Reference Design

LED Flashlight Controller/Driver Using a Z8 Encore! XP MCU

RD003201-0415

Overview

This document describes a Z8 Encore! XP-based LED flashlight controller reference design that employs the PWM block of Zilog's Z8F082A MCU to control the power and functional modes of an LED flashlight.

Portable flashlights were early adopters of LEDs, and LED-based flashlights are now the most prevalent portable lighting solutions available on the market. However, many of these designs use simple resistor circuits that contribute to poor LED performance, decreased functionality, and diminished lifetimes.

The addition of an MCU to power and manage the LED provides opportunities for control of custom lighting patterns and sequencing, user interface control, and increased efficacy (in lumens per Watt) to result in longer battery life at greater lumen output. Additionally, an MCU implementation benefits from an application developer's improved ability to modify or add functionality via a simple program update versus a hardware redesign.

Note: The source code file associated with this reference design, RD0032-SC01.zip, is available free for download from the Zilog website. This source code has been tested with version 5.2.0 of ZDSII for Z8 Encore! XP MCUs.

Features

The key features of this LED Flashlight Controller are:

- Z8F082A MCU with six I/O pins and 8KB Flash
- In-system driver programming using a modified Zilog USB SmartCable
- Fast reprogramming from a hex or batch file to create a library of groups and modes
- 8x AMC7135 stackable pads (2800mA)
- Open source for sharing and potential application improvement
- Low voltage detect is supported by the MCU (not implemented in the initial release)
- MCU temperature sensor is supported (not implemented in the initial release)
- Zilog Developer Studio IDE with C Compiler
- 17mm diameter driver
- 4.5KHz PWM
- 3 groups, multiple modes, and memory at ON time
- Low material cost

Potential Applications

This reference design can be used to develop a number of applications; the brief list below offers a few ideas.

- LED Flashlight Driver Controller
- Alarm system LED controller
- Lighting LED controller

Discussion

This LED Flashlight Driver Controller reference design consists of a single printed circuit board (PCB) featuring Zilog's Z8F082A MCU in an 8-pin SOIC package, plus resistors, AMC7135 current regulators, a diode, and a capacitor, as shown in Figure 1.

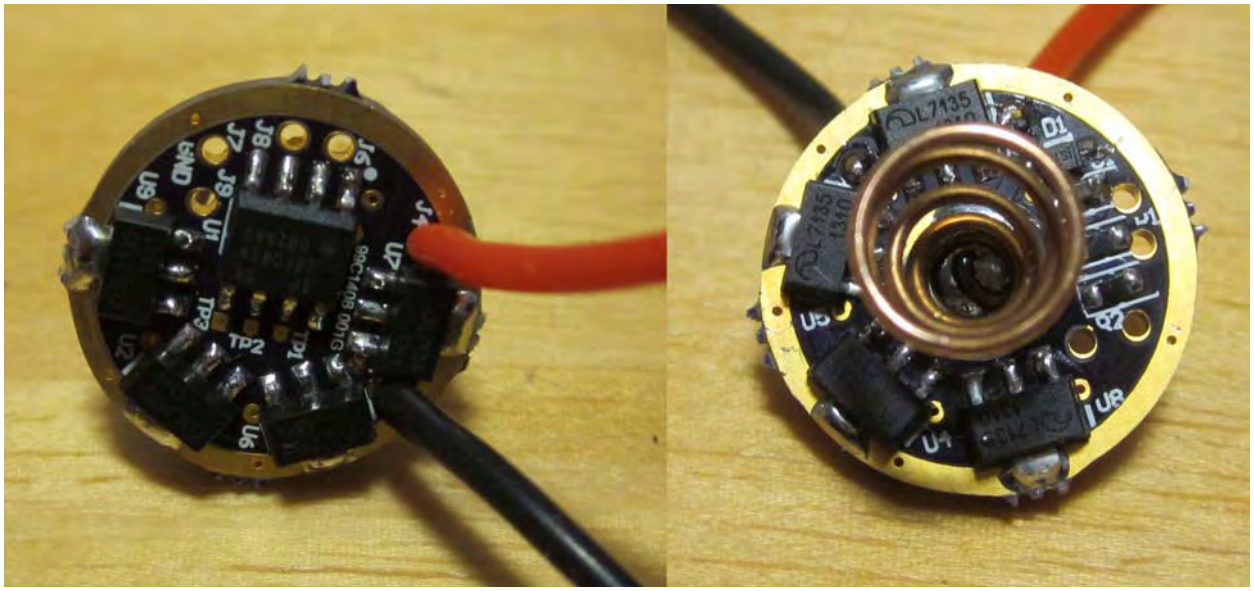

Figure 1. The LED Flashlight Driver Controller

The PCB is powered by a Lithium-ion battery (3.7V to 4.2V) through a battery spring and PCB ground ring. The PCB features four plated through-holes that provide easy access for in-system programming through the spring side of the driver. The 17mm-diameter dimension of the PCB is suitable for most flashlights available in the market.

A schematic diagram of the LED Flashlight Driver Controller is shown in Appendix E. Schematic Diagram on page 22.

Principles of Operation

After battery voltage is applied to the PCB, the MCU will read the contents of Z8F082A Flash memory for group and mode data that was saved in a previous operation. If there is no valid code (i.e., this is the first time you are using the MCU), it will default to Group 1 and Low Mode, as shown in Table 1 on page 3.

Controller Groups and Modes

Table 1 describes controller behavior. To provide an example, when in Group 1, and when the last operation before a power-off was ME (i.e., *medium*), the controller will turn the power on at ME. If power cycling is performed, as in the case of tapping the switch after a power-on, the controller will change the power to the next mode, which for Group 1 is a HI (i.e., *high*). Repeating these steps will cycle all modes within a group.

