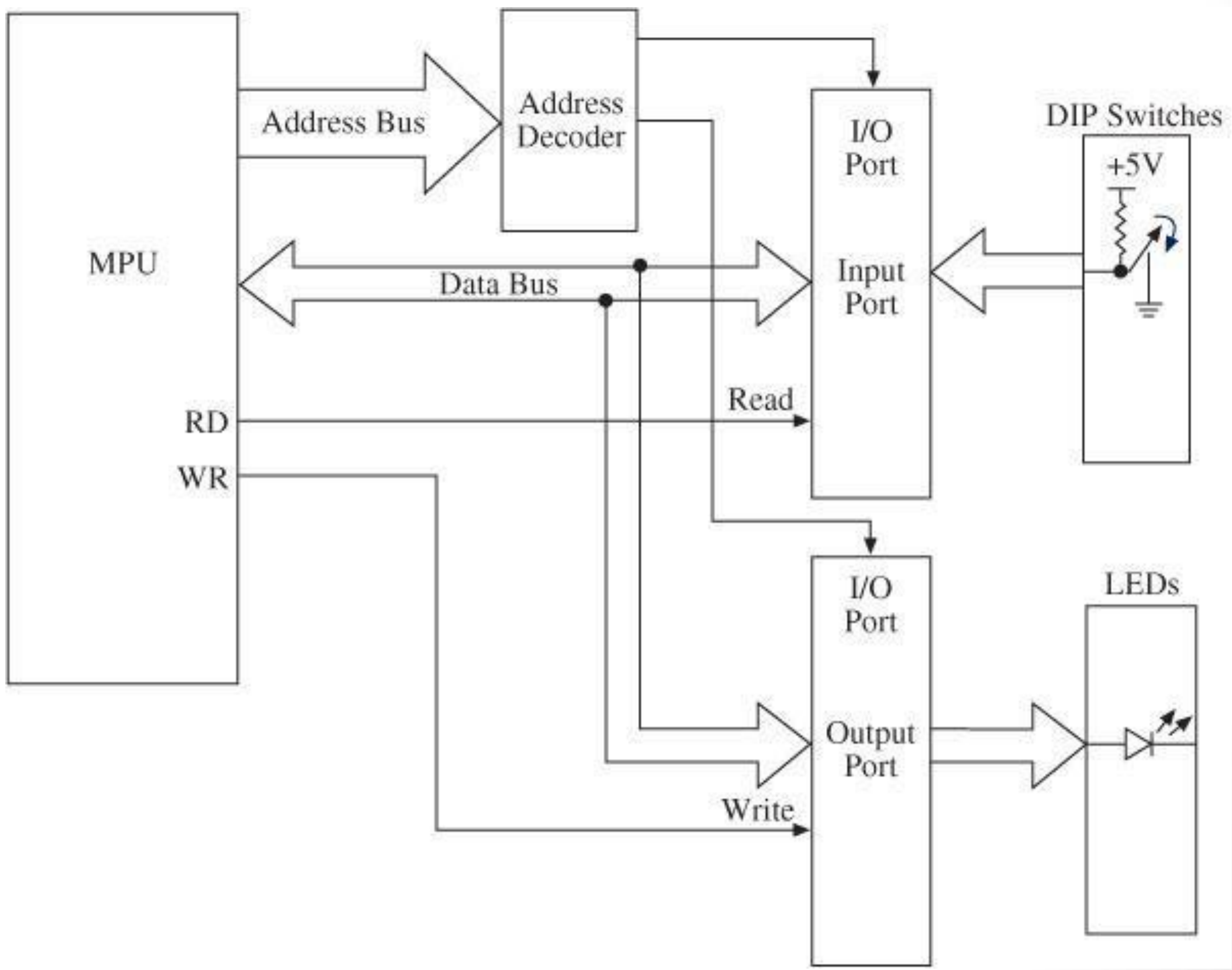
SNS COLLEGE OF TECHNLOGY

Unit-2 Input/Output Ports and Interfacing LCD & Seven Segment Display

Basic I/O Concepts

- Peripherals such as LEDs and keypads are essential components of microcontroller-based systems
- Input devices
  - Provide digital information to an MPU
  - Examples: switch, keyboard, scanner, and digital camera
- Output devices
  - Receive digital information from an MPU
  - Examples: LED, seven-segment display, LCD, and printer
- Devices are interfaced to an MPU using I/O ports

I/O Interfacing



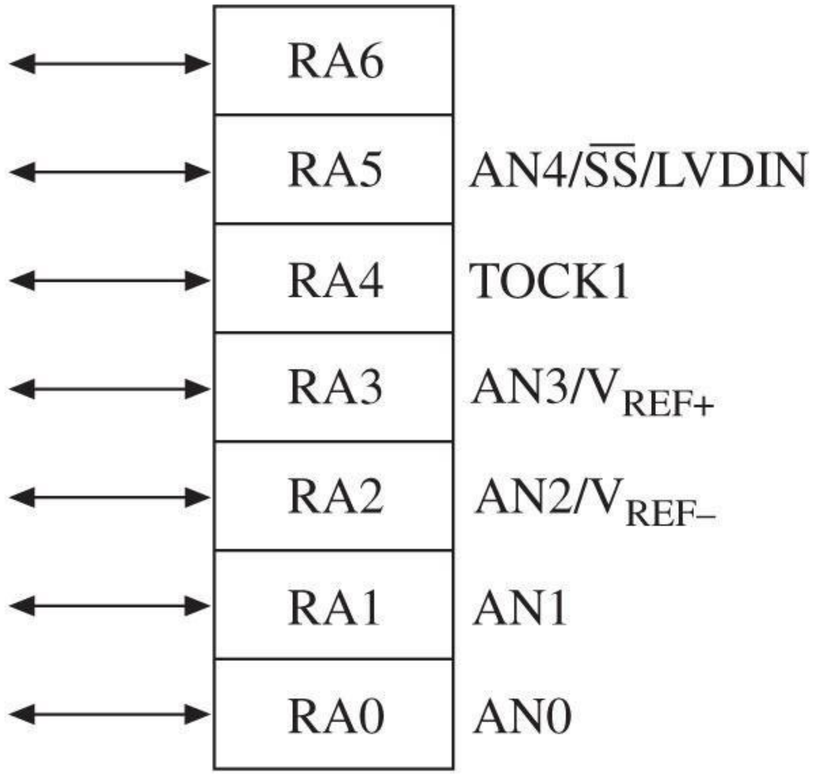
Interfacing and Addressing

- I/O ports
  - Buffers and latches on the MCU chip
    - Assigned binary addresses by decoding the address bus
  - Generally bidirectional
    - Internal data direction registers
  - To read binary data from an input peripheral
    - MPU places the address of an input port on the address bus
    - Enables the input port by asserting the RD signal
    - Reads data using the data bus
  - To write binary data to an output peripheral
    - MPU places the address of an output port on the address bus
    - Places data on data bus
    - Asserts the WR signal to enable the output port

PIC18F452/4520 I/O Ports

- MCU includes five I/O ports
  - PORTA, PORTB, PORTC, PORTD, PORTE
- Ports are multiplexed
  - Can be set up to perform various functions
- Each I/O port is associated with several SFRs
  - PORT
    - Functions as a latch or a buffer
  - TRIS
    - Data direction register
    - Logic 0 sets up the pin as an output
    - Logic 1 sets up the pin as an input
  - LAT
    - Output latch similar to PORT

PIC18F452/4520 I/O Ports

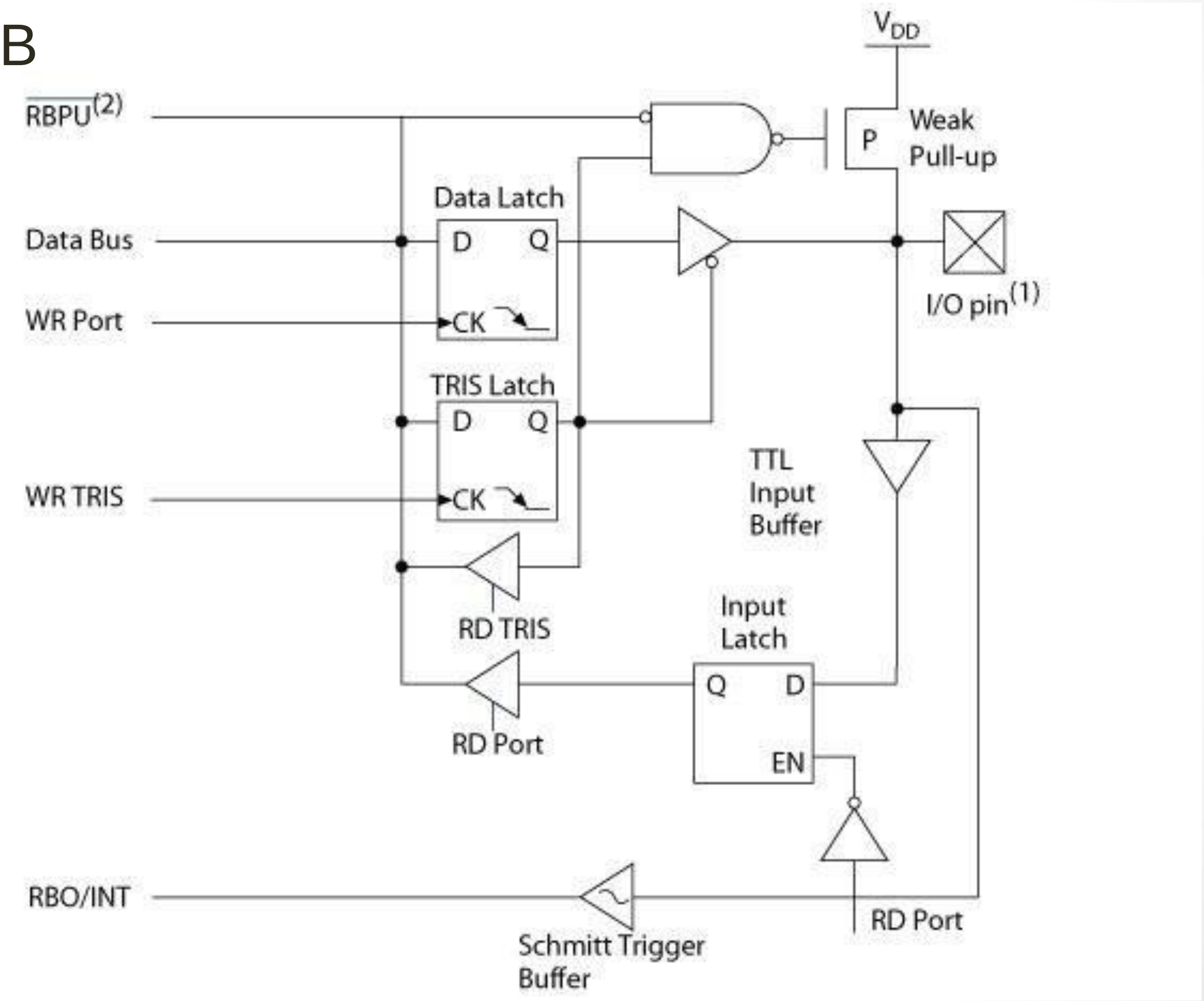


PORTA: Example of Multiple Fns

- Digital I/O: RA6-RA0
- Analog Input: AN0-AN4
- V_{REF}+ : A/D Reference Plus V
- V_{REF}- : A/D Reference Minus V
- TOCK1: Timer0 Ext. Clock
- SS: SPI Slave Select Input
- LVDIN: Low V Detect Input

PIC18F452/4520 I/O Ports

- PORTB



I/O Example

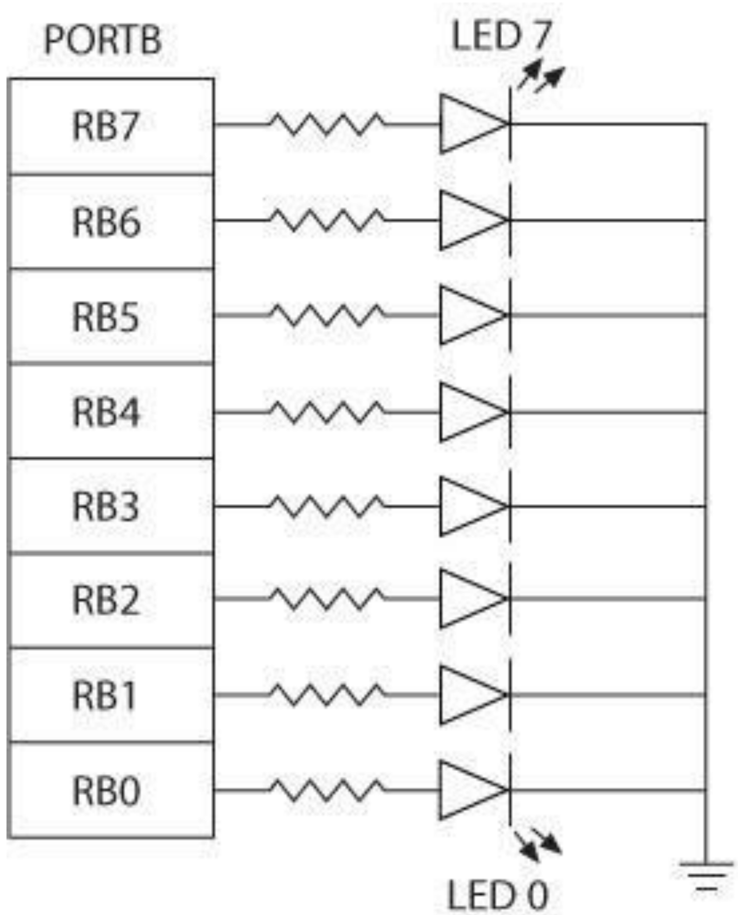
- Write instructions to set up pins RB7-RB4 of PORTB as inputs and pins RB3-RB0 as outputs

Opcode	Operands	Comments
MOVLW	0xF0	;Load B'11110000' into WREG
MOVWF	TRISB	;Set PORTB TRIS Reg

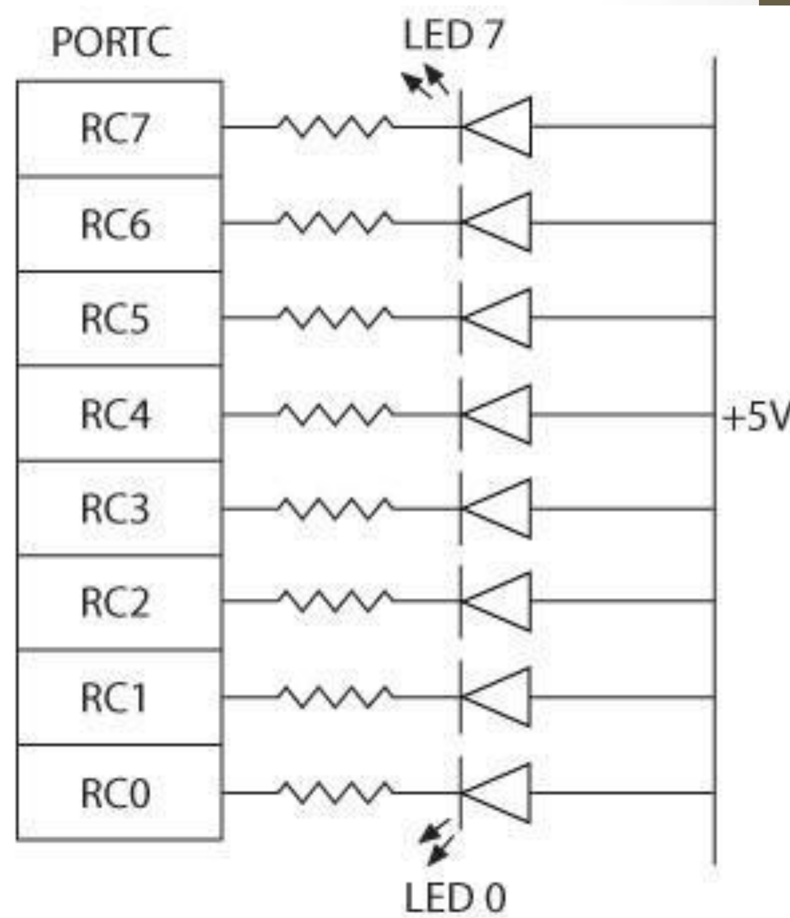
Interfacing Output Peripherals

- Commonly used output peripherals in embedded systems
  - LEDs
  - Seven-Segment Displays
  - LCDs
- Two ways of connecting LEDs to I/O ports
  - Common Cathode
    - LED cathodes are grounded
    - Logic 1 from the I/O port turns on the LEDs
    - Current is supplied by the I/O port called current sourcing
  - Common Anode
    - LED anodes are connected to the power supply
    - Logic 0 from the I/O port turns on the LEDs
    - Current is received by the chip called current sinking

Interfacing Output Peripherals



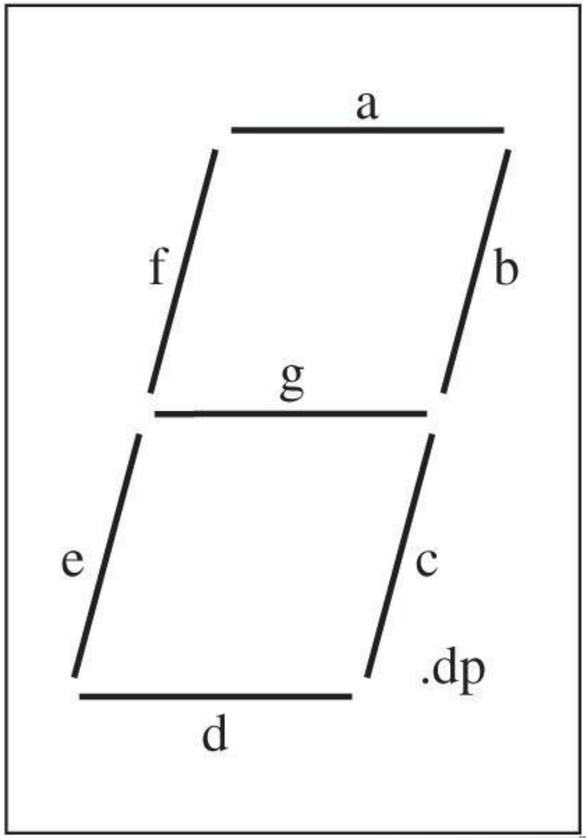
Common Cathode



Common Anode

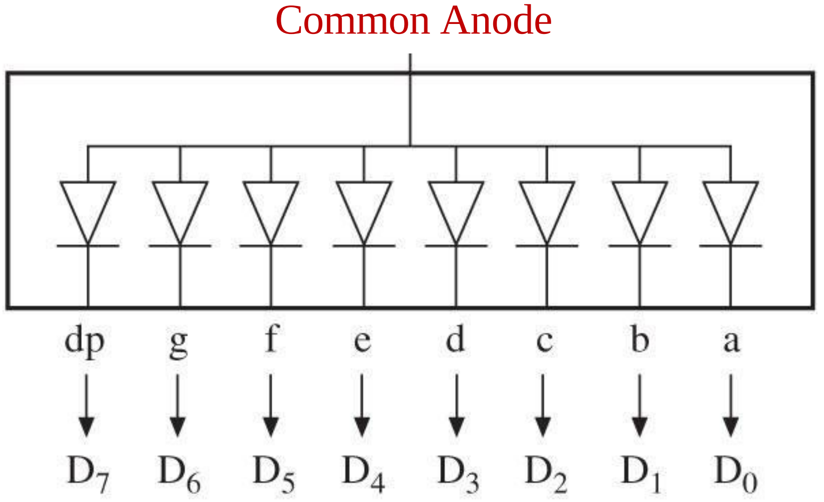
Seven-Segment Display

- Seven-segment Displays
  - Used to display BCD digits
    - 0 thru 9
  - A group of 7 LEDs physically mounted in the shape of the number eight
    - Plus a decimal point
  - Each LED is called a segment
    - ‘a’ through ‘g’
  - Two types
    - Common anode
    - Common cathode



