MPQ3910A Reference Design
High voltage boost for APD in LiDAR applications
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1 Overview

1.1 Description

The autonomous vehicle has been a hot topic for a while, but now it is staring to become a reality. To enable high degrees of autonomy, vehicles are using combined methods of surroundings detection, like cameras, RADAR and LiDAR.

LiDAR is a ranging device that works similar to a RADAR; but uses light waves instead of RF waves. A laser diode emits light pulses, and an advanced photodiode (APD) senses the reflection to determine the time of flight and thus the distance to the reflecting object.

A design challenge that presents when working with LiDAR systems is providing a high voltage power supply to bias the APD sensor, as these kinds of photodiodes can need up to 300V depending on their size. The power supply must be cost effective and pass the EMC regulations in the automotive industry.

This reference design uses the MPQ3910A to control a boost converter working in DCM. This allows the use of cheap small sized components and to overcome the limitations due to very high duty cycle. The boosted voltage is effectively doubled through a charge pump to achieve >350V output capability while still using lower voltage rating semiconductors, which are smaller, cheaper and have better performance than their high voltage counterparts.

1.2 Features

- AEC-Q100 Qualified
- CISPR-25 Class 5 Compliant
- Wide 5V to 35V operating input range
- Single N-Channel MOSFET gate driver with 12V 1A capability
- Programmable frequency range: 30kHz - 400kHz
- External sync clock range: 80kHz - 400kHz
- Programmable soft start (SS)
- Over-current protection (OCP)
- Output over-voltage protection (OVP)
- Short-circuit protection (SCP)
- Internal LDO with external power supply option
- Pulse-skipping operation at light load
- Available in MSOP-10 Package

1.3 Applications

- Automotive LiDAR APD power supply

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2 Reference Design

2.1 Simplified Schematic
Boost converter with 12V nominal input, 300V 15mA output capability, EMI filter and polarity protection.

![Simplified Schematic Diagram]

2.2 Related Solutions
This reference design is based on the following MPS solutions:

<table>
<thead>
<tr>
<th>MPS Integrated Circuit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPQ3910A</td>
<td>5V-35V Input, Peak Current Mode, Asynchronous Boost Controller. AEC-Q100 Qualified</td>
</tr>
</tbody>
</table>

2.3 System Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>3V&lt;sub&gt;DC&lt;/sub&gt; to 35V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Output voltage</td>
<td>300V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Maximum output current</td>
<td>15mA</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>375kHz</td>
</tr>
<tr>
<td>Board form factor</td>
<td>89mmx63mmx5mm</td>
</tr>
<tr>
<td>Peak Efficiency</td>
<td>83%</td>
</tr>
<tr>
<td>300V output ripple</td>
<td>200mV&lt;sub&gt;p-p&lt;/sub&gt;</td>
</tr>
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</table>
3 Design

3.1 Schematics

Figure 3: Schematics
Table 3: Bill Of Materials for the reference design

<table>
<thead>
<tr>
<th>Designator</th>
<th>Qty</th>
<th>Value</th>
<th>Package</th>
<th>Manufacturer</th>
<th>Part Number</th>
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<td>C1, C3, C16</td>
<td>3</td>
<td>0.1µF 250V</td>
<td>0805</td>
<td>TDK</td>
<td>CGA4J3X7T2E104K125AE</td>
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<tr>
<td>C2, C4</td>
<td>2</td>
<td>0.47µF 250V</td>
<td>1812</td>
<td>Murata</td>
<td>GCJ43DR72E474KKJ1L</td>
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<tr>
<td>C5</td>
<td>1</td>
<td>15nF 50V</td>
<td>0603</td>
<td>Murata</td>
<td>GCM188R72A153KA37D</td>
</tr>
<tr>
<td>C6, C8, C9</td>
<td>3</td>
<td>4.7µF 50V</td>
<td>0805</td>
<td>TDK</td>
<td>CGA4J3X5R1H475M125AB</td>
</tr>
<tr>
<td>C7</td>
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<td>TDK</td>
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<tr>
<td>C11</td>
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<td>1µF 50V</td>
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<td>Murata</td>
<td>GCM21BR71H105KA03L</td>
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<tr>
<td>C12</td>
<td>1</td>
<td>4.7µF 25V</td>
<td>0805</td>
<td>TDK</td>
<td>CGA4J1X7R1E475K125AC</td>
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<tr>
<td>C13</td>
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<td>0.47µF 16V</td>
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<td>Murata</td>
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<tr>
<td>C15</td>
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<tr>
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<td>SOD-123</td>
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<td>Comchip</td>
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<td>D6</td>
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<td>SOD-323</td>
<td>Nexperia</td>
<td>PMEG6010CEJ,115</td>
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<td>L1</td>
<td>1</td>
<td>12µH 1.75A</td>
<td>6235</td>
<td>Coilcraft</td>
<td>LPS6235-123MRB</td>
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<tr>
<td>L2</td>
<td>1</td>
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<tr>
<td>L3, L4</td>
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<td>1µH 1.3A</td>
<td>0805</td>
<td>Murata</td>
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<td>Q1</td>
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<td>SO-8FL</td>
<td>Vishay</td>
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<td>R1, R3, R13</td>
<td>3</td>
<td>0Ω 5%</td>
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<td>R4</td>
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<td>Panasonic</td>
<td>ERJ-3EKF6201V</td>
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<tr>
<td>R5</td>
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<td>50mΩ 1%</td>
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<td>Panasonic</td>
<td>ERJ-8CWF9050V</td>
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<td>R6</td>
<td>1</td>
<td>7.5kΩ 5%</td>
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<td>R11</td>
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<tr>
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<td>U1</td>
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<td>MPQ3910</td>
<td>MSOP-10</td>
<td>MPS</td>
<td>MPQ3910GK-AEC1</td>
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</table>
Figure 6: PCB Layer 3

