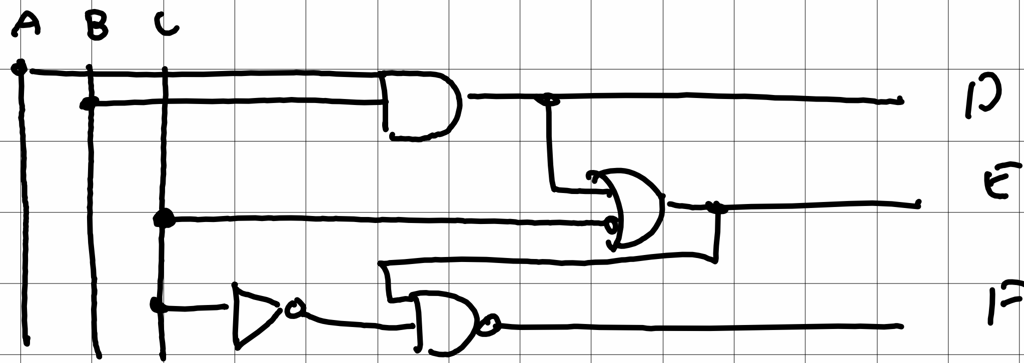
ME 133 Lecture 18 3/10/22

Midterm 2 solutions



(a) $D = A \cdot B$

$E = D + \overline{C} = (A \cdot B) + \overline{C}$

$F = \overline{E \cdot \overline{C}} = \overline{\left((A \cdot B) + \overline{C}\right) \cdot \overline{C}}$

(b)

A	B	C	D	E	F
0	0	0	0	1	0
0	0	1	0	0	1
0	1	0	0	1	0
0	1	1	0	0	1
1	0	0	0	1	0
1	0	1	0	0	1
1	1	0	1	1	0
1	1	1	1	1	1

* (NOTE: F $\longrightarrow$ C) *
according to book

$$D = A \cdot B$$

$$E = D + \overline{C} = (A \cdot B) + \overline{C}$$

$$F = \overline{E \cdot \overline{C}} = \overline{\left((A \cdot B) + \overline{C}\right) \cdot \overline{C}}$$

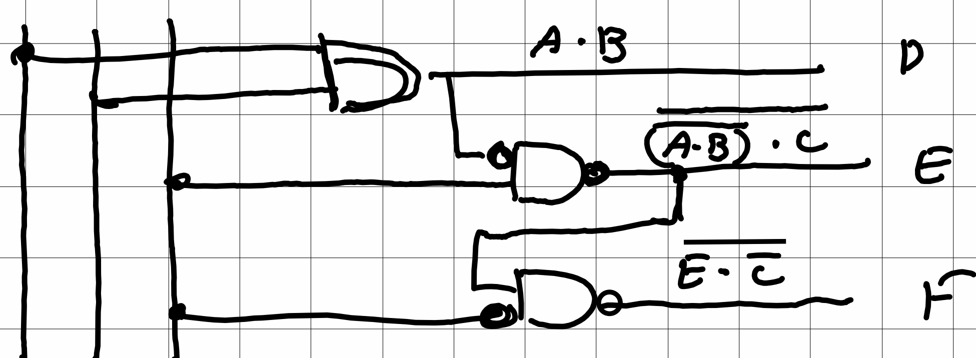
$$E = D + \overline{C}$$

$$= \overline{\overline{D} \cdot C}$$

$$= \overline{\overline{(A \cdot B)} \cdot C}$$

$$F = \overline{E \cdot \overline{C}}$$

$$= \overline{\underbrace{\left[\overline{\overline{(A \cdot B)} \cdot C}\right]}_{E} \cdot \overline{C}}$$



(2.)

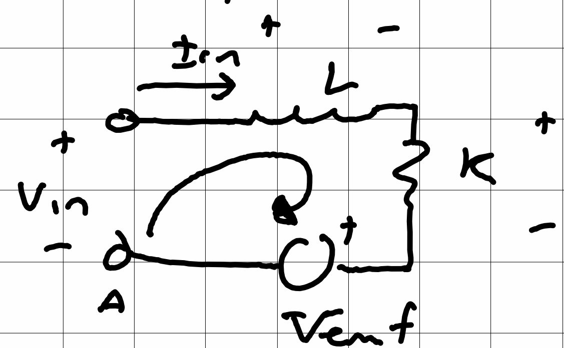
(a.)

a - Brushes
b - commutator
c - rotor
d - stator
e - armature

(b.) 2-pole

(c.) $V_{emf} = K_e \omega$

(d.)



