Application Report
SPRABS0–January 2013

PLC With the AC LED Lighting and Communications Developer's Kit

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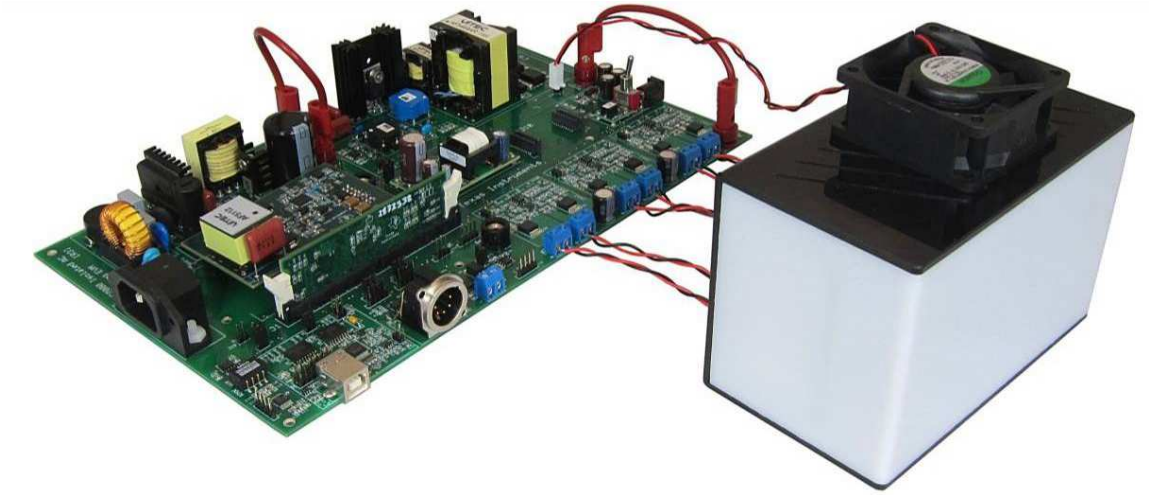
ABSTRACT

This application report provides instructions to demo Power-Line Communication (PLC) on the AC LED Lighting and Communications Developer's Kit (TMDSIACLEDCOMKIT) with the Piccolo™ microcontroller.



Contents

List of Figures

1 PLC Overview

In order to show Cenelec-A band power line communication on the TMDSIACLEDCOMKIT, you will need the following kits:

- TMDSIACLEDCOMKIT that contains the following:
  - The main baseboard that does the power conversion and LED control
  - LED panel and panel enclosure
  - USB cable
  - Power cable
  - Two banana-to-banana plug cables
- TMDSPLCMODA-P3X that contains the following:
  - Two F28035 controlCARDs (R1.2 or greater)
  - PLC AFE Systems Module
- TMDSPLCKIT-V3 that contains the following:
  - One PLC docking station and two PLC docking stations are standard in the kit, but only one is necessary for the demonstration.
  - Power cable
  - 15 V power supply
- One Null modem cable, such as: http://www.tigerdirect.com/applications/SearchTools/search.asp?keywords=null+modem+cable
- One USB-to-serial adapter, such as: http://www.amazon.com/CP-Technologie-SERIAL-ADAPTER-CP-US-03/dp/B0001ELY0K

Power Line Communication (PLC) is an innovative approach to communicating remotely without the need to install additional wiring. Simply, PLC is the idea of using the power line to communicate in addition to transmit power. A power amplifier is used to transmit data through a transformer in order to isolate the power line voltage from the low voltage part of the board. The receive path goes through the transformer and is filtered by pass-band filter where it is then translated into data.

In TI's power-line communications solutions, a C2000™ microcontroller is used as the host processor, the analog-to-digital converter (ADC), and the digital signal processor. With the extra control law accelerator (CLA) core found on many Piccolo™ devices such as the F2803x/F2806x devices or the M3 core found on the F28M35x devices, there is extra bandwidth for control applications. In the demo mentioned in this application report, the F28035's CLA core is used to control the LLC resonant and LED strings while the main C2000 core is used as a PLC processor. The fact that TI's main PLC processor is a programable chip allows for greater flexibility as standards change, become stricter, and more become available.

