Principle and Interface Techniques of Microcontroller

--8051 Microcontroller and Embedded Systems Using Assembly and C

LI, Guang (李光) **Prof. PhD, DIC, MIET**

WANG, You (王酉) **PhD, MIET**

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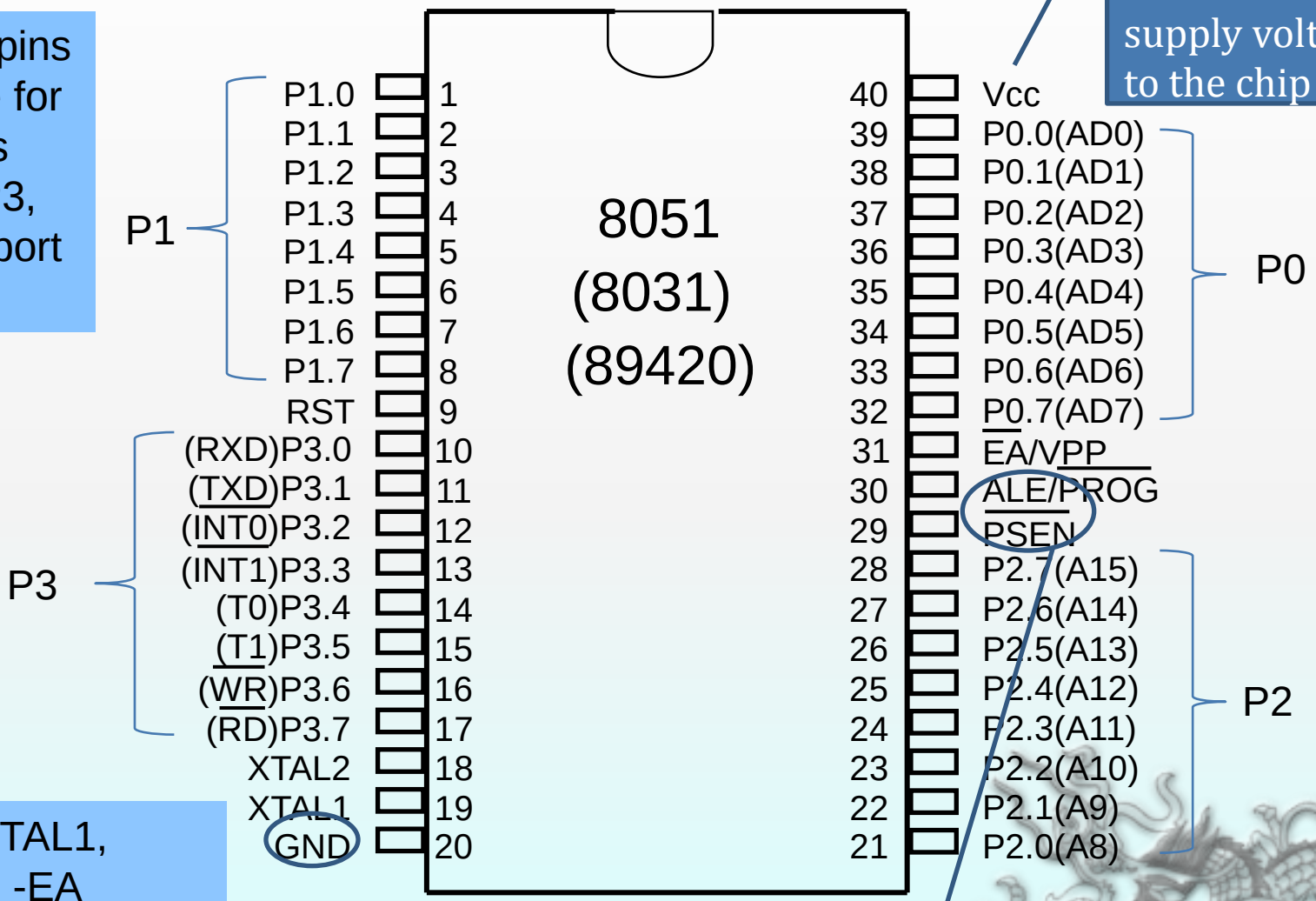
Hardware Connection and Intel Hex File

Pin Description

- 8051 family members (e.g, 8751, 89C51, 89C52, DS89C4x0)
  - ✓Have 40 pins dedicated for various functions such as I/O, -RD, -WR, address, data, and interrupts
  - ✓Come in different packages, such as
    DIP(dual in-line package),
    QFP(quad flat package), and
    LLC(leadless chip carrier)
  - ✓Some companies provide a 20-pin version of the 8051 with a reduced number of I/O ports for less demanding applications

Pin Description

A total of 32 pins are set aside for the four ports P0,P1, P2, P3, where each port takes 8 pins



Provides +5V supply voltage to the chip

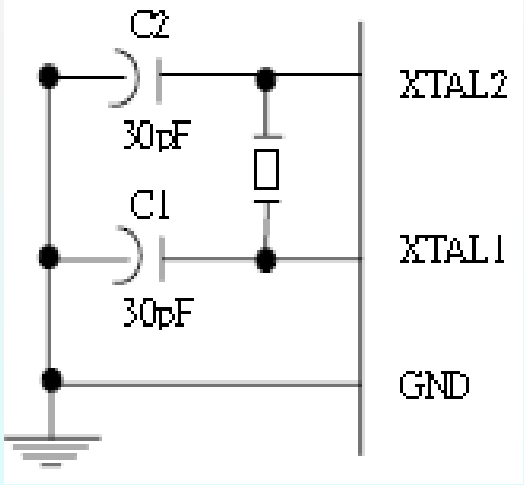
Vcc, GND, XTAL1, XTAL2, RST, -EA are used by all members of 8051 and 8031 families

PSEN and ALE are used mainly in 8031-baded systems

XTAL1 and XTAL2

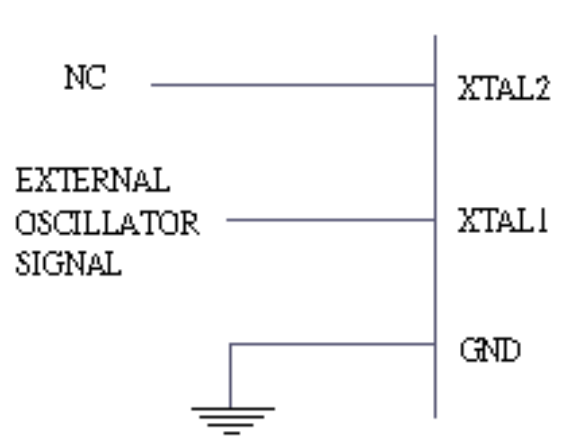
- The 8051 has an on-chip oscillator but requires an external clock to run it
  - ✓A quartz crystal oscillator is connected to inputs XTAL1 (pin19) and XTAL2 (pin18)

    The quartz crystal oscillator also needs two capacitors of 30 pF value



XTAL1 and XTAL2

- If you use a frequency source other than a crystal oscillator, such as a TTL oscillator
  - ✓ It will be connected to XTAL1
  - ✓ XTAL2 is left unconnected



XTAL1 and XTAL2

- The speed of 8051 refers to the maximum oscillator frequency connected to XTAL
  - ✓ex. A 12-MHz chip must be connected to a crystal with 12 MHz frequency or less
  - ✓ We can observe the frequency on the XTAL2 pin using the oscilloscope

RST

- RESET pin is an input and is active high (normally low)
  - ✓Upon applying a high pulse to this pin, the microcontroller will reset and terminate all activities
    - This is often referred to as a power-on reset
    - Activating a power-on reset will cause all values in the registers to be lost

