Xilinx ZU+ Reference Design

Scalable Automotive Power Supply for Xilinx ZU+

Contents

1 Overview

1.1 Description

This reference design is a power supply for automotive applications using the Xilinx Zynq Ultrascale+ family of SoC (System on Chip) from the ZU2CG to the ZU5EG, using a flexible configuration based on multiple small DC/DC converters as PoL (Point of Load) supplies.

The MPQ8886, with its dual 3A output and multi-IC operation, allows scalability to meet the specific needs of each ZU+ device and achieve the most cost-effective solution. The MPQ8886's outputs can be paralleled with a single inductor to reduce cost, or used in 180º phase interleave to improve transient response and reduce the input capacitance and filtering needed to pass automotive EMC qualification. The number of individual MPQ8886 IC needed will depend on the ZU+ device power needs on the VCCINT rail.

Furthermore, the MPQ8886's digital interface allows output adjustment to optimize power consumption, as the output voltage can be modified on the go, and individual phases can be powered down if the power draw is low.

1.2 Features

- AEC-Q100 Qualified
- CISPR-25 Class 5 Compliant
- Wide 5V to 35V operating input range
- -40ºC to +125ºC operating temperature range
- Scalability to meet ZU+ power needs
- AAM mode to reduce power in light-load condition
- Configurable frequency range: 150kHz to 2MHz
- OVP, UVP, OCP, UVLO and Thermal protections
- Programable Frequency Spread Spectrum for low EMI
- Multiple Times Programable memory to define default power-on conditions, with CRC protection

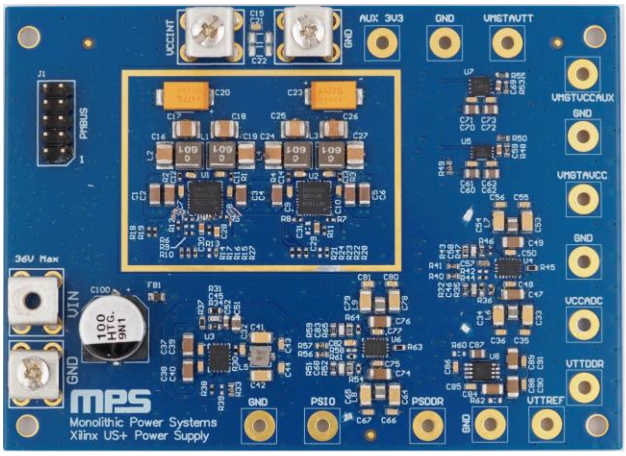


Figure 1: Evaluation Board

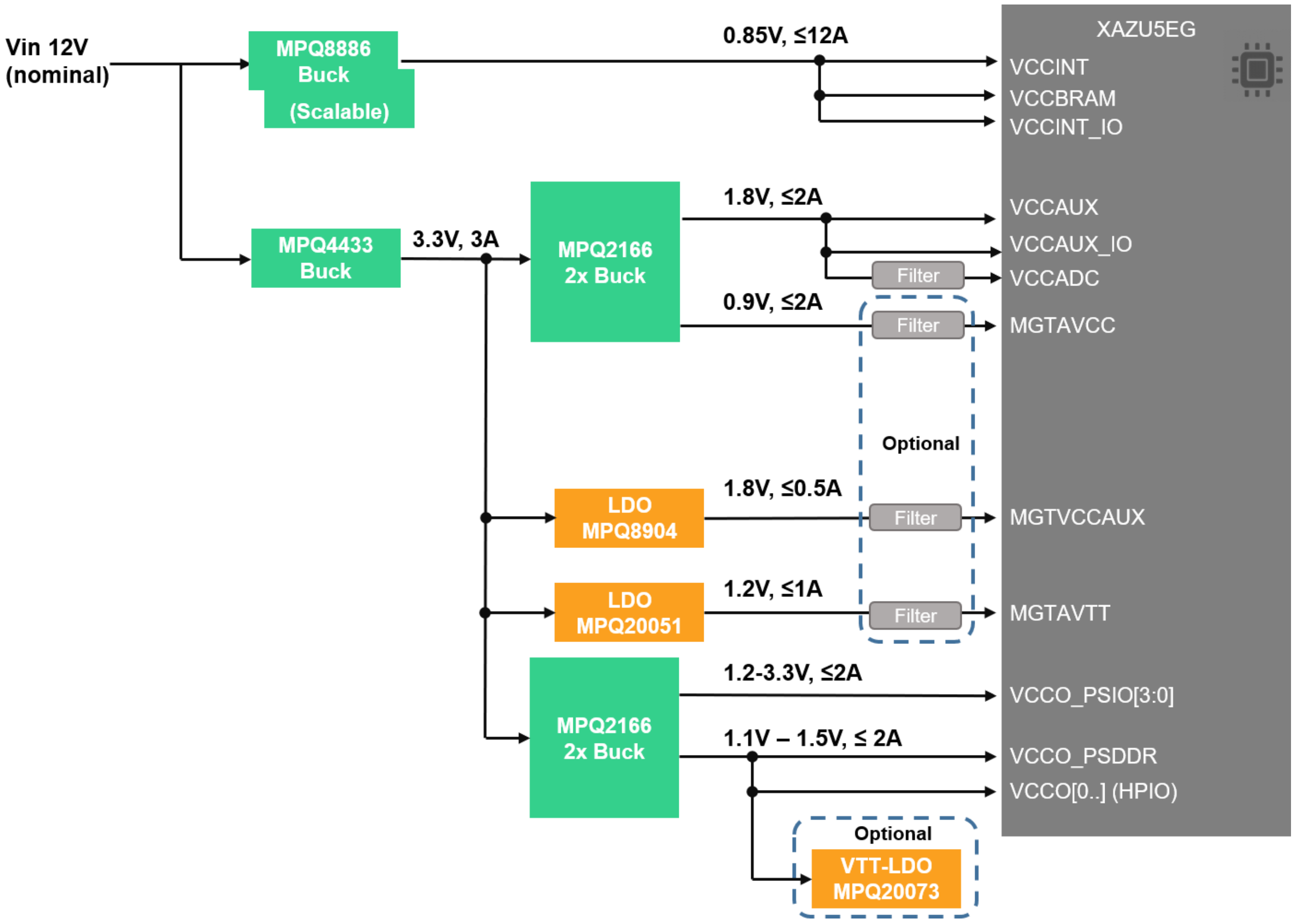
1.3 Applications

- Automotive Cockpit
- Automotive Infotainment
- V2X Communication
- Motion control

2 Reference Design

2.1 Application Block Diagram

Figure 2: Block diagram



2.2 Related Solutions

This reference design is based on the following MPS solutions:

Table 1: MPS Solutions

MPS Integrated Circuit	Description
MPQ8886-0000-AEC1	4V-45V Input, Dual 3A / Single 6A Outputs, Digital Programmable Synchronous Buck Converter, AEC-Q100 Qualified
MPQ4433-AEC1	3.3V-36V Input, 3A Synchronous Buck Converter. AECQ-100 Qualified
MPQ2166A-AEC1	2.7V-6V Input, Dual 2A/2A or 3A/1A Outputs, Synchronous Buck Converter, AEC-Q100 Qualified
MPQ8904-AEC1	2.5V-6.5V Input, 500mA Linear Regulator, AEC-Q100 Qualified
MPQ20051-AEC1	2.5V-5.5V Input, High PSRR 1A Linear Regulator, AEC-Q100 Qualified
MPQ20073-AEC1	1.3V-6V VDDQ, 2A DDR Memory Termination Regulator, AEC-Q100 Qualified

2.3 System Specifications

Table 2: System Specifications

Parameter	Specification
Input voltage range	$4V_{DC}$ to $36V_{DC}$
Output voltage	Multiple Outputs
Maximum output current	12A on VCCINT
Switching frequency	600kHz, 1MHz
Board form factor	99mmx70mmx5mm
Power-on sequencing	Yes
Power-off sequencing	No (Needs external sequencer)

Table 3: ZU+ Rails Distribution

Power Rail	Electrical Characteristics	Source	Power-on Sequence
VCCINT VCCBRAM VCCINT_IO	0.85V ±3%, ≤12A	2x MPQ8886	1
VCCAUX VCCAUX_IO VCCADC	1.8V ±2%, ≤2A	MPQ2166A	2
VMGTAVCC	0.9V ±2%, ≤2A	MPQ2166A	2
VMGTVCCAUX	1.8V ±2%, ≤0.5A	MPQ8904	3
VMGTAVTT	1.2V ±2%, ≤1A	MPQ20051	3
VCCO_PSDDR	1.1V-1.5V ±3%, ≤2A	MPQ2166A	3
VCCO_PSIO [3:0]	1.8V-3.3V ±3%, ≤2A	MPQ2166A	3
VTT	0.5·VCCO_PSDDR, 2A	MPQ20073	4

3 Design

3.1 Schematics

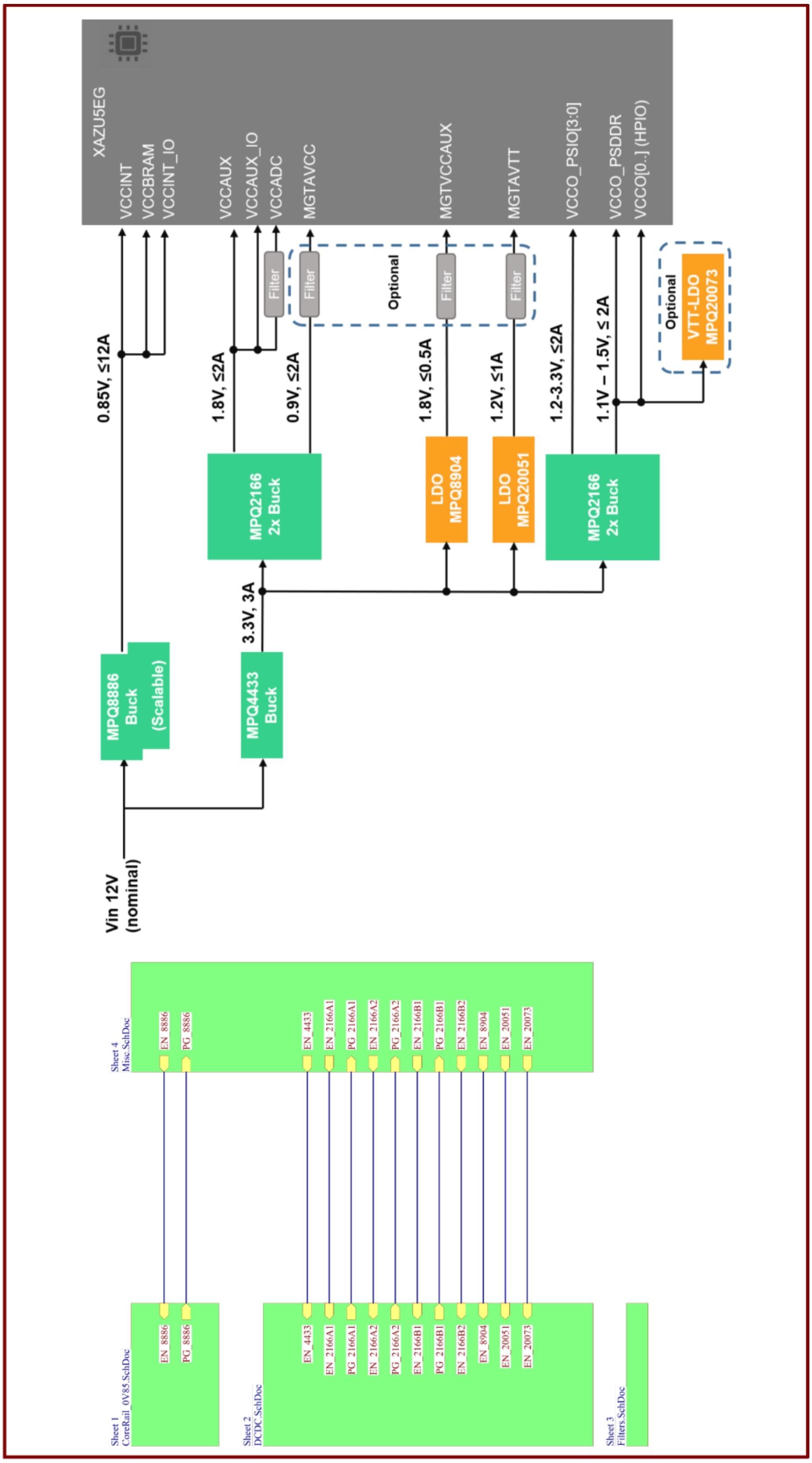


Figure 3: Schematics Hierarchy (Sheet 1)

