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AN56581

PowerPSoC® – Designing LED Driver Circuits for MR-16 Lamps with DMX-512 Interface

Author: Srinivas NVNS

Associated Project: Yes

Associated Part Family: CY8CLED04D01-56LTXI

Software Version: PSoC® Designer™ 5.4

Associated Application Notes: AN47372

AN56581 describes the design of an LED driver circuit in a MR-16 form factor with DMX-512 interface using PowerPSoC controllers. This document demonstrates the use of PowerPSoC to design small form factor fixtures such as MR-16 lamps with DMX-512 interface. It outlines the architecture of the fixture and the LED driver board reference design, followed by its bring up and operation procedure. Code examples to implement color mixing for multicolor lamps and tunable white light systems are also provided.

Introduction

Cypress has developed a compact LED driver solution for use in an MR16 fixture. The controller board uses the PowerPSoC device for lighting control and DMX-512 communication

Light output of LEDs is controlled by the current flowing through them. By controlling the current in the four channels, you can achieve a desired color at the desired intensity. Alternatively, the LEDs are driven with a constant current. You can modulate the time during which the current is driven to achieve a desired color. This function of the solution is implemented by PowerPSoC.

This solution incorporates DMX control, which enables you to network several fixtures, and at the same time, maintain individual control for each fixture. It provides the flexibility to connect a maximum of 85 fixtures in a network through the DMX512 communication protocol, when 6 slots are used per fixture. The fixture has four colors of LEDs: Red, Green, Blue, and Amber (RGBA). If three slots of control per fixture are used, which is similar to the tunable white light firmware variant, you can connect up to 170 fixtures.

The document describes a standard MR16 lamp with integrated LED driver. It gives an overview of the PowerPSoC family of controllers, specifications of the device used in this solution and a brief introduction to the DMX-512 communication protocol.

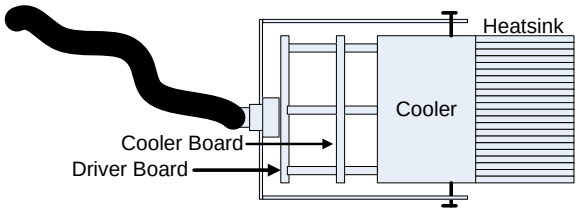
The hardware, firmware details of the solution are explained in later sections.

Figure 1. MR16 Fixture

MR16 Fixture

The MR16 fixture is a lighting industry standard format that has a small form factor. The fixture discussed in this application note has a RGBA LED emitter board (that forms the primary light source) and a heat sink connected to a cooler device. The fixture requires the heat sink to remove the heat generated by LEDs. The cooler on the MR16 fixture is a forced air type of cooler and removes heat from the heat sink by blowing ‘micro’ jets of air. A driver board mounted on the cooler powers it.

Figure 2. Integrated MR16 Fixture



PowerPSoC Overview

The PowerPSoC family incorporates Programmable System-on-Chip (PSoC®) technology with the best-in-class power electronic controllers and switching devices. This combination creates easy to use power system-on-chip solutions for lighting applications. It is an ideal platform to create lighting solutions and is designed to replace the microcontroller, system ICs, and discrete components required for driving high brightness LEDs.

The PowerPSoC family of devices combines up to four independent channels of constant current drivers. These drivers feature hysteretic controllers with the PSoC that contains an 8 bit microcontroller, configurable digital and analog peripherals, and embedded Flash memory. It operates from 7 V to 32 V and drives up to 1 A of current using internal MOSFET switches. It is also used to drive more than 1 A of current using external switches, and supports common power topologies such as buck and boost.

PowerPSoC features three options of hardware modulators, including the Cypress patented Precise Illumination Signal Modulation (PrISM™) scheme, which interfaces with the hysteretic controllers and modulates the signal to provide dimming.

For more information on PowerPSoC, see the datasheet and application notes available on the Internet at http://www.cypress.com/powerpsoc.

Specifications of the PowerPSoC Solution

The following table gives the specifications of the four-channel PowerPSoC solution. This solution drives four channels of HBLEDs.

