Application Report

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AN-2116 SolarMagic™ ICs in Microinverter Applications

ABSTRACT

This application report explores some of the prevalent topologies used in microinverters today, and the use of SolarMagic™ ICs in these demanding applications. In particular, the use of the SM72295 Photovoltaic Full-Bridge Driver is highlighted.

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1 Introduction

Microinverters are a growing and rapidly evolving part of the photovoltaic (PV) system. Modern microinverters are designed to convert the DC power from one PV module (solar panel) to the AC grid, and are designed for a max output power in the range of 180W to 300W. Compared to conventional string or central inverters, microinverters have advantages in ease of installation, localized max power point tracking, and redundancy that provides robustness to failure.

Since this area of power electronics is seeing such rapid innovation, there are many different topologies and variations being developed.

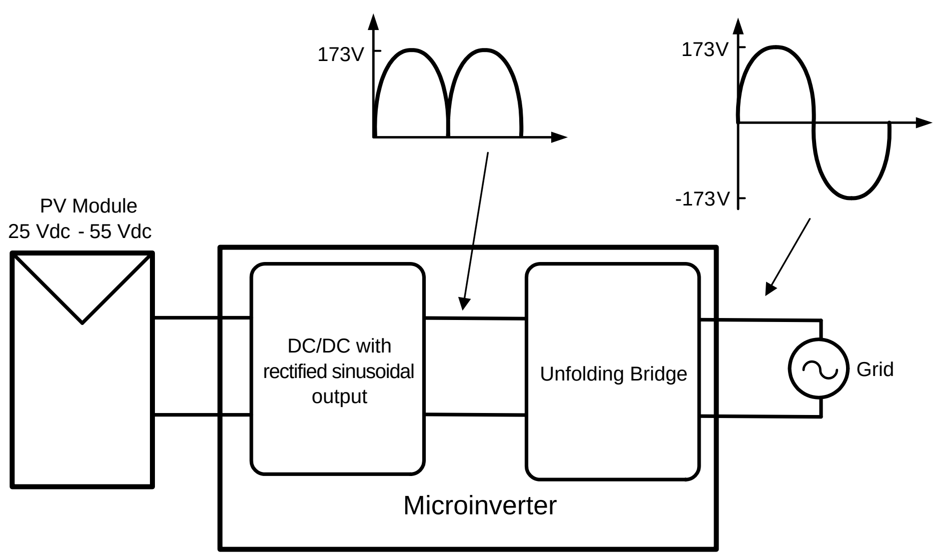
2 SolarMagic Renewable Energy Grade Components

The environment for electronics in PV systems is a very demanding one due to the extremes in temperatures and requirements for long-lifetime. The ambient temperature behind a photovoltaic module can range from below freezing in the winter to over 90°C on a summer day. With this in mind Texas Instruments created the Renewable Energy Grade line of SolarMagic ICs that are all rated for operation from -40°C to +125°C and have all been screened and tested to standards appropriate for products that are designed for a 25 year lifetime. This line of products includes MOSFET gate drives, PWM controllers with integrated switches, LDO regulators, amplifiers, and many other ICs necessary for photovoltaic electronics. All of the ICs recommended in this article are being made available as Renewable Energy Grade components.

3 Single-Stage Microinverters

There have been a multitude of microinverter topologies developed (see [1]), and these topologies can be broken up into two broad categories. The first category depicted in the block diagram of Figure 1 employs a DC/DC converter and controls the converter output voltage to have the shape of a rectified sinusoid. This rectified sinusoid waveform is then inverted into a full sinusoidal waveform using an “unfolding bridge” that interfaces to the grid voltage. Though perhaps not the most accurate name, this category of microinverter topologies is often referred to as a “single-stage microinverter” because the boosting of the panel voltage and shaping of the AC waveform is accomplished in a single stage.

