



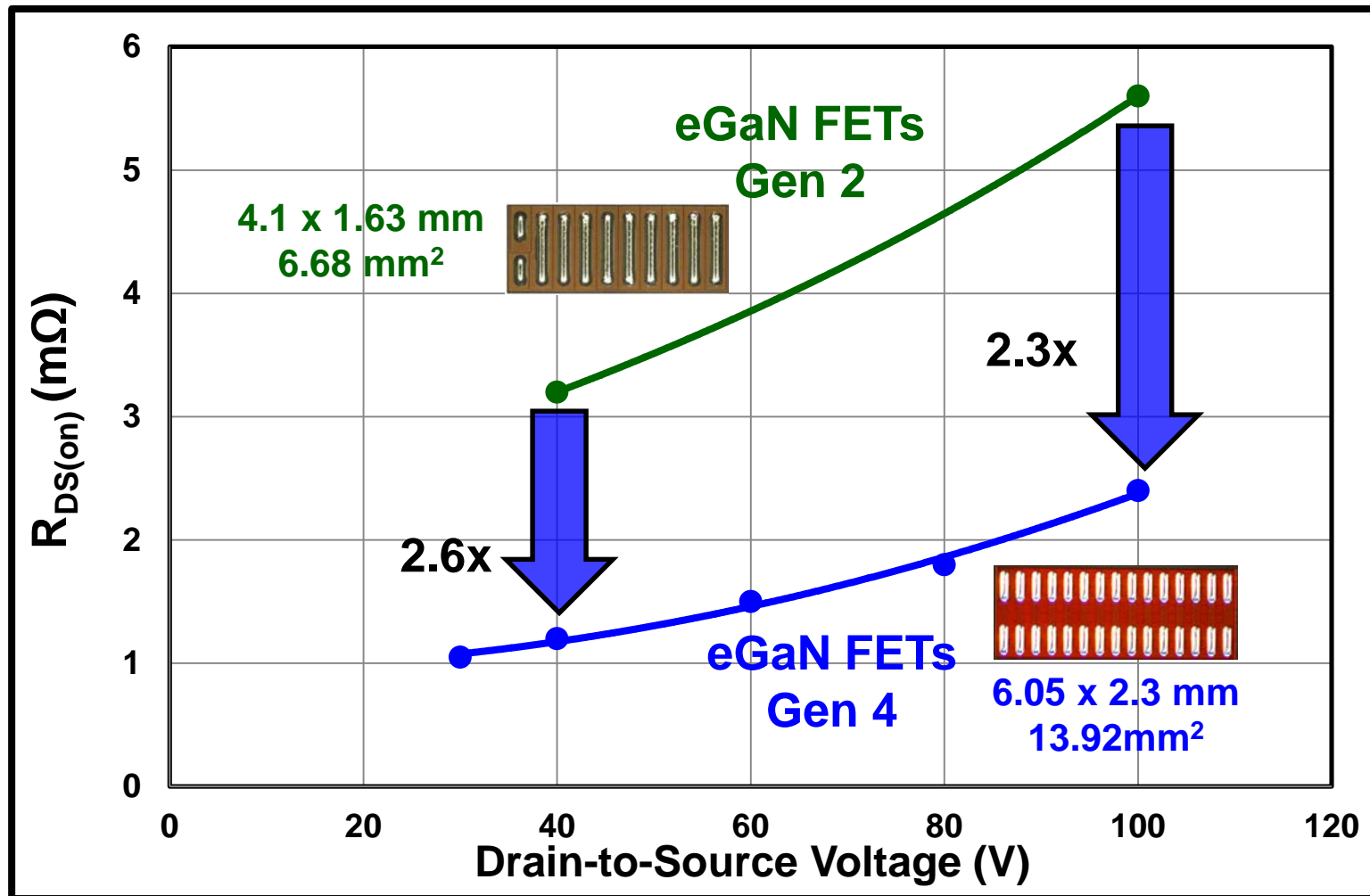
The eGaN[®] FET
Journey Continues

GaN Transistors – Giving New Life to Moore's Law

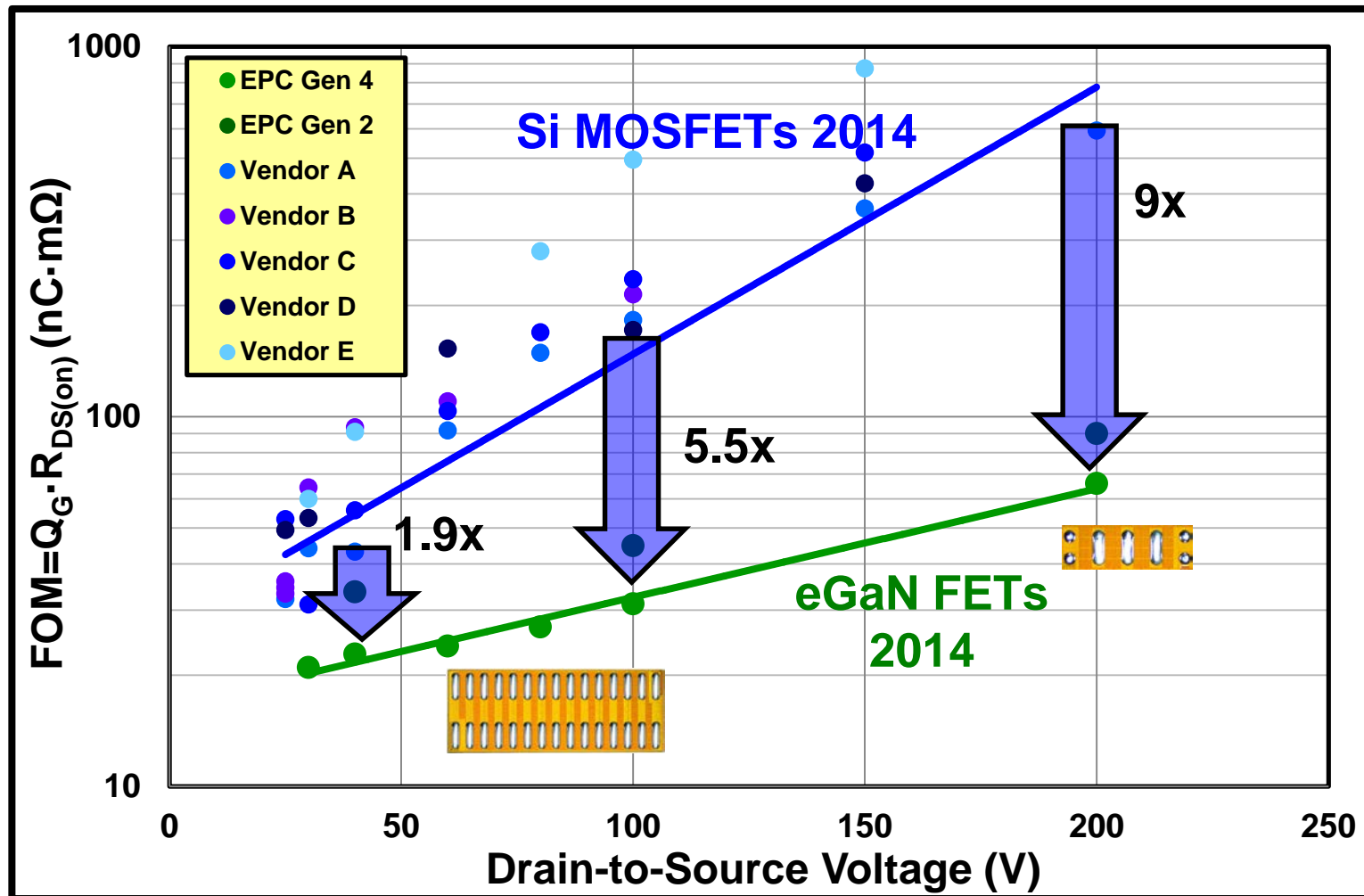
Alex Lidow

- GaN - The Better Switch
- Performance
- Reliability
- Cost
- Summary

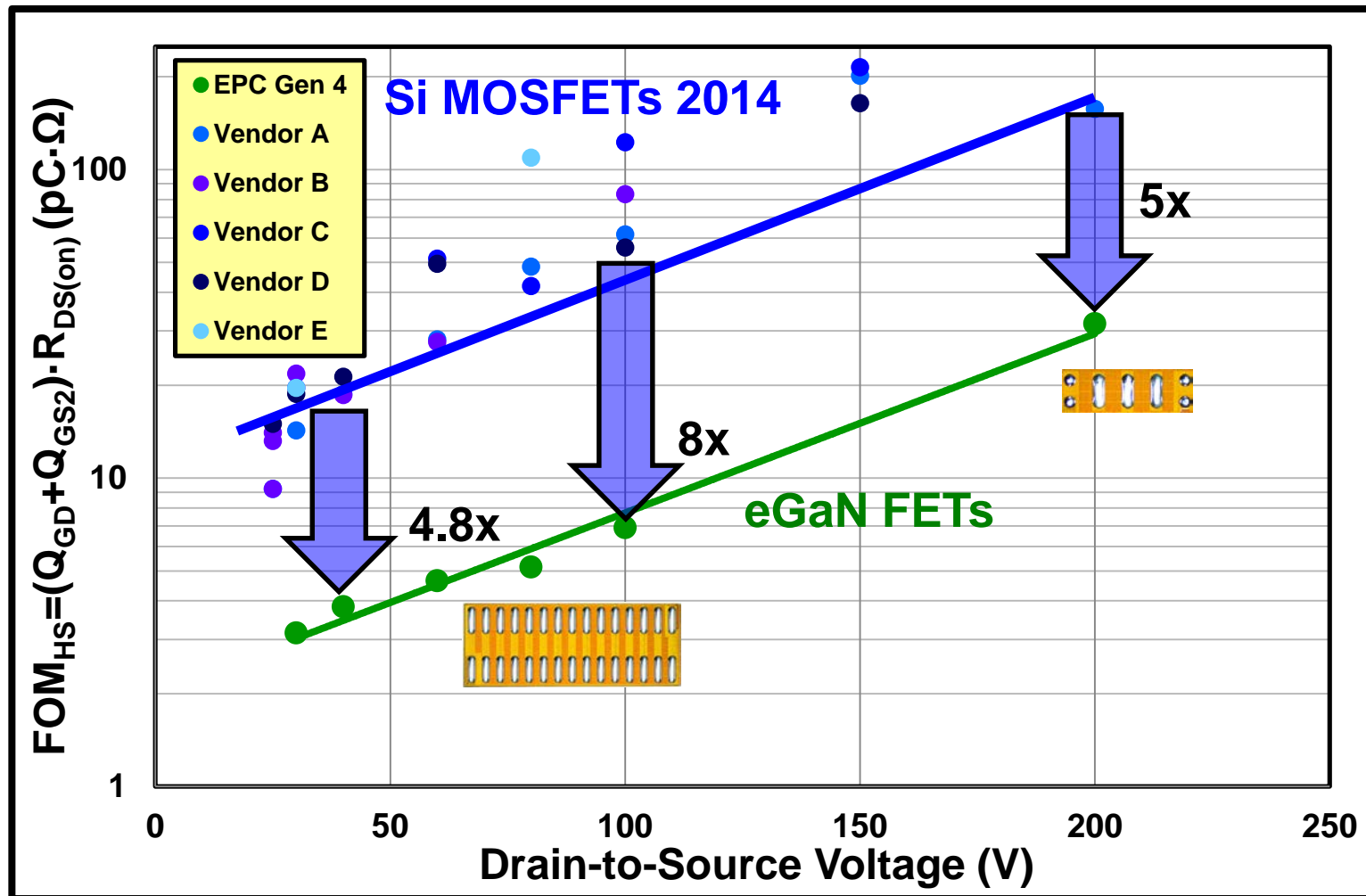
- Lower On Resistance
- Less Capacitance
- Less Inductance
- Lower Thermal Impedance
- Smaller
- Lower Cost



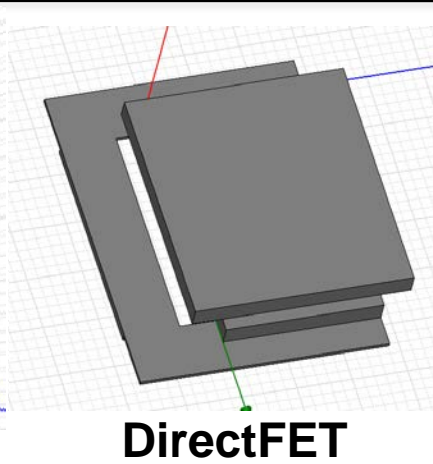
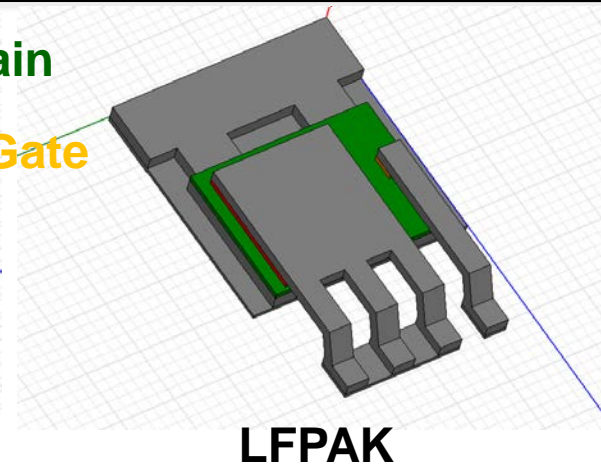
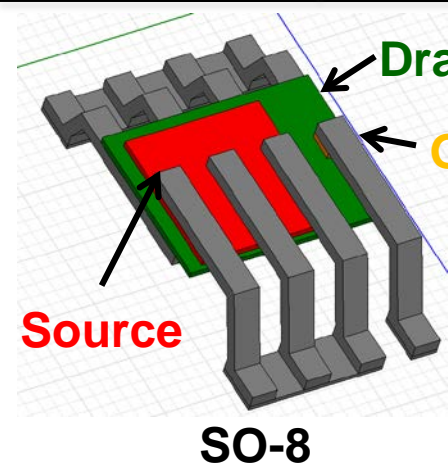
$V_{GS} = 5 \text{ V}$



