



GN001 应用手册

氮化镓半导体功率器件概述

更新于 2022/09/22

GaN Systems Inc.

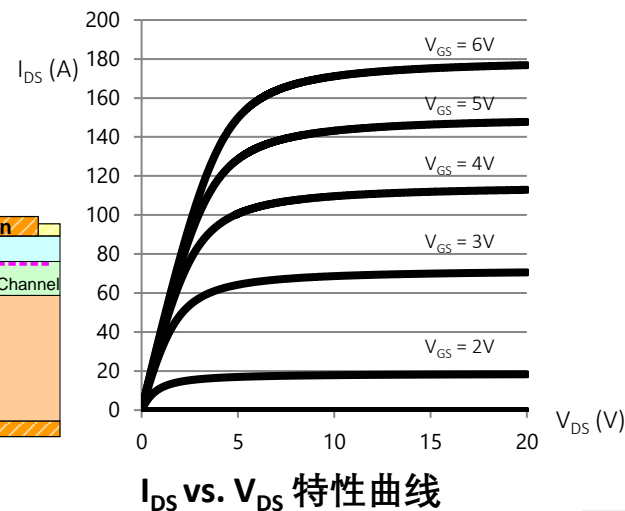
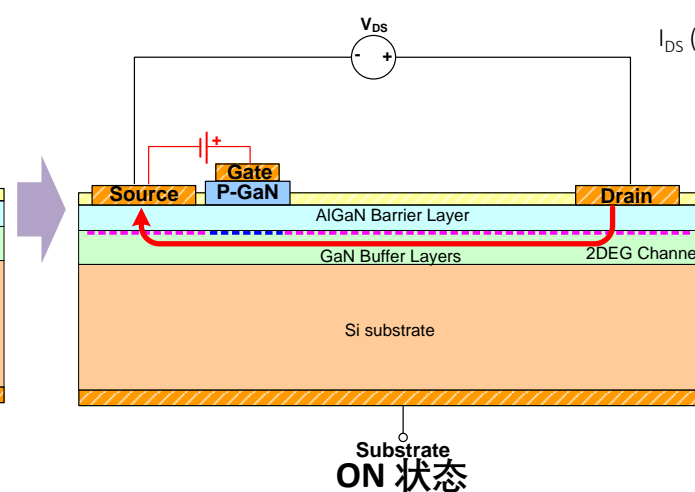
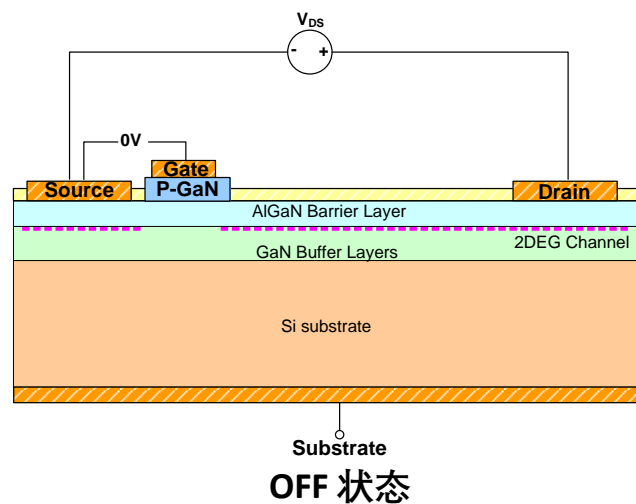


- ❑ 器件原理
 - ❑ 增强型GaN器件原理
 - ❑ GaN Systems易于驱动的GaN功率器件技术简介
- ❑ 器件特性
- ❑ 设计资源

请访问<http://gansystems.com>获取本文件的最新版本

GaN增强型高电子迁移率晶体管(E-HEMT)

- 横向二维电子气体(2DEG) 形成于AlGaN / GaN异质结中，具有极高的电荷密度和迁移率
- 对门极进行p型掺杂，以耗尽二维电子气，保证器件在门极电压为0V时，处于关断状态从而实现常断型器件
- 此技术除了具有更优良的开关性能外，其工作原理类似于MOSFET



与硅MOSFET的共同点

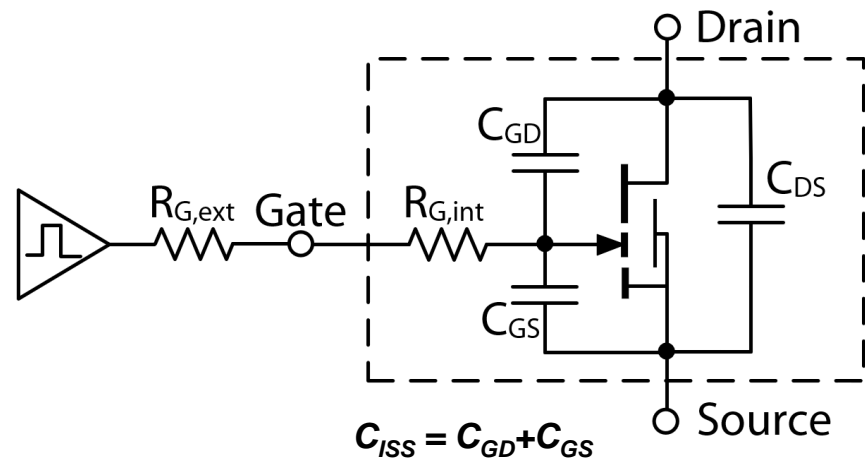
- 真正的增强型器件（常断型器件）
- 电压型驱动
- 开通后驱动只需要提供门极漏电流 I_{GSS}
- 能够通过改变 R_G 控制开关速度
- 与大部分Si MOSFET驱动芯片兼容

