

A green rectangular road sign with rounded corners is mounted on a weathered wooden post. The sign is positioned on the left side of a long, straight road that stretches into the distance. The road is flanked by rolling hills under a dramatic sky with large, white clouds and a bright sun setting or rising on the horizon, creating a golden glow. In the distance, a modern building with a grid-like facade is visible on the horizon. The overall scene conveys a sense of a long journey or a path forward.

The eGaN[®] FET
Journey Continues

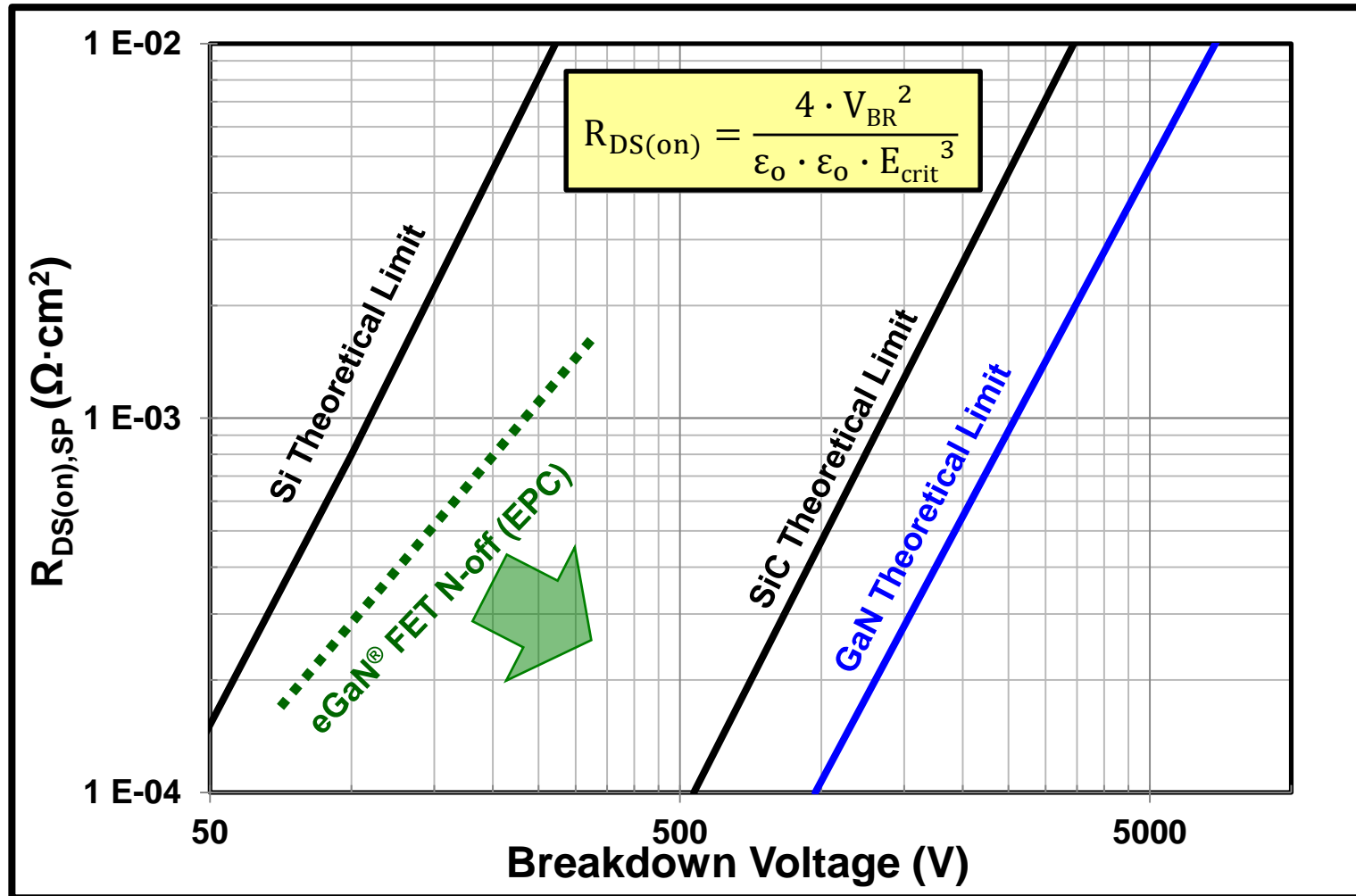
*Ditching the Package to Drive Down GaN
Transistor Costs*

Alex Lidow

Power Switch Wish List

- **Lower On Resistance**
- **Faster**
- **Smaller**
- **Lower Thermal Impedance**
- **Lower Cost**
- **Better Package**

Better Starting Material



Better End Product

100 V eGaN[®] FET
6.05 x 2.3 mm

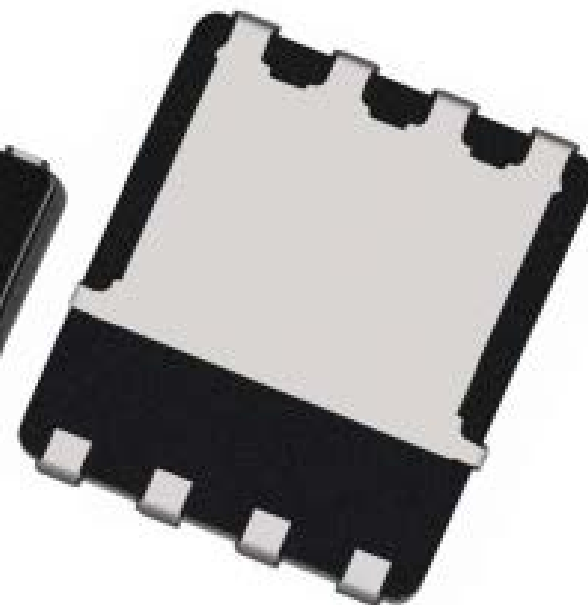
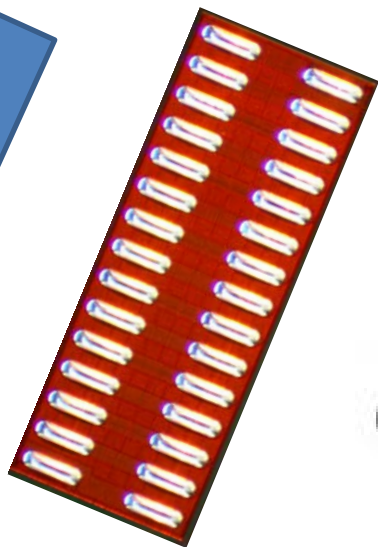
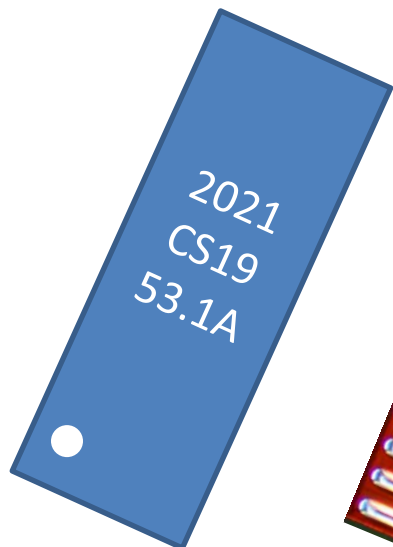
100 V Si MOSFET
6.15 x 5.3 mm