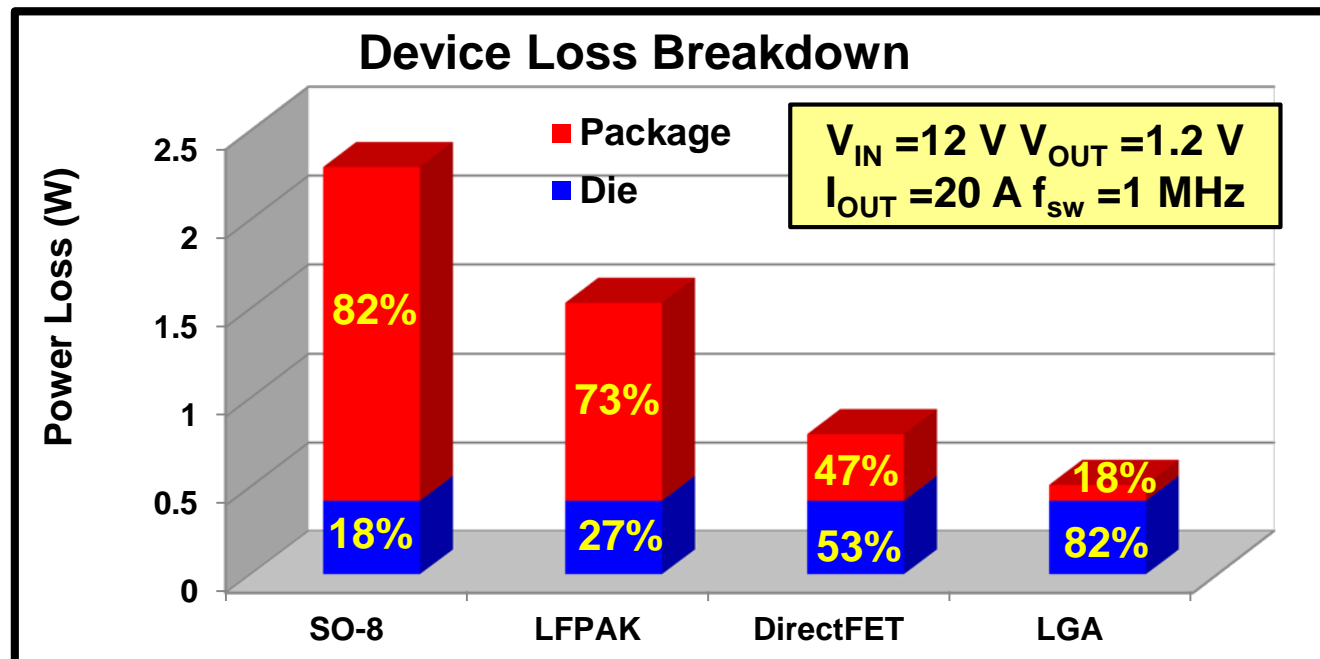
$$V_{DS} = 0.5 \cdot V_{DSS}$$



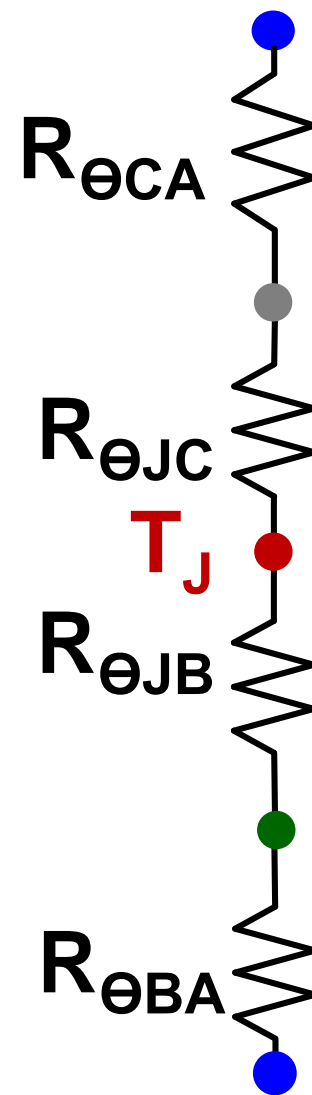
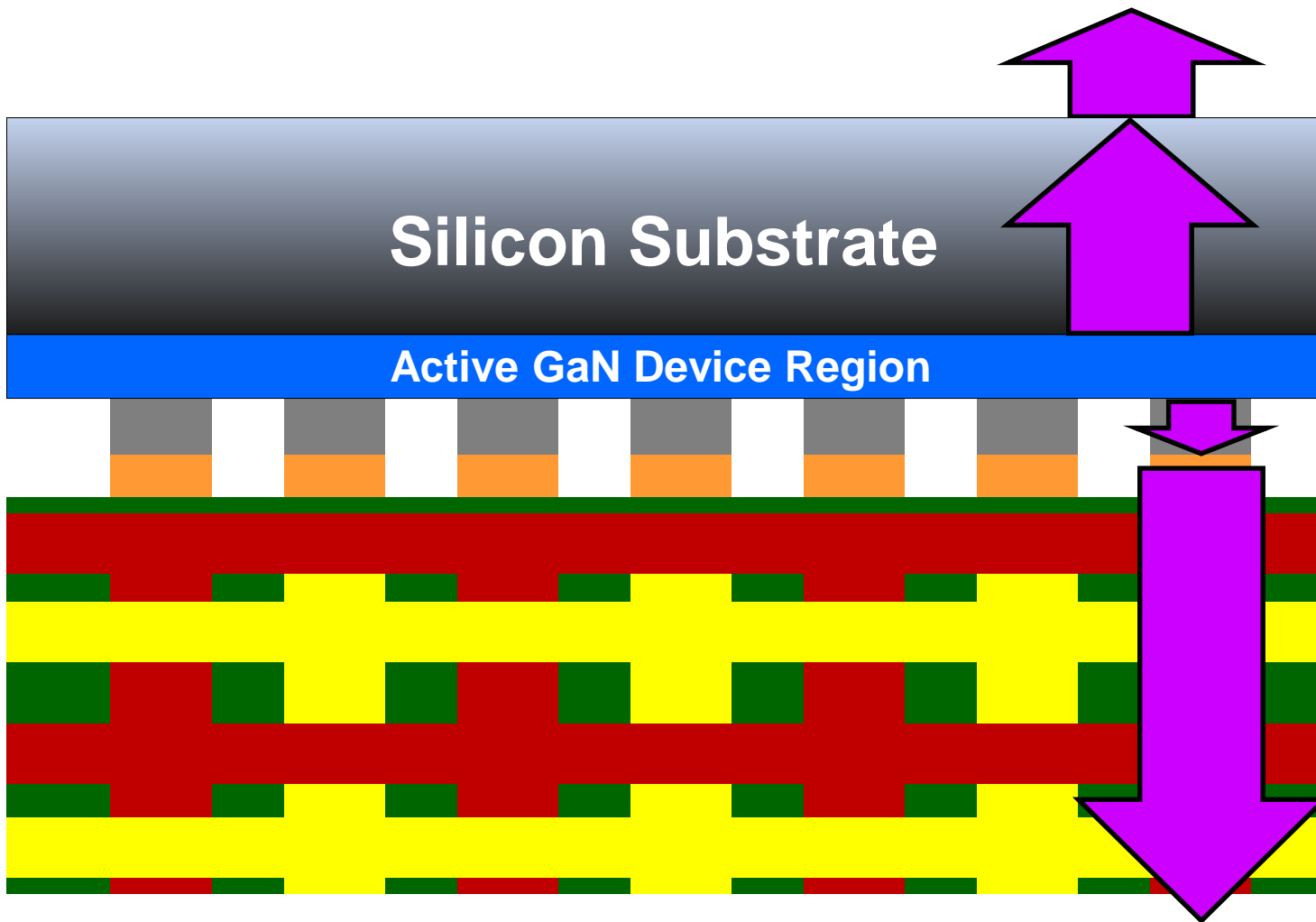
$$V_{DS} = 0.5 \cdot V_{DSS}, I_{DS} = 20 \text{ A}$$

