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LCD Board



Get Up-and-Running Quickly and
Start Developing Your Application On Day 1!

Embedded Artists

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1 Document Revision History

Revision	*Date*	*Description*
A	2011-09-29	First released version.
B	2012-02-13	Added description about LCD controller settings for LPC processors.

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2 Introduction

Thank you for buying the *LCD Board* from Embedded Artists. The board makes it possible for you to get started with graphical user interface development immediately. The board directly interfaces the *OEM Base Board* (also from Embedded Artists) and can be mounted with forming a compact unit.

2.1 Features

The features of the *LCD Board* are:

- Parallel RGB interface, 16-bit color depth (or 12-bit).
- Resistive touch screen controller
- I2C-e2prom with configuration parameters
  - Controller can read which LCD is connected and initialize the LCD controller and control the LCD board accordingly.
- Supply voltage sequence control for LCD via I2C-GPIO
- Back light control, including dimming, via I2C-GPIO
- 50-pos (2x25) IDC interface connector
- Powered via interface connector
  - 3.3V and 5V required
- Compact size: 165 x 150 mm
- Simple mounting together with *OEM Base Board*

2.2 ESD Precaution

Please note that the *LCD Board* comes without any case/box and all components are exposed for finger touches – and therefore extra attention must be paid to ESD (electrostatic discharge) precaution.



Make it a habit always to first touch the metal surface of one of the USB connectors on the OEM Base Board (which the LCD Board is mounted on) for a few seconds with both hands before touching any other parts of the boards. That way, you will have the same potential as the board and therefore minimize the risk for ESD.

Note that Embedded Artists does not replace boards that have been damaged by ESD.

2.3 General Handling Care and Usage

Handle the *LCD Board* with care. The board is not mounted in a protective case/box and is not designed for rough physical handling. Connectors can ware out after excessive use. ***The board is designed for evaluation and prototyping use, and not for integration into consumer or industrial end-products.***

Do not exercise pressure on the display glass area or the flex cable connecting the display to the pcb. That will damage the display.

Note that Embedded Artists does not replace boards where the LCD has been improperly handled.

2.4 Other Products from Embedded Artists

Embedded Artists have a broad range of LPC1000/2000/3000/4000 based boards that are very low cost and developed for prototyping / development as well as for OEM applications. Modifications for

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OEM applications can be done easily, even for modest production volumes. Contact Embedded Artists for further information about design and production services.

2.4.1 Design and Production Services

Embedded Artists provide design services for custom designs, either completely new or modification to existing boards. Specific peripherals and I/O can be added easily to different designs, for example, communication interfaces, specific analog or digital I/O, and power supplies. Embedded Artists has a broad, and long, experience in designing industrial electronics in general and with NXP's LPC1000/2000/3000/4000 microcontroller families in specific. Our competence also includes wireless and wired communication for embedded systems. For example IEEE802.11b/g (WLAN), Bluetooth™, ZigBee™, ISM RF, Ethernet, CAN, RS485, and Fieldbuses.

2.4.2 OEM / Education / QuickStart Boards and Developer's Kits

Visit Embedded Artists' home page, www.EmbeddedArtists.com, for information about other *OEM* / *Education* / *QuickStart* boards / Developer's kits or contact your local distributor.

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3 Getting Started

This chapter describes important aspects of using the *LCD Board*.

3.1 Selecting Display Resolution

It is recommended to prototype with a display that has identical resolution as the intended end-application. If the exact same resolution cannot be used during prototyping, select a resolution as close to the end-application as possible. The reason for this is that different display resolutions give different application program load (program execution time) and different load on the external memory bus, where the frame buffer typically resides. When developing real-time systems, which many embedded system are, it is advised to not alter fundamental things, like system load.

Note that size of the display is of no importance for the discussion above. It is the resolution that gives a certain load on the application and external memory bus. Size can of course also be important when evaluating the usability and interaction with the user.

The *LCD Board* comes in different versions. Currently two LCDs are supported and more are under development:

- 4.3 inch TFT color LCD with 480x272 pixels resolution and resistive touch screen.
  - 16- and 12-bit color depth is supported.
- 7.0 inch TFT color LCD with 800x480 pixels resolution and resistive touch screen.
  - 16- and 12-bit color depth is supported.

