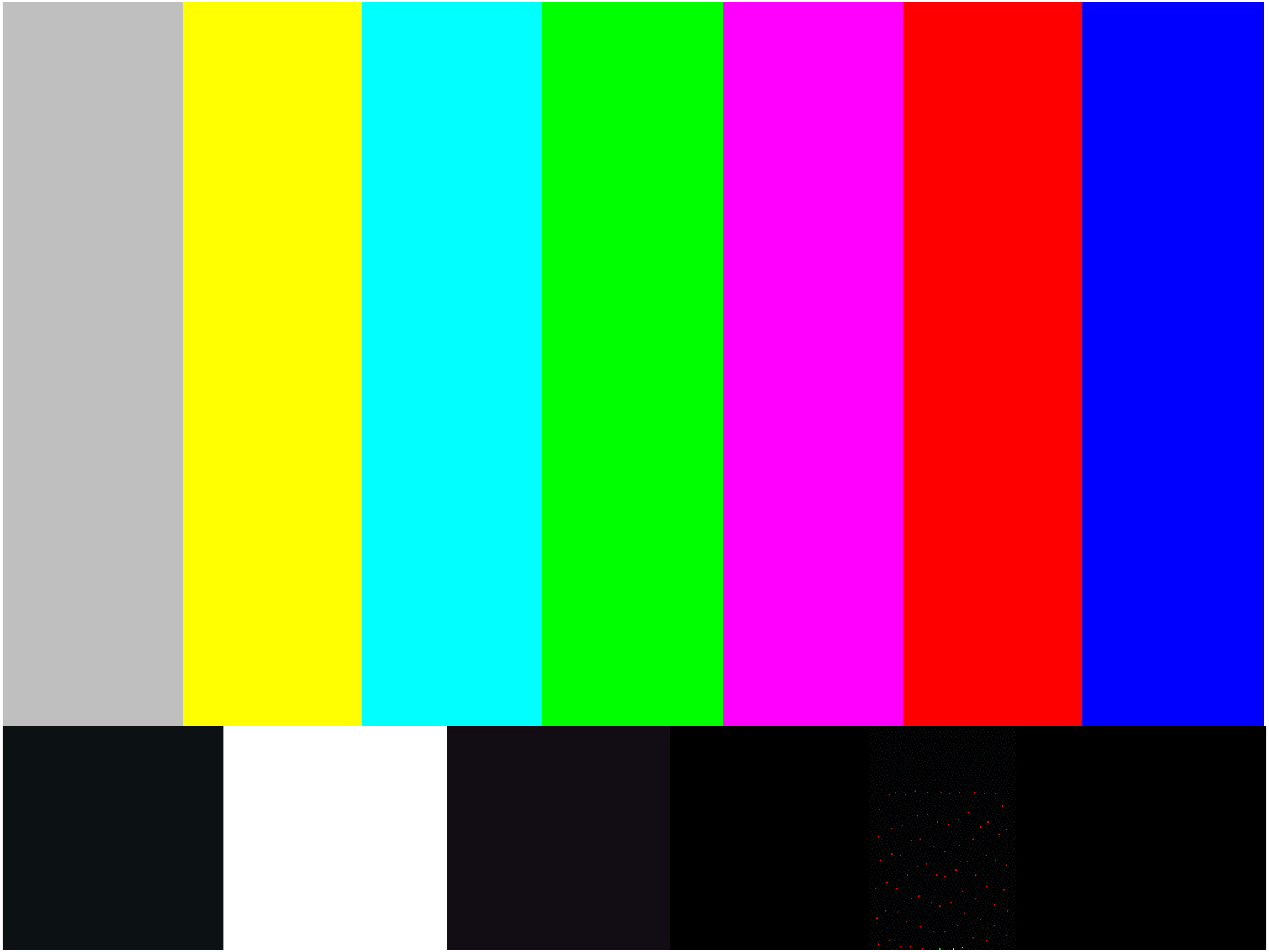


# Sensor and Actuator Characteristics

By:
Engr. Joseph Ronald Cañedo

# Introduction

- Mechatronic systems use a variety of sensors and actuators to measure and manipulate mechanical, electrical, and thermal systems.
- Sensors have many characteristics that affect their measurement capabilities and their suitability for each application.

# Introduction

- Analog sensors have an output that is continuous over a finite region of inputs.
  - potentiometers, LVDTs (linear variable differential transformers), load cells, and thermistors
- Digital sensors have a fixed or countable number of different output values. A common digital sensor often found in mechatronic systems is the incremental encoder. An analog sensor output conditioned by an analog-to-digital converter (ADC) has the same digital output characteristics.