(e.) KVL: $-V_{in} + V_L + V_R + V_{emf} = 0$

$$V_{in} = V_L + V_R + V_{emf}$$

$$\boxed{V_{in} = L\dot{I}_{in} + RI_{in} + K_e\omega}$$

(f.) $\tau = K_\tau \cdot I_{in}$

(g) $\sum M = J\dot{\omega}$

$$\tau = (J_a + J_L)\dot{\omega}$$

(h) $V_{in} = R I_{in} + K_e \omega$

$$\tau = K_\tau I_{in} \rightarrow I_{in} = \frac{\tau}{K_\tau}$$

$$V_{in} = \frac{R}{K_\tau}\tau + K_e \omega$$

$$\boxed{\tau = \underbrace{\frac{K_\tau}{R} V_{in}}_{\tau_s} - \frac{K_e K_\tau}{R}\omega}$$

(i.)

$$\omega_{max} = \frac{\tau_s R}{K_e K_\tau}$$

$$\tau(\omega) = \tau_s\left(1 - \omega/\omega_{max}\right)$$

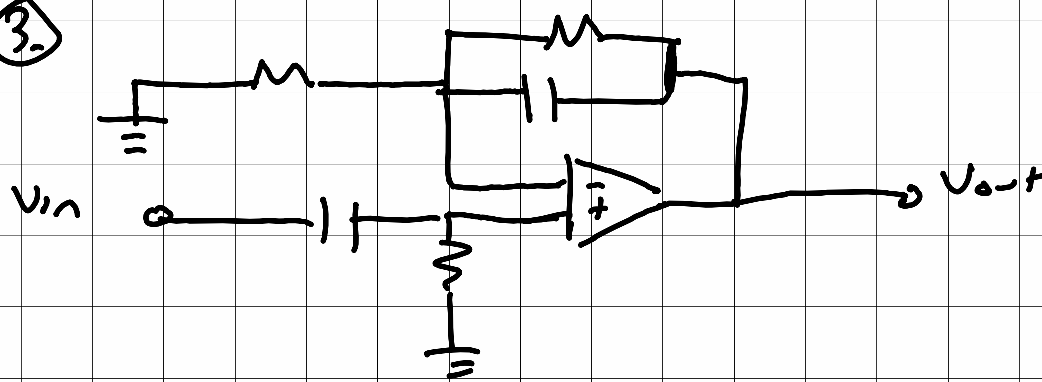
$$P(\omega) = \tau(\omega)\cdot\omega = \tau_s\left(\omega - \frac{\omega^2}{\omega_{max}}\right)$$

$$P(\omega^*) = \frac{1}{4}\tau_s\omega_{max}$$

$$\frac{dP}{d\omega} = 0$$

$$\omega^* = \frac{1}{2}\omega_{max}$$ ✓

(3.)



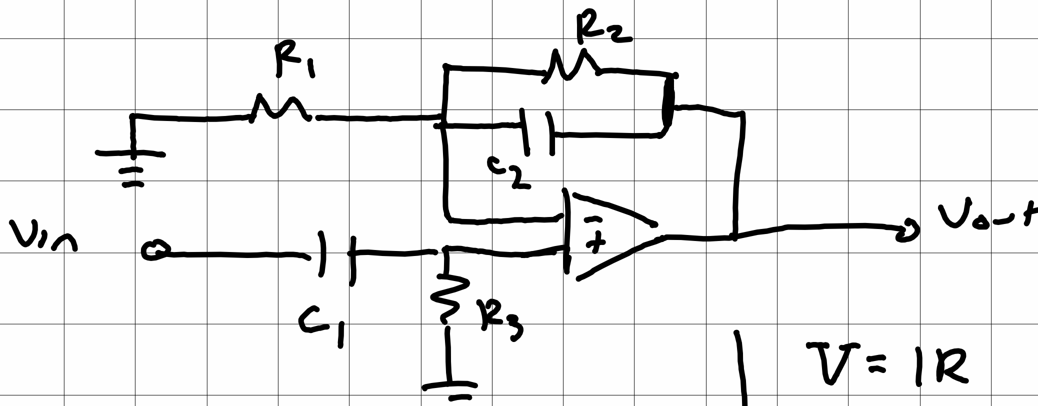
(a) Infinite input impedance $I_+ = I_- = 0$

