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EGCO334: Microprocessor and Interfacing

Input/Output

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Outline

- LCD and Keyboard
- Serial Communication
  - UART
  - I2C

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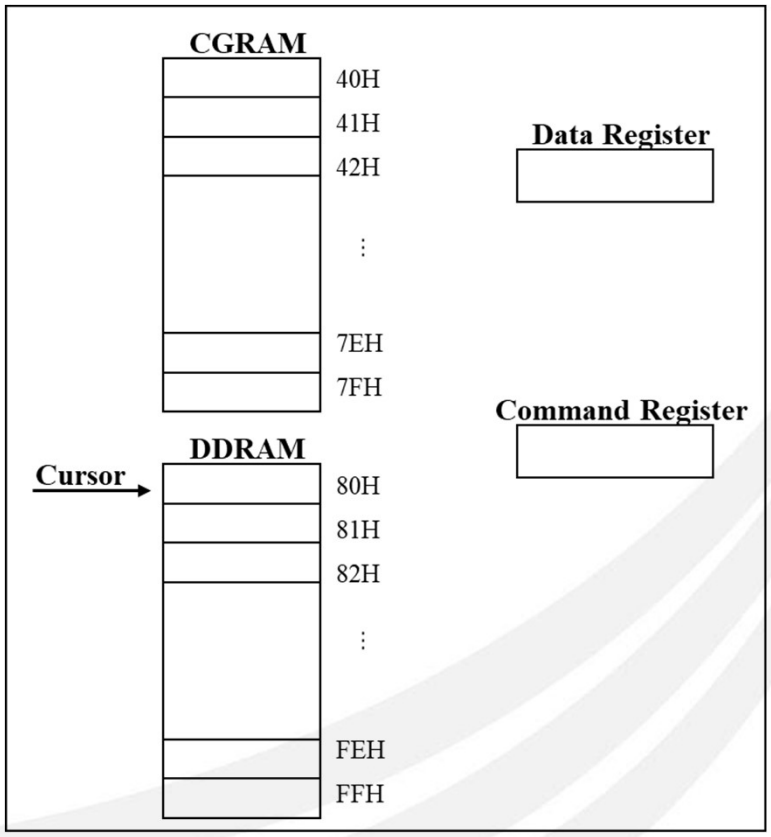
Liquid Crystal Display (LCD)

- Sometimes the embedded system needs to inform the user of something. There are different ways to inform the user, such as LEDs, 7segments and LCDs.
- LCD is one of the most powerful ways; as you can display different texts and icons on it.

Liquid Crystal Display (LCD)

LCD internal components

- DDRAM (Data Display RAM)
- CGRAM (Character Generator RAM)
- Cursor (Address Counter)
- Data Register
- Command Register



Liquid Crystal Display (LCD)

LCD internal components

- DDRAM (Data Display RAM)
  - It is a 128x8 RAM (128 bytes of RAM)
  - Contains the data that should be displayed on the LCD.
  - If we write the ASCII code of a character into the RAM the character will be displayed on the LCD.
- CGRAM (Character Generator RAM)
  - It is a 64x8 RAM (64 bytes of RAM).
  - The fonts of characters 00H to 07H are stored in the RAM.
  - We can change the fonts of the 8 characters by writing into the RAM.
- Cursor (Address Counter)
  - Cursor is a register which points to a location of DDRAM or CGRAM.

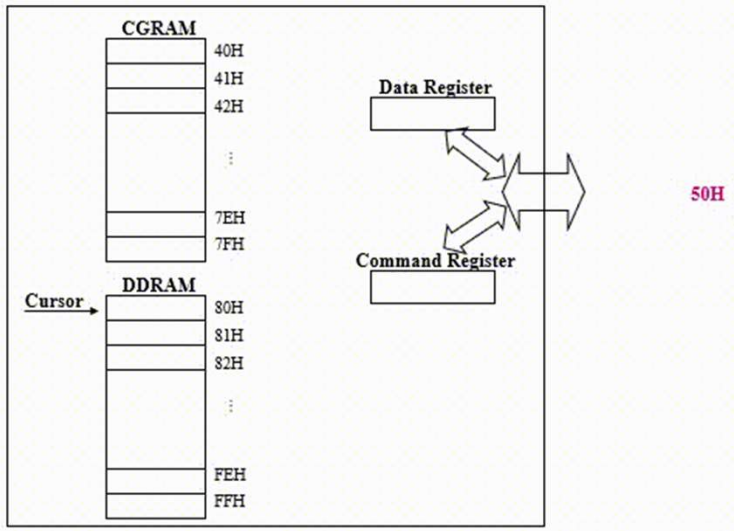
Liquid Crystal Display (LCD)

