The eGaN® FET Journey Continues

Performance Comparison for A4WP Class-3 Wireless Power Compliance between eGaN® FET and MOSFET in a ZVS Class D Amplifier

Agenda

- Introduction to the A4WP Class-3 Specifications
- ZVS Class D Amplifier
- eGaN® FET versus MOSFET Comparison
- Synchronous Bootstrap FET Gate Driver
- Experimental Results
- Summary

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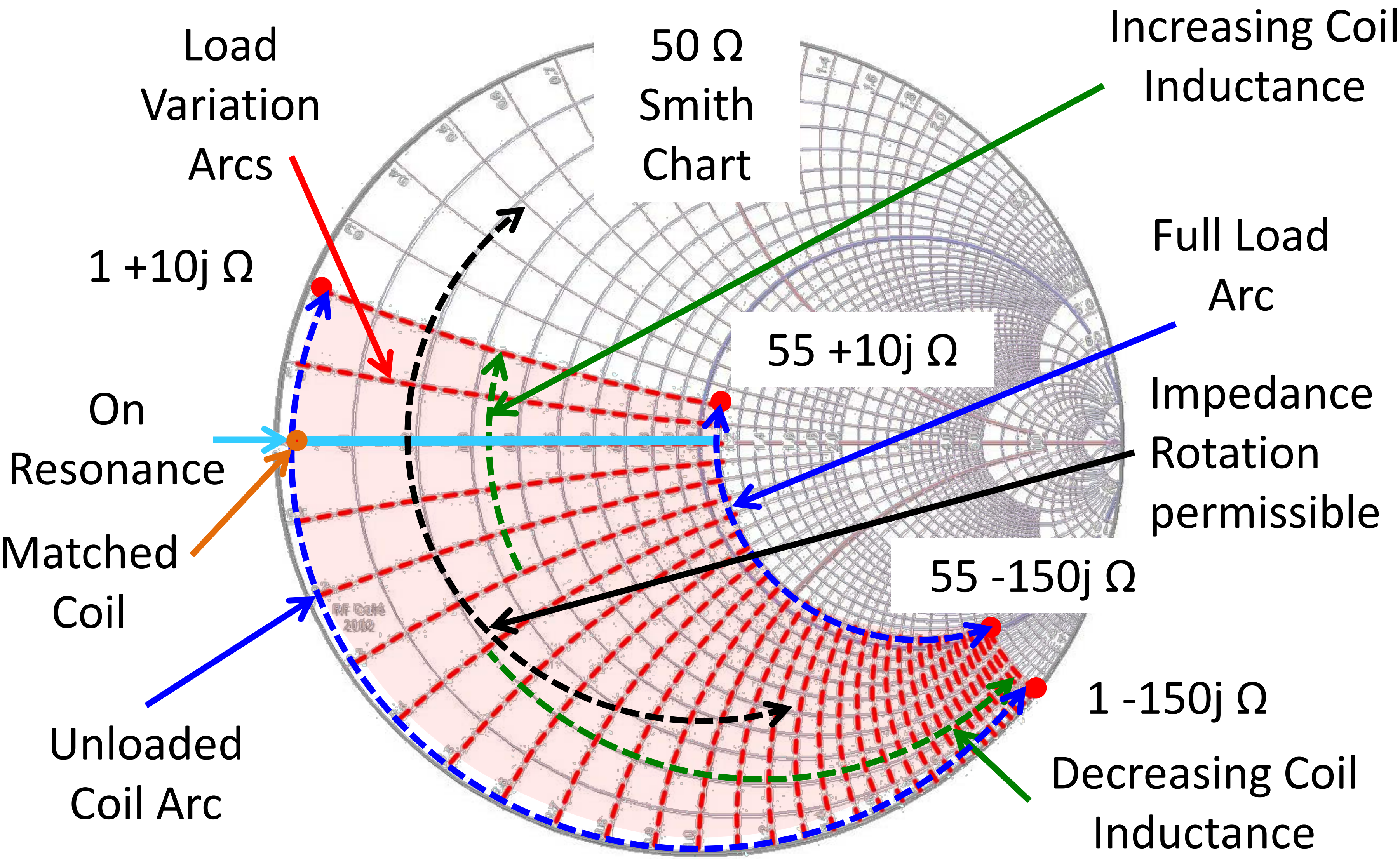
Introduction

