

TI Designs: TIDA-01463

IEEE802.3bt Power Over Ethernet (PoE) Connected LED Lighting Reference Design



Description

This Power over Ethernet (PoE) reference design supplies power and data over a single Ethernet cable to a connected LED lighting ballast. This reference design uses TI's TPS2372-4 PoE powered device (PD) interface, LM3409 buck controller, LM5165 buck converter, TPS62740 buck converter, TM4C1292NCPDT microcontroller (MCU), TPD4E05U06-Q1 ESD protection device, and DP83822I Ethernet PHY to provide power to the LED light remotely controlling the brightness and dimming parameters of the LED light while connected to the network.

Resources

TIDA-01463	Design Folder
TPS2372	Product Folder
LM3409HV	Product Folder
LM5165	Product Folder
TPS62740	Product Folder
TM4C1292NCPDT	Product Folder
DP83822I	Product Folder
TPD4E05U06-Q1	Product Folder

Features

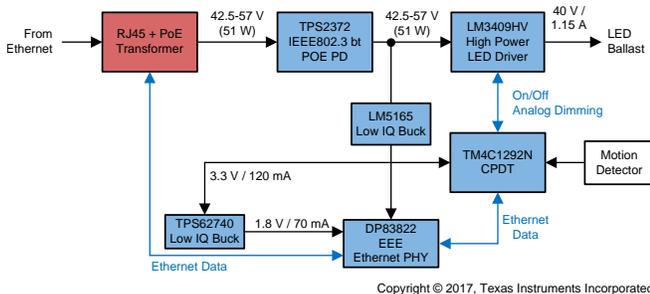
- IEEE802.3bt Compliant PD
- 51W Class 6 Power Level
- IP-Addressable Board for Network Connected Control
- Minimal Standby Power Consumption of 181 mW With EEE (IEEE802.3az) Support
- Automatic Maintain Power Signature
- High Power Allows for Wide Range of Lighting Applications
- Small Board Size Fits Into Typical LED Ballast Enclosure

Featured Applications

- PoE Lighting
- Four Pair Non-Isolated PoE



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1 System Description

The TM4C129x family of MCUs features an integrated Ethernet PHY and MAC with cryptographic modules and many serial interfaces for control and sensor data gain. The TM4C129x adds a layer of intelligence at the remote node when integrated with the PoE design. This addition allows customers to leverage their existing network to communicate and control devices securely. The PoE solution delivers power that reduces the system cost in IoT space, which adds value to the products.

1.1 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
DC input voltage	0 V to 57 V
Maximum sinking current	1.2 A
Maximum output voltage	40 V
Constant output current	1.15 A
Minimum system standby power consumption with EEE enabled	181 mW
MPS overhead power consumption	45 mW
PoE power class	Class 6, 51 W at PD input
System efficiency	90%
Printed circuit board (PCB) size	Rectangular, 1.06" x 6.1" (26.9 mm x 154.9 mm), four-layer PCB

2 System Overview

2.1 Block Diagram

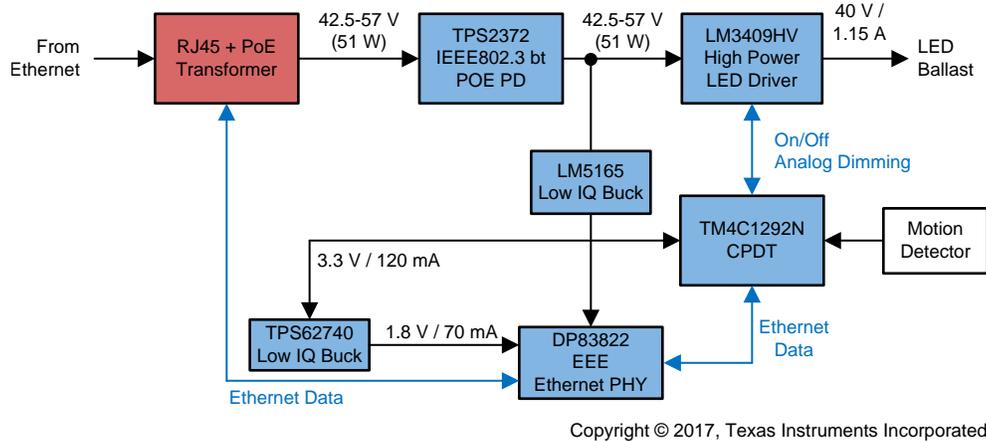


Figure 1. PoE Lighting System Block Diagram

2.2 Design Considerations

This design features a non-isolated buck converter that offers *low voltage* (< 60 V) locally to each LED lighting ballast, so an electrician is not required. The approximate 48 V received by the TPS2372 is bucked down to 3.3 V by the LM5165 to power the MCU, which is again bucked down to 1.8 V to power the ultra-low-power DP83822I Ethernet PHY. The remaining approximate 46 W is sent along to the LED ballast.

2.3 Highlighted Products

This reference design features the devices listed in [Table 2](#).

Table 2. Highlighted Products

PART NUMBER	DESCRIPTION
TPS2372-4	IEEE 802.3bt PoE, high-power PD interface with automatic MPS and autoclass
LM3409HV	PFET buck controller for high-power LED drivers
LM5165	3-V to 65-V, 150-mA synchronous buck converter with ultra-low IQ
TPS62740	Ultra-low-power, 300-mA step-down buck DC/DC converter with 360- η A IQ
TM4C1292NCPDT	IoT-enabled, high-performance, 32-bit ARM® Cortex®-M4F based MCU
DP83822I	Robust, low-power 10/100 Ethernet physical layer transceiver
TPD4E05U06-Q1	Automotive 4-channel ESD protection solution for SuperSpeed (up to 5 Gbps) interface

2.3.1 TPS2372-4

The TPS2372 contains all of the features required to implement an IEEE802.3at or IEEE802.3bt (draft) (Type 1-4) PD. The low internal switch resistance allows the TPS2372-4 and TPS2372-3 to support high-power applications up to 90 W and 60 W respectively. Assuming usage of 100m CAT5 cable, this translates into 71.3 W and 51 W at PD input.

The TPS2372 operates with enhanced features. The automatic MPS function enables applications that require very low-power standby modes. The TPS2372 automatically generates the necessary pulsed current to maintain the power source equipment (PSE) power. An external resistor is used to enable this functionality and to program the MPS pulsed current amplitude.

The TPS2372 also implements a delay function to allow the remote PSE to complete its inrush phase before releasing the Power Good (PG) output. This ensures that the IEEE802.3bt (draft) startup requirements are met. The autotransmission enable input also allows advanced system power optimization modes compliant with IEEE802.3bt (draft) standard.

Figure 2 shows the TPS2372 block diagram.

