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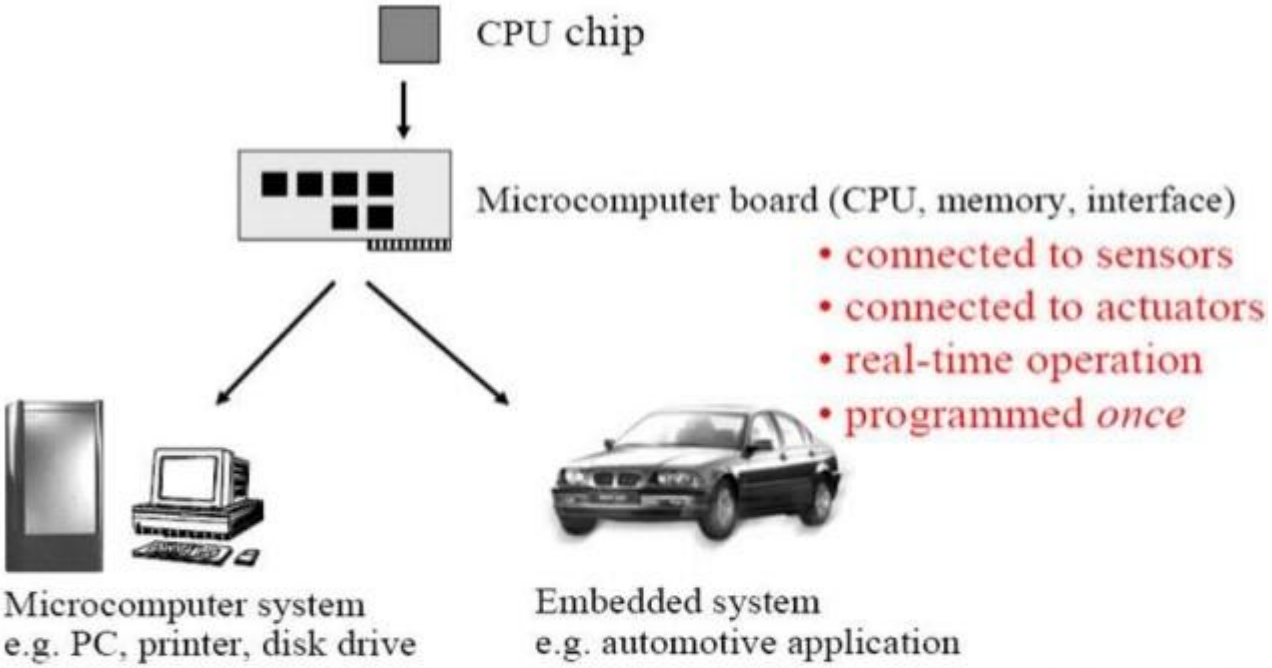
Introduction:-

