EVM User's Guide: CSD967201-Q1EVM

CSD967201-Q1 Synchronous Buck Power Stage Evaluation Module

Description

The CSD967201-Q1EVM is designed to demonstrate the operation of the CSD967201-Q1 device in a single phase, low-output voltage application while providing a number of test points to evaluate the performance of the device. The CSD967201-Q1 is a power stage designed for use in automotive-qualified, high-density, synchronous buck application.

Get Started

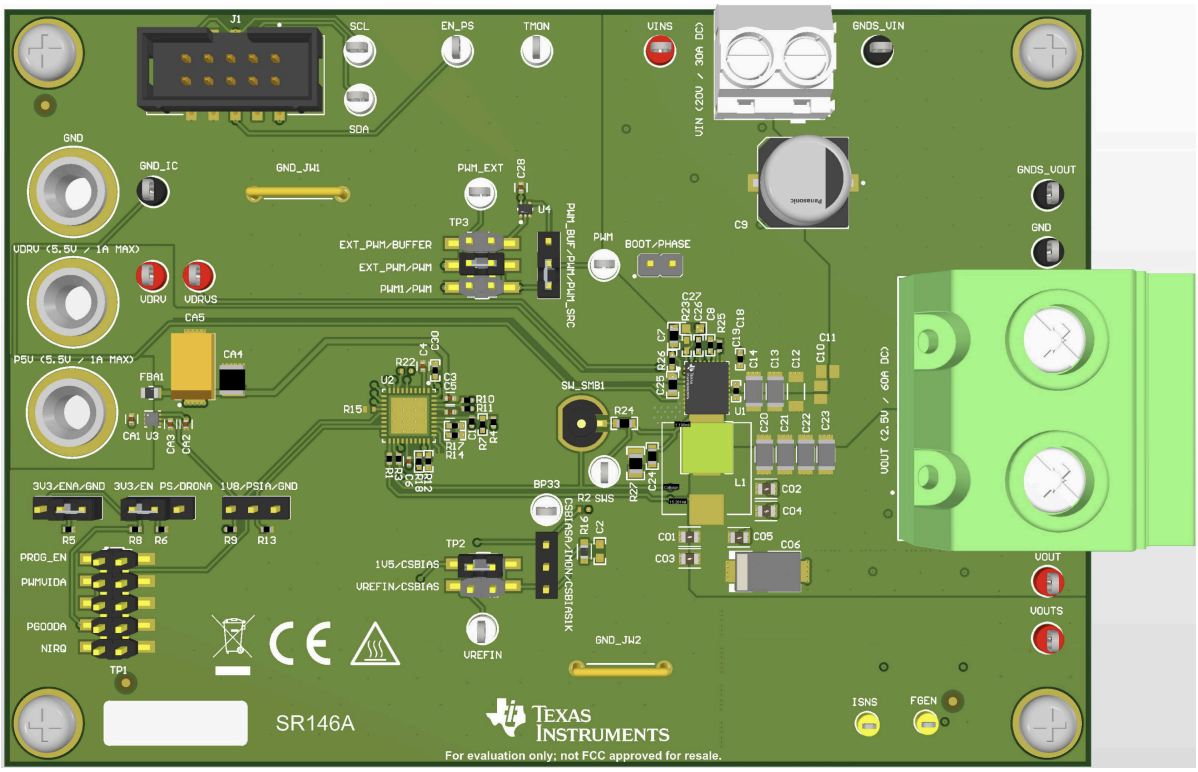
1. Order the CSD967201-Q1EVM on ti.com
2. Download the CSD967201-Q1 datasheet
3. See the latest information on ti.com
4. Go to E2E™ technical support forum

Features

- High-efficiency one phase power stage
- Configured for open loop or closed loop with controller
- Separate input supply terminal for power stage measurement
- Onboard load transient tester
- Common footprint compatible board

Applications

- Automotive ADAS
- Automotive infotainment and cluster
- Software-defined vehicle: High-performance compute



CSD967201-Q1EVM Hardware Board

1 Evaluation Module Overview

1.1 Introduction

The SR146A evaluation board enables evaluation of the CSD967201-Q1 power stage device with a controller or in open loop. This manual describes the setup and configuration of the board.

1.2 Kit Contents

The kit includes the CSD967201-Q1EVM.

1.3 Specification

Section 2.1 lists the electrical performance specifications at room temperature (25°C). Characteristics are for an input voltage of VIN = 12V, unless otherwise specified.

1.4 Device Information

The CSD967201-Q1 power stage is a highly optimized design for use in an automotive-qualified, high-power, high-density synchronous buck application. This product integrates the driver IC and power MOSFETs into one Pb-free monolithic design to complete the power stage switching function. This combination produces a high-current, high-efficiency, and high-speed switching capability in a small industry standard footprint.

The CSD967201-Q1EVM evaluation module integrates accurate current sensing and temperature sensing functionality to simplify the design of the system and improve accuracy. Protections include: cycle-by-cycle overcurrent and negative overcurrent limiting, overtemperature shutdown, HS FET short, and UVLO on VCC, VIN, and BOOT.

The CSD967201-Q1EVM evaluation module is compatible with the TPS64300Q VRS-11 controller, as well as other standard VRS-11 controllers.

2 Hardware

2.1 Power Requirements

Table 2-1. CSD967201-Q1EVM Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS					
Voltage range	VIN voltage	3	12	20	V
	VDRV voltage	4.5	5	5.5	V
	P5V voltage	4.5	5	5.5	V
Input Current	VIN = 12V, IOUT = 0A, EN > 2.5V		35		mA
	VIN = 12V, IOUT = 60A, EN > 2.5V		5.5		A
	VDRV = 5V, Fsw = 650kHz, IOUT = 60A, EN > 2.5V		40		mA
	P5V = 5V, Fsw = 650kHz, IOUT = 60A, EN > 2.5V		24		mA
OUTPUT CHARACTERISTICS					
Output voltage, VOUT	VIN = 12V, IOUT = 60A		0.8		V
Output load current, IOUT	DC Load Current		30	60	A
SYSTEMS CHARACTERISTICS					
Switching frequency	VIN = 12V, VOUT = 0.8V, IOUT = 60A		650		kHz
Peak efficiency	VIN = 12V, VOUT = 0.8V		88.6		%
Full load efficiency	VIN = 12V, VOUT = 0.8V, IOUT = 60A		81.5		
Operating temperature			25		°C

