Benha University
Faculty of Engineering at Shoubra

ECE-312
Electronic Circuits (A)

Lecture # 6
General Frequency Considerations

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Agenda

- Introduction
- Logarithms and Decibels
- General Frequency Considerations
- Normalization Process

INTRODUCTION

Introduction

- The analysis thus far has been limited to a particular frequency.
- We will now investigate the frequency effects introduced by the larger capacitive elements of the network at low frequencies and the smaller capacitive elements of the active device at high frequencies.
- Because the analysis will extend through a wide frequency range, the logarithmic scale will be defined and used throughout the analysis.
- In addition, because industry typically uses a decibel scale on its frequency plots, the concept of the decibel is introduced.

LOGARITHMS AND DECIBELS

Logarithms

- We use it to cover a wide range.

$$a = b^x, \qquad x = \log_b a$$

Common logarithm: $x = \log_{10} a$

Natural logarithm: $y = \log_e a$

$$\log_e a = 2.3 \log_{10} a$$

$\log_{10} 10^0$	$= 0$
$\log_{10} 10$	$= 1$
$\log_{10} 100$	$= 2$
$\log_{10} 1{,}000$	$= 3$
$\log_{10} 10{,}000$	$= 4$
$\log_{10} 100{,}000$	$= 5$
$\log_{10} 1{,}000{,}000$	$= 6$
$\log_{10} 10{,}000{,}000$	$= 7$
$\log_{10} 100{,}000{,}000$	$= 8$
etc.	

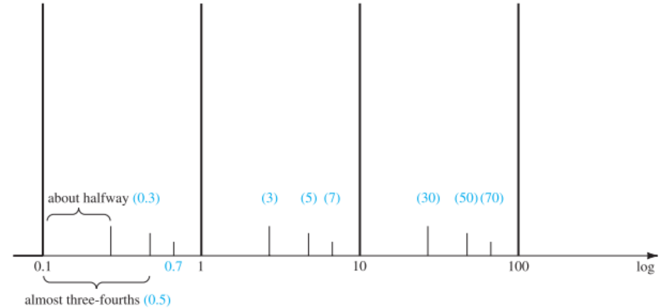
$$\log_{10} 1 = 0$$

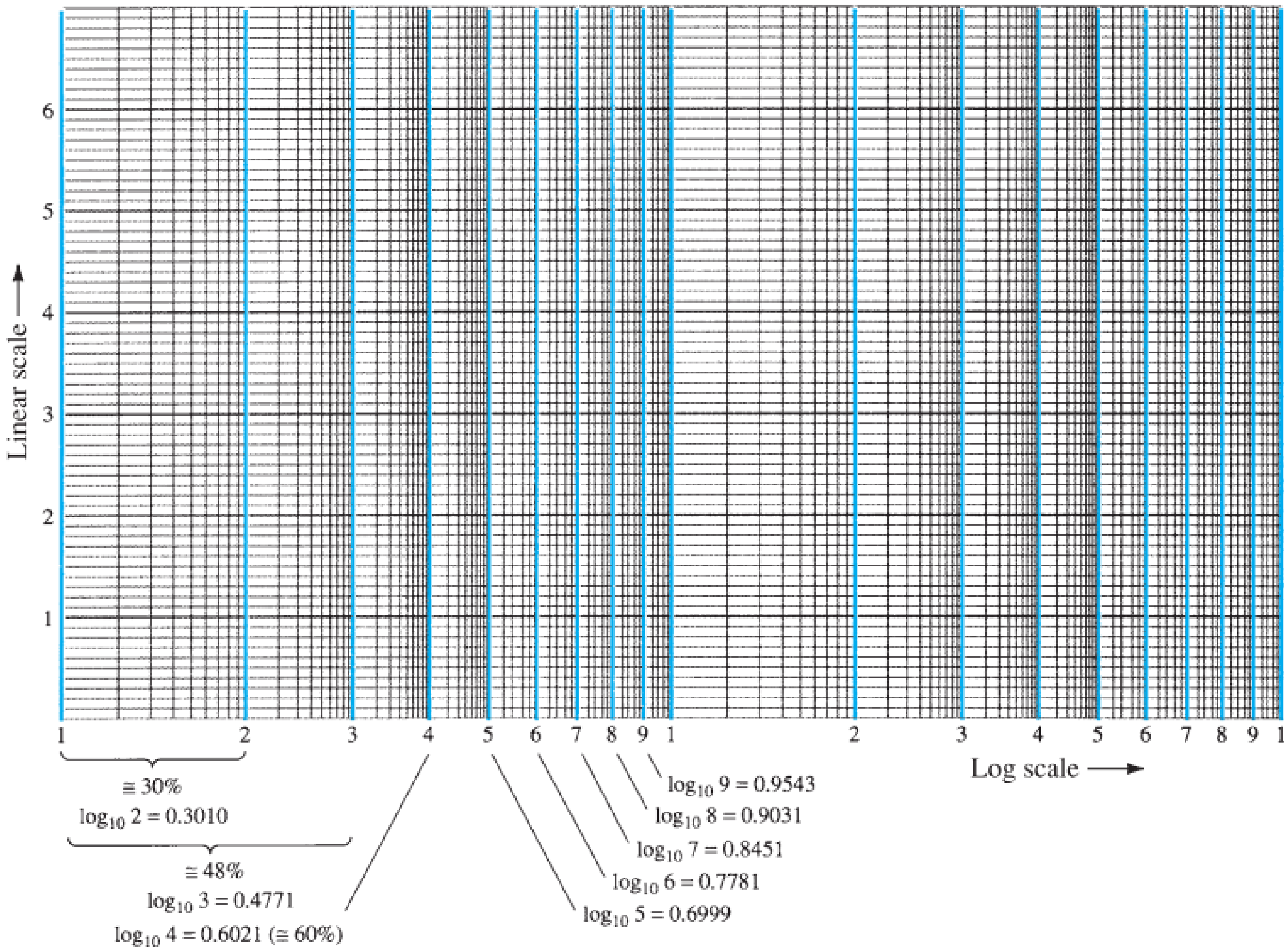
$$\log_{10} \frac{a}{b} = \log_{10} a - \log_{10} b$$

