IWWPE
2014

Crushing Silicon With GaN

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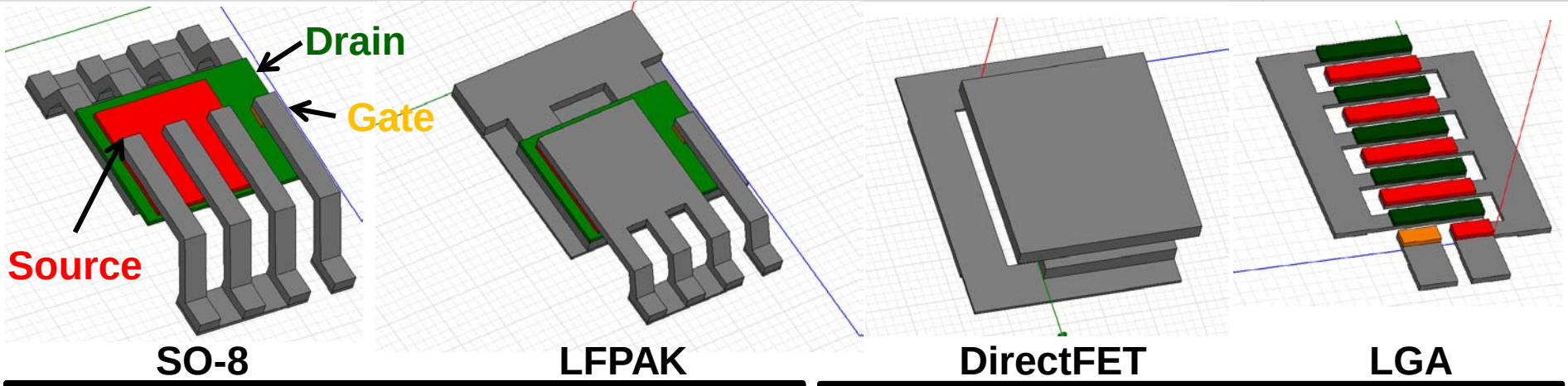
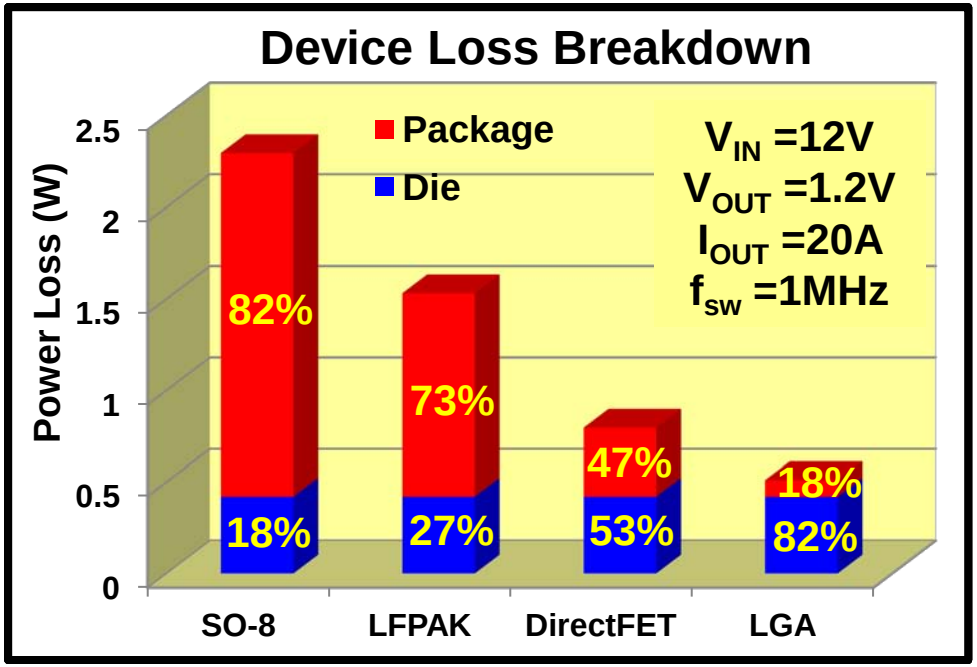
Efficient Power Conversion Corporation

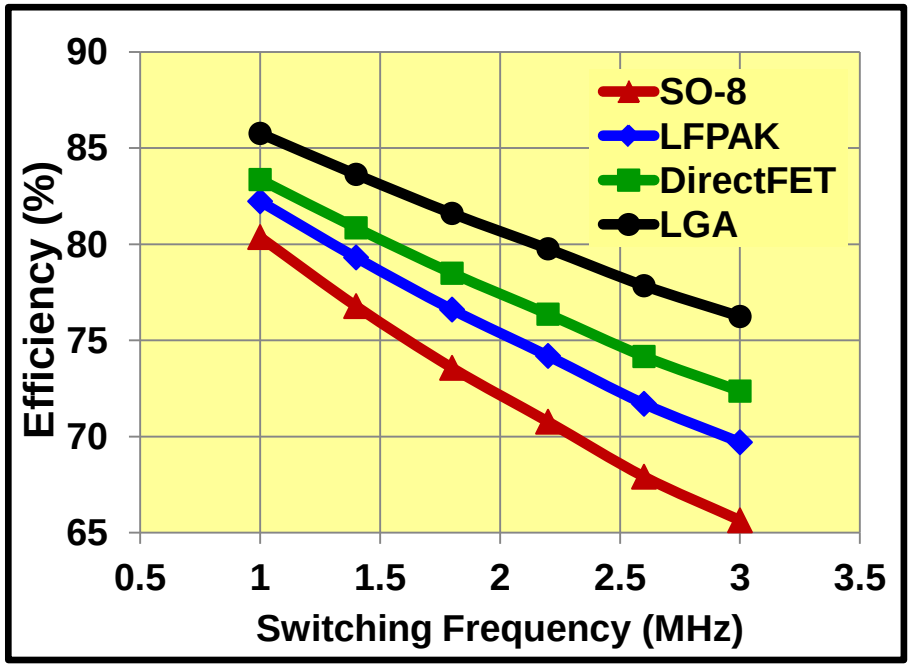
Agenda

- What have we learned?
- Wireless Power
- Envelope Tracking
- Summary

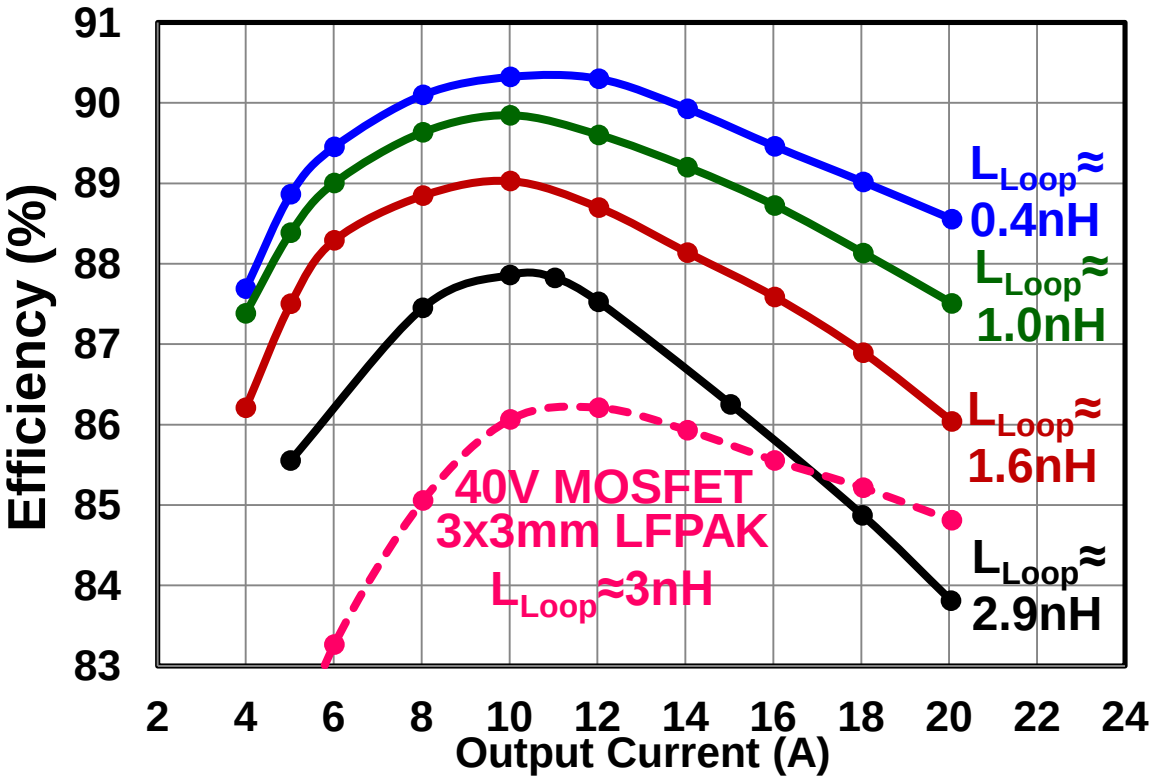
Package Impact on Efficiency







Layout Impact on Efficiency

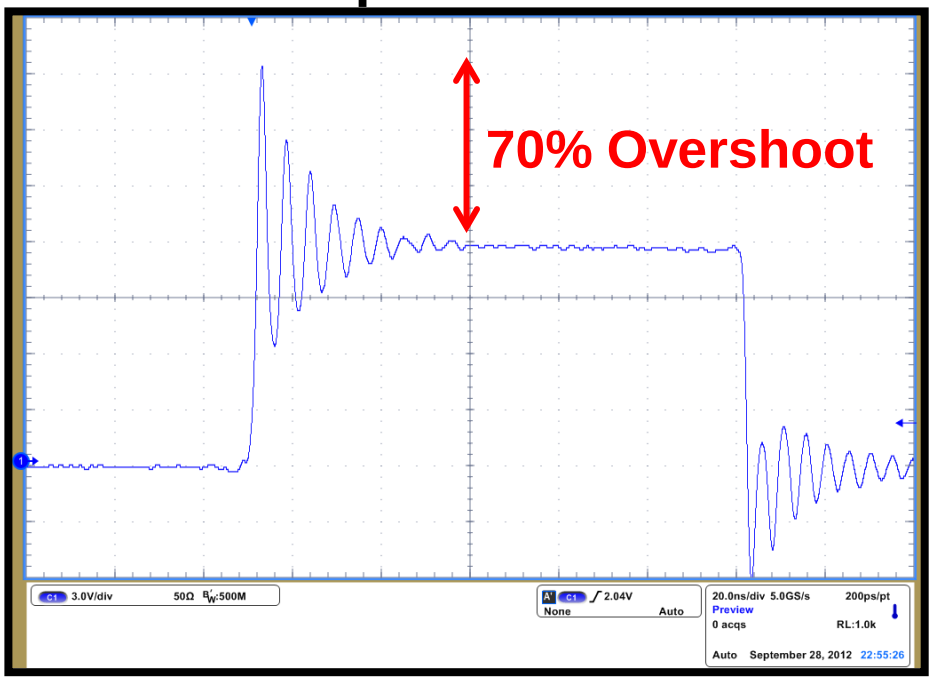


Prototype
L_{LOOP}≈0.4 nH

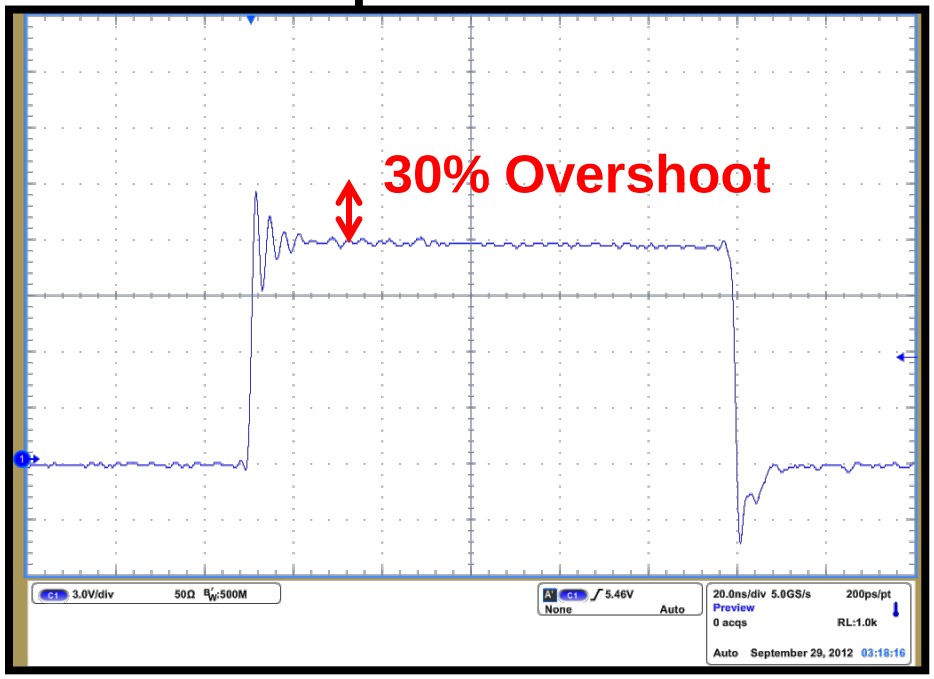
V_{IN}=12 V, V_{OUT}=1.2 V, f_{sw}=1 MHz, L=150 nH