Table 1. PowerPSoC Fixture Controller Specifications

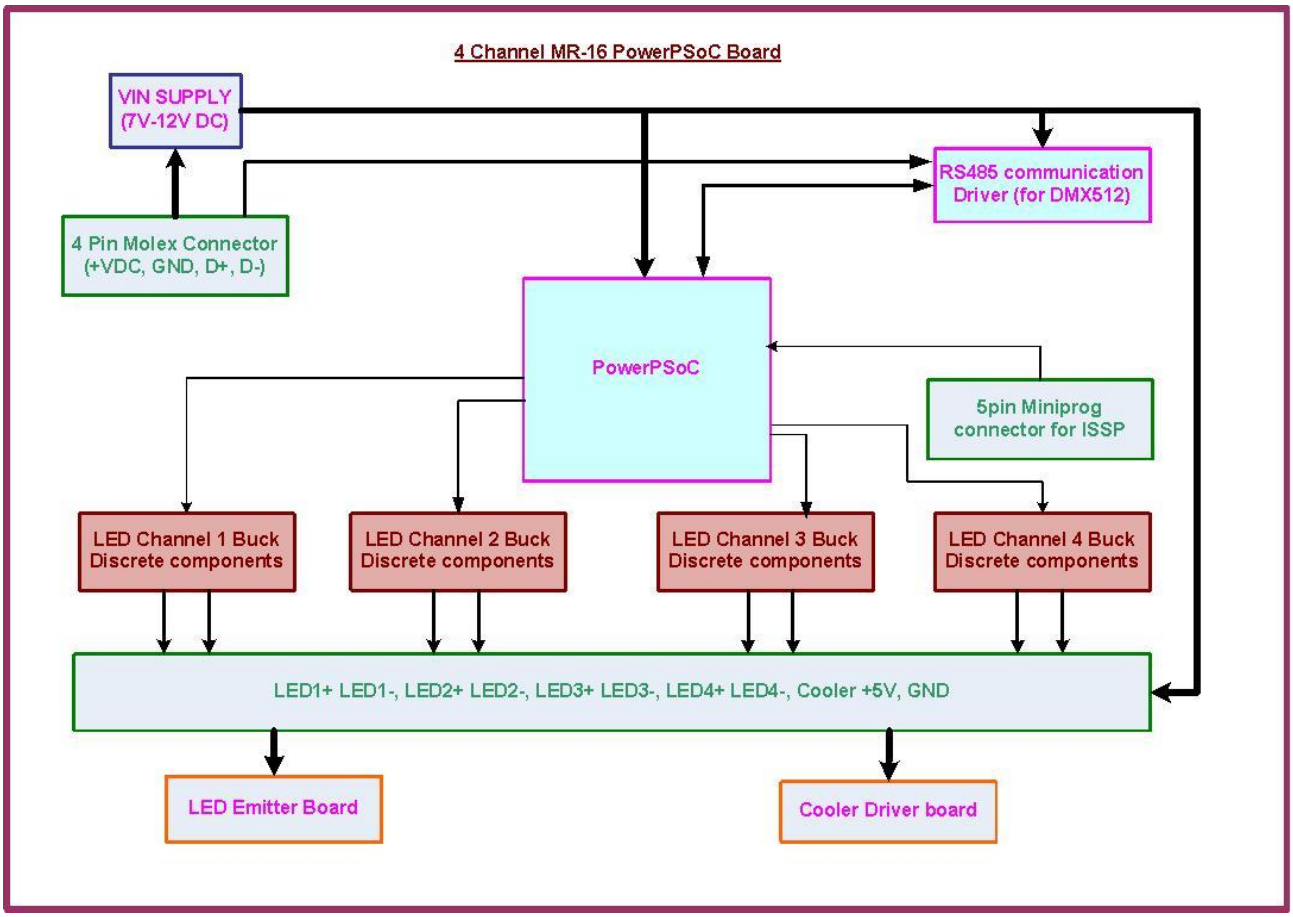
Description	Value
Cypress Solution	PowerPSoC
Number of LED Channels	4
Number of LEDs/Channel	1
LED drive current	700 mA per channel maximum
Features	Color Mix, Tunable white Light
Communication protocol	DMX512 –Physical layer RS485

Block Diagram

Figure 3 shows the block diagram of this solution implementing a four-channel PowerPSoC. The controller is powered by a voltage supply that can vary from 7 V to 12 V, and is input through a 4-pin Molex connector. The DMX controls (D+ and D-) are also input through the same connector. The Cypress device used is a CY8CLED04D01-56LTXI from the PowerPSoC family of devices.