Figure 7: PCB Layer 4
4 Test Results

4.1 Efficiency and Regulation

\[ V_{\text{OUT}} = 300\text{V}, \quad L = 12\mu\text{H}, \quad F_{\text{SW}} = 375\text{kHz}, \quad T_A = 25^\circ\text{C} \]

Figure 8: Efficiency vs. Load Current

Figure 9: Line Regulation

Figure 10: Load Regulation
4.2 Time Domain Waveforms

\( V_{IN} = 12V, V_{OUT} = 300V, L = 12\mu H, F_{SW} = 375kHz, T_A = 25^\circ C \)

Figure 11: Steady state
\( I_{OUT} = 0mA \)

Figure 12: Steady State
\( I_{OUT} = 10mA \)

Figure 13: Start-up through \( V_{IN} \)
\( I_{OUT} = 0mA \)

Figure 14: Start-up through \( V_{IN} \)
\( I_{OUT} = 10mA \)

Figure 15: Shutdown through \( V_{IN} \)
\( I_{OUT} = 0mA \)

Figure 16: Shutdown through \( V_{IN} \)
\( I_{OUT} = 10mA \)
Figure 17: Start-up through EN
$I_{OUT} = 0 mA$

Figure 18: Start-up through EN
$I_{OUT} = 10 mA$

Figure 19: Shutdown through EN
$I_{OUT} = 0 mA$

Figure 20: Shutdown through EN
$I_{OUT} = 10 mA$

Figure 21: Single load step
$I_{OUT} = 0 mA$ to $10 mA$

Figure 22: Single load step
$I_{OUT} = 10 mA$ to $0 mA$
4.3 Thermal Measurements

\( V_{IN} = 12V \), \( V_{OUT} = 300V \), \( L = 12\mu H \), \( F_{SW} = 375kHz \), \( T_A = 25^\circ C \), 2h run time

**Figure 27: Thermal Image**

\( I_{OUT} = 10mA \)
4.4 EMC Measurements

This circuit has a very aggressive square signal in its switch node, with a high dV/dt due to the ~150V voltage swing. The high dV/dt creates strong electric fields which can make noise couple to other circuits and cable harnesses present in the system. To mitigate this, the APD power supply should be placed inside a metallic housing, or near a metallic plate in the car that could act as a shield for the electric fields.

An alternative, in case this is not possible, is to place a small metallic shield on the noisy area of the PCB; it should cover the inductor, MOSFET, rectifier and output capacitors. This is the approach that has been taken to test this PCB as a standalone device for this document. The pictures below show the shield that has been used:

![Figure 28: PCB with a local shield made of copper.](image1)

![Figure 29: Area covered by the shield](image2)

The following graphs show the test results from CISPR25 Conducted Emissions and Radiated Emissions tests performed in an ALSE with this board.
$V_{IN} = 12V$, $V_{OUT} = 300V$, $I_{OUT} = 10mA$ $L = 12\mu H$, $F_{SW} = 375kHz$, $T_A = 25^\circ C$, with shield

Figure 30: CISPR25 Class 5 Conducted Emissions
150kHz – 108MHz

Figure 31: CISPR25 Class 5 Radiated Emissions
150kHz – 30MHz
5 Start-Up

1. Connect the positive and negative terminals of the load to the V_{OUT} and GND pins, respectively. Make sure that the load is suited for voltages of 300V or higher. Be aware that electronic loads represent a negative impedance to the regulator and if set to a too high current will trigger over-current-protection or short-current protection.

2. Preset the power supply output between 3V and 30V, and then turn off the power supply.

3. Connect the positive and negative terminals of the power supply output to the V_{IN} and GND pins, respectively. If the input voltage is higher than 13V make sure R13 is removed.

4. If the input voltage is lower than 5V, remove R1 and connect an auxiliary power supply to VBIAS up to 13V.

5. Turn the power supply on. The board will automatically start up. The default V_{OUT} is 300V.

6. The external resistor divider R7-R11 and R12 are used to set the output voltage. For V_{OUT} = 300 V the sum of R7 -R11 must be 482 kΩ and R12 must be 2 kΩ.

\[ R_{12} = \frac{R_{11}}{V_{OUT} - 1.237} \]

7. In order to increase the output current capabilities, higher power rated parts can be reworked on the board. Make sure that T_J does not exceed 175 °C on the external discrete semiconductors.

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