Dynamic Performance Characteristics

Meteorology 433

Spring 2022

Changing modes

- When the input to a sensor is changing rapidly, we observe performance characteristics that are due to the changing input and not related to static performance.

- Simply put: dynamic performance characteristics define the way instruments react to measurements and fluctuations.

- A real sensor or instrument will always take a finite time to respond to a change in the parameter it is measuring.

- A sensor can be nonlinear in the static sense, but could be linear in the dynamic sense (modeled by a linear differential equation).

- Differential equations describe the behavior of physical systems.

Response to a Step Change

- One of the simplest inputs to consider is the step function.
  - Zero when $t < 0$ and some non-zero constant when $t > 0$, or
  - Some non-zero constant when $t < 0$, and 0 when $t = 0$.

- For a first-order system like this, the differential equation governing this change is

$$\tau \frac{dx}{dt} + \mathrm{x} = x_i$$

  - where τ is the time constant and x_i is some input function.

- Let's look at both of these cases.

63% method

- Find the time it takes the sensor to get 63.2% of its full amplitude.
  - Definition of time constant or e-folding time from equations.
- A thermometer is moved rapidly from an ice bath (0°C) to room temperature (25°C) according to the table below. Find the time constant.

Time(s)	0	1	2	3	4	5
Temperature(°C)	0	7.09	12.16	15.80	18.41	20.28

Experimental Determination of Dynamic Performance

- Time constant calculations we have done are only practical under perfect conditions.

- Data is often noisy, making it difficult to determine the time constant.

- What can you do?
  - Take the logarithm of both sides.

For example

- A thermometer is moved rapidly from an 20°C to a final temperature of 40°C according to the table below. Find the time constant.

Time(s)	0	3	6	9	12	15
Temperature(°C)	20.00	35.54	39.00	39.78	39.95	39.99

Experimental Determination of Dynamic Performance

- Time constant calculations we have done are only practical under perfect conditions.

- Data is often noisy, making it difficult to determine the time constant.

- What can you do?
  - Take the logarithm of both sides.

- Plot the data on a semi-log axis
  - Straight line if system is linear and first order
  - Slope of line is the negative inverse of the time constant.

- Time constant is determined from slope of line fit to all the data.
  - Better overall determination.

Ramp Input - Example

- Suppose you have subjected your thermometer to a steadily rising temperature after it was kept at a constant temperature for a while (equilibrium with environment).

- The reading of the thermometer will always lag with respect to the real temperature – it takes time to settle.

- To minimize this effect, you would choose a thermometer with a very small time constant.

Sinusoidal Input – Example

- Suppose our thermometer was kept at equilibrium with the environment, and then was subjected to a sinusoidal input (change in temperature)

- If the temperature variation is slow (low frequency), the sensor output will simply follow the ambient input.

- If the temperature variation is very fast, the sensor output will change very little (it will stay at the reading prior to the beginning of the input)
  - Simply unable to follow the fast variations!!

- What is slow and what is fast?
  - It relates to the natural "scale" or the time constant or the frequency.

Experimental Determination of Dynamic Performance Parameters

- Determine the time constant:
  - Apply step-function input.
  - Determine the time to reach 63% of the steady state value.

- This approach is practical only under ideal conditions.
  - If the data is noisy or if the data are missing in this critical time period, the method fails.

- What do we do?
  - Better to apply other methods
  - Linear regression method