System Architectures

EE5182 Microcontrollers and Embedded Systems

Microprocessor

- A single chip that contains a whole CPU
  - Has the ability to fetch and execute instructions stored in memory
  - Has the ability to access external memory, external I/O and other peripherals
- Examples:
  - Intel Core or AMD Athlon in desktops/notebooks
  - ARM processor in smartphones

History of Microprocessors

- 1950s – The beginning of the digital era and electronic computing
- 1969 – Intel is a small startup company in Santa Clara with 12 employees
  - Fairchild, Motorola are large semiconductor companies;
  - HP and Busicom make calculators
- 1971 – Intel makes first microprocessor the 4-bit 4004 series for Busicom calculators
- 1972 – Intel makes the 8008 series, an 8-bit microprocessor,
  - ATARI is a startup company
  - Creates a gaming console and releases PONG

History of Microprocessors

- 1974 – the first real useful 8-bit microprocessor is released by Intel – the 8080
  - Motorola introduces the 6800 series
  - Zilog has the Z80
- 1975 – GM and Ford begin to put microcontrollers in cars
  - Many cars today have over 100 microcontrollers
  - TI gets into the microprocessor business with calculators and digital watches
- 1977 – Apple II is released using MOS 6502
  - Similar to Motorola 6800
  - Apple II dominated from 1977 to 1983
- 1978 – Intel introduces the first 16-bit processor, the 8086
  - Motorola follows with the 68000 which is ultimately used in the first Apple Macintosh

Microcontroller

- Essentially a microprocessor with on-chip memories and I/O devices
- Designed for specific functions
- All in one solution
  - Reduction in chip count
  - Reduced cost, power, physical size, etc.

Why Study Microcontrollers

- Build useful applications
- Practice programming and debugging skills
- Understand the inside of computer
- It paves the way to learning embedded systems, computer design, operating systems, compilers, security and other topics.
  - Microcontrollers have everything in a typical computer: CPU, memory and I/O

Microcontroller Classifications

- Classification According to Number of Bits
  - 8-bit microcontrollers
    - Intel 8031/8051, PIC1x and Motorola MC68HC11 families
  - 16-bit microcontrollers
    - Performs greater precision and performance as compared to 8-bit
  - 32-bit microcontrollers
    - Used in automatically controlled devices including implantable medical devices, engine control systems, office machines, appliances and other types of embedded systems

Microcontroller Classifications

- Classification According to Memory Devices
  - Embedded memory microcontroller
    - Microcontroller unit has all the functional blocks such as program & data memory, I/O ports, serial communication, counters and timers and interrupts on the chip is an embedded microcontroller.
  - External Memory Microcontroller
    - Microcontroller unit does not have all the functional blocks available on a chip.

Microcontroller Classifications

- Classification According to Memory Architecture
  - Harvard Memory Architecture Microcontroller
    - Microcontroller unit has a dissimilar memory address space for the program and data memory.
  - Princeton Memory Architecture Microcontroller
    - Microcontroller unit has a common memory address for the program memory and data memory.

Princeton vs Harvard Architectures

Princeton Architecture	Harvard Architecture
Processor needs to fetch code in a separate clock cycle and data in another clock cycle. So it requires two clock cycles.	Single clock cycle is sufficient, as separate buses are used to access code and data.
Simple in design.	Complex in design.

Microcontroller Classifications

- Classification According to Instruction Set
  - Complex Instruction Set Computer (CISC)
    - It allows the programmer to use one instruction in place of many simpler instructions.
  - Reduced Instruction set Computer (RISC)
    - It allows each instruction to operate on any register or use any addressing mode and simultaneous access of program and data.

CISC (complex instruction set computer)

- Computers designed with a full set of computer instructions
  - intended to provide needed capabilities in the most efficient way
- Designed to make programming easier
  - either for assembly programmer or compiler programmer
- One instruction = multiple operations = multiple cycles
- Issues:
  - most programs use only small % of available instructions
  - instruction set & chip hardware become more complex with each generation

RISC (reduced instruction set computer)

- Designed to perform a smaller number of types of computer instructions so that it can operate at a higher speed
- Majority of low end and mobile systems use RISC architecture
  - ARM architecture dominates mobile/embedded systems markets

CISC vs RISC

CISC	RISC
Simpler design of compiler, considering larger set of instructions.	Complex design of compiler.
Instruction length is variable.	Instruction length varies.
Emphasis is on hardware.	Emphasis is on software.
Slower execution, as instructions are to be read from memory and decoded by the decoder unit.	Faster execution, as each instruction is to be executed by hardware.