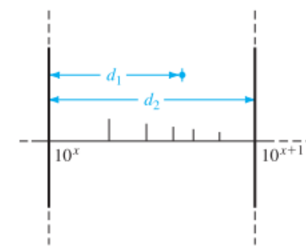
$$\log_{10} \frac{1}{b} = -\log_{10} b$$

$$\log_{10} ab = \log_{10} a + \log_{10} b$$

Semi-log graph paper







$$\text{Value} = 10^x \times 10^{d_1/d_2}$$

Decibels

- **Power Levels**

$$G = \log_{10}\frac{P_2}{P_1} \quad \text{bel}$$

$$G_{dB} = 10\log_{10}\frac{P_2}{P_1} \quad \text{dB}$$

$$G_{dBm} = 10\log_{10}\left.\frac{P_2}{1\text{ mW}}\right|_{600\,\Omega} \quad \text{dBm}$$

$$G_{dB} = 10\log_{10}\frac{P_2}{P_1} = 10\log_{10}\frac{V_2^2/R_i}{V_1^2/R_i} = 10\log_{10}\left(\frac{V_2}{V_1}\right)^2$$

$$G_{dB} = 20\log_{10}\frac{V_2}{V_1} \quad \text{dB}$$

- **Cascaded Stages**

$$|A_{v_T}| = |A_{v_1}|\cdot|A_{v_2}|\cdot|A_{v_3}|\cdots|A_{v_n}|$$

$$G_{dB_T} = G_{dB_1} + G_{dB_2} + G_{dB_3} + \cdots + G_{dB_n} \quad \text{dB}$$

- **Voltage Gains versus dB Levels**

Comparing $A_v = \frac{V_o}{V_i}$ *to dB*

Voltage Gain, V_o/V_i	dB Level
0.5	–6
0.707	–3
1	0
2	6
10	20
40	32
100	40
1000	60
10,000	80
etc.	

- Human Auditory Response !

GENERAL FREQUENCY CONSIDERATIONS

Low, High & Mid Frequency Range

Variation in $X_C = \frac{1}{2\pi f_C}$ with frequency for a 1-μF capacitor

f	X_C	
10 Hz	15.91 kΩ	Range of possible effect
100 Hz	1.59 kΩ	
1 kHz	159 Ω	
10 kHz	15.9 Ω	
100 kHz	1.59 Ω	Range of lesser concern (≅ short-circuit equivalence)
1 MHz	0.159 Ω	
10 MHz	15.9 mΩ	
100 MHz	1.59 mΩ	

Variation in $X_C = \frac{1}{2\pi fC}$ with frequency for a 5 pF capacitor

f	X_C	
10 Hz	3,183 MΩ	Range of lesser concern (≅ open-circuit equivalent)
100 Hz	318.3 MΩ	
1 kHz	31.83 MΩ	
10 kHz	3.183 MΩ	
100 kHz	318.3 kΩ	Range of possible effect
1 MHz	31.83 kΩ	
10 MHz	3.183 kΩ	
100 MHz	318.3 Ω	

- The larger capacitors of a system will have an important impact on the response of a system in the low-frequency range and can be ignored for the high-frequency region.
- The smaller capacitors of a system will have an important impact on the response of a system in the high-frequency range and can be ignored for the low-frequency region.
- The effect of the capacitive elements in an amplifier are ignored for the mid-frequency range when important quantities such as the gain and impedance levels are determined.