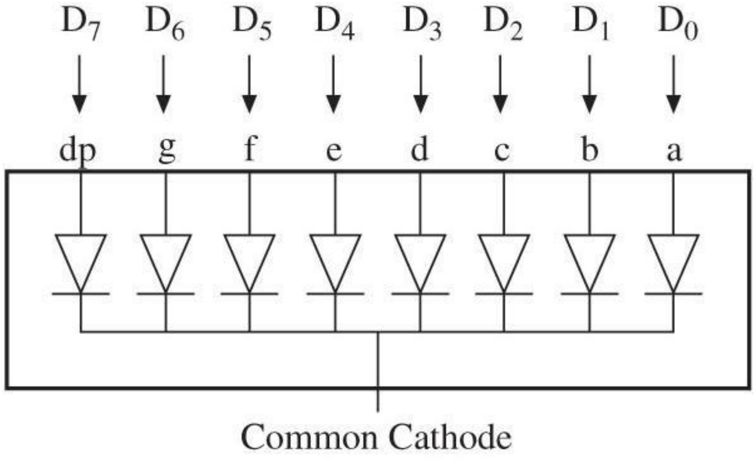
Seven-Segment Display

- Common Anode
  - All anodes are connected together to a power supply
  - Cathodes are connected to data lines
- Logic 0 turns on a segment
- Example: To display the digit 1
  - All segments except b and c should be off
  - 11111001 = $F9_H$



Seven-Segment Display

- Common Cathode
  - All cathodes are connected together to ground
  - Anodes are connected to data lines
- Logic 1 turns on a segment
- Example: To display digit 1
  - All segments except b and c should be off
  - 00000110 = 06_H



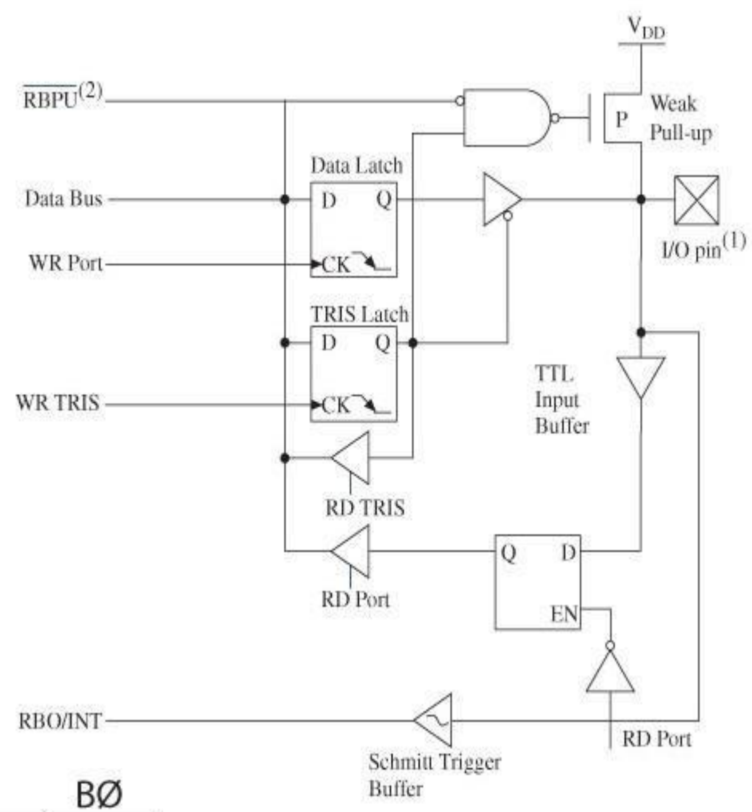
Reading from an I/O Port

- Read input switches on PORTB (RB7-RB4)
  - RB0 set HI (1)
  - Switches Open = LOW (0)
  - Switches Closed = HIGH (1)
- Display on PORTC

Opcode	Operands	Comments
MOVLW	0xF0	;Load B’11110000’ into WREG
MOVWF	TRISB	;Set PORTB TRIS Reg
CLRF	TRISC	;Set PORTC as Output
BSF	PORTB,0	;Set RB0 High
MOVF	PORTB,W	;Read PORTB
MOVWF	PORTC	;Display on PORTC

Internal Pull-Up Resistor

- Turning off the internal FET provides a pull-up resistor
- Bit7 (RBPU) in the INTCON2 register enables or disables the pull-up resistor
  - Instruction to Enable Pull Up Resistors:
    BCF INTCON2,7

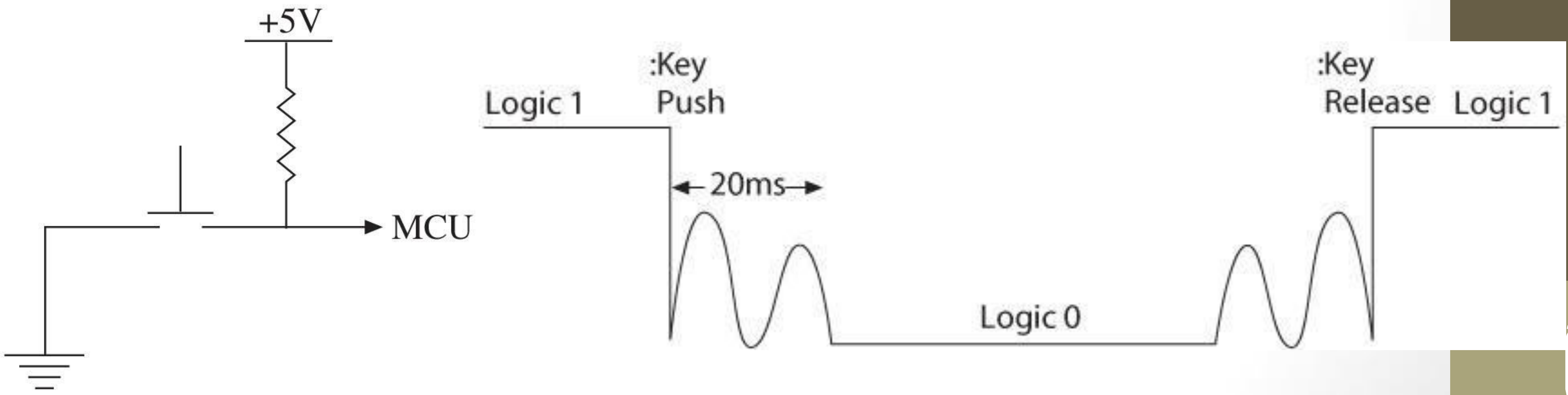


B7	B6	B5	B4	B4	B3	B2	B1	BØ
$\overline{RBPU}$								

$\overline{RBPU}$ = PORTB pull-up resistor enable bit
0 = Pull-up resistors are enabled
1 = Pull-up resistors are disabled

Interfacing Push-Button Keys

- When a key is pressed (or released), mechanical metal contact bounces momentarily and can be read as multiple inputs
- Key debounce
  - Eliminating reading of one contact as multiple inputs
  - Hardware or Software

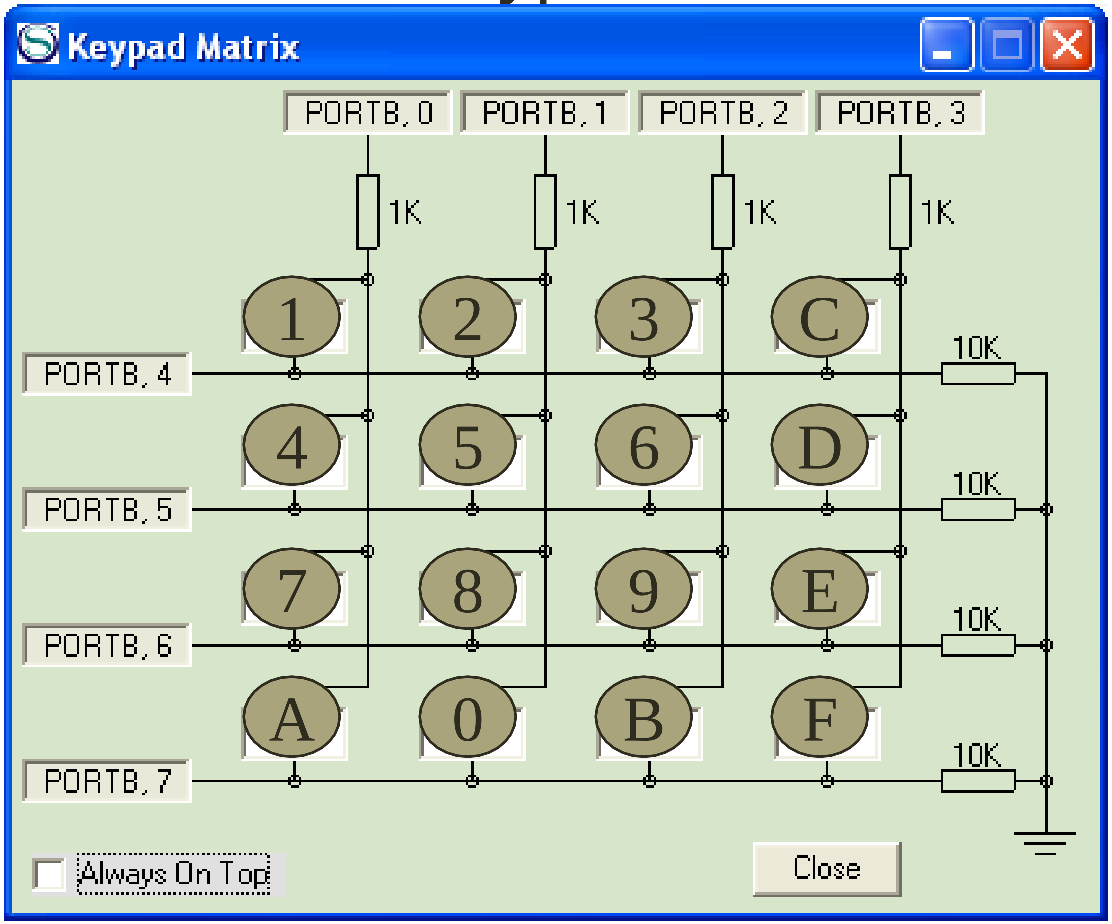


Interfacing a Matrix Keypad

- Hardware (PIC18 Simulator)
  - 4 x 4 matrix keypad organized in the row and column format
  - Four columns are connected to the lower half of PORTB (RB0- RB3)
  - Four rows are connected to upper half of PORTB (RB4-RB7)
  - When a key is pressed, it makes a contact with the corresponding row and column

Interfacing a Matrix Keypad

- PIC18 Simulator Keypad Matrix



Interfacing a Matrix Keypad

- Software
- To recognize and encode the key pressed
  - Set all the columns High by sending ones
    - Check for any key pressed (non-zero)
    - Set one column High at a time
      - Check all the rows in that column
    - Once a key is identified
      - Encode based on its position in the column

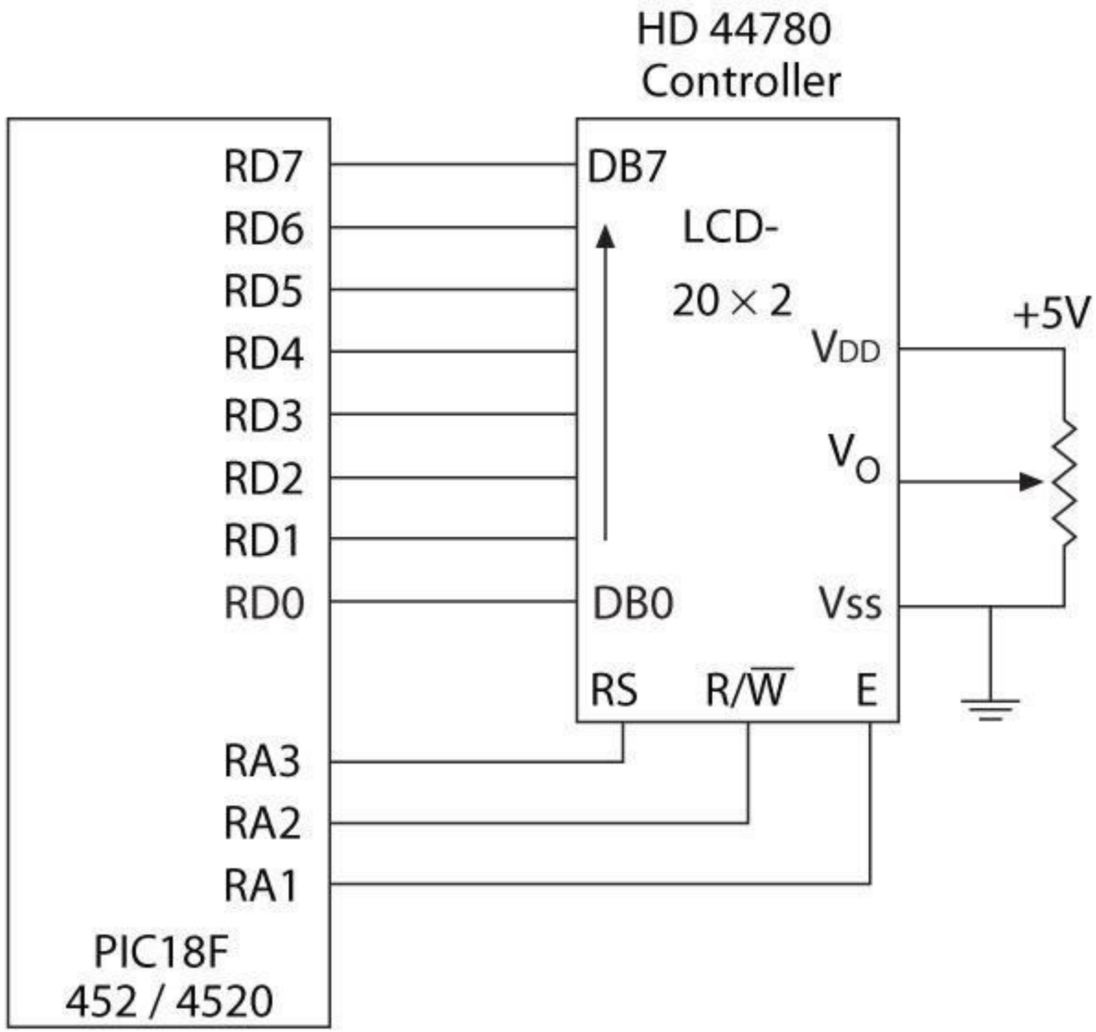
Interfacing LCD

- Problem statement
  - Interface a 2-line x 20 character LCD module with the built-in HD44780 controller to I/O ports of the PIC18 microcontroller.
  - Explain the control signals necessary to read from and write to the LCD.
  - Write a program to display ASCII characters.

Interfacing LCD

- Hardware
  - 20 x 2-line LCD display
    - Two lines with 20 characters per line
  - LCD has a display Data RAM
    - Stores data in 8-bit character code
  - Each register in Data RAM has its own address
    - Corresponds to its position on the line
      - Line 1 is 00_H to 13_H
      - Line 2 is 40_H to 53_H

Interfacing LCD



Interfacing LCD

- Driver HD44780
  - 8-bit data bus (RD7-RD0)
  - Three control signals
    - RS - Register Select (RA3)
    - R/W - Read/Write (RA2)
    - E - Enable (RA1)
  - Three power connections
    - Power, ground, and variable resistor to control brightness

Interfacing LCD

- Can be interfaced either in 8-bit mode or 4-bit mode
  - In 8-bit mode, all eight data lines are connected
  - In 4-bit mode, only four data lines are connected
    - Two transfers per character (or instruction) are needed
- Driver has two 8-bit internal registers
  - Instruction Register (IR) to write instructions to set up LCD
    - Table 9-3
  - Data Register (DR) to write data (ASCII characters)

Interfacing LCD

- LCD Operation
  - When the MPU writes an instruction to IR or data to DR, the controller:
    - Sets DB7 high indicating that the controller is busy
    - Sets DB7 low after the completion of the operation
  - The MPU should always check whether DB7 is low before sending an instruction or a data byte

Interfacing LCD

- Writing to or Reading from LCD (Table 9-4)
  - The MPU:
    - Asserts RS low to select IR
    - Asserts RS high to select DR
    - Reads from LCD by asserting the R/W signal high
    - Writes into LCD by asserting the R/W signal low
    - Asserts the E signal high and then low (toggles) to latch a data byte or an instruction

Interfacing LCD

- Software
  - To write into the LCD
    - Send the initial instructions to set up the LCD
      - 4-bit or 8-bit mode
    - Continue to check DB7 until it goes low
    - Write instructions to IR to set up LCD parameters
      - Number of display lines and cursor status
    - Write data to display a message

I/O devices (Peripherals)

- Examples: switches, LED, LCD, printers, keyboard, keypad
- Interface chips
  - are needed to resolve the speed problem
  - synchronizes data transfer between CPU and I/O device
- Connection of Interface and CPU
  - Data pins are connected to CPU data bus
  - I/O port pins are connected to I/O device
- CPU may be connected to multiple interface
- IO ports are simplest interface

I/O Interfacing

- Dedicated instructions for IO operations (Isolated I/O)
- same instruction for memory and IO (memory-mapped I/O)
- MCS-51 (8051) is memory mapped

Synchronization of CPU and interface chip

- To make sure that there are valid data in the interface
- two ways
  - Polling method: Read status bit - Simple method
  - Interrupt driven method: interface interrupts the CPU when it has new data - CPU executes the ISR

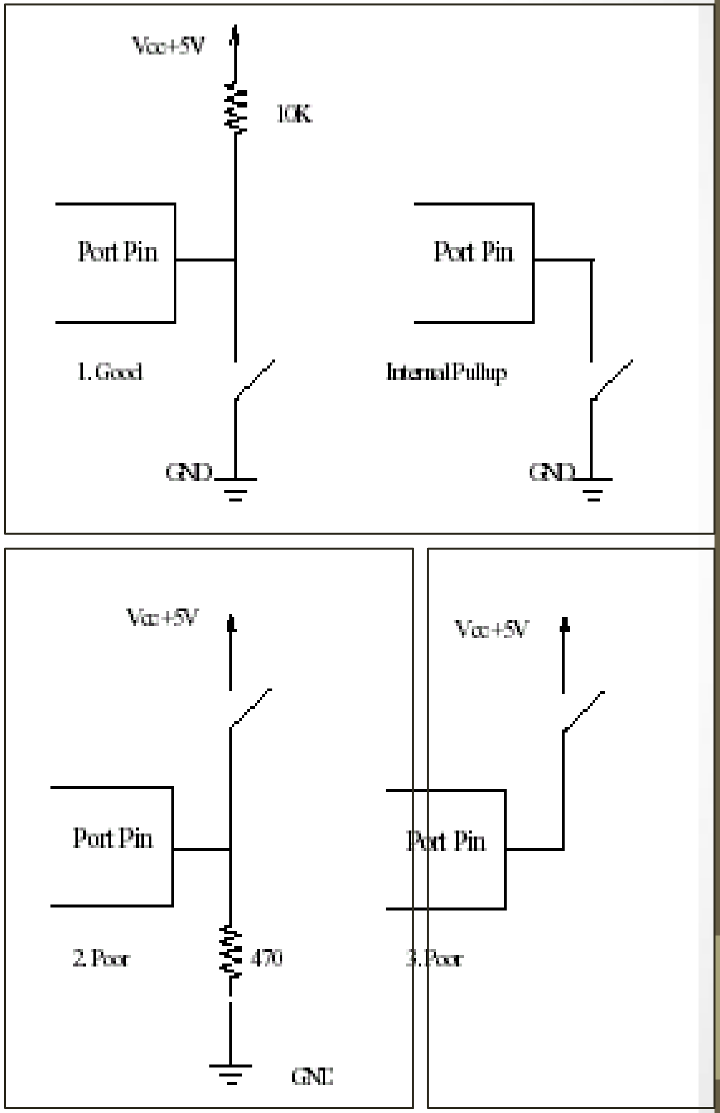
Synchronization of CPU and interface chip