Types of Microcontrollers

- 8051 Microcontroller
  - Developed by Intel in 1980 for use in embedded systems. It has CISC instruction architecture and Harvard memory architecture.
- PIC Microcontroller
  - PIC is a microcontroller, developed by General Instrument's Microelectronics. It has a RISC instruction architecture. Because of it's low cost and high availability, it's widely used globally.
- AVR Microcontroller
  - Developed by Alf-Egil Bogen and Vegard Wollan from Atmel Corporation. It has modified Harvard RISC architecture. The speed of AVR is high when compared to 8051 and PIC.

8051 Microcontrollers

- In 1981, Intel introduced an 8-bit microcontroller called the **8051**.
- It was referred as **system on a chip**.
- It had on a single chip:
  - 128 bytes of RAM
  - 4K byte of on-chip ROM
  - two timers
  - one serial port
  - 4 ports (8-bit wide)
- When it became widely popular, Intel allowed other manufacturers to make and market different flavours of 8051 with its code compatible with 8051.

8051 Family

- **8052 microcontroller** − 8052 has all the standard features of the 8051 microcontroller as well as an extra 128 bytes of RAM and an extra timer. It also has 8K bytes of on-chip program ROM instead of 4K bytes.
- **8031 microcontroller** − This chip is often referred to as a ROM-less 8051. You must add external ROM to it in order to use it, which contains the program to be fetched and executed. This program can be as large as 64K bytes.

Comparison between 8051 Family Members

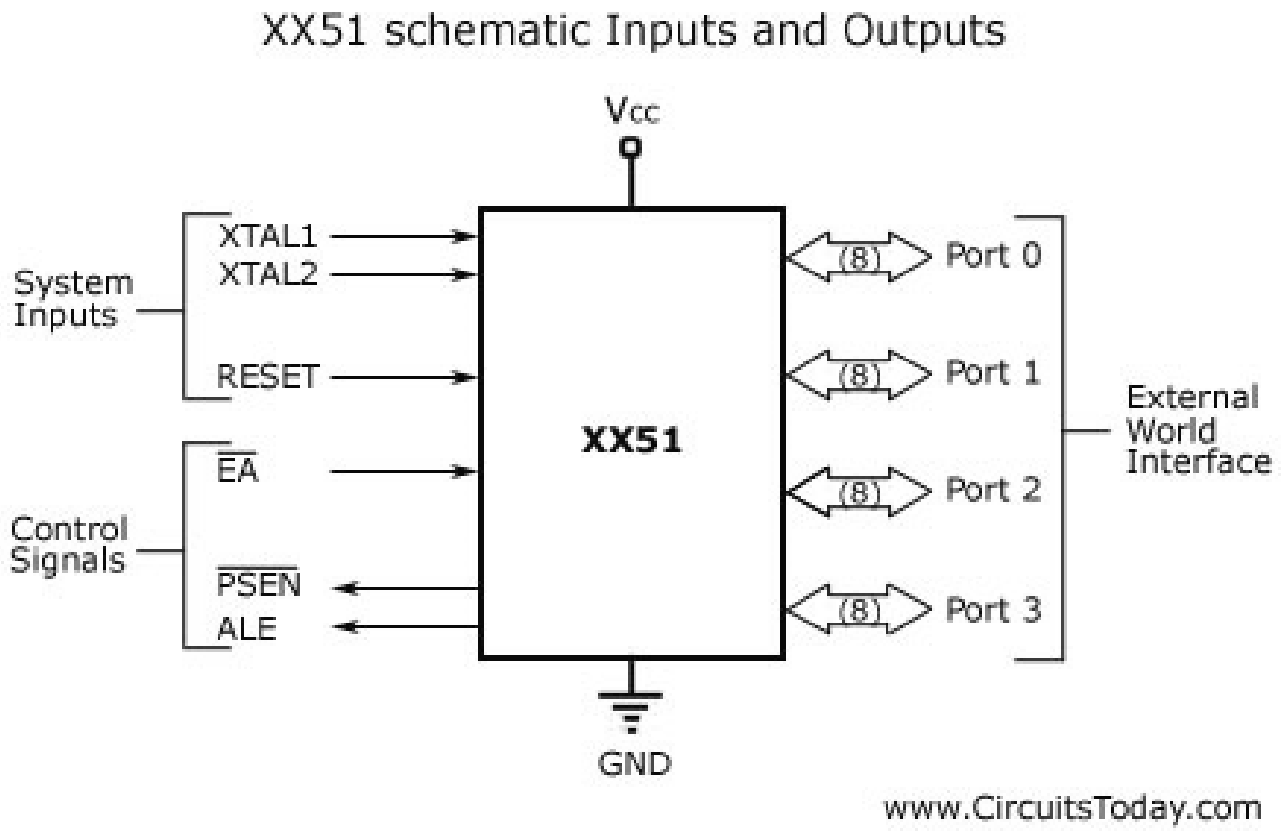
Feature	8051	8052	8031
RAM(bytes)	128	256	128
I/O pins	32	32	32
Interrupt sources	6	8	6

