# AC LED Lighting and Communications

This document provides instructions to run a graphical user interface (GUI) that controls the AC LED lighting and communications developer's kit board using the Piccolo™ F28027 microcontroller.

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# 1 System Overview

## 1.1 Kit Contents

Contents of the DC/DC LED lighting developer's kit:

- AC LED lighting and communication motherboard
- Piccolo F28027 controlCARD
- LED panel
- AC power cable
- Two red banana plug cables
- 12-V DC/DC power supply
- USB cable
- USB Flash drive with GUI executable and Code Composer Studio™ installer

## 1.2 Kit Features

Features of the AC LED lighting developer's kit:

- Independent closed-loop brightness control of six LED strings with pulse width modulator (PWM) dimming
- Closed-loop voltage control of the LED bus with an LLC resonant converter
- Onboard isolated JTAG emulation
- Overcurrent and overvoltage protection for the LLC resonant stage using the F28x on-chip comparators
- Several communications options available for host-control, which are often used in the LED market, including support for DALI, DMX512, and power line communications (PLC). Different application notes describe these options:
  - DALI: TMDSIACLEDCOMKIT-DALIGuide.pdf
  - DMX512: TMDSIACLEDCOMKIT-DMX512Guide.pdf
  - PLC: TMDSIACLEDCOMKIT-PLCQSG.pdf
  - To demonstrate PLC, one TMDSPLCMOD-P3X add-on module and one TMDSPLCKIT-V3 kit is needed.
  - Hardware support for other communication options exist as well
- Hardware developer's package includes schematics, bill of materials (BOM), Gerber files, and so on

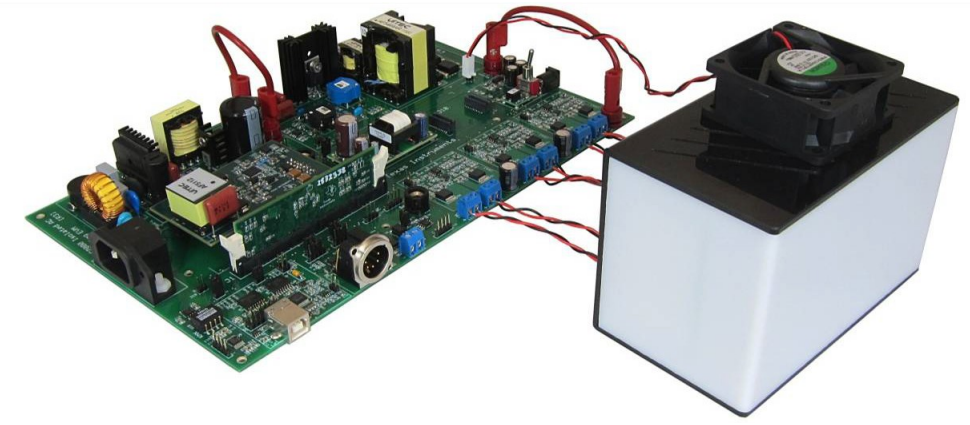

**Figure 1. The AC LED Lighting and Communications Developer's Kit**

## 2 Hardware Overview

The AC LED lighting developer's kit takes in universal (85 to 250-V AC) input. This AC input then goes through a PFC stage to increase the power factor of the downstream power stages. A PFC stage, as shown in Figure 2, helps the board meet IEC61000-3-2 and other on-line regulations. At the output of the PFC stage, the voltage will be roughly 395-V DC. To meet the LED string voltage that is required for each LED string to light, an LLC resonant DC/DC stage is used. The LLC provides isolation between the mains and the LED output, and its turns ratio is chosen so it can output approximately 29 to 36 V. The LLC resonant output is then connected to each of the LED strings. In order to perform independent LED string dimming, a MOSFET is placed in series with each string. The "on" time of each string's MOSFET controls the average current through the LED string. Because the brightness of an LED is roughly proportional to the LED current, use the duty cycle of each string's PWM to control the average current drawn.

In this board, a UCC28810 transition-mode PFC controller manages the PFC stage, and the C2000™ controls the LLC resonant and lumen output of each LED string. In addition, spare bandwidth on the MCU allows communications and system supervisory tasks to also be done by the C2000 device. Figure 2 below illustrates the hardware present on the AC LED lighting and communications developer's kit.

