AST Final Exam

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Q1. When a released (or freely moving) structure is isolated from the substrate / a bigger structure that is immobile) by a thin layer of gases, film damping occurs. When the released structure moves, flow occurs in the thin layer of gas, which causes damping due to energy dissipation.

The released structure moves in squeezed film damping, causing the space between it and substrate to increase and/or contract. The gas film between the two surfaces is compressed as the gap closes. The released structure in slide-film damping moves parallel to the substrate, causing shearing within the gas film. In general, the structure's motion can result in a combination of squeeze & slide film damping, but in actual devices, one process frequently prevails.

Q2.

Capacitance between Plates A & B

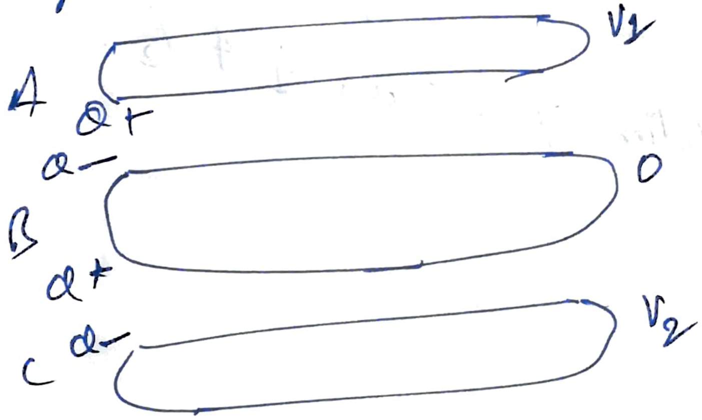
$$C_{AB} = \frac{\epsilon_0 A}{d_1 - x}$$

Where, A is the cross-section Area of the plates.

Capacitance between Plates B & C

$$C_{BC} = \frac{\epsilon_0 A}{d_2 + x}$$

from charge distribution diagram, we can assume the following,



$$V_{AB} = \frac{Q}{C_{AB}} \quad -(1)$$

$$V_{BC} = \frac{Q}{C_{BC}} \quad -(2)$$

from (1) & (2), we got,

$$V_{AB} C_{AB} = V_{BC} C_{BC}$$

$$\Rightarrow (V_A - V_B) C_{AB} = (V_B - V_C) C_{BC}$$

$$\Rightarrow V_1 \times \frac{A \epsilon_0}{d_1 - x} = -V_2 \times \frac{\epsilon_0 A}{d_2 + x}$$

Putting $x = 0.1 d_1$ & $d_2 = 2d_1$

$$\frac{A \varepsilon_0 V_1}{d_1 - 0.1 d_1} = \frac{-A \varepsilon_0 V_2}{2d_1 + 0.1 d_1}$$

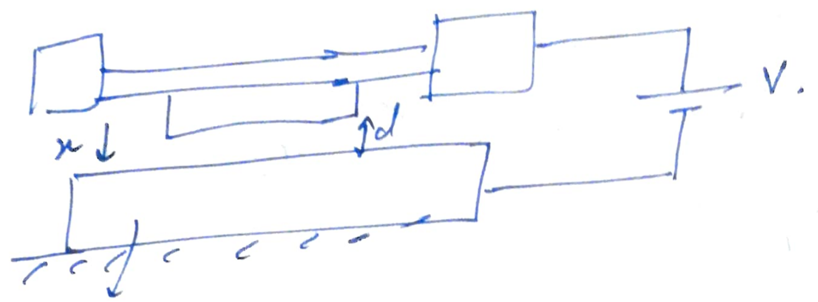
$$\Rightarrow \quad \frac{V_1}{0.9 d_1} = \frac{-\cancel{A} V_2}{2.1 d_1}$$

$$\Rightarrow \quad \frac{V_1}{3} = \frac{-V_2}{7}$$

$$\Rightarrow \quad \boxed{V_1 = \frac{-3V_2}{7}}$$

Relationship between V_1 & V_2.

Q3:



$t = 1\mu m.$

$$C_1 = \frac{\varepsilon_r \varepsilon_0 A}{t}.$$

$$C_2 = \frac{\varepsilon_0 A}{d-x}.$$

$$C_{net} = \frac{C_1 C_2}{C_1 + C_2}.$$

$$= \frac{\frac{\varepsilon_r \varepsilon_0 A}{t} \frac{\varepsilon_0 A}{d-x}}{\frac{\varepsilon_r \varepsilon_0 A}{t} + \frac{\varepsilon_0 A}{d-x}}$$

$$= \frac{\varepsilon_r \varepsilon_0 A}{\varepsilon_r (d-x) + t} = \frac{\varepsilon_0 A}{\left(d + \frac{t}{\varepsilon_r}\right) - x}$$

