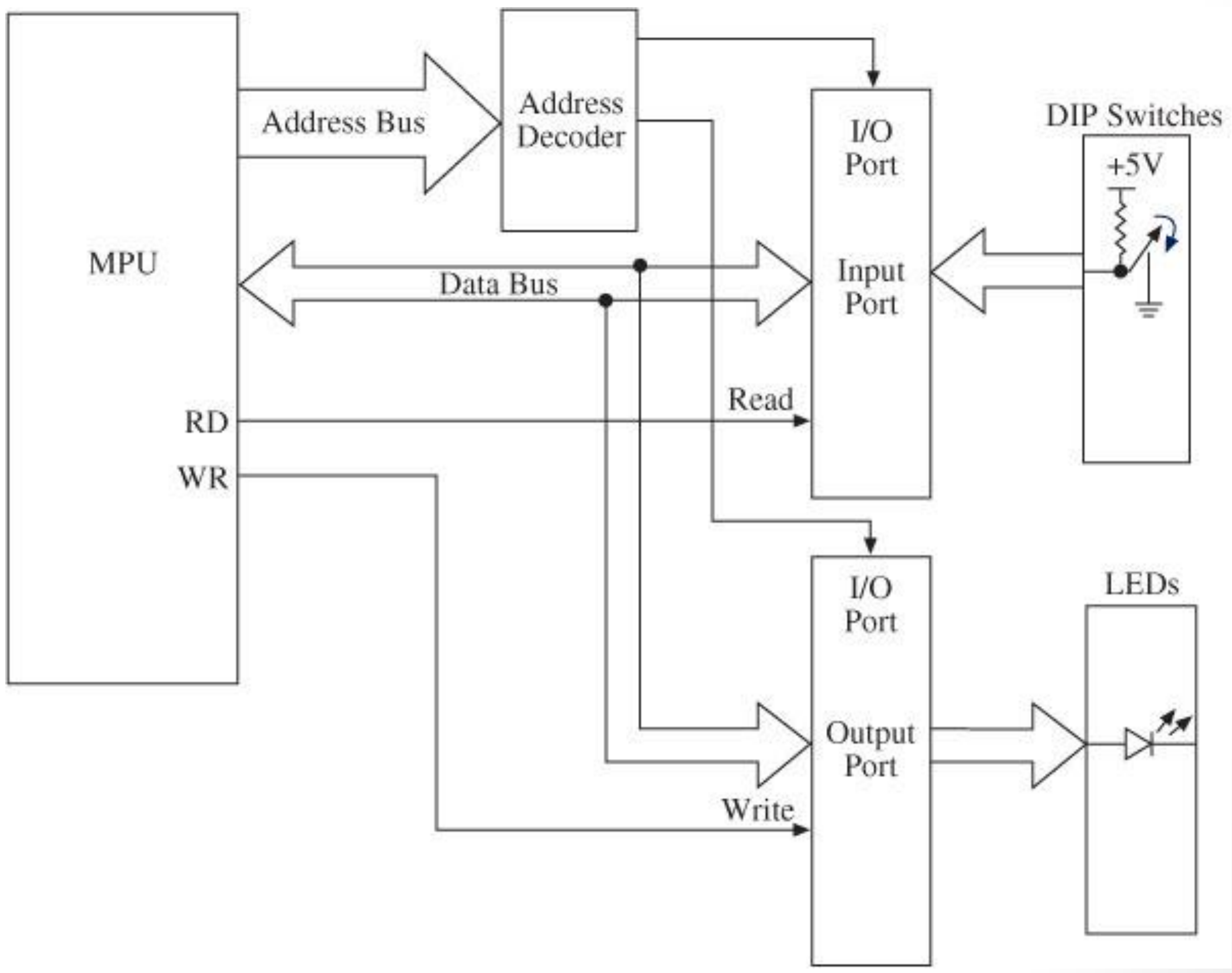
# Input/Output Ports and Interfacing LCD & Seven Segment Display

# 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



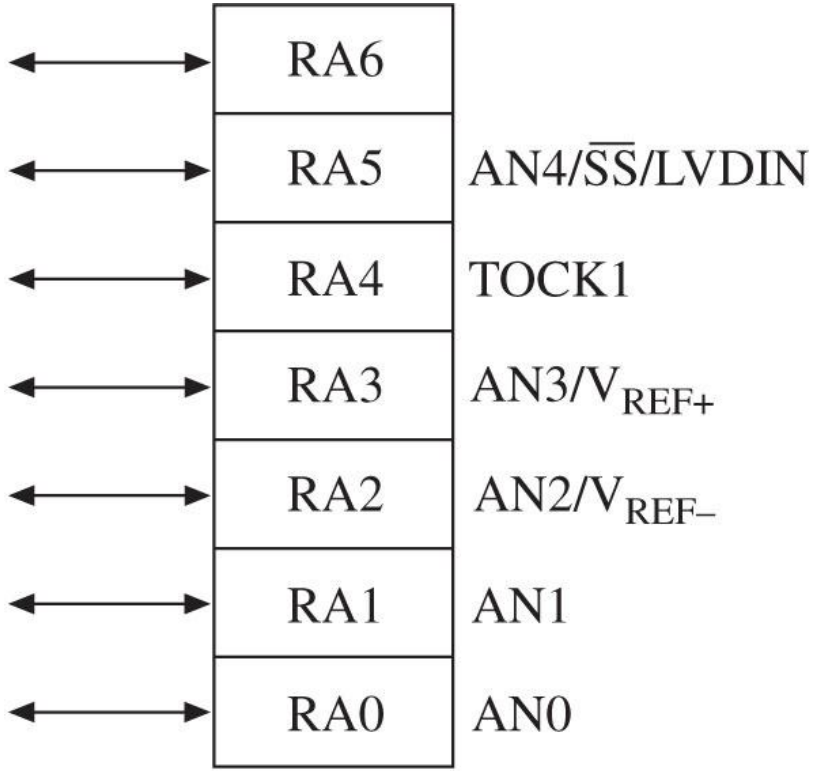
# Interfacing and Addressing

- 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

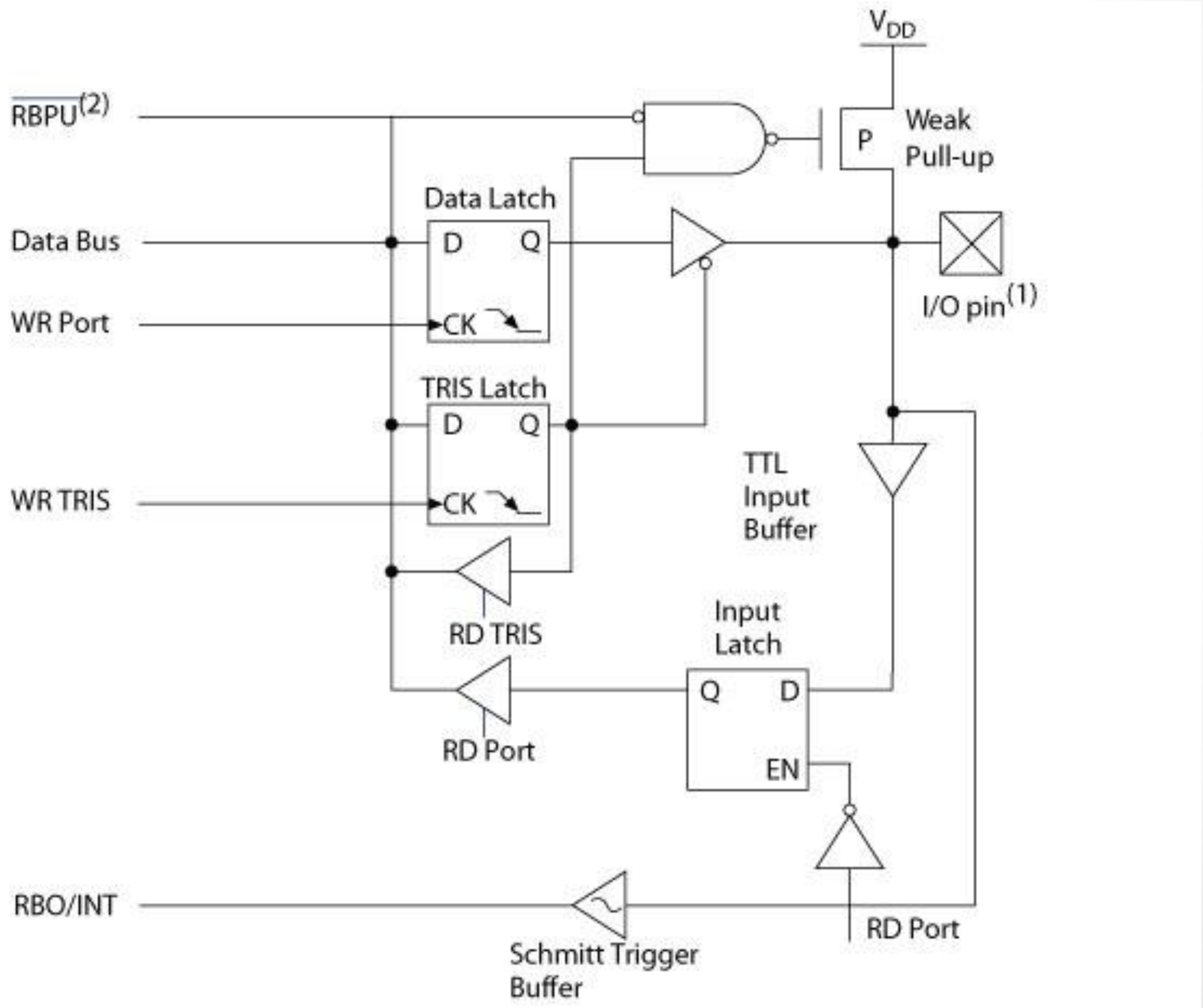



PORTA: Example of Multiple Fns

- 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

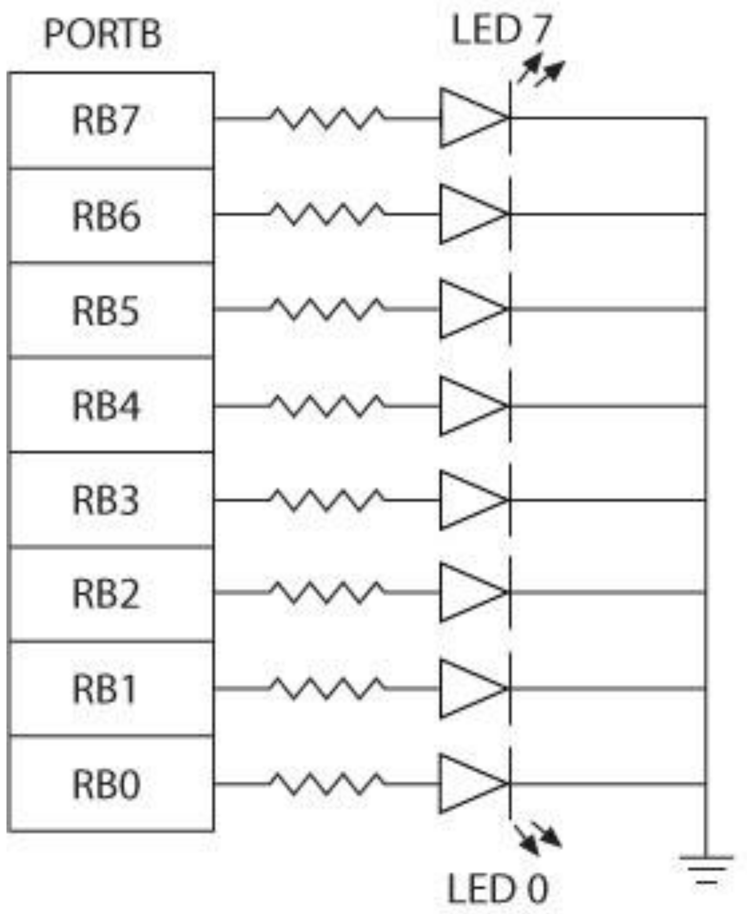
- Write instructions to set up pins RB7-RB4 of PORTB as inputs and pins RB3-RB0 as outputs

