AN185

MPQ5850: 36V, Smart Diode Controller with Reverse Protection, AEC-Q100

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ABSTRACT

The MPQ5850 is a 36V, smart diode controller with reverse polarity protection designed for automotive applications.

The device can rectify alternating voltages up to 100kHz. For example, the MPQ5850 can rectify alternating voltages for a faulty automotive alternator or DC switching power supply.

In switching applications (e.g. O-rings), the MPQ5850 prevents negative currents from flowing back through a power supply unit or a battery.

The MPQ5850 can replace a power diode or an unregulated P-channel MOSFET rectifier solution with a regulated N-channel MOSFET. Replacing either of these with the MPQ5850 reduces power loss and temperature.

INTRODUCTION

The MPQ5850 drives an external N-channel MOSFET and converts it to an active diode with a 20mV forward voltage drop. AN185 shows examples of this, such as LV124 AC rectification, ISO pulses, and parallel connection of voltage sources (e.g. O-rings).

MPQ5850 Applications

The MPQ5850 applications are listed below:

- Automotive System Protections, Reverse Polarity
- Automotive Systems, LV124 and ISO Pulses
- Automotive Advanced Driver-Assistance Systems (ADAS), Cameras
- Automotive Infotainment Systems, Including Digital Clusters and Head Units
- Battery-Powered Systems
- O-Rings

EVQ5850-J-00A EVALUATION BOARD

The EVQ5850-J-00A is an evaluation board designed to demonstrate the capabilities of the MPQ5850. A large number of circuits can be tested on the evaluation board. The EVB layout also allows EMC filters to be tested at the input and the output.

Evaluation Board Layout

Figure 1 shows the evaluation board with a TVS diode, an optional EMC input filter, and an optional EMC output filter, prepared for different MOSFET packages.

Figure 1: EVQ5850-J-00A (4-Layer PCB)

BASIC AUTOMOTIVE MEASUREMENTS

Figure 2 shows the typical application circuit used for LV124 and ISO pulse measurements. This circuit is suitable for a wide range of applications.

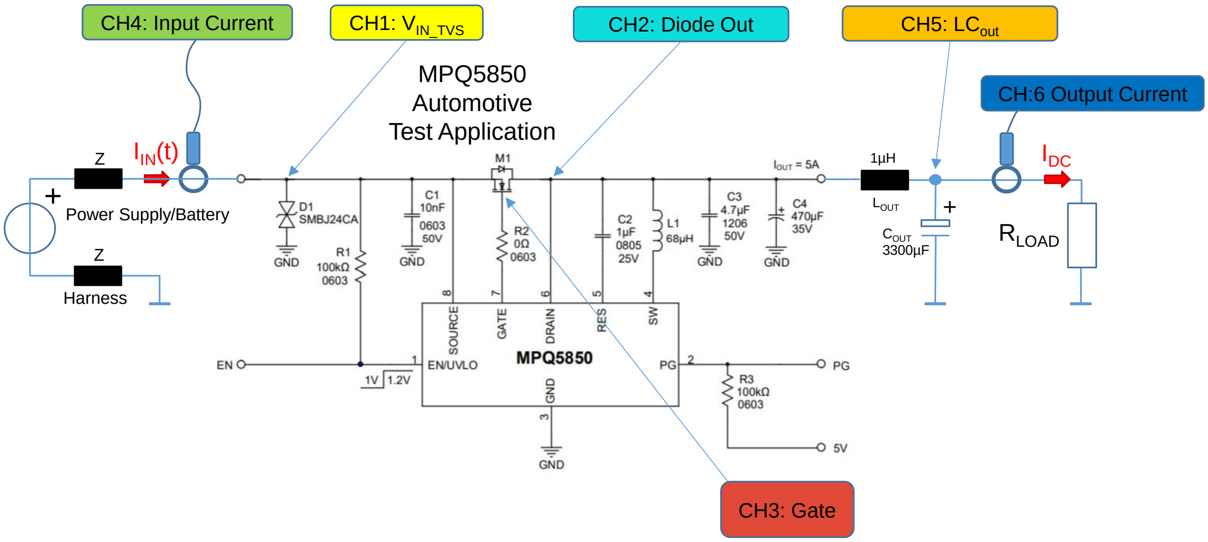


Figure 2: MPQ5850 Automotive Test Application for LV124 and ISO Pulse Measurements (1) (2)

LV124 Measurement

LV124 is a quality and reliability test standard jointly established by German automotive manufacturers, applied to in-vehicle electric components for the 12V electrical system.

The LV124 measurements are made using an Ametek 200Q series voltage-drop simulator (VDS 200Q) and a 180cm harness with an impedance (Z). Each power supply line consists of an impedance (Z) that is measured with an impedance LCR meter for inductance (L) and resistance (R). The impedance (Z) can be calculated with Equation (1):

$$Z = L(\mu H) + R(m\Omega) \tag{1}$$

Where L is 1.1µH, R is 17.5mΩ, and the harness length is 180cm.

ISO 7637-2 Pulse Measurement

The ISO 7637-2 standard defines specific test methods and procedures to ensure that a part's conducted electrical transients are compatible with the passenger cars and commercial vehicles (with 12V or 24V electrical systems) in which the part is installed.

The pulse measurements are made using an Ametek 200N series ultra-compact simulator (UCS 200N), a 200N series load dump generator (LD200N), a 50cm harness with an impedance (Z), and thin lab cables. The impedance (Z) can be calculated with Equation (1). Where L is 0.5µH, R is 15mΩ, and the harness length is 50cm.

Select the optional LC_{OUT} filter for the desired hold-up time. Select D1 for the required pulse strength.

Optional LC_{OUT} Not In Use

The C4 capacitor should be ≥220µF; however, it is recommended that C4 be ≥470µF.

Notes:

1) C1, C3, D1, and LC_{OUT} can be different from the values listed in Figure 2. The minimum C1 is 10nF. A larger C1 improves the stability of the source voltage (V_{SOURCE}). Choose C1 to meet the application's EMC requirements.
2) The C3 capacitor is optional. C3 rejects EMC transients between V_{SOURCE} and the drain voltage (V_{DRAIN}). The MPQ5850 is supplied by V_{DRAIN} internally. C3 can be below 4.7µF.

CONTROL MODES

The MPQ5850 has two control modes: mode A and mode B. The MOSFET source to drain voltage (V_{SOURCE_DRAIN}) can be calculated with equation (2):

$$V_{SOURCE\_DRAIN} = I_{DRAIN} \times R_{(DS)ON} \tag{2}$$

Where I_{DRAIN} is the drain current, and $R_{(DS)ON}$ is the on resistance.

In mode A, V_{SOURCE_DRAIN} is in regulation (20mV), and the MOSFET operates within the analog range. $R_{(DS)ON}$ is set at a higher value than the minimum $R_{(DS)ON}$. The MPQ5850 control loop adjusts $R_{(DS)ON}$ for a constant 20mV V_{SOURCE_DRAIN}.

In mode B, V_{SOURCE_DRAIN} is not in regulation (>20mV), and the gate to source voltage (V_{GATE_SOURCE}) turns on the MOSFET fully. $R_{(DS)ON}$ is set to the minimum $R_{(DS)ON}$ value. The MPQ5850 drives V_{GATE_SOURCE} to its maximum voltage (12V).

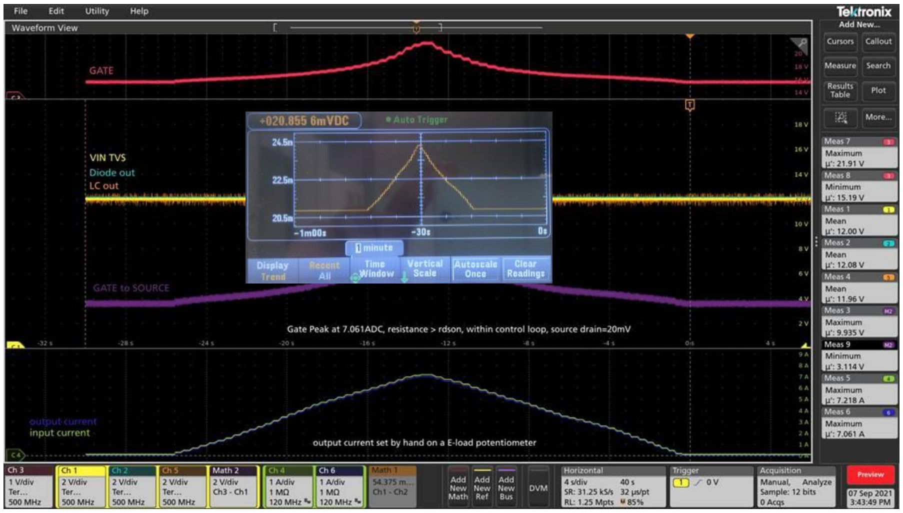
The MPQ5850 transitions between mode A and mode B automatically.

If the rated current is low, then the MPQ5850 operates in mode A. If the rated current is high, then the device operates in mode B.

Select the MOSFET according to the desired $R_{DS(ON)}$ and power dissipation. The MPQ5850 can drive most common-sized N-channel MOSFETs. This included both standard and logic-level MOSFETs.

Mode A (V_{SOURCE_DRAIN} Is in Regulation)

Figure 3 shows a measurement in mode A. V_{GATE_SOURCE} is 9.935V, which is below the maximum V_{GATE_SOURCE} (12V). The MOSFET has not reached the minimum $R_{DS(ON)}$. V_{SOURCE_DRAIN} is measured using a digital multimeter.