与硅MOSFET的差异

- 极低的 Q_G : 更低的驱动损耗; 更快的开关速度
- 更高的跨导和更低的 V_{GS} : 仅需+5-6V 门极偏置电压即可接通元件
- 更低的 $V_{G(th)}$: 典型值为 1.5V

相比其他增强型GaN器件

- 门极更加可靠: -20/+10V 最大额定
- 无需直流电流驱动门极
- 门极结构简单, 无二极管/ PN结



门极偏置等级	GaN Systems GaN E-HEMT	Si MOSFET	IGBT	SIC MOSFET
最大额定值	-20/+10V	-/+20V	-/+20V	-8/+20V
典型门偏置值	0 or -3/+5-6V	0/+10-12V	0 or -9/+15V	-4/+15-20V

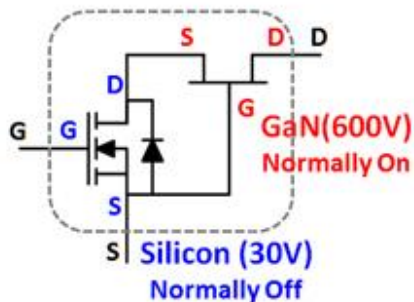
❖ GaN HEMTs 易于驱动, 更多信息请参考应用手册GN012

GaN Systems E-mode HEMT



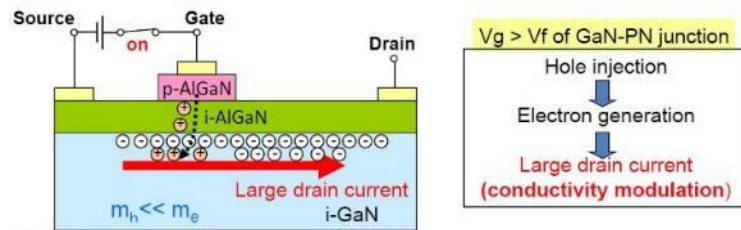
- 真正的增强型器件
- 无附加结构
- 最佳FOM, 最优性能
- 采用GaNPx 嵌入式封装
- 无反向恢复损耗
- 易并联

D-mode GaN (Cascode)



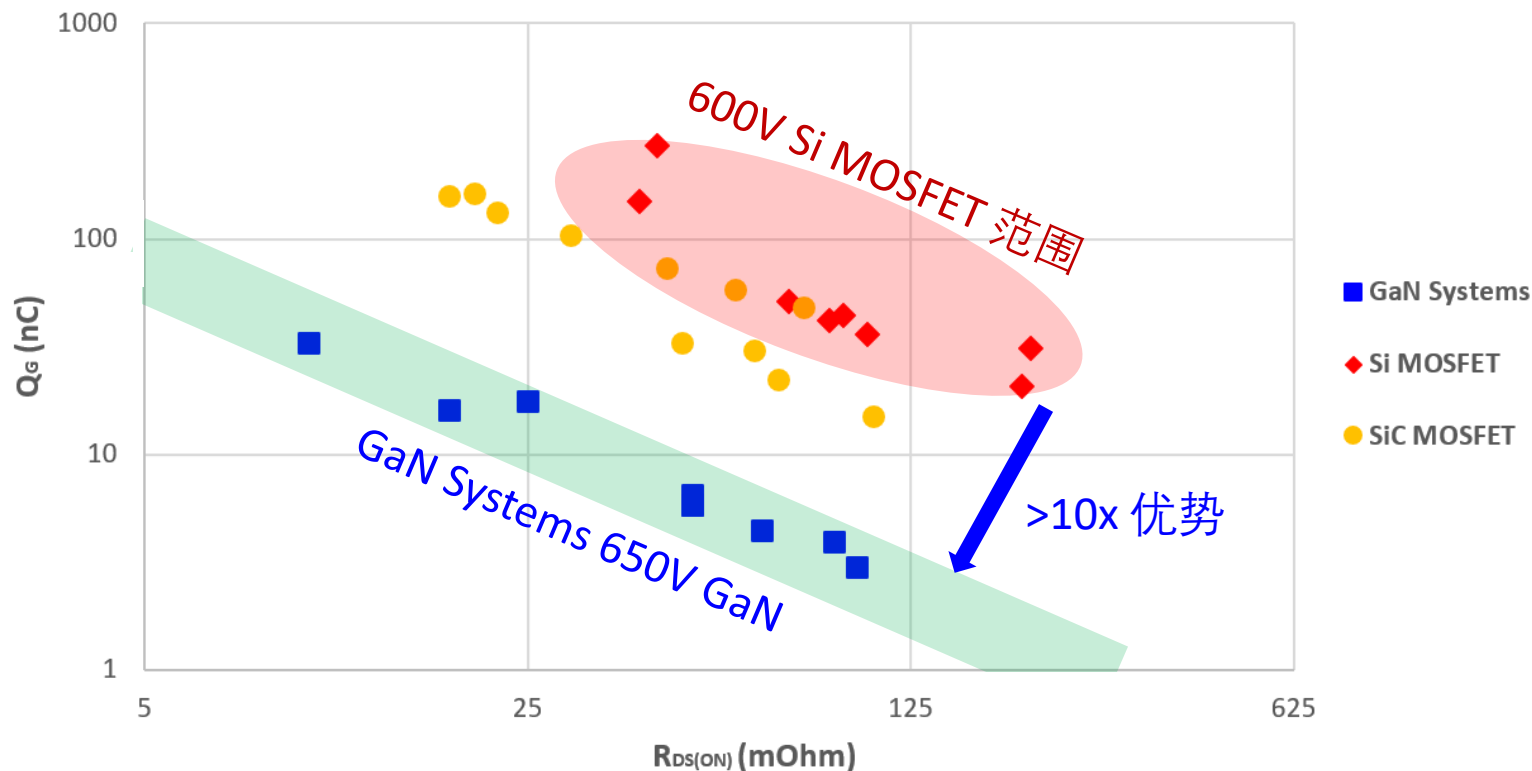
- 采用D-mode 技术
- 开关速度不可控(可能导致EMI问题)
- 复杂结构导致可靠性问题且难以故障排除
- 需要考虑Si/GaN之间的电容匹配, 难扩展
- Si MOSFET 引入反向恢复损耗 (Q_{rr})
- 难并联

