Introduction

Digital control

Dr. Ahmad Al-Mahasneh

Introduction

- Control engineering is concerned with controlling a dynamic system or plant.
- A control engineer manipulates the input variables and shapes the response of a plant in an attempt to influence the output variables such that a required response can be obtained.

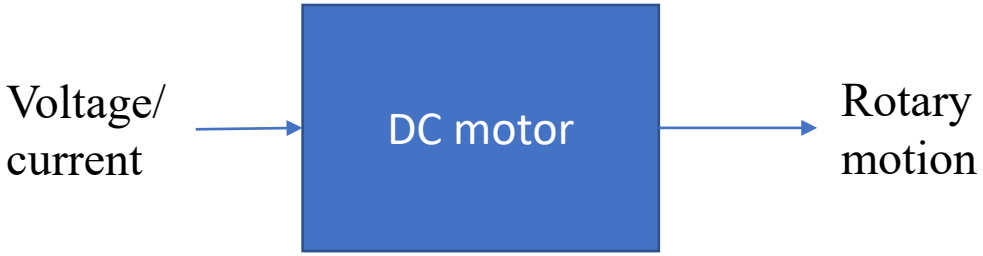
- A dynamic system can be a mechanical system, an electrical system, a fluid system, a thermal system, or a combination of two or more types of system.

  - The behaviour of a dynamic system is described by differential equations. $\dot{\mathbf{x}}(t) = \mathbf{A}(t)\mathbf{x}(t) + \mathbf{B}(t)\mathbf{u}(t)$

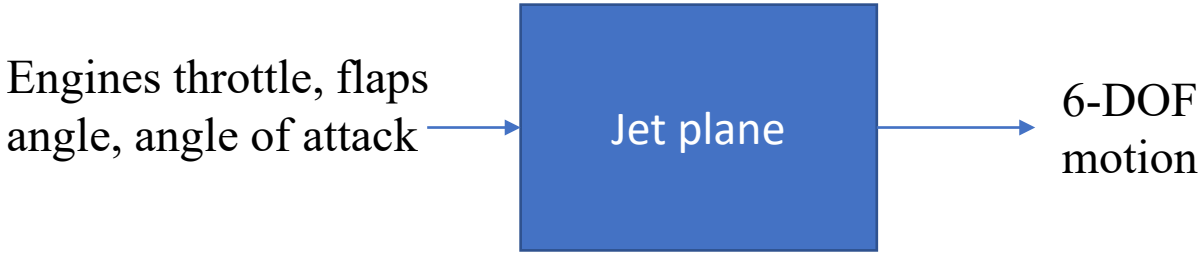
  - Given the model (differential equation), the inputs and the initial conditions, we can easily calculate the system output.

SISO Vs MIMO

- A plant can have single input and single output (SISO), example DC motor



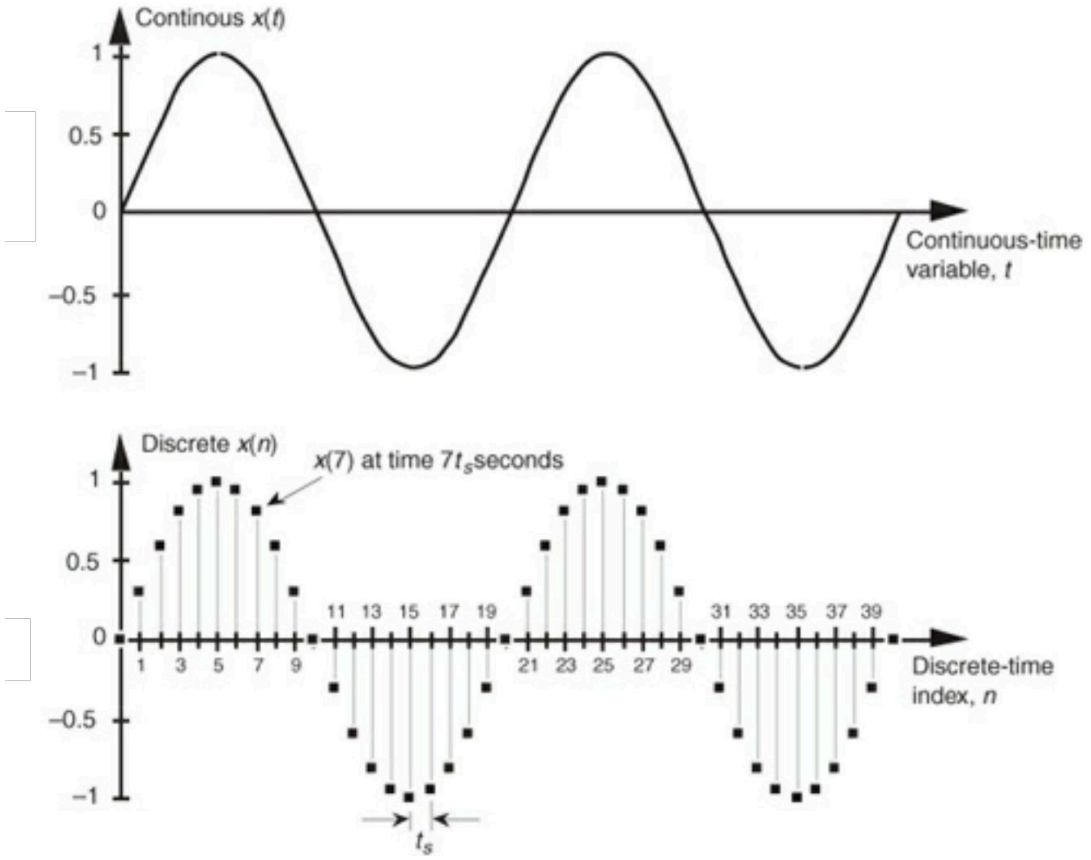
- Multi-inputs and multi-outputs (MIMO), example : Jet plane