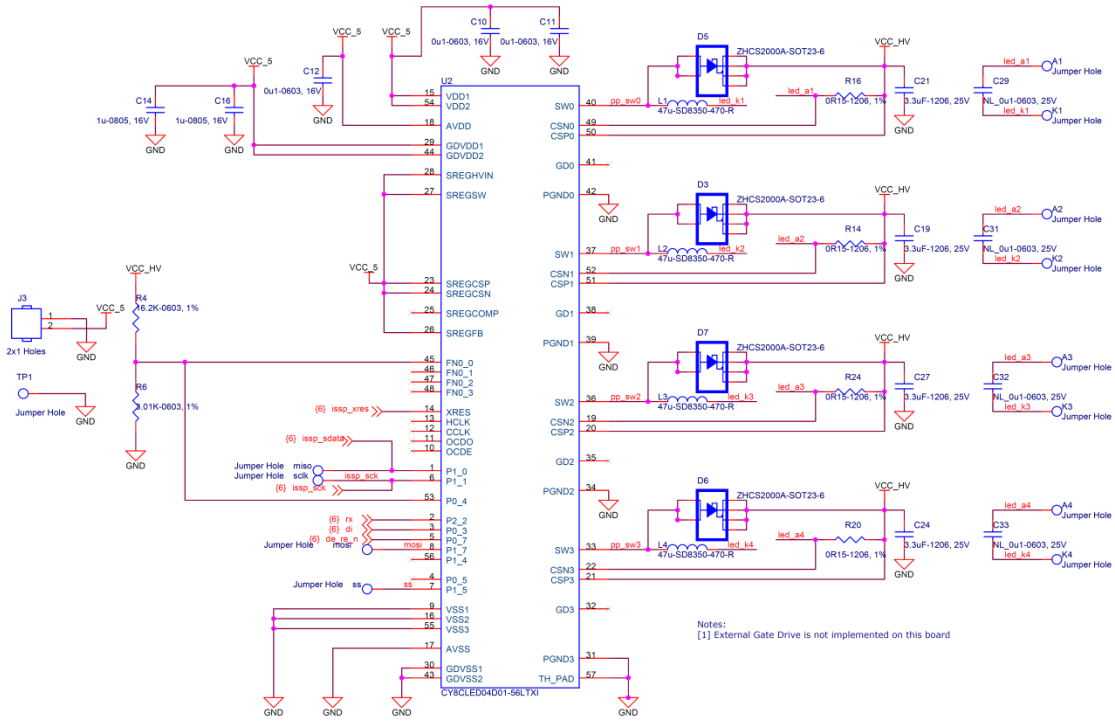
It is programmed through the 5-pin ISSP MiniProg connector. The solution also contains the necessary discrete components, such as inductors and diodes to implement a floating load buck driver to drive current through the LEDs. The solution also provides 5 V supply to the cooler driver board.

Figure 3. High Level Implementation of PowerPSoC Solution



PowerPSoC

Figure 4. PowerPSoC Controller



This solution is centered on the PowerPSoC series CY8CLED04D01-56LTXI Cypress IC. Figure 4 shows this implementation in the schematic. The CY8CLED04D01-56LTXI is a PowerPSoC device that features:

- PSoC core with 8 digital blocks and 6 analog blocks
- 4 channels of constant current drivers
- Internal FETs rated at 32 V/1 A
- PWM/PrISM hardware modulators

This device is used to implement a floating load buck configuration to drive current through the LEDs.

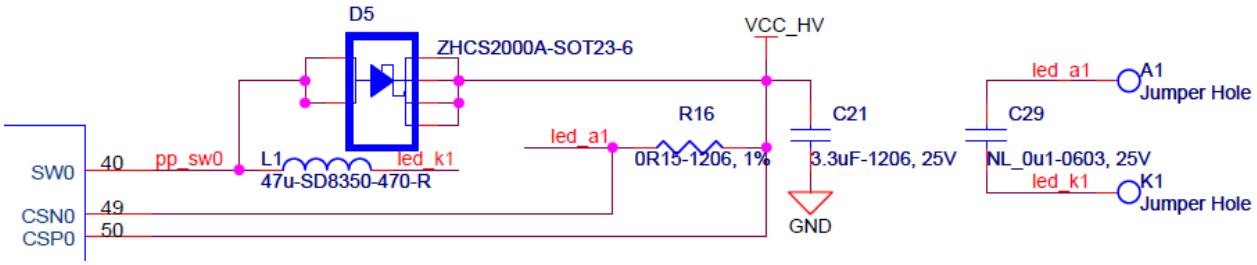
The right side of the schematic in Figure 4 shows the four channels for the LEDs. Each channel is a hysteretic current regulator with a floating load buck topology, which has three implications:

- The regulator channel controls the current through the LED, not the voltage across the LED.
- No part of the LED is directly connected to ground.
- The total voltage drop across the load must be less than the regulator's input voltage.

Several components that make a complete hysteretic controller are integrated into the PowerPSoC chip. This includes current sense amplifiers, comparators, voltage references, power FET switches, and gate drivers. The required external components include the power inductor, current sense resistor, free-wheel diode, input decoupling capacitor, and the output ripple capacitor. The corresponding component designators in the schematic for channel 1 are L1, R16, D5, C21, and C29. The channel 1 schematic is shown in Figure 5 on page 5.

The left side of the schematic shows a connector J3 that provides +5 V and GND to the cooler driver board. There is also a resistive voltage divider circuit comprising of R4 and R6 that can be used to implement under-voltage lock out feature. The pins corresponding to the Built-in Switching Regulator (BSR) of the PowerPSoC are pulled to +5 V to disable it. The left side of the schematic also shows the set of decoupling capacitors for digital power, analog power, and gate drive power pins.

Figure 5. Channel 1 Schematic



DMX Communication

The DMX controller and fixtures communicate through a RS485 transceiver. The PowerPSoC chip can only receive an 8-bit dimming data from a DMX Controller. This dimming data is used to control the current in the respective channel. The controller can send up to 512 bytes of data. Figure 6 shows a sample DMX controller.

Figure 6. DMX Controller

Each fixture has a PowerPSoC device. For a given lighting network, the addresses for the slots are assigned before any communication takes place between the controller and the lighting network. One light fixture can have any number of slots. For example, if the board controls only the Red, Green, Blue, and Amber LEDs, each LED channel is assigned a slot. Additional slots can be assigned for mode selection, intensity control, and more. You can also choose the required color and intensity by tuning the DMX Controller using the slider controls.

The PowerPSoC device uses the DMX512 Rx User Module to receive the data packets sent across the network by the DMX Controller. Figure 7 shows the RS485 transceiver circuit.

Figure 7. RS485 Transceiver Circuit

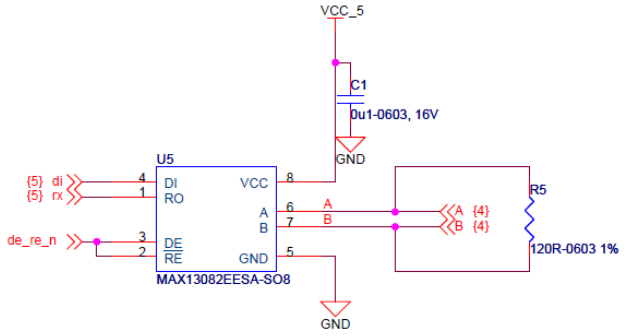


Figure 8. 5 V Generation Circuit

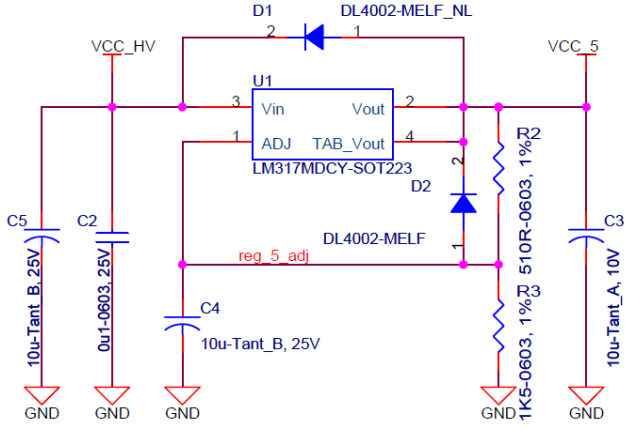


Figure 8 defines the 5-V generation in the fixture controller board. Voltage input of 7 V to 12 V VCC_HV can be provided from an external power supply. LM317 is used to realize a 5-V generation circuit. This circuit powers the PowerPSoC, RS485 interface, and the Cooler Driver board in the fixture.

