UNIVERSITY OF PITTSBURGH
SWANSON school of engineering
Power & Energy Initiative

Modeling and Characterization of GaN Devices for Next Generation Power Electronics

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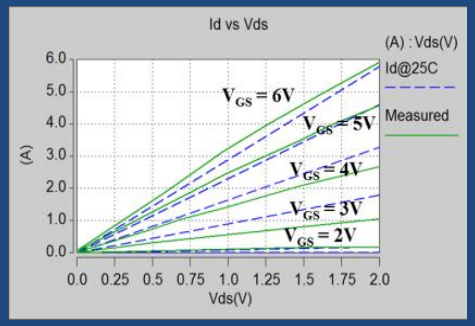
Outline

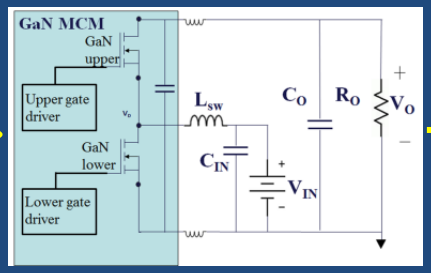
- A 300 V GaN Based Boost Converter
- Voltage Overshoot on Normally Off GaN Devices
- Future Directions

300 V GaN Based Boost Converter

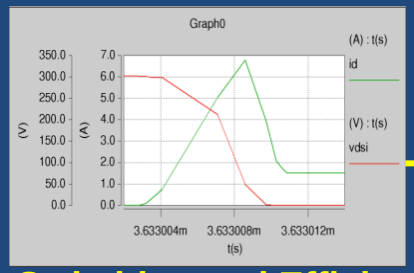
IN SIMULATION



Model Development



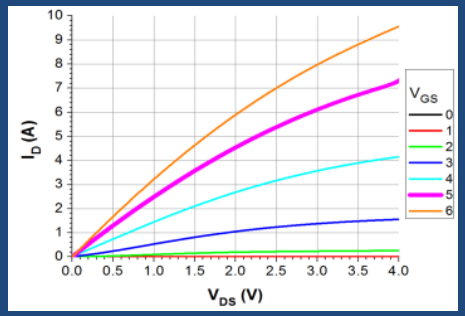
Boost Converter Simulation



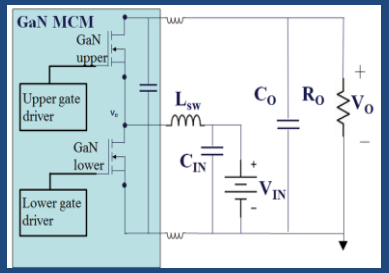
Switching and Efficiency Simulation

Model validation and Future work. What does the model project in higher power circuits?