LCD internal components

- Data Register
  - It is an 8 bit register.
  - When we write a byte of data into the data register, the data will be written where the cursor points to.
  - **For example**, if we write a byte of data into the data register while the cursor points to location 80H of DDRAM, the contents of location 80H will be changed to the data, we have written into the data register.
- Command Register
  - We can command the LCD by writing into the command register.
  - **For example,** we can ask the LCD, to set cursor location, or clean the screen, by writing into the command Register.

Liquid Crystal Display (LCD)

Writing Data to Register



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Liquid Crystal Display (LCD)

LCD commands

We can order the LCD by sending command codes to the command register.

Code (Hex)	Instruction	Code (Hex)	Instruction
1	Clear display screen	2	Return home
10	Shift cursor position to left	14	Shift cursor position to right
18	Shift display left	1C	Shift display right
4	After displaying a character on the LCD, shift cursor to left	6	After displaying a character on the LCD, shift cursor to right
80-FF	Set cursor position	40-7F	Set CG RAM address
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	38	Initializing to 2 lines & 5x7 font

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Liquid Crystal Display (LCD)

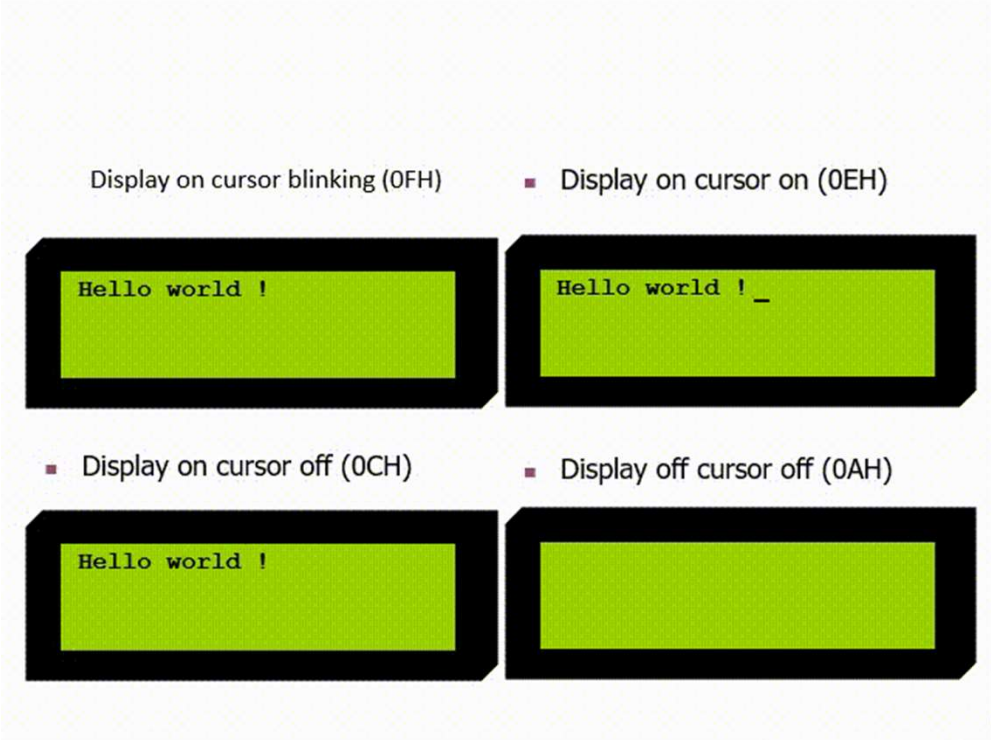
LCD commands

If we write 01H into the command register, LCD clears the display, and sets the cursor address to 0.

