AN52927

PSoC 3 and PSoC 5LP - Segment LCD Direct Drive

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Associated Part Family: All PSoC 3 and PSoC 5LP families

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AN52927 demonstrates how easy it is to drive a segment LCD glass using the integrated LCD driver in PSoC® 3 and PSoC 5LP. This application note gives a brief introduction to segment LCD drive features and provides a step-by-step procedure to design Segment LCD applications using the PSoC Creator™ tool.

Contents

1 Introduction

PSoC Creator, which is used to create PSoC 3 and PSoC 5LP projects, includes building blocks in the form of components for different functions. The segment LCD component is included for the segment LCD drive, which significantly reduces the design cycle time.

This application note takes you through an example project that uses the segment LCD component. If you are unfamiliar with the PSoC 3 and PSoC 5LP device, see the PSoC 3 and PSoC 5 LP Introduction webpage. To learn the basics of the Segment LCD, see Appendix A.

2 Segment LCD Drivers in PSoC

PSoC 3 and PSoC 5LP have 64 inbuilt segment LCD drivers. This gives it the capability to drive up to 768 pixels (16 commons x 48 segments).

Following are the major features of the segment LCD drivers in PSoC 3 and PSoC 5LP:

- Direct drive with internal bias generation—no other external hardware is required.
- Maximum 64 inbuilt LCD drivers (which includes both common and segment pin driver).
- Supports 14-segment and 16-segment alphanumeric display, 7-segment numeric display, dot matrix, and special symbols.

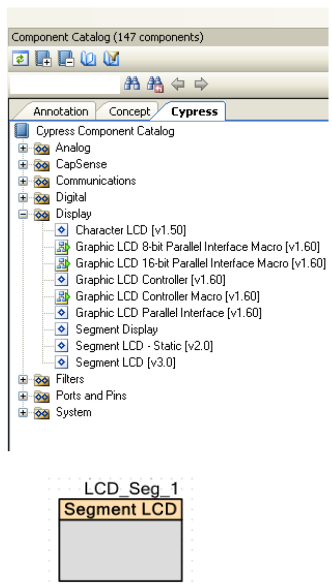
- Supports both Type A and Type B waveforms.
- Wide LCD bias range (2 V to supply voltage).
- Static, 1/3, 1/4, 1/5 bias ratios.
- Supports LCD glass with up to 16 common lines.
- No CPU intervention in LCD refresh.
- Adjustable refresh rate from 10 Hz to 150 Hz.
- Configurable power modes, which allows power optimization.

For a more detailed view of the hardware operation of the LCD drive system, see the Technical Reference Manual.

3 PSoC Creator Component: Segment LCD

To ease the application design process, the PSoC Creator Integrated Design Environment (IDE) includes a Segment LCD Component that does most of the work: from setting the LCD drive configuration registers to LCD refresh. You can find the “Segment LCD” component in the Component Catalog under “display” in PSoC Creator.

Figure 1. Component Catalog in PSoC Creator



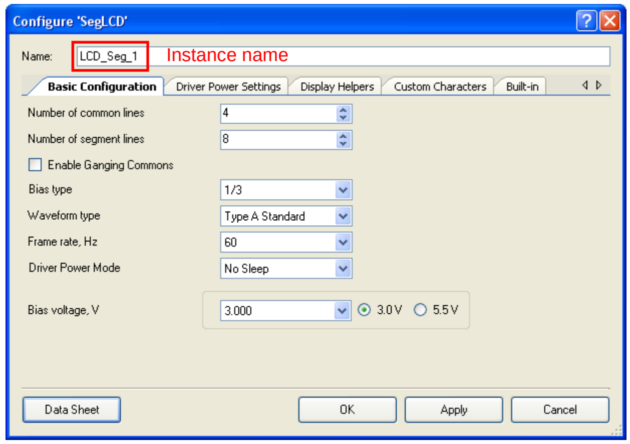
There are two components: one for static segment LCD and another for multiplexed segment LCD. In this application note, only the multiplexed segment LCD component—segment LCD—is discussed. This component can also be configured to drive static LCD.

3.1 Segment LCD Component Configuration

Double-click the component placed in the Top Design. There are four tabs, which configure the SegLCD component completely based on the requirements.

3.1.1 Basic Configuration Tab

Figure 2. Basic Configuration Tab



This tab accepts the following:

- Number of commons and segment lines. The number of commons can be from 1 to 16. The maximum number of segment lines will then depend on the available I/Os in the selected PSoC device.
- Bias Type: 1/3, 1/4, or 1/5
- Waveform Type: Type A or Type B
- Frame Rate or Refresh Rate: 10 Hz to 150 Hz (max value depends on the driver power mode, waveform type, and number of commons).
- Drive Power Mode: This gives power optimization. There are three modes, as shown in the following table.

Table 1. SegLCD Drive Power Modes

Drive Power Mode	Power	Usage Tips
No Sleep	High	Use under two conditions: ▪ When the PSoC is always in active mode and no power saving feature is required ▪ When LCD is not required to be operational when the device is put to sleep
Low Power Using ILO	Low	Use when extremely low power is required. In this mode, the SegLCD component works even when the PSoC is in the sleep mode. The SegLCD component takes the internal low-speed oscillator (ILO) clock for operation. ILO is low power; but, it comes at the cost of accuracy. If accurate LCD refresh rate is not required, you can use this mode.
Low Power using Ext 32KHz crystal	Low	This mode also gives low power operation. The only difference between this mode and “Low Power using ILO” is that this mode requires an external 32 kHz crystal for operation, thereby generating accurate clock for timing LCD refresh events.

Note that if the mode is set to “Low Power using ILO”, there are limited values available for frame rate parameter. This is due to the use of low frequency 1 kHz ILO for the component. Frame rate is also a function of number of commons. As the number of common increases, maximum frame rate decreases.

- Bias Voltage: This defines the contrast of the LCD. There are two ranges available: 3.0 V and 5.5 V. Note that these two voltages represent the supply voltage (V_{DDA}) to PSoC device.

Table 2. SegLCD Bias Voltage

	3.0 V supply	5.5 V supply
Bias Range	2.017 V-3.0 V	2.35 V-5.5 V
Step Size	27 mV	50 mV

This step size comes from the 6-bit DAC that is used to generate these reference voltages. For this reason, you can get a maximum 64 levels of contrast. However, the number of levels of contrast depends on the supply voltage

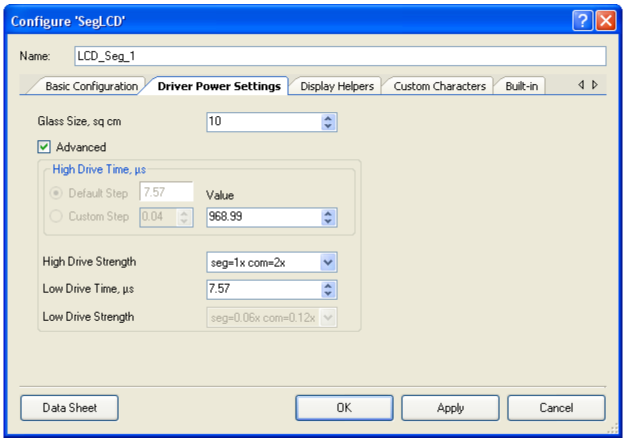
V_{DDA}. The full 64 levels are obtained with a 5.5 V supply, but only 37 levels are obtained with a 3 V supply. Table 2 gives the reference for two supply voltages. The SegLCD component includes the API to adjust this bias level at run time.

- Ganging Commons: This is useful when higher driver strength is required for driving a larger segment LCD display with higher capacitance. When this option is selected, two I/Os will be used to drive a common pin of LCD.

3.1.2 Driver Power Settings

This tab has settings to control the SegLCD component driver power.

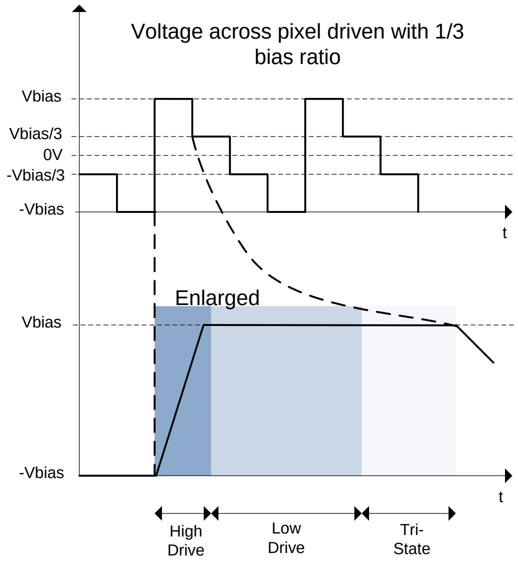
Figure 3. Driver Power Settings Tab



The driver operates in three stages:

- High Drive Stage: During this stage, LCD pixel capacitance is charged quickly using high drive current at the start of each refresh event.
- Low Drive stage: During this stage, power is supplied to the pixel to sustain the voltage, compensating for the leakages from the LCD pixel capacitance. This has less power than high drive stage.
- Tristate (Driver Disabled): During this stage, driver is disabled until the next refresh event. Whatever charge is stored in the pixel capacitance will cause the LCD liquid crystal orientation. Note that leakage can occur during this period. Keeping the driver in this stage for a long time will affect the display contrast. The following figure shows the three stages of the LCD driver.