8051 Microcontroller Features

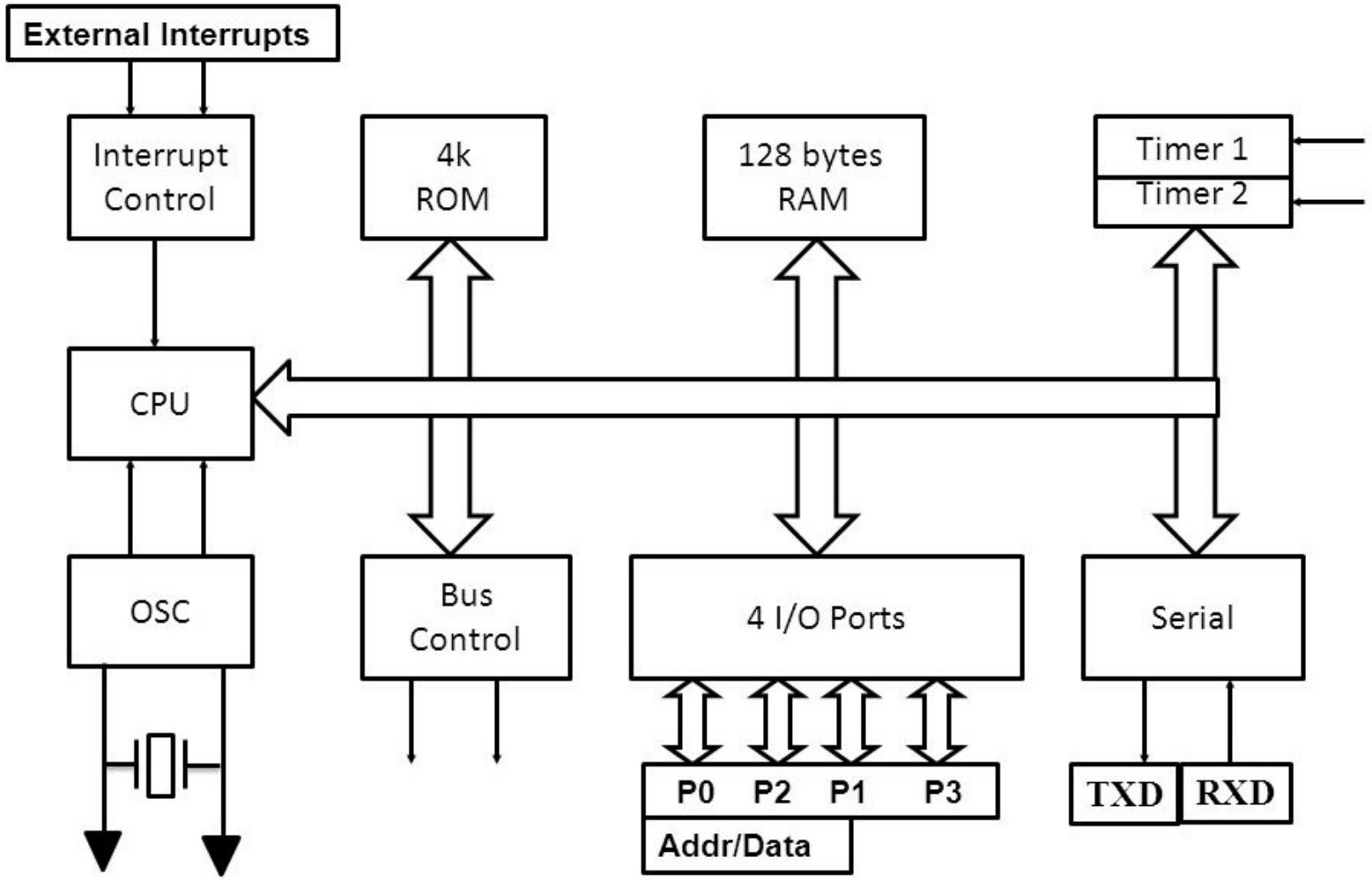
- An 8051 microcontroller comes bundled with the following features:
  - 64K bytes on-chip program memory (ROM)
  - 128 bytes on-chip data memory (RAM)
  - Four register banks
  - 128 user defined software flags
  - 8-bit bidirectional data bus
  - 16-bit unidirectional address bus
  - 32 general purpose registers each of 8-bit
  - 16 bit Timers (usually 2, but may have more or less)
  - Three internal and two external Interrupts
  - Four 8-bit ports,(short model have two 8-bit ports)
  - 16-bit program counter and data pointer
  - 8051 may also have a number of special features such as UARTs, ADC, Op-amp, etc.