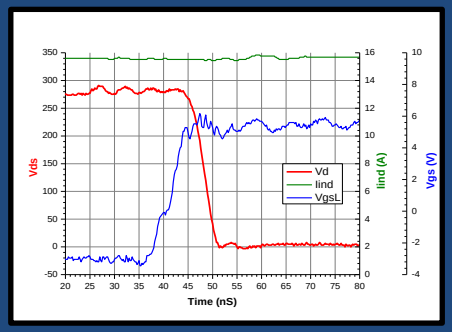
IN EXPERIMENTATION



Device Characterization



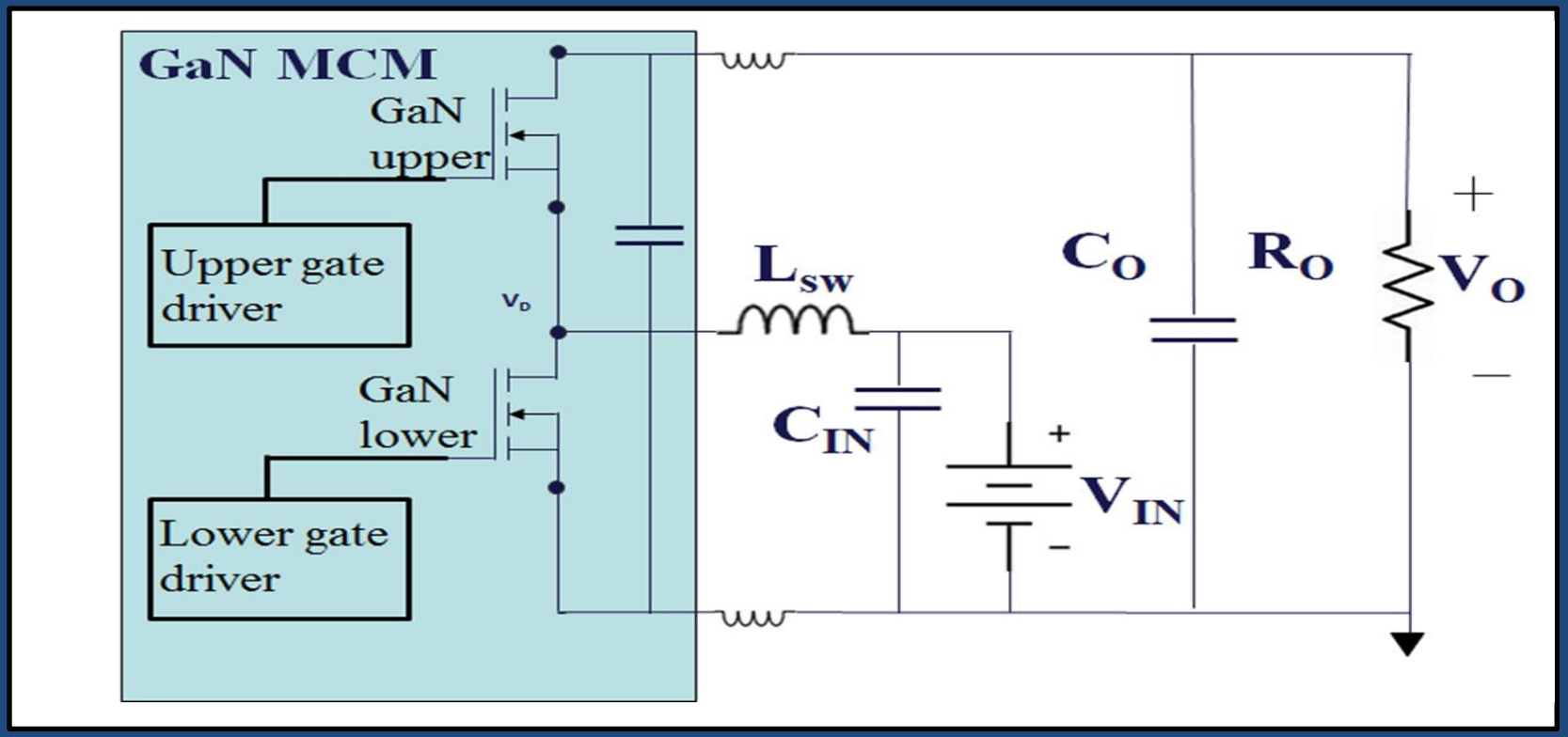
Boost Converter Implementation



Switching and Efficiency Characterization

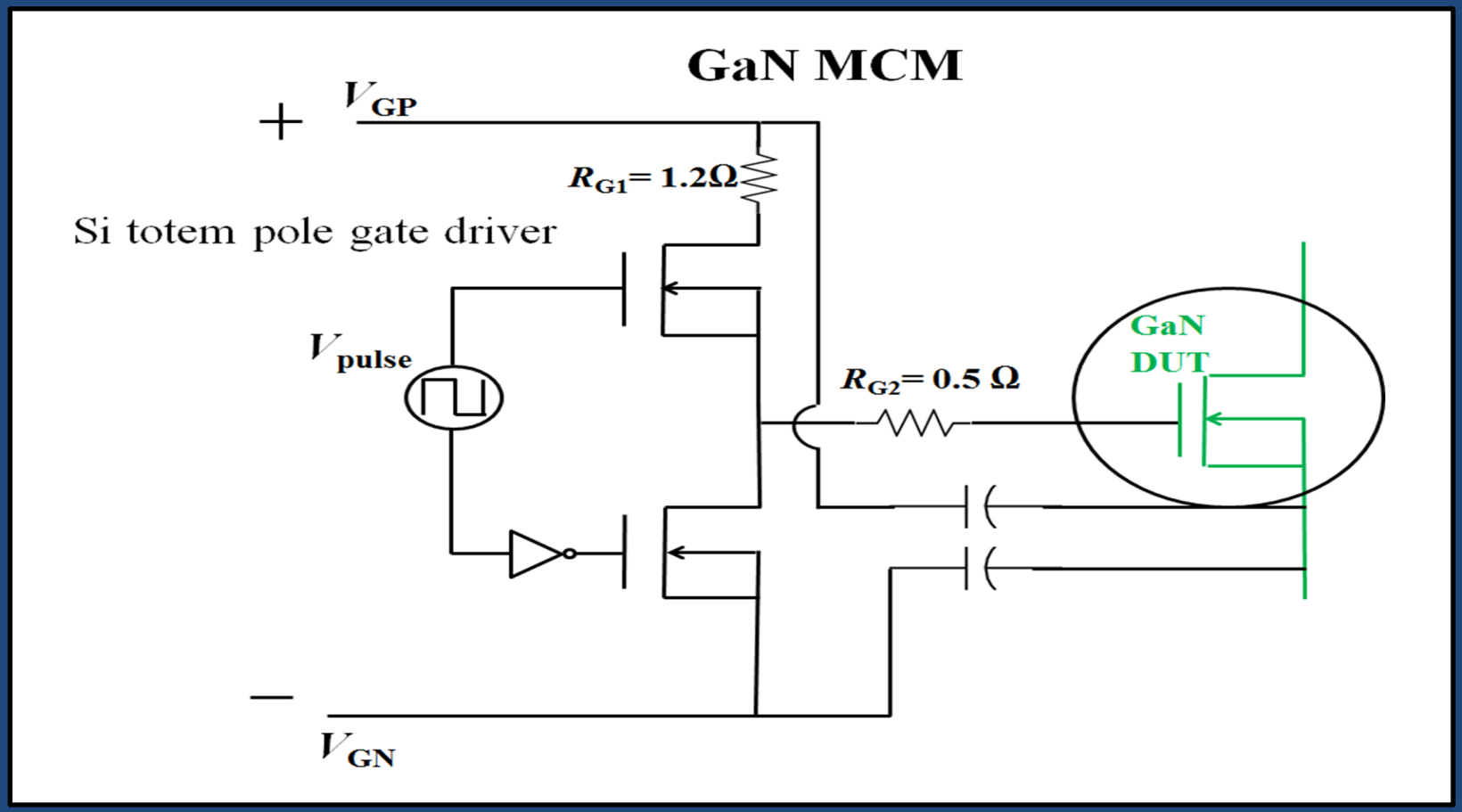
Experimental GaN Boost Converter

- 600 V GaN FETs used to boost 150 V to 300 V @ 1MHz in synchronous configuration. 6 transistors used = 240 mm of gate width.



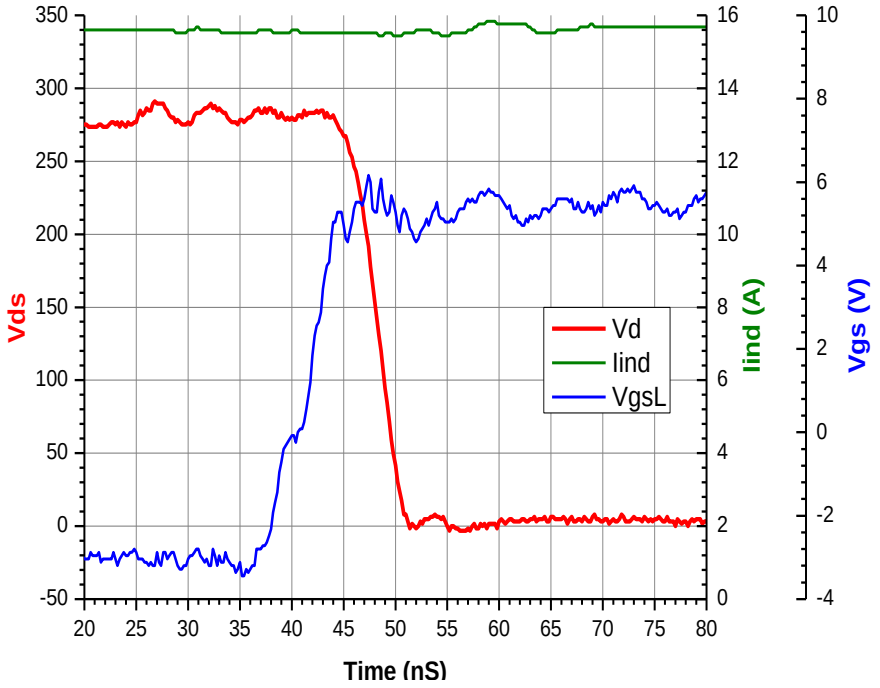
Experimental GaN Boost Converter

- GaN MCM for low stray inductance. Designed to mitigate overshoot and "Miller Turn-On."



