# DC/DC LED Lighting Developer's Kit Hardware

The DC/DC LED lighting developer's kit provides a great way to learn and experiment by 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 reference guide covers the kit contents and hardware details, and explains the functions and locations of the jumpers and connectors present on the board. This document supersedes all documents available for the hardware of this kit.

**WARNING**

**This evaluation module (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 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, do not touch the EVM or components connected to the EVM.**

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# 1 Getting Familiar With the Kit

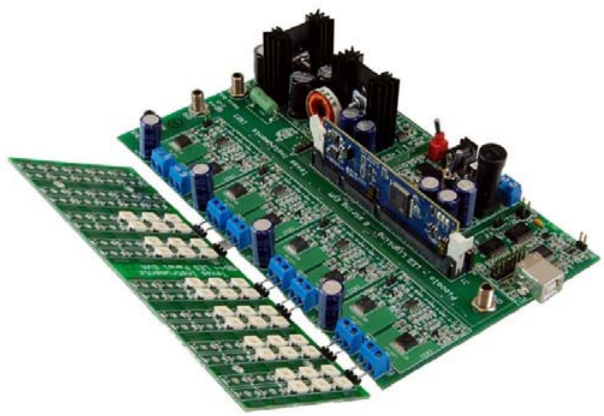

**Figure 1. TMDSDCDCLEDKIT**

## 1.1 Kit Contents

The kit consists of: ™

- DC/DC LED lighting power board
- Piccolo™ F28035 controlCARD
- LED panel that contains OSRAM Golden Dragon or Golden Dragon Plus white LEDs
- 12-V 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. An F28035 control card is shipped with the kit. Some software changes may be necessary to have the board work with a different controlCARD.

## 1.2 Kit Features

The kit has the following features:

- SEPIC power stage used to regulate the LED voltage bus common to all eight LED strings
  - 12-V DC input into [M1]-JP1 or 15 to 36-V DC input into [M1]-TB1
  - Regulated output between 9 and 42 V
  - 100-kHz PWM, analog-to-digital converter (ADC) sampling, and loop frequency
  - Overcurrent and overvoltage 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 to 20.4-V DC input into [Main]-BS3
  - 1-A maximum current per LED string
  - 20-Khz switching frequency for each LED dimming stage

- Onboard isolated JTAG emulation
- Isolated universal asynchronous receiver/transmitter (UART) through the serial communications interface (SCI) peripheral and the FTDI chip
- Inter-integrated circuit (I2C) interface header that could be used to communicate (for example, with a temperature sensor)
- Hardware developer's package, which includes schematics and bill of materials, is available through controlSUITE™

(1)

**NOTE:** The board is shipped with a 5-Amp 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.

## 2 Hardware Overview

Figure 2 illustrates an 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 (see Figure 4).

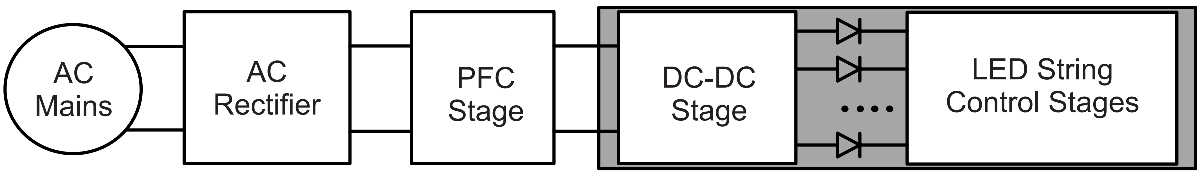


**Figure 2. Block Diagram for a Typical LED Lighting Application**

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

### *2.1 Macro Blocks*

The LED lighting board is separated into functional groups that enable a complete LED system. These groups are referred to as macro blocks. The 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 includes all of the area outside of the macro blocks.

**[M1]—** Generates the 15-V, 5-V, and 3.3-V DC rails from a 12-V supply included with the kit or an external DC power supply.

**[M2]—** Provides an onboard isolated JTAG connection through the USB to the host. This block also provides isolated SCI (UART) communication to connect 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] to [M7]—** Stages used to individually dim an LED string. Each macro consists of the components needed to control two strings.

Figure 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 and blocks to construct a complete system. All of the pulse width modulations (PWMs) and ADC signals, which are the actuation and sense signals, have designated test points on the board, making it easy for an application developer to try out new algorithms and strategies.

(1) The DC input for the LED bus should match 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 and 3.4 V. Therefore, use a 20-V DC input for the LED panel that ships with the kit.

*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.

