



Chapter 6

The 8051 Microcontroller

Introduction



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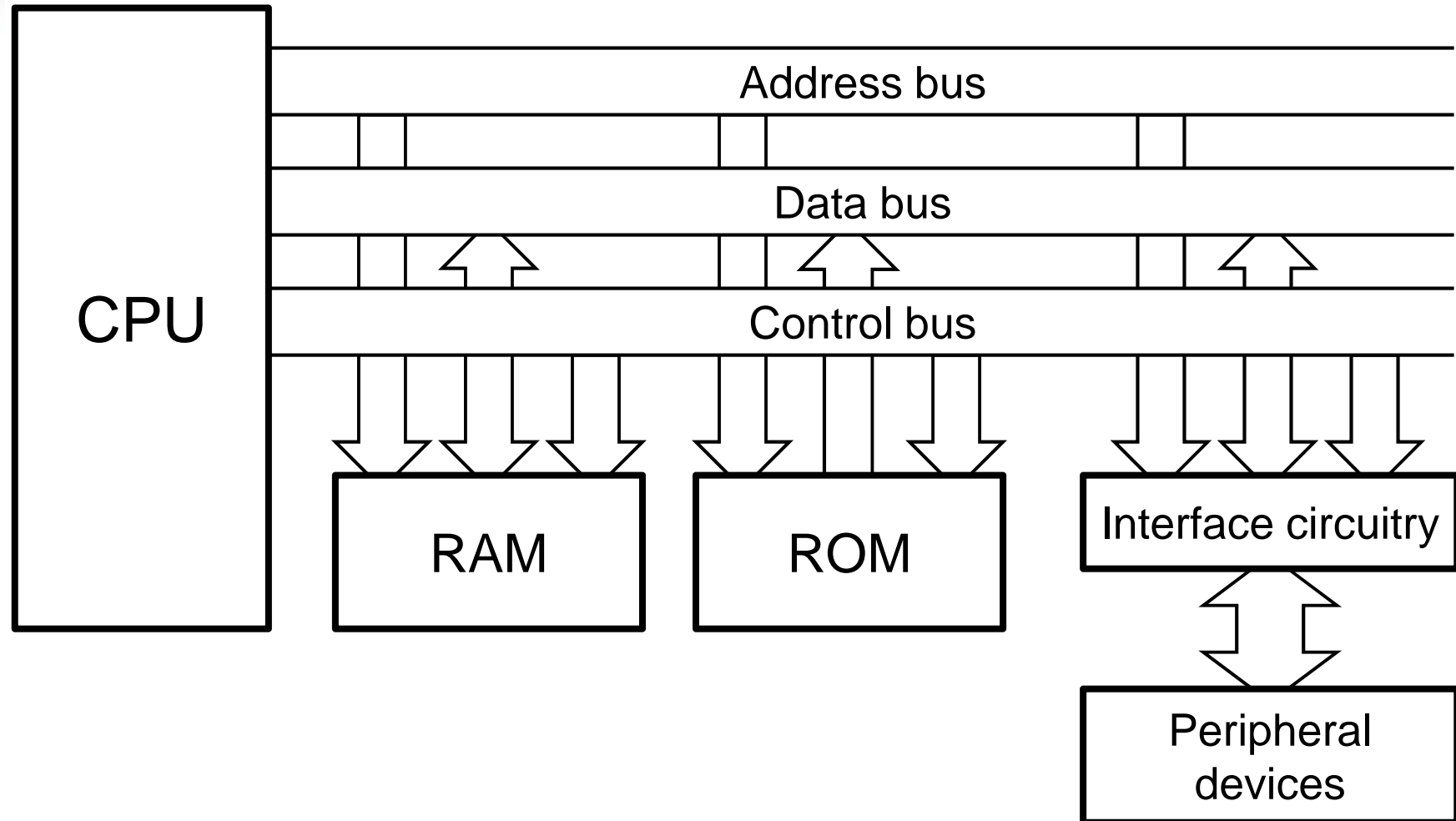
Outline

- Microcomputer System
- Microprocessor vs. Microcontroller
- Embedded System
- 8051 family

