TI Designs
Micro Solar Inverter

TI Designs

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Design Resources

TIDM-MSOLARINVERTER	Design Page
TIDM-MOTOR-WATERMTR	Design Page
MSP430G2553	Product Folder
DRV8837	Product Folder
EVM430-FR6989	Product Folder

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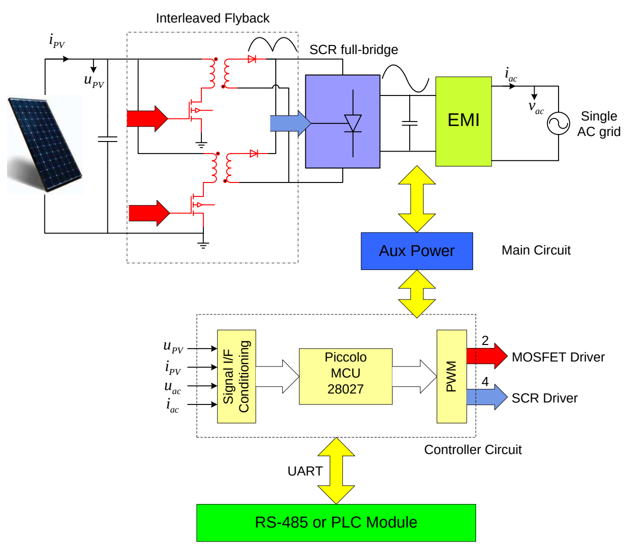
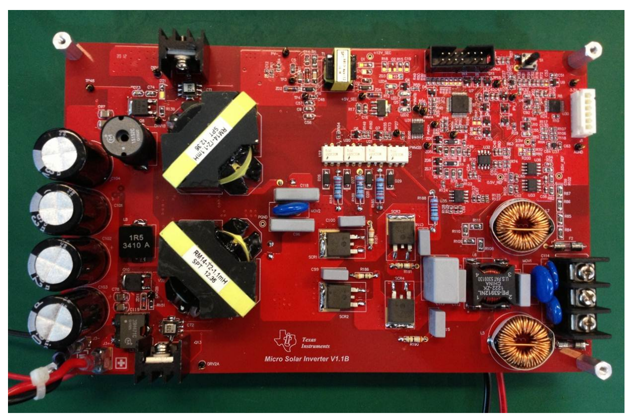
Design Features

- Complete Isolated
- Complete Protection
- Multiple Output and Low Cost Auxiliary Power
- Isolated Bridge Drive

Featured Applications

- Solar Inverter Development





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1 System Description

The current boom of renewable energy development and utilization will trigger a fourth industrial revolution. A vital part of this development is photovoltaic power generation, which uses solar inverters. In all of the solar inverters, the micro solar inverters have been an important member. This guide mainly describes how to use a TMS320F2802x to design a micro solar inverter with low cost and high performance. This design uses the interleaved active-clamp flyback plus a SCR full-bridge to realize a micro solar inverter with a 220-W output, and also give the whole system firmware architecture and control strategy. Section 5 presents the test waveforms from the lab.