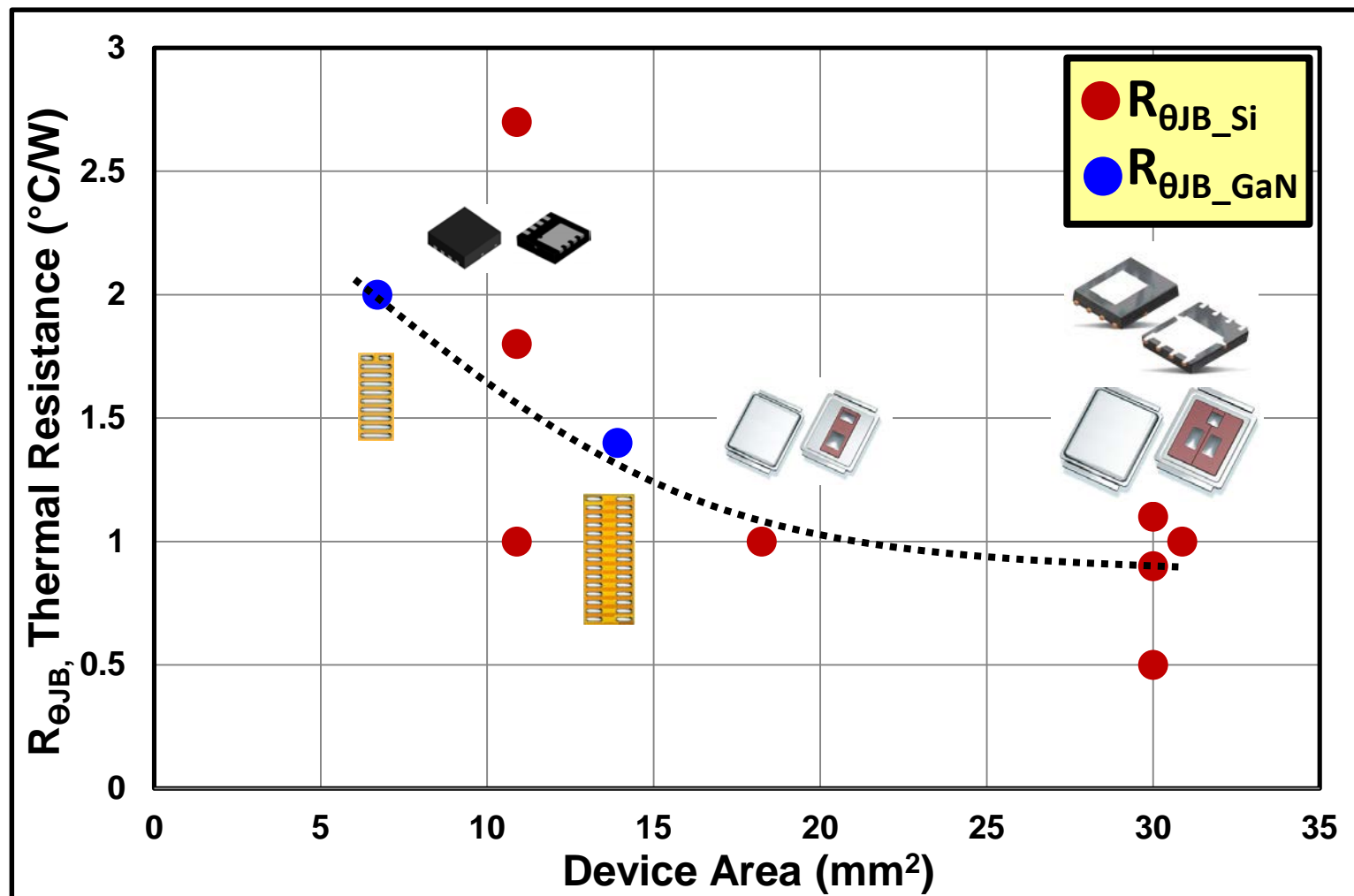


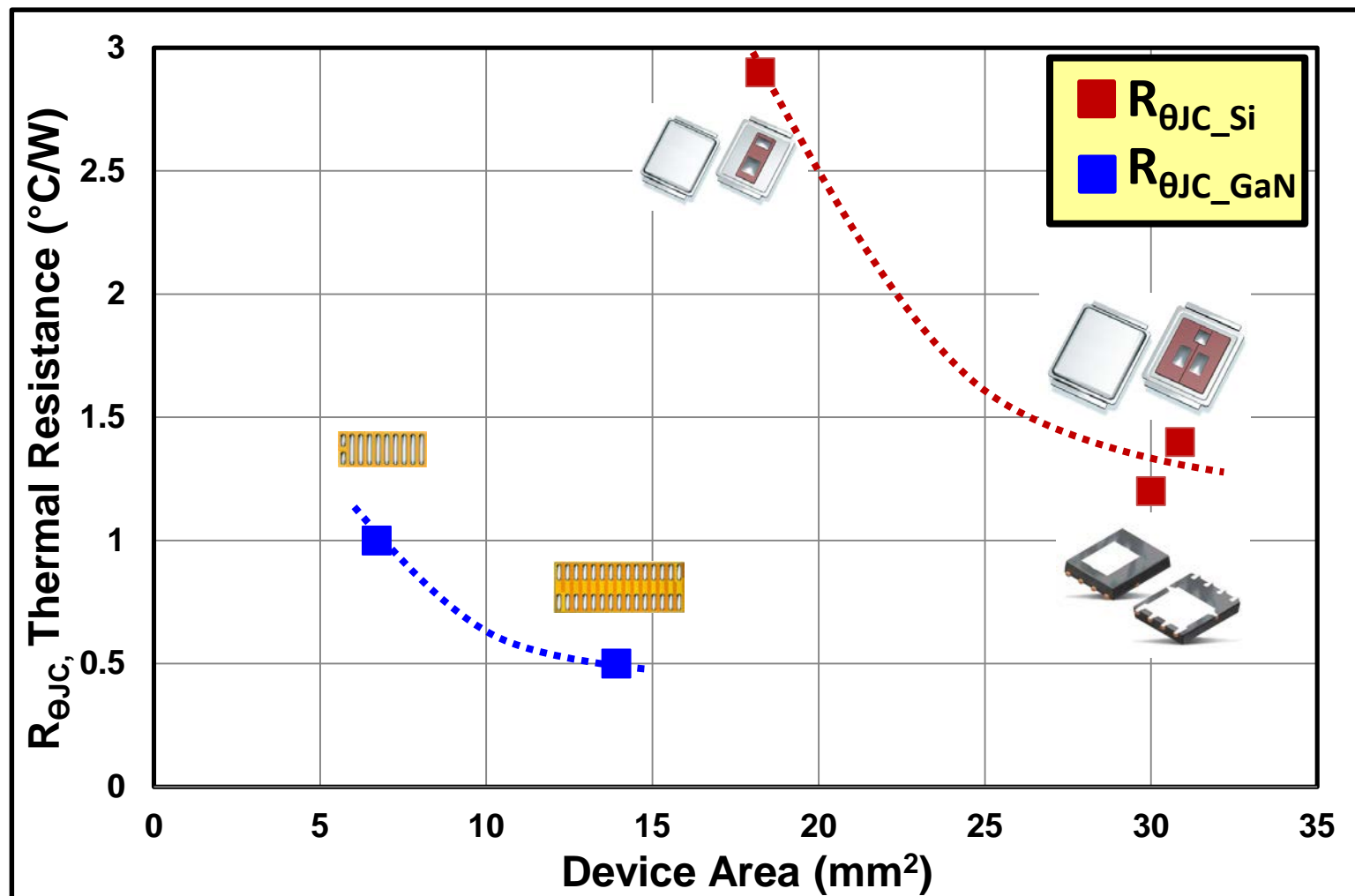
LGA eGaN FET

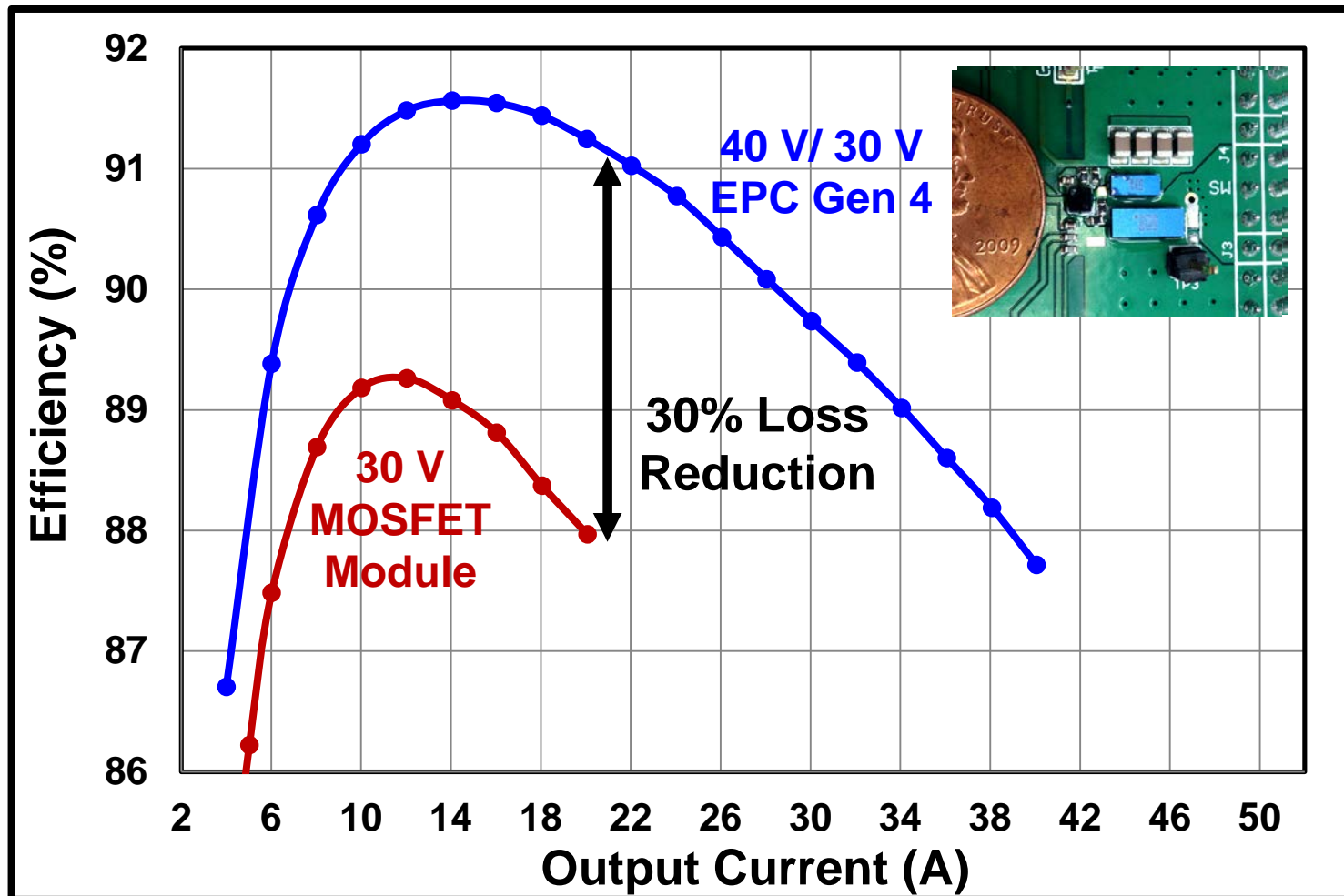


Reference: D. Reusch, D. Gilham, Y. Su, and F.C. Lee, C, "Gallium Nitride Based 3D Integrated Non-Isolated Point of Load Module," APEC 2012