- Most real-world systems are MIMO

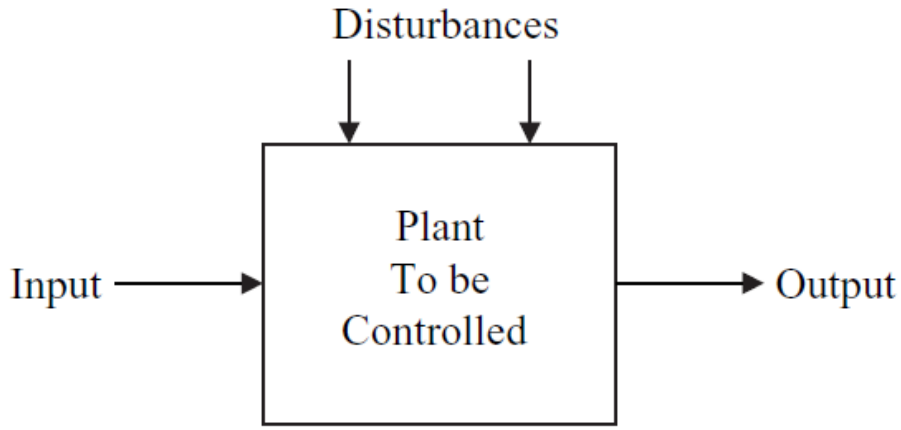
Continuous-time vs Discrete-time

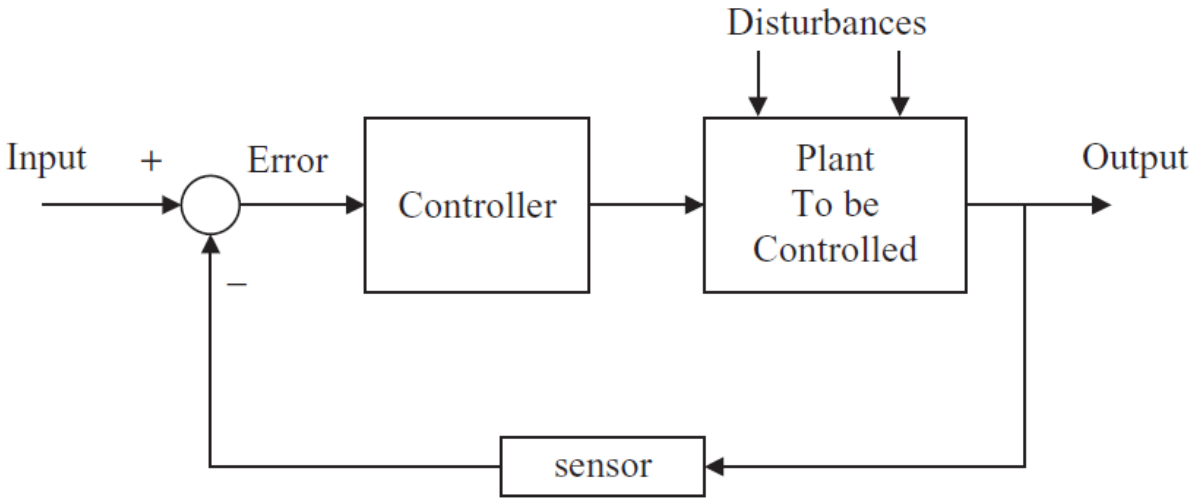
- Generally a plant is a continuous-time system where the inputs and outputs are also continuous in time.
- For example, an electromagnetic motor is a continuous-time plant whose input (current or voltage) and output (rotation) are also continuous signals.
- In discrete-time systems, the inputs and outputs are sampled at certain times (steps).
- Discrete signal is a sequence of numbers corresponds for each sample taken while a continuous signal has value at any time.



Open-loop Vs Closed-loop

- A plant is an *open-loop* system where inputs are applied to drive the outputs.
- For example, a voltage is applied to a motor to cause it to rotate.
- **In an open-loop system there is no knowledge of the system output.**
- The motor is expected to rotate when a voltage is applied across its terminals, but we do not know by how much it rotates since there is no knowledge about the output of the system.
- If the motor shaft is loaded and the motor slows down there is no knowledge about this.
- A plant may also have disturbances affecting its behaviour and in an open-loop system there is no way to know, or to minimize these disturbances.





Open-loop Vs Closed-loop

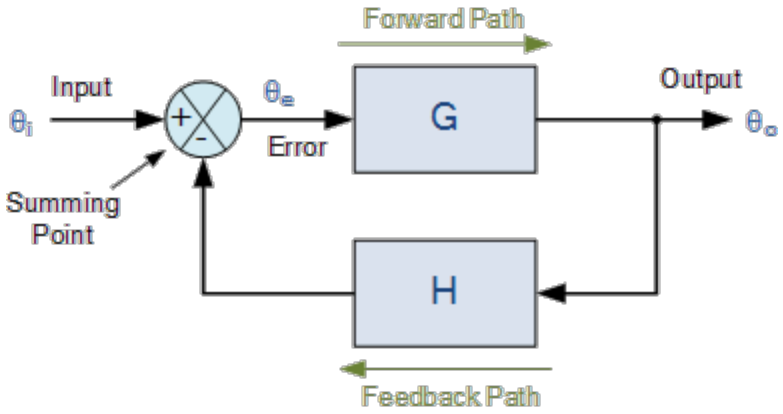
- A *controller* (or a *compensator*) is usually employed to read the error signal and drive the plant in such a way that the error tends to zero.

