MPQ3910A Reference Design

High-Voltage Boost for APD in LiDAR Applications

Contents

1 Overview

1.1 Description

Autonomous vehicles have been a hot topic for some time, but now they are staring to become a reality. To enable high degrees of autonomy, vehicles are using combined methods (cameras, radar, and LiDAR) to detect surroundings.

LiDAR is a ranged device. It functions similarly to 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 flight time and the distance to the reflecting object.

A significant design challenge with LiDAR systems is providing a suitable high-voltage power supply to bias the APD sensor, as these types of photodiodes can require up to 300V, depending on their size. The power supply must be cost-effective and pass automotive EMC regulations.

This reference design uses the MPQ3910A to control a boost converter working in DCM. This design allows cost-effective, space-saving components to overcome LiDAR limitations due to a very high duty cycle. The boosted voltage is effectively doubled through a charge pump to achieve more than 350V of output capability while using semiconductors with a lower voltage rating. These semiconductors are smaller, inexpensive, and perform better than their high-voltage counterparts.

1.2 Features

- CISPR-25 Class 5 Compliant
- Wide 5V to 35V Operating Input Range
- Single N-Channel MOSFET Gate Driver with 12V/1A Capability
- Configurable 30kHz to 400kHz Frequency
- External 80kHz to 400kHz Sync Clock
- Configurable 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 an MSOP-10 Package
- AEC-Q100 Qualified

Figure 1: Evaluation Board

1.3 Applications

- Automotive LiDAR APD Power Supplies

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2 Reference Design

2.1 Simplified Schematic

The MPQ3910A is a boost converter with 12V nominal input, 300V/15mA output capability, EMI filter, and polarity protection. Figure 2 shows a block diagram of the MPQ3910A.

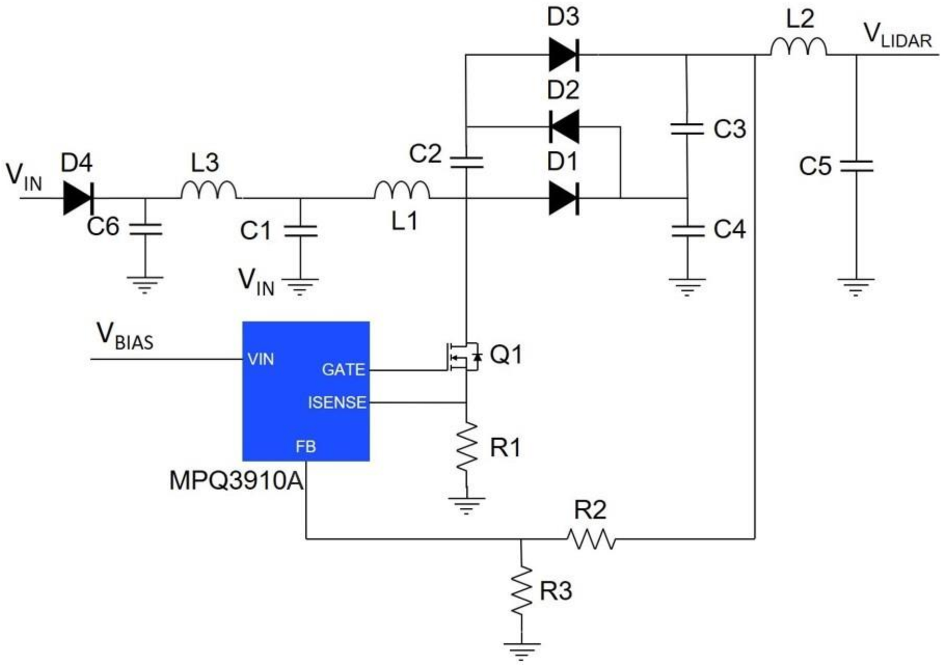


Figure 2: MPQ3910A Block Diagram

2.2 Related Solutions

This reference design is based on the following MPS solution:

Table 1: MPS Solution

MPS Integrated Circuit	Description
MPQ3910A	5V to 35V input, peak current mode, asynchronous boost controller, AEC-Q100 qualified

2.3 System Specifications

Table 2: System Specifications

Parameter	Specification
Input voltage range	$3V_{DC}$ to $35V_{DC}$
Output voltage	$300V_{DC}$
Maximum output current	15mA
Switching frequency	375kHz
Board form factor	89mmx63mmx5mm
Peak efficiency	83%
300V output ripple	$200mV_{P-P}$

