EEM 323/3 - Assignment

1. A platinum resistance sensor has a resistance of $100\ \Omega$ at 0 ℃ and a temperature coefficient of resistance of 4×10^{-3} $^{\circ}C^{-1}$. Given that a 15 V supply is available, design a deflection bridge giving an output range of 0 to 100 mV for an input range of 0 to 100 ℃:
   (a) using the procedure discussed in lectures.
   (b) using the linear approximation discussed in lectures.
   (c) how should the circuit be altered if the input range is changed to 50 to 150 ℃?

   Give values for all circuit components and assume a high impedance load.

2. The resistance $R_\theta(\mathrm{k\Omega})$ of a thermistor at $\theta^{\circ}\ \mathrm{K}$ is given by:

$$R_\theta = 1.68\left[3050\left(\frac{1}{\theta} - \frac{1}{298}\right)\right]$$

   The thermistor is incorporated into the deflection bridge circuit shown in Fig. 2

   (a) Assuming that V_{out} is measured with a detector of infinite impedance, calculate:
      (i) the range of V_{out} corresponding to an input temperature range of 0 to 50 ℃.
      (ii) the non-linearity at 12 ℃ as a percentage of full-scale deflection.
   (b) Calculate the effect on the range of V_{out} of reducing the detector impedance to 1 kΩ.

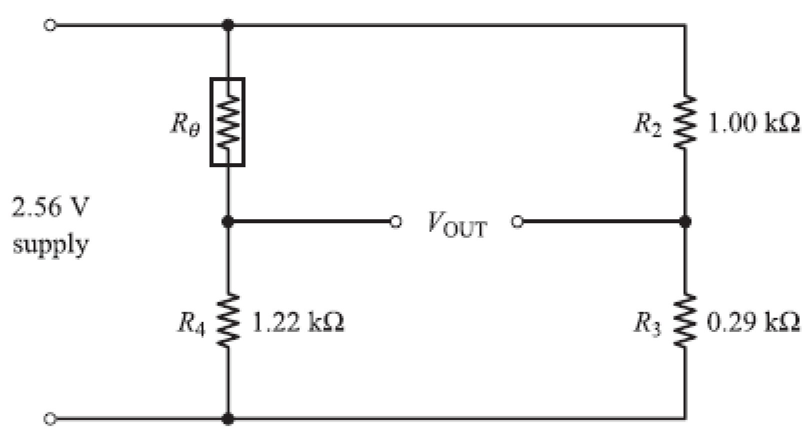

Fig. 2

3. Fig. 3 shows a four-lead bridge circuit; R_c is the resistance of the leads connecting the sensor to the bridge circuit. Show that $E_{Th} \approx V_s \left({R_0}/{R_3}\right) \alpha T$, i.e. the bridge output voltage is unaffected by changes in R_c. State all assumptions.

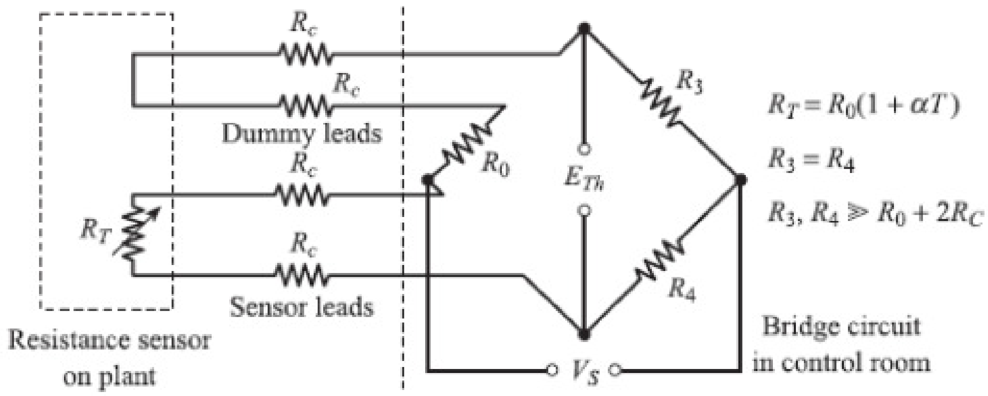

Fig. 3

4. A low-voltage Schering bridge shown in Fig. 4 is used to measure the unknown permittivity of a specimen using 2-plate capacitor, C_1 with area *A* and distance *d*.