# Range

- The range (or span) of a sensor is the difference between the minimum (or most negative) and maximum inputs that will give a valid output.
- Range is typically specified by the manufacturer of the sensor.
  - For example, a common type K thermocouple has a range of 800°C (from – 50°C to 750°C).
  - A ten-turn potentiometer would have a range of 3600 degrees.

# Resolution

- The resolution of a sensor is the smallest increment of input that can be reliably detected.
- Resolution is also frequently known as the least count of the sensor.
- The resolution of analog sensors is usually limited only by low-level electrical noise and is often much better than equivalent digital sensors.
- Resolution of digital sensors is easily determined.
  - A 1024 ppr (pulse per revolution) incremental encoder would have a resolution of

$$\frac{1 \text{ revolution}}{1024 \text{ pulses}} \times \frac{360 \text{ degrees}}{1 \text{ revolution}} = 0.3516 \frac{\text{degrees}}{\text{pulse}}$$

# Sensitivity

- Sensor sensitivity is defined as the change in output per change in input.
- The sensitivity of digital sensors is closely related to the resolution.
- The sensitivity of an analog sensor is the slope of the output versus input line.
  - A sensor exhibiting truly linear behavior has a constant sensitivity over the entire input range.
  - Other sensors exhibit nonlinear behavior where the sensitivity either increases or decreases as the input is changed.

# Error

- Error is the difference between a measured value and the true input value.
- Two classifications of errors are
  - bias (or systematic) errors are present in all measurements made with a given sensor, and cannot be detected or removed by statistical means.
  - precision (or random) errors.

# Error

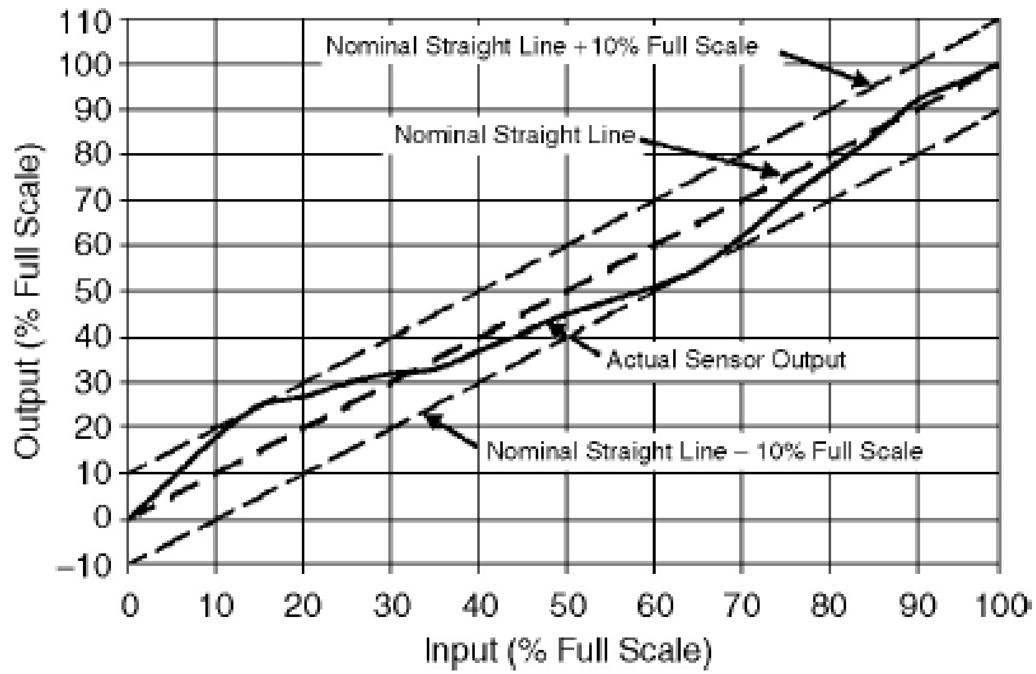
- Bias (or systematic) errors
  - can be further subdivided into
    1. calibration errors (a zero or null point error is a common type of bias error created by a nonzero output value when the input is zero),
    2. loading errors (adding the sensor to the measured system changes the system), and
    3. errors due to sensor sensitivity to variables other than the desired one (e.g., temperature effects on strain gages).

# Repeatability

- Repeatability (or reproducibility) refers to a sensor's ability to give identical outputs for the same input.
- Precision (or random) errors cause a lack of repeatability.
  - Fortunately, precision errors can be accounted for by averaging several measurements or other operations such as low-pass filtering.
  - Electrical noise and hysteresis both contribute to a loss of repeatability.