Gate Peak at 7.061ADC, resistance > rdson, within control loop, source drain=20mV

output current set by hand on a E-load potentiometer

Meas 7 Maximum µ': 21.91 V
Meas 8 Minimum µ': 15.19 V
Meas 1 Mean µ': 12.00 V
Meas 2 Mean µ': 12.08 V
Meas 4 Mean µ': 11.96 V
Meas 3 Maximum µ': 9.935 V
Meas 9 Minimum µ': 3.114 V
Meas 5 Maximum µ': 7.218 A
Meas 6 Maximum µ': 7.061 A

Ch 3: 1 V/div, Ter..., 500 MHz
Ch 1: 2 V/div, Ter..., 500 MHz
Ch 2: 2 V/div, Ter..., 500 MHz
Ch 5: 2 V/div, Ter..., 500 MHz
Math 2: 2 V/div, Ch3 - Ch1
Ch 4: 1 A/div, 1 MΩ, 120 MHz
Ch 6: 1 A/div, 1 MΩ, 120 MHz
Math 1: 54.375 m..., Ch1 - Ch2
Horizontal: 4 s/div, 40 s, SR: 31.25 kS/s, 32 µs/pt, RL: 1.25 Mpts, 85%
Trigger: 1, 0 V
Acquisition: Manual, Analyze, Sample: 12 bits, 0 Acqs
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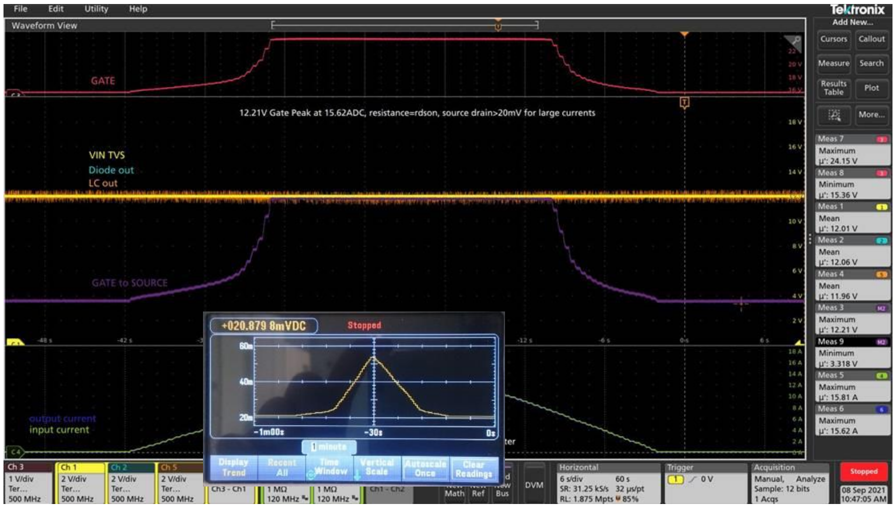
Figure 3: Mode A (V_{SOURCE_DRAIN} = 20mV, I_{LOAD} = 7A)

Mode B (V_{SOURCE_DRAIN} Is Not in Regulation)

Figure 4 shows a measurement in mode B. V_{GATE_SOURCE} is 12.21V, which exceeds the maximum V_{GATE_SOURCE} (12V). The MOSFET has reached the minimum $R_{DS(ON)}$. V_{SOURCE_DRAIN} is measured using a digital multimeter.



12.21V Gate Peak at 15.62ADC, resistance=rdson, source drain>20mV for large currents

+020.879 8mVDC Stopped

Meas 7 Maximum µ': 24.15 V
Meas 8 Minimum µ': 15.36 V
Meas 1 Mean µ': 12.01 V
Meas 2 Mean µ': 12.06 V
Meas 4 Mean µ': 11.96 V
Meas 3 Maximum µ': 12.21 V
Meas 9 Minimum µ': 3.318 V
Meas 5 Maximum µ': 15.81 A
Meas 6 Maximum µ': 15.62 A

Ch 3 1 V/div Ter... 500 MHz
Ch 1 2 V/div Ter... 500 MHz
Ch 2 2 V/div Ter... 500 MHz
Ch 5 2 V/div Ter... 500 MHz
Horizontal 6 s/div 60 s SR: 31.25 kS/s 32 µs/pt RL: 1.875 Mpts 85%
Trigger 1 0 V
Acquisition Manual, Analyze Sample: 12 bits 1 Acqs
Stopped
08 Sep 2021 10:47:05 AM

Figure 4: Mode B (V_{SOURCE_DRAIN} = 54mV, I_{LOAD} = 12A)

EXAMPLE ISO 7637-2 TEST PULSE

The MPQ5850 has a robust design to survive ISO pulses with the use of TVS diodes. Figure 5 shows an ISO7637 test pulse. See Figure 2 on page 5 for the schematic and oscilloscope channel names.

The following are the conditions of Figure 5:

- A: V_{GATE_SOURCE} is 6.5V, I_{LOAD} is 6A, and the MOSFET is within the 20mV control loop
- B: Reverse voltage (D1 is conducting and a negative input current is flowing)
- C: Hold-up time (the load supplied by LC_{OUT})
- D: A 3.3V regulator on the PCB has too low of a voltage at LC_{OUT}

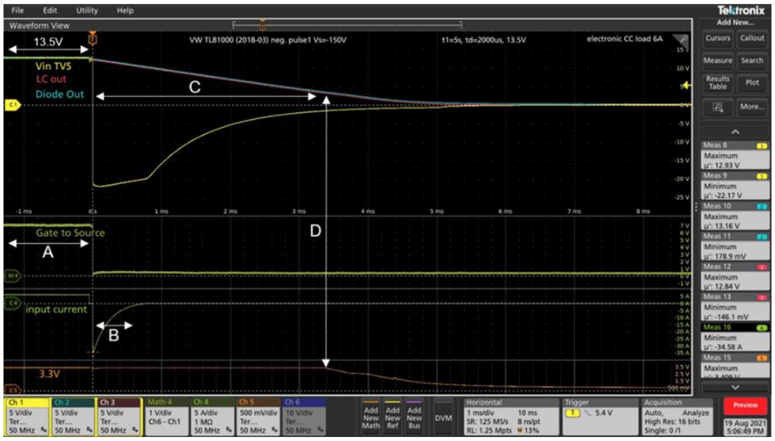


Figure 5: ISO 7637-2 Test Pulse (Pulse Generator Amplitude = -150V, I_{LOAD} = 6A, 50cm Harness)

Surviving an ISO pulse is dependent on the dimensioning of the TVS diode, the wiring harness inductance, and C1. These passive components should ensure that V_{SOURCE} remains within the absolute maximum ratings range (-36V to 42V). A longer harness increases the inductance of the low pass series element, which helps the device withstand a higher pulse energy.

The MPQ5850 is supplied via V_{DRAIN}. It stops the gate activity If V_{DRAIN} drops below the typical 2.6V under-voltage lockout (UVLO) threshold (typically 2.6V), then the device stops the gate activity (see Figure 6 on page 9). During the hold-up time, the capacitance of the electrolytic output capacitor (C4) should be large enough to keep V_{DRAIN} above the UVLO threshold.

Pulse Operation

The MPQ5850 is designed to survive ISO pulses in an automotive environment. The device provides the following features to survive ISO pulses in automotive applications:

- -36V Blocking Voltage
- Load Dump Up to 42V
- V_{DRAIN} UVLO Threshold (Typically 2.6V)
- TVS Diode and LC Series Element (Harness + C1) to Define Passing ISO Pulses

Refer to the Selecting the TVS Diode section in the MPQ5850 datasheet for more details.

The minimum required output capacitor (C4) is determined by the V_{SOURCE} amplitude and frequency, I_{LOAD}, and the required hold-up time. Refer to the Selecting the Electrolytic Capacitor and Ripple Voltage section in the MPQ5850 datasheet for more details.

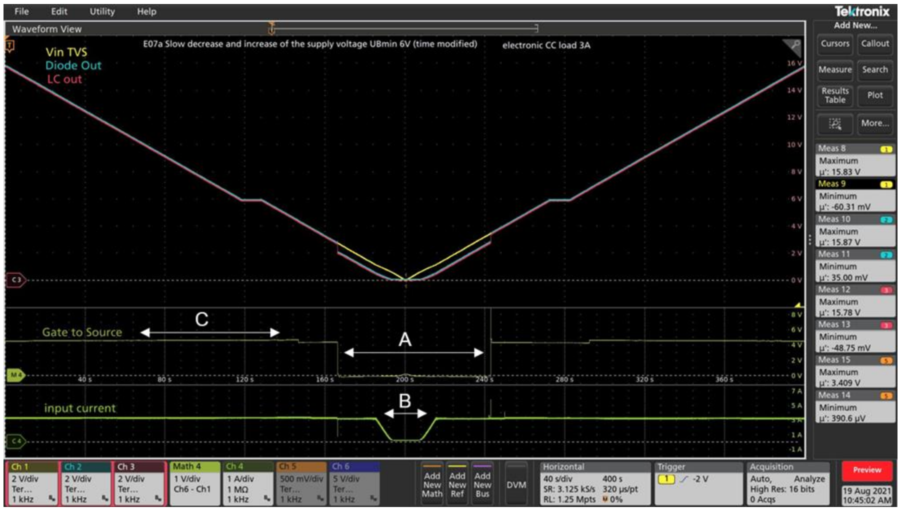
While testing the transient ISO pulses or the minimum output capacitance, use an oscilloscope to measure V_{SOURCE}, V_{DRAIN}, V_{GATE_SOURCE}, the power good voltage (V_{PG}) and (V_{RES}). V_{RES} supplies the booster circuit of the high-side MOSFET (HS-FET) gate driver. Check V_{RES} for stability, while applying transient test signals to V_{SOURCE}.

