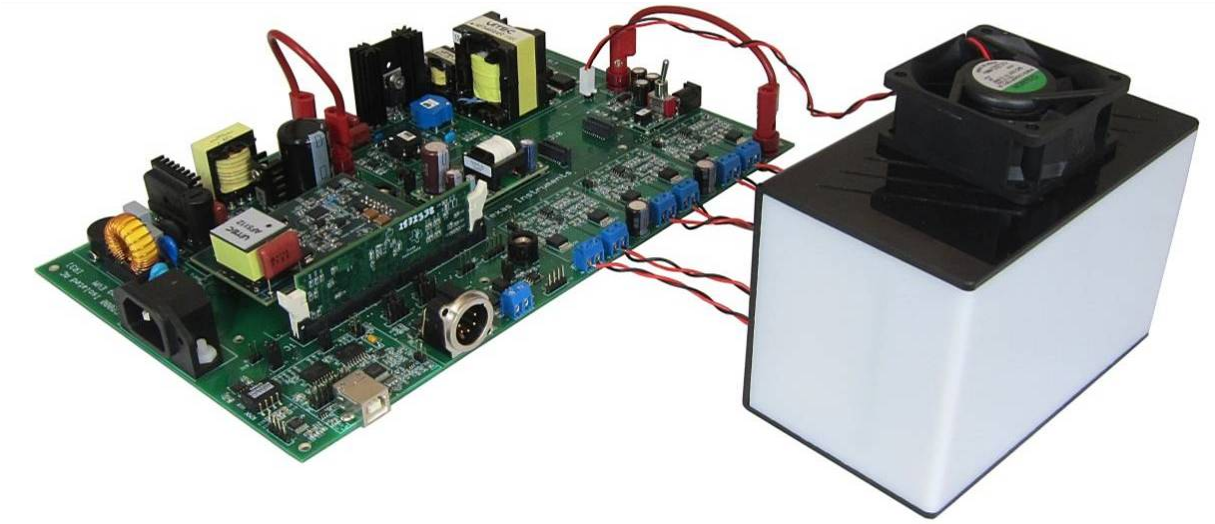
Quick Start Guide - PLC with the AC LED Lighting & Communications Developer's Kit

Version 1.1 – January 2012



The document provides instructions to demo Power-Line Communication (PLC) on the AC LED Lighting & Communications Developer's Kit (TMDSIACLEDCOMKIT) with the Piccolo microcontroller.

In Order to Show Cenelec-A Band Power Line Communication on the TMDSIACLEDCOMKIT you will need the following kits:

- TMDSIACLEDCOMKIT which contains the needed –
  - the main baseboard which does the power conversion and LED control
  - LED Panel and panel enclosure
  - USB cable
  - Power cable
  - Two banana-to-banana plug cables
- TMDSPLCMODA-P3X which contains the needed -
  - Two F28035 controlCARDs (R1.2 or greater)
  - PLC AFE Systems Module
- TMDSPLCKIT-V3 which contains the needed –
  - One Power Line Comms docking station; two PLC docking station stations come in the kit but only one is needed for the demonstration
  - Power cable
  - 15V 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

PLC Overview

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 ADC, and the digital signal processor. With the extra 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 Quick Start Guide 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 flexiblity 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 SPI, providing transmit/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 below. 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 which 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.

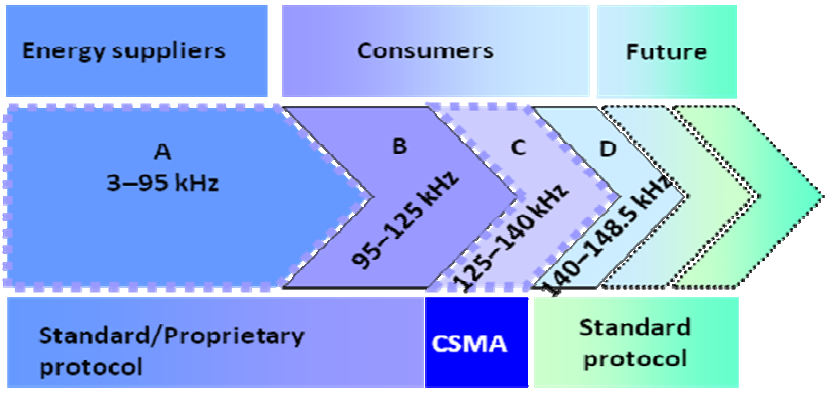


Figure 1: Cenelec Bands

PLC has various standards which are used. 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.

System Overview

In this demo, Power Line Communication with Cenelec-A will be shown. The communication uses the PLC-Lite TI standard.

The system is created such that a host GUI will communicate via RS-232 to a PLCv3 Power Line Comms Dock. The PLCv3 board will then transmit the host GUI's commands over the power line. The TMDSIACLEDCOMKIT (lighting kit) will the receive all commands on the powerline, but only acts on data packets that follow a specific protocol and whose non-header based data begin with 0xA5A5. If the correct type of data is received, the lighting kit will act on the command given. Commands include enabling LED strings, changing the luminous flux output of a particular string, etc. 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 it.

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.

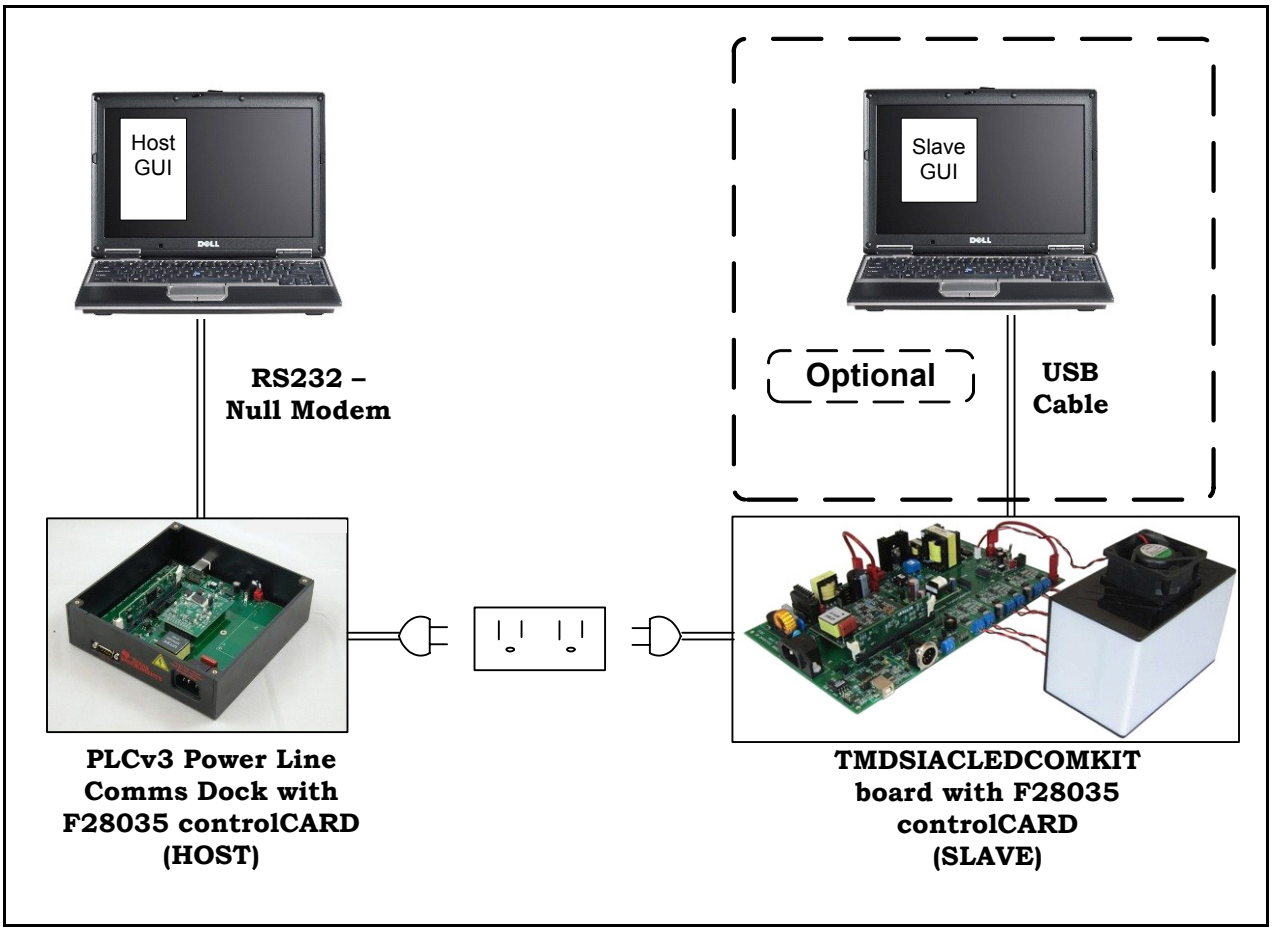


Figure 2: PLC System Diagram

Quick Start GUI

This kit comes with a user-friendly graphical user interface (GUI) which 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 textboxes allows PLC and LED control with the C2000 device to be demonstrated.

Hardware Features

Listed below in Figure 2 are some of the major connectors and features of the AC LED Lighting & Communications (TMDSIACLEDCOMKIT) board.

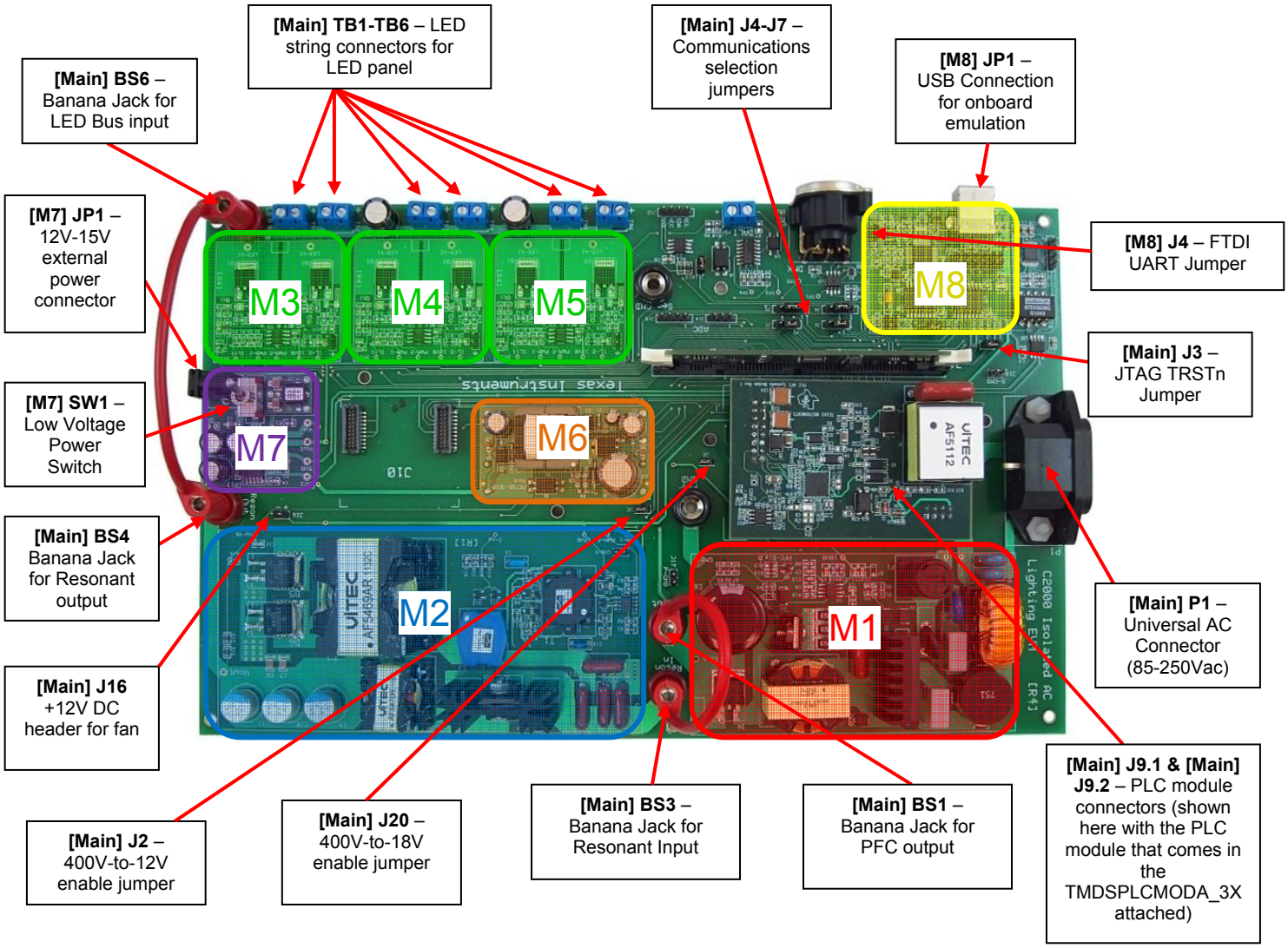


Figure 3: TMDSIACLEDCOMKIT Key Features

Listed below in Figure 3 are some of the major connectors and features that will be used/changed on the Power Line Comms dock board (TMDSPLCKIT-V3 board).

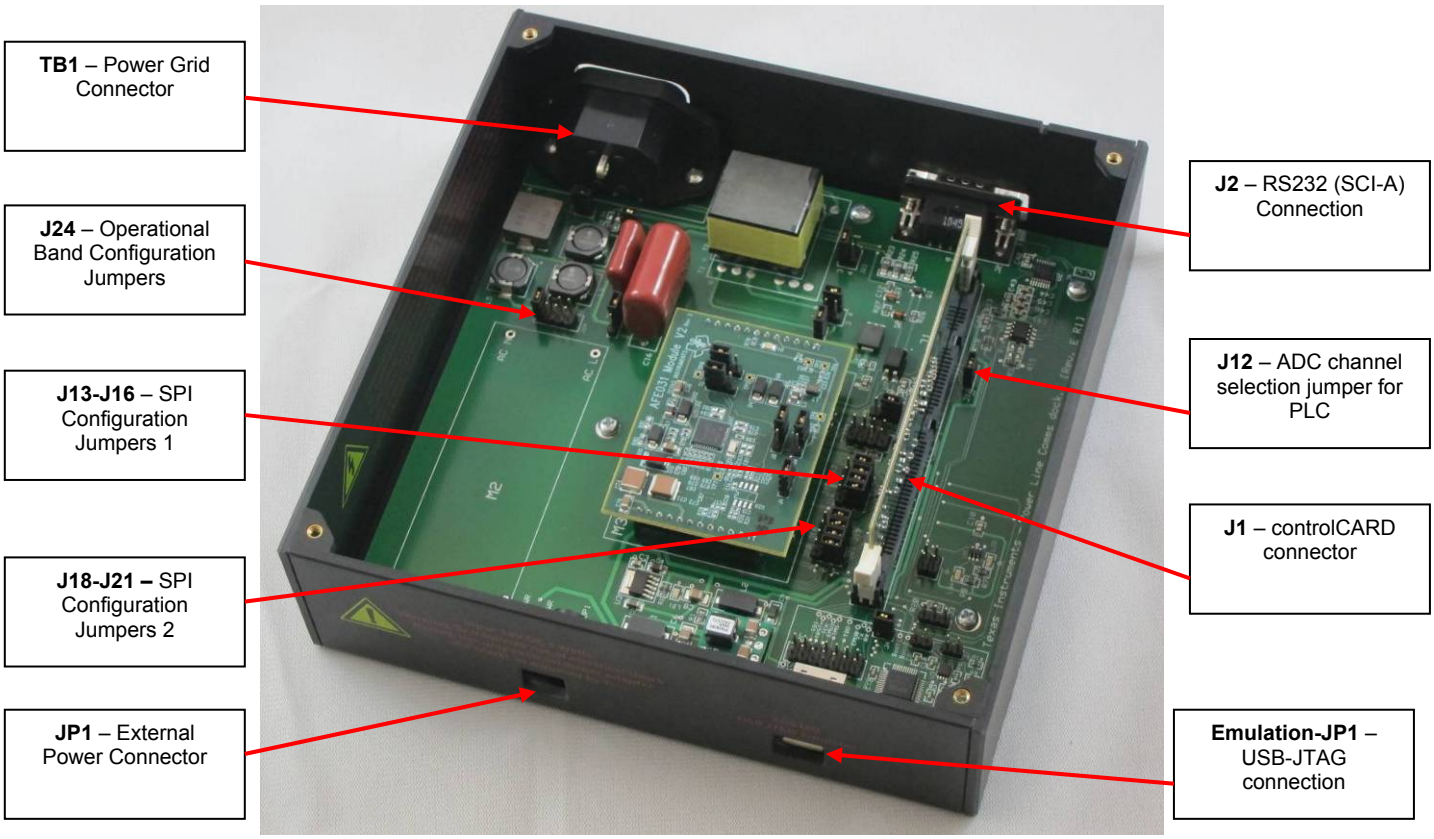


Figure 4: TMDSPLCKIT-V3 board

Schematics for two of the boards can be found in controlSUITE:

- **TMDSIACLEDCOMKIT** - C:\TI\controlSUITE\development_kits\TMDSIACLEDCOMKIT_v1.0\~TMDSIACLEDDCOMKIT-HWdevPkg\
- **TMDSPLCMODA-P3X** – C:\TI\controlSUITE\development_kits\~Modules\TMDSPLCMODA-P3X\PLC_AFE-SystemsModule-HWdevPkg[R2.2]\

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

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:
   C:\TI\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.####.####

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 will be used to program the both F28035 controlCARDs with the two versions of demo code. The other PLCKIT-V3 board will not be used.
3) Put one of the F28035 controlCARDs, which comes 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) After 30 seconds unplug the USB cable from the board and then after 5 seconds reconnect the USB cable to the board.
6) Connect the 15V 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: C:\TI\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 below)

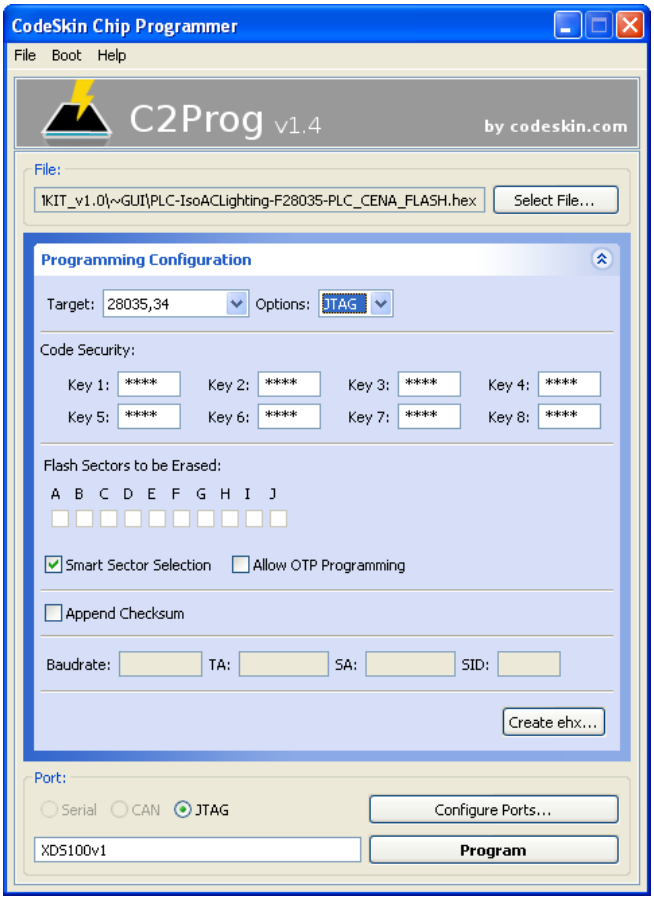


Figure 5: C2Prog

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 15V 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 the 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: C:\TI\controlSUITE\development_kits\TMDSIACLEDCOMKIT_v1.0\~GUI\PLC\PLCLiteforPLCV3KIT_v2.3.hex
23) Repeat steps 10-17 for this new controlCARD.
24) The controlCARD that was just programmed has the code which controls the TMDSPLCKIT-V3. Leave this card in the kit.
25) Unplug the 15V 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.

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 (refer to Figure 2):
   a. [Main]-J6 and [Main]-J7 positions 1&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 (refer to 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) Place 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:
   - SW1, should be in the down ("off") position.
   - SW2, make sure position 1 and 2 are both in the "on" (up) position.
   - SW3, both positions should be in the default (down) position.

Setup for the TMDSPLCKIT-V3

5) Connect a USB-to-serial adapter to the host computer
6) 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.
7) Plug the 15V DC wall supply between the wall and JP1.
8) The F28035 controlCARD's LD2 should now begin blinking.
9) Connect a power cable to TB1.
10) Connect the other end of the power cable to a power outlet.

CAUTION: AFTER THIS STEP, DO NOT TOUCH THE TMDSPLCKIT board!

Setup for the TMDSIACLEDCOMKIT

11) Connect the PLC AFE Systems Module (found in the TMDSPLCMODA-P3X kit) and plug it into [Main]-J9.1 and [Main]-J9.2.
12) Ensure that a jumper is placed on J3 (and not placed on J4 or J5) of the PLC AFE Systems Module.
13) 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.
14) Connect a banana-to-banana plug cable between the PFC output connector ([Main]-BS1) and the Resonant Input Connector ([Main]-BS3).
15) Connect the other banana-to-banana plug cable between the Resonant output connector ([Main]-BS4) and the LED Bus Input Connector ([Main]-BS6).
16) Connect the fan's power cable to [Main]-J16. Connect the red wire toward "+".
17) Plug one end of the AC cable into [Main]-P1.
18) 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 will be 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!

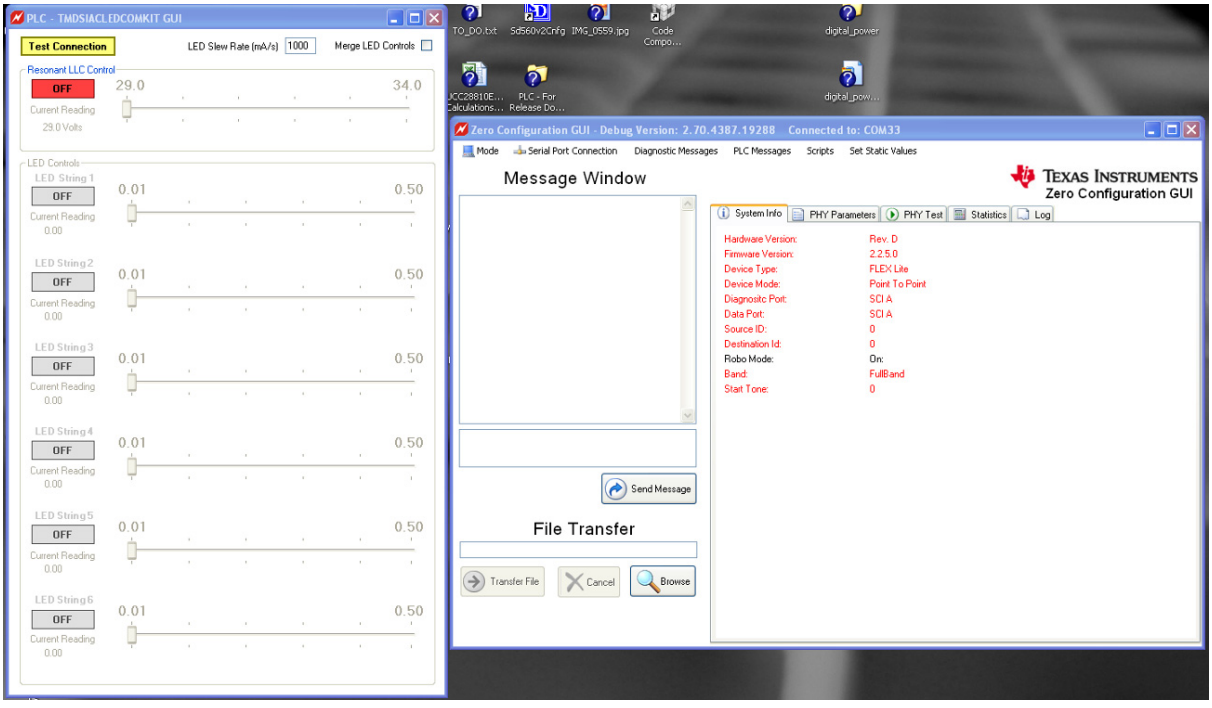
19) After a few seconds, the TMDSIACLEDCOMKIT board should power up, the controlCARD's green LD1 LED should turn on and LD2 should blink.

Run the Demo

20) On Windows, click "Start->All Programs->Accessories->Command Prompt".
21) Type in the following command:

"C:\Program Files\Texas Instruments\Lighting Control\PLC_Application_Suite.exe" script=lightingcontroldemo

22) When the Zero Configuration GUI opens it will scan and use the first available COM port to attach to a PLC board.



If there are no available COM ports the Zero Configuration GUI will display an error message and exit. If a PLC does not respond on the selected PORT a timeout message will be displayed.

You may manually change the selected COM port by using the "Serial Port Connection" drop down menu. It will display all of the available COM ports. When a COM port is selected the Zero Configuration GUI will attempt to connect to that port.

23) Once connected, two windows will pop up. The "Zero Configuration GUI" window is used to configure and test the PLC connection. The other window, labelled "PLC – TMDSIACLEDCOMKIT GUI", is used in this demo.
24) Click the "Test Connection" button. If everything is connected correctly this should cause a command to be transmitted by the PLCKIT-V3. This message will be received by the TMDSIACLEDCOMKIT board and will 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. See the first bullet on Pg 12 to increase the transmit strength.

25) Enable the TMDSIACLEDCOMKIT's Resonant DC/DC converter by clicking the On/Off button in the area labelled "Resonant LLC Control".
26) Move the slider in the area labelled "Resonant LLC Control" to approximately 34V. This sets 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 will stay constant at the given reference voltage.

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27) Enable LED String 1's output by clicking the On/Off button next to LED String 1.
28) Change the value of LED string 1's target current to 0.3A. Note that the "LED String 1 Current" will ramp until it reaches approximately 0.3A. Once the current has ramped to the proper current, "Resonant Output Voltage" should now remain constant at about 34V.
29) 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/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.

30) When finished, click the resonant stage's "OFF" button
31) Close the PLC Application GUI windows.
32) Power off the TMDSIACLEDCOMKIT and TMDSPLCKIT-V3 boards by unplugging both AC cables from the wall.
33) Please wait at least one minute for the board to discharge before touching either board.

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 Level to “0 (MOL): Max” then hit Apply.
    - Then return to the “Zero Configuration GUI” mode.
- Prior to Step 10 of the “Setup and Run the PLC Demo GUI” section, you may 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 which shows 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.
- See http://www.ti.com/plc and download the latest PLC-lite package there for more documentation on the GUI and the underlying PLC protocol. There is also a more in-depth Quick Start Guide there which does more with PLC-Lite. That QSG will use the two TMDSPLCKIT-V3 boards present in the TMDSPLCKIT-V3 kit.

References

For more information please see the following guides:

- **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