- Output synchronization: two ways of doing this

1. Polling method
   - interface chip uses a status bit to indicate that the data register is empty
   - CPU keeps checking status bit until it is set, and then writes data into interface chip
2. Interrupt driven method: interface chip interrupts the CPU when it data register is empty. CPU executes the ISR

8051 - Switch On I/O Ports

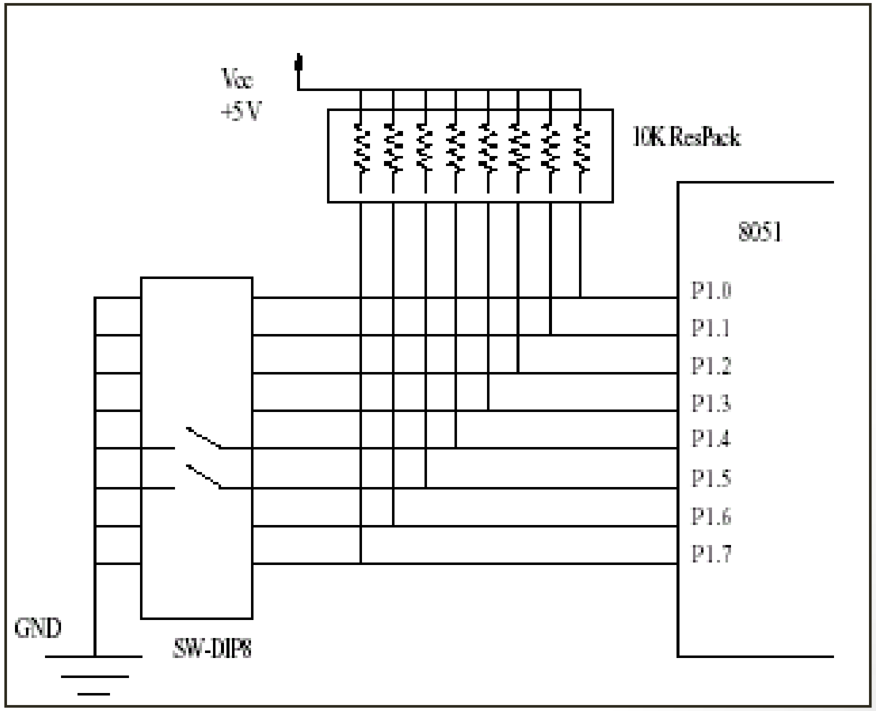
- Case-1:
  - Gives a logic 0 on switch close
  - Current is 0.5ma on switch close
- Case-2:
  - Gives a logic 1 on switch close
  - High current on switch close
- Case-3:
  - Can damage port if 0 is output



Simple input devices

- DIP switches usually have 8 switches
- Use the case-1 from previous page
- Sequence of instructions to read is:

```
MOV     P1,#FFH
MOV     A,P1,
```

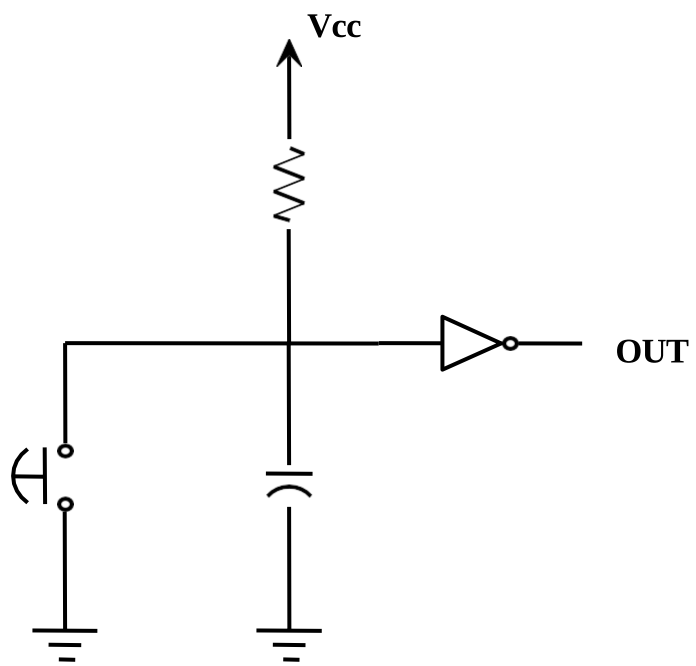


Bouncing contacts

- Contact:
  - Push-button switches
  - Toggle switches
  - Electromechanical relays
- Make and break Contact normally open switch
- The effect is called "contact bounce" or, in a switch, "switch bounce”.
- If used as edge-triggered input (as INT0), several interrupt is accorded

Hardware Solution

- An RC time constant to suppress the bounce
- The time constant has to be larger than the switch bounce



Hardware Solution

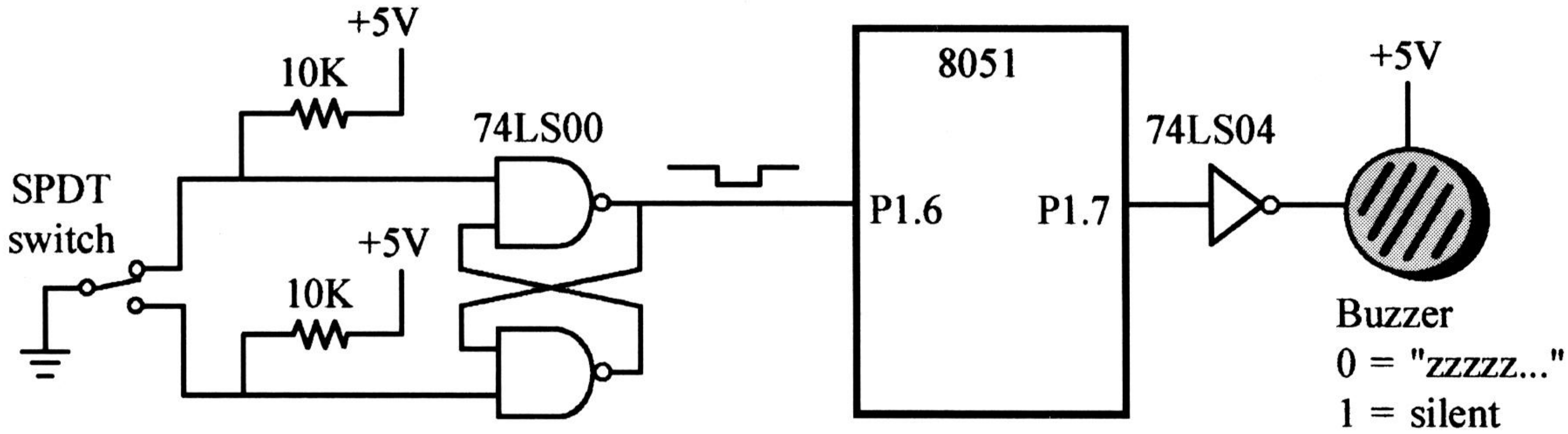


FIGURE 4–7
Buzzer example

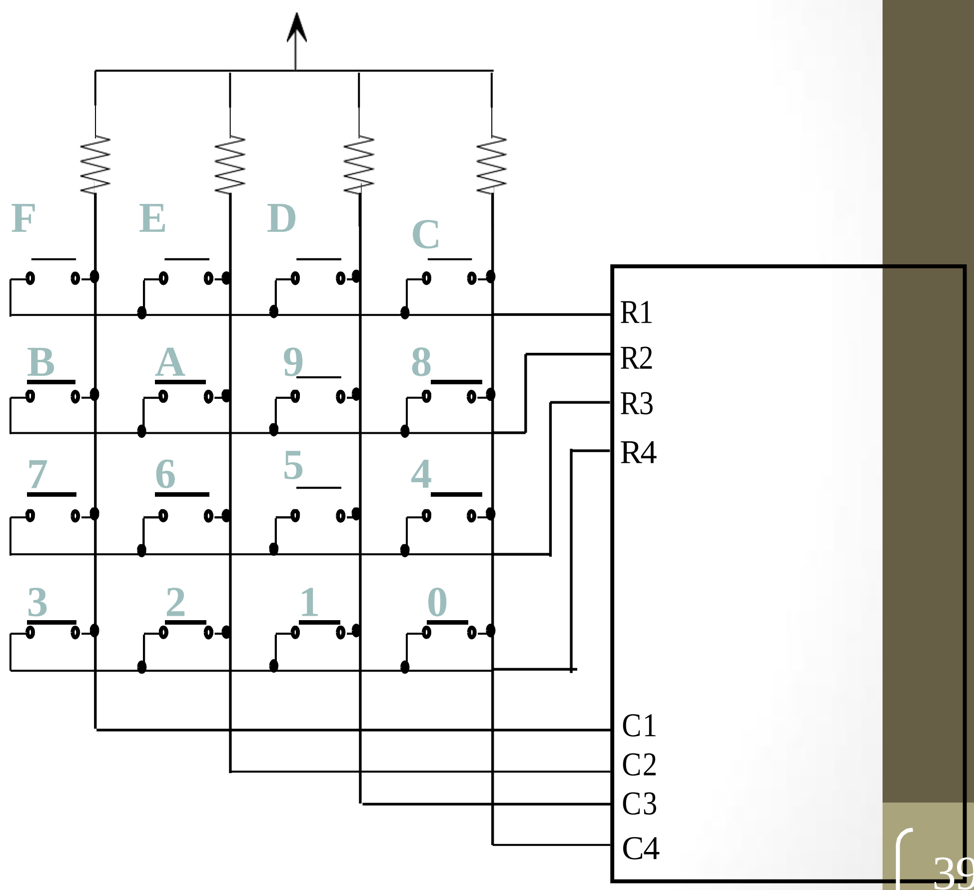
Software Solution

- Read the new state of switch N time
- Wait-and-see technique
  - When the input drops
  - an “appropriate” delay is executed (10 ms)
  - then the value of the line is checked again to make sure the line has stopped bouncing

Interfacing a Keypad

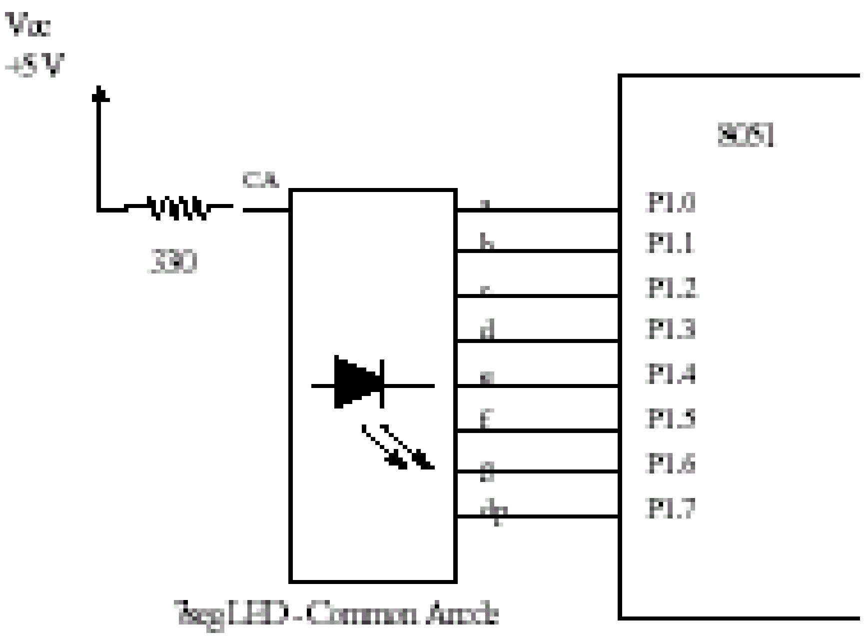
16 keys arranged as a 4X4 matrix

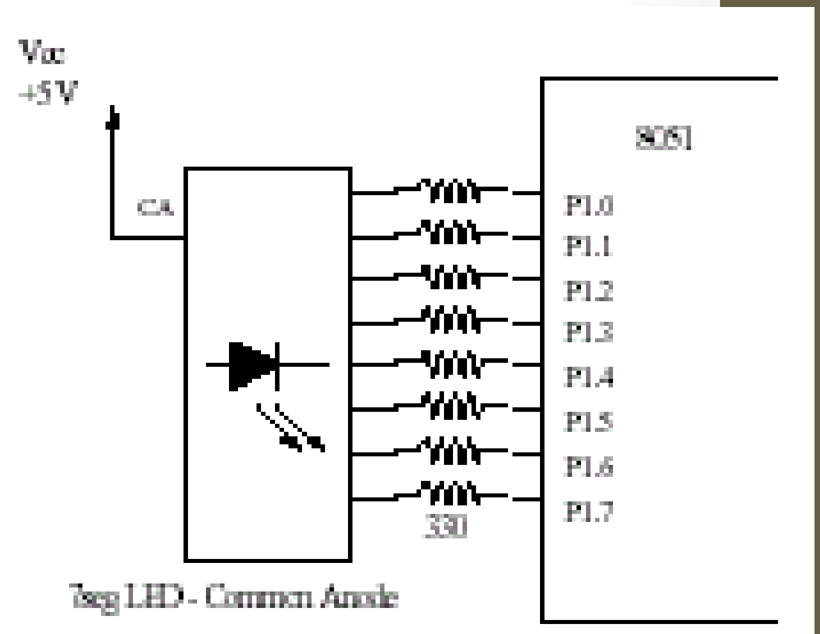
- Place a 0 on R0 port
- Read C port
- If there is a 0 bit then the button at the column/row intersection has been pressed.
- Otherwise, try next row
- Repeat constantly



Interfacing a 7-segment display

- A resistor will be needed to control the current
- This leaves two possibilities:





- Case 2 would be more appropriate
- Case 1 will produce different brightness depending on the number of LEDs turned on.

Use of current buffer

- Interfacing to a DIP switch and 7-segment display
- Output a '1' to ON a segment
- We can use 74244 to common cathode 7_seg

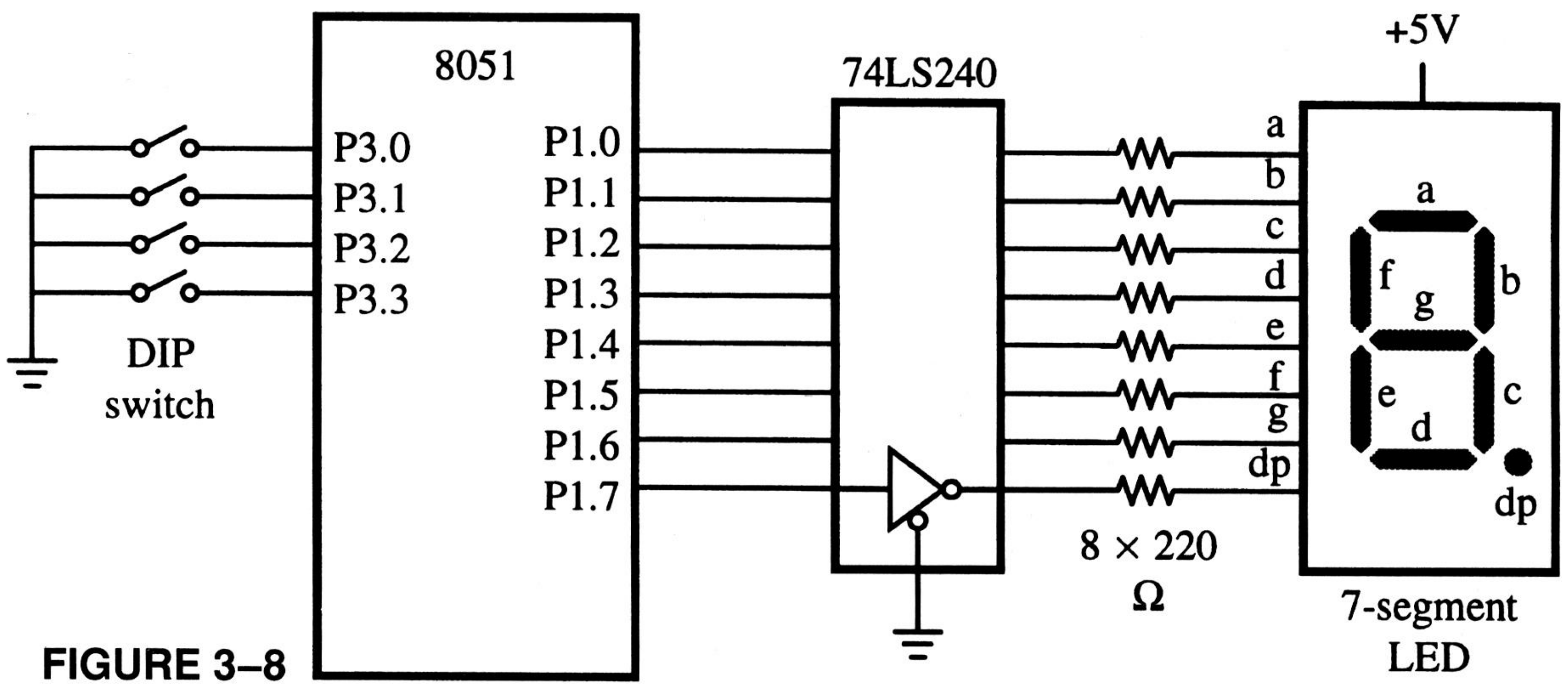


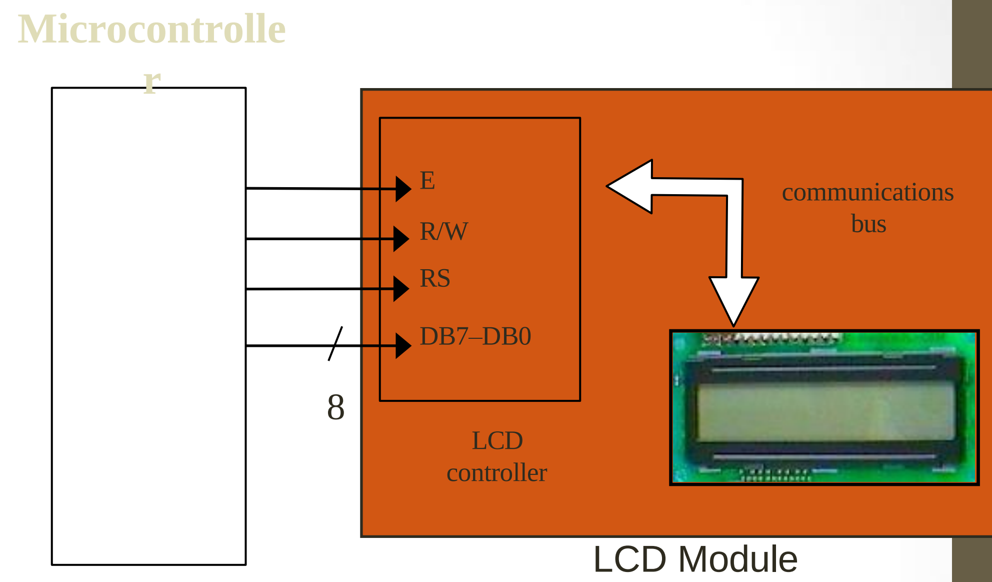
FIGURE 3–8
Interface to a DIP switch and 7-segment LED

LCD Interfacing

- Liquid Crystal Displays (LCDs)
- cheap and easy way to display text
- Various configurations (1 line by 20 X char up to 8 lines X 80)
- Integrated controller
- The display has two register
  - command register
  - data register
- By RS you can select register
- Data lines (DB7-DB0) used to transfer data and commands

Alphanumeric LCD Interfacing

- Pinout
  - 8 data pins D7:D0
  - RS: Data or Command Register Select
  - R/W: Read or Write
  - E: Enable (Latch data)



- RS - Register Select
  - RS = 0 → Command Register
  - RS = 1 → Data Register
- R/W = 0 → Write , R/W = 1 → Read
- E - Enable
  - Used to latch the data present on the data pins.
- D0 - D7
  - Bi-directional data/command pins.
  - Alphanumeric characters are sent in ASCII format.

