Volume

2

DENNIS CHE

All About Liquid Crystal Displays – Character Models

Designer's Guide

ALL ABOUT LIQUID CRYSTAL DISPLAYS

Character Based Liquid Crystal Displays Designer's Guide

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Chapter

1

Things to Know

Before you begin interfacing with your display, there are a few things that you need to know before you should start.

There are many types of character based displays on the market, and most incorporate the Hitachi HD44780 controller chip. All the information in this document will pertain to the programming and interfacing of the Hitachi HD44780 controller chip. You may want to consult with your display manufacturer to see if your display has the Hitachi HD44780 or equivalent.

Type of Display You Have

The first step is to determine the type of display you have. You will need to know the duty cycle, the operating temperature range and if your display contains two controllers.

Duty Ratio

The duty ratio is the number of multiplexed common lines the controller outputs to the liquid crystal panel (see Fig. 1.0).

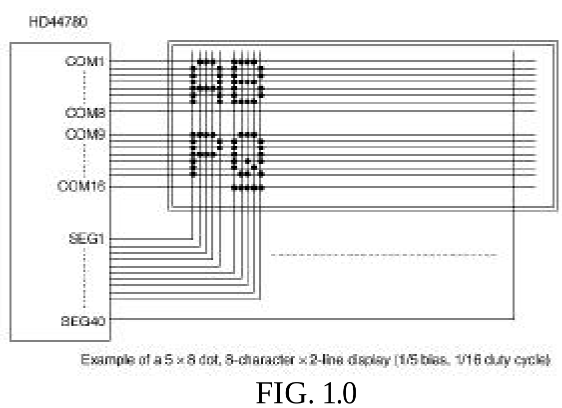


FIG. 1.0

This information can be found in the specifications for the display you are using. The most common duty ratio is the 1/16 duty for character based displays. The other available duty ratios are 1/8 and 1/11. The later duty ratios are little unique in that they are mostly used on 16 character x 1 line displays and those with a 5x10 character matrix.

<u>It is very important to know the duty ratio because it will affect the display mapping.</u> If you have a 1/16 duty 16 character by 1 line display, for example, you will notice that after you write data to the 8th position, your next set of data does not appear in the 9th to 16th position of the display. Instead, the second half of the display is blank. The reason for this is, in a one line, 1/16 duty display, you are multiplexing sixteen common lines instead of eight. Thus, the second half of your display is really a second line in your display. The display mapping below should help explain this dilemma (see Fig. 1.1).

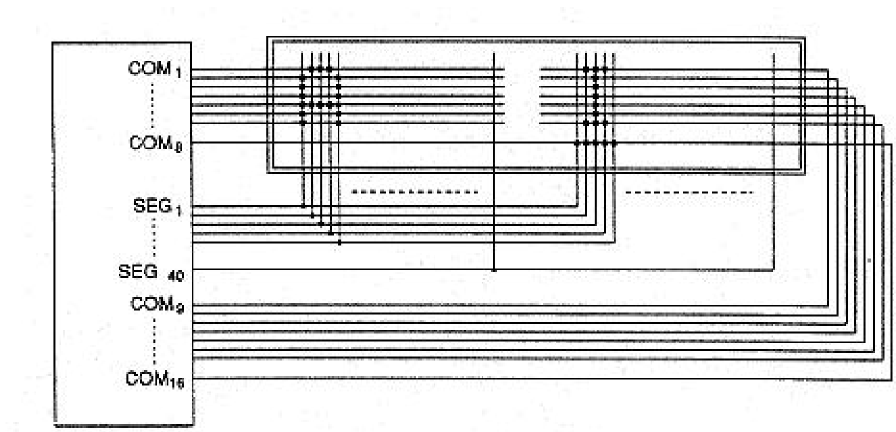
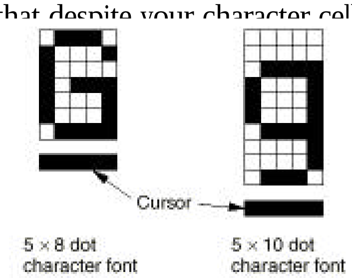


FIG1.1

In a character display, there are eight (8) common (COM) lines assigned to one row. Thus if you had a 2 line display you would need 16 common (COM) lines which equals to 1/16 duty display. In addition, the address of the second line is never the continuation of the first. Example, if the last address of the first line was 27H, then the second line **<u>would NOT</u>** be 28H. The display is designed in this fashion so that each pixel is addressed independently and at the point where the COM and SEG cross.

Or in the case that you have a 1/11 duty 32 character by 1 line display and you notice that your characters are not the full height of the 5x10 character cell. Instead, they seem to float above the cursor. The reason for this phenomena is the Hitachi HD44780 controller has a built-in 5x7 character font set plus a few special characters that are 5x10. This means that despite your character cell height, the fonts will always be 5 dots wide and 7 dot xception of the few special characters and/or those yo GRAM.



Cursor display example

FIG. 1.2

Operating Temperature Ranges

The operating range of your display will not affect your programming as it will your hardware. It is very important to know up front if the display you are using is an extended temperature range display or a normal temperature range display. A normal temperature display usually has the operating range of 0°C~+50°C and an extended temperature display usually has the operating range of -20°C~+70°C.

If you have an extended temperature range display, then your display will require a larger Bias voltage for the contrast adjustment. Normally, this voltage is derived by supplying a -5VDC to one end of a potentiometer, the other end to the +5VDC, and the center tap to the pin labeled as "Power supply for LC drive" or "Supply for Contrast adjustment." You will want to check with your manufacturer as to which pin this may be. Although for most standard models, this would be pin 3 of the display.

40x4 Display?

The last issue to consider before you start programming is to know if your display is a 40 character by 4 line display. If it is, then you will notice that there are 2 Enable lines. In a 40 character by 4 line display, most manufacturers employ a two controller solution. They do this because the Hitachi HD44780 is only capable of outputting a maximum of 80 characters. So, to make a 40 character by 4 line display, they need to use two controllers. So in essence, you have two 40 character by 2 line displays.

Therefore to write data to the third and fourth lines, you will need to send data and clock the Enable line of the second controller.

Interfacing Method

The next major factor to consider before you start programming the display is your interfacing method. Most character models that use the Hitachi HD44780 controller can be interfaced by using either 4 or 8 bit parallel interfacing. If you choose to interface with your display by using 4 bit mode, you will need twice the memory of an 8 bit interfaced display. So the amount of memory you have available will help you decide what interfacing method to use. In addition, in 4 bit mode you will interface only to the upper 4 bits (DB4~DB7) and the lower 4 bits can be left floating - the data lines are internally pulled high (Fig. 1.3).

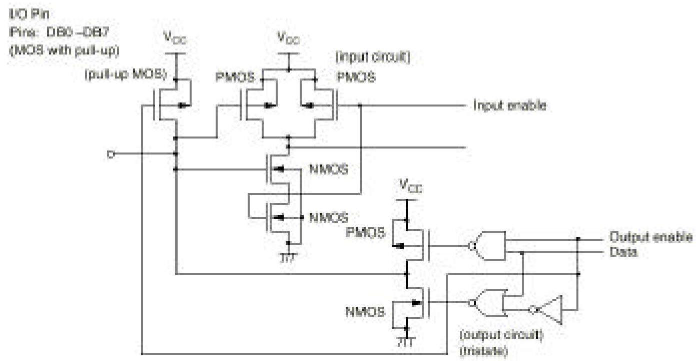


FIG. 1.2

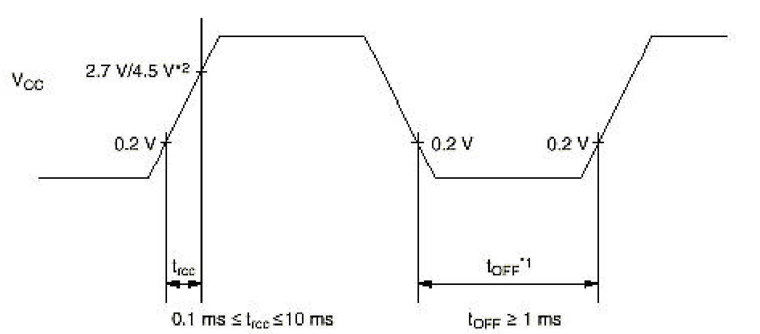
Backlight Type

Knowing which type of backlight you have will also help in designing the surround circuitry. If you chose a display with an EL backlight, then you will need a DC-AC converter or inverter. If your display has an LED backlight, then you will need to place a current limit resistor in series with the backlight terminal to protect the backlight from being over driven. You should check the specifications or with the manufacturer of your display to see if the display has a built-in current limit resistor. Some LCD manufacturers have incorporated the current limiting resistor on the PCB.

Power-up and Power-down Sequencing

The Power-up and Power-down sequence is very important to protect your display against any DC bias being generated on the LC panel (see Volume 1 for information on the effects of DC bias on the LC panel). You will want to make sure that your logic voltage, +5VDC, comes on before any of your data or negative voltage is applied and the reverse when you power-down the display. The logic +5VDC should be the last signal to shut down.

In addition, to ensure that the controller properly resets upon power-up, the timing of



Notes: 1. t_{OFF} compensates for the power oscillation period caused by momentary power supply oscillations.
2. Specified at 4.5 V for 5-V operation, and at 2.7 V for 3-V operation.
3. For if 4.5 V is not reached during 5-V operation, the internal reset circuit will not operate normally.

the logic +5VDC needs to meet the conditions of the following waveform:

If these conditions are not met, the controller may latch up and not function.

Chapter

2

Interface Description

The interface on most character LCD displays are exactly the same. There may be differences in the terminology used from manufacturer to manufacturer.

The interface on most character based Liquid Crystal Displays are the same. Especially if they use the Hitachi HD44780 controller. Normally there will be 14 interface connections and/or 2 additional connections for the backlight. However, on a 40 character by 4 line display, there are usually two additional interface lines. We will explain why the 40 character by 4 line display is different, but will start with the most common interface - displays from 8 character by 1 line to 20 character by 4 lines.

Signal Name	No. of Lines	Input/Output	Function
DB4~DB7	4	I/O	These are the 4 high order data bits. DB7 can be used as a busy flag. Also, these pins are bi-directional and tri-stated.
DB0~DB3	4	I/O	These are the 4 lower order data bits. In the case of 4 bit operation, these pins are not used. These pins are bi-directional, tri-stated, and internally pulled up. Therefore, in 4 bit mode, no pull up is necessary.
E	1	Input	Operation start signal for data read/write
R/W	1	Input	Signal to select Read or Write function 0 : Write Operation 1: Read Operation
RS	1	Input	Signal to select the registers 0 : Instruction register (write), Busy flag; address counter (Read) 1 : Data register (write and read)
V_{CC}	1	-	Power Supply for LCD
V_{SS}	1	-	0V (Ground for LCD)
V_{EE}	1	-	Terminal for LCD Contrast adjustment

Special Notes on the Interface Descriptions

The V_{EE} , Contrast Adjust, or Terminal for LCD Drive Pin

The V_{EE} may be represented differently from manufacturer to manufacturer. Some call it a V_O, or V_{ADJ}, etc. If your specification has a different symbol, check to make sure that this is the pin for adjusting contrast or "Terminal for LCD Drive." In most cases, this pin is for a variable voltage. You may see a setup diagram for this pin like the ones shown in Fig 2.0 and 2.1.