2.2 Header Information

Table 2-2. Header and Jumper Information

Test Point	Type	Name	Description
3V3/ENA/GND	100mil, 3x1, TH	3V3/ENA/GND	Controller enable selection. **PWM configuration**: Place jumper from ENA to GND to disable the controller. This is the default configuration. **Controller configuration**: Place jumper from 3V3 to ENA to enable the controller.
3V3/EN_PS/DRONA	100mil, 3x1, TH	3V3/EN_PS/DRONA	Power stage enable selection. **PWM configuration**: Place jumper from 3V3 to EN_PS to enable the power stage. This is the default configuration. **Controller configuration**: Place jumper from EN_PS to DRONA to allow the controller to enable the power stage.
J1	Connector Header Surface Mount 10 position	J1	Use socket to socket jumper wire to connect serial interface adapter.
TP1	2.54mm, 5x2, SMT	TP1	Test points for controller PIN 29, PIN 15, PIN 11, PIN 12 and the 3.3V and 1.8V supplies. Do not short.
TP2	Header, 2.54mm, 3x2, SMT	TP2	Reference voltage selection for IMON measurement. **PWM configurations using the on-board 1k resistor.** Measure IMON across IMON and CSBIAS1K with a differential probe: 1. Place jumper from 1V5 to CSBIAS to provide a 1.5V reference voltage on the CSBIAS1K pin. This is the default configuration. 2. Place jumper from VREFIN to CSBIAS to supply the voltage on the testpoint VREFIN to the CSBIAS1K pin. **Controller configuration**: Remove all jumpers from TP2 and measure IMON across CSBIASA and IMON with a differential probe.

Table 2-2. Header and Jumper Information (continued)

Test Point	Type	Name	Description
CSBIASA/IMON/ CSBIAS1K	Header, 100mil, 3x1, Gold, TH	CSBIASA/IMON/CSBIAS1K	Current monitor output. **PWM configuration**: Use TP2 to select the CSBIAS1K input and measure IMON across IMON and CSBIAS1K with a differential probe. **Controller configuration**: Remove all jumpers from TP2 and measure IMON across IMON and CSBIASA with a differential probe.
TP3	Header, 2.54mm, 3x2, SMT	TP3	PWM source selection. **PWM configuration**: 1. Place jumper from EXT_PWM to BUFFER to route the signal applied to the PWM_EXT test point through a buffer to the PWM_BUF pin. 2. Place jumper from EXT_PWM to PWM to route the signal applied to the PWM_EXT test point to the PWM_SRC pin. This is the default configuration.
PWM_BUF/PWM/ PWM_SRC	Header, 100mil, 3x1, Gold, TH	PWM_BUF/PWM/ PWM_SRC	Routes PWM input and output. **Non-buffered PWM for controller or PWM configuration**: Place jumper from PWM to PWM_SRC. This is the default configuration. **Buffered PWM for controller or PWM configuration**: Place jumper from PWM_BUF to PWM. **Note** For controller configuration only, this header and jumper can be bypassed by populating R22, which connects the PWM1 output from the controller directly to the PWM input of the power stage. Only do this if there is excessive noise using the jumpers to configure the PWM input to the power stage.
1V8/PSIA/GND	100mil, 3x1, TH	1V8/PSIA/GND	Controller-only rail default is open.
BOOT/PHASE	Header, 100mil, 2x1, Gold, TH	BOOT/PHASE	Boot measurement default is open. Do not short.

2.3 Interfaces

Table 2-3. Interface Information

Test Point	Type	Name	Description
J1	Connector header surface mount 10 position	J1	Use socket to socket jumper wire to connect serial interface adapter. SCL: Pin 5, Pin 9 SDA: Pin 3, Pin 7 GND: Pin 8, Pin 10
J2	Terminal block, 6.35mm, 2x1, TH	J2	Terminal block for input power (30A)
J3	Terminal block 0.591" (15.00mm) through hole	J3	Terminal block for output to electronic load (125A)
VDRV	Banana jack	VDRV	Connect +5V external supply for driver voltage
P5V	Banana jack	P5V	Connect +5V external supply for controller and housekeeping
GND	Banana jack	GND	Ground connection for VDRV and P5V supply

2.4 Test Points

Table 2-4. Test Point Functions

Type	Name	Description
T-H Loop	BP33	Internal 3.3V on power stage
T-H Loop	EN_PS	Power stage enable
T-H Loop	FGEN	Function generator input
T-H Loop	GND	Ground sense at output terminal
T-H Loop	GND_IC	IC ground reference
T-H Loop	GNDS_VIN	Kelvin sense input voltage ground
T-H Loop	GNDS_VOUT	Kelvin sense output voltage ground
T-H Loop	ISNS	Current sense (12.5mV/A)
T-H Loop	PWM	PWM signal to power stage
T-H Loop	PWM_EXT	External PWM input
T-H Loop	SCL	Connect to SCL pin
T-H Loop	SDA	Connect to SDA pin
SMB	SW_SMB1	SMB connector to SW node
T-H Loop	SWS	Switch node
T-H Loop	TMON	Temperature monitor
T-H Loop	VDRV	Driver voltage measurement at terminal
T-H Loop	VDRVS	Driver voltage sense measurement at VDRV pin
T-H Loop	VINS	Kelvin sense input voltage
T-H Loop	VOUT	Output voltage sense at terminal
T-H Loop	VOUTS	Kelvin sense for output voltage at output capacitor
T-H Loop	VREFIN	Reference input voltage

2.5 Best Practices

The following warnings and cautions are noted for the safety of anyone using or working close to the CSD967201-Q1EVM. Observe all safety precautions.

	**Caution**	Hot surface. Contact can cause burns. Do not touch! Circuit module can become hot during operation due to dissipation of heat. Avoid contact with the board. Follow all applicable safety procedures applicable to your laboratory.
	**Caution**	Do not leave the EVM powered when unattended.

WARNING

The circuit module has signal traces, components, and component leads on the bottom of the board. This can result in exposed voltages, hot surfaces, and sharp edges. Do not reach under the board during operation.

WARNING

External connections: All external connections to the hardware must stay within the recommended operating conditions and intended usage for all hardware and components connected in the system.

CAUTION

The circuit module can be damaged by overtemperature. To avoid damage, monitor the temperature during evaluation and provide cooling.

CAUTION

Some power supplies can be damaged by the application of external voltages. If using more than one power supply, check the requirements of your equipment and use blocking diodes or other isolation techniques to prevent damage to the equipment.

CAUTION

The communication interface is not isolated on the EVM. Make sure that there is no ground potential between the computer and the EVM. Be aware that the computer is referenced to the battery potential of the EVM.

3 Implementation Results

3.1 Evaluation Setup

Equipment Needed

- High-current 12V power supply (TI recommends >30A capability)
- Two 5V power supplies (≥1A each)
- One function generator if configured for external PWM input
- One function generator if performing load transient testing with the onboard load transient circuit
- Electronic load (>60A capable)
- Socket-to-socket jumper wires (for connection to a serial interface adapter if using a controller)
- Oscilloscope (optional, for SW node or waveform probing)
- DMMs for measuring power stage input, output, and driver input voltages

Power Sequencing Requirements

VIN and VDRV can be powered in any sequence. When VDRV exceeds VDRV_UVLO_RISING, then TMON/FLT and IMON start rising after the tStartup-Delay time has passed. The CSD967201-Q1 power stage device must be powered up and enabled before the PWM signal is applied; wait 75µs after the enable before applying the PWM signal.