Layout Impact on Peak Voltage

L_{Loop}≈1.0 nH



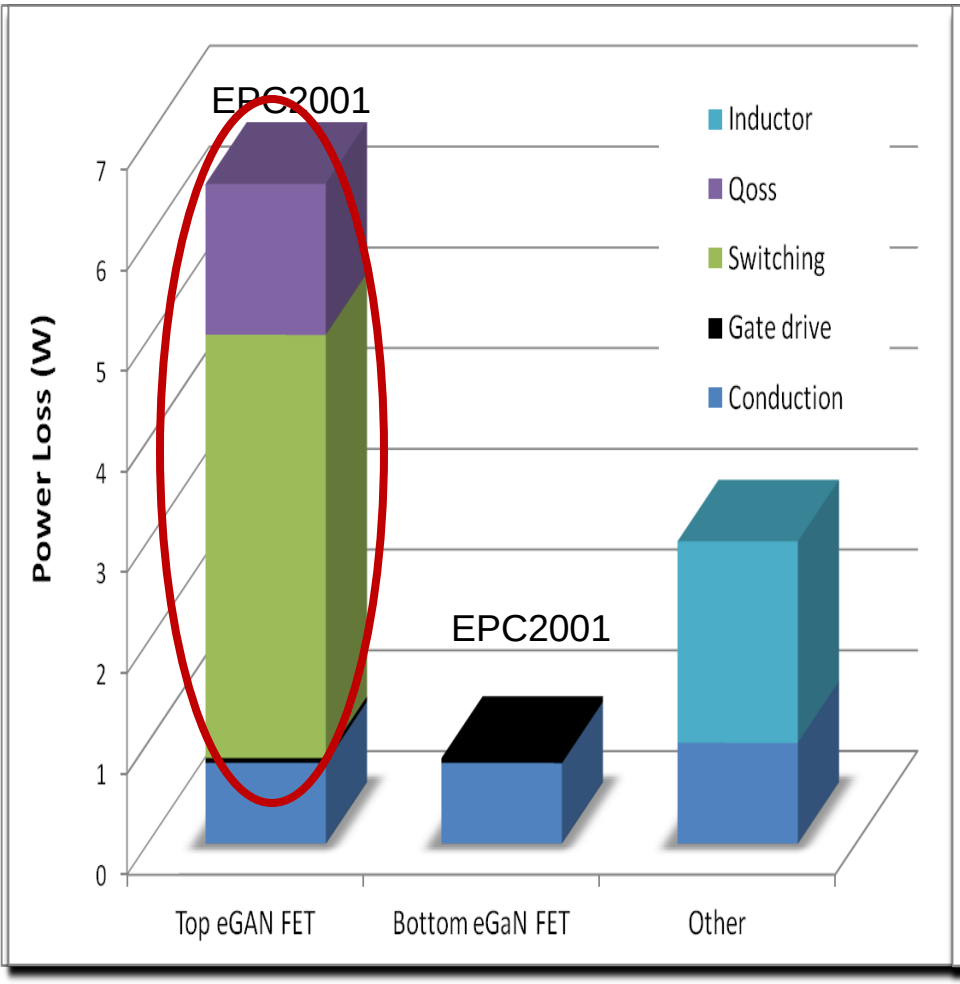
L_{Loop} ≈ 0.4 nH



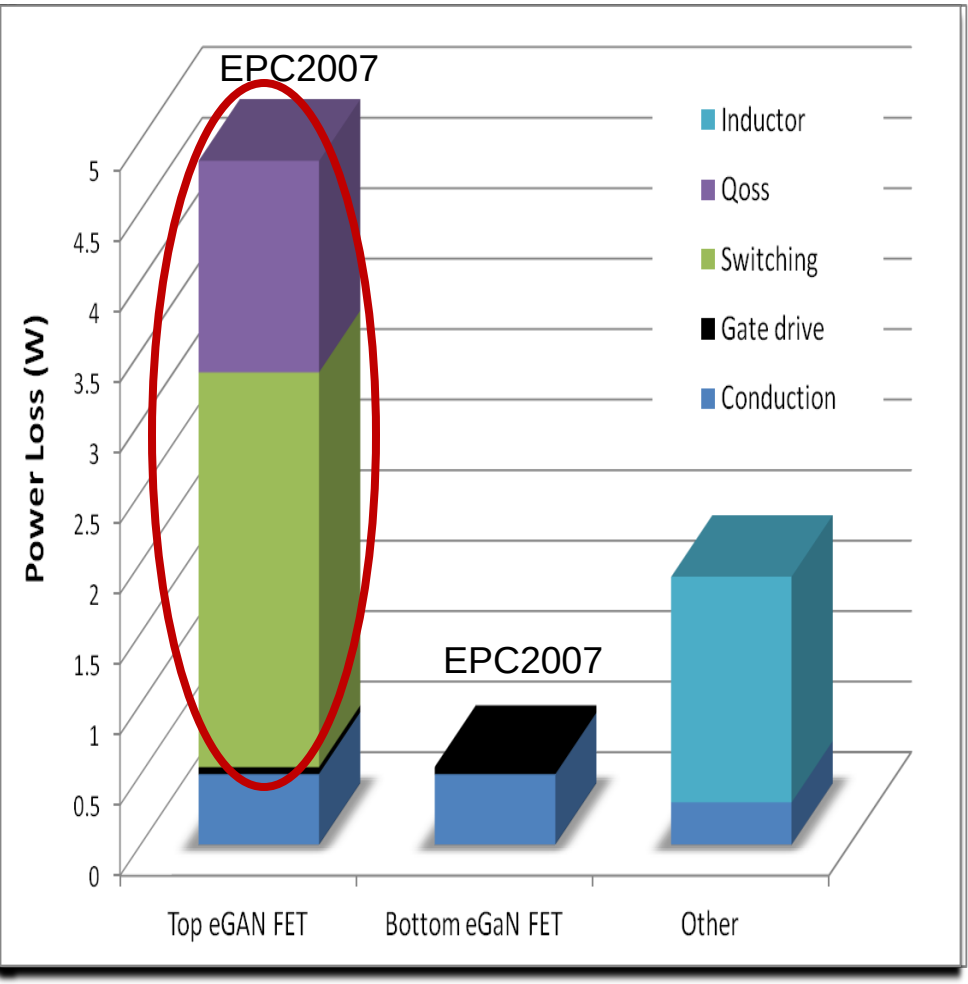
Switching Node Voltage

V_{IN}=12 V V_{OUT}=1.2 V I_{OUT}=20 A f_{sw}=1 MHz L=150 nH

Die Size Impact on Efficiency