2 Block Diagram

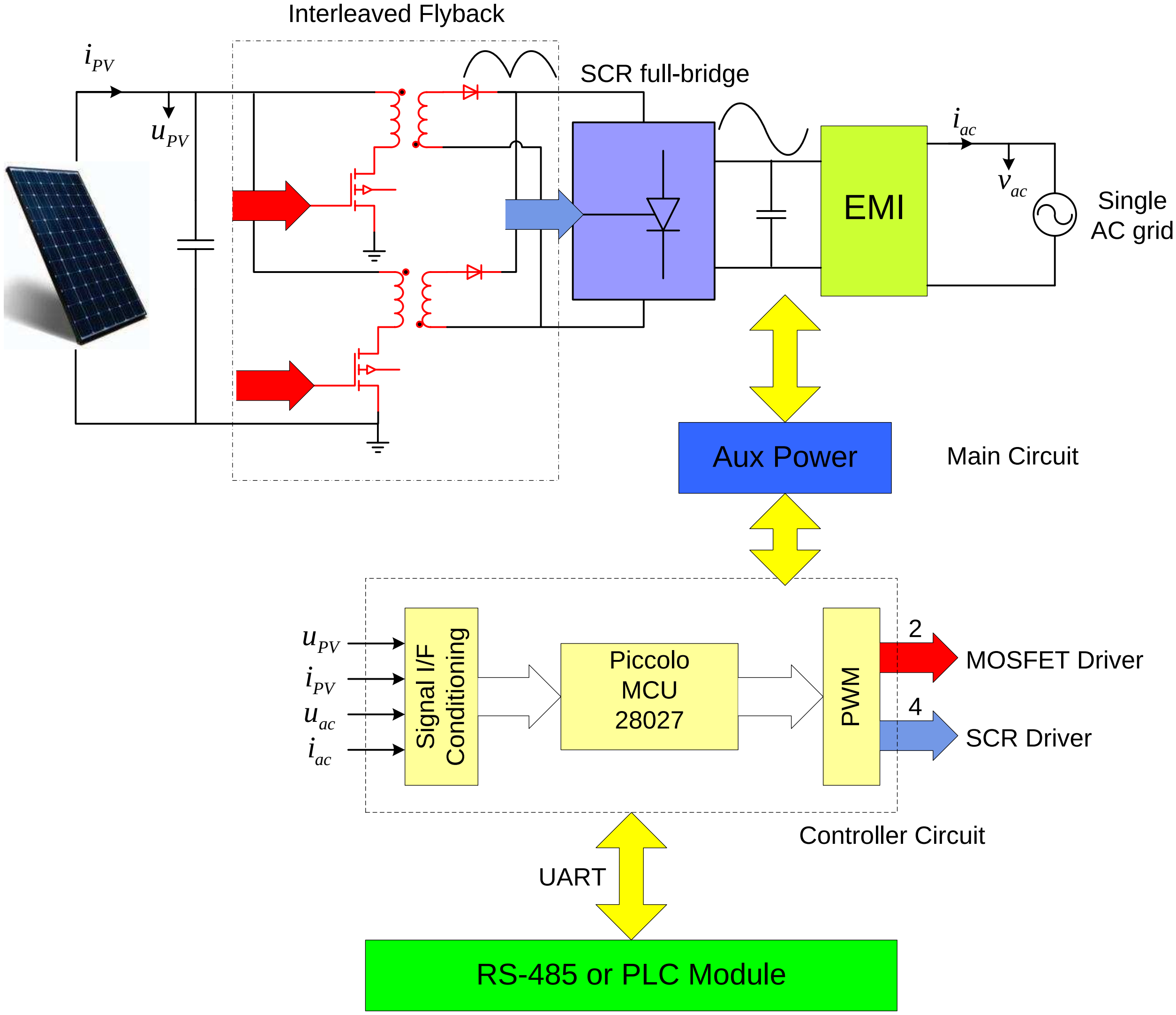

Figure 1. Micro Solar Inverter Block Diagram

3 Circuit Design

This design has a topology that is an interleaved flyback plus SCR full-bridge for industrial frequency inverting. This design has a topology of interleaved flyback with active-clamp plus SCR full-bridge for power converter, and only uses one MCU to realize all of its control. The design also uses an RS-485 interface or PLC for communication, as shown in Figure 1. For detailed specifications, see Appendix A.

This topology has the following features:

- Simple system structure
- High efficiency and low cost
- Complete isolated and high reliability
- Unable to realize the reactive power compensation

4 Software Description

The firmware of the system includes the following functions:

- **Turn On/Off**: The user can turn on or off the system by press the turn on/off button. Enable this function by the software setting.
- **Auto Turn On/Off**: If the turn on condition is satisfied, the system can turn on itself automatically. When the condition is not fit to feed the energy to the grid, the system will stay in the standby mode, and observe the condition changes. If the system is already turn on, the system will turn off automatically when the condition is not fit to feed energy.
- **Soft Start Turning On**: When the system needs to turn on, it will start from the zero current feeding, and the PWM will turn on at the zero-crossing point in order to reduce the rush current to the grid.
- **LED Control**. The system has one status LED. When the system is in standby mode, the corresponding LED will flash every 1.2 s. When the system is turn on, the LED will flash every 2.4 s. When there is a fault, the LED will remain on.
- **User Key Control**: The inverter has a user key that can turn on and off the inverter and can also clear the fault. When the system stays in standby mode, if the key is pressed for over 1 s, the system will turn on if the condition is satisfied. If the system is already turned on when the key is pressed on over 1 s, the system will turn off. When there is a fault and the system stays in fault mode, the fault can be cleared. Go into the standby mode again by holding the user key for over 1 s.

5 Test Setup and Results

Before powering up the entire system, visually inspect that there aren't any damages to the device from the transportation process. Prepare the following equipments or instruments to build a complete test platform for micro solar inverters:

- TI's micro solar inverter reference design circuit board V1.1B suite (includes a TI's micro solar inverter reference design board, a DC input line [red color: positive (+); black color: negative (-)], an AC output line)
- A solar panel with a maximum output power of 220 W (replaceable by PV simulators, such as the 62150H-1000S produced by Chroma Corporation)
- An AC source with a rated output power higher than 500 W (analog power grid), such as the 61505 manufactured by Chroma Corporation
- An air switch with a rated capacity of 50 A
- A variable resistor (resistance value = 50 Ω) with a rated power greater than 300 W
- An oscilloscope (used for waveform measurement)
- A power analyzer (used for efficiency test)

After completing the previous steps, wire the device according to the following steps. In the wiring process, ensure all the power supplies are off, including the solar panel. Shelter the solar panel with black cloths to ensure its output voltage is lower than 15 V), PV simulator, AC source, and so on. Otherwise, an unsheltered panel could cause personal injury as well as damage the entire system.

Wiring procedures and preparations prior to power-up for micro solar inverter test platform:

1. Connect the air switch to the input terminal J3 male tab of the TI's micro solar inverter reference design board using the DC input line. Pay attention to the polarity (the red line connects to the positive, while the black line to the negative).
2. Put the air switch into the off state. Connect with the output of the solar panel or PV simulator to guarantee that the positive and negative polarity connections are correct.
3. Use the AC output line to connect the output terminal J2 of the TI's micro solar inverter reference design board with the AC Source. The pin definition of J2 is as the following:

Table 1. Connector J2

Pin 1	L
Pin 2	E (FG)
Pin 3	N

4. Connect the AC Source with the resistive load.
5. Clip the differential voltage probes onto the L and N lines of the micro inverter's output respectively to monitor grid-connected voltage while clipping the current probe onto the L line of the micro inverter's output to monitor grid-connected current.

Double check the correctness of all the connections (especially if the positive and negative polarity is reversed) after finishing the wiring work, then go on to conduct the power-up test in accordance with the following steps:

1. Remove the black cloths covering the solar panel to make its output voltage higher than the minimum startup voltage of 15 V, or configure the PV simulator to make its maximum power point set at 36-V DC and the desired output power point, which is not allowed to be greater than 200 W. See Appendix B for the configuration steps for the PV simulator. Turn on the air switch. The MCU operation indicator light (red) stays on and the running light (green) quickly flashes, indicating that the control circuit and the auxiliary power supply are working properly.
2. Set the AC source (analog power grid) voltage to 120-V AC/60 Hz and the output power to be higher than 300 W. Then press the switch to make it output.
3. Hold the control switch S1 until the MCU running light (green) changes from a quick flash to a slow flash, indicating that the system has started operating. Observe the grid-connected voltage and grid-connected current on the oscilloscope now.