A TI AFE031 analog front-end chip is used as a companion to the C2000 device. It is responsible for creating the transmit signal as given by the C2000 device through serial peripheral interface (SPI), providing transmit and receive filtering and then being a power amplifier to push the signal on the power line.

The full bandwidth of PLC is broken into various bands by various different governing bodies. Of these, the European standard is the strictest and is shown in Figure 1. Cenelec-A is designated exclusively usable by energy providers, while the other bands are not as regulated yet. However, this means in the EU, most PLC communication is required to be in the Cenelec-B band or higher. Note that as the bands increase in frequency, PLC becomes more difficult (and costly) to implement. For PLC implementations done outside of the EU or in applications that isolate them more fully from the power grid, Cenelec-A may possibly be used. Each specific customer should look at what frequency bands they are restricted to by governing bodies and weigh this with cost on a case-by-case basis. The PLC communication used in this demo runs in the CENELEC-A band.

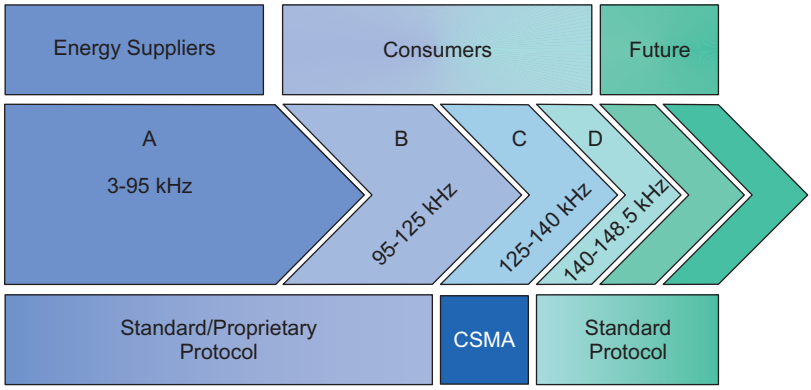


Figure 1. Cenelec Bands

PLC uses various standards. TI has solutions for many of these including G3, PRIME, and various standards of SFSK. In this demo, PLC-lite, a low data-rate proprietary PLC implementation, was used. PLC-lite is based on a memory reduced version of a BPSK-based PRIME-OFDM solution, but adds some of the robustness from what is found in the G3 protocol. It uses only basic addressing and channel control mechanisms. As a result of some of the simplifications, PLC-lite can be run on the F2803x or larger device.

2 System Overview

In this demo, power line communication with Cenelec-A is shown. The communication uses the PLC-Lite TI standard.

The system is created such that a host GUI communicates via RS-232 to a PLCv3 Power Line Comms Dock. The PLCv3 board transmits the host GUI's commands over the power line. The TMDSIACLEDCOMKIT (lighting kit) receives all the commands on the powerline, but only acts on data packets that follow a specific protocol and whose non-header- based data begins with 0xA5A5. If the correct type of data is received, the lighting kit acts on the command given. Commands include enabling LED strings, changing the luminous flux output of a particular string, and so forth. Optionally, a computer can be connected to the lighting kit in order to investigate the quality of communication. Note, the TMDSIACLEDCOMKIT board does not require a connection to a computer to act on commands sent to them.

This PLC system, as implemented, is point-to-point and addressing of individual lighting kits is not currently implemented. Most of the PLC software packages found on http://www.ti.com/plc do support multi-node communication.

