1501326 Computer Control Systems

Course Description:
Computer control system, Input-Output Interface, Graphical programming language, Applications of microcomputers in Electronic Control Systems. Industrial programming for automation*.
(*modified in the framework of an Erasmus + project: Asean Factori 4.0 Across South East Asian Nations: From Automation and Control Training to the Overall Roll-out of Industry 4.0 609854-EPP-1-2019-1-FR-EPPKA2-CBHE-JP)

Learning outcome:
1. Students can discuss the content of electronic engineering.
2. Students can analyze the behavior of electronic components.
3. Students understand the function of industrial equipment and sensors.

Lecturer:
Asst. Prof. Teeravisit Laohapensaeng, Ph.D.

Credit: 3(3-0)
Lecture: 45 Hours (9 hours of modified content)

Assessments:

Attendance	10%
HW/CW	20%
Midterm	25%
Final	25%
Project	20%

Lecture (seminar):

Content	Hours
Computing in control system	12
Control interfaces	12
GUI control models	12
Computer-based controllers*	3
Computer-based feedback control*	3
Tuning of computer-based controllers*	3

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1501326 Computer Control Systems

Program: Bachelor program in Computer Engineering

Credit: 3(3-0)   Lecture: 45 Hours

1st Semester, Academic Year: 2024

Asst. Prof. Teeravisit Laohapensaeng, Ph.D.

FACTORI 4.0 Erasmus +

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Computer Based Controller

1. Introduction to computer control systems

- In modern cities, many facilities and works are controlled by the automation system, which is based on computer control, for example, MTR, electricity supply system, traffic light control system, elevators and CNC machines in factories.
- There are many advantages of automation system such as the increase in efficiency; reduction of the cost, the number of operators, repetitive and boring work; enhancing the safety of workers; improvement of the working performance and completing the work that cannot be done manually.

Computer controlled MTR system

Electricity supply system

CNC machine

1.1 The merits of computer control system

- This section, the merits of the computer system are discussed.

- Computer is not the only ways to control the automation system, other methods include mechanical systems, electrical (relay) systems, pneumatic system, electronic system, etc.

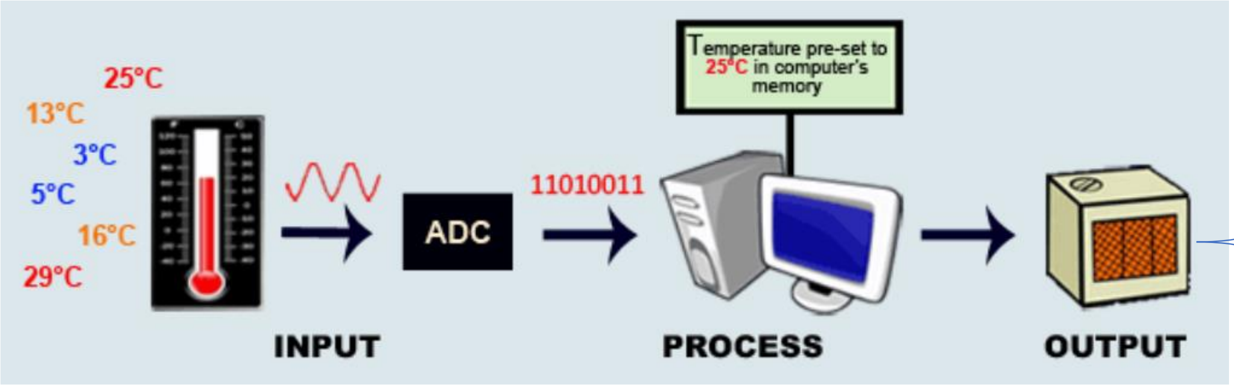
- Computer control system has many advantages over the other control systems. It has fast calculation speed, multiple forms of input and output devices, large memory, programmable control, communication possible, small and light, etc.

Fast calculation speed

- The central processing unit (CPU) of modern computers can do a large number of calculations within one second and it can manage a lot of work and data in a short time.
- The fast calculation speeds of computer make it possible to control a lot of facilities at the same time under different conditions.
- For example, the MTR computer system can control trains in different routes to ensure the system runs normally.

Multiple forms of input and output devices

- Computer has many input devices, including keyboard, mouse, scanner etc. Also, it can use electronic circuits (ADC) to transform signals from electronic sensors to digital data and input them to the computer.
- For example, by using a sensor, the temperature can be transformed into digital data and input in the computer. After processing the data, the computer can generate output signal. Similarly, computer can use electronic circuits to output digital signals which can then control various output devices, for examples, printer, monitor, relay, motor, electromagnetic detecting valve, etc.



Printer
Monitor
Relay
Motor
etc

High capacity of data storage

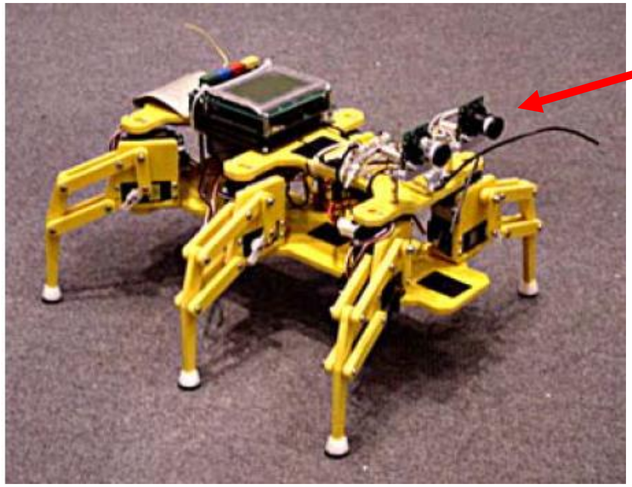
- Computer can use a large number of information storage devices, such as hard disk, CD-ROM, DVD etc. Therefore, computer can use those stored information to perform the controlling work.
- For example, we can use computer to design complicated shape of workpieces. Then we input the relevant data into the storage device of the CNC machine and let the computer to control the cutting work of the workpieces according to the data.

CNC machine

Control Signal

Programmable control

- A program is a set of instructions.
- Computer can operate according to the program. Operators can either input new program or modify the existing program to change the working procedures or methods according to the needs.
- The computer control system not only can operate those simple task and repetitive work, but it can also operate complicated work under different conditions and feedback according to the program. For example, there is a visual system in the computer controlled of robot six legs machine. The computer of the robot can analyze the image and choose the way without any obstacle.

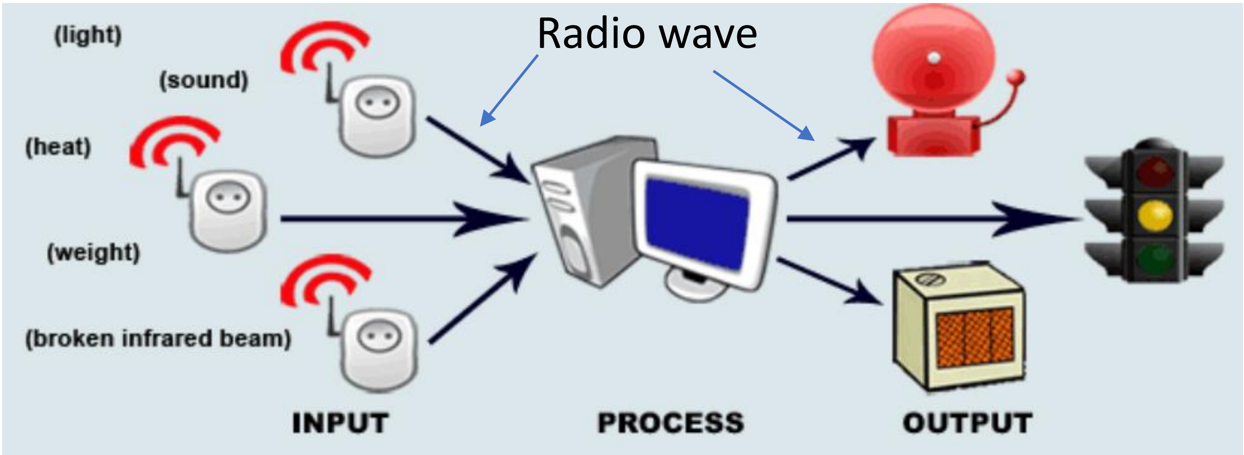


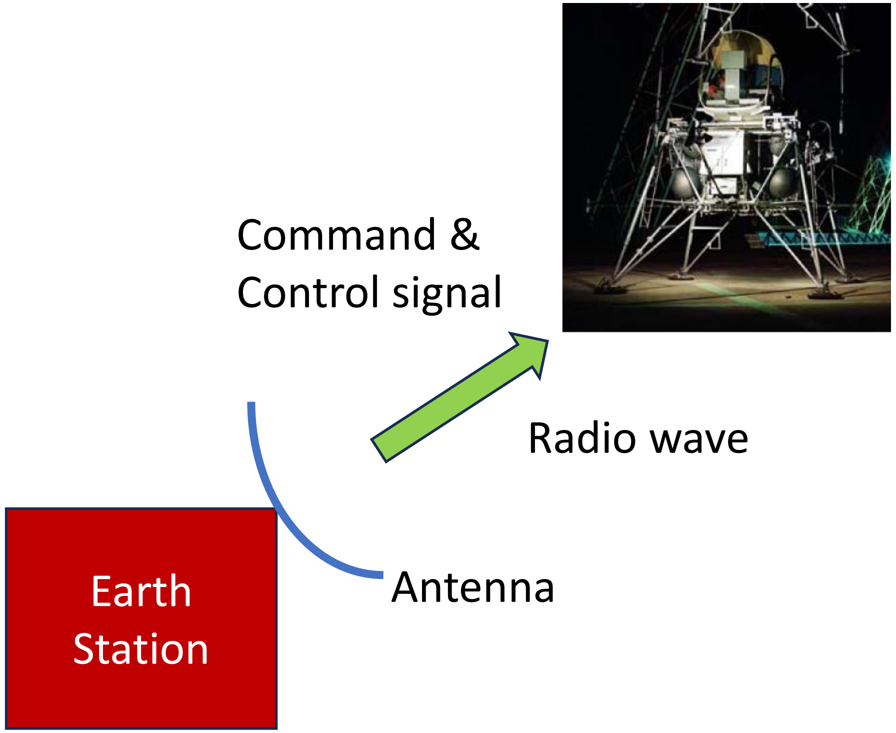
Camera

Robot six legs machine

Communications possible

- Computer information can be transmitted to distant areas by private cables, telephone lines, internet or radio wave.
- For example, computers can control distant video cameras or machines through the internet; computers can also be used to control spacecrafts in space through the use of radio wave (wireless communication).

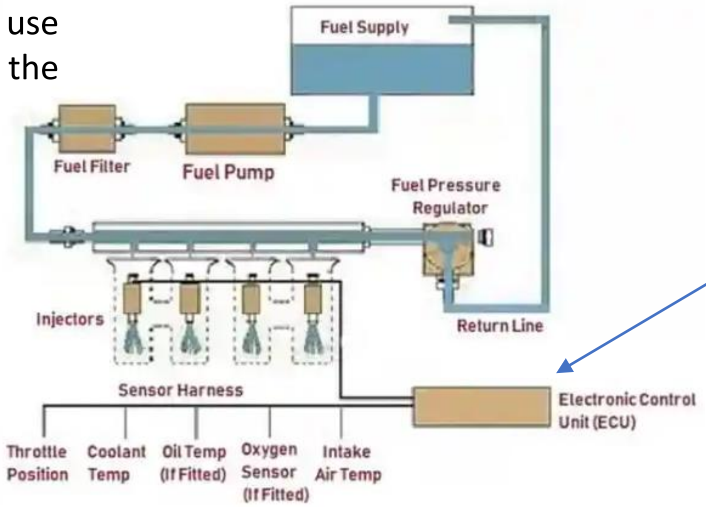




Small and light

- With the advancement of technology, the size and weight of computers have been reduced a lot.
- The microcomputers developed recently are so sophisticated that it is possible to put the microcomputers into a number of utensils, such as washing machines, refrigerators, air-conditioners, car, etc.
- Take the car as an example. For those cars having traditional emulsifier engine, the amount of petrol supply to the engine is controlled by the emulsifier. But nowadays, the car has an Electronic Fuel Injection System (EFI) that can decide the best amount of petrol supply to the engine according to the amount of air input, air temperature, spinning speed of the engine, coolant's temperature, valves' open width, oxygen concentration in the air vent pipe and other important factors.

EFI system that use computer to control the operation.



ECU

1.2 The restrictions of computer control system

- There are many advantages of the computer control system, but there are some restrictions as well.
- For example, the cost is high, the maintenance is difficult, and the control is complicated.
- Also, it is difficult to withstand adverse environment and
- It needs a large amount of accessory devices.

High cost

- To design and make a computer control system takes a long period of time. The equipment is expensive and hence at the total cost is high.
- For example, when a computer is used to control a cutting machine, a suitable set of control program is needed to control the moving path of the tools, moving speed, spinning speed, feeding rate, change of tools, adding of coolants, etc

Cutting machine

Computer to control the machine's operation, which needs a specific control program.

Mechanical system, whose cost is high.

Difficulties in maintenance

- For example, computers are used in mass production of integrated circuit and electronic circuit board. They need new parts to replace those damaged.
- With the rapid development of computer technology, the newly designed parts may not be used in those old-fashioned electronic circuit boards, and so the maintenance will be more difficult. Such as when newly designed random-access memory (RAM) is produced, the production of the old designed RAM will cease. After some time, when the old designed RAM is damaged, it cannot be replaced.

Intolerance under adverse environment

- The electronic parts of the computer control system cannot work under bad environment, for example, too hot, too cold, humid, dusty, vigorous vibration, etc. So, we should avoid using compute control system under these environments. For example, we should avoid using cooling fan to cool down the computer in dusty place

Requirement of large amount of supporting device

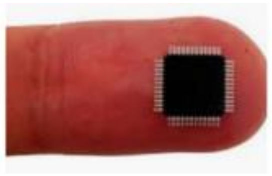
- Computers can manage large amount of data in a short time, but it needs some supporting devices to provide information. That is why a computer control system needs many supporting devices.
- For example, a system is needed to detect the position of the tools and workpieces when a computer is used to control a cutting machine. The system can give feedback to the computer to allow it to control the machine accordingly.

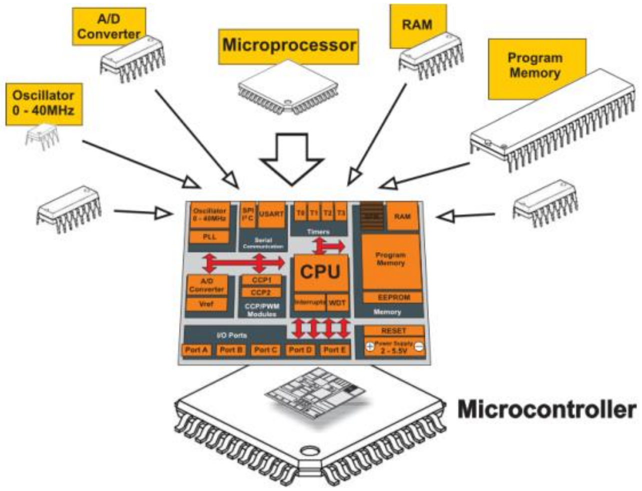
2. Type computer-based controller

- In this section, the types of computer-based controllers are discussed. Nowadays, there are many types of computer using for the control purpose. It can be classified as; The controller using the microcontroller and using the microcomputer.

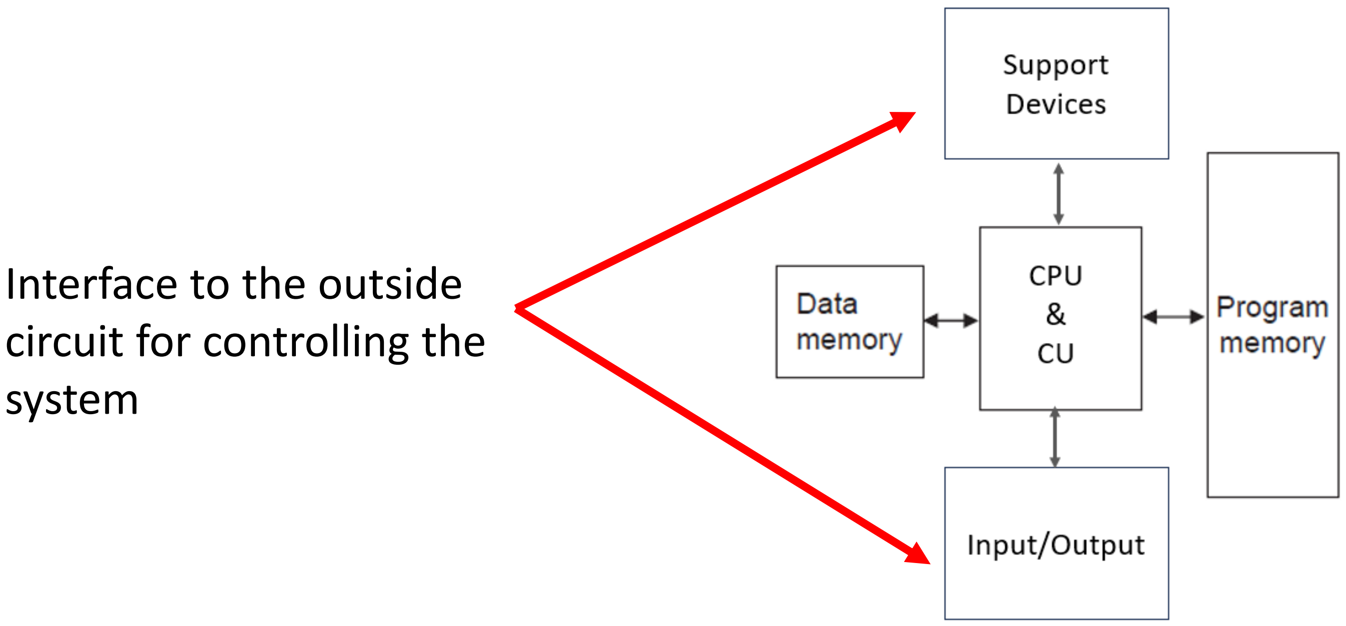
2.1 Microcontroller systems

- A microcontroller is a single-chip computer.
- Micro suggests that the device is small, and controller suggests that it is used in control applications.
- Another term for microcontroller is embedded controller, since most of the microcontrollers are built into (or embedded in) the devices they control.

