Indian Institute of Technology, Bombay
Department of Electrical Engineering
EE 617 Sensors in Instrumentation

Wednesday, 17th November, 2004.
2:30 to 5:30 PM.

Important: Question 1(20 marks) is Compulsory & 5 (16 marks each) out of balance 8 questions.

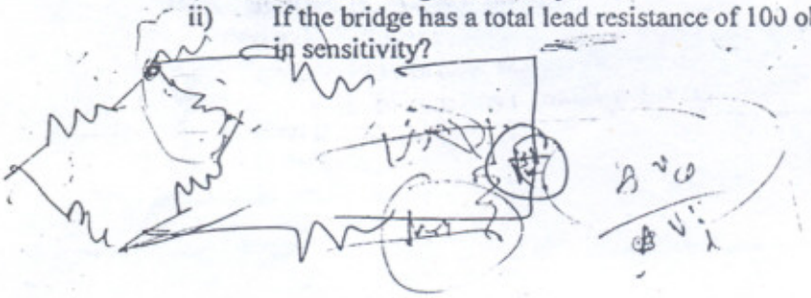
1) Describe the Sensor and its application based on the 'Study for Presentation'. Discuss merits, Demerits, Source impedance, Interface requirements etc. (Do not discuss Capacitance, Strain-gage & Thermocouple sensors discussed in the lecture).

2) A) Define Piezo Electric Constants: d, h & k.
B) Calculate the Voltage developed and Charged accumulated of Piezo crystal with the data provided as below:
Force Applied: 1 Newton; Area of Cross section of crystal- 1cm x 1cm;
Thickness of Crystal: 1mm; Permittivity constant of Crystal- 1200,
Piezo Constant 'd 33' -110x 10^{-12} C/N, Permittivity of Free space-8.8 x 10^{-12} C/V m.
C) Discuss how one can measure Acceleration using Piezo sensors.

3) A) Explain Seebeck, Peltier & Thompson Effect.
B) Discuss Widlar's Temperature CPTAT circuit.
C) How can one use multiple CPTAT devises to
i) measure Average temperature,
ii) measure minimum temperature,
of an enclosed space.

4) A) Discuss the Hall effect Principles.
B) How will one measure the following using Hall sensors:
Vibration or displacement & Angular displacement,
C) Explain how to measure Power of an Electrical Circuit using Hall effect Sensor.

5) A) Explain Gage factor & Poissons' Strain.
B) R_1, R_2, R_3 & R_4 are four arms of a Strain gage bridge, placed in a clockwise manner. R_1 & R_2 are of Strain gages of value 350 Ohms & gage factor 2.0 and R_3 & R_4 are fixed resistances of value 500 ohms. The bridge is excited with 10.5 Volts.
i) Find the bridge sensitivity?
ii) If the bridge has a total lead resistance of 100 ohms, what is the reduction in sensitivity?



P.T.O

6) A) A capacitance sensor has two plates of thickness 't' mm, area of cross section 'A' Sq mm and distance between plates is 'y' mm in free space. A dielectric material of thickness 'x' mm (x<y) of dielectric constant ε_r is introduced between the two plates,

i) What is the capacitance of the sensor,
ii) What is the sensitivity of the thickness measurement of the Dielectric material.

B) Discuss Blumin Bridge for differential capacitance measurement.

7) A) Discuss the difference between electromagnetic & Capacitance interference. What techniques would one use to reduce the interferences?

B) What type of ADC would one use & why for the following signals,

i) Slow varying DC signals with mains frequency noise, — ~~SAR~~ dual slop
ii) Bipolar signals with frequency component up to 100KHz, — SAR
iii) High frequency signals up to 100MHz — Flash converter
iv) Sensor Current output up to 3 decades. — Σ-delta

8) A) Discuss the following aspect of Op-Amp in interface design:

i) Slew rate with respect to Frequency response of amplifier,
ii) Open loop and closed loop frequency performance,
iii) Offset currents & Source impedance,

B) Discuss Input Impedance for

i) Non inverting Amplifier &
ii) Inverting Amplifier, with respect of OP-Amp input impedance and Open loop gain (Avol).

9) A) How does a guard ring help in design of capacitance sensor?

B) What is a 'Phase sensitive detector'? Derive the equation for specific V_S & V_R under conditions of same & different frequencies.

C) Discus why one should not Ground 'shields' at both ends of a shielded cable. How does it degrade the performance of a Data Acquisition system?

Indian Institute of Technology, Bombay
Department of Electrical Engineering
EE 617 Sensors In Instrumentation

Tuesday, 22nd November, 2005.
9:30 AM to 12:30 PM.

Important: Question 1(20 marks) is Compulsory & 5 (16 marks each) out of balance 8 questions.

1) Describe the Sensor and its Interface requirements based on the 'Study for Presentation'. Discuss merits, Demerits, Source impedance, Interface details etc. (Do not discuss Capacitance, Strain-gage & Thermocouple sensors discussed in the lecture).

2) A) Define Piezo Electric Constants: **d, h & k.** (5)

B) Calculate the Voltage developed and Charged accumulated of Piezo crystal with the data provided as below:
Force Applied: 1 Newton; Area of Cross section of crystal- 1cm x 1cm; Thickness of Crystal: 1mm; Permittivity constant of Crystal- 1200, Piezo Constant 'd 33' -110x 10 C/N, Permittivity of Free space-8.8 x 10 C/V m.(6)
C) Discuss how one can measure Acceleration using Piezo sensors. (5)

3) A) Explain Seeback, Peltier & Thompson Effect. (6)
B) Discuss the LVDT sensor and interface requirements including Phase sensitive detection. (10)

4) A) Discuss the Hall effect Principles and interface needs. (6)
B) How will one measure the following using Hall sensors:
Vibration or displacement & Angular displacement, (6)
C) Explain how to measure Power of an Electrical Circuit using Hall effect Sensor. (4)

5) A) Explain Gage factor & Poisson' Strain. (6)
B) R_1, R_2, R_2 & R_4 are four arms of a Strain gage bridge, placed in a clockwise manner. R_1 & R_3 are of Strain gages of value 350 Ohms & gage factor 2.0 and R_2 & R_4 are fixed resistances of value 500 ohms. The bridge is excited with 10.0 Volts.
i) Find the bridge sensitivity?
ii) If the bridge has a total lead resistance of 100 ohms, what is the reduction in sensitivity? (10)

P.T.O

6) A) A capacitance sensor has two plates of thickness 't' mm, area of cross section 'A' Sq mm and distance between plates is 'y' mm in free space. A dielectric material of thickness 'x' mm (x<y) of dielectric constant ' 'is introduced between the two plates,

i) What is the capacitance of the sensor,

ii) What is the sensitivity of the thickness measurement of the Dielectric material. (8)

