The eGaN® FET Journey Continues

EFFICIENT POWER CONVERSION

GaN Brings About a New Way of Thinking to Power Conversion

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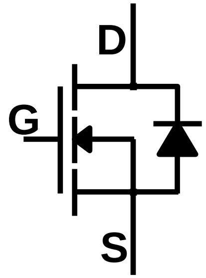
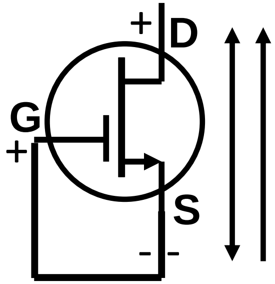
Efficient Power Conversion Corporation

presented on behalf of Steve Colino by: Brian Miller , brian.miller@epc-co.com

Enhancement Mode
Field Effect Transistor (FET)





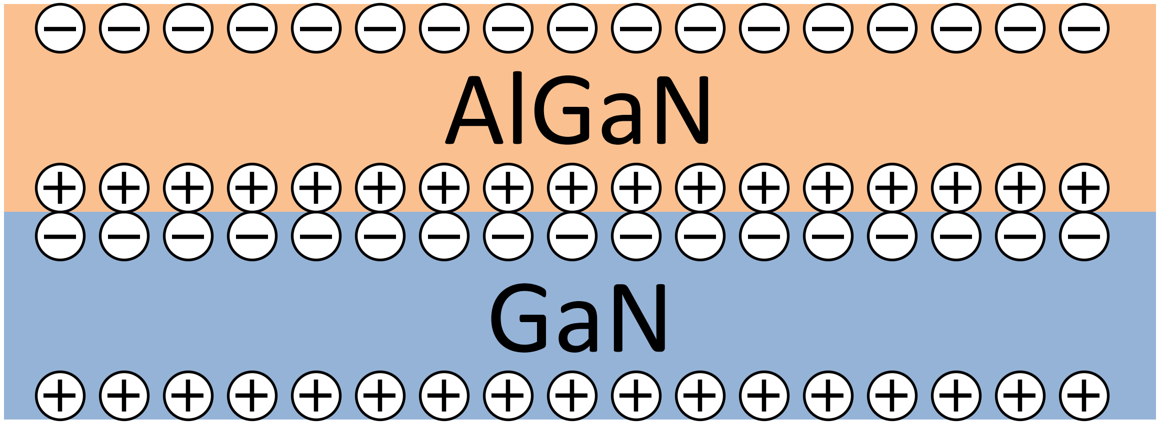
- Enhancement mode – Normally off
  - Supports voltage in one direction
  - Allows current flow in the other
- Positive V_{GS} turns on transistor
  - Bidirectional current flow

Wide Bandgap

Parameter		GaN	Silicon	SiC
Band Gap E_g	eV	3.2	1.12	3.4
Breakdown Field E_{BV}	MV/cm	3.3	0.3	3.5
Electron Mobility μ_n	$cm^2/V \cdot s$	2000	1500	650

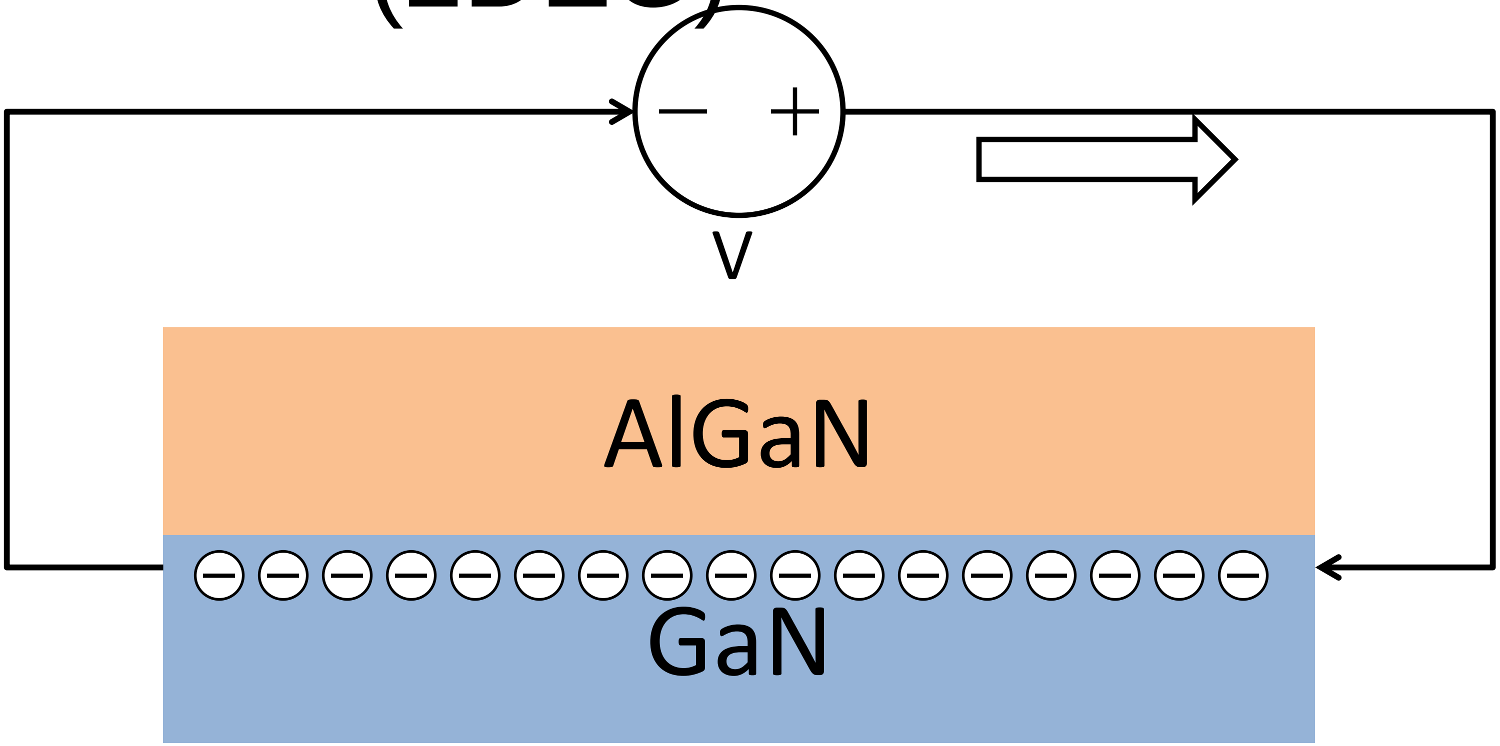
More Voltage is required to break an electron from the atom

Hetero-Junction



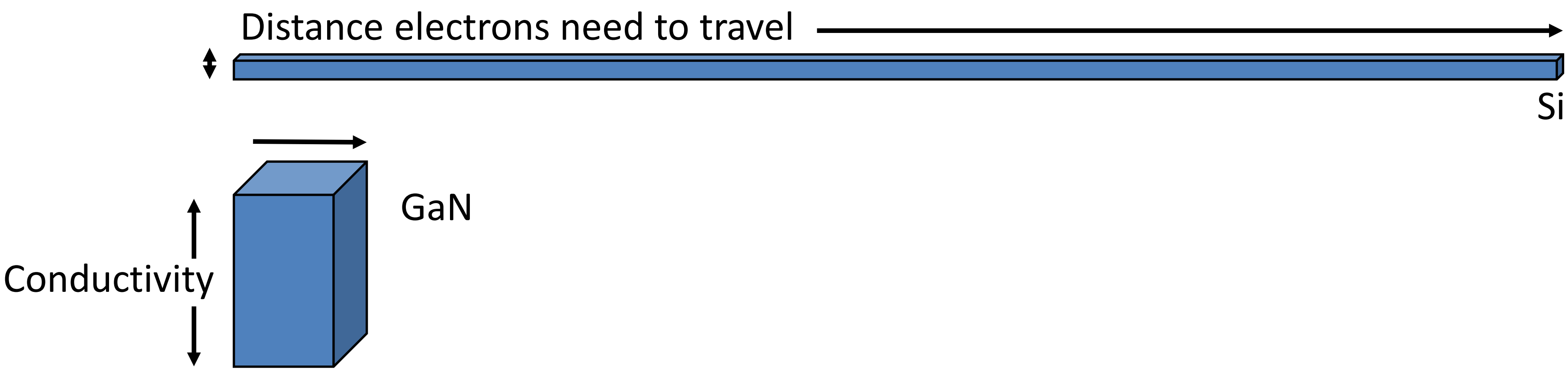
- GaN transistors use a hetero-structure comprised of a thin layer of AlGaN on top of GaN
- The AlGaN applies a mechanical strain on the GaN
- The strain, along with the piezo-electric nature of GaN causes a spontaneous polarization

2 Dimensional Electron Gas (2DEG)



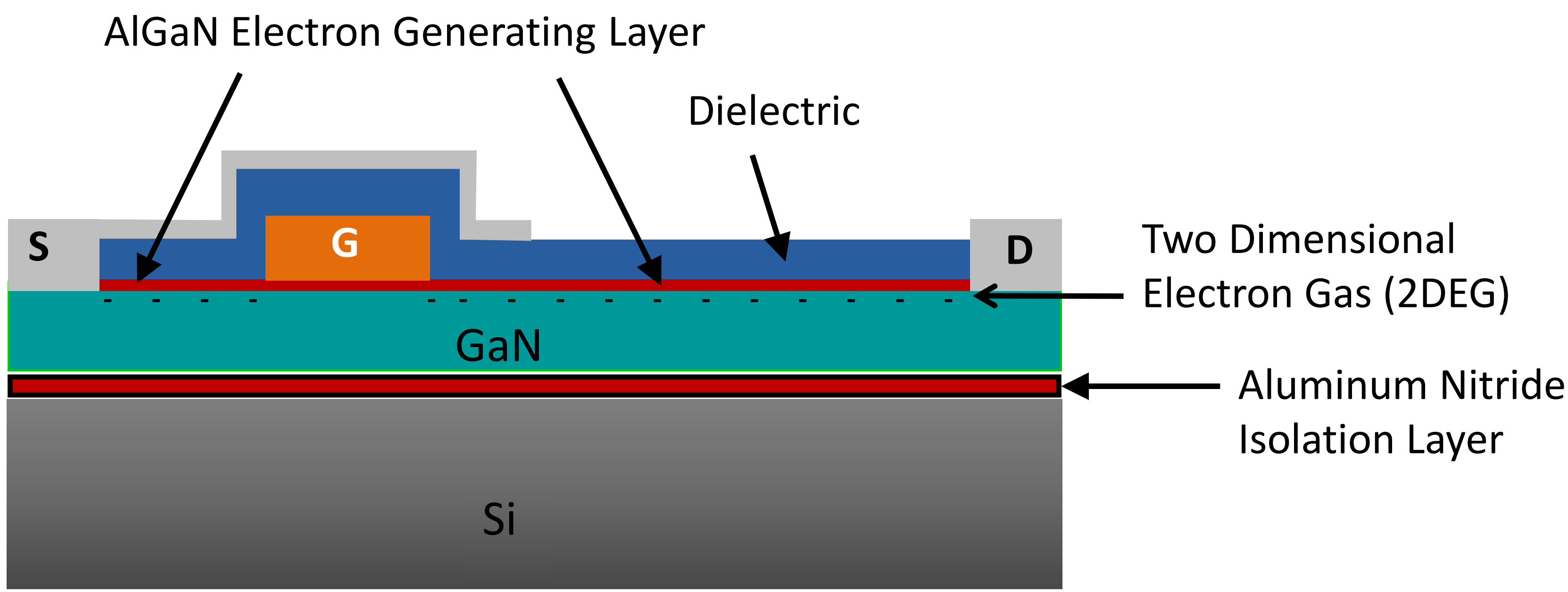
- The spontaneous polarization leave a thin plain of electrons free to carry current
- An electron has the same probability of being anywhere in this plain
- The result is electrons capable of extremely high velocity and conductivity

