RTD

Q.1 A platinum resistance thermometer has a resistance of 140.5 and 100 Ω at 100 and 0°C, respectively. If its resistance becomes 305.3 Ω when it is contact with a hot gas, determine the temprature of the gas. The temprature coefficient of platinum is 0.0039 °C^{-1}.

Ans. The temprature - resistance relationship of platinum is given by:

$$R_2 = R_1 + R_0 \alpha (t_2 - t_1)$$

$$\Rightarrow t_2 = 100 + \frac{305.3 - 140.5}{0.0039 \times 100}$$

$$= 522.56 °C$$

Q.2 An RTD is assumed to be represented in the range 0°C to 100°C by a linear model as $R_T = R_0 (1 + 0.004 T)$ where T is the temprature in °C. $R_0 = 100 \Omega$ with a variation of ± 2 Ω. The true model of RTD is $R_T = R_0 (1 + 0.004T + 6 \times 10^{-7}$ The worst-case error magnitude in the resistance value that will be introduced, if the linear model is used over a range of 0 to 100°C is?

Ans. $R_T = R_0(1+0.004T)$

$R_0 = 100 \pm 2$

$= 102$ or 98

↓ ↓

MV_1 MV_2 MV → Measured Value

$$R_T = R_0(1+0.004T + 6\times10^{-7}T^2)$$

$$= 100(1+0.004(100) + 6\times10^{-7}(100)^2)$$

$$= 140.6\,\Omega \rightarrow TV_{R_T} \text{ (True Value)}$$

$$MV_{1_{R_T}} = 102(1+0.004(100))$$

$$= 142.8\,\Omega$$

$$MV_{2_{R_T}} = 98(1+0.004(100))$$

$$= 137.2\,\Omega$$

$$e_{r_1} = MV_{1_{R_T}} - TV_{R_T}$$

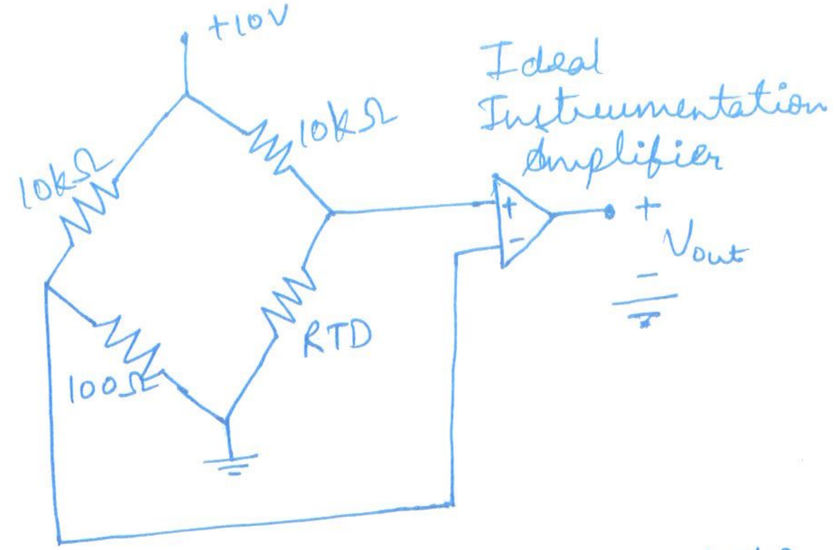
$$= +2.2\,\Omega$$

$$e_{r_2} = MV_{2_{R_T}} - TV_{R_T}$$

$$= -3.4\,\Omega$$

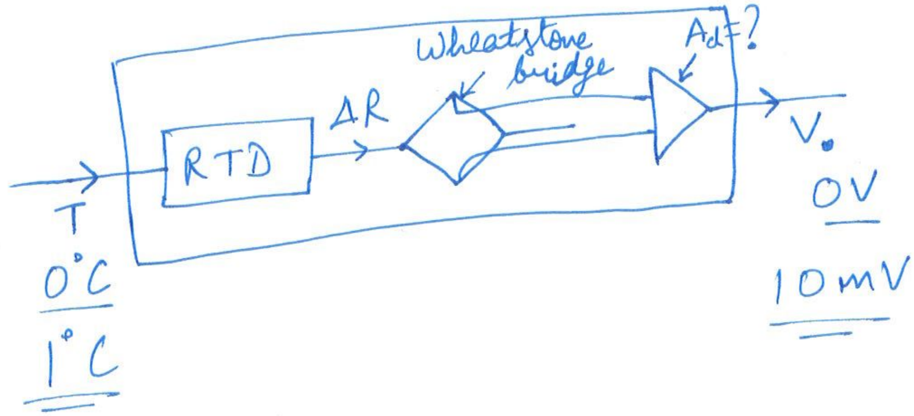
$$|e_{r_{worst}}| = 3.4\,\Omega$$

Q. 3 Consider a temprature measurement scheme shown in the adjoining figure. It uses an RTD whose resistance at 0°c is 100 Ω and temprature coefficient of resistance is 0.0039/°c.