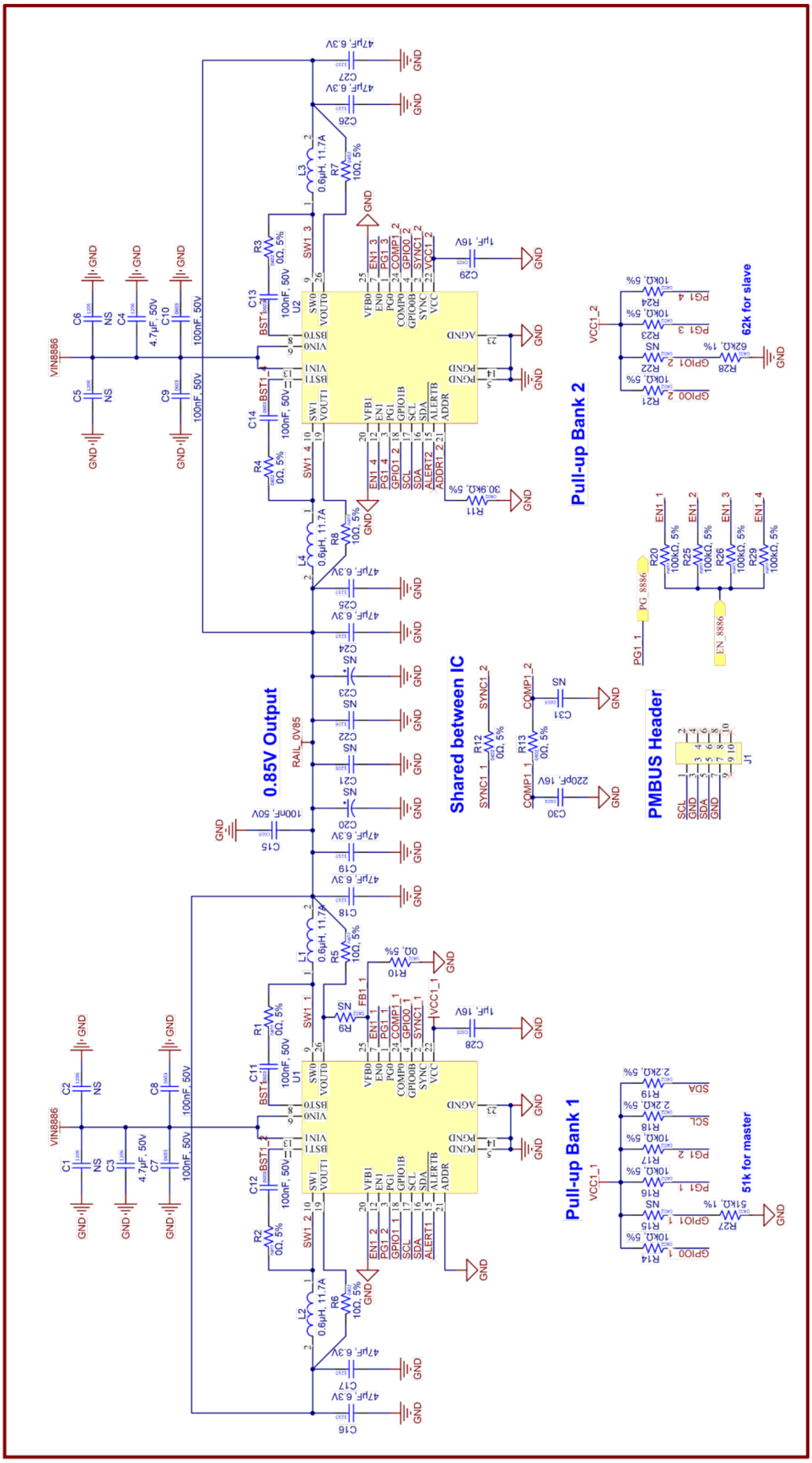


Figure 4: VCCINT Rail (Sheet 2)

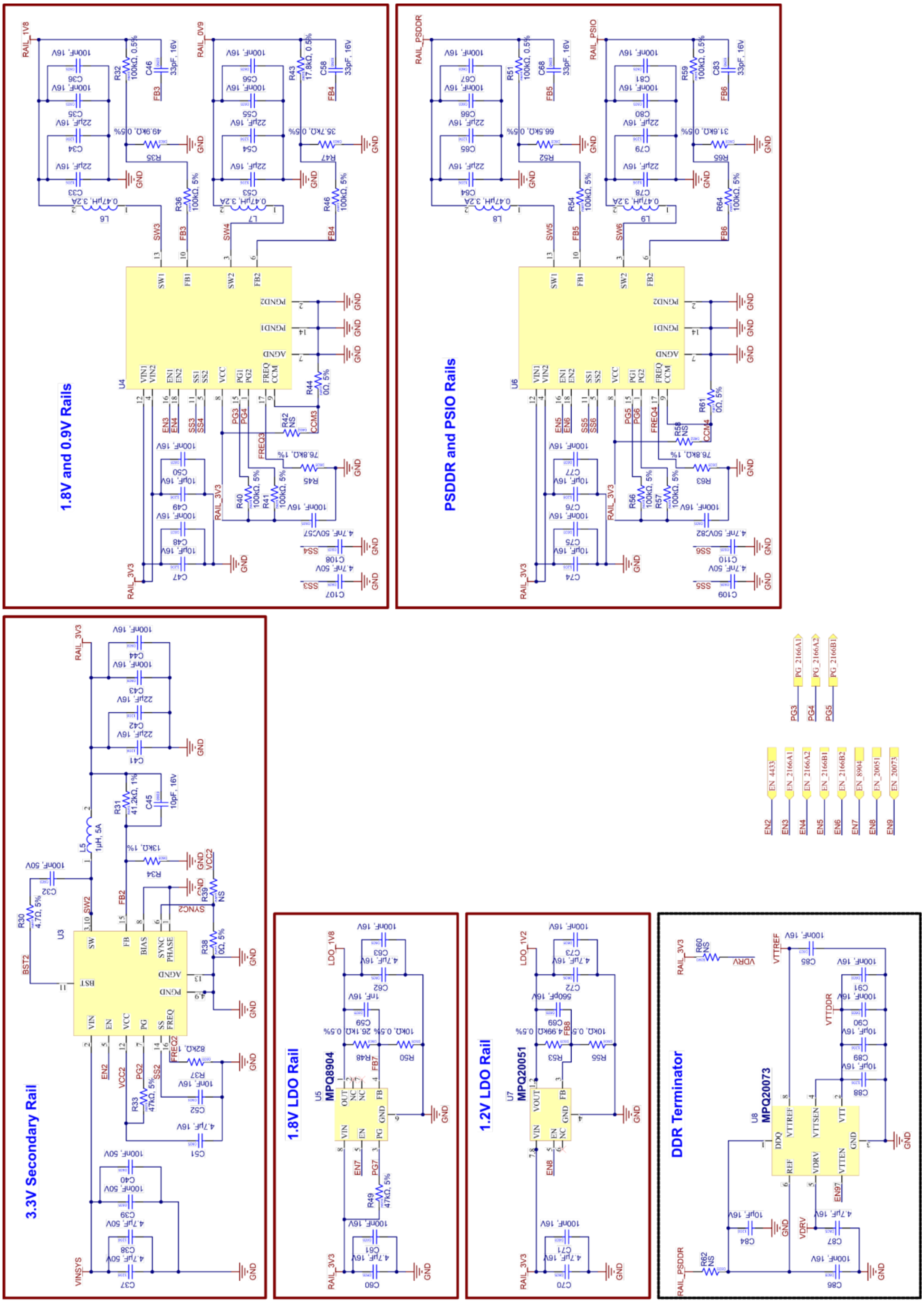


Figure 5: Other rails (Sheet 3)

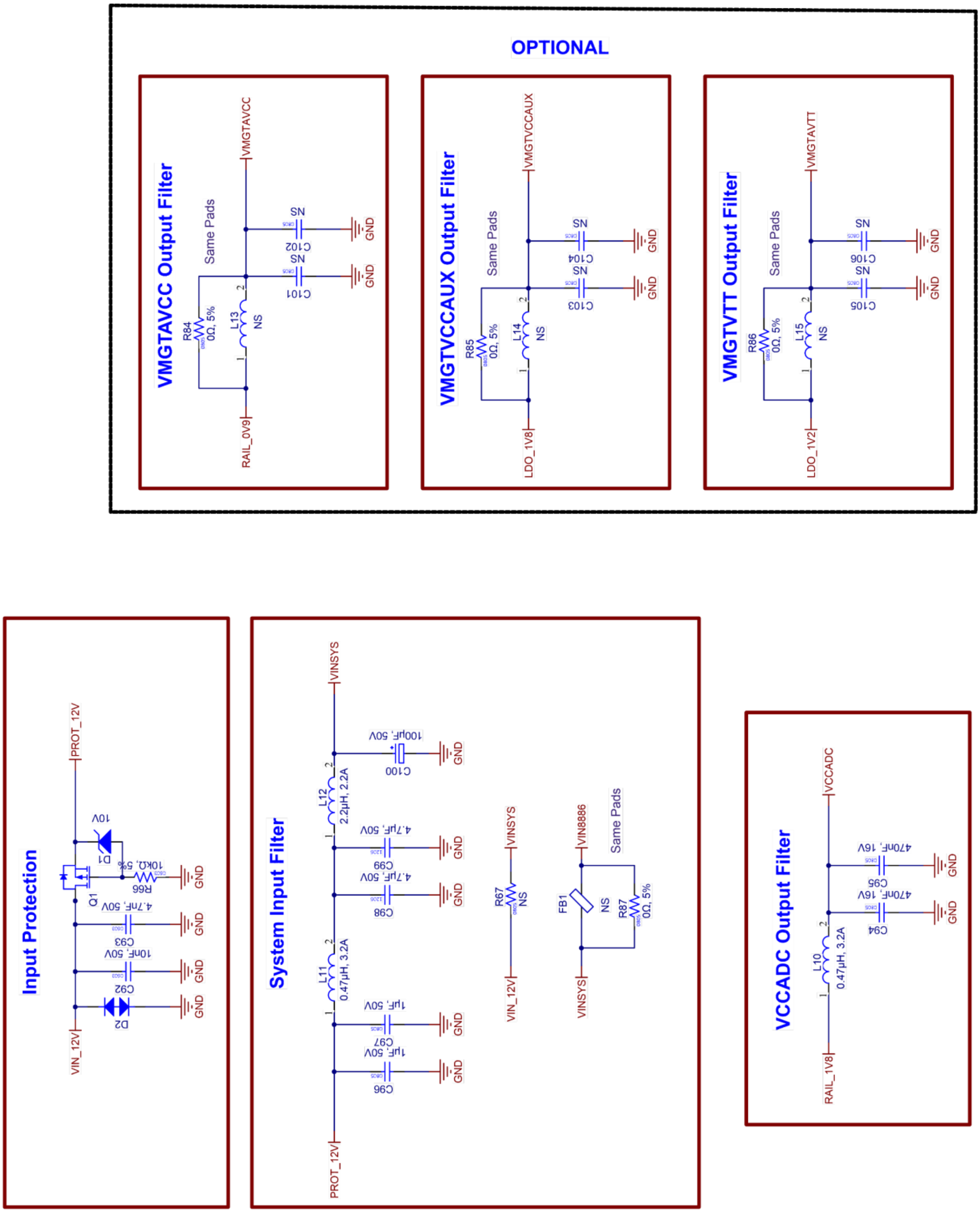
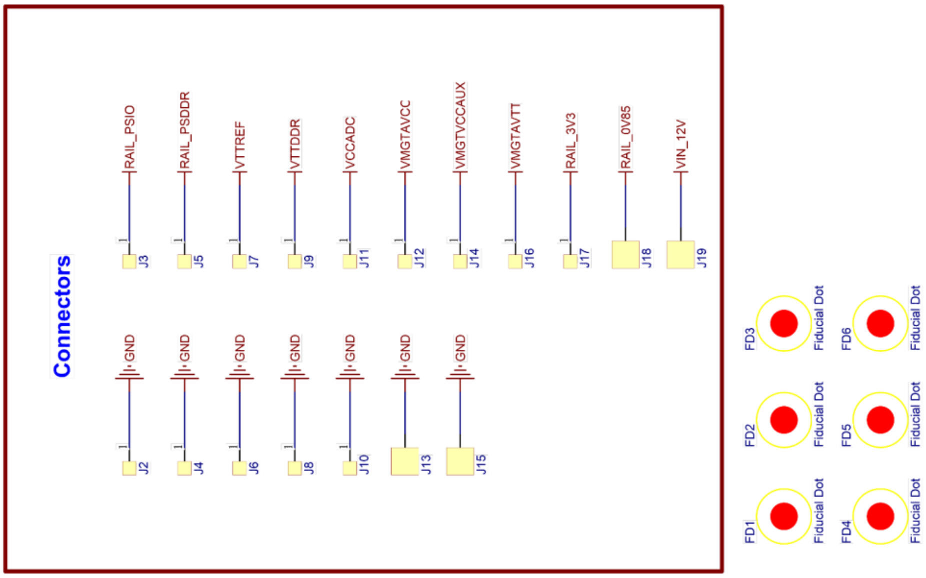


