Microcontroller (EEC421)

Lecture 2

Dr. Islam Mohamed

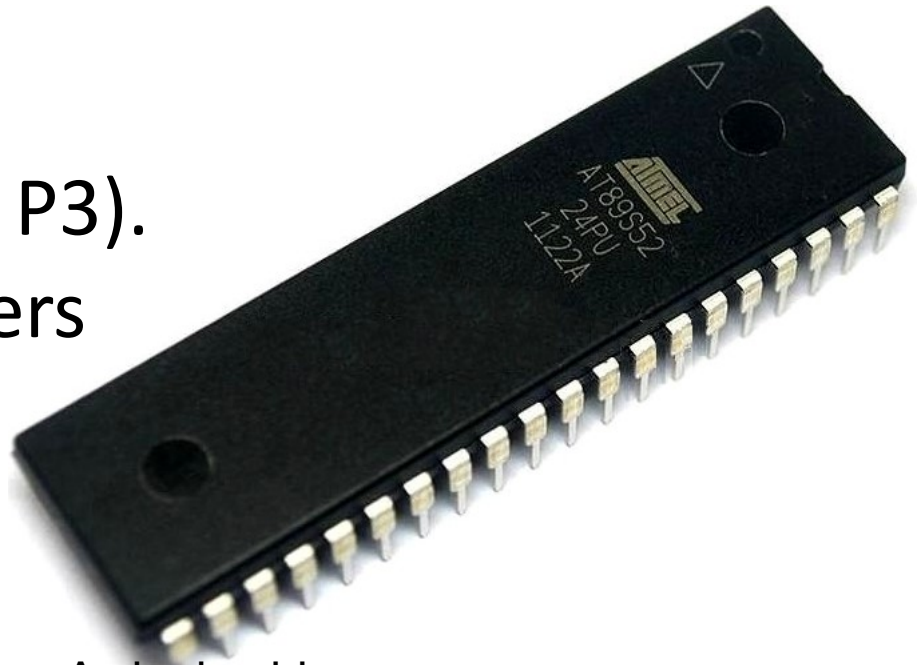
Electrical Engineering Department
Shoubra Faculty of Engineering, Benha University
Islam.ahmed@fen.bu.edu.eg

1- DC Machines

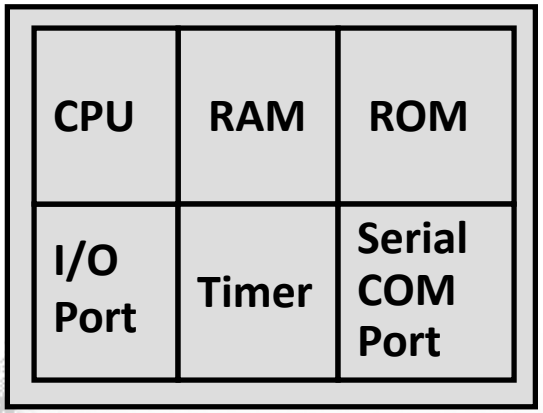
- **Lecture 2: THE 8051 ARCHITECTURE**
- ✓ 8051 Microcontroller Hardware
- ✓ Counters, Registers, Memory
- ✓ Input / Output Pins, Ports, and Circuits
- ✓ Timers, Serial data

8051 Basic Component

- 4K bytes internal ROM
- 128 bytes internal RAM
- Four 8-bit I/O ports (P0 - P3).
- Two 16-bit timers/counters
- One serial interface



A single chip Microcontroller



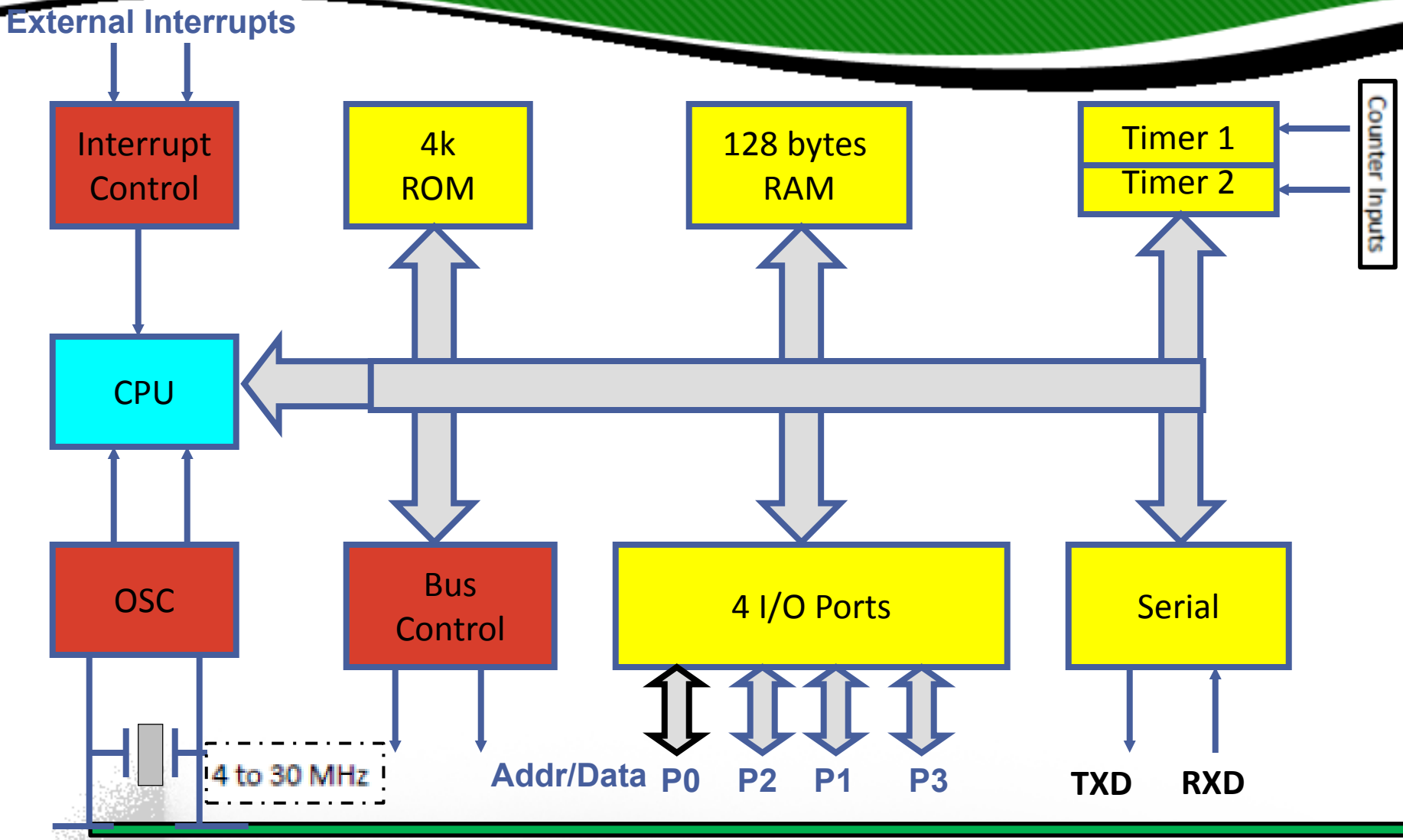
Other 8051 featurs

- only 1 On chip oscillator (external crystal)
- 6 interrupt sources (2 external , 3 internal, Reset)
- 64K external code (program) memory(only read)PSEN
- 64K external data memory(can be read and write) by RD,WR
- Code memory is selectable by EA (internal or external)
- We may have External memory as data and code

criteria in Choosing a Microcontroller

- Meeting the computing needs of the task efficiently and cost effectively
  - speed, the amount of ROM and RAM, the number of I/O ports and timers, size, packaging, power consumption
  - easy to upgrade
  - cost per unit
- Availability of software development tools
  - assemblers, debuggers, C compilers, emulator, simulator, technical support
- Wide availability and reliable sources of the microcontrollers