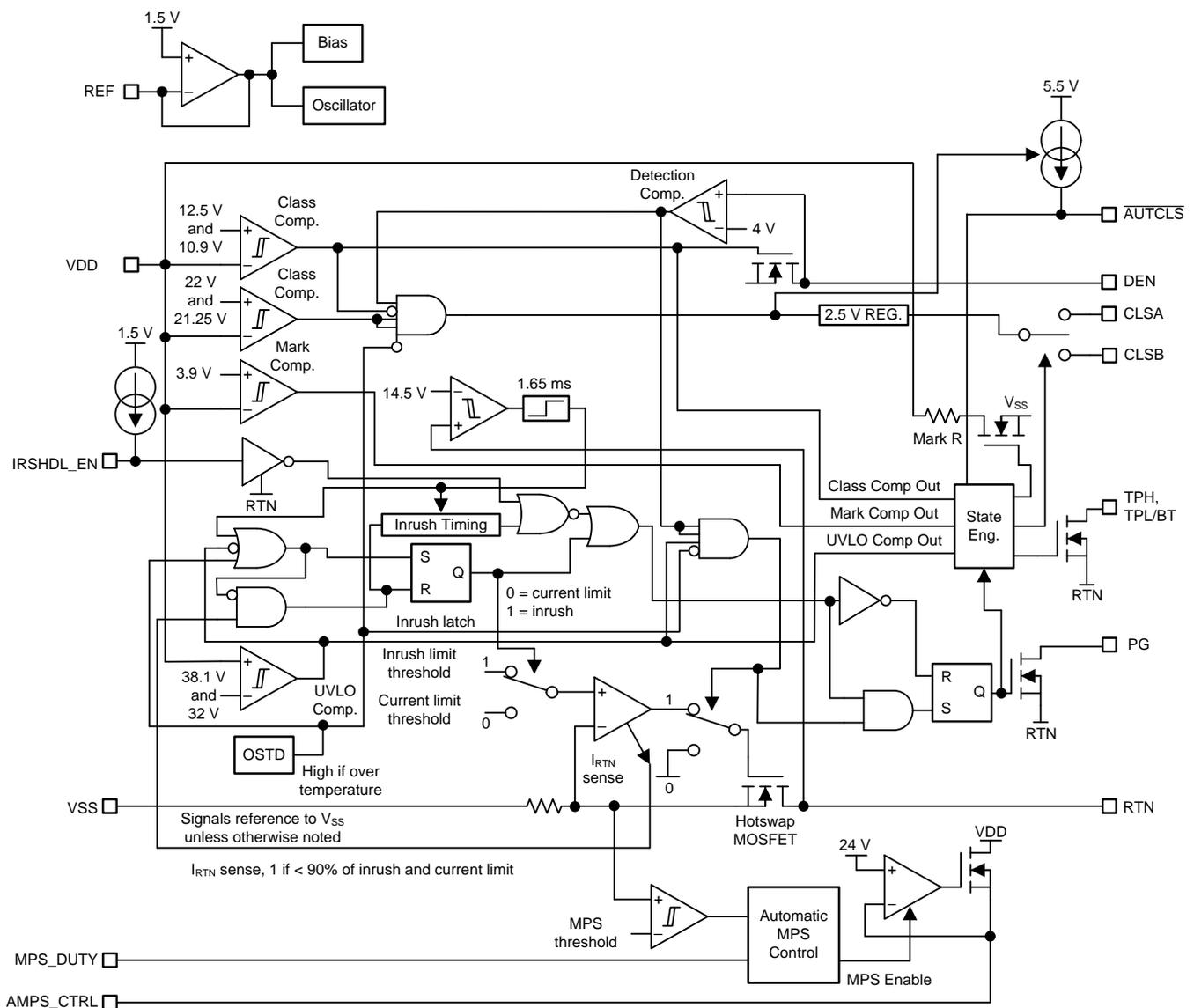


Figure 2. TPS2372 Block Diagram

2.3.2 LM3409HV

The LM3409HV is a P-channel MOSFET (PFET) controller for step-down (buck) current regulators. The device offers a wide input voltage range, high-side differential current sense with low adjustable threshold voltage and fast output enable-disable function, and a thermally enhanced 10-pin, HVSSOP package. These features combine to make the LM3409HV ideal for use as constant current sources for driving the LEDs with a forward current of the necessary 1.15 A.

The LM3409HV device uses constant off-time (COFT) control to regulate an accurate constant current without requiring for external control loop compensation. Analog and pulse width modulation (PWM) dimming are easy to implement and result in a highly-linear dimming range with excellent achievable contrast ratios. Programmable undervoltage lockout (UVLO), low-power shutdown, and thermal shutdown complete the feature set.

Figure 3 shows the LM3409HV block diagram.

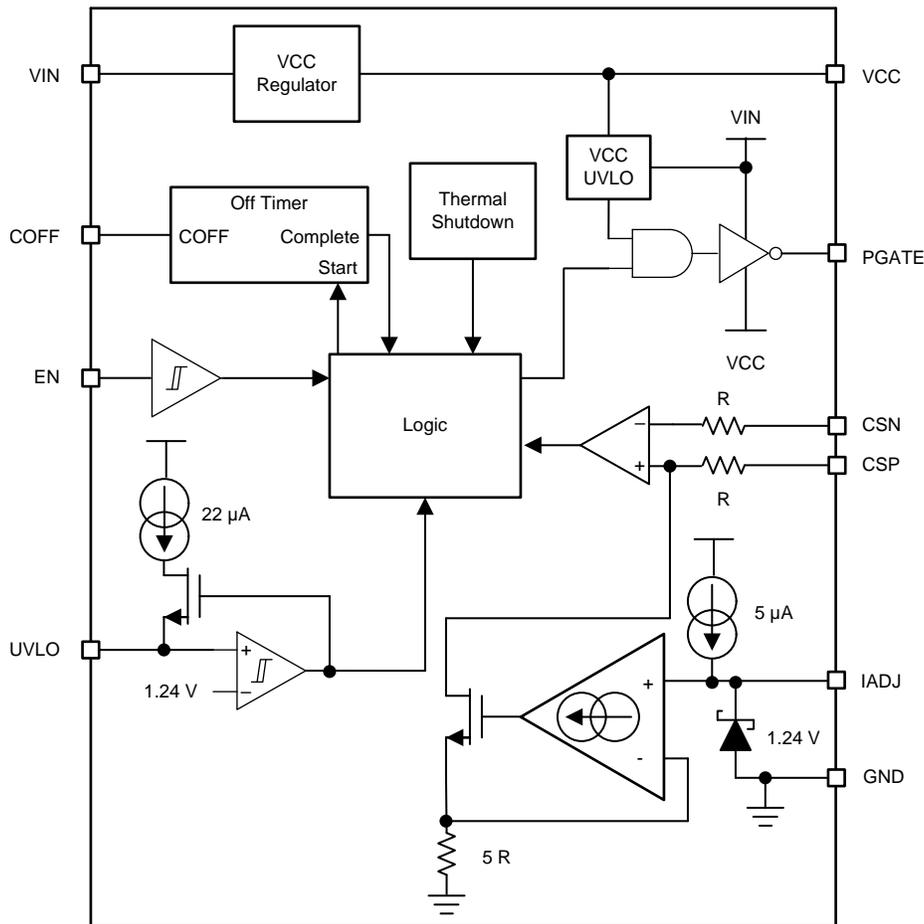


Figure 3. LM3409HV Block Diagram

2.3.3 LM5165

The LM5165 device is a compact, easy-to-use, 3-V to 65-V, ultra-low IQ synchronous buck converter with high efficiency over wide input voltage and load current ranges. With integrated high-side and low-side power MOSFETs, up to 150 mA of output current can be delivered at fixed output voltages of 3.3 V or 5 V or at an adjustable output. The converter is designed to simplify implementation while providing options to optimize the performance for the target application. Pulse frequency modulation (PFM) mode is selected for optimal light-load efficiency or constant on-time (COT) control for nearly constant operating frequency. Both control schemes do not require loop compensation while providing excellent line and load transient response and short PWM on time for large, step-down conversion ratios.

The high-side, P-channel MOSFET can operate at 100% duty cycle for lowest dropout voltage and does not require a bootstrap capacitor for gate drive. Also, the current limit setpoint is adjustable to optimize inductor selection for a particular output current requirement. Selectable and adjustable start-up timing options include minimum delay (no soft start), internally fixed (900 μ s), and externally programmable soft start using a capacitor. An open-drain, PGOOD indicator can be used for sequencing, fault reporting, and output voltage monitoring.

Figure 4 shows the LM5165 block diagram.

