Numericals on Capacitive Transducer (in Hindi)

LESSON 7 OF 28

INDUCTIVE RESISTIVE AND CAPACITIVE TRANSDUCERS

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- A capacitive transducer with its plate separation 0.05mm under static condition has capacitance $5*10^{-12}$ F. find the displacement which cause change of capacitance of $0.75*10^{-12}$ F.

Soln:-

$d = 0.05mm$

$C = 5 \times 10^{-12} F$

$\Delta C = 0.75 \times 10^{-12} F$

$\Delta d = ?$

$$C = \frac{\varepsilon A}{d}$$

Here, d is variable

$$Cd = \varepsilon A = 0.25 \times 10^{-15}$$

$$\Delta C = \frac{\varepsilon A}{\Delta d}$$

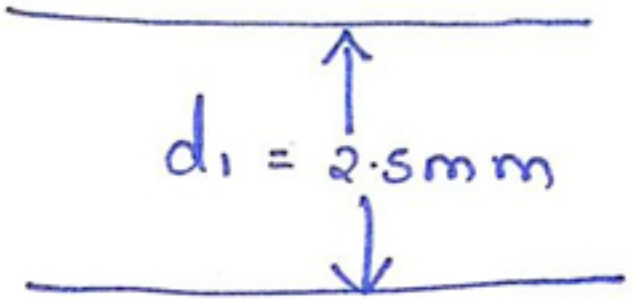
$$\Delta d = \frac{\varepsilon A}{\Delta C}$$

$$\Rightarrow \frac{0.25 \times 10^{-15}}{0.75 \times 10^{-12}}$$

$$\boxed{\Delta d \Rightarrow 0.33 mm}$$

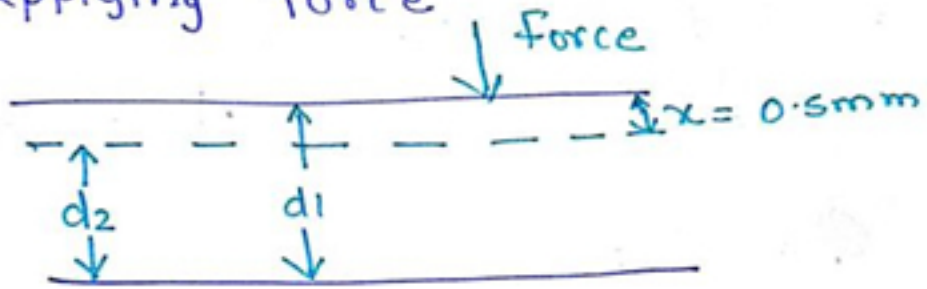
- A Capacitive transducer uses two quartz diaphragms of area $750mm^2$, separated by distance of 2.5mm then capacitance is 400pF.A pressure of $900kN/m^2$ when applied to top diaphragram , it produces a deflection of 0.5mm. Find the capacitance after applying pressure.

Before applying pressure



, $C_1 = 400 \times 10^{-12} F$

After applying force



$d_2 = 2.5 - 0.5\,mm$

$= 2\,mm$

$C \propto \frac{1}{d}$

$\frac{C_1}{C_2} = \frac{d_2}{d_1}$

$C_2 = \frac{d_1 \times C_1}{d_2}$

$\boxed{C_2 = 500\,pF}$

- A capacitive transducer of two parallel plates of overlapping area = 5 *10^{-4} m^2 is immersed in water ,capacitance is found to be 950pF.Calculate the separation between plate and sensitivity with respect to distance. Given relative permittivity of water is 81.

Solution:-

$A_{area} = 5 \times 10^{-4}\ m^2$, $C = 9.50\ pF$

$\varepsilon_r = 81$, $\varepsilon_0 = 8.854 \times 10^{-12}\ F/m$

$d = ?$

(1) $C = \frac{\varepsilon A}{d}$

$C = \frac{\varepsilon_0 \times \varepsilon_r A}{d}$

$d = \frac{8.854 \times 10^{-12} \times 81 \times 5 \times 10^{-4}}{9.50 \times 10^{-12}}$

$\boxed{d = 0.03775\ m}$

(2) Sensitivity, $\frac{\partial C}{\partial d} = ?$

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$\frac{\partial C}{\partial d} = -\frac{\varepsilon_0 \varepsilon_r A}{d^2}$$