Code (Hex)	Instruction	Code (Hex)	Instruction
1	Clear display screen	2	Return home
10	Shift cursor position to left	14	Shift cursor position to right
18	Shift display left	1C	Shift display right
4	After displaying a character on the LCD, shift cursor to left	6	After displaying a character on the LCD, shift cursor to right
80-FF	Set cursor position	40-7F	Set CG RAM address
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	38	Initializing to 2 lines & 5x7 font

Liquid Crystal Display (LCD)

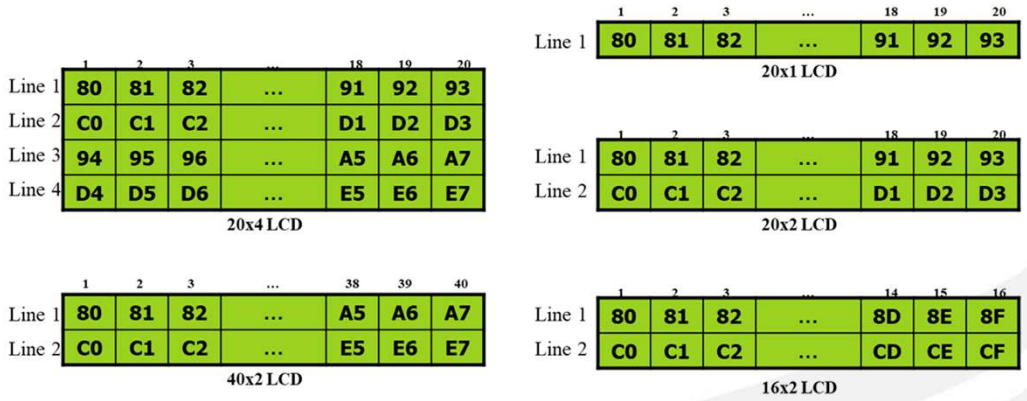
LCD commands



Liquid Crystal Display (LCD)

Set cursor position

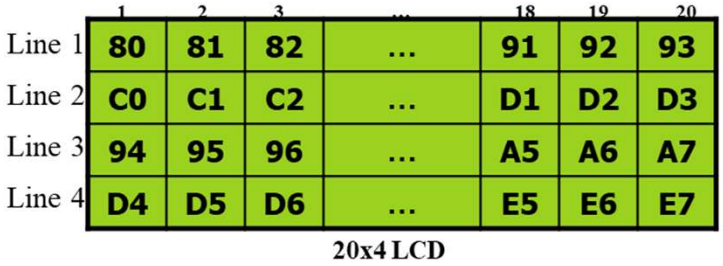
- We mentioned earlier that each location of the DDRAM, retains the character that should be displayed in a location of LCD.
- The following figures, represent that if you want to display a character in each of the rooms of the LCD, you should write into which location of the DDRAM. (The numbers are in hex.)



Liquid Crystal Display (LCD)

Set cursor position

- To move the cursor to any location of the DDRAM, write the address (in hex) of that location into the command register.



	1	2	3	…	18	19	20
Line 1	80	81	82	…	91	92	93
Line 2	C0	C1	C2	…	D1	D2	D3
Line 3	94	95	96	…	A5	A6	A7
Line 4	D4	D5	D6	…	E5	E6	E7

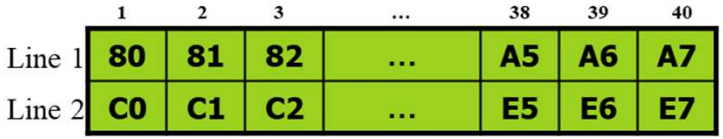
20x4 LCD

	1	2	3	…	18	19	20
Line 1	80	81	82	…	91	92	93

20x1 LCD

	1	2	3	…	18	19	20
Line 1	80	81	82	…	91	92	93
Line 2	C0	C1	C2	…	D1	D2	D3

20x2 LCD



	1	2	3	…	38	39	40
Line 1	80	81	82	…	A5	A6	A7
Line 2	C0	C1	C2	…	E5	E6	E7

40x2 LCD

	1	2	3	…	14	15	16
Line 1	80	81	82	…	8D	8E	8F
Line 2	C0	C1	C2	…	CD	CE	CF

16x2 LCD

Liquid Crystal Display (LCD)

Set cursor position

Example: We want to display a character in line 4 column 1 of a 20x4 LCD. What should we write to the command register to move the cursor to?