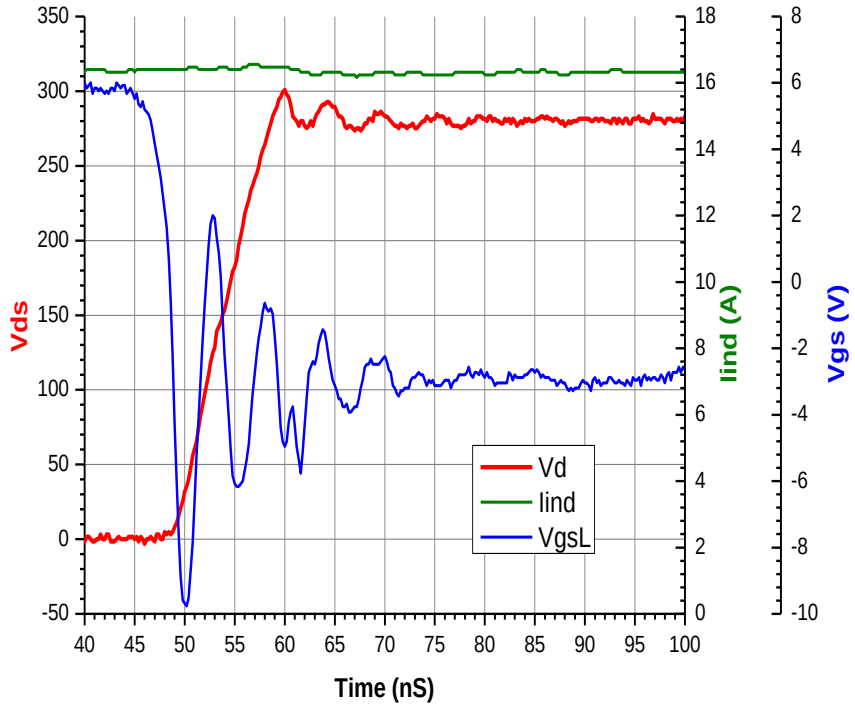
Experimental GaN Boost Converter

Turn-on



6 ns fall time for v_{DS}

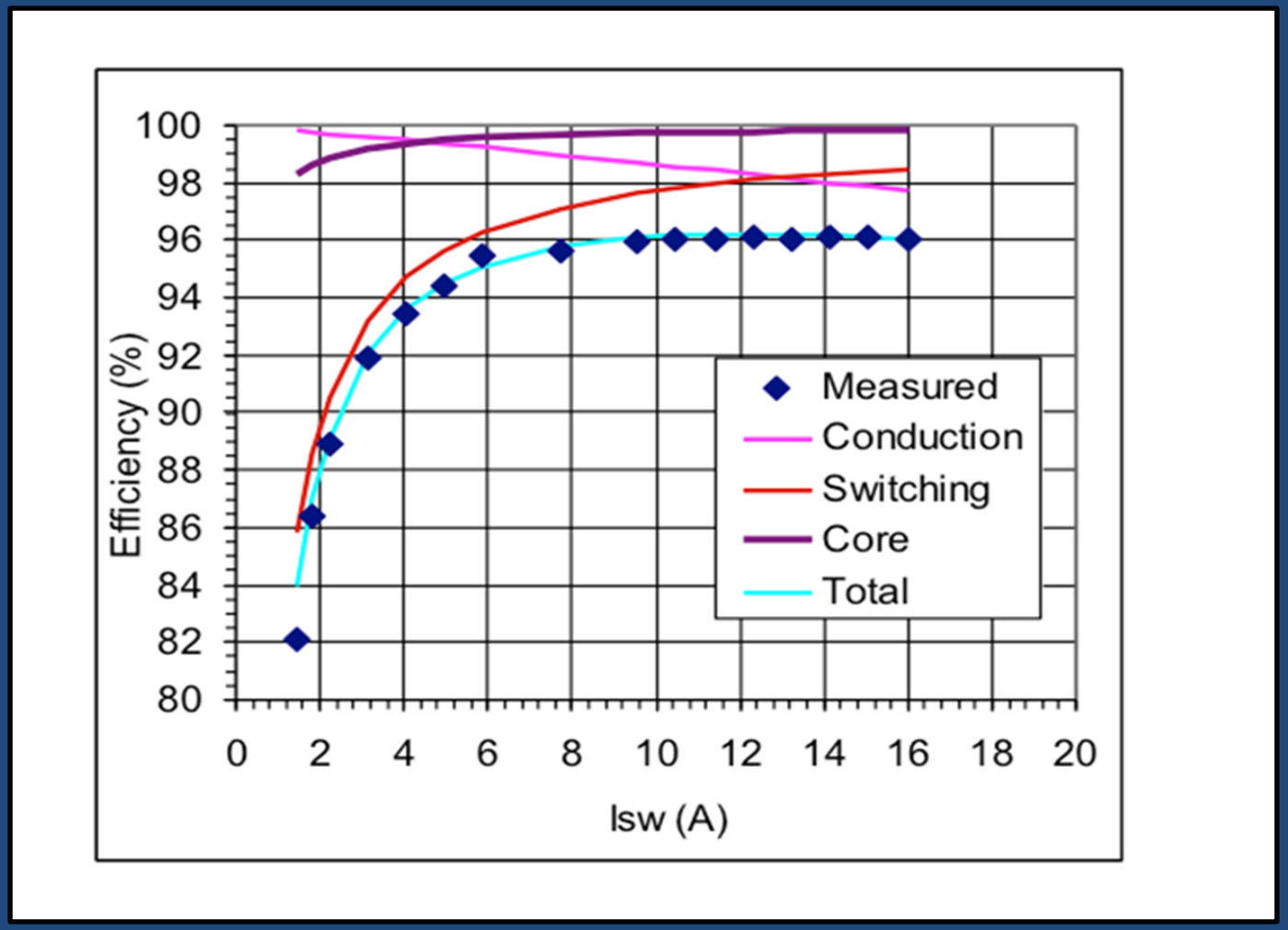
Turn-off



13 ns rise time for v_{DS}

Experimental GaN Boost Converter

- Efficiency vs switching current

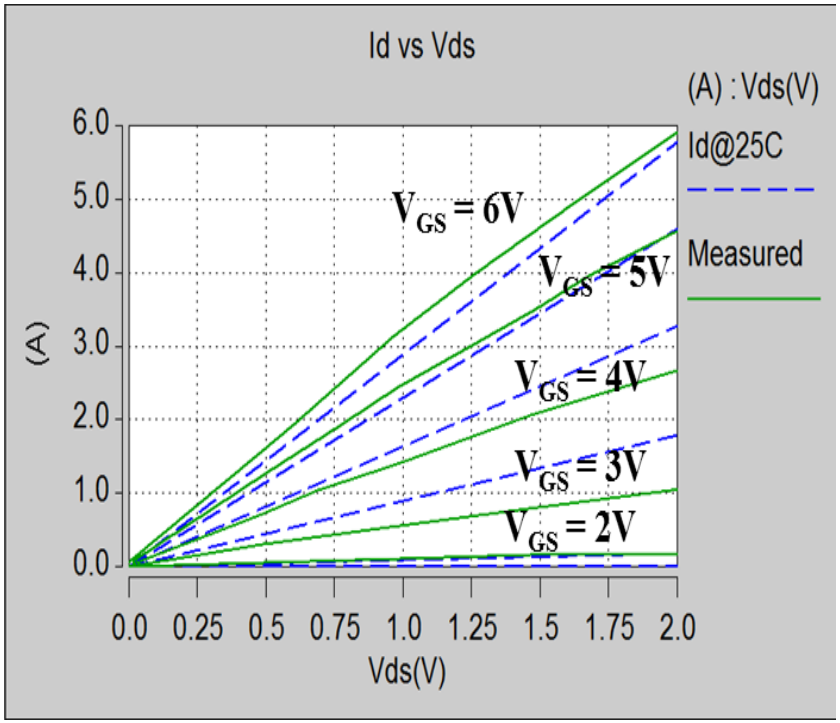


GaN Device Model Development in SaberRD

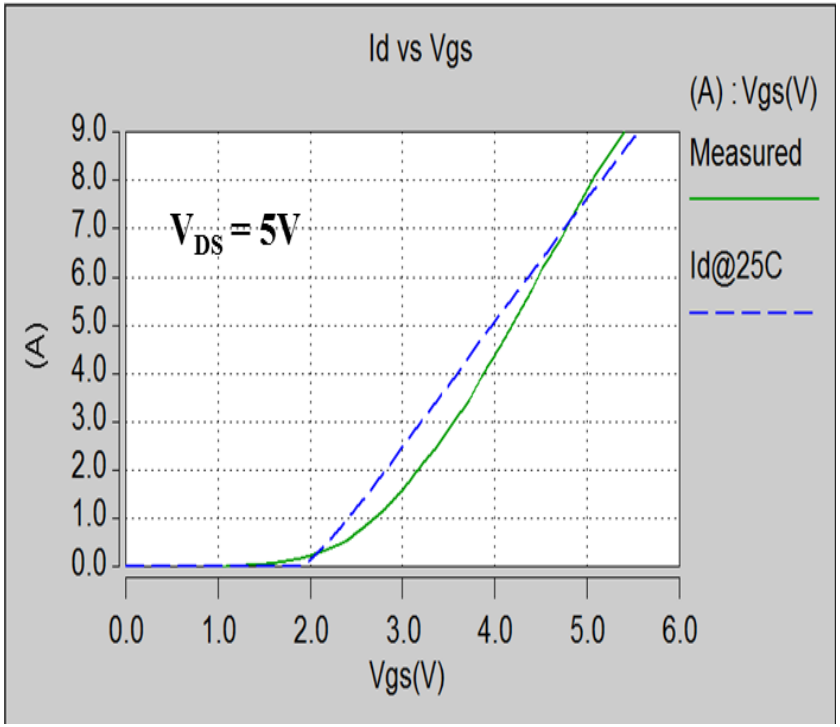
GaN Model Development

- SaberRD used to model 5 essential DC characteristics.