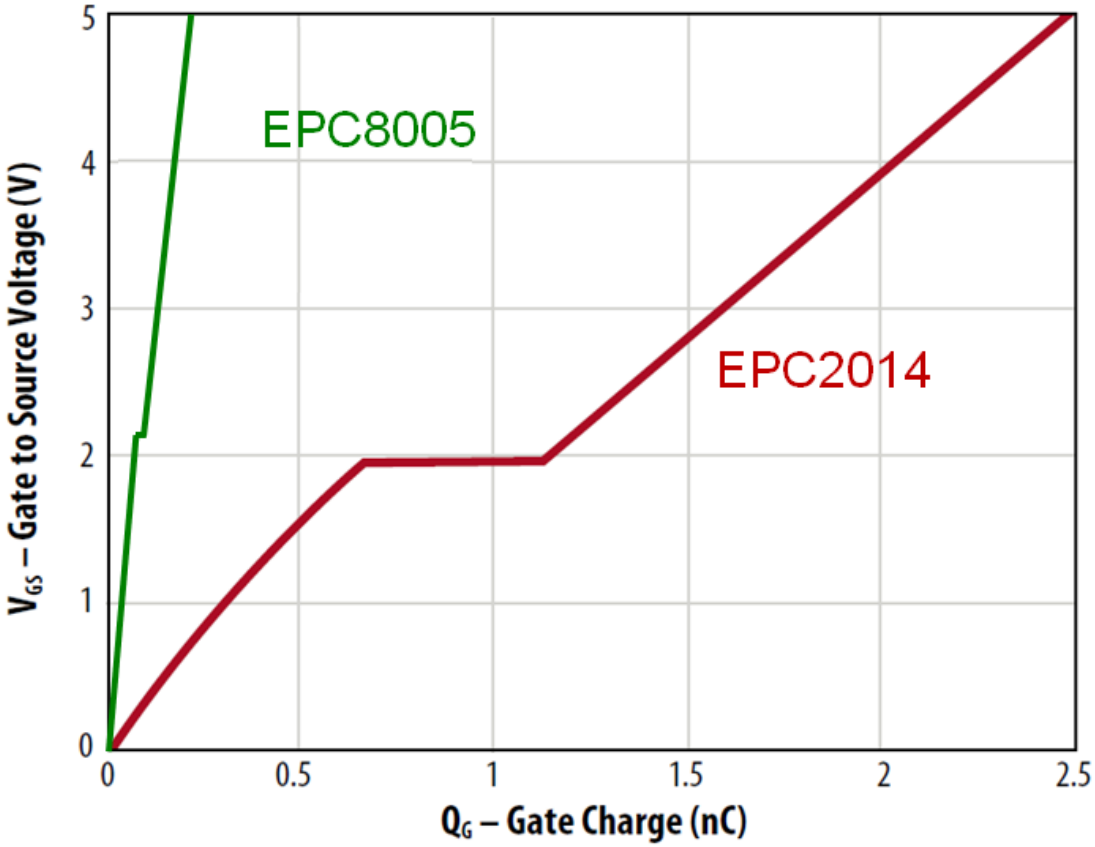
1 MHz EPC9002



4 MHz EPC9006

Crushing Silicon
Generation 3 eGaN FETs

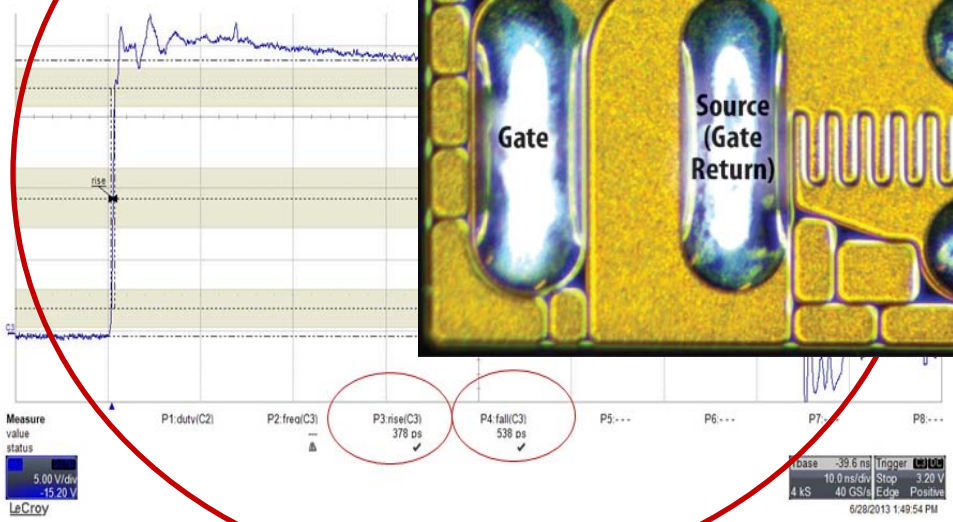
Generation 3 eGaN® FETs

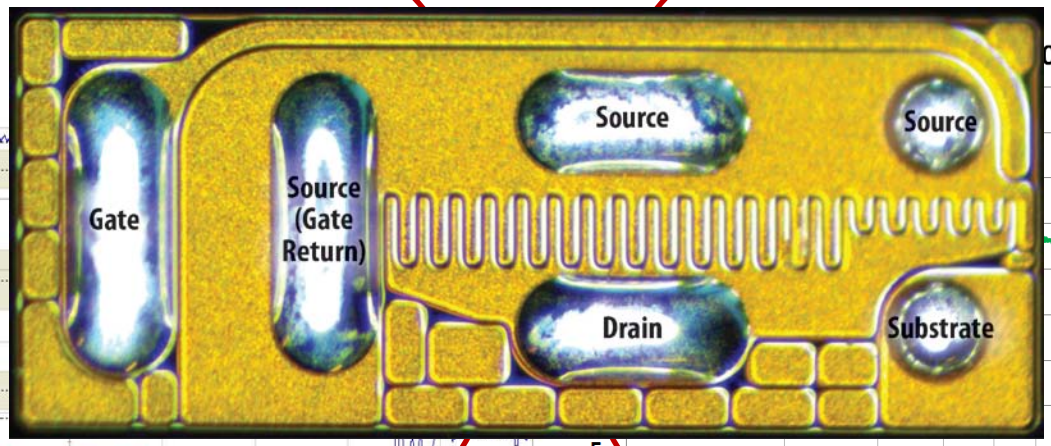


Up to a 2 X FOM Improvement!

