MPQ2908 Reference Design

48V Buck Converter for Automotive Systems

Contents

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1 Overview

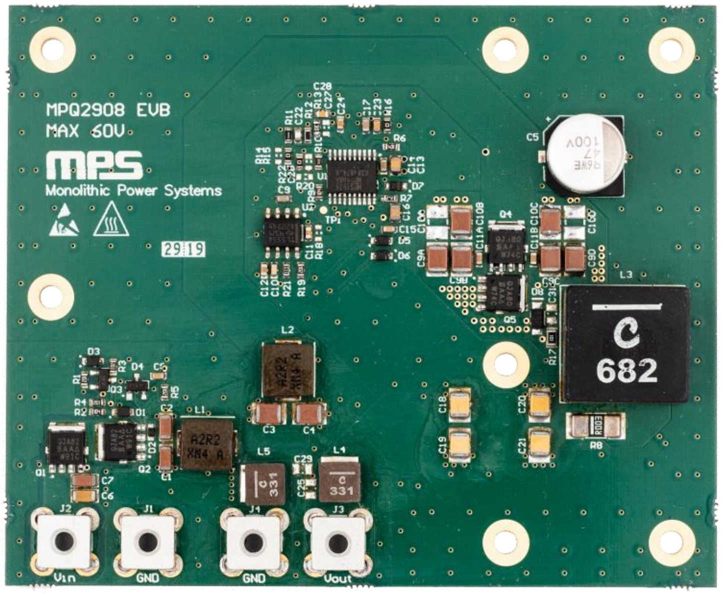
1.1 Description

New automotive designs are adopting 48V power systems to reduce the weight and power loss in the vehicle’s cable harnesses. However, this presents a challenge when trying to comply with EMC regulations. Success is achievable with thoughtful component placement regarding PCB layout, as well as techniques such as frequency spread spectrum (FSS).

This reference design showcases a 12V to 48V buck converter that is capable of delivering 15A of current while complying with Class 5 CISPR-25 EMC standards.

1.2 Features

- Wide 4V to 60V Operating Input Range
- Dual N-Channel MOSFET Driver
- 0.8V Reference Voltage with ±1.5% Accuracy Over-Temperature
- Low-Dropout Operation: Maximum Duty Cycle at 99.5%
- Configurable Frequency Range: 100kHz to 1000kHz
- External Sync Clock Range: 100kHz to 1000kHz
- 180º Out-of-Phase SYNCO Pin
- Configurable Soft Start (SS)
- Power Good (PG) Output Voltage Monitor
- Selectable Cycle-by-Cycle Current Limit
- Output Over-Voltage Protection (OVP)
- Over-Current Protection (OCP)
- Internal LDO with External Power Supply Option
- Configurable Forced CCM and AAM
- External Frequency Spread Spectrum (FSS) Modulation
- External Input Over-Voltage Protection (OVP)
- External Reverse-Polarity Protection (RPP)
- Available in TSSOP20-EP and QFN-20 (3mmx4mm) Packages
- Available in a Wettable Flank Package
- AEC-Q100 Qualified



1.3 Applications

- Automotive Power Systems
- Industrial Systems

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2 Reference Design

2.1 Block Diagram

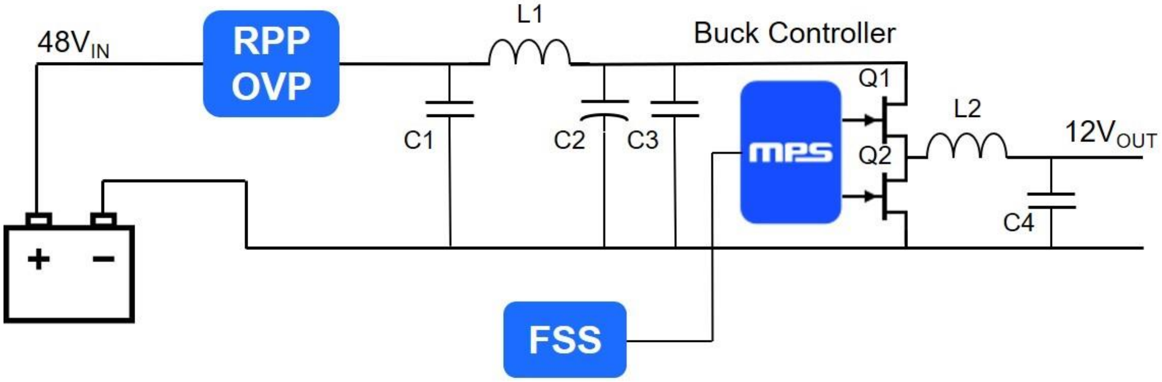

Figure 1: Block Diagram

Buck converter with 48V nominal input, 12V/15A output capability, input EMI filter, reverse-polarity protection (RPP), over-voltage protection (OVP), and frequency spread spectrum (FSS) modulation.

2.2 Related Solutions

This reference design is based on the following MPS solutions:

Table 1: MPS Solutions

MPS Integrated Circuit	Description
MPQ2908A	4V to 60V input, current mode, synchronous step-down controller, AEC-Q100 qualified

2.3 System Specifications

Table 2: System Specifications

Parameter	Specification
Input voltage range	18VDC to 60VDC
Output voltage	12VDC
Maximum output current	15A (with 12V output)
Switching frequency	430kHz
Board form factor	94mmx78mmx12mm
Peak efficiency	94.2%
12V output ripple	$22mV_{P-P}$

