

Architecture of microprocessors and microcontrollers

In the context of computers,
what does *architecture* mean?

Architecture has many meanings

- Computer Organization (or Microarchitecture)
 - Control and data paths
 - I/D pipeline design
 - Cache design
 - ...
- System Design (or Platform Architecture)
 - Memory and I/O buses
 - Memory controllers
 - Direct memory access
 - ...
- Instruction Set Architecture (ISA)

What is an
Instruction Set Architecture (ISA)?

An ISA defines the hardware/software interface

- A “contract” between architects and programmers
- Instruction set
- Register set
- Memory and addressing modes
- Word sizes
- Data formats
- Operating modes
- Condition codes
- Calling conventions

ARM Architecture roadmap



ARM7TDMI
ARM922T
Thumb
instruction set



ARM926EJ-S
ARM946E-S
ARM966E-S
Improved
ARM/Thumb
Interworking
DSP instructions
Extensions:
Jazelle (5TEJ)



ARM1136JF-S
ARM1176JZF-S
ARM11 MPCore
SIMD Instructions
Unaligned data support
Extensions:
Thumb-2 (6T2)
TrustZone (6Z)
Multicore (6K)



Cortex-A8/R4/M3/M1
Thumb-2
Extensions:
v7A (applications) – NEON
v7R (real time) – HW Divide
V7M (microcontroller) – HW
Divide and Thumb-2 only

ARM Cortex-M3 ISA

Instruction Set

ADD Rd, Rn, <op2>

Branching
Data processing
Load/Store
Exceptions
Miscellaneous

Register Set

R0
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13 (SP)
R14 (LR)
R15 (PC)
xPSR