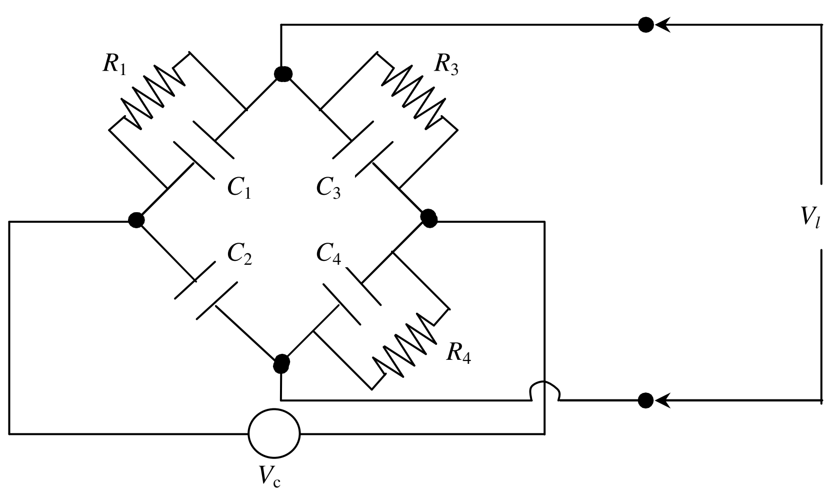

Fig. 4

Referring to Fig. 4, R_1 is a stray resistor, R_3 and R_4 are pure non-reactive resistors, and C_2 , C_3 and C_4 are pure non-reactive capacitors. Without the specimen the following balanced condition are attained: $C_3 = C_4 = 120\ \mathrm{pF}$, $C_2 = 140\ \mathrm{pF}$ and $R_3 = R_4 = 5000\ \Omega$. With the specimen the values changed to $C_3 = 200\ \mathrm{pF}$, $C_4 = 1000\ \mathrm{pF}$, $C_2 = 900\ \mathrm{pF}$, and $R_3 = R_4 = 500\ \Omega$. If $V_c = 10\ \mathrm{V\ (RMS)}$ and $\omega = 5000\ \mathrm{rad/s}$, calculate the relative permittivity of the specimen.

5. (a) List common source of errors in AC bridge circuits. Hence, state several precautions that should be taken to reduce the errors.

(b) In designing a sensing circuit for measuring the level of oil $(\varepsilon_{\text{oil}})$ inside a tank, the capacitive level sensor has been proposed. Meanwhile, the simplified four-arm De-Sauty bridge has been suggested for signal detection. Figure 1 shows the instrumentation and measurement system. In this figure R_4 and C_2 are pure resistance and capacitance respectively, C_h is the sensor capacitance at a height h of the oil and R_4 is the variable resistance.

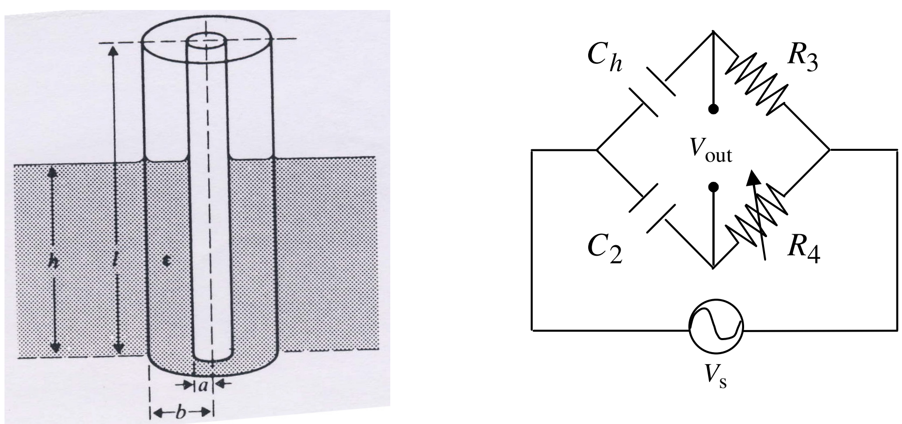

Fig. 5

The relationship between C_h and h of the capacitive sensor is as follows:

$$C_h = \frac{2\pi\varepsilon_0}{\log_e\left(\frac{b}{a}\right)}\left[1+(\varepsilon_{\text{oil}}-1)h\right]$$

(i) Derive the balanced conditions of Fig. 5,

(ii) Calculate h when at balance $C_2 = 1000\,\mu\text{F}$, $R_4 = 10\,\Omega$, $R_3 = 1250\,\Omega$, $\varepsilon_0 = 1$, $\varepsilon_{\text{oil}} = 3$, $b = 2\,\text{cm}$ and $a = 0.5\,\text{cm}$,

(iii) State the main source of error in 1(b) (ii).

6. (a) Explain the important of the quality factor Q and the damping factor ξ in filter design.

(b) The Sallen-Key second order low pass filter is shown in Fig. 6.