3 Design

3.1 Schematics

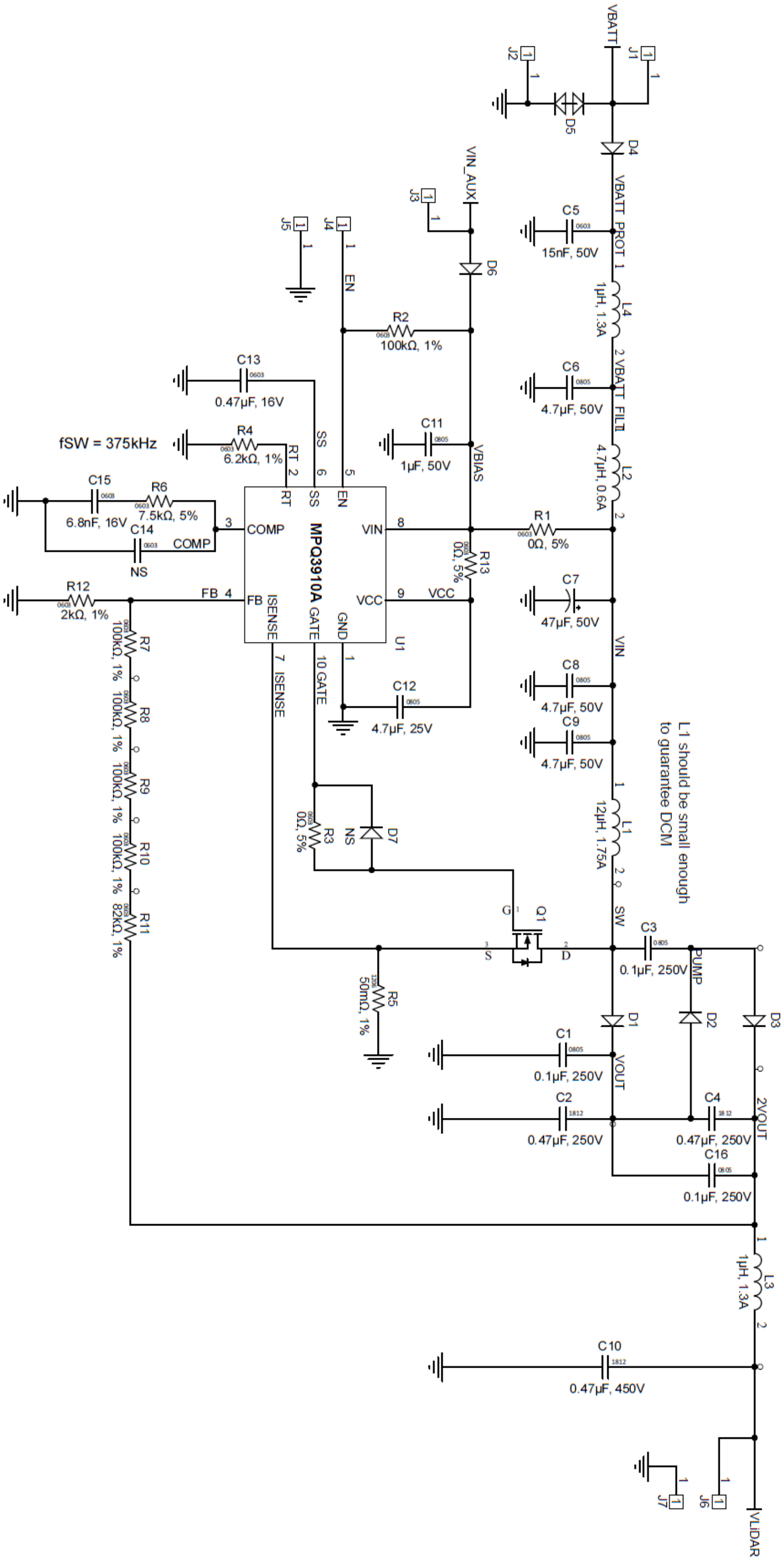


Figure 3: Schematic

3.2 BOM

Designator	Qty	Value	Package	Manufacturer	Manufacturer P/N
C1, C3, C16	3	0.1µF, 250V	0805	TDK	CGA4J3X7T2E104K125AE
C2, C4	2	0.47µF, 250V	1812	Murata	GCJ43DR72E474KXJ1L
C5	1	15nF, 50V	0603	Murata	GCM188R72A153KA37D
C6, C8, C9	3	4.7µF, 50V	0805	TDK	CGA4J3X5R1H475M125AB
C7	1	47µF, 50V	6x6	Panasonic	EEE-FT1H470AP
C10	1	0.47µF, 450V	1812	TDK	C4532X7T2W474M230KE
C11	1	1µF, 50V	0805	Murata	GCM21BR71H105KA03L
C12	1	4.7µF, 25V	0805	TDK	CGA4J1X7R1E475K125AC
C13	1	0.47µF, 16V	0603	Murata	GCM188R71C474KA55D
C15	1	6.8nF, 16V	0603	Murata	GCM188R72A682KA37D
D1, D2, D3	3	BAS21	SOD-323	Rohm	BAS21VMFHTE-17
D4	1	NRVTS245ESFT3G	SOD-123	ON Semiconductor	NRVTS245ESFT3G
D5	1	SMBJ30CA-E3/52	SMB	Comchip	ATV06B240JB-HF
D6	1	PMEG6010CEJ	SOD-323	Nexperia	PMEG6010CEJ,115
L1	1	12µH, 1.75A	6235	Coilcraft	LPS6235-123MRB
L2	1	4.7µH, 0.6A	0805	Murata	LQM21PZ4R7NGRD
L3, L4	2	1µH, 1.3A	0805	Murata	LQM21PZ1R0NGRD
Q1	1	SQJ454EP	SO-8FL	Vishay	SQJ454EP-T1_GE3
R1, R3, R13	3	0Ω, 5%	0603	Vishay Dale	CRCW06030000Z0EB
R2, R7, R8, R9, R10	5	100kΩ, 1%	0603	Vishay	CRCW0603100KFKEA
R4	1	6.2kΩ, 1%	0603	Panasonic	ERJ-3EKF6201V
R5	1	50mΩ, 1%	1206	Panasonic	ERJ-8CWFR050V
R6	1	7.5kΩ, 5%	0603	Vishay	CRCW06037K50FKEA
R11	1	82kΩ, 1%	0603	Vishay	CRCW060382K0FKEA
R12	1	2kΩ, 1%	0603	Vishay	CRCW06032K00FKEA
U1	1	MPQ3910	MSOP-10	MPS	MPQ3910GK-AEC1