32-bits

Endianness

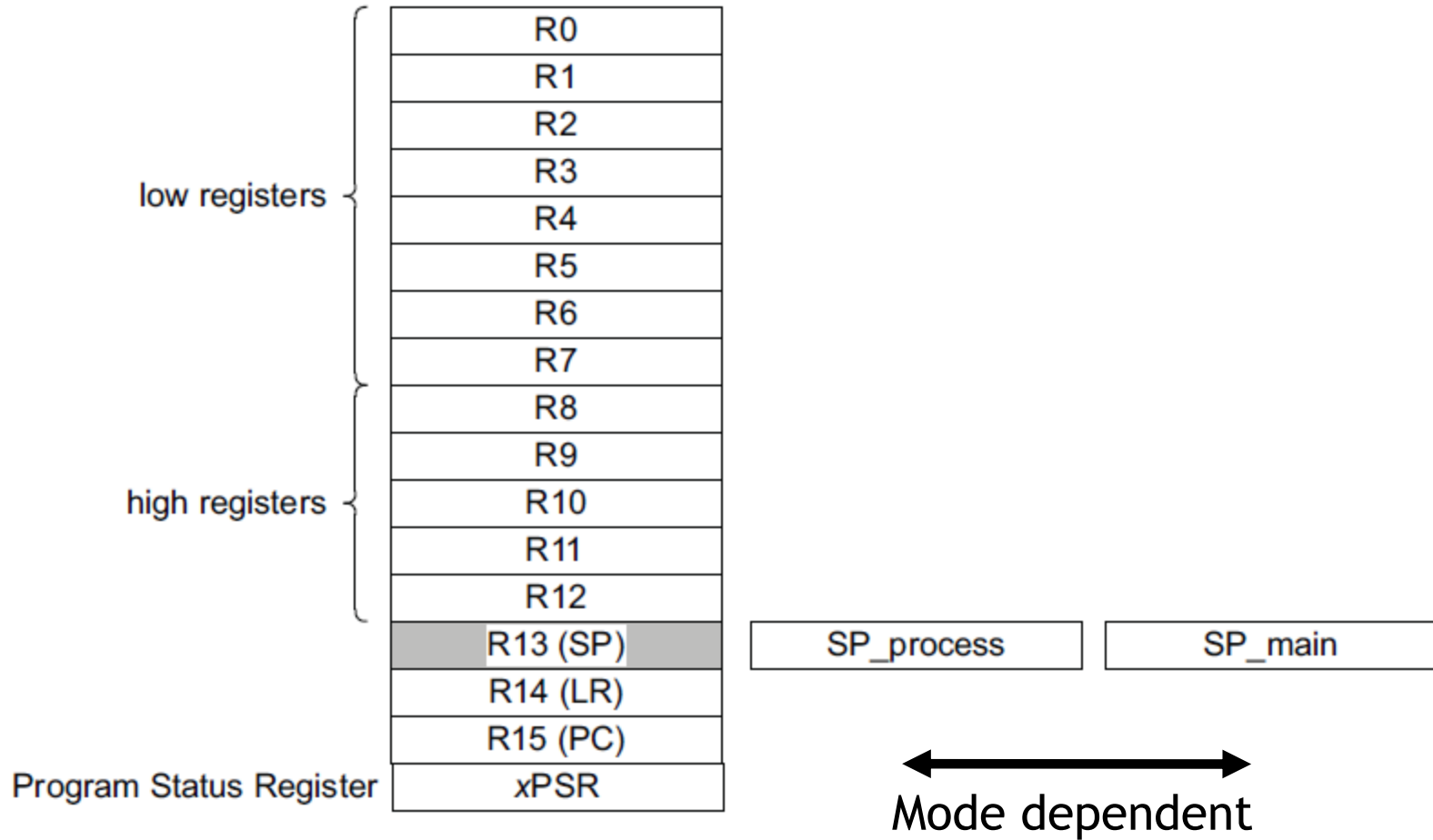
Address Space

System	0xFFFFFFFF
Private peripheral bus - External	0xE0100000
Private peripheral bus - Internal	0xE0040000
	0xE0000000
External device 1.0GB	
	0xA0000000
External RAM 1.0GB	
	0x60000000
Peripheral 0.5GB	
	0x40000000
SRAM 0.5GB	
	0x20000000
Code 0.5GB	
	0x00000000

