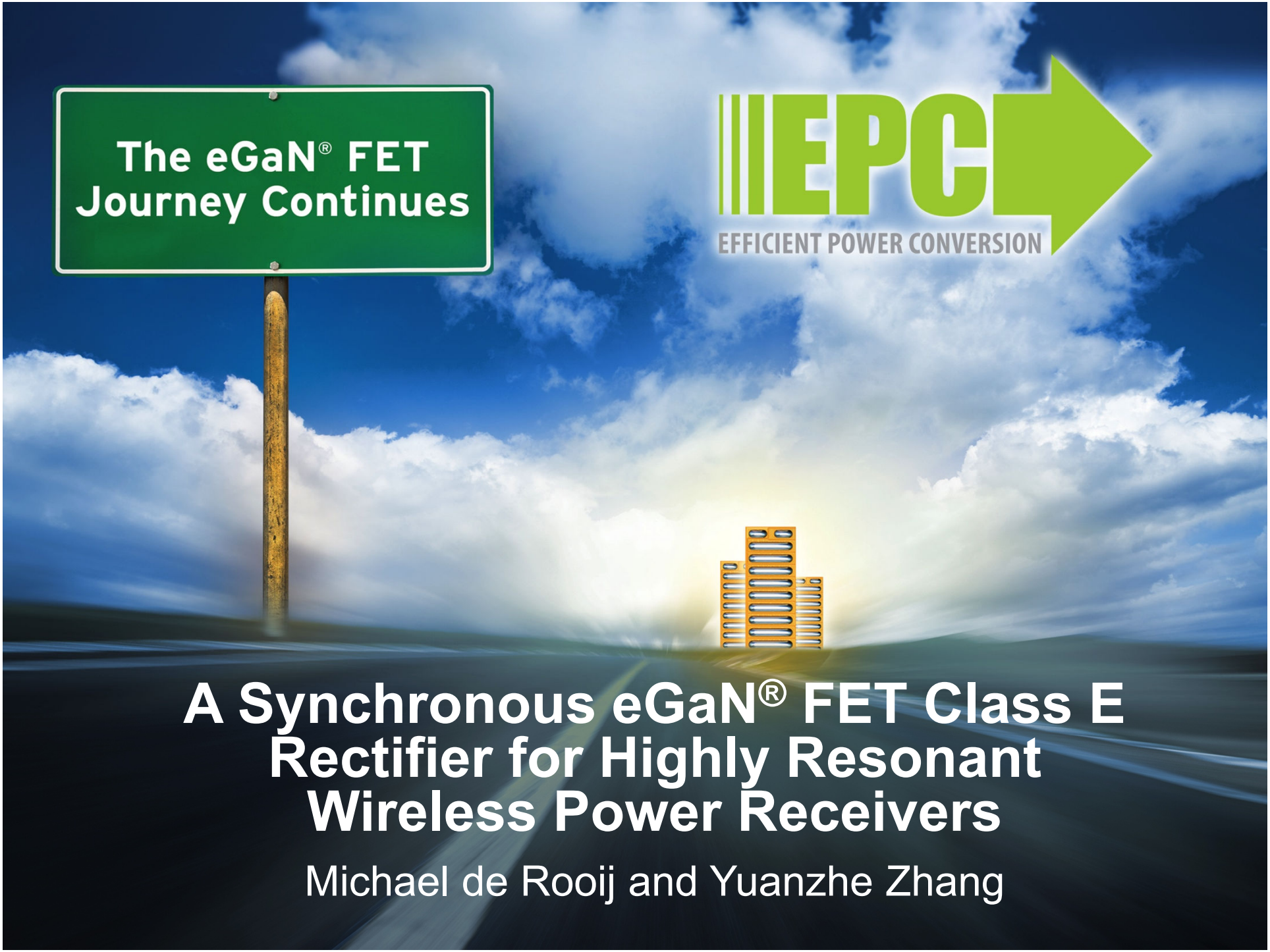


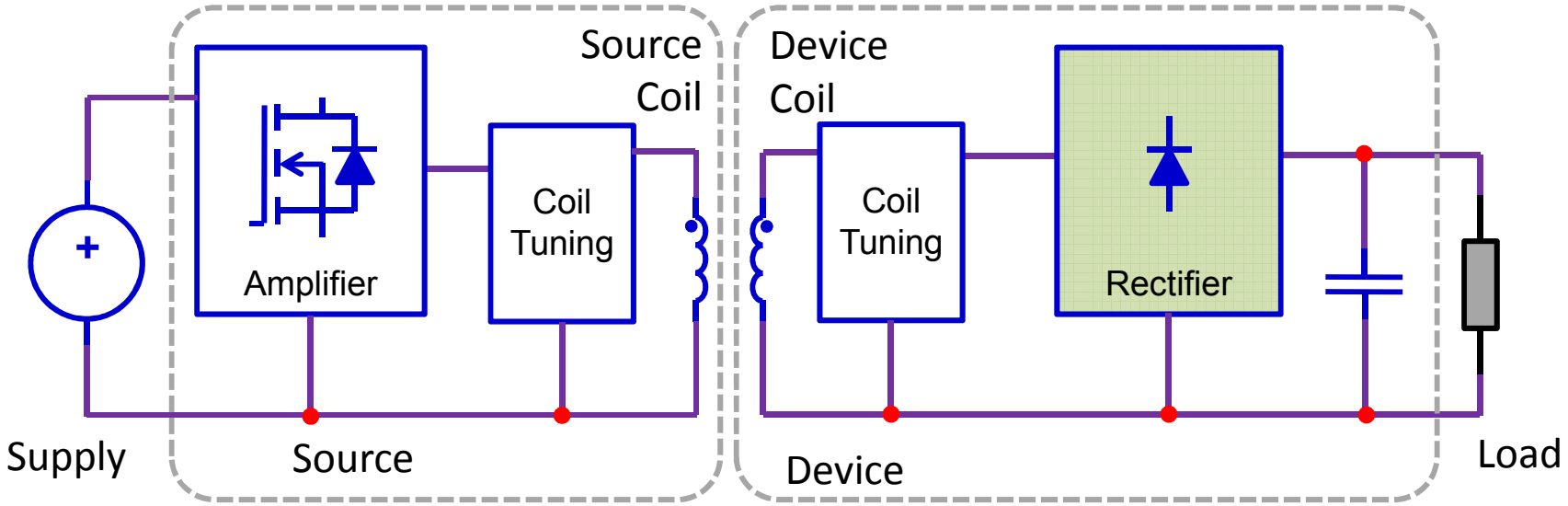
A Synchronous eGaN® FET Class E Rectifier for Highly Resonant Wireless Power Receivers

Michael de Rooij and Yuanzhe Zhang

Outline

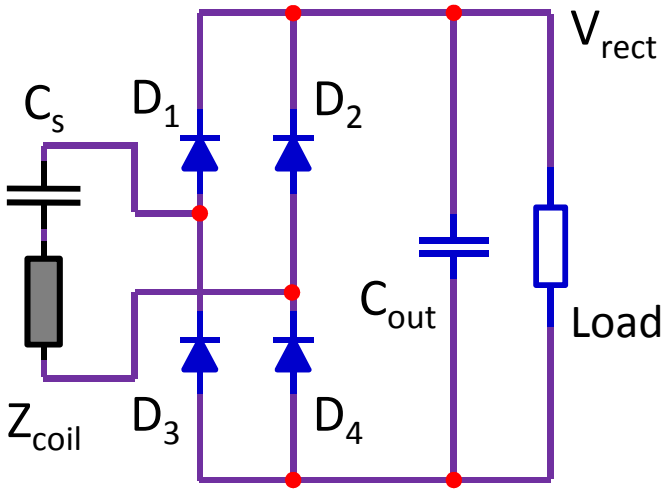
- Resonant wireless power receivers and rectifiers
- Class E rectifier
- Synchronization
- Experimental results
