Application Note

High Brightness LED Reference Design

AN030901-0810

Abstract

This application note demonstrates a reference design for driving High Brightness LED (HBLED) with Z8 Encore! XP® F1680 Series MCU (Z8F2480AN020SG) and IXYS MXHV9910 Off-line HBLED driver. This reference design features dimming control using buck converter topology to control light intensity. ZMOTION™ technology is used to control lighting through motion sensing. Ambient light and photovoltaic sensors are provided to manage the HBLED light intensity or can be used to switching On/Off based on environmental lighting conditions.

> ➢ *Note1: The source code (AN0309-SC01.zip) associated with this application note has been tested with ZDS II – version 4.11.0, and is available for download from www.zilog.com.*

Overview

This HBLED reference design consists of Z8 Encore! XP® F1680 Series MCU (Z8F2480AN020SG), IXYS MXHV9910 Off-line HBLED driver, Nichia HBLED (NS9W153MT), ZMOTION™, photovoltaic, switches, and ambient light sensor.

HBLED is a new lighting system technology. HBLED is energy efficient, eco-friendly, low power, and last longer than the average compact fluorescent and incandescent bulbs.

Zilog's Z8 Encore! XP® F1680 Series MCU family is based on Zilog's advanced 8-bit eZ8 CPU core. This microcontroller is optimized for low-power applications and supports 1.8 V to 3.6 V wide low-voltage operations with extremely Low ACTIVE, HALT, and STOP mode currents. It is an assortment of speed and low-power options. In addition, the feature-rich analog and digital peripherals of the Z8 Encore! XP® F1680 Series makes it suitable for a variety of applications including safety and security, utility metering, digital power supervisory, handheld electronic devices, and general motor control.

Zilog's ZMOTION™ provides an integrated and flexible solution for Passive Infra Red (PIR) based motion detection applications. It includes a high-performance microcontroller with integrated motion detection algorithms and a lens and PIR sensors. It has motion detection algorithms which comprise the ePIR Engine and run in the background while control and status of the Engine is accessed through a software API (Application Programmer Interface). This allows the designer to create application specific software while taking advantage of Zilog's ePIR Motion Detection Technology. The ePIR Motion Detection Technology provides a dramatic improvement in both sensitivity and stability over traditional designs and is scalable to many market segments including Lighting Control, HVAC, Access Control, Vending, Display, Proximity, Power Management, Occupancy Sensing and many others.

The ambient light sensor is a silicon NPN epitaxial planar phototransistor which is sensitive to visible light. It can be used to control HBLED intensity or act as a switch depending on ambient lighting condition.

Monolithic photovoltaic cells are capable of generating a floating voltage and current source to provide trickle charge for battery applications. In this application note, it is used to control the HBLED brightness or act as a switch based on the amount of received light.

Circuit Description

The Z8F2480 MCU acts as the main controller for this reference design. The block diagram on Figure 1 illustrates how ZMOTION^{TM}, ambient light sensor, switches, LEDs, photovoltaic, and HBLED driver are interface to Z8F2480 MCU. This MCU uses different peripherals to handle the devices connected to it. UART1 is used to receive information from ZMOTION^{TM}. Two (2) analog inputs are used to monitor light intensity of its environment through ambient light sensor (ANA2) and photovoltaic (ANA1). Four (4) GPIOs are used for switches, SW1 and SW2, (connected to PE0 and PE6) and 2 light emitting diodes, LED1 and LED2 (connected to PB5 and PB0). Two timers are used: Timer0 on continuous mode to monitor the desired time to turn off the HBLEDs after the last motion detected; and Timer1 on PWM mode with output on /T1OUT to control HBLED brightness through MXHV9910 HBLED driver.
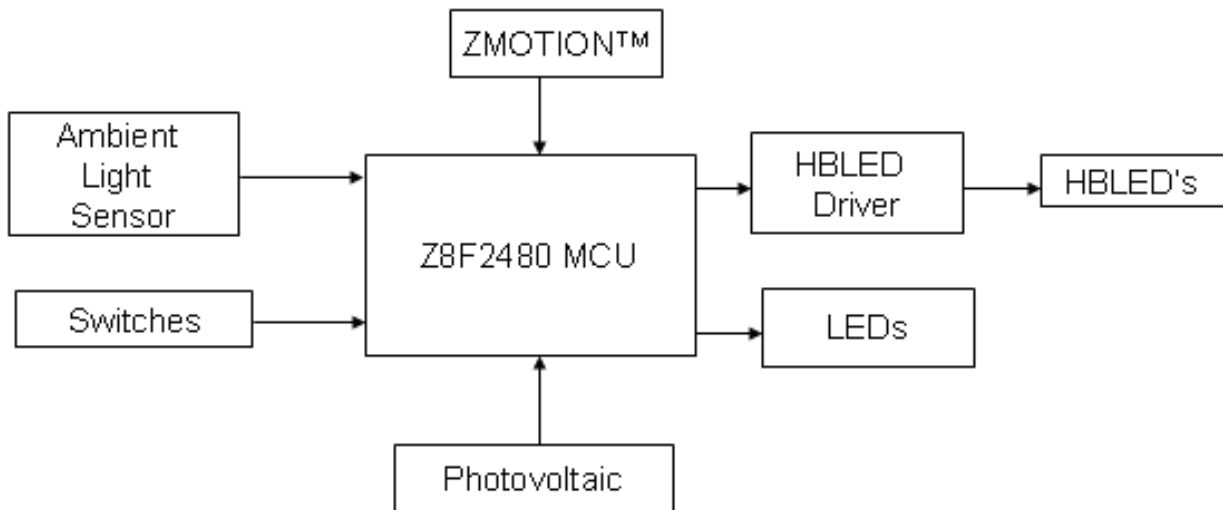

Figure 1: HBLED Driver Block Diagram

The ZMOTION™ (using SERIAL INTERFACE MODE) continuously check for motion to turn the HBLED ON/OFF.

The ambient light sensor (U5), on Figure 2, monitors the environmental lighting conditions. The voltage drop is inversely proportional to light intensity. Low light entering the sensor will result to a higher voltage drop. The voltage drop across the sensor is around 1.2 volts under normal office fluorescent lighting condition. Once light is blocked from entering the sensor, the voltage drop will increased to 2.0V – 2.2V. The voltage drops have corresponding ADC values collected by ANA2. A higher voltage drop will cause the HBLED to increase its light intensity, while a lower voltage drop will decrease the HBLED light intensity. Thus as more light is blocked to the sensor then the HBLED will increase its light intensity even more.
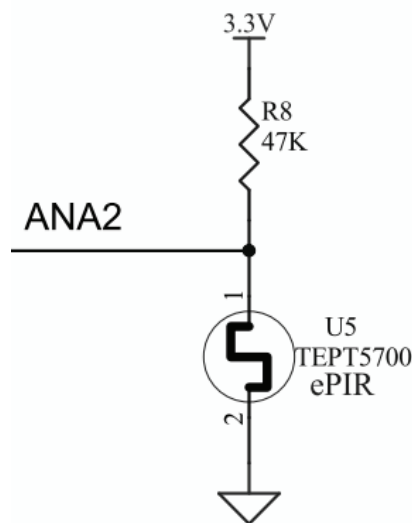

Figure 2: Ambient Light Sensor

The photovoltaic sensor (U2), in Figure 3, also monitors the light intensity of its environment. It generates voltage if there is a presence of light. A higher voltage is generated when more light enters the photovoltaic sensor. The resulting generated voltage value is small and requires an amplifier to make it easier for the MCU to determine changes on the light intensity. A non-inverting amplifier LM358 with a gain of 5.1 is used to amplify this generated voltage.

The gain is computed using the formula for non-inverting operational amplifier which is:

$$Vgain = \frac{Vout}{Vin} = 1 + \frac{R2}{R1}$$

Where R2 = 51 kΩ and R1 = 10 kΩ.

Voltage input (Vin) is from the output voltage of the photovoltaic (PVout) with formula:

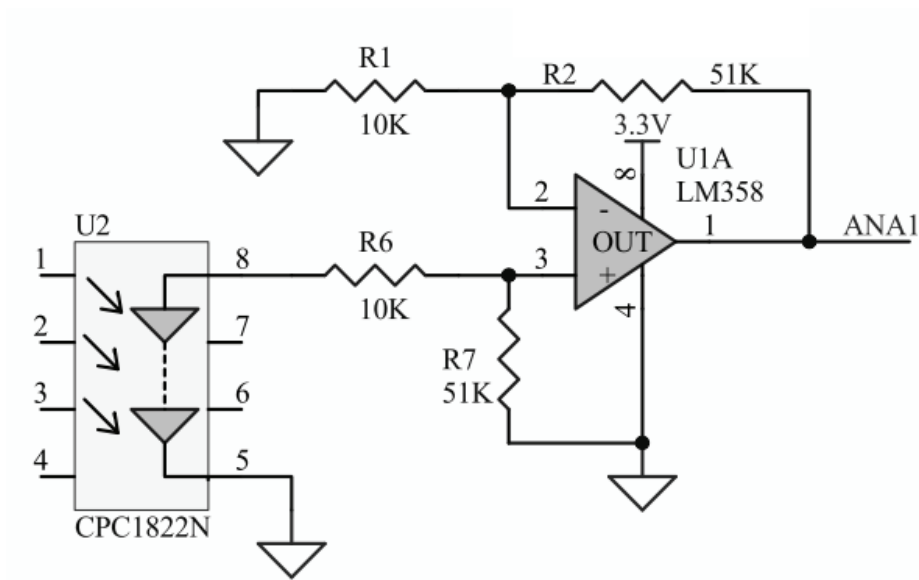$$Vin = PVout * \frac{R7}{R7 + R6}$$

Where R6 = 10 kΩ and R7 = 51 kΩ

Figure 3: Photovoltaic

Part of the buck converter topology HBLED driver, in Figure 4, is IXYS MXHV9910BE (U7). This HBLED driver can be used to control HBLED's brightness either through LD input or PWMD input. On this application note, PWMD input is used to implement HBLED's brightness control.

The HBLED driver pin 1 is the input voltage (VIN) that can handle values from 8V to 400V (VHIGH). Pin 6 is the VDD supply voltage which is set to 3.3V and pin 3 is the ground (GND).

