APPENDIX H

GRAPHIC LCDS

OBJECTIVES

Upon completion of this appendix, you will be able to:

>> Compare graphic LCDs with text LCDs
>> Describe resolution and dot pitch
>> Explain how the graphic LCDs work
>> Describe how texts are displayed on graphic LCDs

In this Appendix, we examine the graphic LCDs, although an entire book can be dedicated to graphic LCD and its programming. Section H.1 covers some basic concepts of graphic LCDs. In Section H.2, we explain displaying texts on graphic LCDs.

SECTION H.1: GRAPHIC LCDS

The screen of graphic LCDs is made of pixels. The pictures and the texts are created using pixels and the programmers have control over each and every individual pixel. See Figures H-1 and H-2.

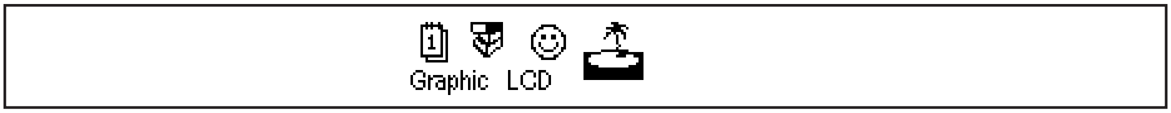


Figure H-1. A picture on a Mono-color LCD

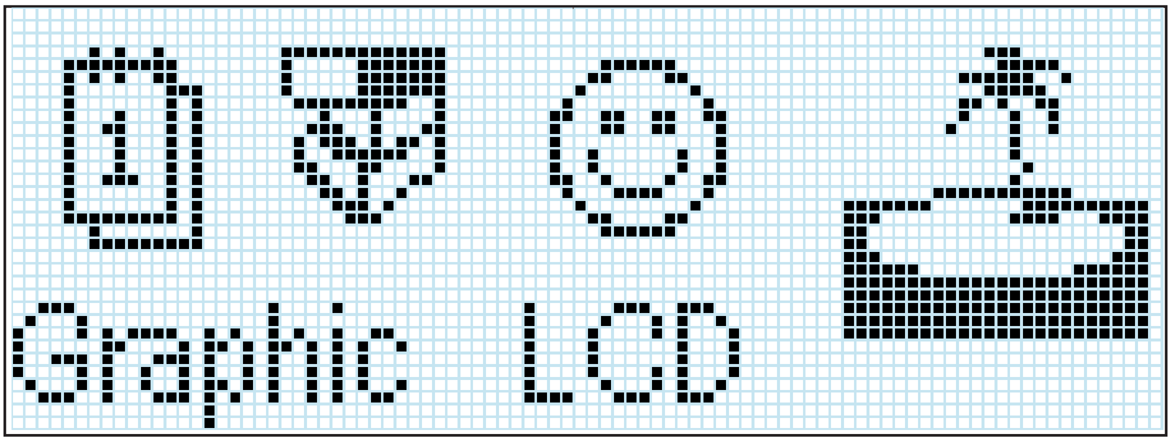


Figure H-2. A Zoomed Picture on a Mono-color LCD

Some LCD Characteristics

Resolution

The total number of pixels (dots) per screen is a major factor in assessing an LCD and is shown below:

Resolution = Pixels per line × number of lines

For example, when the resolution of an LCD is 720 × 350, there are 720 pixels per line and 350 lines per screen, giving a total of 252,000 pixels. The total number of pixels per screen is determined by the size of the pixel and how far apart the pixels are spaced. For this reason, one must look at what is called the dot pitch in LCD specifications.