B) Discuss Blumin Bridge for differential capacitance measurement. (8)

7) A) Discuss the difference between electromagnetic & Capacitance interference. What techniques would one use to reduce various interferences? (8)

B) What type of ADC would one use & why for the following signals,

i) Slow varying DC signals with mains frequency noise,

ii) Bipolar signals with frequency component up to 100KHz,

iii) High frequency signals up to 100MHz

iv) Sensor Current output up to 3 decades. (8)

8) A) Discuss the following aspect of Op-Amp in interface design:

i) Slew rate with respect to Frequency response of amplifier,

ii) Open loop and closed loop frequency performance,

iii) Offset currents & Source impedance, (8)

B) Discuss input Impedance for

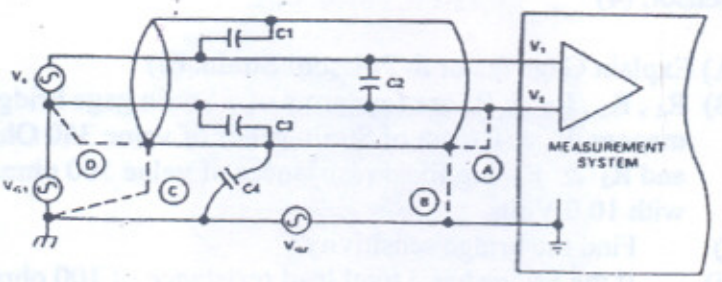
i) Non inverting Amplifier &

ii) Inverting Amplifier, with respect of OP-Amp input impedance and Open loop gain (Avol). (8)

9) A) How does a guard ring help in design of capacitance sensor? (3)

B) Discus why one should not Ground 'shields' at both ends of a shielded cable. How does it degrade the performance of a Data Acquisition system? (4)

C) Discuss, which is the best point (A or B or C or D) to ground in the Input circuit presented below to a Data Acquisition system. (9)



Possible grounds where system and source have differing ground potentials.

EE-617 Sensors in Instrumentation

I Discuss the strain gage and piezoelectric sensors

W.r.to

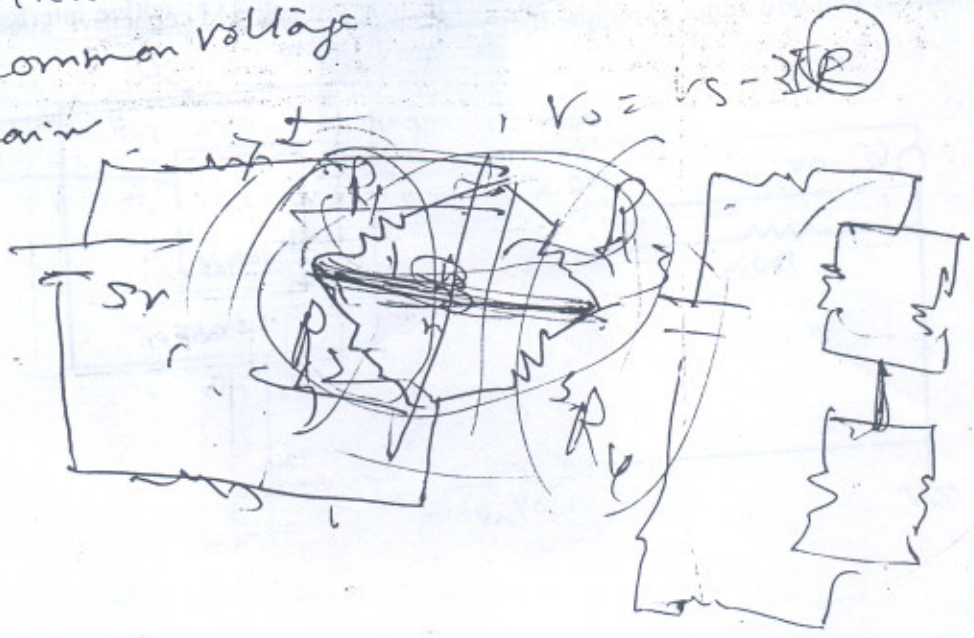
a) source impedance
b) sensor frequency response and the parameters to be modified
c) the circuit of interface amplifier

II Discuss the performance of the following op amplifier circuits

a) inverter
ii) voltage follower
c) Instrumentation amplifier

regarding

1) o/p impedance
2) CMRR
3) Common voltage
4) gain



Avo / Eq

4.a) Explain how a diode can be used as a temperature sensor?

b) The circuit of fig.4 shows a VPTAT with a sensitivity of 10 mV/°C.

i) What is the output voltage at 25° C.

ii) Assume I_1 / I_2 to be 10 and the current through R_2 to be 1.0 mA. What are the values of the string of resistors R_1, R_2 and R_3.

iii) Is the output impedance of the VPTAT high or low compared to the load impedance? Explain.

c) Explain Seebeck, Peltier and Thompson effects.

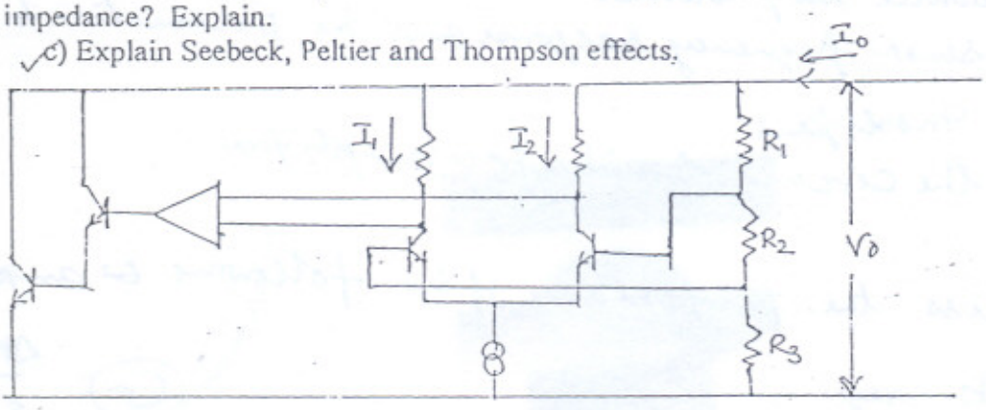


Fig 4

5.a) Discuss the relative merits and demerits of using i) D.C. ii) A.C. iii) Square wave excitations for electromagnets in electromagnetic flow meters. How are the errors with these excitations reduced?

b) Explain the working of a Coirolis flow meter.

c) Explain the need for the calibration coefficient in orifice flow meters.