# Linearity and Accuracy

- The accuracy of a sensor is inversely proportional to error, i.e., a highly accurate sensor produces low errors.
  - Many manufacturers specify accuracy in terms of the sensor's linearity.
- Linearity (or accuracy) is specified as a percentage of full scale (maximum valid input).



# Impedance

- Impedance is the ratio of voltage and current flow for a sensor. For a simple resistive sensor (such as a strain gage or a thermistor), the impedance *Z* is the same as the resistance *R*, which has units of ohms (Ω).

$$Z_R = \frac{V}{I} = R$$

# Nonlinearities

- A systems operates outside of the specified linear region.
- Several nonlinearities commonly found in mechatronic systems
  - static and coulomb friction,
  - eccentricity,
  - backlash (or hysteresis),
  - saturation, and
  - deadband.

# Term Paper !

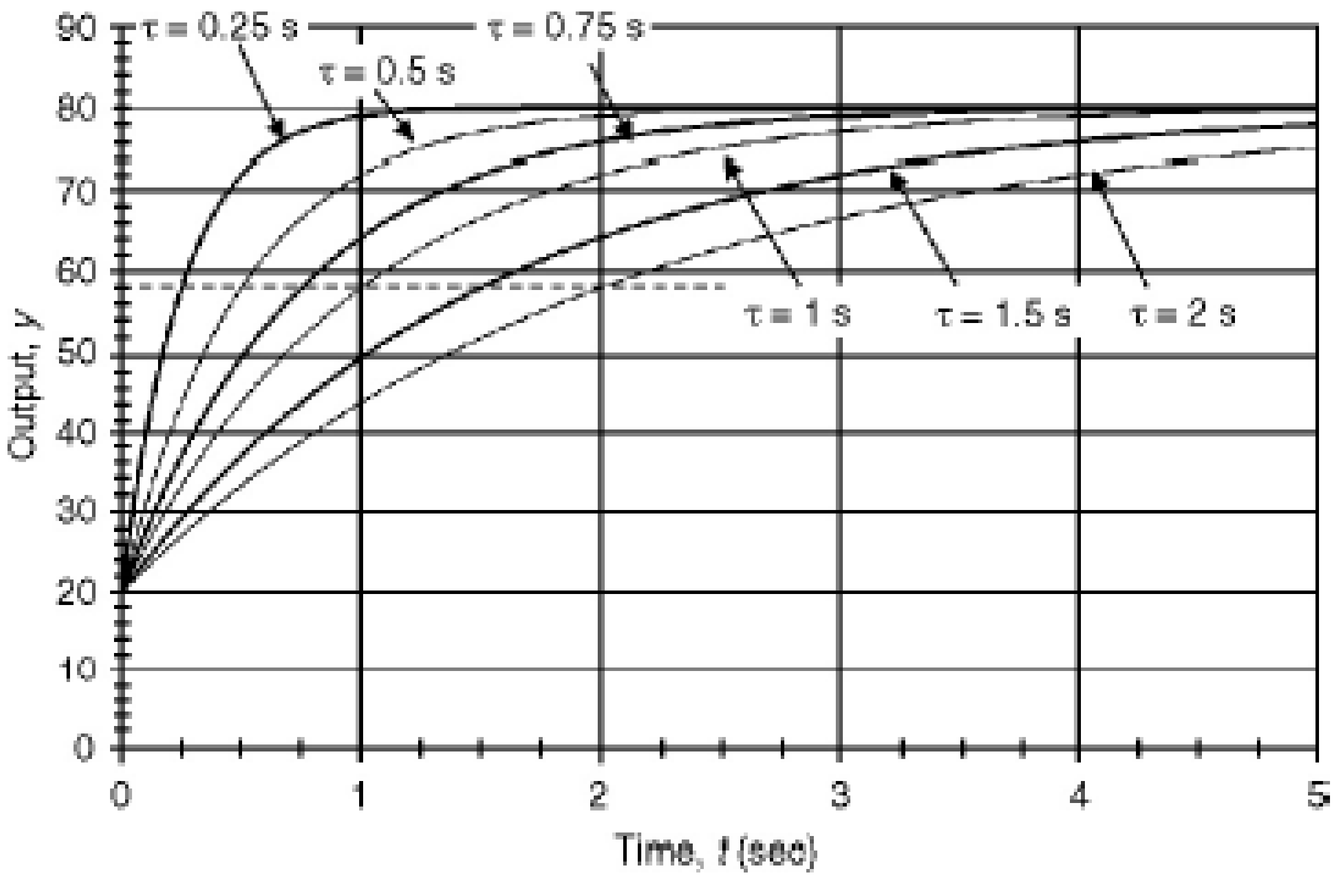
- Create a term paper related to several sources of nonlinearities of a component.
- Deadline of submission: Feb. 20, 2008.