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

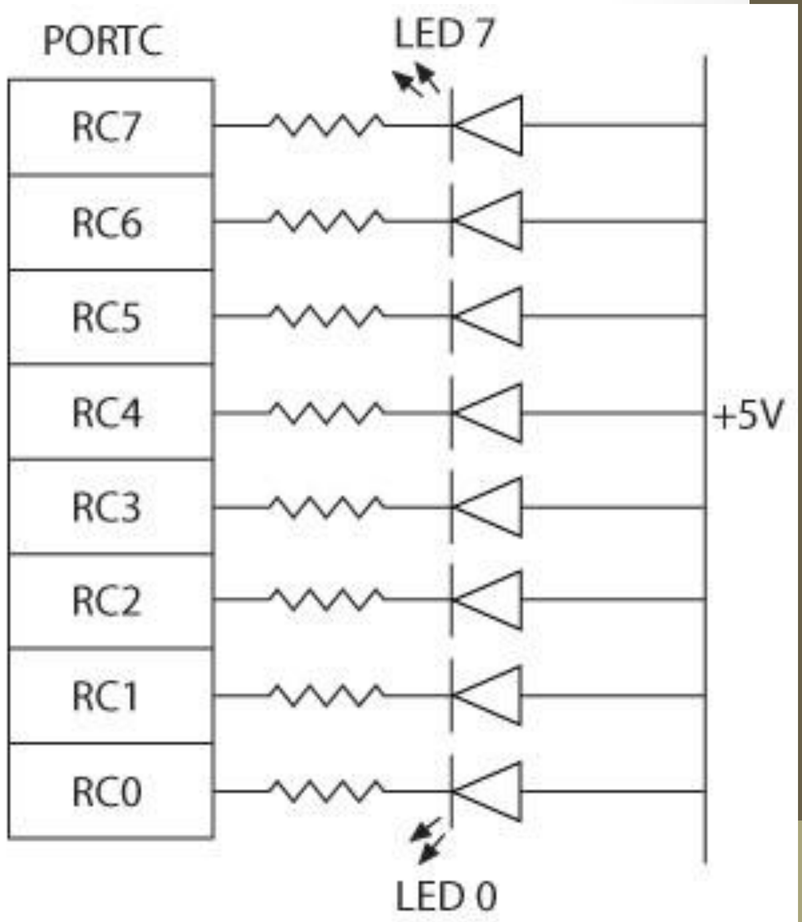
# Interfacing Output Peripherals

- 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



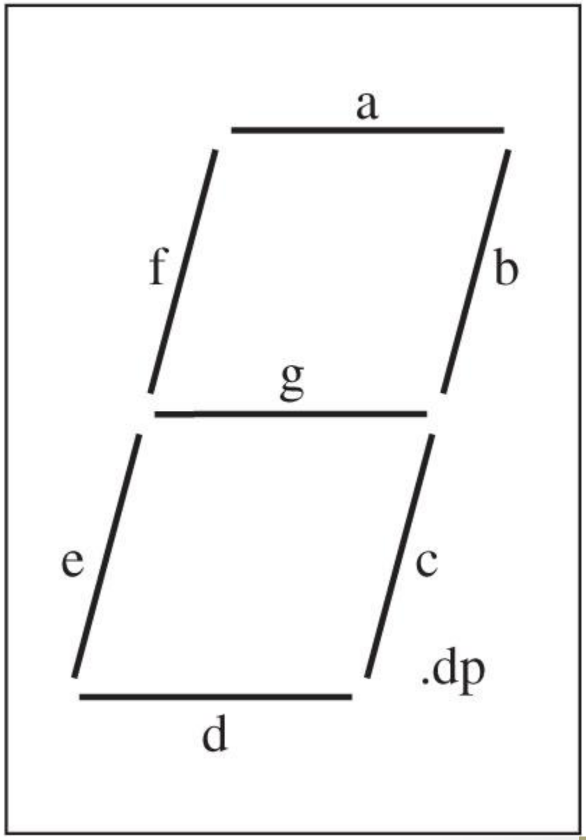

Common Cathode




Common Anode

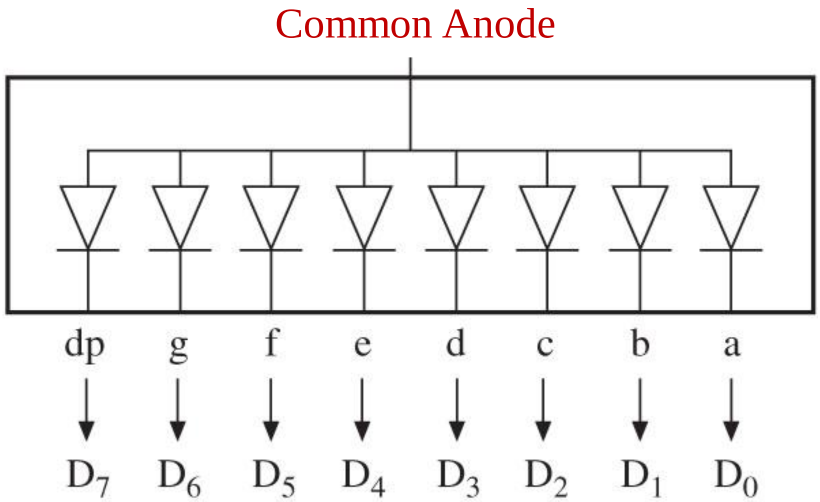
# Seven-Segment Display

- 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



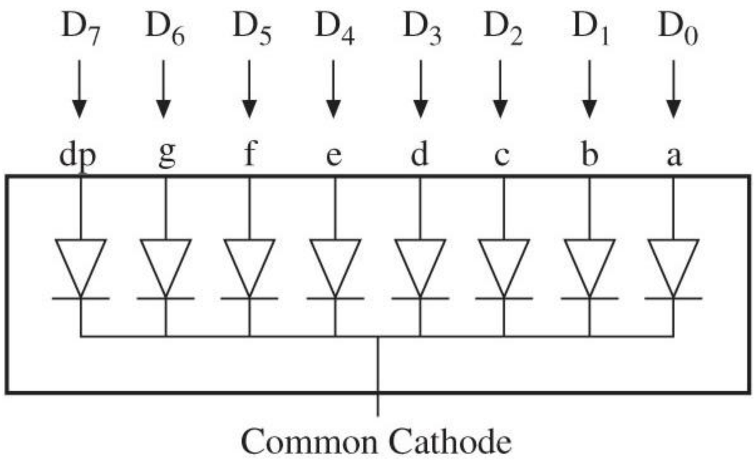
# Seven-Segment Display

- 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 = $06_H$



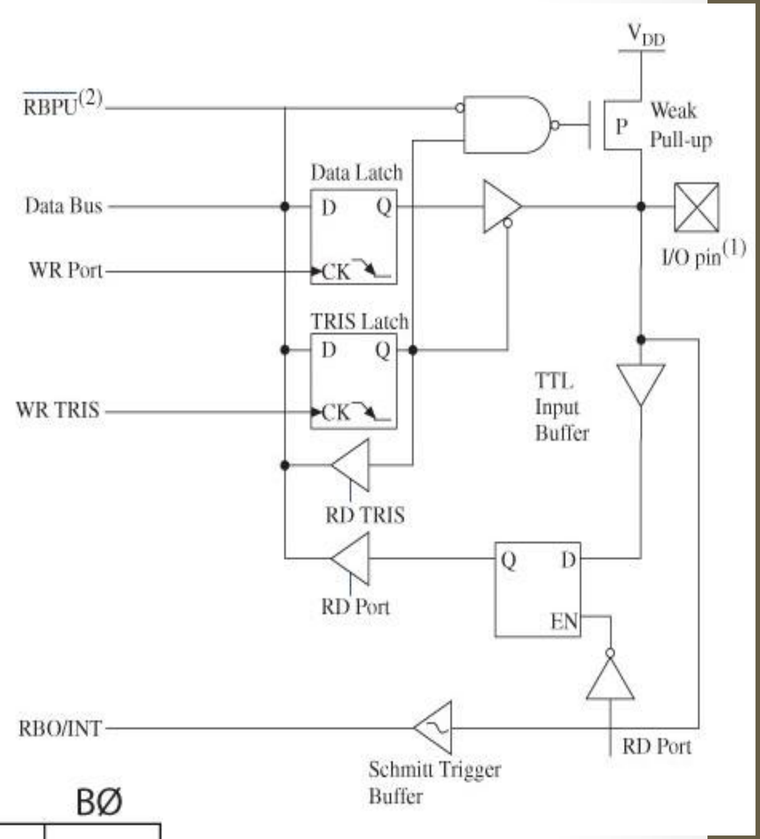
# Reading from an I/O Port

- 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

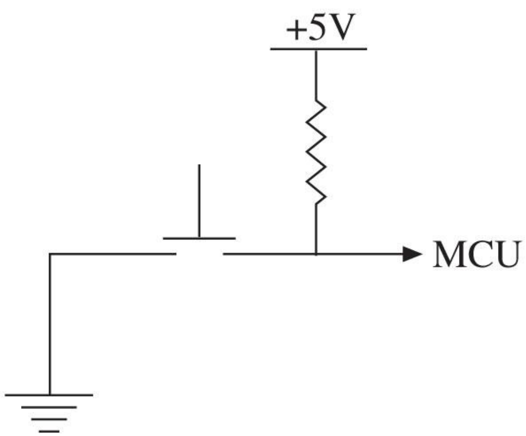


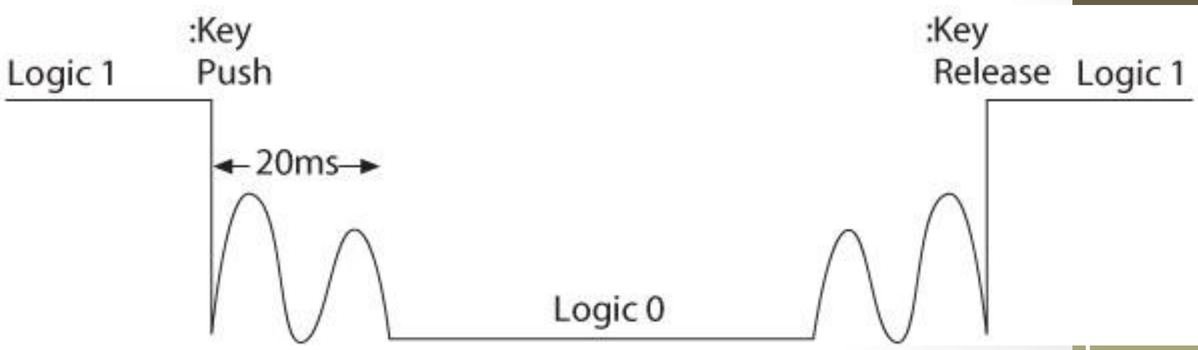

| B7 | B6 | B5 | B4 | B4 | B3 | B2 | B1 | BØ |
|---|---|---|---|---|---|---|---|---|
| $\overline{\text{RBPU}}$ | | | | | | | | |

$\overline{\text{RBPU}}$ = 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



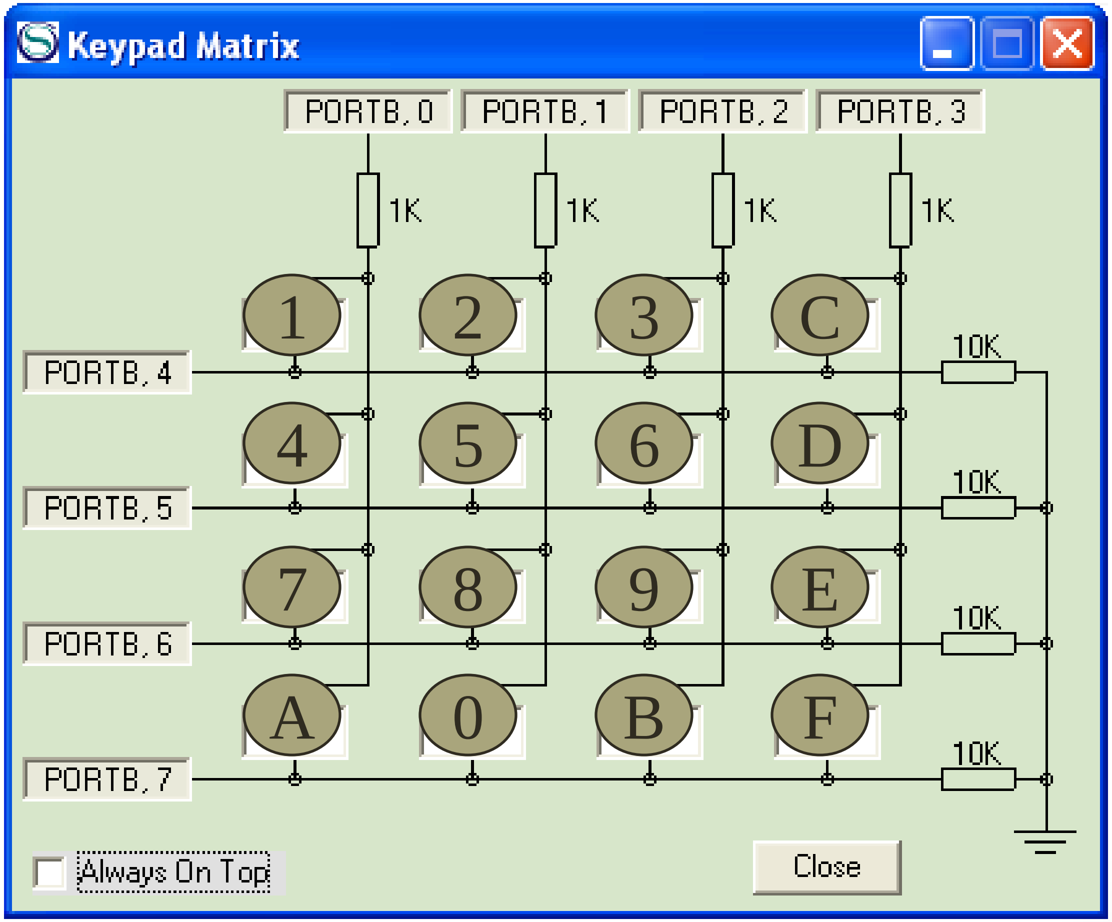



# Interfacing a Matrix Keypad

- 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

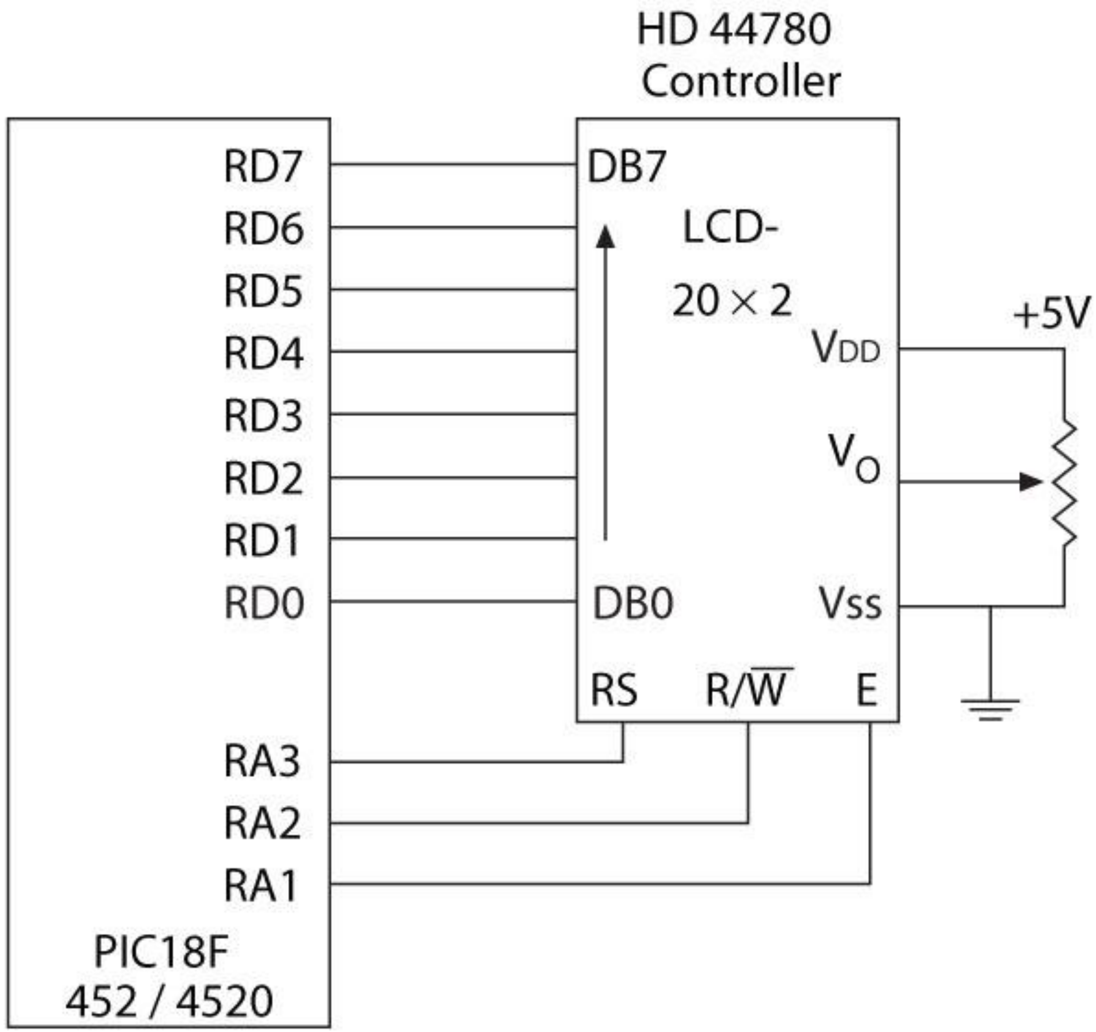
# Interfacing LCD

- 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

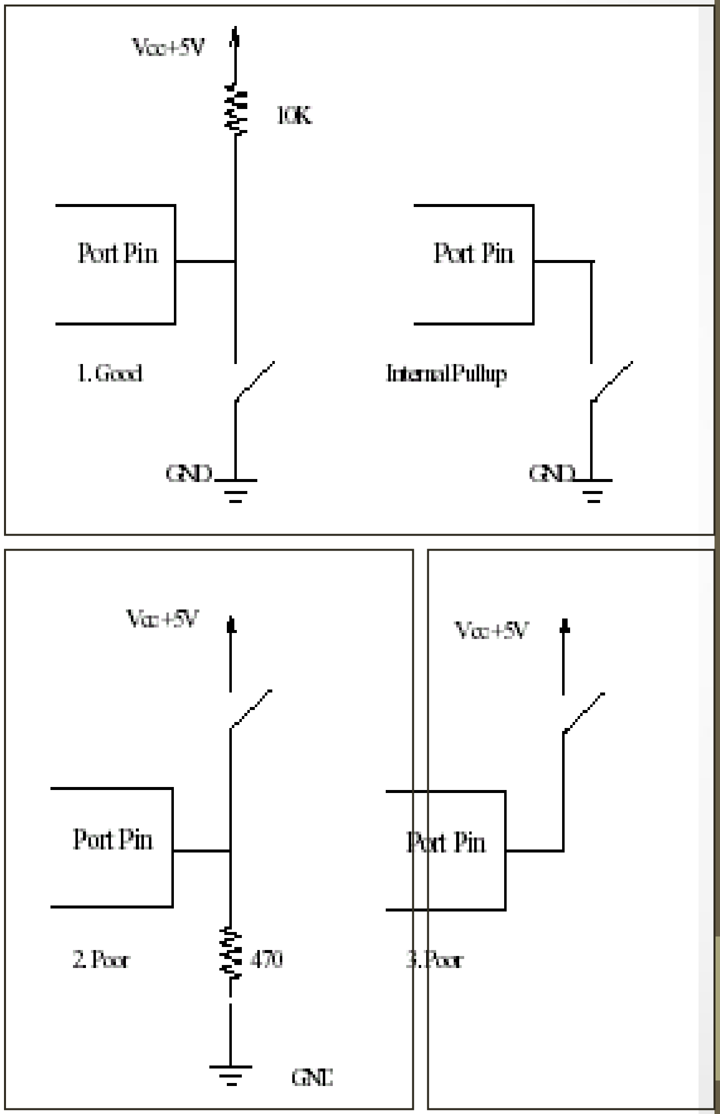
# Synchronization of CPU and interface chip

- 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

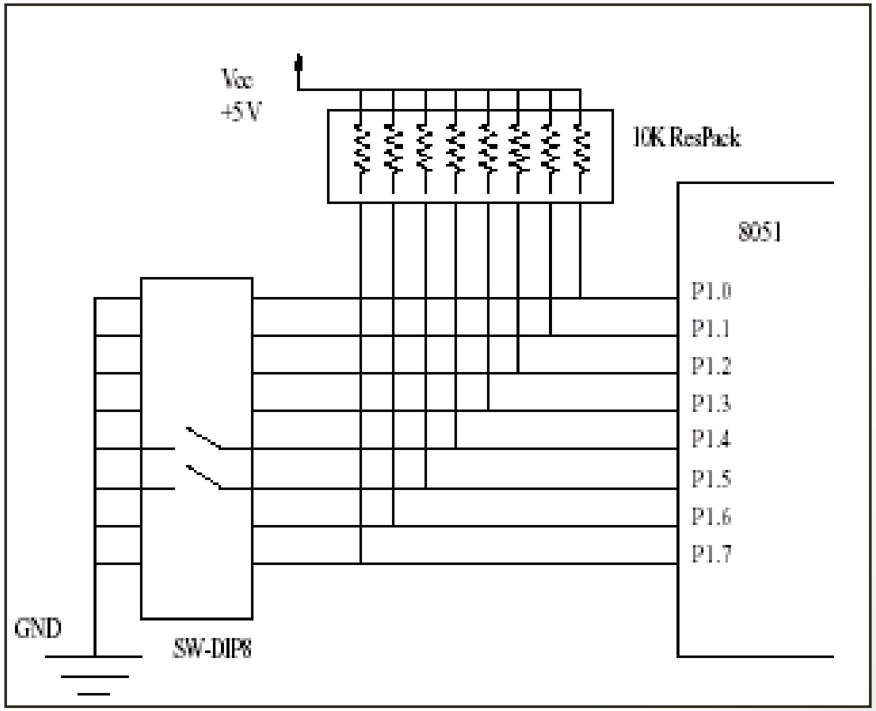
- Case-1:
  - Gives a logic 0 on switch close
  - Current is 0.5ma on switch close
- Case-2:
  - Gives a logic 1 on switch close
  - High current on switch close
- Case-3:
  - Can damage port if 0 is output



