Application Report

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Passive RFID Application Using MSP430F2274 and PaLFI

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MSP430

ABSTRACT

This application report describes a reference design implementing a battery-less RFID application that includes an E-Paper display, using the PaLFI eZ430-TMS37157 RFID board. The sample application code is implemented to run on MSP430F2274 MCU. In addition to handling the communications and E-Paper display driving, the MCU also controls a DC-DC boost converter to supply the higher voltage required by E-Paper.

Project collateral and source code discussed in this application report can be downloaded from the following URL: http://www-s.ti.com/sc/techlit/slaa480.zip.

Contents

List of Figures

List of Tables

1 Introduction

High-contrast and low-power display has been the need for many applications for a long time. This is particularly true for applications such as RFID, in which the physical dimensions cannot fit a built-in battery. The introduction of e-books has drawn the attention of applications to E-Paper, which offers both advantages of high contrast and low power.

Figure 1. Demo Setup E-Paper (Left) and RFID Transmitter (Right)

Figure 1 represents the demo setup with E-Paper (Left) and the RFID Transmitter (Right).

The design features:

- Passive RFID at 134.2 kHz with E-Paper display
- Based on PaLFI eZ430-TMS37157 development tool
- Single MSP430F2274 manages RFID communication, controls the DC-DC boost converter, and drives the E-Paper character display
- Application Examples:
  - Displays embedded in smart cards
  - Electronic price tags
  - Electronic toll devices

1.1 A Brief Description of E-Paper

E-Paper, as its name suggests, is an electronic display that mimics ordinary paper. It is flexible, has high contrast, has a large viewing angle, does not require a backlight for viewing, and is viewable under direct sunlight. E-Paper allows its image to be changed electronically, yet it is capable of maintaining an image when there is no electricity supply.

Figure 2 shows the structure of E-Paper pixels and how an image is formed on E-Paper by electronic means.

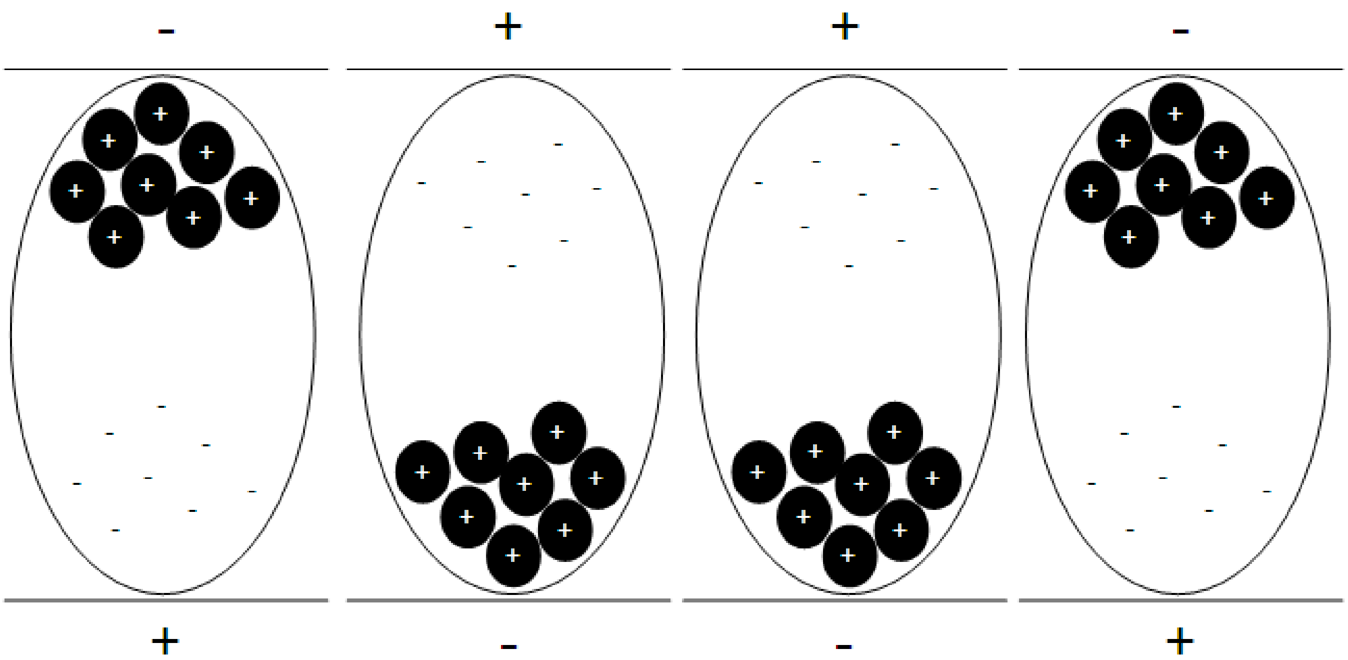

Figure 2. Image Formation on E-Paper

The dye particles inside a pixel of E-Paper are attracted or repelled when different voltages are applied. When a voltage is applied across the two plates, the particles move to the plate having the opposite charge. When the dye particles are attracted or repelled, the pixel appears black or white due to absorption or reflection of the incident light. In this manner, the image is formed by the combination of pixels. As the E-Paper image does not change after the applied voltage is removed, driving an image onto E-Paper need to be done in two steps. First, the original image is erased, and second, the new image is written onto the E-Paper. Experiments with this demo shows that when changing an image with black pixels on a white background, better images result from fading the image through black (that is, making the transition from the original image to an all black state, then showing the new image). In the inverse case, white pixels on a black background, better images result from fading the image fade through white.

2 Hardware

Figure 3 shows the system block diagram of the solution. It consists of the Passive Low Frequency Interface Device (PaLFI) circuit (which is not discussed in this application report - see the *eZ430-TMS37157 Development Tool User's Guide*, SLAU281), the boost circuit, and the serial to parallel E-Paper display driver circuit.

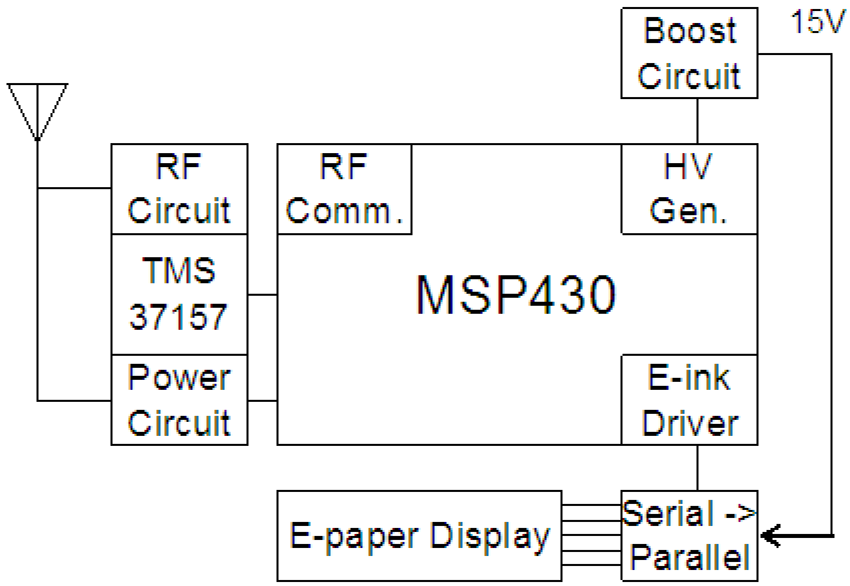

Figure 3. Hardware Implementation

2.1 DC-DC Boost Converter Circuit

Figure 4 shows the boost circuit. It is a simple boost regulator topology having a 15 V zener diode at its output to clamp the output voltage to 15 V as a protection to the E-Paper display. This is a passive RFID system, thus power is supplied from an external source wirelessly. Adding the power consumption of the voltage regulation circuitry and software may consume too much of the radiated power, causing the boost function to fail. This open-loop architecture is used to provide high enough boost voltage to drive the E-Paper to maintain a good contrast ratio.

