GN010 Application Note
EZDrive^{SM} Solution for GaN Systems' E-HEMT

December 21, 2018

Overview

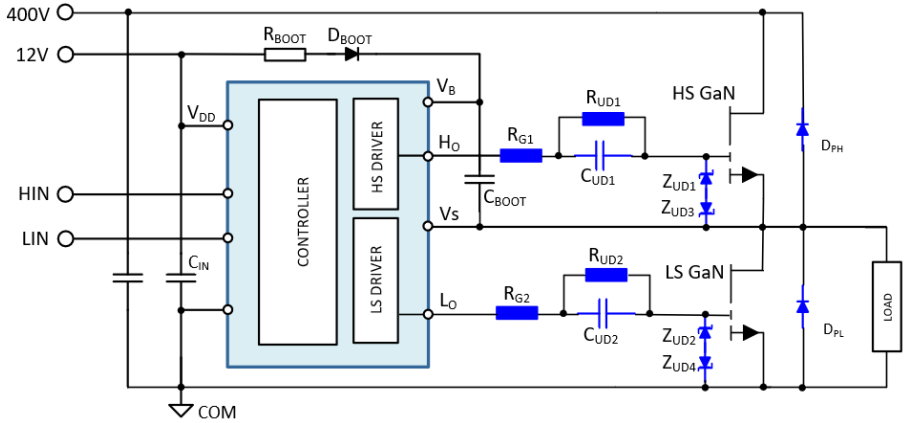
GaN Systems' **EZDrive^{SM}** circuit is a low cost, easy way to implement a **GaN driving circuit.** It is adaptable to any power level, any frequency, and any LLC and PFC controller. The EZDrive^{SM} circuit provides design control for the optimization of efficiency and EMI.

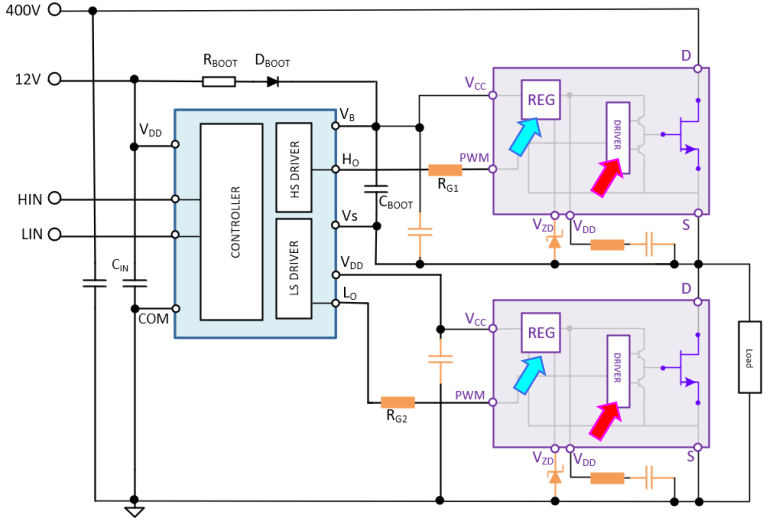
The **EZDrive^{SM}** circuit allows the use of a standard MOSFET controller with integrated driver to drive GaN Systems' E-HEMTs. The table below summarizes the advantages of this circuit.

Application Considerations	Silicon MOSFETs	Monolithic-integrated Driver GaN	GaN Systems E-HEMTs
Total BoM Cost	Lowest	Highest	Low
Choice of devices to optimize design	Widest	Narrow	Wide range from 25 mΩ to 500 mΩ
Utilize controller driver, eliminate driver redundancy, ease-of-use	• Driver integrated in controller • No redundant drivers	• Driver integrated in controller • Redundant drivers in GaN device	• Driver integrated in controller • No redundant drivers
EMI control	Adjustable EMI control with gate resistor R_G	Fixed – cannot control turn-off slew rate	Adjustable EMI control with gate resistor R_G
Power density	Low	High	High

