Questions with Solutions

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ÇANKAYA ÜNİVERSİTESİ
MEKATRONİK MÜHENDİSLİĞİ BÖLÜMÜ

Accuracy

- Accuracy is defined as the degree of conformity of a measured value to the true (conventional true value – CTV) or accepted value of the variable being measured. It is a measure of the total error in the measurement without looking into the sources of the errors.
- Mathematically it is expressed as the maximum absolute deviation of the readings from the CTV. This is called the absolute accuracy.

$$absoluteAccuracy = \left| \text{maximum}\, DeviationFromCTV \right|$$

$$\text{RelativeAccuracy} = \frac{AbsoluteAccuracy}{CTV}$$

$$\text{PercentageAccuracy} = 100 x \text{RelativeAccuracy}$$

Example

- A voltmeter is used for reading on a standard value of 50 volts, the following readings are obtained: 47, 52, 51, 48. What are the
  - absolue acccuracy,
  - relative accuracy and
  - percentage accuracy?

Answer

- Conventional true value (CTV) = 50 volts,
- Maximum (V_{MAX}) = 52 volts and minimum (V_{MIN}) = 47 volts.
- CTV – V_{MIN} = 50 – 47 = 3 volts; V_{MAX} – CTV = 52 – 50 = 2 volts.
- Absolute accuracy = max of {3, 2} = 3 volts.
- Relative accuracy = 3/50 = 0.06 and % accuracy = 0.06x100 = 6%

Accuracy of an multimeter

- The accuracy of an digital multimeter can be expressed as
  - Percentage of reading + resolution error (least significant bit)
- The accuracy of analog multimeter can be expressed as
  - Percentage of full scale + resolution error (±½ the smallest division on an analog scale)

Accuracy

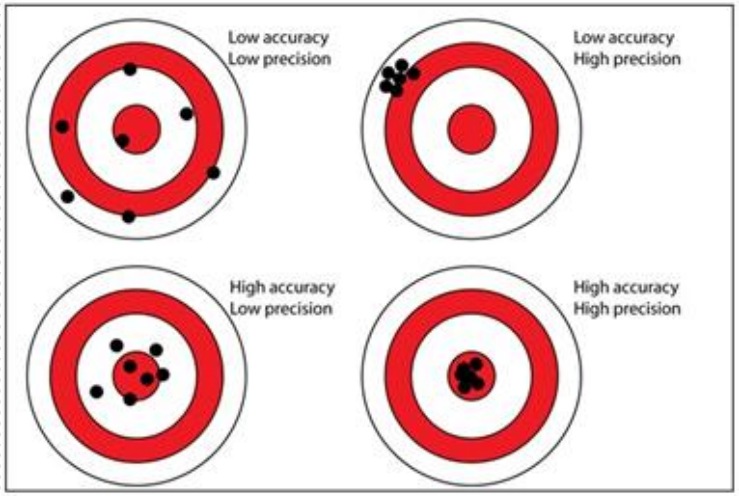
- A 2000 count digital multimeter has %1 reading error. If this multimeter reads a reference value of 2V, what will be the error of this measurement?

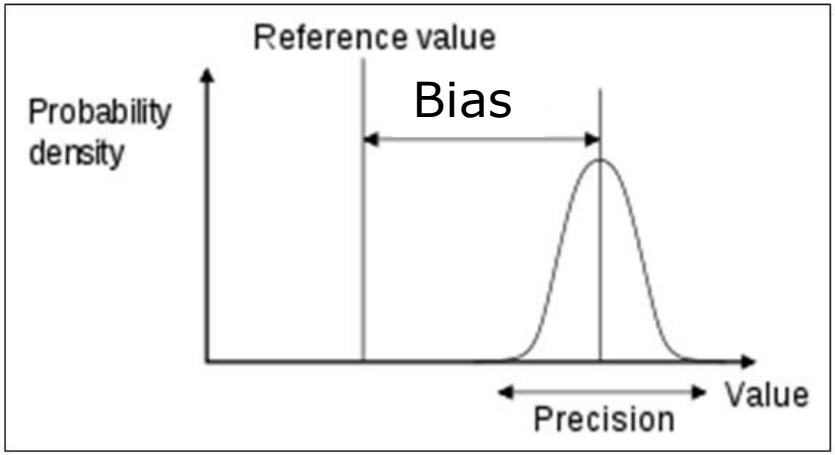
Answer

- Reading error is 2/100=20mV
- The minumum voltage that can be read by multimeter is 0.001V=1mV
- The total measurement error is 20+1=21mV.
- The reading of multimeter varies between 1979mV and 2021mV

