EVME6L_00A

MPSafe™ Power Subsystem Solution for Mobileye's EyeQ6L Platform

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1 Overview

1.1 Description

The EVME6L_00A is an MPSafe™ power subsystem solution for powering Mobileye's EyeQ6L platform, enabling autonomous driving in automobiles. The solution provides excellent power delivery with high-efficiency switching regulators.

The control architectures of these power converters also allow the system to achieve fast and excellent transient response to load transients without increasing the output capacitance. In addition, the MPQ79500FS voltage monitor and MPQ79700FS power sequencer allow the system to achieve a functional safety grade of ASIL-D.

1.2 Features

- 9 Output Rails:
  - 8 Point-of-Load (PoL) Converters
  - 1 Core Rail Provided by 1 Synchronous Buck Converter
- 12 Voltage Rails Monitored with Precision Accuracy for Over-Voltage (OV) Faults, Under-Voltage (UV) Faults, and Power Sequence Recording
- 12 Sequencer Channels with Fault Detection
- 32kHz Crystal Oscillator Driver
- Real-Time Clock (RTC)
- Windowed Watchdog
- Pre-Regulator up to 20A

1.3 Applications

- Autonomous Driving Platforms
- Automotive Advanced Driver Assistance (ADAS) Platforms

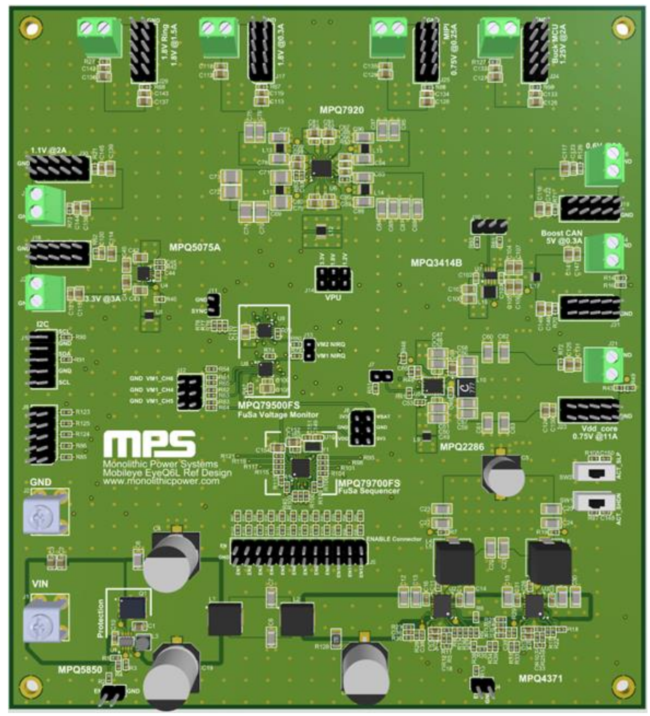


Figure 1: EVME6L_00A Reference Design

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

MPS provides the EVME6L_00A evaluation board as a tool to evaluate and design the power supply for the EyeQ6L system-on-chip (SoC). Figure 2 shows the block diagram of the evaluation board.

The board includes two low-current voltage regulators (the MPQ5075A and MPQ3414B), one PMIC with 6 low-current outputs (the MPQ7920), and one high-current voltage regulator (the MPQ2886). The MPQ2286 provides fixed-frequency zero-delay pulse-width modulation (ZDP) control for fast and excellent transient response. The MPQ7920 provides constant-on-time (COT) control architecture, which also allows the system to achieve a fast transient response. Lastly, the system includes one MPQ79700FS power sequencer and two MPQ79500FS voltage monitors to evaluate the functional safety capabilities of these products.

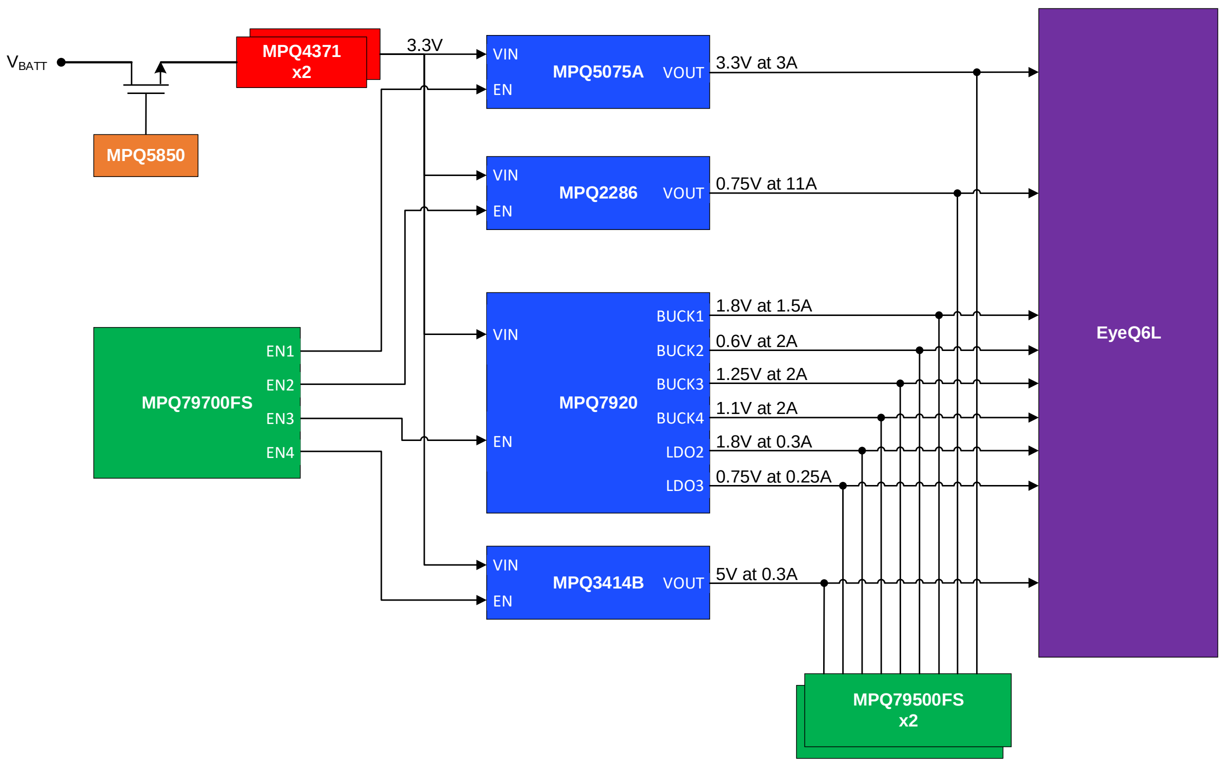


Figure 2: Functional Block Diagram (1) (2)

Notes:

1) The MPQ79700FS is optional. The system can use an application microcontroller (MCU) to enable the regulators.
2) The MPQ5075A and MPQ3414B are optional for user external needs (e.g. CAN and MIPI).

2.2 Rail Assignment

Table 1 shows the comprehensive rail assignments for the system

Table 1: Rail Assignment

DC/DC Converter	Device	Output (V)	Output (A)	MPQ79500 Channel	MPQ79700			
					EN1	EN2	EN3	EN4
HCVR1	MPQ2286	0.75	11	0x30 (Channel 2)		x		
LDO1	MPQ7920	1.8	0.3	0x33 (Channel 4)			x	
LDO0	MPQ7920	0.75	0.25	0x33 (Channel 6)			x	
SW6	MPQ3414B	5	0.3	0x30 (Channel 1)				x
SW5	MPQ5075A	3.3	3	0x30 (Channel 3)	x			
SW4	MPQ7920	1.25	2	0x33 (Channel 3)			x	
SW3	MPQ7920	0.6	2	0x33 (Channel 1)			x	
SW2	MPQ7920	1.8	1.5	0x33 (Channel 5)			x	
SW1	MPQ7920	1.1	2	0x33 (Channel 2)			x	

2.3 Related Solutions

This reference design is based on the following MPS solutions:

Table 2: Related Solutions

MPS Integrated Circuit	Description
MPQ79500FS-AEC1	6-channel, ASIL-D voltage monitor
MPQ79700FS-AEC1	Automotive functional safety power sequencer
MPQ5075A-AEC1	5.5V, 5A, low on resistance ($R_{DS(ON)}$) load switch with configurable current limit
MPQ2286-AEC1	MPSafe™ QM, 6V, 12A, configurable high-frequency buck regulator
MPQ7920-AEC1	5V PMIC with four buck converters, 5 LDOs, and flexible system settings via I^2C and MTP
MPQ3414B-5-AEC1	1.5A, 2.2MHz, 5V V_{OUT}, 52µA I_Q, synchronous step-up converter with output disconnect
MPQ4371GVE-6001-AEC1	36V, 10A, ultra-low quiescent current, synchronous step-down converter
MPQ5850-AEC1	36V, smart diode controller with reverse protection

2.4 System Specifications

Table 3: System Specifications

Parameter	Specifications
Pre-Regulator Input Voltage (V_{IN}) Range	3.3V to 36V
Pre-Regulator Power Rating	33W
Low-Current Rails	8 Rails
Low-Current Voltage Regulator (VR) Output Power	21W
High-Current Rails	1 Rail
High-Current VR Output Power	8.25W
Board Form Factor	145mmx160mmx20mm

Table 4: Detailed System Specifications

Rail	PN	DC Voltage Level (V)	DC Voltage Ripple (3) (mV)	Switching Frequency (kHz)	Peak Efficiency (4) (%)
PRE_REG	MPQ4371	3.35	50.08	2200	90.8
VDD_CORE	MPQ2286	0.76	10.42	2200	90
1V1	MPQ7920 (Buck 1)	1.11	14.58	2000	83.9
1V8_RING	MPQ7920 (Buck 2)	1.79	9.02	2000	89.9
0V6	MPQ7920 (Buck 3)	0.60	5.75	2000	74.6
1V25_MCU	MPQ7920 (Buck 4)	1.26	10.89	2000	84.8
1V8_EQ	MPQ7920 (LDO 0)	1.79	6.90	-	-
0V75_MIPI	MPQ7920 (LDO 1)	0.74	16.34	-	-
3V3	MPQ5075A	3.3	25.97	-	99.7
5V_CAN	MPQ3414B	5.00	16.02	2200	-

Notes:

3) These values are at the maximum load current and 25°C.
4) These values are at the nominal conditions per each power supply unit (PSU) at 25°C.

Table 5: Transient Response Specifications

Rail	Nominal Voltage (V)	Nominal Current (A)	Current Change Rate (A/µs)	Current Change Transient Magnitude (A)	Total Voltage Change (5) (mV_{PP})	Total Voltage Change (5) (%)
VDD_CORE	0.75	11.3	7.5	7.5	30.56	4.07
1V1	1.1	2	1	1	17.71	1.61
1V8_RING	1.8	1.5	0.15	0.15	45.44	2.52
0V6	0.6	2	1	1	14.60	2.43
1V25_MCU	1.25	2	1	1	30.71	2.45
1V8_EQ	1.8	0.3	0.15	0.15	56.73	3.15
0V75_MIPI	0.75	0.25	0.125	0.125	40.06	5.34
3V3	3.3	3	2	2	76.42	2.31
5V_CAN	5	0.3	0.15	0.15	185.90	3.71

Note:

5) Including load transient, DC accuracy, and IR drop

3 Detailed System Description

To guarantee that the SoC operates properly and reliably, ensure that there is optimal power delivery. Mobileye's EyeQ6L SoC requires strict transient responses to load transients. The power regulators that have been included in the system provide specific control architectures that help to overcome this requirement. For the high-current voltage rail, the MPQ2286 provides fixed-frequency zero-delay PWM (ZDP) control architecture for optimal transient response. For the low-current voltage rails, the MPQ7920 is a PMIC that provides constant-on-time (COT) control architecture for faster transient response, higher efficiency, fewer components, and simplified design.

The EVME6L_00A can control the power sequencing using the MPQ79700FS, and it can monitor all the power rails to detect faults using the MPQ79500FS.

3.1 MPQ79700FS

The MPQ79700FS is a 12-channel, functional safety power sequencer. It is engineered for automotive ADAS and autonomous driving platforms, providing control and sequencing for the MPSafe™ platform. Its configurability and flexibility enable the same device to be reused across different applications and SoC generations. The MPQ79700FS contains a crystal driver, as well as a real-time clock (RTC) with an alarm function. The MPQ79700FS also provides a configurable watchdog timer (WDT), which is accessible through the I²C interface, as well as active-low system reset and interrupt outputs. Safety mechanisms such as built-in self-test (BIST) provide high diagnostic coverage, which helps the system achieve the target ASIL rating. The MPQ79700FS is available in a QFN-24 (4mmx4mm) package with wettable flanks. Figure 3 shows the MPQ79700FS's functional block diagram.

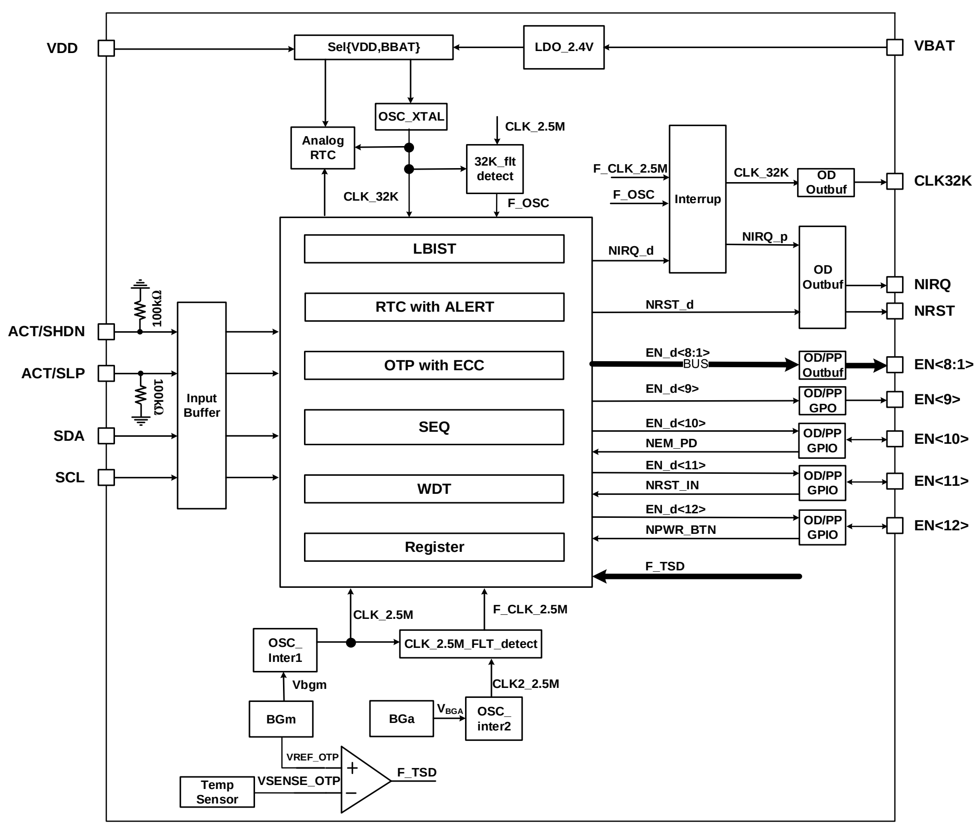


Figure 3: MPQ79700FS Block Diagram

3.2 MPQ79500FS

The MPQ79500FS is a 6-channel voltage monitor engineered for automotive safety applications. Each voltage monitor input has configurable over-voltage (OV) and under-voltage (UV) thresholds with high accuracy for both high-frequency (transient) noise as well as low-frequency DC voltage drifting. Two of the inputs are differential voltage pairs that can be utilized to monitor voltage rails with high current ratings.

The MPQ79500FS can record sequencing timestamps as well as the boot order for the voltage rails that it monitors. It also has a sync I/O function, which allows multiple monitors to be cascaded, for multi-device sequence synchronization and tagging. The MPQ79500FS can be accessed through an I²C interface. With the integration of sophisticated, functional safety features, including built-in self-test (BIST), diagnostic and write protection, this ASIL-certified device helps applications achieve a functional safety grade of ASIL-D. The MPQ79500FS is available in a QFN-16 (3mmx3mm) package with wettable flanks. Figure 4 shows the MPQ79500FS's functional block diagram.

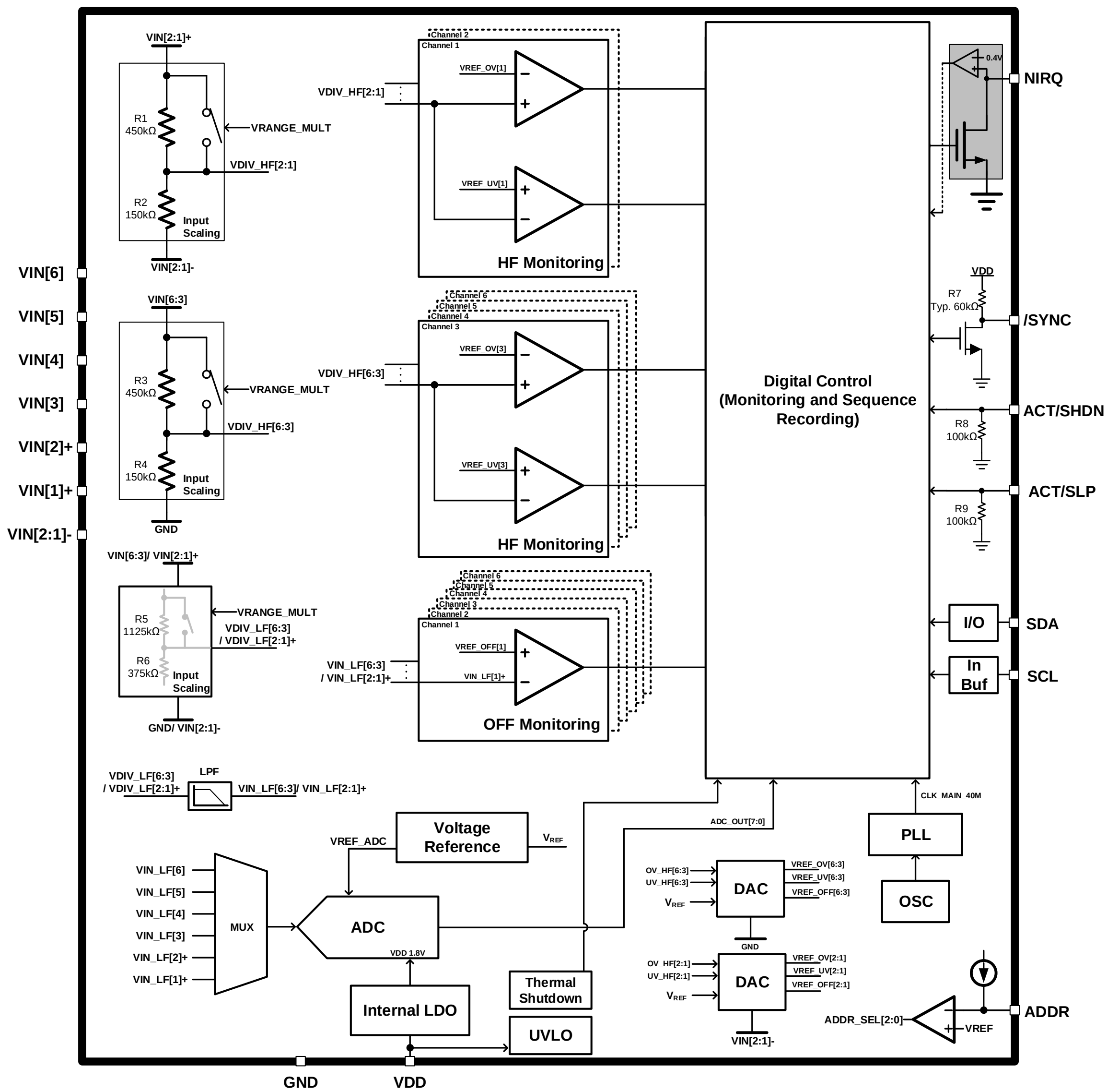


Figure 4: MPQ79500FS Block Diagram

3.3 MPQ2286

The MPQ2286 is a high-frequency, configurable, synchronous buck regulator that operates from a 2.7 to 6V input voltage (V_{IN}) range and provides up to 12A of continuous output current (I_{OUT}) with high efficiency. The differential feedback sense and internal compensation minimize external component count and improve accuracy. The fixed-frequency zero-delay PWM (ZDP) control topology ensures optimal transient response and fixed-frequency operation, regardless of V_{IN} and V_{OUT}. The MPQ2286 is available in a QFN-18 (3mmx4mm) package with wettable flanks. Figure 5 shows the MPQ2286's functional block diagram.

