TI Designs

System on Module for Power Line Communication (FCC Frequency Band)

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

TIDM-SOMPLC-FCC	Tool Folder Containing Design Files
TMDSPLCKIT-V4	Product Folder
TMS320F28375S	Product Folder
AFE032	Product Folder
TPS62240	Product Folder
TPS3828-33	Product Folder
SN74LVC2G07	Product Folder

TI E2E™ Community

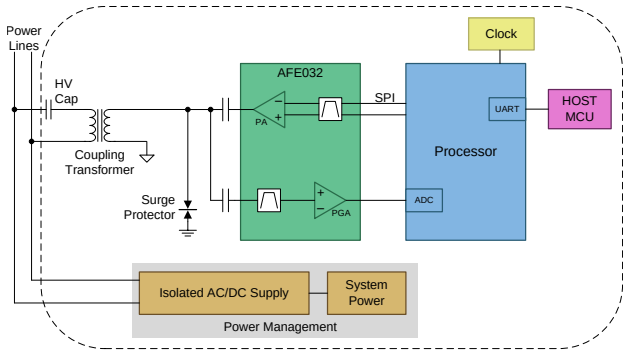
ASK Our E2E Experts
WEBENCH® Calculator Tools

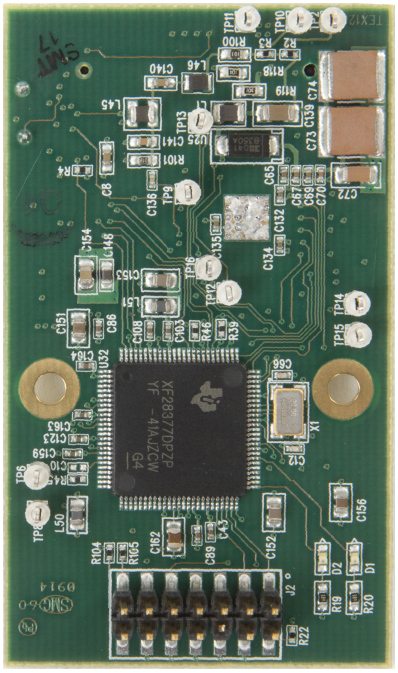
Design Features

- Small Size: 1.5" × 1.9"
- G3-PLC and IEEE 1901.2 Compatible
- F28375 PLC Engine With VCU II
- Support FCC/ARIB Frequency Bands
- AFE032 Integrated Analog Front End
- 34-Pin Mini Header for Interfacing Other Designs
- Multiple Serial Communications Interfaces Available Including UART, SPI, I^2C, and CAN
- Additional ADC Interface
- Additional GPIO Interfaces

Featured Applications

- Power Line Communication Modem
- Smart E-Meter: AMR and AMI
- Solar Power Inverter





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Overview

The SOMPLC-FCC is a single-board system on module (SOM) for PLC in the FCC frequency band. This single hardware design supports several popular PLC industry standards including G3-PLC and IEEE 1901.2. TI's certified PLC software is available along with the SOMPLC-FCC. Engineers can take the SOM design and integrate it into their overall system board or keep the design as an add-on board to their application. The only additional hardware required is the AC mains line coupling circuitry. The included hardware schematics and Gerber files simplify the task for engineers to add PLC to their end system. OEMs will benefit from having the ability to rapidly evaluate and prototype Power Line Communications technology in their application.

2 System Description

The TMS320F28375 PLC MCU is optimized to meet the requirements for PLC networks in Smart Grid deployments around the world. The F28375 MCU features the C28x 32-bit CPU that can execute the narrowband OFDM PLC modem standards, which adhere to key international and industry standards such as G3-PLC, IEEE-1901.2, and ITU G.9903/9904 in the FCC frequency bands. The F28375 MCU is optimized to work with the AFE032 PLC analog front end (AFE). The AFE032 is an integrated PLC AFE that is capable of a transformer coupled connected to the AC mains power line. The AFE032 is ideal for driving high-current, low-impedance lines driving up to 1.9 A into reactive loads.

The F28375 device includes an enhanced VCU engine to fasten digital signal processing, which allows achieving full capacity required by G3/1901.2 FCC standards.

2.1 PLC Development Kit Components

The development kit includes the following hardware:

- Two sets of development board with each set containing:
  - One SOMPLC-FCC (TMS320F28375 + AFE032)
  - One docking board

The development kit includes the following software:

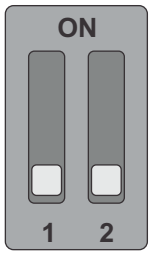
- PLC binaries
- PC software and GUI
  - Zero configuration GUI

The PLC software package includes the following documents:

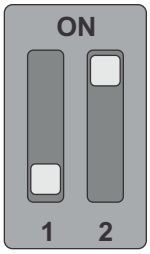
- Software API specification
  - Host message protocol specifications
- Hardware documents
  - AFE daughter card schematics and Gerber files
  - Docking board and SOM schematics and Gerber files
  - Bill of materials (BOM)

3 Boot Modes (SW1 Positions)

Boot mode can be selected using the switch SW1. Figure 1 describes the available settings:



FLASH Boot Mode (Default Setting)
Position 1: OFF
Position 2: OFF



SCI-A Boot Mode
Position 1: OFF
Position 2: ON

Figure 1. Boot Modes

4 UART SCI Communication

To communicate with the SCI, meet the following requirements:

- Baud Rate = 57600
- Message Data Bits = 8
- Stop Bits = One
- Parity = None
- Handshake = None
- RTS Enable = True

NOTE: The SOMPLC does not have a RS-232 driver. Consider communications to RS-232 devices external to this design.