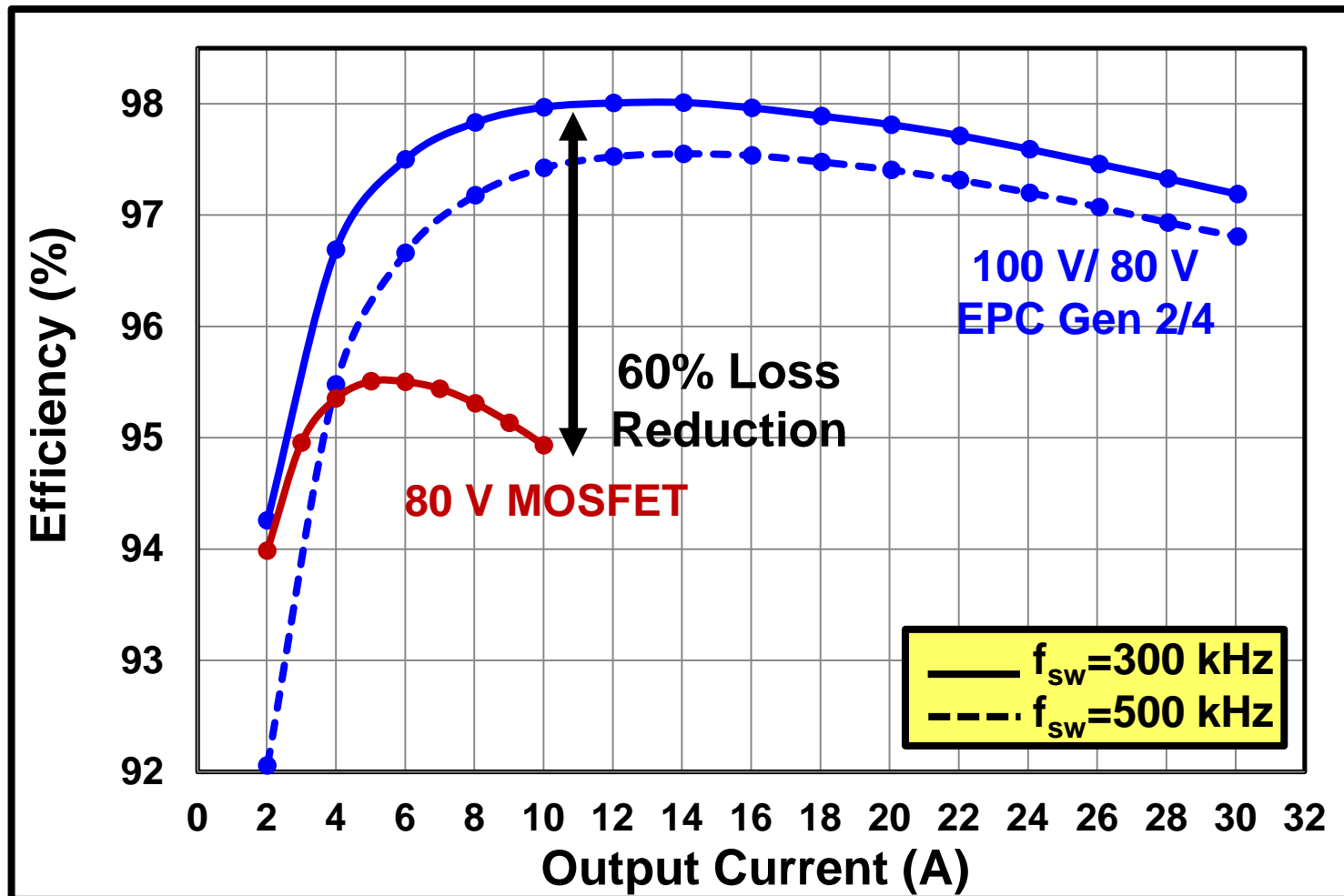








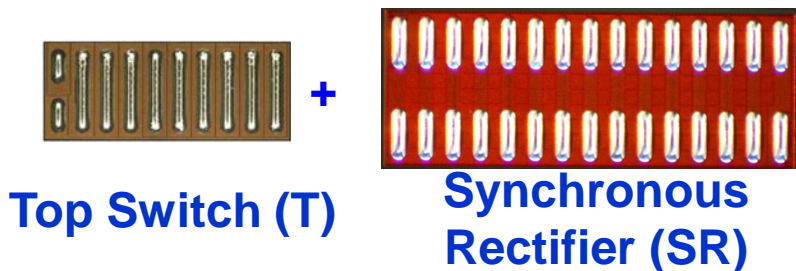
$V_{IN}=12\text{ V}$ $V_{OUT}=1.2\text{ V}$ 1 MHz



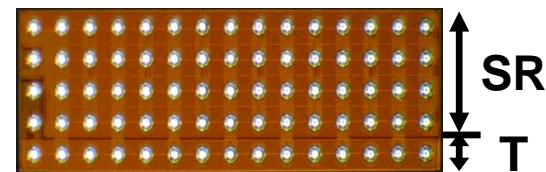
$V_{IN}=48$ V $V_{OUT}=12$ V

Take It Up Another Notch!

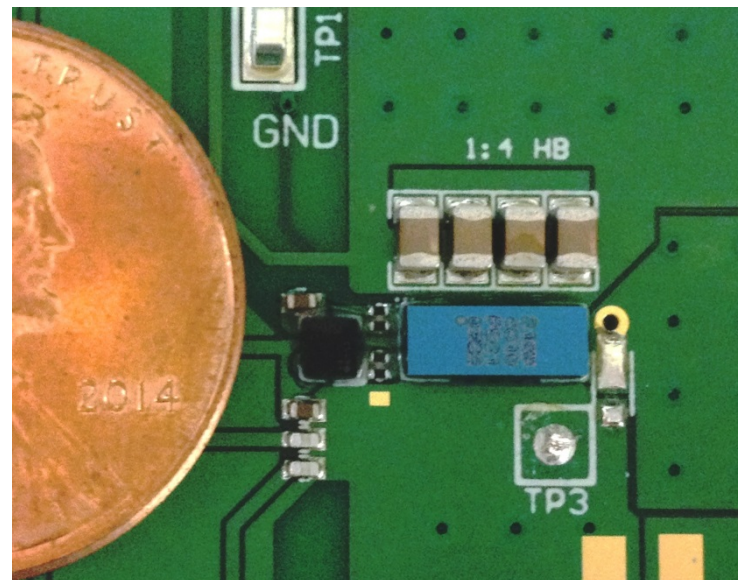
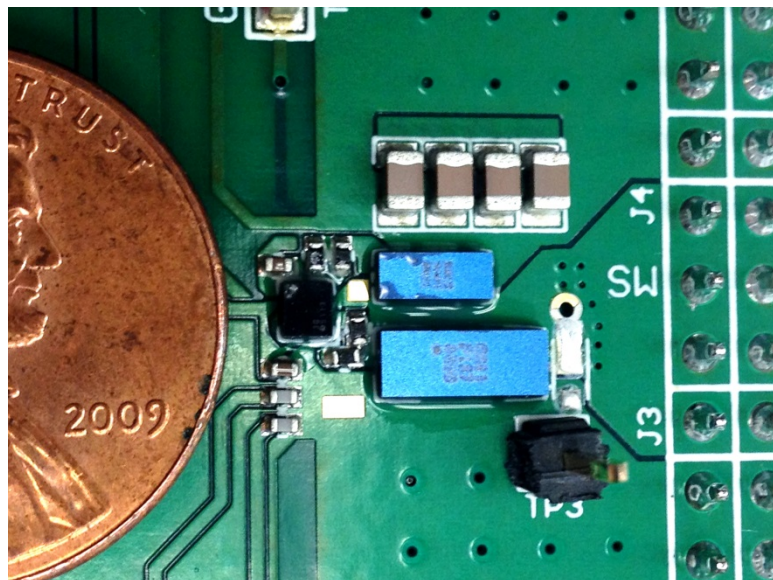
Generation 2/4 Discrete HB

