Solar Explorer Kit Quick Start Guide

Dec. 23, 11

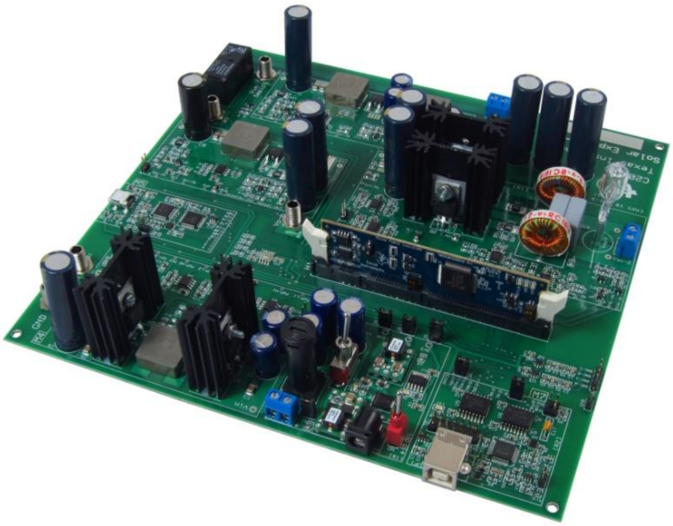

Fig 1 TMDSSOLAR(P/C)EXPKIT

The Texas Instruments Solar Explorer Kit (TMDSSOLAR(P/C)EXPKIT) provides a flexible and safe low voltage platform to evaluate the C2000 microcontroller family of devices for solar power applications. The kit is available with two part numbers depending on which C2000 MCU control card the kit is shipped with, namely TMDSSOLARPEXPKIT (F28035 Control Card) and TMDSSOLARCEXPKIT (F28M35H52C1 Control Card).

The Solar Explorer Kit contains:

- Solar Explorer Board with slot for the controlCARD
- F28035 controlCARD / F28M35H52C1 controlCARD
- 20V 2 Amps DC Power Supply
- Banana Plug Cord
- USB/Ethernet Cables,
- CCS4 CD & USB Stick with Quick Start GUI and Guide

WARNING

This EVM should be used only by qualified engineers and technicians who are familiar with the risks associated with handling electrical and mechanical components, systems and subsystems. The EVM operates at voltages and currents that can result in electrical shock, fire hazard and/or personal injury if not properly handled or applied. Users must use the equipment with necessary caution and employ appropriate safeguards to avoid serious injury. Users must not touch any part of the EVM while energized.

The Solar Panel or the PhotoVoltaic (PV) panel as it's more commonly called is a DC source with a unique Voltage vs Current (V vs I) characteristic. The key challenges in PV system design are to extract maximum power from the panel by operating at the maximum power point (MPP) of the PV panel and use the power to charge batteries, run DC loads, run AC loads, or feed power into the electrical grid. A variety of power topologies are used depending on system needs to realize different PV power systems. The Texas Instruments C2000 microcontroller family, with its enhanced peripheral set and optimized CPU core for control operations, is ideal for these solar power applications.

The Solar Explorer kit consists of stages for DC-DC conversion and DC-AC conversion along with the required sensing signals to perform MPP Tracking. A panel emulator is built onto the board using a DC-DC power stage with light sensor, for quick demonstration of MPPT and PV Inverter control algorithms running on C2000 MCUs.

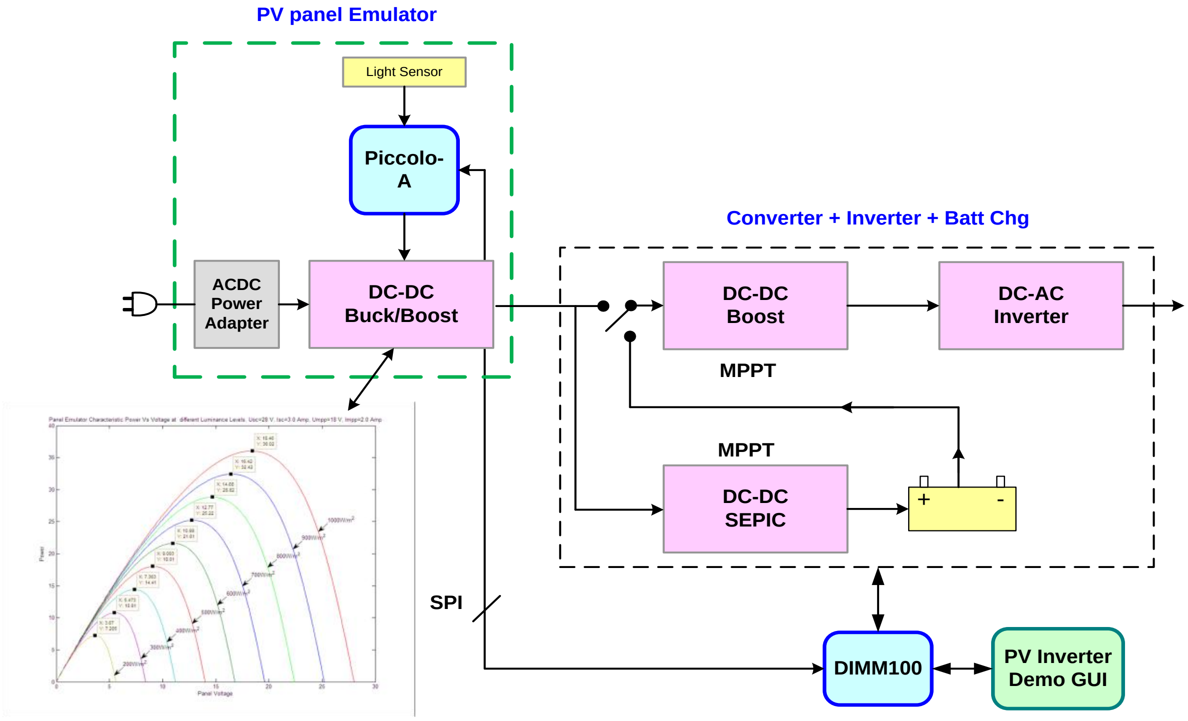

Fig 2 Solar Explorer Kit Block Diagram

Fig 2 depicts the power stages present on the solar explorer board. All three power conversion stages after the panel DC output i.e. DC-DC Boost, DC-DC Sepic, DC-AC Inverter are controlled using a single C2000 family microcontroller, which is installed in the DIMM100 slot on the Solar Explorer base board. The control of the PV emulator stage (DC-DC Buck Boost) is kept separate and is implemented using the TMS320F28027 microcontroller, which is pre-installed on the base board. As PV panels are a light dependent source, a light sensor is present which can be used to change the V vs I curves of the PV emulator. However, for repeatability of the demo, an SPI connection is used to vary the panel emulator's light value through the PV inverter GUI. (Note the SPI is used only for Demo purposes and does not play any part in control of the power stage of the Panel Emulator)

The kit is shipped with a pre-flashed image on the MCU to implement an off grid, DC-AC system. A light bulb is used to as the AC load to show visible power output. Fig 3 represents this system, showing a typical solar powered DC-AC off grid system.

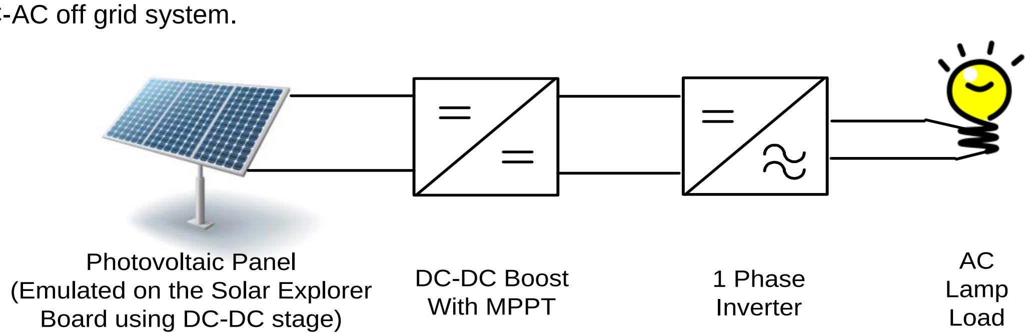

Fig 3 Typical DC-AC off-grid PV System Driving a local AC Load

Hardware Overview

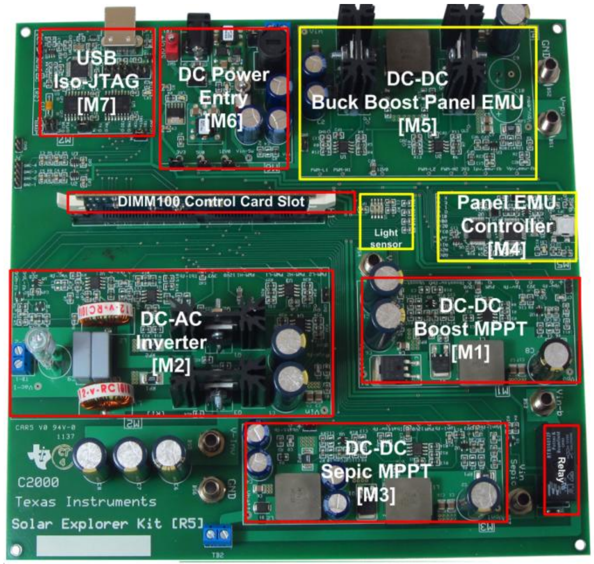

Fig 4 TMDSSOLAREXPLKIT Macros

Below is a list of all the macro block names and numbers present on the board and a short description of their functionality. Fig 4, shows the location of these block on the Solar Explorer Kit.

- **TMDSSOLAREXPL Kit Main Board [Main]** – Consists of controlCARD socket, light sensor, relay, communications, Instrumentation(DAC’s) and routing of signals in between the macros and to the control card.
- **Boost DC-DC Single Phase with MPPT [M1]** – DC-DC Macro accepts DC input, which can be from the solar panel or a battery output (depending on system configuration), and boosts it. This block has the necessary input sensing to implement MPPT.
- **Inverter Single Phase [M2]** – DC-AC Macro accepts a DC voltage and uses a full bridge single phase inverter to generate a sine wave. The output filter filters high frequencies, thus generating a smooth sine wave at the output.
- **Sepic DC-DC with MPPT Battery Charging [M3]** – DC-DC Macro accepts DC input from the solar panel and is used to charge a battery. The sepic stage provides both buck and boost capabilities that are necessary while charging the battery.
- **Sync Buck Boost DC-DC Panel EMU [M4]** – DC-DC Macro accepts DC input from the DC Power Entry Macro (20V typical) and uses it to generate the PV panel emulator output. The module senses the output voltage and current, which makes emulation of the panel’s V vs I characteristics possible.
- **Pic-A USB-mini EMU [M5]** – This is a macro with the TMS320F28027 microcontroller and the JTAG emulator present to control and debug the M4 stage.
- **DC-PwrEntry VinSw 12V 5V 3V3 [M6]** - DC Power Entry, used to generate the 12V, 5V and 3.3V for the board from 20V DC power supply supplied with the kit. This macro also supplies power for the on-board panel emulator, M4.
- **ISO USB to JTAG [M7]** – JTAG connection to the main board.

Nomenclature: Components are referenced with the macro number in brackets, followed by the component label designator. For example, [M3]-J1 would refer to the jumper J1 located in the macro M3. Likewise, [Main]-J1 would refer to the jumper J1 located on the main board outside of any defined macro blocks.

For details on how these blocks are used to implement different solar energy systems refer to the Hardware and Control Design Guide located at the following location:

controlSUITE\development_kits\SolarExplorer\~Docs\SolarExplorer_HWGuide.pdf

Quick Start GUI

The QSG GUI provides a convenient way to evaluate the functionality of the kit without having to learn and configure the underlying project software or install CCS. The interactive interface, using sliders, buttons, textboxes and graphs, enables easy demonstration of MPPT tracking in a DC-AC solar inverter system under different lighting conditions. The QSG GUI can be located in the drive that is shipped with the kit or once controlSUITE is installed at the following location:

controlSUITE\developement_kits\SolarExplorer\~GUI\SolarExplorer_F28M35x_Gui.exe
SolarExplorer_F28035_Gui.exe

The GUI is constructed using the Crosshairs Interface Designer tool. The GUI designed using Crosshairs Interface Designer requires the Microsoft .NET framework version 3.5 to be installed on the machine that runs the GUI. The Release GUI assumes that the PV emulator macro is programmed with the PV emulator code. The kit ships pre-programmed with the PV emulator code; however if for any reason, it becomes necessary to re-program the emulator, the code for the PV emulator is located at:

controlSUITE\developement_kits\SolarExplorer\~GUI\PVEmulatorCode\PVEmulator_F2802x.out

Hardware Setup

Note: Do not power up the board before you have verified these settings!

The kit ships with the controlCARD inserted and the jumper and switch settings preset for connection with the GUI. However the user must ensure that these settings are valid on the board as depicted in Fig 5.

1) Make sure nothing is connected to the board, and no power is being supplied to the board.

2) Insert the controlCARD into the [Main]-J1 controlCARD connector if it is not already installed. This guide assumes that the controlCARD is already pre-flashed with the release image of the GUI.

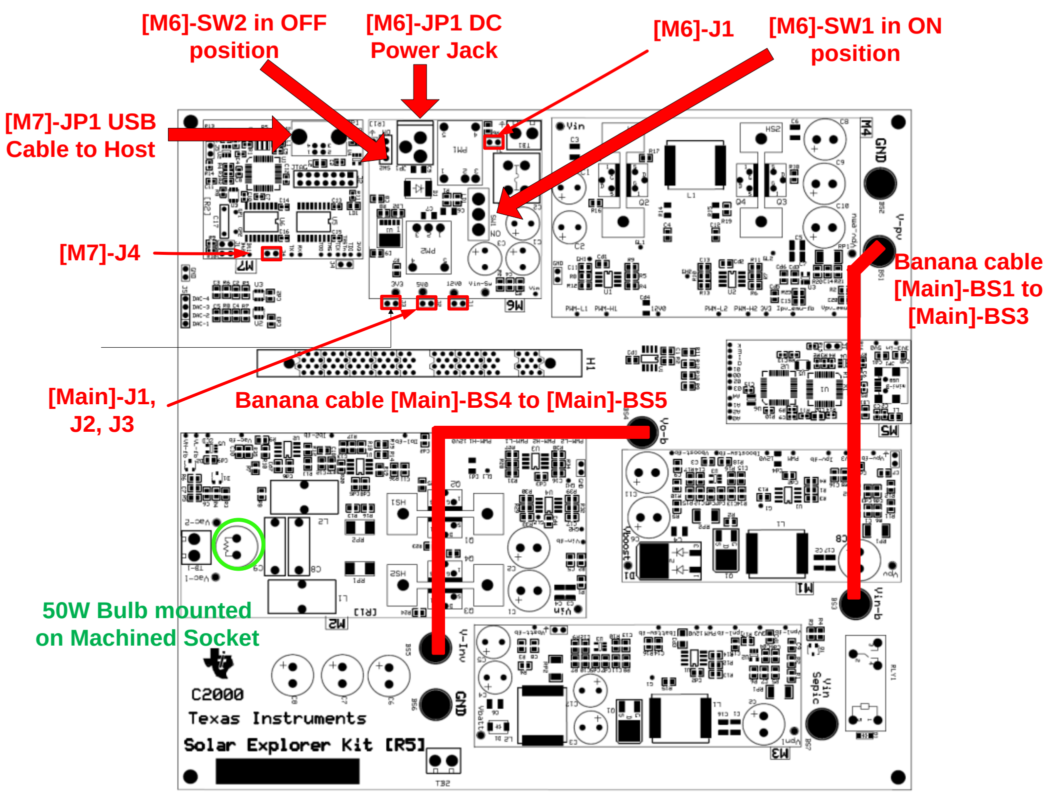

Fig 5 Hardware Setting Solar Explorer Kit GUI

3) The guide assumes that the TMS320F28027 microcontroller present in the M4 macro is pre-flashed with the panel emulator code.

4) Connect a banana cable between [Main]-BS1 and [Main]-BS3

5) Connect a banana cable between [Main]-BS4 and [Main]-BS5

6) Verify the 50W bulb is in the bulb holder in the [M2] macro.

7) Make sure the [Main]-J3, [Main]-J2, [Main]-J1, [M6]-J1 and [M7]-J4 jumpers are populated. Verify [M6]-SW1 is in on position.

8) Now connect the DC power supply shipped with the kit to [M6]-JP1, and turn on [M6]-SW2. [M5]-LD2 will start blinking indicating the PV emulator code is running on the emulator. Turn off [M6]-SW2.

GUI Demo F28035

For the F28035 following settings must be done on the controlCARD for the release GUI to work. Do the following switch settings on the controlCARD:

a. Control Card SW1 is in the OFF position
b. Control Card SW2, Position 1 = ON, Position 2 = ON

The kit ships with the code pre-programmed into the included TMS320F28035 controlCARD; however if needed, the PV inverter code can be located at:

controlSUITE\developement_kits\SolarExplorer\~GUI\PVInverterCode\PVInverter_F2803x.out

Now, Connect a USB cable (B to A Cable) from [M7]-JP1 to the host computer. [M7]-LD1 will light up indicating that the USB is powered. Windows will then search for a driver for the device. If the computer has CCSv4 or prior versions installed, which supported the XDS100 emulator, Windows will be able to find the driver successfully. If not, you may be prompted to install the driver for the newly found hardware. **Installing the driver for USB to serial** : Do not let Microsoft search for the driver, instead browse to the following location on the USB stick drive shipped with the kit <Drive Name:\CDM 2.06.00 WHQL Certified>, Windows should now be able to find the driver and install it. If Windows still does not find the driver, you may have to repeat the process and point to the location pointed out previously. You may have to reboot the computer for the drivers to come into effect. Once installed, you can check if the installation was completed properly by browsing to ControlPanel->System->Hardware->Device Manager and looking for USB Serial Port under Ports(COM&LPT).

Running the F28035 GUI

1) Make sure all the jumper and connector setting are as described in the Hardware setup section.

2) Power up the board by setting switch SW2 to On position. The LED on the controlCARD and the LED in M5 macro will begin blinking, indicating that the code is being executed.

3) Browse to and double click on the SolarExplorer_F2803x_Gui*.exe.* The GUI window should pop up (Fig 6). The GUI will automatically connect to the target board and should show as connected in the GUI window. {Make sure the target board is the only emulator macro connected to the host, i.e. no other embedded target boards are connected to the computer}

4) The QSG GUI enables the user to see the behavior of the PV inverter control under different lighting conditions of the panel and MPP Tracking. The PV emulator is pre-programmed with V vs I characteristics that are interpolated for different lighting conditions linearly. The following table summarizes the PV characteristics under different lighting conditions.

Luminance Ratio (w.r.t 1000W/m^2)	Pmpp =(Pmax * Luminance Ratio) Watts	Vmpp (Volts)
0.8 = 800W/m^2	28.82	14.68
0.6= 600W/m^2	21.61	10.98
0.4=400W/m^2	14.41	7.363
0.2=200W/m^2	7.205	3.67

The GUI limits the luminance to be 0.8 because the kit is shipped with the DC power supply with a limited power output capacity. The user can use the CCS projects and an external DC power supply if the max PV emulator power of 36W is needed.

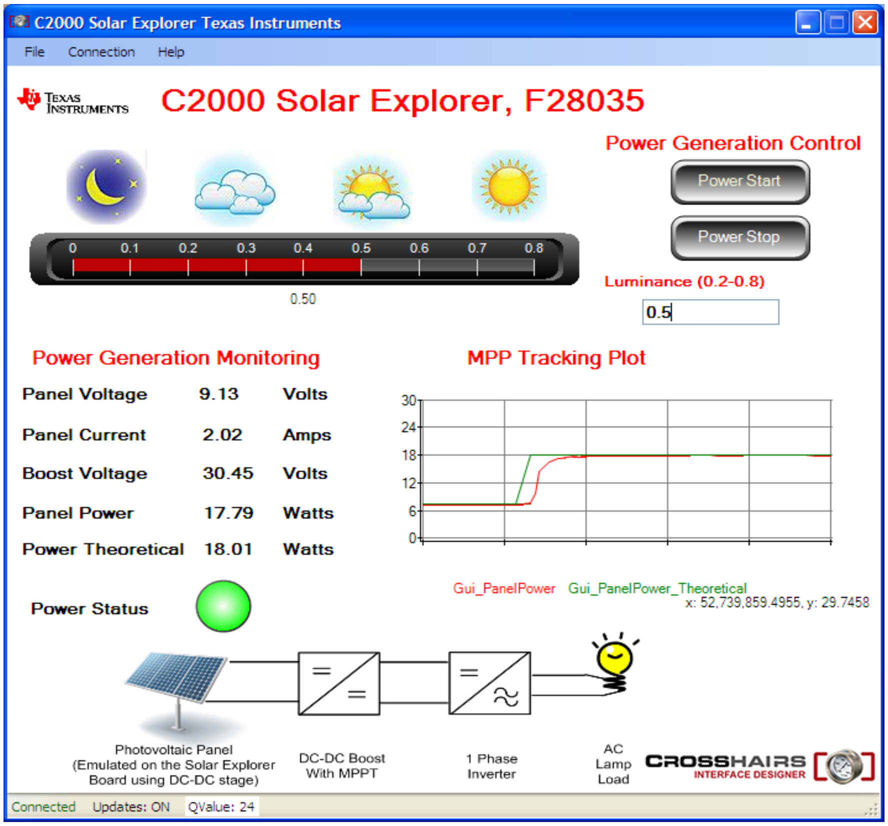

Fig 6 Solar Explorer Kit Gui

5) The GUI is divided into Control and Monitoring sections corresponding to the Solar Explorer Kit design:

   i) **Power Generation Control** section is used to pass commands to the Solar Explorer Kit through the use of buttons and text boxes, which can start or stop production of power and vary lighting condition values.

      a) **Power Start Button** When clicked it sends command to the inverter to start producing power.
      b) **Power Stop Button** When clicked it sends command to the inverter to stop production of power.
      c) **Luminance Text Box** is used to enter a new luminance value. This is communicated to the PV emulator through an SPI connection on the board. Once the PV emulator receives this new luminance value, it changes the Panel Characteristics accordingly.
      d) **Luminance Gauge** is used to graphically depict the current luminance value being used by the PV emulator code.

ii) **Power Generation Monitoring** is used to monitor different variables on the solar energy unit. These monitoring parameters depicts how efficiently the Maximum Power Point (MPP) is being tracked by the PV system.
   a) **Panel Voltage** displays the instantaneous input panel voltage.
   b) **Panel Current** displays the instantaneous current being drawn from the panel.
   c) **Panel Power** displays the instantaneous power being drawn from the panel.
   d) **Panel Power Theoretical** displays the theoretical value of the maximum power point. This is possible to display because the PV emulator is loaded with a pre-determined V vs I curve.
   e) **Power Status LED** indicates whether the inverter is ON or OFF. The status chages when the Power Start or Power Stop buttons are clicked.
   f) **MPPT Tracking Plot** displays the theoretical panel MPP for a given luminance level and also the real-time power being extracted. This shows the MPPT tracking under different luminance conditions.

6) The GUI can be used to change the luminance level (Enter value into the Luminance text box) of the Panel Emulator and also start or stop production of power. This illustrates MPPT tracking from a cold start and under static and dynamic conditions.
7) Once the user is done evaluating, click on Power Stop Button and reduce the luminance value to 0.0.
8) Close the GUI and flip the SW2 to off position.

GUI Demo F28M35H52C1 over Ethernet

F28M35x is a heterogeneous dual core MCU (C28x & M3 CPU). In this demo example, the host subsystem (M3 core) handles communication with the external world using Crosshairs GUI via Ethernet and the C28x handles the control of the power stages. The two cores communicate using shared RAM, message RAM and IPC (Inter Processor Communication) registers. The kit ships with the code pre-programmed into the included F28M35H52C1 controlCARD; however if needed, the PV inverter code can be located at:

controlSUITE\developement_kits\SolarExplorer\~GUI\PVInverterCode\PVInverter_F28M35x_M3.out
PVInverter_F28M35x_C28x.out

On the control card make sure the MAC layer pins from the F28M35x are connected to the PHY layer by connecting the first 15 pins of Row C to the corresponding Row B pins using jumpers (e.g. ***M3_MIII_RXD0*** to ***PH1_GPIO49*** …… ***M3_MIII_PHYRSTn*** to ***PJ7_GPIO63.*** *Look at* the Connectivity Mux section of the control card schematic diagram). The demo uses static IP, to make sure the host machine uses this static IP do the following.

Ethernet setup using static IP

1) Disable any wireless connection that may be active on host computer.
2) Click *start* -> *control panel* -> double click *Network Connections*.
3) Identify the wired connection to use. "Local Area Connection" or "wired Network Connection" or some other name depending on the computer in use.
4) Right click on the identified network connection in step 3 -> click *Properties*. The "*Local Area Connection*" Properties window shows up.
5) In the "*Local Area Connection Properties* "window select the *General* tab and scroll down in the "*this connection uses the following items* " list and select "*Internet Protocol(TCP/IP)*" item. Click *properties*. "*Internet Protocol (TCP/IP) Properties*" window pops up.
6) In "*Internet Protocol (TCP /IP) Properties*" window in *General* tab, click on "Use the following IP address" radio button and enter the numbers shown in the figure below.
7) Click ok in "Internet Protocol (TCP/IP) Properties" window and click close in "Local Area Connection Properties" window.

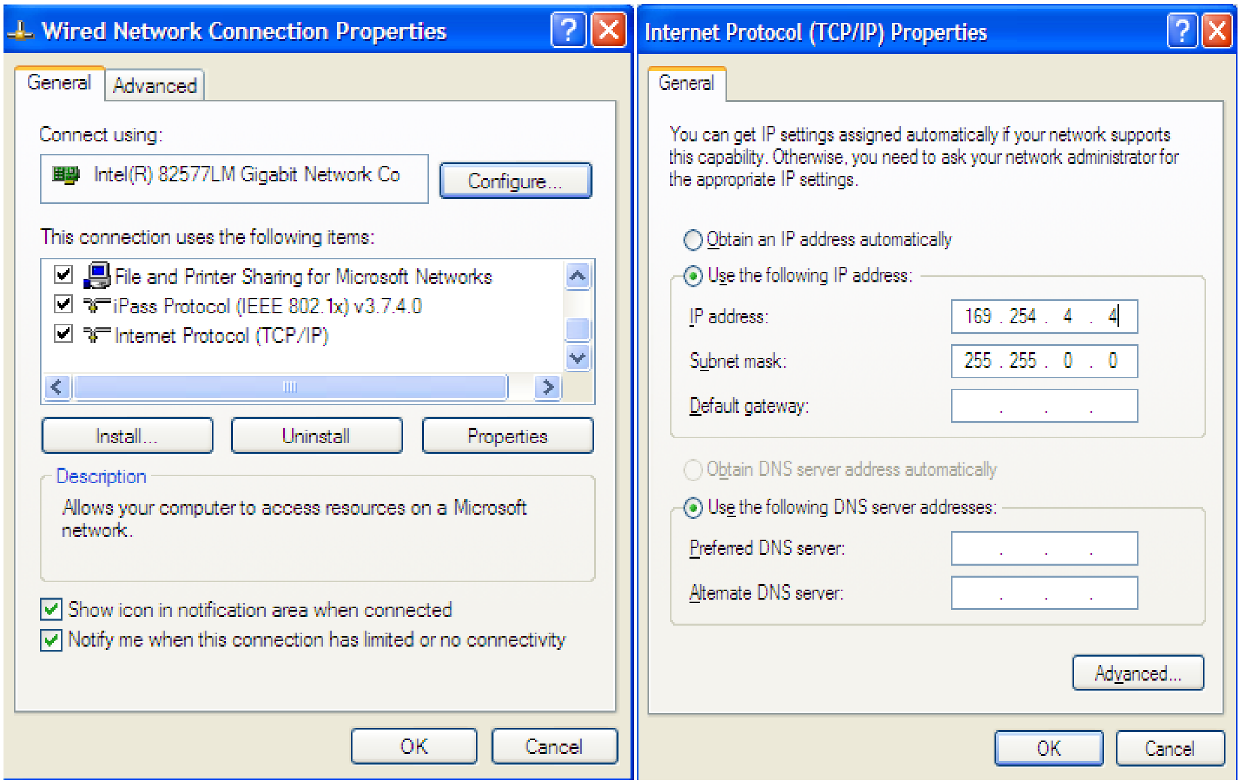

Fig 7: Static IP Setup

Now connect an Ethernet cable from the F28M35x control card to the Ethernet port on the host machine. Power up the board by moving SW2 to On position. The LED on the controlCARD and the LED in M5 macro will begin blinking, indicating that the code is being executed. Wait for the Ethernet address to be resolved.

Running the TMDSSOLAR(C)EXPKIT GUI

1) Double click the SolarExplorer_F28M35x_Gui*.exe* to open up the GUI. In the application GUI click *Connection -> Start Connection wizard.* In the "*Connection wizard window*" click *connect to engine* button. Once connection is made, make selections as below.
   - In the "*Targets*" window select ConcertoM -> F28M35H52C1 M3 device.
   - In the middle window : *Commros Transport -> Ethernet.*
   - In the right window enter a value of the static host IP 169.254.254.169
   - Click *connect*.

2) The Gui as shown in Fig 8 will appear, it is divided into Control and Monitoring sections, similar to the section on the F28035x Gui (details of each are not repeated here for succinctness of the guide). The communication to the host is implemented over Ethernet on the M3 core on the F28M35H52C1 device using CrossHairs tool.

3) The user can now vary light value by entering a value in the text box, to start the inverter operation click PowerStart and see the MPPT tracking on the graph window.

4) User can check MPPT tracking under varying light conditions.

5) To stop, enter Light Command value to zero and also click inverter stop.

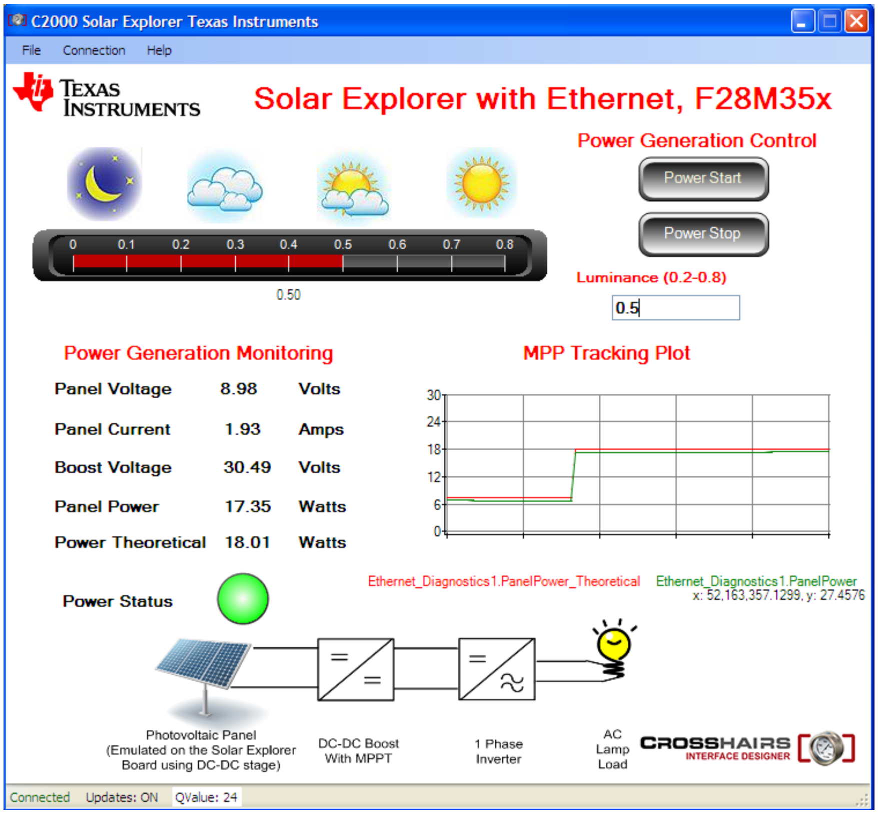

Fig 8: F28M35x Ethernet Gui

References

All Solar Explorer Kit documentation, example projects, hardware development packages, and more are freely available as part of TI's C2000 controlSUITE software package. Download controlSUITE today at www.ti.com/controlSUITE.

Solar Explorer Kit Documentation and Projects

- **SolarExplorer HW & Control Design Reference Guide** – provides detailed information on the Solar Explorer Kit hardware and control system design.
  controlSUITE\development_kits\SolarExplorer\~Docs\SolarExplorer_HWGuide.pdf

- **Solar Explorer-HWdevPkg** – a folder containing various files related to the hardware on the kit board (schematics, bill of materials, Gerber files, PCB layout, etc).
  controlSUITE\development_kits\SolarExplorer\~SolarExplorer-HWdevPkg\

- **Solar Explorer Projects** - All the projects for different systems using the Solar Explorer kit can be found at
  controlSUITE\development_kits\SolarExplorer\SolarExplorer_PVInverter_F2803x
  \SolarExplorer_PVInvertre_F28M35x
  \SolarExplorer_PVEmulator_F2802x

- F28xxx User's Guides
  http://www.ti.com/f28xuserguides