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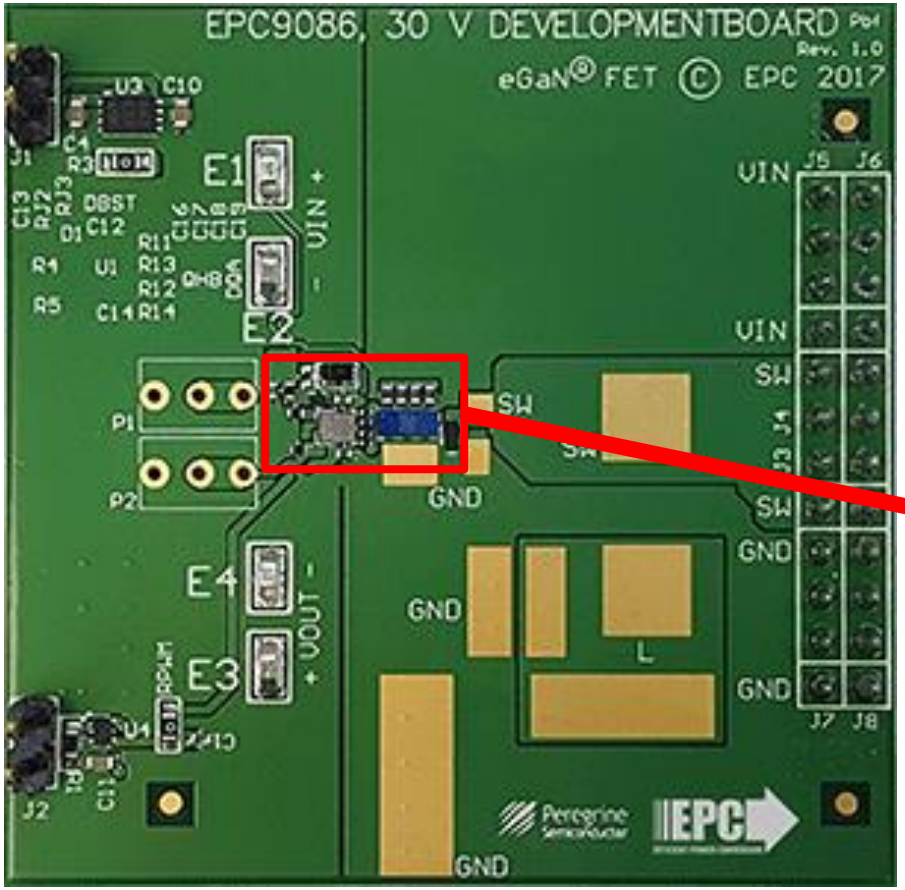
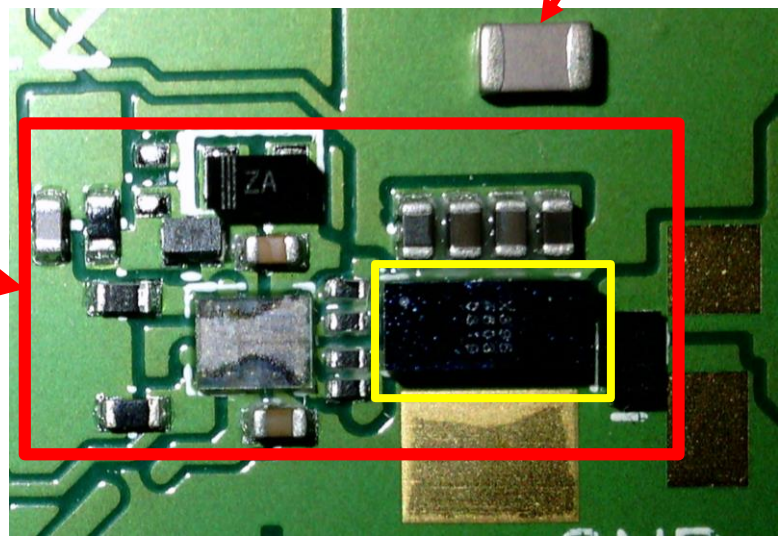
SPACE POWER WORKSHOP

Migrating from Si to GaN

presented by:
Steve Sandler of AEi Systems and Picotest

Giving it Perspective





30V/15 Amp
10MHz half-bridge and driver

Why We're So Excited about GaN

Smaller, lighter cheaper?