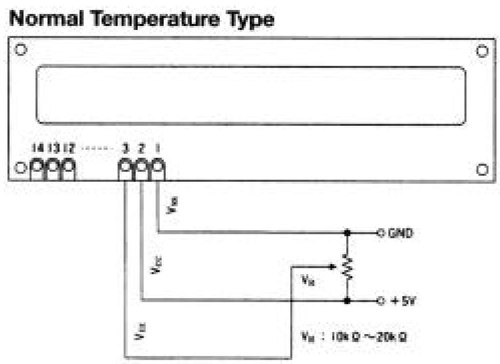


Fig. 2.0

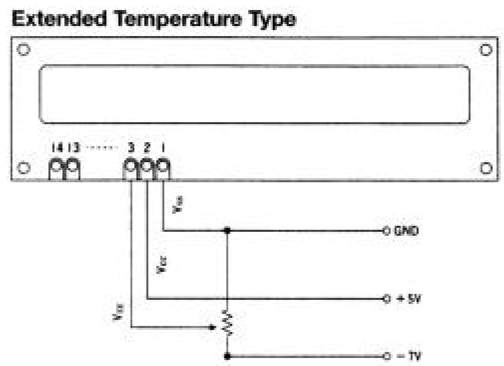


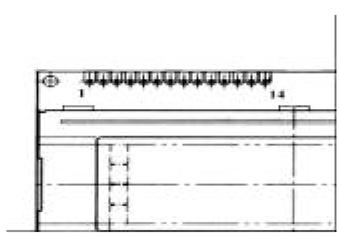
Fig 2.1

40 Character by 4 Line Display

As mentioned earlier, on the 40 character by 4 line displays, there are 2 additional pins. These are E2 and/or V_{SS} or no connection. In this case, E2 is the signal for the second controller. So when you write data to the 3rd and 4th lines, you will be using the E2 line instead of the E1 line and vise versa.

Backlight Interface

The configurations in this section are most commonly applied to LED backlights. Some manufacturers integrate the backlight connections right next to the standard interface pins and/or connect the backlight directly to the power supply lines. To determine if your display is designed in this manner, you will to need look at the number of connections on the main interface. If you display has 14 interface lines (see fig 2.2) then your display has the backlight connections on the side - most common. But, you should still check your specifications carefully, because some manufacturers connect the LED backlight directly to pins 1 (V_{SS}) and 2 (V_{DD}) through a current limiting resistor. And if your display has 16 interface lines (see Fig. 2.3) then your display has the backlight connections in-line with the interface pins.



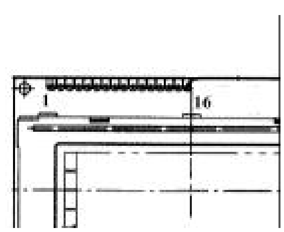


Fig. 2.2 Fig. 2.3

There are advantages and drawbacks to having the LED backlight connected directly to the interface pins. The advantages are no need to make additional connections to power the backlight and no need for a current limiting resistor. But the disadvantage is the in-ability to turn On and Off the backlight independently of the display without turning On or Off the display.

There is one special case that this configuration does not apply to - the 40 character by 4 line display. By default, these displays have 16 pins (dual rows of eight) and the backlight connections are on the side.

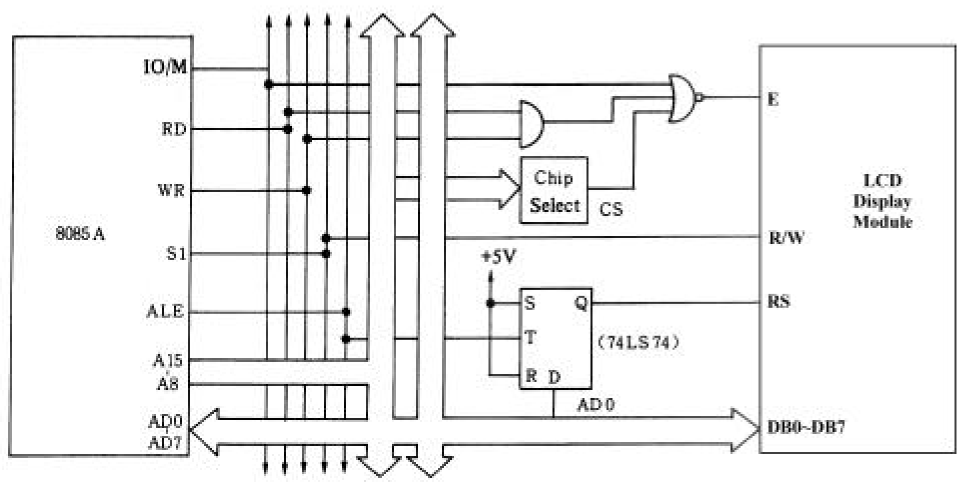
Chapter 3

Sample Circuit Diagrams

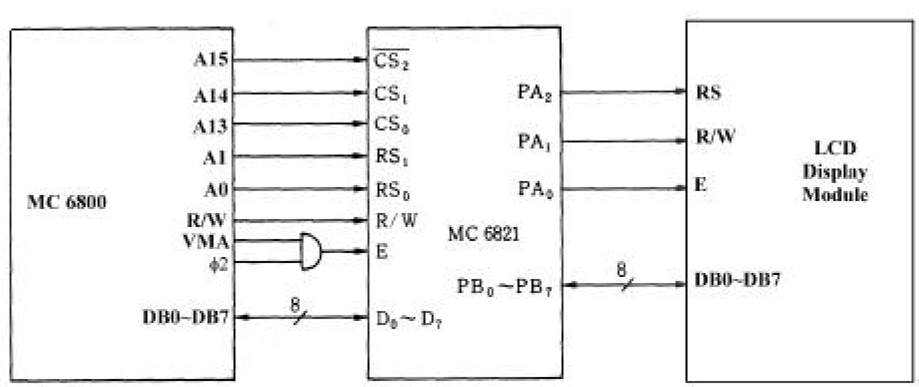
The following schematics are samples for interfacing the Character Based LCD's to the most common microprocessors.

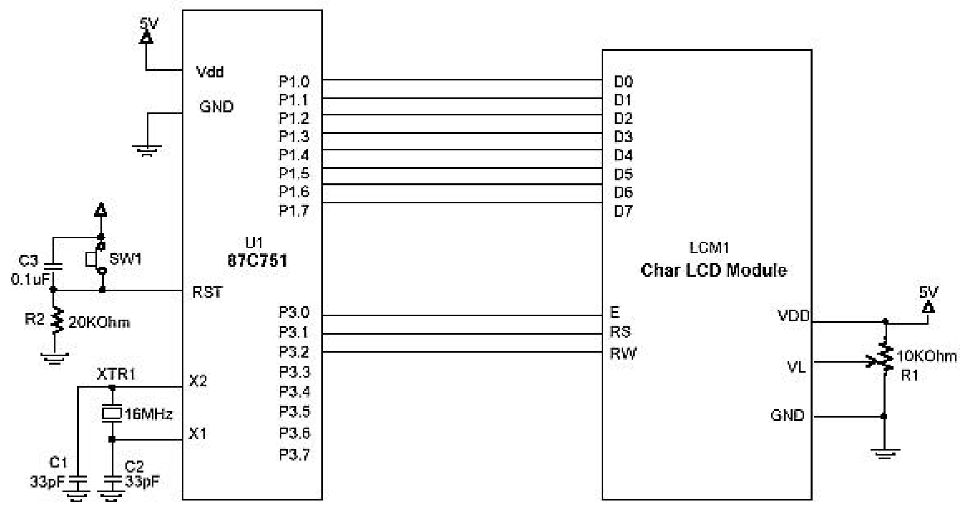
The interfacing is very straight forward. LCD's that use the HD44780 are 8-bit parallel plus a few control and power signals. See the following diagrams for sample interfacing schemes with the microprocessors that closely resemble the one that you are using.

Connection with 8085A

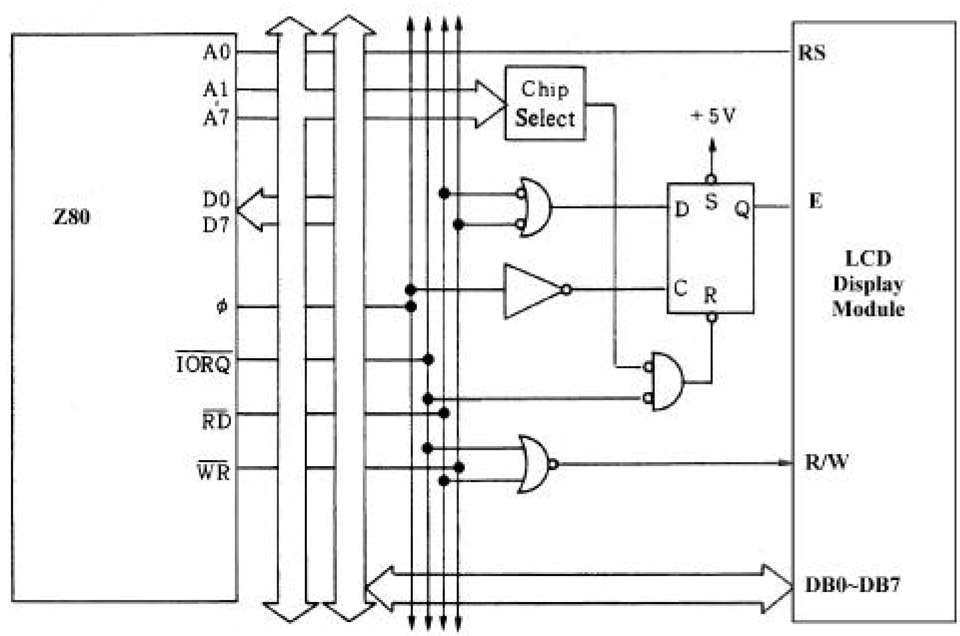


Connection with MC 6800





Connection with Z-80



Chapter

4

Explanation of Register Functions

The registers help the controller interpret the type of data that is on the data lines and how to execute them. There are primarily two types of 8 bit registers, the Instruction Register (IR) and the Data Register (DR).

The IR is a write only register that stores instruction codes like Display Clear and Display ON/OFF, and address information for Display Data RAM (DDRAM) or the Character Generator RAM (CGRAM).

The DR is a read/write register used for temporarily storing data to be read/written to/from the DDRAM or CGRAM. The data written into the DR is also automatically written into DDRAM by an internal function of the controller. In addition, the DR is used to store data when reading information out from the DD RAM or CG RAM.

In order to read data from the controller, address information needs to be written into the IR. Once the address data is written to the IR, an internal operation is performed to place the data of DD RAM or CG RAM into the DR. Then you can read the DR for its contents. After you perform a read function from the DR, the data of the DD RAM or CG RAM in the next address is sent to the DR for the next read cycle.

The Register Select (RS) signal is used to determine which of these two registers are selected (see Fig. 4.0).

RS	R/W	Operation
0	0	Instruction Register (IR) write, internal operation
0	1	Busy Flag (DB7) and address counter (DB0~DB6) read
1	0	Data Register (DR) write, internal operation (DR → DDRAM or CG RAM)
1	1	Data Register (DR) read, internal operation (DR ← DDRAM or CGRAM)

Fig. 4.0

Busy Flag (BF)

When the busy flag is high the LCD module is performing an internal operation and the next instruction will not be accepted. As shown in Fig. 4.0, the busy flag outputs to DB7 when RS=0 and a read operation is performed. The next instruction will not be accepted until the busy flag returns to a “0” or low state.

Address Counter (AC)

The address counter assigns addresses to both the DDRAM and the CGRAM. When the address of an instruction is written into the IR, the address information is sent from the IR to the AC. The selection of either the DDRAM or the CGRAM is also determined concurrently by the same instruction.