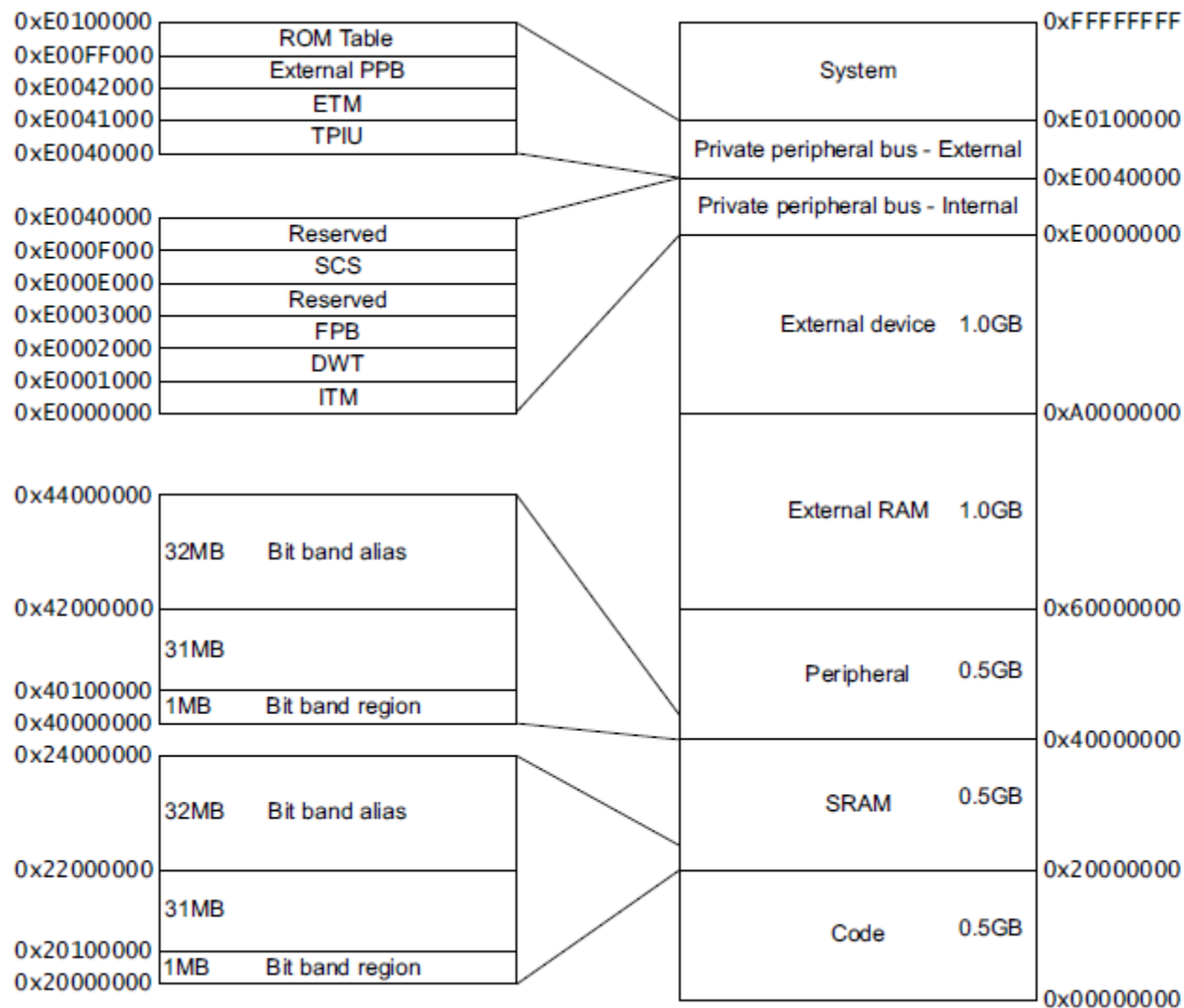
32-bits

Endianness

Registers



Address Space



Addressing Modes

- Offset Addressing
 - Offset is added or subtracted from base register
 - Result used as effective address for memory access
 - [$\langle Rn \rangle$, $\langle \text{offset} \rangle$]
- Pre-indexed Addressing
 - Offset is applied to base register
 - Result used as effective address for memory access
 - Result written back into base register
 - [$\langle Rn \rangle$, $\langle \text{offset} \rangle$]!
- Post-indexed Addressing
 - The address from the base register is used as the EA
 - The offset is applied to the base and then written back
 - [$\langle Rn \rangle$], $\langle \text{offset} \rangle$

Instruction encoding

- Instructions are encoded in machine language opcodes
- Sometimes
 - Necessary to hand generate opcodes
 - Necessary to verify assembled code is correct
- How?

Big endian

Instructions
 movs r0, #10
 movs r1, #0

Register Value	Memory Value
<u>001</u> <u>00</u> <u>000</u> <u>00001010</u>	(LSB) (MSB)
(msb) (lsb)	<u>0a</u> <u>20</u> <u>00</u> <u>21</u>
<u>001</u> <u>00</u> <u>001</u> <u>00000000</u>	

ARMv7 ARM

Encoding T1

All versions of the Thumb ISA.

MOVS <Rd>, #<imm8>

Outside IT block.

MOV<C> <Rd>, #<imm8>

Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	0	0	Rd		imm8								

d = UInt(Rd); setflags = !InITBlock(); imm32 = ZeroExtend(imm8, 32); carry = APSR.C;

What is a Microcontroller ?

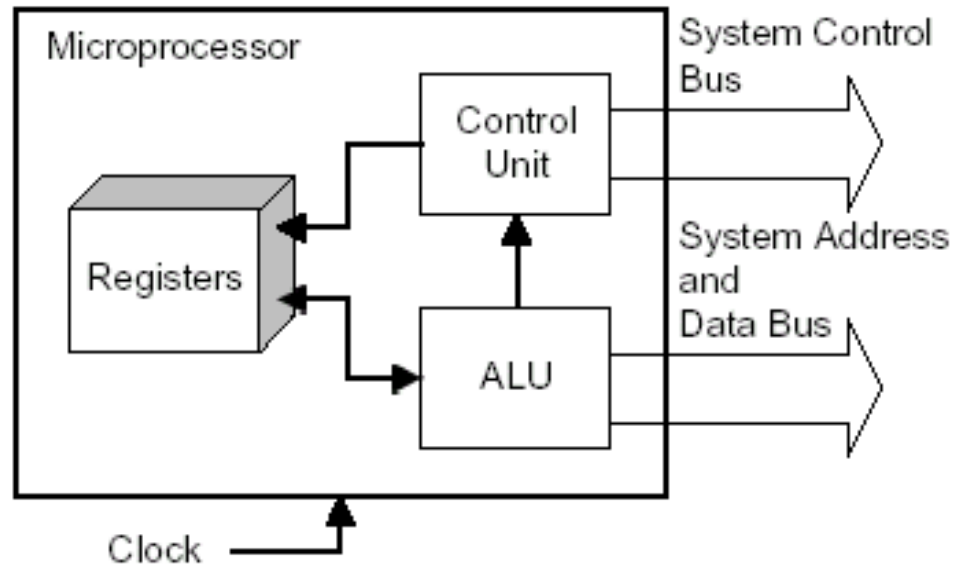
- A microcontroller is a single chip microprocessor system which contains:
 - A processor core.
 - Data and program memory.
 - Serial and parallel I/O.
 - Timers.
 - External and internal interrupt handling mechanism.

