

ME 133 lecture 10

2/3/2022

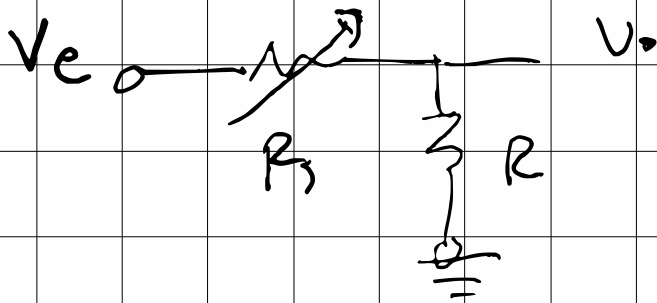
Midterm Review

Exam structure:

- 4-5 problems (1 hr 20)
- no numeric calculations
- two sheets
- mix of conceptual & symbolic derivations

# Correction from last time

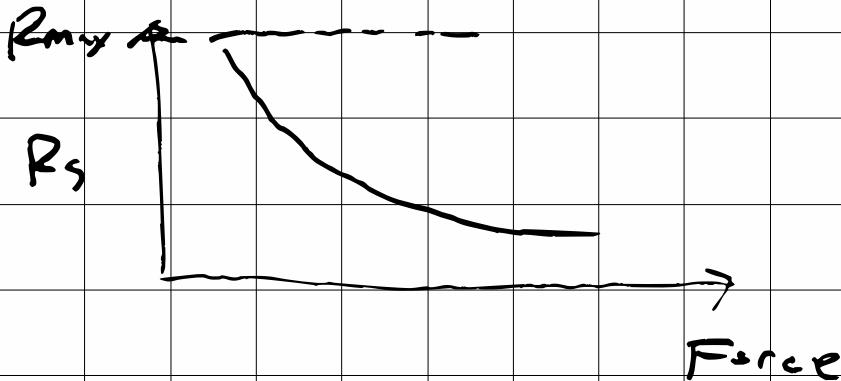
Zero-order systems example FSR.



$$\frac{V_o}{V_e} = \left( \frac{R}{R_s + R} \right)$$

Input: Force

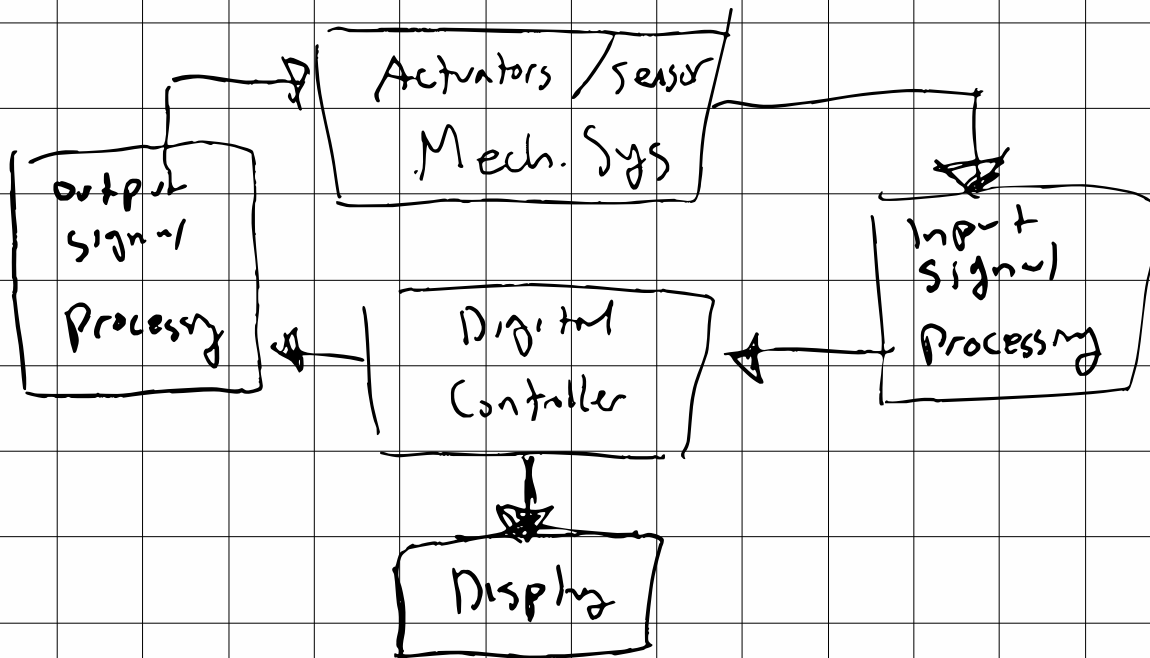
force sensitive resistor



$$\frac{V_o}{F_{in}} = \underbrace{[f(F_{in})]}_{\text{gain}} \cdot V_e$$

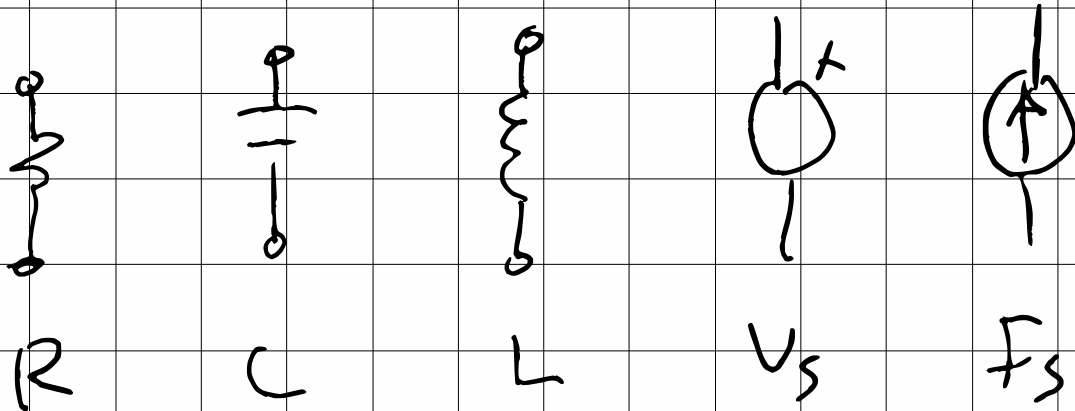
Want to do complicated stuff like this  
on midterm: potentiometer.