GaN门极注入晶体管 (GIT)



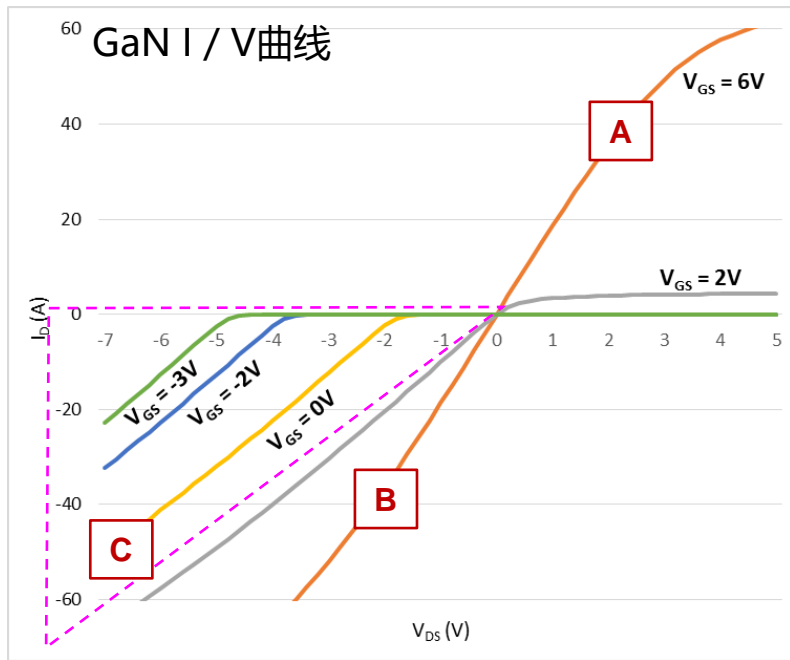
- 门极特性复杂, 电流型驱动(类似于 BJT)
 - 门极电流大且温度依赖性强
 - 并联稳定性差
 - 开关速度慢
 - FOM较差

- 器件原理
- 器件特性
 - FOM
 - 反向导通特性
 - 零反向恢复损耗
 - 输出电容
 - 开关过程
 - 开关损耗
- 设计资源



650V/600V 电源开关 FOM (Feb.2020 update)

- ❖ 相比于Si和 SiC MOSFETs， GaN Systems GaN器件具有极优的 FOM ($R_{DS(ON)} * Q_G$)。相同 $R_{DS(ON)}$ 情况下， GaN器件所需注入的电荷量更少并且开关过程更快

