LCD
Liquid Crystal Display

Types of Displays:

LEDs.

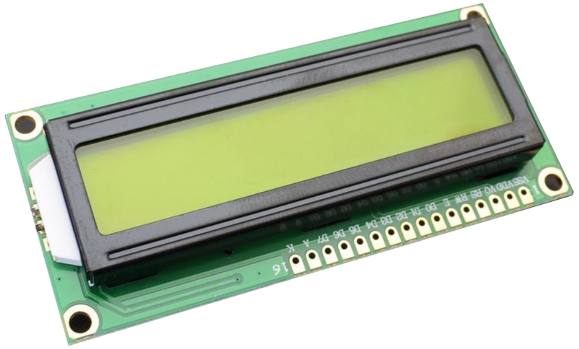
LED Matrix.

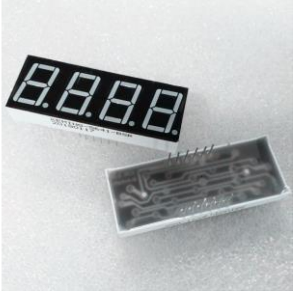
LED Segments.

Character Liquid Crystal Display.

Graphical Liquid Crystal Display.

Thin Film Transistor Liquid Crystal Display (TFT LCD).





The Idea of Character LCD:

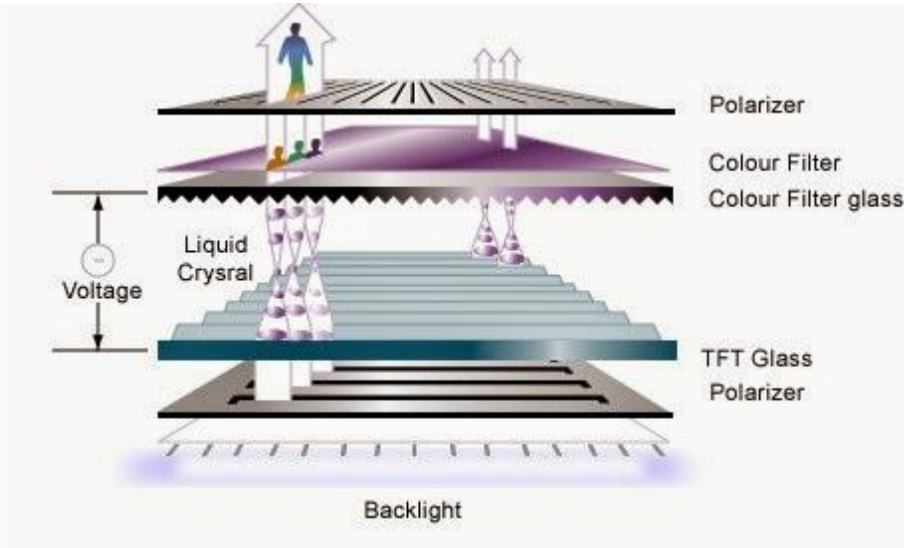
The combination of four facts makes LCDs possible:

- Light can be polarized.
- Liquid crystals can transmit and change polarized light.
- The structure of liquid crystals can be changed by electric current.
- There are transparent substances that can conduct electricity.

How LCD Works:

LCDs in turn, use liquid crystals. These crystals are liquid chemicals with molecular structures that align perfectly when subjected to electrical fields. When they are properly aligned, they allow light to pass through them.

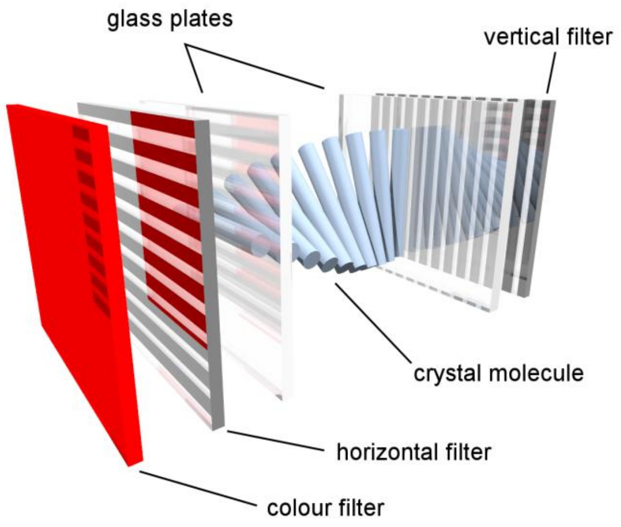
LCDs use this property by using electrical currents to align the crystals, allow varying levels of light to pass through and create the desired images and colors.



How LCD Works:

To be more technical, the liquid crystals are sandwiched between two pieces of polarized glass (“substrate”). The fluorescent light source also known as the backlight originates or radiates light that passes through the first substrate. The polarized light then passes through a layer that contains thousands of liquid crystal blobs arrayed in tiny containers called cells. Electric leads around the edge of the LCD create an electric field that causes the crystals’ aligning and allowing varying levels of light to pass through to the second substrate.

The result is what you see on-screen.

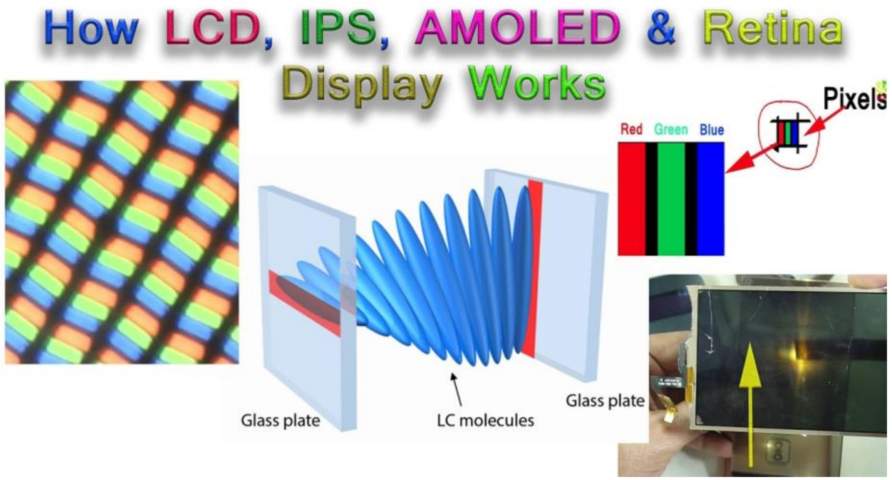


How LCD Works:

In a colored LCD panel, each pixel is made up of three liquid crystal cells.

Each of those three cells is fronted by a red, green or blue filter.

Light passes through the filtered cells and creates the colors what you see on the LCD.