5 SOMPLC 34-Pin Definition

This module supports the following interfaces:

Required Connections

- SCI (UART)
- Line
- 15 V
- 3V3
- GND

Optional Connections

- ADC
- GPIOs
- SCI (UART)
- CAN
- SPI
- I^2C
- Zero Cross
- Analog GND

Table 1. 34-Pin Connector

PIN#	NAME	I/O	ELECTRICAL	DESCRIPTION
1	L1	I/O	0 V (GND)	Neutral (analog ground), connected to the PL coupler
2	L2	I/O	0 V (±6-V Peak)	Analog PLC signal, connected to the PL coupler
3	NC	NC	—	Unused
4	NC	NC	—	Unused
5	GND	—	—	Ground
6	GND	—	—	Ground
7	V15	—	15 to 18 V	Power supply pin (15 V). Peak current 400 mA in transmit mode (average 100 mA).
8	3V3	—	3.14 to 3.47 V	CPU and Logic Digital Power pin (3.3 V). Max current 1000 mA.
9	EN	I-I/O	–0.3 V to VCC+0.3 V	System enable (logical level, active high). Controls power up/down function of the module. When low, the module goes to power down mode. This feature is not yet implemented in software or GPIO13.
10	ZC	I	–0.5 to 6.5 V	Buffered ZC input. This input must be isolated from the power line before entering this pin.
11	RX-A	I	–0.3 V to VCC+0.3 V	Asynchronous serial host-transmit, SCI-A
12	TX-A	O	–0.3 V to VCC+0.3 V	Asynchronous serial host-receive, SCI-A
13	Phase B/GPIO	I-I/O	–0.3 V to VCC+0.3 V	Phase B Enable signal (for 3-phase selection) or GPIO5
14		I/O	–0.3 V to VCC+0.3 V	Phase C enable signal (for 3-phase selection) or GPIO10
15		I/O	–0.3 V to VCC+0.3 V	I^2C data pin
16		I	–0.3 V to VCC+0.3 V	I^2C clock pin
17		I	–0.3 V to VCC+0.3 V	Unused ADC input. (ADC-B0)
18		—	—	Analog ground
19		I/O	–0.3 V to VCC+0.3 V	Unused multi-purpose I/O, GPIO26
20		—	—	Ground
21		I/O	–0.3 V to VCC+0.3 V	Unused multi-purpose I/O, GPIO27
22		—	—	Ground
23		I-I/O	–0.3 V to VCC+0.3 V	CAN RX interface or GPIO30
24		O-I/O	–0.3 V to VCC+0.3 V	CAN TX interface or GPIO31
25		I	–0.3 V to VCC+0.3 V	SPI clock or general purpose I/O (GPIO18)
26		I	–0.3 V to VCC+0.3 V	SPI slave transmit enable or general purpose I/O (GPIO19)
27		I	–0.3 V to VCC+0.3 V	SPI slave in, master out or general purpose I/O (GPIO16)
28		O	–0.3 V to VCC+0.3 V	SPI master in, slave out or general purpose I/O (GPIO17).
29		I	–0.3 V to VCC+0.3 V	Reset of SOMPLC (active low)
30		I/O	–0.3 V to VCC+0.3 V	Unused multi-purpose I/O pin, GPIO04.
31		NC	—	Unused
32		NC	—	Unused
33		I	–0.3 V to VCC+0.3 V	Asynchronous serial host-receive, SCI-B
34		O	–0.3 V to VCC+0.3 V	Asynchronous serial host-transmit, SCI-B

6 Mechanical Specification

The connectors used on the SOMPLC are as follows:

- A male 0.05-mil header (2×17) is placed on the SOMPLC module.
  - This connector is keyed so that the module cannot be placed backwards.
  - An example part that will fit this design is a Sullins Connector Solutions, Part number: SBH31-NBPB-D17-SP-BK, Digikey Part number: S9108-ND
- A female 0.05-mil receptacle (2×17) should be used on the host board to mate with the SOMPLC module.
  - This connector is keyed and should follow the appropriate orientation as the male connector.
  - An example part that will fit this design is a Sullins Connector Solutions, Part Number: SFH31-NPPB-D17-SP-BK, Digikey Part Number:S9117-ND

The top view of the female connector which would be placed on the host board is shown in Figure 2.

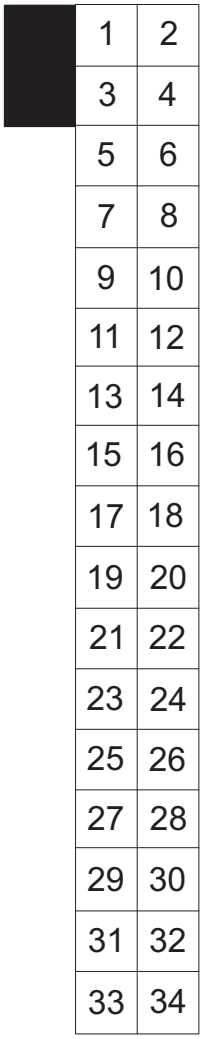


Figure 2. Pin Female Connector Top View

7 PLC SOM Programming

Depending on the end use of the SOM, different versions of the PLC software may be programmed to the module.