# Simple input devices

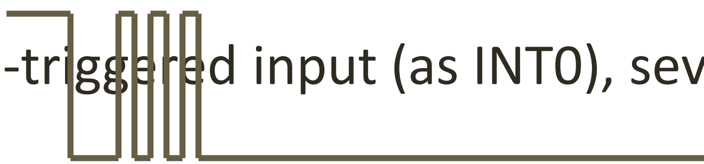
- DIP switches usually have 8 switches
- Use the case-1 from previous page
- Sequence of instructions to read is:

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



# Bouncing contacts

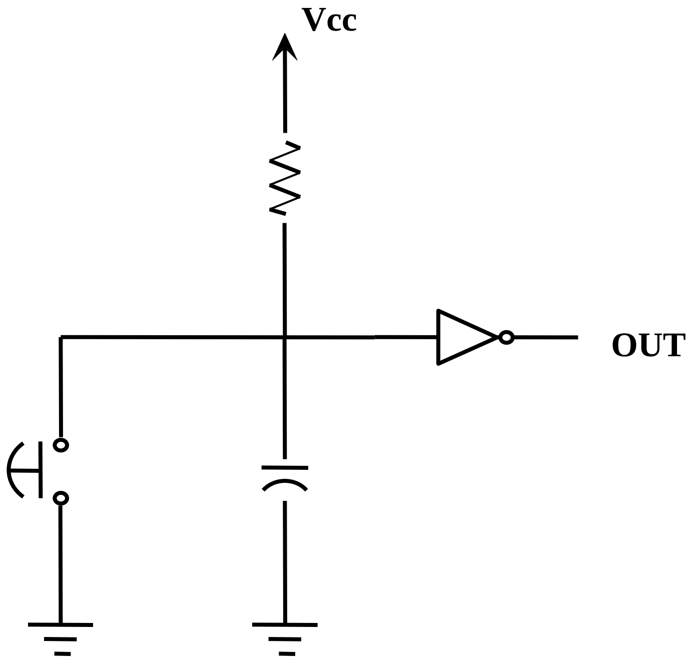
- Contact:
  - Push-button switches
  - Toggle switches
  - Electromechanical relays
- Make and break Contact normally open switch
- The effect is called "contact bounce" or, in a switch, "switch bounce”.



- 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

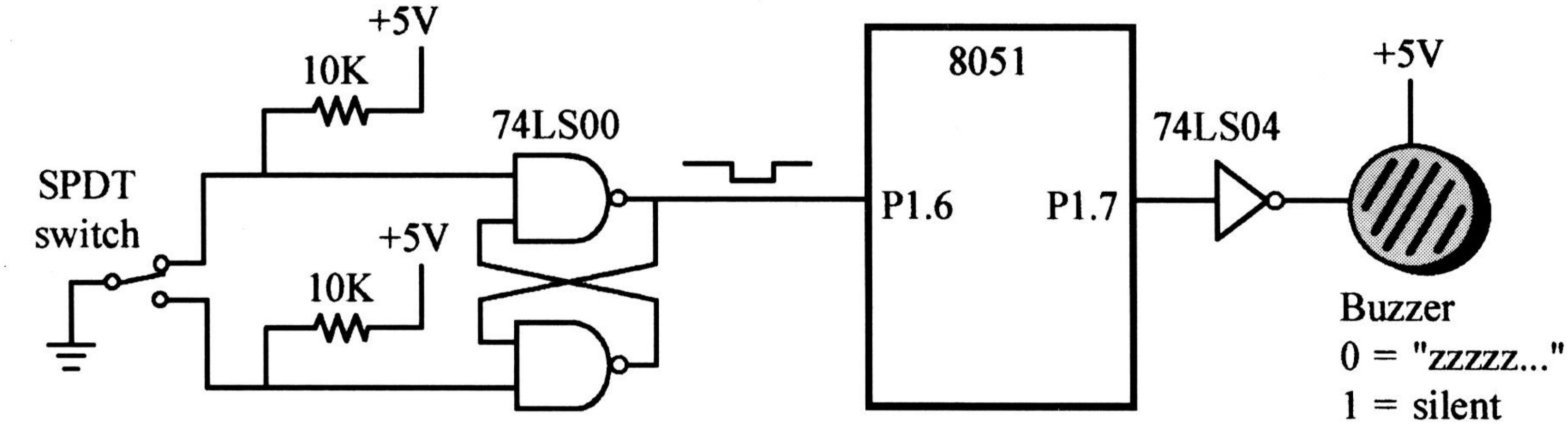



**FIGURE 4–7**
Buzzer example

# Software Solution

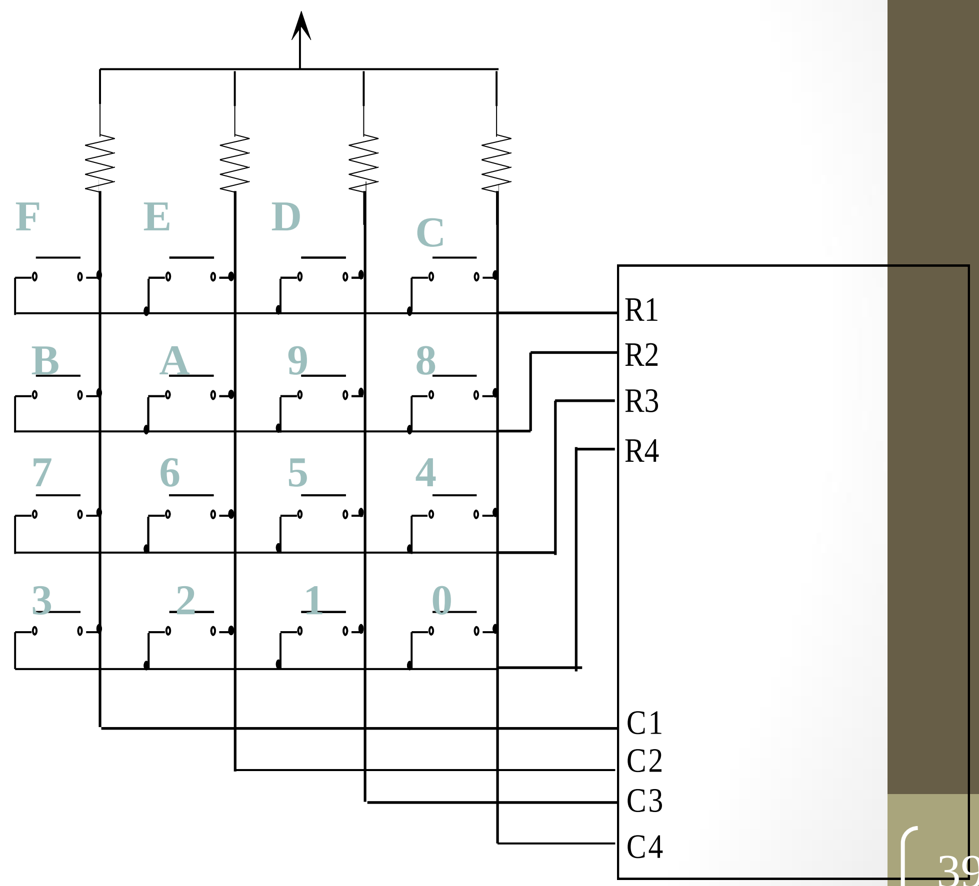
- Read the new state of switch N time

- 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

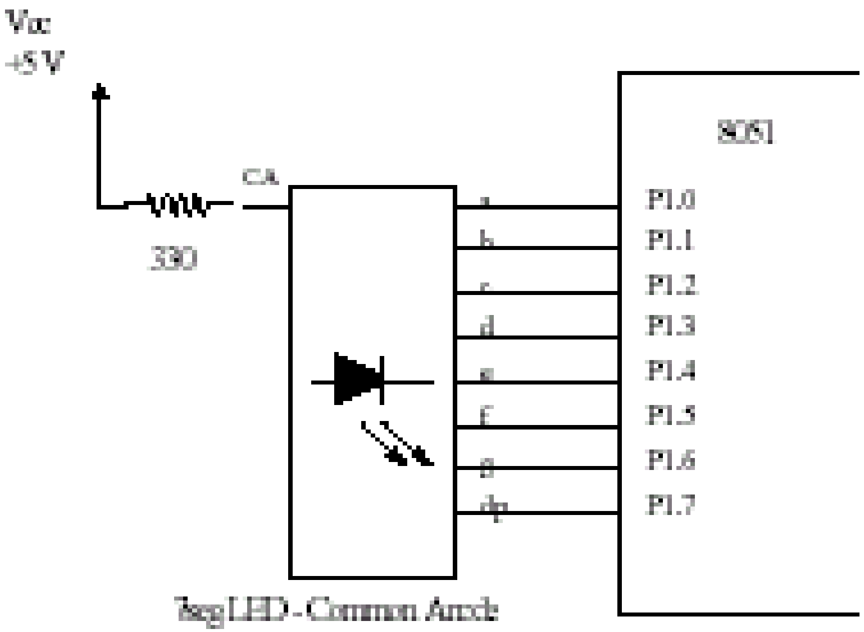
16 keys arranged as a 4X4 matrix

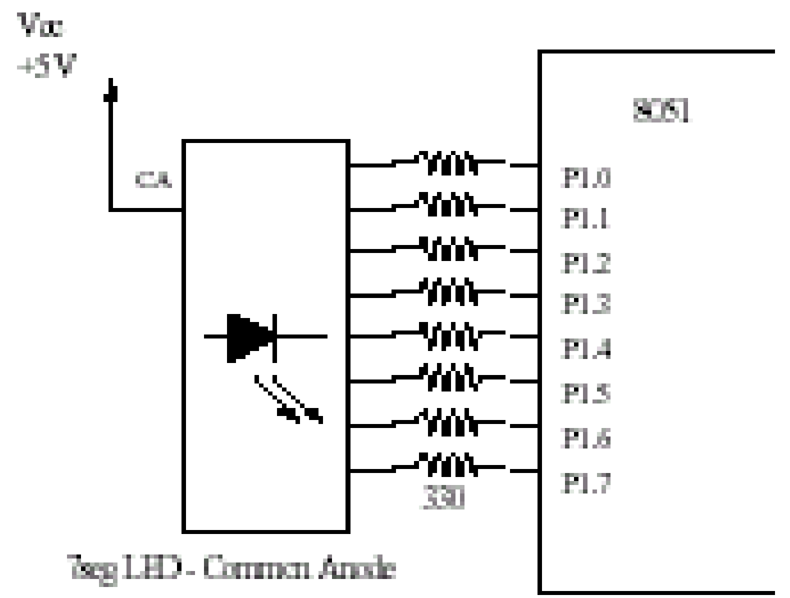
- Place a 0 on R0 port
- Read C port
- If there is a 0 bit then the button at the column/row intersection has been pressed.
- Otherwise, try next row
- Repeat constantly



# 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

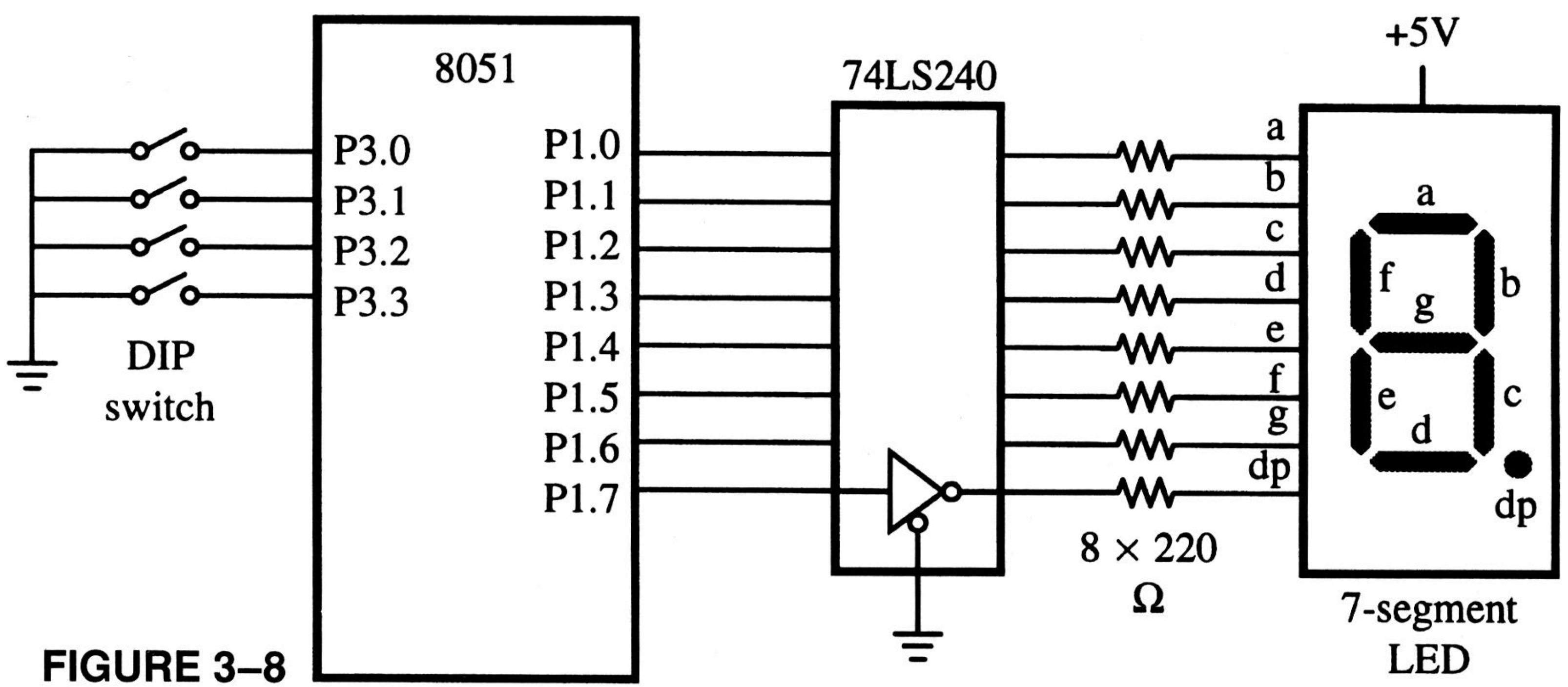
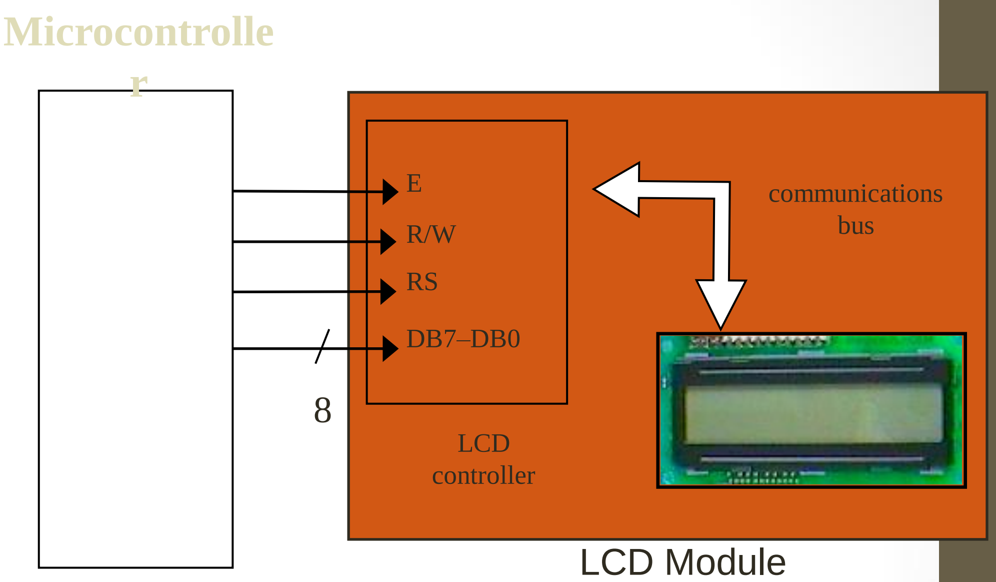



