Darnell Energy Summit 2014

GaN Transistors – Giving New Life to Moore's Law

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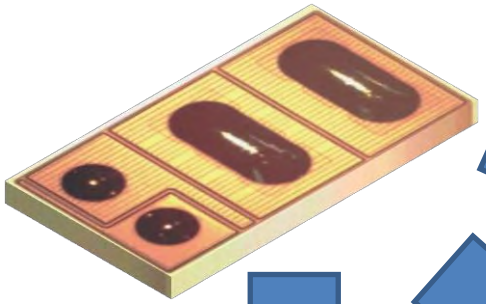
Efficient Power Conversion Corporation

Agenda

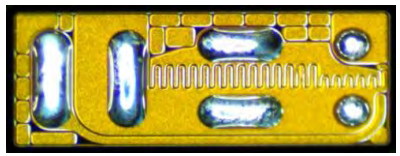
- Moore's Law Revival
- Reliability
- Where is GaN Going?
- Summary

Moore's Law Revival

Gen 2
2010-2013
40 V - 200 V

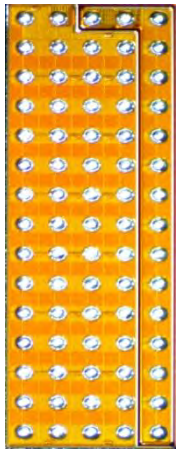


Generation 3
Higher Frequency
Launched September 2013

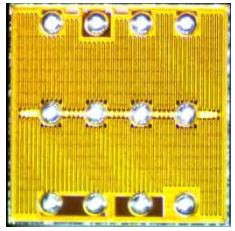


Generation 4
2 X Performance Improvement
Launched June 2014

Half Bridge ICs
September 2014



High Voltage
September 2014



Generation 5
~December 2014

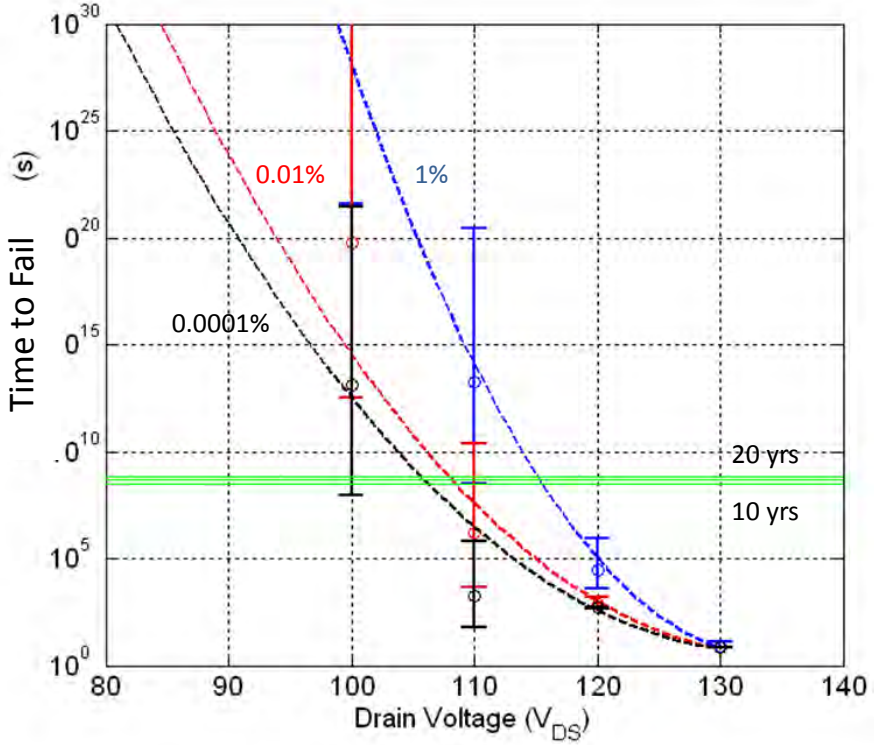
Reliability

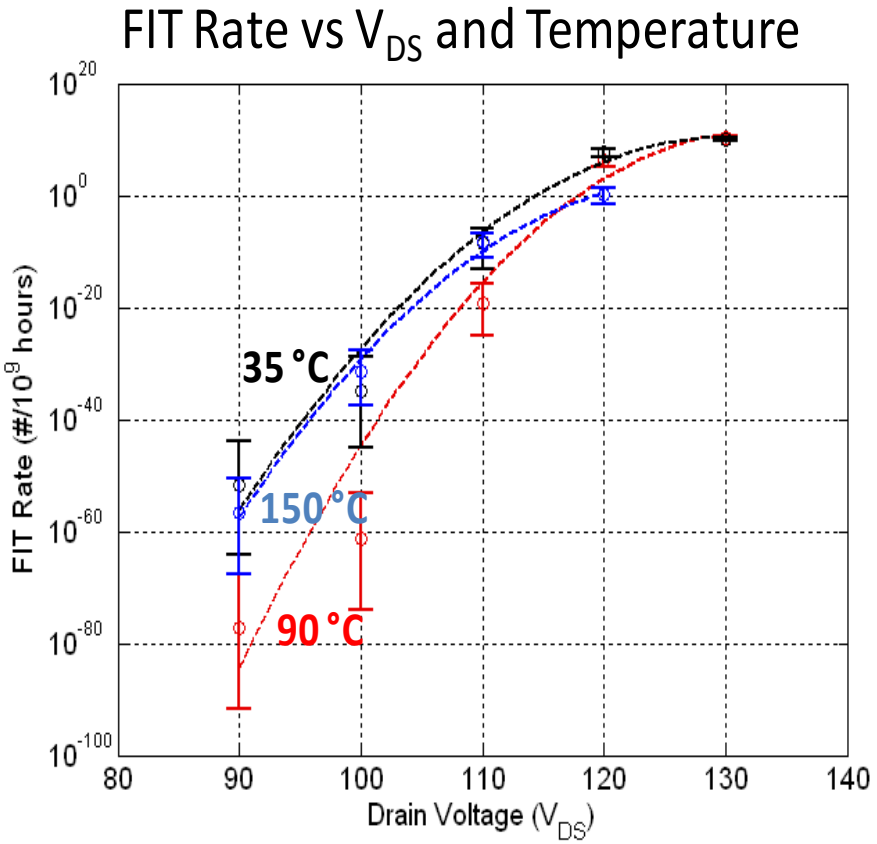
High Temp Reverse Bias (HTRB)

Part Number	Stress V_{DS} (V)	Temperature (°C)	Sample Size	Results (# of fails)	Duration (Hrs)
EPC2001	80	150	207	0	500
EPC2001	80	150	144	0	168
EPC2001	80	150	80	0	1000
EPC2001	80	125	96	0	168
EPC2001	100	125	45	0	1000
EPC2016	80	150	239	0	500
EPC2016	100	150	80	0	168

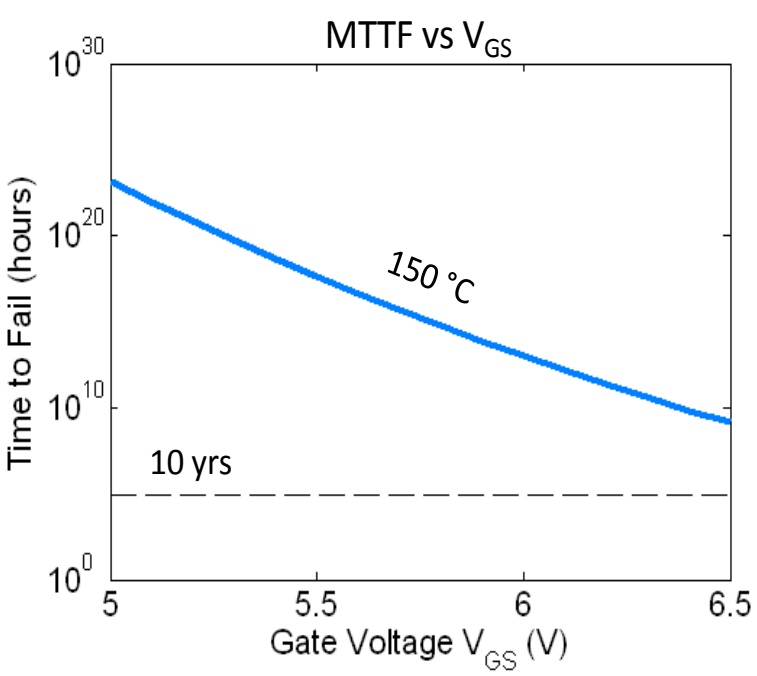
- Over 0.5 million accumulated device hours of reliability testing without failure across 891 devices.

