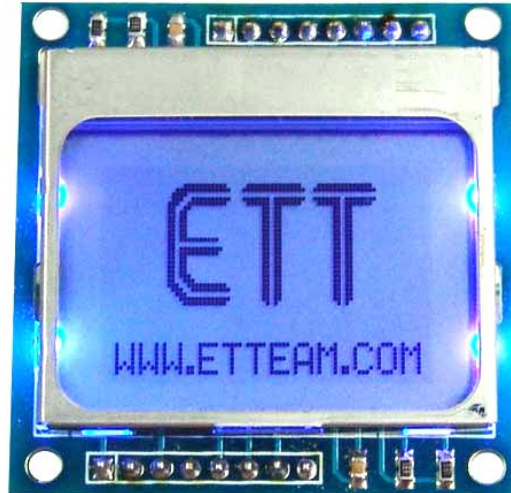


User's Manual of Graphic LCD "ET-NOKIA LCD 5110"



Specifications of LCD 5110

- 48 x 84 Dot LCD Display
- Serial Bus Interface with maximum high speed 4.0 Mbits/S
- Internal Controller No.PCD8544
- LED Back-Light
- Run at Voltage 2.7 -5.0 Volt
- Low power consumption; it is suitable for battery applications
- Temperature range from -25°C to +70°C
- Support Signal CMOS Input

LCD 5110 is 48 x 84 Dot LCD Graphic that has internal Controller/Driver "PCD8544" to control all displays and operations. Diagrammatic structure of internal Controller PCD8544 is shown as in figure 1.

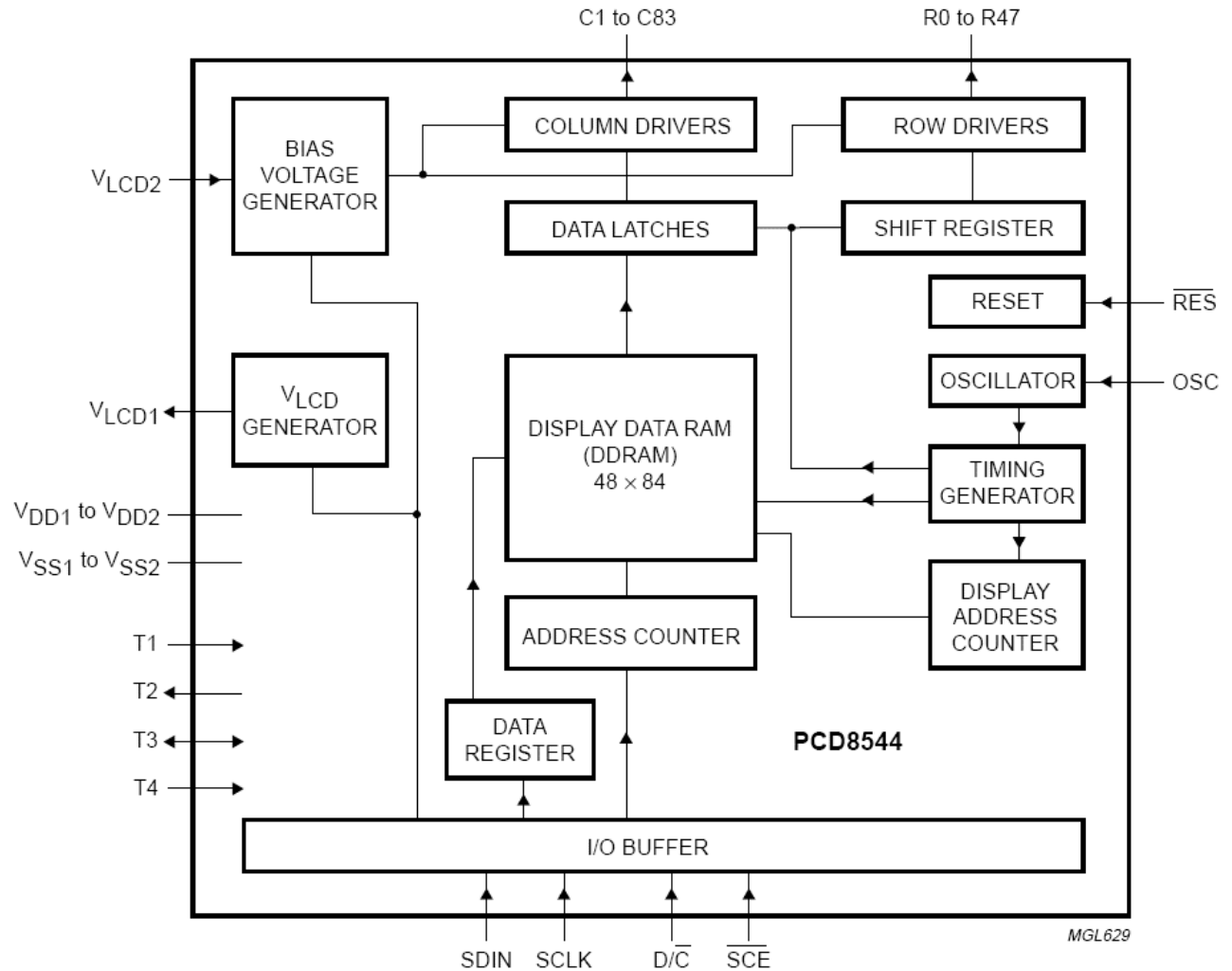


Figure 1 shows internal structure of Controller PCD8544.

Handling of LCD Address (Addressing)

The address arrangement of memory that is shown on LCD Display (DDRAM) is Matrix that consists of 6 rows (Y Address) from Y-Address 0 to Y-Address 5 and 84 columns (X Address) from X-Address 0 to X-Address 83. If user wants to access to the position of displaying result on LCD Display, must refer to the relationship between X-Address and Y-Address. Data that will be sent to display is 8 bit (1 Byte) and it will be arranged as vertical line; in this case, Bit MSB will be lower and Bit LSB will be upper as shown in the following picture;