**FIGURE 3–8**
Interface to a DIP switch and 7-segment LED

# 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 | " " |

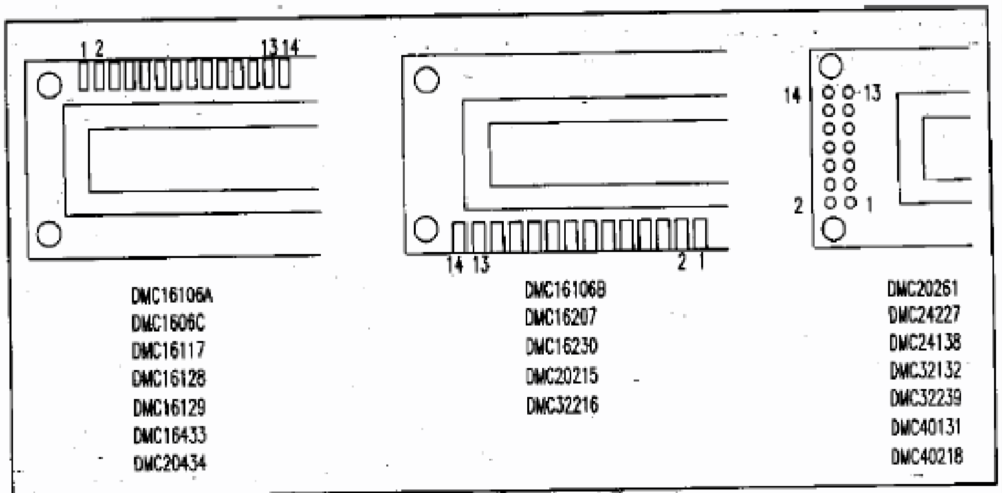



Figure 4-34. Pin Positions for Various LCDs from Optrex

# 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
```

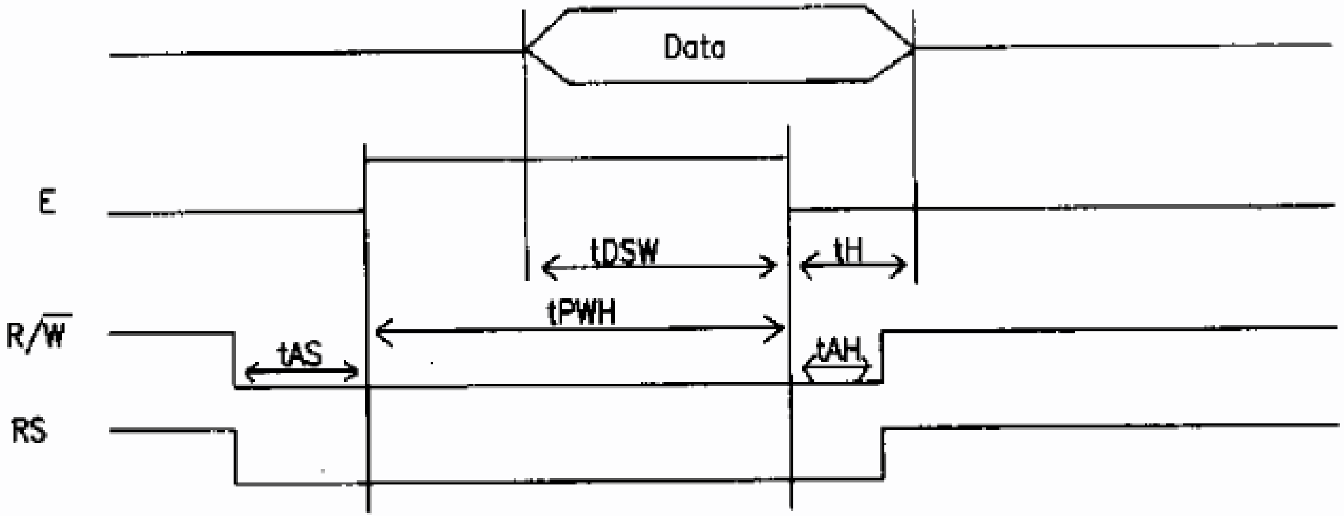
*Note*: All data is in hex.

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



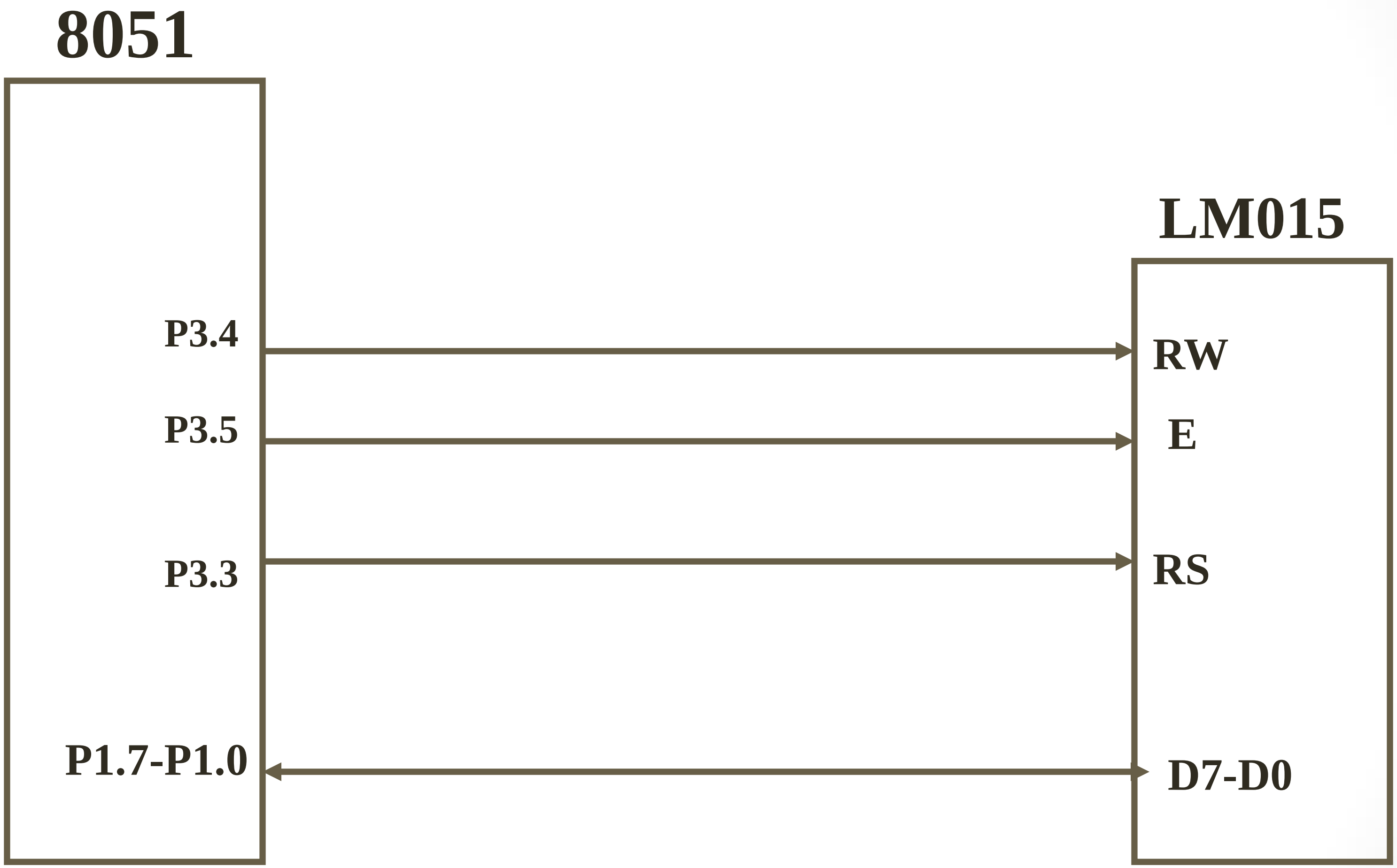

tPWH = Enable pulse width = 450 ns (minimum)
tDSW = Data set up time = 195 ns (minimum)
tH = Data hold time = 10 ns (minimum)
tAS = Set up time prior to E (going high) for both RS and R/W = 140 ns (minimum)
tAH = Hold time after E has come down for both RS and R/W = 10 ns (minimum)

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 | 1/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

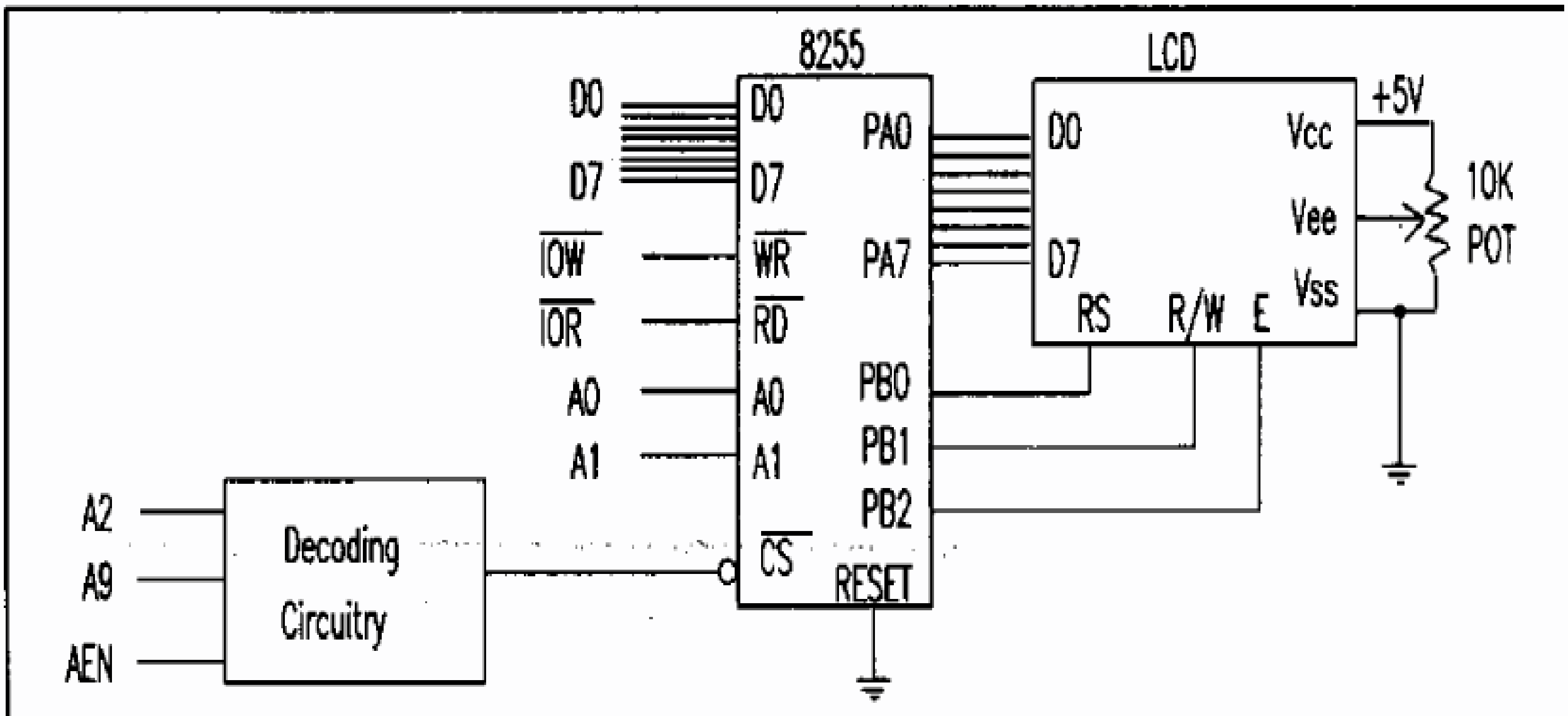



Figure 4-35. 8255-to-PC Interface Connection to LCD

# 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<br>Used by arithmetic and conditional branch instruction. |
| AC | Auxiliary Carry Flag<br>Used by instructions which execute BCD operations. |
| F0 | General Purpose Flag |
| RS1<br>RS0 | Register Bank select control bits<br>These bits are used to select one of the four register banks. |
| OV | Overflow Flag<br>Used by arithmetic instruction. |
| F1 | General Purpose Flag |
| P | Parity Flag<br>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,#38H
ADD A,#2FH

