DC/DC LED Lighting Developer’s Kit Hardware Reference Guide

Version 1.1 – October 2010 *C2000 Systems and Applications Team*

Fig 1: TMDSDCDCLEDKIT

1 Introduction

The DC/DC LED Lighting Developer’s Kit provides a great way to learn and experiment with using a single MCU to accurately control a series of LED strings and efficiently control the power stages needed to make the LEDs work. This document goes over kit contents, the kit hardware details and explains the functions and locations of jumpers and connectors present on the board. This document supersedes all the documents available for the hardware of this kit.

WARNING

This EVM is meant to be operated in a lab environment only and is not considered by TI to be a finished end-product fit for general consumer use.

This EVM must be used only by qualified engineers and technicians familiar with risks associated with handling high voltage electrical and mechanical components, systems and subsystems.

This equipment operates at voltages and currents that can result in electrical shock, fire hazard and/or personal injury if not properly handled or applied. Equipment must be used with necessary caution and appropriate safeguards employed to avoid personal injury or property damage.

It is the user’s responsibility to confirm that the voltages and isolation requirements are identified and understood, prior to energizing the board and or simulation. When energized, the EVM or components connected to the EVM should not be touched.

2 Getting Familiar with the Kit

2.1 Kit Contents

The kit consists of:

- DC/DC LED Lighting power board
- Piccolo F28035 controlCARD
- LED panel which contain OSRAM Golden Dragon or Golden Dragon Plus white LEDs
- 12V power adapter
- Banana Plug Cable
- USB Cable
- USB drive with GUI executable
- CCS4 Installation CD

The board can accept any of the C2000 series controlCARDs. A F28035 control card is shipped with the kit. Some software changes may be necessary to have the board work with a different controlCARD.

2.2 Kit Features: The kit has the following features

- **SEPIC Power Stage** used to regulate the LED Voltage bus common to all 8 LED strings.
    - 12V DC input into [M1]-JP1 or 15-36V DC input into [M1]-TB1
    - Regulated Output between 9-42V
    - 100kHz PWM, ADC sampling and loop frequency
    - Over-current and Over-voltage protection with the on-chip comparators available on C2000's Piccolo series
    - High precision low-side current sensing using the C2000's high-performance ADC and Texas Instruments OPA354 high speed op-amps.
- **LED Dimming Stages** PWM dim each individual LED string to meet a desired average current.
    - 16.8 – 20.4V DC input into [Main]-BS3 *
    - 1A max current per LED string
    - 20Khz switching frequency for each LED dimming stage
- **Onboard Isolated JTAG emulation**
- **Isolated UART** through the SCI peripheral and the FTDI chip.
- **I^2C interface** header that could be used to communication with a temperature sensor for instance
- **Hardware Developer's Package** that includes schematics and bill of materials, is available through controlSUITE.

**The DC input for the LEDBus should match with the specifications for the attached LED string. On the panel that comes with the board, each LED conducts with a forward voltage between 2.8-3.4 volts. Therefore, for the LED panel that ships with the kit using ~20V DC input is recommended.

Note that the board is shipped with a 5 Amps fuse in the DC power entry fuse holder [M1]-TB1, this fuse may need to be replaced with an appropriate rating fuse depending on the application.

3 Hardware Overview

Fig 2, illustrates a LED lighting system running from AC power. The TMDSDCDCLEDKIT board assumes a PFC input and then generates a DC input while controlling the LED strings(Fig 4).

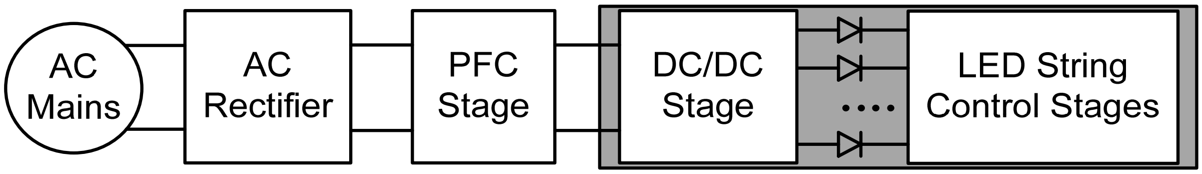


Fig2: Block Diagram for a typical LED lighting application

There are multiple ways of controlling LEDs. On this board, we use the C2000 to generate a common DC supply for all the LED strings. Dimming is then accomplished on the C2000 by varying the time at which an LED is on. In this way, we alter the average current passed through an LED string, and because average current is roughly proportional to lumen output each LED strings' brightness is controlled.