No doubt! But there's more…

- Lower resistance
- Lower capacitance
- Inherent radiation tolerance
- Lower RDSon yields higher efficiency
- Higher transconductance lower excess inductance
- Lower noise
- Higher switching frequency – smaller, lighter, faster dynamics

"This achievement marks the first time in 60 years that any technology rivals silicon both in terms of performance and cost, and signals the ultimate displacement of the venerable, but aging power MOSFET"
--Dr. Alex Lidow (Co-inventer of the HEXFET)

And Excuses For Not Migrating

I tried it and didn't see much improvement

Amara's Law

GaN is a Depletion mode device – we don't like normally on

eGaN is NOT depletion mode. The "e" stands for Enhancement

Insufficient data (failure rate history and radiation performance)

Yes, there IS data

Cost – This doesn't even apply in Space, but it WILL be cheaper

Resonant converters don't benefit

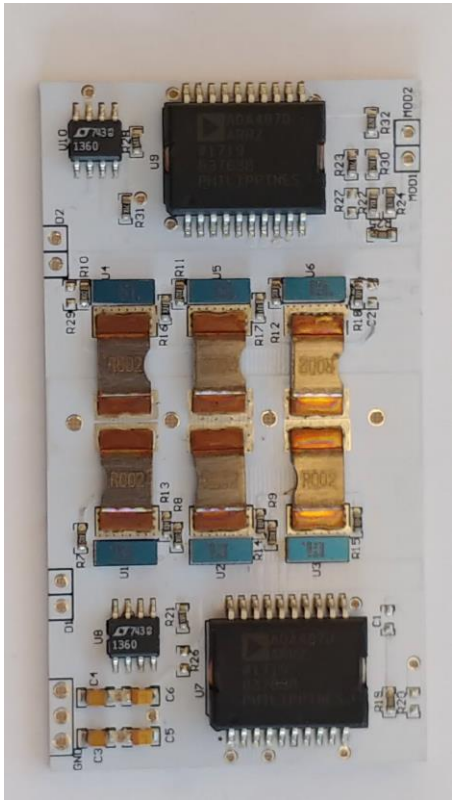
Ha! Of course they do

Achieving the promised gains requires us to do some things differently

or NOT!

The SPACE Applications for GaN

- Linear Regulators
- Fault switches and bus isolators
- Shunt Solar Array Regulators
- RF Amplifiers (LNA's and Power)
- Motor Drivers
- Local Switching Regulators
- High Power DC-DC Converters
- High performance testing



Picotest 500Amp high-speed in-socket 2 channel load

Two Categories

Migrating from Si to GaN means different things for different Power Applications

- Linear Regulators
- Inrush limiters
- Fault switches and bus isolators
- Shunt Solar Array Regulators
- Motor Drivers
- Local Switching Regulators
- High Power DC-DC Converters

https://www.signalintegrityjournal.com/articles/35-evaluation-of-gallium-nitride-hemts-for-vrm-designs