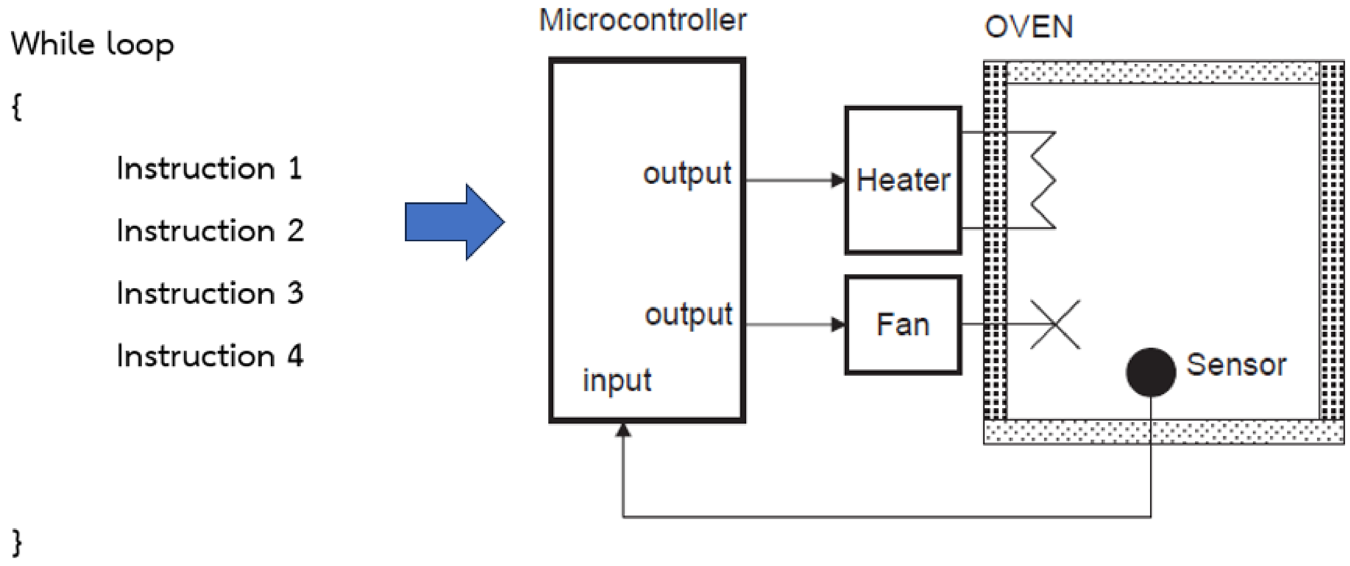




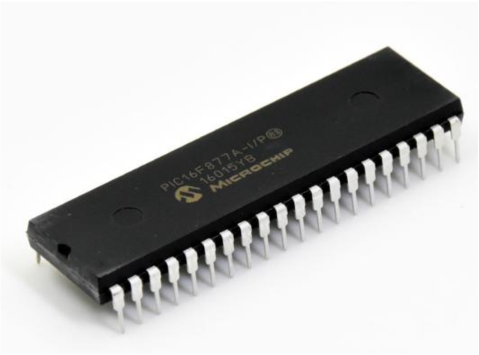
- The simplest microcontroller architecture consists of a microprocessor, memory, support devices, and input-output.
- The microprocessor consists of a central processing unit (CPU) and a control unit (CU).
- The CPU is the brain of the microcontroller; this is where all the arithmetic and logic operations are performed.
- The CU controls the internal operations of the microprocessor and sends signals to other parts of the microcontroller to carry out the required instructions.

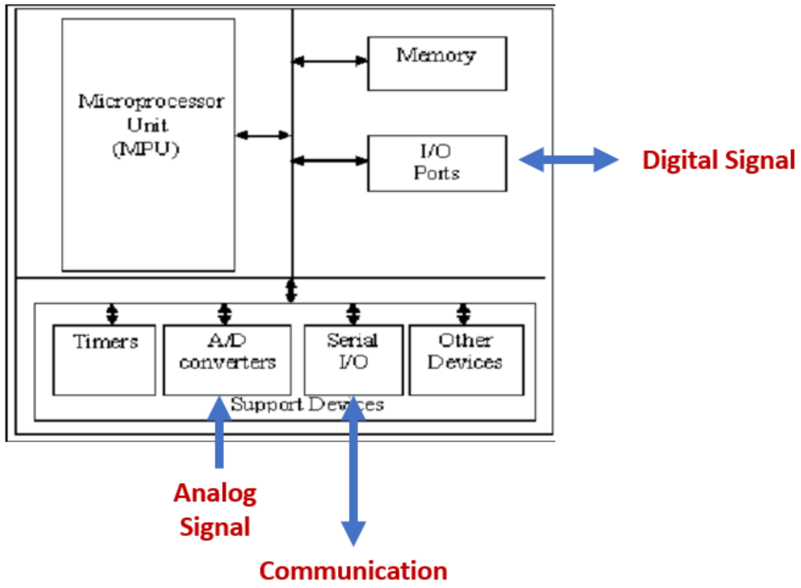


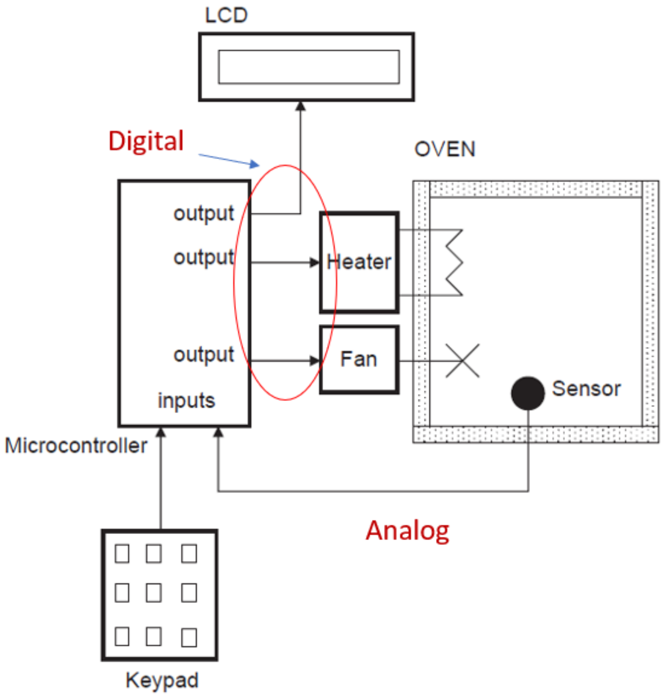
- All microcontrollers operate on a set of instructions (or the program) stored in their memory.
- A microcontroller fetches the instructions from its program memory one by one, decodes these instructions, and then carries out the required operations.

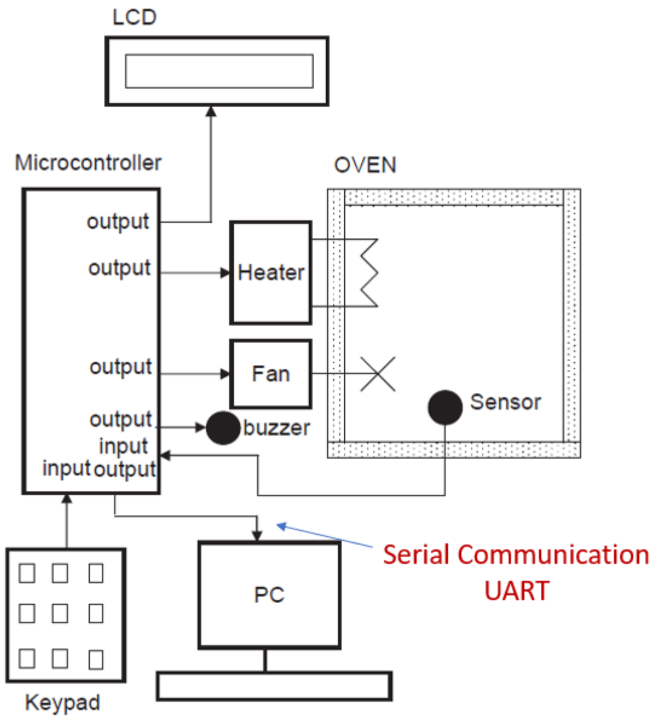


- Microcontroller Interfacing



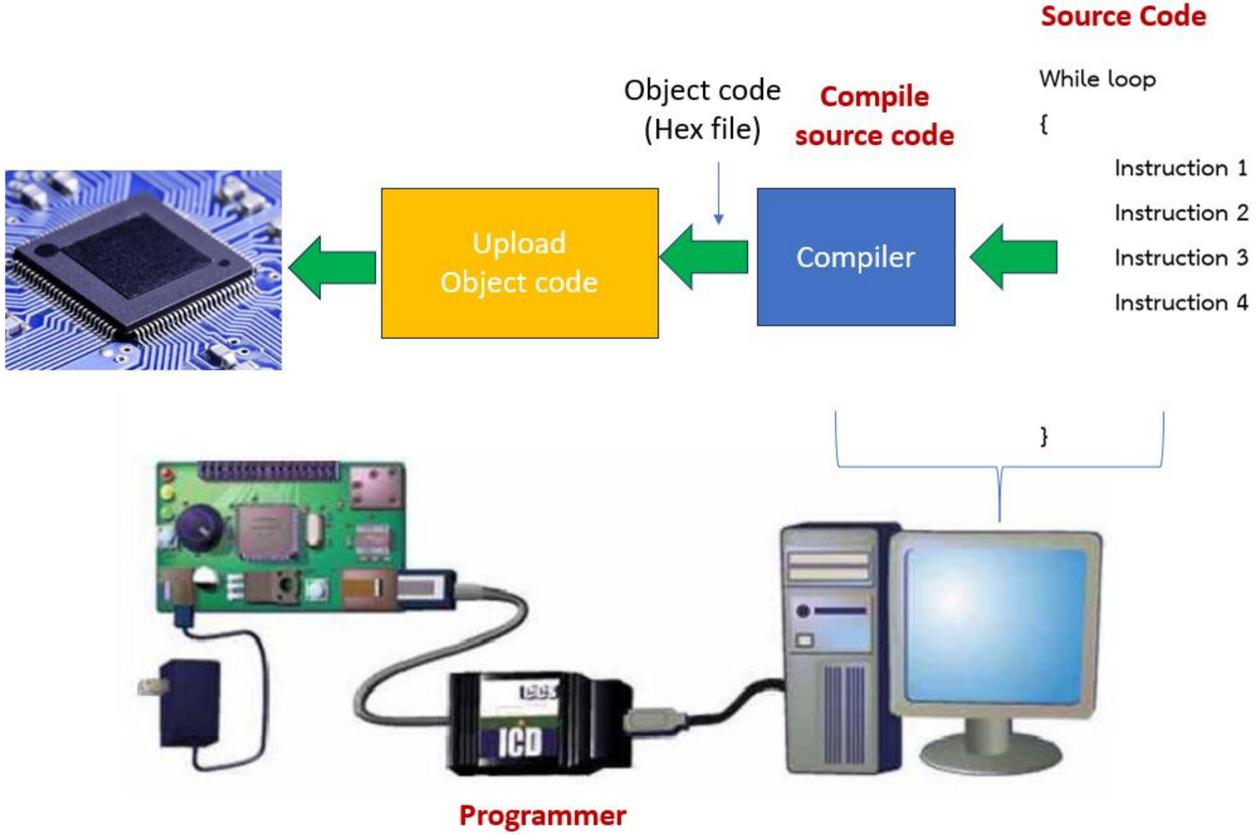




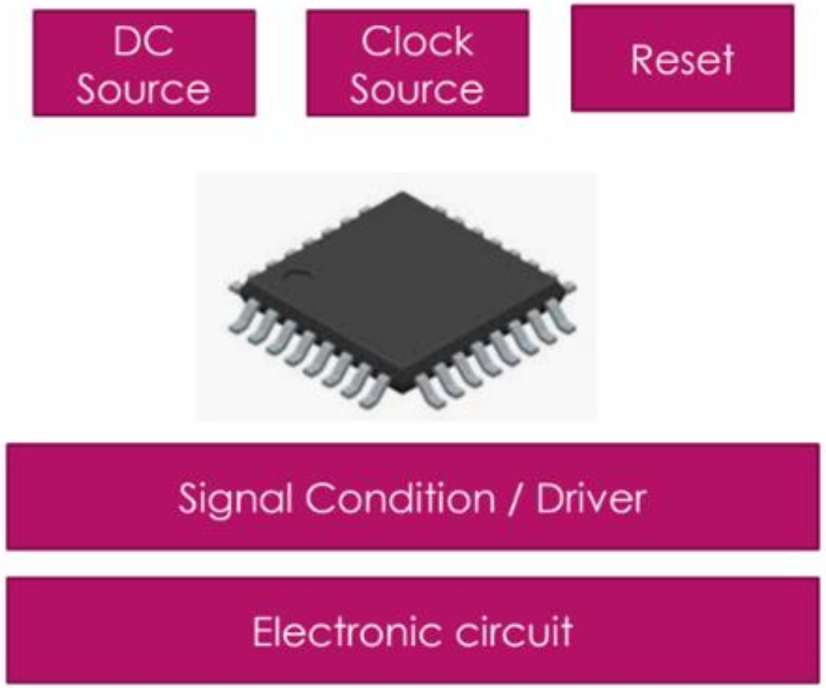


Program control

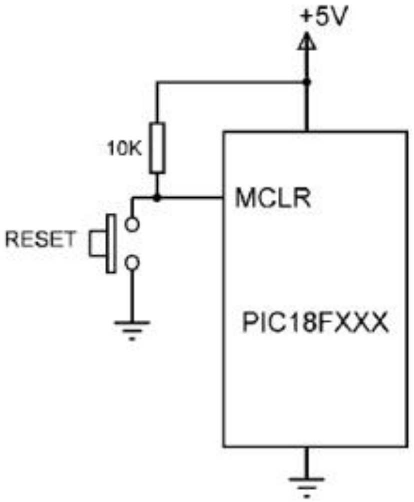
- A microcontroller requires a program to control the system.
- It needs to use a cross-compiler.
- It means that we have to write and compile the source code on a personal computer. Then, upload the object code (Hex file) into the program memory of the microcontroller through the programmer.