IV Output



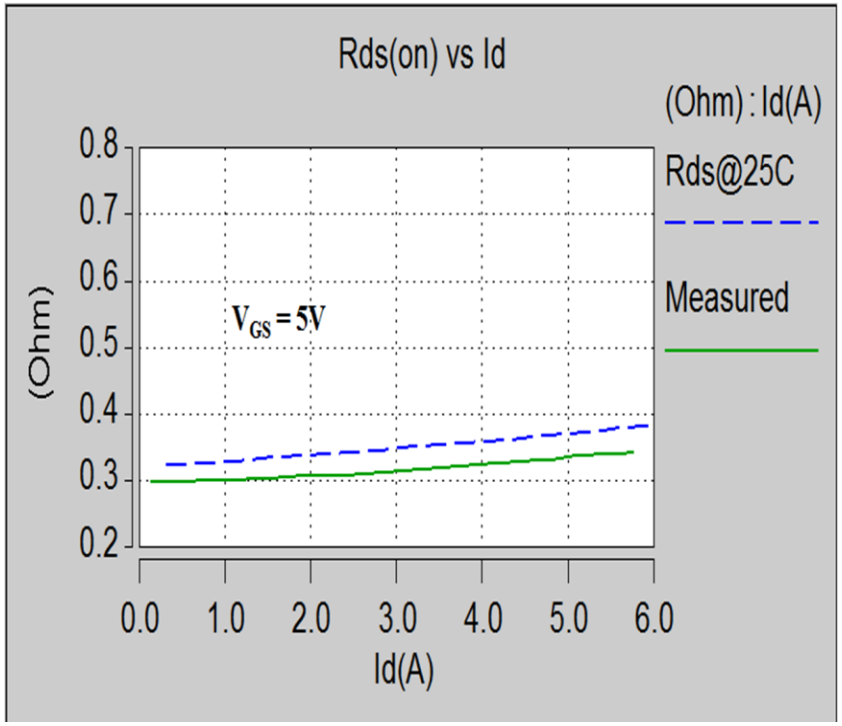
IV Transfer



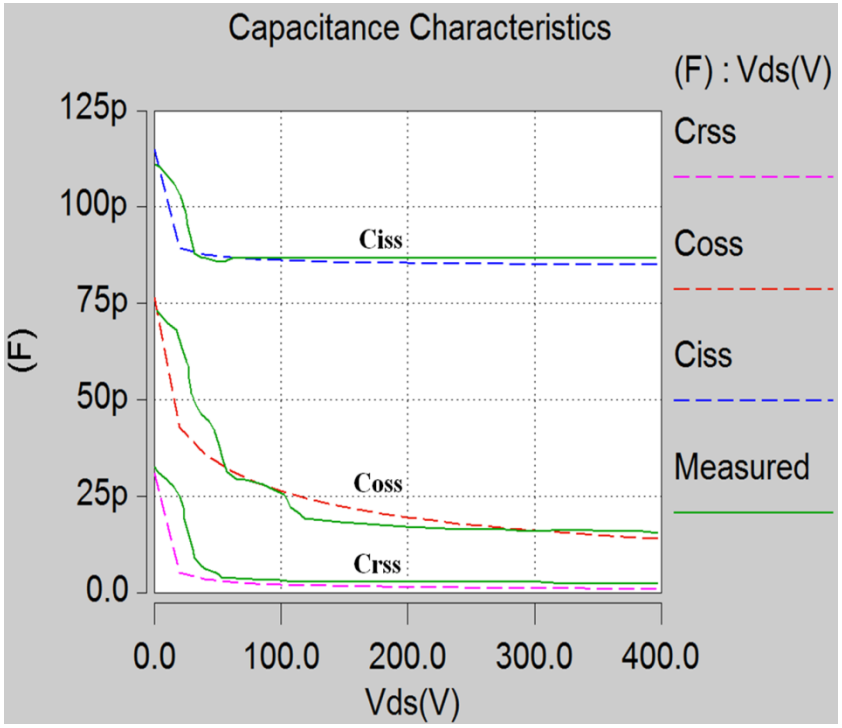
GaN Model Development

- SaberRD used to model 5 essential DC characteristics.

R_{ON} vs I_D



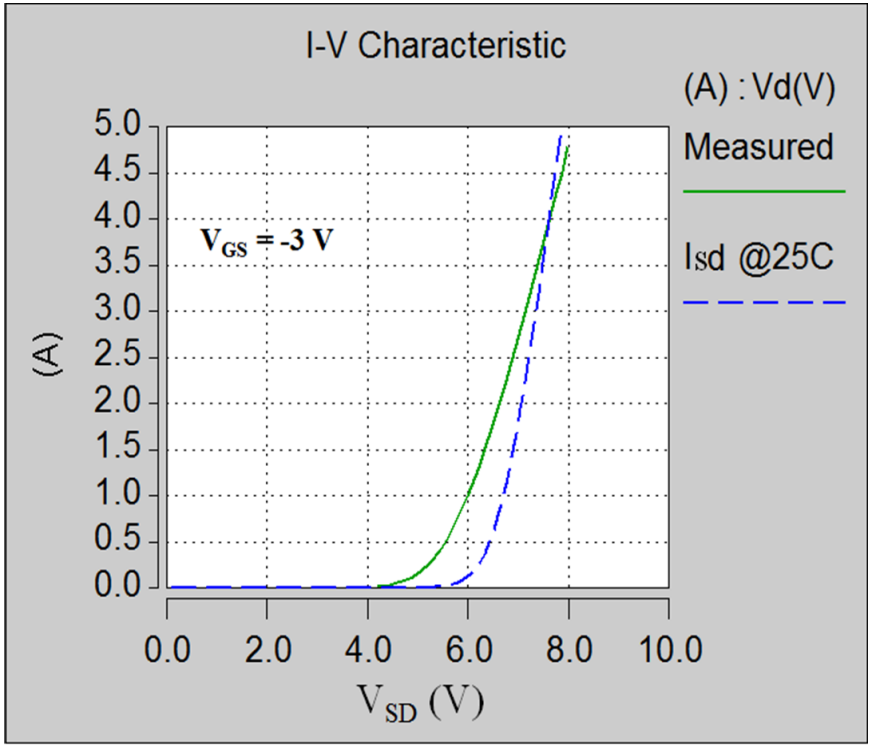
CV Characteristics



GaN Model Development

- SaberRD used to model 5 essential DC characteristics.

