Dr. M. A. de Rooij

The eGaN® FET Journey Continues

Introducing eGaN® IC targeting Highly Resonant Wireless Power

Efficient Power Conversion Corporation

Agenda

- Introducing the Synchronous Bootstrap FET
- eGaN ICs targeting Wireless Power
- Experimental results in a ZVS class D amplifier
- Summary

eGaN® is a registered trademark of Efficient Power Conversion Corporation

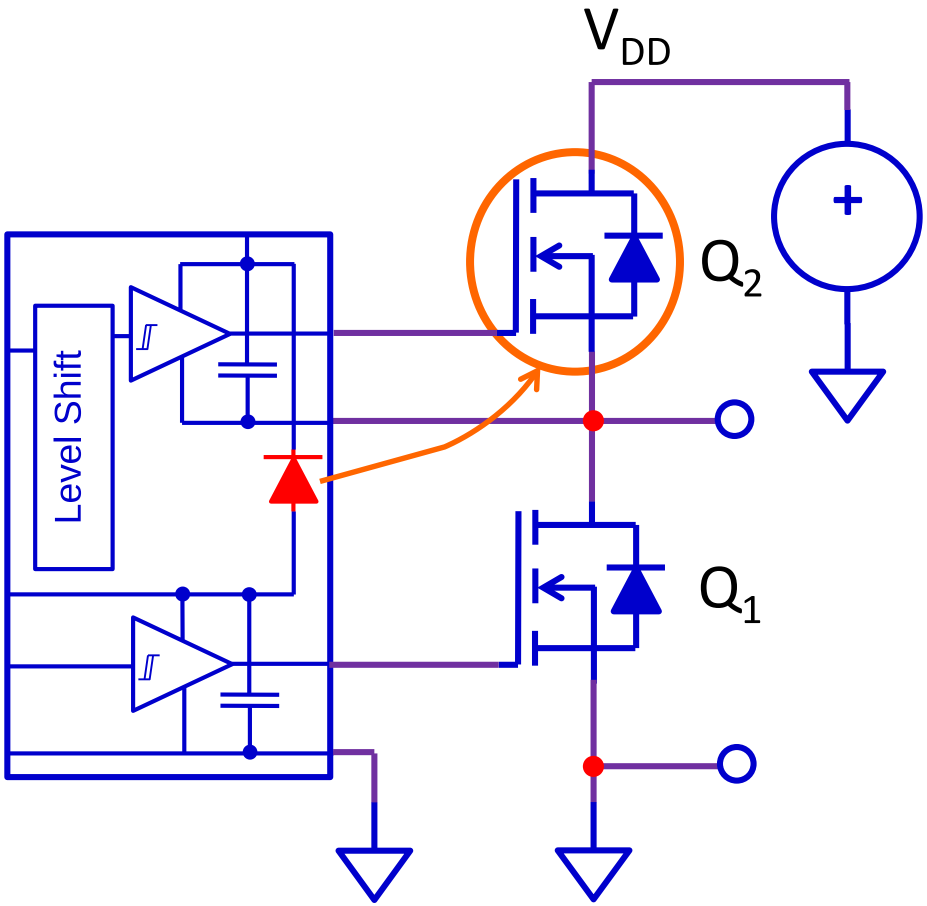
Impact of Gate Driver Bootstrap Diode Q_{RR}

Gate drivers with internal bootstrap diodes have Q_{RR}

- Schottky diode cannot be integrated

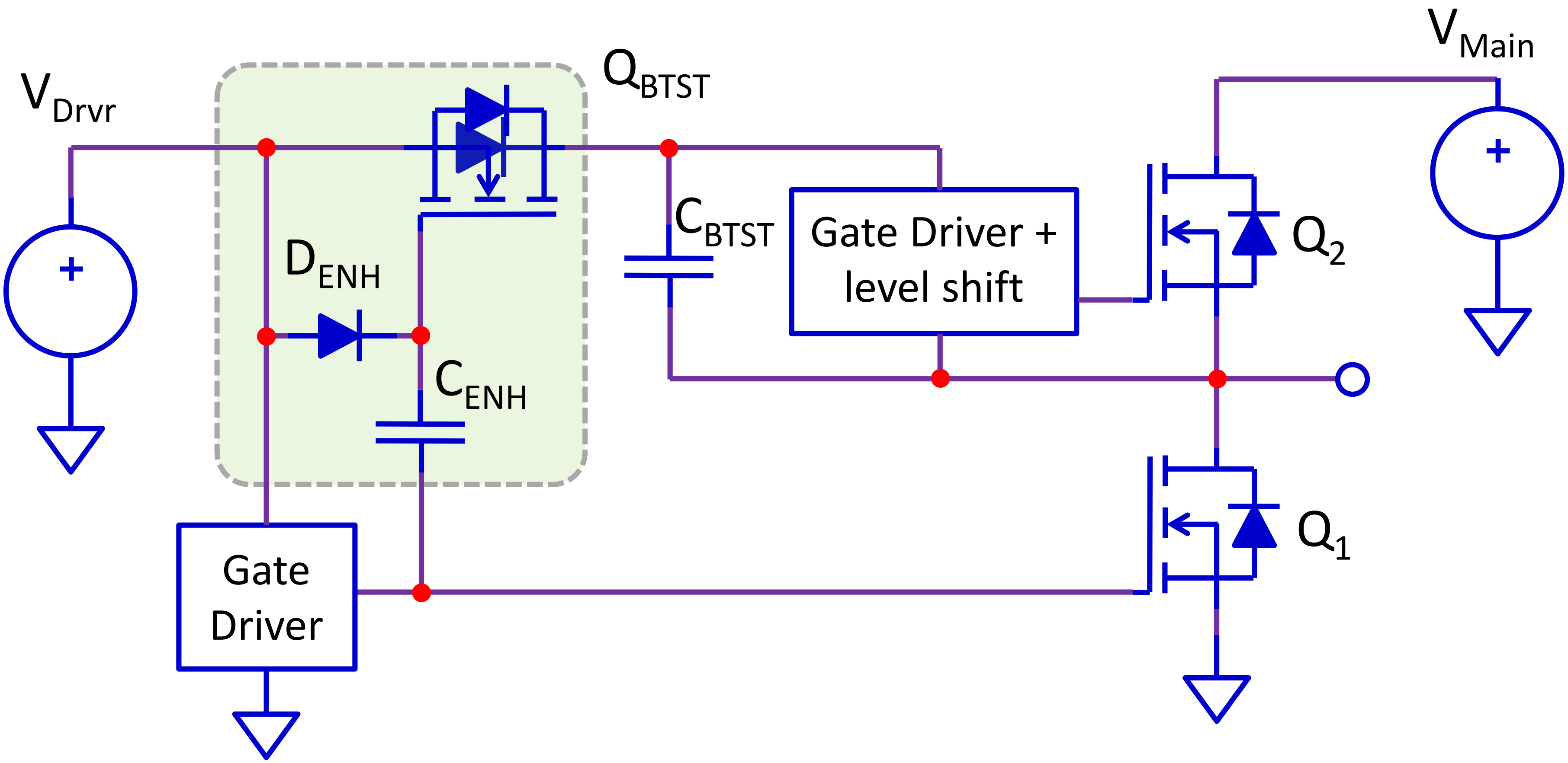
This Q_{RR} induces losses in the high side device:

- Proportional to frequency
- Present even with ZVS



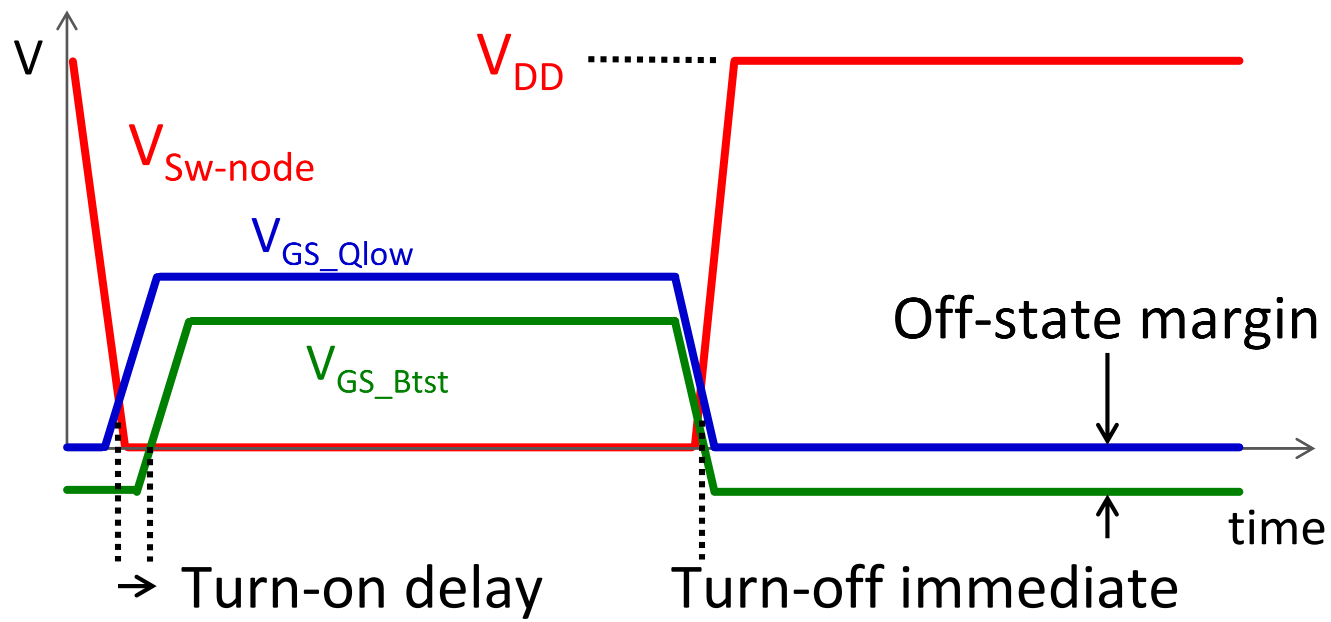
370 mW at 50 V, 6.78 MHz
~ 40% of total FET losses

Implementing a Synchronous FET Bootstrap Supply

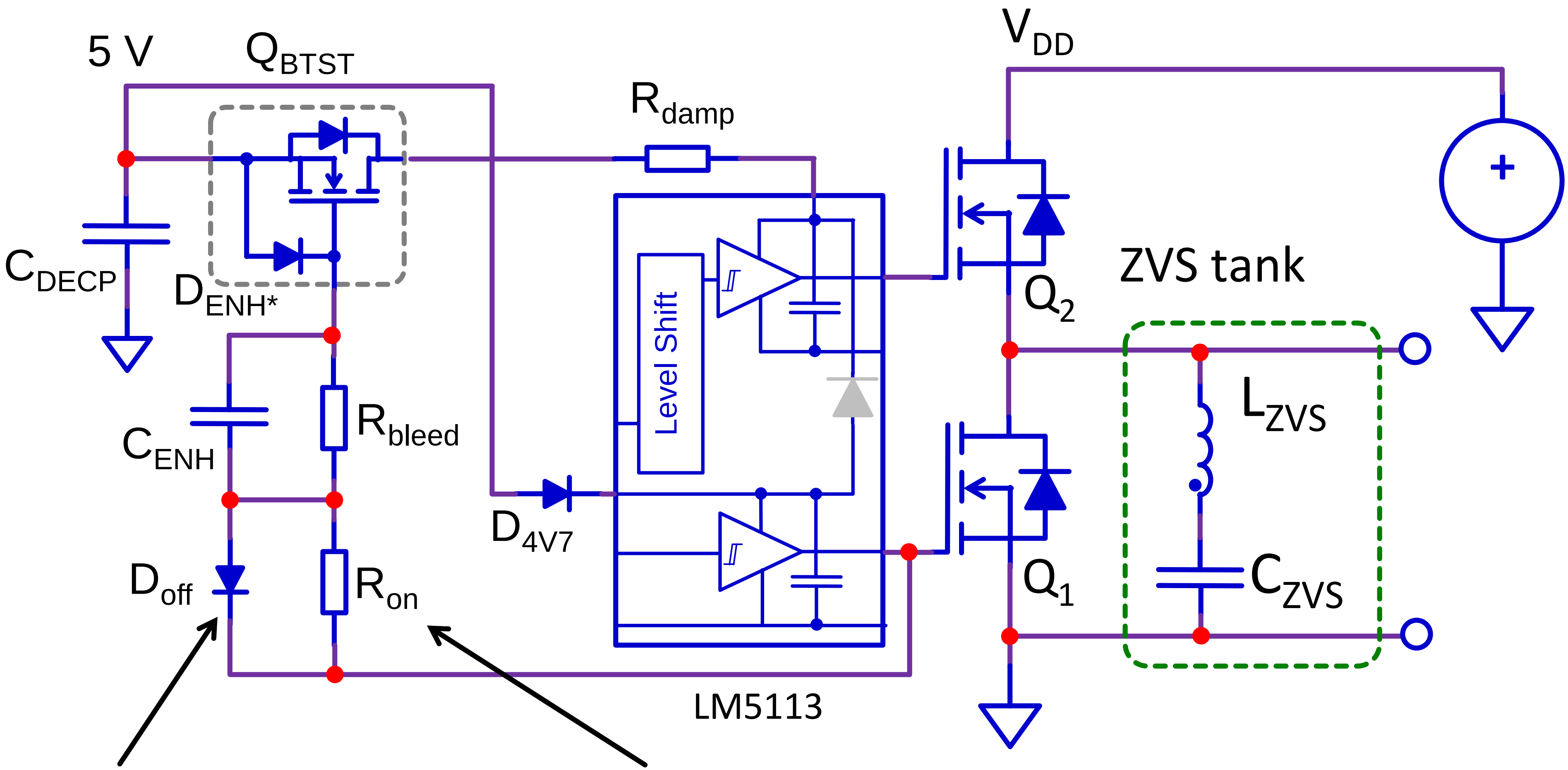


Synchronous Bootstrap FET Design Considerations

- Timing:
  - Turn on - Delay
  - Turn off – Immediate
- Off state margin – if lower FET reverse conducts
- Drain inductance – to prevent over-voltage