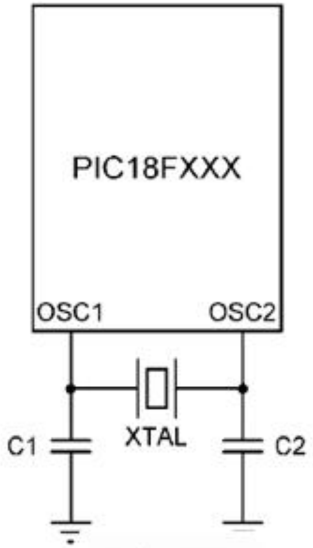
The minimum circuits required for microcontroller



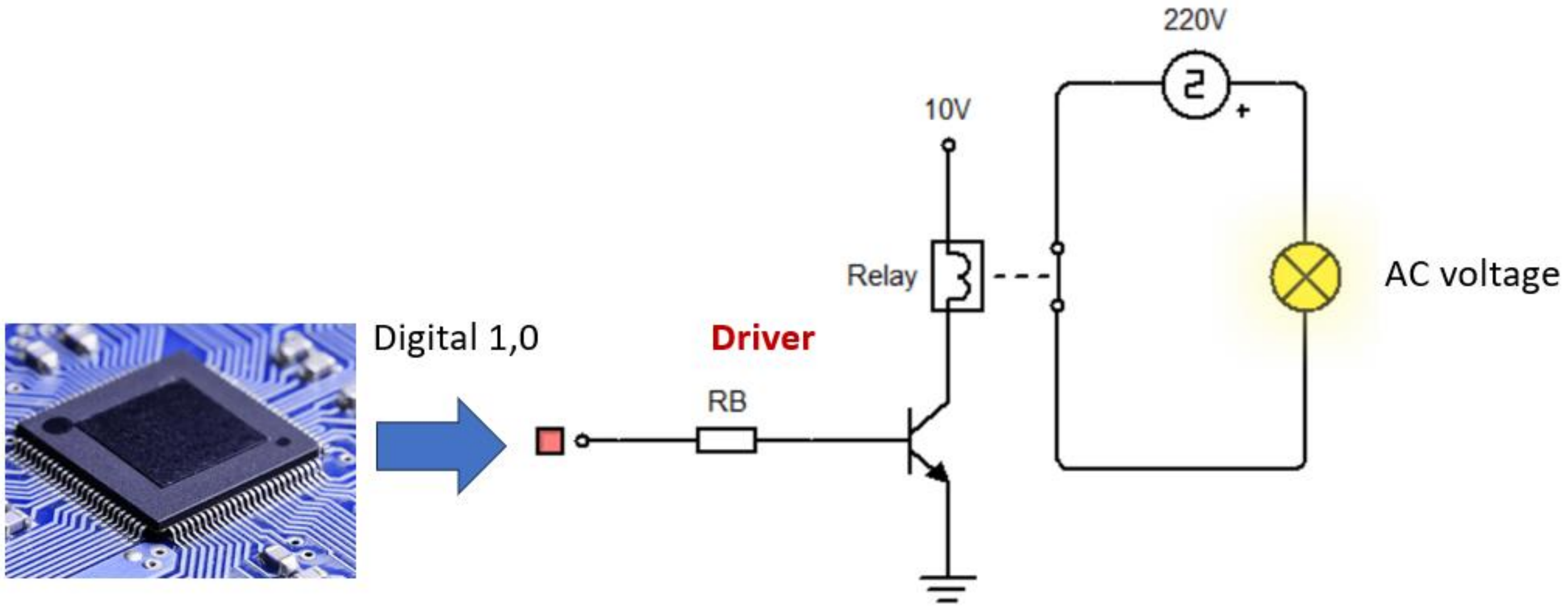
Reset



Clock Source



Crystal

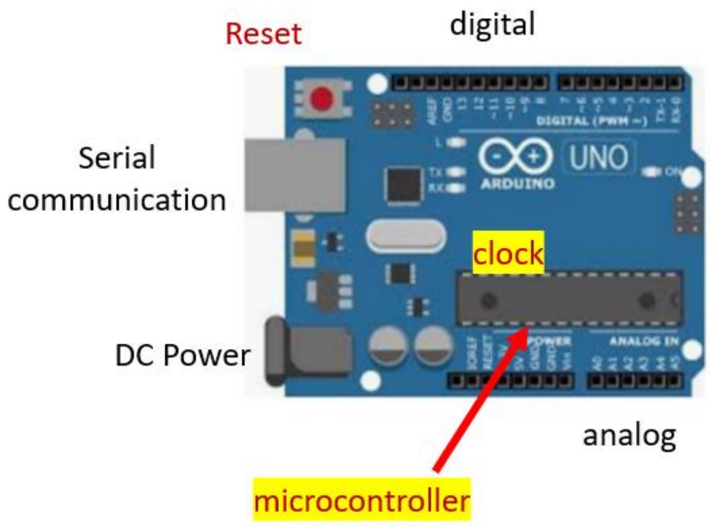

220V
10V
Relay
AC voltage
Digital 1,0
Driver
RB

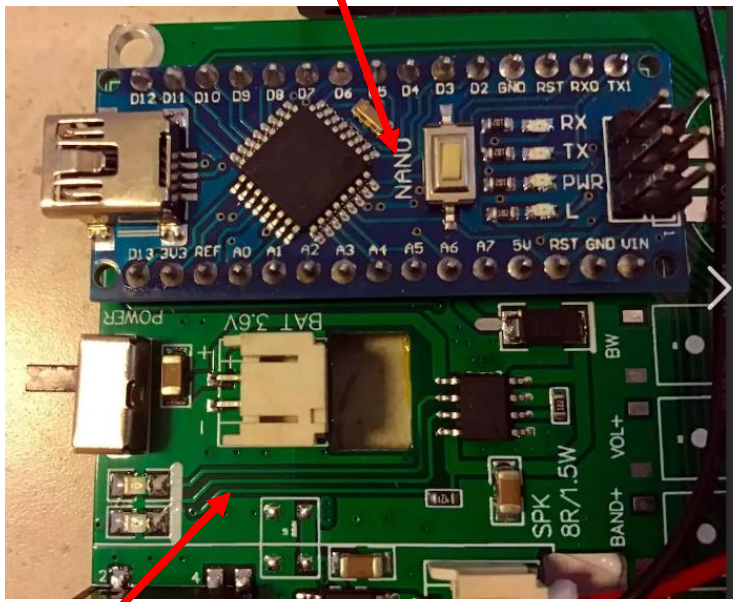

UNO
Arduino
SRD-05VDC-SL-C
Keyes_SRly

Single board microcontroller

- It is a ready to use microcontroller.

Single board microcontroller is embedded on the circuit board to control the functional of the device.

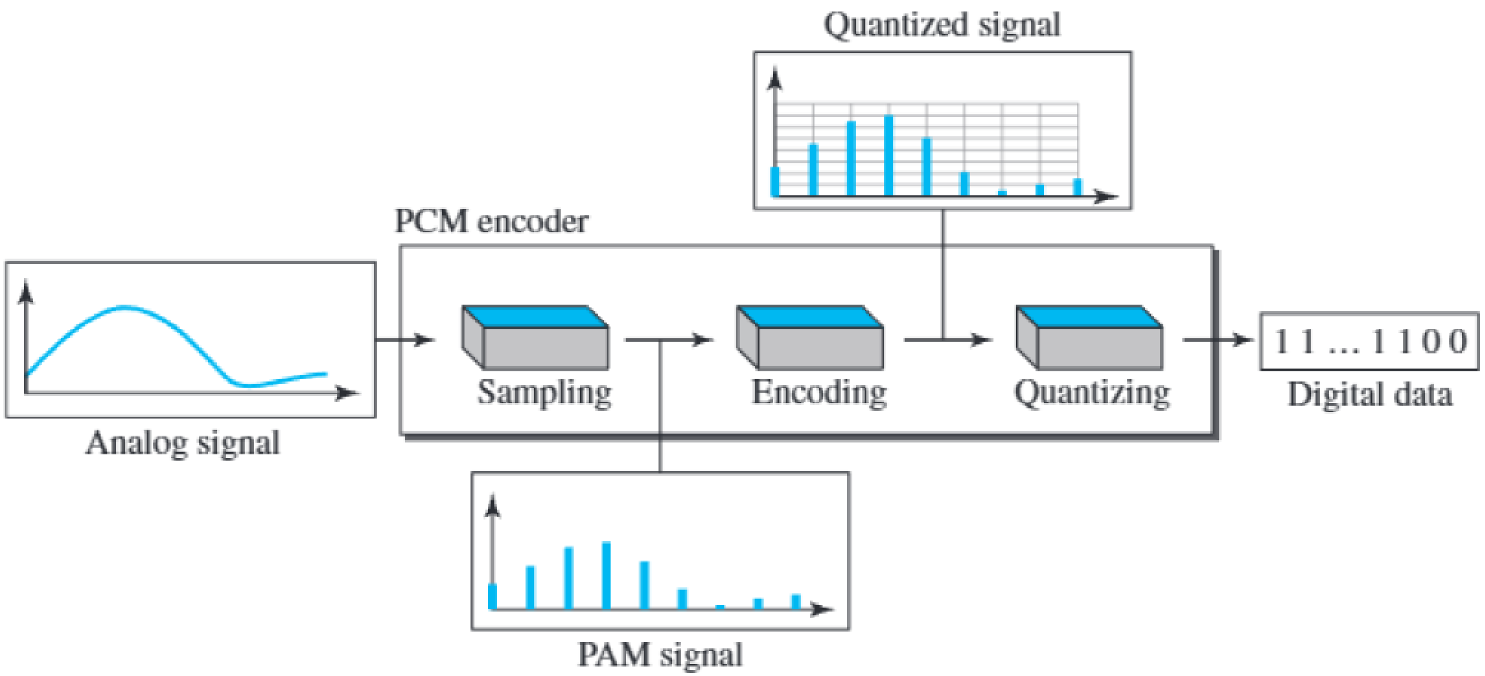




Circuit board of the device, it needs the computer to control the functional.

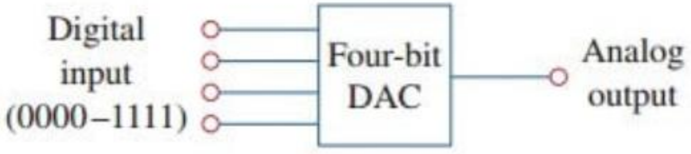
An Analog to digital converter (ADC) module

- Analog-to-digital converter (ADC) is another important peripheral component of a microcontroller. The ADC converts an analog input voltage into a digital number so it can be processed by a microcontroller or any other digital system.
- The process of conversion the analog to digital signal in shown in the Figure.

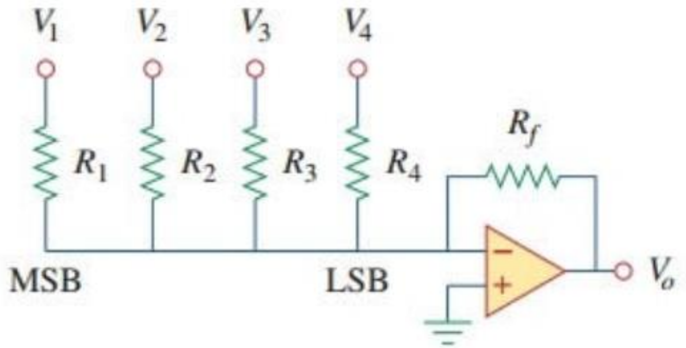


Digital to analog converter (DAC) module

- The output of a digital computer is a digital signal, and this is normally converted into analog form by using a digital-to-analog (DAC) converter.
- The operation of a DAC converter is usually approximated by a zero-order hold transfer function.



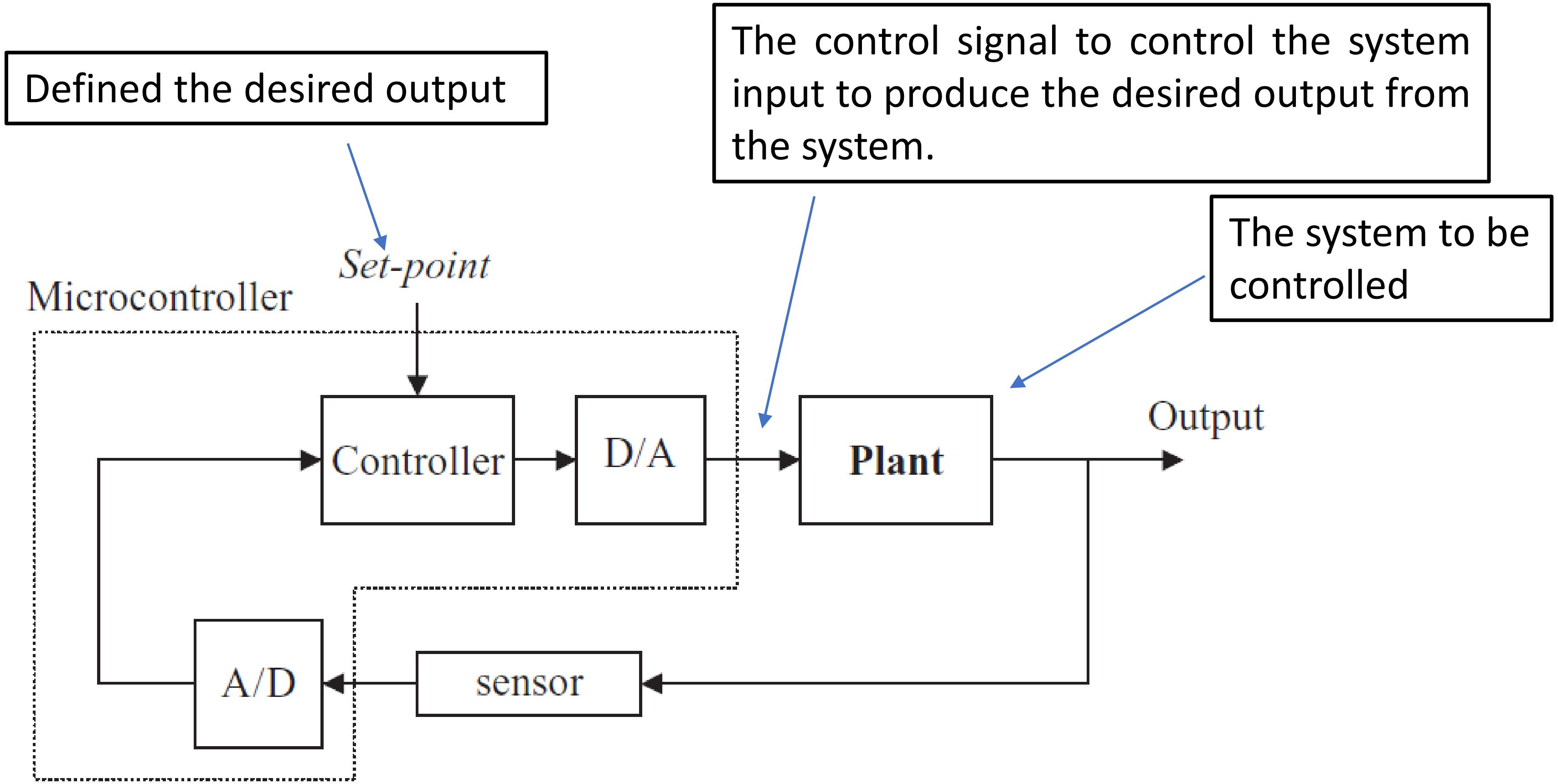
(a)



(b)

Computer Based Feedback Control

The microcontroller in the control loop

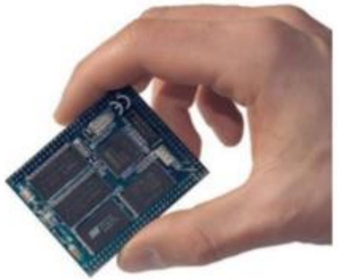


2.2 The microcomputer-based controller

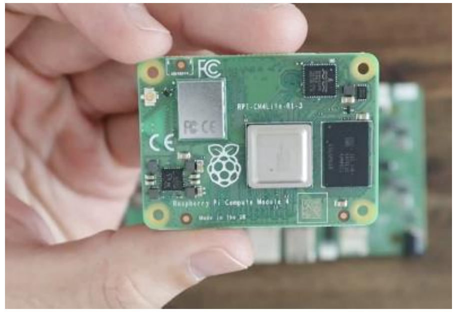
- Single board computers
- General purpose computers

Single board computers

- A single-board computer (SBC) is a complete computer built on a single-circuit board with the microprocessor(s), memory, input/output (I/O), and other features required of a functional computer. It consumes less power than a desktop computer. Also, it provides general-purpose I/O (GPIO) pins for the direct outside electronic circuit connection that the desktop computer lacks.



Micro2440 SBC from Friendly Elec



CM4 Raspberry Pi

Raspberry Pi

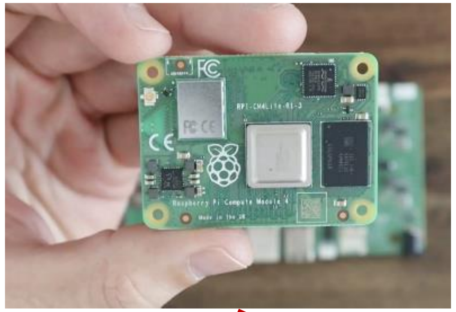
I/O board for single board computer

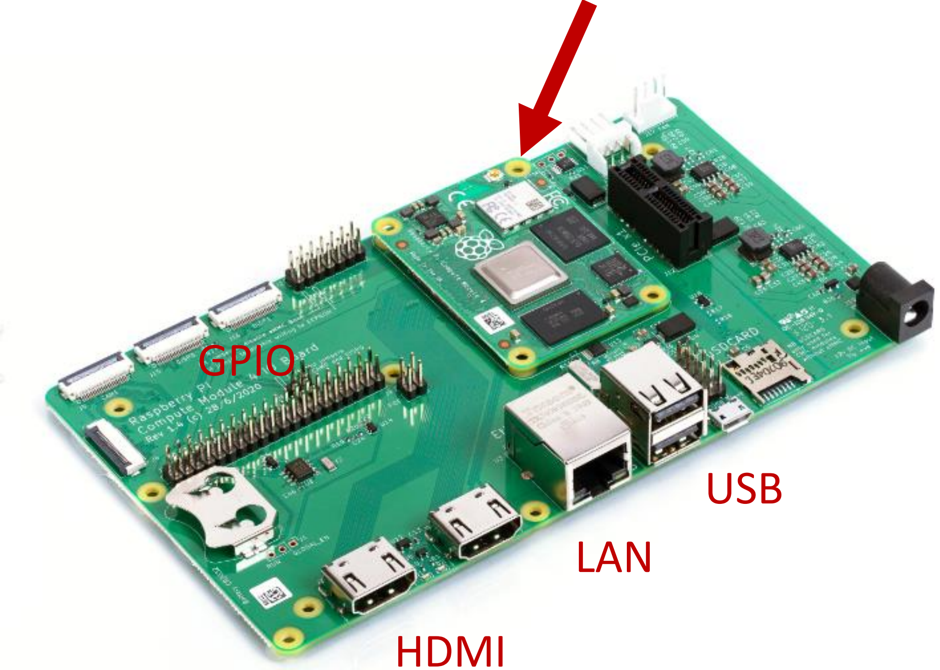
RS232

RS232

LAN

GPIO





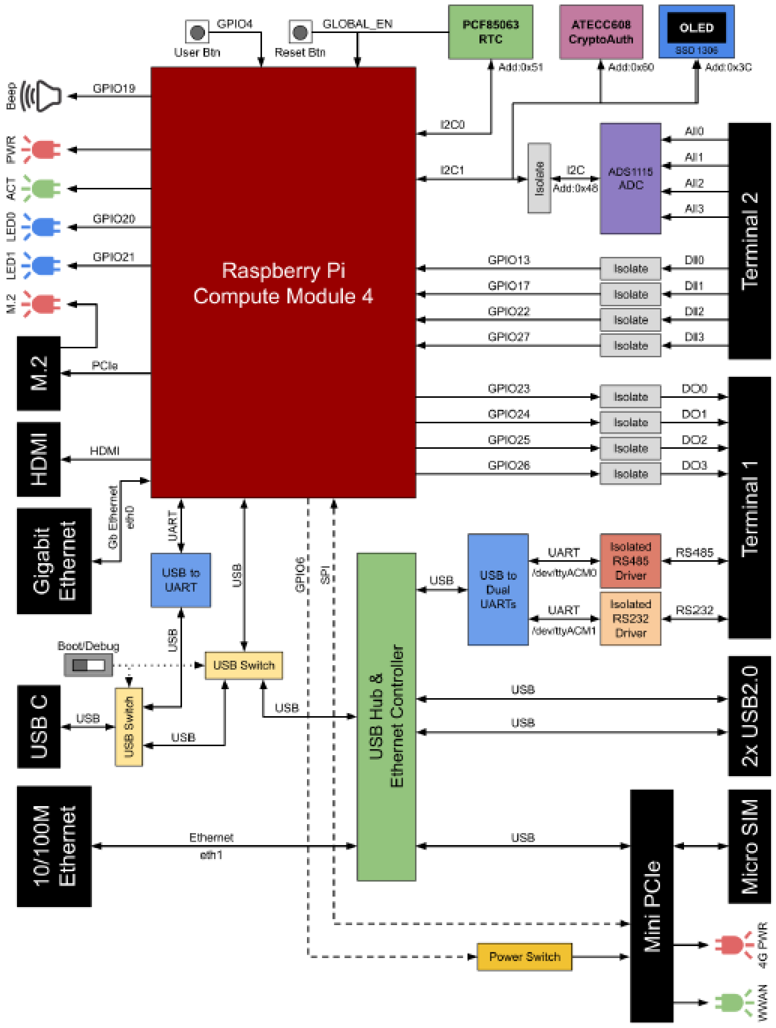
GPIO

USB

LAN

HDMI

- Example of SBC for industrial control application (IRIV PiControl)
- User can connect the sensor and actuator to the board directly.
- The CM4 raspberry Pi is used as its processor board.