Block Diagram



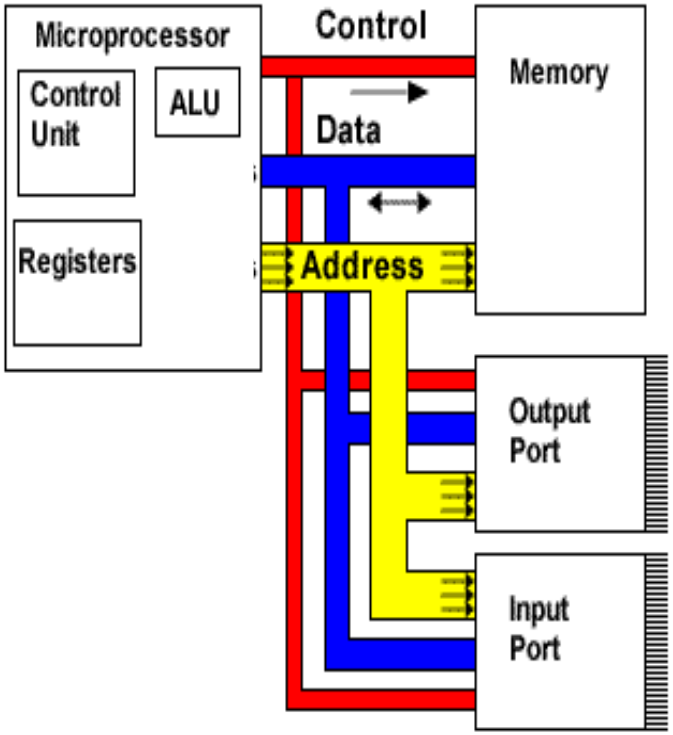
Block Diagram

From the pervious diagram, the system bus connects all the support devices to the CPU. The system bus devices bus consists of an 8-bit data bus, a 16-bit address bus and bus control signals. All other devices like CPU like program memory, ports, data memory, serial interface, interrupt control, timers, and the CPU are are all interfaced together through the system bus.

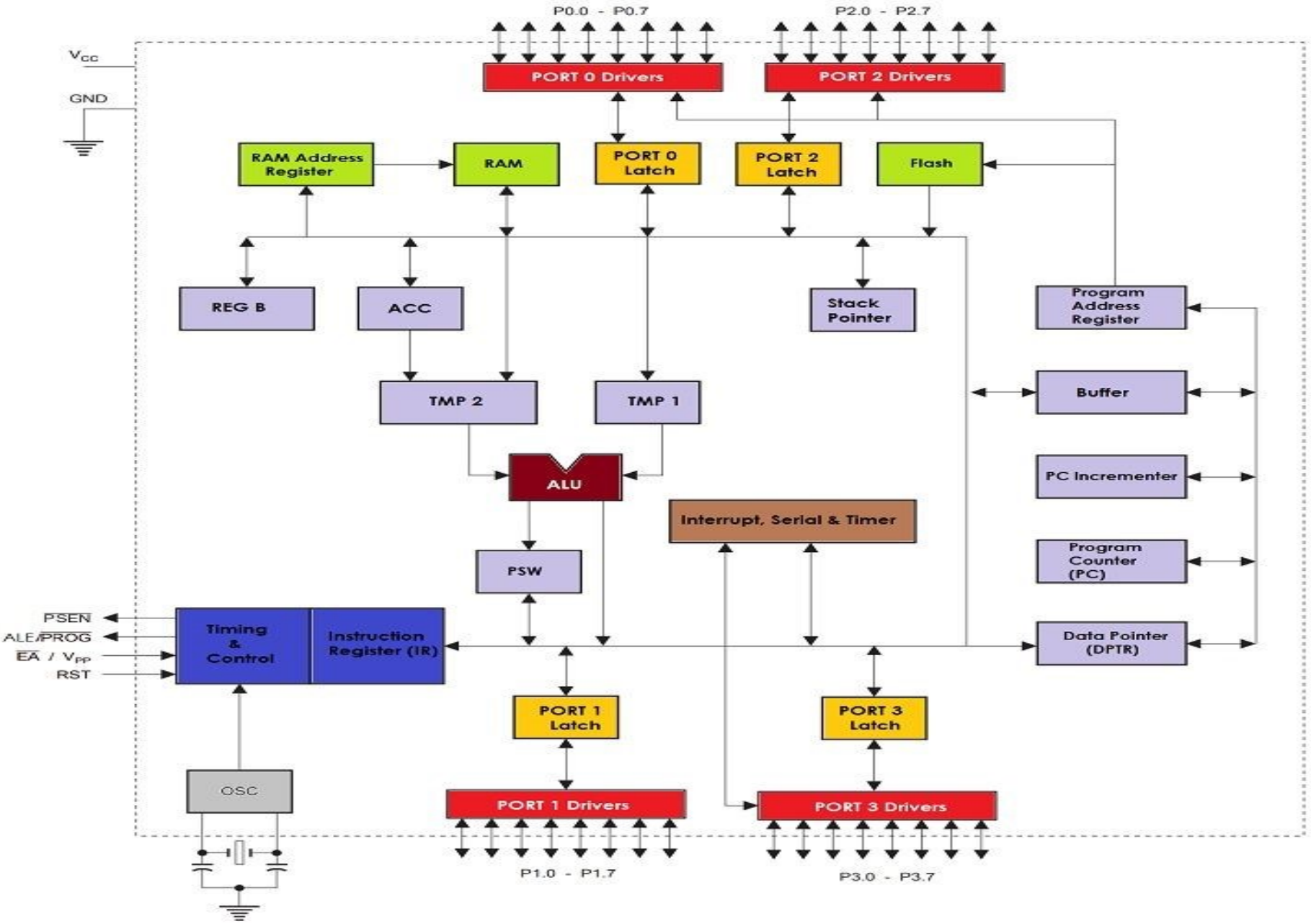
An address bus:
this determines the location in memory that the processor will read data from or write data to.

A data bus:
this contains the contents that have been read from the memory location or are to be written into the memory location.

A control bus:
this manages the information flow between components indicating whether the operation is a read or a write and ensuring that the operation happens at the right time.