A more formal categorization of microinverter topologies (see [2]) refers to this as a PV-side decoupled topology because the input capacitors decouple the AC power variation. The most widespread topology of this category is a quasi-resonant interleaved flyback, however, there are other variants such as interleaved flyback (not quasi-resonant) and interleaved forward converter. The unfolding inverter is generally implemented with 4 SCR’s (silicon controlled rectifiers) that switch at the grid frequency.



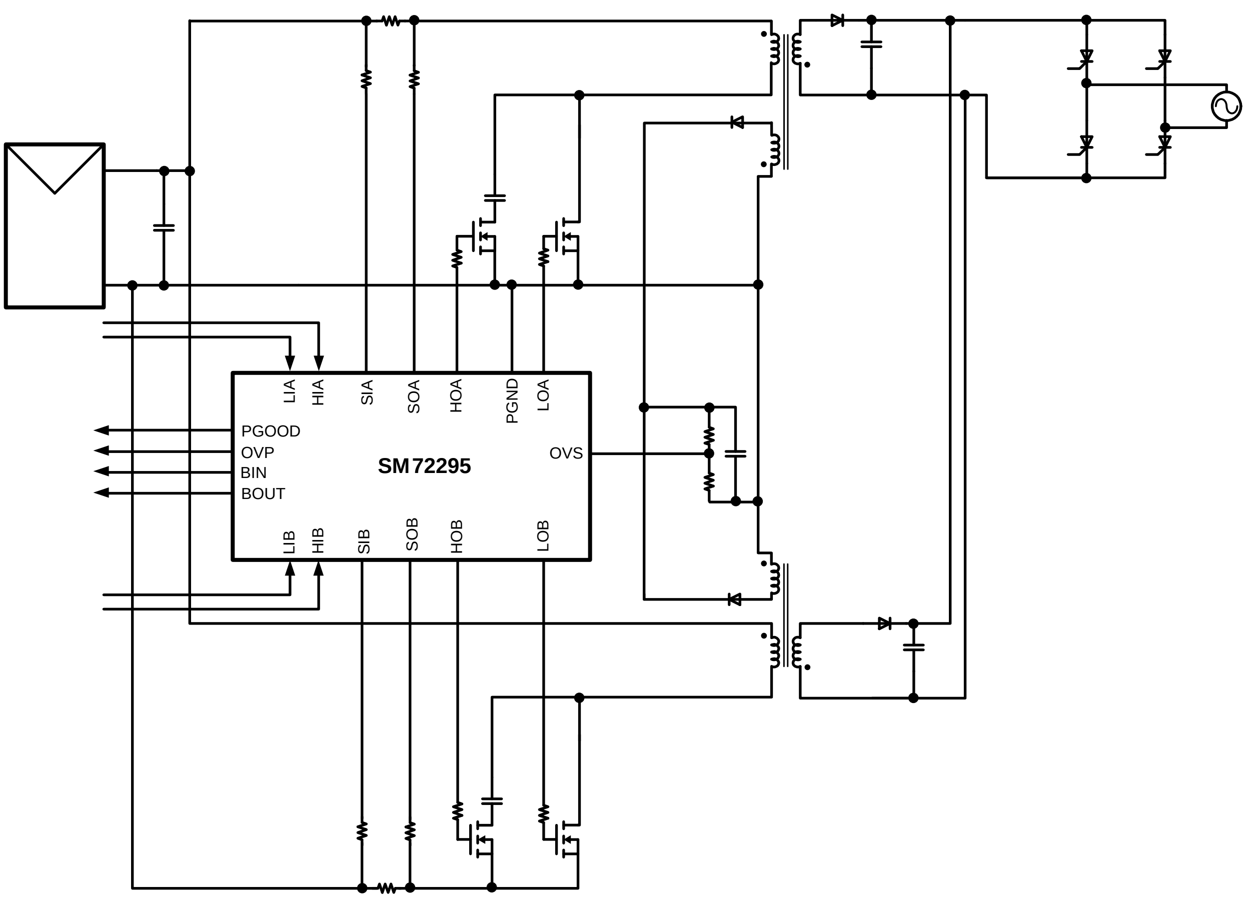
The DC/DC stage can be implemented as a quasi-resonant interleaved flyback or another topology.

