ME 133 2/14/23

# Lecture 10 - midterm Review

## Exam structure

- 4 - 5 problems
- no numeric calculations
- Closed book
- front / back sheet of notes (1 page)
- mix of conceptual & symbolic derivations.

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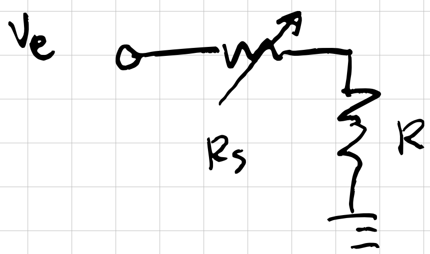
OFFICE HOURS by email first
9 - 6pm. except. 3-4pm.

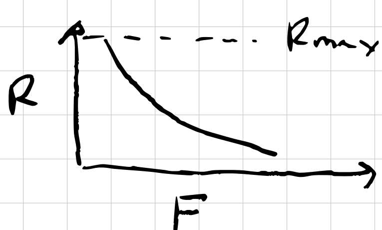
# Correction from Last Lecture

Zero-order system example:

Force sensitive resister



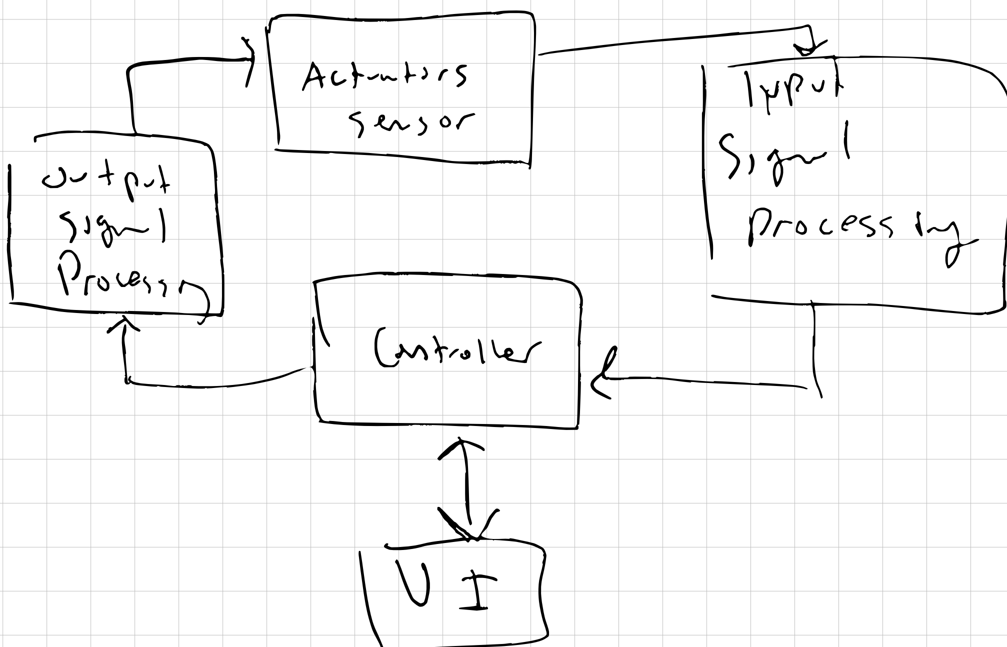

$$\frac{V_o}{V_e} = \frac{R}{R_s + R}$$



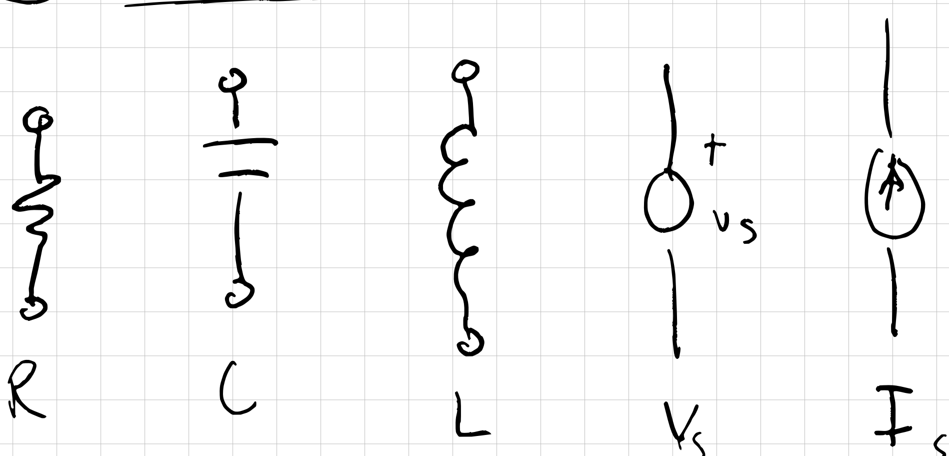

$$\frac{V_o}{\cancel{F_{in}}} = \underbrace{\tilde{f}(F_{in}) \cdot V_e}_{\text{gain}}$$

