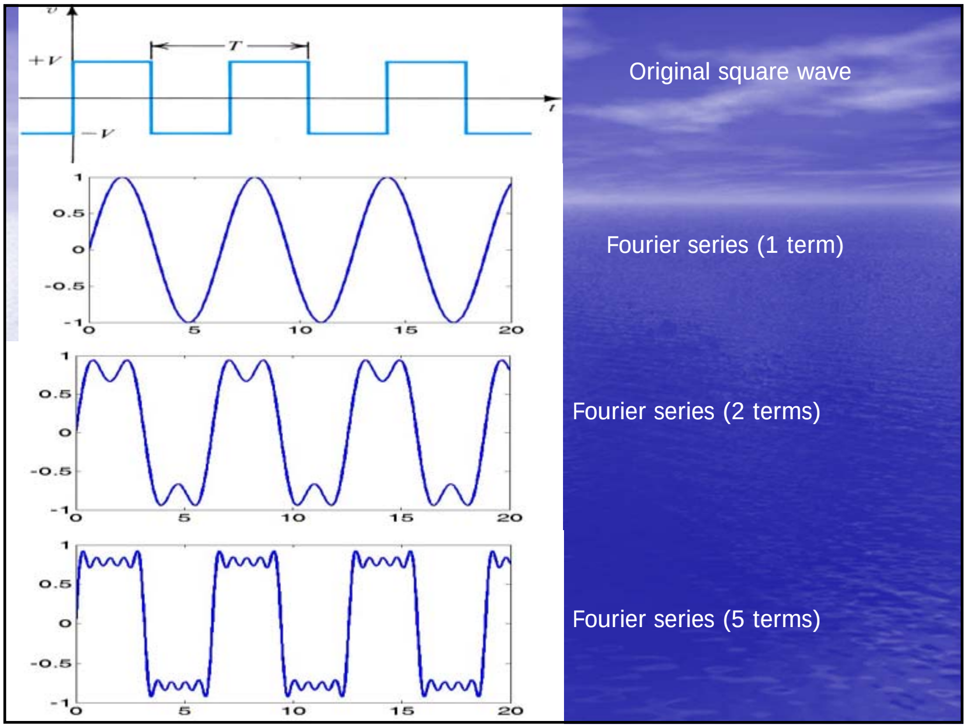
$$= \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos(n\omega_0) + \sum_{n=1}^{\infty} b_n \sin(n\omega_0)$$