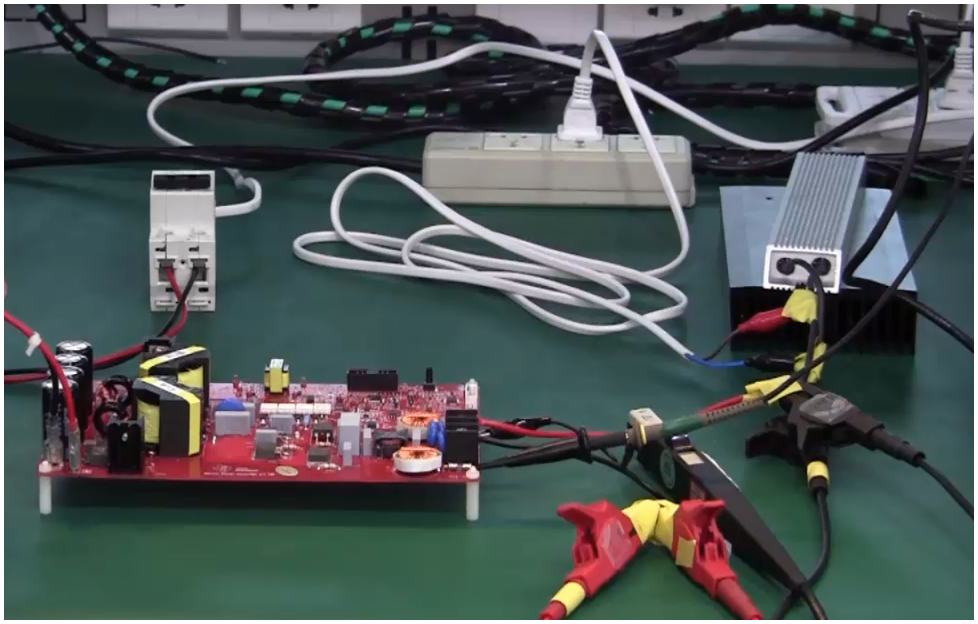

Figure 2. Test Setup

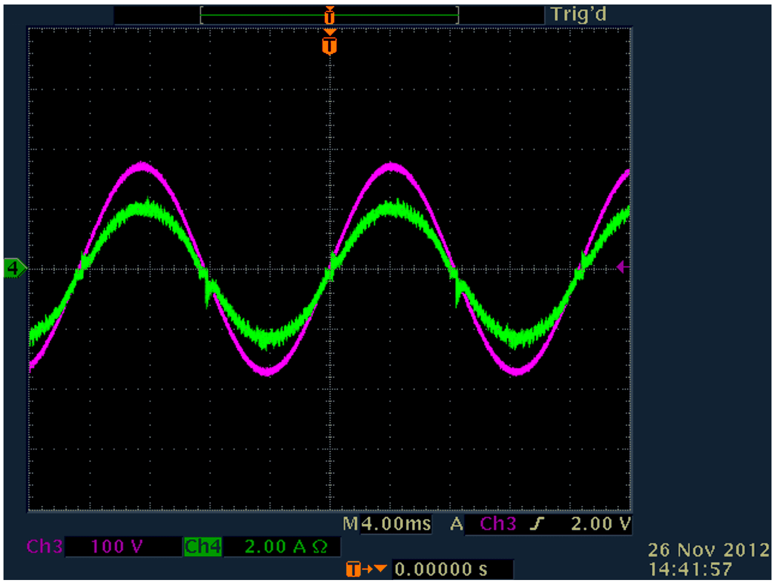

Figure 3. Grid-Tied Waveform (CH3 Voltage = Purple, CH4 Current = Green)

6 Design Files

6.1 Schematics

To download the schematics, see the design files at TIDM-MSOLARINVERTER.

6.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-MSOLARINVERTER.

6.3 Layer Plots

To download the layer plots, see the design files at TIDM-MSOLARINVERTER.

6.4 Altium Project

To download the Altium project files, see the design files at TIDM-MSOLARINVERTER.

6.5 Gerber Files

To download the Gerber files, see the design files at TIDM-MSOLARINVERTER.

6.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDM-MSOLARINVERTER.

6.7 Software Files

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

7 About the Author

YUAN TAO is a senior systems engineer at Texas Instruments China where he is responsible for provide the turn-key solutions for the industrial segment. Yuan Tao has thirteen years of experience in mixed signal board design, analog circuit designs, and EMC-protection circuit design.