Onboard Load Transient Tester

The EVM has a load transient circuit comprised of four 50mΩ resistors in parallel in series with two parallel CSD17579Q5A n-channel MOSFETs. An arbitrary waveform generator and oscilloscope probe are necessary for the setup. The load transient must only be used for short 1ms or less pulses at a frequency of 100Hz or less to limit thermal stress. Connect the scope probe to the ISNS test point and clip the ground lead to the GND_JW2 ground bar. Apply an arbitrary wave generator or function generator that is capable of controlling a pulse rise and fall time independently. Start with a 1ms pulse with a 100µs rise and fall time at 100Hz with an amplitude of 0.5V, and monitor the voltage of the ISNS of the oscilloscope and adjust the amplitude to get the desired load current. The current sense gain is 12.5mV/A. Once load current is set, adjust the rise and fall time to get the desired slew rate.

To Measure the Efficiency of the DC-DC Buck Application

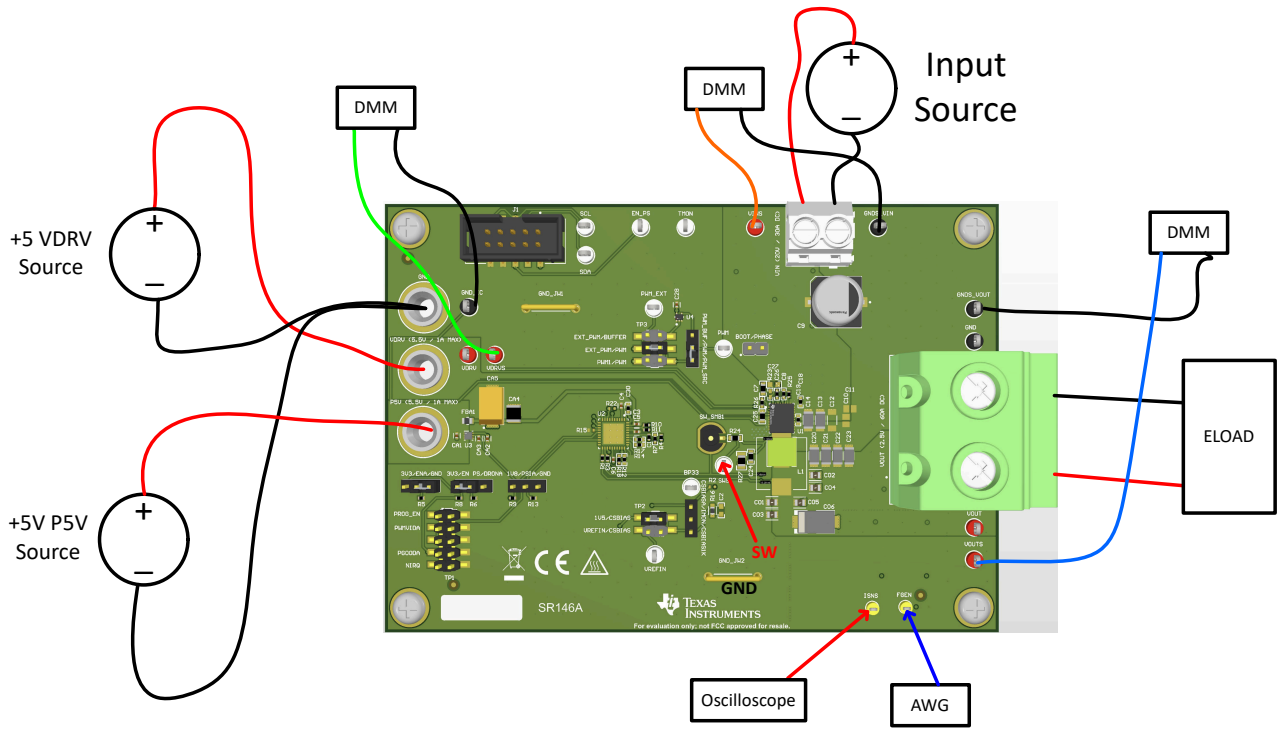
TI recommends completing the efficiency measurement in closed loop as this gives the most accurate and consistent results over the full operating range. The efficiency measurement is possible in a PWM configuration as well, although the duty cycle must be adjusted as the load conditions change, and consistent results are difficult to achieve.

Connect an electronic load to the J3 terminal and take special note of the orientation of GND and VOUT. Connect a 12V voltage source to the J2 terminal. Connect a 5V voltage source to the VDRV and GND plug to supply the gate drive circuits. Connect a 5V voltage source to the P5V and GND plugs to supply the house keeping circuits on the board. The separate P5V supply, provides an accurate measurement of power stage efficiency by detaching controller and housekeeping power loss from power stage loss. Kelvin sensing is essential for accurate efficiency measurements.

Efficiency can be measured two ways:

1. Board efficiency – Includes losses from the power stage and inductor DCR. Use the VOUTS, GNDS_VOUT, VINS, GNDS_VIN, GND_IC, and VDRVS test points. To set up the board to measure efficiency of the DC-DC buck application, connect a DMM to measure the output voltage using the test points: VOUTS and GNDS_VOUT. VOUTS is Kelvin-connected to VOUT pour near the CO1 and CO3 capacitors. The GNDS_VOUT test point is Kelvin-connect at CO1. To measure the input voltage, connect a DMM to VINS and GNDS_VIN. VINS is Kelvin-connected near C18 capacitor and GNDS_VIN connects on the ground pour near pin 19 of the device. To measure the drive voltage, connect a DMM to VDRVS and GND_IC. VDRVS Kelvin-connects to device pin 4 and GND_IC Kelvin-connects to the GND pin 9.
   Ploss = VIN_S x I_{IN} + VDRV_S x I_{VDRV} - (Vout x Iout)

2. Device efficiency – Includes losses only from the power stage. For this measurement, move the DMM probe to measure SWS instead of VOUTS. This uses the DMM averaging function to average the SW node voltage before the inductor so the inductor DCR losses are not included in the loss calculation.
   Ploss_ps = VIN_S x I_{IN} + VDRV_S x I_{VDRV} - (V_{SWavg} x Iout)



Open Loop Test Setup

Connect a function generator to the PWM_EXT test point and GND_JW1 for ground. Set the frequency to 650kHz. The duty cycle must be set between 8% to 9% when the input voltage is 12V. The PWM_EXT pulse width must always be greater than 30ns. The output capacitors have a voltage rating of 2.5V. The external PWM amplitude must be 3V.

Note

When operating the EVM in PWM configuration, enable the CSD967201 device prior to enabling the PWM input. Additionally, if OT is reached while operating in PWM mode, stop the PWM input when the TMON/FLT voltage is raised above 3V. This allows the part to start back up after falling below the OT threshold without PWM running.