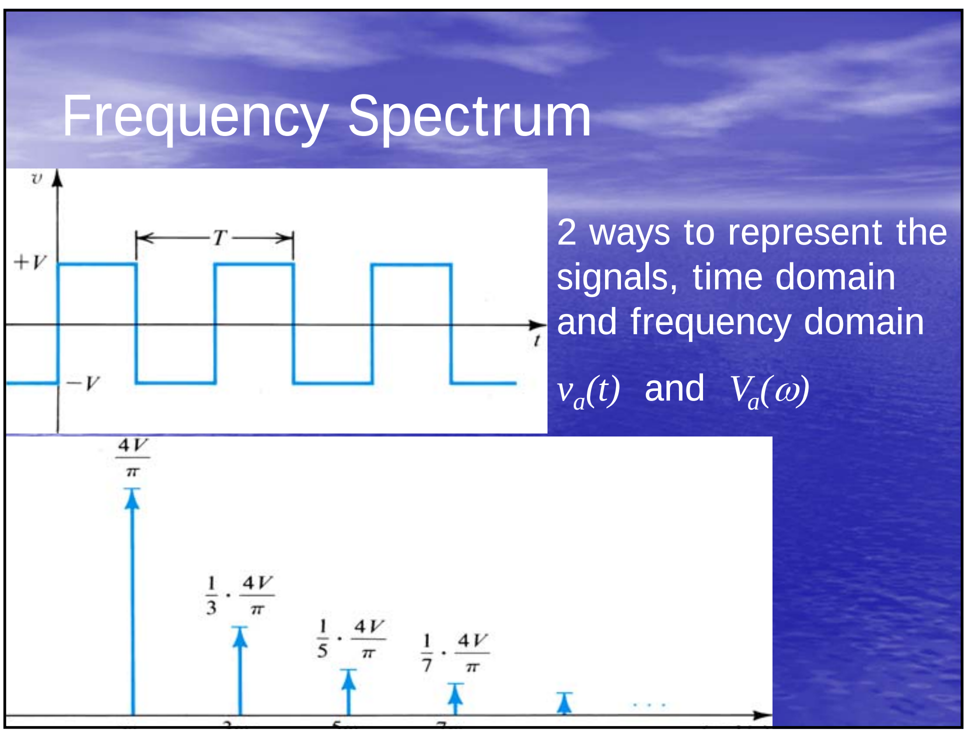
Frequency Sp



- Fourier series allows us to represent any periodic signal as the sum of sin's (possibly infinite), for example

$$v(t) = \frac{4V}{\pi}\left(\sin \omega_0 t + 1/3 \sin 3\omega_0 t + 1/5 \sin 5\omega_0 t + \cdots\right)$$

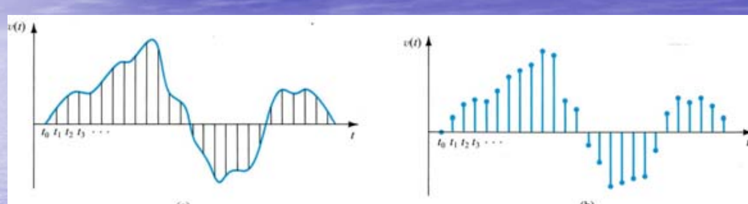

Original square wave
Fourier series (1 term)
Fourier series (2 terms)
Fourier series (5 terms)
+V
−V
T
t
0.5
0
-0.5
-1
0
5
10
15
20

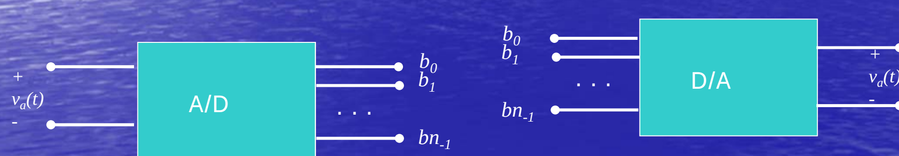

Frequency Spectrum
2 ways to represent the signals, time domain and frequency domain
$v_a(t)$ and $V_a(\omega)$
+V
−V
T
t
$\frac{4V}{\pi}$
$\frac{1}{3} \cdot \frac{4V}{\pi}$
$\frac{1}{5} \cdot \frac{4V}{\pi}$
$\frac{1}{7} \cdot \frac{4V}{\pi}$

Analog and Digital Signals

- The vast majority of signals in the real world are Analog
- The magnitude of analog signals can take on many values
- Discrete signals can take on a specific number of values
- Binary signals take on 2 vlaues (either 0 or 1).
- signals can be transformed to digital signal by sampling, quantization (representation)
- A/D and D/A are used to transform signals from Analog to digital and vise versa