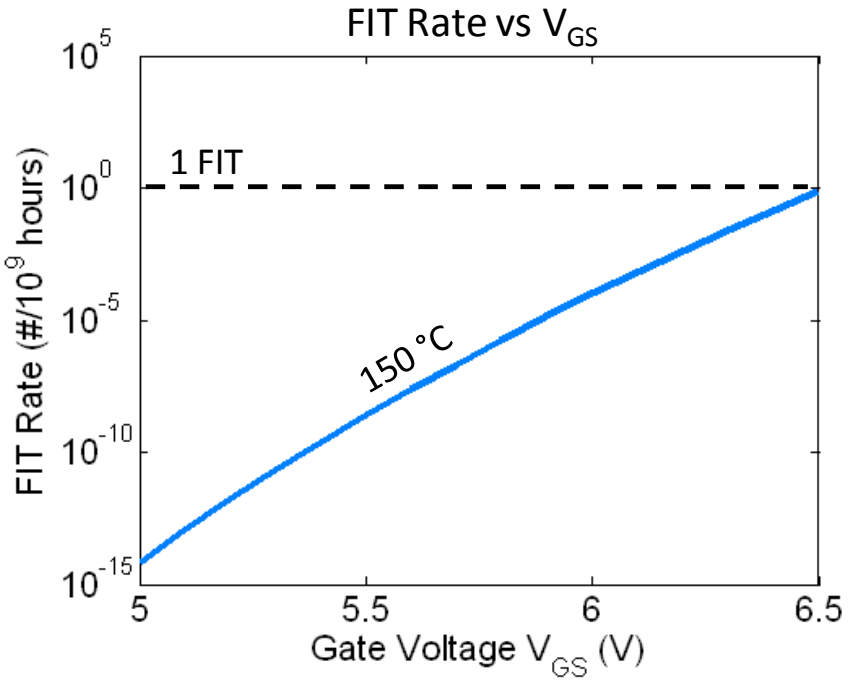
100 V HTRB Acceleration





HTGB Acceleration





High Temp Gate Bias (HTGB)

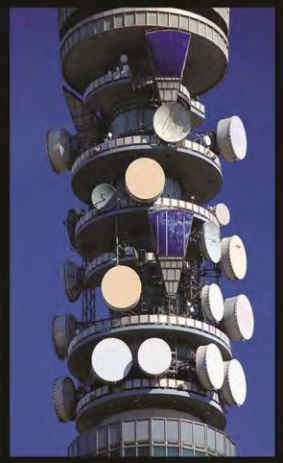
Part Number	Stress V_{GS} (V)	Temperature (°C)	Sample Size	Results (# of fails)	Duration (Hrs)
EPC2001	5	150	48	0	168
EPC2001	5	125	167	0	168
EPC2001	5	150	192	0	500
EPC2001	5	150	125	0	1000
EPC2014	5	150	48	0	500
EPC2015	5	125	96	0	168
EPC2015	5	150	50	0	1000
EPC2001	5.5	150	48	0	168
EPC2001	5.5	150	208	0	500
EPC2016	5.5	150	80	0	168
EPC2016	5.5	150	80	0	500
EPC2001	5.75	150	96	0	168
EPC2001	5.75	125	32	0	168
EPC2001	5.75	125	48	0	181
EPC2001	5.75	125	64	0	200
EPC2001	5.75	150	240	0	500
EPC2001	5.75	125	32	0	500
EPC2016	5.75	90	32	0	200
EPC2016	5.75	150	32	0	350
EPC2016	5.75	150	240	0	500
EPC2019	5.75	150	160	0	168
EPC2001	6	125	24	0	181
EPC2001	6	150	32	0	200
EPC2001	6	150	80	0	437
EPC2001	6	150	32	0	500
EPC2001	6	125	32	0	500
EPC2016	6	90	32	0	200
EPC2016	6	150	32	0	350
EPC2001	6.3	150	32	0	200
EPC2016	6.3	150	32	0	200
EPC2016	6.3	90	32	0	200
EPC2016	6.6	150	32	0	200

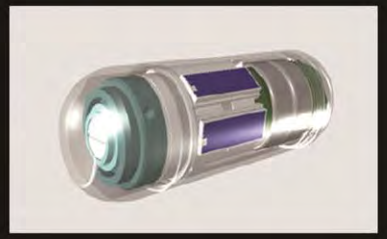
- 0 fail in over 0.97 million accumulated device hours of HTGB reliability testing greater than 5V.
- 0 fail in over 0.6 million accumulated device hours of HTGB reliability testing greater than 5.5V.