Precision and Bias

- **Precision** is a measure of repetability of an measurement. The average value of a set of readings is found by averaging the measurements taken repeatedly with the same measuring device in the same conditions. The deviation of the readings from the mean (average) value determines the precision of the instrument. The figure below illustrates this:
- **Bias**
- The difference between CTV and average value (V_{AV}) is called the bias. Ideally, the bias should be zero. For a high quality digital voltmeter, the loading error is negligible yielding bias very close to zero.





Example

- A voltmeter is used for reading on a standard value of 50 volts, the following readings are obtained: 47, 52, 51, 48. What are the
  - Precision and
  - bias?

Solution

- Bias = CTV – V_{AV}
- average (V_{AV}) = (47+48+51+52)/4 = 49.5 V
- Pr = max {(49.5 – 47), (52 – 49.5)} = 2.5 volts
- Bias = 50 – 49.5 = 0.5 volt

Example

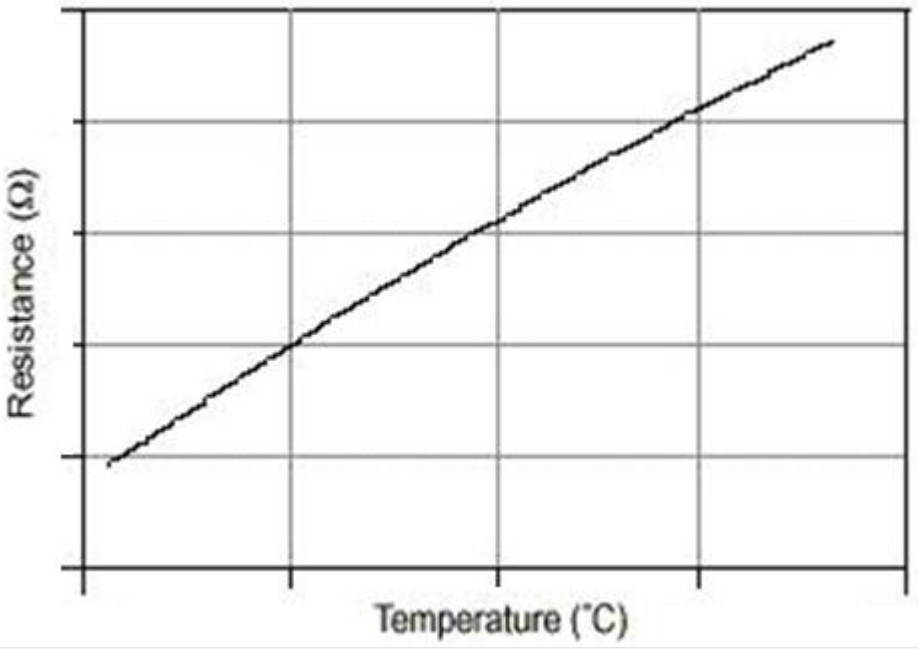
- A digital thermometer is used to measure the boiling point of water (100.0°C). The measurement is repeated 5 times and following readings are obtained: 99.9, 101.2, 100.5, 100.8, 100.1.
- Determine the accuracy, the precision and the bias of the thermometer.

- T_{CTV} = 100.0°C;
- T_{AV} =(99.9 + 101.2 + 100.5 + 100.8 + 100.1)/5 = 100.5°C.
- Absolute Accuracy = max of [(101.2 – 100.0), (100.0 – 99.9)] = 1.2°C;
- Relative Accuracy=0.012
- Percentage Accuracy % acc. = 1.2%
- Pr = max of [(101.2 – 100.5), (100.5 – 99.9)] = 0.7°C
- Bias = T_{CTV} - T_{AV} = -0.5°C.

