SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

Power Electronics Program Kickoff

Ultra Compact Electrolyte-Free Microinverter with Mega-Hertz Switching

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Project Goals

- To develop a cost-effective PV microinverter that fully utilizes potential of wide bandgap semiconductor devices
- To reduce the size of bulky EMI passive filters and excessive potting materials
- To eliminate electrolytic capacitor for long life expectancy

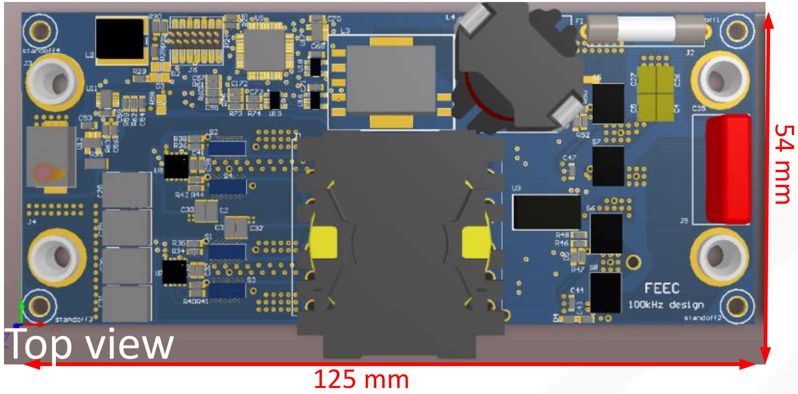
Key Performance Indexes	DOE Goal/State-of-the-Art	Proposed Design
Cost for residential applications ($/W)	0.07	0.06
Warranty life (years)	25	35
CEC efficiency (%)	97	98
Power density (W/liter)	91.5	9150
Mass density (W/kg)	187	1000
Electrolytic capacitors	yes	No
Switching frequency (kHz)	100	1000

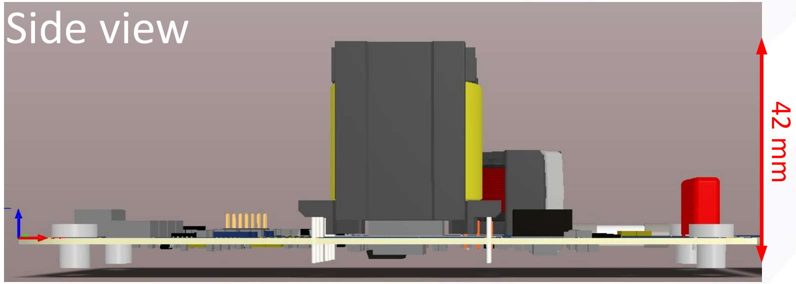
How to achieve the goals?

- Soft switching with ZVZCS – **loss reduction**
- Synchronous rectification – **loss reduction**
- Mega hertz switching – **magnetic size reduction**
- Height shrinking – **potting compound reduction**
- Two-stage design along with resonant controller – **passive size reduction** by low-frequency ripple and electrolytic capacitor elimination
- Quasi-resonant mode along with phase dropping – **light load efficiency improvement**

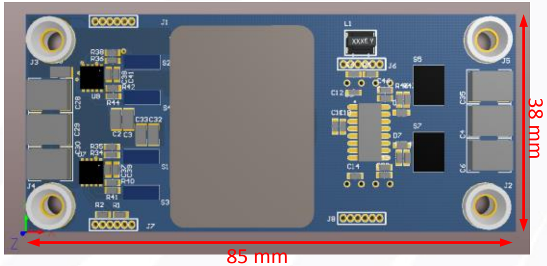
100-kHz vs. 1-MHz 300-W micro-converters

