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A Comparative Analysis of Microcontroller and Microprocessor

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Abstract*: This research paper explores the fundamental distinctions between microcontrollers and microprocessors. Focusing on key characteristics such as processing power, memory, and peripheral integration, the study aims to provide a clear understanding of their individual strengths and weaknesses. Even the pin diagram of 8086 and 8051 are explained briefly. This paper consists of various advantages and applications of microcontroller and microprocessor..*

Keywords: Microcontroller 8051, Microprocessor 8086, ALU, Registers, BUS Architecture, I/O ports

I. INTRODUCTION

Both microprocessors and microcontrollers are types electronic devices that come in the form of integrated circuits (ICs) and are used in different modern electronic equipment such as computers, laptops, washing machines, air conditioners, and many other automated electronic gadgets. The primary function of both microprocessors and microcontrollers is to automate the processes.

A) Microcontroller: A Microcontroller is a compact tiny computer that is fabricated inside a chip and is used in automatic control systems including security systems, office machines, power tools, alarming system, traffic light control, washing machine, and much more. It is economical programmable logic control that can be interfaced with external devices in order to control the devices from a distance.The microcontroller includes a CPU,ROM,RAM,I/O ports. Timer like a standard computer but because they are designed to execute only a single specific task to control a single system they are much smaller and simplified so that they can include all the function required on a single chip. Microcontrollers are sometimes called embedded microcontrollers, which just means that they are part of an embedded system that is, one part of a larger device or system.

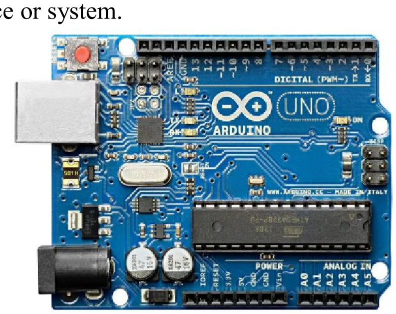

Fig1:Microcontroller

B) Microprocessor: A microprocessor is a computer processor that incorporates the functions of a central processing unit on a single integrated circuit (IC),or sometimes up to 8 integrated circuits. The microprocessoris a multipurpose, clock driven, register based, digital integrated circuit that accepts binary data as input, processes it according to instructions stored in its memory and provides results (also in binary form) as output. In short, it is a controlling unit of micro-computer, fabricated on a small chip capable of performing ALU operation and communicating with the other

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devices connected to it. Microprocessor consists of an ALU , register array ,and a control unit. ALU performs arithmetical and logical operations on the data received from the memory or an input device. Register array consists of registers identified by letter like B,C,D,E,H,L and accumulator. The control unit controls the flow of data and instructions within the computer.

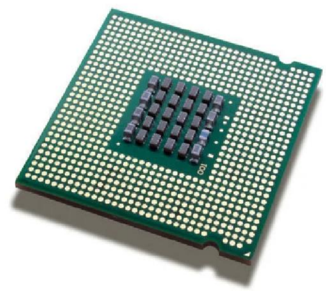

Fig 2: Microprocessor

II. ARCHITECTURE

A) Microcontroller: In 1981, Intel Corporation introduced an 8-bit microcontroller called the 8051. This microcontroller had 128 bytes of RAM, 4K bytes of on-chip ROM, two timers, one serial port, and four I/Oports(each of 8 bits wide) all on a single chip. At the time, it was also referred to as a “system-on-chip”. The 8051 is an 8-bit processor, meaning that the CPU can work on only 8 bits of data at a time. Data larger than 8 bits has to be broken into 8 pieces to be processed by the CPU. The 8051 has a total of 4 input-output ports, each 8 bits wide, see the fig3. Although the 8051 can have a maximum of 64K bytes on-chip ROM, many manufacturers have put only 4K bytes on the chip.