Measuring IMON

In controller configuration, use a differential probe between the CSBIAS and IMON test points on the provided header. The IMON output is scaled across an internal 1kΩ resistor in the controller to provide 5mV/A when measured from IMON to CSBIAS with the differential probe. The IMON waveform is a triangle waveform that mimics the inductor current. The controller uses the average of the waveform to get the average current. If you add parasitic capacitance with a passive oscilloscope probe, the capacitor rounds the upper edge of the triangle waveform and causes the average current to be lower than actual.

In PWM configuration, use a differential probe between the CSBIAS1k and IMON test points on the provided header. The IMON output is scaled across a 1kΩ resistor on the board to provide 5mV/A when measured from IMON to CSBIAS with the differential probe. The IMON waveform is a triangle waveform that mimics the inductor current. If you add parasitic capacitance with a passive oscilloscope probe, the capacitor rounds the upper edge of the triangle waveform and causes the average current to be lower than actual.

Measuring TMON

During normal operation, the TMON/FLT pin provides a highly accurate analog temperature measurement of the power stage die temperature. To measure TMON, connect to the TMON test point. The TMON voltage is proportional to the die temperature, with a temperature coefficient of 8mV/°C. The TMON output has a built-in ORing function, which allows multiple devices to be connected together. When connecting TMON/FLT pins of more than one device, the TMON/FLT bus automatically reads the highest TMON/FLT voltage among all devices. At 25°C, the TMON voltage is typically 800mV (with a range of 776mV to 824mV). This ORing function simplifies temperature sensing and fault reporting in multiphase applications, where a single TMON/FLT bus can be used to monitor the temperature of the hottest device. The TMON/FLT pin can drive up to 470pF of capacitance to accommodate controller-side filtering for enhanced accuracy and noise immunity.

Note

Connecting oscilloscope probes with long leads onto the PWM test point can be a noise source and impact the SW node jitter.

4 Hardware Design Files

4.1 Schematics

Figure 4-1 illustrates the SR146A CSD967201-Q1EVM schematic.

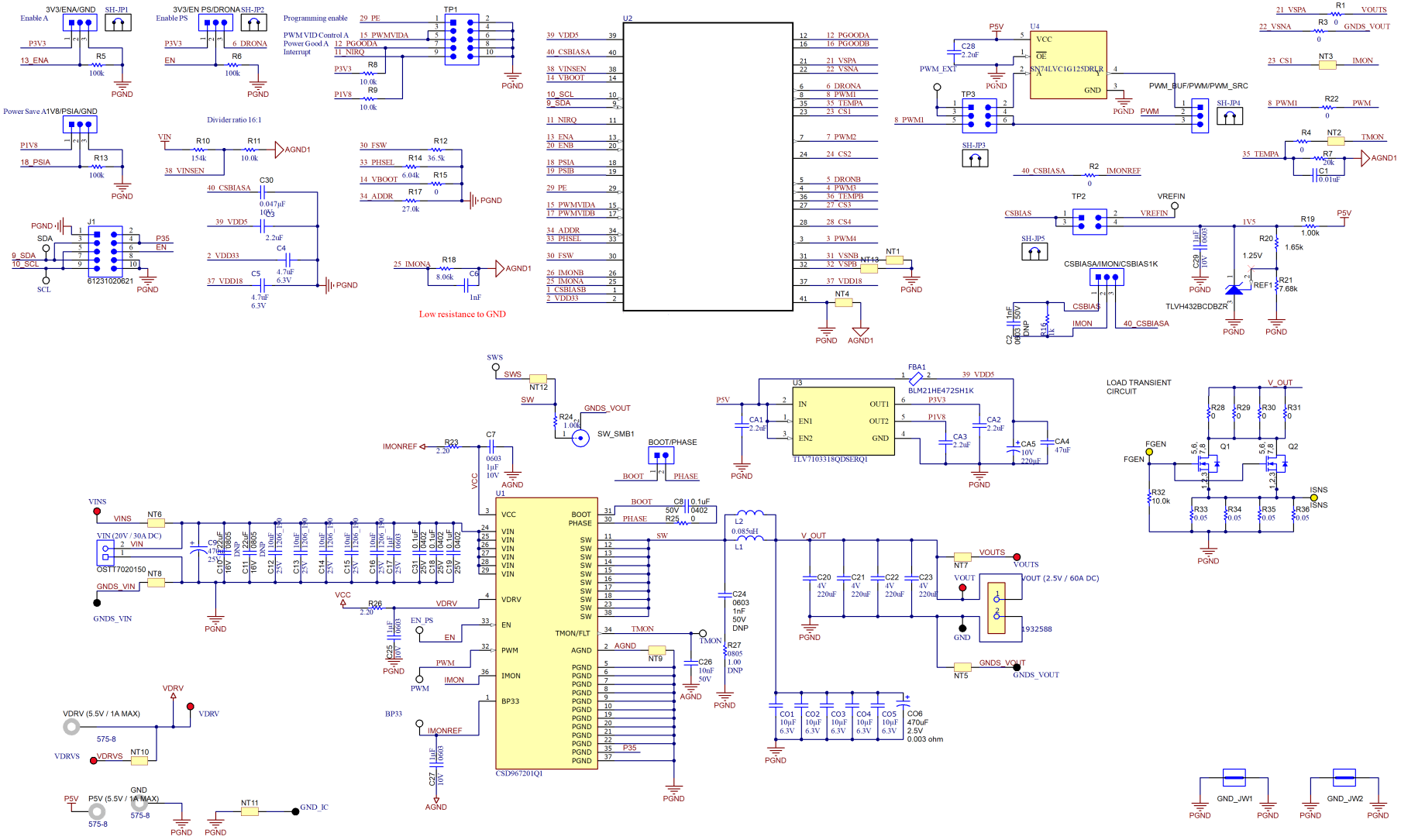


Figure 4-1. CSD967201-Q1EVM

4.2 PCB Layouts

Figure 4-2 through Figure 4-16 show the design of the SR146A CSD967201-Q1EVM printed circuit board.