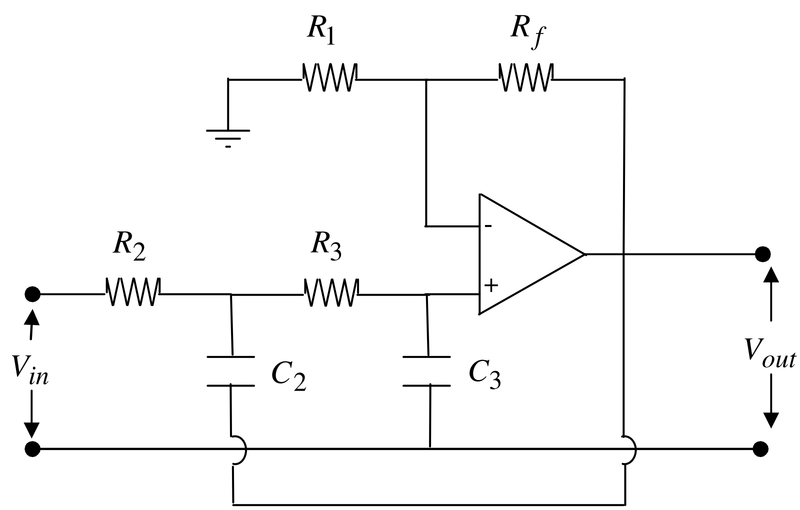

Fig. 6

Prove the transfer function of the above filter is given by

$$H(s) = \frac{\dfrac{G}{R_2R_3C_2C_3}}{s^2 + \left(\dfrac{R_3C_3 + R_2C_3 + R_2C_2 - GR_2C_2}{R_2R_3C_2C_3}\right)s + \dfrac{1}{R_2R_3C_2C_3}}$$

and $G = 1 + \dfrac{R_f}{R_1}$.

Assuming $R_2 = R,\ R_3 = 2R,\ C_2 = C,\ C_3 = 2C$ /and $R_f = R_{1,}$

(i) Design filter in Figure 2 such that the resonance frequency $\omega_o = 1000 \text{ rad/sec}$,

(ii) From 2(b)(ii), calculate the Q and damping ξ factors of the filter,

(iii) Hence, modify Figure 2 so that the above filter has the Butterworth response such that $|H(j\omega_0)| = 1$ or 0 dB.

7. (a) Explain the terms (i) resolution, (ii) quantum error, (iii) acquisition time t_{aq}, (iv) aperture time t_{ap} and (v) settling time t_s with respect to the analogue-to-digital converter.

(b) The 4-bit $R-2R$ type digital-to-analogue converter is shown in Fig. 7.

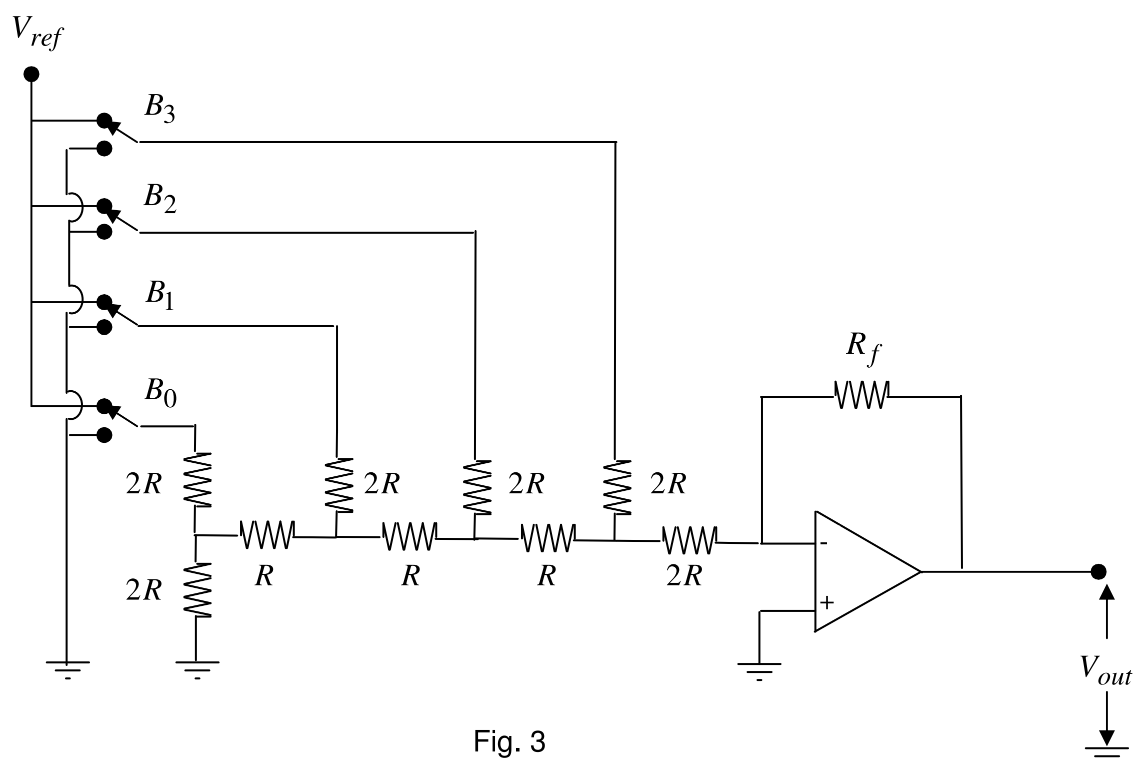

Fig. 3

(i) Derive the output V_{out} when the most significant bit (MSB) is turned on only,

(ii) Repeat 3(b)(i) for the least significant bit (LSB),

(iii) Repeat 3(b)(i) for an input $B_3 B_2 B_1 B_0 = 1001$,

(iv) From 3(b)(i-iii) derive the general expression for V_{out}.