Top View

Bump View

Top View

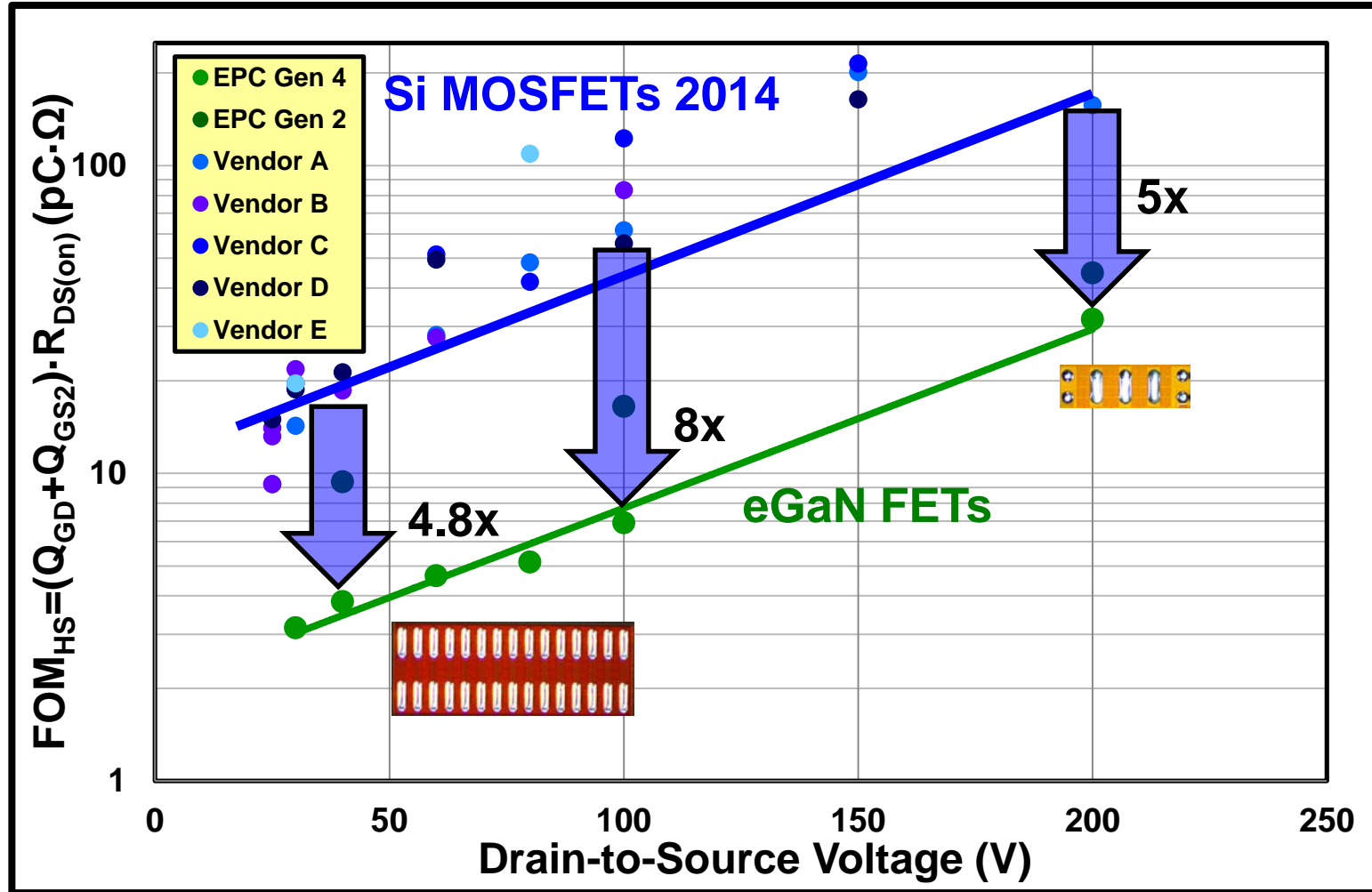
Bump View



$R_{DS(on)}=2.4 \text{ m}\Omega @ 5 \text{ V}$
 $Q_G= 13 \text{ nC}$

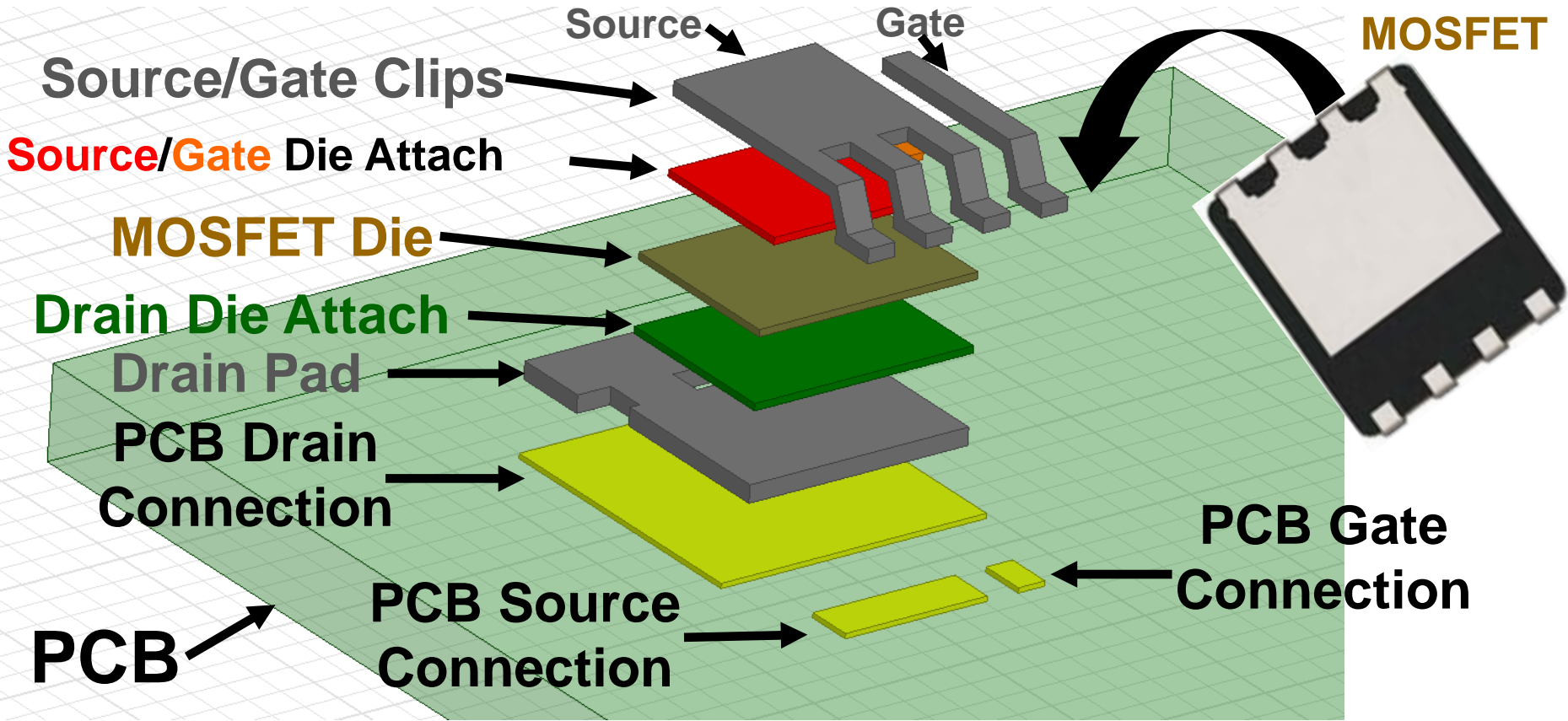
$R_{DS(on)}=3.4 \text{ m}\Omega @ 10 \text{ V}$
 $Q_G= 58 \text{ nC}$

