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Subject Name: Introduction to Electronic Engineering **Faculty: Tejashree S**

Subject Code: 22ESC143/243

Syllabus:

Embedded Systems – Definition, Embedded systems vs general computing systems, Classification of Embedded Systems, Major application areas of Embedded Systems, Elements of an Embedded System, Core of the Embedded System, Microprocessor vs Microcontroller, RISC vs CISC.

Sensors and Interfacing – Instrumentation and control systems, Transducers, Sensors, Actuators, LED, 7-Segment LED Display.

Embedded Systems:

- An embedded system is an electronic/electro-mechanical system designed to perform a specific function and a combination of both hardware and firmware (software).
- Every embedded system is unique and the hardware as well as the firmware is highly specialized to the application domain.
- Embedded systems are becoming an inevitable part of any product or equipment in all fields including household appliances, telecommunications, medical equipment, industrial control, consumer products, etc.
- Embedded system is a combination of 3 things
  1. Hardware
  2. Software
  3. Mechanical component & it is supposed to do only one specific task only

Examples:

Example1: Washing Machine

A washing machine from an embedded systems point of view has:

a. **Hardware:** Buttons, displays & buzzer, electronic circuitry.

b. **Software:** It has a chip on the circuit that holds the software which drives controls & monitors various operations possible.

c. **Mechanical components:** the internals of a washing machine which actually wash the clothes control the input and output of water.

Example-2: Air Conditioner

An Air Conditioner from an embedded systems point of view has:

a. **Hardware:** Remote, display & buzzer, infrared Sensors, electronic circuitry.

b. **Software:** It has a chip on the circuit that holds the software which drives control & monitors the various operations possible. The software monitors the external temperature through the sensos and then releases the coolant or suppresses it.

c. **Mechanical components**: The internals of an air conditioner the motor, the outlet, etc.

Differences between General Purpose computing system and Embedded system:

Contents	A system which is a combination of a generic hardware and general-purpose operating system for executing a variety of applications	A system which is a combination of special-purpose hardware and embedded operating system & for executing specific set of applications
OS	It contains a general-purpose operating system (GPOS)	It may or may not contain an operating system for functioning
Alterations	Applications are alterable (programmable) by the user. (It is possible for end user to re-install the OS and also add or remove user applications)	The firmware of the Embedded system is pre-programmed and it is non-alterable by the end user.
Key Factor	Performance is the key deciding factor in the selection of the system. Faster is better.	Application specific requirements (like performance, power requirements, memory usage etc) are the key deciding factor.
Power consumption	More	Less
Response Time	Not Critical	Critical for some applications
Execution	Need not be deterministic	Deterministic for certain types of ES like 'Hard real time systems'.

Classification of Embedded Systems:

The classification of embedded system is based on following criteria's:

- On generation

- On complexity & performance
- On deterministic behavior
- On triggering

Classification based on generation:

1. First generation (1G):
   - Built around 8bit microprocessor & microcontroller.
   - Simple in hardware circuit & firmware developed.
   - Examples: Digital telephone keypads.
2. Second generation (2G):
   - Built around 16-bit µp & 8-bit µc.
   - They are more complex & powerful than 1G µp & µc.
   - Examples: SCADA systems
3. Third generation (3G):
   - Built around 32-bit µp& 16-bit µc.
   - Concepts like Digital Signal Processors (DSPs), Application Specific Integrated Circuits (ASICs) evolved.
   - Examples: Robotics, Media, etc.
4. Fourth generation:
   - Built around 64-bit µp & 32-bit µc.
   - The concept of System on Chips (SoC), Multicore Processors evolved.
   - Highly complex & very powerful. Examples: Smart Phones.

Classification based on complexity & performance:

1. Small-scale:
   - It is suitable for simple applications.
   - Performance not time-critical.
   - It may oy may not contain OS.
   - Built around low performance & low cost 8 or 16 bit µp/µc.
   - Example: an electronic toy
2. Medium-scale:
   - Slightly complex in hardware & firmware requirement.
   - Built around medium performance & low cost 16 or 32 bit µp/µc.