Figure 4. Drive Stages



Note that when the drive power mode in the “Basic Configuration” tab is set to “No Sleep”, the LCD driver will go through all stages—High Drive, Low Drive, and Tristate. When any of the low power modes is selected in the **Basic Configuration** tab, then there will be no Low Drive stage; the driver will directly transition to Tristate after High Drive stage.

You can configure the drive power strengths during High Drive as well as the period of time it remains in each stage. This gives flexibility in power and performance optimization. There are eight total modes you can use, as shown in the following table.

Table 3. SegLCD Driver Modes

Power strength	Mode	Notes
Seg=1x, Com=1x	High Drive	Configurable by the user
Seg=1x, Com=2x	High Drive	
Seg=1x, Com=4x	High Drive	
Seg=2x, Com=2x	High Drive	
Seg=2x, Com=4x	High Drive	
Seg=4x, Com=4x	High Drive	
Seg=0.06x, Com=0.06x	Low Drive	Configured automatically based on the selected high drive
Seg=0.06x, Com=0.12x	Low Drive	

As shown in Table 3, there are six power modes in High Drive and two power modes in Low Drive. These modes give the ability to adjust the power of the common drive relative to the segment drive. Because the number of commons will be less than the number of segment lines, AC coupling can occur if the drive strengths of both segment driver and common driver are same. To avoid this, programmable drive strengths are given in the driver system. The driver power strengths given in the previous table are comparable across the modes as well between segments and commons. For example, in high drive mode, Power strength Seg=1x, Com=4x implies common line drive strength is four times greater than segment line driver. Also, common line drive strength in this mode is four times stronger than Seg=1x, Com=1x drive mode.

Glass Size Option

You can leave everything to the component to decide the drive strength and duration based on the glass size entered. The component calculates the drive strengths based on number of commons and the glass size value which gives information about the amount of glass capacitance.

Clear the **Advanced** check box to use the glass size option. If advanced is selected, high drive and low drive time and high drive strength must be manually entered. Low drive strength will be automatically selected based on the high drive strength.

Setting High Drive and Low Drive Duration

High Drive and Low Drive duration are the periods when the LCD drive consumes power. Setting the duration too high will cause more power to be consumed. Setting it too low will cause the pixels to be charged for less time over the active common period and will cause contrast issues. It becomes even more important when the component is operated in low power modes and the device is put to sleep. In these modes, the entire device stays active during High Drive stage. The LCD component has the authority to give permission for the device to be put to sleep. If the sleep command is issued through firmware and the LCD driver is currently in high drive stage, the device will not enter sleep mode. The sleep command will be in pending state as long as the driver is in high drive stage. Thus, when operating the component in any of the low power modes, it is important to set the high drive time as low as possible.

Display Helpers

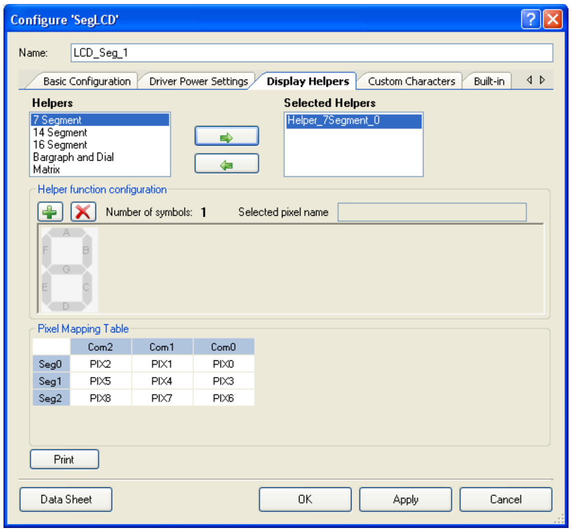
In this tab, LCD functional and hardware specific details are included. There are three sections on this tab:

- Helpers
- Digits information
- Pixel mapping table

Helper represents the kind of display features that you have on an LCD. As shown in Figure 5, helpers include the LCD display feature such as 7 segment, 14 segment, and so on. Click the right arrow to select a helper. To add specific number of digits, click **+**. You can repeat this process for all the display features.

The next step is to set the common-segment mapping (pixel mapping) table. This information is available in the LCD Glass datasheet. Drag the pixel or segment and drop it on the pixel mapping table. To understand this process much more clearly, look at the PSoC Creator project section.

Figure 5. Display Helpers



4 PSoC Creator Project

In this project, you will learn to:

- Configure the segment LCD component based on the LCD
- Use the contrast control feature

As an example, the segment LCD in the Cypress Segment LCD Drive Kit CY8CKIT-029 will be used.

Resources required for building and testing the project:

- PSoC Development Kit— CY8CKIT-050, CY8CKIT-030 or CY8CKIT-001
- LCD Segment Drive Expansion Board Kit—CY8CKIT-029
- PSoC Creator Development Tool
- PSoC Programmer Software

Details of LCD used in CY8CKIT-029:

Segment LCD Glass Features:

- Display Technology: Twisted Nematic (TN)
- 8 common and 16 segment lines
- Viewing direction: 6:00
- Operating voltage: 3 V
- Polarization Mode: Reflective/Positive
- Operating Temperature: 0 °C to 50 °C

Various sections of the LCD are as follows.

Label	Description
A	Battery charge indicator bars
B	Wireless symbol
C	Alarm display
D	7 segment numeric section
E	Medical symbol
F	14 segment alpha numeric section

Figure 6. Different Sections of Segment LCD

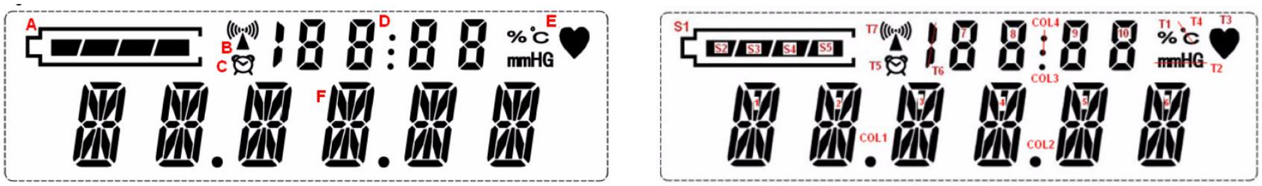
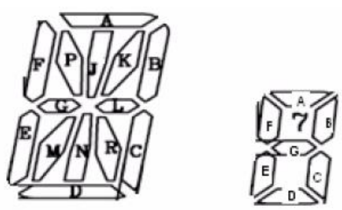


Figure 7. Segment Naming



The segment and common mapping table is given in the following figure.

Table 4. Segment-Common Mapping

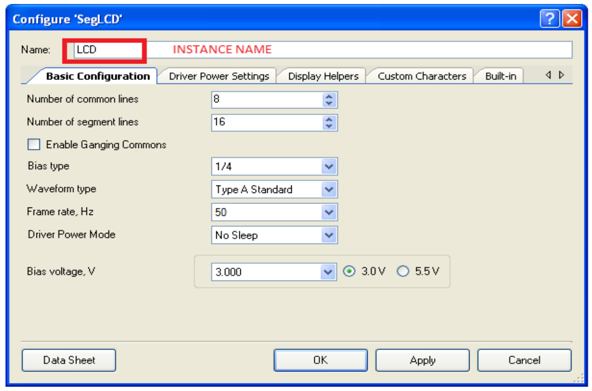
Pin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
COM7	COM7								T7	S1	S2	COL1	S3	S4	S5	COL2	T1	T4	T2	T3	COL3	COL4	T5	T6
COM6		COM6							1A	1J	2A	2J	3A	3J	4A	4J	5A	5J	6A	6J	10D	9D	8D	7D
COM5			COM5						1P	1K	2P	2K	3P	3K	4P	4K	5P	5K	6P	6K	10C	9C	8C	7C
COM4				COM4					1F	1B	2F	2B	3F	3B	4F	4B	5F	5B	6F	6B	10E	9E	8E	7E
COM3					COM3				1G	1L	2G	2L	3G	3L	4G	4L	5G	5L	6G	6L	10G	9G	8G	7G
COM2						COM2			1E	1C	2E	2C	3E	3C	4E	4C	5E	5C	6E	6C	10B	9B	8B	7B
COM1							COM1		1M	1R	2M	2R	3M	3R	4M	4R	5M	5R	6M	6R	10F	9F	8F	7F
COM0								COM0	1N	1D	2N	2D	3N	3D	4N	4D	5N	5D	6N	6D	10A	9A	8A	7A

For more information on segment LCD glass and the EBK, see the user guide of CY8CKIT-029. Now, start to configure the segment LCD component.

