ICT 5307: Embedded System Design

Lecture 1
Introduction

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BUET

Introduction

- Microprocessor has revolutionized various industries and our day-to-day life
- Its use in control, monitoring, measuremant and signal processing has made a breakthrough in electronic industry
- Now-a-days you won't be able to name one electronic device in which microprocessor or its derivative has not been used
- This course is designed to make you familiar with this remarkable piece of wonder

Historical Backgroud

- 1949: Invention of Transistor
- 1959 : Invention of Integrated Circuit
- 1971: Invention of uP
- 1976: Invention of first uC

Invention of Transistor

- In 1947, Willium Schockley and his colleagues in Bell laboratory invented transistor
- That introduced a new era in electronic industry
- Transistor is being used in all electronic circuits replacing its rival vacuum tube
- Vacuum tubes are bulky, consumes lots of power, unreliable, occupies lots of space etc.
- So, a lot of research and development efforts were put in the area of solid state electronics
- The basic idea was that semiconductor materials like germenium, silicon can carry currents and the current can be controlled by the injuction of some impurity

Invention of Integrated Circuit

- Very soon in 1959, another invention made revolution in electronic industry
- Some scientists in Fairchild Semiconductor invented planner technology of transistors which ultimately led to the invention of Integrated Circuit Technology
- An integrated circuit is one in which a number of transistors or components can be fabricated in a single silicon wafer
- The rate of production of IC was progressed rapidly over next few years

Evolution of IC Technology

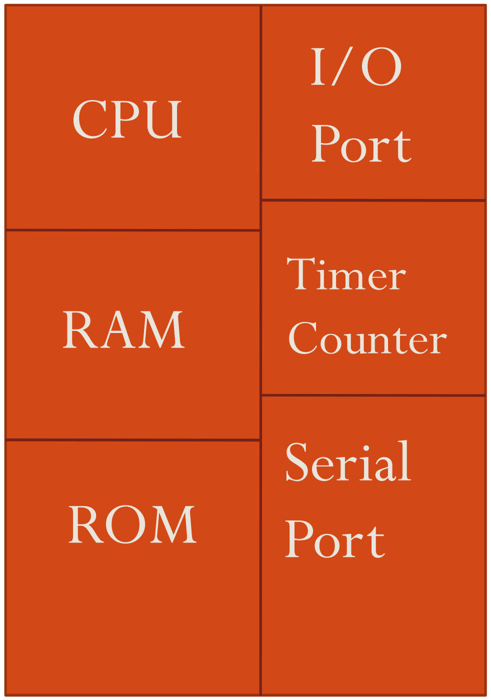
Year	Technology	Number of Devices	Typical Products
1947	Invention of Transistor	1	Transistor
1950-1960	Discrete Components	1	Junction Diode and Transistor
1961-1965	SSI	10-100	Planner Devices, Logic Gates, FFs
1966-1970	MSI	100-1000	Counter, MUX, Decoders
1971-1979	LSI	1000-20000	8-bit uP, RAM, ROM, DSP, RISC
1980-1984	VLSI	20000-50000	16-bit, 32-bit uP
1985-	ULSI	Greater than 50000	64 bit uP

Evolution of Microprocessor

- In 1971, first microprocessor was developed by Intel, this particular device is 4 bit uP called 4004
- By microprocessor we mean that all the components one finds in a CPU (ALU, Register, Timing & Control Unit and the Interfacing circuits) are put together in a single chip
- That is a uP can be considered as "CPU in a Chip"
- Other companies like Texus Instruments, Fairchild etc have started manufacturing uP
- The reason was that although 4004 was developed for making calculator but they found its potential for making any intiligent electronic system

Evolution of Microcontroller

- Very soon in 1976 first microcontroller was produced again by Intel, 8048
- Microcontroller is somewhat different from microprocessor in a sense that not only the CPU but also RAM, ROM, I/O Ports, Timer & Counter, Serial Port all put together in a single chip
- So, it is called as "Computer on a chip"

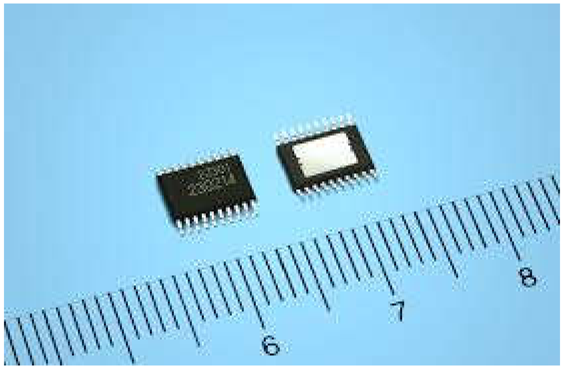


Why uP and uC are so popular?

