Digital control

Introduction part 2

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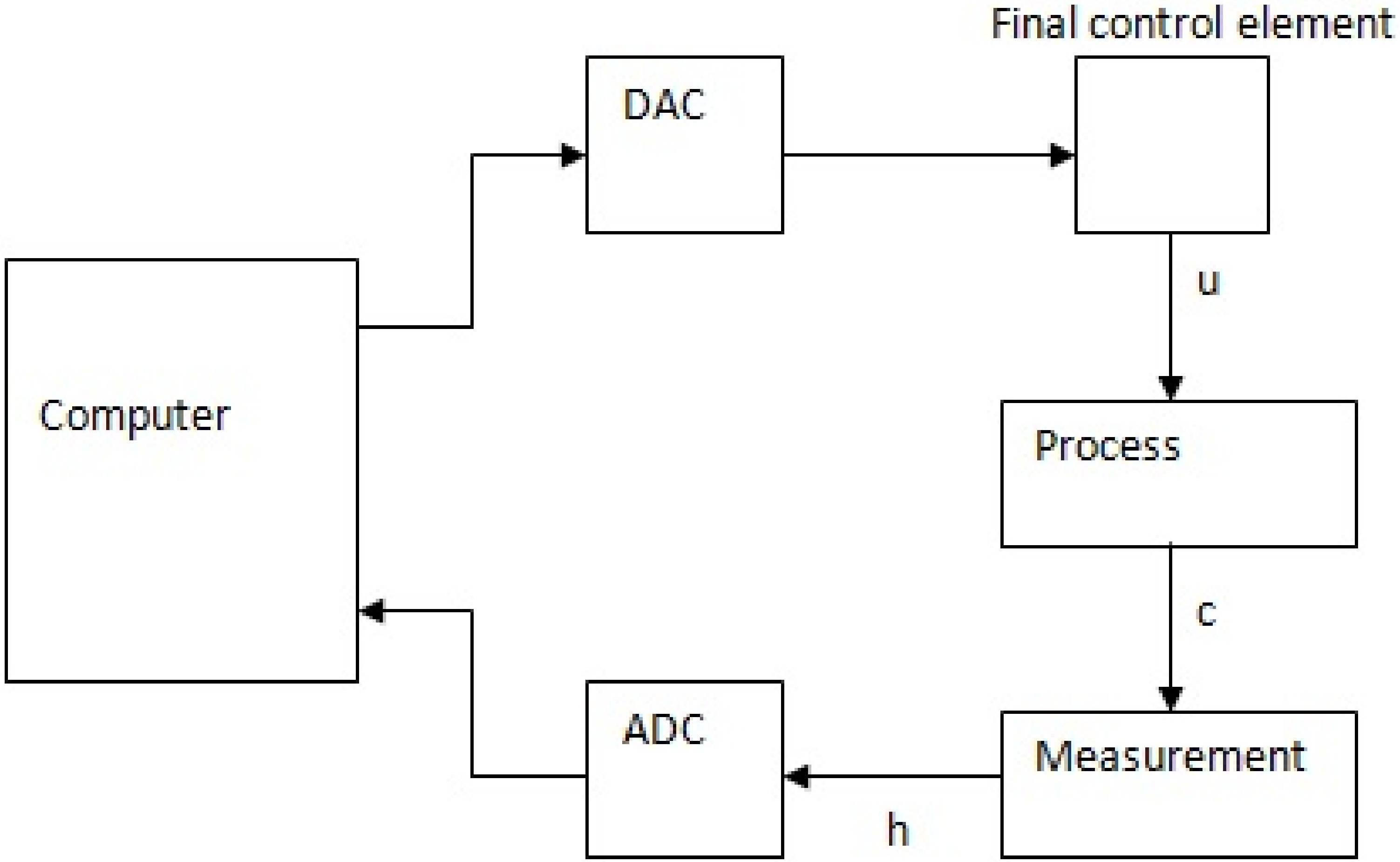
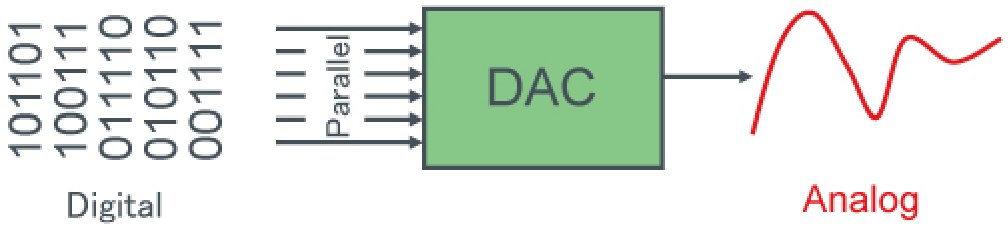
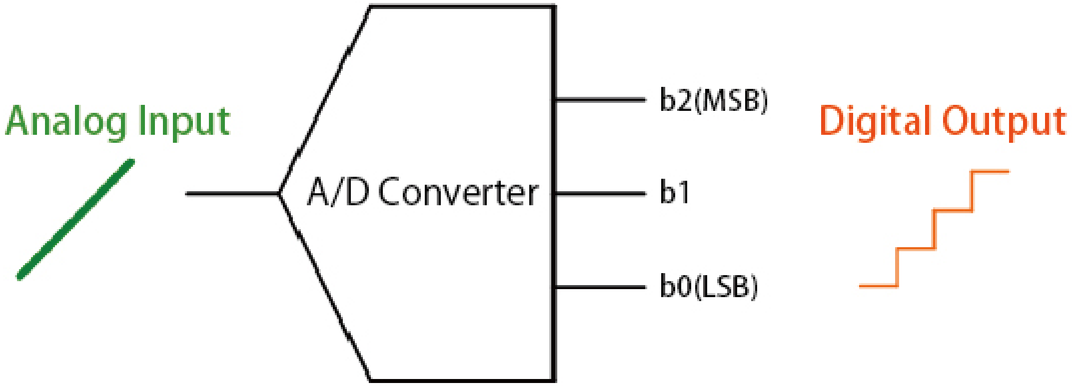