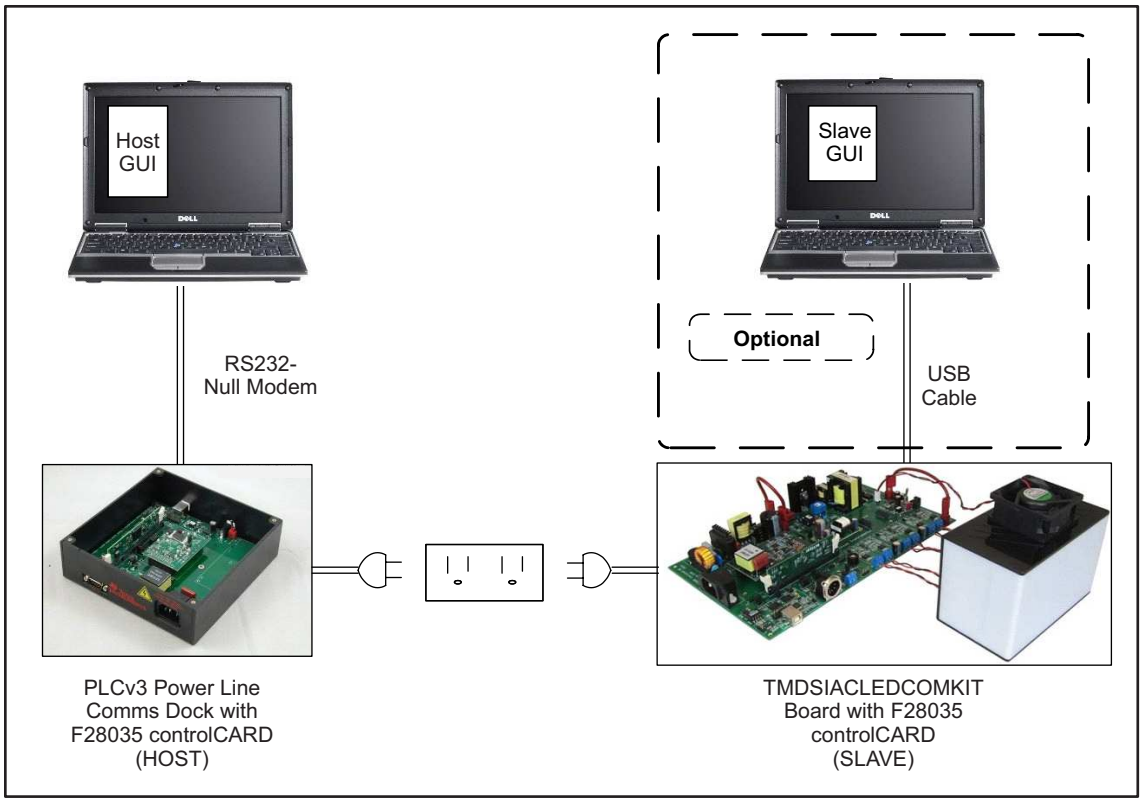


Figure 2. PLC System Diagram

3 Quick Start GUI

This kit comes with a user-friendly graphical user interface (GUI) that provides a convenient way to demonstrate PLC communication on the TMDSIACLEDCOMKIT, without having to learn and configure the underlying project software or install Code Composer Studio™. The interactive interface using sliders, buttons, and text boxes allows PLC and LED control with the C2000 device to be demonstrated.

3.1 Hardware Features

Listed in Figure 3 are some of the major connectors and features of the AC LED Lighting and Communications (TMDSIACLEDCOMKIT) board.