Infinite gain

$$V_+ = V_-$$

Zero output impedance

V_{out} is independent of I_{out}



$V = IR$

$Z_R = R$

$\dot{V} = \frac{1}{C} I$

$j\omega V = \frac{1}{C} I$

$V = \frac{1}{j\omega C} I$

$Z_C = \frac{1}{j\omega C}$

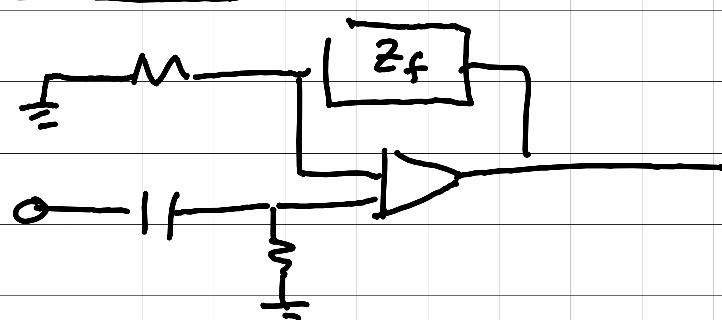
$$Z_f = Z_{R_2} \parallel Z_{C_2}$$

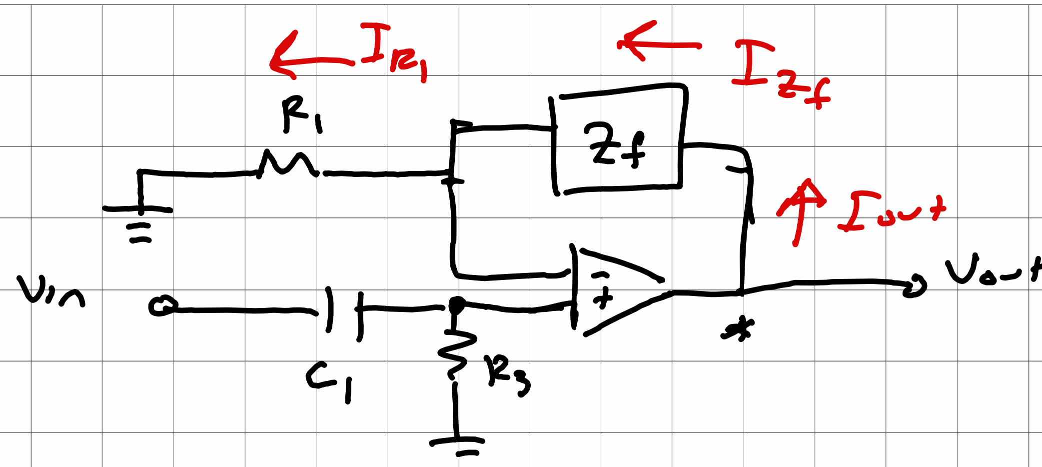
$$\frac{1}{Z_f} = \frac{1}{Z_{R_2}} + \frac{1}{Z_{C_2}}$$