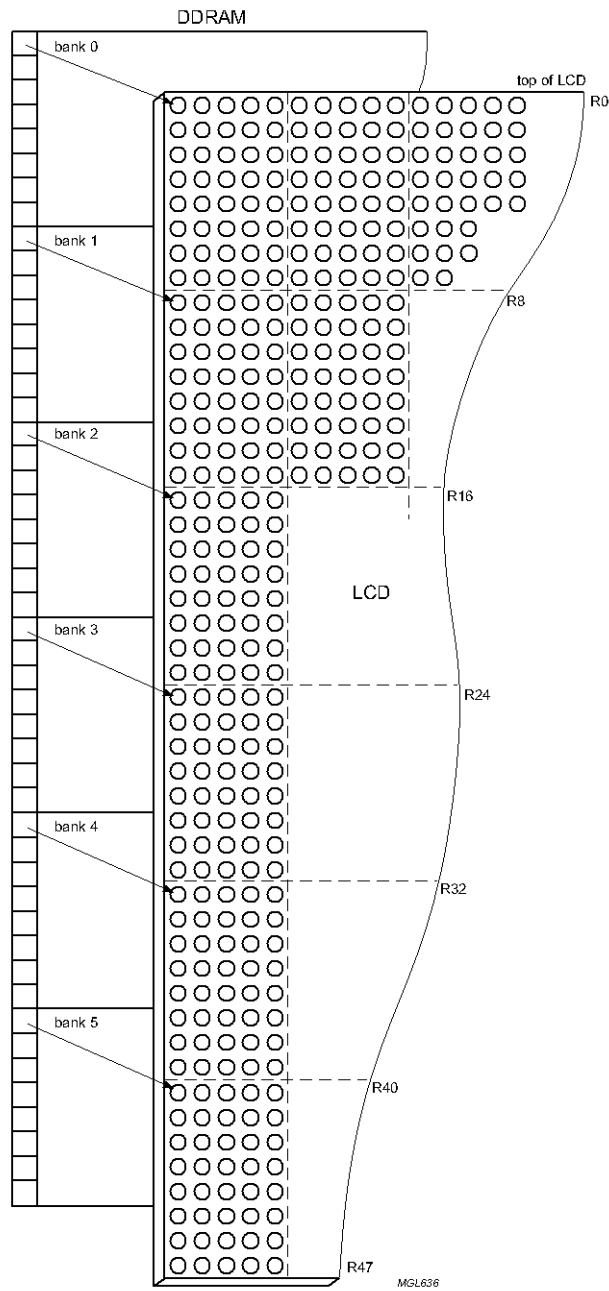
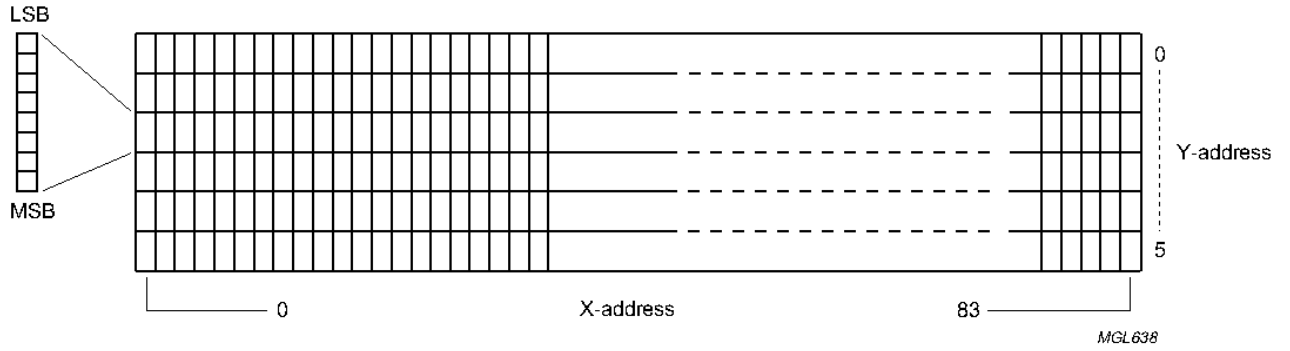


Figure 2 shows structure of Address and Data of LCD Display.

We can write data into the address of memory (DDRAM) continuously and values of X-Address and Y-Address will be increased automatically. In this case, there are 2 methods to configure the operation format of address; firstly, Vertical Addressing Mode (V=1), 1 value of Y-Address will be increased every time (see figure 3); and secondly, Horizontal Addressing Mode (V=0), 1 value of X-Address will be increased every time (see figure 4).

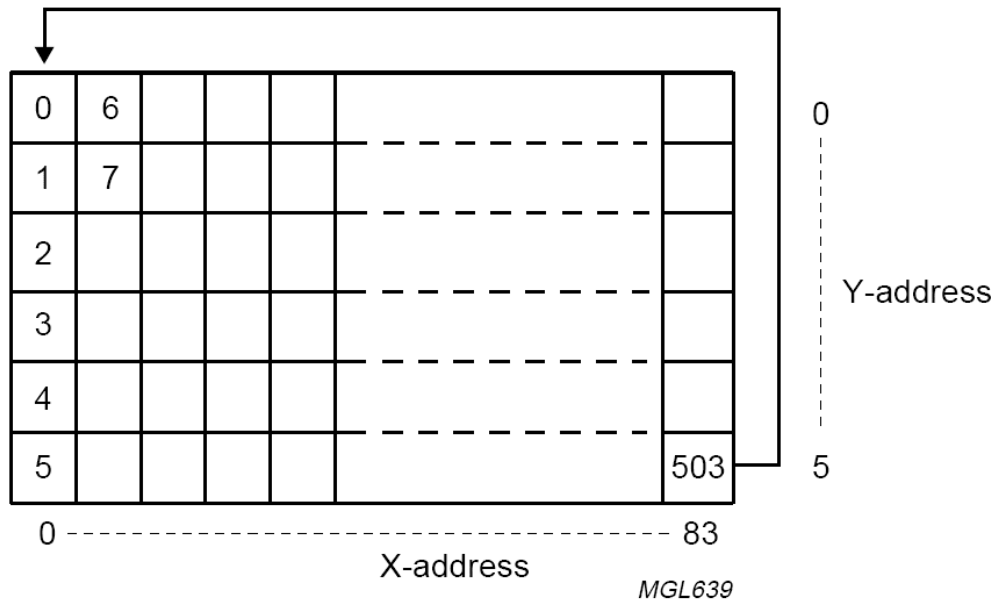


Figure 3 shows the increase of address value on the vertical line (Vertical Addressing Mode (V=1)).

