



TRANSFORMING THE WORLD

WITH SMALLER, LOWER COST,
MORE EFFICIENT POWER
ELECTRONICS

Power Systems Design
Get Going with GaN



Market leader for GaN power transistors

- GaN-on-Silicon transistors for the power conversion market
- Industry's most extensive & highest-performance products
 - Enhancement mode devices
 - 100V & 650V devices; industry-best performance

Global company with decades of experience in GaN

- Parts shipping overnight from Mouser since 2014
- World-class fabless manufacturing and advanced packaging
- HQ and R&D in Ottawa, Canada
- Sales & App. Eng. in Germany, Japan, China, Taiwan, Korea, USA



- **Smaller size** 2x to 10x
- **Lighter weight** 2x to 8x
- **Lower power loss** 2x to 6x
- **BoM cost reduction** 10% to 20%
- **System cost reduction** 10% to 30%



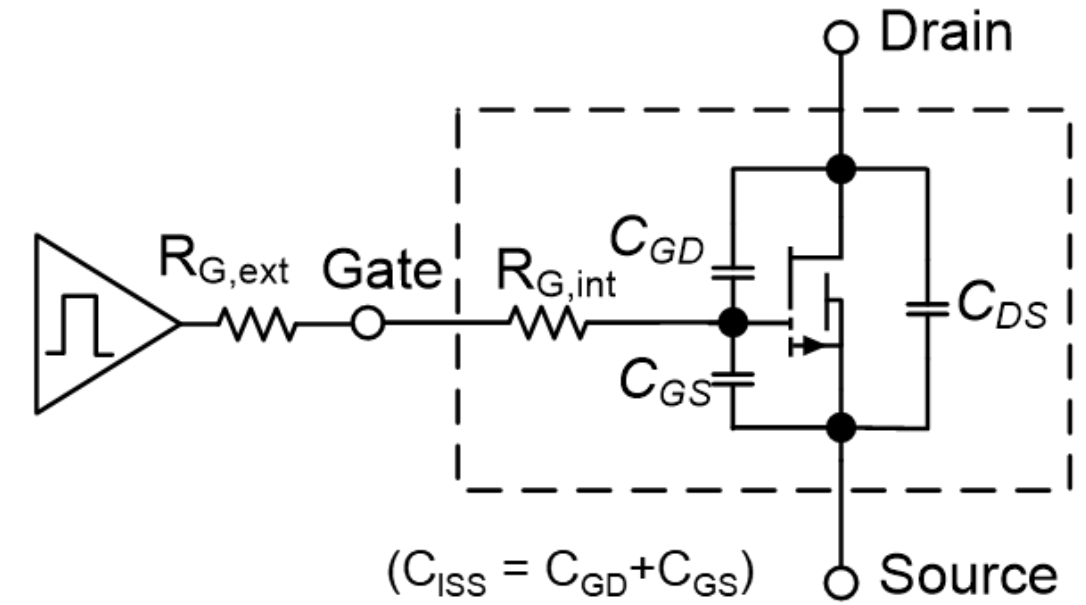
Power Supply with Silicon



Power Supply with GaN

You know the benefits. Is it difficult? How is it done?

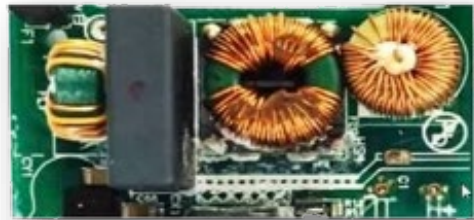
- GaN is a super-fast FET
 - It's not difficult
 - It's not new
- Similarities to a Silicon MOSFET
 - True enhancement-mode, normally off
 - Voltage driven: driver charges/discharges C_{ISS}
 - Supply Gate leakage I_{GSS} only
 - Easy slew rate control by R_G
 - Easily driven by Si gate driver chip
- Differences
 - Much Lower Q_G : lower drive loss; faster switching
 - Higher gain and lower V_{GS} : +5 or +6V gate bias to turn on
 - Lower $V_{G(th)}$: +1.5V