Dot pitch

Dot pitch is the distance between adjacent pixels (dots) and is given in millimeters. For example, a dot pitch of 0.31 means that the distance between pixels is 0.31 mm. Consequently, the smaller the size of the pixel itself and the smaller the space between them, the higher the total number of pixels and the better the

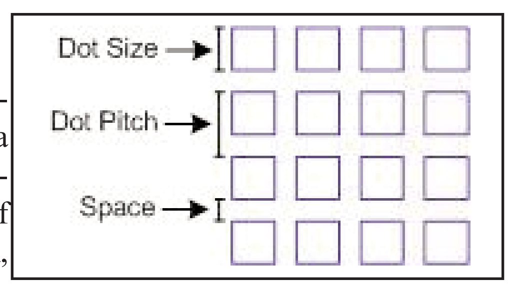
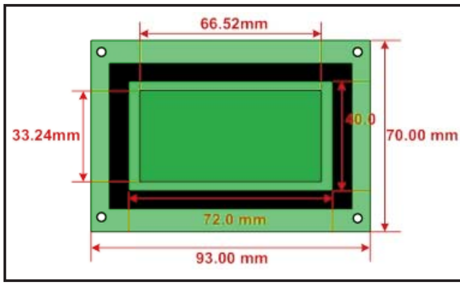


Figure H-3. Dot Pitch and Dot Size



Item	Dimension	Unit
Module Size	93.0*70.0*10.0	mm
Viewing Area	72.0*40.0	mm
Number of Dots	128*64	Pixels
Dot Size	0.48*0.48	mm
Dot Pitch	0.52*0.52	mm
Module Size	93.0*70.0*15.0	mm

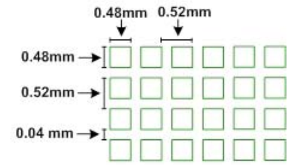


Figure H-4. Mechanical specifications of a GDM12864 128x64 LCD

resolution. Dot pitch varies from 0.6 inch in some low-resolution LCDs to 0.2 inch in higher-resolution LCDs. Figure H-3 shows Dot Pitch and Dot Size parameters. The specifications of a sample mono-colored LCD are shown in Figure H-4.

In some LCD specifications, it is given in terms of the number of dots per square inch, which is the same way it is given for laser printers, for example, 300 DPI (dots per inch).

Dot pitch and LCD size

LCDs, like televisions, are advertised according to their diagonal size. For example, a 14-inch monitor means that its diagonal measurement is 14 inches. There is a relation between the number of horizontal and vertical pixels, the dot pitch, and the diagonal size of the image on the screen. The diagonal size of the image must always be less than the LCD's diagonal size. The following simple equation can be used to relate these three factors to the diagonal measurement. It is derived from the Pythagorean Theorem:

$(\text{image diagonal size})^2 = (\text{number of horizontal pixels} \times \text{dot pitch})^2$
$+ (\text{number of vertical pixels} \times \text{dot pitch})^2$

Since the dot pitch is in millimeters, the size given by the equation above would be in mm, so it must be multiplied by 0.039 to get the size of the monitor in inches. See Example H-1.

Displaying on the graphic LCDs

To display a picture on the screen, a distinct color must be shown on each pixel of the LCD. To do so, there is a display memory (frame buffer) that retrieves the attributes (colors) of the entire pixels of the screen and there is an LCD controller which displays the contents of the frame buffer memory on the LCD. See Figure H-5.