Faster Switching

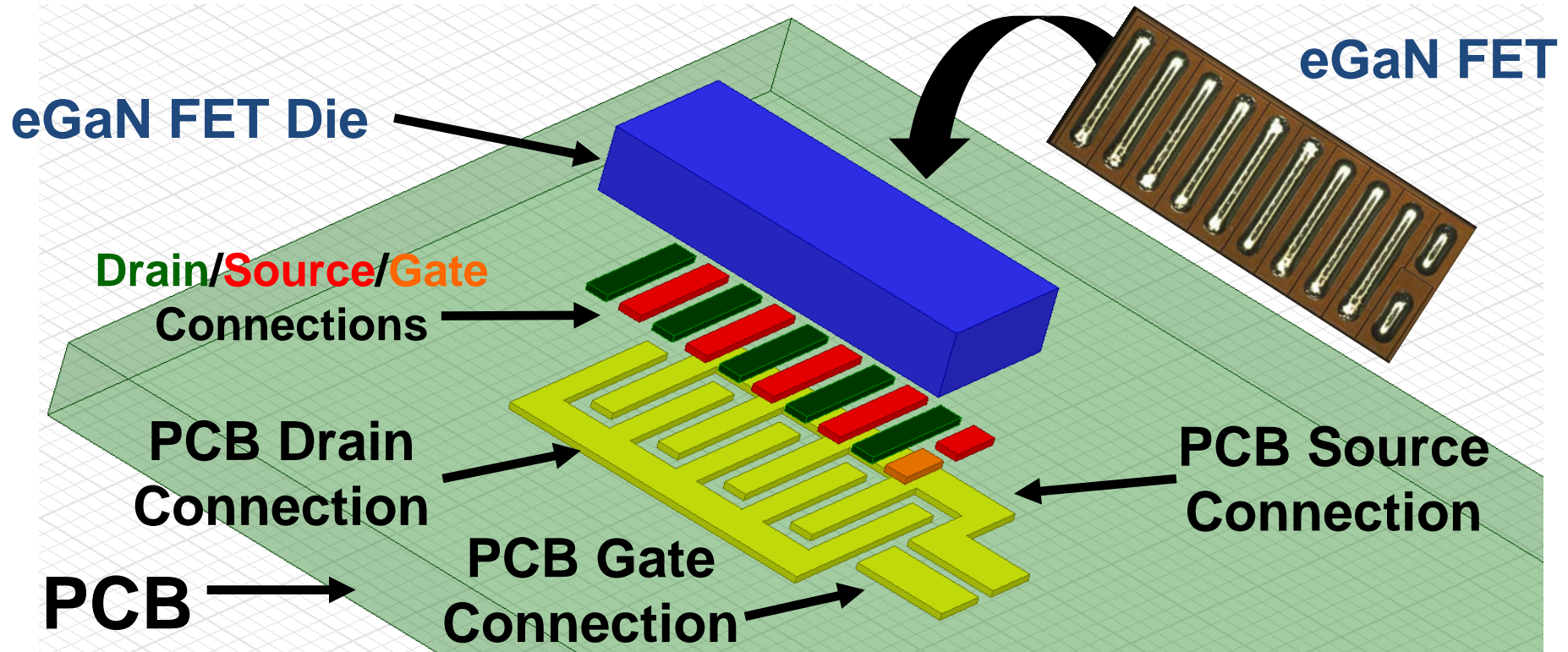


$$V_{DS} = 0.5 \cdot V_{DSS}, I_{DS} = 20 \text{ A}$$

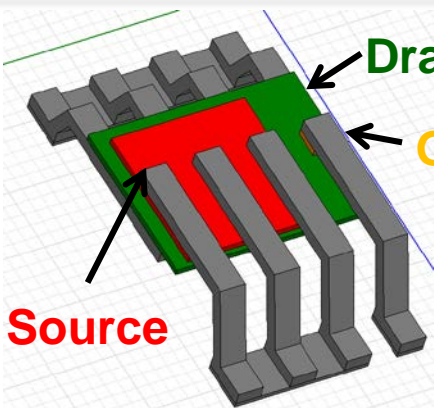
Impact of Package on Power Switch



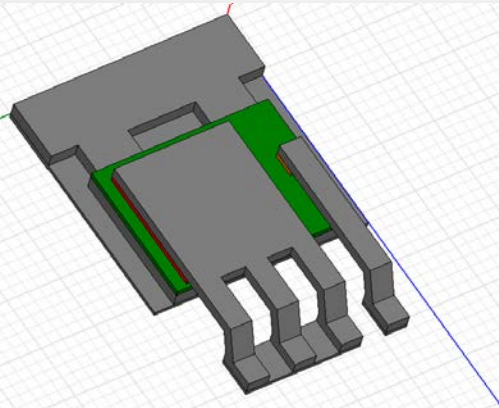
A Better Power Package



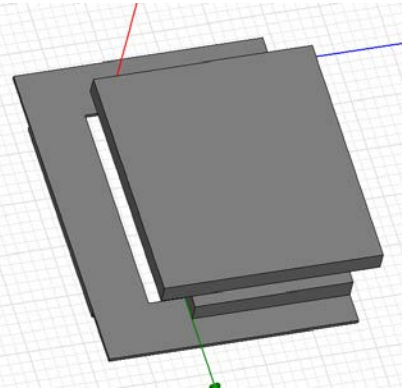
Impact of Package on Power Switch



SO-8



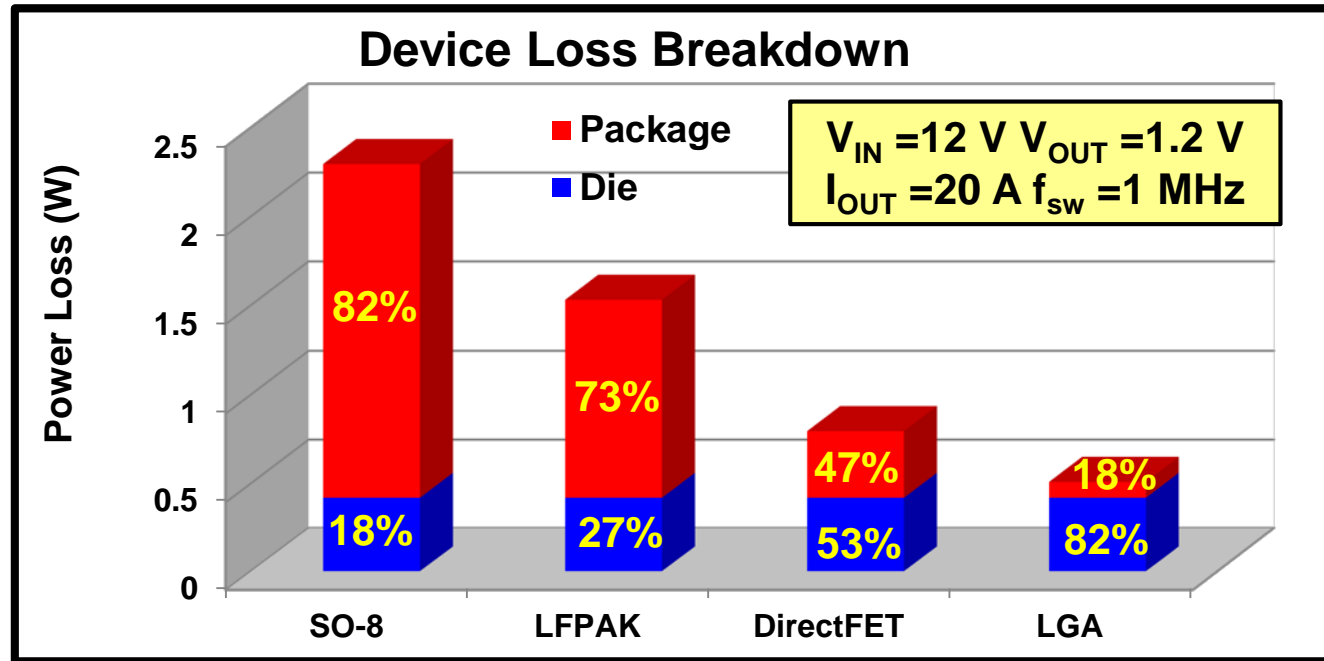
LFPACK



DirectFET

