Domain Control Module Reference Design

Automotive Power Stage for ADAS Applications

Contents

1 Overview

1.1 Description

Advanced driver-assistance systems (ADAS) have experienced an astonishing evolution over the last few decades, and today's cars incorporate a large number of sensors and cameras that monitor every part of the vehicle, as well as its surroundings. As a consequence, the power requirements of these systems has increased, bringing new challenges to the power supply design. This reference design serves as a guideline to help users design a power supply for ADAS, using a domain control module as an example.

A key part of an ADAS power design is how it handles the transient voltage perturbations in the car's battery. The initial voltage spike is especially critical, as some ADAS subsystems must remain operational even under cold start (also called cold-crank) conditions. Under these conditions, the input voltage supply can fall to as low as 2.5V. The load dump can also be dangerous, as it can increase the power dissipation in lossy converters like LDOs.

To ensure that the system operates normally regardless of the input voltage range (while protecting the circuit's components), it is vital to use a buck-boost converter rated for 42V. An example that meets this specification is the MPQ8875A, which will be discussed in this reference design.

1.2 Features

- Wide 2.2V to 36V Operating Input Range
- 15W to 20W Available Total Output Power During Start Impulse
- 4 LDO Channels for Power Over Coaxial with up to 300mA Each
- 4 LDO Channels with Monitoring, Diagnosis, and Protection Features
- Up to 1A of Continuous Output Current at 5V, or 3.3V for Auxiliary Devices (CAN, MCU)
- Buck-Boost and PoC LDOs are Configurable via the I²C Interface and OTP Memory
- Reverse Polarity Protection According to ISO 16750
- CISPR25 Class 5 Compliant
- All Parts AEC-Q100 Qualified

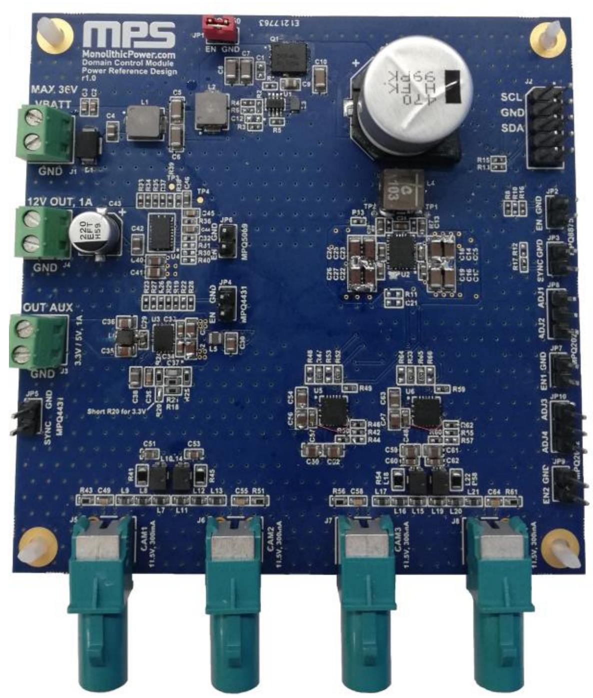
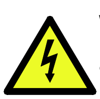


Figure 1: Domain Control Module Reference Design Board

1.3 Applications

- Advanced Driver-Assistance Systems (ADAS)
- Sensor Fusion Systems
- Camera Monitoring Systems
- Information Systems



High Voltage

Warning: Although this board is designed to satisfy safety requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

2 Reference Design

2.1 Block Diagram

Figure 2 shows a block diagram for this system. First, a battery supplies power to the MPQ5850, a smart diode controller that can protect the entire system from reverse input voltages, and rectify any AC voltages superposed on the supply line. Then the MPQ5850 powers the MPQ8875A, a 4-switch, synchronous buck-boost converter that can accommodate the input line transient voltages. The MPQ8875A supplies a stable voltage level to four power devices: two dual-channel LDOs, a load switch, and a buck converter.

The two MPQ2022 devices each provide two LDO channels. The MPQ2022s can supply a current up to 300mA to cameras and sensors through a coaxial cable with an excellent power supply rejection ratio (PSRR). These devices also have an analog-to-digital converter (ADC) and digital diagnostic features. The system also contains the MPQ5069, a load switch that enables an additional regulated output voltage that can be connected to additional ECUs. Lastly, the MPQ4431 is a compact buck converter that can supply 1A to auxiliary devices, such as a microcontroller (MCU) or a CAN driver.

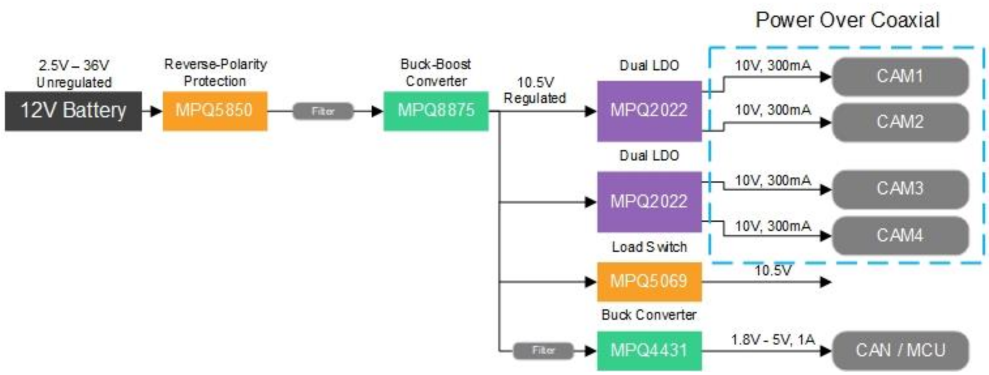


Figure 2: Block Diagram

2.2 Related Solutions

This reference design is based on the following MPS solutions:

Table 1: System Specifications

MPS Integrated Circuit	Description
MPQ5850 (1)	Smart diode controller with ultra-low dropout voltage for reverse input protection
MPQ8875A	Synchronous buck-boost DC/DC converter with I^2C interface
MPQ2022 (1)	Dual-channel (LDO) with I^2C interface
MPQ5069	Hot-swap protection device designed to protect output circuitry from input transients
MPQ4431	Synchronous step-down converter with internal high-side and low-side MOSFETs

Note:

1) This part will be available soon. Contact MPS for details.

2.3 System Specifications

Table 2: System Specifications

Parameter	Specification
Input voltage range	2.5V to 36V
Buck-boost output voltage	10.5V
PoC output voltage	10V
PoC maximum load current	300mA per channel
MPQ4433 maximum load current	1A
Switching frequency	400kHz (under nominal conditions)
MPQ4433 output voltage range	3.3V to 5V
MPQ5069 output voltage	10.5V
MPQ8875A efficiency (V_{IN} = 12V)	98.96% (I_{OUT} = 1A, V_{OUT} = 10.5V)
Board form factor	90mmx90mmx1.6mm

Table 3: Maximum Output Current vs. Output Voltage (MPQ8875A)
(V_{COND_MIN} = 3.2V, Room Temperature, Cold-Crank Profile)

Output Voltage	Maximum Output Current
3.3V	4.3A
5V	4.1A
8V	2.8A
10V	2.1A
12V	1.8A

Table 4: Maximum Output Current vs. Minimum Input Voltage (MPQ8875A)
(V_{OUT} = 10.5V, Room Temperature, Cold-Crank Profile)

Minimum Input Voltage	Maximum Output Current
2.5V	1.42A
3V	1.9A
3.5V	2.2A
4V	2.6A
4.5V	3.1A
5V	3.5A
5.5V	3.9A
6V	4.2A
6.5V	4.5A
7V	4.8A

3 Design

3.1 Selecting the Inductor (MPQ8875A)

Follow the guidelines below to select the optimal inductor:

- The inductor's peak current should not exceed the inductor's saturation current.
- Minimize the DCR to achieve a higher efficiency.
- To reduce radiated emissions, the inductor's physical size should be small.
- The inductor's ripple current should be approximately 30% of the RMS inductor current.

Assuming MPQ8875A works mostly in buck mode, device's inductance value can be calculated with Equation (1):

$$L_{BUCK}=\frac{V_{OUT}}{f_{SW}\cdot\Delta I_L}\times\left(1-\frac{V_{OUT}}{V_{IN}}\right) \tag{1}$$

Where ΔI_L is the peak-to-peak inductor ripple current.

To avoid saturating the component, the selected inductor must have a saturation current (I_{SAT}) that exceeds the peak current flowing through the inductor (I_{L_PEAK}). This current peak must be calculated while considering the highest value of the input current (I_{L_DC}) and the inductors ripple current (ΔI_L). I_{L_PEAK} is reached after the input battery voltage (V_{BATT}) drops during the cold-crank event, and when the load and the inductor ripple current are at their maximum values.

Estimate I_{L_DC} with Equation (2):

$$I_{L\_DC}=\frac{V_{OUT}\times I_{OUT}}{V_{BATT}\cdot\eta} \tag{2}$$

Where V_{OUT} is the MP8875A's output voltage, I_{OUT} is the MP8875A's output current, V_{BATT} is the battery's voltage during the cold-crank event, and η is the efficiency of the buck-boost converter (around 90% during a cold start impulse).

The saturation current of the selected inductor can be calculated with Equation (3):

$$I_{SAT}>I_{L\_PEAK}+\frac{\Delta I_L}{2} \tag{3}$$

In this application, a 10µH inductor with a saturation current of 7.6A is selected. With these values, it is possible to achieve a good compromise between size, losses, ripple current, and radiated emissions.

3.2 Selecting the Output Voltage (MPQ8875A)

Selecting the output voltage is important to achieve maximum efficiency during normal operation and ensure the optimal operation of all the components in the system. To obtain maximum efficiency, note that buck-boost converters are the most efficient while operating in buck mode. This means that the MPQ8875A's output voltage must be assigned a value lower than the input voltage during normal operation. However, this value cannot be too low, because the high voltage requirement of the cameras connected to the circuit must also be considered.

For this reason, the recommended output voltage for this application is 10.5V.

The output voltage is configured using the I^2C interface with registers 0x00 and 0x01. The error amplifier (EA) reference voltage (REF, bits[7:0]) must be written in register 0x00 and the divider ratio of V_{OUT}/V_{REF} (FBDR, bits[2:0]) in register 0x01. VOUT can be calculated with Equation (4):

$$V_{OUT}=\frac{REF[7:0]\times 10mV}{FBDR[2:0]} \tag{4}$$

3.3 Selecting the Input Mode (MPQ8875A)

The MPQ8875A has two input voltage (V_{IN}) ranges that can be selected through the I²C interface. Normal input mode limits the input voltage between 4V and 36V. To maintain buck-boost operation during cold-crank conditions, set the V_{IN} range to low-input mode. In low-input mode, the input voltage ranges between 2.2V and 36V.