EXAMPLE LV124 E-07a TEST (V_{SUPPLY} DECREASES AND INCREASES)

The MPQ5850 can process many automotive LV124 cases (e.g. starter pulses, reset pulses, and rectification). Figure 6 shows an LV124 E-07a test where V_{SUPPLY} decreases and increases slowly, with a V_{DRAIN} UVLO threshold (typically 2.5V).

The following are the conditions of Figure 6:

- A: V_{GATE_SOURCE} is 0V (the device has stopped all gate activity, the MOSFET turns off). If V_{DRAIN} drops below 2.6V, then UVLO protection is triggered. The gate switches on once V_{DRAIN} exceeds the start-up voltage (typically 2.8V).
- B: The MOSFET body diode turns off and stops conducting
- C: V_{GATE_SOURCE} is 4.5V, I_{LOAD} is 3A, and V_{SOURCE_DRAIN} has a 20mV drop



E07a Slow decrease and increase of the supply voltage UBmin 6V (time modified)

electronic CC load 3A

Meas 8 Maximum µ': 15.83 V

Meas 9 Minimum µ': -60.31 mV

Meas 10 Maximum µ': 15.87 V

Meas 11 Minimum µ': 35.00 mV

Meas 12 Maximum µ': 15.78 V

Meas 13 Minimum µ': -48.75 mV

Meas 15 Maximum µ': 3.409 V

Meas 14 Minimum µ': 390.6 µV

Ch 1: 2 V/div, Ter..., 1 kHz

Ch 2: 2 V/div, Ter..., 1 kHz

Ch 3: 2 V/div, Ter..., 1 kHz

Math 4: 1 V/div, Ch6 - Ch1

Ch 4: 1 A/div, 1 MΩ, 1 kHz

Ch 5: 500 mV/div, Ter..., 1 kHz

Ch 6: 5 V/div, Ter..., 1 kHz

Horizontal: 40 s/div, 400 s, SR: 3.125 kS/s, 320 µs/pt, RL: 1.25 Mpts, 0%

Trigger: 1, -2 V

Acquisition: Auto, Analyze, High Res: 16 bits, 0 Acqs

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Figure 6: LV124 E07a Test (I_{LOAD} = 3A, 180cm Harness)

While testing the LV124 cases, use an oscilloscope to measure V_{SOURCE}, V_{DRAIN}, V_{GATE_SOURCE}, V_{PG}, and V_{RES}.

EXAMPLE LV124 E06 TEST (SUPERIMPOSED AC RECTIFICATION)

One of the primary tasks of a diode controller to rectify automotive LV124 AC input voltages. Figure 7 shows an LV124 E06 test of AC rectification at 1kHz, where V_{SOURCE} is $34V_{PEAK\_PEAK}$ and I_{LOAD} is 10A.

Figure 7: LV124 E06 Test ($V_{SOURCE} = 34V_{PEAK\_PEAK}$, Superimposed AC Rectification, FREQ = 1kHz, I_{LOAD} = 10A, $P_{IN} = 843W_{PEAK}$, 180cm Harness)

V_{SOURCE} has a wide -18V to +16V voltage range (see Figure 7). The MPQ5850 operates with a negative V_{SOURCE}, and allows for rectification up to 100kHz. There are no negative input currents, or energy from the electrolytic output capacitor flowing into the power supply.

Hold-Up Time

During the hold-up time, I_{LOAD} (10A) is supplied via C4. Under active V_{GATE_SOURCE}, C4 is charged by a large $56A_{PEAK}$. The time accuracy and fast switching of the MPQ5850 gate driver reduces switching losses in the MOSFET.

Power Dissipation: MPQ5850 Solution vs. Rectifier Diode Solution (Schottky or Silicon)

The MPQ5850 can reduce heat dissipation on the PCB significantly. The maximum power dissipation in the rectifier diode (P_{LOSS_DIODE}) can be calculated with Equation (3):

$$P_{LOSS\_MOSFET} = R_{(DS)ON} \times I_{SOURCE\_PEAK}^2 \tag{3}$$

The maximum power dissipation in the MOSFET (P_{LOSS_MOSFET}) can be calculated with Equation (4):

$$P_{LOSS\_DIODE} = V_{ANODE\_CATHODE} \times I_{SOURCE\_PEAK} \tag{4}$$

For example, if $R_{(DS)ON}$ is 3mΩ, $V_{ANODE\_CATHODE}$ is 700mV, and the measured peak current (I_{SOURCE_PEAK}) is 56A, then P_{LOSS_MOSFET} in the MPQ5850 solution is $9.4W_{PEAK}$ and P_{LOSS_DIDOE} in the rectifier diode solution is $39W_{PEAK}$

Power Dissipation: MPQ5850 Solution vs. P-channel MOSFET Solution

There are advantages of using an N-channel MOSFET solution in place of the more commonly used, unregulated rectifier, P-channel MOSFET solution. For example, in an N-channel MOSFET solution, the MPQ5850's gate driver operates with closed-loop control, and is independent from V_{SOURCE}. This reduces power dissipation significantly across a wide voltage and frequency range. In the MPQ5850 solution, the N-channel MOSFET type can also be exchanged without making any circuit changes. Adjustments are often necessary in a P-channel MOSFET solution.

Example LV124 E06 Test (Superimposed AC Rectification at 100kHz, I_{LOAD} = 6A)

At higher rectifier frequencies, the influence of the low-pass wiring harness increases. The inductance of the wire harness greatly reduces the amplitude of the LV124 generator, and V_{SOURCE} almost becomes a DC voltage.

Figure 8 shows An LV124 E06 test of AC rectification at 100kHz, where I_{LOAD} is 6A.

Figure 8: LV124 E06 Test (AC Rectification, FREQ = 100kHz, I_{LOAD} = 6A, 2cmx180cm Harness)

At 100kHz AC rectification, the harness inductance can be used as an effective series element in a low-pass filter.

The LV124 generator output applied to the harness (13V + $1V_{PP}$ at 100 kHz) combined with the low-pass filter becomes almost a DC voltage.

Consider the required automotive specifications, and whether there is a harness in application. If there is a harness, take its length into consideration.

With a harness (180cm), the MPQ5850 should pass the 100kHz test easily (see Figure 8). See Figure 9 below and Figure 10 on page 12 for comparison. The tests shown in these figures use a harness that is only a few centimeters in length.

Example LV124 E06 Test (Superimposed AC Rectification at 10kHz and 100kHz, P_{OUT} = 7.5W)

Figures 9 shows an LV124 E06 test of AC rectification at 100kHz, with a short cable harness (only a few centimeters in length) and low inductance.

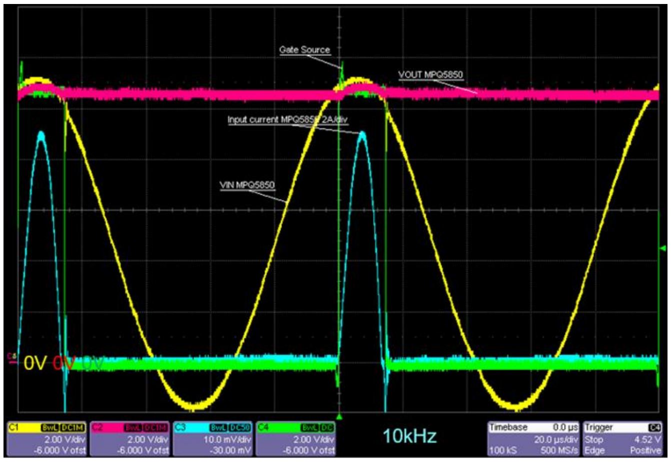


Figure 9: LV124 E06 Test (AC Rectification, FREQ = 10kHz, P_{OUT} = 7.5W, short harness, C4 = 470µF, without LC_{OUT})

Figure 10 shows an LV124 E06 test of AC rectification at 10kHz with a short cable harness (only a few centimeters in length) and low inductance.

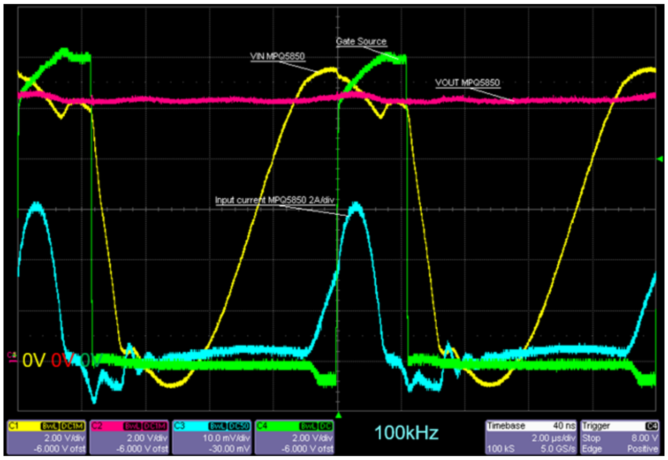


Figure 10: LV124 E06 Test (AC Rectification, FREQ = 100kHz, P_{OUT} = 7.5W, short harness, C4 = 470µF, without LC_{OUT})

Figure 9, Figure 10, and Figure 11 Descriptions

The oscilloscope screenshots in Figure 9 on page 11 and Figure 10 above are measured with a power amplifier (see Figure 11 on page 13). This power amplifier drives the input capacitance (C_{IN}) of the evaluation board without the inductance of a damping harness. C_{IN} can be calculated with Equation (5):

$$C_{IN} = C1 + C_{D1} + C3 + C4 \tag{5}$$

If V_{SOURCE} exceeds V_{DRAIN}, then C3 and C4 are in series with the M1's $R_{(DS)ON}$.