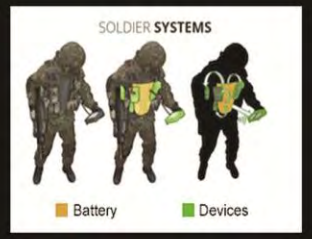
EPC

EFFICIENT POWER CONVERSION

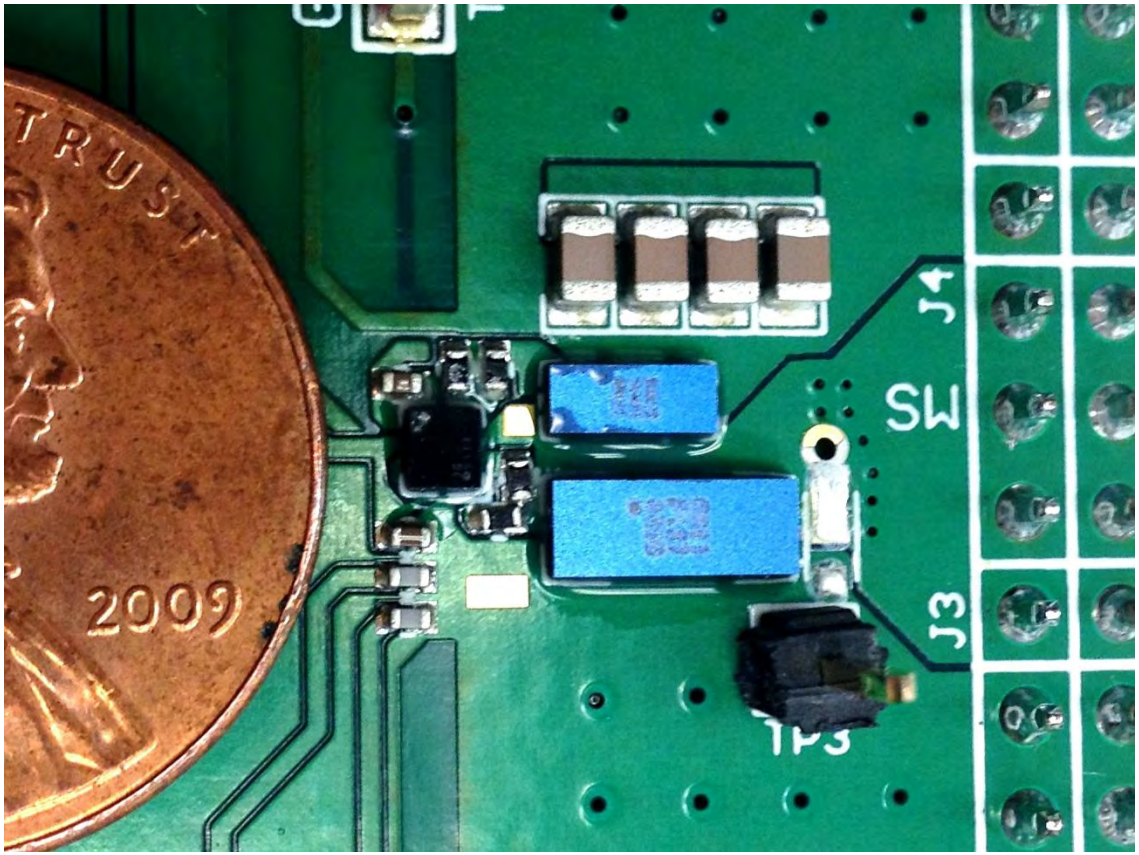
Where is GaN going…



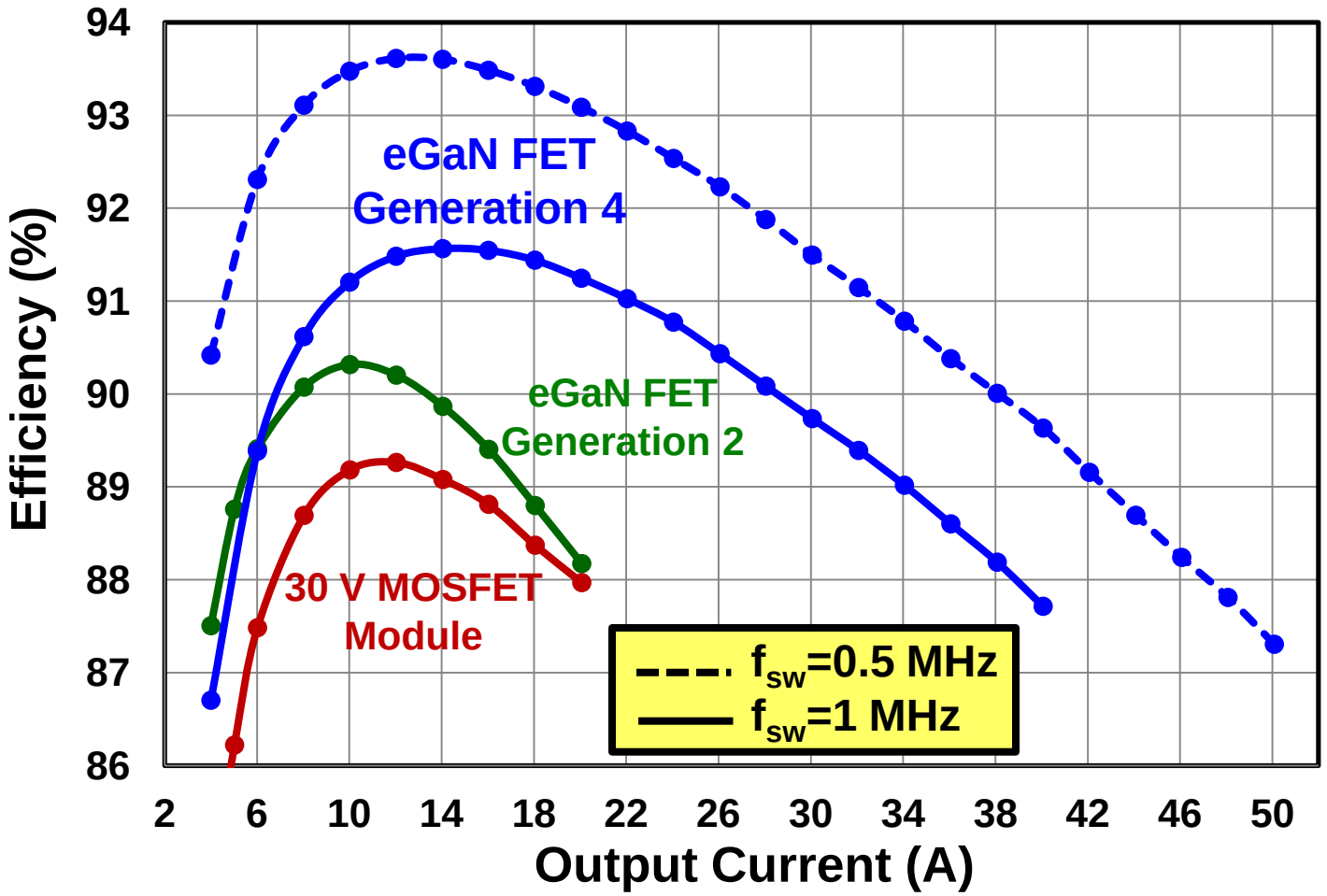




Hard Switching Buck Converter

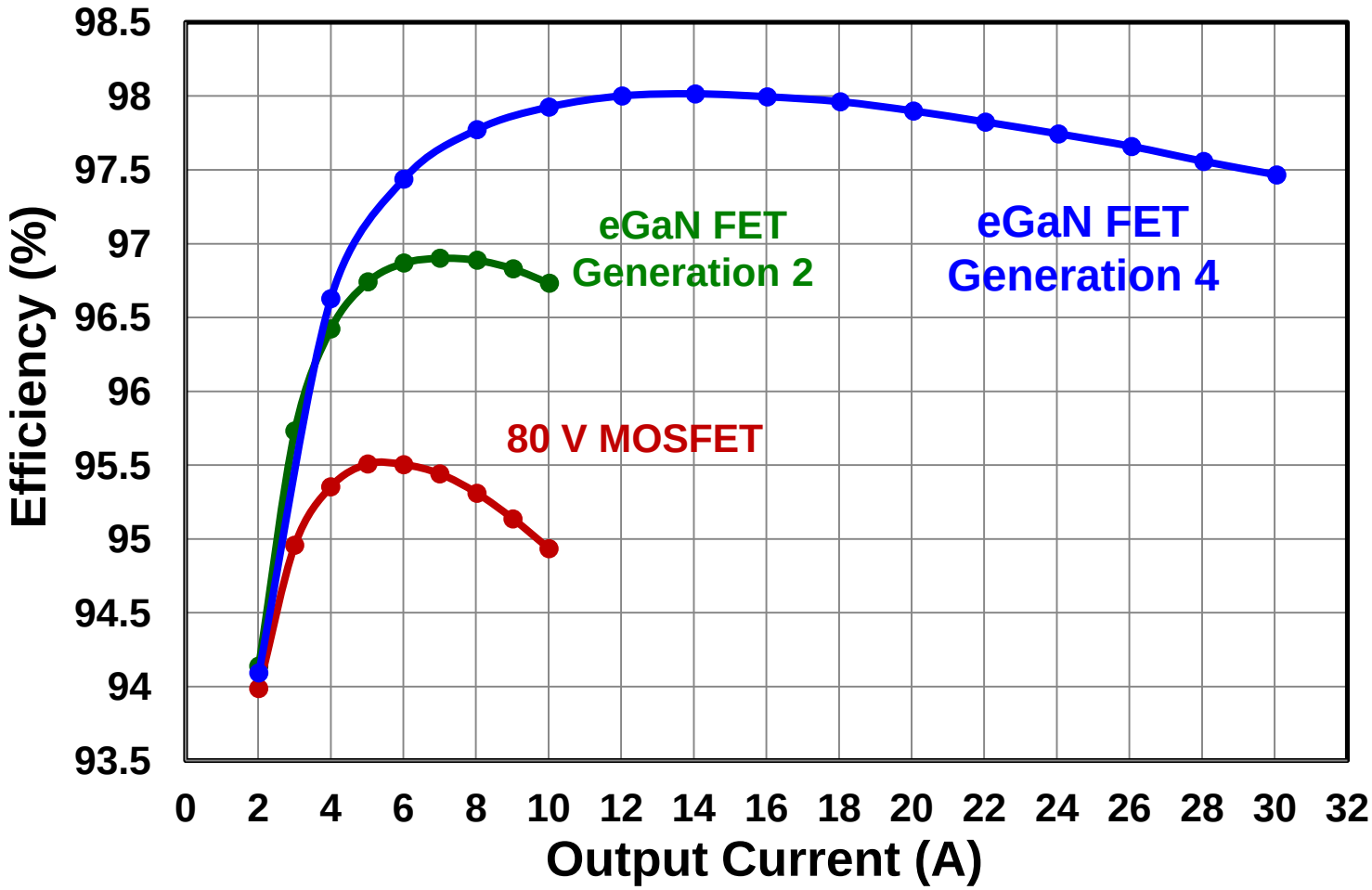


Low Voltage Buck Converter



V_{IN}=12 V V_{OUT}=1.2 V

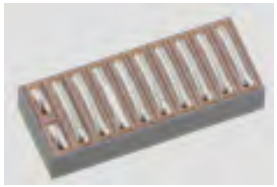
