

# An Overview of Microcontroller Unit: From Proper Selection to Specific Application

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**Abstract**— It is very difficult to choose a particular Microcontroller for specific application. Success or failure of any project largely depends on proper selection of the Microcontroller Unit. In this paper a brief overview of the unit is described as far as the right selection for particular application is concerned. So many manufactures are producing microcontroller in bulk amount. Comparison is based on products of few leading manufactures. System requirements, availability, performance, size, power dissipation, flexibility, Reliability, Maintainability, Environmental constraints, software support, correctness, safety, Cost, manufacturer's history and track records are the vital factors to be considered whenever a system is to be implemented using a microcontroller which is the heart of the device. In this paper several factors are focused and follow up of those factors leads to success of the project.

**Index Terms**—Assembler, Compiler, Debugger, IDE, In-System-Programming, Microcontroller, On-Chip ROM.

## I. INTRODUCTION

With the advancement of semiconductor fabrication technology manufacturers are able to integrate memory, input/output interfacing circuits, Timer, Serial Com port and Analog to Digital Converter and other peripherals into the microcontroller. Thus it is essentially an entire chip fabricated on a single chip. The single chip microcontrollers are used in consumer products like washing machines, copiers, AC machines, printers etc., high speed data processing like video conference, real time compression and security system, image processing etc., automotive systems like electronic power steering system, antilock braking systems etc., Different industrial applications like AC and DC motor Drives, position control, motion control etc. Due to integration of all function blocks on a single chip microcontroller IC, the sizes of control board and power consumption are reduced; system reliability increased and also provides flexibility [3-4]. The other advantages of using such microcontroller based systems are easy troubleshooting and maintenance. All of the above mentioned fields of applications depend on the several factors of choosing the right microcontroller unit for specific applications. This paper gives an overview of the critical consideration of the factors fulfilling the system specification by reducing the total cost which includes the cost of manufacturing, warranty, Research and Development, after sale service, maintenance, replacement etc.

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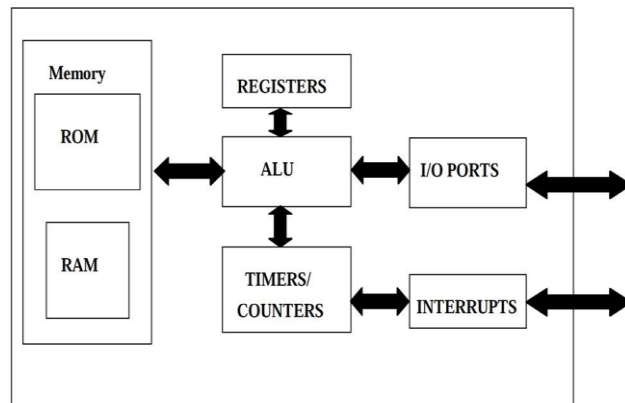


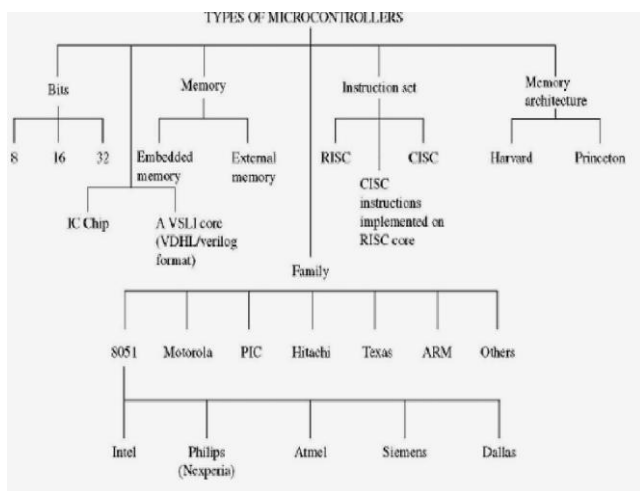
Fig. 1: Schematic Block Diagram of Microcontroller