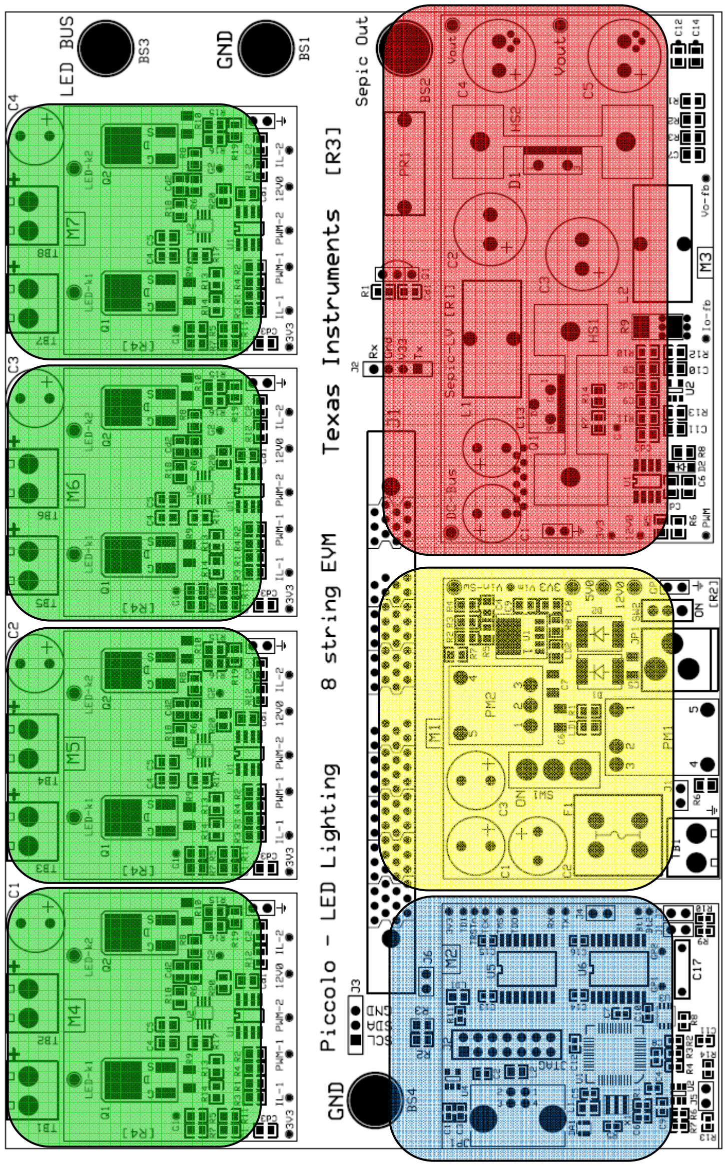
3.1 Macro Blocks

The LED Lighting board is separated into functional groups that enable a complete LED system, these are referred to as macro blocks. Following is a list of the macro blocks present on the board and their functions:

- [Main] – consists of controlCARD socket, a few communications jumpers and the routing of signals between the controlCARD and the macro blocks. This section is all of the area outside of the macro blocks.
- [M1] – Generates the 15V, 5V, and 3.3V DC rails from a 12V supply included with the kit or an external DC power supply.
- [M2] – Provides on-board isolated JTAG connection through USB to the host. Is also used to provide isolated SCI (UART) communcation for connection with the GUI.
- [M3] – A SEPIC DC/DC conversion stage, used to increase or decrease the input voltage to the voltage needed by the LED strings.
- [M4]-[M7] – stages used to individually dim an LED string. Each macro consists of the components needed to control two strings.

Fig 3, illustrates the position of these macro blocks on the board. The use of a macro block approach, for different power stages enables easy debug and testing of one stage at a time. Banana jack connectors can be used to interconnect the power line of these power stages / blocks to construct a complete system. All the PWM's and ADC signals which are the actuation and sense signals have designated test points on the board, which makes it easy for an application developer to try out new algorithms and strategies.

Nomenclature: A component on the board is referred to with a macro number in the brackets followed by a dash and the reference number. For example, [M2]-J1 refers to the jumper J1 located in the macro M2 and [Main]-J1 refers to the J1 located on the board outside of the defined macro blocks.