Higher Voltage Performance



V_{IN}=48 V V_{OUT}=12 V

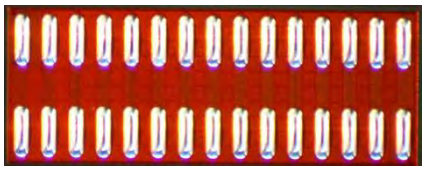
GaN Integration

Generation 2/4 Discrete HB

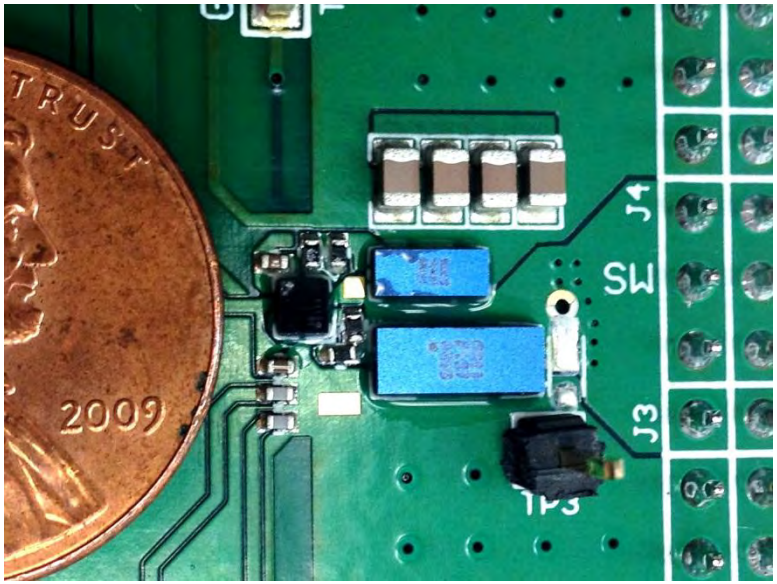


Top Switch (T)

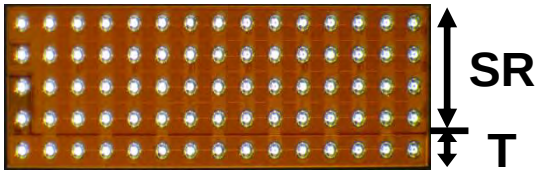
+



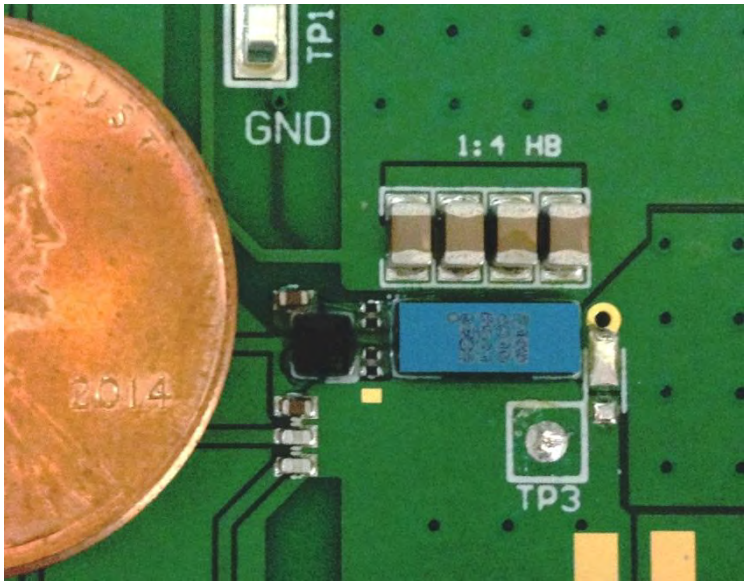
Synchronous Rectifier (SR)