Appendix A Electrical Specifications

Table 2. Appendix A. Electrical Specifications

DC PARAMETERS				
ITEMS	**UNIT**	**MIN**	**TYP**	**MAX**
MPPT voltage range	V	22		40
Operating range	V	20		45
Maximum DC input voltage	V			50
Minimum start voltage	V	18		
Maximum DC input short circuit current	A			15
Maximum DC input current	A			10
AC PARAMETERS				
ITEMS	**UNIT**	**MIN**	**TYP**	**MAX**
Rated AC output power	W		220	
Output power factor (PF)		0.95	0.99	1
Nominal AC output voltage range	V_{RMS}	90	110	135
Nominal AC output current	A		2.1	
Nominal AC output frequency range	Hz		60	
MISCELLANEOUS PARAMETERS				
ITEMS	**UNIT**	**MIN**	**TYP**	**MAX**
Peak inverter efficiency	%			95
Static MPPT efficiency	%		99	
Total harmonic distortion current	%	3	5	
Ambient temperature range	°C	–25		50
Night tare loss	W		1	
SOFTWARE FUNCTIONS				
Communication	PLC or RS-485 (Optional)			
Protection	Islanding/Overrange/Short Circuit			
Status LED display	Aux Power LED, Running LED, Fault LED			
Turn on/off	Manual start, Soft start (Optional)			
Debug support	RS-485 Interface			
GUI	RS-485			
Dimensions (W × H × D)				
Cooling	Natural convection			

Appendix B How to Set Up the Chroma 62150H-1000S PV Emulator

The PV emulator must include the functions of the simulated PV panel. The operation panel of Chroma 62150H-1000S is shown in Figure 4:

Figure 4. Chroma 62150H-1000S Operation Panel

1. Push the *CONF* button, and select "9. OUTPUT MODE". Then, push the *ENTER* button.
2. Select "3. SAS_MODE", then push the *ENTER* button.
3. Set VOC (open-circuit voltage) as 45 V, set ISC (short-circuit current) as 6 A, set VMP (voltage on maximum point) as 36 V, and set IMP (current on maximum point) as 4.8 A.
4. Push the *ON/OFF* button twice.

The output is now enabled. The interface of the output should now resemble Figure 5:

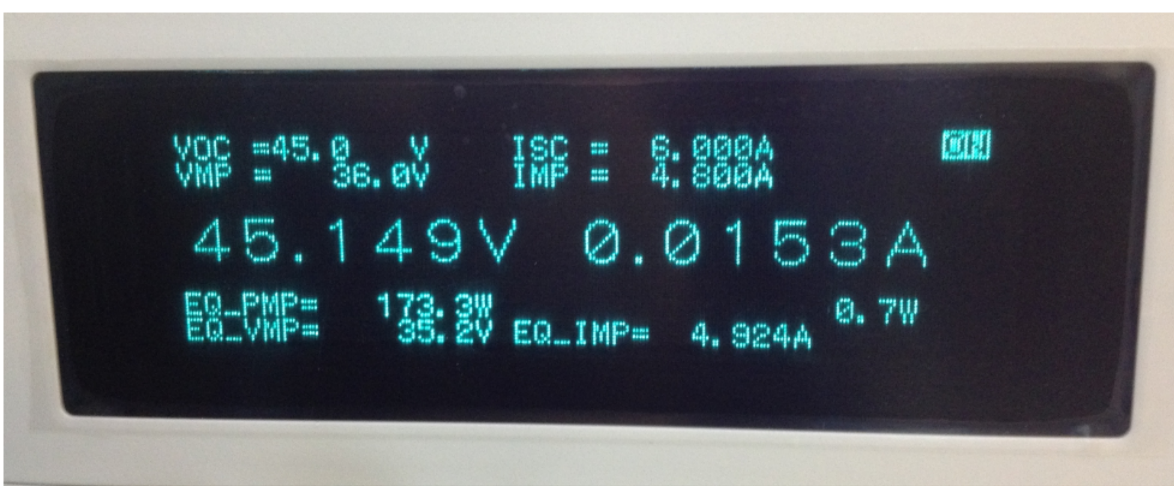

Figure 5. Output Interface

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