Kilowatt Laser Driver with 120 A, sub-10 nanosecond pulses in < 3 cm$^2$ using a GaN FET

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What is Lidar?

- Laser transmitter
- Receiver
- Signal processing
- Scan Optics

Transmitted beam
Reflected beam
Target

3-D point cloud

http://ucanr.edu/blogs/green/blogfiles/11605_original.png
Types of lidar

- Time of flight (TOF) for distance measurement
- Doppler
- Spectroscopic
- Multispectral
- Polarized
- …
LiDAR for Autonomous Vehicles
Importance of pulse shape

\[ t_d = 2d/c \]

Transmission

Reflection
Importance of pulse power

• 300 m range for 10 s response
  – Detection
  – Recognition
  – Decision
  – Controlled deceleration
• High peak laser current ~150 A
• Wider pulse acceptable for distant targets
Leading edge (resonant) control

Lidar is a pulsed power application
Leading edge control

Peak Current:

\[ I_{DLpk} = \frac{V_{IN} - V_{DLF}}{R_0} \]

Half-amplitude pulse width (HAPW):

\[ t_w = t_{res} \frac{\pi - 2 \sin^{-1} \frac{1}{2}}{2\pi} = \frac{t_{res}}{3} \]

Recharge time constant:

\[ \tau_{chrg} = R_1 C_1 \]

Characteristic impedance:

\[ R_0 = \sqrt{\frac{L_1}{C_1}} \]

Resonant frequency:

\[ t_{res} = 2\pi \sqrt{L_1 C_1} = 2t_{wb} \]

Required capacitor charging voltage:

\[ V_{IN} = \frac{2\pi L_1}{3t_w} I_{DLpk} + V_{DLF} \]
# Laser diodes

## SPL PL90_3

![Image of SPL PL90_3](image1)

## TPGAD1S09H

![Image of TPGAD1S09H](image2)

<table>
<thead>
<tr>
<th>Part No.</th>
<th>$\lambda$ [nm]</th>
<th>$I_{F\text{max}}$ [A]</th>
<th>$V_{F\text{max}}$ [V]</th>
<th>$P_{\text{opt,max}}$ [W]</th>
<th>Package</th>
<th>$L$ [nH]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPGAD1S09H</td>
<td>905</td>
<td>30</td>
<td>12.5</td>
<td>75</td>
<td>Surface mount</td>
<td>2</td>
</tr>
<tr>
<td>SPL PL90_3</td>
<td>905</td>
<td>30</td>
<td>9</td>
<td>75</td>
<td>Through hole</td>
<td>5</td>
</tr>
</tbody>
</table>
Impact of stray inductance

Design conditions: Peak current $I_{DL, pk} = 150$ A, $t_w = 8$ ns

Required input voltage $V_{IN}$ (V)

Inductance $L1$ (nH)

Impact of stray inductance

39 V/nH!
## Why GaN?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EPC2001C</th>
<th>BSZ146N10 LS5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>GaN HEMT</td>
<td>Si MOSFET</td>
</tr>
<tr>
<td>$V_{DS,max}$ [V]</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$R_{DS(on)}$ [mΩ]</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>$I_{\text{pulse~max}}$ [A]</td>
<td>150</td>
<td>160</td>
</tr>
<tr>
<td>$Q_{Gtot}$ [nC]</td>
<td>7.5</td>
<td>15</td>
</tr>
<tr>
<td>$R_{gate}$ [$\Omega$]</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>$R_{gate} \cdot Q_{Gtot}$ [$\Omega \cdot nC$]</td>
<td>2.3</td>
<td>15</td>
</tr>
<tr>
<td>$L_{gate}$ [nH]</td>
<td>0.3</td>
<td>3.0</td>
</tr>
<tr>
<td>$L_{source}$ [nH]</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>$L_{drain}$ [nH]</td>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Package [mm x mm]</td>
<td>LGA 4.1 x 1.6</td>
<td>DFN 3.3x3.3</td>
</tr>
</tbody>
</table>

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EPC – The Leader in GaN Technology

www.epc-co.com
EPC9958A test board

- EPC2001C FET
- Laser
- $R_{shunt}$
- $C_1$
- UCC27611
- Gate drive
$V_{IN} = 83\text{ V}$, $C_{BUS} = 7.5\text{ nF}$, 7.4 ns, with a peak current of 123 A.
Texas Instruments announced LMG1020 ultrafast GaN FET driver in March 2018.

0.8 mm x 1.2 mm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (typical)</th>
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<tbody>
<tr>
<td>Propagation delay</td>
<td>2.6 ns</td>
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<tr>
<td>Min. pulse width</td>
<td>1 ns</td>
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<tr>
<td>Turn-on peak current</td>
<td>7 A</td>
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<tr>
<td>Turn-off peak current</td>
<td>5 A</td>
</tr>
<tr>
<td>Parameter</td>
<td>EPC2001C</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Technology</td>
<td>Gen 4</td>
</tr>
<tr>
<td>$V_{DS,max} [V]$</td>
<td>100</td>
</tr>
<tr>
<td>$R_{DS(on)} [m\Omega]$</td>
<td>6</td>
</tr>
<tr>
<td>$I_{pulse,max} [A]$</td>
<td>150</td>
</tr>
<tr>
<td>$Q_{Gtot} [nC]$</td>
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<td>$R_{gate} [\Omega]$</td>
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Gen 5 GaN offers similar performance to Gen 4... at 2X voltage rating

Need higher voltage to reach 150 A goal
EPC9974D test board

- EPC2047 FET
- Laser
- $C_1$
- $R_{shunt}$
- 1.3 cm$^2$
- LMG1020
- Gate drive
EPC2047 with LMG1020

\[ V_{BUS} = 105 \text{ V}, \quad I_{peak} = 155 \text{ A}, \quad 8.0 \text{ ns} \]

\[ i_{LASER}, 25 \text{ A/div} \]

\[ v_D, 20 \text{ V/div} \]

\[ 155 \text{ A}, 6500 \text{ W} \]

\[ 8.0 \text{ ns} \]

\[ 4 \text{ ns/div} \]
Reality Check

• Many more parasitic components
  – Transistor, PCB, passives, etc.
  – Laser diode recovery
  – Very complex behavior possible
• The following practices make parasitics play bigger role:
  – Reducing $L_{\text{stray}}$
  – Forced laser turn-off (clamping and ringing)
  – Increasing switch speed
• Driver mechanical size is important (multi-channel lidar)
• Eye safety!
Improving laser drivers

- Reduction of laser inductance
- Reduction of other stray inductance
- Increase voltage
- Optimize FET parameters for laser pulses
- Integration of gate drive
- Dual edge control
Conclusion

- Time-of-flight lidar drivers are a pulsed power application
- Long range requires high peak power
- GaN FETs are the best known choice
- Inductance dominates the design
- GaN makes well controlled, high power pulses possible:
  - 123 A, 7.5 ns, 4300 W!
  - 155 A, 8.0 ns, 6500 W!
- Multiple paths to increase performance