Caution: *High voltage present on the board*

Current Sense:

Pin 2 is the current sense (CS) input. The current sense resistor (RSENS) connected to this input is selected based on the maximum desired LED current. The typical current sense threshold voltage is 250mV. Assuming 30% ripple (r = 0.3), RSENS is computed using this formula:

$$RSENS = \frac{250mV}{(1 + (0.5 * r)) * ILED\max}$$

Where ILEDmax = 350mA

The RSENS power rating should be at least twice of the calculated power dissipation across the RSENS:

$$RSENSPowerRating = 2 * PowerDissipation$$

Where $RSENSPowerDissipation = ILED\max^2 * RSENS$

NOTE: HBLED Power Dissipation (P_D) = 4.6 W

Gate:

Pin 4 is the GATE output of the HBLED driver. It is connected to the GATE of the power MOSFET (Q1) that drives the HBLEDs. In series to the HBLED's is the inductor (L1). Diode (D1) is connected in parallel to this series connection of HBLED and inductor.

The function of the MOSFET is to turn on and off the HBLED's. When the MOSFET is on, the current flows through HBLEDs and the inductor. On this state, the HBLEDs are on and the diode is reverse biased. When the MOSFET is off, the voltage across the inductor reverses and the diode is forward biased providing path to the current for the HBLED to keep them on. The diode is forward biased as long as there is energy stored in the inductor.

When there is no motion, MCU will send logic 0 to PWMD, instead of PWM signal, and keeps the MOSFET off. This condition will deplete the energy on the inductor thus turning off the HBLED's.

For safety reasons, MOSFET and diode voltage rating should be 50% more than VHIGH. The MOSFET and diode used can handle up to 500V and 400V, respectively. These ratings are more than enough to handle VHIGH of 160V.

For MOSFET current rating, it should be 3 times the maximum RMS current. With maximum duty cycle of 50%:

$$I_{MOSFET\_RMS}\_rating = 3 * I_{MOSFET\_RMS}$$

Where $I_{MOSFET\_RMS} = \sqrt{0.5} * ILED\max$

For the diode current rating, it should be 3 times of the one-half ILEDmax.

The inductor value is determined based on the LED ripple current and switching frequency (selected using ROSC). Assuming 30% ripple (r=0.3):

$$L = \frac{(VHIGH_{\min} - VLED) * t_{on\_\max}}{r * ILED \max}$$

Where:

$$VHIGH_{\min} = \sqrt{2} * Vac\_\min$$

$$D \max = \frac{VLED}{VHIGH \min}$$

$$t_{on\_\max} = \frac{D \max}{Fs}$$

Pulse Width Modulation Dimming Control (PWMD):

Pin 5 is the PWM dimming control input. It receives PWM signal from the MCU to control the HBLED's light intensity. The PWM signal from the MCU for this reference design is fixed at 500 Hz with a default duty cycle of 0.1 %. The 500Hz signal frequency is the nominal PWMD input frequency of IXYS MXHV9910BE. To avoid sub-harmonic oscillations, it is recommended to limit the duty cycle up to 50%.

To compute the PWM period (in seconds) of Z8F2480 MCU:

$$PWM\_Period\_(s) = \frac{\text{Re}loadValue * \text{Pr}escale}{TimerClockFrequency}$$

And the PWM output High time to the total period when TPOL = 0:

$$PWM\_Output\_High\_Time\_Ratio = \frac{\text{Re}loadValue - PWMValue}{\text{Re}loadValue} * 100$$

Linear Dimming (LD):

Pin 7 is the linear dimming input. By changing input voltage to this pin, the user can adjust the current level in the HBLEDs, to increase or decrease the light intensity. When not in used it is recommended to connect this pin to VDD. Since PWM dimming control is used on this application note, this pin is connected to VDD as illustrated on Figure 5.

ROSC:

Pin 8 is the RT or ROSC terminal. It has the external resistor that sets the HBLED driver oscillator or switching frequency (Fs). Typical frequencies should be ranging from 20kHz to 150kHz. Based on the datasheet, an ROSC of 220kΩ provides around 100kHz.
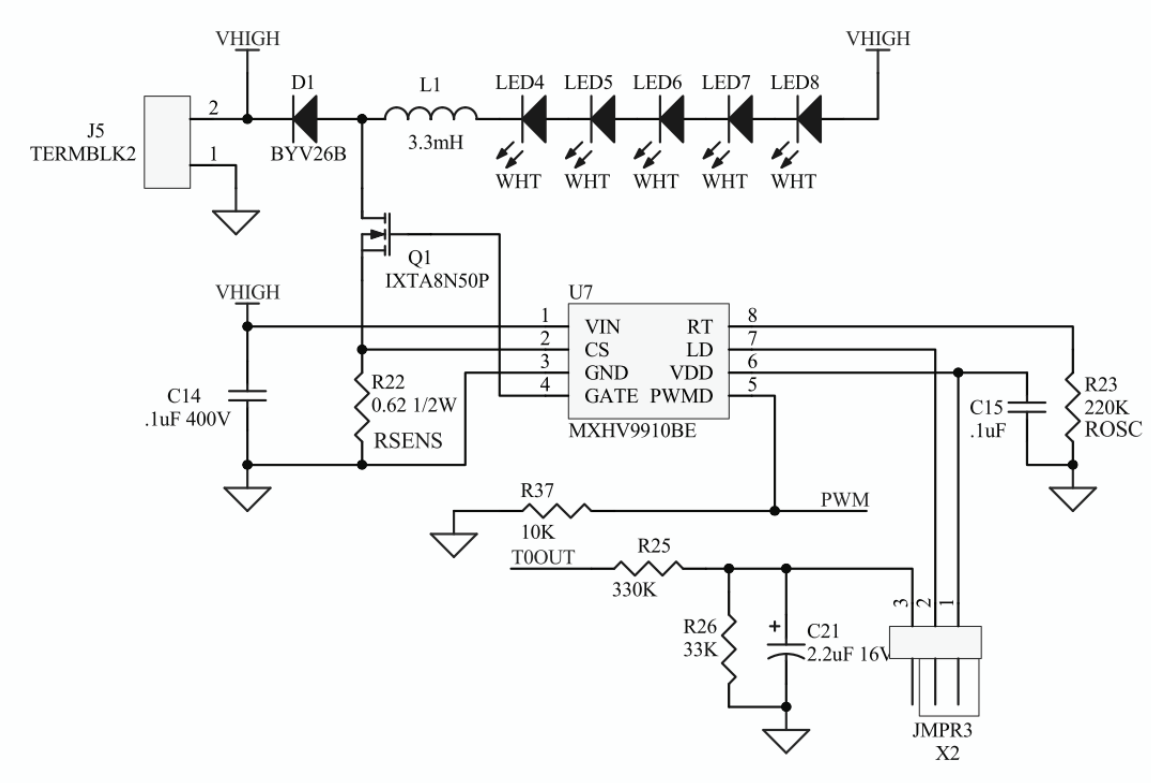

Figure 4: HBLED Driver Circuit

Code Flow Description

Flowchart (refer to Appendix) illustrates the flow of the code used in this application note. Initialization of the peripherals such as Timers, UART, ADC and GPIO is done at the start of the main flow. The last part of the Initializations stage is to set the PWM variables and run the HBLED's on default (500Hz at 0.1% duty cycle).

The Z8F2480 MCU main routine is to continuously check for motion through the ZMOTION^{TM}. The ZMOTION^{TM} (using SERIAL INTERFACE MODE) sends 'M', for with motion detected. If there is no motion detected, ZMOTION^{TM} will not send anything to the MCU.

The MCU turns ON the HBLEDs when motion is detected. The `tickMotion` timer is then reset, and switches and sensors will be checked.

`tickMotion` timer is running on background and it is set to 5 seconds. The `tickMotion` timer is always running and will only reset if there is motion detected. This timer is updated through Timer0.

If no motion detected and `tickMotion` timer is expired, HBLED's will turn OFF and `tickMotion` timer will be reset. The MCU will then check if there is motion detected. If no motion is detected and `tickMotion` timer is not yet expired, the MCU just continue checking for motion detected.

SWITCHES CODE FLOW:

In the switches code routine, switch SW1 and SW2 are checked for their conditions. If switch SW1 is pressed, logic 0 is sent to the MCU, turning ON the Red LED. The HBLEDs intensity will increase by adding 0.1% to the current duty cycle of its PWM signal. Then Red LED will turn OFF before checking switch SW2. Switch SW2 condition will be checked if switch SW1 is not pressed.

If switch SW2 is pressed, logic 0 is sent to the MCU, turning ON the Green LED. The HBLED's intensity will decrease by subtracting 0.1% to the current duty cycle of its PWM signal. Then Green LED will turn OFF before leaving the routine.

If no switches are pressed, the MCU will just leave this routine and go back to the main routine.

SENSORS CODE FLOW:

For the sensors code routine, the ADC channels are assigned to both photovoltaic and ambient light sensors. ADC values are respectively stored for both sensors. These values are compared against set values. By comparing these values, it can be determined whether the light entering on either or both the photovoltaic or ambient light sensor is blocked or not. If the light is not blocked, the current duty cycle of the PWM signal is used for the HBLED's. If the light on either or both of the photovoltaic or ambient light sensor is blocked, the HBLED's intensity will be increased by adding 15% duty cycle on its PWM signal.

Under normal office fluorescent lighting conditions, the ambient light sensor has an ADC values range of 200-700. When light is blocked, its ADC values range is 800-1023. The photovoltaic ADC values range is 6-10 under fluorescent light. When light is blocked, the ADC value is usually below 3.

Testing

This section discusses the setup and procedure to test the High Brightness LED Application.

SETUP:

To test the High Brightness LED board, JMPR1 and JMPR3 should be on the position illustrated in Figure 5. JMPR1 on that position disabled MAX3222 and allow communication between ZMOTION™ and Z8F2480 through UART1. JMPR 3 is set to that position to use PWMD input of IXYS MXHV9910BE to control HBLED brightness.
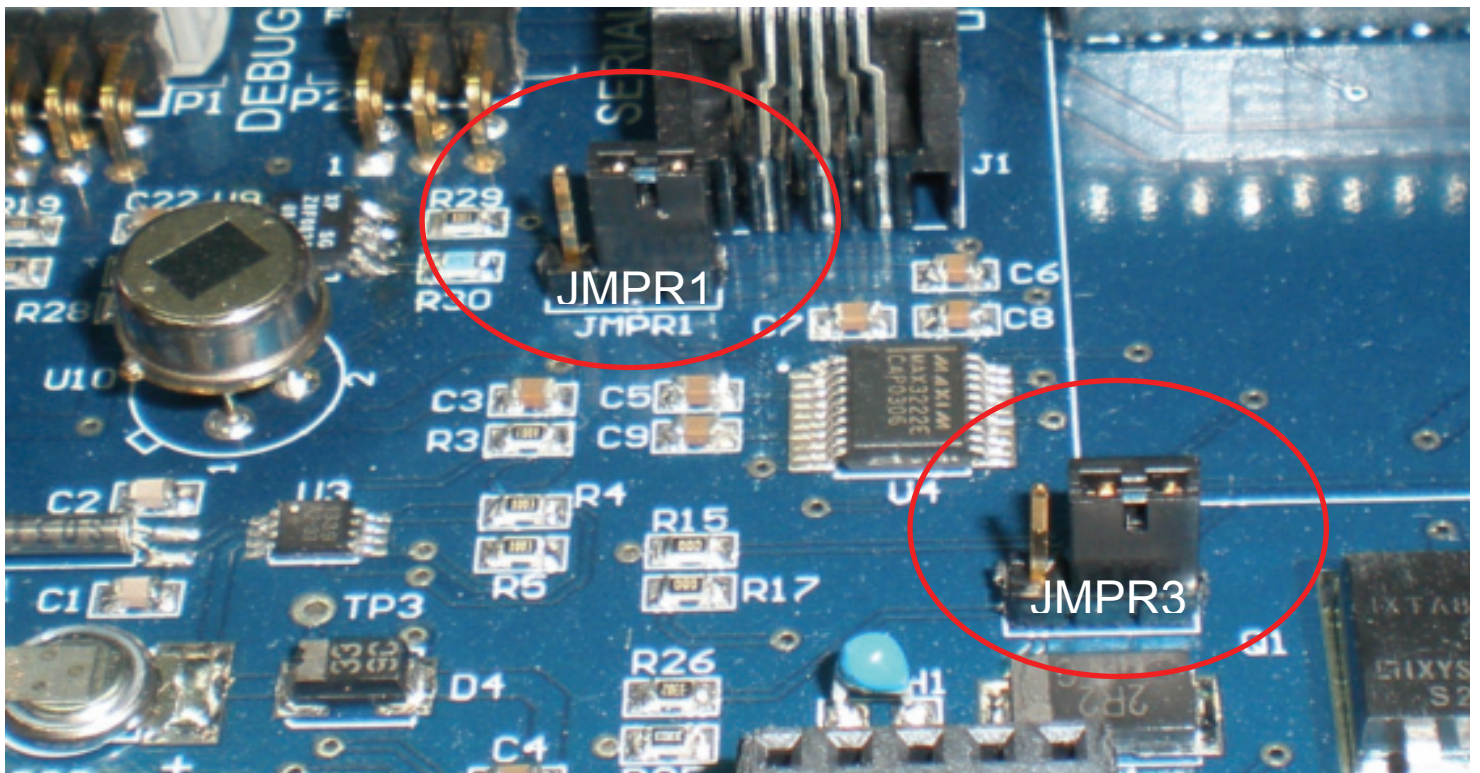

Figure 5. HBLED Board JMPR1 and JMPR3 Setup

PROCEDURE:

To test the High Brightness LED Application, perform the following steps (refer to Figure 6 for illustration):

1. Download the codes for ZMOTION™ and Z8F2480 from www.zilog.com. Extract their contents to a folder on PC.

2. Power up the board by supplying 110 or 220V AC signal.

3. Position switch SW4 to ON state.

4. Launch ZDSII 4.11 for Z8 Encore XP!

5. Connect OPTO-ISOLATED USB SMART CABLE to F04 DBG terminal P2.

6. Download the code for ZMOTION™.

7. Close the project.

8. Remove OPTO-ISOLATED USB SMARTCABLE from P2 and connect to F24 DBG terminal P1.

9. Download the code for Z8F2480.

10. Position switch SW4 to OFF state.

11. Remove OPTO-ISOLATED USB SMARTCABLE from F24 DBG terminal P1.

12. Position switch SW4 to ON state.

13. Observe the HBLED's.

RESULTS:

Since the default duty cycle of the PWM signal to PWMD input of IXYS MXHV9910BE is 0.1%, the HBLED's light intensity is low. By pressing SW1, HBLED's intensity will increase. Also, HBLED's intensity will further increase by blocking the light entering the sensors. Without motion for 5 seconds, HBLED's will turn OFF.
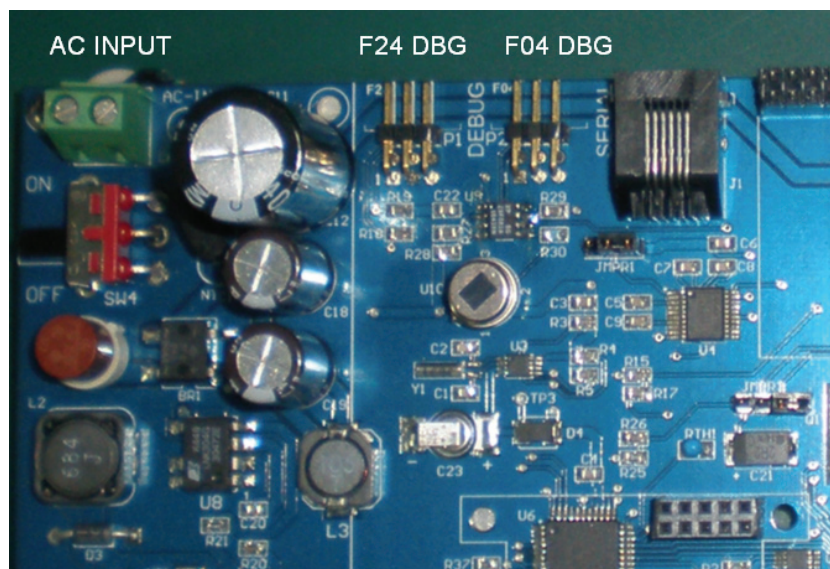

Figure 6. HBLED Board Power and Debug Terminals

Summary

This reference design showcases difference ways of controlling the light intensity of HBLED. The application of this reference can be extended to power management through the use of sensors and switches. Security concern application is enabled with the use of ZMOTION™ technology for motion detection.
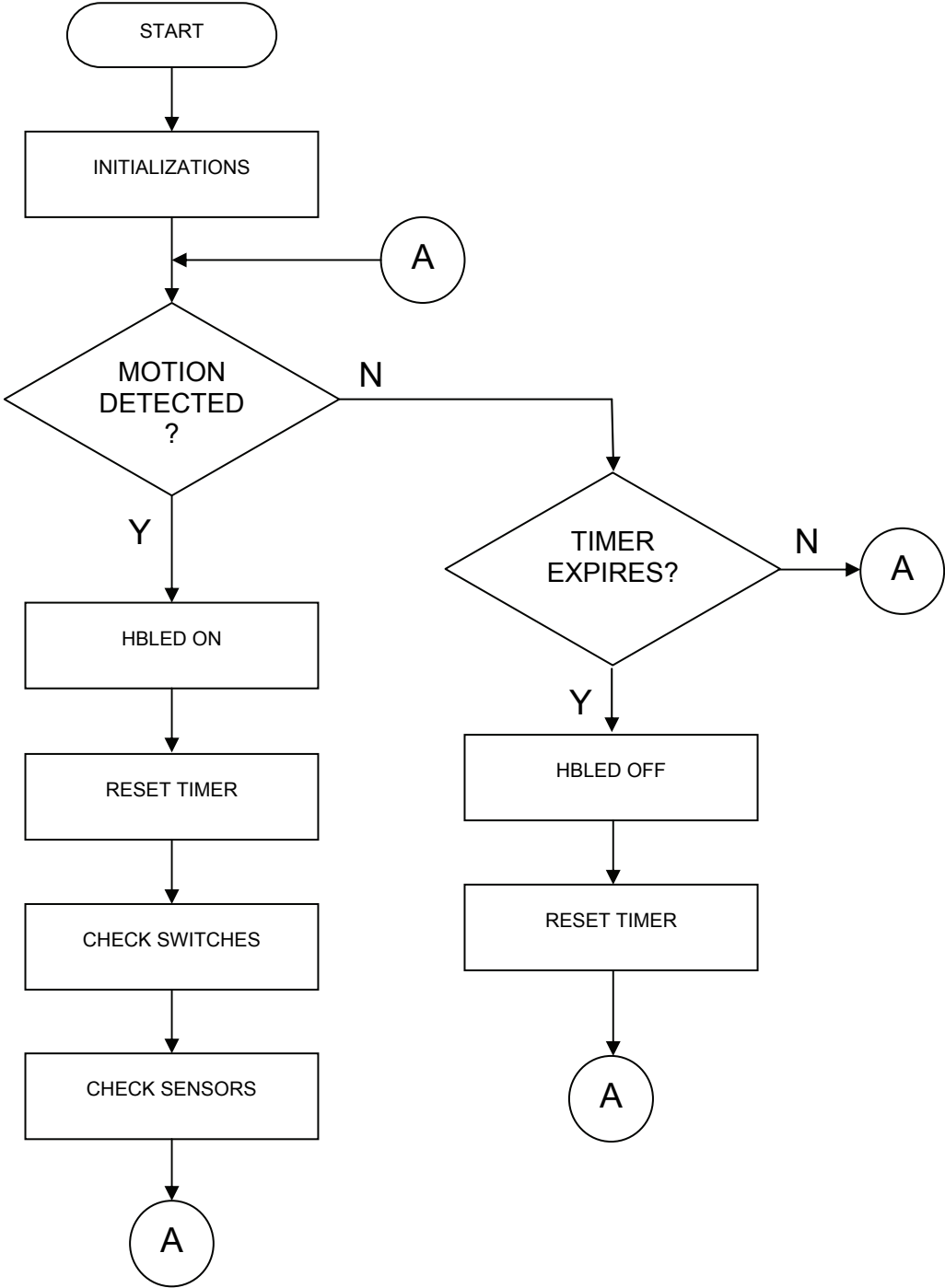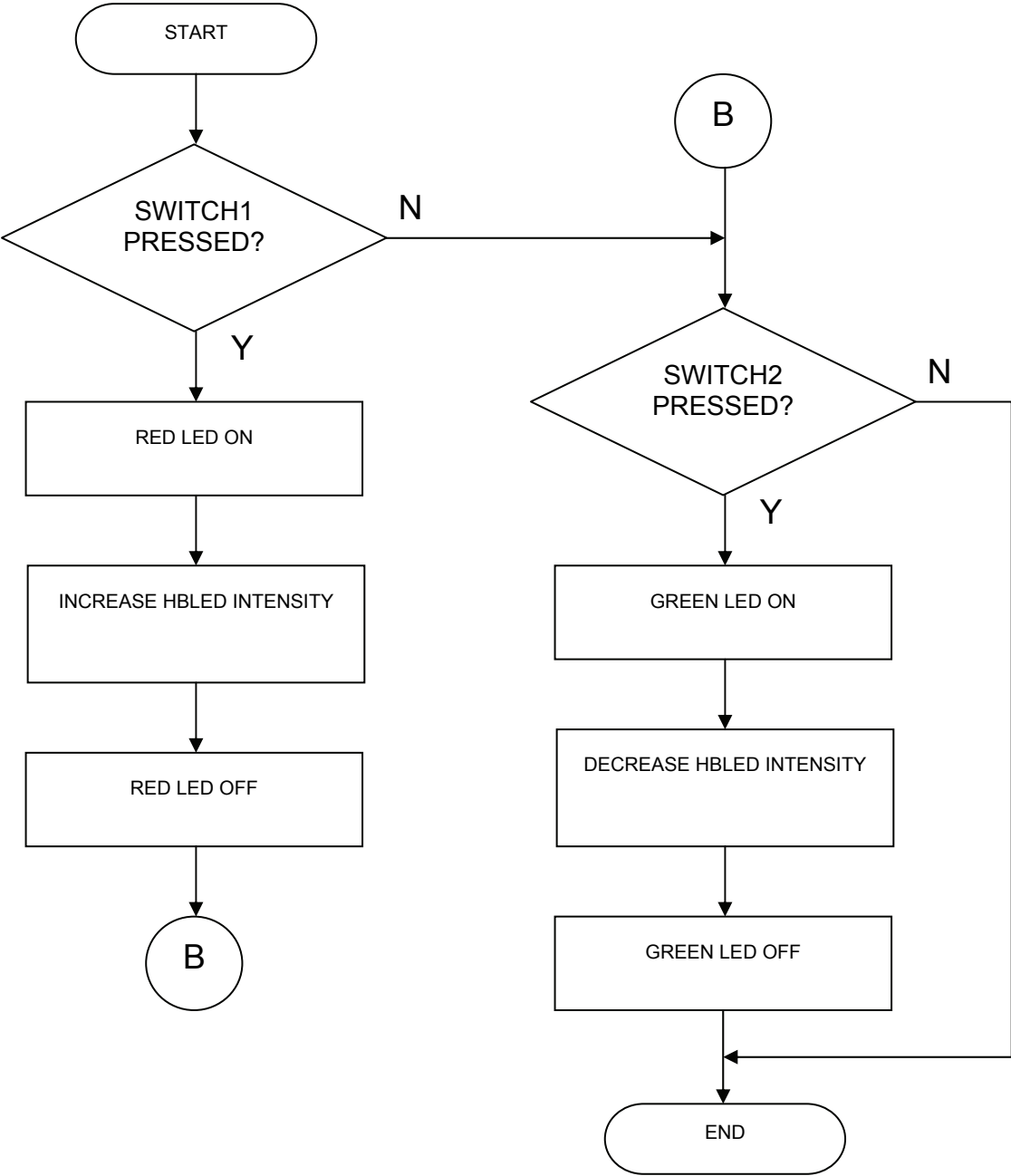
Appendix

```
          ┌─────────────┐
          │    START    │
          └─────────────┘
                 │
                 ▼
        ┌─────────────────┐
        │ INITIALIZATIONS │
        └─────────────────┘
                 │        ◄──────────── (A)
                 ▼
             ╱ MOTION ╲          N
            ╱ DETECTED ╲──────────────────────┐
            ╲    ?     ╱                       │
             ╲       ╱                         ▼
                │ Y                      ╱  TIMER  ╲    N
                ▼                       ╱  EXPIRES? ╲──────► (A)
        ┌─────────────┐                 ╲         ╱
        │  HBLED ON   │                    │ Y
        └─────────────┘                    ▼
                │                   ┌─────────────┐
                ▼                   │  HBLED OFF  │
        ┌─────────────┐            └─────────────┘
        │ RESET TIMER │                   │
        └─────────────┘                   ▼
                │                  ┌─────────────┐
                ▼                  │ RESET TIMER │
        ┌──────────────┐          └─────────────┘
        │CHECK SWITCHES│                  │
        └──────────────┘                  ▼
                │                        (A)
                ▼
        ┌──────────────┐
        │CHECK SENSORS │
        └──────────────┘
                │
                ▼
               (A)
```