Definition

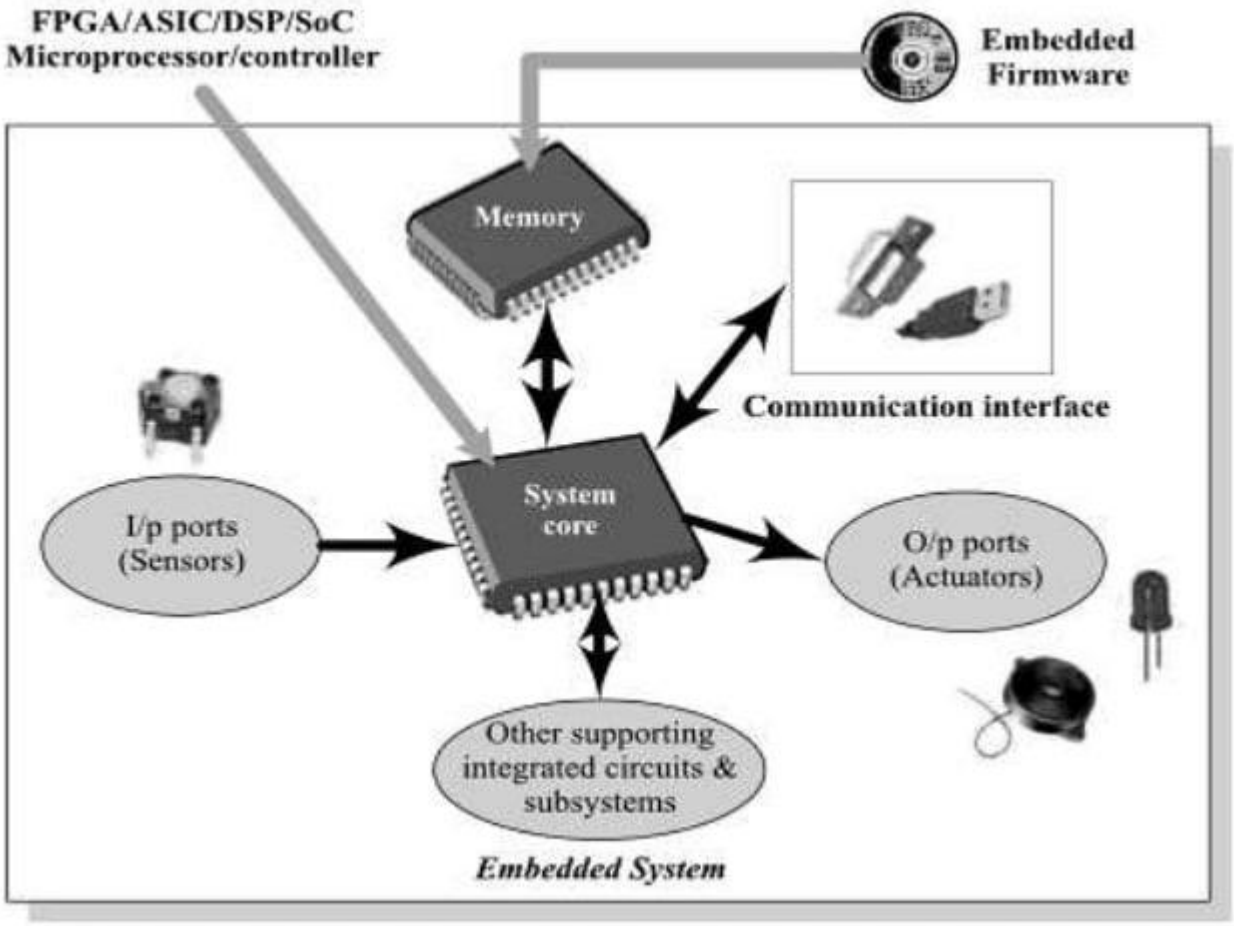
- ***It is an Electronic/Electro-mechanical system designed to perform a specific function and is a combination of both hardware & software.***

OR

- ***A combination of hardware and software which together form a component of a larger machine.***



- An example of an embedded system is a microprocessor that controls an automobile engine.
- An embedded system is designed to run on its own without human intervention, and may be required to respond to events in real time.


FPGA/ASIC/DSP/SoC
Microprocessor/controller
Embedded
Firmware
Memory
Communication interface
I/p ports
(Sensors)
System
core
O/p ports
(Actuators)
Other supporting
integrated circuits &
subsystems
Embedded System

History of Embedded Systems:-

- One of the very first recognizably modern embedded systems was the Apollo Guidance Computer, developed by Charles Stark Draper at the MIT Instrumentation Laboratory

Apollo Guidance Computer:-

1. The Apollo Guidance Computer was the first modern system to collect and provide flight information, and to automatically control all of the navigational functions of the Apollo spacecraft.
2. It was developed in the early 1960s for the Apollo program by the MIT Instrumentation Lab under Charles Stark Draper.
3. "The guidance computer made the moon landings possible.
4. It was designed almost entirely by MIT faculty and alumni from the Draper Lab (then called the Instrumentation Lab) and contractors staffed by MIT alumni.
5. The man on the moon was a huge milestone in the history of technology and of the Cold War, made possible entirely by MIT ingenuity.
6. "The Apollo Guidance Computer (AGC) was the first recognizably modern embedded system, used in real-time by astronaut pilots to collect and provide flight information, and to automatically control all of the navigational functions of the Apollo spacecraft.""