- Conclusions

Resonant Wireless Power Overview



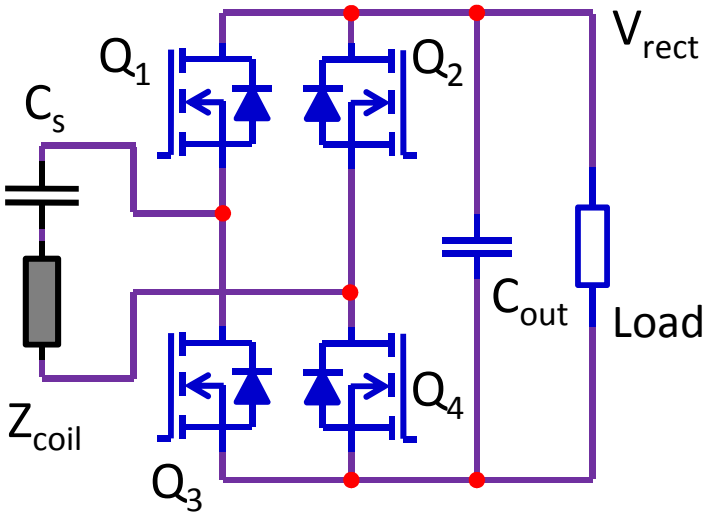
Full Bridge Rectifiers

Typical diode rectifier



- Simple
- popular choice at low frequency
- High Losses at 6.78 MHz

Synchronous rectifier

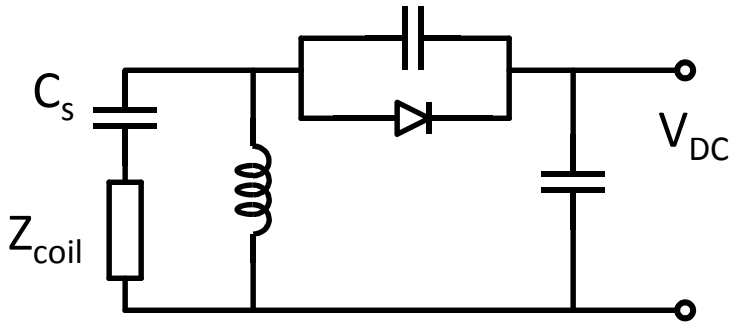


- More efficient
- Complicated gate drive
- Requires controller
- Operating power offsets benefit