Advantages of closed-loop systems:

1. One of the advantages of closed-loop control is the ability to compensate for disturbances and yield the correct output even in the presence of disturbances.
2. Closed-loop systems have the advantage of greater accuracy than open-loop systems.
3. They are also less sensitive to disturbances and changes in the environment.
4. The time response and the steady-state error can be controlled in a closed-loop system.

What are the advantages of open-loop system ?

Open-loop Vs Closed-loop

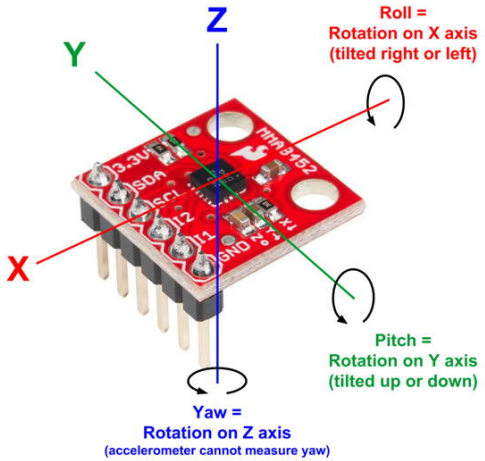


$$\frac{\text{Output}}{\text{Input}} = \frac{\theta_o}{\theta_i} = \frac{G}{1+GH}$$

Sensors

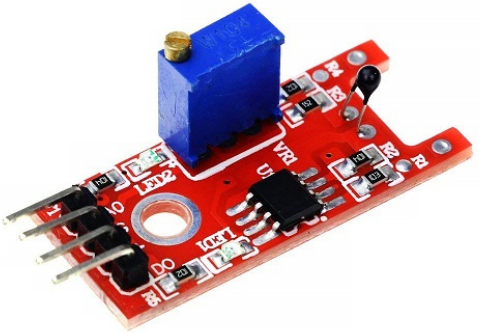
- Sensors are devices which measure the plant output.
- For example, a thermistor is a sensor used to measure the temperature.

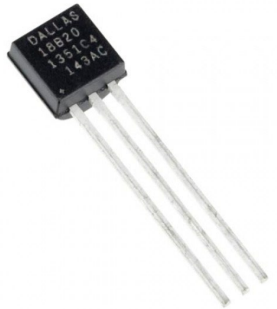
- A tachogenerator is a sensor used to measure the rotational speed of a motor.
- An accelerometer is used to measure the acceleration of a moving body.