Figure 6: Filters (Sheet 4)



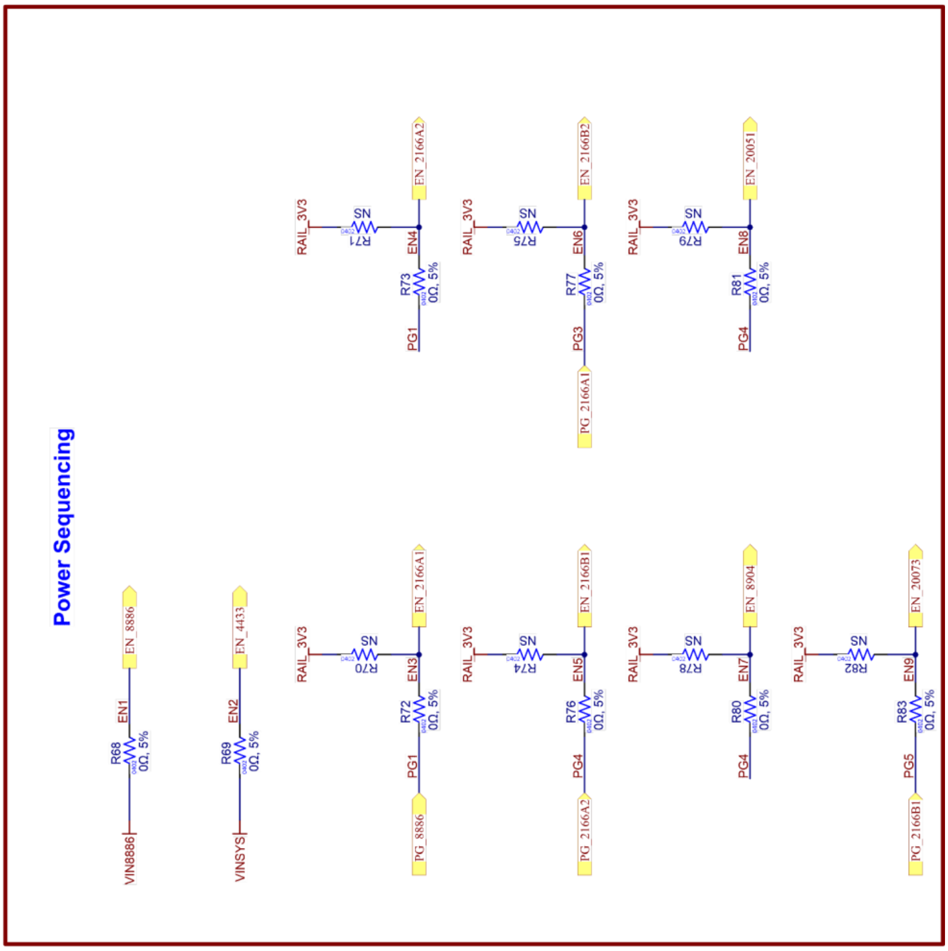


Figure 7: Sequencing and miscellaneous (Sheet 5)

3.2 BOM

Table 4: Bill Of Materials for the reference design

Designator	Qty	Value	Package	Manufacturer	Part Number
C3, C4, C37, C38, C98, C99	6	4.7µF, 50V	1206	TDK	CGA5L3X7R1H475K160AE
C7, C8, C9, C10, C11, C12, C13, C14, C15, C32, C39, C40	12	100nF, 50V	0603	Kyocera AVX	06035C104K4T4A
C16, C17, C18, C19, C24, C25, C26, C27	8	47µF, 6.3V	1210	Murata	GCJ32ER70J476KE01L
C28, C29	2	1µF, 16V	0603	Murata	GCM188R71C105KA64J
C30	1	220pF, 16V	0603	KEMET	C0603C221K5RACAUTO
C33, C34, C41, C42, C53, C54, C64, C65, C78, C79	10	22µF, 16V	1206	Murata	GRT31CC81C226KE01L
C35, C36, C43, C44, C48, C50, C55, C56, C57, C61, C63, C66, C67, C71, C73, C75, C77, C80, C81, C82, C85, C86, C90, C91	24	100nF, 16V	0603	Kyocera AVX	06035C104K4T4A
C45	1	10pF, 16V	0603	Kyocera AVX	0603YA100J4T2A
C46, C58, C68, C83	4	33pF, 16V	0603	Kyocera AVX	0603YC330JAT2A
C47, C49, C74, C76, C84, C88, C89	7	10µF, 16V	1206	Taiyo Yuden	EMK316AB7106KLHT
C51, C60, C62, C70, C72, C87	6	4.7µF, 16V	0805	TDK	CGA4J3X7R1C475K125AB
C52	1	10nF, 16V	0603	KEMET	C0603X103J4HACAUTO
C59	1	1nF, 16V	0603	KEMET	C0603C102K4RECAUTO
C69	1	560pF, 16V	0603	KEMET	C0603C561K4HACAUTO
C92	1	10nF, 50V	0603	Kyocera AVX	06035C103K4Z2A/4K
C93, C107, C108, C109, C110	5	4.7nF, 50V	0603	Kyocera AVX	06035C103K4Z2A/4K
C94, C95	2	470nF, 16V	0805	KEMET	C0805C474K4RACAUTO
C96, C97	2	1µF, 50V	0805	Murata	GCM21BR71H105KA03L
C100	1	100µF, 50V	10mm x 10mm	Panasonic	EEE-TG1H101UP
D1	1	10V	SOD-523	Diodes	BZT585B10T-7
D2	1	SMBJ22CA-E3/5B	SMB	Vishay Semiconductors	SMBJ22CA-E3/5B
J1	1	Header TH 2x5	TH	Harwin	M20-9720546

J13, J15, J18, J19	4	Keystone M3 terminal	Snap-in	Keystone Electronics	7696
L1, L2, L3, L4	4	0.6µH, 11.7A	4020	Coilcraft	XAL4020-601MEC
L5	1	1µH, 5A	3010	Vishay Dale	IHLP1212ABER1R0M11
L6, L7, L8, L9, L10, L11	6	0.47µH, 3.2A	0806	Murata	DFE201612PD-R47M=P2
L12	1	2.2µH, 2.2A	1008	Murata	DFE252012PD-2R2M=P2
Q1	1	NVGS5120PT1G	TSOP-6	ON Semiconductor	NVGS5120PT1G
R1, R2, R3, R4, R10, R12, R13, R38, R44, R61, R68, R69, R72, R73, R76, R77, R80, R81, R83	19	0Ω, 5%	0402	Yageo	RC0402JR-070RL
R5, R6, R7, R8	4	10Ω, 5%	0402	Yageo	RC0402FR-0710RL
R11	1	30.9kΩ, 5%	0402	Panasonic	ERJ-2RKF3092X
R14, R16, R17, R21, R23, R24	6	10kΩ, 5%	0402	Vishay Dale	CRCW040210K0JNED
R18, R19	2	2.2kΩ, 5%	0402	Panasonic	ERJ-2GEJ222X
R20, R25, R26, R29, R36, R46, R54, R64	8	100kΩ, 5%	0402	Panasonic	ERJ-2GEJ104X
R27	1	51kΩ, 1%	0402	Vishay	CRCW040251K0FKED
R28	1	62kΩ, 1%	0402	Vishay	CRCW040262K0FKED
R30	1	4.7Ω, 5%	0402	Panasonic	ERJ-2GEJ4R7X
R31	1	41.2kΩ, 1%	0603	Vishay	CRCW060341K2FKEA
R32, R51, R59	3	100kΩ, 0.5%	0603	Yageo	RT0603DRE07100KL
R33, R49	2	47kΩ, 5%	0603	Yageo	AC0603FR-0747KL
R34	1	13kΩ, 1%	0603	Vishay	CRCW060313K0FKEA
R35	1	49.9kΩ, 0.5%	0603	Panasonic	ERA-3AEB4992V
R37	1	82kΩ, 1%	0603	Panasonic	ERJ-2RKF8202X
R40, R41, R56, R57	4	100kΩ, 5%	0603	Yageo	RC0603JR-10100KL
R43	1	17.8kΩ, 0.5%	0603	Susumu	RR0816P-1782-D-25C
R45, R63	2	76.8kΩ, 1%	0603	Panasonic	ERJ-3EKF7682V
R47	1	35.7kΩ, 0.5%	0603	Yageo	RT0603DRD0735K7L
R48	1	26.1kΩ, 0.5%	0603	Yageo Phycomp	RC0603FR-0726K1L
R50, R55	2	10kΩ, 0.5%	0603	Yageo	RT0603DRD0710KL
R52	1	66.5kΩ, 0.5%	0603	Susumu	RR0816P-6652-D-80C
R53	1	4.99kΩ, 0.5%	0603	Yageo	RT0603DRE074K99L
R65	1	31.6kΩ, 0.5%	0603	Susumu	RR0816P-3162-D-49C
R66	1	10kΩ, 5%	0603	Vishay Dale	CRCW040210K0JNED
R84, R85, R86, R87	4	0Ω, 5%	0805	Panasonic	ERJ-6GEY0R00V
U1, U2	2	MPQ8886	QFN-26	MPS	MPQ8886GU-0000-AEC1
U3	1	MPQ4433	QFN-16	MPS	MPQ4433GLE-AEC1