Example-Sensitivity

The following resistance values of a platinum resistance thermometer were measured at a range of temperatures. Determine the measurement sensitivity of the instrument in ohms/°C.

Resistance (Ω)	*Temperature* (°C)
307	200
314	230
321	260
328	290

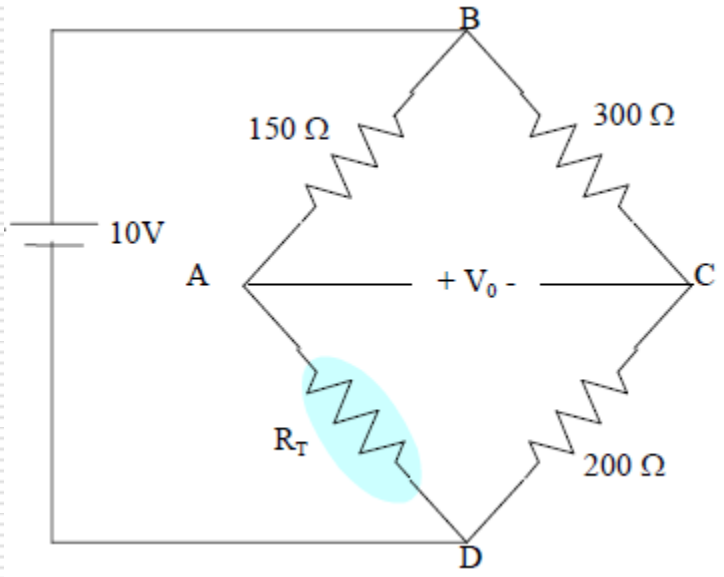


RTD

- A resistance temperature device is placed on the isothermal block.

$$R_T = R_0[1 + \alpha(T - T_0)]$$

- R_0 = 100Ω at T_0=0°C, α=4x10^{-4}/°C. Calculate R_T and its sensitivity to T at the T=25°C.
- Assume R_T is placed into one arm of the Wheatstone bridge as shown in the figure. Calculate the bridge voltage at 0°C and 25 °C.



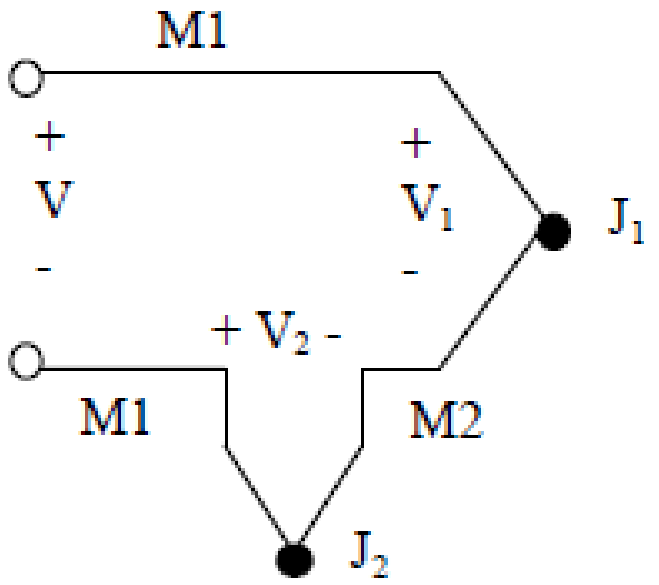
Example

- A thermistor is placed in 100 °C environment, and its measured resistance is 20 KΩ; the thermal constant is β=3650. If the thermistor is used to measure a particular temperature; and its resistance is measured as 500 KΩ, determine the thermistor temperature.

$$R_T = R_{25} e^{\left\{\beta\left[\left(\frac{1}{T+273}\right)-\frac{1}{298}\right]\right\}}$$

Example

- It is required to measure temperature by means of a thermocouple having a sensitivity of $\alpha=\alpha_{SA}-\alpha_{SB}=50\ \mu V/^{\circ}C$.
- The reference temperature $T_0=0\ ^{\circ}C$. Find the temperature for an output of 2.5mV and 10mV.



$$T_{tip} = T_{ref} + \frac{V_{out}}{\alpha_{SA} - \alpha_{SB}}$$