- Wireless power transfer solutions must address convenience-of-use such as:

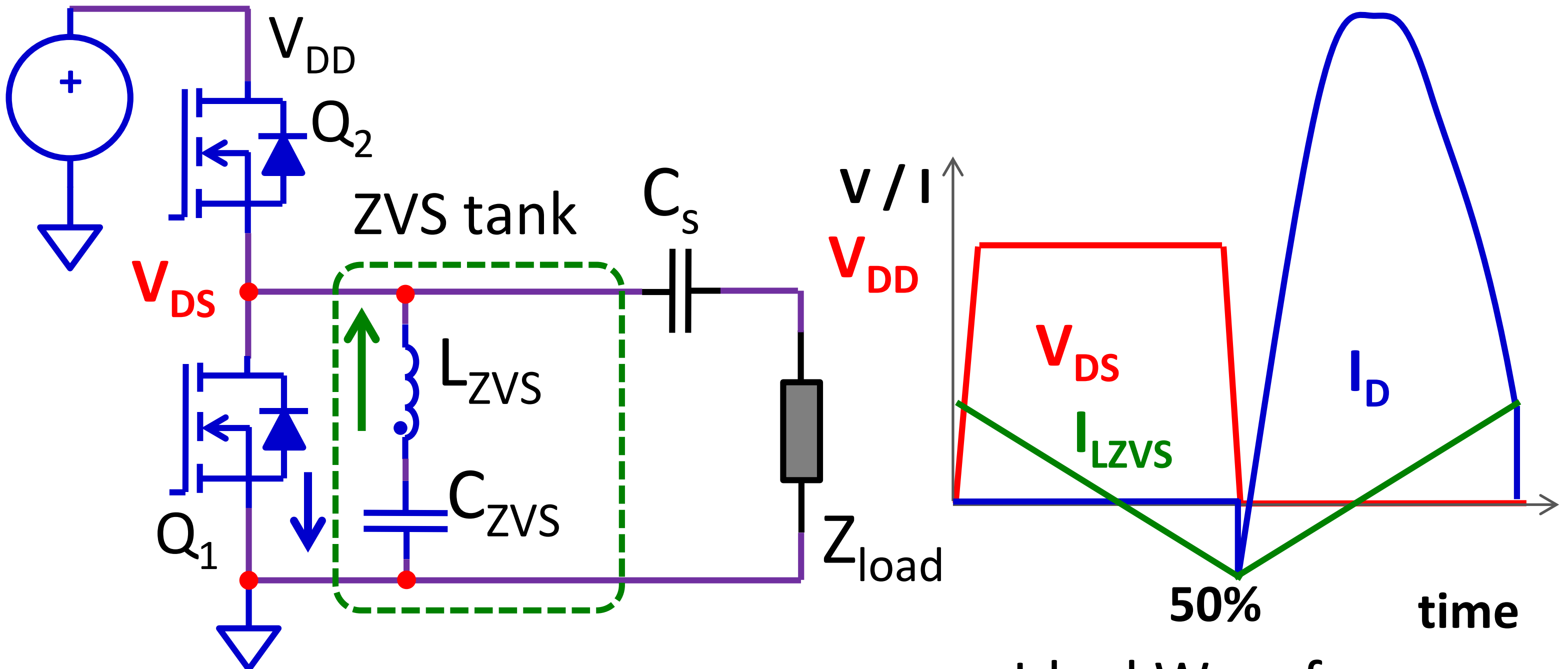
  device orientation and distance, multiple device capability, user simplicity, and power.
- Only the Alliance for Wireless Power (A4WP / Rezence) standard does:
  - Highly resonant (6.78 MHz ISM band)
  - Loosely coupled coils
  - Operation off-resonance
- ZVS Class D amplifier will be tested to the Class-3 requirements

A4WP Class-3 Impedance Requirements



ZVS Class D Amplifier

- Switch voltage rating = Supply (V_{DD}).
- C_{OSS} Voltage is transitioned by the ZVS tank
- ZVS tank circuit does not carry load current
- Coil Voltage $= \frac{\sqrt{2}}{\pi} \cdot V_{DD}$ [V_{RMS}]