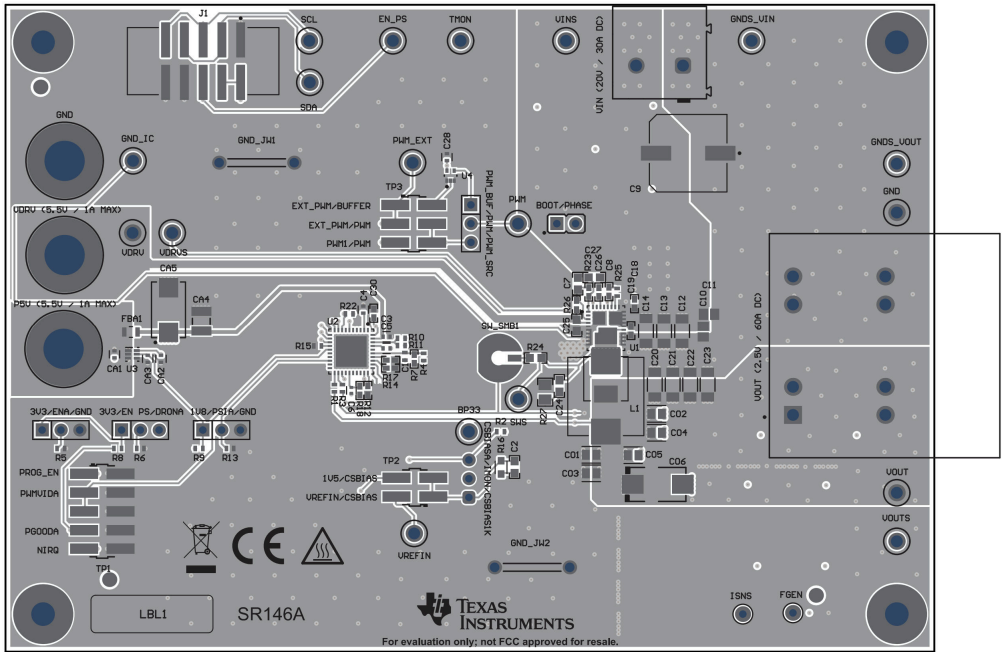


Figure 4-2. SR146A CSD967201-Q1EVM Component View (Top View)

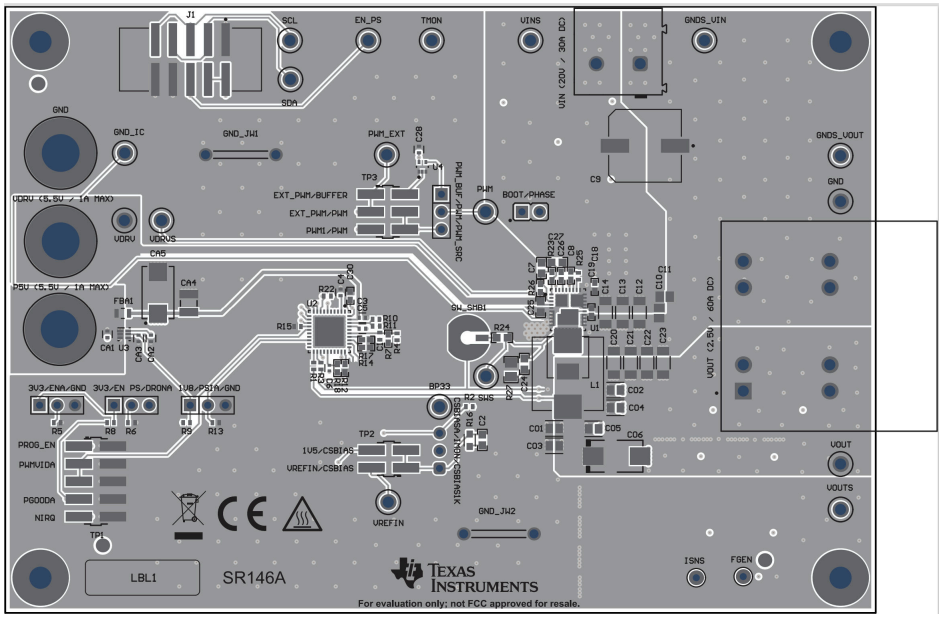


Figure 4-3. SR146A CSD967201-Q1EVM Top Composite View (Top View)

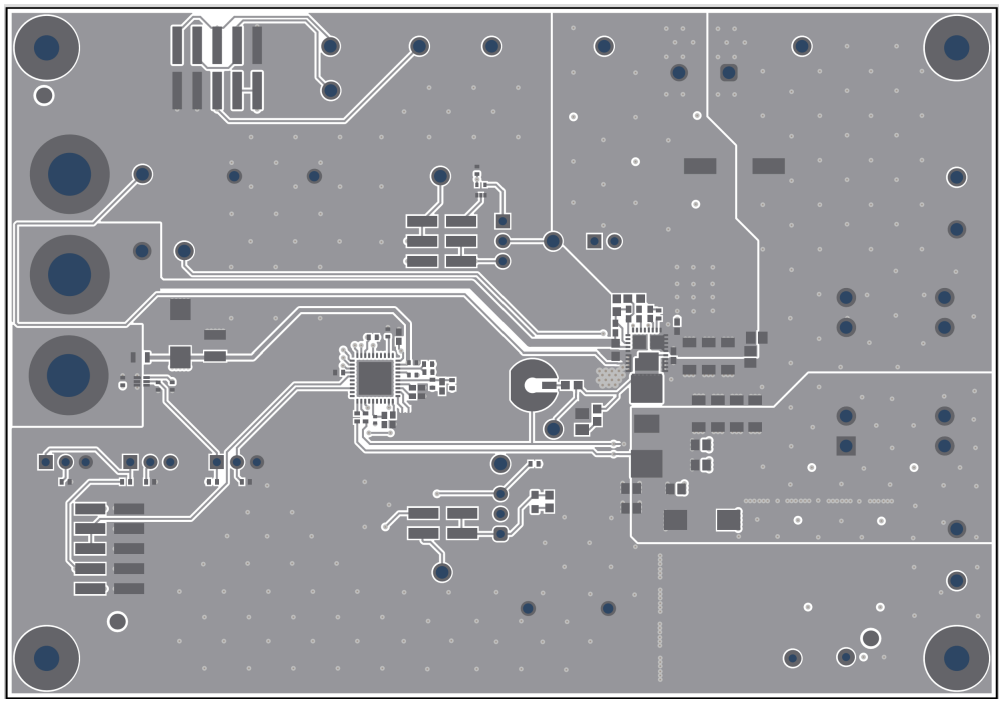


Figure 4-4. SR146A CSD967201-Q1EVM Top Mask (Top View)