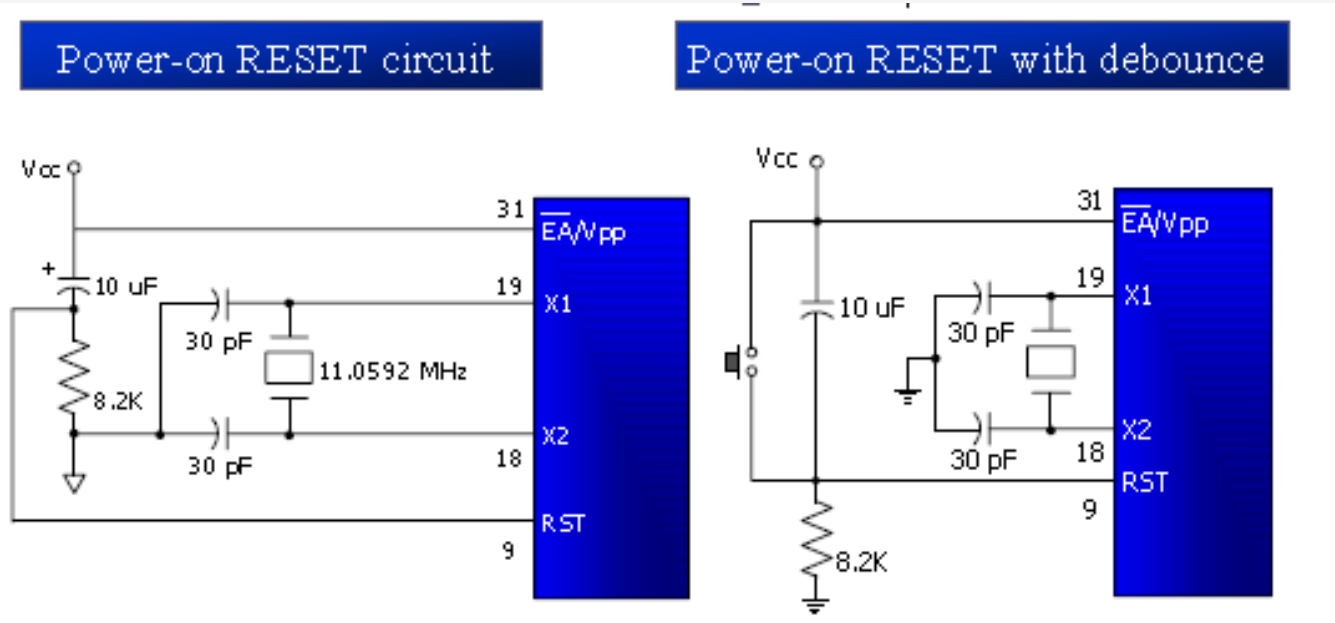
RESET value of some 8051 registers

we must place the first line of source code in ROM location 0

Register	Reset Value
PC	0000
DPTR	0000
ACC	00
PSW	00
SP	07
B	00
P0-P3	FF

RST

- In order for the RESET input to be effective, it must have a minimum duration of 2 machine cycles
  - ✓ In other words, the high pulse must be high for a minimum of 2 machine cycles before it is allowed to go low

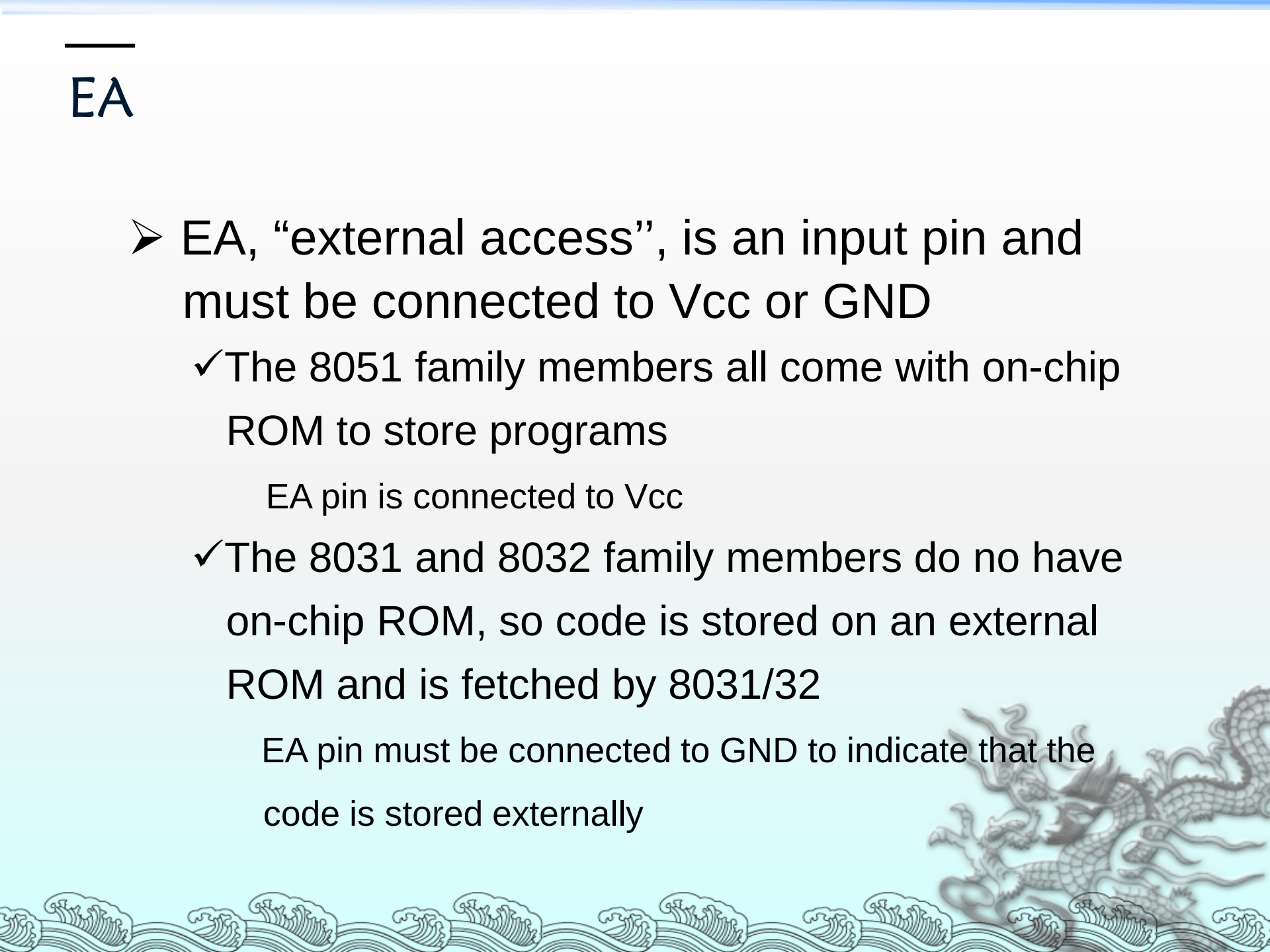


EA

- EA, “external access”, is an input pin and must be connected to Vcc or GND
  - ✓The 8051 family members all come with on-chip ROM to store programs

    EA pin is connected to Vcc
  - ✓The 8031 and 8032 family members do no have on-chip ROM, so code is stored on an external ROM and is fetched by 8031/32

    EA pin must be connected to GND to indicate that the code is stored externally



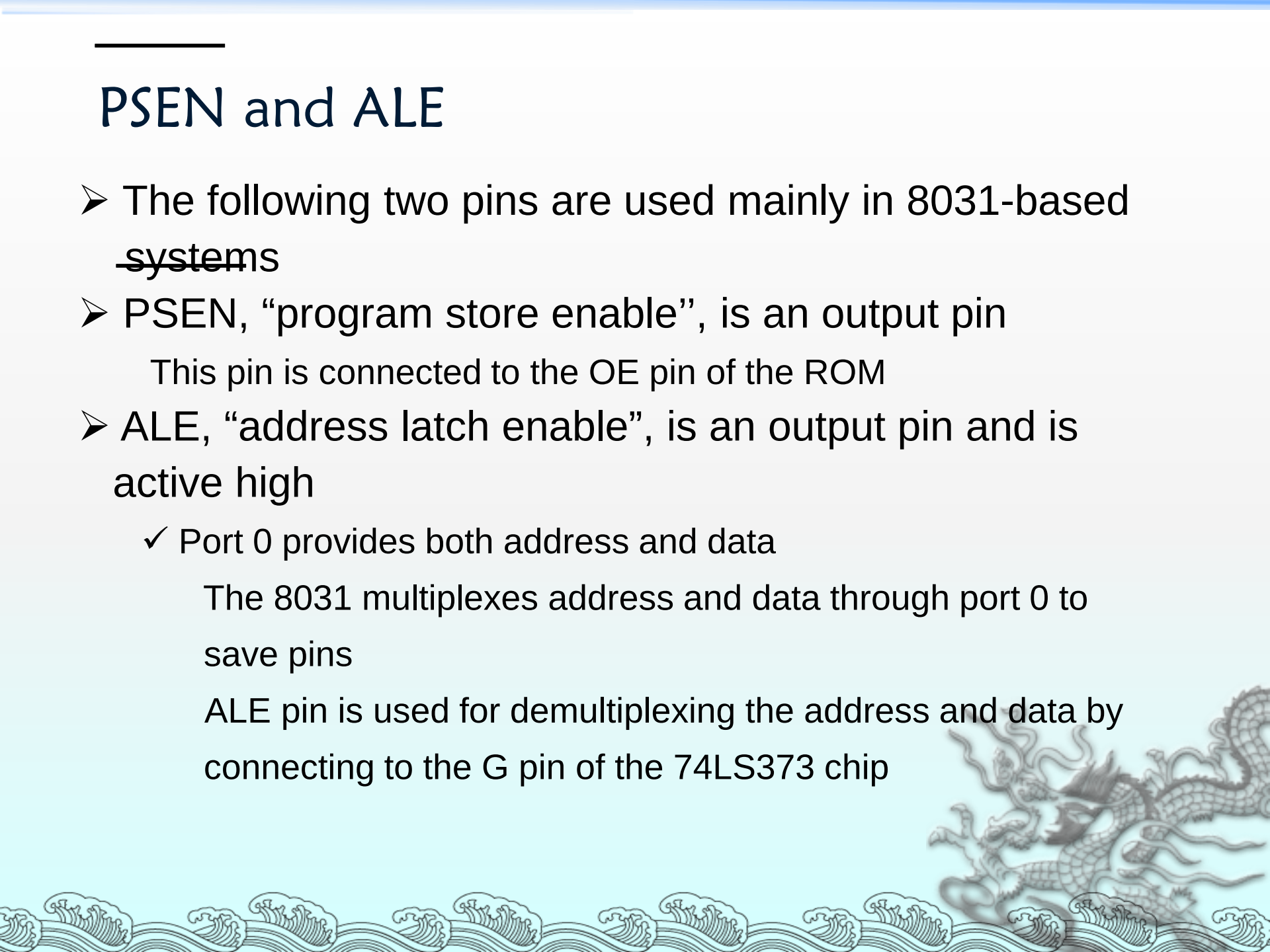
PSEN and ALE

- The following two pins are used mainly in 8031-based ~~system~~s
- PSEN, “program store enable”, is an output pin