100 kHz



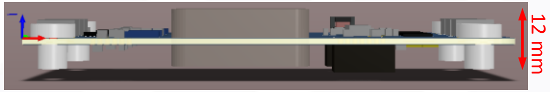


1 MHz



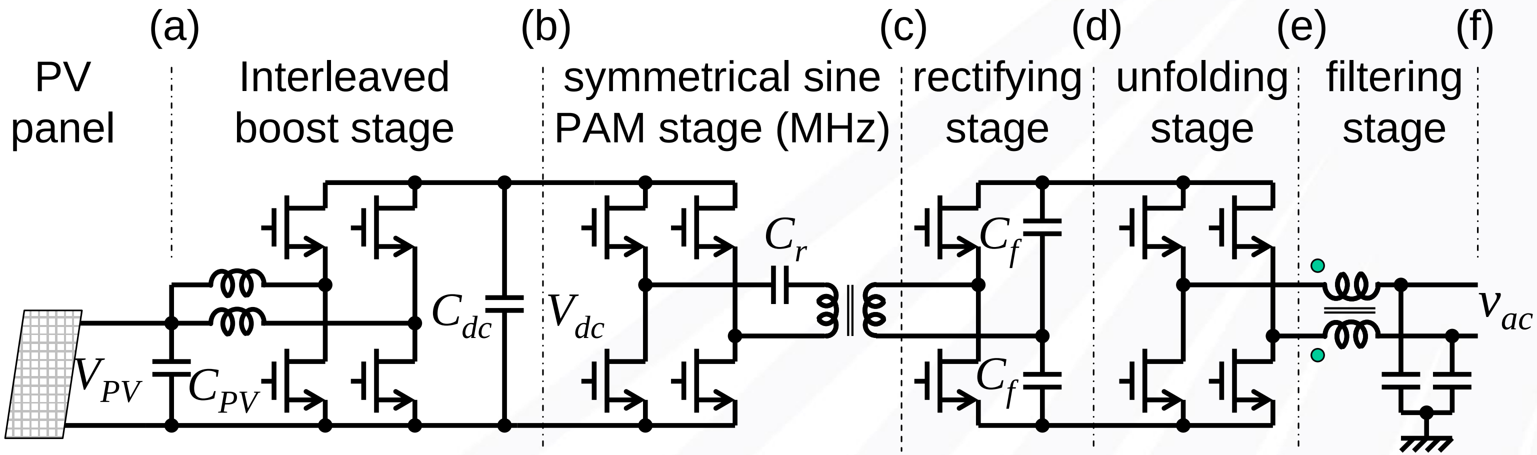
Top view

Side view



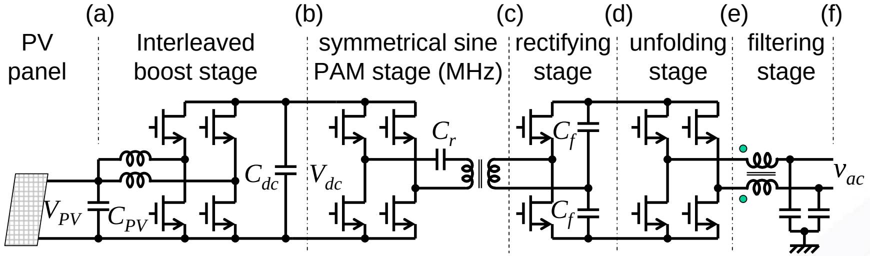
10.65 in^3 vs. 1.34 in^3 ➔ 87.5% volume reduction

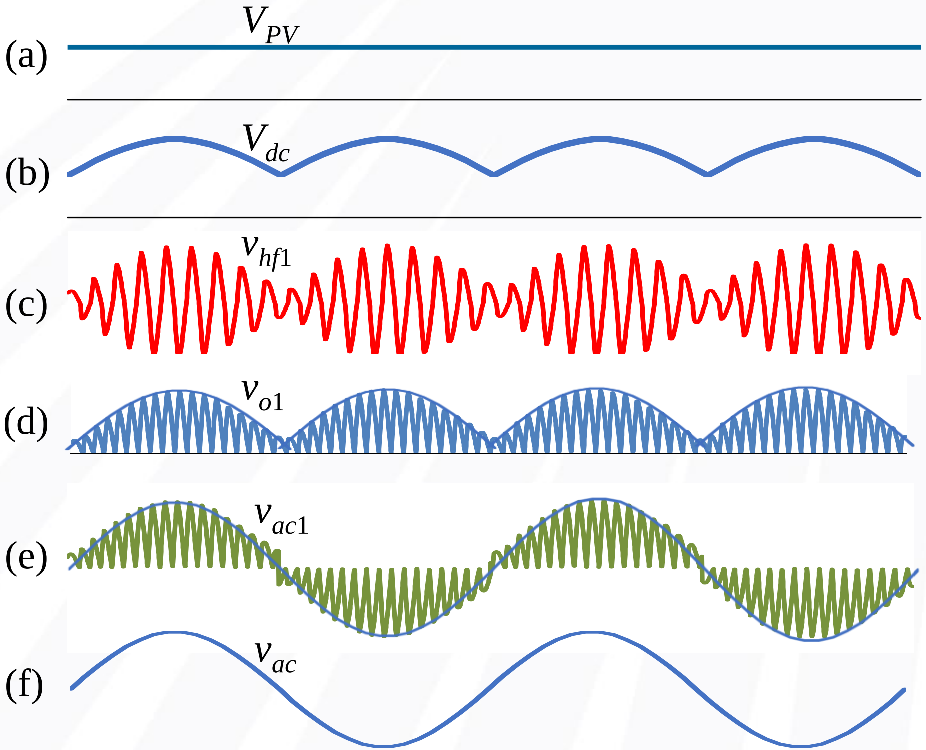
Proposed electrolyte-free solar PV microinverter