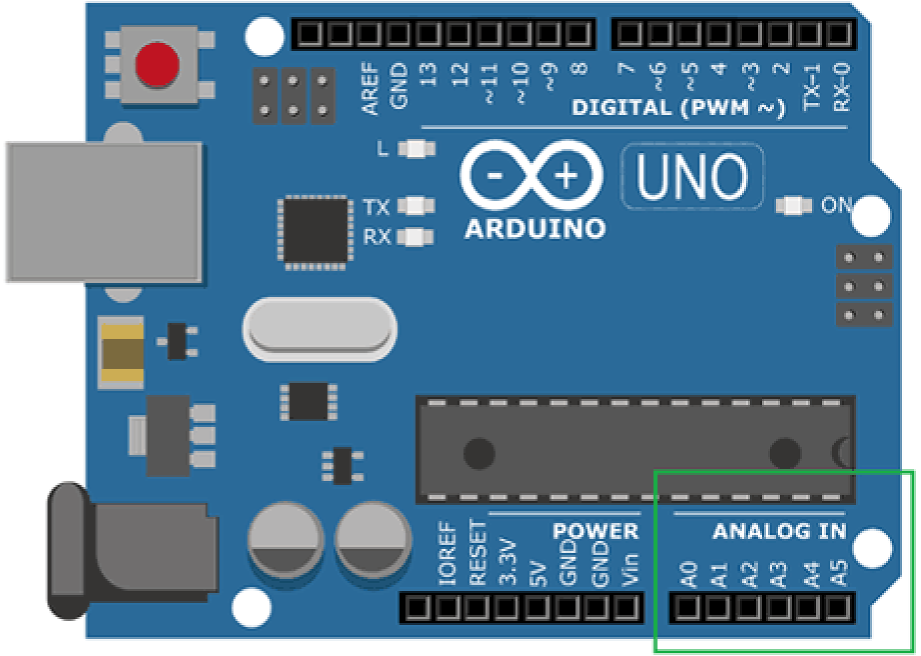
Outline

- D/A and A/D
- Centralized and distributed control
- SCADA SYSTEMS
- Hardware requirements for digital control
- Microcontrollers
- Software requirements for digital control