Figure 1. Block Diagram of Microinverter Using a Single-Stage Topology

Figure 2 shows a simplified schematic of a single-stage microinverter using a quasi-resonant interleaved flyback for the DC-DC stage. In the quasi-resonant interleaved flyback, the SM72295 provides the microinverter designer with a high level of integration and enables maximized power density, reduced component count, and reduced PCB space. The SM72295 combines four independent 3A MOSFET gate drives with signal conditioning, power good, and overvoltage sensing functionality. Gate drive signal inputs are compatible with both 3.3V and 5V logic.

The integrated signal conditioning provides two channels optimized for using high-side current sense resistors with common-mode voltages up to 100V. A transconductance amplifier provides gain and is followed by a low-impedance buffer suitable for interfacing into an analog to digital converter (ADC). The use of current sense resistors is a lower cost alternative to commonly used current-sense transformers. In addition, the ability to put the current sense resistors on the high-side (positive voltage) current path as opposed to the low-side (ground) current return path can ease layout because it does not require segmenting the ground plane and also eliminates the need for a negative rail voltage in cases where the sense resistor voltages goes below ground.

The advantages of the single-stage topology microinverters are their lower component count, low switching frequencies of the unfolding bridge, and ease of implementing isolation. Disadvantages include high voltage ratings on both the primary side switches and the secondary side diode, and high amplitude 120Hz ripple current at the input. This input ripple current must be controlled to maintain an acceptable efficiency level due to the nature of the photovoltaic module.



Current sensing is implemented with high-side current sense resistors, and output overvoltage shutdown is implemented using voltage sense windings and the OVS pin.

Figure 2. Simplified Schematic of a Quasi-Resonant Interleaved Flyback Using the SM72295

A photovoltaic module has a load curve with a specific maximum power point P_{mp} that occurs when its output voltage equals V_{mp} and output current equals I_{mp}. To maximize energy harvest, the microinverter maintains the module output voltage and current as closely as possible to V_{mp} and I_{mp} using a max power point tracking algorithm. Deviations from V_{mp} or I_{mp}, such as those caused by input ripple current, would cause power loss. Therefore the input ripple current of the single-stage inverters must be reduced to minimize the power loss, and this necessitates large capacitors at the input of the microinverter. For practical cost and size purposes these capacitors can only be implemented with electrolytic capacitors.

4 Two-Stage Microinverters

The second category of microinverter topologies depicted in the block diagram of Figure 3 employ an intermediate high voltage DC-bus. These topologies use a DC/DC converter with a high boost ratio to boost from the PV module voltage to the intermediate DC-bus voltage, and then use a conventional PWM controlled MOSFET or IGBT full-bridge to invert the waveform to the grid. This type of microinverter is also referred to as a DC-link topology (see [2]).

There are many different options being implemented for the DC/DC stage in the designs being developed today. Possibilities include:

1. Interleaved flyback
2. Push-pull converter (current-fed or voltage-fed, with passive or active clamp)
3. Full-bridge converter (voltage-fed, current-fed, or resonant)

From a high-level perspective, all of these topologies are more complex and costly than the single-stage microinverter due to the additional high-frequency switching components. At first it may not be obvious why these topologies are being developed. However, for applications in microinverters, there's an overriding focus on maximizing reliability, which puts emphasis on choosing a topology that enables the selection of the highest reliability components. All of the these topologies have much lower input ripple current at the PV input side, and therefore use lower capacitance values that make it practical to use higher reliability film capacitors in the place of electrolytic capacitors.

Another benefit of the two-stage topologies is that it makes it possible to provide reactive power to the grid, whereas it is not possible with single-stage inverters with an SCR unfolding bridge. The ability to provide reactive power is a highly desirable feature for some commercial installations, and it is already a requirement for larger photovoltaic installations in some countries.