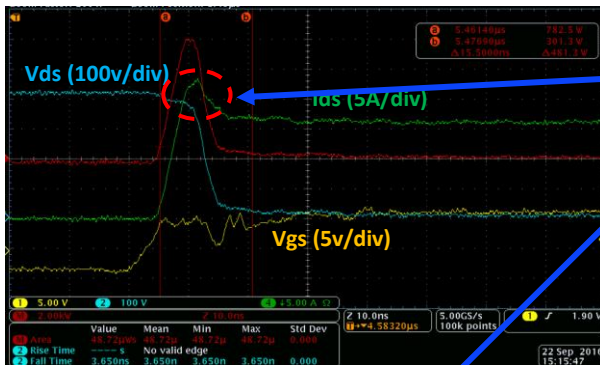
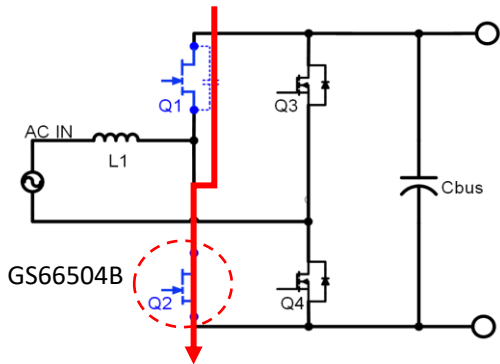


- 当GaN器件关断时 (死区内), 2DEG像二极管, 能反向导通。 $V_F = V_{TH(GD)} + V_{GS(OFF)} + I_{SD} * R_{SD(ON)}$

门极	GaN E-HEMT	MOSFET	Si IGBT
A ON			
B ON			
C OFF			

❖ **无体二极管** (不同于Si 或SiC MOSFETs)

❖ 然而, GaN 2DEG可在第三象限内传导—**无需反向并联的二极管** (不同于Si IGBT)

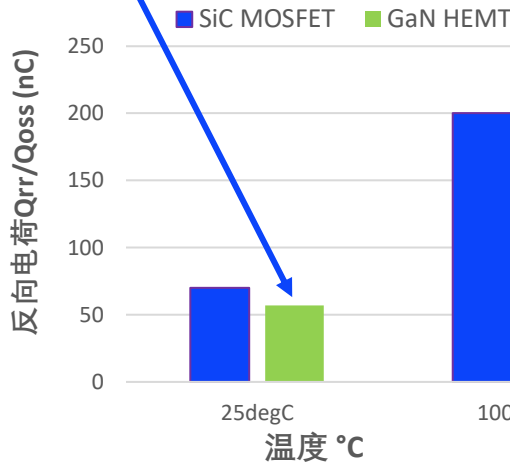
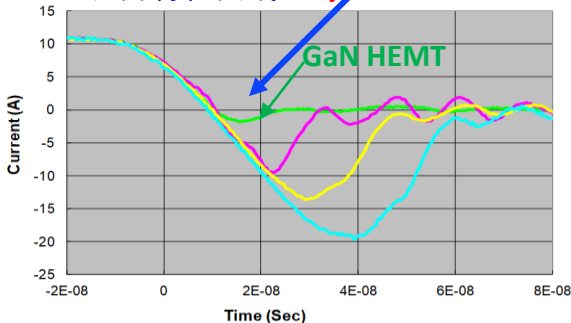
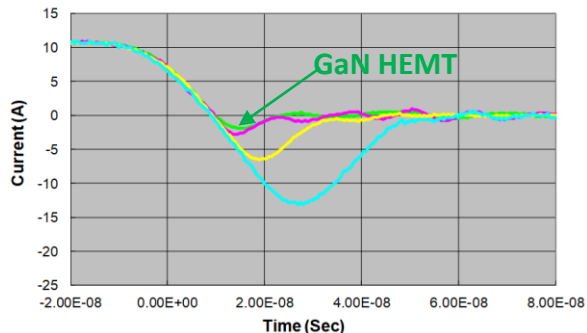


GaN器件:

- 仅有Qoss,
- 零反向恢复

反向特性曲线@ Tj=25°C

反向特性曲线@ Tj=100°C



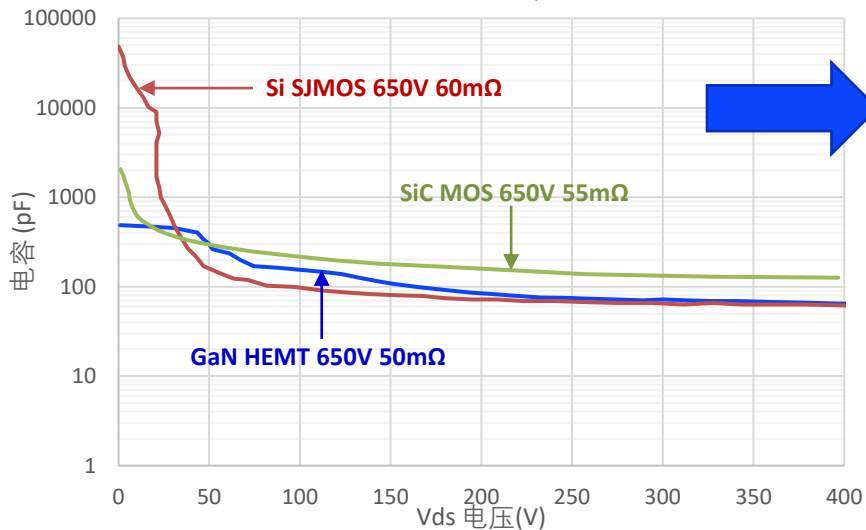
■ GaN HEMT 650V/15A
 ■ SiC MOSFET 650V/120mΩ
 ■ Si MOSFET 650V/15A
 ■ Si 二极管 650V/15A