8051 Internal Block Diagram



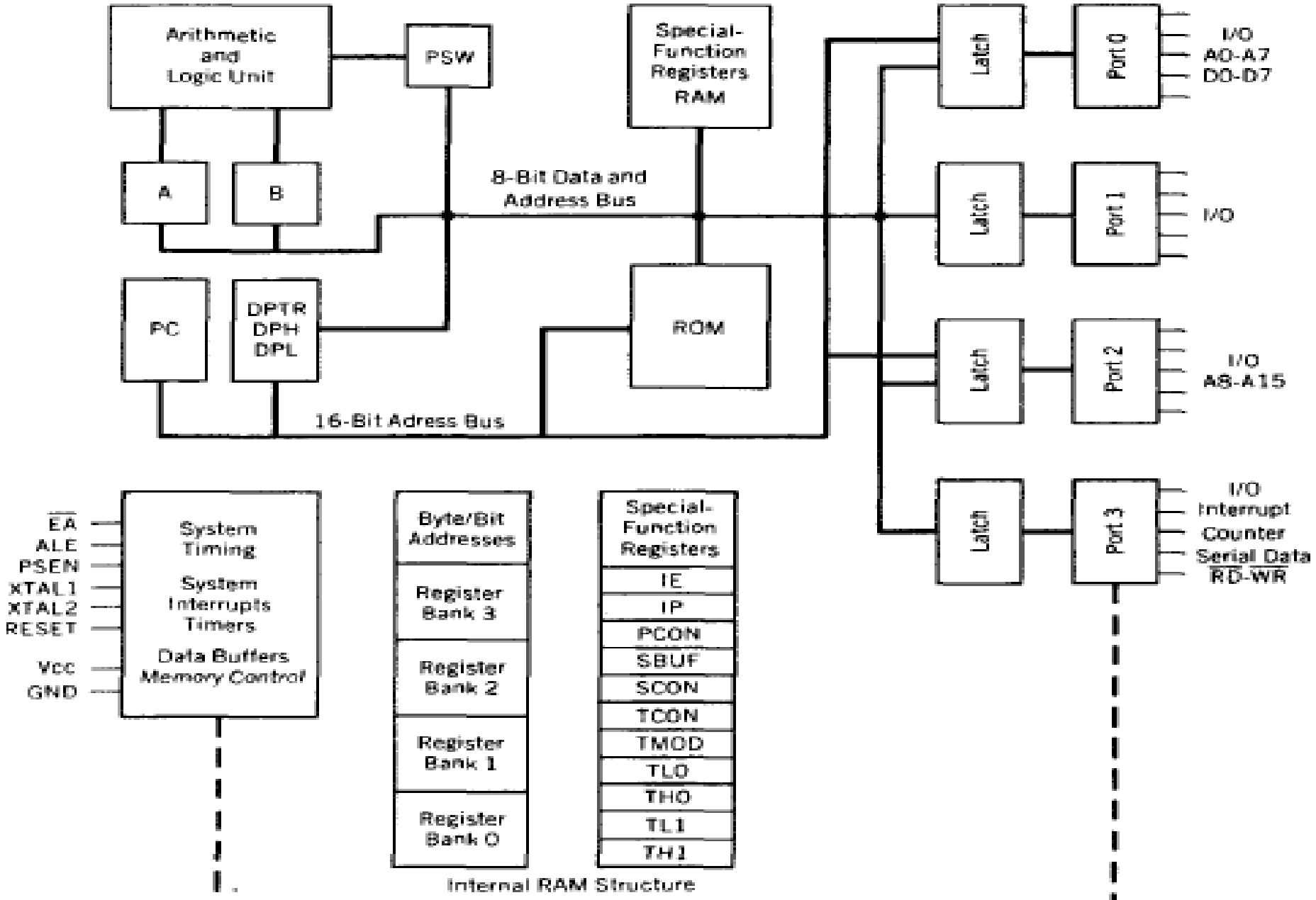


Figure from the Ref.

8051 Internal Block Diagram

Arithmetic and Logical Unit (ALU)

- ALU performs arithmetic like addition, subtraction, multiplication and Logical Operations like NAND, NOR etc.
- Since 8051 is an 8 bit microcontroller, it takes input from two 8 bit registers namely A and B and processes them.

System Timing

refers to the entire timing unit of the microcontroller. The primary source of timing for 8051 is external crystal. The system timing unit is mainly responsible for providing timing to critical events like instruction fetch, decode and execute operations.

Timers/Counters

Again one of the most widely used features, timers are used to count time internally or can be made to count external event as counters.

8051 Internal Block Diagram

Interrupts

- A method to stop current execution and switch over to a priority task with the use of Interrupts. They are associated with external pins P3.2(INT0) and P3.3(INT1). As well as internal units like timers and serial communication. Thus an interrupt to 8051 can be external generated by peripheral device or internal from one of its inbuilt units sometimes referred as software interrupt.

Memory Control

It is an internal unit of the microcontroller, responsible for accessing data from RAM and ROM.

Internal RAM

it is divided into 3 main sections:

1. Register Banks

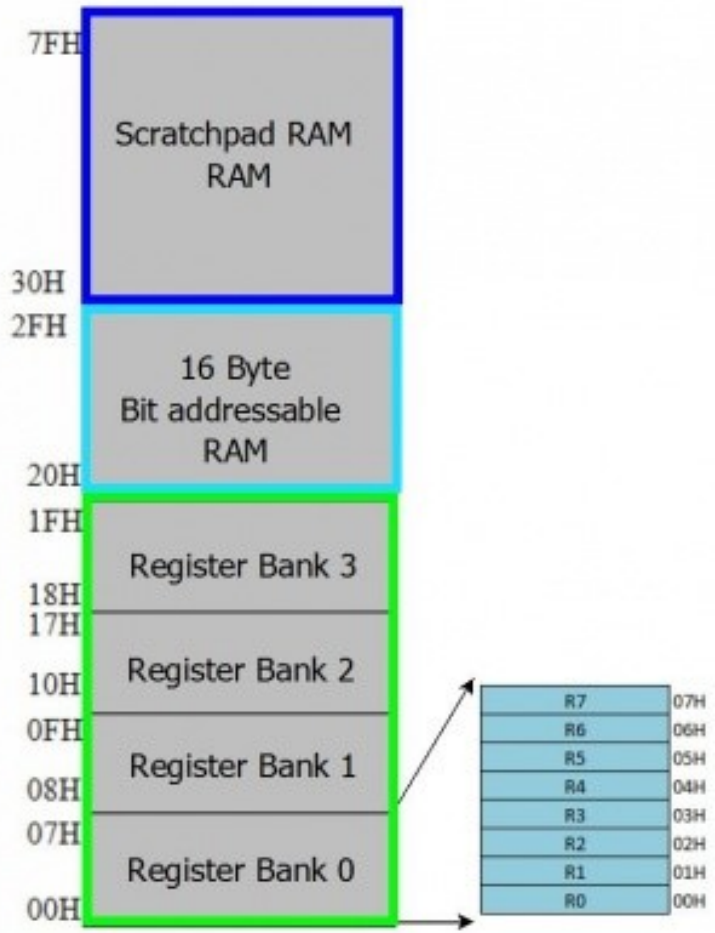
- There are 32 8-bit registers arranged in 4 groups. These are used as general purpose registers.

2. Bit Addressable RAM

- 8051 has 16 bytes of RAM, which is bit addressable. It is grouped as 16, 8 byte arrays and any of the 128 bits can also be set/cleared individually.

3. Scratch PAD RAM

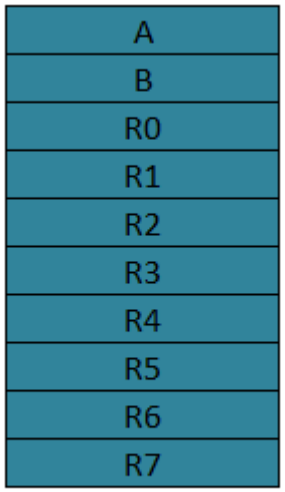
- **The third group of registers occupy addresses 30h-7Fh, i.e. 80 locations, and do not have any special functions or features. Scratch pad RAM is used by the ALU, while fetching, decoding and executing the instructions during operation of the microcontroller.**



