BENHA UNIVERSITY
FACULTY OF ENGINEERING (SHOUBRA)
ELECTRONICS AND COMMUNICATIONS ENGINEERING

ECE 444
Industrial Electronics

(2022 - 2023) 1st term

Lecture 3: Definitions.

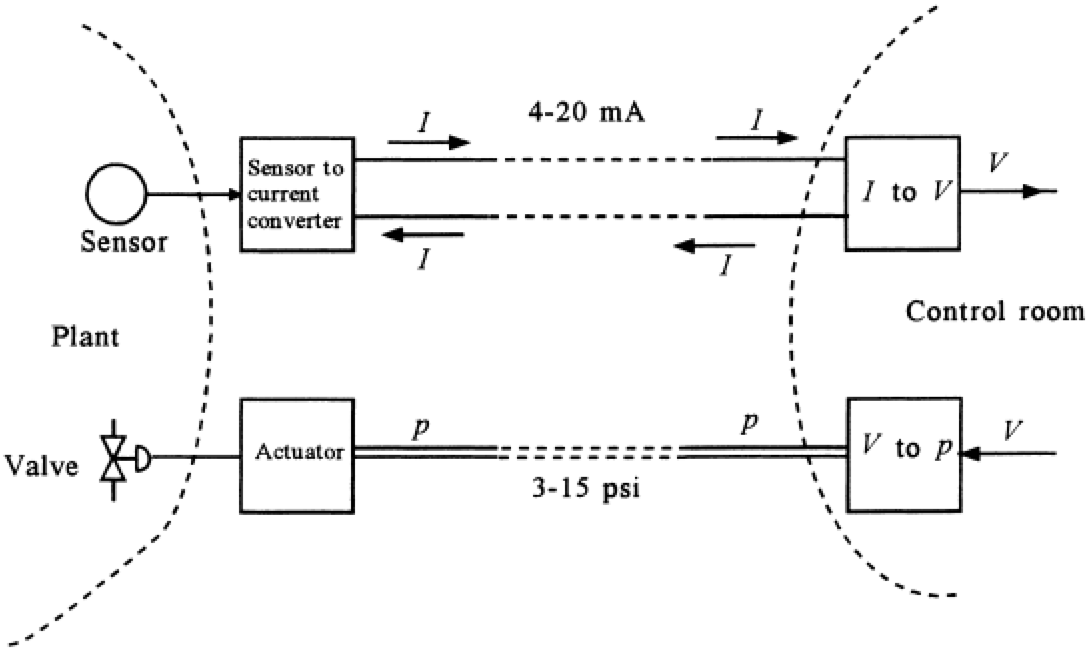
Dr. Ahmed Samir
https://bu.edu.eg/staff/ahmedsaied

Outlines:

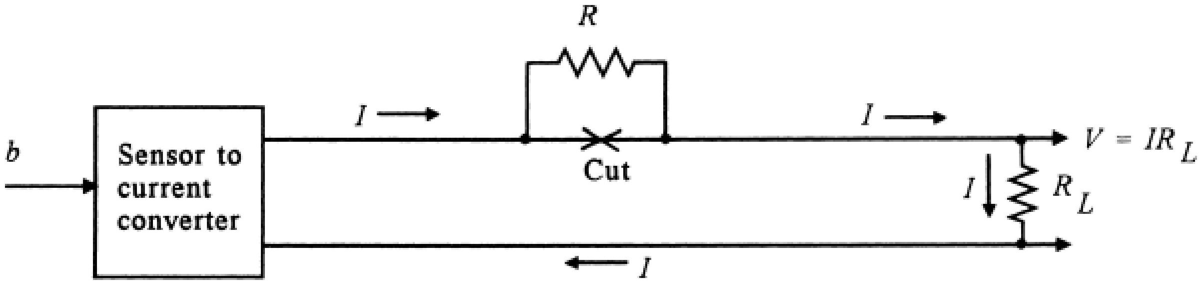
- Analog Data Representation.
- Error.
- Transfer Function.
- Accuracy.
- System Accuracy.
- Sensitivity.
- Hysteresis.

Analog Data Representation:

- For measurement systems or control systems, part of the specification is the range of the variables involved.
- Two analog standards are in common use as a means of representing the range of variables in control systems.
  1) For electrical systems, we use a range of electric current carried in wires.
  2) For pneumatic systems we use a range of gas pressure carried in pipes.



❖ Why current not voltage !?



Analog Data Representation:

EXAMPLE 7

Suppose the temperature range 20° to 120°C is linearly converted to the standard current range of 4 to 20 mA. What current will result from 66°C? What temperature does 6.5 mA represent?