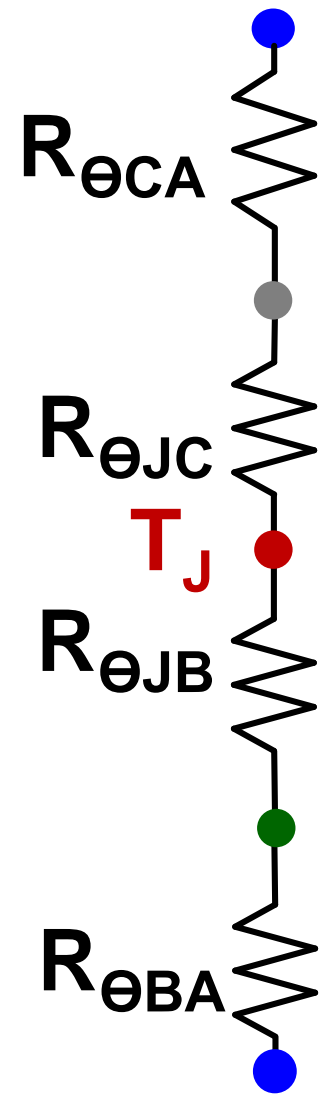
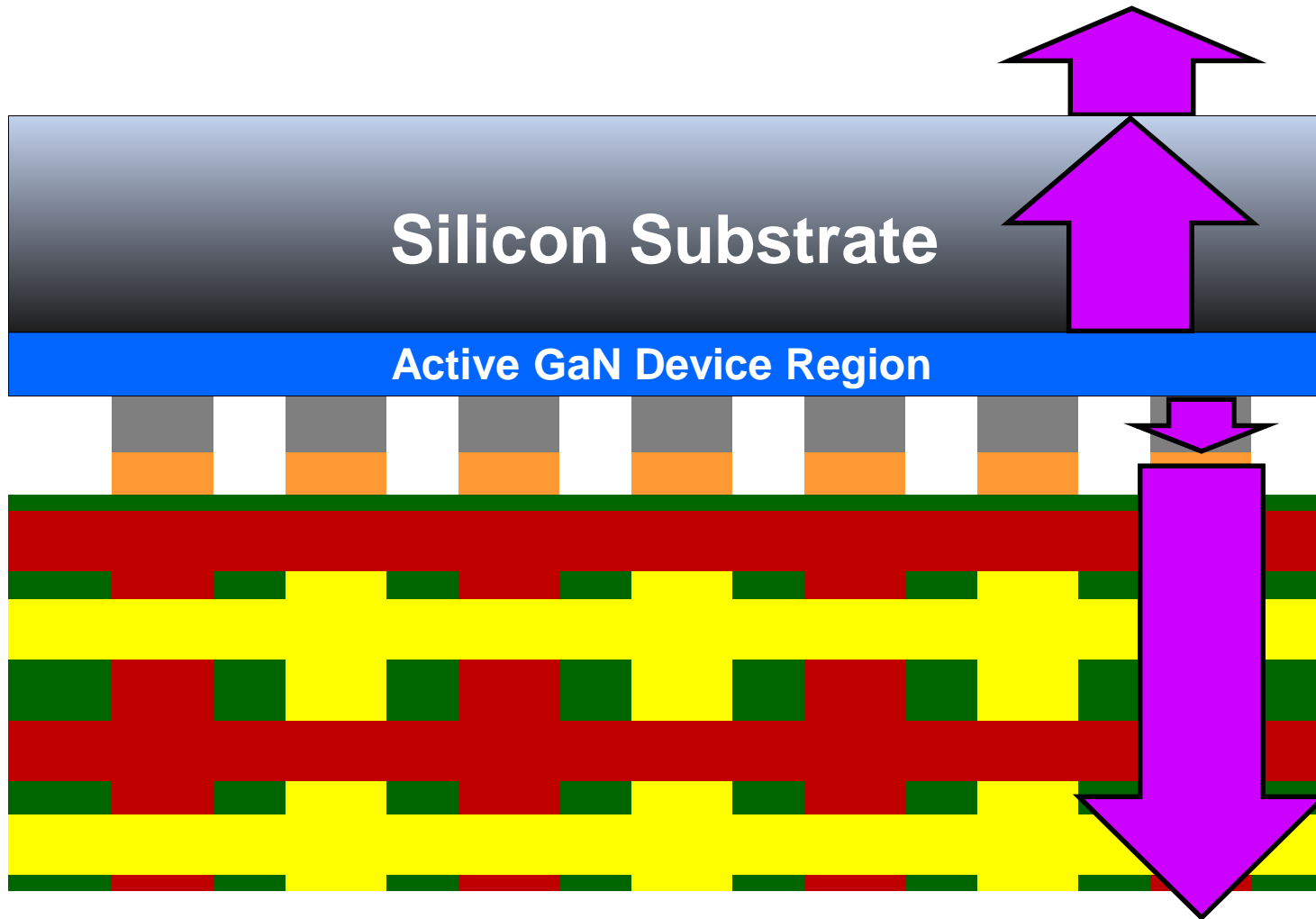


LGA eGaN FET



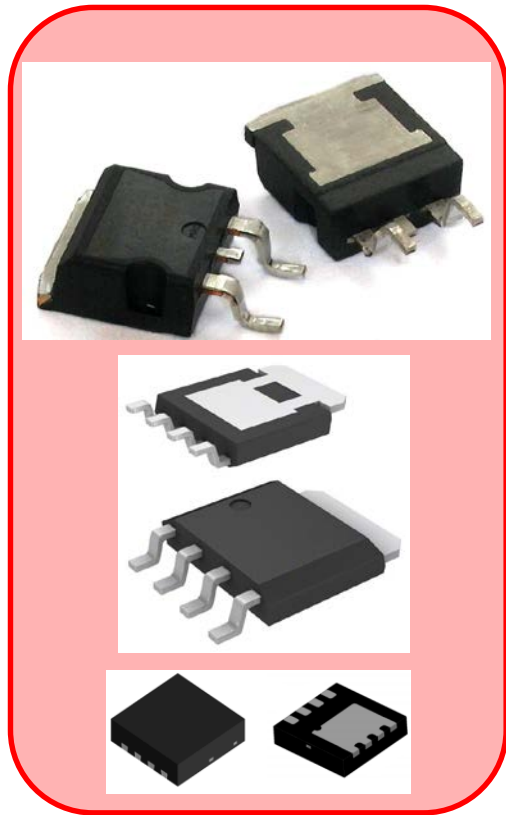
Reference: D. Reusch, D. Gilham, Y. Su, and F.C. Lee, C, "Gallium Nitride Based 3D Integrated Non-Isolated Point of Load Module," APEC 2012

Thermal Management



Thermal Advancements

Single Sided Cooling



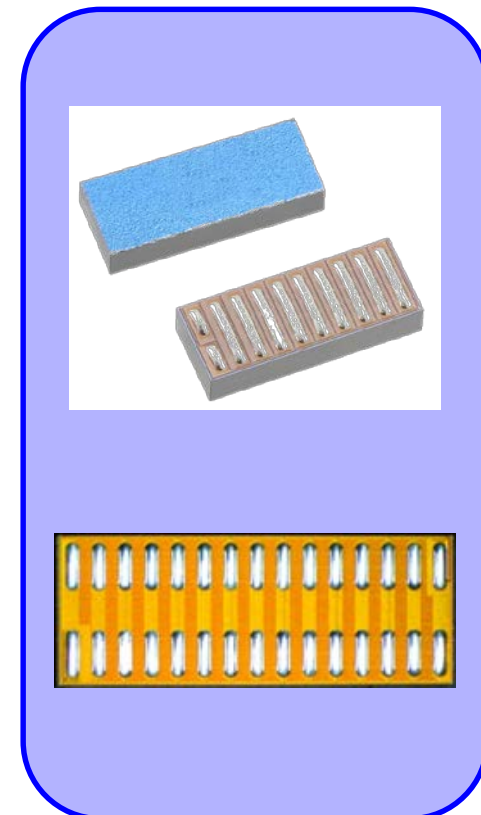
$$R_{\theta JB} \downarrow \ll R_{\theta JC} \uparrow$$