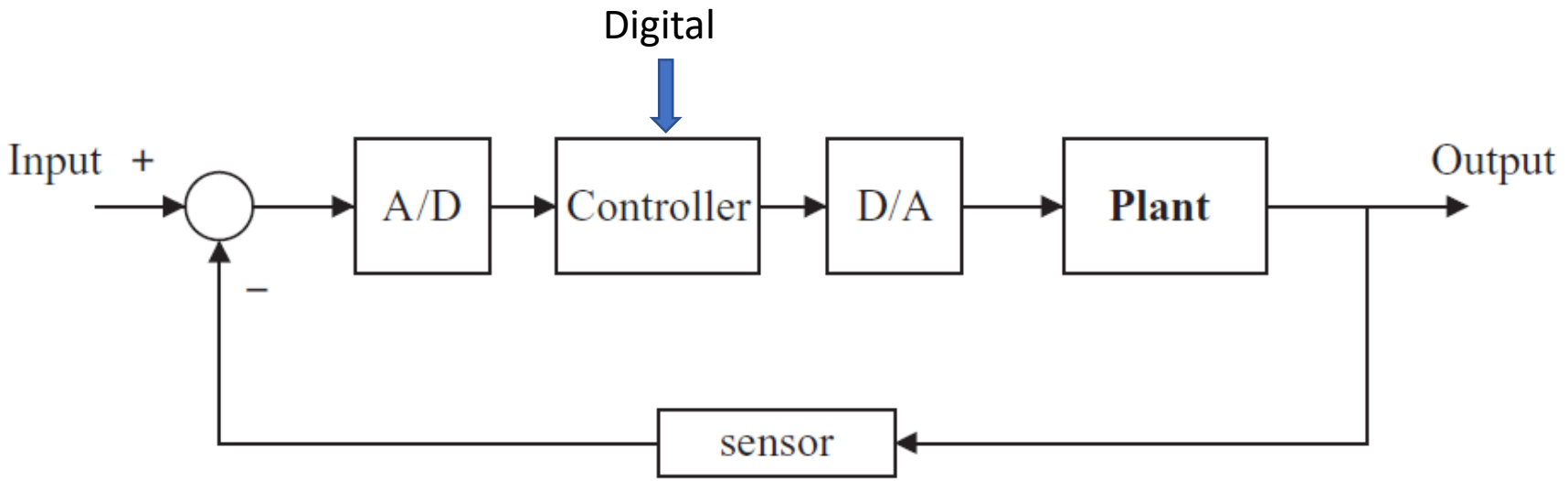
Sensors

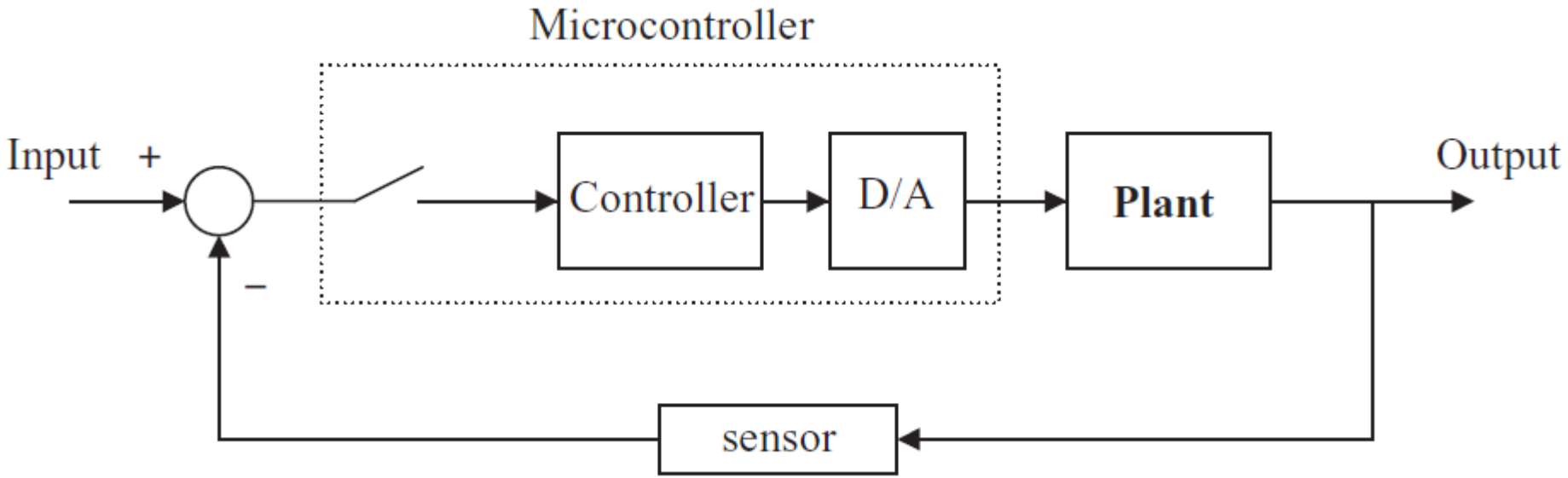
- Most sensors are analog devices, and their outputs are analog signals (e.g. voltage or current).
- These sensors can be used directly in continuous-time systems.
- Analog sensors cannot be connected directly to a digital computer.
- An analog-to-digital (A/D) converter is needed to convert the analog output into digital form so that the output can be connected to a digital computer.
- Some sensors (e.g. temperature sensors) provide digital outputs and can be directly connected to a digital computer.