- Usually contain operating system.
- Examples: Industrial machines.

3. Large-scale:
   - Highly complex hardware & firmware.
   - Built around 32- or 64-bit RISC µp/µc or PLDs or Multicore Processors.
   - Response is time-critical.
   - Examples: Mission critical applications.

Classification based on deterministic behavior:

- It is applicable for Real Time systems.
- The application/task execution behavior for an embedded system can be either deterministic or non-deterministic. These are classified in to two types:

1. Soft Real Time Systems: Missing a deadline may not be critical & can be tolerated to a certain degree
2. Hard Real Time Systems: Missing a program/task execution time deadline can have catastrophic consequences (financial, human loss of life, etc.

Classification based on triggering:

These are classified into two types

1. Event triggered: Activities within the system (e.g., task run-times) are dynamic and depend upon occurrence of different events.
2. Time triggered: Activities within the system follow a statically computed schedule (i.e., they are allocated time slots during which they can take place) and thus by nature are predictable.

Major Application Areas of Embedded Systems:

The application areas and the products in the embedded domain are countless. A few of theimportant domains and products are listed below:

- **Consumer electronics:** Camcorders, cameras, etc.
- **Household appliances:** Television, DVD players, washing machine, fridge, microwave oven, etc.
- **Home automation and security systems:** Air conditioners, sprinklers, intruderdetection alarms, closed circuit television cameras, fire alarms, etc.
- **Automotive industry:** Anti-lock braking systems (ABS), engine control, ignition

systems, automatic navigation systems, etc.

- **Telecom:** Cellular telephones, telephone switches, handset multimedia applications, etc.
- **Computer peripherals:** Printers, scanners, fax machines, etc.
- **Computer networking systems:** Network routers, switches, hubs, firewalls, etc.
- **Healthcare:** Different kinds of scanners, EEG, ECG machines etc.

  Measurement & Instrumentation: Digital multi meters, digital CROs, logic analyzers, HLC systems, etc.
- **Banking & Retail:** Automatic teller machines (ATM) and currency counters, point of sales (POS).
- **Card Readers:** Barcode, smart card readers, hand held devices, etc.

Elements of an embedded system:

- A typical embedded system contains a single chip controller which acts as the master brain of the system. Diagrammatically an embedded system can be represented as follows:

