MCTE 4342 EMBEDDED SYSTEM DESIGN

ASSIGNMENT 1

COMPARATIVE ANALYSIS OF MICROCONTROLLERS, MICROPROCESSORS, AND EMBEDDED SYSTEMS IN MECHATRONICS

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1. Introduction

This assignment will analyse the components of microprocessors, microcontrollers, and embedded systems. It will also review an in-depth analysis of microcontrollers, microprocessors and the strengths and limitations on how their integration to embedded systems.

1.1. Microcontrollers

A microcontroller is a single micro-computer that is designed to control specific tasks within the electronic system. A microcontroller could combine the functions of the central processing unit, memory, and I/O interfaces, all on a single chip.

1.2. Microprocessors

A microprocessor is a processor that performs arithmetic and logical operations to obtain the desired output. A typical microprocessor contains the ALU, registers and control unit, all connected by an internal bus.

1.3. Embedded System

According to Russell and Thornton, an embedded system is an electronic system that has a controller that is hidden to the end user. This controller is usually 'embedded' into the system that users do not know the presence of said controller.

1.4. Importance to Mechatronics

For the microcontroller, the importance of these components in mechatronics are real-time processing. This type of processing is very important as if the system cannot respond to different situations, it can have catastrophic consequences. For the microprocessor, the processing power is crucial due to the processor being able to solve complex algorithms

and instructions in the shortest amount of time. Embedded systems are also important to mechatronics due to the integration between hardware and software. This can help program the system according to the user's needs and improve system performance using only programming software.

2. Microcontrollers

The key components that are included in the microcontroller are:

- Central Processing Unit (CPU): The CPU is the main processor of the device. It is the component that can help compute instructions that are sent to the processor such as arithmetic and logic operations, and I/O operations.
- Memory: The memory that is used to store data and instructions inside the microcontroller and responds to programmed instructions. There are two types of memory in the microcontroller, which are program memory, and data memory. Program memory is the memory used to store data and information for long periods of time, as the memory type is non-volatile. Data memory is a temporary data storage that holds data while the program is being executed, as the memory is volatile.
- I/O peripherals: The input/output peripherals are the interfaces between the processor and the outside world. The input ports are usually sensors that convert energy to be sent to the processor as an electrical signal. The processed data will be sent to the output ports as an electrical signal to an output port. The output port are actuators that convert the electrical signal to another form of energy, and produce an output.

These components can be arranged into specific architectures according to the manufacturer. The architectural example of a microcontroller that will be used is the

Atmel ATMEGA328P. This microcontroller uses a modified Harvard architecture. A typical Harvard architecture contains storage and signal paths that are separated for instruction and data. This causes the CPU to be able to fetch instructions while also being able read or write data at the same time. However, in the context of the Atmel microcontroller, a modified Harvard architecture is used, where the instructions inside the memory can also be used as data. Figure 1 shows the architecture of the Atmel microcontroller.

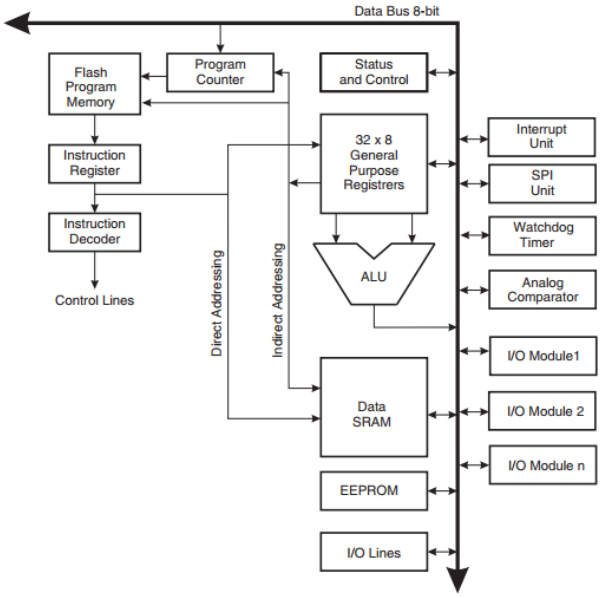

Figure 1: The architecture of Atmel ATMEGA328P

There are many applications of mechatronic systems that can use the microcontroller. These applications are:

- Small robots: Microcontrollers are used to control movement of small robots that require low power consumption.
- Home appliances: Microcontrollers are used for home appliances that require specific functions that help with daily chores.
- Medical devices: Microcontrollers are used for specific devices used in the medical industry such as surgical devices, diseases and therapy.