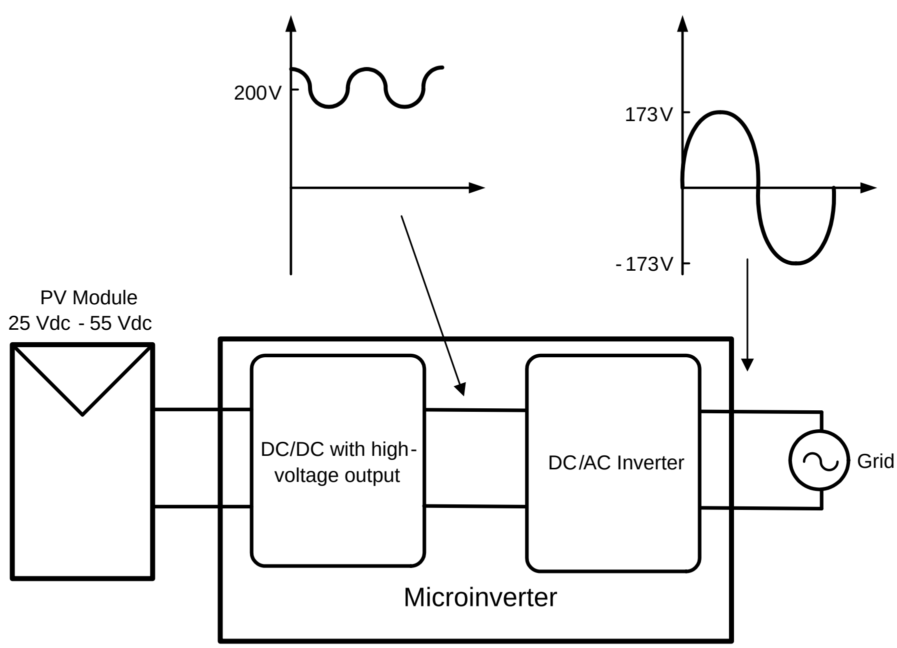
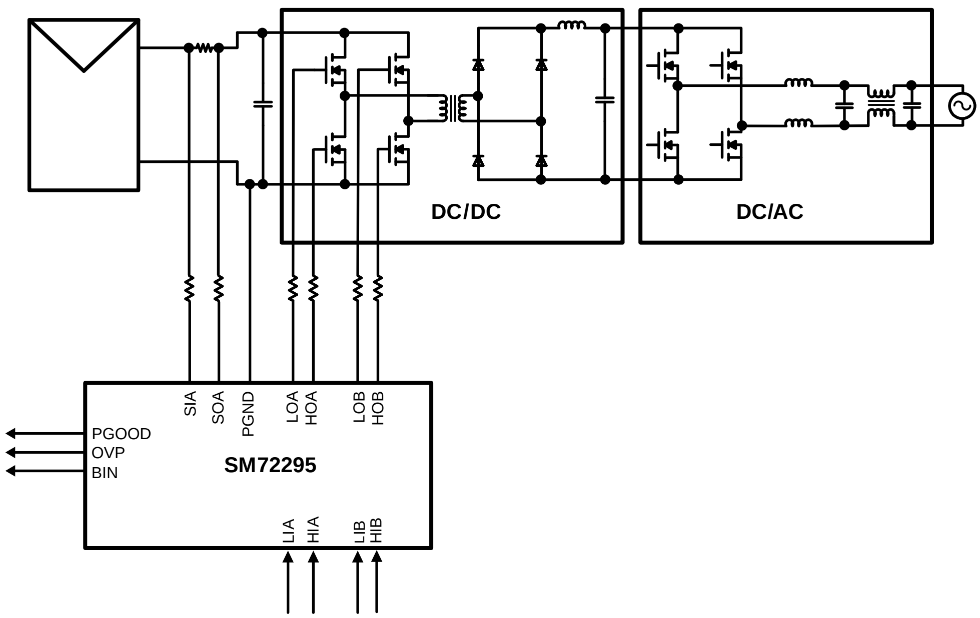


Figure 3. Block Diagram of Two-Stage Inverter With A DC Bus

Figure 4 shows is a simplified schematic of a two-stage microinverter implemented with a voltage-fed full-bridge for the DC/DC stage and a MOSFET full-bridge for the DC/AC stage. In this application, the SM72295 provides gate drives for the four primary side MOSFETs. The SM72295 is ideally suited as a gate driver in many of these two-stage topologies, several of which use a MOSFET full-bridge on their primary side.