GaN
Wide Bandgap Hetero Junction



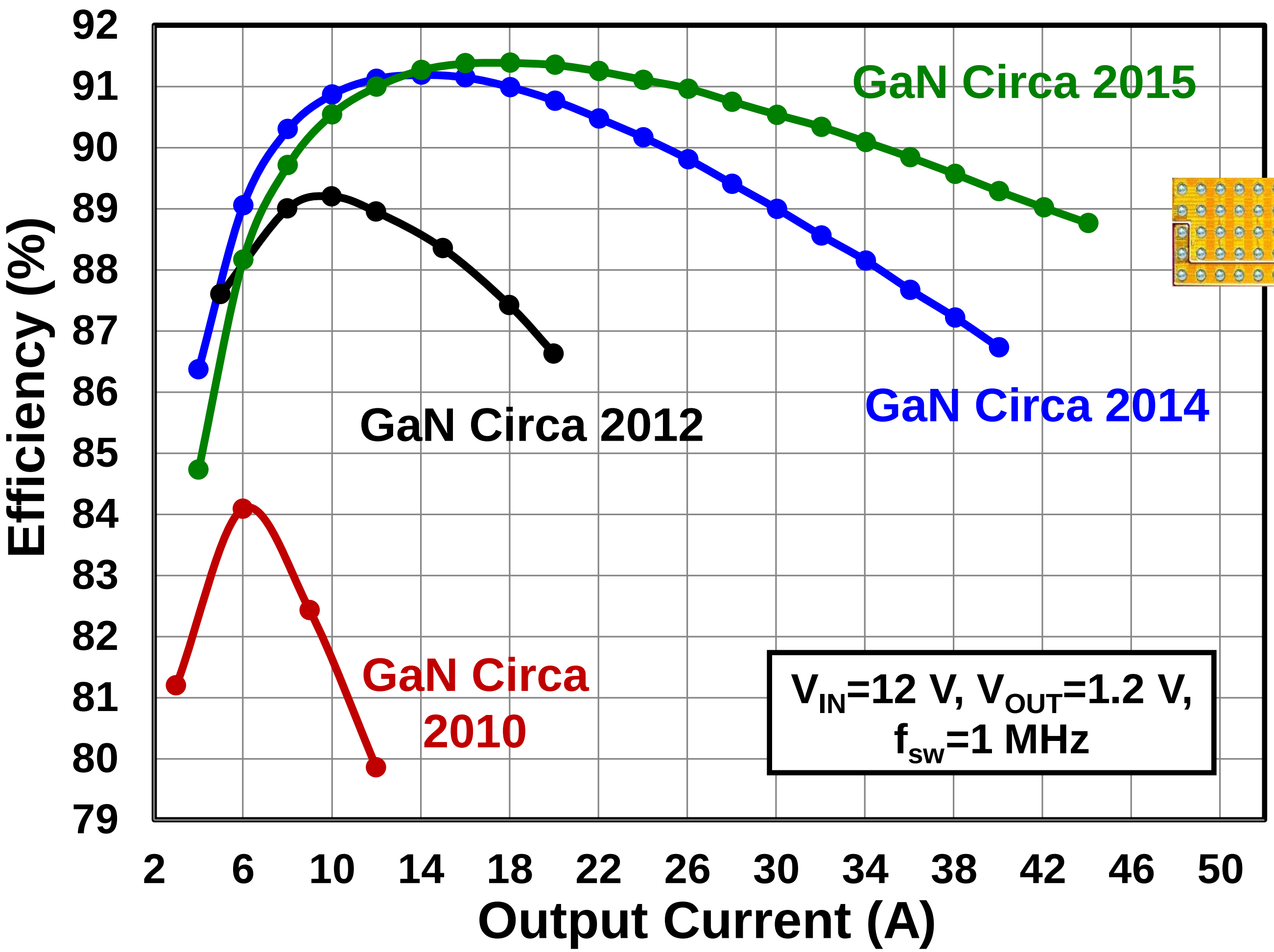
- Wide Bandgap
  - Shorter distance required to support voltage
- Hetero Junction
  - Forms 2 Dimensional Electron Gas (2DEG)
  - Electrons not bound to any particular atom
  - Higher conductivity
- GaN is still far from theoretical limits

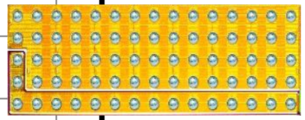
eGaN FET Structure on Silicon



- For a given $R_{DS(on)}$ and V_{DS} capability
  - Smaller device
  - Lower Capacitance
  - Zero Q_{RR}
  - Lower Inductance

GaN Developing Quickly



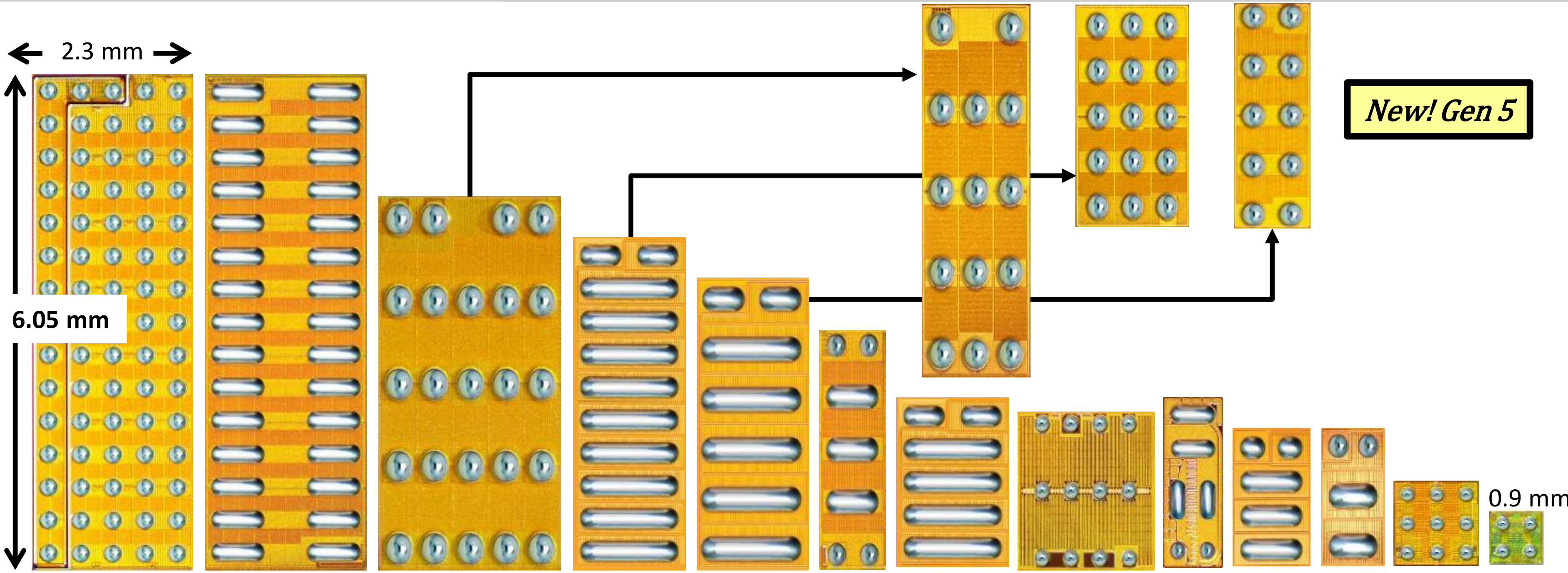


GaN Versus Silicon

Parameter	Conditions	EPC2045	BSC070N10NS5
$R_{DS(on)}$ (typ)	V_{GS} = 5 V*, T_J = 25 °C	5.6 mΩ	6 mΩ
Q_G (typ)	V_{GS} = 5 V, V_{DS} = 50 V, I_D = 16 A*	5.2 nC	30 nC
Q_{GD} (typ)	V_{DS} = 50 V	1.1 nC	6 nC
Q_{SW} (typ)	V_{GS} = 5 V, V_{DS} = 50 V, I_D = 10 A*	1.6 nC	11 nC
Q_{OSS} (typ)	V_{DS} = 50 V	21 nC	30 nC
E_{OSS} (typ)	V_{DS} = 50 V	0.4 µJ	1.45 µJ**
Q_{RR} (typ)	V_{DS} = 50 V, I_F = 20 A, di_F/dt = 100 A/µs	0 nC	89 nC
L_{CS} (estimated)		0.1 pH	0.5 pH
R_G (typ)		0.6 Ω	1 Ω
$R_{DS(on)} \times Q_{SW}$	Switching FOM	8.96 mΩ nC	70.4 mΩ nC
$R_{DS(on)} \times (Q_{OSS} + Q_{RR})$	Rectifier FOM	118 mΩ nC	624 mΩ nC
$R_{\Theta(JC)}$	Thermal impedance to top	1.4 °C/W	20 °C/W
Area		3.75 mm^2	31.7 mm^2

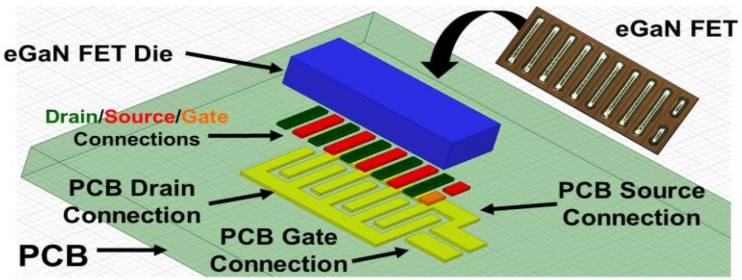
*V_{GS} = 10 V, I_D = 40 A for BSC070N10NS5
**Estimated by taking second integral of C_{OSS} versus C_{DS} curve

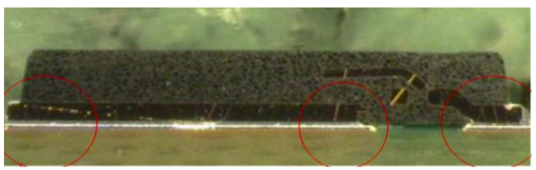
eGaN® FET Packages

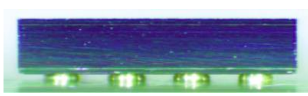


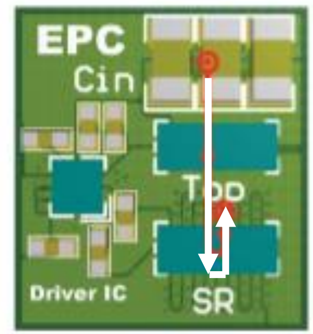
- Absolute minimum lead resistance and inductance
- Minimum footprint on PCB
- Pulls heat away from board
- RoHS 6 of 6 and MSL 1

Wafer Level Packaging

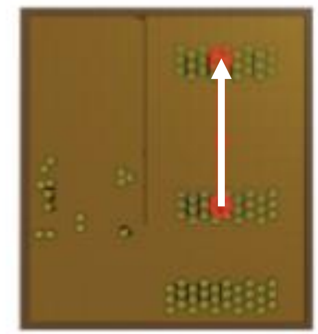


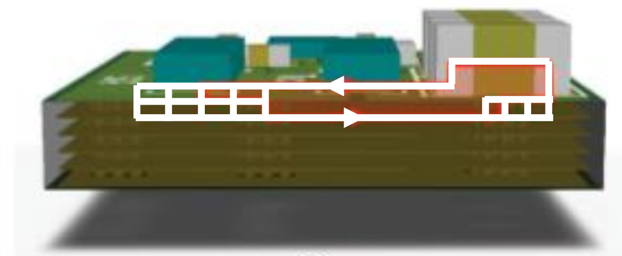






(a)

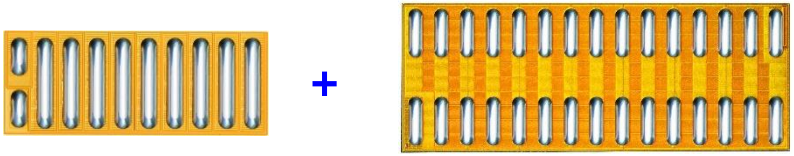

(b)


