Low Voltage GaN Transistors – Applications and Reliability

Alex Lidow

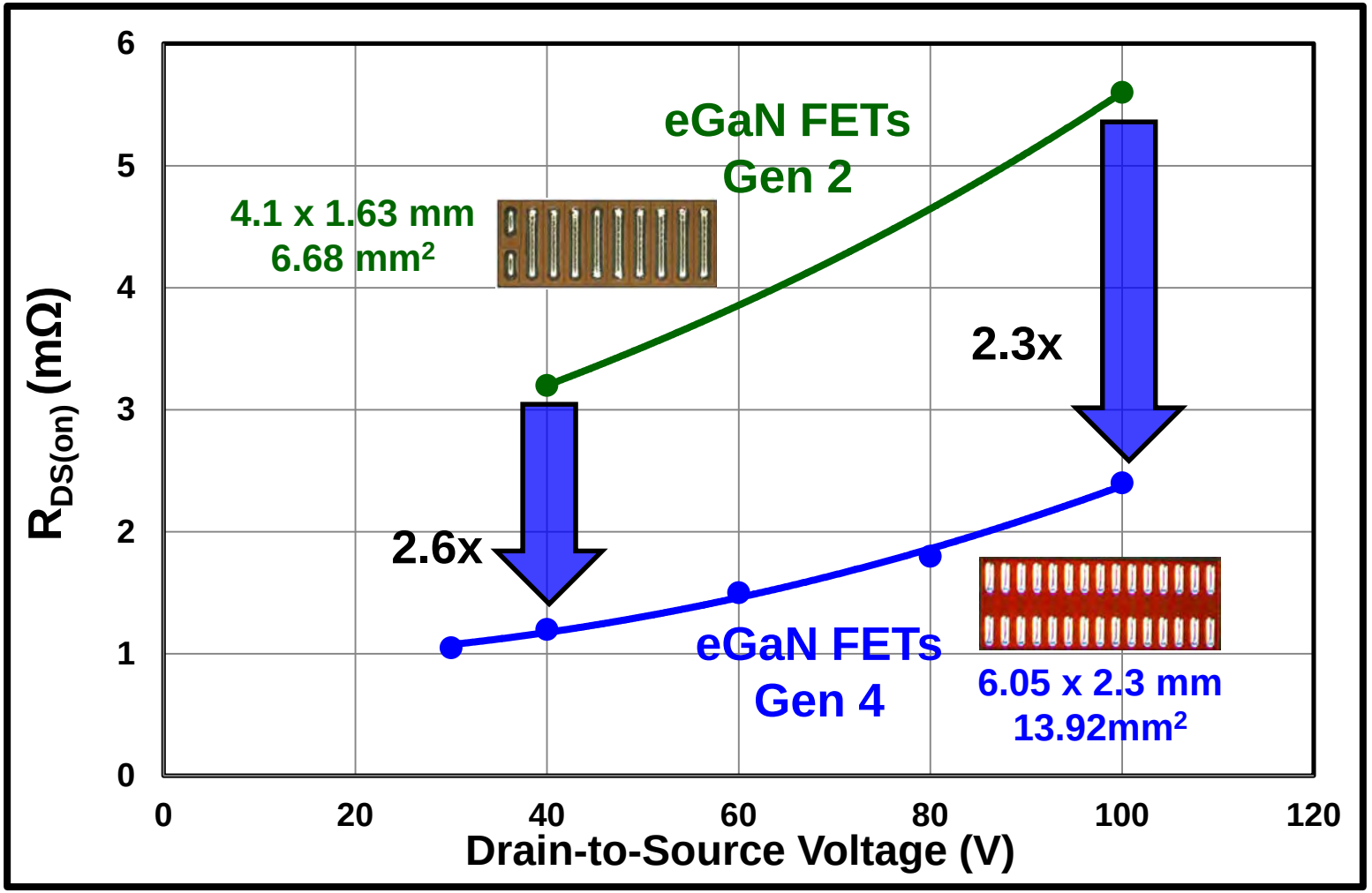
Agenda

- Technology Update
- Reliability Update
- Application Update
- Summary

Power Switch Wish List

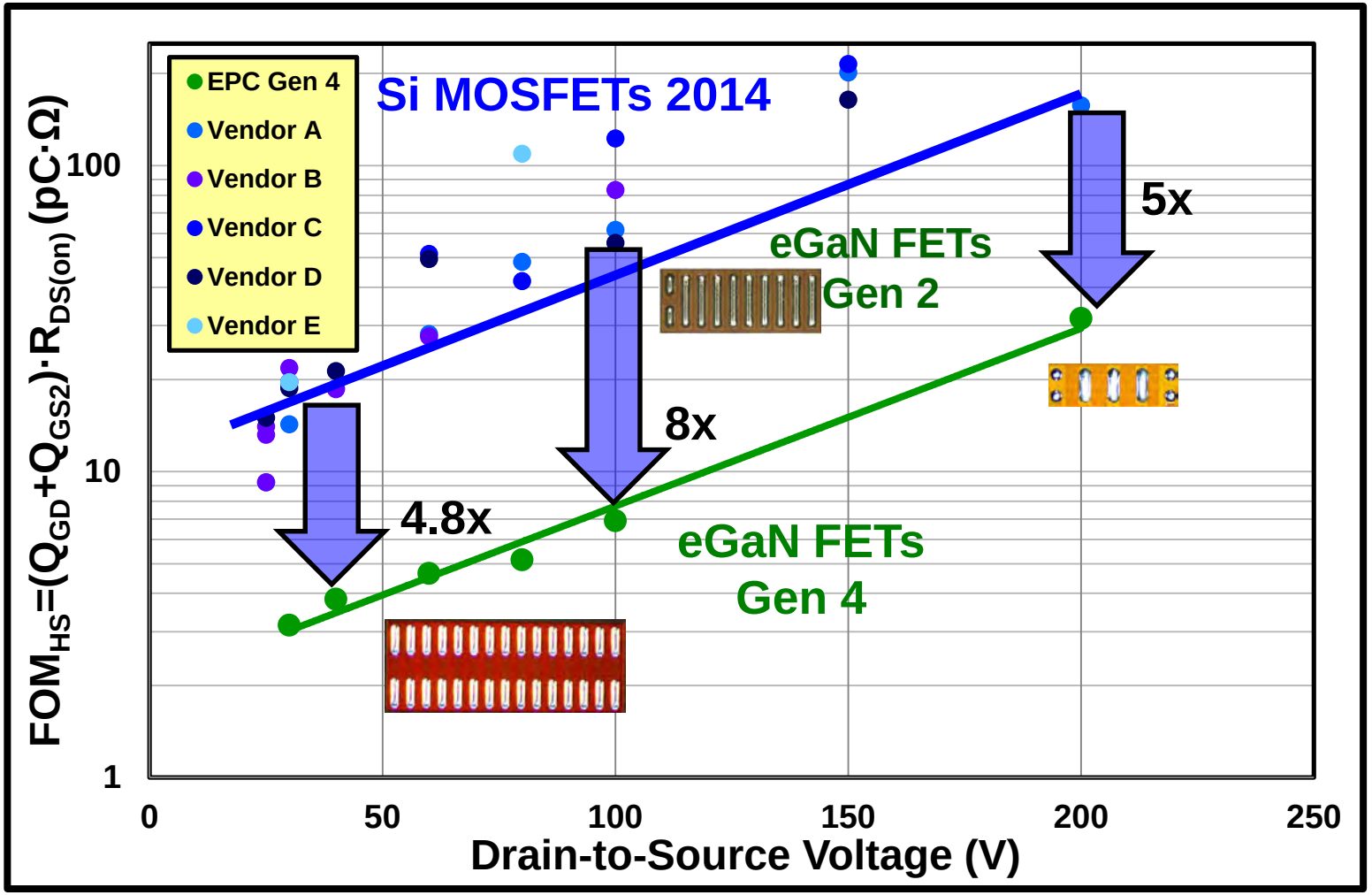
- Lower On Resistance
- Less Capacitance
- Less Inductance
- Lower Thermal Impedance
- Smaller
- Lower Cost