$$d_{eff} = d + \frac{t}{\varepsilon_r}.$$

for a normal capacitor spring system,

$$E_T = E_0 - \frac{1}{2} \frac{\varepsilon_0 A v^2}{d-x} + \frac{1}{2} k x^2$$

$$F_T = \frac{dw}{dx} = 0$$

$$\Rightarrow kx = \frac{\varepsilon A v^2}{2(d-x)^2} \quad -(1).$$

$$\frac{d^2 E_T}{dx^2} = 0$$

$$V_p^2 = \frac{k(d-x)^3}{\varepsilon A} \quad (2)$$

from (1) & (2)

$$V_p = \sqrt{\frac{8kd^3}{27\varepsilon A}}$$

Here $d = d + \frac{t}{\varepsilon_r}$

$$V_{pull\ in} = \sqrt{\frac{8k\left(d + \frac{t}{\varepsilon_r}\right)^3}{27\varepsilon_0 A}}$$

$$= \sqrt{\frac{8 \times 50 \times \left(6 + \frac{1}{2.5}\right)^3 \times 10^{-18}}{27 \times 8.85 \times 10^{-12} \times 0.01 \times 10^{-6}}}$$

$$= 61.243\ V$$

for pull out,

$x = d$

$$kx = \frac{\varepsilon A V^2}{2(d + \frac{t}{\varepsilon_r} - x)^2}$$

$$V_{pull\,out} = \sqrt{\frac{2kd\,(t/t_0)^2}{\varepsilon_0 A}}$$

$$= \sqrt{\frac{2 \times 50 \times 6 \times \left(\frac{1}{2.5}\right)^2 \times 10^{-18}}{8.85 \times 10^{-12} \times 0.1 \times 10^{-6}}}$$

$$= 102415\ V$$

Pull in Voltage.

→ It is the critical voltage at which the force equilibrium is maintained. If the voltage is increased from this value the spring is not able to balance the electrostatic force & the system collapses.

Pull out Voltage

→ After the collapse when the voltage is gradually reduced there is a voltage ($V_{pull\,out}$) at which the system regains its characteristics, the attractive intermolecular forces are once overcome & spring-capacitor system regains its shape.

Q4.

$V = 1 + 3\sin(2\pi \times 100t)$

$F_{electric} \propto V^2$

$V^2 = 1^2 + 9\sin^2(200\pi t) + 6\sin(200\pi t)$

$= 1 + 9\left(\frac{1-\cos 400\pi t}{2}\right) + 6\sin 200\pi t$

There will be a DC shift & the frequencies of movement will be ~~DC &~~ 200 Hz & 100 Hz.

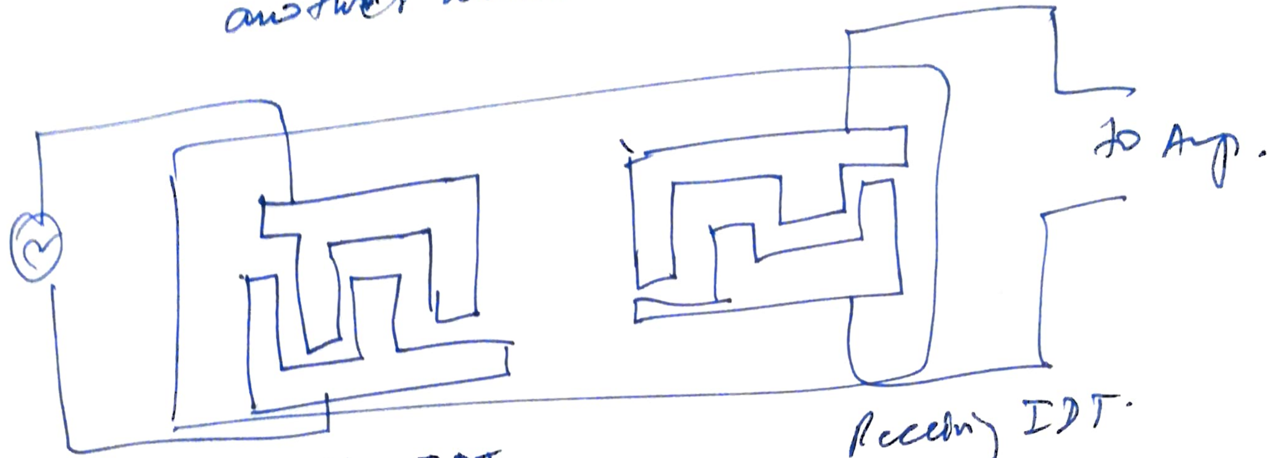
Q6.