Many LCDs support 18- and 24-bit color depth. The *LCD Board*, however, only support 16- and 12-bit color depth because when increasing the color depth above 16-bits, the memory requirements and external bus load will double. This is at least true for NXP's LPC-family of processors with integrated LCD controller. Instead of having 2 bytes per pixel (for 16- and 12-bit color depth) 4 bytes are needed per pixel.

3.2 Mounting

Before start using the *LCD Board* it has to be mounted. The product and support page both contains a link to a short video demonstrating how to mount the *LCD Board* together with the *OEM Base Board*. Before continuing, ***watch the instruction video*** and then mount the *LCD Board*. A Phillips screw driver #1 and a small adjustable spanner are needed to complete the mounting.

Note that it is not strictly needed to mount the *LCD Board* together with the *OEM Base Board*. It is just practical. It is also possible to have the *LCD Board* beside the *OEM Base Board*. Figure 1 below illustrates the two mounting options.

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Figure 1 – LCD Board Mounting Options

3.3 Power Consumption

Different LCD Boards have different power consumption. The subsections below list the different LCD boards' current consumption. The number given is the combined current consumption of the +3.3V and +5.0V supplies. It is the current consumption that is needed from an external +5V supply (when connected to the OEM Base board).

3.3.1 Power consumption of 4.3 inch LCD (EA-LCD-004)

When using the 4.3 inch LCD together with the LPC1788 Developer's Kit (LPC1788 OEM board plus OEM Base board) the current consumption on the +5V (external or USB powering) is about 480 mA. Note that this is close to the limits of many USB Host ports. Therefore an external power supply might be needed. A +5V, 2A external power supply is recommended since it then can be used for other LCD boards also.

3.3.2 Power consumption of 7.0 inch LCD (EA-LCD-006)

When using the 7.0 inch LCD together with the LPC1788 Developer's Kit (LPC1788 OEM board plus OEM Base board) the current consumption on the +5V (external or USB powering) is about 1400 mA. Note that this is way more than a USB Host port can supply. Therefore an external power supply is needed. A +5V, 2A external power supply is recommended.

3.4 Usage - Evaluation

Note that the LCD Board has not been designed for integration into an end-product. It is for evaluation and prototyping.

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4 LCD Board Design

This chapter describes the hardware design of the *LCD Board*. The schematic can be downloaded from the support page after registering the product serial key (that comes with purchase of the *LCD Board*). It can be good to have the schematic side by side when reading this chapter.

4.1 Block Diagram

The block diagram in Figure 2 below gives a quick overview of a design. It illustrates the major components in the design.