Reverse IV Characteristics



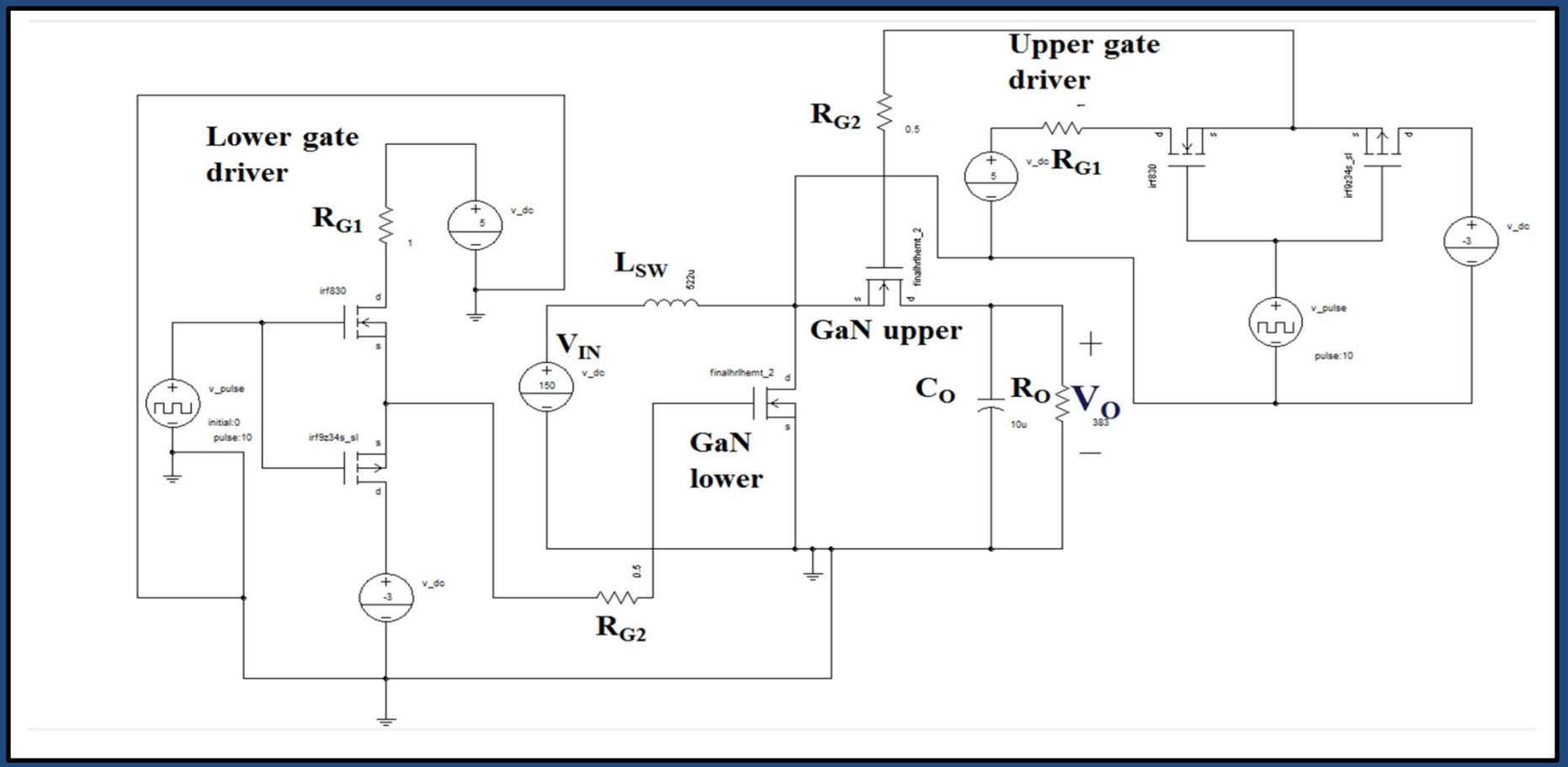
Extracted Parameters

vt	1.4
vgs0	5
vds0	30
ids0	20
rds0	0.32
rd	1m
rs	1m
rg	5
lambda	127u

GaN Model Simulation Results in Boost Converter

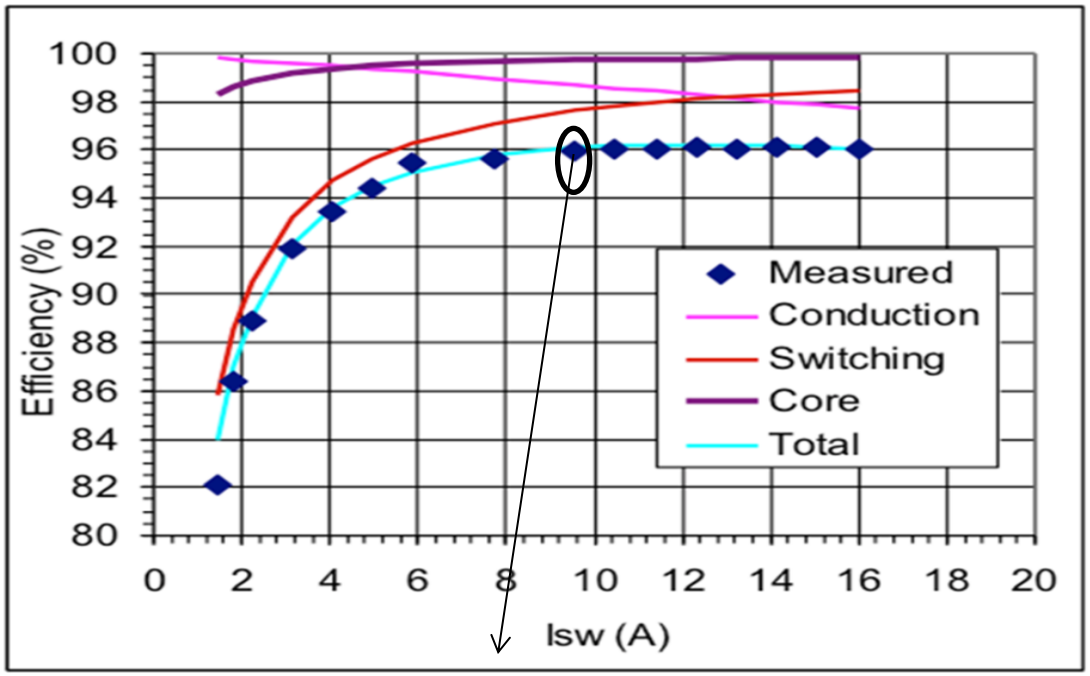
Simulation Results

- Simulated GaN based synchronous boost converter. One 40mm transistor used for each device.



Simulation Results

- Select a point to demonstrate validity of the model. Once the model is deemed valid, higher voltage converters will be used.