After writing into (or reading from) DDRAM or CGRAM, the Address Counter (AC) is automatically incremented or decremented by 1 (determined by the I/D bit in the Entry Mode Set command). AC contents are then output to the data lines (DB0~DB7) when RS=0 and a read operation is performed, shown in Fig 4.0.

Display Data RAM (DDRAM)

The Display Data RAM (DDRAM) stores the data represented in 8-bit character codes. Its capacity is 80x8 bits or 80 characters. The area in Display Data RAM that is not used for the display can be used as a general RAM location.

Character Generator ROM (CGROM)

The Character Generator ROM is an 80 x 8 bit ROM capable of generating 160 types of 5 x 7 character patterns or 32 types of 5 x 10 character patterns from an 8-bit character code. The 5 x 10 character pattern cannot be utilized on all character display modules. Only those that have the 1/11 duty and a 5 x 10 or 5 x 11 character matrix on the panel. In the appendix of this book is a font table of the available characters for the HD44780. Custom characters such as Hebrew are available as customs from most manufacturers.

Character Generator RAM (CGRAM)

The CGRAM is a 64 x 8 bit RAM in which the user can program up to 8 custom character patterns. You can program either eight (8) 5 x 7 character patterns or four (4) 5 x 10 character patterns. Once programmed, the custom characters or symbols are accessed exactly as if they were in ROM. All the dots in the 5 x 8 matrix can be programmed, including the cursor.

Please note: These characters reside in RAM, which is a volatile memory, so power must be continually maintained.

The RAM module is divided into two parts: Display Data RAM (DDRAM) and custom Character Generator RAM (CGRAM). This CGRAM is located between 40H and 7FH and is contiguous. Locations 40H thru 47H hold the first custom 5 x 8 character, 48H thru 4FH hold the second custom 5 x 8 character, etc. until the you reach 78H thru 7FH for the eighth and last custom 5 x 8 character.

If you programmed the display to automatically increment during the initialization, then you only need to send the address 40H once. The next consecutive rows will automatically be incremented until the custom characters are completed. You can program all eight custom 5 x 8 character in 64 consecutive "writes" after sending the first initial start address (40H).

The CGRAM is 8-bits wide but only the first 5-bits are used for the custom 5 x 8 character. The left most dot in the matrix corresponds to DB4 in the most significant nibble of the data bus, with the remaining four dots in the row corresponding to the least significant nibble (D3 thru D0), D0 being the right most dot. Thus 1FH equals all dots on and 00H equals all dots off and 15H equals 3 dots on and alternating (see Fig. 4.1). When all 7 or 8 rows are programmed, then the custom character is complete.

RS	R/W	Data	Display	Description
0	0	40		Addresses 1st row, 1st character
1	0	11	* *	Result of 11, 1st row
1	0	0A	* *	Result of 0A, 2nd row
1	0	1F	* * * * *	Result of 1F, 3rd row
1	0	04	*	Result of 04, 4th row
1	0	1F	* * * * *	Result of 1F, 5th row
1	0	04	*	Result of 04, 6th row
1	0	04	*	Result of 04, 7th row
1	0	00		Result of 00, 8th row (cursor position)
1	0	15	* * *	1st row, 2nd character.

FIG. 4.1

Chapter

5

The Display Data RAM Mapping

The Display Data RAM Mappings on most Character LCD's are the same from manufacturer to manufacturer.

The following tables are the DDRAM addresses for various sized and duty cycle displays. These are the 7-bit addresses for the display mapping.

8 Characters x 1 Line

	1	2	3	4	5	6	7	8
Line 1	00	01	02	03	04	05	06	07

8 Characters x 2 Lines

	1	2	3	4	5	6	7	8
Line 1	00	01	02	03	04	05	06	07
Line 2	40	41	42	43	44	45	46	47

16 Characters x 1 Line

	1	2	3	4	5	6	7	8	9	…	16	Duty
Line 1	00	01	02	03	04	05	06	07	40	…	47	1/16
Line 1	00	01	02	03	04	05	06	07	08	…	0F	1/11, 1/8

16 Characters x 2 Lines

	1	2	3	4	5	6	7	8	9	…	16
Line 1	00	01	02	03	04	05	06	07	08	…	0F
Line 2	40	41	42	43	44	45	46	47	48	…	4F

16 Characters x 4 Lines

	1	2	3	4	5	6	7	8	9	…	16
Line 1	00	01	02	03	04	05	06	07	08	…	0F
Line 2	40	41	42	43	44	45	46	47	48	…	4F
Line 3	10	11	12	13	14	15	16	17	18	…	1F
Line 4	50	51	52	53	54	55	56	57	58	…	5F

20 Characters x 2 Lines

	1	2	3	4	5	6	7	8	9	…	20
Line 1	00	01	02	03	04	05	06	07	08	…	13
Line 2	40	41	42	43	44	45	46	47	48	…	53

20 Characters x 4 Lines

	1	2	3	4	5	6	7	8	9	…	20
Line 1	00	01	02	03	04	05	06	07	08	…	13
Line 2	40	41	42	43	44	45	46	47	48	…	53
Line 3	14	15	16	17	18	19	1A	1B	1C	…	27
Line 4	54	55	56	57	58	59	5A	5B	5C	…	67

24 Characters x 2 Lines

	1	2	3	4	5	6	7	8	9	…	24
Line 1	00	01	02	03	04	05	06	07	08	…	17
Line 2	40	41	42	43	44	45	46	47	48	…	57

40 Characters x 4 Lines

	1	2	3	4	5	6	7	8	9	…	40
Line 1	00	01	02	03	04	05	06	07	08	…	27
Line 2	40	41	42	43	44	45	46	47	48	…	67
Line 3	00	01	02	03	04	05	06	07	08	…	27
Line 4	40	41	42	43	44	45	46	47	48	…	67

* Note: Address locations on Lines 1 & 2 are controlled by the first Enable Line (E1) and the address locations for lines 3 & 4 are controlled by the second Enable Line (E2).

Chapter 6

Instruction Set

The following instruction set is based on the HD44780 controller and can be used on most LCD's by various manufacturers.

The following are the instructions and execution times for the HD44780 controller. If the busy flag is not checked, then each instruction must be allotted the minimum stated execution time before writing the next instruction or data. If you wait longer than the stated execution times before writing the next instruction or data, then you should not have any conflict with the display. The "*" in the tables below indicate a "Don't Care" situation.

Instruction	Code										Description	Execution Time (fcp or fosc is 250kHz)
	RS	R/W	DB_7	DB_6	DB_5	DB_4	DB_3	DB_2	DB_1	DB_0		
Clear Display	0	0	0	0	0	0	0	0	0	1	Clears entire display and sets DDRAM address to 00H in the address counter	1.64ms
Return Home	0	0	0	0	0	0	0	0	1	*	Sets DDRAM address to 00H in the address counter. Also returns a shifted display back to the original position. DDRAM contents remain unchanged	1.64ms
Entry Mode Set	0	0	0	0	0	0	0	1	I/D	S	Set cursor move direction and specifies increment or decrement of cursor position. This operation occurs during the read or write functions	40µs
Display ON/OFF Control	0	0	0	0	0	0	1	D	C	B	Sets the display ON/OFF (D), cursor ON/OFF (C), and character blink (B).	40µs
Cursor or Display Shift	0	0	0	0	0	1	S/C	R/L	*	*	Moves the cursor and shifts the display without changing the DDRAM contents	40µs
Function Set	0	0	0	0	1	DL	N	F	*	*	Sets the interface data length (DL), the number of display lines (L) and the character font (F).	40µs
Set CGRAM Address	0	0	0	1	AGC						Sets CGRAM address. CGRAM data is sent and received after this setting	40µs
Set DDRAM Address	0	0	1	ADD							Sets DDRAM address. DDRAM data is sent and received after this setting	40µs
Read Busy Flag & Address	0	1	BF	AC							Reads Busy Flag (BF) indicating that the controller is performing an internal operation and then reads the Address	40µs

				Counter contents	
Write Data to CG or DDRAM	1	0	Write Data	Writes data into DDRAM or CGRAM	40µs
Read Data form CG or DDRAM	1	1	Read Data	Reads data from DDRAM or CGRAM	40µs
I/D = 1 : Increment I/D = 0 : Decrement S = 1 : Shifts entire display, works with 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 bit interface DL = 0 : 4 bit interface N = 1 : 2 line N = 0 : 1 line F = 1 : 5 x 10 dot matrix F = 0 : 5 x 7 dot matrix BF = 1 : Controller performing internal operation BF = 0 : Controller can accept data from host MPU				DDRAM : Display Data RAM CGRAM : Character Generator RAM ACC : CGRAM address ADD : DDRAM address. Corresponds to cursor address. AC : Address counter used for both DDRAM and CGRAM address.	Execution time changes when frequency changes. (Example): When fcp or fosc is 270kHz: 40µsx250/270= 37µs

Detailed Explanations

1. Clear Display

	RS	R/W	DB_7			---				DB_0
Code	0	0	0	0	0	0	0	0	0	1

Clears all display memory and returns the cursor to the home position. In other words, the cursor returns to the first character position on the first line - which is the upper left character position.

2. Return Home

	RS	R/W	DB_7			---				DB_0
Code	0	0	0	0	0	0	0	0	1	*

Returns the cursor to the home position, which is the upper left most character position or the first character position of the first line.

3. Entry Mode Set

	RS	R/W	DB_7			---				DB_0
Code	0	0	0	0	0	0	0	1	I/D	S

I/D : Increments (I/D=1) or decrements (I/D=0) the DDRAM address by one position when writing or reading a character from the either the DDRAM or CGRAM. The cursor automatically moves to the right when I/D = 1 and to the left when I/D = 0.

S : Shifts the entire display to either the right or left when S=1. It will look like the cursor does not move but the entire content of the display will move. Reading or writing from CGRAM and reading of the DDRAM will not shift the display.

Example:

Bit	Condition	Effect
S I/D	1 1	The entire display shifts one position to the left.
S I/D	1 0	The entire display shifts one position to the right.

Shifting occurs after each data write to the DDRAM.

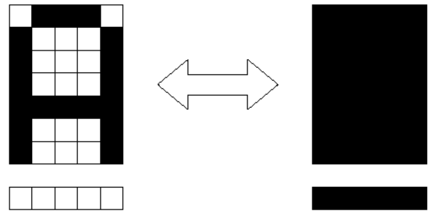
4. Display and Cursor ON/OFF Control

	RS	R/W	DB_7			---				DB_0
Code	0	0	0	0	0	0	1	D	C	B

D : Display is turned ON when D=1 and OFF when D=0. When the display is off, the data in the DDRAM remains intact. The data will return to the display when D=1.

C : Cursor is displayed when C=1 and not displayed when C=0. When the cursor is not visible, the other functions, such as Increment/Decrement are not affected during display data write. In a 5x7 character matrix, there is an eighth line that functions as the cursor.

B : When B=1, the character at the current cursor position begins to blink. When B=0, the character at the current position will not blink. The blink is displayed by switching between all blank dots and display characters at 0.4 sec intervals. The cursor and the blink functions can be set to work simultaneously.



Alternating display

Fig. 4.1

5. Cursor or Display Shift

	RS	R/W	DB_7				---			DB_0
Code	0	0	0	0	0	1	S/C	R/L	*	*

This command moves the cursor or shifts the entire display without changing the DDRAM contents. The cursor position and the AC contents match. This instruction is available for display correction and retrieval because the cursor position or display can be shifted without writing or reading the display data. In the case of a 2-line display, the last character of the first line will wrap to the first character position of the second line. In the case of a 4-line display, the data will wrap on the 1^{st} to 3^{rd} lines and 2^{nd} to 4^{th} line. Then the data will wrap from the 3^{rd} line to the second line. This is due to the mapping of a 4 line display - except for the 40x4.