Linear Applications

Silicon Linear Regulator

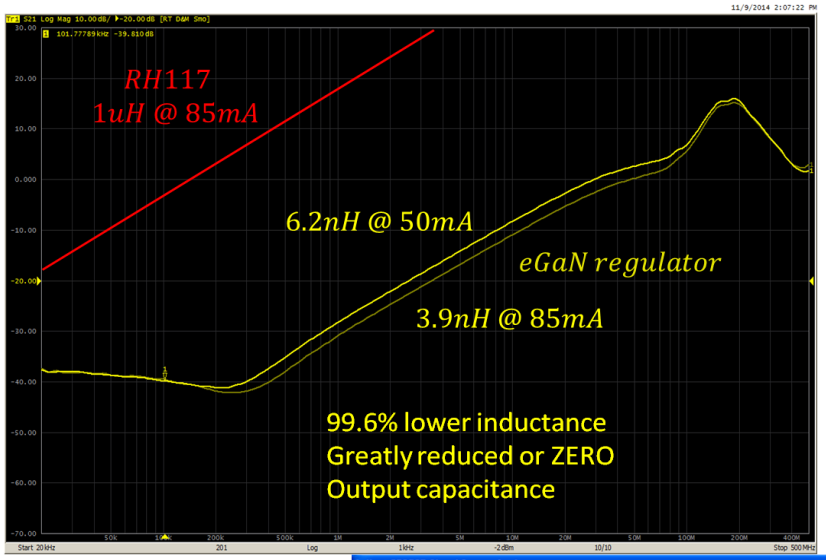
I spoke about this at SPW 2015

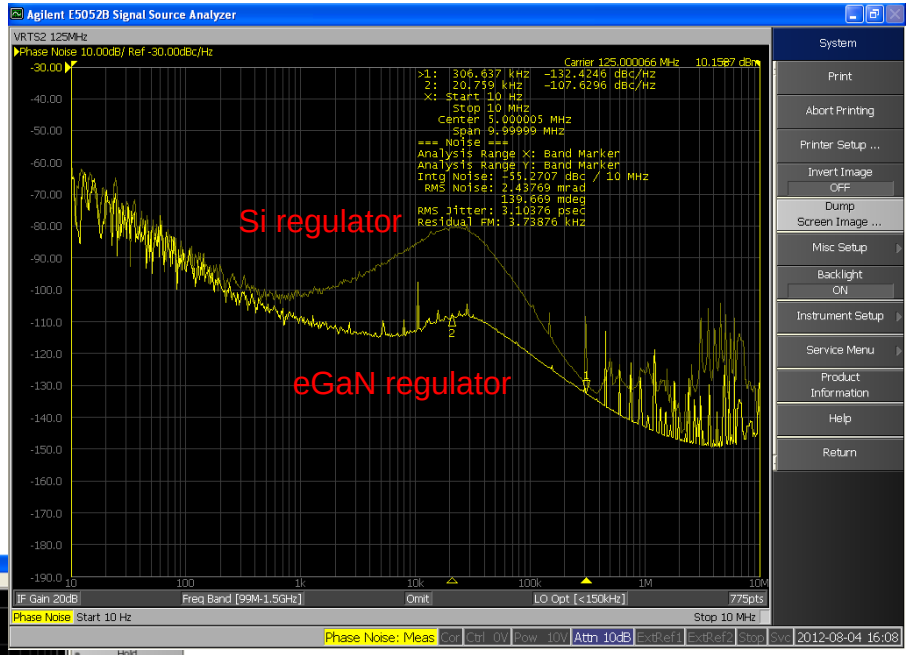
eGaN Linear Regulator

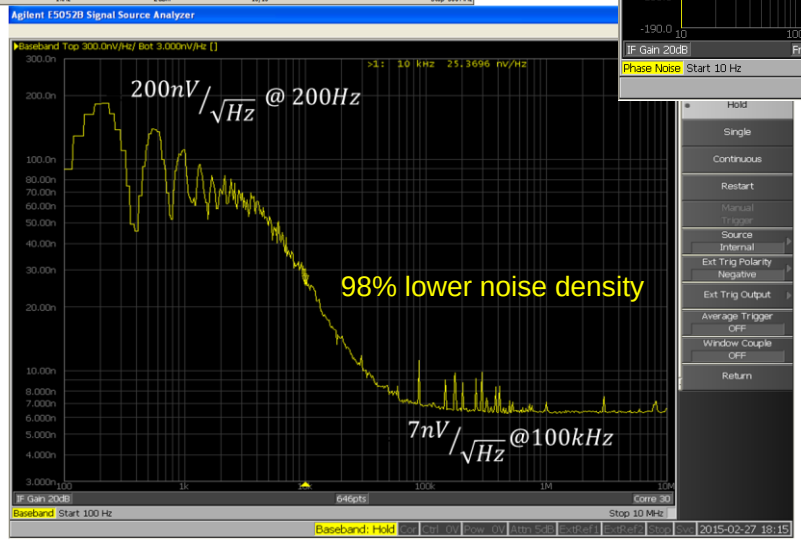
In most linear applications the Si device can be directly replaced with an eGaN device.