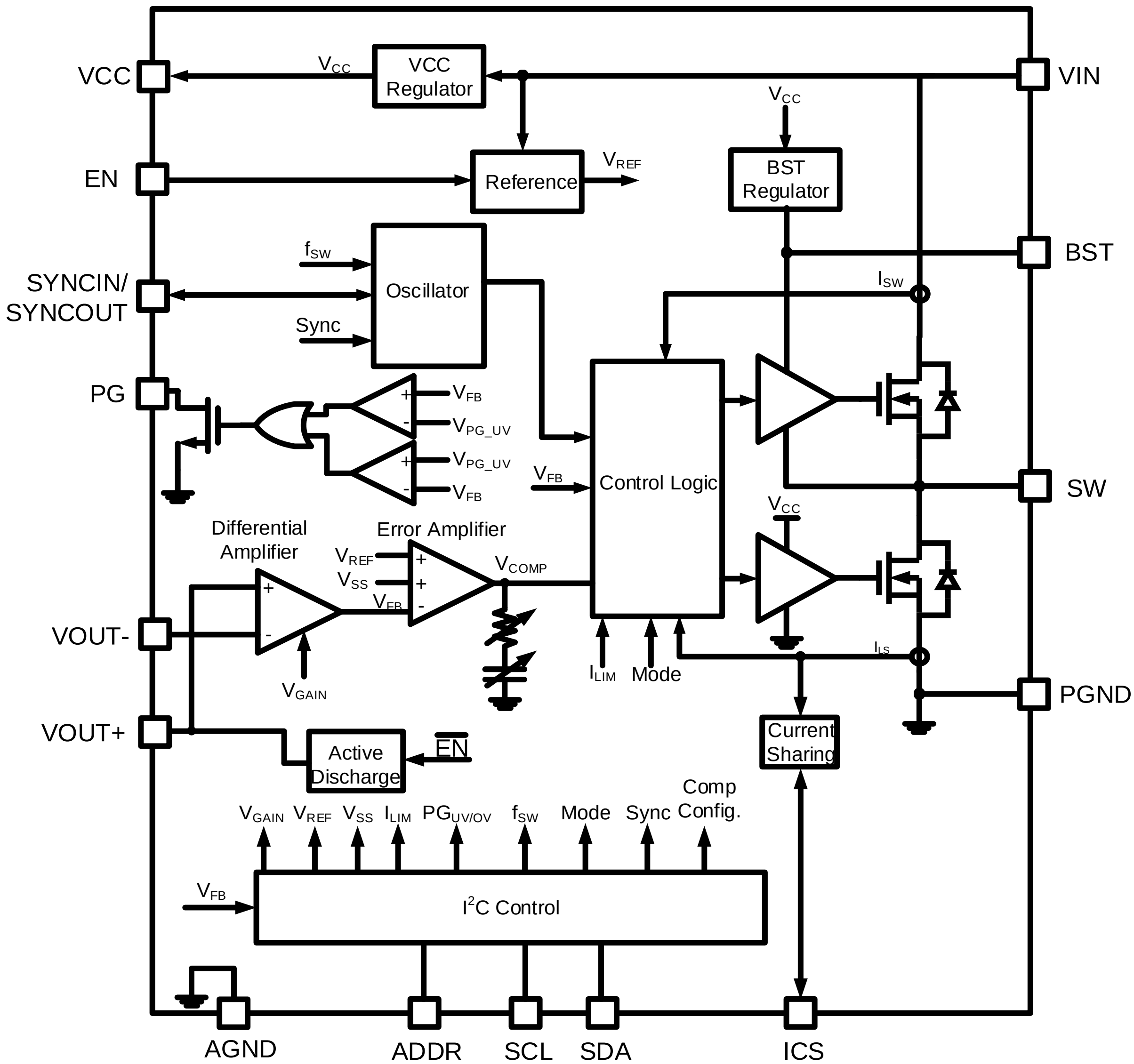


Figure 5: MPQ2286 Block Diagram

3.4 MPQ7920

The MPQ7920 is a complete power management solution that integrates four high-efficiency step-down DC/DC converters, five low-dropout (LDO) regulators, and a flexible logic interface. It operates from a 2.7V to 5.5V V_{IN} and provides a maximum continuous I_{OUT} depending on the step-down converter:

- Buck 1: 4.5A
- Buck 2: 2.5A
- Buck 3: 4.5A
- Buck 4: 2A

In addition to its wide configurability via the I²C interface, which can configure the output voltage of each converter and preset the power on/off sequences, the MPQ7920's constant-on-time (COT) control architecture provides fast and excellent transient response without the need for additional output capacitance. Figure 6 shows the MPQ7920's functional block diagram.

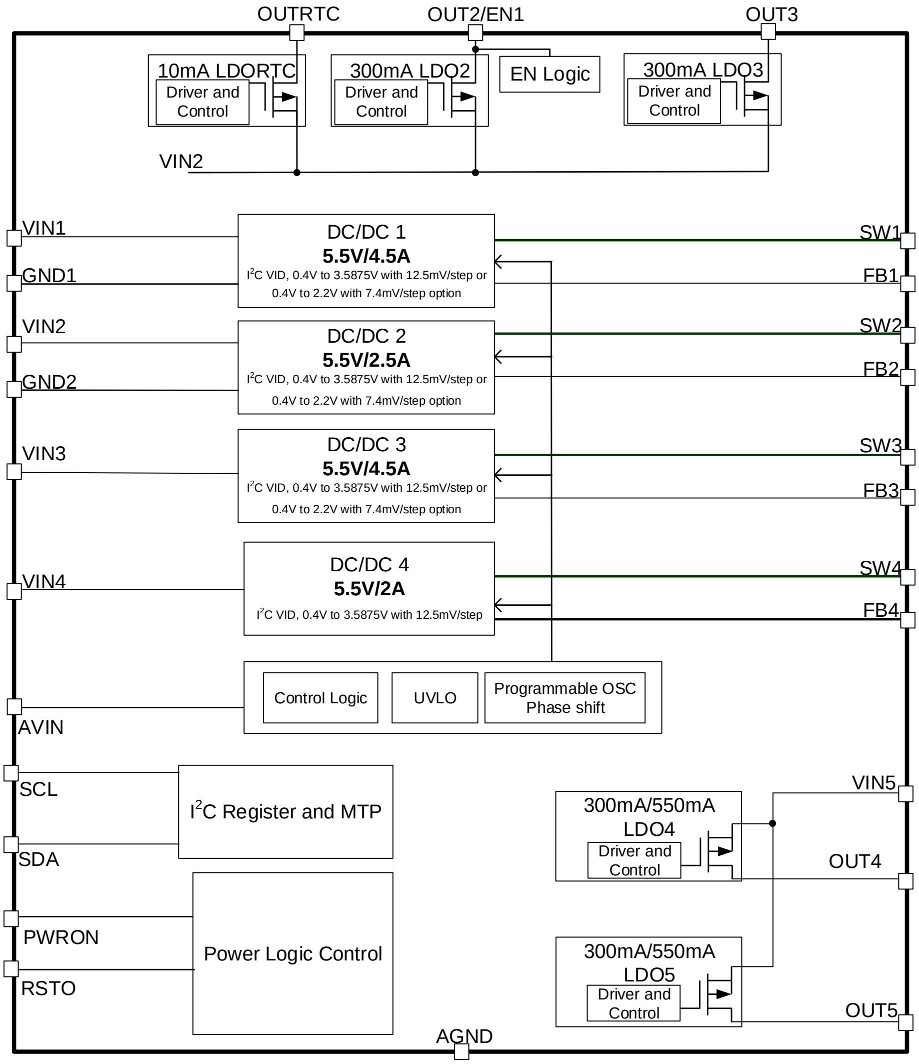


Figure 6: MPQ7920 Block Diagram

3.5 MPQ5075A

The MPQ5075A is a load switch capable of delivering up to 5A of current with a 0.5V to 5.5V V_{IN} range. Thanks to the small $R_{DS(ON)}$ in a small package, the MPQ5075A is an efficient and space-saving solution. With the soft-start function, the MPQ5075A can avoid inrush current during circuit start-up. The MPQ5075A also features configurable a soft-start time, output discharge functions, current limiting, and thermal shutdown. Figure 7 shows the MPQ5075A's functional block diagram.

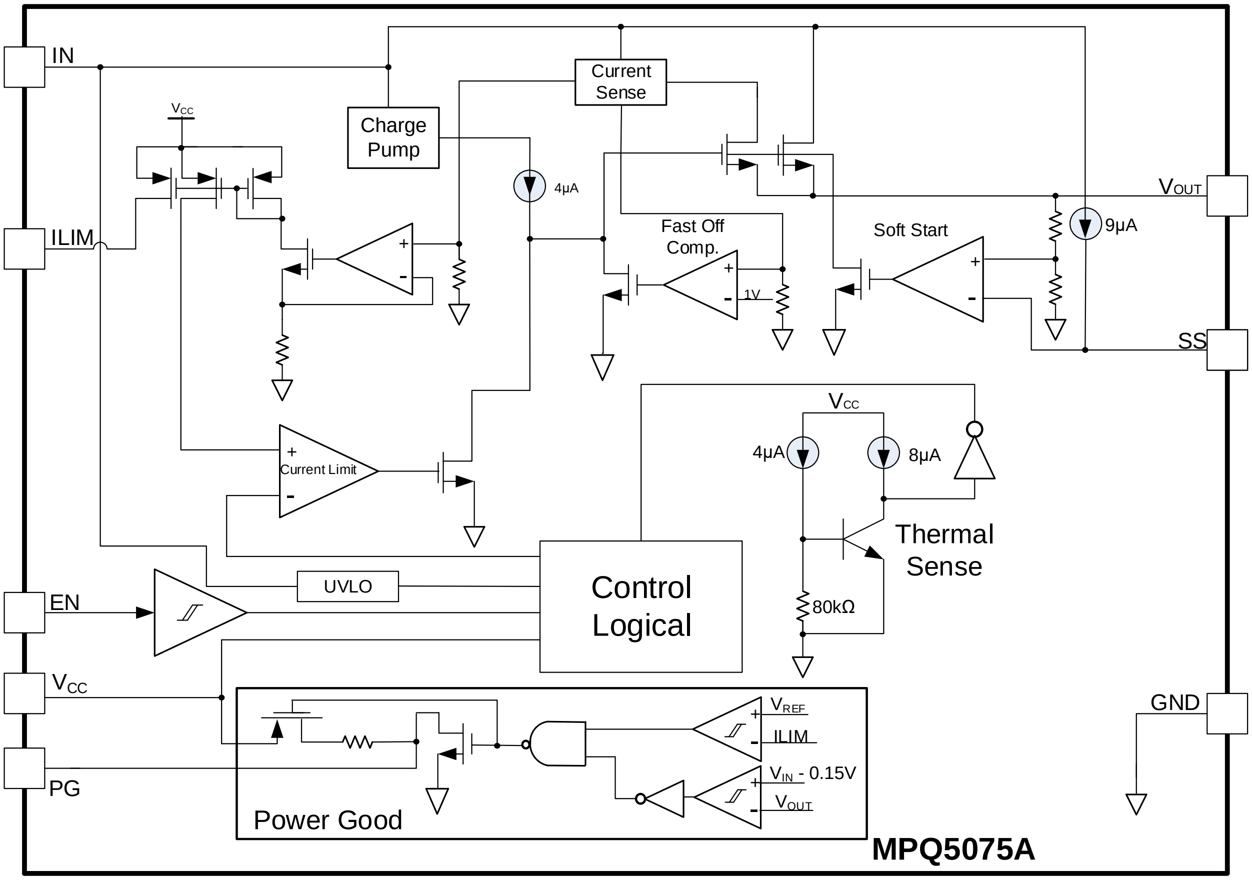


Figure 7: MPQ5075A Block Diagram

3.6 MPQ3414B

The MPQ3414B is a high-efficiency, synchronous, current-mode step-up converter with output disconnect. It can start up from a V_{IN} of 1.8V, with a maximum of up to 4V. The integrated power MOSFET supports up to 5V of V_{OUT} and a maximum I_{OUT} of 0.5A. The MPQ3414B has a fixed switching frequency (f_{SW}) of 2.2MHz, which allows for use with small external components. Moreover, the internal compensation and soft-start mechanism reduce the number of required external components. Figure 8 shows the MPQ3414B's functional block diagram.

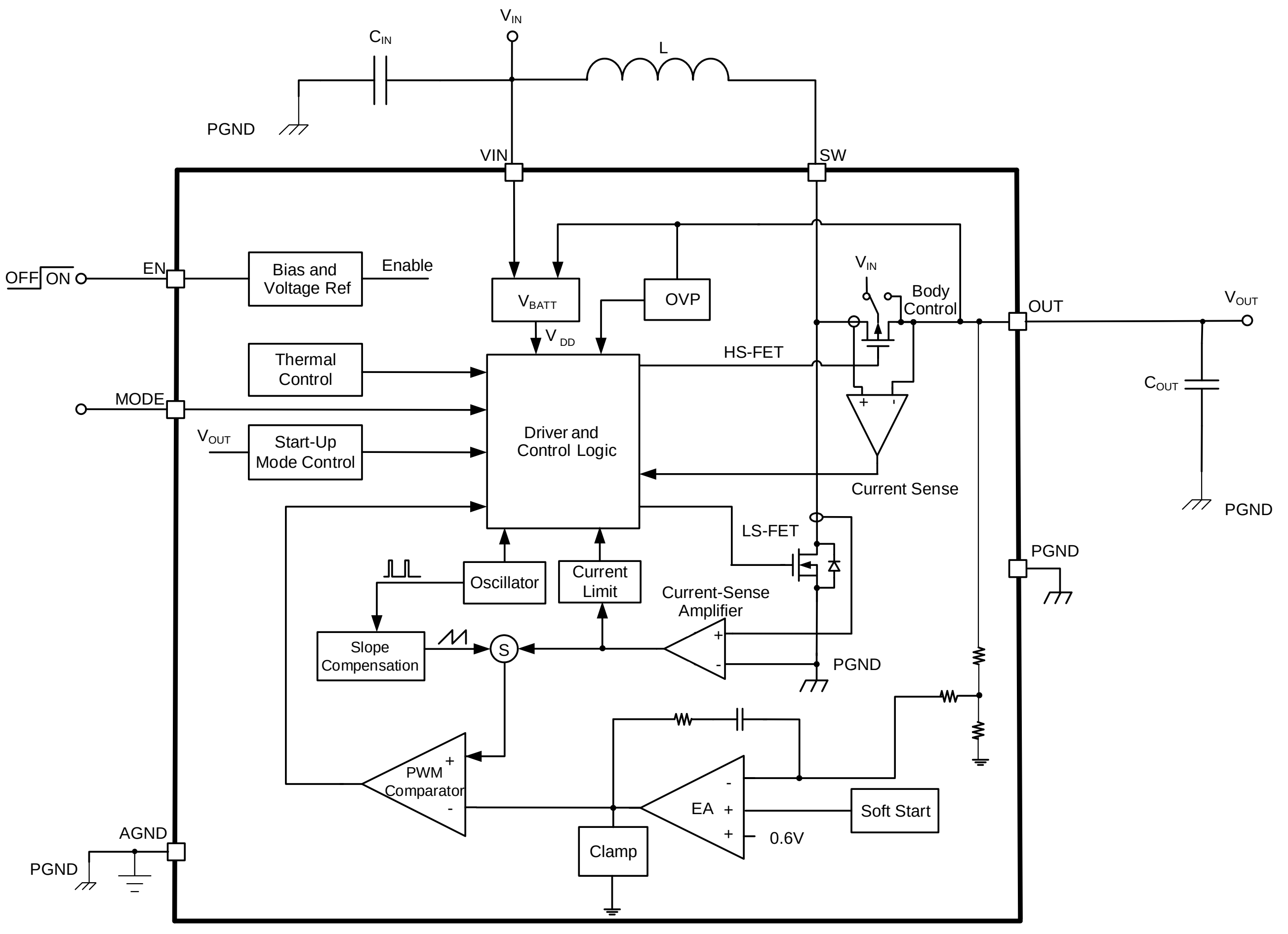


Figure 8: MPQ3414B Block Diagram

3.7 MPQ4371

The MPQ4371 is a configurable-frequency (200kHz to 2.5MHz), synchronous, step-down switching regulator with integrated internal high-side and low side power MOSFETs (HS-FETs and LS-FETs, respectively). It provides 10A of highly efficient output with fixed frequency ZDP control for optimal transient response. With the current share function, it is capable of operating in a multi-phase interleaving topology, which allow for a larger I_{OUT} and low EMI. Figure 9 shows the MPQ4371's functional block diagram.

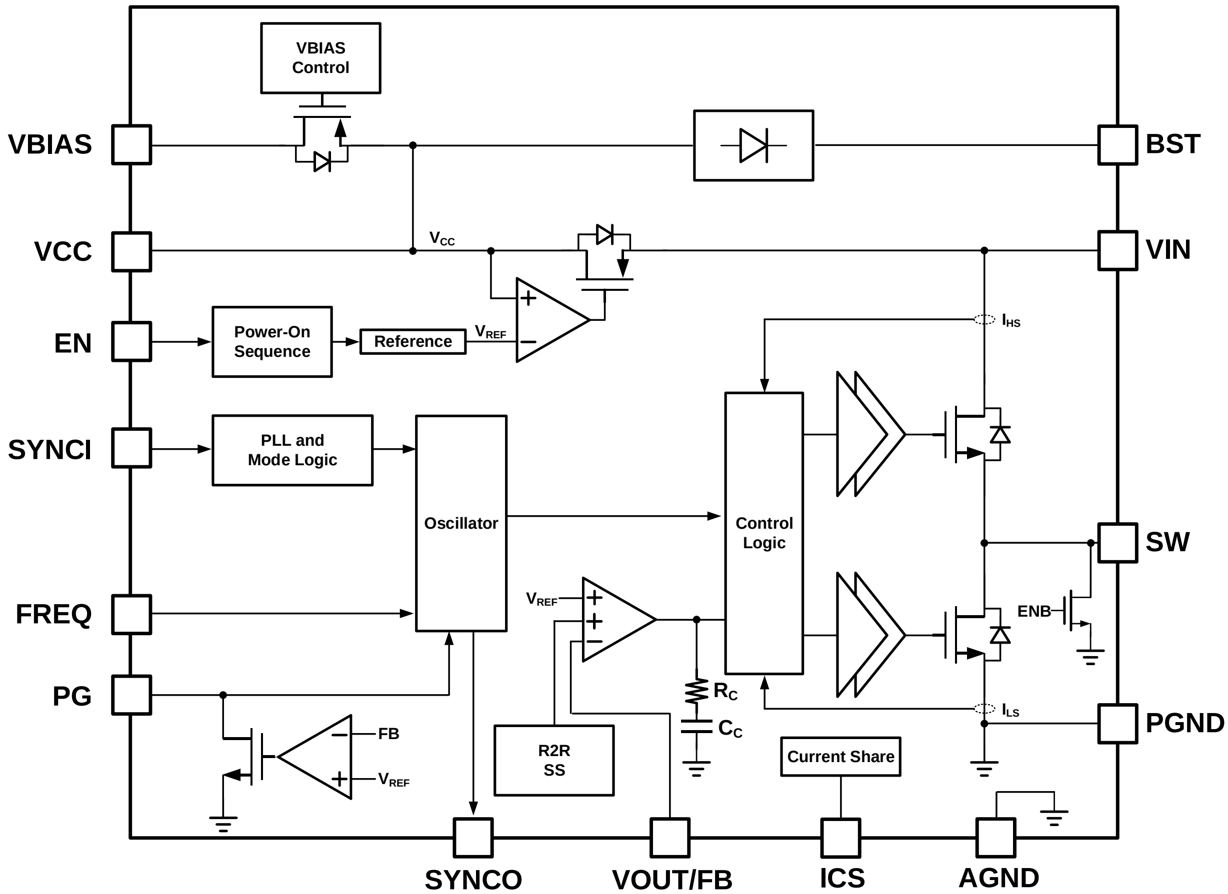


Figure 9: MPQ4371 Block Diagram

3.8 MPQ5850

The MPQ5850 is smart diode controller that can drive an external N-channel MOSFET to replace a Schottky diode for reverse input protection. Its 20mV ultra-low dropout not only minimizes power loss, but also allows for a very low minimum V_{IN}. This device is well-suited for cold-crank conditions in automotive applications. The device's 4µA shutdown current makes it ideal for battery-powered applications. The ultra-fast transient response allows it to meet stringent ISO16750 requirements. The MPQ5850 integrates an internal boost to provide enough voltage to turn on an external N-channel MOSFET, even with a low V_{IN}. The MPQ5850 has an open-drain power good output that signals whether the N-channel MOSFET is fully turned on. The MPQ5850 is available in a TSOT23-8 (2mmx3mm) package. Figure 10 shows the MPQ5850's functional block diagram.

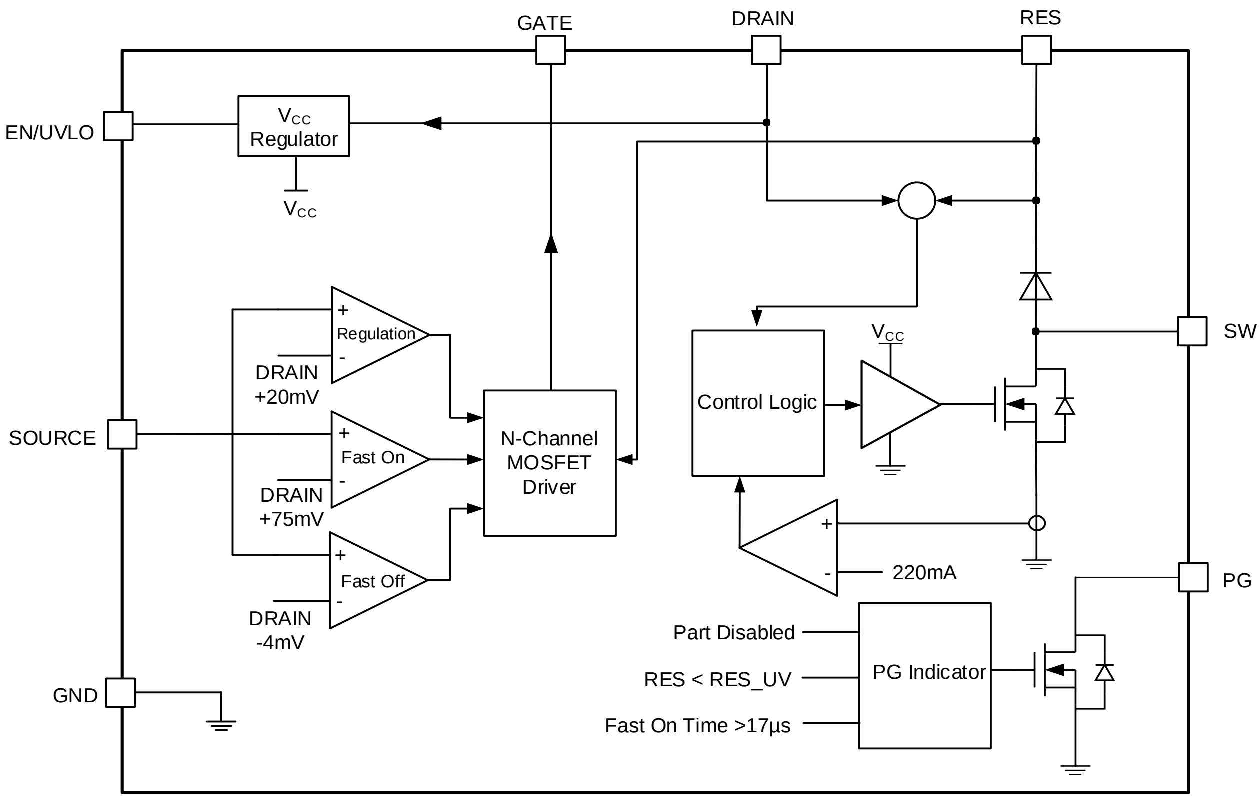


Figure 10: MPQ5850 Block Diagram

4 Achieving System Level Functional Safety

4.1 MPQ79700FS

The MPQ79700FS is a safety element utilized within an electronic / electrical system, as defined in ISO26262. It was developed as a safety element out of context (SEooC) to improve the system's automotive safety integrity level (ASIL). In order to improve the ASIL level, the MPQ79700FS:

- Is powered by an external super capacitor during back-up mode.
- Controls the power up/down sequencing for all relevant SoC voltage rails.
- Provides a 32kHz clock signal to the SoC.
- Provides an external watchdog function to monitor the integrity of the SoC.
- Provides safety mechanisms that monitor the failure modes of its functionality.
- Triggers an interrupt signal to alarm the system when an internal safety relevant failure is detected.