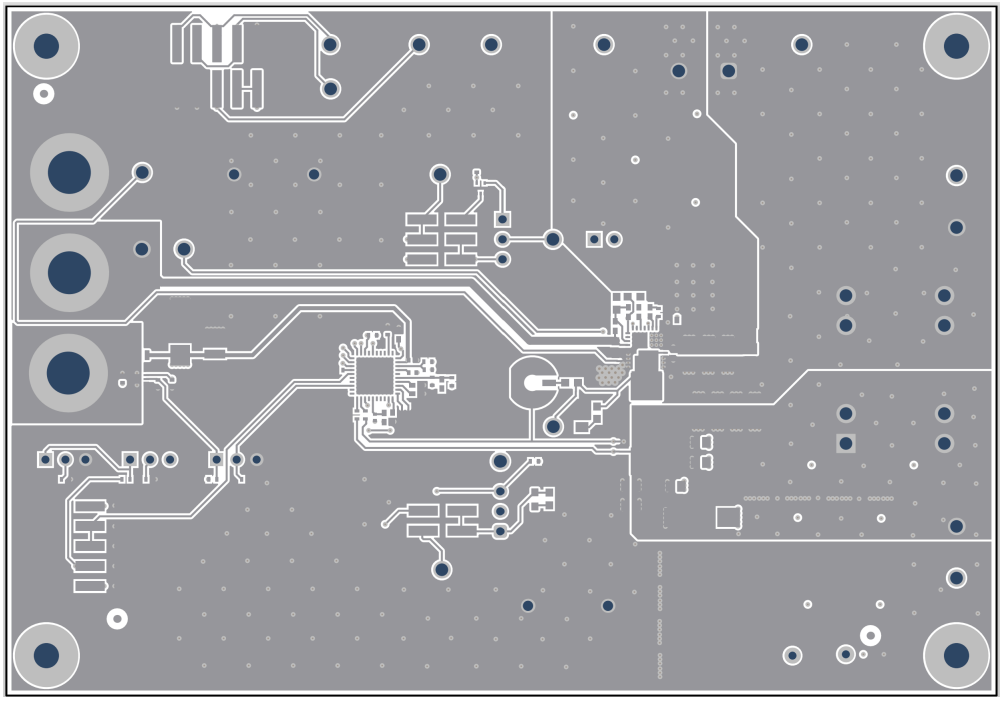


Figure 4-5. SR146A CSD967201-Q1EVM Top Layer (Top View)

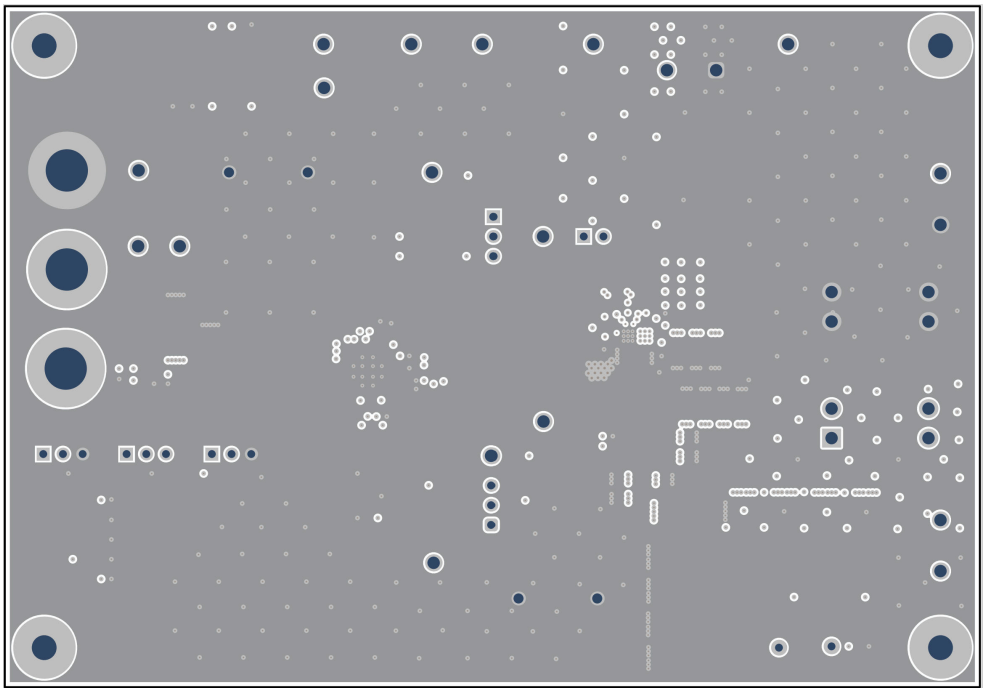


Figure 4-6. SR146A CSD967201-Q1EVM Signal Layer 1 (Top View)

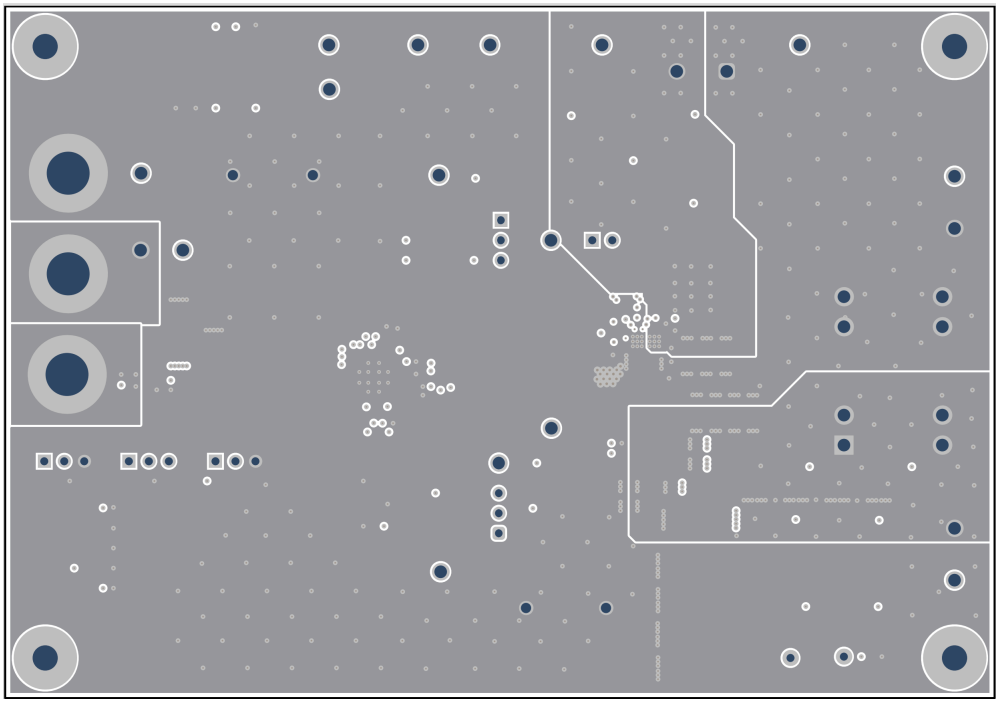


Figure 4-7. SR146A CSD967201-Q1EVM Signal Layer 2 (Top View)