3.3 PCB Layout

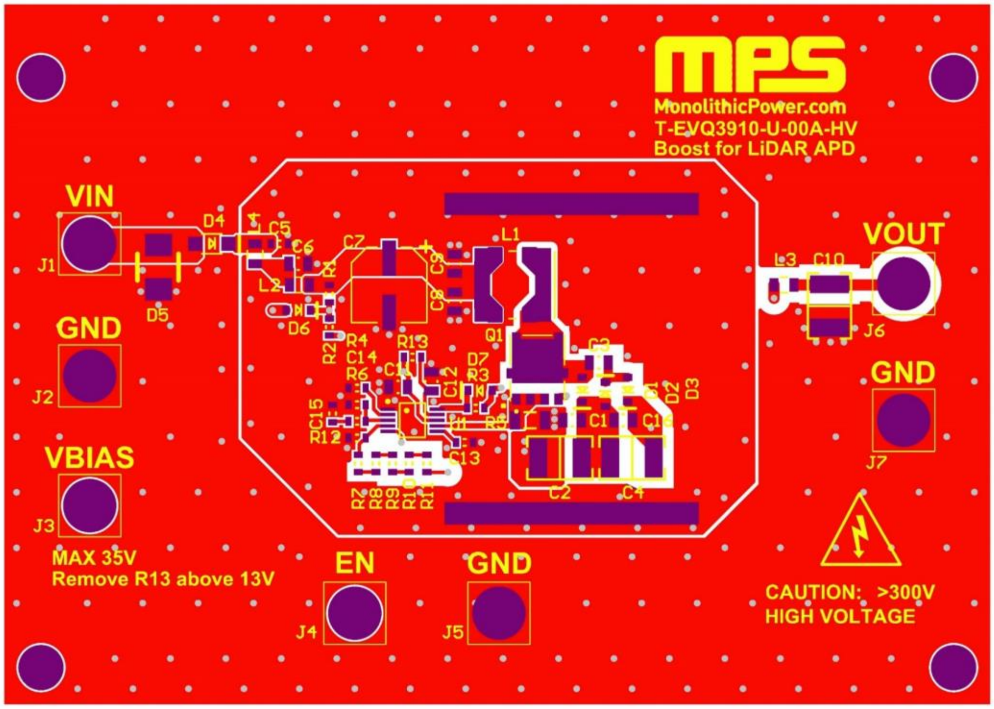


Figure 4: PCB Layer 1

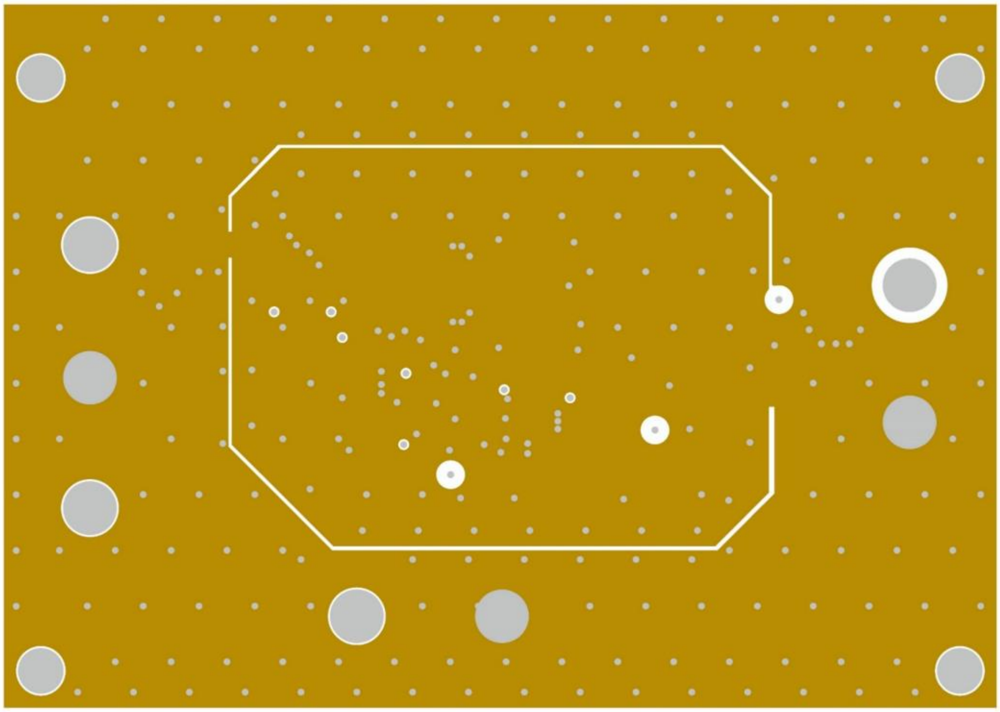


Figure 5: PCB Layer 2

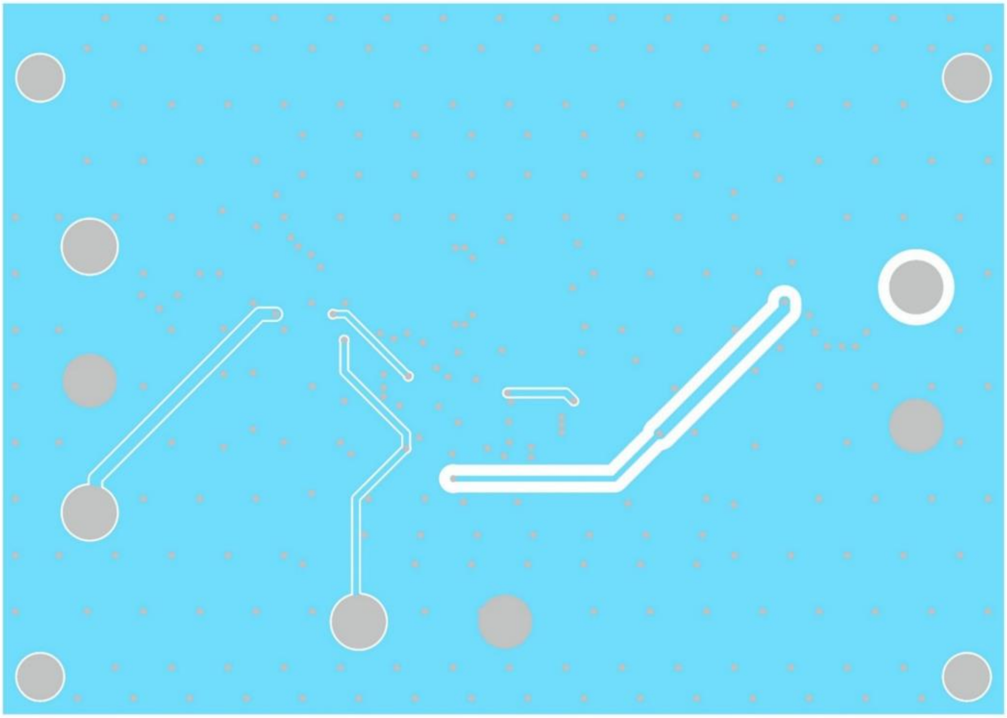


Figure 6: PCB Layer 3

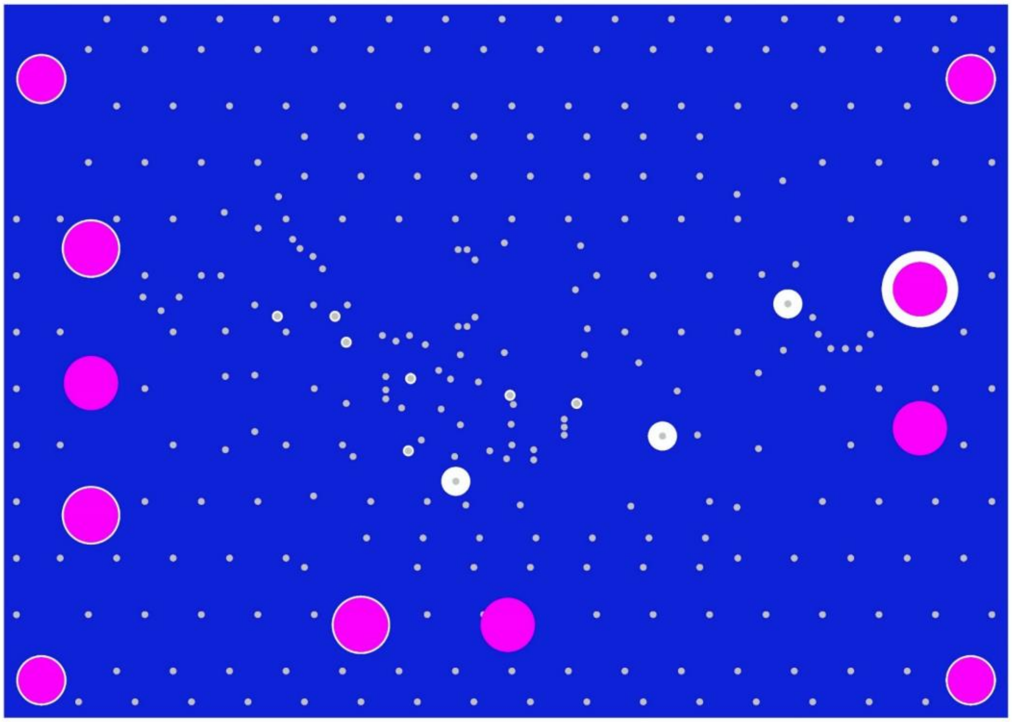


Figure 7: PCB Layer 4

4 Test Results

4.1 Efficiency and Regulation

V_{OUT} = 300V, L = 12µH, f_{SW} = 375kHz, T_A = 25ºC

Figure 8: Efficiency vs. Load Current