Any gate-source protection should be lowered from 12V to 5V.

Linear Application Direct Swap







eGaN regulator:
NO Output Capacitors
Lower Noise
Lower Inductance
Improved Phase Noise and Clock Jitter

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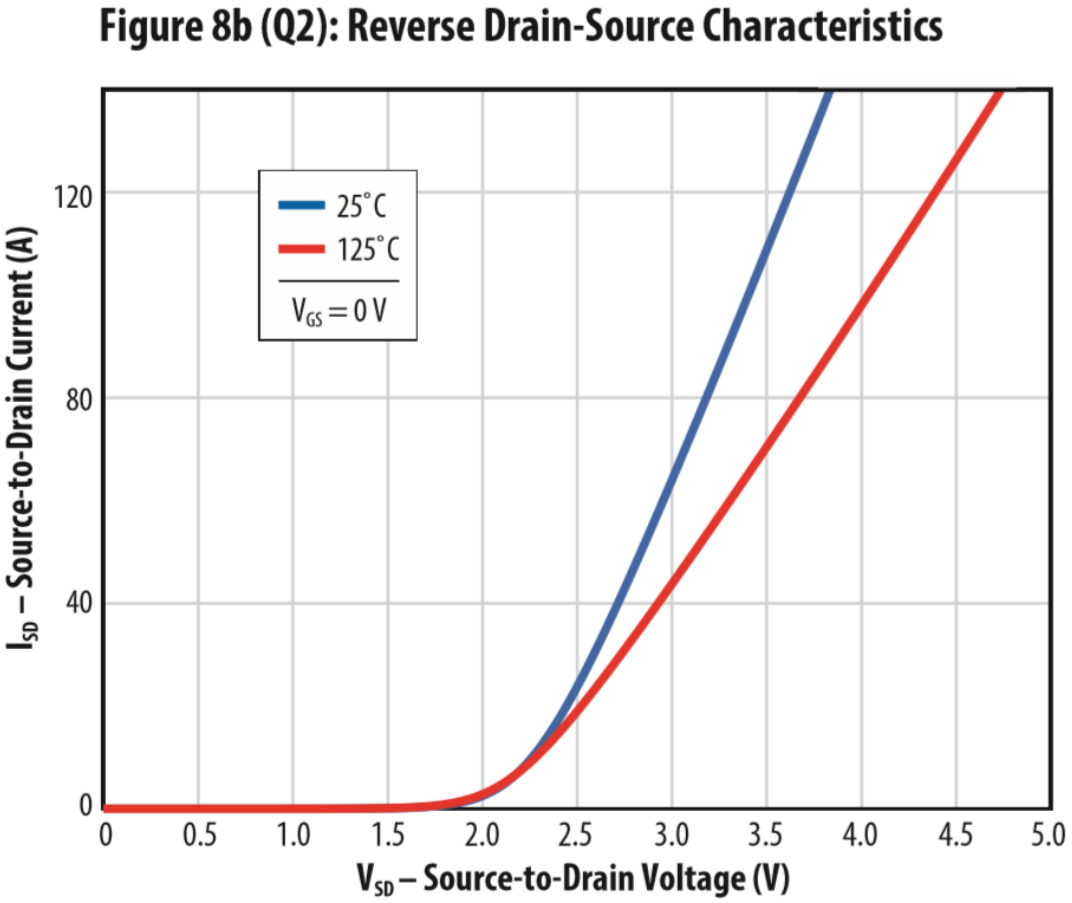
Switching Applications

Four Major Migration Considerations

Gate drive and dead-time
Board plane decoupling
Thermal management

During dead-time the body diode conducts and this is a very lossy path compared with Si devices