  This pin is connected to the OE pin of the ROM
- ALE, “address latch enable”, is an output pin and is active high
  - ✓ Port 0 provides both address and data

    The 8031 multiplexes address and data through port 0 to save pins

    ALE pin is used for demultiplexing the address and data by connecting to the G pin of the 74LS373 chip



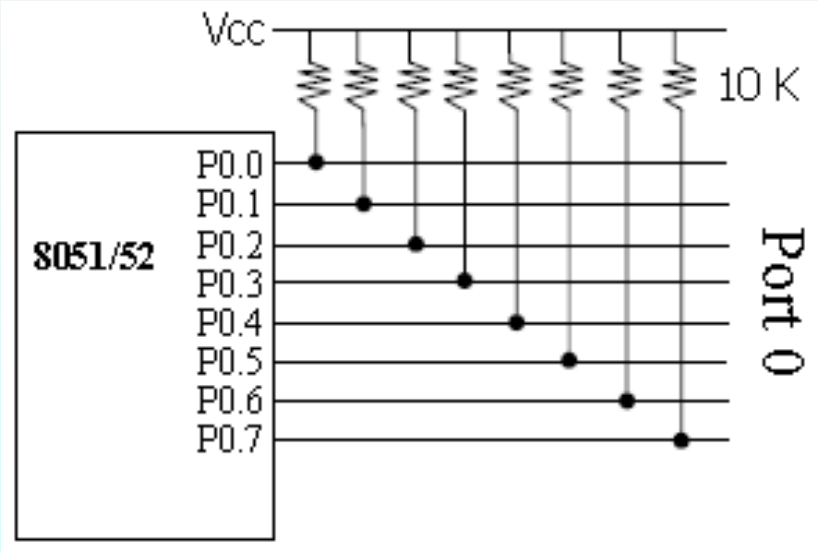
I/O Port Pins

- The four 8-bit I/O ports P0, P1, P2 and P3 each uses 8 pins
- All the ports upon RESET are configured as output, ready to be used as input ports

Port 0

- It can be used for input or output, each pin must be connected externally to a 10K ohm pull-up resistor
  - ✓ This is due to the fact that P0 is an open drain, unlike P1, P2, and P3

    Open drain is a term used for MOS chips in the same way that open collector is used for TTL chips

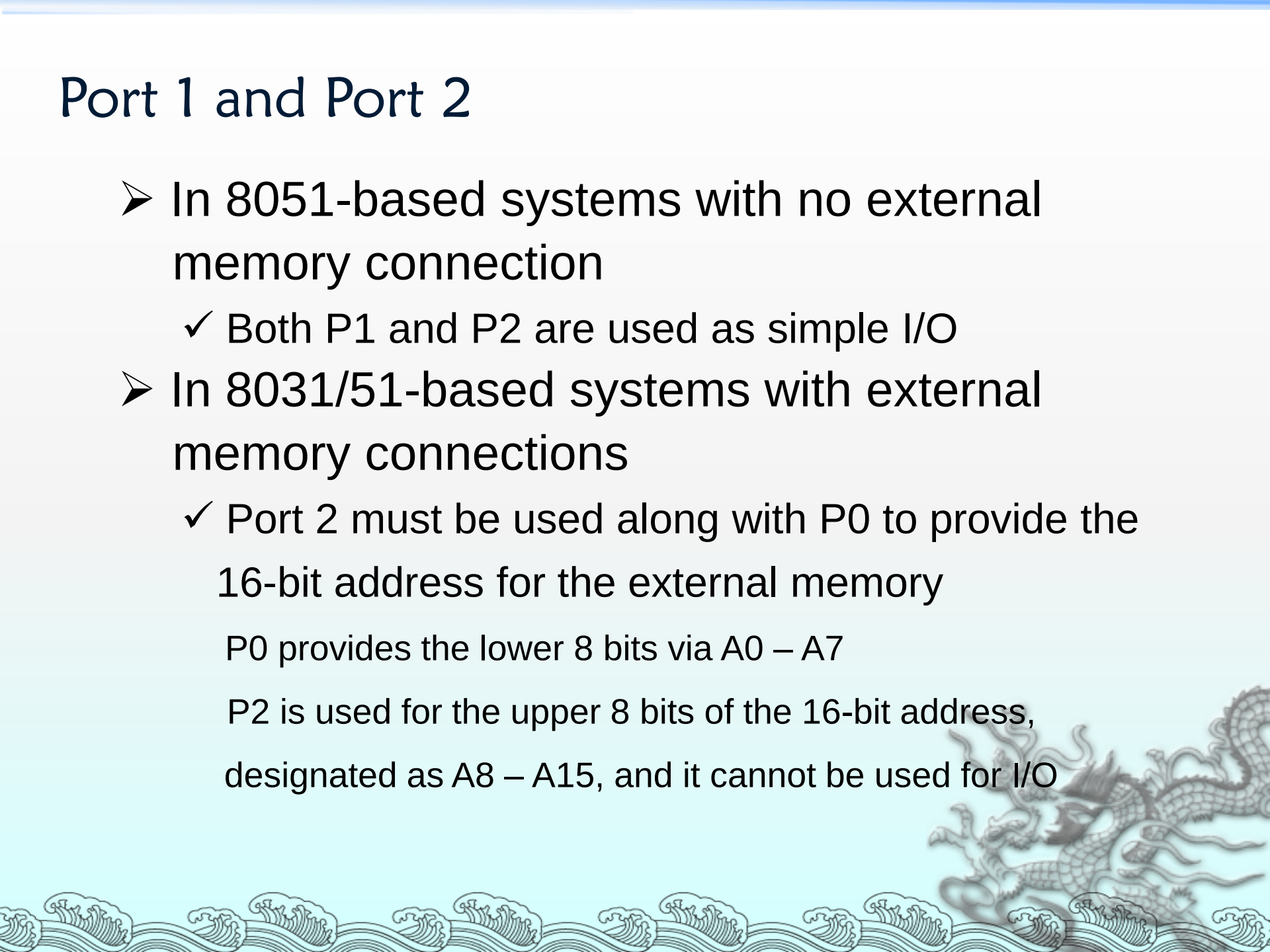


Port 1 and Port 2

- In 8051-based systems with no external memory connection
  - ✓ Both P1 and P2 are used as simple I/O
- In 8031/51-based systems with external memory connections
  - ✓ Port 2 must be used along with P0 to provide the 16-bit address for the external memory