Synchronous FET Bootstrap Supply Implementation

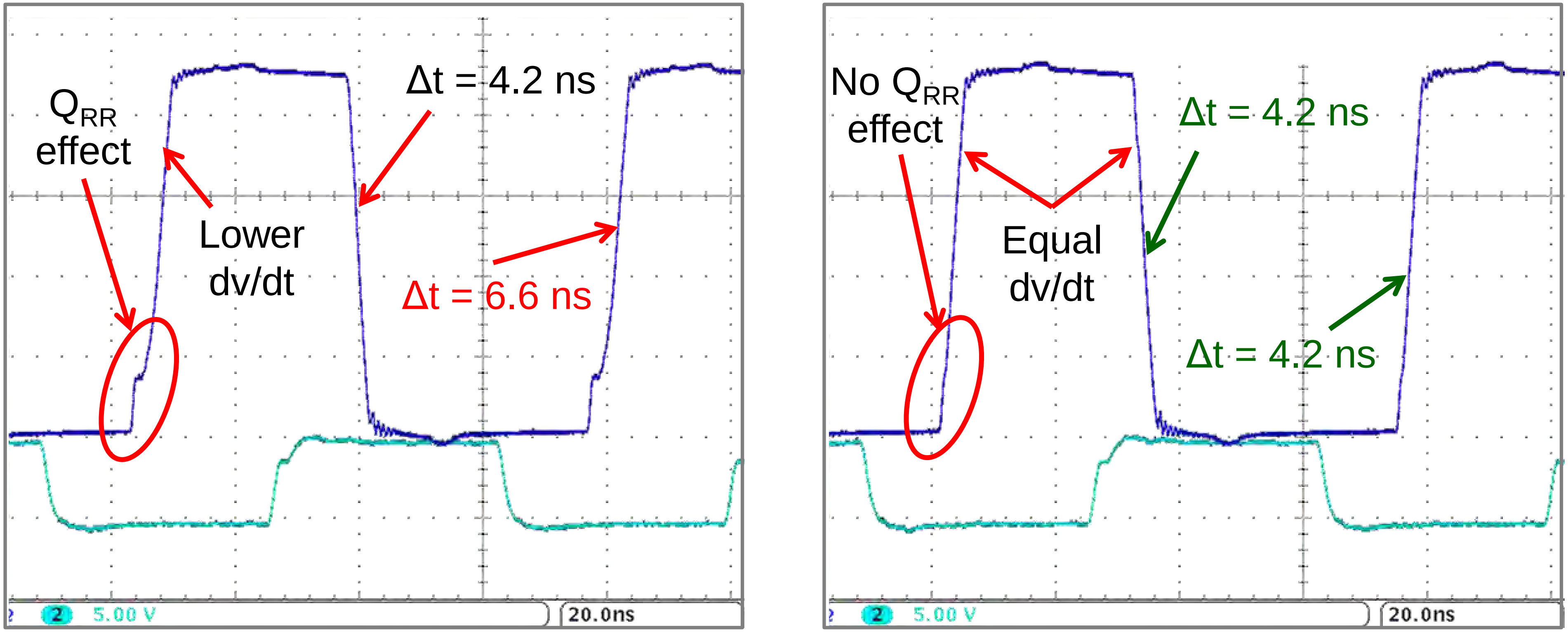


Turn-off immediate | Turn-on delay

Reference: M. A. de Rooij, "*Wireless Power Handbook*," 2nd Edition, El Segundo, October 2015, ISBN 978-0-9966492-1-6.