U4, U6	2	MPQ2166A	QFN-18	MPS	MPQ2166AGRHE-AEC1
U5	1	MPQ8904	QFN-8	MPS	MPQ8904DD-AEC1-LF-P
U7	1	MPQ20051	QFN-8	MPS	MPQ20051DQ-LF-Z
U8	1	MPQ20073	MSOP8E	MPS	MPQ20073DH-AEC1–LF–Z

3.3 PCB Layout

Figure 8: PCB Layer 1

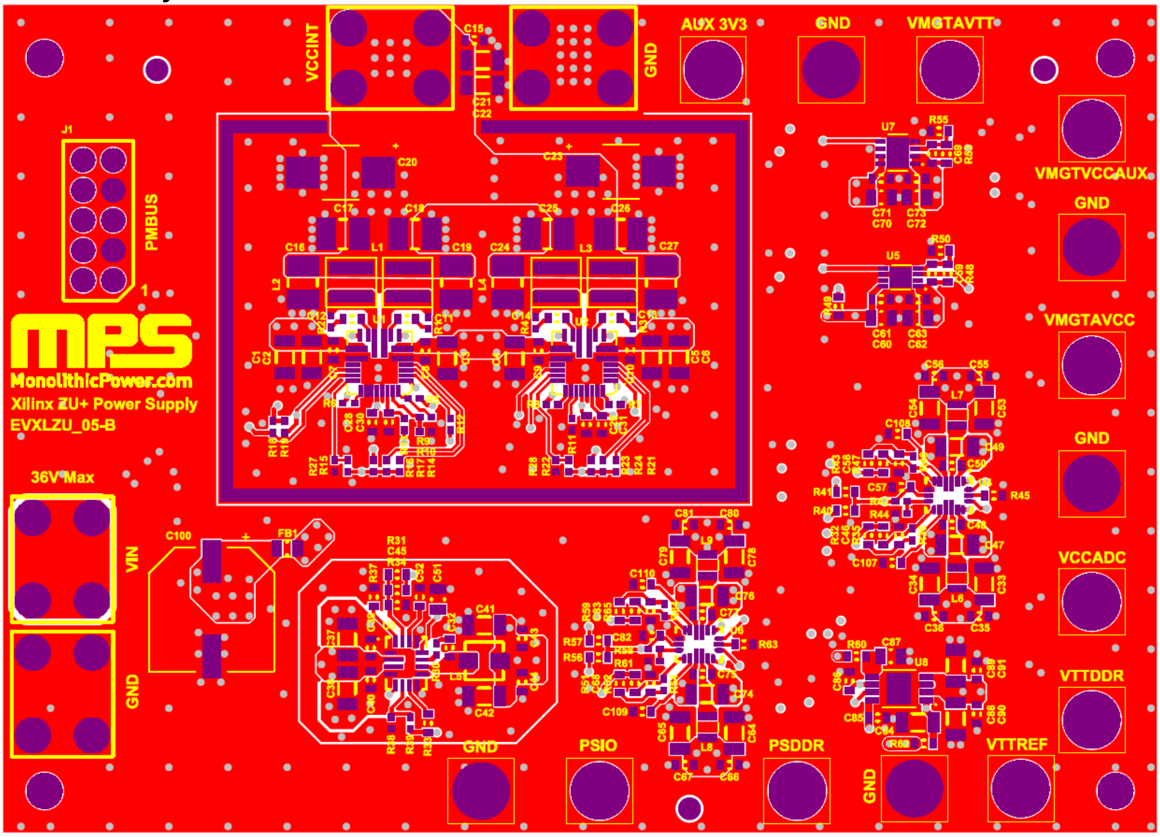


Figure 9: PCB Layer 2

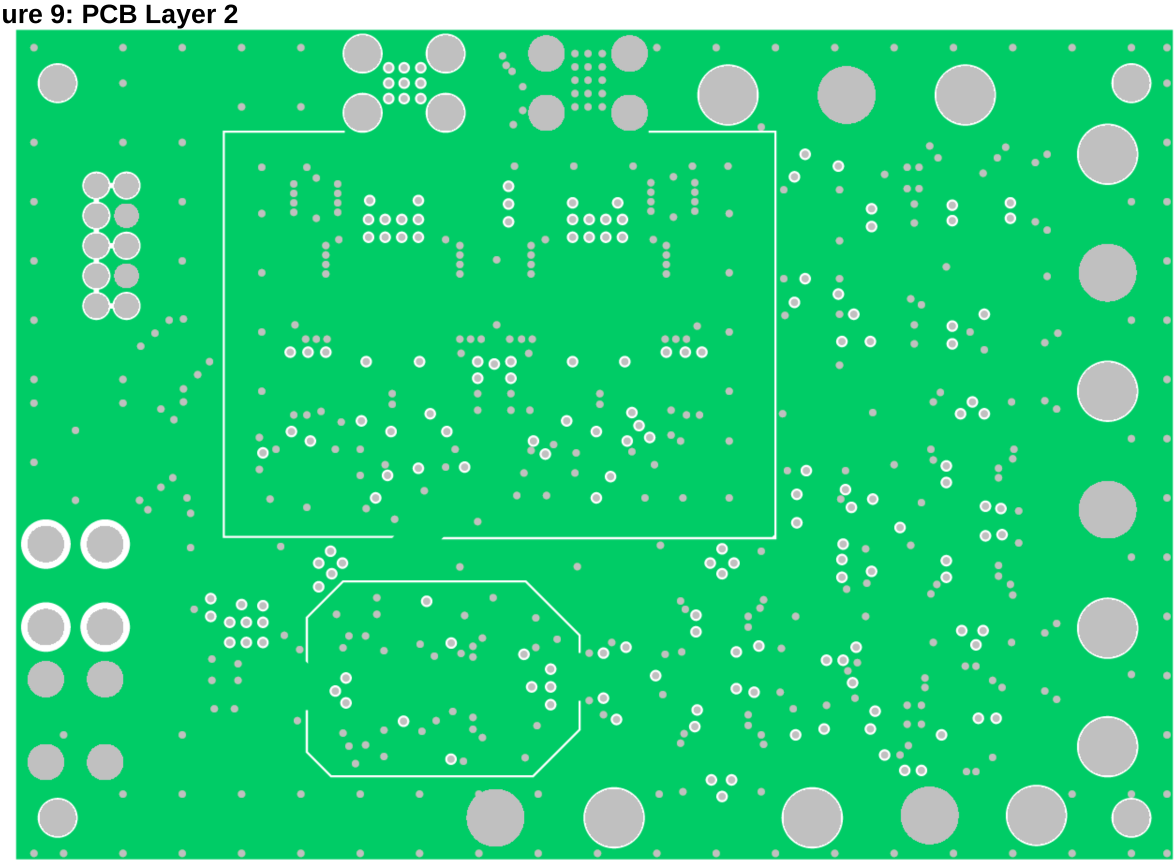


Figure 10: PCB Layer 3

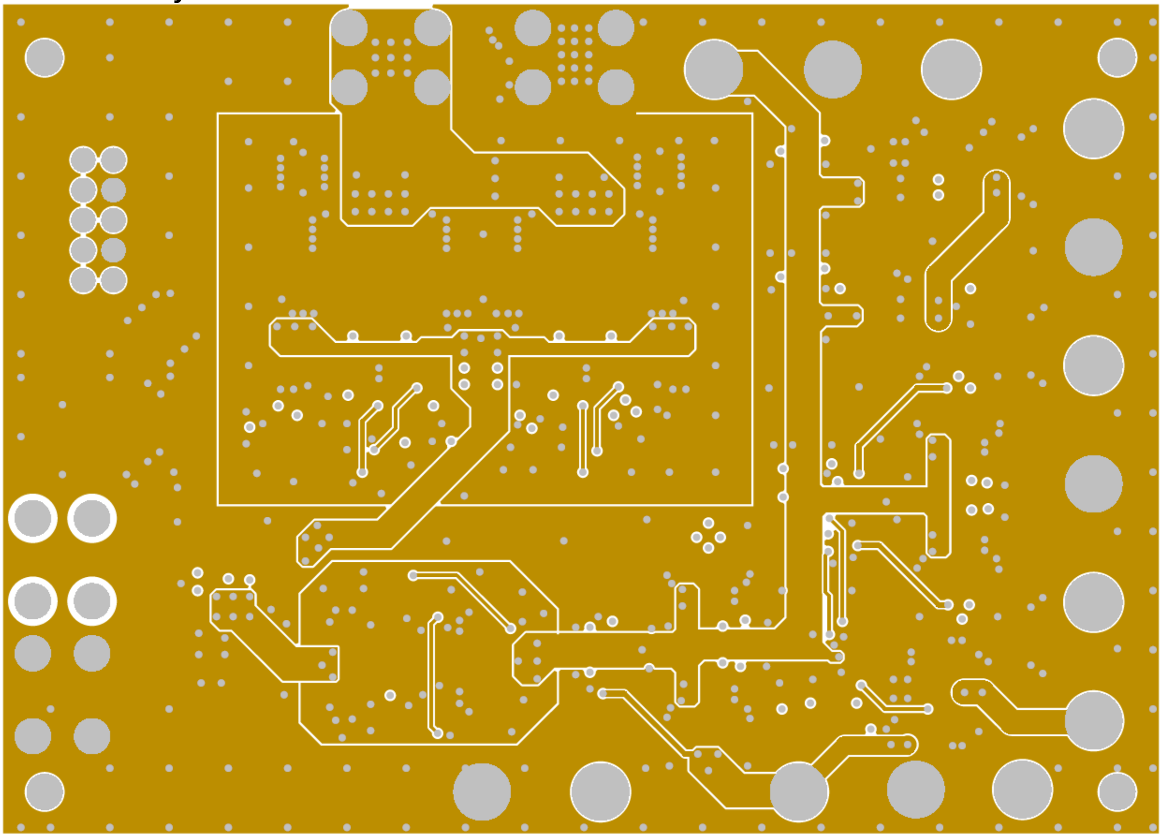


Figure 11: PCB Layer 4