To change group, go to the designated change group level, as indicated in Table 1 by the modes displaying a green background. For example, Group 1 includes LO mode. After a power-on, or if going to this mode, wait for at least 1.2 seconds (your cue to wait is indicated by a short blink), then perform a power cycle by tapping the power switch. The controller will switch groups and will be at a specific mode for that group, as indicated by the red text/mode in Table 1 which, in the case of this driver, is in LO mode.

The levels for Moonlight (ML), Low (LO), Medium (ME), and High (HI) can easily be modified for the requirements of your application. Levels are expressed in decimal notation from 0 to 100, in which 0 = OFF and 100 = ON. Any numbers inside this range represent a percentage of a full ON (i.e., 100%).

Table 1. Groups and Modes Selection Guide

Group Selection by Short Tap After 1.2s								
Group 1	LO	ME	HI					
Group 2	LO	ME	HI	Blinker	Police	Strobe	Pulse	Beacon
Group 3	ML	LO	ME	HI				

Features/Options:
- Change the mode within 1.2s by a a momentary press of the switch (i.e., a *short tap*).
- Change the group after 1.2s at a designated mode within a group; the LED will blink.
- Red text: change the group location.
- Green box: the landing mode when changing a group.

Note: In Table 1, the following default timings and sequences are used for Group 2 functions:
Blinker: 1.5 sec OFF→30 mS HI→and repeats
Police: 1.5 sec OFF→30 mS HI→60 mS OFF→30 mS HI→60 mS OFF→30 mS HI→and repeats
Strobe: 60 mS OFF→30 mS and repeats
Pulse: 50 mS HI→30 mS ME→30 mS LO→30 mS OFF→50 mS MH→30 mS LO→60 mS 6%→1 sec OFF and repeats
Beacon: 3 sec OFF→60 mS MH→30 mS OFF→60 mS→MH→30 mS OFF→60 mS MH and repeats.

Source Code

The source code is easy to understand and modify, and can be summarized as follows:

- Definitions
- Port setup
- PWM setup (4.5KHz)
- Timer setup
- Read previous Group and Mode
- Turn on the LED using Group and Mode info
- Check for Mode and Group change
- Save Group and Mode

Setup, Configuration and Use

This section describes how to set up, configure, and operate this reference design. The LED Flashlight Driver Controller is shipped with the code preprogrammed and ready to use.

Flashlight LED Driver Controller Procedure for a P60 Pill

1. Solder the red and black wires to the LED while observing the correct polarity, as indicated in Figure 2.

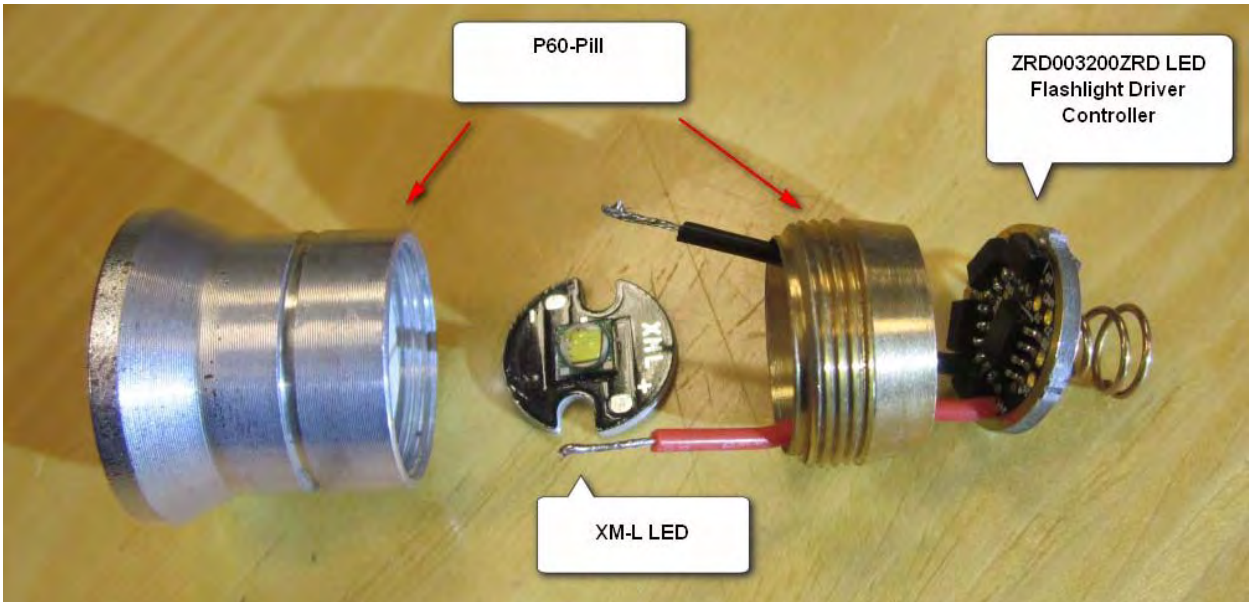

Figure 2. P60 Pill, LED, and LED Flashlight Driver Controller

2. Apply thermal grease between the LED sink pad and the P60 pill for better heat transfer.
3. Secure the LED Flashlight Driver Controller PCB to the P60 pill.
4. Assemble the Flashlight and insert a fully charged 3.7V–4.2V Lithium-ion battery. For optimal battery contact, Zilog recommends slightly crimping the upper end of the battery spring towards the middle, as indicated in Figure 3.