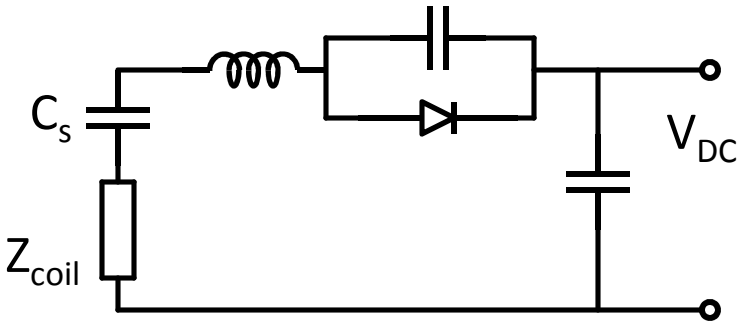
Class E Rectifiers

Typical diode location: in series with output

[1]



[2]

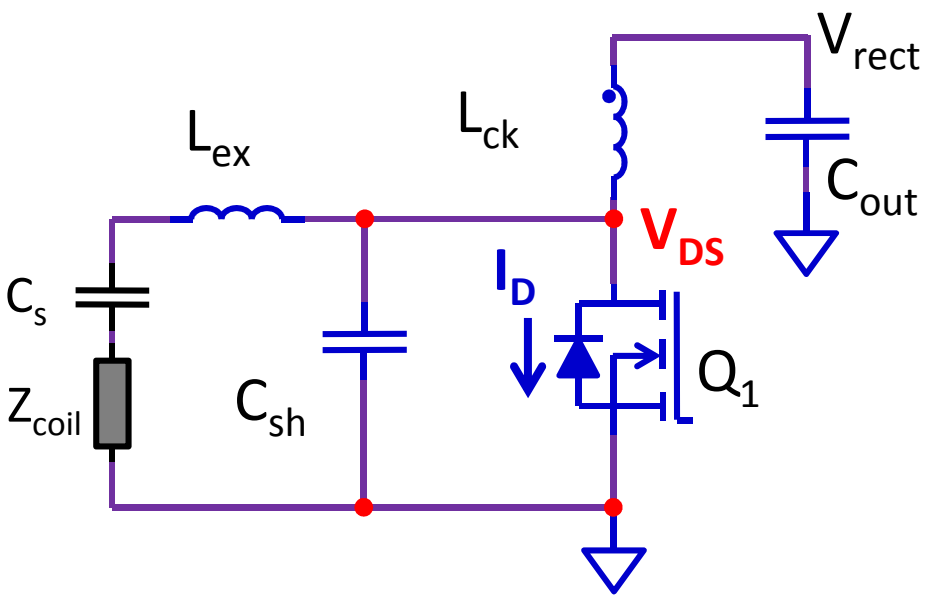


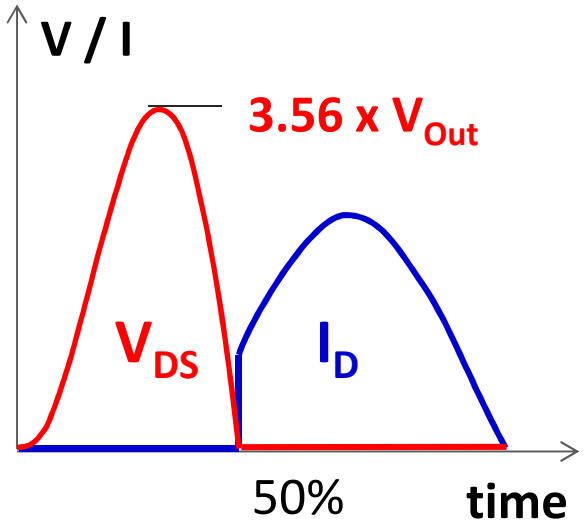
[1] M. Liu, M. Fu, and C. Ma, “Parameter Design for a 6.78-MHz Wireless Power Transfer System Based on Analytical Derivation of Class E Current-Driven Rectifier,” IEEE Trans. Power Electron., vol. 31, no. 6, pp. 4280-4291, June 2016.

[2] S. Aldhaher, P. C.Luk, K. E. K. Drissi, and J. F. Whidborne, “High-Input-Voltage High-Frequency Class E Rectifiers for Resonant Inductive Links”, IEEE Trans. Power Electron., vol. 30, no. 3, pp 1328-1335, Mar. 2015.