For this design, download the G3-PLC software package from the link given in Section 10.6 and check out the PLC binaries (.out or .sbin) under installation directory.

7.1 Using Code Composer Studio™ and JTAG Emulator to Program the F28375 MCU

If the XDS100 emulator is not available, use Code Composer Studio (CCS) and an XDS510 or XDS560 emulator to program the device. Install CCS v5.5 or higher before following this procedure:

1. Install the desired Texas Instruments PLC Development Package from www.ti.com/plc.
2. Set switch SW1 to "FLASH Boot Mode" as described in Section 3. When a JTAG emulator is used, it is capable of interrupting the set boot mode to gain control of the MCU. When the programming procedure is complete, it will be necessary for the mode to be set to "FLASH Boot Mode" for the SOM module to continue to work properly.
3. Power up SOM module by applying both 15 V and 3.3 V through the 34-pin host connector.
4. Connect the emulator to the SOM module with the 14-pin JTAG cable.
5. Open CCS.
6. Create a F28375 target configuration.
7. Connect to F28375 device.
8. Load the PLC specific .out firmware located in c:\Texas Instruments\<PackageName>\SW\bin CCS will automatically flash the firmware onto the F28375 device.

8 Test Setup

To test the SOM modules the operator will need the following items:

- A host computer running Windows® XP® or Windows 7® and two available USB ports
- Two SOM docking stations
- 15-V external power supply for each docking station
- Power line connector for each docking station
- USB cable for connecting to Host PC for each docking station
  - A single host PC can be shared between the two kits
- Zero Configuration GUI
  - Requires a modified .config file

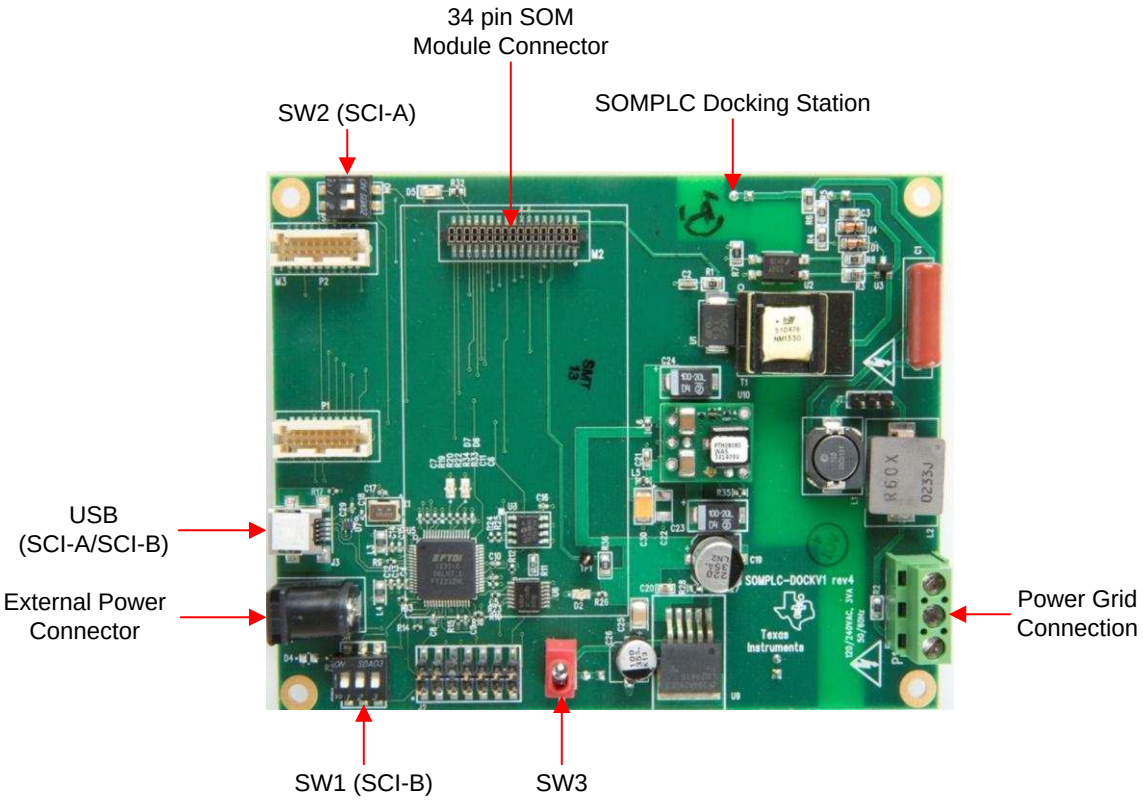


Figure 3. SOMPLC Docking Station

1. Plug in the included SOM module to each 34-pin SOM module connector.
2. Connect Neutral and Line (marked with words on AC power cable) to the power grid connector P1 of each kit; make sure the neutral and line connections are not shorted.

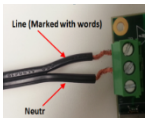


Figure 4. Line Connection

3. Ensure the position of switches SW1 and SW2 are set to default setting as shown in Figure 5 to communicate to PC GUI through SCI-A.

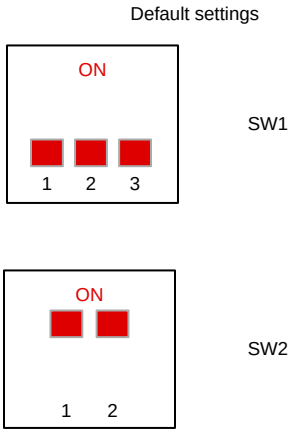


Figure 5. Software Configuration

8.1 Power Up

1. Connect the 15-V wall-mounted power supply to the AC receptacle of each kit.

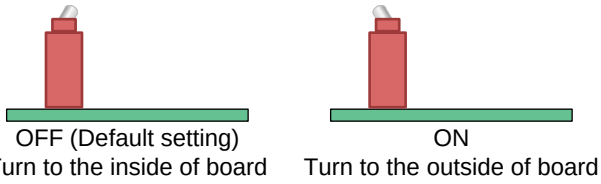


Figure 6. SW3

2. Turn ON Switch SW3 of each kit to power the boards.

8.2 Connecting to a PC

1. Plug in the micro-USB to the kit and connect the USB cable to the PC, repeat this step for the second kit.

NOTE: The program may ask for USB-Serial drivers to be installed. If this occurs, please proceed to install the drivers. The drivers can be found in C:\Texas Instruments\<PackageName>\XDS100 Drivers. It will be necessary to reboot your PC after the drivers are installed, even if you are not asked by windows to do so.

2. Verify the modems have been installed correctly by using the *Device Manager* (*Start→Control Panel→System→Device Manager→Ports*)

NOTE: The four ports on picture are for two boards.

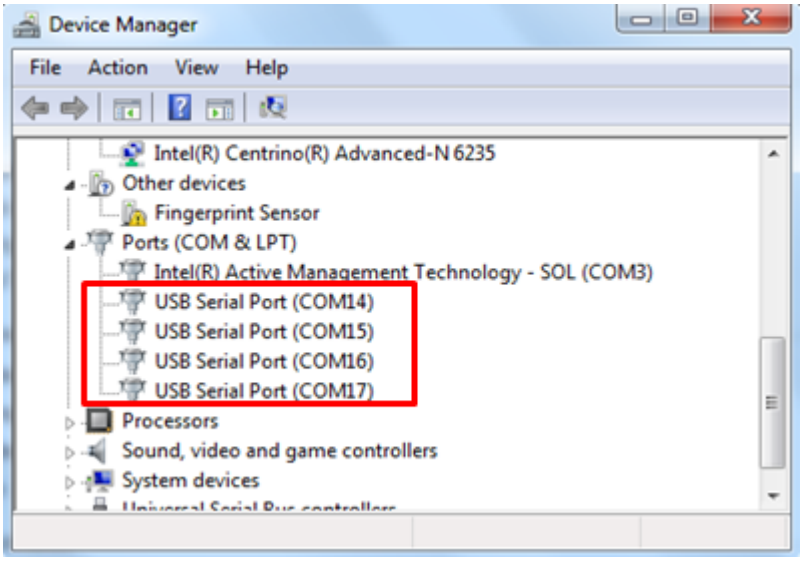


Figure 7. Device Manager: Port Configuration

9 Testing

1. Install the "Zero Configuration" tool from C:\TexasInstruments\<PackageName>\Tools, and launch it. When operating one PC, it will be necessary to launch two instances, one for each modem.
2. When the Zero Configuration GUI opens, it will use the first available COM port to attach to a PLC.

NOTE: Ensure *Diagnostic Port/Data Port* is configured to SCI-A by selecting CTRL+A in GUI window.

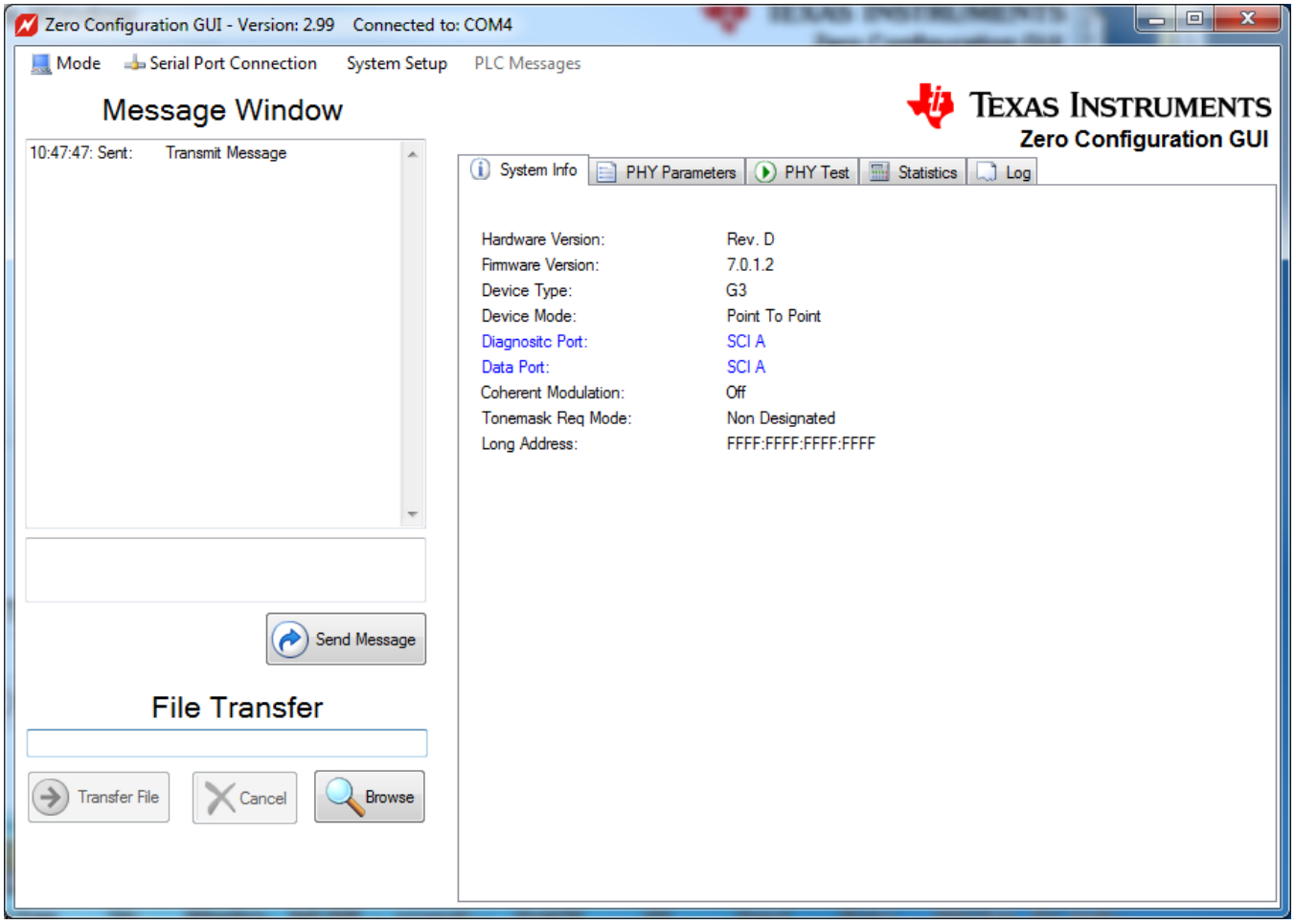


Figure 8. Zero Configuration GUI

3. Connect each PLC kit to the power line. Ensure that devices are connected on same power line phase.

WARNING

HIGH VOLTAGE! Use caution when connecting to the power grid. If there is concern about connecting to the power grid, use a power strip to connect the two modems together. In this case, the power strip does *not* need to be plugged into the power grid.

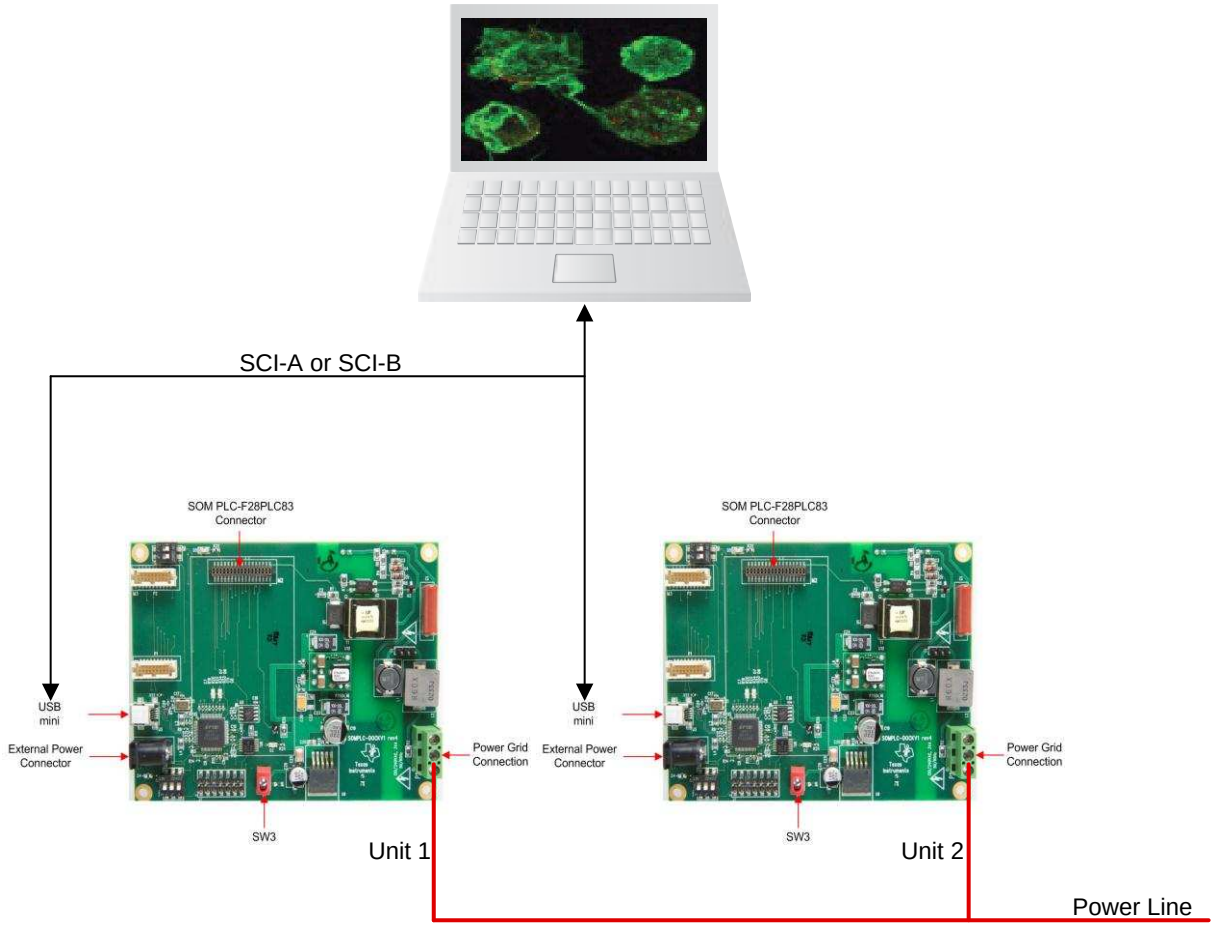


Figure 9. Testing Setup

4. Enter the desired text into the *Message Window*. Press the *Send Message* button. The message will then be received by the other GUI.

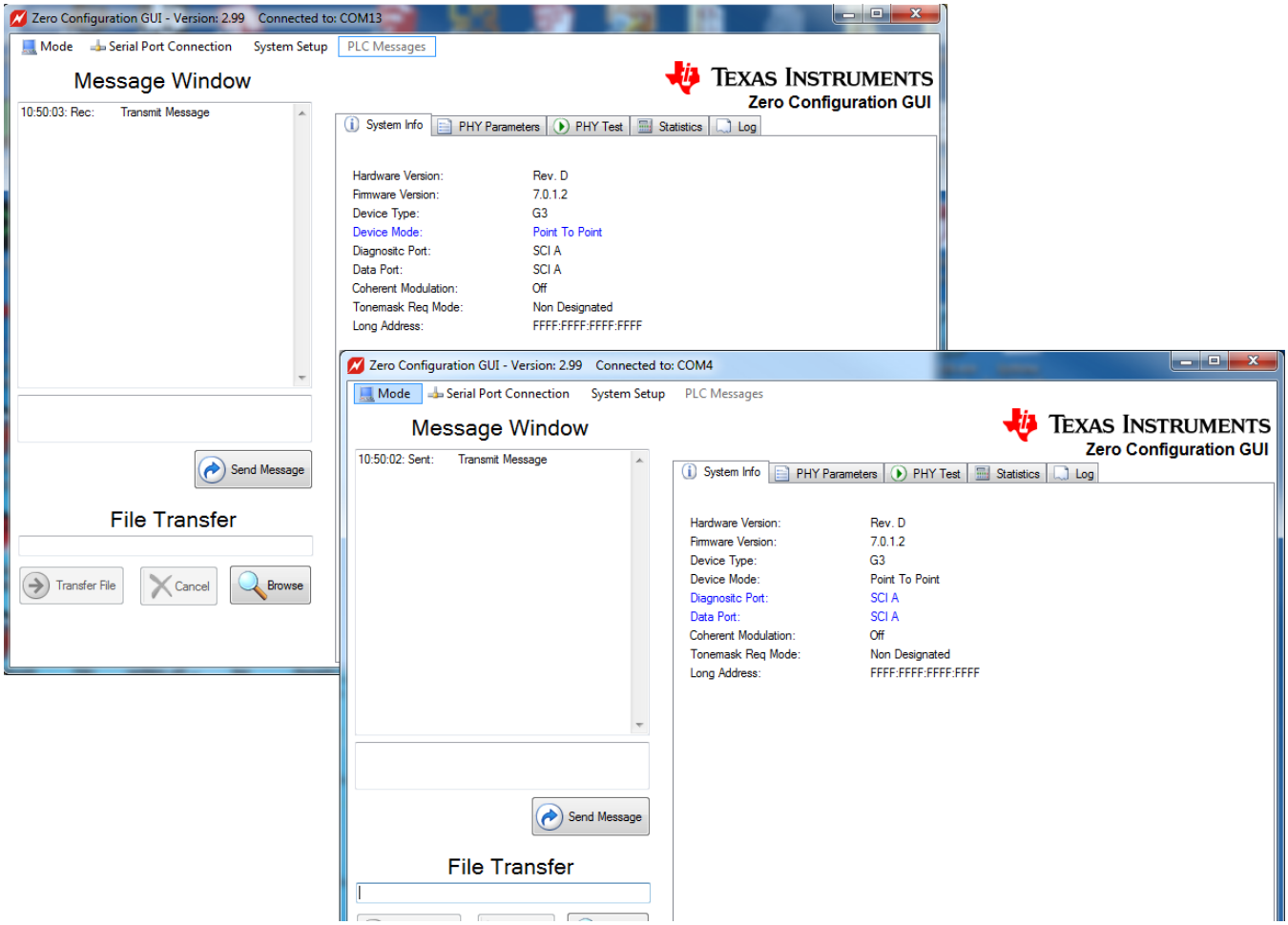


Figure 10. P2P Test With Zero Configuration GUI

The *File Transfer* function contained in the bottom left hand corner of GUI option can be used to transfers files.

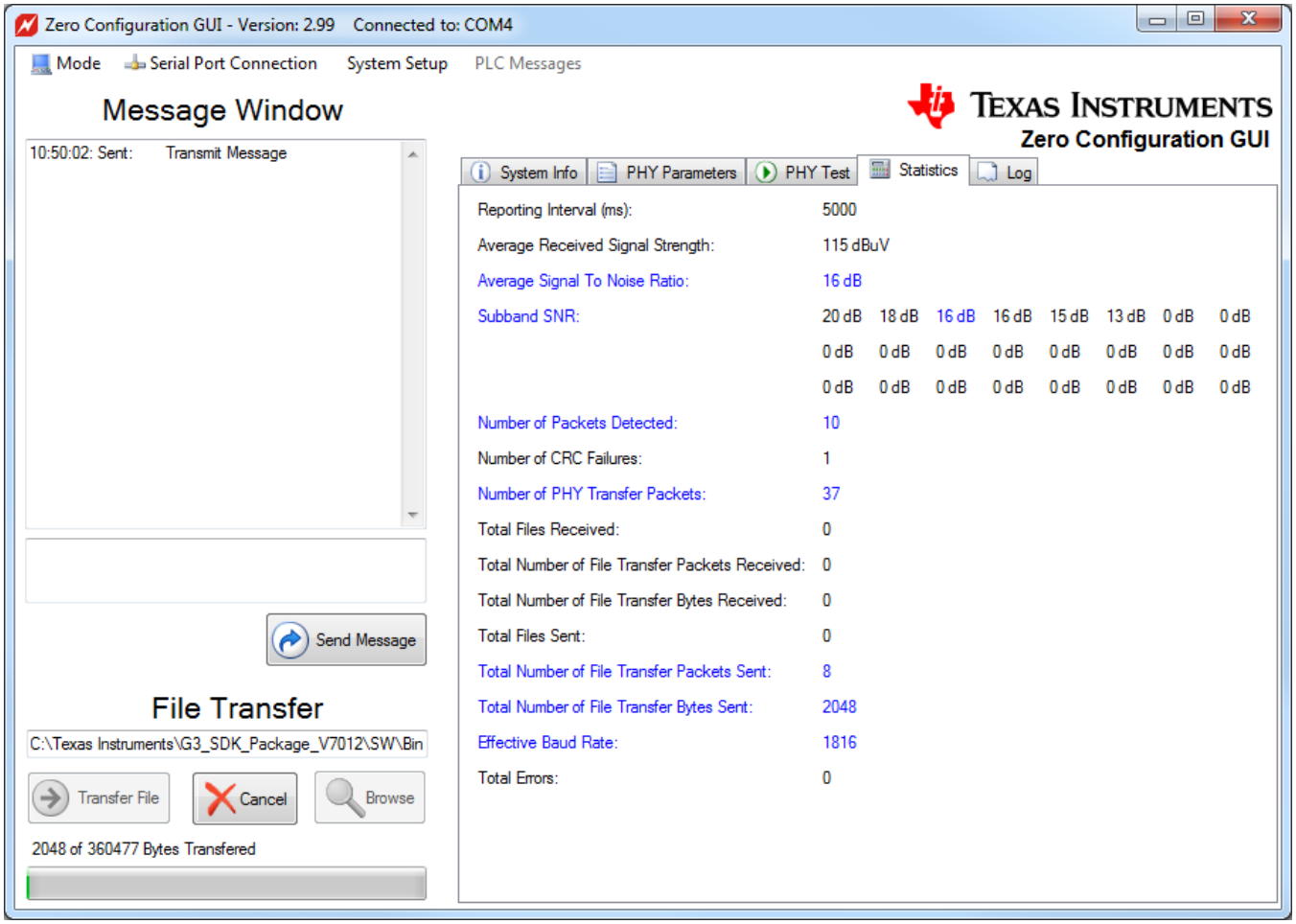


Figure 11. File Transfer TX

5. Click on the *Browse* button to display the standard windows file chooser dialog to choose the file you wish to transfer. Only one file at a time may be chosen for the file transfer.

   After the file is chosen, click on the *Transfer File* button. The other PLC must also be controlled by the Zero Configuration GUI.
   When the transfer starts the GUI will display a progress bar on both Zero Configuration GUIs. The GUI in Figure 12 is the receiving Zero Configuration GUI and displays the path and file name where the received file is being copied. The user is not allowed to change the directory path of the received file.

Figure 12. File Transfer RX

When the file transfer is complete the message box shown in Figure 13 will be displayed on both Zero Configuration GUIs.

