Lecture 1: Introduction of Digital Control Systems

ELEN 472: Introduction to Digital Control

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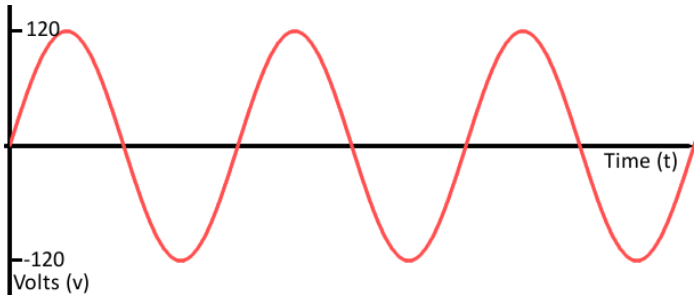
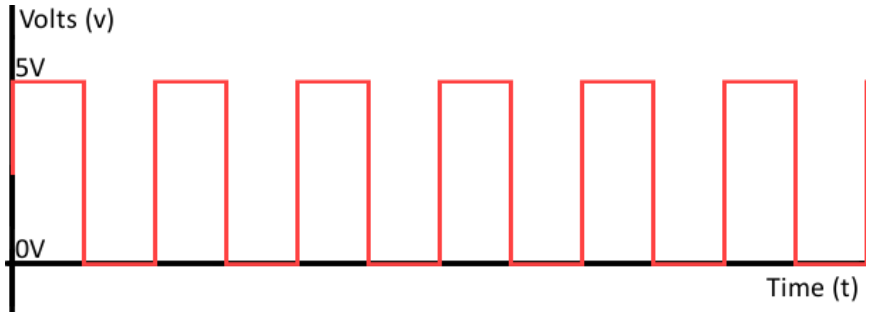
Analog V.S. Digital Signals

- Analog Signals
  - Analog signal is continuous and smooth.
  - Analog signal has infinite states (i.e., values).
  - A typical analog signal example is sine wave.
- Digital Signals
  - Digital signal is discrete and not continuous.
  - Digital signal has two values (i.e., zero and one; low and high).
  - A typical digital signal example is square wave.



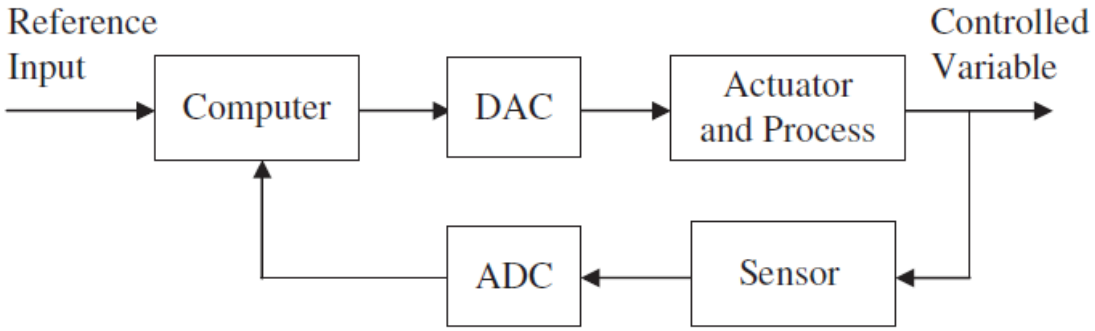


Why Digital Control?

- Digital control offers distinct advantages over analog control, including
  - **Accuracy**: digital signals only have tow possible values, i.e., zeros and ones, which are robust to noises.
  - **Implementation errors**: digital control signals involves addition and multiplication by stored numerical values. The errors in these operations are negligible.
  - **Flexibility:** An analog controller is difficult to modify or redesign once implemented in hardware. A digital controller is implemented in firmware or software and its modification is possible without a complete replacement of the original controller.
  - **Speed**: The speed of computer hardware has increased exponentially since the 1980s. This increase in processing speed has made it possible to sample and process control signals at very high speeds.
  - **Cost:** Although the prices of most goods and services have steadily increased, the cost of digital circuitry continues to decrease.