4.1 Segment LCD configuration

4.1.1 Basic Configuration

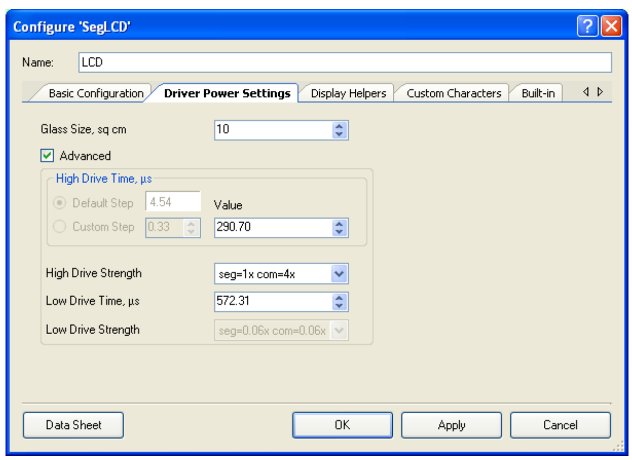
Figure 8. Basic Configuration



The number of commons and segment lines is set to 8 and 16, respectively. The LCD is driven with 1/4 bias ratio which is sufficient for this display. The component is operated in “No Sleep” mode, which means that the LCD will be non-functional if the device is put into sleep mode. In this project, device is always kept in active mode. The bias voltage is set to 3 V. Ganging is not used in this project. However, if the selected glass has high capacitance, then the ganging option should be used.

4.1.2 Driver Power Settings

Figure 9. Driver Power Settings



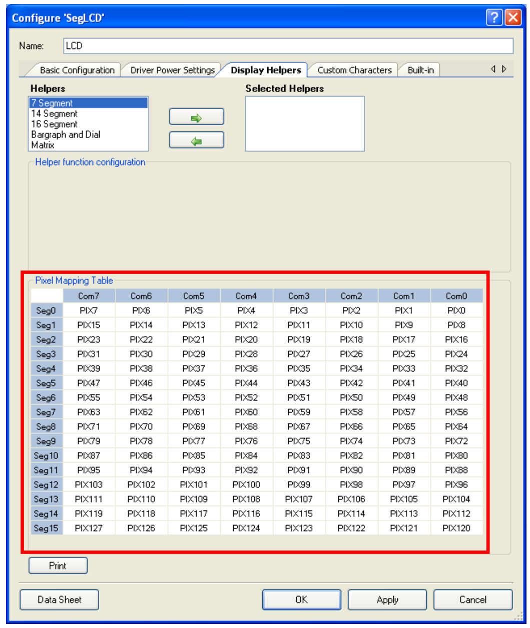
The Advanced setting is selected. By default, the high drive time is set as half of the maximum possible value. The maximum value in this case is ~1158 us. The high drive time is set to 25 percent of this value; that is, 290 us. Low drive time is set to 50 percent of maximum value. During the rest of the 25 percent of the frame time, the driver will be disabled. Tune these values depending on the contrast required and the acceptable power consumption.

In this LCD, one common line is multiplexed to control eight segments. Seg=1x, Com=4x is selected for this project. This is the maximum relative strength drive available in the driver to balance the total drive strengths of segment driver and a common line driver.

4.1.3 Display Helpers

In the **Display Helpers** tab, you can see the pixel mapping table with 8 commons and 16 segment lines listed. This table is prepared based on the information entered in the basic configuration tab.

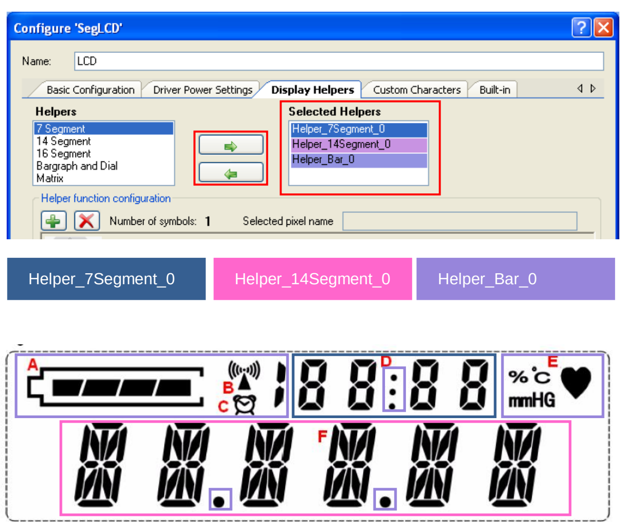
Figure 10. Display Helpers Tab



You must see the LCD datasheet to configure this tab. Use the following steps as a guide:

Step 1: Select the display feature: The LCD used in this project has a 7-segment display section, 14-segment display section, and several symbols. The Helpers box in this tab lists all the features supported by the component. Select the required display feature in the Helpers box one-by-one by clicking the right arrow. The selected display feature will then be displayed in the Selected Helpers list box. To delete the selected helper, use the left arrow.

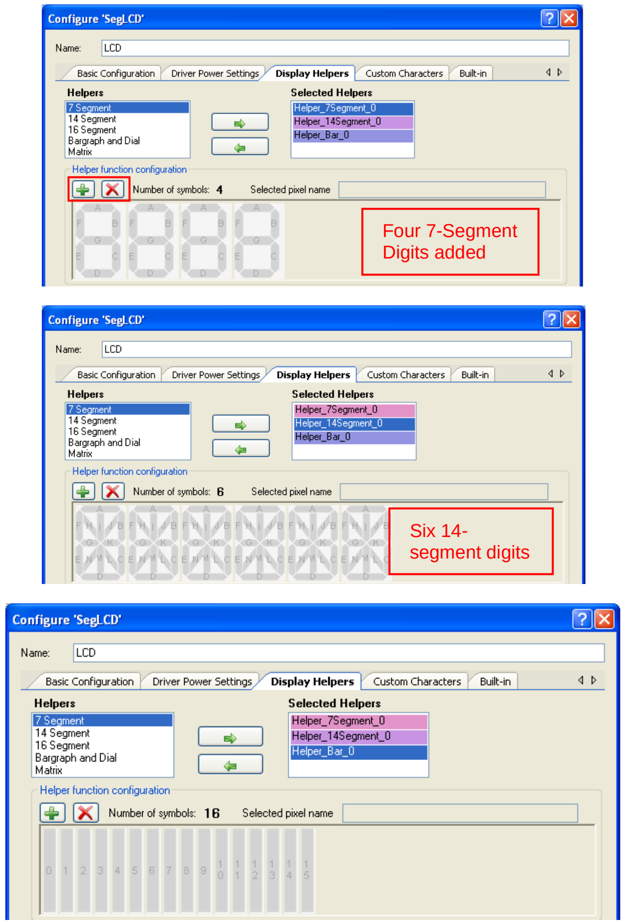
Figure 11. Adding Display Helpers



For special symbols, bargraph and Dial Helper (Helper_Bar_0) is used.

Step 2: Add digits: The LCD has four 7-segment digits, six 14-segment digits, and 16 symbols. Click the selected helper and add the required number of digits/symbols using the "+" button.

Figure 12. Adding More Digits



Step 3: Edit the segment names of each display feature according to the LCD used

It is important that you use the give all the segments of all display types the same name as the one mentioned in the LCD datasheet. In this project, the segment names of 14-segment display and all the symbols are changed based on what is specified in the LCD datasheet. This helps in avoiding mistakes while filling segment-common mapping tables. It also helps in easy identification of each segment/pixel in firmware. To rename the segments, click the segment and type the new name in the **Selected pixel name** text box.

Figure 13. Renaming Segment Name

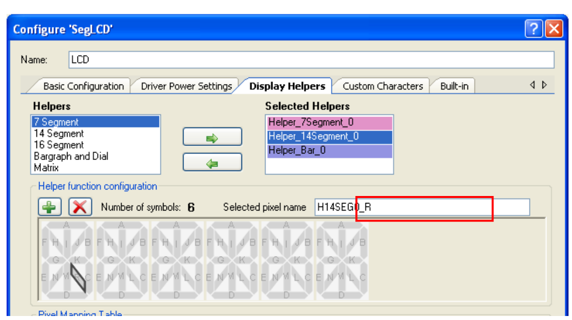
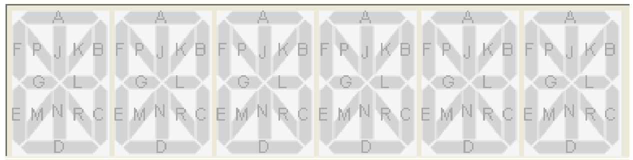
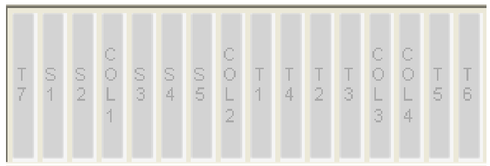


Figure 13 shows that the name of one of the segments of 14-segment display is changed from H14SEG0_**L** to H14SEG0_**R** per the LCD specification shown in Figure 7 All other segment names are also changed. The following figure shows the changed names of a 14-segment display and the symbols.