gain: nonlinear but static → doesn't change w/ time

# ① Overview of Mechatronics

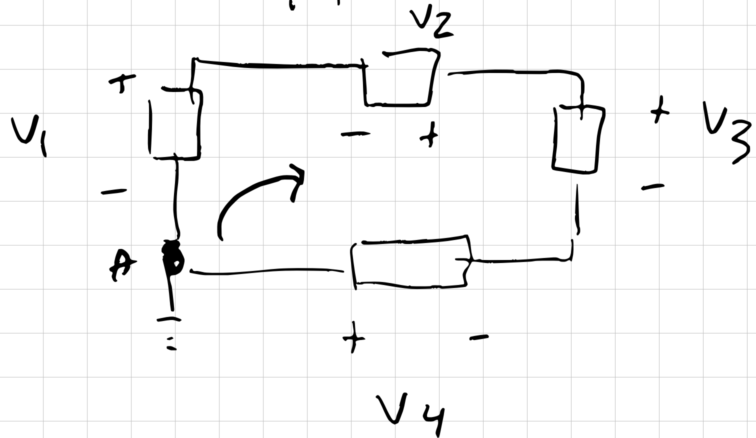



# ② Basic Circuits



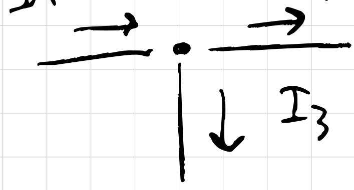
# Kirchoff's Laws

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



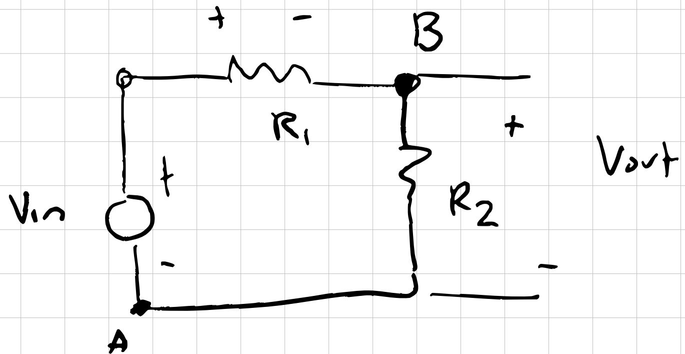

$-V_1 - V_2 + V_3 - V_4 = 0$

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




$I_1 = I_2 + I_3$

Find $V_{out}$?