## II. CLASSIFICATION BASED ON ARCHITECTURE

In 1993, the introduction of EEPROM allowed microcontrollers (beginning with the Microchip PIC16x840) to be electrically erased quickly. It allows both rapid prototyping and In-System-Programming (ISP). The same year, the first microcontroller using Flash memory was introduced by Atmel. 4-bit to 32-bit microcontrollers are available in the market. Based on the number of bits it is broadly classified into four different categories i.e., 4-bit, 8-bit, 16-bit and 32-bit microcontrollers. 4-bit microcontrollers are extensively used in electronic toys. 8-bit microcontrollers are generally used in various control applications such as position control, speed control and any process control system. The 16-bit microcontroller are designed and developed for the purpose of high speed control application such as servo control system, robotics etc. Programming of such microcontroller can be achieved either by high level programming language or by assembly language programming. For very high speed operations in robotics, image processing, automobiles, intelligent control system and telecommunications 32-bit microcontrollers are used. Typical examples of MCU are the Intel MCS48, 51 and 96 families, the Motorola MC68HC11 family and the Zilog z8. Most of these MCUs have an 8-bit word size (except the MCS-96 with a 16-bit word size), at least 64 bytes of R/W memory and 1 KB of ROM. The range of I/O line varies from 16 to 40 lines.

## III. TYPES OF MICROCONTROLLER WITH EXAMPLES

There are several vendors manufacturing different architectures of microcontroller. Intel's 8051, Freescale's 6811, PIC 16X from Microchip Technology, Zilog's Z8 are four major 8-bit microcontrollers. Due to their unique instruction set and register set they are not compatible with each other. Program written for one will not run through the other microcontroller from other manufacturers [1, 7].



**Fig. 2: Classification of Microcontroller**

Table I shows such a list of architecture and the leading manufacturers of different microcontroller for different applications [10].

**Table I: List of Manufacturers and their Products**

Manufacturers/Vendors	Products
Atmel	AT89 series (Intel 8051 architecture), AT90, ATtiny, ATmega, ATmega series (AVR architecture), AT91SAM (ARM architecture), AVR32 (32-bit AVR architecture), MARC4
Dallas Semiconductor	8051 family, MAXQ RISC family, Secure Micros family
ELAN Microelectronic Corp.	EM78PXXX Low pin-Count and GPIO Type, EM78PXXXN ADC Type
EPSON Semiconductor	SIC6x family (4-bit), SIC88 family (8-bit), SIC17 family (16-bit), SIC33 family (32-bit)
Freescale Semiconductor	68HC05, 68HC08, 68HC11 (8-bit), 68HC12, 68HC16 (16-bit), 683XX, MCF5xxx, M-core, MPC500, MPC860 (32-bit)
Holtek	HT48FXX flash I/O type, HT48RXX I/O type, HT46RXX A/D type Series
Intel	MCS-48, MCS-51, 8xC251 (8-bit), MCS-96, Intel MCS-296
Microchip Technology	PIC10, PIC12, PIC16 series, PIC18 series (8-bit), PIC24, dsPIC (16-bit), PIC32MX series
NXP Semiconductor	80C51 (8-bit), XA (16-bit), ARM7/LPC2000, ARM9/LPC3000, ARM Cortex-M0/LPC800, LPC1100, LPC1200, ARM Cortex-M3/LPC1300, LPC1700, LPC1800, ARM Cortex-M4/LPC4300
National Semiconductor	COP400, COP8, SC/MP, CR16
ST Microelectronics	ST6, ST7, STM8, uPSD (8-bit), ST10 (16-bit), ST20, ARM7/STR7, ARM9/STR9, ARM Cortex-M0/STM32 F0, ARM Cortex-M3/STM32 F1, F2, ARM Cortex-M4/STM32 F4
Texas Instruments	TMS370 (8-bit), MSP430 (16-bit), TMS 320, ARM Cortex-R4/TMS570 (32-bit)
Zilog	Zilog eZ8, Zilog eZ80, Zilog Z16
Maxim Integrated	8051, ARM922T, MAXQ20, MAXQ30, MIPS4kSD
NEC	78K, 75X, 17K, MPD78C14, V25, V850

## IV. COMMONLY USED MICROCONTROLLERS AND THEIR FEATURES

A microcontroller is a single integrated circuit, have some important features. Central Processing unit ranges from 4 bit processor to 32 or 64 bit processors. It has Volatile RAM for data storage, ROM, EPROM, EEPROM, Flash memory for programming as well as storage of the processing parameters, Bi-directional I/O pins allowing control and detection of logic state, UART, Serial communication Interfaces like I2C, Serial peripheral interface and controller area network for system interconnect, peripherals like timer, counter, PWM generator, watchdog timer, clock generator, ADC, DAC and finally in circuit programming and debugging support [9, 11].