Waveform Improvements at 13.56 MHz Operation

V_{supply} = 45 V, No load



5 V/Div. 20 ns/Div.

5 V/Div. 20 ns/Div.

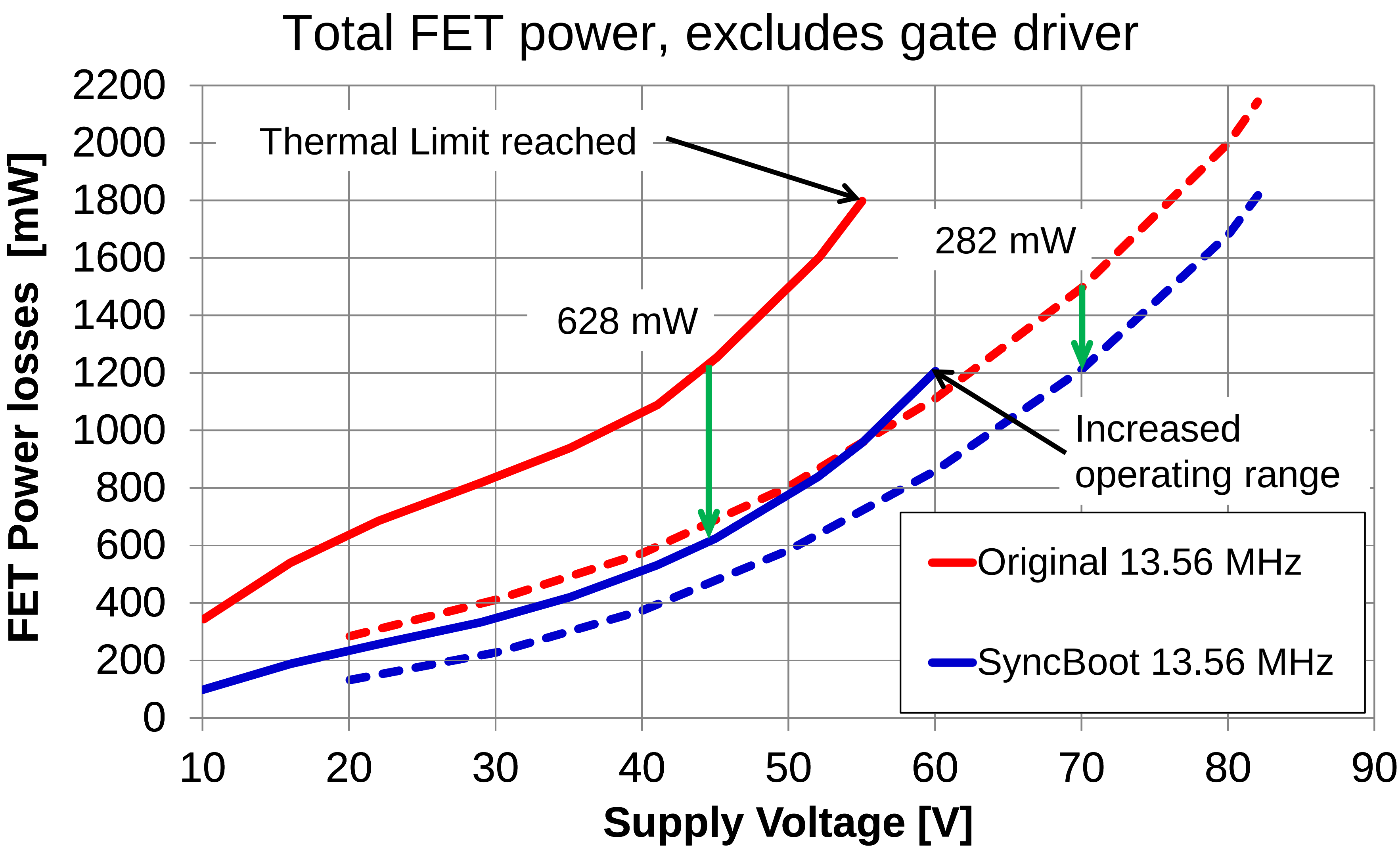
Original Configuration

Sync-Bootstrap Configuration

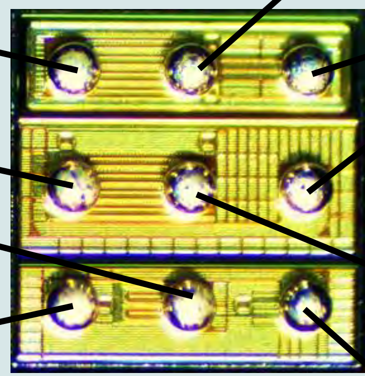
SW Node

Gate Driver Input

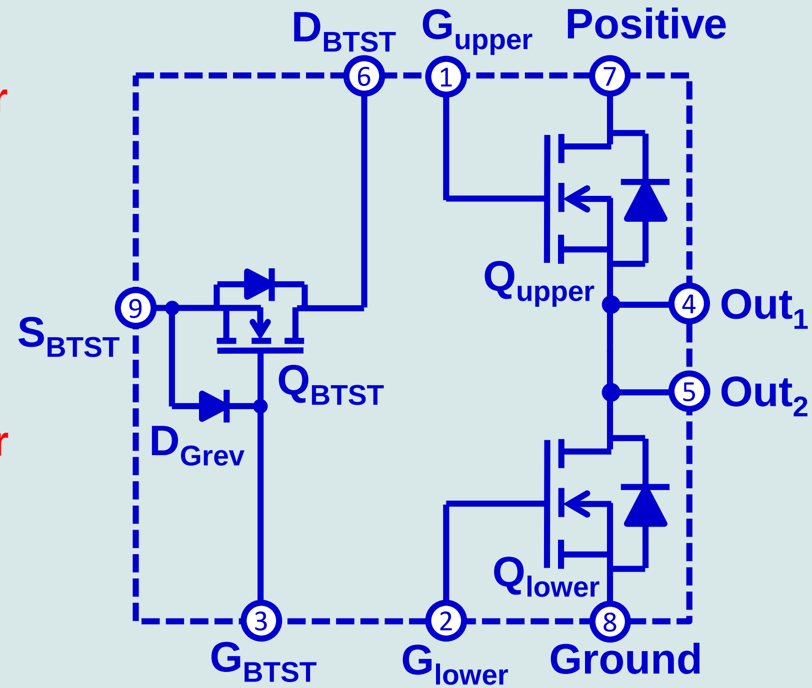
Synchronous Bootstrap Power Dissipation Results



eGaN ICs targeting Wireless Power Applications



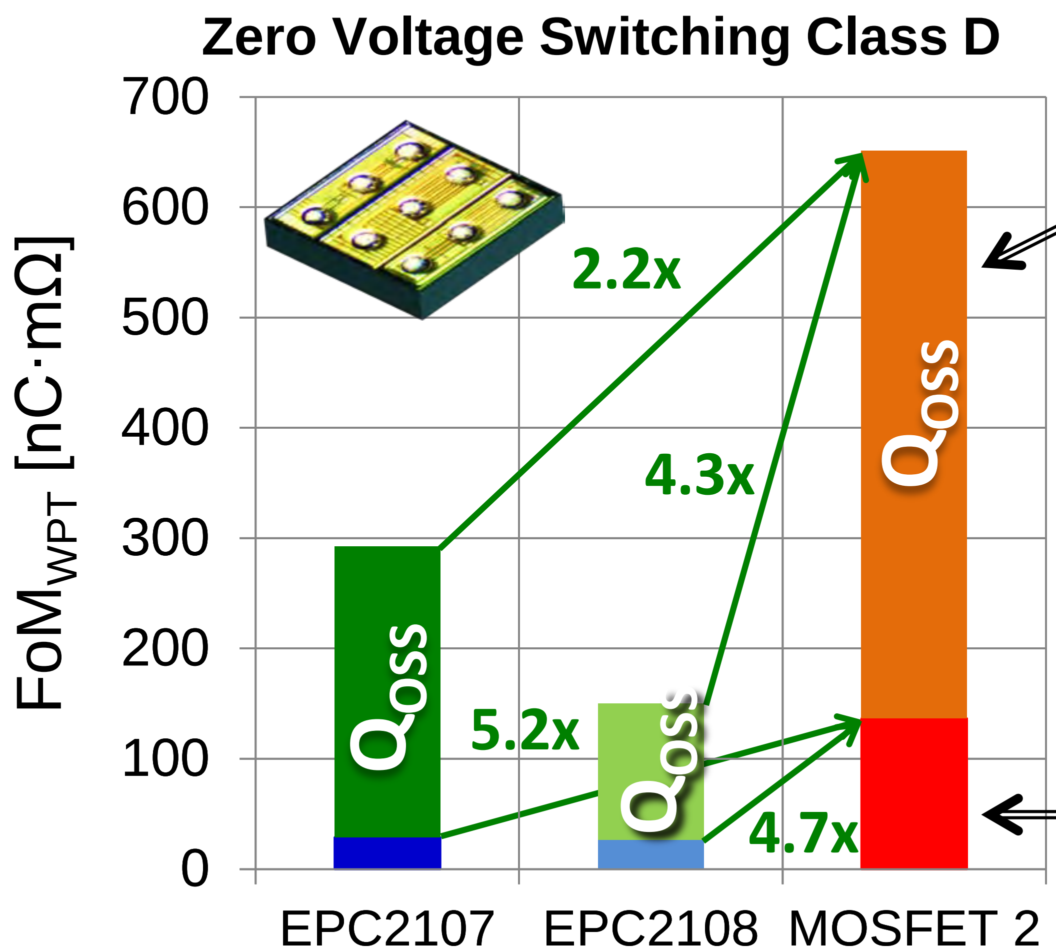
Solder Side View



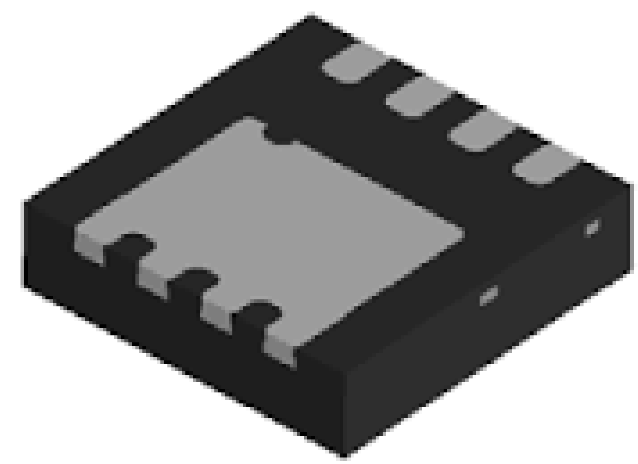
EPC Part Number	Package (mm)	V_{DS} (V)	V_{GS} (V)	$R_{DS(on)}$ @5V (mΩ)	Q_G @5 V Typ. (pC)	Q_{GS} Typ. (pC)	Q_{GD} Typ. (pC)	R_G Typ. (Ω)	V_{th} Typ. (V)	Q_{RR} (nC)	I_D (A)	T_J Max. (˚C)
EPC2107	BGA1.35x1.35	100	6	240	160	65	40	0.6	1.4	0	1.7	150
	BGA1.35x1.35	100	6	240	160	65	40	0.6	1.4	0	1.7	150
	BGA1.35x1.35	100	6	2800	44	16	5	0.6	1.4	0	0.5	150
EPC2108	BGA1.35x1.35	60	6	150	220	85	45	0.6	1.4	0	1.7	150
	BGA1.35x1.35	60	6	150	220	85	45	0.6	1.4	0	1.7	150
	BGA1.35x1.35	100	6	2800	44	16	5	0.6	1.4	0	0.5	150