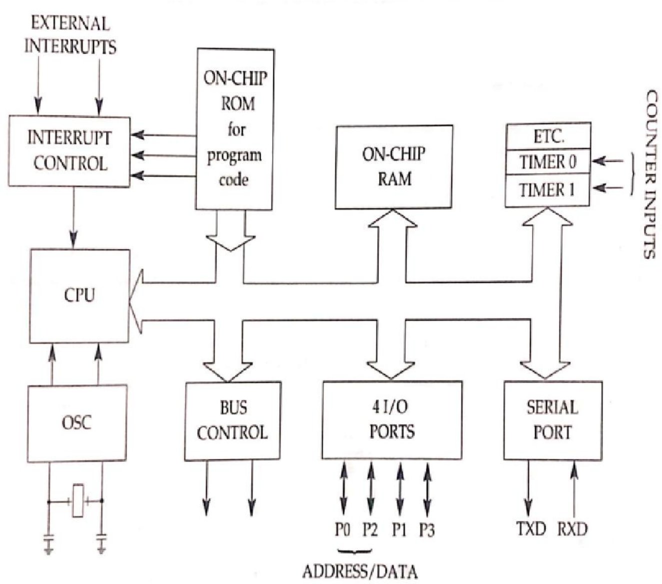

Fig 3: Architecture of 8051 Microcontroller

i) Interrupt Control: In the interrupt method, whenever any device needs its service, the device notifies the microcontroller by sending it an interrupt signal. Upon receiving an interrupt signal, the microcontroller interrupts whatever it is doing and serves the device. The program associated with the interrupt is called as the interrupt service routine(ISR)or interrupt handler. The interrupt control supports five interrupt sources which can interrupt the normal program execution to perform specific event. The five interrupts are INT0,INT1,TF0,TF1 and Serial Communication Interrupt.

ii) Central Processing Unit(CPU): This is the brain of the microcontroller, which is responsible for executing instructions and performing arithmetic and logical operations. The 8051 CPU consists of an ALU, accumulator, registers, and a program counter.

iii) OSC: It requires an external oscillator to provide a clock signal to the microcontroller

iv) Bus control: The 8051 microcontroller includes a bus controller that manages data transfer between the CPU and peripheral devices, such as memory or input/output devices. Bus is a group of wires which uses as a communication canalor acts as means of data transfer. There are two types of bus used in 8051 microcontroller that are Address busi.e.it consist of 16 bit address bus and generally be used for transmitting the data from CPU to Memory and Data bus i.e. it consists of 8 bit data bus and generally be used for transferring data from onr peripheral to other.

v) 4k byte ROM: The 8051 microcontroller architecture includes a 4 kilobyte (4k) read-only memory (ROM) for storing the program instructions that are executed by the CPU.

vi) 128-byte RAM: The 8051 microcontroller also has a 128-byte random-access memory (RAM) for storing data that is used by the program instructions during runtime.

vii) I/O Ports: They have four 8-bit input/output (I/O) ports that can be configured as either input or output.

viii) Timers and Counters: They have two 16-bit timers/counters that can be used for a variety of tasks such as measuring time intervals, generating PWM signals, and counting external events.

ix) Serial Port: It has a built-in serial port that can be used for asynchronous serial communication.

B) Microprocessor:8086 Microprocessor is an enhanced version of 8085 Microprocessor that was designed by Intel in 1976. It is a 16-bit Microprocessor having 20 address lines and16 data lines that provides up to 1MB storage. It consists of powerful instruction set, which provides operations like multiplication and division easily. The 8086 contains two independent functional units, a Bus Interface Unit (BIU) and an Execution Unit (EU. The General Purpose Register, Stack Pointer, Base Pointer, Index Register, ALU, Flag Register, Instruction Decoder and Timing and Control Unit constitute the Execution Unit (EU). The Segment Register, Instruction Pointer and 6-byte Instruction Queue are associated with the Bus Interface Unit(BIU)..The following fig4 illustrate the architecture of 8086 microprocessor.