Figure 9 and Figure 10 show the MPQ5850's excellent AC rectification at 10kHz and 100kHz. If V_{SOURCE} drops below 0V, the MPQ5850 remains on and is supplied by the rectified and stable V_{DRAIN}.

The MPQ5850 rectifies V_{SOURCE} to $13V_{PP}$ without a damping harness at both 10kHz and 100kHz.

The test in Figure 9 simulates an extreme failure in an automotive input environment at 10kHz, and shows how the MPQ5850 can handle this type of fault event. The test in Figure 10 simulates the same failure at 100kHz, and shows how the MPQ5850 can handle this type of fault event.

Figure 11 shows a power amplifier used for the tests shown in Figure 9 and Figure 10.

The EVQ5850-J-00A PCB has been cut into two pieces with a saw to minimize the distance between amp_{OUT} and V_{SOURCE}. This minimizes the inductance.

A smaller inductance allows for measurements at 10kHz or 100kHz to apply a large V_{SOURCE} amplitude. Figure 9 and 10 are extreme examples, which show that the MPQ5850 solution can handle large signal amplitudes at high frequencies.

A longer inductive harness is often installed in automobiles with the PCB capacitors as a second-order, low-pass filter to reduce the V_{SOURCE} amplitude at higher frequencies. The MPQ5850 can handle both long harnesses and low-inductance connections at the power supply.

The ground connection between the amplifier and the evaluation board is made of solid copper, and has a low inductance.

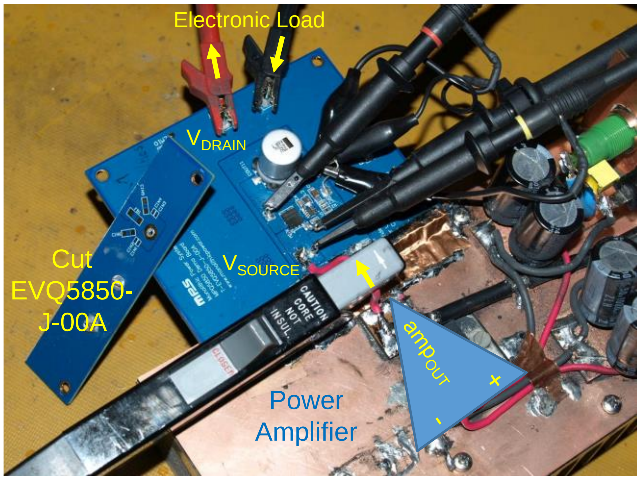


Figure 11: Power Amplifier Provides AC Rectification at Higher Frequencies without a Harness

O-RING EXAMPLES

The MPQ5850 can parallel several power sources to a common output (see Figure 12).

O-Ring Applications

The MPQ5850 O-ring applications are listed below:

- Multiple Paralleled Power Sources
- Power Source Reverse Current Protection
- Plug and Play Sources, Connect and Disconnect
- Equal Voltages Sharing I_{LOAD}
- Paralleled Battery Packs

The MPQ5850 converts a MOSFET to an active diode with a 20mV drop.

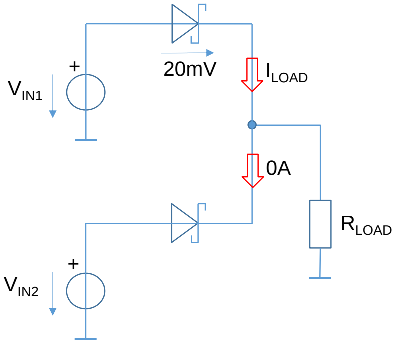


Figure 12: Two MPQ5850 in Parallel to Supply a Common Load (V_{IN1} > V_{IN2})

If V_{IN1} exceeds V_{IN2}, then V_{IN1} supplies the load and there is no current flowing through the diode.

Example O-Ring Schematic with Two Evaluation Boards

There are 16 possible way to use two sources in an O-ring application with two sources (open or closed). Figure 13 shows two MPQ5850s in parallel supplying a common load.

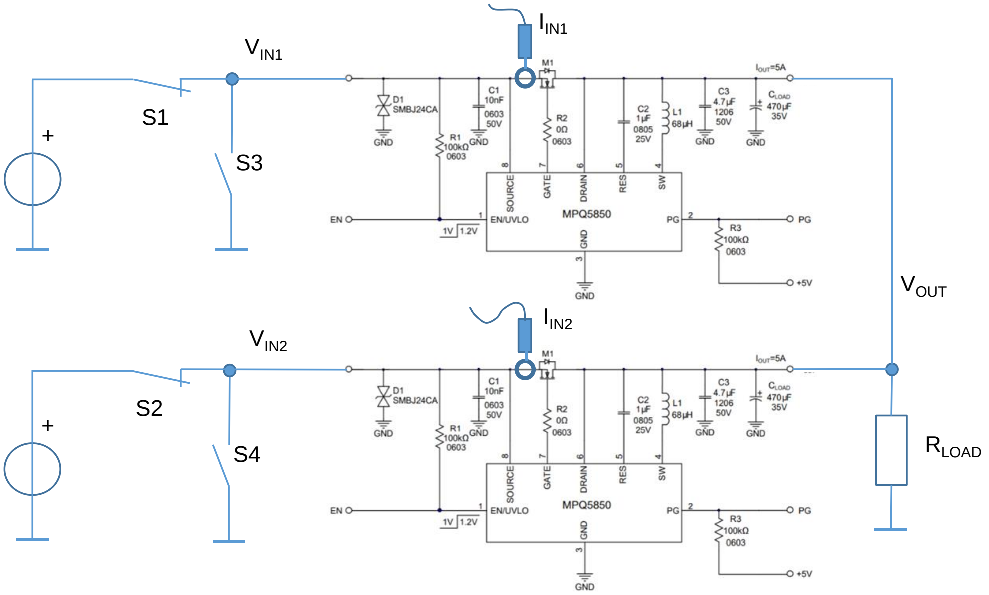


Figure 13: Two MPQ5850s in Parallel Supplying a Common Load

S3 (closed) and S4 (closed) represent a short on the power supply. S1 and S2 represent a connected power supply with a removed or a failed wire interrupt.

Table 1 shows 16 cases of two MPQ5850s used in O-ring applications.

Table 1: Cases of Two MPQ5850s in O-Ring Applications

Case	S1	S2	S3	S4	V_{OUT}	Current Flow into Second Power Supply
1	Open	Open	Open	Open	0V	No
2	Open	Open	Open	Closed	0V	No
3	Open	Open	Closed	Open	0V	No
4	Open	Open	Closed	Closed	0V	No
5	Open	Closed	Open	Open	V_{IN2}	No
6	Open	Closed	Open	Closed	0V	No
7	Open	Closed	Closed	Open	V_{IN2}	No
8	Open	Closed	Closed	Closed	0V	No
9	Closed	Open	Open	Open	V_{IN1}	No
10	Closed	Open	Open	Closed	V_{IN1}	No
11	Closed	Open	Closed	Open	0V	No
12	Closed	Open	Closed	Closed	0V	No
13	Closed	Closed	Open	Open	V_{IN1} or V_{IN2} (whichever is higher)	No
14	Closed	Closed	Open	Closed	V_{IN1}	No
15	Closed	Closed	Closed	Open	V_{IN2}	No
16	Closed	Closed	Closed	Closed	0V	No

A common requirement for O-ring applications is that current cannot flow from one power supply back into the other power supply. This condition is met in all of the 16 cases listed in Table 1. The MPQ5850 blocks the drain to source currents in the MOSFET using fast turn-off to turn the gate off once V_{DRAIN} exceeds V_{SOURCE}.

V_{IN1} or V_{IN2} can be connected or removed from the running circuit without interrupting the power in R_{LOAD}.

If V_{IN1} and V_{IN2} are connected simultaneously, the higher of the two input voltages is uses as the output.

Example O-Ring Measurement Prep

O-ring measurements require a low-inductance set-up to measure switching times accurately without ringing. An electronic short circuit is applied to V_{IN2} via a MOSFET triggered by a signal generator (see Figure 14 below and Figure 15 on page 16).

Figure 14 shows an O-ring with two evaluation boards. The low-inductance ground allows for accurate switching time measurements.

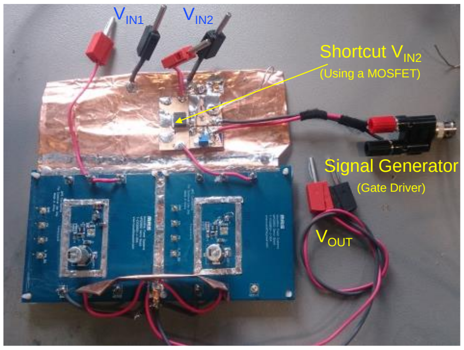


Figure 14: O-Ring with Two EVQ5850-J-00As

Figure 15 shows an N-channel MOSFET being used as an electric shortcut for V_{IN2}.