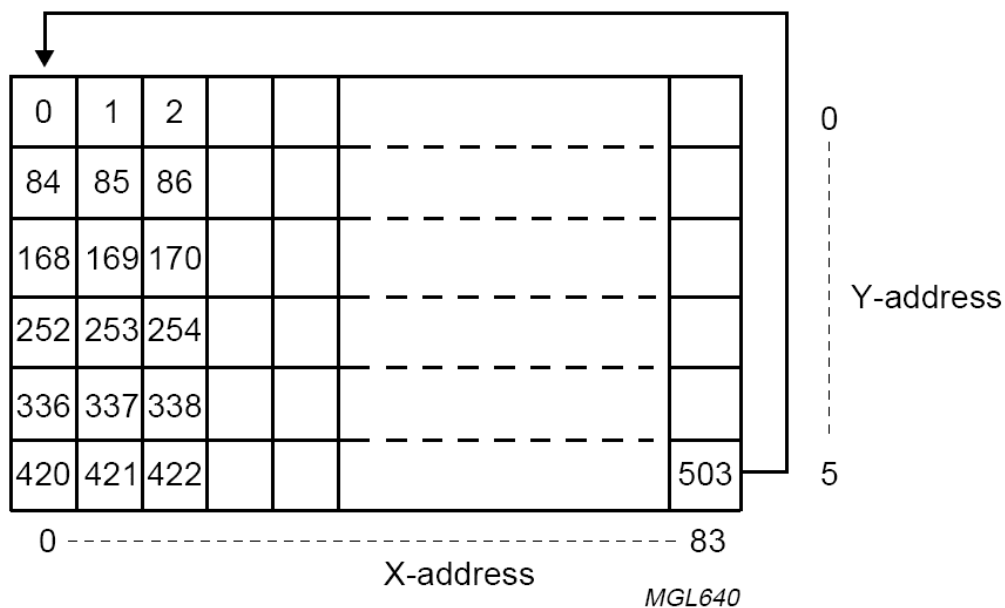


Figure 4 shows the increase of address value on the horizontal line (Horizontal Addressing Mode (V=0)).

Connection for controlling LCD Display

The signal connection for controlling operation of LCD is Serial format and there are several pins as follows;

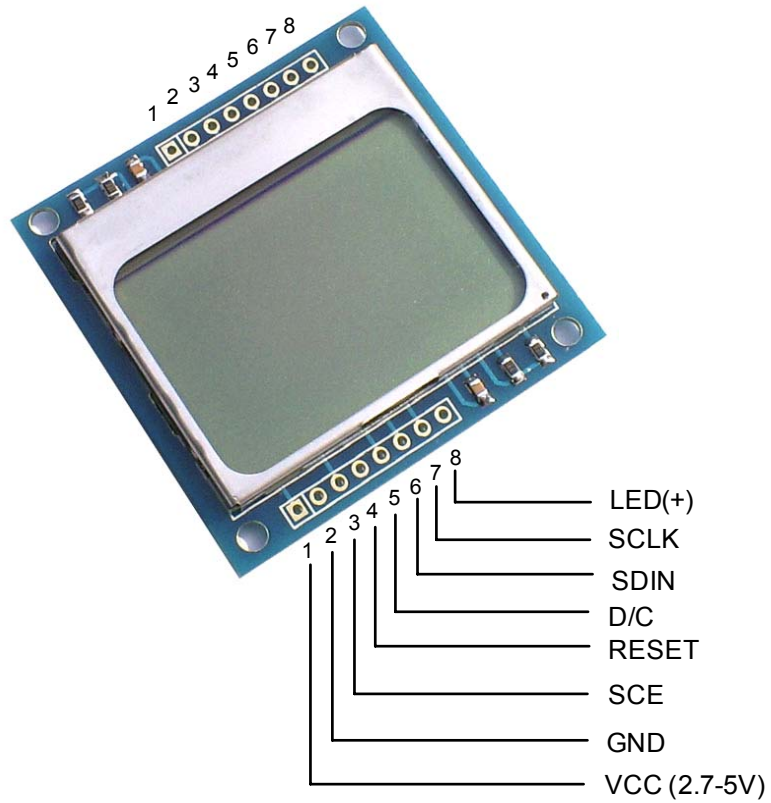


Figure 5 shows the pin positions of LCD.

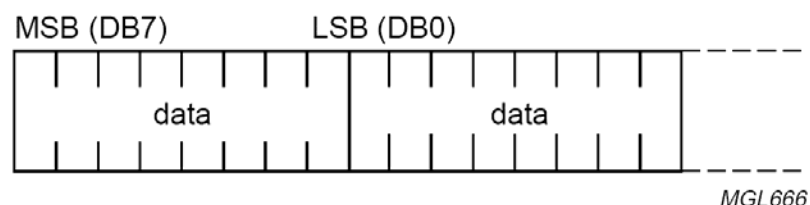
Table 1: Function of Pin LCD

| Pin's Name | Functions |
|------------|---|
| 1. VCC | Pin +VCC; using Power Supply from 2.7 - 5 VCD |

| | |
|----------|---|
| 2. GND | Pin Ground |
| 3. SCE | Pin CHIP ENABLE to control operation of Pin Controllers |
| 4. RESET | Signal RESET for operation of LCD |
| 5. D/C | Pin to configure the data formats between Data and Command. |
| 6. SDIN | Pin DATA (SERIAL DATA LINE) |
| 7. SCLK | Pin CLOCK (SERIAL CLOCK LINE) |
| 8. LED | Pin to control operation of LED (Back Light) |

Communication Format

The format of command that is used to communicate with LCD is divided into 2 modes; Command Mode and Data Mode. In this case, it uses Pin D/C to divide and control signals; if $D/C = 0$, the data that is sent to LCD is Command (see more detailed information of commands in the Table 1); and if $D/C = 1$, the data that is sent to LCD will be Data and it will be placed in DDRAM Memory (Display Data RAM) to be displayed on LCD Display. After 1 byte data has already been written, 1 value of DDRAM address will be increased automatically. The format of data will be serial and it will send MSB (The Most Significant Bit) first. Generally, its structure is displayed as follows;

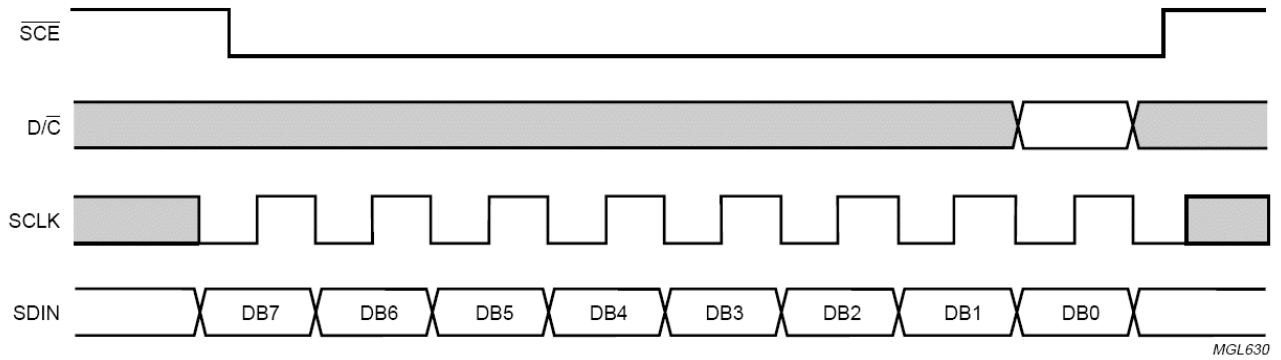


General format of data stream.