The MPQ79700FS has 3 failure modes that could violate the system's safety goal:

- Incorrect power-up sequencing
- Incorrect power-down sequencing
- Incorrect 32kHz clock signal output

The system relies on the MPQ79500FS voltage monitor to detect an incorrect power-up or power-down sequence and guarantee a safe state. The MPQ79700FS monitors the 32kHz clock internally and can alert the host in case of a fault; however, it is not able to detect 32kHz clock signal failures that are caused by an external circuit outside of the IC. If this signal is safety relevant, it shall be monitored by the system.

The interrupt pin (NIRQ) must be tested once every power cycle; the test procedure is described in the device's safety manual.

4.2 MPQ79500FS

The MPQ79500FS is a safety element utilized within an electronic / electrical system, as defined in ISO26262. It was developed as an SEooC to improve the system's ASIL. In order to improve the ASIL level, the MPQ79500FS:

- Provides voltage monitoring and sequencing logging functions.
- Has the ability to monitor six individual voltage rails. This device is designed to monitor for both high-frequency (transient) noise and as well as low-frequency (LF) DC voltage drifting, and can also report a timestamp for the fault if either parameter is out of bounds.
- Monitors the V_{IN} power-up and power-down sequences, and records the sequence via output pulses on the SYNC pin.
- Provides one-time programmable (OTP) memory for flexibility to enable design reuse across different applications and SoC generations.
- Has built-in safety mechanisms such as BIST to provide high diagnostic coverage, helping the system achieve ASIL-D.

The MPQ79500FS voltage monitor cannot directly create a safety violation, but it is must ensure that these following latent faults are not missed:

- Output over-voltage, high-frequency (OVHF) failure
- Output over-voltage, low-frequency (OVLF) failure
- Output under-voltage, high-frequency (UVHF) failure
- Output under-voltage, low-frequency (UVLF) failure
- Incorrect power-up / power-down sequencing failure

To detect those latent faults, the system shall test the safety mechanisms at least once every drive cycle. The test procedure is described in the device's safety manual.

5 Control Architectures

5.1 Constant-On-Time (COT) Control

Constant-on-time (COT) control architecture has a very simple structure compared to traditional voltage-mode and current-mode control topologies. First, V_{OUT} is sensed via feedback resistors (RFB1 and RFB2). Second, the valley of the output ripple voltage is compared directly to the reference voltage (V_{REF}) to generate a fixed on-time pulse. When the FB voltage is below V_{REF}, an on-time pulse is generated and fed into the gate driver.

The most important characteristic of this control architecture is that the on-time is fixed, and f_{SW} changes to compensate for load transients. In steady state, f_{SW} remains approximately constant. However, during a load-step transient, the COT pulse generator outputs consecutive on-time pulses with an internal minimum off time. This minimizes V_{OUT} undershoot.

Because the sensed V_{OUT} is injected directly to the PWM comparator and does not pass through an error amplifier, there are no delays, which results in faster transients. Compared to traditional voltage-mode and current-mode controls, the transient response can be up to two times faster.

Finally, COT control reduces the number of external components because the external compensation network is removed. Since the transient response is faster, the number of external capacitors is also reduced.

In summary, COT offers many advantages compared to traditional compensation architectures due to its faster transient response, higher efficiency and ease of design. Figure 11 shows the COT architecture.

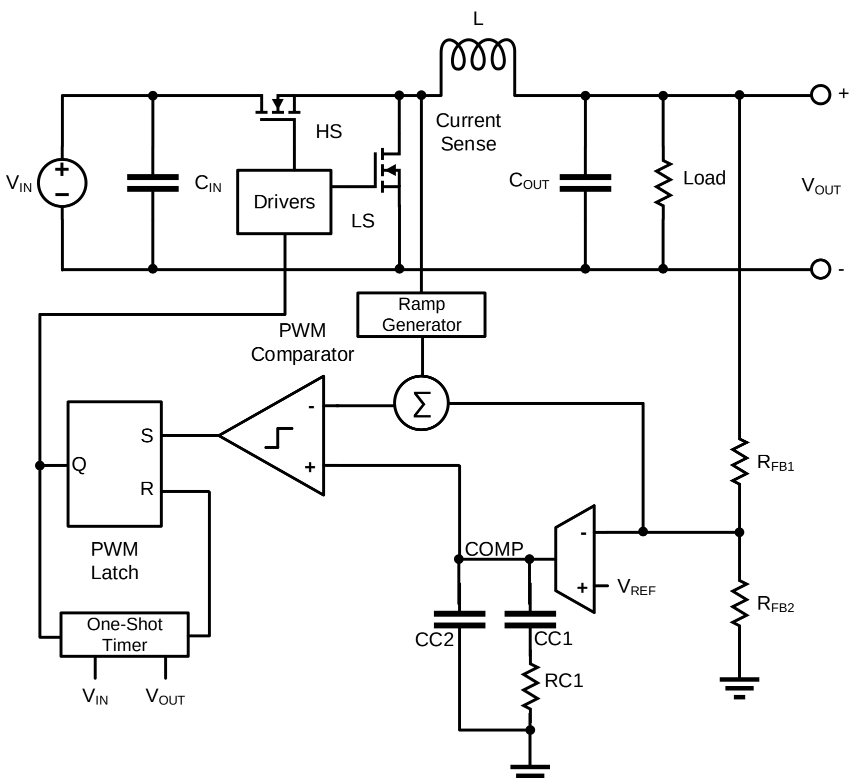


Figure 11: Constant-On-Time Architecture

For more information, refer to the following article on the MPS website.

5.2 Fixed-Frequency Zero-Delay PWM (ZDP) Control

For the high-current rail converter, the design includes a regulator that provides a zero-delay PWM control architecture. Similar to COT control, this control topology provides excellent transient response, though with a fixed-frequency scheme. The fast path between the output voltage and the PWM comparator (with are directly connected) allows the duty cycle to change quickly.

During a load transient, V_{OUT} drops. Then, the voltage drop is sensed through FB resistors (RFB1 and RFB2). This sensed voltage is directly connected to the PWM comparator and compared to V_{REF}. Finally, the duty cycle immediately increases at the next turn-on cycle to deliver more power to the output capacitors, which helps V_{OUT} recover. Unlike in COT control, the ZDP control architecture does not need to vary the f_{SW}.

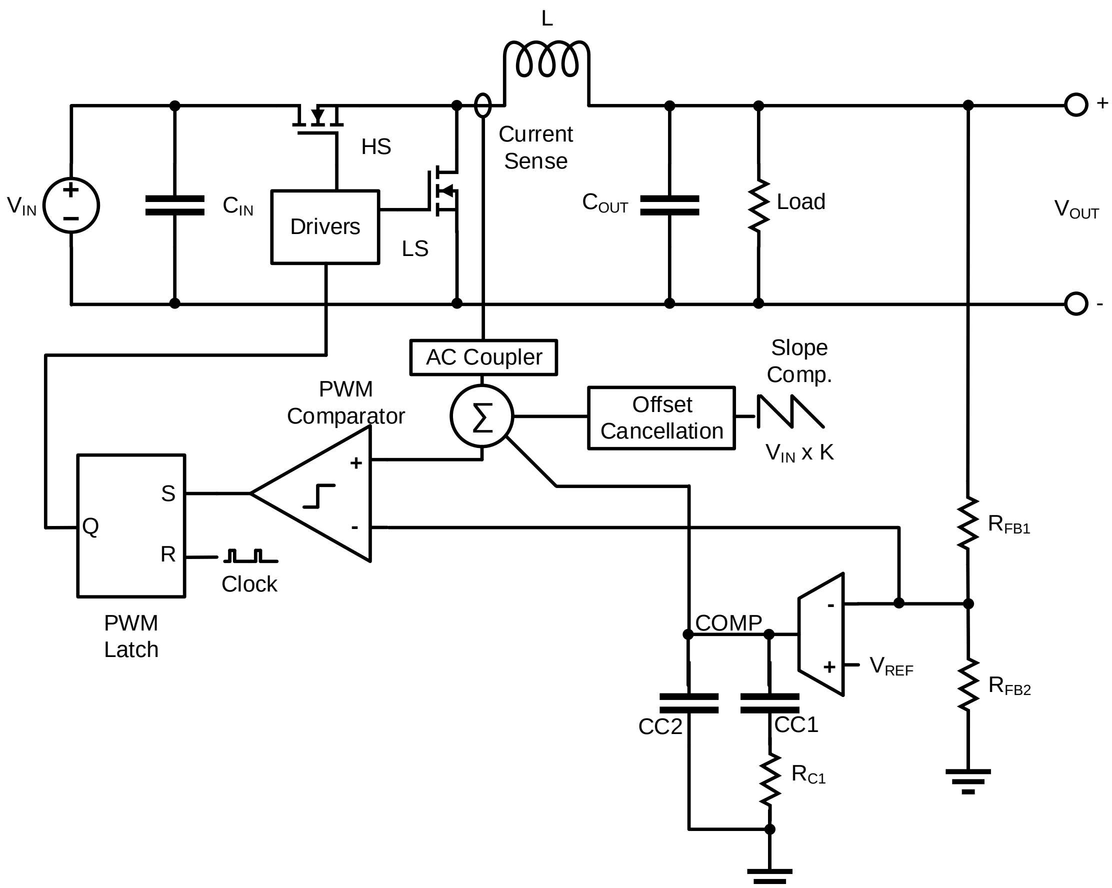


Figure 12: Zero-Delay PWM Architecture

For more information, refer to the following article from the MPS website.