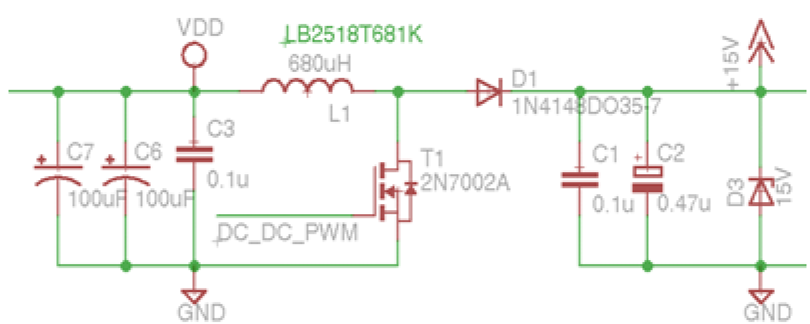

Figure 4. Boost Circuit

Both the E-Paper and the CMOS shift register consume very little current during operation. The rating of the inductor takes the current consumption of the two level shifters divided by the duty ratio of the boost converter for its maximum rating. In this case, the calculated value is approximately 50 to 60 mA.

Any general surface-mount 1N4148 and 2N7002 has more than sufficient rating for this application. The presence of input capacitors C6 and C7 is important for storing energy radiated from the external source. C1 and C2 should not be large, as driving the E-Paper requires very little energy, and the size of C1 and C2 affect the rise time and fall time of the boost output voltage, thus affecting the response time and contrast ratio of the display. The voltage rating of the capacitor is 6.3 V for C3, C6, and C7 and 50 V for C1 and C2.

2.2 Driver Circuit

Figure 5 shows the driver circuit implemented with high voltage CMOS shift register.

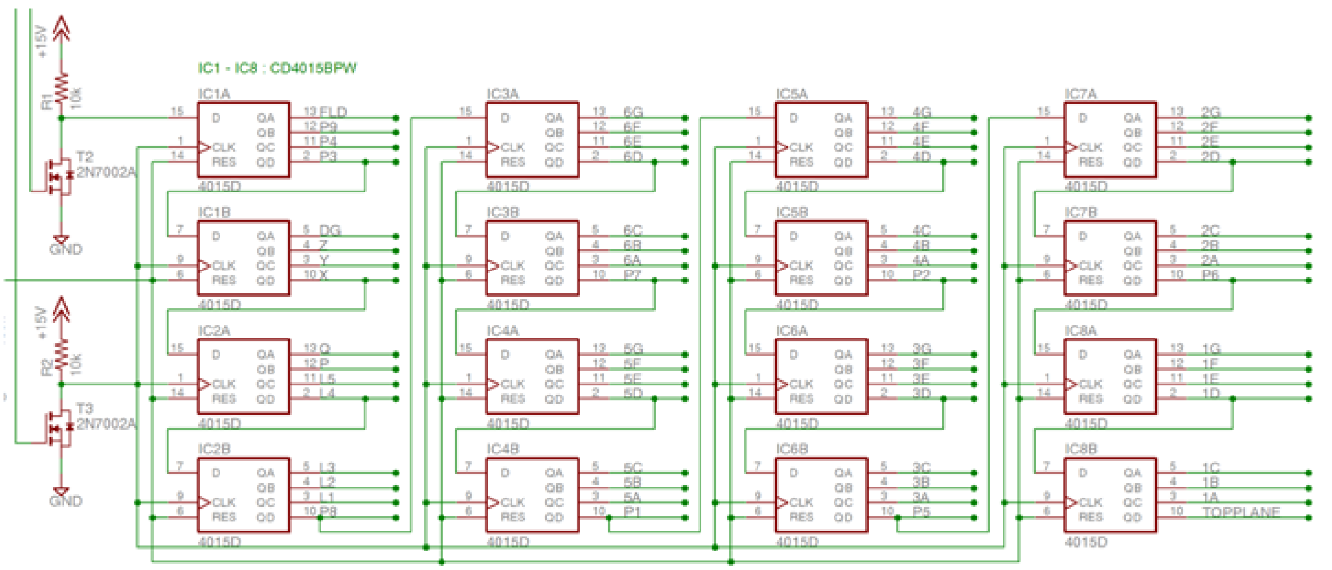

Figure 5. Driver Circuit

The circuit consists of two level shifters implemented with two N-MOS transistors. The 64-segment driver is implemented with eight dual 4-bit high-voltage CMOS shift registers (CD4015B) that are capable of working at 15 V supply. The driver accepts data in a synchronized serial manner with clock and data from the level shifter, and the output drives the E-Paper segments directly. The value of R1 and R2 affect the performance. Using small R1 and R2 values would waste the energy supplied remotely, but could speed up the rising edge that goes into the shift register. Large R1 and R2 values save energy, but the trade off is in the speed of the edge. 10kΩ is chosen for R1 and R2 for a balance between power consumption and edge rise time.

2.3 Connecting to PaLFI Board (eZ430-TMS37157)

These signals are connected from the PaLFI board to the system (see Figure 6).

- P1 : GND – System ground
- P2 : V_{CC} – System supply
- P9 : DATA – Data line to shift register's data input (P4.3 on MCU)
- P11 : CLK – Clock line to shift register's clock input (P4.4 on MCU)
- P13 : DC_DC_PWM – Pulse width modulation (PWM) signal to drive boost regulator (P4.5 on MCU)
- P14 : Reserved for shift register's clear signal (P4.6 on MCU)
- P17 : Reserved for feedback boost regulator control (P3.0 on MCU)

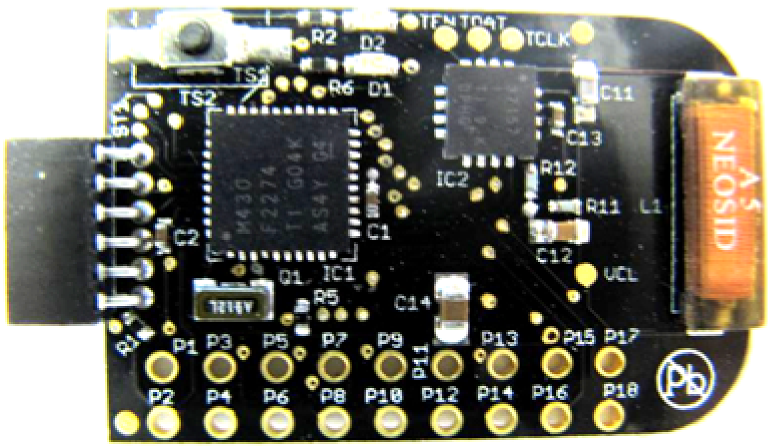

Figure 6. PaLFI Board

3 Software Implementation

Software is implemented into two major functions:

- The PaLFI functions, which are not discussed in detail here. For more information of PaLFI and related documentation, go to http://www.ti.com/palfi.
- The drivers that are used to drive the boost regulator and drive the E-Paper display, which are covered here.

After the power-on reset when the system is powered from remote reader, the MSP430™ hardware is first setup. It then enters the PaLFI command parsing loop in which your data is interpreted and the system determines which actions to take.

3.1 Setup

3.1.1 Clock Setup

Because an accurate MCU clock frequency is not critical for this application, the default Basic Clock Module+ setting of approximately 1 MHz SMCLK is used as the system clock.

3.1.2 Watchdog Setup

The watchdog is disabled in the application.

3.1.3 DC-DC Boost Converter Setup

Setup for boost converter includes two steps. The PWM generated by Timer_B is setup to be driven by SMCLK, running in Up mode with the PWM period set to 64 SMCLK (approximately 16 kHz at the default SMCLK frequency) and the duty cycle set to 3 (approximately 4% to 5%). The next step sets up the input/output (I/O) port pin so that the PWM output is not connected to the I/O port pin. Two utility macros are defined: enable_dc_dc and disable_dc_dc are defined for connecting or disconnecting the pin output with PWM output.

3.2 Clocking Data Into Shift Register

The driver needs 64 bits to control the 64 segments of the E-Paper display. The driver circuit provides a serial-to-parallel interface for clocking the 64-bit map into the high-voltage shift register (see Figure 7). Clocking data into the shift register is simple: the data bit is output first before the rising clock edge. Note that the level shifter has inverted the clock and data value; thus, the firmware needs to take care of this when generating the clock and data signal. Also note that the level shifter, by its construction, consumes minimal power when the FETs are in off state; thus, DATA and CLK pins should always be output low after sending a bit.