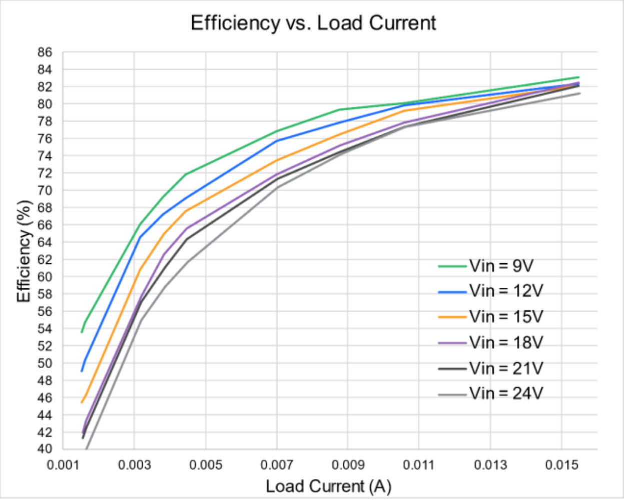


Figure 9: Line Regulation

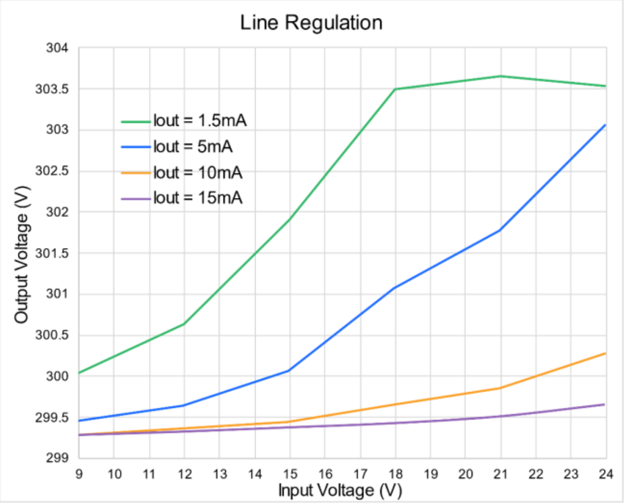
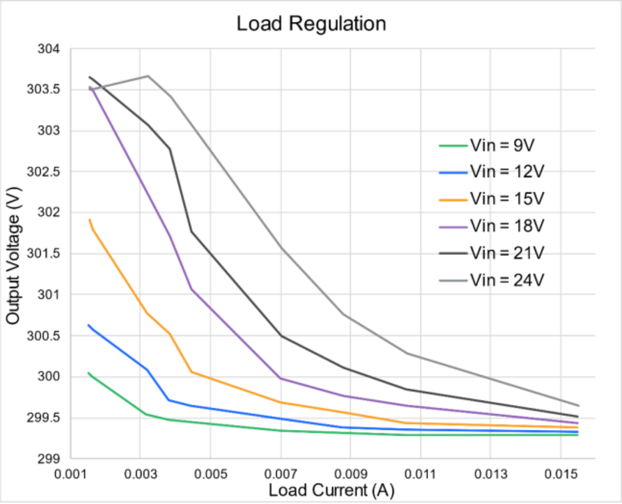


Figure 10: Load Regulation



4.2 Time Domain Waveforms

V_{IN} = 12V, V_{OUT} = 300V, L = 12µH, f_{SW} = 375kHz, T_A = 25°C

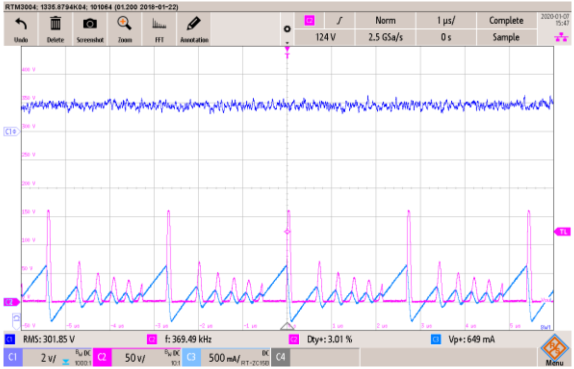
Figure 11: Steady State

I_{OUT} = 0mA

C1: V_{OUT} 2V/div.

C2: V_{SW} 50V/div.

C3: I_L 0.5A/div.



1µs/div.