❖ 零反向恢复可降低开关损耗和EMI噪声

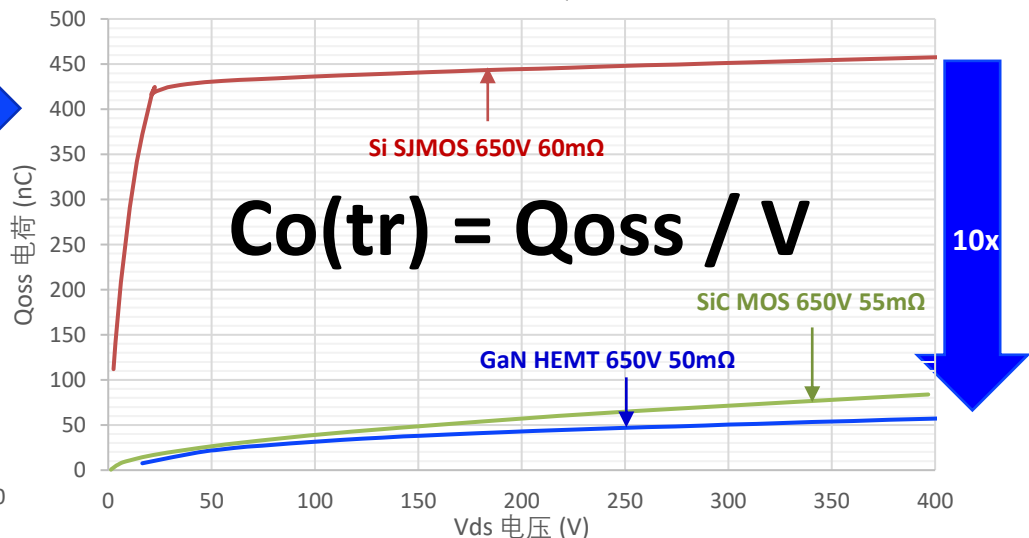
$$\begin{cases} Q_{oss} = C_{o(tr)} \cdot V \\ Q_{oss} = \int_0^{V_{ds}} C_{oss}(v) dv \end{cases}$$

Coss 曲线 → Qoss 曲线 → Co(tr) 值

Coss Vs Vds 电压



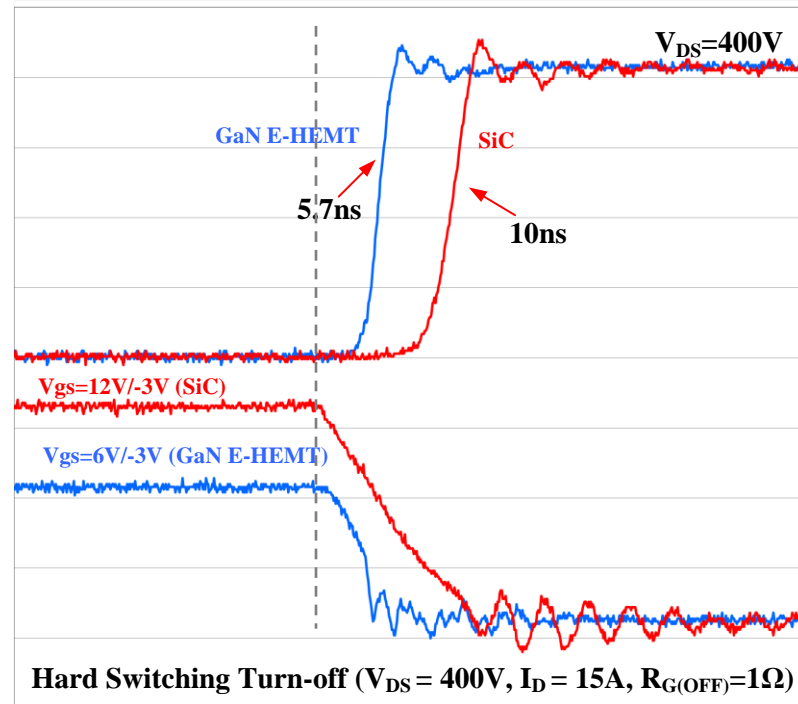
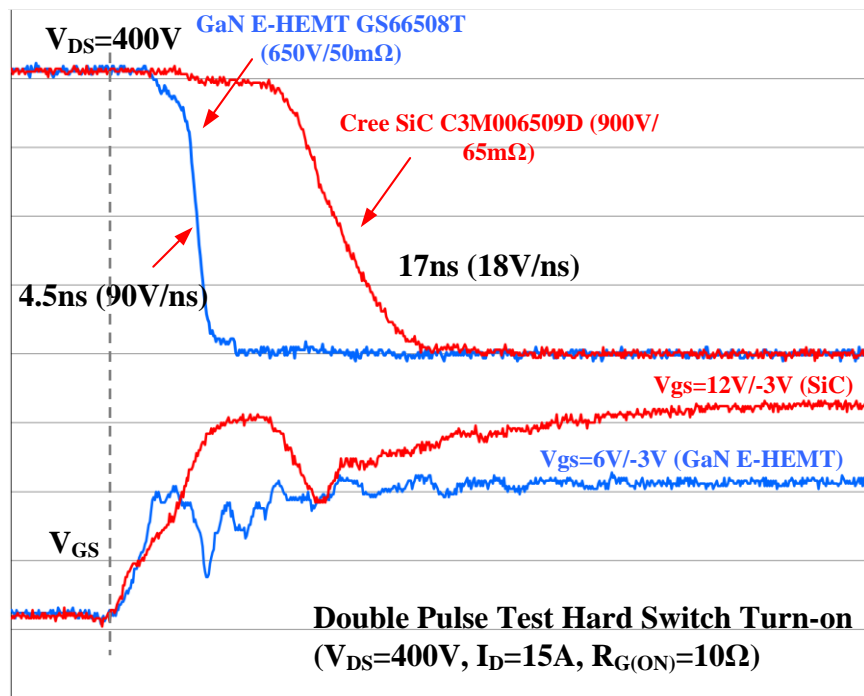
Qoss Vs Vds 电压