Figure 3. Spring, Top View

5. Turn the flashlight on and operate it as described in the Controller Groups and Modes section on page 3.

Note: This reference design is recommended for use on flashlights with a switch turn ON resistance of lower than 0.30Ω.

Viewing and Compiling the Source Code

To view and recompile the source code for this reference design, observe the following procedure:

1. If you have not already done so, download the software for this reference design. In a web browser, visit the Zilog website and navigate via the Applications menu to **Reference Designs → LED Controllers → LED Flashlight Driver Controller**. In the list of **Associated Documentation**, right-click to download the source code for the LED Flashlight Driver Controller; the code and all documentation are contained in a zip file labeled RD0032-SC01.
2. When the download is complete, unzip the file to your hard drive, double-click to launch the installation file named `ZRD00320100ZRD_1.0.exe`, and follow the on-screen instructions.
3. Navigate to the following directory to install ZDSII_Z8Encore! 5.2.0:

   `C:\Program Files (x86)\Zilog\ZRD00320100ZRD_1.0`

   Launch the `zds2_Z8Encore!_<version_build>.exe` file and follow the on-screen instructions.
4. An option to launch ZDSII is presented at the completion of the ZDSII installation prior to exiting; select this option to immediately run ZDSII. As an alternative, launch ZDSII by navigating via the following default path:

   Start → Programs → Zilog ZDS II_Z8Encore!_<version_number> → ZDSII_Z8Encore!<version_number>
5. From the **File** menu in ZDSII, select **Open Project** to display the Open dialog box.
6. Browse to the `src` folder which, by default, is located in the following path:

   `C:\Program Files (x86)\ZiLOG\ZRD00320100ZRD_1.0\src`
7. Select the `ZRD00320100ZRD_1.0.zdsproj` file from the `src` folder and click **Open** to display the initial ZDSII program screens. To view the source file, double-click the **Project Files** folder on the left side of the ZDSII interface. Double-click the `ZRD00320100ZRD_1.0` file to open the file in the ZDSII file editor.
8. Click the **Rebuild All** toolbar icon, which is highlighted in red, in Figure 4.

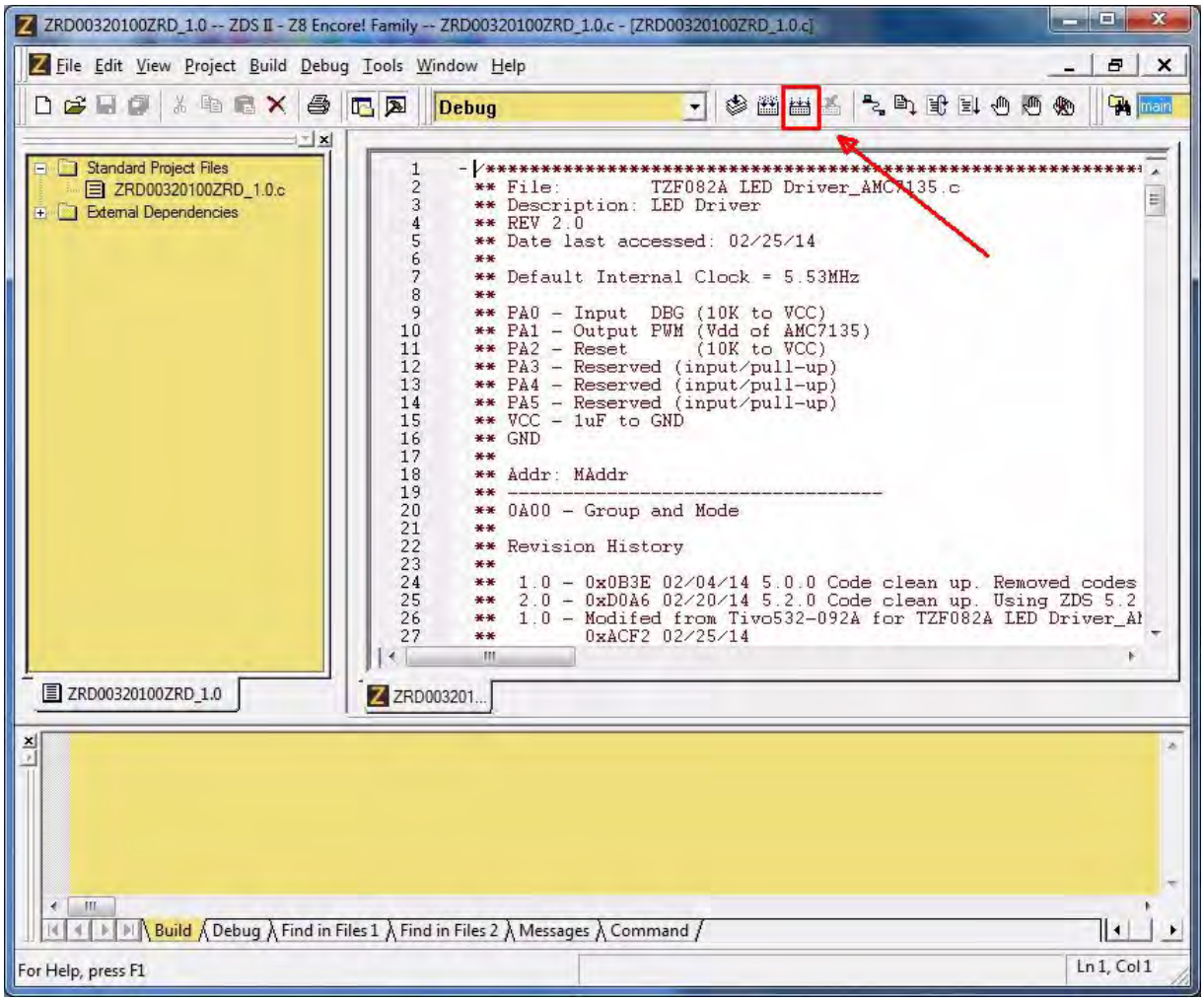

Figure 4. IDE Project Rebuild All

9. When the rebuild is complete, a `Build succeeded` message will appear in the Output window's Build tab, as highlighted in Figure 5.

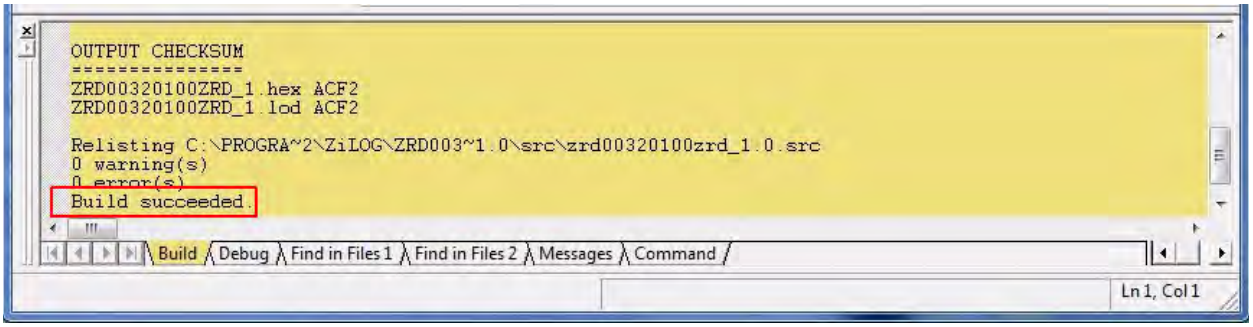

Figure 5. IDE Project Build Succeeded

Note: The output checksum in Figure 5 is for reference only and may not display the same result as at the time of publication.

Reprogramming the LED Flashlight Driver Controller Using a Batch File

This section presents the materials and procedures required to reprogram the LED Flashlight Driver Controller.

Required Materials

One USB SmartCable, Zilog part number ZUSBSC0100ZACG

Procedure

Observe the following procedure to reprogram the controller. The first three steps in this procedure only need to be performed once.

1. Perform the USB SmartCable Programming pin modification described in Appendix B. on page 15.
2. Install the USB SmartCable Driver as described in Appendix C. on page 18.
3. Perform the USB SmartCable serial number procedure described in Appendix D. on page 19.
4. Disconnect the 6-ckt cable from the USB SmartCable to ensure that the driver is not powered up when connecting the programming pins; see Figure 6.

Figure 6. USB SmartCable Module and 6-Circuit Cable

5. Connect the four programming pins to the LED driver, as shown in Figure 7.

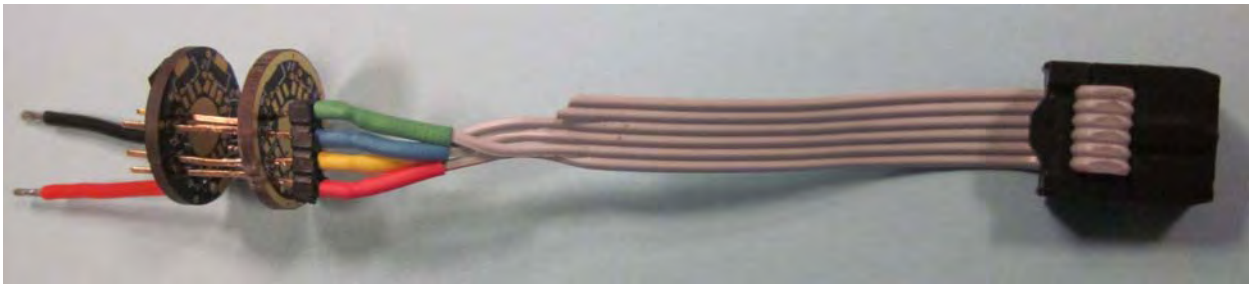

Figure 7. USB SmartCable and LED Flashlight Driver Controller

6. Navigate to the following directory:

   `C:\Program Files (x86)\Zilog\ZRD00320100ZRD_1.0\src`

7. Connect the 6-circuit cable to the USB SmartCable; see Figure 8.

Figure 8. Completed USB SmartCable Assembly

8. Hold the programming pins at enough of an angle to secure the contact to the driver.
9. Double-click the `ZRD00320100ZRD_1.0.bat` file to launch the ZDSII IDE and run a DOS batch file, which will program the MCU. When completed, this batch file will close ZDSII and all DOS windows.
10. Open and view the generated `ZRD00320100ZRD_1.0.log` file to ensure that you see a message similar to the following message.

```
================================================================================
option linker exeform = "OMF695,Intel32"
flash options "ZRD00320100ZRD.hex"
flash options EBF
flash burnverify
Connected to target TZF082A
Successfully initialized target.
Target connection closed
Internal flash erase complete.
File flashed with verification: ZRD00320100ZRD.hex
Flash File Checksum::0xACF2
Flashing complete.
wait 100
close project
```

Note: Different code will cause the Flash File Checksum result to appear different from the result shown above.

Programming the LED Flashlight Driver Controller with a New Code/Hex File

Observe the following procedure to program the controller with a new code/hex file.

1. Create a copy of your hex file and save the new file as `ZRD00320100ZRD.hex`.
2. Return to Step 4 of the previous section and follow the remainder of that procedure.

Programming the LED Flashlight LED Driver Controller Using ZDSII

Observe the following procedure to program the controller using Zilog Developer Studio (ZDSII).