Liquid Crystal Display (LCD)

Set cursor position

Example: We want to display a character in line 4 column 1 of a 20x4 LCD. What should we write to the command register to move the cursor to?

Solution:

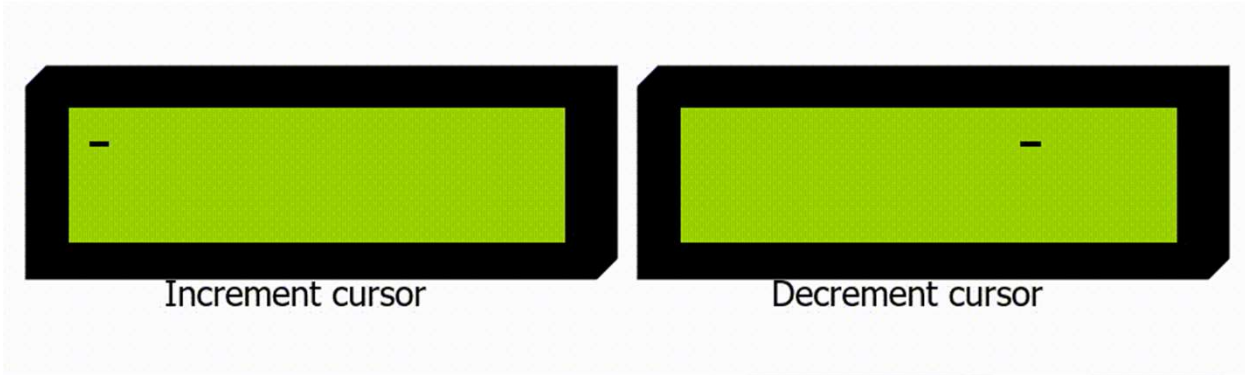
We should move cursor to address D4H of the DDRAM. So, we should write D4H, into the command register.

	1	2	3	...	18	19	20
Line 1	80	81	82	...	91	92	93
Line 2	C0	C1	C2	...	D1	D2	D3
Line 3	94	95	96	...	A5	A6	A7
Line 4	D4	D5	D6	...	E5	E6	E7

Liquid Crystal Display (LCD)

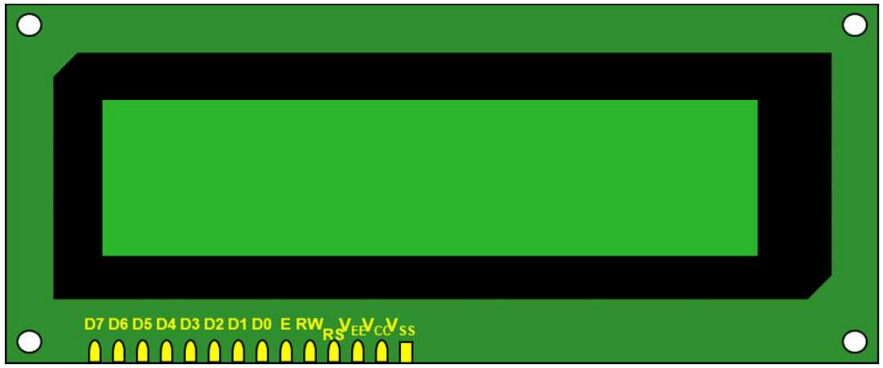
Decrease and Increase Position of Cursor

- If you write a byte of data into the data register, the data will be written where the cursor points to, and cursor will be incremented, by default.
- If you want to make the LCD, to decrement the cursor, you should write 4H into the command register.
- If you want to make the LCD, to reactivate the default (shift cursor to right) you should write 6H into the command register.



