X

Courses » Industrial Instrumentation

Announcements **Course** Forum Progress Mentor

Unit 7 - Week 6

Course outline

Week 6 assignment on LVDT and Capacitance transducers

1) *2 points*

A differential parallel plate capacitive arrangement, where distance between the plate varies, is arranged in a Wheatstone bridge configuration as shown in Fig. 1(a) and 1(b C_1 is the capacitance between plates P and M and C_2 is the capacitance between plate Q and M. The relative permittivity of the medium is 2.5. Common area between th plates is 1 cm^2. Nominal distance between the plates is d = 1 cm. If x = 0.1 cm, Fin output voltage e_o if 2 V peak-to-peak sinusoidal signal (e_{ex}) of 2.5 kHz excitation is used

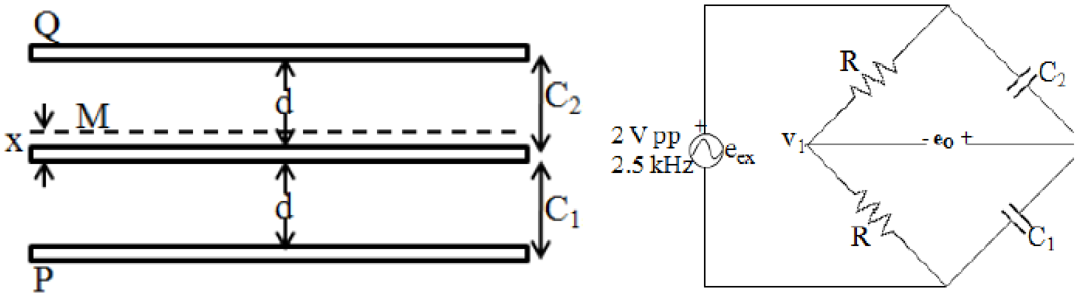

Figure 1: (a) differential capacitive sensor (b) Bridge circuit for differential capacit arrangement

- a) 1 V peak-to-peak
- b) 0.1 V peak-to-peak
- c) 0.05 V peak-to-peak
- d) 2 V peak-to-peak

Accepted Answers:
b) 0.1 V peak-to-peak

2) *2 points*

A differential capacitive arrangement, as in Figure 1(a), is used with the signal conditioning circuit, in Figure 2, to obtain output voltage V_O. If maximum non-linearity of 1 % can be tolerated in output V_O, then find the largest ratio of x/d.

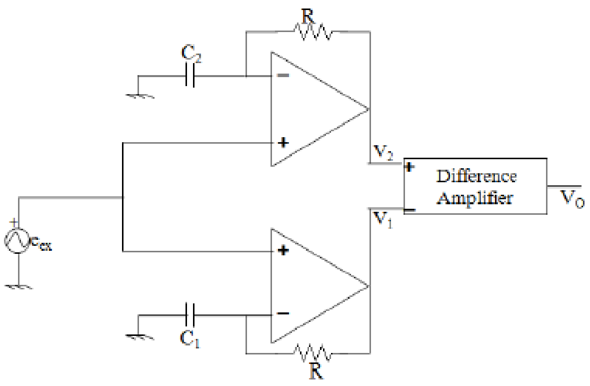

Figure 2

- a) 0.01
- b) 0.05
- c) 0.1
- d) None of these

Accepted Answers:
c) 0.1

3) ***2 points***

Find the sensitivity (assuming linear input-output relationship) of V_O with-respect-to x from the circuit in Figure 2; given V_{ex} = 2V rms at 10 kHz, R = 10 kΩ, d = 1 cm. (Vacuum permittivity = 8.85×10^{-12} F/m)

- a) 0.056 V/m
- b) 0.112 V/m
- c) 5.6 V/m
- d) 11.2 V/m

Accepted Answers:
a) 0.056 V/m

4) ***4 points***

The following circuit, in Figure 3(b), is used with the capacitive level measurement system shown in Figure 3(a). Capacitance (C_h) between the probe and tank well, in Figure 3(a), is giver by, $C_h = a + b \times h$; where, 'a' and 'b' are constants for a particular measuring liquid medium. If a 10V peak-to-peak, 10 kHz sinusoidal excitation signal is used as e_{ex}, then which of the followin options is the best choice for R_f, C_f (assuming C_h varies in the range 200 pf to 800 pf).

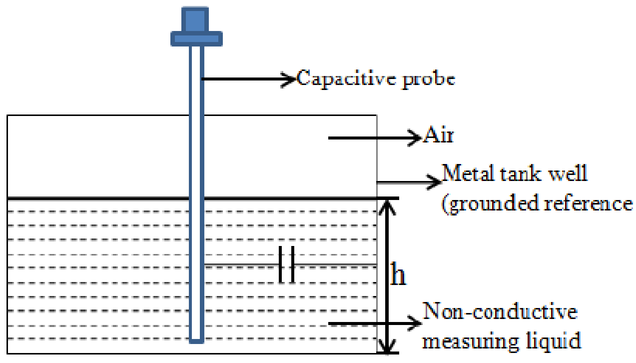

Figure 3(a)

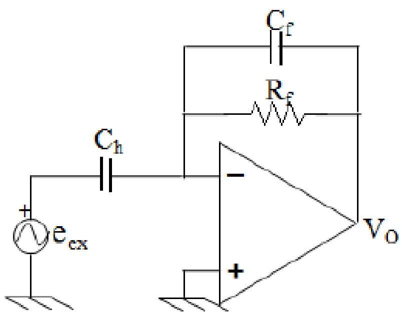

Figure 3(b)

(**Hint:** Obtain the expression for V_O in Laplace domain. Then find which of the followin options is the most suitable for expressing V_O/e_{ex} as only a function of capacitances.