**Table II: MCUs and their features**

Commonly Used MCU	Features
Intel 8051	It is under 8-bit Microcontroller family. Rom ranges from None to 8KB, RAM Size of 128 or 256 bytes (depending on the specific part number). Clock frequency is up to 12 MHz. Ultra violet light erases data and special electrical programmer writes new data. Architectures consist of four bi-directional I/O ports of 8 bits each.
Microchip PIC16C5X/XX	This 8 bit microcontroller family is manufactured by Microchip Technology. Though lower running clock frequency saves energy but maximum clock speed is limited to 40 MHz. Architecture includes 512 bytes to 2K bytes of ROM, 25 to 73 bytes of RAM, 8 bit real time counter, programmable sleep mode and watchdog timer.
Freescale 68HC11	This is under another 8 bit microcontroller family. Either UV erasable or electrically erasable ROM is used here. RAM is in the order of none to 768 bytes of size. They run at clock speeds range up to 3 MHz. Eight 8 bit A to D converters are also embedded for monitoring analog signals.
Atmel AT89CXXXX	ROM used here are of Flash type and size ranges from 1KB to 8 KB. To 256 bytes of RAM. Maximum clock speed is up to 20 MHz. They have 15 to 32 number of bi-directional I/O pins, 1 to 3 number of Timers, 3 to 8 numbers of Interrupts.
Dallas Semiconductor DS89C4XXX, DS5000, DS80C320, DS87520	They use both Flash type and UVROM type ROM. Size ranges from Zero to 64 KB. RAM ranges from 128 bytes to 256 bytes. Total 32 no of bi-directional I/O pins form 4 different ports. 2 to 3 timers and 6 interrupts are available.
Philips Corporation	Major producer of 8051 family. The products includes A to D converters, D to A converters, extended I/O pins, OTP and Flash type ROM.
Texas Instruments ARM Stellaris LM4F	Combines the features of 16 bit and 32 bit. It includes differ type of memory, including 2 KB of electrically erasable ROM, 256 KB of Flash and preloaded software libraries as factory programmed ROM. It runs at clock speed up to 80 MHz. It supports not only universal serial bus 2.0 but also RS-232 data communications.
Zilog Older: Z8, Z180 Newer: eZ8, eZ80, Z16	Z8 has 8 bit Harvard architecture ROM/EPROM/OTP microcontroller with on-chip SRAM. eZ8 has better pipelined Z8 therefore 2-3 times as clock efficient as original Z8 with on-chip flash memory and SRAM. Z16 has fast 8/16/32 bit CPU with compact object code, 16 MB (4 GB possible) addressing range, flash, SRAM, peripherals on-chip

## V. CRITERIA FOR CHOOSING A MICROCONTROLLER

Choosing a microcontroller from a number of different microcontrollers is a very critical decision for the designers. Three are the vital major criteria for selecting them. These are (a) wide availability and reliable sources (b) meeting the requirements efficiently and cost effectively (c) availability of the software development tools like compilers, Assemblers and debuggers etc [1]. The following steps should be followed during selection of the MCU.

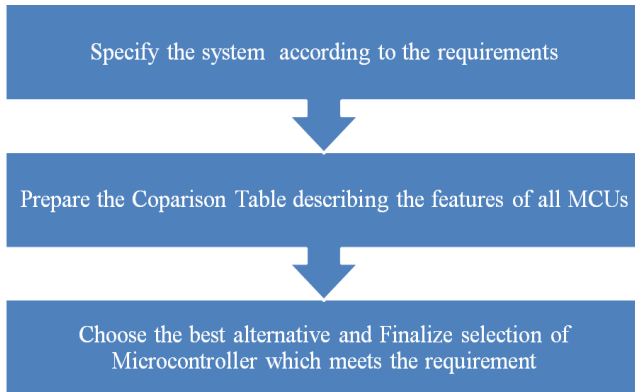


Fig. 3: Selection Process flow

The main criteria in selecting a microcontroller are given below in the order of importance.