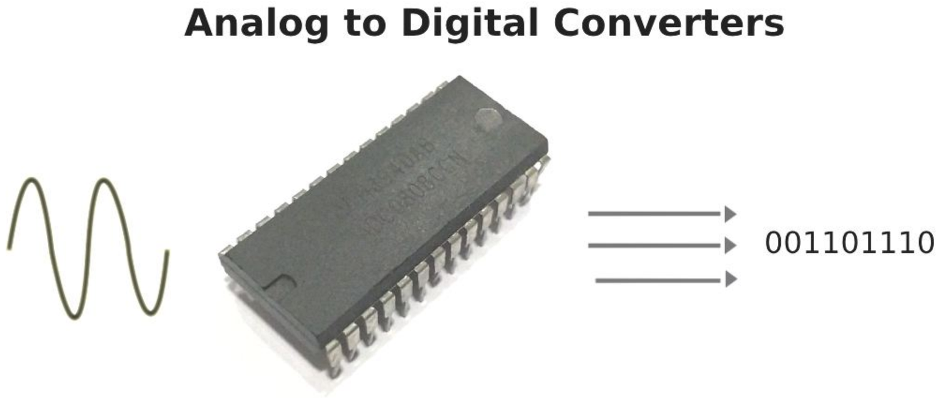
D/A and A/D


101101
100111
011110
010110
001111
Digital
Parallel
DAC
Analog

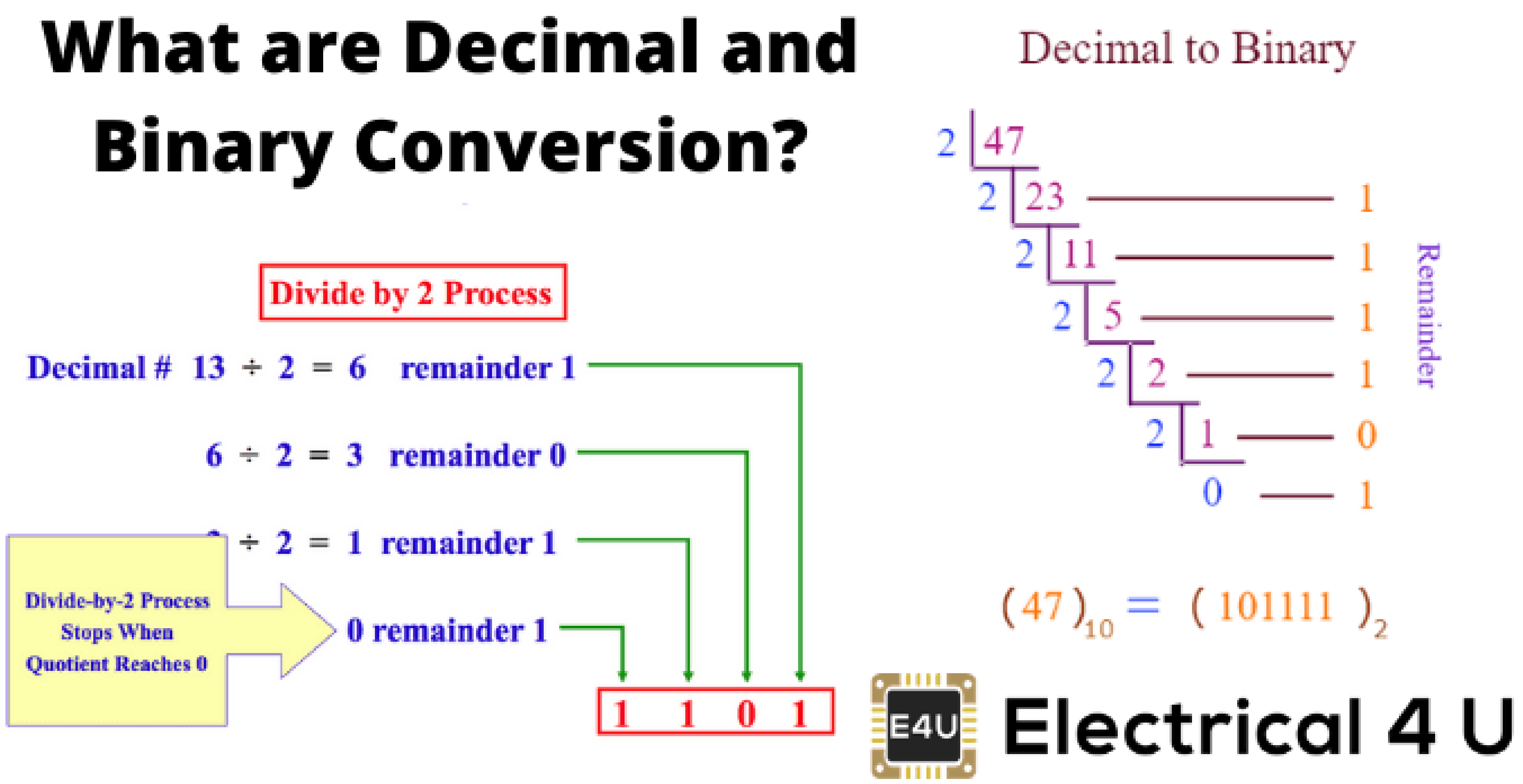

Analog Input
A/D Converter
b2(MSB)
b1
b0(LSB)
Digital Output


AREF
GND
13
12
~11
~10
~9
8
7
~6
~5
4
~3
2
TX-1
RX-0
DIGITAL (PWM ~)
L
TX
RX
ARDUINO
UNO
ON
IOREF
RESET
3.3V
5V
GND
GND
Vin
POWER
ANALOG IN
A0
A1
A2
A3
A4
A5