Comparing GaN Half Bridge Solutions

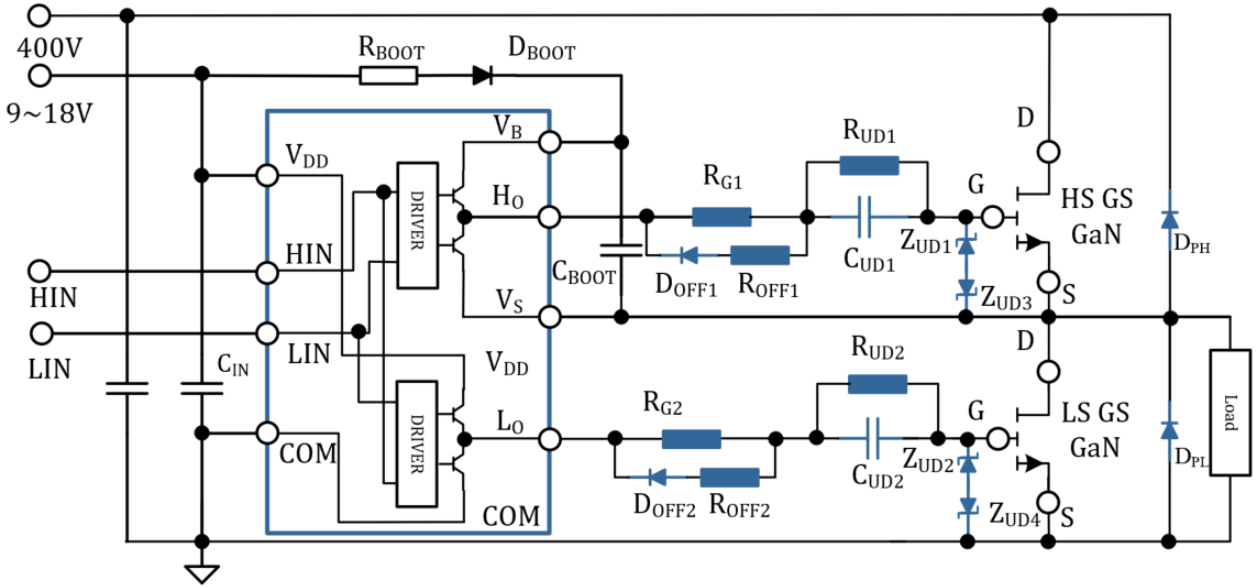
GaN Transistors + EZDrive^{SM} circuit vs Monolithic-integrated GaN transistors + drivers





Fewest circuit blocks + standard componentry (**cost effective**)	Integrated = 2 extra Drivers + 2 extra LDOs (**higher cost and complexity**)
Control Turn-on, turn-off, negative drive (**optimized EMI and efficiency**)	Control of turn-on only (**sub-optimal performance**)

GaN Systems EZDrive^{SM} Solution for GaN HEMTs

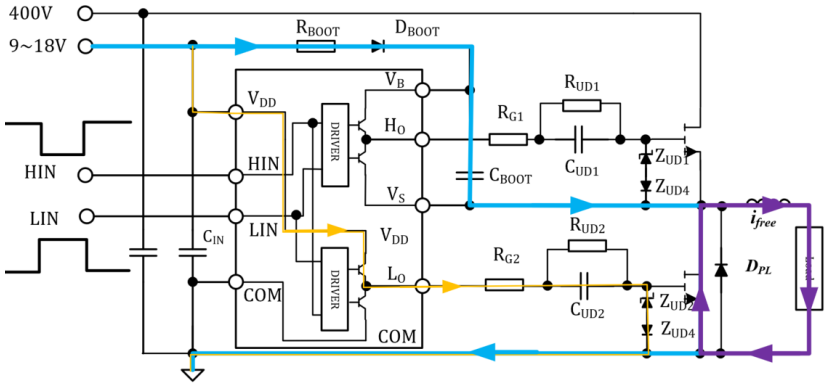


Standard componentry: GaN + MOSFET controller + discrete

- Enable controller to **drive GaN HEMT** with a **small number of external components**
- **Turn ON / OFF slew rate is controllable** with external resistors to optimize EMI
- Applies to **any controllers with single, dual, or high-side/low-side drivers**