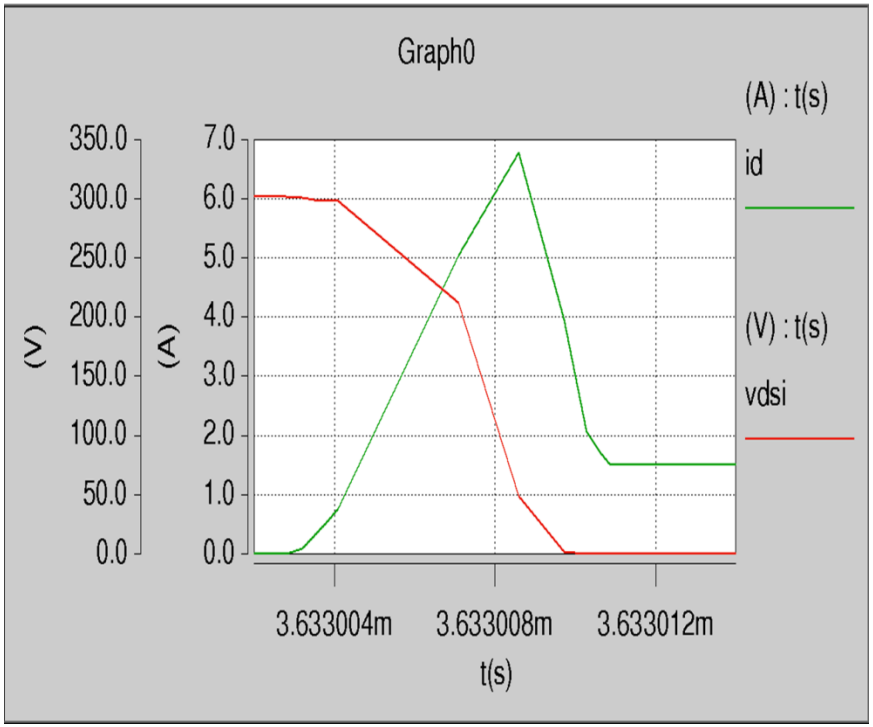


Chosen point for demonstration: 96% @ 9.4 A

Simulation Results

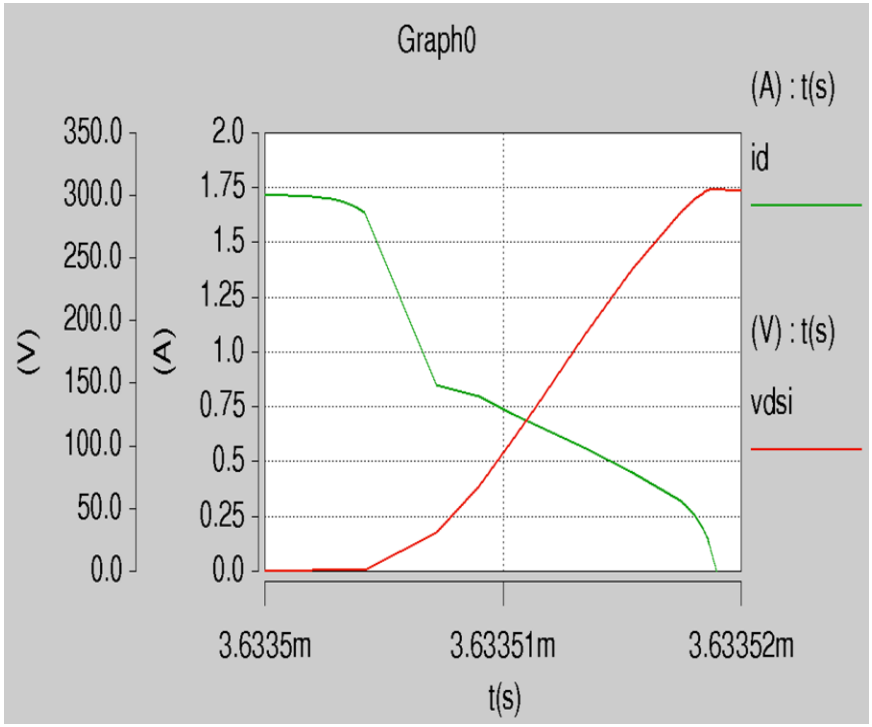
- Switching waveforms at 9.4/6 A. Rise and fall times consistent with experiment.

Turn-on



6 ns fall time for v_{DS}

Turn-off

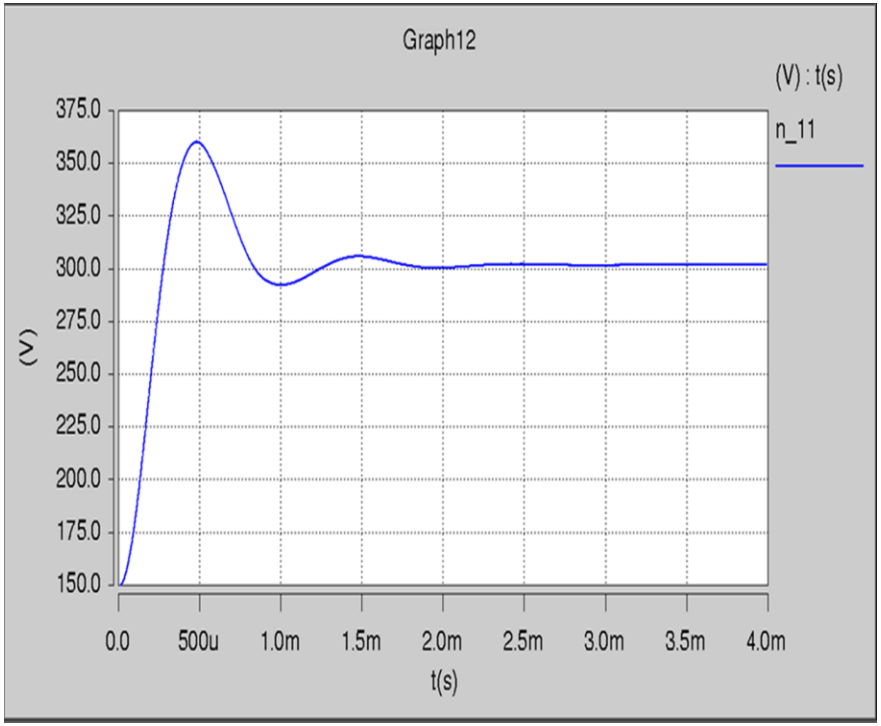


13 ns rise time for v_{DS}

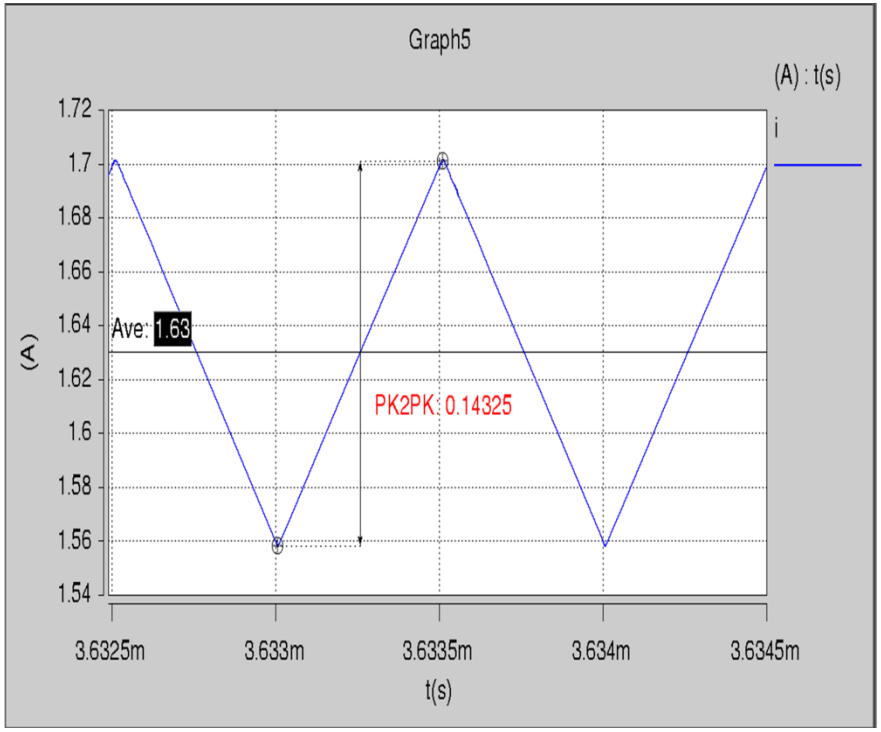
Simulation Results

- Simulated boost converter voltage and current at 9.4/6 A.