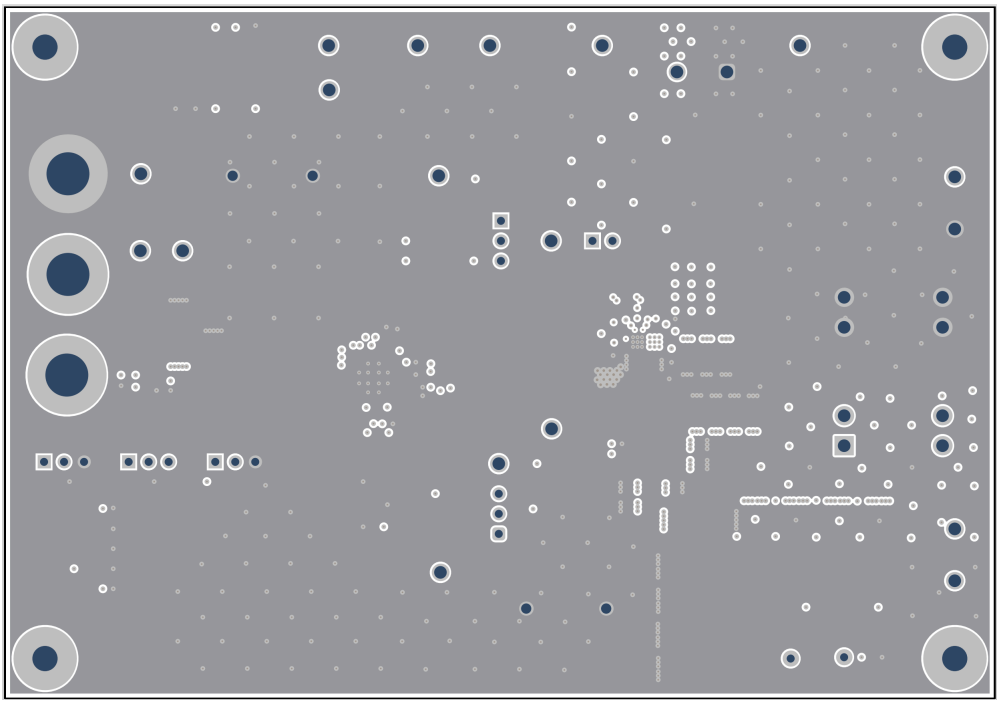


Figure 4-8. SR146A CSD967201-Q1EVM Signal Layer 3 (Top View)

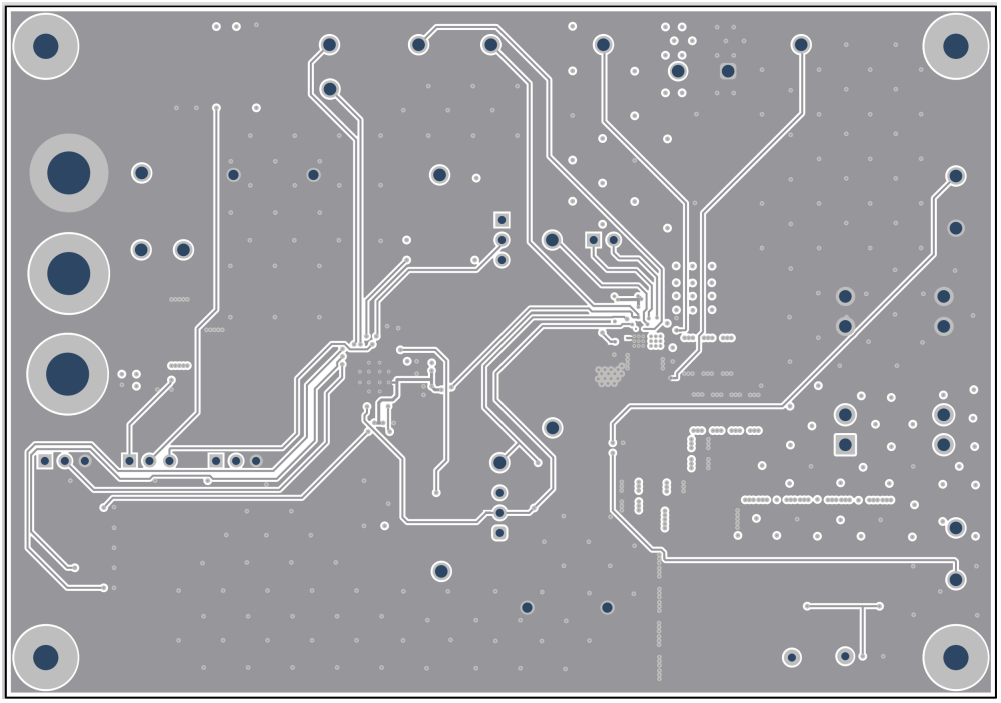


Figure 4-9. SR146A CSD967201-Q1EVM Signal Layer 4 (Top View)

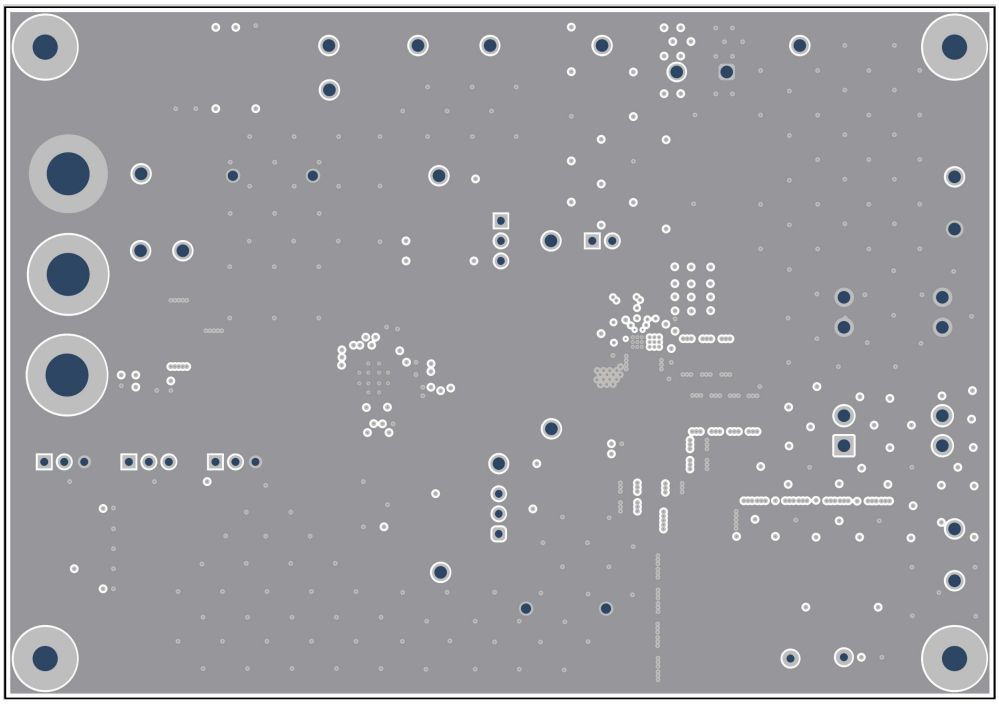


Figure 4-10. SR146A CSD967201-Q1EVM Signal Layer 5 (Top View)