1. Open the project. For assistance, see the Viewing and Compiling the Source Code section on page 6.
2. Assuming you have already performed the hardware and software installations in previous sections, program the LED Flash Driver Controller by clicking the **Download Code** toolbar icon ( ).
3. You may see a message similar to the message shown in Figure 9. Click the **OK** button to continue.

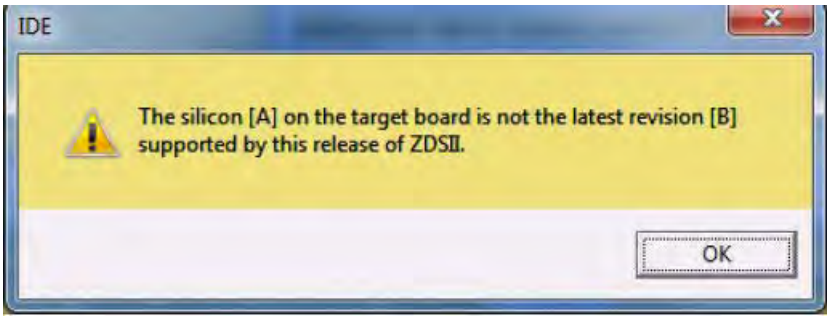

Figure 9. ZDSII Silicon Warning Message

4. A successful programming of the controller will present a message similar to the message shown in Figure 10.

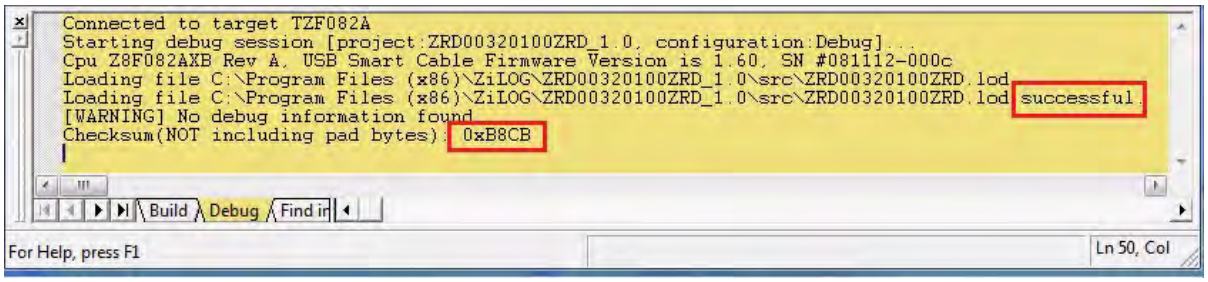

Figure 10. ZDSII Silicon Success Message

Software and Documentation

Upon installation, the software and documentation that support this reference design will be located in the following installation directories:

ZDSII – Z8Encore! 5.2.0

```
C:\Program Files (x86)\ZiLOG\ZDSII_Z8Encore!_5.2.0
```

ZRD00320100ZRD 1.0

```
C:\Program Files (x86)\ZiLOG\ZRD00320100ZRD_1.0
```

All documents associated with the LED Flashlight Driver Controller Reference Design are listed in Table 2. Each of these documents can be obtained from the Zilog website by clicking the link associated with its Document Number.

Table 2. LED Flashlight Driver Controller Documentation

Document Number	Description
RD0032	This LED Flashlight Driver Controller Reference Design document
PS0228	Z8 Encore! XP F082A Series Product Specification
UM0181	USB SmartCable User Manual

Ordering Information

The products associated with this LED Flashlight Driver Controller Reference Design can be ordered from the Zilog Store using the Part Numbers listed in Table 3.

Table 3. Ordering Information

Part Number	Description	Store Product ID
ZRD00320100ZRD	LED Flashlight Driver Controller Reference Design	RD10036
ZUSBSC0100ZACG	USB SmartCable	RD10023

Kit Contents

The LED Flashlight Driver Controller Reference Design contains the following item:

- One (1) LED Flashlight Driver Controller

Results

This LED Flashlight Controller/Driver reference design was designed and tested using an Ultrafire 502B Flashlight as discussed in this document and performed as expected.

Summary

This low-cost reference design demonstrates an LED Flashlight Controller/Driver consisting of a Z8F082A MCU and current regulators. The PWM provides the necessary signal to control the brightness of the LED, while the MCU's Flash memory stores the previous mode of operation.

This very simple design and can be used to control other LED applications.

Appendix A. Bill of Materials

Table 4 lists all parts that comprise the LED Flashlight Driver Controller Reference Design.

Table 4. ZRD00320100ZRD Parts List

Part	Quantity
PCB-99C1408-001G	1
Diode: 1N4148WS	1
Cap: 1µF	1
Resistor: 10KΩ	2
Spring	1
AMC7135	8
Z8F082A MCU	1

Appendix B. USB SmartCable/Programming Pin Modification

This appendix presents the materials and procedures required to modify the USB SmartCable for programming the LED Flashlight Driver Controller. The purpose of this modification is twofold: to modify V_{CC} for applying the appropriate power to the LED driver when programming, and to modify one end of the 6-circuit cable for LED driver programming.

Required Materials

- One Programming Cable, Zilog part number ZUSBSC000100ZACG;[1] see Figure 11.
- Soldering iron and solder

Figure 11. Programming Cable Shown with USB SmartCable Attached

Procedure

Observe the following procedure to modify the USB SmartCable.

1. Open the USB SmartCable casing by unscrewing the two Phillips screws.
2. Solder a connecting wire between the two points shown in Figure 12. In essence, connect the wire from the Blue connector to Pin #1, which is identified on the PCB by a small silkscreened square.