8051 Microcontroller Architecture

- 3 system inputs
- 3 control signals
- 4 ports (for external interfacing)
- V_{cc} power supply and ground



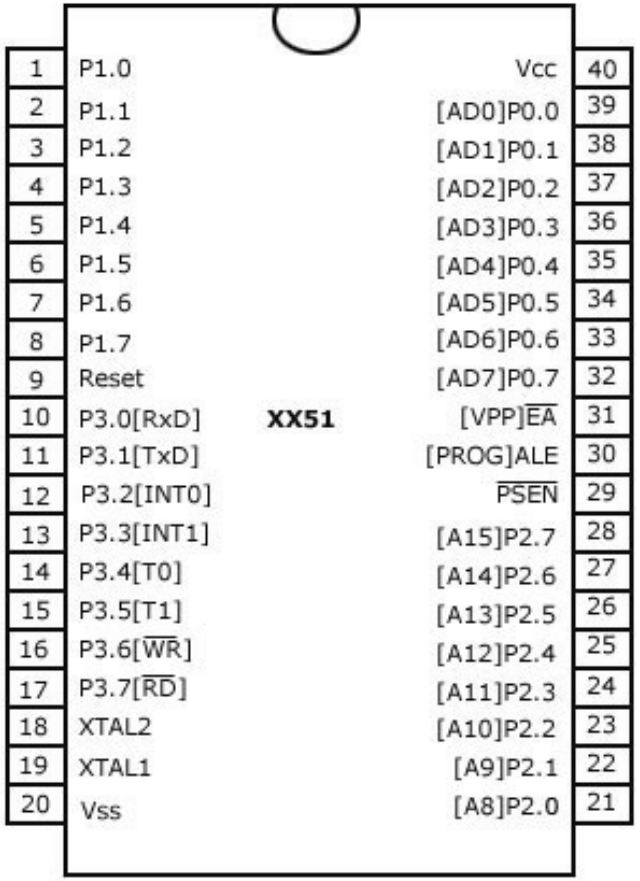
8051 Microcontroller Internal Architecture



8051 Microcontroller Pin Diagram

- **Pin 9** – It is a RESET pin, which is used to reset the microcontroller to its initial values.
- **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.
- **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.
- **Pin 40** – This pin is used to provide power supply to the circuit.