Solution

The easiest way to solve this kind of problem is to develop a linear equation between temperature and current. We can write this equation as $I = mT + I_0$, and we know from the given data that $I = 4$ mA when $T = 20°$C and that $I = 20$ mA when $T = 120°$C. Thus, we have two equations in two unknowns:

$$4\text{ mA} = (20^\circ\text{C})m + I_0$$

$$20\text{ mA} = (120^\circ\text{C})m + I_0$$

so that $m = 0.16\text{ mA}/^\circ\text{C}$ $\quad I_0 = 0.8\text{ mA}$

Thus, the equation relating current and temperature is

$$I = (0.16\text{ mA}/^\circ\text{C})T + 0.8\text{ mA}$$

Now answering the questions is easy. For 66°C, we have

$$I = (0.16\text{ mA}/^\circ\text{C})66^\circ\text{C} + 0.8\text{ mA} = \mathbf{11.36\text{ mA}}$$

For 6.5 mA, we solve for T:

$$6.5\text{ mA} = (0.16\text{ mA}/^\circ\text{C})T + 0.8\text{ mA}$$

for which $T = \mathbf{35.6^\circ C}$.

Error:

- In measurement:

Error =Actual value –Measured indication of the value

Is actual value be known? ....No

So use accuracy to place bounds on the possible error.

- In control system:

Error of the controlled variable = Desired value - Measured value

Transfer Function:

- A transfer function shows how a system-block output variable varies in response to an input variable, as a function of both static input value and time.

- The transfer function is often described in two parts:

1) Static Part (when the input is not changing in time)
   → represented by Equations – Tables – Graphs
2) Dynamic Part (when there is time variation of the input)
   → represented by Differential Equations

- T.F. is valid only over a certain range of variable values.

Accuracy:

- It is the max. expected overall error from a device.
- Forms:

1) Measured variable +/- 2oC

2) % of full-scale +/- 0.5% FS

3) % of span +/-0.5% Span

4) % of the actual reading +/- 1% of reading

Accuracy:

EXAMPLE 8 A temperature sensor has a span of 20°−250°C. A measurement results in a value of 55°C for the temperature. Specify the error if the accuracy is **(a)** ±0.5% FS, **(b)** ±0.75% of span, and **(c)** ±0.8% of reading. What is the possible temperature in each case?

Solution

Using the given definitions, we find

a. Error = (±0.005)(250°C) = **±1.25°C**. Thus, the actual temperature is in the range of 53.75° to 56.25°C.

b. Error = (±0.0075)(250 − 20)°C = **±1.725°C.** Thus, the actual temperature is in the range of 53.275° to 56.725°C.

c. Error = (±0.008)(55°C) = **±0.44°C.** Thus, the temperature is in the range of 54.56° to 55.44°C.

Accuracy:

EXAMPLE 9 A temperature sensor has a transfer function of 5 mV/°C with an accuracy of ±1%. Find the possible range of the transfer function.

Solution

The transfer function range will be $(\pm 0.01)(5\ \text{mV/°C}) = \pm 0.05\ \text{mV/°C}$. Thus, the range is 4.95 to 5.05 mV/°C.

EXAMPLE 10 Suppose a reading of 27.5 mV results from the sensor used in Example 9. Find the temperature that could provide this reading.

Solution

Because the range of transfer function is 4.95 to 5.05 mV/°C, the possible temperature values that could be inferred from a reading of 27.5 mV are

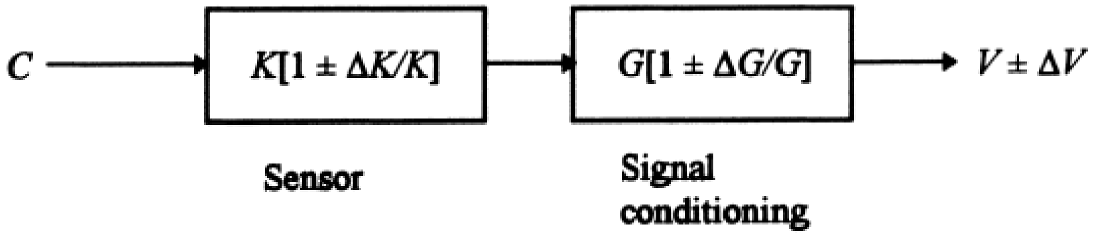
$$(27.5\ \text{mV})\left(\frac{1}{4.95\ \text{mV/°C}}\right) = \mathbf{5.56°C}$$

$$(27.5\ \text{mV})\left(\frac{1}{5.05\ \text{mV/°C}}\right) = \mathbf{5.45°C}$$

Thus, we can be certain only that the temperature is between 5.45°C and 5.56°C.

System Accuracy:

- Often, one must consider the overall accuracy of many elements in a process-control loop to represent a process variable.
- Generally, the best way to do this is to express the accuracy of each element in terms of the transfer functions.



- The worst-case uncertainty would be the sum of the individual uncertainties. $\frac{\Delta V}{V} = \pm\frac{\Delta K}{K} \pm\frac{\Delta G}{G}$
- Statistical analysis teaches us that it is more realistic to use the root-mean-square (RMS) representation of system uncertainty.

$$\left[\frac{\Delta V}{V}\right]_{\text{rms}} = \pm\sqrt{\left(\frac{\Delta K}{K}\right)^2 + \left(\frac{\Delta G}{G}\right)^2}$$

System Accuracy:

EXAMPLE 11 Find the system accuracy of a flow process if the transducer transfer function is $10\ \mathrm{mV/(m^3/s)} \pm 1.5\%$ and the signal-conditioning system-transfer function is $2\ \mathrm{mA/mV} \pm 0.5\%$.