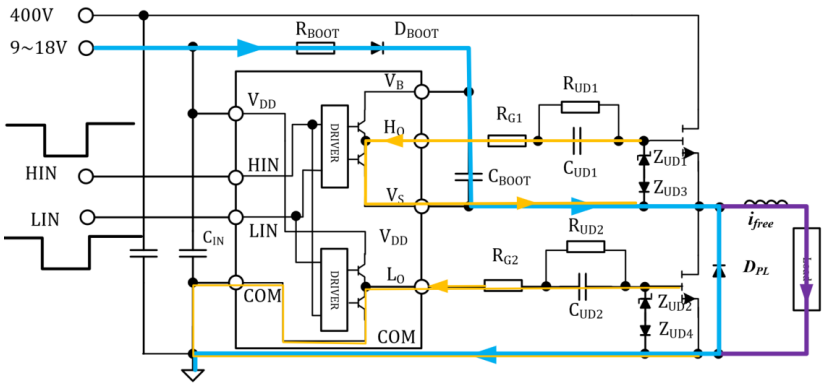
Operation Modes of EZDrive^{SM} Solution

Mode 1: C_{BOOT} Charging (HS GaN: off; LS GaN: on)



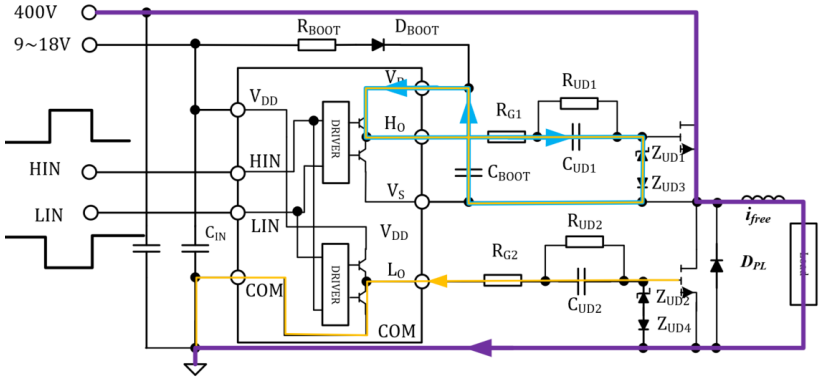
V_{GS_LS}=+6V; V_{GS_HS}=-6V

Mode 2: C_{BOOT} Charging (HS GaN: off; LS GaN: off)



V_{GS_LS}=-6V; V_{GS_HS}=-6V

Mode 3: C_{BOOT} Discharging (HS GaN: on; LS GaN: off)



V_{GS_LS}=-6V; V_{GS_HS}=+6V

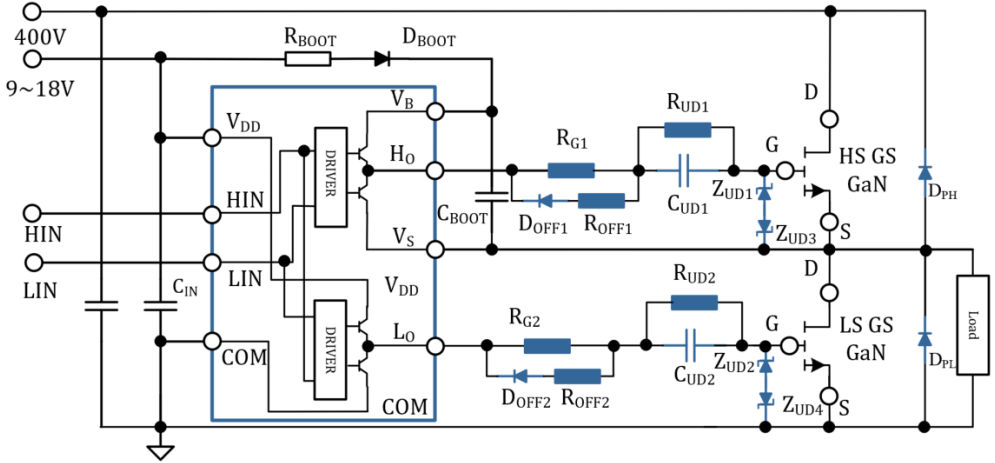
Power Flow

Gate Driving Current Flow

C_{BOOT} Current Flow

- EZDrive^{SM} operation modes are **similar to** conventional non-isolated Bootstrap high side/low side driver
- Allows **wide controller driving voltage range** (9~18V)