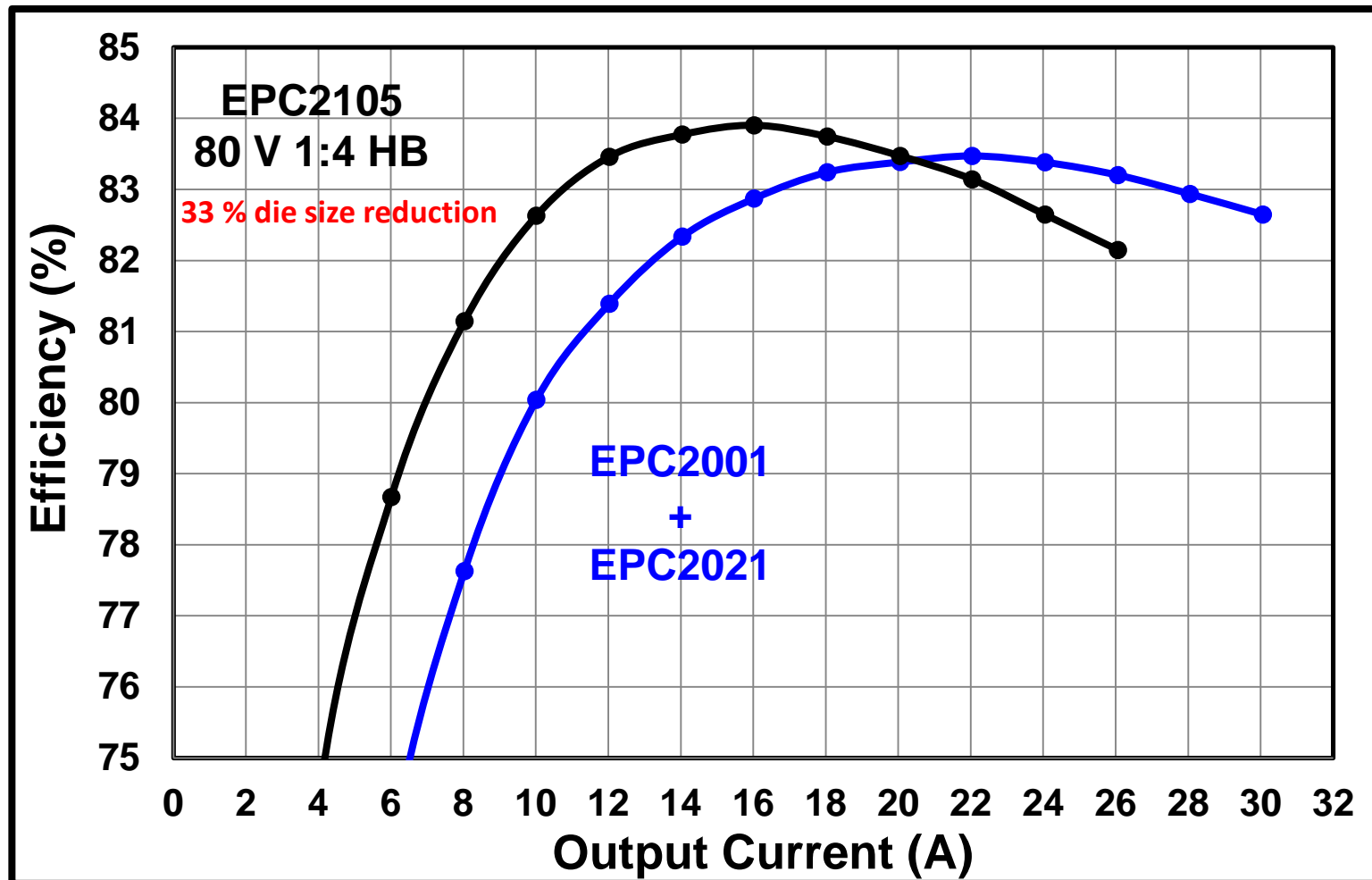


Generation 4 Monolithic 4:1 HB



33 % die size reduction



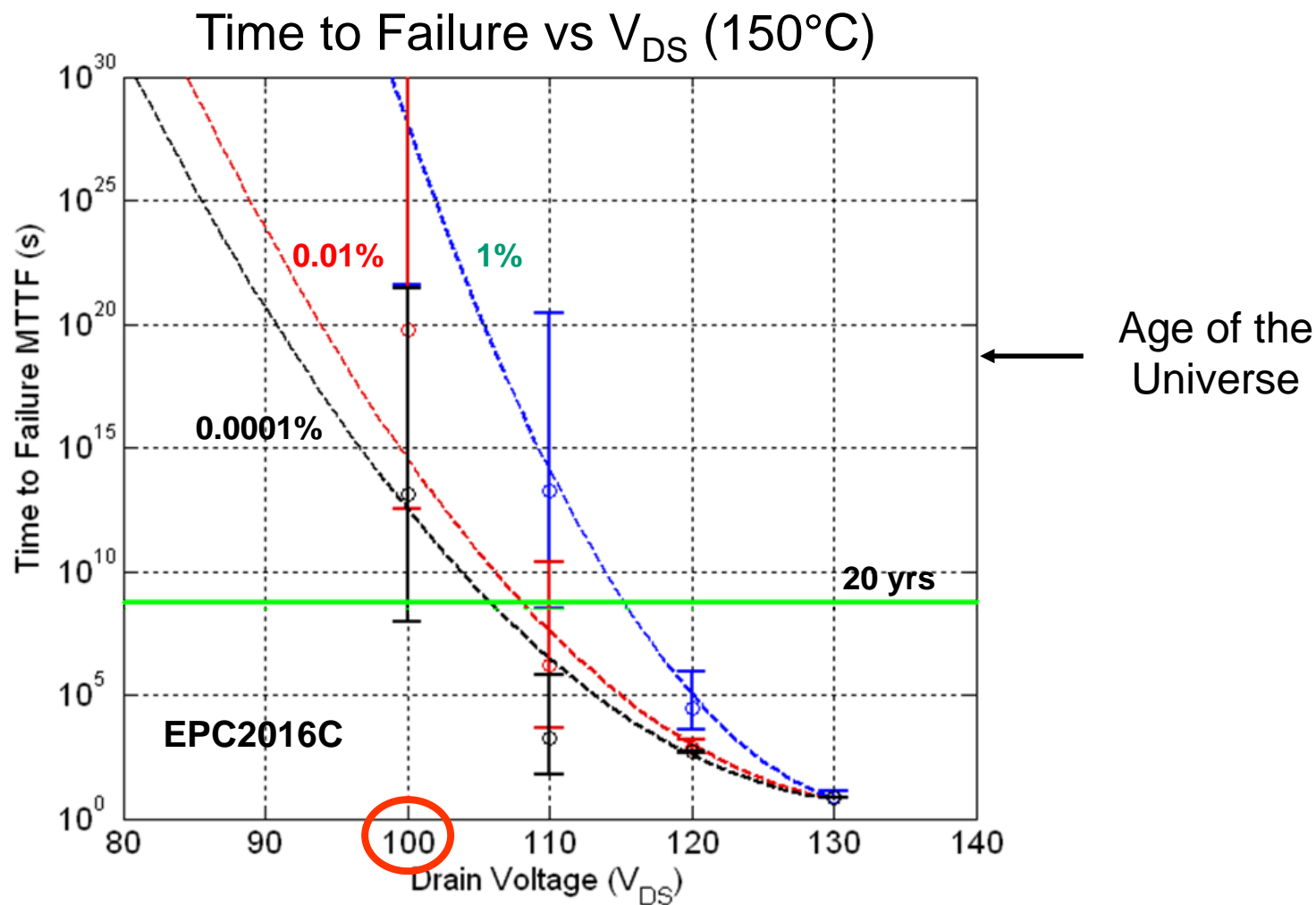


$V_{IN}=48\text{ V}$ $V_{OUT}=1\text{ V}$ 300 kHz L=330 nH

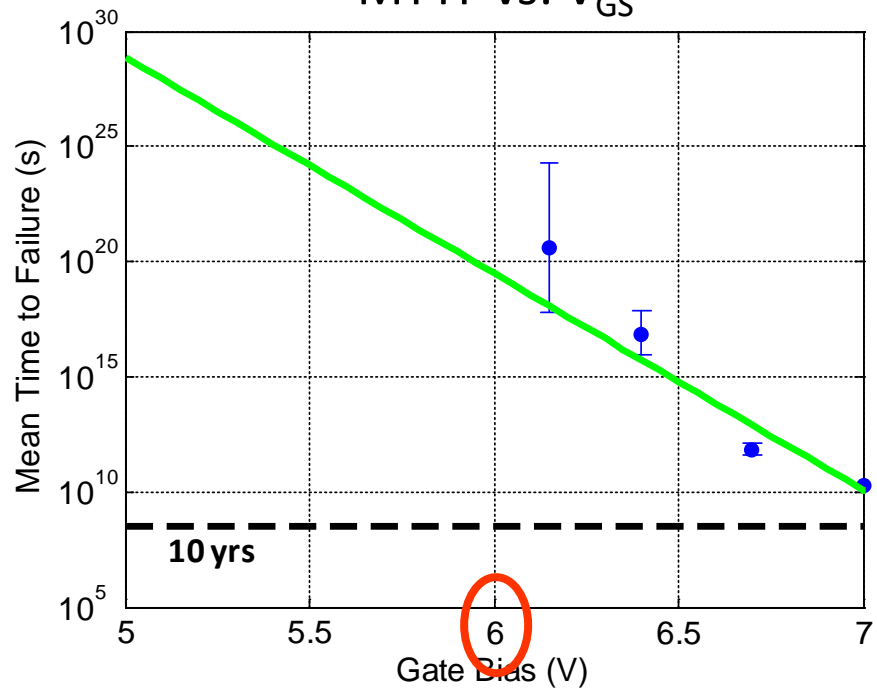
Reliability

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	3000
HTRB	EPC2016C	100	M (2.11 x 1.63)	T=150°C, V _{DS} =80 V	0	77 x 1	3000
HTRB	EPC2016C	100	M (2.11 x 1.63)	T=150°C, V _{DS} =80 V	0	77 x 2	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	3000
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	3000
HTGB	EPC2016C	100	M (2.11 x 1.63)	T=150°C, V _{GS} =5.75 V	0	77 x 1	3000
HTGB	EPC2016C	100	M (2.11 x 1.63)	T=150°C, V _{GS} =5.75 V	0	77 x 2	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	3000
HTGB	EPC2012C	200	M (1.71 x 0.92)	T=150°C, V _{GS} =5.75 V	0	77 x 1	1000