GPIO

Operating System

Raspbian

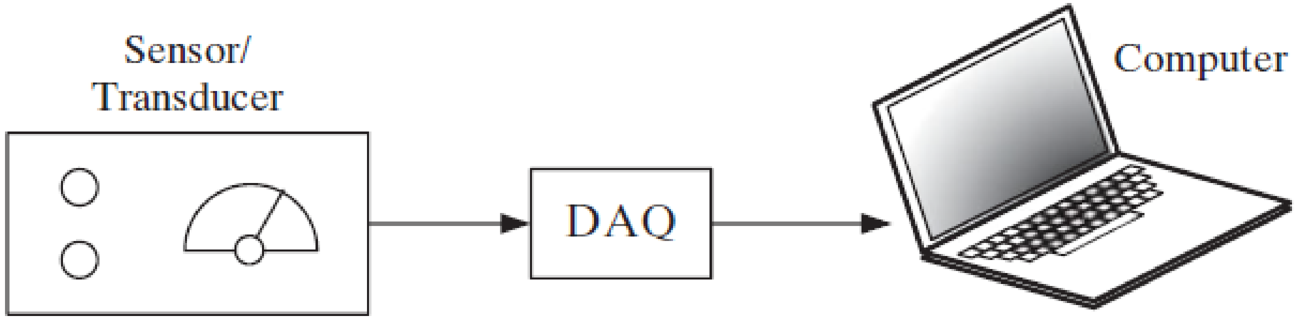
Linux
EMBEDDED

android

Microsoft
Windows CE

General purpose computers

- Besides using the single-board computer for control purposes, the general-purpose computer might be used. However, it requires the DAQ device for interfacing the outside electronic circuits.

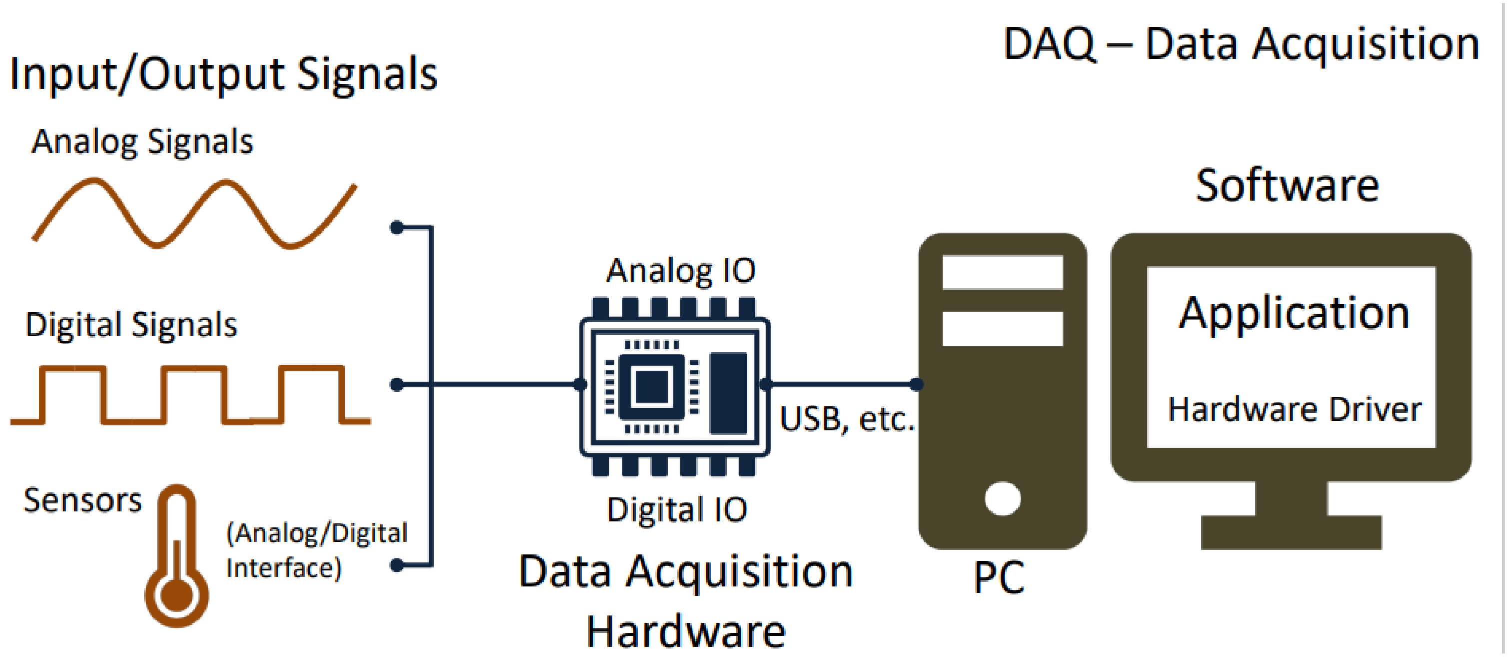


Connect to the USB port of the computer

GPIO I/O for connecting to the sensor or actuator

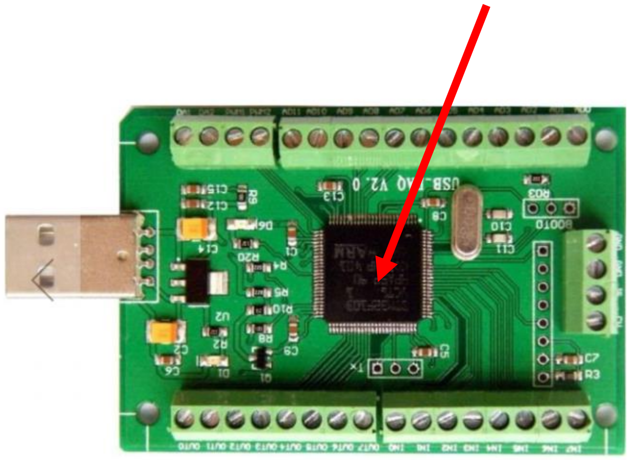
DAQ-Data acquisition

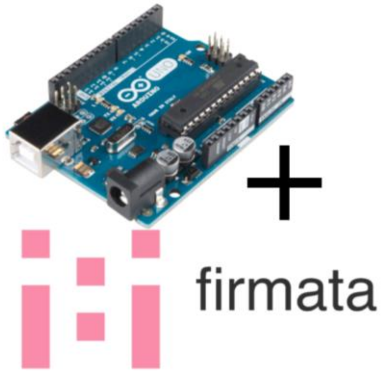
- A DAQ device is a piece of hardware that connects sensors and signal conditioning circuitry to a computer, and converts analog signals into digital values that can be processed by software

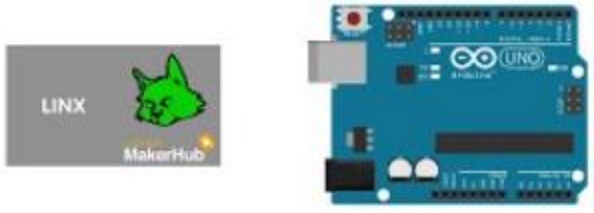


- A simple DAQ device may be constructed using a microcontroller like the Arduino.
- It needs a DAQ firmware, which is a tiny program that makes microcontrollers perform as DAQs.
- There are many free firmwares that can be downloaded from the internet, i.e., Firmata and LINX.

Single Chip Computer
(Microcontroller)





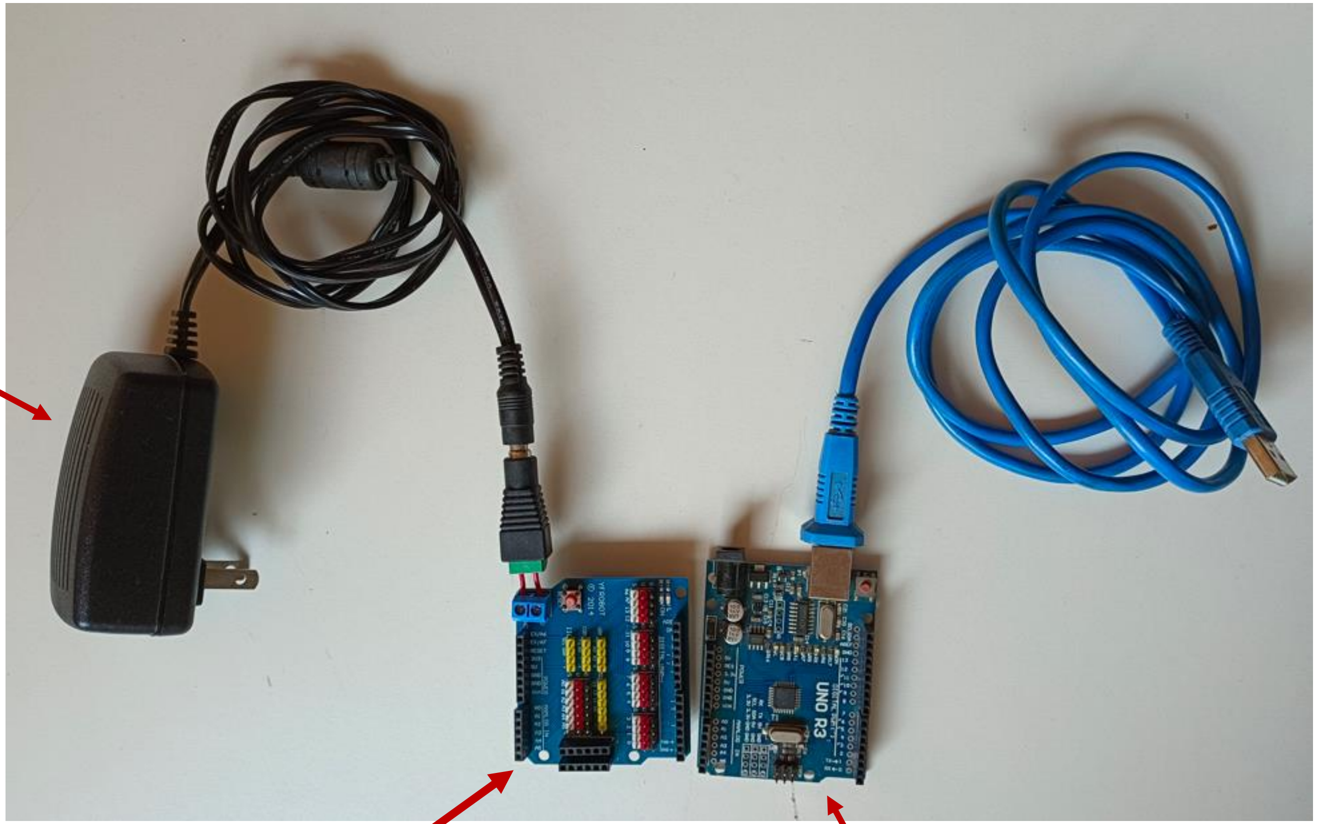


3. LabVIEW

- LabVIEW is a graphical programming environment for applications that require testing, measurement, and control with rapid access to hardware and data insights. It was developed by National Instruments Corporation and has been used in various engineering fields and industries.
- This course, the program for the controller is written using the G language of LabVIEW. The basics of G language programming is given in the following link:
- Basics of LabVIEW Programming Environment Tutorial (youtube.com).

- Also, the DAQ used here is based on Arduino UNO and Linx firmware. The steps of uploading a Linx firmware to the UNO board and the useful tutorial for beginner is shown in the below link.
- Introduction to LabVIEW LINX and Arduino (youtube.com)

Adaptor 5V, for powering the sensor/actuator

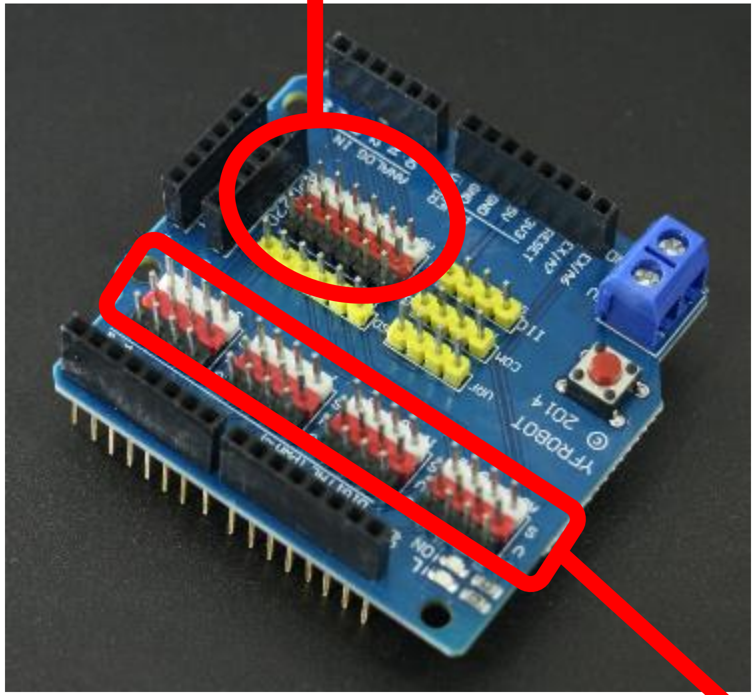


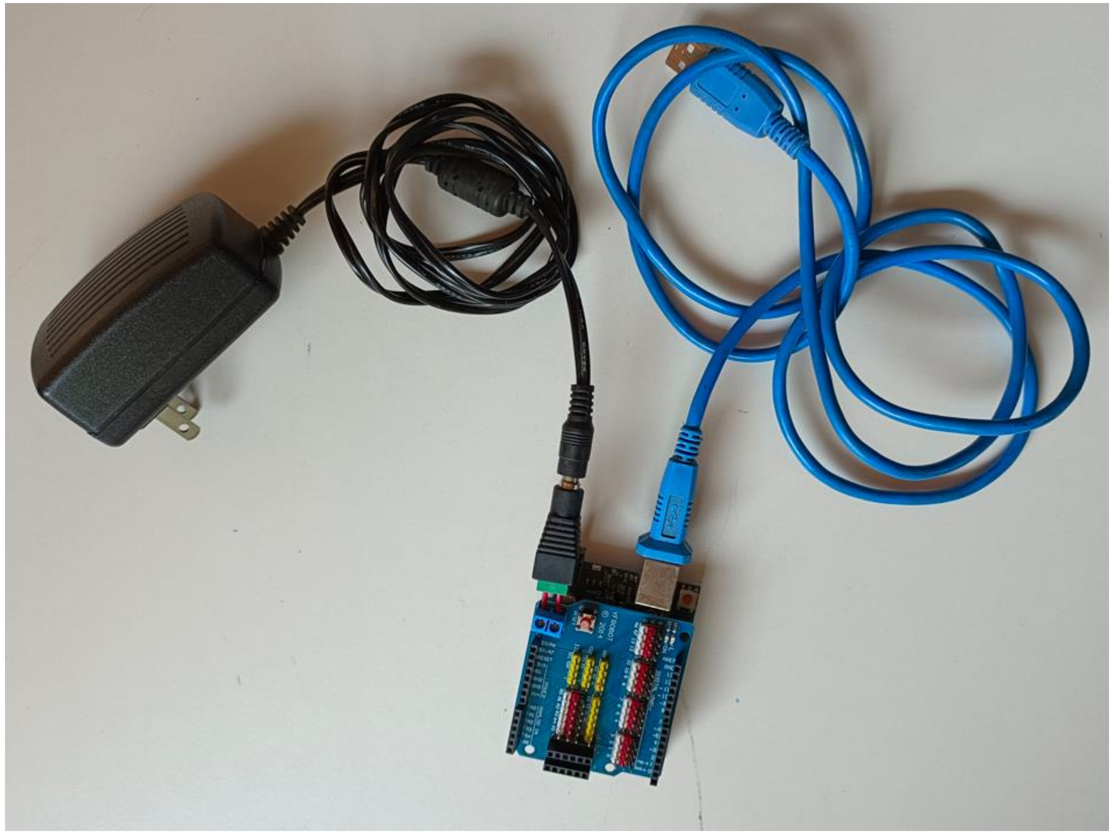
YFROBOT sensor shield

DAQ: Arduino UNO +LINX

The QAD Pinout

- Analog input (0-5V)

