GN010 Application Note
EZDrive℠ Solution for GaN Systems’ E-HEMT

December 21, 2018
Overview

GaN Systems’ EZDrive℠ 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℠ circuit provides design control for the optimization of efficiency and EMI.

The EZDrive℠ 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.

<table>
<thead>
<tr>
<th>Application Considerations</th>
<th>Silicon MOSFETs</th>
<th>Monolithic-integrated Driver GaN</th>
<th>GaN Systems E-HEMTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total BoM Cost</td>
<td>Lowest</td>
<td>Highest</td>
<td>Low</td>
</tr>
<tr>
<td>Choice of devices to optimize design</td>
<td>Widest</td>
<td>Narrow</td>
<td>Wide range from 25 mΩ to 500 mΩ</td>
</tr>
<tr>
<td>Utilize controller driver, eliminate driver redundancy, ease-of-use</td>
<td>• Driver integrated in controller • No redundant drivers</td>
<td>• Driver integrated in controller • Redundant drivers in GaN device</td>
<td>• Driver integrated in controller • No redundant drivers</td>
</tr>
<tr>
<td>EMI control</td>
<td>Adjustable EMI control with gate resistor $R_g$</td>
<td>Fixed – cannot control turn-off slew rate</td>
<td>Adjustable EMI control with gate resistor $R_g$</td>
</tr>
<tr>
<td>Power density</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
Comparing GaN Half Bridge Solutions

GaN Transistors + EZDrive<sup>SM</sup> circuit vs Monolithic-integrated GaN transistors + drivers

<table>
<thead>
<tr>
<th>Fewest circuit blocks + standard componentry (cost effective)</th>
<th>Integrated = ↩ 2 extra Drivers + ↩ 2 extra LDOs (higher cost and complexity)</th>
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</thead>
<tbody>
<tr>
<td>Control Turn-on, turn-off, negative drive (optimized EMI and efficiency)</td>
<td>Control of turn-on only (sub-optimal performance)</td>
</tr>
</tbody>
</table>
GaN Systems EZDrive℠ Solution for GaN HEMTs

- 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

Standard componentry: GaN + MOSFET controller + discrete
Operation Modes of EZDrive℠ Solution

Mode 1: CBOOT Charging (HS GaN: off; LS GaN: on)

\[ V_{GS,LS} = +6V; \ V_{GS,HS} = -6V \]

Mode 2: CBOOT Charging (HS GaN: off; LS GaN: off)

\[ V_{GS,LS} = -6V; \ V_{GS,HS} = -6V \]

Mode 3: CBOOT Discharging (HS GaN: on; LS GaN: off)

\[ V_{GS,LS} = -6V; \ V_{GS,HS} = +6V \]

- EZDrive℠ operation modes are similar to conventional non-isolated Bootstrap high side/low side driver
- Allows wide controller driving voltage range (9~18V)
## Choosing EZDrive<sup>SM</sup> Circuit Component Values

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Rec. Value</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&lt;sub&gt;G1,2&lt;/sub&gt;</td>
<td>5-10 Ω</td>
<td>Control turn ON speed</td>
</tr>
<tr>
<td>R&lt;sub&gt;UD1,2&lt;/sub&gt;</td>
<td>~ 10 kΩ</td>
<td>Keep the driving voltage</td>
</tr>
<tr>
<td>C&lt;sub&gt;UD1,2&lt;/sub&gt;</td>
<td>~ 47 nF</td>
<td>Hold negative voltage for turning off</td>
</tr>
<tr>
<td>Z&lt;sub&gt;UD1,2&lt;/sub&gt;</td>
<td>5.6 V Zener</td>
<td>Clamp the positive gate voltage</td>
</tr>
<tr>
<td>Z&lt;sub&gt;UD3,4&lt;/sub&gt;</td>
<td>9.1 V Zener</td>
<td>Clamp the negative gate voltage</td>
</tr>
<tr>
<td>D&lt;sub&gt;PL&lt;/sub&gt;</td>
<td>600V FRD 1A</td>
<td>Avoid C&lt;sub&gt;BOOT&lt;/sub&gt; overcharging, for reduced low side P&lt;sub&gt;DT&lt;/sub&gt; (Note 1)</td>
</tr>
<tr>
<td>D&lt;sub&gt;PH&lt;/sub&gt;</td>
<td>600V FRD 1A</td>
<td>Optional for reduced high side P&lt;sub&gt;DT&lt;/sub&gt; (Note 1)</td>
</tr>
<tr>
<td>D&lt;sub&gt;OFF1,2&lt;/sub&gt;</td>
<td>20V DIODE 1A</td>
<td>Enable independent turn-off speed control</td>
</tr>
<tr>
<td>R&lt;sub&gt;OFF1,2&lt;/sub&gt;</td>
<td>0 Ω</td>
<td>Control turn-off speed</td>
</tr>
</tbody>
</table>

Note 1: D<sub>PH</sub> and D<sub>PL</sub> are not required if the controller has internal Sync Boot function to regulate bootstrap voltage.
Comparison with Monolithic-integrated GaN Solution

**GaN Systems EZDrive\textsuperscript{SM} Solution**

- **HV HB Bootstrap Driver Simplified Diagram**
- Driver integrated in controller
- Fewest circuit blocks + standard componentry (cost effective)
- Control Turn-on, turn-off, negative drive (optimized EMI and efficiency)

**Monolithic-integrated Solution**

- **Driver integrated in controller**
- Integrated = 2 extra Drivers + 2 extra LDOs (higher cost and complexity)
- Control of turn-on only (sub-optimal performance)

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<th>Fewest circuit blocks + standard componentry (cost effective)</th>
<th>Integrated = 2 extra Drivers + 2 extra LDOs (higher cost and complexity)</th>
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- **Redundant drivers & LDOs**
- HS monolithic-integrated GaN
- LS monolithic-integrated GaN

GaN Systems – 7
### PFC/LLC controller tips for EZDrive℠ Solution

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

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

Schematic of EZDrive\textsuperscript{SM} in Half Bridge

Test board (Top View)

GS66504B x 2

Test board (Bottom View)

Layout of Half Bridge EZDrive\textsuperscript{SM}

EZDrive\textsuperscript{SM} Daughter Card
Verification in LLC stage

Start-up Process

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

Load Step Change

0A to 20A  20A to 0A

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

Static Operation

• No overshoot/undershoot on $V_{GS}$ & $V_{DS}$ in all operating conditions
• Low operating temperatures
Verification in PFC stage

select resistor value based upon specific performance specification

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**

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Recommendations</th>
</tr>
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<tbody>
<tr>
<td>Reduce trace inductance</td>
<td>• Shorten the trace length between the sensing resister and Power GND</td>
</tr>
</tbody>
</table>
| Flux cancellation - reduce the mutual 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 |
| Reduce the parasitic inductance | • SMD current sensing resister |
| Avoid introducing the parasitics from the measurement | • Avoid using probe with long ground wire to sense the signals, isolation probe for VDS measurements is recommended (Note 3) |

Note 3: more details is available in app note GN003 “Measurement Techniques for High-Speed GaN E-HEMTs”
Verification in PFC stage

Start-up Process

@ 110Vac & full load (400V,0.5A)  @ 220Vac & full load (400V,0.5A)

Static Operation

@ 110Vac & full load (400V,0.5A)  @ 220Vac & full load (400V,0.5A)

Load Step Change

@ 110Vac & no load (400V,0A)  @ 220Vac & no load (400V,0A)

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**\textsuperscript{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