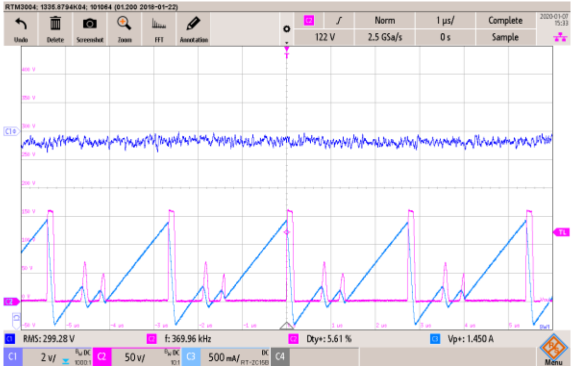
Figure 12: Steady State

I_{OUT} = 10mA

C1: V_{OUT} 2V/div.

C2: V_{SW} 50V/div.

C3: I_L 0.5A/div.



1µs/div.

Figure 13: Start-Up through VIN

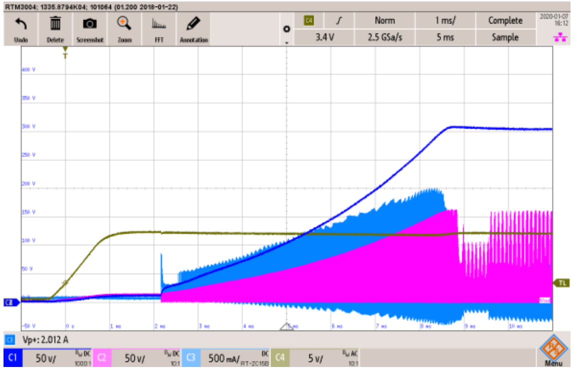
I_{OUT} = 0mA

C1: V_{OUT} 50V/div.

C2: V_{SW} 50V/div.

C3: I_L 0.5A/div.

C4: V_{IN} 5V/div.



1ms/div.

Figure 14: Start-Up through VIN

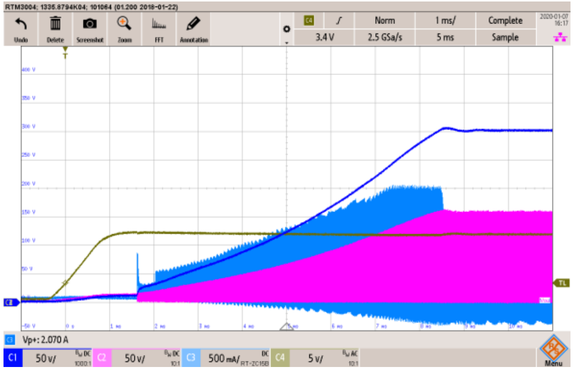
I_{OUT} = 10mA

C1: V_{OUT} 50V/div.

C2: V_{SW} 50V/div.

C3: I_L 0.5A/div.

C4: V_{IN} 5V/div.



1ms/div.

Figure 15: Shutdown through VIN

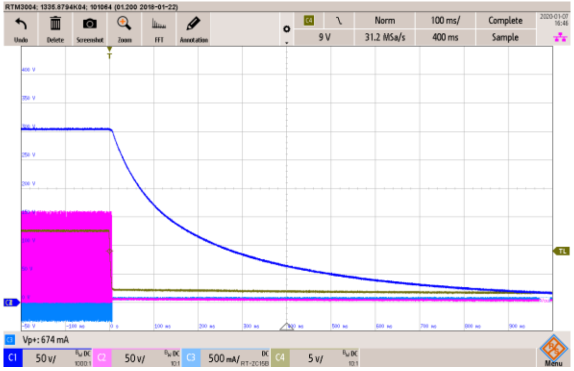
I_{OUT} = 0mA

C1: V_{OUT} 50V/div.

C2: V_{SW} 50V/div.

C3: I_L 0.5A/div.

C4: V_{IN} 5V/div.



100ms/div.

Figure 16: Shutdown through VIN

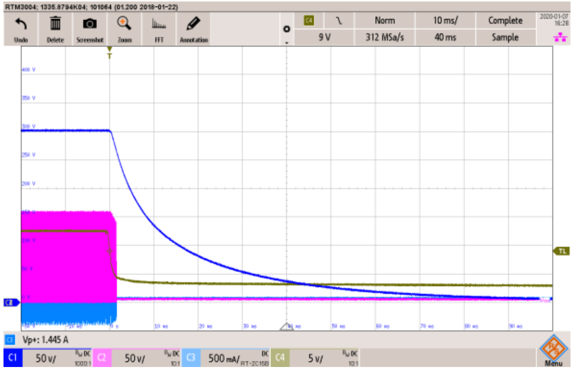
I_{OUT} = 10mA

C1: V_{OUT} 50V/div.

C2: V_{SW} 50V/div.

C3: I_L 0.5A/div.

C4: V_{IN} 5V/div.



10ms/div.