How to get the most advantage for your system

Higher frequency

Magnetics get smaller ... capacitors too



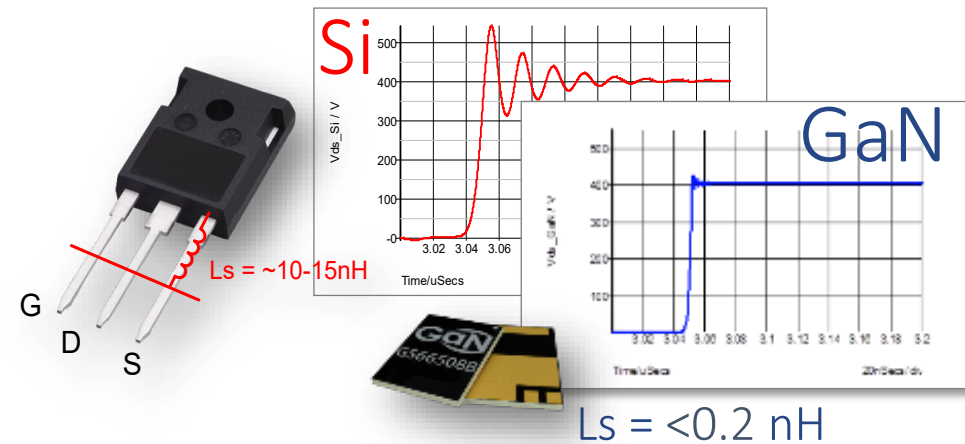
100 kHz
7 W/in³

500 kHz
30 W/in³



4x smaller

EMI filtering reduced

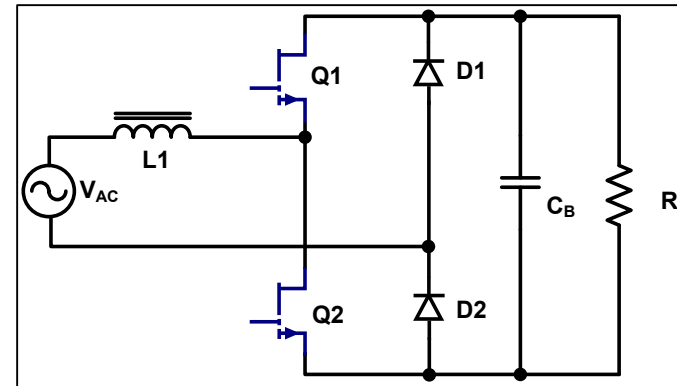


Resulting in power systems that are ...