Proposed Synchronous Class E Rectifier

- Source grounded GaN FET
- Simple gate drive
- High efficiency – no Q_{RR}, low C_{OSS}, C_{ISS}, R_{DSon}

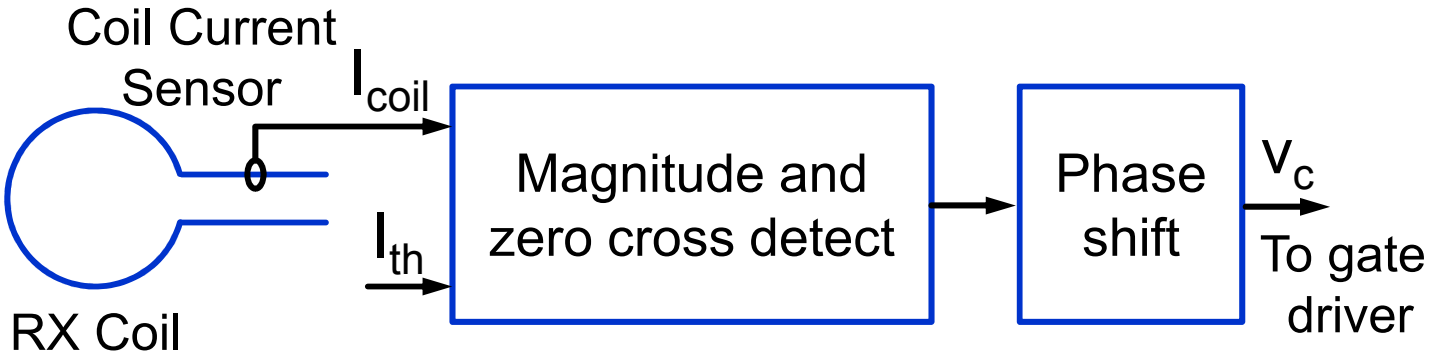




Ideal Waveforms

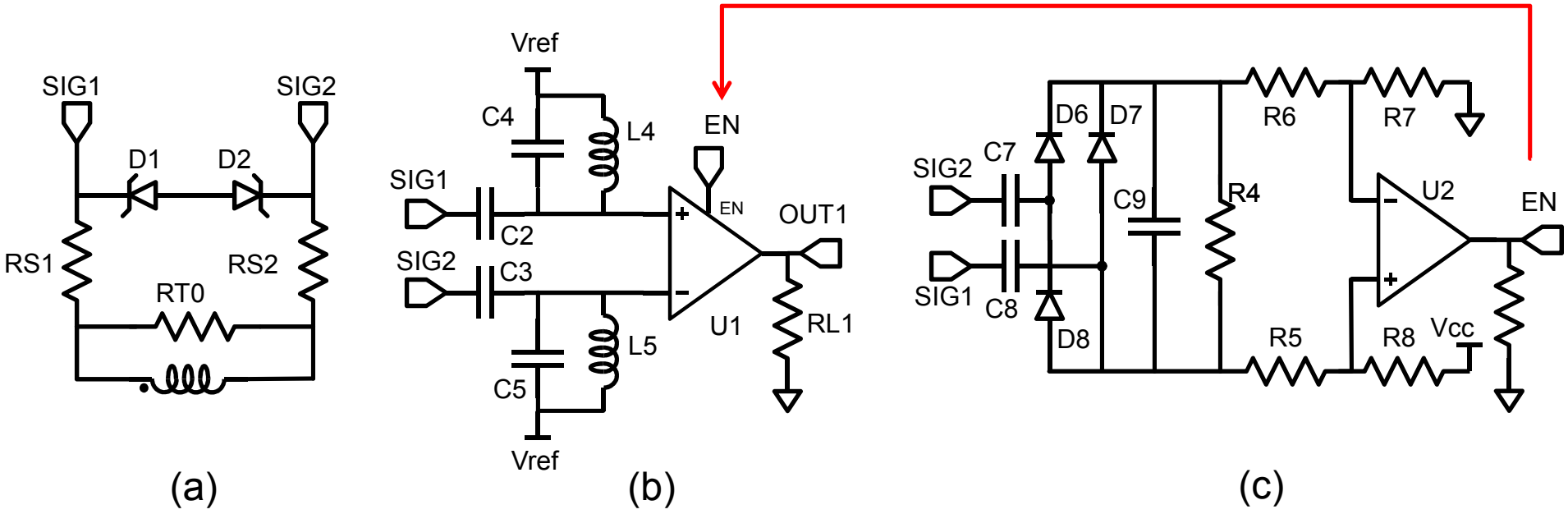
Gating Synchronization

- RX coil zero current cross detect
- Output disabled at low current ($<I_{th}$)