On-Resistance Comparison



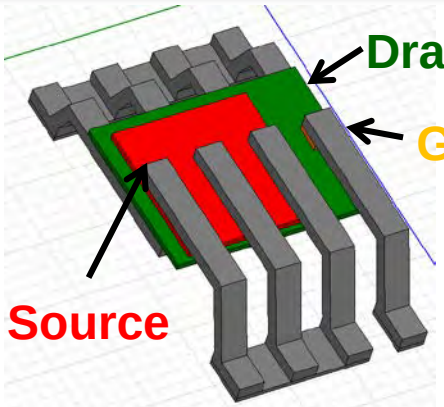
V_{GS}=5 V

Hard Switching FOM

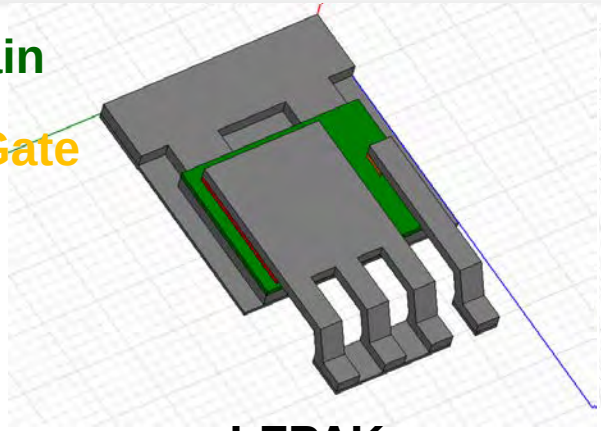


V_{DS}=0.5·V_{DSS}, I_{DS}=20 A

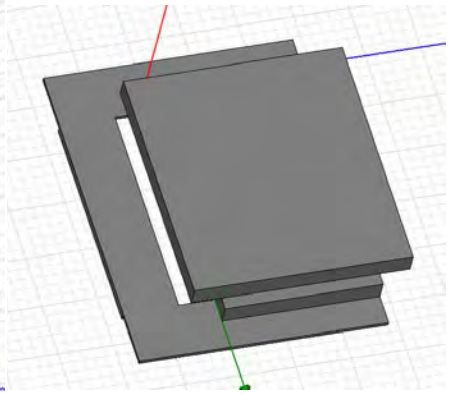
Package Inductance



SO-8

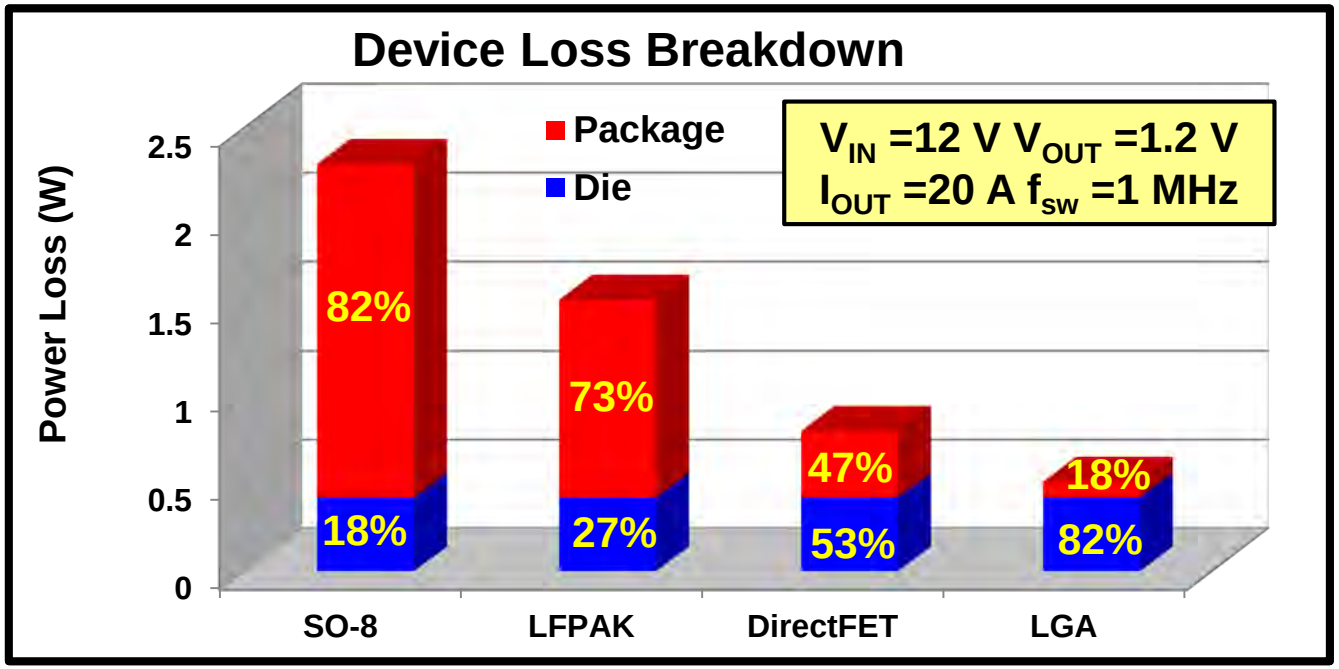


LFPAK



