Digital Control

M. Sami Fadali
Professor of Electrical Engineering
UNR
Outline

• Why digital control?
• Structure of a typical digital control system.
• Examples of digital control systems.
Why Digital Control?

- Digital control systems are far more popular than analog control systems.
- Digital: approximation involved and defined at discrete time points.
- Analog: no approximation and defined over a continuous time interval.
Accuracy

• Accurate representation of digital signals using "0" and "1" with 16 bits or more for a single number.

• Much smaller error than analog signals (due to noise and power supply drift).
Implementation Errors

• Digital processing of control signals: addition and multiplication by stored numerical values.
• Negligible errors due to digital representation.
• Analog signal processing: uses components (e.g. $R$, $C$) whose actual values vary significantly from the nominal design values.
Flexibility

• Analog controllers: difficult to modify or redesign once implemented in hardware.
• Digital controllers (in firmware or software): easily modified without complete replacement of the original controller.
• Complex digital controller require a few extra arithmetic operations.
• Only simple controllers are typically used in analog control.
Speed and Low cost

• Faster computer hardware allows short sampling periods (high sampling rate).
• With short sampling periods, digital controllers monitor controlled variables almost continuously.
• Advances in semiconductor technology provide better, faster and more reliable integrated circuits at lower prices.
Digital Control System Structure

To control a physical system or process using a digital controller, the controller must:

1) Receive measurements from the system.
2) Process them.
3) Send control signals to the actuator to effect the control action.
Digital Control System

Reference Input → Computer → DAC → Actuator & Process

ADC → Sensor → Controlled Variable
Digital Control System

• Plant & actuator are analog but controller is digital: “Translation” is required.

• *Digital-to-analog converter (DAC):* Translates from digital (controller language) to analog (physical process language).

• *Analog-to-digital converter (ADC):* analog to digital.

• *Sensor:* monitors controlled variable for feedback.
Other Control Configurations

Examples include
(i) Several reference inputs, controlled variables, and loops.
(ii) Inner loop with digital or analog control.
Examples of Digital Control Systems

a) Computer Control of an Aircraft Turbojet Engine [2]
b) Control of a Robotic Manipulator [3]
c) Closed-loop Drug Delivery System
Turbojet Engine Control System.
Robotic Manipulator Control
Drug Delivery Digital Control

Reference Blood Level

Computer → DAC → Drug Pump → Patient → Blood Sensor → ADC

Regulated Drug or Nutrient
What is covered?

• Review of the math used to model, analyze, and design digital control systems
• Modeling digital control systems
• Analysis of digital control systems
• Design digital control systems
• State-space models.