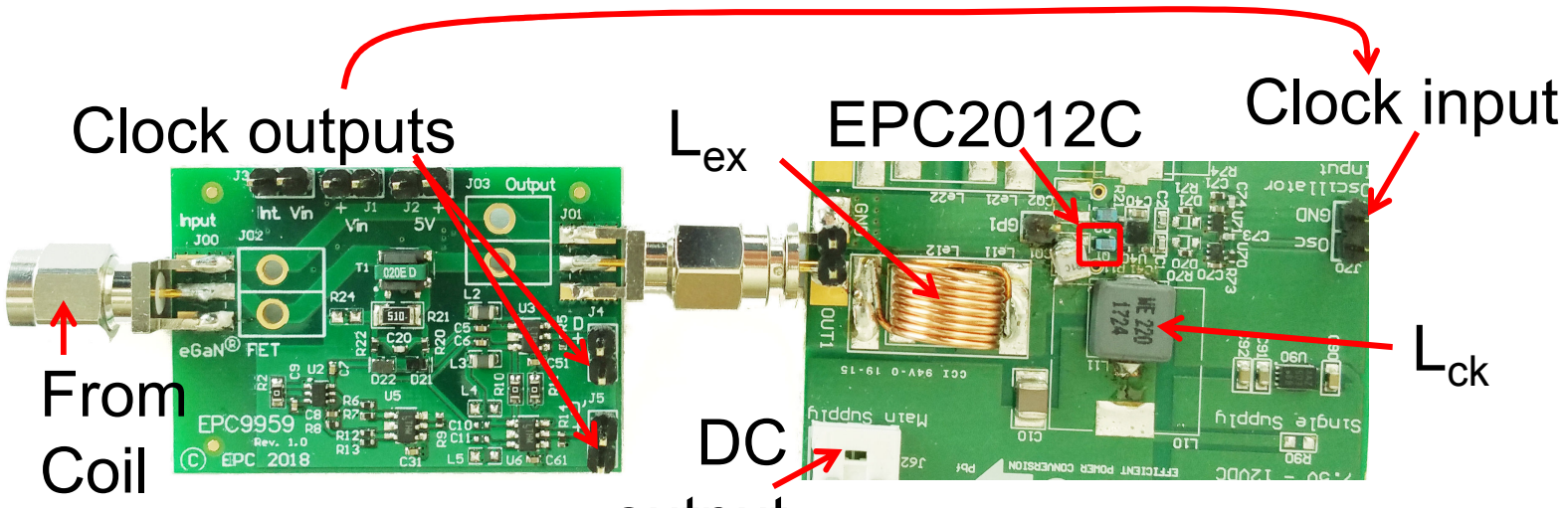
Gating Synchronization Detail

a) Current sensing with waveform clipping
b) AC-coupled zero crossing detect
c) Magnitude detect



Experimental Setup

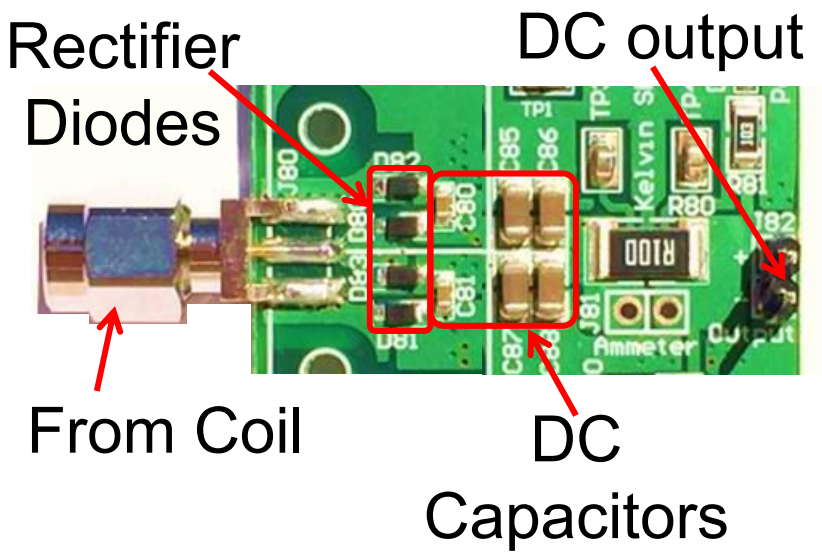
- Transmit coil current: 1.375 A_{RMS}
- Receive coil at 25 mm distance



C_{sh} = 77 pF
L_{ex} = 540 nH
L_{ck} = 22 µH

Diode Rectifier for Comparison

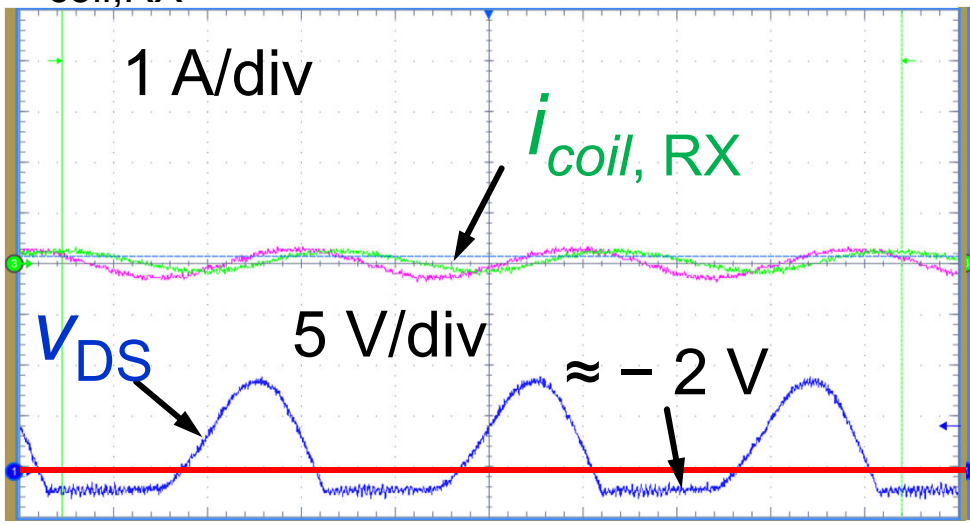
- 60 V best in class Schottky diodes
- Full bridge Configuration