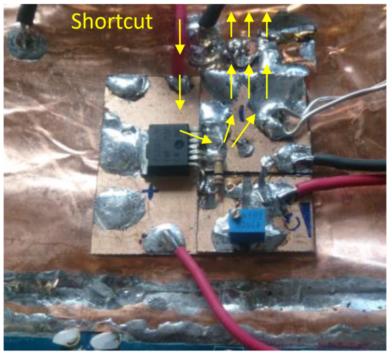


Figure 15: N-Channel MOSFET Used as an Electronic Shortcut for V_{IN2}

Figure 16 shows how to measure the current in an O-ring application.

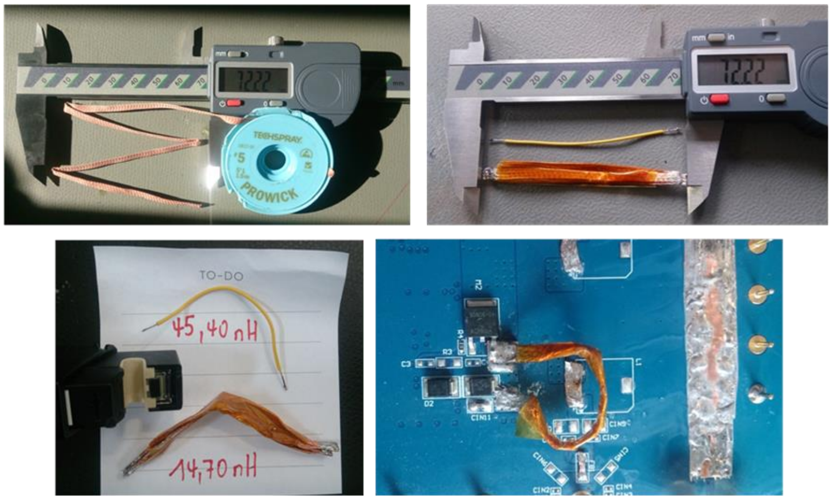


Figure 16: Current Measurement in an O-Ring Application

The current is measured at the MOSFET's source pin. Fast interrupting source currents (e.g. the MOSFET turns off) can cause ringing and voltage peaks on the PCB inductance and harness inductance. A rapidly interrupting current causes a large negative slew rate, which can be measured and expressed as the derivative $\frac{di}{dt}$.

The induced voltage (u(t)) across the inductance (L) can be calculated with Equation (6):

$$u(t) = L \times \frac{di}{dt} \tag{6}$$

The inductance should be as low as possible.

An isolated, tri-folded, de-soldering wick can reduce the current probe inductance by a factor of three (see Figure 16).

O-Ring Application: V_{IN2} Power Supply Drops

The MPQ5850 provides an ideal blocking function for the blocking current (I_{IN2}). This function prevents negative current from flowing into the power supply. Note the constant output power (P_{OUT}) and the lack of I_{IN2} current undershoot. This is the ideal behavior for the MPQ5850.

Figure 17 shows the behavior of the system with the oscilloscope setting and a 200µs/div. time base.

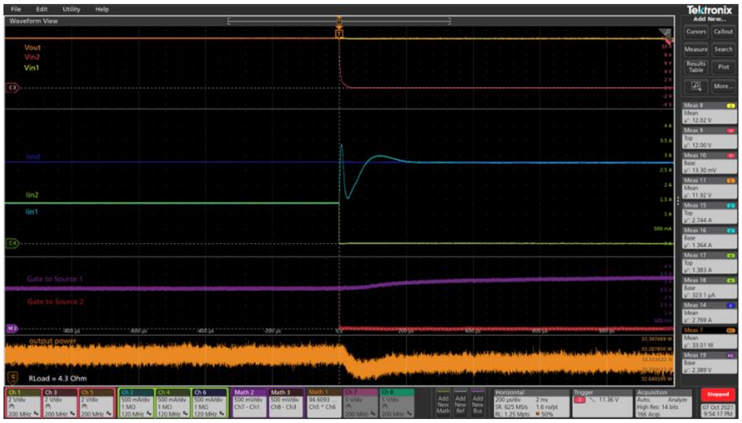


Figure 17: System Behavior (200µs/div. Time Base) (3)

Figure 18 shows the behavior of the system with a 20µs/div. time base.

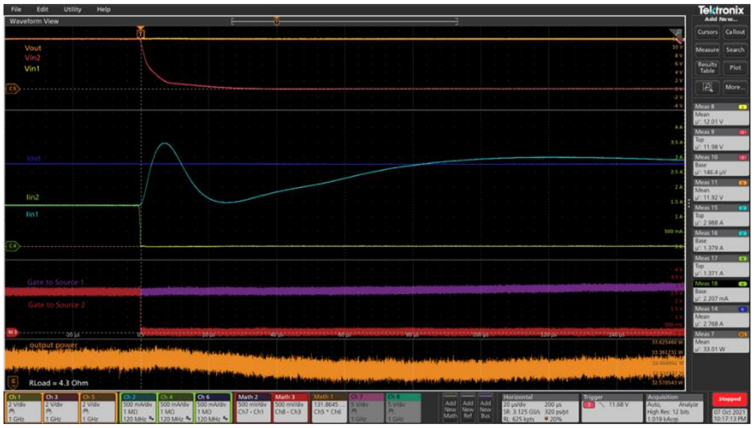


Figure 18: System Behavior (20µs/div. Time Base) (3)

I_{IN2} does not cause negative current to flow back into the source, and does not have undershoot. This provides an excellent square-wave step response when using the MPQ5850 in application. I_{IN1} has waveform distortions, and shows the step response for a sudden current rise in the harness LC tank, the input capacitance, and the electrolytic output capacitor.

Figure 19 shows the behavior of the system with a 200µs/div. time base.

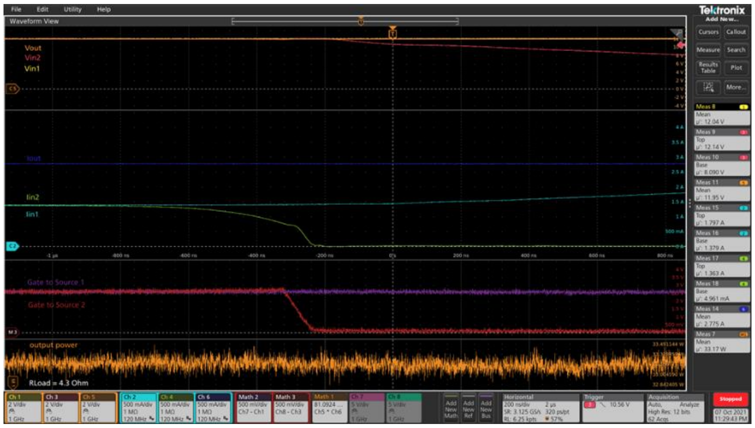


Figure 19: System Behavior (200ns/div Time Base) (3)

I_{IN2} does not cause negative current to flow back into the power supply (V_{IN2}) (see Figure 19 on page 17). The MPQ5850 provides an ideal reverse current-blocking function. The voltage probe measurement bandwidth is 1GHz, and the current probe measurement bandwidth is 120MHz. The high bandwidth makes even the shortest negative I_{IN2} peak current visible. There is no current undershoot on the falling edge of I_{IN2}, as the MPQ5850 blocks these negative currents.

O-Ring Application: O-Ring Measurement Set-Up with an Input Capacitor (C1)

Figure 20 shows the setup and Figure 21 shows a measurement not recommended for fast transient measurements of the reverse current blocking time. This measurement setup contains the currents of the input capacitance C1. However, this measurement is useful when signals are changing slowly or when the input currents of the entire system are of interest.

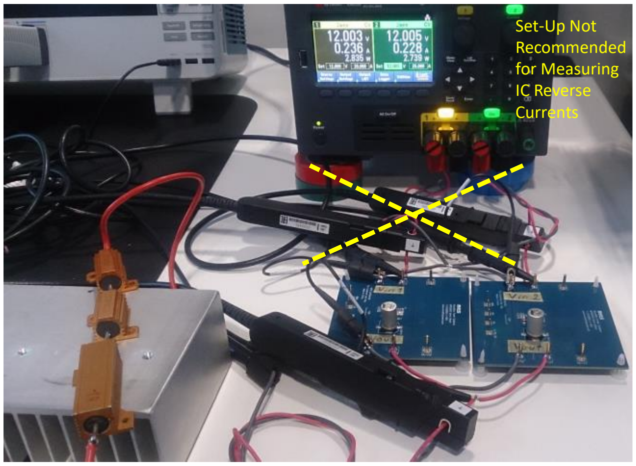


Figure 20: O-Ring Measurement Set-Up with an Input Capacitor (C1)

The I_{IN1} and I_{IN2} current probes in Figure 20 are clamped to the power supply outputs. These current probes measure I_{N1} + the 10nF input capacitor (C1) current (I_{C1}), as well as I_{N2} + I_{C1}. I_{C1} has a ringing waveform (see Figure 21).

Figure 21 shows the behavior of the system with a 1µs/div. time base, where C1 uses the lab cables and set-up shown in Figure 20.