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3 Design

3.1 Schematics

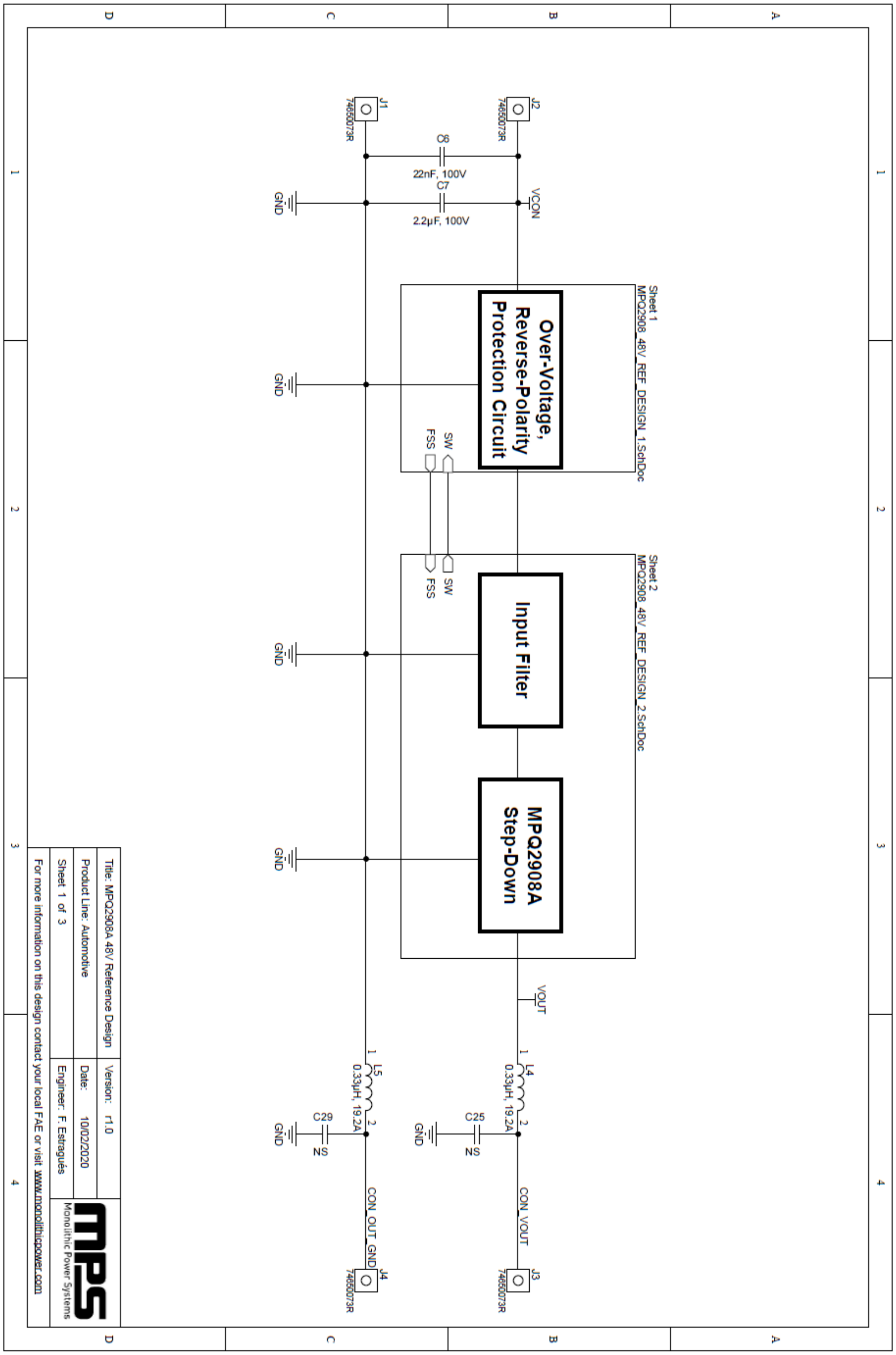

Figure 2: Schematics (Sheet 1)

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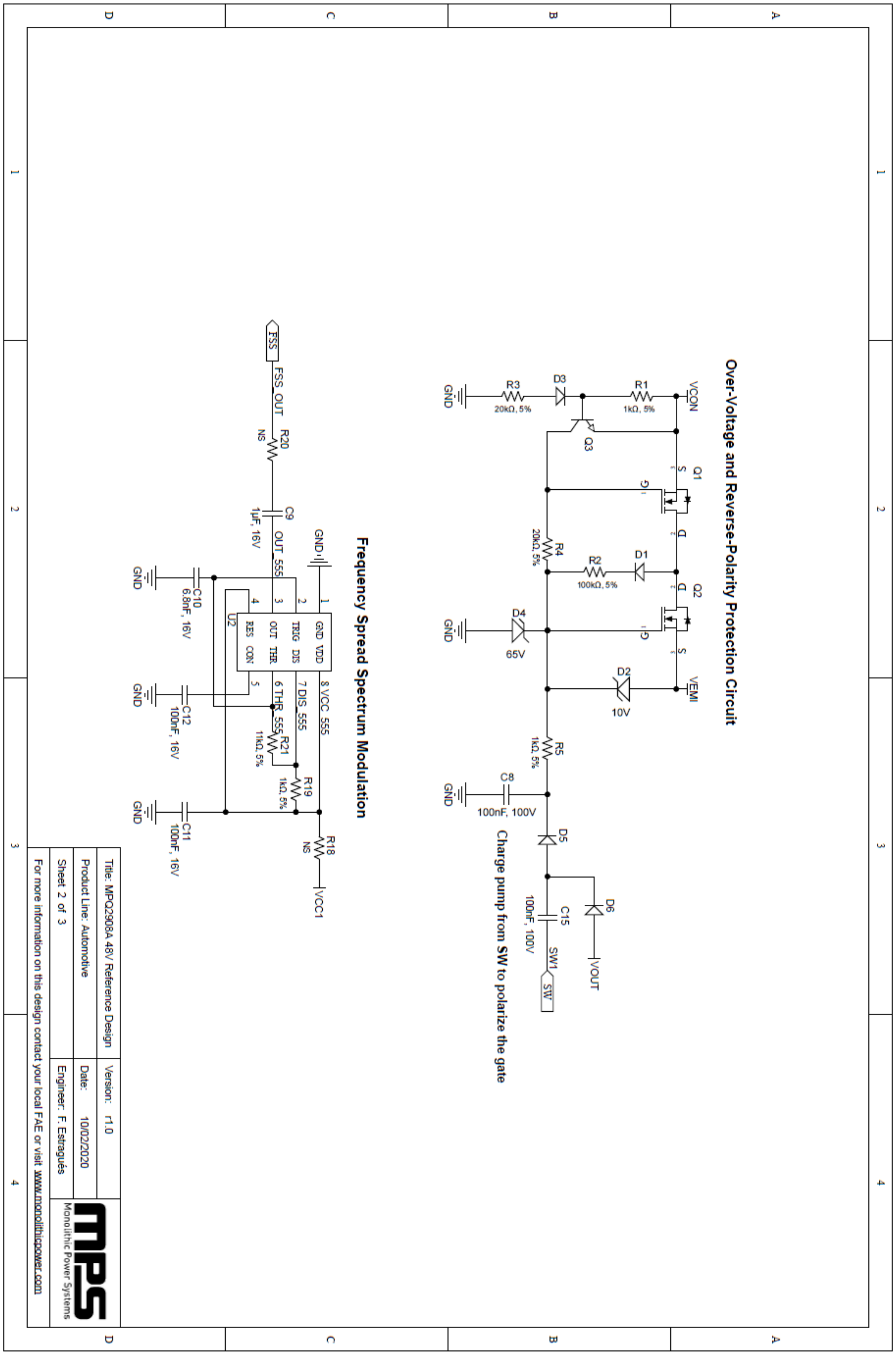

Figure 3: Schematics (Sheet 2)