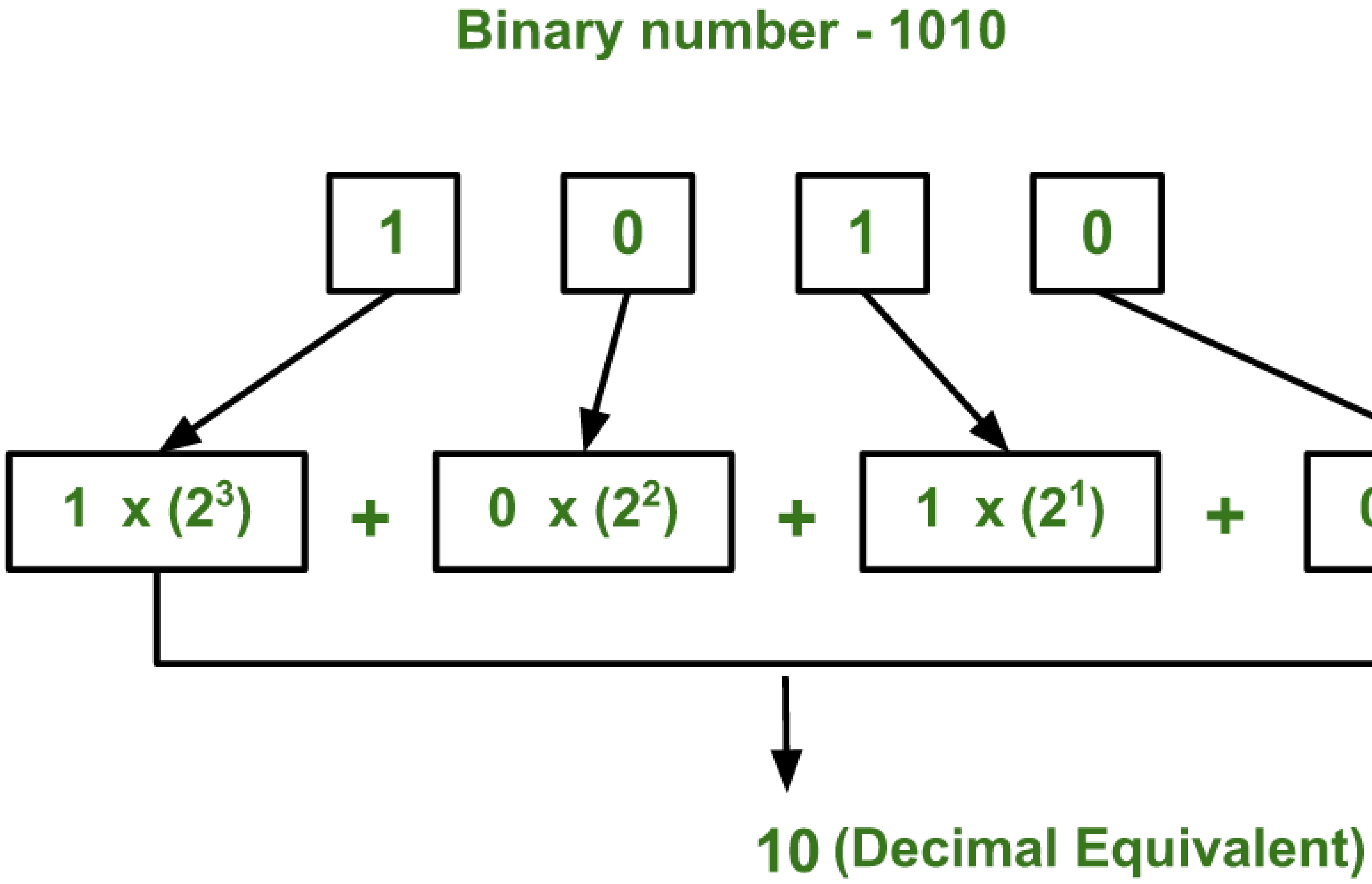

ADC0808


Analog to Digital Converters
001101110

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.