Choosing EZDrive^{SM} Circuit Component Values

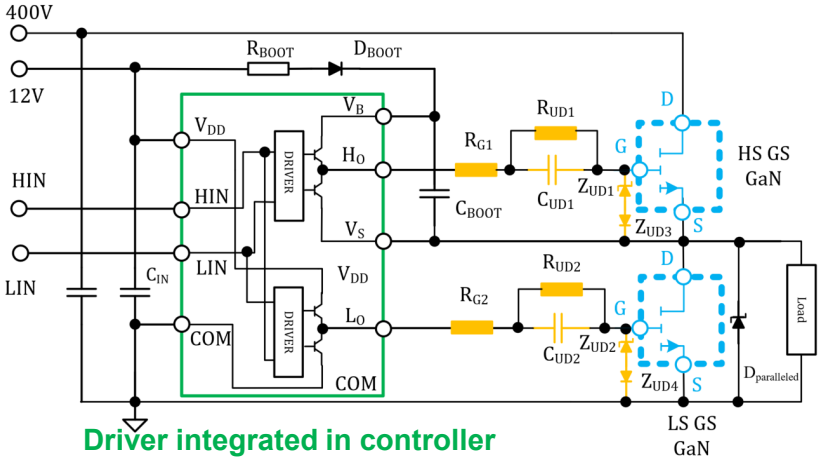


Symbol	Rec. Value	Function
$R_{G1,2}$	5-10 Ω	Control turn ON speed
$R_{UD1,2}$	~ 10 kΩ	Keep the driving voltage
$C_{UD1,2}$	~ 47 nF	Hold negative voltage for turning off
$Z_{UD1,2}$	5.6 V Zener	Clamp the positive gate voltage
$Z_{UD3,4}$	9.1 V Zener	Clamp the negative gate voltage
D_{PL}	600V FRD 1A	Avoid C_{BOOT} overcharging, for reduced low side P_{DT} (Note 1)
D_{PH}	600V FRD 1A	Optional for reduced high side P_{DT} (Note 1)
$D_{OFF1,2}$	20V DIODE 1A	Enable independent turn-off speed control
$R_{OFF1,2}$	0 Ω	Control turn-off speed

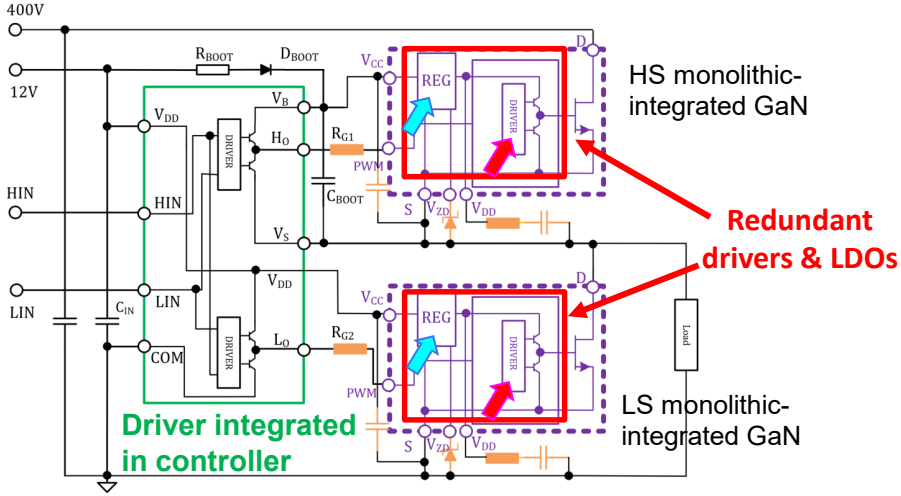
Note 1: D_{PH} and D_{PL} are not required if the controller has internal Sync Boot function to regulate bootstrap voltage