all integrated into **a single chip.**

Block Diagram of a Microprocessor

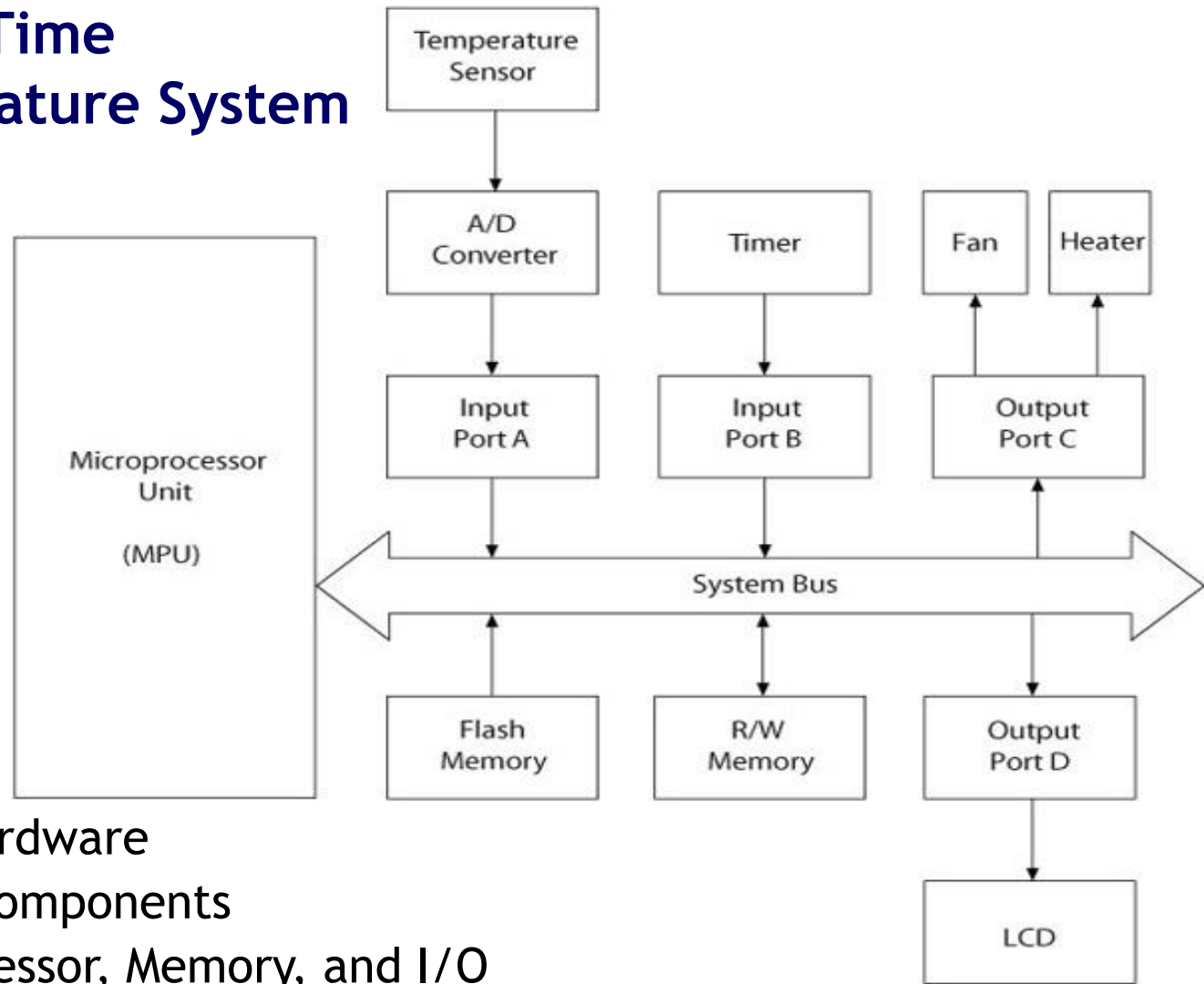
- A microprocessor consists of an ALU to perform arithmetic and logic manipulations, registers, and a control unit.