Smaller size

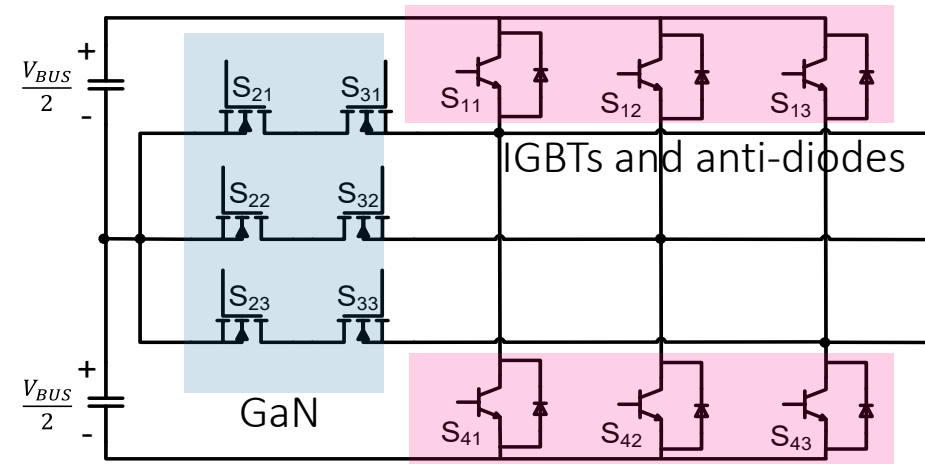
Best topologies

Bridgeless Totem Pole



- More efficient, Lower cost
- Simpler, part count reduced 33%

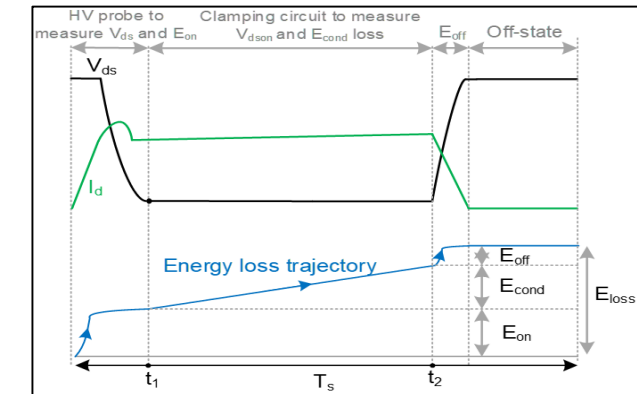
T-type traction inverter



Better performance

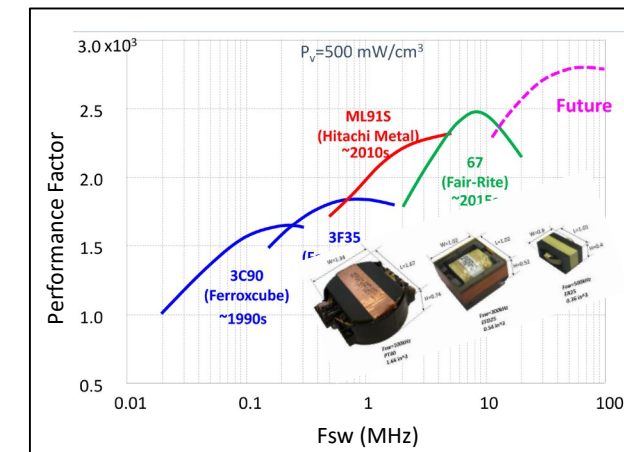
Best components

Gate Driver



- Maximize performance with gate driver that has high CMTI, high dV/dt immunity

Magnetics

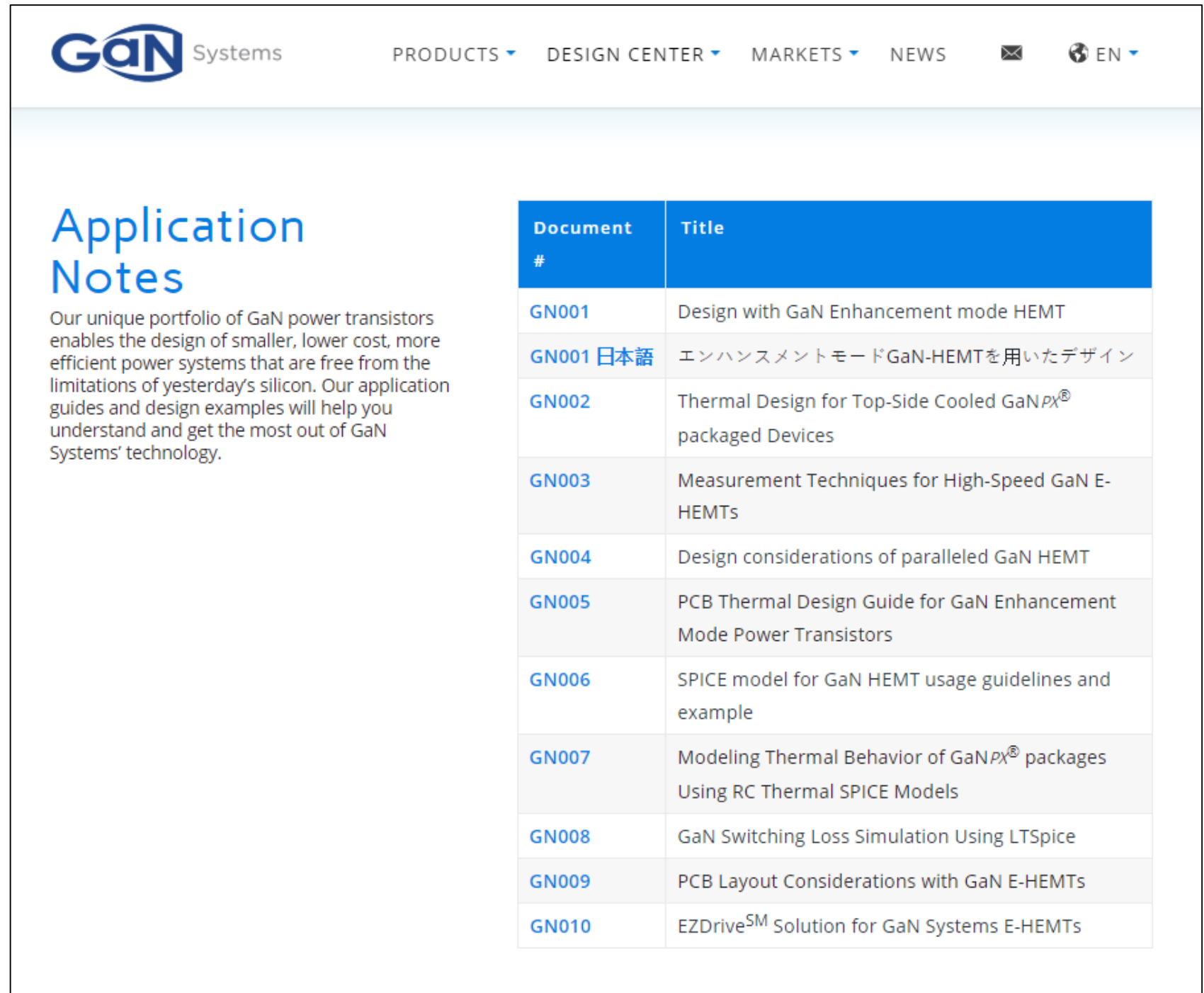


- Select magnetics with low AC core-loss to minimize power loss

Even better performance

How to get the info ?