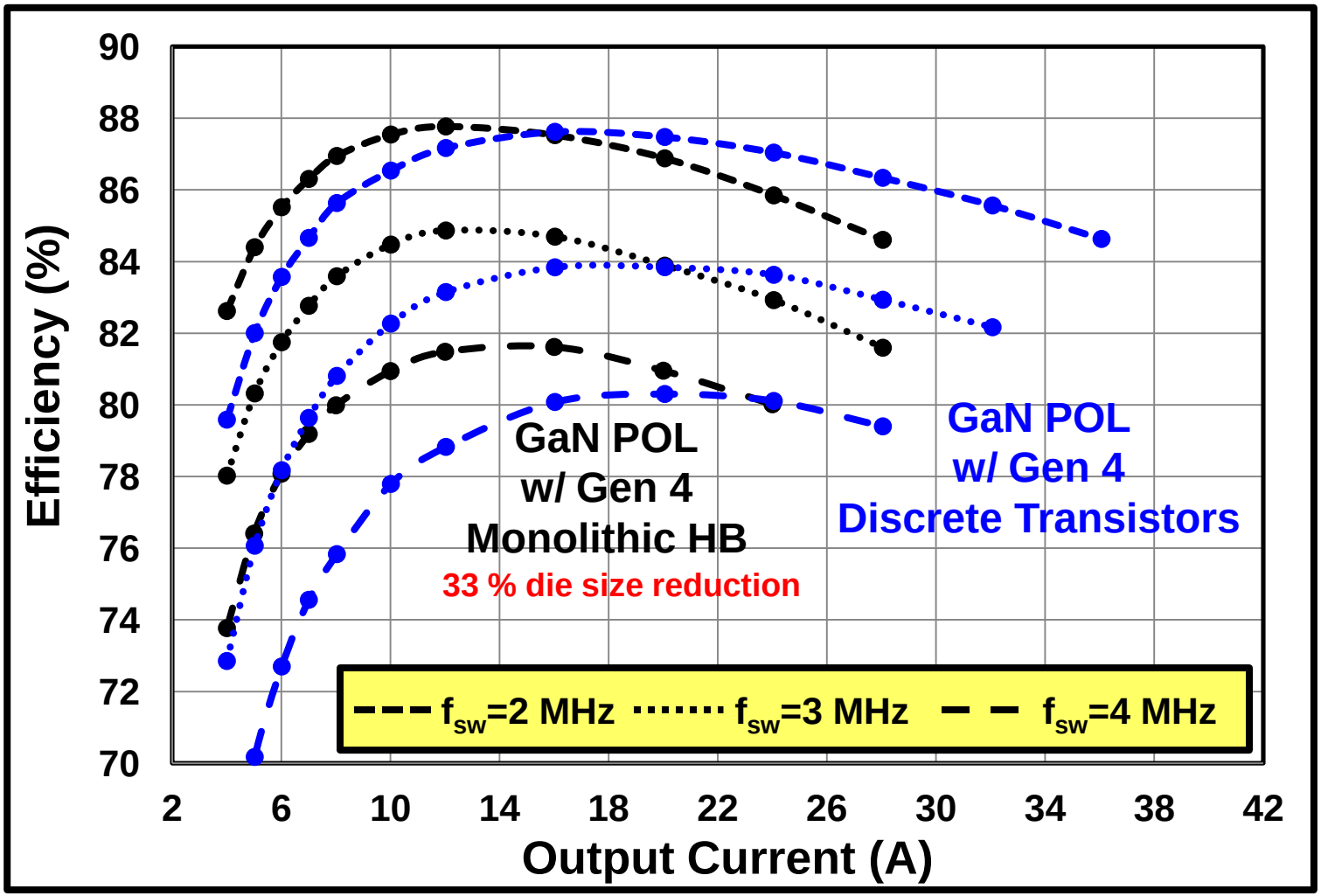
Generation 4 Monolithic 4:1 HB



33 % die size reduction



Monolithic Half Bridge

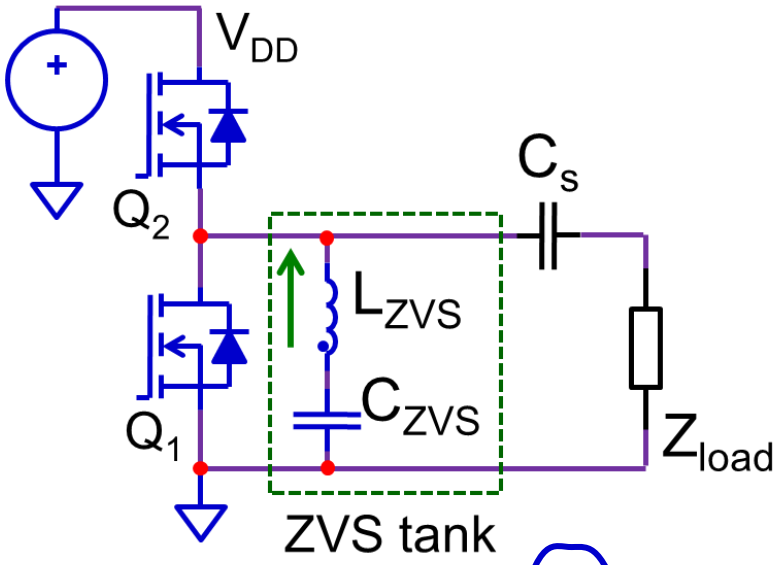


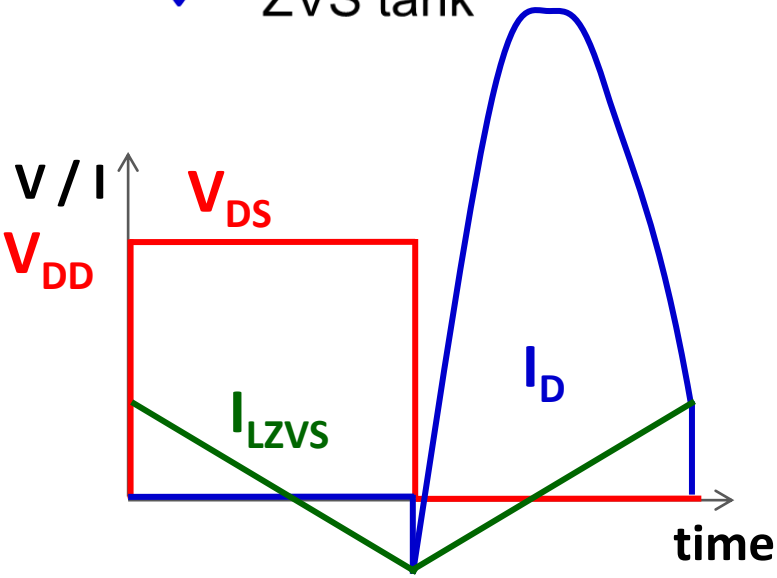
V_{IN}=12 V V_{OUT}=1.2 V L=100 nH

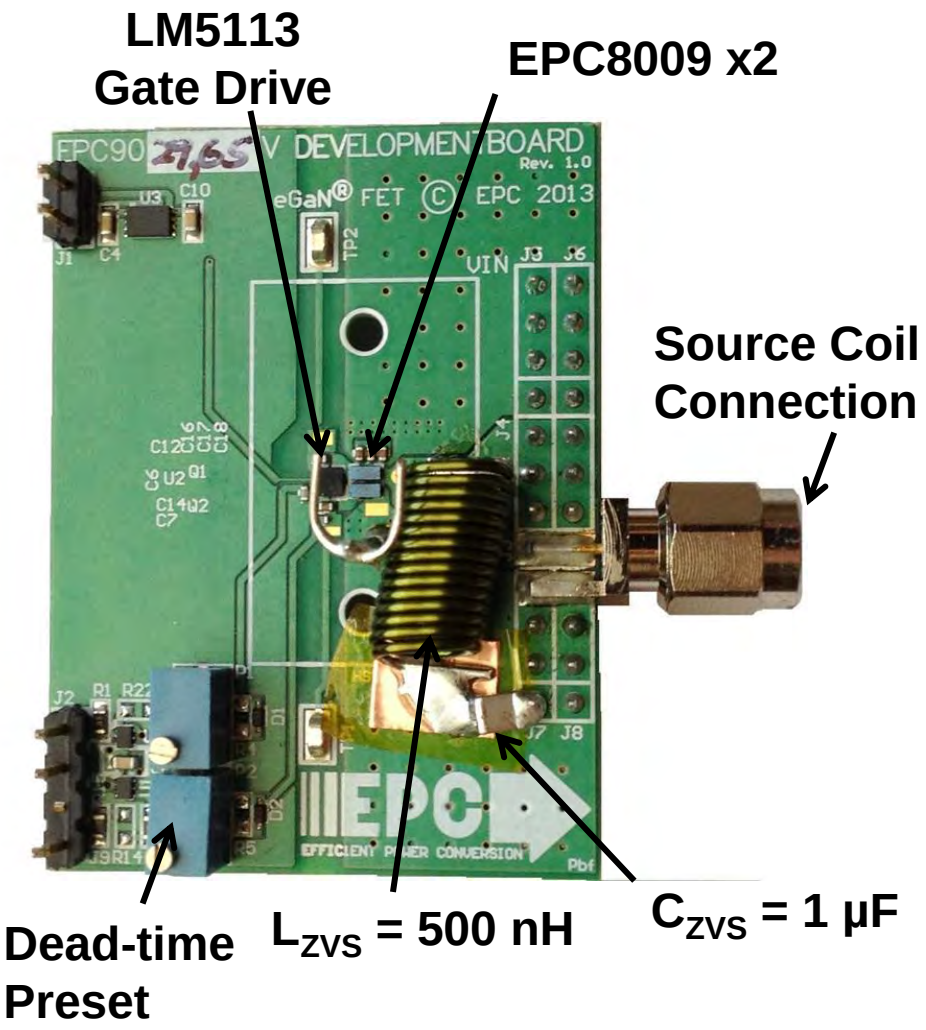
Wireless Power

The global wireless charging market is estimated to grow to $10B by 2018, a CAGR of 42.6%.