Major Application Areas Of Embedded Systems

1. **Consumer Electronics**
   - Camcorders, Cameras, etc…
2. **Household Appliances**
   - Television, DVD Player, Washing machine, fridge, microwave oven, etc.
3. **Home automation and security system**
   - Air conditioners, Sprinkler, intruder detection alarms, fire alarms, closed circuit television cameras, etc
4. **Automotive industry**
   - Anti-lock breaking system (ABS), engine control, ignition control, automatic navigation system, etc..
5. **Telecommunication**
   - Cellular telephones, telephone switches, Router, etc…

Continue...

6. **Computer peripherals**
   - Printers, scanners, fax machines, etc...
7. **Computer Networking systems**
   - Network routers, switches, hubs, firewalls, etc...
8. **Health care**
   - CT scanner, ECG , EEG , EMG ,MRI, Glucose monitor, blood pressure monitor, medical diagnostic device, etc.
9. **Measurement & Instrumentation**
   - Digital multi meters, digital CROs, logic analyzers PLC systems, etc...
10. **Banking & Retail**
    - Automatic Teller Machine (ATM) and Currency counters, smart vendor machine, cash register ,Share market, etc..
11. **Card Readers**
    - Barcode, smart card readers, hand held devices, etc...

Purpose Of Embedded Systems:-

Each Embedded system is designed to serve the purpose of any one or a combination of the following tasks.

1. Data collection/Storage/Representation
2. Data communication
3. Data (Signal) processing
4. Monitoring
5. Control
6. Application specific user interface

- A digital camera is a typical example of an embedded system with data collection / storage / representation of data.
- Images are captured and the captured image may be stored with in the memory of the camera. The captured image can also be presented to the user through a LCD display unit.