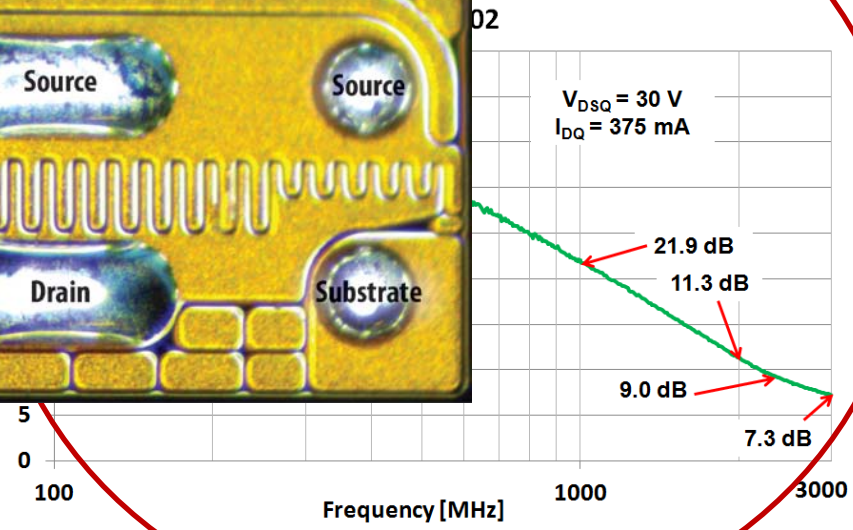
Gen 3 eGaN FETs are *FAST!*

- 4 A load, 1 MHz
- 380 ps rise, 540 ps fall





EPC8007 driven by LM5113



EPC8002

Ultra High Frequency eGaN® FETs

EPC Part No.	BV (V)	Max. $R_{DS(ON)}$ (mΩ) (V_{GS} = 5V, I_D = 0.5 A)	Min. Peak Id (A) (Pulsed, 25 °C, T_{pulse} = 300 µs)	Typical Charge (pC)					Typical Capacitance (pF) (V_{DS} = 20 V; V_{GS} = 0 V)		
				Q_G	Q_{GD}	Q_{GS}	Q_{OSS}	Q_{RR}	C_{ISS}	C_{OSS}	C_{RSS}
EPC8004	40	125	7.5	358	31	110	493	0	45	17	0.4
EPC8007	40	160	6	302	25	97	406	0	39	14	0.3
EPC8008	40	325	2.9	177	12	67	211	0	25	8	0.2
EPC8009	65	138	7.5	380	36	116	769	0	47	17	0.4
EPC8005	65	275	3.8	218	18	77	414	0	29	9.7	0.2
EPC8002	65	530	2	141	9.4	59	244	0	21	5.9	0.1
EPC8003	100	300	5	315	34	110	1100	0	38	18	0.2
EPC8010	100	160	7.5	354	32	109	1509	0	47	18	0.2

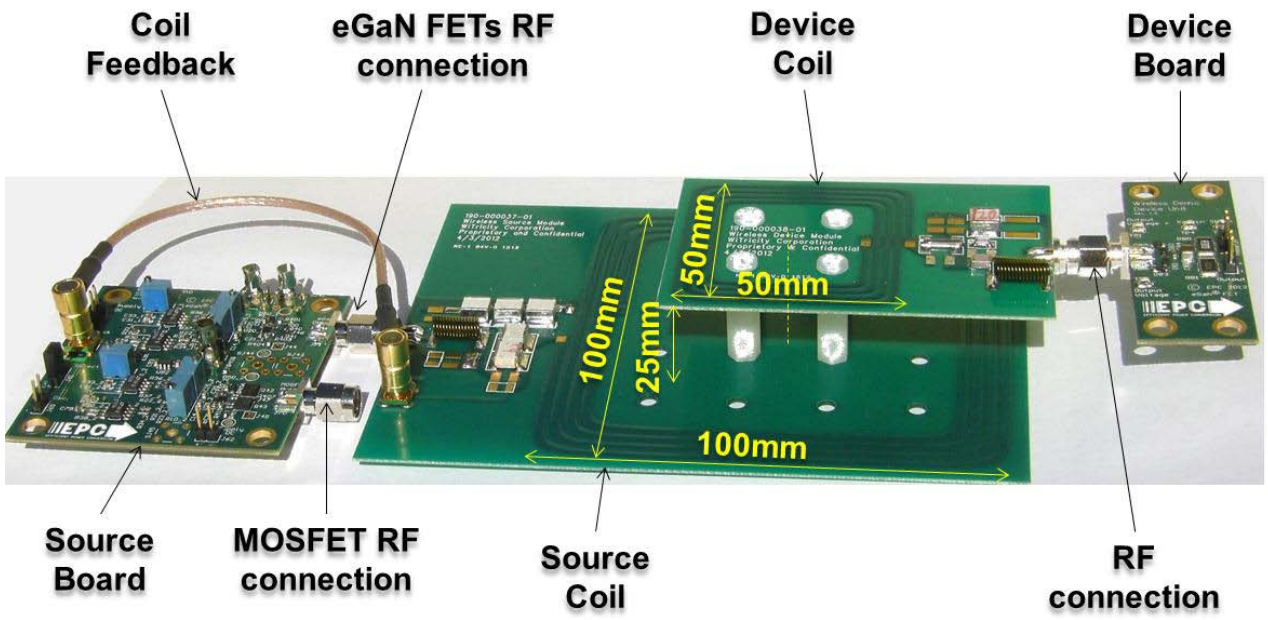
* Preliminary Data – Subject to Change without Notice