As shown in Figure 4, the SM72295 is capable of driving all 4 MOSFETs in the primary side full-bridge. It provides 2 high-side and 2 low-side gate drives, integrated bootstrap diodes, and is suitable for input voltages up to 100V. The additional integration of signal conditioning, undervoltage lockout, and overvoltage shutdown further reduce part count and conserve valuable PCB real-estate.



The DC/DC stage is implemented as a voltage-fed full-bridge converter, and the DC/AC stage is implemented as a MOSFET Full-bridge.

Figure 4. Simplified Schematic of Two Stage Microinverter Using the SM72295

5 Housekeeping Power and Other Applications

In addition to the SM72295, there is a broad range of SolarMagic ICs suitable for application in other areas of the microinverter. As shown in Figure 5 and Table 1, this includes temperature sensors, voltage references, precision amplifiers for current and voltage sensing, and switchers and LDOs for housekeeping power. These ICs have application in both single-stage and two-stage microinverters of all topologies.

6 Conclusion

Microinverters are an exciting and growing application area for power electronics. This article gave a brief overview of some of the topologies being used in microinverters today, and described the SM72295 Photovoltaic Full-bridge Driver which integrates the key functions of MOSFET gate drives, signal conditioning, under-voltage lockout, and overvoltage shutdown. The SM72295 and other SolarMagic ICs support the most prevalent topologies used in microinverters today, and help microinverter designers maximize reliability, minimize complexity, minimize size, and minimize cost.

7 References

1. B. Burger, B. Goeldi, S. Rogalla, H. Schmidt. “Module integrated electronics – an overview” 25th European Photovoltaic Solar Energy Conference and Exhibition. 6-10 Sept. 2010. pp. 3700–3707.
2. Haibing Hu; Harb, S.; Kutkut, N.; Batarseh, I.; Shen, Z.J. “Power decoupling techniques for micro-inverters in PV systems-a review” Energy Conversion Congress and Exposition (ECCE), 2010. pp. 3235–3240.

