GN010 Application Note

EZDrive® Power Stage Solution for GaN Systems’ GaN Transistor

June 2020
GaN Systems Inc.
• Introduction
• GaN discrete versus integrated options
• GaN Systems’ solution: EZDrive circuit
• EZDrive circuit verification
• Summary
• Controllers with Drive have an output signal of 12V
• The GaN transistor needs +6V for turn on
• Additional $V_{gs}$ level shift is needed
Solutions: Integrated or Discrete GaN

- Controllers with Drive have an output signal of 12V
- GaN transistor need +6V for turn on
- Additional Vgs level shift is needed

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GaN discrete versus integrated design

**GaN Systems EZDrive Solution**

- Fewest circuit blocks + standard componentry
  - (cost effective: same number of passive components, no extra driver)

<table>
<thead>
<tr>
<th>Control Turn-on, turn-off, negative drive</th>
<th>Control of turn-on only</th>
</tr>
</thead>
<tbody>
<tr>
<td>(optimized EMI and efficiency)</td>
<td>(sub-optimal performance)</td>
</tr>
</tbody>
</table>

- Driver integrated in controller

**Monolithic-integrated Solution**

- Integrated = 2 extra Drivers + 2 extra LDOs
  - (higher cost and complexity)

<table>
<thead>
<tr>
<th>GaN Systems’ GaN</th>
<th>HV HB Bootstrap Controller/Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Components</td>
<td>Integrated GaN + driver</td>
</tr>
</tbody>
</table>

**Discrete solution is lower in cost and better for EMI and efficiency**
GaN discrete versus integrated $T_{ON}/T_{OFF}$ control

**Monolithic-integrated GaN**

- Drain turn-off rising edge NOT adjustable
- Limits design flexibility, not optimal

**Discrete GaN with EZDrive circuit**

- Drain turn-off rising **AND** turn-on falling edge adjustable
- Optimized EMI and efficiency
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• Summary
GaN Systems’ EZDrive circuit is a low cost, easy way to implement a GaN driving circuit.

- Not original
- Enables 12V driver to drive 6V GaN
- Level shift circuit composed of 4 components
- Turn ON / OFF slew rate is controllable with external resistors Rg to optimize EMI
- Adjustable to any power level, any frequency, and any standard controller/driver
- Applies to any controllers with single, dual, or high-side/low-side drivers
Operation modes of EZDrive solution

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

- $V_{\text{GS_LS}} = +6V; V_{\text{GS_HS}} = -6V$
- Power Flow: Gate Driving Current Flow
- $C_{\text{BOOT}}$ Current Flow

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

- $V_{\text{GS_LS}} = -6V; V_{\text{GS_HS}} = -6V$
- Power Flow: Gate Driving Current Flow
- $C_{\text{BOOT}}$ Current Flow

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

- $V_{\text{GS_LS}} = -6V; V_{\text{GS_HS}} = +6V$

• EZDrive operation modes in half bridge are similar to conventional non-isolated Bootstrap high side/low side driver
• Allows wide controller bias input voltage range (9~18V)
Typical applications with the EZDrive circuit

• Flyback
• Half Bridge
• Boost PFC

Solution = GaN discrete + EZDrive circuit + Controller
Flyback EZDrive circuit

- Flyback controller examples include NCP1342 and NCP1250
- The circuit and tables show recommended values for the Flyback EZDrive circuit
  - As an option, similar to silicon MOSFET-based designs, efficiency and EMI can be further optimized with the labeled “optional circuit”

### EZDrive Circuit

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Footprint</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{EZ}$</td>
<td>~ 10 kΩ</td>
<td>0402 / 0603</td>
<td>Keep the driving voltage</td>
</tr>
<tr>
<td>$C_{EZ}$</td>
<td>~ 47 nF</td>
<td>0402 / 0603</td>
<td>Hold negative voltage for turning off</td>
</tr>
<tr>
<td>$Z_{EZ1}$</td>
<td>5.6 V Zener</td>
<td>SOD923F / 0603</td>
<td>Clamp the positive gate voltage</td>
</tr>
<tr>
<td>$Z_{EZ2}$</td>
<td>9.1 V Zener</td>
<td>SOD923F / 0603</td>
<td>Clamp the negative gate voltage</td>
</tr>
</tbody>
</table>

### Efficiency and EMI Optimization Circuit (Optional)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Rec. Footprint</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{OFF}$</td>
<td>20V Diode 1A</td>
<td>SOD923F / 0603</td>
<td>Enable independent turn-off speed control</td>
</tr>
<tr>
<td>$R_{OFF}$</td>
<td>0 Ω</td>
<td>0402 / 0603</td>
<td>Control turn-off speed</td>
</tr>
</tbody>
</table>
Half Bridge EZDrive circuit

- Half Bridge controller examples include NCP1399 and NCP13992
- The circuit and tables show recommended values for the Half Bridge EZDrive circuit
  - As an option, similar to silicon MOSFET-based designs, efficiency and EMI can be further optimized with the labeled “optional circuit”