- C_{PV}, C_{dc}, C_r, and C_f are all high-frequency capacitors
- Boost stage controller has a high gain at 120 Hz to push current ripple to C_{dc}
- PAM stage has a high gain at 60 Hz to ensure smooth sinusoidal output
- Output stage mega-hertz ripple can be easily filtered with leakage inductance of the common-mode EMI filter

Voltage waveforms at each conversion stage

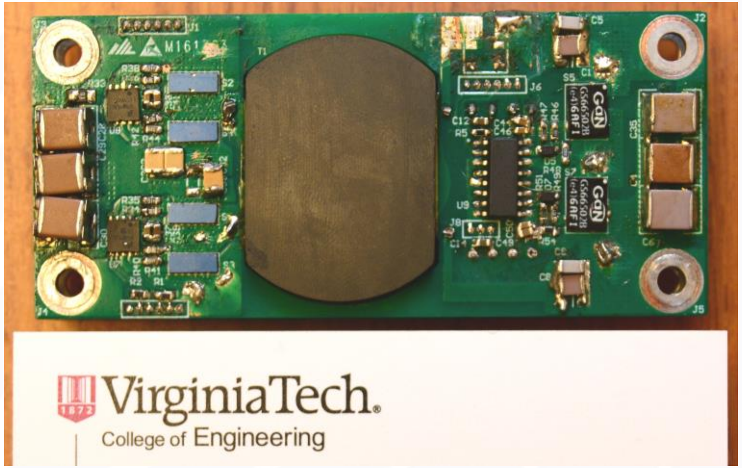




- Soft-switching resonant converter switching at megahertz frequency utilizing wide bandgap devices with a sine wave envelop modulation
- Resonant converter modulated with advanced pulse density and pulse amplitude control to improve light-load efficiency
- Boost converter output voltage is modulated to form a quasi-sinusoidal wave to allow the resonant converter operating at zero-voltage and zero-current to maximize the resonant converter efficiency

Target specifications

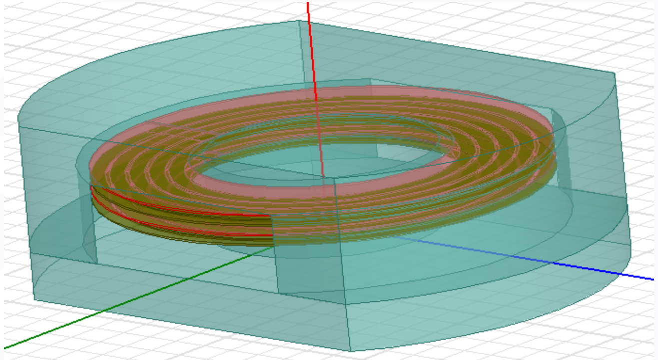
- Target Specifications: 400 W, 25-50V MPPT input, 240V output for 72-cell PV panel
- Target BOM cost: $24 or $0.06/W for 500k quantity
- Target life: >35 years
- CEC Efficiency: 98%
- Power density: 9.15 kW/l or 150 W/in^3
- Mass density: 1 kW/kg or 455 W/lb

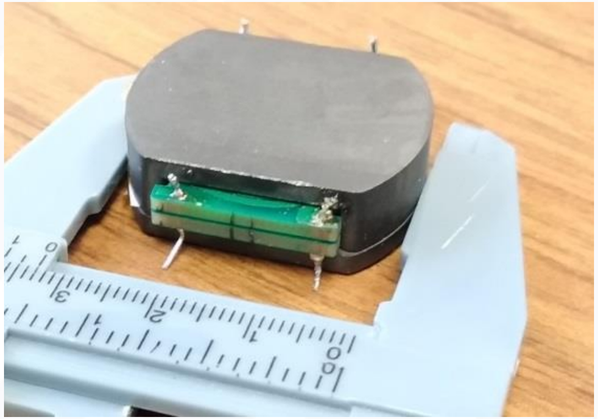


Mega-hertz frequency soft switching to make the board smaller than a business card

Technical challenge – transformer design

- PCB winding with <2oz copper to avoid skin effect
- Interleaving configuration to reduce proximity effect
- EI core for fringing effect reduction
- FEA for design optimization
- Custom-made cores with support from key manufacturers