▪ [Main] - controlCARD connection, jumper configurations, trip zones
▪ [M1] - DC power entry
▪ [M2] - Isolated USB Emulation
▪ [M3] - SEPIC DC/DC Power Stage
▪ [M4]-[M7] - LED Dimming Stages

3.2 Powering the Board:

The DC/DC LED Lighting board has two separate power domains and with this, two major modes of operation. The two power domains are the high voltage rail, which feeds the SEPIC stage, and the controller power which powers all the auxilliary chips as well as the MCU. The question of which mode of operation should be used will depend on if the board is being used for evaluation or for experimentation.

WARNING: Always use caution when using the board's electronics due to presence of high voltages.

1) **Evaluation Mode –** used to quickly show how the boards functions. All power used by the board is provided from a single 12V DC power supply. The CE marked, 12V, 1.5A power supply that is included with the TMDSDCDCLEDKIT is ideal for this mode. Note that total output power will be limited to 18W while in this mode.
    - Jumper [M1]-J1 should be placed.
    - [M1]-SW2 should stay in the "OFF" position.
    - 12V should be connected to [M1]-JP1
2) **Experimentation Mode** – uses two different supplies to minimize the risk of damage caused while experimenting. One supply will be used to power the high voltage line that will feed the SEPIC and the other will power the auxilliary supply that powers the MCU if a fault occurs on the high voltage line. This mode also allows for more experimentation with how the SEPIC works under different input voltages.
    - Jumper [M1]-J1 should NOT be placed
    - 12V DC should be connected to [M1]-JP1
    - 15-36V DC should be connected to [M1]-TB1
    - [M1]-SW1 will control if the high-voltage line is on or off. [M1]-SW2 will control whether the MCU is always on or dependent on the status of [M1]-SW1. For experimentation, the ideal setup would be to program, etc with [M1]-SW2 on while [M1]-SW1 is off. Once the user felt confident that PWM signals are being generated correctly, the user could then turn on [M1]-SW1 and test.

By default a banana-to-banana cable should link the SEPIC power stage to the LED dimming stages via [Main]-BS2 to [Main]-BS3. The user could also choose to experiment with these stages individually. By placing a load between the SEPIC output and ground the user could experiment with how the SEPIC works. Seperately if a user wanted to explore digital dimming, they could power [Main]-BS3 with an approximately 20V* DC power supply and then would not need to control the SEPIC stage.

*If the LEDs used are different from the ones shipped with the board or the user has decided to change the amount of LEDs to better fit their application, the DC bus voltage would need to be altered to compensate.

3.3 Boot Modes

Table1, describes the jumper and switch settings that are needed for booting from FLASH and SCI for the board.

	Boot from FLASH	**Boot from SCI (using iso JTAG macro)**
F2802x	SW1 on controlCARD- Position 1 = 1 Position 2 = 1 Remove the jumper [Main]-J9	SW1 on controlCARD- Position 1 = 1 Position 2 = 0 Unpopulate R10 on controlCARD Remove the jumper [Main]-J9 Populate the jumper [M3]-J4
F2803x	SW2 on controlCARD- Position 1 = 1 Position 2 = 1 Remove the jumper [Main]-J9	SW2 on controlCARD- Position 1 = 1 Position 2 = 0 SW3 on controlCARD should be OFF Remove the jumper [Main]-J9 Populate the jumper [M3]-J4

Table 1: Boot Options

3.4 GUI Connection

The FTDI chip present on the board can be used as an isolated SCI for communicating with a HOST i.e. PC. The following jumper settings must be done to enable this connection

1. Populate the jumper [M2]-J4
2. Remove the jumper [Main]-J6
3. For F28035, put SW3 on the F28035 Control Card to OFF position
   For F28027, unpopulate the resistor R10 on the F28027 control card.
4. Connect a USB cable from [M2]-JP1 to host PC.

Note: If you are going to boot from Flash & connecting using the GUI, you would nee to do the Boot from Flash settings as described in the Table Boot Options.

3.5 Ground Levels and Safety

- The user must not touch any part of the board or components connected to the board while energized.

- The power stages on the board are individually rated. It is the user’s responsibility to make sure that these ratings (i.e. the voltage, current and power levels) are well understood and complied with, prior to connecting these power blocks together and energizing the board and / or simulation.