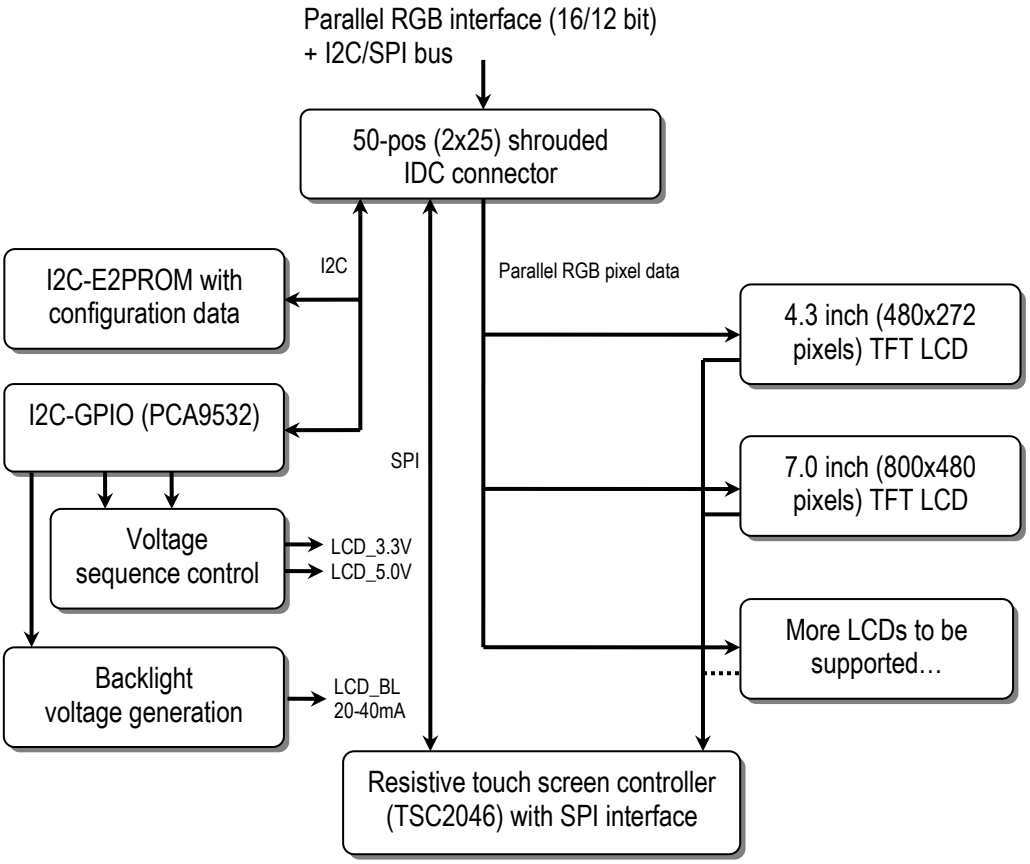


Figure 2 – The LCD Board Block Diagram

4.2 Schematic Walkthrough

4.2.1 Page 2

J1 is the interface connector to the board. It carries the parallel RGB pixel data as well as control signals. SPI and I2C serial channels are also present.

The data signals are connected to that TFT5:6:5 and TFT4:4:4 modes of the LPC on-chip LCD controllers are supported.

All high-speed signals have 100 ohm series resistors in order to minimize signal reflections on the board.

There is a 40MHz oscillator that can generate a pixel clock to the LPC LCD controller. This shall currently not be used since 40MHz will create a higher memory bus load than most designs can handle. The frequency will be changed to 33.333MHz in later revisions of the boards. The oscillator is normally only mounted on 7 inch LCD Board.

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There are also delay logic and an expansion connector that is normally not mounted. These are for internal EA use during development and prototyping of new LCDs to be supported.

4.2.2 Page 3

The resistive touch screen controller, TSC2046 from Texas Instruments, is connected to the SPI bus. See datasheet for details about its operation. There is ESD protection on the wires to the touch screen since these are subject to possible electrostatic discharges from the user.

There is further an I2C port expander, PCA9532 from NXP, which control the supply voltages to the LCD. Both 3.3V and 5.0V can be controlled. The port expander can also generate other control signals, like "reset" and "display enable" signals. The contrast of the backlight voltage generator can also be controlled from the port expander via pulse-width modulation (PWM) of the signal. A frequency of about 1 kHz is recommended when modulating the signal. 0% modulation (= signal always low) means 0% contrast. 100% modulation (= signal always high) means full backlight.

There is also an I2C-E2PROM that contains configuration information. For details see section 4.4 . The controller that generates the LCD signals can read the configuration information and easily configures the LCD controller according to the information found. The memory shall only be read, never written. The WP (Write Protect) signal is controlled from the I2C port expander and shall always be high.

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There is support for the 3.5 inch TFT color LCD with QVGA (landscape, 320x240 pixels). Currently this configuration is not sold.

4.2.4 Page 5

There is support for the 4.3 inch TFT color LCD with 480x272 pixels resolution. The LCD model number is HSD043I9W1-A00-0299 from HannStar. The LCD supports 24-bit color depth but only 16 bits are connected. The MSB bits in each color are repeated on the "unconnected" LSB bits. LCD_DV7, which is the red color MSB bit is connected to the three LSB bits of the red color. LCD_DV15 (green MSB bit) is connected in the same way to the two LCD bits of the green color. LCD_DV23 (blue MSB bit) is connected in the same way to the three LCD bits of the blue color.

The backlight voltage generator is based on LT1932 from Linear Technology. See datasheet for details.

4.2.5 Page 6

There is support for the 7.0 inch TFT color LCD with 800x480 pixels resolution. The LCD model number is AT070TN84 from Innolux. The LCD supports 18-bit color depth but only 16 bits are connected. The MSB bits in each color are repeated on the "unconnected" LSB bits. LCD_DV7, which is the red color MSB bit is connected to the LSB bit of the red color. LCD_DV23 (blue MSB bit) is connected in the same way to the LCD bit of the blue color. The green color has all color bits represented in TFT5:6:5 mode.

The display is driven in "DE" mode, which means that HSYNC and VSYNC are not needed. The LCD can figure out the timing from the DEN (LCD_ENAB) signal.

The LCD has internal backlight generation that is powered by 5V. The contrast is directly controlled by a logic PWM signal (100-300Hz frequency) from the I2C port expander.