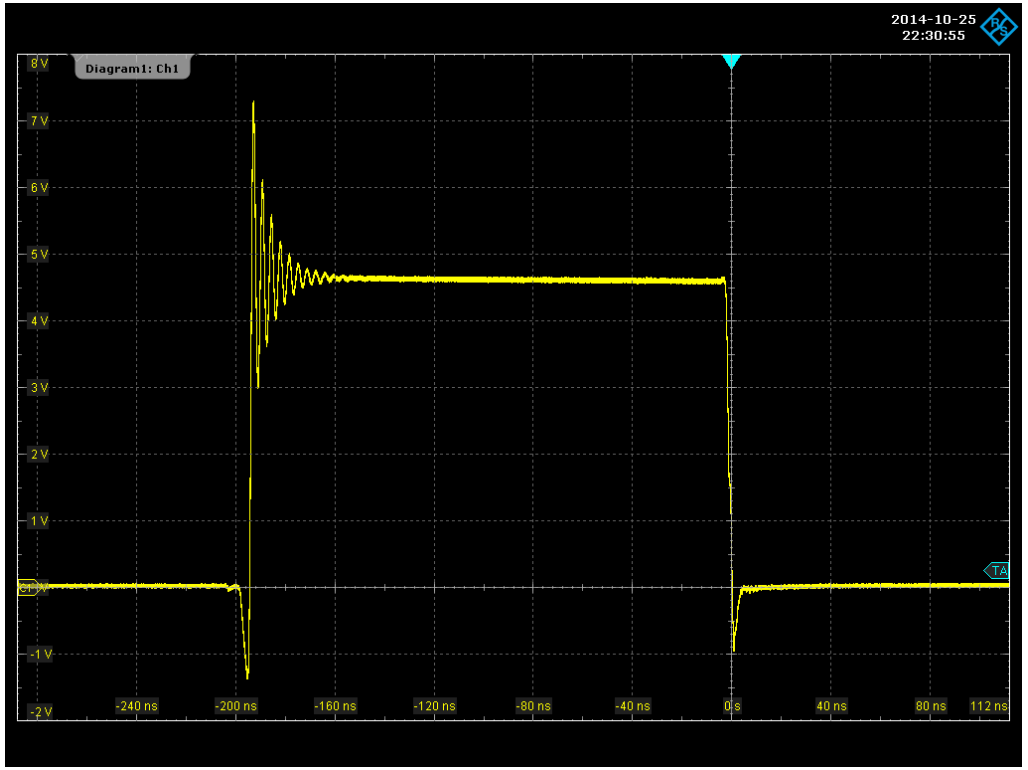


Gate Drive and Dead Time

eGaN body diode has essentially zero recovery, but high voltage drop.

Important to minimize this especially for low voltage high current applications.