Pin-Wise Signal Assignment of XX51



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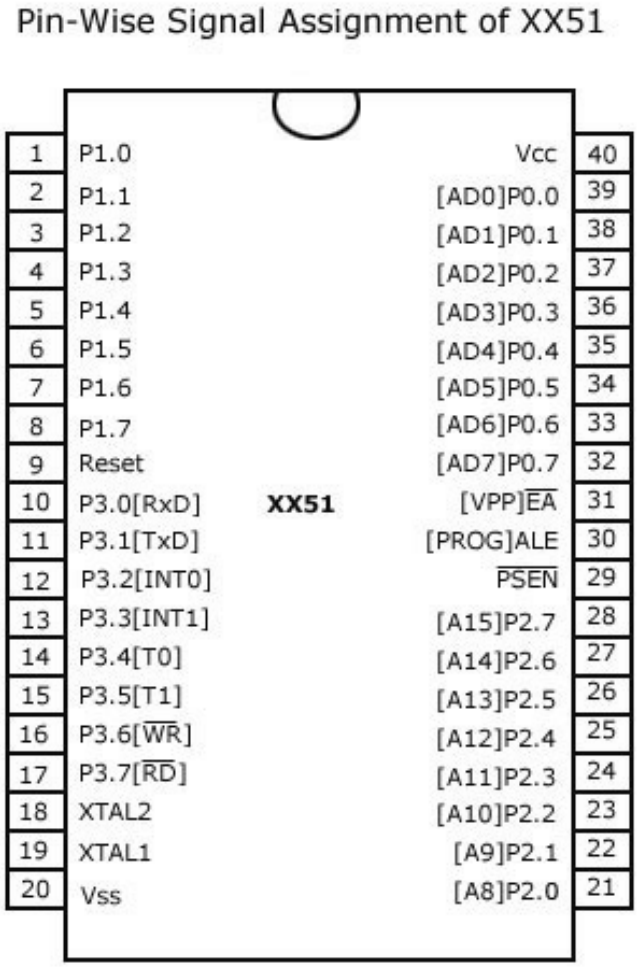
8051 Microcontroller Pin Diagram

- **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.
- **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.
- **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.
- **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



Assessment:

- Study about memory organisation in 8051 microcontroller and it’s memory architecture.
- Write a summary in at least 750 words, discussing program memory, data memory and internal RAM.

- Due: Next class

AVR Microcontrollers

- AVR is an 8-bit RISC architecture microcontroller available from 1996.
- There are 16-bit and 32-bit microcontrollers also available in the same family.
- AVR has 140 instructions which are all 1 cycle based instructions.
- AVR family microcontroller has on-chip boot-loader. By this we can program our microcontroller easily without any external programmer.
- AVR controllers has number of I/O ports, timers/counters, interrupts, A/D converters, USART, I2C interfaces, PWM channels, on-chip analog comparators.

PIC Microcontrollers

- PIC (Programmable interface controller) microcontrollers are available in 3 different architectures.
- Those are 8-bit, 16-bit and 32-bit microcontrollers.
- PIC has nearly 40 instructions which all are take 4 clock cycles to execute.
- The programming part of the PIC microcontroller is very hard. So those who entering into embedded world freshly this is not preferable for them.
- It has on-chip peripherals like SPI, ADC, I2C, UART, analog comparator, internal RC oscillator, in-system programmability, etc.

ARM Processor

- An ARM processor is a family of CPUs based on the RISC architecture developed by Advanced RISC Machines (ARM).
- ARM makes at 32-bit and 64-bit RISC multi-core processors.
- ARM processors are widely used in customer electronic devices such as smart phones, tablets, multimedia players and other mobile devices.

Compare: 8051, PIC, AVR, ARM

	8051	PIC	AVR	ARM
Communication Protocols	UART, USART,SPI,I2C	PIC, UART, USART, LIN, CAN, Ethernet, SPI, I2S	UART, USART, SPI, I2C, (special purpose AVR support CAN, USB, Ethernet)	UART, USART, LIN, I2C, SPI, CAN, USB, Ethernet, I2S, DSP, SAI (serial audio interface), IrDA
Memory	ROM, SRAM, FLA SH	SRAM, FLASH	Flash, SRAM, EEPROM	Flash, SDRAM, EEPROM
Memory Architecture	Von Neumann architecture	Harvard architecture	Modified	Modified Harvard architecture

Compare: 8051, PIC, AVR, ARM

	8051	PIC	AVR	ARM
Community	Vast	Very Good	Very Good	Vast
Cost	Very Low	Average	Average	Low
Popular Microcontrollers	AT89C51, P89v51, etc.	PIC18fXX8, PIC16f88X, PIC32MXX	Atmega8, 16, 32, Arduino Community	LPC2148, ARM Cortex-M0 to ARM Cortex-M7, etc.

Next:
Introduction to ARM Core Architecture