6. a) What type of ADC would you choose for the following signals and why?

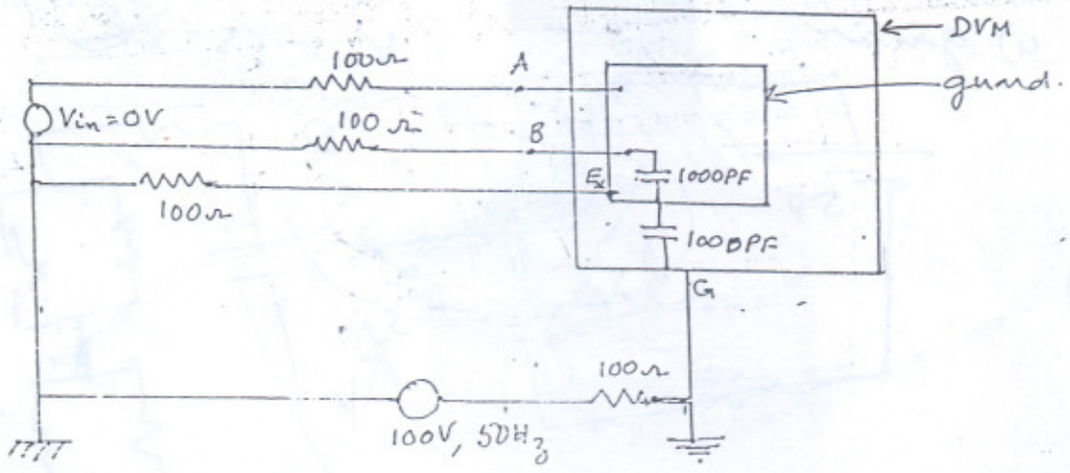
i) Low frequency d.c.signals with mains noise.

ii)Low d.c output current with a current range of over three decades.

iii) T.V.signals

b) The leakage capacitances between E and G and Band E are approximately 1000 pF each. What are the C.M. and D.M. voltages at the input of DVM?. If the DVM has a common mode rejection of 10^4, what is the indication on the DVM?

c) Explain the differences between electromagnetic and capacitive interferences. What methods will you adopt to reduce these interferences?



Indian Institute of Technology, Bombay
Department of Electrical Engineering
EE-617 Sensors in Instrumentation

Saturday, 29th Nov. 2003
2.30 To 5.30 P.M.

1.a) Explain the terms gage factor and cross sensitivity for strain gages. While designing strain gage how do you increase the gage factor and reduce cross sensitivity?

b) R_1, R_2, R_3 and R_4 are four arms of a Wheatstone bridge connected sequentially in a clockwise direction. Of these R_1 and R_2 are active strain gages of 100 ohms each and gage factor 2.0. R_3 and R_4 are fixed resistors of 500 ohms each.

i) Find the bridge sensitivity if the bridge is excited by 6 V.

ii) What would be the sensitivity if R_1 and R_4 are strain gages of 100 ohms and R_2 and R_3 are fixed resistances of 500 ohms? Based on the above suggest how the supply and detector should be connected in a bridge for higher sensitivity.

iii) If the lead wires connecting the supply to the bridge have a resistance of 100 ohms each, what would be the sensitivity in (i)above.

2.a) A capacitance sensor has two plates each of thickness 't' mm and area of cross section 'A' sq. mm. The distance between the plates is 'y' mm and is filled with air. A dielectric material of thickness 'x' mm($x<y$) of dielectric constant is introduced between the plates. What is the capacitance of the sensor? If the sensor is used to find the thickness of the dielectric, what is the sensitivity?

b) Derive an expression for the sensitivity of an inductively coupled ratio arm current comparator bridge circuit for measuring differential capacitances. Compare the sensitivity of this bridge with that of a resonance bridge.

3.a) Define piezoelectric constants d,h and k.

b) A piezoelectric transducer has a capacitance of 1000 pF and a sensitivity of 10^{-5} Coulombs/cm. The connecting cable has a capacitance of 300 pF while the oscilloscope has an input impedance of 1Mohm and a capacitance of 50 pF.

i) What is the sensitivity V/cm of the transducer only.

ii) What is the frequency at which the amplitude error is 5%?

iii) What value of capacitor should be connected to have an error of 5% at 10 Hz?

iv) What is the high frequency sensitivity?

3. A) A voltage $V = 20 \sin(100t + \pi/3) + 20 \sin 530t$ is applied to one of the inputs of a phase sensitive demodulator (PSD). The other input to the PSD is a square wave of unity amplitude and frequency 100 rad/s. The output of the PSD is applied to a low pass filter(LPF). Find the magnitude of the output of LPF. (4)

B) Find the emf generated in an electromagnetic flow meter if the liquid in it is flowing at the rate of Q = 5 litres per second. The pipe diameter is 8 cm. and the flux density is 400 T. (3)

C) List the sources of error in a current transformer? How are they caused? Using a Hall crystal, show how these errors can be reduced. (5)

4. A) Differentiate between Seebeck, Peltier, and Thomson effects. (4)

B) Fig.5 shows a two-terminal IC temperature transducer with a sensitivity of 1.0 μA/Kelvin. All transistors can be assumed to be identical except that transistor Q_4 has an active area which is 8 times the active area of transistor Q_3. Find the value of R in the circuit. Assume $k=1.38 \times 10^{-23}$, $q = 1.6 \times 10^{-19}$ C. (6)

C) A random signal x(t) has a power spectrum ϕ (w) which has a constant magnitude A up to a frequency W_c and is zero for frequencies above W_c. Derive an expression for the auto correlation function. (5)

5. A) Discuss the conditions under which the following two types of converters are preferred in industry --successive approximation and dual slope converters. (3)

B) Differentiate between common mode and isolation mode voltages. How would you ensure high isolation between sensor and signal conditioning circuit? (3)

C) Discuss how shielding reduces capacitive coupled noise. (3)

6. A) A quartz PZT crystal has the following specifications;

area = 1 sq.cm,	thickness = 1 mm,
Young's modulus = 9×10^{10} Pa,	charge sensitivity = 2 pC/N,
relative permittivity = 5,	resistivity $\rho = 10^{14}$ ohm-cm.