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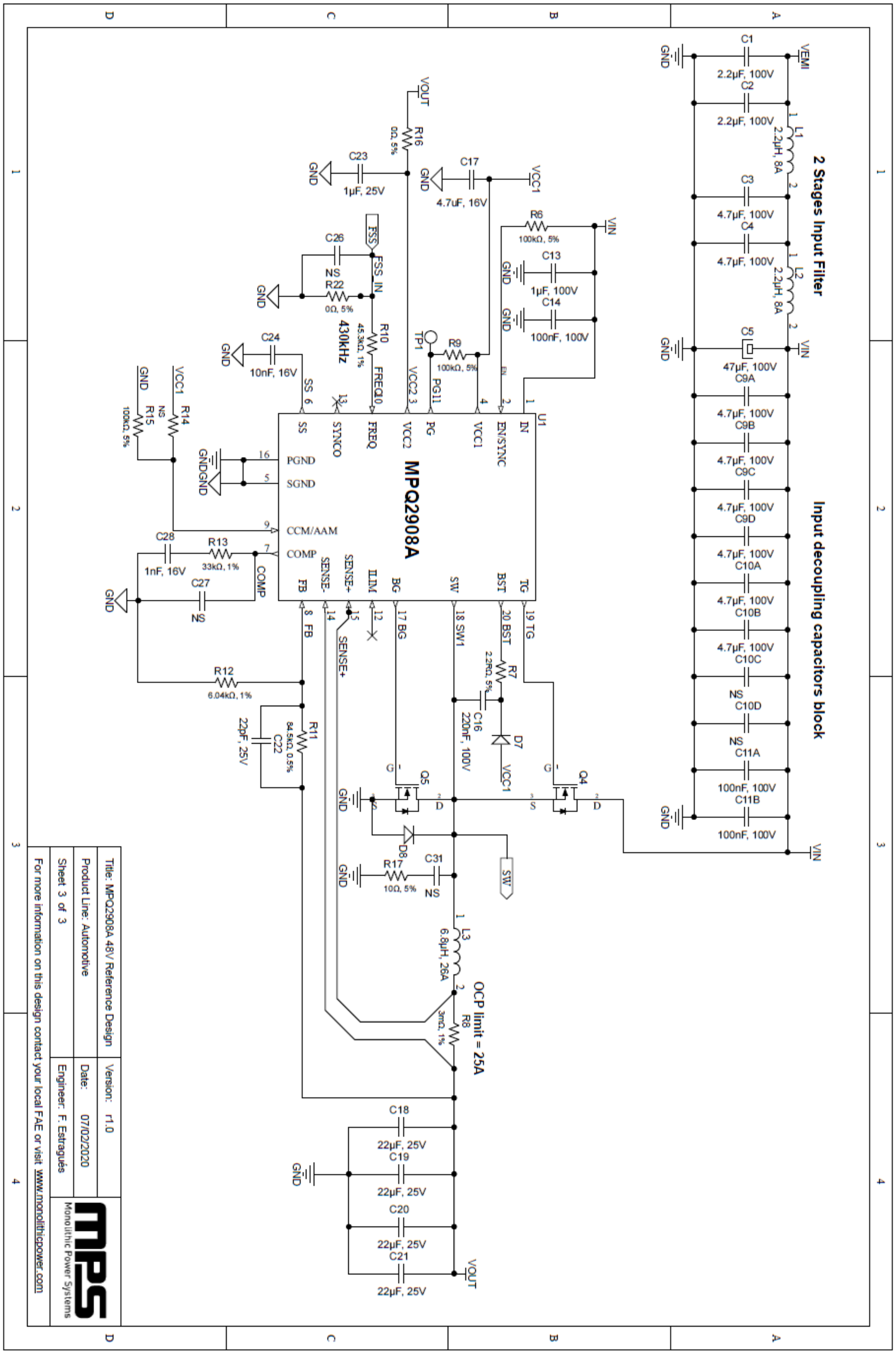

Figure 4: Schematics (Sheet 3)

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3.2 BOM

Table 3: MPQ2908 Bill Of Materials

Designator	Qty	Value	Package	Part Number	Manufacturer
C1, C2, C7	3	2.2µF, 100V	1206	CGA5L3X7S2A225K160AB	TDK
C3, C4, C9A, C9B, C9C, C9D, C10A, C10B	8	4.7µF, 100V	1210	C3225X7S2A475M200AB	TDK
C5	1	47µF, 100V	10mmx 10mm	EMVE101ADA470MJA0G	United Chemi-Con
C6	1	22nF, 100V	1206	C1206C223K1RECAUTO	KEMET
C8, C11A, C11B, C14, C15	5	100nF, 100V	0603	GCJ188R72A104KA01D	Murata
C9	1	1µF, 16V	0603	GCM188R71C105KA64J	Murata
C10	1	6.8nF, 16V	0603	VJ0603Y682KXJCW1BC	Vishay Vitramon
C10C, C10D	2	NS	1210	C3225X7S2A475M200AB	TDK
C11, C12	2	100nF, 16V	0603	C0603X104J4RECAUTO	KEMET
C13	1	1µF, 100V	0805	GCM21BC72A105KE36L	Murata
C16	1	220nF, 100V	0805	C0805C224K1RACTU	KEMET
C17	1	4.7µF, 16V	0603	GRM188R61C475KAAJD	Murata
C18, C19, C20, C21	4	22µF, 25V	1210	GRM32ER61E226KE15L	Murata
C22	1	22pF, 25V	0603	06033A220JAT2A	Kyocera AVX
C23	1	1µF, 25V	0603	CC0603KRX5R8BB105	Yageo
C24	1	10nF, 16V	0603	C0603C103M3RACTU	KEMET
C25, C29	2	NS	0805		
C26, C27	2	NS	0603		
C28	1	1nF, 16V	0603	CC0603JRNPO8BN102	Yageo
C31	1	NS	0805	GCJ188R72A104KA01D	Murata
D1, D3, D5, D6	4	1N4148	SOD-323	1N4148WSQ-7-F	Diodes
D2	1	10V Zener	SOD-523	BZT585B10T-7	Diodes
D4	1	65V Zener	SOT-23	SZBZX84C62LT1G	ON Semiconductor
D7	1	PMEG6010CEJ	SOD-323	PMEG6010CEJ,115	Nexperia
D8	1	RB168MM150TFTR	SOD-123	RB168MM150TFTR	Rohm
J1, J2, J3, J4	4	74650073R		74650073R	Wurth Electronics
L1, L2	2	2.2µH, 8A, 20mΩ	7030	HCMA0703-2R2-R	Eaton
L3	1	6.8µH, 26A, 4.17mΩ	1510	XAL1510-682MEB	Coilcraft
L4, L5	2	0.33µH, 19.2A, 3.52mΩ	5030	XAL5030-331MEC	Coilcraft

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Q1, Q2	2	SQJA80EP	PowerPAK-SO-8L-4	SQJA80EP-T1_GE3	Vishay
Q3	1	SBC846BLT1G	SOT-23-3	SBC846BLT1G	ON Semiconductor
Q4, Q5	2	SQJA82EP-T1_GE3	PowerPAK-SO-8L-4	SQJA82EP-T1_GE3	Vishay
R1, R5, R19	3	1kΩ, 5%	0603	RC0603JR-071KL	Yageo
R2, R6, R9	3	100kΩ, 5%	0603	RC0603JR-07100KL	Yageo
R3, R4	2	20kΩ, 5%	0603	RC0603JR-0720KL	Yageo
R7	1	2.2Ω, 5%	0603	ERJ-3GEYJ2R2V	Panasonic
R8	1	3mΩ, 1%	2512	PA2512FKF7W0R003E	Yageo
R10	1	45.3kΩ, 1%	0603	CR0603-FX-4532ELF	Bourns
R11	1	84.5kΩ, 0.5%	0603	ERJ-PB3D8452V	Panasonic
R12	1	6.04kΩ, 1%	0603	ERJ-3EKF6041V	Panasonic
R13	1	33kΩ, 1%	0603	ERJ-3EKF3302V	Panasonic
R14, R18	2	NS	0603	RC0603JR-070RL	Yageo
R15, R16, R22	3	0Ω, 5%	0603	RC0603JR-070RL	Yageo
R17	1	10Ω, 5%	0805	ERJ-P06J101V	Panasonic
R20	1	NS	0603	ERJ-3GEYJ103V	Panasonic
R21	1	11kΩ, 5%	0603	ERJ-3GEYJ113V	Panasonic
U1	1	MPQ2908A	TSSOP-20EP	MPQ2908AGF-AEC1	MPS
U2	1	TLC555QDRQ1	SOIC-8	TLC555QDRQ1	Texas Instruments