    P0 provides the lower 8 bits via A0 – A7

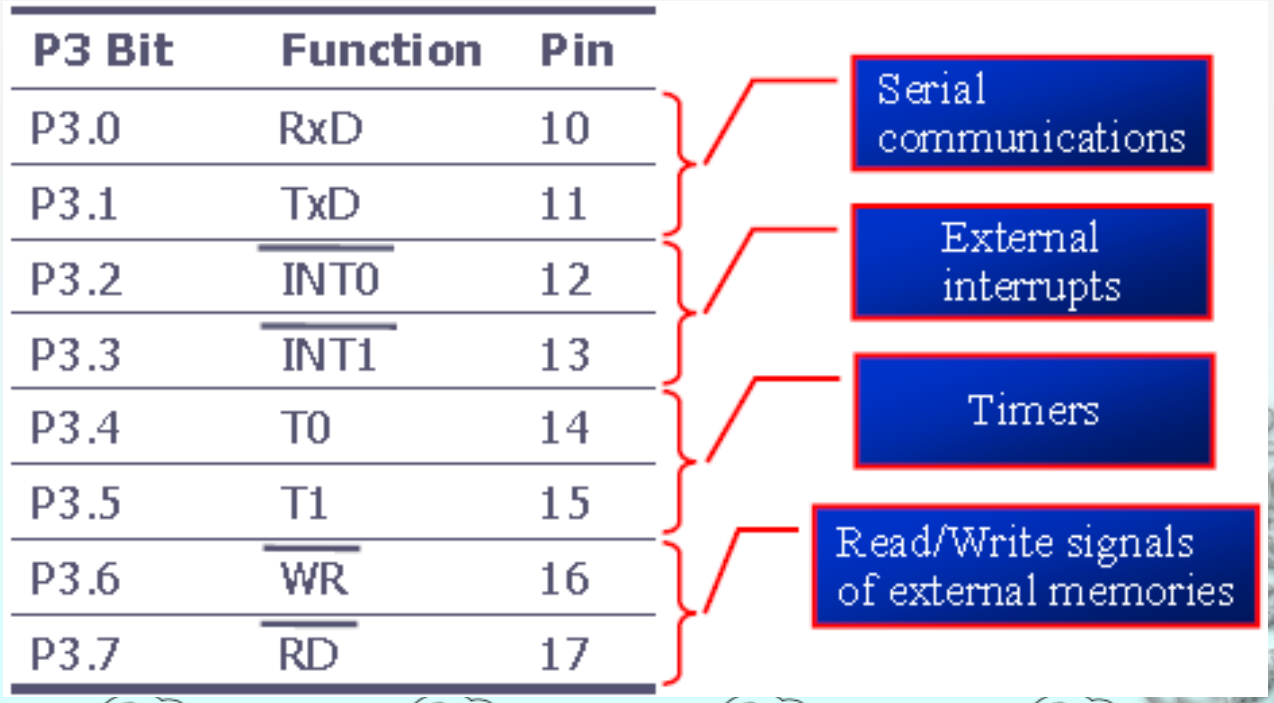
    P2 is used for the upper 8 bits of the 16-bit address, designated as A8 – A15, and it cannot be used for I/O



Port 3

- Port 3 can be used as input or output
  - ✓Port 3 does not need any pull-up resistors
- Port 3 has the additional function of providing some extremely important signals

P3 Bit	Function	Pin
P3.0	RxD	10
P3.1	TxD	11
P3.2	$\overline{\text{INT0}}$	12
P3.3	$\overline{\text{INT1}}$	13
P3.4	T0	14
P3.5	T1	15
P3.6	$\overline{\text{WR}}$	16
P3.7	$\overline{\text{RD}}$	17



Explaining Intel Hex File

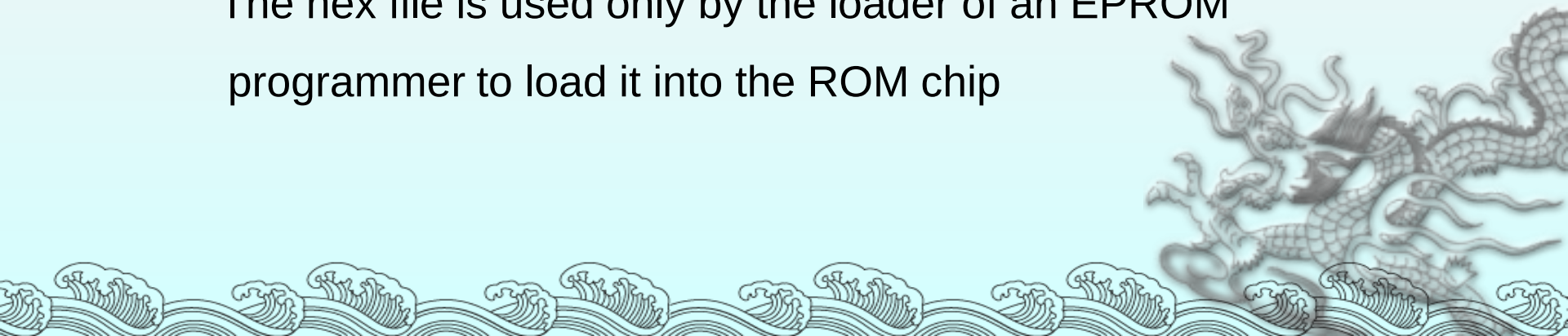
- Intel hex file is a widely used file format
  - ✓ Designed to standardize the loading of executable machine codes into a ROM chip
- Loaders that come with every ROM burner (programmer) support the Intel hex file format
  - ✓ In many newer Windows-based assemblers the Intel hex file is produced automatically (by selecting the right setting)
  - ✓ In DOS-based PC you need a utility called OH (object-to-hex) to produce that

Explaining Intel Hex File

- In the DOS environment
  - ✓ The object file is fed into the linker program to produce the abs file

    The abs file is used by systems that have a monitor program
  - ✓ Then the abs file is fed into the OH utility to create the Intel hex file

    The hex file is used only by the loader of an EPROM programmer to load it into the ROM chip



The location is the address where the opcodes (object codes) are placed

```
LOC   OBJ      LINE
0000           1                ORG 0H
0000 758055    2   MAIN:        MOV P0,#55H
0003 759055    3                MOV P1,#55H
0006 75A055    4                MOV P2,#55H
0009 7DFA      5                MOV R5,#250
000B 111C      6                ACALL MSDELAY
000D 7580AA    7                MOV P0,#0AAH
0010 7590AA    8                MOV P1,#0AAH
0013 75A0AA    9                MOV P2,#0AAH
0016 7DFA      10               MOV R5,#250
0018 111C      11               ACALL MSDELAY
001A 80E4      12               SJMP MAIN
               13  ;--- THE 250 MILLISECOND DELAY.
               14  MSDELAY:
001C 7C23      15  HERE3:       MOV R4,#35
001E 7B4F      16  HERE2:       MOV R3,#79
0020 DBFE      17  HERE1:       DJNZ R3,HERE1
0022 DCFA      18               DJNZ R4,HERE2
0024 DDF6      19               DJNZ R5,HERE3
0026 22        20               RET
               21               END
```

The hex file provides the following:

- ✓ The number of bytes of information to be loaded
- ✓ The infor
- ✓ The starting address where the information must be placed

Each line starts with a colon

Count byte – how many bytes, 00 to 16, are in the line

16-bit address – The loader places the first byte of data into this memory address

Type :
00, there are more lines to come after this line
01, this is the last line and the loading should stop after this line

```
:CC  AAAA  TT  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD  SS
:10  0000  00  758055759055 75A0557DFA111C7580AA  9F
:10  0010  00  7590AA75A0AA7DFA111C80E47C237B4F   01
:07  0020  00  DBFEDCFADDF622                     35
:00  0000  01  FF
```

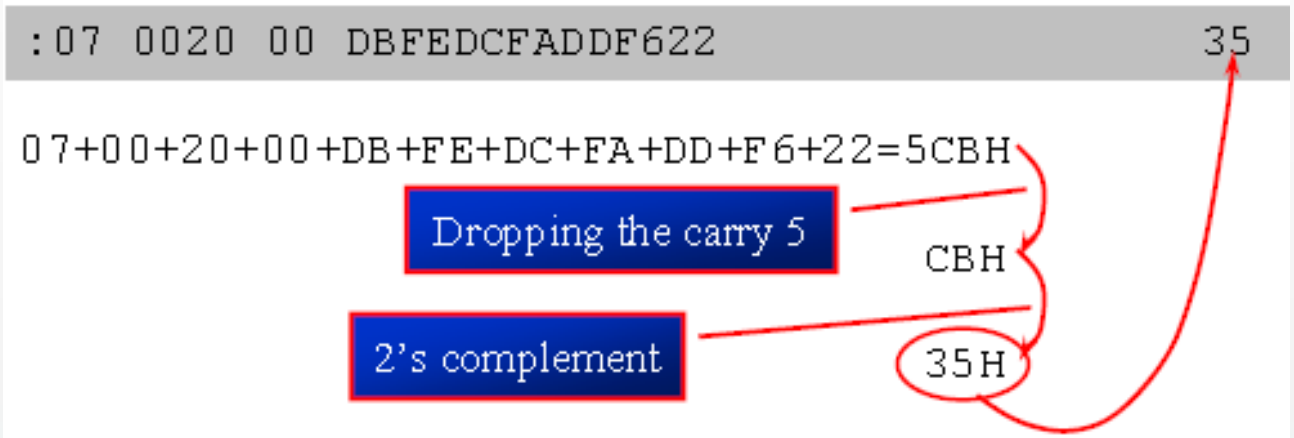
Real information (data or code) – There is a maximum of 16 bytes in this part. The loader places this information into successive memory locations of ROM

Single byte – this last byte is the checksum byte of everything in that line

Example 8-4

Verify the checksum byte for line 3 of Figure 8-9. Verify also that the information is not corrupted.

Solution:



If we add all the information including the checksum byte, and drop the carries, we get 00.