There are two methods to configure the input mode, described below:

- Use MPS's graphics user interface (GUI). On the first page of the platform, modify the input mode by selecting the "Low Input" option.
- Use a master device to send a write command to the MPQ8875A while the MPQ8875A acts as a slave. Write a 1 to register 0x01, bit[1].

Note that low-input mode can slightly decrease the overall converter efficiency.

3.4 Setting the Over-Current Protection (OCP) Mode (MPQ8875A)

The MPQ8875A provides a peak and valley current limit scheme. This ensures that the switch currents remain within the device's capabilities during overload conditions or when the output has been shorted. During cold-crank conditions, the current flowing through the inductor may increase due to the drop in the car battery's voltage. To keep the main power switch on during cold-crank conditions, it is recommended to set the over-current protection (OCP) mode to no response.

To set this mode, write 0x02 or 0x03 to the two LSB bits in the 0x0B register, or use the GUI. If using the register, there must be a master device to send a write command to the MPQ8875A. To use the GUI, change the OCP mode parameter, which can be found on page 2, inside "Protection" section.

3.5 Setting the Thresholds (MPQ8875A)

Apart from selecting the output voltage for maximum efficiency, it is also important to set the correct thresholds for buck, boost, and buck-boost mode. Buck-boost most is the least efficient mode, so it is recommended to use this mode as little as possible. Ensure that the MPQ8875A works in buck or boost mode for as long as possible.

The thresholds for the operating modes can be configured via the I²C interface (register 0x09). The user can use the GUI or a master device to send a write command to the MPQ8875A.

3.6 Selecting the Switching Frequency (MPQ8875A)

The MPQ8875A's switching frequency (f_{SW}) can be set by modifying register 0x03. There are two methods to change the switching frequency, described below:

- Use the GUI to set the switching frequency. On the second page, there is a "SYNC/Fsw" section where the switching frequency can be selected from the related drop-down menu. The switching frequency can range between 100kHz and 2.2GHz with 50kHz steps. However, the allowed frequency range is between 250kHz and 2.2GHz.
- Use a master device to send a write command to the MPQ8875A using the device's register. Use register 0x03 to set the switching frequency, calculated with Equation (5):

$$f_{SW} = FSW[4:0] \times 50kHz \tag{5}$$

When selecting the switching frequency, consider the trade-off between EMC and the inductor ripple current (ΔI_L). EMC performance can be negatively affected by a high switching frequency, while the ripple current improves at higher frequencies. In this application, f_{SW} is set to 400kHz.

In addition to the switching frequency, the MPQ8875A features spread spectrum (FSS) to optimize EMI performance. The reference frequency, frequency spread spectrum modulation range, and cycle are all set via the I^2C Interface. The GUI can be used to configure these parameters by changing the settings that appear in the “Frequency Spread Spectrum (FSS)” section. Otherwise, use a master device to send a write command to register 0x04 through the I^2C interface.

For this application, it is recommended to use the spread spectrum feature. Set the FSS modulation range to ±125, and set the FSS modulation cycle to 9000.

3.7 Schematic

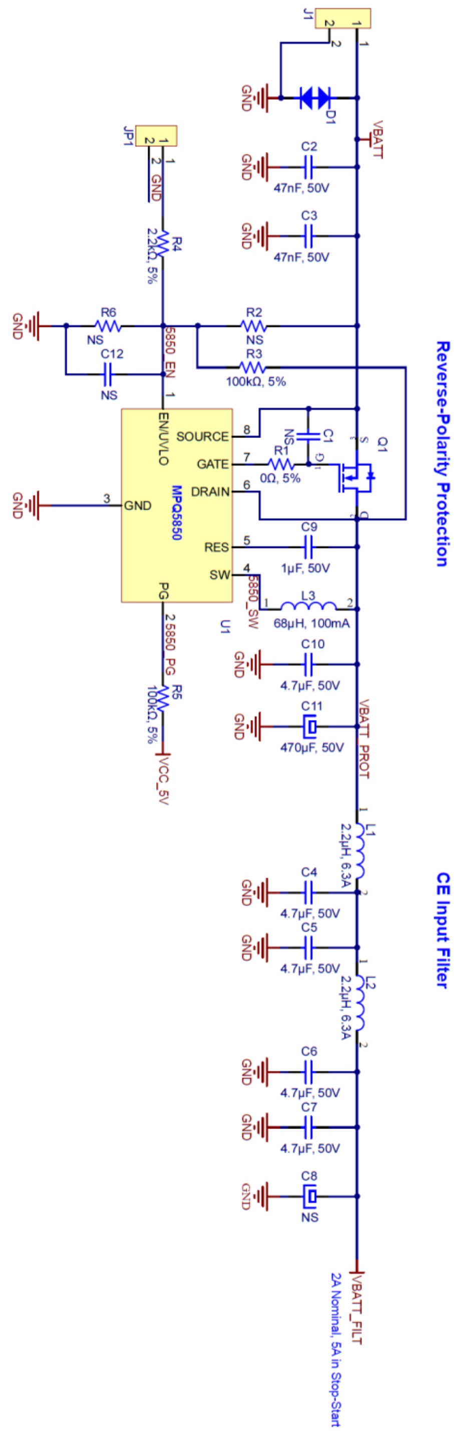


Figure 3: Domain Control Module Schematic (Page 1)

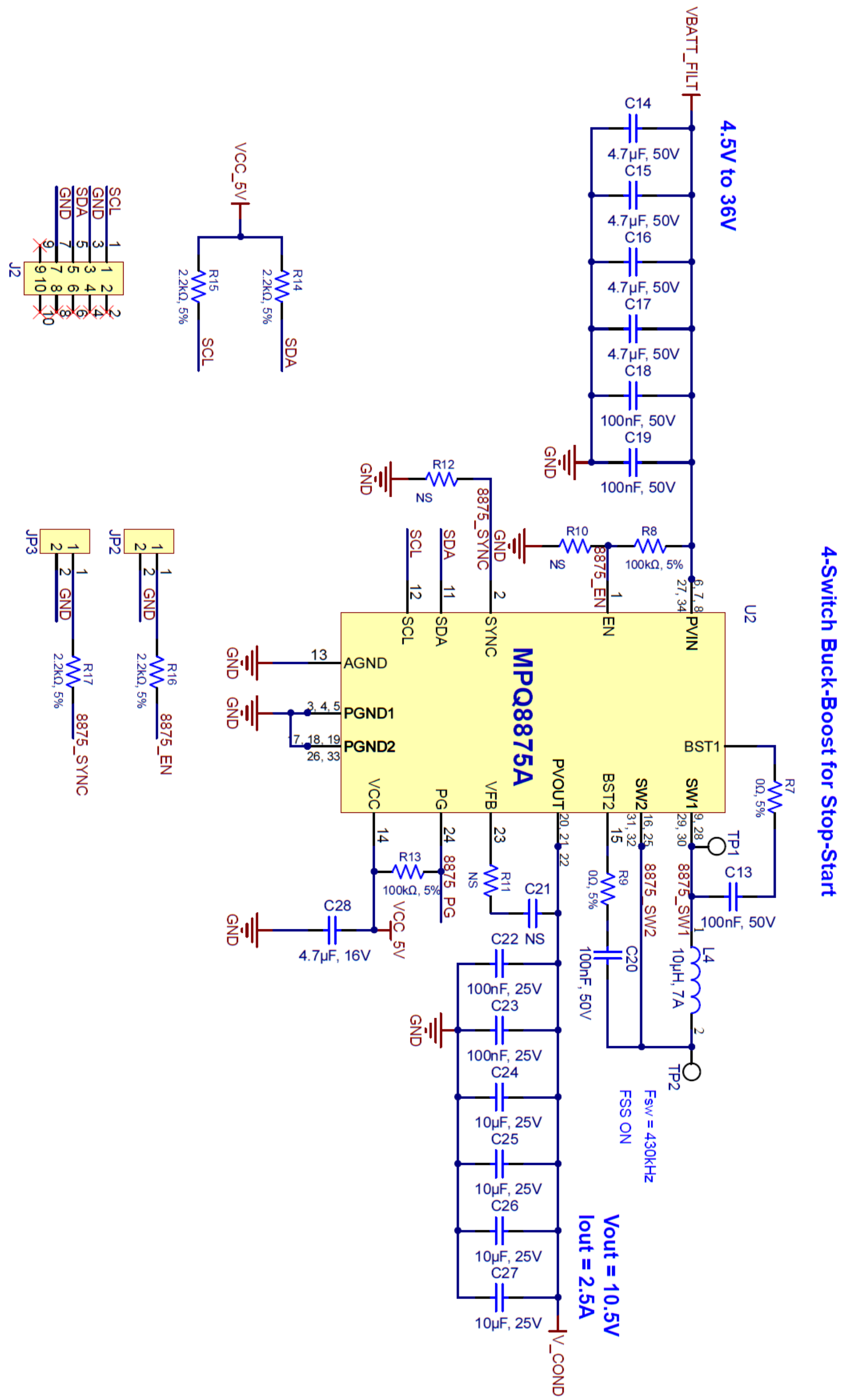


Figure 4: Domain Control Module Schematic (Page 2)