Our Module is Character LCD lm01602A

Pin Description of LCD

Power Pins:

- VSS:

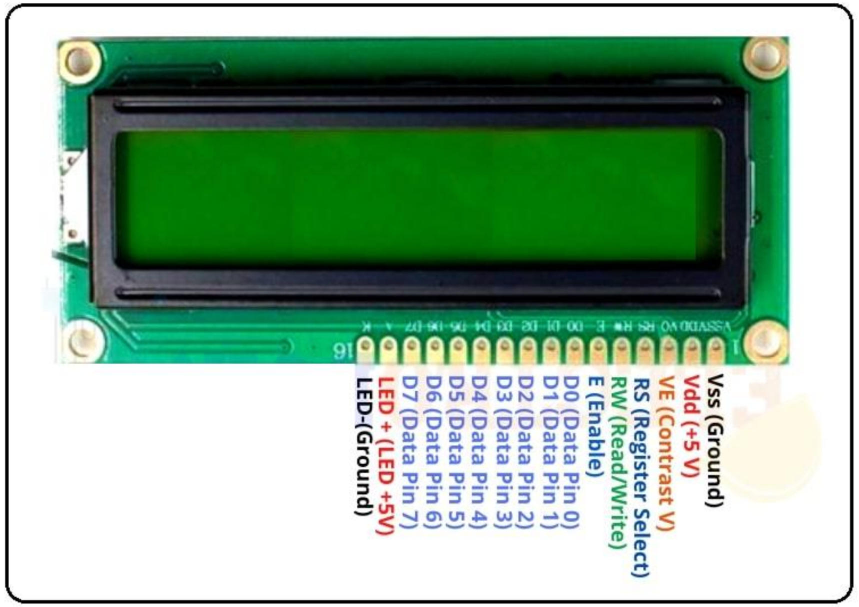
Voltage connected to Source of MOSFET is connected to Ground.

- VDD:

Voltage connected to Drain of MOSFET is connected to High Volt (+5V).

- VE:

Voltage quantity on this pin controls on the Pixels' Contrast. Max Pixel Contrast is at Low Voltage.



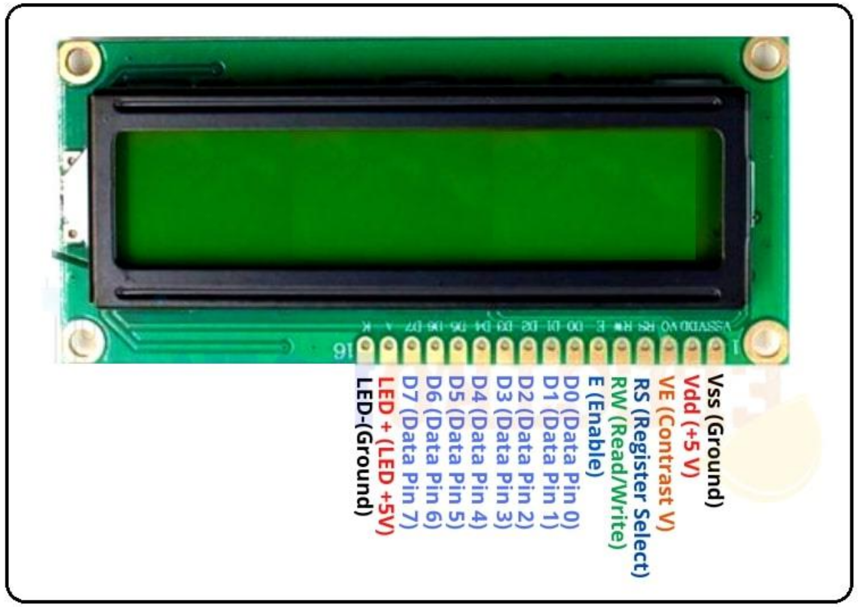
AMIT

Pin Description of LCD

Control Pins:

- RS:

  Register selection pin, which is used to select the type of data exists on data pins (data to display, RS must be pulled up to high (5V)or command to LCD, RS pin must be pulled down to low(Ground)).



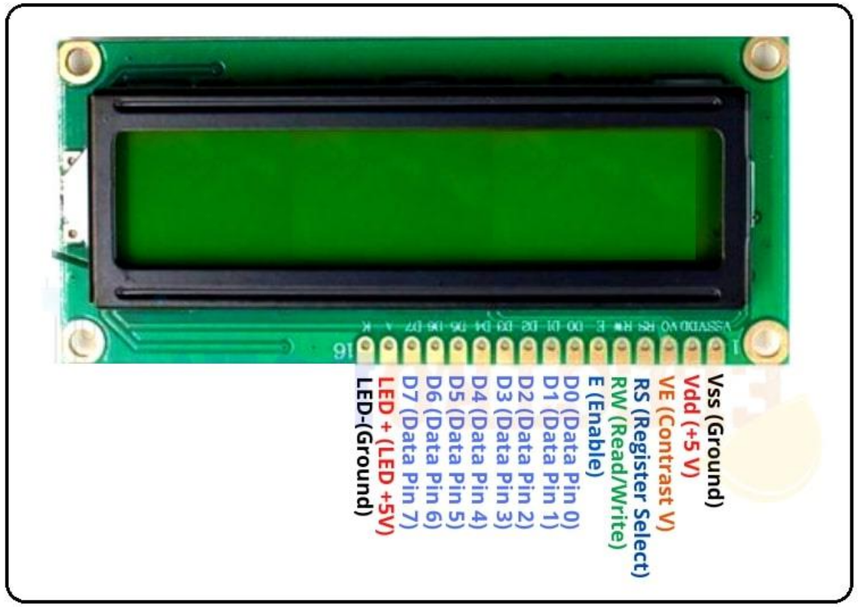
Pin Description of LCD

Control Pins:

- R/W:

  Read/Write pin, which determines the kind of operation on LCD.

- Reading R/W must be pulled up to high (5V) and writing R/W must be pulled down to low (Ground).



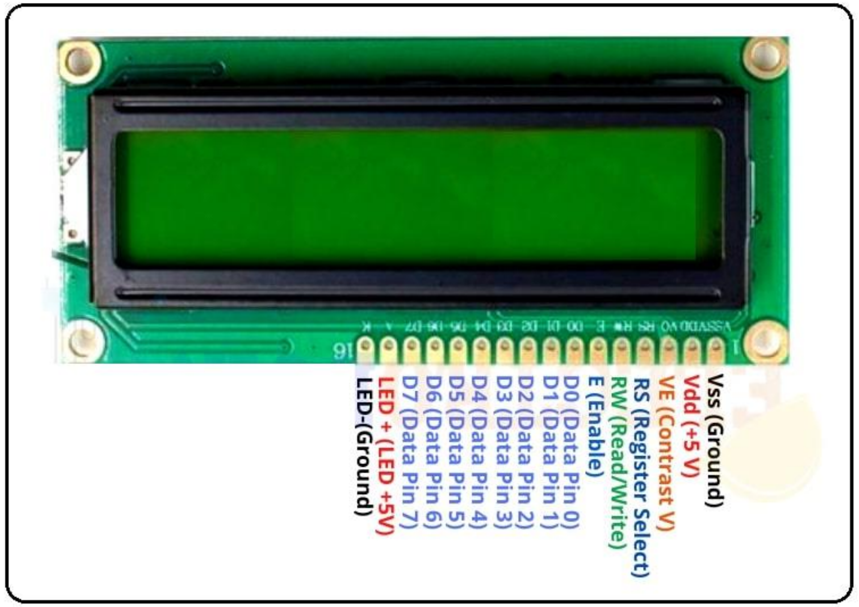
Pin Description of LCD

Control Pins:

- E:

  Enable pin, which used to enable writing or reading operations on data pins of LCD.