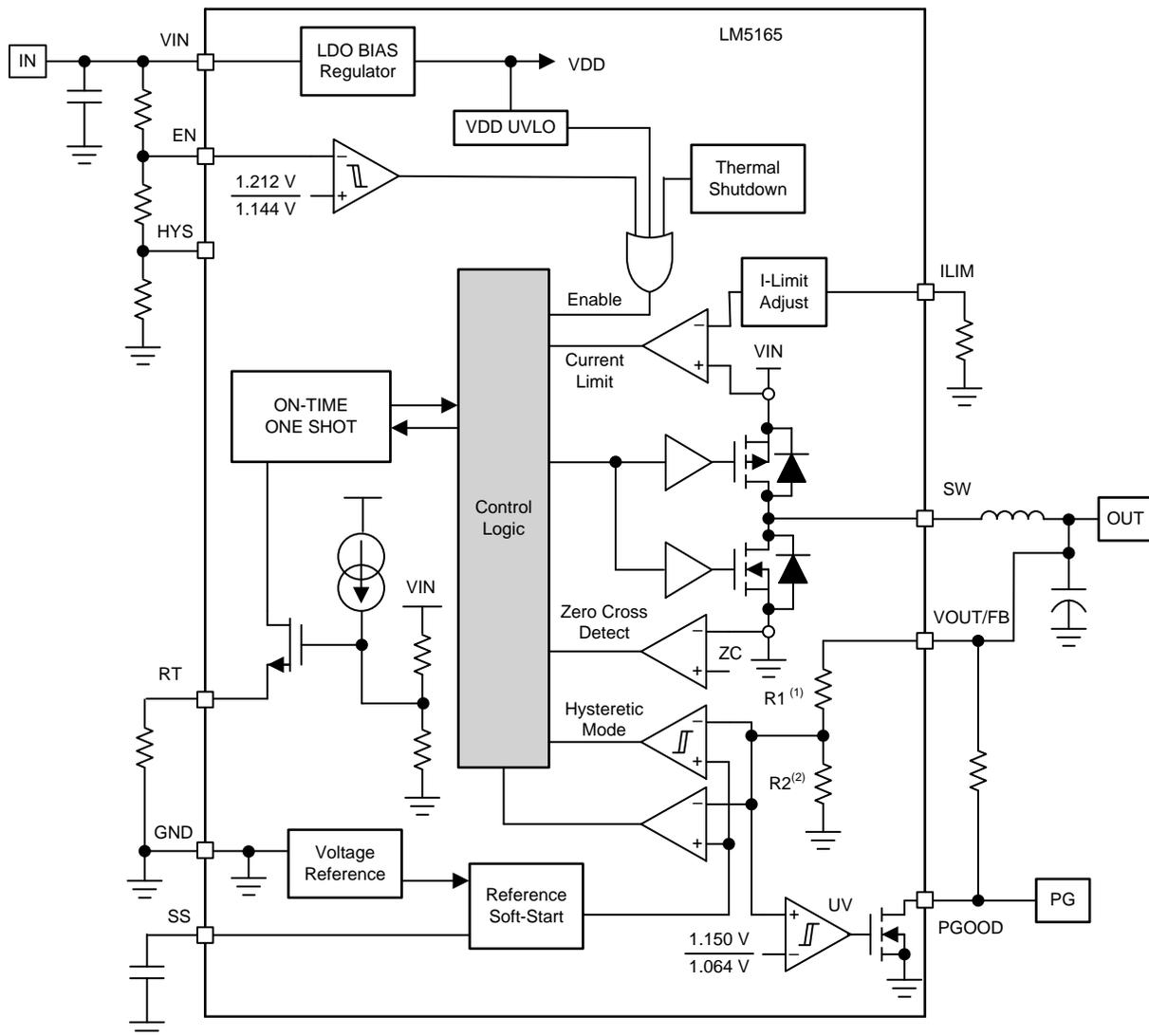


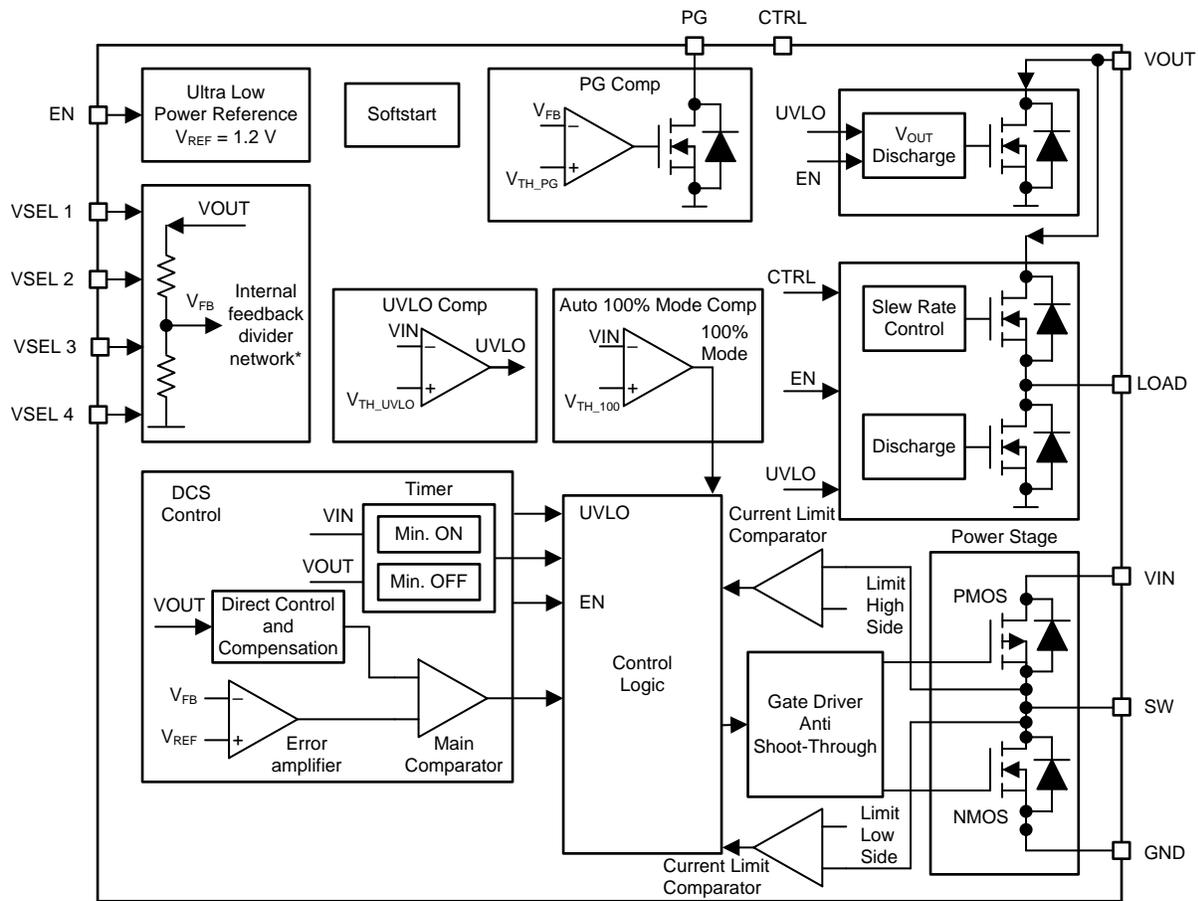
Figure 4. LM5165 Block Diagram

2.3.4 TPS62740

The TPS6274x is the industry’s first step-down converter featuring typical, 360-ηA quiescent current and operating with a tiny 2.2-μH inductor and 10-μF output capacitor. This new DCS-Control™ based device extends the light-load efficiency range below 10-μA load currents. TPS62740 supports output currents up to 300 mA, and TPS62742 supports up to 400 mA. The device operates from rechargeable Li-Ion batteries, Li-primary battery chemistries, such as Li-SOCl2 and Li-MnO2, and two or three cell alkaline batteries. The input voltage range up to 5.5 V also allows operation from a USB port and thin-film, solar modules. The output voltage is user selectable by four VSEL pins within a range of 1.8 V to 3.3 V in 100-mV steps.

TPS6274x features low-output ripple voltage and low noise with a small-output capacitor. Once the battery voltage comes close to the output voltage (close to 100% duty cycle), the device enters no ripple, 100% mode operation to prevent an increase of output ripple voltage. The device then stops switching, and the output is connected to the input voltage. The integrated slew rate controlled load switch provides typical 0.6-Ω on-resistance and can distribute the selected output voltage to a temporarily used subsystem.

Figure 5 shows the TPS62740 block diagram.



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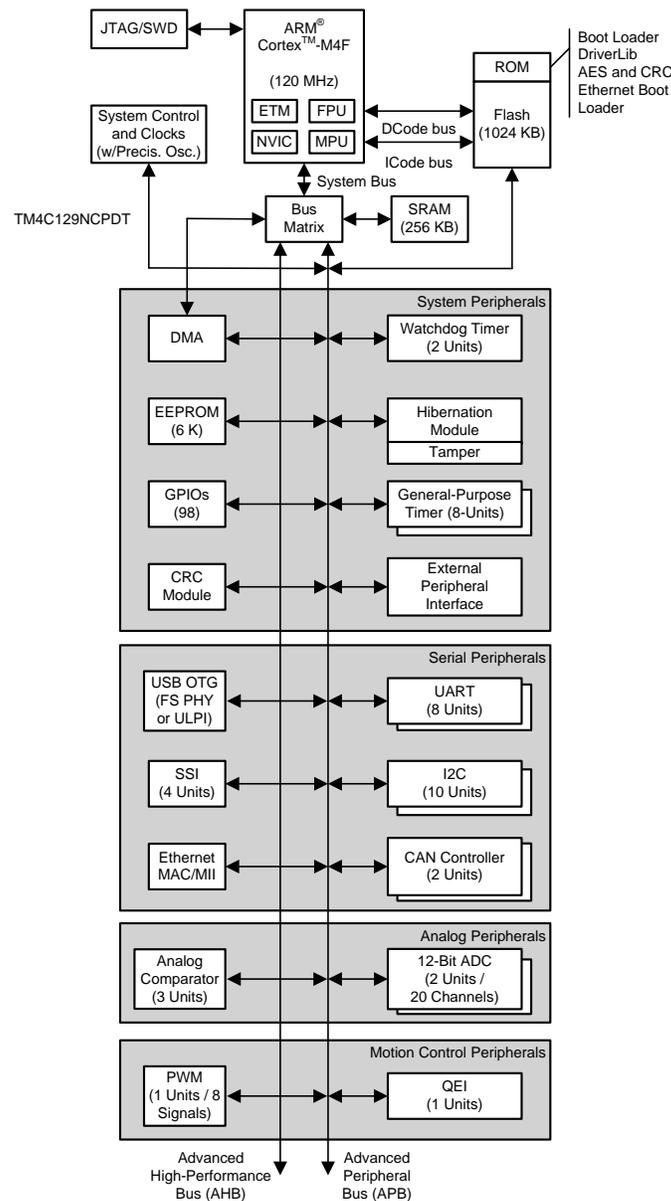
Figure 5. TPS62740 Block Diagram

2.3.5 TM4C1292NCPDT

Tiva™ C Series MCUs integrate a large variety of rich communication features to enable a new class of highly-connected designs with the ability to allow critical, real-time control between performance and power. The MCUs feature integrated communication peripherals along with other high-performance analog and digital functions to offer a strong foundation for many different target uses, spanning from human machine interface (HMI) to networked system management controllers.