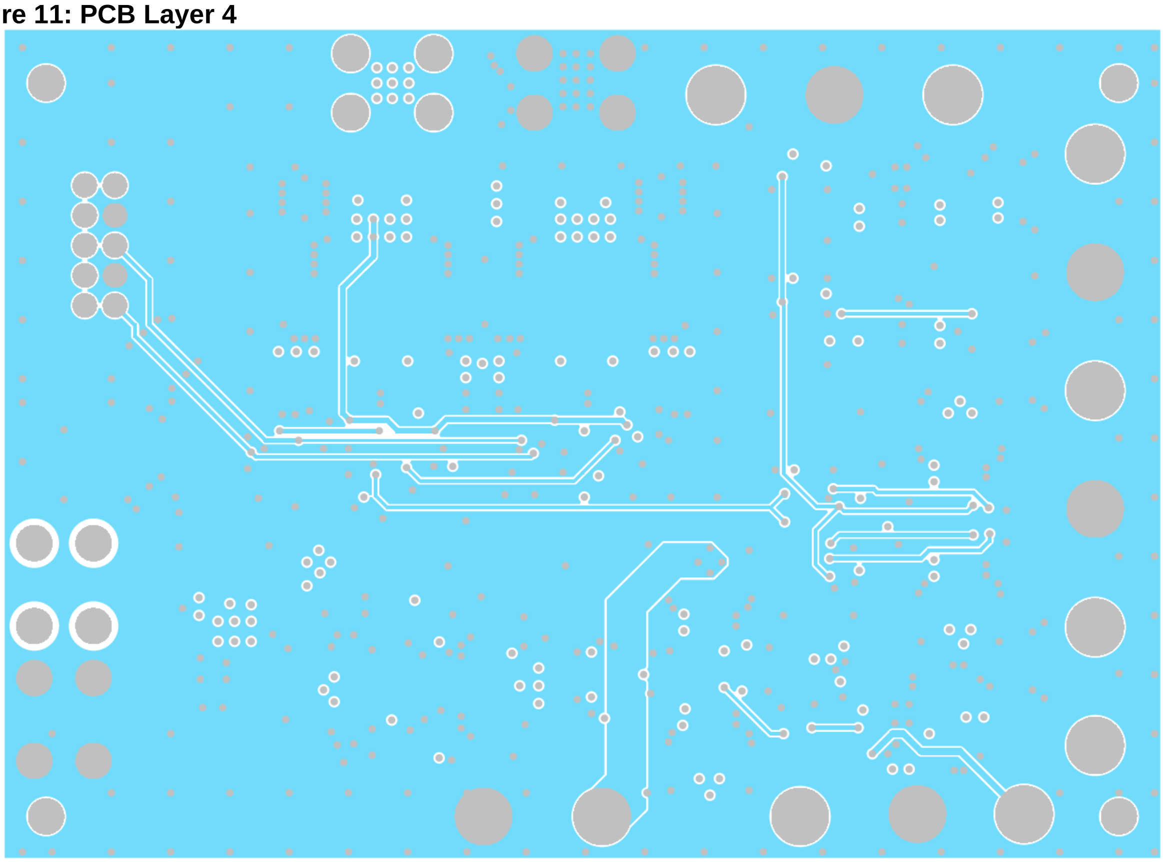


Figure 12: PCB Layer 3

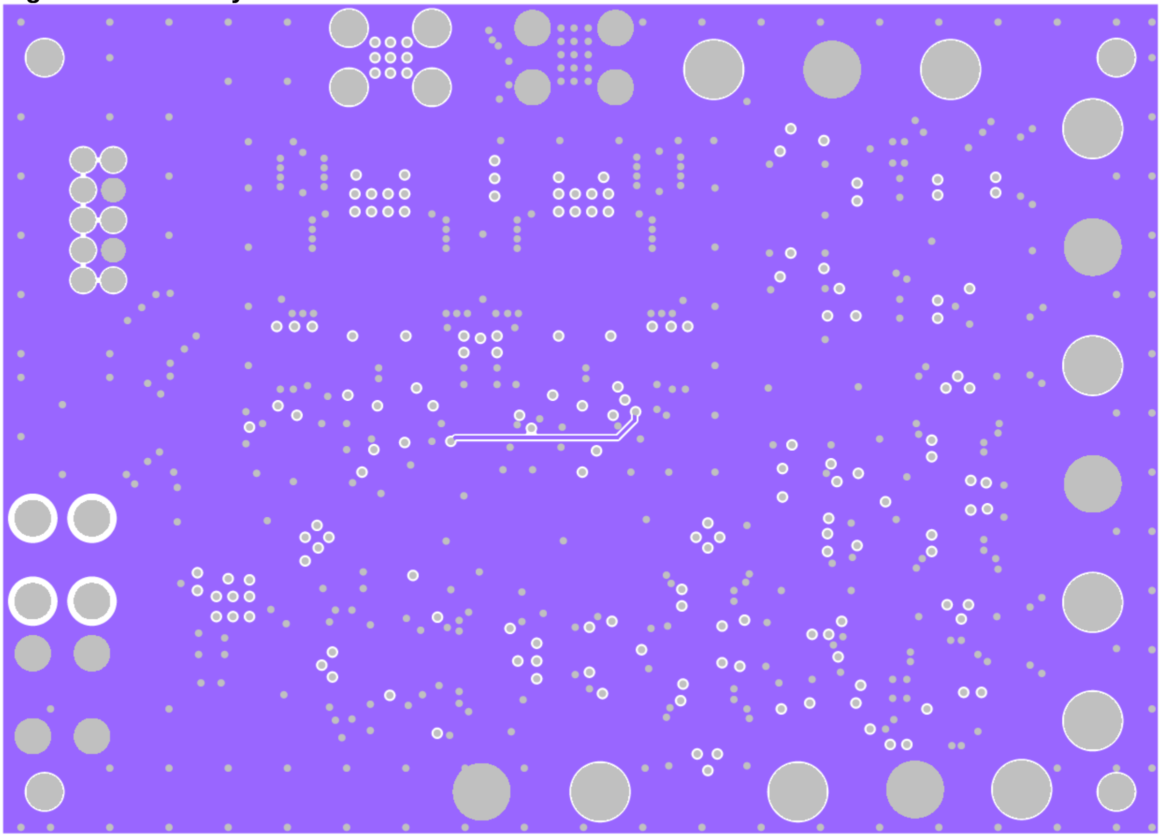


Figure 13: PCB Layer 4

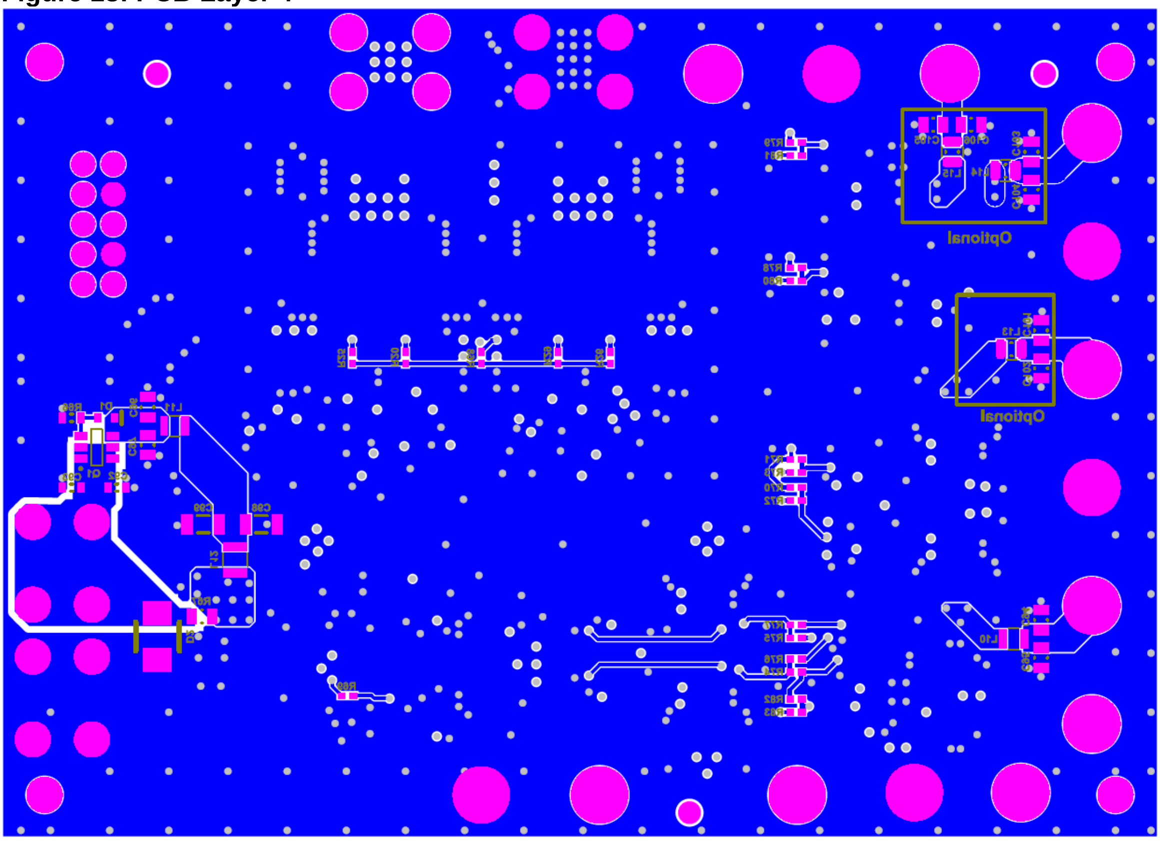
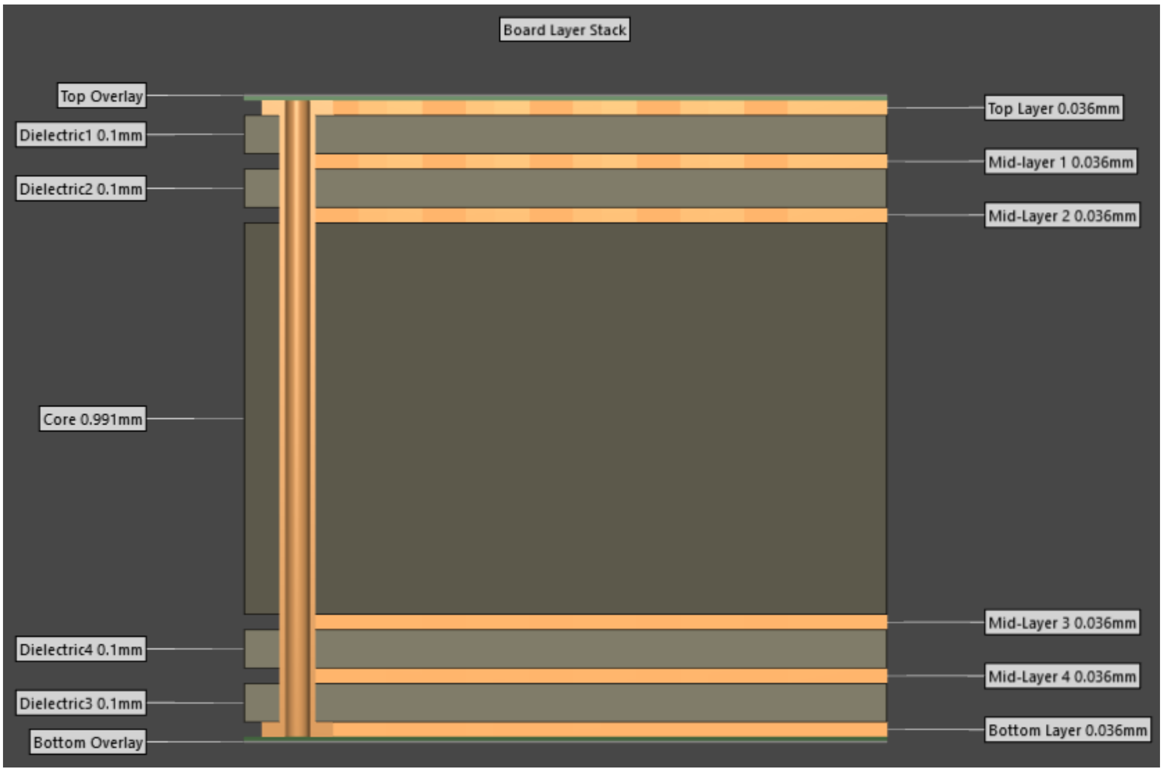


Figure 14: Suggested board layer stack



4 Test Results

4.1 Efficiency

V_{IN} = 12V, T_A = 25ºC

Figure 15: VCCINT Efficiency
V_{OUT} = 0.85V, F_{SW} = 600kHz, L = 600nH, 4 phases