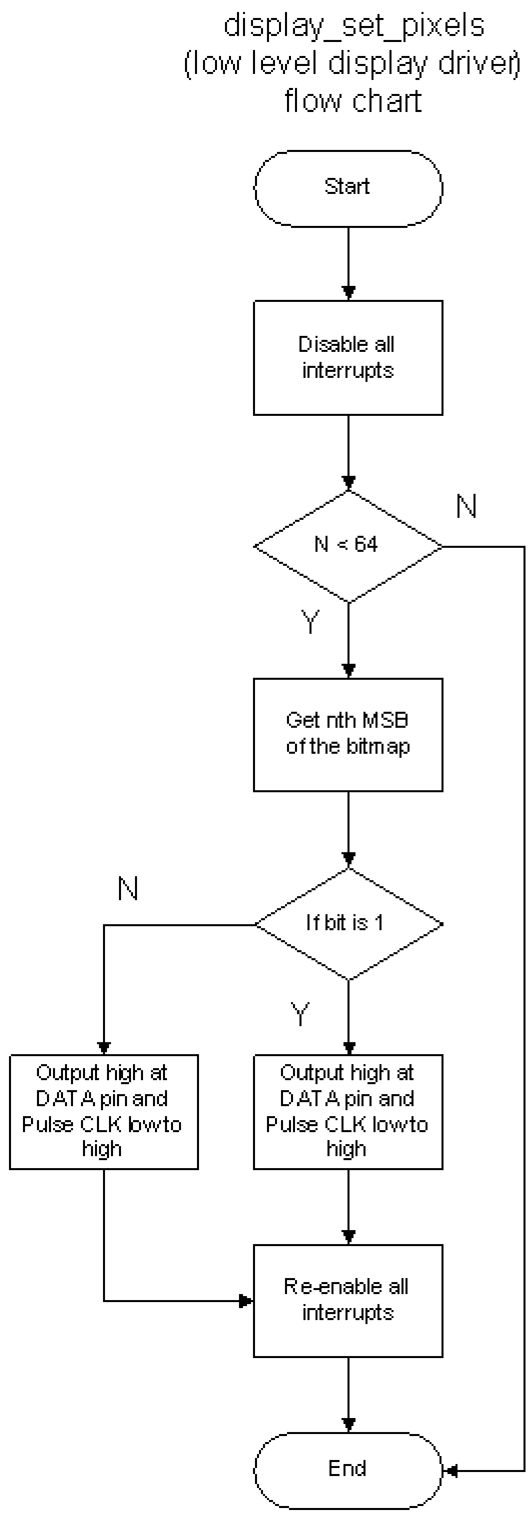

Figure 7. Clocking Data Into Shift Register (display_set_pixels)

3.3 E-Paper Display Driving

3.3.1 E-Paper Driving Wave Form

As mentioned in Section 1.1, E-Paper requires different voltage polarity to turn a segment black or white. The E-Paper used in this demo has 63 segments and 1 common electrode (top plane) for all segments. As shown in Figure 8, to produce positive voltage relative to the top plane (turning segments black), +15 V (or high) is applied to the segment terminal, 0 V (or low) is applied to the top plane, and these voltages are applied for the time Tdb. Similarly, to produce a negative voltage relative to the top plane (turning segments white), 0 V is applied to the segment terminal, +15 V is applied to the top plane, and these voltages are applied for the time Tdw.

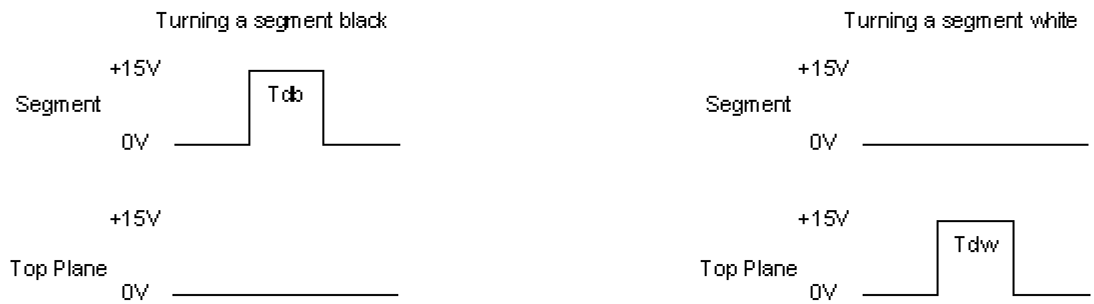

Figure 8. E-Paper Driving Waveform

3.3.2 Generating Display

Changing the display involves first clearing the original image followed by forming the new image. This can be done by fading through black and fading through white. Fading through black means the original image is erased by turning the whole screen black (that is making all the segments turn black) and then form the new image by turning the white segments of the new image white. Fading through white did the reverse to erase the original image by first turning all the segments to white and then form the new image by turning the black segments of the new image black. The procedure and waveform of driving the E-Paper display fading through black is shown below as an example.

Driving the E-Paper display by fading through black includes these steps:

1. An all black (or clear in case of fade through white) image bitmap is shifted into the shift register
2. The boost is enabled to allow 15 V to appear at the driver for 375 ms (Tdb) to stabilize the display
3. The image bitmap (or inverted bitmap) is shifted into the shift register, and this bit pattern stays in the register for 250 ms (TdW)
4. The boost converter is shut down

Figure 9 and Figure 10 shows the waveform on the top plane and segments while driving a fade through black system.

Figure 11 shows a flow chart of the driving routine.

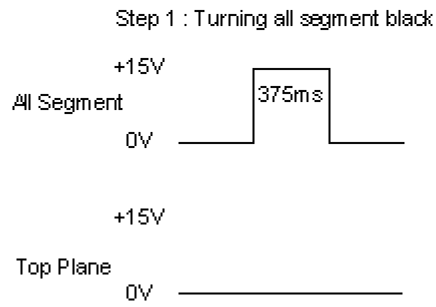

Figure 9. Top Plane and Segment Waveform for Generating Display: Step 1

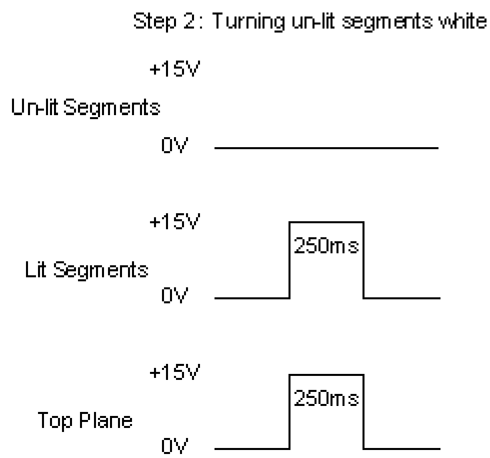

Figure 10. Top Plane and Segment Waveform for Generating Display: Step 2

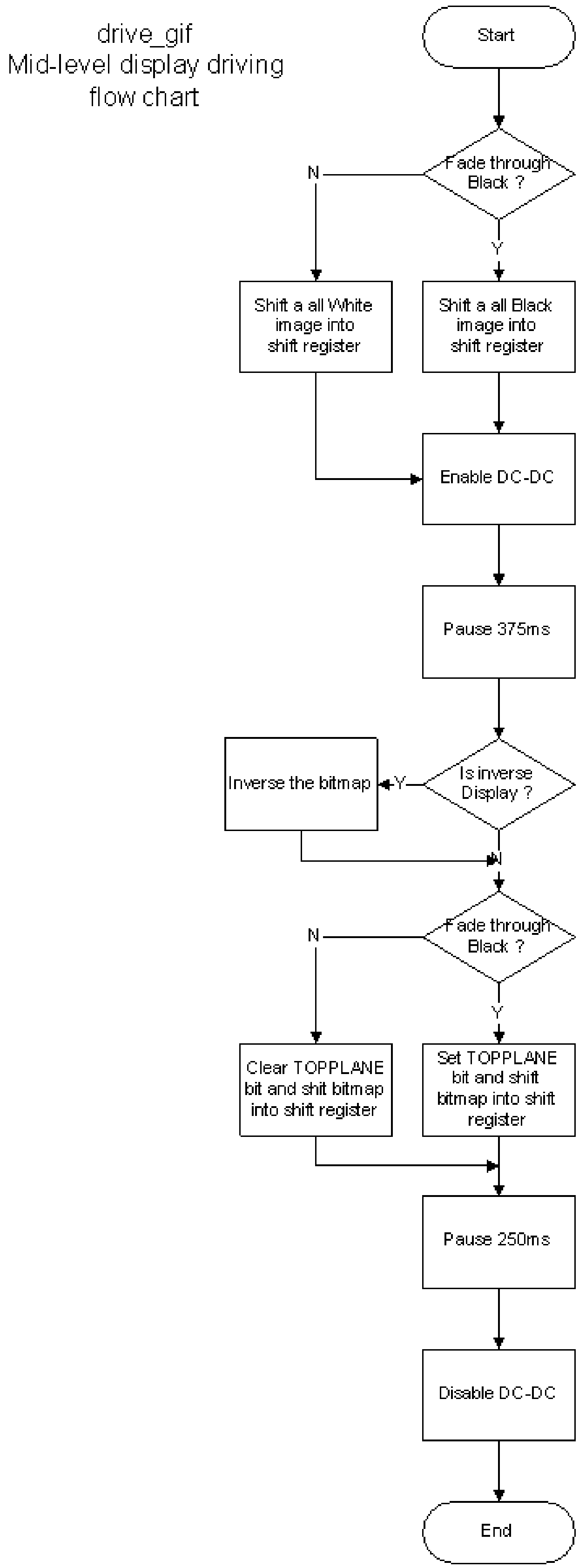

Figure 11. Driving Display

4 Demo Code

4.1 Loading Demo Code

The demo code is compiled with Code Composer Studio™ IDE 4.1.2. The demo code of the PaLFI E-Paper RFID demo application is in PaLFI epaper.zip (http://www-s.ti.com/sc/techlit/slaa480.zip).

To run the demo project:

1. Un-zip the file into a project folder.
2. Launch Code Composer Studio.
3. Select the folder [PaLFI epaper] as the workspace. (See Figure 12 and Figure 13.)

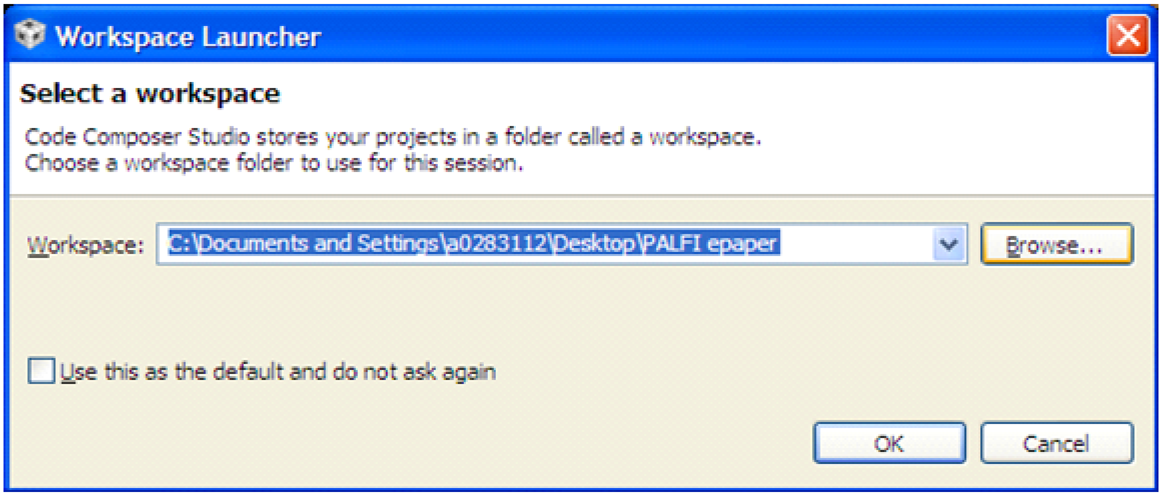

Figure 12. Select Project Workspace

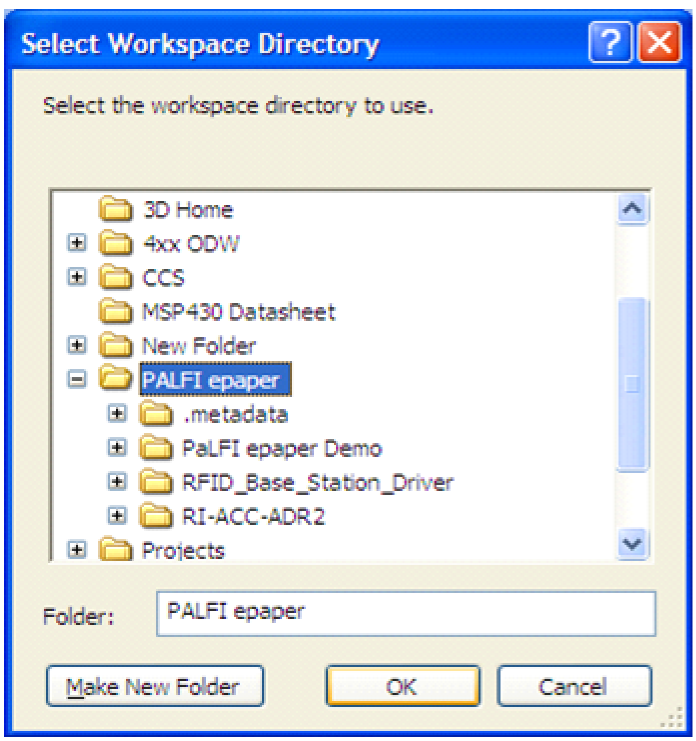

Figure 13. Select Project Workspace Directory

4. Right click on [PaLFI embedded Demo] and select [Set as Active Project] in the dropdown menu, after Code Composer Studio is launched. (See Figure 14)

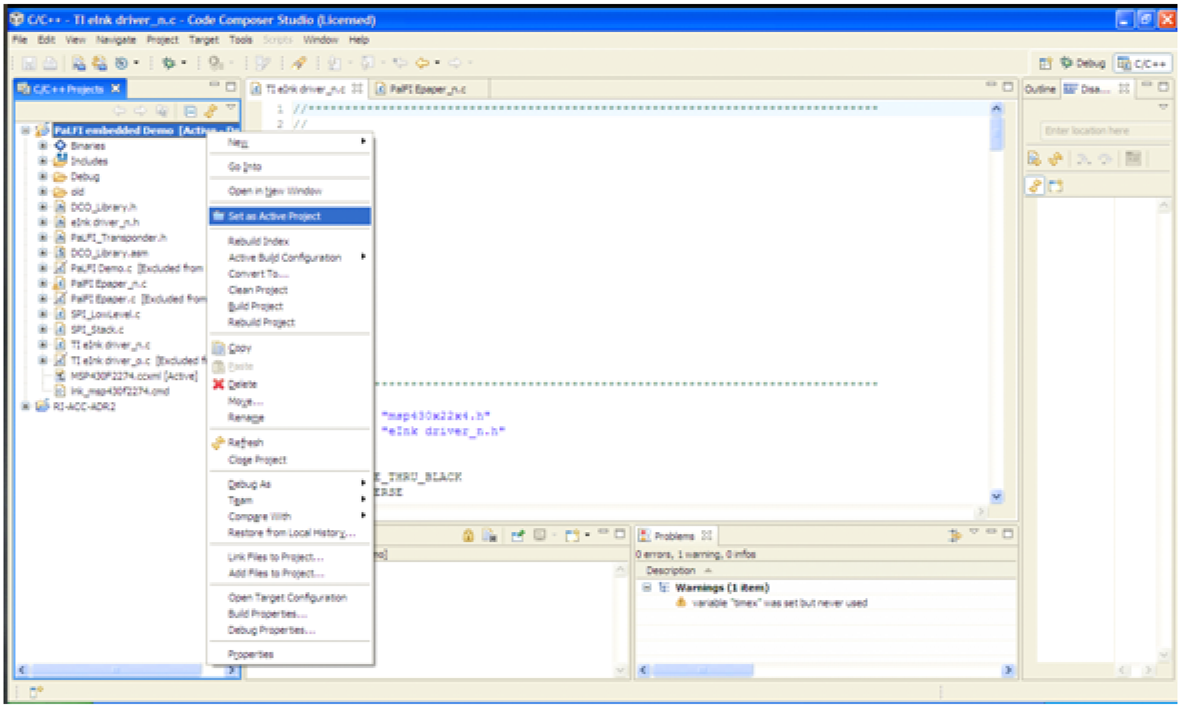

Figure 14. Set PaLFI Embedded Demo as Active Project

5. Move the mouse pointer to [PaLFI embedded Demo] again and right click. Click [Rebuild Project] to completely rebuild the application. (See Figure 15.)

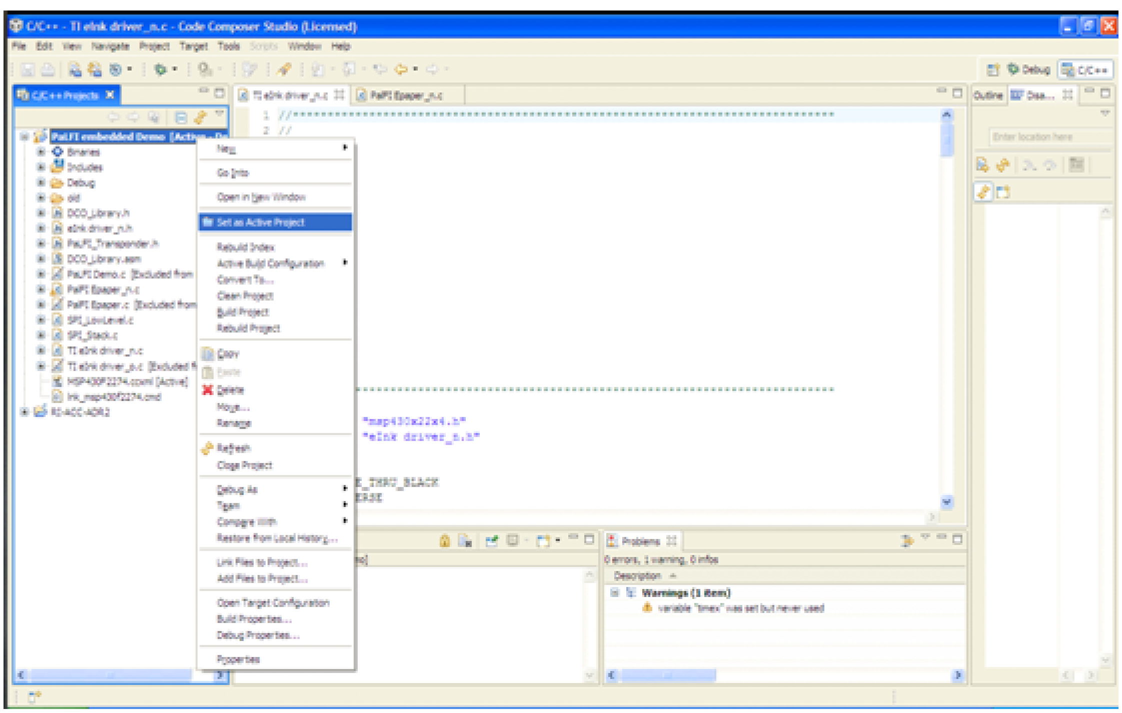

Figure 15. Rebuild Project

6. Connect the FET (14-pin JTAG MSP-FET430UIF) or EZ430 six-pin emulator (Spy-Bi-Wire) MSP-ez430U to the PaLFI development board. Click on the [Debug] button to download the code and launch the debugger. (See Figure 16.)

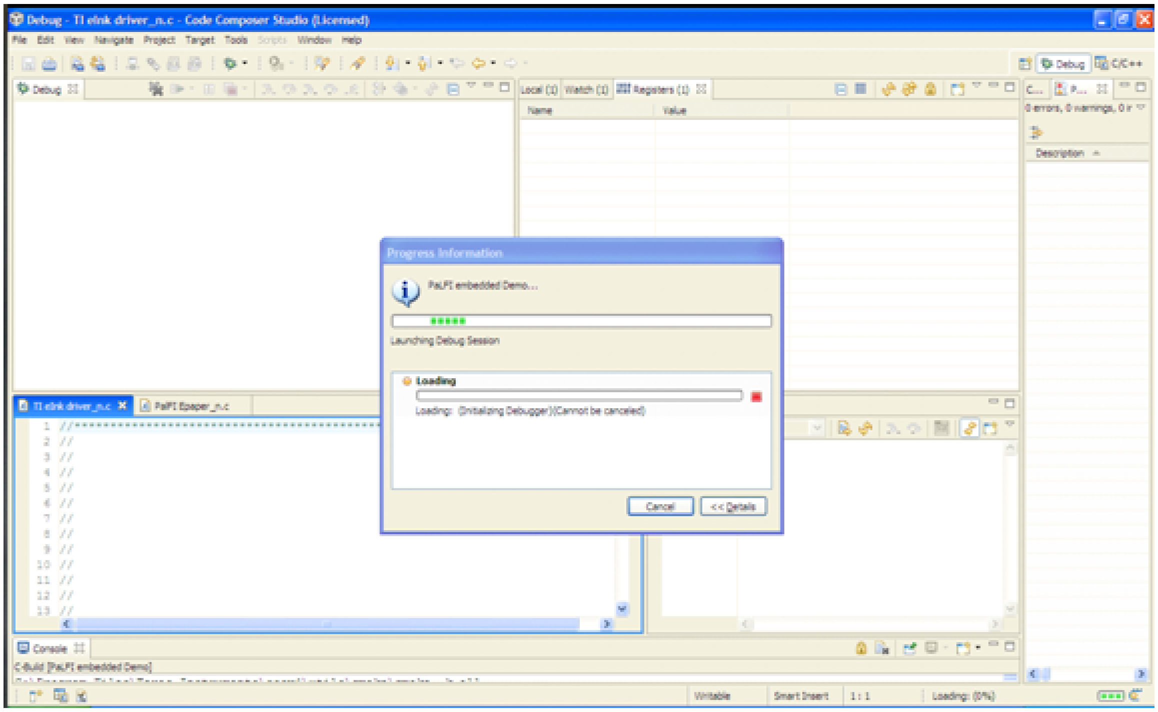

Figure 16. Download Code

7. Remove the FET or EZ430 connection and place the display board near the antenna of the demo base station when the code download is completed and the debugger is launched. Then follow the instruction in Section 5 to play with the demo if code modification is not need. For more information about source code modification, see Section 4.2.

4.2 *Changing Demo Code*

This demo code is modified from the original PaLFI main routine to get the received data and to set the display onto the E-Paper. You can customize the files, but be careful not to accidentally change the behavior of the original PaLFI operation. For more information on PaLFI, see the *eZ430-TMS37157 Development Tool User's Guide* (SLAU281).

The demo code concerning this E-Paper display demo involve three files:`TI eink driver_n.c`, `PalFI Epaper_n.c`, and `eInk driver_n.h`. `TI eink driver_n.c` contains the E-Paper display driver routines, `PalFI Epaper_n.c` contains the PaLFI main routines, and `eInk driver_n.h` contains the character bitmap definition.

These are the E-Paper specific routines:

```
void drive_gif (display_t bitmap);
void display_set_pixels (display_t pix);
void inline enable_dc_dc (void);
void inline disable_dc_dc (void);
void Delay_500ms(void);
void Delay_375ms(void);
void Delay_250ms(void);
void inline init_dc_dc_pwm (void);
```

5 Experimenting With the Demo

5.1 Required Hardware and Software

The demo software requires a PaLFI demo kit: EZ430-TMS37157. This kit can be ordered from TI's website (http://focus.ti.com/docs/toolsw/folders/print/ez430-tms37157.html).

Before running the application program for the demo, make sure that Microsoft® .NET framework 3.5 SP1 is installed. It is downloadable freely from Microsoft's web site (as of this application report writing, the URL for download is http://download.microsoft.com/download/2/0/e/20e90413-712f-438c-988e-fdaa79a8ac3d/dotnetfx35.exe/).

The *RFID Base Station Driver* (SWRC172) must be installed on the PC before plugging in the RFID base station. For detailed steps of installing the RFID Base Station, see the *eZ430-TMS37157 Development Tool User's Guide* (SLAU281).

Next, supply the RFID Base Station 6 V to 15 V 1.2 A via the external supply connector; higher voltage tends to give longer operating distance. Then, connect the RFID Base Station to the PC with a USB A to mini-B cable.