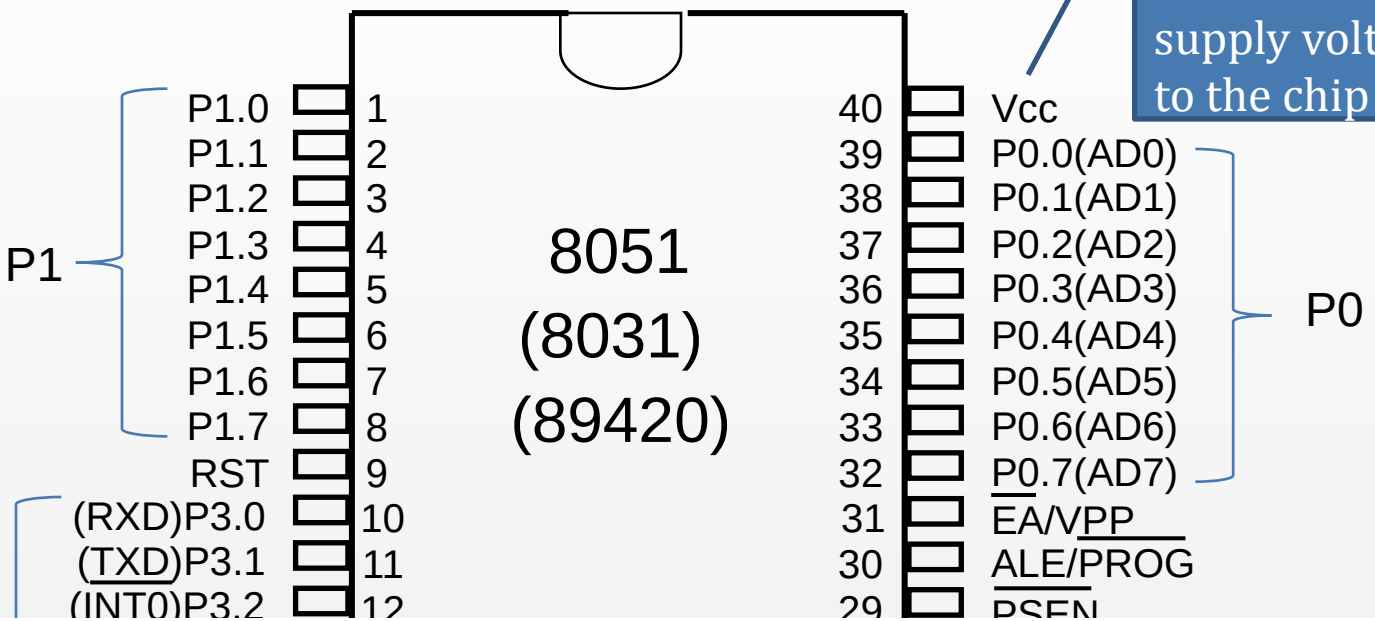
5CBH + 35H = 600H

Chapter 4

I/O Ports Configuration and Programming

I/O Ports Configuration

A total of 32 pins are set aside for the four ports P0,P1, P2, P3, where each port takes 8 pins



- **All the ports upon RESET are configured as input, ready to be used as input ports**

  When the first 0 is written to a port, it becomes an output

  To reconfigure it as an input, a 1 must be sent to the port

  To use any of these ports as an input port, it must be programmed.

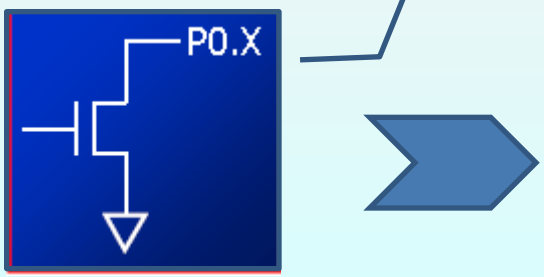
I/O Ports Configuration

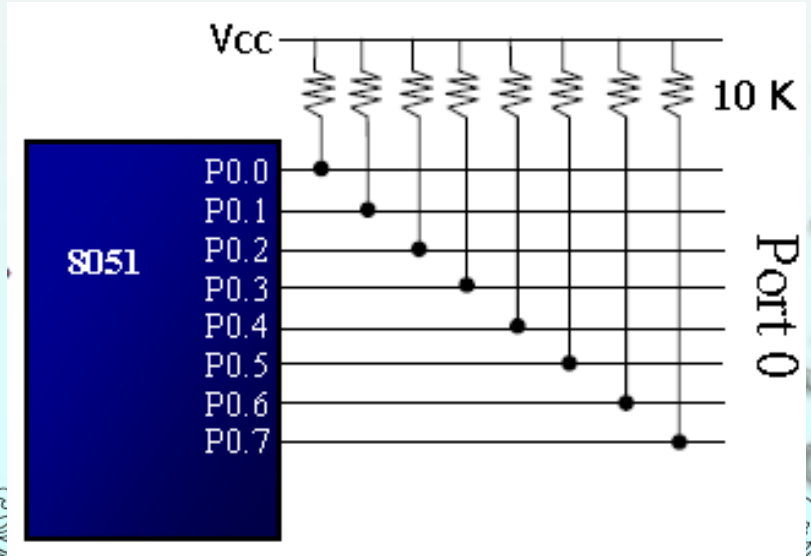
- P0

It can be used for input or output, each pin must be connected externally to a 10K ohm pull-up resistor

This is due to the fact that P0 is an open drain, unlike P1, P2, and P3

Open drain is a term used for MOS chips in the same way that open collector is used for TTL chips





P0

The following code will continuously send out to port 0 the alternating value 55H and AAH

```
BACK:   MOV  A, #55H
        MOV  P0, A
        ACALL  DELAY
        MOV  A, #0AAH
        MOV  P0, A
        ACALL  DELAY
        SJMP  BACK
```

In order to make port 0 an input, the port must be programmed by writing 1 to all the bits

Port 0 is configured first as an input port by writing 1s to it, and then data is received from that port and sent to P1

```
        MOV  A, #0FFH      ;A=FF hex
        MOV  P0, A         ;make P0 an i/p port by writing it all 1s
BACK:   MOV  A, P0         ;get data from P0
        MOV  P1, A         ;send it to port 1
        SJMP  BACK         ;keep doing it
```

Dual Role of Port 0

Port 0 is also designated as AD0-AD7, allowing it to be used for both address and data

When connecting an 8051/31 to an external memory, port 0 provides both address and data.

P1

Port 1 can be used as input or output

- ✓ In contrast to port 0, this port does not need any pull-up resistors since it already has pull-up resistors internally
- ✓ Upon reset, port 1 is configured as an input port

The following code will continuously send out to port 1 the alternating value 55H and AAH

```
        MOV  A, #55H
BACK:   MOV  P1, A
        ACALL  DELAY
        CPL   A
        SJMP  BACK
```

P1

- To make port 1 an input port, it must be programmed as such by writing 1 to all its bits

Port 1 is configured first as an input port by writing 1s to it, then data is received from that port and saved in R7 and R5

```
MOV  A, #0FFH          ;A=FF hex
MOV P1, A         ;make P1 an input port by writing it all 1s
MOV  A, P1             ;get data from P1
MOV  R7, A             ;save it to in reg R7
ACALL  DELAY           ;wait
MOV  A, P1             ;another data from P1
MOV  R5, A             ;save it to in reg R5
```

P2

- Port 2 can be used as input or output

Just like P1, port 2 does not need any pull-up resistors since it already has pull-up resistors internally

