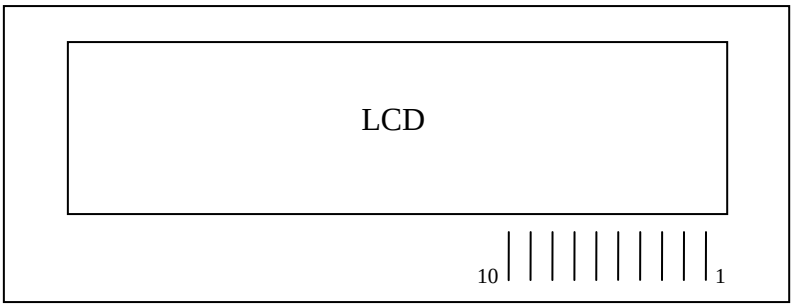
4-bit LCD Interface Notes

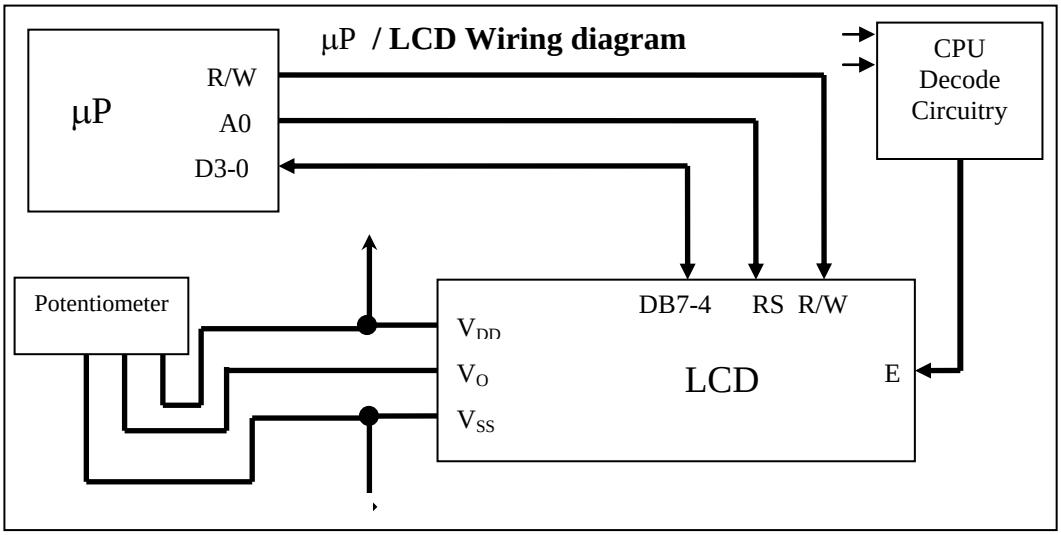
LCD Panel Pinouts and Connections to CPU (for data bus connectivity)

- Verify that the position of pin 1 on your LCD board. There should be a 1 next to pin 1 and a 10 next to pin 10. My LCD board is arranged as shown to the right.