```
  38          00111000
 +2F         +00101111
 ----         --------------
  67          01100111
CY=0   AC=1   P=1
```

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

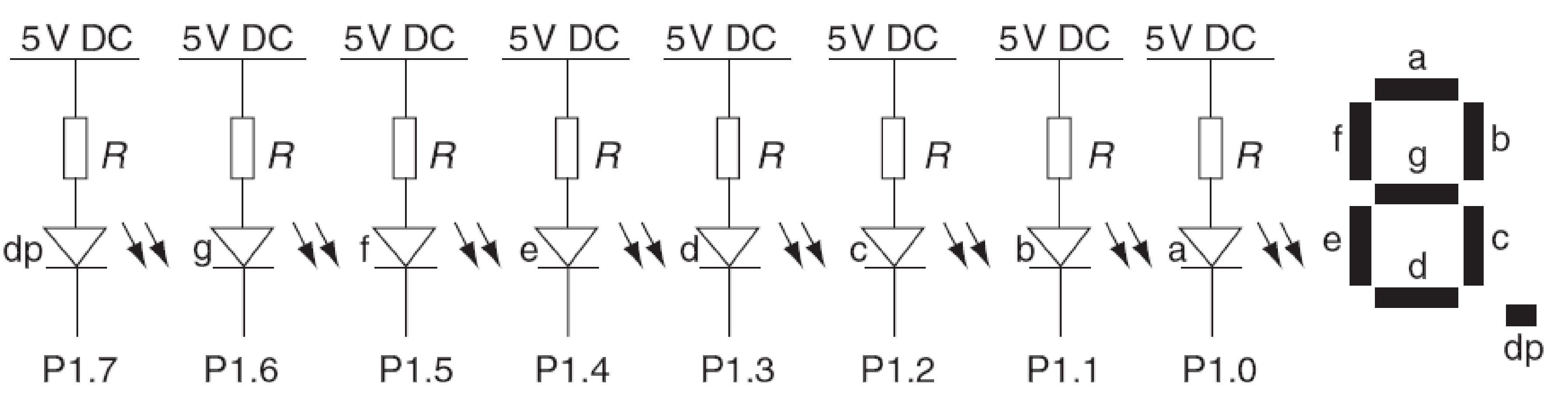
```
MOV    A,#65H
MOV    A,#'A'
MOV    R6,#65H
MOV    DPTR,#2343H
MOV    P1,#65H
```

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:

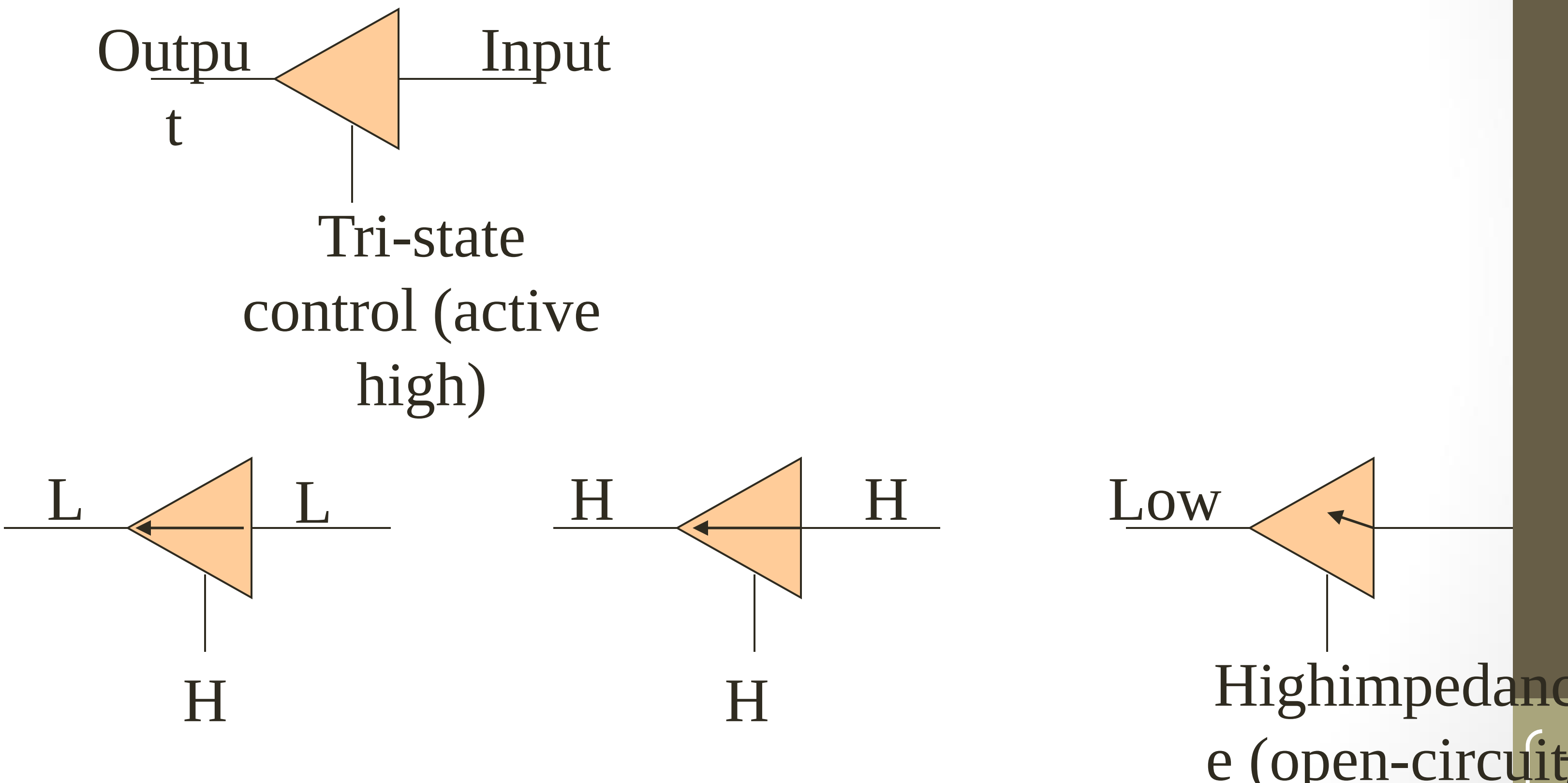
```
    MOV   R0,37h          ; source pointer
    MOV   R1,59h          ; dest pointer
    MOV   R2,10           ; counter
L1: MOV   A,@R0
    MOV   @R1,A
    INC   R0
    INC   R1
    DJNZ  R2,L1
```

jump

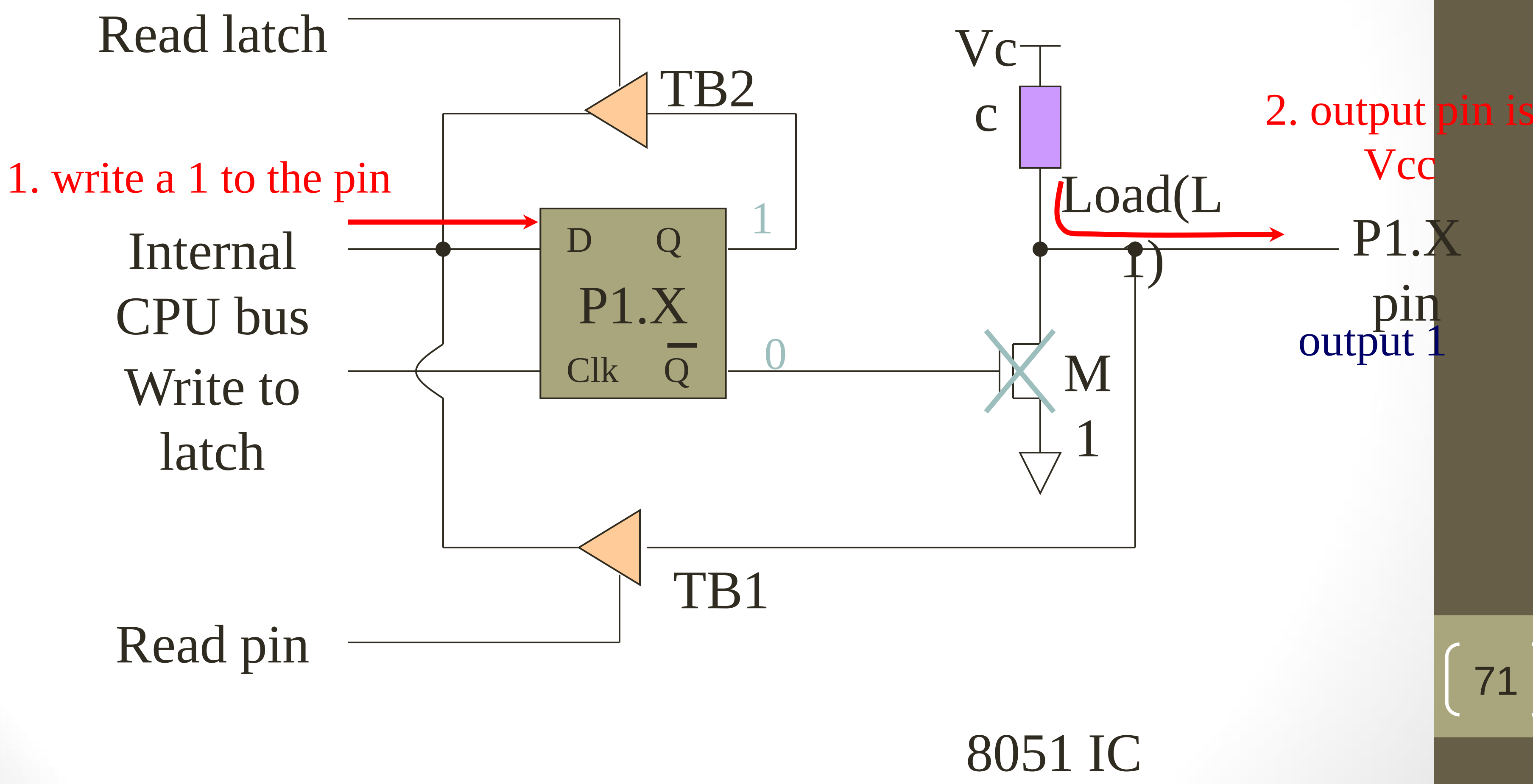
# Hardware Structure of I/O Pin

- 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

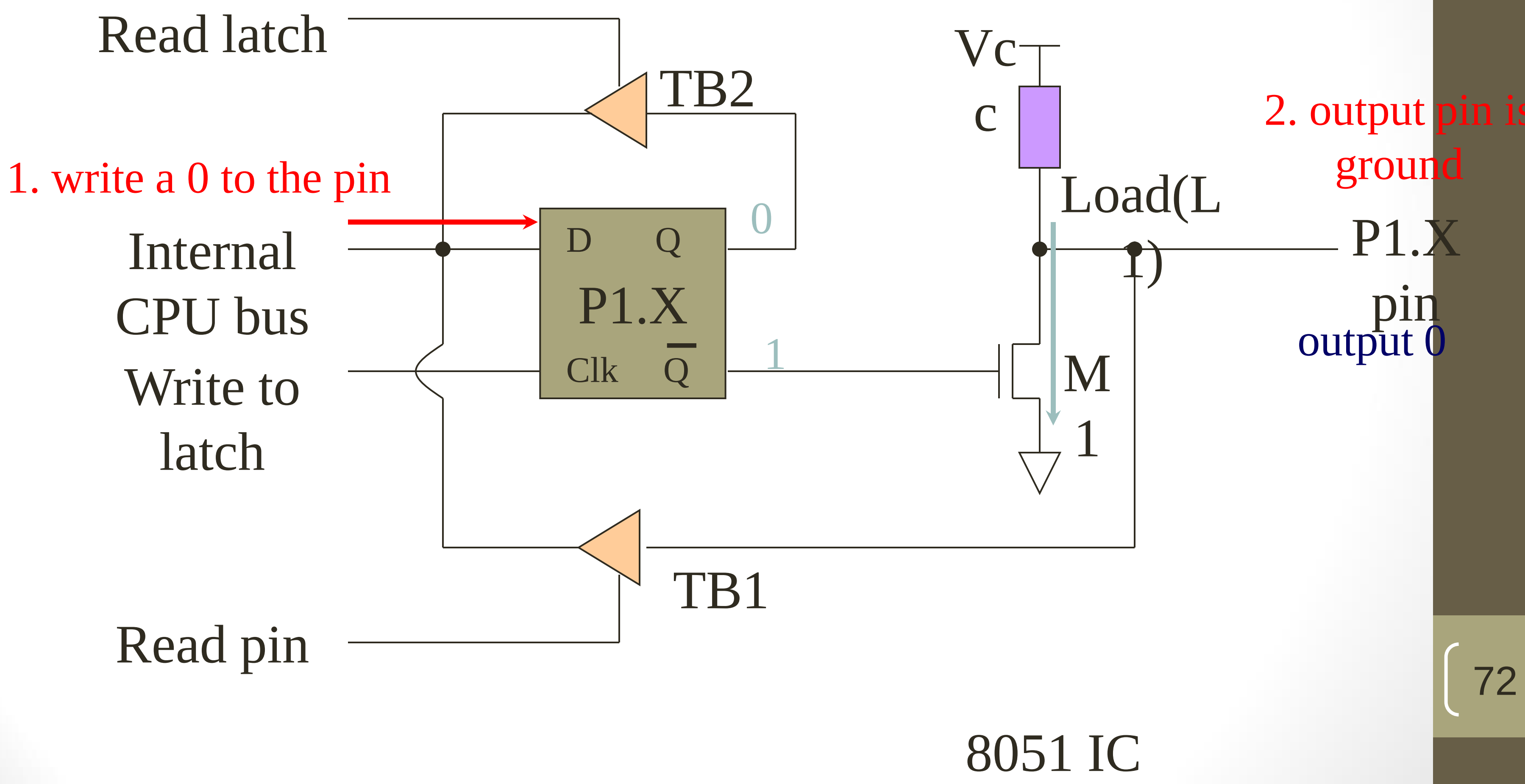
# Tri-state Buffer



# 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：

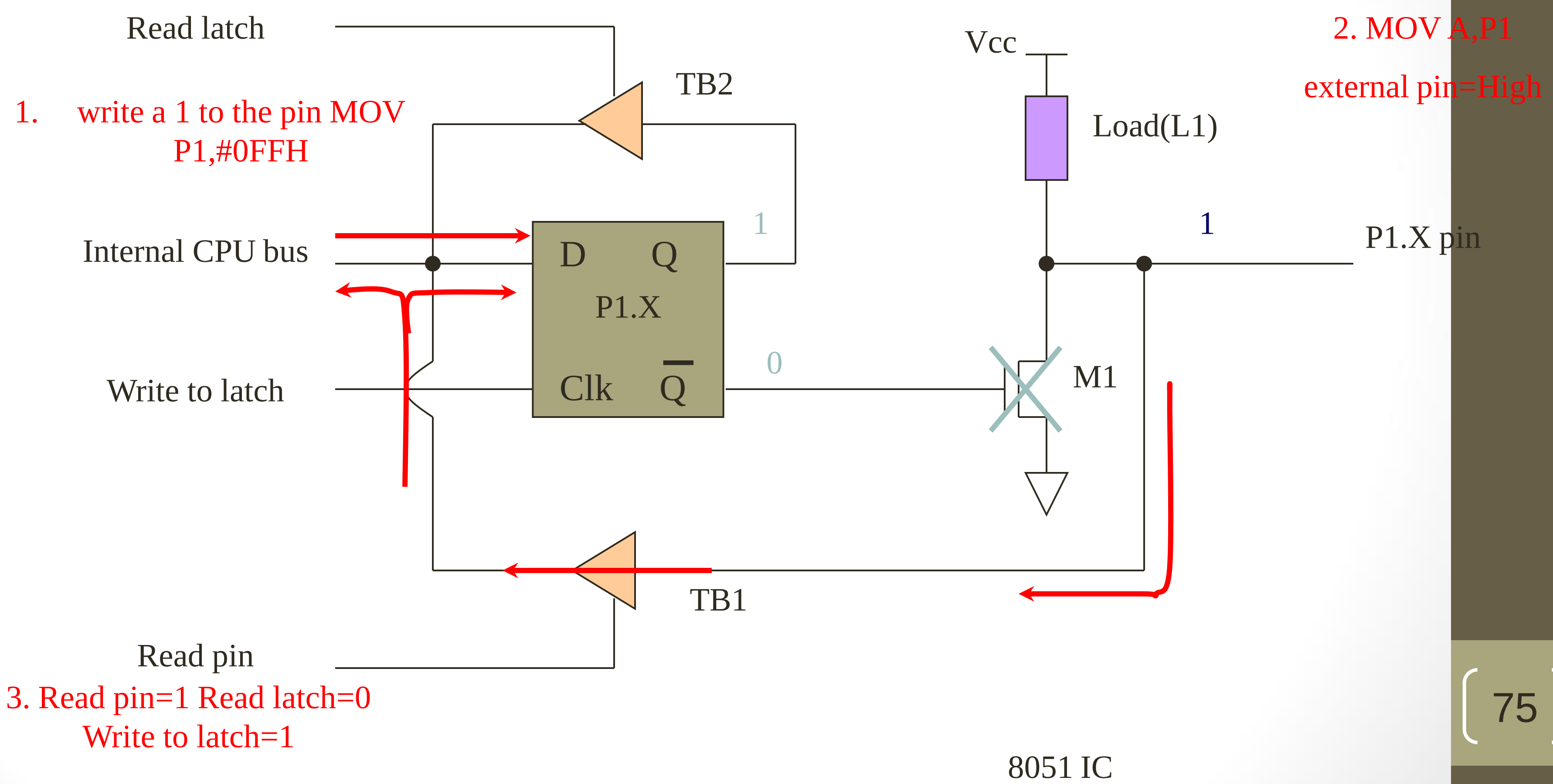
```
        MOV     A,#55H
BACK:   MOV     P1,A
        ACALL   DELAY
        CPL  A
        SJMP  BACK
```

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