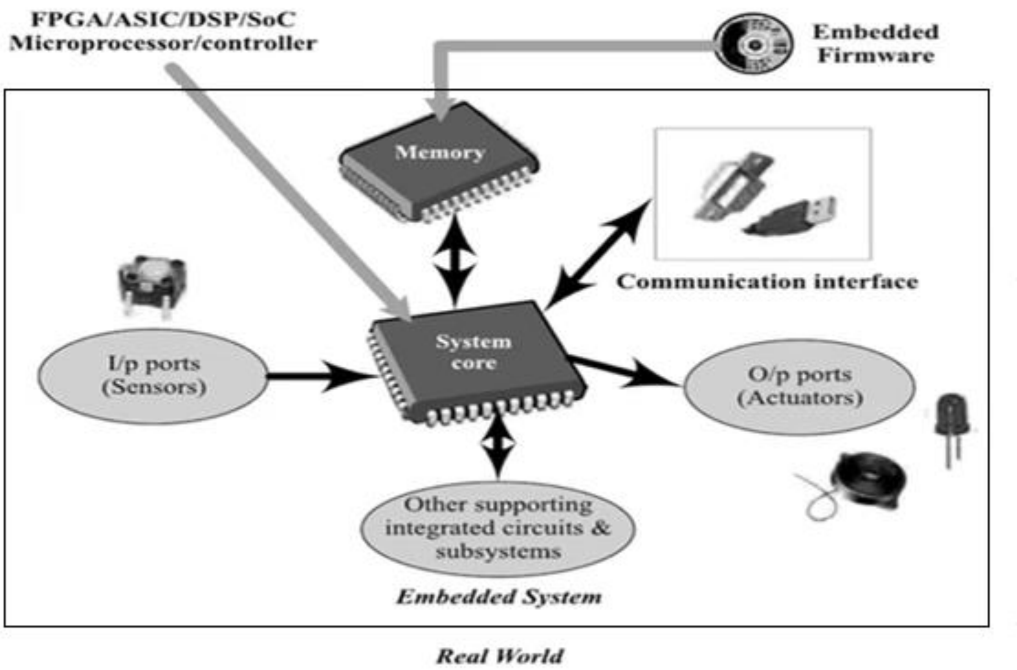


Fig: Elements of Embedded system

- Embedded systems consist of a system core which can be a single chip controller. This system core will act as a brain of the system.
- The system core can be a microprocessor, microcontroller, FPGA, ASIC, DSP, Soc.
- The input signals are sensed through sensors are provided to the embedded

systems through input ports by the end users to the system core.

- The system processes the signals and provide the control signals to the output ports (actuators).
- Keyboards, push button, switches, etc. are examples of common user interface input devices and LEDs, LCDs, Piezoelectric buzzers, etc. examples for common user interface output devices for a typical embedded system.
- Some embedded systems do not require any manual intervention for their operation. They automatically sense the input parameters from real world through sensors which are connected at input port.
- The sensor information is passed to the processor after signal conditioning and digitization. The core of the system performs some predefined operations on input data with the help of embedded firmware in the system and sends some actuating signals to the actuator connect connected to the output port of the system.
- The memory of the system is responsible for holding the code (control algorithm and other important configuration details). There are two types of memories are used in any embedded system. Fixed memory (ROM) is used for storing code or program.
- The user cannot change the firmware in this type of memory. The most common types of memories used in embedded systems for control algorithm storage are OTP, PROM, UVEPROM, EEPROM and FLASH.

The Core of the Embedded Systems:

The core of the embedded system falls into any one of the following categories.

1. General Purpose and Domain Specific Processors
    - Microprocessors
    - Microcontrollers
    - Digital Signal Processors
2. Programmable Logic Devices (PLDs)
3. Application Specific Integrated Circuits (ASICs)
4. Commercial off the shelf Components (COTS)

General Purpose and Domain Specific Processor:

Almost 80% of the embedded systems are processor/ controller based. The processor may be microprocessor or a microcontroller or digital signal processor, depending on the domain and application.

Microprocessor:

- A silicon chip representing a Central Processing Unit (CPU), which is capable of performing arithmetic as well as logical operations according to a pre-defined set of Instructions, which is specific to the manufacturer
- In general, the CPU contains the Arithmetic and Logic Unit (ALU), Control Unit and Working registers
- Microprocessor is a dependent unit and it requires the combination of other hardware like Memory, Timer Unit, and Interrupt Controller etc. for proper functioning.

  Developers of microprocessors:

  - Intel – Intel 4004 – November 1971(4-bit)
  - Intel – Intel 4040.
  - Intel – Intel 8008 – April 1972.
  - Intel – Intel 8080 – April 1974(8-bit).
  - Intel – Intel 8085 – 1976.

Microcontroller:

- A highly integrated silicon chip containing a CPU, scratch pad RAM, Special and General-purpose Register Arrays, On Chip ROM/FLASH memory for program storage, Timer and Interrupt control units and dedicated I/O ports.
- Microcontrollers can be considered as a super set of Microprocessors.
- Since a microcontroller contains all the necessary functional blocks for independent working, they found greater place in the embedded domain in place of microprocessors.
- Microcontrollers are cheap, cost effective and are readily available in the market.
- Texas Instruments TMS 1000 is considered as the world's first microcontroller.

Differences between Microprocessor and Microcontroller:

Microprocessor	Microcontroller
1. Microprocessor are widely used in computer systems.	1. Microcontroller is widely used in embedded systems.
2. It has only a CPU embedded into it	2 It has a CPU, a fixed amount of RAM, ROM and other peripherals all embedded on it.