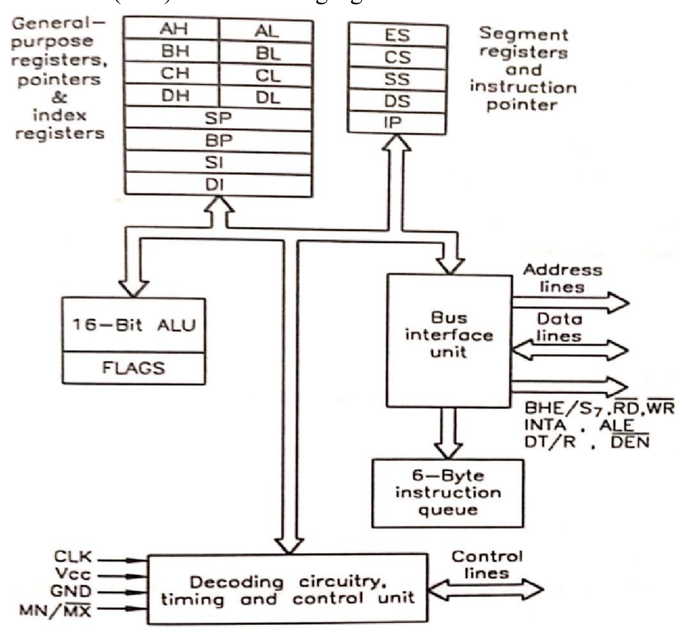

Fig 4: Architecture of 8086 Microprocessor

Bus Interface Unit(BIU):

The BIU handles transfer of data and addresses between the processor and memory input-output devices. It computes and sends out addresses, fetches instruction codes, stores fetched instruction codes in a first-in-first-out register set called as queue, reads data from memory input-output devices, writes data to memory and input-output devices. It relocates addresses of operands since it gets unrelocated operands addresses from EU. The execution unit tells BIU from where to fetch the instruction or to read data.

It has the following functional parts:

Instruction Queue:

When EU executes instructions, the BIU gets 6-bytes of the next instruction and stores them in the instruction queue and this process is known as instruction pre fetch. This process increases the speed of the processor.

Segment Registers:

A segment register contains the addresses of instructions and data in memory which are used by the processor to access memory locations. It points to the starting address of a memory segment currently being used.

There are 4 segment registers in 8086 as given below:

- Code Segment Register (CS): Code segment of the memory holds instruction codes of a program.
- Data Segment Register (DS): The data, variables and constants given in the program are held in the data segment of the memory.
- Stack Segment Register (SS): Stack segment holds addresses and data of subroutines. It also holds the contents of registers and memory locations given in PUSH instruction.
- Extra Segment Register (ES): Extra segment holds the destination addresses of some data of certain string instructions.
- Instruction Pointer (IP): The instruction pointer in the 8086 microprocessor acts as a program counter. It indicates to the address of the next instruction to be executed.

Execution Unit (EU) :

The EU receives opcode of an instruction from the queue, decodes it and then executes it. While Execution, unit decodes or executes an instruction, then the BIU fetches instruction codes from the memory and stores them in the queue. The BIU and EU operate in parallel independently. This makes processing faster.General purpose registers, stack pointer, base pointer and index registers, ALU, flag registers (FLAGS), instruction decoder and timing and control unit constitute execution unit (EU).

It has the following functional parts:

General Purpose Registers:

There are four 16-bit general purpose registers: AX (Accumulator Register), BX (Base Register), CX (Counter) and DX. Each of these 16-bit registers are further subdivided into 8-bit registers as shown below:

Table 1: 16-bit General Purpose Registers

16-bit registers	8-bit high-order registers	8-bit low-order registers
AX	AH	AL
BX	BH	BL
CX	CH	CL
DX	DH	DL

Index Register:

The following four registers are in the group of pointer and index registers:

Stack Pointer (SP)

Base Pointer (BP)

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Source Index (SI)
Destination Index (DI)

ALU:
It handles all arithmetic and logical operations. Such as addition, subtraction, multiplication, division, AND, OR, NOT operations.