6 Design Files

6.1 Schematics

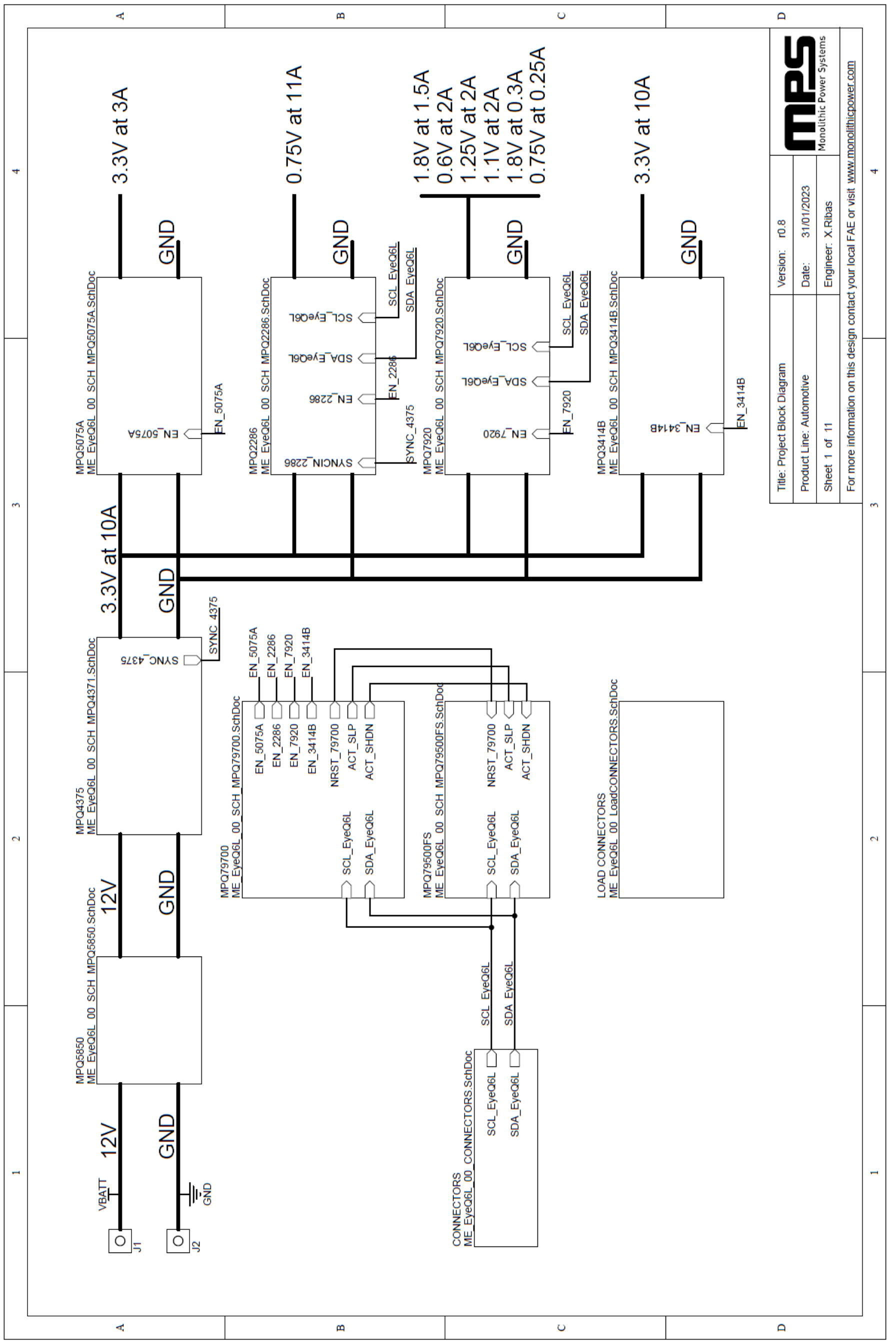


Figure 13: Project Block Diagram

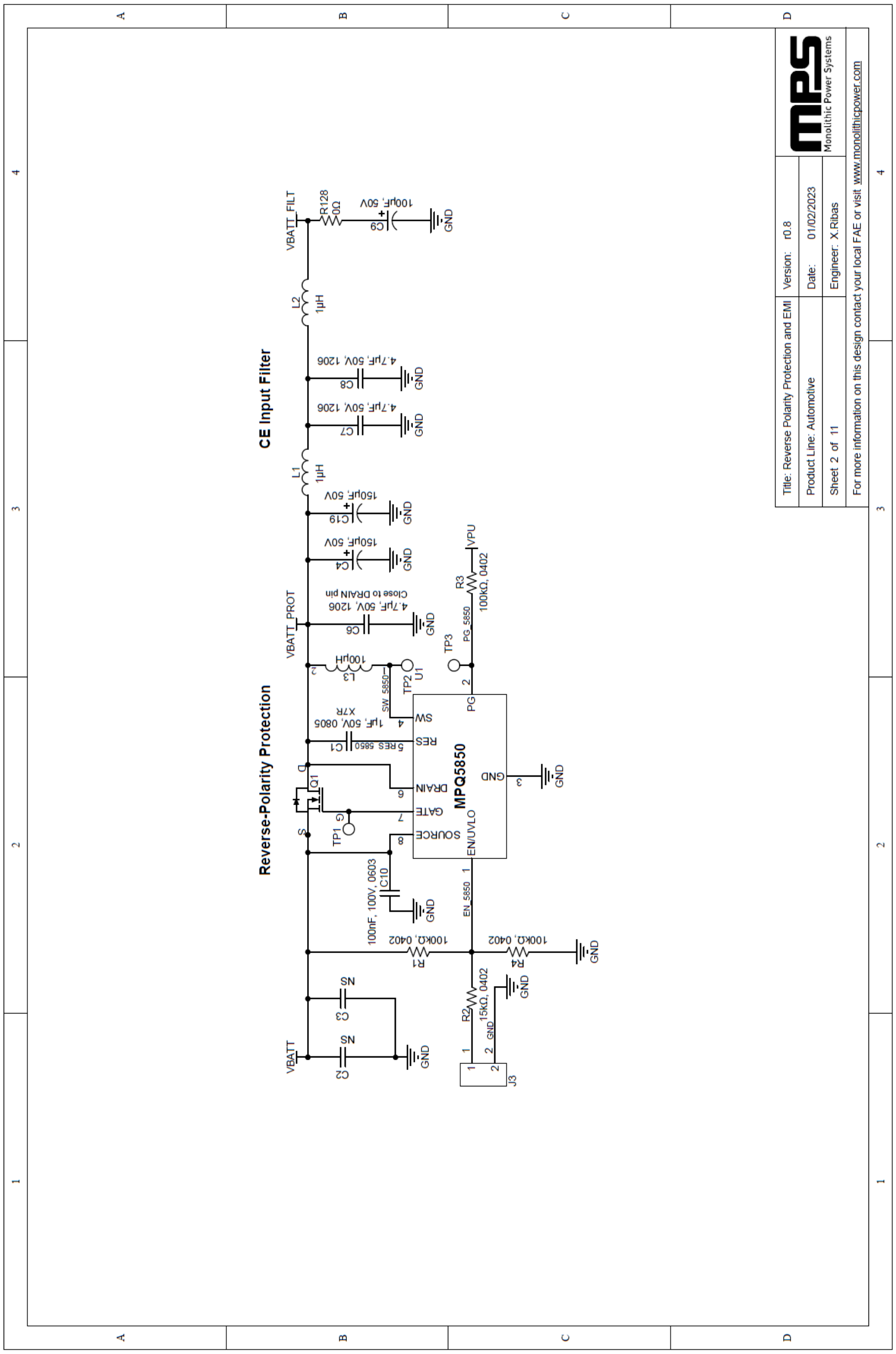


Figure 14: Reverse Polarity Protection and EMI Filter Sheet

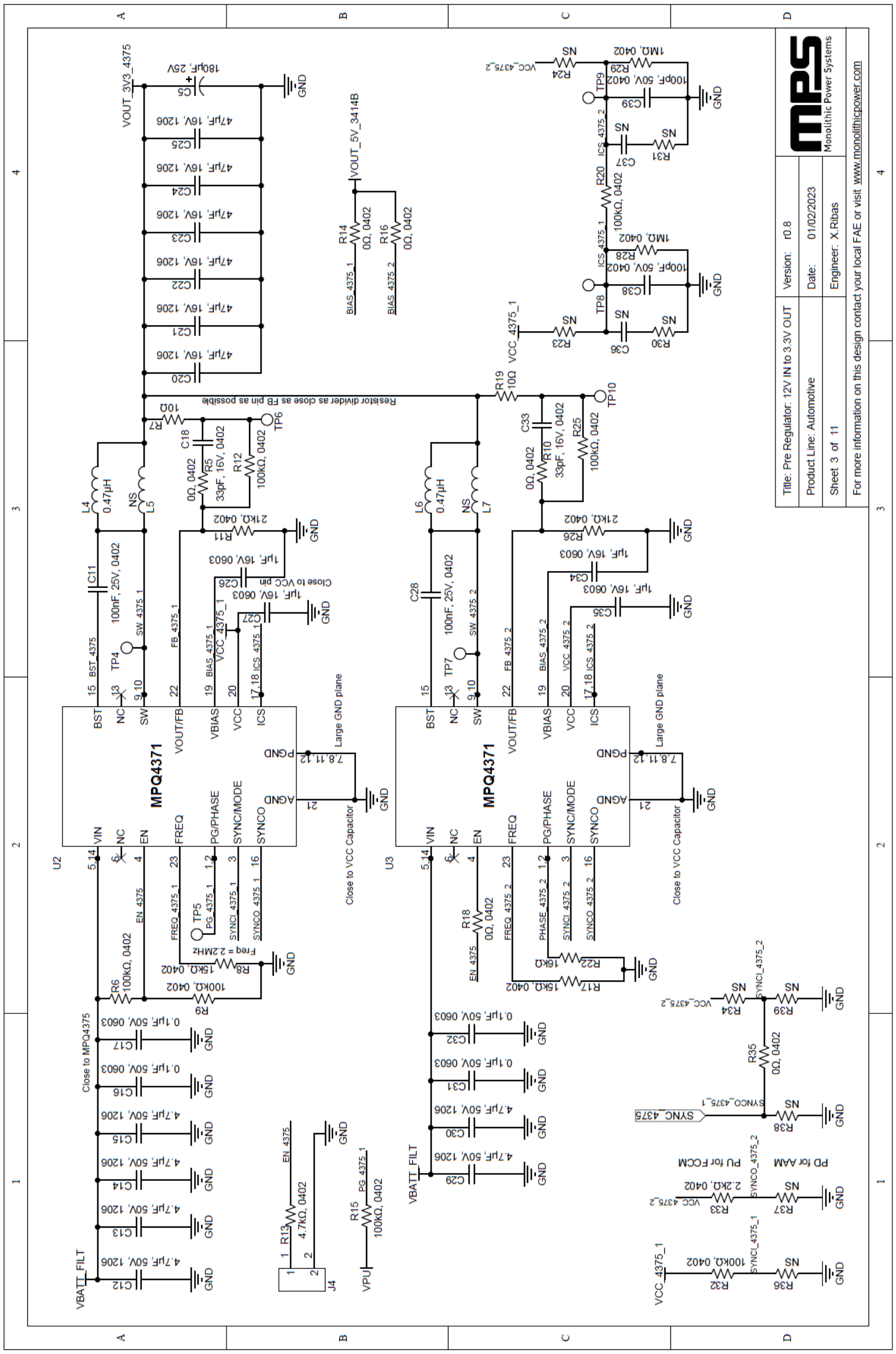


Figure 15: Pre-Regulator 12$_{VIN}$ to 3.3V$_{OUT}$ Sheet

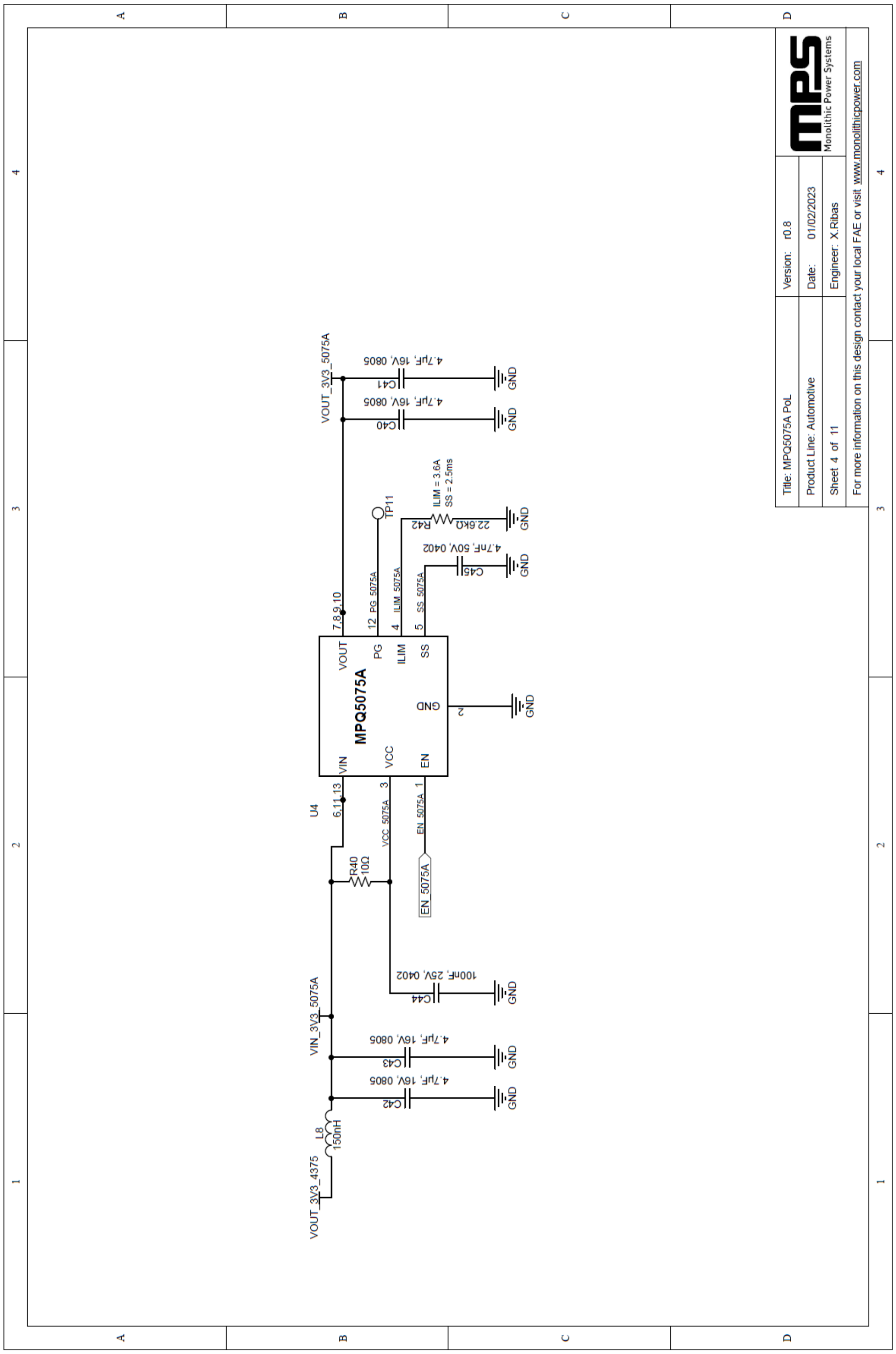


Figure 16: MPQ5075A PoL Sheet

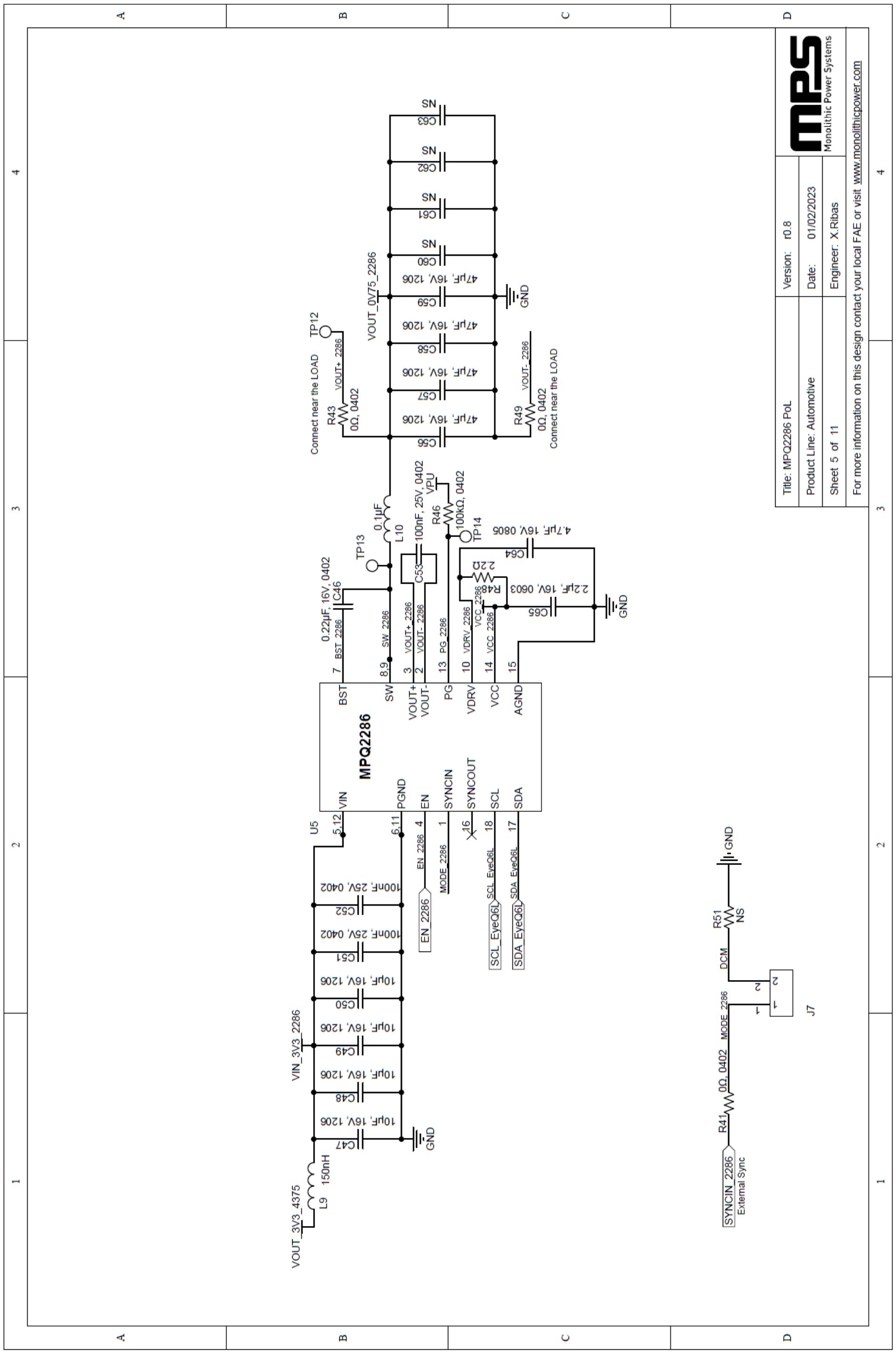


Figure 17: MPQ2286 PoL Sheet

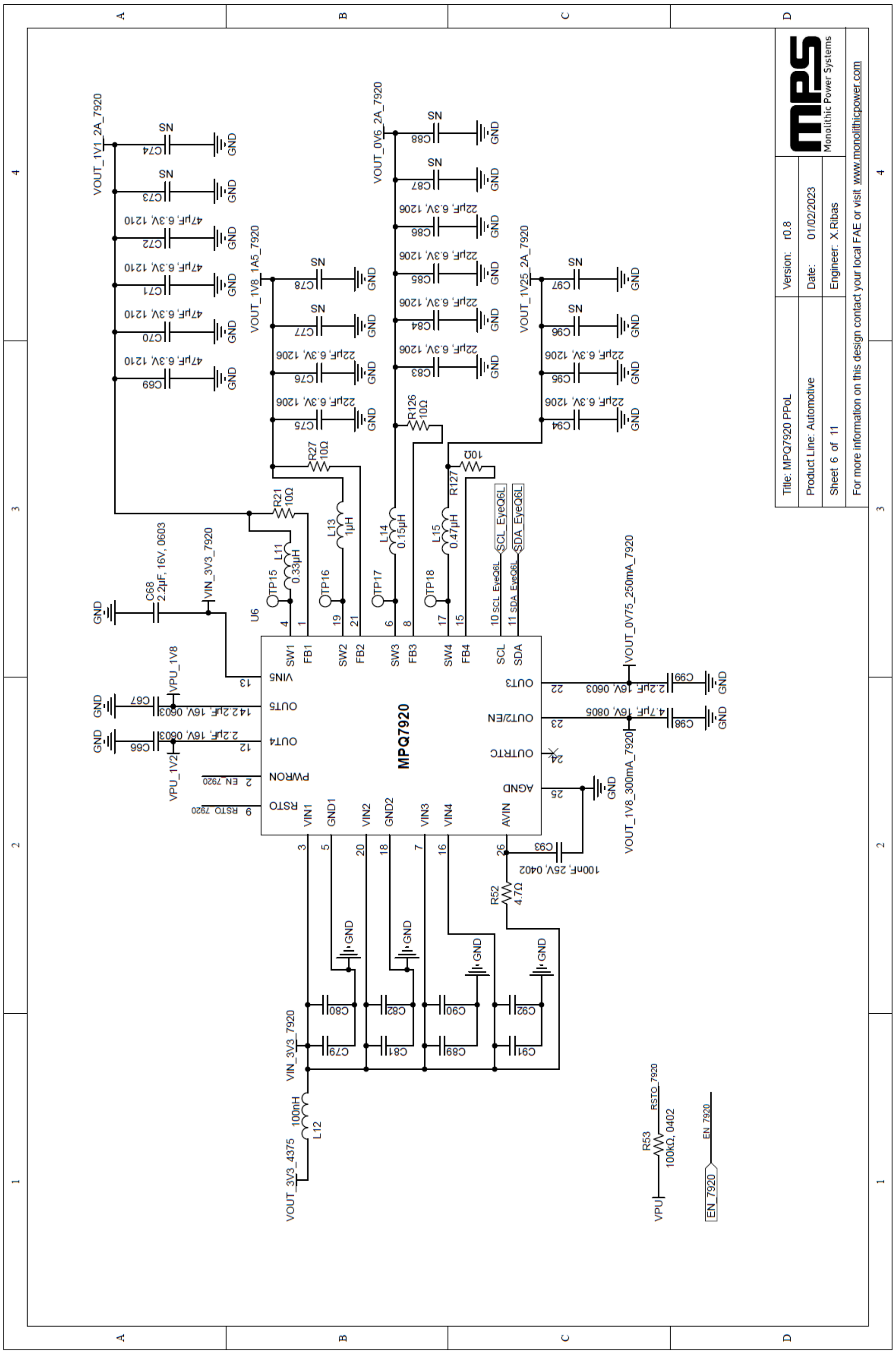


Figure 18: MPQ7920 PPoL Sheet

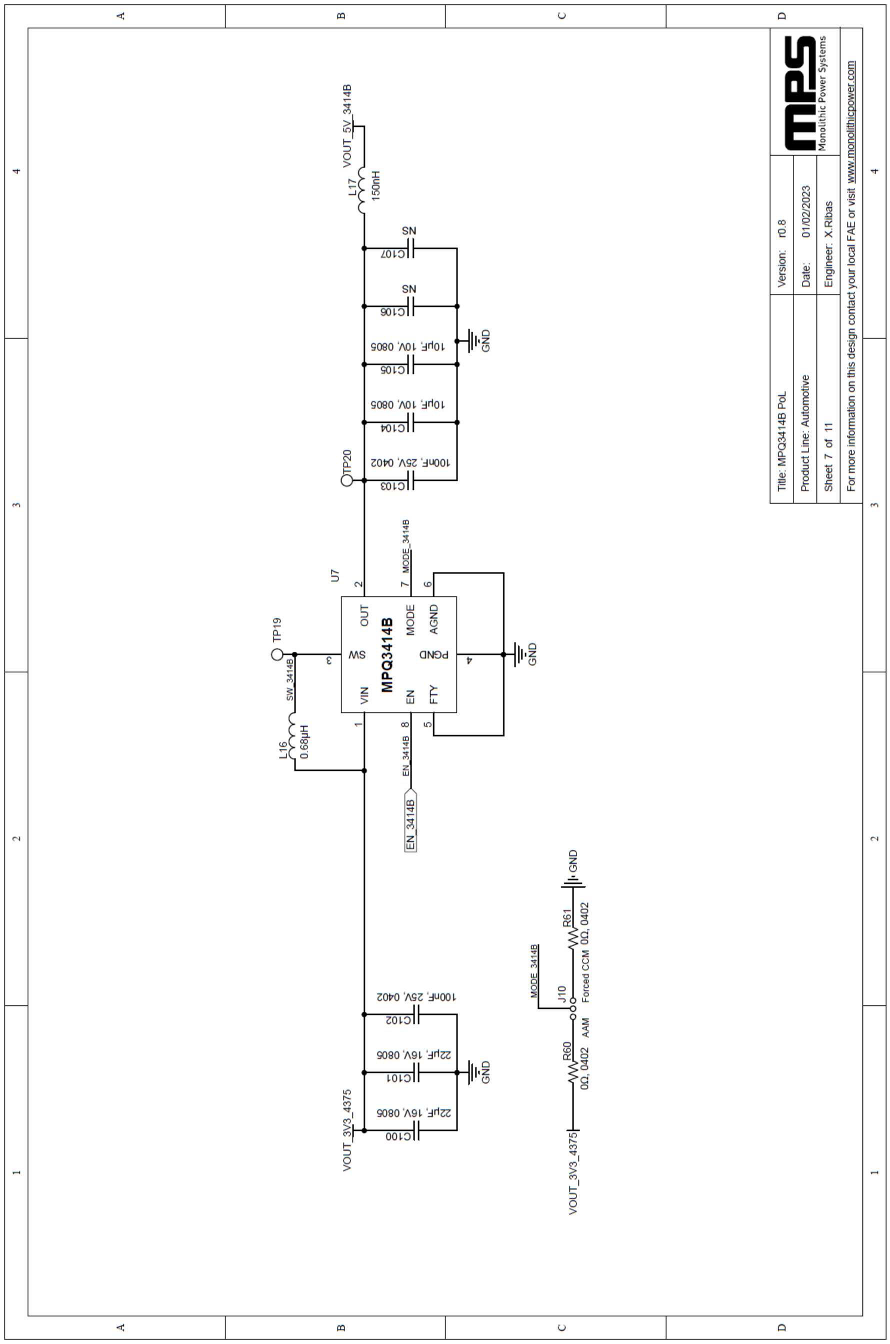


Figure 19: MPQ3414B PoL Sheet

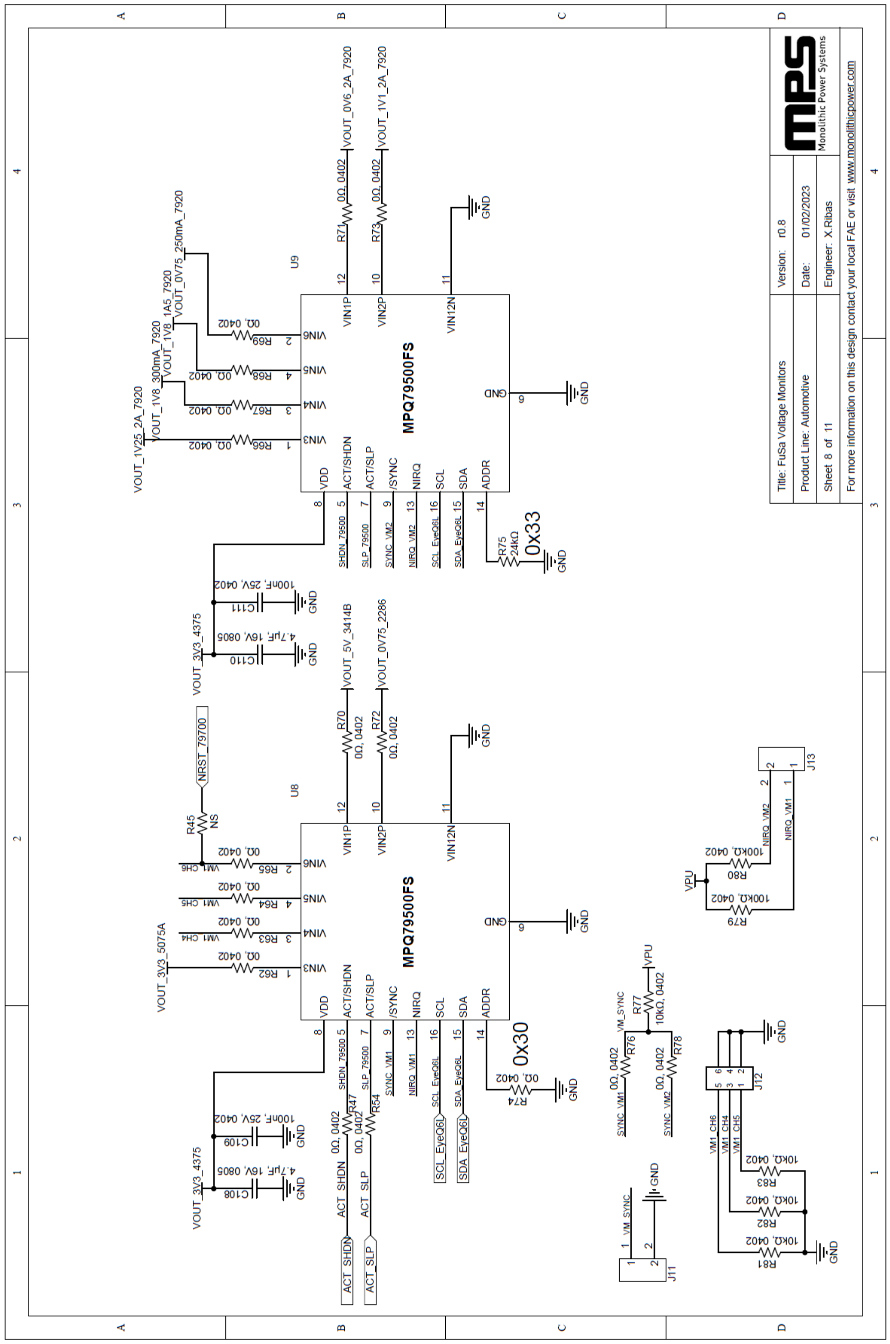


Figure 20: FuSa Voltage Monitor Sheet

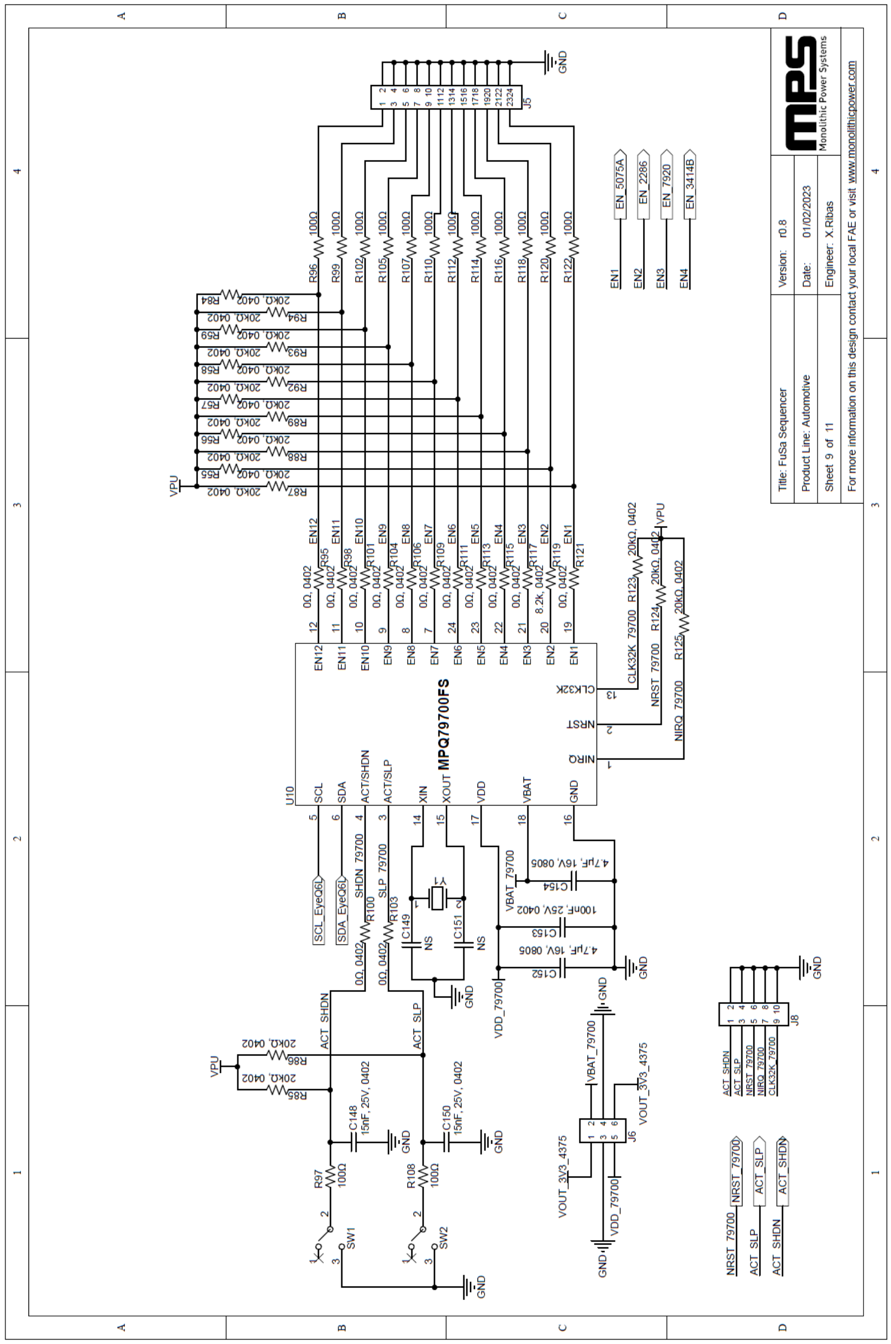


Figure 21: FuSa Sequencer Sheet

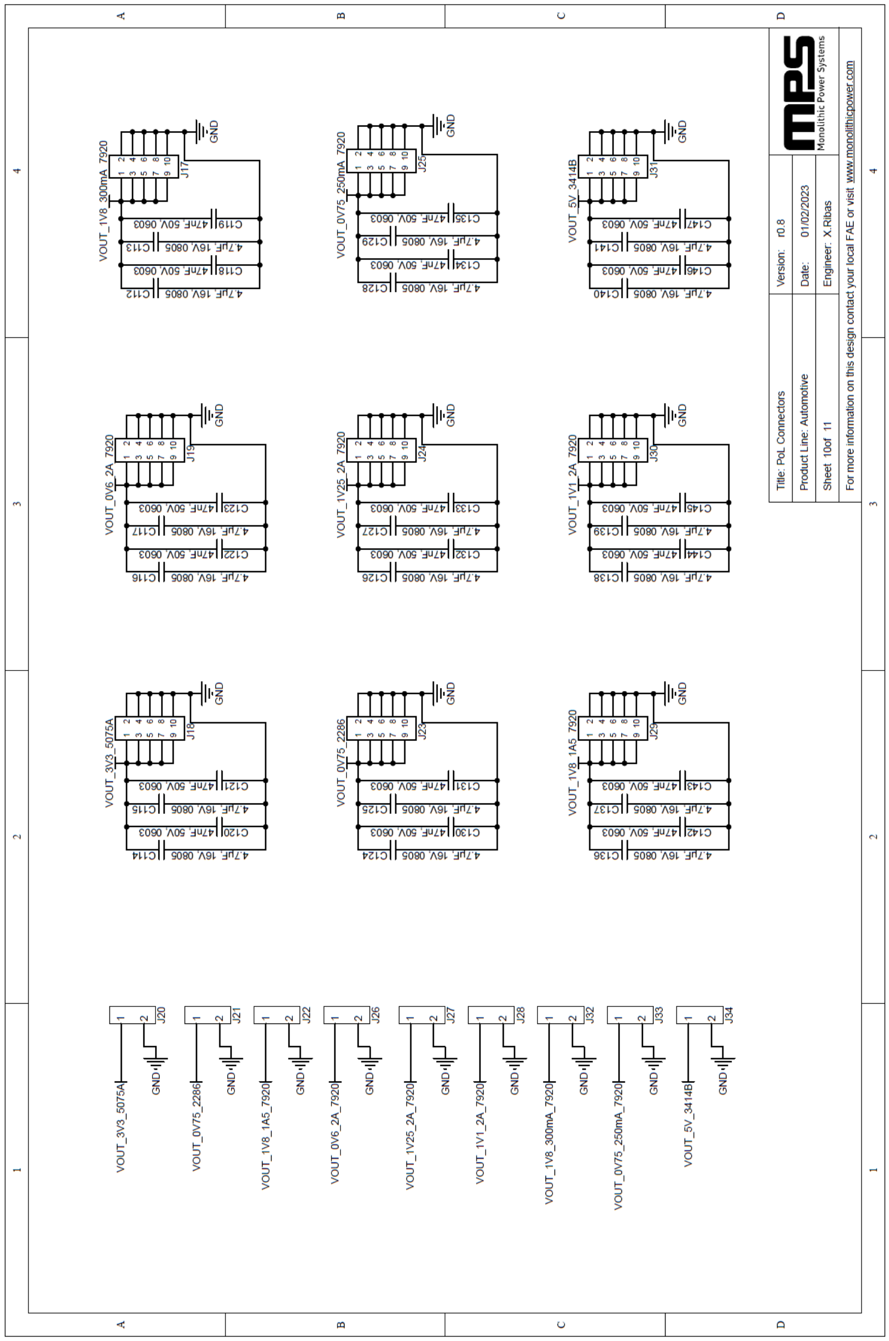


Figure 22: PoL Connectors Sheet

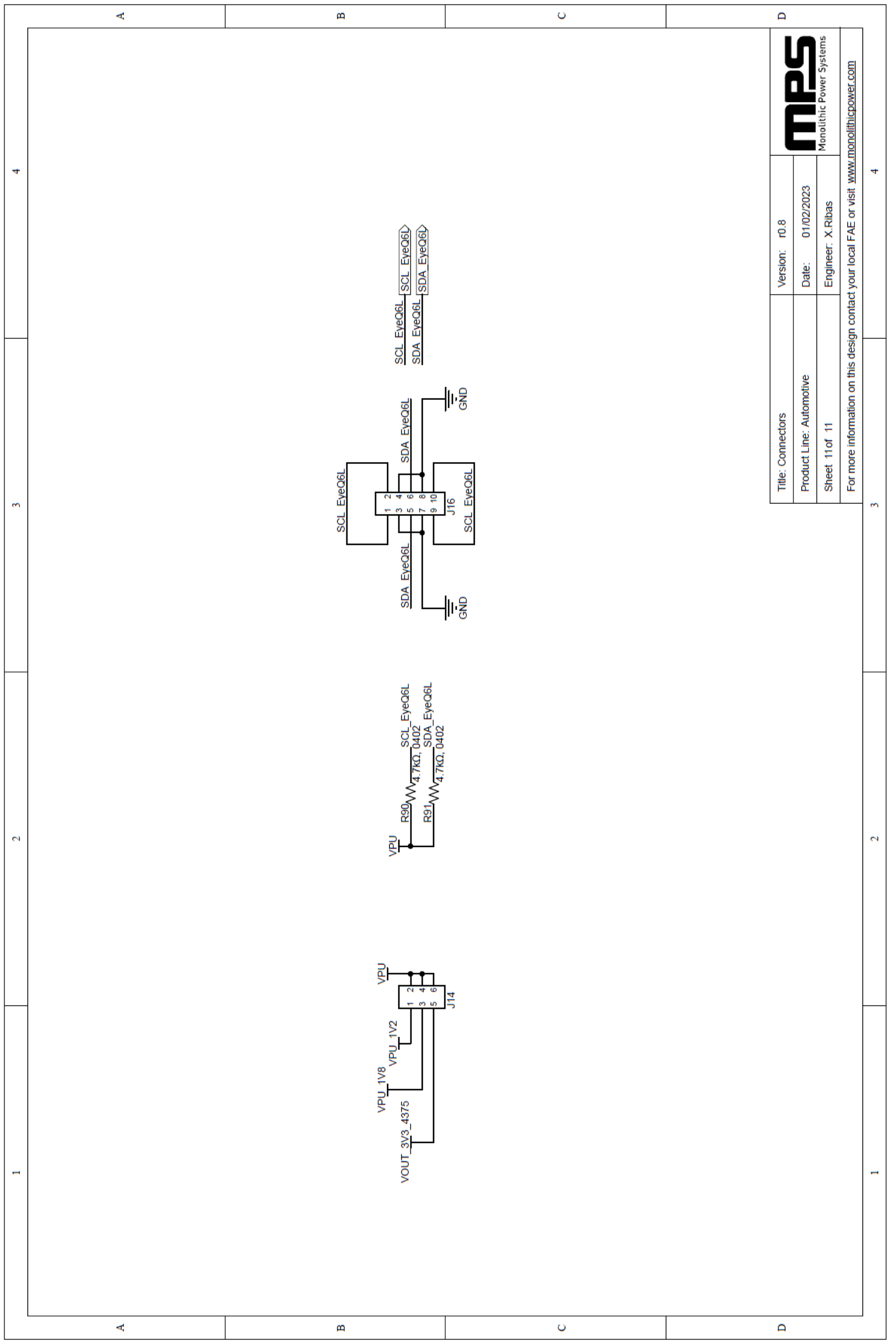


Figure 23: Connectors Sheet

6.2 Bill of Materials

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer PN
1	C1	1µF, 50V	X7R, 10%, MLCC	0805	Kemet	C0805C105K5RACAUTO
2	C4, C19	150µF, 50V	Polymer capacitor	10mmx 12.2mm	Kemet	A768MS157M1HLAV024
1	C5	180µF, 25V	Polymer capacitor	8mmx 6.7mm	Kemet	A768KE187M1ELAS029
9	C6, C7, C8, C12, C13, C14, C15, C29, C30	4.7µF, 50V	X7R, 10%, MLCC	1206	Kemet	C1206X475K5RACAUTO
1	C9	100µF, 50V	Electrolytic capacitor	10mmx 10.2mm	Kemet	EDT107M050S9PAA
1	C10	100nF, 100V	X8L, 10%, MLCC	0603	Murata	GCJ188L8EL104KA07D
16	C11, C28, C44, C51, C52, C53, C80, C82, C90, C92, C93, C102, C103, C109, C111, C153	100nF, 25V	X7R, 10%, MLCC	0402	TDK	CGA2B3X7R1E104K050BB
4	C16, C17, C31, C32	0.1µF, 50V	X7R, 10%, MLCC	0603	Kemet	C0603X104K5RACAUTO
2	C18, C33	33pF, 16V	X7R, 5%, MLCC	0402	Kemet	C0402C330J4RACAUTO
10	C20, C21, C22, C23, C24, C25, C56, C57, C58, C59	47µF, 16V	X5R, 20%, MLCC	1206	TDK	C3216X5R1C476M160AB
4	C26, C27, C34, C35	1µF, 16V	X7R, 10%, MLCC	0603	Kemet	C0603C105K4RACAUTO7411
2	C38, C39	100pF, 50V	C0G, 5%, MLCC	0402	Kemet	C0402C101J5GACAUTO
28	C40, C41, C42, C43, C64, C98, C108, C110, C112, C113, C114, C115, C116, C117, C124, C125, C126, C127, C128, C129, C136, C137, C138, C139, C140, C141, C152, C154	4.7µF, 16V	X7R, 10%, MLCC	0805	Kemet	C0805C475K4RACAUTO
1	C45	4.7nF, 50V	X7R, 10%, MLCC	0402	Murata	GCM155R71H472KA37J

1	C46	0.22µF, 16V	X7R, 10%, MLCC	0402	Murata	GCM155R71C224KE02J
4	C47, C48, C49, C50	10µF, 16V	X7R, 10%, MLCC	1206	Kemet	C1206C106K4RACAUTO
5	C65, C66, C67, C68, C99	2.2µF, 16V	X7S, 10%, MLCC	0603	TDK	CGA3E1X7S1C225K080AC
4	C69, C70, C71, C72	47µF, 6.3V	X7R, 10%, MLCC	1210	Murata	GCM32ER70J476KE19L
8	C75, C76, C83, C84, C85, C86, C94, C95	22µF, 6.3V	X7R, 20%, MLCC	1206	Murata	GCJ31CR70J226ME01L
6	C79, C81, C89, C91, C100, C101	22µF, 16V	X5R, 20%, MLCC	0805	Murata	GRT21BR61C226ME13L
2	C104, C105	10µF, 10V	X5R, 20%, MLCC	0805	Murata	CGA4J3X5R1A106M125AB
18	C118, C119, C120, C121, C122, C123, C130, C131, C132, C133, C134, C135, C142, C143, C144, C145, C146, C147	47nF, 50V	X7R, 10%, MLCC	0603	Kemet	C0603X473K5RACAUTO
2	C148, C150	15nF, 25V	X7R, 5%, MLCC	0402	Kemet	C0402C153J3RACAUTO
2	J1, J2	15A	PC metric screw terminal	8mmx 8mm	Keystone Electronics	7696-3
5	J3, J4, J7, J11, J13	2.54mm	Header	2.54mm	TE Connectivity	4-103327-4
1	J5	2.54mm	Header	2.54mm	Harwin	M20-9761246
3	J6, J12, J14	2.54mm	Header	2.54mm	TE Connectivity	5-146258-3
11	J8, J16, J17, J18, J19, J23, J24, J25, J29, J30, J31	2.54mm	Header	2.54mm	Harwin	M20-9720546