Figure 6 shows the general format of Data.

There are 2 methods to send data into LCD; firstly, sending 1 Byte data in each time and secondly, sending many continuous bytes. The Data format is shown as follows;

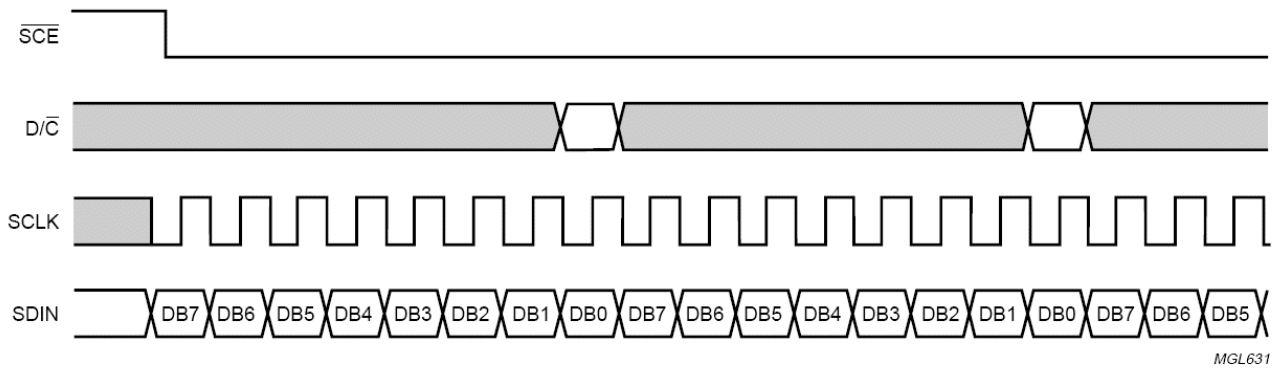
- Sending 1 byte data in each time



Serial bus protocol - transmission of one byte.

Figure 7 shows the format of sending 1 byte data in each time.

- Sending continuous data (more than 1 byte)

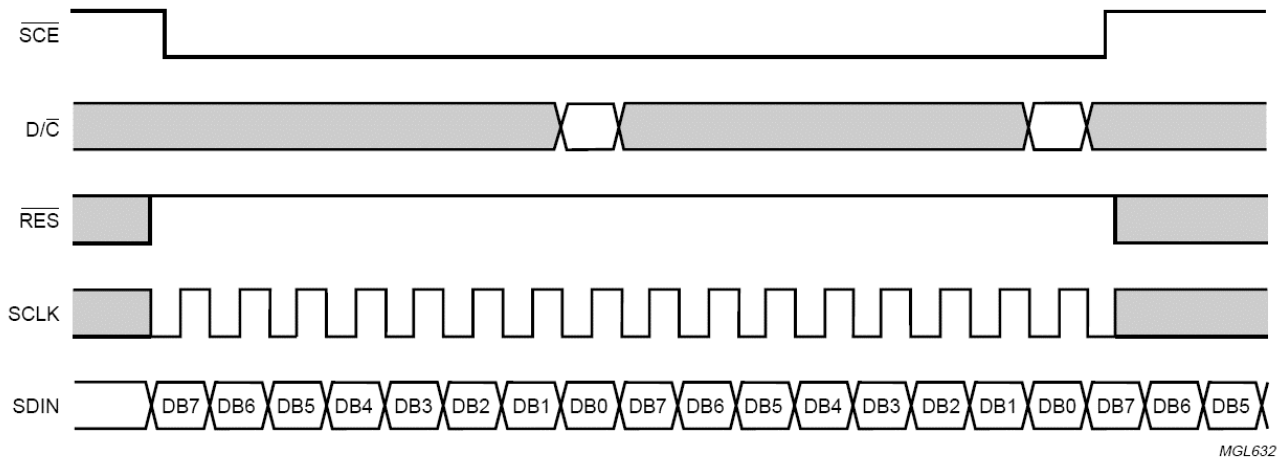


Serial bus protocol - transmission of several bytes.

Figure 8 shows the format of sending the continuous bytes data.

If Pin SCE is in the status of High, any change at signal SCLK is not be affected on LCD; user can send data to LCD when Pin SCE is in status of LOW only. Data will be shifted to Pin SDIN follows the interval of signal CLOCK (Rising Edge). In this case, LCD determines the data to be either Command Mode or Data Mode from status of Pin D/C; if D/C = 0, it is Command Mode; but if D/C = 1, it is Data Mode.

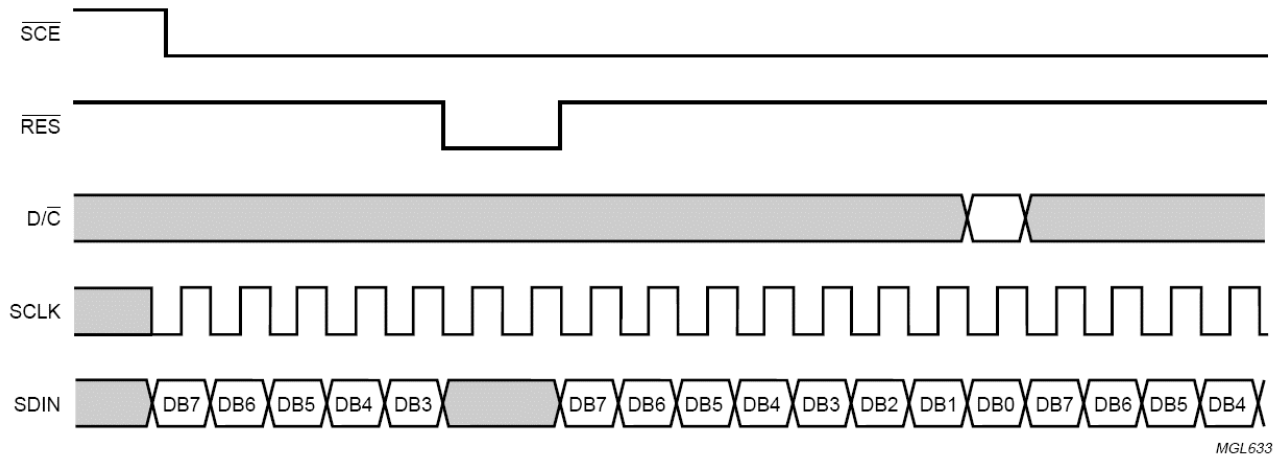
Pin SCE is still Status LOW (SCE = 0) until data byte will be sent successfully as shown in the figure 9.



