MET 487 Instrumentation and Automatic Control

System Response

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Topics of Discussion

- Classification of Systems
- Types of Systems
- Basic Definitions
- Amplitude Linearity
- Fourier Series Representation of Signals
- Bandwidth and Frequency Response
- Phase Linearity
- Distortion of Signals
- Dynamic Characteristics of Systems
- Zero-Order System
- First-Order System
- Second-Order System
- System Modeling and Analogies
Definitions of System

- Merriam-Webster’s Collegiate Dictionary: “a regularly interacting or independent group of items forming a unified whole.”
- EIA/IS-632: “an integrated composite of people, products, and process that provide a capability to satisfy a stated need or objective.”

Definitions of System (cont.)

- MIL-STD-499 standard: “a composite of equipment, skills and techniques capable of performing ad/or supporting an operational role. A complete system includes all equipment, related facilities, material, software, service, and personnel required for its operation and support to the degree that it can be considered a self-sufficient unit in its intended environment.”
General Characteristics of a System

- A system consists of a complex combination of resources in the form of human beings, materials, equipment, software, facilities, data, money, and so on.
- A system is contained within some form of hierarchy.
- A system may be broken down into subsystems and related components.
- A system must have a purpose.

System Classification by Applications

- Electrical and Electronics
- Automatic Control Systems:
  - Open Loop
  - Closed-Loop
- Robotics System
- Process Control System
- Industrial Control and Automation Systems
- etc
Types of System

- Continuous System
- Discrete Systems
- Digital System
- Linear System
- Non-Linear System
- Dynamic System

System-Based Problem Solving

- Problem Statement
- System Analysis
  - System Components: Software, Hardware, Documentation, Staffs, etc
- System Requirements
- System Design
  - Modeling and Simulation
  - Performance Analysis
- System Prototyping
- System Integration & Testing
- Lesson Learned
System Response - Control System

- Linear Control System

\[ x_0(t) \rightarrow \text{Plant} \rightarrow y_0(t) \]

\[ x(t) = U(t) \]

System Response – Measurement System

- Three Parts:
  - A Transducer
  - A Signal Processor
  - A Recorder

- Three Criteria:
  - Amplitude Linearity
  - Adequate Bandwidth
  - Phase Linearity
Amplitude Linearity

- Linear: \[ V_{\text{out}}(t) - V_{\text{out}}(0) = \alpha [V_{\text{in}}(t) - V_{\text{in}}(0)] \]
- Nonlinear

![Amplitude Linearity Diagram]

Bandwidth and Frequency Response

- Frequency Response Curve (Bode Plot)
- 3 dB Frequency (Cutoff Frequency)
  - \( P_{\text{out}}/P_{\text{in}} = \frac{1}{2} \)
  - \( V_{\text{out}}/V_{\text{in}} = \sqrt{P_{\text{out}}/P_{\text{in}}} = \sqrt{\frac{1}{2}} \approx 0.707 \)
  - \( \text{dB} = 20 \log_{10} \sqrt{0.5} \approx -3 \text{ dB} \)
- Bandwidth: \( \omega_H - \omega_L \)
Low-Pass Filter

- **RC Low Pass Filter**
  - Vin – Sine wave signal/
    Vout – Sine wave signal
  - Phase Shift, Amplitude
    Attenuation

\[
\begin{align*}
V_{out} &= \frac{V_{in}}{R + j \omega C} \\
F_{out} &= \frac{1}{f \omega RC + 1} \\
F_{in} &= \frac{1}{\sqrt{1 + (\omega RC)^2}} \\
A(\omega) &= \frac{1}{\sqrt{1 + (\omega RC)^2}}
\end{align*}
\]

Vin – Sine Wave
Vin – Square Wave

\[
X_C = \frac{1}{2\pi f_C} \\
Z = R - jX_C
\]

Low-Pass Filter Lab (First Order System)

- **RC Low Pass Filter**
  - R = 1K, 10K
  - C = 0.1 \mu F, 0.47 \mu F
  - Vin = A Square Wave with
    50% Duty Cycle, 0 to 5V

\[
A(\omega) = \frac{Vin}{Vout} (\omega)
\]

- Vin * 0.707 @
  cutoff frequency
- Vout – Saw tooth
- \(\omega_C = 1/RC = 2\pi f\)
- \(f = 1/(2\pi RC)\) Hz