- Small Size
- Lower Cost
- Higher Reliability
- Lower Power Consumption
- Higher Versatility
- More Powerful

Smaller Size

- A tiny chip can contain hundreds of thousands of transistors and components
- The size of present day microprocessor has now reduced to less than an inch
- With the advent of VLSI technology the microprocessors now come with a large numbers of pins



Lower Cost

- With the advent of complex technology, microprocessor cost does not increase proportionally
- Rather its cost per function has decreased gradually
- As the material cost is negligible in comparison with the initial masking cost, per unit cost decreases as the volume of production increases

Higher Reliability

- With the advent of more sophisticated fabrication technology and testing system microprocessor manufacturing process is now very reliable
- Moreover, the microprocessor based system now-a-days requires less number of chips and so wiring requirement is less making the overall system more reliable

Power consumption

- Present day microprocessors consumes very low power in the order of milliwatt
- This is because of the fact that they are manufactured by transistors using CMOS technology which requires very low power

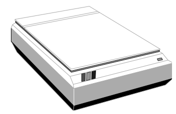
Versatility

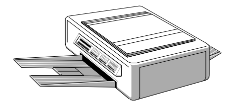
- Since the program stored in a microprocessor system is rewritable hence one system can be reused by loading a new program
- This is especially useful when a new system is being developed. Frequent change in programming is necessary to fix bugs if any

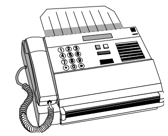
More powerful

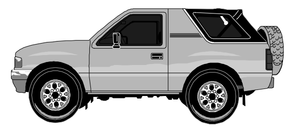
- Present day microprocessor is more powerful than the previous one, w.r.t processing speed, memory and I/O pins
- This becomes possible because of increase in data addressible bit size
- Now 32 bit processor is common in the market
- A 32 bit microprocessor is powerful than the then main frame computer

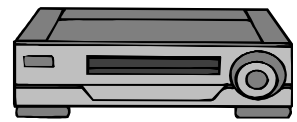
Microprocessor/Microcontroller and some of their applications

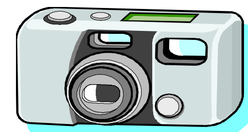


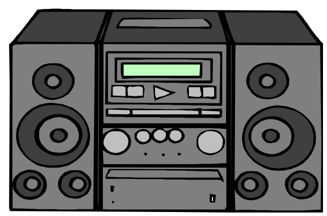


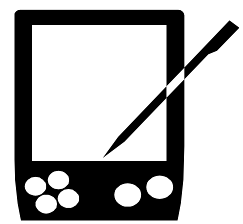


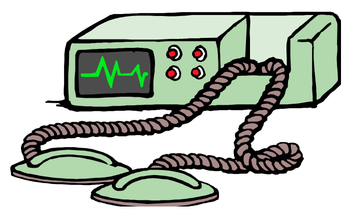


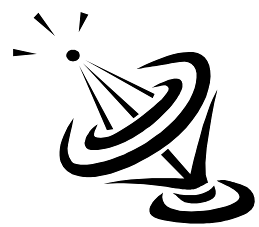


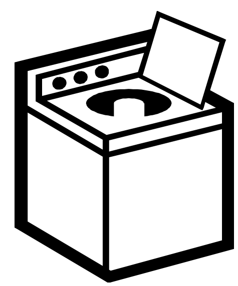












Typical Applications of uP

- Microprocessor is basically a CPU, using CPU general purpose computer can be built
- Desktop computers, PCs, Laptops, Workstations, Servers, Supercomputers
- We are in the era of 32- and 64-bit microprocessor, so we can produce very powerful computers

Typical Application of uC

- Using microcontrollers embedded systems are produced
- An embedded system is a combination of hardware and software built for a specific application
  - Consumer electronics making toys, cameras, camcorders, robots
  - Consumer products - washing machines, microwave ovens etc.
  - Instrumentation - oscilloscopes, various medical equipments,
  - Process control - data aquisition, controlling various industries
  - Communication – Telephone, answering machines
  - Office equipments – Fax, printer, small PABX
  - Micromedia application – Cell phones, PDAs, teleconferencing equipment

Why microcontroller?