Bring Up of the PowerPSoC System

This section explains how to bring up the PowerPSoC fixture controller. Figure 9 and Figure 10 show the top layer and the bottom layer of the board respectively. The power input is through the Molex connector (shown in Figure 9).

1. For a single fixture, set the external power supply to a minimum of 12 V/1 A.
2. Power-up the fixture controller board.
3. Program the part for the desired functionality using ISSP MiniProg connector in reset mode of programming (see Figure 9).
4. Ensure that the Red, Green, Blue, and Amber channels are connected between the LED MCPCB and fixture controller.
5. Connect the D+ and D- lines of the DMX controller cable to the fixture controller input connector pins 3 and 4. These pins are identified by nets A and B on the schematic shown in Figure 7. Ensure that the ground line of the DMX controller cable and the ground wire of the fixture controller cable are connected.

Figure 9. Fixture Controller Board – Top Layer

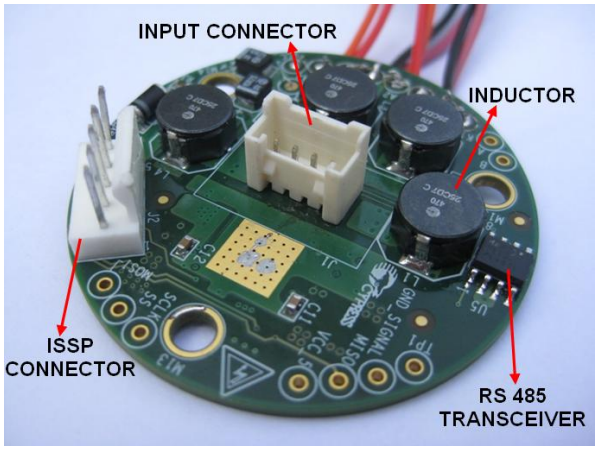
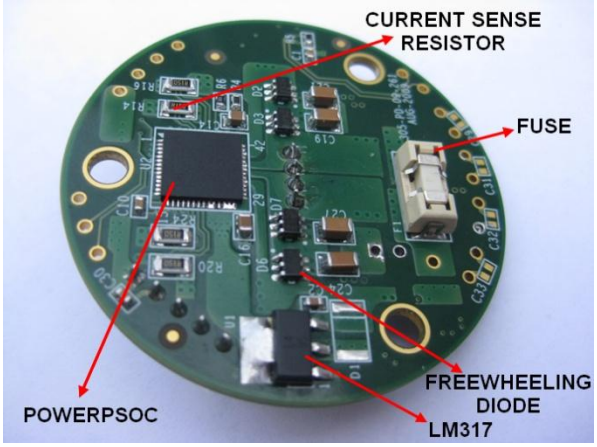


Figure 10. Fixture Controller Board – Bottom Layer



1. Power-up the DMX controller and vary the slider positions in the DMX Controller to see the change in the light output from the fixture. See Figure 6 on page 5.
2. Power-up the fixture controller board.
3. Program the part for the desired functionality using ISSP MiniProg connector in reset mode of programming (see Figure 9).
4. Ensure that the Red, Green, Blue, and Amber channels are connected between the LED MCPCB and fixture controller.
5. Connect the D+ and D- lines of the DMX controller cable to the fixture controller input connector pins 3 and 4. These pins are identified by nets A and B on the schematic shown in Figure 7. Ensure that the ground line of the DMX controller cable and the ground wire of the fixture controller cable are connected.
6. Power-up the DMX controller and vary the slider positions in the DMX Controller to see the change in the light output from the fixture. See Figure 6 on page 5 to see a DMX controller.

Component Reference Designators

Table 2 lists the reference designators of the significant components and connectors used on the PowerPSoC board and their description.