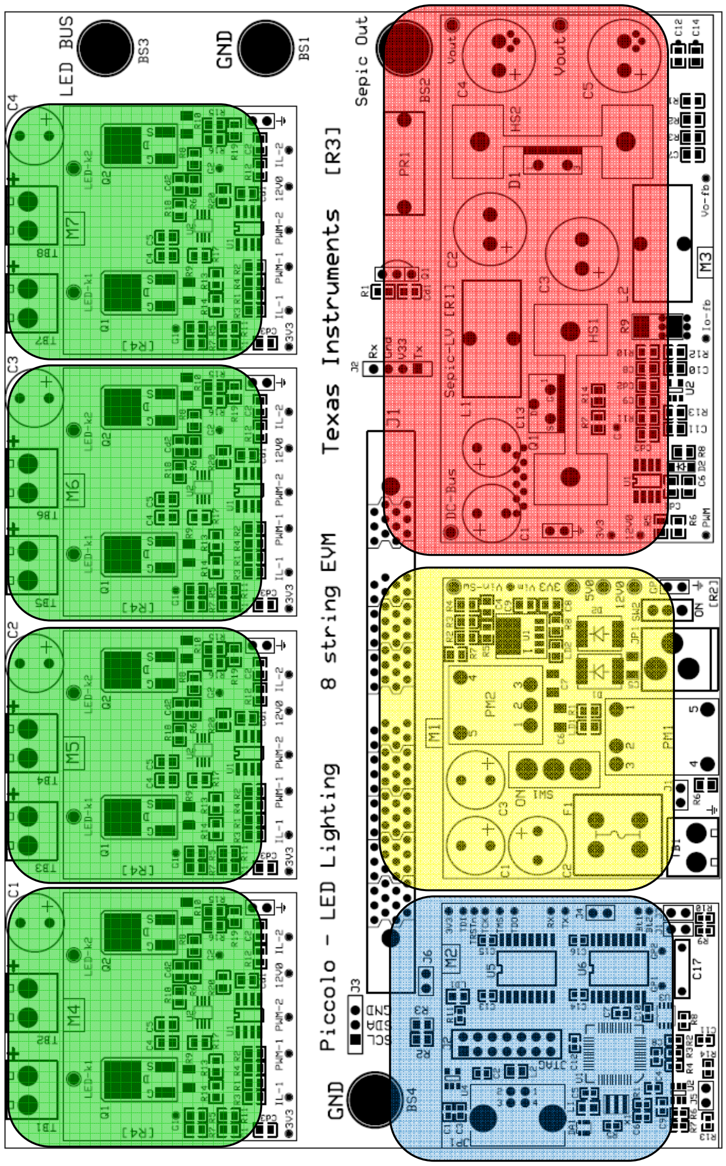


**Figure 3. Defined Macro Blocks**

**Table 1. Defined Macro Blocks Legend**

| |
|---|
| [Main]—controlCARD connection, jumper configurations, trip zones |
| [M1]—DC power entry |
| [M2]—Isolated USB emulation |
| [M3]—SEPIC DC/DC power stage |
| [M4] to [M7]—LED dimming stages |

### 2.2 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 to use depends on whether 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.**

- *Evaluation Mode* quickly shows how the board functions. All power used by the board is provided from a single 12-V DC power supply. The CE marked, 12-V, 1.5-A power supply that is included with the TMDSDCDCLEDKIT is ideal for this mode.
  - Place the jumper [M1]-J1
  - Keep [M1]-SW2 in the *OFF* position
  - Connect 12 V to [M1]-JP1

**NOTE:** The total output power will be limited to 18 W while in this mode.

- *Experimentation Mode* uses two different supplies to minimize the risk of damage caused while experimenting. One supply powers the high voltage line that feeds the SEPIC, and the other powers the auxiliary 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.
  - Do not place the jumper [M1]-J1
  - Connect 12-V DC to [M1]-JP1
  - Connect 15 to 36-V DC to [M1]-TB1
  - [M1]-SW1 controls whether 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 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 the ground, the user could experiment with how the SEPIC works. Separately, to explore digital dimming, the user could power [Main]-BS3 with an approximately 20-V DC** power supply and then would not need to control the SEPIC stage. [(1)]

(1) 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.

## 2.3 Boot Modes

Table 2 describes the jumper and switch settings that are needed to boot from FLASH and SCI for the board.

**Table 2. Boot Options**

| DEVICE | BOOT FROM FLASH | BOOT FROM SCI (USING ISO JTAG MACRO) |
|---|---|---|
| F2802x | SW1 on controlCARD<br>• Position 1 = 1<br>• Position 2 = 1<br>Remove the jumper [Main]-J9 | SW1 on controlCARD<br>• Position 1 = 1<br>• Position 2 = 0<br>Depopulate R10 on controlCARD<br>Remove the jumper [Main]-J9<br>Populate the jumper [M3]-J4 |
| F2803x | SW2 on controlCARD<br>• Position 1 = 1<br>• Position 2 = 1<br>Remove the jumper [Main]-J9 | SW2 on controlCARD<br>• Position 1 = 1<br>• Position 2 = 0<br>SW3 on controlCARD should be OFF<br>Remove the jumper [Main]-J9<br>Populate the jumper [M3]-J4 |

## 2.4 GUI Connection

The FTDI chip present on the board can be used as an isolated SCI for communicating with a host (for example, a PC). Complete the following jumper settings 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 the *OFF* position. For F28027, depopulate the resistor R10 on the F28027 control card.
4. Connect a USB cable from [M2]-JP1 to the host PC.