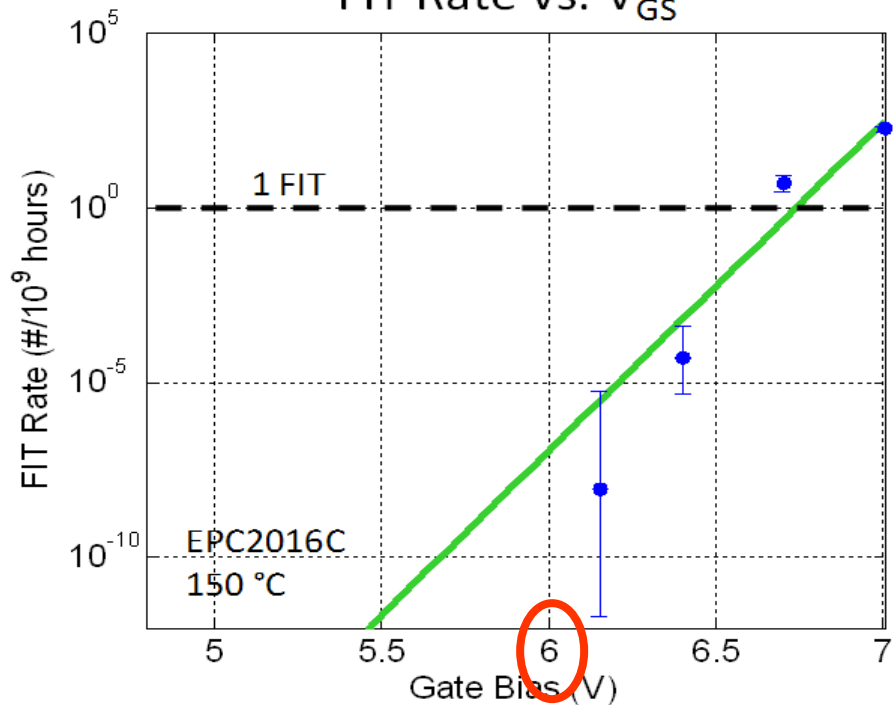
Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (sample x lot)	Duration
H3TRB (JEDEC Standard JESD22A101)							
H3TRB	EPC2001C	100	L (4.11 x 1.63)	T=85°C, RH=85%, V _{DS} =80 V	0	25 x 1	1000 Hrs
H3TRB	EPC2016C	100	M (2.11 x 1.63)	T=85°C, RH=85%, V _{DS} =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