Table 2. List of Component Reference Designators

Reference Designator	Description
U1	LM317 – 5 V LDO regulator
U2	CY8CLED04D01-56LTXI – PowerPSoC device
U5	RS485 Transceiver – the physical layer for DMX512-MAX13082EESA
J1	Molex Connector
J2	ISSP Connector
R14, R16, R20, R24	Current Sense Resistors
D2, D3, D6, D7	Freewheeling Diodes
L1, L2, L3, L4	Inductors for the buck stage of LED drivers
C29, C31, C32, C33	Output Capacitors
C19, C21, C24, C27	Input Capacitors
F1	Fuse

Firmware Functionality

There are two firmware variants:

1. Color Mix
2. Tunable White Light

Color Mix

Six DMX512 sliders are required for Color Mix. The sliders are mapped to slots 1 to 6. The value of Slot 1 selects the mode of operation and the value of Slot 6 controls the output light intensity described in Table 3.

The Color Mix functionality has the following two modes of operation.

- **Direct Control Mode:** Sliders 2 to 5 are used to directly control the intensity of the Red, Green, Blue, and Amber LEDs individually.
- **Preset Color Mode:** Seven colors are sequentially displayed continuously. The seven colors, in order are White, Red, Green, Blue, Yellow, Magenta, and Cyan. The system displays each color for 5 seconds and then switches to the next color in the list. Slots 2 through 5 have no effect in this mode. In this mode, the intensity of the light output can be varied from 0% to 100% by varying the value of slot 6 from 0 to 255. A value of 0 corresponds to 0%, 127 corresponds to 50%, and 255 corresponds to 100% brightness.

Table 3. DMX 512 Slider Positions for Color Mix Demo

Slider	Slider Position	
Slider 1	Value <= 85	LEDs are OFF
	Value > 85 to <= 170	Direct Control Mode
	Value >170 to <= 255	Preset Color Mode
Sliders 2-5	Controls the Intensity of Red, Green, Blue, and Amber LEDs respectively	
Slider 6	Controls the Intensity of light output in the Preset Color Mode	

Instructions

1. Power-up the DMX512 Controller.
2. To enable Direct Control mode of operation, set Slider 1 to a value between 86 and 170.
3. Increase the value of slider 2 from 0 to 255; you can see the intensity of the red LED vary from minimum to maximum.
4. Similarly, increase Slider 3 to 5 from 0 to 255 for the other three LEDs.
5. Vary the slider positions in different combinations to output different colors with varying intensity.
6. Next, set the value of slider 1 to a value greater than 170 to change to the Preset Color mode of operation. Set the value of slot 6 to 255 for maximum intensity. Seven colors are displayed in a sequential manner with a 5-second delay between them. In this mode, sliders 2 through 5 have no effect.
7. Vary the value of slot 6 from 0 to 255 to vary the intensity of the light output from 0% to 100%.

Tunable White Light

Three DMX512 Sliders are required for Tunable White Light. The sliders are mapped to slots 1 through 3.

The Tunable White Light functionality has the following two modes of operation.

- **Direct Control Mode:** In this mode, the White Light varies from Warm White to Cool White. Use Slider 2 to vary the color temperature from 2,600 K to 25,000 K, in steps of 90 K.
- **Preset Color Mode:** In this mode, ten different shades of white light are displayed sequentially. The corresponding color temperatures are 2,700 K, 3,000 K, 3,500 K, 4,000 K, 4,500 K, 5,000 K, 5,700 K, 6,700 K, 8,000 K, and 10,000 K. Each color temperature is ON for five

seconds and automatically switches to the next preset value.

In both of these modes, the intensity of the light output can be varied from 0% to 100% by varying the value of Slot 3 from 0 to 255. A value of 0 corresponds to 0%, 127 corresponds to 50%, and 255 corresponds to 100% brightness.

Table 4. Tunable White Light Slider Positions

Slider	Slider Position	
Slider 1	Value <= 85	LEDs are OFF
	Value > 85 to <= 170	Direct Control Mode
	Value >170 to <= 255	Preset Color Mode
Slider 2	Vary the Color Temperature from 2,600K to 25,000K	
Slider 3	Controls the intensity of light output in both Direct Control and Preset Color modes	

Instructions

1. Power-up the DMX512 Controller.
2. Set the value of slot 1 to any number between 86 and 170 to enable Direct Control mode of operation. Set the value of slot 3 to 255.
3. Increase value of slot 2 from 0 to 255; you can see the output color temperature varying from warm white (2,600 K) to cool white (25,000 K).
4. Vary the value of slot 3 from 0 to 255, to see the intensity of light output vary from minimum to maximum.
5. Next, set the value of slot 1 to a value greater than 170 to change the mode of operation to Preset Color Mode. Set the value of slot 3 to 255 for maximum output light intensity. Ten color temperatures are displayed in a sequential manner with a 5-second delay.
6. Vary the value of slot 3 from 0 to 255 to vary the intensity of the light output from 0% to 100%.