$$\frac{1}{Z_f} = \frac{1}{R_2} + j\omega C_2$$

$$= \frac{1 + j\omega C_2 R_2}{R_2}$$

$$Z_f = \frac{R_2}{1 + j\omega C_2 R_2}$$





(c.) $$V_+ = \left(\frac{Z_{R_3}}{Z_{R_3} + Z_{C_1}}\right) V_{in}$$

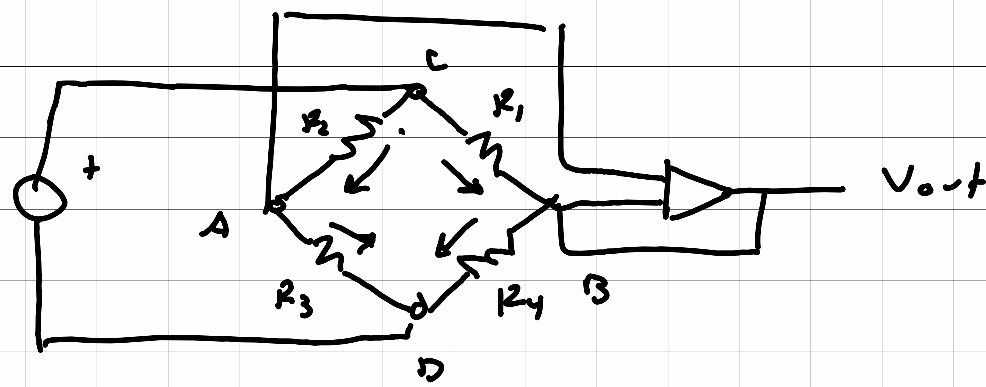
$$= \left(\frac{R_3}{R_3 + \frac{1}{j\omega C_1}}\right) V_{in} = \left(\frac{j\omega C_1 R_3}{1 + j\omega C_1 R_3}\right) V_{in}$$

(d.) $$I_{Z_f} = I_{R_1}$$

$$\boxed{\frac{V_{out} - V^-}{Z_f} = \frac{V^-}{R_1}}$$

$V^- = V^+$

(e.) $$V_{out} = \left(\frac{Z_f}{R_1} + 1\right) V^-$$



(a) $\dfrac{V_{out}}{V_{ex}} = ?$

$$V_{out} = R_1 I_1 - R_2 I_2 = -I_1 R_4 + I_2 R_3$$

$$V_{ex} = I_1 (R_1 + R_4) = I_2 (R_2 + R_3)$$

$$I_1 = \frac{V_{ex}}{R_1 + R_4}, \quad I_2 = \frac{V_{ex}}{R_2 + R_3}$$

$$V_{out} = \left(\underbrace{\frac{R_1}{R_1 + R_4}} - \frac{R_2}{R_2 + R_3} \right) V_{ex}$$

everyone gets points.

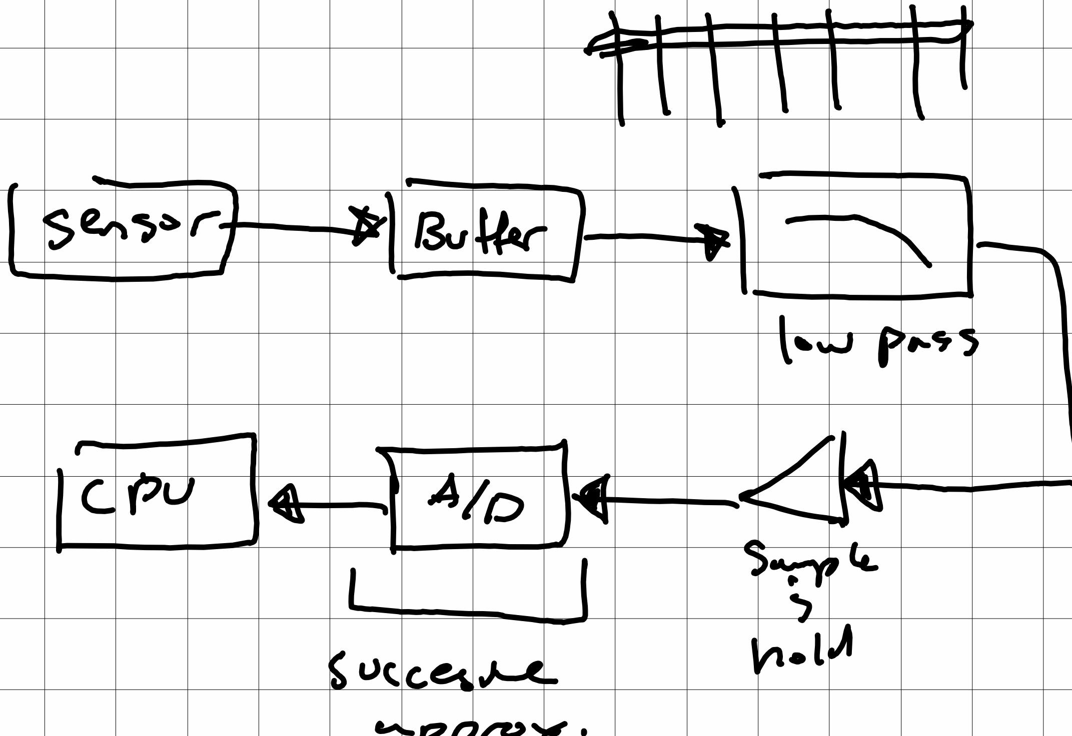
(b)