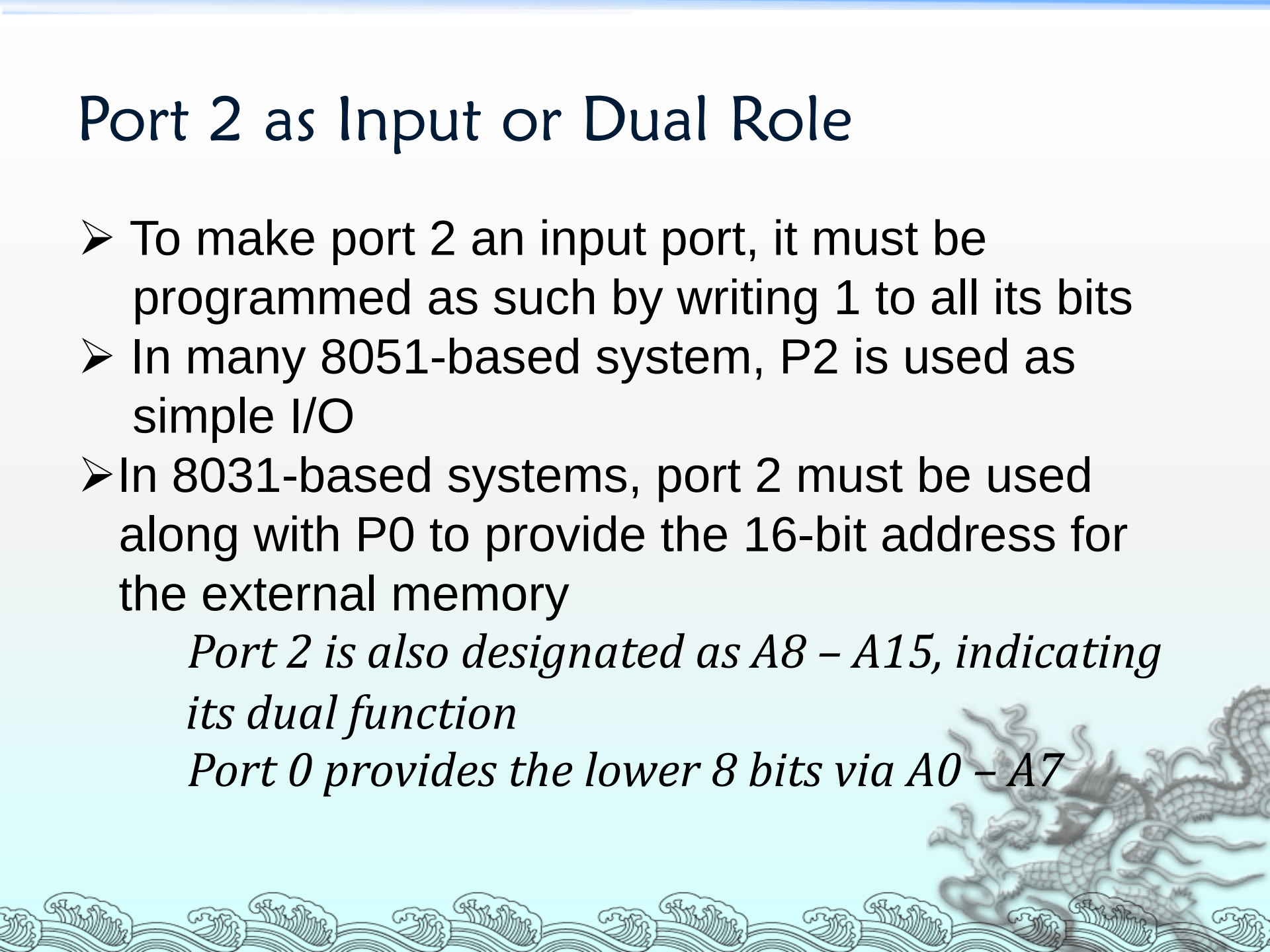
Upon reset, port 2 is configured as an input port

Port 2 as Input or Dual Role

- To make port 2 an input port, it must be programmed as such by writing 1 to all its bits
- In many 8051-based system, P2 is used as simple I/O
- In 8031-based systems, port 2 must be used along with P0 to provide the 16-bit address for the external memory

  Port 2 is also designated as A8 – A15, indicating its dual function

  Port 0 provides the lower 8 bits via A0 – A7



P3

- Port 3 can be used as input or output

Port 3 does not need any pull-up resistors

Port 3 is configured as an input port upon reset, this is not the way it is most commonly used

P3

- Port 3 has the additional function of providing some extremely important signals

P3 Bit	Function	Pin
P3.0	RxD	10
P3.1	TxD	11
P3.2	$\overline{\text{INT0}}$	12
P3.3	$\overline{\text{INT1}}$	13
P3.4	T0	14
P3.5	T1	15
P3.6	$\overline{\text{WR}}$	16
P3.7	$\overline{\text{RD}}$	17

Serial communications

External interrupts

Timers

Read/Write signals of external memories

In systems based on 8751, 89C51 or DS89C4x0, pins 3.6 and 3.7 are used for I/O while the rest of the pins in port 3 are normally used in the alternate function role

Write a program for the DS89C420 to toggle all the bits of P0, P1, and P2 every 1/4 of a second

```
                ORG  0
BACK:           MOV  A, #55H
                MOV  P0, A
                MOV  P1, A
                MOV  P2, A
                ACALL  QSDELAY          ;Quarter of a second
                MOV  A,#0AAH
                MOV  P0,A
                MOV  P1,A
                MOV  P2,A
                ACALL  QSDELAY
                SJMP  BACK
QSDELAY:
                MOV R5, #11
H3:             MOV  R4, #248
H2:             MOV  R3, #255
H1:             DJNZ  R3, H1            ;4 MC for DS89C4x0
                DJNZ  R4, H2
                DJNZ  R5, H3
                RET
                END
```

Delay
$= 11 \times 248 \times 255 \times 4\ \text{MC} \times 90\ \text{ns}$
$= 250{,}430\ \mu\text{s}$

Different ways of Accessing Entire 8 Bits

The entire 8 bits of Port 1 are accessed

```
BACK:   MOV  A, #55H
        MOV  P1, A
        ACALL  DELAY
        MOV  A, #0AAH
        MOV  P1, A
        ACALL  DELAY
        SJMP  BACK
```

Rewrite the code in a more efficient manner by accessing the port directly without going through the accumulator

```
BACK:   MOV P1,#55H
        ACALL DELAY
        MOV P1,#0AAH
        ACALL DELAY
        SJMP BACK
```

Another way of doing the same thing

```
        MOV  A, #55H
BACK:   MOV  P1, A
        ACALL  DELAY
        CPL  A
        SJMP  BACK
```

I/O Ports and Bit Addressability

- Sometimes we need to access only 1 or 2 bits of the port

```
BACK:    CPL  P1.2          ;complement P1.2
         ACALL DELAY
         SJMP BACK
;another variation of the above program
AGAIN:   SETB  P1.2         ;set only P1.2
         ACALL  DELAY
         CLR  P1.2          ;clear only P1.2
         ACALL  DELAY
         SJMP AGAIN
```

P0	P1	P2	P3	Port Bit
P0.0	P1.0	P2.0	P3.0	D0
P0.1	P1.1	P2.1	P3.1	D1
P0.2	P1.2	P2.2	P3.2	D2
P0.3	P1.3	P2.3	P3.3	D3
P0.4	P1.4	P2.4	P3.4	D4
P0.5	P1.5	P2.5	P3.5	D5
P0.6	P1.6	P2.6	P3.6	D6
P0.7	P1.7	P2.7	P3.7	D7

Example 4-1

Write the following programs.

Create a square wave of 50% duty cycle on bit 0 of port 1.

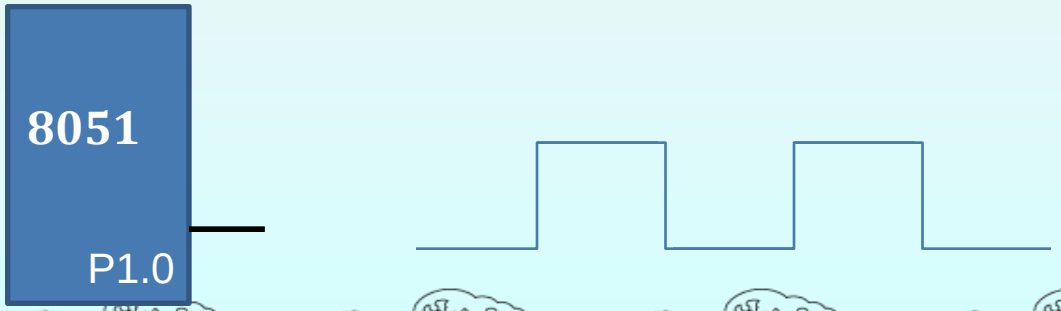
Solution:

The 50% duty cycle means that the “on” and “off” state (or the high and low portion of the pulse) have the same length. Therefore, we toggle P1.0 with a time delay in between each state.

```
HERE:   SETB P1.0          ;set to high bit 0 of port 1
        LCALL DELAY        ;call the delay subroutine
        CLR P1.0           ;P1.0=0
        LCALL DELAY
        SJMP HERE          ;keep doing it
```

Another way to write the above program is:

```
HERE:   CPL P1.0           ;set to high bit 0 of port 1
        LCALL DELAY        ;call the delay subroutine
        SJMP HERE          ;keep doing it
```



I/O Ports and Bit Addressability

- Instructions that are used for signal-bit operations are as following

Single-Bit Instructions

Instruction	Function
SETB bit	Set the bit (bit = 1)
CLR bit	Clear the bit (bit = 0)
CPL bit	Complement the bit (bit = NOT bit)
JB bit, target	Jump to target if bit = 1 (jump if bit)
JNB bit, target	Jump to target if bit = 0 (jump if no bit)
JBC bit, target	Jump to target if bit = 1, clear bit (jump if bit, then clear)

Checking an Input Bit

- The JNB and JB instructions are widely used single-bit operations

  They allow you to monitor a bit and make a decision depending on whether its 0 or 1