### Efficiency and EMI Optimization Circuit

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Rec. Value</th>
<th>Rec. Footprint</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{EZ1,2}$</td>
<td>$\sim 10 , k\Omega$</td>
<td>0402 / 0603</td>
<td>Keep the driving voltage</td>
</tr>
<tr>
<td>$C_{EZ1,2}$</td>
<td>$\sim 47 , nF$</td>
<td>0402 / 0603</td>
<td>Hold negative voltage for turning off</td>
</tr>
<tr>
<td>$Z_{EZ1,2}$</td>
<td>5.6 V Zener</td>
<td>SOD923F / 0603</td>
<td>Clamp the positive gate voltage</td>
</tr>
<tr>
<td>$Z_{EZ3,4}$</td>
<td>9.1 V Zener</td>
<td>SOD923F / 0603</td>
<td>Clamp the negative gate voltage</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Symbol</th>
<th>Rec. Value</th>
<th>Rec. Footprint</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{OFF1,2}$</td>
<td>20V DIODE 1A</td>
<td>SOD923F / 0603</td>
<td>Optional for Enabling independent turn-off speed control</td>
</tr>
<tr>
<td>$R_{OFF1,2}$</td>
<td>0 $\Omega$</td>
<td>0402 / 0603</td>
<td>Optional for Controlling turn-off speed</td>
</tr>
<tr>
<td>$D_{PL}$</td>
<td>600V FRD 1A</td>
<td>SOD123F / SMA</td>
<td>Avoid $C_{BOOT}$ overcharging, for reduced low side $P_{DT}$ (Note 1)</td>
</tr>
<tr>
<td>$D_{PH}$</td>
<td>600V FRD 1A</td>
<td>SOD123F / SMA</td>
<td>Optional for reduced high side $P_{DT}$ (Note 1)</td>
</tr>
</tbody>
</table>

Note 1: $D_{PH}$ and $D_{PL}$ are not required if the controller has an internal Sync Boot function to regulate bootstrap voltage
• Boost PFC controller examples include NCP1616, NCP1615, and L6562A
• The circuit and tables show recommended values for the Boost PFC EZDrive circuit
  ▪ As an option, similar to silicon MOSFET-based designs, efficiency and EMI can be further optimized with the labeled “optional circuit”
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Flyback topology verification test setup

- Populate GaN daughter card with GaN transistor and EZDrive components
- Modify off-the-shelf adapter
- Solder in GaN + EZDrive circuit daughter board
Flyback topology verification data

EZDrive Waveforms ($V_{PWM}$ & $V_{GS}$) @ full load (18V/1.67A output)

Temp. Distribution @ full Load

115Vac input at 18V/1.67A output

230Vac input at 18V/1.67A output

Skip frequency: 1.2KHZ

Pulse frequency: 22KHZ

Skip frequency: 1.6KHZ

Pulse frequency: 22KHZ

115Vac input, Average frequency = 13KHz

230Vac input, Average frequency = 8KHz

• **No overshoot/undershoot** on $V_{GS}$ in all operating conditions
• **Low operating temperatures**
Flyback topology verification data

**Temp. Distribution @ full Load**
- 115Vac input at 18V/1.67A output
- 230Vac input at 18V/1.67A output

**EZDrive Waveforms (V_{PWM} & V_{GS}) @ full load (18V/1.67A output)**

**Skip Mode Operation @ 5% Loads**
- Skip frequency: 1.2KHz
- Pulse frequency: 22KHz

115Vac input, Average frequency = 13KHz
230Vac input, Average frequency = 8KHz

- No overshoot/undershoot on V_{GS} in all operating conditions
- Low operating temperatures
Half Bridge LLC topology verification setup

Half Bridge LLC EZDrive schematic

GS66504B GaN x 2

Test board (Top View)

Half Bridge EZDrive layout

Half Bridge EZDrive layout

EZDrive Daughter Card

Test board (Bottom View)
Half Bridge LLC verification data

Start-up Process

@ no load ($I_{out}=0A$)
@ full load ($I_{out}=20A$)

Load Step Change

0A to 20A
20A to 0A

Static Operation

@ no load ($I_{out}=0A$)
@ full load ($I_{out}=20A$)

Temperature Distribution

@ half load (10A)
@ full load (20A)

- No overshoot/undershoot on $V_{GS}$ & $V_{DS}$ in all operating conditions
- Low operating temperatures
Boost PFC topology verification test setup

EZDrive PFC daughter card schematic

PFC with transition-mode controller L6562A (Top View)

PFC with transition-mode controller L6562A (Side View)

650V 15A GaN Transistor: GS66504B
Boost PFC daughter card layout

• For power greater than 65W, a daughter card is typically used in the design for improved thermal performance
• The table below provides layout recommendations

<table>
<thead>
<tr>
<th>Layout recommendations</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Shorten the trace length between the sensing resistor and Power GND</td>
<td>Reduce trace inductance</td>
</tr>
<tr>
<td>• Put the sensing resistor and GaN back-to-back on the 2-layer board</td>
<td>Flux cancellation → reduce the mutual inductance</td>
</tr>
<tr>
<td>• Using a 4-layer PCB will further reduce the common inductance and result in improved thermal performance</td>
<td></td>
</tr>
<tr>
<td>• Optionally use SMD current sensing resistor instead of THT</td>
<td>Reduce the parasitic inductance</td>
</tr>
</tbody>
</table>
Boost PFC topology verification data

Start-up Process

• No overshoot/undershoot on $V_{GS}$ & $V_{DS}$ in all operating conditions
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**EZDrive circuit solution summary**

<table>
<thead>
<tr>
<th>Application Considerations</th>
<th>Silicon MOSFETS</th>
<th>GaN Systems EZDrive circuit</th>
<th>Monolithic GaN + driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total BoM Cost</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Choice of devices to optimize design</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Use controller driver, eliminate redundancy</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>EMI control</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Power density</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

GaN Systems **EZDrive circuit** is a **low cost**, easy way to implement a GaN driving circuit with a standard MOSFET controller with integrated driver.
EZDrive solution resources

• GaN transistor information
  ▪ https://gansystems.com/gan-transistors/

• EZDrive evaluation kit
  ▪ https://gansystems.com/evaluation-boards/gs65011-evbez/

• Technical article

• Reference Designs
  ▪ Contact us for information, samples and designs