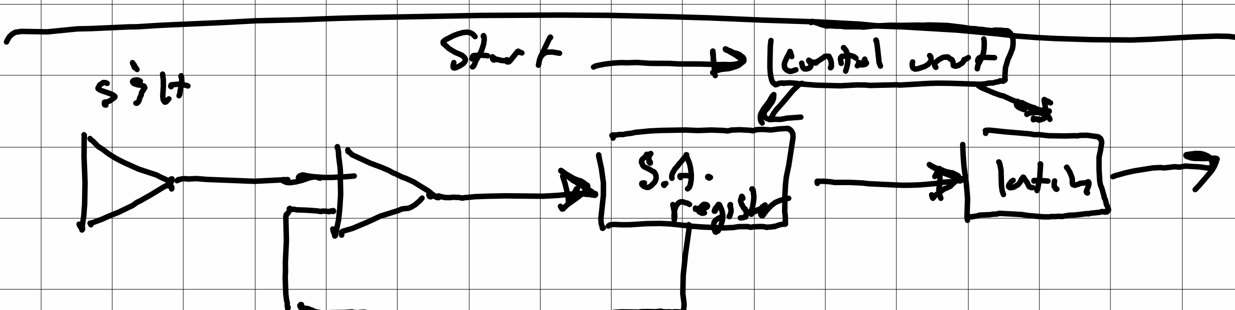
$$\Delta V_{out} = \left[\frac{R_1 + \Delta R_1}{R_1 + \Delta R_1 + R_4} - \frac{R_2}{R_2 + R_3} \right] V_{ex}$$

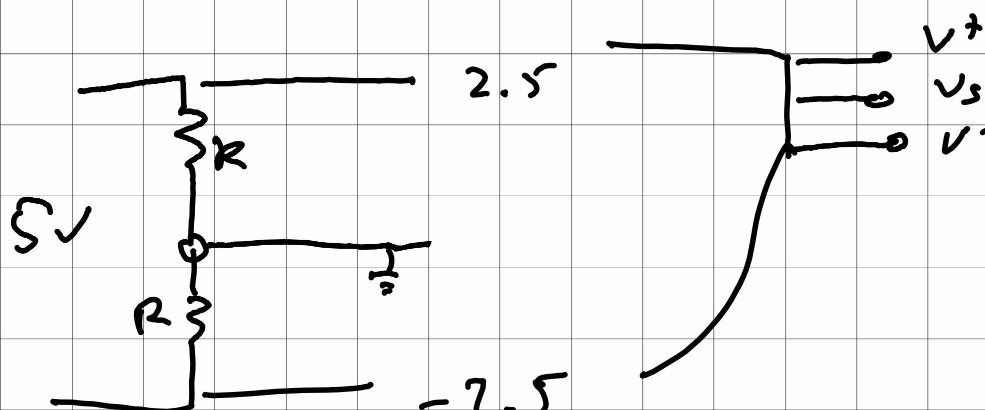
$$\frac{\Delta R_1}{R_1} = \frac{\frac{R_4}{R_1}\left(\frac{\Delta V_{out}}{V_{ex}} + \frac{R_2}{R_2 + R_3} \right)}{\left(1 - \frac{\Delta V_{out}}{V_{ex}} - \frac{R_2}{R_2 + R_3} \right)} - 1$$

(c.) Isolates the bridge from rest of circuit.

(d.) add another strain gauge.


sensor
Buffer
low pass
CPU
A/D
sample & hold
successive approx.


S & H
Start
control unit
S.A. register
latch


2.5
R
5V
R
-2.5
V+
Vs
V-