Typical Frequency Response

$$P_{o_{mid}} = \frac{|V_o^2|}{R_o} = \frac{|A_{v_{mid}} V_i|^2}{R_o}$$

$$P_{o_{HPF}} = \frac{|0.707\, A_{v_{mid}} V_i|^2}{R_o} = 0.5\, \frac{|A_{v_{mid}} V_i|^2}{R_o}$$

$$P_{o_{HPF}} = 0.5\, P_{o_{mid}}$$

$$\text{bandwidth (BW)} = f_H - f_L$$

The band frequencies define a level where the gain or quantity of interest will be 70.7% of its maximum value.

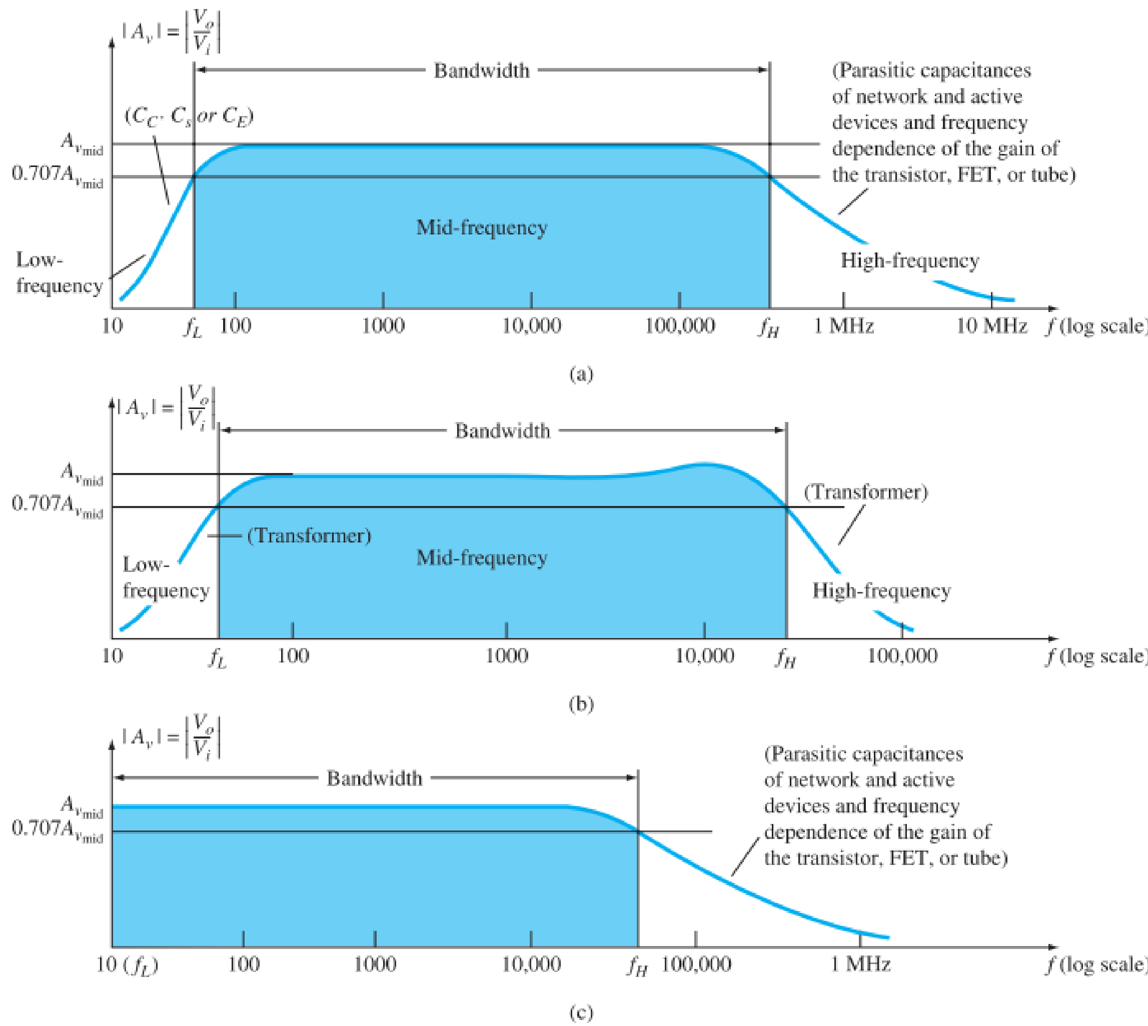


FIG. 9.8

Gain versus frequency: (a) RC-coupled amplifiers; (b) transformer-coupled amplifiers; (c) direct-coupled amplifiers.