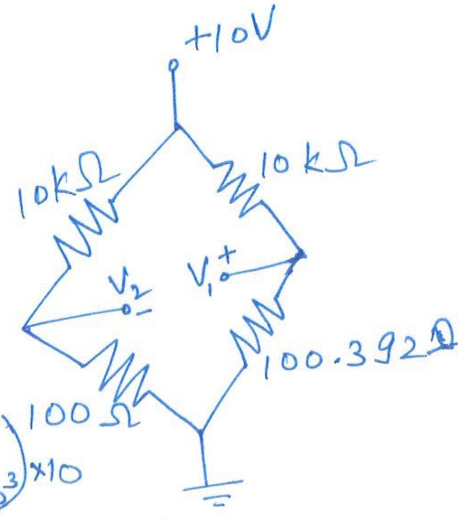


The differential gain of instrumentation amplifier to achieve a voltage sensitivity of 10 mV/°C at 0°C should be approximately?

Ans.



$$R_T = R_o(1+\alpha\Delta T)$$
$$= 100(1+0.00392\times 1)$$
$$= 100.392\,\Omega$$



$$V_{Bri} = V_1 - V_2$$
$$= \left(\frac{100.392}{100.392+10\times10^3} - \frac{100}{100+10\times10^3}\right)\times 10$$
$$= 0.384\,mV$$

$V_o = A_d V_{Bri}$

$\Rightarrow A_d = \dfrac{V_o}{V_{Bri}}$

$= \dfrac{10}{0.384}$

$= 26.04$

Q.4 The RTD placed in hot water bath of temperature 100°C. Based on the gain calculated above Q3, the error in the measured value of the temperature due to bridge nonlinearity is?

Ans. $R_T = R_o(1 + \alpha \Delta T)$

$= 100(1 + 0.00392 \times 100)$

$= 139.2\ \Omega$

$V_{Bri} = \left(\dfrac{139.2}{139.2 + 10\times10^3} - \dfrac{100}{100 + 10\times10^3} \right) \times 10$

$= 0.0382\ V$

$V_o = A_d V_{Bri}$

$= 26.04 \times 0.0382$

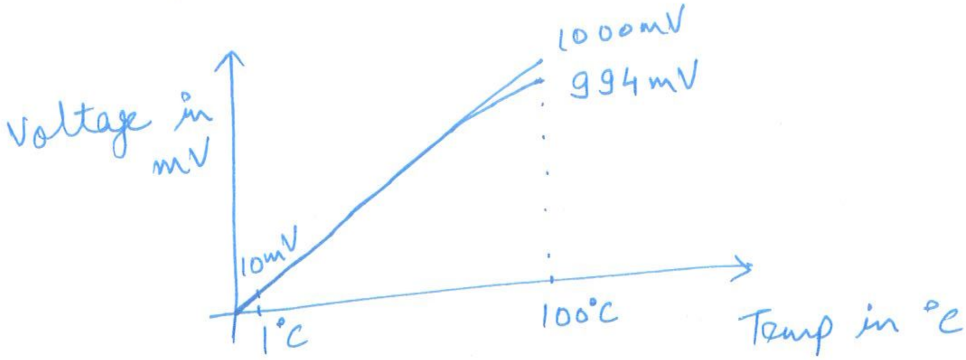
$= 994.7\ mV$

Sensitivity of system $= \dfrac{10\ mV}{1\ °C}$

$0°C \longrightarrow 0V$

$1°C \longrightarrow 10\ mV$

$100°C \longrightarrow 10 \times 100\ mV$



$error = 994 - 1000$

$= -6\ mV$

$1\ mV \longrightarrow 0.1\ °C$

$\Rightarrow -6\ mV \longrightarrow -0.6°C$

$= -0.6\ °C$

Thermistor

Q.1 For a certain thermistor, $\beta = 3140\,K$ and the resistance at $27^\circ C$ is known to be $1050\,\Omega$. The thermistor is used for temprature measurement and the resistance measured is as $2330\,\Omega$. Find the measured temperature.