In addition, Tiva C Series MCUs offer the advantages of ARM's widely available development tools, System-on-Chip (SoC) infrastructure, and a large user community. Additionally, these MCUs use ARM's Thumb®-compatible Thumb-2 instruction set to reduce memory requirements and, thereby, cost. Finally, the TM4C1292NCPDT MCU is code-compatible to all members of the extensive Tiva C Series, which provide flexibility to fit precise needs.

Figure 6 shows the TM4C1292NCPDT block diagram.



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Figure 6. TM4C1292NCPDT Block Diagram

2.3.6 DP83822I

The DP83822I is a low-power, single-port 10/100 Mbps Ethernet PHY. The device provides all physical layer functions required to transmit and receive data over both standard, twisted-pair cables or connect to an external, fiber-optic transceiver. Additionally, the DP83822I provides flexibility to connect to a MAC through a standard MII, RMII or RGMII interface.

The DP83822I offers integrated cable diagnostic tools, built-in self-test (BIST), and loopback capabilities for ease of use. The device supports multiple industrial buses with its fast, link-down timing as well as Auto-MDIX in forced modes.

The DP83822I offers an innovative and robust approach for reducing power consumption through EEE, Wake on Lan (WoL), and other programmable energy savings modes.

Figure 7 shows the DP83822I block diagram.

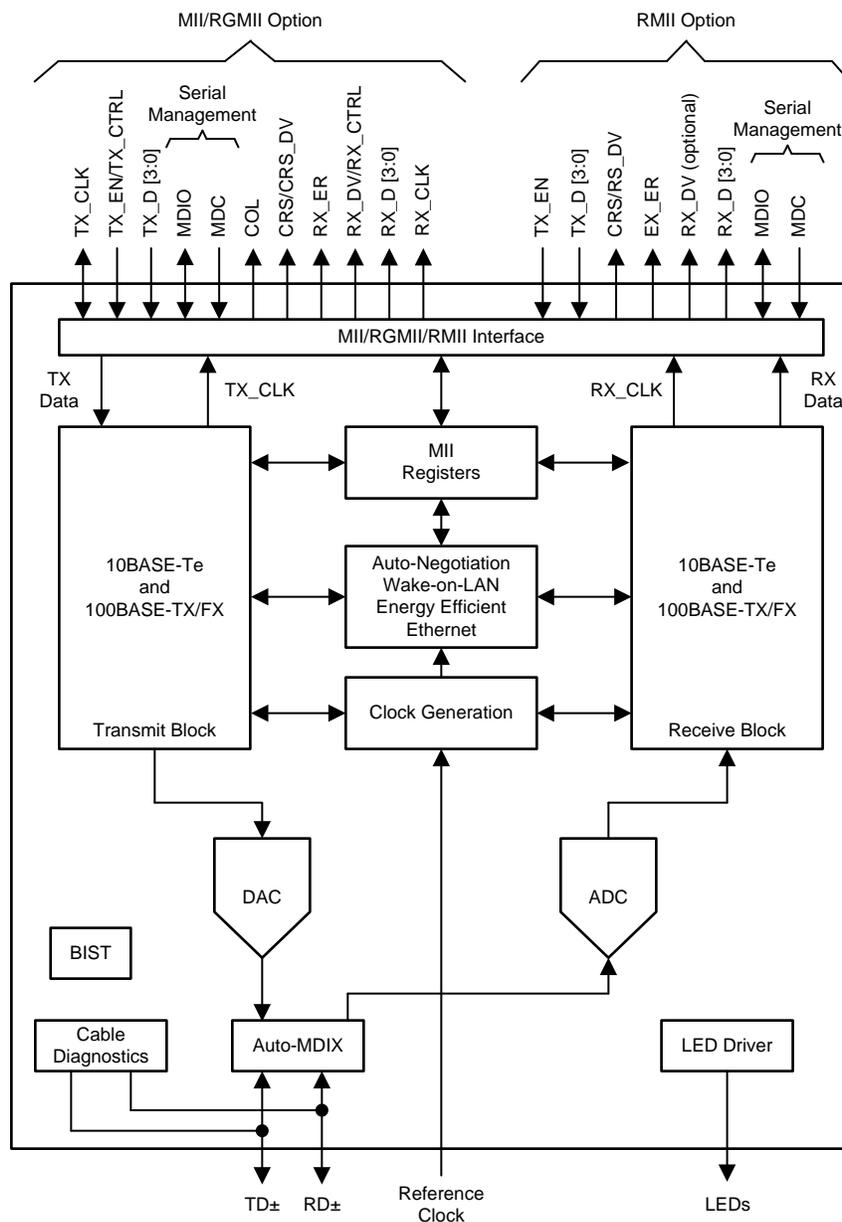


Figure 7. DP83822I Block Diagram

2.3.7 TPD4E05U06-Q1

The TPDxE05U06-Q1 is a family of unidirectional transient voltage suppressor (TVS) electrostatic discharge (ESD) protection diodes with ultra-low capacitance. They are rated to dissipate ESD strikes above the maximum level specified in the IEC 61000- 4-2 level 4 international standard. The ultra-low loading capacitance makes these devices ideal for protecting any high-speed signal applications up to 6 Gbps. These devices are also available without automotive qualification: TPDxE05U06.

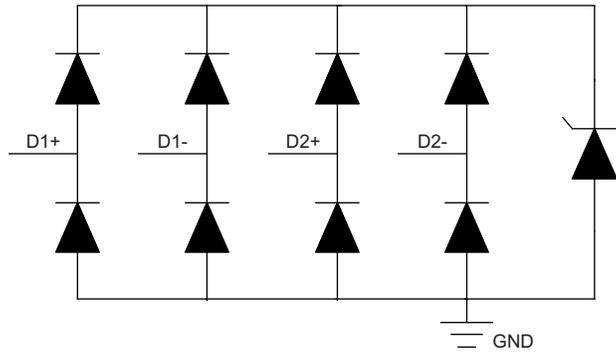


Figure 8. TPD4E05U0-Q1 Block Diagram

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

This section provides an overview of the TIDA-01463 design board and all the external connections required to evaluate the reference design.

3.1.1 Hardware

To create the solution, the design board must be used as the base board to which the LED lighting ballast is connected. As the solution is PoE, the user must have a PoE PSE available that powers the board during configuration, a debug probe to load the firmware to run the application, and a computer to run the software.

Table 3. Hardware Setup

ITEM	COMMENTS	PART NUMBER
TIDA-01463 PCB with IR sensor	—	TIDA-01463
Two CAT5e Ethernet	Both <100-m length	—
PSE	Must be IEEE 802.3bt compliant and capable of supplying 60 W	TPS23861EVM-612
XDS110 JTAG debug probe	Debugger option one	TMDSEMU110-U
MSP432P401R LaunchPad™	Debugger option two	MSP-EXP432P401R
LED lighting ballast	Must be <40 V and <46 W	—
PC with Ethernet port	For running PMP20537 demonstration	—

3.1.1.1 TIDA-01463 PCB With IR Sensor

The TIDA-0463 reference design kit includes the TIDA-01463 PCB, an IR sensor board, and a 4-pin header for clearance between the capacitor and the sensor board.

The sensor board uses the Panasonic EKMB1301111K passive infrared sensor to detect motion. The use of this board is required for basic operation of the TIDA-01463 reference design. The design files for the IR sensor board are included with the TIDA-01463 design files.



Figure 9. TIDA-01463 PCB With IR Sensor

To setup the demonstration, configure the headers as in [Table 4](#).

Table 4. Header Configurations

DESIGNATOR	CONFIGURATION	DESCRIPTION
J1	—	PoE input
J2	Short	Short to enable autoclass
J3	Open	Open selects 5.4% MPS duty cycle
J4	Open	Open to enable 8.4ms inrush delay
J5	Short	Short to connect PoE input current
J6	Short	Short to enable automatic MPS
J7	—	LED Output
J8	Short	Short to connect 3.3 V to MCU V _{DD}
J9	—	10-Pin JTAG connects to debug probe
J10	—	4-Pin I2C connects to IR sensor
J11	Short middle to low	3-pin connects Ethernet PHY Vcc (middle pin) to 1.8 V (lower pin) or 3.3 V (higher pin)
J12	Short	Connects 3.3 V to MCU V _{DDIO}

Figure 10 shows these headers.