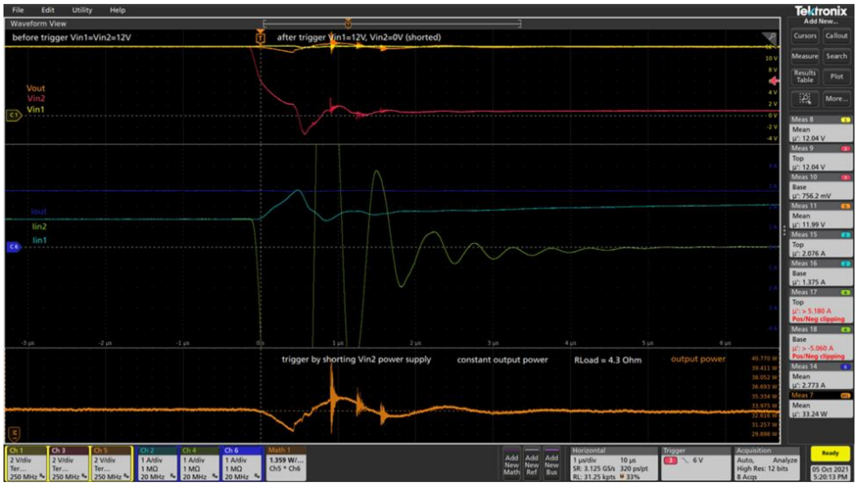


Figure 21: System Behavior (1µs/div. Time Base) (3)

The measurement shown in Figure 21 is not recommended for fast transients of the reverse-current-blocking time.

The IC does not cause I_{IN2} ringing. The lab cable inductance and C1 cause I_{IN2} ringing while using the set-up in Figure 20 on page 18. The purpose is to measure the MOSFET current from drain to source to determine whether the MPQ5850 can block the current fast enough, which it does. Do not measure the current flowing from C1 back into the power supply. Place the current probe after C1 (see Figure 13 on page 14).

O-Ring Application: Set-Up for a Long Time Base

Figure 22 and Figure 23 below, as well as Figure 24 and Figure 25 on page 20 are measured with the set-up shown in Figure 2 on page 5. The system behavior shown in these figures has been measured with a long oscilloscope time base (4ms/div.). The short transient current caused by C1 is not visible on an oscilloscope when using a long 4ms/div. time base.

Figure 22 shows the behavior of the system with a 4ms/div. time base, where P_{LOAD} is 5.6W.

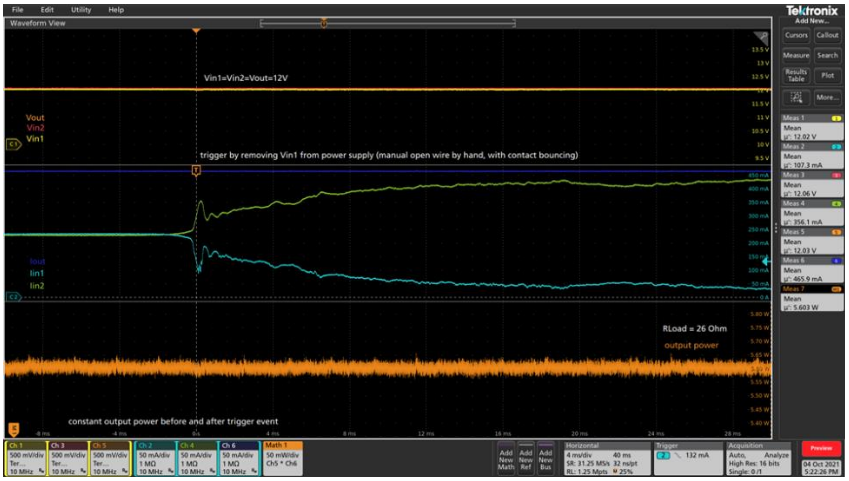


Figure 22: System Behavior (4ms/div. Time Base, P_{LOAD} = 5.6W) (4)

Note that P_{OUT} is constant, and that I_{IN1} and I_{IN2} have the same current distribution. This current distribution is possible only if both power packs are set to the same voltage. V_{IN1} and V_{IN2} remain at the same level, since no current can flow back into the open V_{IN1} supply.

Figure 23 shows the behavior of the system while the power supply is off with a 4ms/div. time base, where P_{LOAD} is 5.6W. V_{IN1} is slowly discharged via an internal circuit in the power supply.

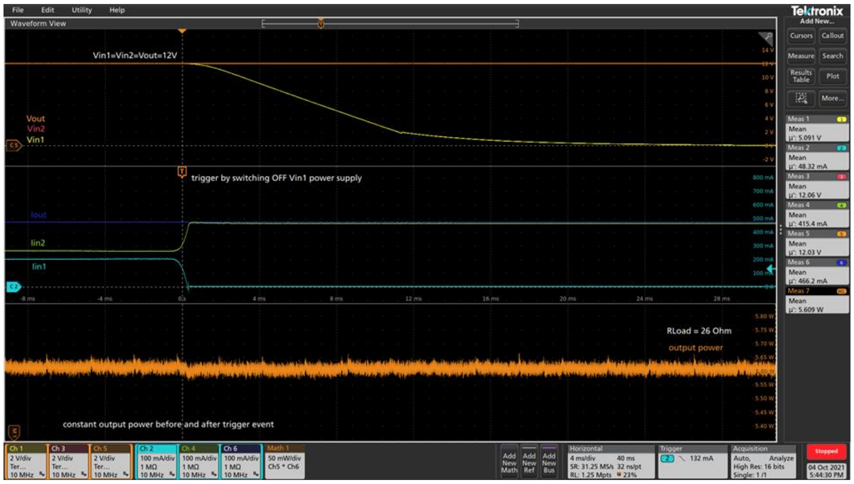


Figure 23: System Behavior (4ms/div. Time Base, V_{IN1} is Off, P_{LOAD} = 5.6W)

Figure 24 shows the behavior of the system while the power supply is off with a 4ms/div. time base where P_{LOAD} is 30W. V_{IN1} is slowly discharged via an internal circuit in the power supply.

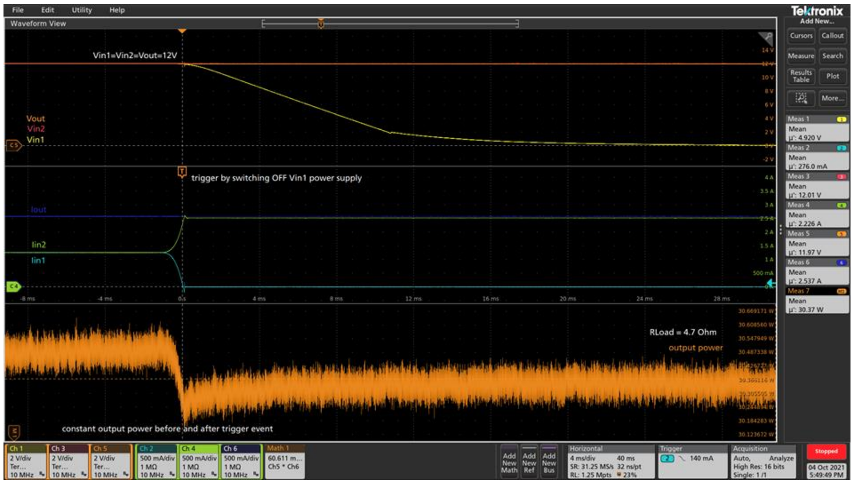


Figure 24: System Behavior (4ms/div. Time Base, V_{IN1} is Off, P_{LOAD} = 30W)

If the higher voltage (V_{IN1}) is turned off via the on/off button, then the output voltage is clamped at the lower voltage (V_{IN2}), and P_{LOAD} transitions from 41.23W to 21.14W (see Figure 25).

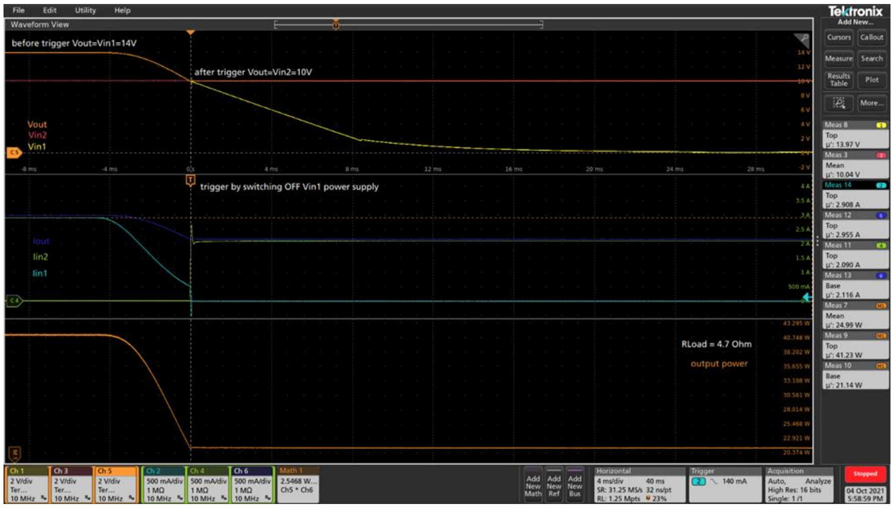


Figure 25: System Behavior (4ms/div. Time Base, P_{LOAD} = 21W) (5)

Note:

3) The V_{IN2} power rail turns off, the output is uninterrupted, and V_{IN1} is protected.
4) Open V_{IN1} by removing a cable manually from the V_{IN1} power supply.
5) The power supply voltage transitions from V_{IN1} to V_{IN2}. P_{LOAD} transitions from 41W to 21W.