3. In case of microprocessors we have to connect all the components externally so the circuit becomes large and complex.	3. As all the components are internally connected in microcontroller so the circuit size is less.
4. It consumes more power.	4. It consumes less power than a microprocessor.
5. Used for high scale applications.	5. Used for low scale applications.
6. High processing power.	6. Low processing power.
7. Relatively slower in speed.	7. Relatively faster in speed.
8. Clock in GHz	8. Clock in MHz
9. Access time for memory and input devices are more.	9. Access time for memory and input devices are less.
10. More flexible in design	10. Less flexible in design

Difference between CISC and RISC Processor:

CISC	RISC
1. Complex instructions.	1. Simple instructions.
2. Main focus is hardware.	2. Main focus is software.
3. Complexity lies in Processor.	3. Complexity lies in Compiler.
4. Multiple clock cycle.	4. Single clock cycle.
5. Transistors are used to store complex instructions.	5. Transistors are used for storing memory.
6. CISC has 100-300 minimum Instructions.	6. RISC uses few instructions (30-40).
7. 8-10 Addressing modes.	7. Few Addressing modes.
8. Variable size/length instructions.	8. Fixed size/length instructions.

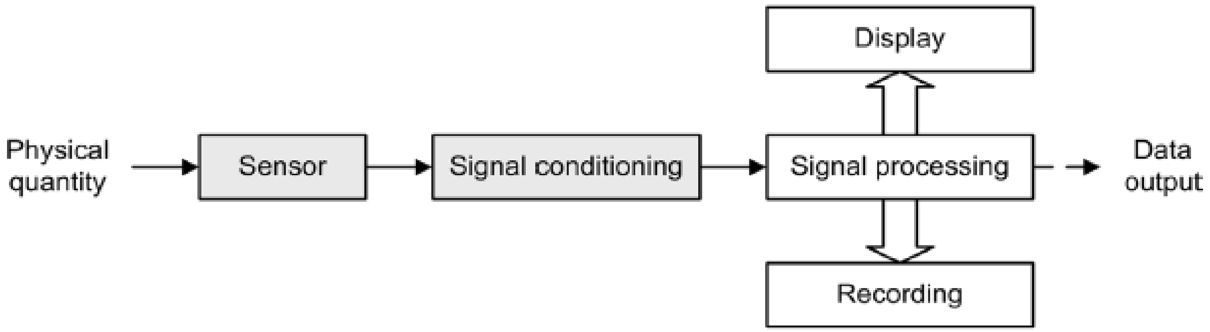
Sensors and Interfacing:

Instrumentation and control systems:

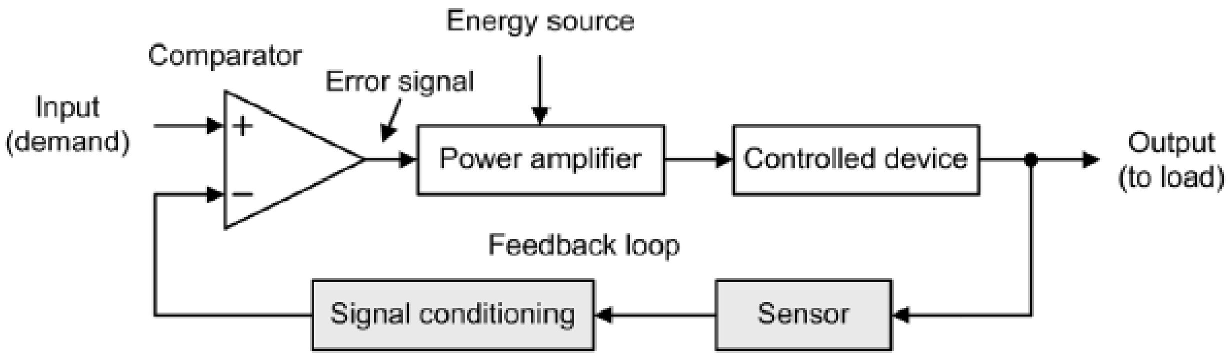
- Instrumentation and control systems Fig.(a) Shows the arrangement of an instrumentation system.
- The physical quantity that is needed to be measured (e.g., temperature) acts upon

a sensor that produces an electrical output signal.

- This signal is an electrical analogue of the physical input but note that there may not be a linear relationship between the physical quantity and its electrical equivalent.