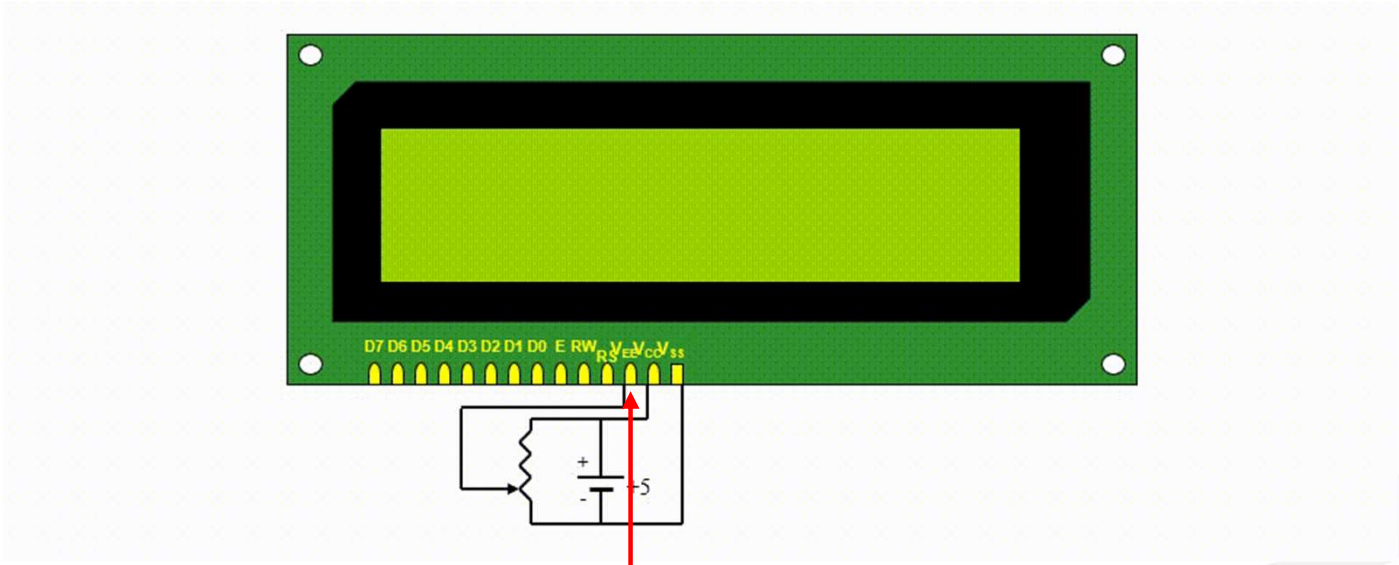
Liquid Crystal Display (LCD)

LCD pins



Liquid Crystal Display (LCD)

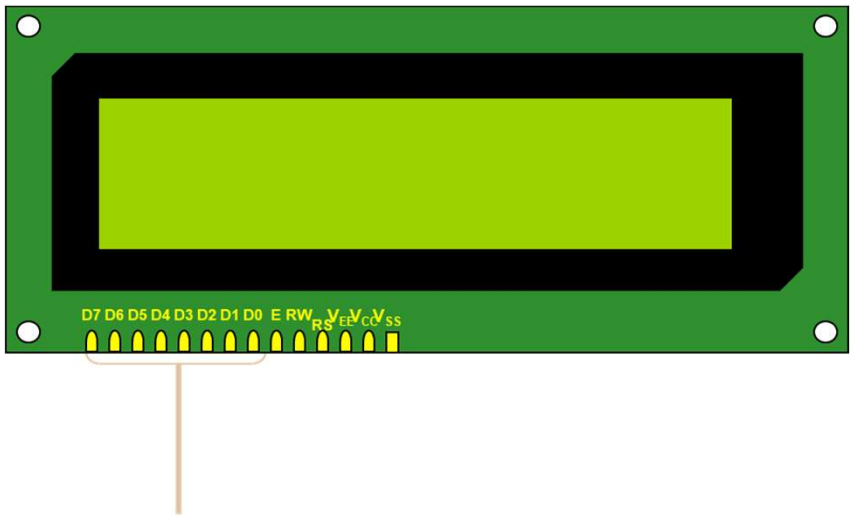
LCD pins



- VEE: We control the contrast of the LCD by giving a voltage between 0V and +5V to the pin.