1	J10	2.54mm	Header	2.54mm	TE Connectivity	4-103321-5
9	J20, J21, J22, J26, J27, J28, J32, J33, J34	13.5A, 200V	PCB terminal block	3.81mm	Phoenix Contact	1727010
2	L1, L2	0.68µH, 17A	Fixed inductor	7.1mmx 6.6mm	Bourns	SRP6030VA-R68M
1	L3	100µH, 0.43A	Fixed inductor	3030	Murata	LQH3NPZ101MMEL
2	L4, L6	0.47µH, 19A	Fixed inductor	8.1mmx 8.1mm	Wurth	7843340047
3	L8, L9, L17	150nH, 4.8A	Fixed inductor	0806	Murata	DFE2MCAHR15MJ0L

1	L10	0.1µF, 19.9A	Fixed inductor	4020	Coilcraft	XEL4020-101MEC
1	L11	0.33µH, 4.3A	Fixed inductor	0806	TDK	TFM201610ALMAR33M TAA
1	L12	100nH, 12A	Fixed inductor	1008	TDK	TFM252012ALMAR10M TAA
1	L13	1µH, 3.1A	Fixed inductor	0806	TDK	TFM201610ALMA1R0M TAA
1	L14	0.15µH. 7.3A	Fixed inductor	1008	TDK	TFM252012ALMAR15M TAA
1	L15	0.47µH, 3.9A	Fixed inductor	0806	TDK	TFM201610ALMAR47M TAA
1	L16	0.68µH	Fixed inductor	1210	TDK	TFM322512ALMAR68M TAA
1	Q1	60V, 250A	N-channel MOSFET	SO-8	On Semiconductor	NVMFS5C612NLAFT1G
14	R1, R3, R4, R6, R9, R12, R15, R20, R25, R32, R46, R53, R79, R80	100kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-07100KL
3	R2, R8, R17	15kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-0715KL
40	R5, R10, R14, R16, R18, R35, R41, R47, R49, R54, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R76, R78, R95, R98, R100, R101, R103, R104, R106, R109, R111, R113, R115, R117, R121	0Ω, 5%	Thick film resistor	0402	Yageo	AC0402JR-070RL
8	R7, R19, R21, R27, R40, R43, R126, R127	10Ω, 5%	Thick film resistor	0402	Panasonic	ERJ-2GEJ100X
2	R11, R26	21kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-0721KL
3	R13, R90, R91	4.7kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-074K7L
1	R22	16kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-2RKF1602X
2	R28, R29	1MΩ, 5%	Thick film resistor	0402	Yageo	AC0402JR-071ML
1	R33	2.2kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-072K2L

1	R42	22.6kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-U02F2262X
1	R48	2.2Ω, 1%	Thick film resistor	0402	Panasonic	ERJ-U02F2R20X
1	R52	4.7Ω, 5%	Thick film resistor	0402	Panasonic	ERJ-2GEJ4R7X
17	R55, R56, R57, R58, R59, R84, R85, R86, R87, R88, R89, R92, R93, R94, R123, R124, R125	20kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-0720KL
1	R75	24kΩ, 1%	Thick film resistor	0402	Panasonic	ERJ-U02F2402X
4	R77, R81, R82, R83	10kΩ, 5%	Thick film resistor	0402	Yageo	AC0402JR-7W10KL
14	R96, R97, R99, R102, R105, R107, R108, R110, R112, R114, R116, R118, R120, R122	100Ω, 1%	Thick film resistor	0402	Panasonic	ERJ-2RKF1000X
1	R119	8.2kΩ, 1%	Thick film resistor	0402	Yageo	AC0402FR-078K2L
1	R128	0Ω, jumper	Thick film resistor	1206	Panasonic	ERJ8GEY0R00V
2	SW1, SW2	10mm	Mini slide switch	D0.8mm	Wurth	450301014042
1	Y1	32.768kHZ, 12.5pF	Low-profile crystal	CSMD	Abracon	815-ABS07-32.768KHZT
1	U1	MPQ5850	Smart diode controller	TSOT-238	MPS	MPQ5850GJ-AEC1
2	U2, U3	MPQ4371	Buck converter	QFN-23 (4mmx 5mm)	MPS	MPQ4371GVE-6001-AEC1
1	U4	MPQ5075A	Load switch	QFN-12 (2.5mmx 3mm)	MPS	MPQ5075AGQBE-AEC1
1	U5	MPQ2286	Buck converter	QFN-18 (3mmx 4mm)	MPS	MPQ2286GLE-0011-AEC1
1	U6	MPQ7920	PMIC	QFN-26 (3.5mmx 4.5mm)	MPS	MPQ7920GRM-0073-AEC1

1	U7	MPQ3414B	Boost converter	TSOT23-8	MPS	MPQ3414BGJ-5-AEC1
1	U8	MPQ79500FS	Voltage monitor	QFN-16 (3mmx 3mm)	MPS	MPQ79500FSGQE-0016-AEC1
1	U9	MPQ79500FS	Voltage monitor	QFN-16 (3mmx 3mm)	MPS	MPQ79500FSGQE-0015-AEC1
1	U10	MPQ79700FS	Power sequencer	QFN-24 (4mmx 4mm)	MPS	MPQ79700FSGRE-0013-AEC1