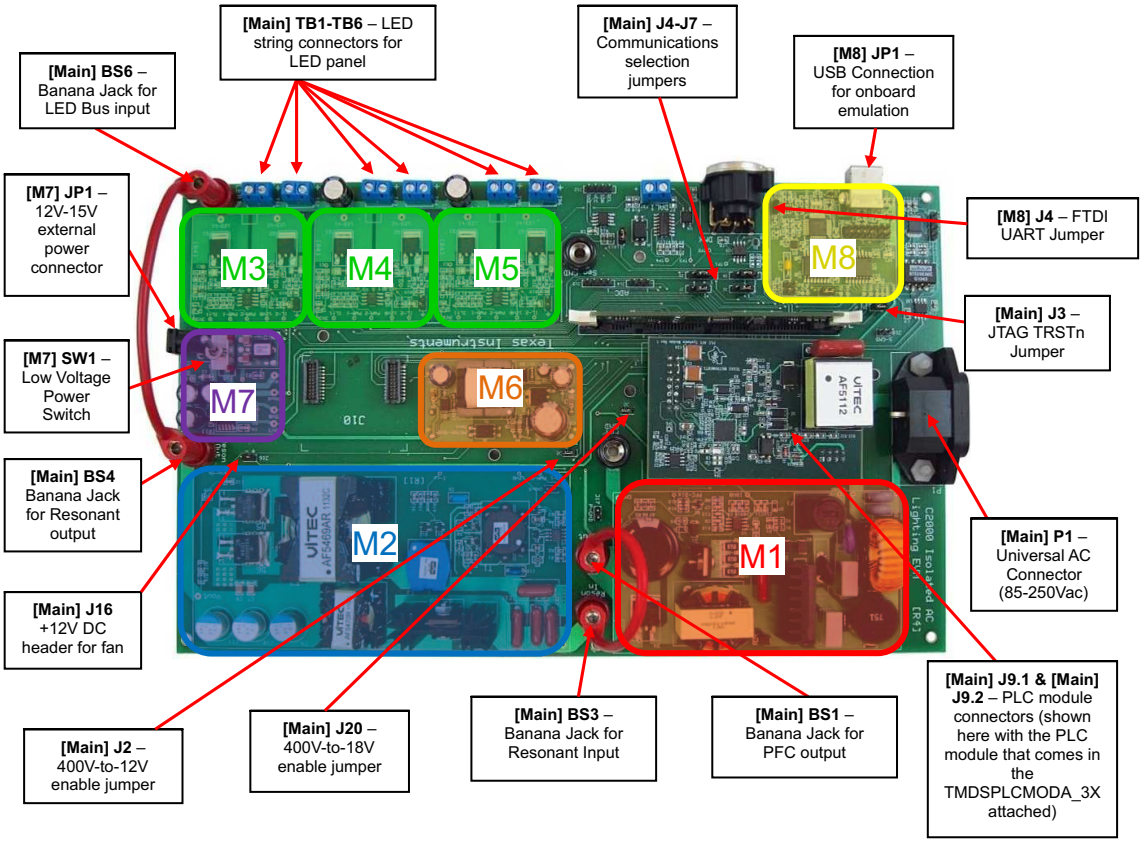


Figure 3. TMDSIACLEDCOMKIT Key Features

Listed in Figure 4 are some of the major connectors and features that will be used or changed on the Power Line Comms dock board (TMDSPLCKIT-V3 board).