LCD Commands

- The LCD's internal controller can accept several commands and modify the display accordingly. Such as:
  - Clear screen
  - Return home
  - Decrement/Increment cursor

- After writing to the LCD, it takes some time for it to complete its internal operations. During this time, it will not accept any new commands or data.
  - We need to insert time delay between any two commands or data sent to LCD

Pin Description

Table 4-7: Pin Descriptions for LCD

Pin	Symbol	I/O	Description
1	V_{SS}	--	Ground
2	V_{CC}	--	+5V power supply
3	V_{EE}	--	Power supply source to control contrast
4	RS	I	Register select: RS=0 to select instruction command register, RS = 1 to select data register
5	R/$\overline{W}$	I	Read/write: R/W=0 for write, R/W=1 for read
6	E	I	Enable
7	DB0	I/O	The 8-bit data bus
8	DB1	I/O	" "
9	DB2	I/O	" "
10	DB3	I/O	" "
11	DB4	I/O	" "
12	DB5	I/O	" "
13	DB6	I/O	" "
14	DB7	I/O	" "

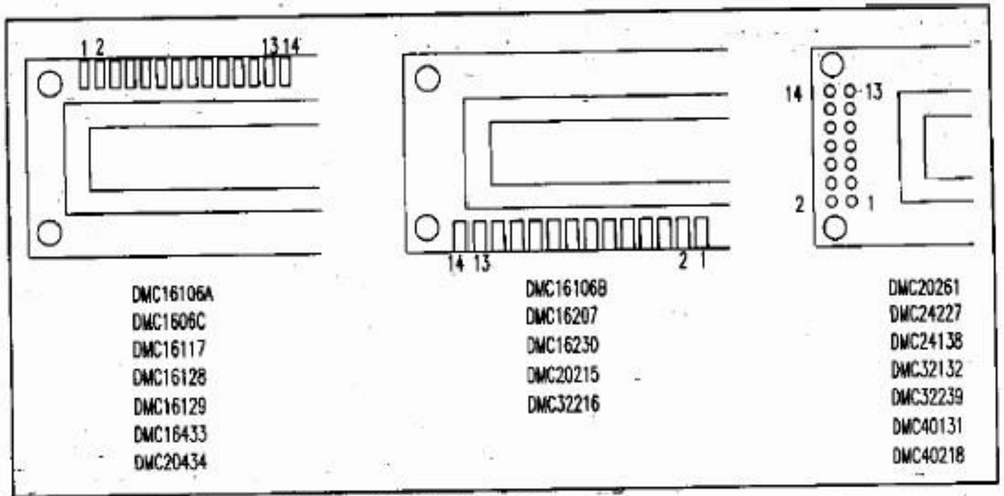


Figure 4-34. Pin Positions for Various LCDs from Optrex

Command Codes

Table 4-8: LCD Command Codes

Code (hex)	Command to LCD Instruction Register
1	Clear display screen
2	Return home
4	Decrement cursor (shift cursor to left)
6	Increment cursor (shift cursor to right)
5	Shift display right
7	Shift display left
8	Display off, cursor off
A	Display off, cursor on
C	Display on, cursor off
E	Display on, cursor on
F	Display on, cursor blinking
10	Shift cursor position to left
14	Shift cursor position to right
18	Shift the entire display to the left
1C	Shift the entire display to the right
C0	Force cursor to beginning of 2nd line
38	2 lines and 5x7 matrix

Note: This table is extracted from Table 4-10.

LCD Addressing

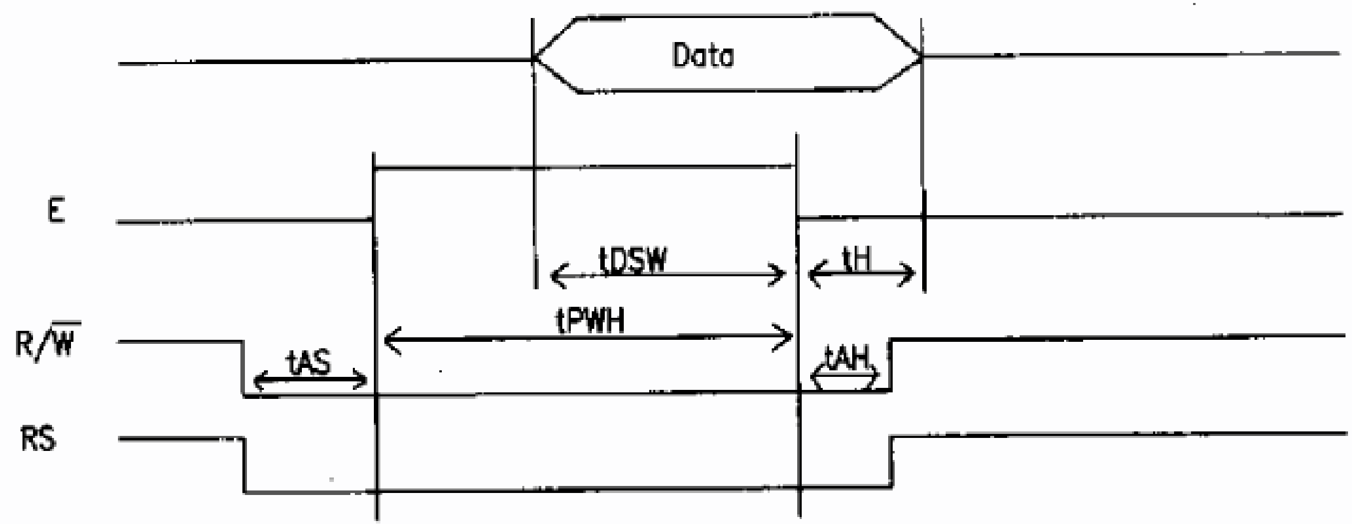
16 x 2 LCD
```
80 81 82 83 84 85 86 through 8F
C0 C1 C2 C3 C4 C5 C6 through CF
```
20 x 1 LCD
```
80 81 82 83          through 93
```
20 x 2 LCD
```
80 81 82 83          through 93
C0 C1 C2 C3          through D3
```
20 x 4 LCD
```
80 81 82 83          through 93
C0 C1 C2 C3          through D3
94 95 96 97          through A7
D4 D5 D6 D7          through E7
```
40 x 2 LCD
```
80 81 82 83          through A7
C0 C1 C2 C3          through E7
```
Note: All data is in hex.

Figure 4-36. Cursor Addresses for Some LCDs

Table 4-9: LCD Addressing

	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
Line 1 (min)	1	0	0	0	0	0	0	0
Line 1 (max)	1	0	1	0	0	1	1	1
Line 2 (min)	1	1	0	0	0	0	0	0
Line 2 (max)	1	1	1	0	0	1	1	1

LCD Timing



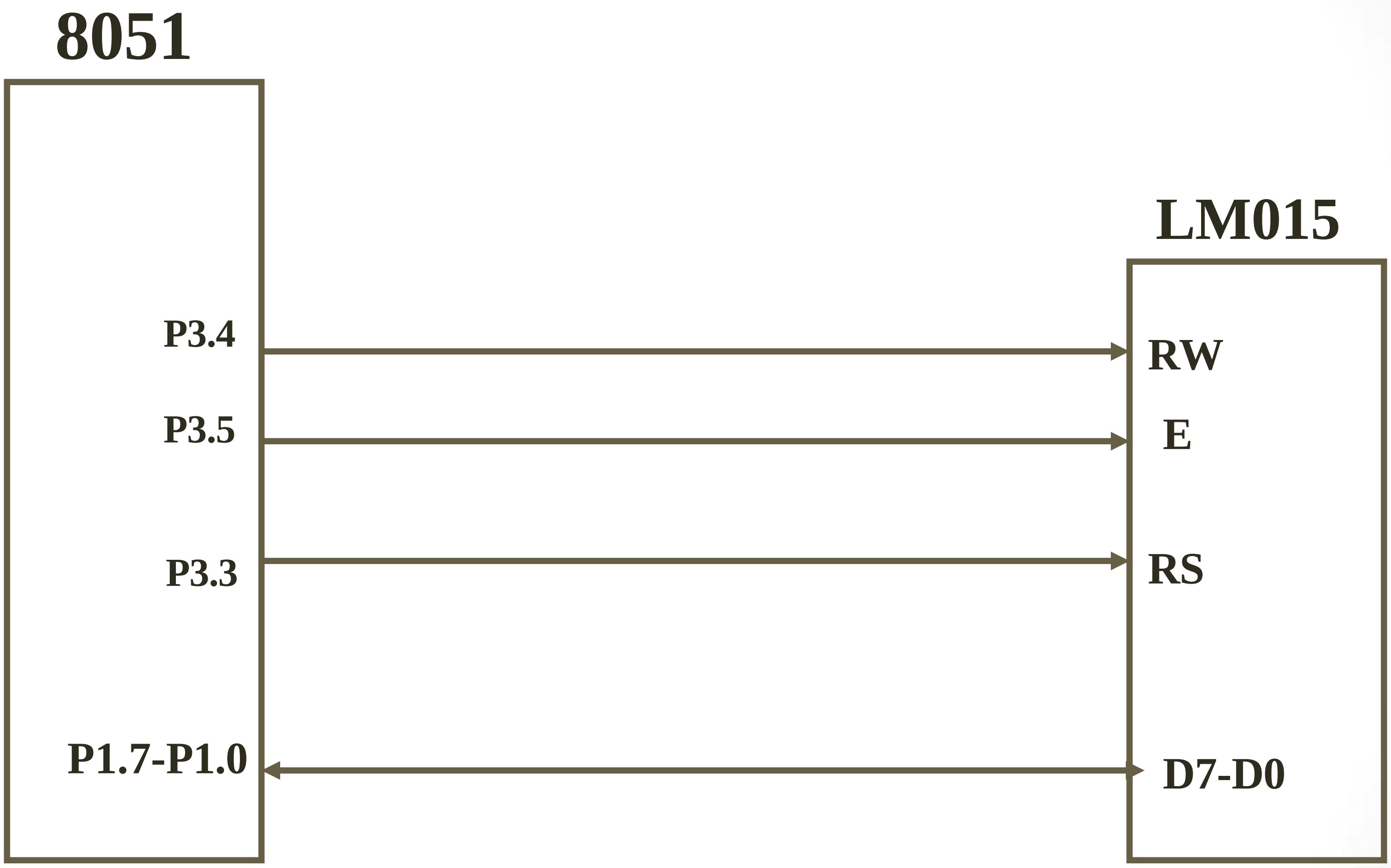
tPWH = Enable pulse width = 450 ns (minimum)
tDSW = Data set up time = 195 ns (minimum)
tH = Data hold time = 10 ns (minimum)
tAS = Set up time prior to E (going high) for both RS and R/W = 140 ns (minimum)
tAH = Hold time after E has come down for both RS and R/W = 10 ns (minimum)

Figure 4-37. LCD Timing

Table 4-10: List of Instructions (Courtesy of Optrex Corporation)

Instruction	Code										Description	Execution Time (max)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Clear Display	0	0	0	0	0	0	0	0	0	1	Clears entire display and sets DD RAM address 0 in address counter.	1.64 ms
Return Home	0	0	0	0	0	0	0	0	1	--	Sets DD RAM address 0 as address counter. Also returns display being shifted to original position. DD RAM contents remain unchanged.	1.64 ms
Entry Mode Set	0	0	0	0	0	0	0	1	I/D	S	Sets cursor move direction and specifies shift of display. These operations are performed during data write and read.	40 µs
Display ON/OFF Control	0	0	0	0	0	0	1	D	C	B	Sets ON/OFF of entire display (D), cursor ON/OFF (C), and blink of cursor position character (b).	40 µs
Cursor or Display Shift	0	0	0	0	0	1	S/C	R/L	--	--	Moves cursor and shifts display without changing DD RAM contents.	40 µs
Function Set	0	0	0	0	1	DL	N	F	--	--	Sets interface data length (DL), number of display lines (L) and character font (F).	40 µs
Set CG RAM Address	0	0	0	1	AGC						Sets CG RAM address. CG RAM data is sent and received after this setting.	40 µs
Set DD RAM Address	0	0	1	ADD							Sets DD RAM address. DD RAM data is sent and received after this setting.	40 µs
Read Busy Flag & Address	0	1	BF	AC							Reads Busy flag (BF) indicating internal operation is being performed and reads address counter contents.	40 µs
Write Data to CG or DD RAM	1	0	Write Data								Writes data into DD RAM or CG RAM.	40 µs
Read Data from CG or DD RAM	1	1	Read Data								Reads data from DD RAM or CG RAM.	40 µs

Interfacing LCD with 8051



Interfacing LCD with 8051

```
mov A, command
call cmd
delay
mov A, another_cmd
call cmd
delay
mov A, #'A'
call data
delay
mov A, #'B'
call data
delay
….
Command and Data Write Routines
data:mov P1, A          ;A is ascii data
     setb P3.3          ;RS=1 data
     clr P3.4           ;RW=0 for write
     setb P3.5          ;H->L pulse on E
     clr P3.5
     ret
cmd:mov P1,A            ;A has the cmd word
     clr P3.3           ;RS=0 for cmd
     clr P3.4           ;RW=0 for write
     setb P3.5          ;H->L pulse on E
     clr P3.5
     ret
```

Example

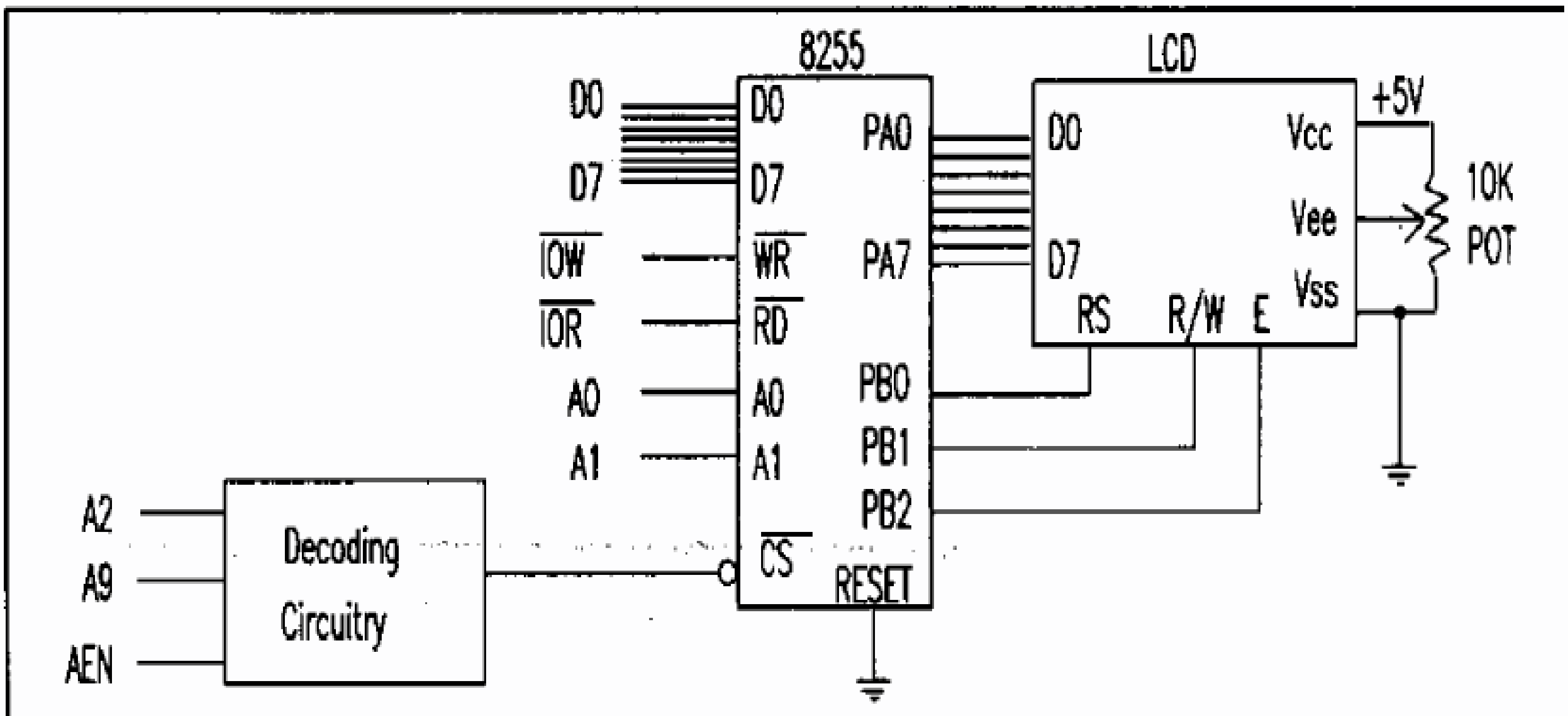


Figure 4-35. 8255-to-PC Interface Connection to LCD

8255 Usage: Simple Example

- 8255 memory mapped to 8051 at address C000H base
  - A = C000H, B = C001H, C = C002H, CR = C003H
- Control word for all ports as outputs in mode0
  - CR : 1000 0000b = 80H

```
test:        mov    A, #80H        ; control word
       mov    DPTR, #C003H  ; address of CR
       movx   @DPTR, A      ; write control word
       mov    A, #55h       ; will try to write 55 and AA
                             ;               alternatively
repeat:mov    DPTR,#C000H   ; address of PA
       movx   @DPTR, A      ; write 55H to PA
       inc    DPTR          ; now DPTR points to PB
       movx   @DPTR, A      ; write 55H to PB
       inc    DPTR          ; now DPTR points to PC
       movx   @DPTR, A      ; write 55H to PC
       cpl    A             ; toggle A (55→AA, AA→55)
       acall  MY_DELAY      ; small delay subroutine
       sjmp   repeat        ; for (1)
```

Interfacing Keyboard and Display Devices

- Topics Covered:
- Interface switches and keyboard to the 8051
- Interface LED displays to the 8051
- Overcome Keybounce and multiple key press problems
- Design a microcontroller based system with keyboard and display devices
- Interface and program the LCD controller

Registers

A
B
R0
R1
R2
R3
R4
R5
R6
R7

Some 8-bit Registers of the 8051

A: Accumulator
B: Used specially in MUL/DIV
R0-R7: GPRs

DPTR	DPH	DPL

PC	PC

Bit No.	MSB 7	6	5	4	3	2	1	LSB 0	
$D0_H$	CY	AC	F0	RS1	RS0	OV	F1	P	PSW

Bit	Function
CY	Carry Flag Used by arithmetic and conditional branch instruction.
AC	Auxiliary Carry Flag Used by instructions which execute BCD operations.
F0	General Purpose Flag
RS1 RS0	Register Bank select control bits These bits are used to select one of the four register banks.
OV	Overflow Flag Used by arithmetic instruction.
F1	General Purpose Flag
P	Parity Flag Always set/cleared by hardware to indicate an odd/even number of "one" bits in the accumulator.

RS1	RS0	Function
0	0	Registerbank 0 at data address 00_H - 07_H selected
0	1	Registerbank 1 at data address 08_H - $0F_H$ selected
1	0	Registerbank 2 at data address 10_H - 17_H selected
1	1	Registerbank 3 at data address 18_H - $1F_H$ selected

8051 Programming using Assembly

The MOV Instruction – Addressing Modes

MOV dest,source ; dest = source

```
MOV    A,#72H        ;A=72H
MOV    A, #'r'       ;A='r' OR 72H
MOV    R4,#62H       ;R4=62H
MOV    B,0F9H        ;B=the content of F9'th byte of RAM

MOV    DPTR,#7634H
MOV    DPL,#34H
MOV    DPH,#76H

MOV    P1,A          ;mov A to port 1
```

Note 1:

MOV A,#72H ≠ MOV A,72H

After instruction "MOV A,72H " the content of 72'th byte of RAM will replace in Accumulator.