4 Hardware Resource Mapping

4.1 Resource Allocation

The Fig 4 shows the various stages of the board in a block diagram format and illustrates the major connections and feedback values that are being mapped to the C2000 MCU. Table 2, below lists these resources.

Macro Name		Signal Name	PWM Channel/ ADC Channel No Mapping for F28035	Function
DC-PwrEntry		Vin-meas	ADC-A6	SEPIC input voltage sense
SEPIC-LV Stage		PWM	PWM-1A	SEPIC converter PWM
		Vout-Fb	ADC-A4	SEPIC output voltage feedback
		Iout-Fb	ADC-A2	SEPIC current sense
LED-Dimmming-Dual Stages	M4	PWM-1	PWM-2A	String 1 PWM
		PWM-2	PWM-2B	String 2 PWM
		IL-1	ADC-B0	String 1 current sense
		IL-2	ADC-A0	String 2 current sense
	M5	PWM-1	PWM-3A	String 3 PWM
		PWM-2	PWM-3B	String 4 PWM
		IL-1	ADC-B1	String 3 current sense
		IL-2	ADC-B2	String 4 current sense
	M6	PWM-1	PWM-4A	String 5 PWM
		PWM-2	PWM-4B	String 6 PWM
		IL-1	ADC-B3	String 5 current sense
		IL-2	ADC-A3	String 6 current sense
	M7	PWM-1	PWM-5A	String 7 PWM
		PWM-2	PWM-5B	String 8 PWM
		IL-1	ADC-B4	String 7 current sense
		IL-2	ADC-A1	String 8 current sense