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3.3 PCB Layout

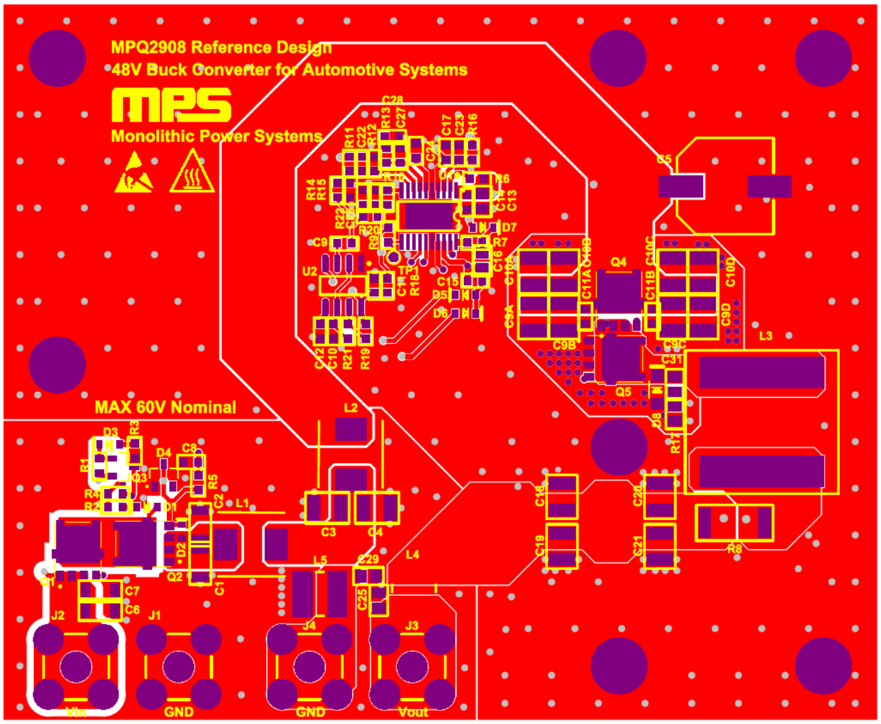

Figure 5: PCB Layer 1

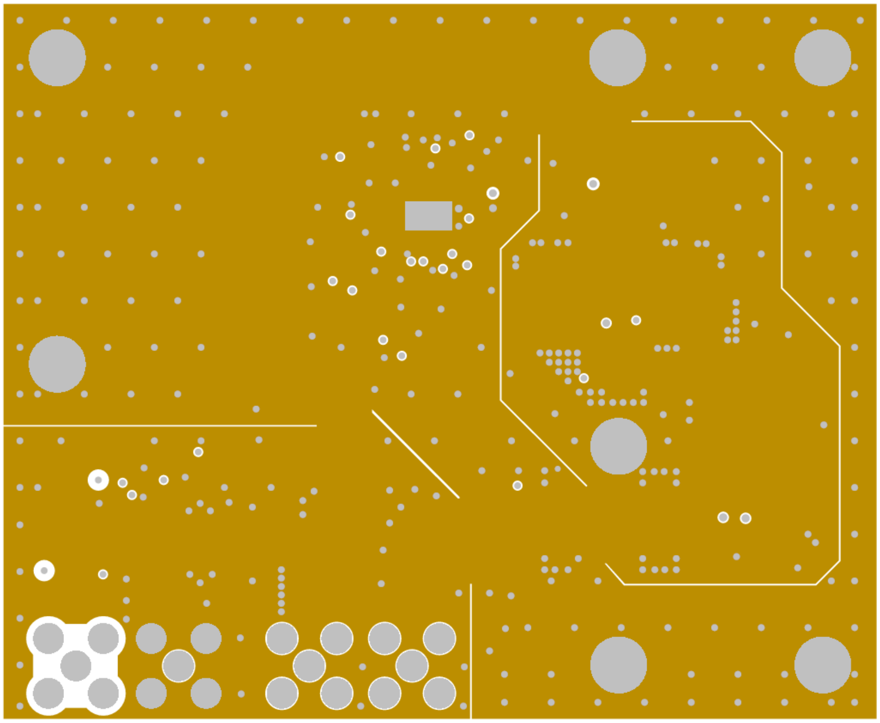

Figure 6: PCB Layer 2

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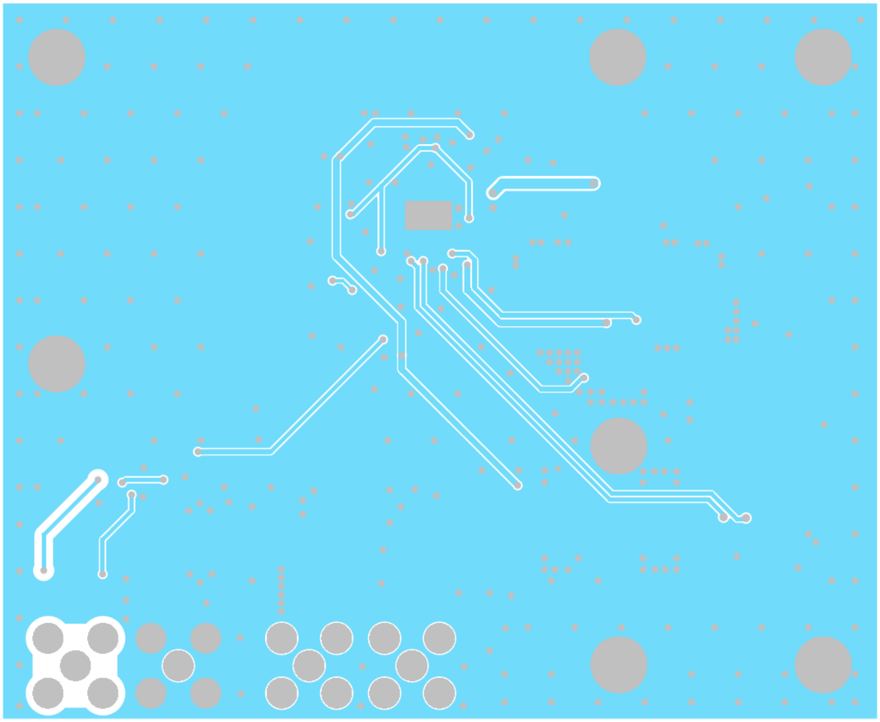