Among the advantages of using the microcontroller are:

- Size. The microcontroller is very small and can be used in small mechatronic systems.
- Cost. Due to less amount of circuitry, the microcontroller is cheaper compared to a microprocessor.
- Real-time processing. Microcontrollers are designed to operate with real-time processing, which is necessary for mechatronic based systems.

Among the limitations of using the microcontroller are:

- Operating voltage. Due to the miniscule size of the microcontroller, it is not recommended to use it on circuits using high voltage.
- Structure. Microcontroller uses a complex structure
- Processing power: Microcontroller lower processing power than other computer chips, which can inhibit their ability to perform complex tasks.

3. Microprocessors

Stallings have defined the components of the microprocessor, which are:

- Control Unit: Controls all of the operation of the CPU, and the entire computer.
- Arithmetic and Logic Unit (ALU): Performs the CPU processing functions such as arithmetic calculations and logic
- Registers: Stores a small amount of data in a CPU

- CPU Interconnection: Mechanism for communication between the control unit, ALU and the registers.

The microprocessor that will be used as an example is the Intel 8086 microprocessor. Figure 2 shows the architecture of the microprocessor:

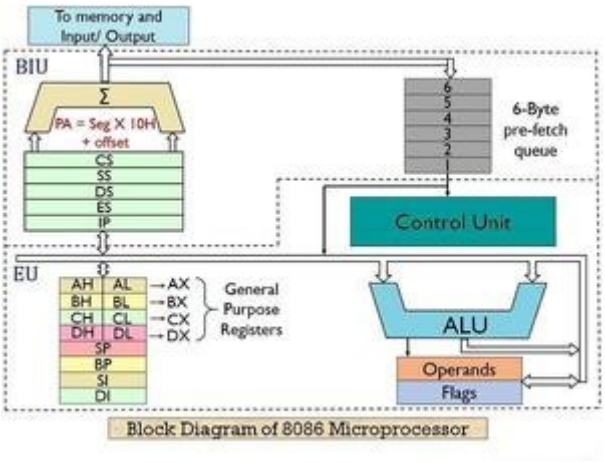

Figure 2: Intel 8086 architecture

Typical applications of microprocessors in mechatronics are:

- Automotive systems: Microprocessors are used to control various mechanical systems inside the automotive such as engine, transmission, and suspension.
- Control systems: Microprocessors are used to control systems in robotics to control various manufacturing processes.
- Aerospace: Microprocessors are used in aerospace equipment such as drones and UAVs.

Advantages of microprocessors in mechatronics are:

- Processing speed: Microprocessors have a much faster processing speed which determines the number of instructions that can be completed per second

- Handling complex tasks: Microprocessors can handle more complex tasks due to most microprocessors using the CISC architecture. Thus, it can be used to many computing applications.
- Data transfer speed: Microprocessors are able to transfer more data due to the presence of registers on the CPU.

Limitations of microprocessors in mechatronics are:

- Cost: Microprocessors are more expensive due to the number of cores that are included in the processors.
- External peripherals: Microprocessors require external components to work such as memory and I/O peripherals.

4. Comparison between Microprocessors and Microcontrollers

Microprocessors	Comparison	Microcontrollers
Higher processing power	Processing Power	Lower processing power
More expensive	Cost	Cheaper
Support high power usage	Power Usage	Support low power usage
Used in much larger mechatronic applications	Applications	Used in smaller mechatronic applications
Requires external peripherals	Peripherals	Peripherals are connected on the same board (internal)
Can support large amount of memory	Memory	Only supports a small amount of memory

Choosing the correct type of processor would depend on a few important factors such as:

- Complexity of the system: A microprocessor would be more preferable if the system has complex instructions and algorithms.
- Cost: A microcontroller would be more preferable if the system needs to be created on a tight budget.
- Memory: A microprocessor would be necessary to hold large data and information.

5. Case Studies

For small applications using a microcontroller, there are many case studies that are available. One example is Nasreldin et. Al. has used a PID controller that can be used to define the speed of a DC motor. The PID controller is implemented using an Arduino UNO, that contains an Atmel Microcontroller. The system uses an optical encoder to track the input speed as feedback to the system and compare with the reference speed to determine the controller input's error signal [1]. This case study chose the microcontroller due to the lower voltage required to turn on the DC motor. Figure 4 shows the block diagram of the closed loop PID control system.