Serial bus reset function (\overline{SCE}).

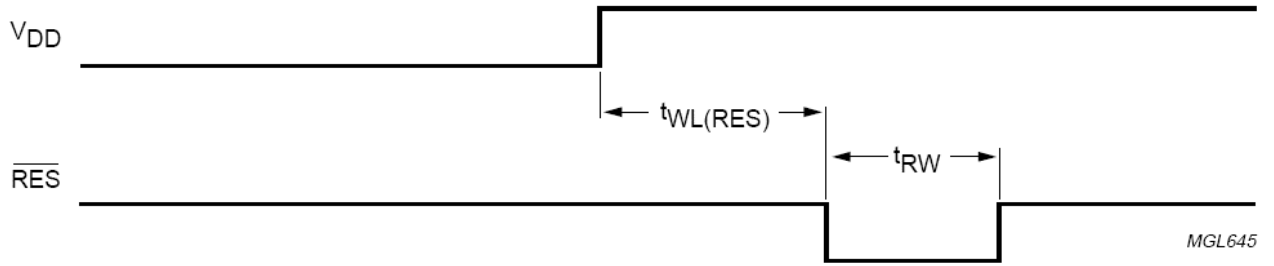
Figure 9 shows diagram of signal RES that is in status of High.

The method to create Signal RESET (RES) is to create Pulse Low at Pin RES; if Signal RESET is occurred (RES = 0) while sending 8 bit data (1 byte) is not complete, data in that byte will be canceled. When status of signal RES is in High (RES = 1), at the next Signal Clock+ will be data that starts at Bit 7 of data again as shown in the figure 10.



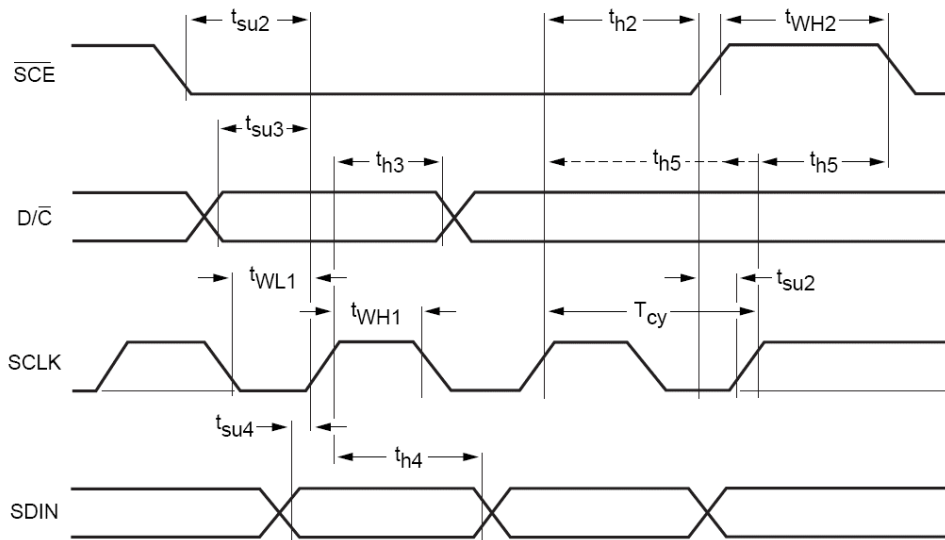
Serial bus reset function (\overline{RES}).

Figure 10 shows diagram of signal RES that is in the status of RESET.



Reset timing.

Figure 11 shows the period of occurring Signal RESET.



Serial interface timing.

Figure 12 shows the period of signals.

Table 2: Parameter values

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|---|--|------------------|------|------|------|
| f _{OSC} | oscillator frequency | | 20 | 34 | 65 | kHz |
| f _{clk(ext)} | external clock frequency | | 10 | 32 | 100 | kHz |
| f _{frame} | frame frequency | f _{OSC} or f _{clk(ext)} = 32 kHz; note 1 | – | 67 | – | Hz |
| t _{VHRL} | V _{DD} to $\overline{\text{RES}}$ LOW | Fig.16 | 0 ⁽²⁾ | – | 30 | ms |
| t _{WL(RES)} | $\overline{\text{RES}}$ LOW pulse width | Fig.16 | 100 | – | – | ns |
| Serial bus timing characteristics | | | | | | |
| f _{SCLK} | clock frequency | V _{DD} = 3.0 V ±10% | 0 | – | 4.00 | MHz |
| T _{cy} | clock cycle SCLK | All signal timing is based on 20% to 80% of V _{DD} and maximum rise and fall times of 10 ns | 250 | – | – | ns |
| t _{WH1} | SCLK pulse width HIGH | | 100 | – | – | ns |
| t _{WL1} | SCLK pulse width LOW | | 100 | – | – | ns |
| t _{su2} | $\overline{\text{SCE}}$ set-up time | | 60 | – | – | ns |
| t _{h2} | $\overline{\text{SCE}}$ hold time | | 100 | – | – | ns |
| t _{WH2} | $\overline{\text{SCE}}$ min. HIGH time | | 100 | – | – | ns |
| t _{h5} | $\overline{\text{SCE}}$ start hold time; note 3 | | 100 | – | – | ns |
| t _{su3} | D/ $\overline{\text{C}}$ set-up time | | 100 | – | – | ns |
| t _{h3} | D/ $\overline{\text{C}}$ hold time | | 100 | – | – | ns |
| t _{su4} | SDIN set-up time | | 100 | – | – | ns |
| t _{h4} | SDIN hold time | 100 | – | – | ns | |

Notes

1. $T_{\text{frame}} = \frac{f_{\text{clk(ext)}}}{480}$
2. $\overline{\text{RES}}$ may be LOW before V_{DD} goes HIGH.
3. t_{h5} is the time from the previous SCLK positive edge (irrespective of the state of $\overline{\text{SCE}}$) to the negative edge of $\overline{\text{SCE}}$