- In many applications, the points of consideration are:
  - Space
  - Cost
  - Power consumption
  - Price
- Computing power gets less consideration
- Choice of microcontroller is obvious

Criteria for choosing a microcontroller

- The first and foremost criterion in choosing a microcontroller is that it must meet the task at hand efficiently and cost effectively
- In analyzing the need of a microcontroller based project, we must see whether an 8-bit, 16-bit or 32-bit microcontroller can best handle the computing needs of the task most effectively.

Criteria for choosing a microcontroller (continued)

- Among other considerations in this category are:
  - (a) Speed: What is the highest speed that the microcontroller supports?
  - (b) Packaging: DIP of QFP or any other
  - (c) Power Consumption: critical for battery powered products
  - (d) The amount of ROM and RAM on chip
  - (e) The number of I/O pins and the timers on the chip
  - (f) Upgradability
  - (g) Cost per unit

Criteria for choosing a microcontroller (continued)

- How easy it is to develop product around it – Availability of assembler, debugger, code efficient compiler, emulator, technical support
- Availability : now and in future

Introduction to Atmel AVR

- **Atmel Corporation** is a manufacturer of semiconductors, founded in 1984.
- Atmel introduced the first 8-bit flash microcontroller in 1993, based on the 8051 core.
- In 1996, a design office was started in Trondheim, Norway, to work on the AVR series of products.
- Its products include microcontrollers (including 8051 derivatives and AT91SAM and AT91CAP ARM-based micros), and its own Atmel AVR and AVR32 architectures.

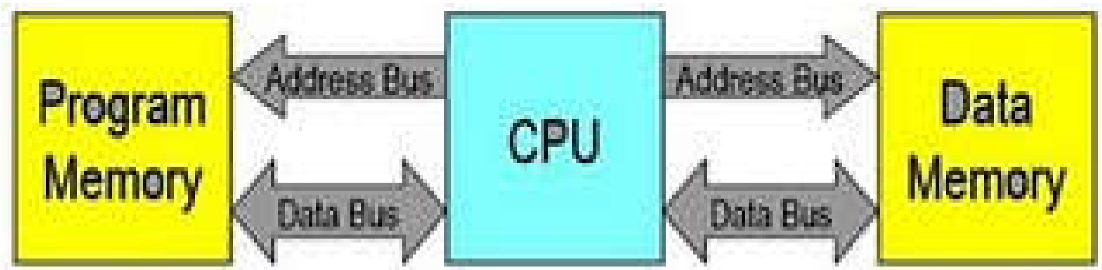
Introduction to Atmel AVR

- The AVR architecture was conceived by two students at the Norwegian Institute of Technology (NTH) Alf-Egil Bogen and Vegard Wollan.
- The AVR is a modified **Harvard** architecture 8-bit **RISC** single chip microcontroller which was developed by Atmel in 1996.
- The AVR was one of the first microcontroller families to use on-chip flash memory for program storage, as opposed to one-time programmable ROM, EPROM, or EEPROM used by other microcontrollers at that time.

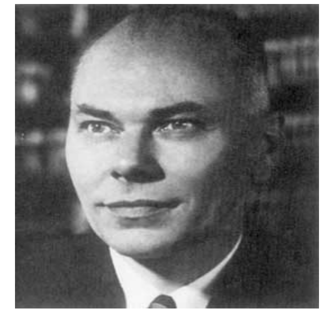
Introduction to Atmel AVR

- The AVR is a modified Harvard architecture machine
  - where program and data is stored in separate physical memory systems that appear in different address spaces,
  - but having the ability to read data items from program memory using special instructions.