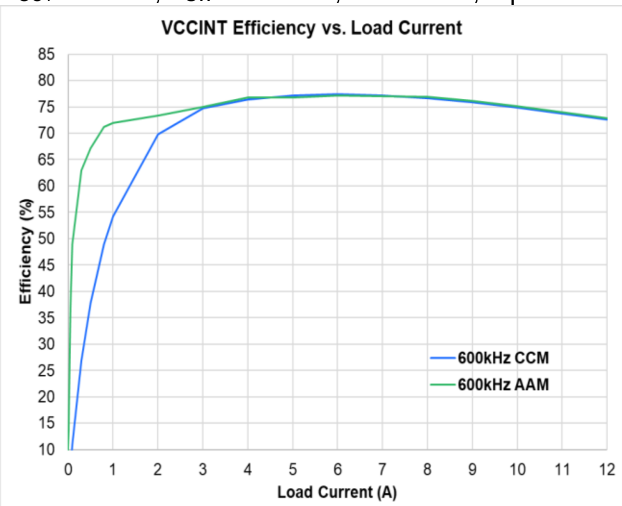
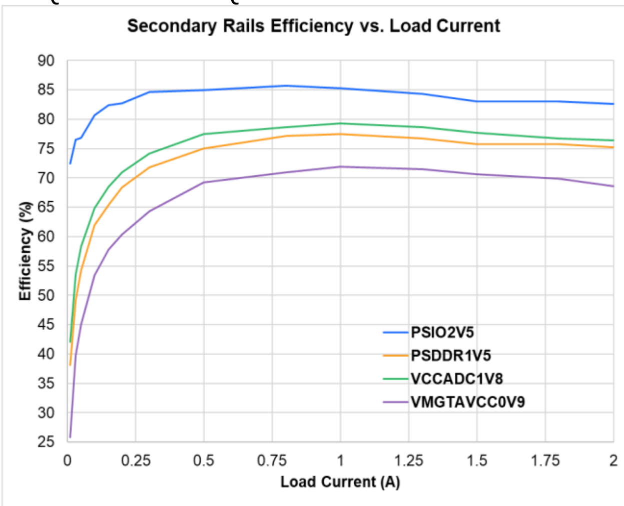


Figure 16: Secondary Rails Efficiency
MPQ4433 and MPQ2166 in series conversion

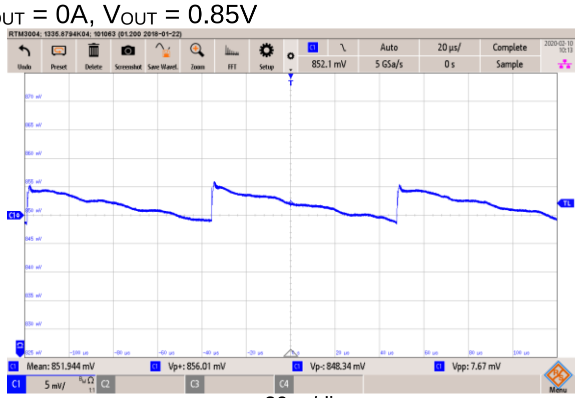


4.2 Time Domain Waveforms

V_{IN} = 12V, T_A = 25ºC, AAM Mode

Figure 17: VCCINT Steady state
I_{OUT} = 0A, V_{OUT} = 0.85V

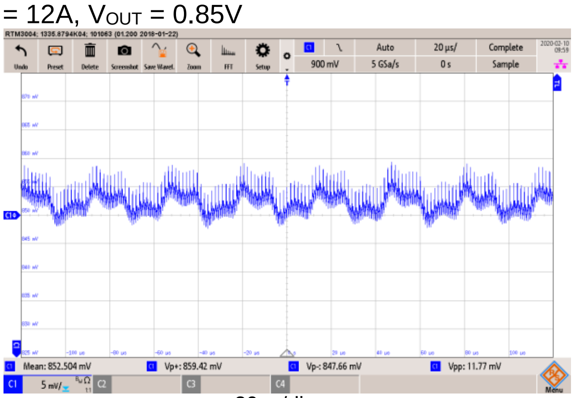
C1: V_{OUT}
5mV/div.



20µs/div.

Figure 18: VCCINT Steady state
I_{OUT} = 12A, V_{OUT} = 0.85V

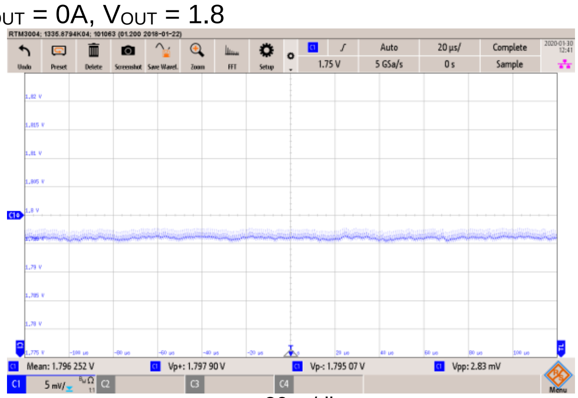
C1: V_{OUT}
5mV/div.



20µs/div.

Figure 19: VCCADC Steady state
I_{OUT} = 0A, V_{OUT} = 1.8

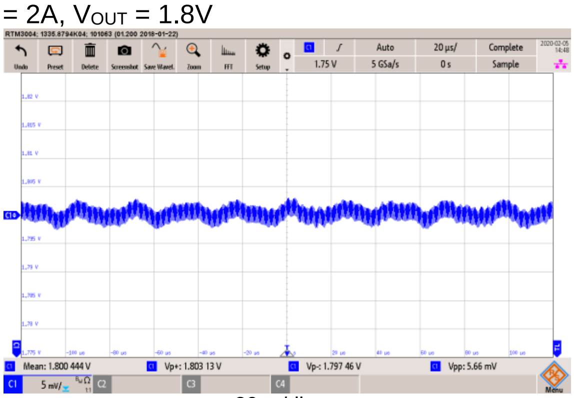
C1: V_{OUT}
5mV/div.



20µs/div.

Figure 20: VCCADC Steady state
I_{OUT} = 2A, V_{OUT} = 1.8V

C1: V_{OUT}
5mV/div.



20µs/div.