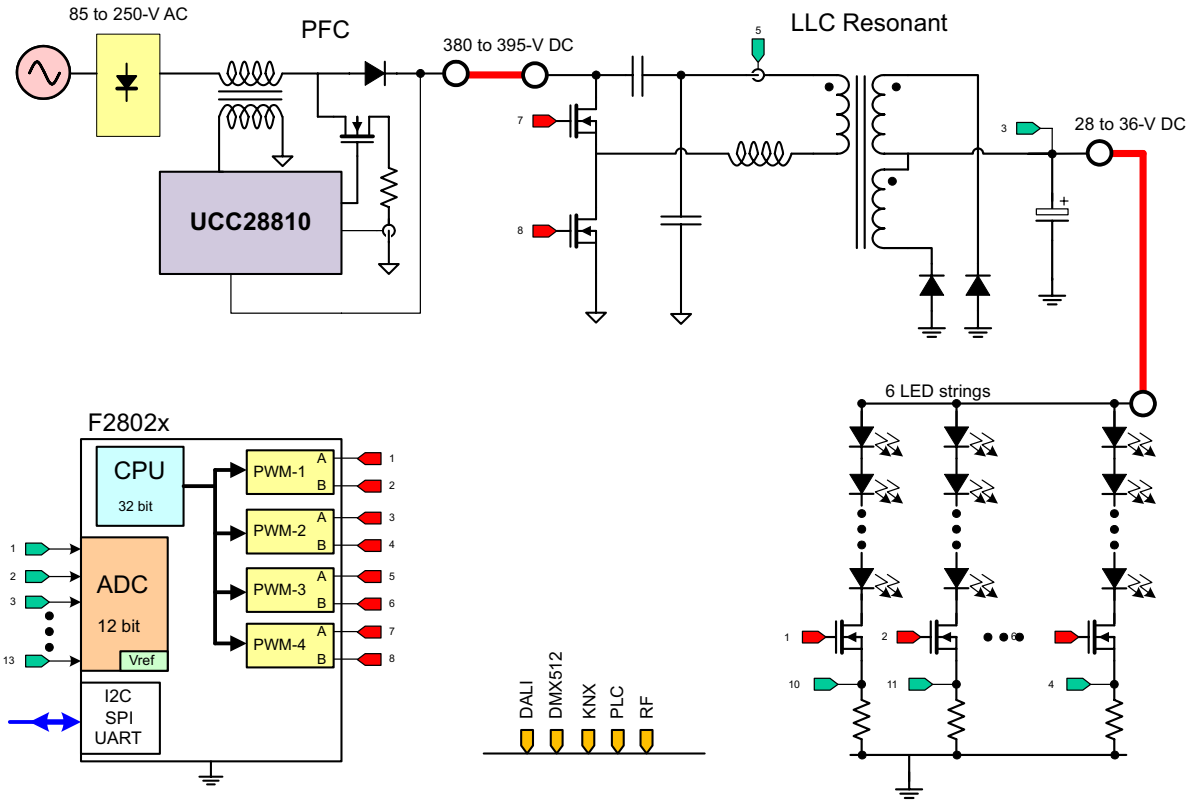


**Figure 2. Block Diagram**

A typical power conversion board is made up of several power stages. On the AC LED lighting and communications board, each of these power stages is organized into distinct macro blocks for ease of development. Each of these macro sections is bounded by its own silkscreen area. Table 1 lists of all the macro blocks' names and a short description of its function. See Figure 3 for placement of macro areas.

**Table 1. Layout Descriptions**

| NAME | MACRO | DESCRIPTION |
|---|---|---|
| AC LED Lighting and Communications main board | [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. |
| PFC stage macro | [M1] | A single-phase PFC boost stage |
| LLC resonant stage macro | [M2] | A step-down DC/DC LLC resonant stage |
| LED dimming stage macros | [M3-M5] | Stages used to individually dim each individual LED string |
| Isolated DC/DC converter module | [M6] | Converts a 400-V DC input into 18-V DC for the primary side and 12 V for the secondary side |
| DC power entry macro | [M7] | Generates the 12, 5, and 3.3-V DC rails |
| Isolated USB-to-JTAG emulation macro | [M8] | Provides onboard isolated JTAG connection through USB to the host. Also used to provide isolated SCI (UART) communication for connection with the GUI. |

Each component in this document is named first with their macro number followed by the reference name. For example, [M2]-J1 would refer to the jumper J1 located in the macro M2, and [Main]-J1 would refer to the jumper J1 located on the main board, outside of the other defined macro blocks.