Comparison with Monolithic-integrated GaN Solution

GaN Systems EZDrive^{SM} Solution



Monolithic-integrated Solution



HV HB Bootstrap Driver Simplified Diagram

External Components

GaN Systems' GaN

Integrated GaN + drivers

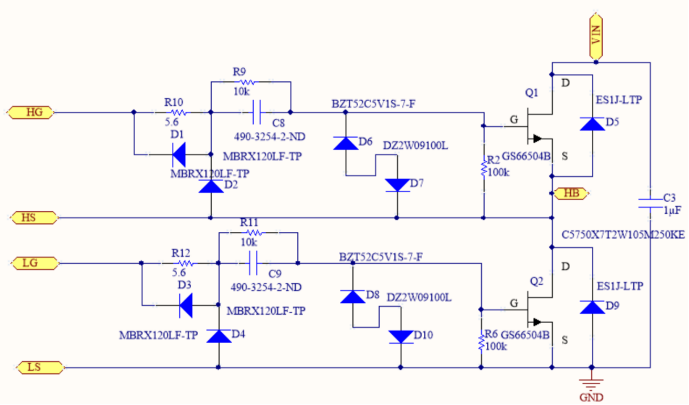
Fewest circuit blocks + standard componentry (cost effective)	**Integrated = 2 extra Drivers + 2 extra LDOs (higher cost and complexity)**
Control Turn-on, turn-off, negative drive (optimized EMI and efficiency)	Control of turn-on only (sub-optimal performance)

PFC/LLC controller tips for EZDrive^{SM} Solution

Transistor	PFC/LLC Controller	External Driver	Integrated Driver in FETs	Multisource Devices	Transistor Range
Silicon MOSFET	Several available from ON Semi, TI, ST Micro and others. Examples include: PFC • NCP1616, NCP1615, L6562A LLC • NCP1399, NCP13992	NO	NO	YES	Widest
Monolithic-integrated GaN		NO	YES	NO	Narrow
GaN Systems		NO	NO	YES	25, 50, 67, 100, 150, 200, 225, 500 mΩ

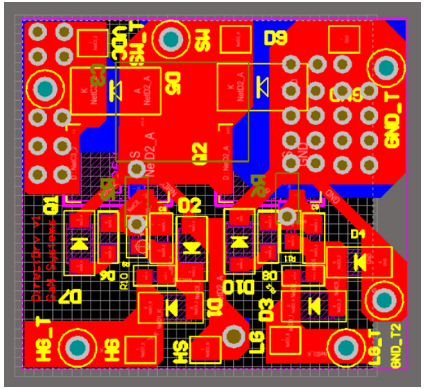
- Driving GaN transistors directly with controllers **simplifies and reduces the cost** of the circuit
- Using discrete GaN transistors provides customers
  - **a wide range of products**
  - **multiple sources of GaN devices**

Verification in LLC stage



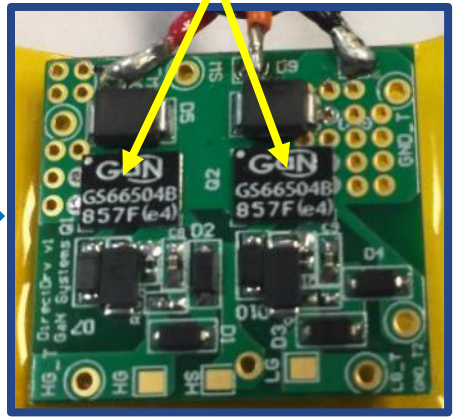
Schematic of EZDrive^{SM} in Half Bridge

Test board (Top View)



Layout of Half Bridge EZDrive^{SM}

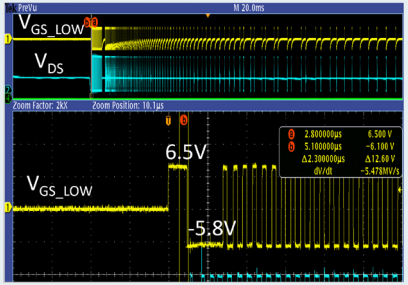
GS66504B x 2



EZDrive^{SM} Daughter Card

Test board (Bottom View)

Verification in LLC stage



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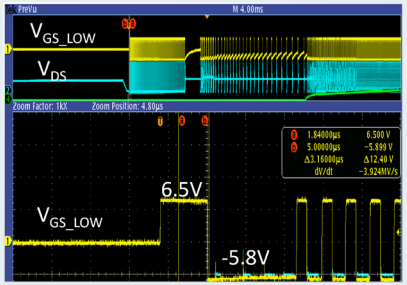
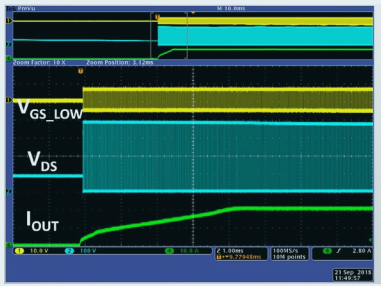
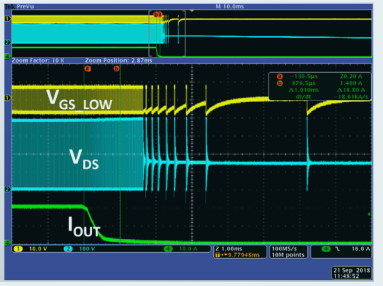