Figure 21: VCCAUX Steady state

I_{OUT} = 0A, V_{OUT} = 1.8

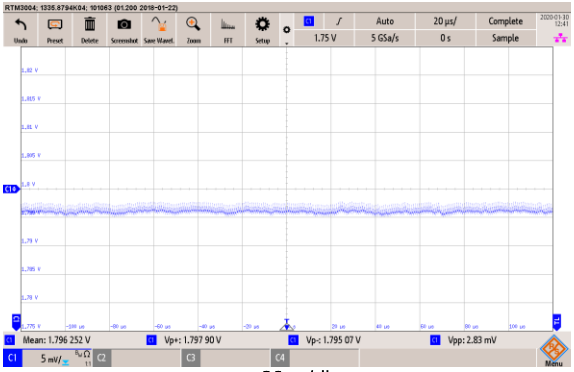


Figure 22: VCCAUX Steady state

I_{OUT} = 2A, V_{OUT} = 1.8V

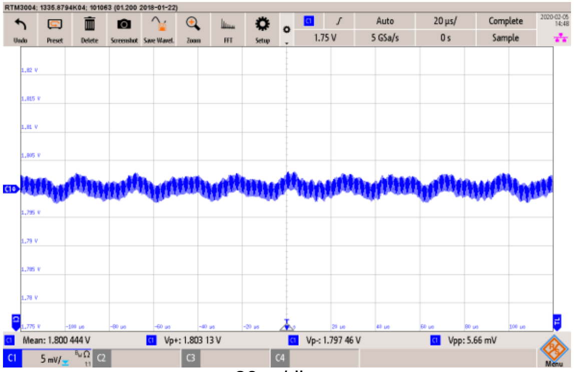


Figure 23: VMGTAVCC Steady state

I_{OUT} = 0A, V_{OUT} = 0.9V

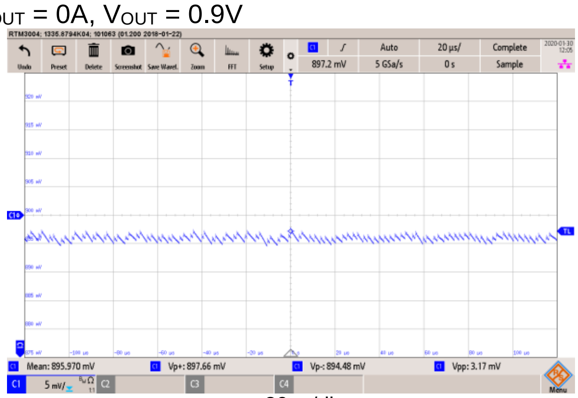


Figure 24: VMGTAVCC Steady state

I_{OUT} = 2A, V_{OUT} = 0.9V

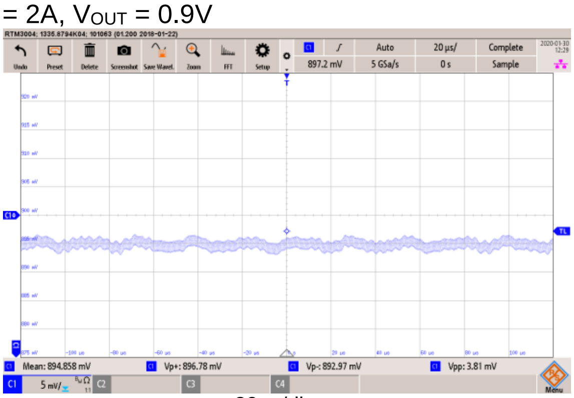


Figure 25: VMGTVCCAUX Steady state

I_{OUT} = 0A, V_{OUT} = 1.8

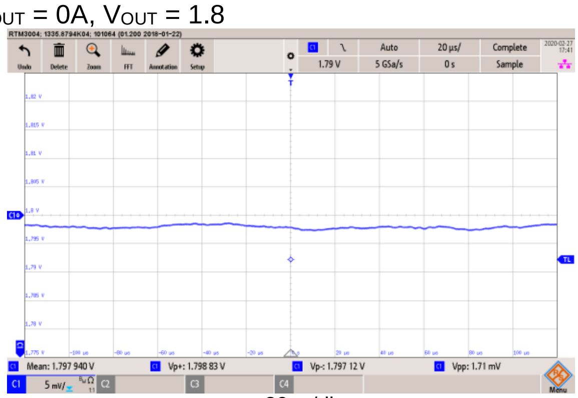


Figure 26: VMGTVCCAUX Steady state

I_{OUT} = 0.5A, V_{OUT} = 1.8V

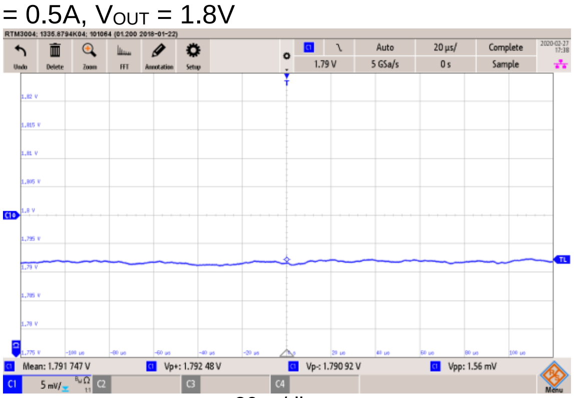


Figure 27: VMGTAVTT Steady state
I_{OUT} = 0A, V_{OUT} = 1.2

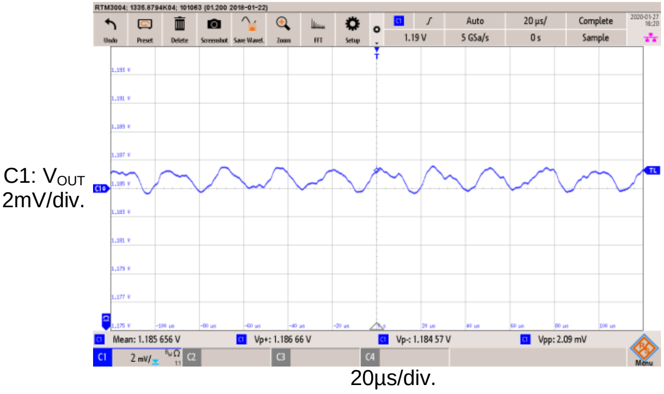


Figure 28: VMGTAVTT Steady state
I_{OUT} = 1A, V_{OUT} = 1.2V

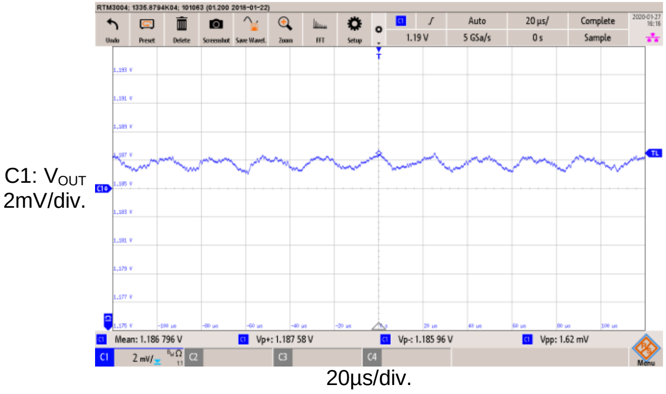


Figure 29: VCCO_PSDDR Steady state
I_{OUT} = 0A, V_{OUT} = 1.5V

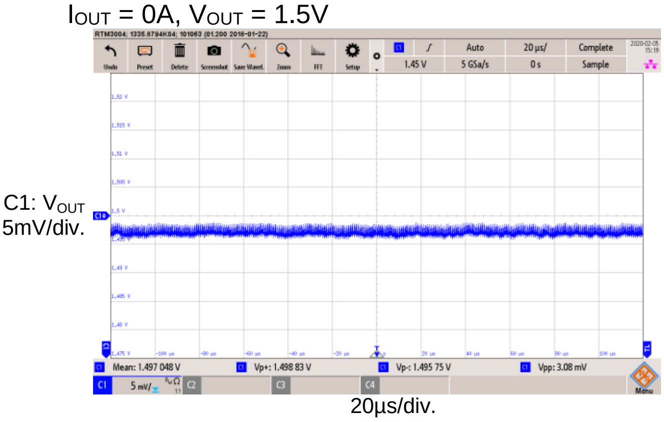


Figure 30: VCCO_PSDDR Steady state
I_{OUT} = 2A, V_{OUT} = 1.5V

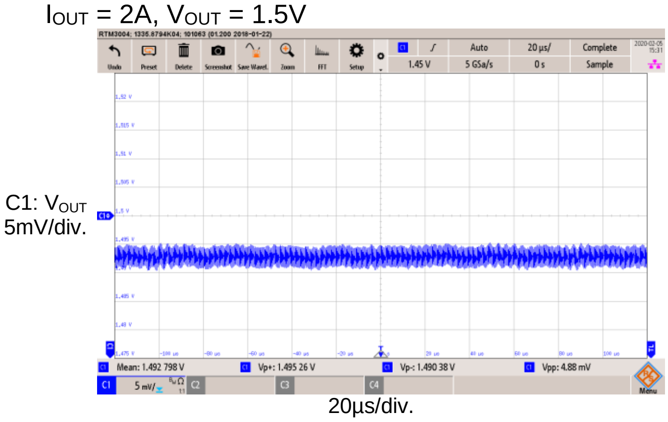


Figure 31: VCCO_PSIO Steady state
I_{OUT} = 0A, V_{OUT} = 2.5V

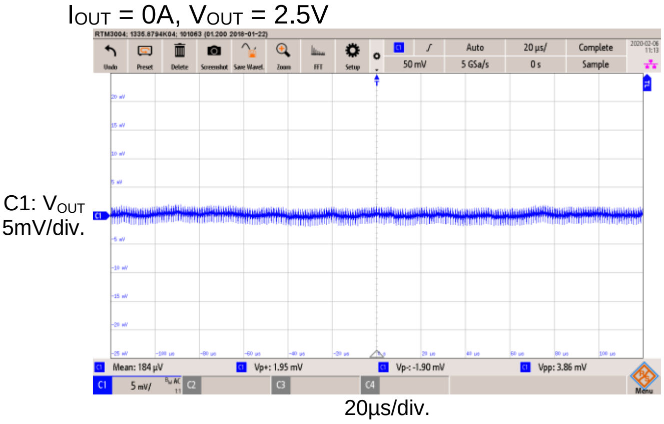


Figure 32: VCCO_PSIO Steady state
I_{OUT} = 2A, V_{OUT} = 2.5V

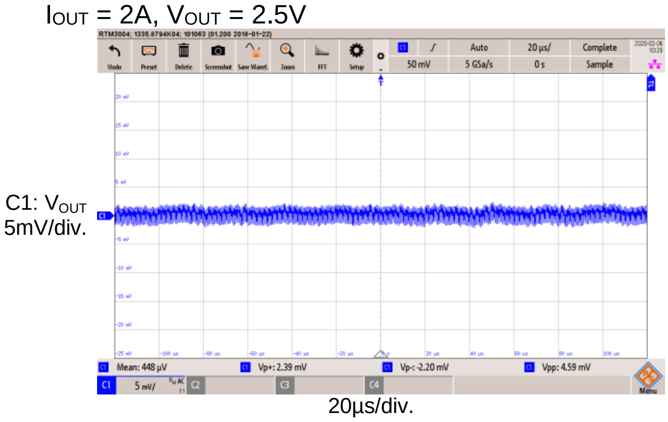
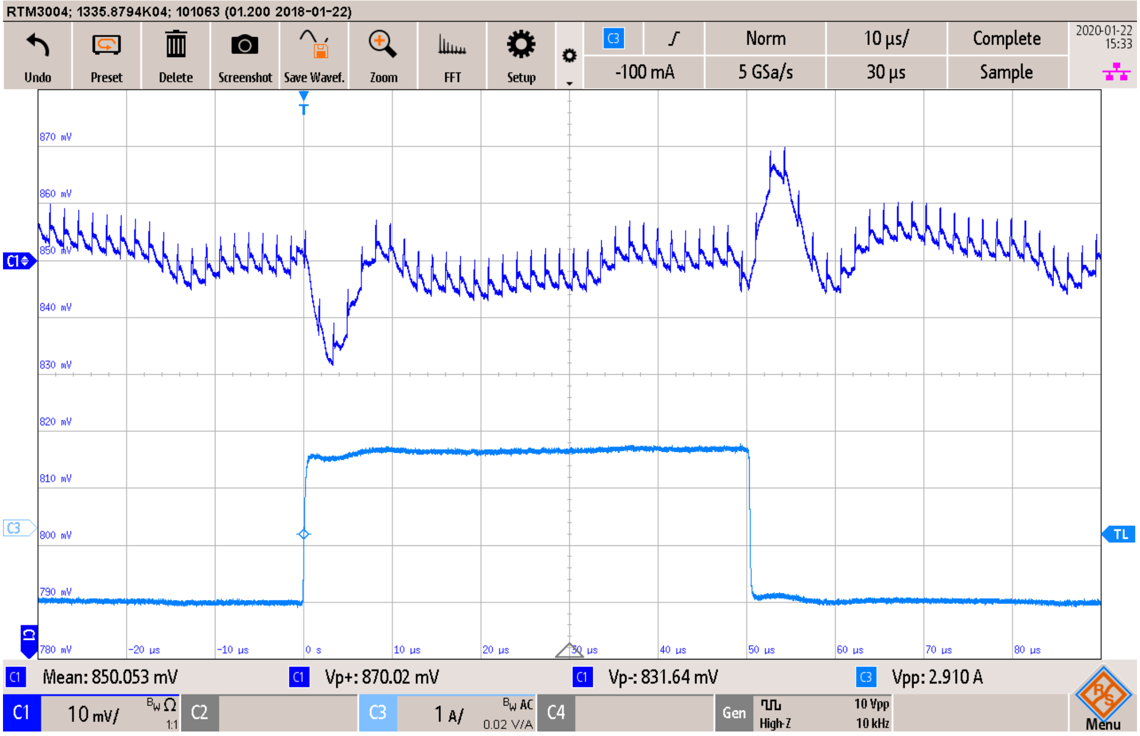


Figure 33: VCCINT response to a 25% load step

I_{OUT} = 5.5A to 8.5A, V_{OUT} = 0.85V

C1: V_{OUT} 10mV/div.

C3: I_{OUT} 1A/div.



10µs/div.

Figure 34: Power-on sequence

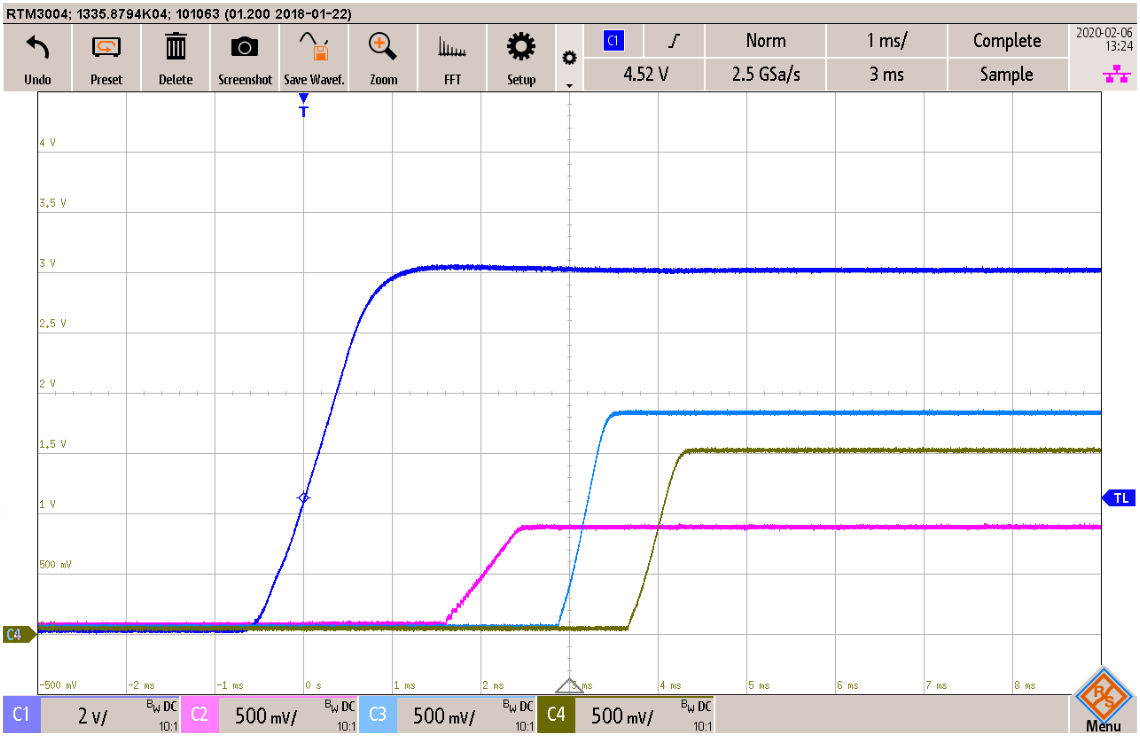
Start from V_{IN}

C1: V_{IN} 2V/div.

