Implementation of a Long-Lifespan, Two-Stage Photovoltaic AC-Module

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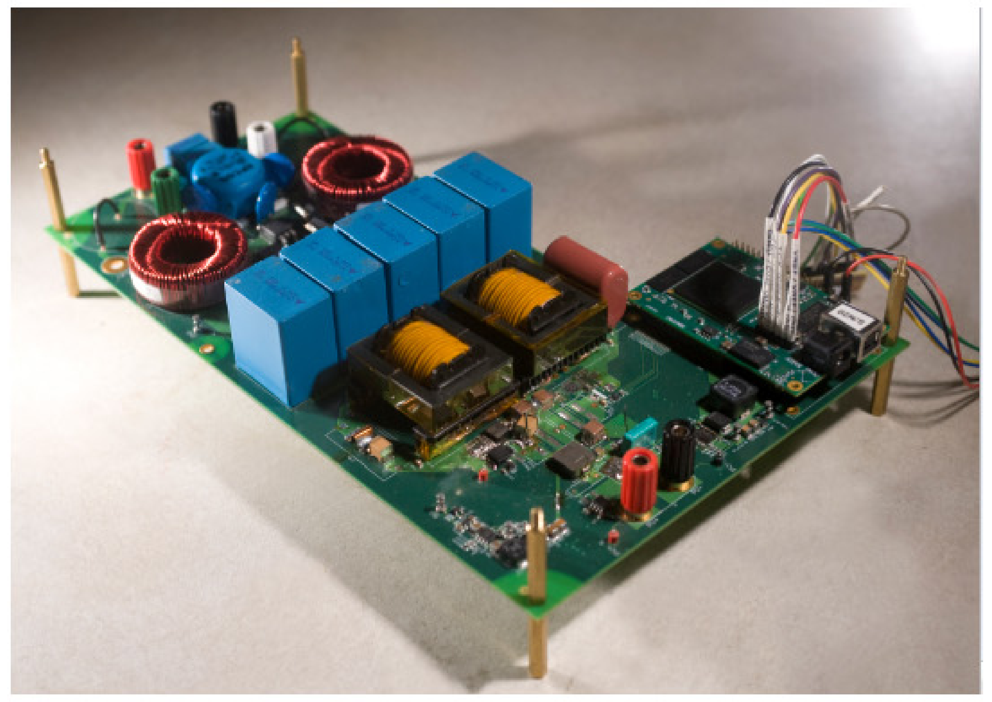
A modular, grid-tied Photovoltaic (PV) system can improve system reliability, ease maintenance efforts, and improve the effectiveness of the overall system compared to a centralized-inverter system. The current focus for modular PV systems is micro-inverters, or AC-modules. Each micro-inverter is intended to match to a single PV panel to convert a dc, low-voltage PV source into an ac, high-voltage power-source.

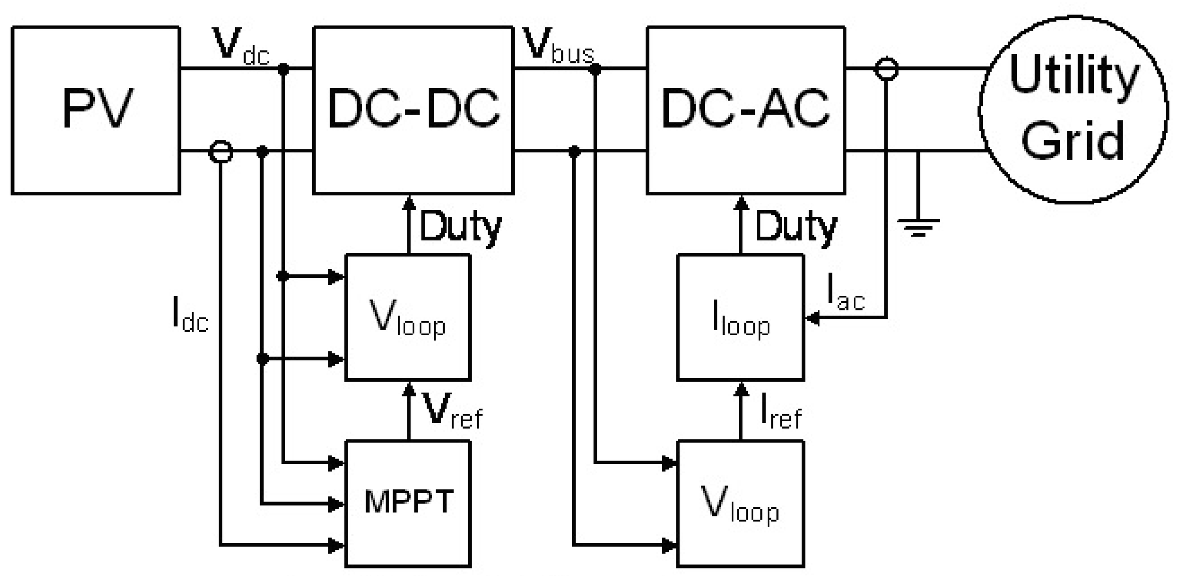
Existing commercial sytems use 1-, 2-, and 3-stage cascaded topologies.