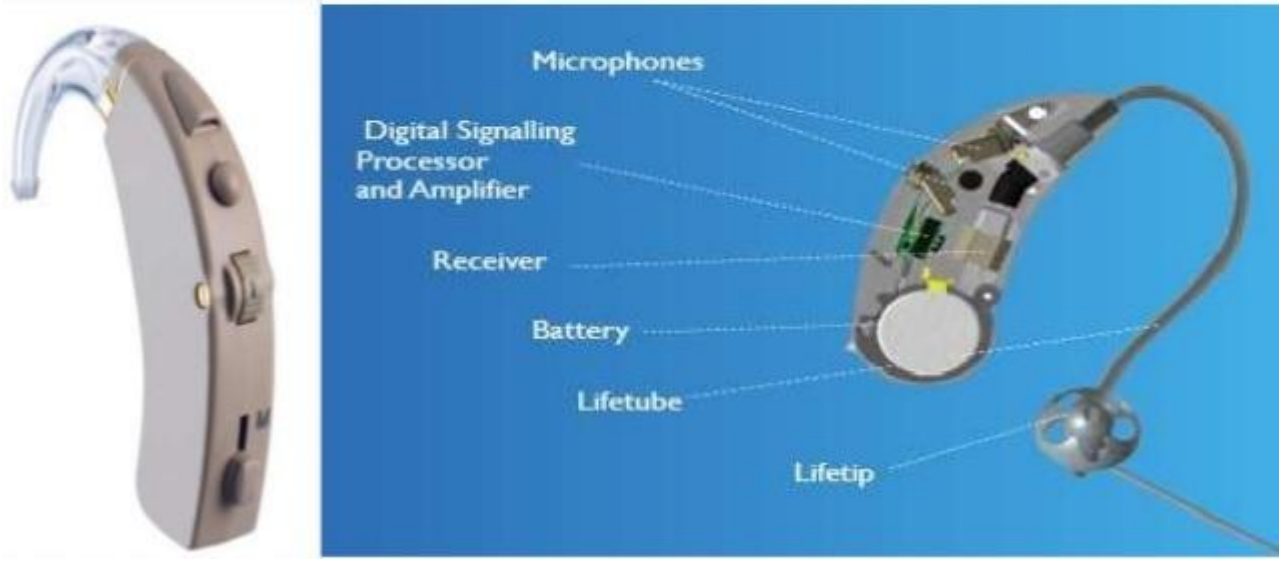
2. Data communication

- Embedded data communication systems are developed in applications ranging from complex satellite communication systems to simple home networking systems.

Figure: - A wireless network router for data communication

3. Data (Signal) Processing

- The data collected by embedded system may be used for various kinds of signal processing.
- A digital hearing aid is a typical example of an embedded system employing data processing.



4. Monitoring

- All embedded products coming under the medical domain are with monitoring functions only. They are used for determing the state of some variables using input sensors.
- A very good example is the electro cardiogram (ECG) machine for monitoring the heartbeat of patient.

Figure:- A patient monitoring system for monitoring for heartbeat

5. Control

- Embedded system with control functionalities impose control over some variables according to the input variables.
- A system with control functionality contains both sensors and actuators.
- Sensors are inputs ports for capturing the changes in environment variables or measuring variable.
- Actuators are output ports are controlled according to the changes in input variable.

Figure:- An Air conditioner for controlling room temperature

6. Application specific user interface

- These are embedded systems with application specific user interfaces like buttons, switches, keypad, lights, bells, display units, etc..
- Mobile phone is an example for this, in mobile phone the user interface is provided through the keyboard, graphic LCD module, system speaker, vibration alert, etc...

Core of the Embedded Systems:-

Embedded systems are domain and application specific and are built around a central core. The core of the embedded system falls into any one of the following categories.

1. General Purpose and Domain Specific Processors
    - 1.1 Microprocessors
    - 1.2 Microcontrollers
    - 1.3 Digital Signal Processors
2. Application Specific Integrated Circuits (ASICs)
3. Programmable Logic Devices (PLDs)
4. Commercial Of The Shelf Component (COTS)

1. General Purpose and Domain Specific Processors

1.1 Microprocessors

1.2 Microcontrollers

1.3 Digital Signal Processors

- Almost 80% of Embedded systems are processor/Controller based. The processor may be a Microprocessor or a Micro-controller or a Digital signal Processor depending on domain and application.
- Most of the embedded system in the industrial control and monitoring applications make use of the commonly available microprocessors or microcontrollers.
- where as domains which require signal processing such as speech coding, speech reorganization, etc. make use of Digital signal processors supplied by manufactures like Analog Devices, Texas Instruments, etc.

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2. Application Specific Integrated Circuits (ASICs)

- Application Specific Integrated Circuits (ASICs) is a micro chip designed to perform a specific or unique application.
- It is used as replacement to conventional general purpose logic chips.
- It integrates several functions into a single chip and there by reduce s the system development cost.

3.Programmable Logic Devices (PLDs)

- Logic devices provides specific functions, including device to device interfacing, data communication, signal processing, data display, timing & control operations, and almost every other function a system must perform.
- Logic devices → Fixed logic devices
  Programmable Logic devices
- Fixed logic devices are permanent they perform one function or set of functions once manufactured, they cannot be changed.
- Programmable Logic devices offer customers a wide range of logic capacity, features, speed, and voltage characteristics and these devices can be re-configured to perform any number of functions at any time.