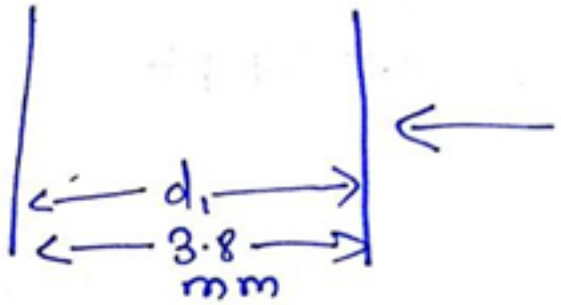
$$= \frac{8.854 \times 10^{-12} \times 81 \times 5 \times 10^{-4}}{(0.03775)^2}$$

$$S \Rightarrow 0.025 \times 10^{-8} \text{ F/m}$$

- A capacitive transducer is used in pressure measuring instrument which has a spacing of 3.8mm between its diaphragm . A pressure of 500kN/m produces average deflection of 0.25mm of diaphragm of transducer. A transducer which has a capacitance of 280pF before the application of pressure and it is connected to oscillator circuit having a frequency of 100kHz . Find the change in frequency of oscillator after the application of pressure to the transducer.

Solution->

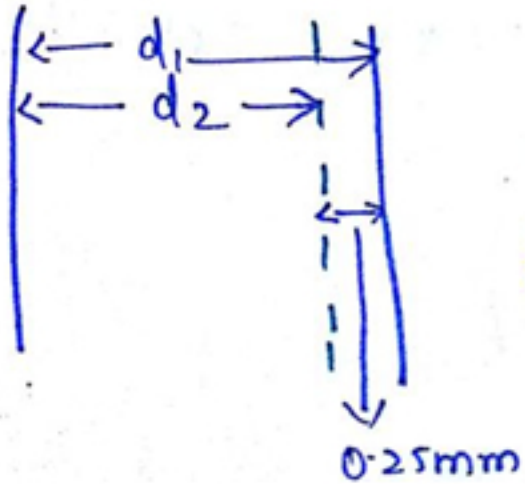
Before applying pressure



$C_1 = 280\,pF$

$fr_1 = 100kH_z$

After applying pressure



$C_2 = ?$

$d_2 = 3.8\,mm - 0.25mm$

$\Rightarrow 3.5\,mm$

and frequency of oscillation $f_{u_2} = ?$

$$\Delta f_u = f_{u_1} - f_{r_2}$$

$$\frac{C_1}{C_2} = \frac{d_2}{d_1}$$

$$C_2 = \frac{280 \times 3.8}{3.5}$$

$$C = 304 \text{ pF}$$

f_u is given by $= \frac{1}{2\pi\sqrt{LC}}$

$f_{u_1} = \frac{1}{2\pi\sqrt{LC_1}}$ .. $f_{u_2} = \frac{1}{2\pi\sqrt{LC_2}}$

$$\frac{f_{u_2}}{f_{u_1}} = \sqrt{\frac{C_1}{C_2}}$$

$$= \sqrt{\frac{\frac{\varepsilon A}{d_1}}{\frac{\varepsilon A}{d_2}}} \Rightarrow \sqrt{\frac{d_2}{d_1}}$$

$$\frac{f_{u_2}}{f_{u_1}} = \sqrt{\frac{d_2}{d_1}}$$

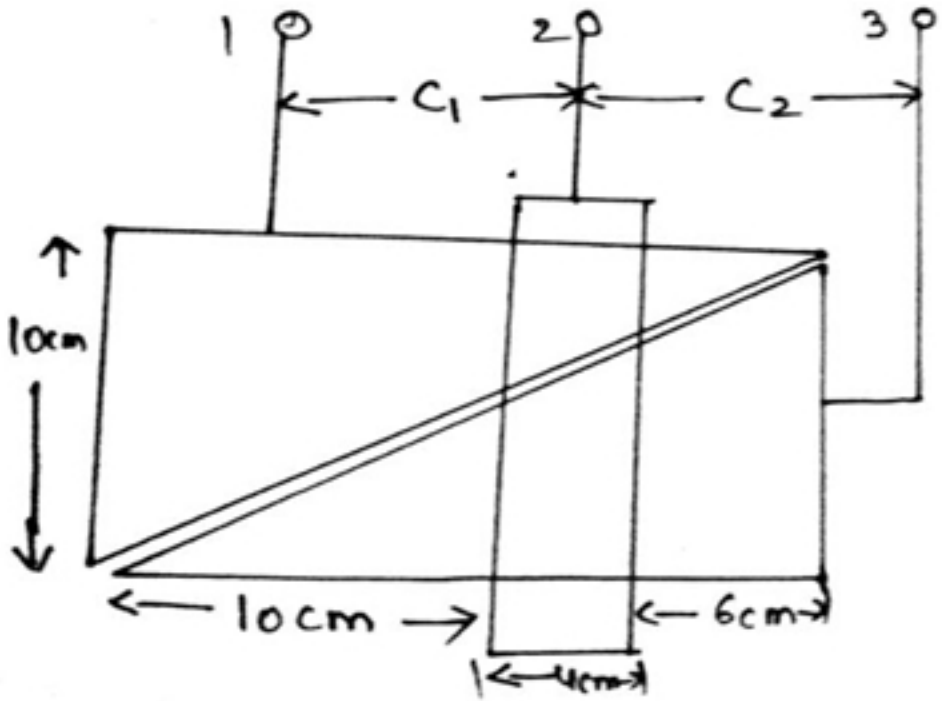
$$f_{u_2} = 100 \times \sqrt{\frac{3.5}{3.8}}$$