- In addition, it has some interfaces to the outside world in the form of busses.



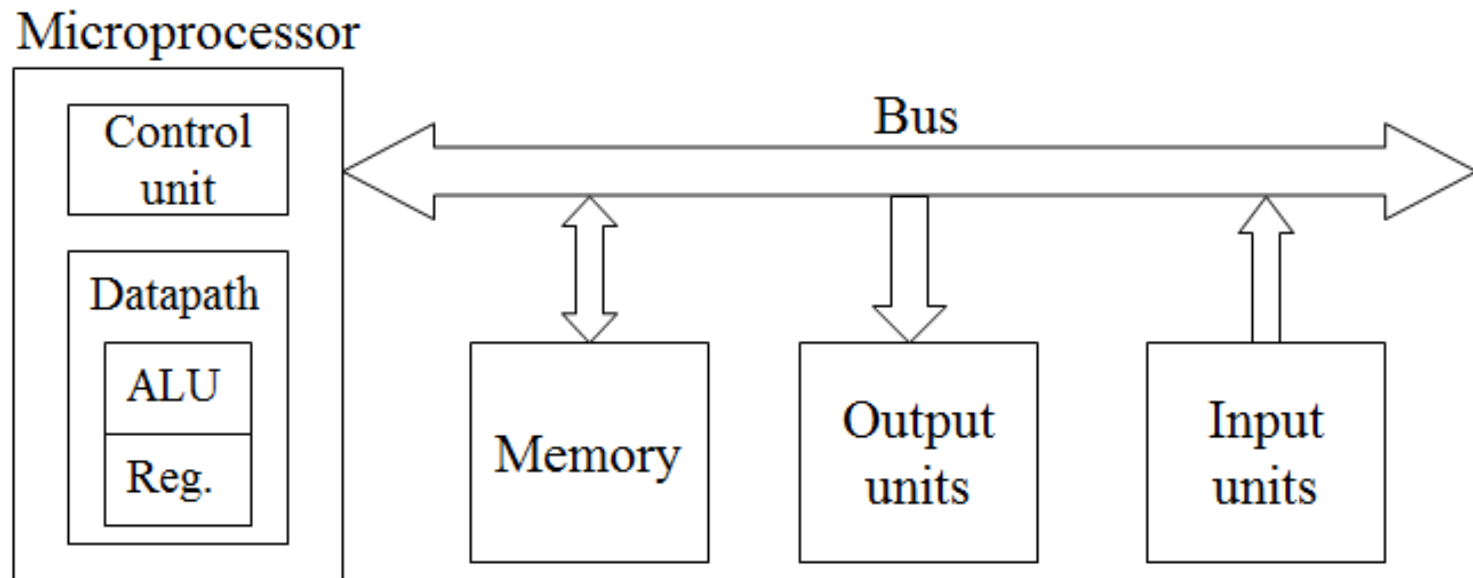
- What is missing?
 - Memory and the peripherals.