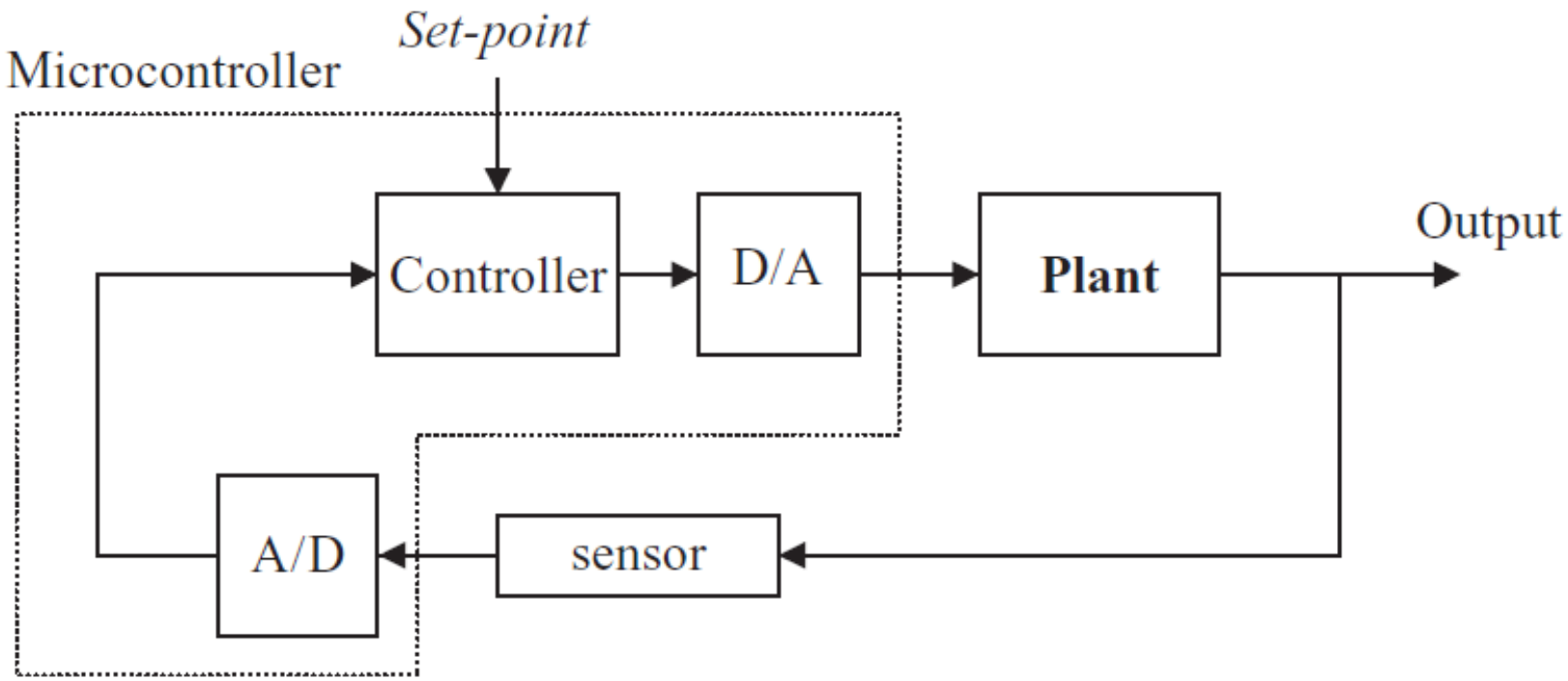


Digital control system

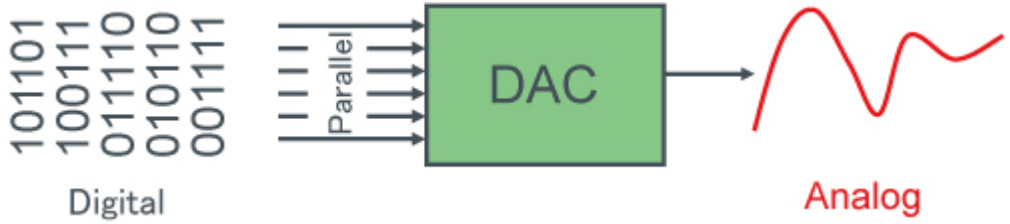


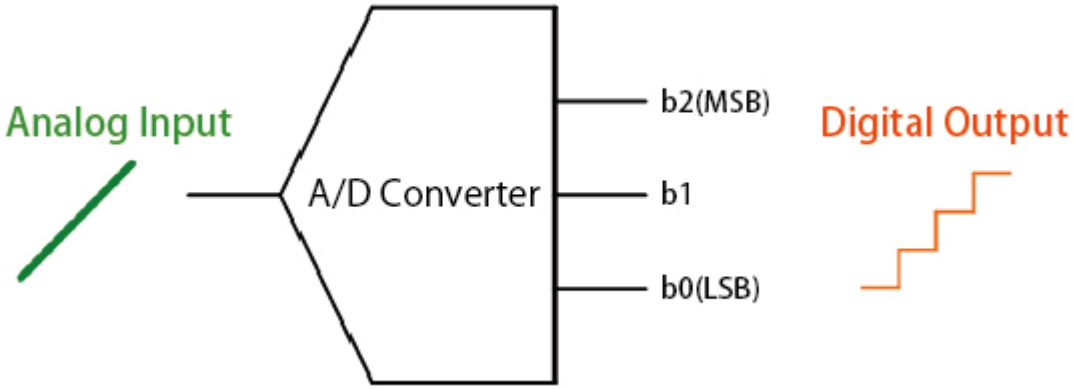


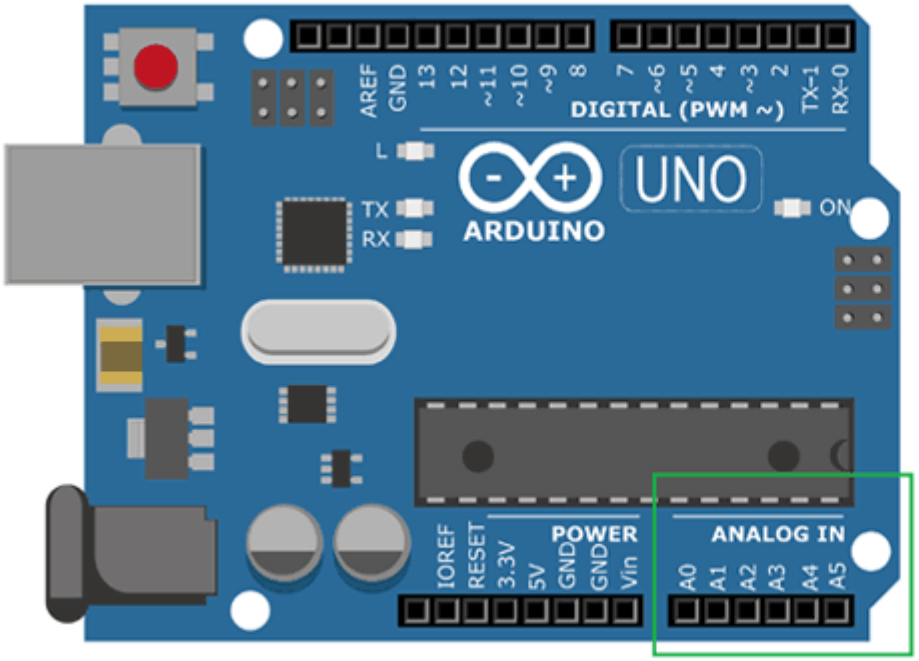
Digital control system



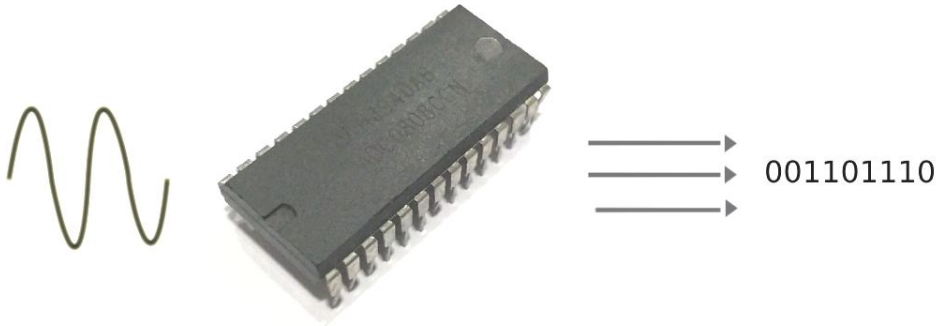
D/A and A/D



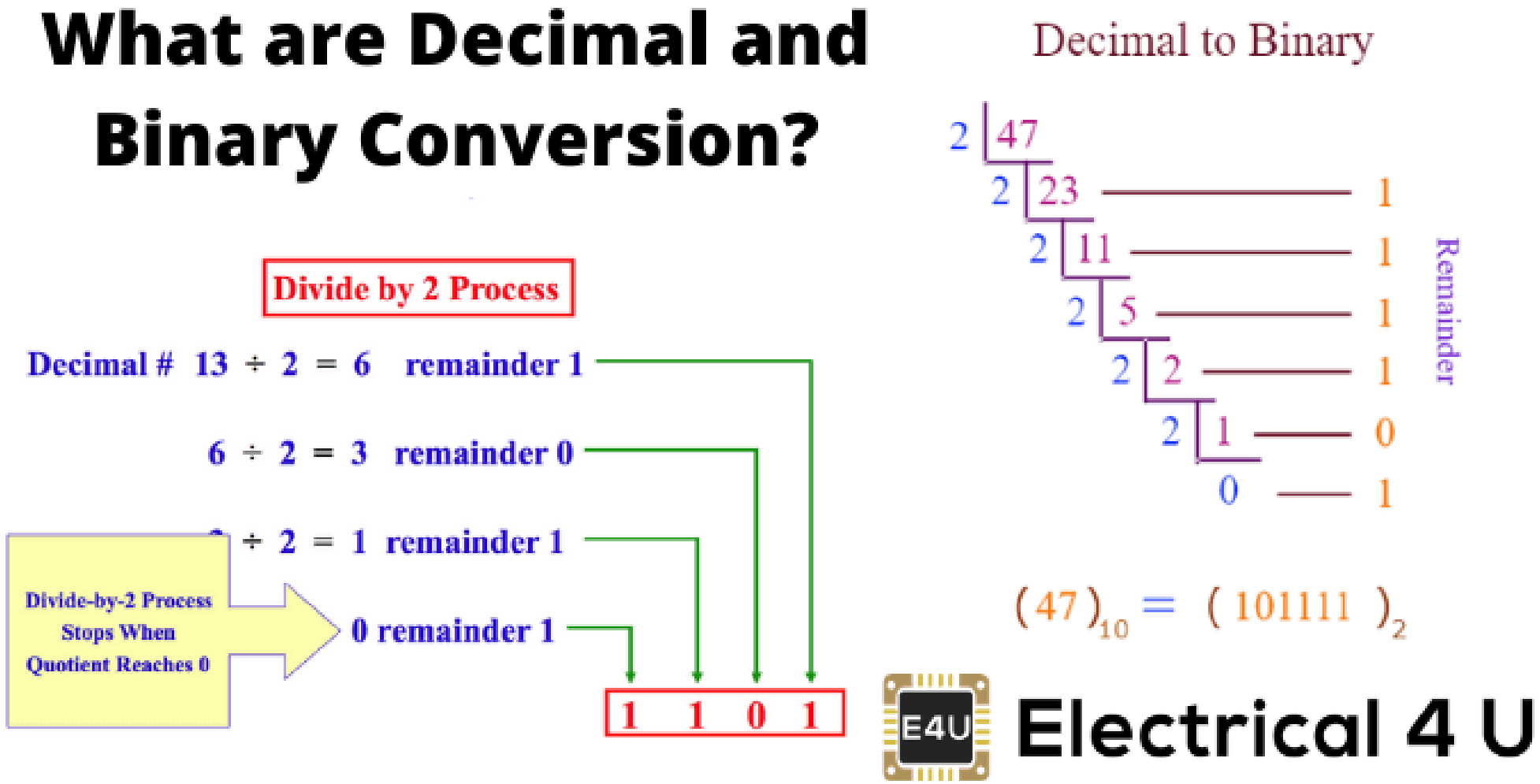




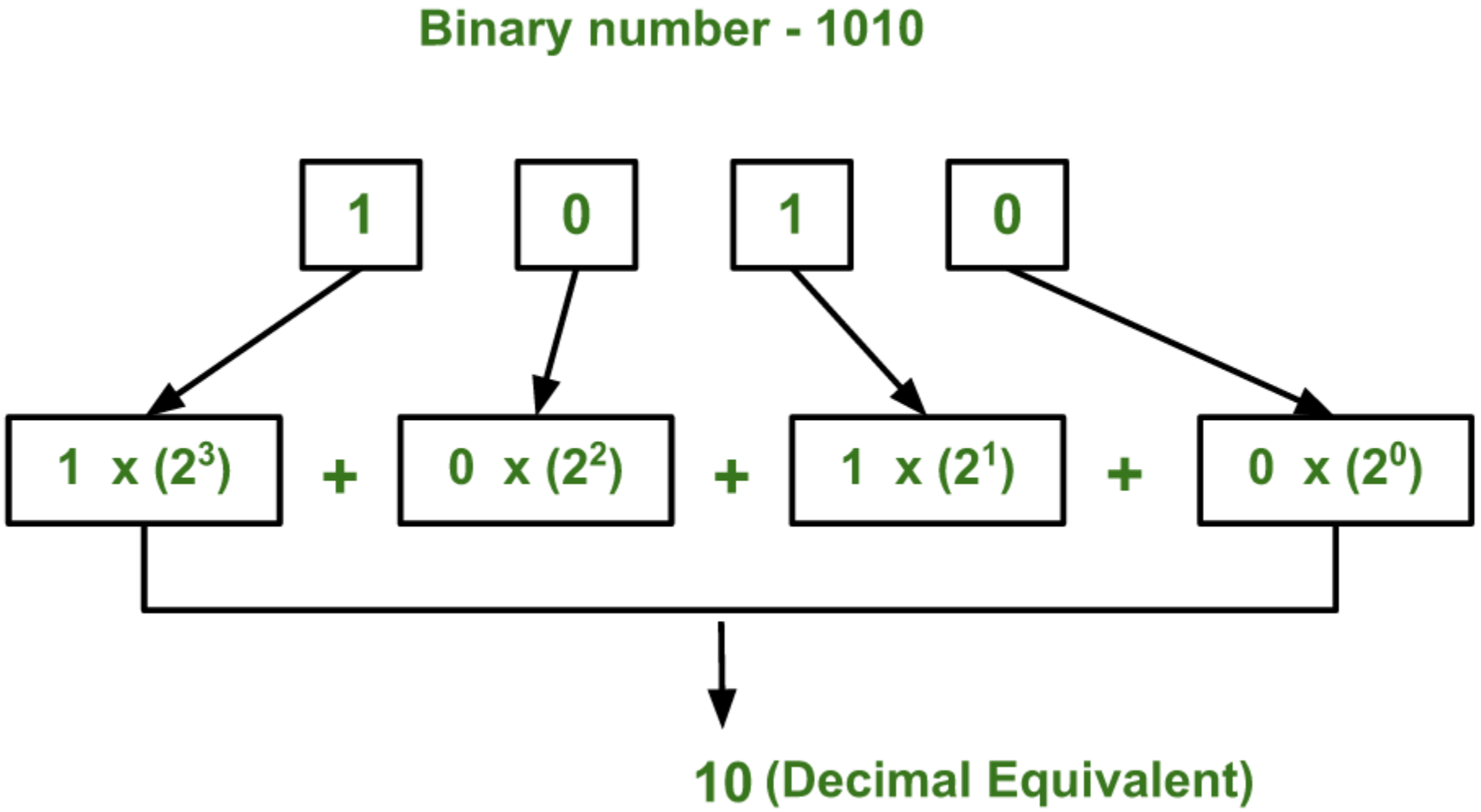
Analog to Digital Converters



D/A and A/D


