MECE 102 – Mechatronics Engineering
Orientation
Mechatronic System Components

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Compulsory Course in Mechatronics Engineering
Credits (2/0/2)
Course Webpage: http://MECE102.cankaya.edu.tr

Overview

1. Overview
2. Control Systems
3. Control Architectures
4. Input/Output Signal Interface
5. Digital Control Loop
6. Relation to Curriculum
Introduction: System Overview

**Mechatronics System Components**

**MECHANICAL SYSTEM**
- system model - dynamic response

**ACTUATORS**
- solenoids, voice coils
- dc motors
- stepper motors
- servo motors
- hydraulics, pneumatics

**SENSORS**
- switches - strain gage
- potentiometer - thermocouple
- photoelectrics - accelerometer
- digital encoder - MEMs

**INPUT SIGNAL CONDITIONING AND INTERFACING**
- discrete circuits - filters
- amplifiers - A/D, D/D

**OUTPUT SIGNAL CONDITIONING AND INTERFACING**
- D/A, D/D
- amplifiers
- PWM
- power transistors
- power op amps

**GRAPHICAL DISPLAYS**
- LEDs
- digital displays
- LCD
- CRT

**DIGITAL CONTROL ARCHITECTURES**
- logic circuits
- microcontroller
- SBC
- PLC
- sequencing and timing
- logic and arithmetic
- control algorithms
- communication

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Control Systems: Basics

**Control**

*Control is a discipline that is concerned with the automatic manipulation of a dynamic system’s behavior*

**Dynamic System**

*System that shows dynamic dependency between input and output signals*

- Signal is a time-varying physical quantity (e.g. position, velocity, temperature, voltage, current, . . .)
- Usually, dynamic systems possess memory
- Dynamic systems are for example modeled by differential equations, difference equations, transfer functions
- Dynamic systems are for example electronic systems, mechanical systems, biological systems, etc.

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Control Systems: Dynamic System in Control

**Detailed Graphical Representation**

**Manipulation of a Dynamic System**

Application of appropriate inputs such that the system state/output behaves as desired even in the presence of disturbances

Control Systems: Vehicle Speed

**Schematic**

**Graphical Representation**

**Control Task**
- Desired (specified) behavior: keep vehicle speed constant
- Manipulation: automatically adjust pedal position
Control Systems: Movies

**Inverted Pendulum**
- Desired (specified) behavior: Keep pendulum upright
- Manipulation: horizontally move cart
  \[\Rightarrow \text{http://www.rt.eei.uni-erlangen.de/FGNls/video/inverted_pendulum.wmv}\]

**Automatic Parking**
- Desired (specified) behavior: Reach parking position (without collision)
- Manipulation: automatically adjust speed and steering angle
  \[\Rightarrow \text{http://www.rt.eei.uni-erlangen.de/FGNls/video/automatic_parking.wmv}\]

**Ball on Plate**
- Desired (specified) behavior: follow path/keep position
- Manipulation: automatically change orientation of plate
  \[\Rightarrow \text{http://www.rt.eei.uni-erlangen.de/FGNls/video/ball_on_plate.wmv}\]
Control Systems: Examples

Graphical Representation

Control Architectures: Basic Task

Main Task of Control Engineering

*Design and realize technical appliance – controller – that enforces the desired output behavior of the plant when connected to the plant*

Feedforward Control

⇒ Feedforward controller provides appropriate input such that the plant follows a given reference signal
Control Architectures: Basic Principles

Feedback Control

⇒ Feedback controller tries to compensate the difference between a reference signal and the measured output signal

Remarks

- Control problems occur in many subject areas
- Examples: process engineering, electrical engineering, communication networks, automotive applications, medicine, chemistry, biology, ...
  ⇒ Mathematical abstraction of control problems to enable interdisciplinary application

Control Architectures: General Solution Procedure

Procedure

1. Mathematical modeling of plant
   ⇒ Abstraction from the physical problem
2. Analysis of the plant behavior
   ⇒ Determine basic properties of the plant and their implications on the design
3. Controller design
   ⇒ Achieve desired plant behavior
4. Simulation and test on the real system
   ⇒ Verify if design goals are achieved
Input/Output Signal Interface: A/D Conversion

**Analog/Digital (A/D) Converter**
- Interface at the input of the digital controller
- Samples the analog signal and generates
- Generates a new sample at each sampling time
- Provides input for digital controller

**Sample and Hold Circuit**
- Output follows input voltage if switch is on
- Output keeps last input voltage value if switch is off

**A/D Conversion**
- Converts input voltage to digital number
- Quantization of input voltage
Input/Output Signal Interface: D/A Conversion

**Digital/Analog Converter**
- Receives digital signal from digital controller and holds it for one sampling period
  ⇒ Generates analog signal for actuator
- Technical realization: customary D/A converters usually realized as zero-order hold

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Digital Control Loop: Overview

**Diagram**

<table>
<thead>
<tr>
<th>Output</th>
<th>Actuator</th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controller</td>
<td>Input</td>
<td>Sensor</td>
</tr>
</tbody>
</table>

**Remarks**
- Between input and output signal conditioning: digital signals
- Between output and input signal conditioning: analog signals
Relation to Curriculum

**Mechanical System**
- ME 113/114: Computer Aided Engineering Drawing I/II
- ME 211: Thermodynamics I
- ME 251: Statics and Strength of Materials
- ME 204: Dynamics
- ME 307: Machine Elements I
- ME 306: Mechanisms

**Actuators**
- ECE 240: Electromechanical Energy Conversion
- MECE 401: Introduction to Robotics

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Relation to Curriculum

**Sensors**
- MSE 235: Materials Science for Electronic Engineers
- ECE 347: Electronics + Lab.
- MECE 302: Sensors and Measurement

**Input/Output Signal Interface**
- IE 227: Introduction to Probability
- ECE 233: Electrical Circuit Analysis + Lab.
- ECE 232: Advanced Electrical Circuit Analysis + Lab.
- ECE 223: Digital Design I + Lab.
- ECE 347: Electronics + Lab.
- ECE 218: Principles of Signals and Systems + Lab.

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Relation to Curriculum

Control Architecture and Implementation

- CENG 161: Introduction to Computer Science + Lab.
- CENG 162: Computer Programming I + Lab.
- MCS 155/156: Calculus for Engineering I/II
- PHYS 111/112: General Physics for Engineering I/II
- MCS 258: Introduction to Differential Equations
- ECE 425: Microprocessors I + Lab.
- ME 204: Dynamics
- ECE 218: Principles of Signals and Systems + Lab.
- ECE 388: Automatic Control + Lab.
- MECE 401: Introduction to Robotics