Table 3: Commands Sets for controlling LCD Display

| INSTRUCTION | D/C | COMMAND BYTE | | | | | | | | DESCRIPTION | |
|----------------------|-----|----------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-------------|--|
| | | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 | | |
| (H = 0 or 1) | | | | | | | | | | | |
| NOP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | no operation |
| Function set | 0 | 0 | 0 | 1 | 0 | 0 | PD | V | H | | power down control; entry mode; extended instruction set control (H) |
| Write data | 1 | D ₇ | D ₆ | D ₅ | D ₄ | D ₃ | D ₂ | D ₁ | D ₀ | | writes data to display RAM |
| (H = 0) | | | | | | | | | | | |
| Reserved | 0 | 0 | 0 | 0 | 0 | 0 | 1 | X | X | | do not use |
| Display control | 0 | 0 | 0 | 0 | 0 | 1 | D | 0 | E | | sets display configuration |
| Reserved | 0 | 0 | 0 | 0 | 1 | X | X | X | X | | do not use |
| Set Y address of RAM | 0 | 0 | 1 | 0 | 0 | 0 | Y ₂ | Y ₁ | Y ₀ | | sets Y-address of RAM; 0 ≤ Y ≤ 5 |
| Set X address of RAM | 0 | 1 | X ₆ | X ₅ | X ₄ | X ₃ | X ₂ | X ₁ | X ₀ | | sets X-address part of RAM; 0 ≤ X ≤ 83 |
| (H = 1) | | | | | | | | | | | |
| Reserved | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | | do not use |
| Reserved | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | X | | do not use |
| Temperature control | 0 | 0 | 0 | 0 | 0 | 0 | 1 | TC ₁ | TC ₀ | | set Temperature Coefficient (TC _x) |
| Reserved | 0 | 0 | 0 | 0 | 0 | 1 | X | X | X | | do not use |
| Bias system | 0 | 0 | 0 | 0 | 1 | 0 | BS ₂ | BS ₁ | BS ₀ | | set Bias System (BS _x) |
| Reserved | 0 | 0 | 1 | X | X | X | X | X | X | | do not use |
| Set V _{OP} | 0 | 1 | V _{OP6} | V _{OP5} | V _{OP4} | V _{OP3} | V _{OP2} | V _{OP1} | V _{OP0} | | write V _{OP} to register |

Table 4: Detail of Parameter values from Table 3

| BIT | 0 | 1 |
|-------------------------------------|--|------------------------------|
| PD | chip is active | chip is in Power-down mode |
| V | horizontal addressing | vertical addressing |
| H | use basic instruction set | use extended instruction set |
| D and E | display blank normal mode all display segments on inverse video mode | |
| TC ₁ and TC ₀ | V _{LCD} temperature coefficient 0 V _{LCD} temperature coefficient 1 V _{LCD} temperature coefficient 2 V _{LCD} temperature coefficient 3 | |

Detail of Commands

Command NOP: No Operation

| | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $\overline{D/C}$ | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Command Function Set: It is command to set function for operations of LCD.

| | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $\overline{D/C}$ | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 0 | 0 | 1 | 0 | 0 | PD | V | H |

-PD: It is Bit to select operation mode.

PD=0: Active Mode

PD=1: Power-Down Mode

-V: It is Bit to select the format of increasing address value of (DDRAM) Memory.

V=0: It increases address value on the horizontal line (Horizontal Addressing Mode) see figure 4 above.

V=1: It increases address value on the vertical line (Vertical Addressing Mode) see figure 3 above.

-H: It is Bit to select format of using commands of SCD.

H=0: Using the basic commands (see more information from Table 3)

H=1: Using the additional commands (see more information from table 3)

Command Write Data: It is command to write data into DDRAM Memory to display result on LCD Display.

| | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $\overline{D/C}$ | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 1 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

D7-D0: It is 8 Bit data that must be written to display on LCD Display.

▪ **Command Set in Basic Mode (H = 0)**

Command Display Control: It is command to control displaying result on LCD Display.

| | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $\overline{D/C}$ | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 0 | 0 | 0 | 0 | 1 | D | 0 | E |

Table 5: Meaning of setting values in Bit D and E

| D | E | Meaning |
|---|---|---|
| 0 | 0 | Data on the LCD Display is in status of blank or not display (Display Blank). |
| 0 | 1 | It displays results as usual (Normal Mode). |
| 1 | 0 | Data at every positions on the display is in status of ON. |
| 1 | 1 | Display data on LCD Display inversely (inverse Mode) |

Command Set Y-Address of RAM: It is command to set value of Y-Address in RAM Memory; in this case, Y value is in the range of 0 to 5.

| | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $\overline{D/C}$ | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 0 | 1 | 0 | 0 | 0 | Y2 | Y1 | Y0 |

Table 6: Meaning of setting values into Y2, Y1 and Y0

| Y2 | Y1 | Y0 | Position of Y-Address |
|----|----|----|-----------------------|
| 0 | 0 | 0 | Bank 0 |
| 0 | 0 | 1 | Bank 1 |
| 0 | 1 | 0 | Bank 2 |
| 0 | 1 | 1 | Bank 3 |
| 1 | 0 | 0 | Bank 4 |
| 1 | 0 | 1 | Bank 5 |

Command Set X-Address of RAM: It is command to set value of X-Address of RAM Memory.

| | | | | | | | | |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $\overline{D/C}$ | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 1 | X6 | X5 | X4 | X3 | X2 | X1 | X0 |

Value of X-Address on LCD Display is in the range of 0 to 83; so, the method to set position address of X-Address of X6, X5, X4, X3, X2, X1 and X0 must be in the range of **000000 (00H)** to **1010011 (53H)**.

▪ **Command Set in addition mode (H = 1)**

Command Temperature Control: It is command to control temperature to be in the suitable range. From the specification of LCD that is fluid; if it is in too low temperature, it maybe sticky and display results incompletely. So, it is necessary to compensate the temperature value to be in the suitable range; in this case, user must select value of coefficient V_{LCD} suitably. There are 4 values and can set them by Bit TC1 and TC0.