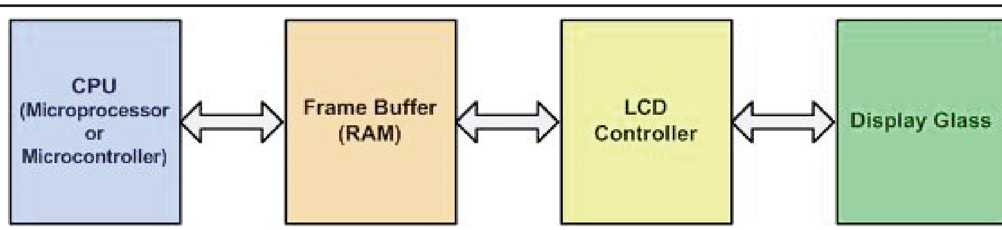


Figure H-5. Mechanical specifications of a GDM12864 128x64 LCD

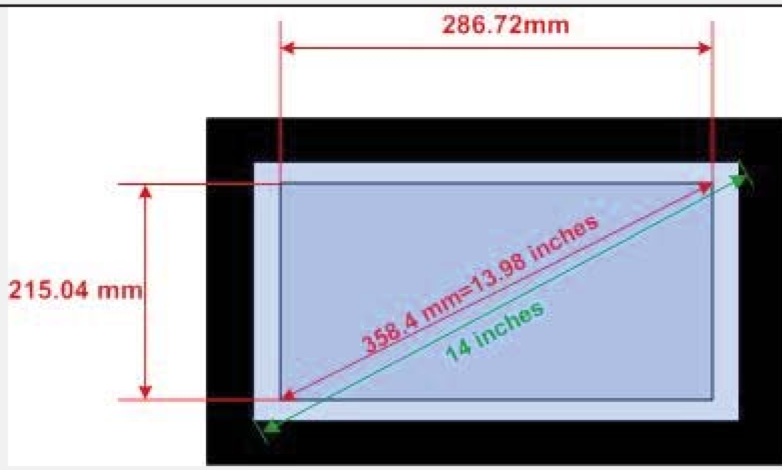
Graphic LCDs might come with or without frame buffer and the LCD controller. In cases that the LCD does not have frame buffer memory or controller they must be provided externally. Some new microcontrollers have the LCD controllers internally which can directly drive the LCDs. To display a picture on the screen the microcontroller writes it to the frame buffer memory.

Example H-1

A manufacturer has advertised a 14-inch monitor of 1024 × 768 resolution with a dot pitch of 0.28. Calculate the diagonal size of the image on the screen. It must be less than 14 inches.

Solution:

The calculation is as follows:
(image diagonal size)^2 = (number of horizontal pixels × dot pitch)^2 + (number of vertical pixels × dot pitch)^2
(diagonal size)2 = (1024 × 0.28 mm)2 + (768 × 0.28 mm)2 = 358.4 mm
diagonal size (inches) = 358.4 mm × 0.039 inch per mm = 13.98 inches
In the LCD the diagonal size of the image area is 13.98 inches while the diagonal size of the viewing area is 14 inches.



Since the attributes (colors) of the entire pixels are stored in the frame buffer memory, the higher the number of pixels and colors options, the larger the amount of memory is needed to store them. In other words, the memory requirement goes up as the resolution and the number of supported colors go up. The number of colors displayed at one time is always 2n where n is the number of bits set aside for the color. For example, when 4 bits are assigned for the color of the pixel, this allows 16 combinations of colors to be displayed at one time because $2^4 = 16$. The number of bits used for a pixel color is called color depth or bits per pixel (BPP). See Table H-1 and Example H-2.

Table H-1: BPP (bit per pixel) vs. color

BPP	Colors
1	on or off (monochrome)
2	4
4	16
8	256
16	65,536
24	16,777,216

In Table H-1, notice that in a monochrome LCD a single bit is assigned for the color of the pixel and it is for "on" or "off".

Mixing RGB (Red, Green, Blue) colors

We can get other colors by mixing the three primary colors of Red, Green, and

Example H-1

In a certain graphic LCD, a maximum of 256 colors can be displayed at one time. How many bits are set aside for the color of the pixels?

Solution:

To display 256 colors at once, we must have 8 bits set for color since 28 = 256.
A manufacturer has advertised a 14-inch monitor of 1024 × 768 resolution with a dot pitch of 0.28. Calculate the diagonal size of the image on the screen. It must be less than 14 inches.

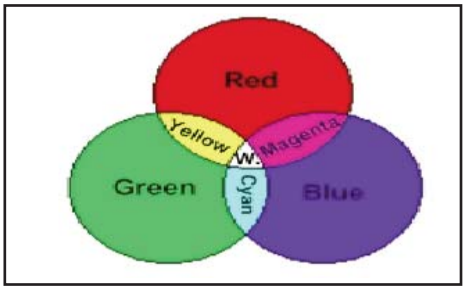


Figure H-3. Making New Light Colors by Mixing the 3 Primary Light Colors

Blue. The intensity (proportion) of the colors mixed can also affect the color we get. In many high-end graphics systems, an 8-bit value is used to represent the intensity. Its value can be between 0 and 255 (0 to 0xFF) representing high intensity (255) and zero intensity. See Table H-2. Using three primary colors and intensity, we can make many colors we want. See Figure H-6.