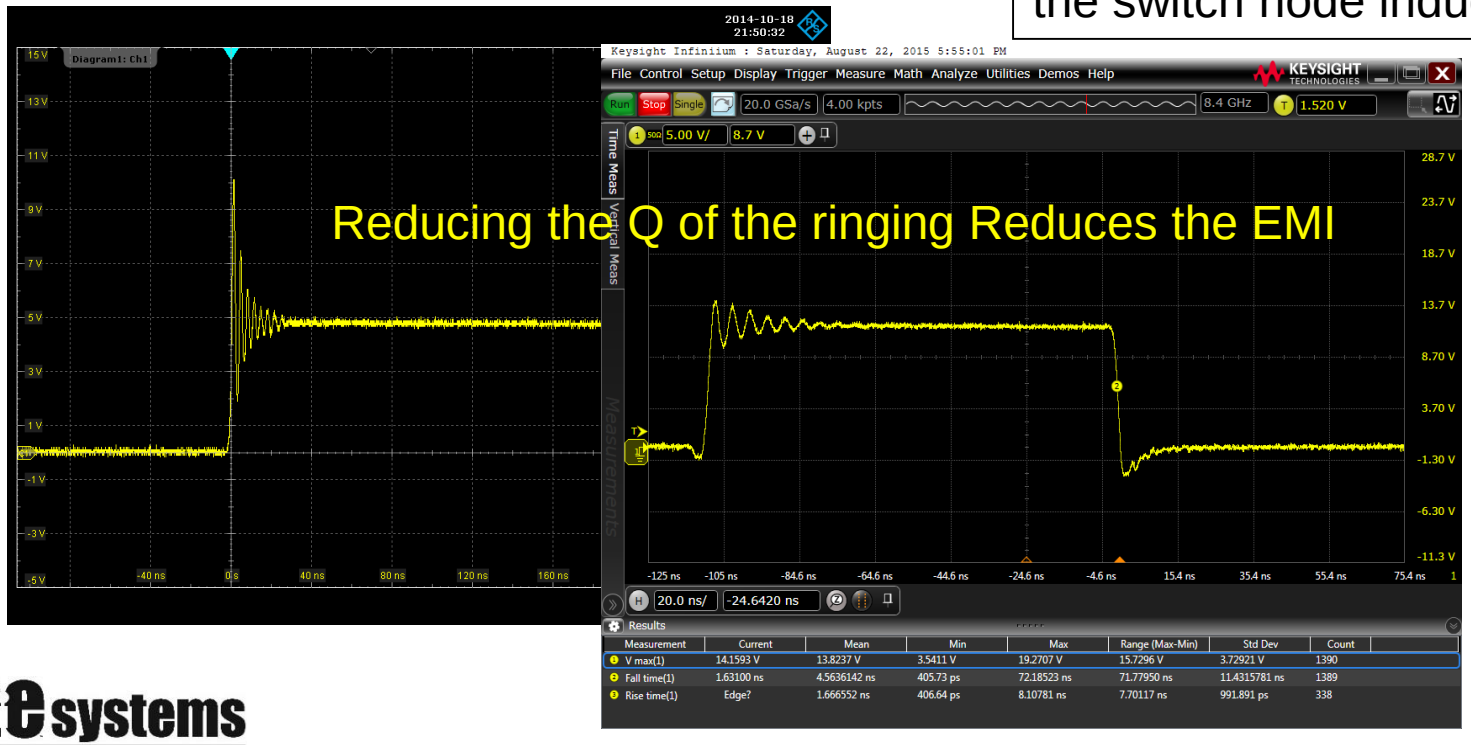
New, more advanced drivers will offer better dead time control.



Plane Decoupling

Power Integrity decoupling techniques are used to minimize the loop inductance at the Drain and the Source. This minimizes the spike amplitude and EMI.

Half bridge devices help minimize the switch node inductance



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Thermal

Thermal Characteristics			
PARAMETER		TYP	UNIT
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.3	°C/W
$R_{\theta JB}$	Thermal Resistance, Junction to Board	6.6	
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (Note 1)	58	

Cooling from the TOP is 5 times more effective than cooling from the BOTTOM

eGaN in 2018

PE29102

Document Category: Product Specification

UltraCMOS® High-speed FET Driver, 40 MHz

Peregrine Semiconductor

Features

- High- and Low-side FET drivers
- Dead-time control
- Fast propagation delay, 9 ns
- Tri-state enable mode
- Sub-nanosecond rise and fall time
- 2A/4A peak source/sink current
- Package – Flip chip

Applications

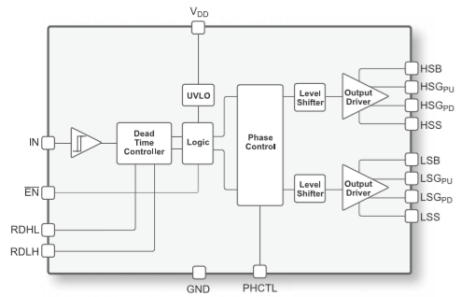
- Class D audio
- DC–DC / AC–DC converters
- Wireless charging
- Envelope tracking
- LiDAR