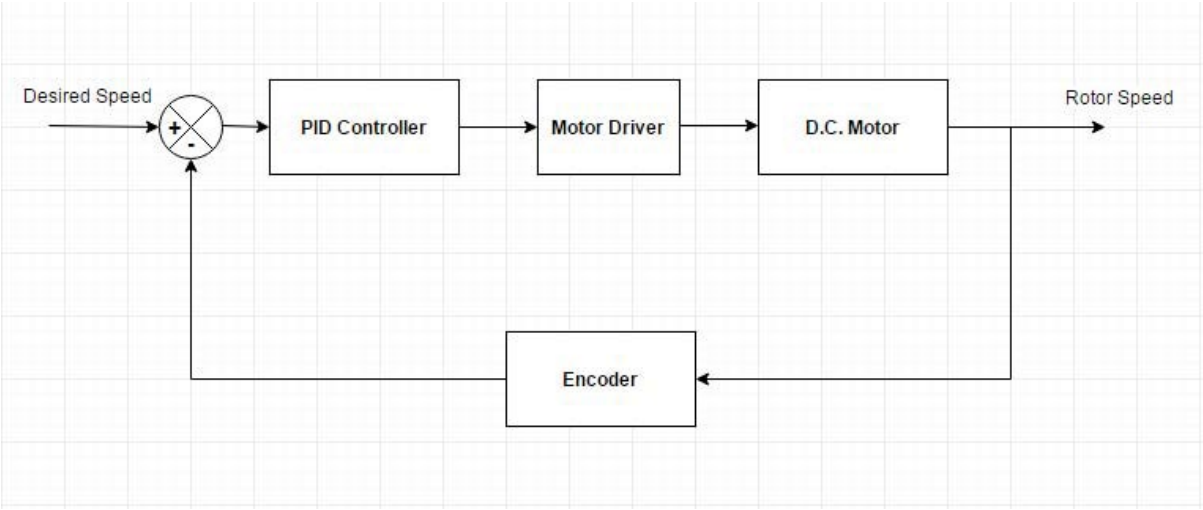

Figure 4: Block diagram of PID control system.

For a microprocessor included mechatronic system, Mondal et. Al. created a color detection robotic arm. They used a specific camera sensor to detect colors that will work with an independent microprocessor. The microprocessor is used due the usage of color-filtering algorithm according to the hue, which requires a lot of processing power [2]. Figure 5 shows the block diagram of their works.

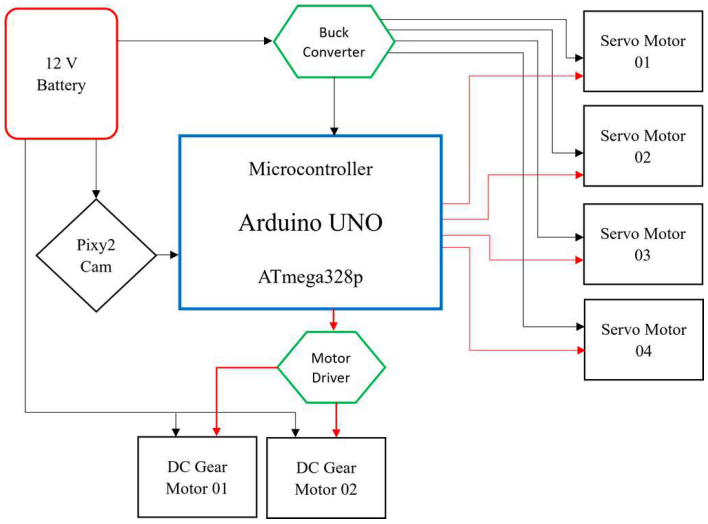

Figure 5: Block diagram of robotic arm.

6. Conclusion

In a nutshell, there were key differences in microprocessors and microcontrollers in the context of embedded systems. Microprocessors are used in larger, and more complex systems, while microcontrollers are used in smaller, and simpler systems. The choice between choosing a microprocessor and microcontroller depends on the embedded system according to the user, where it can depend of the complexity of the software, and the cost to manufacture the embedded system. It is also worth noting that building an embedded system using a microprocessor may require to by external peripherals such as memory and I/O peripherals, which can increase the cost a lot more. Therefore, user's specifications

must be defined before determining the ‘brain’ that will be used for making an embedded system.

7. References

[1] N. M. A. Mohamed, A. A. A. Abdalaziz, A. A. Ahmed, and A. A. A. Ahmed, “Implementation of a PID control system on microcontroller (DC motor case study),” *Proceedings - 2017 International Conference on Communication, Control, Computing and Electronics Engineering, ICCCCEE 2017*, no. 1, pp. 1–5, 2017, doi: 10.1109/ICCCCEE.2017.7866088.

[2] S. Mondal, N. F. Sharon, K. M. Tabassum, U. H. Muna, and N. Alam, “Development of a Low-Cost Real Time Color Detection Capable Robotic Arm,” *2023 26th International Conference on Computer and Information Technology (ICCIT)*, no. December, pp. 1–6, 2023, doi: 10.1109/ICCIT60459.2023.10441038.