Figure 7: PCB Layer 3

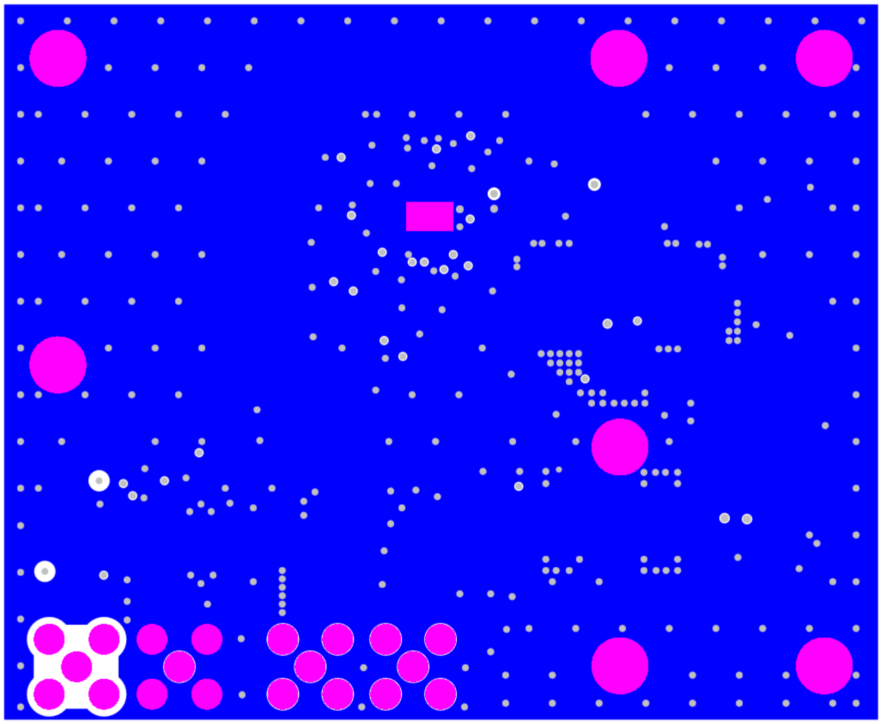

Figure 8: PCB Layer 4

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4 Test Results

4.1 Efficiency and Regulation

V_{OUT} = 12V, L = 6.8µH, f_{SW}= 400kHz, CCM, copper thickness = 35µm, T_A = 25°C.

Figure 9: Efficiency vs. Load Current

With OVP and EMI filter

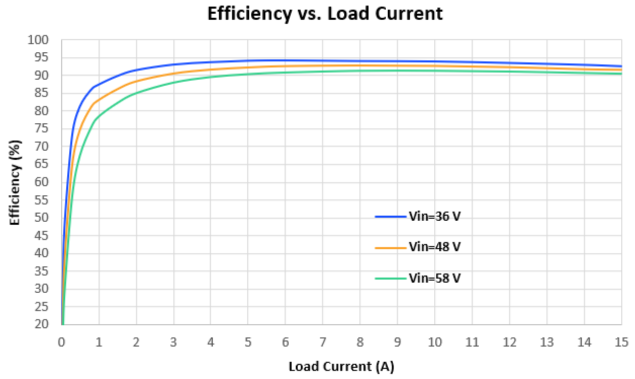


Figure 10: Load Regulation

Without OVP and EMI filter

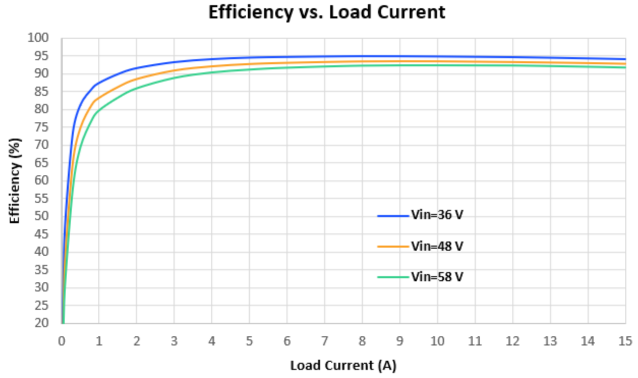


Figure 11: Line Regulation

With OVP and EMI filter, measured at output connector

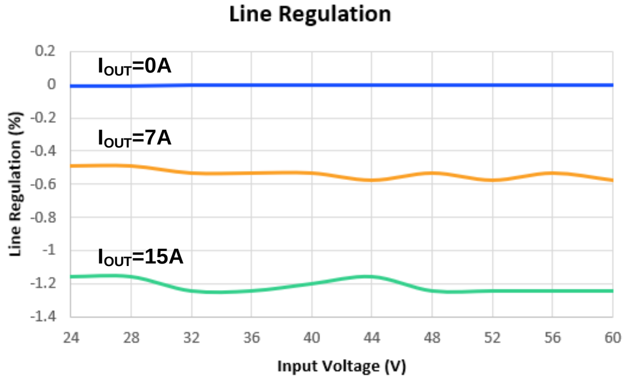


Figure 12: Line Regulation

With OVP and EMI filter, measured at output capacitor

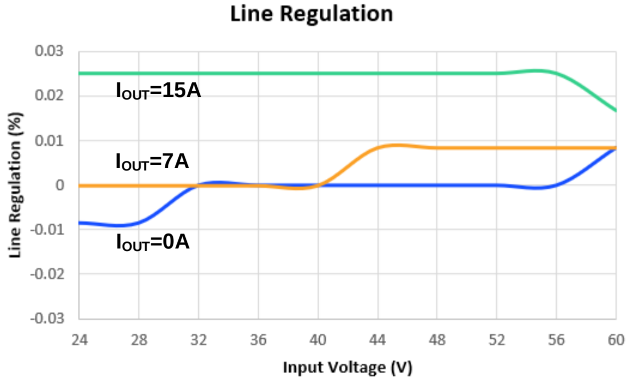
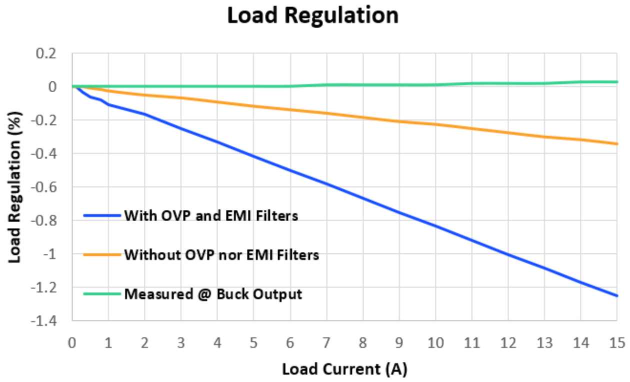


Figure 13: Load Regulation

V_{IN} = 48V



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4.2 Time Domain Waveforms

V_{IN} = 48V, V_{OUT} = 12V, L = 6.8µH, T_A = 25°C, CCM.