A 20 pF capacitance and a 100M ohm resistor are connected across the electrodes of the crystal. A force $F = 0.02 \sin 1000t$ is applied. Find

i) resistance and capacitance of the crystal
ii) the peak-to-peak voltage generated across the electrodes
iii) the maximum change in the crystal thickness. (9)

B) Describe a DC input module of a PLC. (3)

C) Write the ladder diagram to represent a motor to be switched on by pressing a push button and remains on till another stop button is pressed. (2)

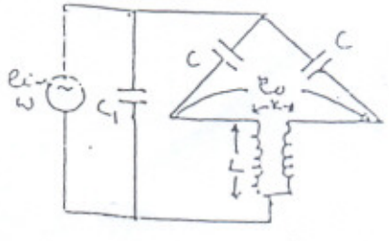


Fig 4. Q.2 C

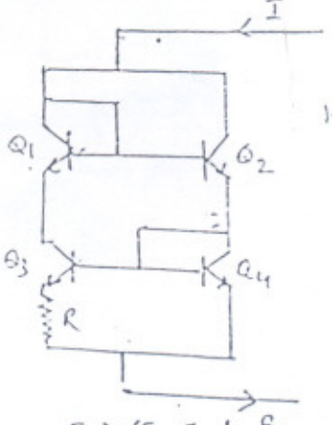


Fig 5. Q. 4 B

$K = 1.38 \times 10^{-23}$ J/K

$I = I_0 \left[e^{\frac{V_{BE}}{\eta V_T}} - 1 \right]$, $V_T = \frac{kT}{q}$

INDIAN INSTITUTE OF TECHNOLOGY

Department of Electrical engineering

Semester-end Examination

Course no.& name: EE627 Transducers in Instrumentation

Tuesday, 27thNov, 2001 2.30 to 5.30 P.M.

Note: Answer all the SIX questions. Marks for each part are indicated in the parentheses, for a total of 70.

1. A) Four capacitors of values 36.3 μF, 3.8524 μF, 34.002 μF, 34.2 pF are connected in parallel. What is the combined capacitance? Give only significant figures in your answer. (2)

B) A single arm active strain gage with 120 ohms resistance and a gage factor of 2.0 is placed in an equal arm Wheatstone bridge. The gage is subjected to a strain of 1000 micro strain. What will be the output of the bridge, if the bridge supply current is 20 mA? (2)

C) A potentiometric transducer is shown in Fig.1 .R is the resistance of the potentiometer and represents the fractional displacement (x varying between 0 and 1).

i) Derive an expression for e_o/e_{in} in terms of x.

ii) What is the maximum non-linearity error when $R/R_L = 1$. (6)

2. A) A capacitive sensor is made up of two parallel plates of area of cross section A and the separation between the plates is t. A dielectric material of thickness x (x<< t) is placed between the plates and covers the entire area A. Derive an expression for the sensitivity of the sensor for percentage changes in t. (See Fig.2). (3)

B) The height of a liquid column in a cylindrical metallic tank of diameter D and height H is measured by measuring the capacitance between a cylindrical electrode in the tank and the tank as shown in Fig.3. The electrode has a diameter d and height H. If the height of the liquid in the tank is h and its dielectric is ε_r... Find an expression for the capacitance measured in terms of the height h of the liquid. (3)

C) In the Bluemlein's bridge, a differential capacitance is connected as shown in Fig.4 The coupling coefficient of the 1:1 transformer is k, and the self inductance of the winding is L. Derive an expression for the sensitivity of the bridge, for (i) k=1 and (ii) k=0. (4)

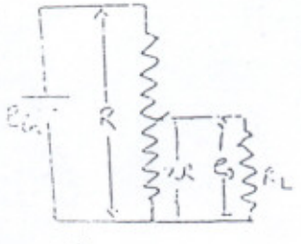


Fig 1 Q 1.B

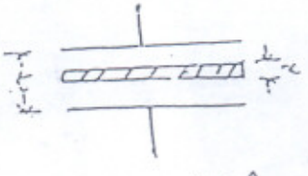


Fig 2 . Q 2.A

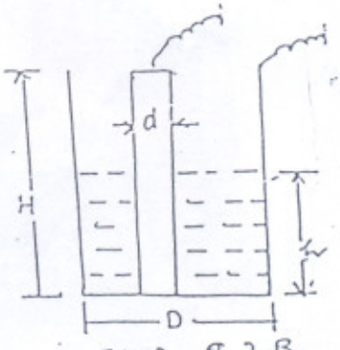


Fig 3. Q 2 B.

Indian institute of Technology
EE Department
Sensors in Instrumentation
Second class Test 7th Oct. 2002

1. R_1, R_2, R_3, and R_4 constitute four arms of a Wheatstone Bridge of which R_1 and R_2 are strain gages of 100 ohms each and R_3 and R_4 are fixed resistors of 1000 ohms each. If the bridge is excited by 10V supply, what is the sensitivity of the bridge. What would be the sensitivity if in the above bridge R_1, R_4, are strain gages and R_2, R_3 are fixed resistors ?
2. A thermocouple voltage measuring scheme is shown in Fig2. In the fig V is the thermo couple voltage, R is the cable resistance, C is the leakage capacitance. The difference in ground potentials is 100 V, 50 Hz.
   a) Find approximately the C.M. and D.M. voltages at the input of DVM.
   b) If the DVM has a CMRR of 10^4, find the maximum and minimum voltages indicated on the DVM.
   c) What modifications will you suggest to reduce the errors?
3) What is a PSD? Show a scheme to measure the direction and magnitude of displacement with LVDT using a PSD. If there is a phase difference of 30 degrees between input and reference voltages, what is the percentage error in indication?

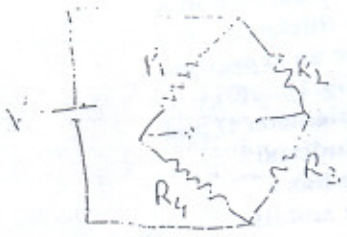


fig-1

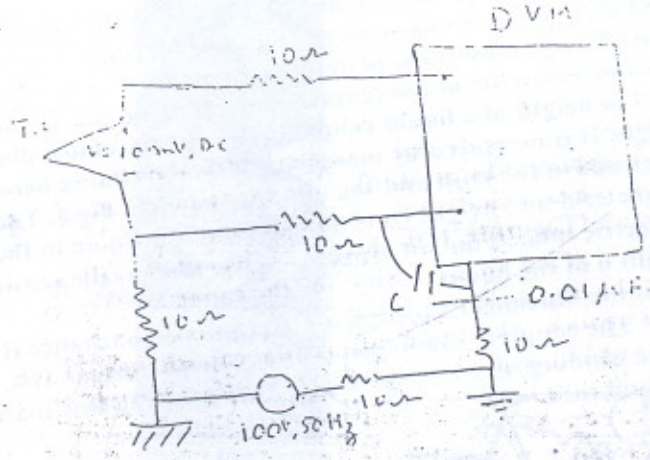


Fig 2

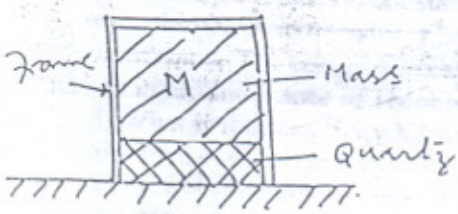
Department of Electrical Engineering
EE-627 Transducers in Instrumentation

Date: Nov. 6, 2001 Time: 1 hour

1. a) An elastic force sensor has a seismic mass of 0.1Kg, a spring stiffness of 10 N/m, and a damping constant of 1.4 Ns/m.
i) Find the natural frequency.
ii) What is the sensor damping ratio?
iii) What is the transfer function relating displacement to force?
b) If the maximum error (up to natural resonance frequency) is to be limited to 10%, find the optimum damping ratio.
c) Design a R L C network to make the damping ratio of the combination to be 0.5.