What are Decimal and Binary Conversion?
Divide by 2 Process
Decimal # 13 ÷ 2 = 6 remainder 1
6 ÷ 2 = 3 remainder 0
÷ 2 = 1 remainder 1
0 remainder 1
Divide-by-2 Process Stops When Quotient Reaches 0
1 1 0 1
Decimal to Binary
2 | 47
2 | 23 — 1
2 | 11 — 1
2 | 5 — 1
2 | 2 — 1
2 | 1 — 0
0 — 1
Remainder
$(47)_{10} = (101111)_2$
E4U
Electrical 4 U

D/A and A/D


Binary number - 1010
1
0
1
0
1 x (2^3)
+
0 x (2^2)
+
1 x (2^1)
+
0 x (2^0)
10 (Decimal Equivalent)

Digital control system

- With the advent of the digital computer and low-cost microcontroller processing elements, control engineers began to use these programmable devices in control systems.

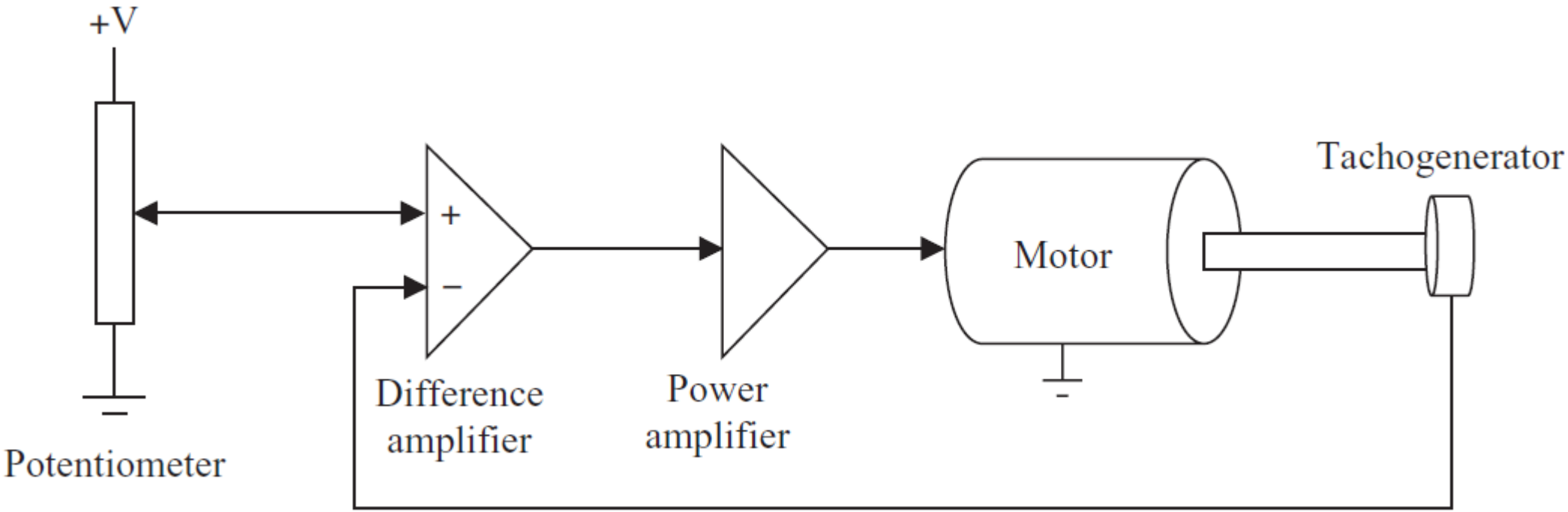
- A digital computer can keep track of the various signals in a system and can make intelligent decisions about the implementation of a control strategy.