LCD Board Pinout

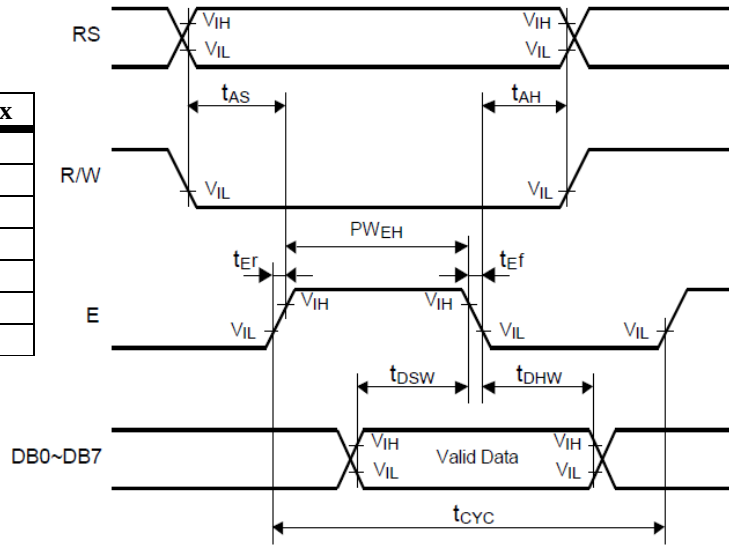


- The register select signal (RS) can be viewed as an address input and can be connected directly to the CPU's address pin A_0. This bit selects between the two addressable registers called Command (with A_0=0) and Data (with A_0=1).
- The enable pin (E) is the chip select/enable for the LCD. A memory mapped decoded E signal must be created for enabling/disabling this device. The LCD can be considered a write-only device. [If you want to read from the device, DB7 is the busy flag (BF) that when clear means the LCD is ready for the next command. If this is done the delays in the below flow chart are unnecessary.]
- You can verify that your LCD works properly before connecting your LCD data pins. Give power to the device and twist the potentiometer one way or the other until you see black lines appear.
- Data or commands are read at the **falling edge of E**.



From the Densitron LM2022 LCD specifications posted on our website.

Parameter (in ns)	Symbol	Min	Max
Enable Cycle Time	T_{CYC}	500	–
Enable Pulse Width	PW_{EH}	230	–
Enable Rise/Fall Time	t_{Er} / t_{Ef}	–	20
Address Setup Time	t_{AS}	40	–
Address Hold Time	t_{AH}	10	–
Write Data Setup Time	t_{DSW}	80	–
Write Data Hold Time	t_{DHW}	10	–



4-bit LCD Interface Notes

Important Notes regarding 4-bit mode:

The difference between 4-bit and 8-bit LCD operation is that data is sent out as **nibbles** instead of a single **byte**. DB7:DB4 are used to transfer nibbles to/from the LCD module (DB7 is the MSB). Commands and data are still 8 bits long, but are transferred as two 4-bit nibbles on the LCD data bus lines DB7:DB4. **The most significant nibble should be transferred first, followed by the least significant nibble.** There must be a delay (approx. 1.5 ms) between each nibble transfer. The optimal contrast for the LCD (Vo) is 3.3 - 3.7V.

LCD Pin assignments
Adapted from the Densitron LM2022 LCD SpecSheet

Pin #	Symbol	I/O	Function
1	V_{SS}	-	Ground (0V)
2	V_{DD}	-	Logic Supply Voltage (+5V)
3	V_O	-	LC Drive voltage for contrast adjustment
4	RS	I	Register Select 0: Command Register 1: Data Register
5	R/W	I	Read/Write 0: Data Write (Module ← MPU) 1: Data Read (Module → MPU)
6	E	I	Enable Signal Active High
7	DB4	I/O	Bi-directional data bus line 4 (LSB)
8	DB5	I/O	Bi-directional data bus line 5
9	DB6	I/O	Bi-directional data bus line 6
10	DB7	I/O	Bi-directional data bus line 7 (MSB)

Initialization for 4-bit operation

The module powers up in 8-bit mode. The initial start-up instructions are sent in 8-bit mode, with the lower four bits (which are not connected) of each instruction as don't cares. The first block of the flow chart is described below. See the LCD notes on the website for more similar info.

<POWER ON>
<Wait at least 15ms>

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

<Wait at least 4.1ms>

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

<Wait at least 100us>

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

<Wait 4.1ms>

(4-bit operation)

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

4-bit LCD Interface Notes

Normal Further Initialization

<Wait 40us or till BF=0>

(Two lines) [DB=$28]

RS	R/W	DB7	DB6	DB5	DB4
0	0	0	0	1	0
0	0	1	0	0	0

<Wait 40us or till BF=0>

(Display on; cursor on; blink on) [DB=$0F]

RS	R/W	DB7	DB6	DB5	DB4
0	0	0	0	0	0
0	0	1	1	1	1

<Wait 40us or till BF=0>

(Clear screen; cursor home) [DB=$01]