  These two instructions can be used for any bits of I/O ports 0, 1, 2, and 3

  Port 3 is typically not used for any I/O, either single-bit or byte-wise

Instructions for Reading an Input Port

Mnemonic	Examples	Description
MOV A,PX	MOV A,P2	Bring into A the data at P2 pins
JNB PX.Y, ..	JNB P2.1,TARGET	Jump if pin P2.1 is low
JB PX.Y, ..	JB P1.3,TARGET	Jump if pin P1.3 is high
MOV C,PX.Y	MOV C,P2.4	Copy status of pin P2.4 to CY

Checking an Input Bit

Example 4-2

Write a program to perform the following:

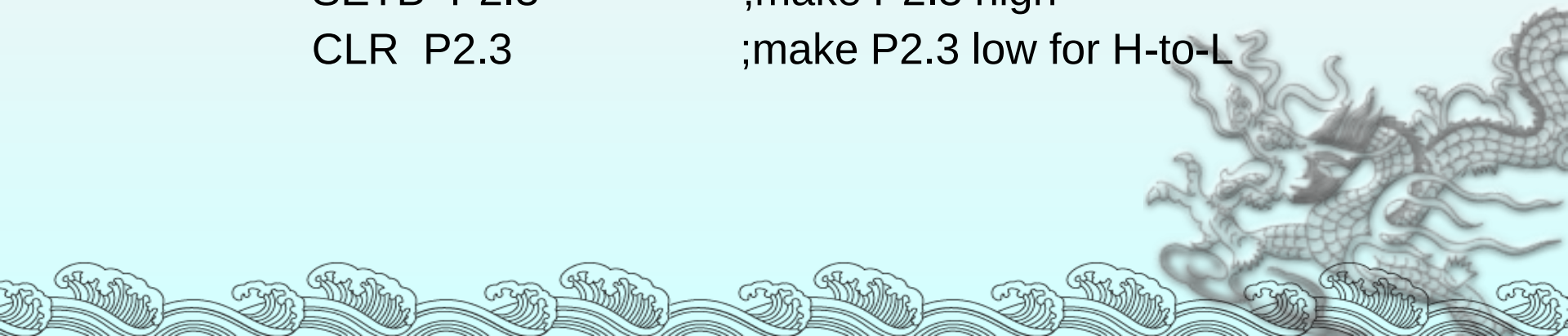
(a) Keep monitoring the P1.2 bit until it becomes high

(b) When P1.2 becomes high, write value 45H to port 0

(c) Send a high-to-low (H-to-L) pulse to P2.3

Solution:

```
        SETB P1.2          ;make P1.2 an input
        MOV  A, #45H       ;A=45H
AGAIN:  JNB  P1.2, AGAIN    ; get out when P1.2=1
        MOV  P0, A         ;issue A to P0
        SETB  P2.3         ;make P2.3 high
        CLR  P2.3          ;make P2.3 low for H-to-L
```



Checking an Input Bit

Example 4-3

Assume that bit P2.3 is an input and represents the condition of an oven. If it goes high, it means that the oven is hot. Monitor the bit continuously. Whenever it goes high, send a high-to-low pulse to port P1.5 to turn on a buzzer.

Solution:

```
HERE:   JNB  P2.3, HERE     ;keep monitoring for high
        SETB  P1.5          ;set bit P1.5=1
        CLR  P1.5           ;make high-to-low
        SJMP  HERE          ;keep repeating
```

Reading Single Bit into Carry Flag

Example 4-4

A switch is connected to pin P1.0 and an LED to pin P2.7. Write a program to get the status of the switch and send it to the LED

Solution:

```
        SETB P1.7          ;make P1.7 an input
AGAIN:  MOV C, P1.0        ;read SW status into CF
        MOV P2.7, C        ;send SW status to LED
        SJMP  AGAIN        ;keep repeating
```

The instruction 'MOV P2.7,P1.0' is wrong , since such an instruction does not exist

However 'MOV P2,P1' is a valid instruction

Reading Input Pins vs. Port Latch

- In reading a port

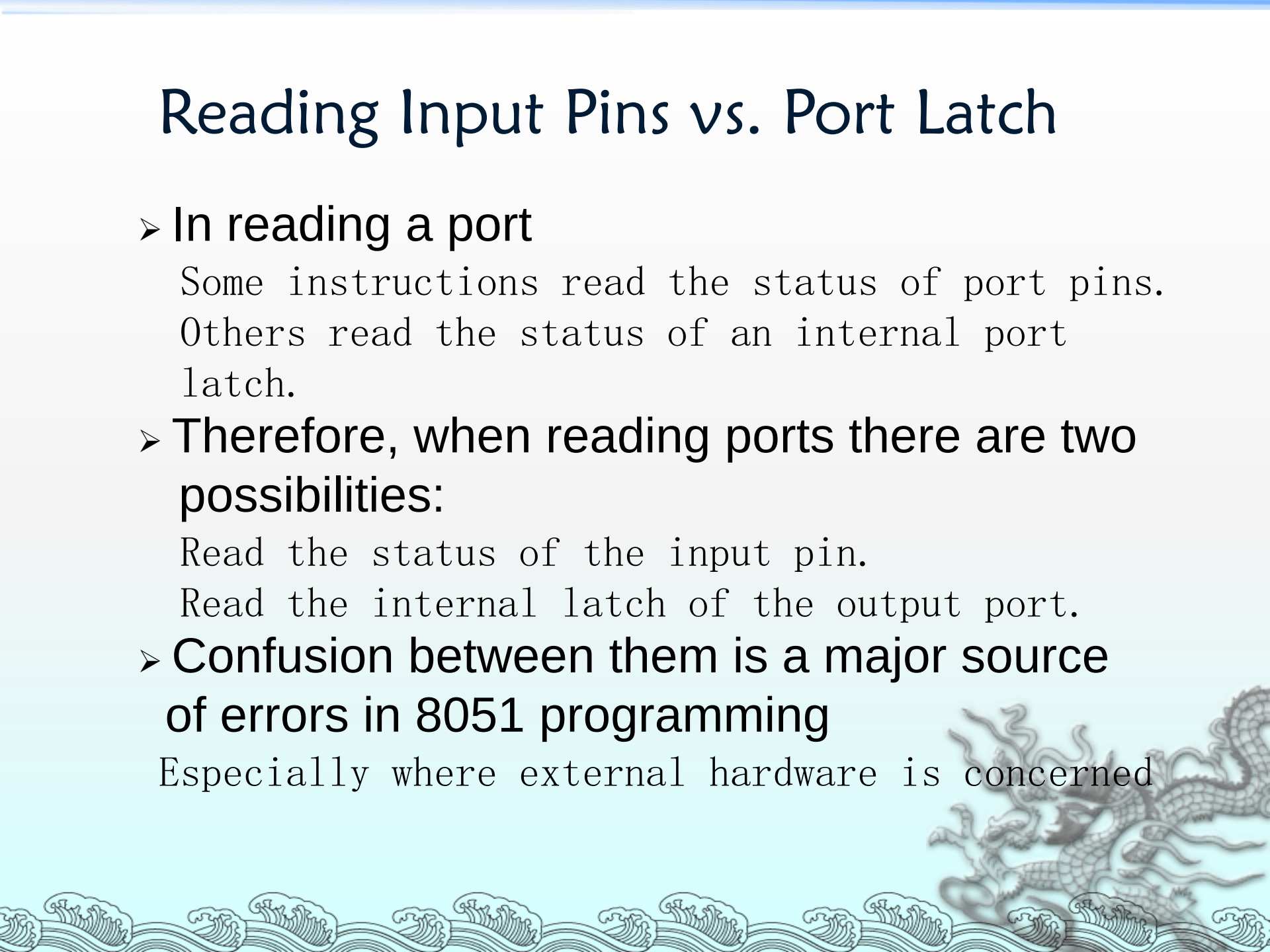
  Some instructions read the status of port pins.
  Others read the status of an internal port latch.

- Therefore, when reading ports there are two possibilities:

  Read the status of the input pin.
  Read the internal latch of the output port.