Flag Register:
It is a 16?bit register which exactly behaves like a flip-flop, means it changes states according to the result stored in the accumulator. It has 9 flags and they are divided into 2 groups i.e. conditional and control flags.

Conditional Flags:
This flag represents the result of the last arithmetic or logical instruction executed. Conditional flags are:
Carry Flag
Auxiliary Flag
Parity Flag
Zero Flag
Sign Flag
Overflow Flag
Control Flags:
It controls the operations of the execution unit. Control flags are:
Trap Flag
Interrupt Flag
Direction Flag

III. PIN DIAGRAM

A) Microcontroller:
The pin diagram of 8051 microcontroller looks as follows −

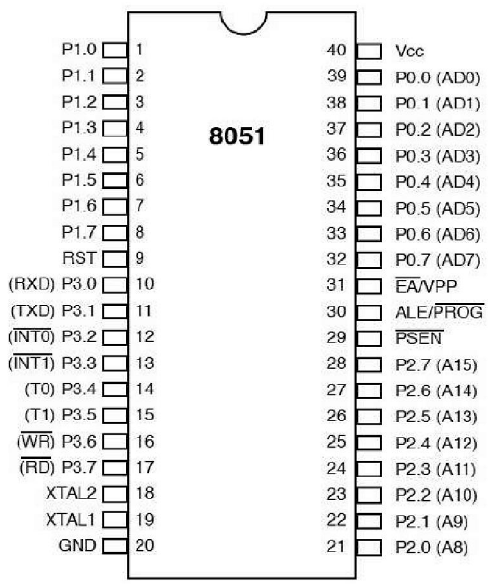

Fig5: 8051 Pin Diagram

Pins 1 to 8 − These pins are known as Port 1. This port doesn't serve any other functions. It is internally pulled up, bi-directional I/O port.

Pin 9 − It is a RESET pin, which is used to reset the microcontroller to its initial values.

Pins 10 to 17 − These pins are known as Port 3. This port serves some functions like interrupts, timer input, control signals, serial communication signals RxD and TxD, etc.

Pins 18 & 19 − These pins are used for interfacing an external crystal to get the system clock.

Pin 20 − This pin provides the power supply to the circuit.

Pins 21 to 28 − These pins are known as Port 2. It serves as I/O port. Higher order address bus signals are also multiplexed using this port.

Pin 29 − This is PSEN pin which stands for Program Store Enable. It is used to read a signal from the external program memory.

Pin 30 − This is EA pin which stands for External Access input. It is used to enable/disable the external memory interfacing.

Pin 31 − This is ALE pin which stands for Address Latch Enable. It is used to demultiplex the address-data signal of port.

Pins 32 to 39 − These pins are known as Port 0. It serves as I/O port. Lower order address and data bus signals are multiplexed using this port.

Pin 40 − This pin is used to provide power supply to the circuit.

B) Microprocessor:

8086 is designed to operate in two modes, i.e., Minimum and Maximum mode.