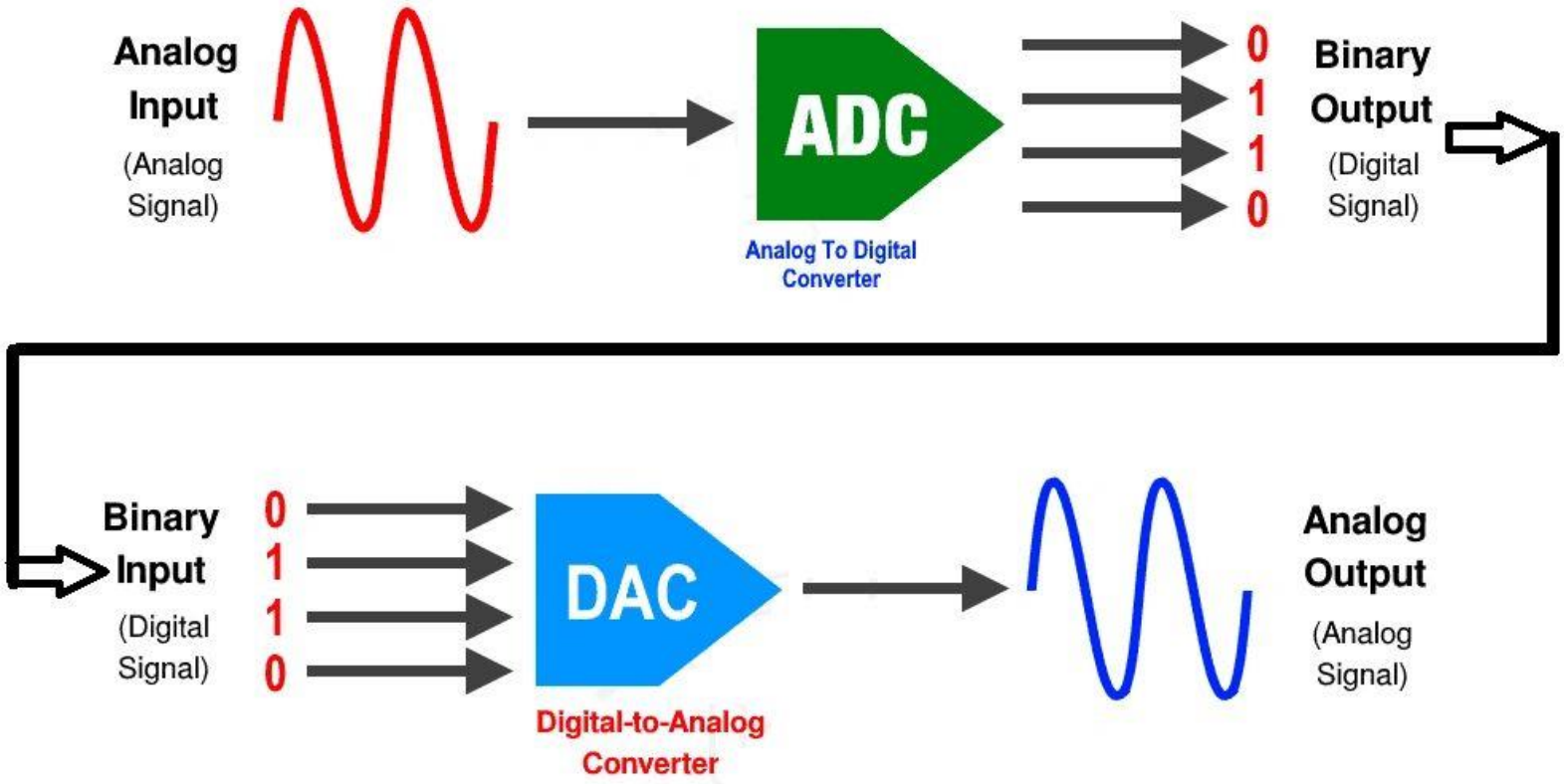
The Structure of a Digital Control System

- To control a physical system or process using a digital controller, the controller must receive measurements from the system, process them, and then send control signals to the actuator that effects the control action.