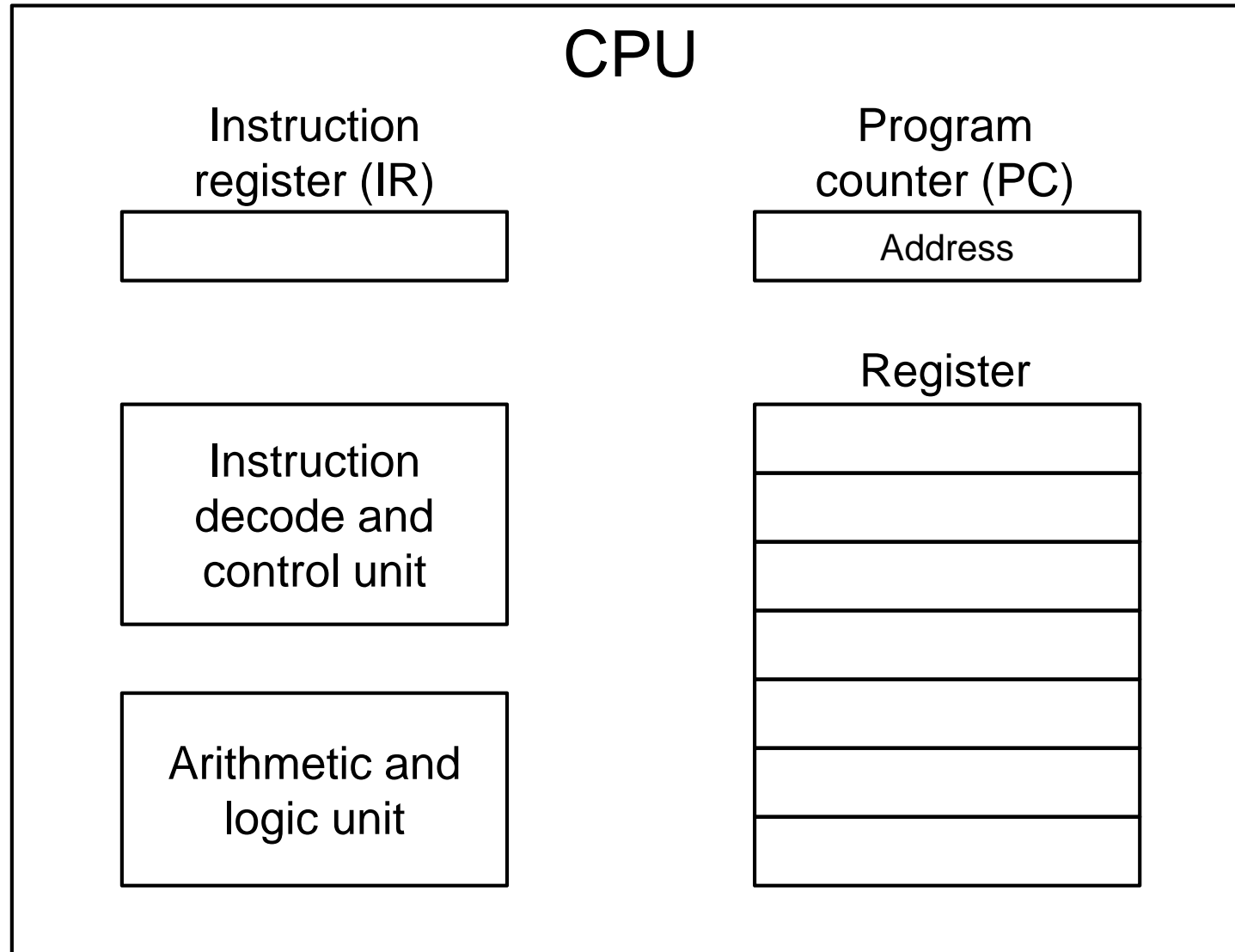
Microcomputer System

- Key traits
 - The ability to be programmed to operate on data without human intervention
 - The ability to store and retrieve data
 - The peripheral devices for communicating with humans
 - Programs that process data
- Hardware + Software = Function Unit

Microcomputer System



Central Processing Unit (CPU)



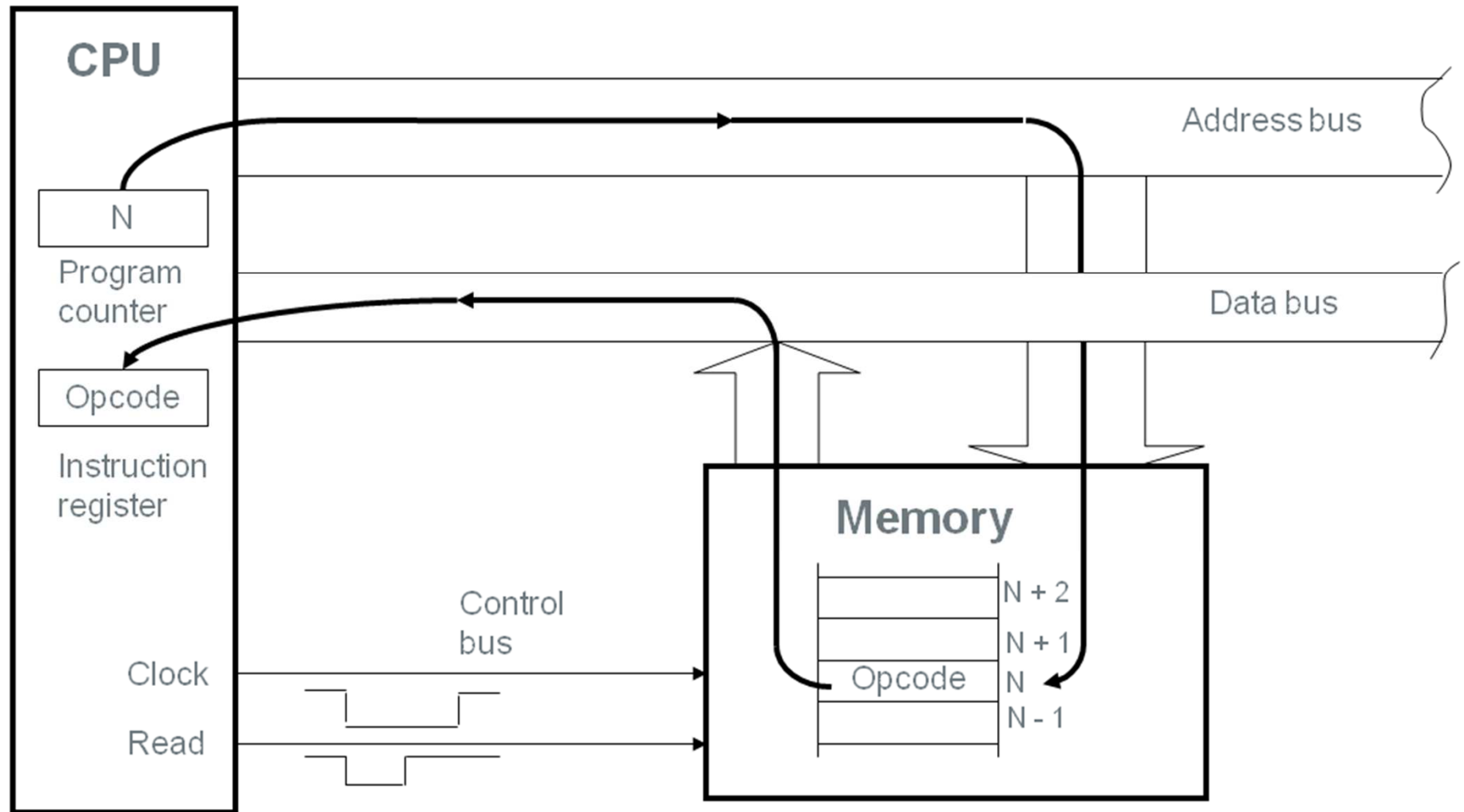
Central Processing Unit (CPU)

- **Instruction Set:** set of binary codes, representing simple operation (instruction) that CPU can understand and execute
 - CISC: Complex Instruction Set Computer
 - RISC: Reduced Instruction Set Computer
- Opcode, Register (8-, 16-, 32-, 64-bit)
- Basic 4-stage operation of CPU
 - Fetch
 - Decode
 - Execute
 - Write back (Store result)
- Pipeline, Superpipeline, Superscalar

Central Processing Unit (CPU)

- Fetching an instruction from RAM
 1. The contents of program counter (PC) are placed on address bus
 2. READ control signal is activated
 3. Data (instruction opcode) are read from RAM and placed on data bus
 4. Opcode is latched into CPU's instruction register (IR)
 5. PC is incremented to prepare for the next fetch from RAM