2. The input signal to a phase sensitive demodulator is 10 sin(100t + Π/3) and the reference signal is 2 sin 100t.
a) What is the magnitude of the output signal
b) If the input signal is 10 sin(100t + Π/3) +2 sin 40 t, find the output, reference signal is the same as above.

3. Figure below shows a piezoelectric accelerometer in which a mass of 0.05 Kg is constrained to move vertically by a quartz crystal of area 1 sq. cm and thickness 0.5mm. The signal from the crystal is fed to a charge amplifier. Quartz has an elastic modulus of 10^{11} Nm and a dielectric constant of 4.5, charge /force coefficient of 2×10^{-12} C/N.
a) What is the stiffness coefficient of quartz?
b) What is the resonance frequency?
c) What is the capacitance of the sensor?
d) What is the voltage output for 0.5 N force?
e) What should be the value of feedback capacitor if the output is to be 1 V for 0.1 N (neglect frequency effect).
f) What value of resistance is to be connected across the capacitance (found in e above), if the measurement is to be up to 10 KHz.?



M.T
A.D. Dar
Gayathri N

Department of Electrical Engineering
EE-617 Sensors in Instrumentation

Class test- Thursday, 18th September, 2003.
Time-5 to 6.15 P.M.

I. a) In the circuit of Fig.1 assume the op-amp to be ideal. Find the gain and input impedance of the circuit.
b) If the op-amp in fig.1 has a finite gain of 10,000, and difference mode input impedance of 100K, what are the values of gain and impedance of the amplifier?

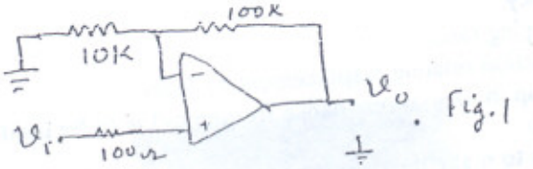


Fig.1

II. a) Four strain gages R_1 to R_4 are connected to form a Wheatstone bridge for maximum sensitivity. Gages R_1 and R_2 measure axial strain R_3 and R_4 Poisson strain. The current in each gage is to be limited to 20 mA. The gage factor of the strain gages is 2.1. The axial strain is 2.4×10^{-3}. Find the output voltage of the bridge. $R_1 = R_2 = R_3 = R_4 = 1000\,\Omega$.

b) A fixed resistance R_p is connected across R_1. Assuming no axial strain find the value of R_p to give the same output as in 2a.

c) What is radiometric method? Why is it used?

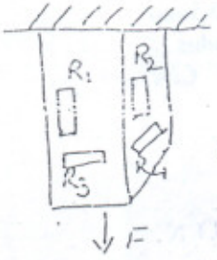


Fig.2

III a) A square wave source of peak to peak amplitude 2E at a frequency f is applied to the circuit in fig.3. Derive an expression for the current in the circuit as a function of C_1-C_2. Assume the diodes to be ideal.

b) Why is a guard circuit used?

c) Why is the gage factor of semiconductor gages much higher than metal gages?

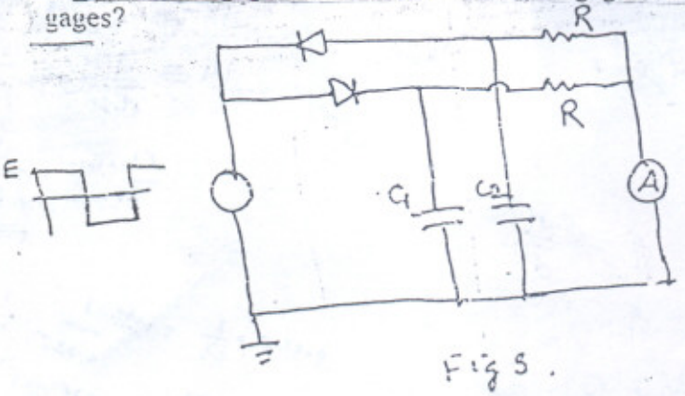


Fig 3.

Venkat

Indian Institute of Technology, Bombay
Department of Electrical Engineering
EE-617 Sensors in Instrumentation

Saturday, 29th Nov. 2003
2.30 To 5.30 P.M.

1.a) Explain the terms gage factor and cross sensitivity for strain gages. While designing strain gage how do you increase the gage factor and reduce cross sensitivity?

b) R_1, R_2, R_3 and R_4 are four arms of a Wheatstone bridge connected sequentially in a clockwise direction. Of these R_1 and R_2 are active strain gages of 100 ohms each and gage factor 2.0. R_3 and R_4 are fixed resistors of 500 ohms each.

i) Find the bridge sensitivity if the bridge is excited by 6 V.

ii) What would be the sensitivity if R_1 and R_4 are strain gages of 100 ohms and R_2 and R_3 are fixed resistances of 500 ohms? Based on the above suggest how the supply and detector should be connected in a bridge for higher sensitivity.

iii) If the lead wires connecting the supply to the bridge have a resistance of 100 ohms each, what would be the sensitivity in (i)above.

2.a) A capacitance sensor has two plates each of thickness 't' mm and area of cross section 'A' sq. mm. The distance between the plates is 'y' mm and is filled with air. A dielectric material of thickness 'x' mm($x<y$) of dielectric constant is introduced between the plates. What is the capacitance of the sensor? If the sensor is used to find the thickness of the dielectric, what is the sensitivity?

b) Derive an expression for the sensitivity of an inductively coupled ratio arm current comparator bridge circuit for measuring differential capacitances. Compare the sensitivity of this bridge with that of a resonance bridge.

