

Basic Embedded Systems

Embedded systems are computer systems designed for a specific function inside a larger device.

Examples:

- washing machine controller,
- car ABS system,
- microwave oven,
- smart watch,
- printer controller.

Embedded system characteristics

- task-specific,
- resource constrained,
- often real-time,
- reliable,
- low power,
- interacts with hardware sensors/actuators.

Microprocessor vs Microcontroller

Microprocessor	Microcontroller
CPU only	CPU + memory + I/O on one chip
Needs external RAM/ROM/peripherals	Built-in peripherals
Used in PCs/general systems	Used in embedded systems
Higher processing capability	Lower cost/power

Sensor and actuator

Sensor: converts physical quantity to electrical signal.

Examples: temperature sensor, pressure sensor.

Actuator: converts electrical signal to physical action.

Examples: motor, relay, buzzer.

ADC and DAC

ADC: Analog to Digital Converter.

Used when sensor signal is analog but microcontroller processes digital values.

DAC: Digital to Analog Converter.

Used when digital output must become analog voltage/current.

Interrupt

Interrupt is a signal that temporarily stops normal program execution and runs an Interrupt Service Routine.

Advantages:

- fast response,
- avoids constant checking.

ISR:

Interrupt Service Routine, the function executed when interrupt occurs.

Polling vs Interrupt

Polling	Interrupt
CPU repeatedly checks status	Device notifies CPU
Simple	More efficient
Wastes CPU time	Better for real-time events

Timer

Timer generates accurate delays or periodic events.

Uses:

- delays,
- PWM generation,
- event counting,
- scheduling.

Watchdog timer

Watchdog resets system if software hangs.

Method:

- Program must periodically reset/kick watchdog.
- If not, watchdog assumes failure and resets device.

RTOS

RTOS = Real-Time Operating System.

It gives deterministic response within deadlines.

Key terms:

- task/thread,
- priority,
- scheduler,
- latency,
- deadline,
- semaphore,
- mutex.

Hard real-time:

- Missing deadline is system failure.
- Example: airbag.

Soft real-time:

- Missing deadline degrades quality.
- Example: video streaming.

Communication protocols

UART

- asynchronous serial communication,
- uses TX/RX lines,
- no clock line,
- common in debugging and modules.

SPI

- synchronous,
- fast,
- master-slave,
- uses MOSI, MISO, SCLK, SS.

I2C

- synchronous,
- two wires: SDA and SCL,
- supports multiple devices using addresses.

Memory in embedded systems

- ROM/Flash: stores program permanently.
- RAM: temporary runtime data.
- EEPROM: non-volatile small data storage.

Common MCQ traps

- Microcontroller includes CPU, memory, and peripherals.
- Interrupt is event-driven.
- Polling wastes CPU cycles.
- ADC converts analog to digital, not digital to analog.
- Watchdog improves reliability by resetting stuck systems.