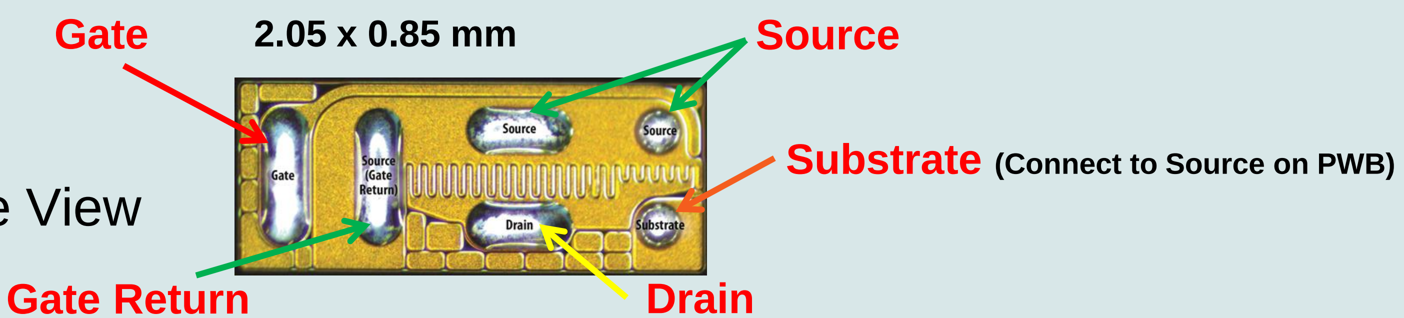


Ideal Waveforms

Ultra High Frequency eGaN FETs

- Proven in various wireless power transfer amplifiers
- Low C_{ISS}
- Low C_{OSS}
- Zero Q_{RR}
- Full dv/dt immunity