Figure 17: Start-Up through EN

I_{OUT} = 0mA

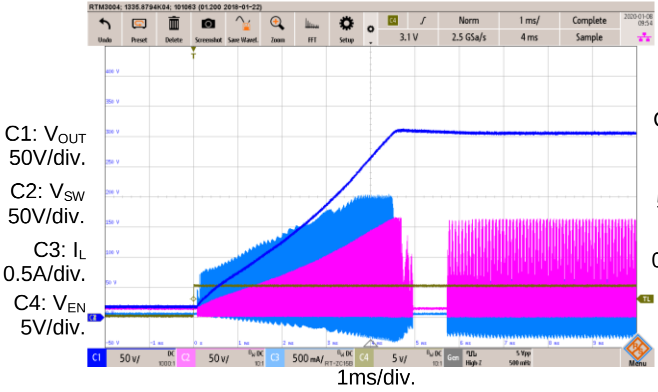


Figure 18: Start-Up through EN

I_{OUT} = 10mA

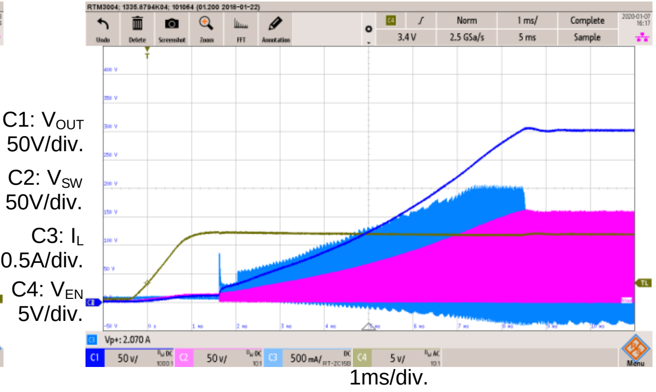


Figure 19: Shutdown through EN

I_{OUT} = 0mA

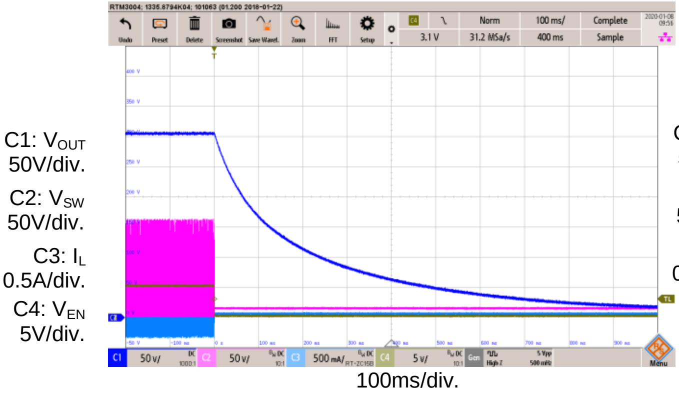


Figure 20: Shutdown through EN

I_{OUT} = 10mA

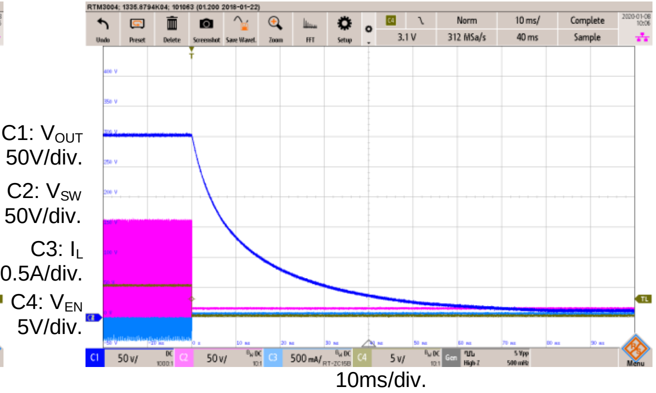


Figure 21: Single Load Step

I_{OUT} = 0mA to 10mA

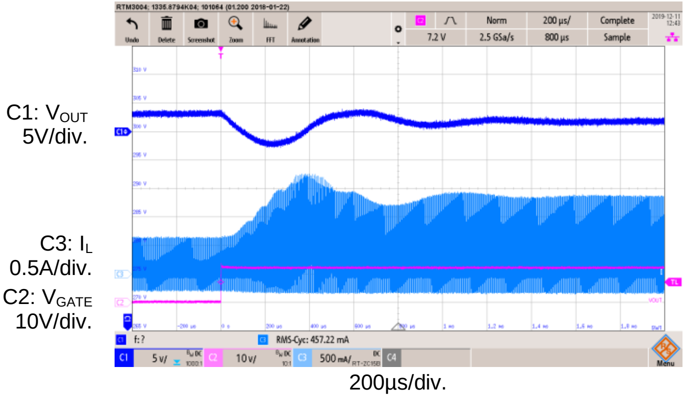


Figure 22: Single Load Step

I_{OUT} = 10mA to 0mA

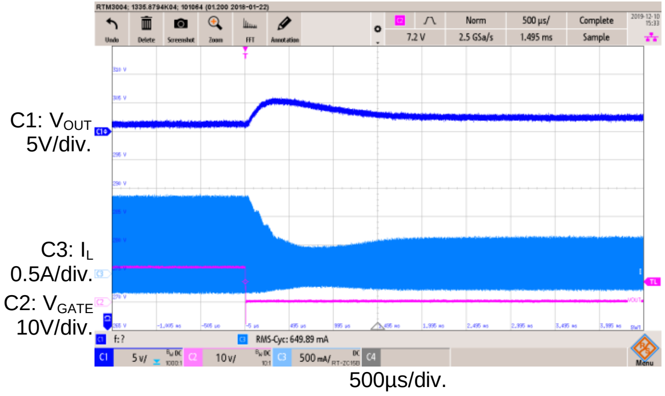


Figure 23: Repetitive Load Step, 5kHz

I_{OUT} = 0mA to 10mA

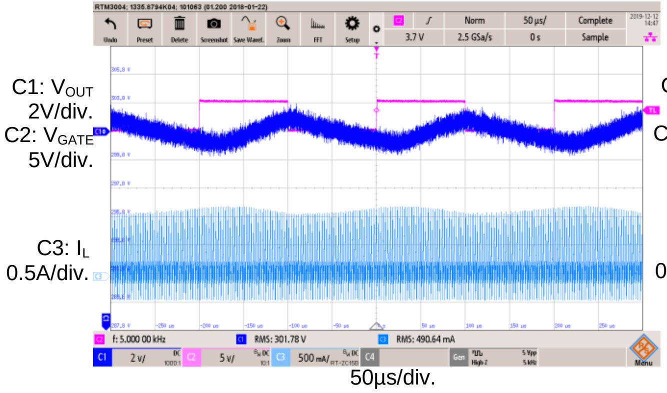


Figure 24: Repetitive Load Step, 10kHz

I_{OUT} = 0mA to 10mA

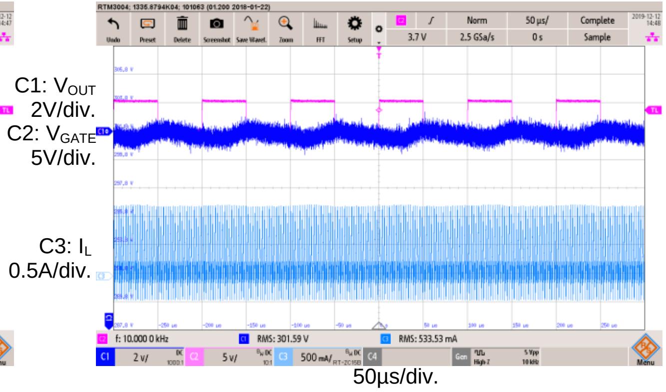


Figure 25: Repetitive Load Step, 20kHz

I_{OUT} = 0mA to 10mA

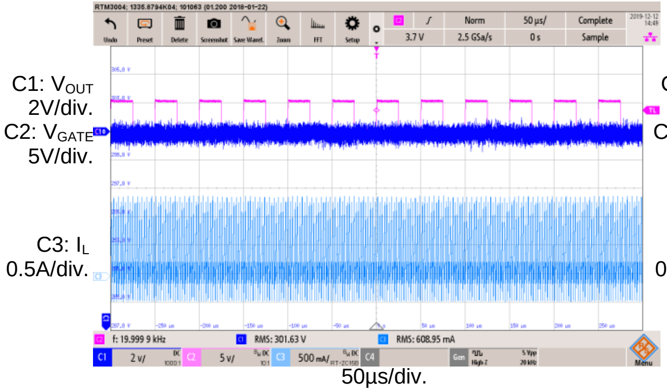
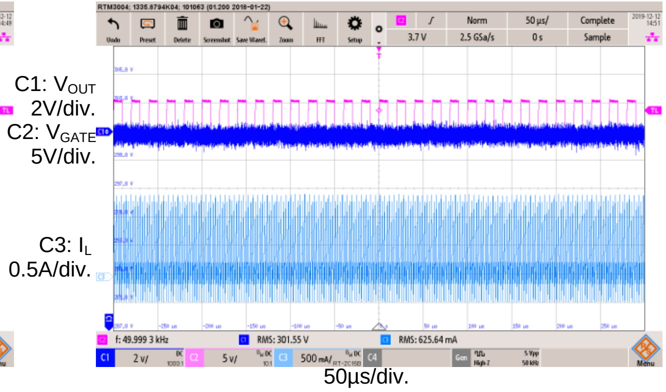


Figure 26: Repetitive Load Step, 50kHz

I_{OUT} = 0mA to 10mA

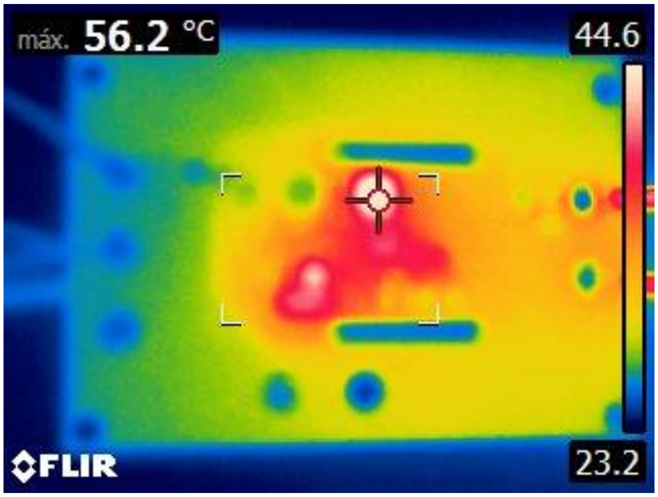


4.3 Thermal Measurements

V_{IN} = 12V, V_{OUT} = 300V, L = 12µH, f_{SW} = 375kHz, T_A = 25°C, 2h runtime