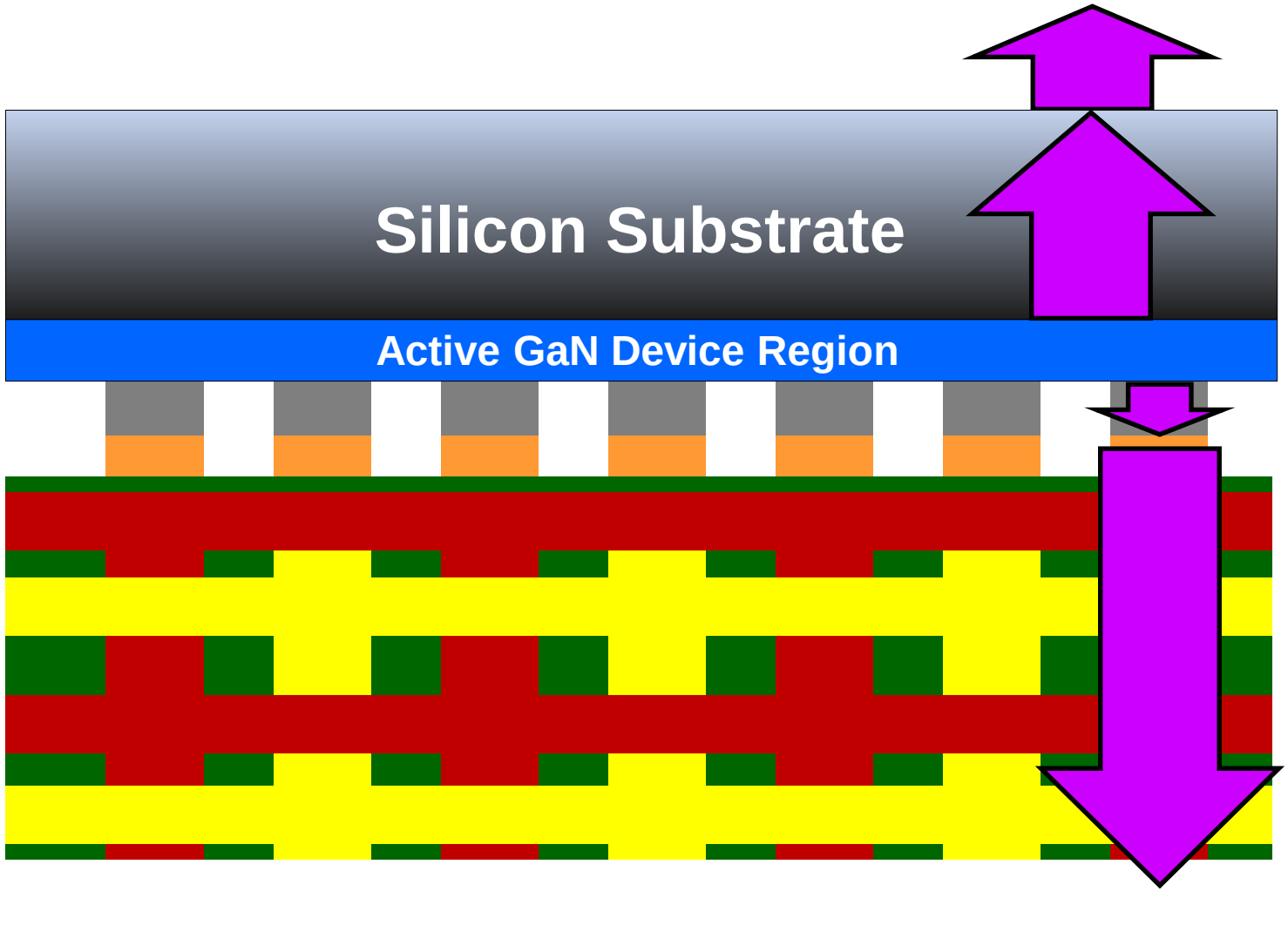
DirectFET

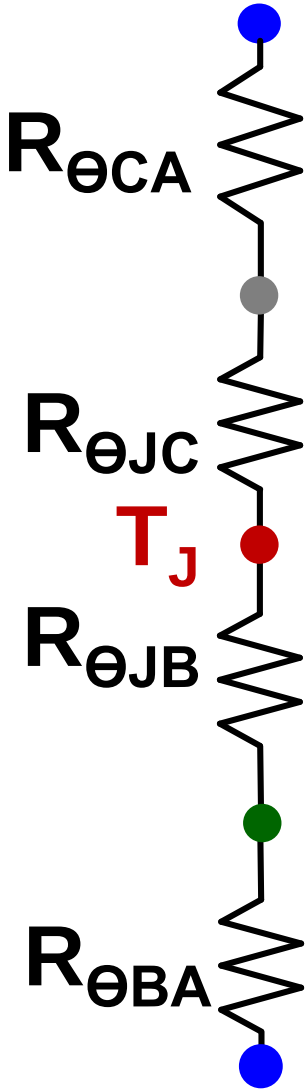
LGA eGaN FET



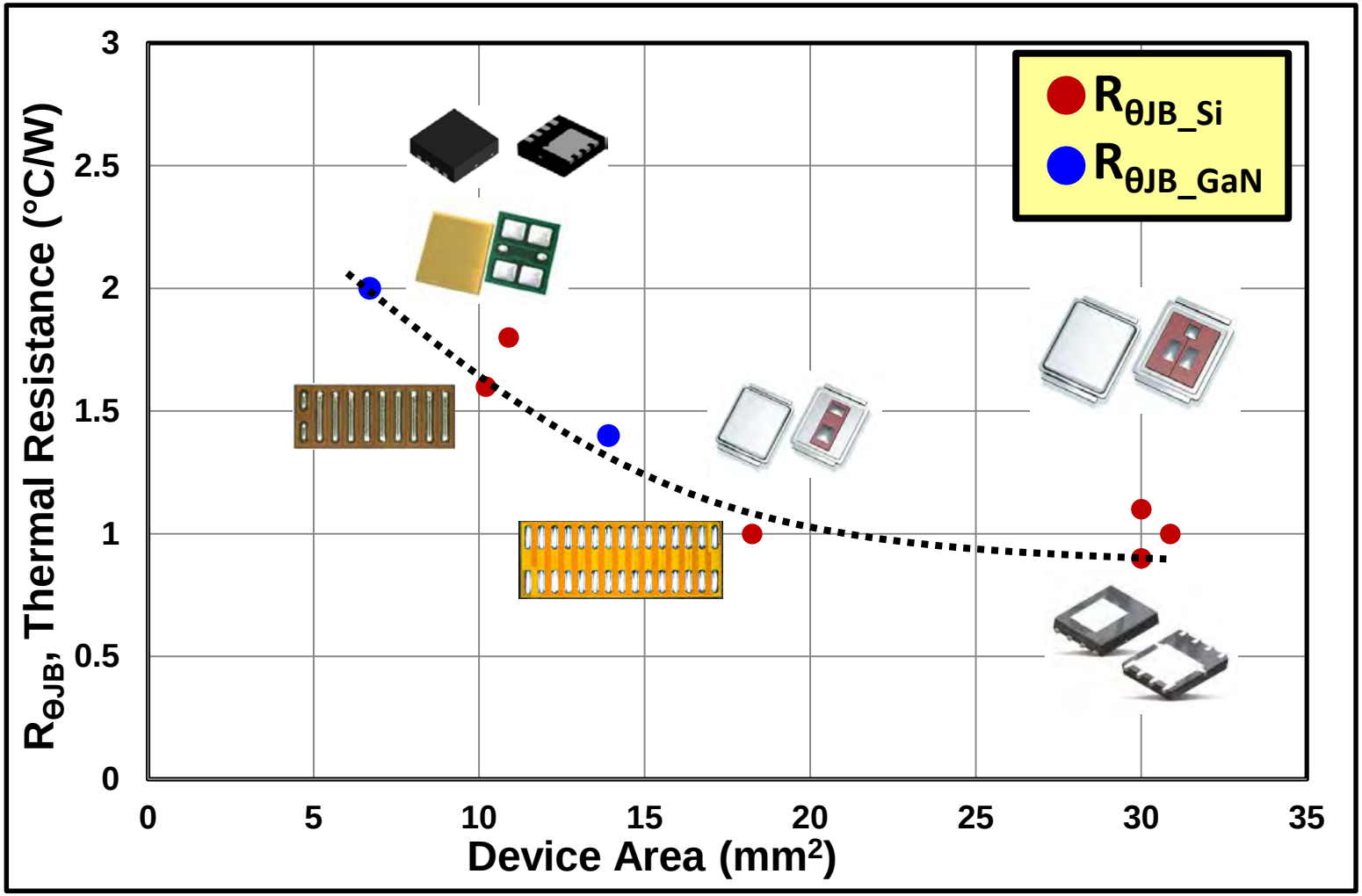
Reference: D. Reusch, D. Gilham, Y. Su, and F.C. Lee, C, "Gallium Nitride Based 3D Integrated Non-Isolated Point of Load Module," APEC 2012