(a) An instrumentation system



(b) A control system

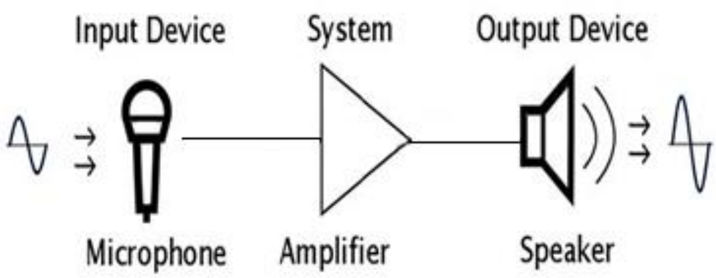
- Because of this and since the output produced by the sensor may be small or may suffer from the presence of noise (i.e., unwanted signals).
- Further signal conditioning will be required before the signal will be at an acceptable level and in an acceptable form for signal processing, display and recording.
- Furthermore, because the signal processing may use digital rather than analog signals an additional stage of analog-to-digital conversion may be required.
- Fig.(b) shows the arrangement of a control system. This uses negative feedback in order to regulate and stabilize the output.
- It thus becomes possible to set the input or demand (i.e., what we desire the output to be) and leave the system to regulate itself by comparing it with a signal derived from the output (via a sensor and appropriate signal conditioning).

- A comparator is used to sense the difference in these two signals and where any discrepancy is detected the input to the power amplifier is adjusted accordingly.
- This signal is referred to as an error signal (it should be zero when the output exactly matches the demand).
- The input (demand) is often derived from a simple potentiometer connected across a stable d.c. voltage source while the controlled device can take many forms (e.g., a d.c. motor, linear actuator, heater, etc.).

Transducers:

- Transducers are devices that convert energy in the form of sound, light, heat, etc., intoan equivalent electrical signal, or vice versa.
- Ex: A loudspeaker is a transducer that converts low frequency electric current into audible sounds.

  A microphone, on the other hand, is a transducer that performs the reverse function i.e. that of converting sound pressure variations into voltage or current. Loudspeakers and microphones can thus be considered as complementary transducers.
- Transducers may be used both as inputs to electronic circuits and outputs from them. From the two previous examples, it should be obvious that a loudspeaker is an **output transducer** designed for use in conjunction with an audio system.
- A microphone is an **input transducer** designed for use with a recording or sound reinforcing system.



Sensors:

- A sensor is a special kind of transducer that converts energy from one form to anotherfor any measurement or control purpose.
- Ex. A Temperature sensor. The signal produced by a sensor is an electrical analogy of a physical quantity, such as distance, velocity, acceleration,

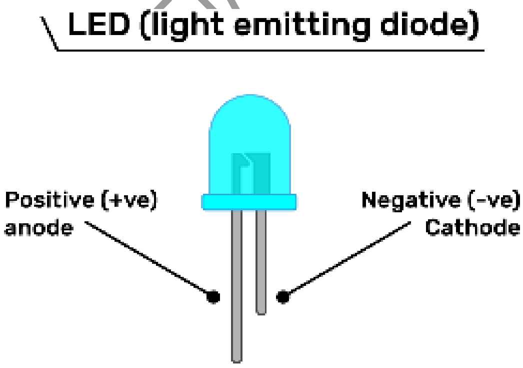
temperature, pressure, light level, etc.

- The choice of sensor is governed by a number of factors including accuracy, resolution, cost and physical size.
- Sensors can be categorized as either **active** or **passive.** An **active sensor** generates a current or voltage output. A **passive transducer** requires a source of current or voltage and it modifies this in some way (e.g. by virtue of a change in the sensor's resistance).
- Sensors can also be classed as either digital or analog. The output of a digital sensorcan exist in only two discrete states, either 'on' or 'off', 'low' or 'high', 'logic 1' or 'logic 0', etc.

Actuator:

Actuator is used for output. It is a transducer that may be either mechanical orelectrical which converts signals to corresponding physical actions.

- **LED (Light Emitting Diode):**
  - LED is a p-n junction diode and contains a CATHODE and ANODE for functioning the anode is connected to +ve end of power supply and cathode is connected to –ve end of power supply.
  - The maximum current flowing through the LED is limited by connecting a resistor in series between the power supply and LED as shown in the figure.