RS	R/W	DB7	DB6	DB5	DB4
0	0	0	0	0	0
0	0	0	0	0	1

<Wait 1.64ms or till BF=0>

<INITIALIZATION COMPLETE>

Other useful Commands

***(Increment cursor to the right when writing; don't shift screen) [DB=$06]**

RS	R/W	DB7	DB6	DB5	DB4
0	0	0	0	0	0
0	0	0	1	1	0

<Wait 40us or till BF=0>

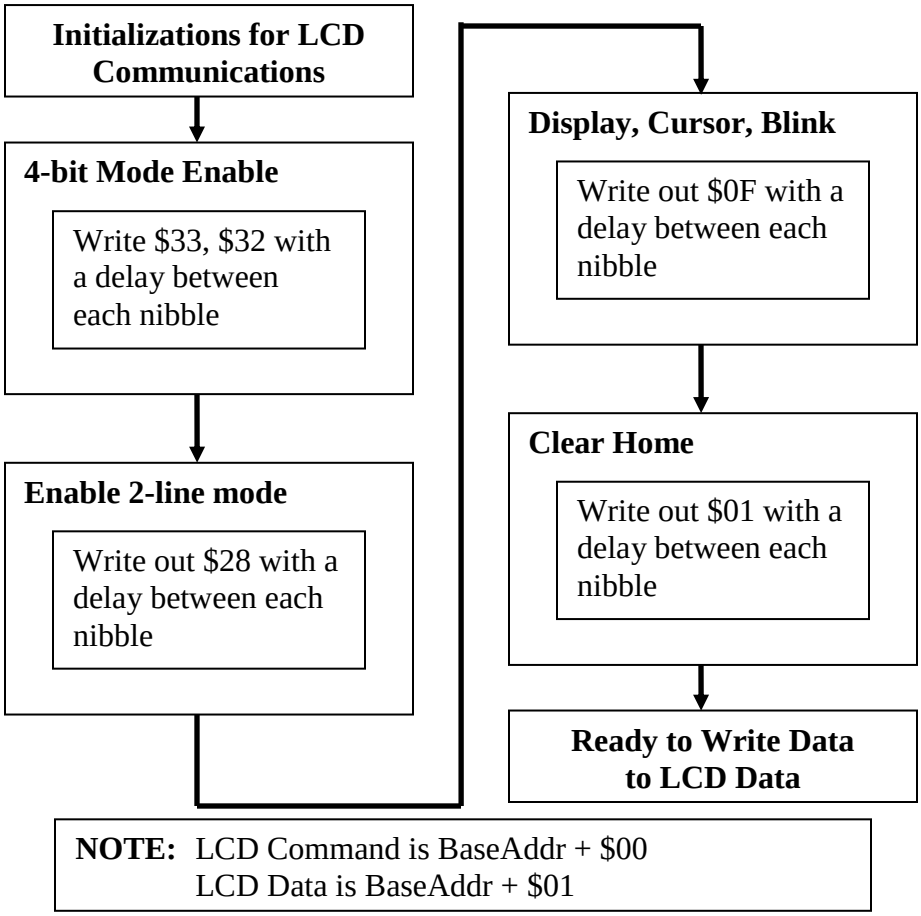
(Display off; cursor off; blink off) [DB=$08]