S/C	R/L	Operation
0	0	The cursor position is shifted to the left (the AC decrements by one)
0	1	The cursor position is shifted to the right (the AC increments by one)
1	0	The entire display is shifted to the left with the cursor
1	1	The entire display is shifted to the right with the cursor

6. Function Set

	RS	R/W	DB_7				---			DB_0
Code	0	0	0	0	1	D/L	N	F	*	*

The Function Set command sets the interface data length, the number of display lines and character font.

D/L : When D/L=1, the data length is set to eight bits (DB_7 to DB_0). When D/L=0, the data length is set to four bits (DB_7 to DB_4). The upper four bits are transferred first, and then the lower four bits follow.

When using in four bit mode, it is not necessary to use pull-up or pull-down resistors. The Data Bus is internally pulled high.

N : Number of display lines or display duty cycle

This parameter sets the number of display lines and duty cycle of the display. When N=1, the display is set for 1/8 or 1/11 duty. When N=0, the display is set for 1/16 duty. On a one line display with 1/16 duty, the display will work as if it was a two line display. The second half of the display is effectively the start of the second line (see the DDRAM Addressing for more details). The 1/16 duty configuration is very common for display with more than two lines of data.

F : Sets the character font size

N	F	Character Font	Duty	Remarks
0	0	5 x 8 dots	1/8	
0	1	5 x 10 dots	1/11	
1	*	5 x 8 dots	1/16	Cannot display two lines for 5x10 character font

Note: =”*” - Indicates don’t care.

The Function Set instruction needs to be the first command in the initialization routine before any other command (except for the Busy Flag/address read). No other function can be executed except for changing the interface data length.

7. CGRAM Address Set

	RS	R/W	DB_7			---				DB_0
Code	0	0	0	1	A	A	A	A	A	A

← Higher order bits Lower order bits→

This binary expression sets the CGRAM address into the Address Counter. Data is then written/read from the CGRAM.

8. DDRAM Address Set

	RS	R/W	DB_7			---				DB_0
Code	0	0	1	A	A	A	A	A	A	A

← Higher order bits Lower order bits→

This binary expression sets the DDRAM address into the Address Counter. Data is then written/read from the DDRAM.

For a one line display, the valid addresses are 00H ~ 4FH. For a two line display, the valid addresses are 00H ~ 27H for the first line and 40H ~ 67H for the second line (see DDRAM Addressing for details).

9. Read Busy Flag and Address

	RS	R/W	DB_7			---				DB_0
Code	0	1	BF	A	A	A	A	A	A	A

← Higher order bits Lower order bits→

The BF signal is a read only function indicating that the display is performing an internal operation. When BF=1, the display is performing an internal operation and the next instruction sent will not be executed until the BF=0. When BF=0, the next instruction will be accepted.

The BF should be checked before each write operation.

The Address Counter content is also read at the same time of the busy flag check. The Address Counter addresses are used for both CGRAM and DDRAM and the value is determined by the previous instruction.

10. Write Data to CGRAM or DDRAM

	RS	R/W	DB_7			---				DB_0
Code	1	0	D	D	D	D	D	D	D	D

← Higher order bits Lower order bits→

This command writes an 8-bit binary data DDDDDDD to the CGRAM or DDRAM. The CGRAM Address Set or DDRAM Address Set command determines which RAM will be written into. After a write, the Entry Mode command determines whether the address will be incremented or decremented by 1. The display shift function will also be determined by the Entry Mode Set command.

11. Read Data from CGRAM or DDRAM

	RS	R/W	DB_7			---				DB_0
Code	1	1	D	D	D	D	D	D	D	D

← Higher order bits Lower order bits→

This command reads an 8-bit binary data DDDDDDD from the CGRAM or DDRAM. The CGRAM Address Set or DDRAM Address Set command determines which RAM will be read. Before executing this command, you must first set the CGRAM or DDRAM address by using the CGRAM or DDRAM Address Set command. If you don't, the first data read will be invalidated.

When you read the data continuously, the next address data is normally read from the second read. However, if the cursor is shifted by the Cursor Shift command when reading the DDRAM, there is no need to set the address using the Address Set command because the Cursor Shift command already performs this.

After the read operation, the address is automatically incremented or decremented by one according to the Entry Mode Set command, but the display will not be shifted.

Note: the Address Counter will automatically increment or decrement by one after a write instruction to either the CGRAM or DDRAM, depending on the setting in the Entry Mode Set command. However, the data in the RAM selected by Address Counter cannot be read even if a read command is performed immediately after.

To read the data correctly, you will need to execute the Address Set command or Cursor Shift command (only with DDRAM).

Chapter 7

Initialization of the LCD

To ensure that your display runs properly, the following section provides information on the timing and initialization routine for the LCD for both 4-bit and 8-bit operation.

Upon power up of the display, provided that your timing meets those in Fig. 7.0, the display will perform an internal reset, and then the first stream of data can be sent to the display. In order for the display to perform correctly, the first stream of data should be the initialization routine. In addition, between each data write, you need to observe the timing required before sending the next set of data.

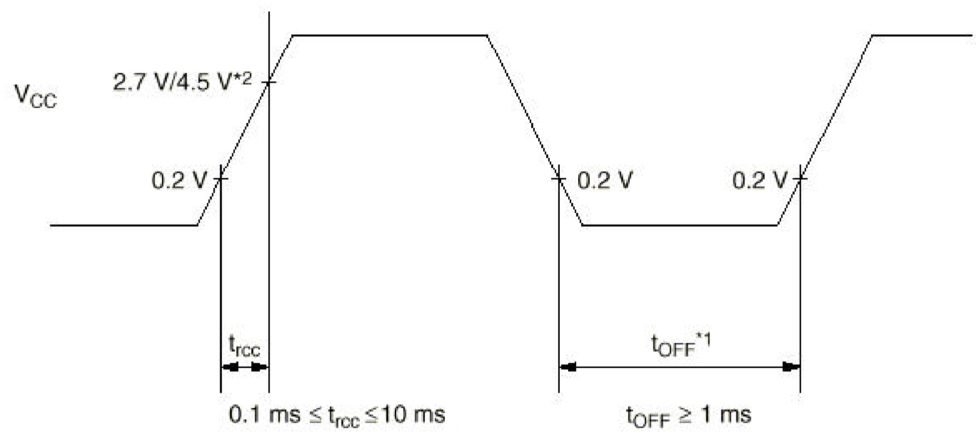


FIG 7.0

Notes:

1. T_{off} compensates for the power oscillation period caused by momentary power oscillations.
2. Specified at 4.5VDC for 5VDC operation.
3. If 4.5VDC is not reached within the time specified, the internal reset circuit will not function normally.

If the above conditions are met, the busy flag will go active 10ms after V_{cc} rises to 4.5VDC. The busy flag will remain active until the following commands are sent:

A. Display Clear
B. Function Set
C. Display ON/OFF Control
D. Entry Mode Set

The following flow chart shows the timing and the binary data required to initialize the LCD.

For 8-bit interface,

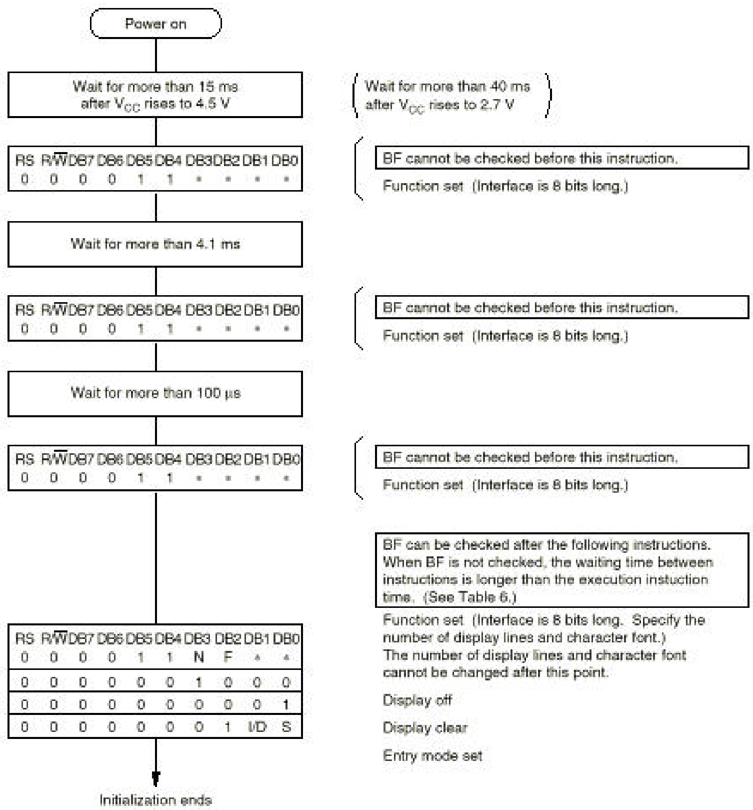


FIG. 7.1

For 4-bit interface,

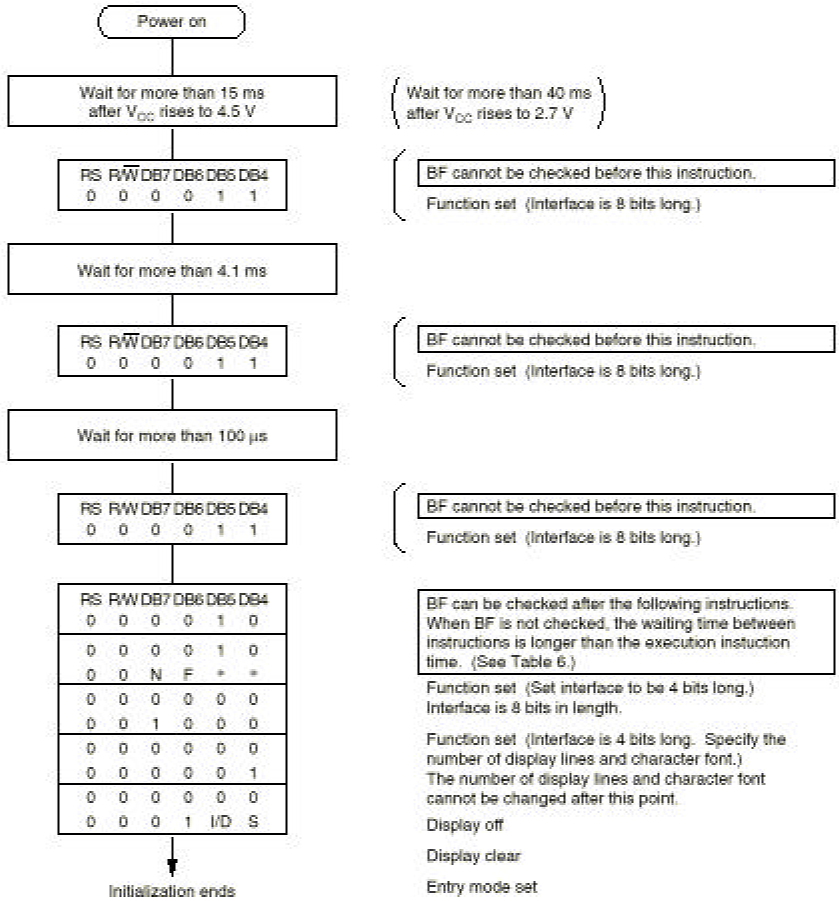


FIG 7.2

During these initialization sequences, the Busy Flag cannot be checked. You simply need to ensure that you provide ample timing between each command.