Single-Stage has highest efficiency, but requires passive decoupling of double-line-frequency power ripple via electrolytic capacitors.

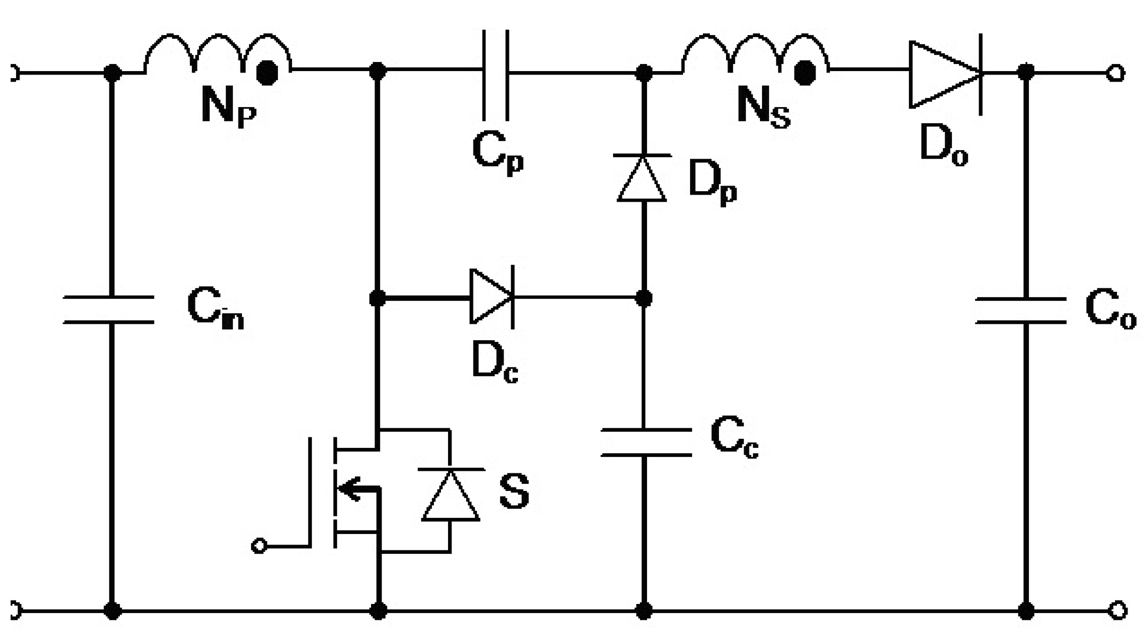
Two-Stage design has slightly lower efficiency, but can decouple ripple between the two stages, eliminating large passive components.