1. The Programming Cable is available from both Digikey and Mouser.

Figure 12. Solder Connections for Modifying the USB SmartCable

3. With Figure 13 as your guide, modify one end of the 6-circuit cable for LED driver programming, as follows:
   a. Cut one end of the cable near the connector (or in the middle to build two shorter versions).
   b. Solder the four wires to the following pins, as follows:
      - Pin #1: V_{CC} (starting from the red stripe end)
      - Pin #2: RST
      - Pin #3: GND
      - Pin #4: DBG

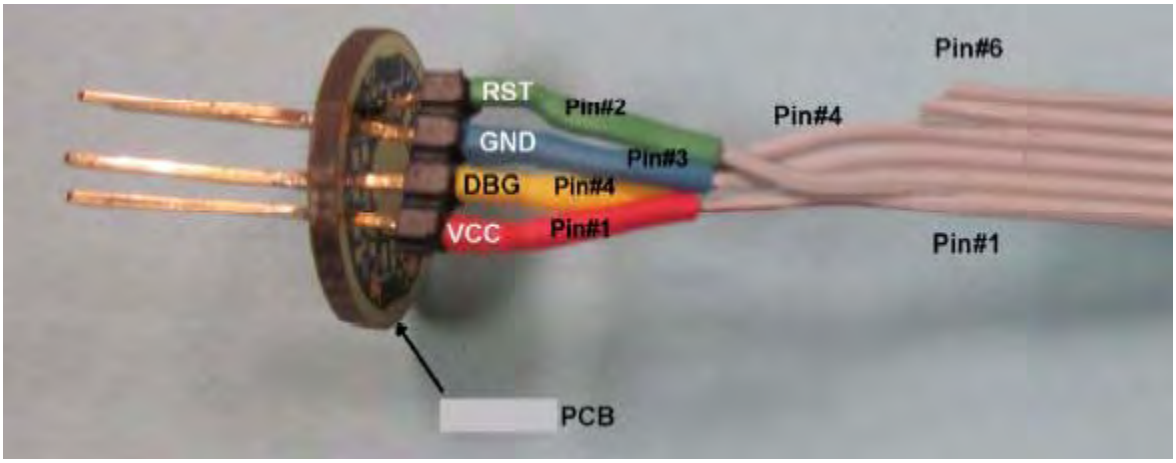

Figure 13. 6-Circuit Cable Modified for Programming

c. Trim to remove lines #5 and #6.

Note: The PCB is optional. It is the same PCB as the driver PCB, and is used to guide/align the pins during programming. To prevent accidental shorting, place a Kapton or insulating tape at the bottom (i.e., pin) side of the PCB when programming the driver.

4. Connect the other end of the 6-circuit ribbon cable to the USB SmartCable unit, ensuring that the ribbon's male connector is aligned correctly with the female connector on the unit.
5. Install the USB SmartCable driver – see Appendix C. Installing the USB SmartCable Driver on page 18.

Appendix C. Installing the USB SmartCable Driver

Observe the following procedure to install the USB SmartCable on a Windows 7 system.

1. Connect the USB SmartCable to a USB port on your development PC. When the PC detects the new hardware, it will display the Installing device driver software dialog.
2. Windows automatically searches for the driver; this process can take a few moments. Because there is no option to terminate this search process, wait for the search to complete. If the driver was previously installed, Windows will automatically install the USB SmartCable driver. If this is the case, skip ahead to Step 9. If Windows cannot find the driver, close the search dialog and proceed to the next step.
3. In the Search programs and files field in the Windows Start menu, enter Device Manager. The Device Manager will appear in a list of search results.
4. From this list of results, click Device Manager to open the Device Manager dialog, which presents a list of devices that operate on your PC. Find and toggle Other devices to view a sub list of additional devices, and right-click your mouse on USB SmartCable.
5. In the submenu that appears, click Update Driver Software....
6. In the Update Driver Software – USB SmartCable dialog that appears, click the Browse my computer for driver software option.
7. Click the Browse... button to browse to one of the following driver directories, depending on the configuration of your PC.

   On 32-bit Windows 7 systems, navigate to:

   ```
   <ZDS II Installation Directory>\device drivers\USB\x32
   <ZDS II Installation CD>\device drivers\USB\x32
   ```

   On 64-bit Windows 7 systems, navigate to:

   ```
   <ZDS II Installation Directory>\device drivers\USB\x64
   <ZDS II Installation CD>\device drivers\USB\x64
   ```

8. Click Next to install the driver. On 32-bit Windows systems, a security dialog will appear; select Install this driver software anyway.
9. After the Wizard finishes the installation, click Close.

Appendix D. USB SmartCable Serial Number

Observe the following procedure to determine the unique serial number that identifies your USB SmartCable.

1. Launch ZDSII - Z8 Encore! 5.2.0 via the Windows Start menu, and navigate to Zilog ZDSII > Z8 Encore! 5.2.0 > ZDSII – Z8Encore! 5.2.0.
2. From the File menu in ZDSII, choose Open Project and navigate the following path:

   `C:\Program Files (x86)\ZiLOG\ZRD00320100ZRD_1.0\src`

3. Select the `ZRD00320100ZRD_1.0.zdsproj` project file and click **Open**; see Figure 14.

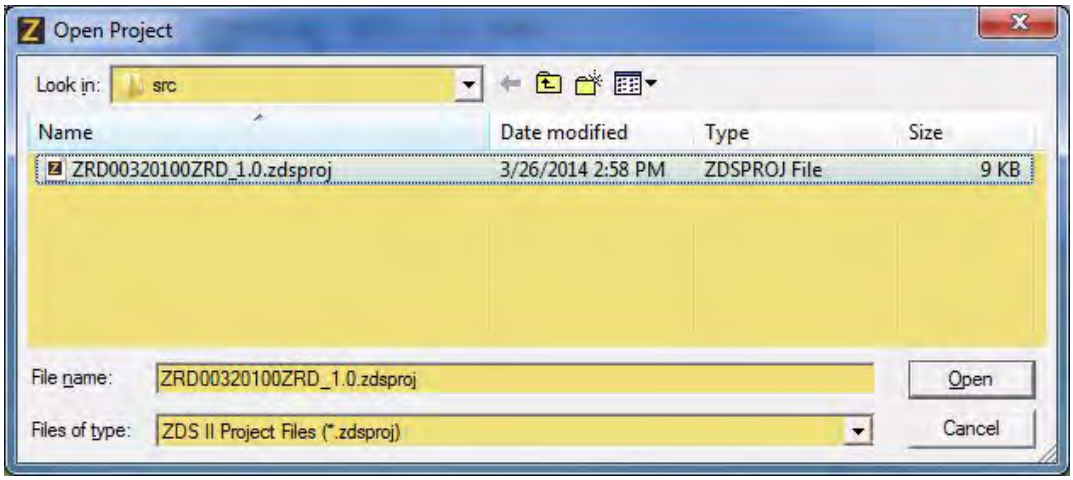

Figure 14. Select a Project File from the Open Project Dialog

4. From the **Project** menu in ZDSII, choose **Settings**. Click **Debugger** in the left panel and, in the **Debug Tool** panel, select **USBSmartCable** from the **Current:** menu, as shown in Figure 16.

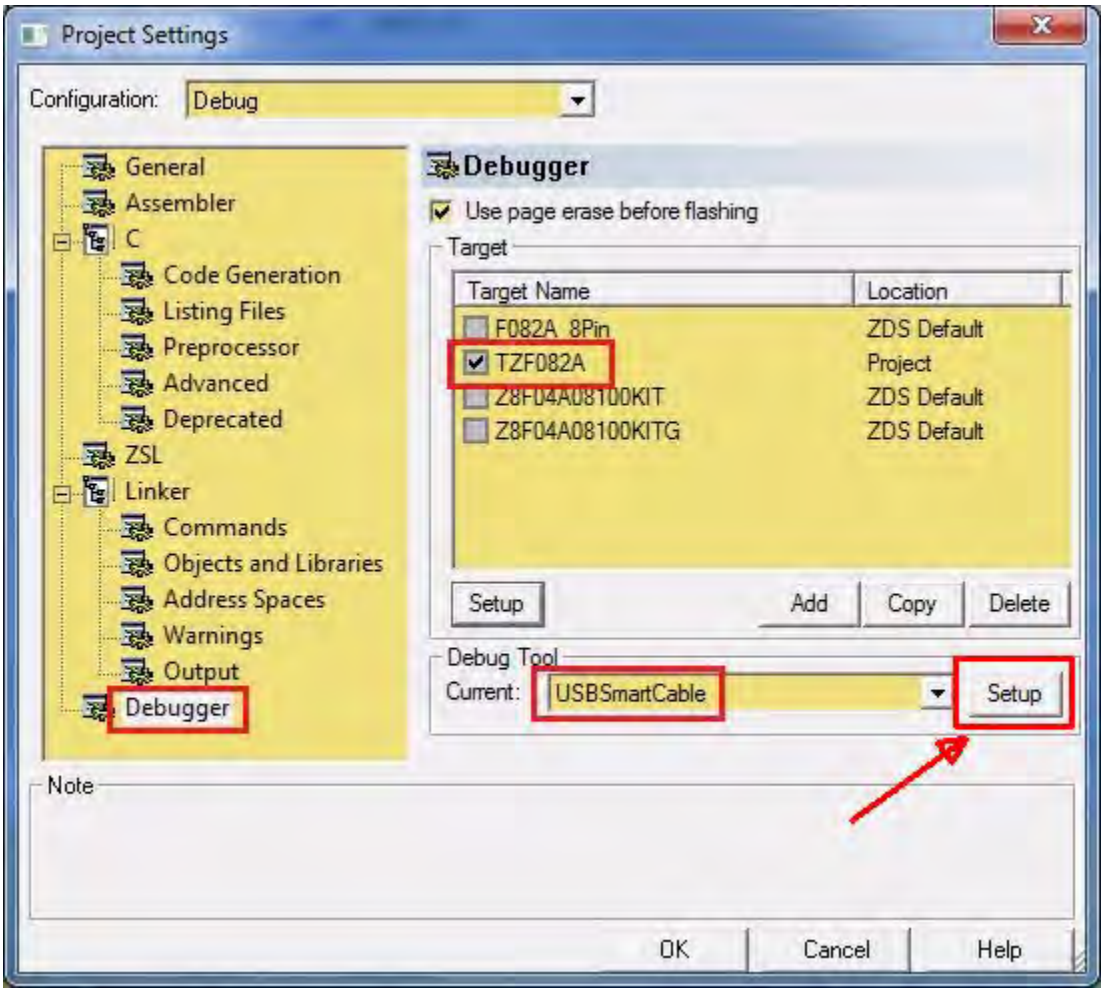

Figure 15. The ZDSII Project Settings Dialog

5. Click the **Setup** button in the Project Settings dialog. The Setup USB Communication window appears, as shown in Figure 16.