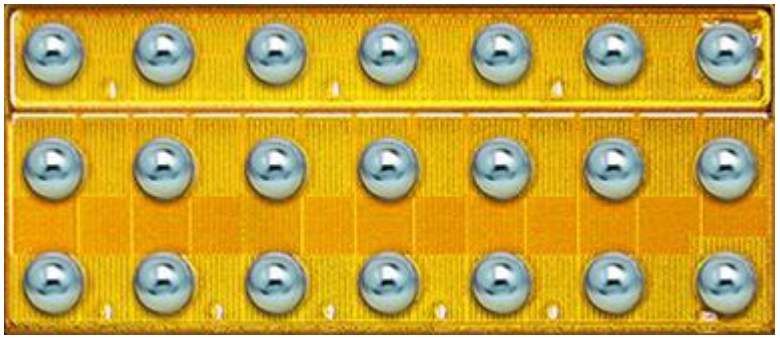
Product Description

The PE29102 is an integrated high-speed driver designed to control the gates of external power devices, such as enhancement mode gallium nitride (GaN) FETs. The outputs of the PE29102 are capable of providing switching transition speeds in the sub-nanosecond range for switching applications up to 40 MHz. The PE29102 is optimized for matched dead time and offers best-in-class propagation delay to improve system bandwidth. High switching speeds result in smaller peripheral components and enable innovative designs for applications such as class D audio and wireless charging. The PE29102 is available in a flip chip package.

The PE29102 is manufactured on Peregrine's UltraCMOS process, a patented advanced form of silicon-on-insulator (SOI) technology, offering the performance of GaAs with the economy and integration of conventional CMOS.