(c)

- Single interface with PCB
- No wires or clips
- Active area Intimate with PCB for inductance cancelling
- RoHS 6 of 6
- MSL-1

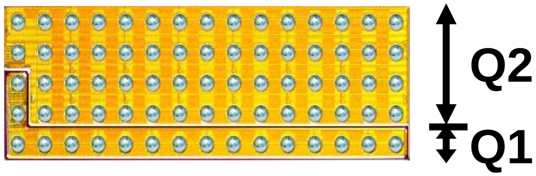
Integrated Half-Bridge

Generation 2/4
Discrete HB

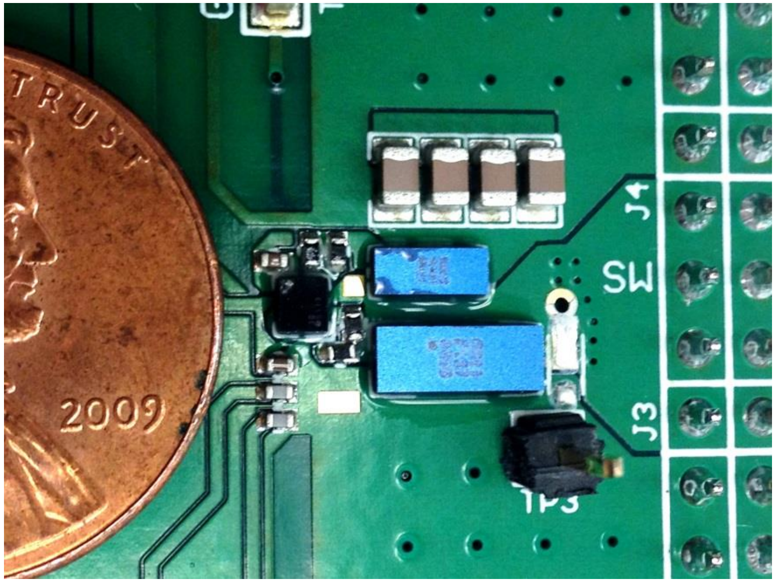


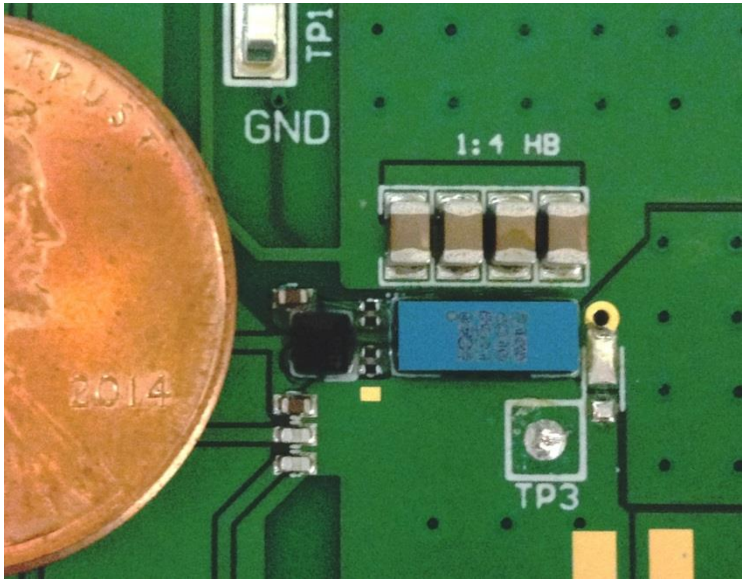
Top Switch (Q1) Bottom Switch (Q2)

Generation 4
Monolithic 1:4 HB

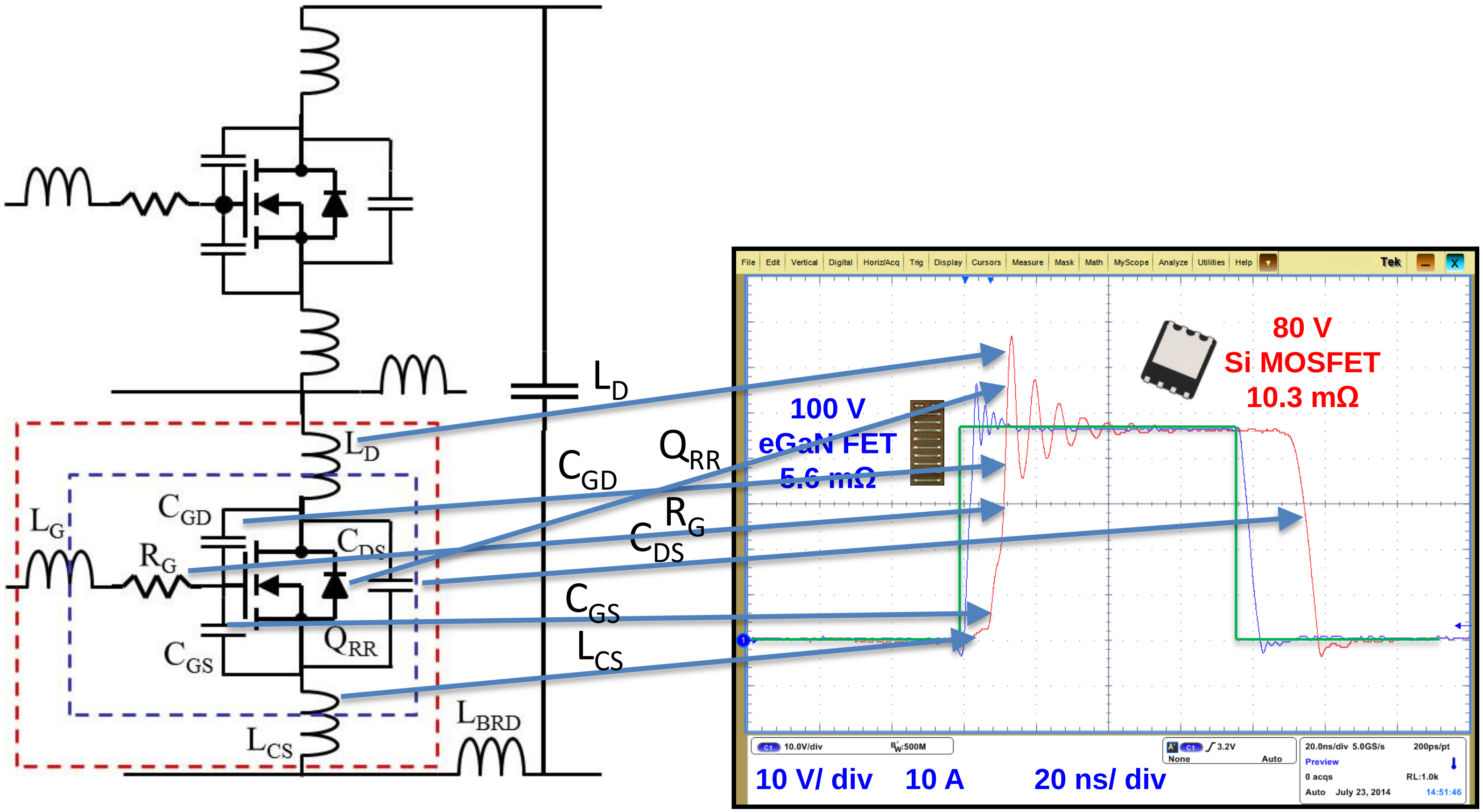


33 % die size reduction



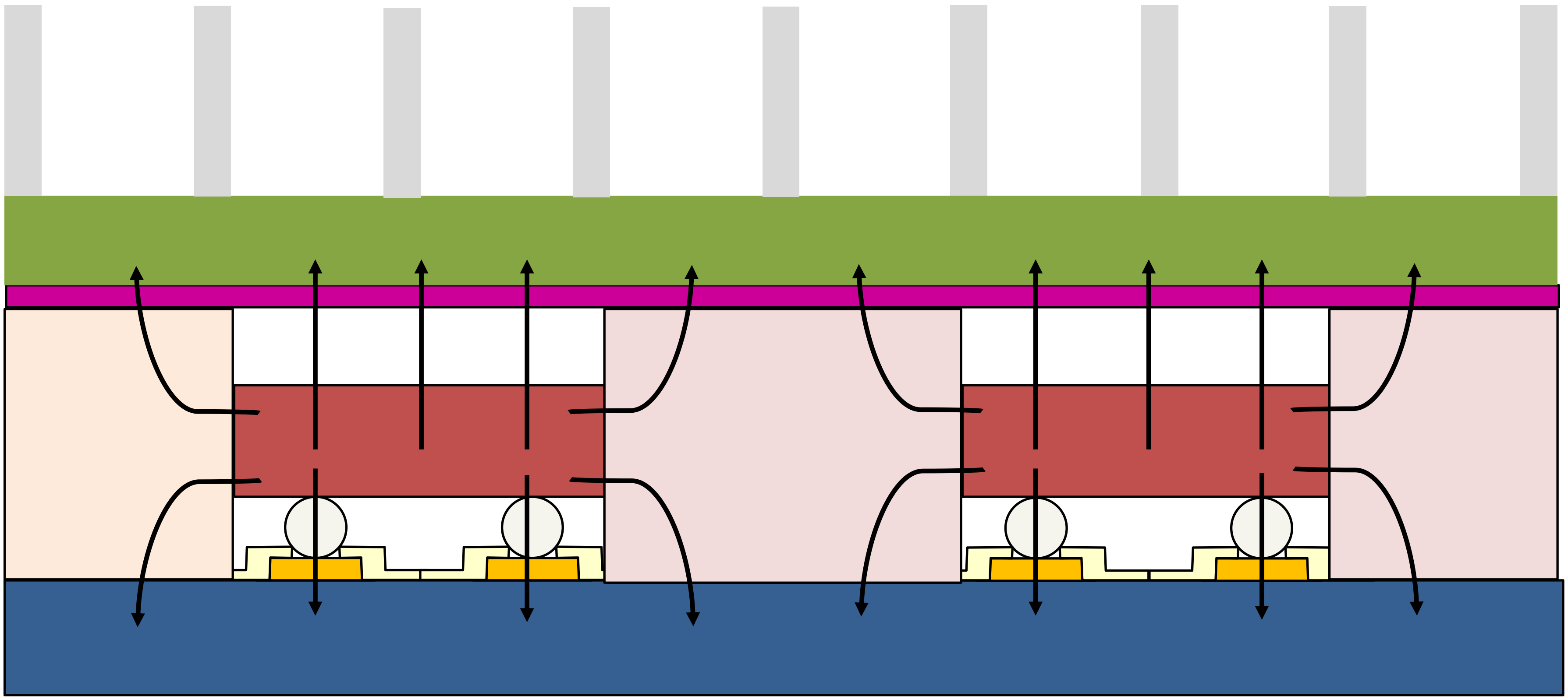


What eGaN Technology Has Less Of



- Less parasitic capacitance and inductance
  - Efficient at high frequency
  - Less overshoot and ringing