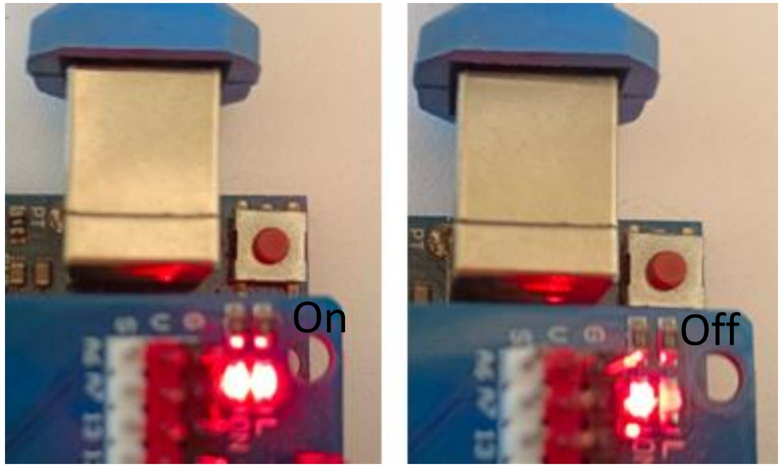


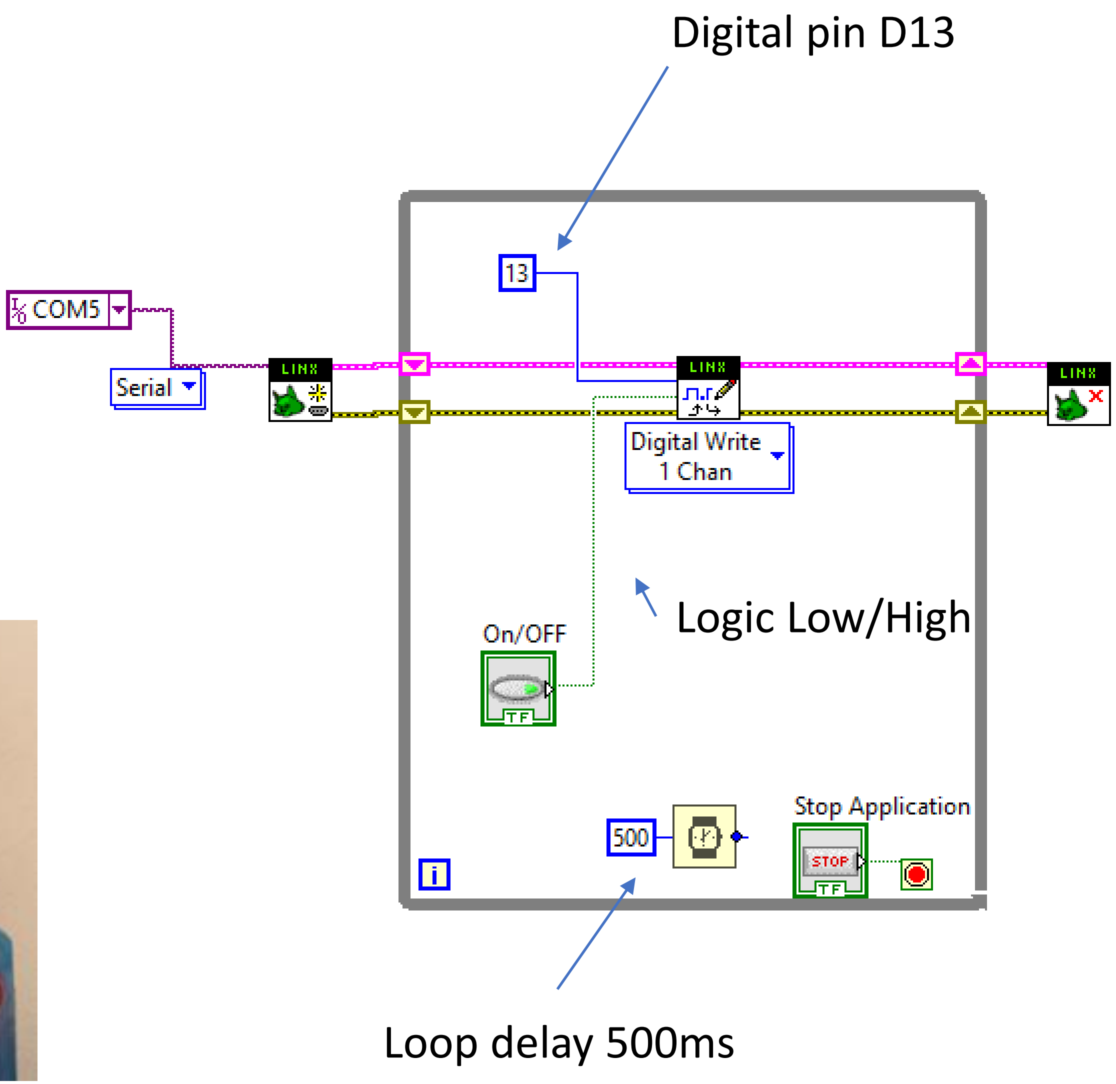


- Digital I/O (Low =0V, High=5V)
- PWM (Analogy to analog output 0 -5 V)

Digital Output

- On/Off an LED connected to digital pin D13





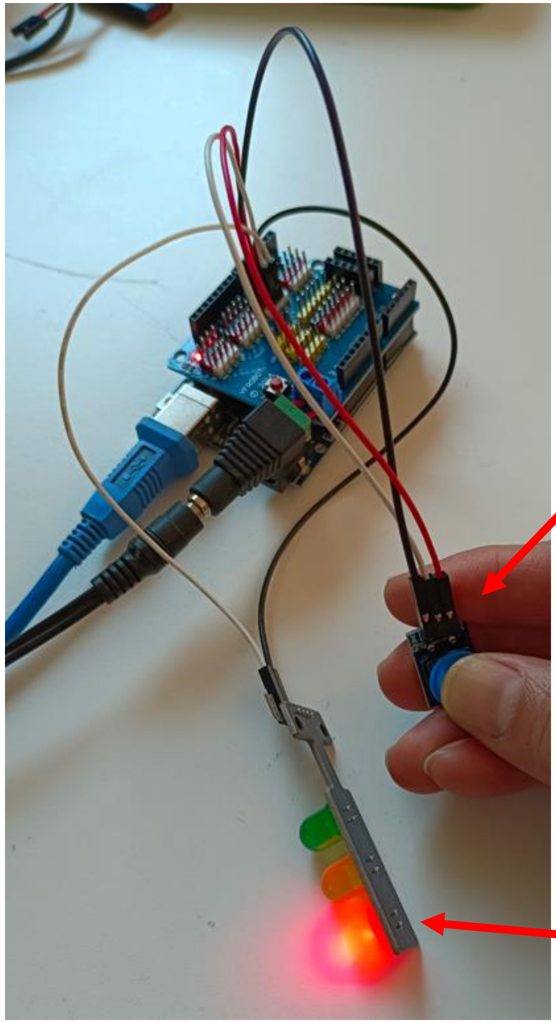
Digital input

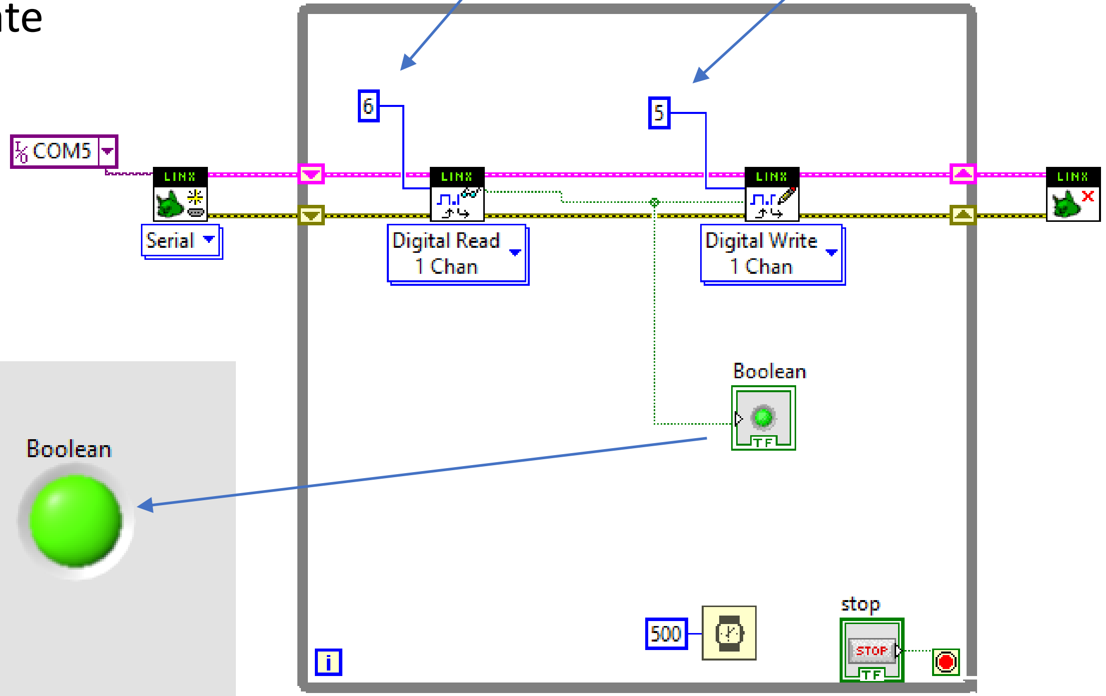
- Read digital signal from pin D6 then show its value through LED connected to pin D5.

Digital pin D5 (output)

Digital pin D6 (input)

Use a switch with pullup resistor connected to pin D6 to generate the digital signal

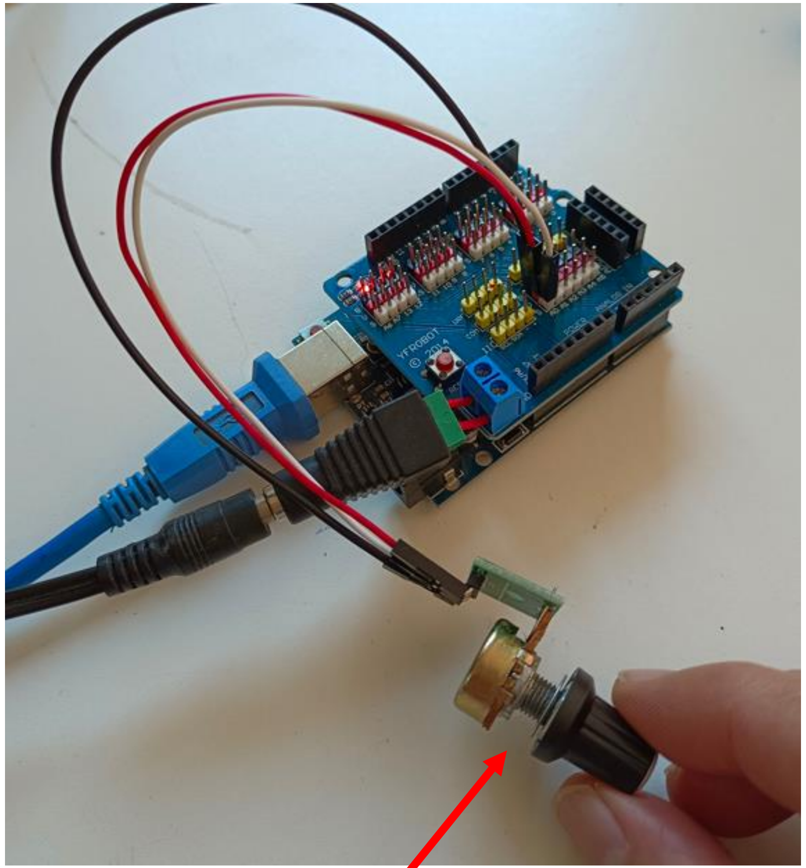


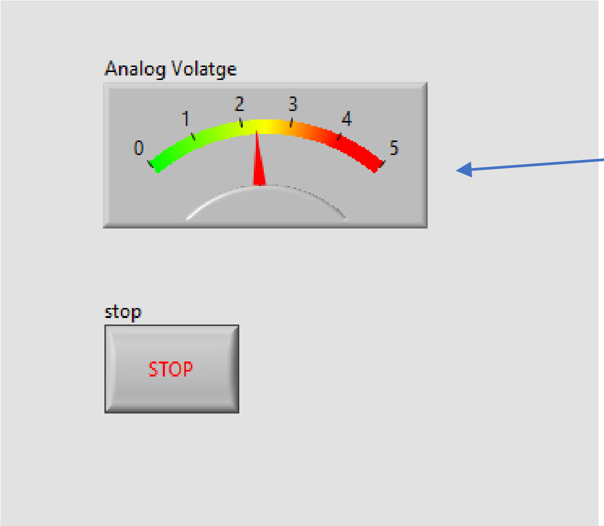


LED connected to pin D5

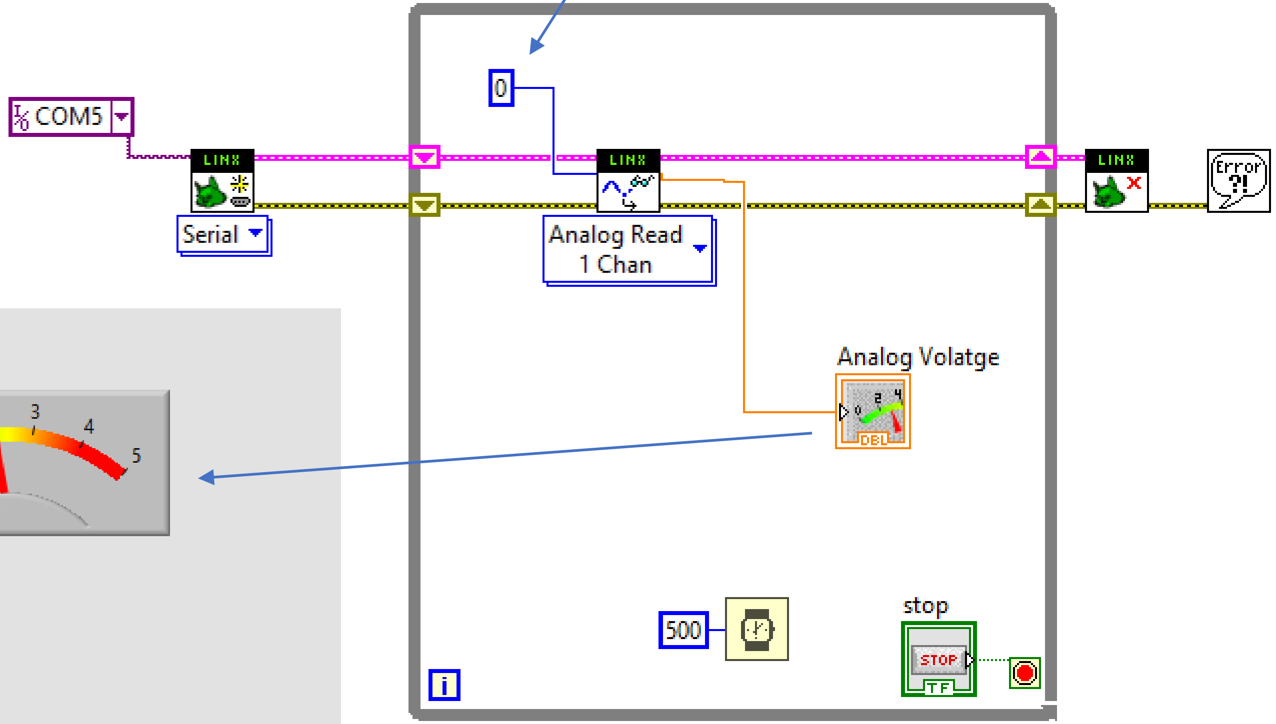
Analog input

- Read the analog signal between 0 and 5 V from pin A0. Then show its value with an analog meter.