Relationship Between CGRAM Address, Character Codes (DDRAM) and Character Patterns (CGRAM Data)

This following section should give you a better understanding of the relationships between the CGRAM Address, Character Codes and Character pattern for both a 5 x 7 character as well as a 5 x 10 character

For 5x8 dot character pattern:

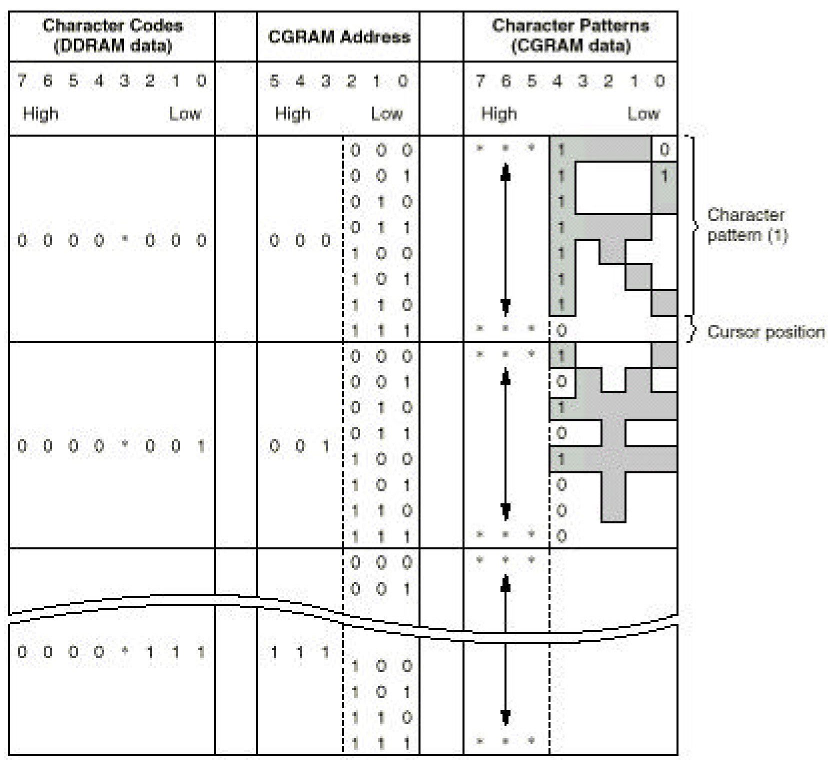


FIG. 8.0

Note:

1. Character codes 0~2 correspond to CGRAM address bits 3~5 (3 bits: 8 types).
2. CGRAM address bit 0~2 specify the line position for a character pattern. The 8th line is the cursor position and the logical OR of the 8th line and the cursor determines display. When the data in line 8 is set to a logic "0", the cursor is displayed. If the data is changed to a logic "1", one bit lights regardless of the cursor.
3. The character pattern columns positions corresponds to CGRAM data bits 0~4 and bit 4 is the left most position. CGRAM data bit 5~7 are not displayed but can be used for general data RAM.
4. When reading a character from pattern from CGRAM, set bit 4~7 of the character codes to a logic "0". Bits 0~2 determine which pattern will be read. Since Bit 3 is not valid, 00H and 08H select the same character.
5. In CGRAM data, a logic "1" corresponds to a selected pixel and a logic "0" for a non-selected pixel.

For 5x10 character pattern:

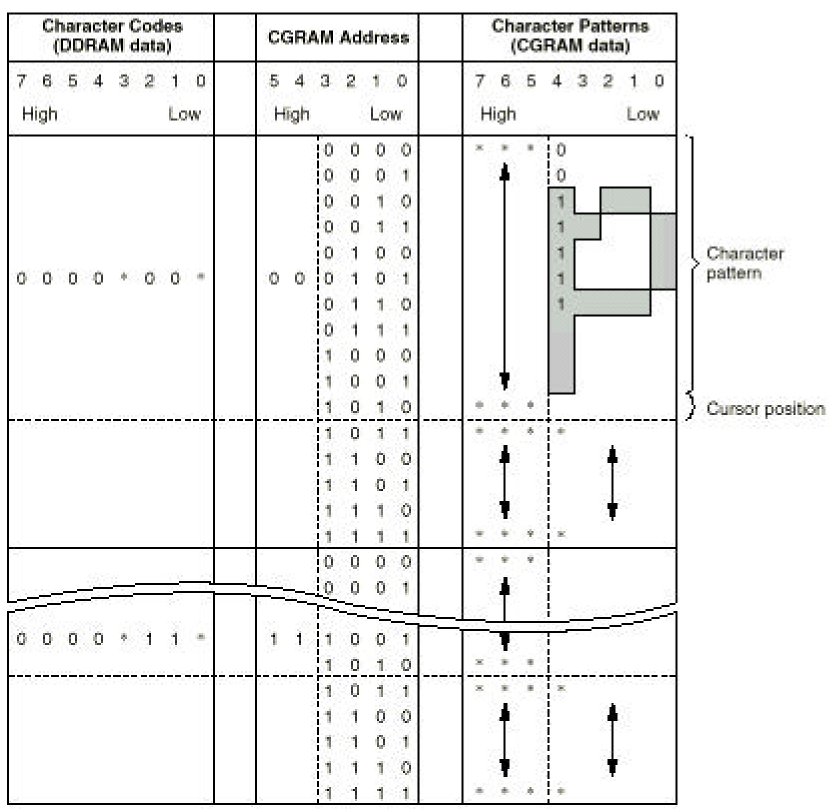


FIG 8.1

Note:

1. Character codes 1 & 2 correspond to CGRAM address bits 4 & 5 (2 bits: 4 types).

2. CGRAM address bit 0~3 specify the line position for a character pattern. The 11th line is the cursor position and the logical OR of the 11th line and the cursor determines display. When the data in line 8 is set to a logic "0", the cursor is displayed. If the data is changed to a logic "1", one bit lights regardless of the cursor.
3. The character pattern columns positions corresponds to CGRAM data bits 0~4 and bit 4 is the left most position. CGRAM data bit 5~7 are not displayed but can be used for general data RAM.
4. When reading a character from pattern from CGRAM, set bit 4~7 of the character codes to a logic "0". Bits 0~2 determine which pattern will be read. Since bit 0 and bit 3 is not valid, 00H, 01H, 08H and 09H select the same character.
5. In CGRAM data, a logic "1" corresponds to a selected pixel and a logic "0" for a non-selected pixel.

Chapter
9

Peripheral Circuits

This section should be used as a reference when designing peripheral circuits for the Liquid Crystal Display. The circuits mentioned are only examples and you need to adjust accordingly to your systems requirements.

There are various peripheral circuits that can be incorporated with the character based Liquid Crystal Display. For example, temperature compensation circuits, back-lighting types, and charge pump circuits. The manufacturer of your Liquid Crystal Display may have already incorporated some of these options.

Back-lighting Types

There are three basic types of backlight schemes that you can use to backlight your display - Electroluminescent Backlight (EL), Light Emitting Diode Backlight (LED), and Cold Cathode Fluorescent Lamp (CCFL, CFT). Each of these back-lighting schemes has their benefits as well as their drawbacks. We will discuss each type and give you a better understanding on which type of back-light is suitable for your application. In addition, we will discuss the driving method for each back-lighting scheme.

Electroluminescent Backlight (EL)

EL for short, this type of backlight is the most commonly used backlight for small character Liquid Crystal Displays. There are numerous reasons why this is the case:

1. It is a cold light source - the backlight does not generate any heat.
2. Emitted light is uniform across the display.
3. Backlight can be easily replaced.
4. Low power.
5. Thin.

The EL lamp is constructed with two coated electrode plates and an aluminum reflector. When an AC voltage is applied to the electrodes, the electrons collide with the light emission core. The energy given off is light. Fig. 9.0 shows the construction of an EL panel.

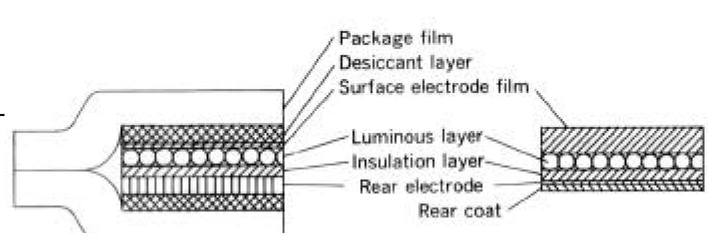


Fig. 9.0

The EL backlight is usually assembled with the display module and operated separately. In order for the EL backlight to work effectively, the display must be either a Transflective type or a Transmissive type (see Volume 1 or glossary for definitions) . In addition, the EL backlight requires an AC power supply. These AC power supplies are commonly known as Inverters and they can be purchased from the manufacturer or from third party manufacturers. The output from the Inverters are usually about 100~130VAC at a frequency of 400~1kHz with an input of +5VDC.

Despite the numerous benefits of the EL backlight, there is one major drawback - it's service life span. EL has the shortest usable life of only 2,000~5,000 hours. That's less than one year if you ran it 24hrs a day. When you reach this limit, the backlight is about half it's initial brightness from the day you first turned it on.

If the backlight is completely burned out or the brightness is no longer suitable for your application, you can usually replace the backlight by desoldering the EL lamp from the pads and sliding it out from the display.

Light Emitting Diode Backlight (LED)

This is the next most commonly used backlight with character based Liquid Crystal Displays. This type of backlight has some advantages over the EL backlight but also suffers in other areas.

The main benefit is the driving method. The LED backlight does not require an Inverter and it can be driven directly from a +5VDC supply with a current limiting resistor. Some of the other benefits include:

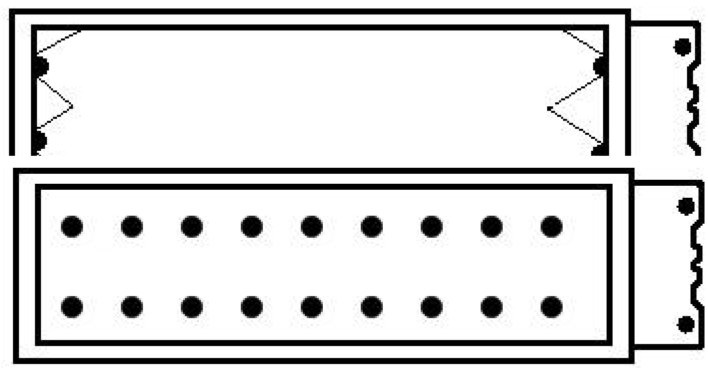
1. Longer service life - typically 50,000hrs
2. No DC-AC Inverter required
3. Uniform light source
4. Simple +5VDC operation
5. Available in Side-lit or Array configurations

The LED backlight has two configurations - an Edge-lit or Array configuration. In the Edge-lit configuration the LED's are mounted on the sides of a light guide that diffuses the light behind the display (see Fig. 9.1). This configuration uses the least amount of LED dies and consumes little power. Depending on the number of dies, the Edge-lit backlight can consume up to 20mA.

Fig. 9.1

However, the Edge-lit LED backlight has the poorest of brightness and uniformity. The emitted light is usually brightest at the LED and darkest near the center of the display (see Fig. 9.2). This effect is known as "Hot Spots." As the display gets larger, the Hot Spots become more prominent. Thus, this configuration is normally used on very small displays - like those used in cellular phones.