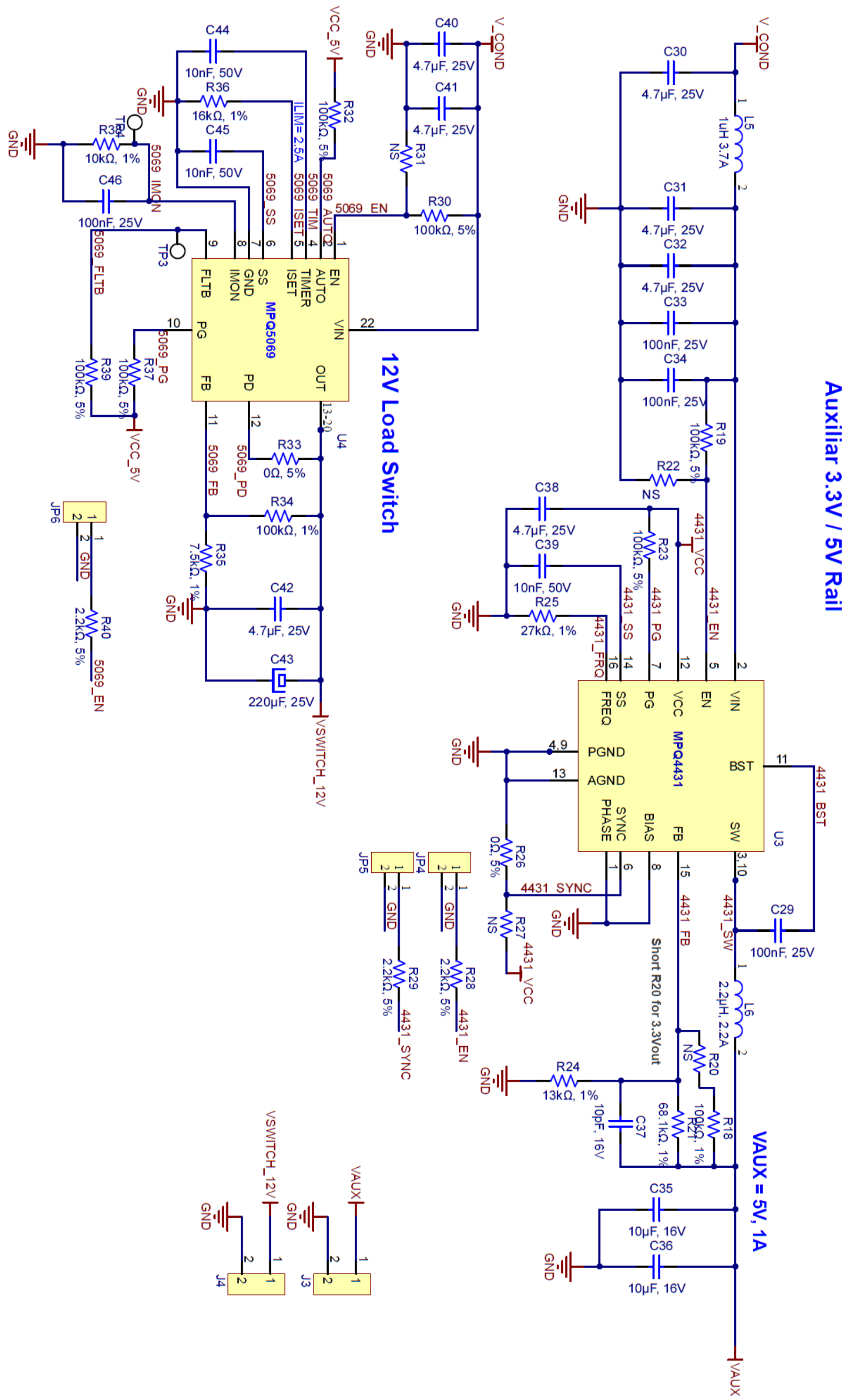


Figure 5: Domain Control Module Schematic (Page 3)

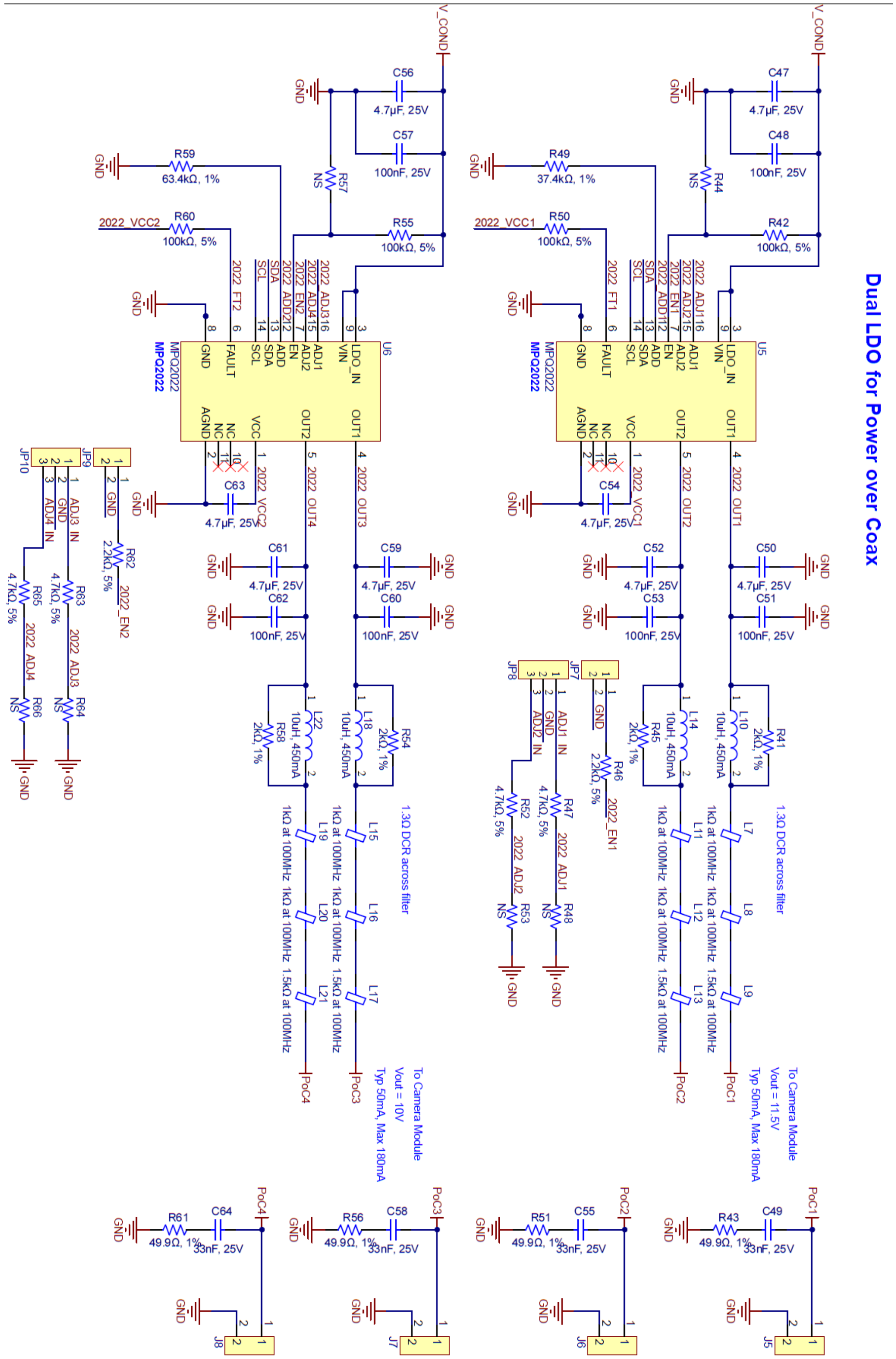


Figure 6: Domain Control Module Schematic (Page 4)

3.8 BOM

Table 5: Bill of Materials

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer P/N
2	C2, C3	47nF, 50V	MLCC, X7R	0603	Kemet	C0603C473K5RACTU
9	C4, C5, C6, C7, C10, C14, C15, C16, C17	4.7µF, 50V	MLCC, X7S	1206	Murata	GCM31CC71H475KA03L
1	C9	1µF, 50V	MLCC, X7R	0805	Murata	GCM21BR71H105KA03L
1	C11	470µF, 50V	Electrolytic capacitor	(16mmx 16mm)	Panasonic	EEE-FK1H471AM
4	C13, C18, C19, C20	100nF, 50V	MLCC, X7R	0603	Murata	GCJ188R71H104KA12D
12	C22, C23, C29, C33, C34, C46, C48, C51, C53, C57, C60, C62	100nF, 25V	MLCC, X8R	0603	Murata	GCM188R91E104KA37D
4	C24, C25, C26, C27	10µF, 25V	MLCC, X7R	1206	Kemet	C1206C106K3RACAUTO
1	C28	4.7µF, 16V	MLCC, X6S	0603	Murata	GRT188C81C475KE13D
15	C30, C31, C32, C38, C40, C41, C42, C47, C50, C52, C54, C56, C59, C61, C63	4.7µF, 25V	MLCC, X7S	0805	Murata	GCM21BC71E475KE36L
2	C35, C36	10µF, 16V	MLCC, X7S	0805	TDK	CGA4J1X7S1C106K125 AC
1	C37	10pF, 16V	MLCC, C0G	0603	Kyocera AVX	0603YA100J4T2A
3	C39, C44, C45	10nF, 50V	MLCC, X7R	0603	Kemet	C0603C103K5RACAUTO 7411
1	C43	220µF, 25V	Electrolytic capacitor	(7mmx 7mm)	Panasonic	EEEFTE221XAP
4	C49, C55, C58, C64	33nF, 25V	MLCC, X7R	0603	Kemet	C0603C333K3RACAUTO
1	D1	SMBJ30CA -E3/52	TVS diode	SMB	Diodes	SMBJ22CAQ-13-F
3	J1, J3, J4	Terminal block	Terminal block	TH	Phoenix Contact	1727010
1	J2	Header	Header	TH	Harwin	M20-9720546
4	J5, J6, J7, J8	Coax	Coaxial connector	TH	Amphenol RF	FA1-NZRP-PCB-8
2	L1, L2	2.2µH, 6.3A	Fixed inductor	5030	Panasonic	ETQP3M2R2KVP
1	L3	68µH, 100mA	Fixed inductor	0806	Murata	LQH2MPZ680MGRL
1	L4	10µH, 7A	Fixed inductor	6060	Coilcraft	XAL6060-103MEC

1	L5	1µH, 3.7A	Fixed inductor	0806	TDK	TFM201610ALMA1R0MTAA
1	L6	2.2µH, 2.2A	Fixed inductor	1008	Murata	DFE252012PD-2R2M=P2
8	L7, L8, L11, L12, L15, L16, L19, L20	1kΩ at 100MHz	Ferrite bead, 800mA	0603	TDK	MPZ1608S102ATD25
4	L9, L13, L17, L21	1.5kΩ at 100MHz	Ferrite bead, 300mA	0603	TDK	MMZ1608Y152BTD25
4	L10, L14, L18, L22	10uH, 450mA	Fixed inductor	1210	TDK	ADL3225VT-100M-TL000
1	Q1	NVMFS5C646NLAFT1G	MOSFET, 60V	SO-8-FL	On Semiconductor	NVMFS5C646NLAFT1G
5	R1, R7, R9, R26, R33	0Ω, 5%	Thick film resistor	0402	Yageo	RC0402JR-070RL
14	R3, R5, R8, R13, R19, R23, R30, R32, R37, R39, R42, R50, R55, R60	100kΩ, 5%	Thick film resistor	0402	Panasonic	ERJ-2GEJ104X
10	R4, R14, R15, R16, R17, R28, R29, R40, R46, R62	2.2kΩ, 5%	Thick film resistor	0402	Panasonic	ERJ-2GEJ222X
1	R18	100kΩ, 1%	Thick film resistor	0603	Panasonic	ERJ3EKF1003V
1	R21	68.1kΩ, 1%	Thick film resistor	0603	Panasonic	ERJ-3EKF6812V
1	R24	13kΩ, 1%	Thick film resistor	0603	Panasonic	ERJ-3EKF1302V
1	R25	27kΩ, 1%	Thick film resistor	0603	Panasonic	ERJ-3EKF2702V
1	R34	100kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-2RKF1003X
1	R35	7.5kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-2RKF7501X
1	R36	16kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-2RKF1602X
1	R38	10kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-2RKF1002X
4	R41, R45, R54, R58	2kΩ, 1%	Thick film resistor	0805	Vishay	CRCW08052K00FKEA
4	R43, R51, R56, R61	49.9Ω, 1%	Thick film resistor	0603	Panasonic	ERJ3EKF49R9V
4	R47, R52, R63, R65	4.7kΩ, 5%	Thick film resistor	0603	Panasonic	ERJ-3GEYJ472V
1	R49	37.4kΩ, 1%	Thick film resistor	0402	Panasonic	ERJU02F3742X
1	R59	63.4kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-U02F6342X
1	U1	MPQ5850	Smart diode controller	TSOT-238	MPS	MPQ5850GJ-AEC1

