1. **Explain the components used as the core of an Embedded System.**
    - **Microprocessors** A Microprocessor is 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. A microprocessor is a dependent unit and it requires the combination of other hardware like memory, timer unit, and interrupt controller, etc. for proper functioning.
    - **Microcontrollers** A Microcontroller is a highly integrated chip that contains 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. They are cheap, cost effective and are readily available in the market.
    - **Digital Signal Processors** Digital Signal Processors (DSPs) are powerful special purpose 8/16/32 bit microprocessors designed specifically to meet the computational demands and power constraints of today’s embedded audio, video, and communications applications. Digital signal processors are 2 to 3 times faster than the general purpose microprocessors in signal processing applications. This is because of the architectural difference between the two. DSPs implement algorithms in hardware which speeds up the execution whereas general purpose processors implement the algorithm in firmware and the speed of execution depends primarily on the clock for the processors. In general, DSP can be viewed as a microchip designed for performing high speed computational operations for ‘addition’, ‘subtraction’, ‘multiplication’ and ‘division’.
    - **Application Specific Integrated Circuits (ASICs)** Application Specific Integrated Circuit (ASIC) is a microchip 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 reduces the system development cost.
    - **Programmable Logic Devices** Logic devices provide specific functions, including device-to-device interfacing, data communication, signal processing, data display, timing and control operations, and almost every other function a system must perform. Programmable Logic Devices (PLDs) offer 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. With programmable logic devices, designers use inexpensive software tools to quickly develop, simulate, and test their designs.
    - **Commercial Off-the-Shelf (COTS)** 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.

2. Differentiate between Microprocessor and Microcontroller.

Microprocessor	Microcontroller
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	A microcontroller is a highly integrated chip that contains a CPU, scratchpad 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
It is a dependent unit. It requires the combination of other chips like timers, program and data memory chips, interrupt controllers, etc. for functioning	It is a self-contained unit and it doesn't require external interrupt controller, timer, UART, etc. for its functioning
Most of the time general purpose in design and operation	Mostly application-oriented or domain-specific
Doesn't contain a built in I/O port. The I/O port functionality needs to be implemented with the help of external programmable peripheral interface chips like 8255	Most of the processors contain multiple built-in I/O ports which can be operated as a single 8 or 16 or 32 bit port or as individual port pins
Targeted for high end market where performance is important	Targeted for embedded market where performance is not so critical (At present this demarcation is invalid)
Limited power saving options compared to microcontrollers	Includes lot of power saving features

3. Differentiate between Big Endian and Little Endian.

Little-endian (Fig. 2.3) means the lower-order byte of the data is stored in memory at the lowest address, and the higher-order byte at the highest address. (The little end comes first.) For example, a 4 byte long integer **Byte3 Byte2 Byte1 Byte0** will be stored in the memory as shown below:

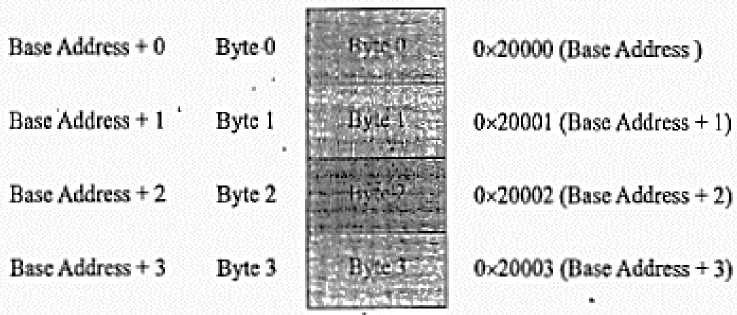

Fig. 2.3 **Little-Endian operation**

Big-endian (Fig. 2.4) means the higher-order byte of the data is stored in memory at the lowest address, and the lower-order byte at the highest address. (The big end comes first.) For example, a 4 byte long integer **Byte3 Byte2 Byte1 Byte0** will be stored in the memory as follows[1]:

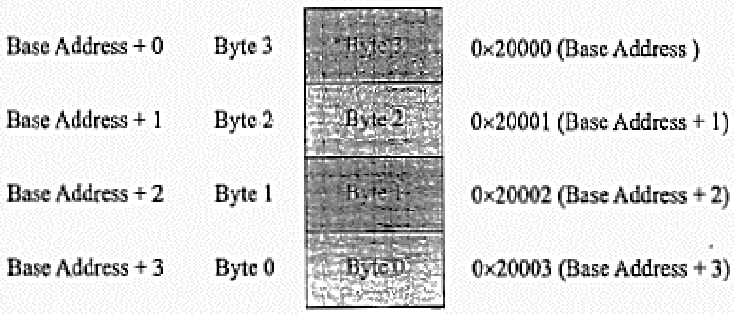

Fig. 2.4 **Big-Endian operation**

4. **Differentiate between RISC and CISC processors.**

RISC	CISC
Lesser number of instructions	Greater number of Instructions
Instruction pipelining and increased execution speed	Generally no instruction pipelining feature
Orthogonal instruction set (Allows each instruction to operate on any register and use any addressing mode)	Non-orthogonal instruction set (All instructions are not allowed to operate on any register and use any addressing mode. It is instruction-specific)
Operations are performed on registers only, the only memory operations are load and store	Operations are performed on registers or memory depending on the instruction
A large number of registers are available	Limited number of general purpose registers
Programmer needs to write more code to execute a task since the instructions are simpler ones	Instructions are like macros in C language. A programmer can achieve the desired functionality with a single instruction which in turn provides the effect of using more simpler single instructions in RISC
Single, fixed length instructions	Variable length instructions
Less silicon usage and pin count	More silicon usage since more additional decoder logic is required to implement the complex instruction decoding.
With Harvard Architecture	Can be Harvard or Von-Neumann Architecture