Harvard Architecture



Howard Hathaway Aiken

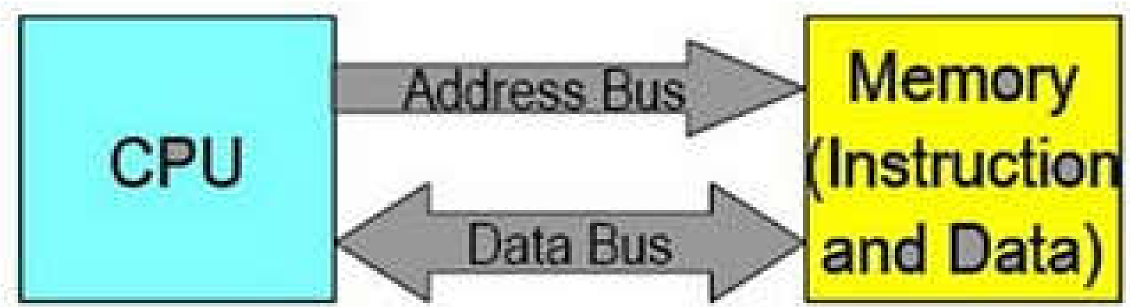


- The **Harvard architecture** is a computer architecture with physically separate storage and signal pathways for instructions and data.
- The term originated from the Harvard Mark I relay-based computer, which stored instructions on punched tape (24 bits wide) and data in electro-mechanical counters.

Harvard Architecture

- In a Harvard architecture, there is no need to make the two memories share characteristics.
- In particular, the word width, timing, implementation technology, and memory address structure can differ.
- In some systems, instructions can be stored in read memory while data memory generally requires read write memory.
- In some systems, there is much more instruction memory than data memory so instruction addresses are wider than data addresses.

Von Neumann Architecture



John von Neumann

- In contrast with the Harvard architecture, the **Von Neumann architecture** has a single storage structure to hold both instructions and data.
- The meaning of the phrase has evolved to mean a stored-program computer in which an instruction fetch and a data operation cannot occur at the same time because they share a common bus.
- This is referred to as the Von Neumann bottleneck and often limits the performance of the system.

Processor ISA: RISC versus CISC

CISC	RISC
Emphasis on hardware	Emphasis on software
Include multi-clock complex instructions	Include single-clock reduce instruction only
Memory-to-memory: “Load” and “Store” incorporated in instructions	Register-to-register: “Load” and “Store” are independent instructions
Small code sizes, high cycles per second	Low cycles per second, large code sizes
Transistors used for storing complex instructions	Spends more transistors on memory registers