Thermal Efficiency

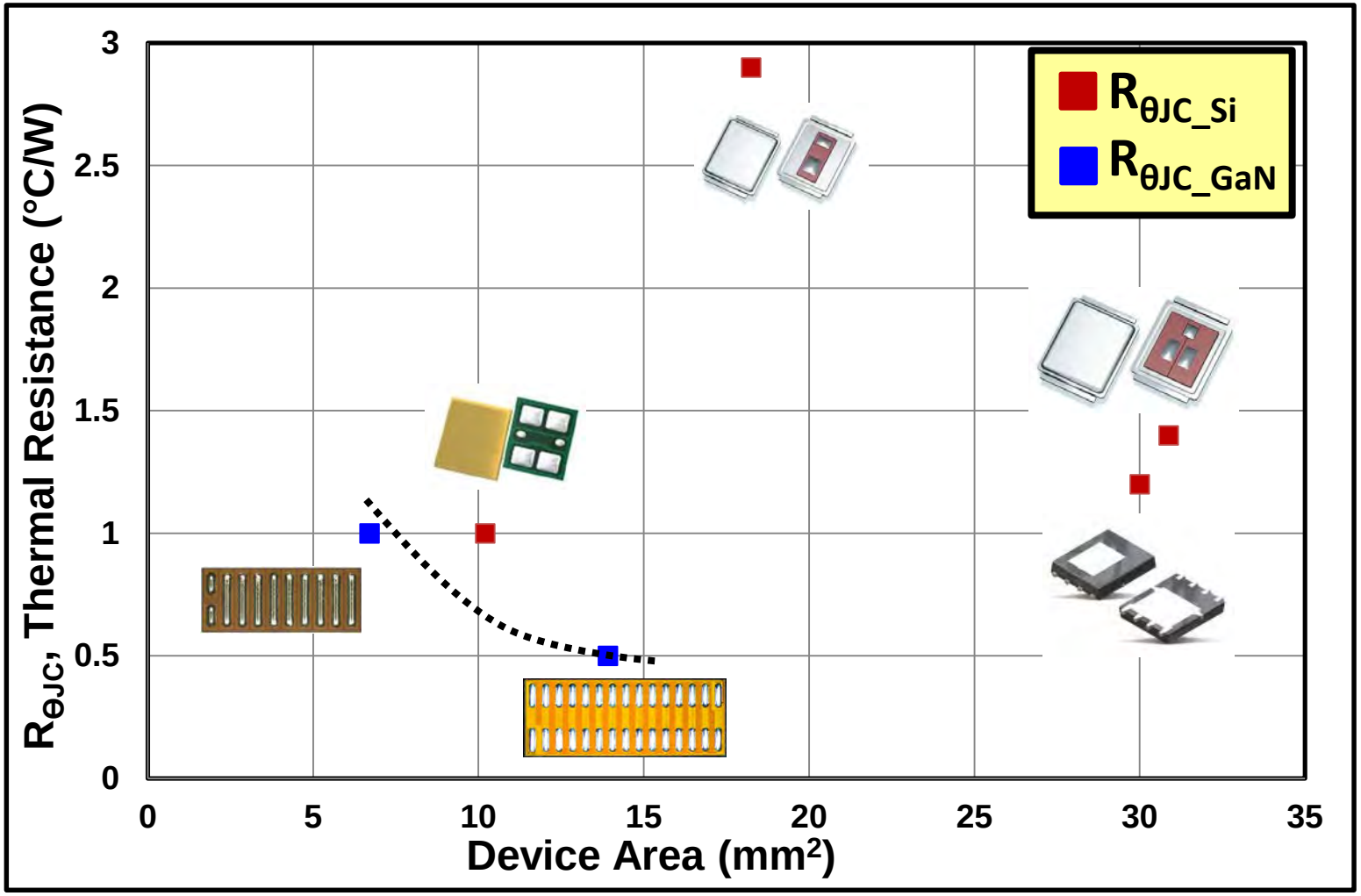




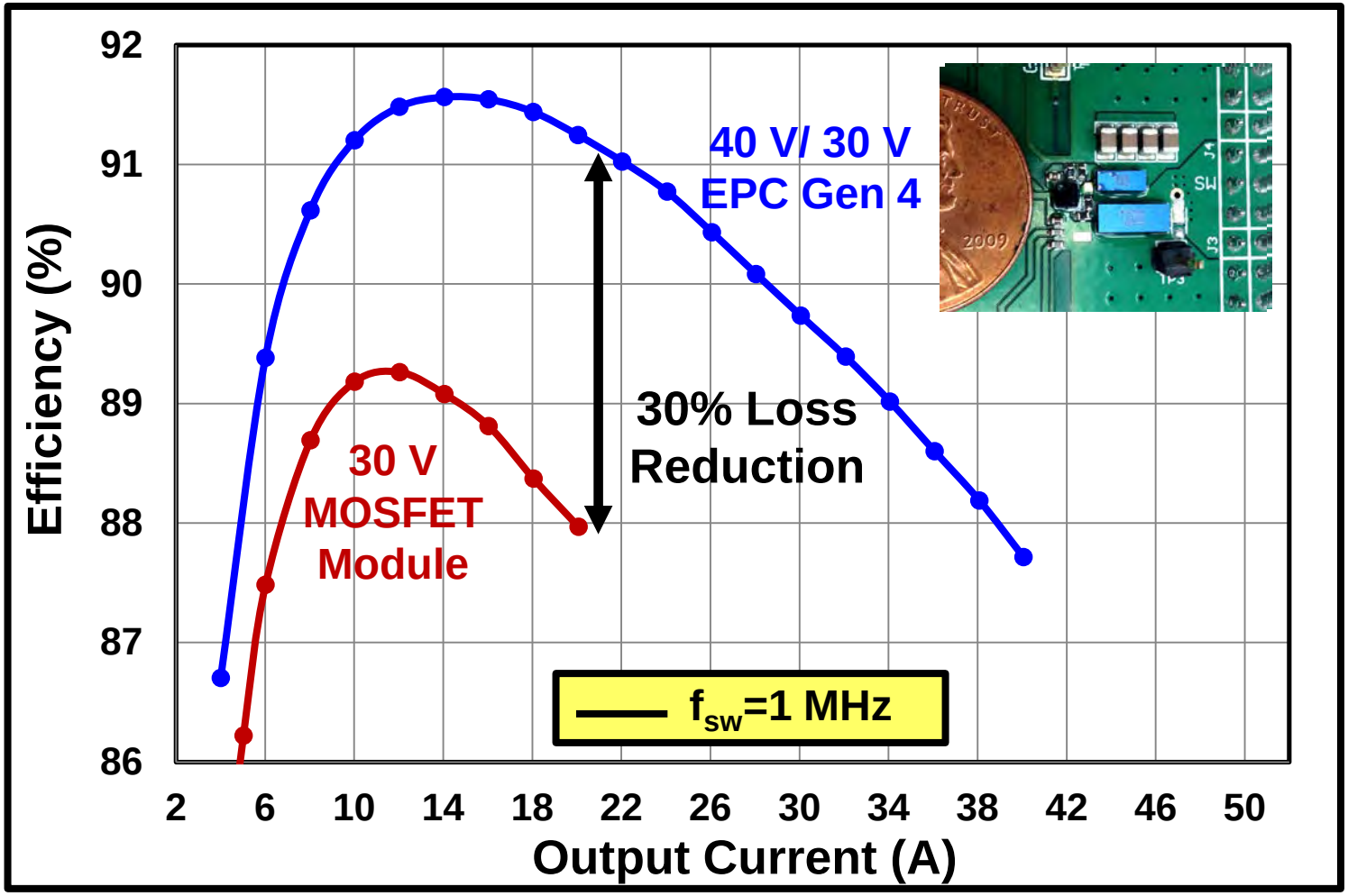
Package Comparisons



Package Comparisons

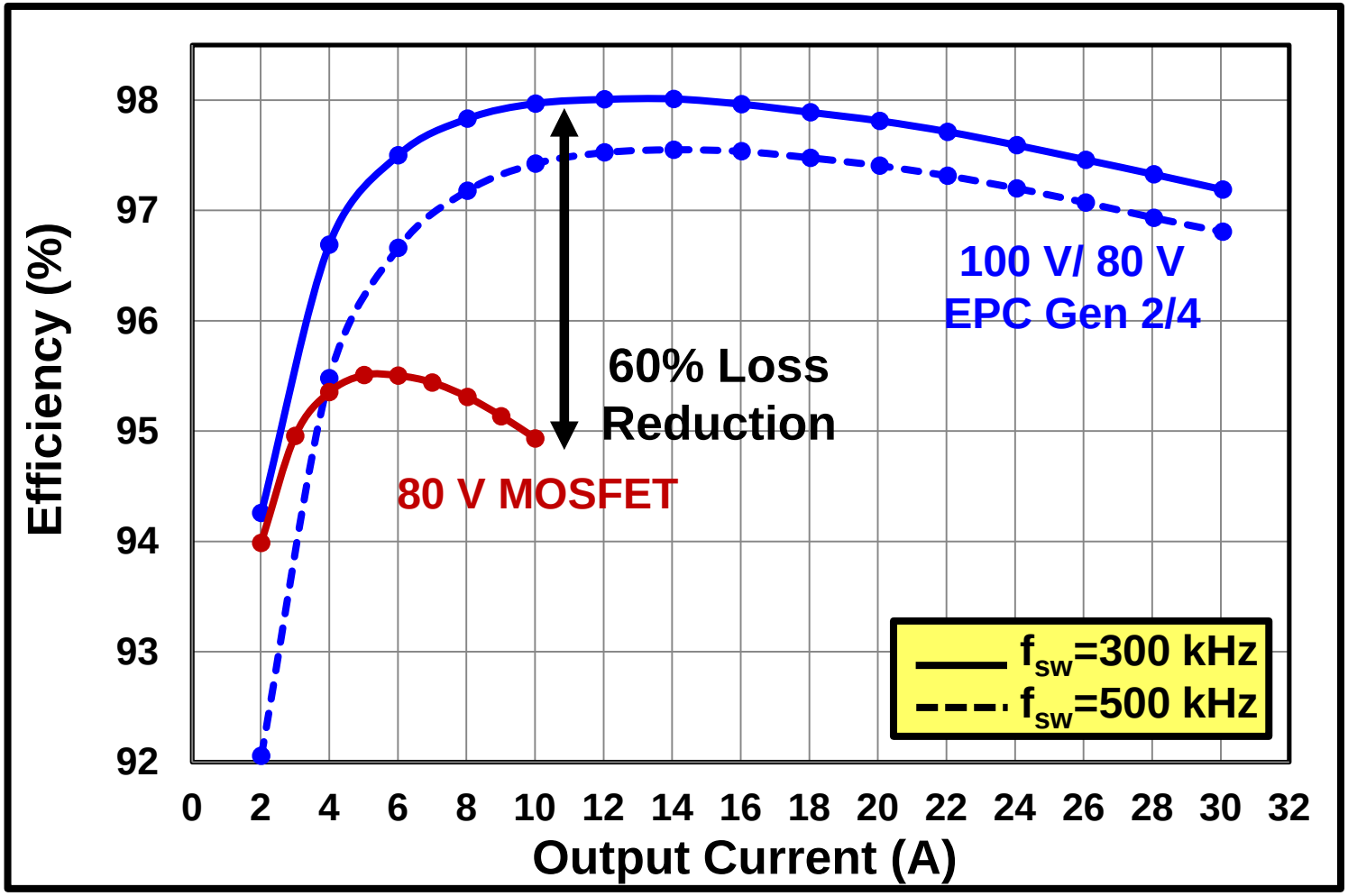


DC-DC Performance



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

Higher Voltage DC-DC Performance



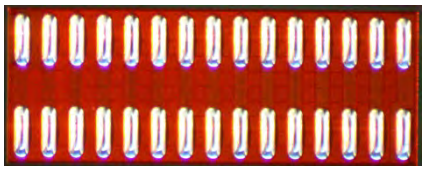
V_{IN}=48 V V_{OUT}=12 V

Take It Up Another Notch!

GaN Integration

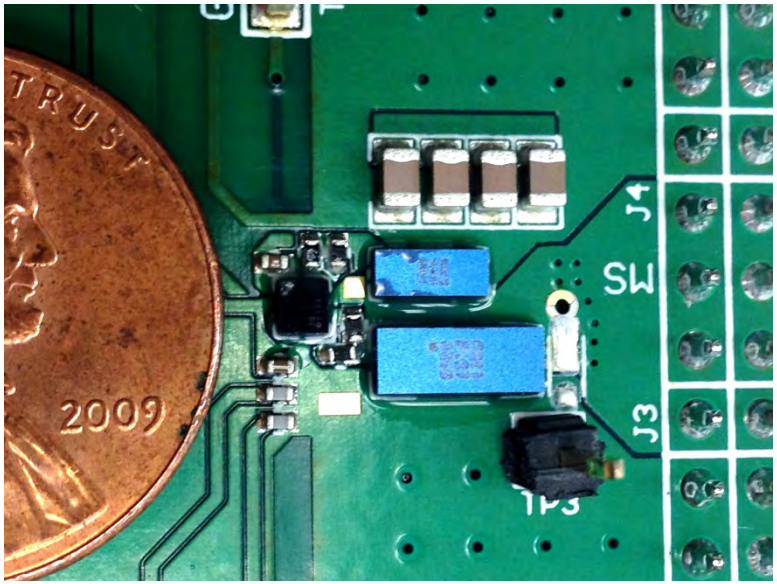
Generation 2/4 Discrete HB

+

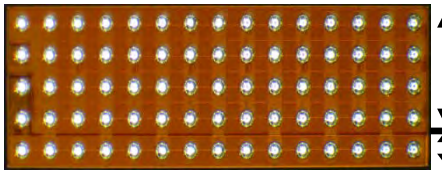


Top Switch (T)

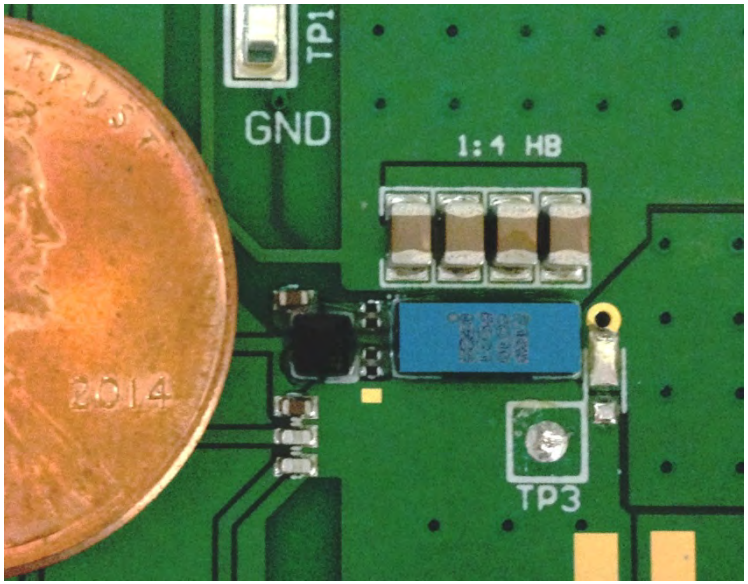
Synchronous Rectifier (SR)