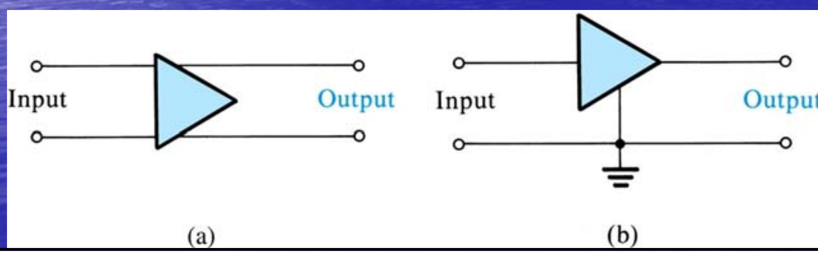
A/D and D/A



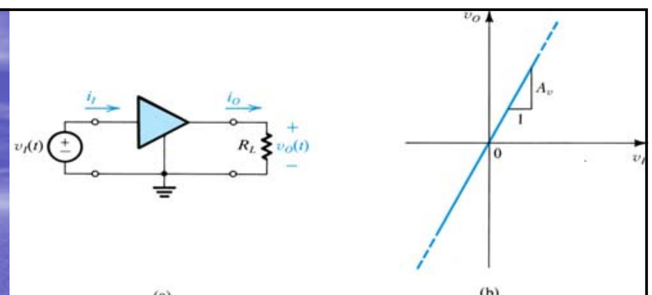


Amplifiers

- Usually transducers provides a very weak signal (mV or µV), we need to amplify it.
- if $v_i(t)$ is the input and $v_o(t)$ is the output then $v_0(t)=Av_i(t)$ where A is the amplifier gain.
- The above is a linear amplifier.
- Power amplifiers have a small voltage gain, but a large current gain.



Amplifiers



Voltage Gain

$$A_v = \frac{v_0}{v_i}$$
$$= 20 \, |A_v| \log$$

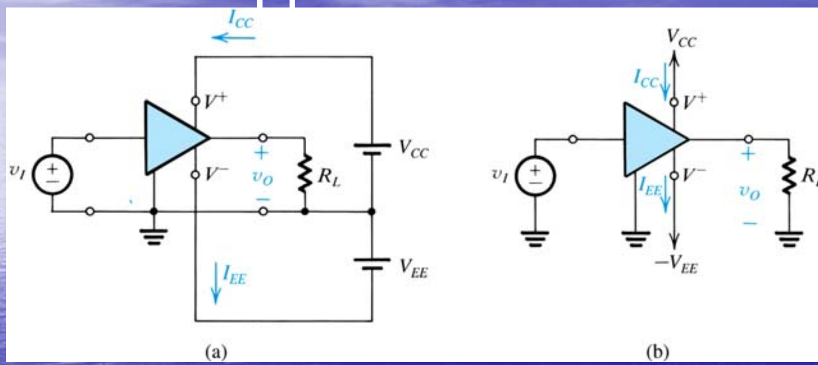
Power Gain

$$A_p = \frac{\text{Load Power}}{\text{Input Power}}$$
$$= \frac{v_0}{v_i}$$
$$= 10 \, |A_p| \log$$

Current Gain

$$A_i = \frac{i_0}{i_i}$$
$$= 20 \, |A_i| \log$$

Power supplies

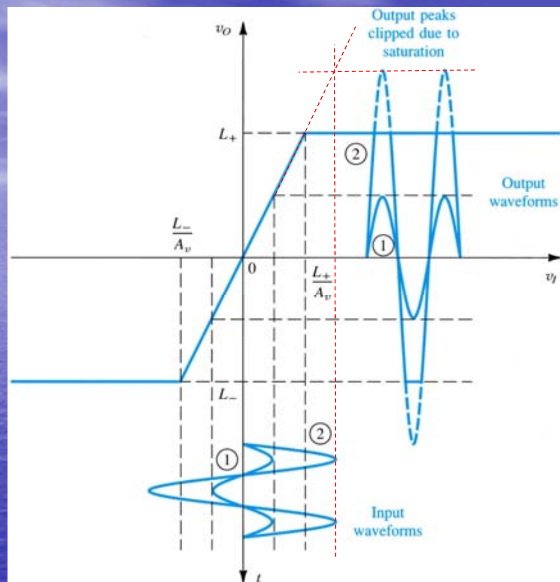


(ideal)