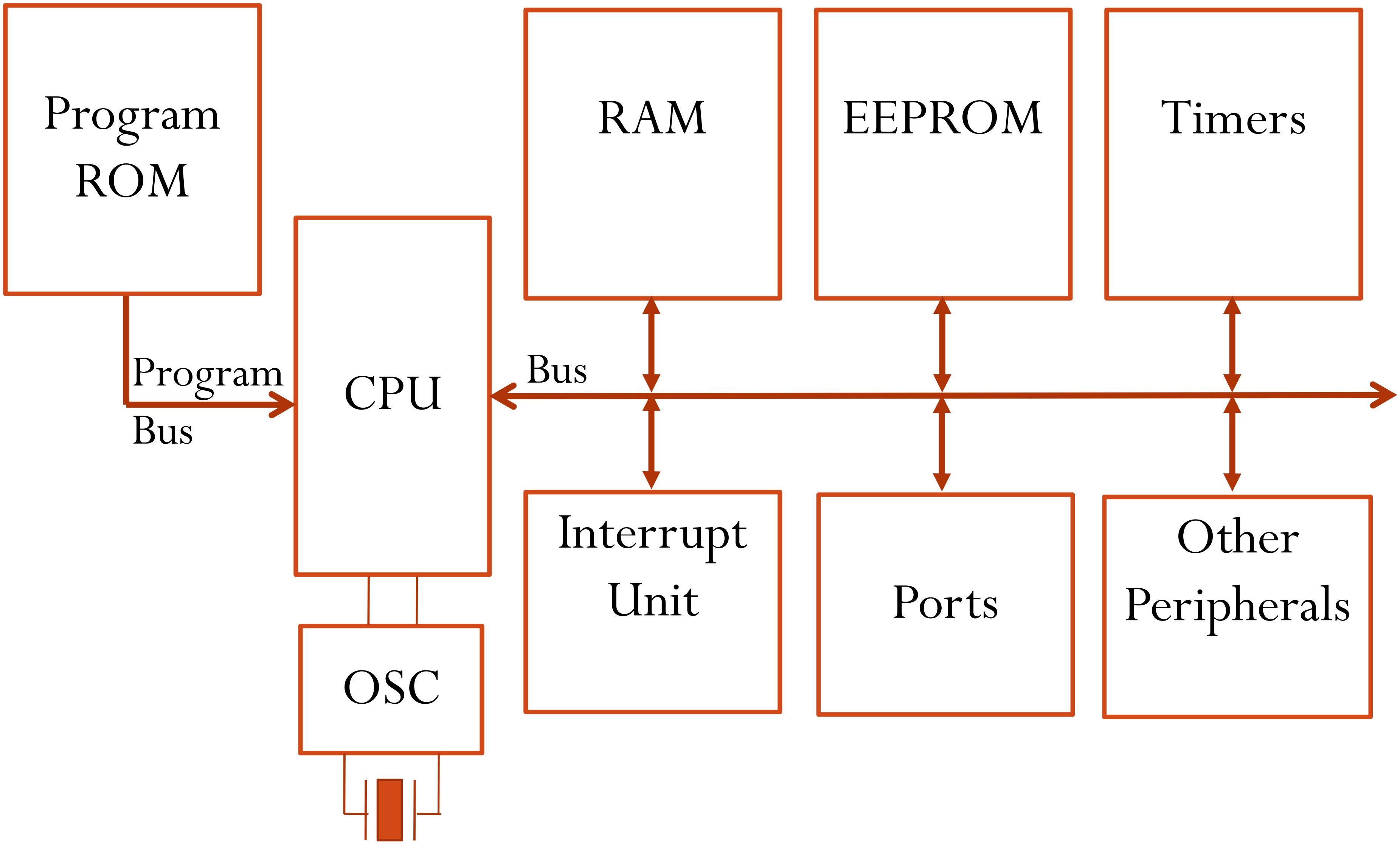
Processor ISA: RISC versus CISC

- Most PCs use CPU based on CISC architecture. For instance Intel and AMD CPU's are based on CISC architectures.
- Many claim that RISC is the architecture of the future.
- But even though RISC has been in the market since 1980, it hasn't managed to kick CISC out of the picture, some argue that if it is really the architecture of the future it should have been able to do this by now.

AVR features

- The AVR is an 8-bit RISC single-chip microcontroller with Harvard Architecture
- They come with some standard features
  - Program (code) ROM
  - Data RAM
  - Data EEPROM
  - Timers
  - I/O ports
- Most AVRs have some additional features like
  - ADC
  - PWM
  - Different Serial Interface such as USART, SPI, I2C (TWI)
  - CAN
  - USB, etc

Simplified View of an AVR Microcontroller



AVR different groups

- **Classic AVR**
  - e.g. AT90S2313, AT90S4433
- **Mega**
  - e.g. ATmega8, ATmega32, ATmega128
- **Tiny**
  - e.g. ATtiny13, ATtiny25
- **Special Purpose AVR**
  - e.g. AT90PWM216,AT90USB1287

Table 1-3: Some Members of the Classic Family

Part Num	Code ROM	Data RAM	Data EEPROM	I/O pins pins	ADC	Timers	Pin numbers & Package
AT90S2313	2K	128	128	15	0	2	SOIC20,PDIP20
AT90S2323	2K	128	128	3	0	1	SOIC8,PDIP8
AT90S4433	4K	128	256	20	6	2	TQFP32,PDIP28

Notes:

1. All ROM, RAM, and EEPROM memories are in bytes.
2. Data RAM (General-Purpose RAM) is the amount of RAM available for data manipulation (scratch pad) in addition to the Registers space.