$$= 96.65 \text{ kHz}$$

$$\Delta f = 100 - 96.65$$

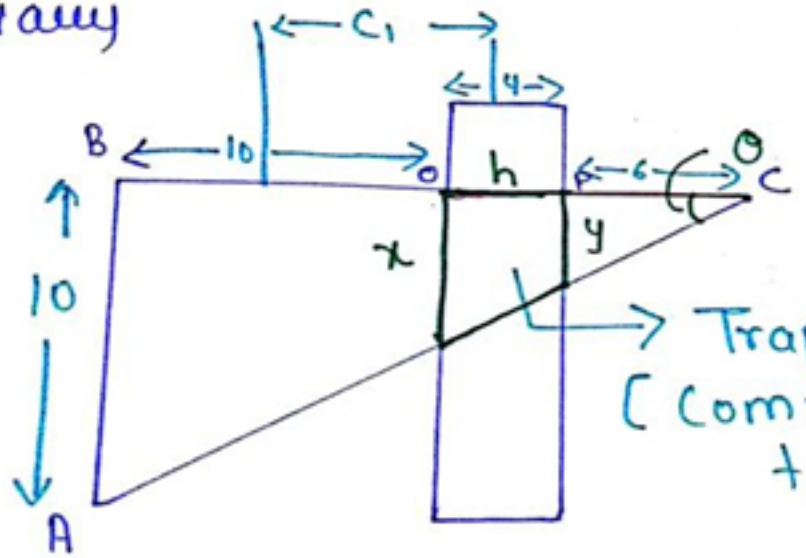
$$\boxed{\Delta f = 3.35 \text{kHz}}$$

- A capacitive type displacement transducer with to triangular plate side by side. A rectangular plate move laterally with uniform air gap of 1mm.find the value of capacitor C1 and C2 . For the given diagram and dimension.



Solution:-

rectangle plate is moving upward 1mm will vary



Trapezium
[Common area betn two plates A]

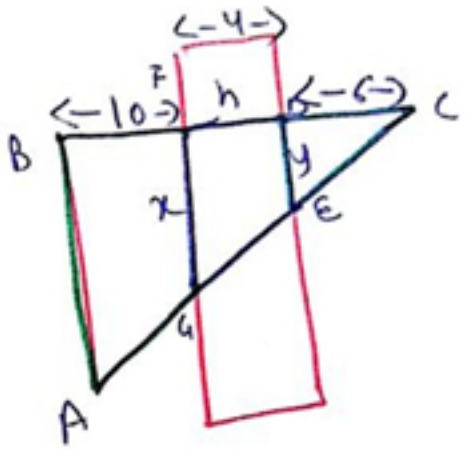
$h = 4cm$, $x = ?$ $= y = ?$

Area of trapezium $= \frac{1}{2} h (x+y)$

$= \frac{1}{2} \times 4 (x+y)$

$$\tan\theta = \frac{10}{10+4+6} = \frac{10}{20}$$

$$\theta = 26.56$$



$$\tan 26.56 = \frac{x}{10}$$

$$x = 5\,cm$$

$$\tan 26.56 = \frac{y}{6}$$

$$y = 3\,cm$$

$$A = 16\,cm^2$$

$$C_1 = \frac{\varepsilon \times A}{d}$$

$$\Rightarrow \frac{8.854 \times 10^{-12} \times 16 \times 10^{-4}}{1 \times 10^{-3}}$$