Table 2: PWM and ADC resource allocation

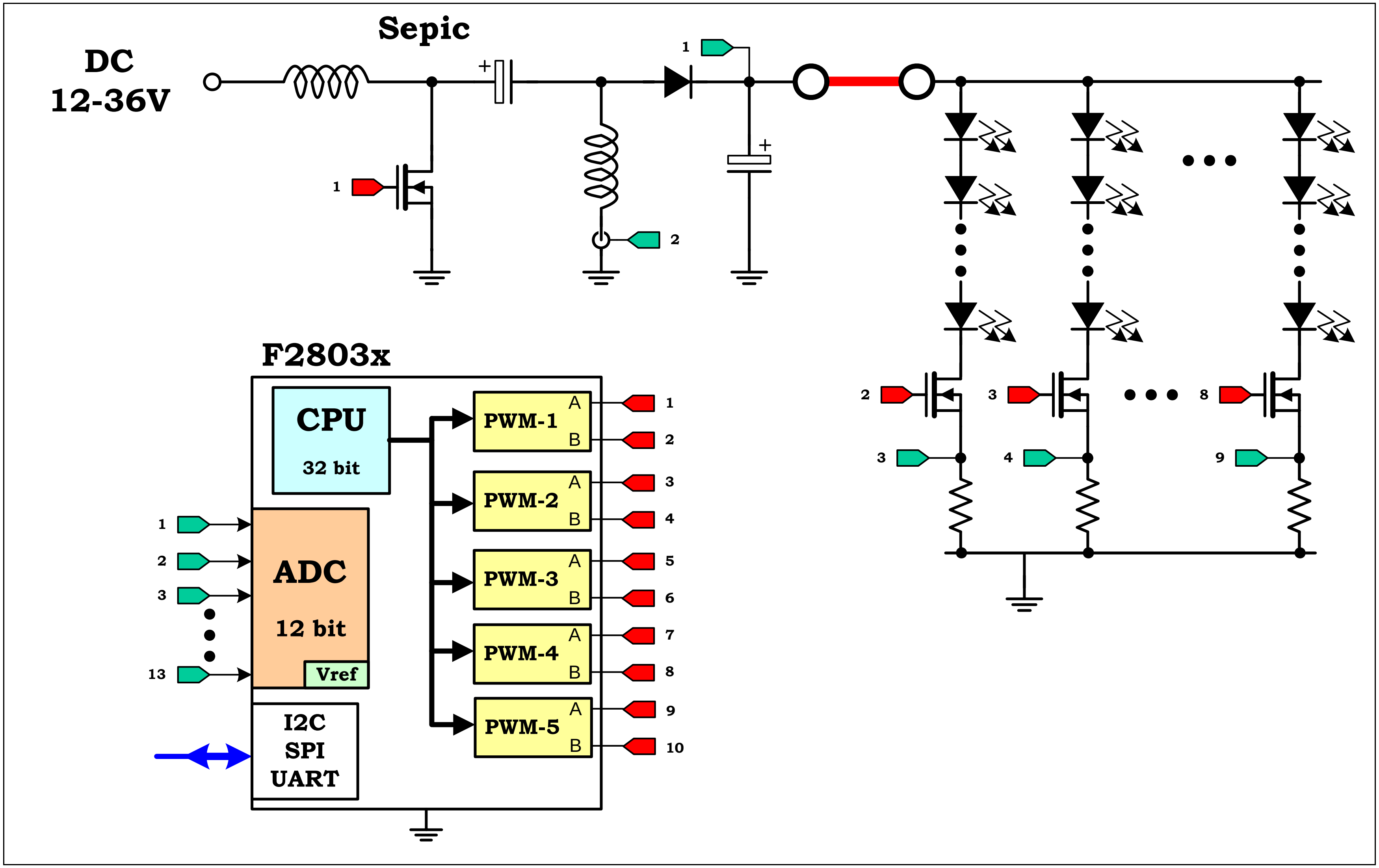


Fig4: DC/DC LED Lighting Board Block diagram with F28035

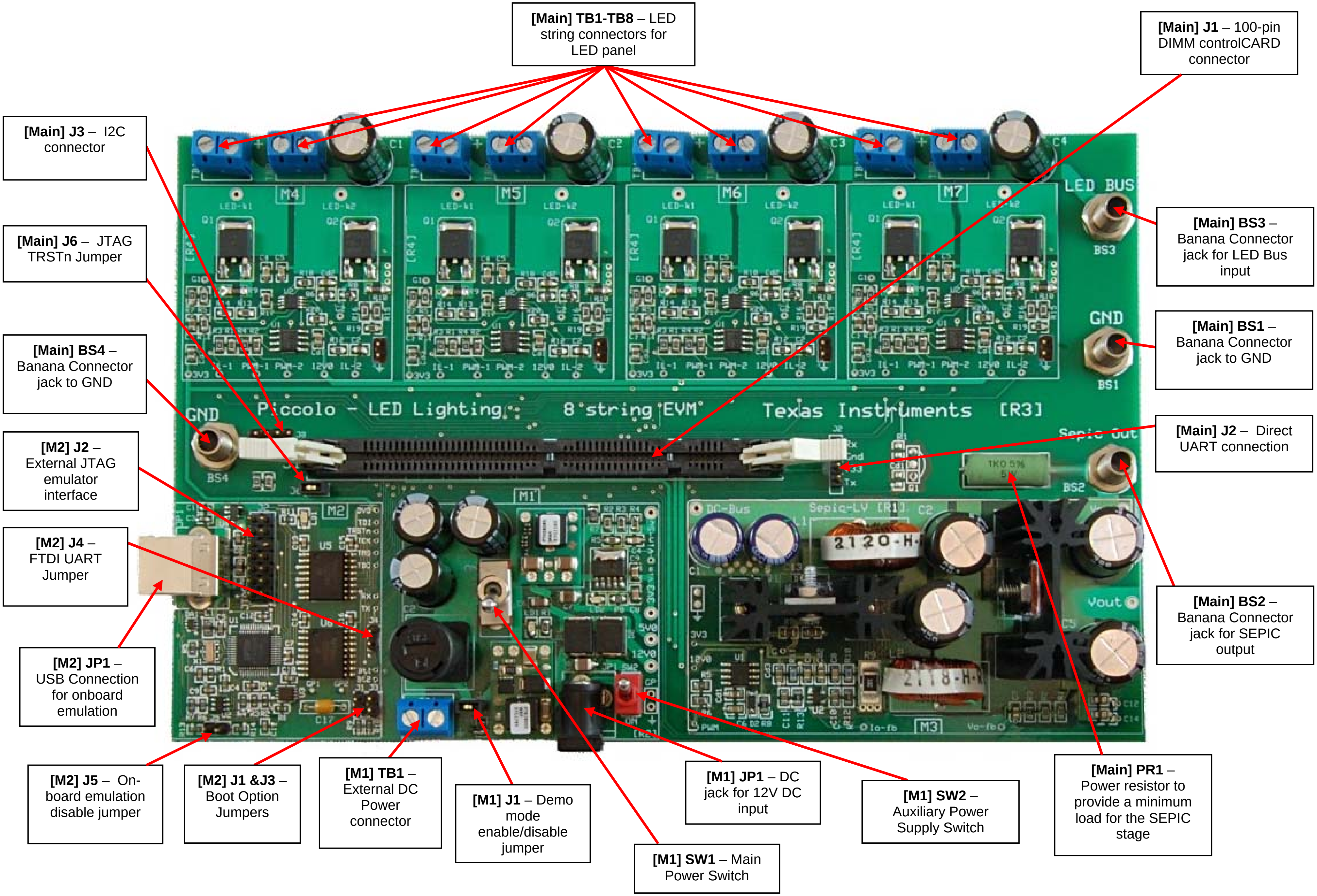


Fig5. DC/DC LED Lighting Kit Jumpers and Connectors Diagram

4.2 Jumpers and Connectors

Table 3 below shows the various connections available on the board, and is split up by the macro each connection is included in. Fig 5, above, illustrates the location of these connections on the board with help of a board image:

[Main]-BS1, BS4	Banana Jack for GND Connection
[Main]-BS2	Banana Jack for SEPIC Output
[Main]-BS3	Banana Jack for LED Bus Input
[Main]-J1	100-pin DIMM controlCARD connector
[Main]-J2	UART Connector. UART connectivity can either be through this header or through USB emulation (via the FTDI chip), but not both at the same time. To enable this connection, [M2]-J4 must be populated, and the controlCARD must be set to use the on-board RS-232 transceiver. For the F2803x controlCARD, this means that SW1 on the controlCARD must be switched to the "ON" position.
[Main]-J3	I^2C Connector. Enables connectivity to an external device, like a temperature sensor. Not used in kit software.
[Main]-J6	JTAG TRSTn disconnect jumper, populating the jumper enables JTAG connection to the microcontroller. The jumper needs to be unpopulated when booting from FLASH, SCI, or another medium.
[Main]-PR1	Power resistor that is used to provide a minimum load to the SEPIC stage. Without a minimum load the SEPIC stage could have difficulty regulating at high boost levels. The SEPIC power stage may need to be altered to keep the stage in continuous current mode to fit a specific application.
[Main]-TB1-TB8	Terminal blocks used to connect an LED panel to the DC/DC Lighting board.