Solution

Here we have a direct application of

$$\frac{\Delta V}{V} = \pm\left[\frac{\Delta K}{K} + \frac{\Delta G}{G}\right]$$

$$\frac{\Delta V}{V} = \pm[0.015 + 0.005]$$

$$\frac{\Delta V}{V} = \pm 0.02 = \pm 2\%$$

so that the net transfer function is $20\ \mathrm{mA/(m^3/s)} \pm 2\%$. If we use the more statistically appropriate rms approach, the system accuracy would be

$$\left[\frac{\Delta V}{V}\right]_{\mathrm{rms}} = \pm\sqrt{(0.015)^2 + (0.005)^2}$$

$$= \pm 0.0158$$

So the accuracy is about $\pm 1.6\%$.

System Accuracy:

20 A sensor has a transfer function of 0.5 mV/°C and an accuracy of ±1%. If the temperature is known to be 60°C, what can be said with absolute certainty about the output voltage?

Solution

Well, 0.5 mV/°C with a ± 1% accuracy means the transfer function could be 0.5 ± 0.005 mV/°C or 0.495 to 0.505 mV/°C. If the temperature were 60 °C the output would be in the range, (0.495 mV/°C)(60 °C) = 29.7 mV to (0.505 mV/°C)(60 °C) = 30.3 mV

or 30 ± 0.3 mV. Which is, of course, ± 1%.

See p.21,22

Sensitivity:

- It is a measure of the change in output of an instrument for a change in input.
- Generally indicated by the T.F.
- High sensitivity is desirable in an instrument because a large change in output for a small change in input implies that a measurement may be taken easily.
- Thus, when a temperature transducer outputs 5 mV per degree Celsius, the sensitivity is 5 mv/C

Resolution:

- It is the minimum measurable value of the input variable.
- It is expressed in % FS.
- In digital world 1-bit change in binary word
- In some cases, the resolution of a measurement system is limited by the sensitivity of associated signal conditioning.

EXAMPLE 13 A sensor has a transfer function of 5 mV/°C. Find the required voltage resolution of the signal conditioning if a temperature resolution of 0.2°C is required.

Solution

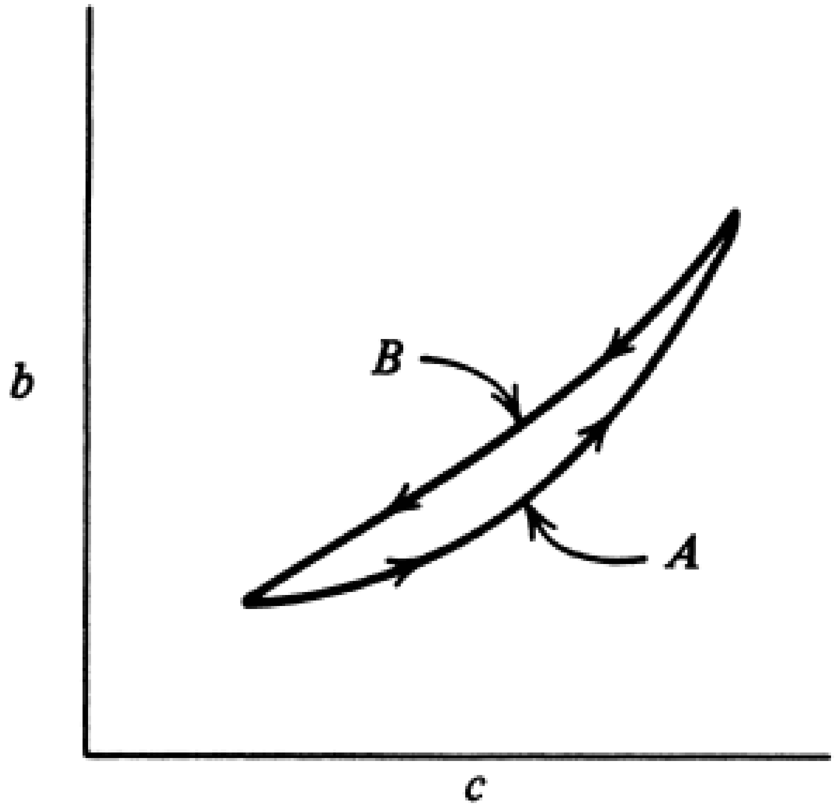
A temperature change of 0.2°C will result in a voltage change of

$$\left(5\frac{\text{mV}}{°\text{C}}\right)(0.2°\text{C}) = \mathbf{1.0\ mV}$$

Thus, the voltage system must be able to resolve 1.0 mV.

Hysteresis:

- is different reading results for a specific input, depending on whether the input value is approached from higher or lower values.



END OF LECTURE

BEST WISHES