14-segment configured in component



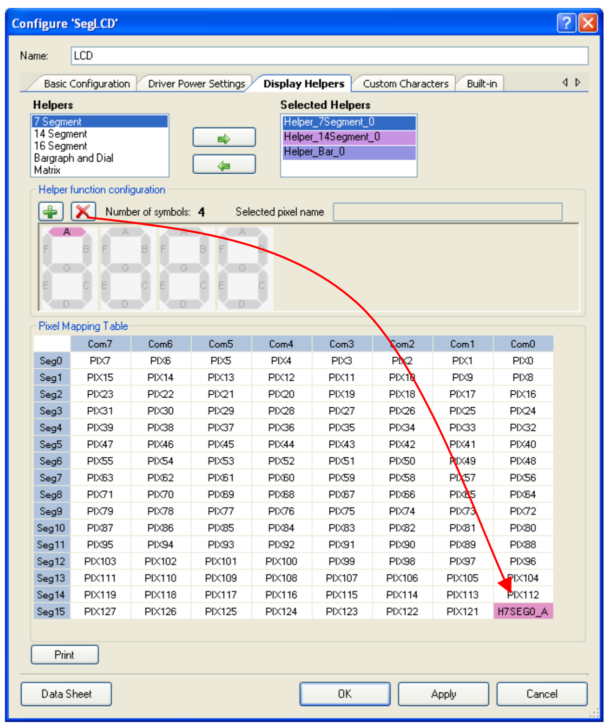
Symbols configured in component



In the case of symbols, it does not matter which segment you want to rename; segment-common mapping must be done appropriately.

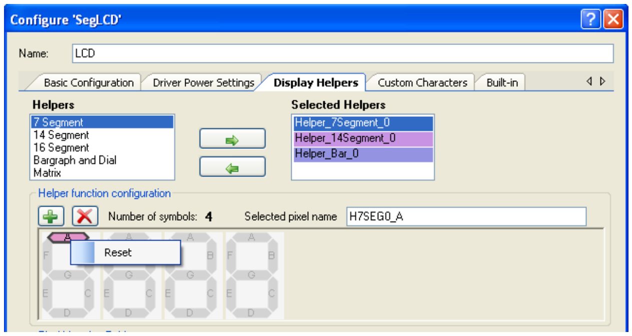
Step 4: Fill segment-common mapping table: Drag the segment from the digits and drop it on the pixel mapping table. You should see the segment-common mapping table given in the LCD datasheet (shown in Table 4).

Figure 14. Pixel Mapping Procedure



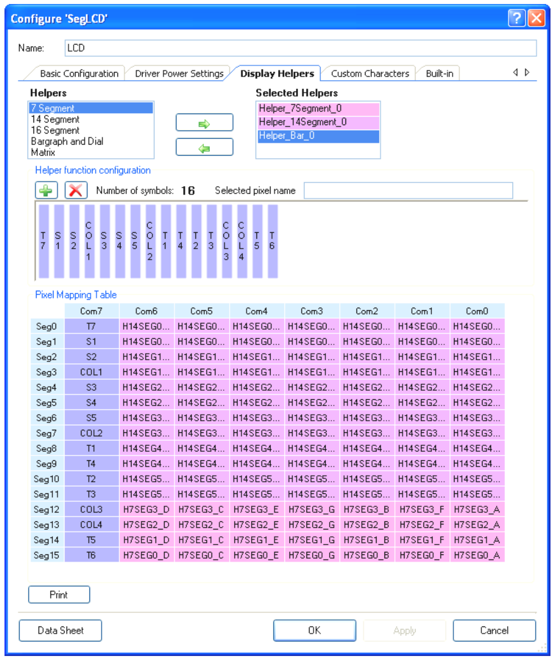
If you want to clear any mapping, right-click the pixel and select **Reset** as shown in Figure 15:

Figure 15. Clearing the Existing Mapping



Repeat the process of mapping for all segments of display sections. You can choose any segment row in the pixel mapping table, as long as you put other corresponding segments sharing the LCD pin in the same row and do proper pin assignment. The completed table looks like this.

Figure 16. Completed Pixel Mapping Table



Segment-common mapping table for your reference

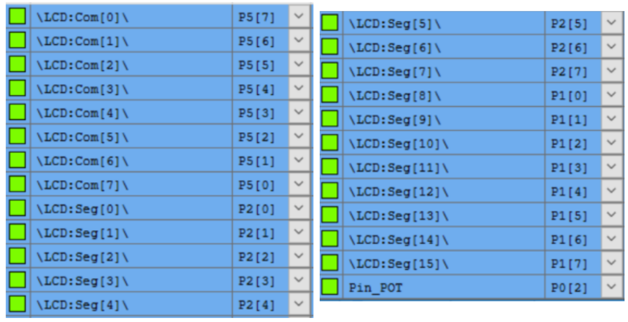
	Com7	Com6	Com5	Com4	Com3	Com2	Com1	Com0
Seg0	T7	H14SEG0_A	H14SEG0_P	H14SEG0_F	H14SEG0_G	H14SEG0_E	H14SEG0_M	H14SEG0_N
Seg1	S1	H14SEG0_J	H14SEG0_K	H14SEG0_B	H14SEG0_L	H14SEG0_C	H14SEG0_R	H14SEG0_D
Seg2	S2	H14SEG1_A	H14SEG1_P	H14SEG1_F	H14SEG1_G	H14SEG1_E	H14SEG1_M	H14SEG1_N
Seg3	COL1	H14SEG1_J	H14SEG1_K	H14SEG1_B	H14SEG1_L	H14SEG1_C	H14SEG1_R	H14SEG1_D
Seg4	S3	H14SEG2_A	H14SEG2_P	H14SEG2_F	H14SEG2_G	H14SEG2_E	H14SEG2_M	H14SEG2_N
Seg5	S4	H14SEG2_J	H14SEG2_K	H14SEG2_B	H14SEG2_L	H14SEG2_C	H14SEG2_R	H14SEG2_D
Seg6	S5	H14SEG3_A	H14SEG3_P	H14SEG3_F	H14SEG3_G	H14SEG3_E	H14SEG3_M	H14SEG3_N
Seg7	COL2	H14SEG3_J	H14SEG3_K	H14SEG3_B	H14SEG3_L	H14SEG3_C	H14SEG3_R	H14SEG3_D
Seg8	T1	H14SEG4_A	H14SEG4_P	H14SEG4_F	H14SEG4_G	H14SEG4_E	H14SEG4_M	H14SEG4_N
Seg9	T4	H14SEG4_J	H14SEG4_K	H14SEG4_B	H14SEG4_L	H14SEG4_C	H14SEG4_R	H14SEG4_D
Seg10	T2	H14SEG5_A	H14SEG5_P	H14SEG5_F	H14SEG5_G	H14SEG5_E	H14SEG5_M	H14SEG5_N
Seg11	T3	H14SEG5_J	H14SEG5_K	H14SEG5_B	H14SEG5_L	H14SEG5_C	H14SEG5_R	H14SEG5_D
Seg12	COL3	H7SEG3_D	H7SEG3_C	H7SEG3_E	H7SEG3_G	H7SEG3_B	H7SEG3_F	H7SEG3_A
Seg13	COL4	H7SEG2_D	H7SEG2_C	H7SEG2_E	H7SEG2_G	H7SEG2_B	H7SEG2_F	H7SEG2_A
Seg14	T5	H7SEG1_D	H7SEG1_C	H7SEG1_E	H7SEG1_G	H7SEG1_B	H7SEG1_F	H7SEG1_A
Seg15	T6	H7SEG0_D	H7SEG0_C	H7SEG0_E	H7SEG0_G	H7SEG0_B	H7SEG0_F	H7SEG0_A

This completes the component configuration. You now must assign the pins for the segment and common lines.

Pin Assignment

For pin assignment, use the *.cydwr* file. You must make the hardware compatible with the pins selected here.

