Interfacing an LCD to the 8051

LCD Operation

LCD is gaining popular and replacing LEDs (7-segment …), due to

1. declining price
2. the ability to display numbers, characters, and graphics
3. relieving the CPU task by incorporating a refreshing controller
4. ease of programming for characters and graphics (OLED is the coming display)

LCD Pin Descriptions

14-pin LCD module is discussed here, table 12-1 lists pin's function, Fig 12-1 shows the pin positions for various LCDs

– Vcc, Vss provide +5V and ground

– Vee is used for contrast controlling

– RS (register select) is used to select the instruction command code register (RS = 0) or data register (RS = 1)

– LCD command codes is listed at table 12-2

– R/W (read/write) allows user to write to (R/W = 0) or read from (R/W = 1) information

– E (enable) latch information at data pins; when data is supplied to data pins, a high-to-low pulse must be applied to this pin

– D0-D7 are the 8-bit data pins; send information to LCD (R/W = 0) and read contents of LCD internal registers (R/W = 1)

– to display letters and numbers, ASCII codes are sent while RS = 1

Table 12-1. Pin Descriptions for LCD

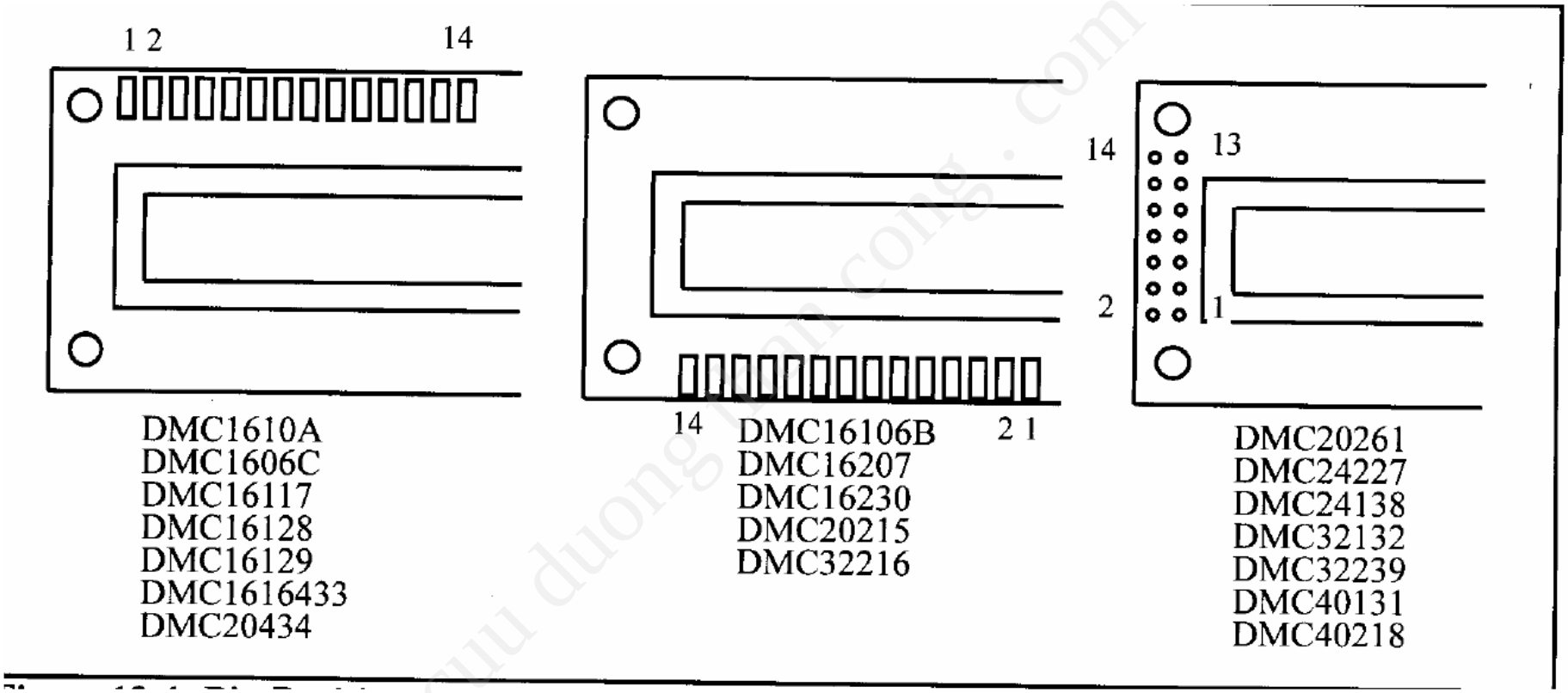
Pin	Symbol	I/O	Description
1	V_{SS}	--	Ground
2	V_{CC}	--	+5V power supply
3	V_{EE}	--	Power supply to control contrast
4	RS	I	RS=0 to select command register, RS=1 to select data register
5	R/W	I	R/W=0 for write, R/W=1 for read
6	E	I/O	Enable
7	DB0	I/O	The 8-bit data bus
8	DB1	I/O	The 8-bit data bus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