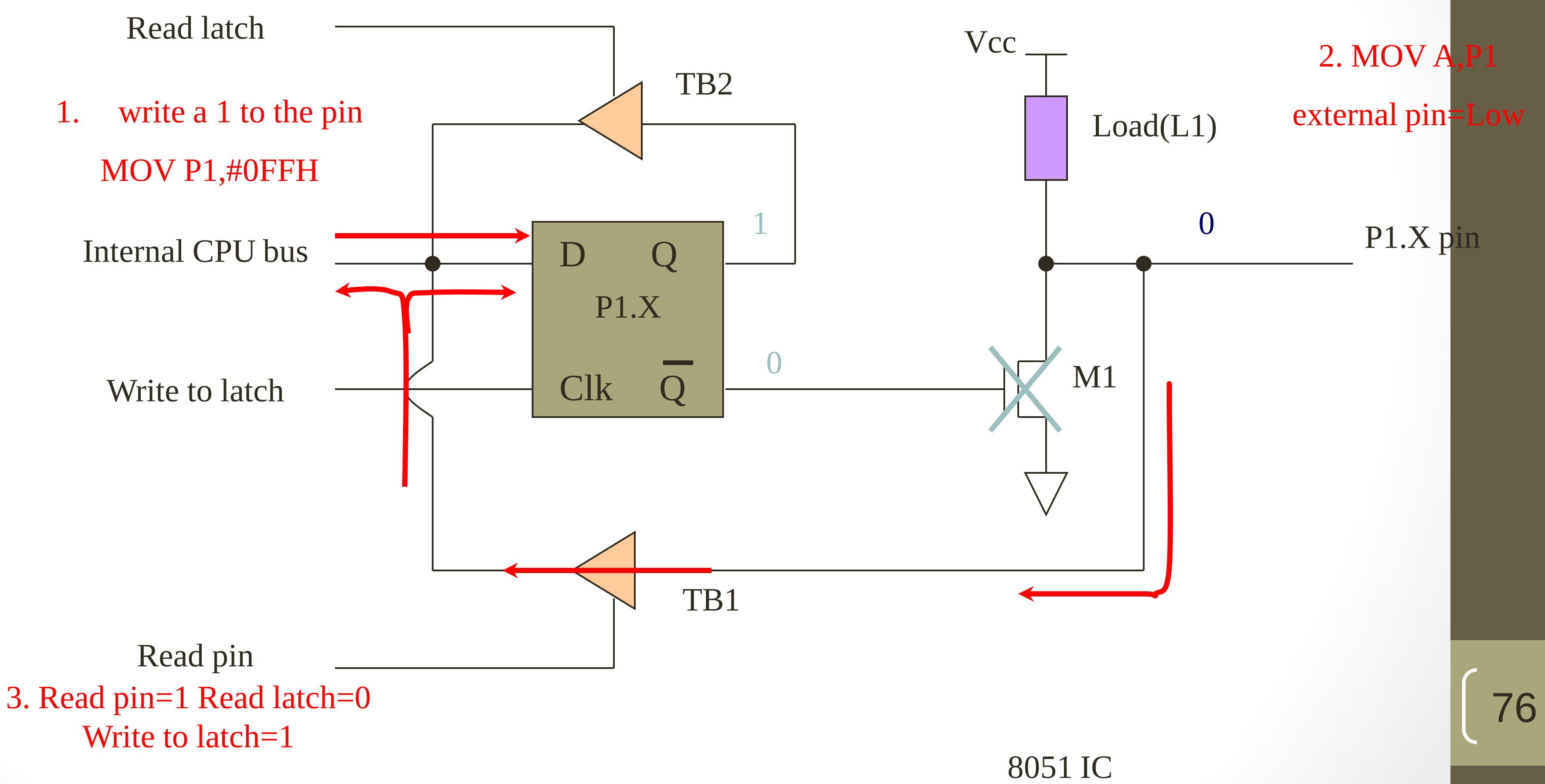
# Reading Input v.s. Port Latch

- 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.

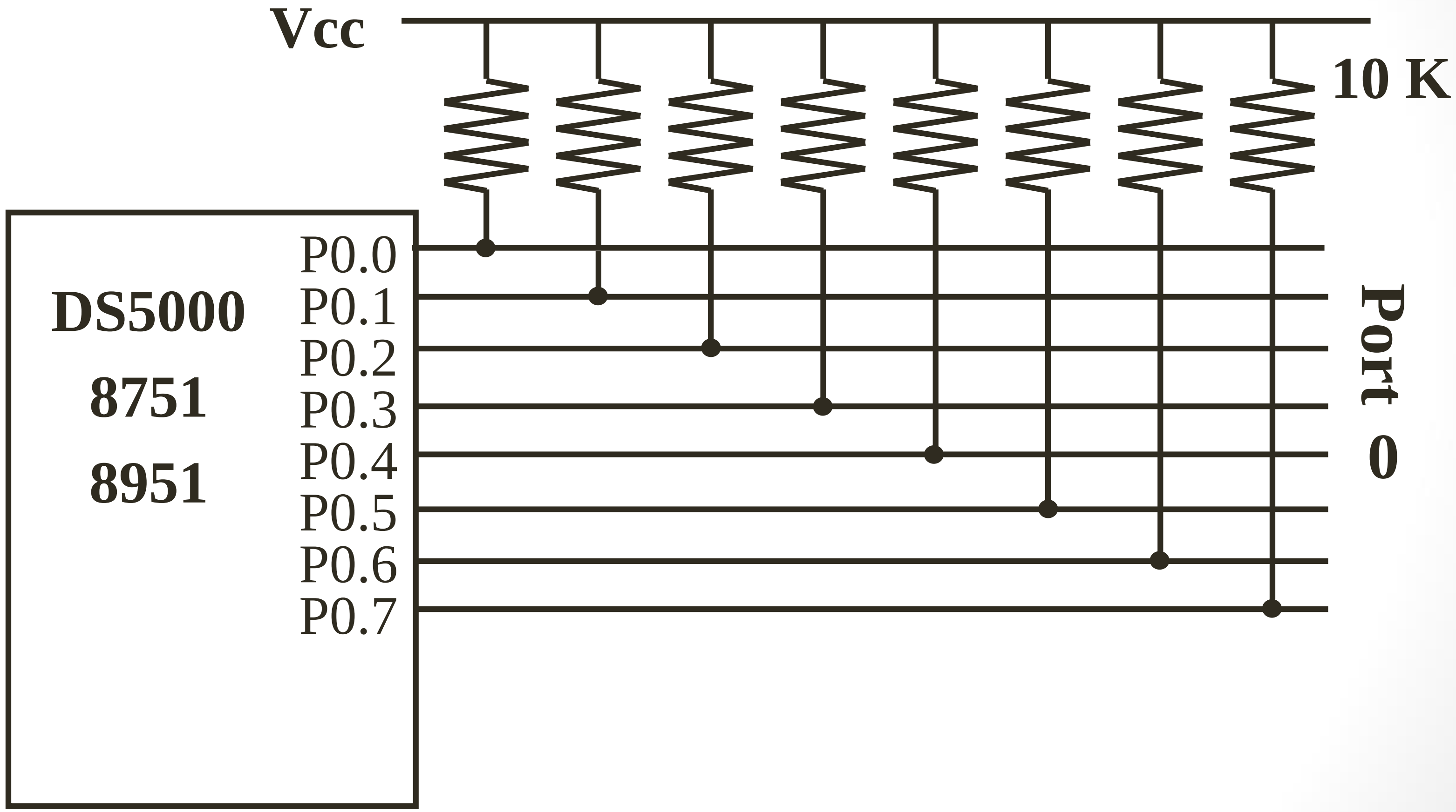
# Port 1 as Input（Read from latch）

- 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*

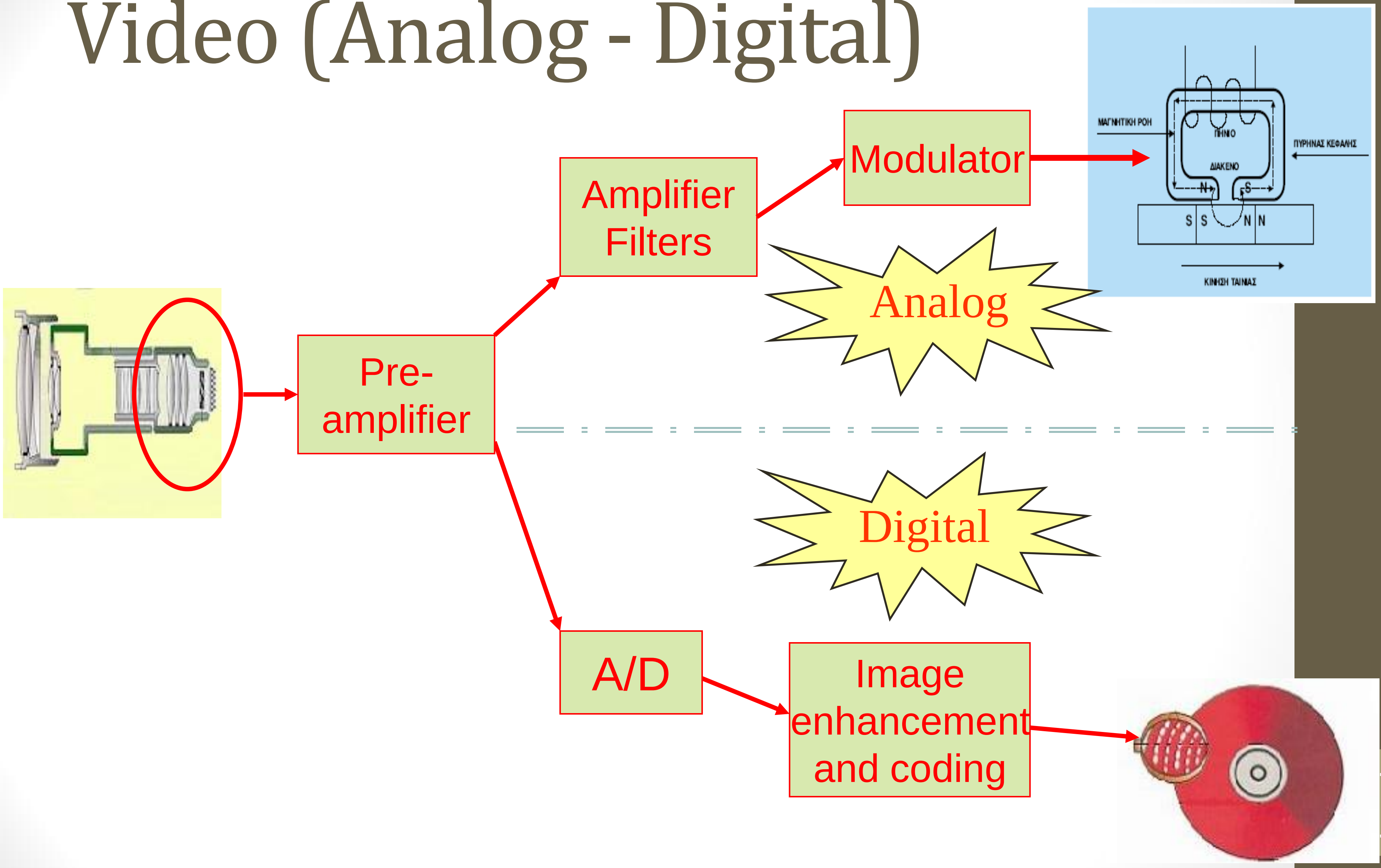
- **Interrupt:**
  Description: defines interrupt service routine
  void External_Int0() interrupt 0{
  *//code*
  }

# Data Converters

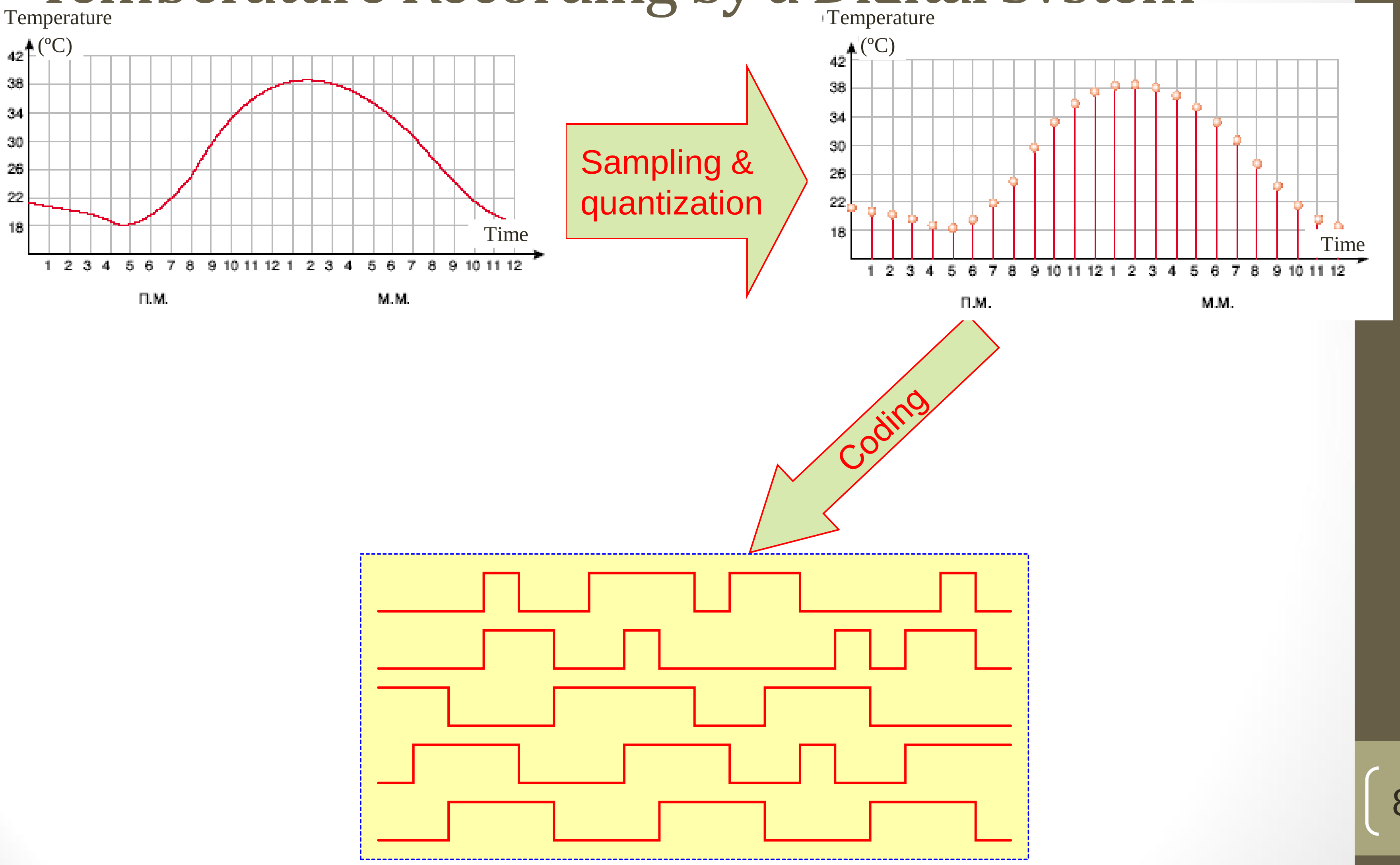
- Analog to Digital Converters (ADC)
  - Convert an analog quantity (voltage, current) into a digital code
- Digital to Analog Converters (DAC)
  - Convert a digital code into an analog quantity (voltage, current)

Dr. Konstantinos Tatas and Dr. Costas Kyriacou

# Video (Analog - Digital)



# Temperature Recording by a Digital System



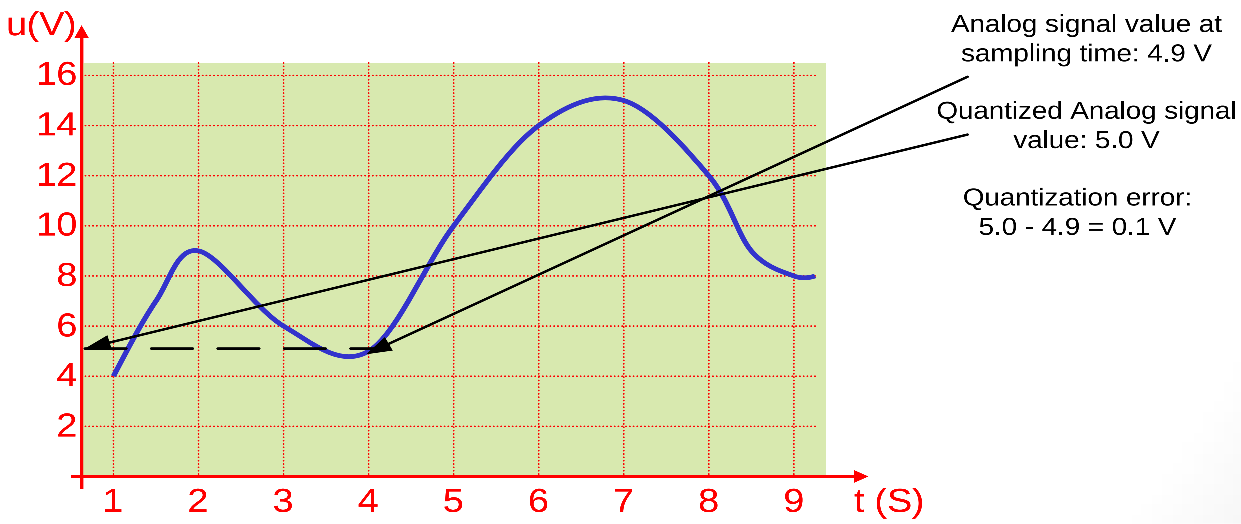
# Need for Data Converters

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

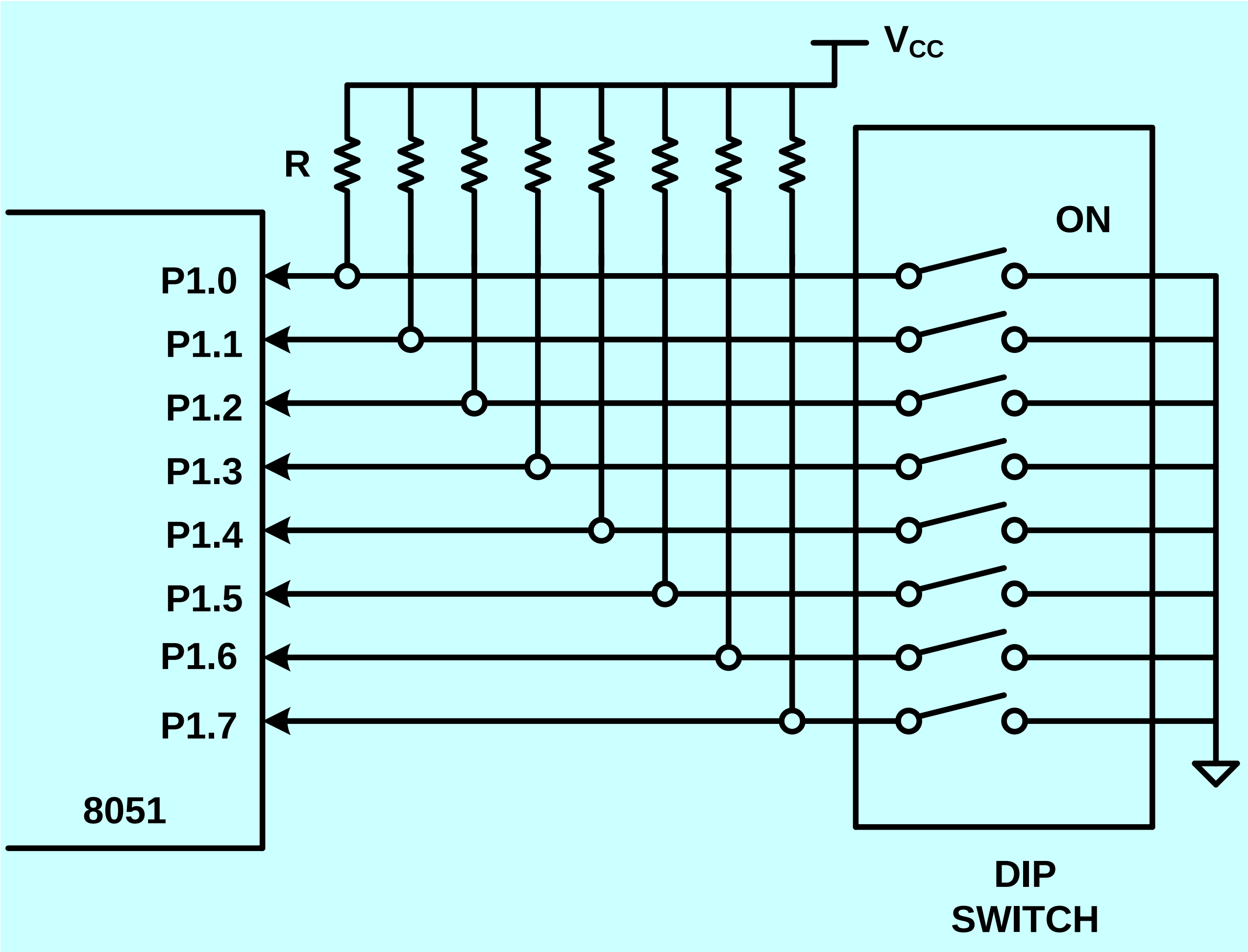