@ full load (Iout=20A)

Start-up Process

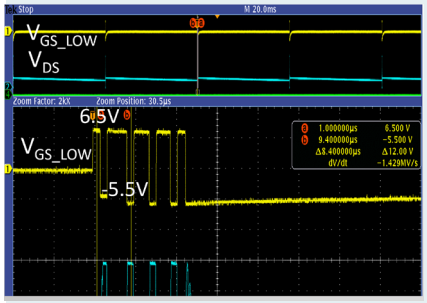


0A to 20A



20A to 0A

Load Step Change



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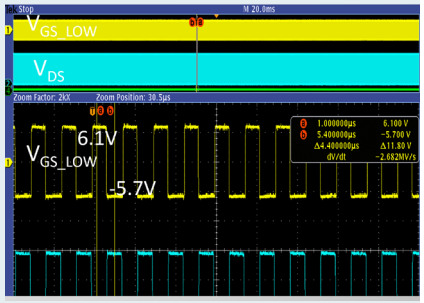
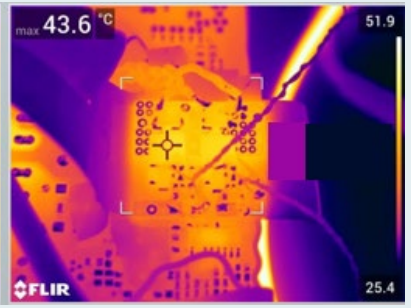


@ full load (Iout=20A)

Static Operation

@ half load (10A)



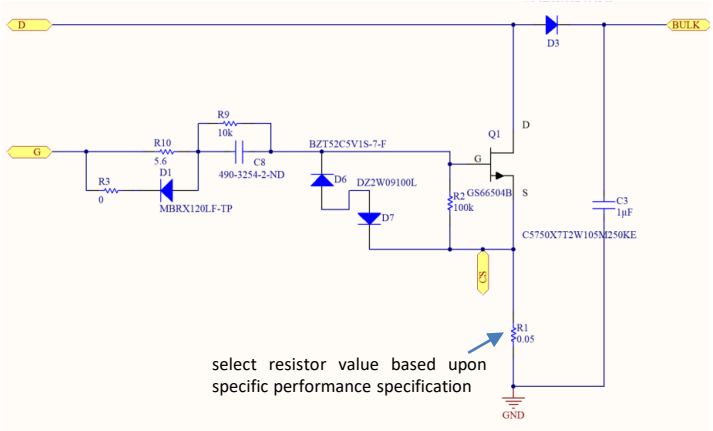
@ full load (20A)

Temperature Distribution

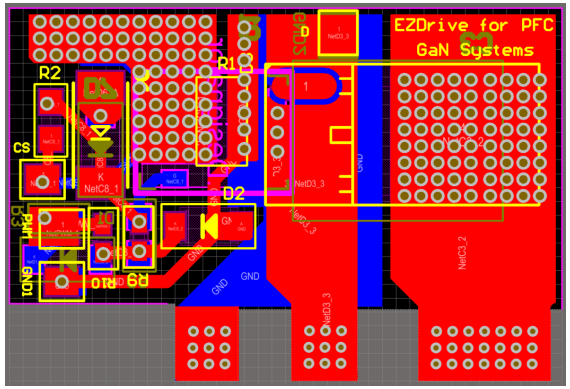
- **No overshoot/undershoot** on V_{GS} & V_{DS} in all operating conditions
- **Low operating temperatures**