Device Comparison

$$FOM_{WPT} = R_{DS(on)} \cdot \left(Q_G - Q_{GD} + Q_{OSS}\right)$$

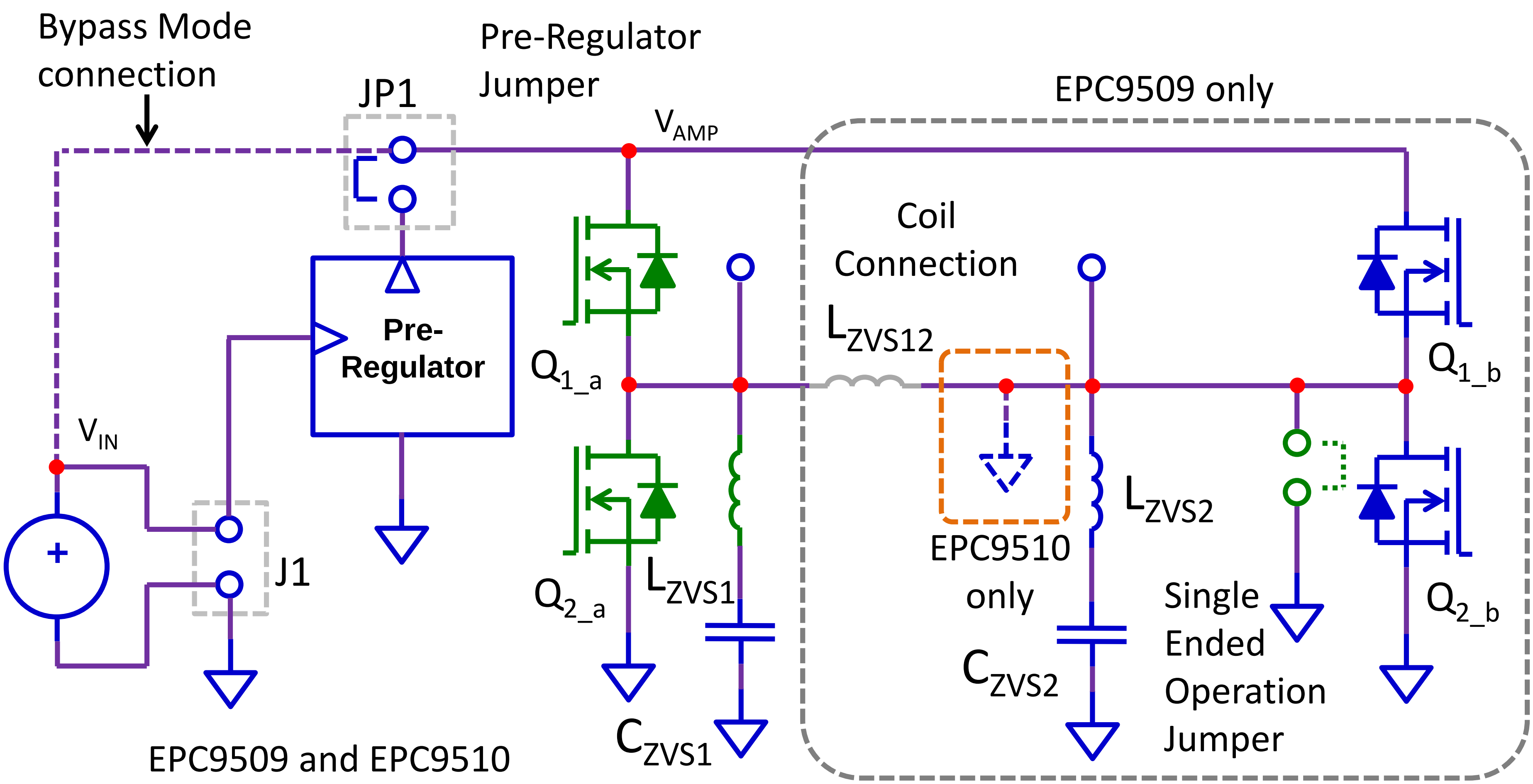


$$FOM_{WPT} = R_{DS(on)} \cdot \left(Q_{OSS}\right)$$



$$FOM_{WPT} = R_{DS(on)} \cdot \left(Q_G - Q_{GD}\right)$$

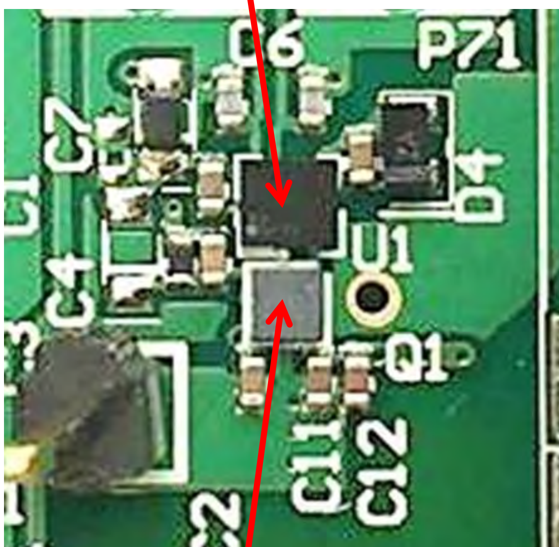
ZVS Class D Experimental Power Schematic



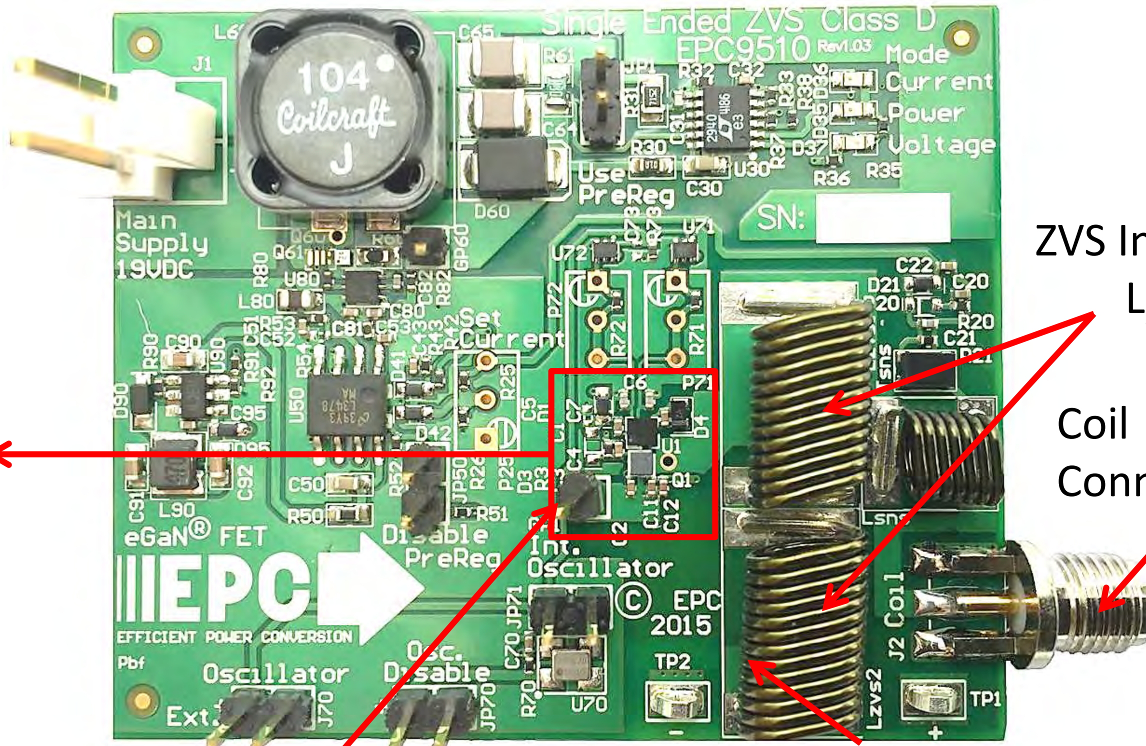
Experimental Single-Ended ZVS Class D Amplifier

Configured for 6.78 MHz Operation

Gate Driver
LM5113 (5 V)



eGaN IC



ZVS Inductor
L_{ZVS}

Coil
Connection

Oscilloscope
Probe Post

ZVS Capacitor C_{ZVS}
(Bottom Side)