Surface Acoustic Wave (SAW) is known as Rayleigh wave. This wave travels along the surface and it's intensity decreases exponentially with depth.

This wave can be generated by using an interdigital transducer (IDT) that is fabricated by depositing metal on a piezoelectric crystal. When the IDT is excited at high frequency deformation takes place & due to piezoelectric effect, this wave is generated.

It can be used as an indirect physical sensor & can detect gases like NO_2, H_2S & SO_2

Two IDTs ~~we~~ are placed one acts as transmit another receiver.

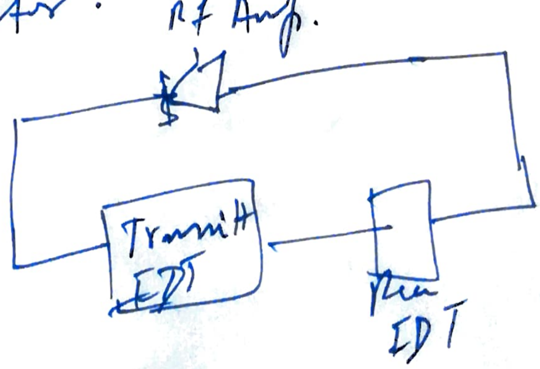


$$\tau = \frac{l}{v}$$ $v \to$ velocity of wave. $l \to$ length ~~from~~ travelled.

$$\omega = \frac{2\pi n - \phi_e}{\tau}$$ $\phi_e \to$ phase delay due to electrical comp.

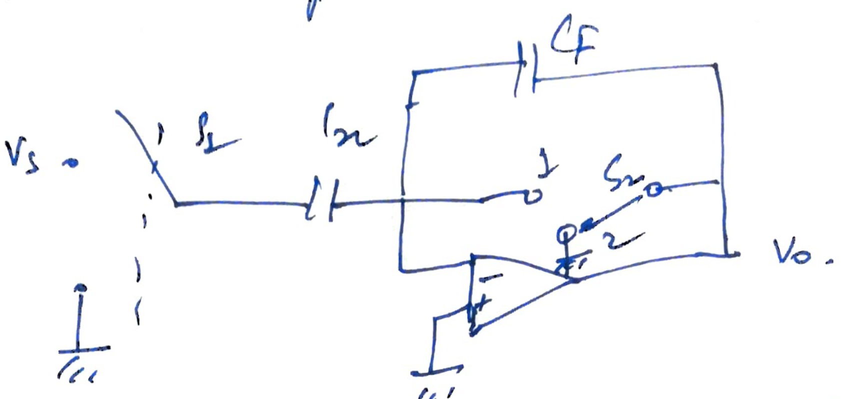
$$\frac{\Delta f}{f} = S_m \, \Delta m$$ $\Delta m \to$ change in mass due to absorption of gases

When the molecules gets absorbed it changes then mass & hence frequency gets changed, we measure the time lag using an SAW oscillator.



SAW oscillator.

Q 8 Switched Capacitance.



At $S_1 = 1$ when $S_1 = 1$ C_f is selected $V_0 = 0$.

C_x will be charged to V_{SS}.

When S_1 at 2.
charge stored in C_x will be transferred to C_f.

$$V_o C_f = V_{SS} C_x$$

$$\rightarrow V_o = \frac{C_x}{C_f} V_{SS}.$$

A switched capacitor is an electric circuit element which mainly implements a filter. It works by moving charges in - & out of the capacitors when switches are opened & closes.

Advantages:

1. They can be easily implemented on an IC. chip area is minimized. These can be used to
2. mimic the behaviour of resistors.
3. Digital processing in chip is reduced.

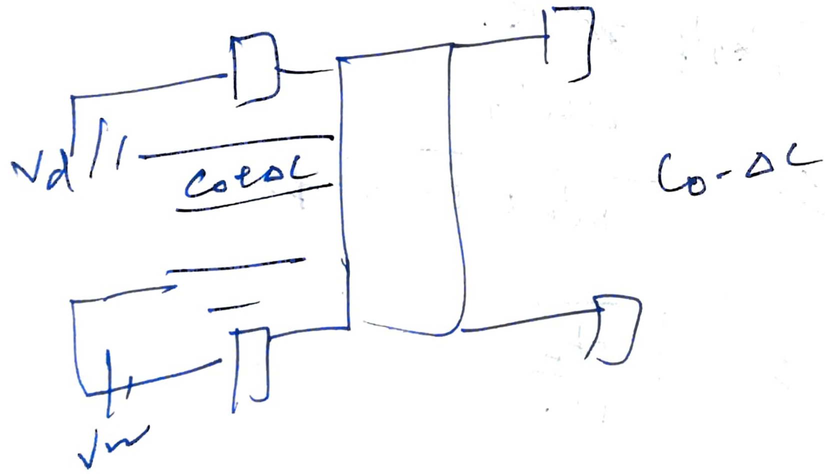
Q.5

Advantages of using feedback in Instrumentation :-

- Sensitivity reduction due to variation of parameters in transfer function.
- Reduction of noise.
- Increases stability.