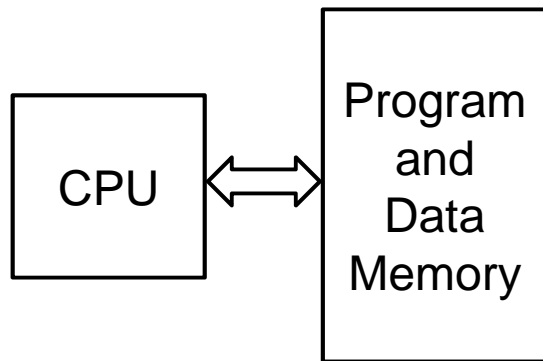
Bus Activity for Opcode Fetch Cycle



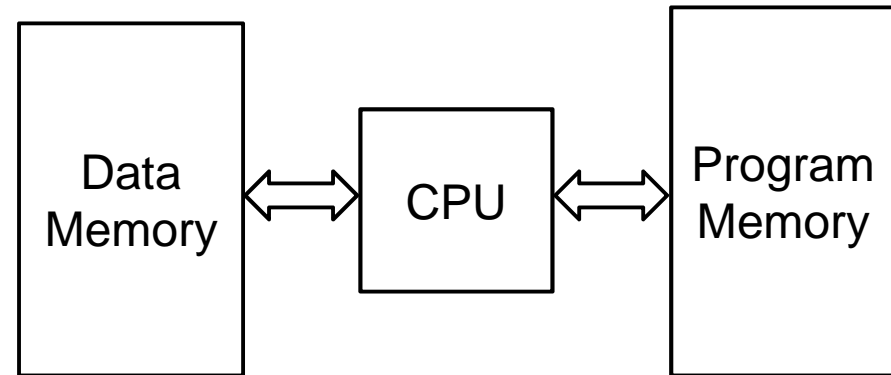
Memory

- Program and data are stored in memory

Von Neumann Architecture



Harvard Architecture

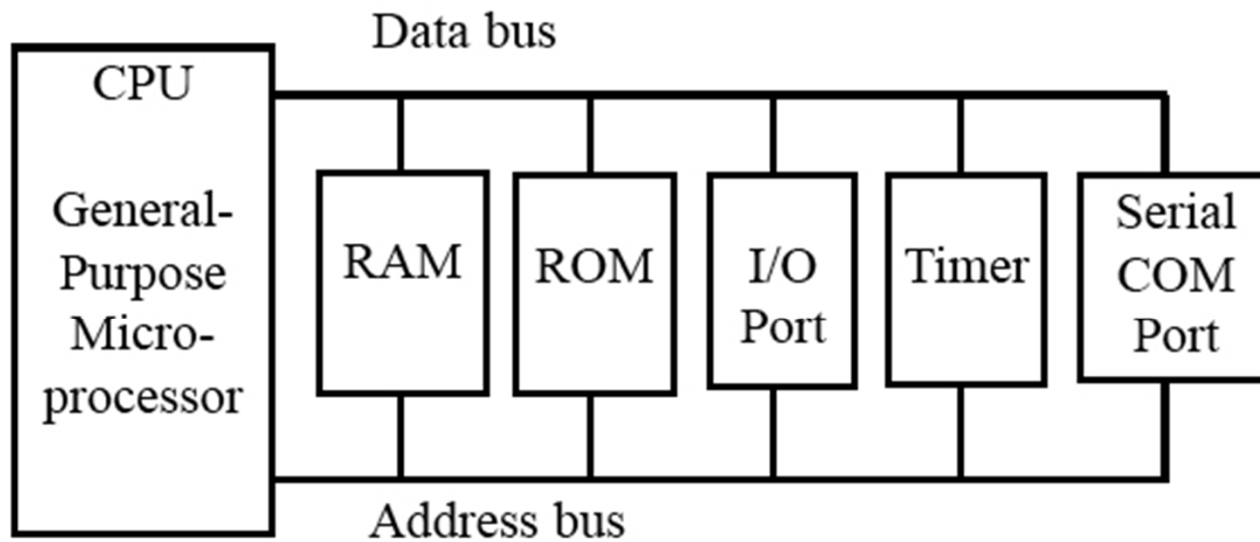


- RAM: *temporary storage* of program and data that computer is running
- ROM: *nonvolatile memory*, contain program and information essential to operation of the computer, fixed and permanent

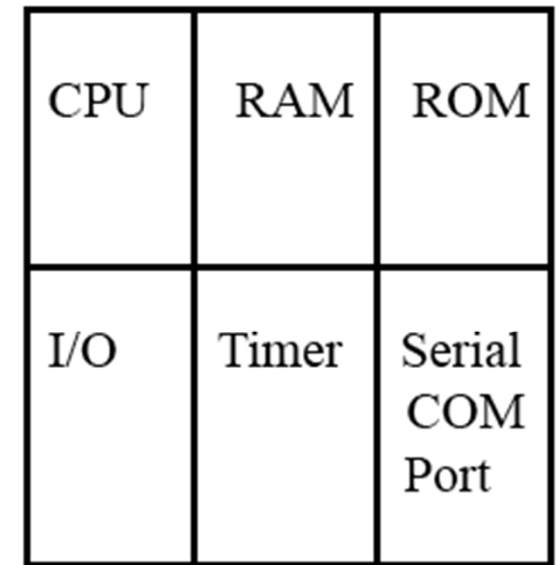
Input/Output Devices

- I/O devices or “computer peripheral”
 - The path for communication between the computer system and the “real world”
 - 3 classes of I/O devices
 - Mass Storage Devices: disk, CD-ROM, ...
 - Human Interface Devices: keyboard, mouse, printer, monitor, speaker, joystick, ...
 - Control/Monitor: actuators, sensors

Microprocessor vs. Microcontrollers



(a) General-Purpose Microprocessor System



(b) Microcontroller

Microprocessor vs. Microcontrollers

- Microprocessors are single-chip CPUs
 - No RAM, ROM and I/O ports
 - Must add RAM, ROM, I/O ports, and timers externally to make them functional
 - Make the system bulkier and much more expensive
 - Have the advantage of versatility on the amount of RAM, ROM, and I/O ports
- Microcontrollers
 - Has a CPU (a microprocessor)
 - Fixed amount of on-chip RAM, ROM, I/O ports, timer, serial interface, built-in interrupt system and other peripheral functions

Microprocessor vs. Microcontrollers

- Microprocessors
 - Most commonly used as the CPU in microcomputer systems (computing, processing purpose)
 - Instruction Sets: powerful addressing modes with many instructions operate on large volumes of data
- Microcontrollers
 - Small, minimum-component designs performing control-oriented activities
 - Ideal for many applications in which cost and space are more critical than the computing power
 - Instruction Sets: many instructions operate on individual bit