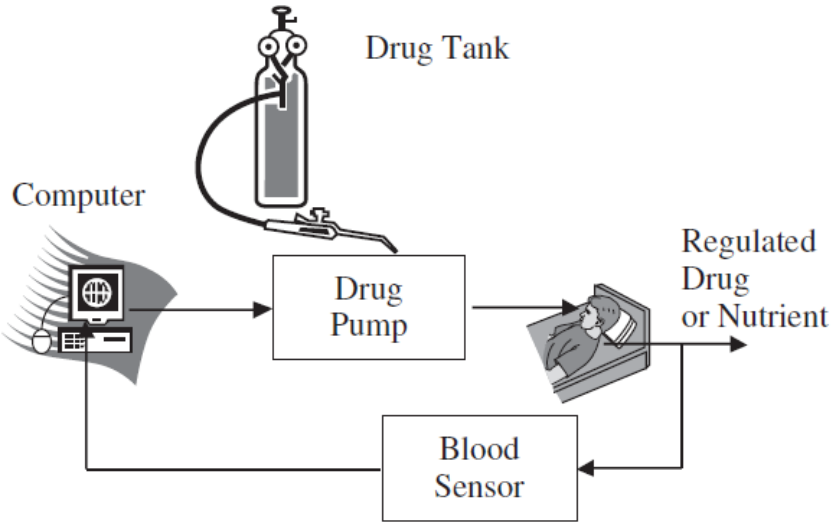
- In almost all applications, both the plant and the actuator are **analog** systems. This is a situation where the controller and the controlled do not "speak the same language," and some form of translation is required.
  - Digital-to-analog converter (DAC)
  - Analog-to-digital converter (ADC)
- Sensor is needed to monitor controller variable for feedback control.

ADC and DAC


Analog
Input
(Analog
Signal)
ADC
Analog To Digital
Converter
0
1
1
0
Binary
Output
(Digital
Signal)
Binary
Input
(Digital
Signal)
0
1
1
0
DAC
Digital-to-Analog
Converter
Analog
Output
(Analog
Signal)