5.2 Launching the Demo Software

After installing the RFID Base Station, the associated software, and driver, launch the demo software "RFID Demo Software". Place the E-Paper demo with the antenna in proximity to the RFID base station as shown in Figure 17 through Figure 23 to experiment with the demo.

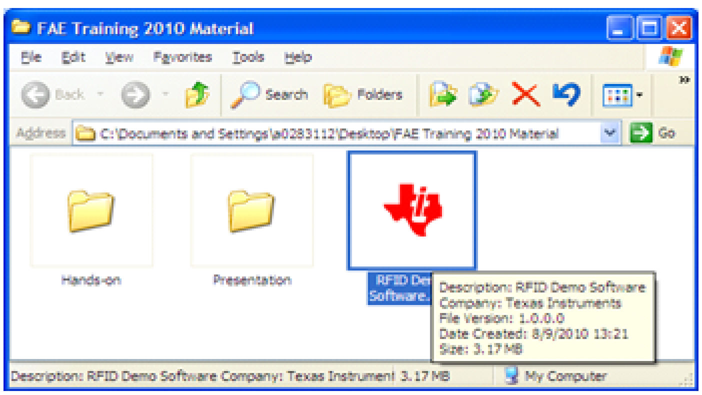

Figure 17. Launch the Application Program

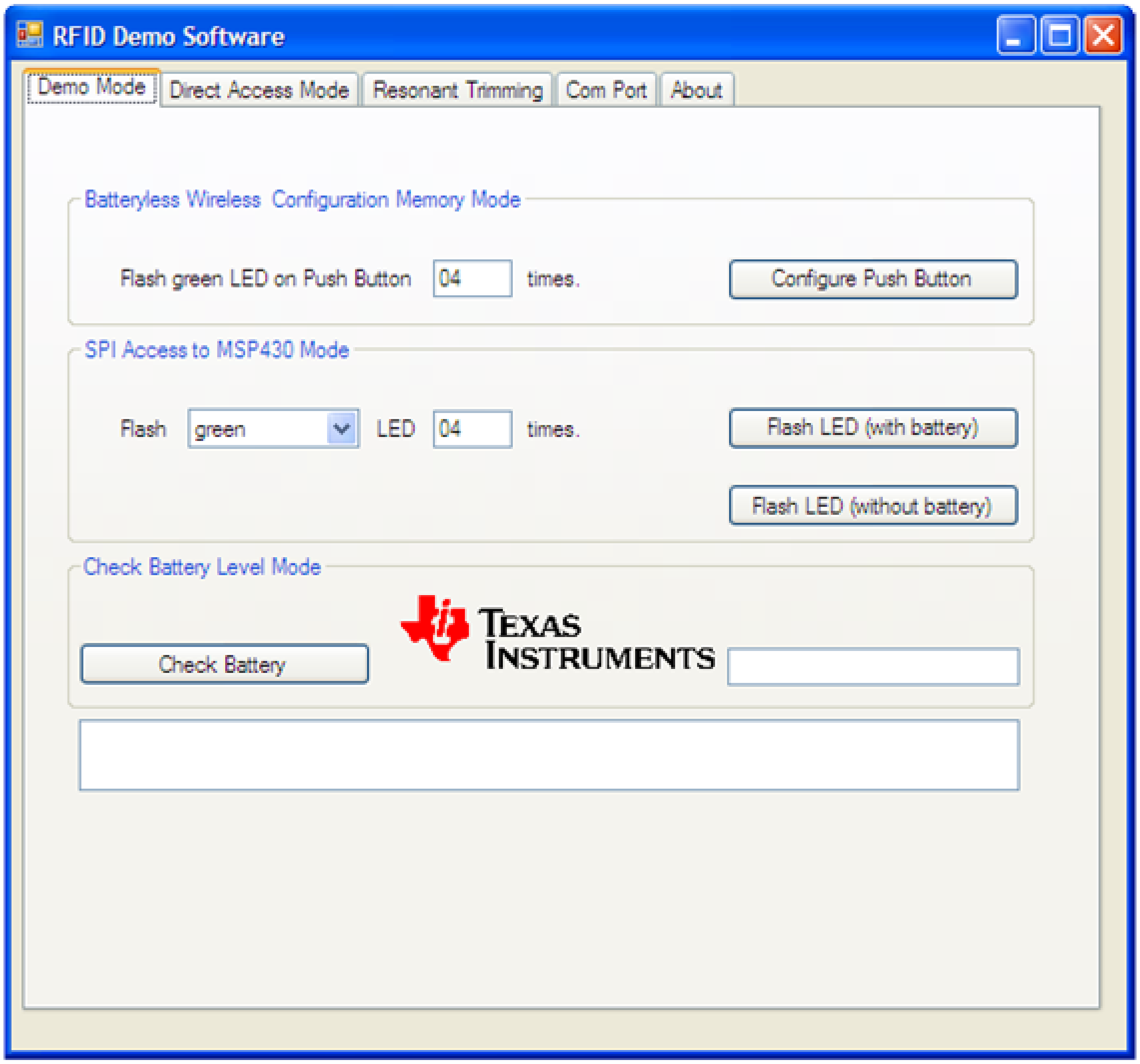

Figure 18. To Show "Green" on Display

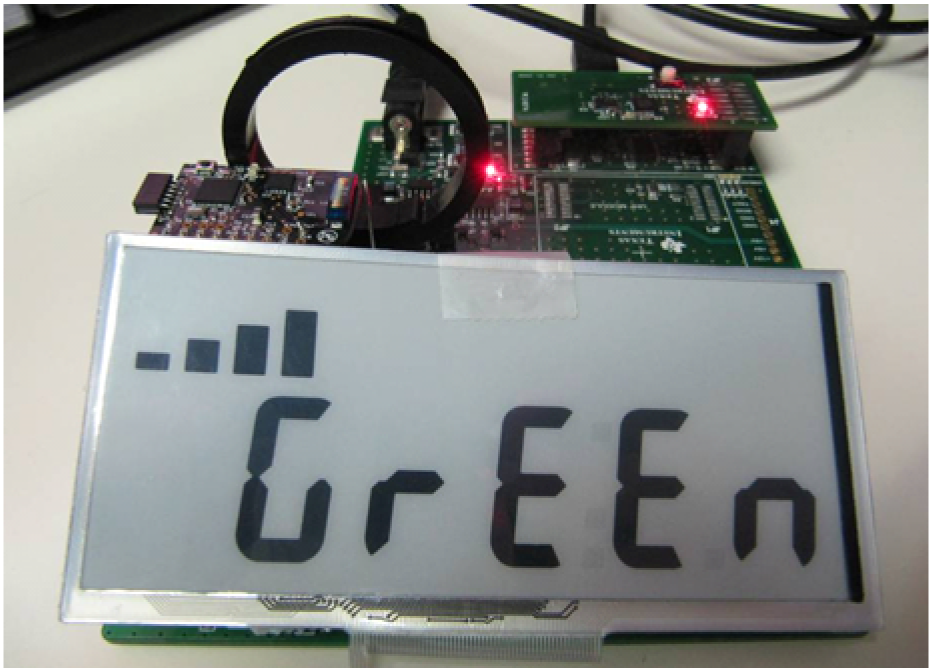

Figure 19. "Green" on Display