6.3 PCB Layout

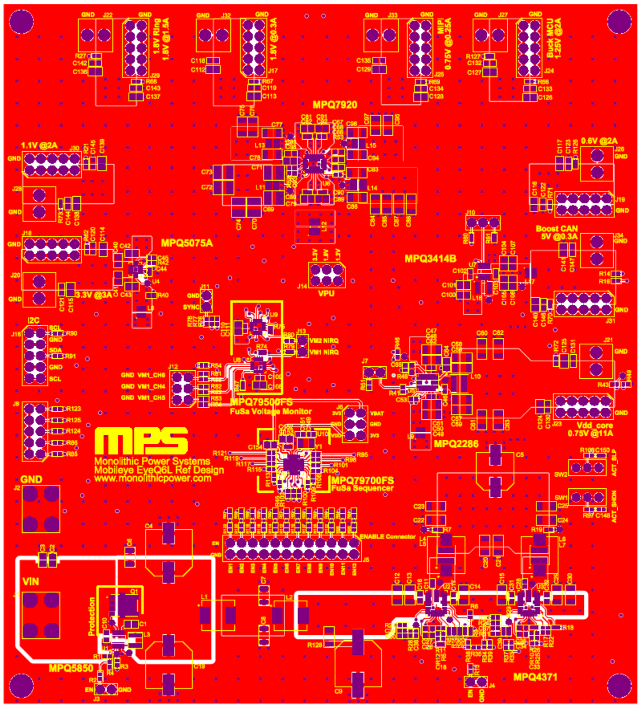


Figure 24: Top Layer

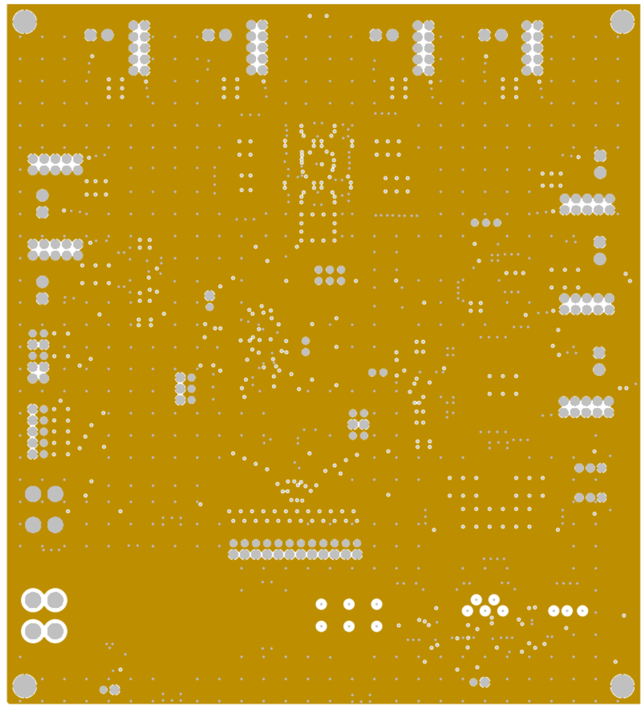


Figure 25: Ground Plane

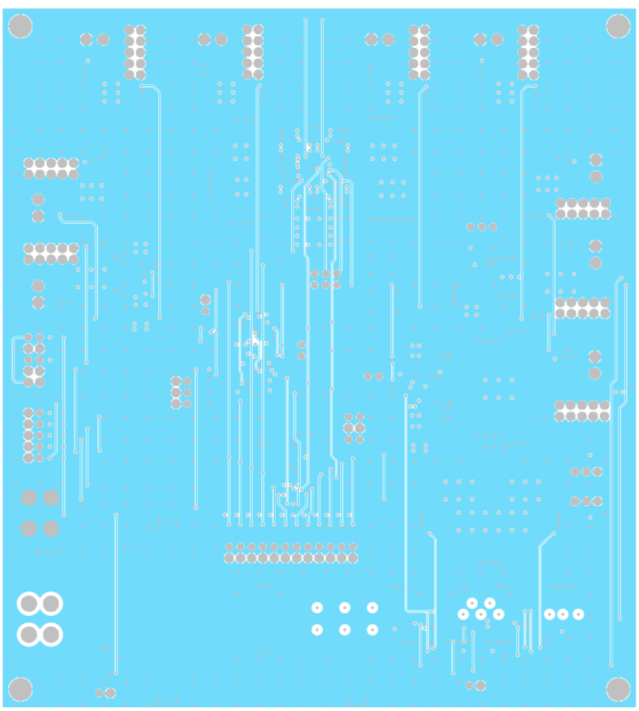


Figure 26: Vertical Routing

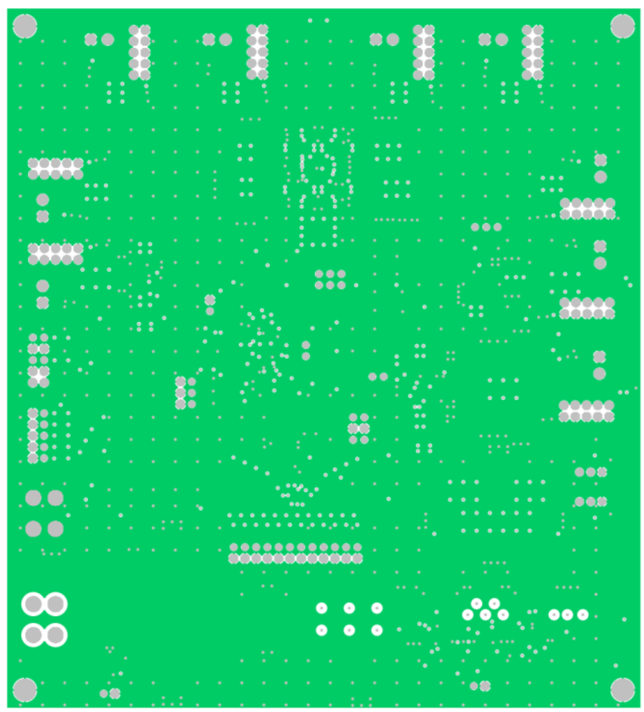


Figure 27: Ground Plane

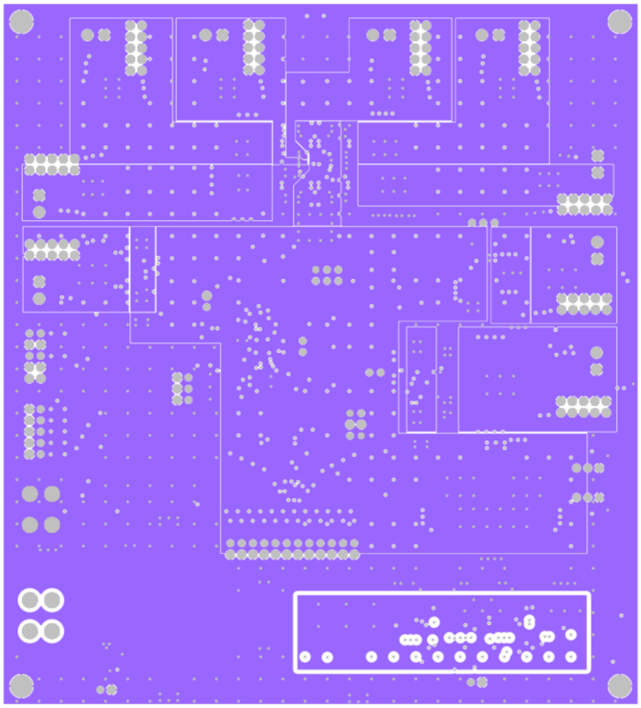


Figure 28: Power Plane

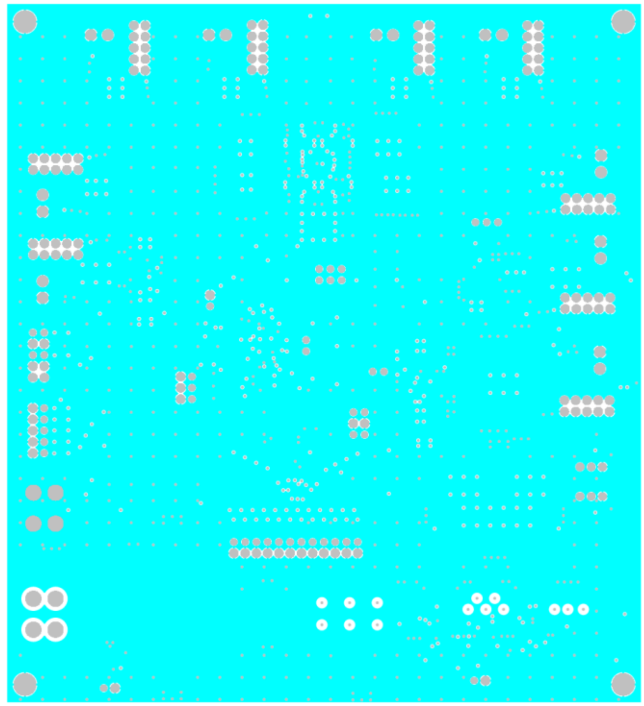


Figure 29: Ground Plane

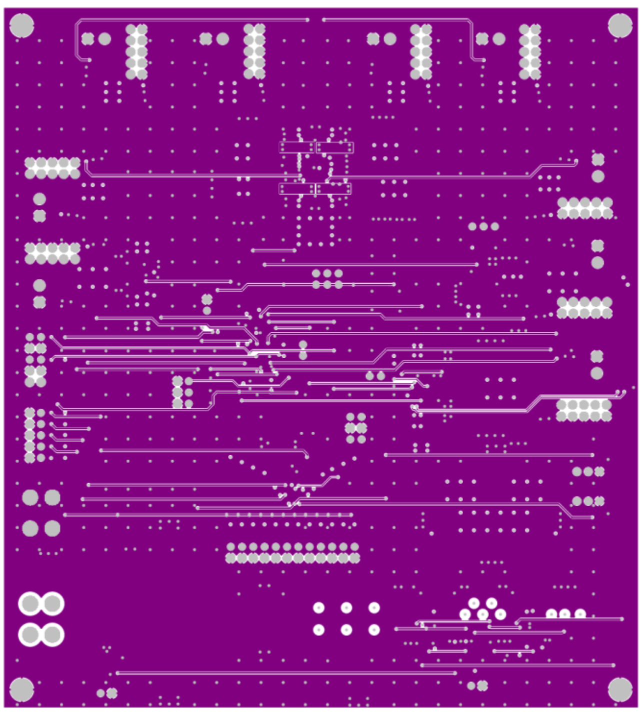


Figure 30: Horizontal Routing

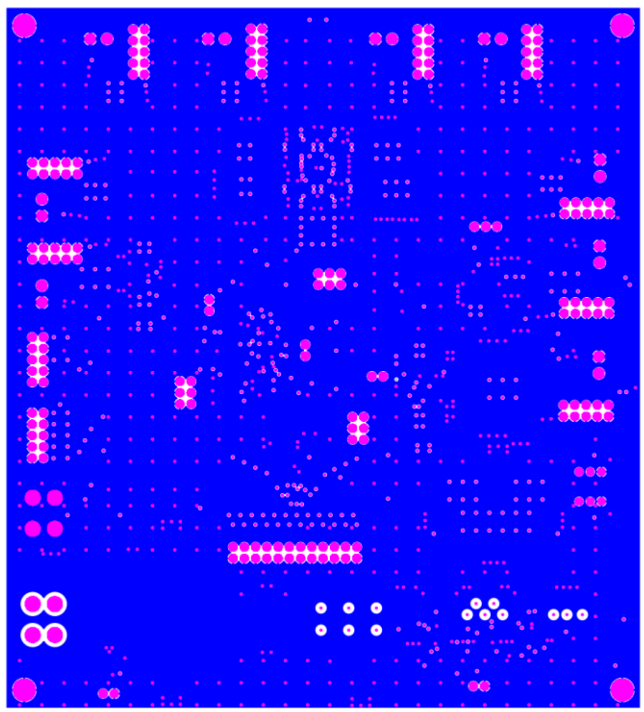


Figure 31: Bottom Layer

7 Test Results

7.1 Output Ripple and Regulation

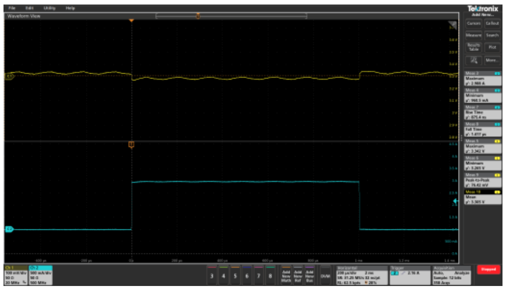
VIN_3V3_4371 = 3.3V, $T_{AMBIENT}$ = 25°C, unless otherwise noted.

LSW1: GPIO_3V3_3A

Load transient = 1A to 3A

C1: V_{OUT} 100mV/div.

C2: I_{OUT} 500mA/div.

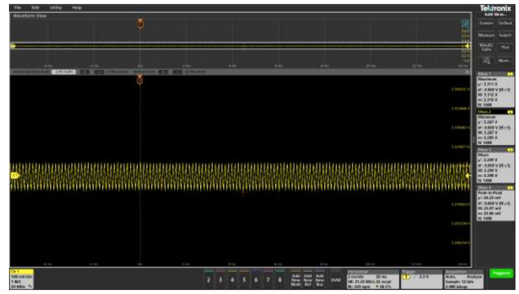


200µs/div.

LSW1: GPIO_3V3_3A

Output ripple = 3A

C1: V_{OUT} 100mV/div.



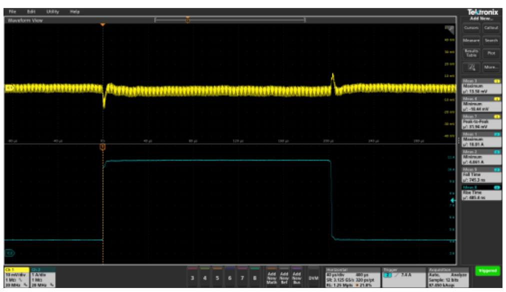
2ms/div.

SW1: VDD_CORE_0V75_11A

Load transient = 3.8A to 11.3A

C1: V_{OUT} 10mV/div.

C2: I_{OUT} 1.2A/div.

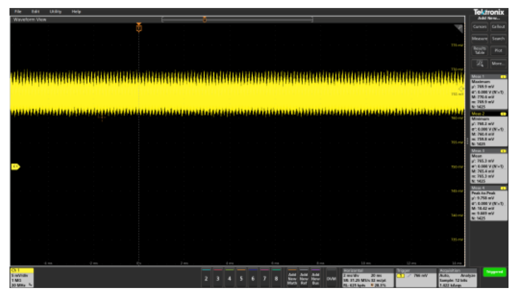


200µs/div.

SW1: VDD_CORE_0V75_11A

Output ripple = 11.3A

C1: V_{OUT} 5mV/div.



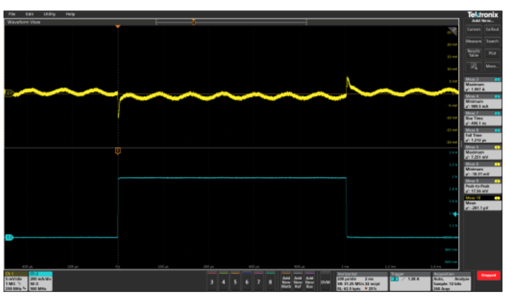
2ms/div.

SW2_1: LPDDR4_1V1_2A

Load transient = 1A to 2A

C1: V_{OUT} AC 5mV/div.

C2: I_{OUT} 200mA/div.

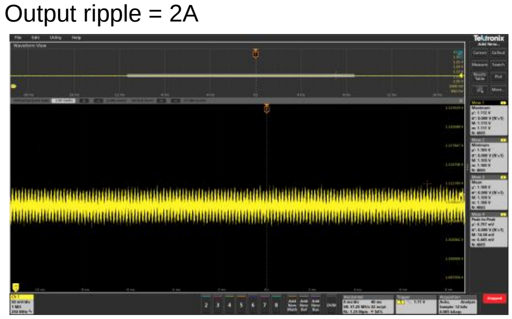


200µs/div.

SW2_1: LPDDR4_1V1_2A

Output ripple = 2A

C1: V_{OUT} 50mV/div.

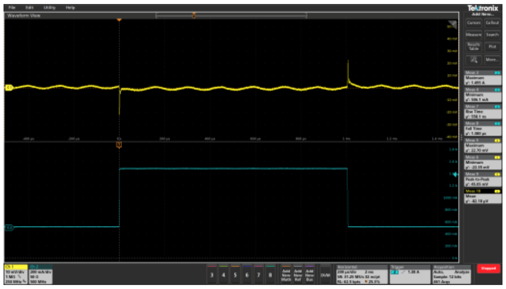


4ms/div.

SW2_2: 1V8_RING_1V8_1A5
Load transient = 0.5A to 1.5A

C1: V_{OUT} AC 10mV/div.

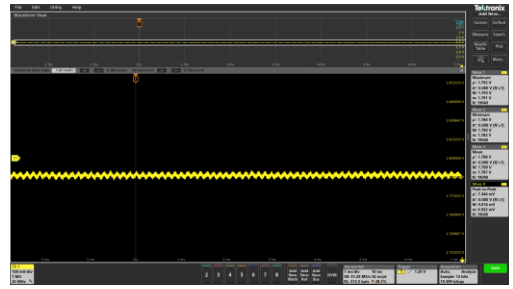
C2: I_{OUT} 200mA/div.



200µs/div.

SW2_2: 1V8_RING_1V8_1A5
Output ripple = 1.5A

C1: V_{OUT} 100mV/div.

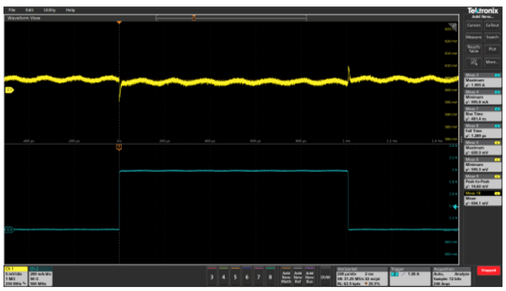


1ms/div.

SW2_3: LPDRRX_0V6_2A
Load transient = 1A to 2A

C2: I_{OUT} 200mA/div.

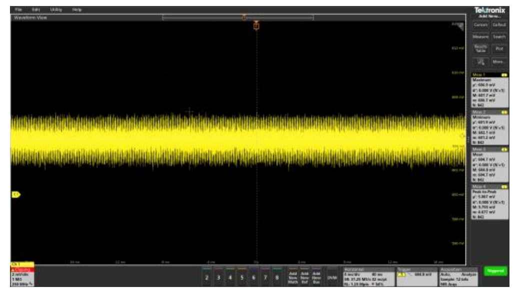
C1: V_{OUT} 5mV/div.



200µs/div.

SW2_3: LPDRRX_0V6_2A
Output ripple = 2A

C1: V_{OUT} 2mV/div.

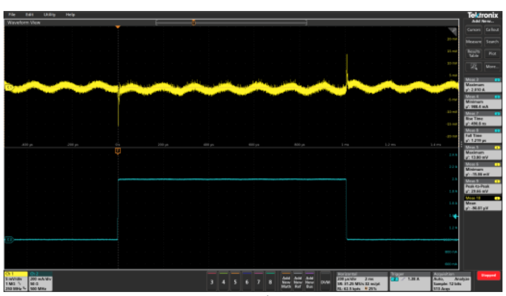


4ms/div.

SW2_4: MCU_1V25_2A
Load transient = 1A to 2A

C1: V_{OUT} AC 5mV/div.

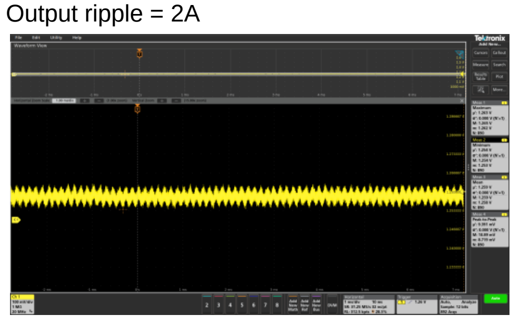
C2: I_{OUT} 200mA/div.



200µs/div.

SW2_4: MCU_1V25_2A
Output ripple = 2A

C1: V_{OUT} 100mV/div.

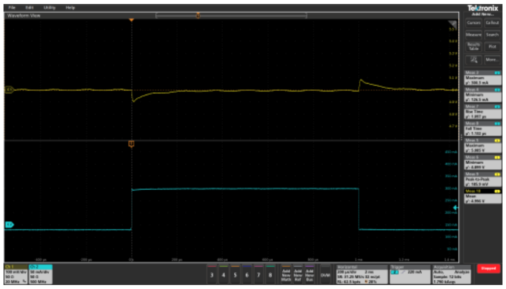


1ms/div.

SW3: CAN_5V_0A3
Load transient = 0.15A to 0.3A

C1: V_{OUT} 100mV/div.

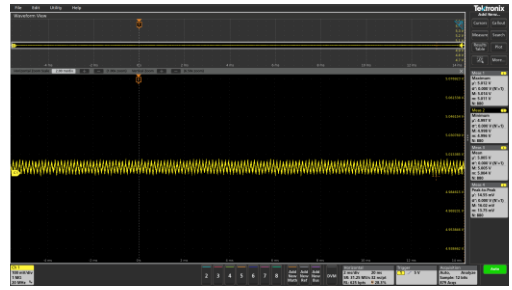
C2: I_{OUT} 50mA/div.



200µs/div.

SW3: CAN_5V_0A3
Output ripple = 0.3A

C1: V_{OUT} 100mV/div.

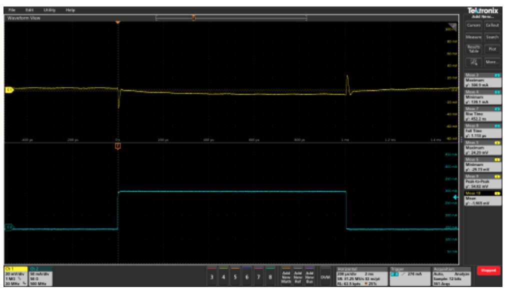


2ms/div.

LDO1: MIPI_PLL_1V8_0A3
Load transient = 0.15A to 0.3A

C1: V_{OUT} AC 20mV/div.

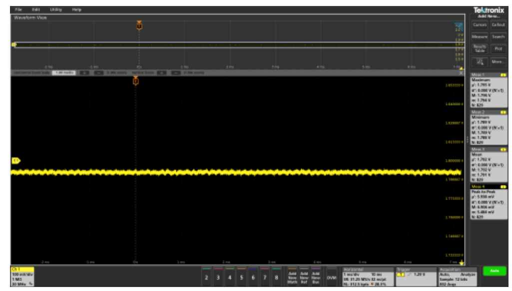
C2: I_{OUT} 50mA/div.



200µs/div.

LDO1: MIPI_PLL_1V8_0A3
Output ripple = 0.3A

C1: V_{OUT} 100mV/div.

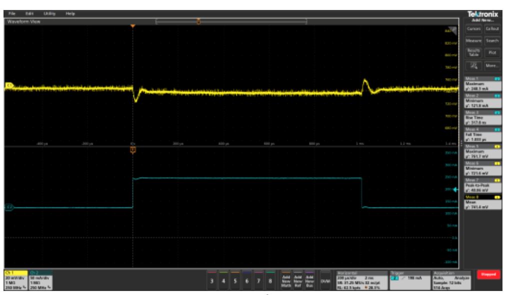


1ms/div.

LDO2: MIPI_0V75_0A25
Load transient = 0.125A to 0.25A

C1: V_{OUT} 20mV/div.

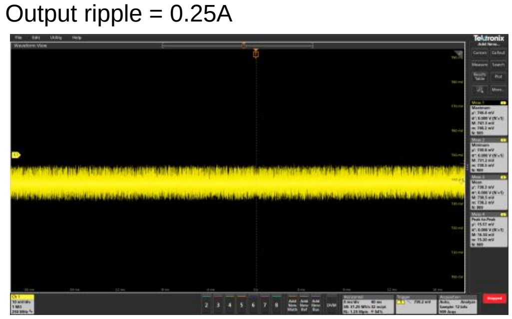
C2: I_{OUT} 50mA/div.



200µs/div.

LDO2: MIPI_0V75_0A25
Output ripple = 0.25A

C1: V_{OUT} 10mV/div.

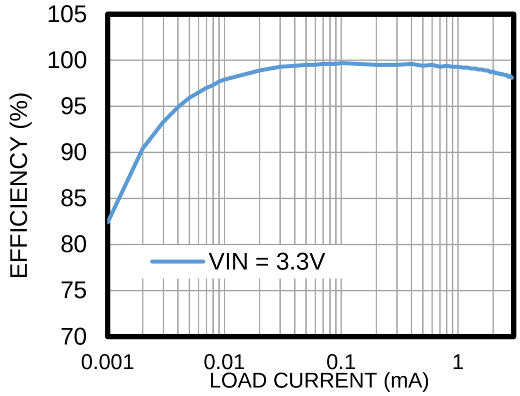


4ms/div.