REVERSE-CURRENT-BLOCKING TIME

The reverse-current-blocking time is the delay time from a detection of V_{DRAIN}>V_{SOURCE} until $V_{GATE\text{-}SOURCE}$ went low and the MOSFET has switched-off its channel.

The reverse current blocking time is related to an O-Ring application and becomes important if one power supply failed by a short-cut. A fast reverse current blocking time prevents a large current flowing from the active supply back into the failed shorten supply.

Reverse current blocking time is also important for an AC rectification application, when V_{DRAIN}>V_{SOURCE}, a fast time can stops a discharge of the output electrolytic capacitor back into the power supply. Such a negative current is unwanted, creates additional heat dissipation in the MOSFET and output electrolytic capacitor.

It is also a loss of efficiency, the amount of the reverse current in one AC period must be charged back again in the output electrolytic capacitor in the next following period.

Reverse-Current-Blocking Time Measurement Set-Up

Figure 26 shows the reverse-current-blocking time. The channel 4 input current is measured in the front of the input capacitor (C1).

The signal generator is shorted to the power supply via an N-channel MOSFET. Measure the delay time between the short and the M1 V_{GATE_SOURCE} turn-off times.

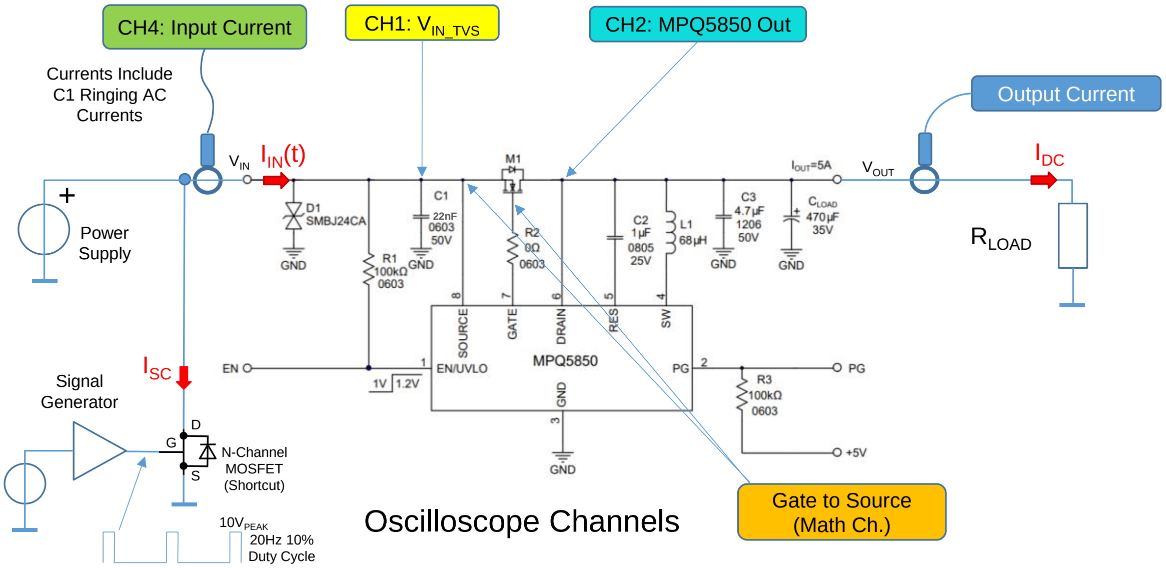


Figure 26: Reverse-Current-Blocking Time

Figure 27 shows the reverse-current blocking time measurement set-up.

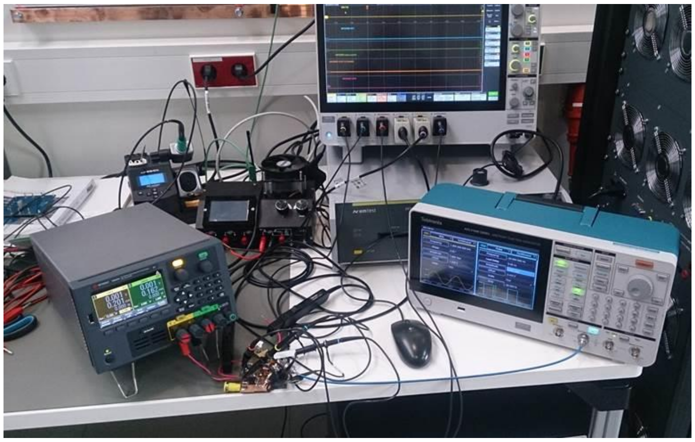


Figure 27: Reverse-Current-Blocking Time Measurement Set-Up

Figure 28 shows a small test PCB with a low ground plane inductance, which is suitable for use in the measurement set-up shown in Figure 27.

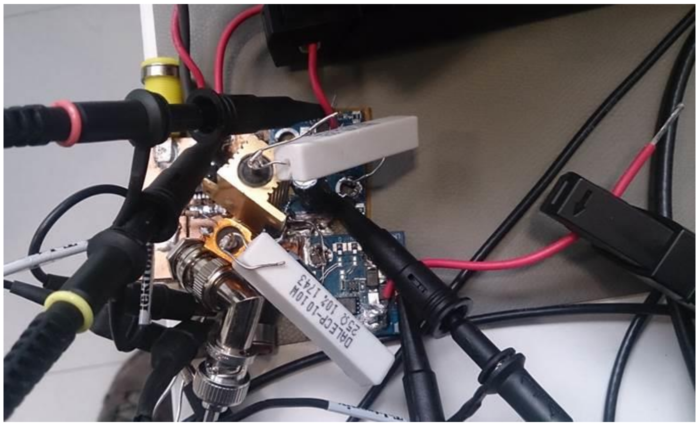


Figure 28: Small Test PCB with Low Ground Plane Inductance

Reverse-Current-Blocking Time Measurement Results

Figure 29 shows the behavior of the system with ringing caused by the wire inductance and C1.

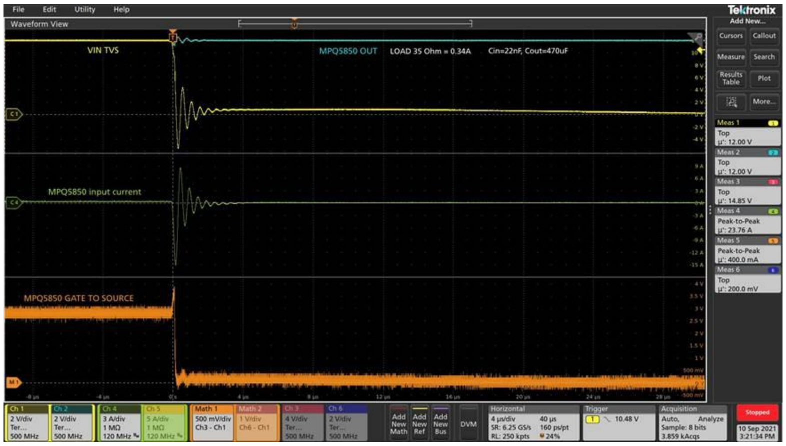


Figure 29: System Behavior (4ms/div. Time Base, V_{SOURCE} Drops Below V_{DRAIN}, R_{LOAD} = 35Ω)

The left vertical line indicates when V_{SOURCE} drops below V_{DRAIN}, and the MOSFET turns off. The reverse-current-blocking time can be defined as the delay time between when V_{SOURCE} drops below V_{DRAIN} and the V_{GATE_SOURCE} threshold.

Figure 30 shows the behavior of the system with a 100ns/div. time base.

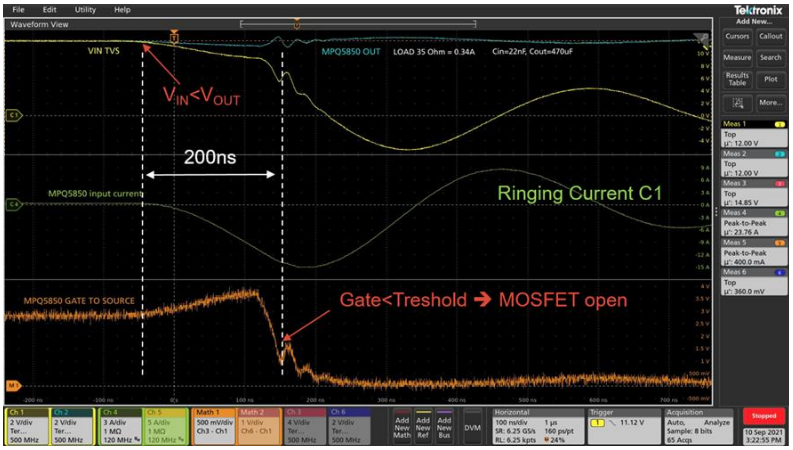


Figure 30: System Behavior (100ns/div. Time Base, V_{SOURCE} Drops Below V_{DRAIN}, R_{LOAD} = 35Ω)

BOOST GATE DRIVER

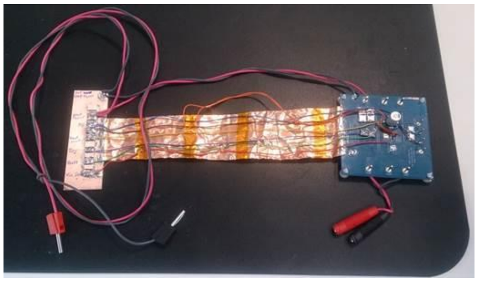
The MPQ5850 uses a boost gate driver, with the advantage of having constant gate driver performance over the full V_{SOURCE} operating and temperature range. The boost driver itself has high efficiency and the gate driver is capable to drive a wide range of N-Ch. MOSFETs under all specified conditions.