Table 12-2: 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 blinking
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
80	Force cursor to beginning of 1st line
C0	Force cursor to beginning of 2nd line
38	2 lines and 5x7 matrix

Note: This table is extracted from Table 12-4.

Pin diagrams



– RS = 0, the command code register is selected, we can send instruction to LCD to perform clear, shift, blink …

– when RS = 0, and R/W = 1, D7 is busy flag, when D7 = 0, LCD is ready to receive new information; it is recommended to check the busy flag before writing any data to the LCD

Sending commands and data to LCDs with a time delay

To send any of the commands from Table 12-2 to the LCD, make pin RS = 0. For data, make RS = 1. Then send a high-to-low pulse to the E pin to enable the internal latch of the LCD. This is shown in the code below. See Figure 12-2.

```
;calls a time delay before sending next data/command
; P1.0-P1.7 are connected to LCD data pins D0-D7
; P2.0 is connected to RS pin of LCD
; P2.1 is connected to R/W pin of LCD
; P2.2 is connected to E pin of LCD
        ORG
        MOV     A,#38H  ;init. LCD 2 lines,5x7 matrix
        ACALL   COMNWRT         ;call command subroutine
        ACALL   DELAY           ;give LCD some time
        MOV     A,#0EH          ;display on, cursor on
        ACALL   COMNWRT         ;call command subroutine
        ACALL   DELAY           ;give LCD some time
        MOV     A,#01           ;clear LCD
        ACALL   COMNWRT         ;call command subroutine
        ACALL   DELAY           ;give LCD some time
        MOV     A,#06H          ;shift cursor right
        ACALL   COMNWRT         ;call command subroutine
        ACALL   DELAY           ;give LCD some time
        MOV     A,#84H          ;cursor at line 1,pos. 4
        ACALL   COMNWRT         ;call command subroutine
        ACALL   DELAY           ;give LCD some time
        MOV     A,#'N'          ;display letter N
        ACALL   DATAWRT         ;call display subroutine
        ACALL   DELAY           ;give LCD some time
        MOV     A,#'O'          ;display letter O
        ACALL   DATAWRT         ;call display subroutine
```

```
AGAIN:   SJMP     AGAIN          ;stay here
COMNWRT:                        ;send command to LCD
         MOV      P1,A           ;copy reg A to port1
         CLR      P2.0           ;RS=0 for command
         CLR      P2.1           ;R/W=0 for write
         SETB     P2.2           ;E=1 for high pulse
         CLR      P2.2           ;E=0 for H-to-L pulse
         RET
DATAWRT:                        ;write data to LCD
         MOV      P1,A           ;copy reg A to port1
         SETB     P2.0           ;RS=1 for data
         CLR      P2.1           ;R/W=0 for write
         SETB     P2.2           ;E=1 for high pulse
         CLR      P2.2           ;E=0 for H-to-L pulse
         RET
DELAY:    MOV      R3,#50        ;50 or higher for fast CPUs
HERE2:     MOV     R4,#255       ;R4=255
HERE:      DJNZ    R4,HERE       ;stay until R4 becomes 0
           DJNZ    R3,HERE2
           RET
           END
```

Sending code or data to the LCD with checking busy flag

The above code showed how to send commands to the LCD without checking the busy flag. Notice that we must put a long delay in between issuing data or commands to the LCD. However, a much better way is to monitor the busy flag before issuing a command or data to the LCD. This is shown below.