Double Sided Cooling



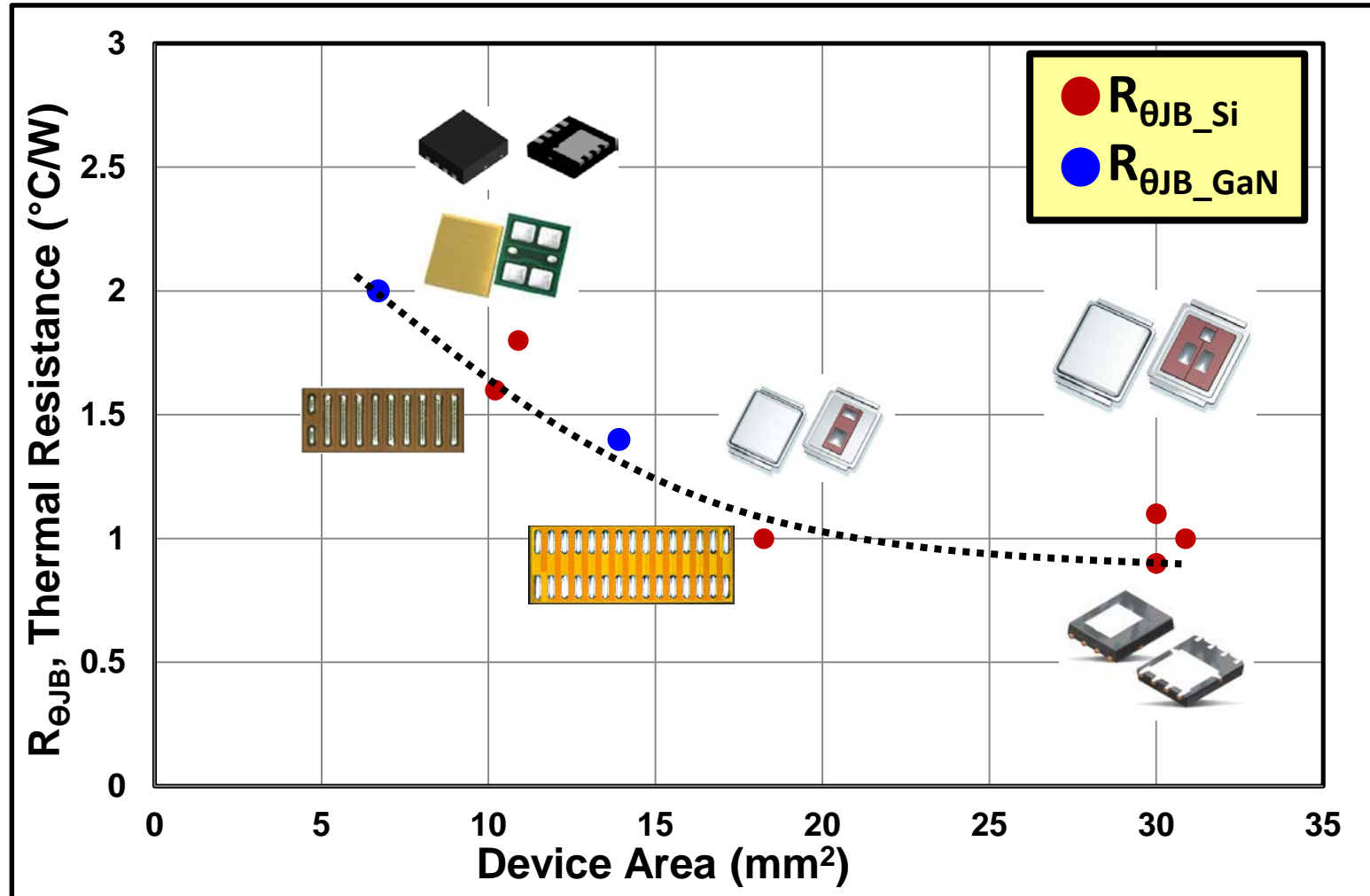
$$R_{\theta JB} \downarrow \quad R_{\theta JC} \downarrow$$