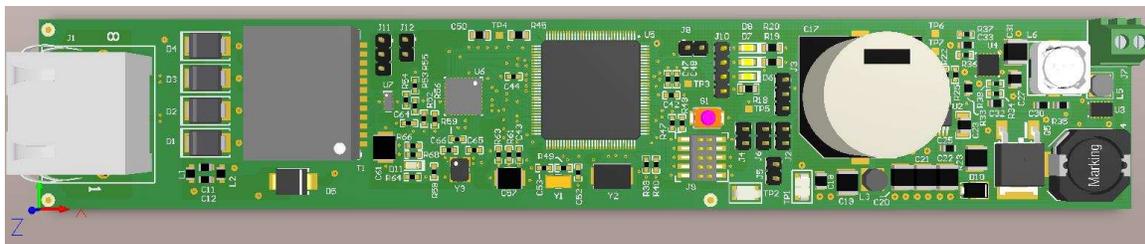


Figure 10. TIDA-01463 PCB Headers

3.1.1.2 CAT5e Ethernet Cable

The IEEE802.3bt standard recommends using CAT5e cable at the minimum. Greater cable standards (CAT6, 6A) may reduce cable losses and improve system efficiency. The cable length between the PSE and PD must be less than 100 m.

3.1.1.3 Power Sourcing Equipment (PSE)

To take full advantage of this reference design, the PSE must be compliant with the IEEE 802.3bt standard and must be able to source 60 W from its PoE output (PoE class 6). [Figure 11](#) shows a Phihong® midspan PSE that meets these requirements.



Figure 11. Phihong® Class 6 PSE

3.1.1.4 Debug Probe for Tiva™ C Series

There are two hardware options: using a standalone XDS110 debug probe or using the XDS110 debugger from the MSP432™ LaunchPad (MSP EXP432P401R).

The TI XDS110 connects to the TIDA-01463 design board through a TI 20-pin connector with an attached adapter for the ARM, 10-pin, JTAG cable. The design board then connects to the host PC using USB2.0. [Figure 12](#) shows the XDS110 debug probe.



Figure 12. XDS110 JTAG Debug Probe

The XDS110-ET debug probe above the dotted line on the MSP432P401R LaunchPad will work the same, but the probe must be isolated from the bottom of LaunchPad by depopulating the RST, TMS, TCK, TDO, and TDI headers on the isolation block, J101. A 10-pin JTAG cable can be attached to J102, which then connects to the host PC using a micro USB.

Figure 13 shows the MSP432P401R LaunchPad with depopulated JTAG headers.

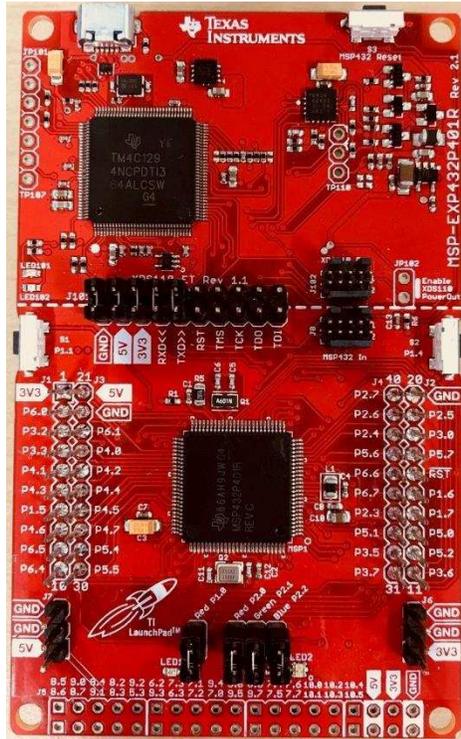


Figure 13. MSP432P401R LaunchPad™

3.1.1.5 LED Lighting Ballast

A CREE LMH2 LED module was used for the demonstration. This module is rated for 39 V, 900 mA.



Figure 14. CREE LMH2 LED Module

3.1.2 Software

The UniFlash and PMP20537 demonstrations are the required software to run the TIDA-01463 demonstration.

3.1.2.1 UniFlash

UniFlash is used to flash firmware on to the TIDA-01463, assign a MAC address, and perform other debug utilities for the onboard TM4C1292NCPDT MCU.

1. UniFlash can be downloaded from the [UniFlash tool folder](#) by clicking *Get Software* beside the most current version of the software.
2. This link will open the [CCS UniFlash](#) page on *processors.wiki.ti.com*. There, the desktop version of UniFlash can be downloaded for Windows, Linux, or MacOS.
3. Run the installer. Version 4.2 of UniFlash is installed under *C:\ti\uniflash_4.2* by default.

Instructions for how to use UniFlash can be found in [Section 3.2.1.2](#).

3.1.2.2 PMP20537 Demonstration

The PMP20537 demonstration is used to control the LED lighting ballast attached to the TIDA-01463 design PCB on the network.

1. Download PMP20537 demonstration from the TIDA-01463 tools folder.
2. Run the Setup_PMP20537_DEMO installer. The program will be installed under *C:\Program Files (x86)\Texas Instruments\PMP20537* by default.

Instructions of how to run PMP20537 demonstration can be found in [Section 3.2.1.5](#).

3.2 Testing and Results

3.2.1 Test Setup

This section elaborates on how to flash PCB, connect the system, and run the application software.

3.2.1.1 Attaching Debug Probe From MSP432P410R LaunchPad™ to TIDA-01463 PCB

The standalone XDS110 debug probe has a very simple hardware setup. Attaching the 10-pin ARM JTAG adapter to the debug port and connecting to the TIDA-01643 debug pins, J9, is all that is required.

The XDS110-ET debug probe on the MSP432P410R LaunchPad development kit can externally interface to most ARM Cortex-M devices. This functionality is enabled by the J102, 10-pin, Cortex-M JTAG connector. The 10-pin cable can be purchased from Digi-Key Electronics® (sold separately from the LaunchPad development kit).

If unable to provide power to the TIDA-01463 PCB through its PoE port while using UniFlash, 3.3 V of output power can be sourced from the XDS110-ET when jumper JP102 is connected. This connection allows the XDS110-ET to power the external target at 3.3 V through pin 1. By default JP102 is not populated.

1. Remove jumpers on the JTAG signals on the J101 isolation block including RST, TMS, TCK, TDO, and TDI as seen in [Figure 15](#).



Figure 15. MSP432P410R LaunchPad™ Isolation Block

2. Connect the 10-pin JTAG connector from J102 on the LaunchPad to J9 on the TIDA-0163 PCB, and connect the LaunchPad's micro USB to a computer.
3. If power is not sent through JTAG, the PCB must receive power through the PoE input.

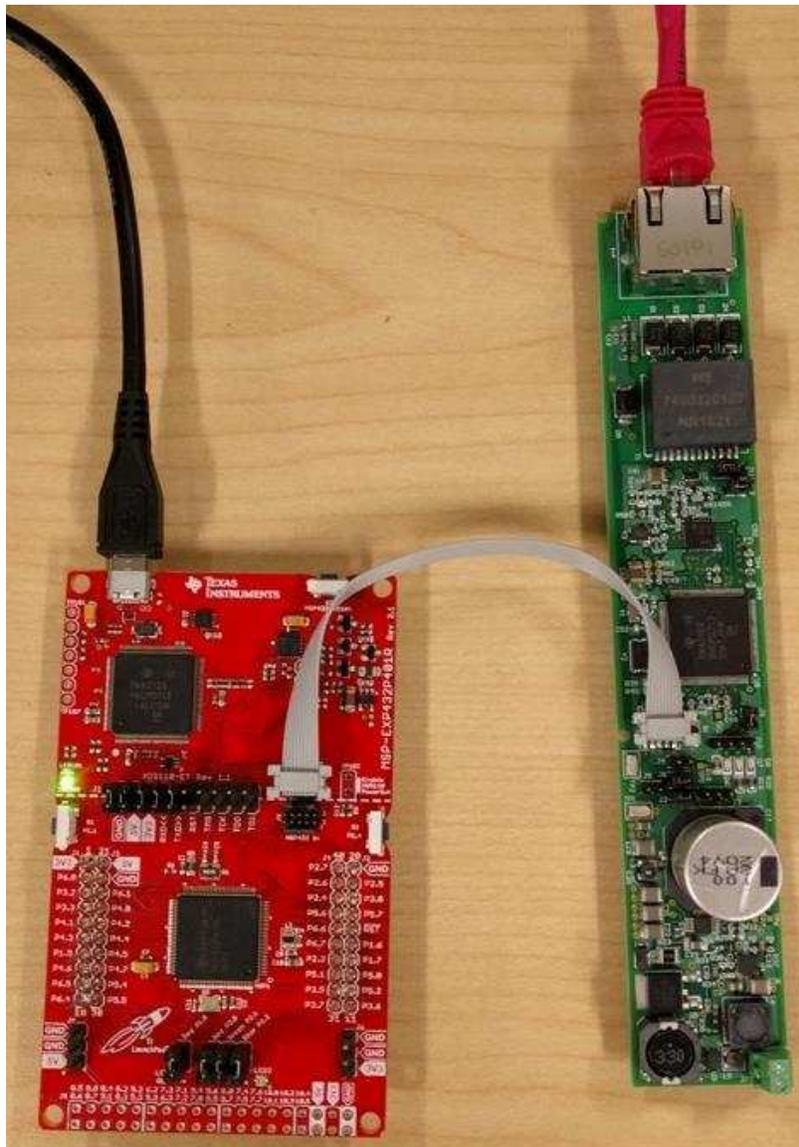


Figure 16. PCB Connected to XDS110-ET on LaunchPad

3.2.1.2 Flashing TIDA-01463 PCB Using UniFlash

UniFlash is a standalone tool used to program on-chip flash memory on many TI MCUs, including the Tiva C. Below are instructions on how use UniFlash to flash firmware and assign a MAC address to the TIDA-01463 PCB.