Table H-2: The 16 Possible Colors

I	R	G	B	Color
0	0	0	0	Black
0	0	0	1	Dark Blue
0	0	1	0	Dark Green
0	0	1	1	Dark Cyan
0	1	0	0	Dark Red
0	1	0	1	Dark Magenta
0	1	1	0	Brown
0	1	1	1	Light Gray
1	0	0	0	Dark Gray
1	0	0	1	Light Blue
1	0	1	0	Light Green
1	0	1	1	Light Cyan
1	1	0	0	Light Red
1	1	0	1	Light Magenta
1	1	1	0	Yellow
1	1	1	1	White

LCD Buffer memory size and color

In discussing the graphics, we need to clarify the relationship between pixel resolution, the number of colors supported, and the amount of frame buffer RAM needed to store them. There are two facts associated with every pixel on the screen:

1. The location of the pixel
2. Its attributes: color and intensity

These two facts must be stored in the frame buffer RAM. The higher the number of pixels and colors options, the larger the amount of memory that is needed to store them. In other words, the memory requirement goes up as the resolution and the number of colors supported goes up. As we just mentioned, the number of colors displayed at one time is always 2n where n is the number of bits set aside for the color. For example, when 4 bits are assigned for the color of the pixel, this allows 16 combinations of colors to be displayed at one time because 24 = 16. The commonly used graphics resolutions are 176 x 144 (QCIF), 352x288 (CIF), 320x240 (QVGA), 480x272 (WQVGA), 640x480 (VGA) and 800x480 (WVGA). You may find the definitions of these abbreviations on the Internet.

We use the following formula to calculate the minimum frame buffer memory requirement for a graphic LCD:

Buffer memory size (in byte)=(Horizontal Pixels × Vertical Pixels × color BPP)/8

Example H-3 shows how to calculate the memory need for various resolutions and color depth.

Example H-3

Find the frame buffer RAM needed for (a) 176x144 with 4 BPP and (b) 640x480 resolution with 256 colors.

Solution:

(a) For this resolution, there are a total of 25,344 pixels (176 columns × 144 rows = 25,344). With 4 bits for the color of each pixel, we need total of (25,344 × 4)/8= 16,672 bytes of frame buffer RAM. These 4 bits give rise to 16 colors.
(b) For this resolution, there are a total of 640 × 480=307200 pixels. With 256 colors, we need 8 bits for color of each pixel. Now, total of (640 × 480 × 8) / 8 = 307200 bytes of frame buffer RAM needed.

In VGA, 640 x 480 resolution with support for 256 colors displayed at one time requires a minimum of 640 × 480 × 8 = 2,457,600 bits =307,200 bytes of memory, but due to the memory organization used, the amount of memory used is higher.

Storing pixels in the memory of mono-color LCDs

In mono-colored LCDs each pixel can be on or off. Therefore, 1 bit can preserve the state of 1 pixel and a byte preserves 8 adjacent pixels. In some LCDs, e.g. GDM12864A and PCD8544, pixels are stored vertically in the bytes, as shown in Figure H-7, while in some other LCDs, e.g. T6963, the pixels are stored horizontally.