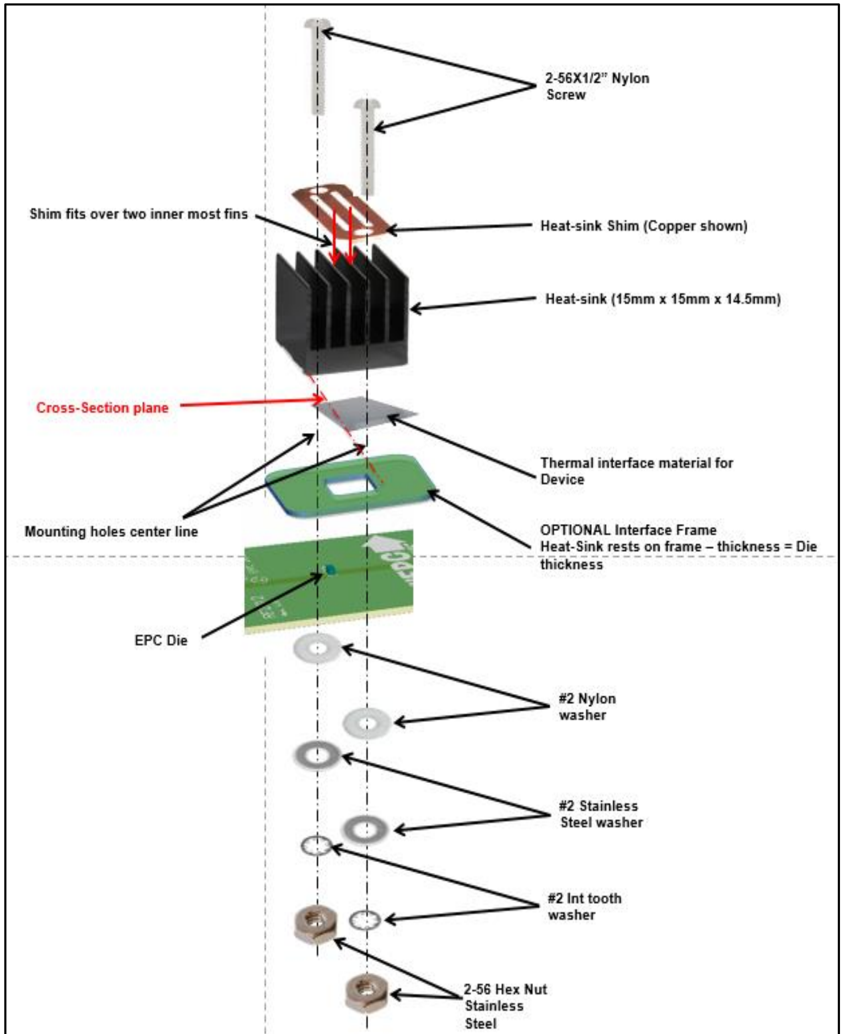
Excellent Thermally



- Substrate is at source potential
- Gap Filler
- Thermal interface (electrically isolating)
- Heatsink
  - (200 PSI max)

Thermals

Topside Heatsink Assembly for eGaN FETs (OPTIONAL)



Heat-sink Hardware						
Item	Qty. per HS Kit	Description	Manufacturer	Manufacturer P/N	Digikey P/N	Notes
1	2	Screw Mach Phil 2-56X1/2 Nylon	B&F Fastener Supply	NY PMS 256 0050 PH	H534-ND	Use nylon to prevent over-tightening and die damage
2	1	Heatsink mounting shim	Coastal	PCBshim	n/a	EPC custom part
3	1	Heat-sink 15mm X 15mm X 14.5mm	Advanced Thermal Sol	ATS-54150K-C2-R0	ATS1212-ND	Remove graphine thermal interface material
4	1	Thermal interface pad with adhesive	Wakefield	173-7-1212A	17371212A-ND	Custom cut to fit EPC FETs and other components
5	2	Nylon washer	Keystone Electronics	3347	36-3347-ND	Used for insulation to the PCB
6	2	Washer Flat #2 Stainless Steel	B&F Fastener Supply	FWSS 002		Used between nylon washer and spring washer
7	2	Washer internal tooth #2 Stainless Steel	B&F Fastener Supply	INT LWSS 002	H728-ND	Used to ensure a good fit over time
8	2	Hex Nut 3/16" 2-56 Stainless Steel	B&F Fastener Supply	HNSS256	H723-ND	
8	2	Hex Nut 3/16" Nylon 2-56	B&F Fastner	NY HN 256	H612-ND	Alternative to the metal nuts

EPC now recommends Fujipoly SARCON XR-m thermally conductive gap filling gel sheets. Insulated: 21kV/mm breakdown.

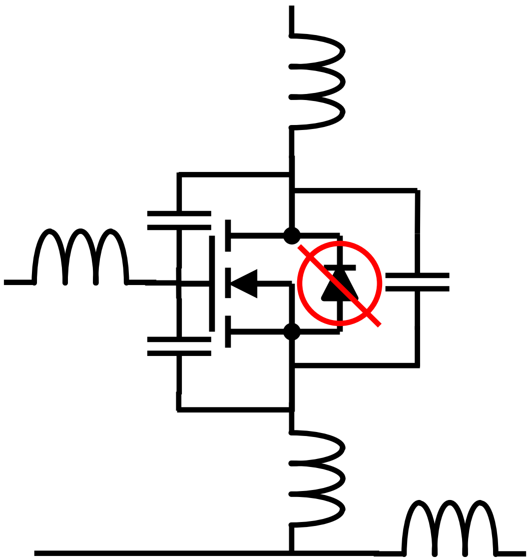
Fundamental Advantage

- GaN gives a smaller device with lower $R_{DS(on)}$
  - With lower capacitance and gate resistance
    - Faster voltage commutation
    - Lower loss switching
  - Lower inductance
    - Faster current commutation
    - Lower EMI
  - Zero Q_{RR}
    - Lower Switching losses

200 V Silicon Device
(30 mΩ)

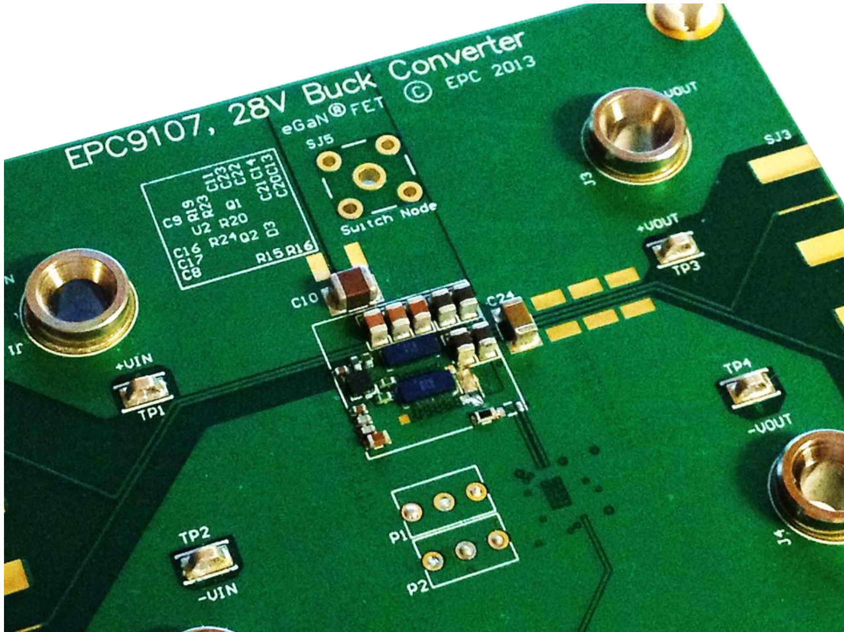
Gen 4 Gen 5

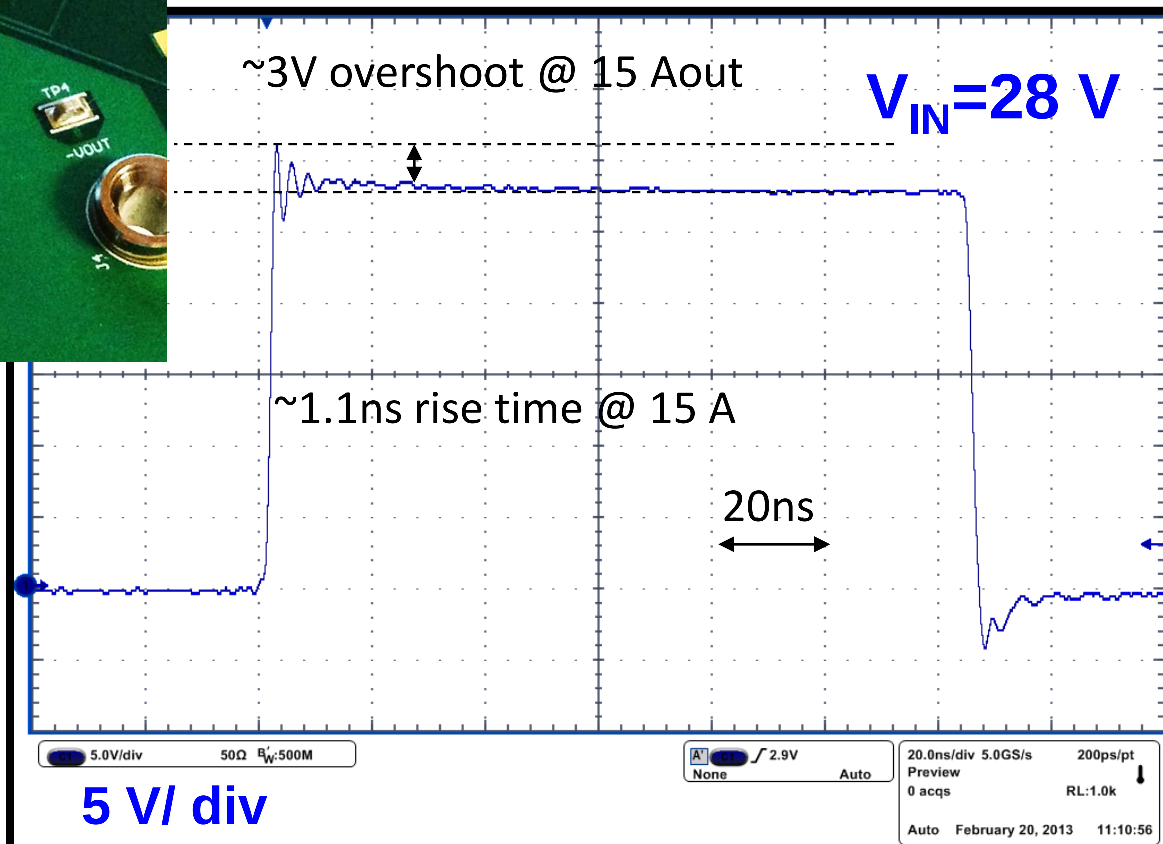
200 V eGaN FET
(25 mΩ)



