Reference Design

ZMOTION Occupancy Sensor

RD003502-1016

Overview

This ZMOTION Occupancy Sensor reference design demonstrates the use of Zilog's ZMOTION microcontroller and key IXYS components as a passive infrared (PIR) sensor-based motion detector lighting system that can operate in two modes – Occupancy Mode and Vacancy Mode. Both modes can use either PWM or 1–10V interfaces to control dimmable lighting ballasts. These ballasts typically drive fluorescent/compact fluorescent (CFL), High Intensity Discharge (HID), or High Power LED lighting. A DIP switch is used to select features and modes such as sensitivity, delay time, dim level, pass through mode, vacancy mode, and occupancy mode. Ambient light detection, AC power control, and certain advanced features offered by ZMOTION, such as Pass Through and Hyper sense, are also supported.

Note: The source code file associated with this reference design, RD0035-SC01.zip, is available free for download from the Zilog website.

Features

Key features of this ZMOTION Occupancy Sensor reference design include the following:

- Uses the ZMOTION MCU (part number Z8FS040BHH20EG) to perform all motion detection and output control
- 1–10V output with voltage feedback and fault detection (can support up to 25 ballasts)
- PWM output
- AC switch supporting 3A/220VAC load
- Ambient light sensor with light gate adjustment
- Occupancy and Vacancy modes
- Pass Through and Hyper Sense detection
- Programmable output level for unoccupied state
- Dimming control of light output level
- LED indicator (for motion detection and external wiring fault detection)
- Push button to toggle light output (manual override)
- 9-position DIP switch for configuration of parameters
- Supports ZMOTION L200 development kit lenses

- USB serial interface for debugging

Potential Applications

This reference design can be used to develop applications for areas such as:

- Open/partitioned offices
- Private offices and conference rooms
- Classrooms and lecture halls
- Data centers
- Lobbies and hallways
- Pantries
- Libraries
- Rest rooms
- Gymnasiums
- Warehouses

Discussion

This section describes the system operation, hardware, and firmware design of the ZMOTION Occupancy Sensor reference design.

Operation

In this reference design, the operation depends on the DIP switch settings, shown in Figure 1, which can be modified in real-time; these settings include sensitivity, delay time, output level, occupancy mode (with Pass Through enabled or disabled), and vacancy mode.

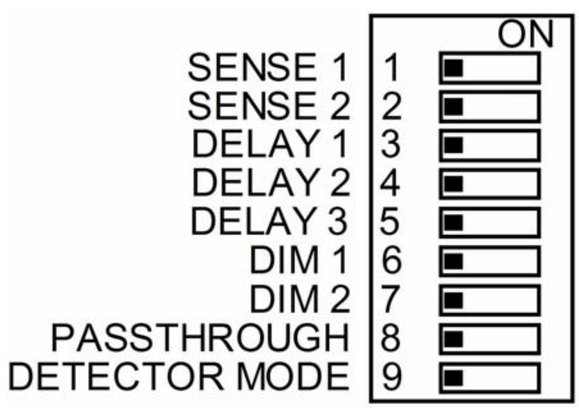


Figure 1. DIP Switch Positions

> **Note:** In the following sections, any reference to the light (connected to the ballast) being in an OFF state indicates that the light is set to either the OFF or DIM position.

Sensitivity

Motion sensitivity is controlled by the two DIP switch positions, SENSE1 and SENSE2, providing four levels of sensitivity – Minimum, Low, Medium, and Maximum.

Table 1 lists the DIP switch settings for Sensitivity.

Table 1. DIP Switch Setting – Sensitivity

DIP Switch Positions		Sensitivity Level
SENSE2	**SENSE1**	
OFF	OFF	Minimum
OFF	ON	Low
ON	OFF	Medium
ON	ON	Maximum

The selected level determines the ZMOTION Engine API setting based on the Lens Configuration file (`API_INIT_xx`). Hyper Sense is automatically implemented for medium and maximum settings.

Hyper Sense provides automated control of sensitivity settings based on detected motion. When the light is ON and a number of *N* motion events are detected, motion sensitivity is temporarily increased to detect micro-motion events such as hand, arm, and head movements. When the light is switched to the OFF state, motion sensitivity is returned to its default level.

The ZMOTION registers used to set the sensitivity levels are ePIR_Sensitivity register, Extended Detection bits of ePIR_SC0[7:6] register, Range Control bits of ePIR_SC2[6:3] register, and Lock Level bits of ePIR_ASC2[7:5] register.

Table 2 lists the values of the ZMOTION registers for Sensitivity Levels.

Table 2. Sensitivity Level

Sensitivity Level	ePIR_Sensitivity	Extended Detection	Range	Lock Level
		ePIR_SC0[7:6]	ePIR_SC2[6:3]	ePIR_ASC2[7:5]
Minimum	EPIR_SENSITIVITY_DEF x 2	Disabled	Range + 1	Default Lock Level + 1 (max value = 7)
Low	EPIR_SENSITIVITY_DEF x 1.3	Disabled	Default Range	Default Lock Level
Medium	EPIR_SENSITIVITY_DEF	Default	Default Range	Default Lock Level
Medium Hyper Sense	EPIR_SENSITIVITY_DEF x 0.9	Default + 1 (max level = 2)	Default Range	Default Lock Level
Maximum	EPIR_SENSITIVITY_DEF x 0.9	Default	Default Range	Default Lock Level
Maximum Hyper Sense	EPIR_SENSITIVITY_DEF x 0.9	Default + 1 (max level = 2)	Default Range – 1 (min level = 0)	Default Lock Level – 1 (min level = 0)

Delay Time

Delay time defines the length of time for which the light remains in the ON state. With a pushbutton or motion-detected event, the light is turned ON and the delay timer starts running. After the light is turned ON, delay time dictates how long the light stays ON. Each motion event reloads the delay timer. When the delay time expires, the light is turned OFF.

Table 3 lists the DIP switch settings for Delay Time values.

Table 3. DIP Switch Setting – Delay Time

DIP Switch Positions			Delay Time
DELAY3	DELAY2	DELAY1	
OFF	OFF	OFF	15sec
OFF	OFF	ON	30sec
OFF	ON	OFF	1min
OFF	ON	ON	2min
ON	OFF	OFF	3min
ON	OFF	ON	5min
ON	ON	OFF	10min
ON	ON	ON	15min

Output Level

Output level defines the lighting level when the light is considered to be in the OFF state. The two output levels for the light which can be selected through the DIP switch are OFF and DIM. For DIM levels, there are three options – 10%, 20%, and 40%.

Table 4 lists the DIP switch settings for Output Levels.

Table 4. DIP Switch Setting – Output Level

DIP Switch Positions		Output Level
DIM2	**DIM1**	
OFF	OFF	Off
OFF	ON	10%
ON	OFF	20%
ON	ON	40%

Detector Mode

Detector mode refers to the behavior of detection events, and how to control the light states. The two detector modes are Occupancy mode and Vacancy mode. Four parameters are controlled by the detector mode function – motion event, pushbutton event (press-and-release), ambient light level, and delay time.

Occupancy Mode

In Occupancy mode, there are two events that can turn the light ON:

- Pushbutton event – A pushbutton event will turn ON the light regardless of ambient light level
- Motion event – A motion event will turn ON the light only if the ambient light level is lower than the defined level.