The pin diagram of 8086 microprocessor looks as follows −

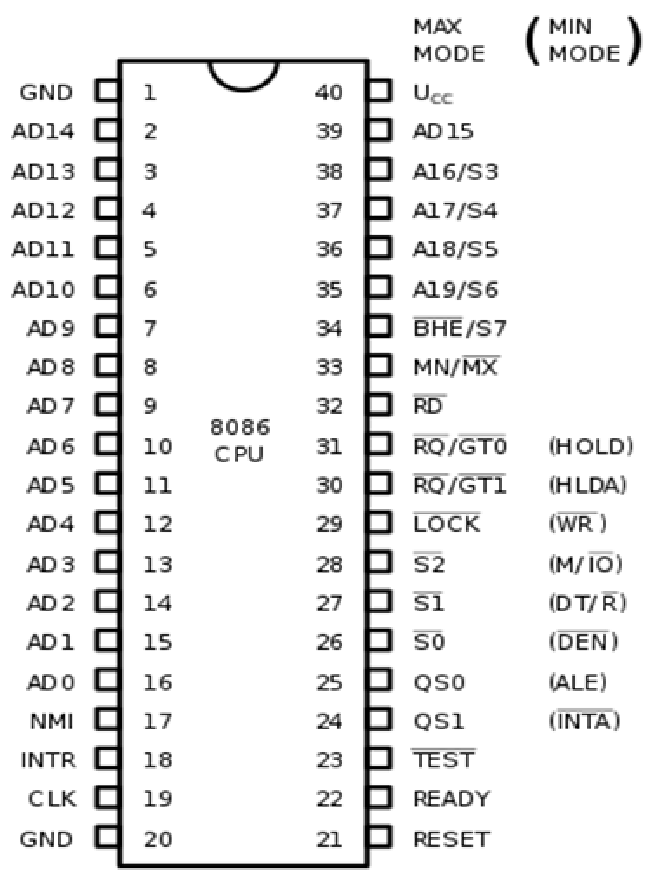

Fig 6: 8086 Pin diagram

The description of the pins of 8086 is as follows:

AD0-AD15 (Address Data Bus): Bidirectional address/data lines. These are low order address bus. They are multiplexed with data.

When these lines are used to transmit memory address, the symbol A is used instead of AD, for example, A0- A15.

A16 - A19 (Output): High order address lines. These are multiplexed with status signals.

A16/S3, A17/S4: A16 and A17 are multiplexed with segment identifier signals S3 and S4.

A18/S5: A18 is multiplexed with interrupt status S5.

A19/S6: A19 is multiplexed with status signal S6.

BHE/S7 (Output): Bus High Enable/Status. During T1, it is low. It enables the data onto the most significant half of data bus, D8-D15. 8-bit device connected to upper half of the data bus use BHE signal. It is multiplexed with status signal S7. S7 signal is available during T3 and T4.

RD (Read): For read operation. It is an output signal. It is active when LOW.

Ready (Input): The addressed memory or I/O sends acknowledgment through this pin. When HIGH, it denotes that the peripheral is ready to transfer data.

RESET (Input): System reset. The signal is active HIGH.

CLK (input): Clock 5, 8 or 10 MHz.

INTR: Interrupt Request.

NMI (Input): Non-maskable interrupt request.

TEST (Input): Wait for test control. When LOW the microprocessor continues execution otherwise waits.

VCC: Power supply +5V dc.

GND: Ground.

Pin Description for Minimum Mode

In this minimum mode of operation, the pin MN/MX is connected to 5V D.C. supply i.e. MN/MX = VCC.

The description about the pins from 24 to 31 for the minimum mode is as follows:

INTA (Output): Pin number 24 interrupts acknowledgement. On receiving interrupt signal, the processor issues an interrupt acknowledgment signal. It is active LOW.

ALE (Output): Pin no. 25. Address latch enable. It goes HIGH during T1. The microprocessor 8086 sends this signal to latch the address into the Intel 8282/8283 latch.

DEN (Output): Pin no. 26. Data Enable. When Intel 8287/8286 octal bus transceiver is used this signal. It is active LOW.

DT/R (output): Pin No. 27 data Transmit/Receives. When Intel 8287/8286 octal bus transceiver is used this signal controls the direction of data flow through the transceiver. When it is HIGH, data is sent out. When it is LOW, data is received.

M/IO (Output): Pin no. 28, Memory or I/O access. When this signal is HIGH, the CPU wants to access memory. When this signal is LOW, the CPU wants to access I/O device.

WR (Output): Pin no. 29, Write. When this signal is LOW, the CPU performs memory or I/O write operation.

HLDA (Output): Pin no. 30, Hold Acknowledgment. It is sent by the processor when it receives HOLD signal. It is active HIGH signal. When HOLD is removed HLDA goes LOW.

HOLD (Input): Pin no. 31, Hold. When another device in microcomputer system wants to use the address and data bus, it sends HOLD request to CPU through this pin. It is an active HIGH signal.