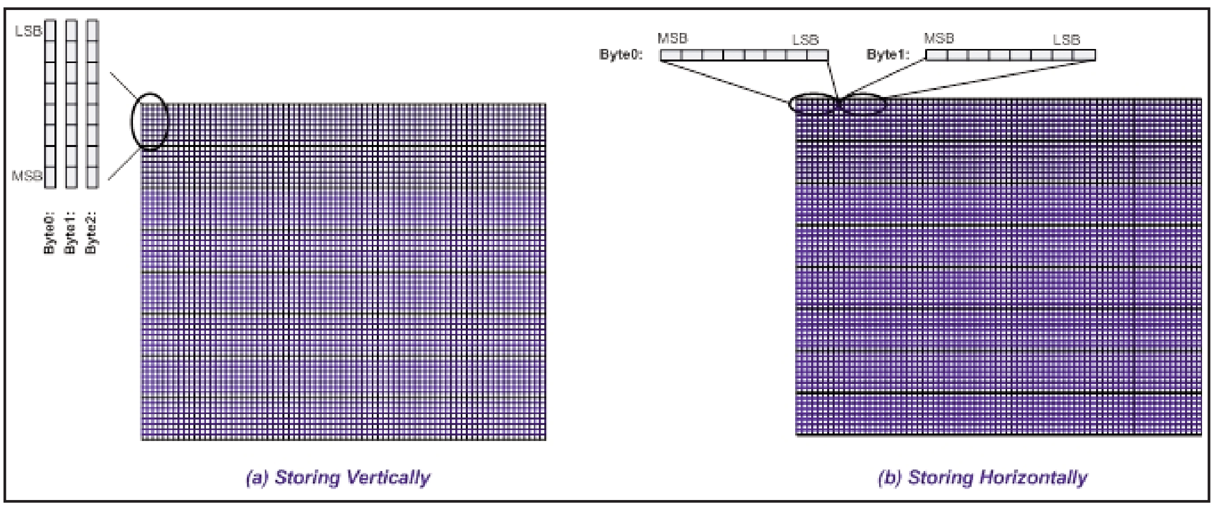


Figure H-7. Storing Data in the LCD Memory of Mono-colored LCDs

Review Questions

1. As the number of pixels goes up, the size of display memory _______ (increases, decreases).

2. If a total of 24 bits is set aside for color, how many colors are available?
3. Calculate the total video memory needed for 1024 × 768 resolution with 16 colors displayed at the same time.
4. With BPP of 16, we get ________colors.

Section H.2: Displaying Texts on Graphic LCDs

As shown in Figure H-8 each character can be made by putting pixels next to each other.

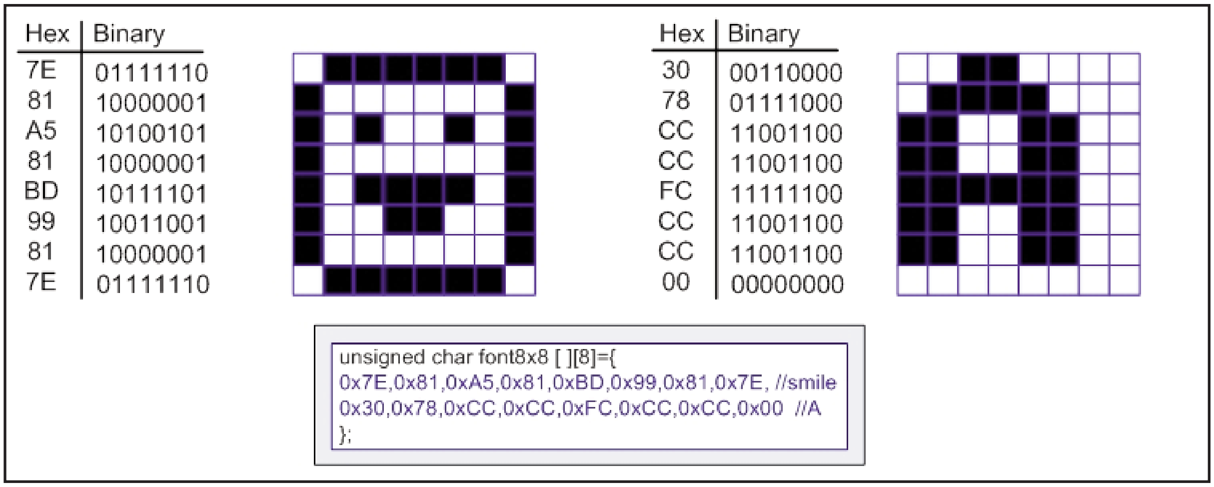


Figure H-8. Pixel Patterns of Characters Happy Face and Letter A

To display characters on the screen, we must have the pixel patterns of the entire characters. Whenever we want to display a character on the screen we copy its pixel pattern into the display memory. See Figure H-9.