# 1. Overview of Mechatronic System.



## 2. Circuits

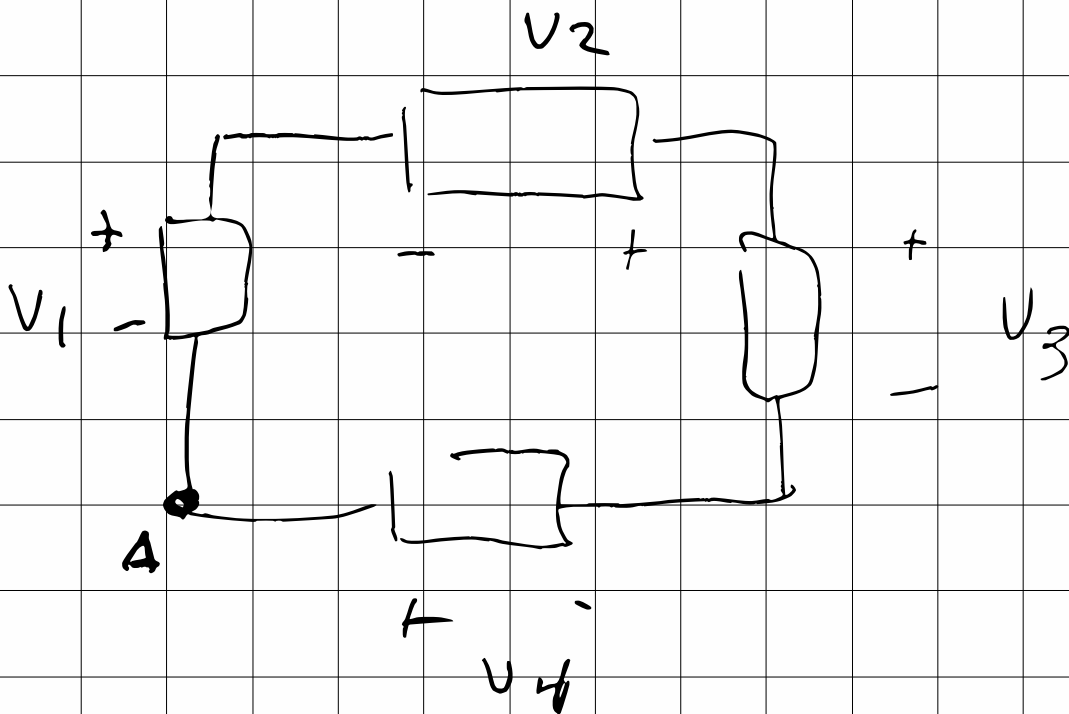
### • Basic components



# Kirchoff's Laws

KVL: voltage Law:

$$\sum_{i=1}^N V_i = 0$$

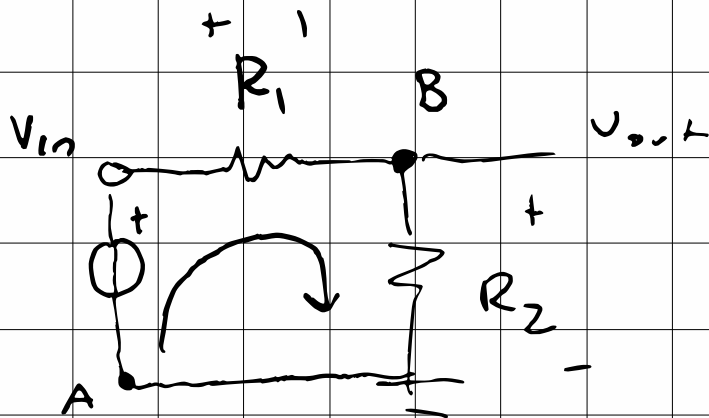
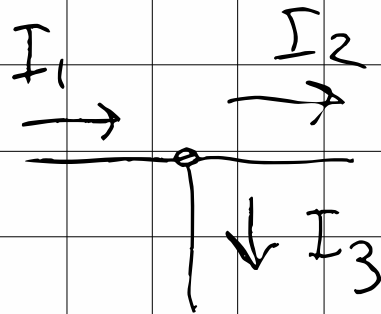


$$-V_1 - V_2 + V_3 - V_4 = 0$$

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Current Law : KCL :

$$\sum_{i=1}^N I_i = 0$$



1. KVL :

$$-V_{in} + V_{R_1} + \overbrace{V_{R_2}}^{V_{out}} = 0$$

2. KCL :  $I_{R_1} = I_{R_2} \Rightarrow \frac{V_{R_1}}{R_1} = \frac{V_{R_2}}{R_2}$

$$V_{in} = \left( \frac{R_1}{R_2} + 1 \right) V_{out} \rightarrow \frac{V_{out}}{V_{in}} = \left( \frac{R_2}{R_1 + R_2} \right)$$

$V_{R_1} = \frac{R_1}{R_2} V_{R_2}$

1. KVL:

$$-V_{in} + V_{R_1} + \overbrace{V_{R_2}}^{V_{out}} = 0$$

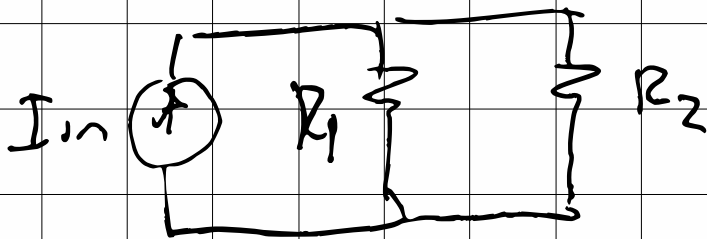
2. KCL:  $I_{R_1} = I_{R_2} \Rightarrow \frac{V_{R_1}}{R_1} = \frac{V_{R_2}}{R_2}$

$$V_{in} = \left(\frac{R_1}{R_2} + 1\right) V_{out} \rightarrow \frac{V_{out}}{V_{in}} = \left(\frac{R_2}{R_1 + R_2}\right)$$

Voltage divider.