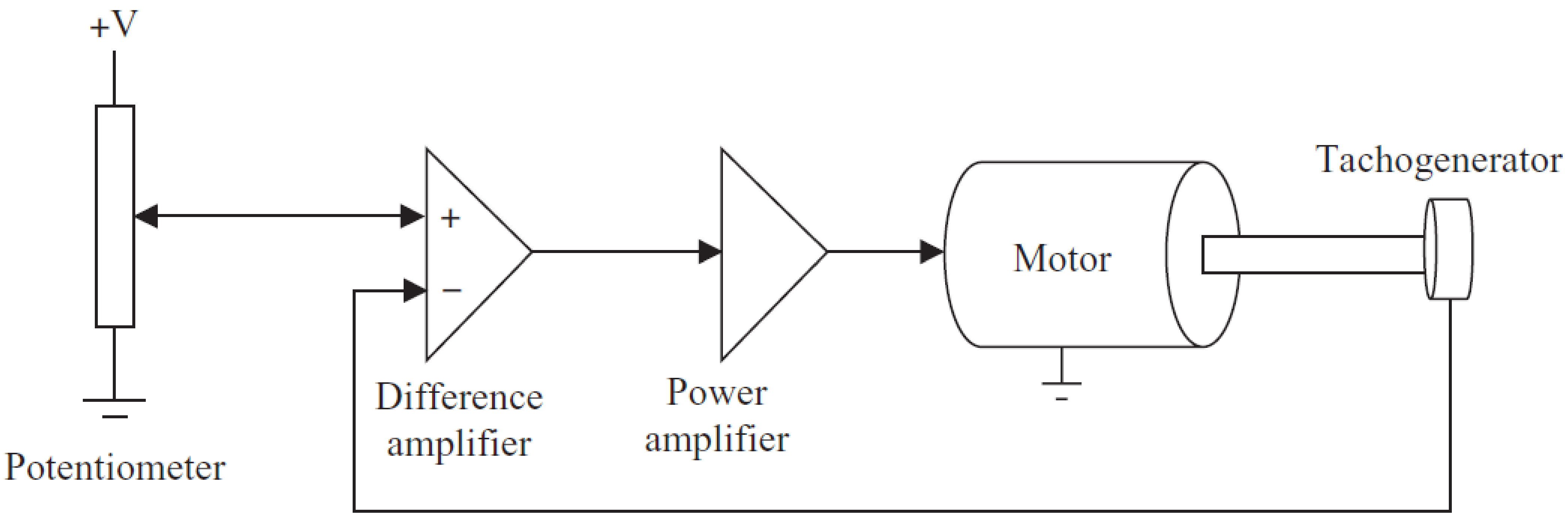
- A digital computer can keep track of the various signals in a system and can make intelligent decisions about the implementation of a control strategy.

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