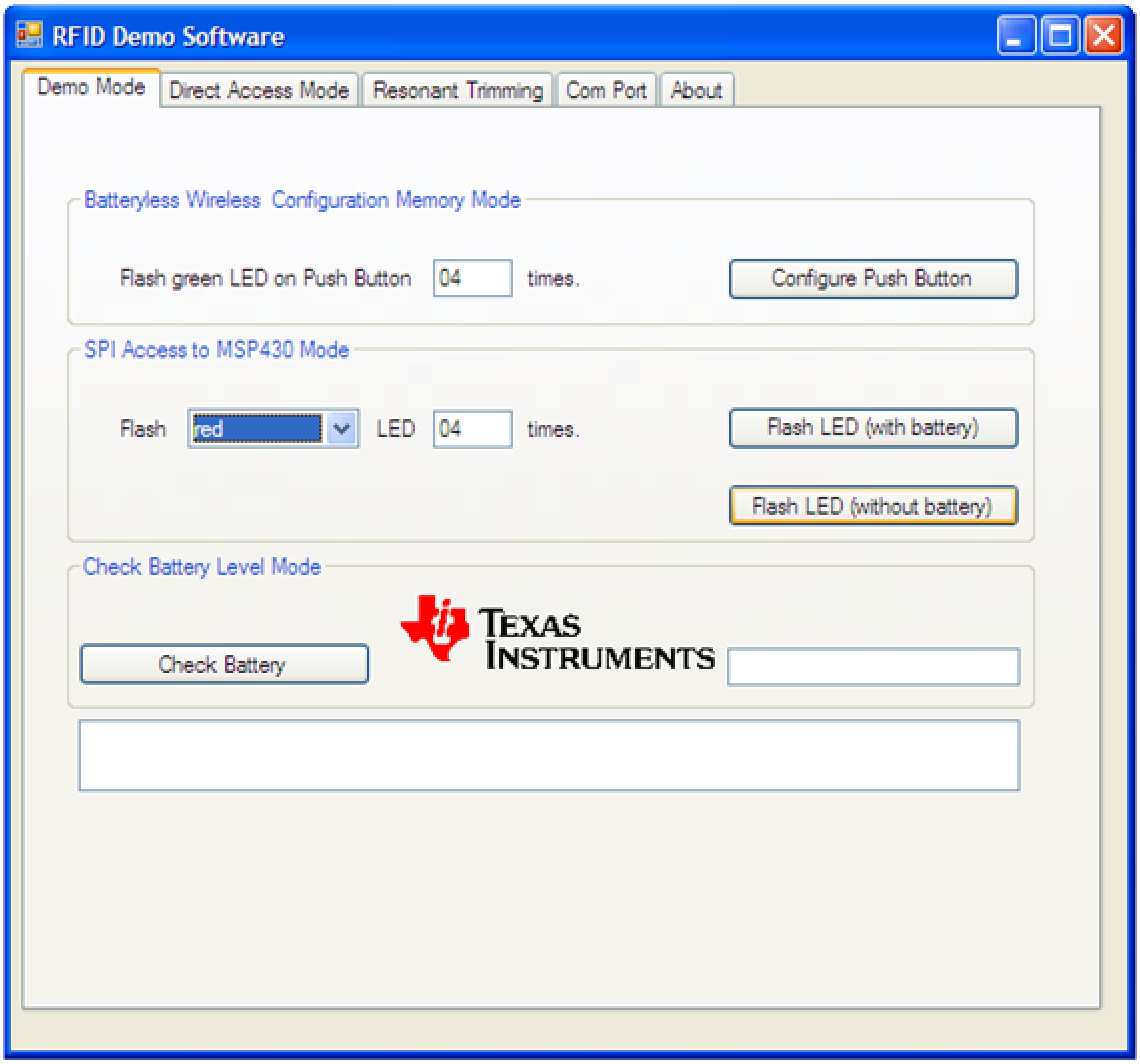

Figure 20. To Show "Red" on Display

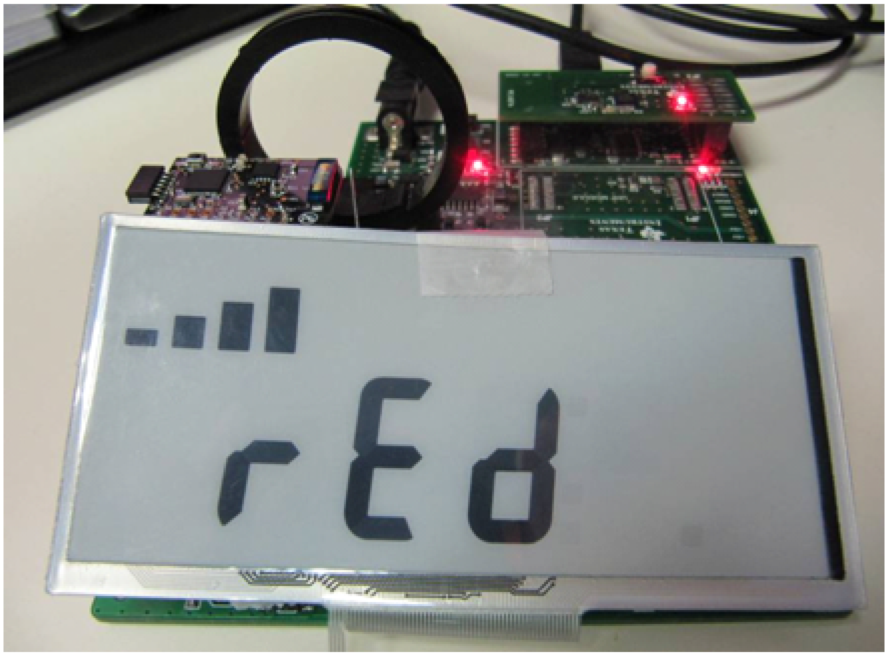

Figure 21. "Red" on Display

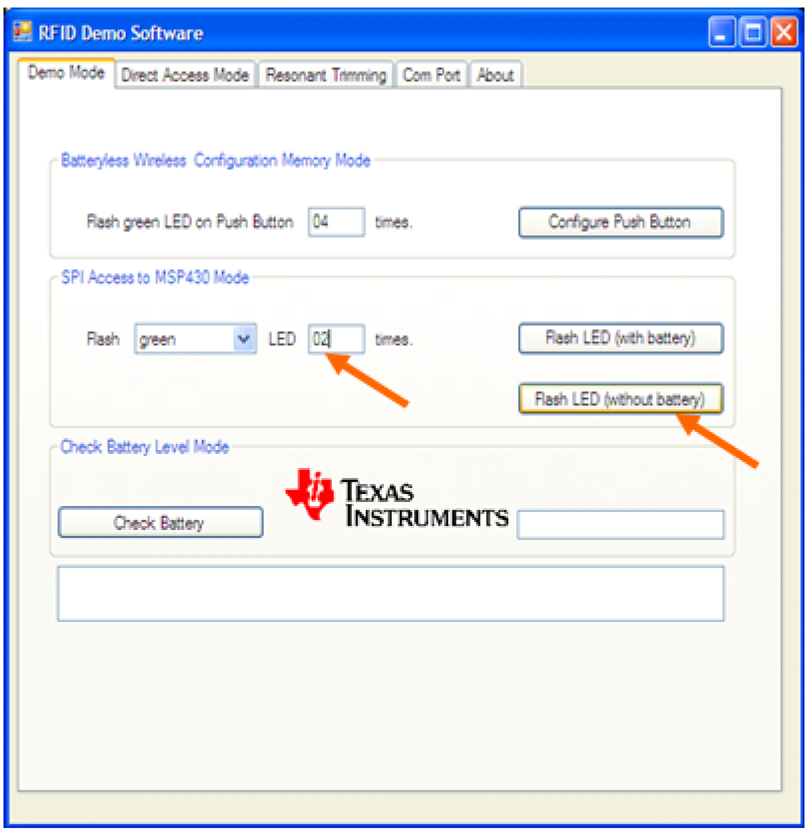

Figure 22. Change the Number of Bars on Upper Left

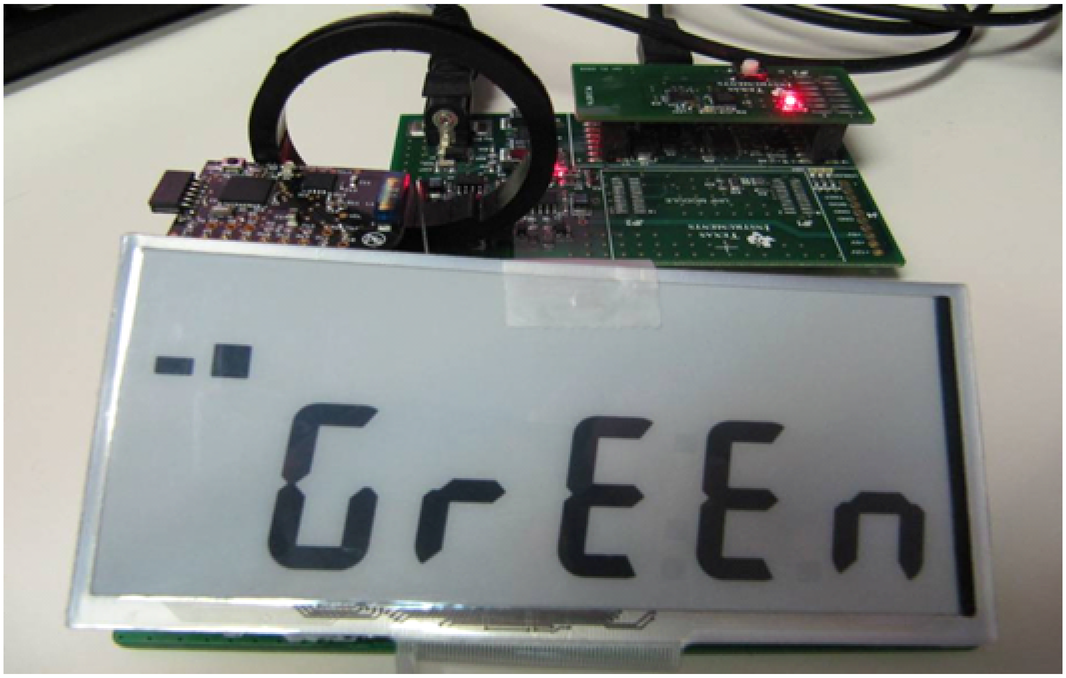

Figure 23. Number of Bars on Upper Left Changed

6 Circuit Diagram

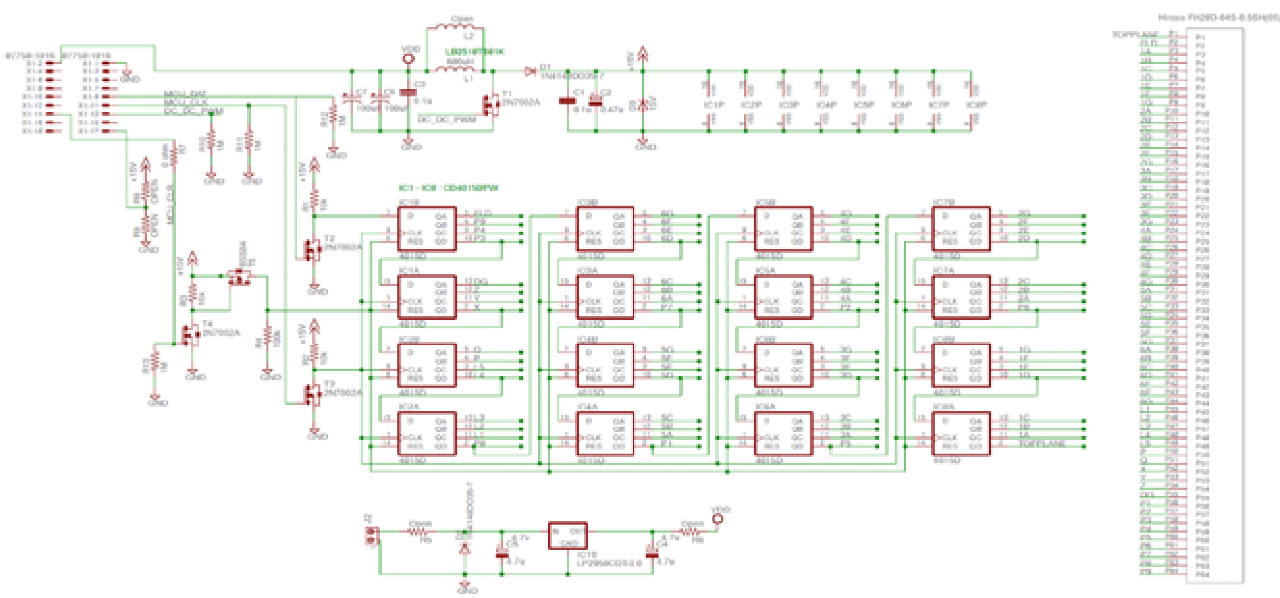

Figure 24. Circuit Diagram

7 References

- MSP430F2274 data sheet (SLAS504)
- MSP430x2xx Family User's Guide (SLAU144)