Liquid Crystal Display (LCD)

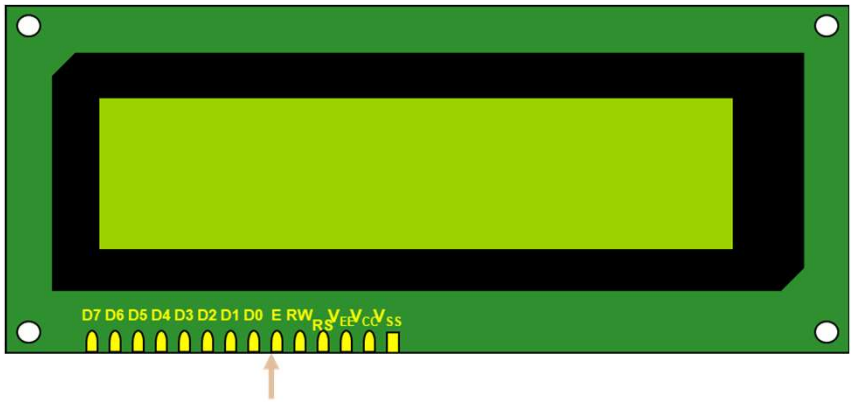
LCD pins



- D0 to D7: LCD sends and receives data, through the 8 pins.

Liquid Crystal Display (LCD)

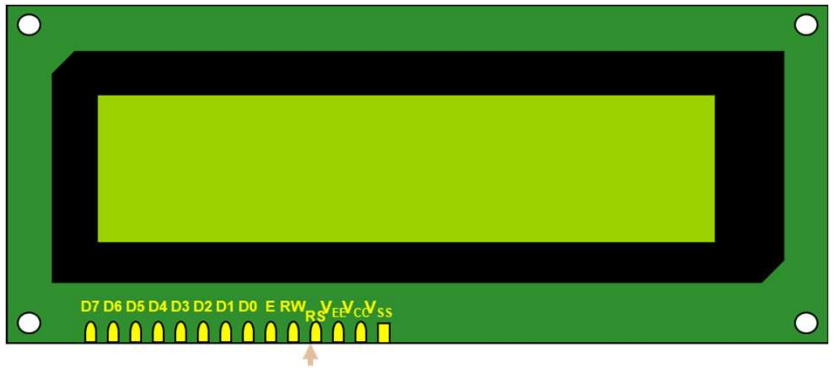
LCD pins



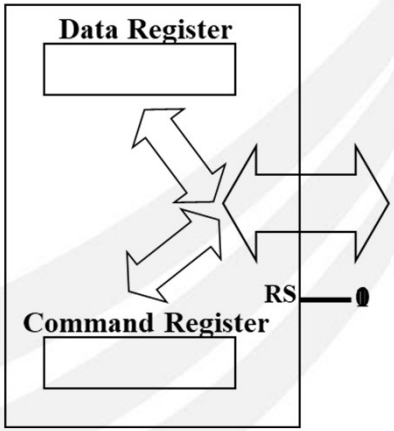
- E (Enable): We activate the pin when we want to send or receive data from the LCD.
  - When we want to send data to the LCD, we make the RW pin, low; and supply the data to data pins (D0 to D7); and then apply a high to low pulse to the Enable pin.
  - When we want to receive data from the LCD, we make the RW pin, high; and then apply a low to high pulse to the Enable pin. LCD supplies data to the data pins (D0 to D7).

Liquid Crystal Display (LCD)

LCD pins



- RS (Register select): There are two registers with names of command register and data register in the LCD.
- If RS = 1, whenever we send data to the LCD, the data will be located in the data register.
- If RS = 0, whenever we send data to the LCD, the data will be located in the command register



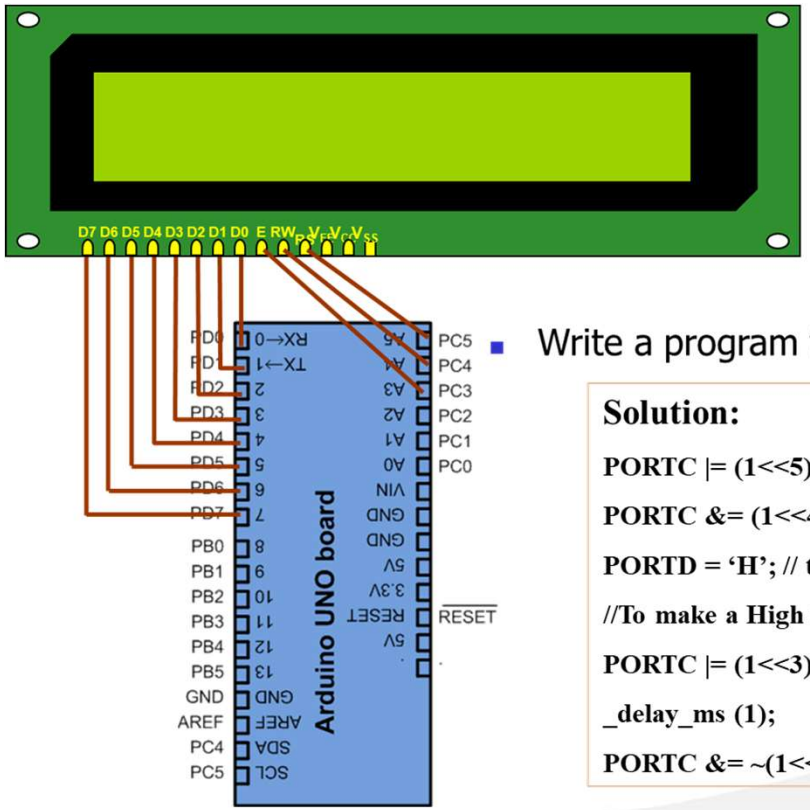
Liquid Crystal Display (LCD)