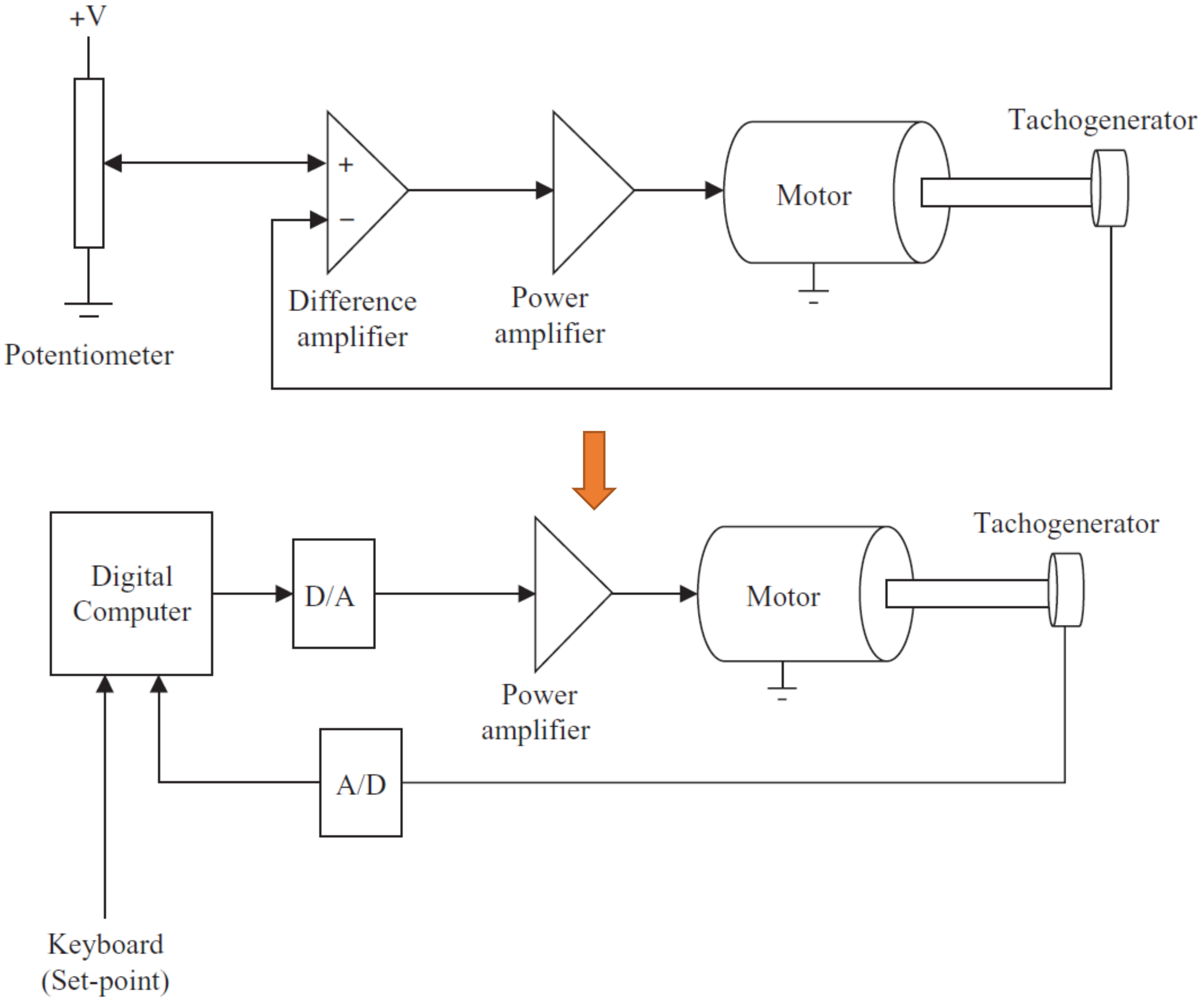
- The purpose of developing the digital control theory is to be able to understand, design and build control systems where a computer is used as the controller in the system.