Solder side View

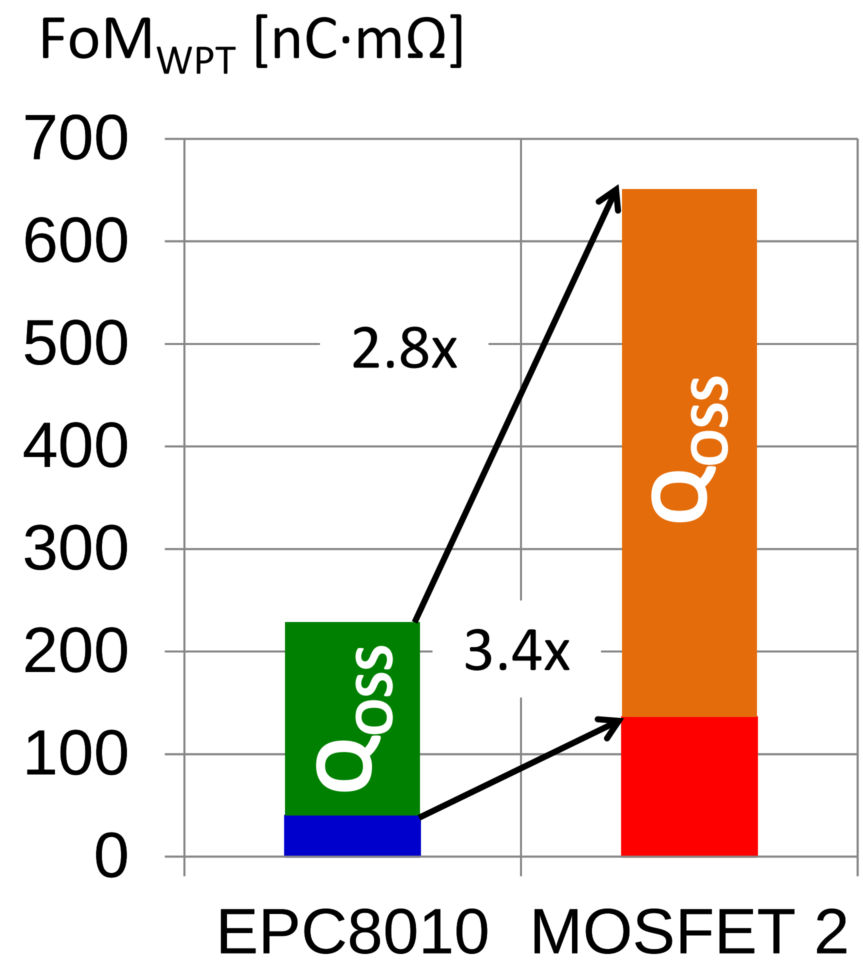


Part Number	Package (mm)	V_{DS} (V)	V_{GS} (V)	$R_{DS(on)}$ @5 V (mΩ)	Q_G @5 V Typ. (pC)	Q_{GS} Typ. (pC)	Q_{GD} Typ. (pC)	R_G Typ. (Ω)	V_{th} Typ. (V)	Q_{RR} (nC)	I_D (A)	T_J Max. (˚C)
EPC8004	LGA 2.05x0.85	40	6	125	358	110	31	0.34	1.4	0	2.7	150
EPC8009	LGA 2.05x0.85	65	6	138	380	116	36	0.3	1.4	0	2.7	150
EPC8010	LGA 2.05x0.85	100	6	160	354	109	32	0.3	1.4	0	2.7	150

Wireless Power Transfer Figure of Merit

<u>Best-In-Class MOSFET comparison</u>

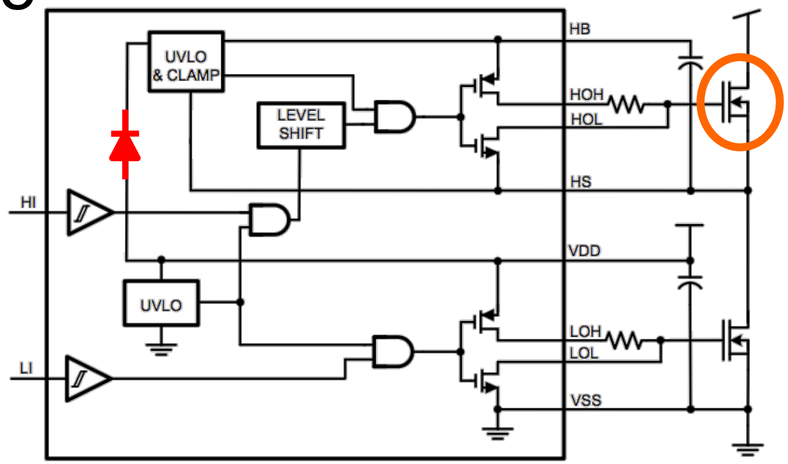
- All topologies are ZVS: $Q_G - Q_{GD}$
- C_{OSS} is "absorbed" in matching but is important as it:
  - Drives off resonance losses
  - Determines design-ability
- Q_{RR} ignored – poorly defined, amplifier is soft switching, BUT, transition time < t_{RR}:
  - eGaN FET Q_{RR} = 0 nC
  - MOSFET 2 Q_{RR} = 18.1 nC ! (FoM = 1900 nC·mΩ)