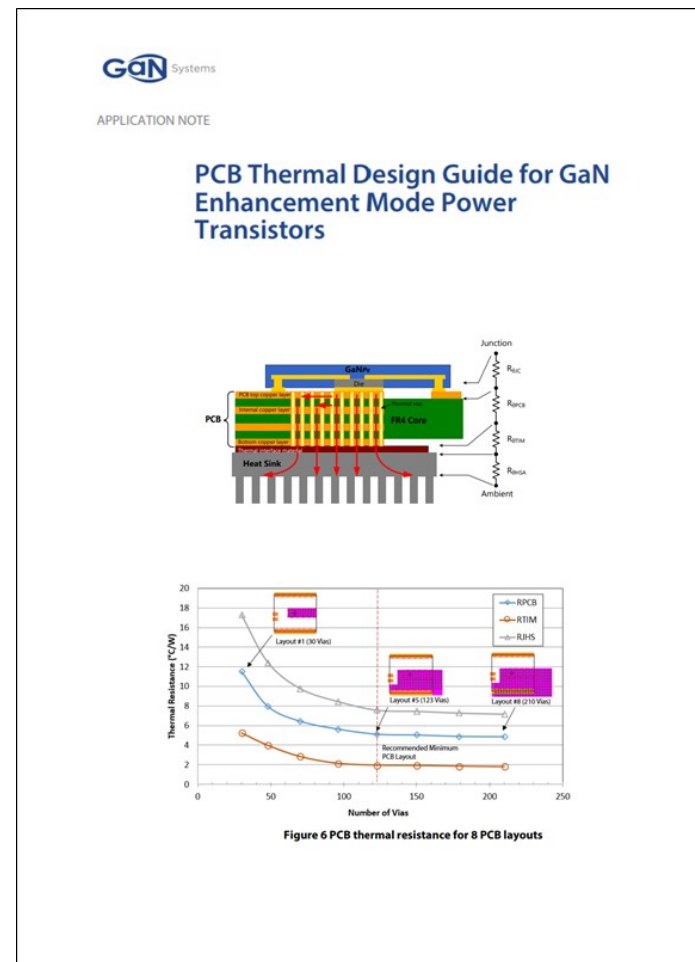
- Layout
- Gate Driver
- Paralleling
- Thermals
- EMI
- Dynamic Rdson



The screenshot shows the GaN Systems website with a navigation bar at the top containing links for PRODUCTS, DESIGN CENTER, MARKETS, and NEWS, along with a mail icon and a language selector set to EN. The main content area is titled "Application Notes" and includes a descriptive paragraph about the company's GaN power transistor portfolio. To the right of the text is a table listing ten application notes, each with a document number and a title.

Document #	Title
GN001	Design with GaN Enhancement mode HEMT
GN001 日本語	エンハンスメントモードGaN-HEMTを用いたデザイン
GN002	Thermal Design for Top-Side Cooled GaN _{PM} [®] packaged Devices
GN003	Measurement Techniques for High-Speed GaN E-HEMTs
GN004	Design considerations of paralleled GaN HEMT
GN005	PCB Thermal Design Guide for GaN Enhancement Mode Power Transistors
GN006	SPICE model for GaN HEMT usage guidelines and example
GN007	Modeling Thermal Behavior of GaN _{PM} [®] packages Using RC Thermal SPICE Models
GN008	GaN Switching Loss Simulation Using LTSpice
GN009	PCB Layout Considerations with GaN E-HEMTs
GN010	EZDrive SM Solution for GaN Systems E-HEMTs

- Circuit design
 - Control noise coupling from power to gate drive loop
 - Mitigate gate ringing/oscillations
- Minimizing parasitics
 - 5 step list including guidance on loop inductance and loop capacitance
- Layout best practice
 - 5 key areas to maximize performance



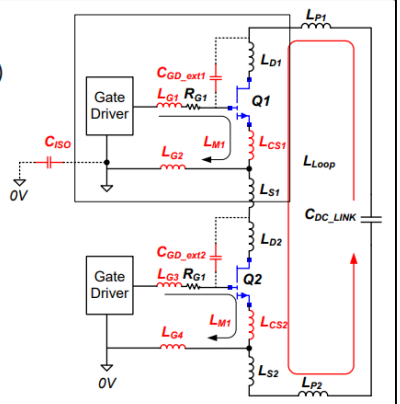
PCB Layout Checklist

- GaN_{PM}® package bottom-side cooled (B, P)
- GaN_{PM}® package Top-side cooled (T)
- Thermal design

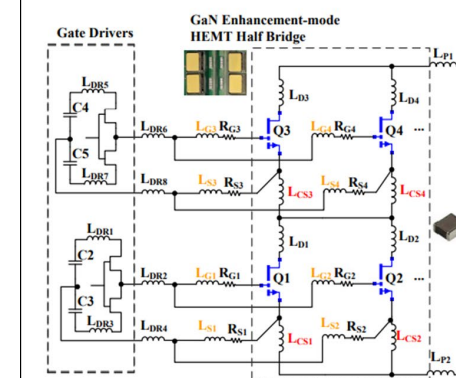
Minimize layout parasitics in the following order:

1. Common source / mutual inductance L_{CS}

1. Common source / mutual inductance
2. Gate loop inductance L_G
3. Power Loop inductance L_{loop}
4. Drain to gate loop capacitance C_{GD_ext}
5. Isolation coupling capacitance C_{ISO}



Key layout parasitics



Critical parasitic parameters that have high impact on GaN paralleling:

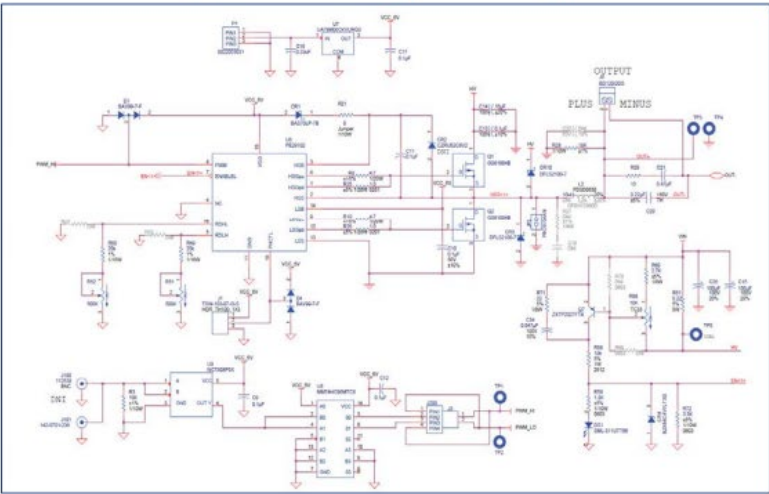
- L_{G1-4} & L_{S1-4} : **gate/source inductance**
- Unbalanced L_G/L_S increases the gate ringing and risk of oscillation
 - Equalize L_G/L_S using star connection and keep as low as possible
 - **Individual R_G/R_S is recommended to reduce gate ringing among paralleled devices**
- L_{CS1-4} : **Common source inductance**
 - Defined as any inductance that couples power loop switching noise ($L \cdot di/dt$) into the gate drive circuit
 - Including the shared/common source inductance and mutual inductance between power and drive loops
 - **Feedback switching di/dt to V_{GS} , impact gate drive stability and performance**
 - Minimize as much as possible.

- Validated list of drivers and controllers
- Half bridge and Full Bridge
- Design examples included


100V half bridge GaN driver – PE29102

PE29102 - 60V Half Bridge GaN driver, optimized for high frequency applications:

- Class D Audio, DC/DC, wireless power charging

































GS61004B-EVBCD



100V GaN E-HEMT Full Bridge Evaluation Board, optimized for Class D Amplifiers

For more details on the GS61004B-EVBCD evaluation board, visit: <http://gansystems.com/design-center/evaluation-boards/>

Recommended GaN driver/controller ICs		
The following drivers have been verified by GaN Systems and are recommended for use with our GaN E-HEMTs:		
Configurations	Gate Driver/Controller IC	Design resources
650V Half/Full Bridge: <ol style="list-style-type: none"> DC/DC: LLC, PSFB, Sync Boost/Buck AC/DC: Totem pole PFC, Active Clamp Flyback Inverter, motor drive 	 Si8271 – Single; Si8273/4/5 – HB/Dual -GB (0-6V) or -AB (-3/+6V)	 Si827x Datasheet  Si8271 demo board (GS66508T)  IMS evaluation board User Guide
	 ADuM4121ARIZ (0-6V Drive) ADuM4121BRIZ (-3/+6V Drive)	 ADuM4121 Datasheet
	 ACPL-P346 Use -4/+6V gate drive	 ACPL-P346 Datasheet  ACPL-P346 Evaluation Board with GS66508T
80-100V Half/Full bridge <ol style="list-style-type: none"> 48V DC/DC 48V POL Sync. Buck/Boost Class D Audio Wireless Power Transfer 	 LM5113(NRND) : 100V, max 5MHz LMG1205 : 80V/5A HB Driver	 LM5113 Datasheet  LMG1205 Datasheet
	 PE29101 : 100V, 48V DC/DC, 33MHz PE29102 : 60V, Class D Audio, WPT, 40MHz	 PE29100 Datasheet  PE20102 Datasheet  PE29102 Demo board (GS61004B)
	 UPI Semi GaN FET drivers: uP1966A : Dual-Channel GaN driver	 uP1966A GaN Driver  Ultra High Speed 80V HB Driver for GaN Application

Recommended GaN driver/controller ICs		
Configurations	Gate Driver/Controller IC	Design resources
Low side non-isolated driver for 650V/100V GaN: <ol style="list-style-type: none"> Flyback, Push-pull Forward Boost PFC Secondary SR Class E P/A 	 LM5114/UCC27511 : Single Channel, 4A, 5-6V drive UCC27611 : w/ internal LDO (5V)	 LM5114 Datasheet  UCC2751x Datasheet
	 uP1964 : Internal LDO for 6V drive	 uP1964 Datasheet
	Other GaN compatible drivers IXD609SI : Single, 6V drive, high drive current (9A) FAN3122/TC4422 : Single, 6V drive, high drive current (9A) FAN3223/4/5 : Dual 4A, 6V drive, for push-pull or SR application	
Sync Buck DC/DC (100V GaN): <ol style="list-style-type: none"> 48V-12V DC/DC 	 LTC7800 : 60V, Sync. Step-Down Controller (up to 2.2MHz, w/ integrated GaN compatible drivers)	 LTC7800 Datasheet
Secondary side Rectification (100V GaN): <ol style="list-style-type: none"> High frequency LLC Flyback 	 NCP4305A : 5V gate drive clamp, 1MHz max	 NCP4305 Datasheet
	 SRK2001 : Adaptive SR controller for LLC, 5-6V drive for GaN, 500KHz max	 SRK2001 Datasheet