RS	R/W	DB7	DB6	DB5	DB4
0	0	0	0	0	0
0	0	1	0	0	0

<Wait 40us or till BF=0>

4-bit LCD Interface Notes

LCD Initialization



NOTE: LCD Command is BaseAddr + $00
LCD Data is BaseAddr + $01

4-bit LCD Interface Notes

MORE LCD COMMANDS

Command	Code	Delay
Clear Display, Cursor to Home	**$01**	1.65ms
Cursor to Home	**$02**	1.65ms
Entry Mode:		
Cursor Decrement, Shift off	**$04**	40µs
Cursor Decrement, Shift on	**$05**	40µs
Cursor Increment, Shift off	**$06**	40µs
Cursor Increment, Shift on	**$07**	40µs
Display Control:		
Display, Cursor, and Cursor Blink off	**$08**	40µs
Display on, Cursor and Cursor Blink off	**$0C**	40µs
Display and Cursor on, Cursor Blink off	**$0E**	40µs
Display, Cursor, and Cursor Blink on	**$0F**	40µs
Cursor / Display Shift: (nondestructive move)		
Cursor shift left	**$10**	40µs
Cursor shift right	**$14**	40µs
Display shift left	**$18**	40µs
Display shift right	**$1C**	40µs
Display Function (2 rows for 4-bit data; big)	**$2C**	40µs
Display Function (2 rows for 4-bit data; small))	**$28**	40µs
Display Function (1 row for 4-bit data; big)	**$24**	40µs
Display Function (1 row for 4-bit data; small)	**$20**	40µs
Display Function (2 rows for 8-bit data; big)	**$3C**	40µs
Display Function (2 rows for 8-bit data; small)	**$38**	40µs
Display Function (1 row for 8-bit data; big)	**$34**	40µs
Display Function (1 row for 8-bit data; small)	**$30**	40µs
Move cursor to beginning of second row	**$C0**	40µs
Character Generator RAM Address set	**$40-$7F**	40µs
Display RAM Address set	**$80-$FF**	40µs

4-bit LCD Interface Notes

LCD Character Codes

4-bit LCD Interface Notes

SUMMARY OF LCD COMMANDS

Instruction	Code										Description
	RS	**R/W**	**DB7**	**DB6**	**DB5**	**DB4**	**DB3**	**DB2**	**DB1**	**DB0**	
Clear display	0	0	0	0	0	0	0	0	0	1	Clears display and returns cursor to the home position (address 0).
Cursor home	0	0	0	0	0	0	0	0	1	*	Returns cursor to home position (address 0). Also returns display being shifted to the original position. DDRAM contents remains unchanged.
Entry mode set	0	0	0	0	0	0	0	1	I/D	S	Sets cursor move direction (I/D), specifies to shift the display (S). These operations are performed during data read/write.
Display On/Off control	0	0	0	0	0	0	1	D	C	B	Sets On/Off of all display (D), cursor On/Off (C) and blink of cursor position character (B).
Cursor/display shift	0	0	0	0	0	1	S/C	R/L	*	*	Sets cursor-move or display-shift (S/C), shift direction (R/L). DDRAM contents remains unchanged.
Function set	0	0	0	0	1	DL	N	F	*	*	Sets interface data length (DL), number of display line (N) and character font(F).
Set CGRAM address	0	0	0	1	CGRAM address						Sets the CGRAM address. CGRAM data is sent or received after this setting.
Set DDRAM address	0	0	1	DDRAM address							Sets the DDRAM address. DDRAM data is sent or received after this setting.
Read busy-flag and address counter	0	1	BF	DDRAM address							Reads Busy-flag (BF) indicating internal operation is being performed and reads address counter contents.
Write to CGRAM or DDRAM	1	0	write data								Writes data to CGRAM or DDRAM.
Read from CGRAM or DDRAM	1	1	read data								Reads data from CGRAM or DDRAM.

Schwartz, Eric M. "EEL 4744: Microprocessor Applications." LCD Commands. 17 Mar. 2002. <http://mil.ufl.edu/4744/docs/lcdmanual/commands.html>.

Bit names

Bit	Settings	
I/D	0 = Decrement cursor position	1 = Increment cursor position
S	0 = No display shift	1 = Display shift
D	0 = Display off	1 = Display on
C	0 = Cursor off	1 = Cursor on
B	0 = Cursor blink off	1 = Cursor blink on
S/C	0 = Move cursor	1 = Shift display
R/L	0 = Shift left	1 = Shift right
DL	0 = 4-bit interface	1 = 8-bit interface
N	0 = 1/8 or 1/11 Duty (1 line)	1 = 1/16 Duty (2 lines)
F	0 = 5x7 dots	1 = 5x10 dots
BF	0 = Can accept instruction	1 = Internal operation in progress

Notes:

- DDRAM = Display Data RAM.
- CGRAM = Character Generator RAM.
- DDRAM address corresponds to cursor position.
- Address Counter is used for both DDRAM and CGRAM.
- *= Don't care.
- DL: 0 = 4-bit interface; 1 = 8-bit interface
- N: 0 = 1 line; 1 = 2 lines
- F: 0 = 5x7 dots; 1 = 5x10 dots
- For more info, see: http://mil.ufl.edu/4744/docs/lcdmanual/commands.html

LCD 4bit Mode *main()* Flow