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Current divider:



KVL:  $V_{in} = V_{R_1} = V_{R_2}$

KCL:  $I_{in} = I_{R_1} + I_{R_2}$

$\Rightarrow \frac{I_{out}}{I_{in}} = \frac{R_1}{R_1 + R_2}$

# • Equivalent Circuit analysis

→ Thevenin

→ Norton

Thevenin :



Norton



# AC - analysis

$$V = V_m e^{j(\omega t + \phi)}$$

↑                      ↑  
mag.                      phase

$$= V_m \angle \phi$$

Ohm's Law generalize for AC:

$$V = Z I$$

↑  
Impedance

$$Z = f(\omega)$$

Know how to derive

$$Z_C = \frac{1}{j\omega C}, \quad Z_L = Lj\omega, \quad Z_R = R$$

Transformers :

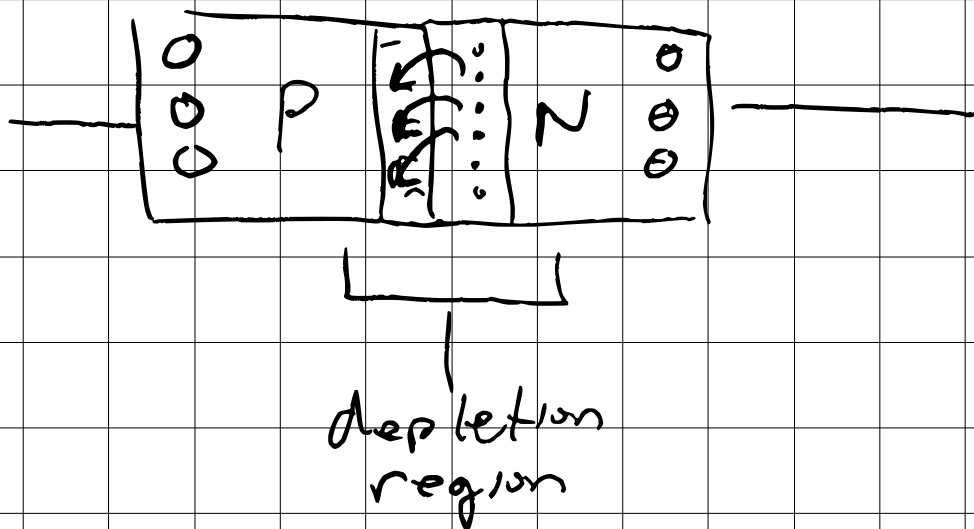
$$V_s = \frac{N_s}{N_p} V_p$$

$$I_s = \frac{N_p}{N_s} I_p$$

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Ch. 3 semiconductor

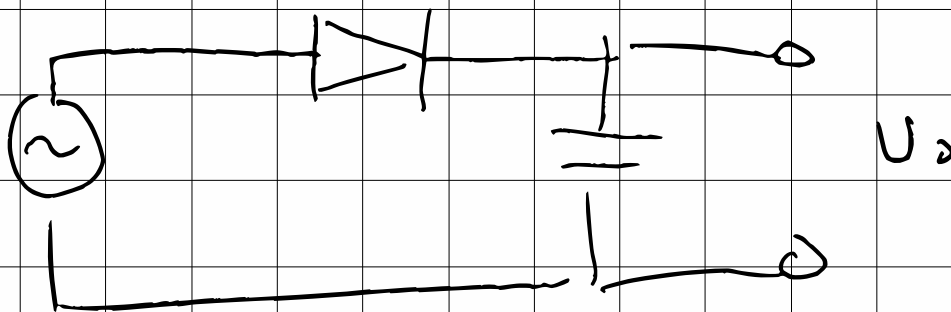
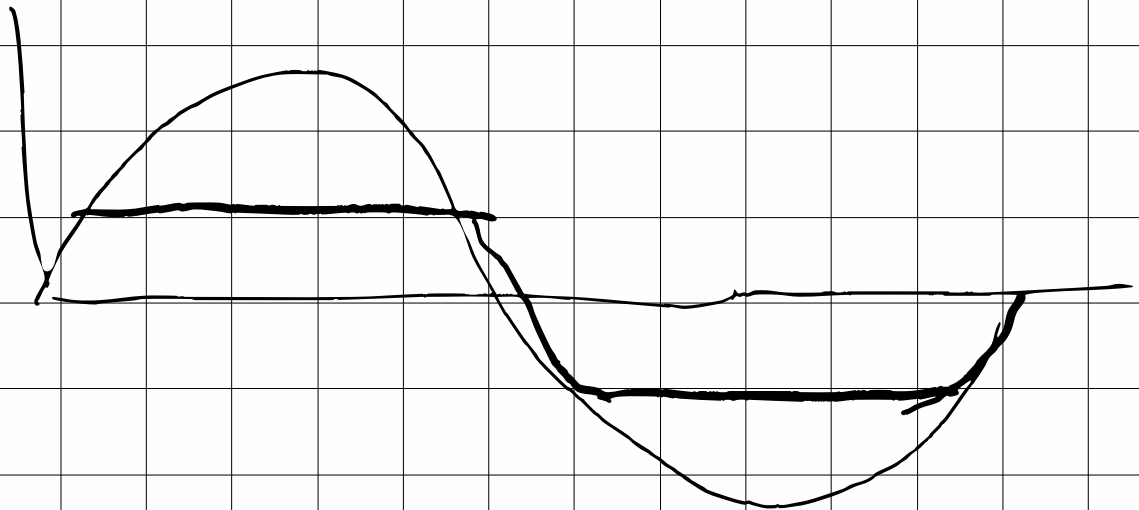
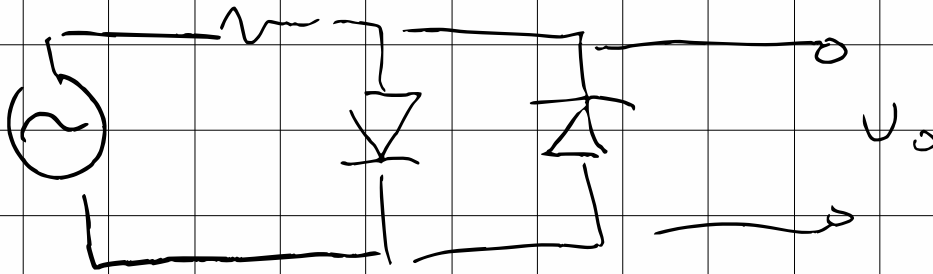
a. Know basis physics  
(conceptually)