- Better and cheaper technology compared to the analog
- More reliable in terms of storage, transfer and processing
    - Not affected by noise
- Processing using programs (software)
    - Easy to change or upgrade the system
        - (e.g. Media Player 7 → Media Player 8 ή Real Player)
    - Integration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



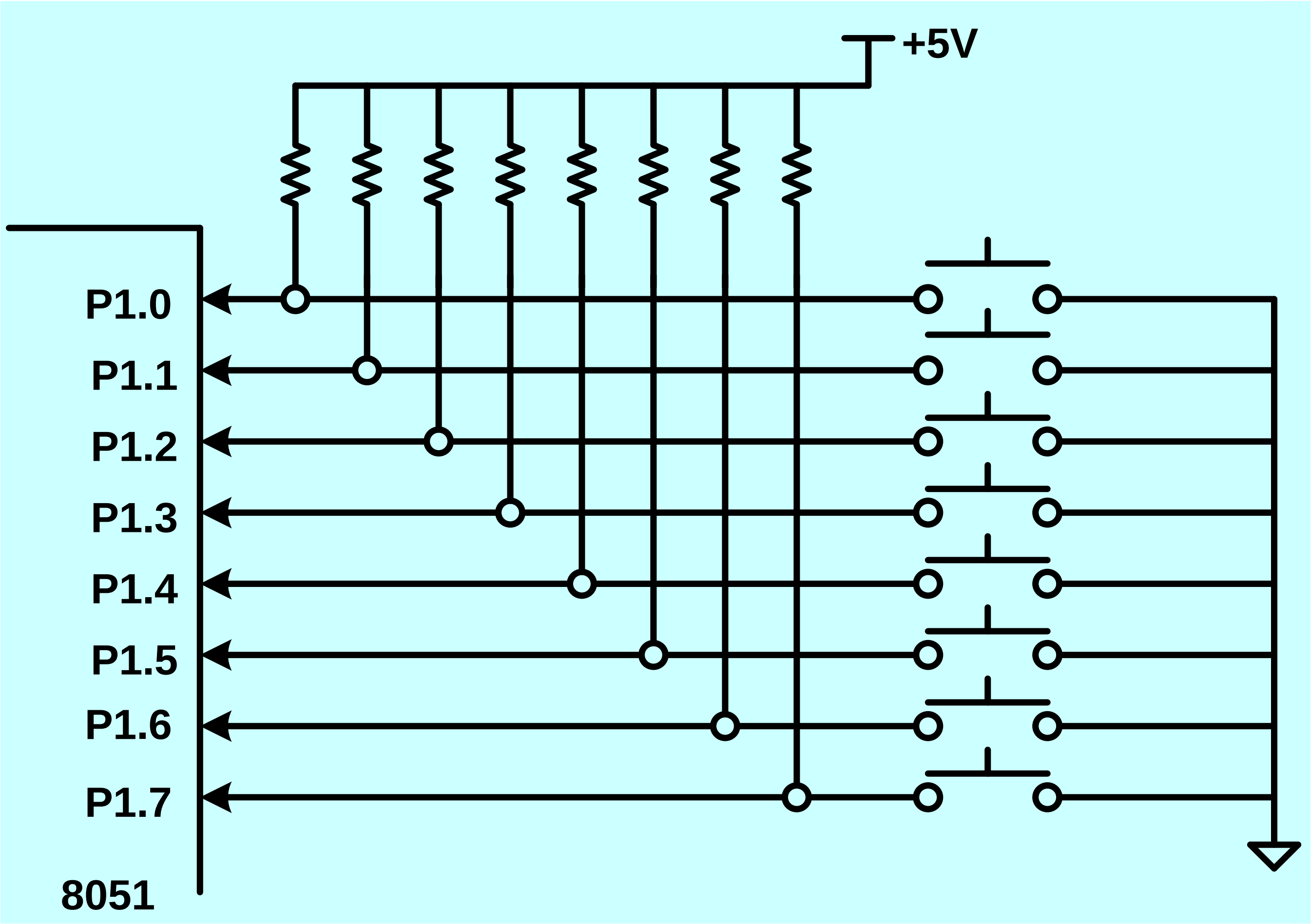
# Interfacing Switches



# What is a Keyboard ?

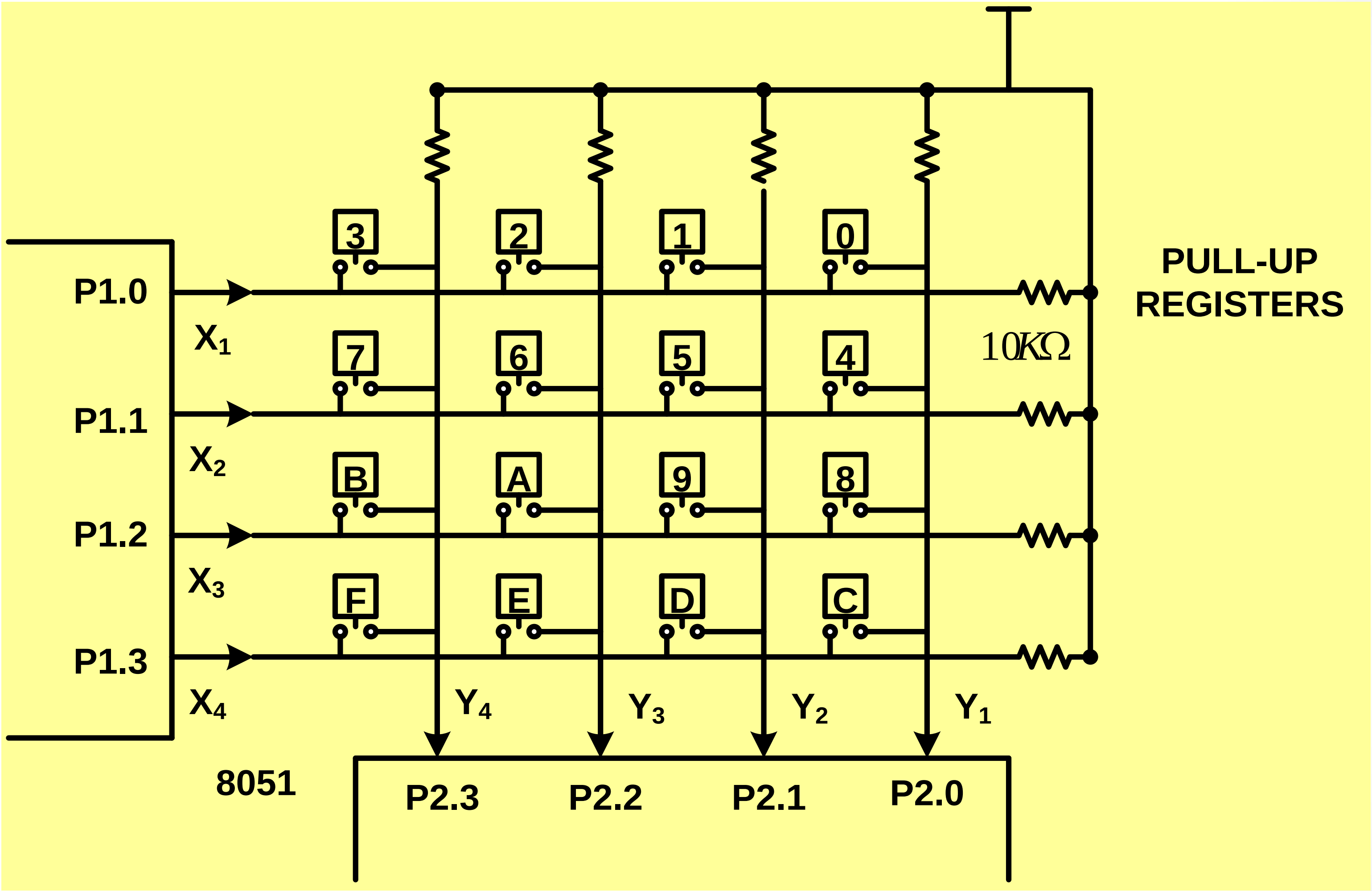
- Collection of keys interfaced to the microcontroller
- Arranged in the form of two dimensional matrix
- Matrix arrangement used for minimizing the number of port lines
- Junction of each row and column  forms the key

# Interfacing a Keyboard



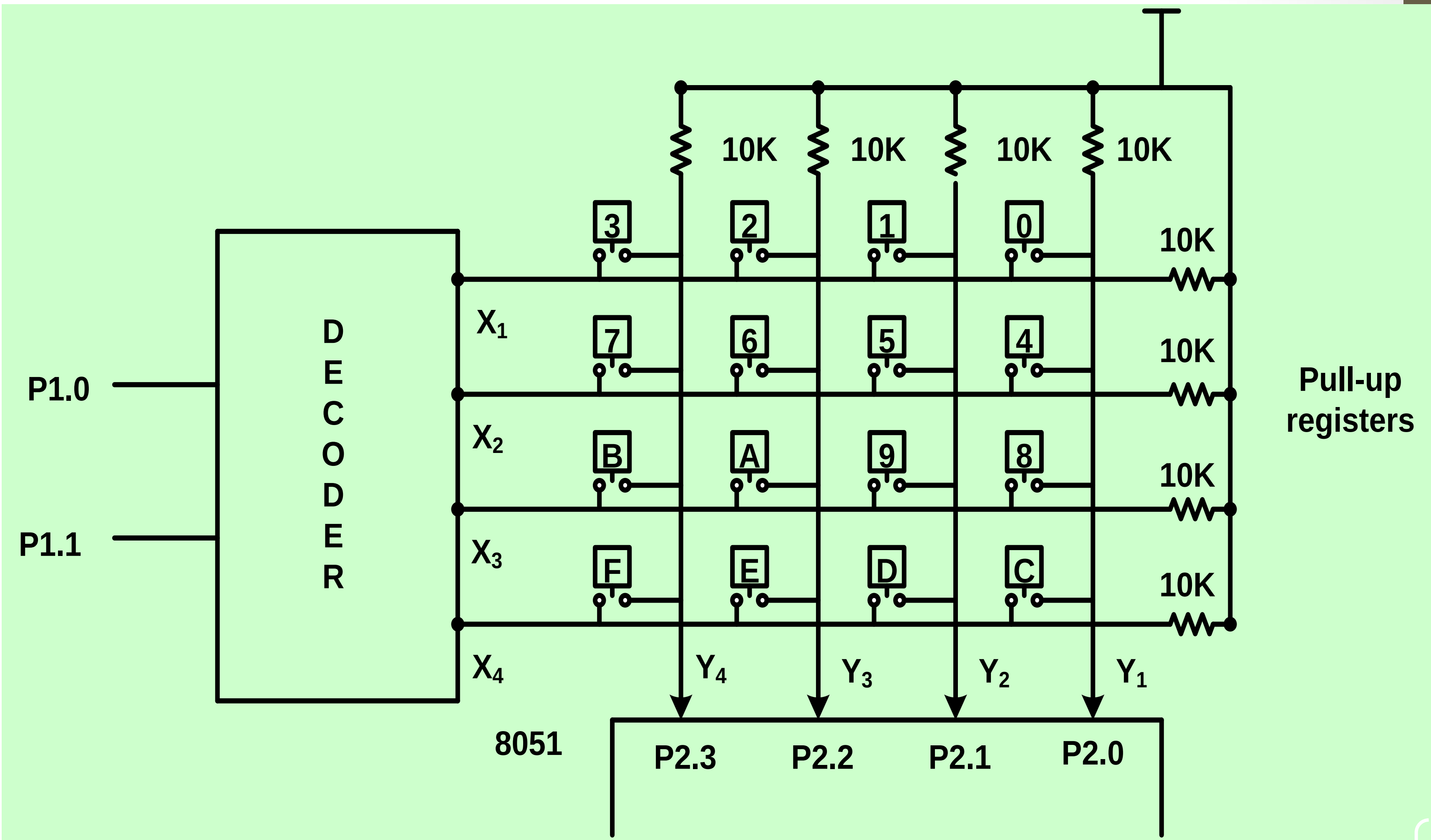

- **One key per port line**

# Interfacing a Keyboard




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

# Interfacing a Keyboard



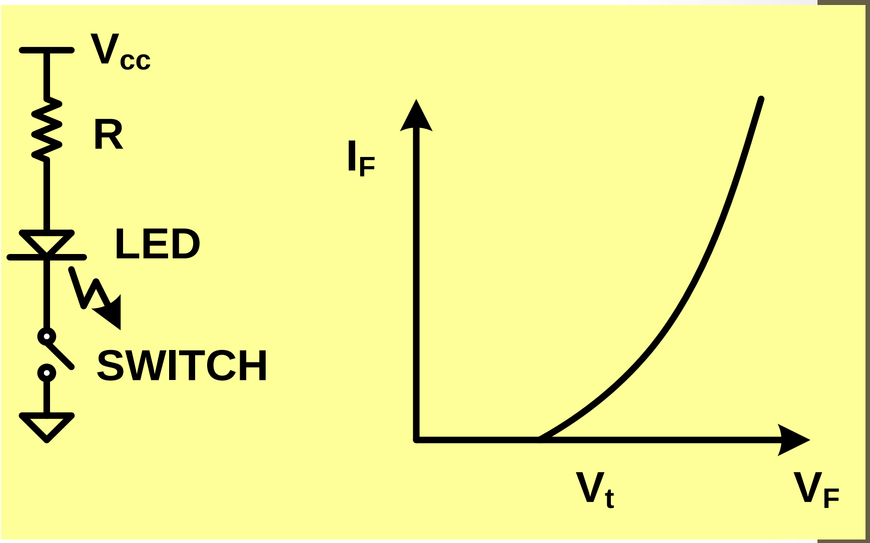

- Use of decoder further reduces the number of port lines required

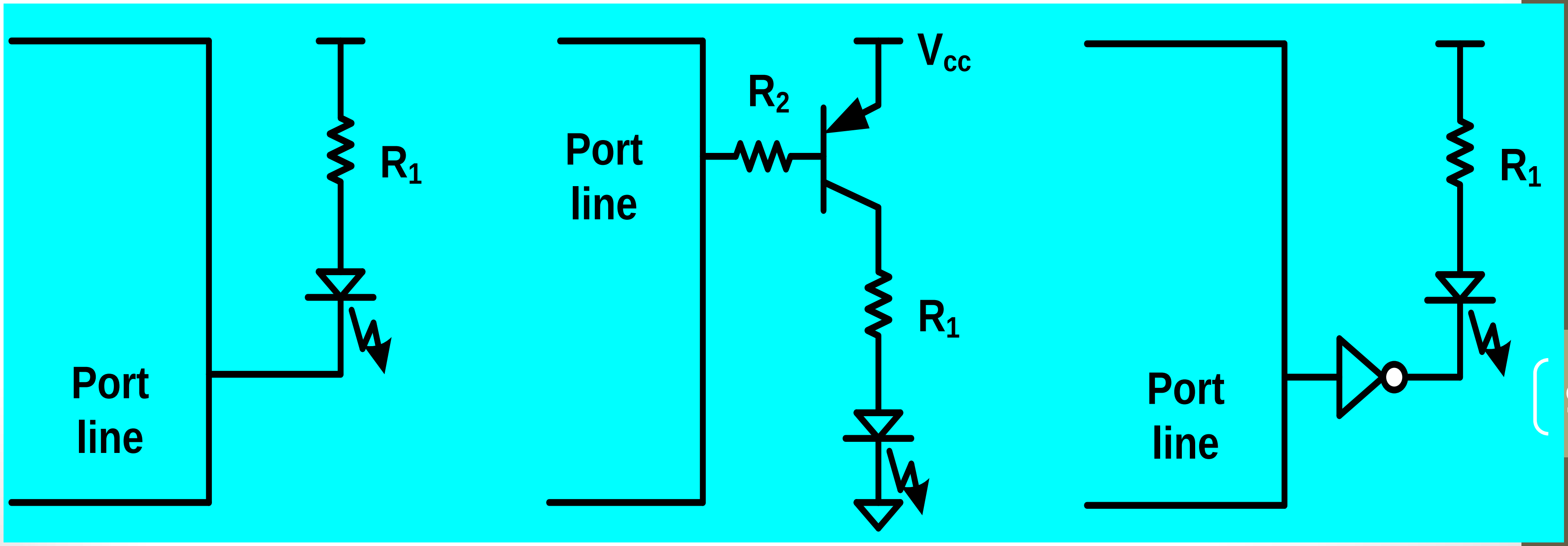
