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E-Paper demo design with the LPC82x

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Document information

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Keywords	LPC824M201JHI33, LPC822M101JHI33, LPC824M201JDH20, LPC822M101JDH20, E-paper, E-ink
Abstract	This application note illustrates how to design an E-paper system. Board-schematics and LPC824 demo code projects for Keil MDK, IAR EWARM, and LPCXpresso IDE are included.

Revision history

Rev	Date	Description
1.0	20151201	Initial version

Contact information

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1. Introduction

This application note details an E-paper display system driven by the LPC824, introducing a driver circuit, presenting how to prepare and encode the black and white picture and providing demo code to display the picture on a 4-grey level E-paper display.

The E-paper display used in this application is the GDE029 from Good Display, featuring a 2.9 inches active area containing 128x296 pixels, with 2-bit full display capabilities. For more details about the E-paper see the GDE029 http://www.good-display.com.

2. Hardware design introduction

This demo system is based on the LPC824 LPCXpresso V2/mbed board and a custom E-paper display daughter board. For connection details refer to schematics in the zip package.

2.1 Functional block diagram

The system block diagram is shown below in Fig 1.

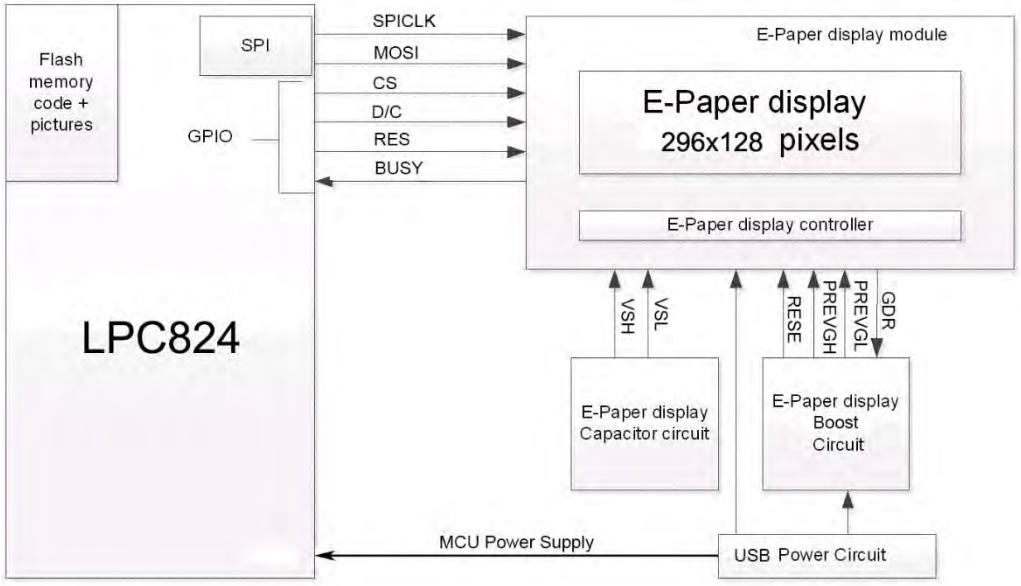

Fig 1. E-paper demo functional block diagram

In addition to SPI signals, some external signals are used to exchange information between LPC824 and E-paper display implemented with GPIO:

- **RES**: This signal is generated by LPC824, it is used to reset the E-paper Registers and to clear any on-going refresh.
- **D/C**: Data/Command line. This output signal is generated by LPC824 and used to alert the E-paper display if a Command or Data value is being sent via the SPI.

- **CS**: This is a Chip Select pin. This output signal is generated by LPC824 and used to enable the SPI Slave embedded in the E-paper display module.
- **BUSY**: This signal is generated by the E-paper display module used to inform the LPC824 about the module status. When the software launches a refresh, the busy bit is set and no more action should be taken on the E-paper display (no more command or data) to avoid any corruption on the display.