1	U2	MPQ8875A	Synchronous buck-boost DC/DC converter	QFN-34 (4mmx 5mm)	MPS	MPQ8875AGVE-9000-AEC1
1	U3	MPQ4431	Synchronous step-down converter	QFN-16 (3mmx 4mm)	MPS	MPQ4431GLE-AEC1
1	U4	MPQ5069	Hot-swap protection device	QFN-22 (3mmx 5mm)	MPS	MPQ5069GQV-AEC1
2	U5, U6	MPQ2022	Dual-channel LDO	QFN-16 (4mmx 4mm)	MPS	MPQ2022GRE-AEC1

3.9 PCB Layout

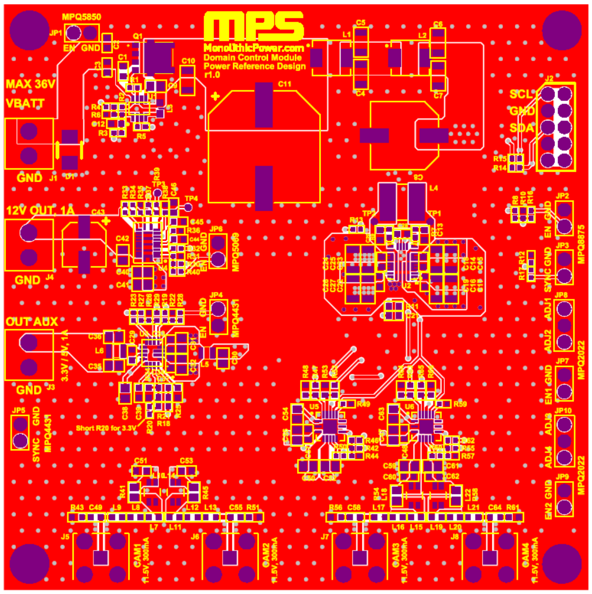


Figure 7: PCB Layer 1

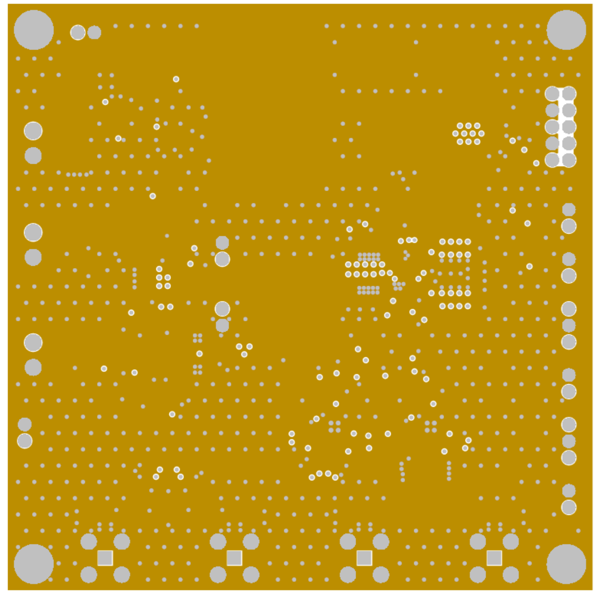


Figure 8: PCB Layer 2

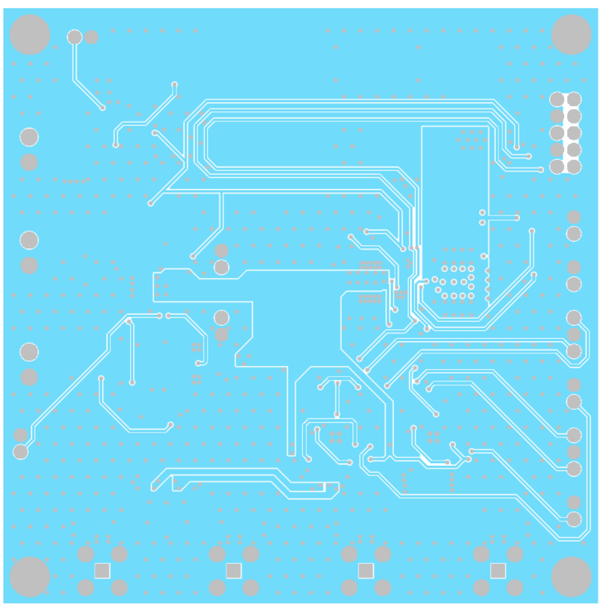


Figure 9: PCB Layer 3

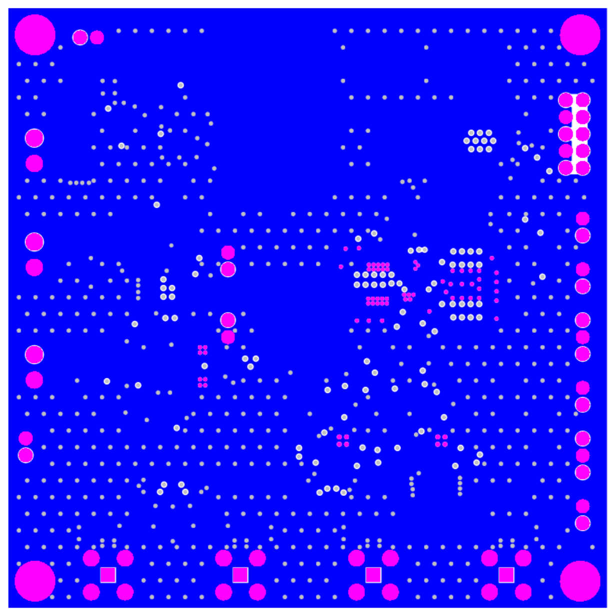


Figure 10: PCB Layer 4

4 Test Results

4.1 Efficiency and Regulation

V_{COND} = 10.5V, $V_{OUT-LDO}$ = 10V, L = 10µH, T_A = 25°C, unless otherwise noted.

Figure 11: Efficiency vs. Load Current
Buck-boost converter (MPQ8875A)

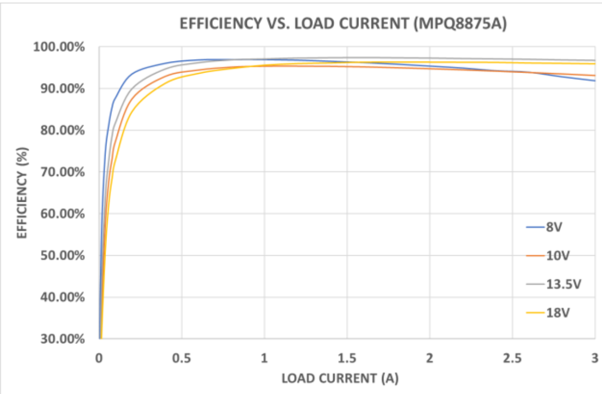


Figure 12: Efficiency vs. Load Current
System with one LDO channel connected

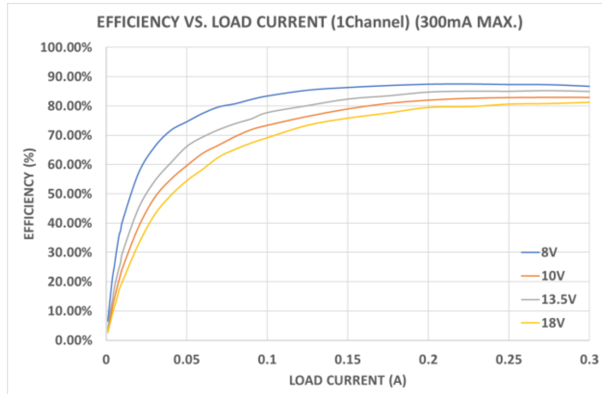


Figure 13: Efficiency vs. Load Current
System with two LDO channels connected

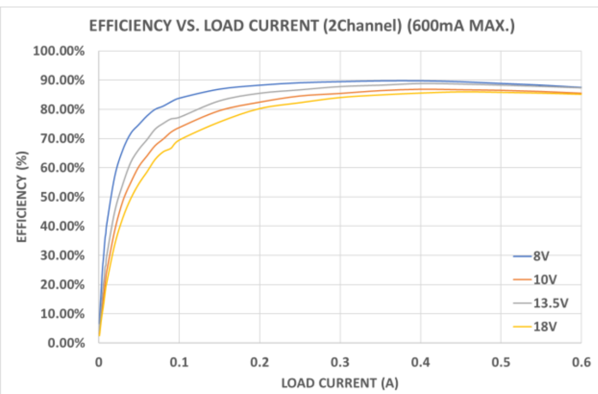


Figure 14: Load Regulation
Buck-boost converter (MPQ8875A)

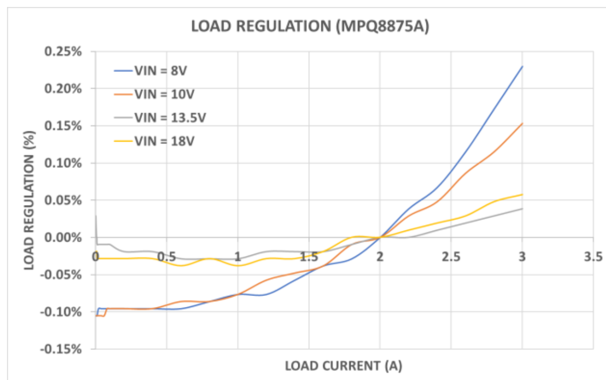
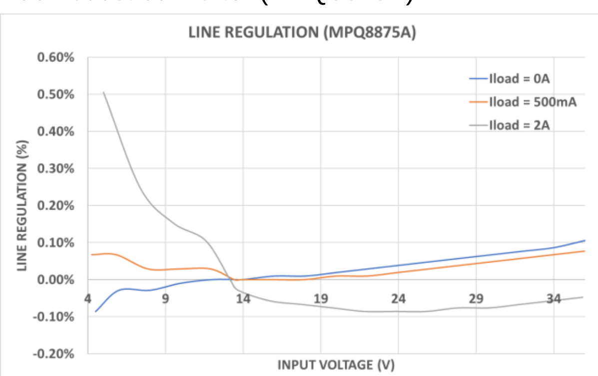


Figure 15: Line Regulation
Buck-boost converter (MPQ8875A)



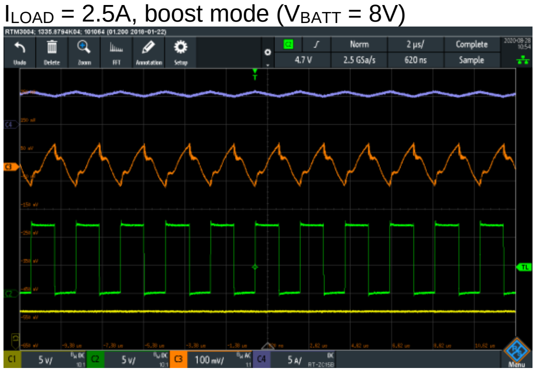
4.2 Time Domain Waveforms

V_{BATT} = 12V, V_{COND} = 10.5V, $V_{OUT-LDO}$ = 10V, $L_{BUCK-BOOST}$ = 10µH, T_A = 25°C, unless otherwise noted.

Figure 16: Steady State (MPQ8875A)

I_{LOAD} = 2.5A, boost mode (V_{BATT} = 8V)

C4: $I_{INDUCTOR}$ 5A/div.
C3: V_{COND}/AC 100mV/div.
C2: V_{SW2} 5V/div.
C1: V_{SW1} 5V/div.

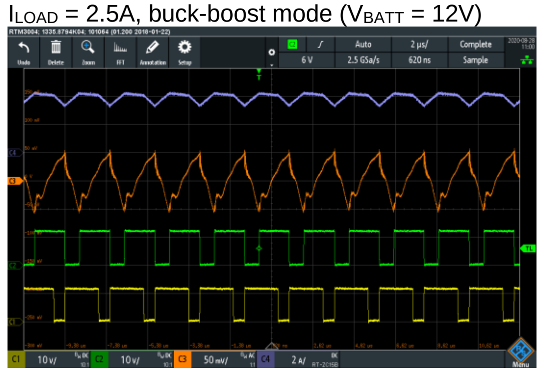


2µs/div.

Figure 17: Steady State (MPQ8875A)

I_{LOAD} = 2.5A, buck-boost mode (V_{BATT} = 12V)

C4: $I_{INDUCTOR}$ 2A/div.
C3: V_{COND}/AC 50mV/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

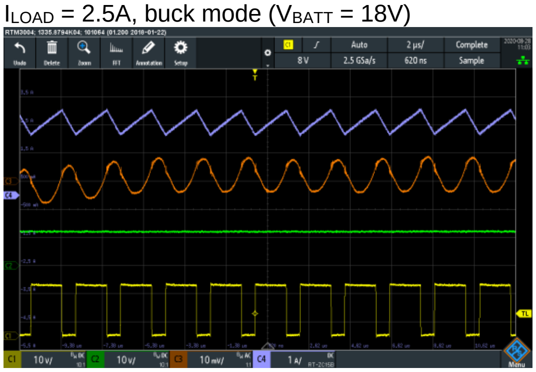


2µs/div.

Figure 18: Steady State (MPQ8875A)

I_{LOAD} = 2.5A, buck mode (V_{BATT} = 18V)

C4: $I_{INDUCTOR}$ 1A/div.
C3: V_{COND}/AC 10mV/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

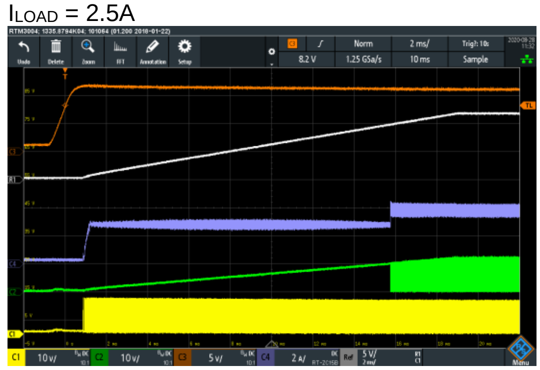


2µs/div.

Figure 19: Start-Up through VIN (MPQ8875A)

I_{LOAD} = 2.5A

C3: V_{BATT} 5V/div.
REF: V_{COND} 5V/div.
C4: $I_{INDUCTOR}$ 2A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

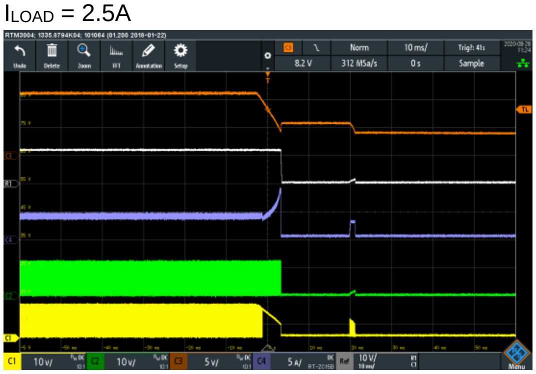


2ms/div.

Figure 20: Shutdown through VIN (MPQ8875A)

I_{LOAD} = 2.5A

C3: V_{BATT} 5V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 5A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.



10ms/div.

Figure 21: Start-Up through EN (MPQ8875A)

I_{LOAD} = 2.5A

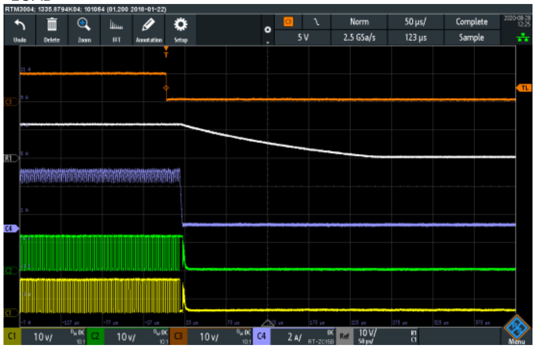
C3: V_{EN} 10V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 2A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

2ms/div.

Figure 22: Shutdown through EN (MPQ8875A)

I_{LOAD} = 2.5A

C3: V_{EN} 10V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 2A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

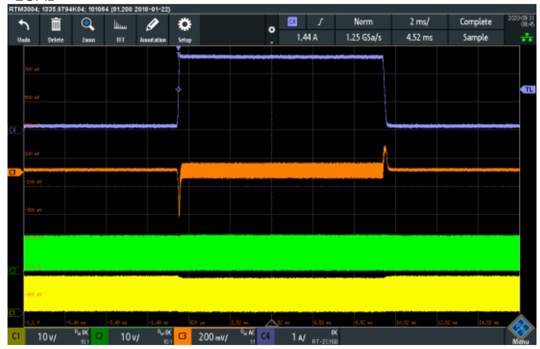


50µs/div.

Figure 23: Load Transient (MPQ8875A)

I_{LOAD} = 0A to 2.5A to 0A

C4: $I_{INDUCTOR}$ 1A/div.
C3: V_{COND}/AC 200mV/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

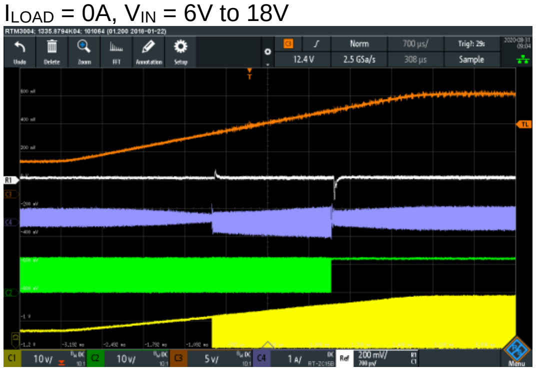


2ms/div.

Figure 24: Line Transient (MPQ8875A)

I_{LOAD} = 0A, V_{IN} = 6V to 18V

C3: V_{IN} 5V/div.
REF: V_{COND}/AC 200mV/div.
C4: $I_{INDUCTOR}$ 1A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 10V/div.

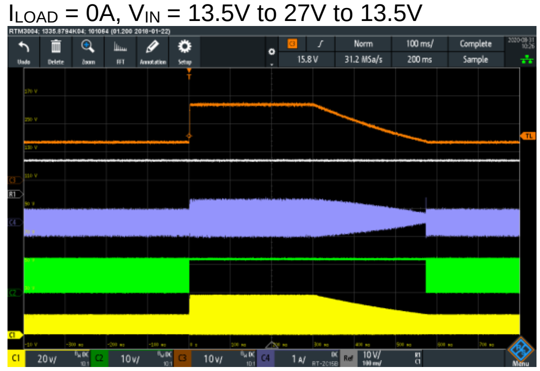


700µs/div.

Figure 25: Load Dump (MPQ8875A)

I_{LOAD} = 0A, V_{IN} = 13.5V to 27V to 13.5V

C3: V_{IN} 10V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 1A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 20V/div.

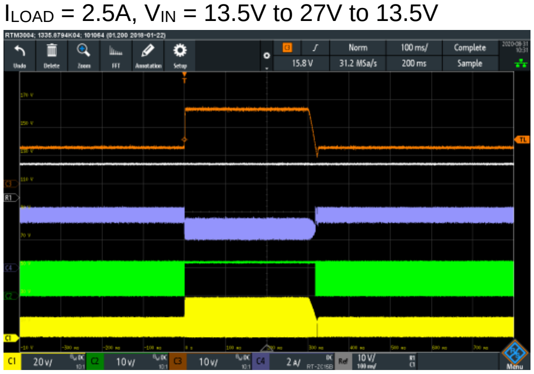


100ms/div.

Figure 26: Load Dump (MPQ8875A)

I_{LOAD} = 2.5A, V_{IN} = 13.5V to 27V to 13.5V

C3: V_{IN} 10V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 2A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 20V/div.

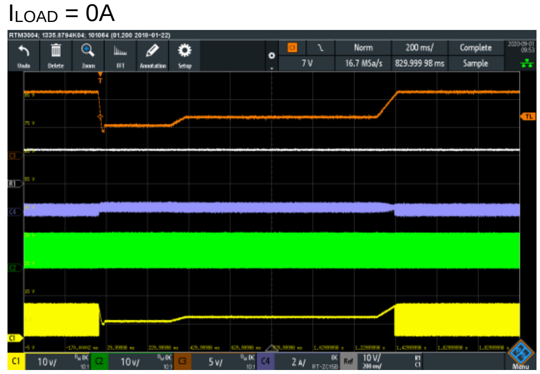


100ms/div.