- To enable writing on the LCD, this pin must be triggered by falling edge ” latch pulse “ (It must be pulled up to high and after very short time (2 MS as example). It must be pulled down to low to generate a falling edge.



Pin Description of LCD

Data Pins:

- D7…..D0:

These pins are used to send/receive one byte from/to LCD.

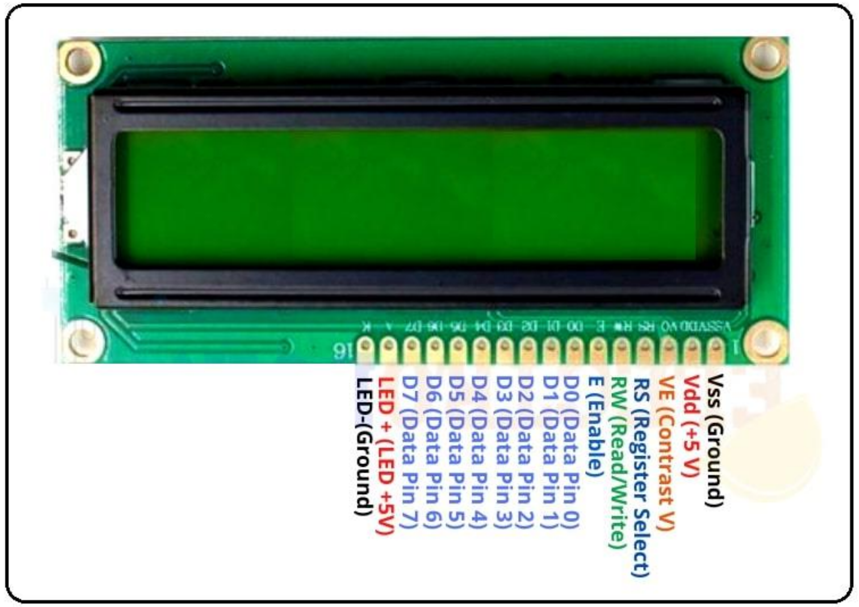
Each pin number indicates to the bit order that must be transferred on it.

So,

b0 of data on D0 pin.

b1 of data on D1 pin.

and so on…..,



Pin Description of LCD

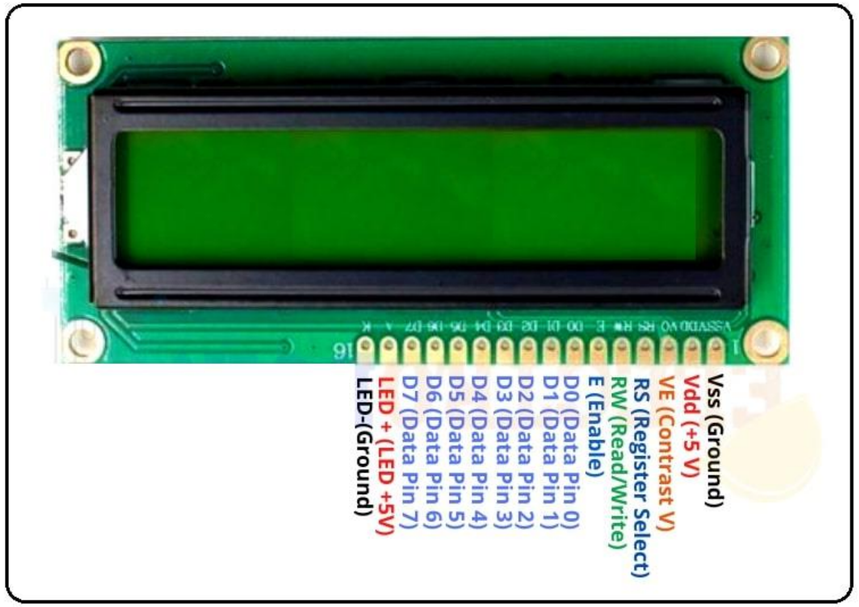
Back Light Pins:

- A pin:

This pin is connected to the power source (5V) to turn on the back light.

- K pin:

This pin is connected to the power sink (0V) to turn on the back light.



How LCD Works:

- LCD is integrated with a separated computing system which its function is to display on LCD. So, it has a processor, a memory and I/O peripherals.
- This computing system communicates with others by parallel connection through data pins.

How LCD Works:

LCD has three types of memories:

- DDRAM:

Data Display RAM.

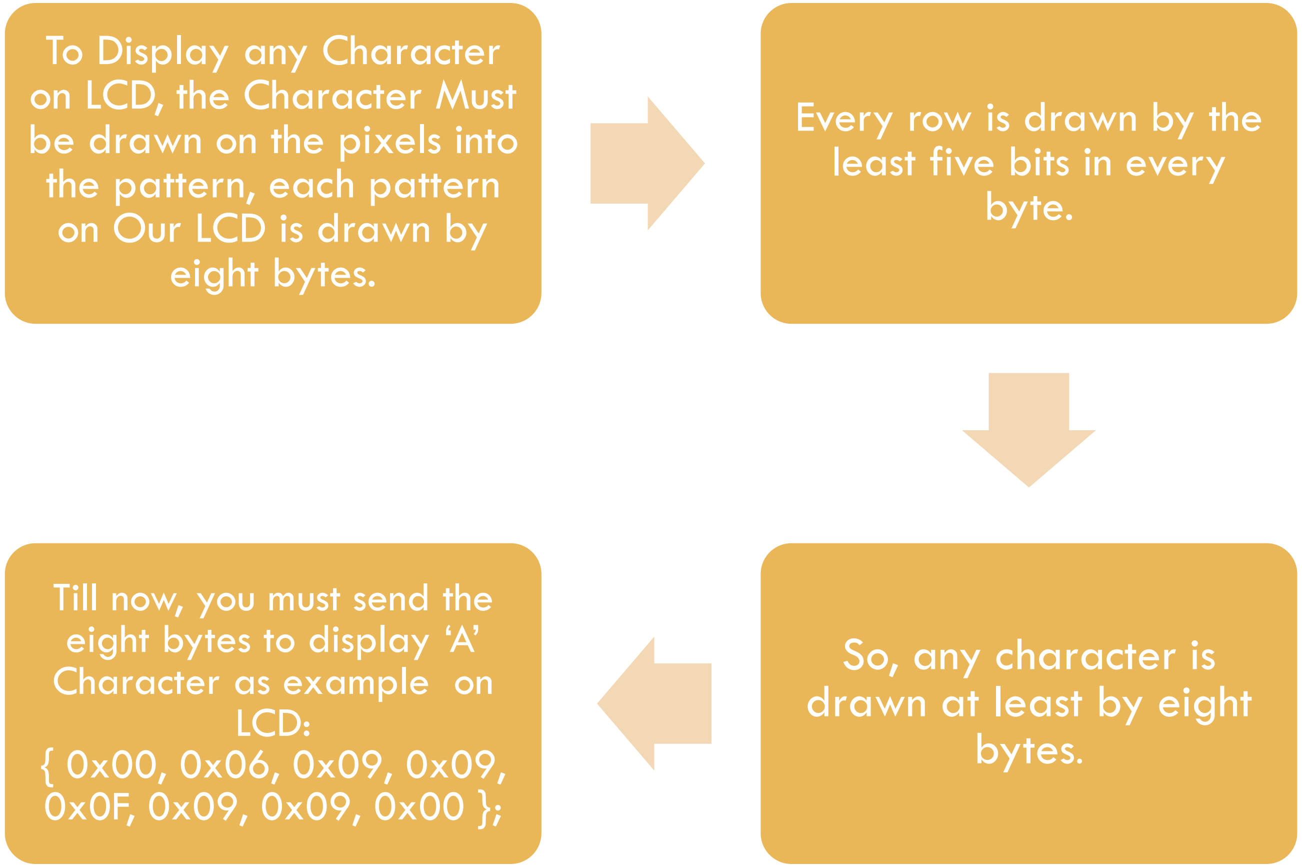
- CGRAM:

Character Generator RAM.

- CGROM:

Character Generator ROM.

How LCD Works:

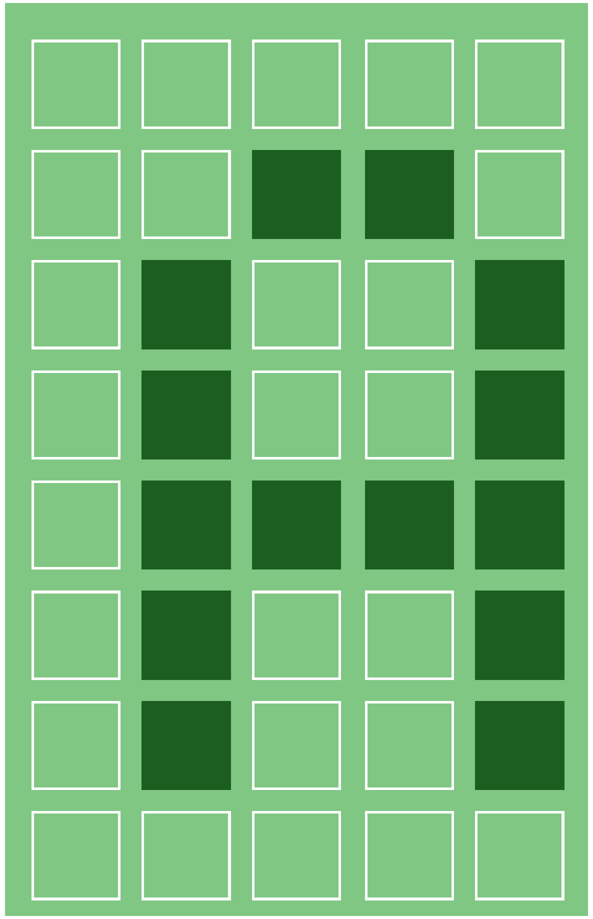


To Display any Character on LCD, the Character Must be drawn on the pixels into the pattern, each pattern on Our LCD is drawn by eight bytes.

Every row is drawn by the least five bits in every byte.

So, any character is drawn at least by eight bytes.

Till now, you must send the eight bytes to display 'A' Character as example on LCD:
{ 0x00, 0x06, 0x09, 0x09, 0x0F, 0x09, 0x09, 0x00 };



How LCD Works:

CGROM:

- Because of English is the most common language used around the world in addition to ASCII standards also, all of ASCII characters’ patterns have been stored into CGROM. So, you can now only send the address of the pattern what you want to display.
- To be easier, CGROM is manufactured to store the pattern of characters into addresses that equalize with character ASCII number.
- Now as an example to display ‘A’ Character, you can only send its ASCII number and the processor will Display the ‘A’ Pattern.

How LCD Works:

DDRAM:

- This memory is used for displaying.
- When you send the character ASCII value, it will be stored into DDRAM.
- After fetching its pattern, DDRAM will display the pattern on the LCD.

How LCD Works:

CGRAM:

- It is memory which is used to draw any pattern did not exist into the CGROM.
- It is a free memory used to display extra characters.
- This memory is RAM not ROM, because ROM memory is a read-only memory for processors. So, RAM is the excellent choice.

How LCD Works:

How to initialize LCD:

After power on, you must delay for more than 30 MS until VDD pin reaches 4.5 volt.

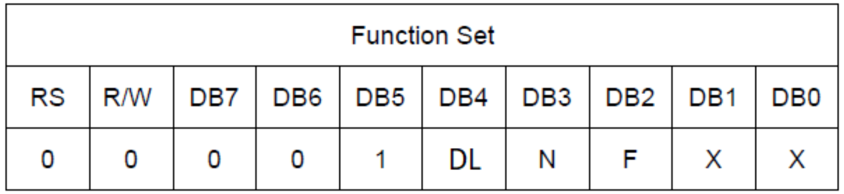
Now, send the Function Set Command to LCD:

- RS, R/W are pulled down to write a command to LCD.
- Write 001 on D7,D6,D5 respectively.
- DL: Data Length, write one for Eight-bits Mode, Zero for Four-bits Mode.

N: Number of Lines, write one for two-line activation and Zero for one-line activation.

F: Font size, write one for 5x11-dot activation, and Zero for 5x8-dot activation, but our LCD has 5x8 only.

D1,D0 values are not imported in this command.



Function Set									
RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	1	DL	N	F	X	X

0 0 1 1 1 0 0 0

for Eight-bit Mode, 2 lines , 5x8 dots

0 0 1 0 1 0 0 0

for Four-bit Mode, 2 lines , 5x8 dots

How LCD Works:

How to initialize LCD:

After sending function set, you must delay for more than 39 US.

Now, send the Display-Control Command to LCD:

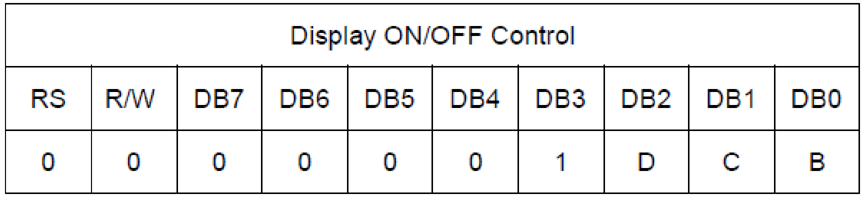
RS, R/W are pulled down to write a command to LCD.