Microcontrollers for embedded systems

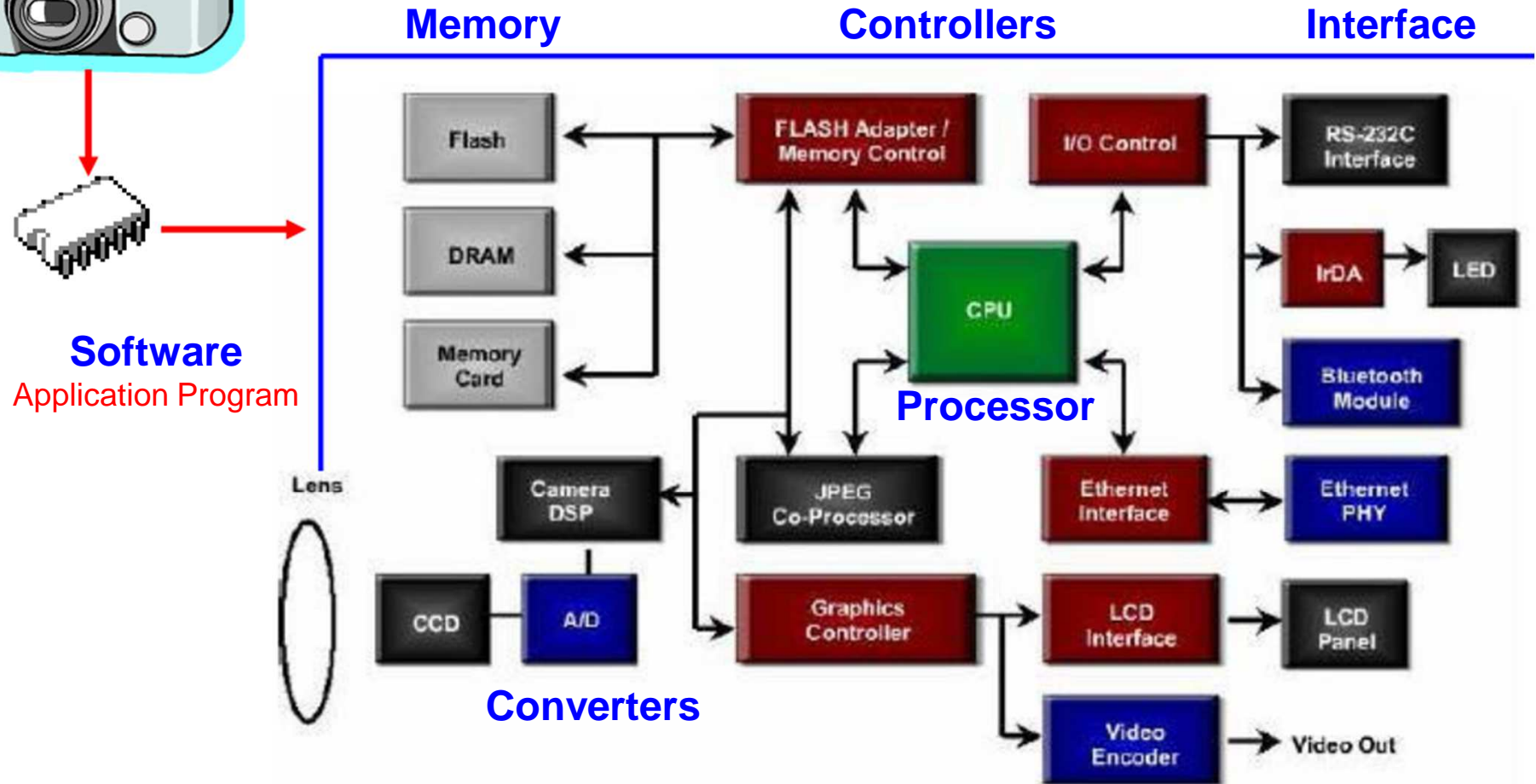
- Embedded System

- Use a microcontroller (or microprocessor) to do one task and one task only
 - Only 1 application software that is typically burned into ROM
- Contrast with a PC, used for any number of applications
- Both hardware and software is designed to perform a dedicated function
- Characteristics: Efficiently, cost effective, power efficiently, real-time, ...
- Challenges: low cost, low power, portable, reliability, real-time processing, security, ...

Examples of Embedded System



Digital Camera Block Diagram



Examples of Embedded System

- Home
 - Garage door openers, washing machines, microwave oven, TVs, remote controls, cellular phones, camera, exercise equipment, ...
- Office
 - Telephones, computers, security systems, fax, copier, laser printer, scanner, ...
- Automotive
 - Engine control, air bag, ABS, ...
- Industrial Control
 - Robotics, control systems, ...

Microcontroller for Embedded System

- Criteria for choosing a Microcontroller
 - Meet the task at hand efficiently and cost effectively
 - Speed
 - Packaging (DIP, QFP, surface-mount)
 - Power consumption
 - The amount of RAM and ROM on chip
 - The number of I/O pins and the timer on the chip
 - How easy to upgrade to higher-performance or lower power-consumption versions
 - Cost per unit
 - How easy to develop products (Software development tools – compiler, assembler, debugger, emulator, ...)
 - Wide availability and reliable sources of the microcontroller