Wireless Power

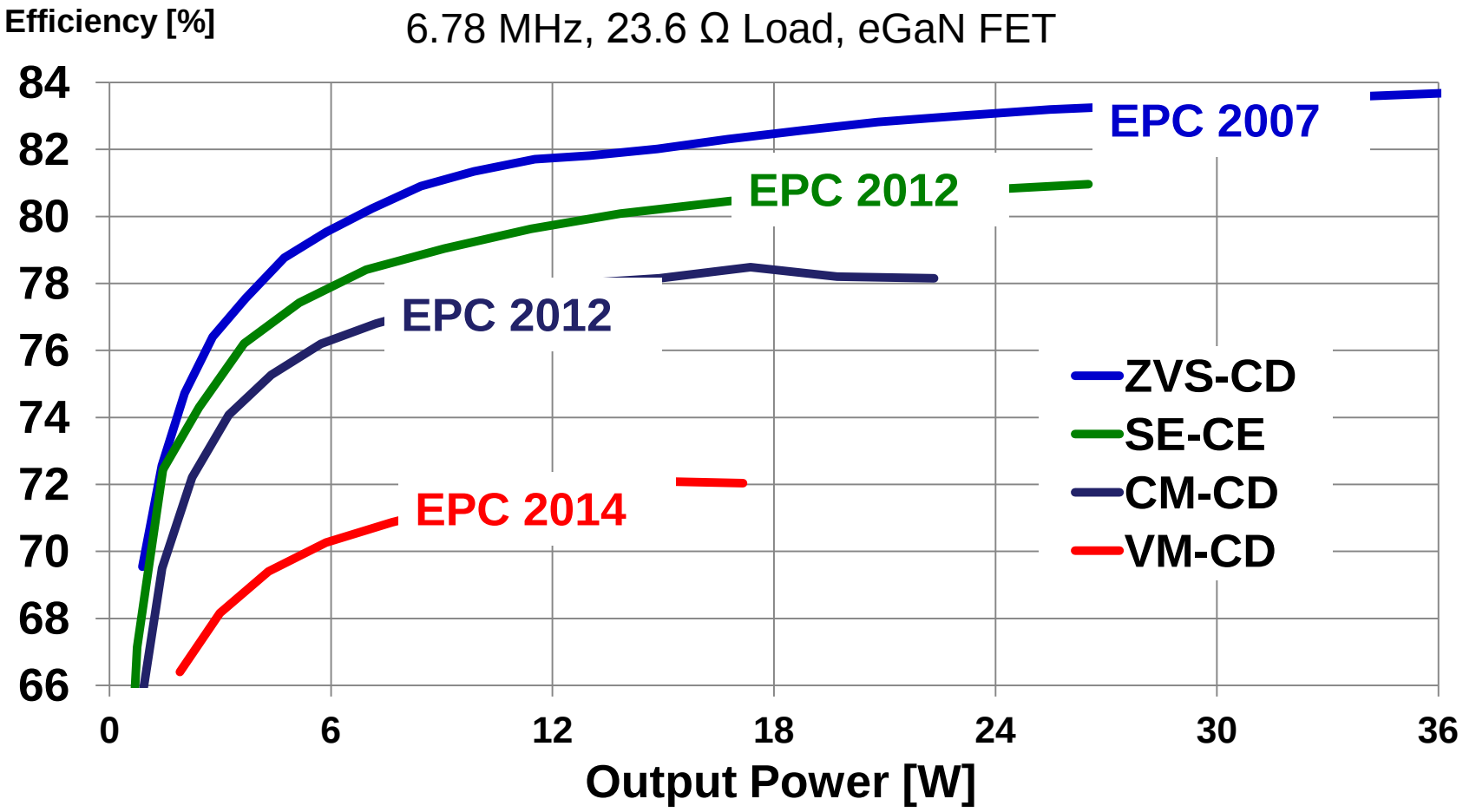
Why Wireless Power?

- eGaN FETs enable higher efficiency and operation at safer frequencies
- The global wireless charging market is estimated to grow to $10B by 2018, a CAGR of 42.6%

Wireless Power

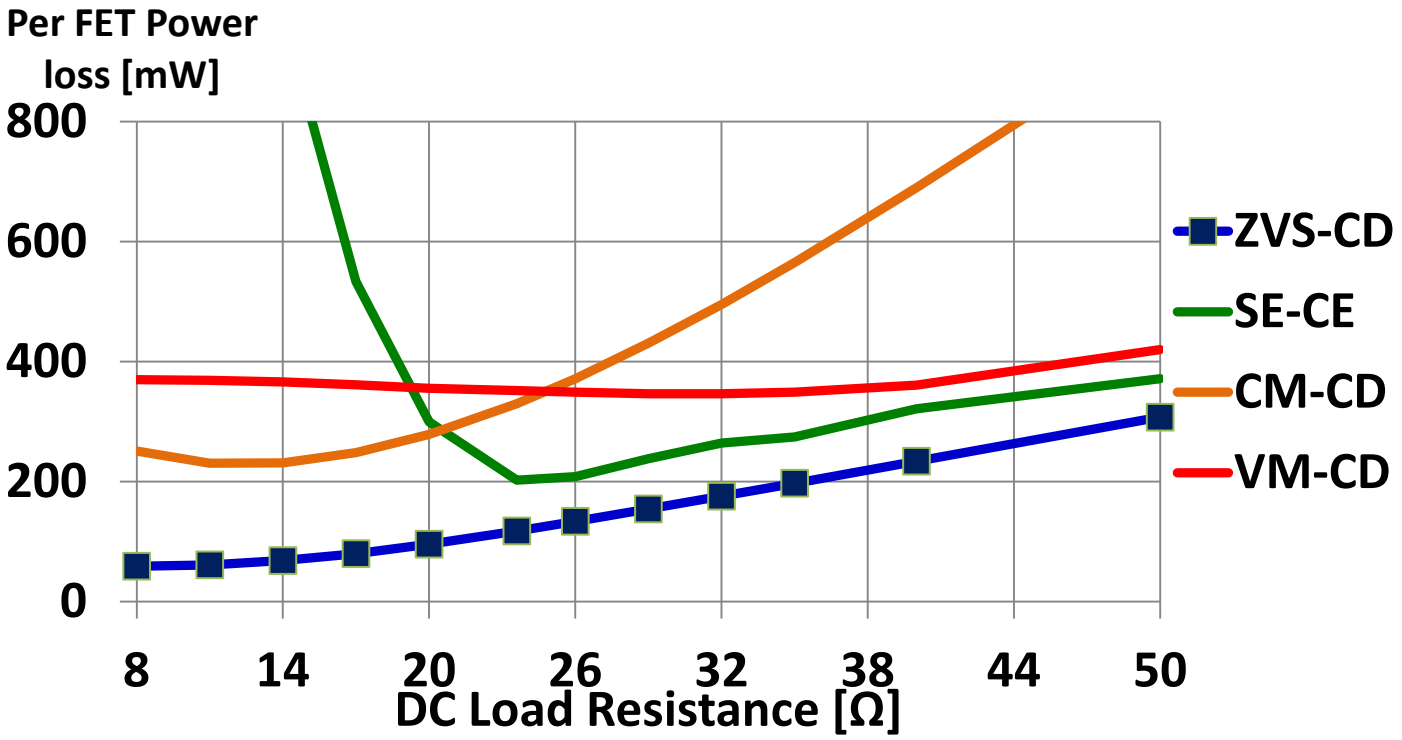


Efficiency



eGaN FETs enable the highest efficiency in all topologies using 6.78 MHz and 13.56 MHz frequencies.