8 SolarMagic ICs in a Microinverter Application

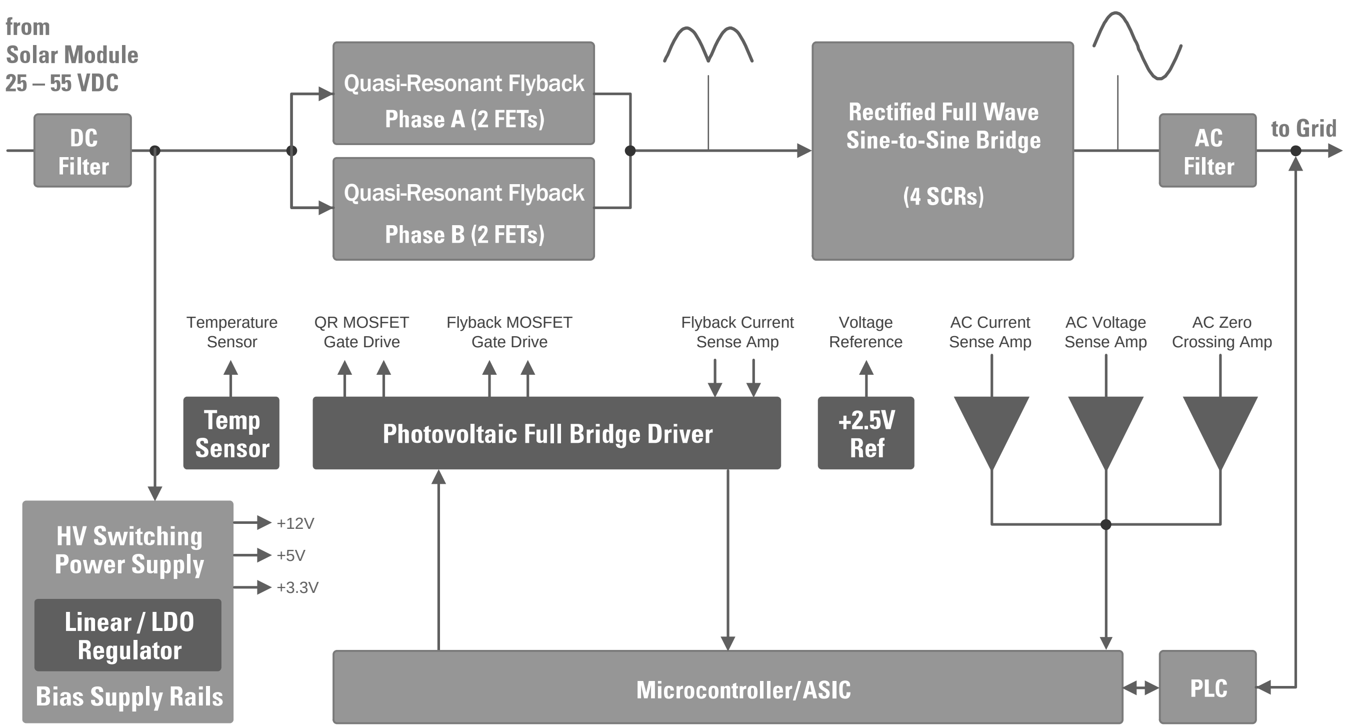


Figure 5. Block Diagram of SolarMagic ICs in a Microinverter Application

9 List of Devices

Table 1. List of Devices

Gate Drives	Description
SM72295	Photovoltaic Full-Bridge Driver
SM72482	Dual 5A Compound Gate Driver
SM74101	Tiny 7A MOSFET Gate Driver (LLP-6 package)
SM74104	High Voltage Half-Bridge Gate Driver with Adaptive Delay
High Voltage Switching Regulators with Integrated Switch	
SM72485	100V, 150mA Step-Down (Buck) Converter
SM74301	100V, 350 mA Constant On-Time Buck Switching Regulator
SM74304	80V, 500mA Step Down Swithching Regulator
Low Dropout Voltage Regulators	
SM74501	50mA Low Dropout Voltage Regulator (3.3V, 5.0V), max Vin 40V
SM72238	100mA Low Dropout Voltage Regulator (3.3V, 5.0V), max Vin 30V
SM74503	800mA Low-Dropout Regulator (3.3V, 5.0V), max Vin 15V
Amplifiers for current sensing, voltage sensing, and buffering	
SM72501	Precision, CMOS Input, Rail-to-Rail Input Output, Wide Supply Range Amplifier
SM73301	Rail-to-Rail Input Output, High Output Current & Unlimited Cap Load Op Amp
SM73302	88 MHz, Precision, Low Noise, 1.8V CMOS Input, Op Amp
SM73303	5 MHz, Low Noise, Rail-to-Rail Output, Dual Operational Amplifier with CMOS Input
SM73304	Dual 17 MHz, Low Noise, CMOS Input Amplifier
SM73305	17 MHz, Low Noise, CMOS Input Amplifier
SM73306	Dual CMOS Rail to Rail Input and Output Operational Amplifier
Comparators	
SM72375	Dual Micro-Power CMOS Comparator
SM73402	Low Power Low Offset Quad Comparators
SM73403	Single General Purpose Voltage Comparator
Reset and Supervisory	
SM72240	5-Pin Microprocessor Reset Circuit (3.08V, 4.63V thresholds)
SM74601	Precision Micropower Series Voltage Reference (2.5V)
Thermostats and Temperature Sensors	
SM72480	125°C, 120°C, and 105°C Thermostat
SM73710	±4°C Accurate, Temperature Sensor

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