Registers of 8051

8 bit Registers

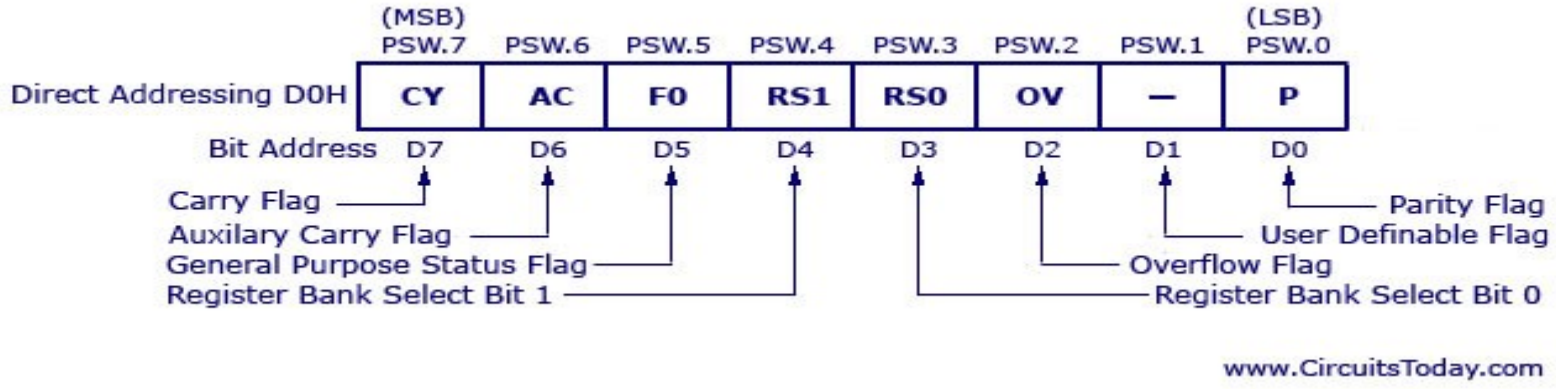
The commonly used registers are R0 to R7, A, B, PSW These are all 8 bit registers. The registers associated with the ALU are A, B and PSW. In most operations, ALU performs specified operation on registers 'A' and 'B' and the result is stored back in 'A'. Hence Register 'A' is often called accumulator.



8-bit Registers

Program Status Word (PSW)

'PSW' indicates various flags associated with the operation performed. Figure below shows the 8 bits of the PSW register and their function is shown in the table.



Registers of 8051

D7	D6	D5	D4	D3	D2	D1	D0
CY	AC	F0	RS1	RS	OV	———	P

Bit No	Bit Symbol	Direct Address	Name	Function
0	P	D0	Parity	This bit will be set if ACC has odd number of 1's after an operation. If not, bit will remain cleared.
1	–	D1		User definable bit
2	OV	D2	Overflow	OV flag is set if there is a carry from bit 6 but not from bit 7 of an Arithmetic operation. It's also set if there is a carry from bit 7 (but not from bit 6) of Acc
3	RS0	D3	Register Bank select bit 0	LSB of the register bank select bit. Look for explanation below this table.

Registers of 8051

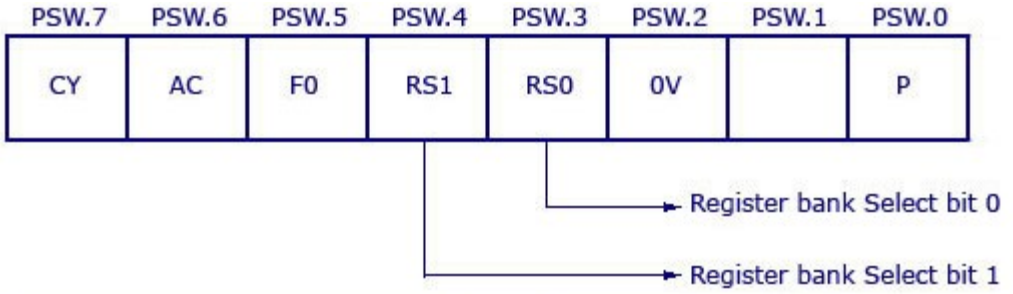
D7	D6	D5	D4	D3	D2	D1	D0
CY	AC	F0	RS1	RS	OV	———	P

4	RS1	D4	Register Bank select bit 1	MSB of the register bank select bits.
5	F0	D5	Flag 0	User defined flag
6	AC	D6	Auxiliary carry	This bit is set if data is coming out from bit 3 to bit 4 of Acc during an Arithmetic operation.
7	CY	D7	Carry	Is set if data is coming out of bit 7 of Acc during an Arithmetic operation.

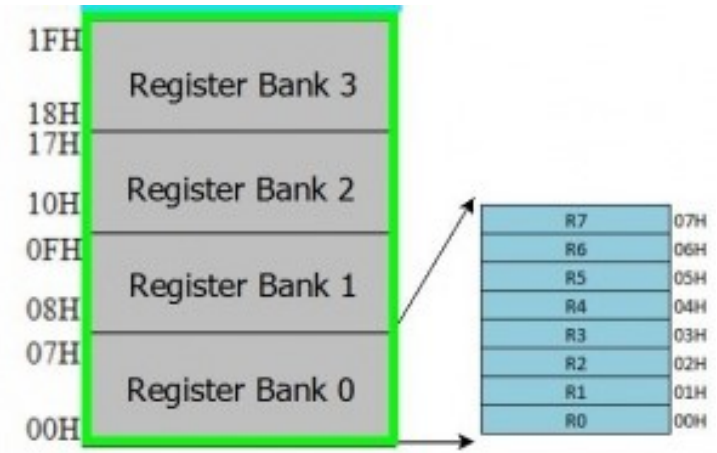
Registers of 8051

D7	D6	D5	D4	D3	D2	D1	D0
CY	AC	F0	RS1	RS	OV	———	P

registers can take value from R0,R1…to R7. You may already know there are 32 such registers. So how you access 32 registers with just 8 variables to address registers? Here comes the use of register banks. There are 4 register banks named 0,1,2 and 3. Each bank has 8 registers named from R0 to R7. At a time only one register bank can be selected. Selection of register bank is made possible through PSW register bits PSW.3 and PSW.4, named as RS0 and RS1.These two bits are known as register bank select bits as they are used to select register banks. The picture will talk more about selecting register banks.



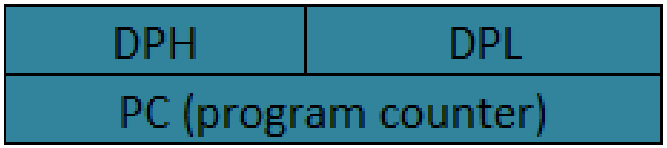
RS1	RS0	Register Bank	Register Bank Status
0	0	0	Register Bank 0 is selected
0	1	1	Register Bank 1 is selected
1	0	2	Register Bank 2 is selected
1	1	3	Register Bank 3 is selected



Registers of 8051

16 bit Registers

There are also some 16 bit registers in 8051 as shown in the figure. The program counter points to the next instruction that the CPU executes.



16 bit Registers

SFR	Address	Function
DPH	83	Data pointer registers (High). Only byte addressing possible.
DPL	82	Data pointer register (Low). Only byte addressing possible.

The data pointer (DPTR) and other special function registers like SCON, TCON,P0,P1,P2 etc will be discussed while using microcontroller features like timers, counter, serial communication, Interrupts etc.

8051 Schematic Pin out

- 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.