Analog pinA0

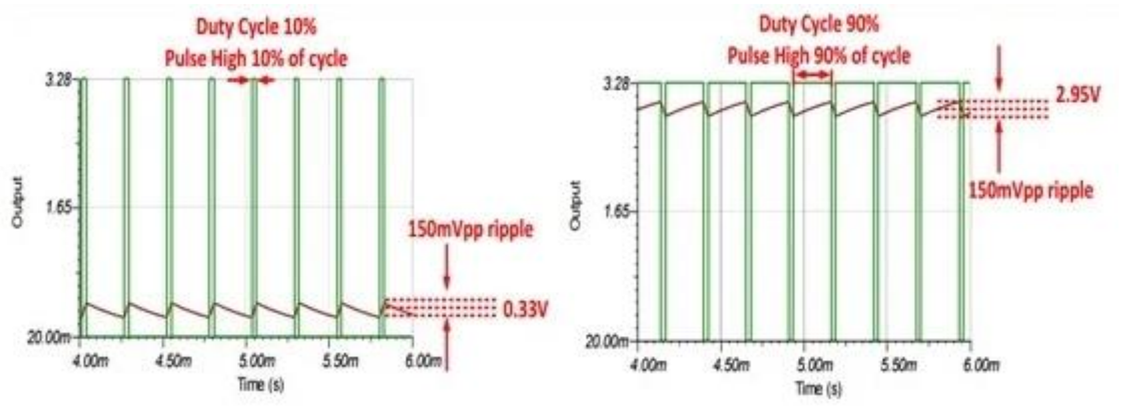


Use POT to generate an analog signal between 0 and 5 volts at pin A0.

PWM

- PWM stands for pulse width modulation. It refers to variations in the pulse width.
- The microcontrollers support PWM outputs. The digital pulses are available as output at some of the digital pins (Note for Arduino Uno, following pins are to be used 3,5,6,9,10,11).
- The different pulse widths will provide different DC voltages (average), which is analogous to the DAC.
- Following equation mentions relationship between average output voltage and duty cycle. The term duty cycle refers to ratio of amount of ON time and period of the pulse train. It is specified in percentage. Hence 10% refers to 10/100 and 90% refers to 90/100 in decimal format.

Average DC voltage output = Voltage to represent High State x Duty Cycle



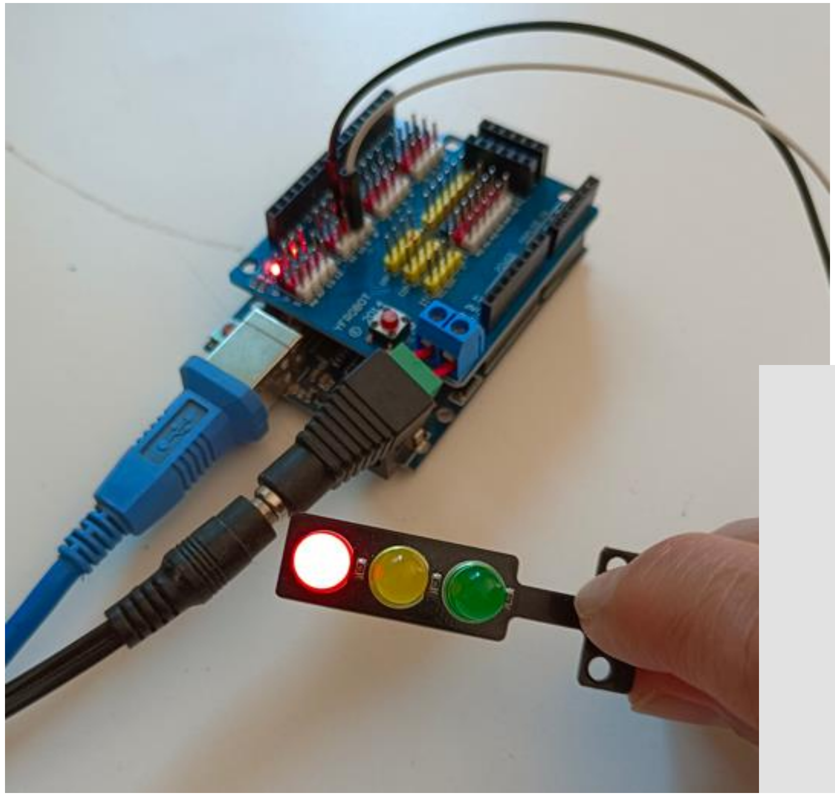
Example:

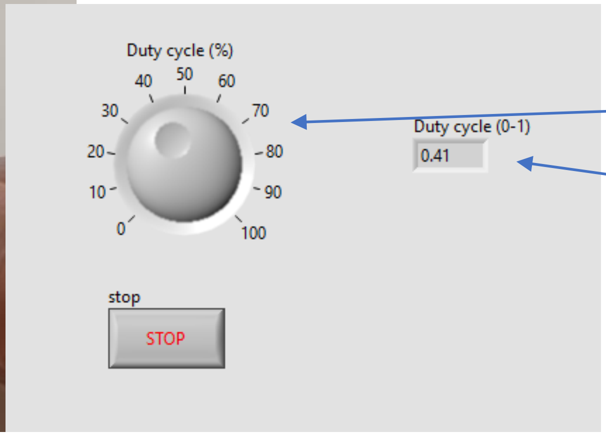
For 3.28V and 10% duty cycle, Output = 0.328

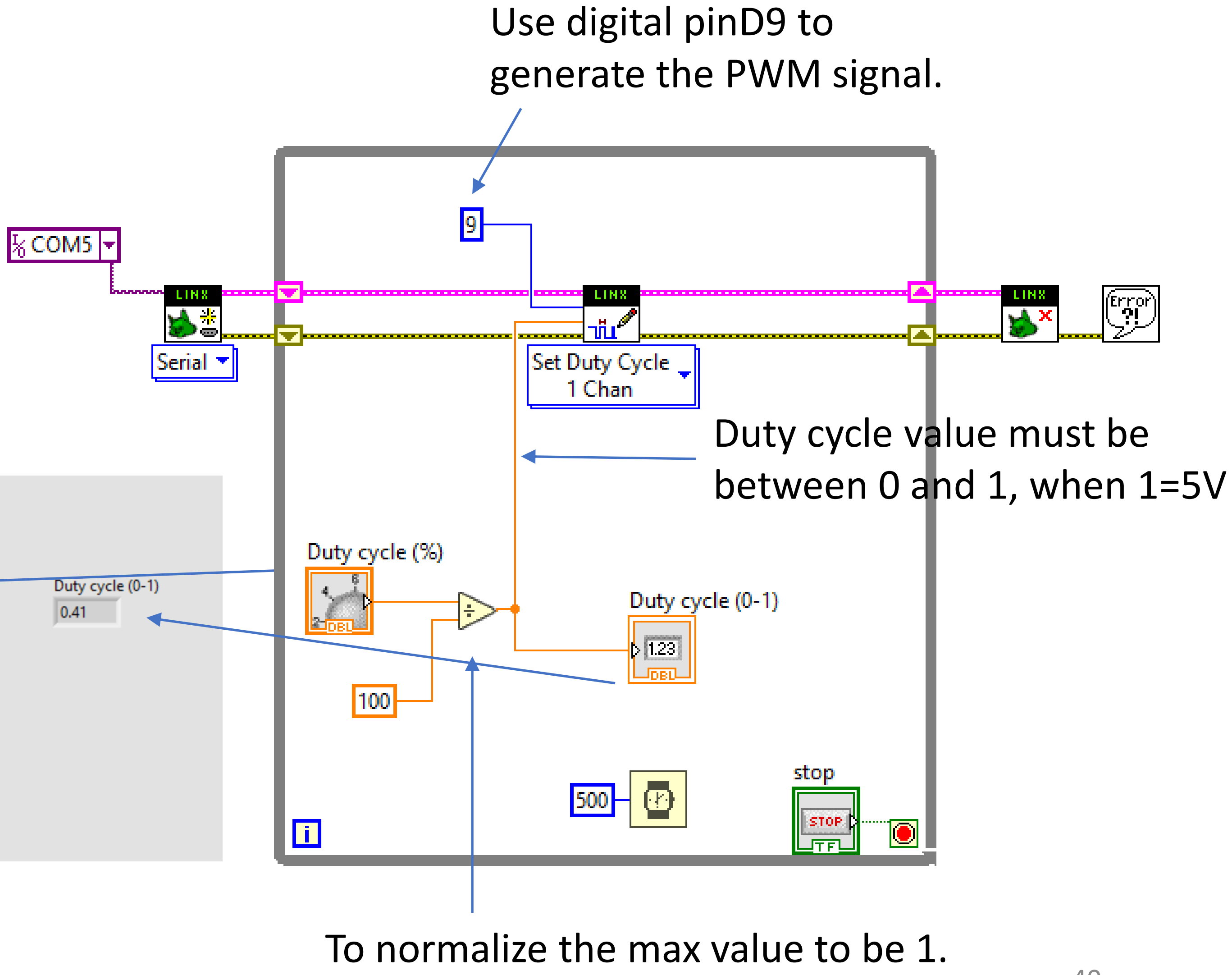
For 3.28V and 90% duty cycle, output = 2.952

Analog output (PWM)

- To demonstrate controlling the brightness of an LED through the PWM signal.



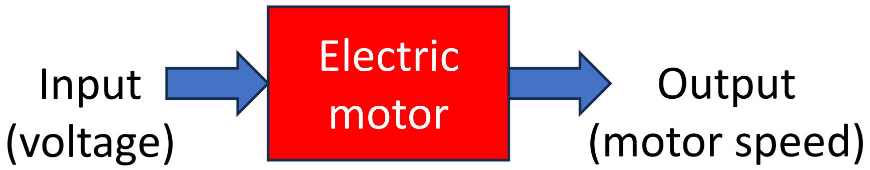




Tuning of computer-based controllers

1. System and Control system

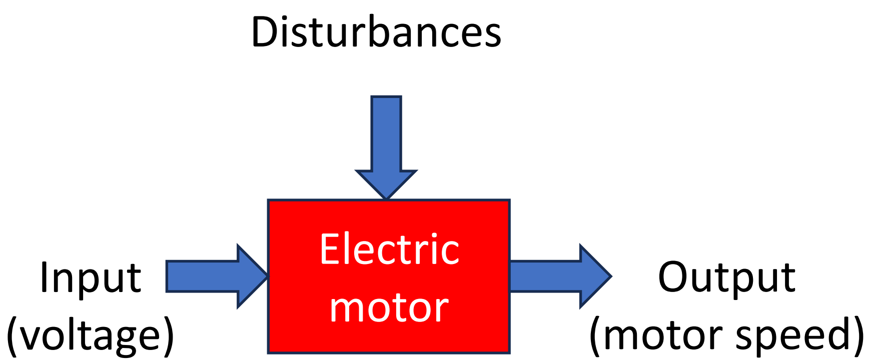
- System can be thought of a black box which has an input and output.
- It is a control system if the output of the system is controlled to be at some specific value or to change in some prescribed way as determined by the input to the system.



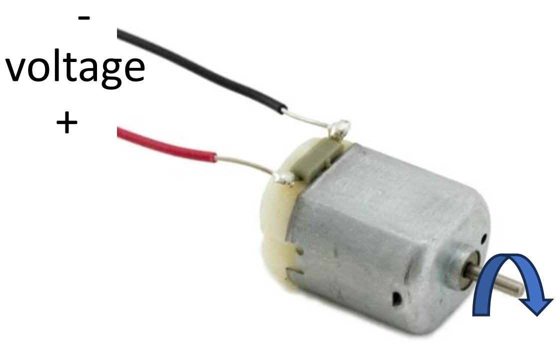
Motor speed can be controlled
by the voltage at the input

2. Feedback control system

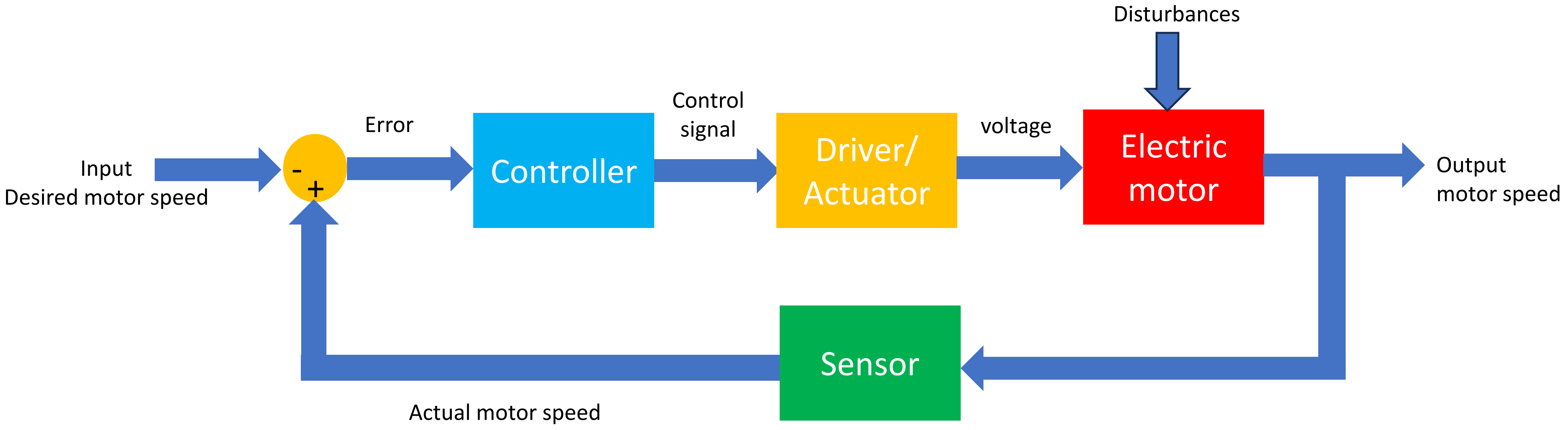
- A control system in the Figure is an open-loop control system, which it is not attractive.
- In an open-loop control system there is no knowledge of the system output. The motor is expected to rotate when a voltage is applied across its terminals, but we do not know by how much it rotates since there 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 system may also have disturbances affecting its behavior, which there is no way to know, or to minimize these disturbances



Open-loop control system

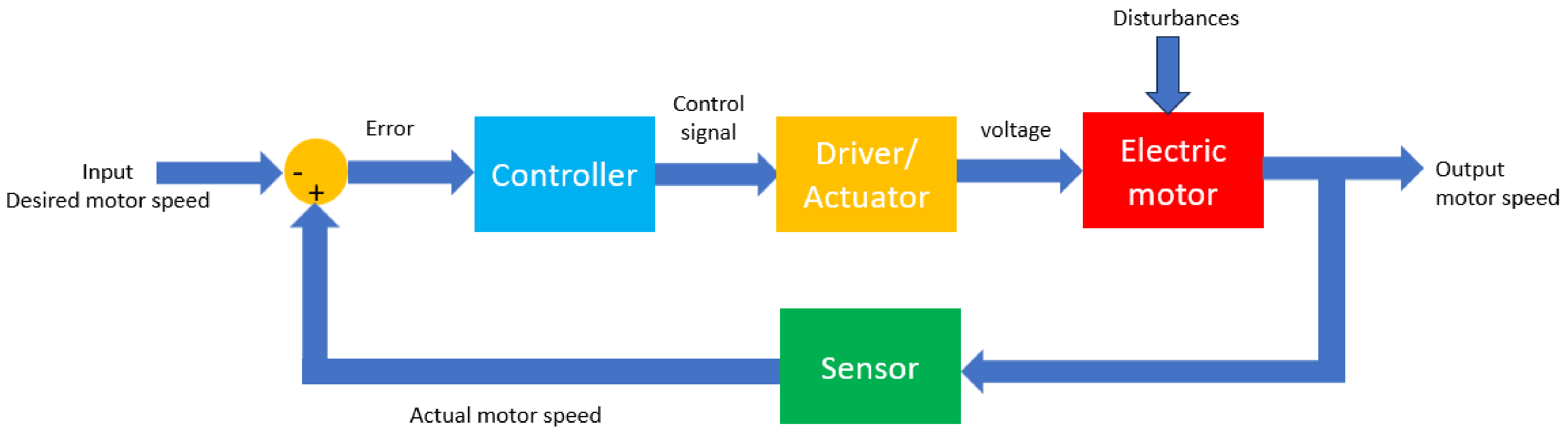


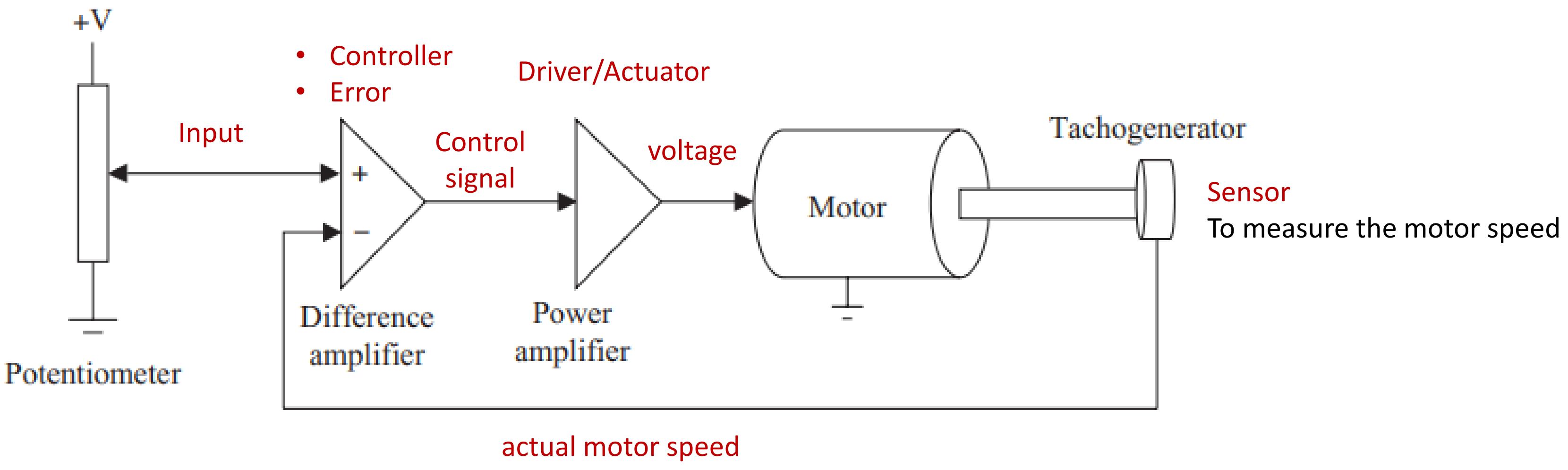
- There is a better way to control the system as depicted in the Figure, and this is by using a sensor to measure the output and then comparing this output with what we would like to see at the system output.
- The difference between the desired output value and the actual output value is called the error signal. The error signal is used to force the system output to a point such that the desired output value and the actual output value are equal. This is termed closed-loop control, or feedback control.
- A controller is employed to read the error signal and drive the system through the driver in such a way that the error tends to zero.