Table 1-4: Some Members of the Mega Family

Part Num	Code ROM	Data RAM	Data EEPROM	I/O pins pins	ADC	Timers	Pin numbers & Package
ATmega8	8K	1K	0.5K	23	8	3	TQFP32,PDIP28
ATmega16	16K	1K	0.5K	32	8	3	TQFP44,PDIP40
ATmega32	32K	2K	1K	32	8	3	TQFP44,PDIP40
ATmega64	64K	4K	2K	54	8	4	TQFP64,MLF64
ATmega1280	128K	8K	4K	86	16	6	TQFP100,CBGA

Notes:

1. All ROM, RAM, and EEPROM memories are in bytes.
2. Data RAM (General-Purpose RAM) is the amount of RAM available for data manipulation (scratch pad) in addition to the Registers space.
3. All the above chips have USART for serial data transfer.

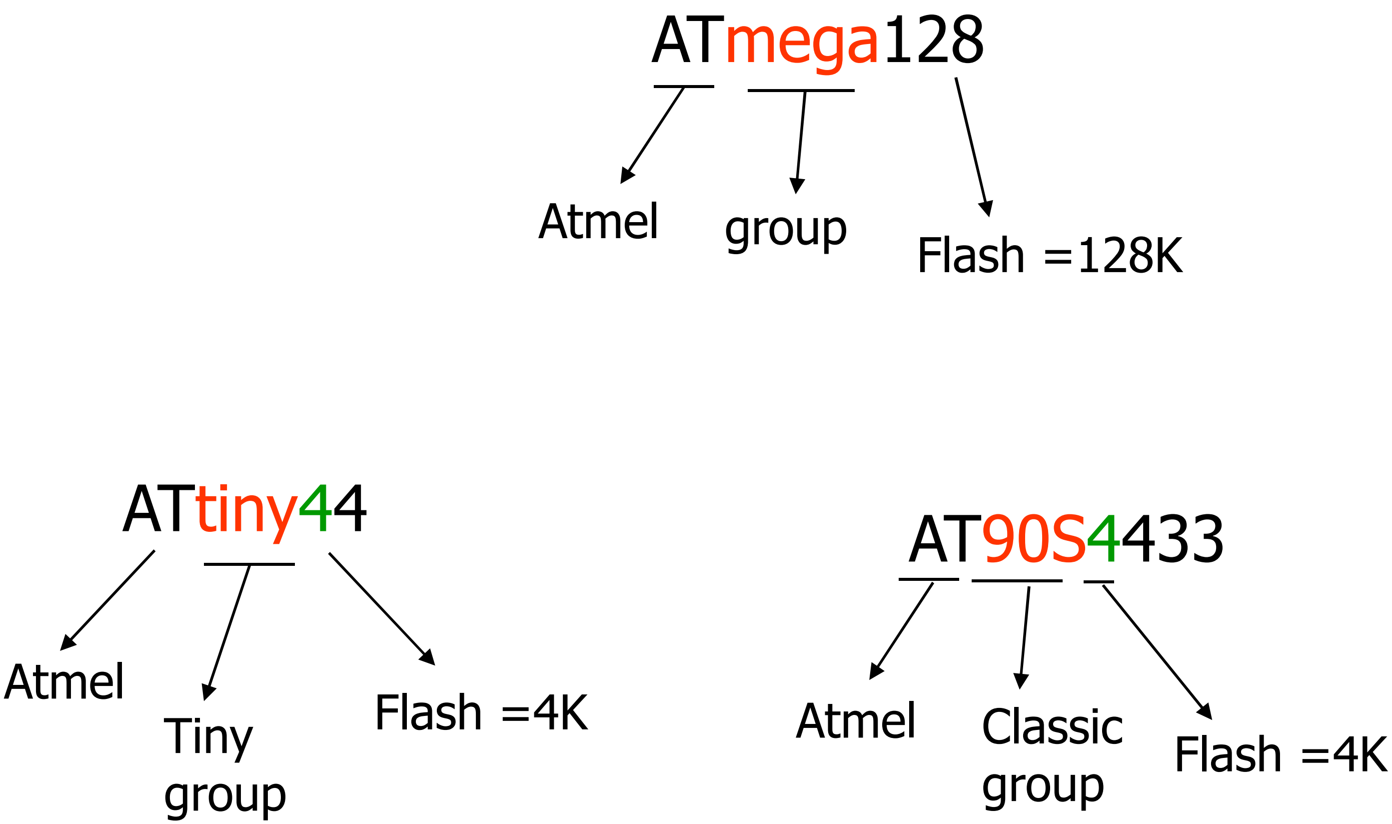
Table 1-5: Some Members of the Tiny Family