MPU-Based Time and Temperature System

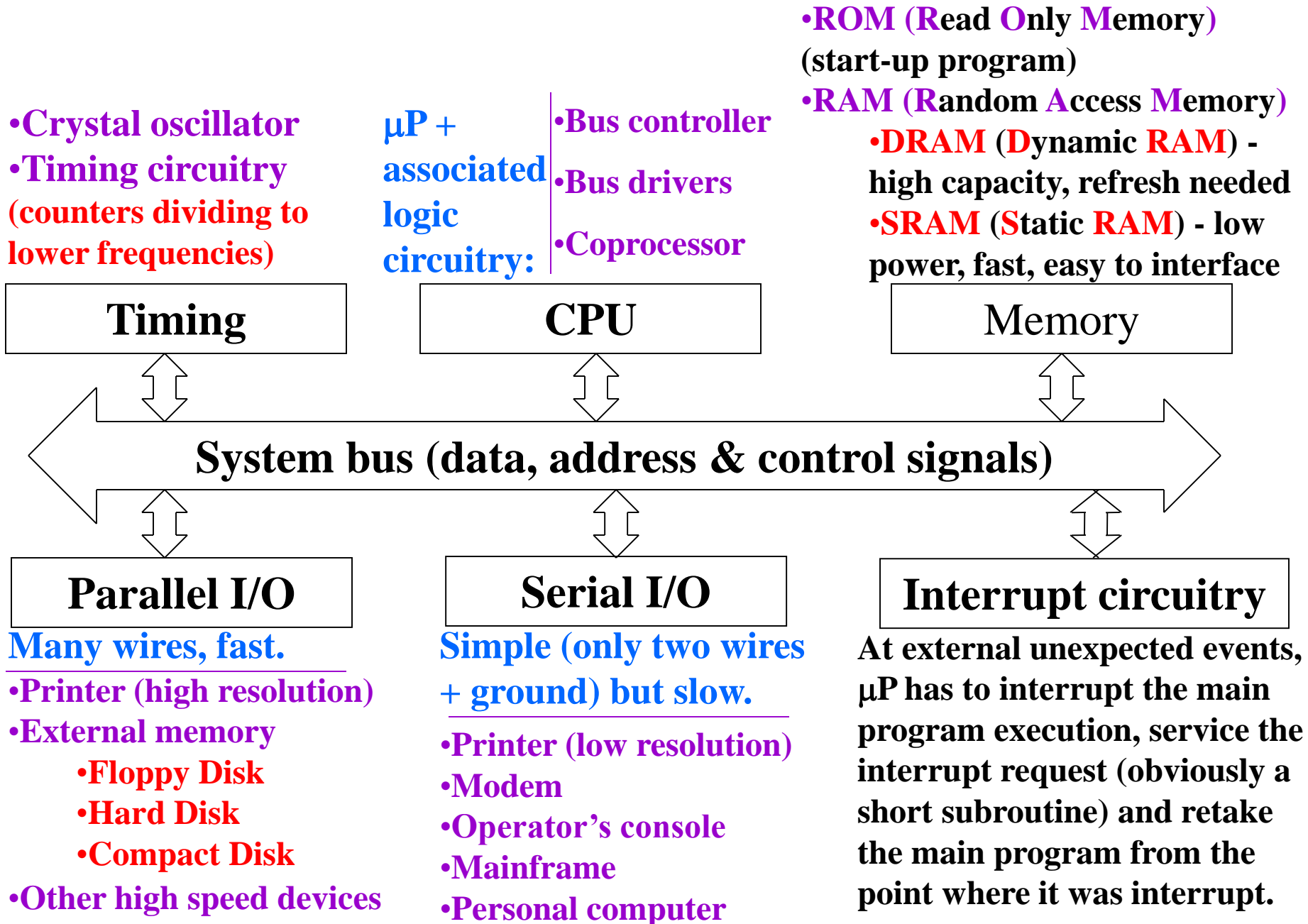


- System hardware
- Discrete components
- Microprocessor, Memory, and I/O
- Components connected by buses
- Address, Data, and Control
- System software
- Group of programs that monitors the functions of the entire system