1. KVL: $-V_{in} + V_{R_1} + \overbrace{V_{R_2}}^{V_{out}} = 0$

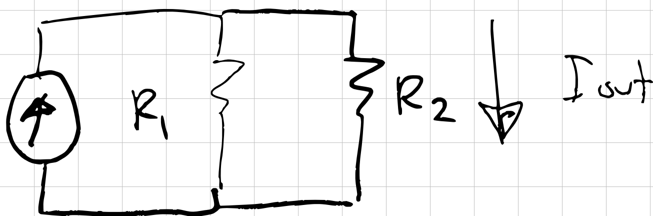
2. KCL: $I_{R_1} = I_{R_2}$

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

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

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

# Current Divider



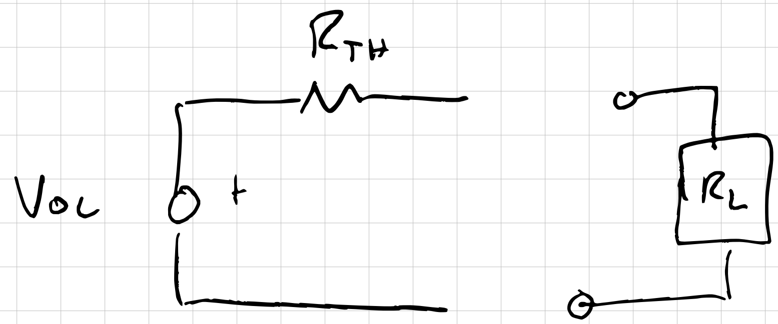

KVL: $V_{in} = V_{R_1} = V_{R_2}$

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

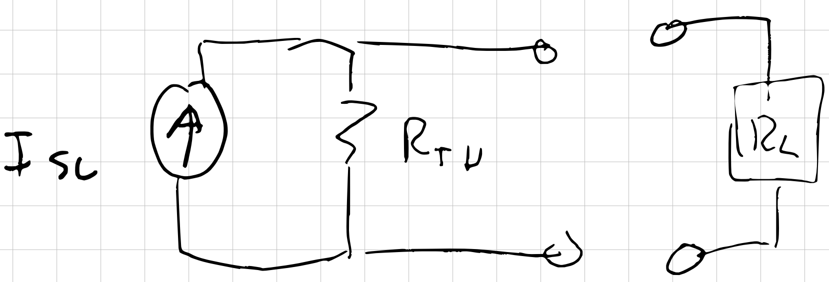
$$\frac{I_{out}}{I_{in}} = \frac{R_1}{R_1 + R_2}$$

- Equivalent Circuit Analysis
  - → Thevenin
  - → Norton

Thevenin:




Norton



# AC- Analysis

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

$$= V_m \angle \phi$$

$$= V_m \sin(wt + \phi)$$

Ohm's Law generalized:

$$V = Z I$$

$Z$ ← impedance

$$Z = f(w)$$

$$Z_C = \frac{1}{jwC}, \quad Z_L = Ljw, \quad Z_R = R$$

## Transformers

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

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

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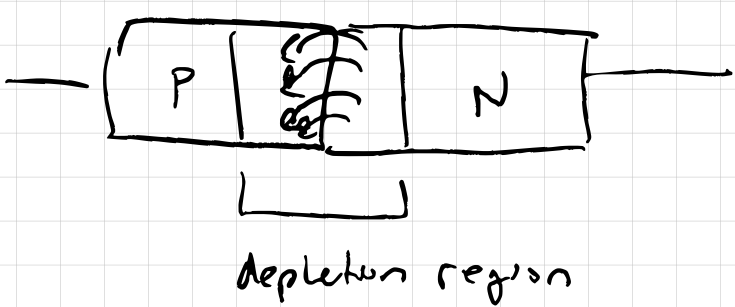
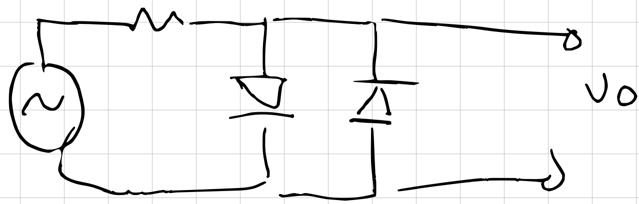
## Ch. 3 Semiconductors



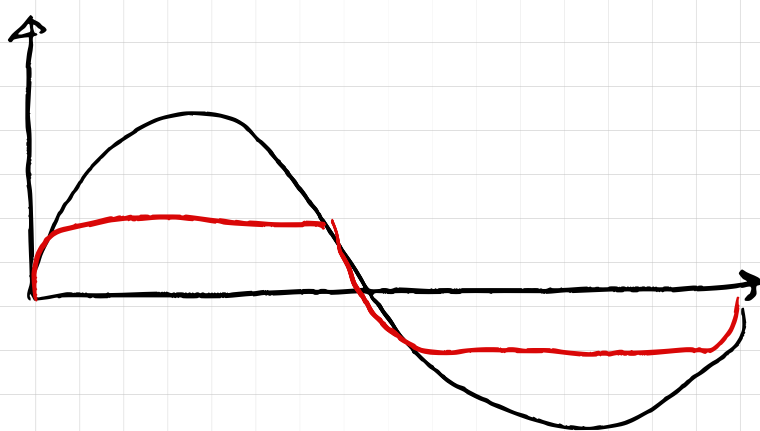

contact potential $0.7\ V$

- Reverse bias vs forward bias

- Know basic circuits




Draw the output in $V_{in} = \sin(\omega t)$



ideal vs approximate model.