Figure 27: Cold Crank (MPQ8875A)

I_{LOAD} = 0A

C3: V_{IN} 5V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 2A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 20V/div.

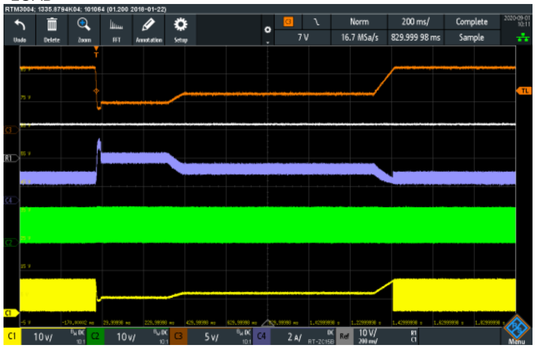


200ms/div.

Figure 28: Cold Crank (MPQ8875A)

I_{LOAD} = 1A

C3: V_{IN} 5V/div.
REF: V_{COND} 10V/div.
C4: $I_{INDUCTOR}$ 2A/div.
C2: V_{SW2} 10V/div.
C1: V_{SW1} 20V/div.

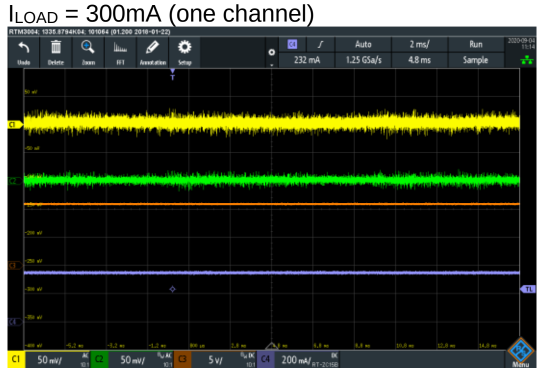


200ms/div.

Figure 29: Steady State (MPQ2022)

I_{LOAD} = 300mA (one channel)

C1: V_{CH1}/AC 50mV/div.
C2: V_{CH2}/AC 50mV/div.
C3: V_{COND} 5V/div.
C4: I_{CH1} 200mA/div.

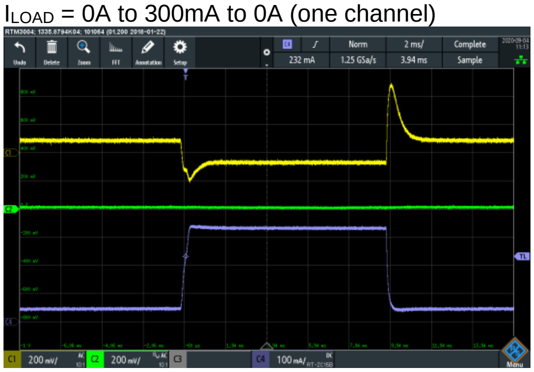


2ms/div.

Figure 30: Load Transient (MPQ2022)

I_{LOAD} = 0A to 300mA to 0A (one channel)

C1: V_{CH1}/AC 200mV/div.
C2: V_{CH2}/AC 200mV/div.
C4: I_{CH1} 100mA/div.

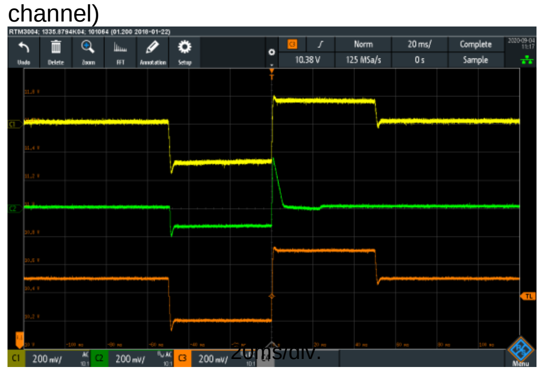


2ms/div.

Figure 31: Line Transient (MPQ2022)

V_{COND} = 10.5V to 10.2V to 10.7V, I_{LOAD} = 300mA (one channel)

C1: V_{CH1}/AC 200mV/div.
C2: V_{CH2}/AC 200mV/div.
C3: V_{IN} 200mV/div.

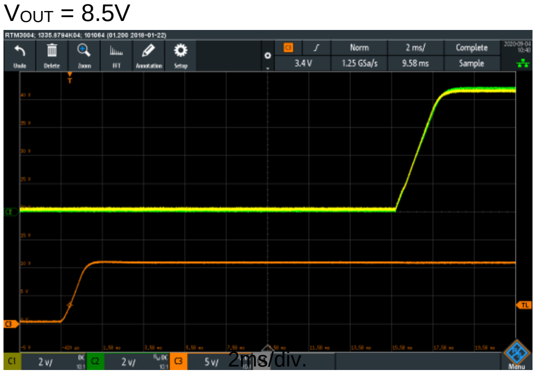


20ms/div.

Figure 32: Start-Up through VIN (MPQ2022)

V_{COND} = 0V to 11.6V, I_{OUT} = 300mA (one channel), V_{OUT} = 8.5V

C1: V_{CH1} 2V/div.
C2: V_{CH2} 2V/div.
C3: V_{IN} 5V/div.



2ms/div.

Figure 33: Shutdown through VIN (MPQ2022)

V_{COND} = 11.6V to 0V, I_{OUT} = 300mA (one channel), V_{OUT} = 8.5V

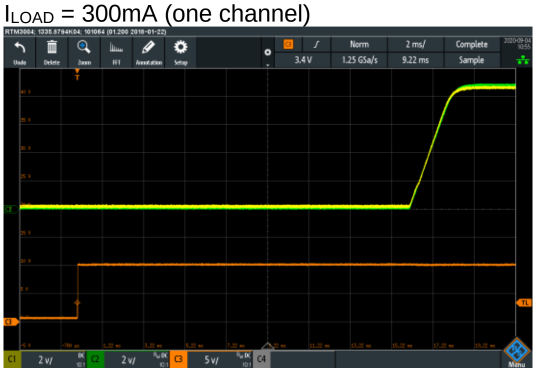
C1: V_{CH1} 2V/div.
C2: V_{CH2} 2V/div.
C3: V_{IN} 5V/div.

5ms/div.

Figure 34: Start-Up through EN (MPQ2022)

I_{LOAD} = 300mA (one channel)

C1: V_{CH1} 2V/div.
C2: V_{CH2} 2V/div.
C3: V_{EN} 5V/div.

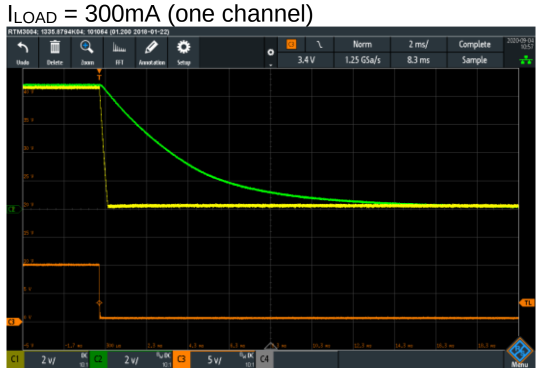


2ms/div.

Figure 35: Shutdown through EN (MPQ2022)

I_{LOAD} = 300mA (one channel)

C1: V_{CH1} 2V/div.
C2: V_{CH2} 2V/div.
C3: V_{EN} 5V/div.

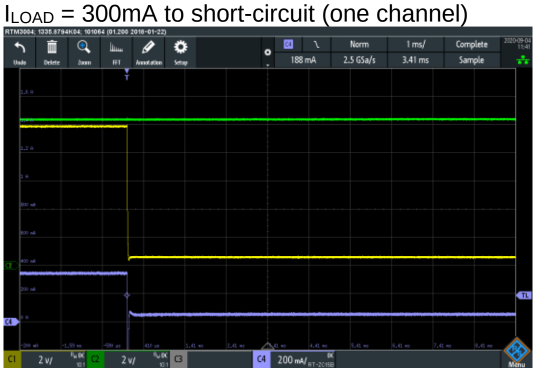


2ms/div.

Figure 36: SCP Entry (MPQ2022)

I_{LOAD} = 300mA to short-circuit (one channel)

C1: V_{CH1} 2V/div.
C2: V_{CH2} 2V/div.
C4: I_{CH1} 200mA/div.

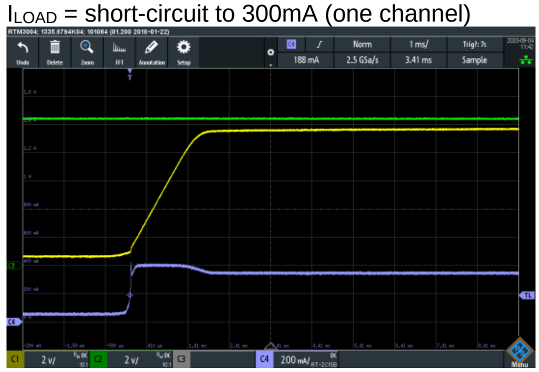


1ms/div.

Figure 37: SCP Recovery (MPQ2022)

I_{LOAD} = short-circuit to 300mA (one channel)

C1: V_{CH1} 2V/div.
C2: V_{CH2} 2V/div.
C4: I_{CH1} 200mA/div.

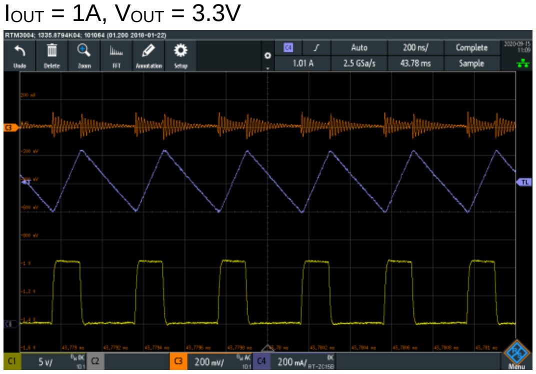


1ms/div.

Figure 38: Steady State (MPQ4431)

I_{OUT} = 1A, V_{OUT} = 3.3V

C3: V_{OUT}/AC 200mV/div.
C4: I_L 200mA/div.
C1: V_{SW} 5V/div.

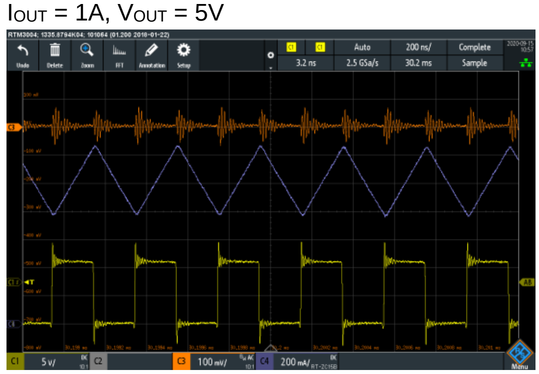


200ns/div.