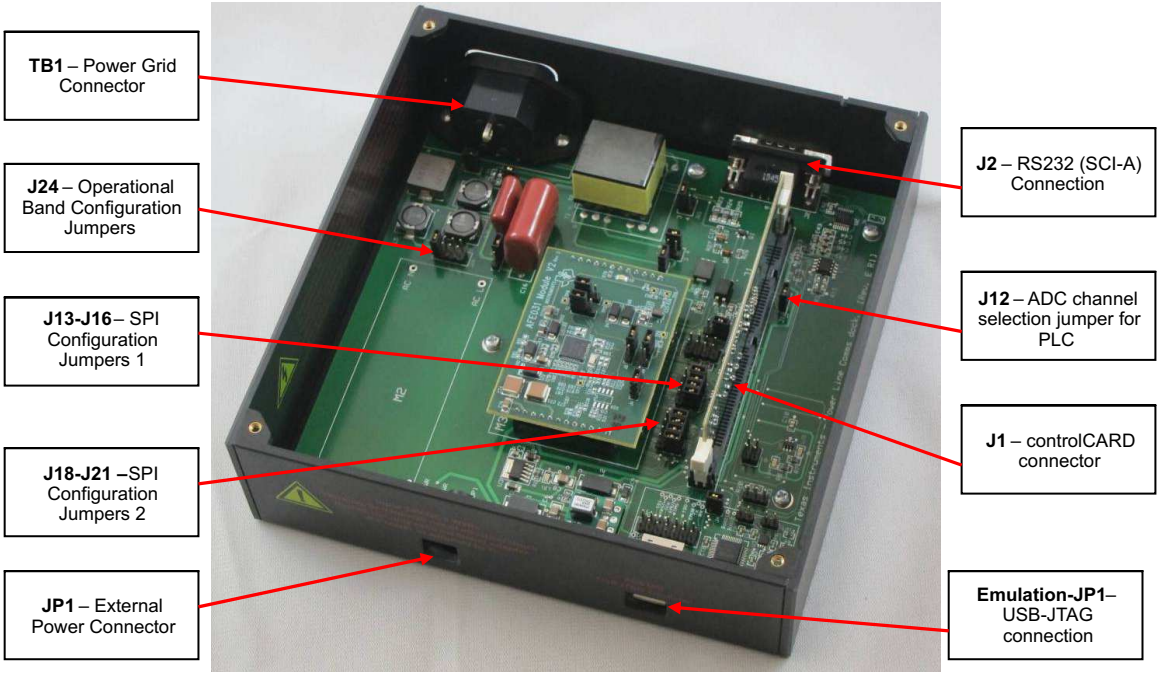


Figure 4. TMDSPLCKIT-V3 Board

Schematics for two of the boards are located at: controlSUITE: www.ti.com/controlsuite

- TMDSIACLEDCOMKIT:
  - \development_kits\TMDSIACLEDCOMKIT_v1.0\~TMDSIACLEDDCOMKITHWdevPkg\
- TMDSPLCMODA-P3X:
  - \development_kits\~Modules\TMDSPLCMODA-P3X\PLC_AFESystemsModule- HWdevPkg[R2.2]\

The TMDSPLCKIT-V3 schematics can be found within the PLC development packages found at: http://www.ti.com/plc.

3.2 Install the PLC-Lite Package and GUI

NOTE: In order to install and use the GUI, Microsoft® .NET Framework 3.5 SP1 or greater must be installed. If not installed, please install this package before continuing.

1. Browse to: www.ti.com/controlsuite - \development_kits\TMDSIACLEDCOMKIT_v1.0\~GUI\PLC\.
2. Double-click and install the “PLC – TMDSIACLEDCOMKIT GUI.msi”.

   Tip: Please allow these tools to install to their default location.

NOTE: The version of the Zero Configuration GUI package installed will be 2.70.####.####.

3.3 Program the controlCARDs

1. Download and install the basic version of C2Prog from http://www.codeskin.com/programmer.
2. Remove one of the TMDSPLCKIT-V3 motherboards from the TMDSPLCKIT-V3 kit. This board is used to program the both F28035 controlCARDs with the two versions of the demo code. The other PLCKIT-V3 board will not be used.
3. Put one of the F28035 controlCARDs (provided with the TMDSPLCMODA-P3X kit) into J1 of the TMDSPLCKIT-V3 board.
4. Connect one end of a USB cable to the host computer and the other end to Emulation-JP1.
5. Unplug the USB cable from the board after 30 seconds, and then reconnect the USB cable to the board after 5 seconds.
6. Connect the 15 V DC power supply into JP1 and the other end to the wall.
7. Ensure that switch SW1 on the TMDSPLCKIT-V3 board is in the EXT. PWR position. Once done, the controlCARD's LD1 should turn on.
8. Open C2Prog.
9. Click Select File and browse to: www.ti.com/controlsuite - \development_kits\TMDSIACLEDCOMKIT_v1.0\~GUI\PLC\IsoACLighting- F28035-PLC_CENA_FLASH.hex
10. Click Open.
11. Expand the Programming Configuration section, if necessary.
12. In the Programming Configuration section:
    (a) Choose the Target as: 28035,34.
    (b) Choose the programming option: JTAG.
    (c) Keep the other options as default (as shown in Figure 5).