- Pin 9

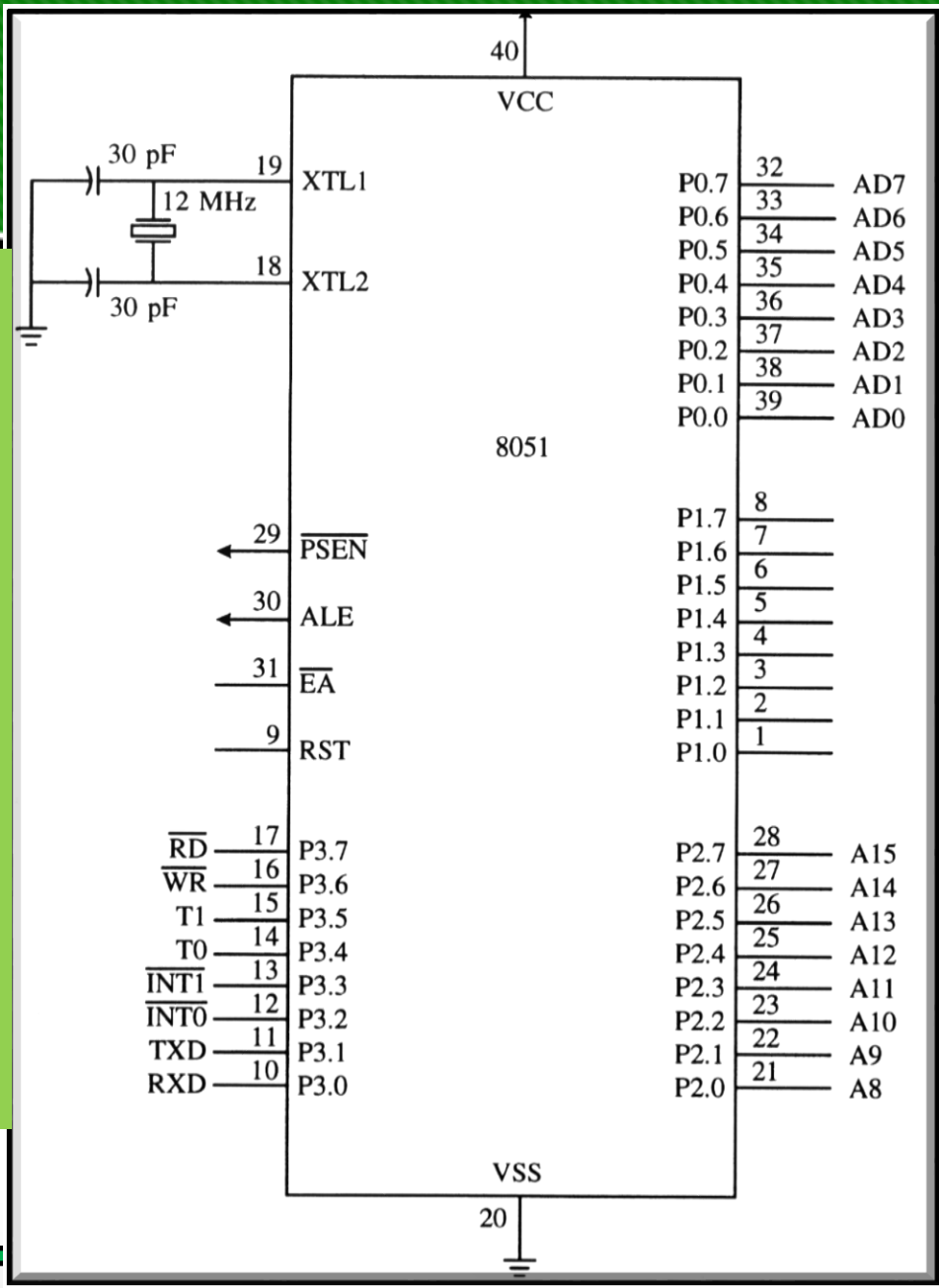
– It is a RESET pin, which is used to reset the microcontroller to its initial values.

- 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.

- Pins 18 & 19

– These pins are used for interfacing an external crystal to get the system clock. clock.



8051 Schematic Pin out

- Pin 20

– This pin provides the power supply to the circuit.

- Pins 21 to 28

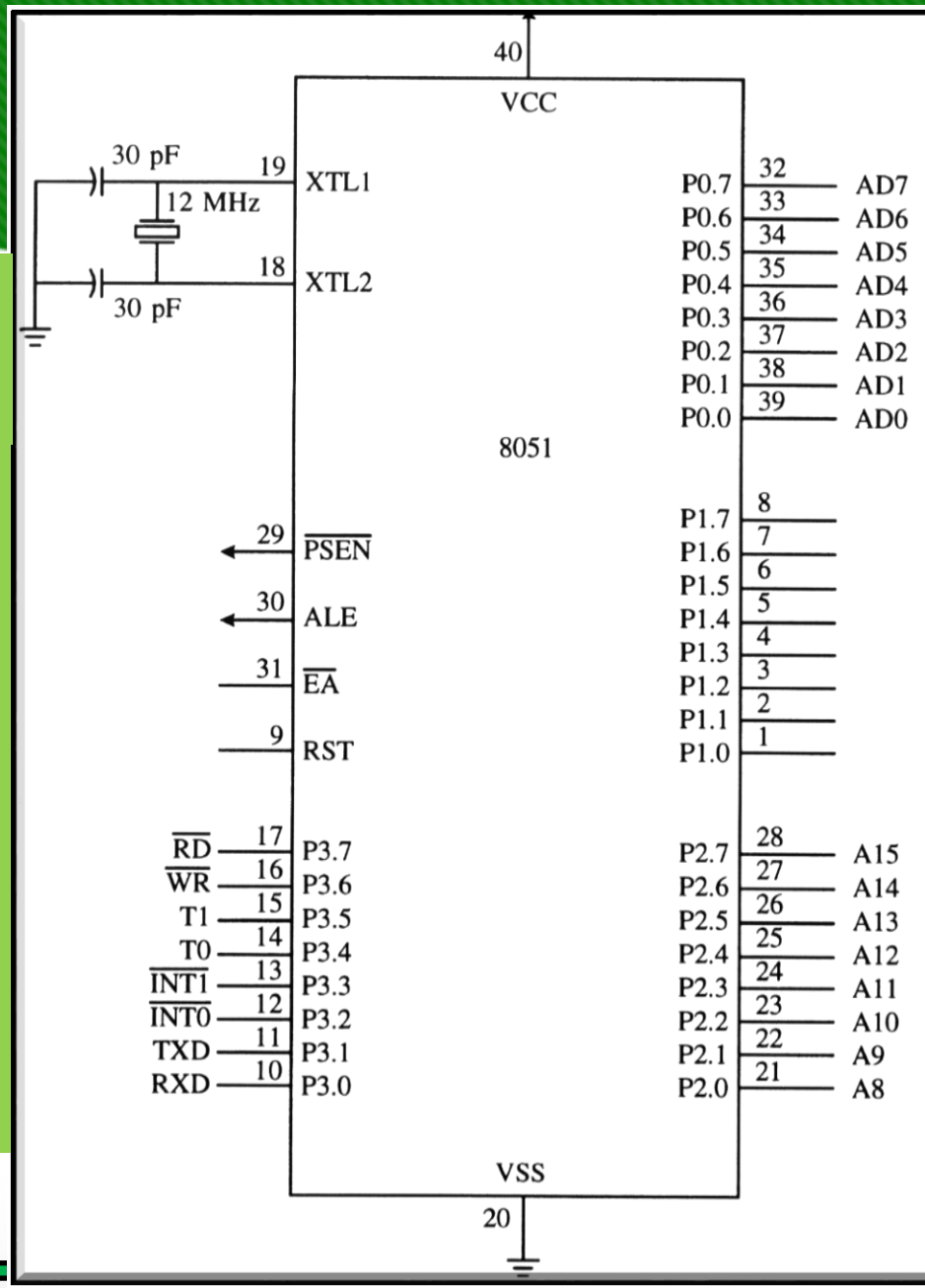
– These pins are known as Port 2. It order It serves as I/O port. Higher order address address bus signals are also multiplexed using this port.

- 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 31

– This is EA pin which stands for External Access input. It is used to enable/disable the external memory interfacing.