Figure 39: Steady State (MPQ4431)

I_{OUT} = 1A, V_{OUT} = 5V

C3: V_{OUT}/AC 100mV/div.
C4: I_L 200mA/div.
C1: V_{SW} 5V/div.



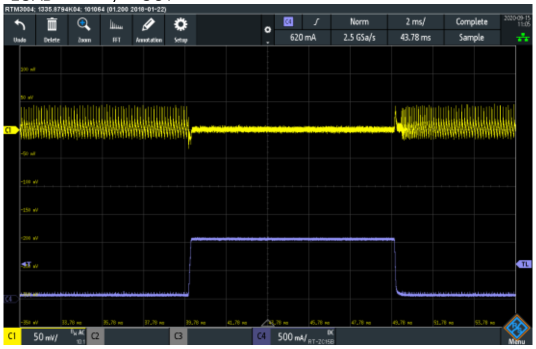
200ns/div.

Figure 40: Load Transient (MPQ4431)

I_{LOAD} = 1A, V_{OUT} = 3.3V

C1: V_{OUT}/AC 50mV/div.

C4: I_{LOAD} 500mA/div.



2ms/div.

Figure 41: Load Transient (MPQ4431)

I_{LOAD} = 1A, V_{OUT} = 3.3V

C1: V_{OUT}/AC 50mV/div.

C4: I_{LOAD} 500mA/div.

2ms/div.

Figure 42: Steady State (MPQ5850)

I_{OUT} = 2A

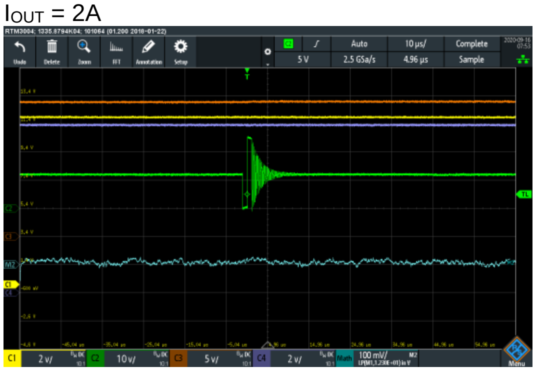
C3: V_{RES} 5V/div.

C1: V_{SOURCE} 2V/div.

C4: V_{DRAIN} 2V/div.

C2: V_{SW} 10V/div.

M1: V_{SD} 100mV/div.



10µs/div.

Figure 43: Cold Crank (MPQ5850)

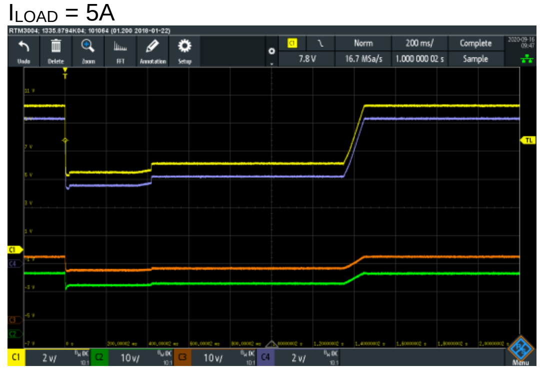
I_{LOAD} = 5A

C1: V_{SOURCE} 2V/div.

C4: V_{DRAIN} 2V/div.

C3: V_{RES} 10V/div.

C2: V_{GATE} 10V/div.



200ms/div.

Figure 44: Start-Up through VIN (MPQ5069)

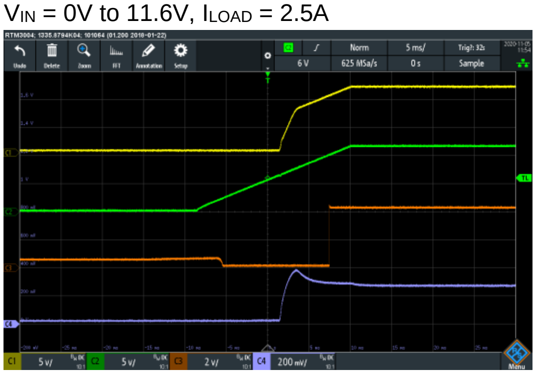
V_{IN} = 0V to 11.6V, I_{LOAD} = 2.5A

C1: V_{OUT} 5V/div.

C2: V_{IN} 5V/div.

C3: V_{TIMER} 2V/div.

C4: V_{IMON} 200mV/div.



5ms/div.

Figure 45: Shutdown through VIN (MPQ5069)

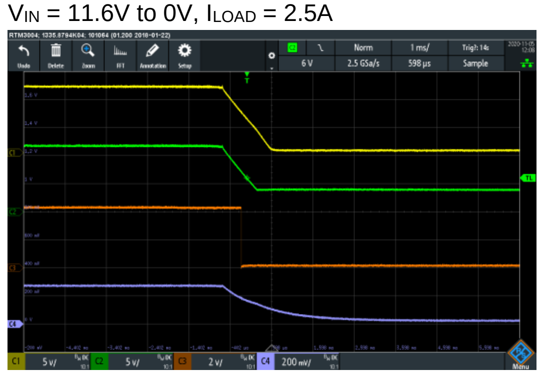
V_{IN} = 11.6V to 0V, I_{LOAD} = 2.5A

C1: V_{OUT} 5V/div.

C2: V_{IN} 5V/div.

C3: V_{TIMER} 2V/div.

C4: V_{IMON} 200mV/div.

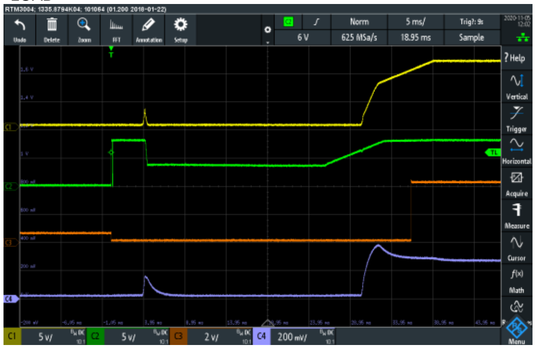


1ms/div.

Figure 46: Start-Up through EN (MPQ5069)

I_{LOAD} = 2.5A

C1: V_{OUT} 5V/div.
C2: V_{EN} 5V/div.
C3: V_{TIMER} 2V/div.
C4: V_{IMON} 200mV/div.

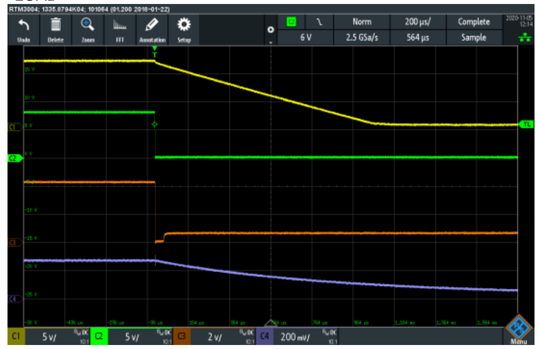


5ms/div.

Figure 47: Shutdown through EN (MPQ5069)

I_{LOAD} = 2.5A

C1: V_{OUT} 5V/div.
C2: V_{EN} 5V/div.
C3: V_{TIMER} 2V/div.
C4: V_{IMON} 200mV/div.

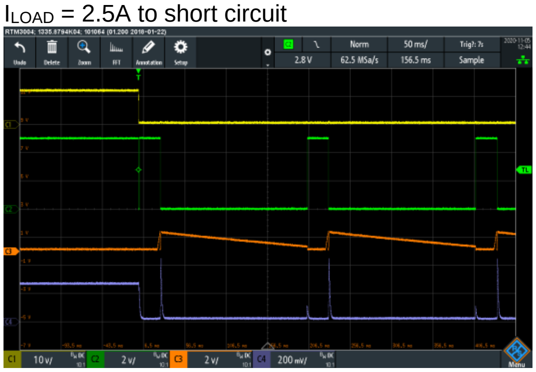


200µs/div.

Figure 48: SCP Entry (MPQ5069)

I_{LOAD} = 2.5A to short circuit

C1: V_{OUT} 10V/div.
C2: V_{FLTB} 2V/div.
C3: V_{TIMER} 2V/div.
C4: V_{IMON} 200mV/div.

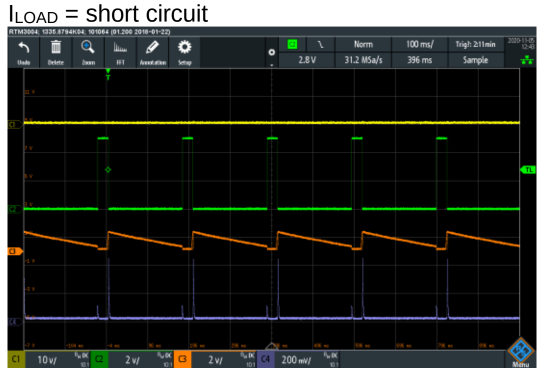


50ms/div.

Figure 49: SCP Steady State (MPQ5069)

I_{LOAD} = short circuit

C1: V_{OUT} 10V/div.
C2: V_{FLTB} 2V/div.
C3: V_{TIMER} 2V/div.
C4: V_{IMON} 200mV/div.

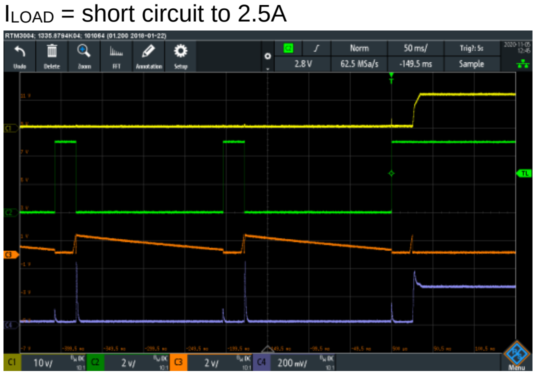


100ms/div.

Figure 50: SCP Recovery (MPQ5069)

I_{LOAD} = short circuit to 2.5A

C1: V_{OUT} 10V/div.
C2: V_{FLTB} 2V/div.
C3: V_{TIMER} 2V/div.
C4: V_{IMON} 200mV/div.



50ms/div.