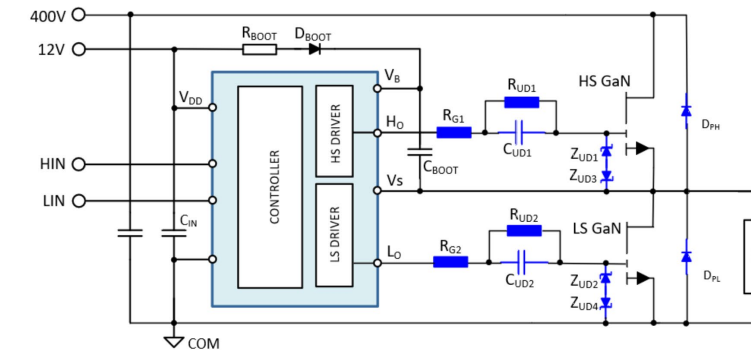
[*] Low side non-isolated drivers can also be used on high side / half bridge configurations by combining with level-shift / signal isolators, see [page 29](#) for design example.

EZDrive™ circuit

- Use standard MOSFET controller with integrated driver to drive GaN Systems' transistors
- Low cost, easy way to implement a GaN driving circuit
- Adaptable to wide range of power levels, frequency, and LLC and PFC controllers
- The EZDrive circuit also provides design control for the optimization of efficiency and EMI

Summary – GaN Systems' EZDriveSM Solution

- Universally converts any IC controller/driver to properly drive GaN Systems transistors
- Eliminates the redundant GaN drivers & LDOs of a monolithic integrated driver GaN device
- Turn ON / OFF slew rate is controllable with external resistors for complete control of EMI
- Applies to single, dual, or high-side/low-side controllers with drivers



- **Simple**
- **Eliminates drivers**
- **Higher power density**
- **Lower Cost**

- Device-level simulation
 - LTspice and Pspice
 - Device characteristics (Q_g , C_{oss}/C_{iss} , IV/CV curve, E_{on}/E_{off})
 - Simple system simulation
 - Capability to observe parasitic effect on switching performance
- System-level simulation
 - PLECS
 - Simplify the switching transient
 - Observe converter operating waveforms
 - Accommodate complicated device-based, system-level simulation and analysis

Spice

plecs

APPLICATION NOTE – GN006

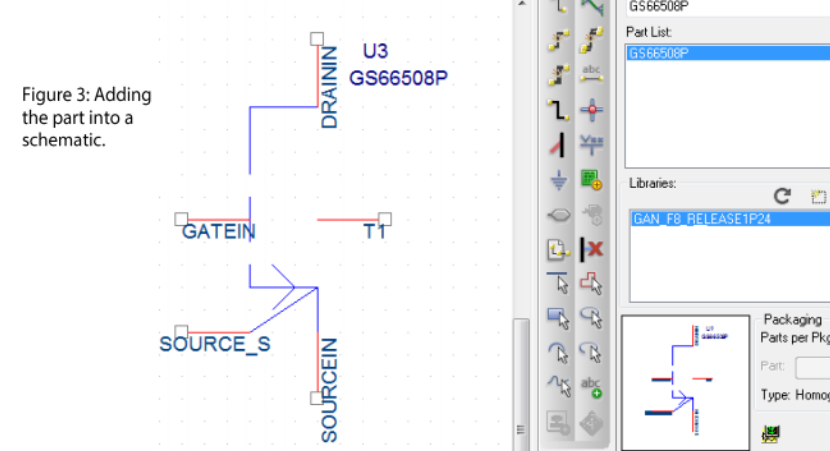


Figure 3: Adding the part into a schematic.

Recommended PSpice settings

For the model to better converge it is recommended to adjust the PSpice parameters VNTOL to 10uV and ABSTOL to 1.0nA. The following steps describe how to adjust the two parameters:

1. On the schematic page click on Edit Simulation Profile.
2. Click on Options.
3. Change VNTOL to 10uV, and ABSTOL to 1.0nA.