Feedback control system

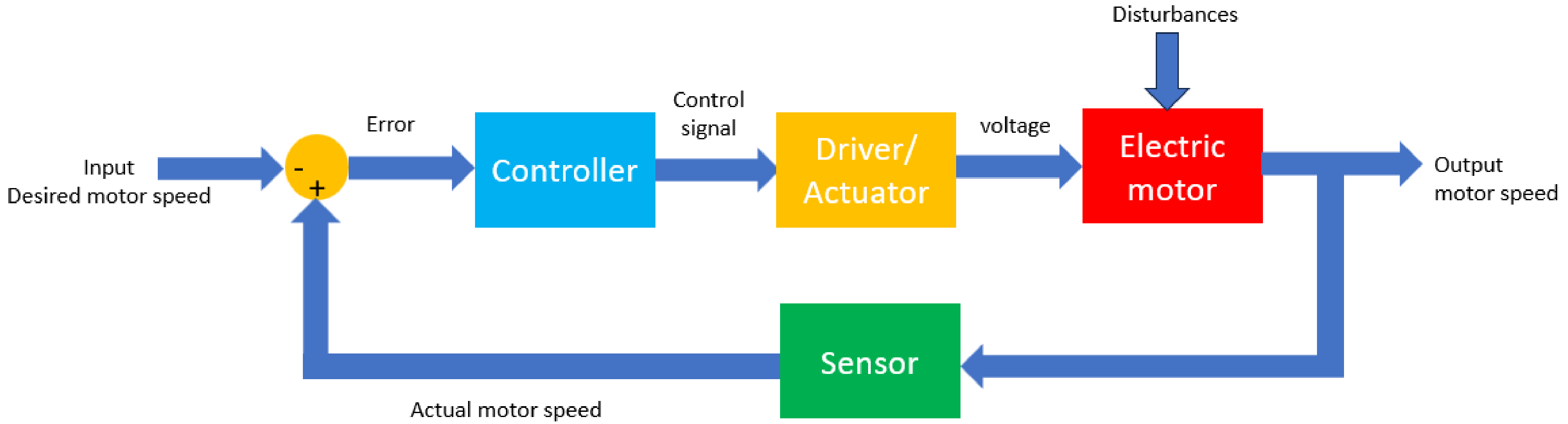
Feedback control in practice

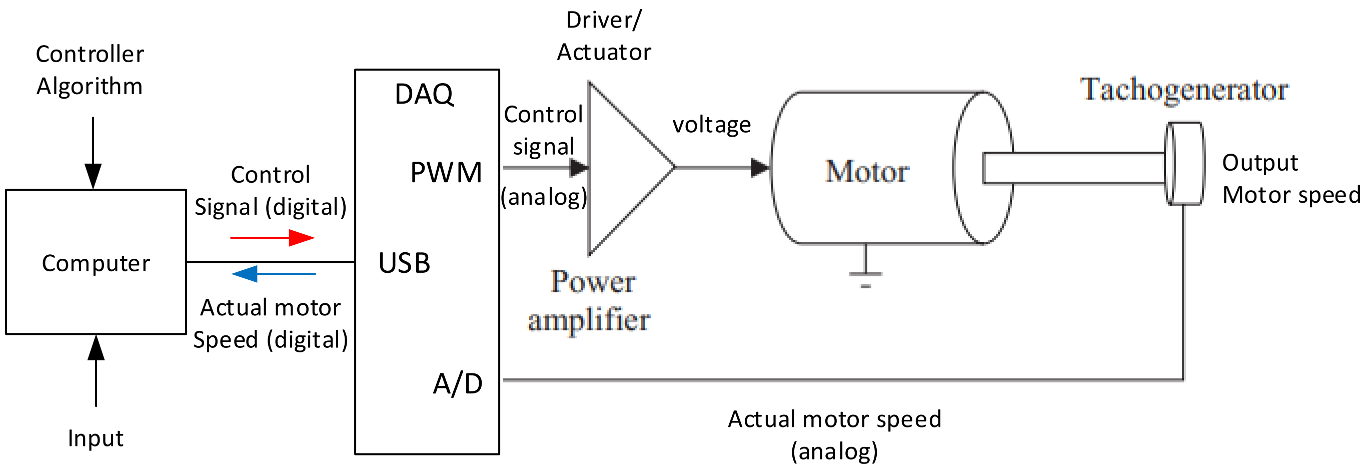




Analog feedback control

2. Digital controller





Digital feedback control

3. The controller algorithm

- The controller algorithm in a computer is implemented as a program which runs continuously in a loop.
- 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 or PWM which generates an analog equivalent of the desired control action. This signal is then fed to an actuator which in turn drives the system to the desired point.

Repeat Forever

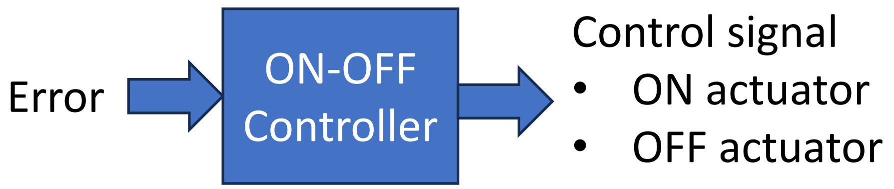
When it is time for next sampling instant

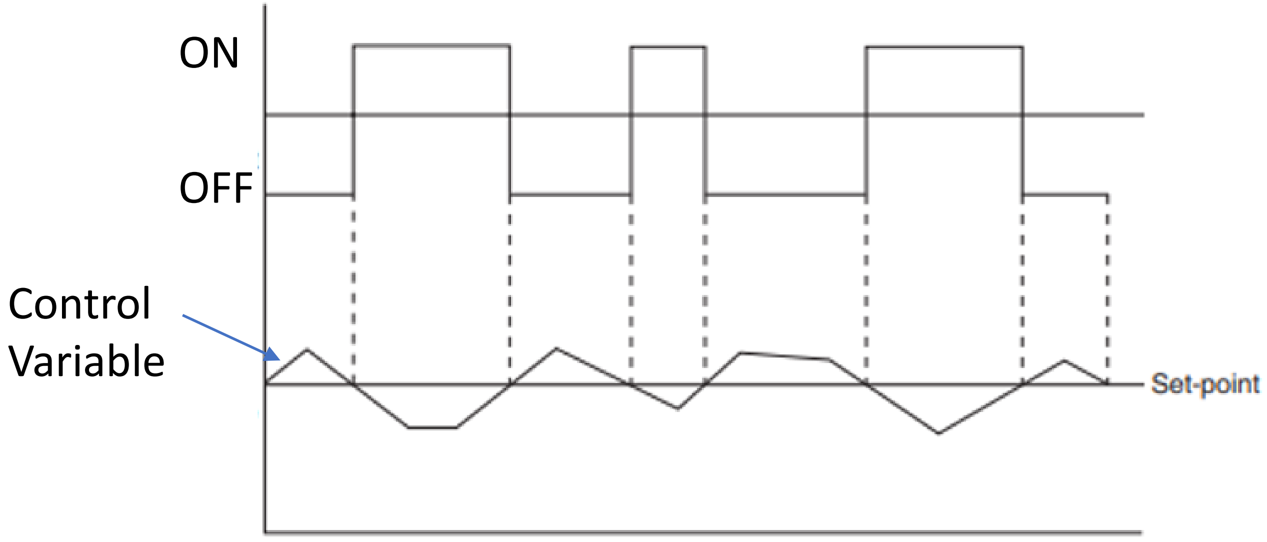
- Read the desired value, R
- Read the actual plant output, Y
- Calculate the error signal, $E = R - Y$
- Calculate the controller output, U
- Send the controller output to D/A converter
- Wait for the next sampling instant

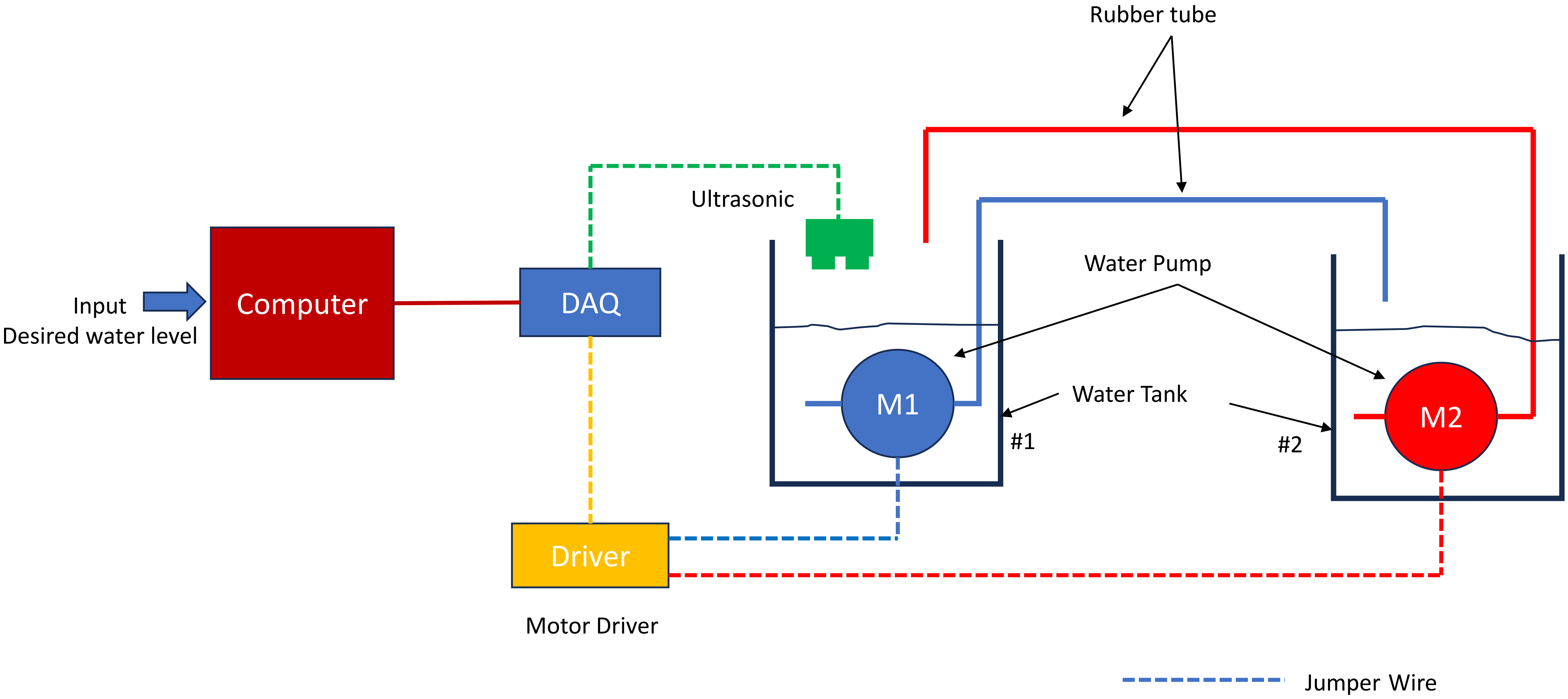
End

ON-OFF controller

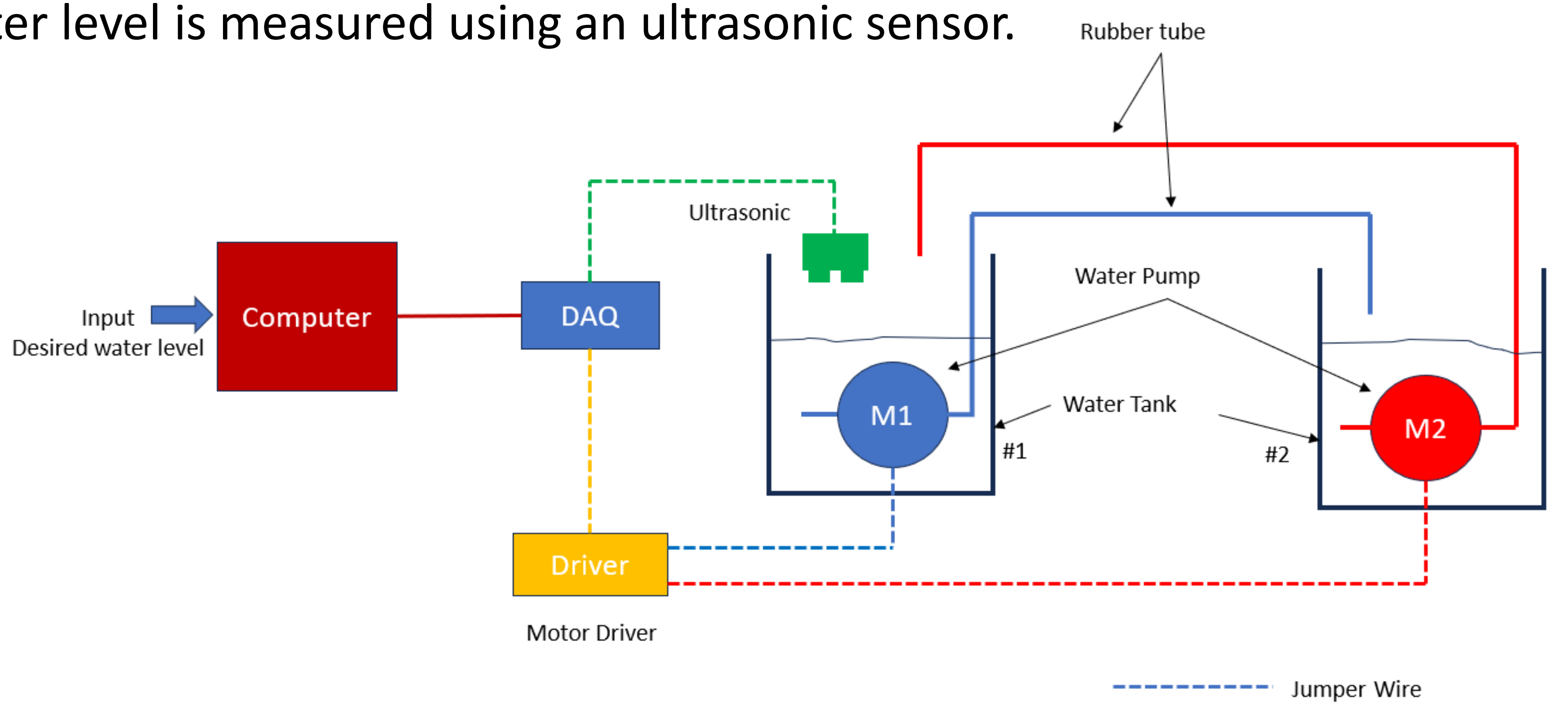
- It is the simplest digital controller.
- This is used when the control variables need not be maintained at precise values.