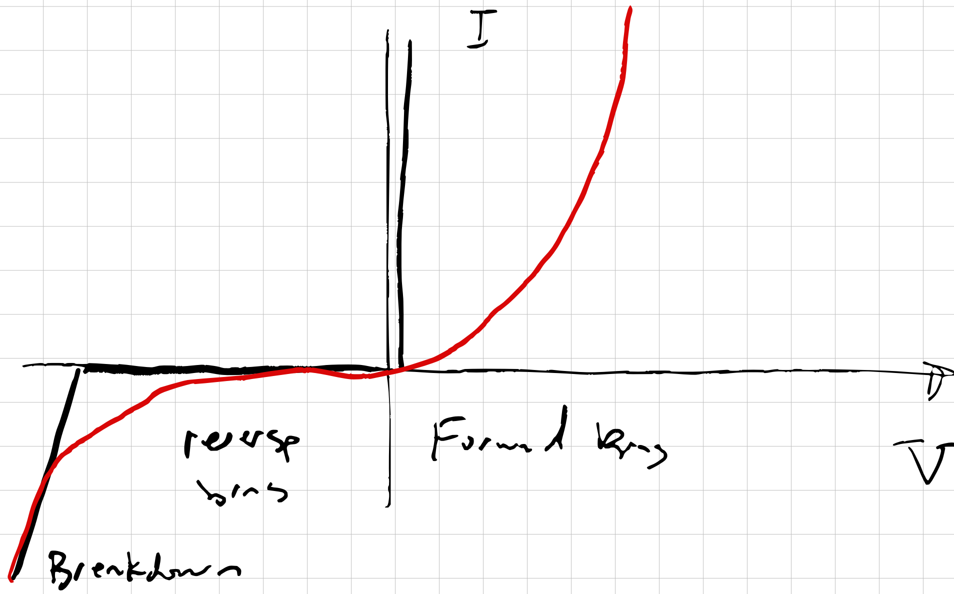
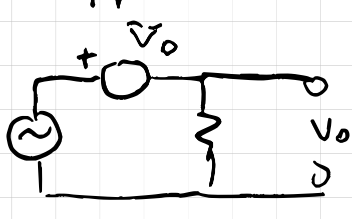



Fig. 3.6


approximate mode

0.7V

$V_s > V_D$




$V_O = V_s - V_D$

- Transistors

→ Function :

* amplification
* switch

→ BJTs & FETs

- what's the difference

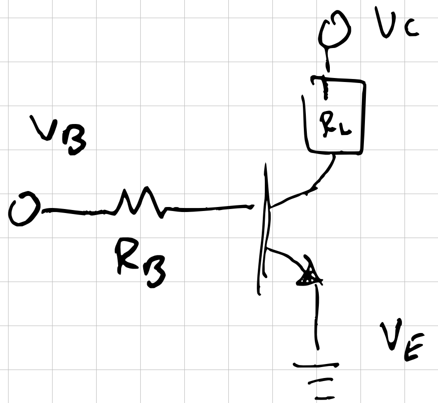
BJT : current controlled

FET : voltage controlled

only ask about <u>NPN</u> or

N-channel transistors

# Common-emitter circuit




- When is the transistor on?

$$\begin{cases} V_B = V_E + 0.7\,V \\ V_C \geq V_B \end{cases}$$

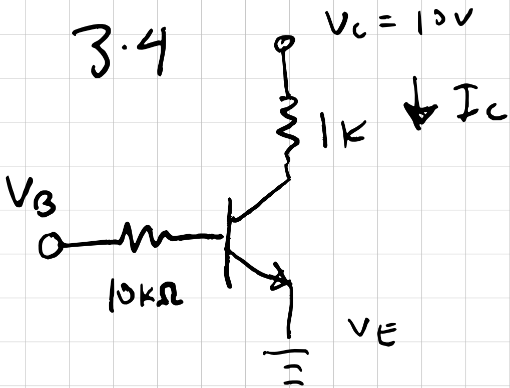
- Know how to choose $\underline{\underline{R_B}}$

↳ want to ensure that its in saturation

$$I_{B_{min}} \approx \frac{I_C}{\beta}$$ ← $h_{FE}$ (2-5)

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

# 3.4




$V_{CE} = 0.2V$

$\beta = 100$

$V_{BE} = 0.7V$

Find $V_B$ to saturate BJT:

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

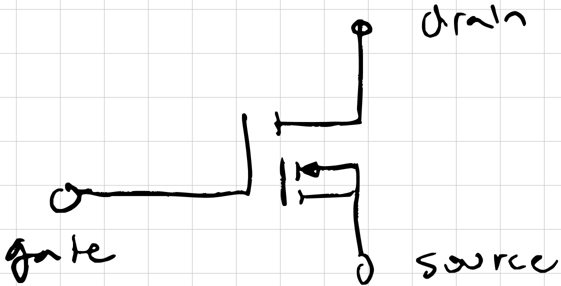
$$= 9.8\,mA$$

$$I_{B_{min}} = \frac{I_C}{\beta} = 0.098\,mA$$

$$V_{B_{min}} = I_{B_{min}} \cdot R_B + V_{BE}$$

$$= 1.68V$$

- FET Basic

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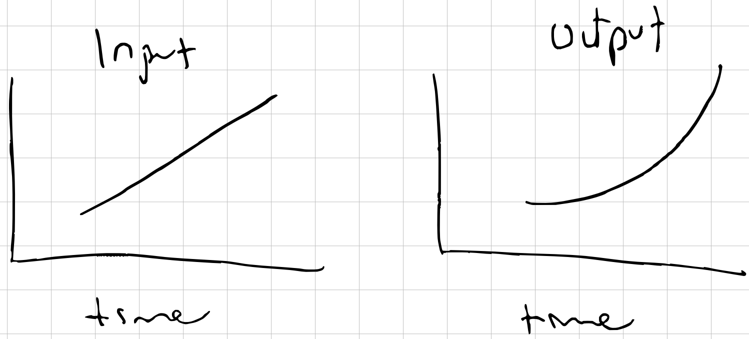
CH. 4.


"measurement system"

What makes a good measurement system?

- Amplitude linearity
- Bandwidth
- Phase linearity

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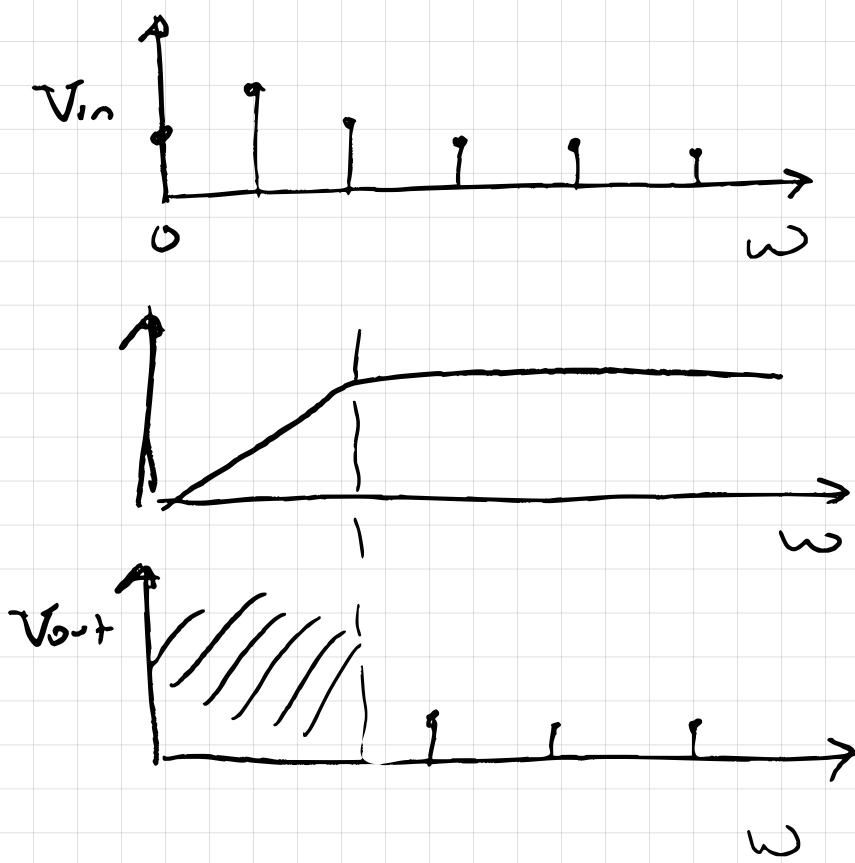
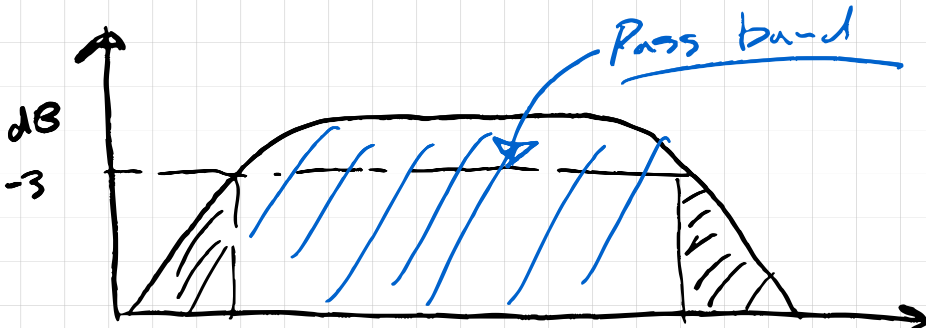
- Fourier Analysis