Figure 51: Cold-Crank Conditions (System)

I_{LOAD} = 0A (one channel), V_{OUT} = 10V

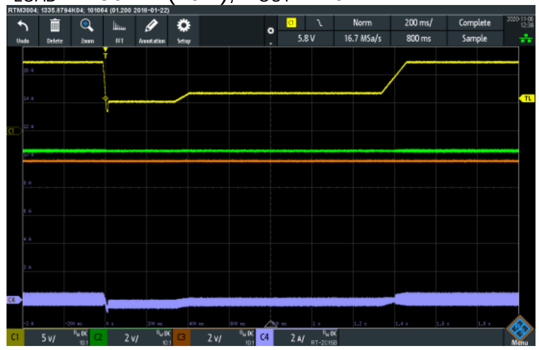
C1: V_{BATT} 5V/div.
C2: V_{COND} 2V/div.
C3: V_{CH1} 2V/div.
C4: I_L 2A/div.

200ms/div.

Figure 52: Cold-Crank Conditions (System)

I_{LOAD} = 250mA (1ch.), V_{OUT} = 10V

C1: V_{BATT} 5V/div.
C2: V_{COND} 2V/div.
C3: V_{CH1} 2V/div.
C4: I_L 2A/div.



200ms/div.

Figure 53: Cold-Crank Conditions (System)

I_{LOAD} = 250mA (2 channels), V_{OUT} = 10V

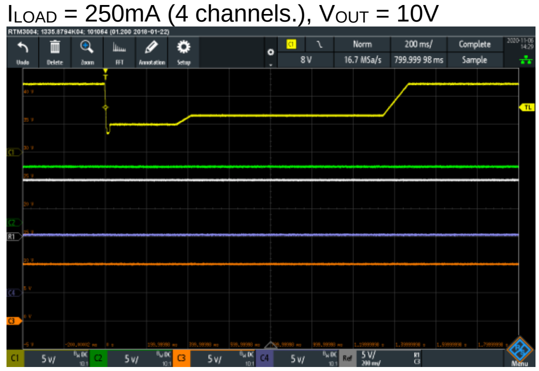
C1: V_{BATT} 5V/div.
C2: V_{COND} 5V/div.
C3: V_{CH1} 5V/div.
C4: V_{CH2} 5V/div.

200ms/div.

Figure 54: Cold-Crank Conditions (System)

I_{LOAD} = 250mA (4 channels.), V_{OUT} = 10V

C1: V_{BATT} 5V/div.
C2: V_{CH1} 5V/div.
REF: V_{CH4} 5V/div.
C4: V_{CH3} 5V/div.
C3: V_{CH2} 5V/div.



200ms/div.

4.3 EMC Measurements

V_{IN} = 13.5V, $V_{OUT-LDO}$ = 10V, I_{LOAD_CH} = 250mA, L = 10µH, f_{SW} = 450kHZ, spread spectrum, T_A = 25°C, unless otherwise noted.

Figure 55: CISPR25 Class 5 Conducted Emissions

150kHz to 108MHz

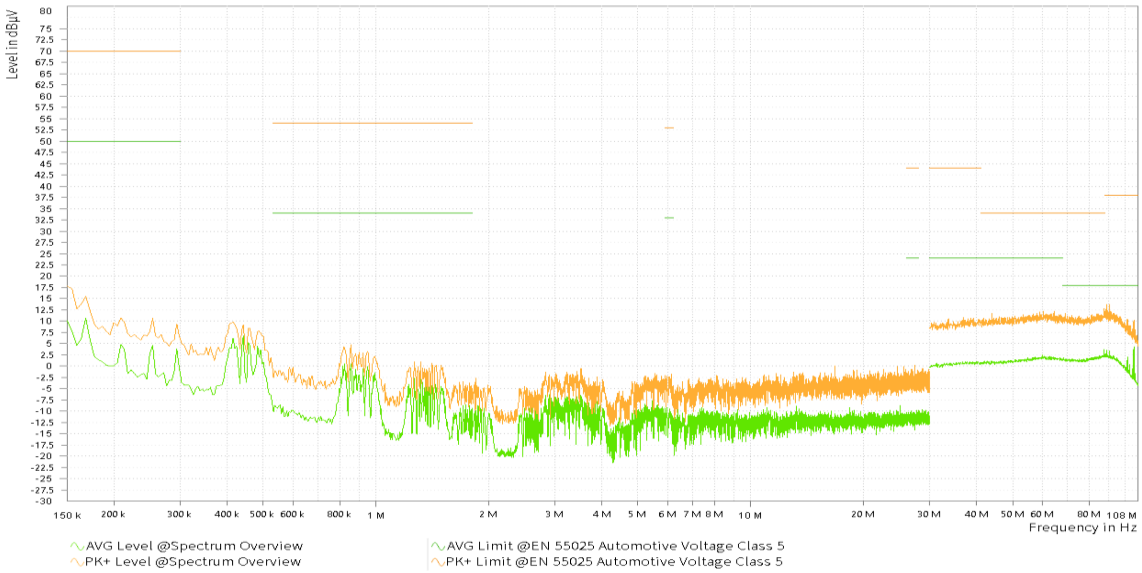
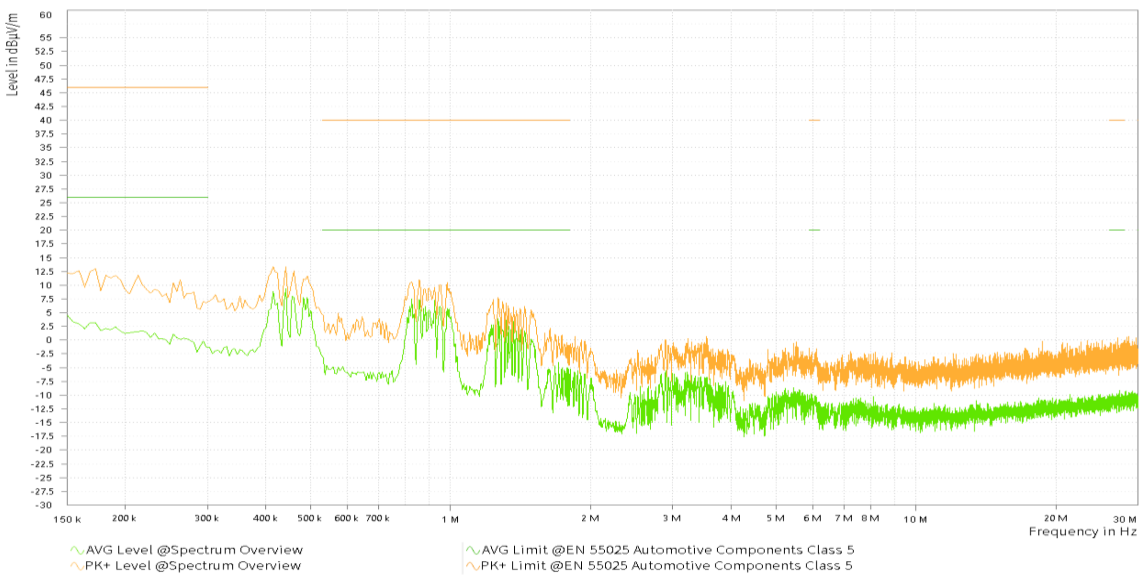


Figure 56: CISPR25 Class 5 Radiated Emissions

150kHz to 30MHz



5 Start-Up

1. Set the power supply to 12V. The evaluation board can tolerate up to 36V.
2. Connect the power supply terminals to:
   a. Positive (+): VBATT
   b. Negative (-): GND
3. Connect the 10V loads (maximum 300mA) with coaxial wires to CAM 1, CAM2, CAM3, and CAM4.
4. Connect the 12V load (maximum 2.5A) to:
   a. Positive (+): 12V OUT
   b. Negative (-): GND
5. Connect the 3.3V (or 5V) load (maximum 1A) to:
   a. Positive (+): OUT AUX
   b. Negative (-): GND
6. Turn the power supply on after making these connections
7. Set the desired configuration of the buck-boost converter (MPQ8875A) using the GUI or via the I^2C signals (SDA, SCL, GND). Follow the steps below to set the recommended configurations:
   a. Input mode: low input
   b. Output set-up:
      i. V_{REF}: 1.05V
      ii. V_{OUT} divider ratio: 1/10
   c. Current limit:
      i. Valley current limit: 8A
      ii. Peak current limit: 9A
   d. Protection:
      i. OCP mode: no response
   e. Buck-boost:
      i. Threshold to transition from buck-boost mode to buck mode: 110%
      ii. Threshold to transition from boost mode to buck-boost mode: 90%
   f. Frequency spread spectrum (FSS): On
   g. SYNC/f_{SW}:
      i. SYNC mode: OFF
      ii. f_{SW}: 400kHz

8. Configure the LDOs (MPQ2022) using the GUI or via the I²C signals (SDA, SCL, and GND). The recommended configurations for this design are as follows:
   a. SETVOUT_1:
      i. VOUT1_SET: 10V
   b. SETVOUT_2:
      i. POWER_SEQ: Powered simul
      ii. VOUT2_SET: 10V
   c. Device control:
      i. LDO_1_EN: enabled
      ii. LDO_2_EN: enabled
9. To disable one of the parts, connect a jumper to the according connector listed below:
   a. JP1 disables the MPQ5850.
   b. JP2 disables the MPQ8875.
   c. JP7 disables the first MPQ2022.
   d. JP9 disables the second MPQ2022.
   e. JP4 disables the MPQ4431.
   f. JP6 disables the MPQ5069.
10. To use the enable function for any IC, apply a digital output to the EN pin of the connectors:
    a. For the MPQ5850, drive EN above 1.28V to turn the IC on; drive EN below 1.21V to turn the IC off.
    b. For the MPQ8875A, drive EN above 1.55V to turn the IC on; drive EN below 1.4V to turn the IC off.
    c. For the MPQ2022, drive EN above 2.5V to turn the IC on; drive EN below 2.3V to turn the IC off.
    d. For the MPQ4431, drive EN above 1.05V to turn the IC on; drive EN below 0.93V to turn the IC off.
    e. For the MPQ5069, drive EN above 1.8V to turn the IC on; drive EN below 1.6V to turn the IC off.
11. The MPQ4433's oscillating frequency can be configured using an external resistor (R25). For more details, refer to the MPQ4433 datasheet.
12. To use the SYNC function for the MPQ8875A and the MPQ4431, apply a clock signal to the SYNC pin and follow the steps below:
    a. For the MPQ8875A, apply a 250kHz to 2.2MHz clock signal. The external clock signal must exceed the configured frequency set in the OTP register by 20%. Additionally, the GUI's SYNC Mode parameter must be set to "on."
    b. For the MPQ4433, apply a 350kHz to 2.5Mhz clock signal. The external clock signal must be at least 250kHz greater than the oscillating frequency set by R25.
13. To change the MPQ2022's I²C address, change the resistors connected to the ADD pins (R49 and R59). For more details, refer to the MPQ2022 datasheet.
14. To change the MPQ5069's current limit, use the resistor (R36) and follow Equation (2) on page 5.

6 Disclaimer

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