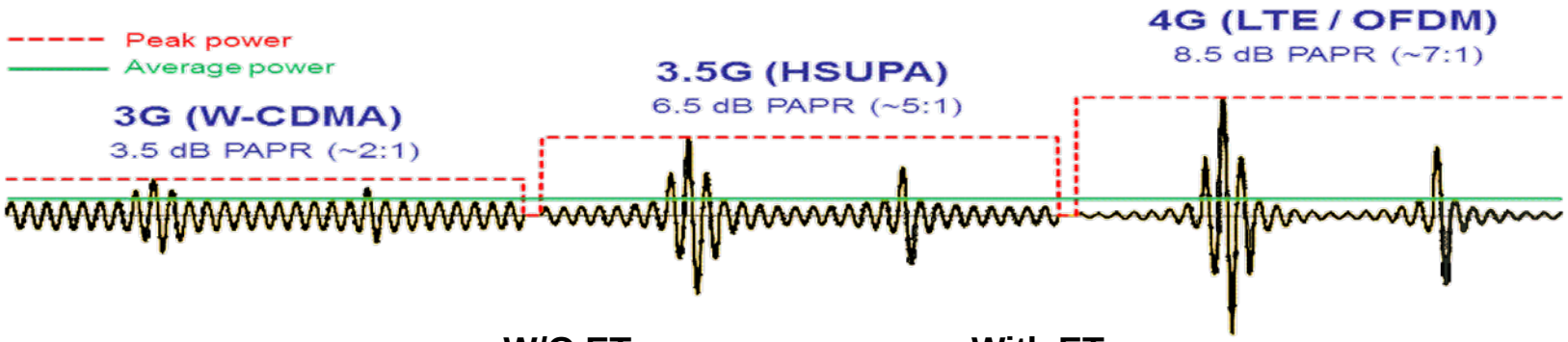
ZVS Class D



ZVS class D has higher efficiency and a broader operating range than class E.