8086		**8051**	
MOV	AL,72H	MOV	A,#72H
MOV	AL,'r'	MOV	A,#'r'
MOV	BX,72H		
MOV	AL,[BX]	MOV	A,72H

Note 2:

MOV A,R3 ≡ MOV A,3

Arithmetic Instructions

ADD A, Source ;A=A+SOURCE

ADD	A,#6	;A=A+6
ADD	A,R6	;A=A+R6
ADD	A,6	;A=A+[6] or A=A+R6
ADD	A,0F3H	;A=A+[0F3H]

Set and Clear Instructions

SETB	**bit**	**; bit=1**
CLR	**bit**	**; bit=0**

```
SETB   C         ; CY=1
SETB   P0.0      ;bit 0 from port 0 =1
SETB   P3.7      ;bit 7 from port 3 =1
SETB   ACC.2     ;bit 2 from ACCUMULATOR =1
SETB   05        ;set high D5 of RAM loc. 20h
```

Note:

CLR instruction is as same as SETB
i.e:

```
CLR    C    ;CY=0
```

But following instruction is only for CLR:

```
CLR    A    ;A=0
```

SUBB A,source ;A=A-source-CY

```
SETBC          ;CY=1
SUBB    A,R5        ;A=A-R5-1
```

ADC A,source ;A=A+source+CY

```
SETBC          ;CY=1
ADC     A,R5        ;A=A+R5+1
```

8051 Flag bits and the PSW register

- PSW Register

CY	AC	F0	RS1	RS0	OV	--	P

Carry flag	PSW.7	**CY**
Auxiliary carry flag	PSW.6	**AC**
Available to the user for general purpose	PSW.5	**--**
Register Bank selector bit 1	PSW.4	**RS1**
Register Bank selector bit 0	PSW.3	**RS0**
Overflow flag	PSW.2	**OV**
User define bit	PSW.1	**--**
Parity flag Set/Reset odd/even parity	PSW.0	**P**

RS1	**RS0**	**Register Bank**	**Address**
0	0	0	00H-07H
0	1	1	08H-0FH
1	0	2	10H-17H
1	1	3	18H-1FH

Instructions that Affect Flag Bits:

Instructions	CY	OV	AC
ADD	X	X	X
ADDC	X	X	X
SUBB	X	X	X
MUL	0	X	
DIV	0	X	
DA	X		
RRC	X		
RLC	X		
SETB C	1		
CLR C	0		
ANL C,bit	X		
ANL C,/bit	X		
ORL C,bit	X		
MOV C,bit	X		
CJNE	X		

Note: X can be 0 or 1

Example:
MOV A,#88H
ADD A,#93H

88	10001000
+93	+10010011
----	--------------
11B	00011011

CY=1 AC=0 P=0

Example:
MOV
A,#38

38	00111000
+2F	+0010111 1
----	------------- -
67	

CY=0

Example:
MOV A,#9CH
ADD A,#64H

9C	10011100
+64	+01100100
----	--------------
100	00000000

CY=1 AC=1 P=0

Addressing Modes

- Immediate
- Register
- Direct
- Register Indirect
- Indexed

Immediate Addressing Mode

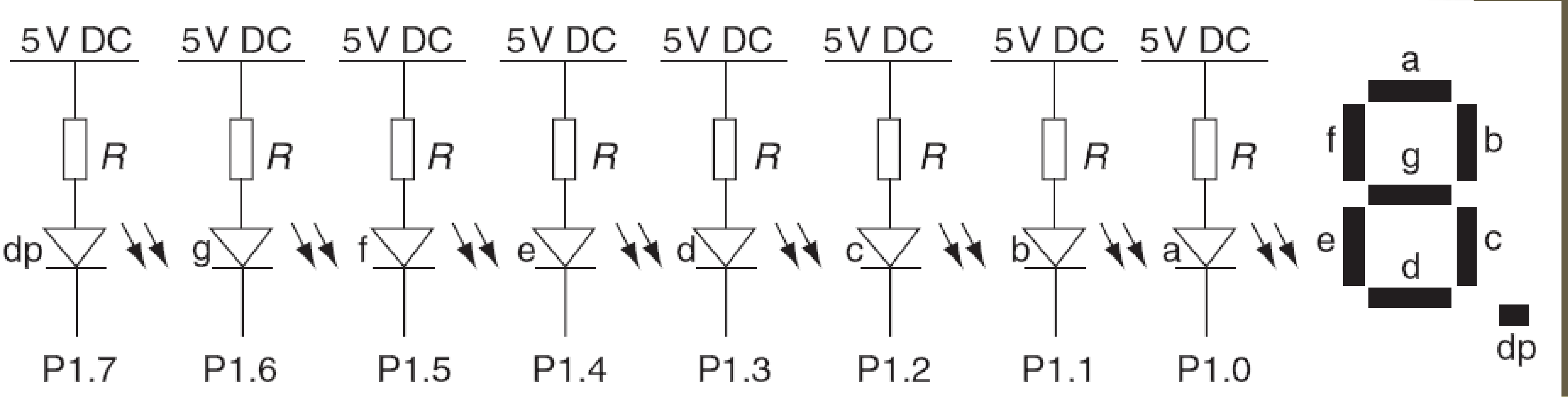
```
MOV    A,#65H
MOV    A,#'A'
MOV    R6,#65H
MOV    DPTR,#2343H
MOV    P1,#65H
```

Example :

```
Num          EQU      30
…
MOV          R0,Num
MOV          DPTR,#data1
…
ORG          100H
data1:       db       "Example"
```

Example

- Write the decimal value 4 on the SSD in the following figure. Switch the decimal point off.



Direct Addressing Mode

Although the entire of 128 bytes of RAM can be accessed using direct addressing mode, it is most often used to access RAM loc. 30 – 7FH.

```
MOV   R0, 40H
MOV   56H, A
MOV   A, 4                 ; ≡ MOV A, R4
MOV   6, 2                 ; copy R2 to R6
                           ; MOV  R6,R2 is invalid !
```

SFR register and their address

```
MOV   0E0H, #66H           ; ≡ MOV A,#66H
MOV   0F0H, R2             ; ≡ MOV B, R2
MOV   80H,A                ; ≡ MOV P1,A
```

Register Indirect Addressing Mode

- In this mode, register is used as a pointer to the data.

```
MOV     A,@Ri     ; move content of RAM loc.Where address is held by Ri into A
                  ( i=0 or 1 )
MOV     @R1,B
```

In other word, the content of register R0 or R1 is sources or target in MOV, ADD and SUBB insructions.

Example:

Write a program to copy a block of 10 bytes from RAM location sterting at 37h to RAM location starting at 59h.

Solution:

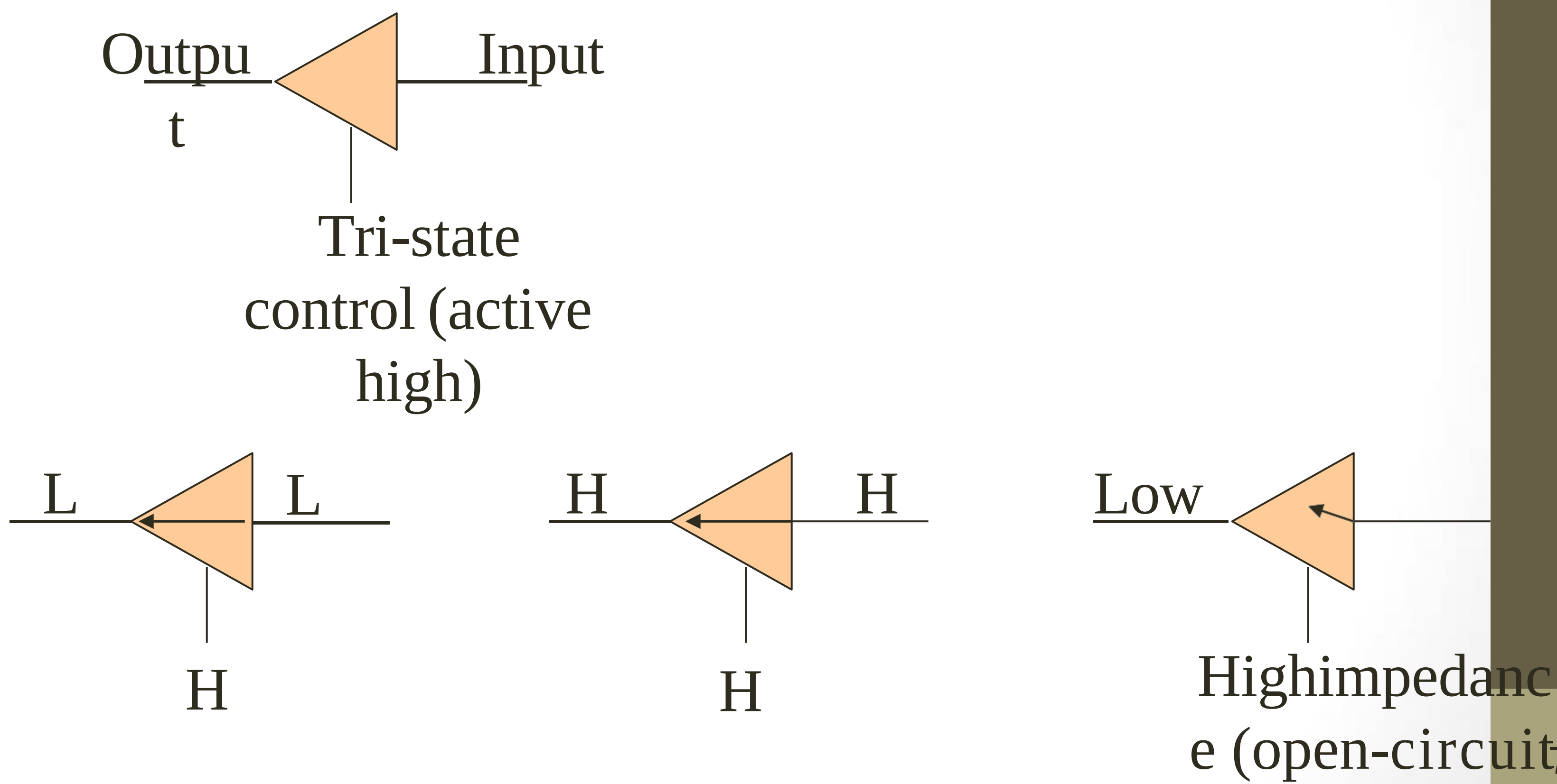
```
    MOV   R0,37h          ; source pointer
    MOV   R1,59h          ; dest pointer
    MOV   R2,10           ; counter
L1: MOV   A,@R0
    MOV   @R1,A
    INC   R0
    INC   R1
    DJNZ  R2,L1
```

jump

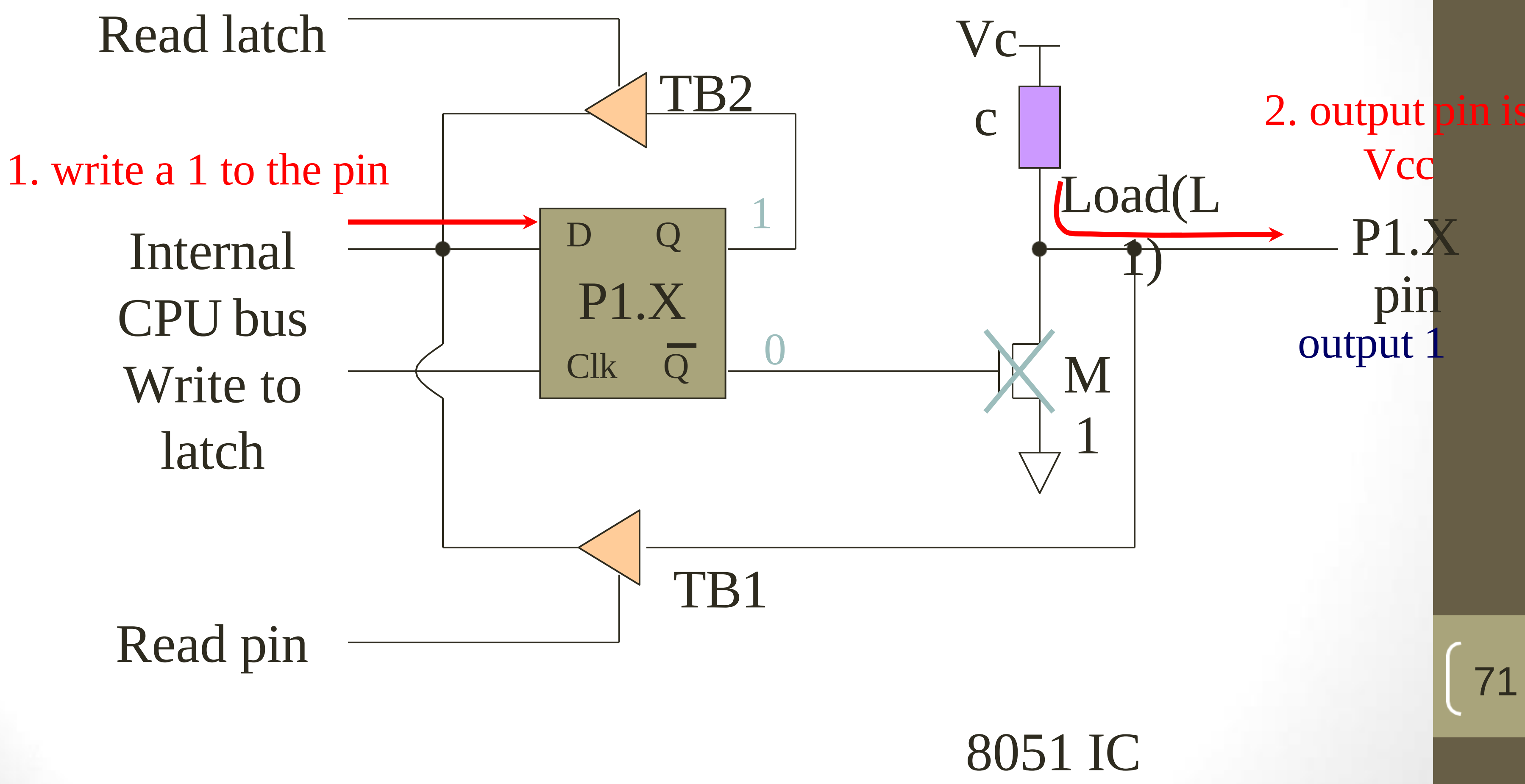
Hardware Structure of I/O Pin

- Each pin of I/O ports
  - Internal CPU bus：communicate with CPU
  - A D latch store the value of this pin
    - D latch is controlled by “Write to latch”
      - 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

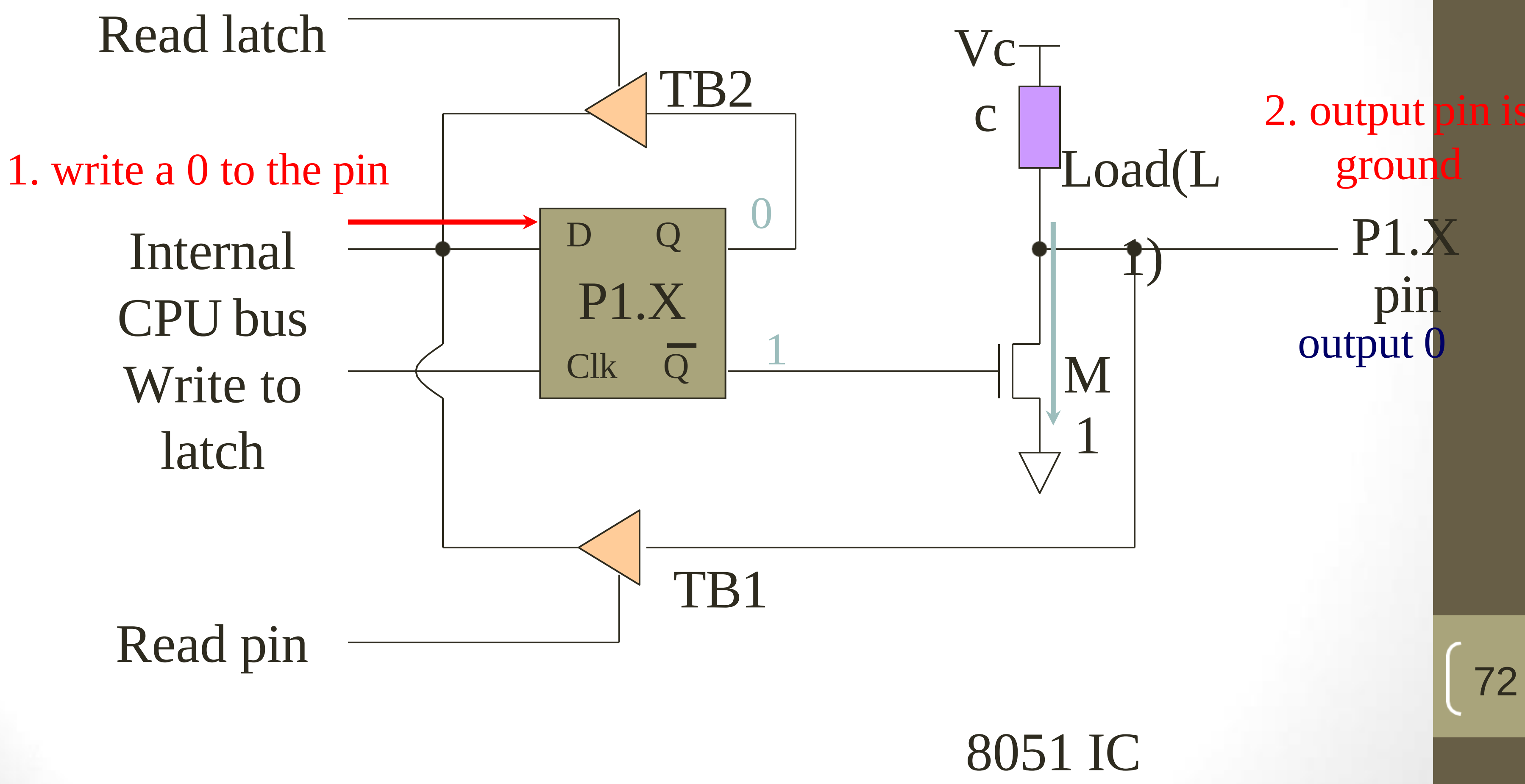
Tri-state Buffer



Writing "1" to Output Pin P1.X



Writing “0” to Output Pin P1.X



Port 1 as Output（Write to a Port）

- Send data to Port 1：

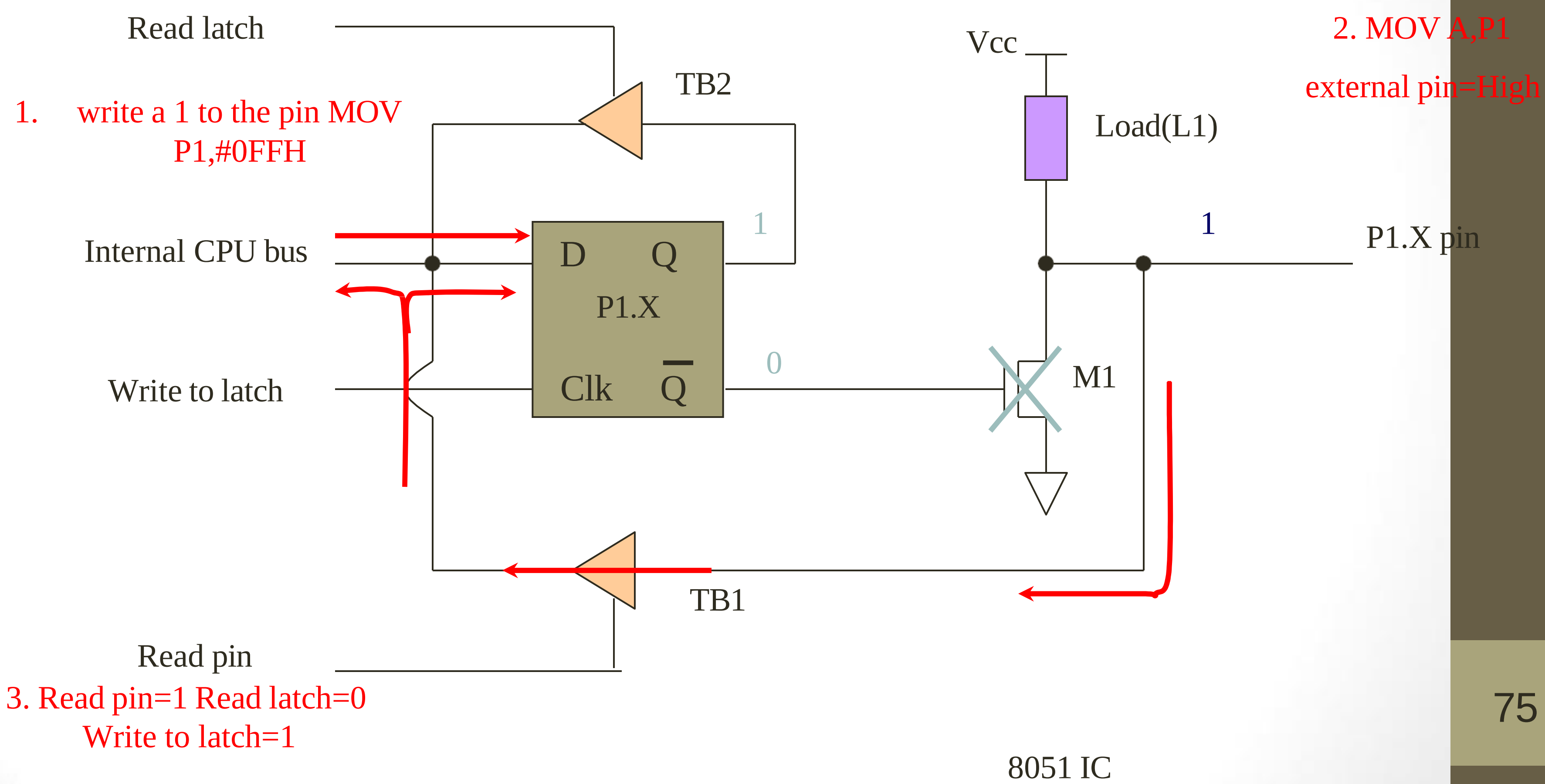
```
        MOV     A,#55H
BACK:   MOV     P1,A
        ACALL   DELAY
        CPL  A
        SJMP  BACK
```

  - Let P1 toggle.
  - You can write to P1 directly.