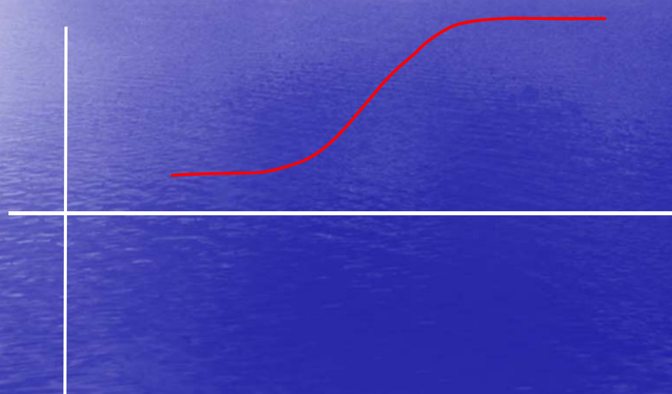
Simplified notations much less messy

Amplifier Saturation

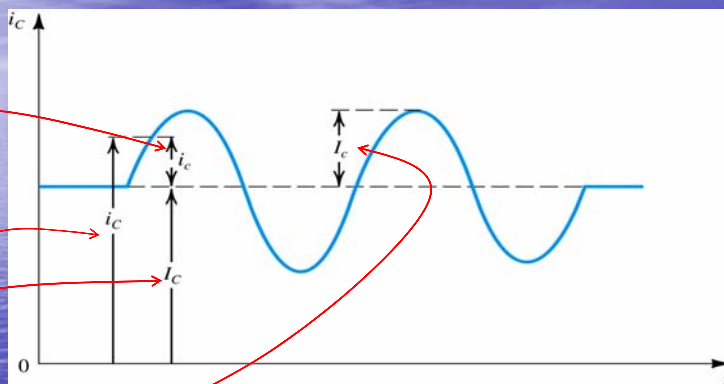
- The gain of the amplifier is over a small operating region.
- The output can not exceed the power supply limit
- if the amplifier is operated by 2 power supplies $+V_{CC}$ and -V_{EE}, the output is within that limit.
- Put a limit on the input signel, otherwise saturation occurs.



Nonlinear Transfer Characteristics

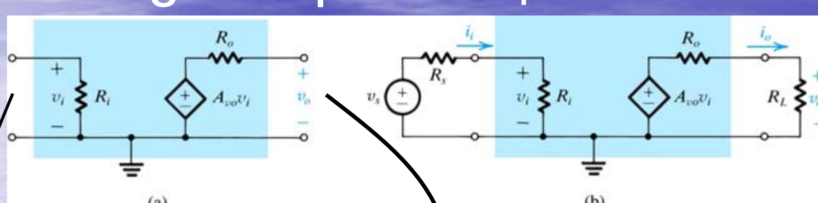


Symbols Convention

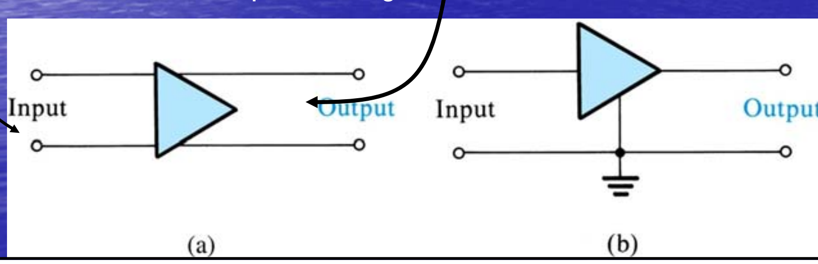


- Total instantaneous quantities lower case with upper case subscript.
- DC quantities, upper case with upper case subscript
- Time varying signal (no DC) quantities lower case with lower case subscript
- Sine wave, magnitude upper case with lower case subscript