Pin Description for Maximum Mode

In the maximum mode of operation, the pin MN/¯MX is made LOW. It is grounded. The description about the pins from 24 to 31 is as follows:

QS1, QS0 (Output): Pin numbers 24, 25, Instruction Queue Status. Logics are given below:

Table 2: Logic for Queue Status

QS1	QS2	Operation
0	0	No operation

0	1	1st byte of opcode from queue.
1	0	Empty the queue
1	1	Subsequent byte from queue

S0, S1, S2 **(Output):** Pin numbers 26, 27, 28 Status Signals. These signals are connected to the bus controller of Intel 8288. This bus controller generates memory and I/O access control signals. Logics for status signal are given below:

Table3: Logics for status signals

S2	S1	S0	Operation
0	0	0	Interrupt acknowledgement
0	0	1	Read data from I/O port
0	1	0	Write data from I/O port
0	1	1	Halt
1	0	0	Opcode fetch
1	0	1	Memory read
1	1	0	Memory write
1	1	1	Passive state

LOCK (Output): Pin no. 29. It is an active LOW signal. When this signal is LOW, all interrupts are masked and no HOLD request is granted. In a multiprocessor system all other processors are informed through this signal that they should not ask the CPU for relinquishing the bus control.

RG/GT1, RQ/GT0 (Bidirectional): Pin numbers 30, 31, Local Bus Priority Control. Other processors ask the CPU by these lines to release the local bus.

In the maximum mode of operation signals WR, ALE, DEN, DT/R etc. are not available directly from the processor. These signals are available from the controller 8288.

IV. DIFFERENCE

The following table highlights all the important differences between microprocessors and microcontrollers –

Parameter	**Microcontroller**	**Microprocessor**
Definition	Microcontrollers can be understood as the heart of an embedded system.	Microprocessors can be understood as the heart of a computer system.
What is it?	A microcontroller is a controlling device wherein the memory and I/O output component are present internally.	A microprocessor is a processor where the memory and I/O component are connected externally.
Circuit complexity	Microcontrollers are present on chip memory. The circuit is less complex.	The circuit is complex due to external connection.
Memory and I/O components	The memory and I/O components are available.	The memory and I/O components are to be connected externally.
Compact system compatibility	Microcontrollers can be used with a compact system.	Microprocessors can't be used in compact system
Efficiency	Microcontrollers are efficient.	Microprocessors are not efficient.
Zero status flag	Microcontroller doesn't have a zero status flag.	Microprocessors have a zero status flag.
Number of registers	Microcontrollers have more number of registers.	Microprocessors have less number of registers.
Applications	Microcontrollers are generally used in washing machines, and air conditioners.	Microprocessors are generally used in personal computers.

V. ADVANTAGES

A) Microcontroller:

The following are advantages of the microcontroller:-

a) Low time required for performing operation.

b) It is easy to use, troubleshooting and system maintenance is straightforward.

c) At an equivalent time, many tasks are often performed therefore the human effect are often saved.

d) Processor chip is extremely small and adaptability occurs.

e) Cost and size of the system is less.

f) Microcontroller is straightforward to interface additional RAM, ROM, and I/O port.

g) Once microcontroller is programmed then they can't be reprogrammed.

h) Small size: Microcontrollers are small and compact, which makes them well-suited for use in small electronic devices and systems.

i) Low power consumption: Microcontrollers are designed to be energy-efficient, which can extend the battery life of electronic devices and systems.

j) Cost-effective: Microcontrollers are generally less expensive than other types of computer chips, which can make them a cost-effective choice for manufacturers.

k) Real-time processing: Microcontrollers are designed to perform real-time processing, which is important for devices that require rapid response times, such as in automotive and aerospace applications.