- Confusion between them is a major source of errors in 8051 programming

  Especially where external hardware is concerned



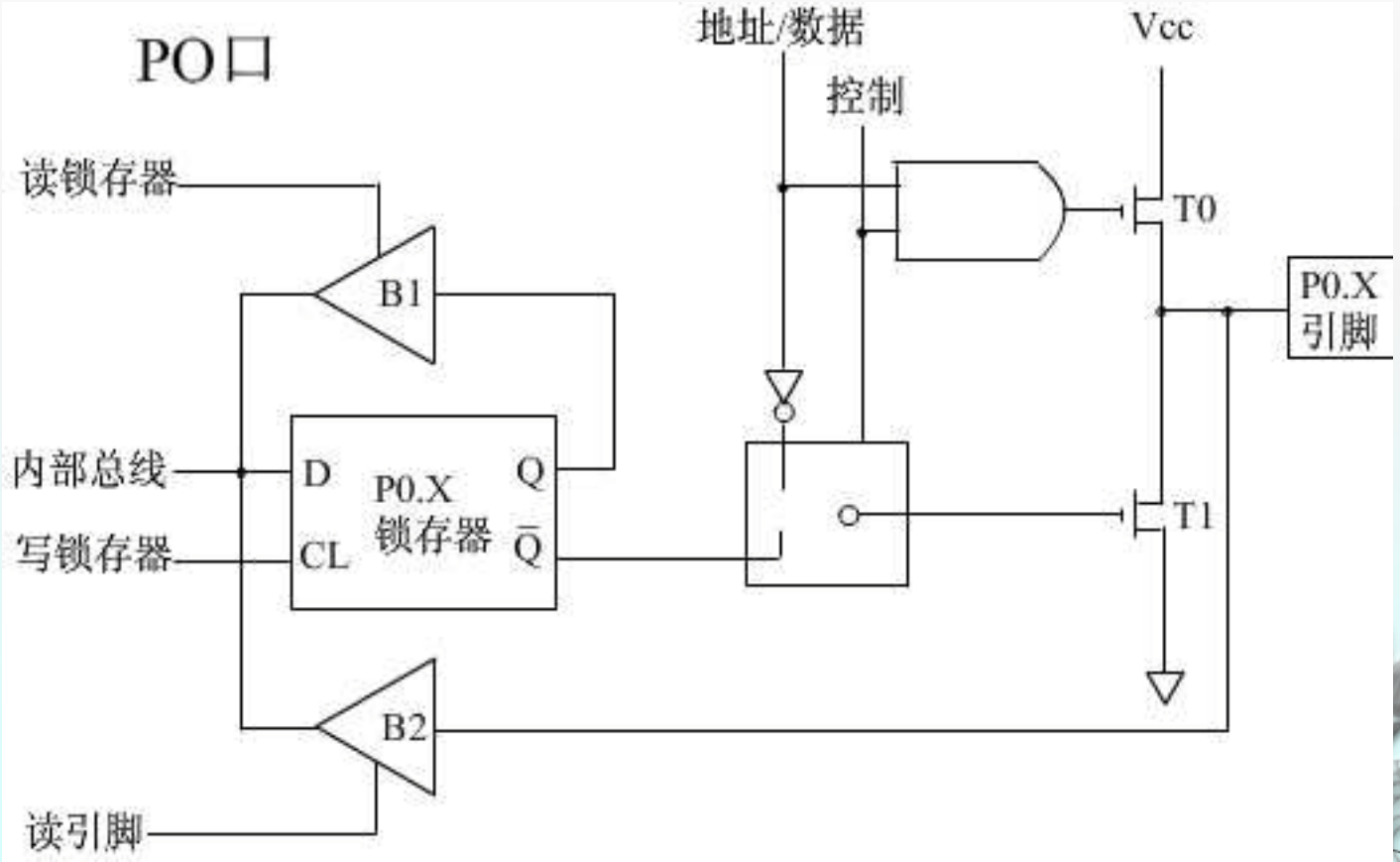
Reading Latch for Output Port

- Some instructions read the contents of an internal port latch instead of reading the status of an external pin

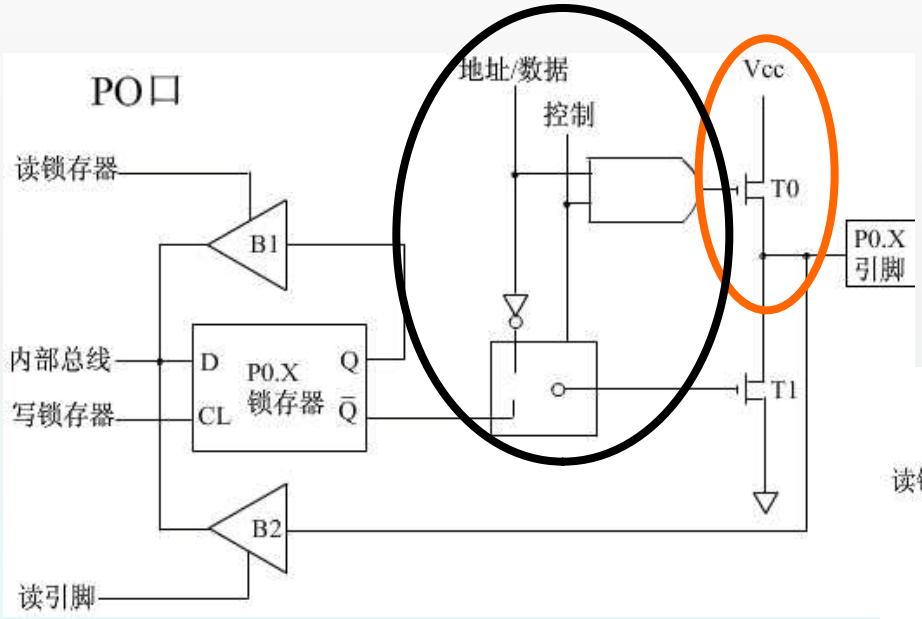
  For example, look at the ANL P1,A instruction and the sequence of actions is executed as follow

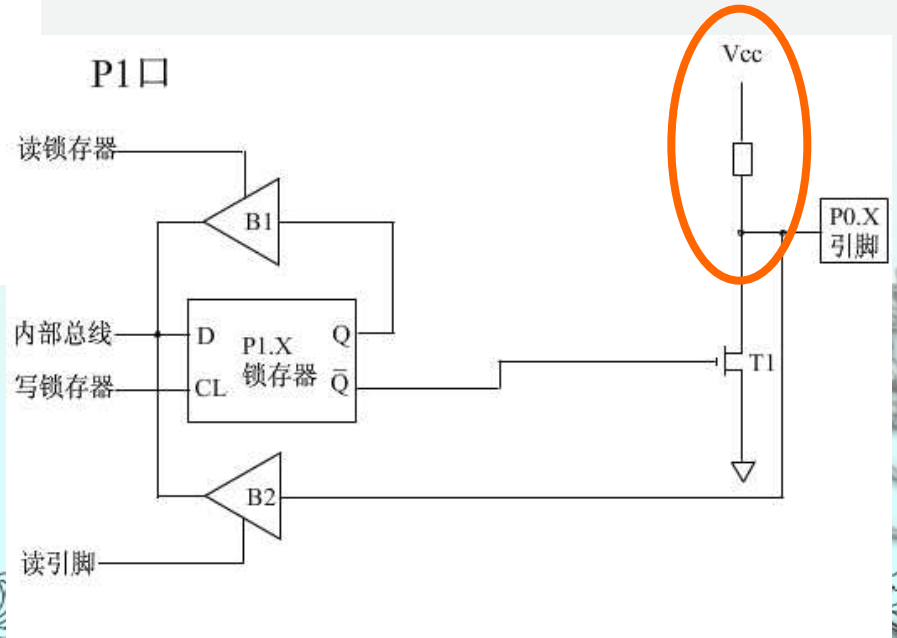
  1. It reads the internal latch of the port and brings that data into the CPU
  2. This data is ANDed with the contents of register A
  3. The result is rewritten back to the port latch
  4. The port pin data is changed and now has the same value as port latch

P0


P0口
地址/数据
控制
Vcc
读锁存器
B1
T0
P0.X
引脚
内部总线
D
P0.X
锁存器
Q
写锁存器
CL
Q
T1
B2
读引脚

P0 Vs P1


P0口
地址/数据
控制
Vcc
读锁存器
B1
T0
P0.X
引脚
内部总线
D
P0.X
锁存器
Q
写锁存器
CL
Q̄
T1
B2
读引脚


P1口
Vcc
读锁存器
B1
P0.X
引脚
内部总线
D
P1.X
锁存器
Q
写锁存器
CL
Q̄
T1
B2
读引脚

Reading Latch for Output Port

Read-Modify-Write

The instructions read the port latch normally read a value, perform an operation then rewrite it back to the port latch.

Instructions Reading a latch (Read-Modify-Write)

Mnemonics	Example
ANL PX	ANL P1,A
ORL PX	ORL P2,A
XRL PX	XRL P0,A
JBC PX.Y,TARGET	JBC P1.1,TARGET
CPL PX.Y	CPL P1.2
INC PX	INC P1
DEC PX	DEC P2
DJNZ PX.Y,TARGET	DJNZ P1,TARGET
MOV PX.Y,C	MOV P1.2,C
CLR PX.Y	CLR P2.3
SETB PX.Y	SETB P2.3

Note: x is 0, 1, 2, or 3 for P0 – P3

Read-modify-write Feature

- The ports in 8051 can be accessed by the Read-modify-write technique

  This feature saves many lines of code by combining in a single instruction all three actions

  1. Reading the port
  2. Modifying it
  3. Writing to the port

```
        MOV  P1, #55H          ;P1=01010101
AGAIN:  XRL  P1, #0FFH         ;EX-OR P1 with 1111 1111
        ACALL  DELAY
        SJMP  BACK
```

THANK YOU!!