# 3 Quick Start GUI

This kit comes with a user-friendly GUI that provides a convenient way to evaluate the functionality of this kit and the F28027 microcontroller without having to learn and configure the underlying project software or install Code Composer Studio (CCS). The interactive interface uses sliders, buttons, and text boxes to demonstrate the LED lighting with the C2000 device quickly and easily.

## *3.1 Hardware Setup*

Figure 3 lists some of the major connectors and features of the AC LED lighting and communications board.

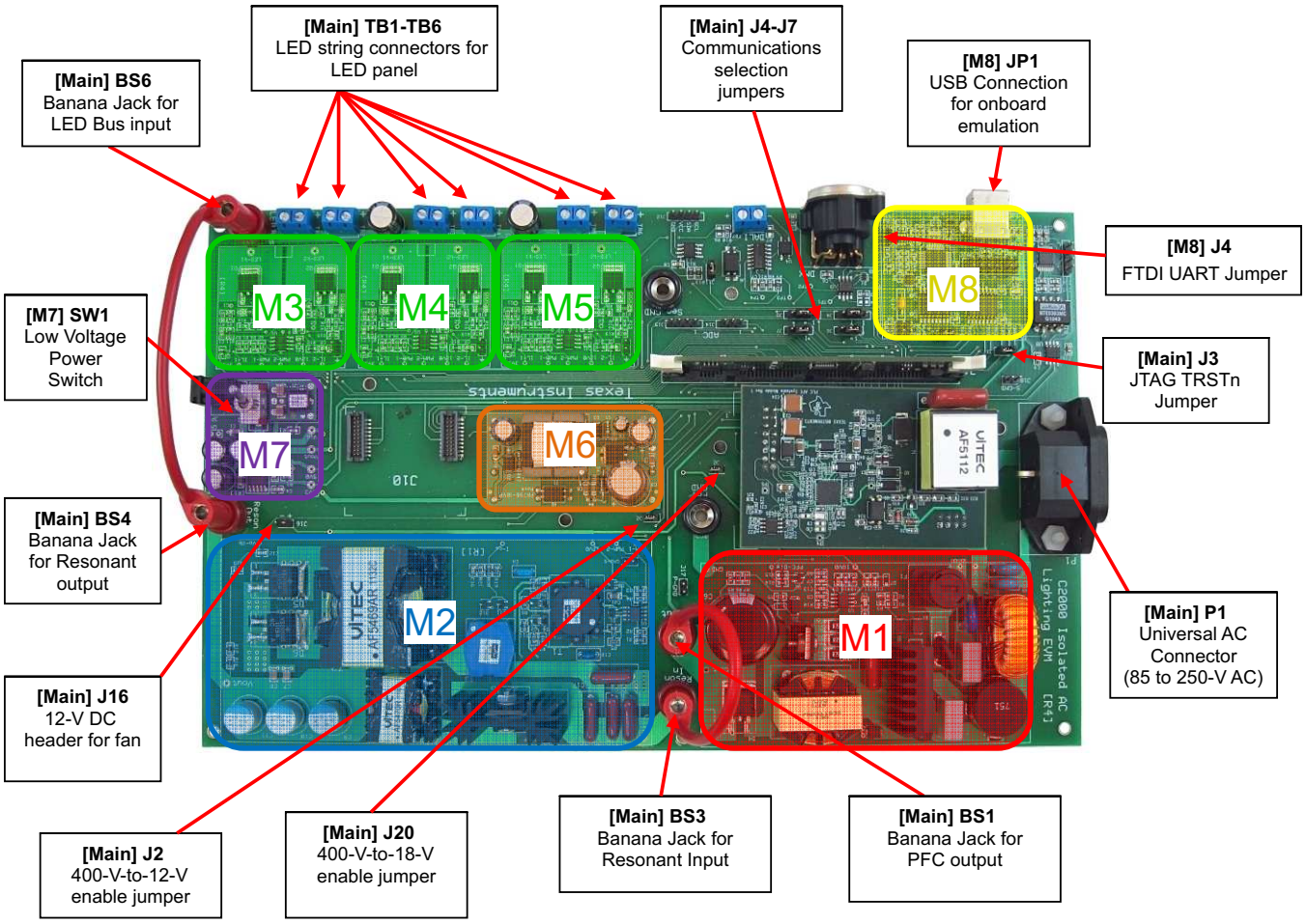


**Figure 3. Layout of Macro Blocks**

1. On the Piccolo F28027 controlCARD, check the following switches:
   (a) For SW1, make sure position 1 and 2 are both in the “on” (up) position.
   (b) SW2, SW3, and SW4 should all be in the default down position.
   (c) Do not place a jumper at R10 (if applicable).
2. Put a F28027 controlCARD into the socket on the AC LED lighting and communications board and connect a cable from the USB connector on the board to the computer. [M8]-LD1, near the AC LED lighting board’s USB connector, should turn on.