→ interpret



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

60 dB → $A_{out} = 1000 \cdot A_{in}$



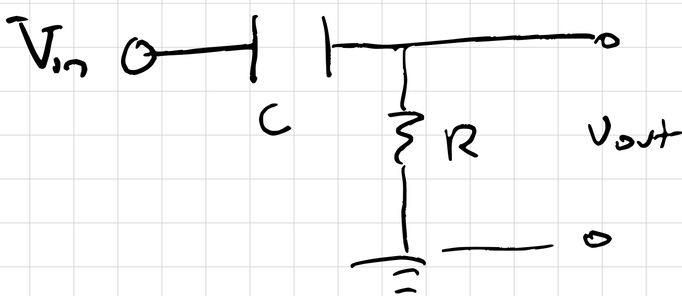

- Why -3 dB ?

$$\frac{P_{in}}{P_{out}} \text{(Power)} = \frac{1}{2}$$

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

Half power point!

Example: what is the cutoff freq?




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

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

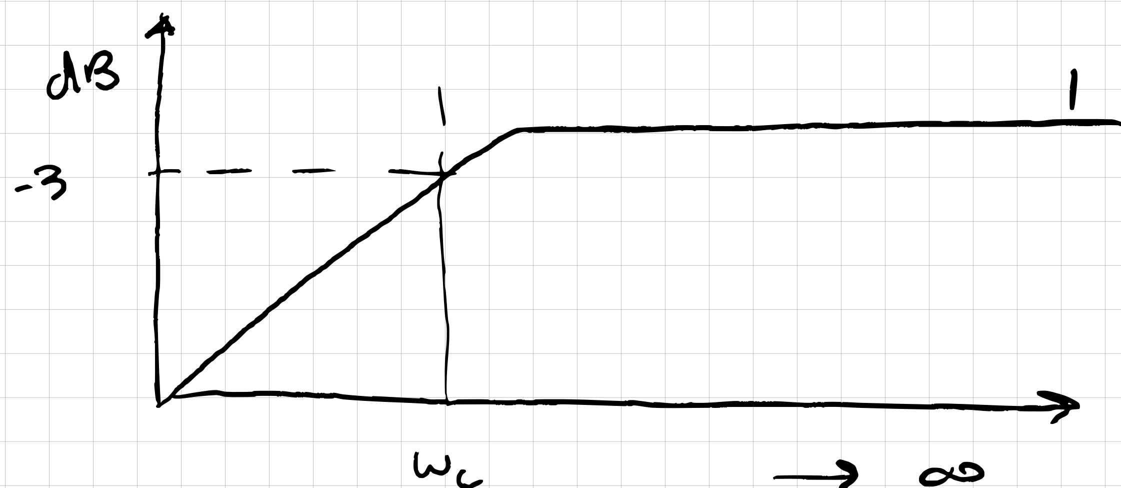
$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{\omega RC}{\sqrt{1 + (\omega RC)^2}} = \frac{1}{\sqrt{2}}$$

$$\omega = \boxed{\frac{1}{RC} = \omega_c}$$

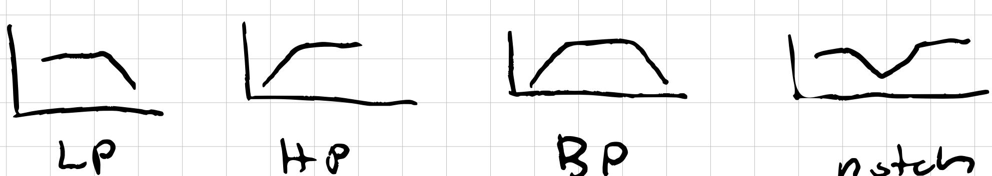
$\omega \to 0 \quad \left| \frac{V_{out}}{V_{in}} \right| \to 0$

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

$$\omega_c = \frac{1}{RC}$$




Should know other filters:



- phase linearity

$$\phi = k \cdot f$$

phase scaled with frequency.

↳ time delay is constant across freq.

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- zero-order system.

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

↑ gain or sensitivity

- first order system

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

↑ time constant.

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

Step response

⚠ recover $\tau$ → system ID