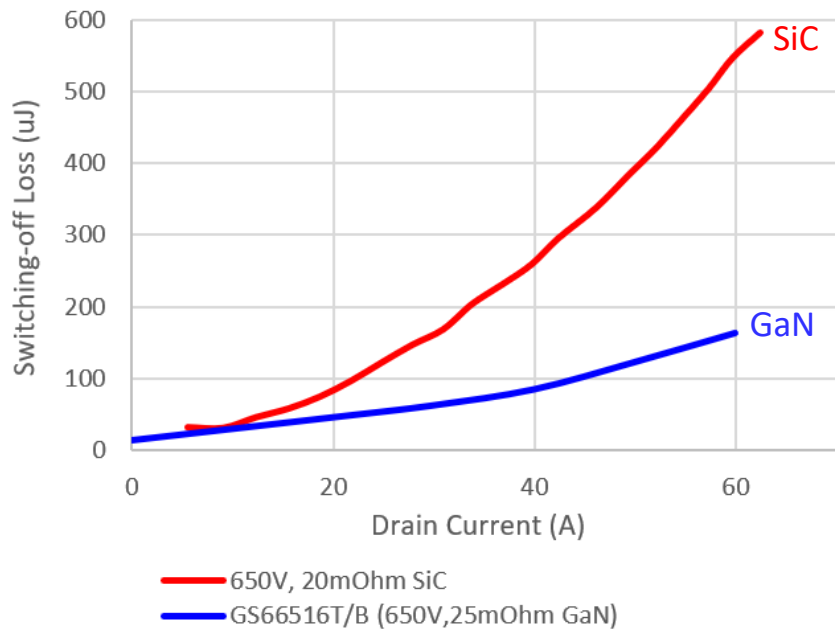
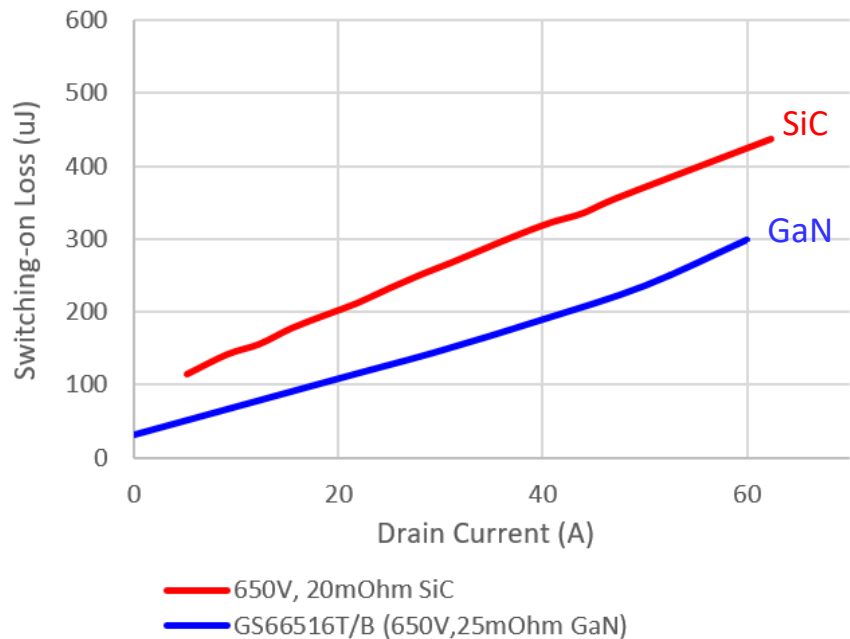
$$C_{o(tr)} = Q_{oss} / V$$