Block Diagram of a Microcontroller



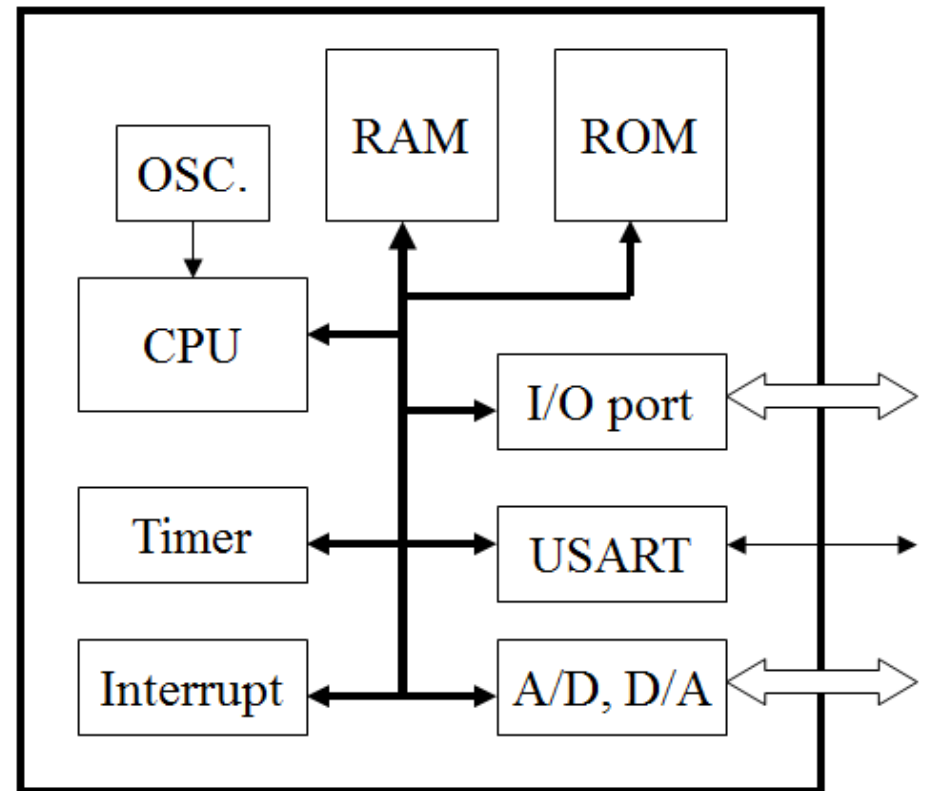
Explanation System block diagram



Applications of Microprocessor-Based Systems

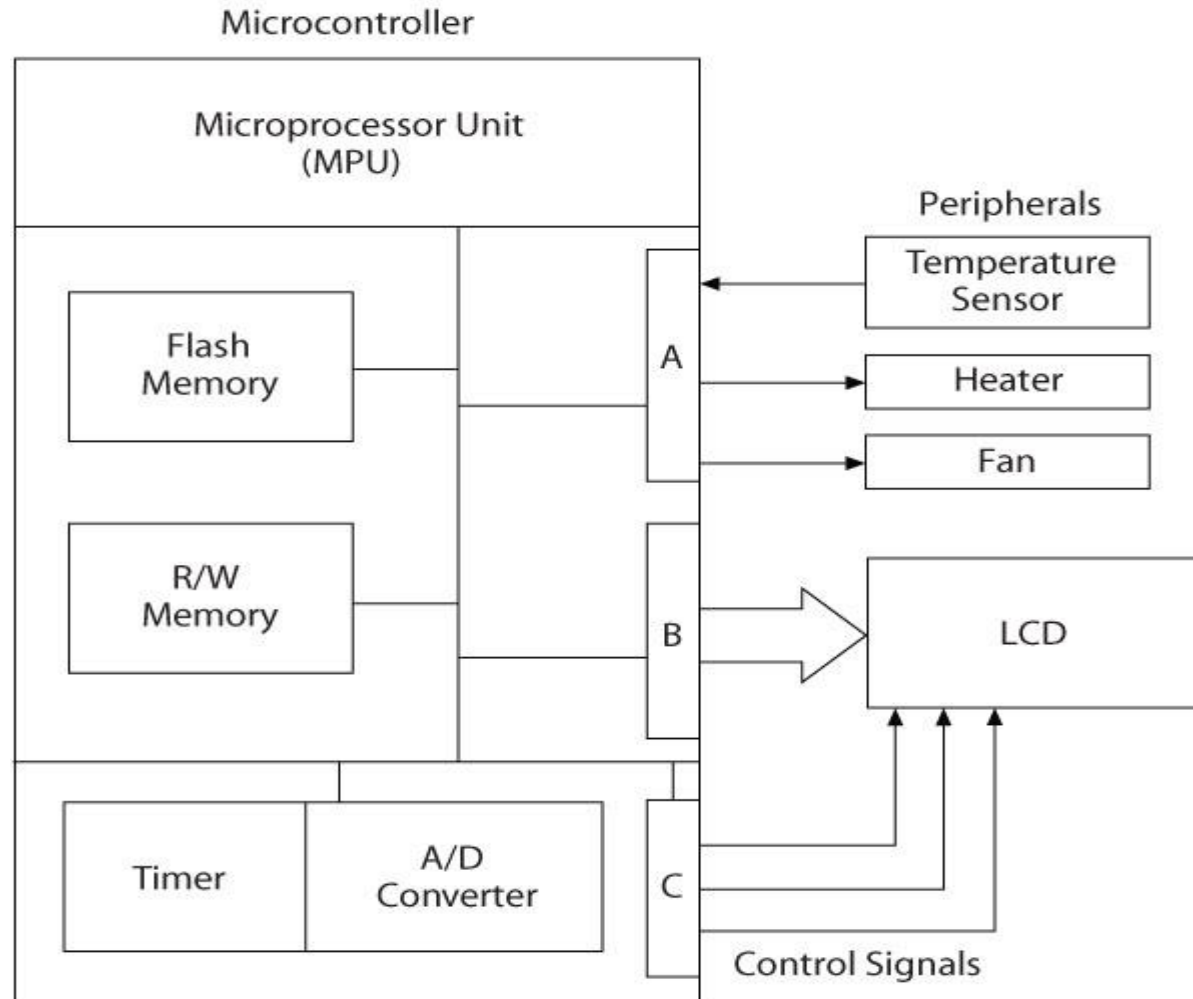
❑ Microcontrollers

- A microcontroller is a simple computer implemented in a single VLSI chip.
- In general, microcontrollers are cheap and have low performance
- Microcontrollers are widely used in industrial control, automobile and home applications



Block diagram of a microcontroller

MCU-Based Time and Temperature System