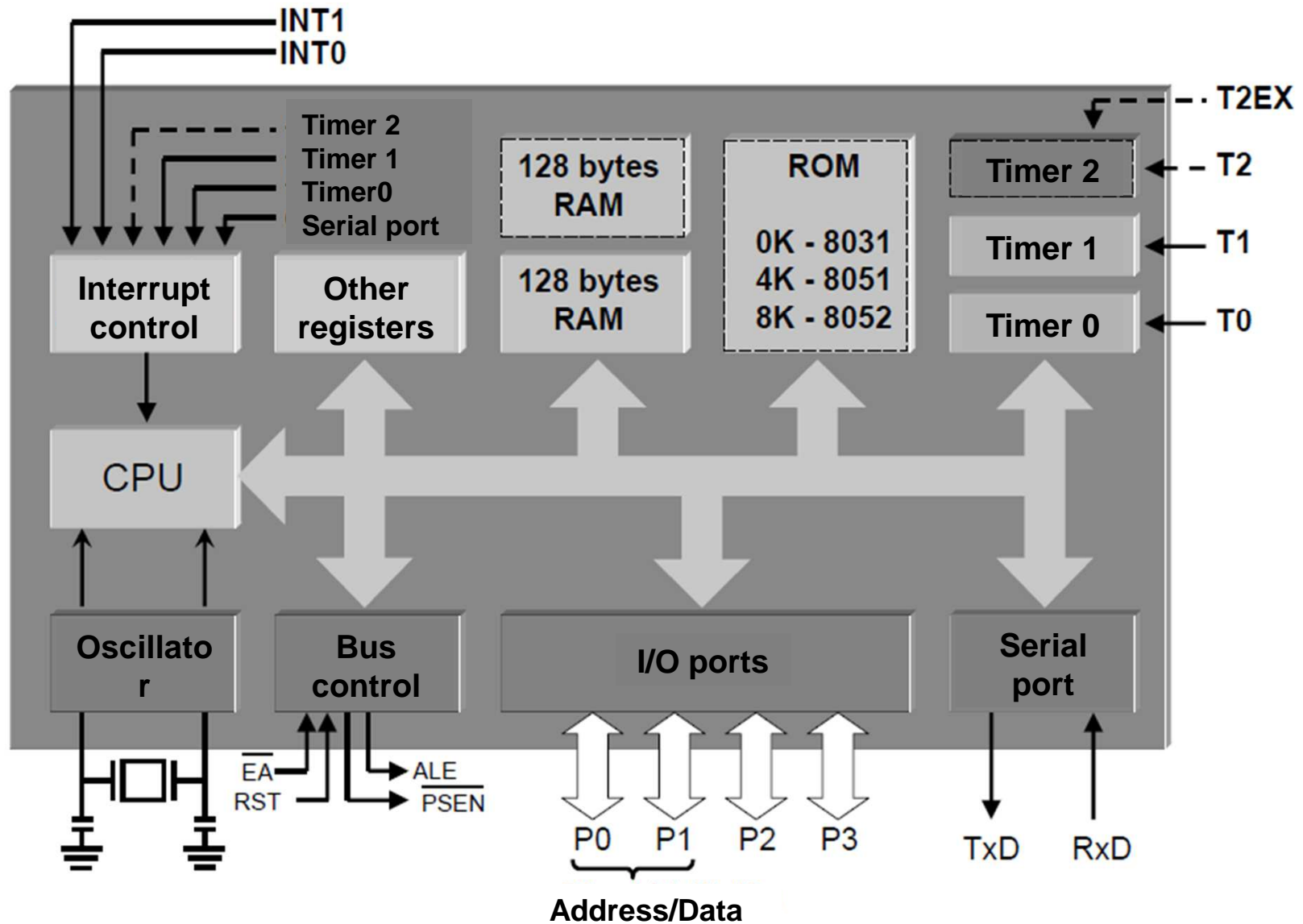
The 8051 Family

- Introduced in 1981 by Intel, referred as MCS-51
- 8051 is 8-bit microcontroller
 - Work on 8 bits of data at a time
- Features
 - 128 bytes of RAM
 - 4K bytes of on-chip ROM (Maximum 64Kb)
 - Two timers
 - One serial port
 - 4 I/O ports, each 8 bits wide
 - 6 interrupt sources
 - Internal oscillator

The 8051 Family

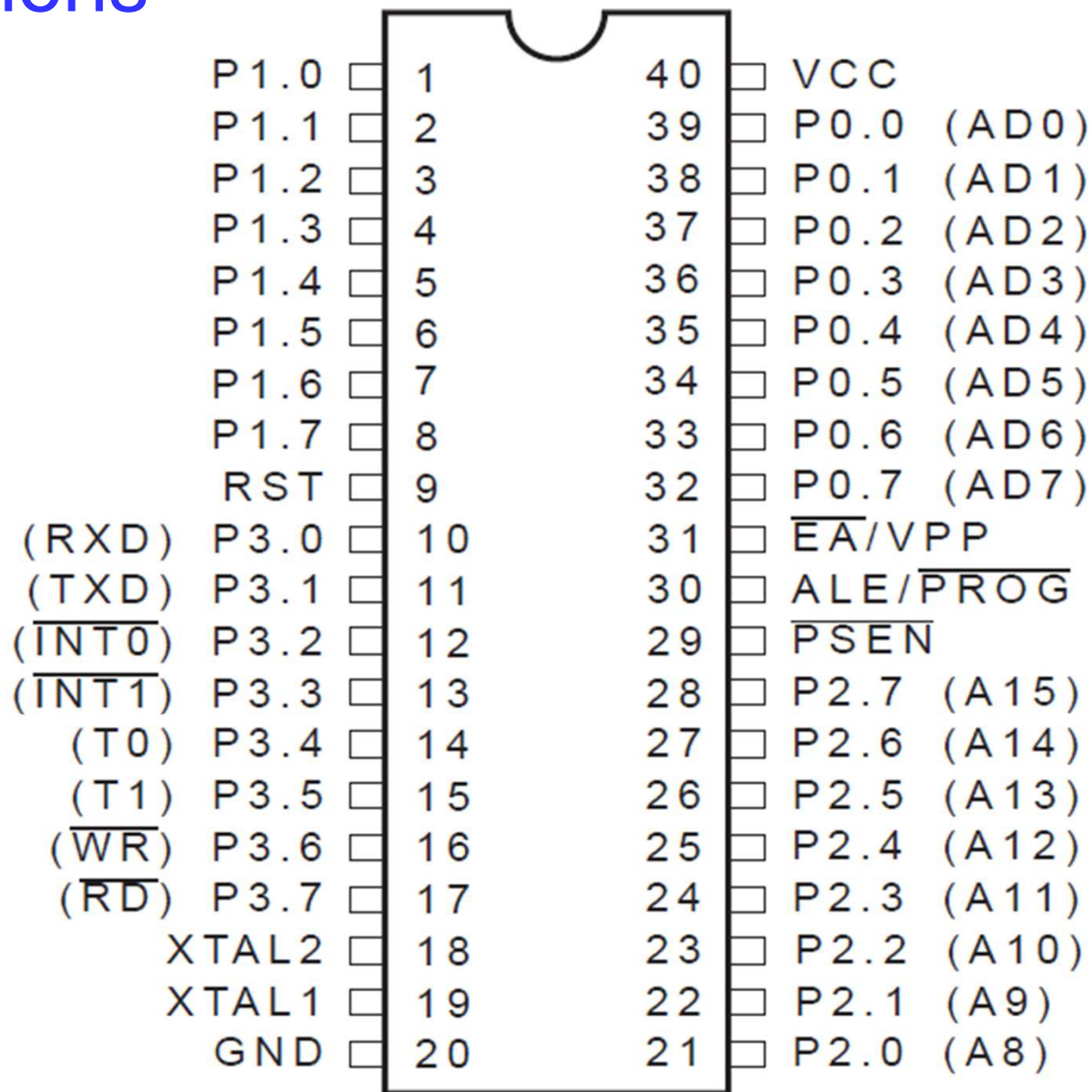
Feature	8051	8052	8031
ROM (on-chip program space in bytes)	4K	8K	0K
RAM (bytes)	128	256	128
Timers	2	3	2
I/O pins	32	32	32
Serial port	1	1	1
Interrupt sources	6	8	6

8051 Microcontroller



Pin Configurations

PDIP



Pin Descriptions

- Port 0, 1, 2, 3 – general purpose I/O port
 - Port 0, 2: accessing external memory
 - Port 3: alternative purpose related to special features

BIT	NAME	BIT ADDRESS	ALTERNATE FUNCTION
P3.0	RXD	B0H	Receive data for serial port
P3.1	TXD	B1H	Transmit data for serial port
P3.2	INT0	B2H	External interrupt 0
P3.3	INT1	B3H	External interrupt 1
P3.4	T0	B4H	Timer/counter 0 external input
P3.5	T1	B5H	Timer/counter 1 external input
P3.6	WR	B6H	External data memory write strobe
P3.7	RD	B7H	External data memory read strobe
P1.0	T2 (8052)	90H	Timer/counter 2 external input
P1.1	T2EX (8052)	91H	Timer/counter 2 capture/reload