Double Sided Cooling

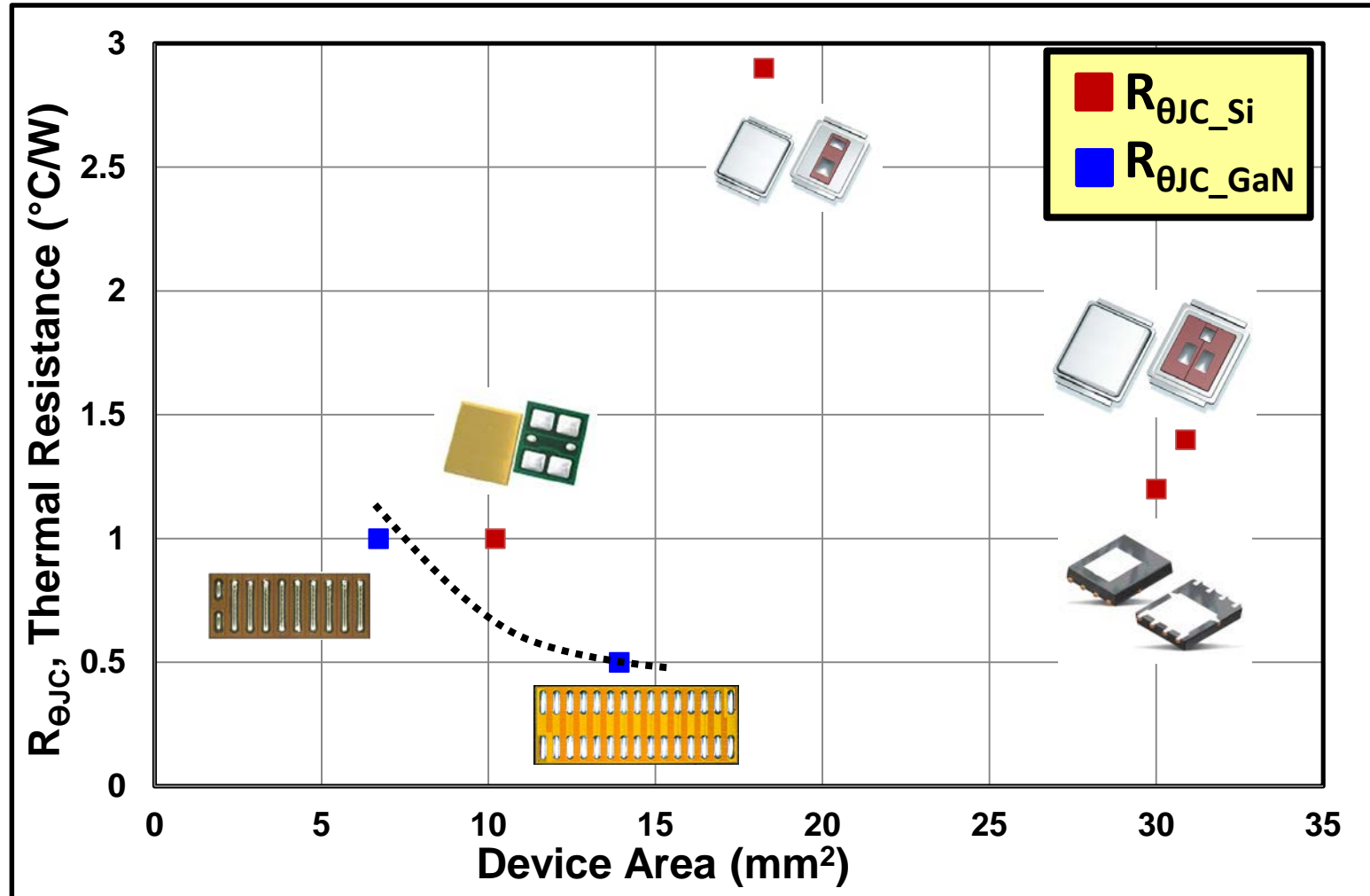


$$R_{\theta JB} \downarrow \quad R_{\theta JC} \downarrow$$

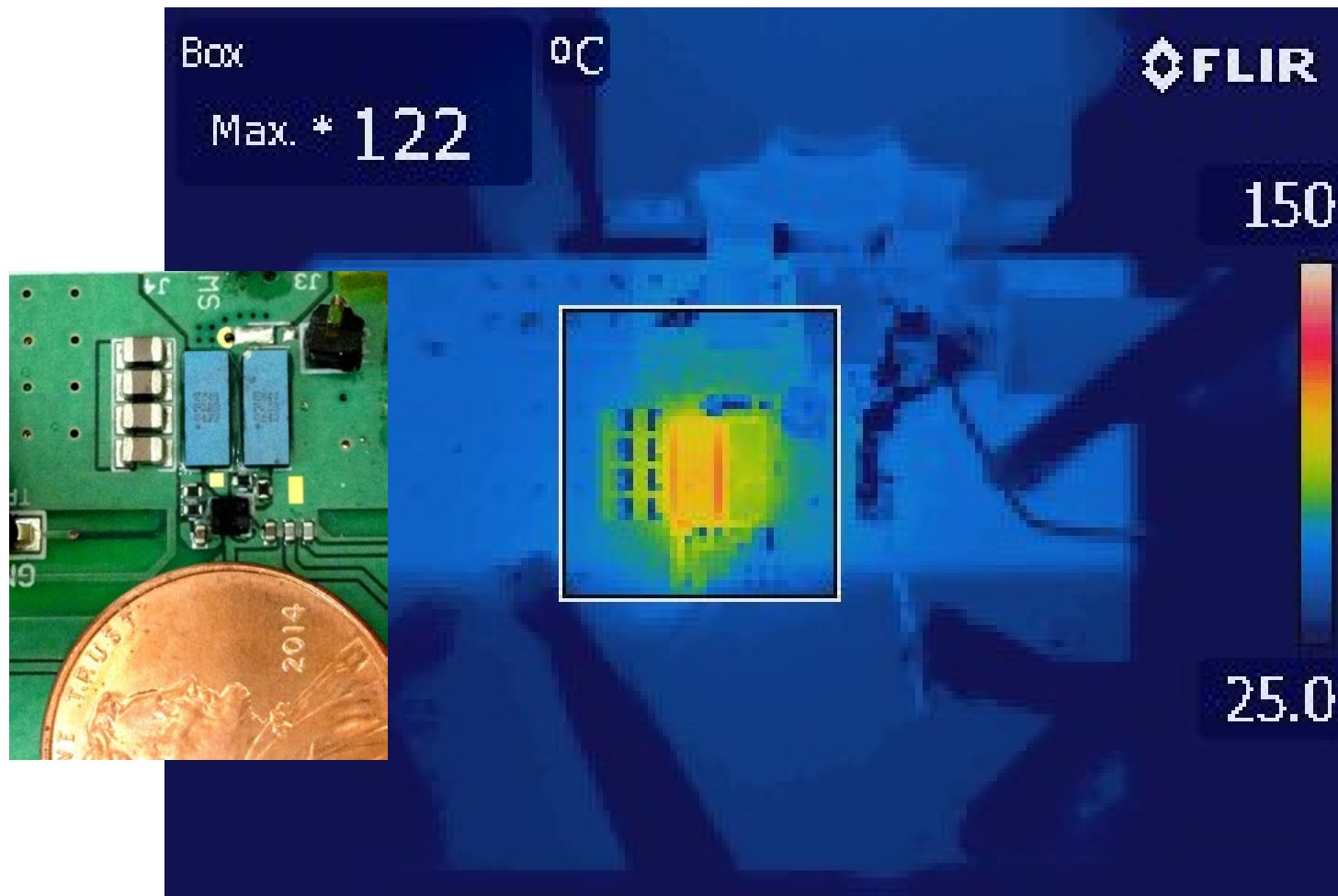
Thermal Comparisons



Thermal Comparisons

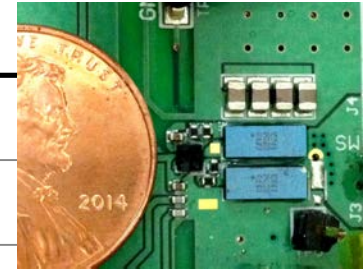
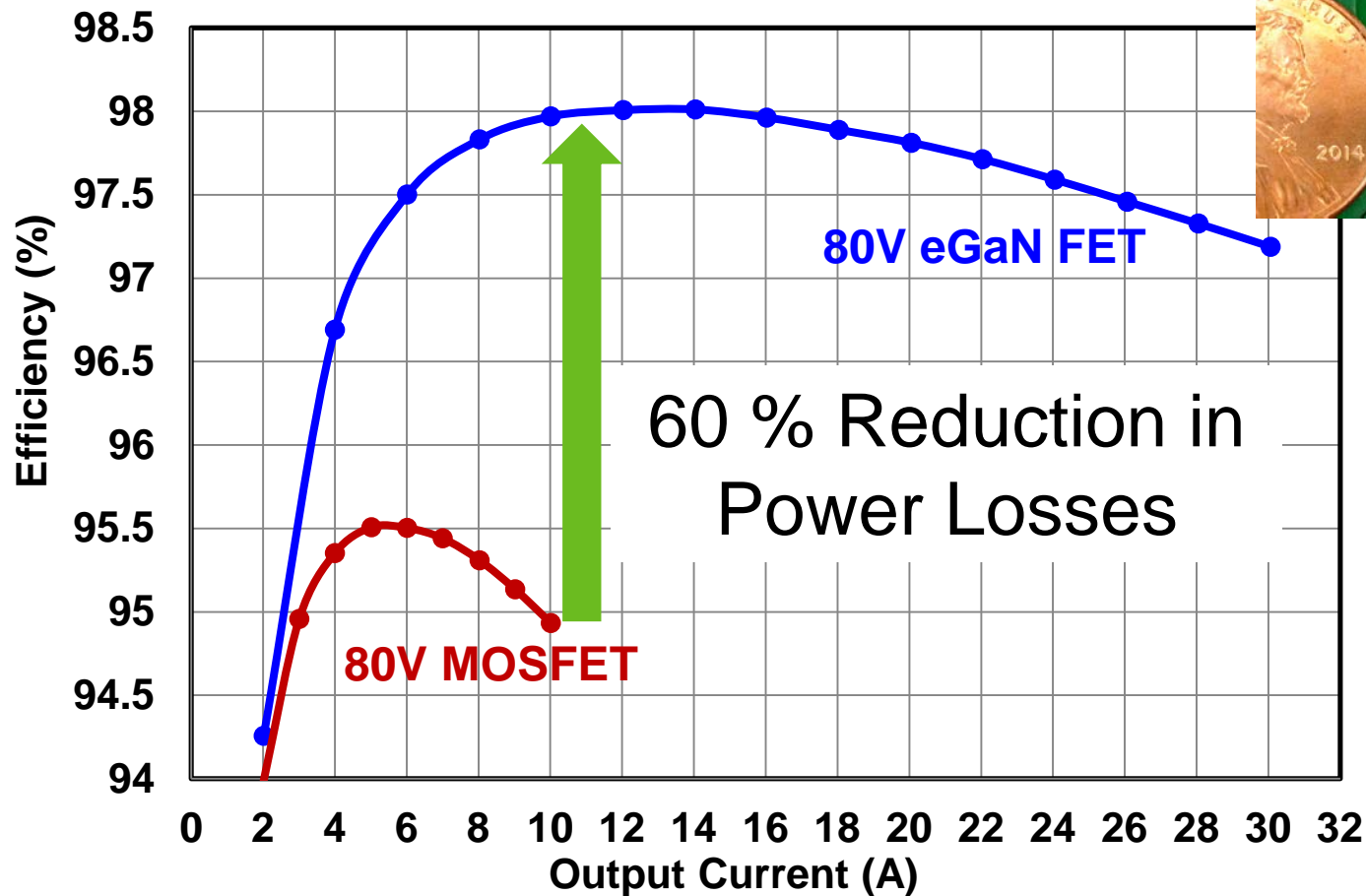