Figure 27: Thermal Image

I_{OUT} = 10mA



4.4 EMC Measurements

V_{IN} = 12V, V_{OUT} = 300V, I_{OUT} = 10mA L = 12µH, f_{SW} = 375kHz, T_A = 25ºC, with shield.

This circuit has an aggressive square signal in its switch node, and a high dV/dt due to the voltage swing, which is generally 150V. The high dV/dt creates strong electric fields, which can lead to noise coupling with 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 vehicle that could act as a shield for the electric fields.

If this solution is not feasible, place a small metallic shield over the noisy area of the PCB. This shield should cover the inductor, MOSFET, rectifier, and output capacitors. This approach was used to test this PCB as a standalone device for this document. Figure 28 and Figure 29 show how to place a shield on the PCB.

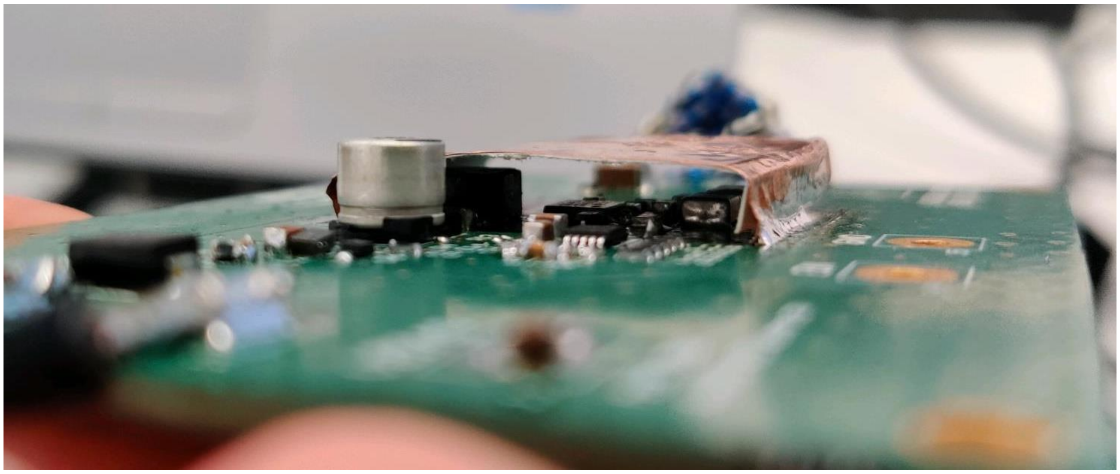


Figure 28: PCB with Local Copper Shield

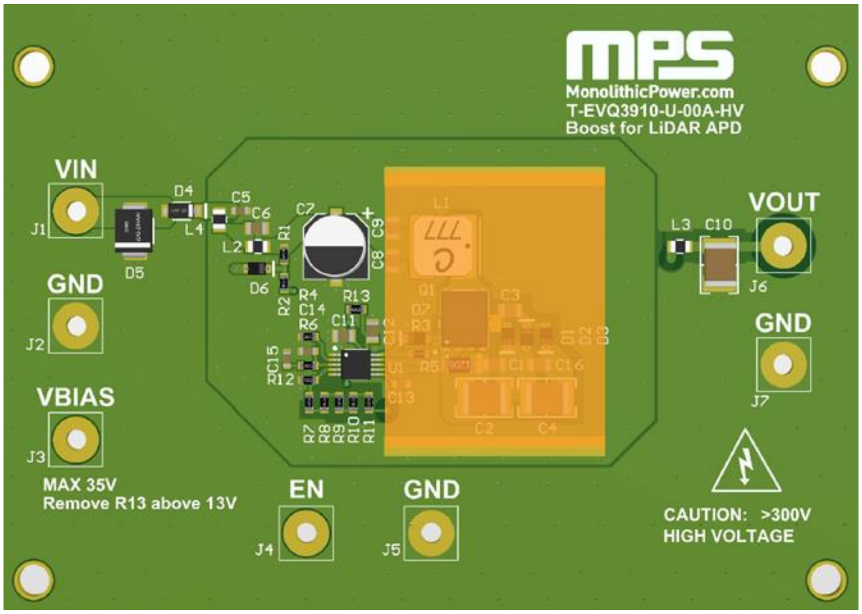


Figure 29: Area Covered by Copper Shield

Figure 30 and Figure 31 show the test results from CISPR25 Conducted Emissions and Radiated Emissions tests performed with this board in an ALSE.