**NOTE:** If CCS has never been installed, it may be necessary to install drivers to make the board work correctly. If a window comes up when the USB cable is connected from the board to the computer, use the install wizard to install drivers from the XDS100v1 directory of the USB drive included with this kit.

3. When Windows® asks to search for Windows Update, select *No, not this time* and click *Next* (see Figure 4).


**Figure 4. Windows Update Options**

4. On the next screen, select *Install from a list or specific location* and click *Next* (see Figure 5).

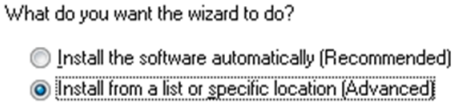


**Figure 5. Wizard Options**

5. Select *Search for the Best Driver in these locations*, uncheck *Search removable media*, check *Include this location in the search*, and browse to [USB Drive]:\XDS100 Drivers (see Figure 6).

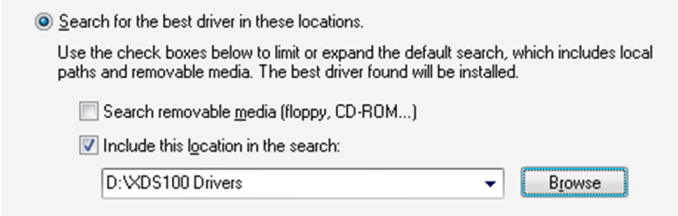


**Figure 6. Driver Options**

6. Click *Next* to install the drivers. The driver install screen will appear three times. Repeat this procedure each time.
7. Connect the LED panel from [Main]-TB1 to [Main]-TB6 on the AC LED Lighting and Communication board. For each twisted cable from the LED panel, make sure to connect the red wire to the positive (“+”) terminal and the black wire to the negative (“-“) terminal.
8. Connect or verify the following:
   (a) Connect a jumper on [Main]-J2.
   (b) Connect a jumper on [Main]-J20.
   (c) Connect a jumper on [M8]-J4.
   (d) Remove any jumpers placed on [Main]-J3.
   (e) Switch [M7]-SW1 to the internal position (switched away from “Ext”).
9. Connect the banana-to-banana plug cable (that came with the kit) between the PFC Output Connector ([Main]-BS1) and the Resonant Input Connector ([Main]-BS3).
10. Connect the other banana-to-banana plug cable (that came with the kit) between the Resonant Output Connector ([Main]-BS4) and the LED Bus Input Connector ([Main]-BS6).
11. Connect the fan’s power cable to [Main]-J16. Connect the red wire toward “+”.

### 3.2 Software Setup

The GUI used to evaluate the kit (*TMDSIACLEDCOMKIT_GUI.exe*) can be found on the USB drive that is included with this kit. This .exe file is all the software necessary to quickly evaluate this kit. To explore deeper, the underlying reference software can be found as a CCS project within controlSUITE™.

**NOTE:** The GUI requires Microsoft® .NET® framework 3.5 to run. Ensure that this software is installed prior to running this program.

To install the CCS v4 project built to run with this kit, use the most up-to-date software, and to find all reference material for the C2000 MCU, install controlSUITE. The *AC LED Lighting and Communications Kit* option downloads this kit's software. controlSUITE can be downloaded at:

- http://www.ti.com/controlSUITE

Once controlSUITE is installed, the GUI mentioned in this guide can be found at the following location:

- *controlSUITE/development_kits/TMDSIACLEDCOMKIT_vX.X/~GUI/TMDSIACLEDCOMKIT_GUI.exe*

The source code for this GUI was written in C# using Microsoft Visual Studio® .NET and can be found at:

- *controlSUITE/development_kits/TMDSIACLEDCOMKIT_vX.X/~GUI/~Source/*

The kit ships with an F28027 controlCARD that has been pre-flashed with the code that enables it to run with the kit's GUI. If, for any reason, the software needs to be re-flashed so that it works with the GUI again, this flash image can be found at:

- *controlSUITE/development_kits/TMDSIACLEDCOMKIT_vX.X/~GUI/ TMDSIACLEDCOMKIT-FlashImage_v1.0.out*

The underlying CCS project documentation and how-to-run guide can be found at:

- *controlSUITE/development_kits/TMDSIACLEDCOMKIT_vX.X/~Docs/ TMDSIACLEDCOMKIT_CCS.pdf*

**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 or simulation. When energized, do not touch the EVM or components connected to the EVM.**

### 3.3 Running the GUI

1. Browse to and double-click on *TMDSIACLEDCOMKIT_GUI.exe*. If this is the first time that the GUI is running, the GUI will ask the user to read a license agreement. Assuming that the license is accepted, Figure 7 should be seen.

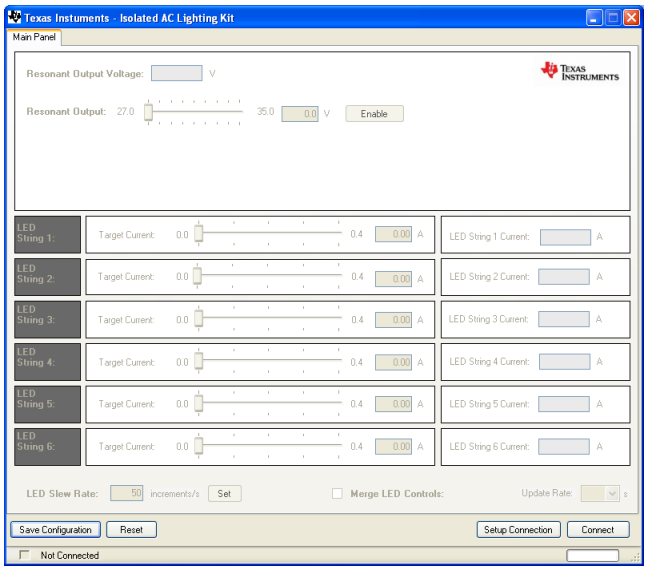


**Figure 7. Main Panel**

2. Click *Setup Connection* on the GUI and ensure the *Baud Rate* is set to 57600 and that the *Boot on Connect* box is unchecked, as shown in Figure 8.

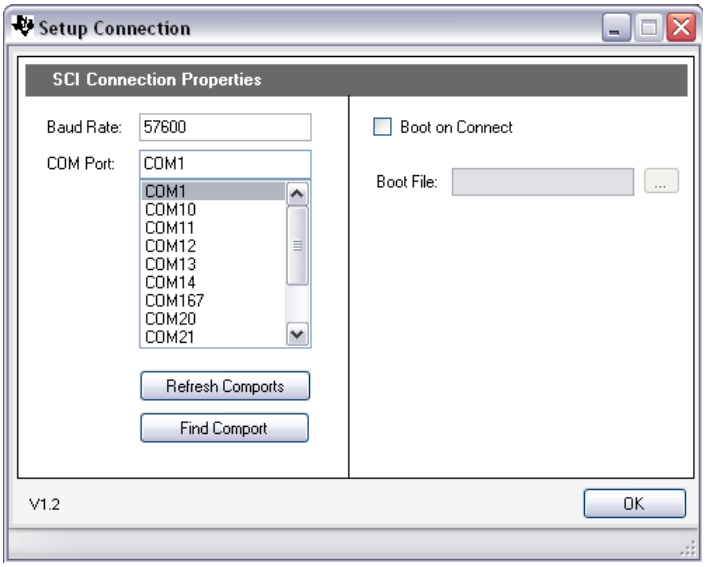


**Figure 8. The GUI Setup Connection Window**

3. Select a serial comport, which can be found by going to:

   (a) *Control Panel→System→Hardware* tab*→Device Manager→Ports (COM and LPT)*

   Look for the comport that is named *USB Serial Port* or something similar, and then select this comport in the *Setup Connection* window.

4. Click *OK* to close the *Setup Connection* window.
5. Plug one end of the AC cable into [Main]-P1.

**CAUTION**

After the AC cable is plugged in, consider the board live and has the potential for hazardous shock. Take all necessary precautions before completing this step.

6. Carefully plug the other end of the AC cable into a power strip (recommended) or a wall outlet and flip its switch to enable power.
7. Wait five seconds.
8. On the *Main Window*, click *Connect*. When connected, the status bar at the bottom left of the GUI should say *Connected*.
9. Enable the resonant DC/DC converter by clicking the *Enable* button in the area labeled *Resonant Output*.
10. Move the slider labeled *Resonant Output Voltage* to approximately 34 V to set the reference that the controller will try to regulate the output of the resonant DC/DC stage to.

**NOTE:** With no load, the resonant DC/DC stage may not be able to regulate the output to exactly the reference given. Once loaded, the output stays constant at the given reference voltage.

**WARNING**

**The LED panel is capable of driving the LEDs at a very high intensity. Face the LED panel away from people and use eye protection.**

11. Change the value of LED string 1's target current to 0.3 A. Note that the *LED String 1 Current* ramps until it reaches approximately 0.3 A. The *Resonant Output Voltage* should also remain constant at about 34 V.

12. Edit the other strings' target currents as desired. The average LED current draw is proportional to LED lumen output for most high brightness LEDs. Therefore, in this program, the brightness of the LEDs is being controlled.

**NOTE:** Near the bottom of the GUI, there is a checkbox control named *Merge LED Controls*. This control enables and disables individual control of each LED string and has the controller try and output the same current for each string. This reference is set by LED string 1's slider.

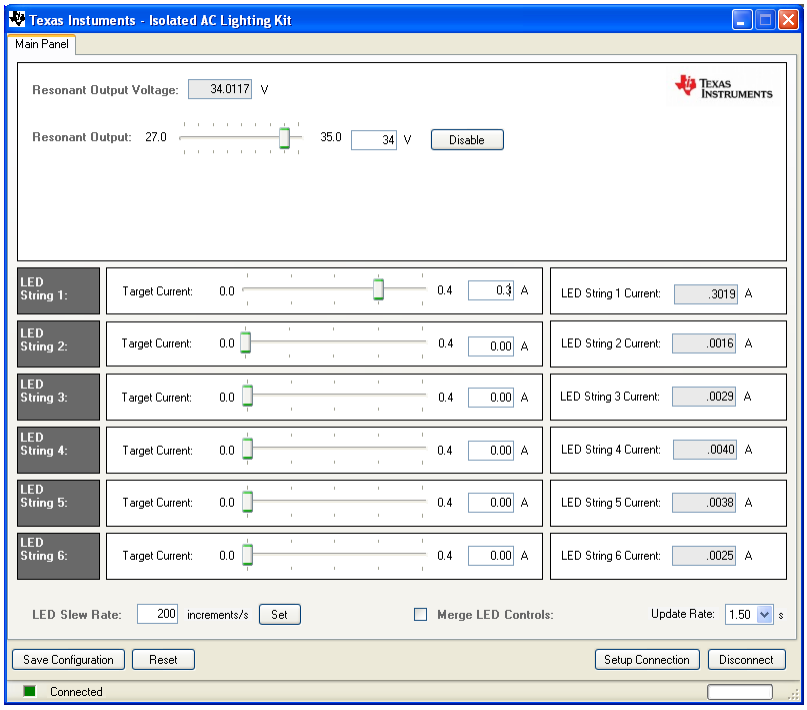


**Figure 9. Slider Settings**

13. When finished, click the resonant stage's *Disable* button then click *Disconnect*.
14. Power off the board by unplugging the AC cable from its outlet.
15. Wait a minute before touching the board.

## 4 References

- TMDSIACLEDCOMKIT_CCS: provides detailed information on the IsoACLighting project within Code Composer Studio. The document goes through the project in an easy to use lab-style format.
  - *C:\TI\controlSUITE\development_kits\TMDSIACLEDCOMKIT_vX.X\~Docs\TMDSIACLEDCOMKIT_CCS.pdf*
- TMDSIACLEDCOMKIT-HWdevPkg: a folder containing various files related to the hardware on the AC LED Lighting and Communications Developer's Kit board (schematics, bill of materials, Gerber files, PCB layout, etc).
  - *C:\TI\controlSUITE\development_kits\TMDSIACLEDCOMKIT_vX.X \ ~TMDSIACLEDCOMKIT-HwdevPkg[R4]*
- TMDSIACLEDCOMKIT-HWGuide: presents full documentation on the hardware found on the AC LED Lighting and Communications Developer's board.
  - *C:\TI\controlSUITE\development_kits\TMDSIACLEDCOMKIT_vX.X\~Docs\ TMDSIACLEDCOMKIT-HWGuide.pdf*

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