8051 Schematic Pin out

- **Pin 30**

– This is ALE pin which stands for Address Latch Enable. It is used to demultiplex the address-data signal of port. Where It is used when multiple memory chips are connected to the controller and only one of them needs to be selected.

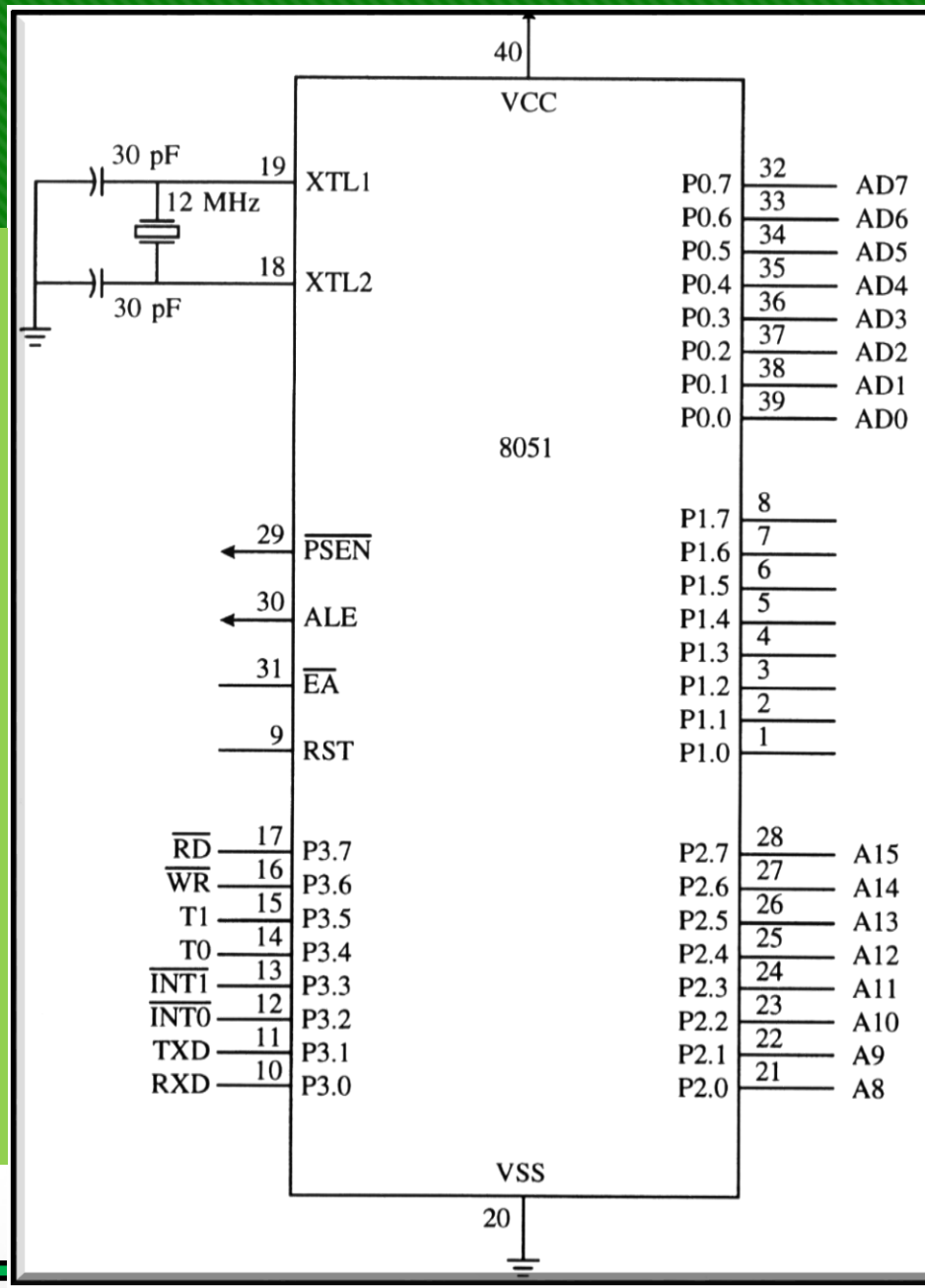
- **Pins 32 to 39**

– 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.

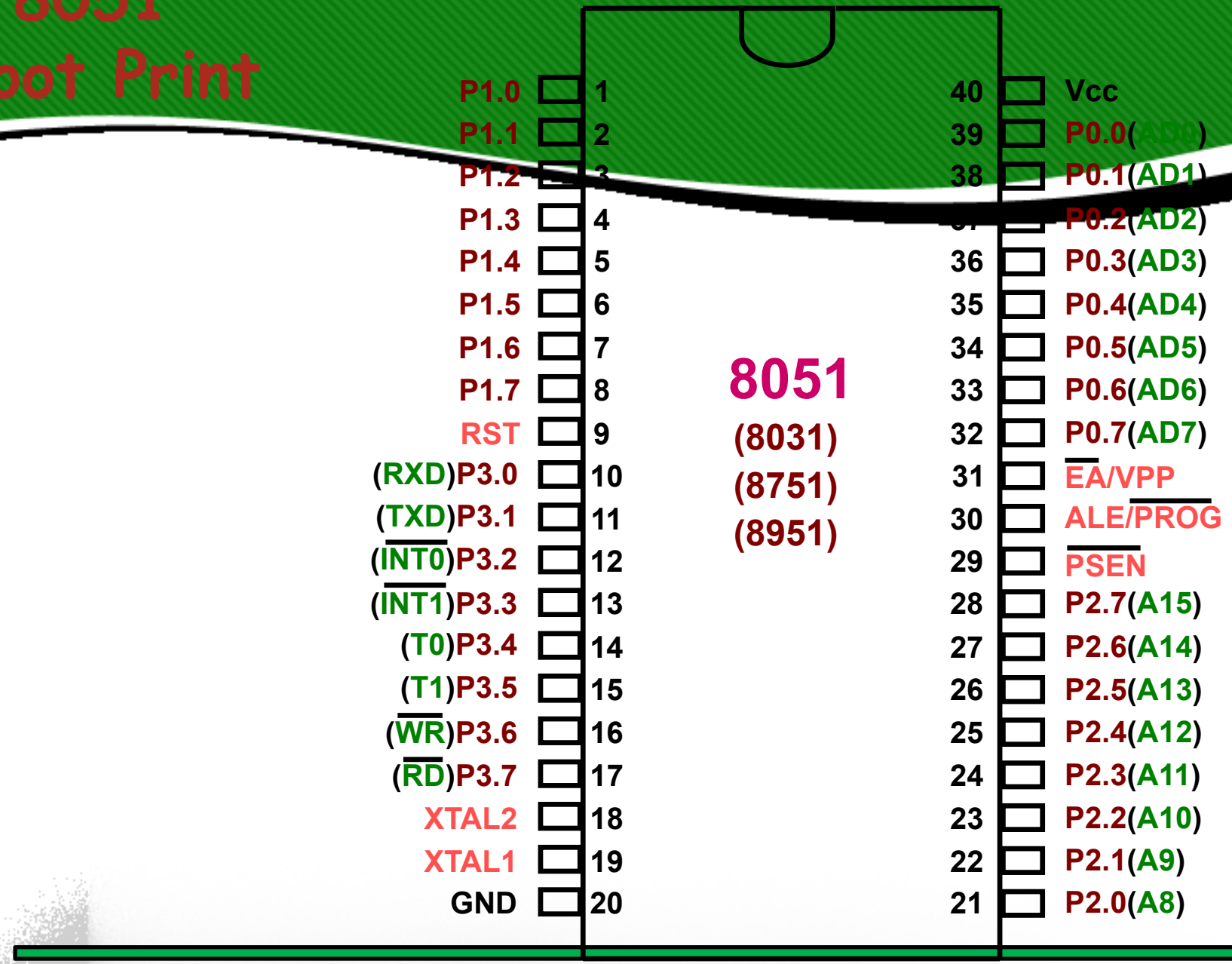
- **Pin 40**

– This pin is used to provide power supply to the circuit.