The main communication between the MCU and the E-paper module happens through SPI interface.

Fig 2. E-paper display demo

3. GDE029 E-paper introduction

The main GDE029 E-paper features are summarized below:

- 2.9 inches active area
- 128x296 pixels
- 2-bit full display capabilities.

3.1 Picture and data size

To display an image, the E-paper module's internal RAM must be filled with data through the LPC824 SPI interface. Each picture or frame consists of 128x296 pixels with 2-bit display capabilities. This results in a RAM size per frame = (128/4) x 296 = 9472 Byte

The frame data is stored in FLASH memory, the LPC824 has 32k Byte flash and can store up to 3 pictures depending on the application.

The RAM size and organization is illustrated in Fig 3.

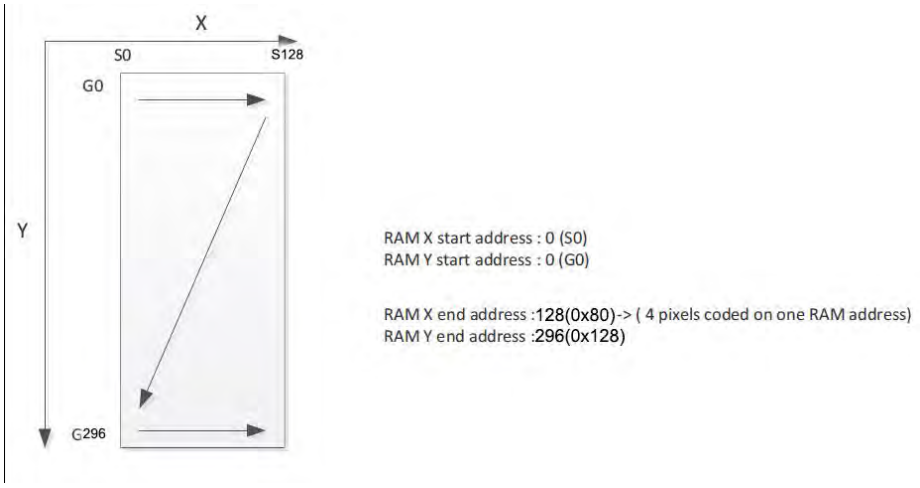

Fig 3. GDE029 RAM size and organization

3.2 E-paper power management

For power optimization the display supports a Power Off command. After the Power Off command is issued, the display driver will power off based on the power off Sequence and the BUSY line will be turned low. This command will turn off charge pump, T-con, source driver, gate driver, VCOM and temperature sensor but the register data will be retained until VDD is turned off. This command can be active only when BUSY = '1'.

Power OFF

Code	Inst/Para	R/W	DC	D7	D6	D5	D4	D3	D2	D1	D0	Default
R02H	POF	W	0	0	0	0	0	0	0	1	0	(02H)

Fig 4. E-paper power off command

This command will result E-paper enter into sleep mode, reducing the module power below 50uA.

If using the above method, the power consumption still cannot fit the application requirements, then a MOSFET can be used to control all power to the E-paper, taking advantage of the fact that the E-paper keeps the picture without any power. Once the picture refresh is completed, the MCU shuts down the power to E-paper via the MOSFET, at this point the MCU can be put in to the appropriate power saving mode.

In most application of E-paper, e.g. electric price label, the second solution can be implemented.

3.3 E-paper picture creation

To generate a picture for the e-paper, the user can use any picture-to-LCD software to get a C constant code from a picture.

One free tool can be download from NXP website:

https://www.lpcware.com/content/nxpfile/emwin-installler-lpc1788-ea-board-keil-mdk

Follow the steps below to generate C constant code from a .bmp image file,

- Generate a .bmp file with 128x296 pixels by Paint
- Open the .bmp file with BmpCvt.exe
- On menu select: Image – Convert Into – Gray4
- Then: Image – Invert – Indices
- Then: Image – Transparency – Index0:000000
- At last: File – Save As - *.c (select '2 bit pixel format' in format selection window).