Figure 7: Main Code Routine

Figure 8: Switch Code Routine

```
                          ┌─────────────┐
                          │    START    │
                          └──────┬──────┘
                                 │
                                 ▼
                    ┌──────────────────────┐
                    │ GET PHOTOVOLTAIC ADC  │
                    │        VALUE          │
                    └──────────┬───────────┘
                               │
                               ▼
                    ┌──────────────────────┐
                    │ GET AMBIENT LIGHT     │
                    │ SENSOR ADC VALUE      │
                    └──────────┬───────────┘
```
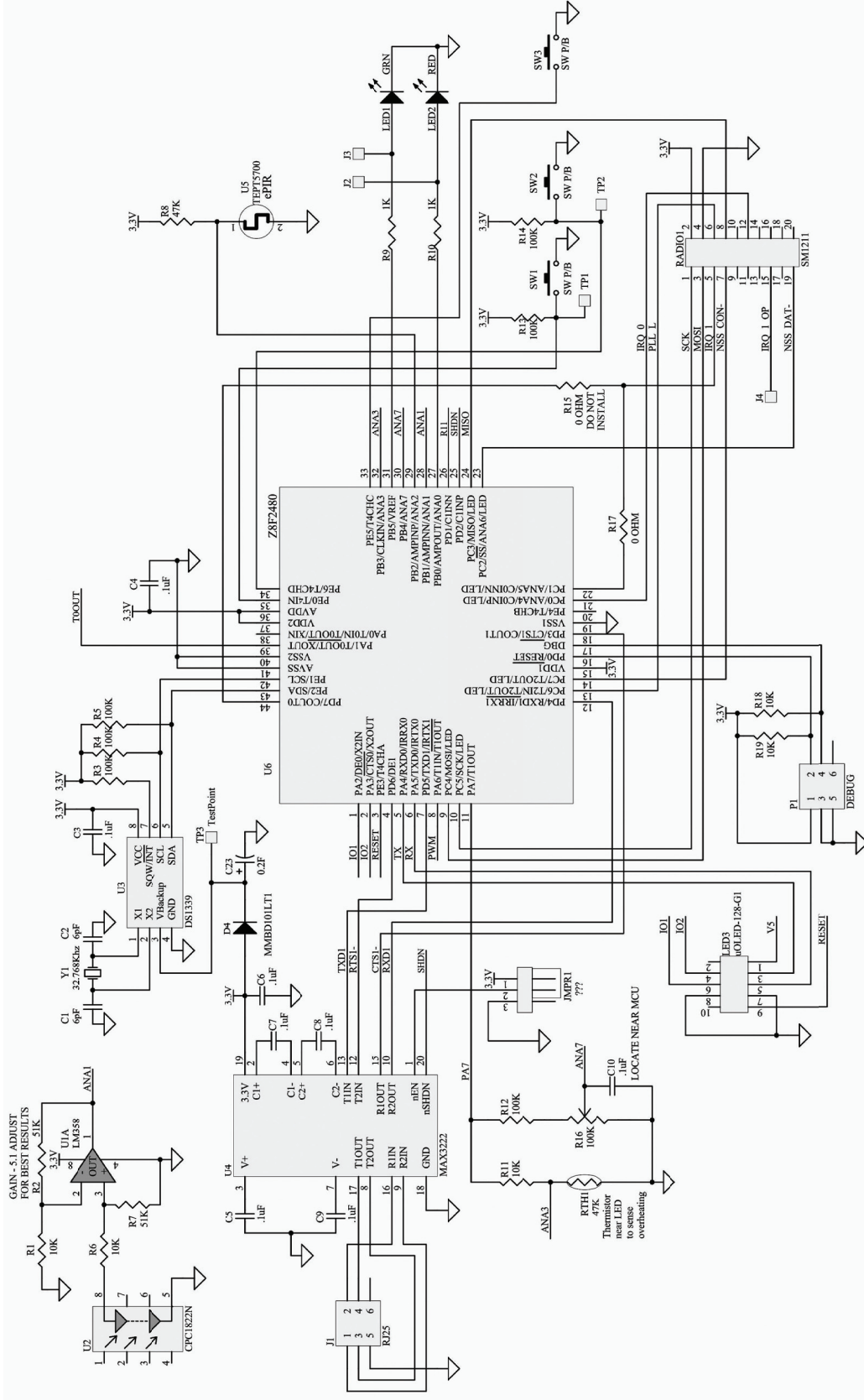
LIGHT ENTERING THE SENSORS BLOCKED?

N

Y

INCREASE HBLED INTENSITY

CURRENT HBLED INTENSITY

END

Figure 9: Sensors Code Routine

Schematic Diagram

NOTE: OLED Display and RF socket are optional

References

- Z8 Encore! XP® F1680 Series Product Specification – PS0250
  http://www.zilog.com/docs/z8encorexp/PS0250.pdf

- ZMOTION^{TM} Documentation
  http://www.zilog.com/index.php?option=com_product&Itemid=26&mode=showProductDetails&familyId=149&productId=ZMOT0BSB

- MXHV9910 Design Considerations Application Note AN-300 (Clare – An IXYS Company)
  http://www.clare.com/home/pdfs.nsf/www/MXHV9910.pdf/$file/MXHV9910.pdf
  http://www.clare.com/home/pdfs.nsf/www/AN-300_R00E.pdf/$file/AN-300_R00E.pdf

- Nichia HBLED Product Specification
  http://www.nichia.co.jp/specification/en/product/led/NS9W153M-E.pdf

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