4. Commercial Of The Shelf Component (COTS)

- A Commercial Off the Shelf product is one which is used "as-is".
- COTS products are designed in such a way to provide easy integration and interoperability with existing system components.
- The COTS component itself may be developed around a general purpose or domain specific processor or an Application Specific Integrated Circuit or a Programmable Logic Device.
- Typical Examples of COTS hardware unit is remote controlled toy car controlled units including RF circuitry part, high performance, high frequency microwave electronics (2-200GHz),electro-optic IR imaging arrays, UV/IR detectors, etc..
- The major advantage of using COTS is that they are readily available in the market.

Sensors and Actuators

Sensor:-

A sensor is a transducer device that converts energy from one form to another for any measurement or control purpose.

Actuator:-

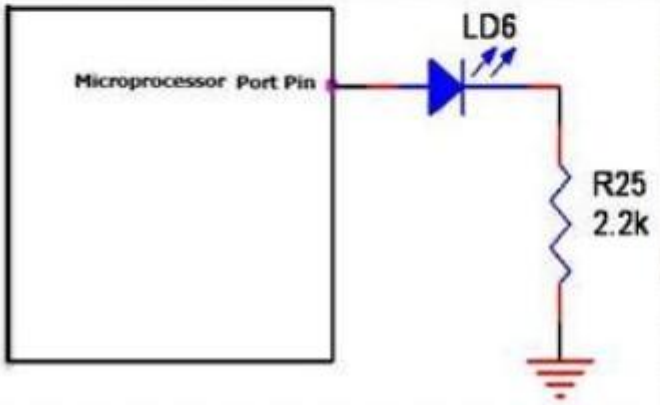
Actuator is a form of transducer device which converts signals to corresponding physical action(motion). Actuator act as output device

The I/O Subsystem

- Examples for some of the sensors & Actuators used in embedded system.
  - LED
  - 7 segment LED display
  - Optocoupler
  - Stepper motor
  - Relay
  - Piezo Buzzer
  - Push button switch
  - Keyboard
  - Programmable Peripheral Interface (PPI)

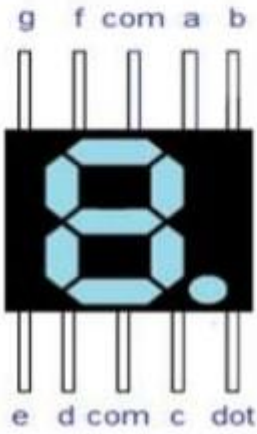
LED (Light Emitting Diode):-

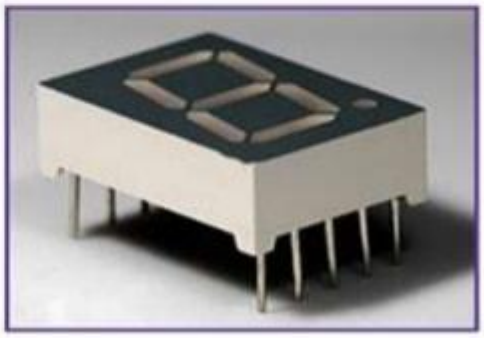
- It is an important output device for visual indications in any embedded system.
- LED can be used as an indicator for the status of various signals or situations.
- Typical examples are indicating the presence of power conditions like 'Device ON', 'Battery low', or ' Charging of Battery' for battery operated handheld embedded devices.