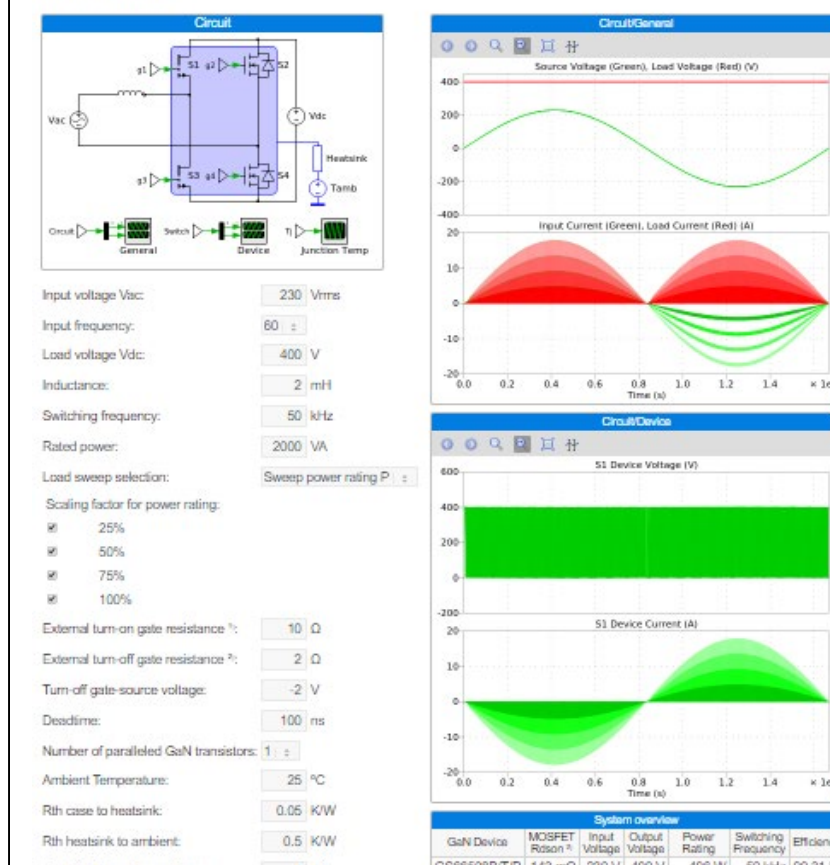
Depending on the specific application some other parameters may need to be changed as well.

“Auto Converge” should be enabled to improve convergence. The maximum time step can be modified if needed.

Typical option settings can be seen below.

Bridgeless Totem Pole Circuit Simulation Tool

Choose various source and load parameters, number of devices to parallel, heat sink parameters etc. Live simulated operating and switch waveforms are generated as well as data tables showing calculations for loss and junction temperature allowing you to compare the efficiency of different parts directly. If you are interested in receiving the PLECS device model for GaN Systems, contact us.



Input parameters:

- Input voltage V_{dc}: 230 Vrms
- Input frequency: 60 Hz
- Load voltage V_{dc}: 400 V
- Inductance: 2 mH
- Switching frequency: 50 kHz
- Rated power: 2000 VA
- Load sweep selection: Sweep power rating P
- Scaling factor for power rating: 25%, 50%, 75%, 100%
- External turn-on gate resistance R_g: 10 Ω
- External turn-off gate resistance R_g: 2 Ω
- Turn-off gate-source voltage: -2 V
- Deadtime: 100 ns
- Number of paralleled GaN transistors: 1
- Ambient Temperature: 25 °C
- R_{th} case to heatsink: 0.05 K/W
- R_{th} heatsink to ambient: 0.5 K/W
- Heatsink thermal capacitance: 1 J/K

System Overview Table:

GaN Device	MCSPET Resonant	Input Voltage	Output Voltage	Power Rating	Switching Frequency	Efficiency
GS66508B/T/P	143 mΩ	230 V	400 V	498 W	50 kHz	99.31 %
GS66508B/T/P	108 mΩ	230 V	400 V	998 W	50 kHz	99.00 %
GS66508B/T/P	82 mΩ	230 V	400 V	1,498 kW	50 kHz	98.57 %
GS66508B/T/P	62 mΩ	230 V	400 V	1,999 kW	50 kHz	98.03 %

- Clear analysis presented at PCIM
 - Define what it is
 - How to test
 - Measure the loss
 - Quantify the impact
- Conclusion
 - Power loss due to dynamic Rds is insignificant in total system power loss
 - Total system power loss: GaN outperforms silicon by a wide margin

pcim
EUROPE

Conference Thursday, 9 May 2019
Afternoon Oral Sessions
Room Brüssel 1

15:15

The Effect of Dynamic On-State Resistance to System Losses in GaN-based Hard-Switching Applications
Ruoyu Hou, Juncheng Lu, GaN Systems, CDN

GaN Systems PRODUCTS DESIGN CENTER MARKETS NEWS EN

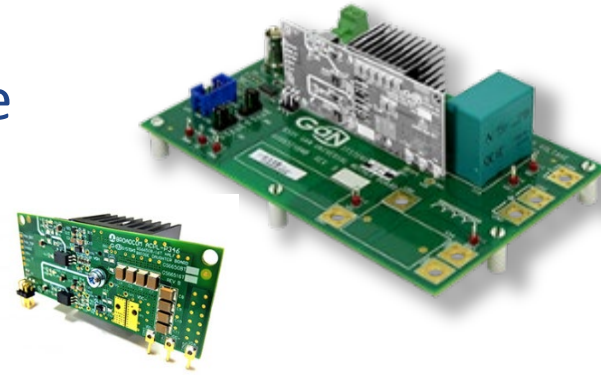
Webinar:
Dynamic Rds(on) effect
on total system losses