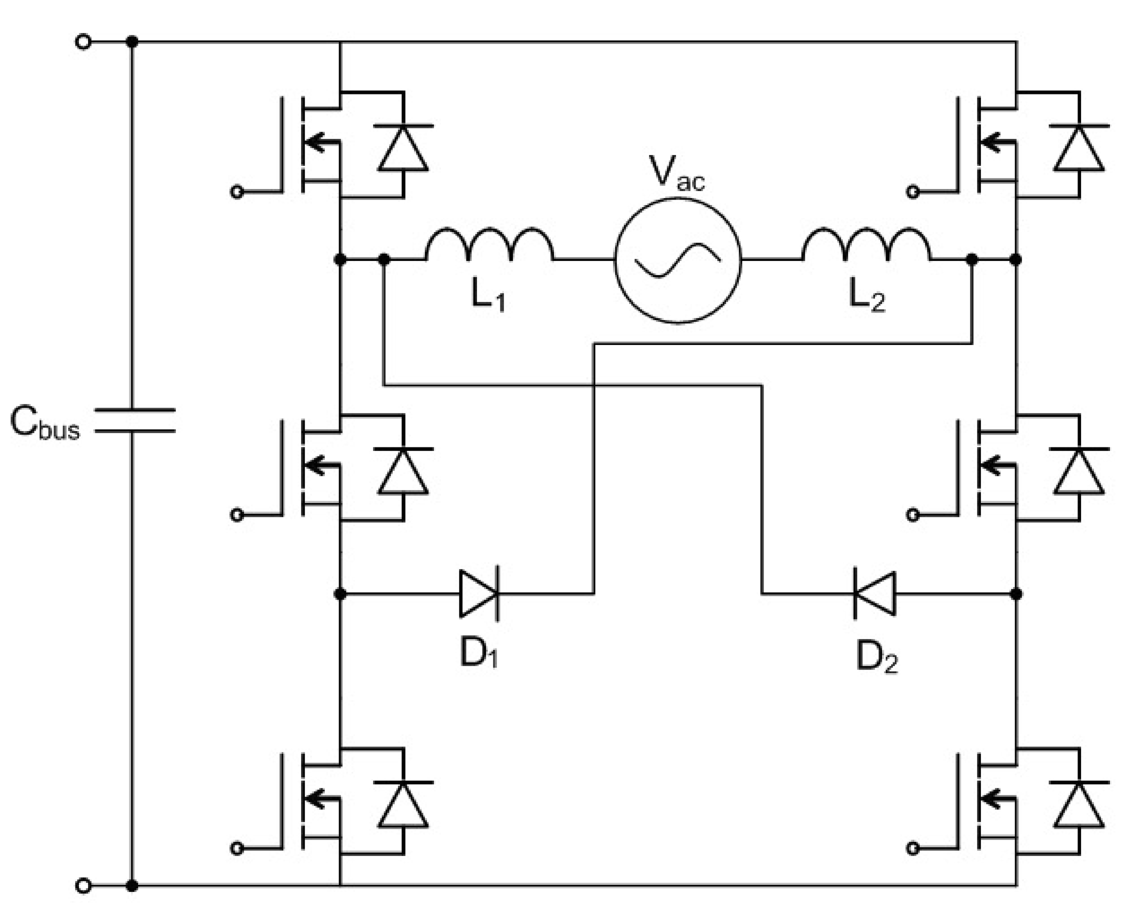
Picture of Micro-inverter board



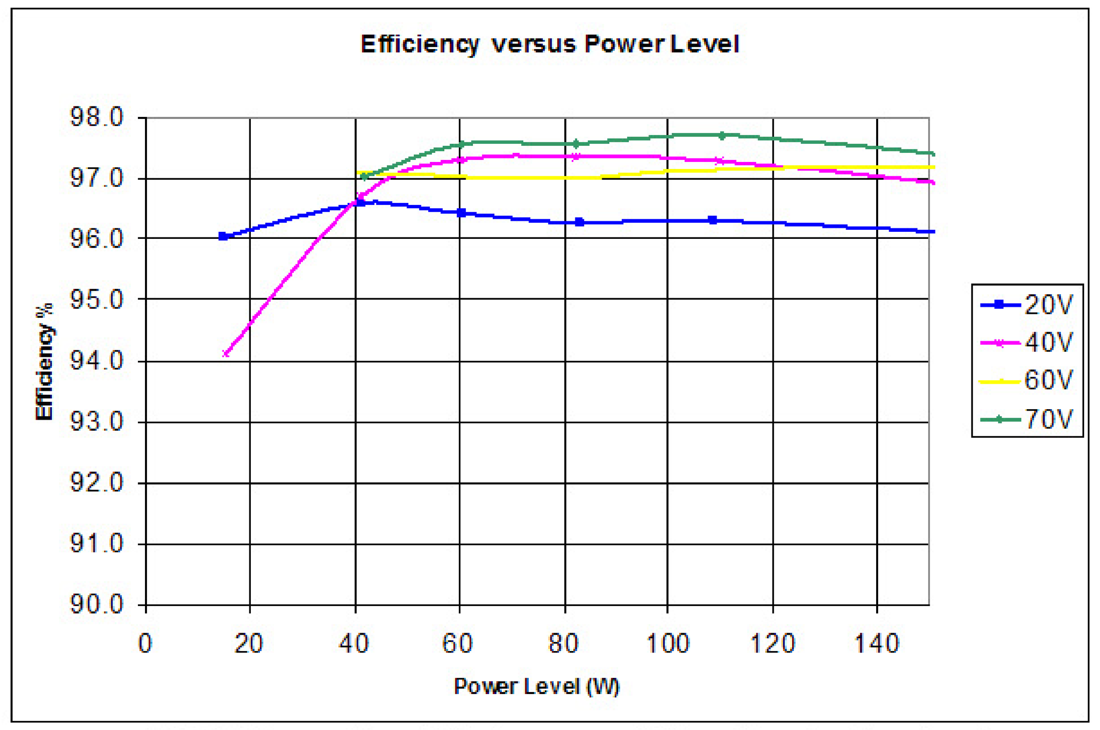
Overall AC-Module System Structure