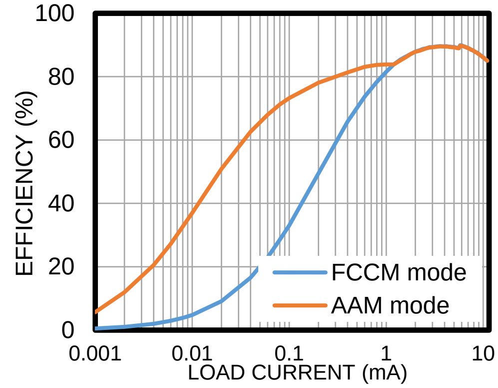
7.2 Efficiency vs. Load Current

VIN_3V3_4371 = 3.3V, $T_{AMBIENT}$ = 25°C, unless otherwise noted

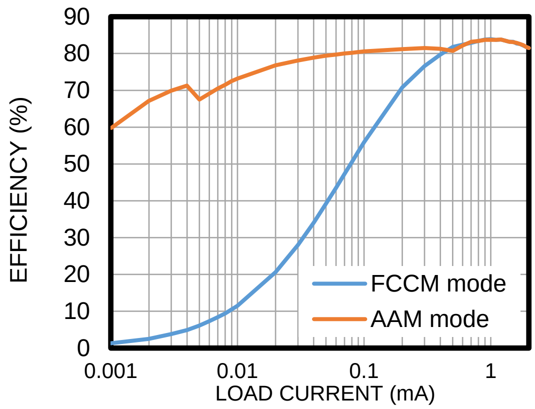
LSW1: GPIO_3V3_3A
MPQ5075A, V_{OUT} = 3.3V



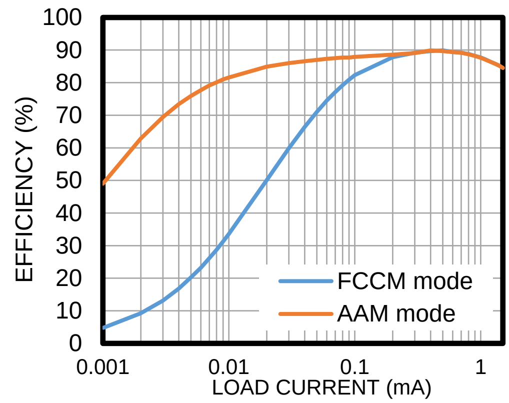
SW1: VDD_CORE_0V75_11A
MPQ2286, V_{OUT} = 0.75V, f_{SW} = 2200kHz,
L = 100nH



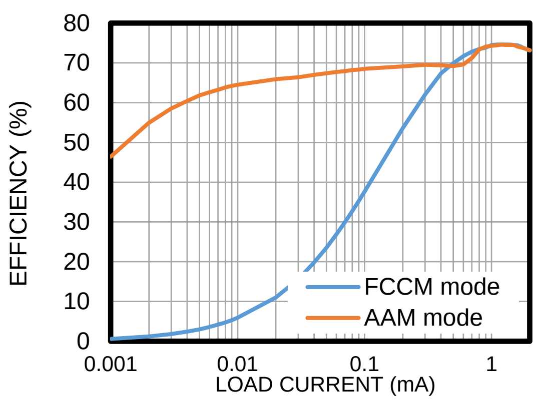
SW2_1: LPDDR4_1V1_2A
MPQ7920, V_{OUT} = 1.1V, f_{SW} = 2200kHz,
L = 330nH



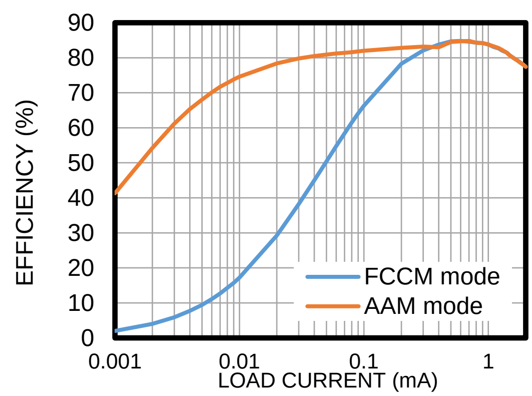
SW2_2: 1V8_RING_1V8_1A5
MPQ7920, V_{OUT} = 1.8V, f_{SW} = 2200kHz,
L = 1000nH



SW2_3: LPDRRX_0V6_2A
MPQ7920, V_{OUT} = 0.6V, f_{SW} = 2200kHz,
L = 150nH



SW2_4: MCU_1V25_2A
MPQ7920, V_{OUT} = 1.25V, f_{SW} = 2200kHz,
L = 470nH



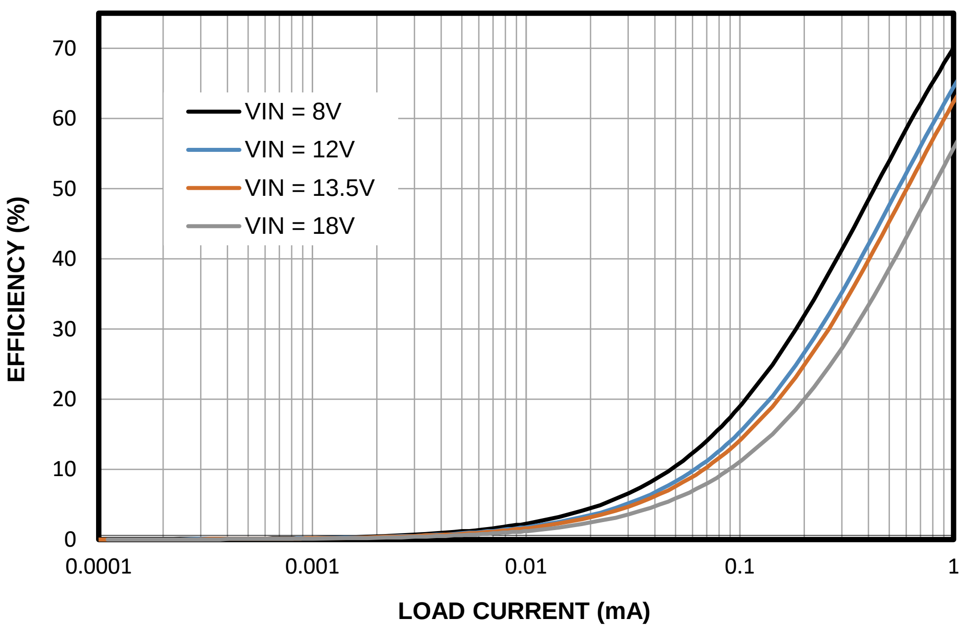
8 System Level Measurements

8.1 Pre-Regulator Efficieny vs. Load Current

V_{OUT} = 3.3V, L = 0.47µH, f_{SW} = 2200kHz, $T_{AMBIENT}$ = 25°C, unless otherwise noted.

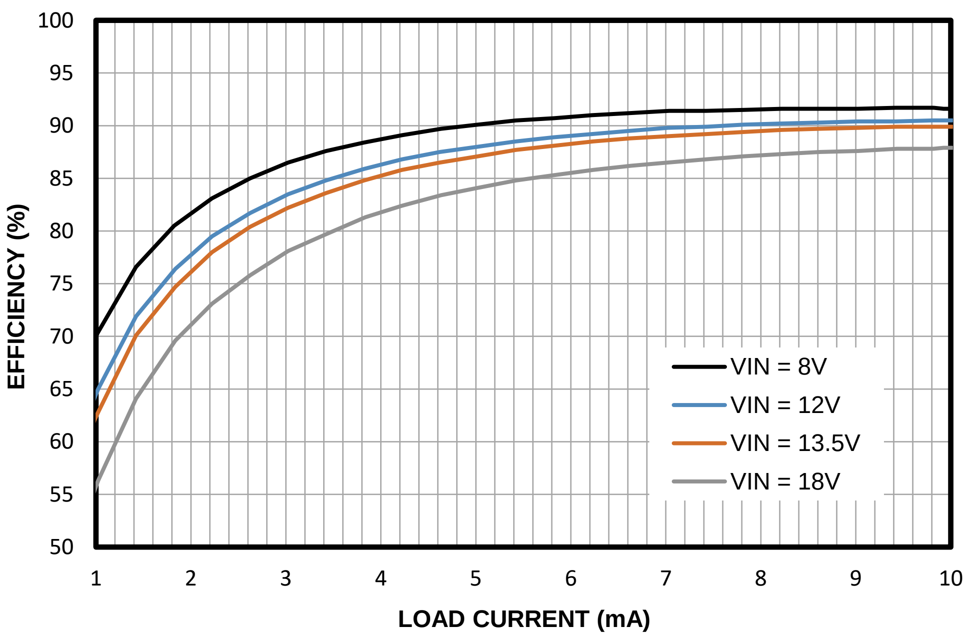
VIN_3V3_4371 Efficiency

FCCM, V_{BIAS} = 5V, MPQ3414B connected to the regulator

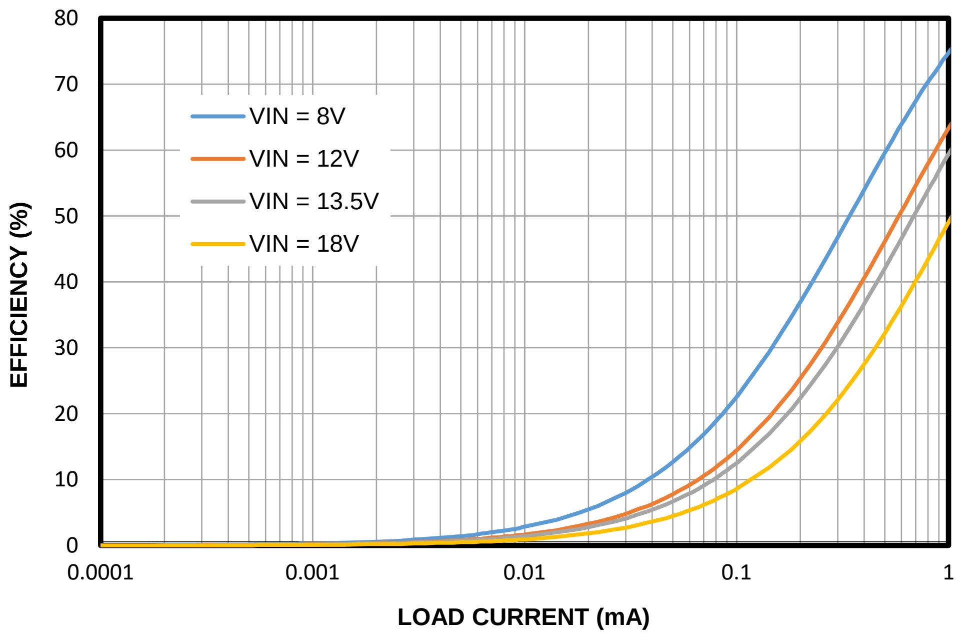


VIN_3V3_4371 Efficiency

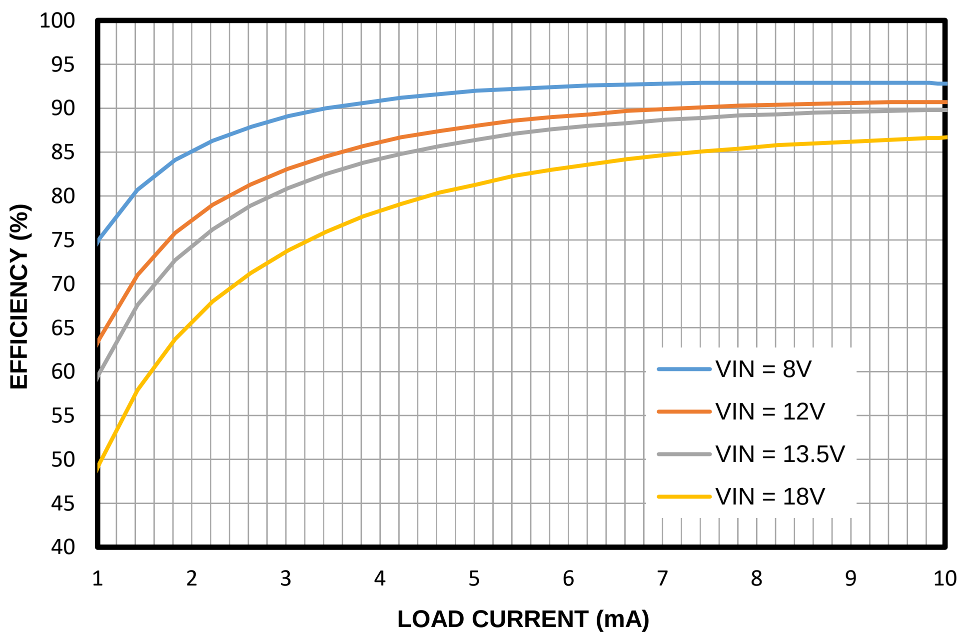
FCCM, V_{BIAS} = 5V, MPQ3414B connected to the regulator



VIN_3V3_4371 Efficiency
FCCM, V_{BIAS} = GND

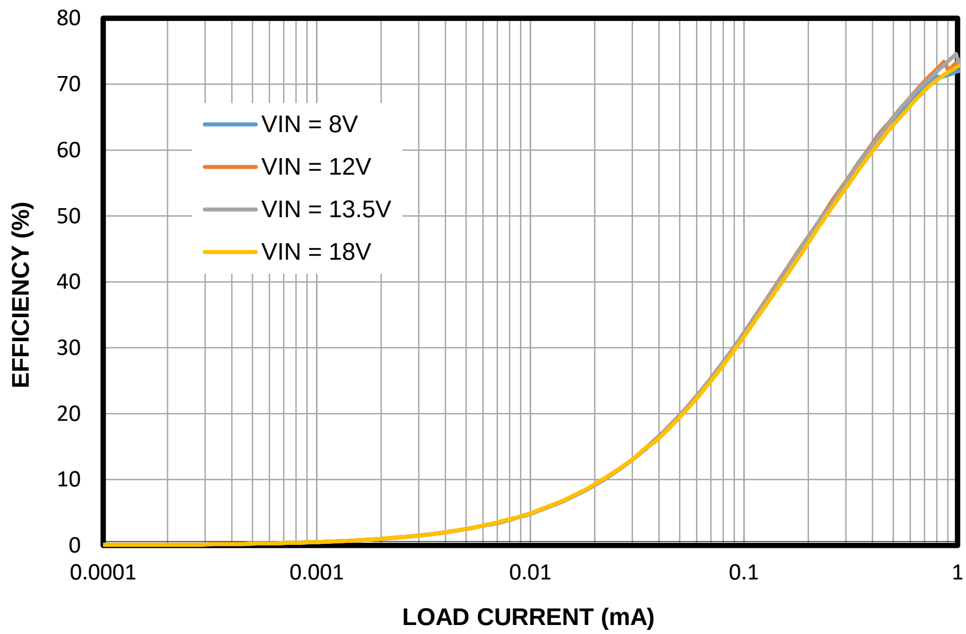


VIN_3V3_4371 Efficiency
FCCM, V_{BIAS} = GND



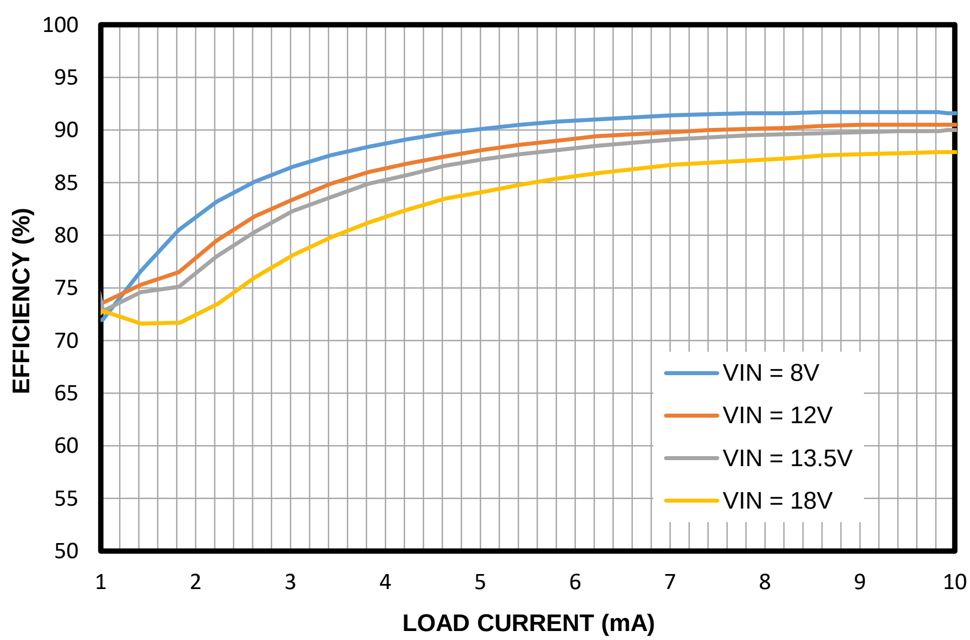
VIN_3V3_4371 Efficiency

AAM mode, V_{BIAS} = 5V, MPQ3414B connected to the regulator

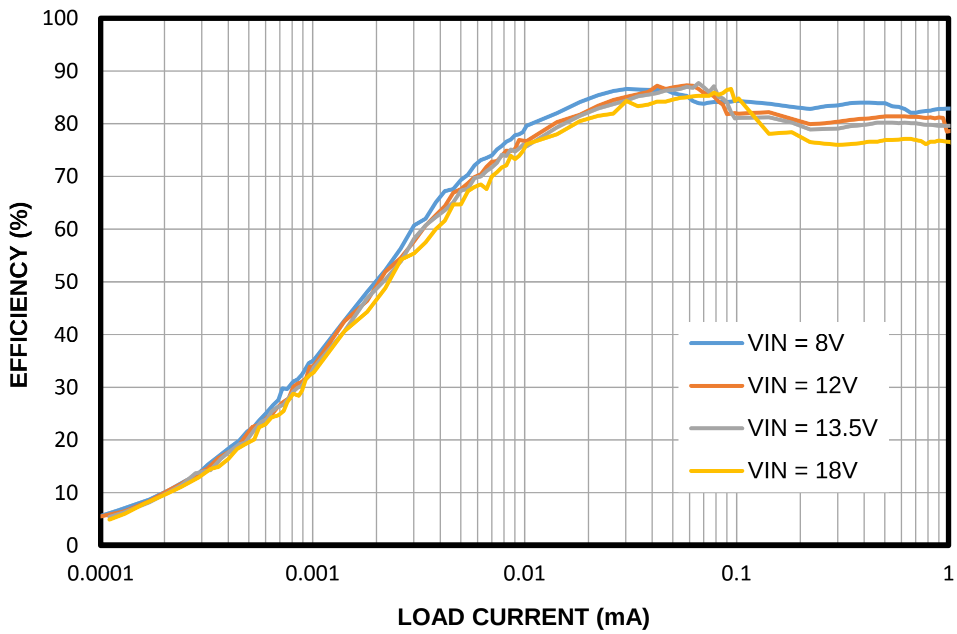


VIN_3V3_4371 Efficiency

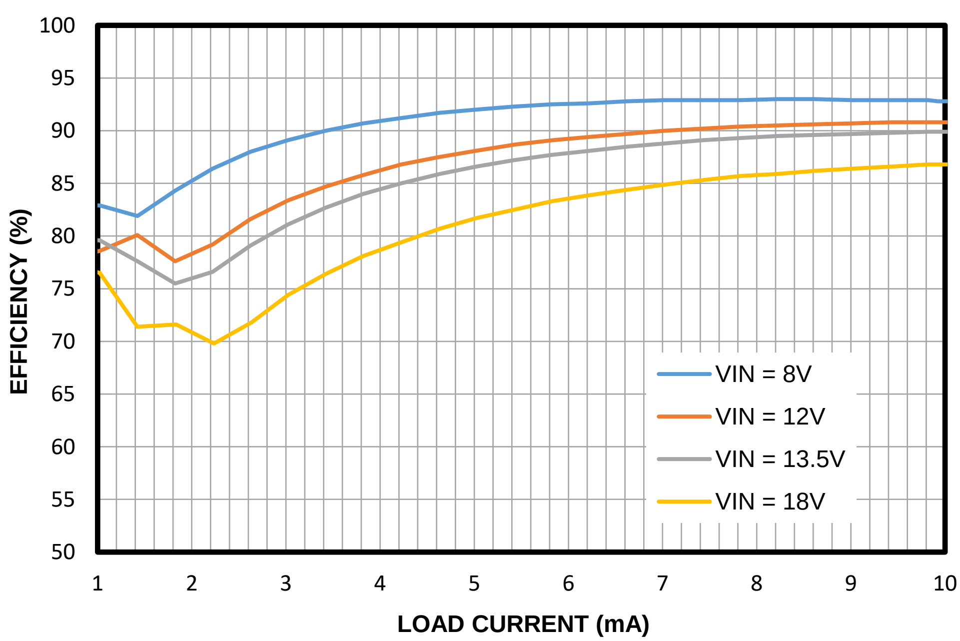
AAM mode, V_{BIAS} = 5V, MPQ3414B connected to the regulator