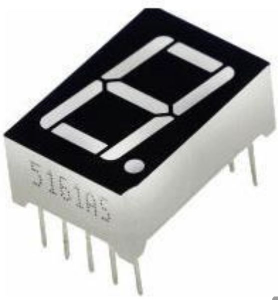


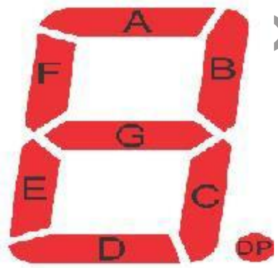
There are two ways to interface an LED to a microprocessor/microcontroller:

- The Anode of LED is connected to the port pin and cathode to Ground: In this approach the port pin sources the current to the LED when it is at logic high (ie. 1).
- The Cathode of LED is connected to the port pin and Anode to Vcc : In this approach the port pin sources the current to the LED when it is at logic high

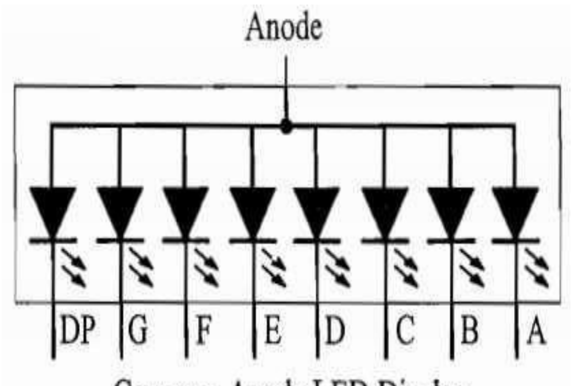
(ie. 1). Here the port pin sinks the current and the LED is turned ON when the port pin is at Logic low (ie. 0).

- **7-Segment Display:**
  - A seven-segment display (SSD), or seven-segment indicator, is a form of electronic display device for displaying decimal numerals that is an alternative to the more complex dot matrix displays.
  - Seven-segment displays are widely used in digital clocks, electronic meters, basic calculators, and other electronic devices that display numerical information
  - The seven elements of the display can be lit in different combinations to represent the Arabic numerals. Often the seven segments are arranged in an oblique (slanted) arrangement, which aids readability.

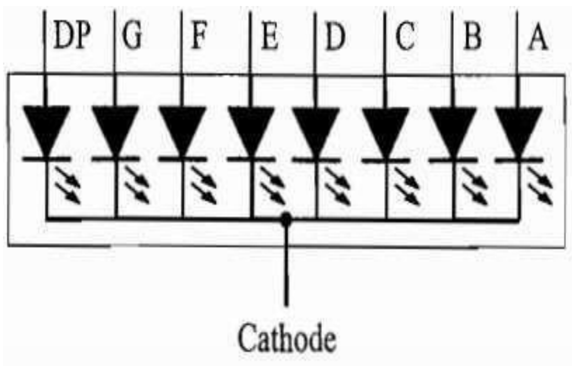




  - In most applications, the seven segments are of nearly uniform shape and size (usually elongated hexagons, though trapezoids and rectangles can also be used), though in the case of adding machines, the vertical segments are longer and more oddly shaped at the ends in an effort to further enhance readability.
  - The segments of a 7-segment display are referred to by the letters A to G, where the optional decimal point (an "eighth segment", referred to as DP) is used for the display of non-integer numbers.



Common Anode LED Display



Common Cathode LED Display

Question Bank

1. Define embedded system. Give classification of embedded system. And also mention the Applications of embedded system.
2. Differentiate the Embedded systems and general computing systems.
3. Explain Elements of an Embedded System with the neat diagram.
4. Explain in detail the core of the Embedded System.
5. Differentiate the following
   a. Microprocessor and Microcontroller.
   b. RISC and CISC processor.
6. Explain the arrangement of an instrumentation and control system with neat diagram.
7. Write a note on
   a. 7 segment LED display
   b. Transducers
   c. LED
   d. Sensors and Actuators