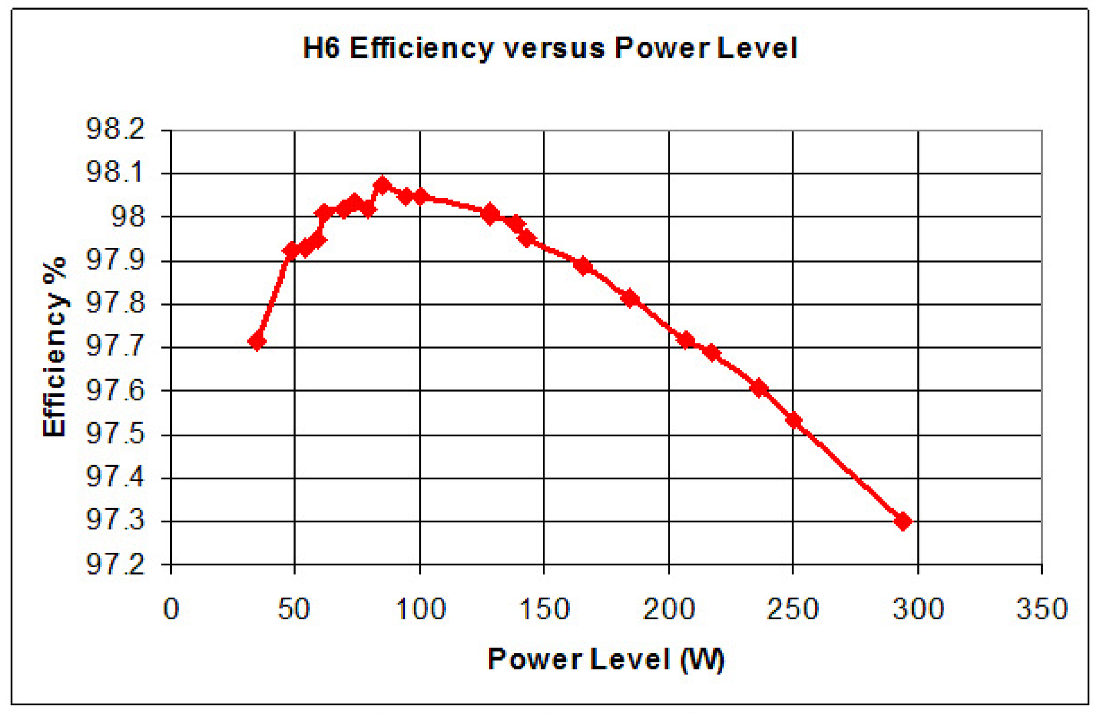
High-Boost Ratio DC-DC Power Conversion Stage
20-70 Vdc input, 200Vdc Output, 300 Watts