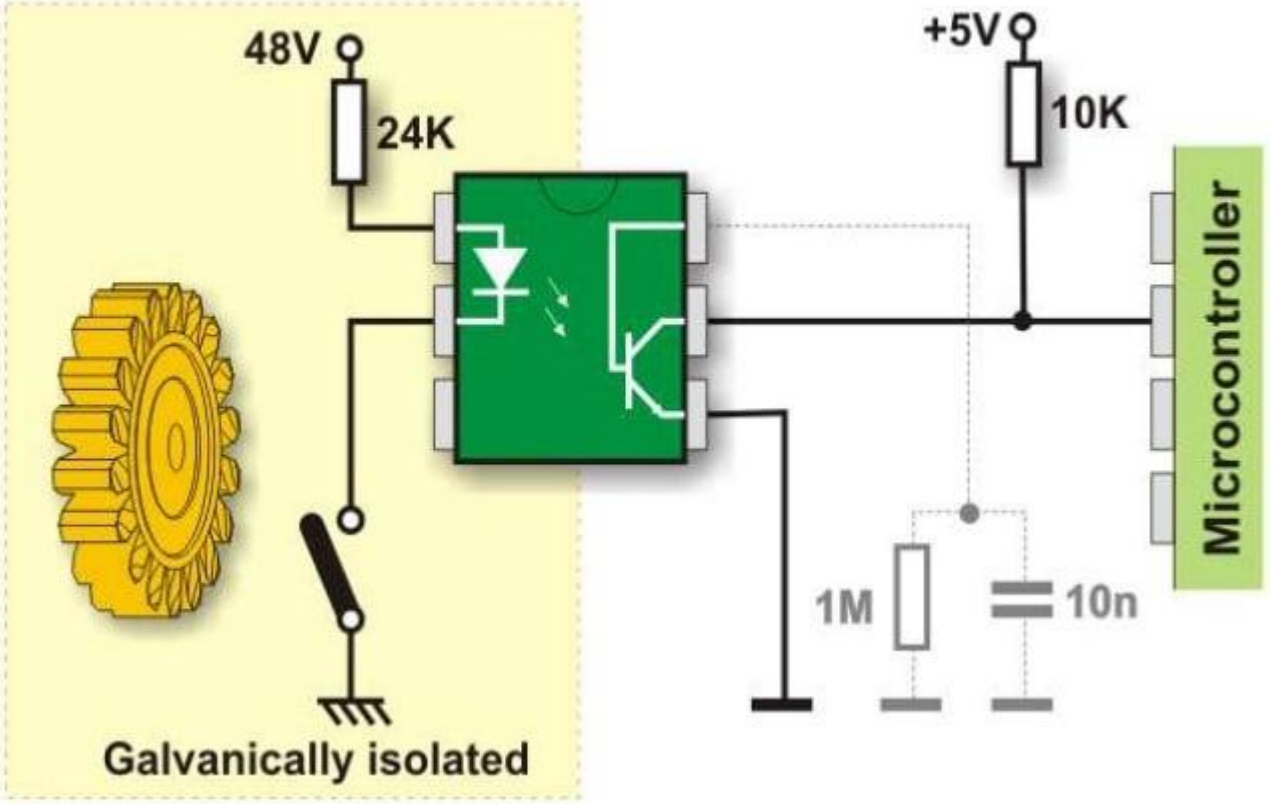
7 segment LED display:-

- It is an output device for displaying alpha numeric characters.
- It contains 8 light emitting diode (LED) segments arranged in a special form.
- Out of 8 LED segments 7 are used for displaying alpha numeric characters and 1 LED is used for representing 'decimal point' in decimal numbers.





Optocoupler:-



Communication Interface

1. On board Communication Interface or
   (Device/Board level communication interface)
2. External Communication Interface or
   (Product level communication interface)

1. On board Communication Interface or

(Device/Board level communication interface)