4.3 Interface Connector Pinning

The table below lists the signals on the interface connector, J1. All signals are inputs (to the LCD Board) except where noted.

The I2C interface is for the e2prom containing configuration information. It is also for communicating with the i2c port expander (for voltage sequence control, back light control and some other control signals). The SPI interface is for the resistive touch screen controller. It is also for future use for example for LCD:s that have drivers that must be initialized via SPI.

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Interface connector (J1)	*Usage*	*TFT5:6:5 mode*	*TFT4:4:4 mode*
1	Ground (GND)		
2	Ground (GND)		
3	Currently not used.		
4	Currently not used.		
5	Currently not used.		
6	Currently not used.		
7	LCD_DV4 signal from LPC LCD controller.	RED1	RED0 (LSB)
8	LCD_DV5 signal from LPC LCD controller.	RED2	RED1
9	LCD_DV6 signal from LPC LCD controller.	RED3	RED2
10	LCD_DV7 signal from LPC LCD controller.	RED4 (MSB)	RED3 (MSB)
11	Ground (GND)		
12	Ground (GND)		
13	I2C-SCL signal		
14	I2C-SDA signal (bidirectional pin)		
15	LCD_DV10 signal from LPC LCD controller.	GREEN0 (LSB)	
16	LCD_DV11 signal from LPC LCD controller.	GREEN1	
17	LCD_DV12 signal from LPC LCD controller.	GREEN2	GREEN0 (LSB)
18	LCD_DV13 signal from LPC LCD controller.	GREEN3	GREEN1
19	LCD_DV14 signal from LPC LCD controller.	GREEN4	GREEN2
20	LCD_DV15 signal from LPC LCD controller.	GREEN5 (MSB)	GREEN3 (MSB)
21	Ground (GND)		
22	Ground (GND)		
23	Currently not used.		
24	Reset input to the LCD Board.		
25	LCD_DV18 signal from LPC LCD controller.	RED0 (LSB)	
26	LCD_DV19 signal from LPC LCD controller.	BLUE0 (LSB)	
27	LCD_DV20 signal from LPC LCD controller.	BLUE1	BLUE0 (LSB)
28	LCD_DV21 signal from LPC LCD controller.	BLUE2	BLUE1
29	LCD_DV22 signal from LPC LCD controller.	BLUE3	BLUE2
30	LCD_DV23 signal from LPC LCD controller.	BLUE4 (MSB)	BLUE3 (MSB)
31	Ground (GND)		
32	Ground (GND)		

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33	Currently not used.		
34	Currently not used.		
35	Vertical sync (VSYNC). Also called LCD_FP.		
36	Pixel data enable signal (DEN). Also called LCD_ENAB.		
37	Horistontal sync (HSYNC). Also called LCD_LP.		
38	Pixel data clock.		
39	Ground (GND)		
40	External pixel clock to LCD controller (output signal from the LCD board).		
41	+3.3V supply to the LCD Board.		
42	+5.0V supply to the LCD Board.		
43	SPI interface, clock signal		
44	SPI interface, mosi signal		
45	SPI interface, miso signal (output from the *LCD Board*)		
46	SPI interface, ssel signal when communication with on-board LCD drivers/controllers.		
47	General purpose input. Can be used when 4-wire SPI interface is used. The 4th wire signals control information of display data. Used to communicate with LCD drivers. For future expansion. Currently not used.		
48	SPI interface, ssel signal when communicating with resistive touch screen controller (TSC2046).		
49	Interrupt output signal from resistive touch screen controller (TSC2046).		
50	Currently not used.		

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4.4 Software Driver

A general software driver has been created to in order to make it simple and non-complex to work with different LCD:s. This section contains a very brief description of the structure. The code is the general documentation in itself, simply because the software will likely be updated

The software driver package (a zip-file) is downloaded from Embedded Artists support page for the *LCD Board*. The support site is available after registration of the product serial key that comes with purchase of an LCD Board. The package shall be unzipped in the same directory as the sample applications for the LPC1788 Developer's Kit. The default name of that directory is oem_lpc1788. The sample application is called **s_display_board**.

There is a support library called **Lib_Displays**. The code in this library contains all low-level details.

The I2C-E2PROM contains configuration information. The I2C address of the memory is 0x56 (1.0.1.0.1.1.0.RW). An application can begin with detecting if an I2C-E2PROM is present on this address. If so, an *LCD Board* is attached to the system and the LCD controller and graphical application can be started.