Improved Thermal Performance



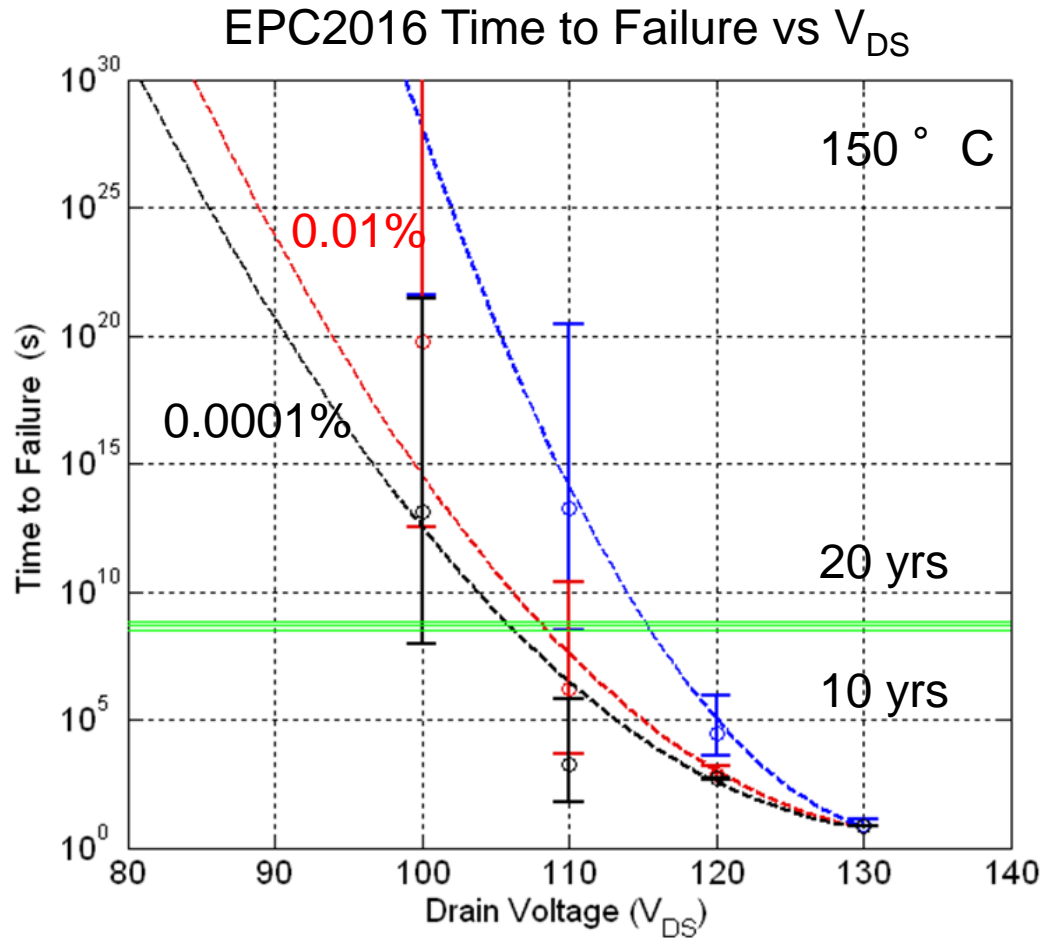
Fan Speed=200 LFM $f_{\text{sw}}=300$ kHz $V_{\text{IN}}=48$ V $V_{\text{OUT}}=12$ V $I_{\text{OUT}}=30$ A

Better In-Circuit Performance

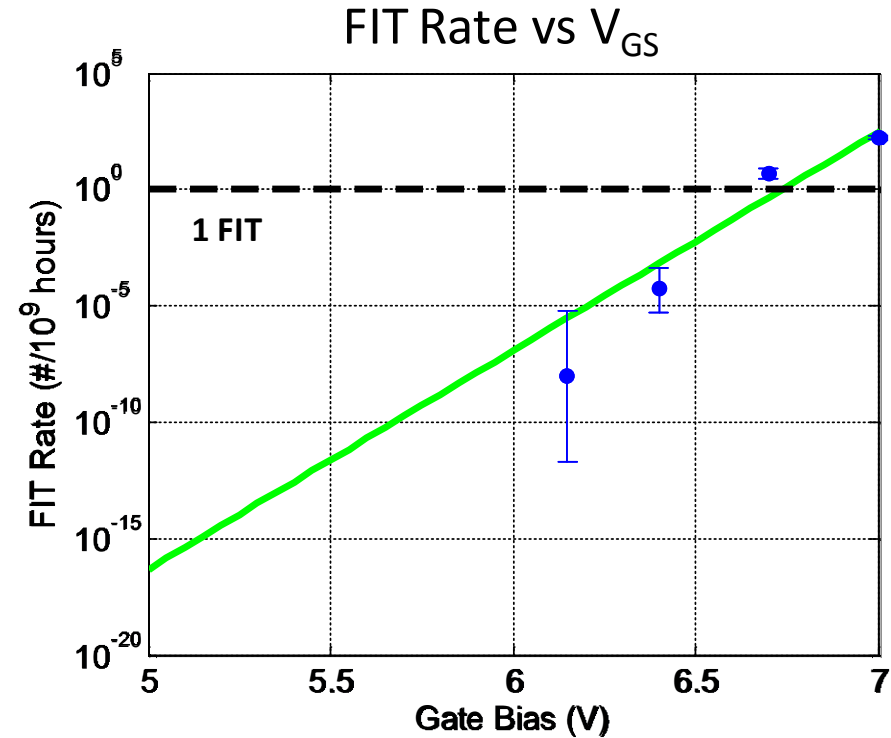
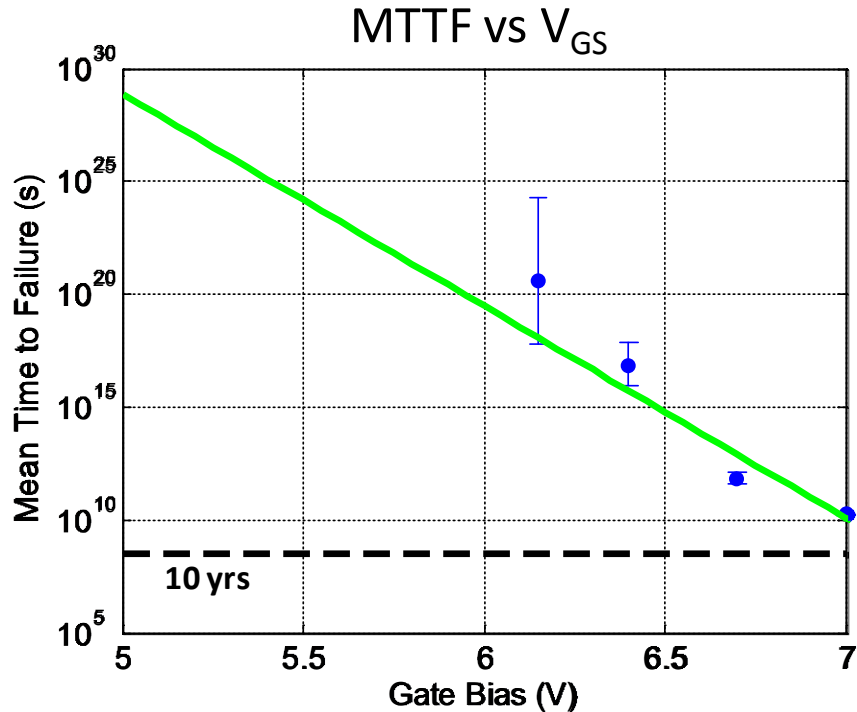


$V_{IN}=48\text{ V}$, $V_{OUT}=12\text{ V}$, 300 kHz

Lifetime Prediction



Lifetime Prediction



MOSFET vs. eGaN Costs*

| | 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 | <i>~higher</i> | <i>lower!</i> |

* Product with the same on resistance and voltage rating

MOSFET vs. eGaN Costs*

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

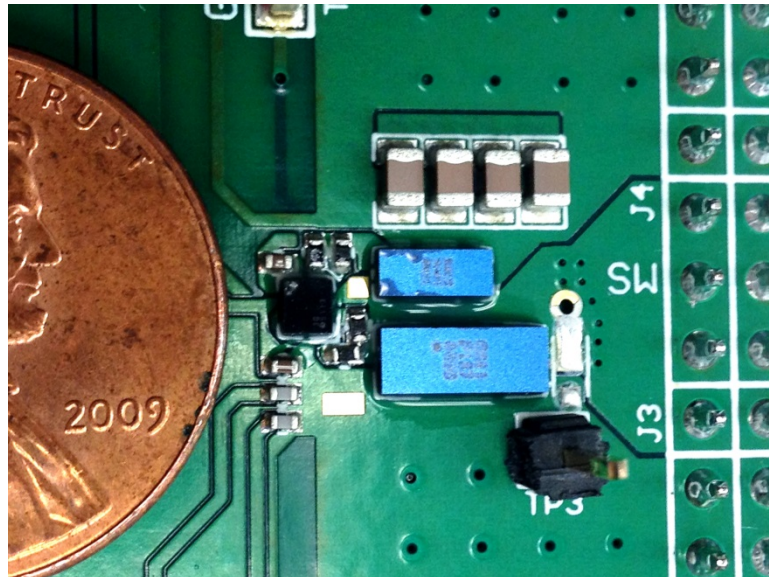
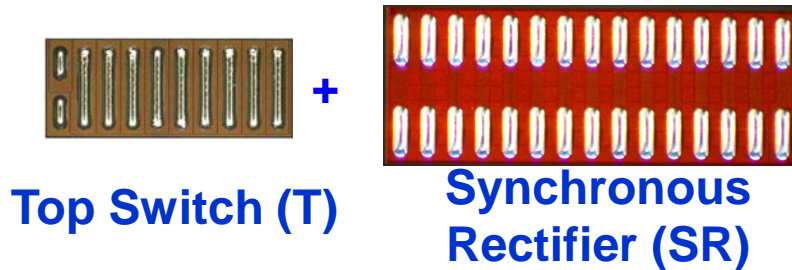
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| OVERALL | <i>lower!</i> | <i>lower!</i> |

