Advanced Techniques for Driving Floating Switches in the Flying Capacitor Multi-level converter

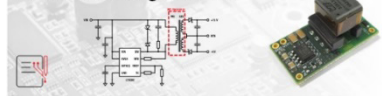infineon · arpa·e · BPEC · Berkeley Power and Energy Center

Motivation and Application
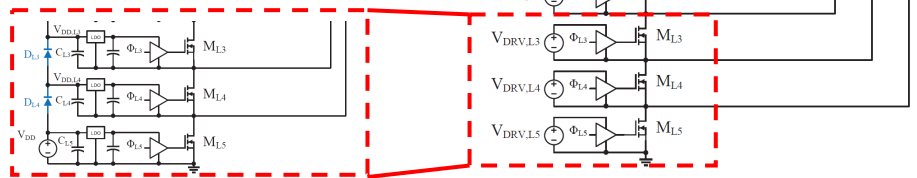
Floating switches need floating power supplies
- Typically use isolated power supply for each switch
- Large volume (due to isolation transformer) and high cost

6 W Isolated auxiliary power supply for SiC-MOSFET gate driver

"Cascaded bootstrap" proposed for reduced volume and cost

Challenges with Bootstrap Solution and Innovations

Voltage drops in bootstrap diodes require supply significantly higher than gate-drive voltage
- Local regulation necessary for driving GaN-FETs at 5-6V

Synchronous Bootstrapping

Replace bootstrap diodes with FETs
- Reduced voltage drop, bidirectional power delivery

Charge-Pump Technique

Oscillator driven charge pump: can be easily integrated with existing isolated drivers

Device overview

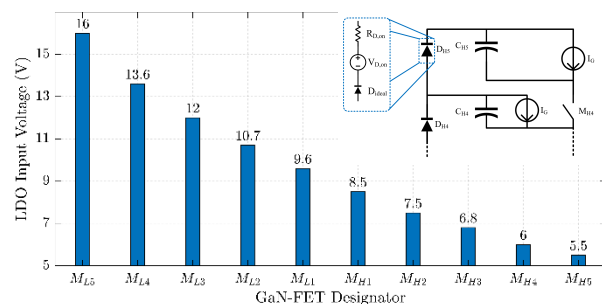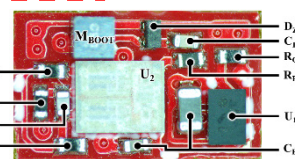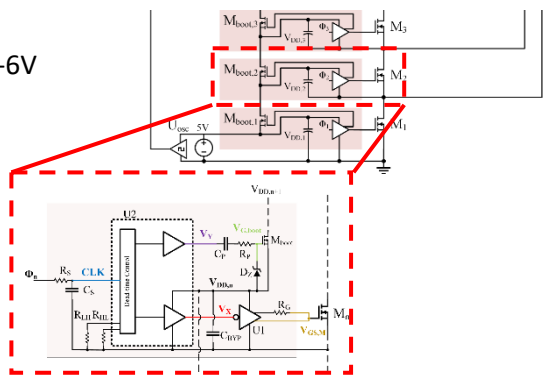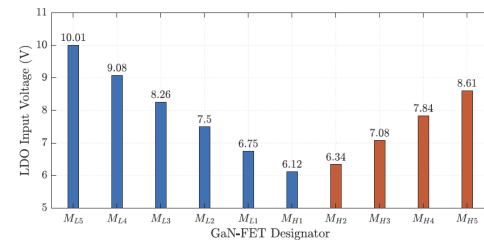EiceDRIVER™ 2EDF7275K, 2EDF7235K block diagram
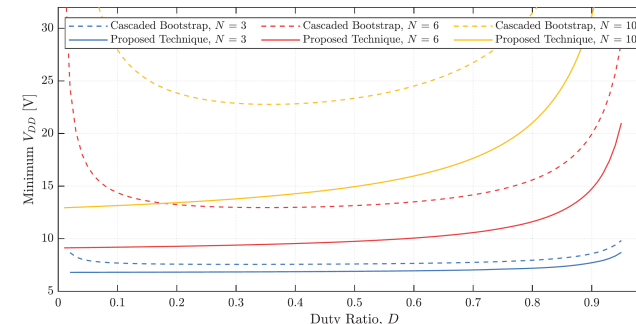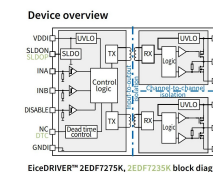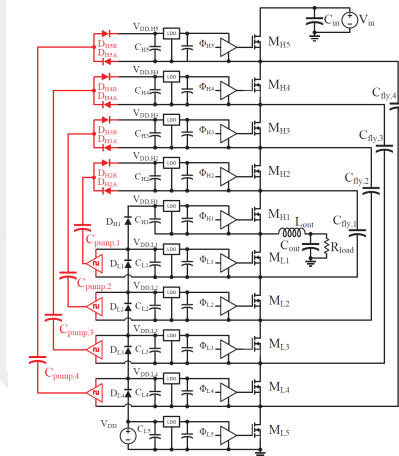
Can operate at low duty ratios with reduced gate-drive supply
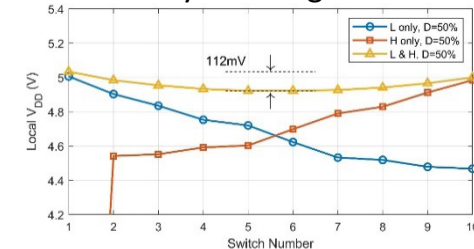- Higher gate drive efficiency

Experimental Verification

Reduced gate-drive supply with high-side switches fed by charge-pump

Synchronous bootstrapping:
- power delivery from high and low-sides

6-level FCML (top side of PCBA) — 123 mm, 14 mm
EPC 2218 GaN-FET
Decoupling Flying Capacitors
Bulk Flying Capacitors
5V LDO (TI TPS709Q1)
Low-side bootstrap diode
Gate drive circuitry (bottom side of PCBA)
Oscillator-driven charge pump (Microchip MIC1557 + Infineon 1EDN7550U)
Dual-channel isolated gate driver (Infineon 2EDF7275K)

References:
[1] Z. Ye, et al., "Improved Bootstrap Methods for Powering Floating Gate Drivers of Flying Capacitor Multilevel Converters and Hybrid Switched-Capacitor Converters," in IEEE Transactions on Power Electronics.
[2] R. K. Iyer, N. M. Ellis, Z. Ye and R. C. N. Pilawa-Podgurski, "A High-Efficiency Charge-Pump Gate Drive Power Delivery Technique for Flying Capacitor Multi-Level Converters with Wide Operating Range," 2021 IEEE Energy Conversion Congress and Exposition (ECCE).
[3] N. M. Ellis, R. Iyer and R. C. N. Pilawa-Podgurski, "A Synchronous Boot-strapping Technique with Increased On-time and Improved Efficiency for High-side Gate-drive Power Delivery," 2021 IEEE Workshop on Wide Bandgap Power Devices and Applications in Asia (WiPDA Asia)

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