# System Response

- Sensors and actuators respond to inputs that change with time.
- Any system that changes with time is considered a dynamic system.
  - Understanding the response of dynamic systems to different types of inputs is important in mechatronic system design.
- The most important concept in system response is stability.

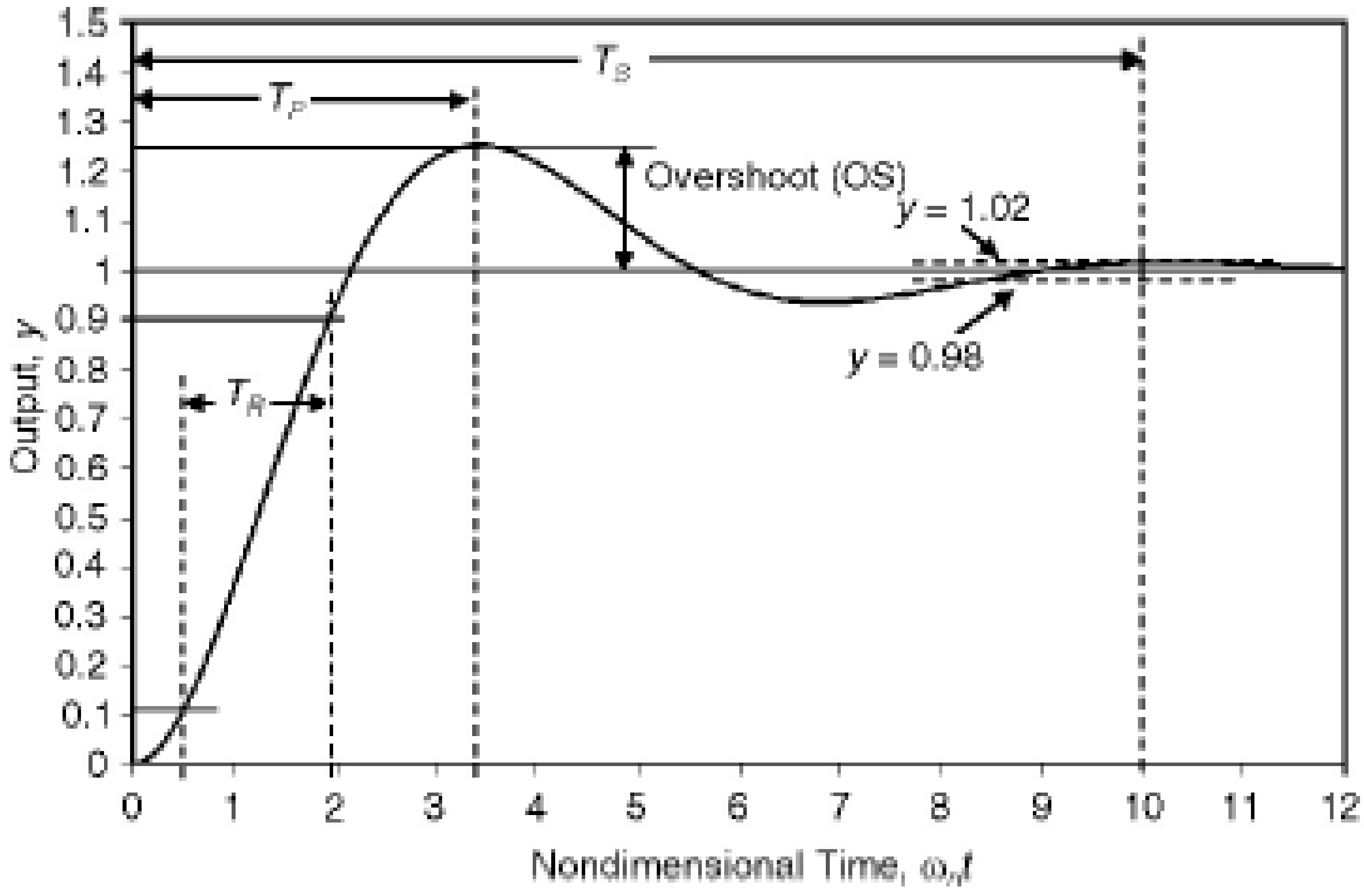
# Step System Response

- First-Order System Response



# Step System Response

- Under damped Second-Order System Response



# Frequency System Response

- Types of Frequency Response
  - First Order
  - Second Order
  - Third Order