The boost inductance can be small sized in the range of approximately 33-100µH, the boost section in the MPQ5850 datasheet describes the selection. The largest minimum inductance is required under the highest V_{SOURCE}=36V and highest temperature.

The EMC caused by the boost gate driver is negligible. The frequency under V_{SOURCE}=DC is in the lower kHz range and the frequency rise with an increased gate activity, for example under AC-Rectification. In general EMC radiation requirements are specified under DC operating voltage.

An increased gate activity does not increase the boost inductance peak current, only the frequency rises. The peak currents are typical 220mA$_{PEAK}$, the magnetic field of such a low current as source for an EMC radiation is negligible, and the boost inductance must not be magnetic shielded to fulfill automotive EMC specifications. The EMC radiation caused by the boost inductance is near to the noise floor of the EMC measurement receiver.

Figure 31 shows a quick set-up for a measurement in a climate chamber.



The copper ground plane with a low inductance can be further improved with shielded wires.

Place all of the probes outside of the climate chamber, and as close as to the DUT as possible.

Figure 31: Quick Measurement Set-Up

Figure 32 shows the boost inductor waveform.

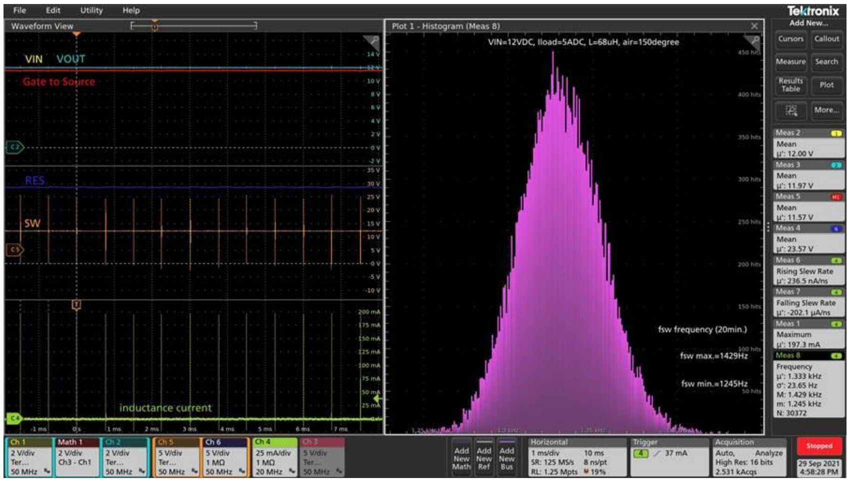


Figure 32: Boost Inductor Current Waveform (Low f_{SW}, with Gaussian Distribution)

If V_{SOURCE} is 12V, T_{AIR} is 150°C, and I_{LOAD} is 5A, then the switching frequency (f_{SW}) is 1333Hz with Gaussian distribution.

Figure 33 shows the boost inductor current triangular waveform.

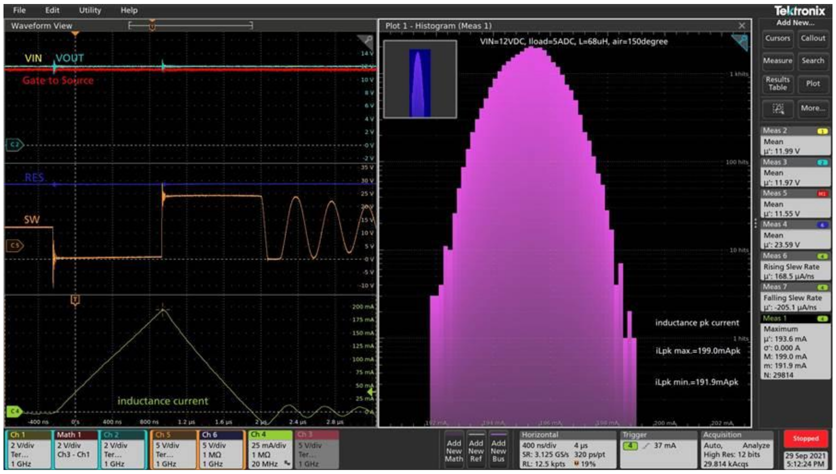
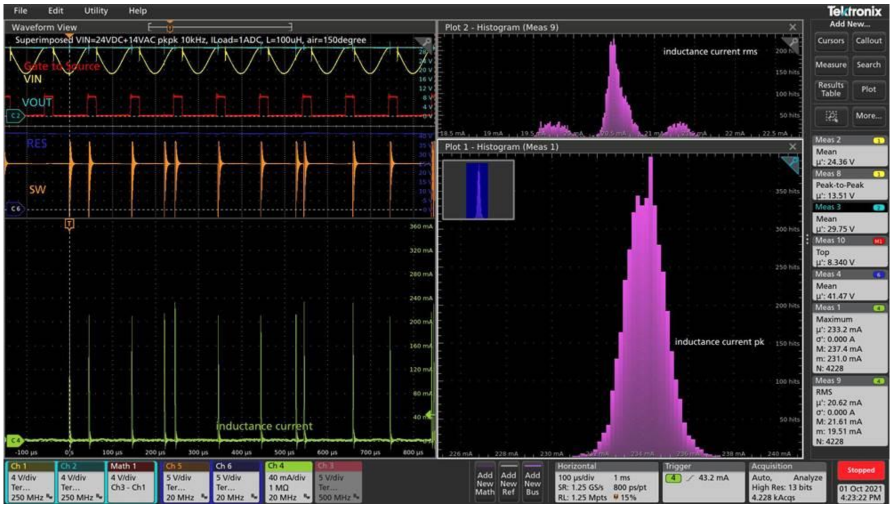


Figure 33: Boost Inductor Current Triangular Waveform (Low f_{SW}, with Gaussian Distribution)

The current in the inductor should be the shape of a triangle. This indicates a constant inductance vs. the inductor current.

Figure 34 shows a low inductance RMS current waveform, where T_{AIR} is 150°C, V_{SOURCE} has a large amplitude (10kHz), and the V_{SOURCE} transient results in higher gate activity. f_{SW} is 10kHz, and the RMS current in the inductor is low.



Meas 2: Mean µ': 24.36 V
Meas 8: Peak-to-Peak µ': 13.51 V
Meas 3: Mean µ': 29.75 V
Meas 10: Top µ': 8.340 V
Meas 4: Mean µ': 41.47 V
Meas 1: Maximum µ': 233.2 mA, σ': 0.000 A, M: 237.4 mA, m: 231.0 mA, N: 4228
Meas 9: RMS µ': 20.62 mA, σ': 0.000 A, M: 21.61 mA, m: 19.51 mA, N: 4228
Ch 1: 4 V/div, Ter..., 250 MHz
Ch 2: 4 V/div, Ter..., 250 MHz
Math 1: 4 V/div, Ch3 - Ch1
Ch 5: 5 V/div, Ter..., 20 MHz
Ch 6: 5 V/div, Ter..., 20 MHz
Ch 4: 40 mA/div, 1 MΩ, 20 MHz
Ch 3: 5 V/div, Ter..., 500 MHz
Horizontal: 100 µs/div, 1 ms, SR: 1.25 GS/s, 800 ps/pt, RL: 1.25 Mpts, 15%
Trigger: 4, 43.2 mA
Acquisition: Auto, Analyze, High Res: 13 bits, 4.228 kAcqs
01 Oct 2021 4:23:22 PM

Figure 34: Low Inductance RMS Current Waveform (f_{SW} follows f_{IN}, with Gaussian Distribution)

The scenario shown in Figure 34 is considered extreme; however, the device still provides excellent AC rectification under these conditions.

CONCLUSION

The MPQ5850 is a smart diode controller that can be used in a wide range of applications:

- Reverse-Polarity Protection
- Automotive LV124 Cases and ISO Pulses
- AC Rectification Up to 100kHz
- Battery Systems
- O-Rings, Paralleled Power Sources, and Plug and Play Power Supplies
- Reverse-Current Blocking

The MPQ5850 can replace a power Schottky diode with a 20mV forward voltage drop.

The device's active control loop reduces heat dissipation more affectively compared to a diode solution. The use of an N-channel MOSFET in the control loop is an improvement on the typical P-channel MOSFET solution, which can be uncontrolled and functional only within a small V_{SOURCE} range.

The MPQ5850 reduces the overall solution cost with the following:

- The reduced PCB board space requires less copper to cool the N-channel MOSFET
- N-channel MOSFETs smaller than and less expensive than P-channel MOSFETs
- Fast reverse-current blocking for lower output capacitor RMS currents
- Low heat dissipation for improved mechanical design

ADDITIONAL READING

For more information about MPS automotive products, contact an MPS FAE or visit the MPS website: https://www.monolithicpower.com/en/applications/automotive.html