NOTE: While using UniFlash, do not connect the data side of the PSE into the host computer. UniFlash is a web-based application, so it will need internet access to successfully communicate with the TM4C1292NCPDT through JTAG.

1. After starting a new UniFlash session, the detected device will be an MSP432P401R LaunchPad if using the onboard XDS110-ET. A new configuration must be selected. The device is a *Tiva TM4C1292NCPDT*, and the connection is the *Texas Instruments XDS110 USB Debug Probe* (see [Figure 17](#)).

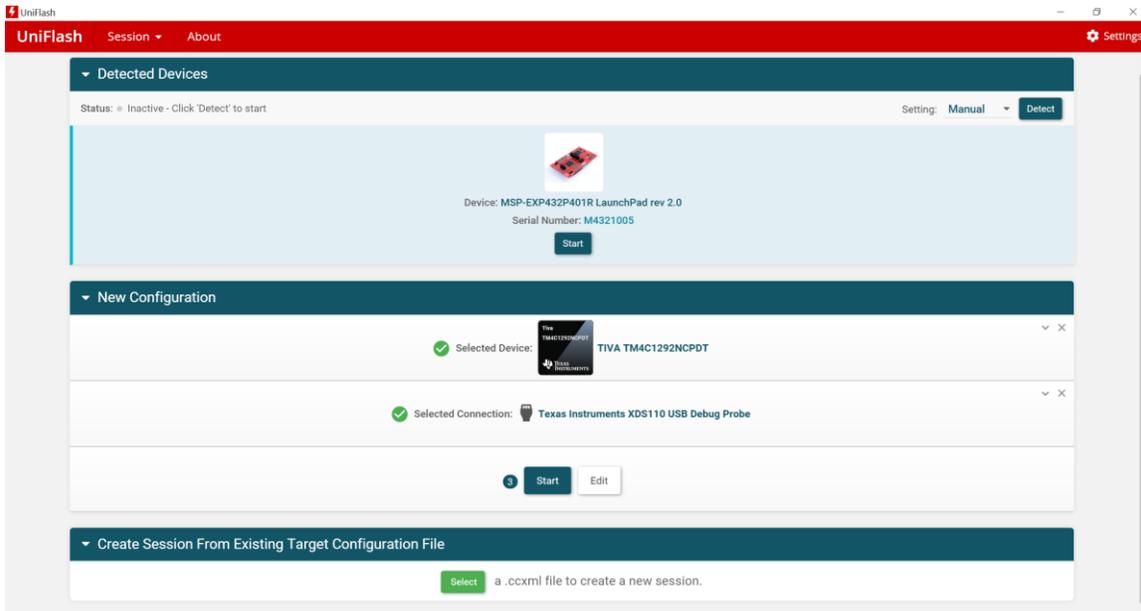


Figure 17. Device Configuration in UniFlash

2. To flash an image on to the TM4C1292NCPDT, navigate to the *Program* tab on the left sidebar. Browse for the *poe_light.bin* file (downloaded from TIDA-01463 tools folder), then click *Load Image* (see [Figure 18](#)).

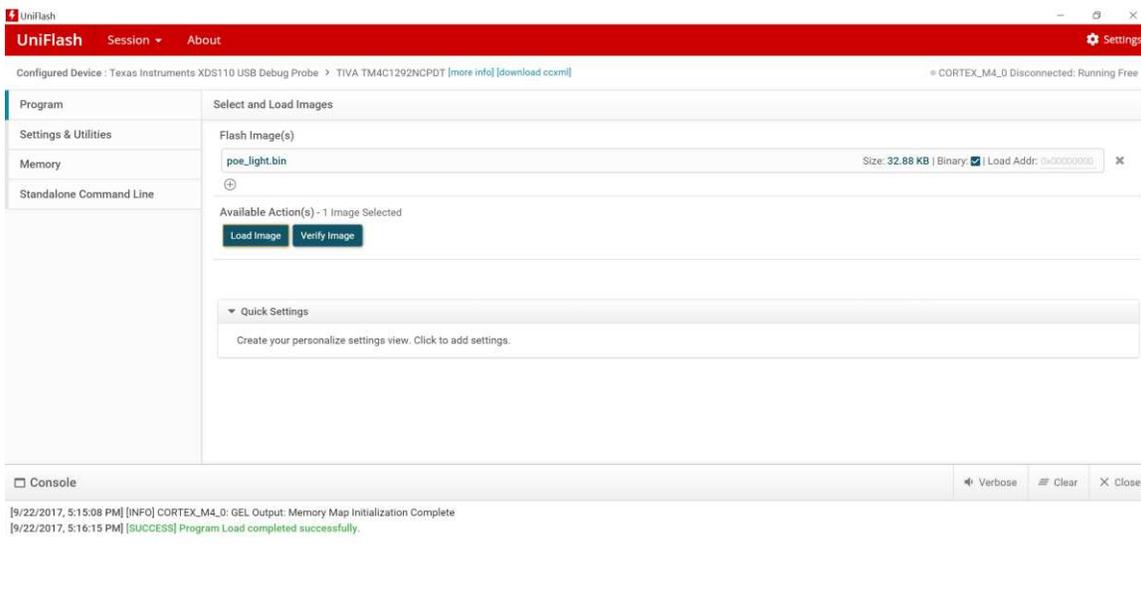


Figure 18. Flashing the PCB in UniFlash

- To assign a MAC address to the TM4C1292NCPDT, go to the *Settings & Utilities* tab and scroll to *MAC Address Mode*. If there is an unused board, the MAC address will be *ff-ff-ff-ff-ff-ff* after clicking *Read MAC Address Value*.

WARNING

Note that committing a MAC address is permanent. If applicable, be sure that the MAC address to be assigned is a part of the block of addresses assigned to the designated organization.

A good practice is to assign the MAC address without checking *Commit MAC Address*, then reading the MAC address from the board to be sure there are no typos. Only then should a commit operation be performed.

- To permanently assign a MAC address, check *Commit MAC Address* before clicking *Program MAC Address*.

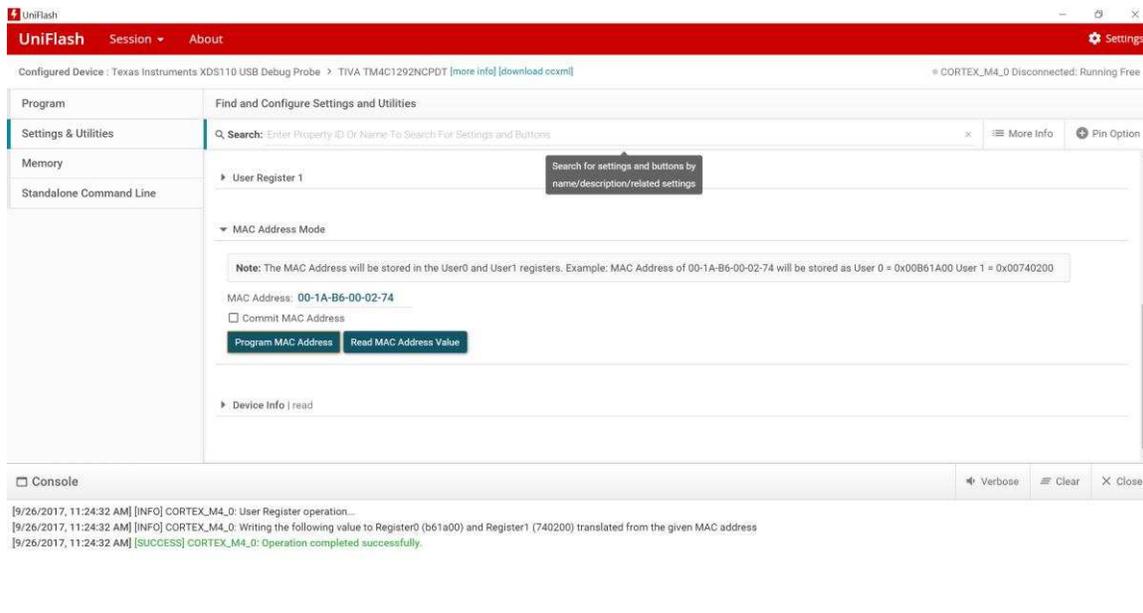


Figure 19. Assigning MAC Address in UniFlash

- Once the board is flashed and a MAC address is assigned, the board is ready to use.