a) I2C Inter Integrated Circuit

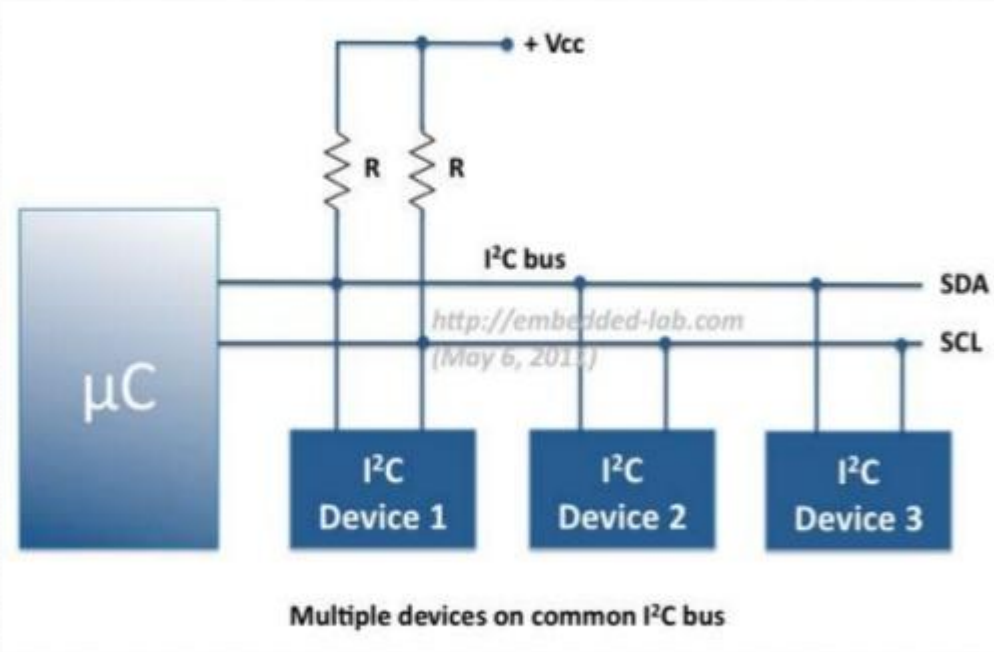
b) SPI (Serial Communication Interface)

c) UART (Universal Asynchronous Rx and Tx)