Vcc provides supply voltage to the chip. The voltage source is +5V.



8051 Foot Print



IMPORTANT PINS (IO Ports)

- **One of the most useful features of the 8051 is that it contains four I/O ports (P0 - P3)**

- Port 0 （pins 32-39）：P0（P0.0～P0.7）
  - 8-bit R/W - General Purpose I/O
  - Or acts as a multiplexed low byte address and data bus for external memory design

- Port 1 （pins 1-8） ：P1（P1.0～P1.7）
  - Only 8-bit R/W - General Purpose I/O

- Port 2 （pins 21-28）：P2（P2.0～P2.7）
  - 8-bit R/W - General Purpose I/O
  - Or high byte of the address bus for external memory design

- Port 3 （pins 10-17）：P3（P3.0～P3.7）
  - General Purpose I/O
  - if not using any of the internal peripherals (timers) or external interrupts.
- **Each port can be used as input or output (bi-direction)**

Port 3 Alternate Functions

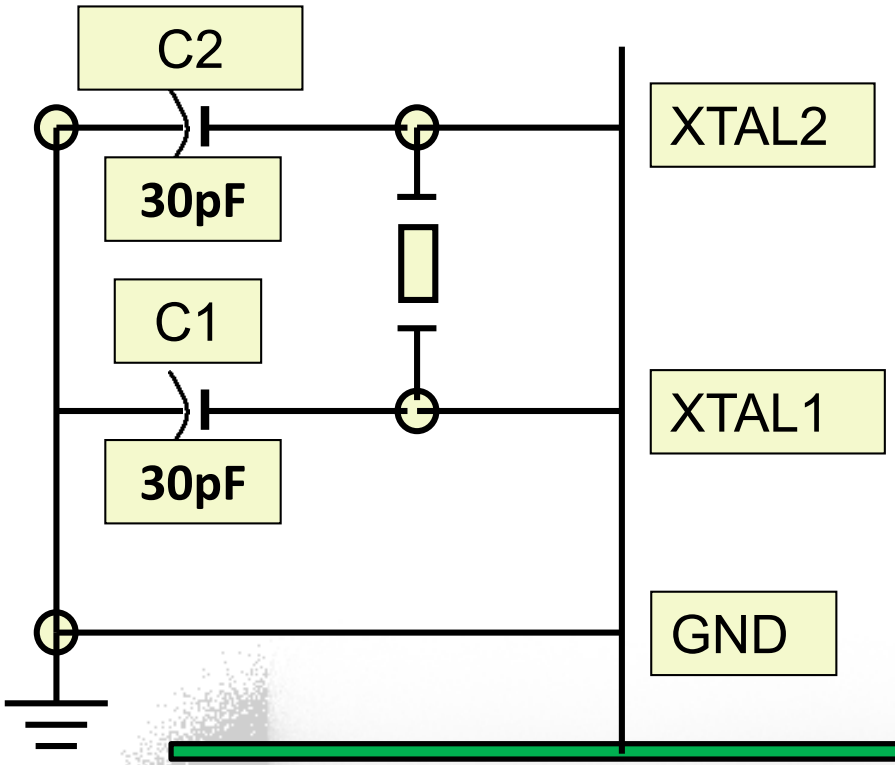
Port Pin	Alternate Function
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (Timer 0 external input)
P3.5	T1 (Timer 1 external input)
P3.6	$\overline{\text{WR}}$ (external data memory write strobe)
P3.7	$\overline{\text{RD}}$ (external data memory read strobe)

IMPORTANT PINS

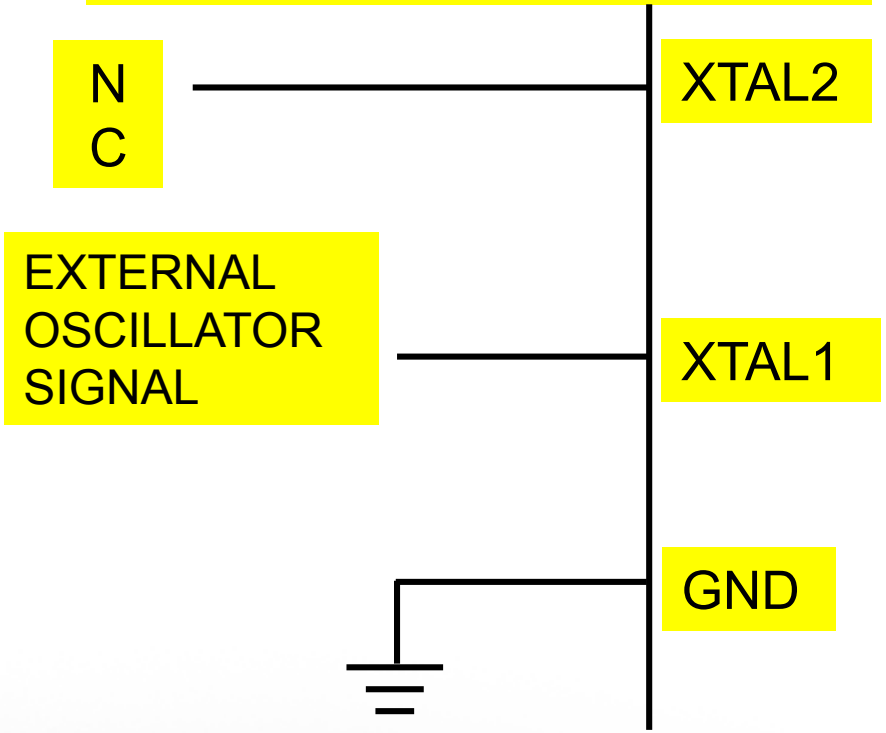
- **PSEN** (out): Program Store Enable, the read signal for external program memory (active low).
- **ALE** (out): Address Latch Enable, to latch address outputs at Port0 and Port2.
- **EA** (in): External Access Enable, active low to access external program memory locations 0 to 4K
- **XTAL1** & **XTAL2** （pins 19,18）： Crystal inputs for internal oscillator.
  - These 2 pins provide external clock.
  - Way 1：using a quartz crystal oscillator
  - Way 2：using a TTL oscillator
  - Example 4-1 shows the relationship between XTAL and the machine cycle.

XTAL Connection to 8051

- Using a quartz crystal oscillator
- We can observe the frequency on the XTAL2 pin.