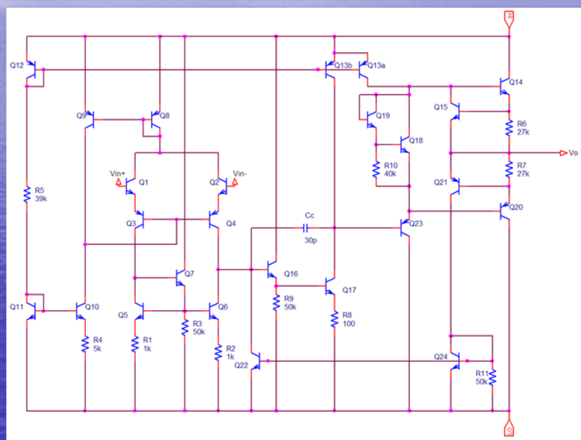
Voltage Amplifier Equivalent Circuit



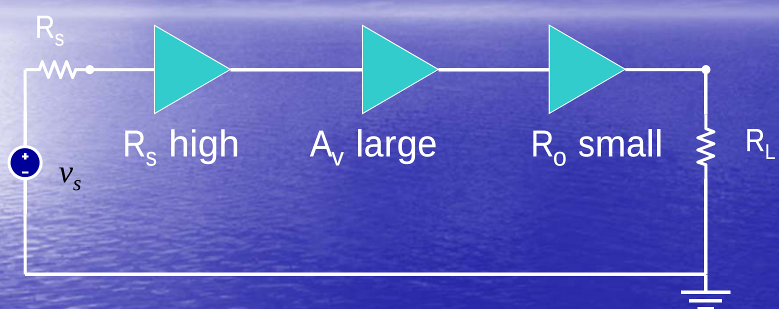
- Open circuit voltage gain.
- Effect of R_i and R_o on the gain