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

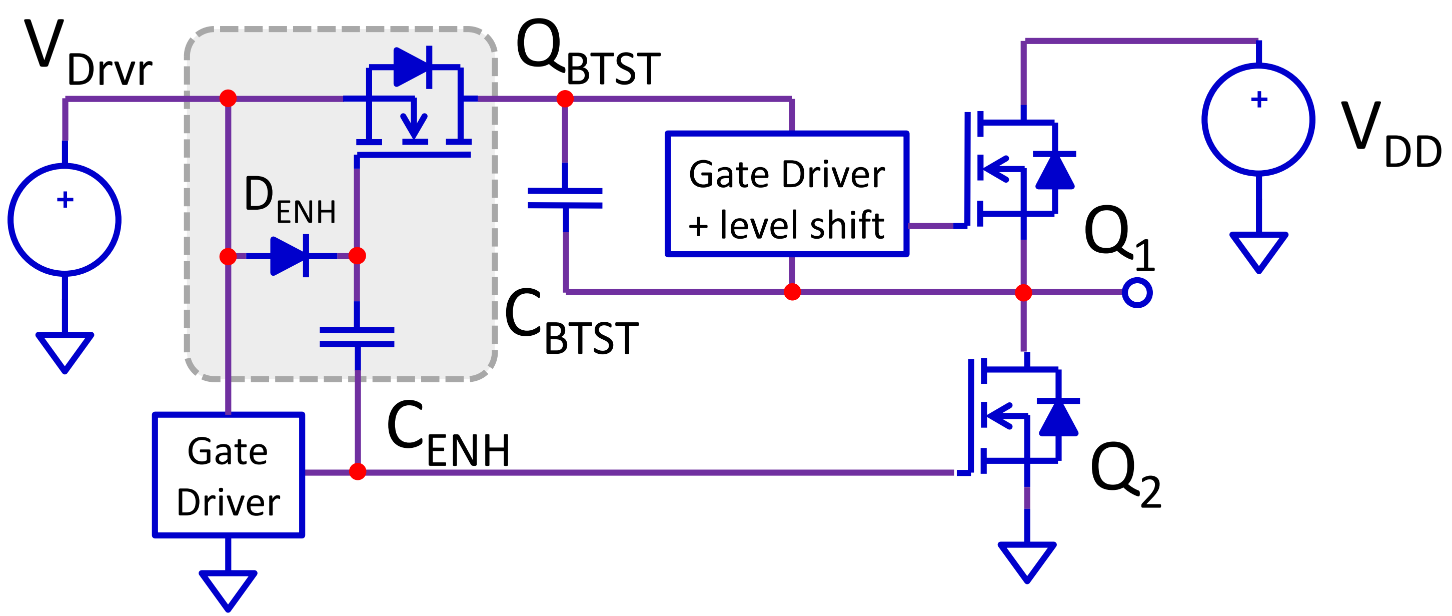
Gate Driver Induced Losses

- Gate drivers with internal bootstrap diodes always have Q_{RR} (schottky diode is very difficult to implement in IC form)
- Bootstrap diode Q_{RR} induces losses in the high side device
  - Q_{RR} losses proportional to frequency
  - Present even with ZVS as t_{ZVS} (Switch-node voltage transition time) is shorter than t_{RR}