3.a) Define piezoelectric constants d,h and k.

b) A piezoelectric transducer has a capacitance of 1000 pF and a sensitivity of 10^{-5} Coulombs/cm. The connecting cable has a capacitance of 300 pF while the oscilloscope has an input impedance of 1Mohm and a capacitance of 50 pF.

i) What is the sensitivity V/cm of the transducer only.

ii) What is the frequency at which the amplitude error is 5%?

iii) What value of capacitor should be connected to have an error of 5% at 10 Hz?

iv) What is the high frequency sensitivity?

K → sensitivity
h →

4.a) Explain how a diode can be used as a temperature sensor?

b) The circuit of fig.4 shows a VPTAT with a sensitivity of 10 mV/C°.

i) What is the output voltage at 25° C.

ii) Assume I_1 / I_2 to be 10 and the current through P_2 to be 1.0 mA. What are the values of the string of resistors R_1, R_2 and R_3.

iii) Is the output impedance of the VPTAT high or low compared to the load impedance? Explain.

c) Explain Seebeck, Peltier and Thompson effects.

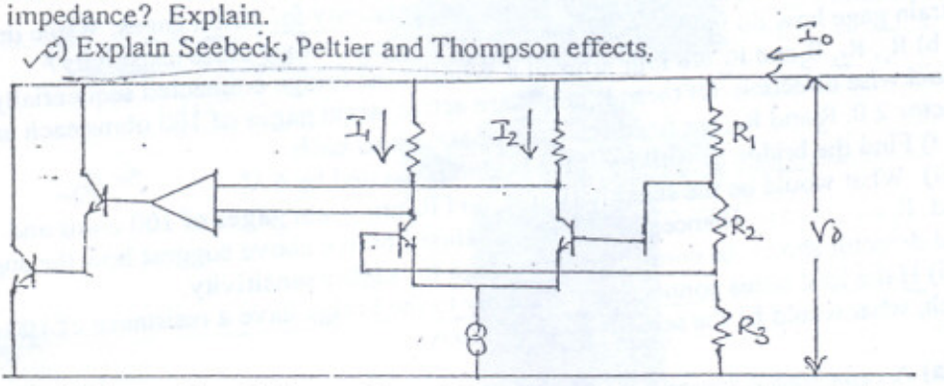


Fig 4

5.a) Discuss the relative merits and demerits of using i) D.C. ii) A.C. iii) Square wave excitations for electromagnets in electromagnetic flow meters. How are the errors with these excitations reduced?

b) Explain the working of a Coirolis flow meter.

c) Explain the need for the calibration coefficient in orifice flow meters.

6. a) What type of ADC would you choose for the following signals and why?

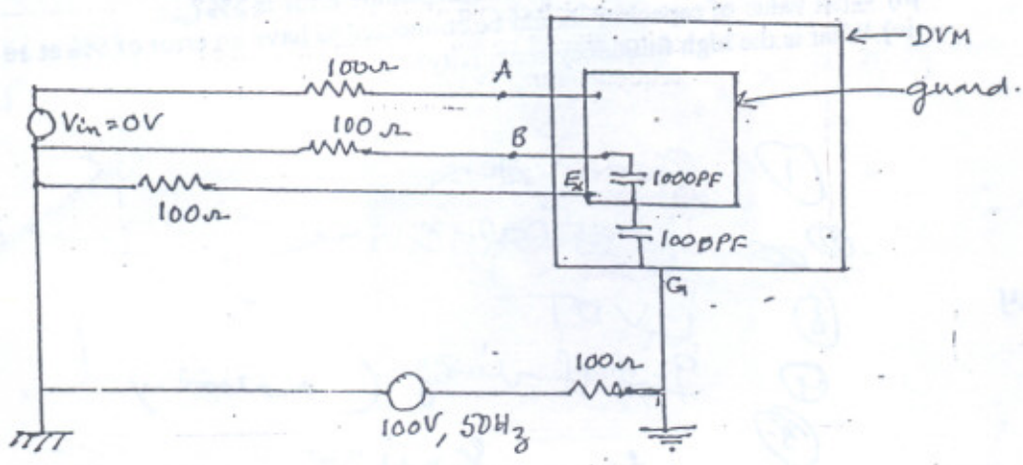
i) Low frequency d.c.signals with mains noise.

ii)Low d.c output current with a current range of over three decades.

iii) T.V.signals

b) The leakage capacitances between E and G and Band E are approximately 1000 pF each. What are the C.M. and D.M. voltages at the input of DVM?. If the DVM has a common mode rejection of 10^4, what is the indication on the DVM?

c) Explain the differences between electromagnetic and capacitive interferences. What methods will you adopt to reduce these interferences?



Venkat Ramana Reddy.

Indian Institute of Technology, Bombay
Department of Electrical Engineering
EE 617 Sensors in Instrumentation

Wednesday, 17th November, 2004.
2:30 to 5:30 PM.

Important: Question 1(20 marks) is Compulsory & 5 (16 marks each) out of balance 8 questions.

1) Describe the Sensor and its application based on the 'Study for Presentation'. Discuss merits, Demerits, Source impedance, Interface requirements etc. (Do not discuss Capacitance, Strain-gage & Thermocouple sensors discussed in the lecture).

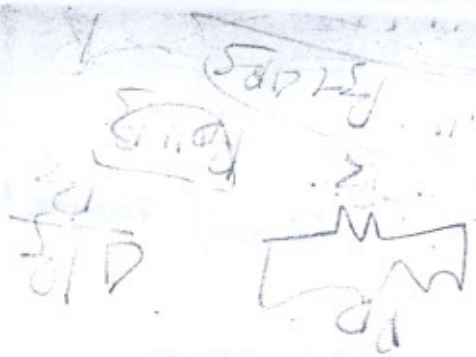
2) A) Define Piezo Electric Constants: **d, h & k.**
B) Calculate the Voltage developed and Charged accumulated of Piezo crystal with the data provided as below:
Force Applied: 1 Newton; Area of Cross section of crystal- 1cm x 1cm; Thickness of Crystal: 1mm; Permittivity constant of Crystal- 1200, Piezo Constant 'd 33' -110x 10^{-12} C/N, Permittivity of Free space-8.8 x 10^{-12} C/V m.
C) Discuss how one can measure Acceleration using Piezo sensors.

3) A) Explain Seeback, Peltier & Thompson Effect.
B) Discuss Widlar's Temperature CPTAT circuit.
C) How can one use multiple CPTAT devises to
i) measure Average temperature,
ii) measure minimum temperature,
of an enclosed space.

4) A) Discuss the Hall effect Principles.
B) How will one measure the following using Hall sensors:
Vibration or displacement & Angular displacement,
C) Explain how to measure Power of an Electrical Circuit using Hall effect Sensor.