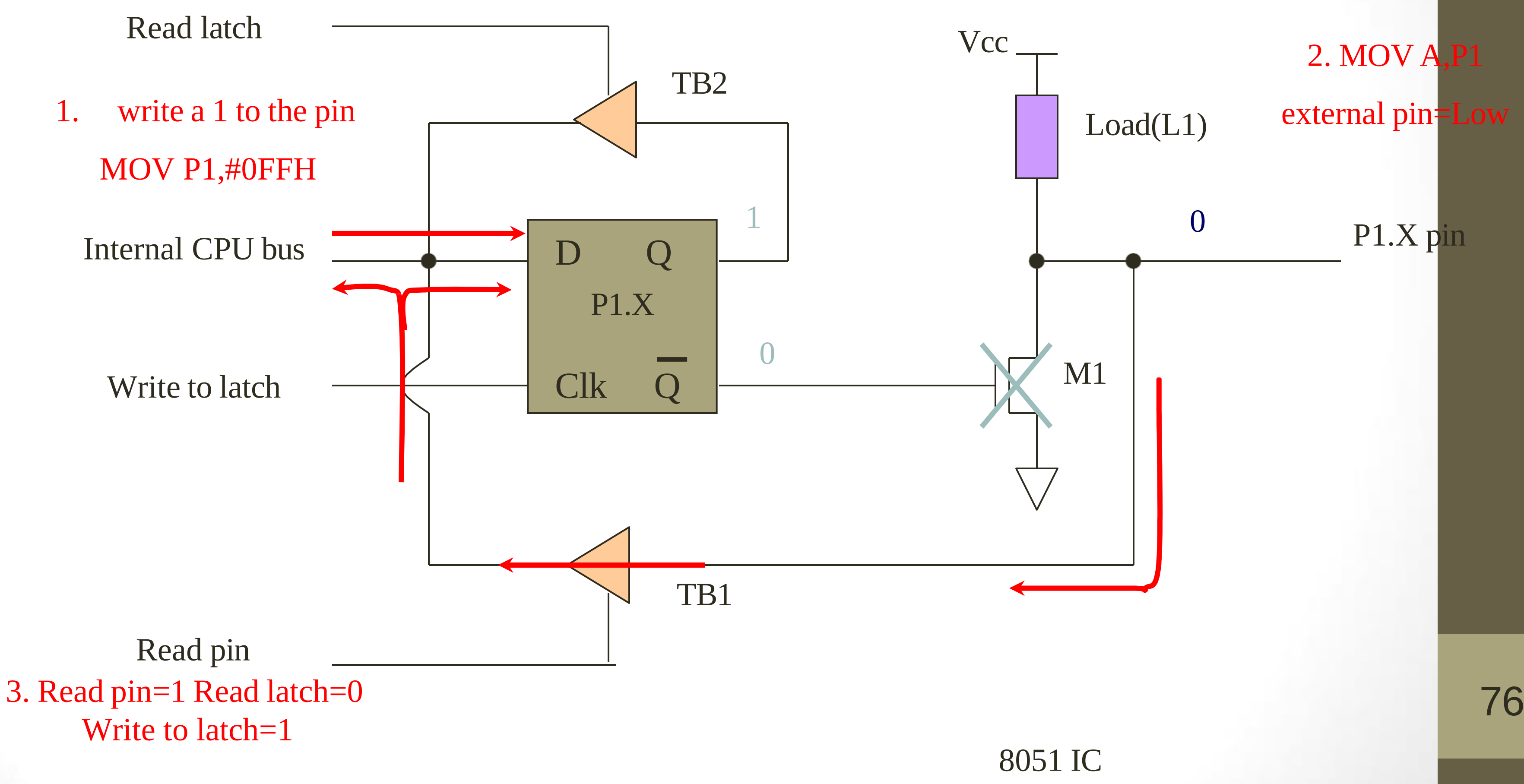
Reading Input v.s. Port Latch

- When reading ports, there are two possibilities：
  - Read the status of the input pin. （from *external pin value*）
    - MOV A, PX
    - JNB P2.1, TARGET ; jump if P2.1 is not set
    - JB P2.1, TARGET ; jump if P2.1 is set
    - Figures C-11, C-12
  - Read the *internal latch* of the output port.
    - ANL P1, A ; P1 ← P1 AND A
    - ORL P1, A ; P1 ← P1 OR A
    - INC P1 ; increase P1
    - Figure C-17
    - Table C-6 Read-Modify-Write Instruction (or Table 8-5)
- See Section 8.3

Reading “High” at Input Pin



Reading "Low" at Input Pin



Port 1 as Input（Read from Port）

- In order to make P1 an input, the port must be programmed by writing 1 to all the bit.

```
        MOV   A,#0FFH    ;A=11111111B
        MOV   P1,A       ;make P1 an input port
BACK:   MOV   A,P1       ;get data from P0
        MOV   P2,A       ;send data to P2
        SJMP  BACK
```

- To be an input port, P0, P1, P2 and P3 have similar methods.

Instructions For Reading an Input Port

- Following are instructions for reading external pins of ports:

Mnemonics	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

Read-modify-write Feature

- Read-modify-write Instructions
  - Table C-6
- This features combines 3 actions in a single instruction：

1. CPU reads the latch of the port
2. CPU perform the operation
3. Modifying the latch
4. Writing to the pin

  - Note that 8 pins of P1 work independently.

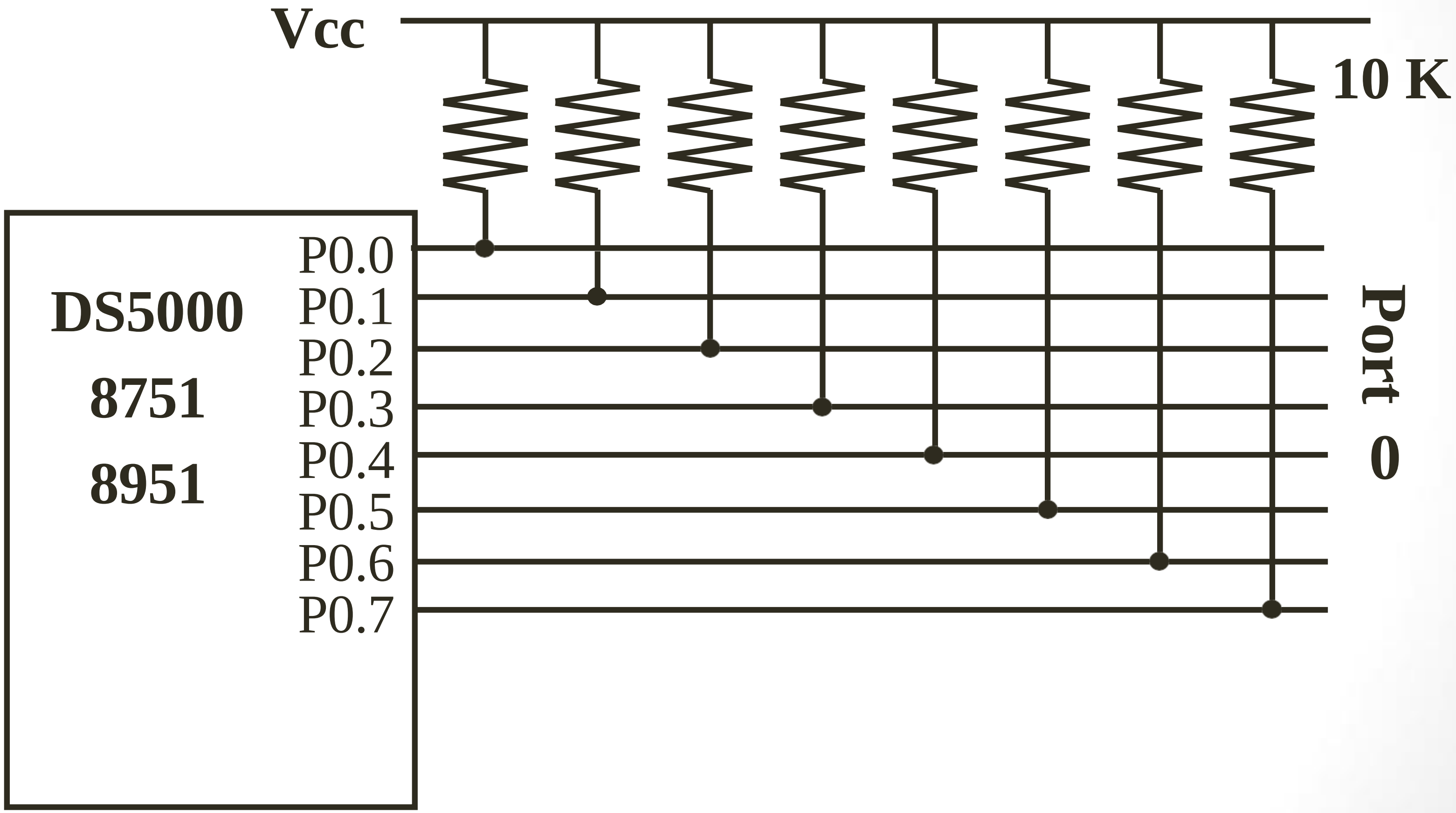
Port 1 as Input（Read from latch）

- Exclusive-or the Port 1：

```
        MOV   P1,#55H   ;P1=01010101
AGAIN:  XOR   P1,#0FFH  ;complement
        ACALL DELAY
        SJMP  AGAIN
```

  - Note that the XOR of 55H and FFH gives AAH.
  - XOR of AAH and FFH gives 55H.
  - The instruction read the data in the latch (not from the pin).
  - The instruction result will put into the latch and the pin.

Port 0 with Pull-Up Resistors



8051 Programming Using C

Programming microcontrollers using high-level languages

- Most programs can be written exclusively using high-level code like ANSI C
- Extensions
  - To achieve low-level (Assembly) efficiency, extensions to high- level languages are required
- Restrictions
  - Depending on the compiler, some restrictions to the high-level language may apply

Keil C keywords

- **data/idata:**
  Description: The variable will be stored in internal data memory of controller.

  example:
  unsigned char data x;
  //or
  unsigned char idata y;

- **bdata:**
  Description: The variable will be stored in bit addressable memory of controller.

  example:
- unsigned char bdata x;
  //each bit of the variable x can be accessed as follows
  x ^ 1 = 1; *//1st bit of variable x is set*
  x ^ 0 = 0; *//0th bit of variable x is cleared*

- **xdata:**
  Description: The variable will be stored in external RAM memory of controller.

  example:
  unsigned char xdata x;

Keil C keywords

- **sfr:**
  Description: sfr is used to define an 8-bit special function register from sfr memory.

  example:
  sfr Port1 = 0x90;
  // Special function register with name Port1 defined at addrress 0x90

- **sfr16:**
  Description: This keyword is used to define a two sequential 8-bit registers in SFR memory.

  example:
  sfr16 DPTR = 0x82;
  // 16-bit special function register starting at 0x82
  // DPL at 0x82, DPH at 0x83

- **using:**
  Description: This keyword is used to define register bank for a function. User can specify register bank 0 to 3.

  example:
  void **function** () using 2{
  // code
  }
  // Funtion named "function" uses register bank 2 while executing its code

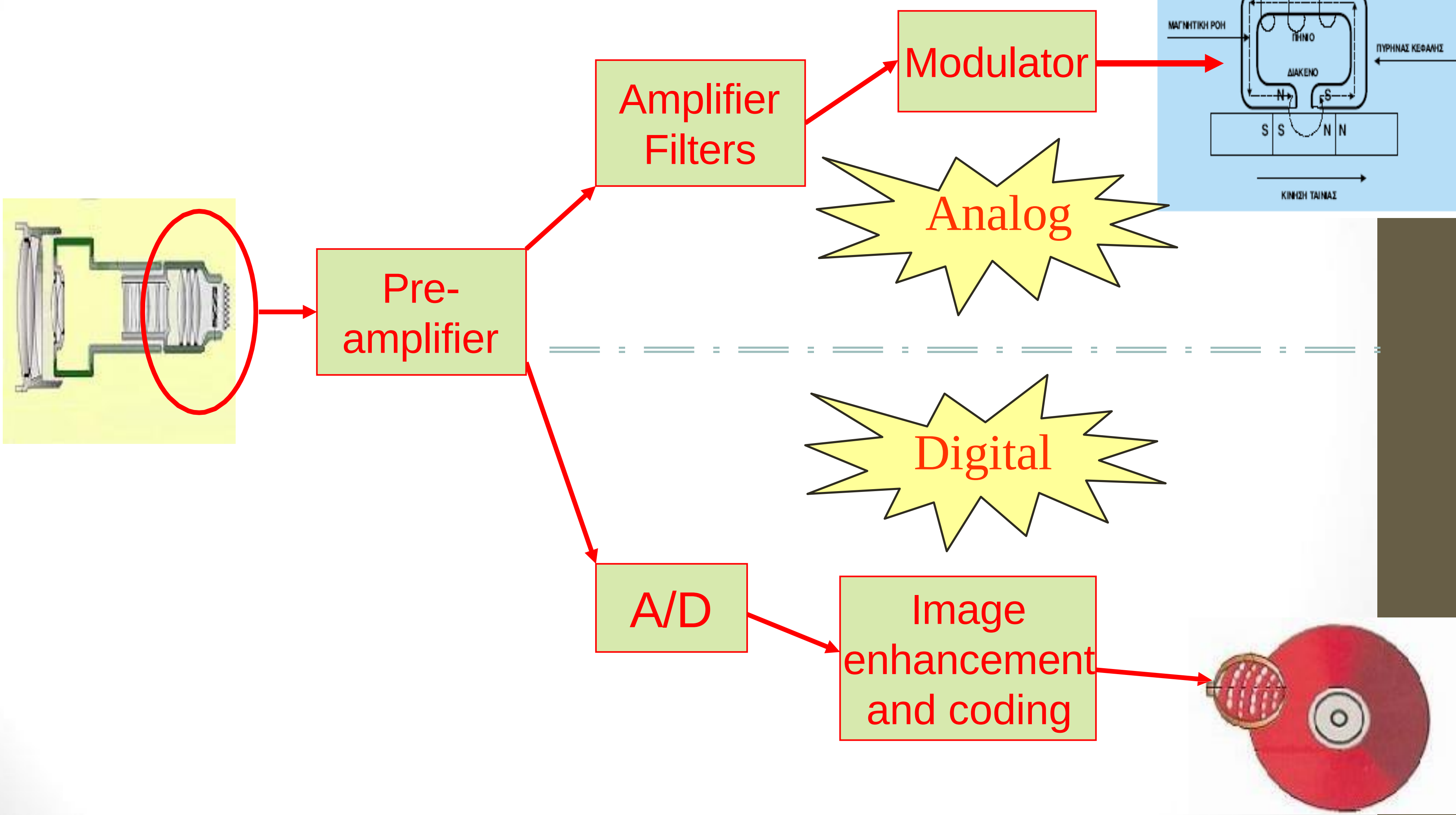
- **Interrupt:**
  Description: defines interrupt service routine
  void External_Int0() interrupt 0{
  //code
  }

Data Converters

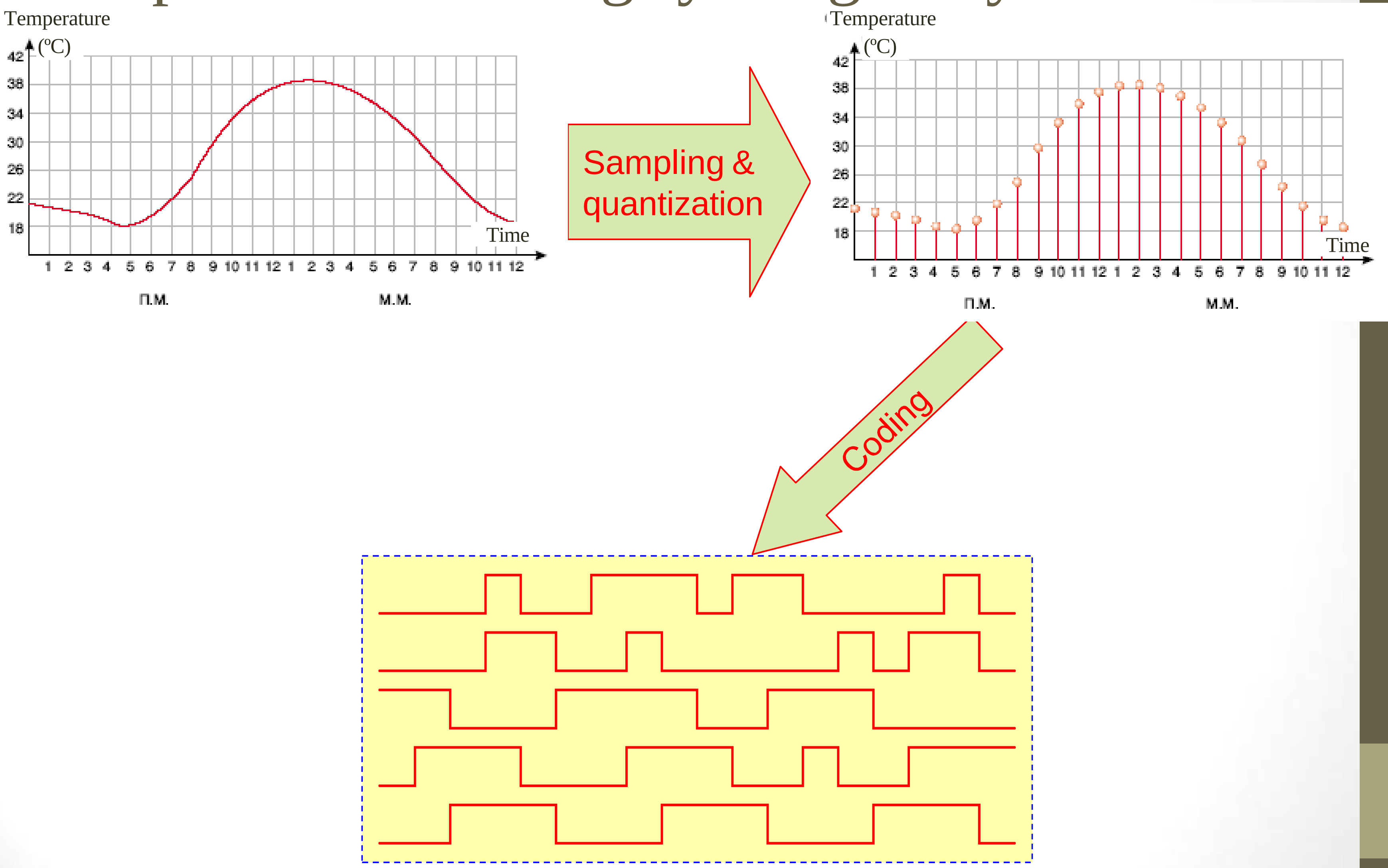
- Analog to Digital Converters (ADC)
  - Convert an analog quantity (voltage, current) into a digital code
- Digital to Analog Converters (DAC)
  - Convert a digital code into an analog quantity (voltage, current)