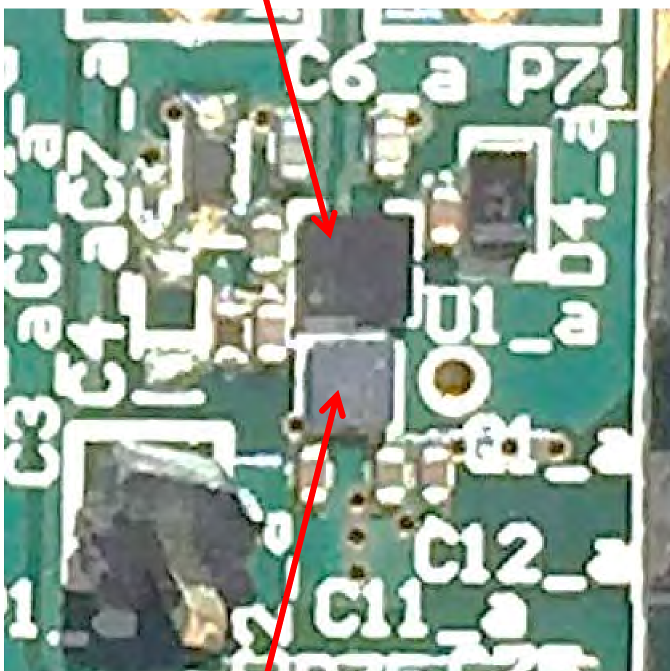
EPC9510

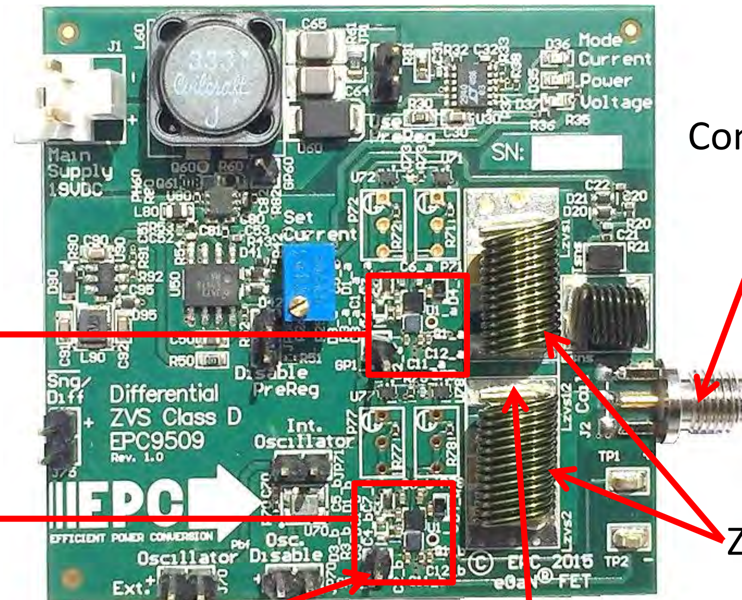
EPC2107 – 100 V, 220 mΩ, V_{GS} = 5 V

Experimental Differential-Mode ZVS Class D Amplifier

Configured for 6.78 MHz Operation

Gate Driver
LM5113 (5 V)





Coil Connection

ZVS Inductor L_{ZVS}

Oscilloscope
Probe Post

ZVS Capacitor C_{ZVS}
(Bottom Side)