5) A) Explain Gage factor & Poissons' Strain.
B) R_1, R_2, R_3 & R_4 are four arms of a Strain gage bridge, placed in a clockwise manner. R_1 & R_2 are of Strain gages of value 350 Ohms & gage factor 2.0 and R_3 & R_4 are fixed resistances of value 500 ohms. The bridge is excited with 10.5 Volts.
i) Find the bridge sensitivity?
ii) If the bridge has a total lead resistance of 100 ohms, what is the reduction in sensitivity?

P.T.O



6) A) A capacitance sensor has two plates of thickness 't' mm, area of cross section 'A' Sq mm and distance between plates is 'y' mm in free space. A dielectric material of thickness 'x' mm (x<y) of dielectric constant ε_r is introduced between the two plates,

   i) What is the capacitance of the sensor,
   ii) What is the sensitivity of the thickness measurement of the Dielectric material.

   B) Discuss Blumin Bridge for differential capacitance measurement.

7) A) Discuss the difference between electromagnetic & Capacitance interference. What techniques would one use to reduce the interferences?

   B) What type of ADC would one use & why for the following signals,

   i) Slow varying DC signals with mains frequency noise,
   ii) Bipolar signals with frequency component up to 100KHz,
   iii) High frequency signals up to 100MHz
   iv) Sensor Current output up to 3 decades.

8) A) Discuss the following aspect of Op-Amp in interface design:

   i) Slew rate with respect to Frequency response of amplifier,
   ii) Open loop and closed loop frequency performance,
   iii) Offset currents & Source impedance,

   B) Discuss Input Impedance for

   i) Non inverting Amplifier &
   ii) Inverting Amplifier, with respect of OP-Amp input impedance and Open loop gain (Avol).

9) A) How does a guard ring help in design of capacitance sensor?

   B) What is a 'Phase sensitive detector'? Derive the equation for specific V_S & V_{R0} under conditions of same & different frequencies.

   C) Discus why one should not Ground 'shields' at both ends of a shielded cable. How does it degrade the performance of a Data Acquisition system?

Department of Electrical Engineering
EE –617 Sensors in Instrumentation

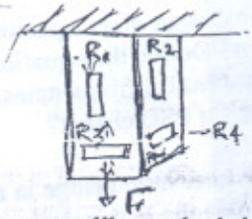
Mid Semester Exam
Time 10:00AM to 12:00 PM – 18-09-2004

Attempt six questions (min two questions from Sr nos 1 to 4 and min two questions from 5 to 10).

1 - A) Derive the general Equation for a Strain gage Wheatstone Bridge output with strains $\varepsilon_1, \varepsilon_2, \varepsilon_3 \& \varepsilon_4$ and all gage resistances equal to R.

B) If the gage resistances have a temperature co-ef of strain (ε_i^T etc), how does the bridge output get modified.

2 - A) Four Strain gages R_1 to R_4 (each of 1000 ohms resistance) in a Wheatstone bridge provide maximum sensitivity. Gages R_1 & R_2 measure axial strain and R_3 & R_4 measure Poisson strain. The bridge is fed by a constant current source of 40 mA. The gage factor of the strain gages is 2.0. The axial strain is 2.5×10^{-3}. Find the output voltage. $\mu = 0.3$



$V_0 = \frac{V_s}{4}\{R(1+\mu)\}$ GF

B) One technique to calibrate the bridge is to shunt one of the Bridge resistances (say R_1) with a resistance R_p. Find value of R_p to provide the same output as in 2A.

3 - A) What is Ratio-metric method? Why is it used?

B) Derive the equation of Output voltage of a strain gage bridge using one Strain gage element with respect to $\alpha = \frac{\Delta R}{R}$. Assume all other resistances of the bridge are same as gage resistance R.

C) Describe any one technique to linearise the output with respect to α.

4 - A) Derive the equation of Strain for bridge with single gage resistance based on measurement of Unstrained and Strained output voltages.

B) How does this technique help in measuring strain?

5 – A) One technique to measure an unknown value C_x of a Capacitor Sensor is to use a 'Variable frequency (ω) voltage source' with either a series or parallel resonance circuit employing a known value of inductor 'L'. Derive the equations for capacitance in terms of L & ω.

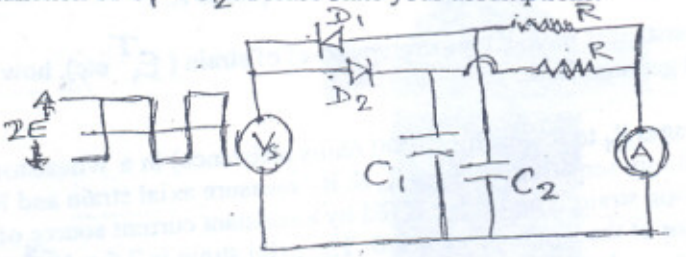
B) What are the major disadvantages in this technique? Is there a method to avoid the problems of Stray capacitances.

P.T.O.

C) Find out the uncertainty in measurement of Capacitance with respect to measurement of L and ω. Assume full scale values for capacitance, inductance and frequency.

6 - A) Derive the equation for measurement of linear displacement 'd' with capacitance sensor using differential capacitance.

B) A square wave source with 2E as peak to peak amplitude at a frequency 'f' is applied to the circuit in Fig 2. Derive an expression for the current in the circuit as a function of C_1 - C_2. Please state your assumptions.



7 – A) How does a guard ring help in the design of a Capacitance sensor?

B) What is a phase sensitive detector? Derive the equation for a specific V_s & V_R under conditions of different & identical frequencies.

C) How does one measure noise using PSD circuit?

8 – A) Derive the equation for the transformer ratio bridge in measurement of differential capacitance. Please state the assumptions in this derivation.