C2: V_{CCINT} 0.5V/div.

C3: V_{CCADC} 0.5V/div.

C4: V_{CCO_PSDDR} 0.5V/div.



1ms/div.

Figure 35: Power-off sequence

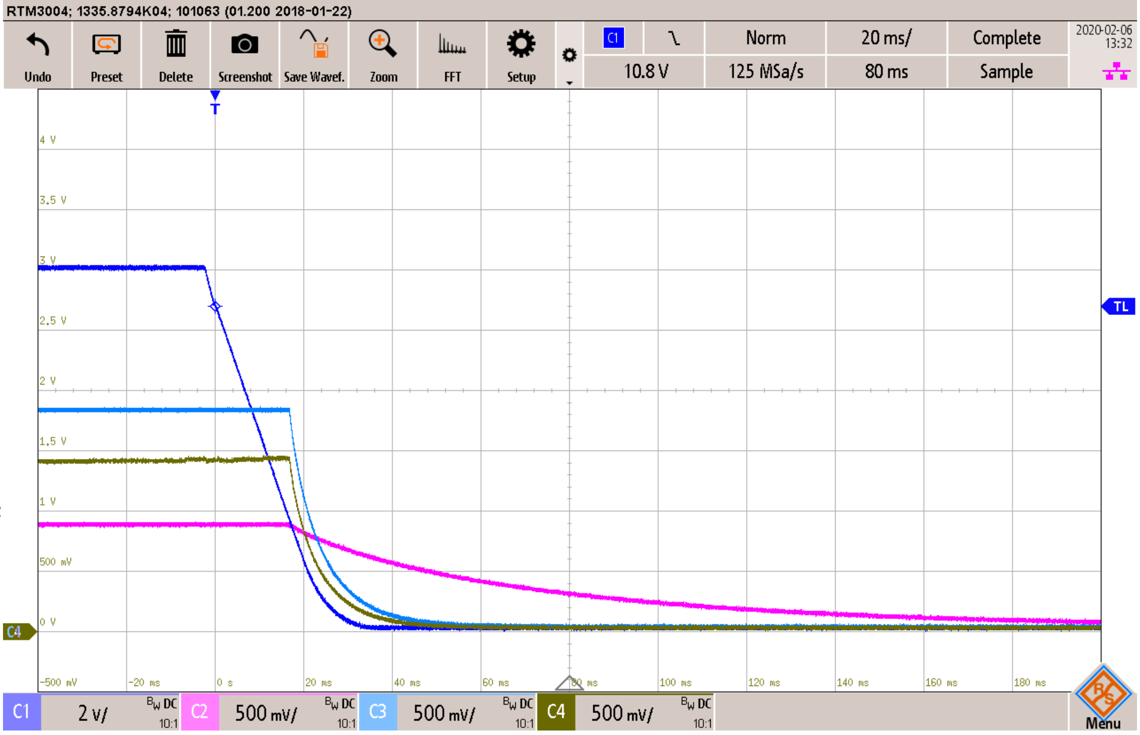
Shut down from V_{IN}

C1: V_{IN}
2V/div.

C2: V_{CCINT}
0.5V/div.

C3: V_{CCADC}
0.5V/div.

C4: V_{CCO_PSDDR}
0.5V/div.



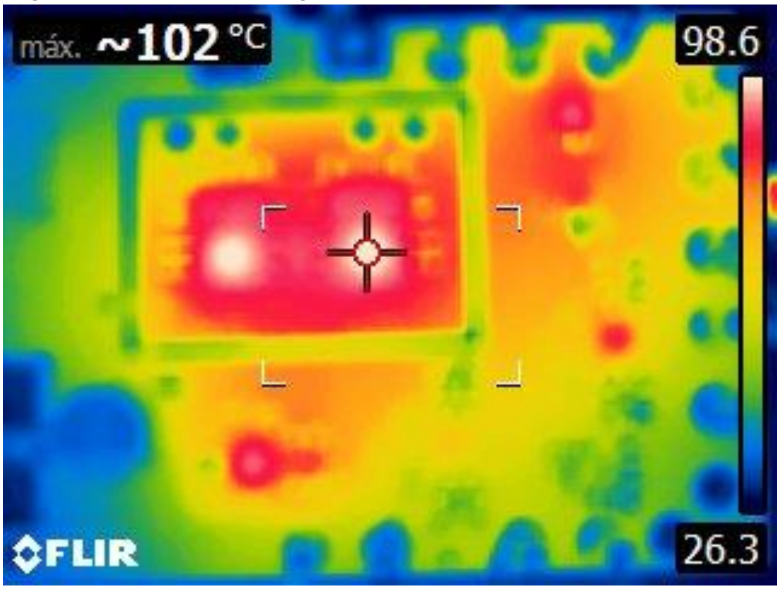
20ms/div.

4.3 Thermal Measurements

V_{IN} = 12V, T_A = 25ºC, 2h run time

I_{VCCINT} = 12A, I_{VCCAUX} = 1A, $I_{VMGTAVCC}$ = 1.5A, $I_{VMGTVCCAUX}$ = 0.2A, $I_{VMGTAVTT}$ = 0.5A, I_{VCCO_PSDDR} = 0.5A, I_{VCCO_PSIO} = 0.5A

Figure 36: Thermal Image



4.4 EMC Measurements

V_{IN} = 12V; $F_{SW\_MPQ8886}$ = 600kHz, 10% Spread spectrum; $F_{SW\_MPQ4433}$ = 1MHz, T_A = 25°C
I_{VCCINT} = 12A, I_{AUX_3V3} = 2A

Figure 37: CISPR25 Class 5 Conducted Emissions
150kHz – 108MHz

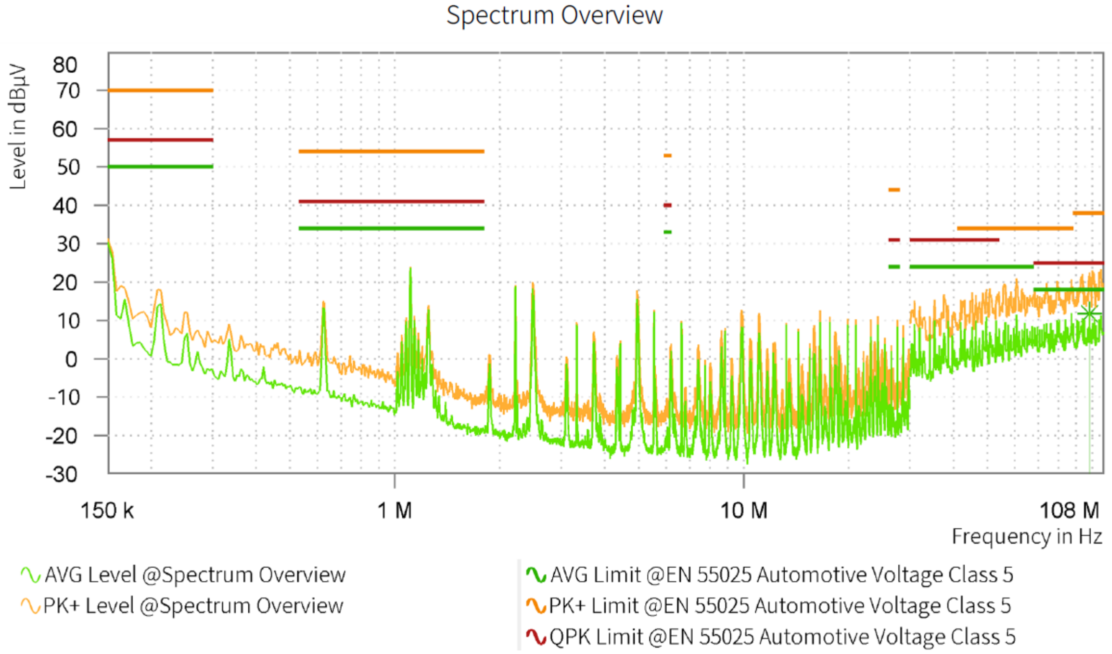
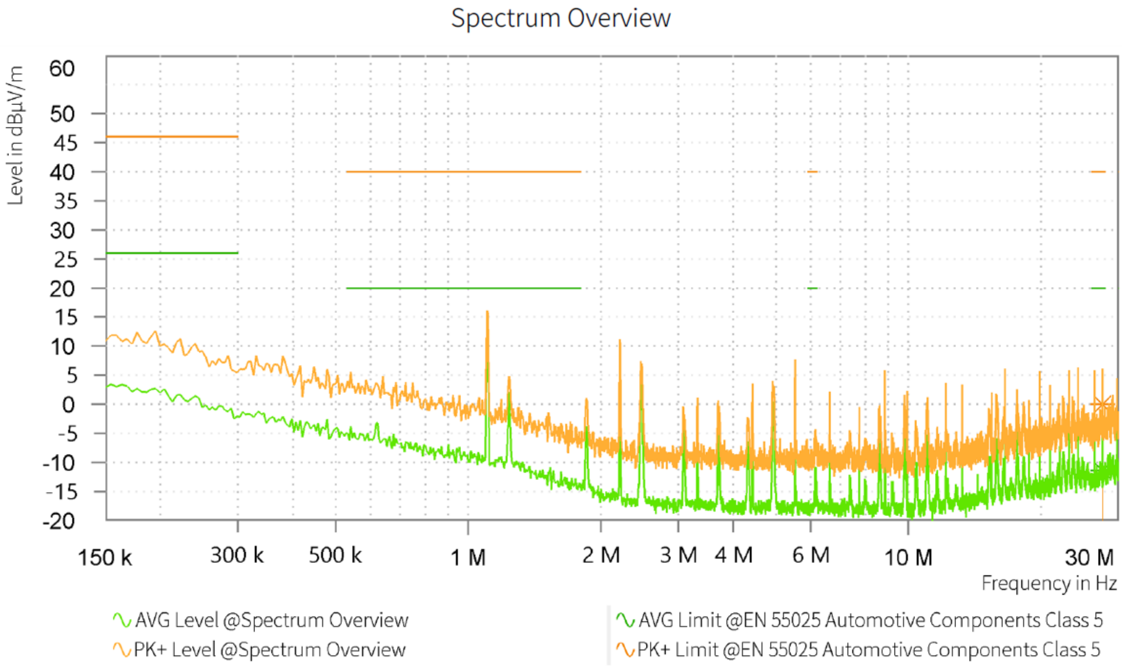


Figure 38: CISPR25 Class 5 Radiated Emissions
150kHz – 30MHz



5 Start-Up

1. Connect the positive and negative terminals of the load to the rail's V_{OUT} and GND pins, respectively. Electronic loads should be avoided when testing the transient response of these rails, as the connecting cables and internal circuitry will create a big parasitic inductance which limits the load current slew rate. Instead, the load can be a resistor of suited value, which is switched on and off with an N channel FET, and connected directly at the output pins of the converter.

2. Preset the power supply output between 9V and 36V, and then turn off the power supply.

3. Connect the positive and negative terminals of the power supply output to the V_{IN} and GND pins, respectively.

4. Turn the power supply on. The board will automatically start up.

5. Use MPS' Virtual Bench Pro 3.0 to configure and program the MPQ8886. The software can be downloaded here. EVKT-USBI2C-02 is needed as an interface between USB and I^2C communication to the MPQ8886.

6 Disclaimer

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