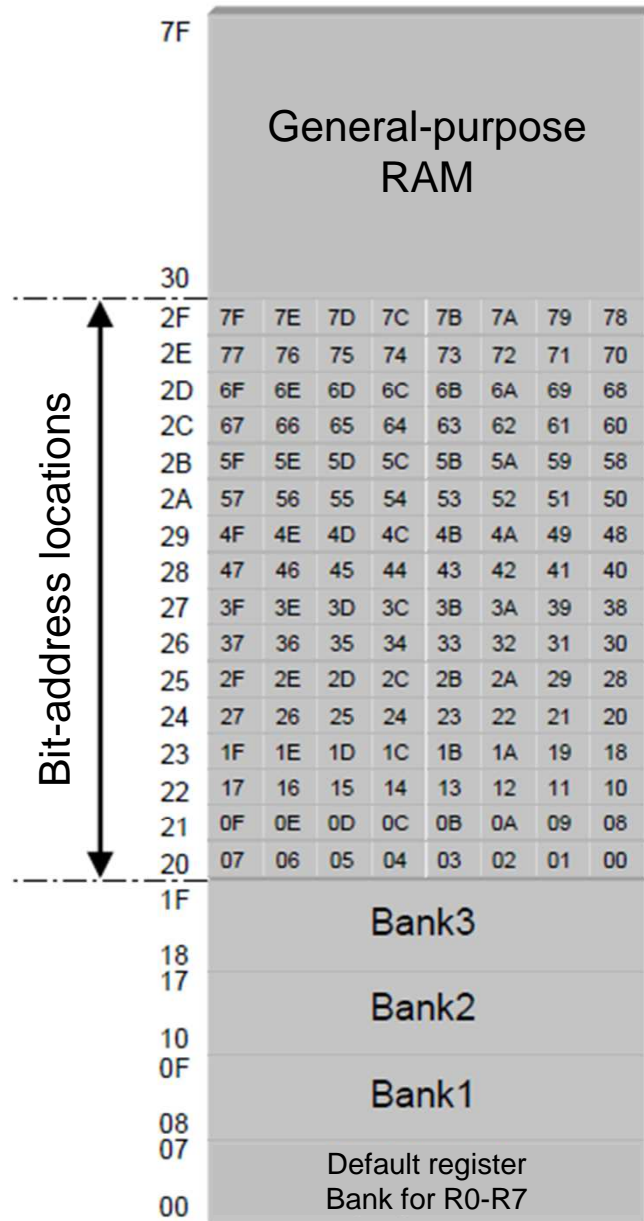
Pin Descriptions

- $\overline{\text{PSEN}}$ (Program Store Enable)
 - Connect to a ROM's Output Enable → permit reading
- ALE (Address Latch Enable)
 - Demultiplexing the address and data bus
 - Used as general-purpose clock
- $\overline{\text{EA}}$ (External Access)
 - HIGH: execute program from internal ROM
 - LOW: execute from external memory only
- $\overline{\text{RST}}$ (Reset)
- On-chip Oscillator Inputs (XTAL1, XTAL2)
- Power Connections (V_{cc}/V_{ss})

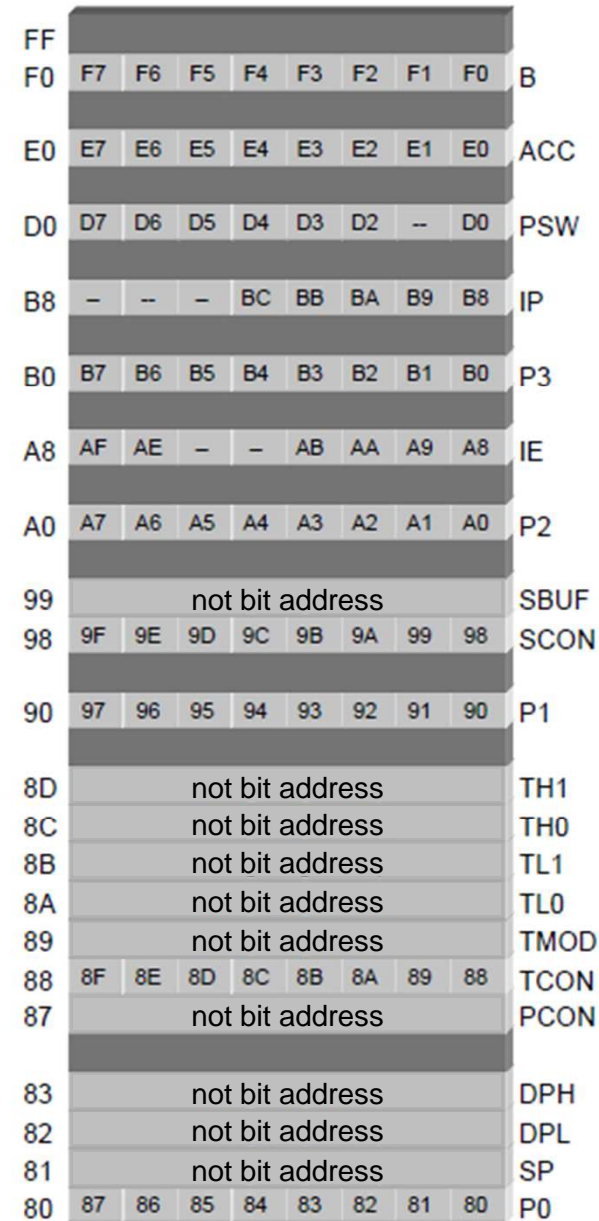
Memory Organization

- Limited memory, no disk drive or disk operating system
- Control program must reside in ROM
- Separate memory space for programs (code) & data
- On-chip ROM and on-chip data RAM
- 2 notable features
 - Registers and I/O ports are memory mapped and accessible like any other memory location
 - Stack resides within the internal RAM rather than external RAM as typical of microprocessors