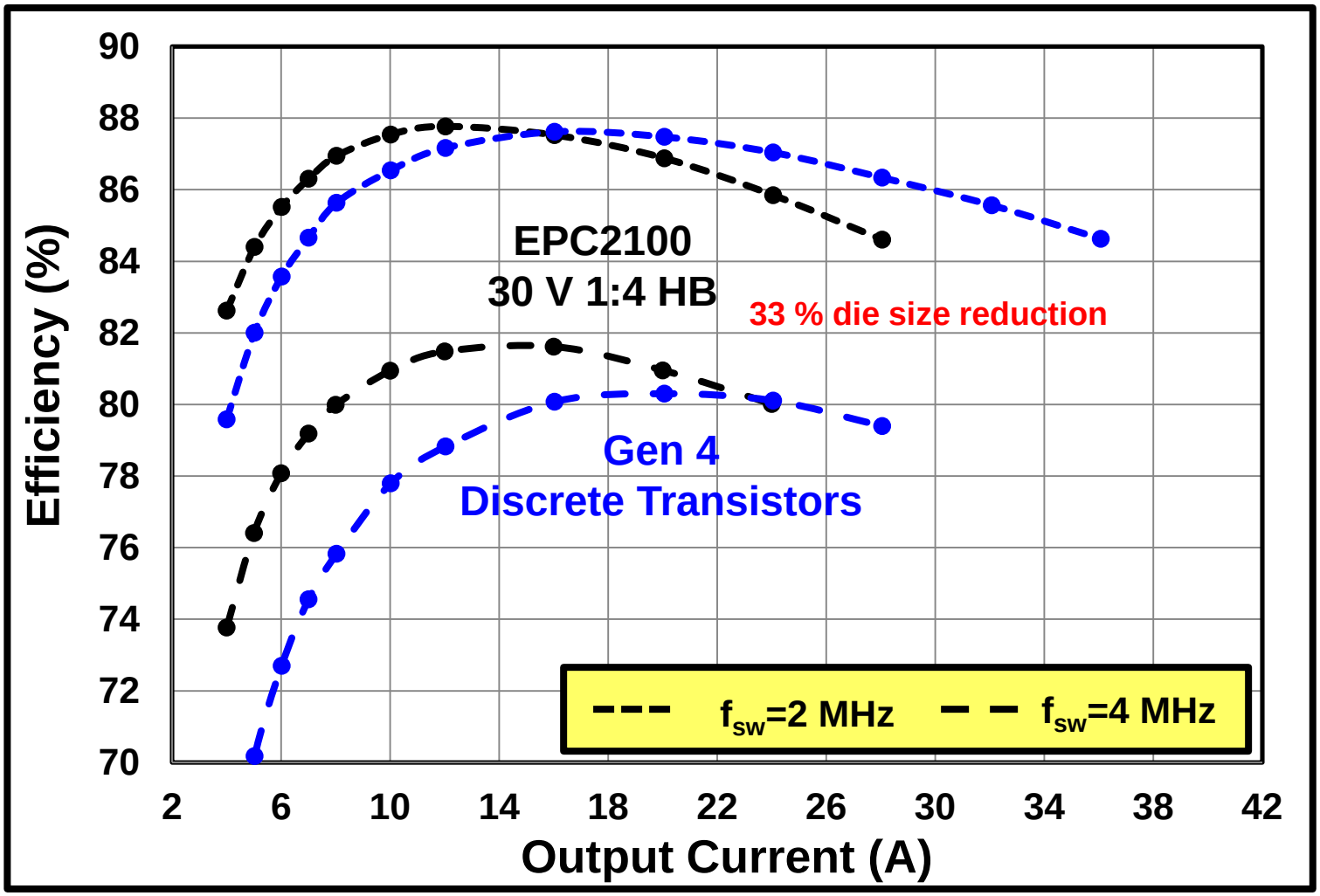
Generation 4 Monolithic 4:1 HB



33 % die size reduction

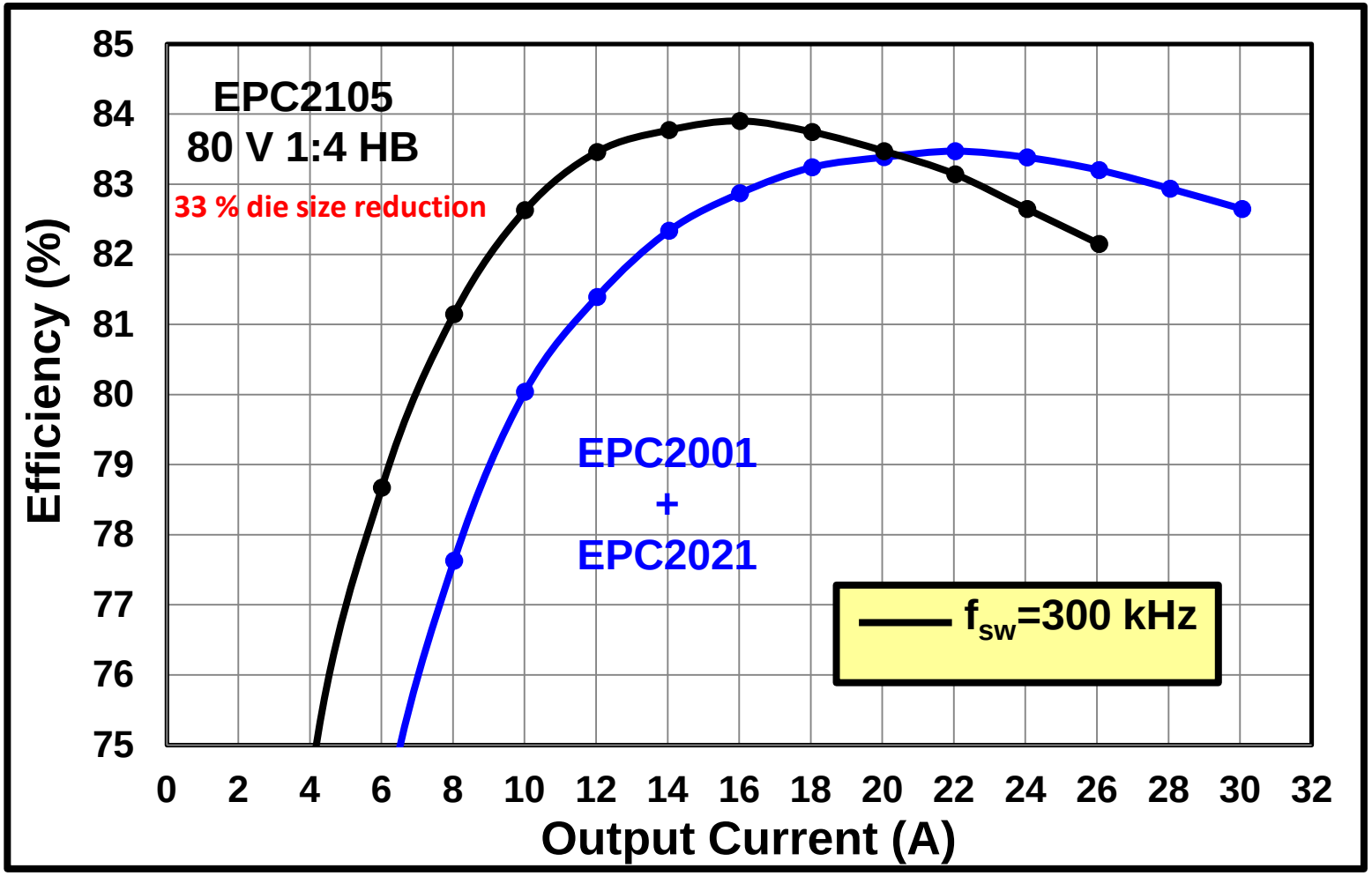


Monolithic Half Bridge



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

Monolithic Half Bridge



V_{IN}=48 V V_{OUT}=1 V L=330 nH

Reliability

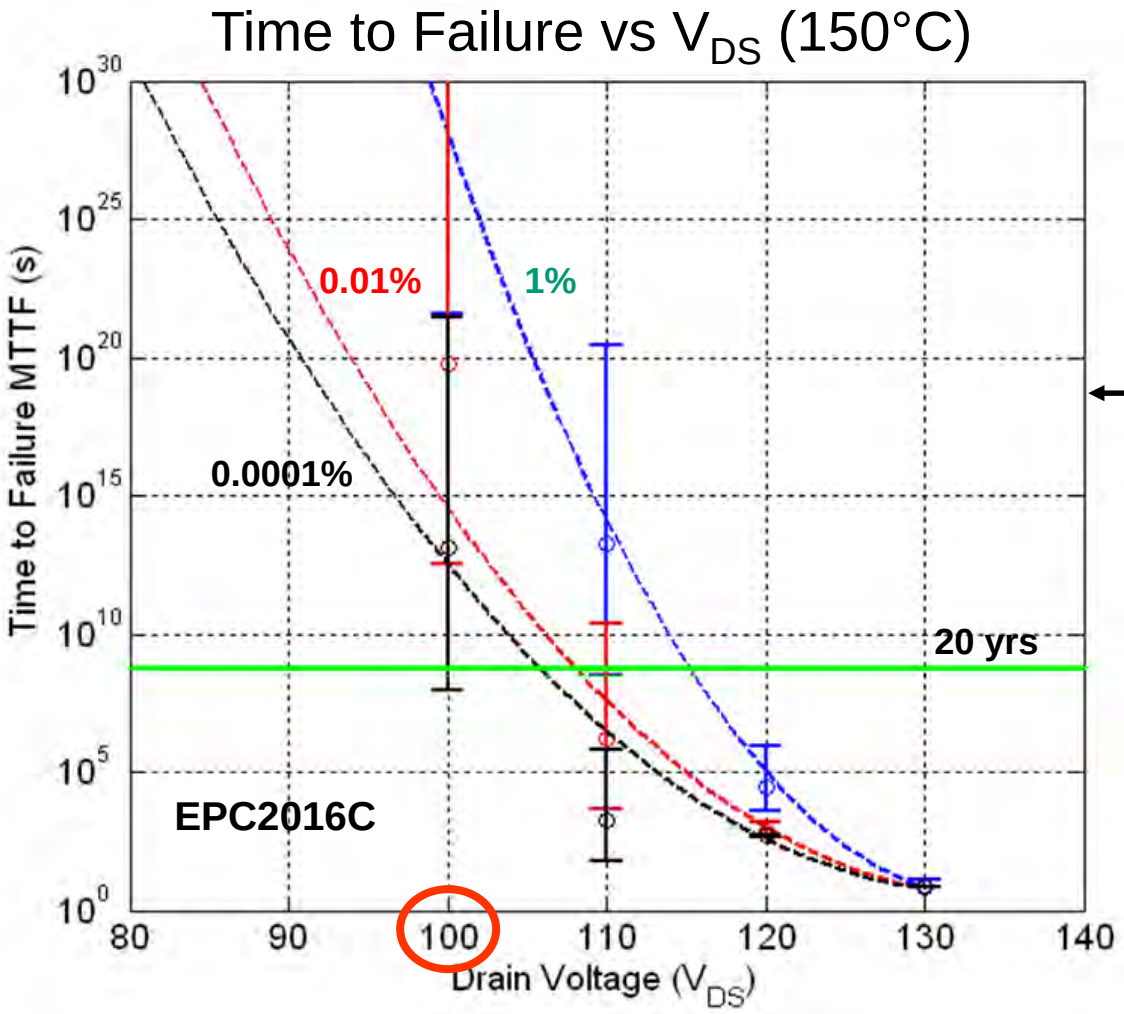
HTRB and HTGB Reliability

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failures	Sample Size (sample x lot)	Duration (Hrs)
HTRB							
HTRB	EPC2001C	100	L (4.11 x 1.63)	T=150°C, V_{DS}=80 V	0	77 x 2	2000
HTRB	EPC2016C	100	M (2.11 x 1.63)	T=150°C, V_{DS}=80 V	0	77 x 3	2000
HTRB	EPC2014C	40	M (1.70 x 1.09)	T=150°C, V_{DS}=32 V	0	77 x 1	2000
HTRB	EPC8004	40	S (2.05 x 0.85)	T=150°C, V_{DS}=32 V	0	77 x 1	2000
HTRB	EPC2010C	200	L (3.55 x 1.63)	T=150°C, V_{DS}=160 V	0	77 x 2	2000
HTRB	EPC2012C	200	M (1.71 x 0.92)	T=150°C, V_{DS}=160 V	0	77 x 1	1000
HTGB							
HTGB	EPC2001C	100	L (4.11 x 1.63)	T=150°C, V_{GS}=5.75 V	0	77 x 2	2000
HTGB	EPC2016C	100	M (2.11 x 1.63)	T=150°C, V_{GS}=5.75 V	0	77 x 3	2000
HTGB	EPC2014C	40	M (1.70 x 1.09)	T=150°C, V_{GS}=5.5 V	0	77 x 1	2000
HTGB	EPC8004	40	S (2.05 x 0.85)	T=150°C, V_{GS}=5.5 V	0	77 x 1	2000
HTGB	EPC2010C	200	L (3.55 x 1.63)	T=150°C, V_{GS}=5.75 V	0	77 x 2	2000
HTGB	EPC2012C	200	M (1.71 x 0.92)	T=150°C, V_{GS}=5.75 V	0	77 x 1	1000