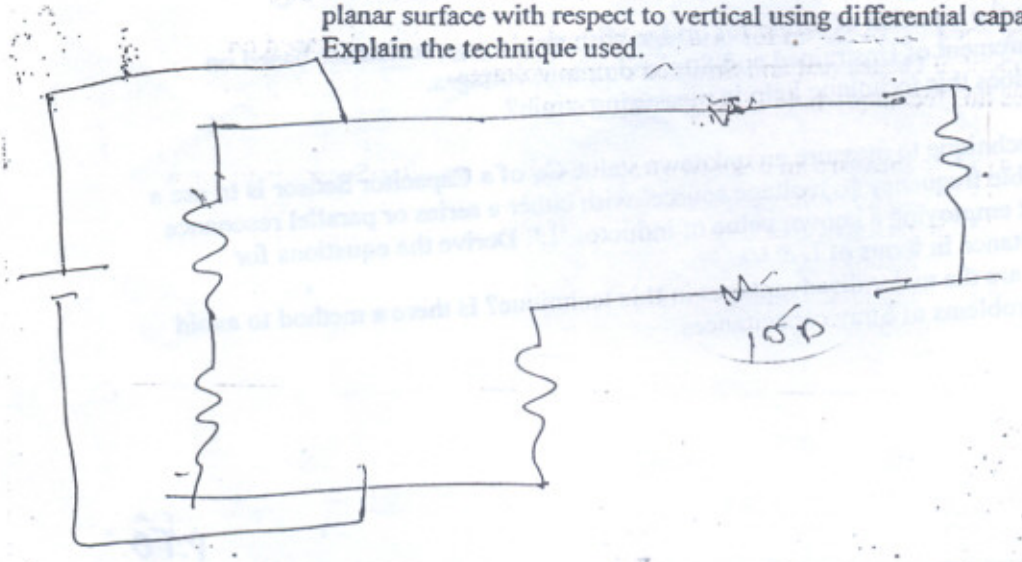
B) Why does one use the Blumlein bridge for measurement of differential capacitance?

9 - A) Draw the essential circuit to measure directly Liquid level in a tank and explain the various parts of the circuit and techniques implemented.

B) Derive the equation for liquid height?

10 - A) How will you measure Humidity using Capacitance sensor?

B) Design an electronic Spirit level to measure the angle of Tilt of a horizontal planar surface with respect to vertical using differential capacitance technique. Explain the technique used.



Indian Institute of Technology, Bombay
Department of Electrical Engineering
EE 617 Sensors In Instrumentation

Tuesday, 22nd November, 2005.
9:30 AM to 12:30 PM.

Important: Question 1(20 marks) is Compulsory & 5 (16 marks each) out of balance 8 questions.

1) Describe the Sensor and its Interface requirements based on the 'Study for Presentation'. Discuss merits, Demerits, Source impedance, Interface details etc. (Do not discuss Capacitance, Strain-gage & Thermocouple sensors discussed in the lecture).

2) A) Define Piezo Electric Constants: **d, h & k.** (5)

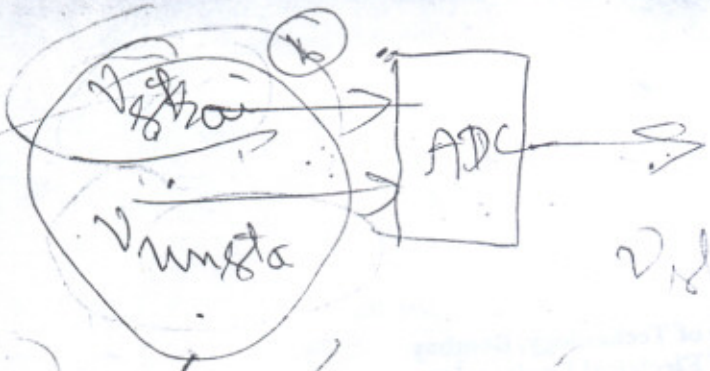
B) Calculate the Voltage developed and Charged accumulated of Piezo crystal with the data provided as below:
Force Applied: 1 Newton; Area of Cross section of crystal- 1cm x 1cm; Thickness of Crystal: 1mm; Permittivity constant of Crystal- 1200, Piezo Constant 'd 33'-110x 10^{-12} C/N, Permittivity of Free space-8.8 x 10^{-12} C/V m.(6)
C) Discuss how one can measure **Acceleration** using Piezo sensors. (5)

3) A) Explain Seeback, Peltier & Thompson Effect. (6)
B) Discuss the LVDT sensor and interface requirements including Phase sensitive detection. (10)

4) A) Discuss the Hall effect Principles and interface needs. (6)
B) How will one measure the following using Hall sensors:
Vibration or displacement & Angular displacement, (6)
C) Explain how to measure Power of an Electrical Circuit using Hall effect Sensor. (4)

5) A) Explain Gage factor & Poisson' Strain. (6)
B) R_1, R_2, R_2 & R_4 are four arms of a Strain gage bridge, placed in a clockwise manner. R_1 & R_3 are of Strain gages of value 350 Ohms & gage factor 2.0 and R_2 & R_4 are fixed resistances of value 500 ohms. The bridge is excited with 10.0 Volts.
i) Find the bridge sensitivity?
ii) If the bridge has a total lead resistance of 100 ohms, what is the reduction in sensitivity? (10)

P.T.O



6) A) A capacitance sensor has two plates of thickness 't' mm, area of cross section 'A' Sq mm and distance between plates is 'y' mm in free space. A dielectric material of thickness 'x' mm (x<y) of dielectric constant ' 'is introduced between the two plates,
   i) What is the capacitance of the sensor,
   ii) What is the sensitivity of the thickness measurement of the Dielectric material. (8)

   B) Discuss Blumin Bridge for differential capacitance measurement. (8)

7) A) Discuss the difference between electromagnetic & Capacitance interference. What techniques would one use to reduce various interferences? (8)

   B) What type of ADC would one use & why for the following signals,
   i) Slow varying DC signals with mains frequency noise,
   ii) Bipolar signals with frequency component up to 100KHz,
   iii) High frequency signals up to 100MHz
   iv) Sensor Current output up to 3 decades. (8)

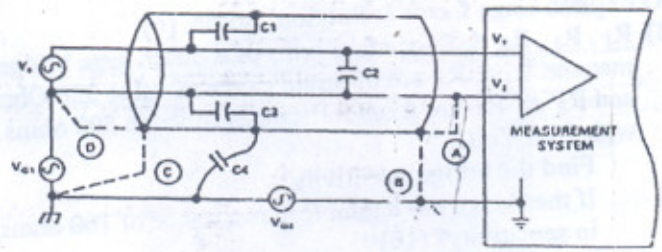
8) A) Discuss the following aspect of Op-Amp in interface design:
   i) Slew rate with respect to Frequency response of amplifier,
   ii) Open loop and closed loop frequency performance,
   iii) Offset currents & Source impedance, (8)

   B) Discuss Input Impedance for
   i) Non inverting Amplifier &
   ii) Inverting Amplifier, with respect to OP-Amp input impedance and Open loop gain (Avol). (8)

9) A) How does a guard ring help in design of capacitance sensor? (3)

   B) Discus why one should not Ground 'shields' at both ends of a shielded cable. How does it degrade the performance of a Data Acquisition system? (4)

   C) Discuss, which is the best point (A or B or C or D) to ground in the Input circuit presented below to a Data Acquisition system. (9)



Possible grounds where system and source have differing ground potentials.