- a) $R_f = 10\ k\Omega$, $C_f = 1\ nF$
- b) $R_f = 100\ k\Omega$, $C_f = 10\ nF$
- c) $R_f = 100\ k\Omega$, $C_f = 470\ pF$
- d) $R_f = 220\ k\Omega$, $C_f = 100\ pF$

Accepted Answers:
b) $R_f = 100\ k\Omega$, $C_f = 10\ nF$

5) ***2 points***

Answer questions 5 to 9 based on Figure 4

A LVDT is to be designed with the following specifications (Refer to Figure 4):

Range of operation: ± 10 mm; Maximum frequency of displacement: 1 kHz; Supply voltage: 5 rms; maximum non- linearity: 1 %; wire used for windings: 19 SWG (wire diameter: 1.016 mm)

There are 1 primary and 2 secondary windings of inner diameter d_i and outer diamet d_O. Output voltage is given by, $e_O = e_1 - e_2 = \omega I_P \left[\frac{4\pi N_P N_S \mu_o L_P \times x}{3 \sin\left({d_o}/{d_i} \right)} \left(1 - \frac{x^2}{2 L_P{}^2} \right) \right]$.

Where, x – displacement of the core from null position; ω – frequency of excitatic signal; L_P – current in primary winding; N_P, N_S – number of turns in primary and seconda windings; μ_o – permeability of free space ($4\pi \times 10^{-7}$ H/m).

It is also given, $\frac{d_i}{L_a} \cong 0.1$; $\frac{d_o}{d_i} = 4$; $L_a = 3L_P$; $L_g << L_P$.

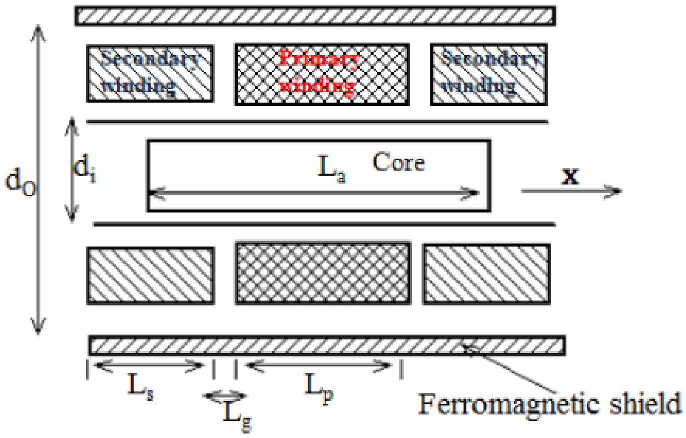

Figure 4

Find the following parameters:-

5. Length (L_P) of the primary

(Hint: Observe the expression of e_O above and given maximum non-linearity)

- a) 500 mm
- b) 22.36 mm
- c) 44.72 mm
- d) 70.7 mm

Accepted Answers:
d) 70.7 mm

6) **2 points**

Length (L_s) of each of the secondary

(Hint: Find expression for L_s from different length parameters (i.e.,L_a, L_p and x) given in Figure 4

- a) 8 mm
- b) 70.7 mm
- c) 80.7 mm
- d) 212.1 mm

Accepted Answers:
c) 80.7 mm

7) Length (L_a) of the core. **2 points**

- a) 67.08 mm
- b) 134.16
- c) 212.1 mm
- d) 500 mm

Accepted Answers:
c) 212.1 mm

8) Inner and outer diameter (d_i and d_O) of the secondary. **2 points**

- a) 21.21 mm, 84.84 mm
- b) 13.42 mm, 53.68 mm
- c) 26.84 mm, 107.36
- d) None of these

Accepted Answers:
a) 21.21 mm, 84.84 mm

9) *4 points*

Number of turns (N_P and N_S) of primary and secondary respectively.

(Hint: N_p = (number of layers of winding in primary)×(number of turns in each layer). No. o layers depend on d_O, d_i and wire diameter. No. of turns in each layer depends on length o primary/secondary.)

- a) 2449, 2139
- b) 2139, 2449
- c) 2319, 2944
- d) 2449, 2449

Accepted Answers:
b) 2139, 2449

10) *3 points*

Assume the following parameter-values for an LVDT (Refer to Figure 4):

L_p = 80 mm, L_s = 100 mm, $\frac{d_o}{d_i} = 4$, N_P = 2000 and N_S = 2500 (meanings of the notations are sam as in the previous problem)

Using the values these parameters, find out e_O for displacement of core x = 5 mm, given I_P = mA peak current at 10 kHz frequency.

Permeability of free space (μ_O) = $4\pi\times10^{-7}$ H/m
(Ignore sign of output, if any)

- a) 4.36 V peak
- b) 54.64 V peak
- c) 5.46 V peak
- d) 43.6 V peak

Accepted Answers:
a) 4.36 V peak

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