VIN_3V3_4371 Efficiency
AAM mode, V_{BIAS} = GND



VIN_3V3_4371 Efficiency
AAM mode, V_{BIAS} = GND



8.2 Power-On and Power-Off Sequence

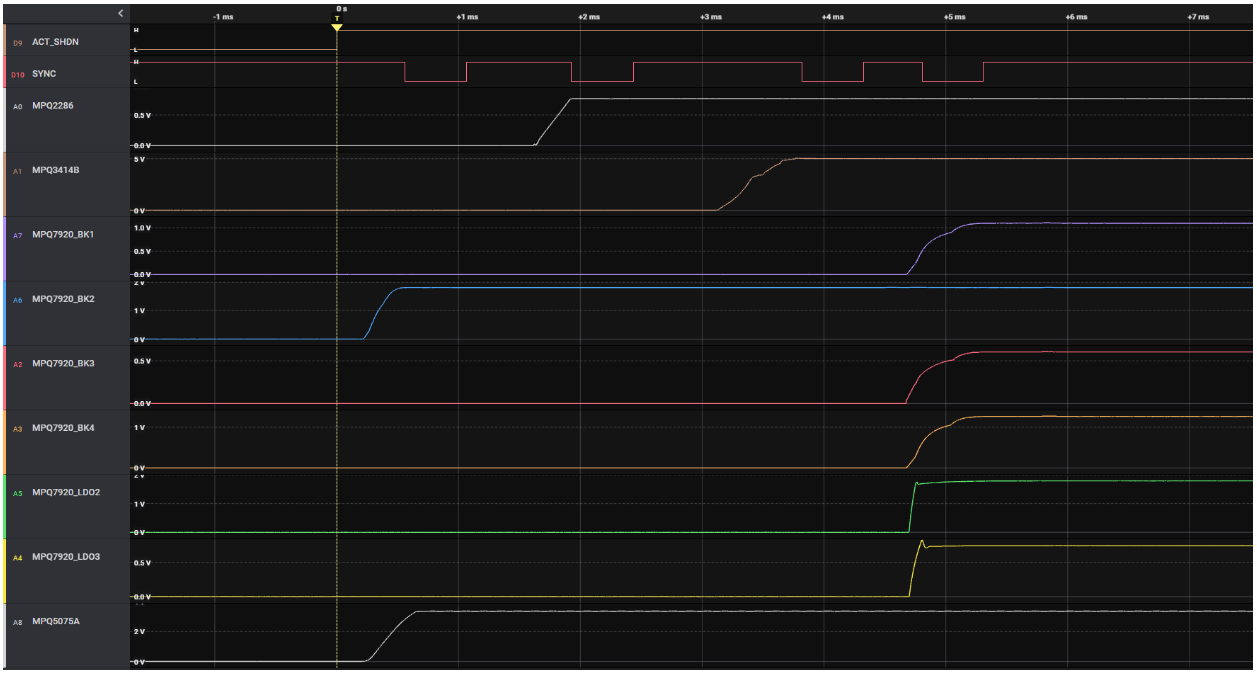


Figure 32: Power-On Sequence

Figure 33: MPQ79700FS Enable during Power-On Sequence

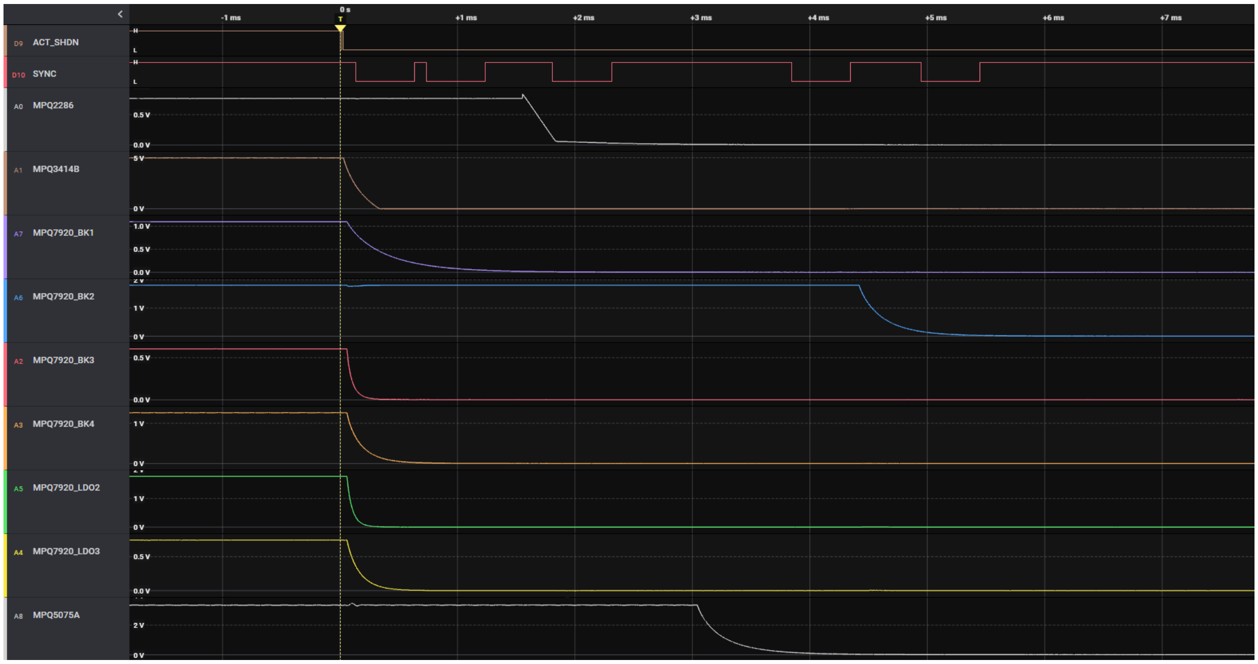


Figure 34: Power-Off Sequence

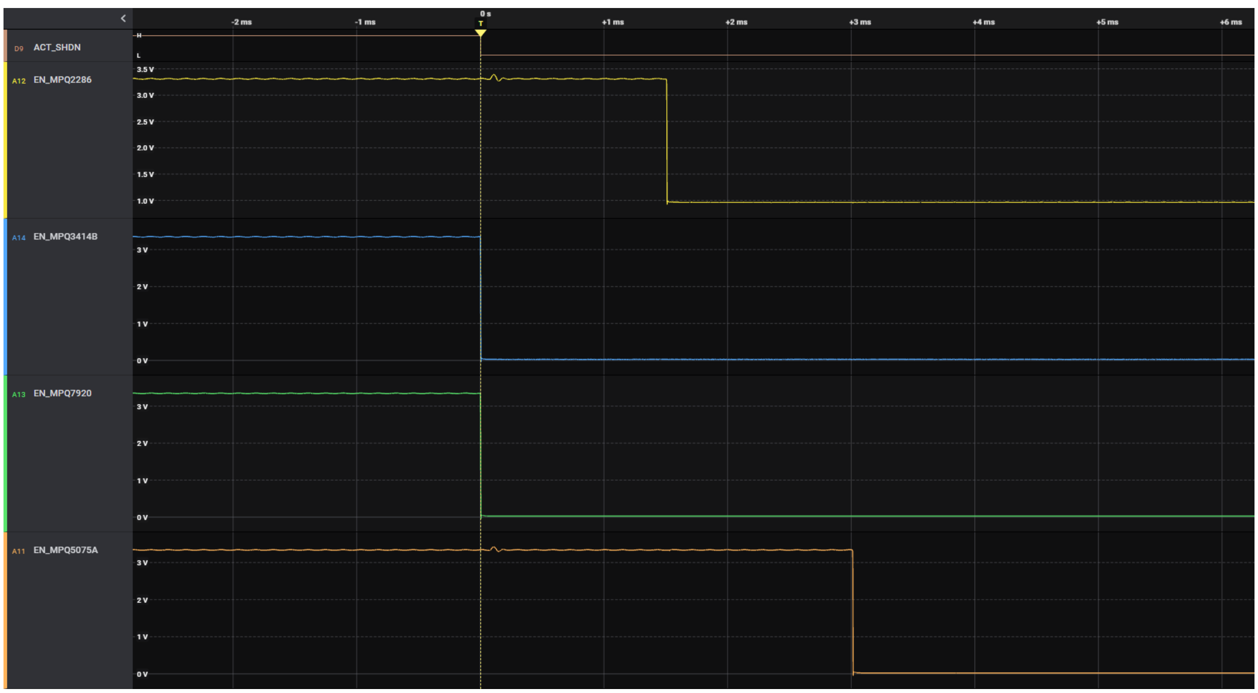


Figure 35: MPQ79700FS Enable during Power-Off Sequence

MPQ79500FS (0x30)

VINLVL		ONLOG		OFFLOG		EXSLOG		ENSLOG		TIME	
Vin1	4.98 V	ONLOG1	3	OFFLOG1	1	EXSLOG1	0	ENSLOG1	0	TimeStamp1	0 ms
Vin2	0.765 V	ONLOG2	2	OFFLOG2	3	EXSLOG2	0	ENSLOG2	0	TimeStamp2	0 ms
Vin3	3.34 V	ONLOG3	1	OFFLOG3	4	EXSLOG3	0	ENSLOG3	0	TimeStamp3	0 ms
Vin4	0.205 V	ONLOG4	0	OFFLOG4	0	EXSLOG4	0	ENSLOG4	0	TimeStamp4	0 ms
Vin5	0.205 V	ONLOG5	0	OFFLOG5	0	EXSLOG5	0	ENSLOG5	0	TimeStamp5	0 ms
Vin6	0.205 V	ONLOG6	0	OFFLOG6	0	EXSLOG6	0	ENSLOG6	0	TimeStamp6	0 ms

MPQ79500FS (0x33)

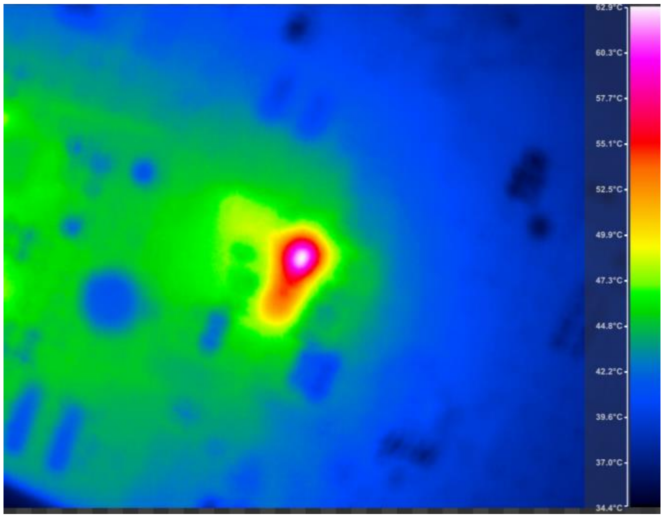
VINLVL		ONLOG		OFFLOG		EXSLOG		ENSLOG		TIME	
Vin1	0.605 V	ONLOG1	4	OFFLOG1	1	EXSLOG1	0	ENSLOG1	0	TimeStamp1	0 ms
Vin2	1.095 V	ONLOG2	4	OFFLOG2	2	EXSLOG2	0	ENSLOG2	0	TimeStamp2	0 ms
Vin3	1.26 V	ONLOG3	4	OFFLOG3	1	EXSLOG3	0	ENSLOG3	0	TimeStamp3	0 ms
Vin4	1.78 V	ONLOG4	4	OFFLOG4	1	EXSLOG4	0	ENSLOG4	0	TimeStamp4	0 ms
Vin5	1.82 V	ONLOG5	1	OFFLOG5	5	EXSLOG5	0	ENSLOG5	0	TimeStamp5	0 ms
Vin6	0.745 V	ONLOG6	4	OFFLOG6	1	EXSLOG6	0	ENSLOG6	0	TimeStamp6	0 ms

Figure 36: MPQ79500FS Power-On and Power-Off Sequence Monitoring

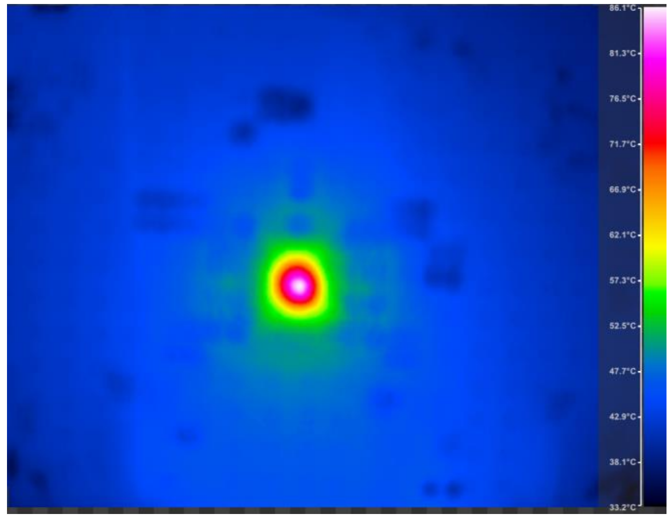
8.3 Thermal Measurements

V_{IN} = 3.3V, all rails at 100% load; $T_{AMBIENT}$ = 25°C, unless otherwise noted.

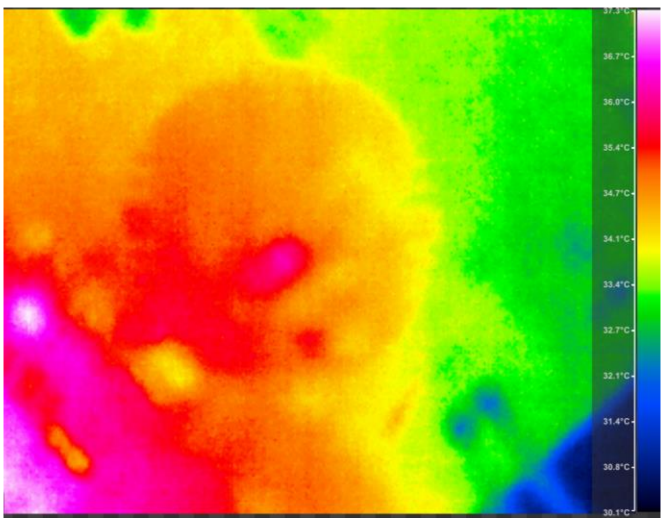
Thermal Image
MPQ2286, T_{IC} = 62.5°C



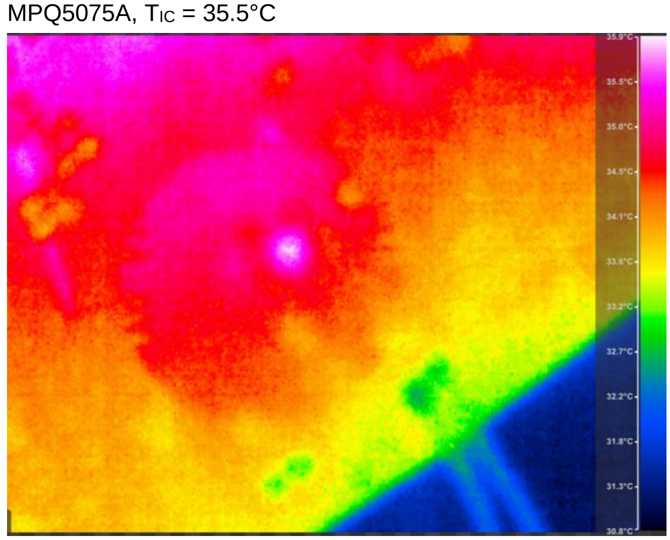
Thermal Image
MPQ7920, T_{IC} = 85.8°C



Thermal Image
MPQ3414B, T_{IC} = 36.2°C

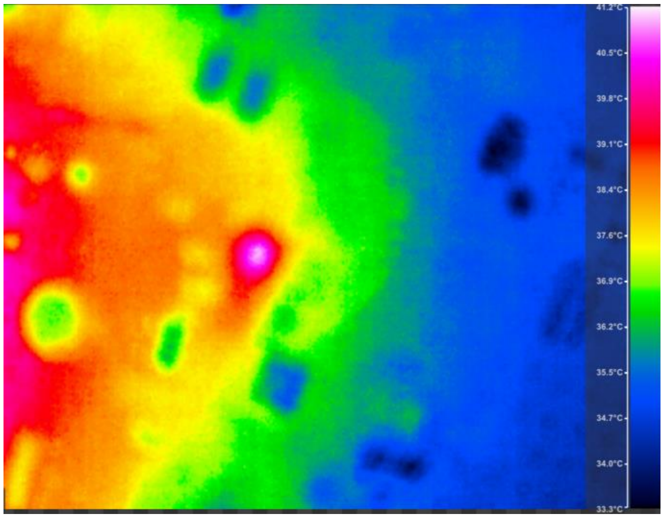


Thermal Image
MPQ5075A, T_{IC} = 35.5°C

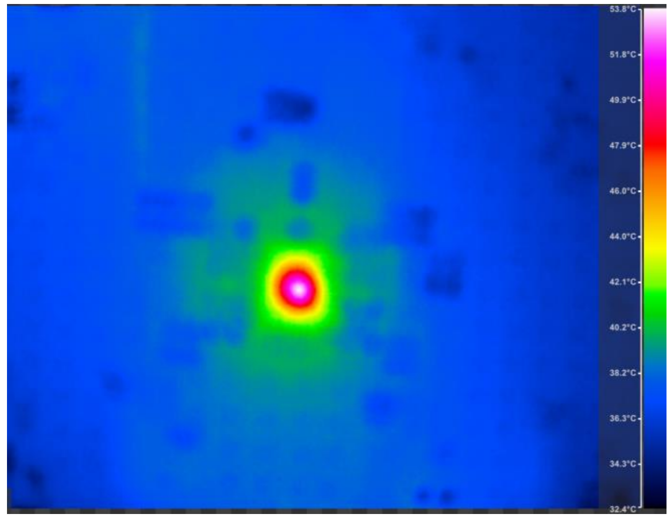


V_{IN} = 3.3V, all rails at 50% load, $T_{AMBIENT}$ = 25°C, unless otherwise noted.

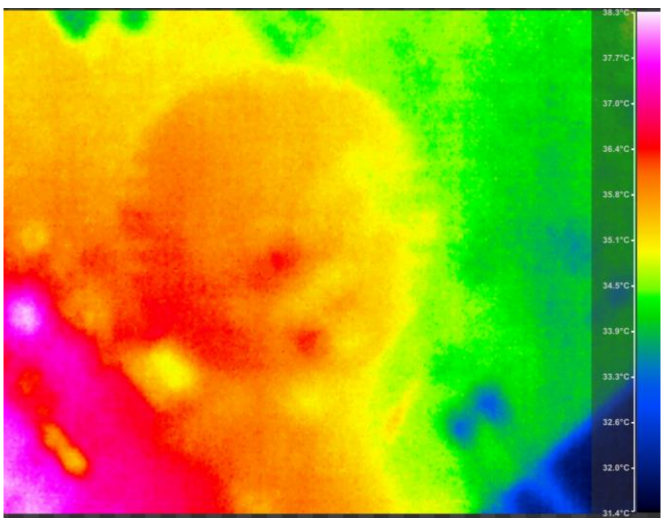
Thermal Image
MPQ2286, T_{IC} = 40.6°C



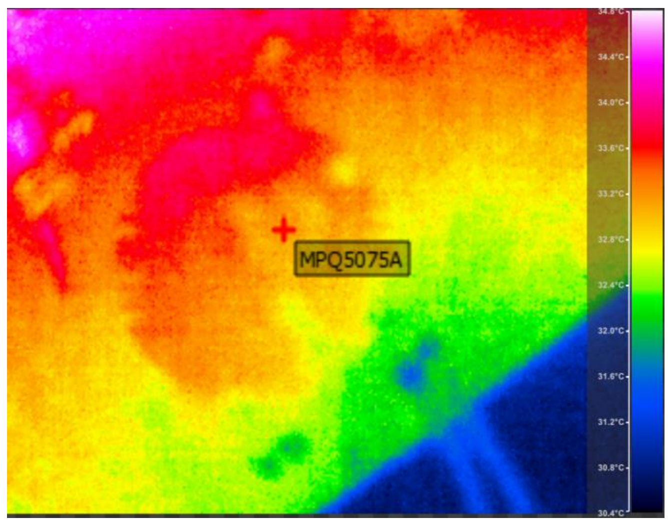
Thermal Image
MPQ7920, T_{IC} = 53.9°C



Thermal Image
MPQ3414B, T_{IC} = 35.4°C

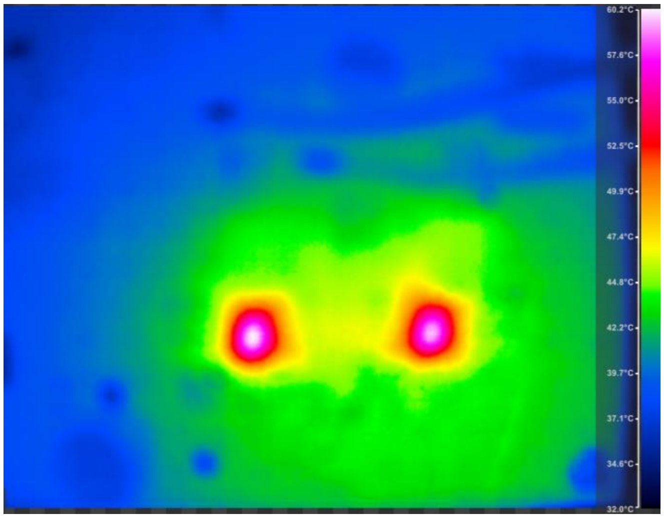


Thermal Image
MPQ5075A, T_{IC} = 33.4°C

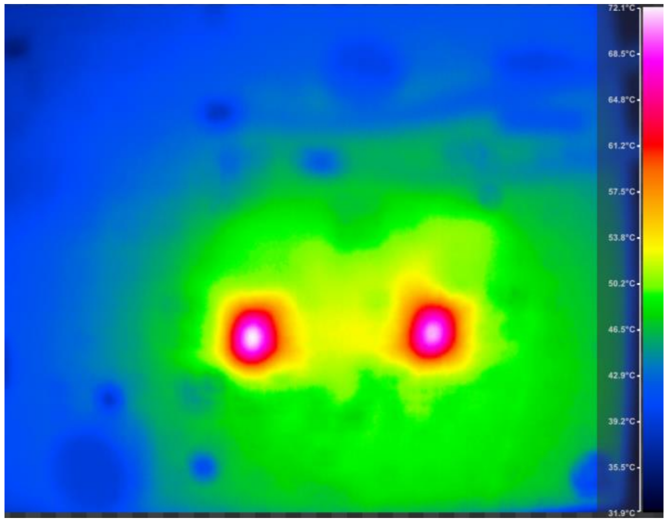


V_{IN} = 13.5V, dual-phase MPQ4371, $T_{AMBIENT}$ = 25°C, unless otherwise noted.

Thermal Image
I_{LOAD} = 5A, T_{MASTER} = 60°C, T_{SLAVE} = 59.6°C



Thermal Image
I_{LOAD} = 10A, T_{MASTER} = 72.2°C, T_{SLAVE} = 71°C



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REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	3/3/2023	Initial Release	-