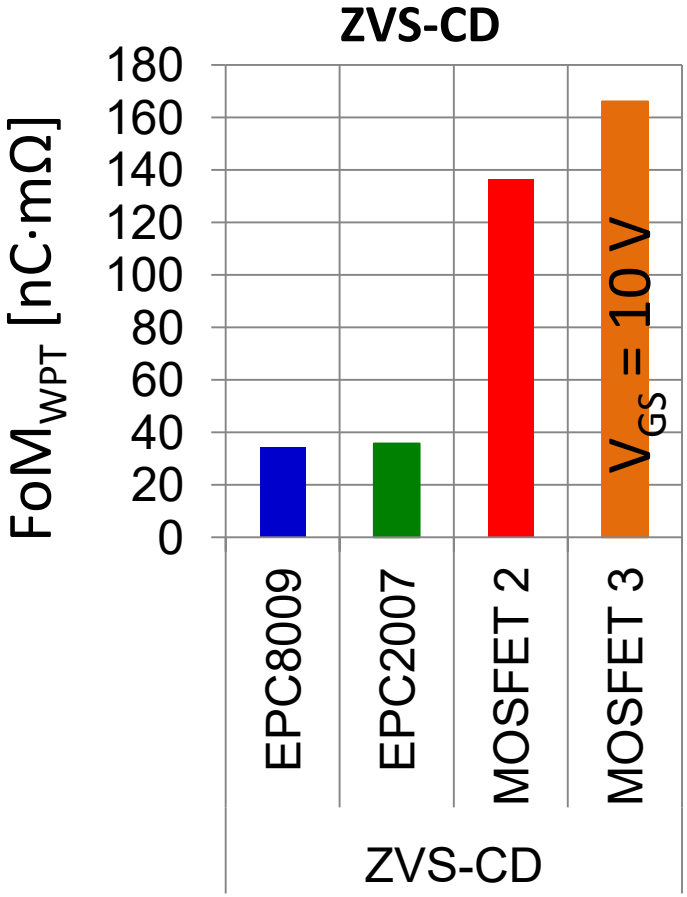
ZVS Class-D Power Amplifier





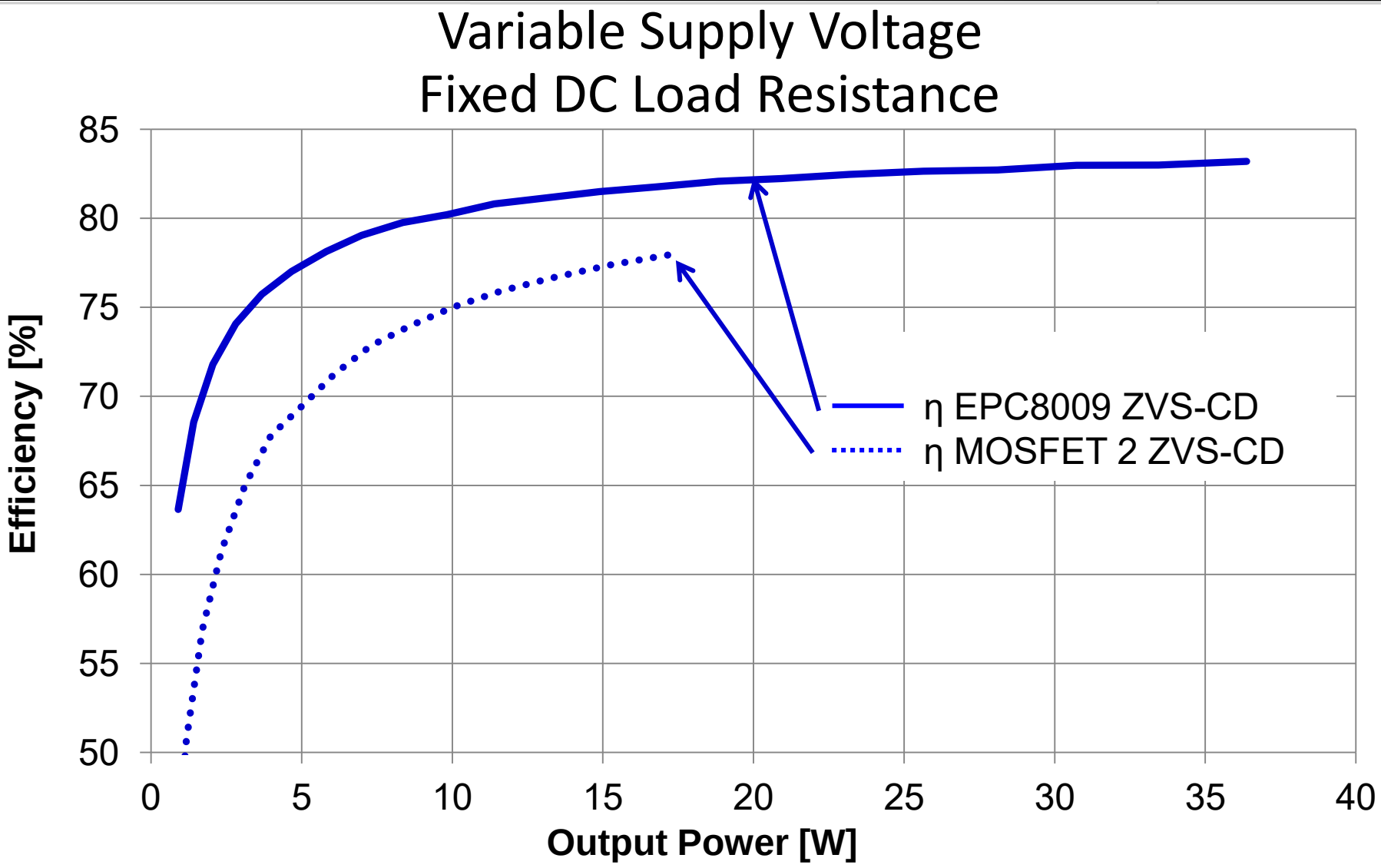


Device Comparison

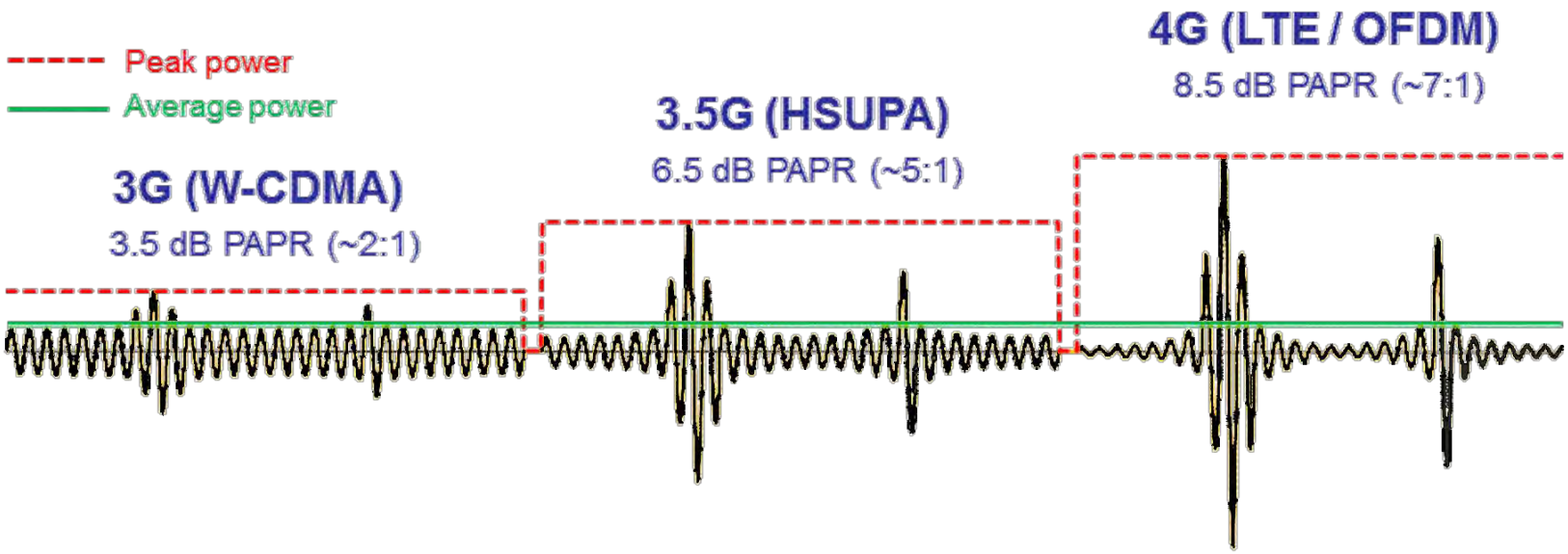


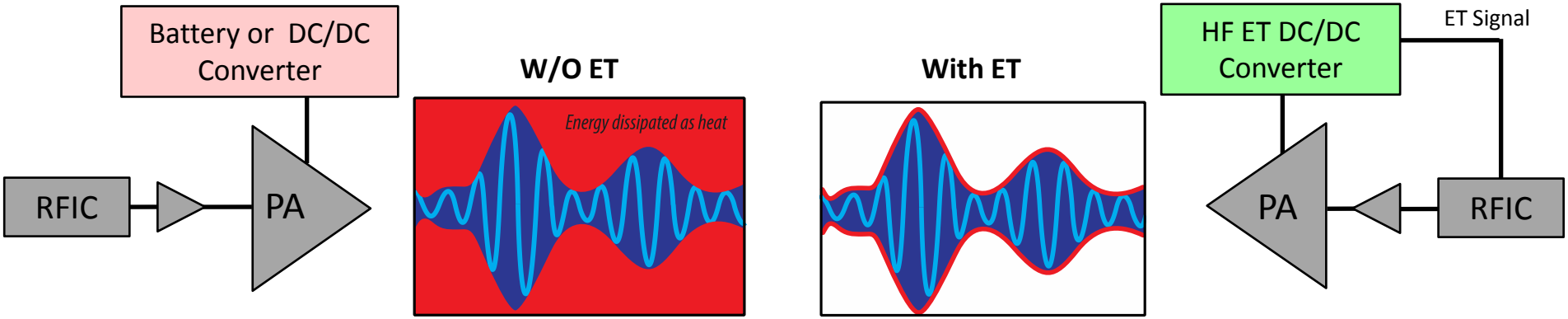
$$FOM_{WPT} = R_{DS(on)} \cdot (Q_G - Q_{GD})$$