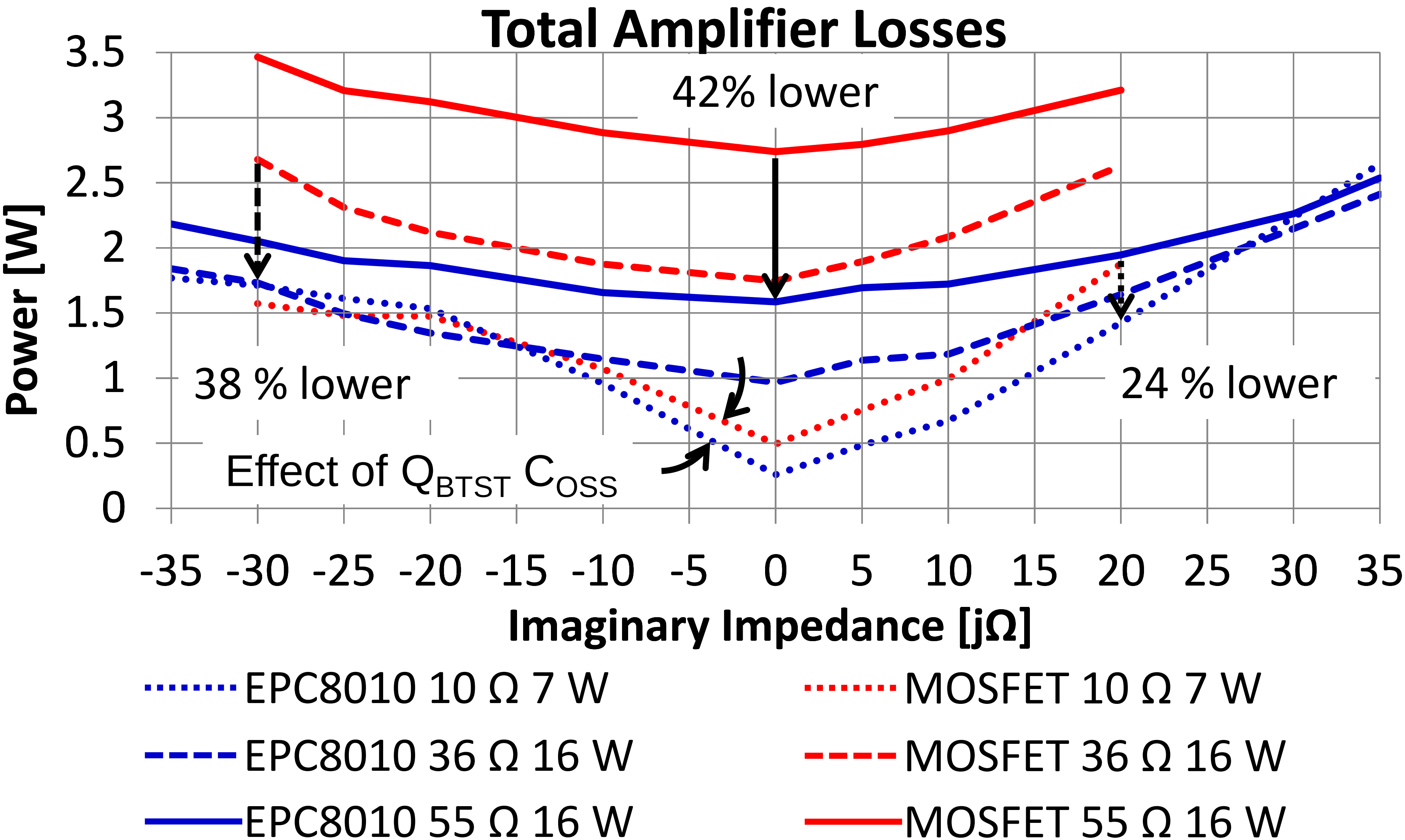


Synchronous FET Bootstrap

- Q_{BTST} – Bootstrap FET for main switch (Q_1) zero Q_{RR}
- Q_{BTST} – Switches synchronously with Q_2
- No additional active gate driver circuitry needed
- C_{ENH} – Used for level shifting
- D_{ENH} – Bootstrap diode for C_{ENH} (Low voltage < 20V zero Q_{RR})