The following two events can turn the light OFF:

- Pushbutton event
- Delay time expiration

Vacancy Mode

In Vacancy mode, the ambient light sensor is disabled and turning the light ON depends only upon the pushbutton event. If the light is in the OFF state and a pushbutton event occurs, the light will turn ON. Turning the light to the OFF state depends on two events – pushbutton event and delay time expiration.

Table 5 provides the DIP switch settings for the Detector mode.

Table 5. DIP Switch Setting – Detector Mode

DIP Switch Positions	Detector Mode
OFF	Occupancy
ON	Vacancy

Pass Through Mode

Pass Through mode is useful when a person enters and leaves a room quickly. Instead of turning the light ON for the full delay time, the light stays ON only for a shorter pass through time. This feature only applies when delay time is set to 1 minute or greater.

Pass Through mode can only be enabled when occupancy mode is selected. This mode works similar to occupancy mode, with the addition of a pass through timer. Unlike delay time, the pass through time is not user-selectable; instead, it is defined in the firmware. Typically, the pass through time value is less than the delay time value.

There are two events that can turn the light ON:

- Pushbutton event
- Motion event

When the light is turned ON, the delay timer and pass through timer start counting. With each detected motion, the delay timer is reloaded whereas the pass through timer is not. Detected motions are counted within the duration of the pass through time.

When the pass through time expires and the counted detected motions are fewer than *N* motion events (defined in the firmware), the light is turned to the OFF state and the delay timer is stopped.

When the pass through time expires and the counted detected motions are greater that *N* motion events, the light is turned to the OFF state after the delay time expires.

Table 6 lists the DIP switch settings for the Pass Through mode.

Table 6. DIP Switch Setting – Pass Through Mode

DIP Switch Positions	Pass Through Mode
OFF	Disabled
ON	Enabled

Hardware

This reference design provides a single board solution based on the ZMOTION development kit form factor (to accommodate the size of the lens holder) that can be powered with a 12–24V DC supply. This board has all the necessary holes to support the same lenses as the ZMOTIONL200 kit. The status LED, ambient light sensor, and PIR sensor are placed on the lens side (top) of the board while the remaining components are placed on the bottom side, as shown in Figures 2 and 3.

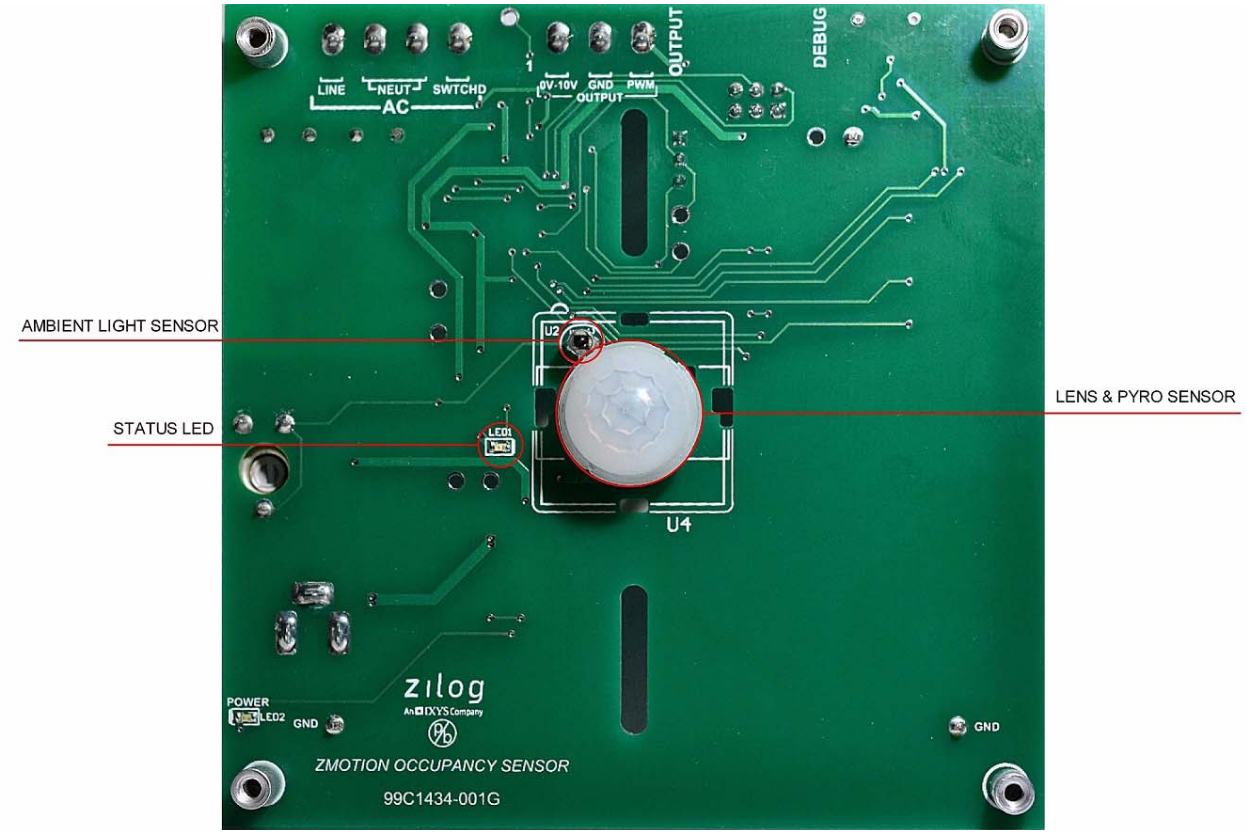


Figure 2. PCB Top Side

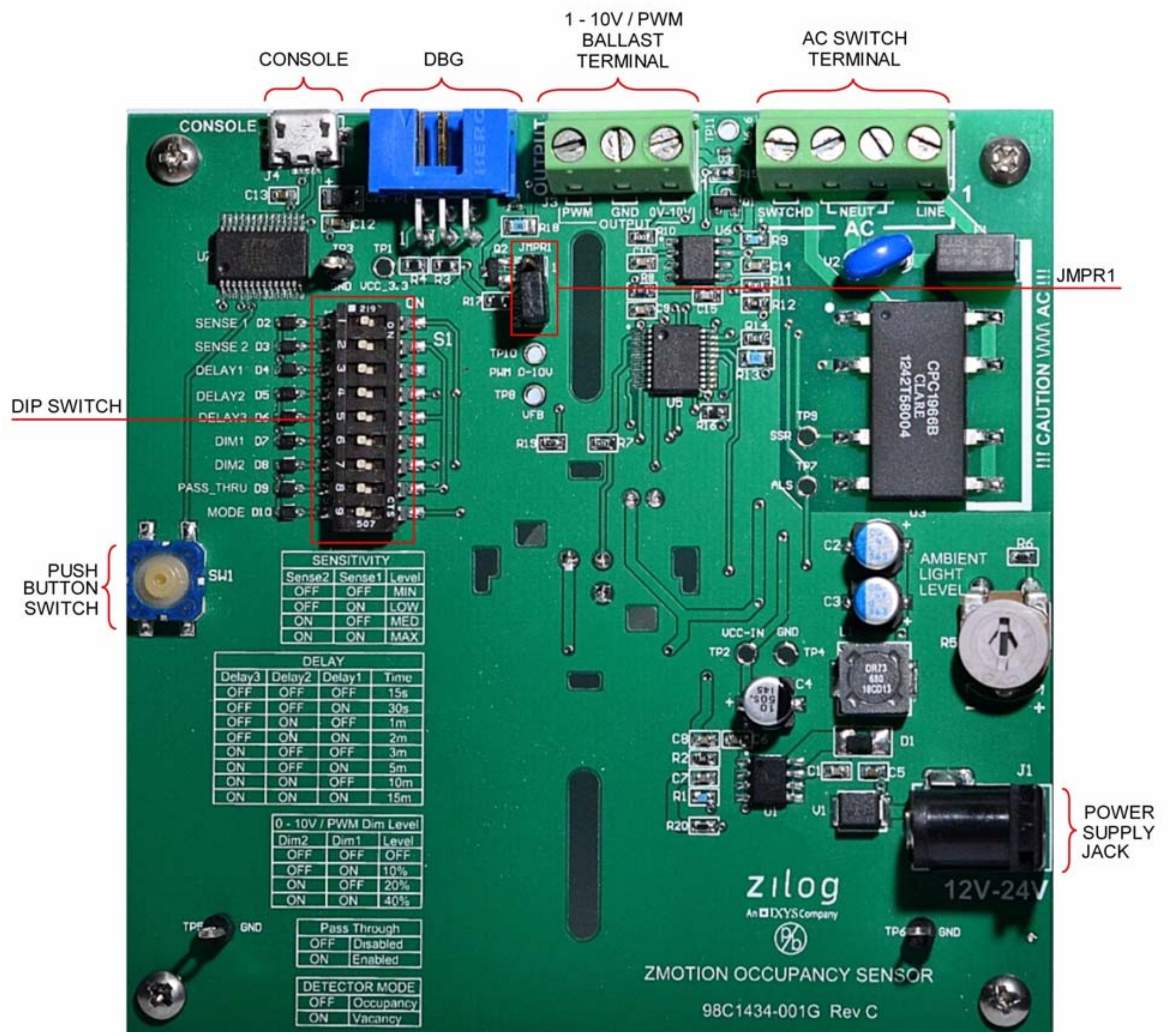


Figure 3. PCB Bottom Side

Figure 4 shows a block diagram of the reference design. It consists of:

- PIR sensor and lens
- Ambient light sensor
- DIP switch
- 1–10V interface
- PWM interface
- AC switch

- Status LED
- Push button switch
- UART/USB interface, and
- Debug interface

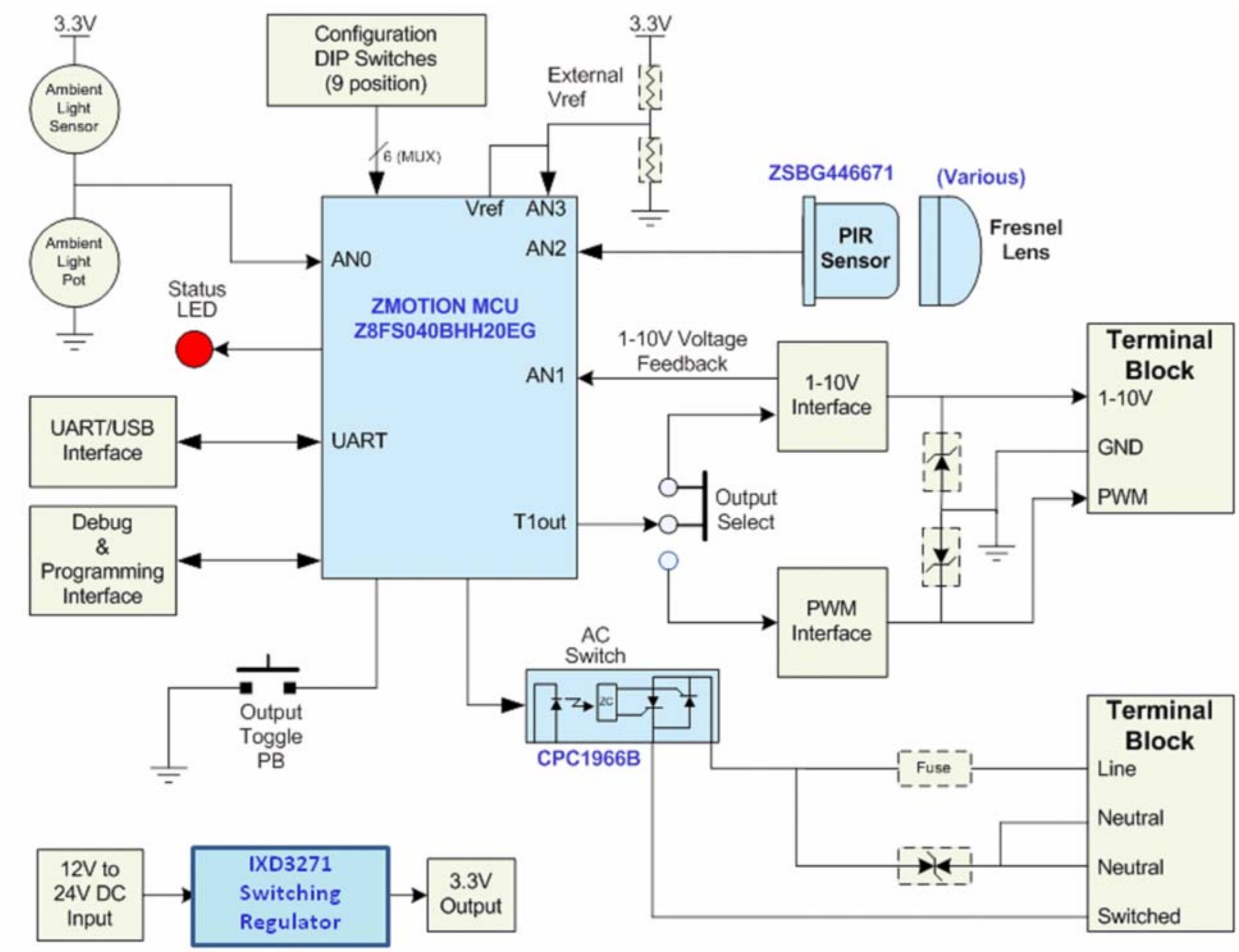


Figure 4. Block Diagram

Ambient Light Sensor

The Ambient Light Sensor (ALS) is used as a light gate to any of the light control outputs, based on the available ambient light present in the room. The ambient light potentiometer scales the voltage generated by the TEPT4400 current source such that brighter ambient light generates a higher voltage at the ADC ANA0 input. The light gate is only available in Occupancy mode.

The light gate is effective when switching between the light's OFF and ON states. If the light is OFF, motion is detected, and the measured ambient light is greater than the preset voltage (suggested value 1V–1.5V), the light remains OFF. If the light is OFF, motion is detected, and the measured ambient light is less than the preset voltage, the light will turn ON. If the light is already ON and motion is detected, ALS input is ignored.

DIP Switch

Features and parameters such as sensitivity, delay time, output level, Pass Through mode, Occupancy mode, and Vacancy mode are set through the DIP switch. The DIP switch is a 9-position rocker-type switch that can be turned ON or OFF. The nine switches are configured into a 3 x 3 multiplexer.

Figure 5 shows a 1 x 3 multiplexer as an example of a 3 x 3 implementation.

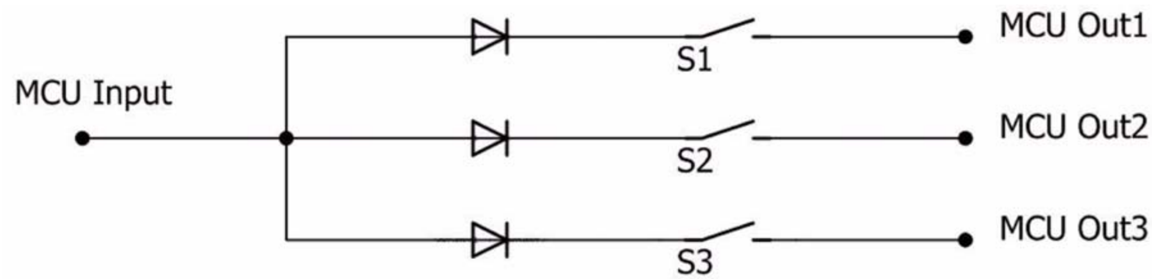


Figure 5. Switch MUX

To determine whether a switch is ON or OFF, logic 0 is applied to the switch through the MCU Out pins and the state is read at MCU Input. Diodes are used to avoid ghost paths.

The data for the MCU Out pins when testing a switch are listed in Table 7.

Table 7. MCU Out Data

MCU Out 1	MCU Out 2	MCU Out 3	Switch To Be Read
0	1	1	S1
1	0	1	S2
1	1	0	S3

Lighting Control Interfaces

This reference design can support either 1–10V or PWM lighting control interfaces to control dimmable lighting ballasts. These ballasts typically drive fluorescent/CFL, HID, or High Power LED lighting. Both interfaces are driven by the Timer1 PWM output (PA7). The interface can be selected through a jumper (JMPR1).

After the power cycle, PA7 is configured as input and reads the pin state. If the pin state is logic 1, the PWM output is selected due to the pull-up resistor on the gate of the 2N7002 transistor driver. If the pin state is logic 0, then 1–10 V output is selected due to the pull-down resistor on the input of the interface circuit.

After the MCU has determined the interface circuit to be used, PA7 is reconfigured as Timer1 PWM output.

The 1–10 V interface is a current sink circuit as described in IEC 60929 Annex E. The standard requires that the ballast provides full light output when the control voltage is 10 V or above. If the control voltage is 1 V or below, the ballast provides its minimum light level. The 1–10 V interface consists of an RC filter, inverting amplifier using an operational amplifier, and a 2N3904 transistor (current sink).

In addition to the Timer1 PWM output, the ADC channel (ANA1) is also used for this interface. The ADC monitors the output voltage of the interface to ensure that the desired voltage level is achieved. Additionally, the ADC is used to check fault conditions such as open or short circuits on the input of the lighting ballast.

The PWM interface only uses the Timer1 PWM output. It has a 2N7002 transistor that drives the lighting ballast. There is no feedback circuit to monitor the output voltage level or fault conditions.

AC Switch

The CPC1966B AC power switch is implemented to directly control up to a 3 A load at 240 V AC. This switch is directly controlled with a GPIO from the MCU and is used in the 1–10 V interface to switch off the output completely.

The PWM interface consists only of a 2N7002 transistor to drive the dimmable lighting ballast. The input of this interface is the PWM signal generated by the Timer1 PWM output.

Push Button Switch

The push button switch is used to toggle the light state. It is used in Occupancy and Vacancy modes.

Status LED

The status LED is used as an indicator for a detected motion and external wiring fault. The status LED flashes every time a motion is detected. If an external wiring fault is detected, the LED flashes continuously and motion detection is discontinued. The fault should be fixed prior to the start of another power cycle. When no fault is detected, the system returns to normal operation.

Firmware

Figure 6 illustrates the structure of the program files for this reference design.

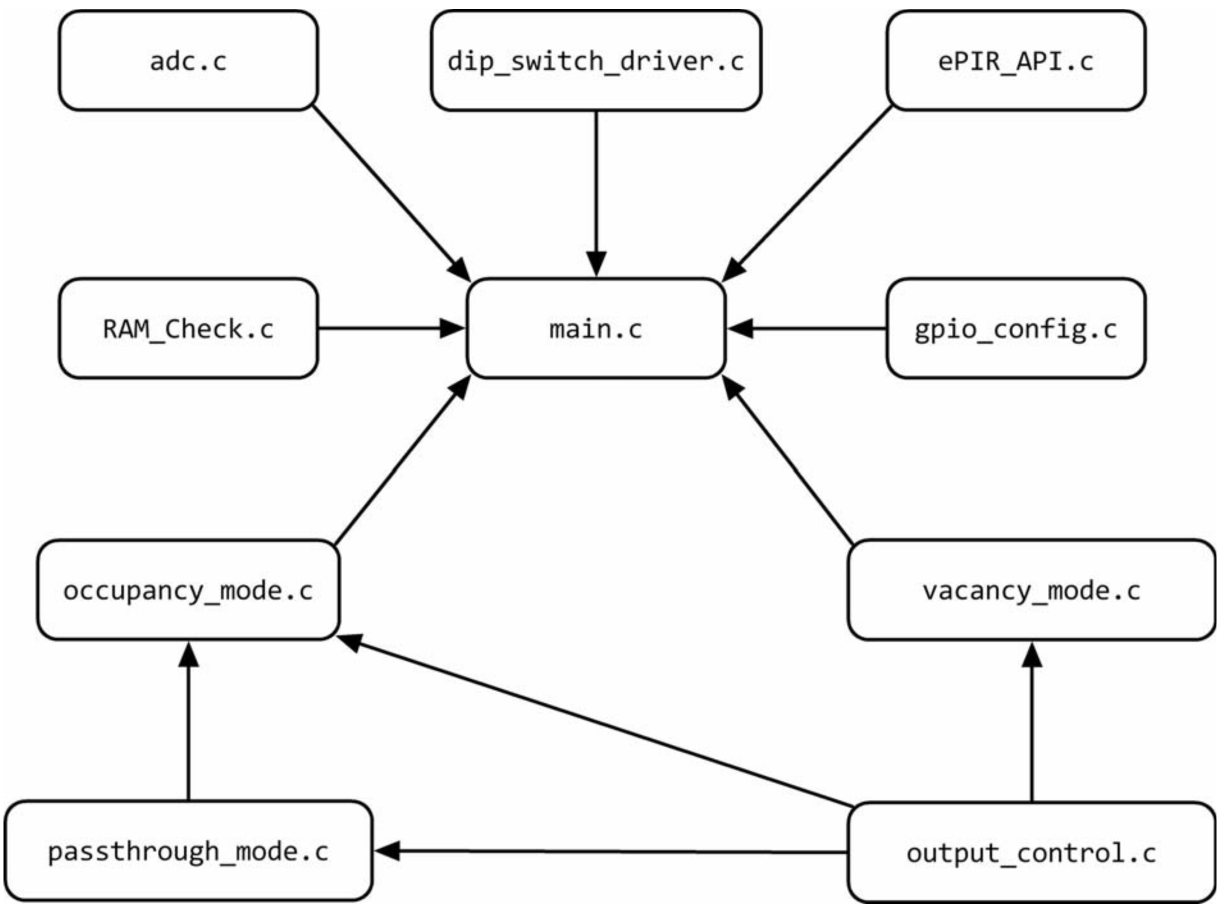


Figure 6. Program Files

The main.c function calls most of the routines from adc.c, dip_switch_driver.c, ePIR_API.c, RAM_Check.c, gpio_config.c, occupancy_mode.c, and vacancy_mode.c.

Occupancy_mode.c calls passthrough_mode.c.

Output_control.c is called by occupancy_mode.c, vacancy_mode.c, and passthrough_mode.c.

The main.c file handles the application initialization and main application loop. Included in this file are two interrupt routines – one for monitoring pushbutton events and the other for the application timer.

The adc.c file handles the ADC interrupt routine of the ZMOTION Engine. It also handles the request for ADC of the ambient light sensor signal and feedback voltage from the 1–10V interface.

The dip_switch_driver.c function performs the 3 x 3 multiplexing of the DIP switch. It identifies the DIP switch settings selected by the user.

The ePIR_API.c file provides the ZMOTION PIR API register definitions.

The gpio_config.c file contains the configuration settings of the ports for all the devices connected to the MCU.

The occupancy_mode.c function keeps the output control in its OFF state until a motion is detected. When a motion is detected, the output control turns on the delay time, as set through the DIP software. Each motion event triggers this delay time. Ambient light sensing acts as a gate for output control. If the ambient light level is higher than the selected level, the output control will be off.

The vacancy_mode.c function waits for a pushbutton event. The pushbutton event toggles the state of the light.

The passthrough_mode.c function sets the pass through timer and counts the number of detected motions within the pass through period.

The RAM_Check.c function checks these RAM values and ensures values do not change due to stack corruption or environmental (ESD/EMI) events.

The output_control.c function handles the dimming and turning ON/OFF of light. It also monitors short and open wire circuit connection on the output of the 1–10V interface circuit.

Note: The values in the ePIR_API.c file must not be modified or removed.

Testing Procedure

To test this reference design, connect the ballast with High Power LED to the board, as shown in Figure 7.

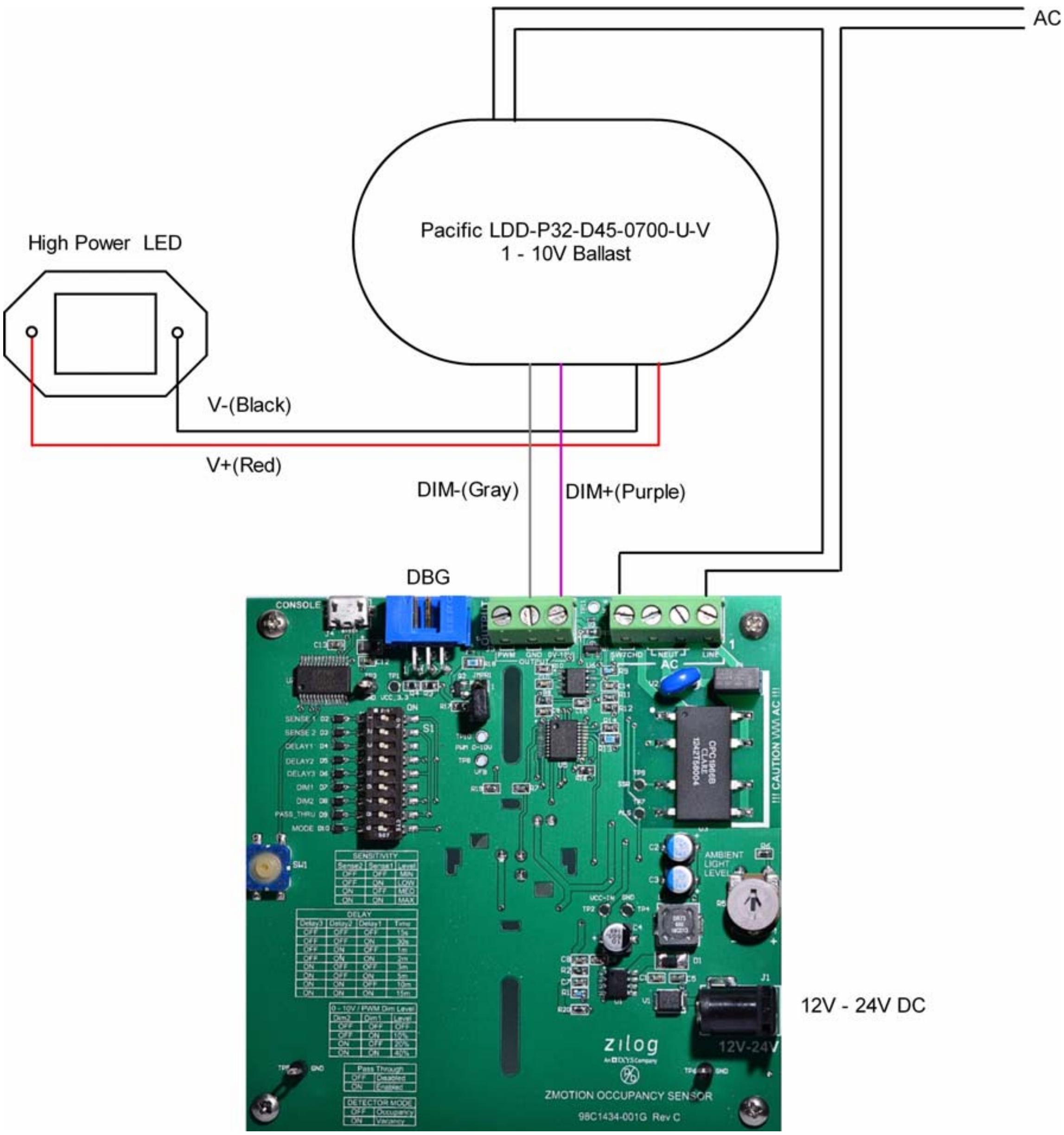


Figure 7. Hardware Setup

The [LDD P32 D45 0700 U V](#) 1–10V ballast and the [30W High Power LED Emitter Light Oval Shape 6000-7000k 30-36V 1000mA 1500-2400LM](#) High Power LED are used to test this reference design.

1. Connect the USB Smart Cable to the DBG terminal of the board.
2. Power the board using a 12V–24V DC supply. The power LED indicator (LED2) turns on when power is applied to the board.
3. Download [RD0035-SC01.zip](#) from the Zilog website to the `<ZDS Install>\samples\XP_F6482` folder.
4. Open Windows File Explorer and navigate to the `<ZDS Install>\samples\XP_F6482` folder. Unzip the [RD0035-SC01](#) file.
5. Open the ZDS II –Z8 Encore 5.2.1 (or later) IDE and select the **Open Project...** option from the **File** menu.
6. Navigate to the `<ZDS Install>\samples\XP_F6482\RD0035-SC01\` folder, select the `RD0035_OccupancySensor.zdsproj` project and click **Open** to open the project.
7. From the **Build** menu, select the **Rebuild All** option to rebuild the project.
8. From the **Debug** menu, select **Download Code** to load the program to the MCU.
9. After programming is complete, from the **Debug** menu, select **Stop Debugging**.
10. Remove power from the board.
11. Disconnect the 6-pin ribbon cable from the DBG connector on the board.
12. Set DIP Switch S1 to minimum sensitivity, 1 minute delay time, and OFF output level. See Figure 8.

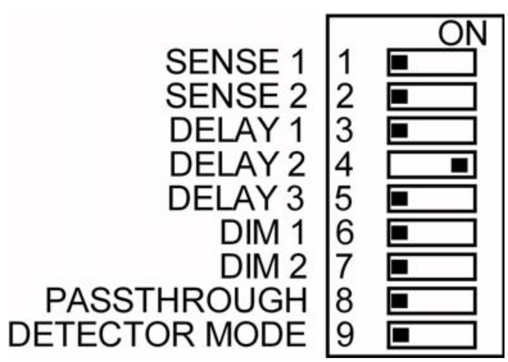


Figure 8. DIP Switch Settings for Test Procedure

13. Set JMPR1 to 2-3 position (1–10V interface).
14. Connect a voltmeter to the ambient light sensor output (TP7) to monitor ambient light voltage value.
15. Power cycle the board and power the AC line.

Vacancy Mode Testing

Use the following procedure to test Vacancy mode:

1. Set DIP Switch S1 to enable Vacancy Mode. See Figure 9.

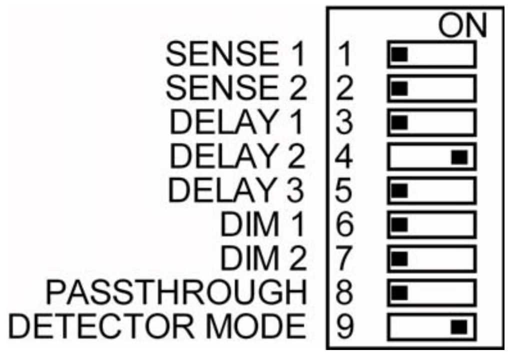


Figure 9. DIP Switch Settings - Vacancy Mode Testing

2. Push the pushbutton momentarily.
   - If the High Power LED is OFF, it will be turned ON
   - If the High Power LED is ON, it will be turned OFF

3. When the High Power LED is ON AND there is NO motion AND NO pushbutton event, the High Power LED will be turned OFF after the timer delay expires.

Occupancy Mode Testing

Use the following procedure to test and observe the results of Occupancy mode – Pass Through Disabled and Occupancy mode – Pass Through Enabled testing:

Pass Through Disabled

1. Set DIP Switch S1 to enable Occupancy mode and disable Pass Through. See Figure 10.

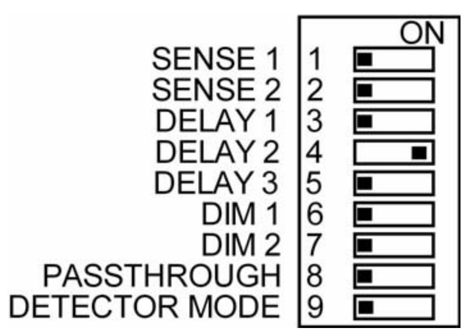


Figure 10. DIP Switch Settings - Occupancy Mode with Passthrough Disabled Testing

2. The following results are observed:
   - If there is a motion AND the High Power LED is OFF AND ambient light is LESS THAN the LG threshold value (1.55V), the High Power LED will turn ON AND the timer delay starts.
   - If there is a motion AND the High Power LED is OFF AND ambient light is EQUAL TO OR GREATER THAN the LG threshold value, the bulb remains OFF.
   - If the High Power LED is ON, timer delay is refreshed every time there is a motion.
   - If High Power LED is ON AND there is NO motion AND the delay timer expires, the High Power LED will turn OFF.
   - Regardless of the ambient light value, if there is a pushbutton event, the High Power LED toggles between ON and OFF.
   - The red LED flashes every time there is a motion.

Pass Through Enabled

1. Set DIP Switch S1 to enable Occupancy mode and Pass Through. See Figure 11.

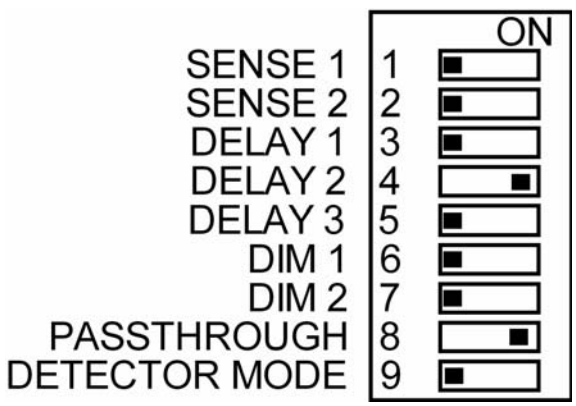


Figure 11. DIP Switch Settings - Occupancy Mode with Passthrough Enabled Testing

2. The following results are observed:
   - If there is a motion AND the High Power LED is OFF AND ambient light is LESS THAN the LG threshold value, the High Power LED will turn ON, the timer delay starts AND pass through timer starts.
   - If there is a motion AND the High Power LED is OFF AND ambient light is EQUAL OR GREATER THAN the LG threshold value, the bulb remains OFF.
   - If High Power LED is ON, timer delay is refreshed every time there is a motion.
   - If High Power LED is ON AND there are less than *N* motions detected within passthrough time, the High Power LED will turn OFF after the pass through timer expires. The default passthrough delay value is 15 seconds. This value is defined as `PASSTHROUGH_DELAY_DEF` in the main.h file.

– If the High Power LED is ON AND there are *N* or more motions detected within pass through time, the bulb will turn OFF after the delay timer expires. The number of motions, *N*, can be changed in the firmware. By default, this value is 3 and is defined as `N_MOTION_EVENTS` in the main.h file.
– Regardless of the ambient light value, if there is a pushbutton event, the High Power LED toggles.
– The red LED flashes every time there is a motion.

Electrical Specifications

Stresses greater than those listed in Table 8 may cause permanent damage to the device. These ratings are stress ratings only. Operation of the device under any conditions outside those indicated in the operational sections of these specifications is not implied. Exposure to absolute maximum rating conditions for extended periods affects device reliability. For improved reliability, unused inputs must be tied to one of the supply voltages.

Table 8 lists the electrical characteristics of the ZMOTION Occupancy Sensor reference design and reflects all available data as a result of testing prior to qualification and characterization. As such, the data presented is subject to change.

Table 8. Electrical Specifications for the ZMOTION Occupancy Sensor Reference Design

Parameter	Minimum	Maximum	Units	Notes
Board Supply Voltages	12	24	VDC	
AC Switch Load (V)		240	VAC	
AC Switch Load (I)		3	A	
Board Power Consumption	7.2	11.2	mA	With Load (ballast)

Packaging

Figures 12 and 13 display the assembly diagram (top and bottom view respectively) of the ZMOTION Occupancy Sensor reference design.

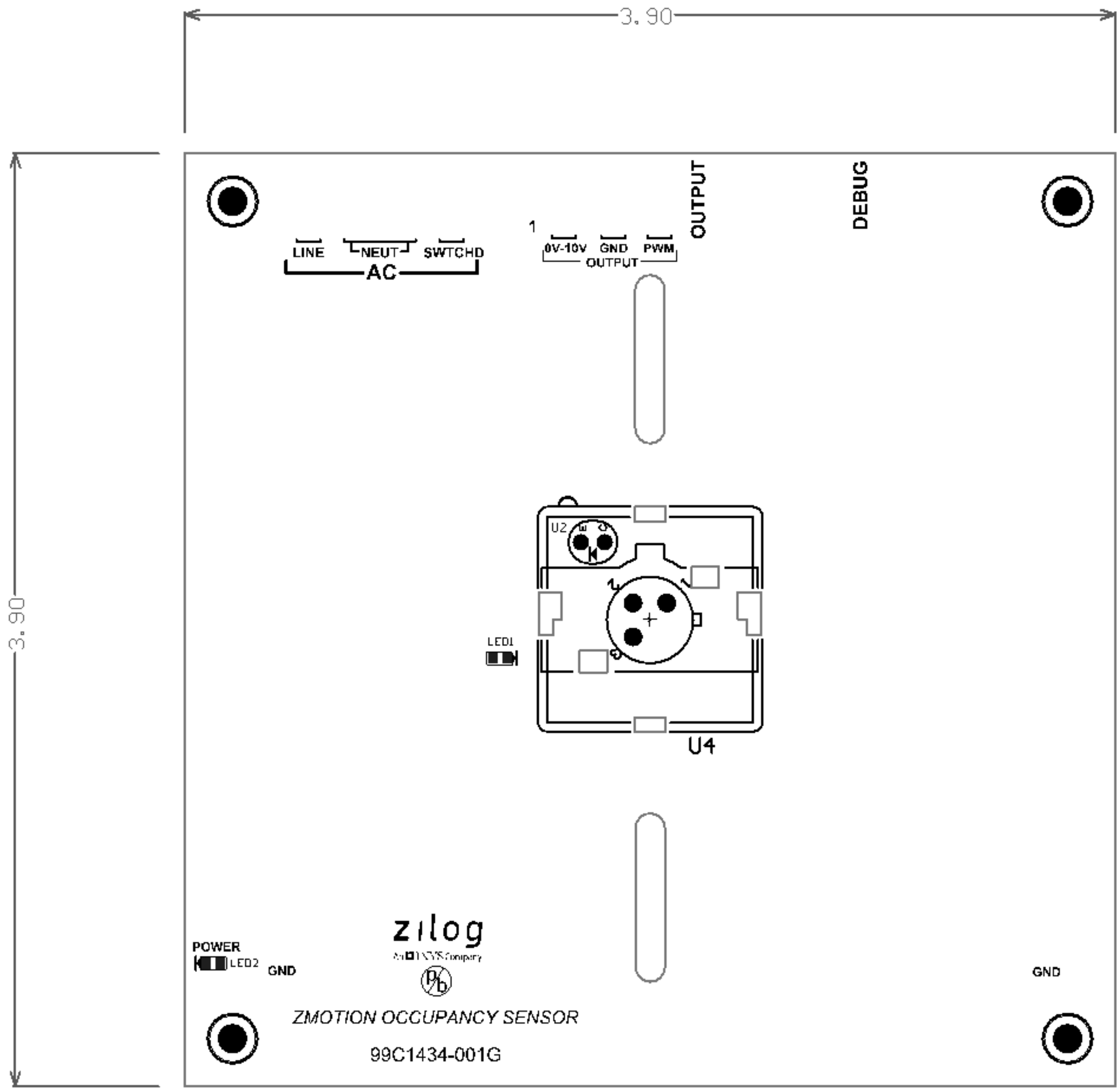


Figure 12. Assembly Diagram (Top View)

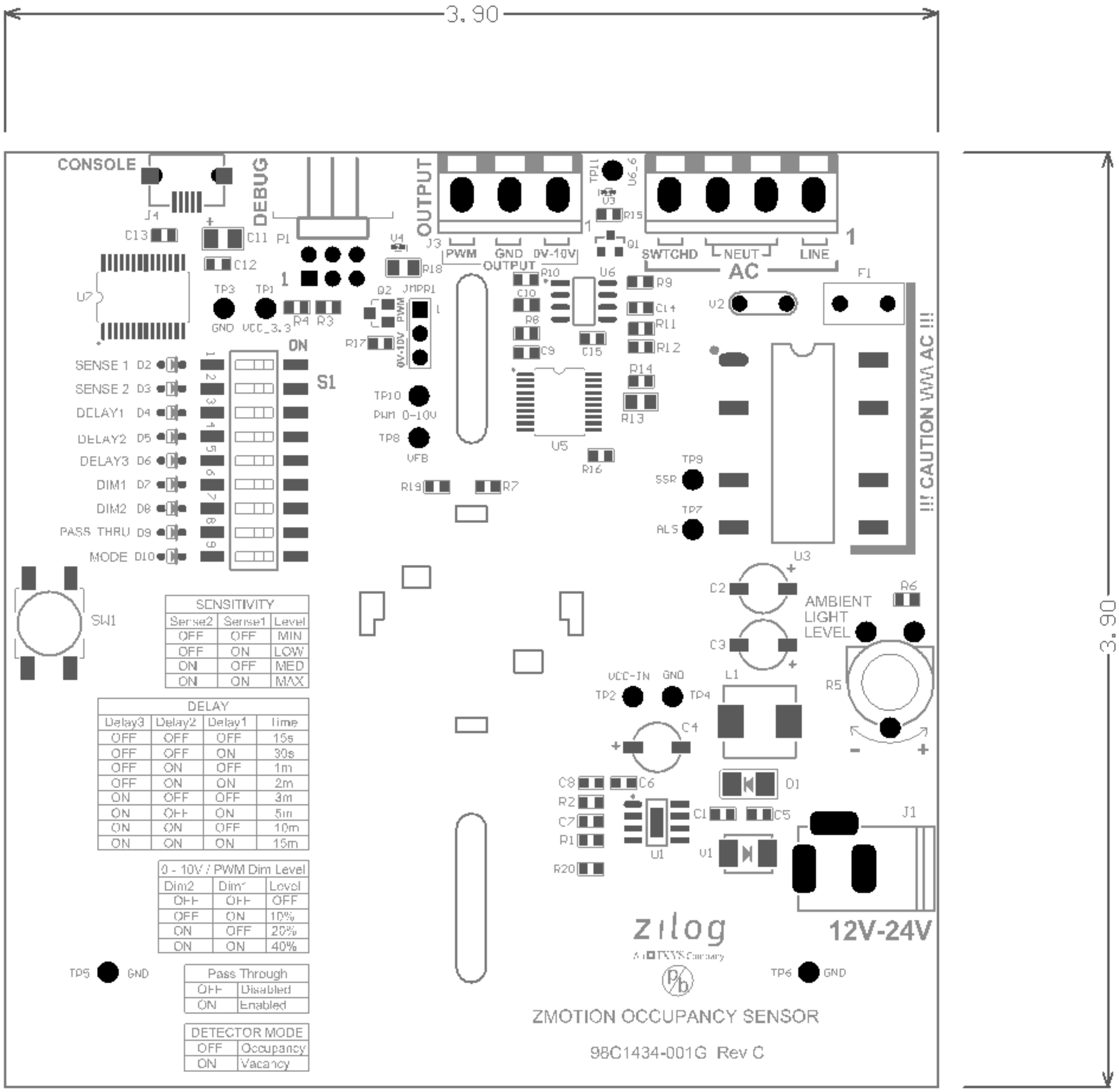


Figure 13. Assembly Diagram (Bottom View)

Ordering Information

The products associated with this ZMOTION Occupancy Sensor reference design are available as a kit and can be ordered from the Zilog Store using the part number listed in Table 9.

Table 9. Ordering Information

Part Number	Description	Store Product ID
ZMOTIONL200ZRDG	ZMOTION Occupancy Sensor Reference Design Kit	RD10045

Kit Contents

The ZMOTION Occupancy Sensor Reference Design Kit contains the following items:

- Occupancy Sensor Design Board
- Power Adapter
- Lenses: ZNCL-9(26), NCL-10IL, ZNCL-3B, NCL-10S, ZNCL-11
- ZMOTION Occupancy Sensor Kit Insert

Note: The USB SmartCable used in this reference design can be ordered separately from the Zilog Store (RD10039).

Related Documentation

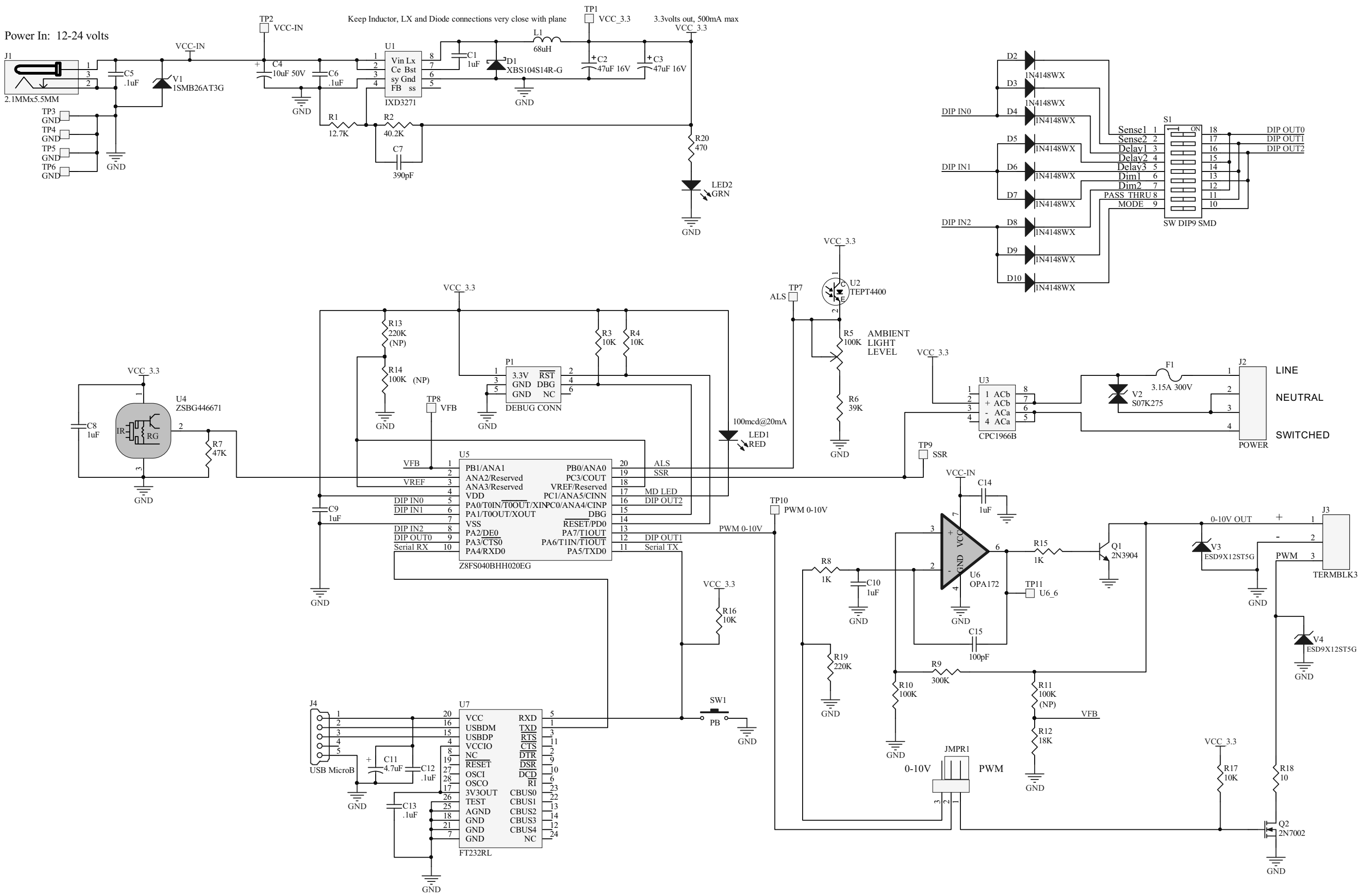
The documents associated with the ZMOTION Occupancy Sensor reference design are listed in Table 10. Each of these documents can be obtained from the Zilog website by clicking the link associated with its document number.

Table 10. Related Documentation

Document Number	Description
RD0035	This ZMOTION Occupancy Sensor Reference Design document
PS0228	Z8 Encore! XP F082A Series Product Specification
PS0286	ZMOTION Lenses Product Specification
PS0336	ZMOTION Pyroelectric Sensors Product Specification
PS0285	ZMOTION Detection and Control Product Specification

Appendix A. Schematic Diagram

Figure 14 shows the schematic diagram for the ZMOTION Occupancy Sensor reference design.



Silkscreen Labels for S1

- S1-1 = SENSE1
- S1-2 = SENSE2
- S1-3 = DELAY1
- S1-4 = DELAY2
- S1-5 = DELAY3
- S1-6 = DIM1
- S1-7 = DIM2
- S1-8 = PASS_THRU
- S1-9 = MODE

SENSITIVITY		
Sense2	Sense1	Level
OFF	OFF	MIN
OFF	ON	LOW
ON	OFF	MED
ON	ON	MAX

DELAY			
Delay3	Delay2	Delay1	Time
OFF	OFF	OFF	15s
OFF	OFF	ON	30s
OFF	ON	OFF	1m
OFF	ON	ON	2m
ON	OFF	OFF	3m
ON	OFF	ON	5m
ON	ON	OFF	10m
ON	ON	ON	15m

0 - 10V / PWM Dim Level		
Dim2	Dim1	Level
OFF	OFF	OFF
OFF	ON	10%
ON	OFF	20%
ON	ON	40%

Pass Through	
OFF	Disabled
ON	Enabled

DETECTOR MODE	
OFF	Occupancy
ON	Vacancy

Figure 14. ZMOTION Occupancy Sensor Reference Design Schematic Diagram

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As used herein

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

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