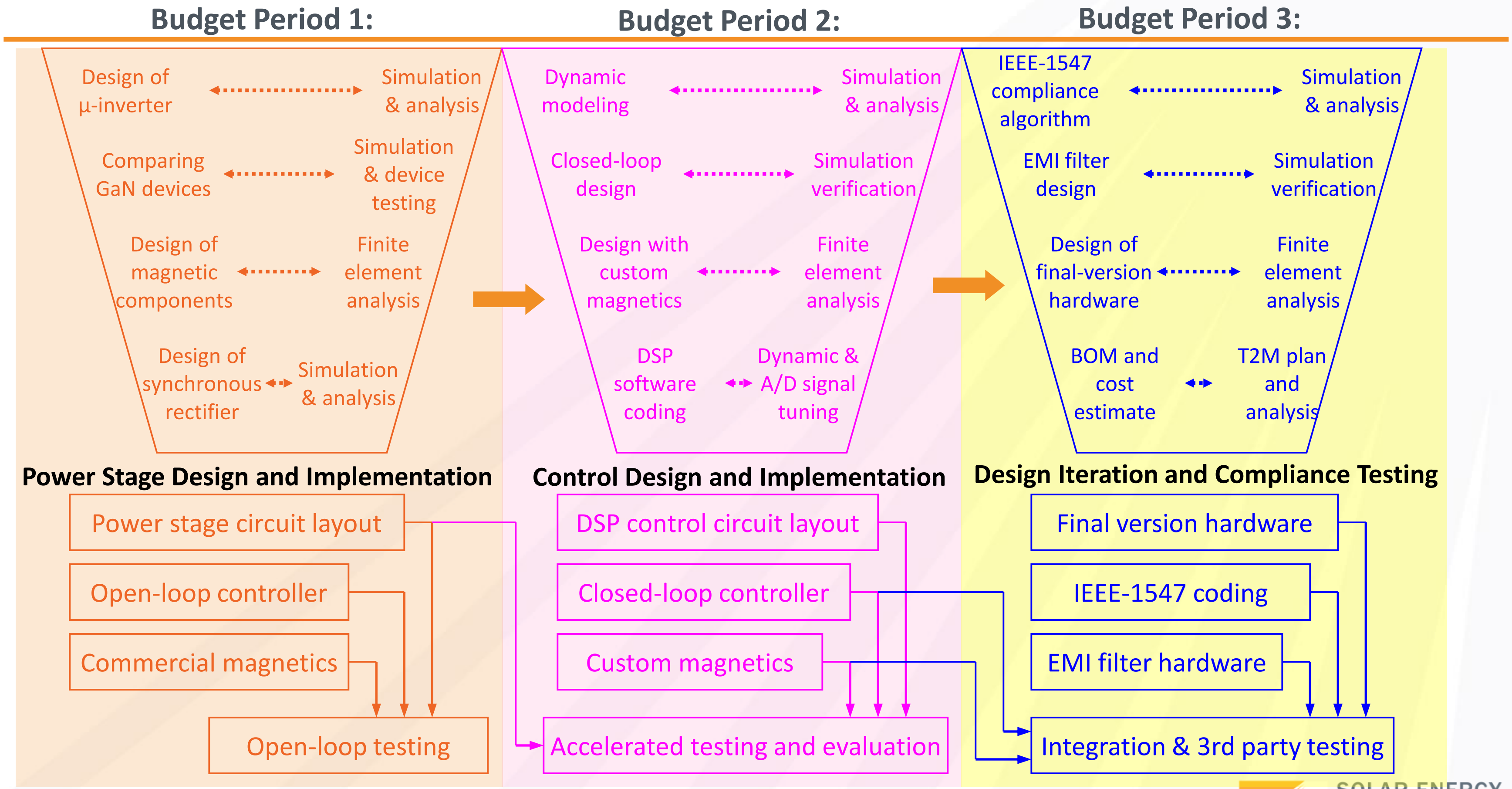




Other technical challenges

- Need highly integrated GaN devices/modules for low parasitic inductance and reliable gate drives
- Need low-cost low-power consumption microprocessor but sufficient processing power
- Need reliable synchronous rectification implementation
- Need high-voltage GaN devices with low junction capacitance
- Need to cool GaN devices with special thermal design

Research & development flow of each budget period



Key milestones

- Budget Period 1 (Aug 2018 – July 2019): The power stage efficiency meets the target of 98% efficiency or higher
- Budget Period 2 (Aug 2019 – July 2020): Demonstrate operation with power stage efficiency >98%, THD <5%, MPPT efficiency >99.8%, and ripple current<10%
- Budget Period 3 (Aug 2020 – July 2021): Pass required tests to IEEE 1547 and UL requirements and efficiency target with third-party test
- Technology-to-Market (T2M) plan follows

QUESTIONS?