10x

- ❖ Si SJMOS的Co(tr)比GaN高~10倍; SiC MOS的Co(tr)比GaN高~50%.
- ❖ 输出电容越小, 开关损耗越低, 零电压开关 (ZVS) 越容易实现



- ❖ 与同等 $R_{DS(ON)}$ 的SiC MOSFET相比, GaN的开通速度快~4倍, 关断速度快~2倍
- ❖ 更快的开关过程=更低的开关损耗
- ❖ PCB layout对于优化GaN HEMTs的性能至关重要. 更多信息请参考: GN009 <https://gansystems.com/>



❖ GaN HEMT的开关损耗远低于同等 $R_{DS(ON)}$ 的650V SiC MOSFET

- 器件原理
- 器件特性
- 设计资源

GaN Systems 设计中心

• 大量技术文档

- 易找
- 易用

GaN Systems的设计中心

欢迎。设计中心是您能够找到关于如何使用GaN Systems的器件资源的平台。包括应用手册，评估套件，参考设计等等。

充分利用GaN Systems技术带来的优势



应用手册

- Layout
- 驱动设计
- 器件并联
- 热设计
- 仿真
- 焊接

应用手册

我们独特的氮化镓(GaN)功率器件系列能够设计出体积更小, 成本更低, 效率更高的电源系统, 从而突破基于硅的传统器件的限制。我们的应用指南和设计实例将帮助您了解并充分利用氮化镓系统(GaN Systems)的技术。

[App Notes - English](#)

文档 #	标题
GN001	基于GaN增强型HEMT的设计
GN002	GaNPX®封装器件的热设计
GN003	高速GaN E-HEMT的测量技巧
GN004	氮化镓晶体管的并联设计
GN006	GaN HEMT的SPICE模型使用指南及示例
GN007	基于RC热阻SPICE模型的GaNPX®封装的热特性建模
GN008	基于LTSpice的GaN开关损耗的仿真
GN009	GaN E-HEMT的PCB布线考虑
GN010	氮化镓系统(GaN Systems) E-HEMTs的EZDrive™方案
GN011	GaNPX®封装器件的焊接建议
GN012	氮化镓半导体功率器件门极驱动电路设计

在线仿真工具

欢迎来到GaN Systems电路仿真工具

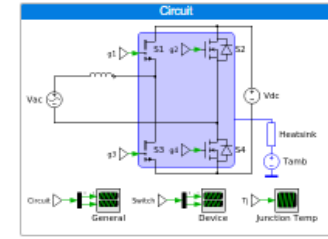
电路仿真工具通过您给定的系统运行参数来帮助您进行系统应用的比较。可选择不同的电源和负载参数，器件并联数量，以及散热参数等等。系统输入输出，器件开关波形，以及器件的损耗与其结温的数据都将被显示。这些使您能够观察并比较通过器件及系统参数的改变带来的不同结果。

- > 无桥图腾柱PFC
- > 单相两电平逆变器
- > 单相三电平半桥逆变器
- > 单相T-型3电平逆变器
- > 隔离半桥LLC变换器
- > 隔离移相全桥变换器
- > 三相牵引逆变器
- > 双有源桥隔离DC/DC变换器



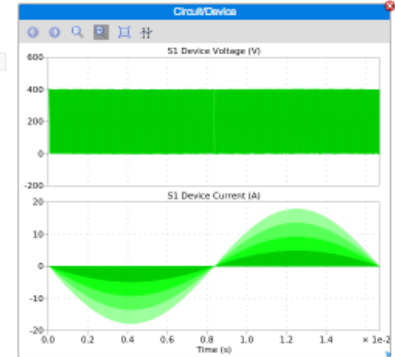
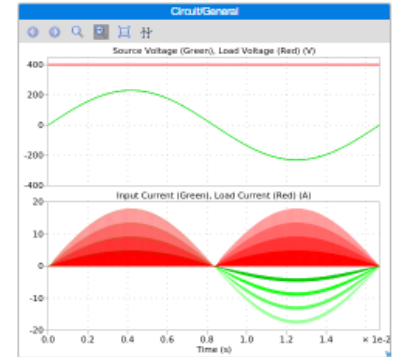
Bridgeless Totem Pole Circuit Simulation Tool

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



Input voltage V_{in} : 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 $r_{g,off}$: 2 Ω
Turn-off gate-source voltage: -2 V
Deadtime: 100 ns
Number of paralleled GaN transistors: 1
Ambient Temperature: 25 $^{\circ}\text{C}$
R θ case to heatsink: 0.05 K/W
R θ heatsink to ambient: 0.5 K/W
Heatsink thermal capacitance: 1 J/K
GaN HEMT:
 GS86502B 650 V, 7.5 A, 200 mD
 GS86504B 650 V, 15 A, 100 mD
 GS86506T 650 V, 22.5 A, 67 mD
 GS86506B/T/P 650 V, 30 A, 50 mD
 GS86516B/T 650 V, 60 A, 25 mD