Some of the parameters are just to copy directly into the LCD controller of the LPC processors. Other information is stored in readable command strings. The configuration information stored is:

- Magic number to detect that information has been stored.
- Name of LCD and manufacturer in readable strings.
- LCD controller setup, including timing parameters. Can be directly copied to LCD controller registers.
- Init sequence command string. The string must be interpreted by the software driver.
- Power down command string. The string must be interpreted by the software driver.
- Parameters related to touch screen.

The general structure of an application utilizing the *LCD Board* can be found in **main()** in **main.c** of the **s_display_board** sample application. A call to **ea_lcdb_open(…)** will read the configuration e2prom and initialize the application. A call to **ea_lcdb_getLcdParams(..)** will get the retrieved parameters, where the main parameters are width and height of the display.

There is also a function for power down of the LCD. Most LCD:s have strict requirements regarding power-up and power-down when it comes to supply sequencing and control signals. It is important to adhere to these requirements in order not to damage the display or reducing its performance or lifetime.

4.4.1 Note about 4.3 inch LCD (EA-LCD-004)

The code listing below contains the LCD controller settings for the controller that is used on many LPC processors. It also lists parameters about the touch screen and startup/power down behavior for the general driver that Embedded Artists has created.

```
static const LCD_PARAM_T lcdParams =
{
   40,       /* Horizontal back porch */
    5,       /* Horizontal front porch */
    2,       /* HSYNC pulse width */
  480,       /* Pixels per line */
    8,       /* Vertical back porch */
    8,       /* Vertical front porch */
    2,       /* VSYNC pulse width */
  272,       /* Lines per panel */
    0,        /* Invert output enable */
    0,        /* Do not invert panel clock */
    1,        /* Invert HSYNC */
```

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```
    1,        /* Invert VSYNC */
    1,        /* AC bias frequency (not used) */
   16,        /* Bits per pixel */
  9000000,    /* Optimal clock rate (Hz) */
  TFT,        /* LCD panel type */
    0,        /* Single panel display */
};
static eaLcdbTouchParams_t touchParam =
{
  0,   // don't swap
  630, // x resistance
  250, // y resistance
};
static char* initSeqStr = "v1,cd0,cc0,c30,d100,c31,d100,cd1,d10,o,cc100";
static char* pdSeqStr   = "v1,cd0,d1,cc0,q,c30";
static char* lcdName    = "HSD043I9W1-A00-0299";
static char* lcdMfg     = "Hannstar";
```

4.4.2 Note about 7.0 inch LCD (EA-LCD-006)

It is recommended to generate the highest possible internal pixel clock from the LPC LCD controller. According to the datasheet a minimum clock frequency of 32.4MHz is needed, but 30MHz will work just fine. Do not use the on-board 40MHz oscillator (on rev A of the *LCD Board*) to generate the pixel clock. The clock frequency is too high for the LCD controllers on most LPC processors.

The code listing below contains the LCD controller settings for the controller that is used on many LPC processors. It also lists parameters about the touch screen and startup/power down behavior for the general driver that Embedded Artists has created.

```
static const LCD_PARAM_T lcdParams =
{
   45,       /* Horizontal back porch */
   17,       /* Horizontal front porch */
    2,       /* HSYNC pulse width */
  800,       /* Pixels per line */
   22,       /* Vertical back porch */
   22,       /* Vertical front porch */
    2,       /* VSYNC pulse width */
  480,       /* Lines per panel */
    0,       /* Invert output enable */
    0,       /* Do not invert panel clock */
    1,       /* Invert HSYNC */
    1,       /* Invert VSYNC */
    1,       /* AC bias frequency (not used) */
   16,       /* Bits per pixel */
  36000000,  /* Optimal clock rate (Hz) between 32.4-43.0 MHz according to DS */
  TFT,       /* LCD panel type */
    0,       /* Single panel display */
};
static eaLcdbTouchParams_t touchParam =
{
  0,   // don't swap
  775, // x resistance
  350, // y resistance
};
static char* initSeqStr = "v1,cc0,c31,d50,o,d200,c51,cc100";
static char* pdSeqStr   = "v1,c50,d200,q,d50,c30";
static char* lcdName    = "AT070TN84-02";
static char* lcdMfg     = "Innolux";
```

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5 Further Information

The datasheet of the LCD can be downloaded on the support page (requires registering of product serial key on Embedded Artists' web site).

Always check for the latest information/version on the support page.

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