Write 00001 on D7,D6,D5,D4,D3 respectively.

D: Display ON/OFF, write one for Enabling Display and Zero for Disabling Display.

C: Cursor ON/OFF, write one for Cursor activation and Zero for Cursor Deactivation.

B: Cursor Blinking, write one for Blinking activation and Zero for Blinking Deactivation.



Display ON/OFF Control									
RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	1	D	C	B

0 0 0 0 1 1 1 1

for Display ON, Cursor ON, Blinking ON

How LCD Works:

How to initialize LCD:

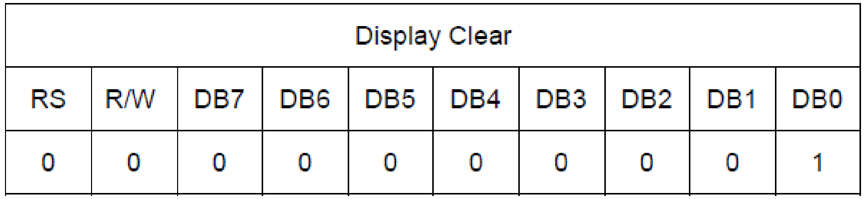
After sending Display Control, you must delay for more than 39 US.

Now, send the Display Clear Command to LCD:

RS, R/W are pulled down to write a command to LCD.

Write 0000001 on D7,D6,D5,D4,D3,D2,D1,D0 respectively.

This Command is used to clear the Display.



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

0 0 0 0 0 0 0 1

for Display ON, Cursor ON, Blinking ON

How LCD Works:

How to initialize LCD:

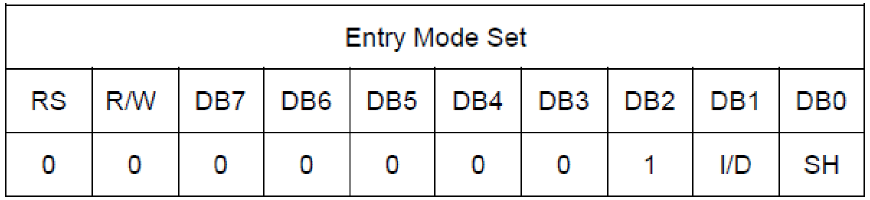
After sending Display Clear, you must delay for more than 1.53 MS.

Now, send the Display-Control Command to LCD:

RS, R/W are pulled down to write a command to LCD.

Write 000001 on D7,D6,D5,D4,D3,D2 respectively.

- I/D: Iocreases (I/D = 1) or decreases (I/D = 0) the DD RAM address by 1 when a character code is written into or read from the DD RAM.
  - The cursor or blink moves to the right when it be increased by 1 and to the left when it be decreased by 1.
  - The same applies for writing and reading the CGRAM.
- SH: Cursor ON/OFF, write one for Cursor activation and Zero for Cursor Deactivation.



Entry Mode Set

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	1	I/D	SH

0 0 0 0 0 1 1 0

for Increase(to right), No Shifting

How LCD Works:

sow to initialize LCD:

Initialization LCD with Four bits did not differ than the Eight-bit mode except the value of DL-bit in the Function-set Command will be Pulled down(0).

In Four-bits Mode, D3,D2,D1,D0 will not be connected to anything, so their values are not important.

D7,D6,D5,D4 will send/receive the data within two different cycles.

Any Data or command will be divided to two parts, Upper bits are b7..b4, Lower bits are b3..b0, and sent twice respectively Except the first command, function set, the upper bits will be sent twice then the lower bit.

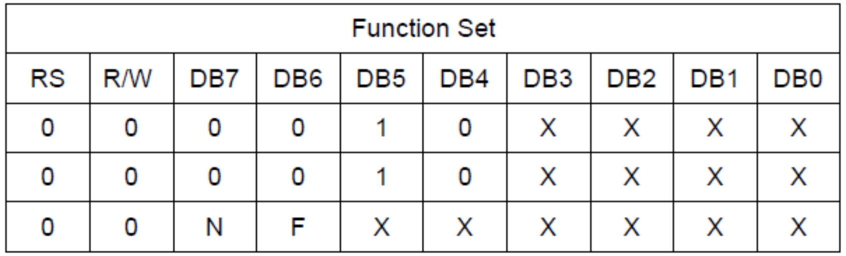
How LCD Works:

How to initialize LCD:

First cycle bits of data (b7,b6,b5,b4) must be sent to (D7,D6,D5,D4) respectively.

Second cycle bits of data (b3,b2,b1,b0) must be sent to (D7,D6,D5,D4) respectively.

After each cycle, EN pin must be Latched.



Function Set

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	1	0	X	X	X	X
0	0	0	0	1	0	X	X	X	X
0	0	N	F	X	X	X	X	X	X

Function set must be sent triple, because it is first command that is sent, it means that the LCD has been started. So, the default mode of it is Eight bit, and when it receive the value again, it will change its mode to four bit.

LCD Basic Driver:

Software Driver of the LCD:

- The functionality of Initial function is to initiate the LCD to be ready to run as we mentioned before.
- The functionality of Send Data function is to Display the sending data on LCD.
- The functionality of Send Command function is to send a specific instruction to LCD to run.
- Configuration file is used to ask the user before building which mode will be requested and the pins connections.

LCD Basic Driver:

Software Driver of the LCD:

- The functionality of Initial function is to initiate the LCD to be ready to run as we mentioned before.
- It sets the directions of all pins connected to LCD for Output.
- It sets all steps of initialization that mentioned before.

LCD Basic Driver:

Software Driver of the LCD:

- The functionality of Sending a Data function is to Display the sending data on LCD.
- It sets the RS pin to High, R/W to Low because of sending data.
- It sets all data pins of LCD to its bit into data.
- It generates the Latched Pulse on EN pin.

LCD Basic Driver:

Software Driver of the LCD:

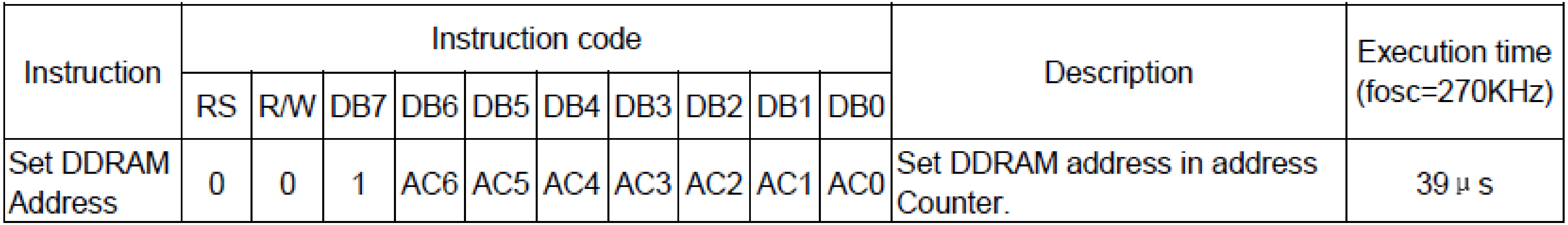
- The functionality of Sending a Command function is to send a specific instruction to LCD to run.
- It sets the RS pin to Low and R/W to Low because of sending a Command.
- It sets all data pins of LCD to its bit into Command.
- It generates the Latched Pulse on EN pin.