Simulate Hold result



System overview						
GaN Device	MOSFET R θ son $^{\circ}$	Input Voltage	Output Voltage	Power Rating	Switching Frequency	Efficiency
GS86508B/T/P	143 mD	230 V	400 V	496 W	50 kHz	99.31 %
GS86508B/T/P	108 mD	230 V	400 V	996 W	50 kHz	99.00 %
GS86508B/T/P	82 mD	230 V	400 V	1,498 kW	50 kHz	98.57 %
GS86508B/T/P	62 mD	230 V	400 V	1,999 kW	50 kHz	98.03 %

GaN transistor thermal overview				
Device	Switching	Conduction	Combined Losses $^{\circ}$	Junction Temperature
GS86508B/T/P	1.44 W	0.29 W	3.42 W	28 $^{\circ}\text{C}$
GS86508B/T/P	1.74 W	1.62 W	9.59 W	33 $^{\circ}\text{C}$
GS86508B/T/P	2.06 W	4.48 W	21.46 W	40 $^{\circ}\text{C}$
GS86508B/T/P	2.48 W	9.58 W	39.41 W	51 $^{\circ}\text{C}$

快速评估GaN器件特性 - GaN Systems 评估板



65W PD QR & ACF
Chargers



100W PFC + QR Type-C
USB PD 2C port Charger



250W AC/DC PFC &
LLC Charger



400W Class D Audio
Amp & SMPS Eval Kit



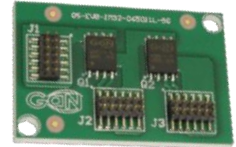
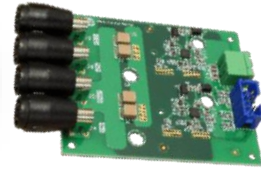
12V High-Efficiency Class D
Audio Reference Designs



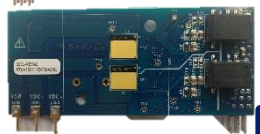
650V test kit



EZDrive™ Eval Kit



650V 300W~500W Low
Power IMS2
GaN Half-Bridge & driver
board



50W Wireless Power
Amplifier



100W Wireless Power
Amplifier



300W Wireless Power
Amplifier



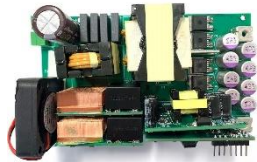
100V Buck/Boost Evaluation Board
with Driver GaN Power Stage



650 V Universal Motherboard



650V 150A HB IPM



3KW High Efficiency LLC



3kW bridgeless
totem pole PFC



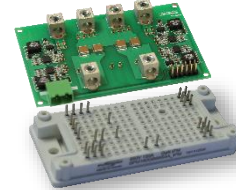
High Power Dual Half Bridge
Full Bridge, driver board



Non-isolated Half Bridge
Driver evaluation board



650 V GaN E-HEMT Daughter
Board



650V 150A FB Module
With driver board



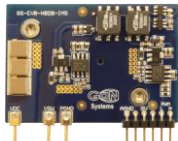
100V High-Speed
GaN Half-Bridge



High Power half bridge
driver board



650 V Half Bridge Bipolar
Gate Drive Evaluation Board



650 V Universal HB Isolated Driver
Motherboard for IMS2 & IMS3



3kW & 6kW IMS3 half bridge power boards



650 V 30A & 60A GaN
Half-Bridge and Driver
with Over Current
Protection

器件文档

- 下载
- 数据表
 - Spice Models
 - Step File
 - Allegro库
 - Altium库

- 应用手册
- 质量达标声明
- 合规证书

设计中心

- 概述
- 应用手册
- 电路仿真工具
- 论文和报告
- 伙伴



Simulation Software for Power Electronics

PLECS® 用于电力电子系统的高速仿真。有两种版本可供选用: 集成在MATLAB®/Simulink®中的PLECS Blockset 和独立运行的 PLECS Standalone. .



<https://gansystems.com/>

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常见问题

所有 / 入门 / 器件特性 / 封装及装配 / 温度控制 / 综合 / 驱动 / 高频

- 氮化镓(GaN)与硅(Si)相比有哪些优势?
 - 哪些工业行业使用GaN器件会产生巨大的变化?
 - 为什么公司高层应该像电力电子设计工程师一样关心GaN技术呢?
 - GaN Systems的产品系列有哪些?
- etc ...

论文, 文章和报告

- Seven Steps to Highly Effective GaN Designs
- Webinar: Benefits and Advantages of a GaN-based 3kW AC/DC...
- Webinar: Using Simulation to Maximize GaN Powered Design
- GaN Transistors: Moving To Mainstream
- Webinar: Comprehensive System Design with GaN
- Boosting efficiency in fast-charge adapters
- 2021 Technology Predictions in Power Electronics
- Webinar: Gate Driver Circuit Design for GaN Power Applic...
- GaN Technology and The Renewable Energy World
- A Modular, Designed Three-phase High-efficiency High-power...
- WEBINAR: Class D Audio with GaN
- GaN in Class-D Audio: Advantages with GaN Systems - A ...



Product and application support at
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