$$\boxed{C_1 = 14.17\ pF}$$

a) $C_1 = 2.14\,pF$, $C_2 = 1.29\,pF$

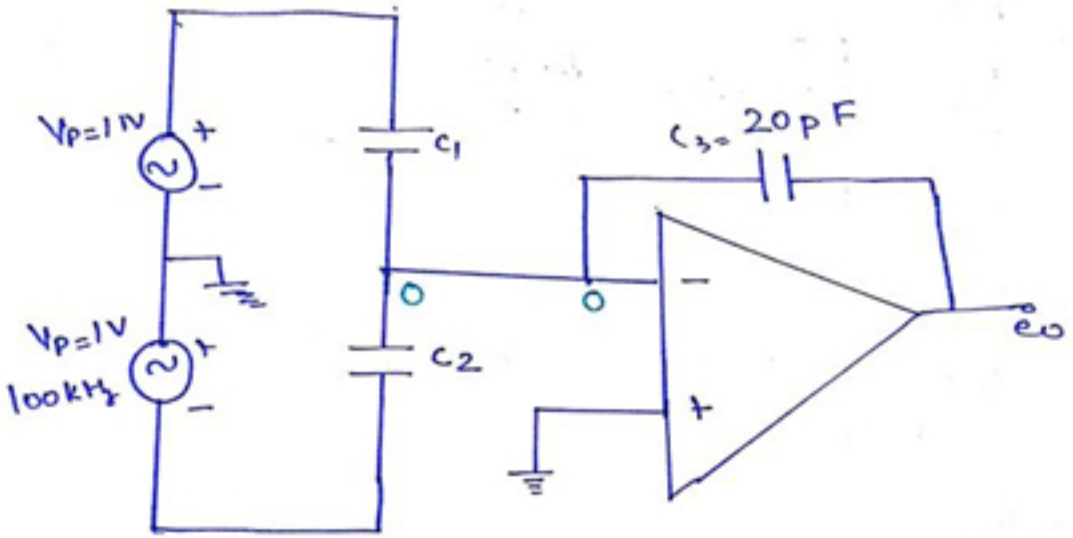
b) $C_1 = 74.17\,pF$, $C_2 = 21.25\,pF$

c) $C_1 = 339\,pF$, $C_2 = 212\,pF$

d) $C_1 = 18.16\,nF$, $C_2 = 23.2\,nF$

- The above sensor placed in capacitance measuring ckt as shown in the given fig. Assume ideal opamp. find output voltage.

A. 0.012V
B. 0.354V
C. 1.23V
D. 2.541V



Solution:-

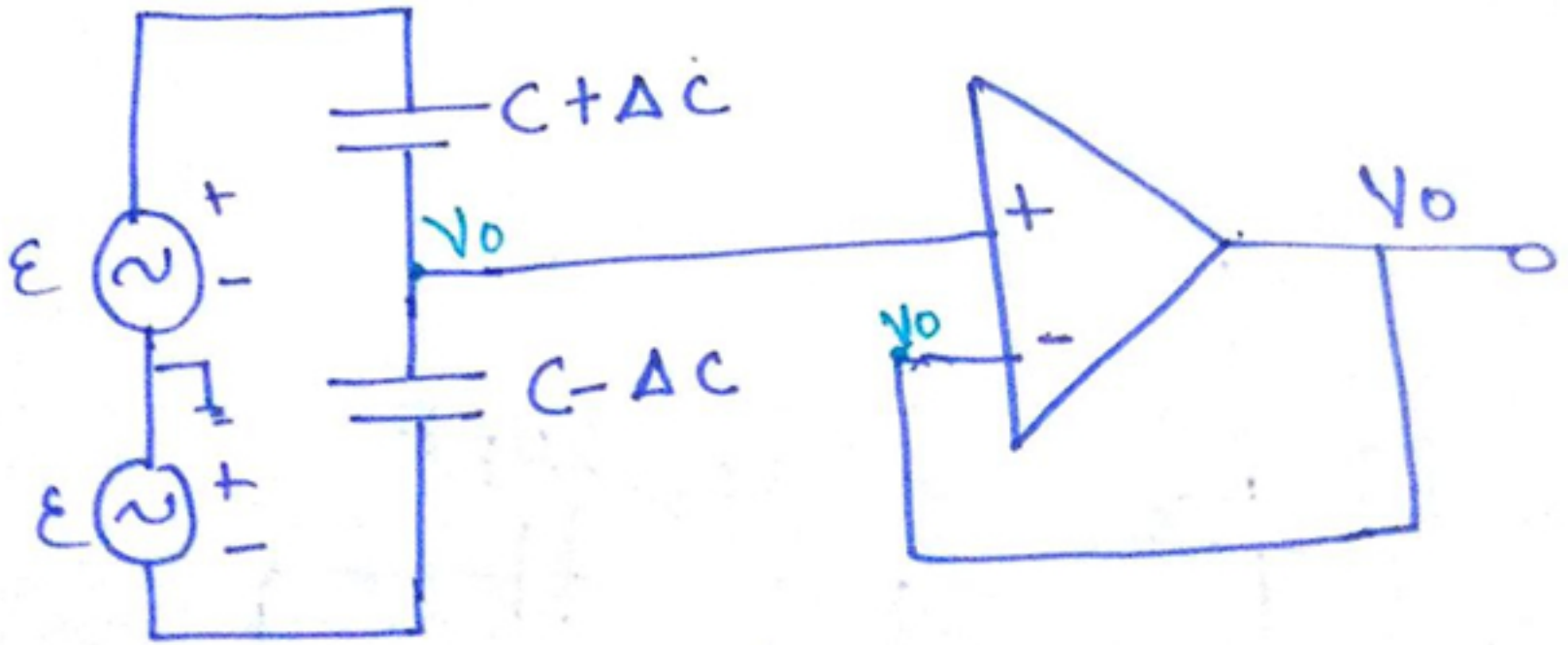
$$\frac{0-1}{1/sC_1} + \frac{0-(-1)}{1/sC_2} + \frac{0-e_o}{1/sC_3} = 0$$