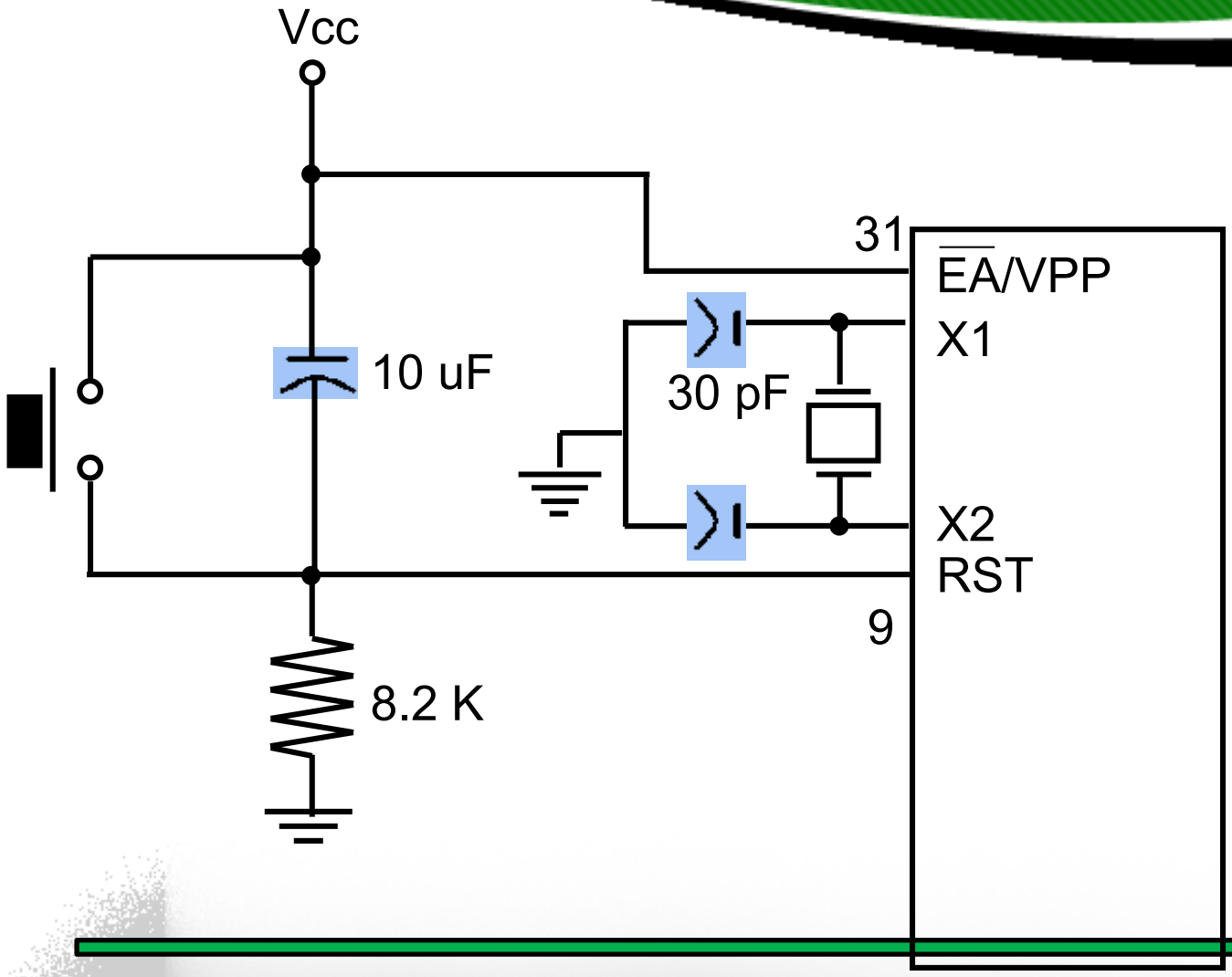
- Using a TTL oscillator
- XTAL2 is unconnected.



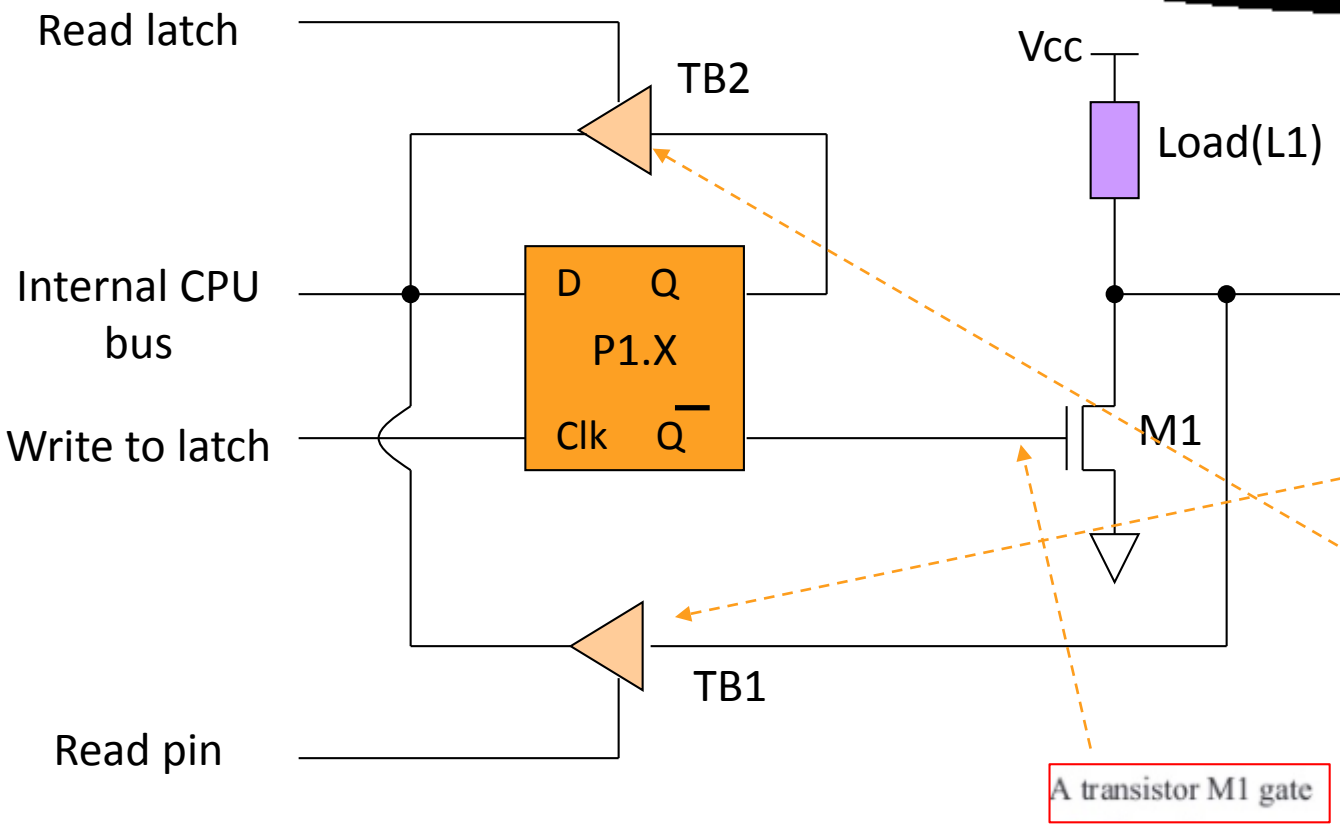
Pins of 8051

- RST（pin 9）：reset
  - input pin and active high（normally low）.
    - The high pulse must be high at least 2 machine cycles.
  - power-on reset.
    - Upon applying a high pulse to RST, the microcontroller will reset and all values in registers will be lost.

Power-On RESET



Hardware Structure of I/O Pin



2 Tri-state buffer :

- TB1: controlled by "Read pin"
  - Read pin = 1 : really read the data present at the pin
- TB2: controlled by "Read latch"
  - Read latch = 1 : read value from internal latch

Hardware Structure of I/O Pin

- Each pin of I/O ports
  - Internally connected to CPU bus
  - A D latch store the value of this pin
    - Write to latch＝1：write data into the D latch
  - 2 Tri-state buffer：
    - TB1: controlled by “Read pin”
      - Read pin＝1：really read the data present at the pin
    - TB2: controlled by “Read latch”
      - Read latch＝1：read value from internal latch
  - A transistor M1 gate
    - Gate=0: open
    - Gate=1: close

Writing "0" & "1" to Output Pin P1.X