* Product with the same on resistance and voltage rating

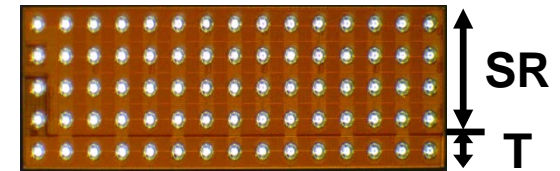
A Look Into the Future

GaN Integration

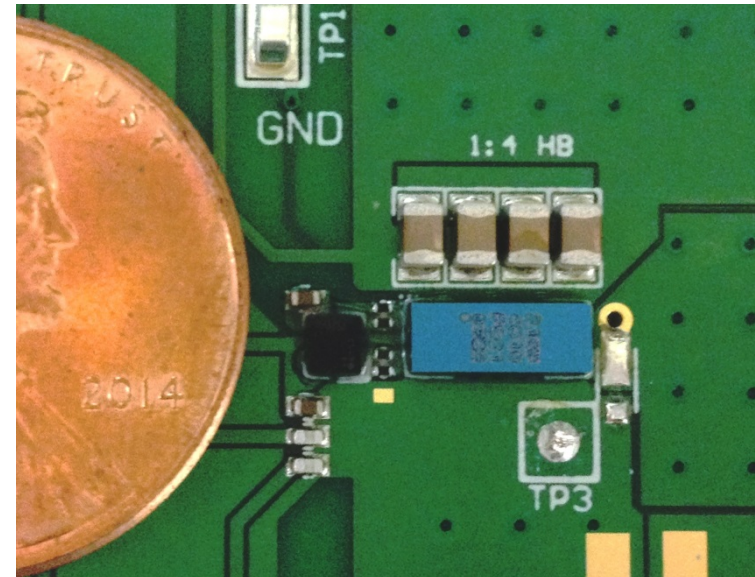
Generation 2/4 Discrete HB



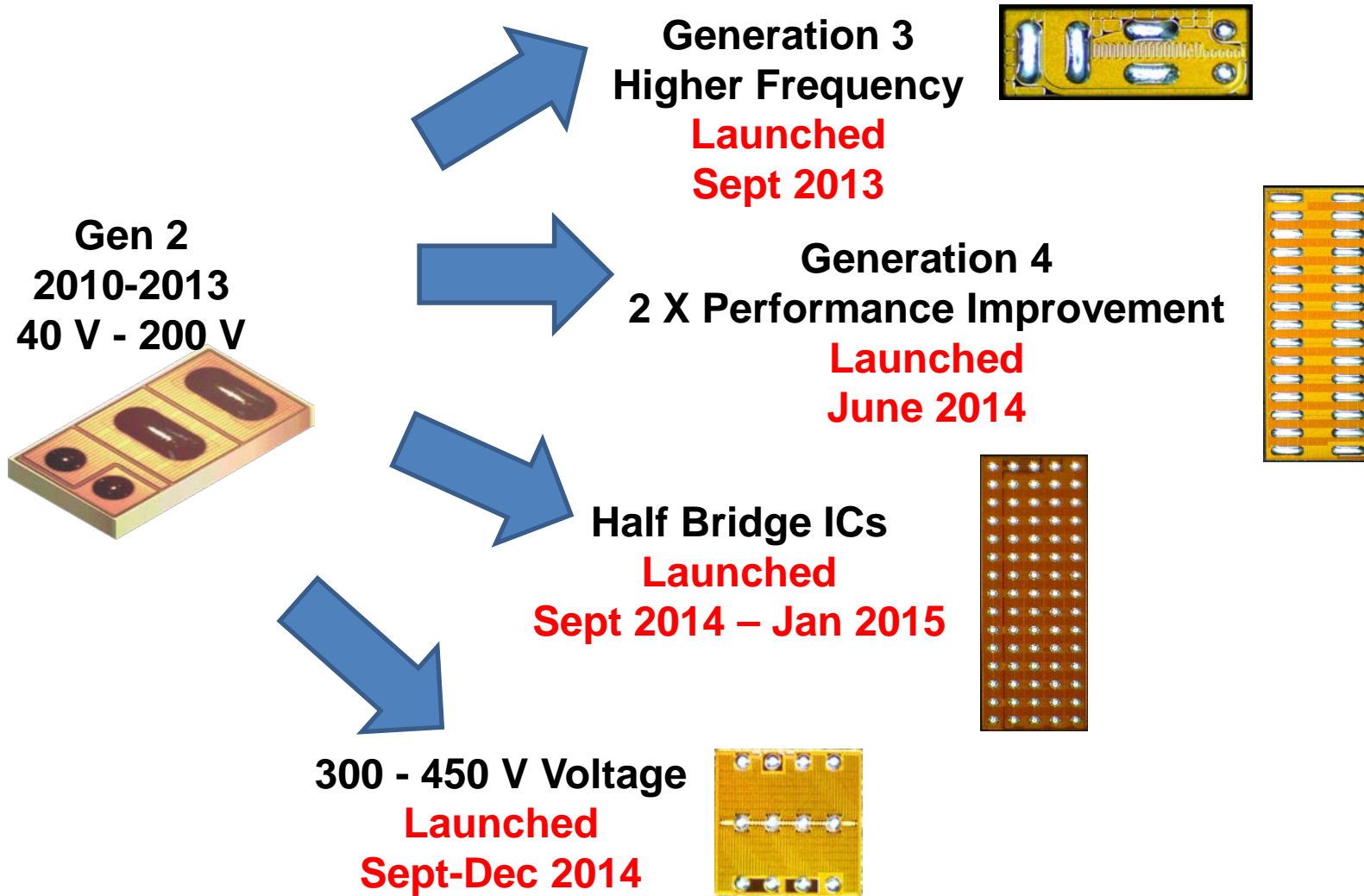
Generation 4 Monolithic 4:1 HB



33 % die size reduction



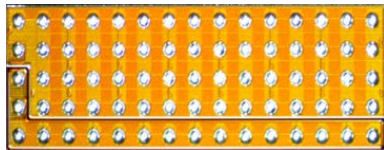
Moore's Law Revival



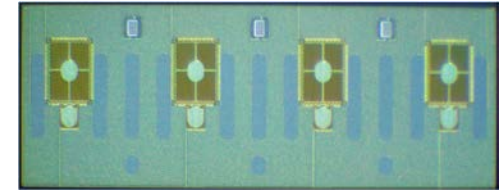
Moore's Law Revival

Gen 3 & 4 FETs and ICs
2014

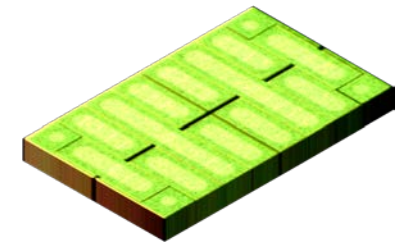
30 V - 450 V



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



Higher Scale Integrated Circuits
Q2-Q4/2015



Generation 5
Lower R x A
Q2-Q4 2015

Summary

- Gallium nitride has enabled smaller and faster power transistors.
- The elimination of all packaging has unleashed additional performance advantages due to reduced size, cost, parasitic inductance, thermal efficiency, reliability, and cost.
- For the first time in 60 years there is a technology that is both higher performance and lower cost than silicon!

EPC

EFFICIENT POWER CONVERSION

Where is GaN going...