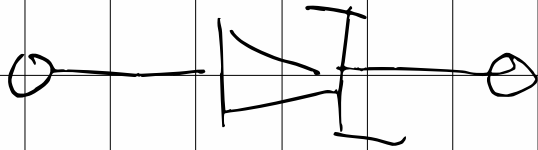


contact potential 0.7 V

- Reverse bias  
 $U_S$   
forward bias

- Know basic circuits

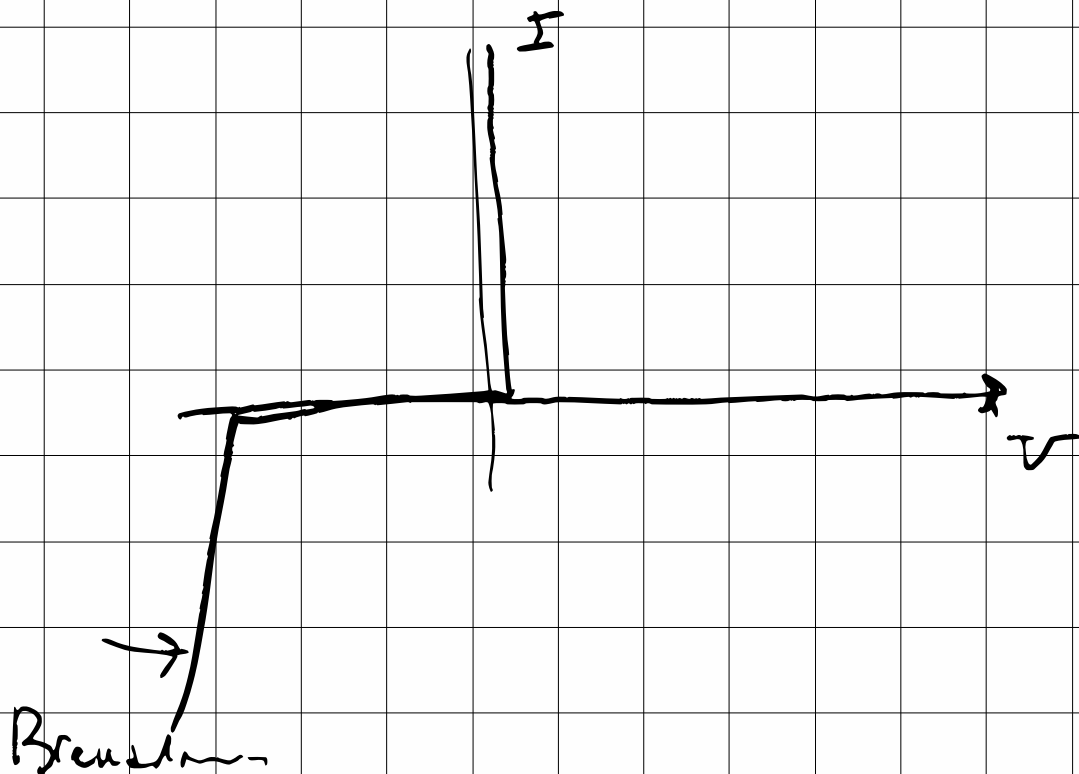


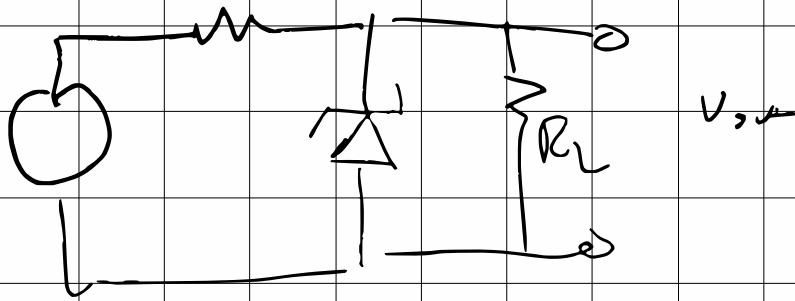


• operating principle :