Part Num	Code ROM	Data RAM	Data EEPROM	I/O pins pins	ADC	Timers	Pin numbers & Package
ATtiny13	1K	64	64	6	4	1	SOIC8,PDIP8
ATtiny25	2K	128	128	6	4	2	SOIC8,PDIP8
ATtiny44	4K	256	256	12	8	2	SOIC14,PDIP14
ATtiny84	8K	512	512	12	8	2	SOIC14,PDIP14

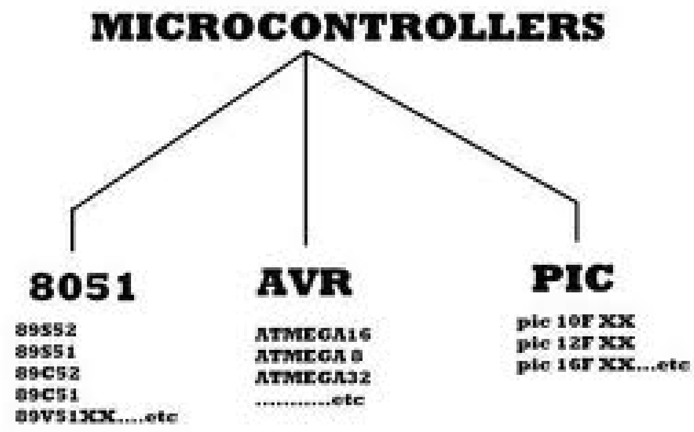
Table 1-6: Some Members of the Special purpose Family

Part Num	Code ROM	Data RAM	Data EEPROM	Max I/O pins	Special Capabilities	Timers	Pin numbers & Package
AT90CAN128	128K	4K	4K	53	CAN	4	LQFP64
AT90USB1287	128K	8K	4K	48	USB Host	4	TQFP64
AT90PWM216	16K	1K	0.5K	19	Advanced PWM	2	SOIC24
ATmega169	16K	1K	0.5K	54	LCD	3	TQFP64,MLF64

Let's get familiar with the AVR part numbers



Other Microcontrollers



- Besides AVR chips there are other 8-bit microcontrollers
- A list containing some examples is provided below:

Part Name	Manufacturer
8051	Intel and a number of Companies
HCS08	Freescale (Formerly MOTOROLA)
PIC	Microchip
Z8	Zilog

- Among all microcontrollers, 8051, AVR and PIC are widely used.

A Comparison between 8052, PIC and AVR

Features	8052	PIC 18F452	ATmega32
Program ROM	8K	32K	32K
Data RAM (max^m space)	256 bytes	2K	2K
EEPROM	0 bytes	256 bytes	1K
Timers	3	4	3
I/O pins	32	35	32

Class Schedule

Class 1: Introduction and AVR Architecture & Organization

Class 2: Program Execution and Input-Output Ports, LCD and 7-Segment Display

Class 3: **Class Test-1**, Subroutine & Stack, Keyboard & Example Programs

Class 4: ADC Operation and Timer/ Counter (1^{st} part)

Class 5: Timer/ Counter (2^{nd} part)

Class 6: **Class Test-2,** Relay, Opto-isolator & Stepper Motor and Revision

Class 7: **Mid Term Exam**

Class 8: Interrupt

Class 9: Serial Communication

Class 10: **Class Test-3** & Issues related to Interfacing

Class 11: DAC, temperature sensor & RTC

Class 12: PWM & DC Motor

Class 13: **Class Test-4** & Revision

Class 14: **Final Examination**

Distribution of Marks for Assessment of this course

- *Attendance – 5%*
- *Class Tests (best 3 out of 4) – 15%*
- *Mid Term – 20%*
- *Project – 20%*
- *Final – 40%*

Special NOTES

- **Course materials**

- **Book Reference**
  - M. A. Mazidi, S. Naimi and S. Naimi : "*The AVR microcontroller and embedded System – Using Assembly and C*", Prentice Hall (PEARSON), 2011.
- **Consultation**
  - Rm #615, on appointment by mob: 01819-276-951 or by sending an email: lutfulkabir82@gmail.com

Thanks