Dr. Konstantinos Tatas and Dr. Costas Kyriacou

Video (Analog - Digital)



Temperature Recording by a Digital System



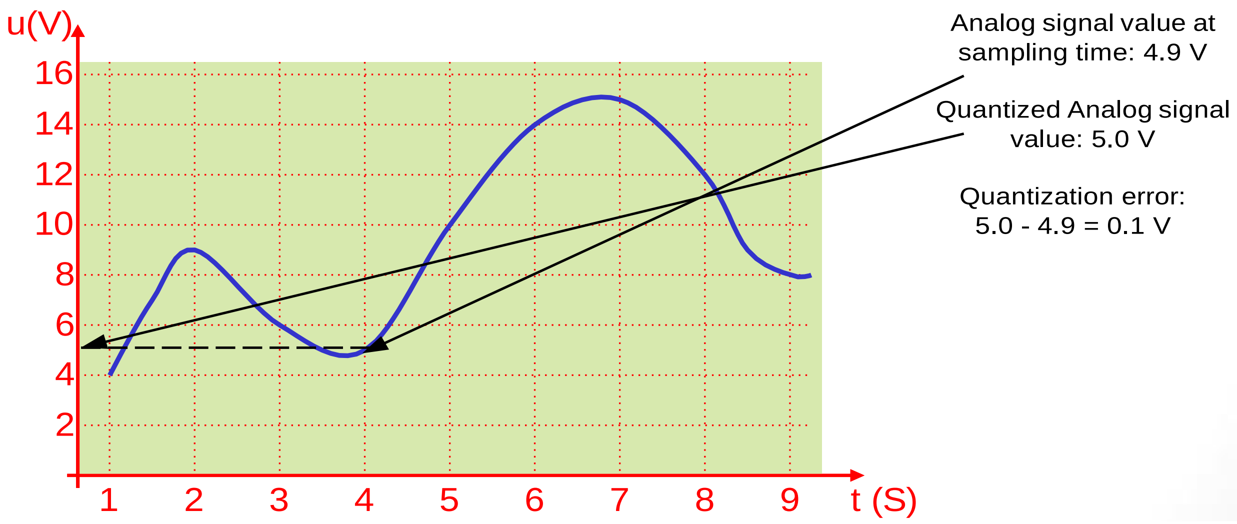
Need for Data Converters

Digital processing and storage of physical quantities (sound, temperature, pressure etc) exploits the advantages of digital electronics

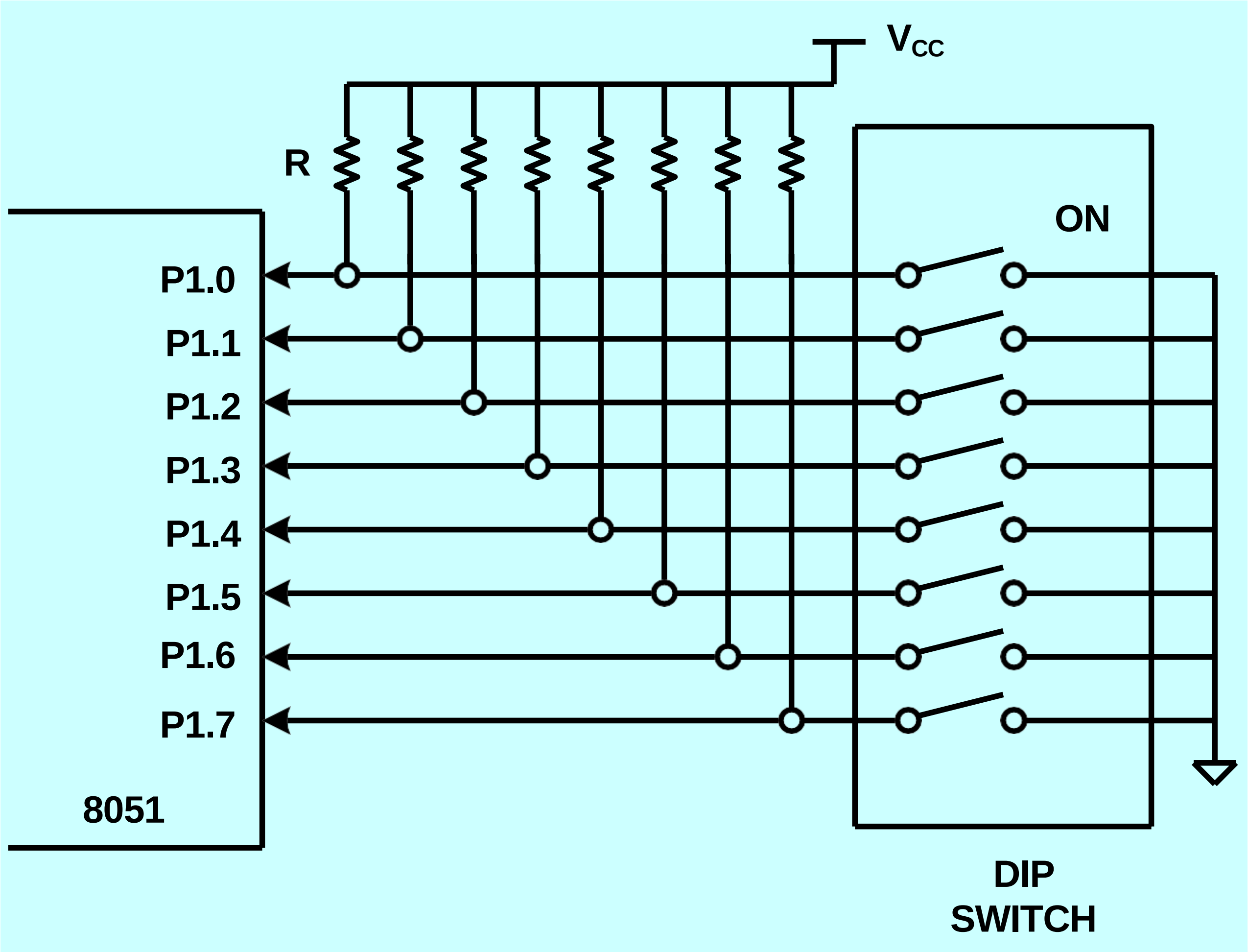
- Better and cheaper technology compared to the analog
- More reliable in terms of storage, transfer and processing
  - Not affected by noise
- Processing using programs (software)
  - Easy to change or upgrade the system
    - (e.g. Media Player 7 → Media Player 8 ή Real Player)
  - Integration of different functions
    - (π.x. Mobile = phone + watch + camera + games + email +

QUANTIZATION ERROR

- The difference between the true and quantized value of the analog signal
- Inevitable occurrence due to the finite resolution of the ADC
- The magnitude of the quantization error at each sampling instant is between zero and half of one LSB.
- Quantization error is modeled as noise (quantization noise)



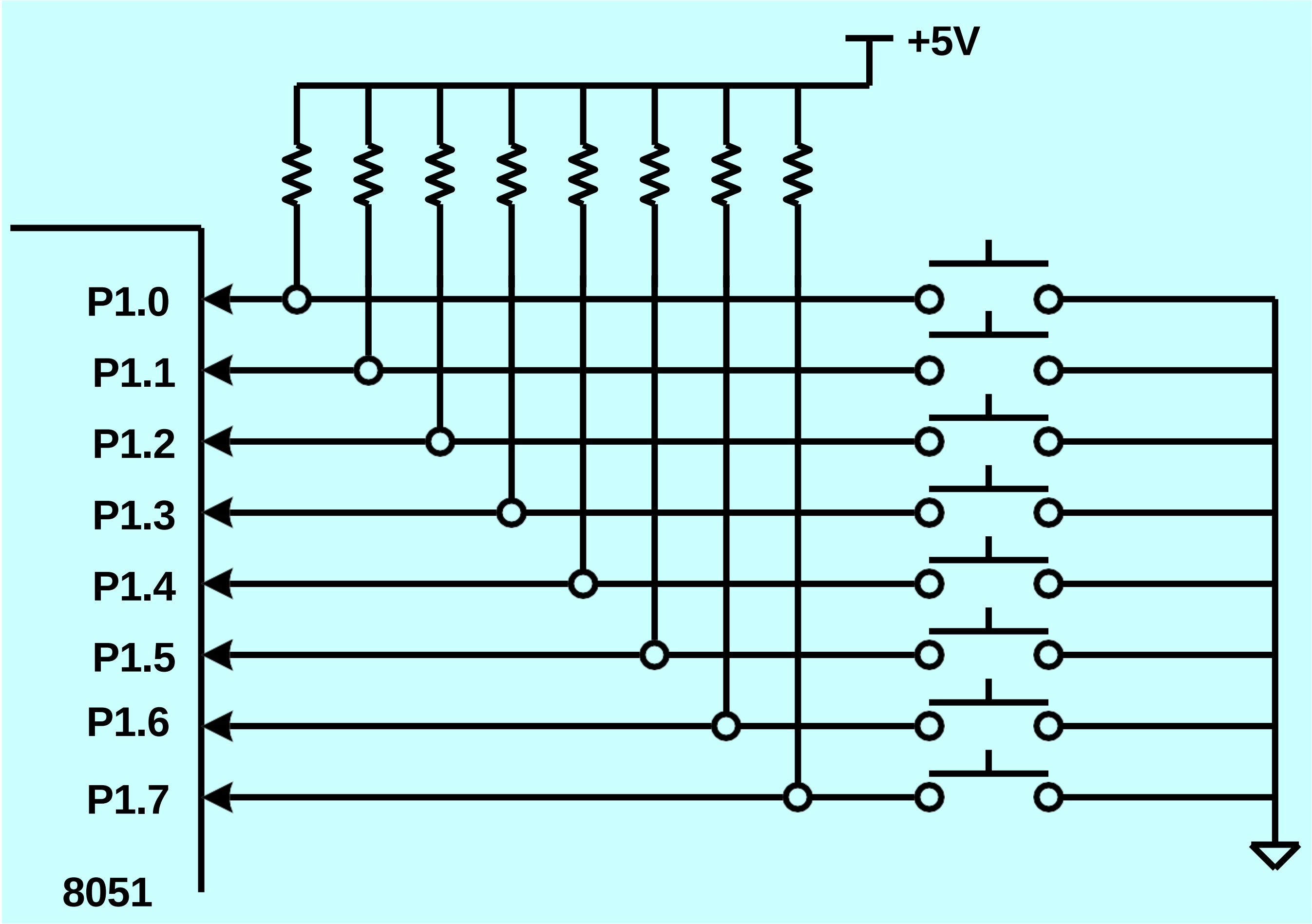
Interfacing Switches



What is a Keyboard ?

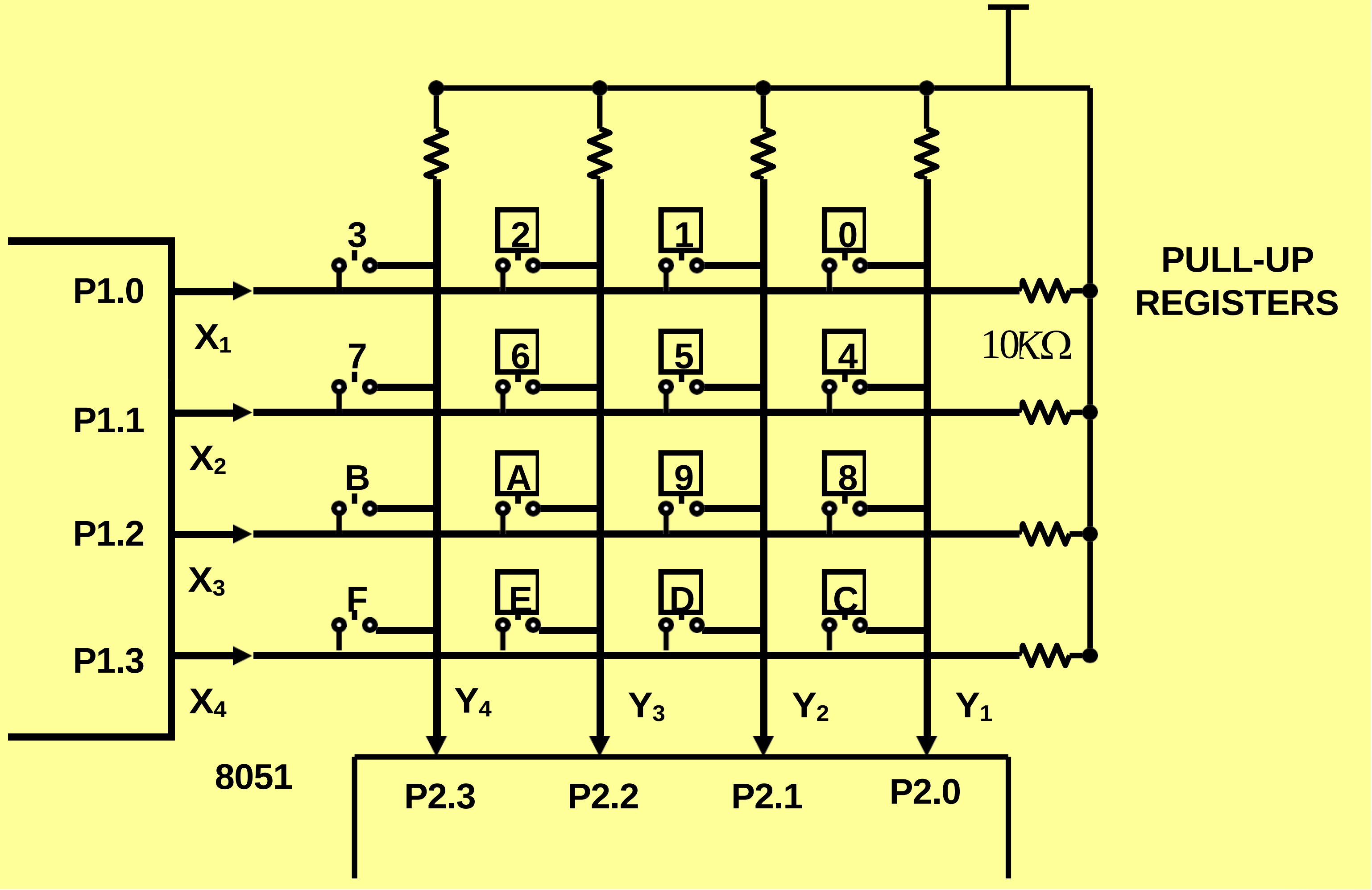
- Collection of keys interfaced to the microcontroller
- Arranged in the form of two dimensional matrix
- Matrix arrangement used for minimizing the number of port lines
- Junction of each row and column forms the key

Interfacing a Keyboard



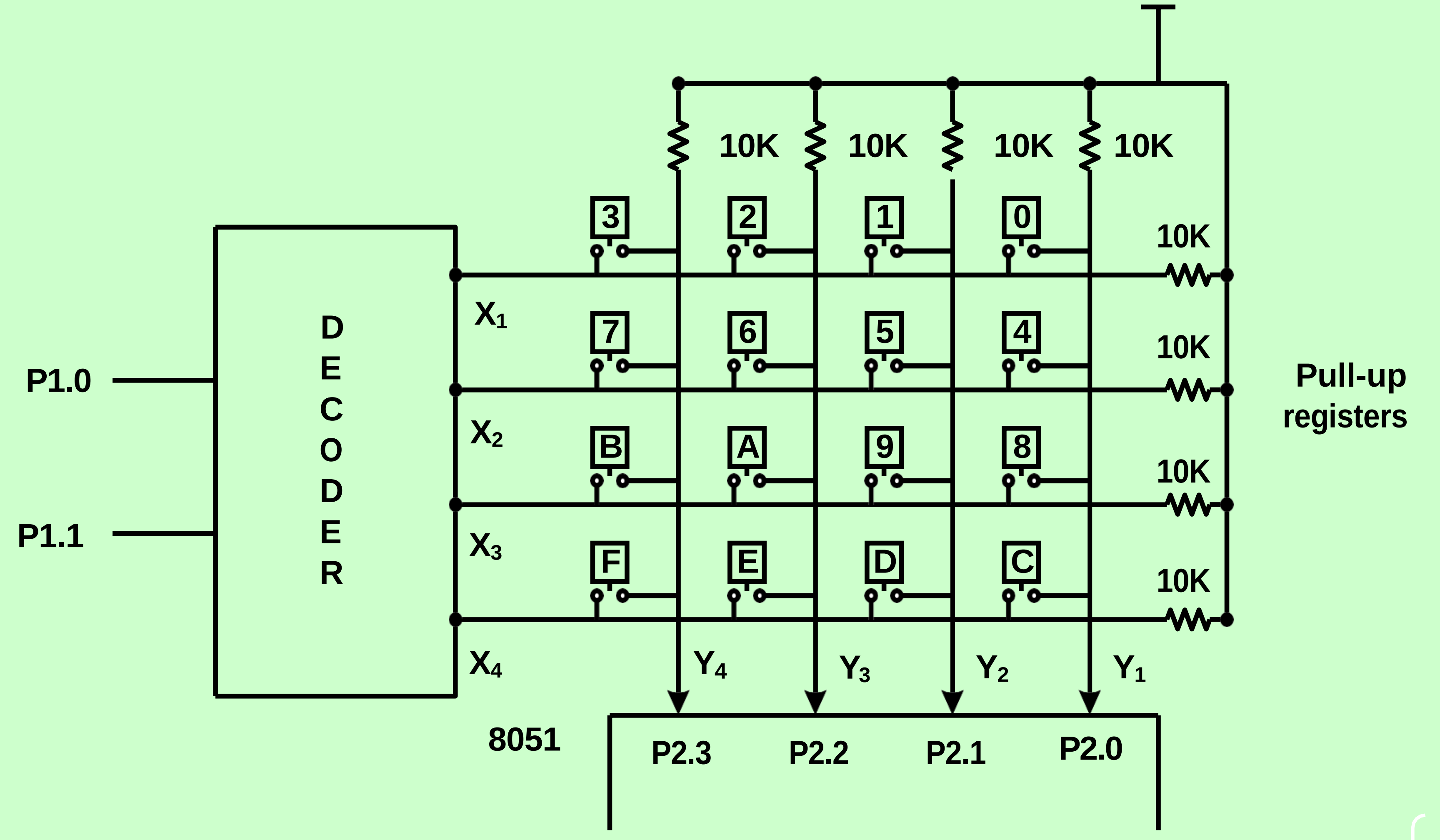
- **One key per port line**

Interfacing a Keyboard



- **Keys are organized in two-dimensional matrix to minimize the number of ports required for interfacing**