- 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?



CENTRALIZED AND DISTRIBUTED CONTROL SYSTEMS

- In a centralized control system, the controller algorithm is implemented in a single central computer. Hence, all sensors, actuators, input units and output units must be connected directly to this central computer.
- **The advantages of centralized control are as follows:**

1. It is easy to manage the computer.
2. Only one computer is used.
3. Less number of people are required.

CENTRALIZED AND DISTRIBUTED CONTROL SYSTEMS

- A distributed control system (DCS) consists of a number of computers installed at different locations, each performing an independent control action.
- Distributed control has emerged as a result of the sharp decrease in price, and the consequent widespread use, of computers. Also, the development of computer networks has made it possible to interconnect computers in a local area network (LAN), as well as in a wide area network (WAN).
- **The main advantages of DCSs are as follows:**

1. A higher performance is obtained from a distributed system than from a centralized control system.
2. A distributed system is more reliable than a centralized system. In the case of a centralized system, if the computer fails, the whole plant becomes unusable. In a DCS, if one computer fails, only a small part of the plant will be affected and the load of the failed computer can usually be distributed among the other computers.
3. A DCS can easily be expanded by adding more computers to the network. For example, if 10 computers are used to control the temperature of 10 ovens, then if the number of ovens is increased to 15, it is easy to add five more computers to the network.
4. A DCS is more flexible than a centralized control system as it can be easily adjusted to plant requirements.

SCADA SYSTEMS

- The term SCADA is an abbreviation for *supervisory control and data acquisition*.
- SCADA systems integrate the data acquisition and system monitoring and control activities using graphical software packages.
- A SCADA system is nothing but a customized graphical applications program with all the necessary hardware components.
- It can be developed using the popular visual programming languages such as *Visual C*++ or *Visual Basic*.
- Good human–computer interface techniques should be employed in the design of the user interface.
- Alternatively, graphical programming languages such as *Labview* or *VisiDaq* can be used to create powerful, user-friendly SCADA systems.
- The advantage of a SCADA system is that the user can easily monitor the status of the overall system.
- It is important that a SCADA system should be secure and password protected to avoid unauthorized access to the control screens.