Verification in PFC stage

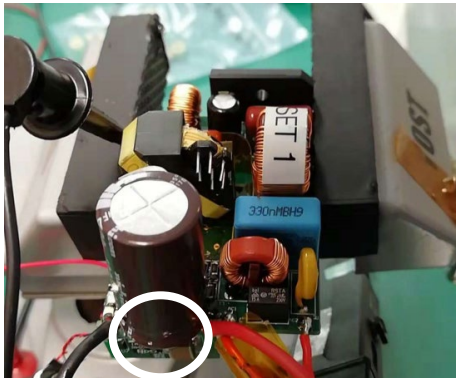
EZDrive^{SM} PFC daughter card schematic



EZDrive^{SM} PFC daughter card



PFC with transition-mode controller L6562A (Top View)



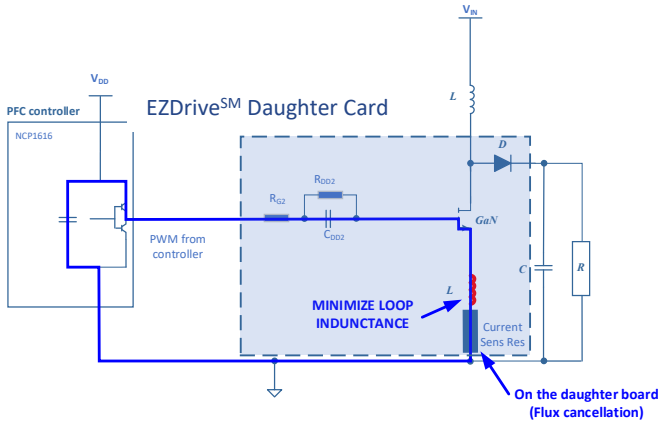
PFC with transition-mode controller L6562A (Side View)

650V 15A GaN E-HEMT: GS66504B

top

bottom

Suggestions for PFC Daughter Cards Layout

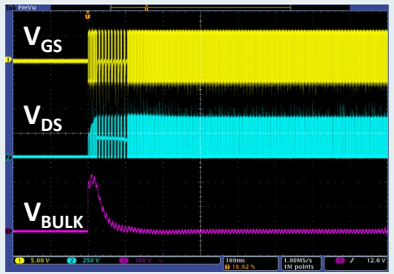


Recommendations for PFC daughter cards Layout	Objectives
• Shorten the trace length between the sensing resister and Power GND	Reduce trace inductance
• Put the sensing resister and GaN back-to-back on the 2-layer board • 2-layer PCB is the low cost solution, using 4-layer PCB will further reduce the common inductance and get better thermal performance	Flux cancellation - reduce the mutual inductance
• SMD current sensing resister	Reduce the parasitic inductance
• Avoid using probe with long ground wire to sense the signals, isolation probe for VDS measurements is recommended (Note 3)	Avoid introducing the parasitics from the measurement

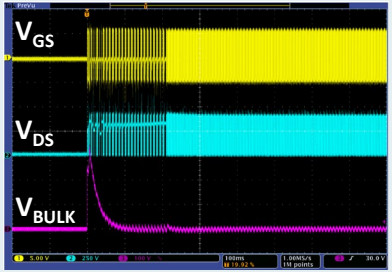
Note 3: more details is available in app note GN003 “Measurement Techniques for High-Speed GaN E-HEMTs”
https://gansystems.com/wp-content/uploads/2018/08/GN003-Measurement-Techniques-for-High-Speed-GaN-E-HEMTs_20180816.pdf

Verification in PFC stage

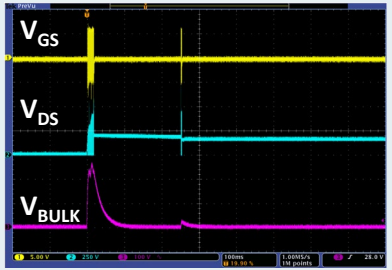
Start-up Process



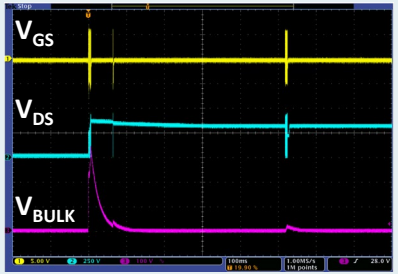
@ 110Vac & full load (400V,0.5A)



@ 220Vac & full load (400V,0.5A)