Inside the DDRAM

The size of our LCD’s DDRAM is 128 bytes.

Some of them are into the visible range and the others are into the invisible range.

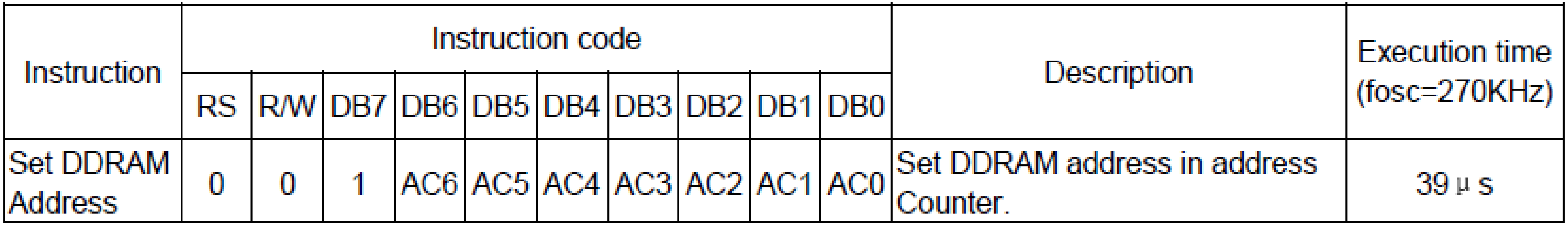
Our LCD is 16x2 character patterns into the visible range.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address Counter.	39 μ s

Inside the DDRAM

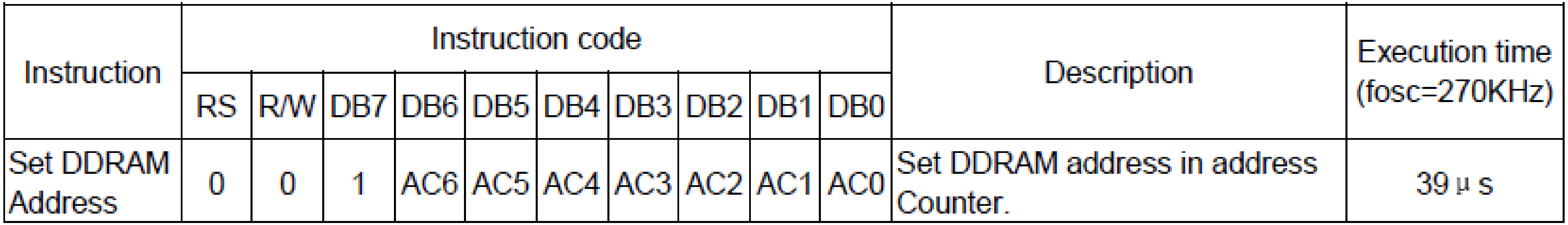
- According to the datasheet, the base address of DDRAM starts from 0x80 as an instruction code.
- So, first line starts from 0x80 to 0x8F into the visible range.
- Invisible range starts from 0x90 to 0xBF.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address Counter.	39 μ s

Inside the DDRAM

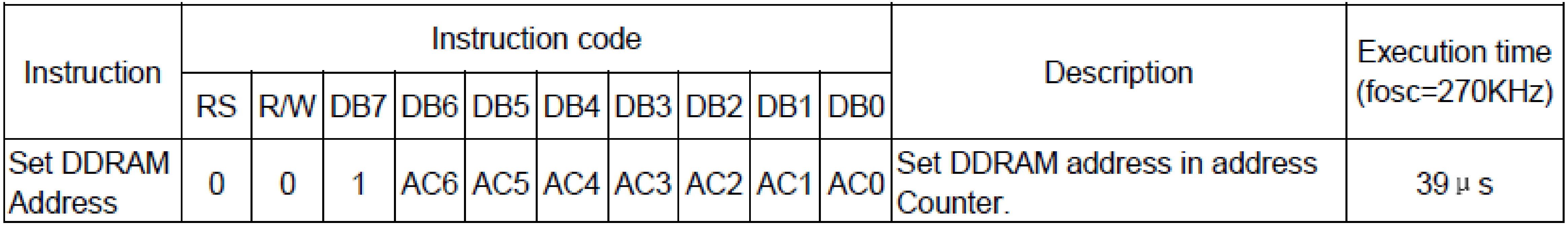
- Second line into our LCD starts from 0xC0 to 0xCF into the visible range.
- Invisible range from the second line into our LCD starts from 0xD0 to 0xFF.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address Counter.	39 μ s

Inside the DDRAM

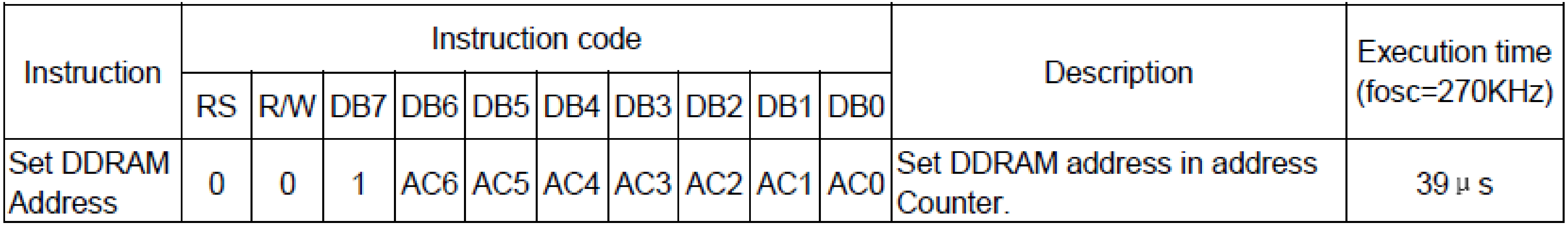
- The last addresses will be active if the LCD is initialized by two lines.
- If it is initialized by single line, the addresses will become the addresses of first line only.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address Counter.	39 μ s