# Key Issues

- 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

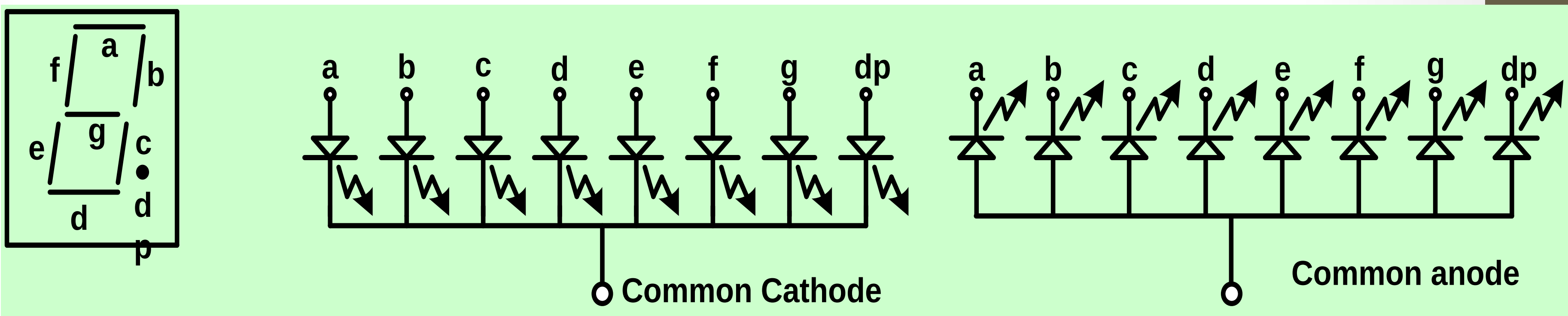
# Interfacing a single LED

- Driver circuit to interface a single LED

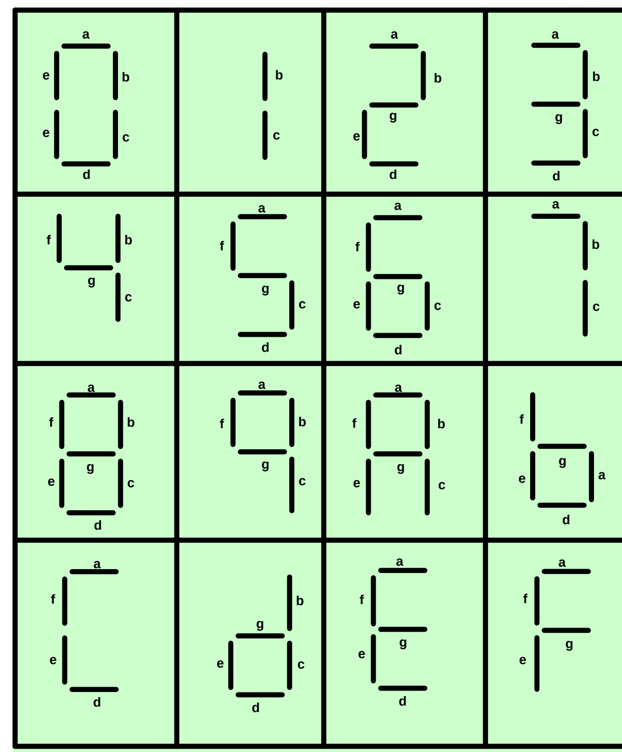


# Seven Segment LEDs




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



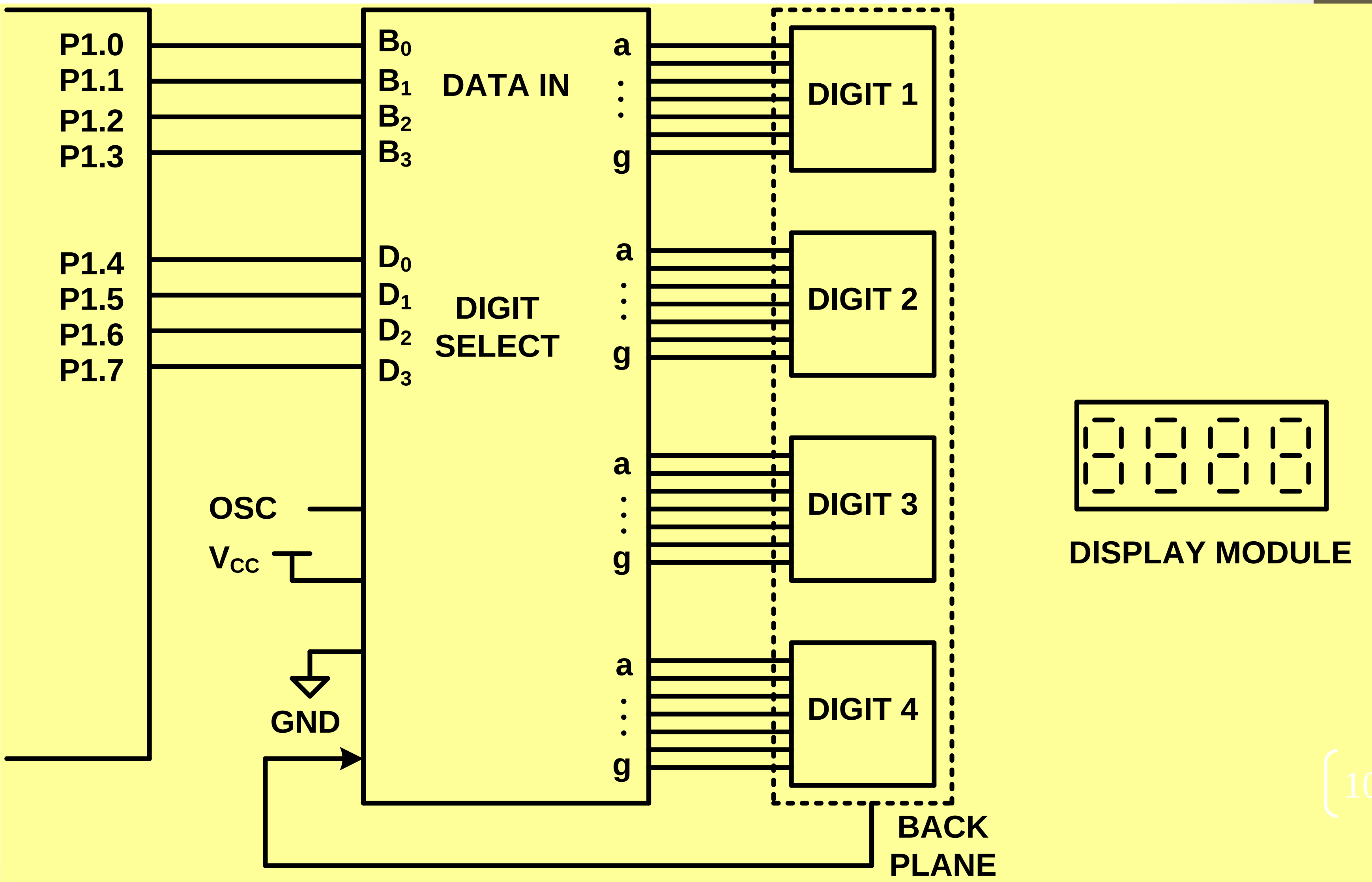
# Multidigit Driver

- **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 $DA_{0-2}$**
  - **Write data using $ID_{0-3}$ 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

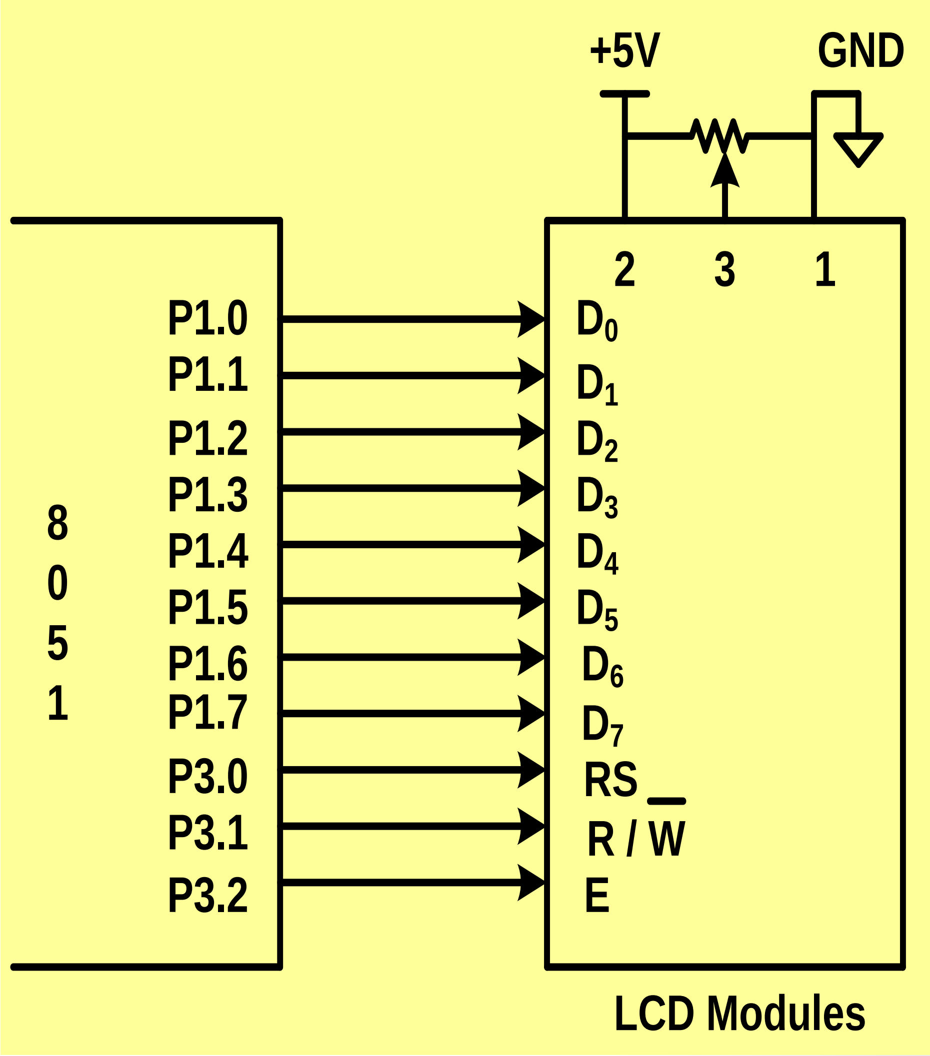


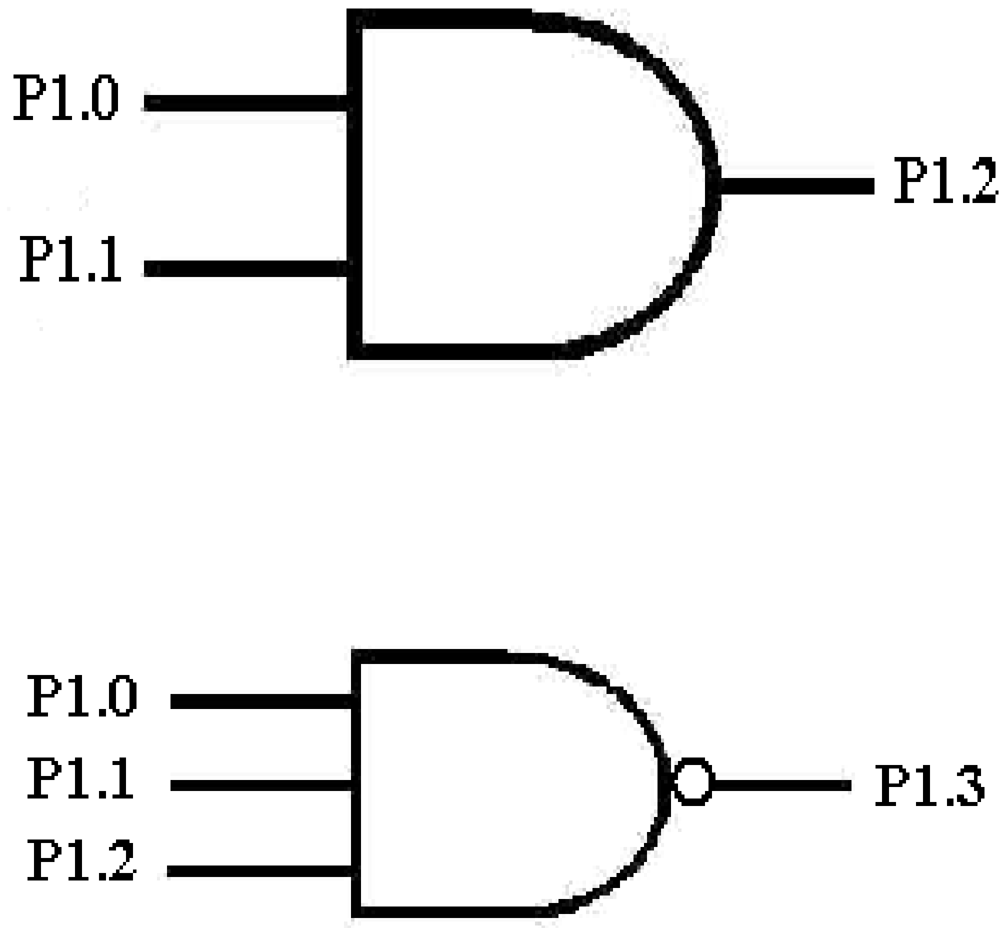
# LCD Display Module

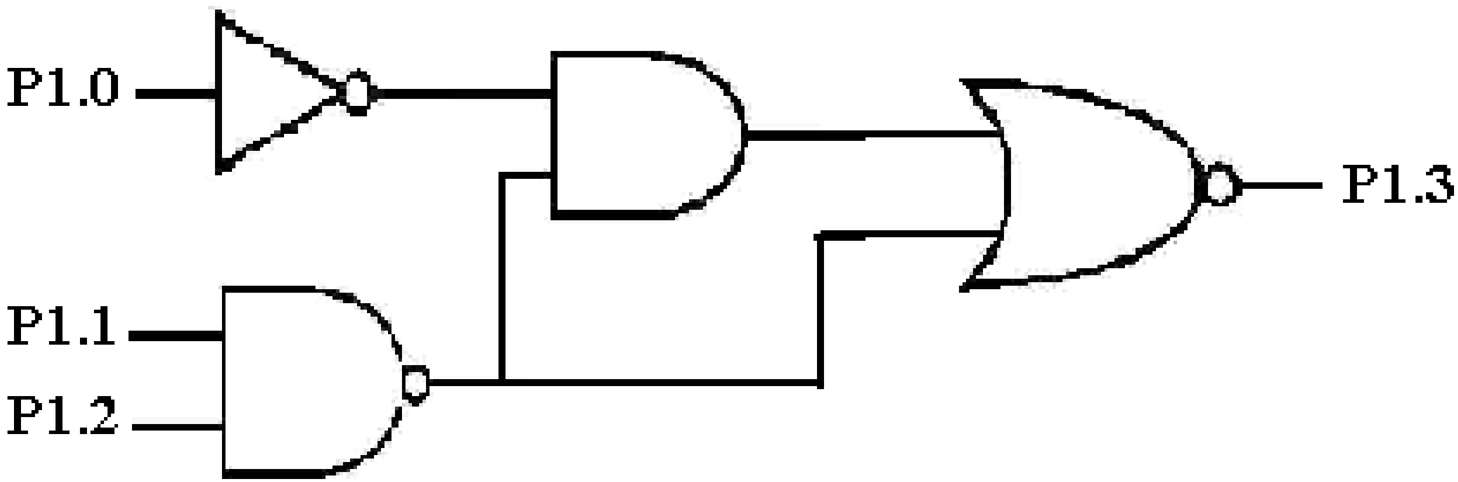
- **LCD modules:**
  - An LCD panel and small circuit board containing the controller chip
  - 14 – pin connections to microcontroller
  - HITACHI'S HD44780 controller can control up to 80 characters
  - Easy to program
  - 2 rows, 20/40 character in each row
  - Each character can be 5X8 or 5X11 matrix

# 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