Figure 17. Pin Assignment



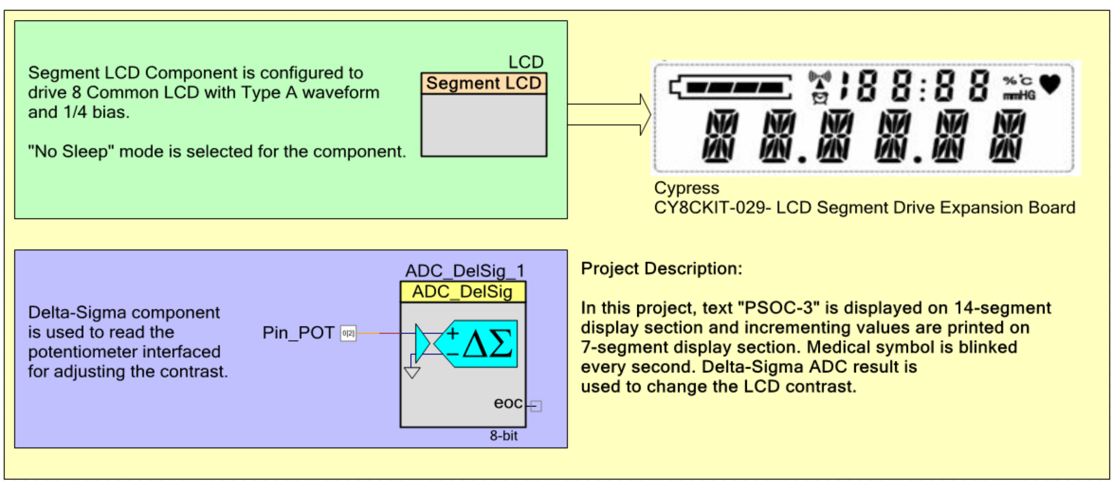
Here the pins are assigned considering that the Segment LCD Drive Kit CY8CKIT-029 is plugged to port D of the CY8CKIT-050. If you are using a different kit, see the kit guide for pin assignment.

4.2 Other Components in the Design

Delta-Sigma ADC: A potentiometer is connected to port P0[2] of the device for contrast adjustment. The Delta-Sigma component is used to read the potentiometer value.

4.3 Top Design

Figure 18. Top Design of the Project



5 Firmware

The component offers several APIs. For details of all the APIs, see the Segment LCD component datasheet. In this project:

- Text “PSOC” is displayed on the 14-segment display section
- Incrementing values (every second) are printed on the 7-segment display section
- Medical symbol blinks every second

This example will give an introduction to APIs associated with all types of display sections. You will also learn about the contrast control API.

Segment LCD APIs used in the project:

1. API to print string on 14 segment display

   ```
   Void LCD_WriteString14Seg_1(uint8* character, uint8 position);
   ```

   This prints the string on the 14-segment display with the specified start position.

2. API to display number on 7-segment display

   ```
   void    LCD_Write7SegNumber_0(uint16 value, uint8 position, uint8 mode);
   ```

   This API prints the specified value on the 7-segment display with the specified starting position. Mode value, when set to 1, appends 0 to the MSB positions. When set to 0, it retains the previous value for MSB positions.

3. API to control particular pixel/segment

   In the present project, a medical symbol is blinked every second. This is done by controlling an individual pixel. Segment LCD component gives the API:

   ```
   uint8   LCD_WritePixel(uint16 pixelNumber, uint8 pixelState);
   ```

   Pixel number can be obtained from the component *.h* file. Every pixel of all the display sections is uniquely addressed based on the name set while configuring the component. If 1 is passed to pixel state, the pixel is turned ON.

4. API to control the contrast of LCD

   ```
   uint8   LCD_SetBias(uint8 biasLevel) ;
   ```

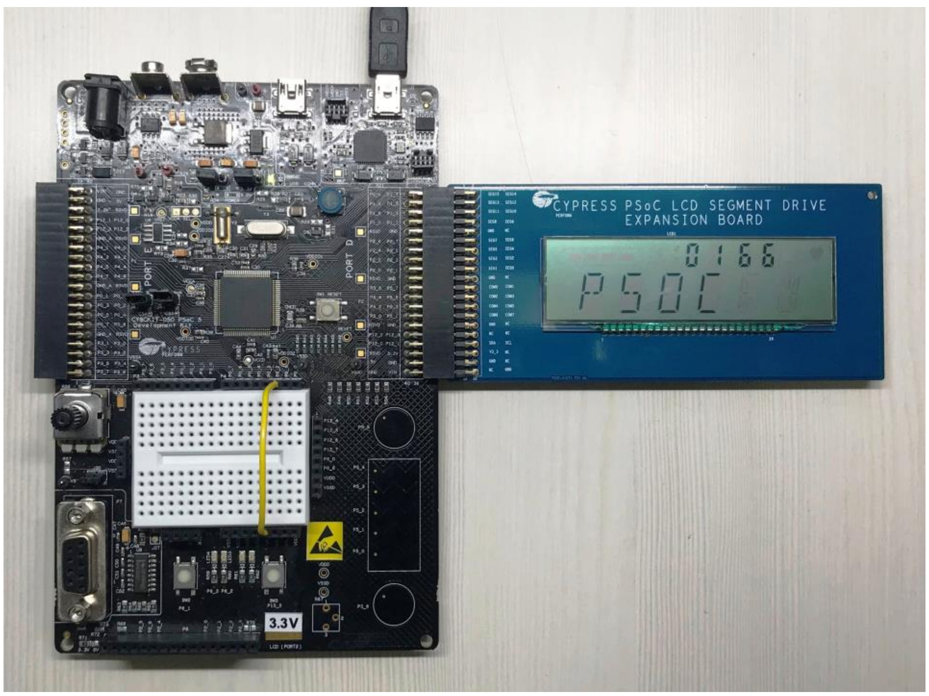
   This API sets the bias level controlling the contrast of LCD. This API accepts values between 1 and 64.

The *main.c* code is shown here:

```
int main()
{

    uint8 ADCValue;
    uint8 msCounter=0;
    uint16 DisplayCount=0;
    uint8 BlinkStatus=0;

    /* Starts the Segment LCD */
    LCD_Start();

    /* Start ADC */
    ADC_DelSig_1_Start();
    ADC_DelSig_1_StartConvert();

/* Write on 14 segment display section */
LCD_WriteString14Seg_1("PSOC",0);

while(1)
{

    /* Give 100ms delay */
    CyDelay(100);

     ADC_DelSig_1_IsEndConversion
    (ADC_DelSig_1_WAIT_FOR_RESULT);

     ADCValue=ADC_DelSig_1_GetResult8();

     /* Divide the 8bit value by 4 as SetBias function accepts 6 bit value */

     ADCValue=ADCValue>>2;

     /* Set the LCD bias which controls the contrast */
```

```
      LCD_SetBias(ADCValue);

      /* Increment counter every 100ms */
      msCounter++;

      if(msCounter==10)
      {
         msCounter=0;

/* 1 sec has elapsed, blink medical symbol and increment count on seven segment
display */

        /* Blink Medical Symbol (T3) */
        LCD_WritePixel(LCD_T3,BlinkStatus);
        BlinkStatus^=0x1; /* Toggle status */

       /* Update display on 7-segment */
       LCD_Write7SegNumber_0(DisplayCount,0,1);

        /* Increment display count */
        DisplayCount++;
        if(DisplayCount>9999)
            DisplayCount=0;

       }

    }
}
```

6 Test Setup



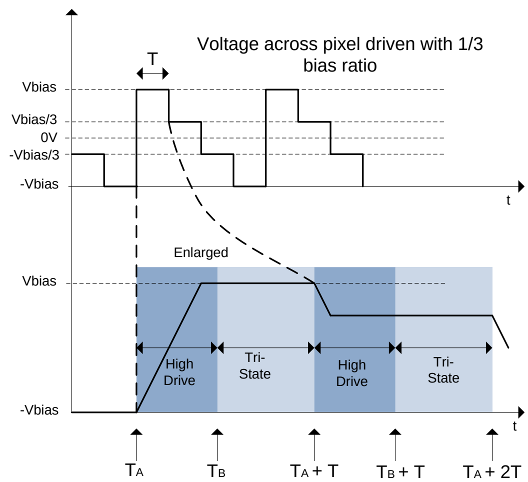
7 LCD Component Low Power Modes

There are two low power modes include in the Segment LCD component:

- Low power using ILO
- Low power using external 32-kHz crystal

With either of these modes, you can put the device to sleep and keep the LCD functional. The LCD component is equipped with a timer that gives periodic interrupt to the device to wake up and refresh the LCD glass. To understand the component behavior in low power mode, see Figure 19.

Figure 19. Segment LCD Component Behavior in Low Power Mode



In low power modes, LCD operates only in high drive stage. After the defined high drive time, the LCD driver is disabled (but timer enabled) and all the LCD pins are tristated.

Following events occur at time T_A and shortly afterward:

- LCD timer issues interrupt. If the device is put in sleep mode, it wakes up the device. LCD component is completely powered ON.
- LCD component enters high drive stage

Following events occur at time T_B and shortly afterward:

- LCD driver is disabled; common and segment pins are tristated.
- If the sleep command is issued in firmware between time instants TA and TB, then the device enters sleep mode.

If the sleep command is issued between T_A and T_B through firmware, the LCD component will keep that command in pending state as long as it is in High Drive stage. After the high drive stage is completed at T_B, it gives permission to put the device to sleep.