→ design to operate in the Break down region

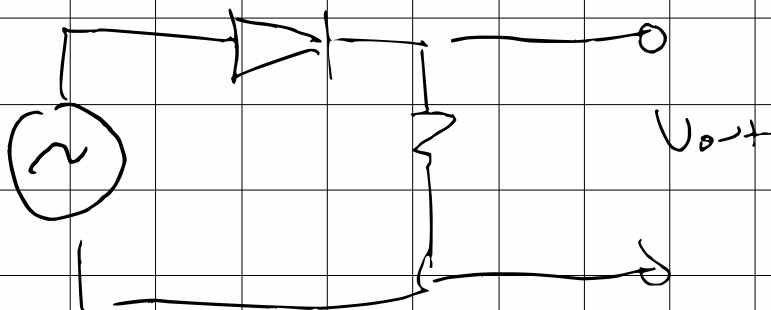
F.g. 3.6 4th



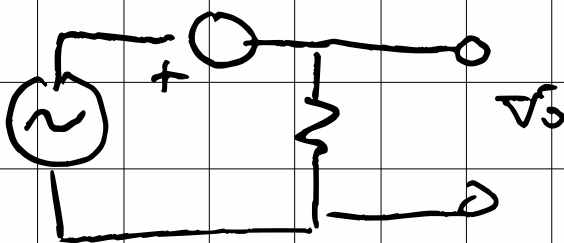


- Know how to analyze

- ideal model vs diode assumption model

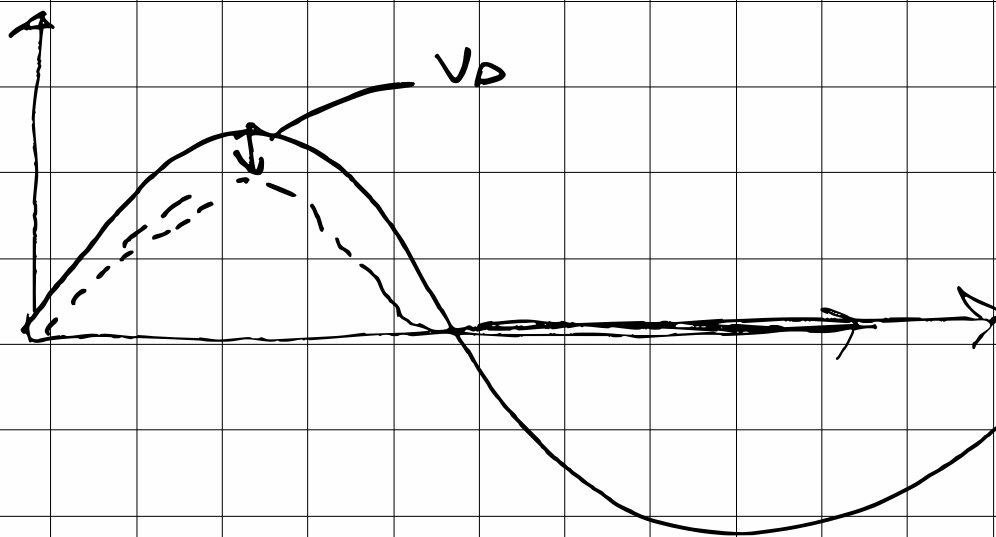


$$V_s > V_D$$



$$V_o = V_s - V_D$$

0.7V



• Transistors

→ Function

- amplification
- Switch.

→ BJT & FETs

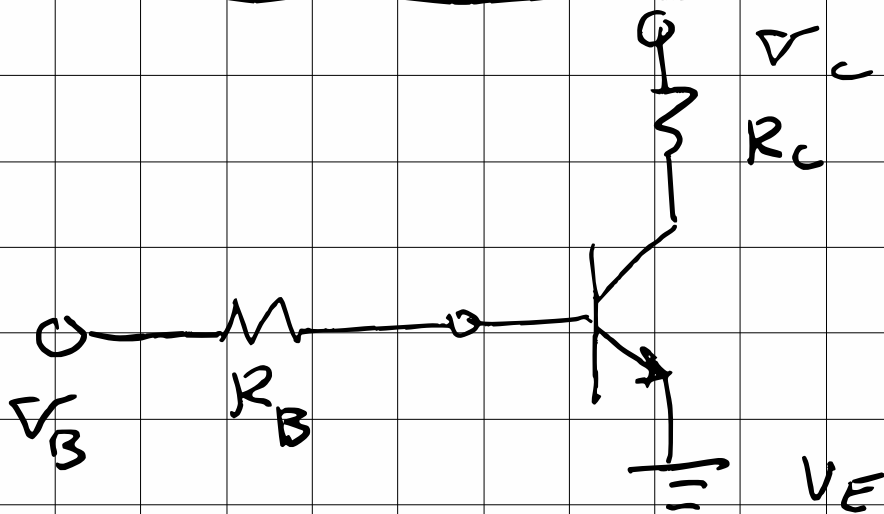
• What difference?

BJT: current controlled

FET: voltage controlled

→ only use about NPN (BJT)  
N-channel (FET)

## common-emitter circuit



When is it on?

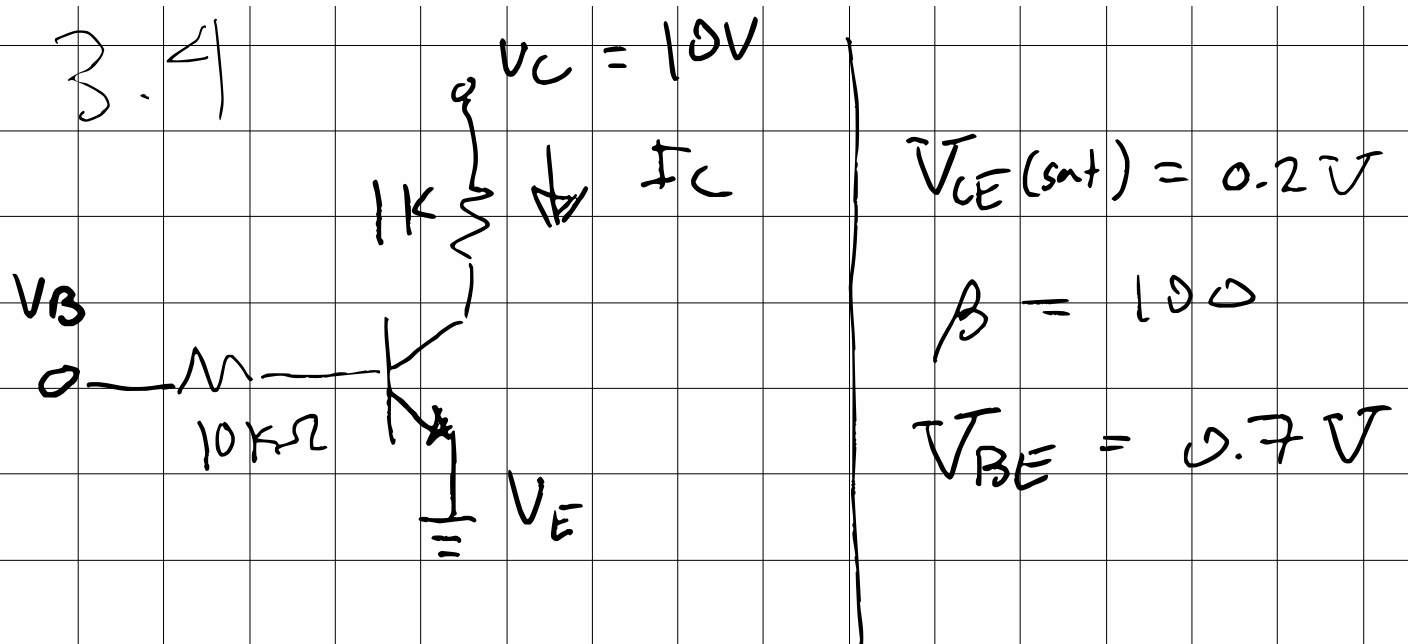
$$V_B = V_E + \underbrace{0.7 \text{ V}}_{\text{bias voltage}}$$
$$V_C \geq V_B$$