Figure 14: Steady State

I_{OUT} = 0A

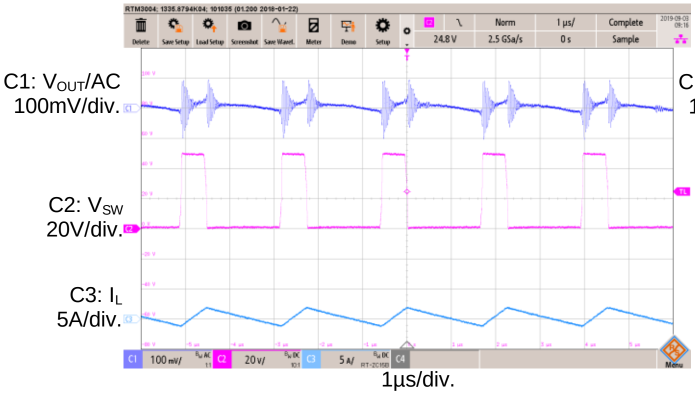

Figure 15: Steady State

I_{OUT} = 15A

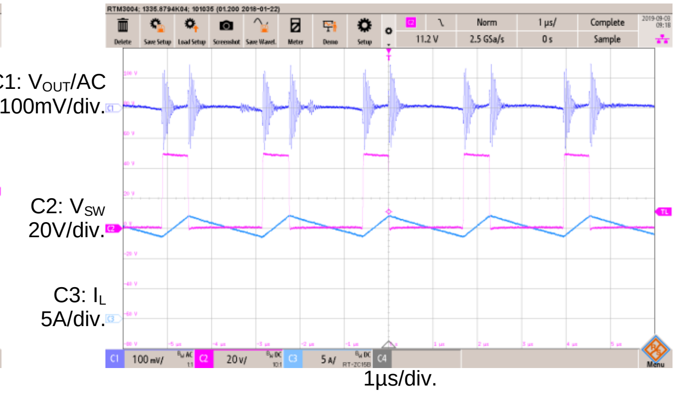

Figure 16: Start-Up through V_{IN}

I_{OUT} = 0A

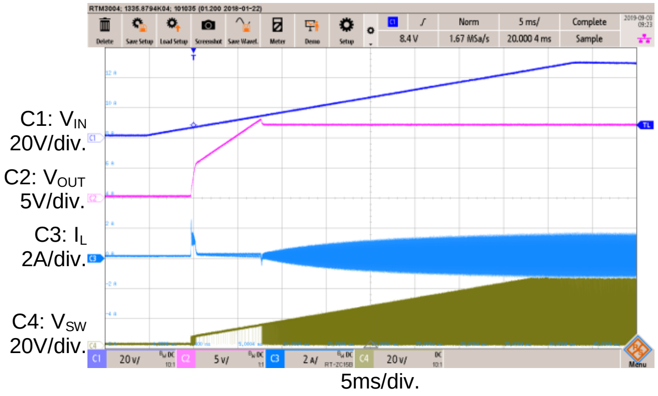

Figure 17: Start-Up through V_{IN}

I_{OUT} = 15A

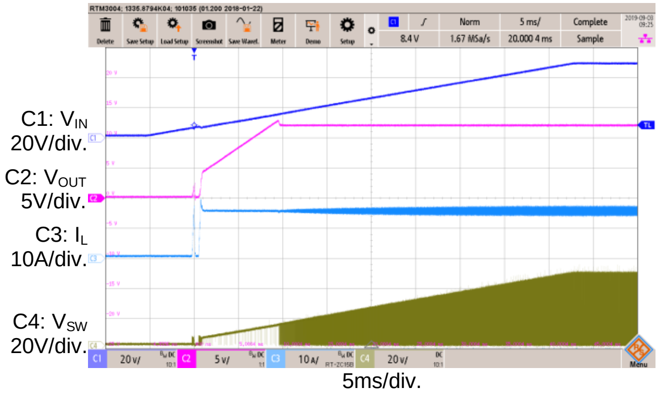

Figure 18: Shutdown through V_{IN}

I_{OUT} = 0A

Figure 19: Shutdown through V_{IN}

I_{OUT} = 15A

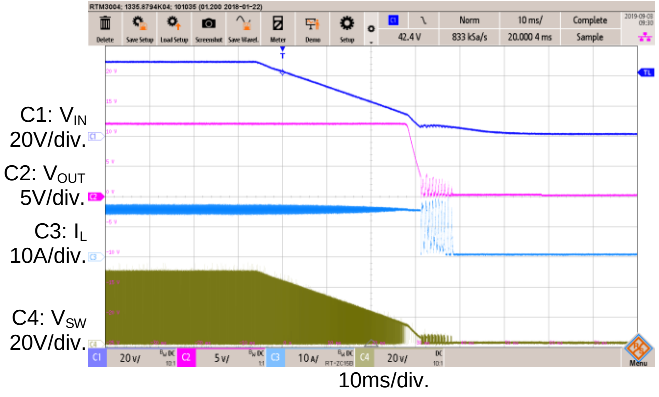

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Figure 20: SCP Entry

I_{OUT} = 0A

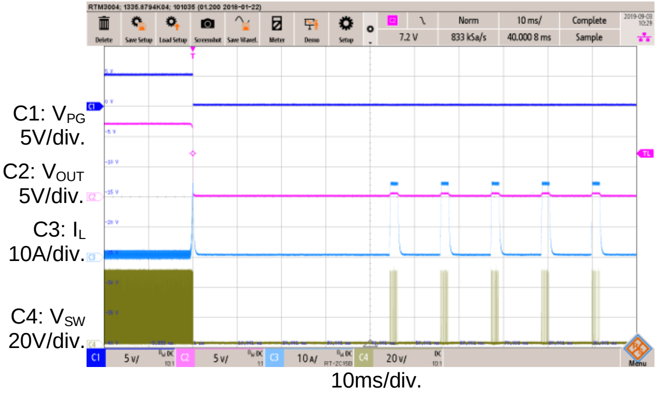

Figure 21: SCP Entry

I_{OUT} = 15A

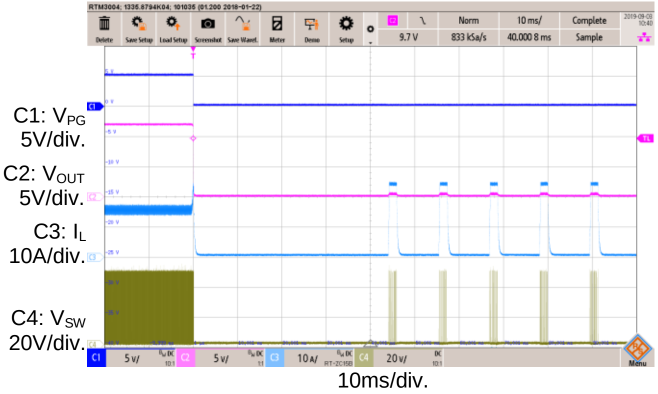

Figure 22: SCP Steady State

C_{SS} = 10nF

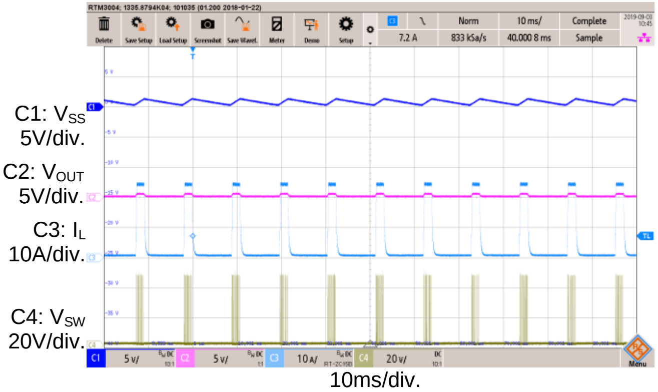

Figure 23: SCP Recovery