Ultra-Fast Switching

V_{IN}=12-28 V V_{OUT}=3.3 V
I_{OUT}=15 A F_S=1 MHz
2 x EPC2015



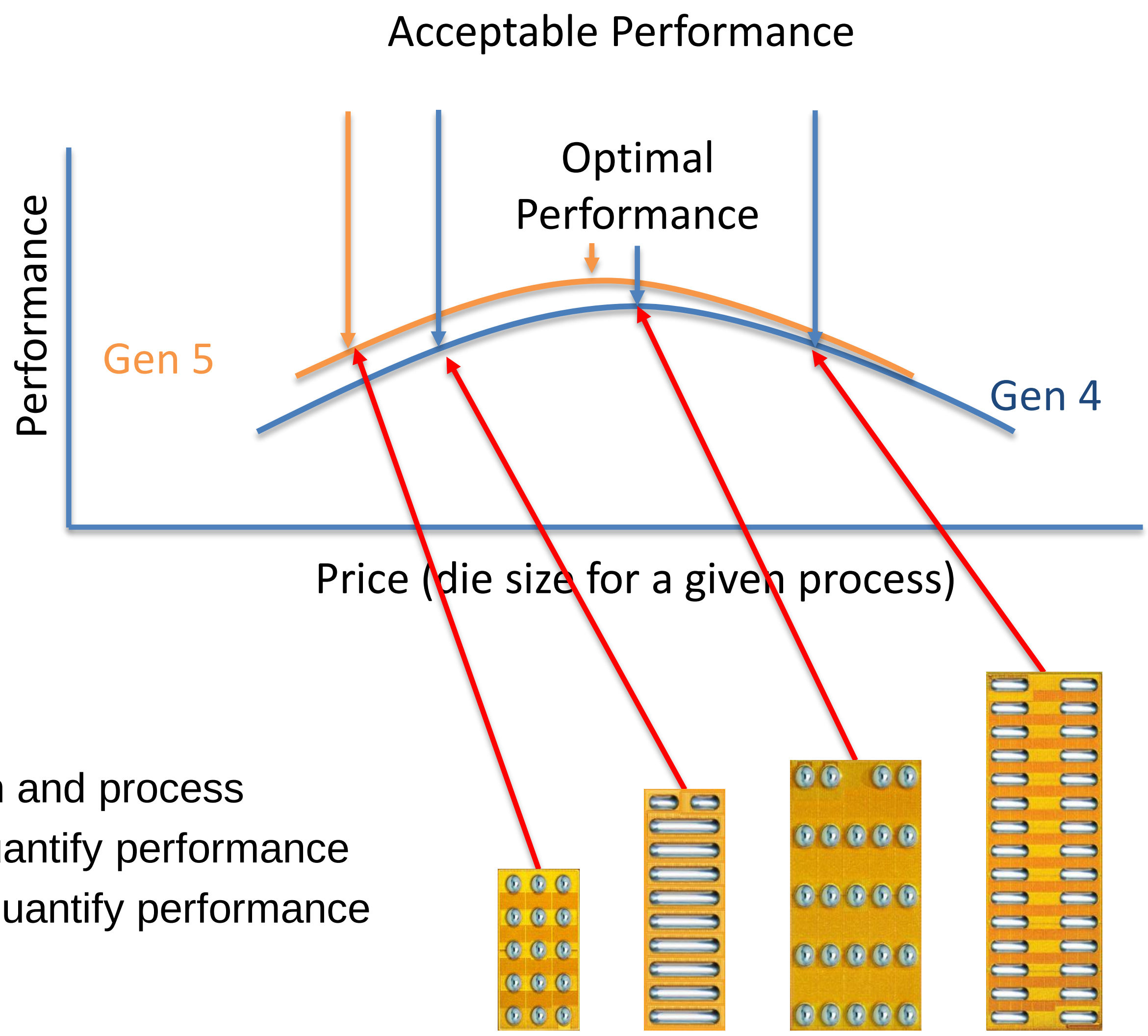


Switching Node Voltage

V_{IN}=28 V I_{OUT}=15 A

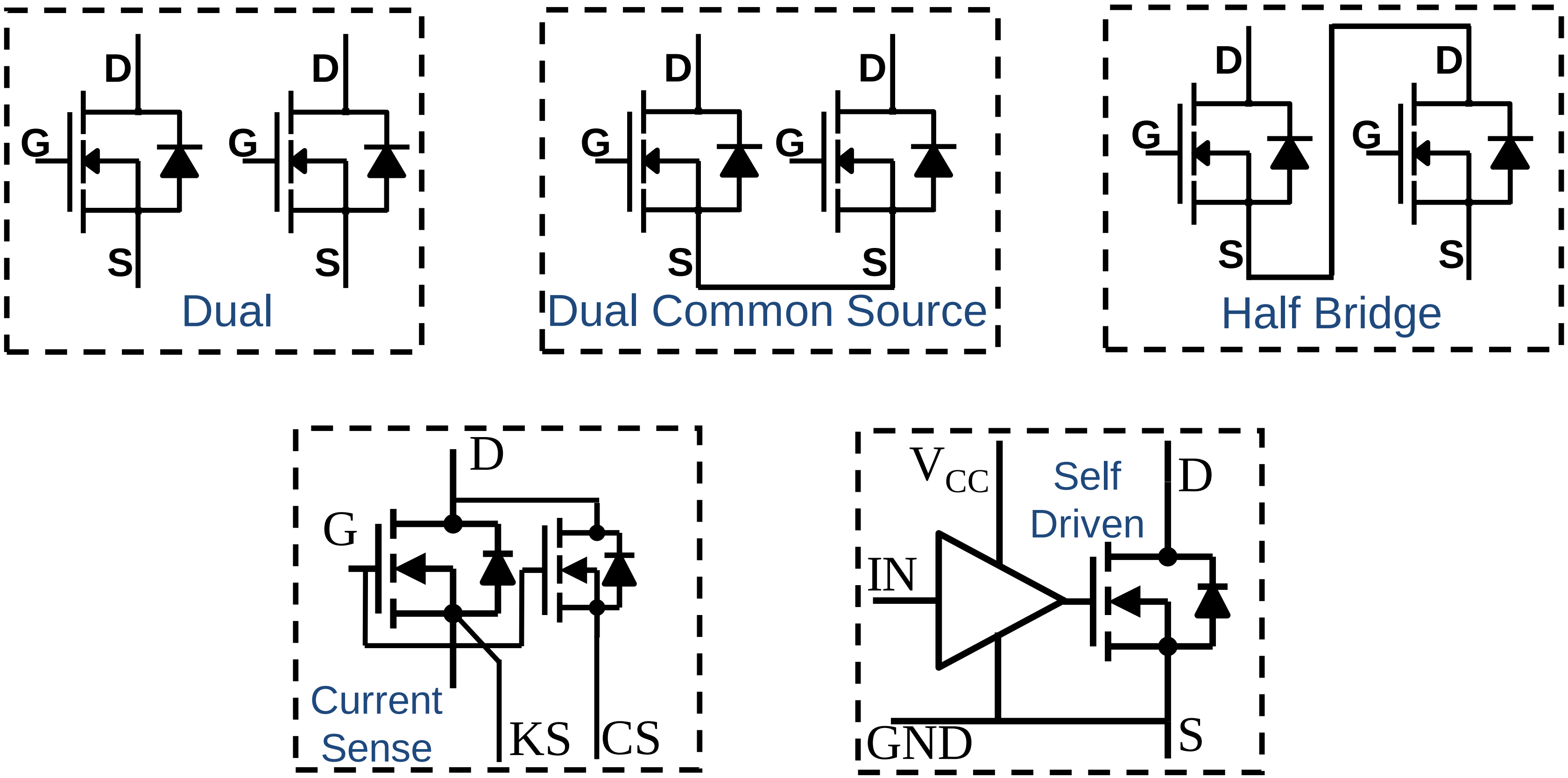
Little ringing for low EMI

Die Size Optimization



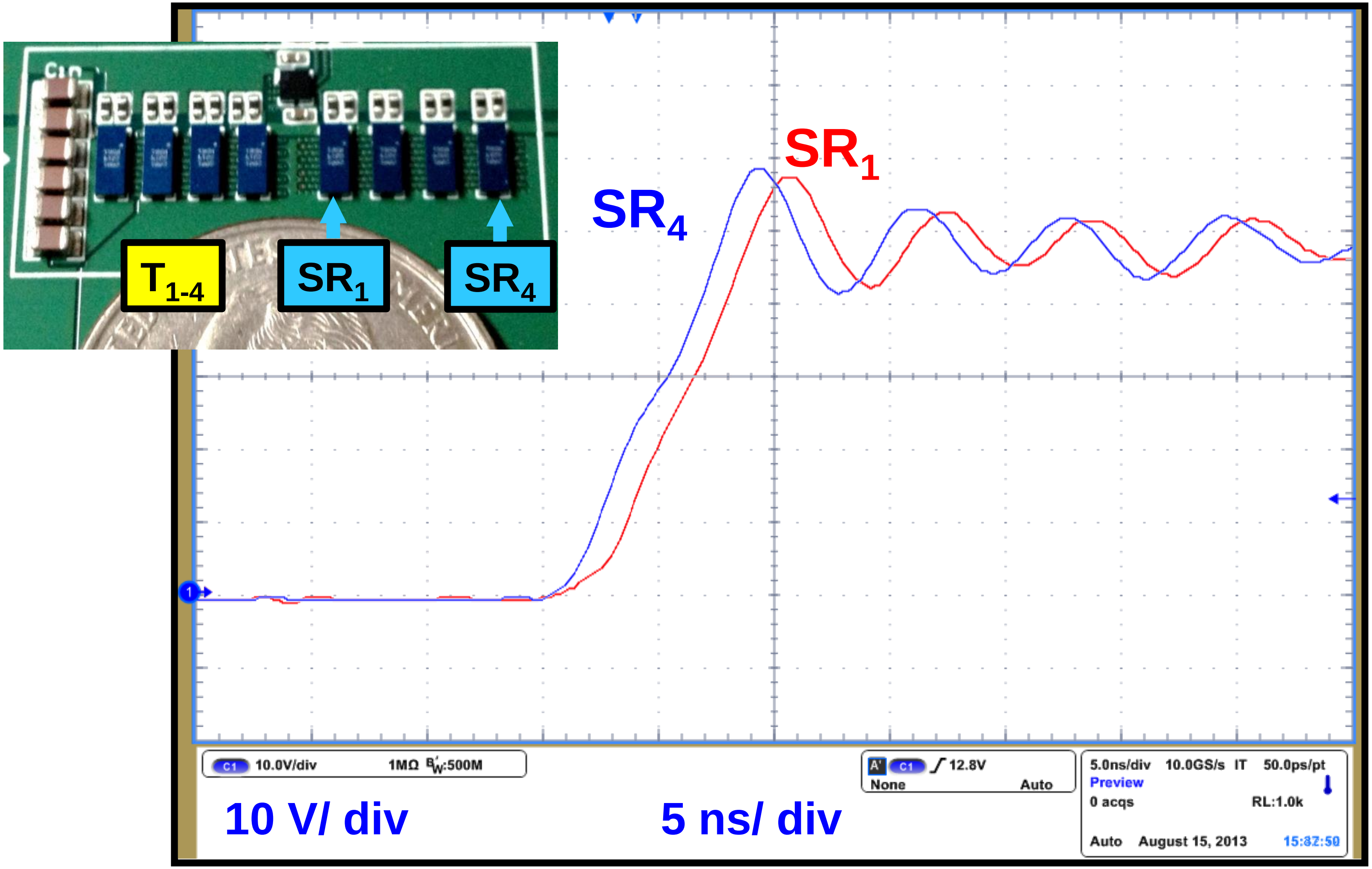
- For a given application and process
- Define equations to quantify performance
- Apply parametrics to quantify performance
- Gen 5