LCD Programming

- Initialization
  - We must initialize the LCD before we use it.
  - To initialize an LCD, for 5×7 matrix and 8-bit operation, 0x38, 0x0E, and 0x01 are send to the command register.
- Sending commands to the LCD
  - Make pins RS and R/W = 0
  - Put the command number on the data pins (D0–D7)
  - Send a high-to-low pulse to the E pin to enable the internal latch of the LCD (**wait about 100us after each command**)
- Sending data to the LCD
  - make pins RS = 1 and R/W = 0.
  - put the data on the data pins (D0–D7)
  - send a high-to-low pulse to the E pin (**wait about 100us**)

Liquid Crystal Display (LCD)

LCD Programming



- Write a program that displays 'H' on the LCD.

Solution:

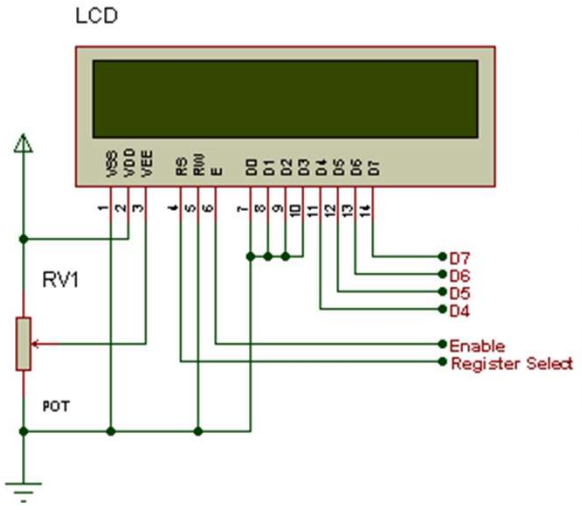
```
PORTC |= (1<<5); // (RS = 1) to write to the data register
PORTC &= (1<<4); // (RW = 0) to send data to the LCD.
PORTD = 'H'; // to send 'H' to the LCD.
//To make a High to low pulse on the Enable pin :
PORTC |= (1<<3);
_delay_ms (1);
PORTC &= ~(1<<3);
```

Liquid Crystal Display (LCD)

LCD Programming in 4-bit mode

- To save pins of the AVR, we can use 4-bit operating mode.
- The initialization of 4-bit mode is somehow different:
  - In 4-bit mode, we initialize the LCD with the series 33, 32, and 28 in hex.
    - This represents nibbles 3, 3, 3, and 2, which tells the LCD to go into 4-bit mode. The value $28 initializes the display for 5 × 7 matrix and 4-bit operation

- Sending commands and data to the LCD
  - Sending data and commands to the LCD is like the 8-bit mode but we should only use D4 – D7
  - First we should send the high nibble to D4-D7, then, to send the low nibble, swap the low nibble with the high nibble, and send it to D4-D7



Examples

- 13 LCD eg 1.asm / LCD examples 1.pcf
- 13 LCD eg 2.asm / LCD examples 2.pcf
- 13 LCD eg 3.asm / LCD examples 3.pcf
- 13 LCD eg 4.asm / LCD examples 3.pcf

Exercise 13

- Write LCD program using C
- Print a single “*”
- Have it move from left to right across the LCD screen
- Make repeating pattern