Interfacing a Keyboard



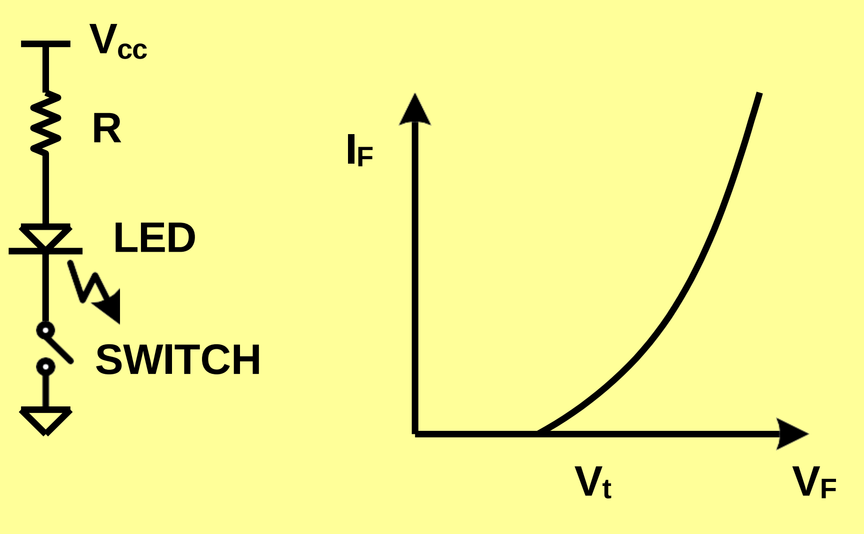
- Use of decoder further reduces the number of port lines required

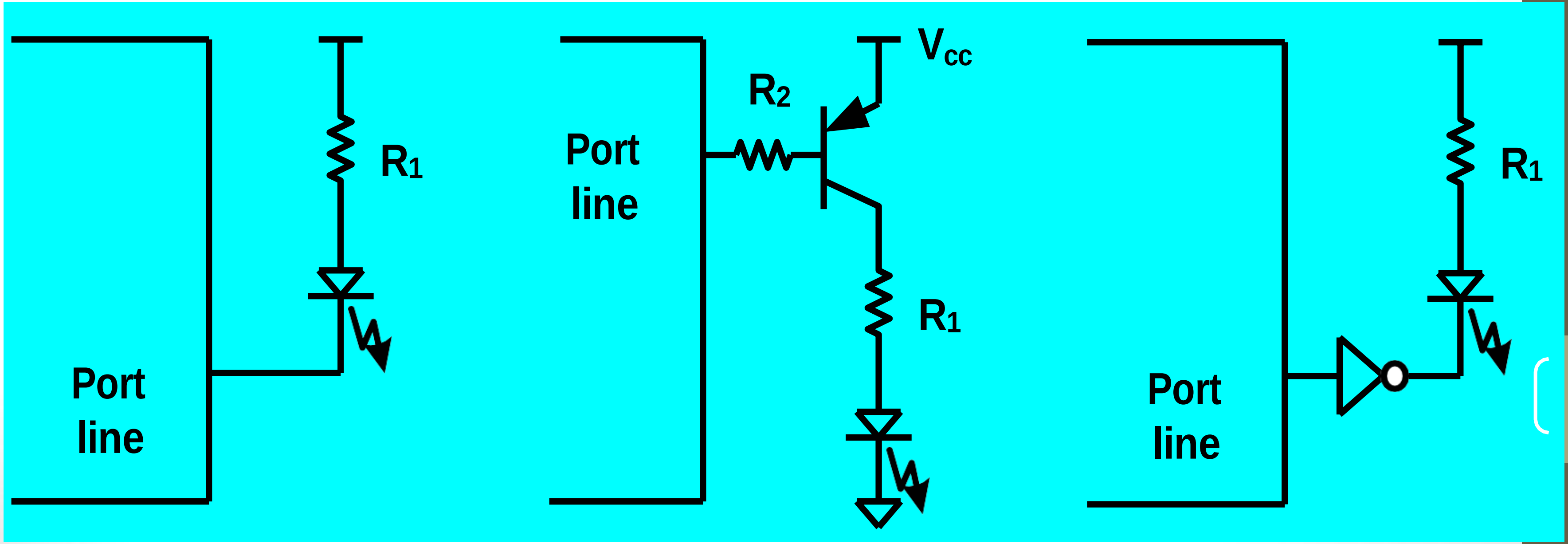
Key Issues

- Key bounce can be overcome using Software/Hardware approach
- Keyboard Scanning
- Multiple Key Closure
  - 2-key lockout
  - 2-key rollover
- Minimize Hardware Requirement:
  - Use of Keyboard Encoder
- Minimize Software Overhead

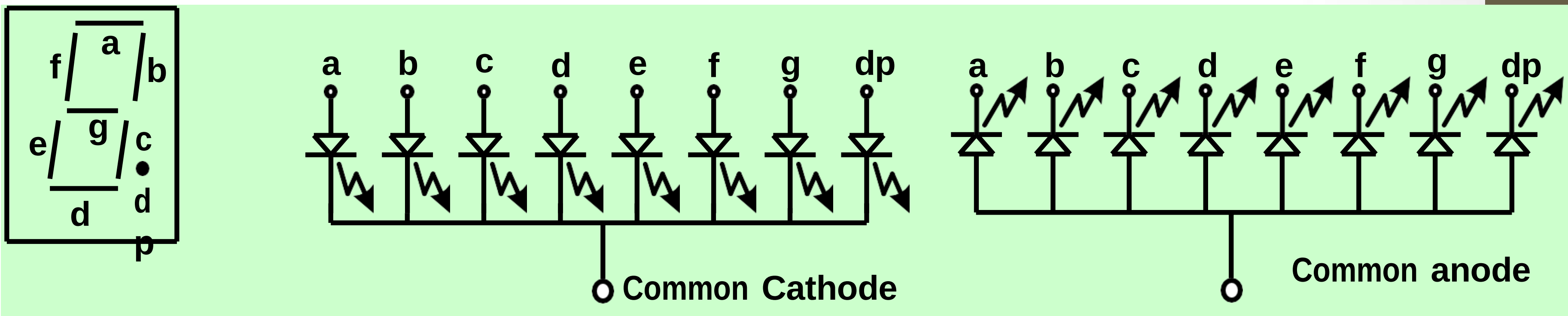
Interfacing a single LED

- Driver circuit to interface a single LED

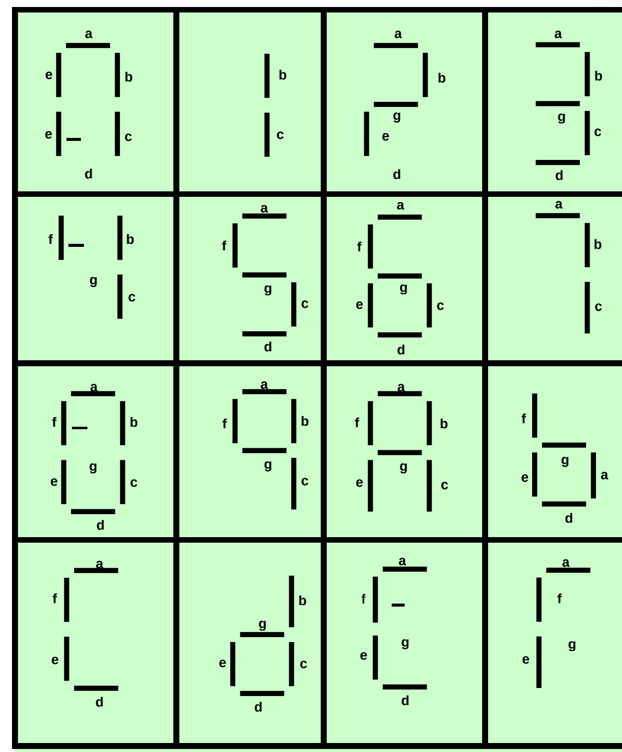




Seven Segment LEDs



- Two types: Common cathode and common anode type
- Seven-segment LEDs can be conveniently used to display HEX characters



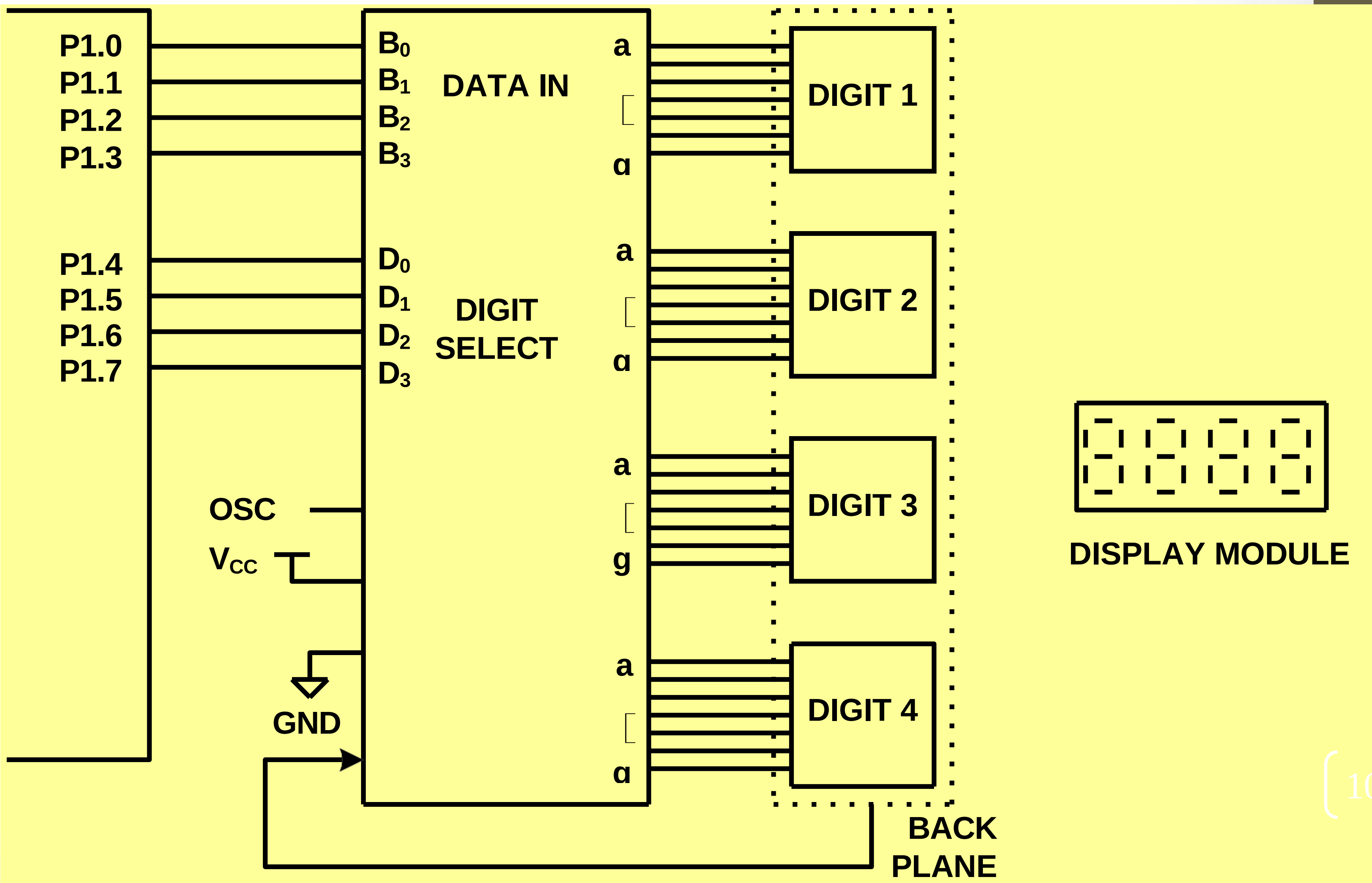
Multidigit Driver

- **Features of Multidigit Driver**
  - 8-segment driver output lines
  - 8-digit driver lines
  - 20 mA peak current
  - LEDs can withstand high peak current
- **Sequencing operation:**
  - Select data using digit address lines $DA_{0\text{-}2}$
  - Write data using $ID_{0\text{-}3}$ and ID_7 lines
- **Three modes of operation:**
  - HIGH: HEX, LOW: OFF, OPEN: CODED-HELP

Liquid Crystal Displays

- **Key features:**
  - Low Power Consumption
  - Voltage Controlled
  - Easy to read in bright light
  - Declining Cost
  - Ability to display Characters/Graphics
  - Intelligent controller and LCD display panels readily available

Liquid Crystal Displays

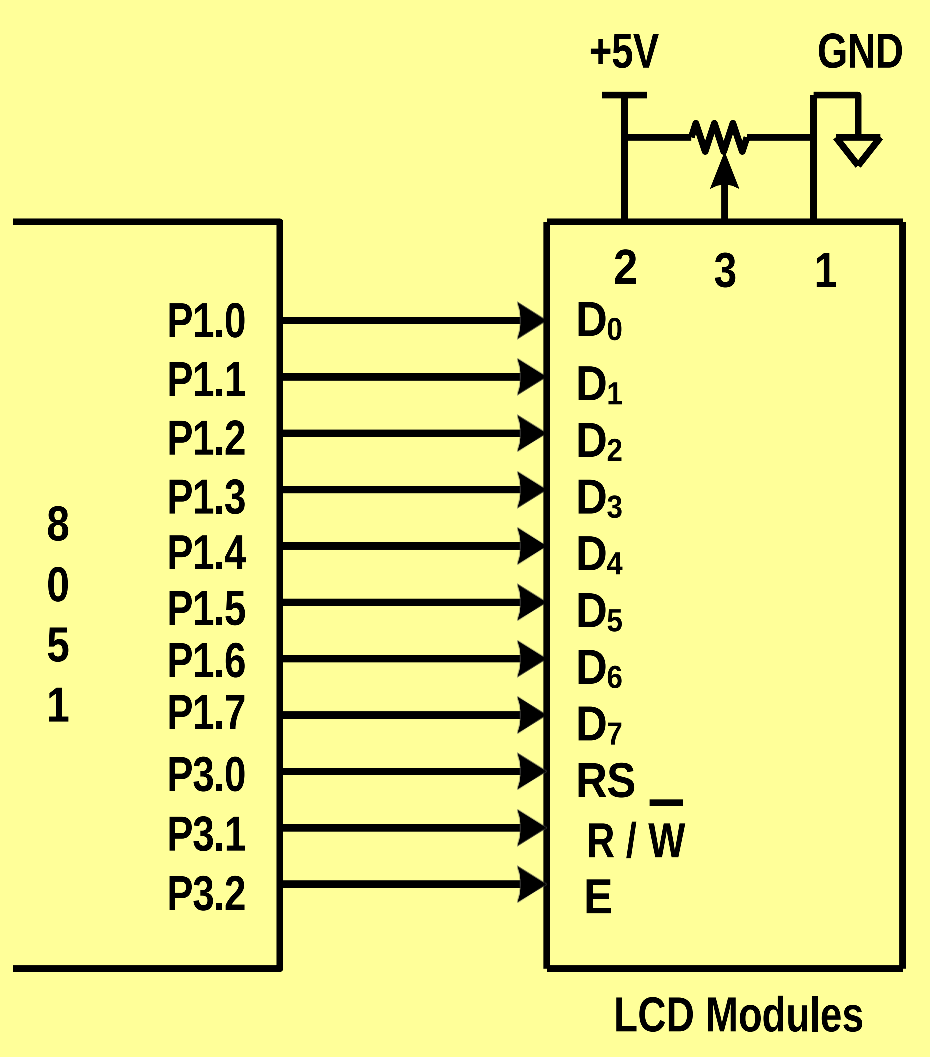


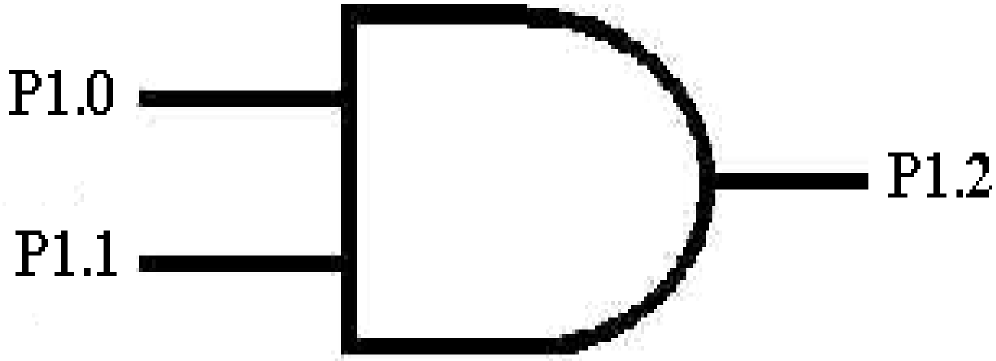
LCD Display Module

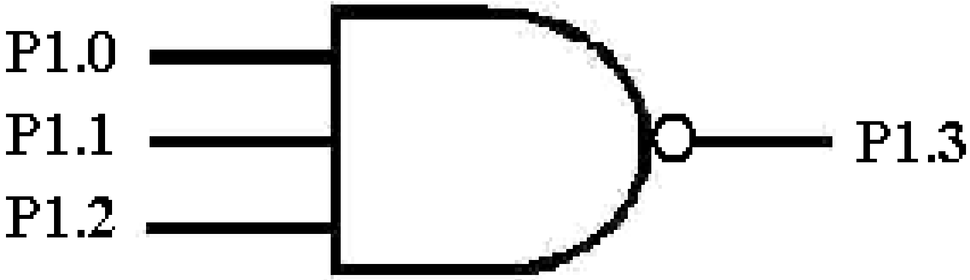
- **LCD modules:**
  - **An LCD panel and small circuit board containing the controller chip**
  - **14 – pin connections to microcontroller**
  - **HITACHI'S HD44780 controller can control up to 80 characters**
  - **Easy to program**
  - **2 rows, 20/40 character in each row**
  - **Each character can be 5X8 or 5X11 matrix**

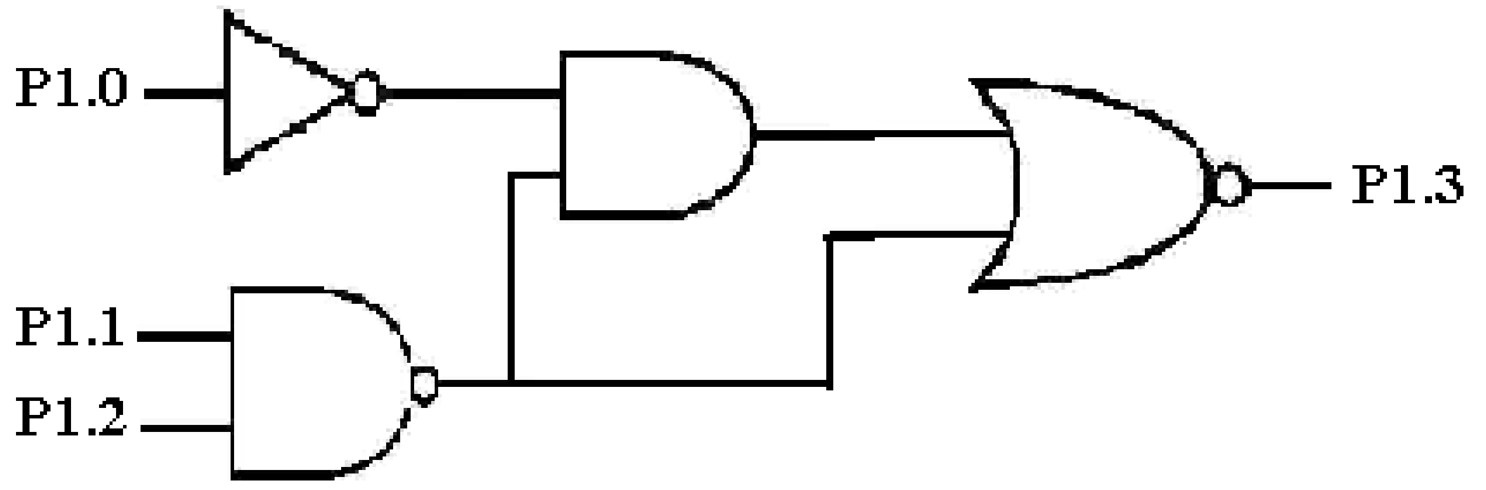
LCD Display Module

- CG ROM stores segment pattern of 192 char.
- CG RAM stores segment patterns of 16 user-designed char.
- An 8-bit instruction reg.
- An 8-bit data reg.
- DD RAM stores up to 80 8-bit char. Codes
- 11 instructions clear display, return home




P1.0
P1.1
P1.2


P1.0
P1.1
P1.2
P1.3


P1.0
P1.1
P1.2
P1.3