Know how to choose  $R_B$   
for saturation.

$$I_{B_{\min}} \approx \frac{I_C}{\beta}$$

$h_{FE}$   
DC gain

$$I_B = I_{B_{\min}} \times 10$$



Find  $V_B$  to saturate BJT.

$$I_C = \frac{V_C - V_{CE}}{R_C} = \frac{10V - 0.2V}{1k\Omega}$$

$$= 9.8mA$$

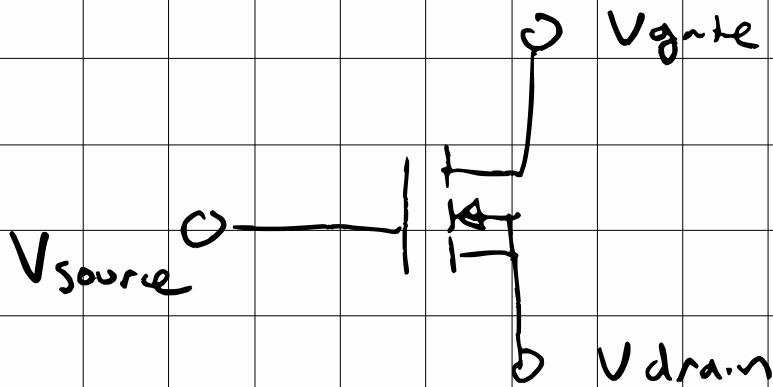
$$I_{Bmin} = \frac{I_C}{\beta} = 0.098mA$$

$$V_{Bmin} = I_{Bmin} \cdot R_B + V_{BE}$$

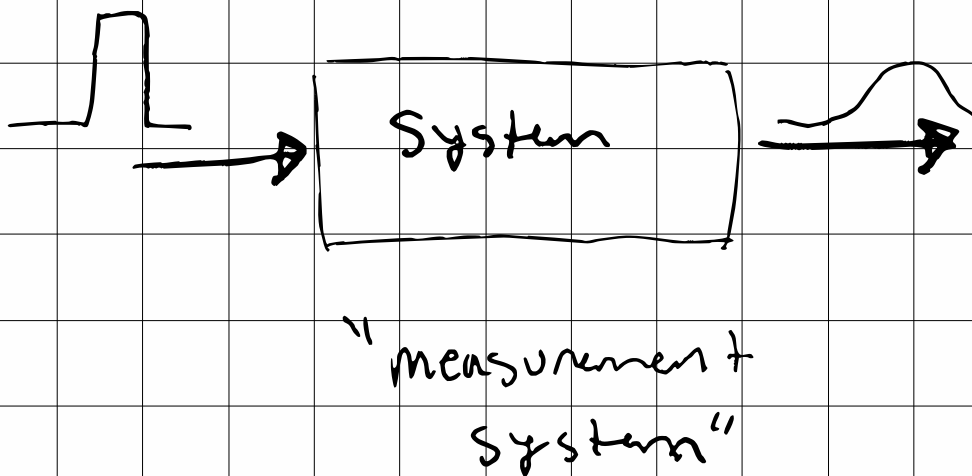
$$= 0.098mA \cdot 10k\Omega + 0.7V$$

$$= \underline{1.68V}$$

# • FET Basics



Ch. 4.



What makes good measurement systems?

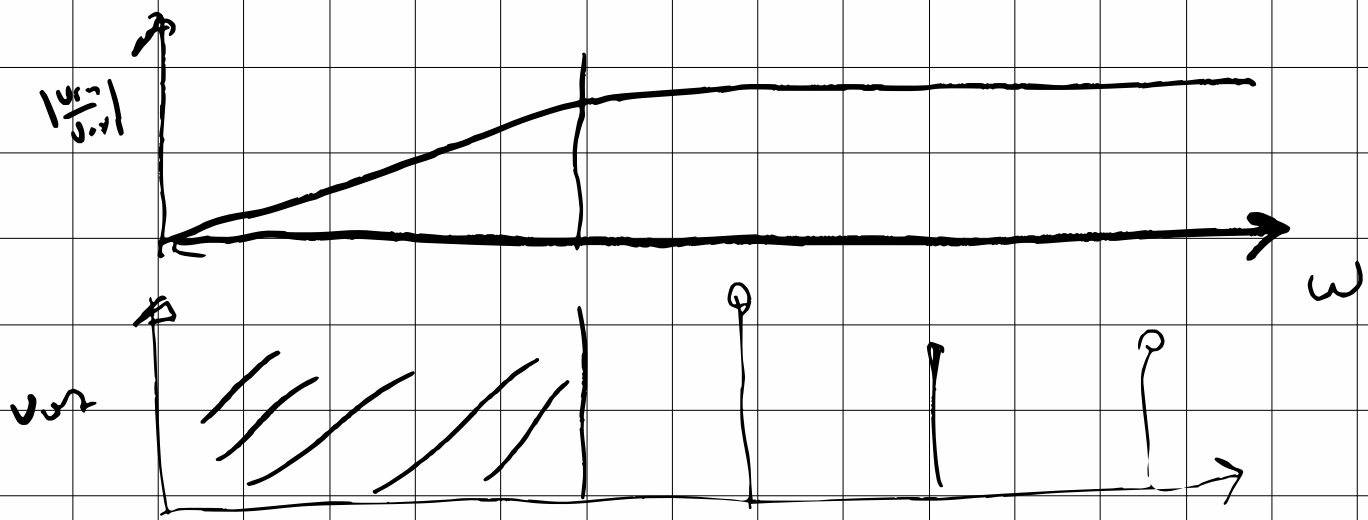
- Amplitude linearity
- Bandwidth
- Phase linearity