When generating an output picture of 128x296 pixels with 4-grey level, then the .c file should be 9472 byte in size.

For the example demo code to display a picture shown in Fig 5 the user must generate a C constant code, shown in Fig 6, using the picture to LCD conversion software.

The generated C constant code contains a 2D array of 128x592 bits that represents pixel values. User can update one of the three pictures displayed in demo code by replacing one of the arrays in Ap_29demo.h file with the newly generated array.

Fig 5 is the picture to display on screen and Fig 6 represents demo C code for that picture.

Fig 5. Picture example

Fig 6. 9472 Byte C constant code

4. Software

Project code for this demo application is provided for the following toolchains:

- Keil MDK v5.14
- IAR EWARM v740
- LPCXpresso v7.9.0

4.1 Software Flowchart

The code operational flowchart is shown in Fig 7.

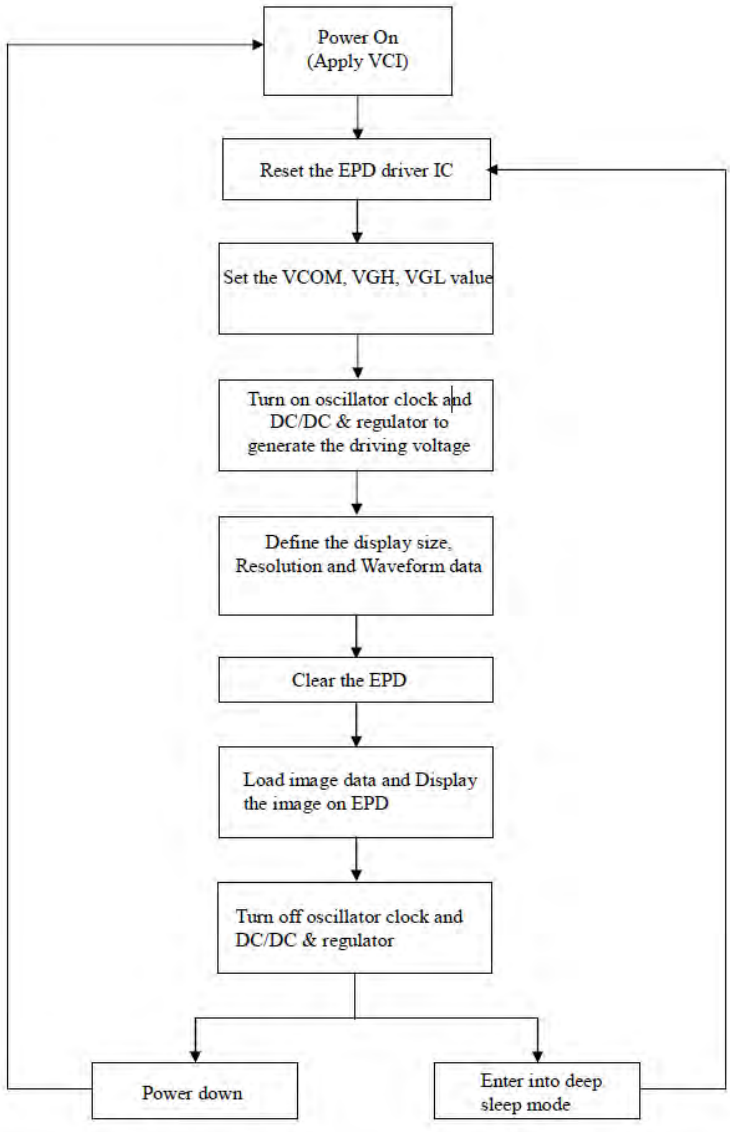

Fig 7. Software Flowchart

4.2 Software functions description

The main software routines used by this application code are described in the Table 1:

Table 1. Software functions description

Software functions	Description
EPD_W21_Init(void)	Initialize the E-paper.
Chip_GPIO_SetPinOutLow(LPC_GPIO_PORT, 0, RES); Chip_GPIO_SetPinOutHigh(LPC_GPIO_PORT, 0, RES);	Generate the reset signal to the E-paper display.
Chip_GPIO_SetPinOutLow(LPC_GPIO_PORT, 0, CS); Chip_GPIO_SetPinOutHigh(LPC_GPIO_PORT, 0, CS);	Control CS pin of the E-paper
Chip_GPIO_SetPinOutLow(LPC_GPIO_PORT, 0, DC); Chip_GPIO_SetPinOutHigh(LPC_GPIO_PORT, 0, DC);	Command write. Data write.
EPD_W21_WriteCMD( ); EPD_W21_WriteDATA();	Write command to E-paper, need wait for the BUSY signal de-assertion from the E-paper. Write data follow the command sent.

5. Demo introduction

5.1 Demo under Keil

Use an on board debugger (MBED CMSIS-DAP) to debug and download the project.

- Library files are already extracted to the project. No need to compile the library for board and chip. Compile and download the project and press “reset” button or unplug & plug power to execute the downloaded project.
- Project file can be found at:

  ..\applications\lpc8xx\keil_uvision_projects\nxp_lpcxpresso_824\periph\E-paper
- Default project will display 3 pictures turn-by-turn.

NOTE: If your IDE does not detect CMSIS-DAP, try installing serial port driver for mbed Windows from https://developer.mbed.org/handbook/Windows-serial-configuration#1-download-the-mbed-windows-serial-port.

5.2 Demo under IAR

Use an on board debugger to debug and download the project.

- Open the E-paper workspace, can be found at:

  ..\applications\lpc8xx\iar_ewarm_projects\nxp_lpcxpresso_824\periph\E-paper
- Import Chip and Board library to E-paper workspace through ‘Import existing project’ option. The Chip and Board libraries can be found at:

  .. \software\lpc_core\lpc_chip\chip_8xx

  ..\software\lpc_core\lpc_board\boards_8xx\nxp_lpcxpresso_824

  Compile the Chip and Board library project respectively.

NOTE: To compile the project successfully, “MAKE” board library twice after compiling to get “board_nxp_lpcxpresso_824.a”.

- Compile and download E-paper project to the board.
- After the project is downloaded to the board, unplug and plug power cable to reboot the system. Wait for at least 2 seconds before plugging in the power cable.

NOTE: If your IDE does not detect CMSIS-DAP, try installing serial port driver for mbed windows from: https://developer.mbed.org/handbook/Windows-serial-configuration, search for “Windows Serial Configuration” string and navigate to the first link appeared after the search.

5.3 Demo under LPCXpresso

Use an on board debugger to debug and download the project.

- In ‘Quickstart panel’ window, click on ‘Import new project’ option and enter .zip file’s path to import an E-paper project “AN_E_paper_LPCXpresso.zip”.
- Build the project. Click on ‘Build all projects’ option in ‘Quickstart Panel’ window to build.
- Flash the project on the board, use program flash button in symbol tray and browse for the .axf file of the project in ‘Select File’ field.
- Press the “reset” button, or unplug & plug power to reboot the system.
- Only 2 pictures can be displayed as LPCXpresso generates larger compiled files then Keil & IAR.

NOTE: If your IDE does not detect CMSIS-DAP, try installing serial port driver for mbed Windows from https://developer.mbed.org/handbook/Windows-serial-configuration#1-download-the-mbed-windows-serial-port.

6. Conclusion

The LPC824 LPCXpresso V2/mbed board provides functionality to interface 4-grey level E-paper display daughter board. The application note describes how a picture can be created by using NXP’s emWin tool and display it on E-paper display, how the power optimization is done in the system, and the demo to run the E-paper display on Keil/IAR/LPCXpresso.

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