eGaN FET Integration



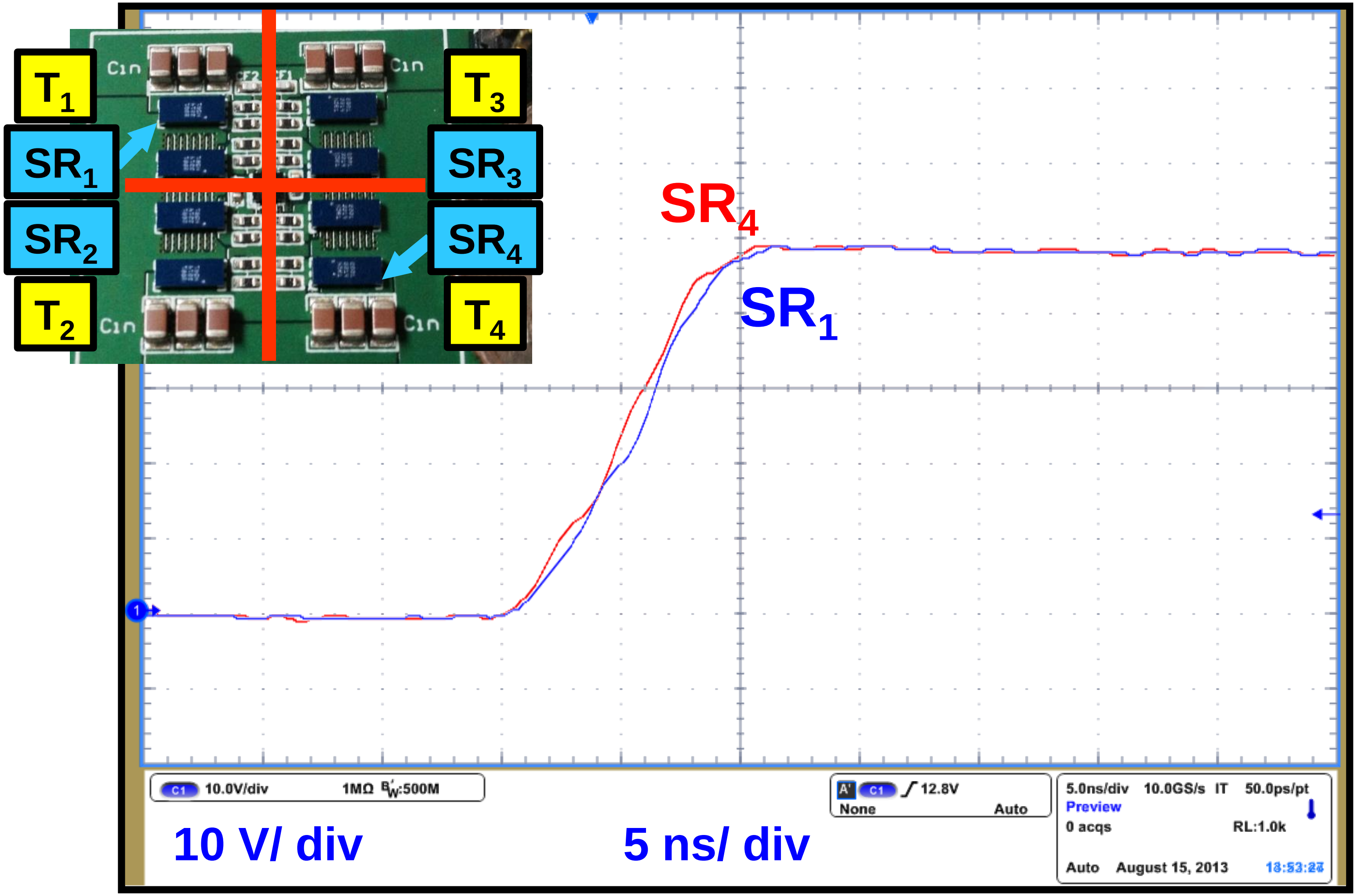
- Lateral structure allows cost effective integration

Single Loop Optimal Layout



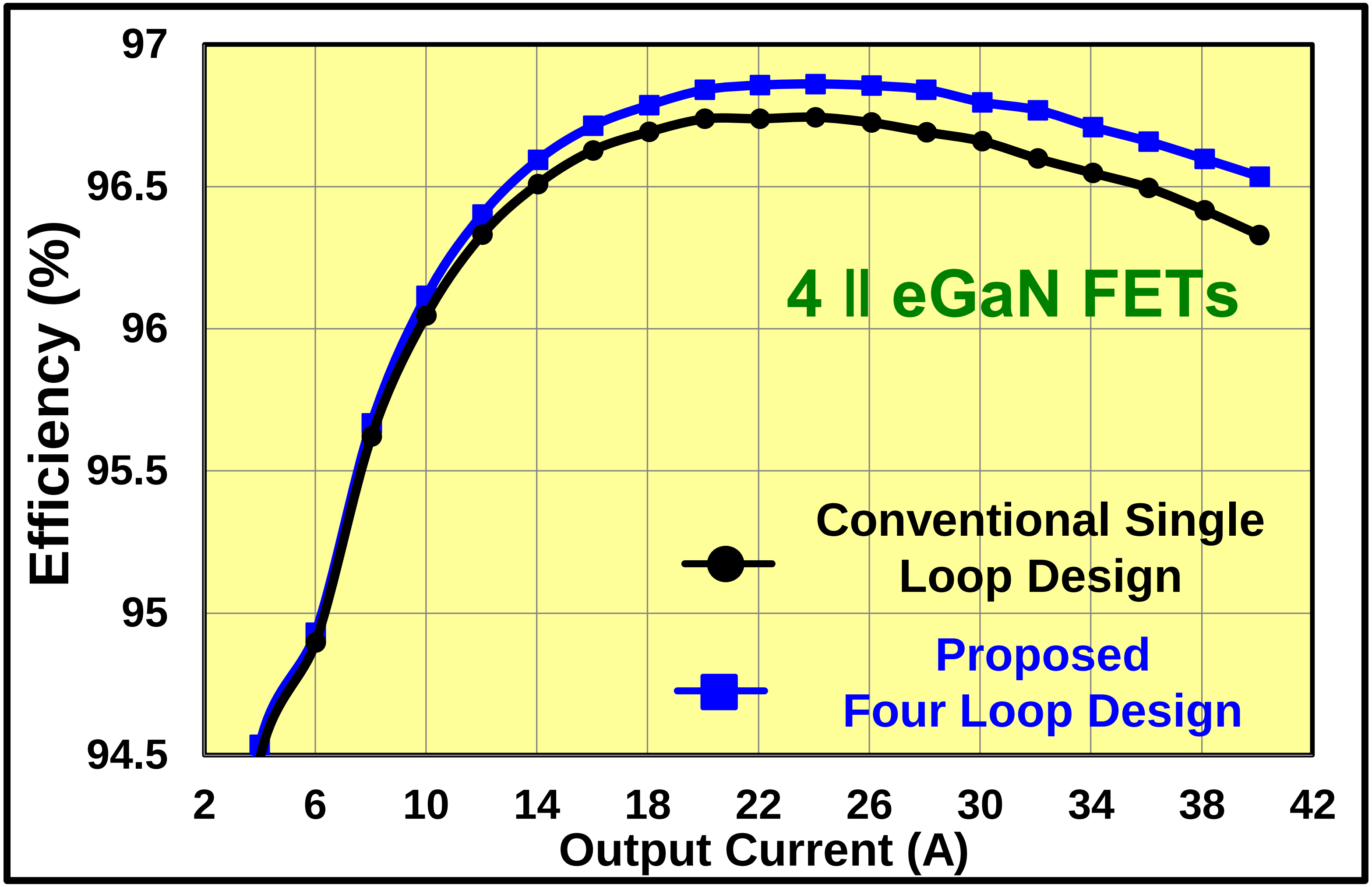
V_{IN}=48 V V_{OUT}=12 V I_{OUT}=30 A F_S=300 kHz L=3.3 uH GaN FET T/SR: 100 V EPC2001

Parallel Loop Optimal Layout



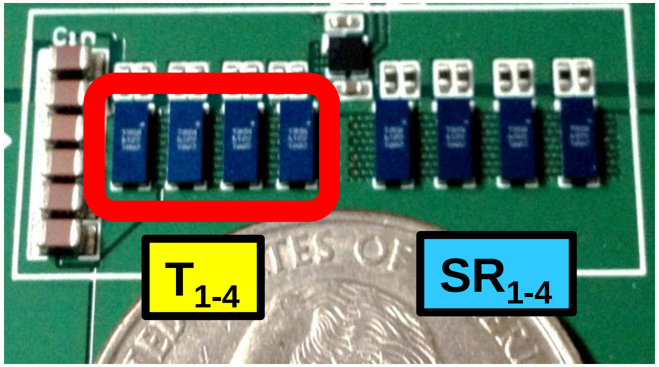
V_{IN}=48 V V_{OUT}=12 V I_{OUT}=30 A F_S=300 kHz L=3.3 uH GaN FET T/SR: 100 V EPC2001

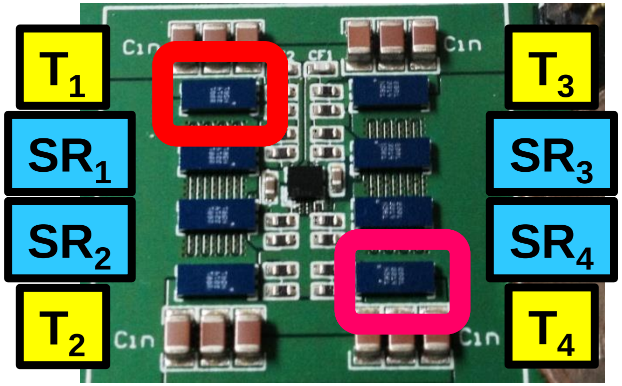
Parallel Layout Performance

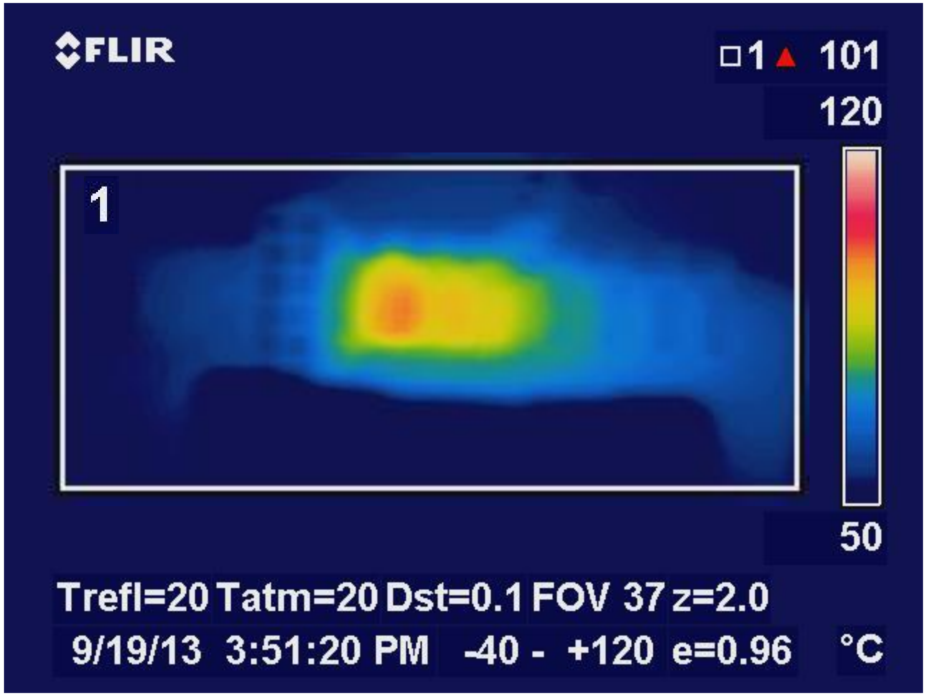


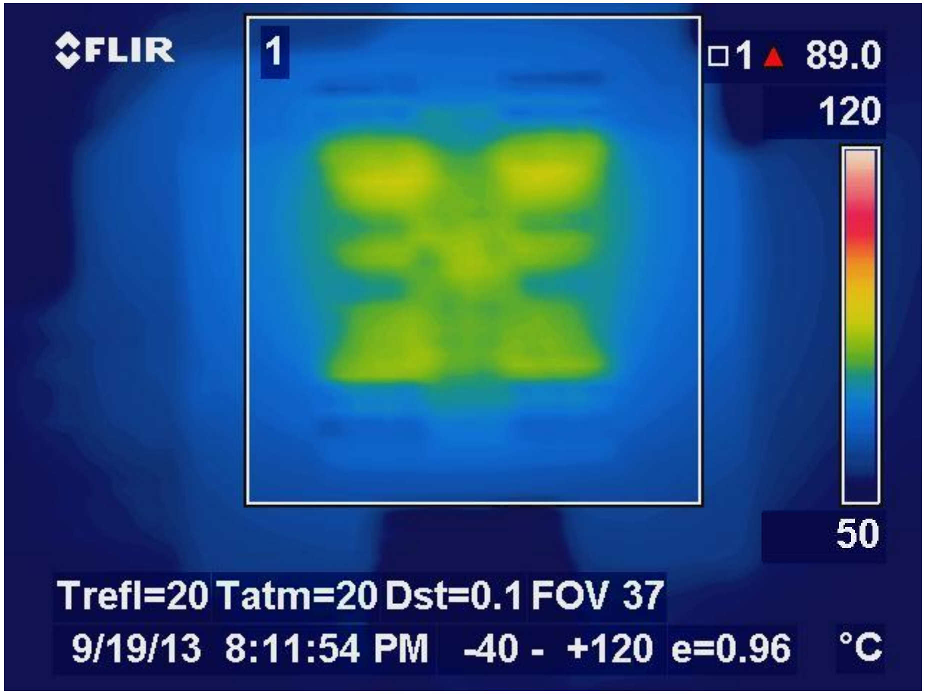
V_{IN}=48 V V_{OUT}=12 V F_S=300 kHz L=3.3 uH GaN FET T/SR: 4x100 V EPC2001
4 Layer 2 oz PCB