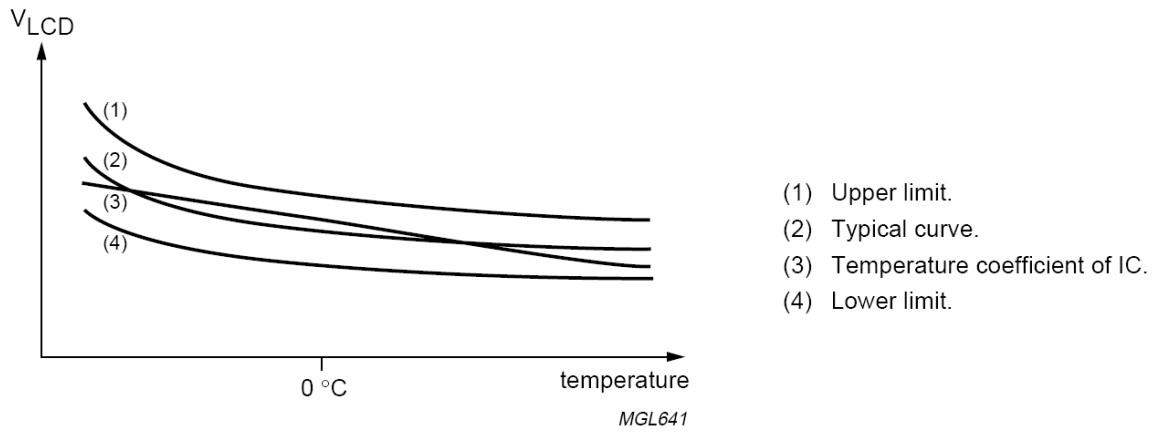


Figure 13 displays graph of the relationship between VLCD and temperature.

| | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| D/C | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | TC1 | TC0 |

Table 7: Meaning of setting Bit TC1 and TC0

| TC1 | TC0 | Coefficient value of VLCD and Temperature |
|-----|-----|---|
| 0 | 0 | VLCD temperature coefficient 0 |
| 0 | 1 | VLCD temperature coefficient 1 |
| 1 | 0 | VLCD temperature coefficient 2 |
| 1 | 1 | VLCD temperature coefficient 3 |

Command Bias System: It is command to set value of Bias Voltage Level by Bit BS2, BS1 and BS0.

| | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| D/C | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | 0 | 0 | 0 | 1 | 0 | BS2 | BS1 | BS0 |

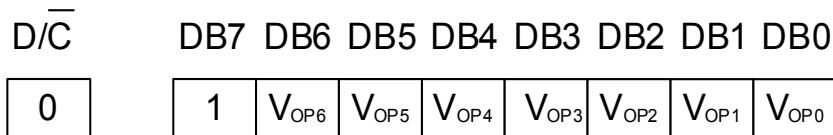
Table 8: Meaning of setting Bit BS2, BS1 and BS0

| BS ₂ | BS ₁ | BS ₀ | n | RECOMMENDED MUX RATE |
|-----------------|-----------------|-----------------|---|----------------------|
| 0 | 0 | 0 | 7 | 1 : 100 |
| 0 | 0 | 1 | 6 | 1 : 80 |
| 0 | 1 | 0 | 5 | 1 : 65/1 : 65 |
| 0 | 1 | 1 | 4 | 1 : 48 |
| 1 | 0 | 0 | 3 | 1 : 40/1 : 34 |
| 1 | 0 | 1 | 2 | 1 : 24 |
| 1 | 1 | 0 | 1 | 1 : 18/1 : 16 |
| 1 | 1 | 1 | 0 | 1 : 10/1 : 9/1 : 8 |

Table 9: Bias Voltage

| SYMBOL | BIAS VOLTAGES | BIAS VOLTAGE FOR 1/8 BIAS |
|--------|------------------|---------------------------|
| V1 | V _{LCD} | V _{LCD} |
| V2 | (n + 3)/(n + 4) | 7/8 × V _{LCD} |
| V3 | (n + 2)/(n + 4) | 6/8 × V _{LCD} |
| V4 | 2/(n + 4) | 2/8 × V _{LCD} |
| V5 | 1/(n + 4) | 1/8 × V _{LCD} |
| V6 | V _{SS} | V _{SS} |

Command Set V_{OP}: it is command to set voltage for V_{LCD} (Voltage Operation).



User can set it from Bit V_{OP6} - V_{OP0} and can calculate value of Voltage V_{LCD} from following equation;

$$V_{LCD} = a + (V_{OP6 \text{ to } V_{OP0}}) \times b$$

Coefficient value
 a = 3.06
 b = 0.06

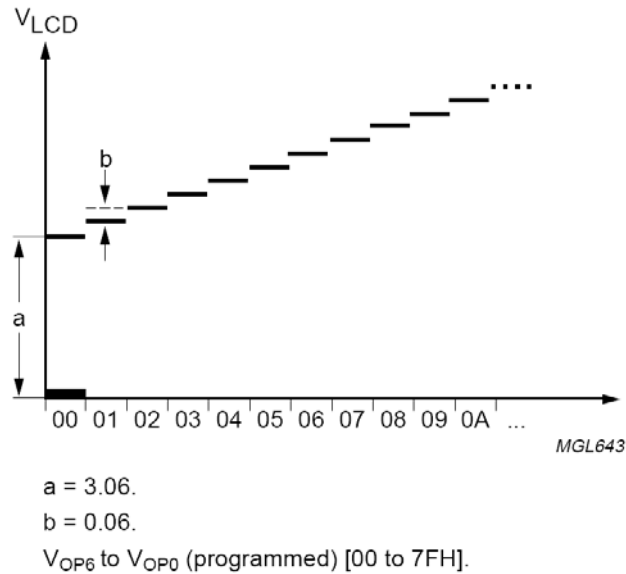


Figure 14 shows graph of Voltage VLCD from Parameter a and b.

Example: If user wants value of V_{LCD} at 5 volt

$$5 = 3.06 + (\text{VOP6 to VOP0}) \times 0.06$$

$$(\text{VOP6 to VOP0}) = (5 - 3.06) / 0.06$$

$$(\text{VOP6 to VOP0}) = 32.33 \text{ approximately } 32 \text{ (20H) or } 0100000B$$

So, the command that will be sent to LCD to set value of VOP is **11000000B** or **COH**.