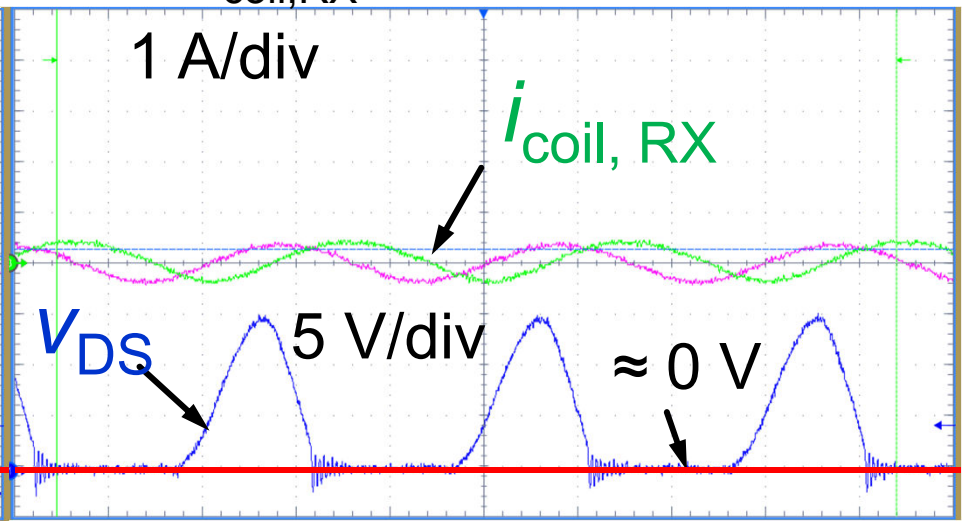
Synchronization Circuit Test

- I_{th} set to 100 mA_{RMS}
- Compensated for proper phase shift
- Both gate signals are off in “diode” mode