Envelope Tracking

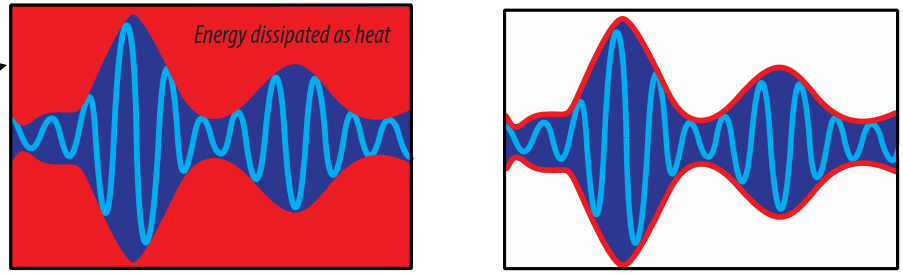
Envelope Tracking



W/O ET

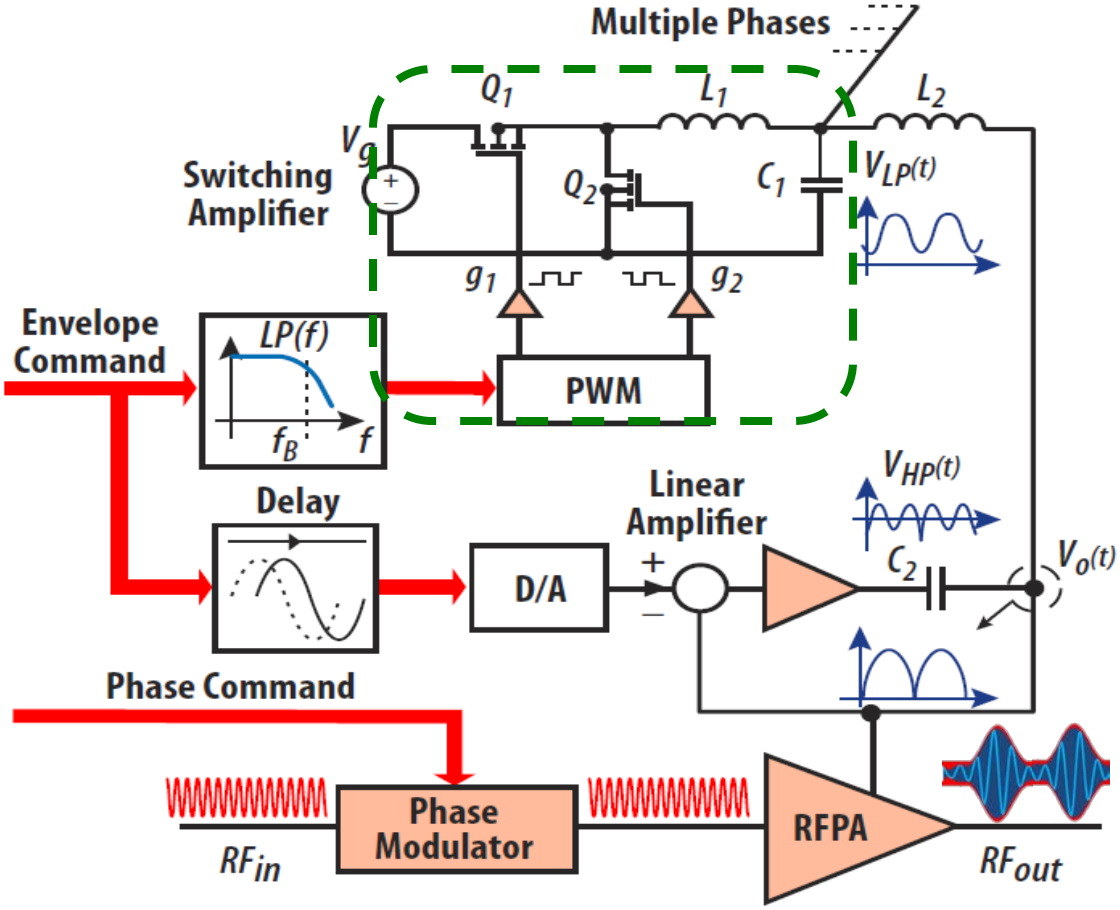
With ET

Red represents wasted energy dissipated as heat

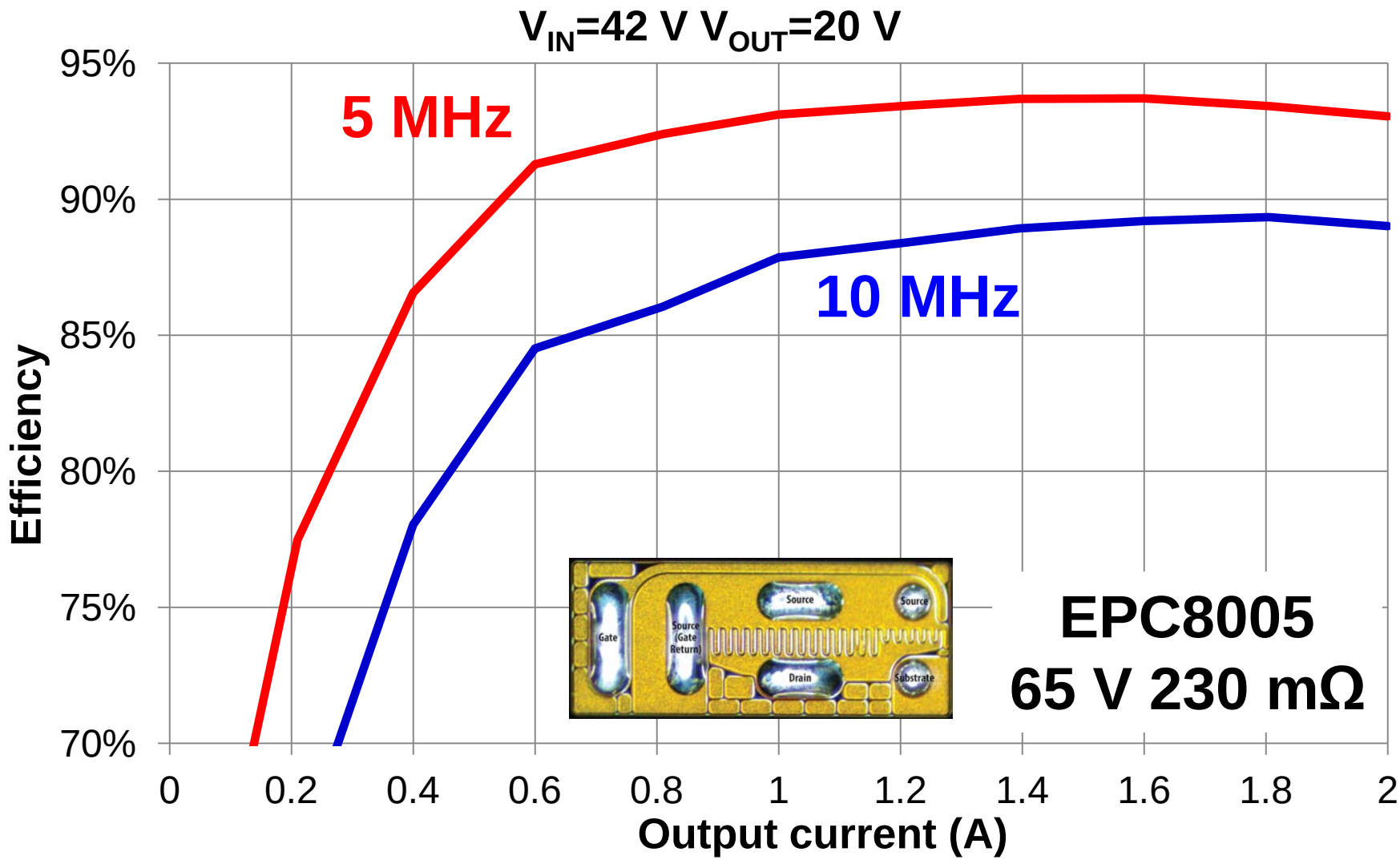


- **Envelope Tracking can *double* base station efficiency.**

Linear-Assisted Buck ET



Efficiency


V_{IN}=42 V V_{OUT}=20 V
95%
90%
85%
80%
75%
70%
Efficiency
5 MHz
10 MHz
Gate
Source (Gate Return)
Source
Source
Drain
Substrate
EPC8005
65 V 230 mΩ
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Output current (A)

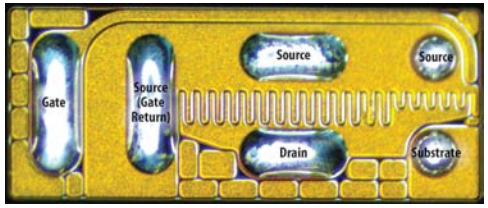
A Look into the Future

Silicon vs. eGaN FET Costs

	2013	2016
Starting Material	lower	lower
Epi Growth	***higher***	***~same?***
Wafer Fab	lower	lower
Test	same	same
Assembly	lower	lower
OVERALL	**higher**	***lower!***

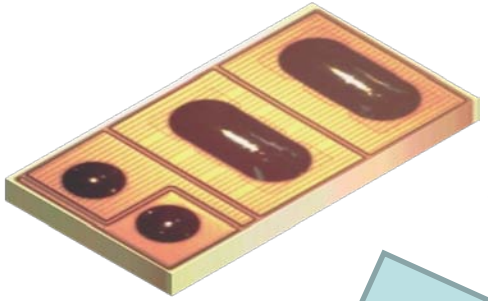
EPC Into the Future

Ultra High Frequency Family
1 - 3 GHz
Launched Sept 2013



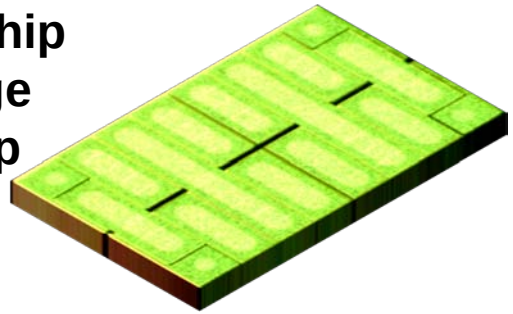
Mass Production
40 V - 200 V
~500 MHz

Higher Current
45 A



Higher Voltage
600 V

More functions on a chip
Monolithic half bridge
Driver on power chip



Next Generation Devices
2 x FOM Improvement

Summary

- Circuit layout is critical to get the most out of the efficiency improvements from GaN technology.
- Smaller Gen 3 eGaN FETs have been optimized for wireless power and envelope tracking systems and enable significant performance improvements over Gen 2.
- Efficient power conversion can now be done at frequencies well above 10 MHz.
- Even at lower frequencies you can always improve efficiency with eGaN FETs!

EFFICIENT POWER CONVERSION

The end of the road for silicon…..

is the beginning of the eGaN FET journey!