I_{OUT} = 0A

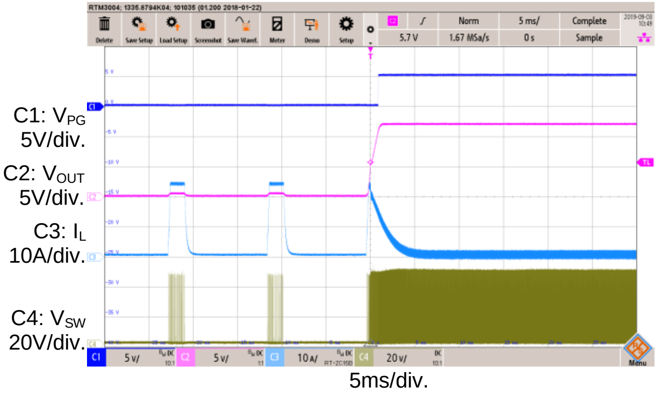

Figure 24: SCP Recovery

I_{OUT} = 15A

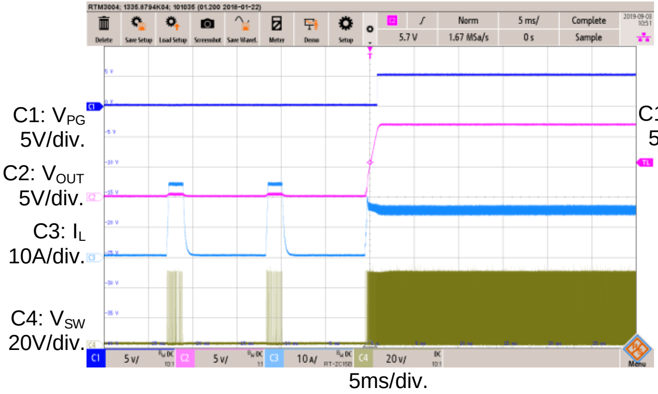

Figure 25: Load Transient

I_{OUT} = 5A to 10A

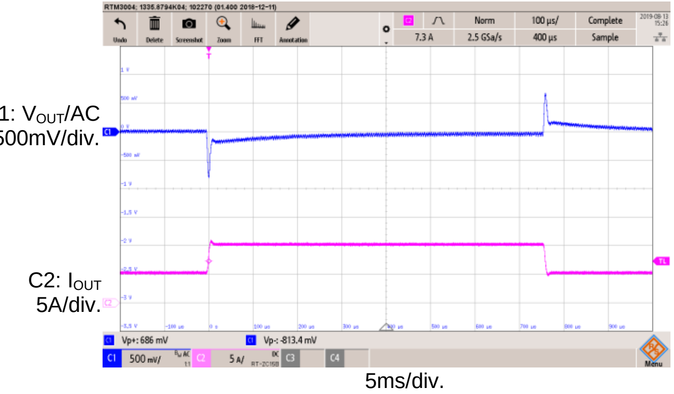

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Figure 26: Transient Over-Voltage Test

LV148 E48-02, V_{IN+} = 72V, t_{PEAK} = 30ms, I_{OUT} = 7A

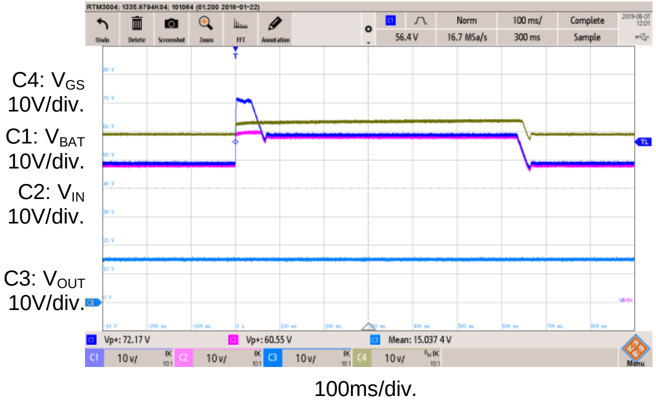
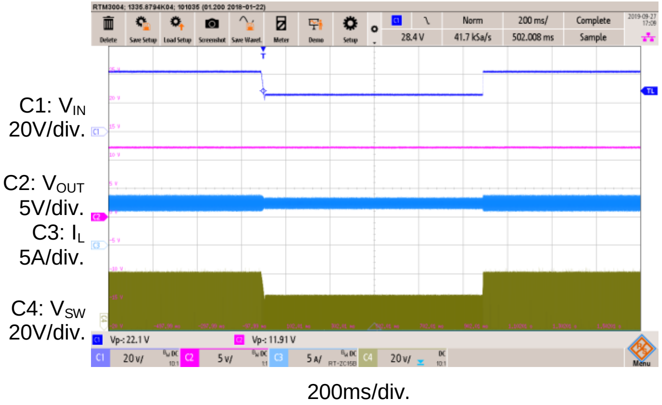


Figure 27: Cold-Crank Test

LV148 E48-10 V_{IN-} = 24V, $t_{TRANSIENT}$ = 1s, I_{OUT} = 7A



4.3 Thermal Measurements

V_{IN} = 48V, V_{OUT} = 12V, L = 6.8µH, f_{SW} = 400kHz T_A = 25°C, CCM mode, no airflow.

Figure 28: Thermal Image

I_{OUT} = 10A, without heatsink

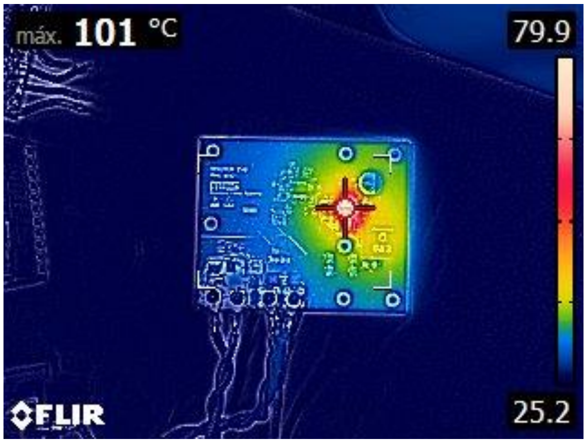
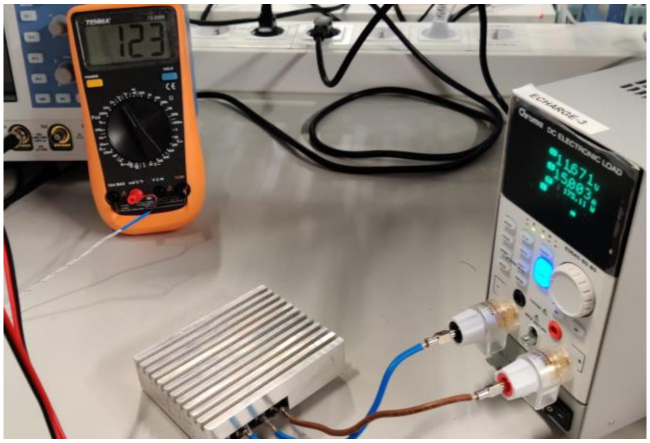