$I_{coil,RX}$ = 99 mA rms, ‘diode’ mode

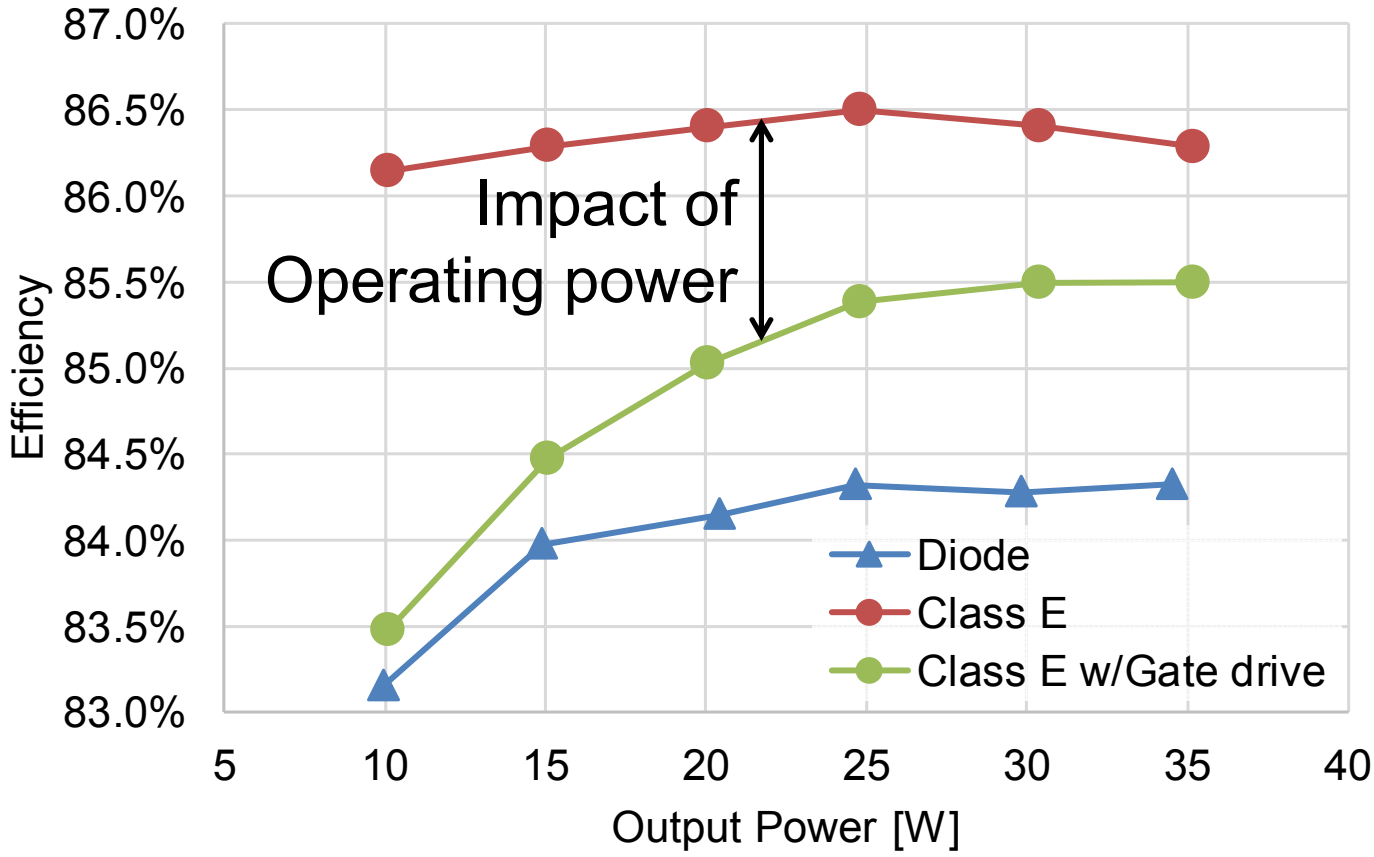


$I_{coil,RX}$ = 127 mA rms



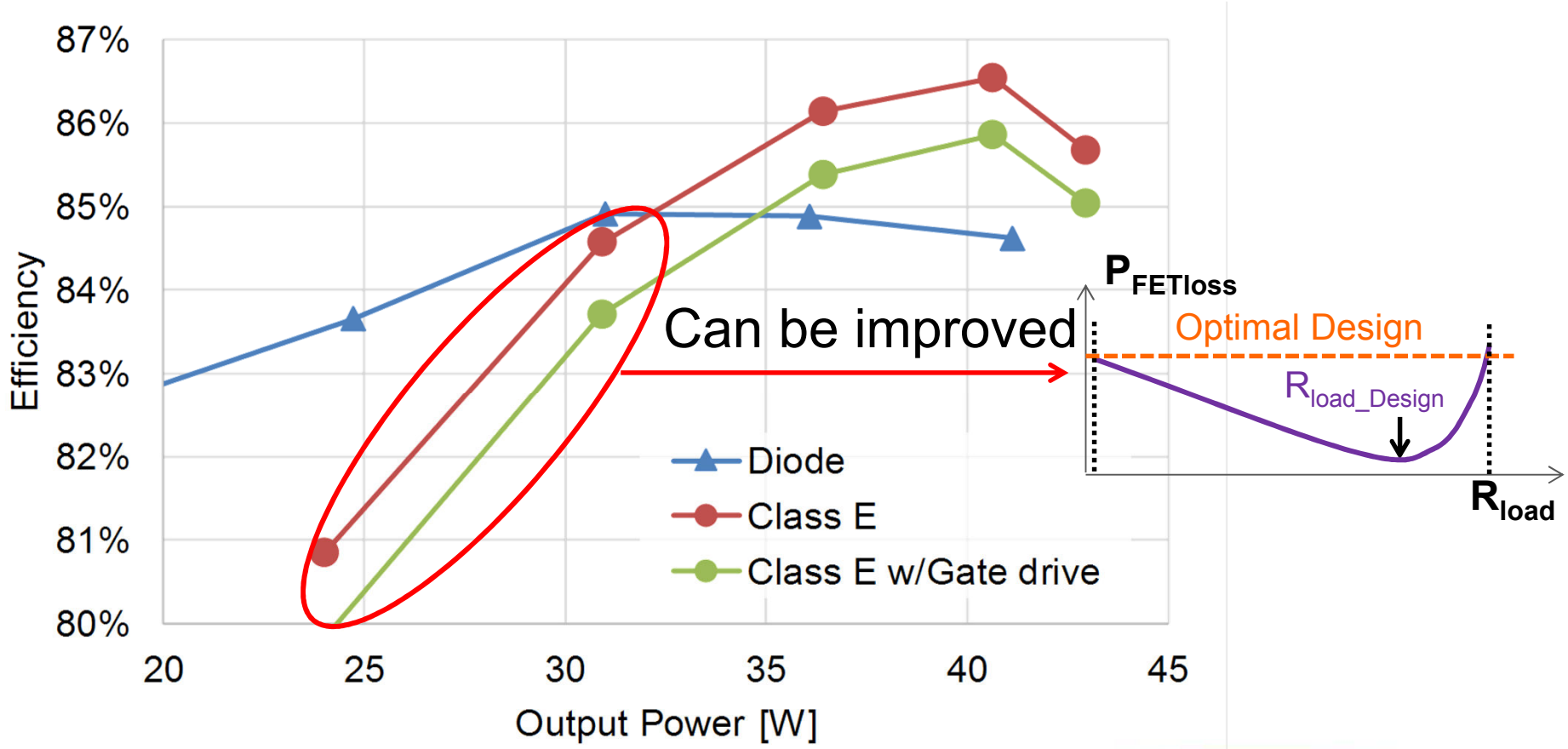
Measured Efficiency

Total system efficiency at fixed 40 Ω DC load



Measured Efficiency

- Fixed $I_{coil,TX}$ = 1.375 A_{RMS}
- Variable DC load (Resistance)