Uni-directional DC-AC Power Conversion Stage
200Vdc input, 120Vrms Output, 300Watts



DC-DC Power Stage Efficiency over different input voltage levels



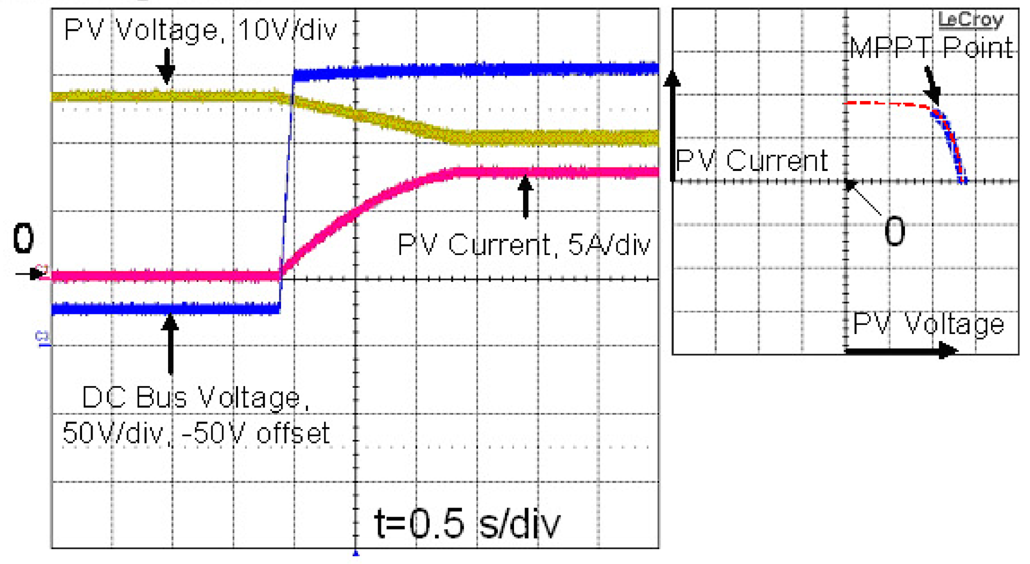
DC-AC Power Stage Efficiency

The DC-DC stage is a high-boost ratio converter similar to a tapped-inductor boost converter, but with the addition of a clamp circuit and passive charge-pump to recycle the clamp energy to the output [1]. The power stage of the DC-AC inverter is a buck-type inverter with excellent common-mode performance which reduces the size of any necessary EMI filtering [2]. The efficiency of both power stages are shown above. Typical efficiency of the dc-dc stage is greater than 97%, and typical efficiency of the dc-ac stage is greater than 97.5%, giving a typical system efficiency of more than 94.5%. Peak system efficiency should be 95.5% at 100 watts.

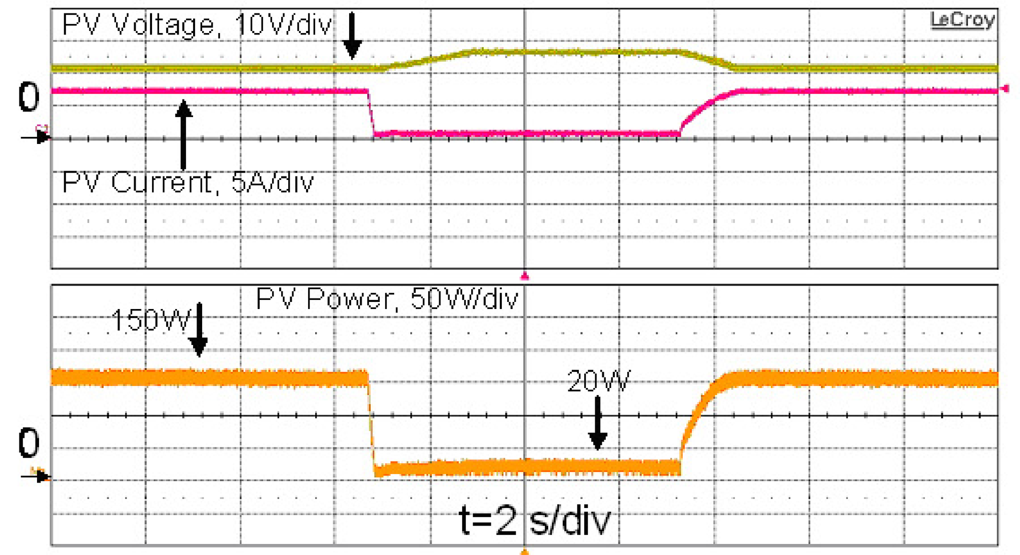
Test Setup showing single-unit with resistive load and battery-stack clamp for DC-bus.