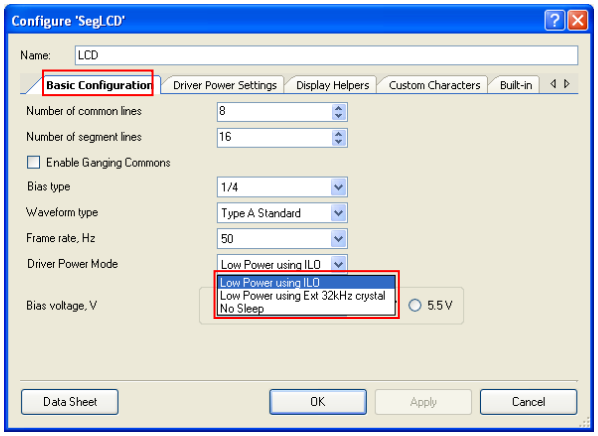
8 Using Segment LCD Component in Low Power Mode

Here is the list of things that you need to do in PSoC creator to use the component in Low Power mode:

1. **Set the operating mode of the component to one of the Low Power modes**

   In the driver mode settings under the **Basic Configuration** tab, select either **Low Power using ILO** or **Low Power using external 32 kHz crystal**.

Figure 20. Low Power Mode Selection

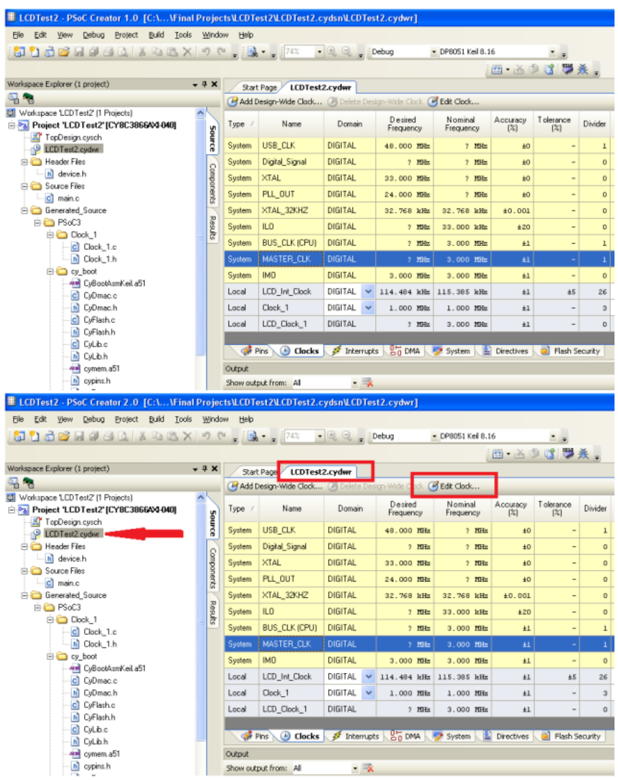


2. **Select the High Drive time based on contrast and power requirement**

   As mentioned in "Setting High Drive and Low Drive duration", it is important that High Drive time is not set too high because it will block the device from going into sleep mode, which leads to higher power consumption. Keeping a low value of high drive time will cause contrast issues. Consider contrast and power requirements when you set the high drive time.

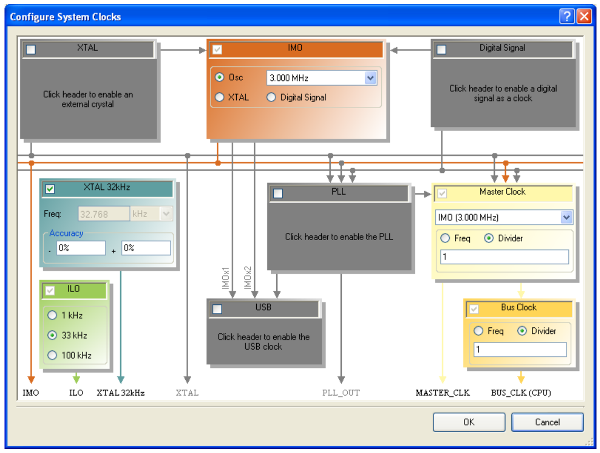
3. **Clock Settings**

Figure 21. Clocks Window



In the *.cydwr* file, go to the Clocks tab. Click **Edit** to open the Clock Settings window.

Figure 22. Clock Settings



Settings for component configured in “Low power using external 32 kHz crystal”:

- Enable 32 kHz crystal oscillator
- Disable PLL for reducing power consumption

4. Firmware

LCD Low power modes are used along with device sleep mode. It is the responsibility of the user to put the device to sleep. The LCD component will wake the device but does not put the device back to sleep after LCD refresh. For this reason, it is important that the firmware is structured properly. The following snippet shows how the code can be structured if the design has multiple interrupt sources.

```
void main()
{
    /*Enable Global interrupt */
    CYGlobalIntEnable;

   /* Initialize all the components and   variables used */

    /* Start the Segment LCD component */
    LCD_Start();
    LCD_EnableInt();

    while(1)
    {

          /* Put the device to sleep */
          CyPmSleep(PM_SLEEP_TIME_NONE,PM_SLEEP_SRC_LCD);

          /* Device wakes up from sleep */

          /* Check if other interrupts (non-LCD) in the design have triggered else
          put the device back to sleep */

          if ( condition )
          {
            /*non-LCD interrupt has triggered */

            /* User code */
          }

    }
}
```

Use this kind of firmware structure when operating the device in sleep mode with the LCD component configured in low power mode.

9 Summary

PSoC 3 and PSoC 5LP offer segment LCD drive as a value-added feature in addition to other major functions with its configurable digital and analog hardware. This application note explains the PSoC 3 and PSoC 5LP segment LCD drive component through one simple example project.

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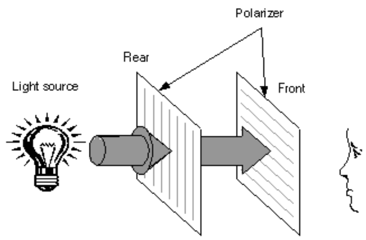
Appendix A. LCD

A.1 LCD Operating Principle

LCD operates based on the light polarization concept. Polarization is defined based on the electric field vector direction associated with light. To understand the fundamental concept, consider the diagram shown in Figure 23.

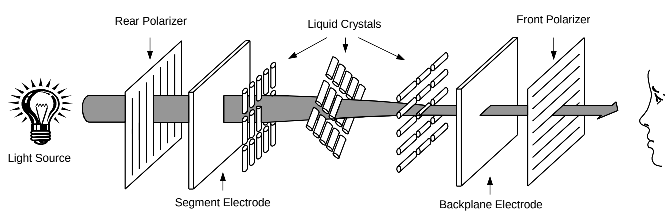
Figure 23. Basic LCD Concept



Generally, the available light source produces unpolarized light rays; that is, electric field vector direction is continuously and rapidly changing. Pass this unpolarized light through a polarizer sheet, which passes only light rays whose electric field is aligned vertically. Then, place a second polarizer, which passes light with horizontal polarization behind the first polarizer. No light rays will pass through the second polarizer. If you place some mysterious material between the two polarizers to control the polarization of light based on need, this will reorient the light parallel to the second polarizer or simply pass the light with the polarization created by the first polarizer which will be blocked by the second polarizer. This mysterious material is the liquid crystal by which LCD got its name.

Figure 24 shows the basic LCD assembly consisting of rear polarizer, front polarizer, segment and backplane electrode, and Liquid crystal. The liquid crystal is sandwiched between the electrodes and polarizers.

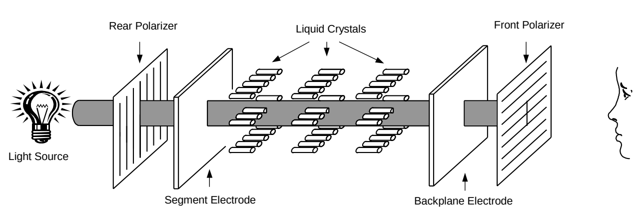
Figure 24. Liquid Crystal – No Excitation



Liquid crystal orientation is changed by application of electrical signal across it with the help of electrodes- backplane (common) and segment. To avoid permanent orientation of liquid crystal, alternating waveform needs to be applied between the electrodes so that average voltage across the liquid crystals to be 0. Figure 24 shows the case when the pixel is in off state, that is, when light simply passes through the front polarizer. This is the case when no voltage is given between the electrodes. By default, liquid crystals orient the light by 90°. This is an example of TN LCD glass which will be explained later in the document.

To turn ON the pixel, liquid crystals are excited causing it to align parallel to the electric field as shown in Figure 25.

Figure 25. Liquid Crystal – With Excitation

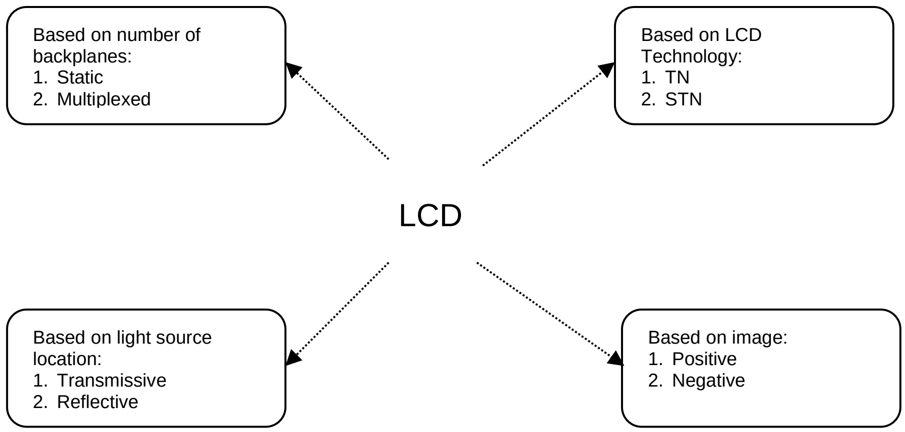


In this case, liquid crystal will not change polarization of light coming from the rear polarizer and it will be blocked by the front polarizer. It will be seen as a dark spot on the LCD front panel.