Hardware requirements for digital control

- A general-purpose computer consists of the following basic building elements:

- Central processing unit (CPU):
- Program memory:
- Data memory:
- Input–output devices:

Microcontrollers

- A microcontroller is a single-chip computer that is specifically manufactured for embedded computer control applications.
- These devices are very low-cost and can be used very easily in digital control applications.
- Most microcontrollers have the built-in circuits necessary for computer control applications. For example, a microcontroller may have A/D converters so that the external signals can be sampled.
- They also have parallel input–output ports so that digital data can be read or output from the microcontroller.
- Some devices have built-in D/A converters and the output of the converter can be used to drive the plant through an actuator (e.g. an amplifier).
- Microcontrollers may also have built-in timer and interrupt logic. Using the timer or the interrupt facilities, we can program the microcontroller to implement the control algorithm accurately.

Microcontrollers

- Microcontrollers have traditionally been programmed using the assembly language of the target device.
- As a result, the assembly languages of the microcontrollers manufactured by different firms are totally different and the user has to learn a new language before being able program a new type of device.
- Nowadays microcontrollers can be programmed using high level languages such as BASIC, PASCAL or C.

- **High-level languages offer several advantages compared to the assembly language:**

1. It is easier to develop programs using a high-level language.
2. Program maintenance is much easier if the program is developed using a high-level language.
3. Testing a program developed in a high-level language is much easier.
4. High-level languages are more user-friendly and less prone to making errors.
5. It is easier to document a program developed using a high-level language.

- In addition to the above advantages, high-level languages have some disadvantages.
- For example, the length of the code in memory is usually larger when a high-level language is used, and the programs developed using the assembly language usually run faster than those developed using a high-level language.

SOFTWARE REQUIREMENTS FOR COMPUTER CONTROL

- The software requirements in a control computer can be summarized as follows:

1. the ability to read data from input ports;
2. the ability to send data to output ports;
3. internal data transfer and mathematical operations;
4. timer interrupt facilities for timing the controller algorithm.

- All of these requirements can be met by most digital computers, and, as a result, most computers can be used as controllers in digital control systems.
- The important point is that it is not justified and not cost-effective to use a minicomputer to control the speed of a motor, for example. A microcontroller is much more suitable for this kind of control application.
- On the other hand, if there are many inputs and many outputs, and if it is required to provide supervisory tasks as well then the use of a minicomputer can easily be justified.

The control algorithms

- The controller algorithm in a computer is implemented as a program which runs continuously in a loop which is executed at the start of every sampling time.
- Inside the loop, the desired reference value is read, the actual plant output is also read, and the difference between the desired value and the actual value is calculated. This forms the error signal.
- The control algorithm is then implemented and the controller output for this sampling instant is calculated.
- This output is sent to a D/A converter which generates an analog equivalent of the desired control action.
- This signal is then fed to an actuator which in turn drives the plant to the desired point.

The control algorithms

- The operation of the controller algorithm, assuming that the reference input and the plant output are digital signals, is summarized below as a sequence of simple steps:

Repeat Forever

When it is time for next sampling instant

- Read the desired value, R
- Read the actual plant output, Y
- Calculate the error signal, $E = R - Y$
- Calculate the controller output, U
- Send the controller output to D/A converter
- Wait for the next sampling instant

End

The control algorithms

- Similarly, if the reference input and the plant output are analog signals, the operation of the controller algorithm can be summarized as:

Repeat Forever

When it is time for next sampling instant

- Read the desired value, R, from A/D converter
- Read the actual plant output, Y, from the A/D converter
- Calculate the error signal, $E = R - Y$
- Calculate the controller output, U
- Send the controller output to D/A converter
- Wait for the next sampling instant

End

Synchronization

- One of the important features of the above algorithms is that once they have been started they run continuously until some event occurs to stop them or until they are stopped manually by an operator.

- It is important to make sure that the loop is run continuously and exactly at the same times, i.e. exactly at the sampling instants. This is called synchronization.

END

Questions