eGaN IC

EPC9509

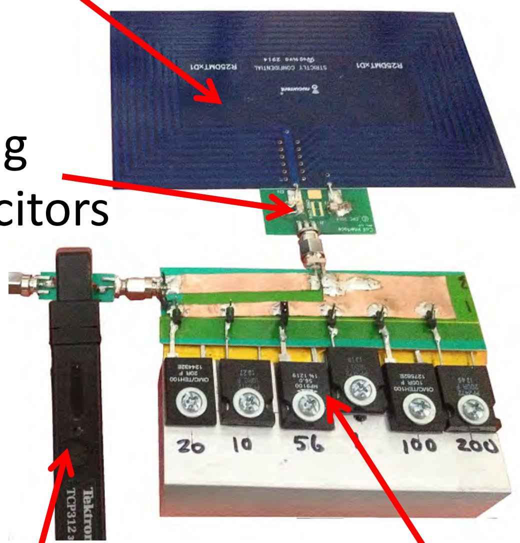
EPC2108 – 60 V, 150 mΩ, V_{GS} = 5 V

Load Calibration Results for Class 2

Measured at 6.78 MHz

High Q coil used as an inductor ONLY

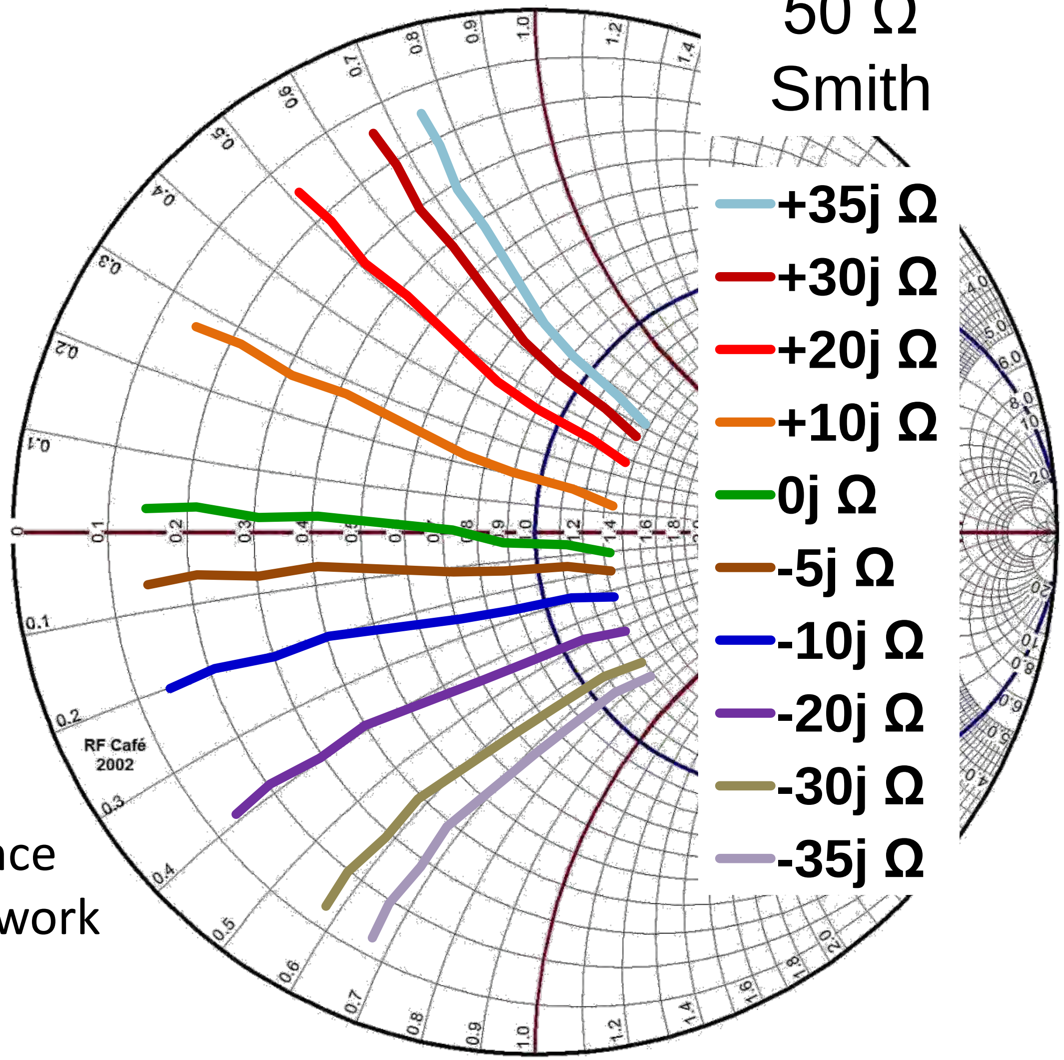
Tuning Capacitors



Current Probe

Low Inductance Resistance Network

50 Ω Smith

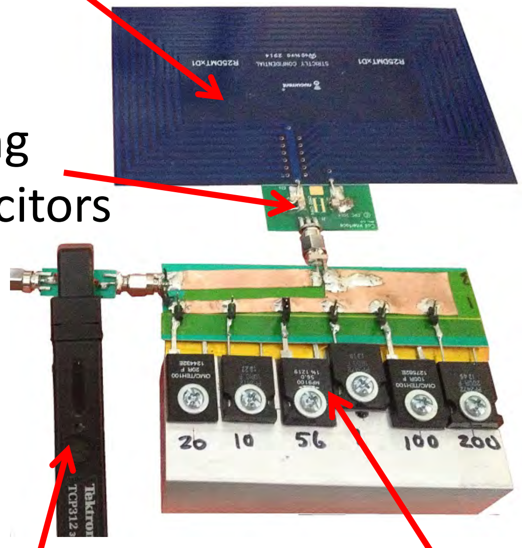


Load Calibration Results for Class 3

Measured at 6.78 MHz

High Q coil used as an inductor ONLY

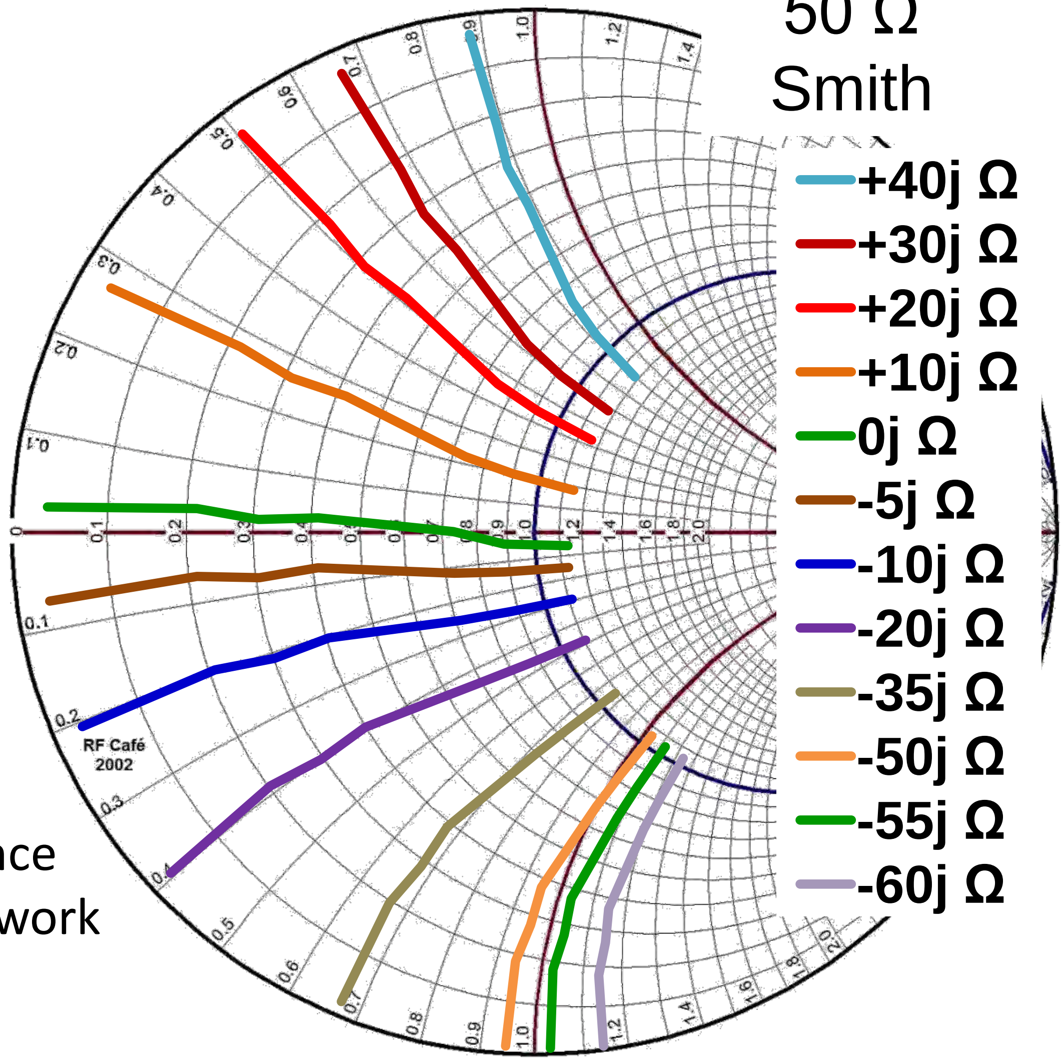
Tuning Capacitors



Current Probe

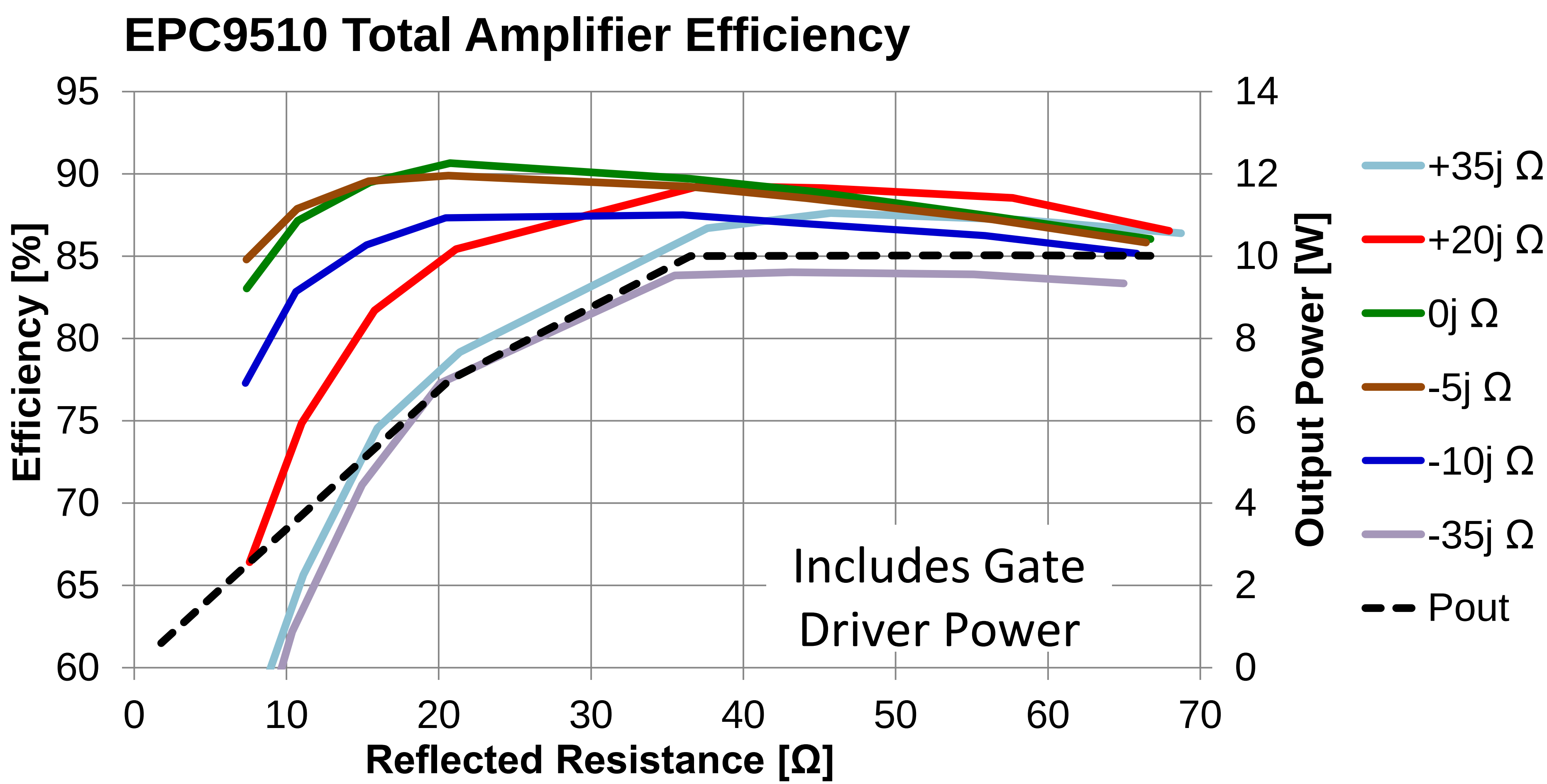
Low Inductance Resistance Network

50 Ω Smith



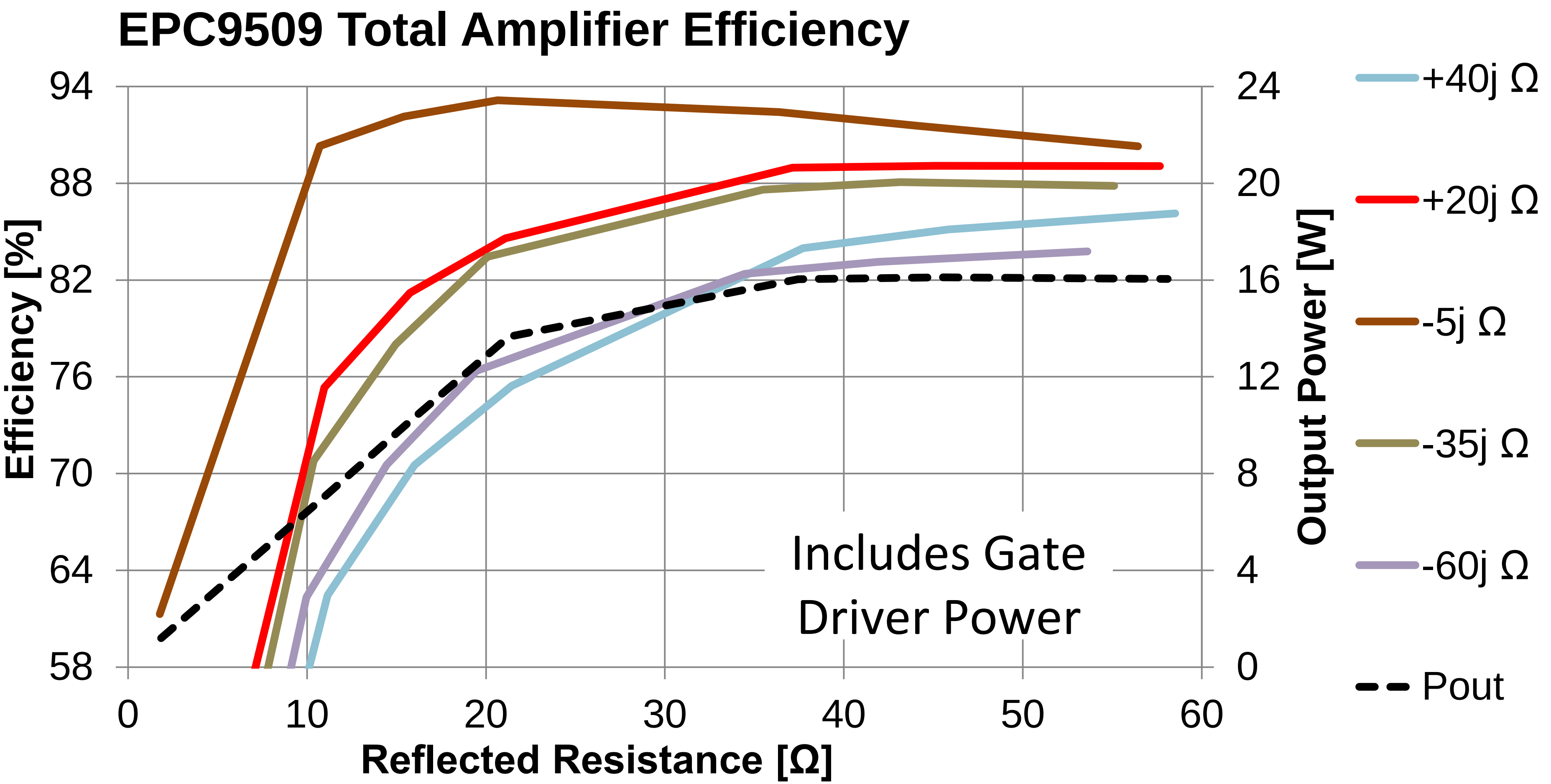
Single-Ended ZVS Class D Class 2 Experimental Results