Fig. 9.2



The Array LED backlight configuration on the other hand provides excellent uniformity and almost no Hot Spots. In this configuration, the LED dies are mounted in a series-parallel configuration directly behind the display panel - see Fig. 9.3. Due to the number of LED dies, this configuration can consume up to 800mA or more! In addition, with more LED dies, the potential for heat build up is greatly increased and thus hindering display performance at higher temperatures - excessive heat can cause the display background to darken and eventually the display will have all pixels turn dark. This phenomenon is not permanent and the display will restore to it's normal condition once it is placed back into room temperature - **ONLY IF THE SURFACE TEMPERATURE OF THE DISPLAY DID NOT EXCEED THE MANUFACTURER'S SPECIFICATIONS!**

Fig. 9.3

Due to the reason of heat build-up, a current-limiting resistor is recommended for proper operation. Also, the current limiting resistor will ensure that the LED dies will not burn out due to excessive current. The value of the current limiting resistor is dependent on your preferences of brightness vs. maximum allowed current. Using Ohms Law you can determine the manufacturers recommended value, since the manufacturer usually provides the Forward Voltage and Current values.

Alternative LED Backlight Driving Methods

LED backlights are generally driven with a DC voltage through a current limiting resistor. This simple approach is perfectly acceptable for most applications. However, you can also drive the LED backlight by means of Pulse Width Modulation.

There are several advantages to using this method. Firstly, the main advantage is efficiency. For example, if the nominal driving current for an LED backlight is 100mA and produces a brightness of 25cd/m^2. If instead of using a constant current, we apply 5 times the current (500mA), for 20% of the time. The average current would be the same (see Fig 9.4).

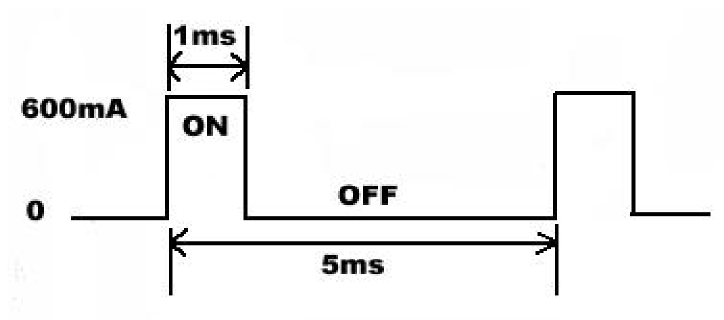


Fig 9.4

The second advantage is the ability to increase the brightness of the LED backlight without changing any components. To do this, all you need to do is vary the ON/OFF ratio (see Fig 9.5).

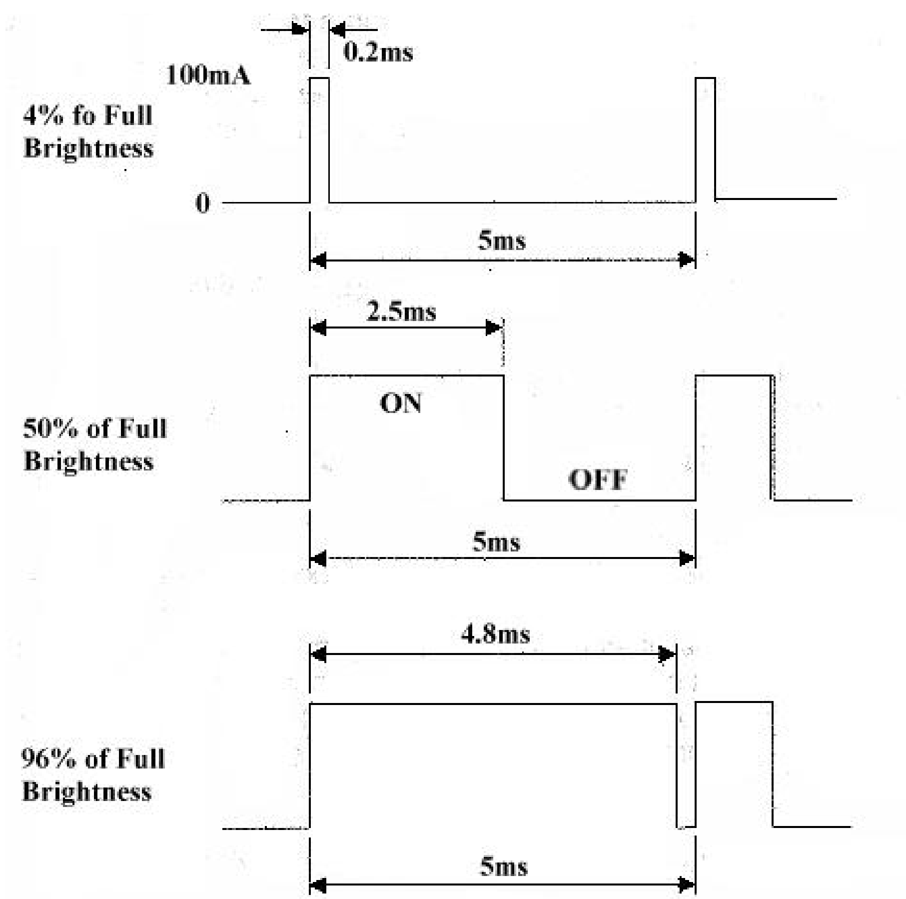


Fig 9.5

NOTE: To effectively implement the PWM method, the frequency of repetition should be greater than 100Hz and less than 1kHz. This will eliminate flickering.

Cold Cathode Fluorescent Lamp (CCFL)

You will see different abbreviations for this type of backlight; like CCFL, CFL, CCFT, and CFT. They are all basically the same. The abbreviations stand for Cold Cathode Fluorescent Lamp, Cold Fluorescent Lamp, Cold Cathode Fluorescent Tube, and Cold Fluorescent Tube, respectively.

This type of backlight is not very common with character based Liquid Crystal Displays. This type of backlight is usually found on graphics model, like those found in laptop computers.

This type of backlight requires an Inverter that will convert a DC voltage to an AC voltage, similar to the EL backlight. However, the Inverters for the CCFL are very different from those of the EL backlight. For starters, the CCFL lamp requires a start -up voltage of approx. 1KVAC and a driving voltage of approx. 600VAC~800VAC @ 30kHz. Be sure to check your specifications for exact driving conditions. If your inverter is not within the specifications, you can cause degraded life of the lamp.

One of the biggest benefits of using a CCFL backlight is the brightness it offers (approx. 200~600 cd/m^2). Another benefit is the white color emitted from the backlight.

This type of backlight is the most costly among the three (3) backlights that are available. Typical costs for the inverter alone can be in the low $20's to low $30's. Whereas and EL inverter can cost anywhere from $5~$15.

Summary of Backlighting Schemes

	EL	**LED**	**CCFL**
Thickness (mm)	0.6, 0.8, 1.5	2.0~6.0*	4.0~15.0*
Surface Brightness	65~100 cd/m^2	120 cd/m^2	200~600 cd/m^2
Color	Blue, Green, White	Yellow-Green, Green, Amber-Red	White
Life	2,000~5,000 Hrs.	50,000 Hrs (typ.)	15,000~20,000 Hrs.
Power	7mW/cm^2	50mW per 2 dies (typ.)	3W per tube
Voltage	100~130VAC 400Hz~1kHz	4VDC~8VDC	600~1000VAC 30kHz
Inverter Required	Yes (5VDC)	N/A	Yes (5 and 12VDC)

Fig. 9.6

Temperature Compensation Circuits

A Temperature Compensation Circuit will adjust the driving voltage to the display over temperature, since temperature affects the display characteristics - slow response time and poor contrast ratio at low temperatures and dark display at high temperatures. If your system allows the user to adjust the contrast, then a Temperature Compensation Circuit may not be necessary.

Depending on the type of display you have, the values used in a Temperature Compensation Circuit will be different. For example, if you had a 1/8 duty display, the driving voltage will be much lower than that of a 1/16 duty display (see Fig. 9.7). Thus, the output from the Temperature Compensation Circuit will need to be adjusted to the type of display you have.

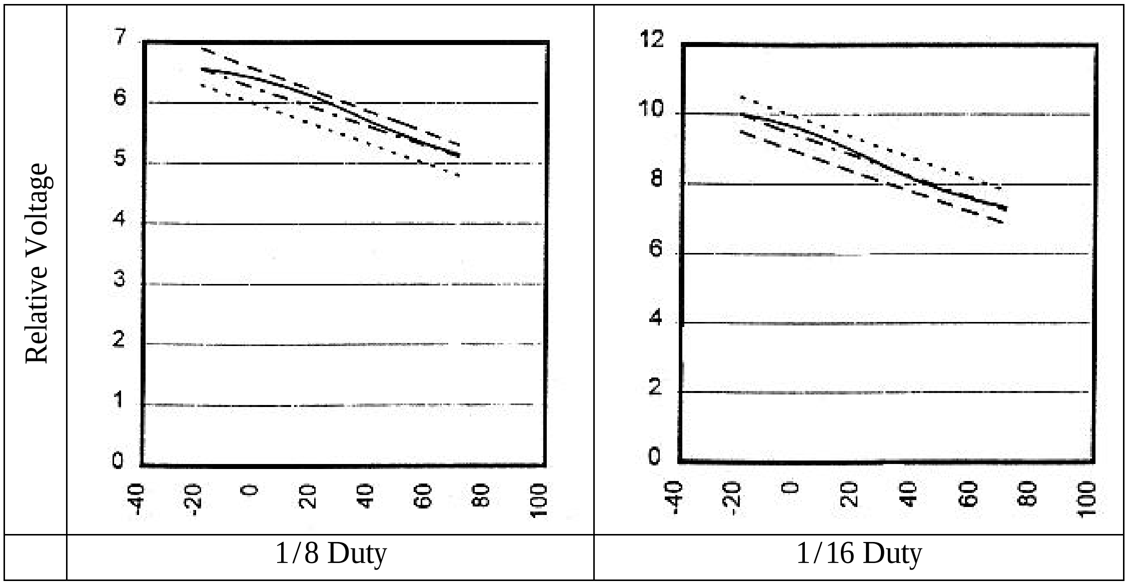


Fig. 9.7

Here is an example of a Temperature Compensation Circuit to drive both the 1/8 and 1/16 duty cycle display – you will need to adjust the values of the components to match your displays drive requirements:

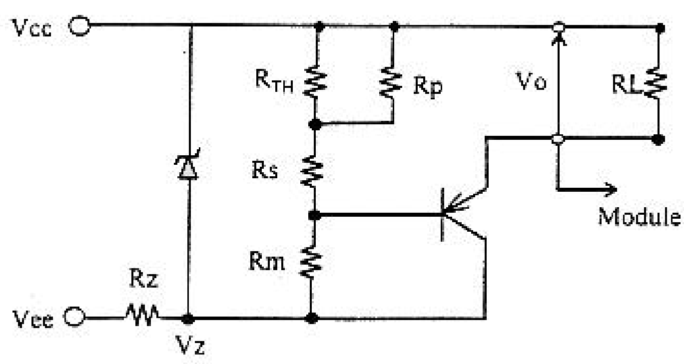


Fig. 9.8

Negative Voltage Charge Pump

In the case of an extended temperature LCD, a negative voltage is usually necessary to obtain satisfactory contrast. This negative voltage is applied to one end of a potentiometer and the other end of the potentiometer is applied to V_{CC}. Then the center tap of the potentiometer is applied to Pin 3 or the Operating Voltage for LCD drive pin (V_{ADJ}, V_{EE}, or V_O – depending on the labeling used by the LCD manufacturer). Fig. 9.9 shows a sample connection to the Operating Voltage for LCD drive pin and Fig 9.10 shows a sample –5V Charge Pump.