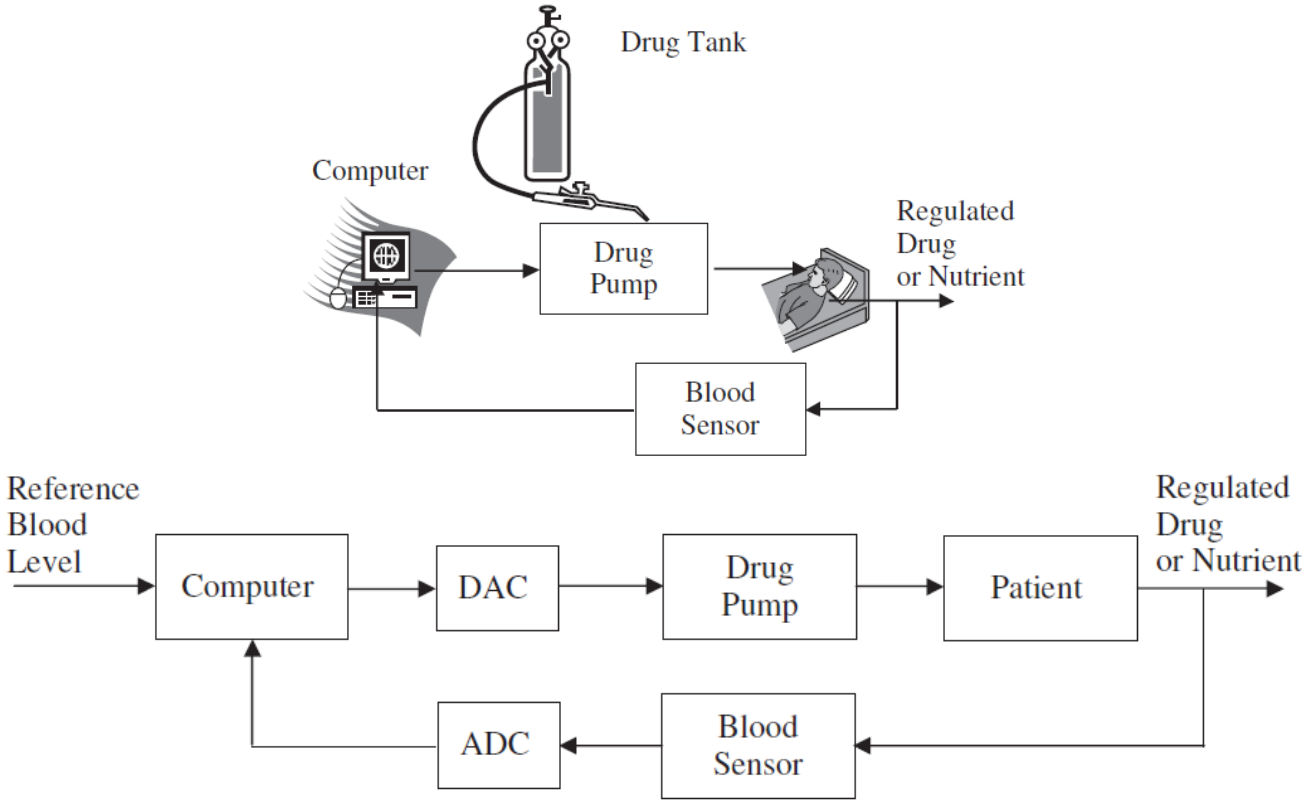
Closed-loop Drug Delivery System

- In this section, we briefly discuss examples of control systems where digital implementation is now the norm.
- Several chronic diseases require the regulation of the patient's blood levels of a specific drug or hormone.
  - For example, some diseases involve the failure of the body's natural closed-loop control of blood levels of nutrients.
- To design a closed-loop drug delivery system, a sensor is utilized to measure the levels of the regulated drug or nutrient in the blood.



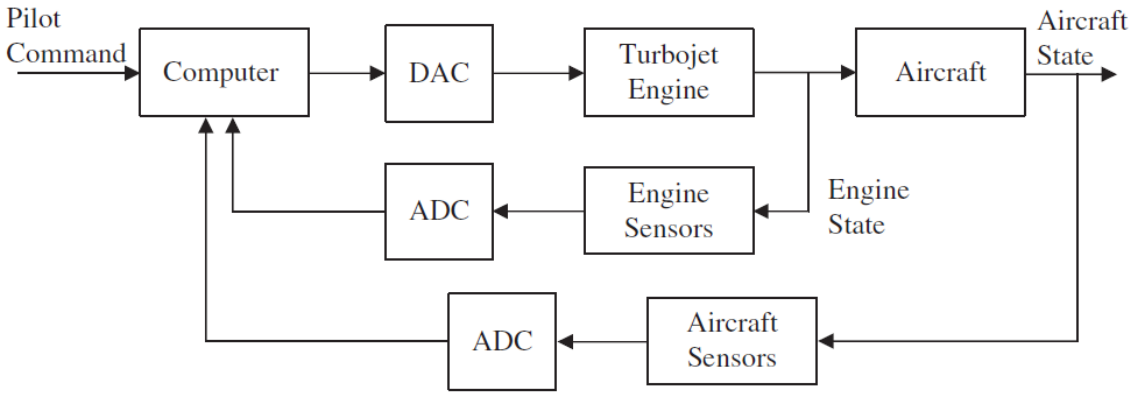
Closed-loop Drug Delivery System

- Sensor measurement is converted to digital form and fed to the control computer, which drives a pump that injects the drug into the patient's blood.



Computer Control of an Aircraft Turbojet Engine

- To achieve the high performance required for today's aircraft, turbojet engines employ sophisticated computer control strategies.
  - The control requires feedback of the engine state (speed, temperature, and pressure), measurements of the aircraft state (speed and direction), and pilot command.



Control of a Robotic Manipulator

- Robotic manipulators are capable of performing repetitive tasks at speeds and accuracies that far exceed those of human operators.
  - such as spot welding and painting
- To perform their tasks accurately and reliably, manipulator hand (or end-effector) positions and velocities are controlled digitally.
- The computer also provides an interface between the robot and the operator that allows programming the lower-level controllers and directing their actions.