Load Variation (jΩ) Results



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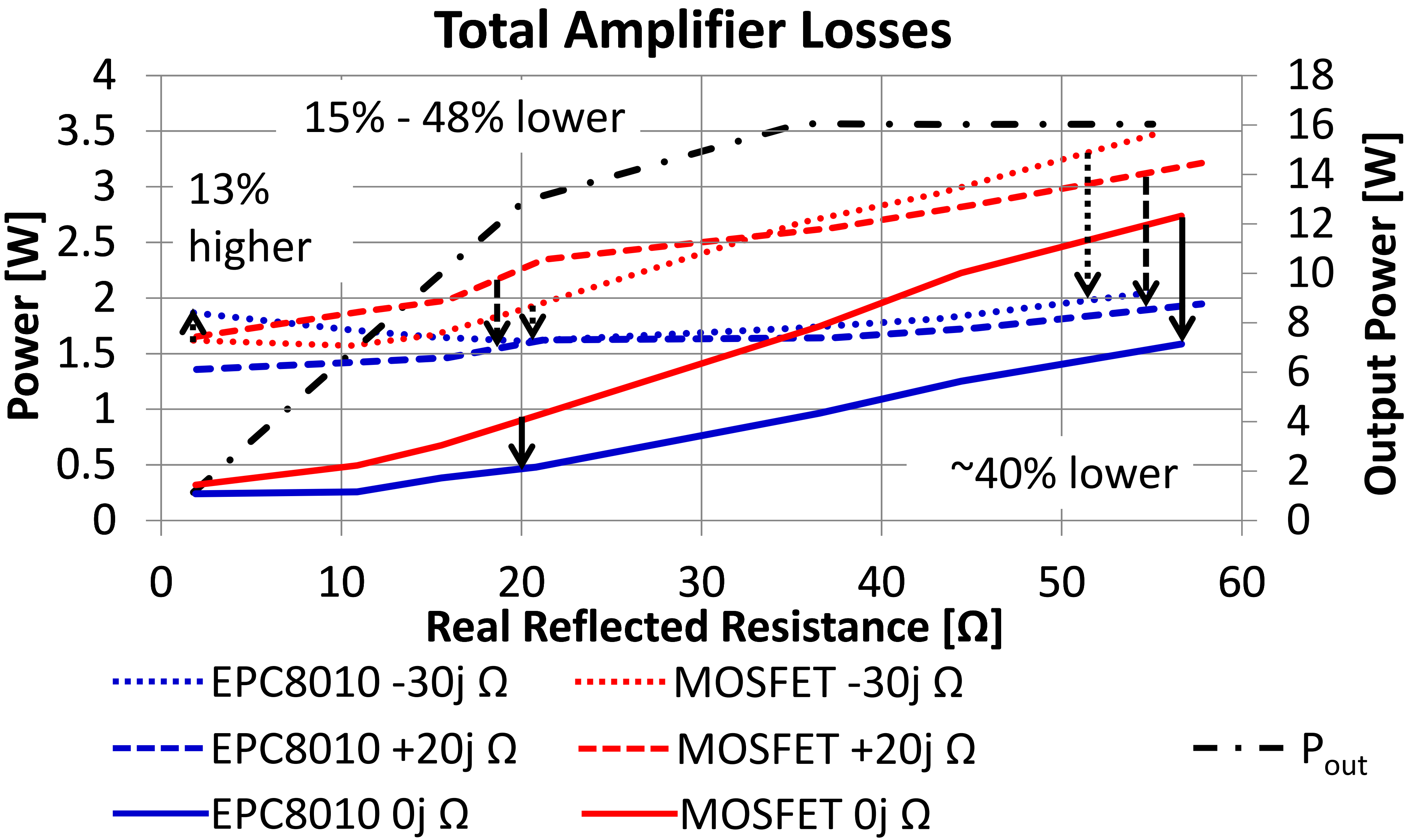
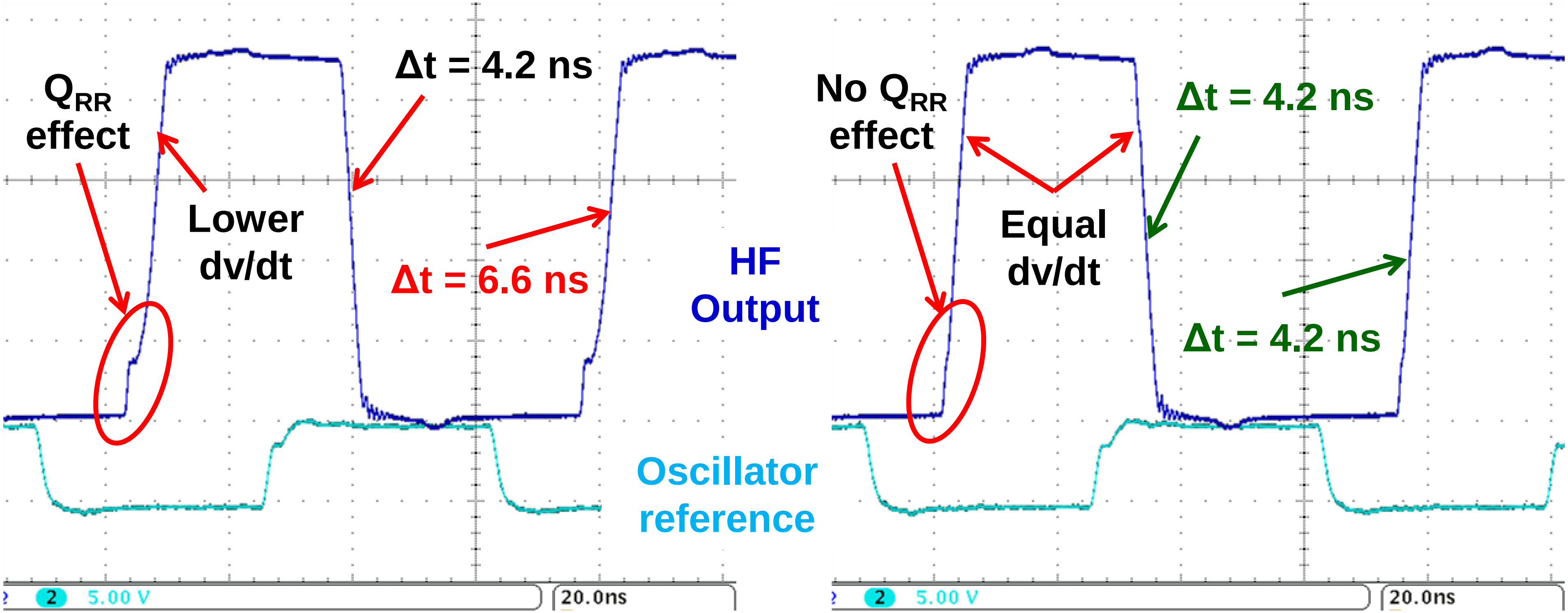