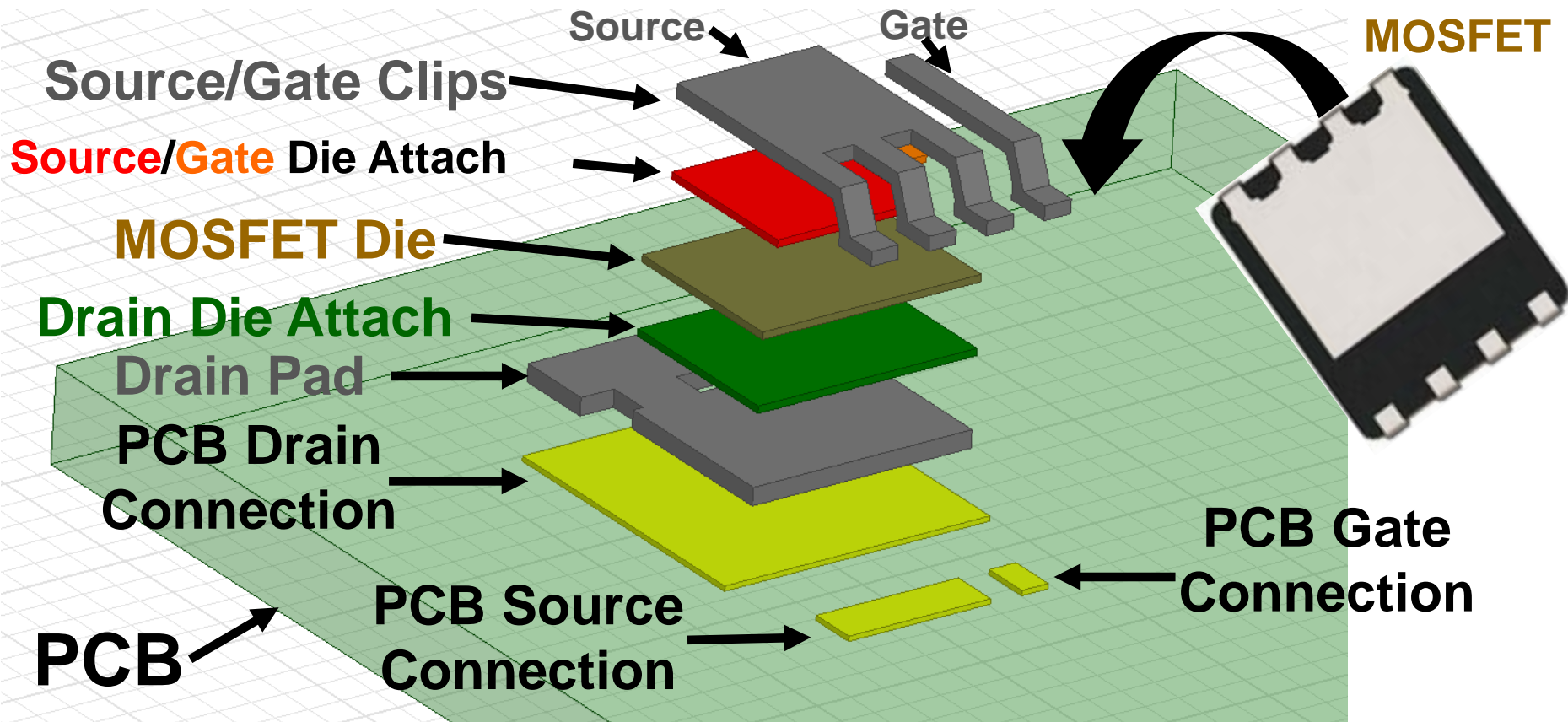
MTTF vs. V_{GS}

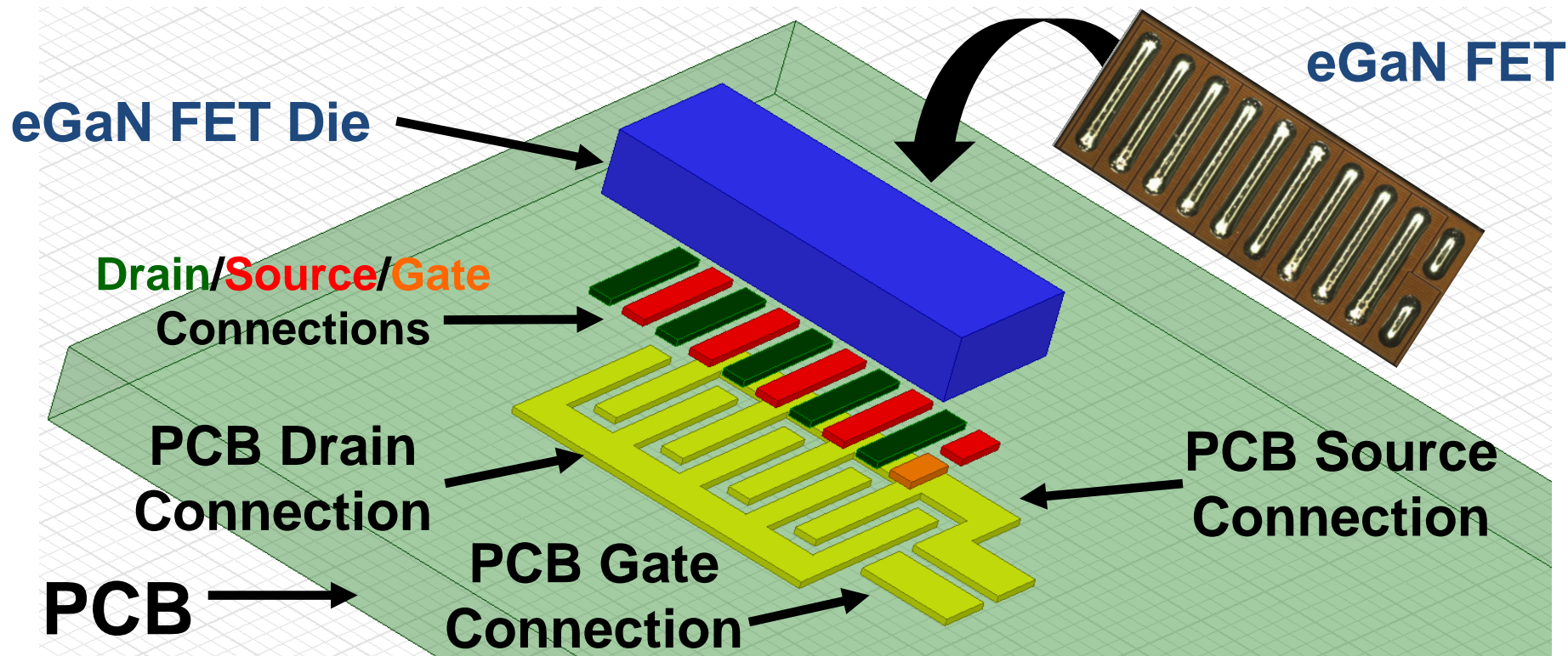


FIT Rate vs. V_{GS}



Technology	Part	Fully Enhanced Gate Voltage (V)	Stress Conditions	HTGB FIT Rate (#/billion hours)
eGaN FET	EPC2016	5	150 °C 5V	<< 1
Silicon n-MOSFET	IRF6795M	10	150 °C 10V	7 [Ref 13]
SiC n-MOSFET	CPM2-1200-0025B	20	150 °C 20V	100 [Ref 14]
Technology	Part	Maximum Drain Voltage (V)	Stress Conditions	HTRB FIT Rate (#/billion hours)
eGaN FET	EPC2016	100	150 °C 100V	<< 1
Silicon n-MOSFET	A03160	600	150 °C 480V	20 [Ref 19]
SiC n-MOSFET	CPM2-1200-0025B	1200	150 °C 800V	25 [Ref 14]





	2014	2016
Starting Material	lower	lower
Epi Growth	<i>~higher</i>	<i>~same?</i>
Wafer Fab	lower	lower
Test	same	same
Assembly	lower	lower
OVERALL	~higher	lower!

* Product with the same on resistance and voltage rating

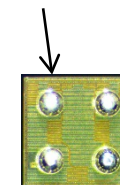
Active die $<3 \text{ mm}^2$

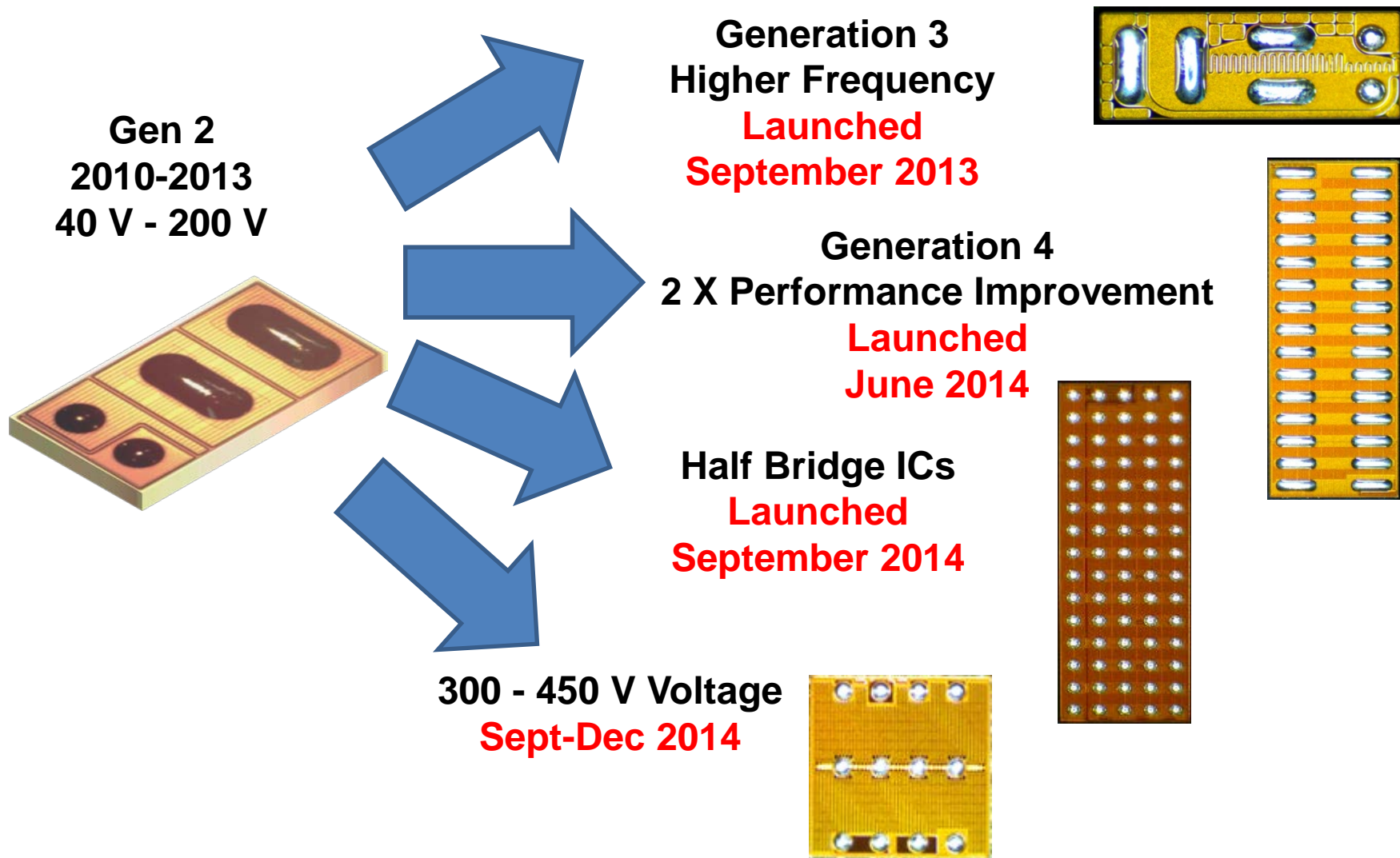
	2014	2016
Starting Material	lower	lower
Epi Growth	<i>~same</i>	<i>~same?</i>
Wafer Fab	lower	lower
Test	same	same
Assembly	lower	lower
OVERALL	<i>lower!</i>	<i>lower!</i>

* Product with the same on resistance and voltage rating