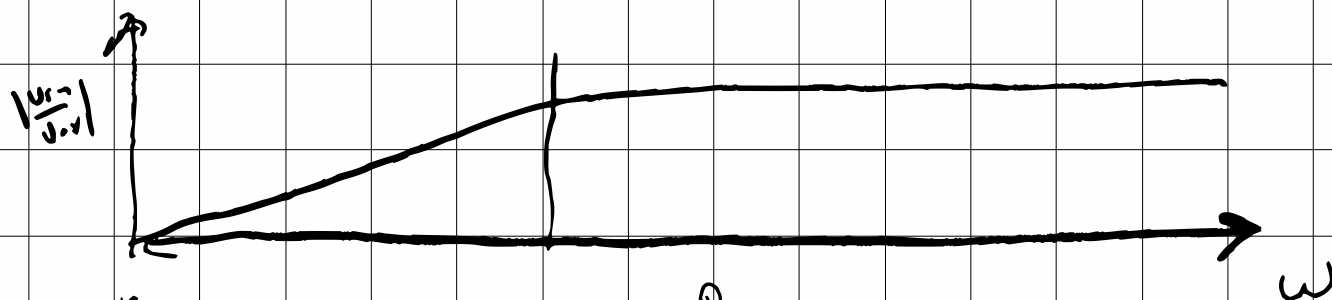
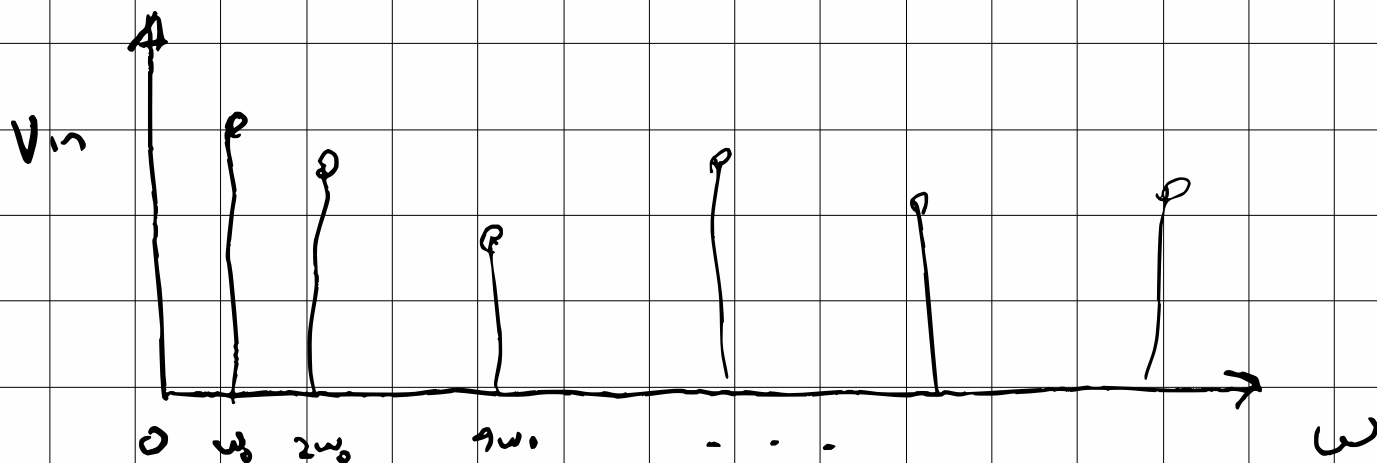
- Fourier Analysis

$$\omega_0 = \frac{2\pi}{T} = 2\pi f_0$$

- Interpret Signal Spectrum



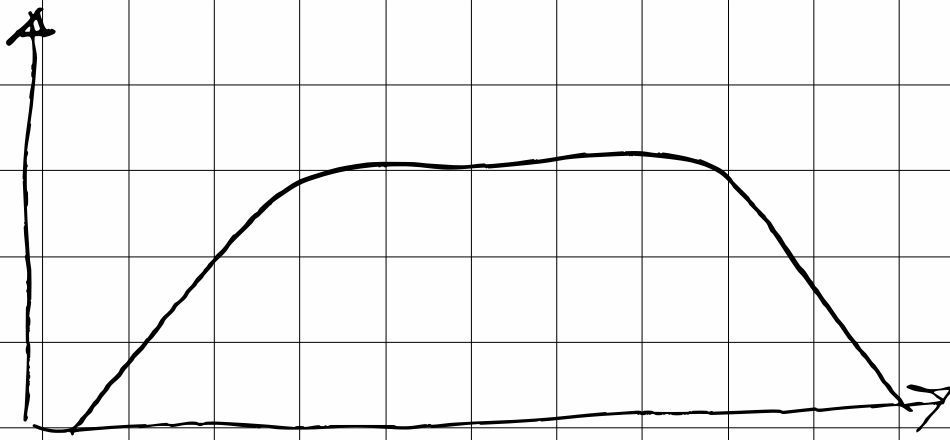
# Interpret Signal Spectrum



decibels:

$$dB = 20 \log_{10} \left( \frac{A_{out}}{A_{in}} \right)$$

$$60 \text{ dB} \rightarrow A_{out} = 1000 \cdot A_{in}$$



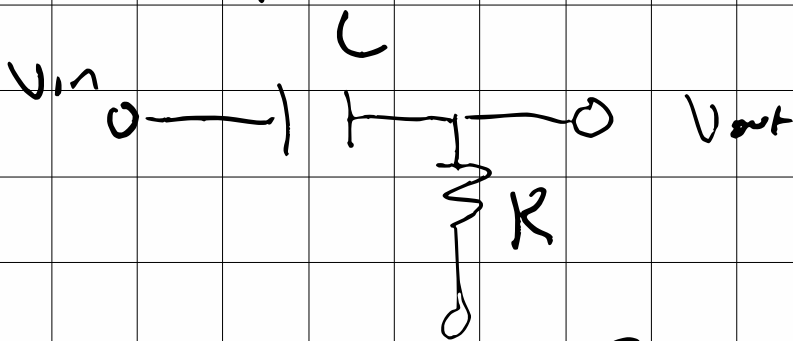
What's the Bandwidth.