Ans. The governing equation of the temperature-resistance characteristics of the thermistor is given by

$$R = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

The given data is

$$R_0 = 1050\,\Omega$$

$$T_0 = 273 + 27 = 370\,K$$

$$\beta = 3140\,K$$

$$R = 2330\,\Omega$$

Taking the logarithm of both sides of equation and rearranging we get,

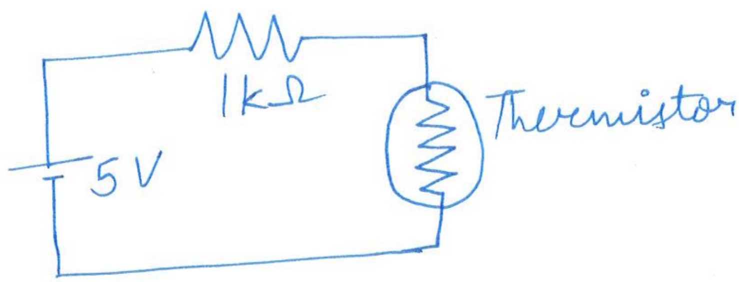
$$\frac{1}{T} = \frac{\ln R - \ln R_0}{\beta} + \frac{1}{T_0}$$

$$= \frac{7.754 - 6.957}{3140} + \frac{1}{300} = 3.587 \times 10^{-3}$$

$\Rightarrow T = 278.77K$

$= 5.77°C$

Q.2 A thermistor has a resistance of 10kΩ at 25°C and 1kΩ at 100°C. The range of operation is 0°C – 150°C. The excitation voltage is 5V and a series resistor of 1kΩ is connected to the thermistor. The power dissipated in the thermistor at 150°C is?



Ans. $R_0 = 10\ k\Omega$, $T_0 = 25°C$

$R_T = 1k\Omega$, $T = 100°C$

$$\ln\left(\frac{R_T}{R_0}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\Rightarrow \ln\left(\frac{1000}{10000}\right) = \beta\left(\frac{1}{\cancel{100}\ 373} - \frac{1}{\cancel{25}\ 298}\right)$$

$\Rightarrow \beta = 3412.42\ K$

@ $T = 150°C = 423\ K$

$R_T = ?$

$$\ln\left(\frac{R_T}{R_0}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\Rightarrow \quad R_T = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

$$= 10\times10^3 \exp\left[3412.42\left(\frac{1}{423} - \frac{1}{373}\right)\right]$$

$$= 339\ \Omega$$

Power dissipated $= I^2R$

$$= \left(\frac{5}{1000+339}\right)^2 \times 339$$

$$= 4.7\ mW$$

Q.3 A thermistor has a resistance of $1k\Omega$ at temprature 298 K and $465\ \Omega$ at temperature 316 K. The temperature sensitivity in K^{-1} [i.e. $\frac{1}{R}\frac{dR}{dT}$ where R is the resistance at temperature T (in K)] of this thermistor at 316 K is?

Ans.

298 K — $1k\Omega$

316 K — $465\ \Omega$

$$\alpha = \frac{1}{R}\frac{dR}{dT} = ?$$

$$\ln\left(\frac{R_T}{R_0}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\Rightarrow \ln\left(\frac{465}{1000}\right) = \beta\left(\frac{1}{316} - \frac{1}{298}\right)$$

$$\Rightarrow \beta = 4005.89\,K$$

$$\alpha = \frac{-\beta}{T^2}$$

$$= -\frac{4005.89}{(316)^2}$$

$$= -0.040\,/K$$

Q.4 A thermistor has a resistance of 10kΩ at 25 °C. The resistance temperature coefficient is -0.05/°C. A Wien's bridge oscillator uses two identical thermistors in the frequency determining part of the bridge. The value of capacitance used in the bridge is 500pF. Calculate the value of frequency of oscillations for 20°C. The frequency of oscillations is $f = \frac{1}{2\pi RC}$ Hz.

Ans. Resistance of thermistor at 20°C =

$$10000(1-0.05(20-25))$$

$$= 12500\,\Omega$$

Frequency of oscillations $= \dfrac{1}{2\pi RC}$

$$= \frac{1}{2\pi \times 12500 \times 500 \times 10^{-12}}$$

$$= 25.46\ \text{kHz}$$