Test Building showing 6 Kyocera KD180GX-LP Panels

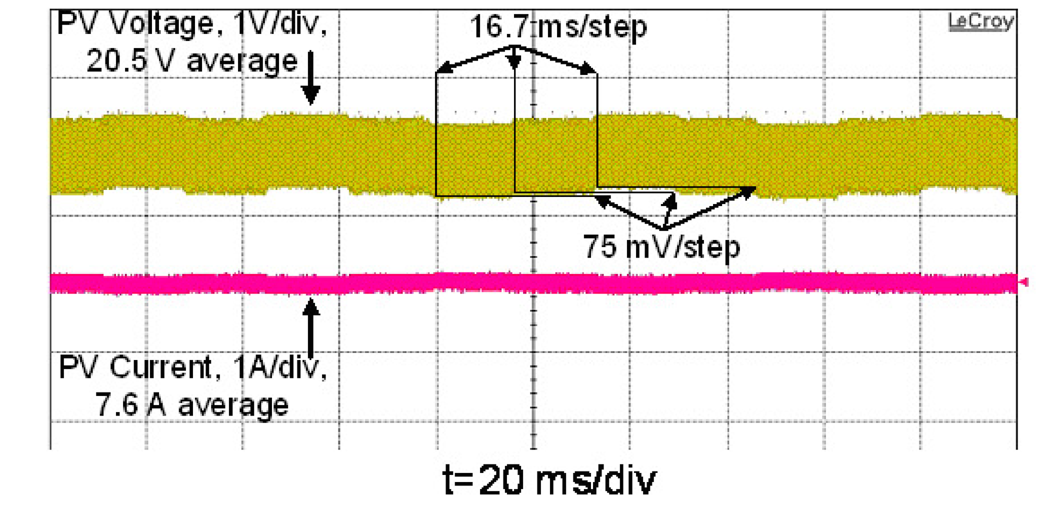
DC-Side Start-Up Waveform



Shading Transient Waveform

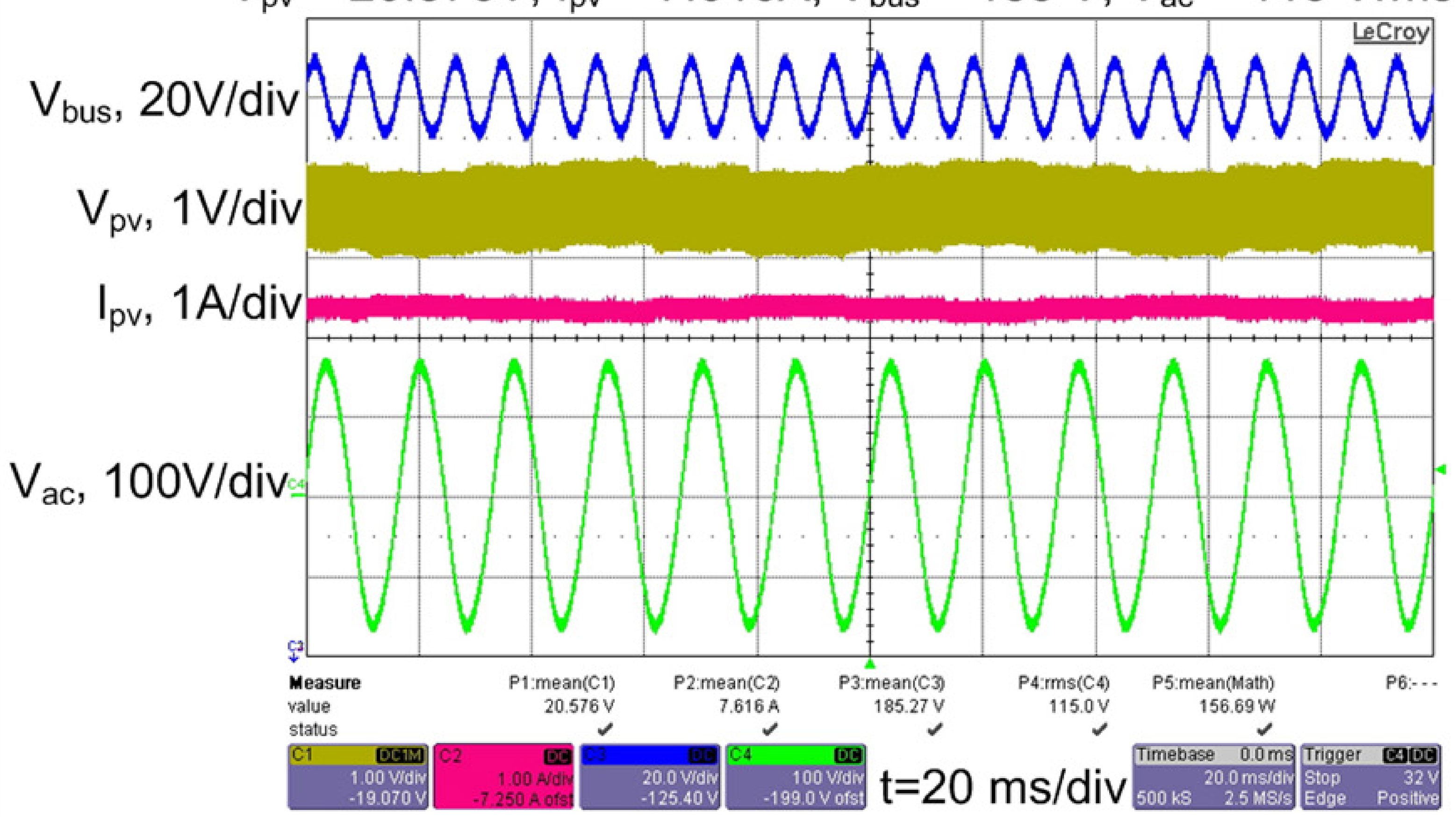


Steady-State MPPT Waveform



Steady-State System Waveforms

V_{pv} = 20.576V, I_{pv} = 7.616A, V_{bus} = 185 V, V_{ac} = 115 Vrms



The overall system behavior is governed by the PV source. From the startup waveform shown at the top, the panel is taken from zero power to full power in approximately 1.5 seconds. If there is an abrupt shading transient, the panel power output can change very quickly (< 0.1 seconds) independently of the maximum power point tracker (MPPT). The MPPT runs a hill-climb algorithm which updates at a rate of 60Hz with a step size of 75mV.

The final system waveform shows the double-line-frequency ripple across the intermediate dc-bus capacitor, voltage and current ripple at the PV source, and AC-module output. The low-frequency ripple across the intermediate DC-bus can be attenuated sufficiently at the PV source to eliminate its effect on power capture or system stability.

[1] W. Yu, C. Hutchens, et al., "High efficiency converter with charge pump and coupled inductor for wide input photovoltaic AC module applications," in Energy Conversion Congress and Exposition, 2009. ECCE 2009. IEEE, 2009, pp. 3895-3900.
[2] W. Yu, J. S. Lai, H. Qian, et al, "High-efficiency inverter with H6-type configuration for photovoltaic non-isolated ac module applications," in Applied Power Electronics Conference and Exposition, 2010. APEC 2010. IEEE, 2010, pp. 3895-3900.