Peak Performance Results



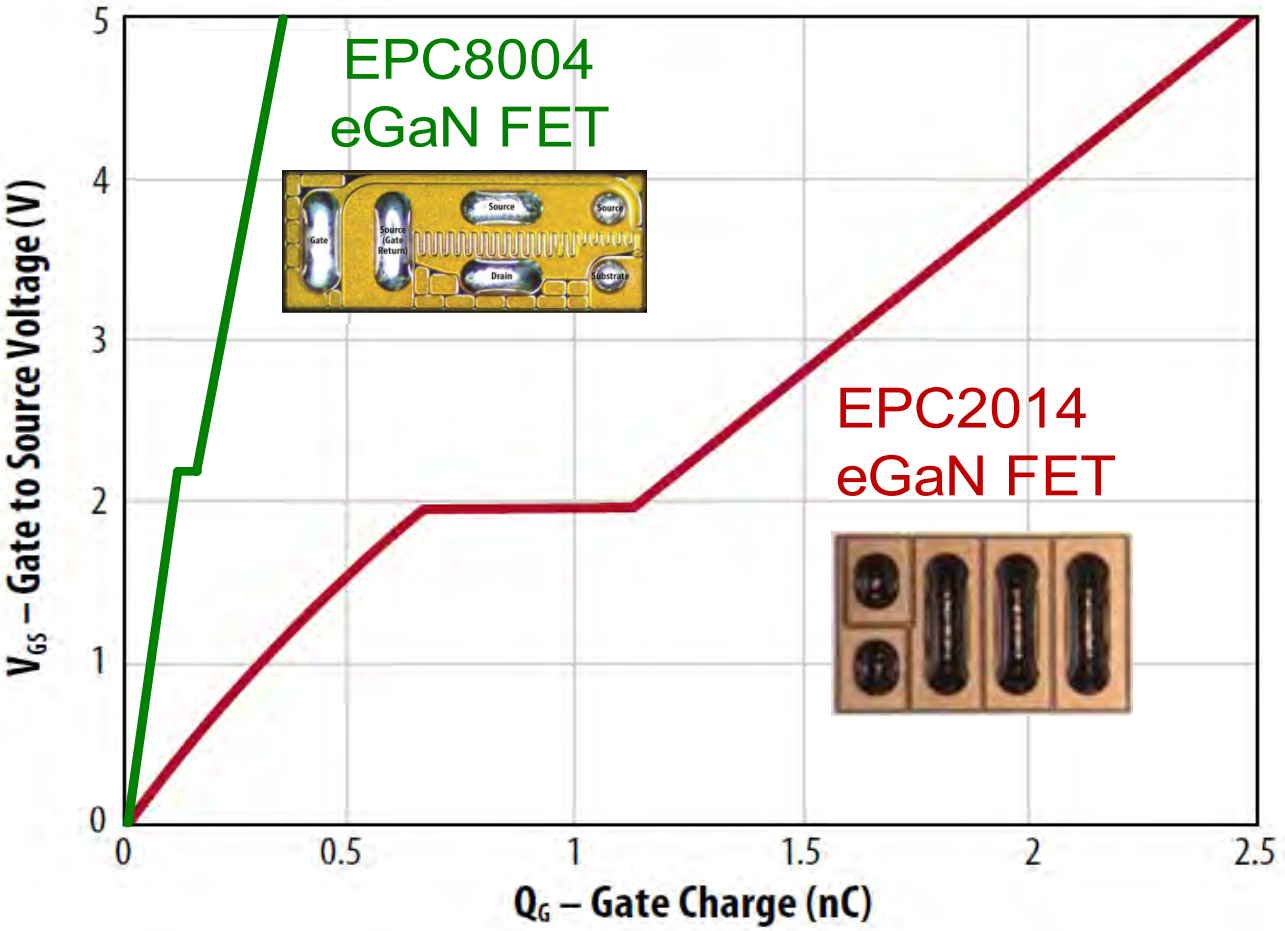
Envelope Tracking



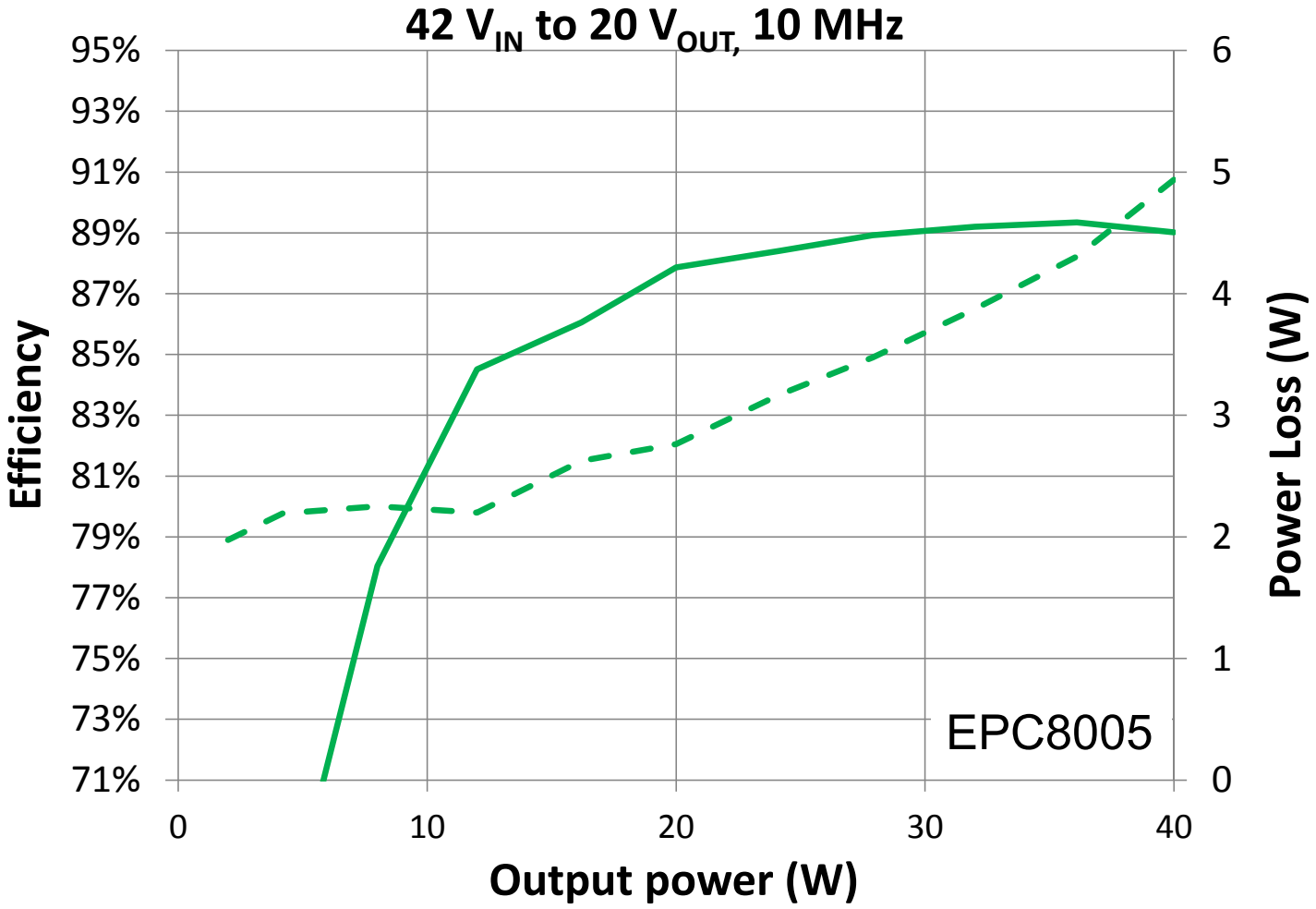


Reference: Nujira.com website

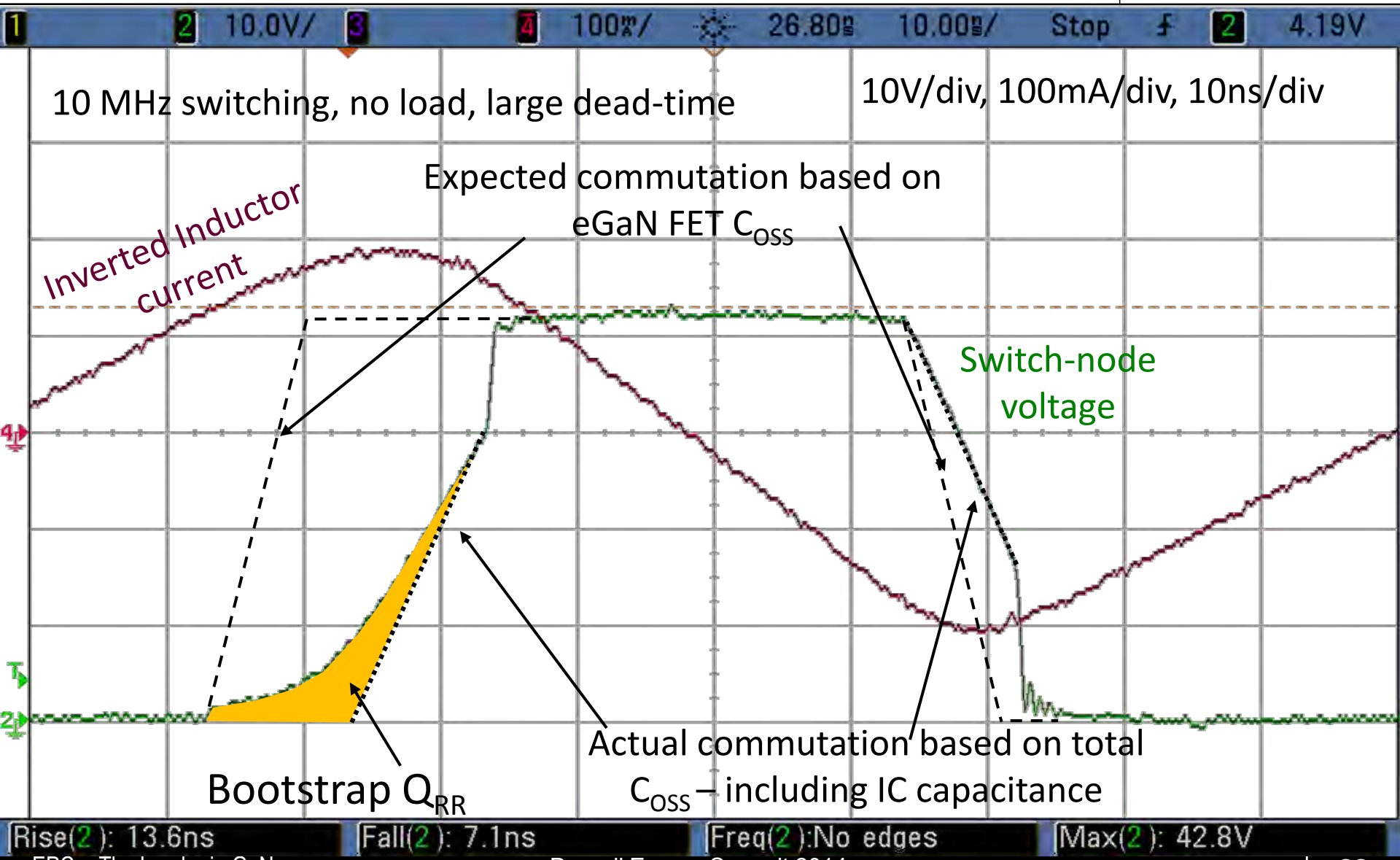
Very High Frequency eGaN FETs



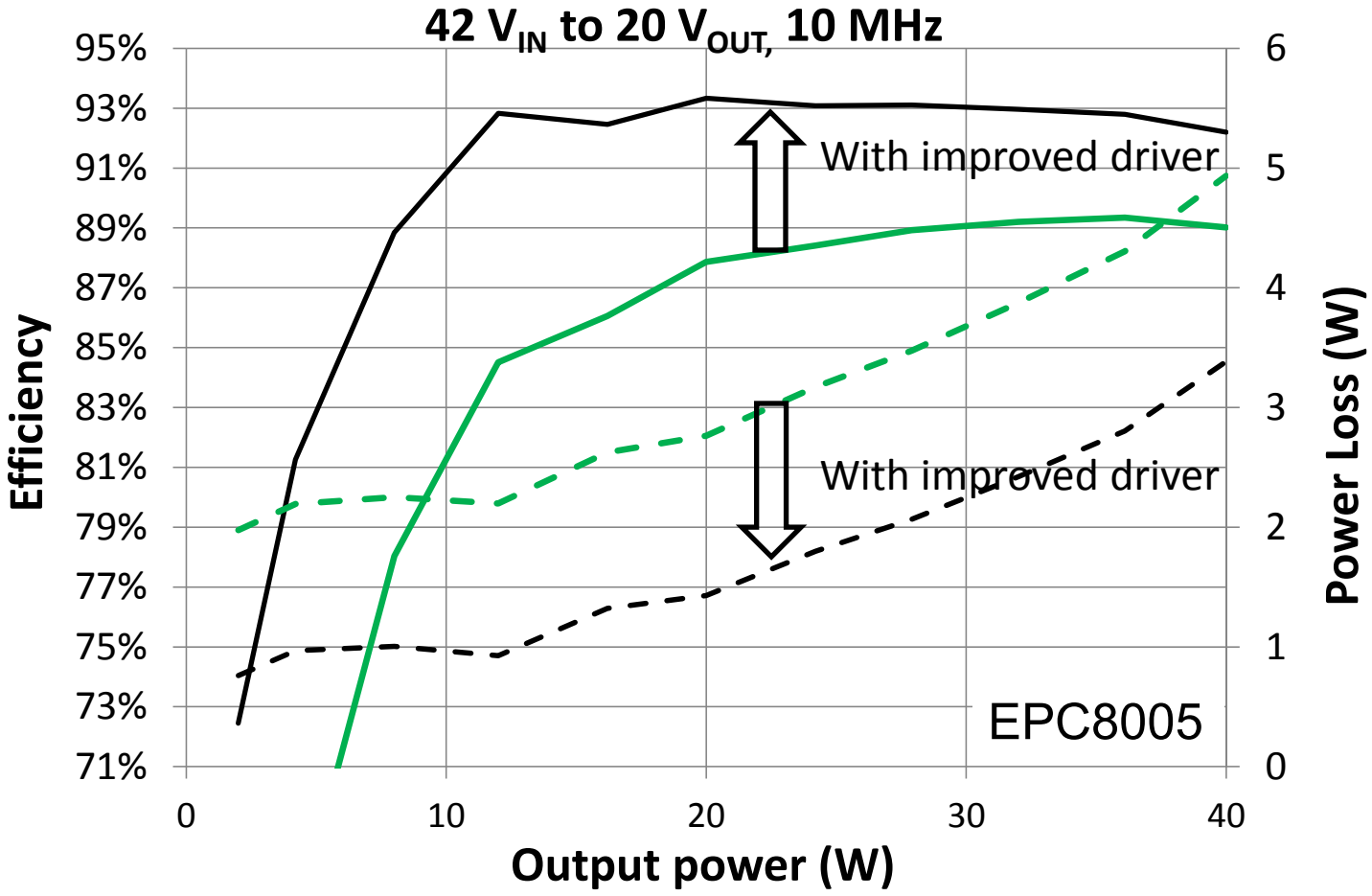
Efficiency Results



Switching Waveforms



Improving HF Performance



Other Key Applications

- LiDAR
- High Resolution MRI Imaging
- Network and Server Power Supplies
- AC Adapters
- Class-D Audio
- Energy Efficient Lighting
- Robotics

Summary

- GaN is a technology that, *for the first time in 60 years,* can both outperform and can be cost competitive with silicon devices.
- Improved gate driver ICs will greatly increase multi-megahertz system efficiencies.
- GaN technology is enabling whole new applications that will impact our daily lives and expand the overall market for semiconductors.

EFFICIENT POWER CONVERSION

The end of the road for silicon…..

is the beginning of the eGaN FET journey!