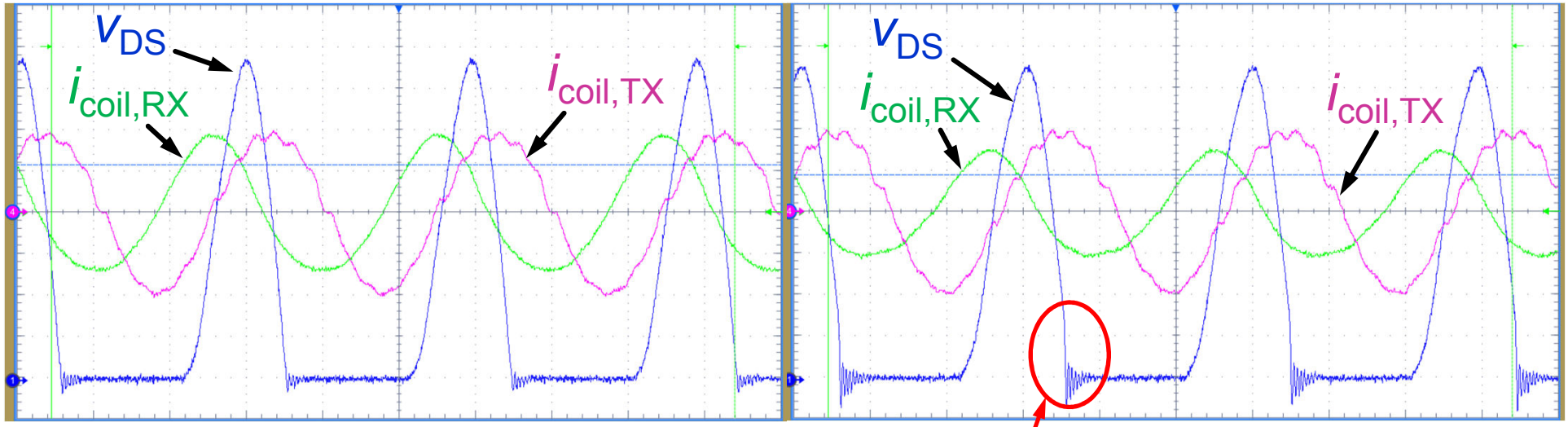


Experimental Waveforms

Fixed $I_{coil,\ TX}$ = 1.375 A_{RMS}

40 Ω load, 38.2 V_{DC},
36 W output

67 Ω load, 40 V_{DC},
24 W output



20 V/div 1 A/div

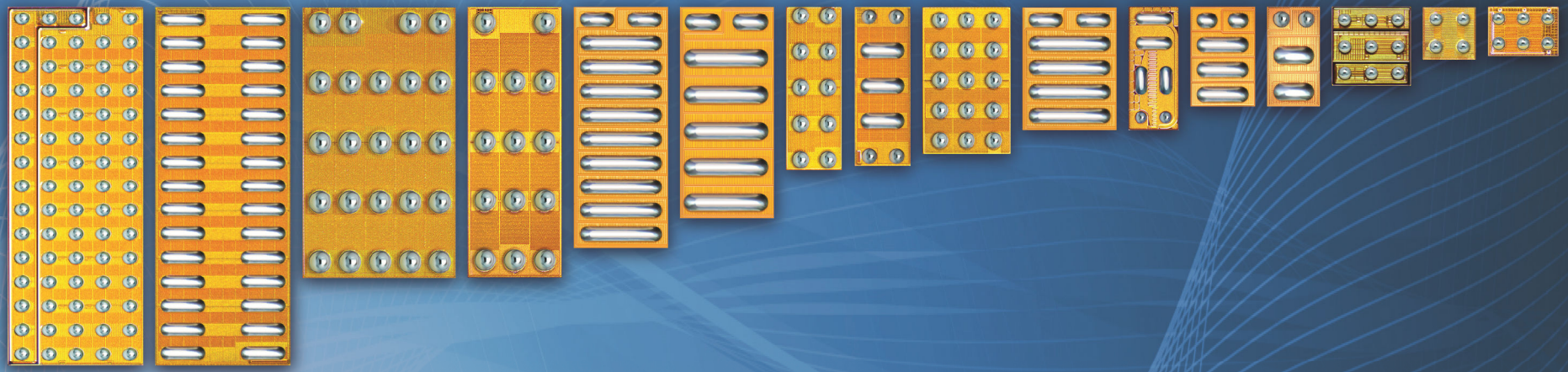
20 V/div 1 A/div

Hard switching

Conclusions

6.78 MHz eGaN FET synchronous class E rectifier

- More efficient than Schottky diode
- > 20% lower system power loss at > 35 W load
- Concept can be monolithically integrated
  - Gate driver
  - Signal detect



Thank You

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