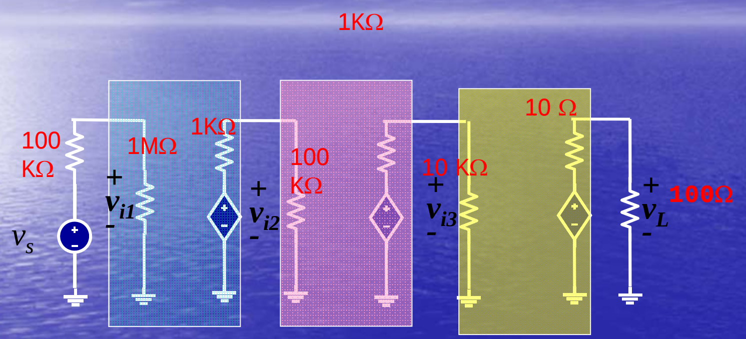
741 opamp



Multistage (cascaded) Amplifiers



Example Multistage Amplifiers

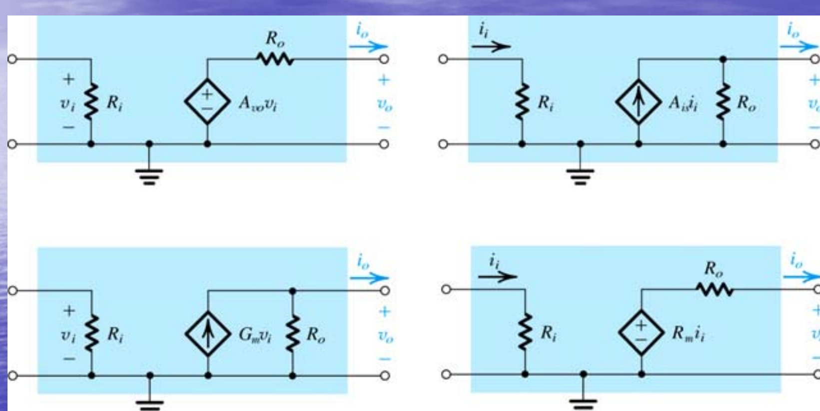


High R_{in} and a modest gain 10

High gain 100 and low input resistance

Unity gain and low output resistance

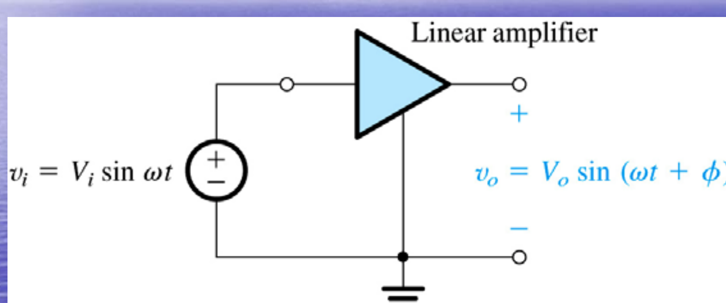
Other Amplifier Types



Frequency Response of an Amplifier

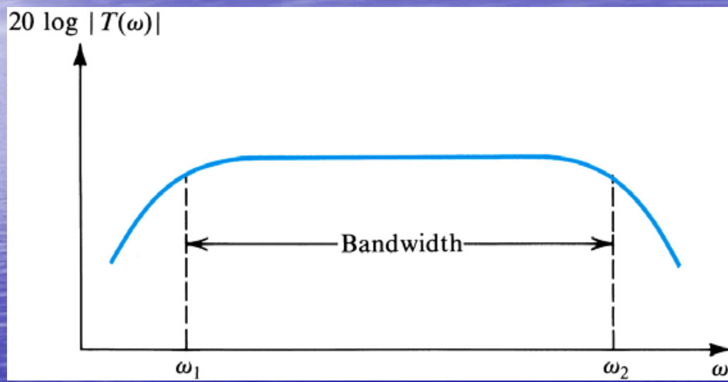
- For a linear system, if the input is a sine wave, the output is a sine wave with the same frequency.
- The amplitude and phase may be different
- Transfer function is the ratio of the output to the input as a function of frquency.

Frequency Response of an Amplifier

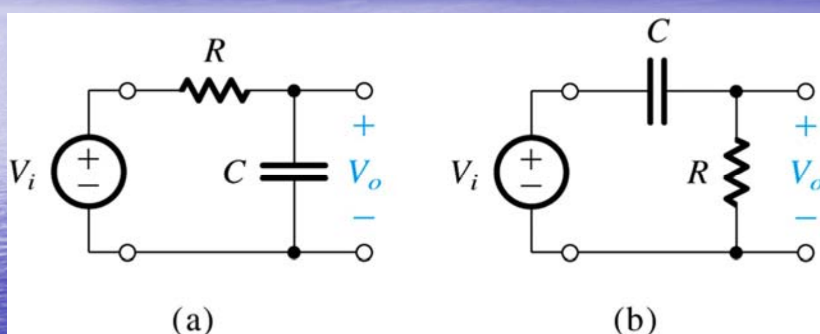


$$T(\omega), \text{ where } |T(\omega)| = \frac{V_o}{V_i}, \angle T(\omega) = \phi$$

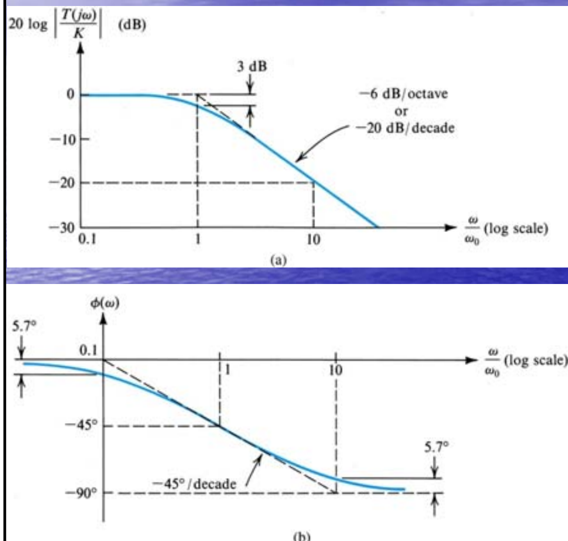
Amplifier Bandwidth



Single time Constant Networks Review (ENG2200)