Parallel Layout Implementation

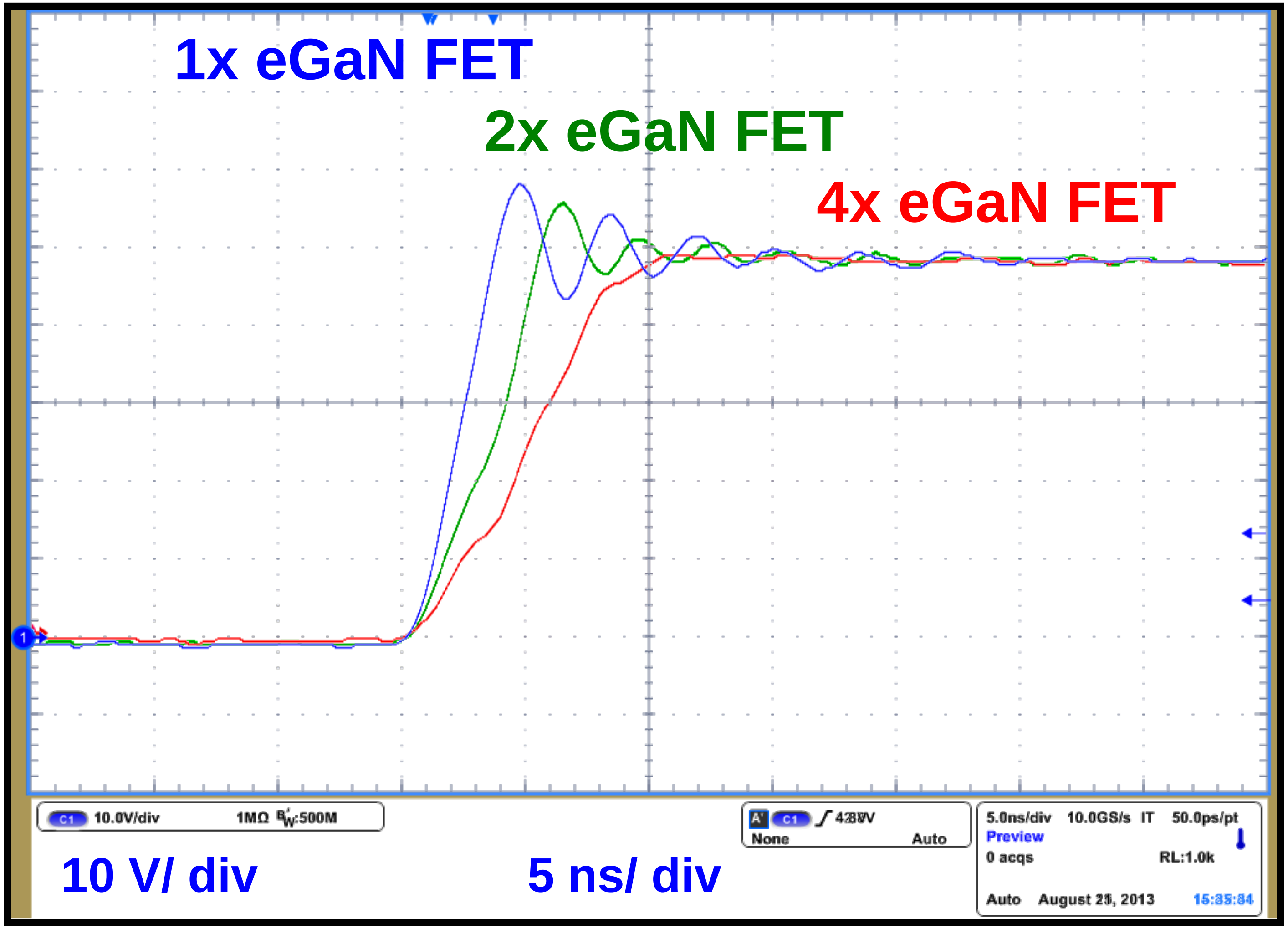






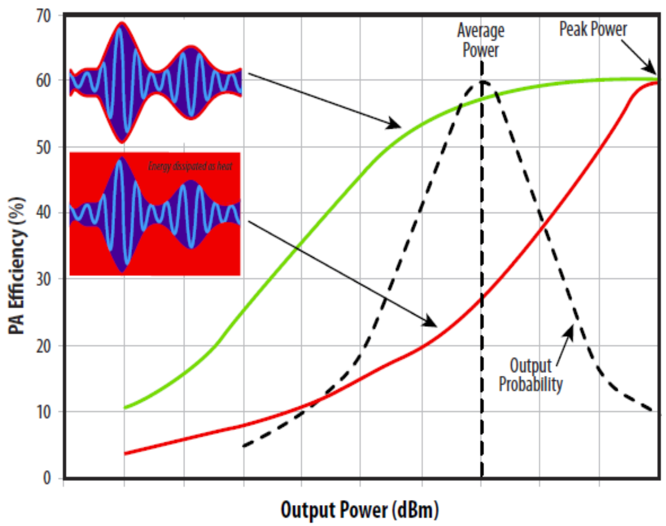


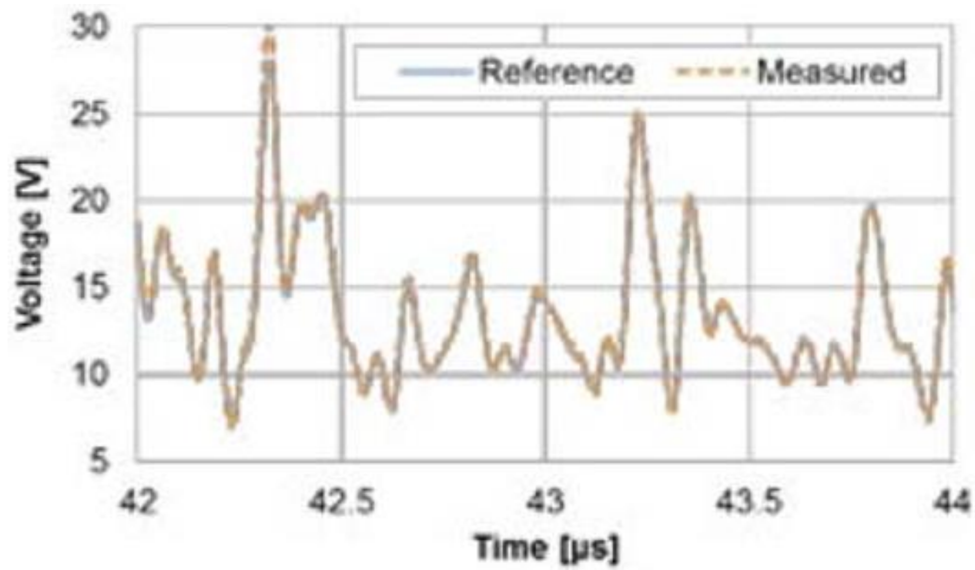
Parallel eGaN FET Swithcing



V_{IN}=48 V V_{OUT}=12 V F_S=300 kHz L=10 uH GaN FET T/SR: 100 V EPC2001

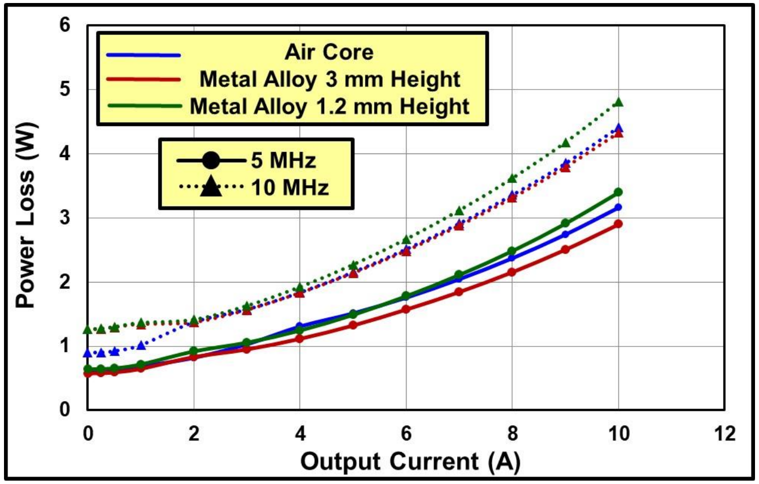
What Does Fast, Low Loss Switching Buy?



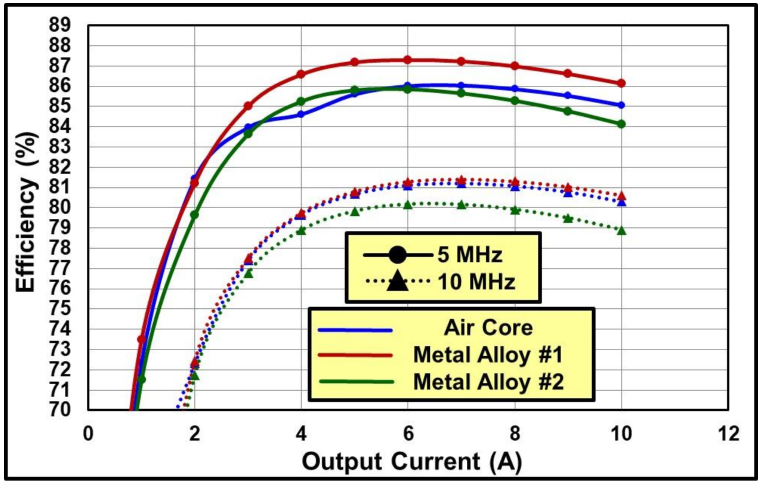


- PA with constant voltage acts as constant power dissipater
- GaN enables high bandwidth power supply
- 4 phase, 60 W
  - 92% Power system efficiency
  - 20 MHz, 7 dB PAPR LTE envelope signal

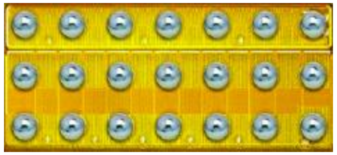
Reduce Notebook and Tablet Size



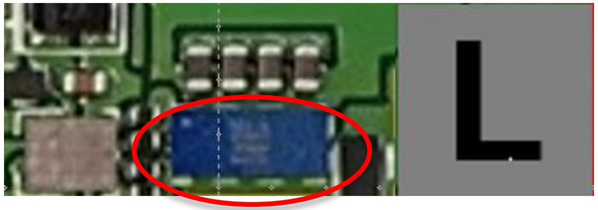
V_{IN}=12 V V_{OUT}=1.8 V



V_{IN}=12 V V_{OUT}=1.8 V



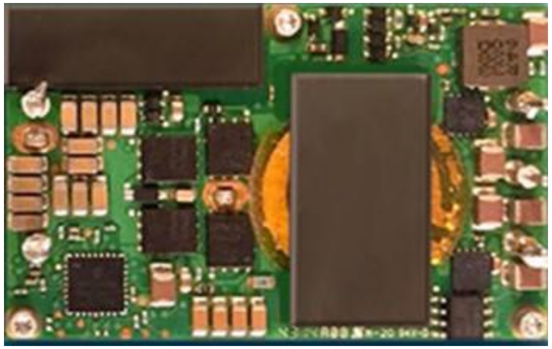
3 mm x 1.5 mm half bridge



50 mm^2 x 1.2 mm high

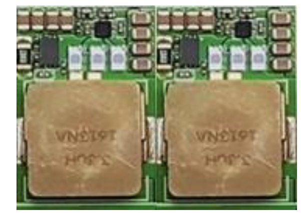
- 100 nH inductor
- Reduces board system height
- Reduces voltage regulator footprint