$$-C_1 + C_2 + C_3 \times (-e_o) = 0$$

$$-14.17 + 21.2s - 20e_o = 0$$

$$\boxed{e_o = 0.354V}$$

- A signal conditioning circuit for push pull type capacitive transducer which is given below . Find it output voltage.



Soln:-

Vlg follower Circuit

$V_{in} = V_{out}$

$$\frac{V_0 - \cancel{\mathcal{E}}}{C + \Delta C}$$

$$\frac{V_0 - \mathcal{E}}{\frac{1}{s(C+\Delta C)}} + \frac{V_0 + \mathcal{E}}{\frac{1}{s(C-\Delta C)}} = 0$$

$$(C+\Delta C)(V_0 - \mathcal{E}) + (C - \Delta C)(V_0 + \mathcal{E}) = 0$$

$$(C + \cancel{\Delta C} + C - \cancel{\Delta C})V_0 + (-\cancel{C} - \Delta C + \cancel{C} - \Delta C)\mathcal{E} = 0$$

$$2C V_0 = 2\Delta C \mathcal{E}$$

$$\boxed{V_0 = \frac{\Delta C}{C}\mathcal{E}}$$

- The expression for capacitance in pF of a parallel plate capacitor is given

$$C = 6.94*10^{-3}\, d^2/S$$

The diameter d of each plate is 20mm. Spacing b/w plate 'S' is 0.25mm.The displacement sensitivity is approximately.

Solution:-

Here, 'd' is diameter of each plate & 's' is seperation or distance between plates.

$$S = \frac{\partial C}{\partial S} = -\frac{6.994 \times 10^{-3} \times d^2}{S^2}$$

$$\Rightarrow -\frac{6.94 \times 10^{-3} \times (20 \times 10^{-3})^2}{(0.25 \times 10^{-3})^2}$$

$$S = \frac{\partial C}{\partial S} \Rightarrow -44.41 \text{ PF/m}$$

- A variable air gap type capacitor with 2 parallel plate at a distance x . If a potential V is applied across the two plates , then force of attraction between in the plate is related to x.

Solution:-

if Voltage = V , then E

$$E = \frac{V}{x}$$

$$f = qE = CVE$$

$$\Rightarrow \frac{\varepsilon A V E}{x}$$

$$\Rightarrow \frac{\varepsilon A V^2}{x^2}$$

$$\boxed{F \propto \frac{1}{x^2}}$$

Thank you

1 sec → 10°C

70°C → 70 sec

Its related to ramp i/p with first order system

$$C(t) = t - \tau\left(1 - e^{-t/\tau}\right)$$

$$\Rightarrow 70 - (100 \times 10^{-3})\left(1 - e^{-70/(100 \times 10^{-3})}\right)$$

$$C(t) \Rightarrow 69.9$$