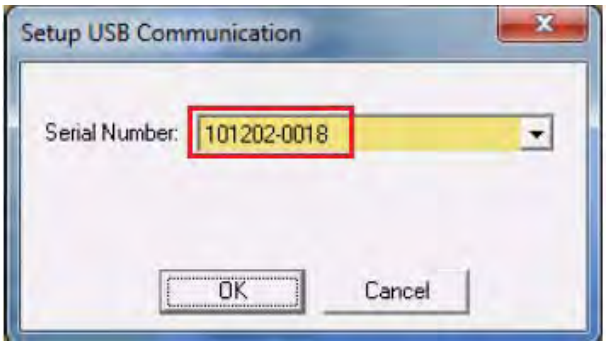

Figure 16. The Setup USB Communication Dialog

6. The serial number assigned to your USB SmartCable unit will be different than the serial number shown in Figure 16. Write this serial number down; you will need it in Step 11. Click **OK**.
7. Click **OK** a second time to exit the Project Settings dialog box.
8. From the File menu in ZDSII, choose **Exit** to close the program.
9. Launch Notepad or similar text editor, then navigate via the following path to open the `ZRD00320100ZRD_1.0.txt` file:

   ```
   C:\Program Files (x86)\ZiLOG\ZRD00320100ZRD_1.0\src\
   ZRD00320100ZRD_1.0.txt
   ```

10. Locate the following line in the `ZRD00320100ZRD_1.0.txt` file:

    ```
    debugtool set "usbSerialNumber" "000000"
    ```

11. Replace the null serial number, `000000`, with the serial number you wrote down in Step 6; for example:

    ```
    debugtool set "usbSerialNumber" "101202-0018"
    ```

12. Save the file.

Appendix E. Schematic Diagram

Figure 17 displays a schematic diagram of the LED Flashlight Driver Controller.

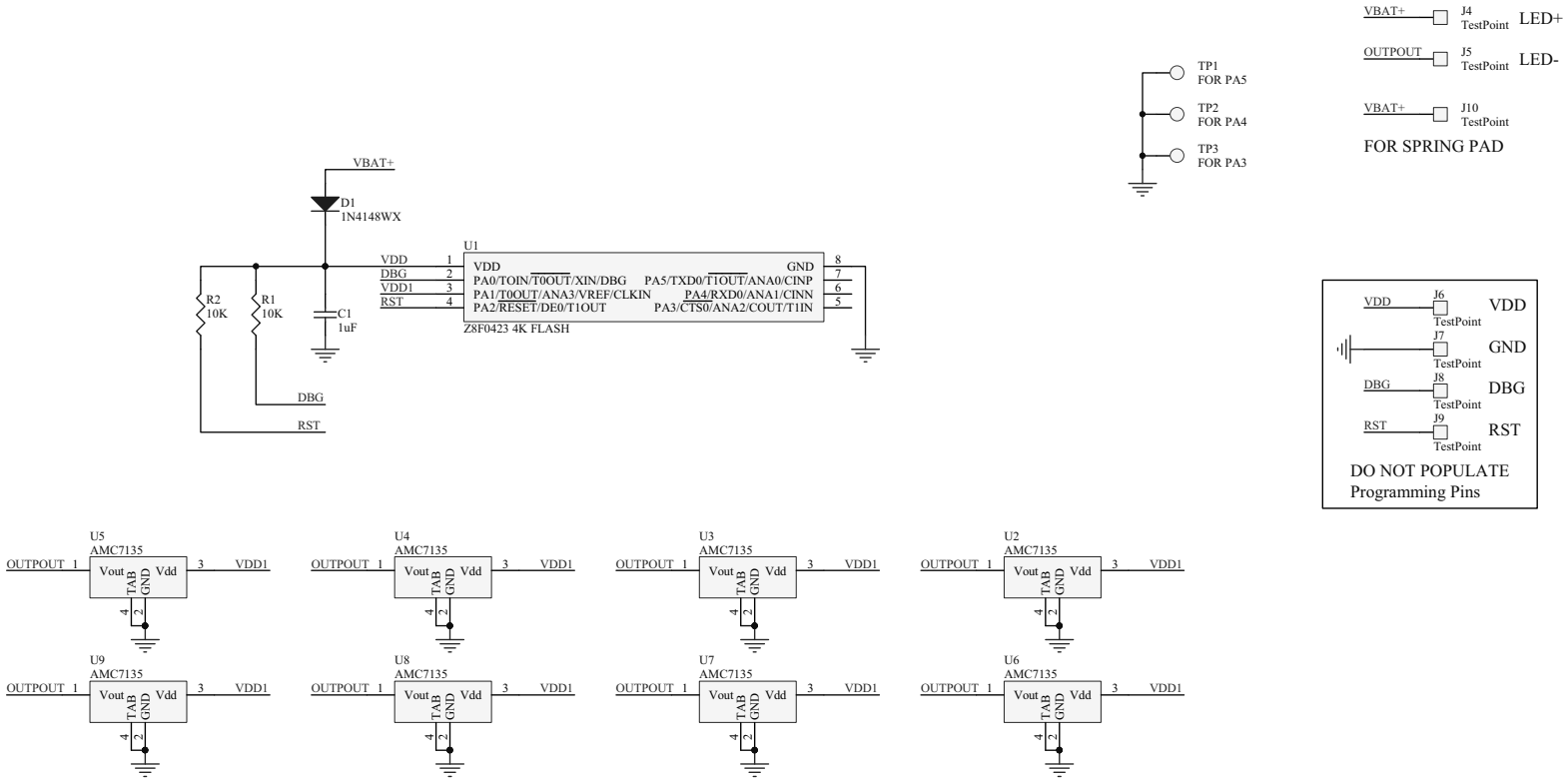

Figure 17. Schematic Diagram of the LED Flash Driver Controller

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