d) 1-WIRE

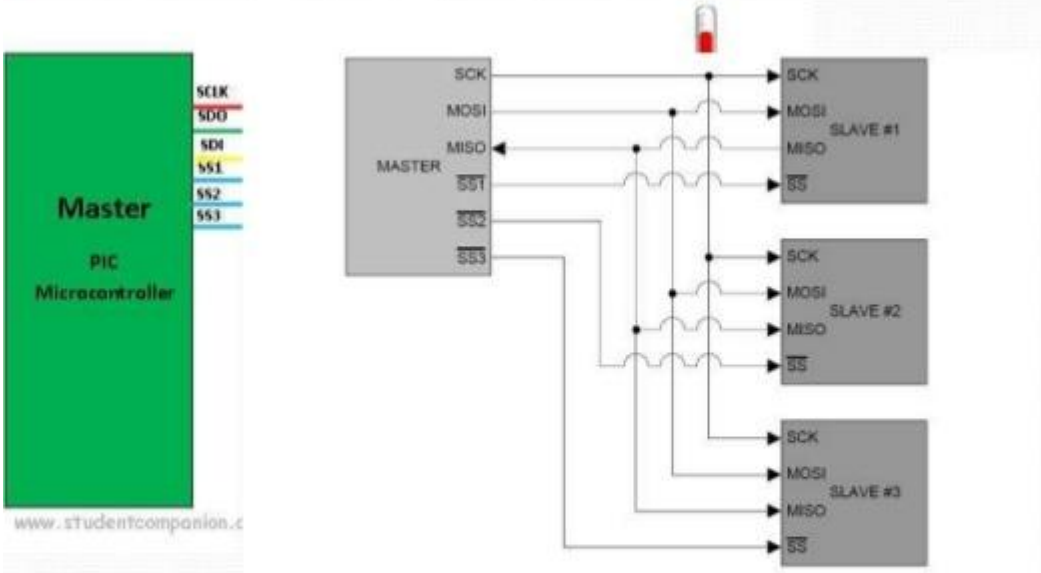
e) Parallel Communication Interface

a) I2C Inter Integrated Circuit

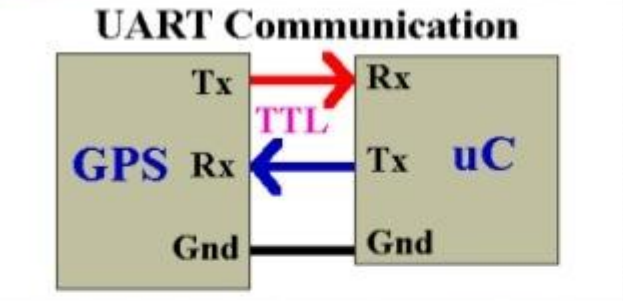


Multiple devices on common I²C bus

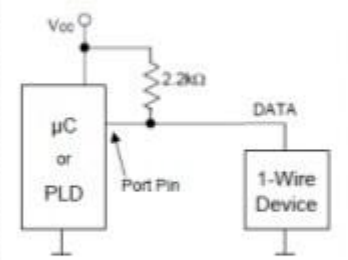
b) SPI (Serial Communication Interface)

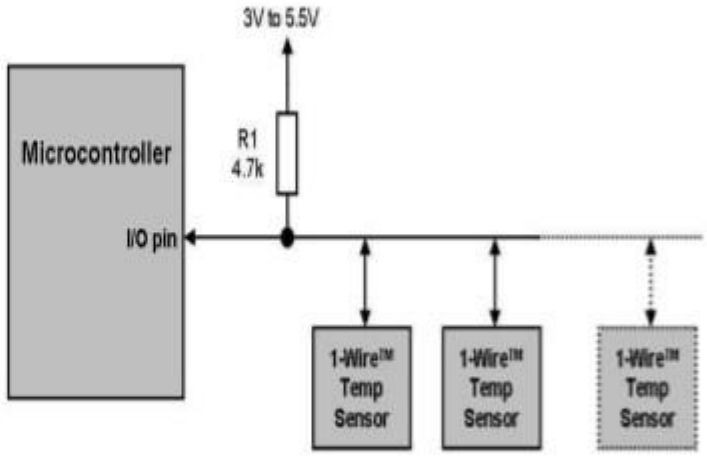


c) UART (Universal Asynchronous Rx and Tx)

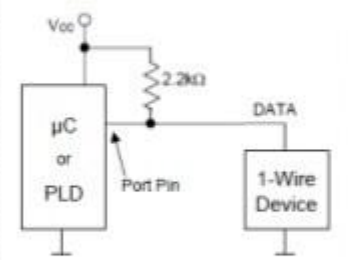


d) 1-WIRE


Vcc
2.2kΩ
DATA
µC
or
PLD
Port Pin
1-Wire
Device


3V to 5.5V
Microcontroller
R1
4.7k
I/O pin
1-Wire™
Temp
Sensor
1-Wire™
Temp
Sensor
1-Wire™
Temp
Sensor

d) 1-WIRE


Vcc
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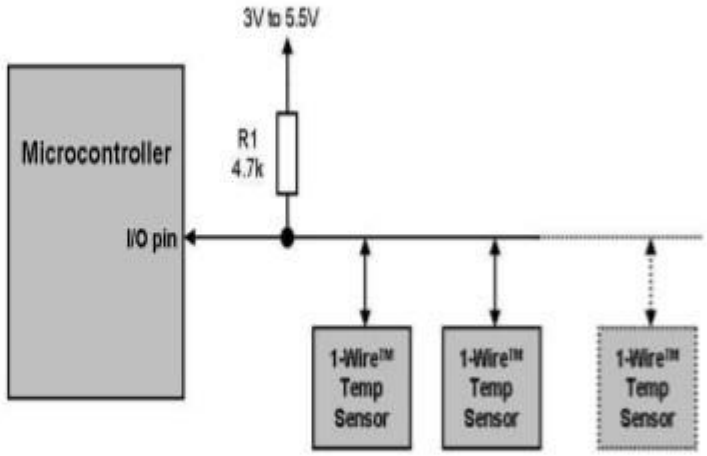
3V to 5.5V
Microcontroller
R1
4.7k
I/O pin
1-Wire™
Temp
Sensor
1-Wire™
Temp
Sensor
1-Wire™
Temp
Sensor

e) Parallel Communication Interface