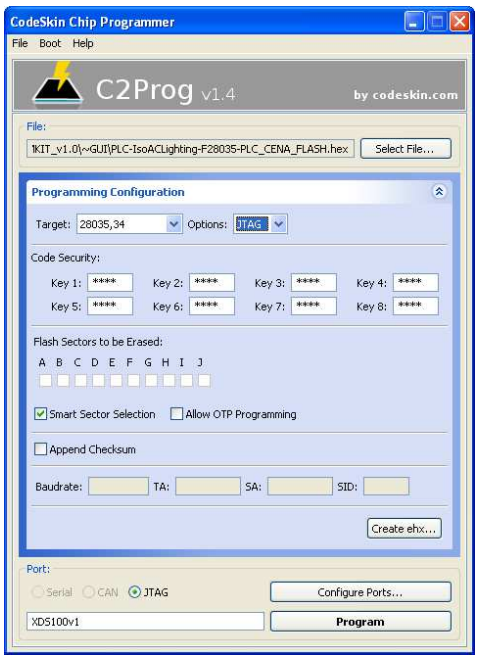


Figure 5. C2Prog

13. Click Configure Ports…
14. In the JTAG port dropdown choose XDS100v1.
15. Click OK.
16. Click Program. A new window should popup showing the status of the programming.
17. Once done, click OK.

18. Unplug 15 V from JP1 of the TMDSPLCKIT-V3. This will turn off the controlCARD's LD1.
19. Remove the F28035 controlCARD from its slot and put it in into [Main]-J1 of the TMDSIACLEDCOMKIT board. This controlCARD is now programmed to control the power stages in addition to doing PLC on the TMDSIACLEDCOMKIT board.
20. Plug a second controlCARD into controlCARD socket J1 of the TMDSPLCKIT-V3 board.
21. The F28035 controlCARD LD1 should turn on.
22. Click Select File… Browse and select the following file: www.ti.com/controlsuite - \development_kits\TMDSIACLEDCOMKIT_v1.0\~GUI\PLC\PLCLiteforPLCV3 KIT_v2.3.hex
23. Repeat steps 10 through 17 for this new controlCARD.
24. The controlCARD that was just programmed has the code that controls the TMDSPLCKIT-V3. Leave this card in the kit.
25. Unplug the 15 V supply from JP1 of the TMDSPLCKIT-V3.
26. Unplug the USB cable from Emulation-JP1 of the TMDSPLCKIT-V3 board.

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.

3.4 Setup and Run the PLC Demo GUI

NOTE: This section assumes that the sections "Install the PLC-Lite package and the GUI" and "Program the controlCARDs" have been done at least once prior to this section.

1. Move or place the following jumpers on the TMDSIACLEDCOMKIT board (see Figure 2):
   (a) [Main]-J6 and [Main]-J7 positions 1 and 2 jumpered
   (b) [M8]-J4 jumpered
   (c) [Main]-J3 un-jumpered
   (d) [Main]-J2 and [Main]-J20 jumpered
   (e) Switch [M7]-SW1 to the internal position (switched away from "Ext")

2. Move or place the following jumper on the TMDSPLCKIT-V3 board (see Figure 3):
   (a) J13-J16 should be placed at position 1-2
   (b) J18-J21 should be placed at position 2-3 (note the jumper positions are labelled differently than J13-J16)
   (c) J24 should be placed at position 7-8
   (d) J12 should be placed at position 2-3
   (e) SW1 should be in the “EXT. PWR” position
3. A F28035 flashed with “PLCLiteforPLCV3KIT_v2.3.hex” is put into the TMDSPLCKIT-V3 kit and a F28035 flashed with “IsoACLighting-F28035-PLC_CENA_FLASH.hex” is put into the TMDSIACLEDCOMKIT board (if not already done from the previous section).
4. On both Piccolo F28035 controlCARDs, check the following switches:
   (a) SW1, should be in the down (“off”) position.
   (b) SW2, make sure position 1 and 2 are both in the “on” (up) position.
   (c) SW3, both positions should be in the default (down) position.

3.4.1 Setup for the TMDSPLCKIT-V3

1. Connect a USB-to-serial adapter to the host computer.
2. Connect a null modem cable between the USB-to-serial adapter and J2 on the TMDSPLCKIT-V3 board. Make sure the applicable USB-to-serial driver has been installed.
3. Plug the 15 V DC wall supply between the wall and JP1.
4. The F28035 controlCARD’s LD2 should now begin blinking.
5. Connect a power cable to TB1.
6. Connect the other end of the power cable to a power outlet.

CAUTION

AFTER THIS STEP, DO NOT TOUCH THE TMDSPLCKIT board!

3.4.2 Setup for the TMDSIACLEDCOMKIT

1. Connect the PLC AFE Systems Module (found in the TMDSPLCMODA-P3X kit) and plug it into [Main]-J9.1 and [Main]-J9.2.
2. Ensure that a jumper is placed on J3 (and not placed on J4 or J5) of the PLC AFE Systems Module.
3. Connect the LED panel to [Main]-TB1 through [Main]-TB6 on the TMDSIACLEDCOMKIT 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.
4. Connect a banana-to-banana plug cable between the PFC output connector ([Main]-BS1) and the Resonant Input Connector ([Main]-BS3).
5. Connect the other banana-to-banana plug cable between the Resonant output connector ([Main]- BS4) and the LED Bus Input Connector ([Main]-BS6).
6. Connect the fan’s power cable to [Main]-J16. Connect the red wire toward “+”.
7. Plug one end of the AC cable into [Main]-P1.
8. Carefully, plug the other end of the AC cable into the wall outlet. Or (recommended), plug the AC cable into a power strip and then flip its switch to enable power. Note that PLC communication is significantly less stable if the two outlets chosen are connected to different phases of the power line.

CAUTION

AFTER THIS STEP, DO NOT TOUCH THE TMDSIACLEDCOMKIT board!

9. After a few seconds, the TMDSIACLEDCOMKIT board should power up, the controlCARD's green LD1 LED should turn on, and LD2 should blink.

3.4.3 Run the Demo

1. In Windows®, click Start → All Programs → Accessories → Command Prompt.
2. Type in the following command:

   "C:\Program Files\Texas Instruments\Lighting Control\PLC_Application_Suite.exe" script=lightingcontroldemo
3. When the Zero Configuration GUI opens, it scans and uses the first available COM port to attach to a PLC board.

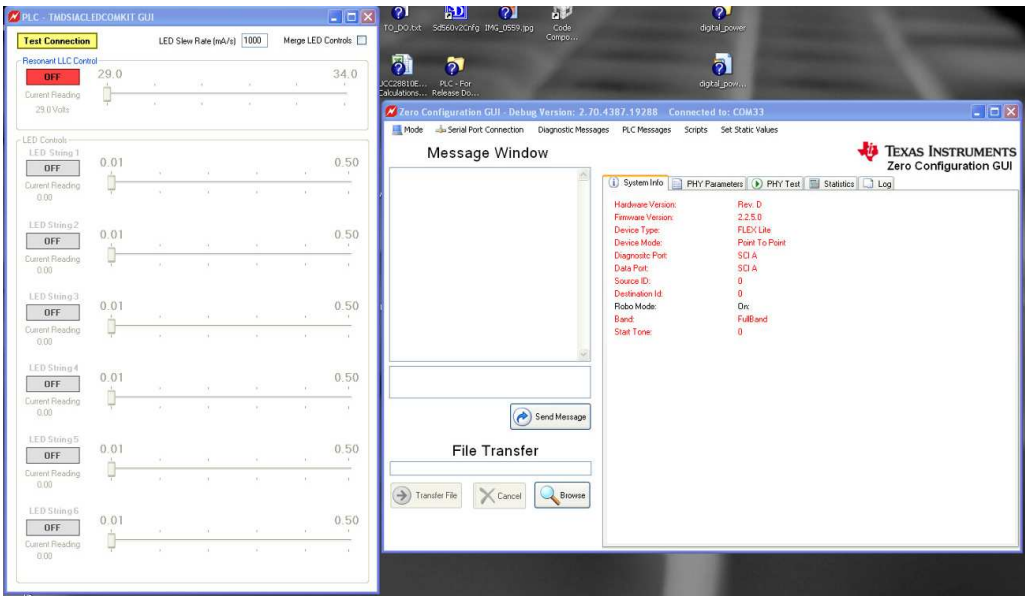


Figure 6. PLC Board

If there are no available COM ports, the Zero Configuration GUI displays an error message and exits. If a PLC does not respond on the selected PORT, a timeout message is displayed.

You can manually change the selected COM port by using the "Serial Port Connection" drop down menu, which displays all of the available COM ports. When a COM port is selected, the Zero Configuration GUI attempts to connect to that port.

4. Once connected, two windows will pop up. The "Zero Configuration GUI" window is used to configure and test the PLC connection. The other window, labeled "PLC – TMDSIACLEDCOMKIT GUI", is used in this demo.
5. Click the "Test Connection" button. If everything is connected correctly, a command will be transmitted by the PLCKIT-V3. The message will be received by the TMDSIACLEDCOMKIT board and cause the controlCARD's LD3 to toggle between on or off.

NOTE: If pressing the "Test Connection" button does not work, please power off the board and check all connections. If there continues to be an issue, it is possible that your power line is extremely noisy. To increase the transmit strength, see bullet 1 in Section 4.

6. Enable the TMDSIACLEDCOMKIT's Resonant DC/DC converter by clicking the On and Off button in the area labeled "Resonant LLC Control".
7. Move the slider in the area labeled "Resonant LLC Control" to approximately 34 V. **This sets the reference that the controller will try to regulate the output of the Resonant DC/DC stage to (not sure what is being said in this sentence?)**.

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.

8. Enable LED String 1's output by clicking the On and Off button next to LED String 1.
9. Change the value of LED string 1's target current to 0.3A. Note that the "LED String 1 Current" ramps until it reaches approximately 0.3A. Once the current has ramped to the proper current, "Resonant Output Voltage" should now remain constant at about 34 V.
10. 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 top 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.

11. When finished, click the resonant stage's "OFF" button.
12. Close the PLC Application GUI windows.
13. Power off the TMDSIACLEDCOMKIT and TMDSPLCKIT-V3 boards by unplugging both AC cables from the wall.
14. Wait at least one minute for the board to discharge before touching either board.

4 Other Ideas That Can be Explored

- If you click on "Mode → Intermediate Mode" in the Zero Configuration GUI window, you can go to a more advanced GUI where it is possible to increase the transmit strength of the transmitter so that it is more immune to noise.
  - Go to "Options → PHY Options" and change the Level to "0 (MOL): Max" then select Apply.
  - Then, return to the "Zero Configuration GUI" mode.
- Prior to Step 6 in Section 3.4 - *Setup and Run the PLC Demo GUI*, you can connect a USB cable between the TMDSIACLEDCOMKIT and a computer. If this is done, you can open up a second "PLC_TMDSIACLEDCOMKIT GUI" and have it connect up to the TMDSIACLEDCOMKIT. This allows you to connect one GUI up to the PLCKIT-V3 and another to the lighting kit and run tests to find out the reliability of the system.
- The TMDSIACLEDCOMKIT source code that shows you how to use the PLC library while doing digital control at the same time is included with the kit. If interested, feel free to examine it.
- For more documentation on the GUI and the underlying PLC protocol, go to http://www.ti.com/plc and download the latest PLC-lite package. There is also a more in-depth quick start guide that uses the two TMDSPLCKIT-V3 boards present in the TMDSPLCKIT-V3 kit.

5 References

For more information please see the following guides that are located at: www.ti.com/controlsuite

- 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.

  \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, and so forth).

  \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.

  \development_kits\TMDSIACLEDCOMKIT_vX.X\~Docs\ TMDSIACLEDCOMKIT -HWGuide.pdf

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