Figure 1 • *PE29102 Functional Diagram*

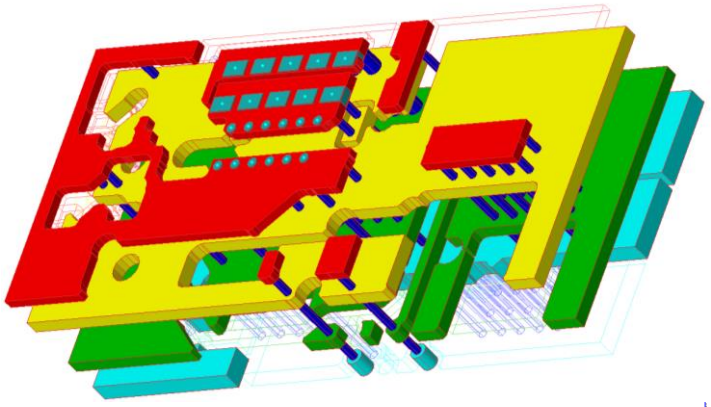


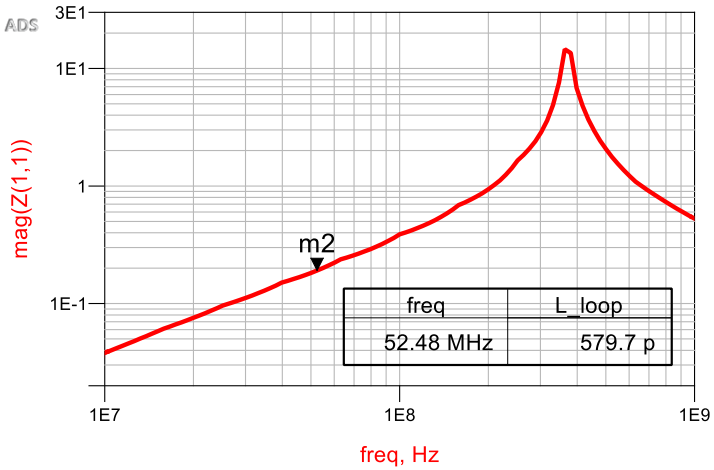


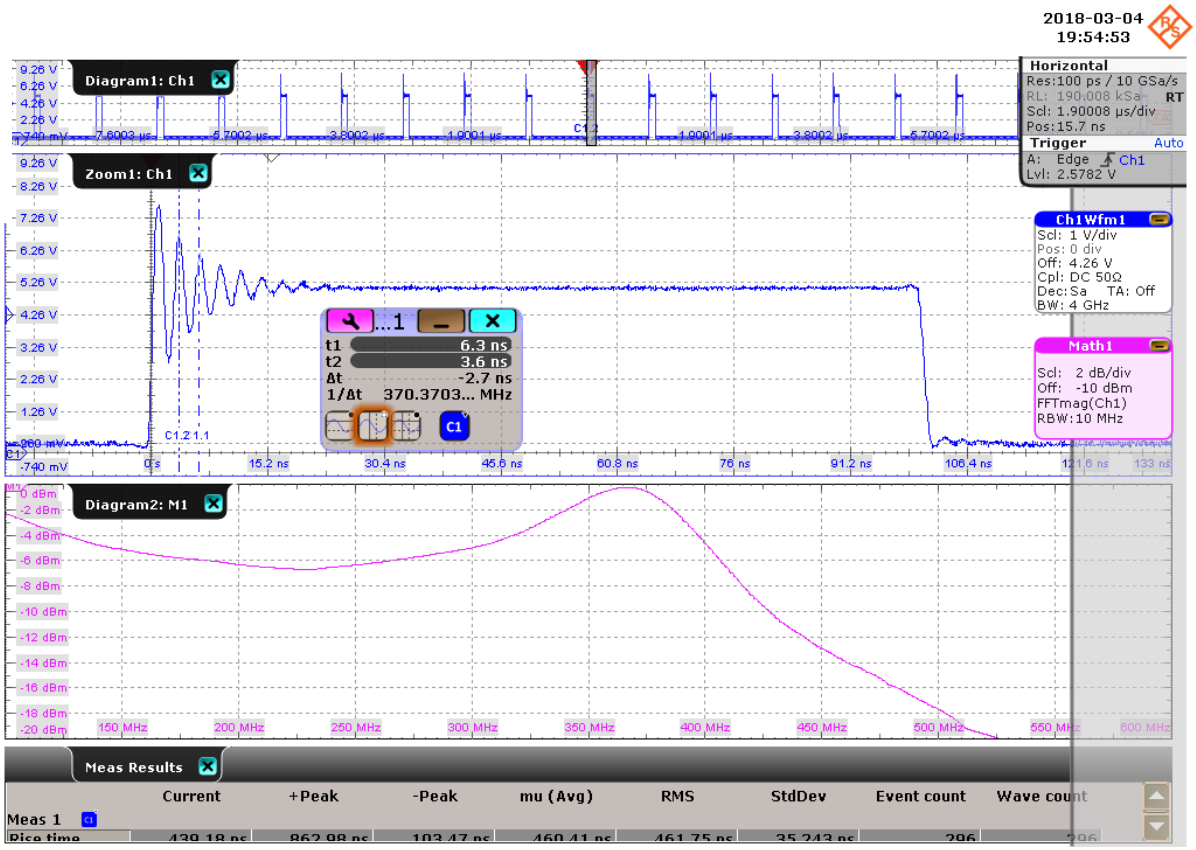
High Density Half-Bridge

Faster drivers are here
eGaN device are smaller and more efficient than ever

Plan on EM Simulation







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What's next

New Topologies - Valley-Switched Current-Fed Push-Push*
Resonant Current Multiplication
Multi-Level conversion

Higher frequency magnetic materials are here

https://en.tdk.eu/tdk-en/373388/company/press-center/press-releases/press-releases/ferrites--low-losses-at-high-frequencies/2167276

* Link for Designing High Current 48V to Core – Sandler DesignCon 2018

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Conclusions

GaN migration can result in higher efficiency, smaller size, lower cost, improved radiation tolerance and lower noise, BUT

- Direct replacement in linear regulators has many benefits
  - Lower impedance
  - Lower noise
  - Smaller capacitors due to higher bandwidth
- Switching regulators are not generally a direct replacement
  - Lower maximum gate voltage
  - Hyper fast requires careful EM considerations
  - Different cooling mechanism
  - Body diode losses are higher

Thank You

Additional References

S.M. Sandler, Power Integrity McGraw-Hill 2014

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http://www.edn.com/electronics-blogs/impedance-measurement-rescues/4438578/The-inductive-nature-of-voltage-control-loops?isCmsPreview=true

http://epc-co.com/epc/documents/papers/Radiation%20Tolerant%20eGaN%20FETs%20in%20DC-DC%20Converters.pdf

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