5. **What is Programmable Logic Device(PLD)? Explain Different types of PLDs.**
    - Logic devices provide specific functions, including device-to-device interfacing, data communication, signal processing, data display, timing and control operations, and almost every other function a system must perform.
    - Programmable Logic Devices (PLDs) offer 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.
    - With programmable logic devices, designers use inexpensive software tools to quickly develop, simulate, and test their designs.
    - Then, a design can be quickly programmed into a device, and immediately tested in a live circuit. The PLD that is used for this prototyping is the exact same PLD that will be used in the final production of a piece of end equipment, such as a network router, a DSL modem, a DVD player, or an automotive navigation system.
    - There are no NRE costs and the final design is completed much faster than that of a custom, fixed logic device.
    - Another key benefit of using PLDs is that during the design phase-customers can change the circuitry as often as they want until the design operates to their satisfaction. That’s because PLDs are based on re-writable memory technology-to change the design, the device is simply reprogrammed. Once the design is final, customers can go into immediate production by simply programming as many PLDs as they need with the final software design file.
    - The two major types of programmable logic devices are
        - **Field Programmable Gate Arrays (FPGAs)** offer the highest amount of logic density, the most features, and the highest performance. The largest FPGA provides eight million “system gates” (the relative density of logic). These advanced devices also offer features such as built-in hardwired processors (such as the IBM power PC), substantial amounts of memory, clock management systems, and support for many of the latest, very fast device-to-device signaling technologies. FPGAs are used in a wide variety of applications

ranging from data processing and storage, to instrumentation, telecommunications, and digital signal processing.
    - **Complex Programmable Logic Devices (CPLDs)** offer much smaller amounts of logic- up to about 10,000 gates. But CPLDs offer very predictable timing characteristics and are therefore ideal for critical control applications. CPLDs series also require extremely low amounts of power and are very inexpensive, making them ideal for cost-sensitive, battery-operated, portable applications such as mobile phones and digital handheld assistants.

6. Explain Commercial Off-the-Shelf (COTS).

- Commercial Off-the-Shelf (COTS) 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 are remote controlled toy car control units including the RT circuitry part, high performance, high frequency microwave electronics (2-200 GHz), high bandwidth analog-to-digital converters, devices and components for operation at very high temperatures, electro-optic IR imaging arrays, UV/IR detectors, etc.
- The major advantage of using COTS is that they are readily available in the market, are cheap and a developer can cut down his/her development time to a great extent. This in turn reduces the time to market your embedded systems.
- Though multiple vendors supply COTS for the same application, the major problem faced by the end user is that there are no operational and manufacturing standards.
- A Commercial off-the-shelf (COTS) component manufactured by a vendor need not have hardware plug-in and firmware interface compatibility with one manufactured by a second - vendor for the same application. This restricts the end-user to stick to a particular vendor for a particular COTS. This greatly affects the product design.
- The major drawback of using COTS components in embedded design is that the manufacturer of the COTS component may withdraw the product or discontinue the production of the COTS at any time if a rapid change in technology occurs, and this will adversely affect a commercial manufacturer of the embedded system which makes use of the specific COTS product.

7. **What is Read-Write Memory? Explain the categories of Read-Write Memory.**

- RAM is the data memory or working memory of the controller/processor. Controller/processor can read from it and write to it.
- RAM is volatile, meaning when the power is turned off, all the contents are destroyed.
- RAM is a direct access memory, meaning we can access the desired memory location directly without the need for traversing through the entire memory locations to reach the desired memory position (i.e. random access of memory location).
- RAM generally falls into three categories: Static RAM (SRAM), dynamic RAM (DRAM) and non-volatile RAM (NVRAM)
    - **Static RAM (SRAM)** Static RAM stores data in the form of voltage. They are made up of flip-flops. Static RAM is the fastest form of RAM available. In typical implementation, an SRAM cell (bit) is realised using six transistors (or 6 MOSFETs). Four of the transistors are used for building the latch (flip-flop) part of the memory cell and two for controlling the access. SRAM is fast in operation due to its resistive networking and switching capabilities.
    - **Dynamic RAM (DRAM)** Dynamic RAM stores data in the form of charge. They are made up of MOS transistor gates. The advantages of DRAM are its high density and low cost compared to SRAM. The disadvantage is that since the information is stored as

charge it gets leaked off with time and to prevent this they need to be refreshed periodically. Special circuits called DRAM controllers are used for the refreshing operation. The refresh operation is done periodically in milliseconds interval. The MOSFET acts as the gate for the incoming and outgoing data whereas the capacitor acts as the bit storage unit.

- **NVRAM Non-volatile RAM** is a random access memory with battery backup. It contains static RAM based memory and a minute battery for providing supply to the memory in the absence of external power supply. The memory and battery are packed together in a single package. NVRAM is used for the non-volatile storage of results of operations or for setting up of flags, etc. The life span of NVRAM is expected to be around 10 years. DS1744 from Maxim/Dallas is an example for 32KB NVRAM.