Derivation in content of MEMS capacitive accelerometer :-

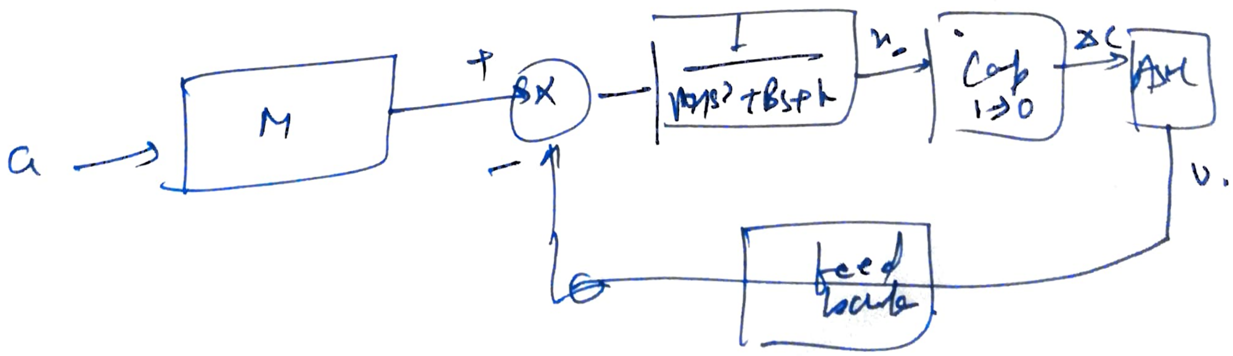
Closed loop MEMS capacitive Accelerometer



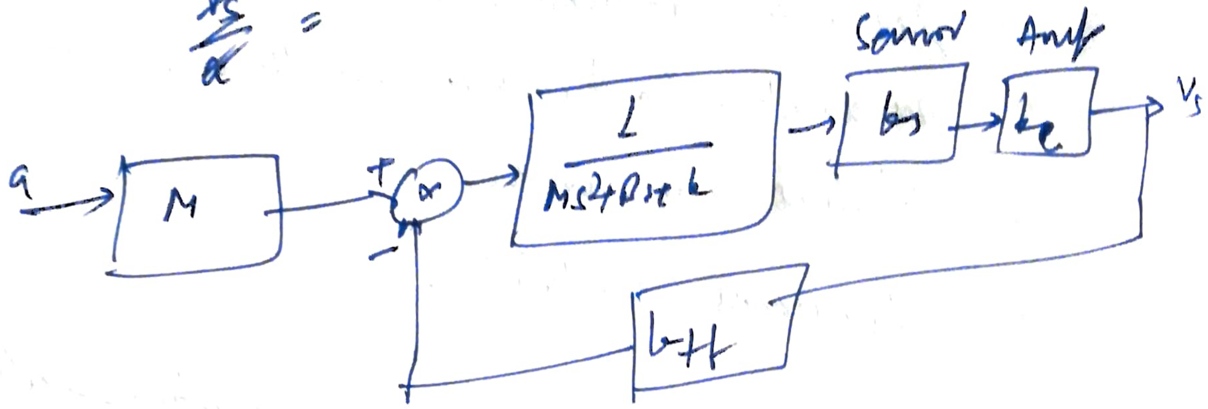
$E = \frac{1}{2}CV^2$

$C = \frac{\epsilon A}{d-x}$

$\frac{dE}{dx} = \frac{1}{2}\frac{\epsilon A}{(d-x)^2}$.



$$\frac{V_s}{a} =$$



$$\frac{V_s}{a} = \frac{M k_s k_a}{Ms^2 + Bs + k + k_s k_a k_{ff}}.$$

$$k_s k_a k_{ff} \gg k.$$

$$\simeq \frac{M k_s k_a}{Ms^2 + Bs + k_s k_a k_{ff}}.$$

$$\omega = \sqrt{\frac{k_{ff}}{M}}.$$

Q 7.   Lab-on-chip.

It incorporates several laboratory functions on a single chip. The MEMS device takes a tiny amount of blood through a microgrooves, splits into a diff. microchannels using micro-fluidic technology & perform diff. tests

E-nose.

E nose is an instrument designed to detect complex odours using chemical sensor array.

Differences:

In lab on chip blood (a liquid blue) mixture is passed, whereas in E nose gaseous mixture is passed through the sensor array.