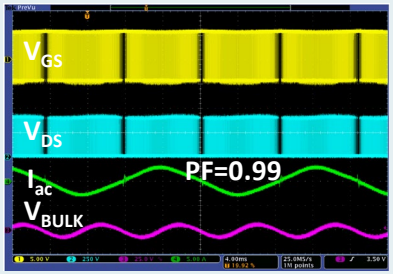


@ 110Vac & no load (400V,0A)



@ 220Vac & no load (400V,0A)

Static Operation



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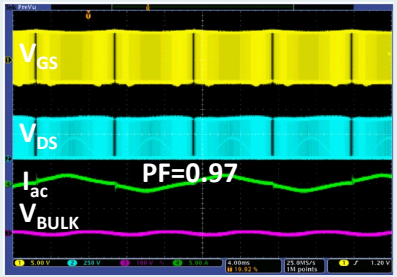

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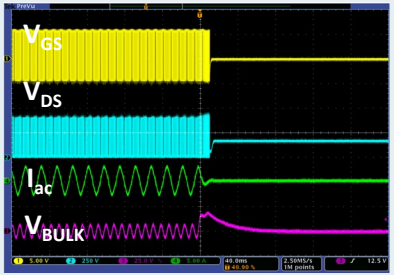
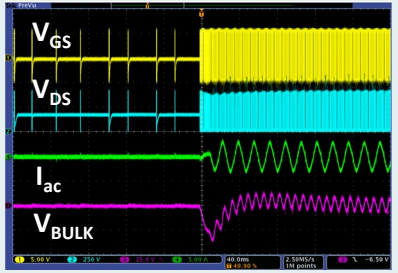
Load Step Change



Full load to no load (0.5A to 0A)

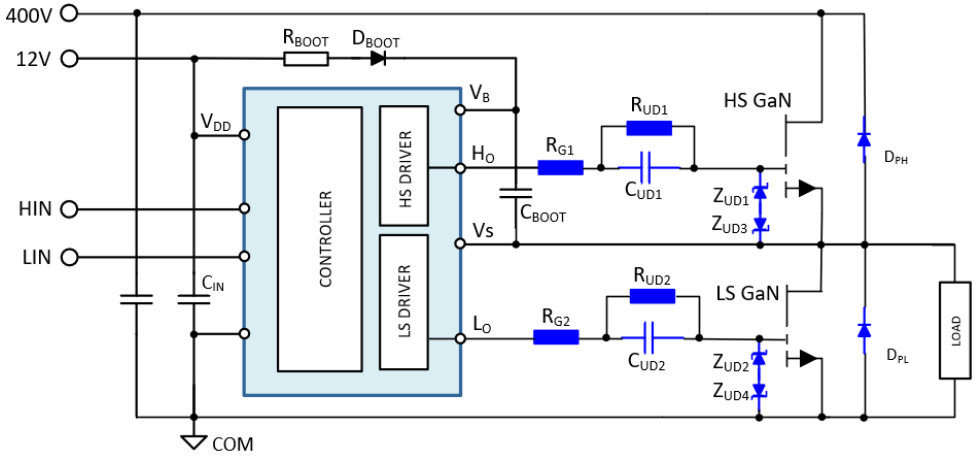


No load to full load (0A to 0.5A)

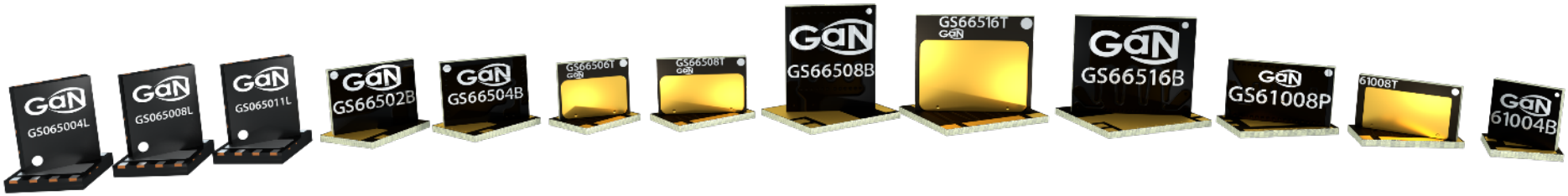
- **No overshoot/undershoot** on V_{GS} & V_{DS} in all operating conditions

Summary – GaN Systems' EZDrive^{SM} 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**



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