Measured at 6.78 MHz



Differential-Mode ZVS Class D Class 3 Results

Measured at 6.78 MHz



Summary

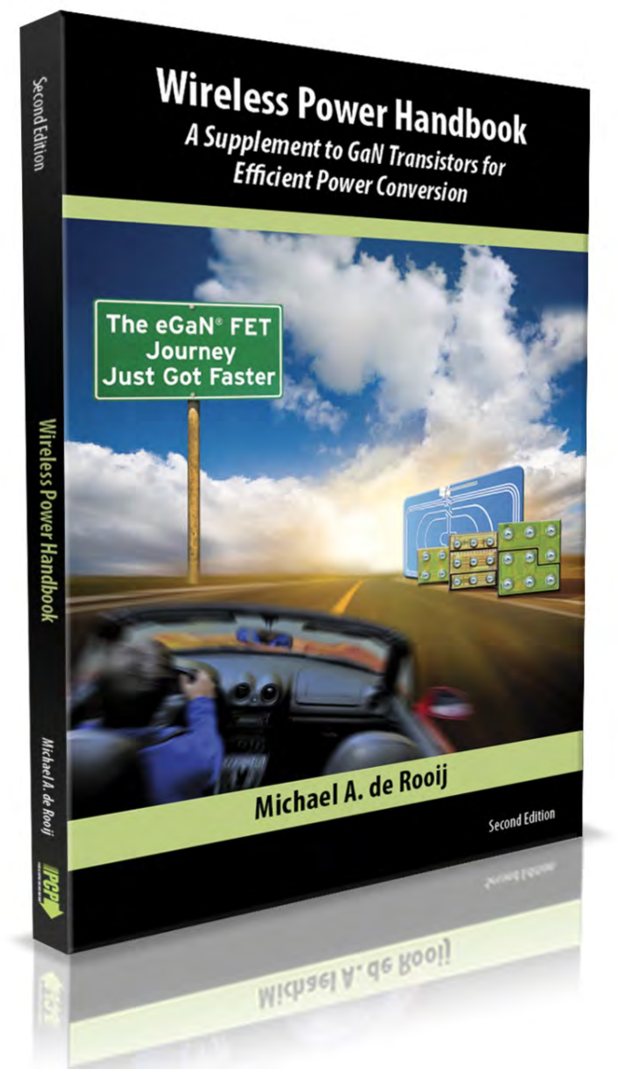
Introduced the eGaN IC

- Lateral eGaN FET structure enables high voltage integration
- Three (3) FETs in one 1.35 mm x 1.35 mm chip-scale package
- Integration improves efficiency and power density

- Experimentally verified in a ZVS Class D amplifier
- eGaN ICs enable lower cost, higher performance wireless power

Wireless Power Handbook

- Visit EPC's Booth #2244 to see several demonstrations in operation
- 2nd Edition Handbook on wireless power that covers this work and much more – available at Digikey (917-1136-ND) or Amazon



Where is GaN going…