Output voltage

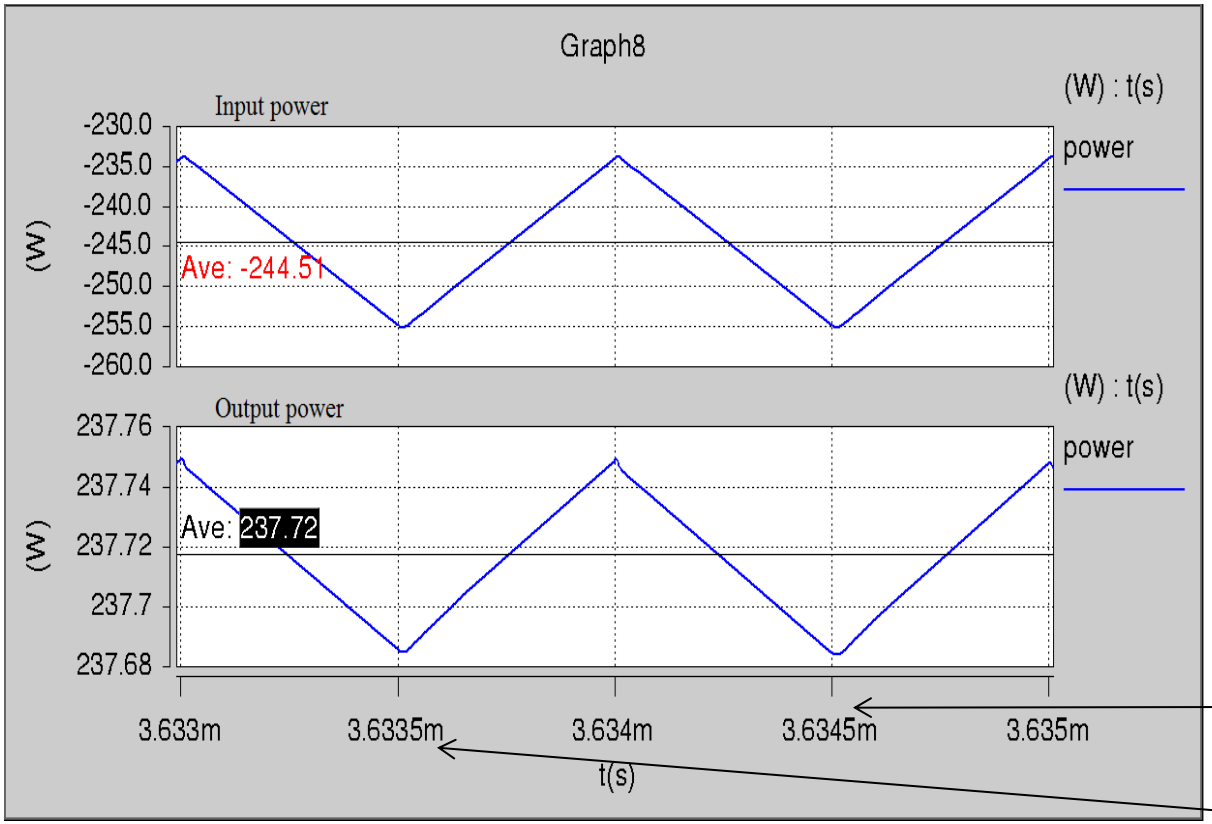


Inductor current



Simulation Results

- Boost converter input/output power and efficiency.

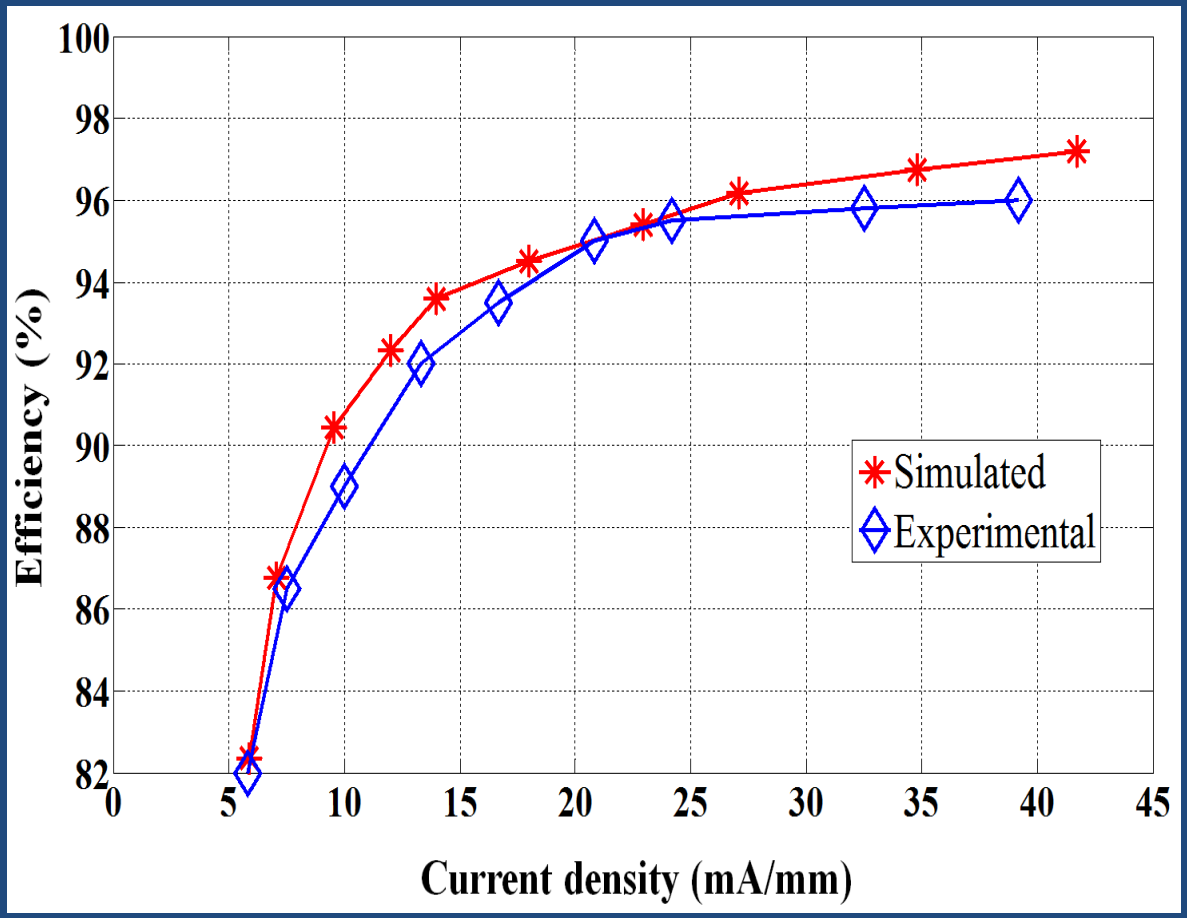


$$\frac{P_O}{P_{IN}} = \frac{237.7}{244.5} = 97\%$$

1 MHz

Simulation vs Experiment

- Efficiency vs switching current in mA/mm



Concluding Remarks

- GaN technology is well suited to revolutionize next generation power electronics, enabling converter efficiencies of 96% at 1 MHz

- Considerable technology readiness factors at both device circuits and device physics levels have hindered their widespread adoption

Acknowledgements

- Dr. William Stanchina, Pitt
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Thank you, questions?

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