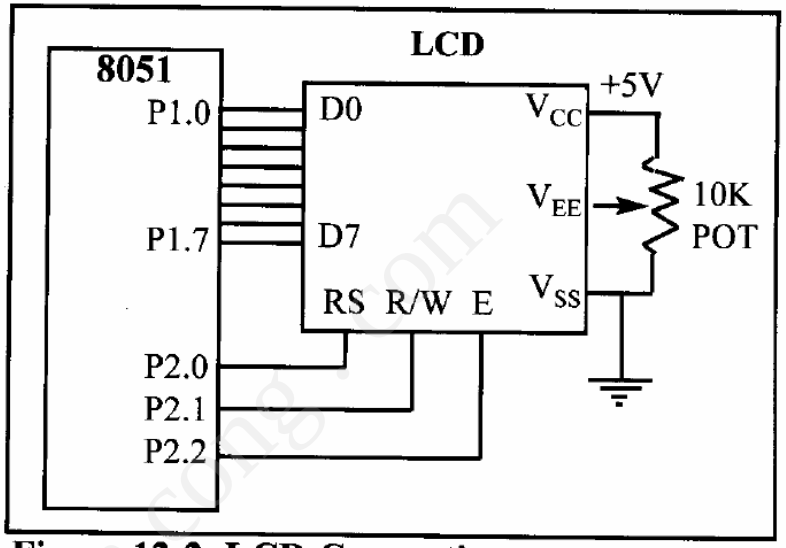


Figure 12-2. LCD Connection

```
;Check busy flag before sending data, command to LCD
;P1=data pin
;P2.0 connected to RS pin
;P2.1 connected to R/W pin
;P2.2 connected to E pin
          ORG
          MOV     A,#38H  ;init. LCD 2 lines,5x7 matrix
          ACALL   COMMAND      ;issue command
          MOV     A,#0EH       ;LCD on, cursor on
          ACALL   COMMAND      ;issue command
          MOV     A,#01H       ;clear LCD command
          ACALL   COMMAND      ;issue command
          MOV     A,#06H       ;shift cursor right
          ACALL   COMMAND      ;issue command
          MOV     A,#86H       ;cursor: line 1, pos. 6
          ACALL   COMMAND      ;command subroutine
```

```
            MOV     A,#'N'          ;display letter N
            ACALL   DATA_DISPLAY
            MOV     A,#'O'          ;display letter O
            ACALL   DATA_DISPLAY
HERE:       SJMP    HERE            ;STAY HERE
COMMAND:    ACALL   READY           ;is LCD ready?
            MOV     P1,A            ;issue command code
            CLR     P2.0            ;RS=0 for command
            CLR     P2.1            ;R/W=0 to write to LCD
            SETB    P2.2            ;E=1 for H-to-L pulse
            CLR     P2.2            ;E=0 ,latch in
            RET
DATA_DISPLAY:
            ACALL   READY           ;is LCD ready?
            MOV     P1,A            ;issue data
            SETB    P2.0            ;RS=1 for data
            CLR     P2.1            ;R/W=0 to write to LCD
            SETB    P2.2            ;E=1 for H-to-L pulse
            CLR     P2.2            ;E=0, latch in
            RET
```

```
READY:
      SETB     P1.7              ;make P1.7 input port
      CLR      P2.0              ;RS=0 access command reg
      SETB     P2.1              ;R/W=1 read command reg
;read command reg and check busy flag
BACK:CLR       P2.2              ;E=1 for H-to-L pulse
      SETB     P2.2              ;E=0 H-to-L pulse
      JB       P1.7,BACK         ;stay until busy flag=0
      RET
      END
```

Notice in the above program that the busy flag is D7 of the command register. To read the command register we make R/W = 1, RS = 0, and a H-to-L pulse for the E pin will provide us the command register. After reading the command register, if bit D7 (the busy flag) is high, the LCD is busy and no information (command or data) should be issued to it. Only when D7 = 0 can we send data or commands to the LCD. Notice in this method that there are no time delays used since we are checking the busy flag before issuing commands or data to the LCD.

LCD data sheet

In the LCD, one can put data at any location. The following shows address locations and how they are accessed.

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	1	A	A	A	A	A	A	A

where AAAAAAA = 0000000 to 0100111 for line 1 and AAAAAAA = 1000000 to 1100111 for line 2. See Table 12-3.