Accompanying Software

The firmware described in this application note is developed using PSoC Designer. The latest version of PSoC Designer is available for free, and can be downloaded from http://www.cypress.com/psocdesigner/.

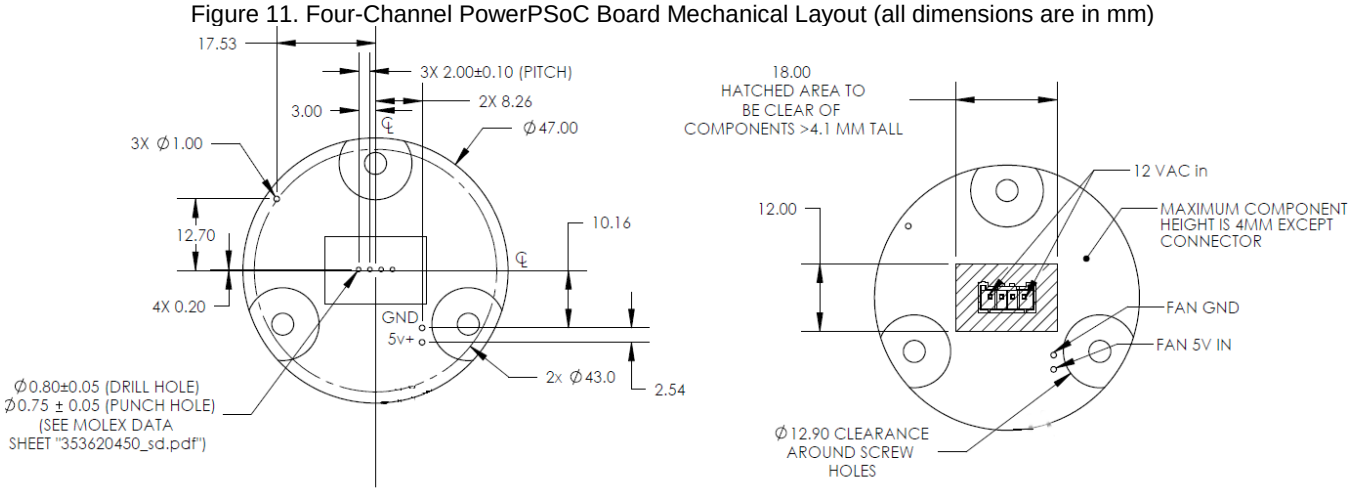
Summary

This application note gives detailed instructions to develop a small form factor integrated MR16 Fixture Controller System based on the PowerPSoC family of devices. In addition, this solution enables you to create a network of lighting fixtures based on the DMX512 communication interface.

Appendix

Figure 11 illustrates the form factor of the four-channel PowerPSoC based LED fixture controller.

Figure 11. Four-Channel PowerPSoC Board Mechanical Layout (all dimensions are in mm)



References

See the following application notes to know more about DMX 512 interfacing and implementation of PowerPSoC Lighting solutions:

- AN47372: PrISM™ Technology for LED Dimming
- CY8CLED0xx0x: Topology and Design Guide for Circuits Using PowerPSoC
- CY8CLED0xx0x - PowerPSoC® Firmware Design Guidelines, Lighting Control Interfaces

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**	2769369	SNVN	09/25/2009	New Spec.
*A	2811898	SNVN	11/20/2009	Update operating voltage max to 12 V. Updated Figure 11 with latest mechanical layout. Updated Figure 3 with latest block diagram.
*B	3176807	SNVN	02/18/2011	Updated software version with PSoC Designer 5.1 and PSoC Programmer 3.12 Updated firmware to remove warnings when compiled with ImageCraft compiler Document updated based on MEH-126
*C	3385166	MKKU	09/27/2011	Projects updated and tested with PD 5.1 SP2. Updated template.
*D	4542414	SNVN	10/17/2014	Projects updated with PD 5.4. Images updated. Updated template.
*E	4559173	SNVN	11/05/2014	Corrected the abstract.

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