Inside the DDRAM

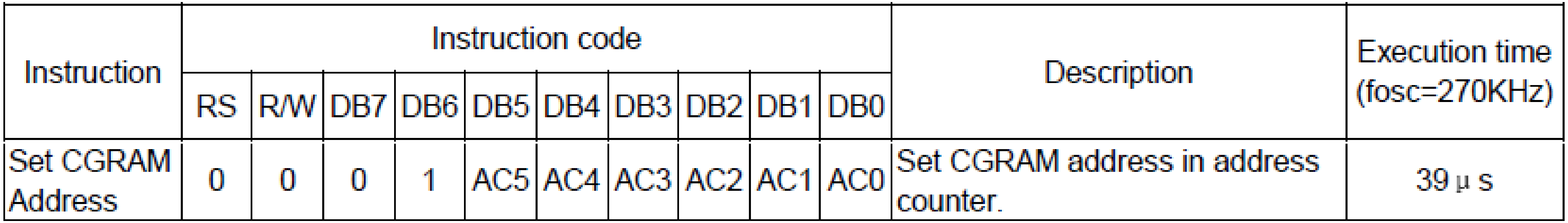
- Any location can be reached or jumped to it by sending this address as a writing-command operation.
- So, it is easy to display your data into any location by sending the location before displaying.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address Counter.	39 µ s

Inside the CGRAM

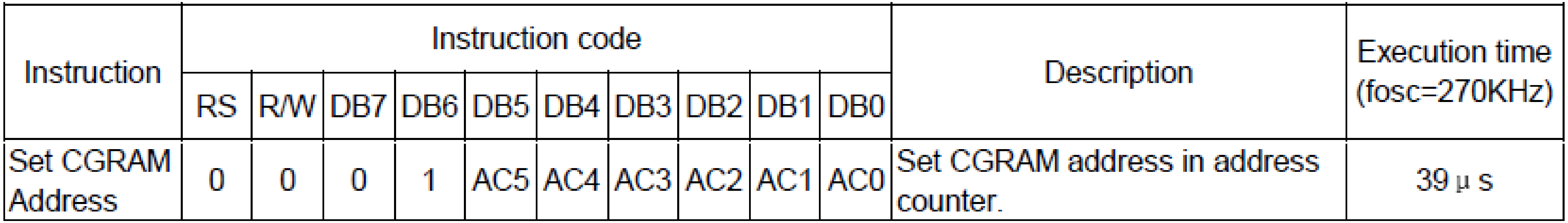
- The size of our LCD’s CGRAM is 64 bytes.
- This memory is used for drawing any pattern did not exist into ASCII standard, I mean drawing any pattern did not exist into the CGROM.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address counter.	39 μ s

Inside the CGRAM

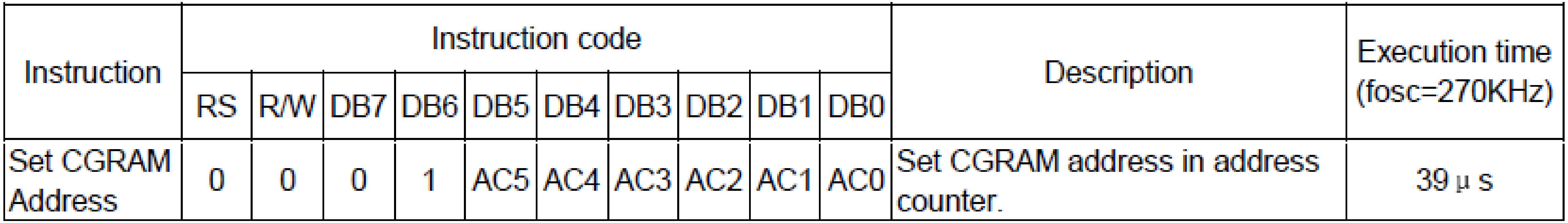
- As we mentioned before, any character or pattern needs eight bytes to be drawn by pixels.
- So, this memory can only store eight patterns.
- The base address of CGRAM is 0x40.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address counter.	39 μ s

Inside the CGRAM

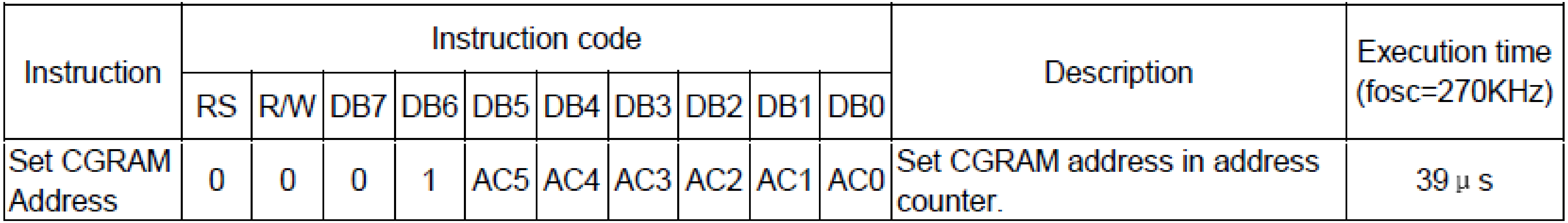
- CGRAM addresses start from 0x40, the base address to 0x7F which is the address before DDRAM.
- To jump to CGRAM, send a writing-command operation to LCD by any location exists into CGRAM.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address counter.	39 μ s

Inside the CGRAM

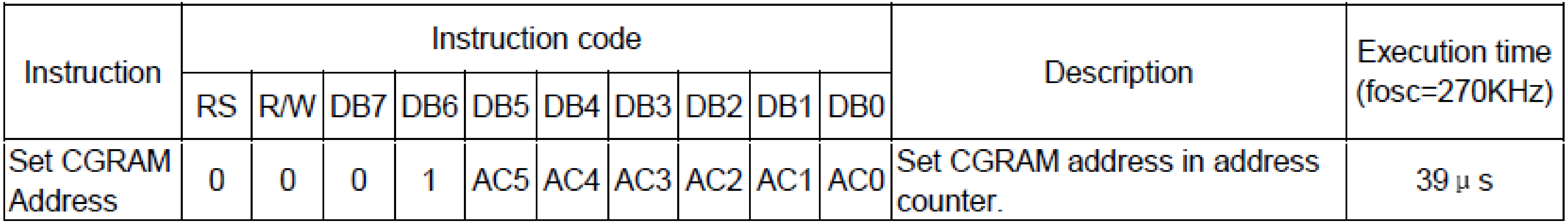
- As we mentioned, CGRAM can only store eight patterns.
- Pushing the values of pattern must start from the base address of this pattern.
- Patterns’ locations start from 0 to 7.