A.2 Classification of LCDs

There are many ways LCDs available in market can be classified.

Figure 26. Classification of LCDs



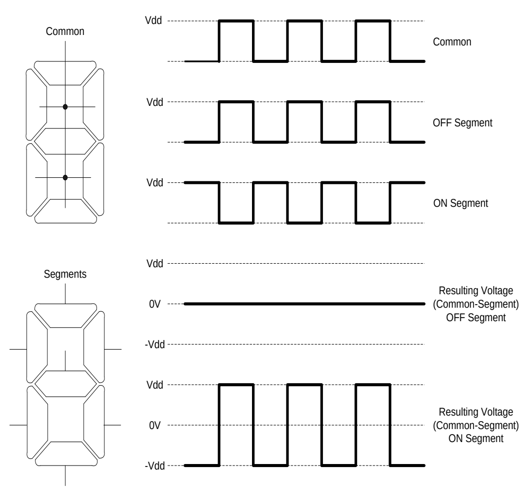
A.2.1 Classification (Based on Number of Backplanes/Commons)

- Static
- Multiplexed

Static LCD

There is only one backplane or common in static LCDs and independent control for the segments. The voltage between the common and the segment pin decides the state of the pixel. As mentioned earlier alternating waveform needs to be applied to avoid permanent damage to the LCD. Following diagram shows the typical waveforms of static LCD:

Figure 27. Static LCD Waveforms



For the segment to be OFF, the segment and common signals are kept in phase. This results in 0 Vrms across the segment and common pin.

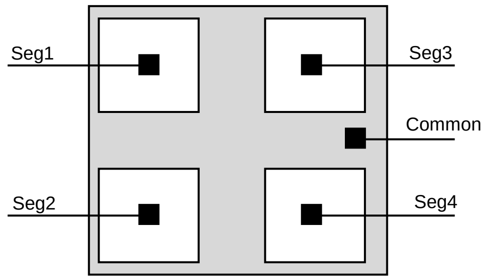
For the segment to be in ON state, segment and common signal are kept 180° out of phase. If the peak value of the square waveform is say V_{DD}, then it results in RMS voltage of V_{DD} across the segment and the common and average voltage of 0 which is the fundamental requirement.

Multiplexed LCD

In Static LCD, the number of pins and drivers to control the pixel is equal to the number of segments or pixels LCD has. This becomes a problem as the complexity of LCD increases which requires use of higher I/O count LCD drivers. Instead of having individual control pin for a segment or pixel, we can multiplex the use of control pin for other segments/pixels. Then, a question arises while exciting one pixel; how to avoid affecting another pixel controlled by same pin. The answer is to use multiple commons. These types of LCDs are called as multiplexed LCD. Multiplexed LCDs are specified based on the number of commons it has.

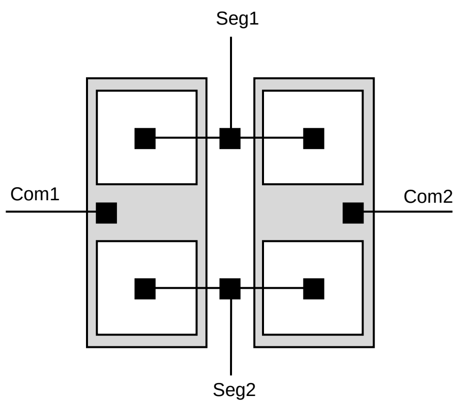
As an example, consider four segments or pixels in an LCD. In static LCD, there will be four segment control pins and one common pin as shown in the following figure. Therefore, it requires a total of five pins or drivers in a static configuration.

Figure 28. Static LCD Configuration



In two common multiplexed LCDs, two segments will share the same pin. This configuration will result in four pins or drivers, that is, one less than static configuration. This advantage becomes clearly evident as the number of segments increases.

Figure 29. Multiplexed LCD Configuration



Driving Multiplexed LCDs

Before considering the details of drive waveforms, it is necessary to understand some of the terms associated with multiplexed LCDs.

Frame Frequency

Frame frequency is the rate at which the drive waveform repeats for each segment line. In simple terms, it is the rate at which each segment LCD pixel is refreshed. It is generally in the range of 30 Hz to 150 Hz. High frame frequency results in higher power consumption and lower frequency causes flickering on LCD. Therefore, there is a tradeoff between power consumption and image display quality.

Duty Ratio/Multiplex Ratio

This term indicates the number of commons or backplanes multiplexed LCD has. It is specified inverse of number of commons/backplanes. For example, if multiplexed LCD has 4 commons, duty ratio is equal to ¼. While driving multiplexed LCDs, the segments associated with one common, gets refreshed for 1/(number of commons) of the frame period; that is Duty Ratio x Frame period.

Bias Ratio/Type

Bias is the number of voltage steps applied to the LCD. The number of voltage levels should be increased with increase in number of commons of LCD. This is done to avoid high RMS voltage across the pixel in OFF state.

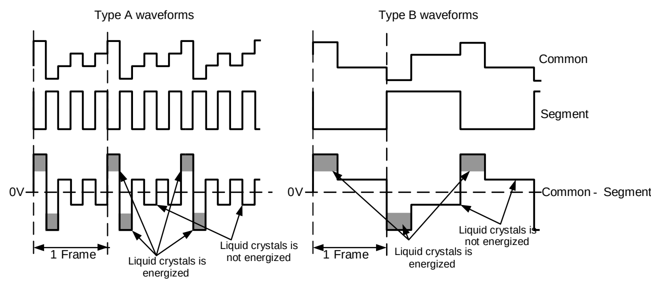
Each multiplexed LCD manufacturer has a recommended bias ratio for the LCD. Common bias ratio values are 1/2, 1/3, ¼, and 1/5.

Drive Waveforms

Multiplexed LCDs can be driven by two types of waveforms. These are called Type A and Type B waveforms.

Type A waveforms take single frame to maintain zero average voltage across each pixel whereas Type B waveforms take two frames.

Figure 30. Multiplexed LCD Drive Waveforms



Type B waveforms contain fewer edges than Type A waveforms in a given time duration. This is one major advantage of Type B waveforms. LCD pixel is modeled as a capacitor. So there will be current flow from the driver only during edges. Therefore, a Type B waveform results in lower power consumption compared to a Type A waveform.

The drive waveforms for various combinations of Duty ratio and Bias ratio are discussed earlier in Appendix A. In all the waveforms, it should be noted that a frame consists of some number of phases (equal to number of commons). During each phase, one common is made active and it is driven with extreme voltage levels. All the other commons are pulled to intermediate voltage levels; value depends on the bias ratio. The segments associated with the active common which needs to be turned ON are driven with opposite phase signals with respect to active common. This generates peak RMS voltage across the pixel necessary to turn it ON, at the same time maintaining zero average voltage. The segments associated with the active common which needs to be turned OFF are driven with in-phase signals. This generates zero RMS voltage across the pixel.

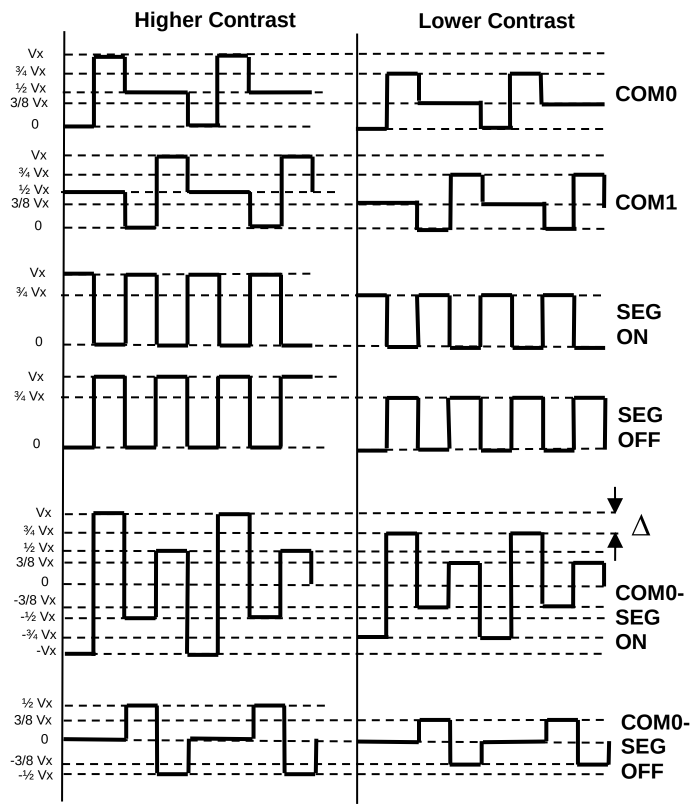
The segments associated with inactive commons will not experience high excitation as the inactive commons are excited with intermediate levels. Thus, the segments associated with inactive commons will remain unaffected when other commons are active.