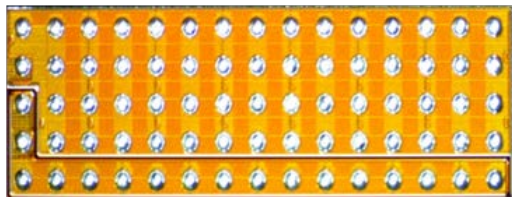
							Price Comparison		
Device	V _{DS} (MAX)	R _{DS(on)} (max)	Q _{GD} (typ @50%BV)	Q _{OSS} (typ @50%BV)	Q _G (typ @5V)	Device Area	1Ku	10Ku	100Ku
EPC2035	60 V	45 mΩ	0.16 nC	3 nC	1.2 nC	0.81 mm ²	\$ 0.360	\$ 0.293	\$ 0.230
FDS5351	60 V	35 / 42 mΩ	3.5 nC	7 nC	19 nC	31 mm ²	\$ 0.382	\$ 0.313	\$ 0.285
EPC2036	100 V	65 mΩ	0.15 nC	4 nC	1 nC	0.81 mm ²	\$ 0.376	\$ 0.306	\$ 0.240
FMDS8622	100 V	56 / 88 mΩ	1.3 nC	6.5 nC	2.8 nC	32.5 mm ²	\$ 0.396	\$ 0.324	\$ 0.295

0.9mm x 0.9 mm

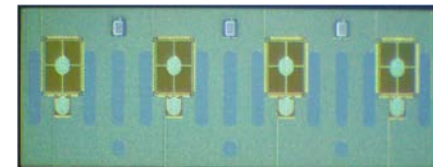




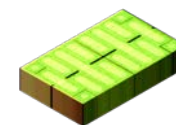
Gen 3 & 4 FETs and ICs
2014
30 V - 450 V
3 GHz



Higher Power
RF FETs and ICs
Broadband to 6 GHz
Q3/2015



Higher Scale Integrated Circuits
Q2/2015



MOSFET killer minimum size die
Q2/2015



Generation 5
Lower R x A
Q2-Q4 2015

- eGaN FETs are smaller and faster.
- eGaN technology is very thermally efficient and reliable.
- eGaN technology costs less than silicon MOSFET technology.
- eGaN technology is moving quickly.
- eGaN technology is making serious inroads into silicon's territory.

EPC

EFFICIENT POWER CONVERSION

Where is GaN going...