Byte address



Byte address

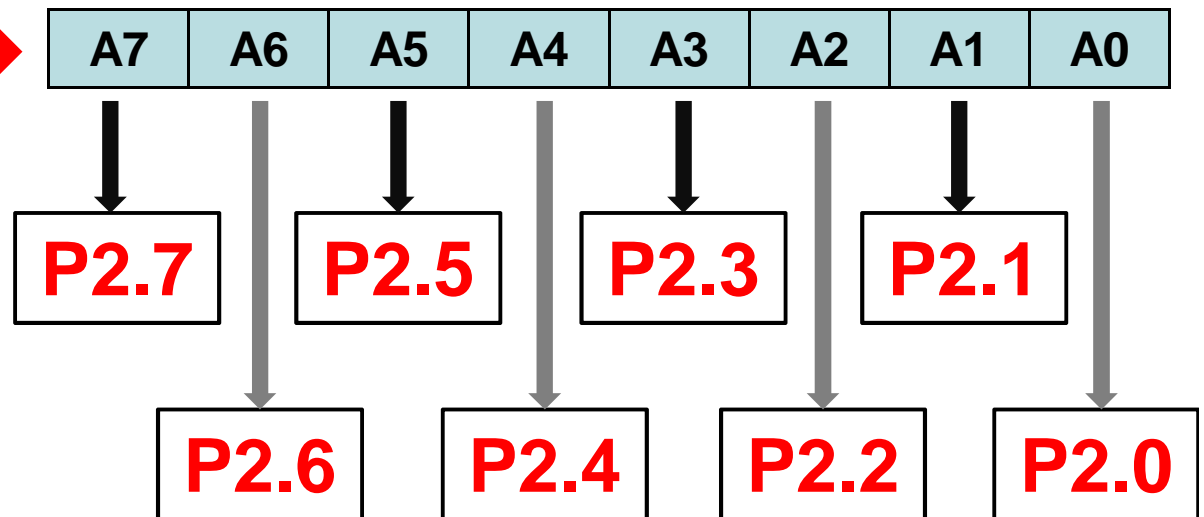


RAM Memory

Byte address

FF									
F0	F7	F6	F5	F4	F3	F2	F1	F0	B
E0	E7	E6	E5	E4	E3	E2	E1	E0	ACC
D0	D7	D6	D5	D4	D3	D2	--	D0	PSW
B8	--	--	--	BC	BB	BA	B9	B8	IP
B0	B7	B6	B5	B4	B3	B2	B1	B0	P3
A8	AF	AE	--	--	AB	AA	A9	A8	IE
A0	A7	A6	A5	A4	A3	A2	A1	A0	P2
99	not bit address								SBUF
98	9F	9E	9D	9C	9B	9A	99	98	SCON
90	97	96	95	94	93	92	91	90	P1
8D	not bit address								TH1
8C	not bit address								TH0
8B	not bit address								TL1
8A	not bit address								TL0
89	not bit address								TMOD
88	8F	8E	8D	8C	8B	8A	89	88	TCON
87	not bit address								PCON
83	not bit address								DPH
82	not bit address								DPL
81	not bit address								SP
80	87	86	85	84	83	82	81	80	P0

P2 (RAM address)



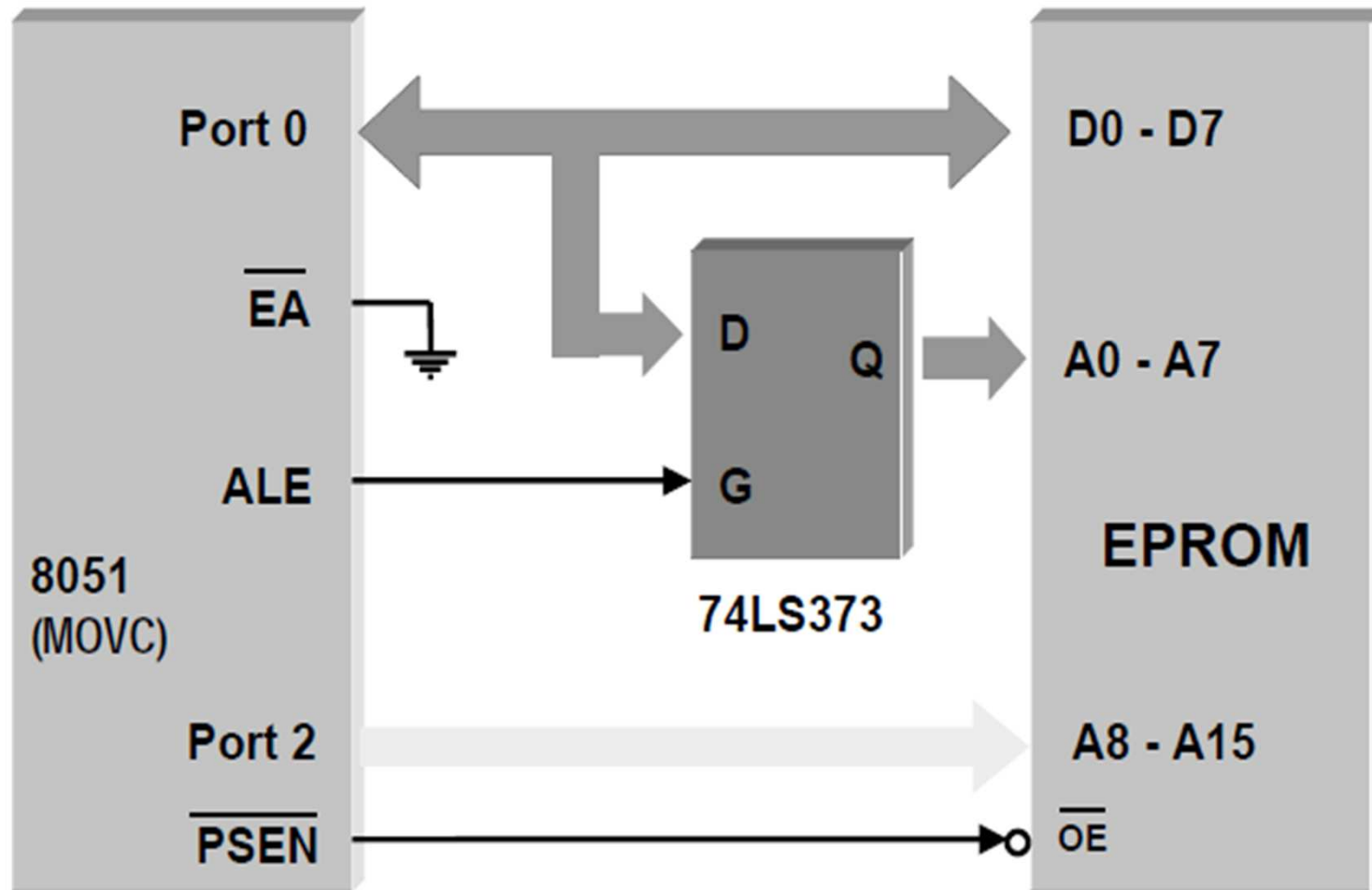
RAM Memory

- 80 bytes of general purpose RAM 30H – 7FH
- 210 bit-addressable locations
 - 128 general-purpose bit-addressable locations are byte 20H – 2FH (access as bytes or bits)
 - The rest are in the **special function registers**
 - Program Status Word, B register, Stack/Data Pointer, Port/Timer/Serial Port/Interrupt/Power Control Register
- Register banks
 - 32 locations of internal memory contain the register banks
 - 8051 instruction set support 8 registers: R0 - R7
 - By default: at address 00H – 07H
 - Register banks: permit fast and effective “context switching”