**NOTE:** If you are going to boot from Flash and connect using the GUI, complete the *Boot from Flash* settings as described in Table 2.

## 2.5 Ground Levels and Safety

Do 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 (for example, the voltage, current, and power levels) are well understood and complied with prior to connecting these power blocks together and energizing the board or simulation.

# 3 Hardware Resource Mapping

## 3.1 Resource Allocation

Figure 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 (detailed in Table 3).

**Table 3. PWM and ADC Resource Allocation**

| MACRO NAME | | SIGNAL NAME | PWM CHANNEL OR 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 Dimming—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 |

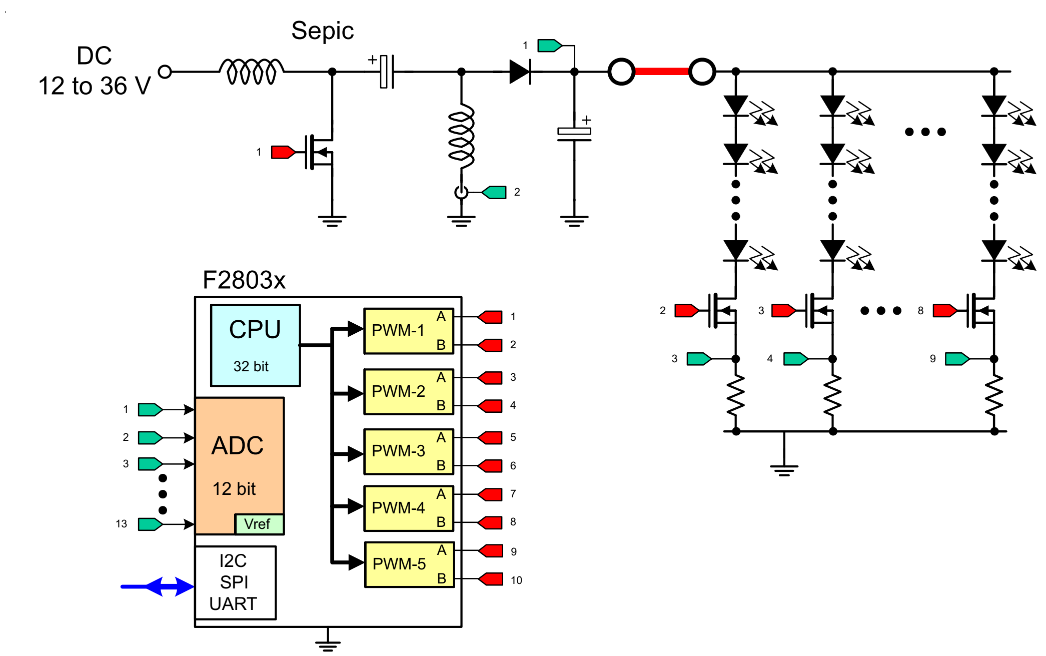


**Figure 4. DC-DC LED Lighting Board Block Diagram with F28035**

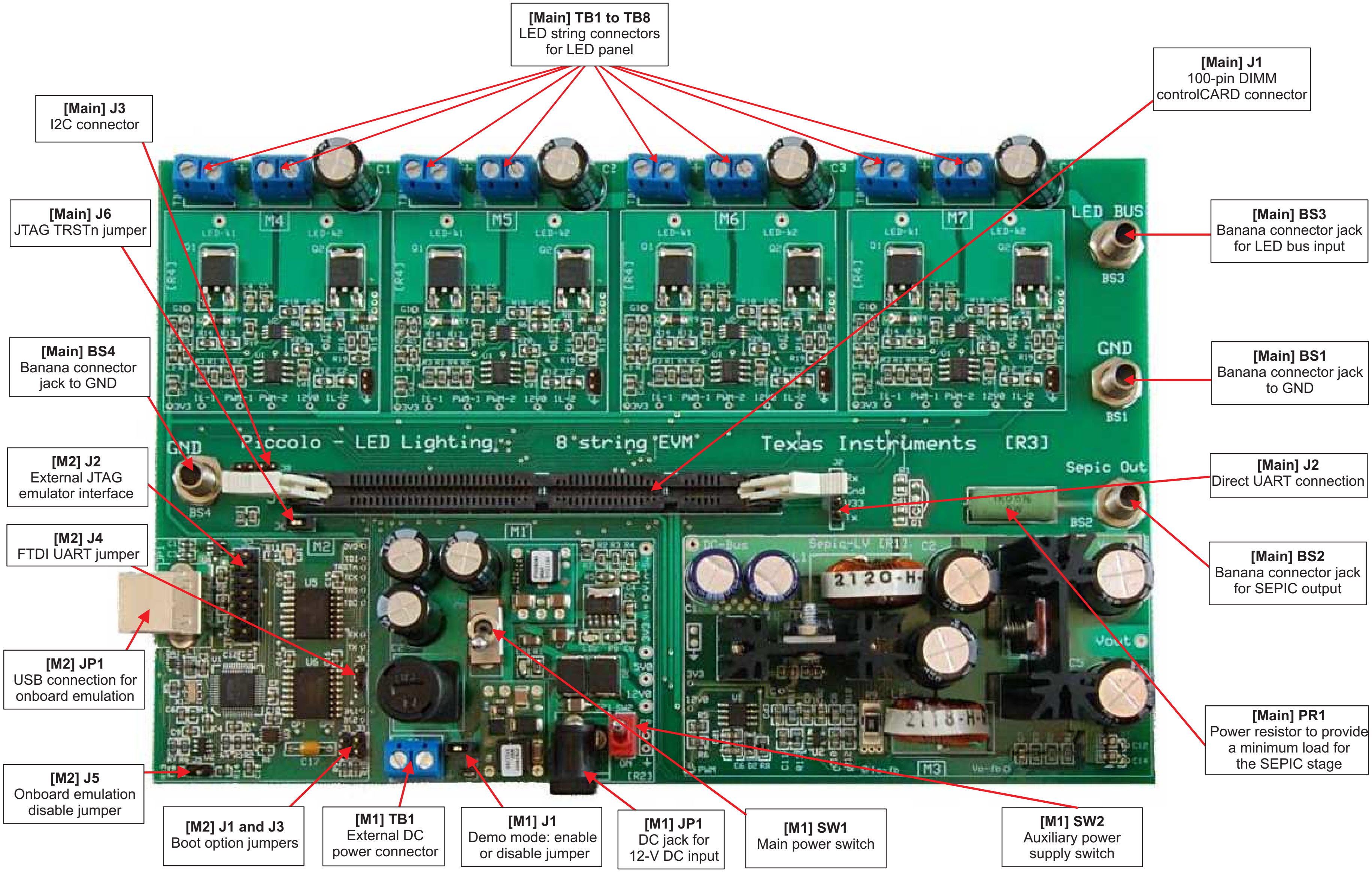


**Figure 5. DC-DC LED Lighting Kit Jumpers and Connectors Diagram**

### 3.2 Jumpers and Connectors

Table 4 shows the various connections available on the board and is split up by the macro each connection is included in. Figure 5 illustrates the location of these connections on the board.

**Table 4. Key Features Explanation**

| COMPONENT | DESCRIPTION |
|---|---|
| [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.<br>To enable this connection, populate [M2]-J4 and set the controlCARD to use the onboard RS-232 transceiver. For the F2803x controlCARD, this means that SW1 on the controlCARD must be switched to the "ON" position. |
| [Main]-J3 | I2C 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 depopulated 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 to enable or disable jumper. This jumper determines whether the 12-V input from [M1]-JP1 will also be what feeds the SEPIC stage. For more information, see Section 2.2. |
| [M1]-JP1 | 12-V DC input. This connector is designed to connect up with the 12-V power supply included with this kit. |
| [M1]-SW1 | Main power switch. This switch determines whether power is passed to the SEPIC power stage.<br>• On: Power is passed to the SEPIC stage and 12 V, 5 V, and 3.3 V automatically generate<br>• Off: Power is not passed to the SEPIC stage. 12 V, 5 V, and 3.3 V do not generate, but could generate if [M1]-JP1 is connected to 12 V and [M1]-SW2 is on |
| [M1]-SW2 | Auxilliary power switch. Helps to determine whether 12 V, 5 V, and 3.3 V lines are powered.<br>• On: If [M1]-JP1 is connected to 12 V, this power is then used to generate the 12-V, 5-V, and 3.3-V rails.<br>• Off: The 12-V, 5-V, and 3.3-V 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 or power is needed than that given by the included power supply. Can handle 15 to 36-V DC input. Left terminal is +, right is –. |
| [M2]-JP1 | USB connection for onboard emulation |
| [M2]-J1 and 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 (when using a GUI to interact with the MCU). |
| [M2]-J4 | On-board emulation disable jumper: Place a jumper here to disable the on-board emulator and give access to the external interface. |

## IMPORTANT NOTICE



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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265