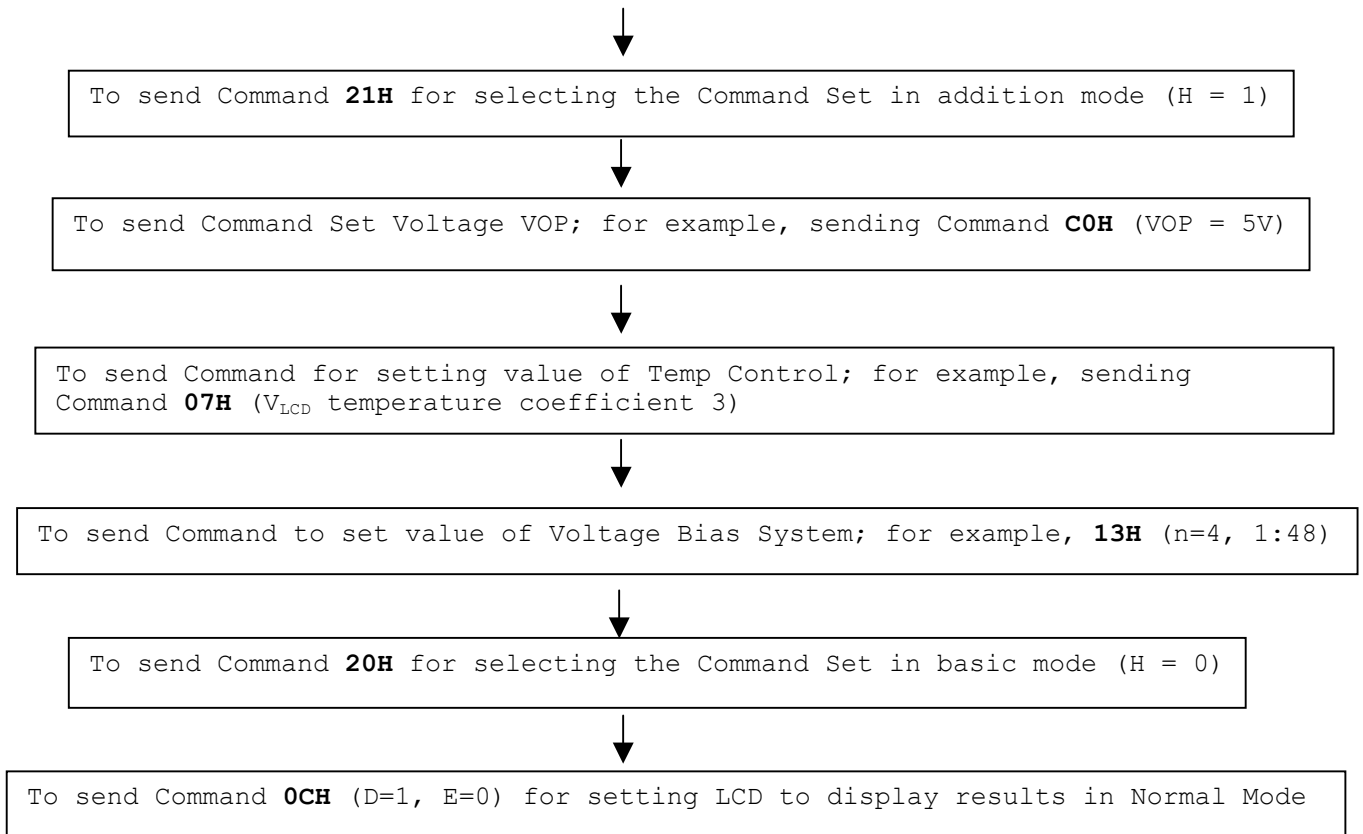
NOTE: Do not set value of VOP too high, the maximum voltage of VLCD is not higher than 8.5 volt.

Initial recommendation to write program for LCD applications

The method to write program for controlling operation of LCD whichever Microcontroller family or number is the same because user must writes program to create signals for controlling operation of LCD. If using function SPI, we recommend user to use Mode MSB First.

The method to write program for controlling operation of LCD is to set operation of LCD first or called "Initial LCD". Normally, its operation order is;

To create signal RESET LCD



After the procedure of Initial LCD is completely, user can write program and send data to display at positions of LCD. Generally, user must specify the required positions of X-Address and Y-Address to display results first.

For example, setting position X = 0, Y = 0 as follows;

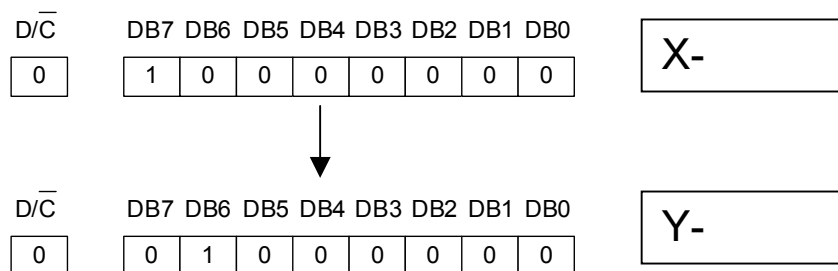


Table 10: Example of creating characters on LCD Display

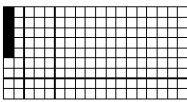
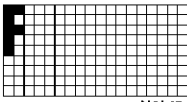
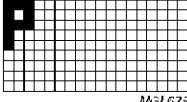
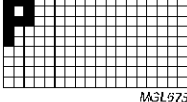
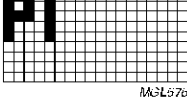
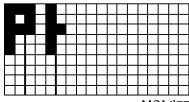
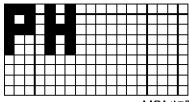



| STEP | SERIAL BUS BYTE | | | | | | | | | DISPLAY | OPERATION |
|------|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|---|--|
| | D/C | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 | | |
| 1 | start | | | | | | | | | | SC \bar{E} is going LOW |
| 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | | function set PD = 0 and V = 0, select extended instruction set (H = 1 mode) |
| 3 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | set V _{OP} ; V _{OP} is set to a +16 × b [V] |
| 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | function set PD = 0 and V = 0, select normal instruction set (H = 0 mode) |
| 5 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | | display control set normal mode (D = 1 and E = 0) |
| 6 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |  MAGL573 | data write Y and X are initialized to 0 by default, so they are not set here |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |  MAGL574 | data write |
| 8 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |  MAGL575 | data write |
| 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  MAGL575 | data write |
| 10 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |  MAGL576 | data write |

Table 10 (Continue): Example of creating characters on LCD Display

| STEP | SERIAL BUS BYTE | | | | | | | | | DISPLAY | OPERATION |
|------|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|---|---|
| | D/C | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 | | |
| 11 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |  | data write |
| 12 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |  | data write |
| 13 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |  | display control; set inverse video mode (D = 1 and E = 1) |
| 14 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | set X address of RAM; set address to '0000000' |
| 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | data write |