May 16, Thursday, 2019
11:00am EDT

LEARN MORE

MOVING FROM LIMITATIONS TO POSSIBILITIES

1.5-2.5kW Half bridge power stage
and universal motherboard

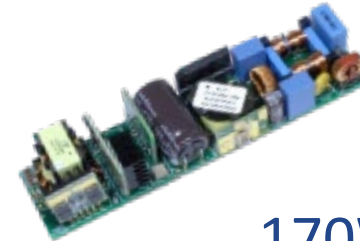


2-7 kW Insulated Metal Substrate
Configurable Full/Half Bridge

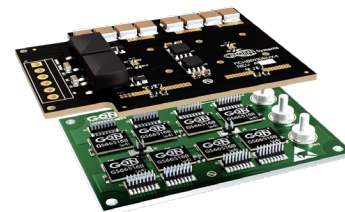
3 kW bridgeless
totem pole PFC



170W AC/DC PFC/LLC



14 kW Insulated Metal Substrate
Reference Design



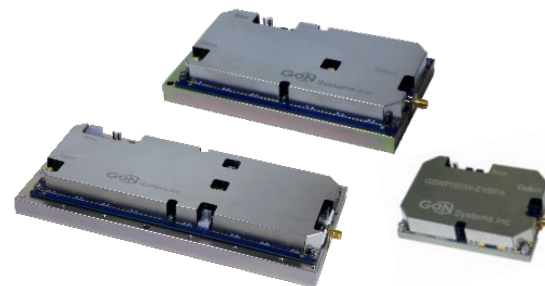
Buck Converter with
5MHz GaN Driver



EZDrive™ Eval Kit



50W, 100W to 300W+
Wireless Power Transfer
Power Amplifiers



Full Bridge optimized
for Class D Amplifier



- GaN is not difficult
 - Many similarities to MOSFET
 - Differences require attention to detail but no new concepts
- Many resources available
 - Easy to find
 - Easy to use
 - GaN Systems applications engineering team to help

The screenshot shows the GaN Systems Design Center website. At the top is the GaN Systems logo and a navigation bar with links for PRODUCTS, DESIGN CENTER, MARKETS, NEWS, and a language selector (EN). Below the navigation bar is a large banner with the title "GaN SYSTEMS' DESIGN CENTER" and a welcome message: "Welcome. The design center is where you'll be able to find resources for GaN Systems' transistors. These include application notes, evaluation kits, reference designs and more." Below the banner is a section titled "GET THE MOST OUT OF GaN SYSTEMS' TECHNOLOGY" which features four circular images and corresponding text blocks. Each block has an "Explore" button.

GaN Systems

PRODUCTS ▾ DESIGN CENTER ▾ MARKETS ▾ NEWS ▾ EN ▾

GaN SYSTEMS' DESIGN CENTER

Welcome. The design center is where you'll be able to find resources for GaN Systems' transistors. These include application notes, evaluation kits, reference designs and more.

GET THE MOST OUT OF GaN SYSTEMS' TECHNOLOGY



APPLICATION NOTES
Guides and design examples

Explore



CIRCUIT SIMULATION TOOL
Quickly compare application conditions

Explore



EVALUATION BOARDS
Hardware assets and reference designs

Explore






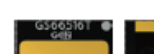








PAPERS AND PRESENTATIONS
Expert insights on GaN technology and applications



Explore

Broadest line of Products

650 V GaN

 GS66502B 7.5 A, 200 mΩ 6.6 x 5.0 mm	 GS66504B 15 A, 100 mΩ 6.6 x 5.0 mm	 GS66506T 22 A, 67 mΩ 5.6 x 4.5 mm	 GS66508T 30 A, 50 mΩ 7.0 x 4.5 mm
 GS66508B 30 A, 50 mΩ 8.4 x 7.0 mm	 GS66516T 60 A, 25 mΩ 9.0 x 7.6 mm	 GS66516B 60 A, 25 mΩ 11.0 x 9.0 mm	
 GS-065-080-1-D1 80 A, 18 mΩ 6.6 x 5.6 mm	 GS-065-150-1-D1 150 A, 10 mΩ 12.7 x 5.6 mm		
 GS-065-004-1-L 3.5 A, 500 mΩ 5.0 x 6.0 mm	 GS-065-008-1-L 8 A, 225 mΩ 5.0 x 6.0 mm	 GS-065-011-1-L 11 A, 150 mΩ 5.0 x 6.0 mm	

100 V GaN

 GS61004B 45 A, 15 mΩ 4.6 x 4.4 mm	 GS61008P 90 A, 7 mΩ 7.6 x 4.6 mm	 GS61008T 90 A, 7 mΩ 7.0 x 4.0 mm	 GS-010-120-1-P 120 A, 5 mΩ 7.6 x 4.6 mm
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Many Eval Kits & Reference Designs



Half bridge
power stage



High power
Paralleling



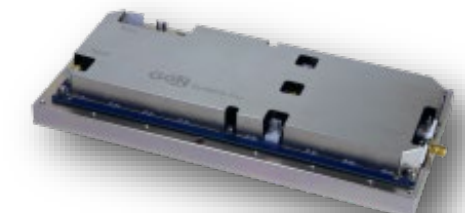
High density
PFC/LLC



650 V test kit



3 kW bridgeless
totem pole PFC



300 W wireless
power transfer

Come see us at Stand 9-507

gansystems.com

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