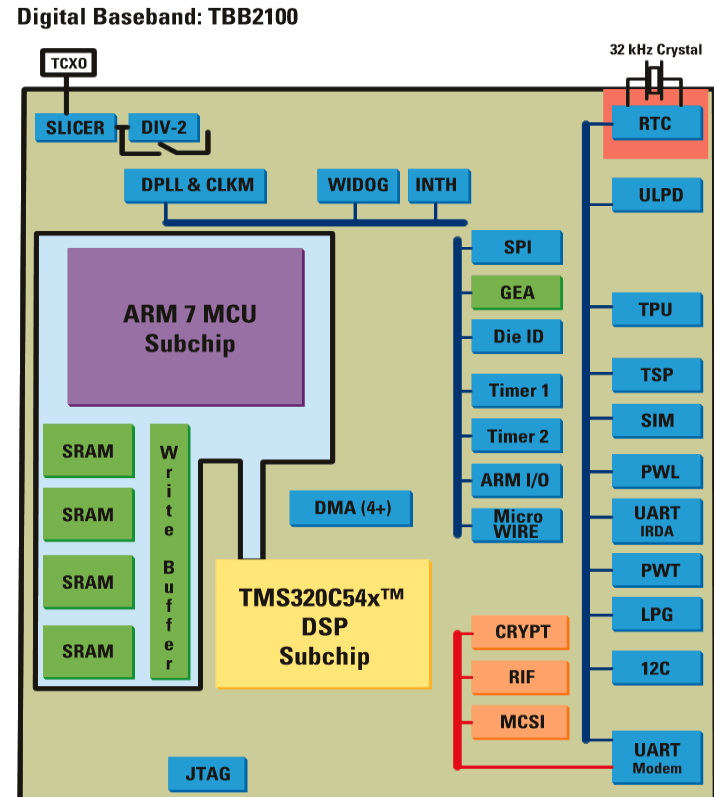
- Microprocessor, memory, I/O ports, and support devices on a single chip
- Buses generally not available to a system designer
- I/O ports generally multiplexed and can be programmed to perform different functions

Applications of Microprocessor-Based Systems

❑ ASICs

Microprocessors are embedded into ASIC chips to implement complex functions

In general, it requires that the microprocessors have low power consumption and take small silicon area



A TI baseband chip for cellular phone applications