NORMALIZATION PROCESS

- Normalized plot

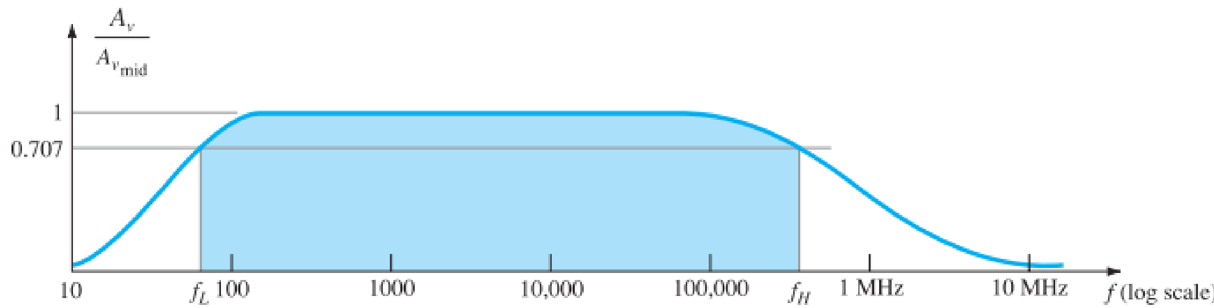


FIG. 9.9
Normalized gain versus frequency plot.

- Decibel plot

$$\left.\frac{A_v}{A_{v_{mid}}}\right|_{dB} = 20 \log_{10} \frac{A_v}{A_{v_{mid}}}$$

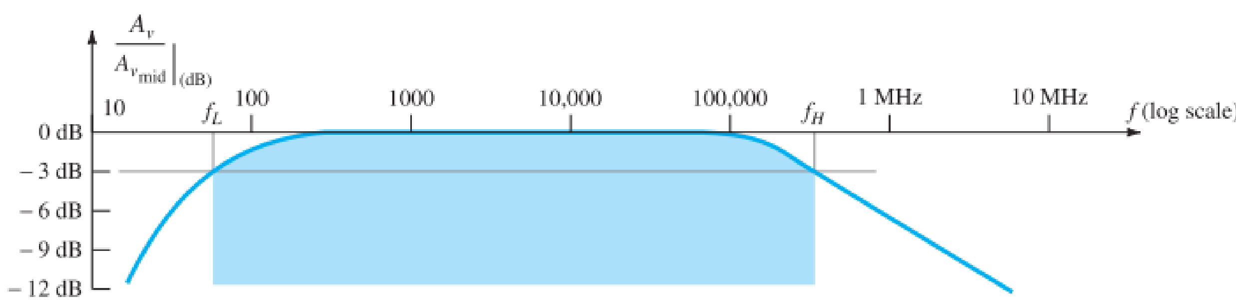


FIG. 9.12
Decibel plot of the normalized gain versus frequency plot of Fig. 9.9.

- Phase plot

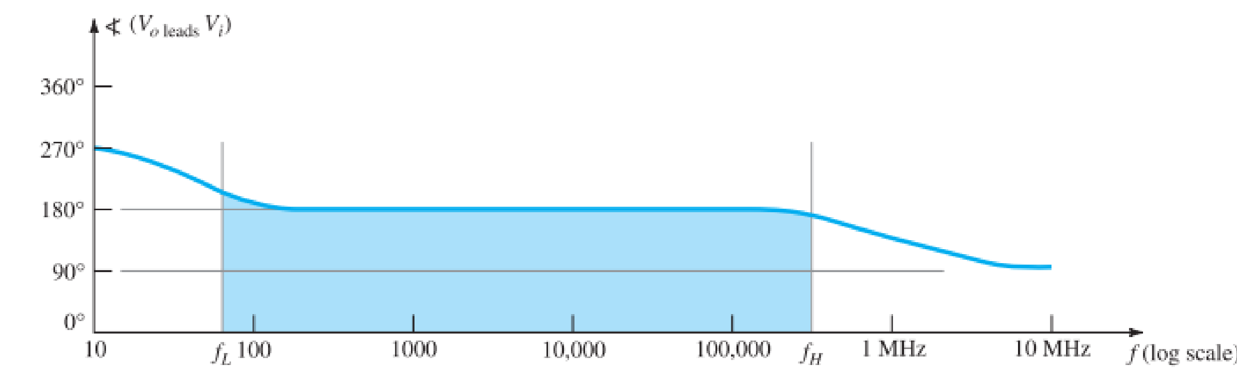


FIG. 9.13
Phase plot for an RC-coupled amplifier system.

- For more details, refer to:
  - Chapter 9 at R. Boylestad, **Electronic Devices and Circuit Theory**, 11th edition, Prentice Hall.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/11966
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg