TEXAS INSTRUMENTS

Solar Explorer Kit Hardware and Control Reference Guide

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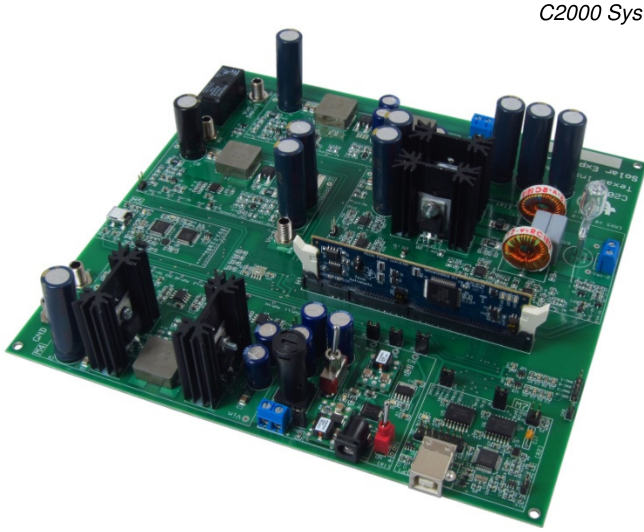


Fig 1 TMDSSOLAR(P/C)EXPKIT

1. Introduction

The Solar Explorer kit (TMDSSOLAR(P/C)EXPKIT, Fig 1), provides a flexible and low voltage platform to evaluate the C2000 microcontroller family of devices for variety of solar power applications. This document goes over the kit contents and hardware details, and explains the functions and locations of jumpers and connectors present on the 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.

Contents

2. Getting Familiar with the Kit

2.1 Kit Contents

The kit follows the control card concept and hence any device from the C2000 family with DIMM100 control card can be used with the kit. The kit is available with two part numbers, TMDSSOLARPEXPKIT and TMDSSOLARCEXPKIT. The TMDSSOLARPEXPKIT ships with F28035 MCU control card, which is part of the Piccolo family in the C2000 MCU product line and highlights the control of the solar power stage. The TMDSSOLARCEXPKIT ships with the F28M35x control card, which is part of the Concerto family and has heterogeneous dual cores, where one handles the control of the power stage and the other handles the communication such as USB, Ethernet etc. highlighting control and communication using a single MCU.

The kit consists of

- F28M3H52C controlCARD (TMDSSOLARCEXPKIT)
- F28035 controlCARD (TMDSSOLARPEXPKIT)
- Solar Explorer Base Board
- 20V 2 Amps Power Supply
- Banana Plug Cords (installed on the board)
- 50W 24Vac Light Bulb
- USB-B to A Cable
- USB mini to A Cable

The control cards are pre-flashed to run with the respective GUI for a quick demo. All the software projects are available for the kit through controlSUITE.

2.2 Kit Overview

The Solar Panel or PhotoVoltaic (PV) panel, as it's more commonly called, is a DC source with a non linear V vs I characteristics. The key challenges in PV system design are to extract maximum power from the panel by operating at the maximum power point (MPP) of this non linear V vs I curve of the panel, and to convert the power such that it can be used to charge batteries, run DC loads, run AC loads, or feed power into the electrical grid.

A variety of power topologies are used for different PV based systems depending on system requirements. The Texas Instruments C2000 microcontroller family, with its enhanced peripheral set and optimized CPU core for control tasks, is ideal for these solar power control applications.

Fig 2 gives a block diagram of different stages present on the Solar Explorer kit to process power from the solar panel. The input to the solar explorer kit is a 20V DC power supply which powers the controller and the supporting circuitry. A 50W solar panel can be connected to the board (Typical values Vmpp 17V, Pmax 50W). However for quick demonstration of the power processing from the solar panel, a PV emulator power stage is integrated on the board along with other stages that are needed to process power from the panel. The control of the PV panel is kept separate from the control of the other stages.

Thus, the board uses two C2000 controllers, a dedicated Piccolo-A device is present on the base board and is used to control the PV emulator stage. The other stages such as, DC-DC Boost and DC-AC and DC-DC Sepic are controlled by a single C2000 device using a control –card that can be placed in the DIMM100 control card slot on the EVM board. Any of C2000 device with a compatible control card can be used for this operation.

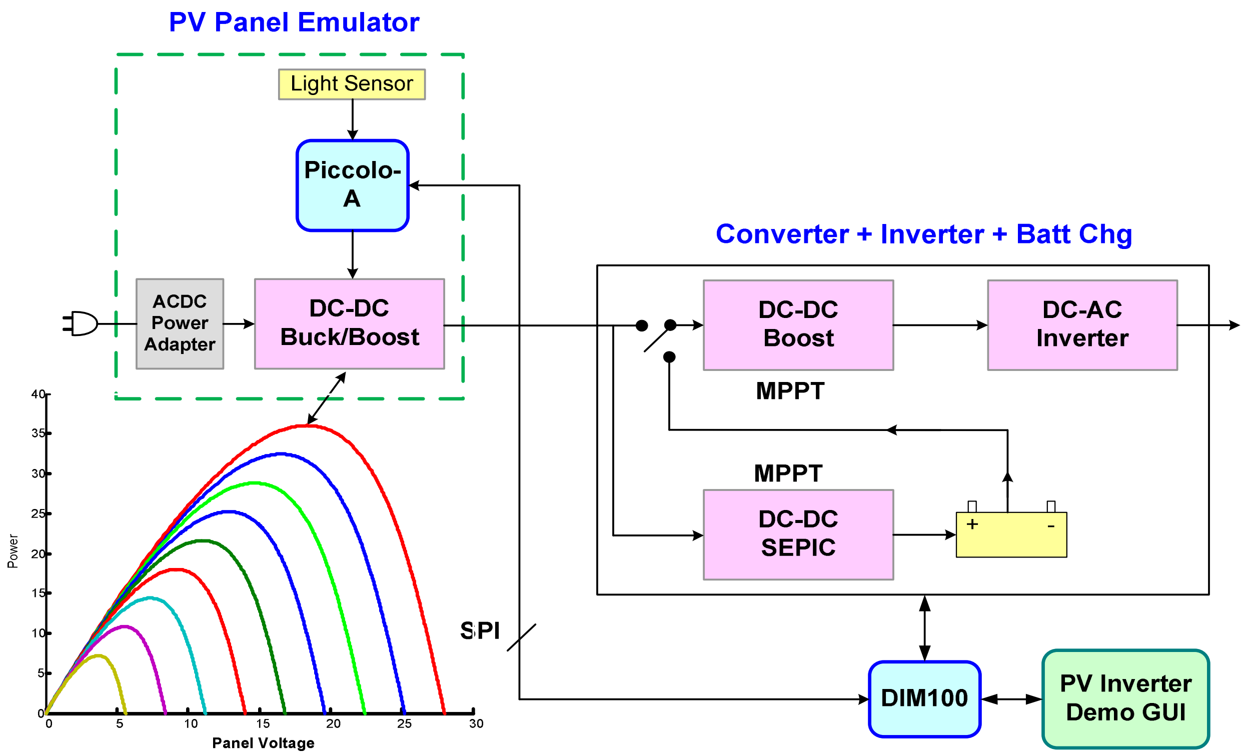


Fig 2 Solar Explorer Kit Overview

PV is a light dependent source, therefore a light sensor is integrated on the board which can be used to change behavior of the panel under different lighting conditions. The various stages on the board are rated to interface with a typical 50W solar panel (refer to the detailed hardware specification of each stage for details)

3. Power Stages on the Kit

3.1 Macros Location & Nomenclature

Fig 3, shows the location of the different power stage blocks / macros present on the board.

- **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 PV 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 PV 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.

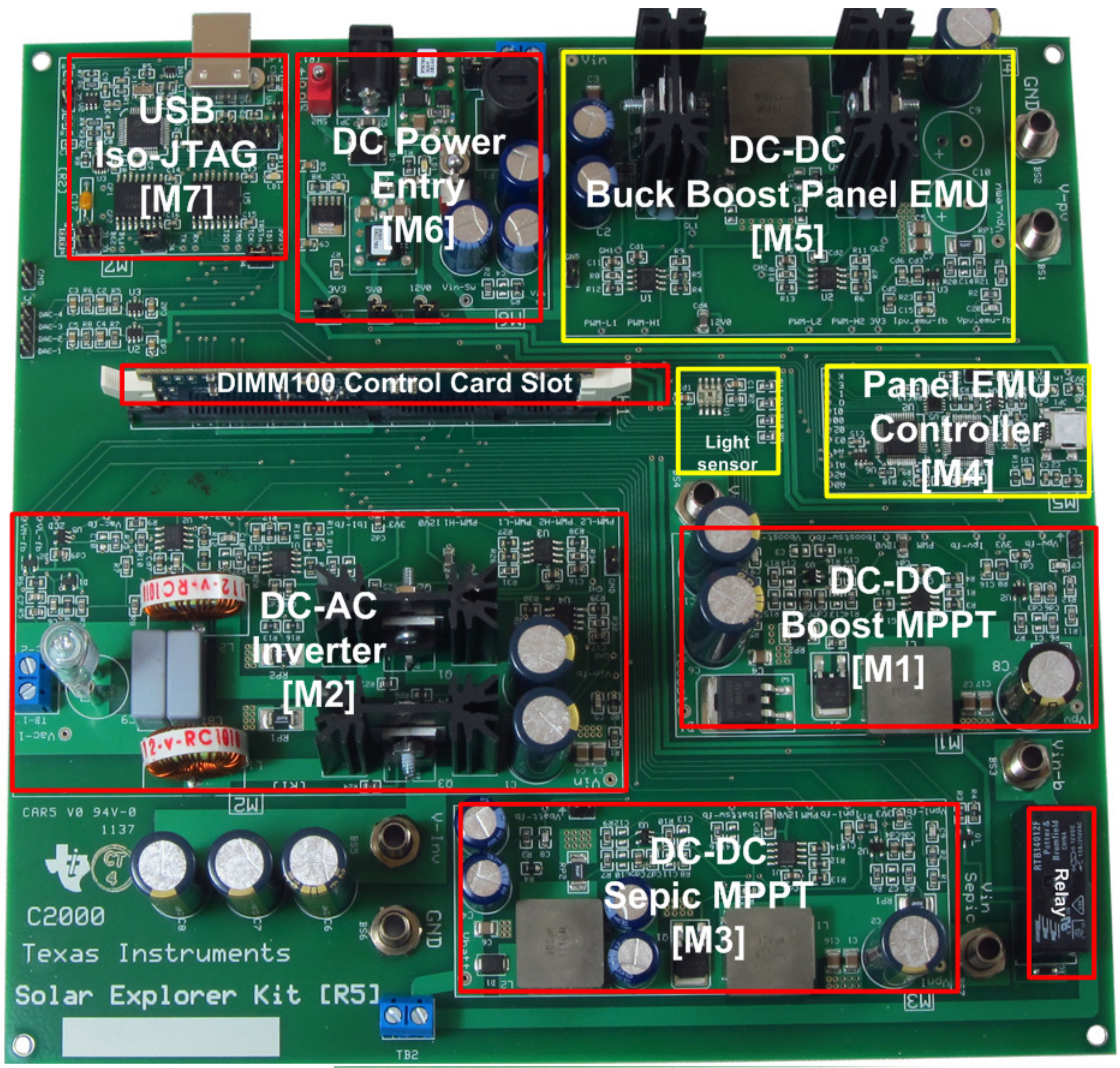


Fig 3 Macro Block on Solar Explorer Kit

To enable easy debug of individual power stages input and output of the power stages are kept as terminal blocks or banana jacks. With help of a macro approach in hardware it is possible to realize different PV systems using the solar explorer kit.

3.1 Boost DC-DC Single Phase with MPPT

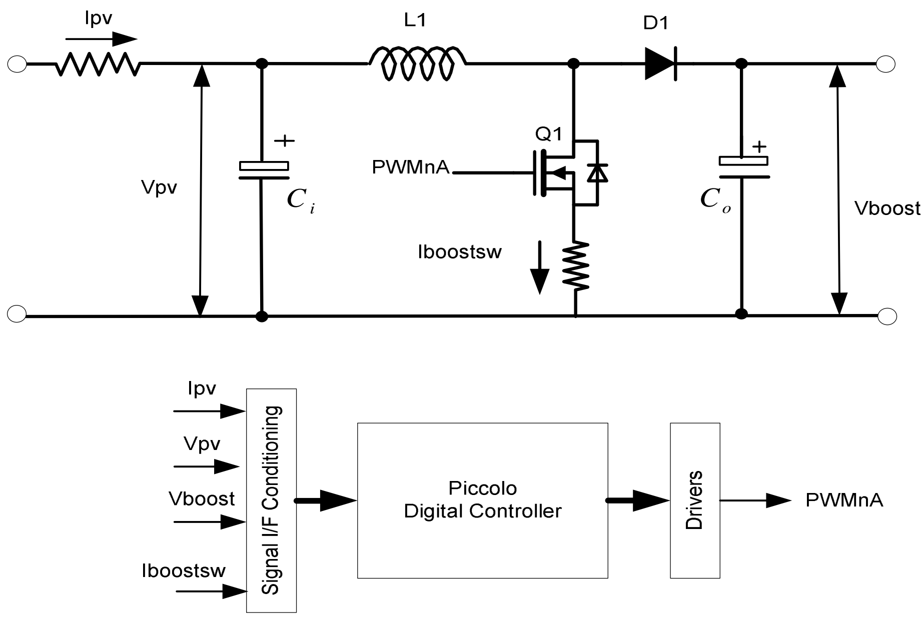


Fig 4 Boost DC-DC Single Phase with MPPT Power Stage

Power Stage Parameters

Input Voltage : 0 -30V (Panel Input)
Input Current : 0- 3.5 Amps (Panel Input)
Output Voltage : 30V DC Nominal
Output Current: 0-2 Amps
Power Rating: 50W
fsw = 100Khz

Control Description

A single phase boost stage is used to boost the voltage from the panel and track the MPP of the panel. The input current I_{pv} is sensed before the input capacitance C_i along with the panel voltage V_{pv}. These two values are then used by the MPPT algorithm.

The MPPT is realized using an outer voltage loop that regulates the input voltage i.e. panel voltage by modulating the current reference for the inner current loop of the boost stage. Increasing the current reference of the boost, i.e. current drawn through the boost, loads the panel and hence results in the panel output voltage drop. Therefore the sign for the outer voltage compensator reference and feedback are reversed. It is noted that the output of the boost is not regulated. However to prevent the output voltage from rising higher than rating of the components, the voltage feedback is mapped to the internal comparators which can do a cycle by cycle trip of the PWM in case of over voltage.

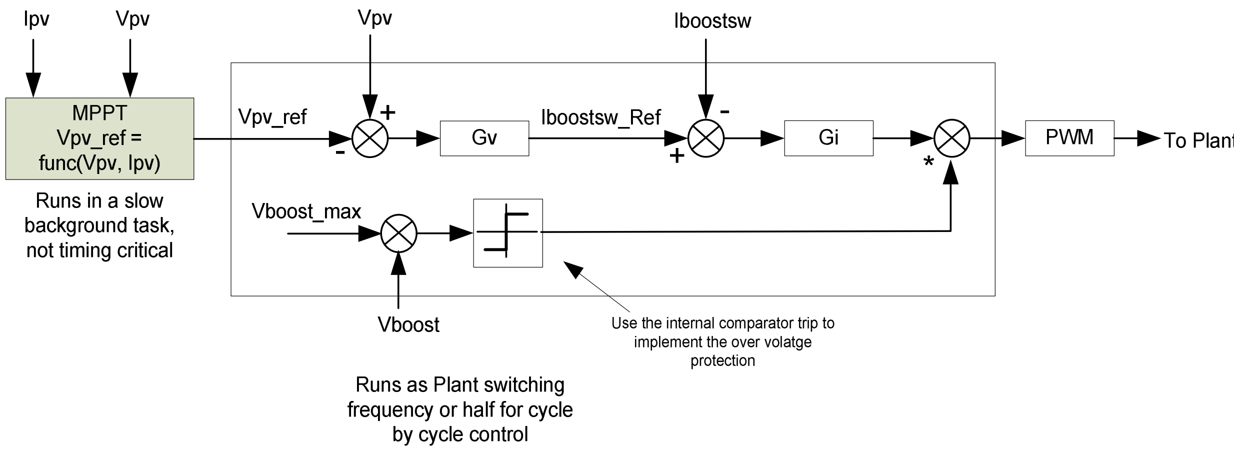


Fig 5 Boost with MPPT Control Diagram

3.2 DC-DC Battery Charging, Sepic

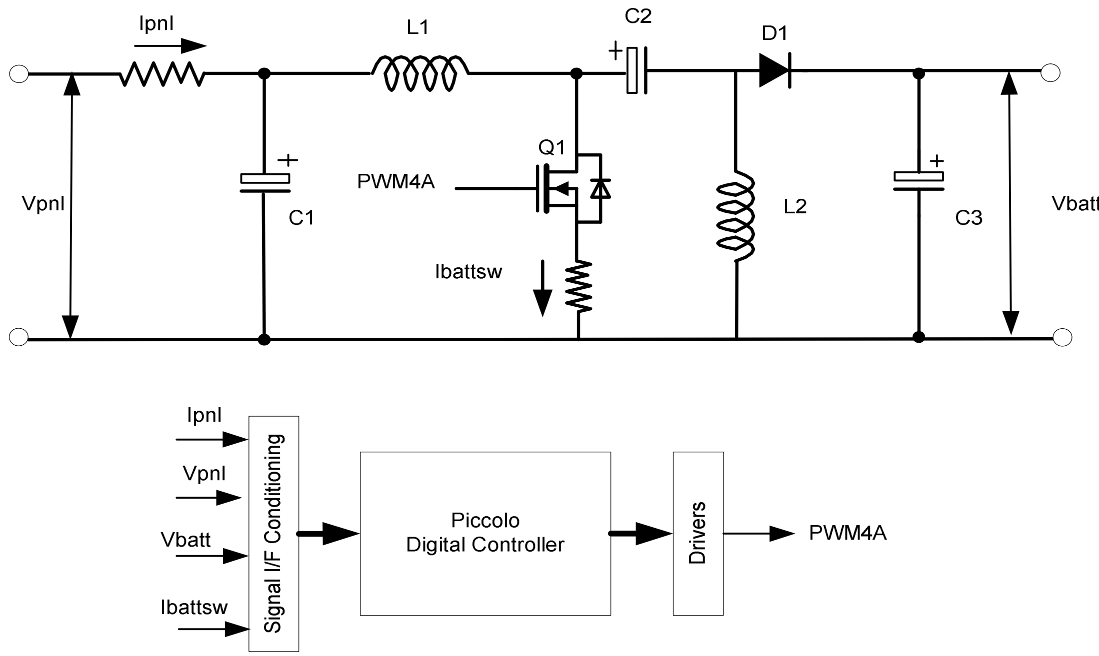


Fig 6 DC-DC Battery Charging Sepic Power Stage

Power Stage Parameters

Input Voltage : 0 -30V (Panel Input)
Input Current : 0- 3.5 Amps (Panel Input)
Output Voltage : 10V-16V DC max
Output Current: 0-3.5 Amps
Power Rating: 50W Max
fsw = 200Khz

Control Description

This stage is responsible for charging a typical 12V battery from the solar panel, and therefore has panel current I_{pv} and panel voltage V_{pv} sensing to track MPP of the panel. A sepic stage was chosen to realize this function, as both buck and boost are possible using the sepic stage. A typical lead acid battery charging can be divided into four stages, stage determination and transition is done as:

1. **Trickle Charging State**: When the battery voltage is below a discharge threshold V_{chgenb}, the battery has been deeply discharged or has shorted cells. In this case the charging begins with a very low trickle current I_{tc}. If the battery cells are shorted then the battery voltage would remain below the V_{chgenb}, thus preventing the charging state from going to the bulk charging stage. Otherwise the battery voltage would slowly build up and would come within a nominal range i.e. above V_{chgenb}. At this stage the state would move to Bulk charging. While in Trickle charging mode MPPT may not be needed.
2. **Bulk Charging State**: In this stage the charger acts like a current source for the battery providing a constant current I_{bulk}. As the PV may not be able to supply the ideal I_{bulk} to charge the battery, however it tries its best by operating at MPP. As the battery voltage exceeds 0.95 V_{oc}, the charger enters the Over Charger Mode.
3. **Over Charging State**: The role of this state is to restore the full capacity in minimum amount of time at the same time avoiding over charging. All the battery voltage and current loop are enabled while MPPT is disabled. $V_{Batt\mathrm{Re}f}$ now equals V_{oc}. Initially overcharge current equals bulk charge current, but as over charge voltage is approached, the charge current diminishes. IBref is determined by the voltage loop.
4. **Float Charge State**: During this state the battery voltage is maintained at V_{float} to maintain battery capacity against self discharge. The charger would deliver as much current is needed for sustaining the float voltage.

The battery would remain in the float state until the battery voltage drops below 90% of the float voltage due to discharging at which point operation is reverted to bulk charging.

Typical values for 12V battery are

Overcharge Voltage, V_{oc} =15V

Floating Voltage, V_{float} = 13.5V

Discharge Threshold, V_{chgenb} = 10.5V

Load disconnect voltage, V_{ldv} = 11.4

Load reconnect voltage, V_{rv}= 12.6V

The following block diagram illustrates the control proposed for this stage when doing MPPT. The control when doing MPPT is similar to the boost stage however when the battery is not in the bulk charging stage the MPP cannot be maintained as the battery cannot absorb the max power from the panel.

Hence the control of the stage changes from input voltage of the stage/ output of the panel regulation to the output voltage of the stage regulation. The instance when the control is switched is dependent on the battery type and charging algorithm.

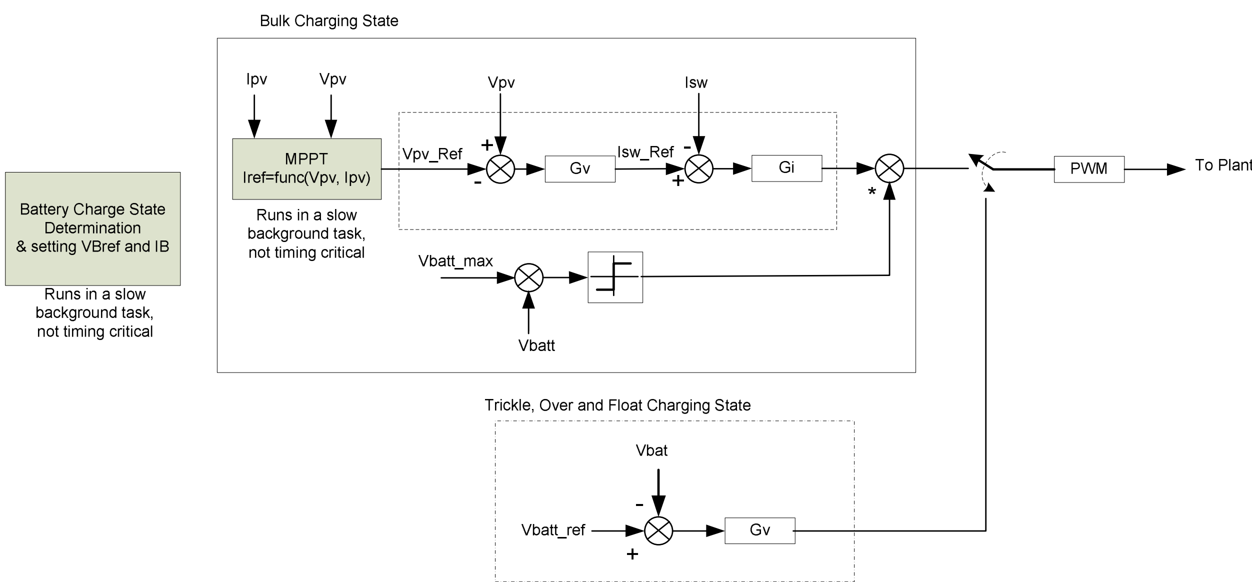


Fig 7 Battery Charging with MPPT Control Diagram

3.3 Single Phase Inverter

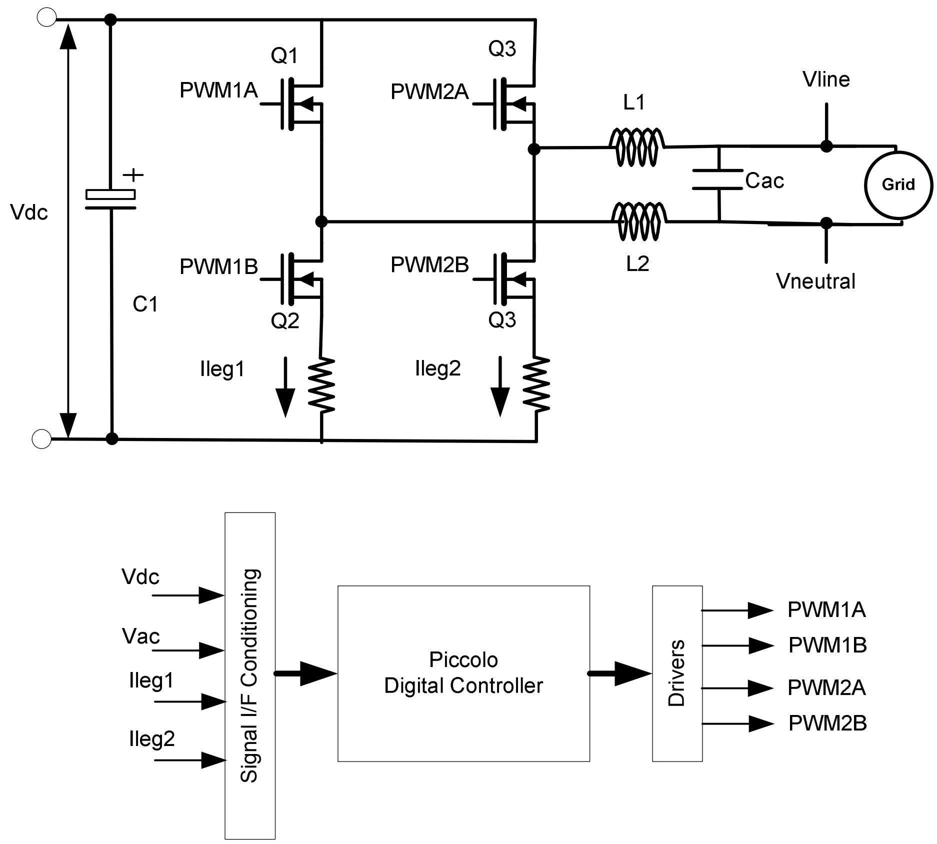


Fig 8 Single Phase Full Bridge Inverter Power Stage

Power Stage Parameters

Input Voltage : 30V DC Nominal
Input Current : 0- 2 Amps
Output Voltage : 20-24Vrms Max
Output Current: 0-2 Amps
Power Rating: 50W
fsw = 10Khz-20Khz

Control Structure

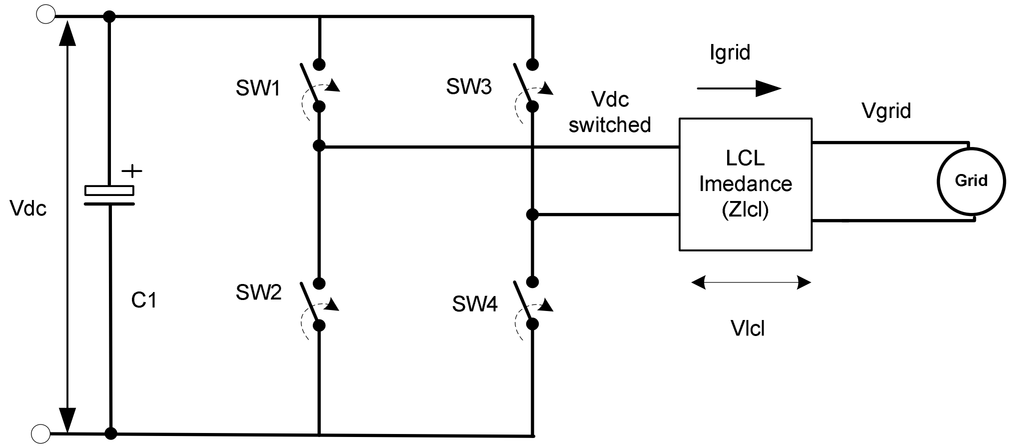
To appreciate the control of a full bridge inverter, first the mechanism how the High Frequency Full Bridge Inverter feeds current into the grid/line needs to be understood. Several modulation schemes exist for achieving this, the following derivations uses the **Unipolar Modulation** to scheme to analyze the current fed form the converter.

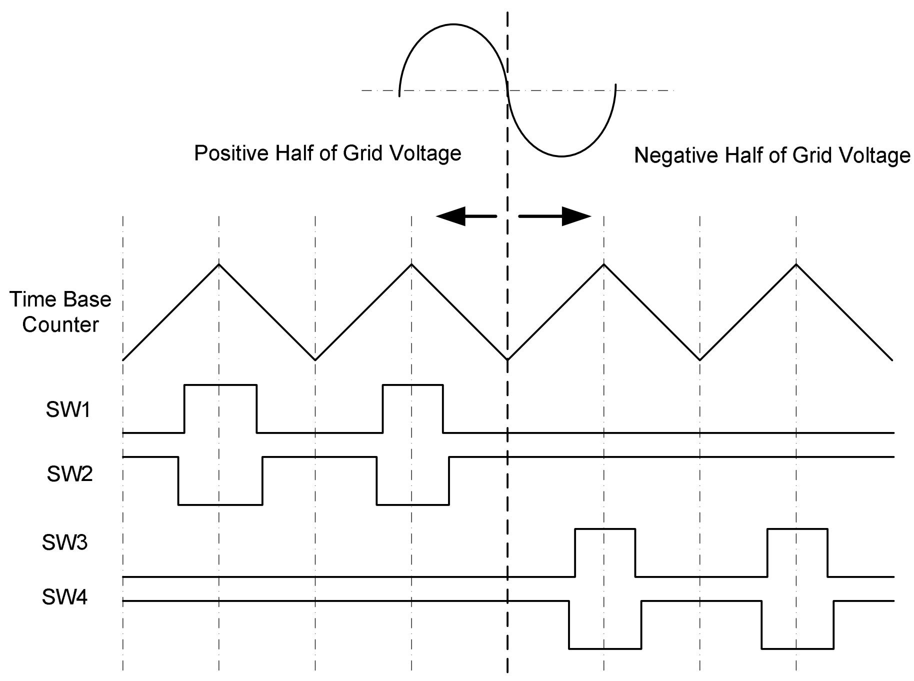
Current Control

In a unipolar modulation scheme, alternate legs are switched depending on which half of the sine of the AC signal is being generated.

Positive Half: SW1 and SW2 are modulated & SW4 is always ON, SW3 is always OFF
Negative Half: SW3 and SW4 are modulated & SW2 is always ON, SW1 is always OFF

This modulation scheme is highlighted in the following figure.





Unipolar Modulation

LCL filter at the output of the inverter filters this waveform. Now the voltage across the LCL filter can be written as

$V_{LCL,on} = V_{dc} - v_{grid}$, when SW1 and SW4 are conducting,

$V_{LCL,on} = -V_{dc} - v_{grid}$, when SW3 and SW4 are conducting,

$V_{LCL,off} = -v_{grid}$, when SW2 and SW4 are conducting,

Thus the change in grid current per switching cycle is computed as:

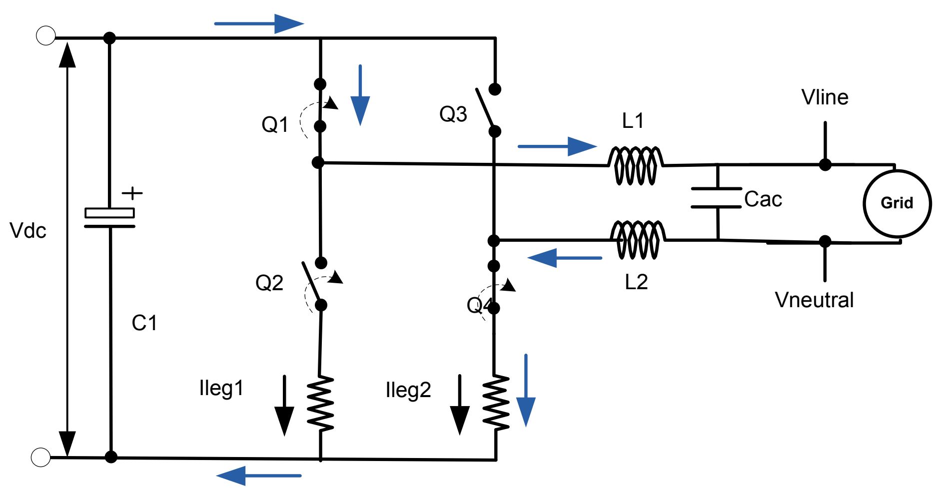
$$\Delta i_{grid} = \frac{(V_{dc} - v_{grid}).D}{Z_{LCL}(F_{sw})} + \frac{(0 - v_{grid})(1-D)}{Z_{LCL}(F_{sw})} = \frac{V_{dc} * D - v_{grid}}{Z_{LCL}(F_{sw})}$$

From this equation it is noted that the current can be controlled by varying the Duty Cycle. Typically a current transformer is used to measure the gird current. However on the Explorer kit as this is a learning platform shunt current measurement is used.

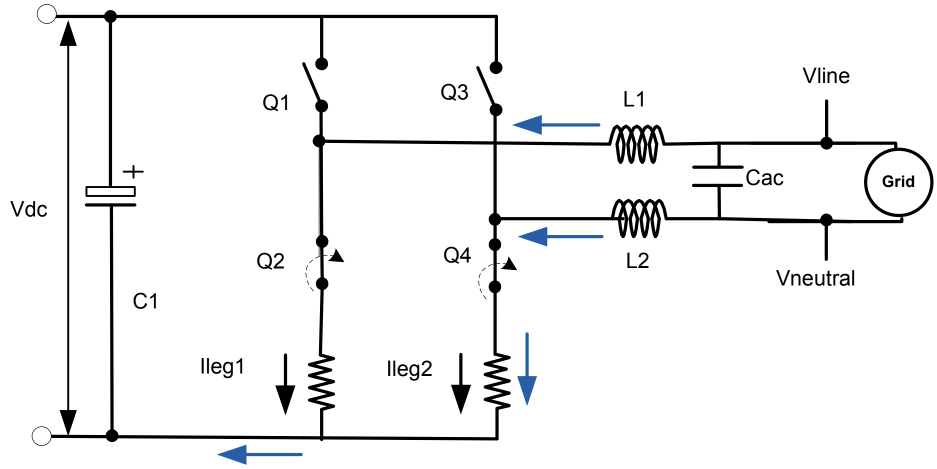
Two shunt current measurement resistors are placed, the grid current (i.e. the current fed into the grid from the inverter) is estimated by subtracting the two leg currents).

$$\Delta i_{grid} = i_{leg2} - i_{leg1}$$

Let's assume positive half of the sine wave i.e. we should feed current into the grid

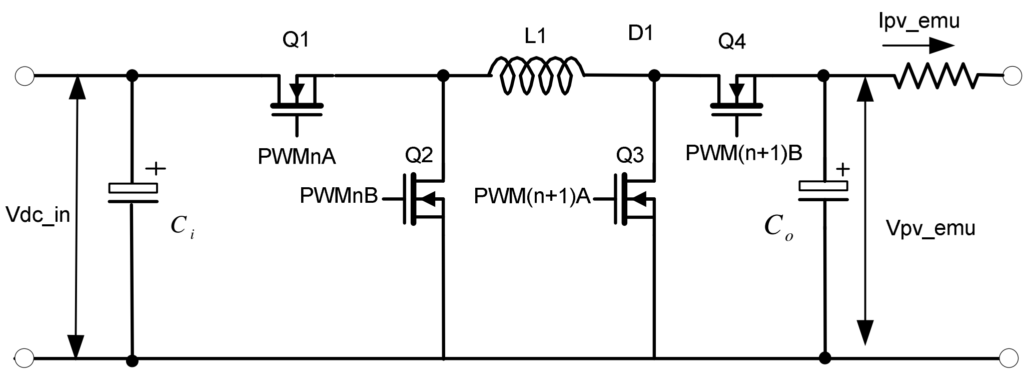


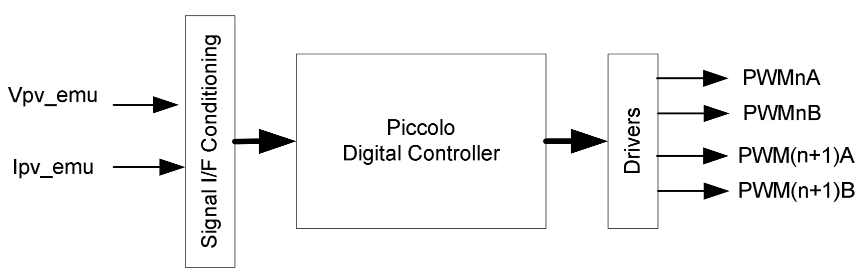
Primary Current fed into the grid during the positive half is i_{leg2}, i_{leg1} will measure zero. However when the current reference for the inverter is very low i.e. Q1 is open most of the times, this can result in shorting the grid across SW2 and SW4. When shorted a high current flows through both Leg1 and Leg2. This is why the Leg1 current is subtracted from the Leg1 current at all times to get the change in the grid current.



Shorting the grid under low modulation case, then negative current is not sensed.

3.4 PV Emulator





Synchronous Buck Boost

Power Stage Parameters

Input Voltage : 24V , DC Power Supply
Input Current : 2.5 Amps Max , DC Power Supply
Output Voltage : 0-30 V DC Max

Output Current: 0-2.5 Amps
Power Rating: 50W Max
fsw = 200Khz

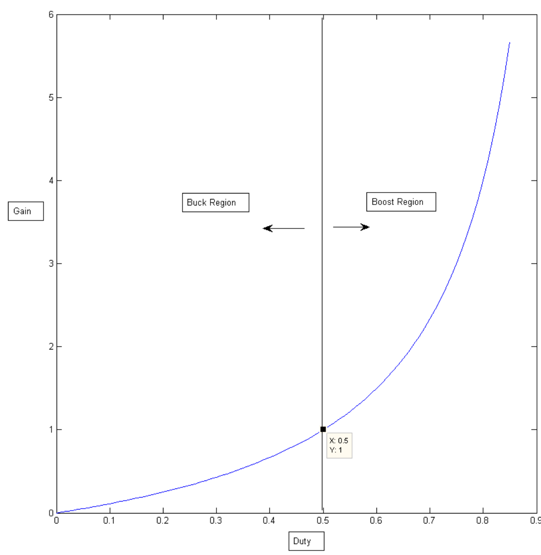
Note the ratings mentioned above are max ratings, depending on the panel emulator characteristics the max ratings would be different.

Control Description

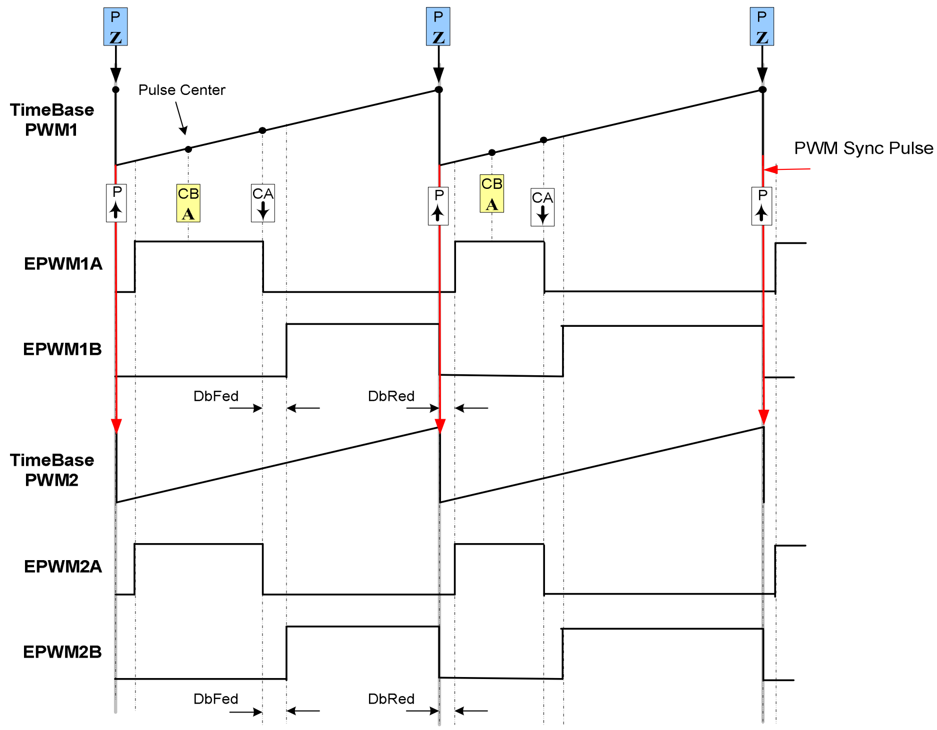
A synchronous buck boost stage is used to realize the PV array. The power stage comprises of buck side switches Q1 and Q2, boost side switches Q3 and Q4, an inductor L1 and input and output capacitor Ci and Co. The ideal DC gain of the stage is given by

$$G = \frac{V_o}{V_i} = \frac{D_{bu}}{1 - D_{bo}}$$

Where D_{bu} is the duty of the buck stage and D_{bo} is the duty of the boost stage. If the power stage is switched such that the buck and the boost duty are the same i.e. $D_{bu} = D_{bo}$ the gain curve is as follows:



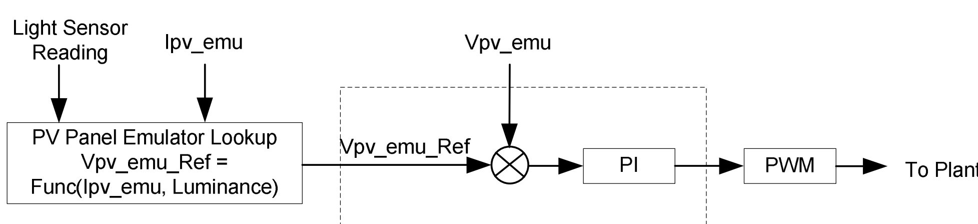
Therefore it can be concluded for duty less than 50% the stage behaves as a buck and 50% and above as a boost. The detailed switching diagram using C2000 PWM module is depicted below.



This stage is controlled using Piccolo-A (F28027) which is present on the EVM base board. This controller is separate from the controller that does the DC-DC boost, battery charging and the DC-AC conversion present on the board.

The input voltage to the buck boost stage is from the DC Power entry block. This voltage is 20V, as the power adapter shipped with the kit is 20V. However the user can use another voltage input by connecting it to the Terminal Block present on the board.

To emulate the panel characteristics the stage needs to operate as a current controlled voltage source i.e. depending on the load current demand the output voltage will change. This is achieved by changing the voltage reference of the stage based on look up table value.

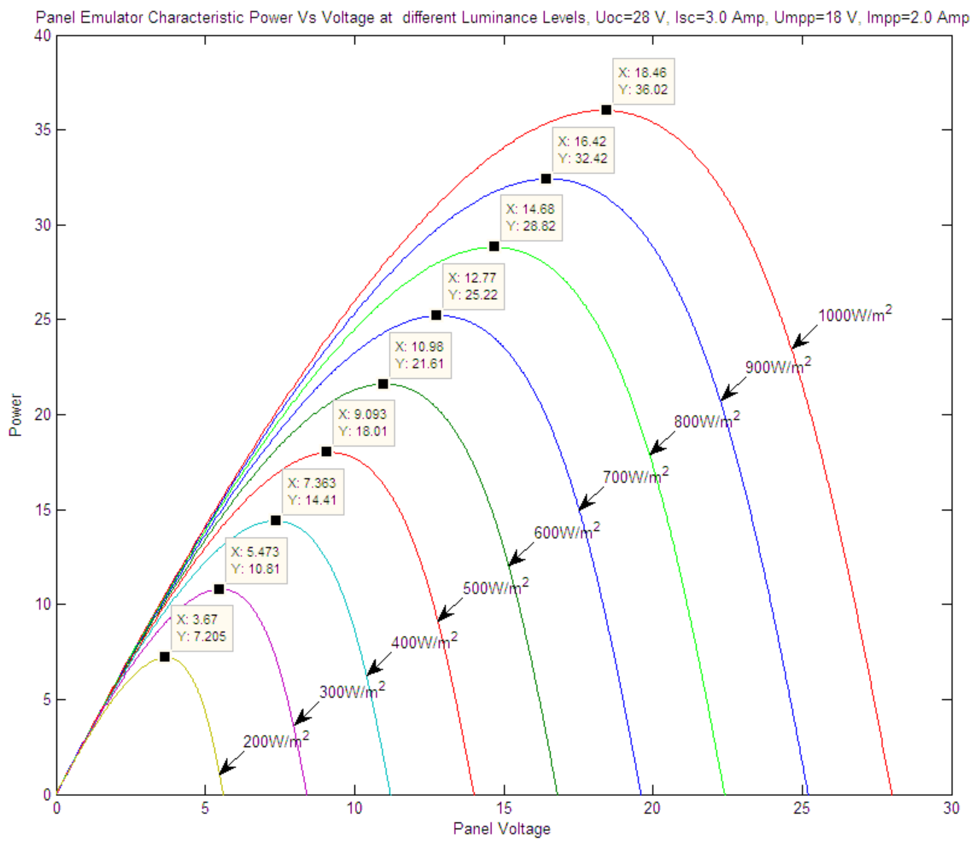


The current being drawn by the panel I_{pv} is used as the index for the look up table that is stored on the controller. The look up table is then used to provide the voltage reference V_{pv_ref} for the panel corresponding to the I_{pv}. A light sensor is placed on the board to control the irradiance level and produce a corresponding V-I curve. For getting curves between different luminance levels the values from the stored curve are interpolated using the following equation.

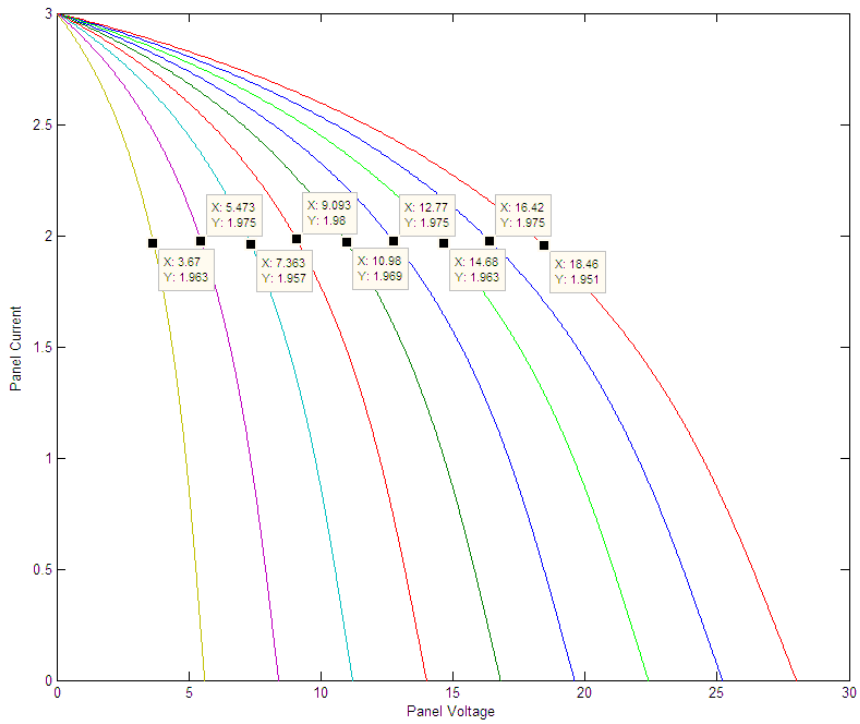
$$V_{pv\_ref\_G2} = \frac{G2}{G1} * V_{pv\_ref}$$

Where G2 is the new luminance value and G1 is the old luminance value. (Note this is just an approximation of the PV characteristics, the real panel characteristics may differ)

Following are the curves of the PV emulator table that is stored for the PV emulation on the controller.



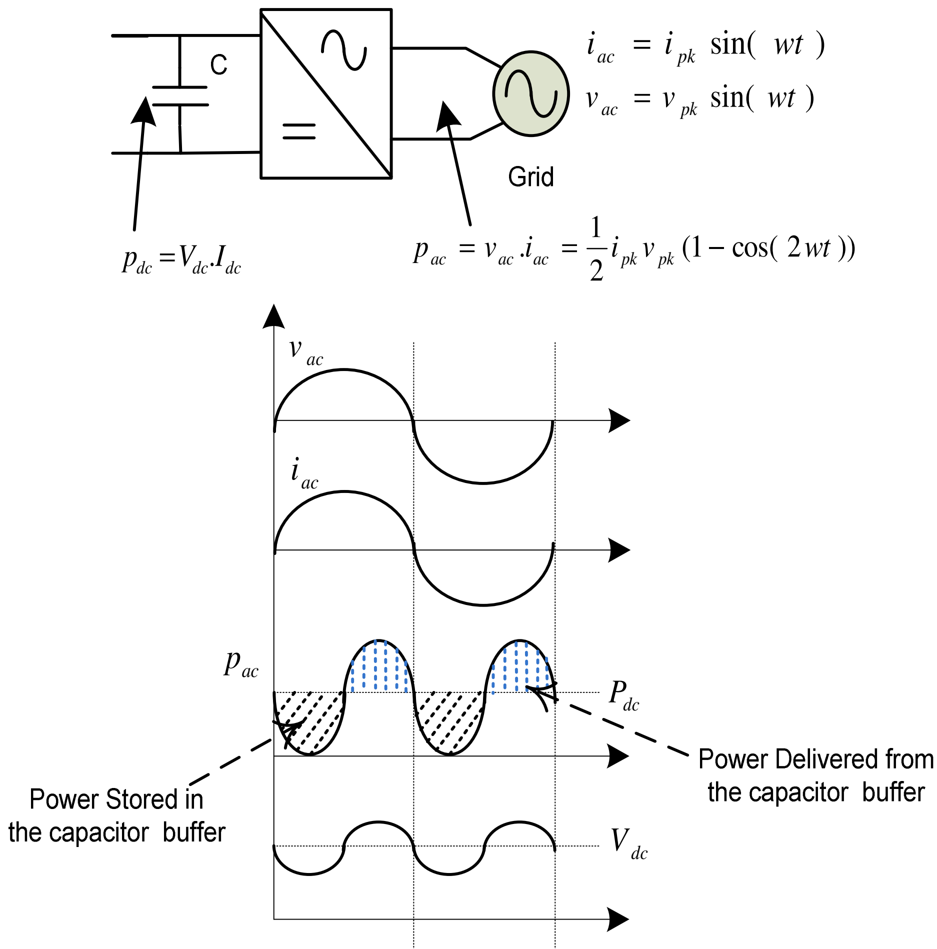
Luminance Ratio (w.r.t 1000W/m^2)	Pmpp =(Pmax * Luminance Ratio) Watts	Vmpp (Volts)
1.0 = 1000 W/m^2	36.02	18.46
0.9 = 900W/m^2	32.42	16.42
0.8 = 800W/m^2	28.82	14.68
0.7 = 700W/m^2	25.22	12.77
0.6= 600W/m^2	21.61	10.98
0.5=500W/^2	18.01	9.093
0.4=400W/m^2	14.41	7.363
0.3=300W/m^2	10.81	5.473
0.2=200W/m^2	7.205	3.67



Note in a PV inverter system the DC-DC Boost stage feeds the input to the inverter stage. As the inverter provides an AC load which causes a 100-120Hz ripple (depending on the frequency of the AC load) on the DC bus of the inverter. A DC Link capacitor is typically used to compensate for this power ripple.

3.5 DC Link Capacitor Requirement

Note in a PV inverter system the DC-DC Boost stage feeds the input to the inverter stage. As the inverter provides an AC load which causes a 100-120Hz ripple (depending on the frequency of the AC load) on the DC bus of the inverter. A DC Link capacitor is typically used to compensate for this power ripple. The following derivation shows the relation between this DC Link capacitor and ripple on the DC Bus.



Let the AC current being fed to the grid/ load and the AC voltage be:

$$i_{ac} = I_{pk} \sin(wt)$$
$$v_{ac} = V_{pk} \sin(wt)$$

Which implies the power supplied by the inverter is:

$$p_{ac} = v_{ac} * i_{ac} = \frac{1}{2} V_{pk} I_{pk} [1 - \cos(2wt)]$$

In the equation the power injected into a single-phase grid follows a sinusoidal waveform with twice the frequency of the grid. The PV module cannot be operated at the MPP if this alternating power is not decoupled by means of an energy buffer. Therefore a capacitor bank is typically used for buffering this energy.

To estimate the amount of capacitance needed to buffer this energy, let the magnitude of the ripple induced on the DC bus due to the alternating nature of the power being drawn be ΔV. Now Looking at a quarter of the sinusoidal power waveform the equation for the power being drawn for 1/8th of the grid cycle can be written as follows:

$$P_{ac} = \frac{\Delta E}{T/8} = \frac{\frac{1}{2}CV^2 - \frac{1}{2}C(V - \Delta V)^2}{\frac{1}{(8 * f_{ac})}} = 4 * f_{ac} * C * (V^2 - (V - \Delta V)^2)$$

Now assuming the inverter can deal with a 10% voltage ripple on the input DC bus we get the Capacitance required for this stage.

$$C = \frac{P_{ac}}{4 * f_{ac} * (V^2 - (V - \Delta V)^2)}$$

As is clear from the equation the minimum capacitance required is a function of the value of voltage this energy buffer is kept at and the AC power delivered.

4 PV Systems using Solar Explorer Kit

PV energy can be utilized in a wide variety of fashion, from powering street light, feeding current into the grid, powering remote base stations etc. The solar explorer kit can be used to experiment with a variety of these applications.

4.1 PV DC-DC Systems

PV powered street lighting, parking stations and thin clients are all part of DC-DC applications for which PV can e used. The Fig 9 depicts a PV powered street light configuration that can be experimented with the solar explorer kit. (Note the idea is not to illustrate the most optimal power stage, but to illustrate the control of such a system using C2000 MCU's)

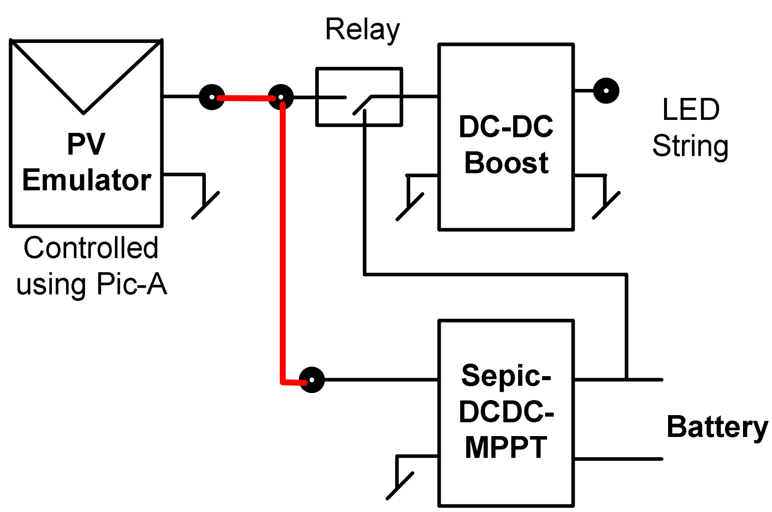


Fig 9 DC-DC PV Street Lighting

Fig 10 illustrates the control of the battery charging system, along with the LED control using the DC-DC Sepic stage and the DC-DC boost stage. In such systems, during daylight the battery gets charged and in the evening the charge from the battery is used to drive the LED's.

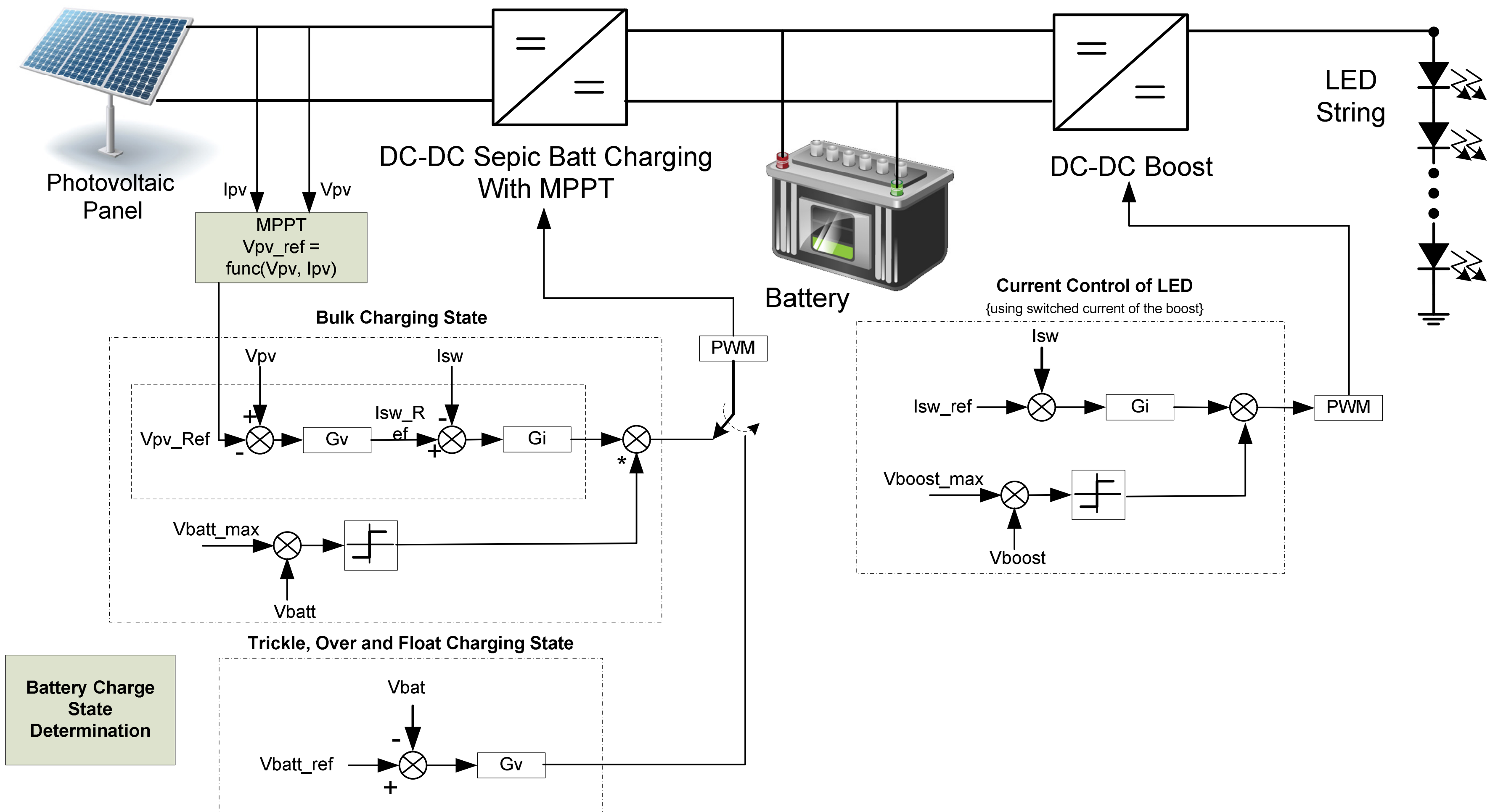


Fig 10 Control of PV Street Light with Battery Charging

4.2 PV Grid Tied Inverter

PV energy can be fed into the grid using a current control inverter. A typical PV Grid tied inverter uses a boost stage to boost the voltage from the PV panel such that the inverter can feed current into the grid. (The DC Bus of the inverter needs to be higher than the maximum Grid Voltage) Fig 11 illustrates a typical grid tied PV inverter using the macros present on the solar explorer kit.

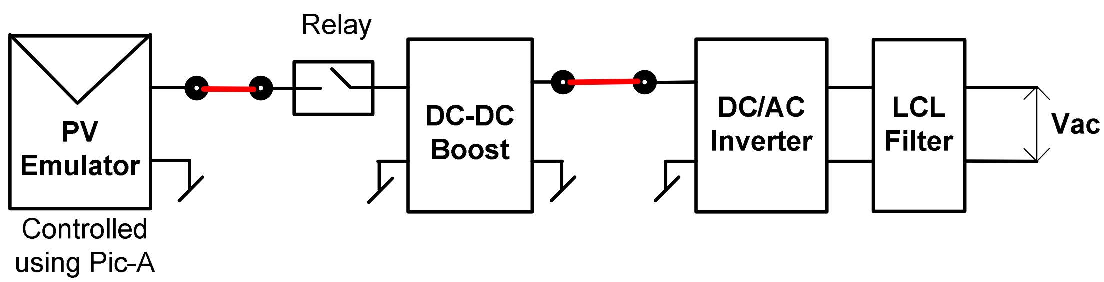


Fig 11 PV Grid Tied Inverter

The DC-DC stage is responsible to maintain MPPT of the panel and the inverter is responsible for the synchronization with the grid and feeding current into the grid. Fig 12 shows the control of a PV inverter stage.

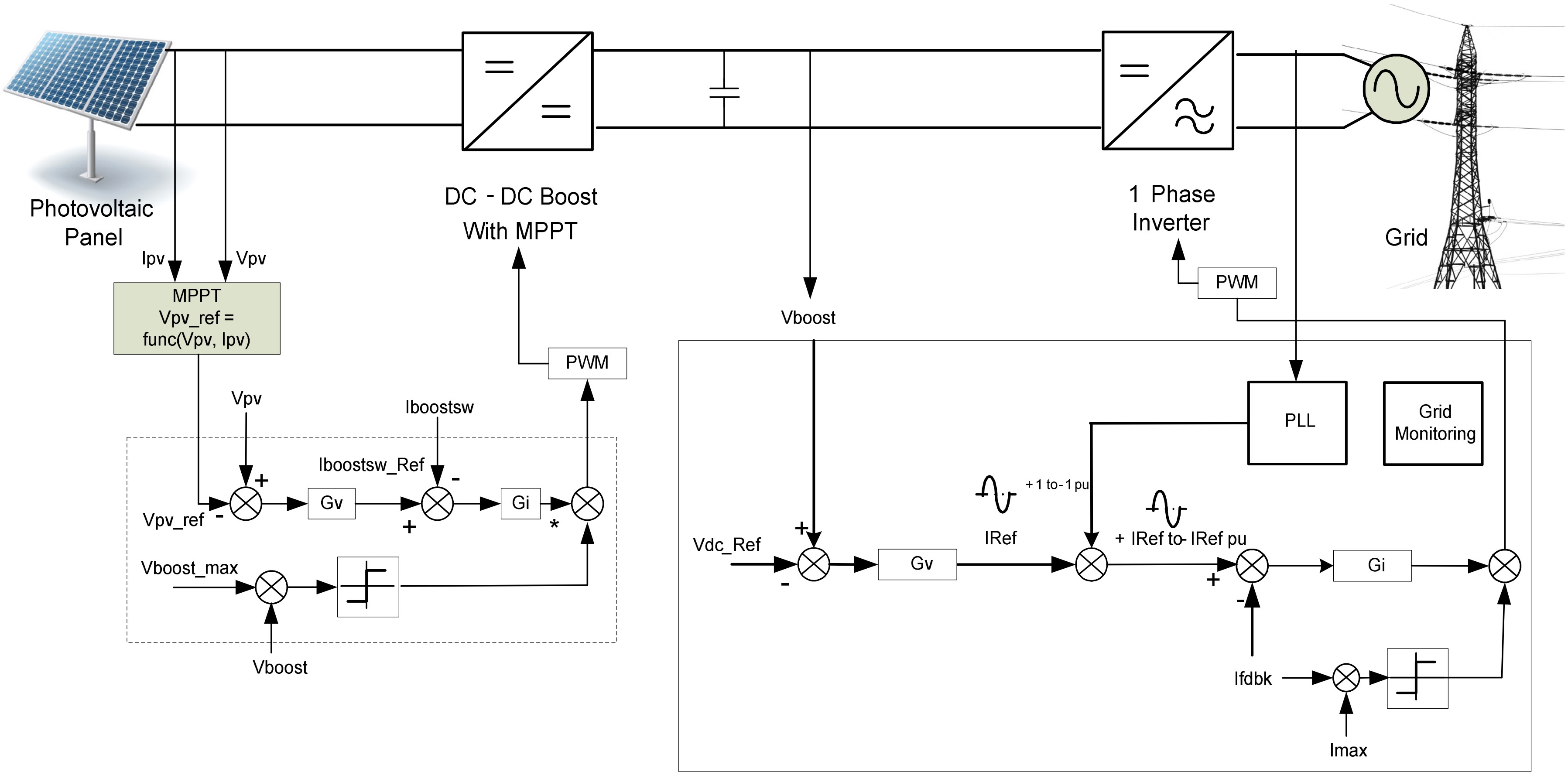


Fig 12 Control of PV Grid Tied Inverter

4.3 PV Off Grid Inverter

PV energy is not a steady source of energy, in daytime the PV generates power whereas at night time it does not generate any power. For PV to supply power to a standalone installation a power storage element is needed, this is done with help of a battery charging stage. Such a system can be realized using the solar explorer kit as shown in the Fig 13. The controls of such a system are described in the Fig 14.

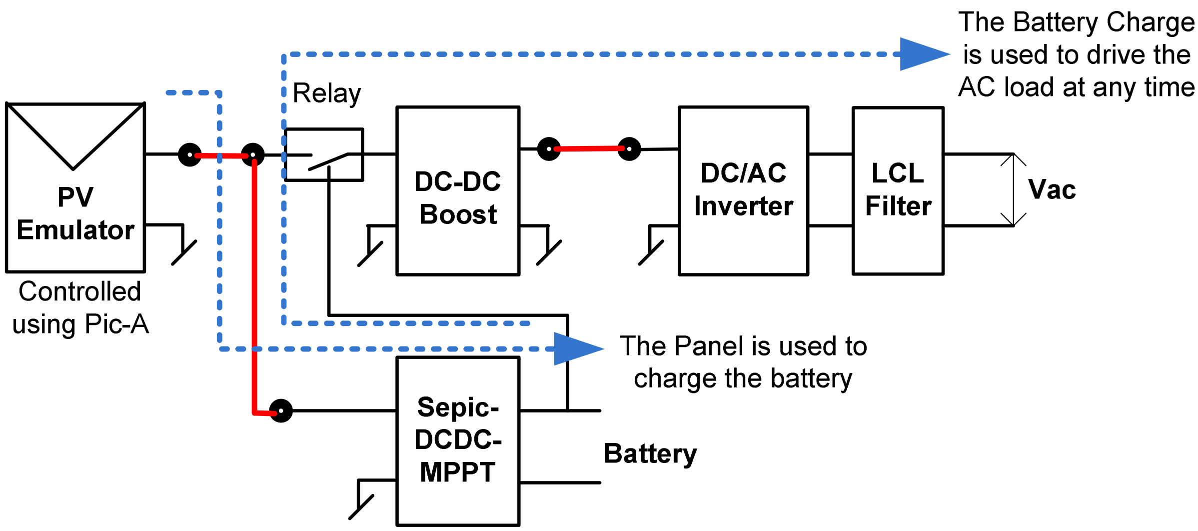


Fig 13 PV Off Grid Inverter System

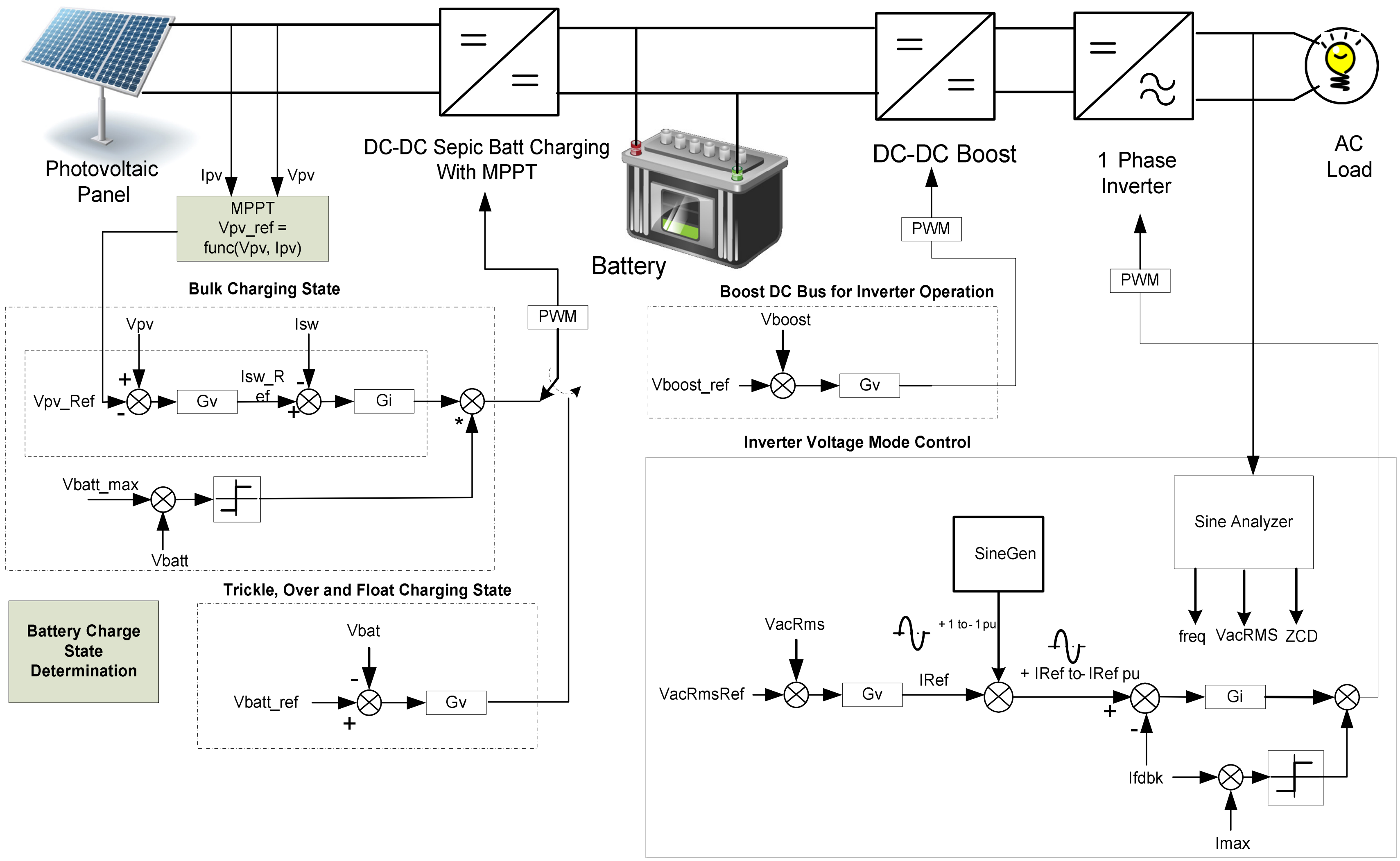


Fig 14 PV Off Grid Inverter Control

5 Hardware Details

5.1 Resource Allocation

The Fig 15 shows the various stages of the board in a block diagram format and illustrates the major connections and feedback values that are being mapped to the C2000 MCU. Table 1, below lists these resources. The table below only lists the resources used for power stages that convert power from the panel and that are mapped to the DIMM100 connector on the board, and not of the panel emulation stage.

Table 1 Resource Mapping: PWM, ADC, GPIO, Comms

Macro Name	Signal Name	PWM Channel/ ADC Channel No/ Resource Mapping F2803x	PWM Channel/ ADC Channel No/ Resource Mapping F28M35x	Function
Single Phase Inverter	PWM-1L	PWM-1A	PWM-1A	Inverter drive PWM
	PWM-1H	PWM-1B	PWM-1B	Inverter drive PWM
	PWM-2L	PWM-2A	PWM-2A	Inverter drive PWM
	PWM-2H	PWM-2B	PWM-2B	Inverter drive PWM
	Ileg1-fb	ADC-A4	ADC1-A4	Leg1 Current
	Ileg2-fb	ADC-A6	ADC1-A6	Leg2 Current
	VL-fb	ADC-B1	ADC2-B0	Line Voltage Feedback
	VN-fb	ADC-A5	ADC1-B4	Neutral Voltage Feedback
	Vac-fb	ADC-A7	ADC1-A7	AC Voltage Feedback
	VdcBus-fb	ADC-A3	ADC1-A3	DC Bus Voltage Feedback
	ZCD	ECAP1	ECAP1	ZCD Capture
DC-DC Single Phase Boost with MPPT	PWM	PWM-3A	PWM-3A	Boost PWM
	Vpv-fb	ADC-A1	ADC1-B0	Panel Voltage Feedback
	Ipv-fb	ADC-A0	ADC1-A0	Panel Current Feedback
	Iboostsw-fb	ADC-B6	ADC2-A6	Boost Switched Current
	Vboost-fb	ADC-A2	ADC1-A2	Boost Voltage Feedback
DC-DC Sepic with MPPT	PWM	PWM-4A	PWM-4A	Sepic PWM
	Vpnl-fb	ADC-B2	ADC2-A2	Panel Voltage Feedback
	Ipnl-fb	ADC-B3	ADC2-A3	Panel Current Feedback
	Ibattsw-fb	ADC-B7	ADC2-A7	Battery Switched Current
	Vbatt-fb	ADC-B4	ADC2-A4	Battery Voltage
Main –Board	RLY-en	GPIO-12	GPIO-12	Relay Switch
	Light-fb	ADC-B0	ADC2-A0	Light Sensor Feedback
	PWM	PWM-5A	PWM-5A	DAC-1
	PWM	PWM-6A	PWM-6A	DAC-2
	PWM	PWM-7A	Not Available	DAC-3
	PWM	PWM-7B	Not Available	DAC-4
	SPISOMI-B	SPISOMI-B	SSI	Comm. to PV Emu
	SPISIMO-B	SPISIMO-B	SSI	Comm. to PV Emu
	SPISTE-B	SPISTE-B	SSI	Comm. to PV Emu
	SPICLK-B	SPICLK-B	SSI	Comm. to PV Emu
	Tx-slave	SCITX-A	Not used	Comm. to SCI GUI
	Rx-slave	SCIRX-A	Not used	Comm. to SCI GUI

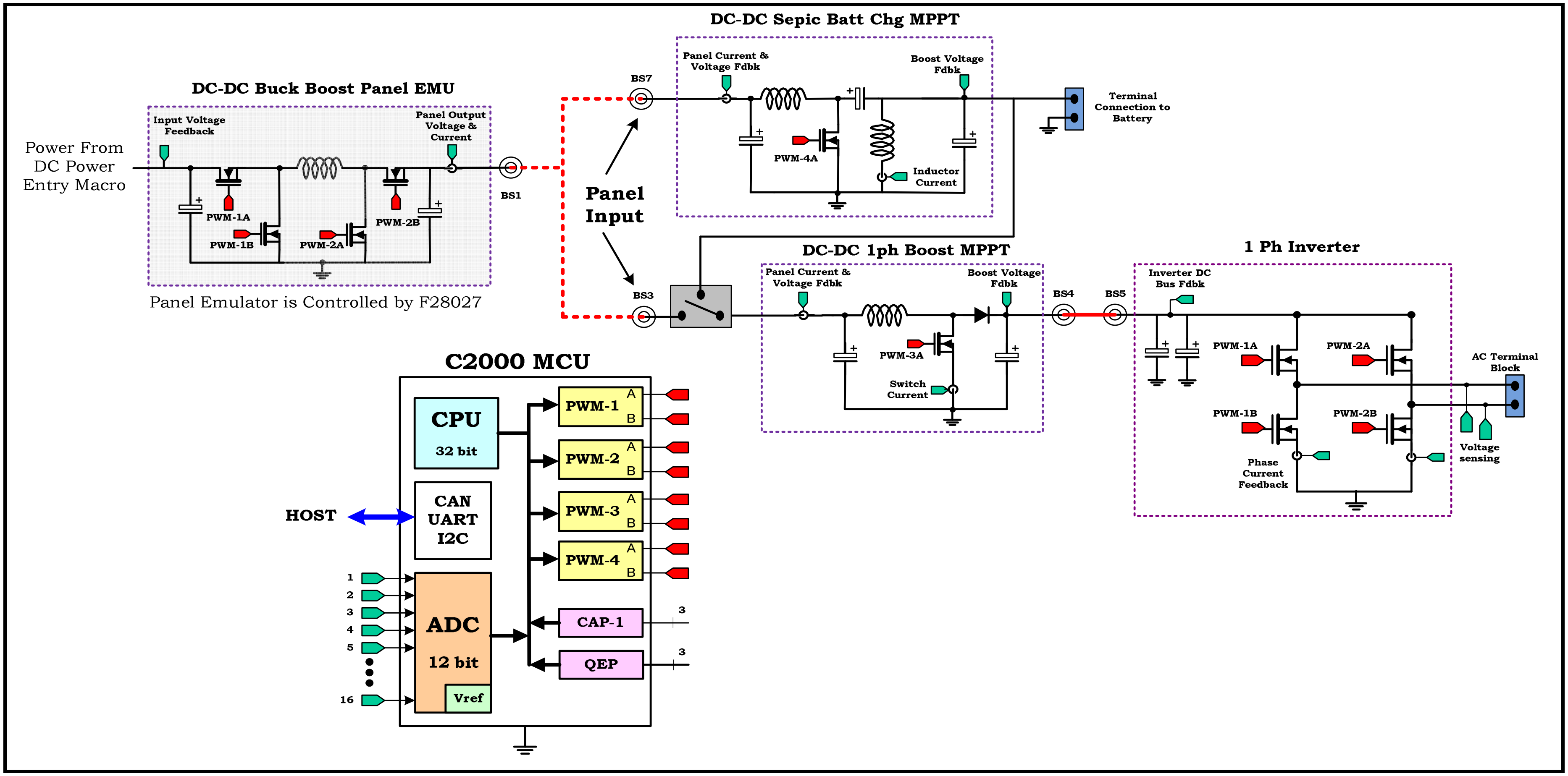


Fig 15 Solar Explorer Kit Block Diagram with C2000 MCU

(Connectivity Peripherals may differ from one device to the other inlcuding Ethernet, USB, CAN, SPI etc)

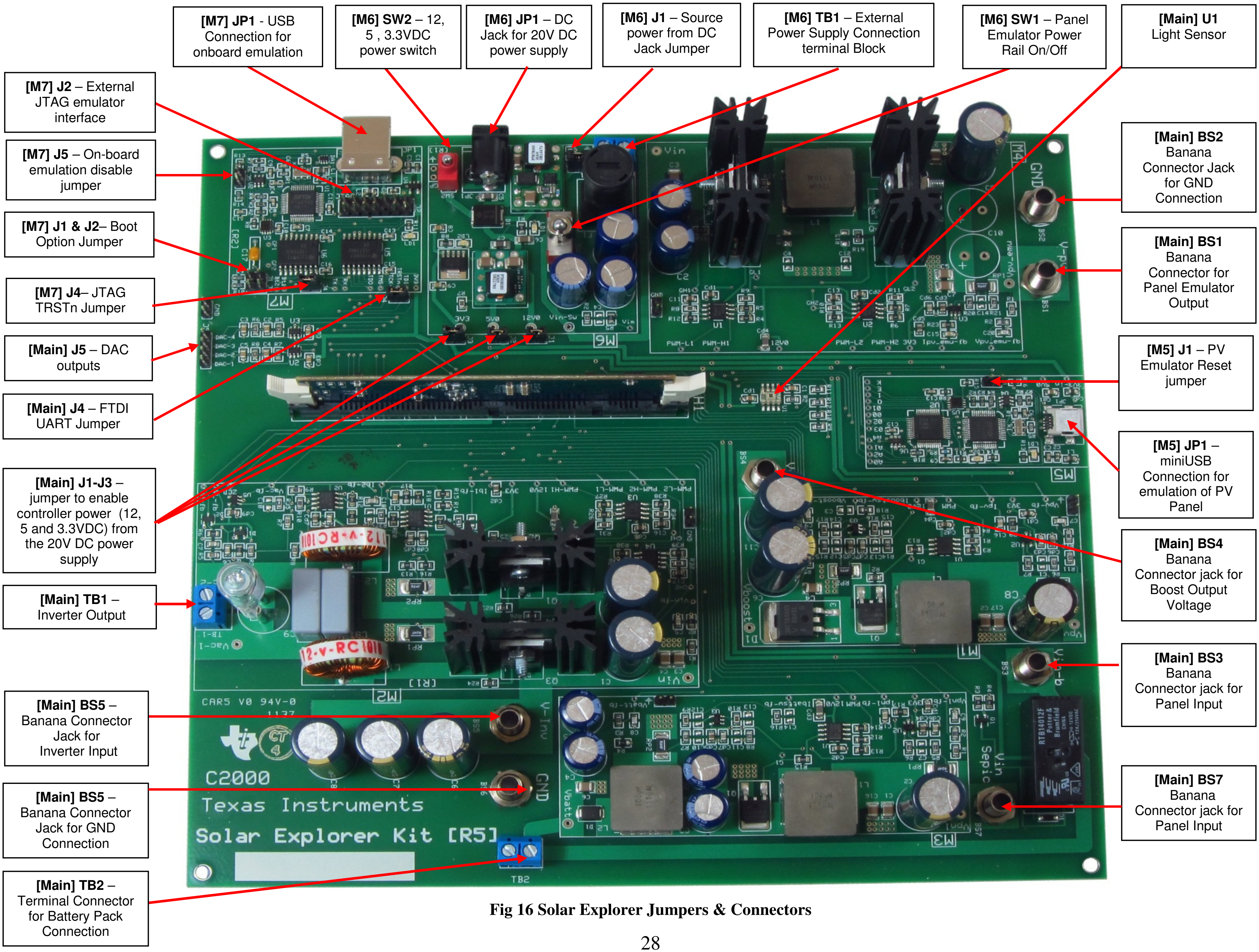


Fig 16 Solar Explorer Jumpers & Connectors

5.2 Jumpers and Connectors

Table 2 below shows the various connections available on the board, and is split up by the macro each connection is included in. Fig 16 above, illustrates the location of these connections on the board with help of a board image:

Table 2 Jumpers & Connectors on Solar Explorer Board

[Main]-BS1	Banana Jack for Panel Emulator Output Connection
[Main]-BS2, BS6	Banana Jack for GND Connection
[Main]-BS3, BS7	Banana Jack for Panel Input Connection
[Main]-BS4	Banana Jack for Boost Voltage Connection
[Main]-BS5	Banana Jack for connecting the input to the DC-AC inverter, typically this is the Boost Output an input voltage
[Main] J1, J2, J3	Jumpers J1,J2 and J3 are used for sourcing 12V, 5V and 3.3V power respectively for the board from the DC Power Entry block [M6] on the board
[Main] J4	JTAG TRSTn disconnect jumper, populating the jumper enables JTAG connection to the microcontroller. The jumpers needs to be unpopulated when no JTAG connection is required such as when booting from FLASH
[Main] J5	DAC outputs: Gives voltage outputs that result from a PWM being attached to a first-order low-pass filter. Pins 1,2,3 and 4 are attached to low pass filtered PWM-5A, PWM-6A, PWM-7A and PWM-7B respectively. These are used in conjunction with the PWMDAC DMC library components to observe system variables on an oscilloscope
[Main]-H1	DIMM100 Connector, used to insert the C2000 MCU control card
[Main]-TB2	Terminal Block for output of Sepic stage[M3], used to connect to battery pack
[M2]-TB1	Inverter Output Voltage Connection Terminal Block
[M6]-JP1	DC Power Jack, Input Connection from the DC Power Supply
[M6]-SW1	Switch to enable/disable power to the PV Emulator stage, When in ON position 20V from the DC Power entry macro goes to the Panel Emulator stage
[M6]-SW2	Switch to enable/disable power to the board. When in On position the input voltage is used to generate 12V, 3.3V and 5V rail on the board. Also if the [M6]-J1 jumper is populated the power from the DC Jack is also used for the power rail of the Panel Emulator Stage
[M6]-J1	When jumper is populated the power for the PV emulator stage is the input of the DC Power Jack [M6]-JP1. When unpopulated a separate external power supply can be connected to [M6]-TB1 to source power for the Panel Emulator Stage.
[M6]-TB1	External Power supply connection for the PV emulator, the PV emulator can source power from the 20V power supply that feeds into [M6]-JP1, however if it is desired an external power supply can be connected to [M6]-TB1 which will separate the DC Link from the controller power. When using external power supply [M6]-J1 needs to be depopulated.
[M7]-JP1	USB connection for on-board emulation
[M7]-J1&J3	Boot Option Jumpers, not used for F2802x, F2803x or F2833x devices.
[M7]-J2	External JTAG interface: this connector gives access to the JTAG emulation pins. If external emulation is desired, place a jumper across [M3] J5 and connect the emulator to the board. To power the

	emulation logic a USB connector will still need to be connected to [M7] JP1.
[M7]-J4	Populate when using FTDI chip as a UART i.e. when using a GUI to interact with the MCU.
[M7]-J5	On-board emulation disable jumper: Place a jumper here to disable the on-board emulator and give access to the external interface.

5.3 GUI Connection

The FTDI chip present on the board can be used as an isolated SCI for communicating with a HOST i.e. PC. The following jumper settings must be done to enable this connection.

As the GUI software with SCI is provided for F28035 control card only, F28035 settings are discussed below,

1. Populate the jumper [M7]-J4
2. Remove the jumper [Main]-J4, this disables JTAG connection.
3. For F28035, put SW3 on the F28035 Control Card to OFF position
4. Connect a USB cable from [M7]-JP1 to host PC.

Note: If you are going to boot from Flash & connecting using the GUI, you would need to do the Boot from Flash settings as described in the Table Boot Options.

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