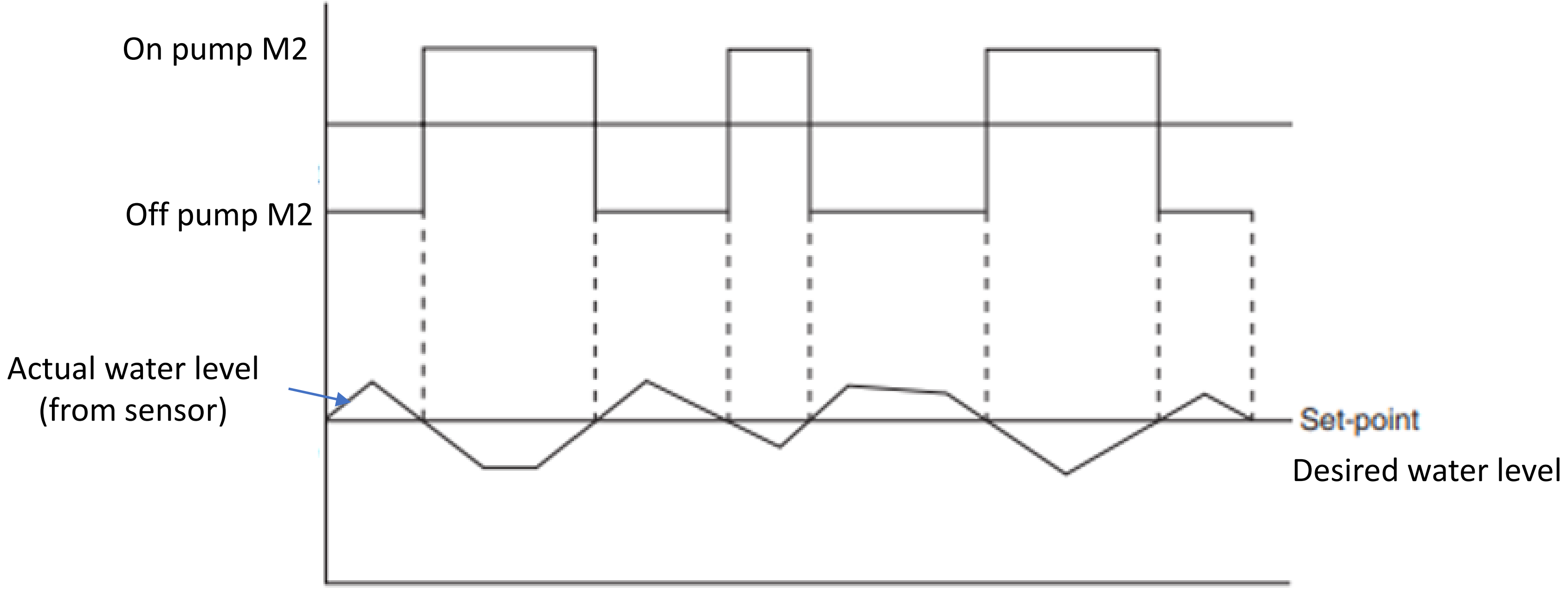





Rubber tube
Ultrasonic
Water Pump
Input
Desired water level
Computer
DAQ
M1
Water Tank
#1
#2
M2
Driver
Motor Driver
Jumper Wire

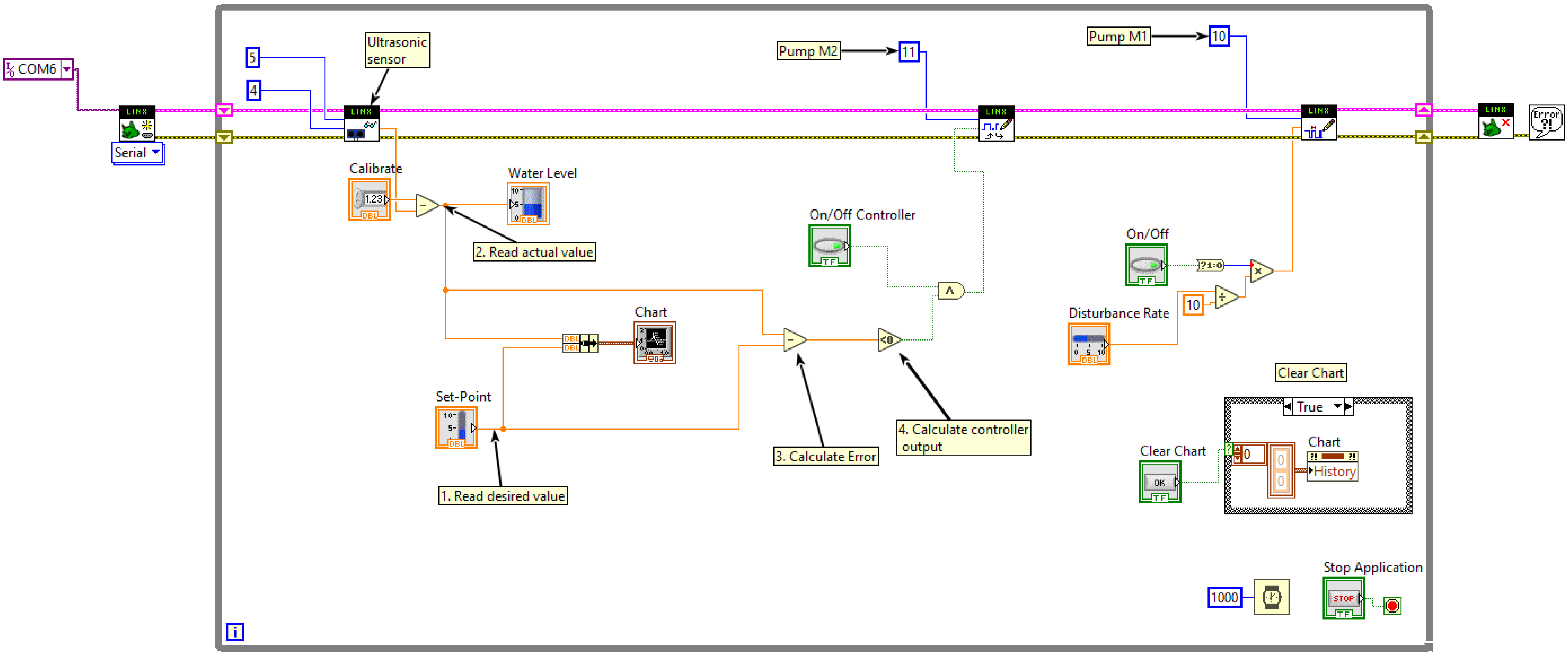
- The operation of the ON-OFF controller will be demonstrated through the water level control system.
- The water level of tank #1 (the control variable) is controlled to equal the desired water level as defined by the user.
- The water pump M1 serves as the disturbance; it pumps water out of tank #1.
- The water pump M2 is controlled by an ON-OFF controller to pump water into tank #1, reaching the desired level.
- The water level is measured using an ultrasonic sensor.



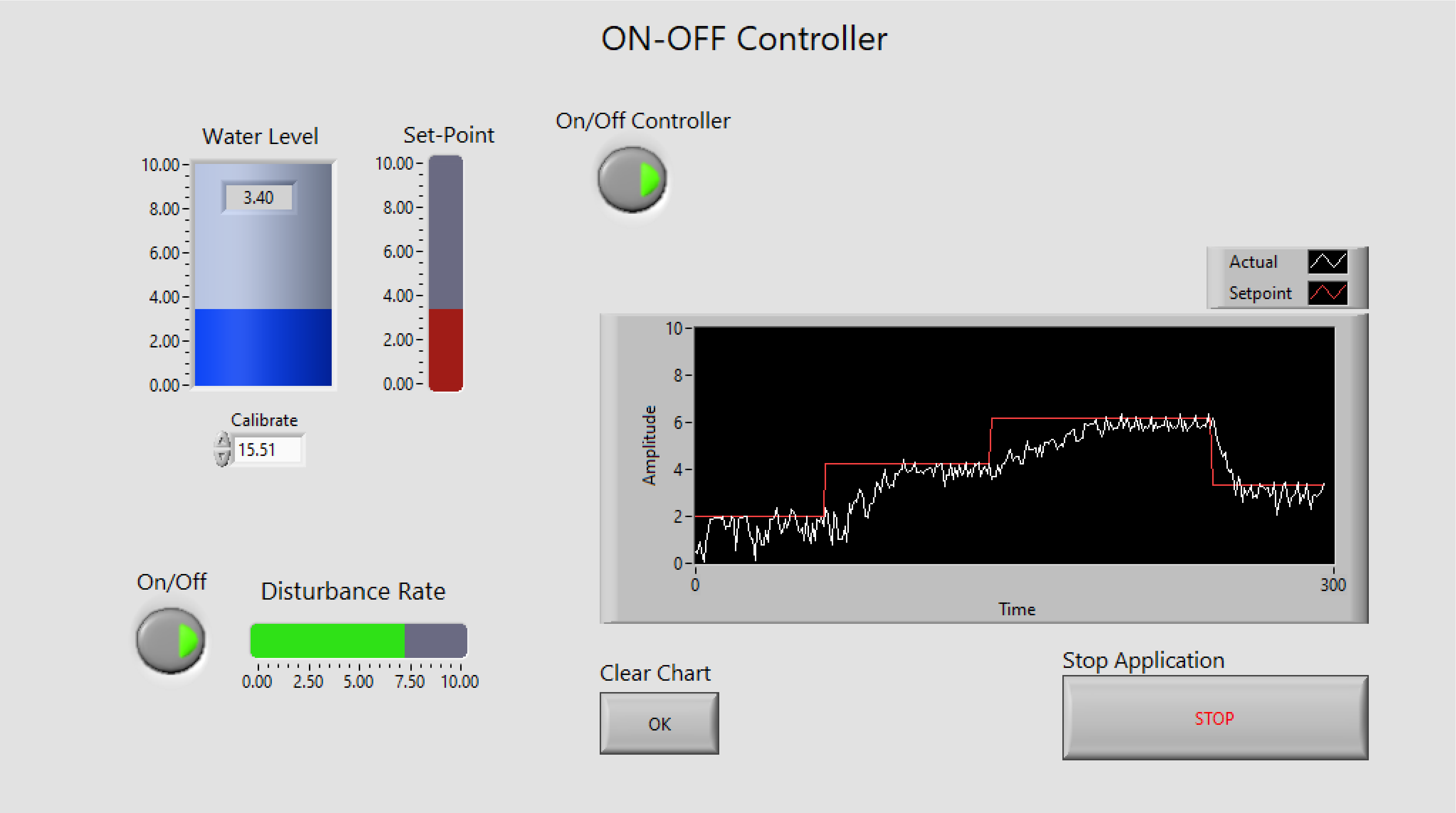


ON-OFF control algorithm

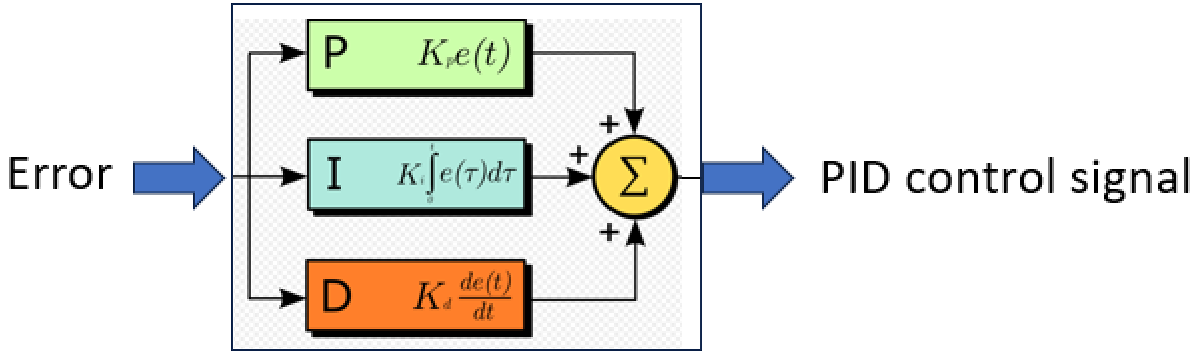
Source code of ON-OFF controller

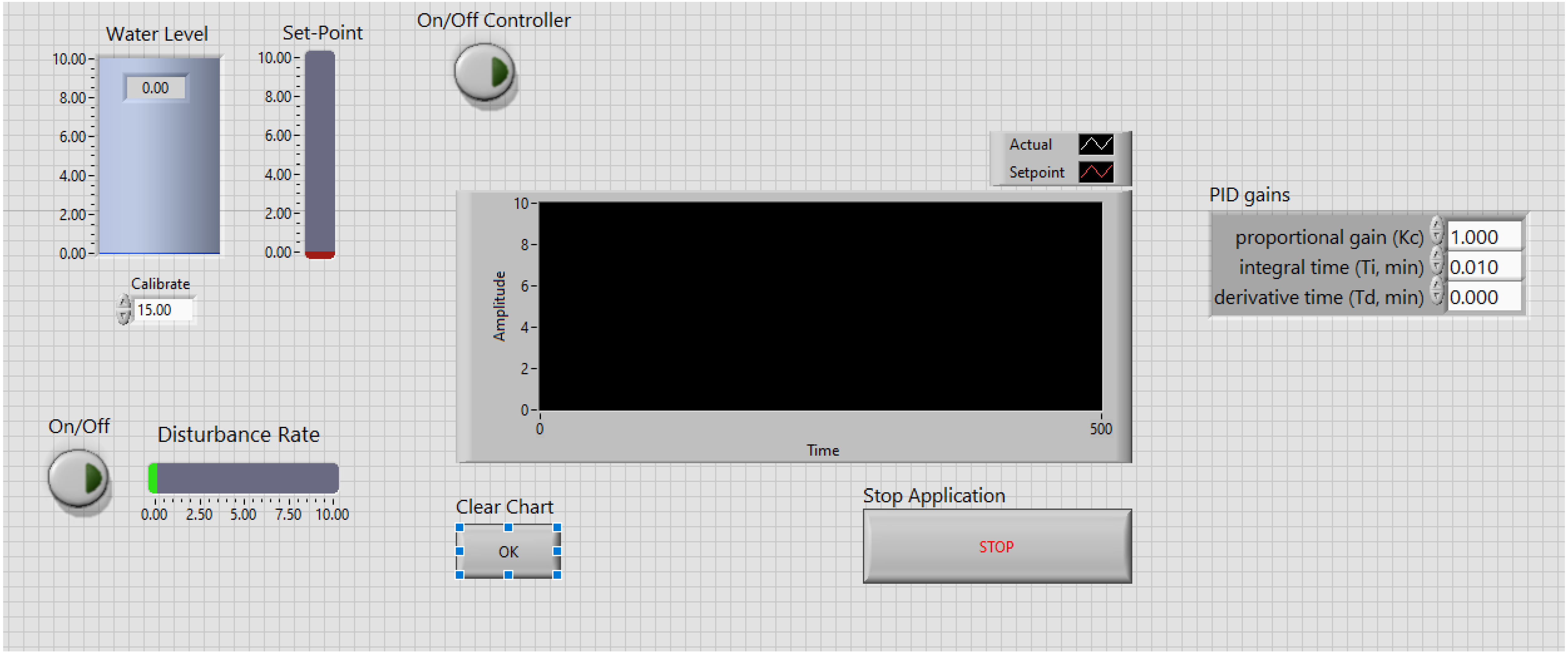


Experimental result

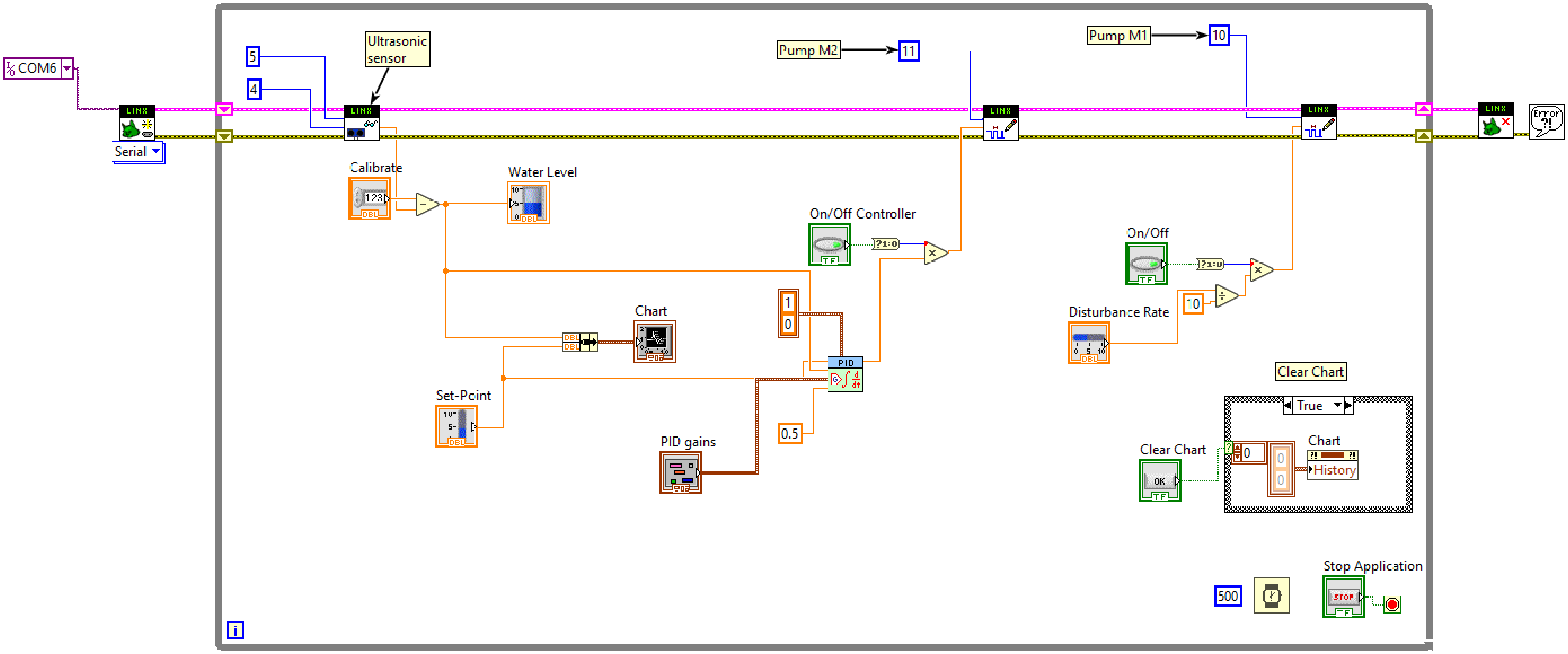


- PID controller





Water Level
10.00
8.00
6.00
4.00
2.00
0.00
Set-Point
10.00
8.00
6.00
4.00
2.00
0.00
On/Off Controller
Calibrate
15.00
Actual
Setpoint
Amplitude
Time
0
500
PID gains
proportional gain (Kc) 1.000
integral time (Ti, min) 0.010
derivative time (Td, min) 0.000
On/Off
Disturbance Rate
0.00 2.50 5.00 7.50 10.00
Clear Chart
OK
Stop Application
STOP



COM6
Serial
5
4
Ultrasonic sensor
Calibrate
Water Level
Chart
Set-Point
PID gains
1
0
0.5
Pump M2
11
Pump M1
10
On/Off Controller
On/Off
Disturbance Rate
Clear Chart
True
Chart
History
500
Stop Application