Figure 30: CISPR25 Class 5 Conducted Emissions

150kHz to 108MHz

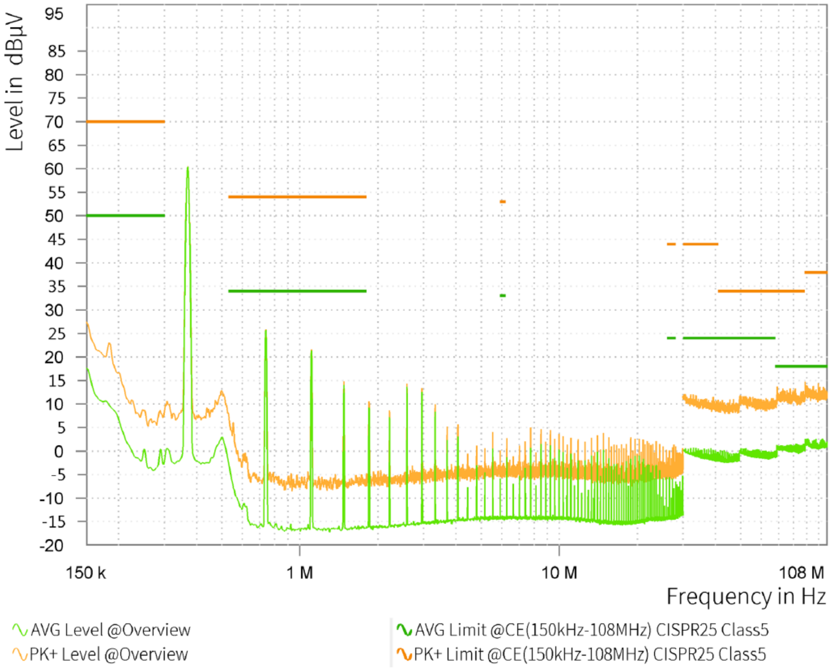
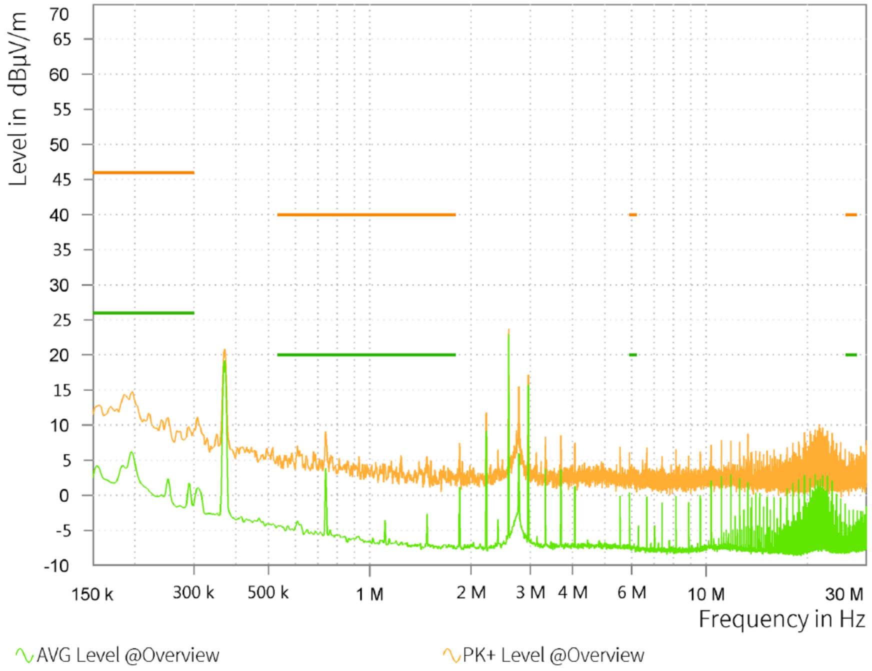


Figure 31: CISPR25 Class 5 Radiated Emissions

150kHz to 30MHz



5 Start-Up

1. Connect the load to:
    a. Positive (+): VOUT
    b. Negative (-): GND

    Ensure that the load is suited for voltages exceeding 300V. Electronic loads introduce a negative impedance to the regulator, so if the current is set too high, it can trigger over-current protection (OCP) or short-current protection (SCP).
2. Preset the power supply output between 3V and 30V, then turn off the power supply.
3. Connect the power supply output to:
    a. Positive (+): VIN
    b. Negative (-): GND
4. If the input voltage is set to exceed 13V, remove R13.
5. If the input voltage is below 5V, remove R1 and connect an auxiliary power supply (up to 13V) to VBIAS.
6. Turn the power supply on. The board should automatically start up. The default output voltage (V_{OUT}) is 300V.
7. The external resistor dividers (R7–R12) are used to set V_{OUT}. For V_{OUT} to be equal to 300V, the sum of R7–R11 must be 482kΩ, and R12 must be 2kΩ. R12 can be calculated with Equation (1):

$$R12 = \frac{R11}{\frac{V_{OUT}}{1.237} - 1} \quad (1)$$

8. To increase the output current capabilities, rework the high-power parts on the board. Ensure that T_J does not exceed 175°C on the external discrete semiconductors.

6 Disclaimer

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Inclusion of MPS products in critical applications is understood to be fully at the risk of the customer.

Questions concerning potential risk applications should be directed to MPS.

MPS semiconductors are typically used in power supplies in which high voltages are present during operation. High-voltage safety precautions should be observed in design and operation to minimize the chance of injury.

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	10/10/2022	Initial Release	-
1.1	10/20/2022	Updated features (external sync clock)	3