B) Microprocessor:

The following are advantages of the microprocessor:-

a) Microprocessor helps to perform all complex arithmetically and logically instructions.

b) Microprocessor has more power to execute 3-4 billion instructions in one second, and it measure in Hertz.

c) Microprocessor is able to transfer huge data one memory location to other location.

d) Microprocessor can be performed floating point number in few milliseconds.

e) Microprocessor is generic product, means it can be used in various electronic processing devices.

f) Microprocessor helps to provide accessibility for controlling of couple of equipments with in time sharing.

g) Microprocessor is able to multiprocessing and Parallel Processing.

h) Easy to modification.

i) Low cost.

j) Better Reliability and Versatility

VI. APPLICATIONS

A) Microcontroller:

Microcontrollers are used in a wide variety of applications, including controlling machines, sensing and monitoring devices, and automated systems. Some common examples of microcontroller applications include:

- **Industrial automation:** Microcontrollers are commonly used to control industrial machines, such as robotic arms, conveyor belts, and other manufacturing equipment.
- **Automotive:** Microcontrollers are used in automobiles to control a variety of systems, including the engine, transmission, and brakes.
- **Home appliances:** Many household appliances, such as washing machines, refrigerators, and microwave ovens, contain microcontrollers to control their various functions.
- **Consumer electronics:** Microcontrollers are used in a wide range of consumer electronics, including smartphones, tablets, and other portable devices.
- **Medical devices:** Microcontrollers are used in a variety of medical devices, such as heart rate monitors, blood pressure monitors, and insulin pumps.
- **Military systems:** Microcontrollers are used in military systems, such as missiles, aircraft, and other defense systems.

- **Environmental monitoring:** Microcontrollers are used in sensors and other devices that monitor environmental conditions, such as temperature, humidity, and air quality.
- **Robotics:** Microcontrollers are used in robots to control their movements and perform various tasks.
- **Internet of Things (IoT):** Microcontrollers are used in IoT devices to collect and transmit data, and to control various functions.

B) Microprocessor:

1. Smartphones, tablets, and other mobile devices all rely on microprocessors to function. They execute instructions, process data, and perform various operations to make these devices work.
2. It is used in every computer, ranging from personal computers to supercomputers. All the instruction execution and operational execution work are done by microprocessors present inside them.
3. It is used in automobiles to control a wide range of functions including engine management, and entertainment systems.
4. Computers are used in database management and storing data through the internet. Microprocessors present inside the computing device store and manage the data according to the instructions given to it.
5. It is used in lift control, Traffic light control, fuel control of furnaces in power plants, etc.
6. It is used in robots, video games, smart cameras, etc.
7. Microprocessors having a single chip are known as microcontrollers, which are used for automatic control. For example, It is used to measure and control the temperature of the furnace and oven, the speed of the running car, the pressure of the boiler, etc.
8. Microprocessors are used in various aerospace applications, including aircraft navigation, guidance systems, and flight control systems.
9. It plays an important role in server management where it executes millions of data stores and retrieves instructions in milliseconds.

Fig 7: Applications of Microcontroller and Microprocessor

VII. CONCLUSION

In conclusion, our comparative analysis delved into various aspects of microcontrollers and microprocessors, shedding light on their unique characteristics and applications. Microcontrollers, with their integrated peripherals and specialized design, are optimal for tasks demanding real-time processing, making them ideal for embedded systems like IoT devices and robotics. On the other hand, microprocessors, with their broader processing capabilities, suit general-purpose computing needs, excelling in tasks such as data processing and multitasking.

Cost considerations play a pivotal role in the decision-making process, as microcontrollers often present a more economical solution for specific applications due to their targeted functionalities. Power consumption emerged as a crucial factor, with microcontrollers generally consuming less power, making them suitable for battery-powered and energy-efficient devices.

Furthermore, the analysis highlighted the significance of performance metrics, illustrating how microprocessors outshine microcontrollers in raw computational power. This is particularly advantageous in scenarios where computational complexity is a priority, such as in personal computers or servers.

As technology advances, the boundary between microcontrollers and microprocessors continues to blur, with hybrid solutions and integrated systems becoming more prevalent. The evolving landscape emphasizes the need for developers and engineers to adapt their choices based on the evolving demands of specific applications, considering factors like scalability, ease of programming, and the rapidly changing landscape of both microcontrollers and microprocessors in the realm of embedded systems and general-purpose computing.

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