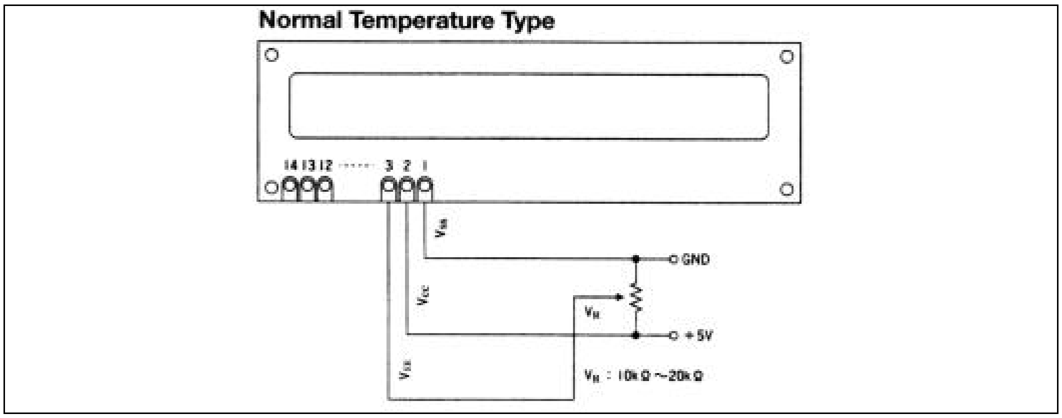


Fig 9.9

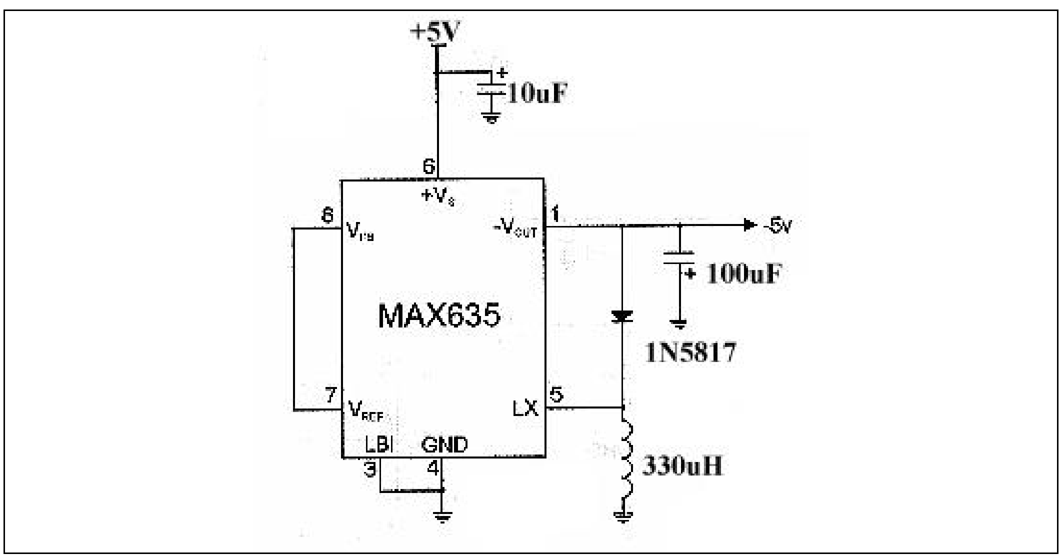


Fig 9.10

Chapter

10

Troubleshooting

Despite the perfect execution of a plan and design, there may still be problems with the operation of the Liquid Crystal Display. This section will answer the most commonly encountered problems and provide you with suggestions to correct them..

Although the following problems and possible solutions are not all inclusive, they do represent the most common problems experienced, by not only the first time user, but also by experienced users. If your display still exhibits some problems after reviewing this section, you should contact your manufacturer for more information.

Most Common Problems and Solutions

Symptoms	Solutions
IC's become very HOT to the touch!	• Check the power supply lines are connected to the right terminals (+5VDC = Vcc, 0VDC = GND). • Check to make sure you are not supplying too much voltage. • Too much voltage on V_{DD}. • Load is being placed on the data lines when power to the display is OFF.

Display is blank after turning on power and sending initialization sequence.	• Check the power supply lines are connected to the right terminals (+5VDC = Vcc, 0VDC = GND).
	• Check to make sure you are not supplying too much voltage.
	• Too much drive voltage. Adjust the potentiometer.
	• Add a 10k~20k potentiometer to the LCD drive Pin (V_{EE} or V_{ADJ}).
	• Failure to properly initialize the display. Check initialization for either 4-bit or 8-bit operation. Make sure that the sequence 3*H is sent three times with the appropriate delay times between each.
	• Data is being sent too fast:
	  • Wait more than 15mS after V_{CC} reaches +4.5VDC.
	  • Wait more than 1.6mS after initialization before

	sending Clear Display and Return Home commands. • Check to make sure that you allow more than 50µS between each command during the initialization routine. • The display input is conFig.d as an IC. The Enable line cannot be tied to V_{CC} or GND. This is a clocking signal to latch the data into the registers. • Check the time interval on the falling edge of the enable pulse. Should not exceed 25nS.

Wrong information being displayed.	• Failure to properly initialize the display. Check initialization for either 4-bit or 8-bit operation. Make sure that the sequence 3*H is sent three times with the appropriate delay times between each.
	• Data is being sent too fast:
	  • Wait more than 15mS after V_{CC} reaches +4.5VDC.
	  • Wait more than 1.6mS after initialization before sending Clear Display and Return Home commands.
	  • Check to make sure that you allow more than 50µS between each command during the initialization routine.
	• Check the time interval on the falling edge of the enable pulse. Should not exceed 25nS.
	• More than one external bus being selected. Check data bus connection.
	• Signal levels are too low. Insure that the signals are more than 2.4VDC.

Cannot enter information to the second line.	• Failure to properly initialize the display. Check initialization for either 4-bit or 8-bit operation. Make sure that the sequence 3*H is sent three times with the appropriate delay times between each. • Check address locations for the first position on the second line (see DDRAM addressing).
Cannot enter information to the 3rd and 4th line of a 40x4 display.	• Check that your E2 (second Enable line) is clocked when writing to the 3rd and 4th lines.
Display does not display characters beyond the 8th character of a 16x1 display.	• This is a 1/16 duty cycle display. The 8th thru 16th characters are really a second line in the display. See DDRAM address for the correct position of the 8th to 16th character.
Data on display is garbled on a 20x4 display.	• Failure to properly initialize the display. Check initialization for either 4-bit or 8-bit operation. Make sure that the sequence 3*H is sent three times with the appropriate delay times between each. • Oscillation frequency and timing is different. Most

	manufacturers use a 200kΩ Oscillation resistor for the HD44780 on the 20x4 displays to reduce flickering. Therefore, the timing diagrams and commands will be different. • Older controller was used on your display. Check the HD44780 on the display for an "S" mark on the chip. If exists, then you have an older chip. This model has been discontinued and replaced with a new model. The new chip has an "U" imprinted on the LSI. The "U" chip has improved timing and is more sensitive to noise. See "U vs. S" in appendix for resolution.
Display is completely dark.	• Too much drive voltage. Adjust the potentiometer. • Add a 10k~20k potentiometer to the LCD drive Pin (V_{EE} or V_{ADJ}).
New display placed into same system does not work the same.	• Older controller was used on your display. Check the HD44780 on the display for an "S" mark on the chip. If exists, then you have an older chip. This model has been discontinued and replaced with a new model. The new chip has an "U" imprinted on the LSI. The "U" chip has improved timing and is more sensitive to noise. See "U vs. S" in appendix for resolution.

Other Problems You May Encounter

The following are other phenomena that you may encounter while using the display.

1) Discoloration along the edges and/or "Veining effect":
   - Too much pressure has been exerted by your enclosure and has collapsed the LCD cell. Reduce the amount of pressure applied to the display bezel. **DO NOT SANDWICH THE DISPLAY** to hold it in position.
   - Avoid torquing the display. Loosen up the mounting on the display.
2) Bubble on display:
   - Air bubble caused by improper application of polarizers.
3) Surface of display not even:
   - Too much heat on display and caused de-lamination of polarizers. If you have an LED backlight, add a current limiting resistor to reduce the current. You will sacrifice brightness for improved display performance.
   - Do not operate the display beyond the manufacturers operating temperature specifications.
4) Missing lines - Elastomer Strip Connection (horizontal and/or vertical):
   - Elastomer Strip has shifted from original position. Possibly caused by excessive shock and vibration. Re-alignment of elastomer strip required.
   - Trace from driver(s)/controller damaged. Check for nicks and broken traces on the PCB.
   - Check for shorts on the LSI that are mounted on the PCB.
5) Missing lines - Heat Seal Connection (horizontal and/or vertical):
   - Heat seal has been damaged. Check for cuts in the heat seal.
   - Connection faulty on either end of the heat seal.
   - Trace from driver(s)/controller damaged. Check for nicks and broken traces on the PCB.
   - Check for shorts on the driver(s)/controller.
6) Contrast not even in each character cell:
   - Check the BIAS resistor network is not damaged (4~5 resistors placed in series on PCB).
   - Driver and/or controller may have suffered ESD damage.

- Driver and/or controller may have suffered excessive voltage. Check noise spikes do not exceed the absolute maximum for the display.

Appendix

A

Appendix A : U vs. S

The controller that is used on the character modules has been upgraded. However, some manufacturers still have excess inventory of this chip and still use them on some of their products.

The Hitachi HD44780 chip is the industry standard LSI for character based LCD's. However, in the early 90's the LSI was upgraded and improved. The LSI was claimed to be 100% compatible with the older version LSI, but this was not the case. The new LSI was about 90% compatible. The remaining 10% was all timing issues.

Most of the customers that were using the older chip, known as the "S" chip, were automatically upgraded to the new chip, known as the "U" chip. But this created some problems in the industry. Some customers were experiencing display problems ranging from words missing characters to data placed in the wrong location. But when they replaced the new display with the original display, the problem went away.

It turned out that the new "U" chip was more sensitive to noise. Small ripples on the control lines would actually cause the display to perform erratically.

If the above situation applies to you, then try the following fixes (try the first item, if problem still persists, then try the second and so forth):

1. Place a 500pF~800pF capacitor across the Enable line and V_{SS}.
2. Place a 500pF~800pF capacitor across the R/W and RS lines
3. Place a 4.7µF~33µF capacitor across V_{CC} and V_{SS}.
4. Place a 0.1µF~0.01µF capacitor in parallel with #3.

Appendix

B

Appendix B : Font Table

Here is the standard font table for the HD44780 controller..

Lower 4 Bits \ Upper 4 Bits	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
xxxx0000	CG RAM (1)			0	@	P	`	p				ー	タ	ミ	α	p
xxxx0001	(2)		!	1	A	Q	a	q			。	ア	チ	ム	ä	q
xxxx0010	(3)		"	2	B	R	b	r			「	イ	ツ	メ	β	θ
xxxx0011	(4)		#	3	C	S	c	s			」	ウ	テ	モ	ε	∞
xxxx0100	(5)		$	4	D	T	d	t			、	エ	ト	ヤ	μ	Ω
xxxx0101	(6)		%	5	E	U	e	u			・	オ	ナ	ユ	σ	ü
xxxx0110	(7)		&	6	F	V	f	v			ヲ	カ	ニ	ヨ	ρ	Σ
xxxx0111	(8)		'	7	G	W	g	w			ァ	キ	ヌ	ラ	g	π
xxxx1000	(1)		(	8	H	X	h	x			ィ	ク	ネ	リ	√	x̄
xxxx1001	(2)		)	9	I	Y	i	y			ゥ	ケ	ノ	ル	⁻¹	y
xxxx1010	(3)		*	:	J	Z	j	z			ェ	コ	ハ	レ	j	千
xxxx1011	(4)		+	;	K	[	k	{			ォ	サ	ヒ	ロ	ˣ	万
xxxx1100	(5)		,	<	L	¥	l	|			ャ	シ	フ	ワ	¢	円
xxxx1101	(6)		-	=	M	]	m	}			ュ	ス	ヘ	ン	£	÷
xxxx1110	(7)		.	>	N	^	n	→			ョ	セ	ホ	゛	ñ	
xxxx1111	(8)		/	?	O	_	o	←			ッ	ソ	マ	゜	ö	█

Appendix

C

Appendix C : Sample Software

The following are samples of the initialization routine and data for both 4-bit operation and 8-bit operation. These programs are only meant for reference purposes only!