- Why is -3dB significant.

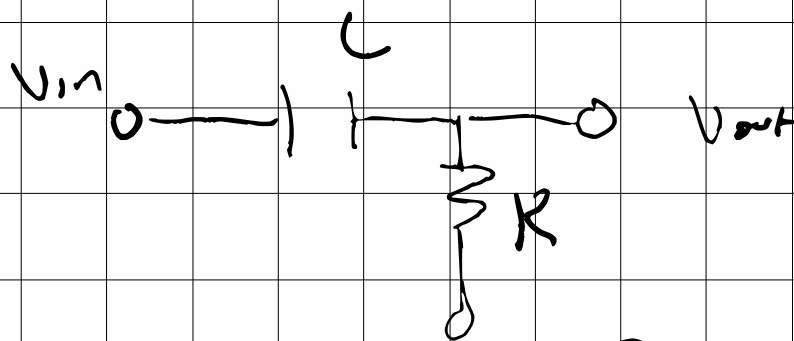
$$\frac{P_{out}}{P_{in}} = \frac{1}{2} \Rightarrow \frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{2}} = 0.707$$


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Example: What is the cutoff freq?



$$\frac{V_{out}}{V_{in}} = \frac{Z_R}{Z_L + Z_R}$$



$$\frac{V_{out}}{V_{in}} = \frac{Z_R}{Z_C + Z_R}$$

$$\frac{V_{out}}{V_{in}} = \frac{R}{\frac{1}{j\omega C} + R} = \frac{j\omega RC}{j\omega RC + 1}$$

$$\left| \frac{V_{out}}{V_{in}} \right| = \frac{\omega RC}{\sqrt{1 + (\omega RC)^2}} = \frac{1}{\sqrt{2}}$$

$$\omega = \left| \frac{1}{RC} \right| = \omega_c$$

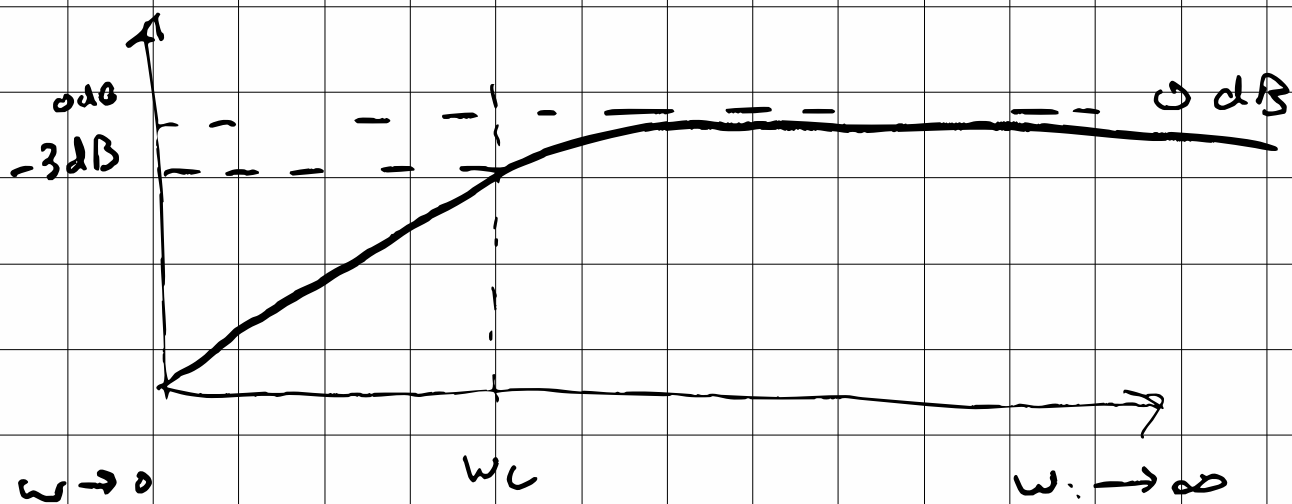
$$\omega \rightarrow 0 \quad \left| \frac{V_{out}}{V_{in}} \right| \rightarrow 0$$

$$\omega \rightarrow \infty \quad \left| \frac{V_{out}}{V_{in}} \right| \rightarrow 1$$

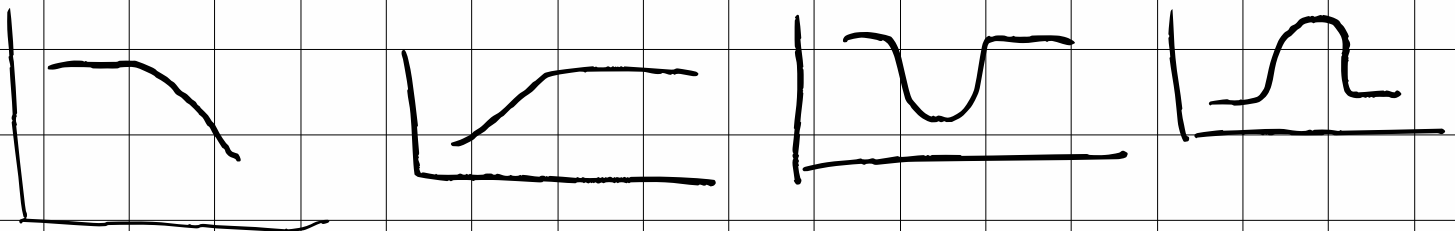
$$\omega = \left| \frac{1}{R_C} = \omega_c \right|$$

$$\omega \rightarrow 0 \quad \left| \frac{V_{out}}{V_{in}} \right| \rightarrow 0$$

$$\omega \rightarrow \infty \quad \left| \frac{V_{out}}{V_{in}} \right| \rightarrow 1$$



Should be able to identify the four filter types



- Phase Inver. by

$$\phi = K - f$$

- Zero-order system

$$X_{out} = \left( \frac{B_0}{A_0} \right) X_{in}$$

↑ sensitivity or gain.

- first order systems

$$\tau \dot{X}_{out} + X_{out} = K X_{in}$$

→ Step response:

show:  $X_{out} = K A_m \left( 1 - e^{-t/\tau} \right)$

→ system ID