[M1]-J1	Demo mode enable/disable jumper. This jumper determines whether the 12V input from [M1]-JP1 will also be what feeds the SEPIC stage. See section 3.2 of this guide for more information.
[M1]-JP1	12V DC input. This connector is designed to connect up with the 12V power supply included with this kit.
[M1]-SW1	Main Power Switch. This switch determines whether power is passed to the SEPIC power stage. • On – Power is passed to the SEPIC stage and 12, 5, and 3.3V are automatically generated. • Off – Power is not passed to the SEPIC stage. 12, 5, and 3.3V are not generated, but could be genererated if [M1]-JP1 is connected to 12V and [M1]-SW2 is "ON".
[M1]-SW2	Auxilliary Power Switch. Helps to determine whether 12, 5, and 3.3V lines are powered. • On – If [M1]-JP1 is connected to 12V, this power is then used to generated the 12V, 5V, and 3.3V rails. • Off – The 12V, 5V, and 3.3V rails will be powered if [M1]-SW1 is on and [M1]-JP1 or [M1]-TB1 is powered.
[M1]-TB1	External DC Power connector. Can be used to power the board if more flexibility/power is needed than that given by the included power supply. Can handle 15-36V DC input. Left terminal is +, right is -.
[M2]-JP1	USB connection for on-board emulation
[M2]-J1&J3	Boot Option Jumpers, not used for F2802x or F2803x devices.

[M2]-J2	External JTAG interface: this connector gives access to the JTAG emulation pins. If external emulation is desired, place a jumper across [M3] J5 and connect the emulator to the board. To power the emulation logic a USB connector will still need to be connected to [M2] JP1.
[M2]-J4	Populate when using FTDI chip as a UART i.e. when using a GUI to interact with the MCU.
[M2]-J5	On-board emulation disable jumper: Place a jumper here to disable the on-board emulator and give access to the external interface.

Table 3: Key features explanation

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