### A. System Requirement

Design should start with a blank sheet of paper specifying the application needs, if the system requires a single chip MCU or additional peripherals are to be used with it. Selection process starts with a decision of choosing either the 4-bit, 8-bit, 16-bit or 32-bit microcontroller required by the application. To develop code for 4-bit architectures is harder and handling 4-bit instructions and data widths can limit arithmetic capabilities. Most of the embedded applications are implemented using 8-bit microcontroller as the technology has been around a long time and huge number of controllers is available in the market. They are used from low cost, low speed 4-bit micro replacement to device which deliver tens of MIPS, such as Atmel's AVR series which achieves a 50 ns instruction cycle time when clocked from a 20 MHz crystal. If the application needs more processing power the choice is most likely to be 16-bit or 32-bit MCU. Vendors offer 32-bit performance cost effectively. 32-bit devices come at virtually no cost to the user.

The on chip peripherals available exhibit heavy influence on component selection. Check the availability of Timers, Serial interfaces, ROM, RAM, A/D converter, D/A converter sufficient number of I/O ports. Too many I/O ports lead to bear excessive cost but few cannot do the job [5-6].

### B. Memory Architecture

This is very important factor while designing any microcontroller based system. Three different types of memory play an important role in the selection process are (a) program memory i.e. Flash, OTP, ROM and ROM less components, (b) Data memory i.e. on-chip SRAM or external SDRAM and (c) Non volatile Memory i.e. EEPROM or Flash. Whether the memory is on-chip or off-chip and how much the size is required may be a key factor defines cost of building the system and speed of operation. For an example Atmel AVR family include Flash memory of 1KB to 128KB,

on chip SRAM for data storage and for the storage of configuration information and serial numbers a few bytes of EEPROM are reserved. These golden features make the AVR family more popular in different applications. Flash gives the flexibility to make code changes and provides facility to use In-System-Programmed. Atmel 89C51 and Mega AVR families have the segmented Flash blocks which allows reprogram one segment under control of another segment, without removing the power [6].

Lastly it is best to choose a device from a family which provides sufficient or more memory space than the expectation of need.

### C. Availability

Before going to implement the system, the availability of the device should be checked. The criteria in choosing microcontroller is its ready availability in needed quantities both now and future. If sufficient quantities are available with bright future then no need to be worried about the failure of the project.

### D. Size

If IC of 15 I/O pins is required to develop the system there is no need to use 40 pin IC with 32 I/O pins. In this way the size of the IC can be reduced and thus physical space required to implement the system is also reduced. So, physical size of IC may well be critical factor for specific applications.

### E. Compatibility

The function of a system can be changed or upgraded by changing the software or replacing one IC with another one without incurring heavy additional cost. The new one will be pin compatible as well as function compatible.

### F. Functionality Testing

To check the function of the implemented system correctly the function of the MCU should be checked within the test circuit designed earlier before going to develop the overall system.

### G. Power Management

More power means more heat dissipation which leads to wastage of energy. Power consumed by the system determines the lifetime of the battery. Due to reduction in size of the devices the size of the components are reduced and their placement within the design is very compact. This phenomenon makes the devices to be sensitive to the heat dissipated from the MCU and the other peripherals connected with it. It is the duty of an engineer to look first at the power required at the clock speed necessary to run the application. ROM based devices tolerate very low operating voltages (around 0.9v). In case of Atmel AVR devices Flash based microcontroller can be operated at the voltages down to 1.8V. Most microcontrollers have the features of power down, idle & sleep modes and consideration needs to be given to maximize the use of intelligent power management systems to reduce power consumption [6].

### H. Manufacturer's Track Record

Manufacturers should ensure the stability, good performance, better throughput, Reliability; better Serviceability, software support, correctness, wide and timely availability of their products. For an example product of Intel, Freescale, Zilog, and Microchip Technology are stable, mature and single sourced. The points like design challenges, on time delivery, performance, years in business



and year of transaction, financial report should be followed as the track record of the manufacturers. They must provide the datasheet or user guide which consists of characteristics, functionality, sample test circuit, electrical characteristics and dimension etc. The documentation of maintenance of the development system, the range of services and its associated software must be available for the common user [5].

## I. Manufacturer's Support

During the step by step implementation of the system if the design engineer faces any kind of problem he/she may communicate with the marketing/sales, field application engineers. The manufacturers should have some facilities like a help line, toll free number, fax number, after-sales support, sufficient knowledgeable and helpful expertise support personnel who will give a prompt reply or they will follow through in a regular manner when they promise to do something.