4-Bit Operation

Code (Hex)	D7	D6	D5	D4	D3	D2	D1	D0	Description
									Wait more than 15mS after VCC=4.5V
3H	0	0	1	1	-	-	-	-	Reset Sequence *
3H	0	0	1	1	-	-	-	-	Reset Sequence *
3H	0	0	1	1	-	-	-	-	Reset Sequence *
2H	0	0	1	0	-	-	-	-	Function Set • 4 bit data length
8H	1	0	0	0	-	-	-	-	Function Set • 2 Line • 5x7 Character Font
0H	0	0	0	0	-	-	-	-	Entry Mode Set
6H	0	1	1	0	-	-	-	-	Entry Mode Set • Increment Cursor Position • No display shifting
0H	0	0	0	0	-	-	-	-	Display ON / OFF Control
EH	1	1	1	0	-	-	-	-	Display ON / OFF Control • Display ON • Cursor ON • Blink OFF
0H	0	0	0	0	-	-	-	-	Display Clear
1H	0	0	0	1	-	-	-	-	Display Clear

8H	1	0	0	0	-	-	-	-	DDRAM Address Set - Home Position
0H	0	0	0	0	-	-	-	-	Top left most Character of the display.
End Initialization Routine									
4H	0	1	0	0	-	-	-	-	Write the high order bit for H
8H	1	0	0	0	-	-	-	-	Write the low order bit for H
4H	0	1	0	0	-	-	-	-	Write the high order bit for E
5H	0	1	0	1	-	-	-	-	Write the low order bit for E
4H	0	1	0	0	-	-	-	-	Write the high order bit for L
CH	1	1	0	0	-	-	-	-	Write the low order bit for L
4H	0	1	0	0	-	-	-	-	Write the high order bit for L
CH	1	1	0	0	-	-	-	-	Write the low order bit for L
4H	0	1	0	0	-	-	-	-	Write the high order bit for O
FH	1	1	1	1	-	-	-	-	Write the low order bit for O

*** - The Busy Flag cannot be checked during these stages.**

8-Bit Operation

Code (Hex)	D7	D6	D5	D4	D3	D2	D1	D0	Description
									Wait more than 15mS after VCC=4.5V
3xH	0	0	1	1	-	-	-	-	Reset Sequence *
3xH	0	0	1	1	-	-	-	-	Reset Sequence *
3xH	0	0	1	1	-	-	-	-	Reset Sequence *
38H	0	0	1	1	1	0	0	0	Function Set • 8 bit data length • 2 Line display • 5x7 Character dot format
06H	0	0	0	0	0	1	1	0	Entry Mode Set • Auto Cursor increment • No display shifting
0EH	0	0	0	0	1	1	1	0	Display ON/OFF Control • Display ON • Cursor ON • Cursor Blink OFF
01H	0	0	0	0	0	0	0	1	Clear Display Command
80H	1	0	0	0	0	0	0	0	DDRAM Address Set to the Home Position - Top left most character

									position.
End Initialization Routine									
48H	0	1	0	0	1	0	0	0	Writes the Character H
45H	0	1	0	0	0	1	0	1	Writes the Character E
4CH	0	1	0	0	1	1	0	0	Writes the Character L
4CH	0	1	0	0	1	1	0	0	Writes the Character L
4FH	0	1	0	0	1	1	1	1	Writes the Character O

Appendix
D

Appendix D : Glossary

Active Area: The dimensions of the conductive area that is within the viewing area or the area that contains the pixels.

Aperture Ratio: This is the ratio of active contrast producing area to overall display area. Aperture ratio is reduced by bus lines, masks, or switching devices on the display substrate that are not optically active. Aperture ratio is also called fill factor. It is used to describe the ratio of width to height of a display screen.

Bezel: A metal or plastic frame that fits over the LCD panel. The bezel acts as a pressure device that compresses the elastomer connector between the glass and PCB. Or this is the frame that holds the display together.

Birefringence: The resolution or splitting of a light wave into two unequally reflected waves by an optically anisotropic medium.

Cell Gap: The spacing between the two sheets of glass that contains the Liquid Crystal Fluid.

Chip-On-Board: A controller mounting technique that involves the mounting of the bare die to the PCB and then wiring micro diameter gold wires from the die to the PCB. Then a coat of hard epoxy protects the entire die and the wires.

Chip-On-Glass: A controller mounting technique that involves the mounting of the bare die to the glass.

Chip-On-Flex: A controller mounting technique that involves the mounting of the bare die to a flex circuit.

Common: The conductive surface on one of the two pieces of glass, which superimposes the pattern on the second piece of glass. The number of commons corresponds to the duty ratio.

Cold Cathode Fluorescent Backlight: A type of backlight that uses a gas sealed in a vacuum that is ignited by a high AC voltage and driven by a constant current.

Contact Edge: The extended area of the LCD glass that contains the conductive leads/traces, to which the electrical connections are made.

Contrast Ratio: The difference in luminance between the unselected area and the selected area. This number can vary depending on the manufacturers measuring method.

Cross-talk: See Ghosting.

Cursor: A row or block of dots used to indicate the location of the character.

DIL (Dual-In-Line): This refers to the physical interface connection scheme. A DIL display means that the interface comprises of two rows of PTH (Plated Thru Holes).

Direct/Static Drive: Each conductive lead on the contact edge connects to one segment or Icon. The number of segments corresponds to the number of connections on the contact edge of the display. The duty ratio is 1:1.

Dithering: this is similar to half-toning, where the number of ON pixels per unit area is changed in order to produce gray scales.

Dot/Pixel: The active element is the display. When combined together in a matrix, the dots form a character or symbol.

Dot Matrix: A group of dots/pixels forming a character or symbol.

Duty Ratio: Usually specified as 1/N, where N equals the number of energized or un-energized segments selected by one complete cycle. N also refers to the number of multiplexed lines.

Elastomer Connector/Zebra Strip: A strip of silicone rubber made up of sequentially spaced conductive and non-conductive material.

Electrophoresis: A phenomenon that occurs when excess DC voltage is applied to the LC panel. Conductive particles from one sheet of glass are transferred through the LC fluid and deposited on the conductive surface of the opposite sheet of glass.

Electroluminescent Lamp: A backlight system that is comprised of two coated electrode plates with an aluminum reflector covered in a translucent soft plastic housing. When an AC voltage is applied to the electrodes, the electrons collide with the light emission core and the energy given off is light.

End Seal: This is the bump found on one side of all LCD's. This bump is used to seal the liquid crystal material from spilling out of the module.

Fill Hole: The gap left between the epoxy seals after the assembly on one of the LCD glass. This space is used to fill the glass with the Liquid Crystal fluid and then is sealed off by the End Seal.

Film Compensated STN (FSTN): See "Retardation Film."

Flicker Fusion Rate: This is the rate above which the human eye can no longer recognize discontinuous changes in brightness as an annoying flicker. Provided the frame frequency is above this rate, the eye automatically integrates the signal into a continuos whole. The flicker fusion rate is 31.25Hz.

Font: The active pattern that has all the information to be displayed on the LCD glass.

Ghosting: A phenomenon which occurs when voltage from an energized pixel leaks to an adjacent OFF pixel and turns the adjacent pixel partially ON. This is also known as cross-talk.

Gray Scale: Term used to describe the ability of a display to be in the state of intermediate ON and OFF. These states are called "Gray Levels." The gray scale is then composed of a number of gray levels.

Heat Seal: A flat and flexible adhesive connector that is bonded to the contact edge of the display by heat. The other side of the connector is bonded to the PCB in the same manner.

Indium Tin Oxide (ITO): The conductive traces on the contact edge of the sheet of glass.

Interconnect Dot: The conductive elements that connect the back-plane to the contact edge of the sheet of glass.

Inverter: A DC-AC converter that converts the DC voltage to AC voltages to drive the Electroluminescent and Cold Cathode Fluorescent backlights.

Isotropic Stage: When the fluid heats up or cools down to the point where the fluid is no longer in the mesophase state. The molecules can no longer twist light and, therefore, all incoming light is absorbed.

LED Backlight: A form of backlighting that incorporates surface mount LED's mounted on a substrate with a light diffuser over the top (Array or direct backlit). In some cases, the LED's are placed at the ends of the module and light is directed towards the center (edgelit backlight).

Liquid Crystal Fluid: A substance that has the properties of both a fluid and a solid. The Liquid Crystal Fluid is a bi-polar rod shaped molecule, which in the off state is capable of twisting polarized light.

Module: A complete display assembly consisting of an LCD glass connected to a PCB with drive electronics.

Multiplex: Using multiple commons in order to reduce the number of connections between the drivers and the LCD panel.

Negative Image: In the off state, the viewing area of the display is dark. When an image is displayed, the image is a lighter color than the background. The activated pixels are of a lighter color or white.

Pitch: The center to center dimension of an adjacent conductive trace, dot, or connector.

Polarizers: Made of a polymer acetate with iodide molecules incorporated in the material. The molecules are arranged to only allow scattered light to enter in one plane/axis. Most LCD's incorporate two polarizers – one on the front of the panel and one behind the back panel. For more details on polarizers, see All About LCD's - Volume 1.

Positive Image: In the off state, the viewing area of the display is light. When an image is displayed, the image is a darker color than the background. The activated pixels are dark or black.

Retardation Film: A thin piece of material laminated to the front and/or rear polarizer to change the color of the dark blue pixel to black. Most commonly used on large graphic LCD's with CCFL backlights and called FSTN.

Reflective: A term used to describe the polarization of the display. A reflective display cannot be backlit and is used primarily in very well lit areas. The display reflects the incoming ambient light.

Saturation Voltage: The RMS voltage required to turn the fluid to 90% ON.

Segment: An active element in the display.

Single-In-Line (SIL): This refers to the physical interface connection scheme. A SIL display means that the interface comprises of one single row of PTH (Plated Thru Holes).

Supertwisted Nematic (STN): A Twisted Nematic fluid that has a better contrast ratio and viewing angle of the standard Twisted Nematic. The rotation of the molecule in the Cell Gap is rotated between 180° to 240°.

Tape Automated Bonding (TAB): The LSI die is encapsulated in a thin, hard plastic substrate. The TAB is mounted onto the LCD panel by anisotropic adhesive and the other side of the TAB is soldered to the PCB.

Threshold Voltage: The RMS voltage required to turn the LC fluid to 10% ON.

Transflective: A term used to describe the polarization of the display. A Transflective display can be backlit and used in very well lit or dark areas. The display can reflect the incoming ambient light or transmit the light from its backlight source.

Transmissive: A term used to describe the polarization of the display. A Transmissive display must be backlit and is used primarily in low light areas. The display transmits the light from its backlight source. If the ambient light is brighter than the backlight, the display will be washed out.

Twisted Nematic: A type of Liquid Crystal Fluid where the molecule's orientation on the front panel to the rear panel is rotated by 90°.

Viewing Angle: A cone perpendicular to the LCD surface in which the minimum contrast can be seen.

Viewing Area: The dimensions measured from the inside perimeter of the LCD Bezel or LCD panel seal area.