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address counter.	39 μ s

Inside the CGRAM

- Pattern 0 starts from 0x40 to 0x47, pattern 1 starts from 0x48 to 0x4F, Pattern 2 starts from 0x50 to 0x57,… and so on.
- If pushing does not start from any base address of any pattern, the pattern will be divided into two



Instruction	Instruction code										Description	Execution time (fosc=270KHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address counter.	39 μ s

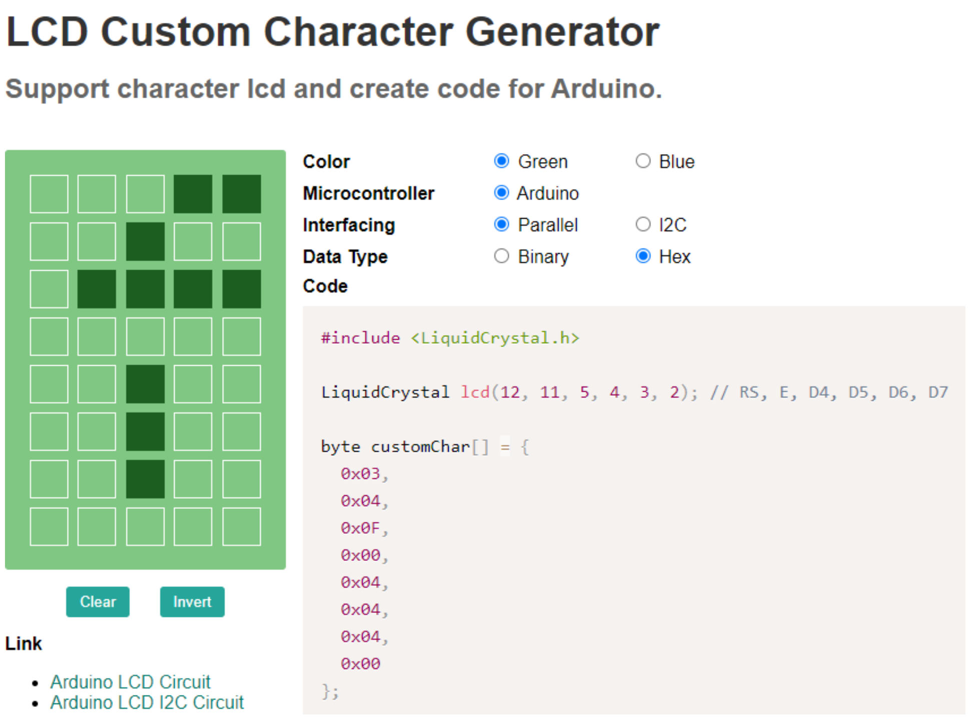
HOW TO USE THE CGRAM

To know which pixels will be lightened or not , you can use the following platform:

https://maxpromer.github.io/LCD-Character-Creator/

Accessing the CGRAM

- I drew أcharacter in Arabic and the eight bytes of this pattern are generated.
- Now how can we push this pattern to LCD and display it:



LCD Custom Character Generator

Support character lcd and create code for Arduino.

```
□□□■■
□□■□□
□■■■■
□□□□□
□□■□□
□□■□□
□□■□□
□□□□□
```

Color ● Green ○ Blue

Microcontroller ● Arduino

Interfacing ● Parallel ○ I2C

Data Type ○ Binary ● Hex

Code

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(12, 11, 5, 4, 3, 2); // RS, E, D4, D5, D6, D7

byte customChar[] = {
  0x03,
  0x04,
  0x0F,
  0x00,
  0x04,
  0x04,
  0x04,
  0x00
};
```

Link

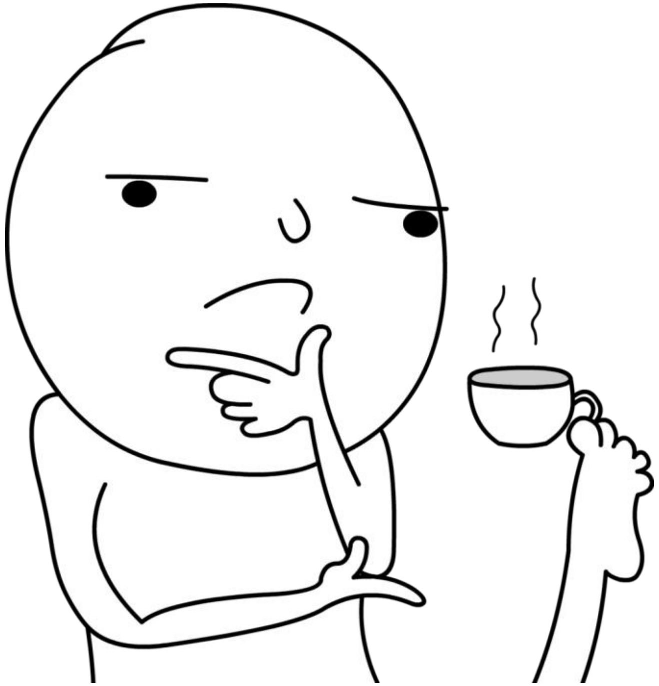
- Arduino LCD Circuit
- Arduino LCD I2C Circuit

Accessing the CGRAM

- First go to any pattern into CGRAM like pattern 5 which starts from 0x68 to 0x6F by sending 0x68 as a writing-command operation.
- Then, send all bytes of pattern as a writing-data operation respectively.
- After that, return to any location of DDRAM like first location on the second line 0xC0 as a writing-command operation.
- Finally as we mentioned before, to display any character on LCD, you must send its pattern's address into CGROM if it was an ASCII standard. But, now we need to display the pushed pattern into CGRAM. So, it's simple to just send the pattern number 5 as a writing-data operation.

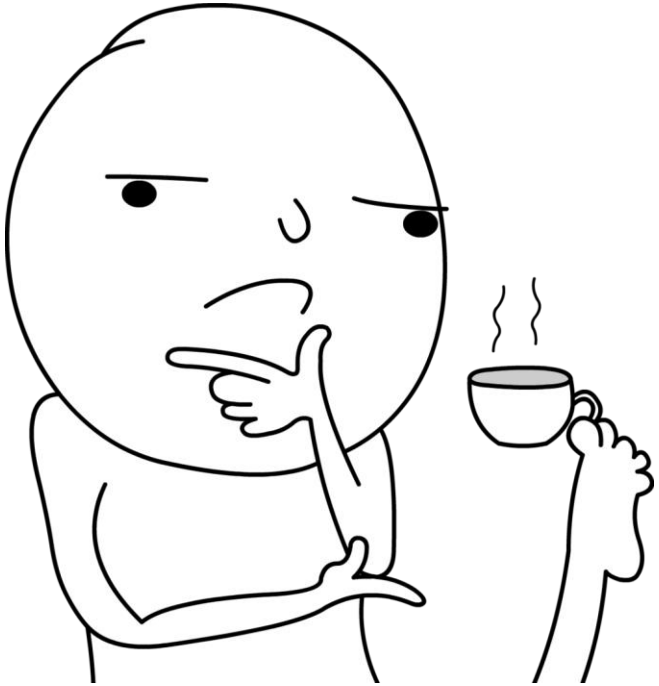
How to write an Integer Number on LCD:

- First check if it is negative or not.
- If it is print Dash character on LCD’-’.
- Then, divide the number into single digits.
- Then transfer it to ASCII code by to the ASCII number of ‘0’.
- Send all digits to LCD as a writing-data operation.
- The number will be successfully displayed on the LCD.
- Now, Can you write its function?



Lab:

- Write a function which its functionality is to display a float number on LCD.



THANK YOU!

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