Adjusting Contrast

Contrast level of LCD is adjusted by the changing the gap between ON Segment Voltage and OFF segment Voltage.

As an example, consider two common LCD drive with ½ bias as shown in Figure 31. To reduce the contrast, all the voltage levels are scaled down. In the waveform shown, all the voltages are scaled down by a factor of ¾. This results in decreased RMS value across pixels. RMS voltage controls the amount of twist to the light polarization in the assembly. As the RMS voltage goes down, the change in light polarization due to liquid crystal also goes down. This results in increased passing of light through the front polarizer which means lower contrast.

Figure 31. Contrast Control



A.2.2 Classification (Based on Light Source)

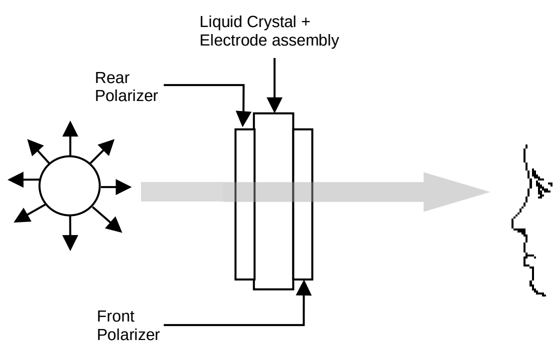
- Transmissive
- Reflective
- Transflective

All LCDs are passive. They require an external light source to display information.

Transmissive LCD

If the light source is required to be behind the rear polarizer, then it is Transmissive LCD. Figure 24, shown earlier, is an example of Transmissive LCD. A simplified form is shown in Figure 32. This type of LCD requires a backlight source. Depending on backlight brightness it can be used in either indoor or outdoor applications.

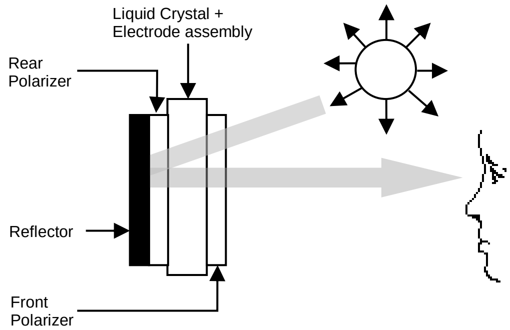
Figure 32. Transmissive LCD



Reflective LCDs

Reflective LCDs are equipped with a reflector behind the rear polarizer. This reflector allows external light to be reflected. These LCDs do not require any backlight. For this reason, they are used in low power systems. This also gives good contrast in display under high ambient light conditions.

Figure 33. Reflective LCD



Transflective LCDs

Transflective LCDs are equipped with special semi-reflector which has the capability to reflect as well as pass fraction of light, thereby allowing both features of Transmissive and Reflective type LCDs.

9.1 Classification (Based on LCD Technology)

- Twisted Nematic (TN)
- Super Twisted Nematic (STN)
- Film Compensated STN (FSTN)

Twisted Nematic (TN)

This type of liquid crystal gives 90° twist to the incoming light. The two polarizers (rear and front) mounted on the LCD have direction of polarization perpendicular to the each other. The example shown in Figure 24 is Twisted Nematic type of display. This type of display suffers from lower contrast and smaller viewing angle. Also these displays are not suitable for LCDs with higher number of commons.

Super Twisted Nematic (STN)

This type of liquid crystal gives greater than 90° twist to the incoming light and gives a steeper change in transmission-voltage curve. With this feature, RMS voltage of ON LCD pixel can be very close to the RMS voltage of OFF LCD pixel, still providing acceptable contrast. Due to this reason, it is suitable for LCDs with higher number of commons. The typical twist angle is between 180° to 270°. This has better contrast and viewing angle as compared to TN displays.

These displays are available in couple of colorations: Yellow/Green and Grey background with dark blue characters.

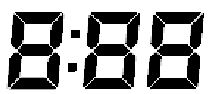
Film Compensated STN (FSTN)

This type is a modification of STN displays. STN displays have color added that appears in display background due to birefringence effect. To compensate for this effect, additional film is introduced in the assembly which eliminates this coloration. These types of displays, thus, are available only in White/Grey Background with black characters. Along with the advantage in eliminating coloration, these displays also give good contrast and wide viewing angle.

A.2.3 Classification (Based on Image Produced)

- Positive
- Negative

Positive



This type of LCD displays dark characters on a bright background. This type of display is suitable for reflective type LCD with high ambient light conditions or for Transmissive type LCD with good backlight.

Negative

This type of LCD displays bright characters on a dark background. This type of display is suitable for Transmissive LCDs under good backlight conditions.

A.3 LCD Viewing Angle

Viewing angle of LCD depends on the type of liquid crystal used and the duty cycle. There are two terms associated with the viewing region - Bias angle and the Viewing angle.

Bias angle is the angle between the perpendicular axis of LCD and the line along which best possible view is obtained. Bias angle is set when the LCD is manufactured.

Viewing angle refers to angle spacing around the bias line where satisfactory view is obtained.

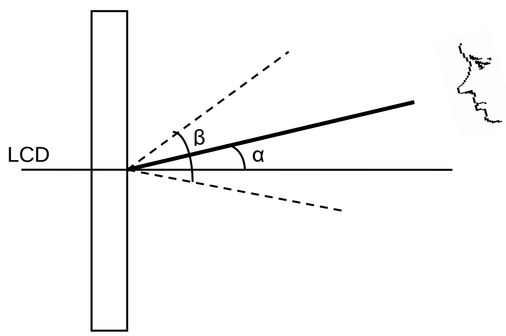
Depending on where the bias line is located, LCD view positions are referred to as:

- 12:00 Clock view
- 6:00 Clock view

These terms are with reference to a clock. If the bias line bends towards top portion of the LCD display then it is referred to as 12:00 Clock or Top view. If the bias angle bends towards bottom portion, then it is referred to as 6:00 Clock or Bottom view.

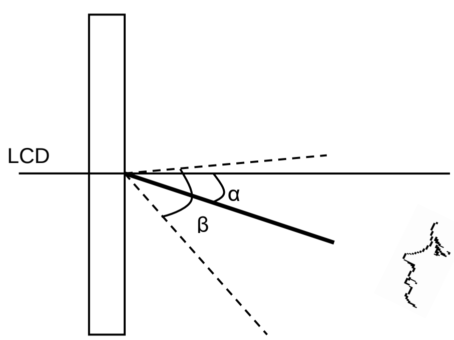
Figure 34 shows the 12:00 view. α is the bias angle and β is the viewing angle.

Figure 34. 12:00 or Top View



Similarly, 6:00 view is shown in the following figure.

Figure 35. 6:00 or Bottom View



Document History

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Document Number: 001-52927

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	2711107	GDN	05/26/2009	New application note
*A	2765916	GDN	09/18/2009	Changed the figures to latest version of PSoC Creator (Beta 2 Nightly build 5307) and updated related text with respect to Figure 5. Changed eight entries in Table 4. Updated C code for LCDExcercise1 (now display starts from right instead of left) and the same is updated in project goal.
*B	2958667	RJVB	06/22/2010	Added one more project with Segment LCD Drive EBK CY8CKIT-029 Updated the project with PSoC Creator Beta 4.1 Updated content to include the PSoC 5 device Added images of test setup for all projects Added Summary
*C	3010629	RJVB	08/17/2010	Updated the projects on Beta 5.0 Updated the customizer and top design screenshots in the document Changed the driver mode to low power to add more variety
*D	3178537	RJVB	02/21/2011	Complete rewrite. The document and project are updated to suit PSoC 3 LCD Driver Hardware.
*E	3296494	RJVB	06/29/2011	Title changed Moved LCD Basics to Appendix Updated introduction to include links for PSoC3 Learning Changed project to be based on CY8CKIT-029; deleted second project Added section: LCD component low power modes
*F	3444949	NIDH/ RJVB	11/22/2011	Updated for PSoC Creator 2.0 Updated template
*G	3809482	VVSK	11/12/2012	Updated for PSoC 5LP
*H	4454392	RKRM	07/24/2014	Updated Abstract Updated content to address few grammatical issues Updated the project to PSoC Creator 3.0 SP1
*I	5705852	AESATP12	04/26/2017	Updated logo and copyright.
*J	6135146	NIDH	04/12/2018	Updated project to PSoC Creator 4.2. Minor edits throughout the document. Updated template

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