3.2.1.3 Connecting TIDA-01463 PCB

1. First, connect the IR sensor board to header J10 on the TIDA-01463 PCB. The board will function without the sensor. For the correct connection, the board must hang over the large capacitor, so an additional 4-pin header is included to ensure height clearance. [Figure 20](#) shows the orientation of the IR sensor board..

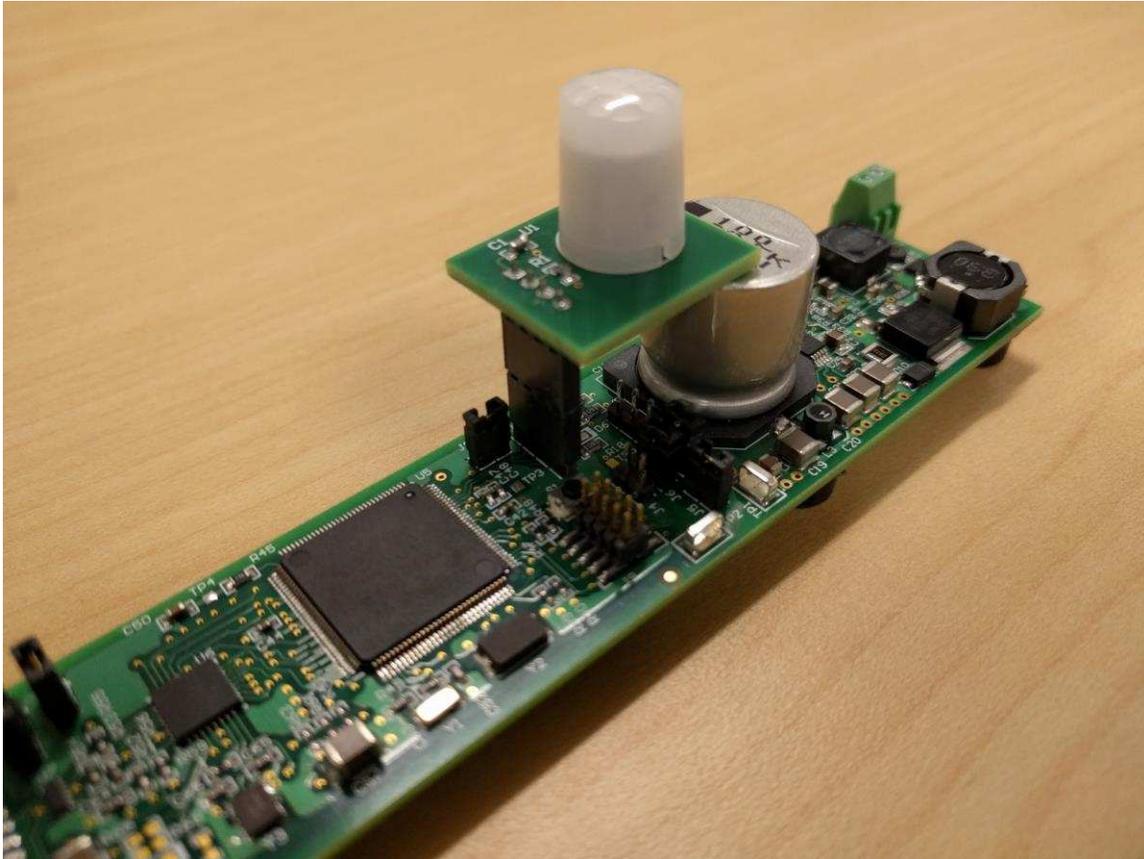


Figure 20. TIDA-01463 PCB With IR Sensor Attached

2. Connect the LED light to the output terminal, J7. If unsure about the polarity of the terminals, check the bottom of the PCB. The right terminal (+) is connected to the trace, and the left terminal (-) is connected to the ground plane (see [Figure 21](#)).

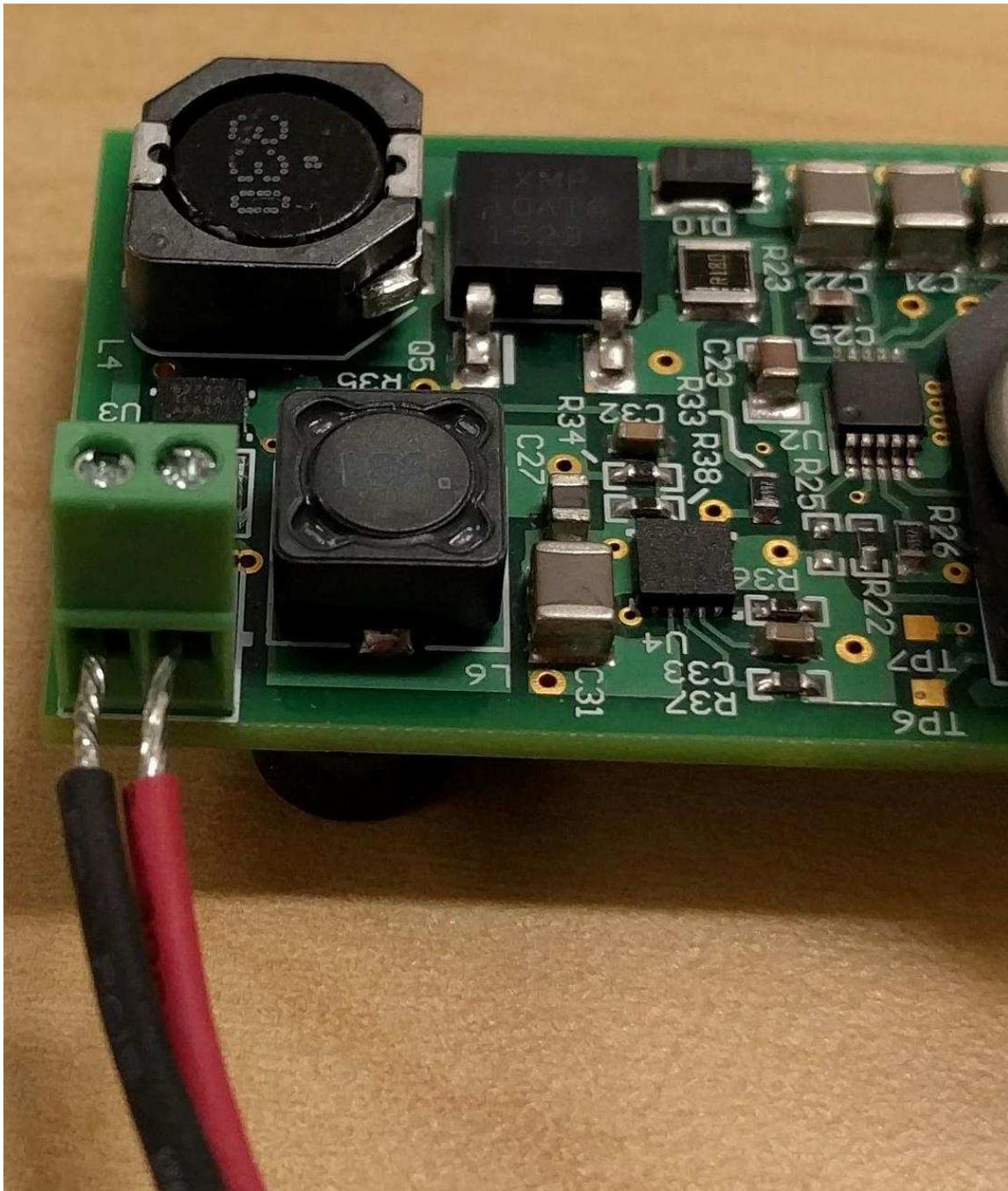


Figure 21. TIDA-01463 LED Output Connection on PCB

3.2.1.4 Powering TIDA-01463

CAUTION

LED ballasts similar to the CREE LMH2 LED module (39 V, 900 mA) are used as down-lights in retail spaces and commercial settings. At maximum brightness, eye exposure at short distance can cause disorientation, vertigo, headaches, and possible eye damage with prolonged exposure.

When testing the light at short distance, it is recommended to cover the LED ballast with a box or filter before initiating the GUI software. A box used to cover the LED is shown in [Figure 22](#).