## J. Availability of Development Support

Here the key consideration includes Assembler, Debugger, a code efficient C compiler, emulator, technical support. Trend towards programming in high level language like C is increasing day by day. This language allows using of some portability of code and libraries. This provides more practical consideration using different microcontroller family. Choosing the appropriate Hardware and software development tools is also important while selecting MCU. An integrated development environment (IDE) facilitates the development efforts by providing the project management tools. IDE enables to create source files and their organization in to a project, creation of database for many devices. An example of IDE is Keil uVision 2 which compiles to point out and correct the errors, assembles and links the device datasheet, user guides and development tool manuals. Another good example is MPLAB for PIC and dsPIC microcontrollers from Microchip Technology. This is mainly used for development of embedded systems [8].

## K. Cost

This is the most important factor. If the system is to be implemented within the limit of the budget calculated earlier the cost of each and every component (selected MCU along with supporting ICs) used to build the system should be minimized tactfully to fulfill the requirements. On chip features will trade with inventory and assembly cost of using extra supporting external components. They can also cut development time and effort by providing a ready integrated solution [6].

Design of special hardware requires non recurring engineering cost and cost for manufacturing the unit. Integration of some peripherals like 10/100 base T Ethernet MACs, CAN bus interfaces, USB, RF transmitter and graphics driver cuts the system cost in some great extent. For high volume applications most users prefer ROM based devices due to their lower cost and code security.

## VI. CONCLUSION

This paper presents various criteria to select MCU and the application note will enumerate most of them. The decision is not so easy and it will become critical as the technology is upgrading rapidly. Few guidelines of choosing the right one have been focused here. Anyone can include other grading scale and their personal decision. So the selection process is not restricted to the views and thoughts highlighted in this paper.

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## REFERENCES

- [1] M. A. Mazidi, J.G. Mazidi, R. D. Mckinlay, "The 8051 Microcontroller and Embedded Systems: using Assembly and C", Pearson Education, Inc., 2<sup>nd</sup> edition 1999.
- [2] Takawira F., Dawoud D.S., "Selecting the Right Microcontroller Unit", Zimb. J. Sci. Technol., Vol. 4, no. 1, p 39-46
- [3] Gonzales D.R., "Understanding the Key Architectural Features of a Microcontroller", Available at : <http://www.dedicatedsystem.com>
- [4] Gajski, Daniel D., Principles of Digital Design. Englewood Cliffs, NJ: Prentice-Hall, 1997.
- [5] "Selecting the Microcontroller Unit", Freescale Semiconductor, Application Note Available at: [http://www.freescale.com/files/microcontrollers/doc/app\\_note/AN1057.pdf](http://www.freescale.com/files/microcontrollers/doc/app_note/AN1057.pdf)
- [6] Technical Guide to Microcontroller Selection, "Microcontrollers: options and trends in today's applications", Wednesday, January 25, 2006 Available at website: [http://fr.farnell.com/images/en/ede/pdf/micro\\_tech.pdf](http://fr.farnell.com/images/en/ede/pdf/micro_tech.pdf)
- [7] Types of Microcontroller: Application note available at: <http://my.safaribooksonline.com/book/electrical-engineering/semiconductor-technology/9788131759905/types-selection-and-applications-of-microcontrollers/ch001#X2ludGVybmlFsX0h0bWxWaWV3P3htbGlkPTk3ODgxMzE3>
- [8] Selection of a microcontroller: <http://my.safaribooksonline.com/book/electrical-engineering/semiconductor-technology/9788131759905/types-selection-and-applications-of-microcontrollers/ch001#X2ludGVybmlFsX0h0bWxWaWV3P3htbGlkPTk3ODgxMzE3NTk5MDUIM>
- [9] "Comparison of Microcontroller", Documentation available at [www.ehow.com/info\\_12184119\\_comparison-microcontrollers.html](http://www.ehow.com/info_12184119_comparison-microcontrollers.html)
- [10] "List of Microcontrollers", Software documentation – Available: [http://en.wikipedia.org/wiki/List\\_of\\_common\\_microcontrollers](http://en.wikipedia.org/wiki/List_of_common_microcontrollers)
- [11] "Software documentation – Available: <http://en.wikipedia.org/wiki/Microcontroller>", November, 2009.