Reduce Size and Cost of 48 V to 12 V



600 W Isolated

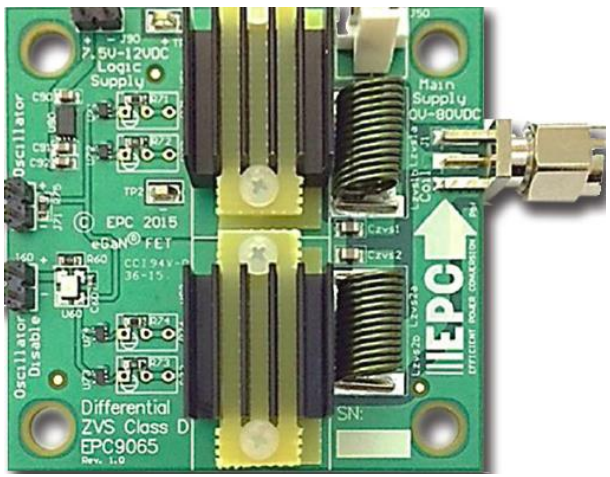
600 W Isolated



500 W Buck (or Boost)

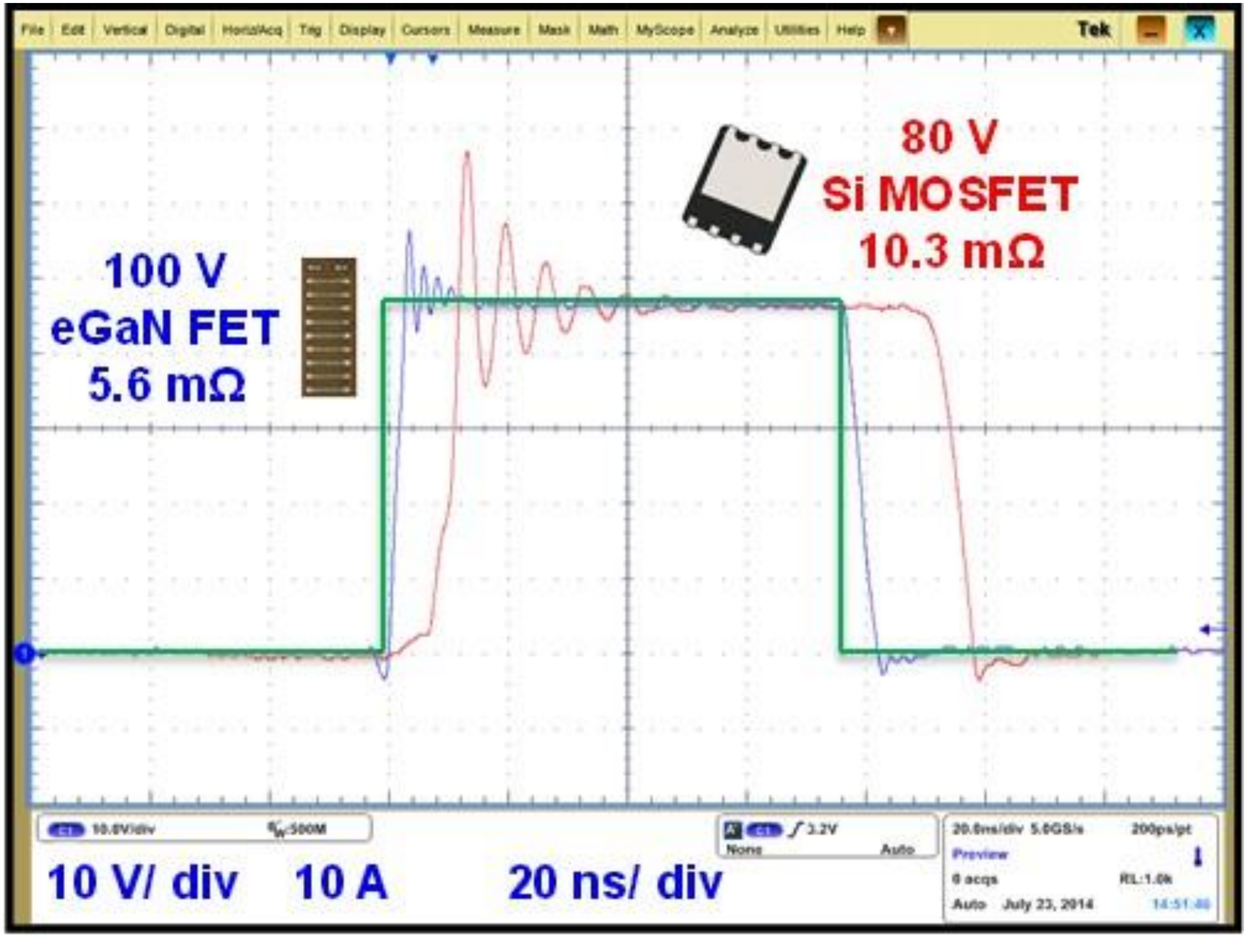
f	100 kHz	200 kHz	500 kHz	1 MHz
L	6.8 uH	3.3 uH	1 uH	0.68 uH
I_{PP}	13.2 A	13.6 A	18 A	13.2 A
Inductor	IHLP8787GZ-51	IHLP6767GZ-51	IHLP5050CE-01	IHLP3232DZ-01
Size (mm)	22 x 22.5 x 13	17 x 17.2 x 7	12.9 x 13.2 x 3.5	8.2 x 8.6 x 4
DCR (mΩ)	3.09	3.27	3.5	3.67

Wireless Power Transfer

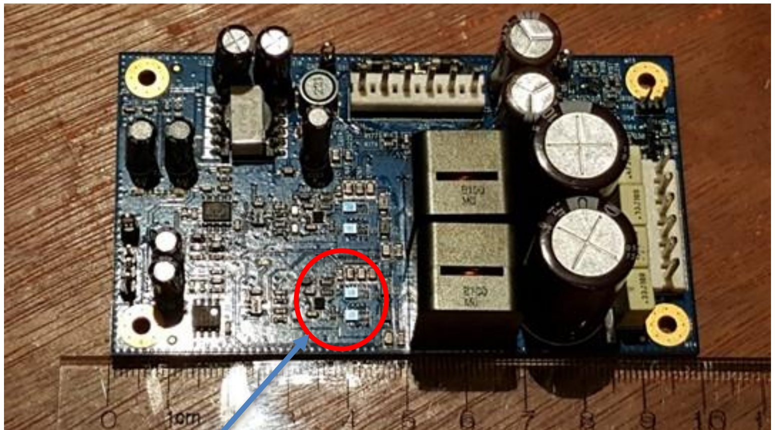


- 6.78 MHz and 13.56 MHz magnetic resonance
- Power into the body
- Power a desk
- 100 W + demonstrated

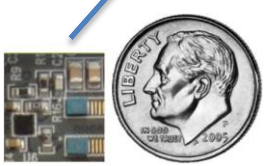
Find the Richness in Music

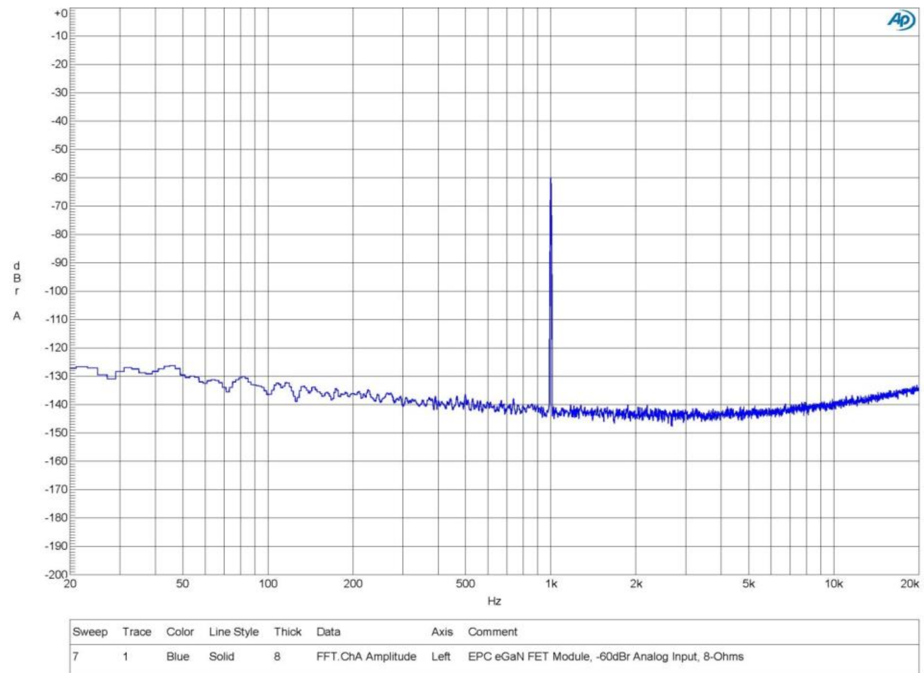


Find the Richness in Music



400 W into 4 ohms

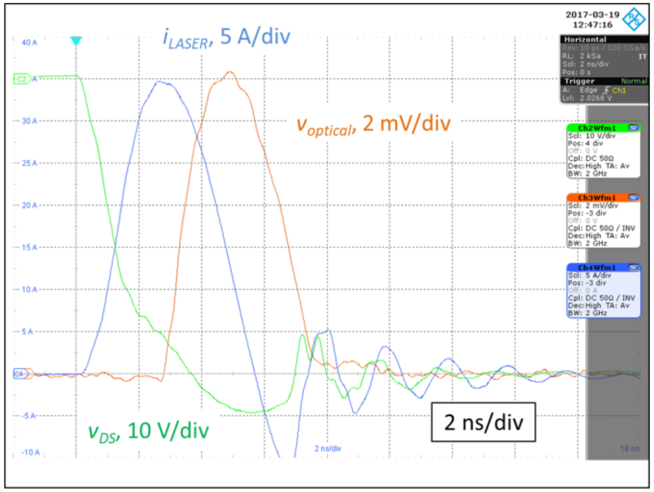




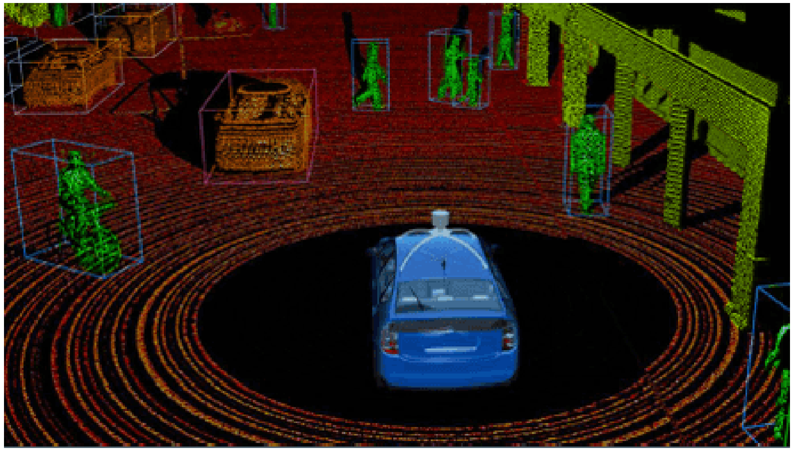
FFT from 20 Hz to 20 kHz of a 1 kHz signal at -60 dBr

- Where’s the heatsink?
- Increased open loop linearity reduces magnitude of feedback

Increase Resolution of 3D Imaging



V_{BUS} = 75 V, I_{peak} = 35 A,



- LiDAR 3D imaging systems chase the speed of light (30 cm/ns (1 ft/ns))
- Breaking distance is 150 m at 160 km/h
- Identify the object

Conclusions

- GaN provides fast, low loss switching
- Fast, low loss switching enables different ways to solve power conversion and delivery problems

- *presentation made by Steve Colino*
- *presented on behalf of Steve Colino by: Brian Miller, field application engineer, brian.miller@epc-co-com, 919-680-2902*
- *EPC's Sales reps for Long Island: Aurora, auroragroup.net*