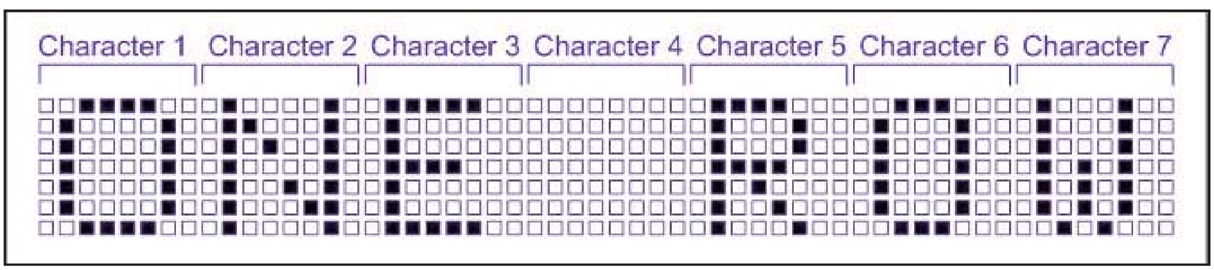


Figure H-9. A Sample Text

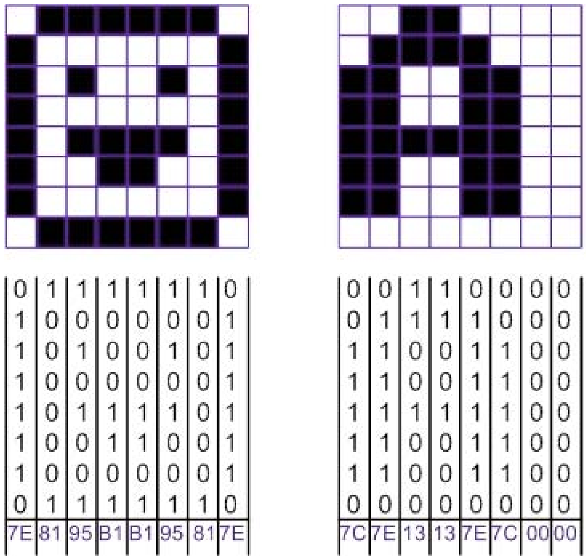
The pixel patterns are stored in an array in the same way that they should be stored in the LCD memory. This means that for horizontal LCDs the bits are stored horizontally and for vertical LCDs the pixels are stored vertically. Figure H-8 shows the way patterns are stored for horizontal LCDs. In Figure H-10 the same patterns are stored for vertical LCDs.

To get better-looking characters, the font resolution must be increased, which translates to more pixels horizontally and vertically. See Figure H-11.

Review Questions

1. True or false. The same font table can be used for vertical and horizontal LCDs.

2. True or false. To display a character on the LCD, its pixel pattern should be copied onto the LCD display memory.




```
unsigned char font8x8 [ ][8]={
0x7E,0x81,0x95,0xB1,0xB1,0x95,0x81,0x7E, //smile
0x7C,0x7E,0x13,0x13,0x7E,0x7C,0x00,0x00  //A
};
```

Figure H-10. Pixel Patterns of Happy Face and Character A and its Font for Ver. LCD

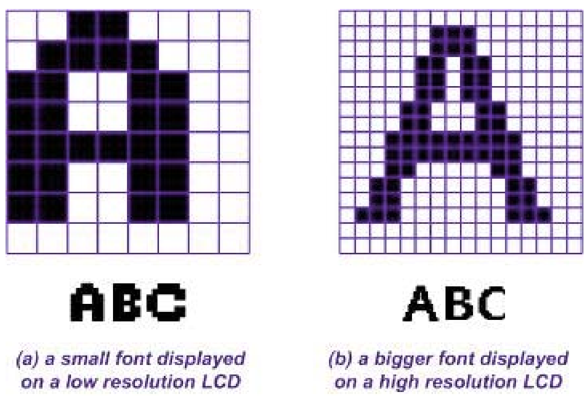


Figure H-11. A Bigger Font vs. a Smaller Font

Answers to Review Questions

Section H-1:

1. increases
2. 224 = 16.7 million
3. 1024 × 768 × 4 = 3,145,728 bits = 384K bytes, but it uses 512 KB due to bit planes.
4. 216 = 65,536

Section H-2:

1. False
2. True