Figure 29: MOSFET Case Temperature: 123°C

I_{OUT} = 15A, heatsink mounted, 2hr runtime



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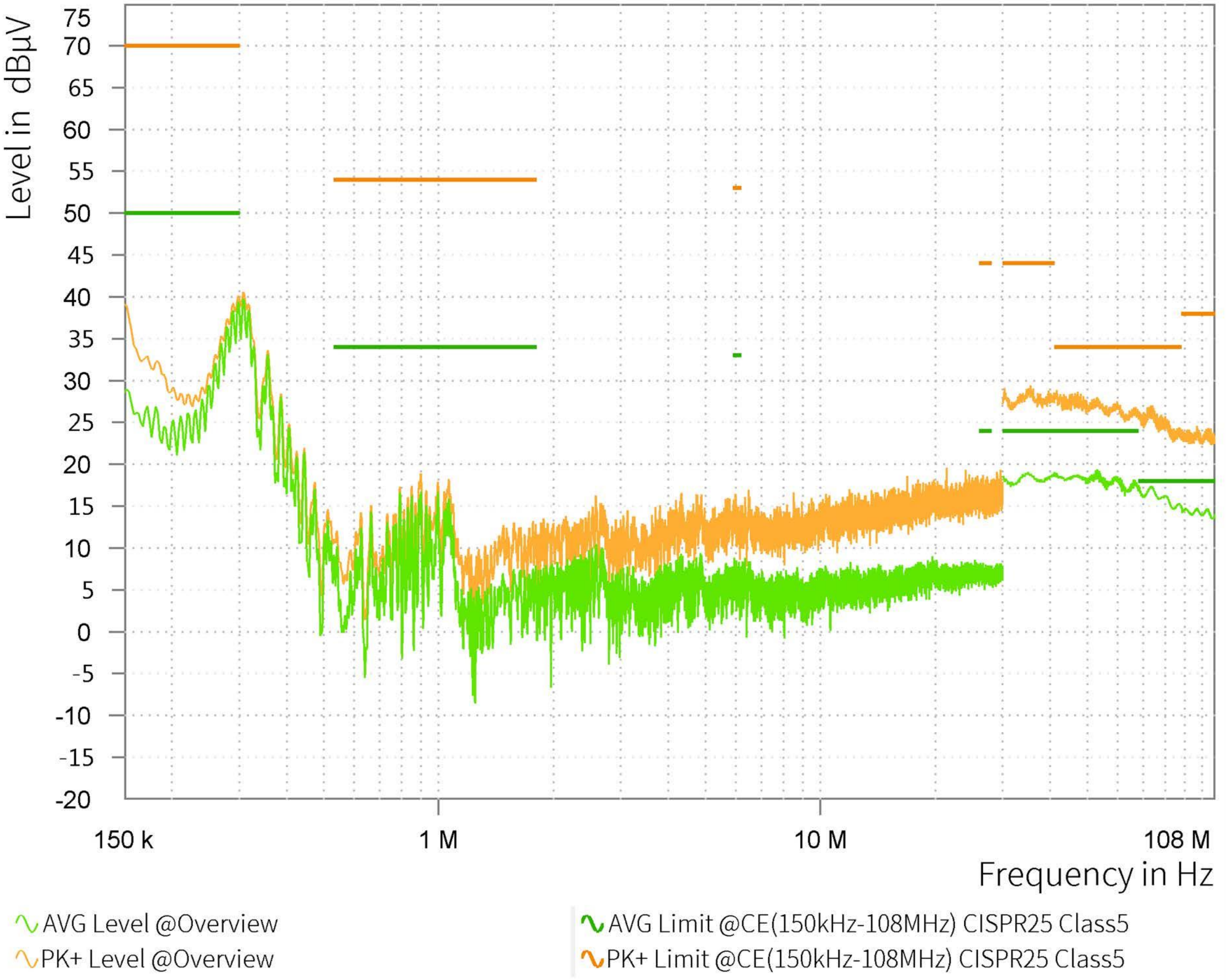
4.4 EMC Measurements

V_{IN} = 48V, V_{OUT} = 12V, I_{OUT} = 15A, L = 6.8µH, C_{OUT} = 88µF, f_{SW} = 400kHz, T_A = 25°C, FSS activated.

Figure 30: CISPR25 Class 5 Conducted Emissions

150kHz to 108MHz



5 Start-Up

1. Connect the load to:
    a) Positive (+): VOUT
    b) Negative (-): GND
2. Set the load current between 0A and 15A. Be aware that electronic loads represent a negative impedance to the regulator, and will trigger over-current protection or short-circuit protection if set to an exceedingly high current.
3. Preset the output power supply between 24V and 60V, then turn off the power supply.
4. Connect the power supply terminals to:
    a) Positive (+): VIN
    b) Negative (-): GND
5. Turn the power supply on. The board should automatically start up. The default V_{OUT} is 12V.
6. The external resistor dividers (R11 and R12) set the output voltage. If V_{OUT} = 12V, R11 and R12 must be 84.5kΩ and 6.04kΩ, respectively. R11 and R12 can be calculated with Equation (1):

$$R_{12} = \frac{R_{11}}{\frac{V_{out}}{0.8} - 1} \tag{1}$$

7. If the part is working at high V_{IN} and f_{SW}, ensure the junction temperature (T_J) of the high-side MOSFET does not exceed 175°C.

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6 Frequency Spread Spectrum

Most switch-mode power supplies (SMPS) will generate a lot of noise when working from 48V systems. This board has an optional frequency spread spectrum (FSS) modulation feature that can be used to improve its EMC performance when the device fails to comply with EMC regulations by a few dB.

FSS makes the switching power supply commute on several side bands around its fundamental switching frequency, instead of having just one fixed frequency. This side bands are created by modulating the switching frequency with a triangle modulation waveform. The emission power of the fundamental switching frequency and its harmonics is distributed into smaller pieces, which significantly reduces peak EMI noise .

FSS is especially effective in reducing the noise level during low-frequency operation, and its effect decreases as the measurement frequency increases.

MPS has conducted an in-depth webinar on FSS, explaining how it works, and what improvements can be expected from FSS. For more information, view the full webinar at this link: https://www.monolithicpower.com/en/support/webinars.html.

To enable FSS modulation, the following components on the board must be modified:

- Mount a 0Ω 0603 resistor on R18
- Mount a 10kΩ 0603 resistor on R20
- Mount a 100nF 0603 capacitor (with a voltage rating of at least 6.3V) on C26
- Remove R22 and replace it with a 1kΩ 0603 resistor

To disable FSS, revert these changes.

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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.

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REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	8/24/2022	Initial Release	-

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