- SURF Electronic Paper Displays Application Note : Waveform Driving Schemes E-Ink Corporation, July 2008
- *RFID Base Station Driver* (SWRC172)
- *eZ430-TMS37157 Development Tool User's Guide* (SLAU281)

8 Demo Package

The E-Paper demo kit includes :

- The PaLFI E-Paper demo unit and the PaLFI transmitter
- The software package
  - RFID Demo Software.exe
  - Zipped source code package (see Section 4.2 for details)

9 E-Paper Display Information

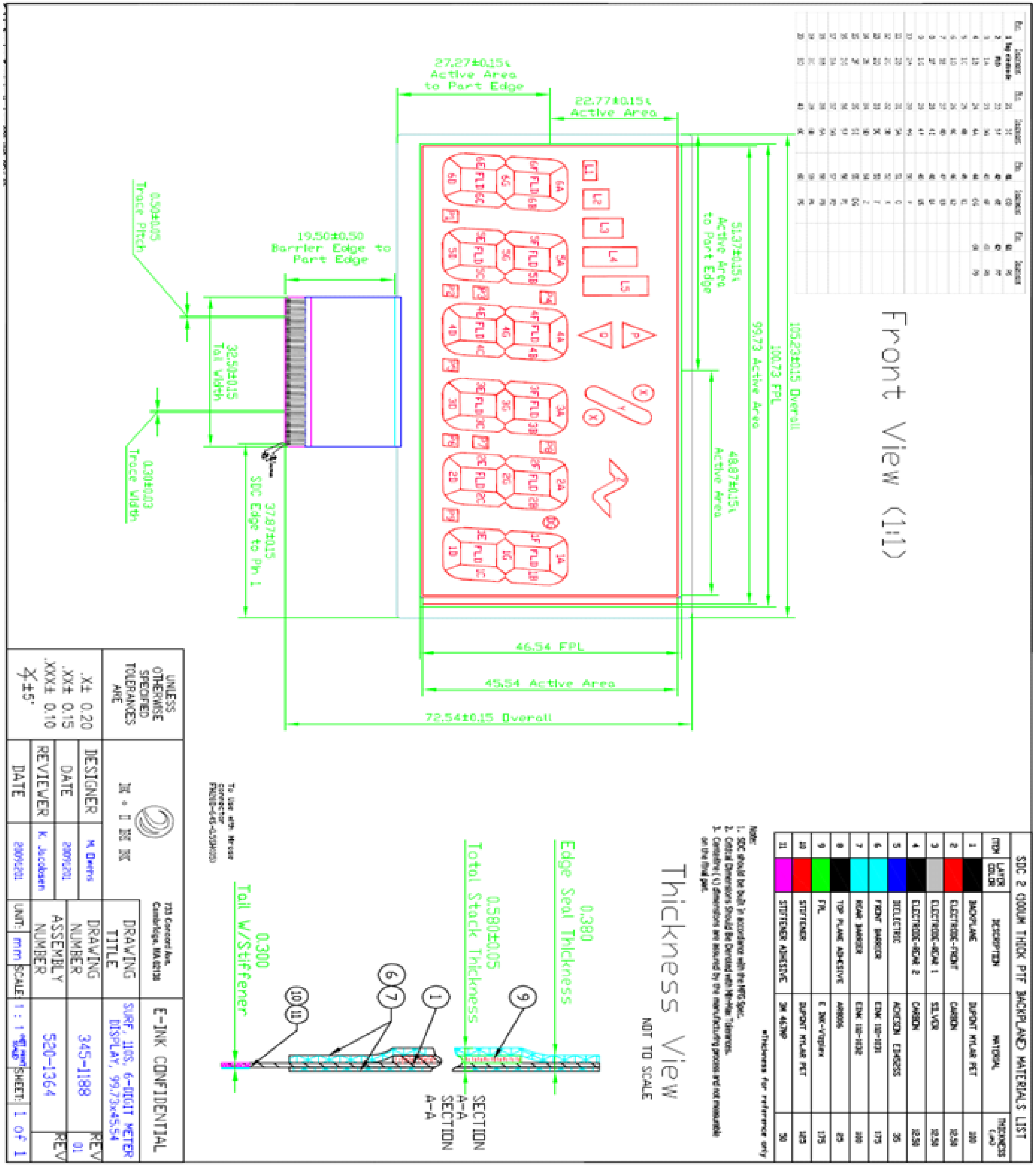

Figure 25. E-Paper Display Information