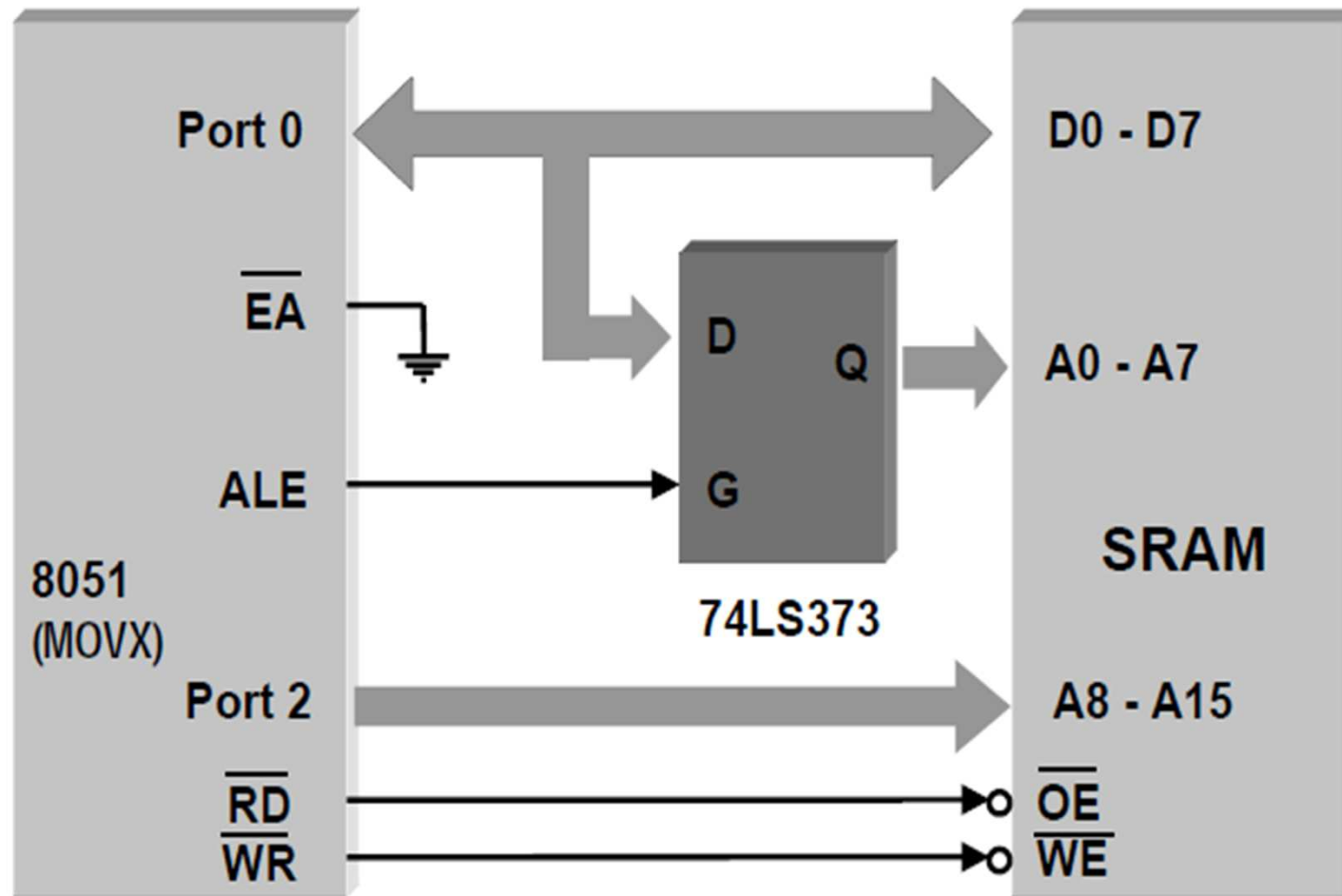
External Memory

- Maximum: 64K external code memory space and 64K external data memory space
- Port 0 becomes a multiplexed address (A0 – A7) and data (D0 – D7) bus
 - ALE: latch the low-byte of address
- Port 2 is usually (not always) employed for the high-byte of the address bus

Accessing External ROM

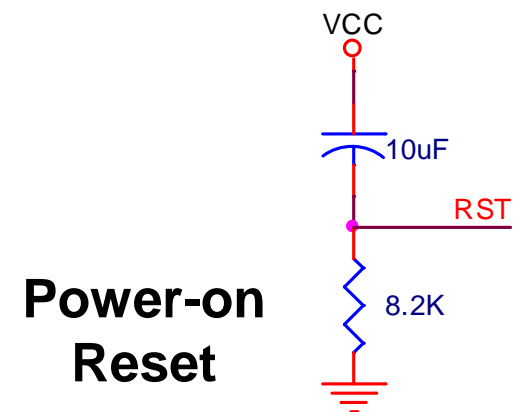
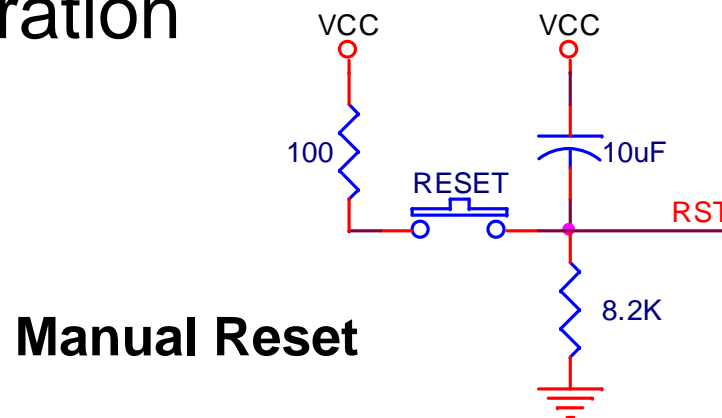


Accessing External RAM



Reset Operation

- The 8051 is reset by holding RST high for at least two machine cycles and then returning it low
- RST may be activated
 - Manually by using a switch
 - Upon power-up using an R-C (resistor – capacitor) network
- Program counter is loaded with 0000H
- The content of on-chip RAM is not affected by a reset operation



Reference

- “*The 8051 Microcontroller and Embedded Systems Using Assembly and C – 2nd*” - Muhammad Ali Mazidi, Janice Gillispie Mazidi, Rolin D.McKinlay
- “*The 8051 Microcontroller - 2nd*” - I. Scott Mackenzie, Prentice-Hall 1995