Table 12-3: 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

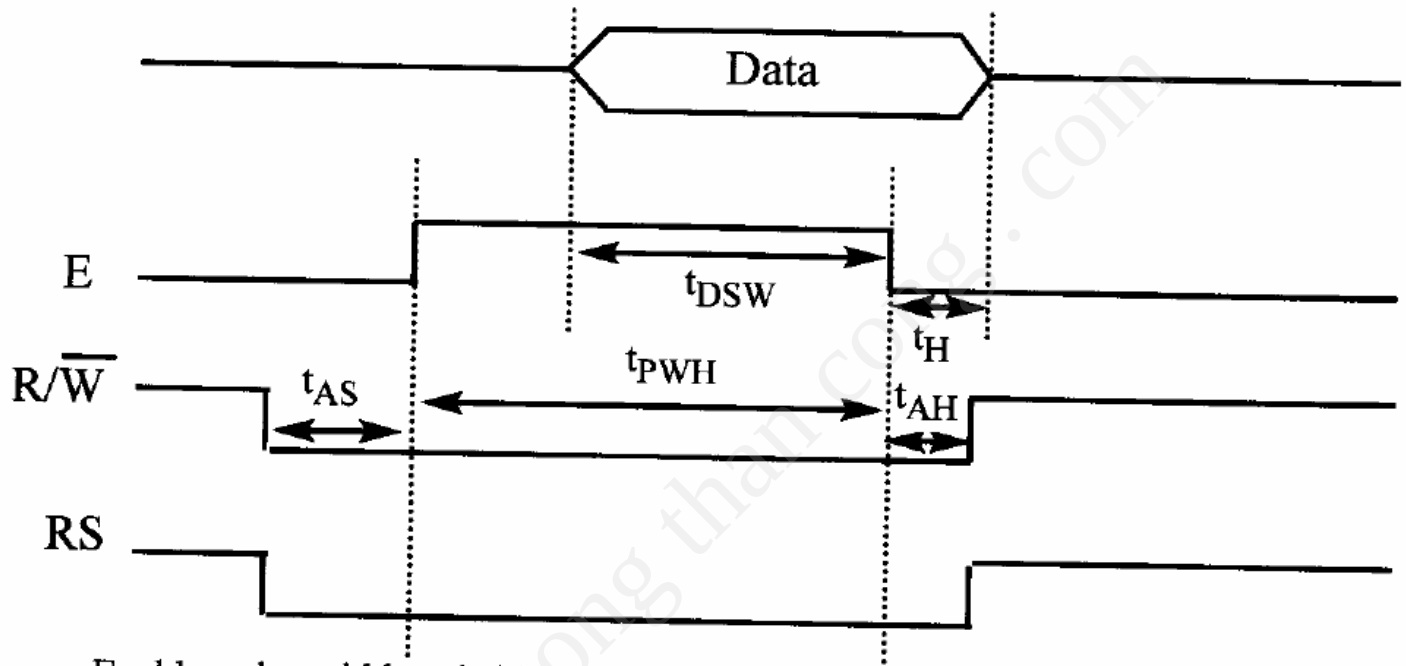
The upper address range can go as high as 0100111 for the 40-character-wide LCD while for the 20-character-wide LCD it goes up to 010011 (19 decimal = 10011 binary). Notice that the upper range 0100111 (binary) = 39 decimal which corresponds to locations 0 to 39 for the LCDs of 40x2 size.

From the above discussion we can get the addresses of cursor positions for various sizes of LCDs. See Figure 12-3. Note that all the addresses are in hex. Figure 12-4 gives a diagram of LCD timing. Table 12-4 provides a detailed list of LCD commands and instructions. Table 12-2 is extracted from this table.

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 12-3 Cursor Addresses for Some LCDs



t_{PWH} = Enable pulse width = 450 ns (minimum)
t_{DSW} = Data set up time = 195 ns (minimum)
t_H = Data hold time = 10 ns (minimum)
t_{AS} = Set up time prior to E (going high) for both RS and R/W = 140 ns (minimum)
t_{AH} = Hold time after E has come down for both RS and R/W = 10 ns (minimum)

Figure 12-4: LCD Timing

Table 12-4: List of LCD Instructions

Instruction	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	Description	Execution Time (Max)
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 CG or DD RAM	1 0	Write Data	Writes data into DD or CG RAM.	40 µs
Read Data CG or DD RAM	1 1	Read Data	Reads data from DD or CG RAM.	40 µs

Notes:

1. Execution times are maximum times when fcp or fosc is 250 kHz.
2. Execution time changes when frequency changes. Ex: When fcp or fosc is 270 kHz: 40 µs × 250 / 270 =37 µs.
3. Abbreviations:

DD RAM	Display data RAM	
CG RAM	Character generator RAM	
ACC	CG RAM address	
ADD	DD RAM address, corresponds to cursor address	
AC	Address counter used for both DD and CG RAM addresses.	
1/D = 1	Increment	1/D = 0 Decrement
S=1	Accompanies display shift	
S/C = 1	Display shift;	S/C = 0 Cursor move
R/L = 1	Shift to the right;	R/L = 0 Shift to the left
DL = 1	8 bits, DL = 0: 4 bits	
N = 1	1line, N = 0 : 1 line	
F = 1	5 x 10 dots, F = 0 : 5 x 7 dots	
BF = 1	Internal operation;	BF = 0 Can accept instruction