- Most control engineering applications nowadays are computer based, where a digital computer or a microcontroller is used as the controller.

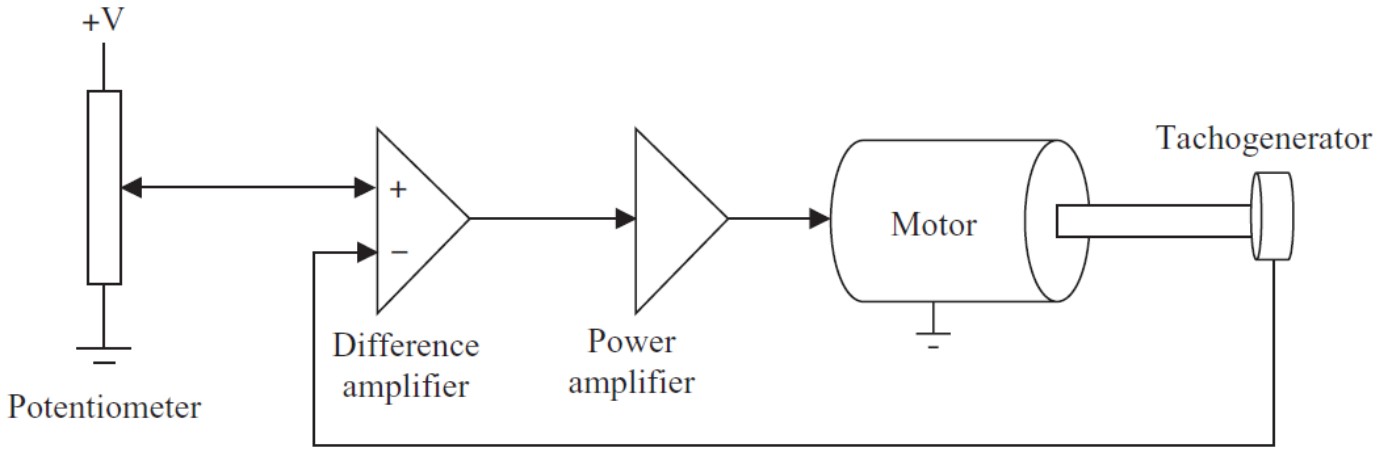
- The purpose of developing the digital control theory is to be able to understand, design and build control systems where a computer is used as the controller in the system.

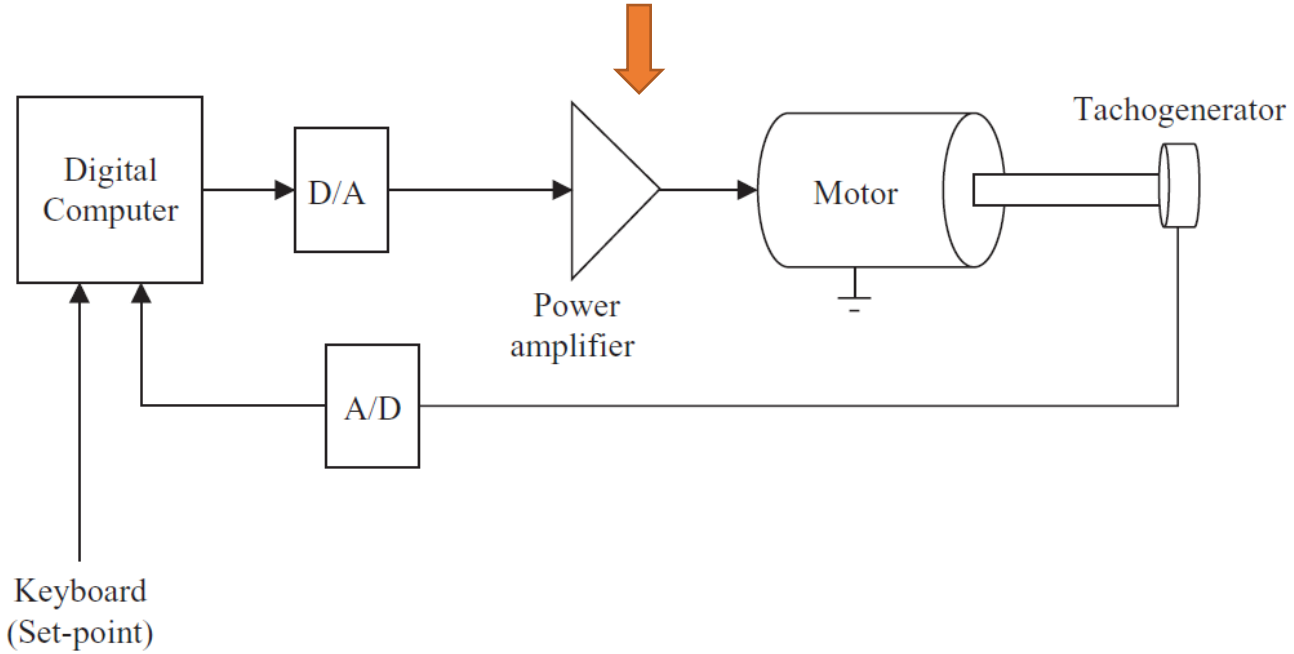
- In addition to the normal control task, a computer can perform supervisory functions, such as reading data from a keyboard, displaying data on a screen or liquid crystal display, turning a light or a buzzer on or off and so on.

Is it digital or analogue control system?



Can we convert analogue to digital control system?





References

- Chapter 1 in our text book (Microcontroller Based Applied Digital Control by Dogan Ibrahim)

Thanks for your attention

Questions