Low Pass Filter



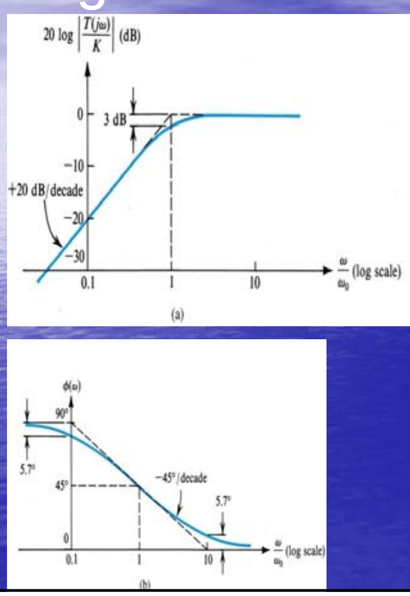
$$T(s) = \frac{K}{1+(s/\omega_0)}$$

$$T(j\omega) = \frac{K}{1+(\omega/\omega_0)}$$

$$|T(j\omega)| = \frac{K}{\sqrt{1+(\omega/\omega_0)^2}}$$

$$\angle T(j\omega) = -\tan^{-1}(\omega/\omega_0)$$

High Pass Filter

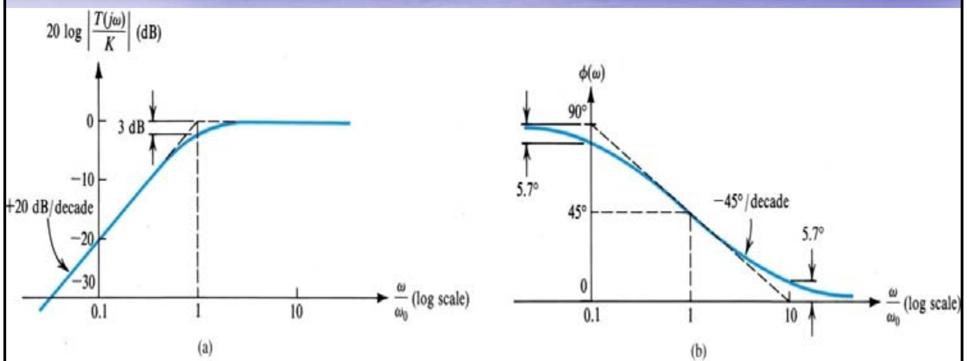


$$T(s) = \frac{Ks}{s+\omega_0}$$

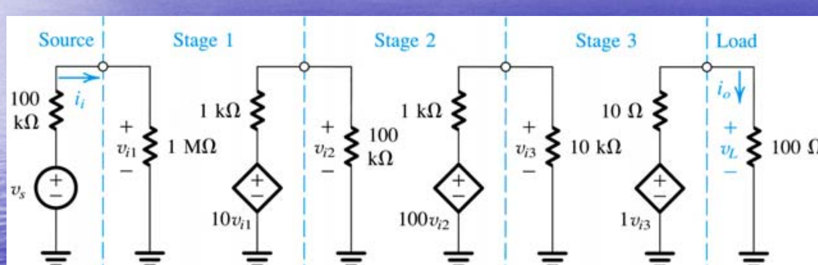
$$T(j\omega) = \frac{K}{1-(\omega_0/\omega)}$$

$$|T(j\omega)| = \frac{|K|}{\sqrt{1+(\omega_0/\omega)^2}}$$

$$\angle T(j\omega) = \tan^{-1}(\omega_0/\omega)$$


20 log |T(jω)/K| (dB)
0
3 dB
−10
+20 dB/decade
−20
−30
0.1
1
10
ω/ω0 (log scale)
(a)
φ(ω)
90°
5.7°
45°
−45°/decade
5.7°
0
0.1
1
10
ω/ω0 (log scale)
(b)

Example


Source
Stage 1
Stage 2
Stage 3
Load
100 kΩ
ii
vs
vi1
1 MΩ
1 kΩ
10vi1
vi2
100 kΩ
1 kΩ
100vi2
vi3
10 kΩ
10 Ω
1vi3
io
vL
100 Ω