Environmental Reliability

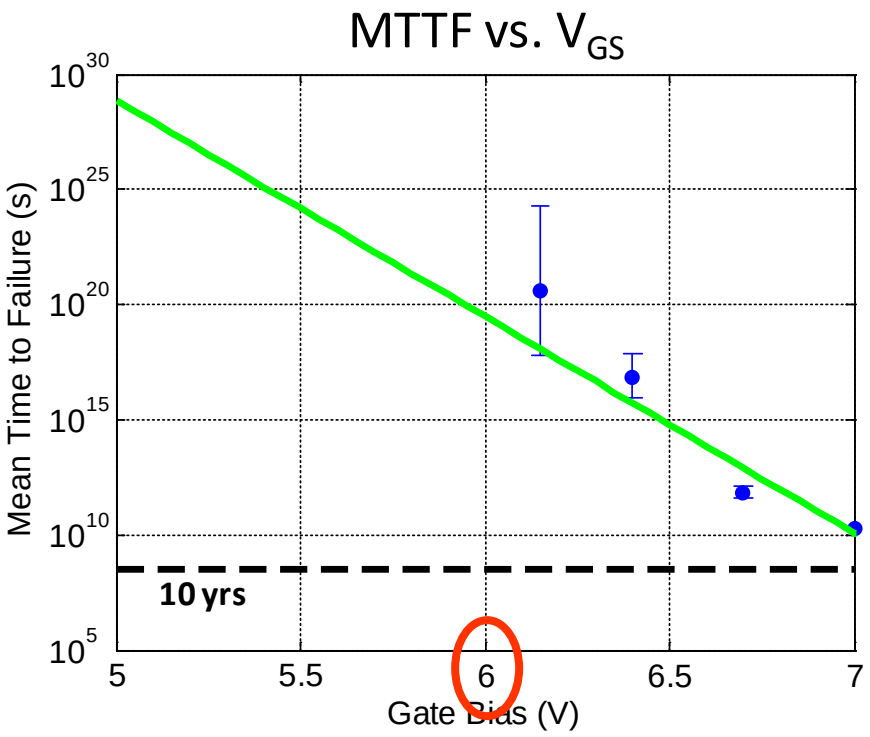
Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (sample x lot)	Duration
H3TRB (JEDEC Standard JESD22A101)							
H3TRB	EPC2001C	100	L (4.11 x 1.63)	T=85°C, RH=85%, V_{DS}=80 V	0	25 x 1	1000 Hrs
H3TRB	EPC2016C	100	M (2.11 x 1.63)	T=85°C, RH=85%, V_{DS}=80 V	0	25 x 2	1000 Hrs
H3TRB	EPC2015	40	L (4.11 x 1.63)	T=85°C, RH=85%, V_{DS}=40 V	0	50 x 1	1000 Hrs
H3TRB	EPC2010	200	L (3.55 x 1.63)	T=85°C, RH=85%, V_{DS}=100 V	0	50 x 1	1000 Hrs
H3TRB	EPC2012	200	M (1.71 x 0.92)	T=85°C, RH=85%, V_{DS}=100 V	0	50 x 1	1000 Hrs
HTS							
HTS	EPC2001C	100	L (4.11 x 1.63)	T=150°C, Air	0	77 x 1	1000 Hrs
HTS	EPC2016C	100	M (2.11 x 1.63)	T=150°C, Air	0	77 x 2	1000 Hrs
TC (JEDEC Standard JESD22A104)							
TC	EPC2001	100	L (4.11 x 1.63)	-40 to +125°C, Air	0	35 x 3	1000 Cys
TC	EPC8007	40	S (2.05 x 0.85)	-40 to +125°C, Air	0	35 x 1	1000 Cys
TC	EPC2010	200	L (3.55 x 1.63)	-40 to +125°C, Air	0	35 x 1	1000 Cys
MSL1 (IPC/JEDEC joint Standard J-STD-020)							
MSL1	EPC2001	100	L (4.11 x 1.63)	T=85°C, RH=85%, 3 reflow	0	25 x 1	168 Hrs
MSL1	EPC8003	40	S (2.05 x 0.85)	T=85°C, RH=85%, 3 reflow	0	25 x 1	168 Hrs
MSL1	EPC8007	40	S (2.05 x 0.85)	T=85°C, RH=85%, 3 reflow	0	25 x 1	168 Hrs
AC (JEDEC Standard JESD22A102)							
AC	EPC2001C	100	L (4.11 x 1.63)	T=121°C, RH=100%	0	25 x 1	96 Hrs
AC	EPC2016C	100	M (2.11 x 1.63)	T=121°C, RH=100%	0	25 x 2	96 Hrs

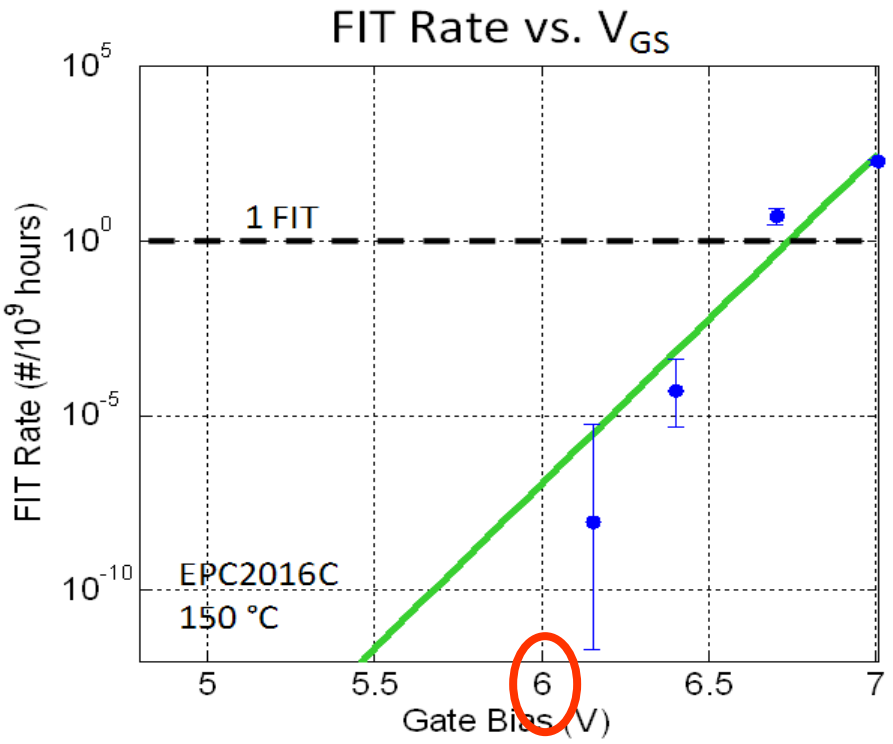
Failure under Drain Stress



Age of the Universe

Gate Stress

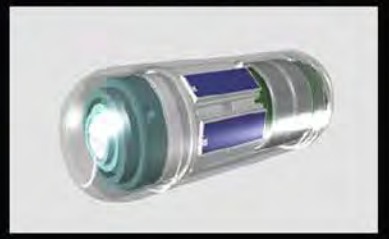

MTTF vs. V_{GS}
Mean Time to Failure (s)
10^{30}
10^{25}
10^{20}
10^{15}
10^{10}
10^{5}
10 yrs
5
5.5
6
6.5
7
Gate Bias (V)


FIT Rate vs. V_{GS}
FIT Rate (#/10^9 hours)
10^{5}
10^{0}
10^{-5}
10^{-10}
1 FIT
EPC2016C
150 °C
5
5.5
6
6.5
7
Gate Bias (V)