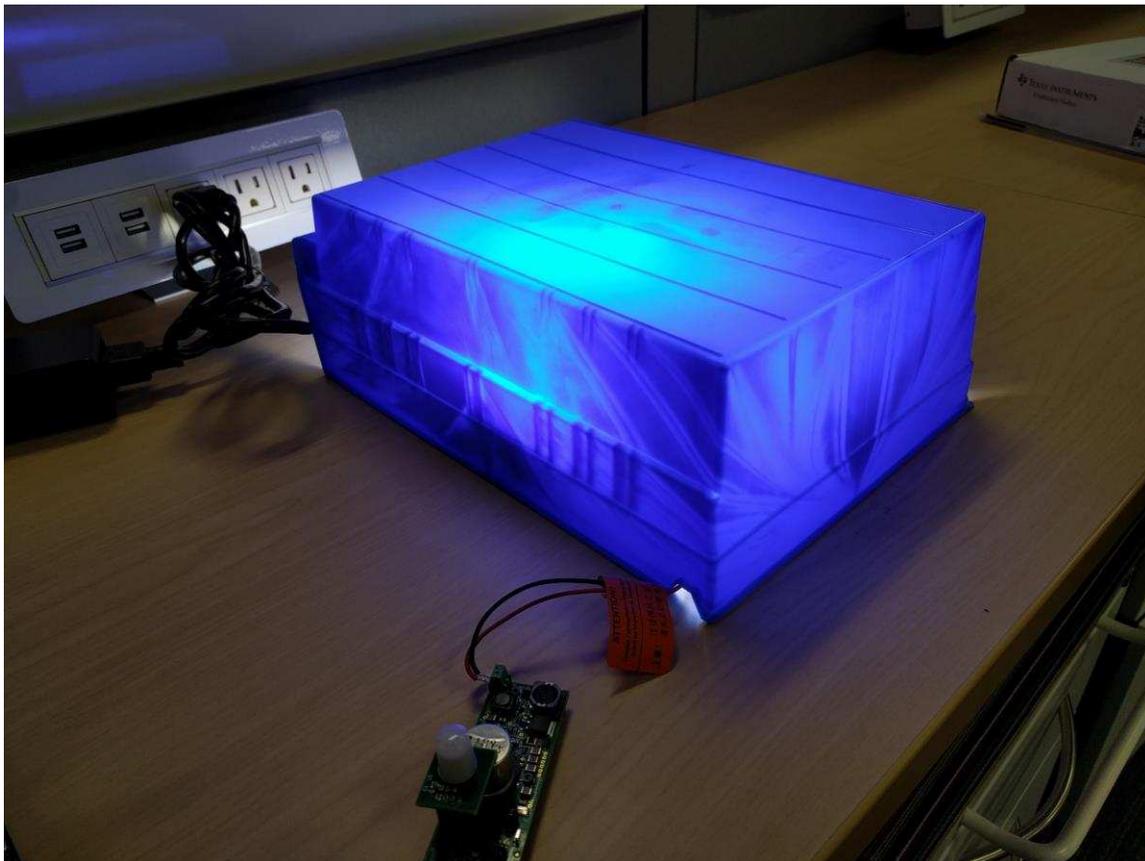


Figure 22. Plastic Box Covering LED Ballast

1. Connect a CAT5e Ethernet cable from the computer into the data input of the PSE.

NOTE: The TIDA-01643 supports Energy Efficient Ethernet (EEE), so the data side of the PSE can be connected to a switch with EEE support to enable the lowest power consumption during in its idle state (45 mW).

2. Connect another CAT5e Ethernet cable from the output of the PSE into the PD. The LED will turn on to full brightness after all connections are made, so be sure to cover the light if close by. The fully-connected test setup is shown in [Figure 23](#).



Figure 23. Full Test Setup

3. After going to full brightness, the light will eventually dim if the IR sensor does not sense motion. If the user moves near the IR sensor, the LED will increase brightness.
4. To change the behavior of the dimming and the brightness level of the LED, see [Section 3.2.1.5](#).

3.2.1.5 Controlling TIDA-01463 With PMP20537 Demonstration

After connecting the test setup to the PC and powering on the light, start *PMP20537 Demo*. The window in [Figure 24](#) appears.

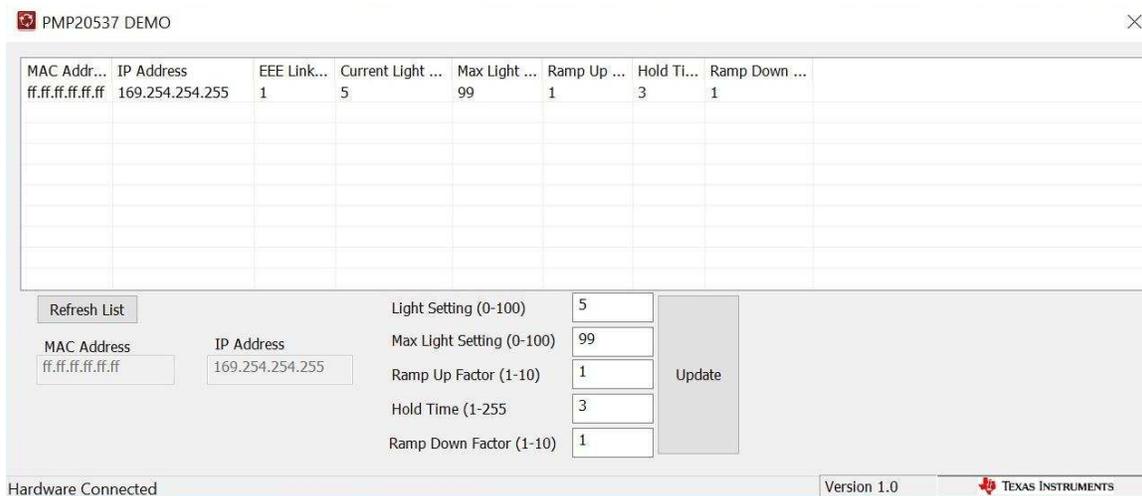


Figure 24. PMP20537DEMO Software

The settings for the LED light are described in [Table 5](#)

Table 5. PMP20537 DEMO Settings

SETTING	DESCRIPTION
Light setting (0 to 100)	Idle brightness
Maximum light setting (0 to 100)	Maximum brightness when in motion is sensed
Ramp up factor (1 to 10)	Transition time from idle to maximum
Hold time (1 to 225)	Time to stay bright if proximity has not been detected
Ramp down factor (1 to 10)	Transition time from maximum to idle

Each of the table entries corresponds to an IP-addressable TIDA-01643 PCB connected to a light. To makes changes to a light:

1. Double click one of the table entries.
2. Make the changes to the settings.
3. Click *Update*.
4. Click *Refresh* to see the settings reflected on [Figure 24](#).

3.2.2 Test Results

This section highlights the collected data from PD operation.

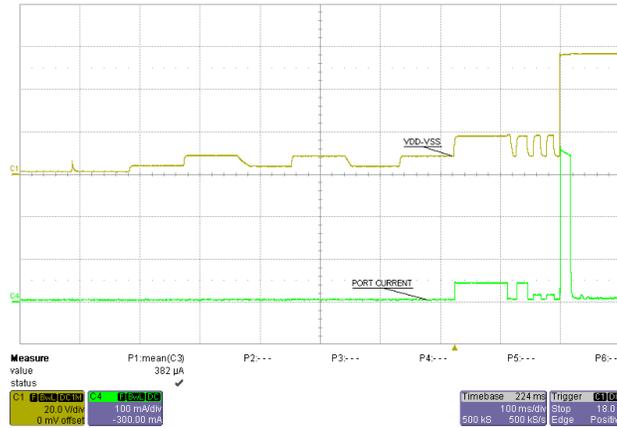


Figure 25. PoE Class and Detection

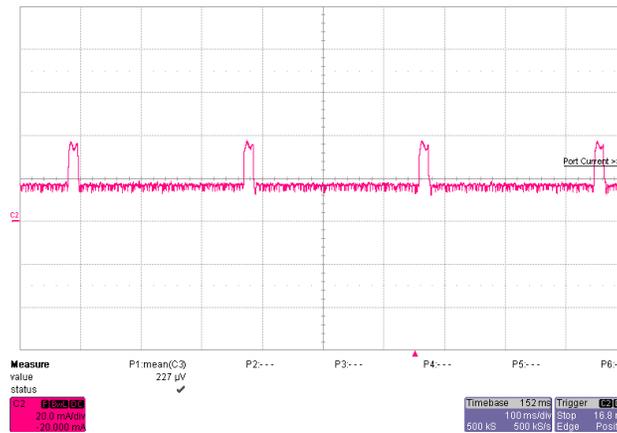


Figure 26. Auto MPS

4 Design Files

4.1 Schematics

To download the schematics, see the design files at [TIDA-01463](#).

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-01463](#).

4.3 Layout Prints

To download the layer plots, see the design files at [TIDA-01463](#).

4.4 Altium Files

To download the Altium project files, see the design files at [TIDA-01463](#).

4.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-01463](#).

4.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-01463](#).

5 Software Files

To download the software files, see the design files at [TIDA-01463](#).

6 Related Documentation

1. Texas Instruments, [MSP432P401R SimpleLink™ Microcontroller LaunchPad™ Development Kit \(MSP-EXP432P401R\) User's Guide](#)
2. Texas Instruments, [XDS110 Debug Probe User's Guide](#)

6.1 Trademarks

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7 About the Author

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