Waveform Improvements

V_{DD} = 45 V, No load



Original Internal Bootstrap Diode

eGaN FET Synchronous Bootstrap FET

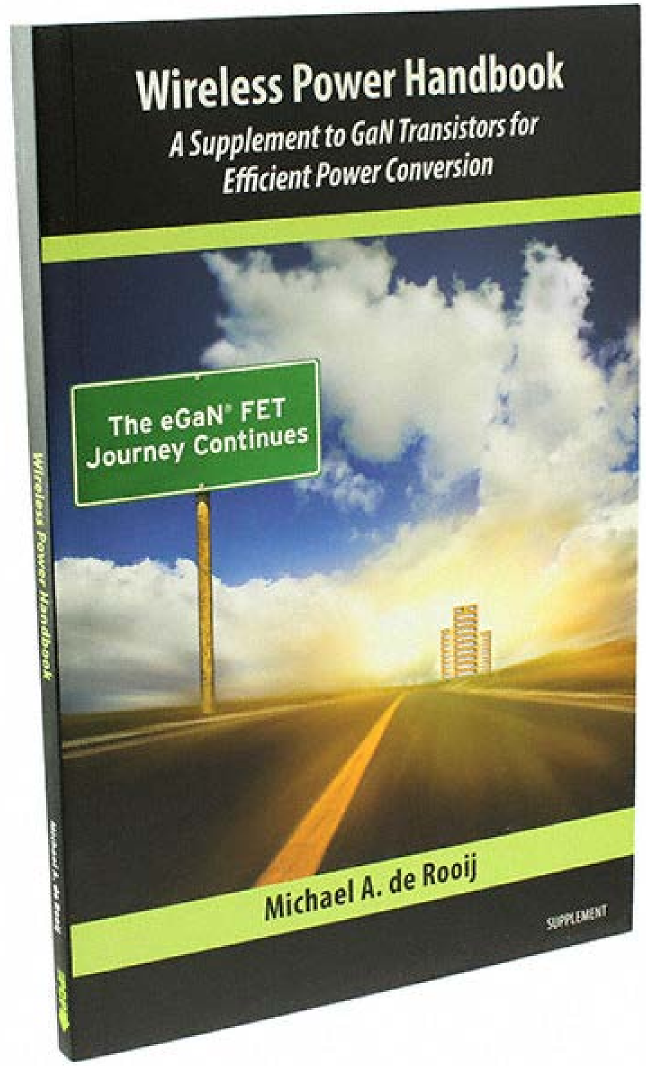
Summary

eGaN FETs in a ZVS Class D amplifier were tested to the A4WP Class-3 specifications :

- eGaN FETs always yield higher efficiency than best-in-class MOSFETs
- Gate driver and eGaN FET temperature remain below 100˚C
- eGaN FET's lower C_{OSS} reduces the ZVS current needed, resulting in lower power dissipation for both FET and L_{ZVS}
- eGaN FETs reduce board space by 40 %
- eGaN FETs enable a wider impedance drive range than MOSFETs

Wireless Power Handbook

Handbook on wireless power that covers this work and much more – available at Digi-Key (917-1098-ND)



Where is GaN going…