EPC

EFFICIENT POWER CONVERSION

Where is GaN going…



eGaN FET Applications

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

Wireless Power

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

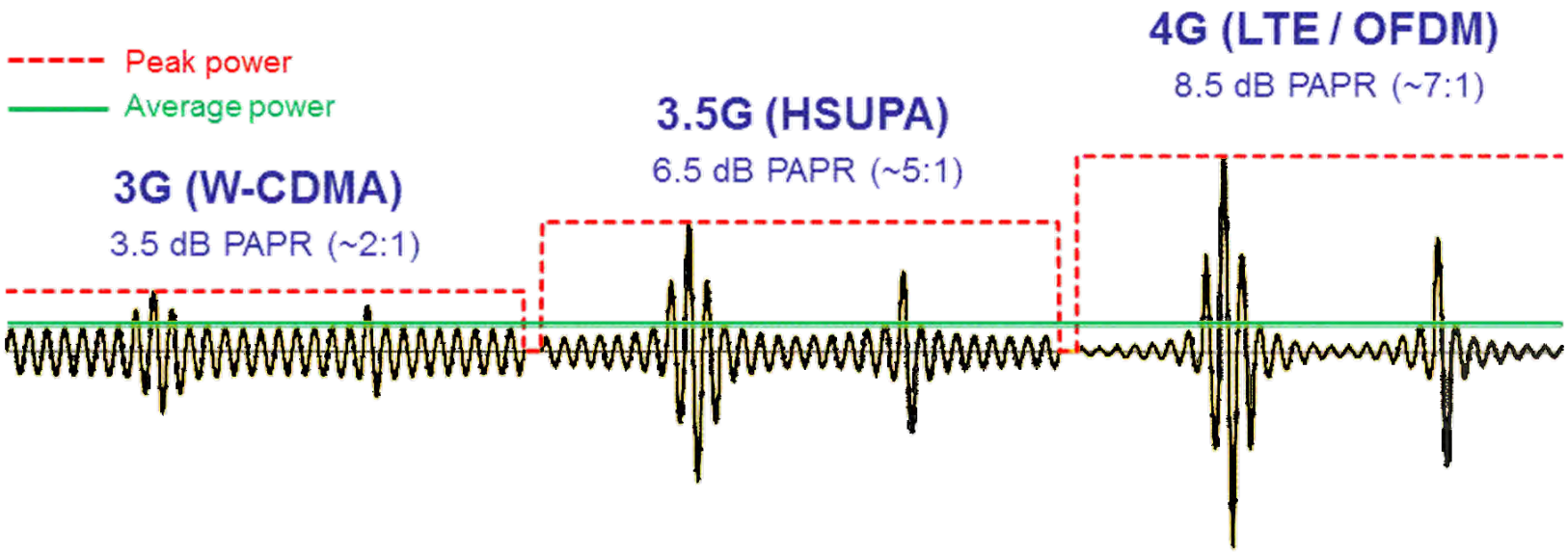
LiDAR

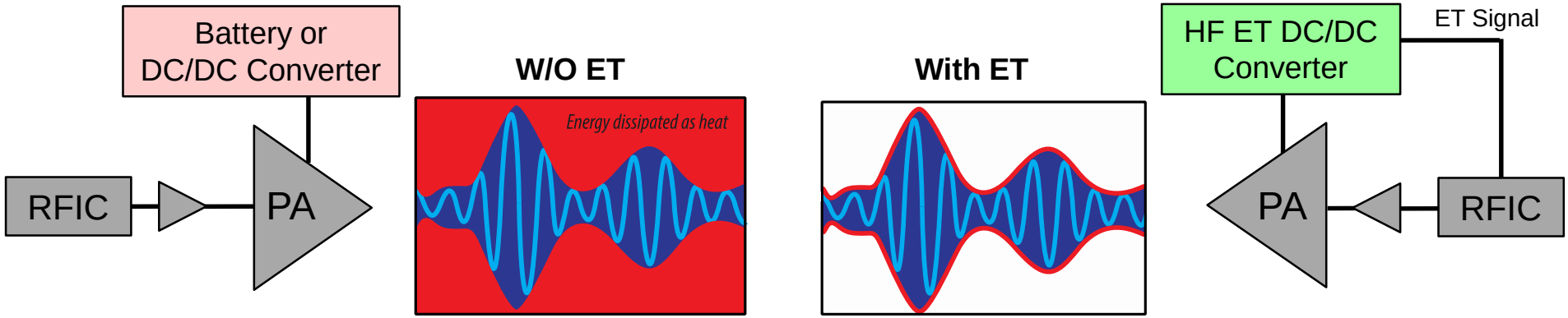
LiDAR system used for 3D orientation in virtual reality systems

eGaN FETs in a LiDAR system on an autonomous prototype

LiDAR uses lasers pulsed by eGaN FETs to rapidly create a 3D image of the surrounding area.

Envelope Tracking



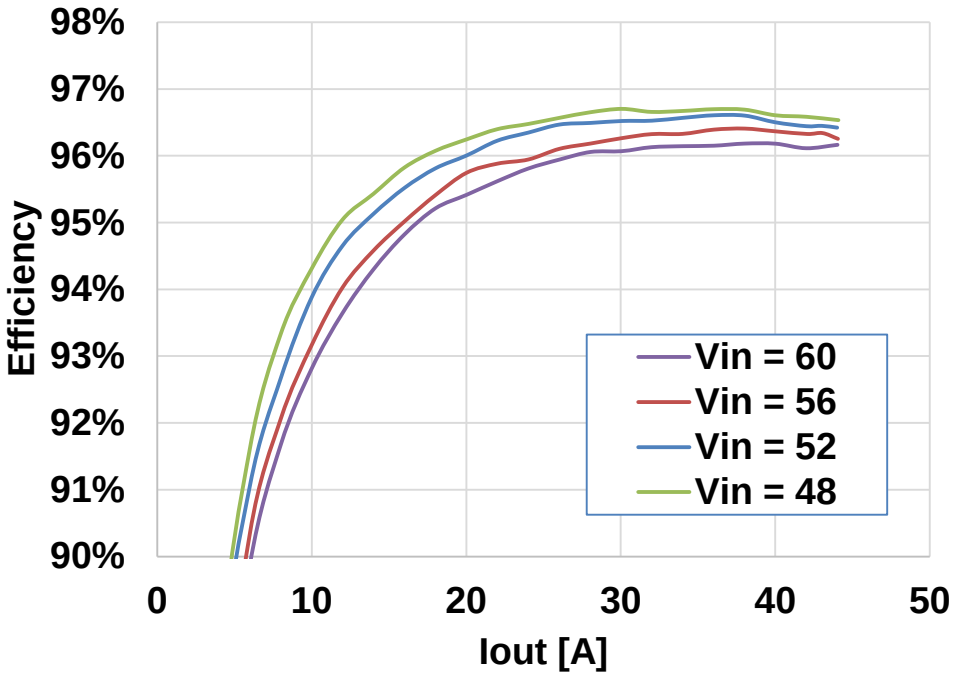


Reference: Nujira.com website

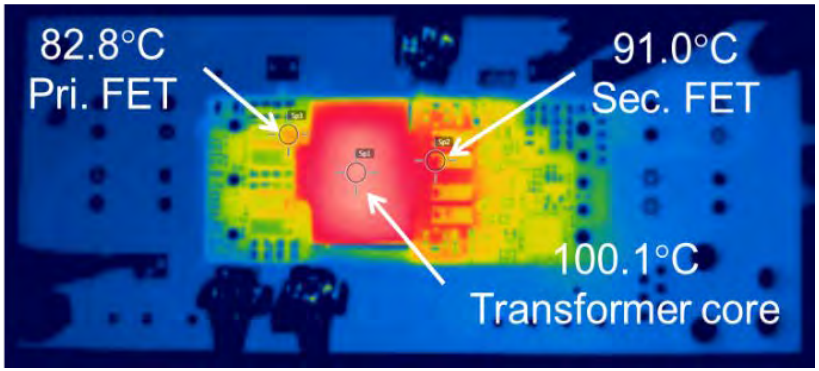
DC-DC 1/8th Brick

- Fully regulated
- Isolated
- 52 V nominal input (4:1 transformer)
- DOSA-compliant footprint
- 500 W output at 12V

500 W 1/8 Brick Efficiency



2m/s airflow



MOSFET vs. eGaN Costs*

	2014	2016
Starting Material	lower	lower
Epi Growth	***~higher***	***~same?***
Wafer Fab	lower	lower
Test	same	same
Assembly	lower	lower
OVERALL	**~higher**	***lower!***

* Product with the same on resistance and voltage rating

MOSFET vs. eGaN Costs*

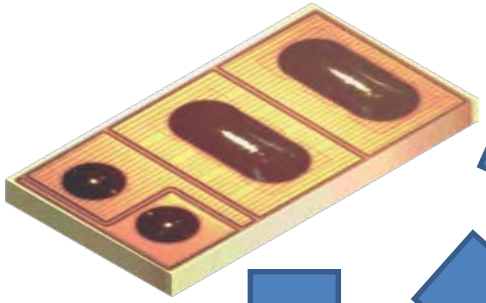
Active die <3 mm^2

	2014	2016
Starting Material	lower	lower
Epi Growth	***~same***	***~same?***
Wafer Fab	lower	lower
Test	same	same
Assembly	lower	lower
OVERALL	***lower!***	***lower!***

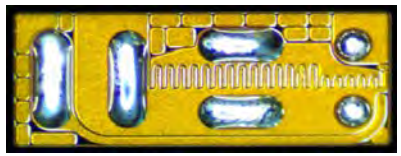
* Product with the same on resistance and voltage rating

Moore's Law Revival

Gen 2
2010-2013
40 V - 200 V



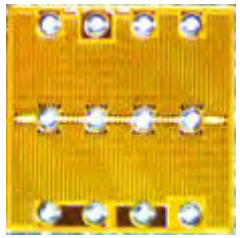
Generation 3
Higher Frequency
Launched
September 2013



Generation 4
2 X Performance Improvement
Launched
June 2014

Half Bridge ICs
Launched
September 2014

High Voltage
Launched
September 2014



Generation 5
Soon!

Summary

- eGaN technology is moving quickly. The latest generation of products more than doubles DC-DC converter power density.
- eGaN technology is proving to be very thermally efficient and reliable.
- eGaN technology is making serious inroads into silicon's territory.

EPC

EFFICIENT POWER CONVERSION

Where is GaN going…