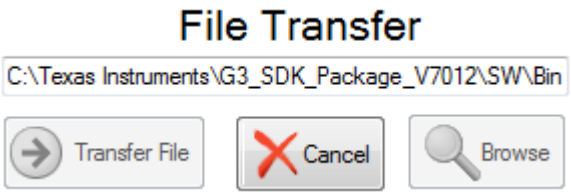


Figure 13. Message Box

If the file transfer fails, the one of following message boxes will be displayed by the sending GUI.

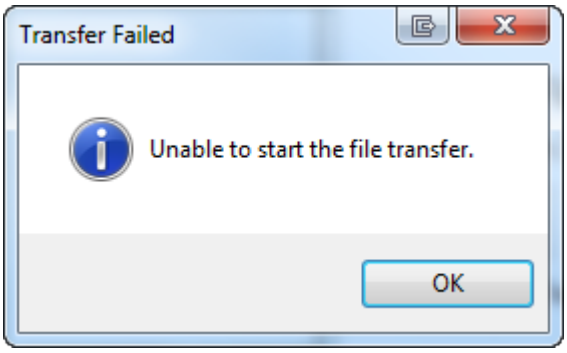


Figure 14. Case 1: File Transfer Failed

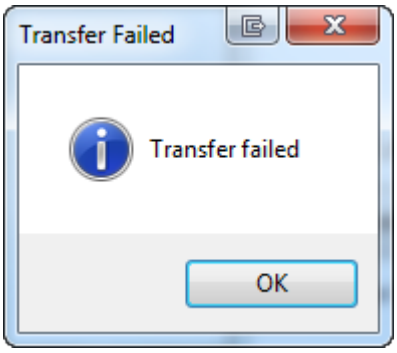


Figure 15. Case 2: File Transfer Failed

10 Design Files

10.1 Schematics

To download the most recent schematics, see the design files at TIDM-SOMPLC-FCC.

NOTE: The transformer in the schematic may not be necessary in a production design.

10.2 Bill of Materials

To download the most recent bill of materials (BOM), see the design files at TIDM-SOMPLC-FCC.

10.3 Layer Plots

To download the most recent layer plots, see the design files at TIDM-SOMPLC-FCC.

10.4 Gerber Files

To download the most recent Gerber files, see the design files at TIDM-SOMPLC-FCC.

10.5 Assembly Drawings

To download the most recent assembly drawings, see the design files at TIDM-SOMPLC-FCC.

10.6 Software Files

To download the software files, see the design files at TIDM-SOMPLC-FCC.

11 About the Author

WONSOO KIM is a system applications engineer at Texas Instruments, where he is responsible for providing technical support and training on communication software and system for smart grid applications and driving solutions for Smart Grid/Metering, and working on defining future requirements in roadmap. He received the Ph.D. degree in electrical and computer engineering, the University of Texas at Austin.

NAVEEN KALA is a system applications engineer at Texas Instruments, where he is responsible for providing technical support and training on PLC hardware and driving solutions for Smart Grid/Metering, and working on defining future requirements in roadmap. He received the M.Eng. degree in electrical and computer engineering from the University of Iowa.

IMPORTANT NOTICE FOR TI REFERENCE DESIGNS

Texas Instruments Incorporated ("TI") reference designs are solely intended to assist designers (“Buyers”) who are developing systems that incorporate TI semiconductor products (also referred to herein as “components”). Buyer understands and agrees that Buyer remains responsible for using its independent analysis, evaluation and judgment in designing Buyer’s systems and products.

TI reference designs have been created using standard laboratory conditions and engineering practices. **TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design.** TI may make corrections, enhancements, improvements and other changes to its reference designs.

Buyers are authorized to use TI reference designs with the TI component(s) identified in each particular reference design and to modify the reference design in the development of their end products. HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY THIRD PARTY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT, IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI REFERENCE DESIGNS ARE PROVIDED "AS IS". TI MAKES NO WARRANTIES OR REPRESENTATIONS WITH REGARD TO THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, EXPRESS, IMPLIED OR STATUTORY, INCLUDING ACCURACY OR COMPLETENESS. TI DISCLAIMS ANY WARRANTY OF TITLE AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, QUIET POSSESSION, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS WITH REGARD TO TI REFERENCE DESIGNS OR USE THEREOF. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY BUYERS AGAINST ANY THIRD PARTY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON A COMBINATION OF COMPONENTS PROVIDED IN A TI REFERENCE DESIGN. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, SPECIAL, INCIDENTAL, CONSEQUENTIAL OR INDIRECT DAMAGES, HOWEVER CAUSED, ON ANY THEORY OF LIABILITY AND WHETHER OR NOT TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, ARISING IN ANY WAY OUT OF TI REFERENCE DESIGNS OR BUYER’S USE OF TI REFERENCE DESIGNS.

TI reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques for TI components are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

Reproduction of significant portions of TI information in TI data books, data sheets or reference designs is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards that anticipate dangerous failures, monitor failures and their consequences, lessen the likelihood of dangerous failures and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in Buyer’s safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed an agreement specifically governing such use.

Only those TI components that TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components that have ***not*** been so designated is solely at Buyer's risk, and Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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