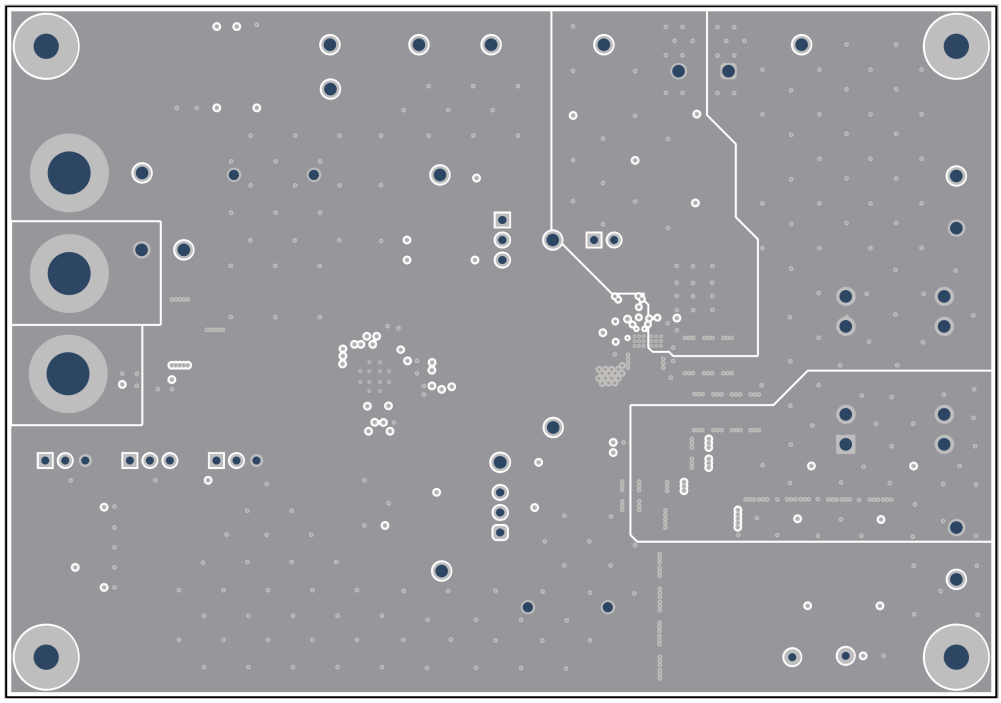


Figure 4-11. SR146A CSD967201-Q1EVM Signal Layer 6 (Top View)

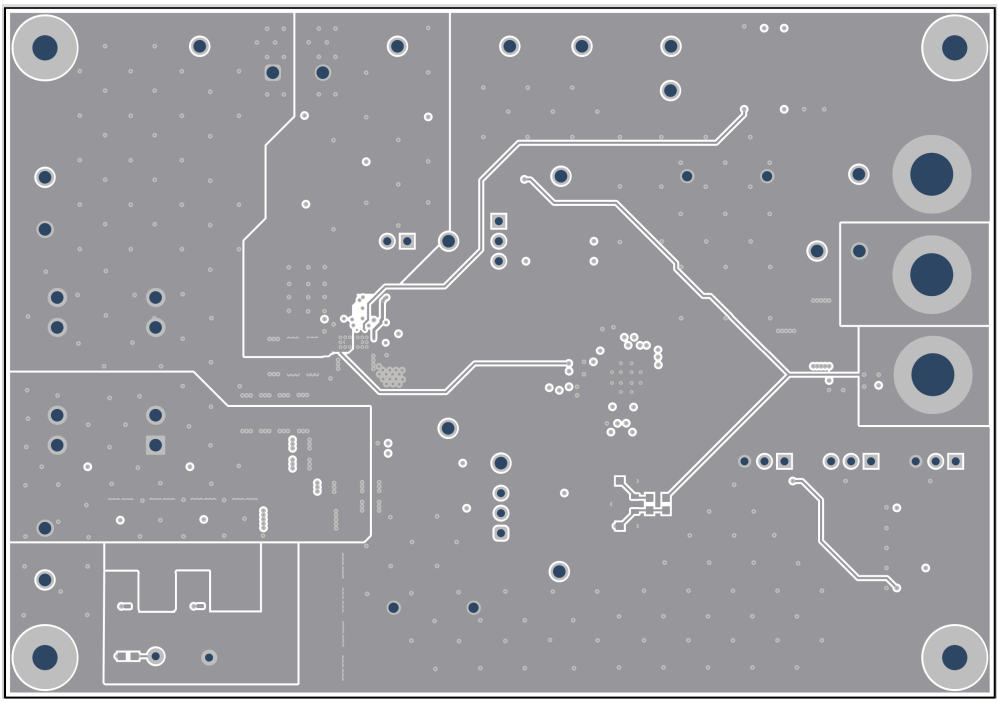


Figure 4-12. SR146A CSD967201-Q1EVM Bottom Layer View (Bottom View)

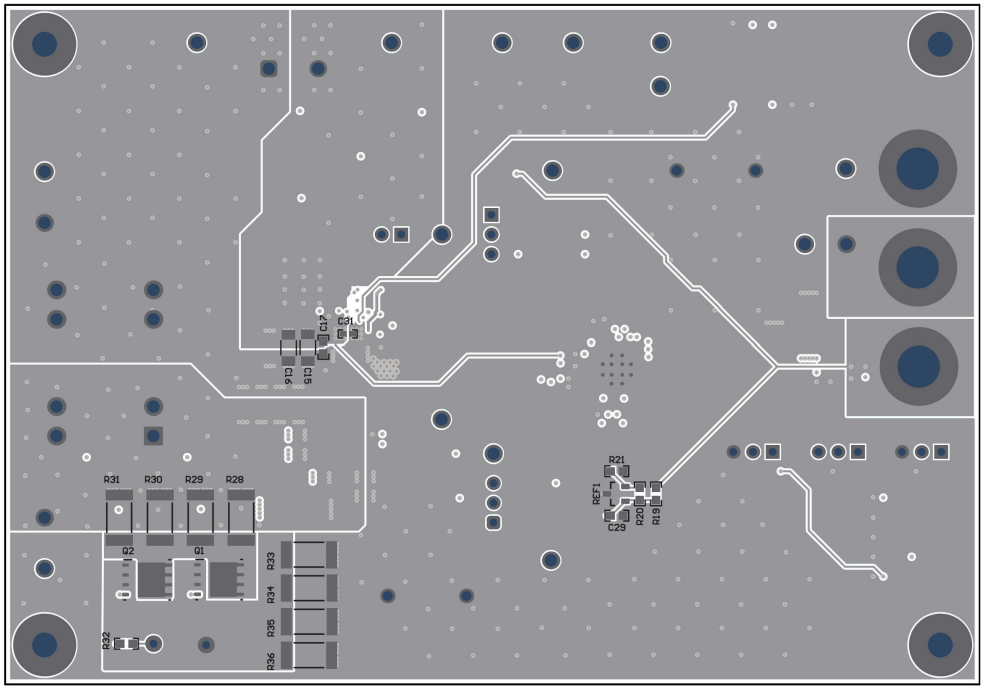


Figure 4-13. SR146A CSD967201-Q1EVM Bottom Component (Bottom View)

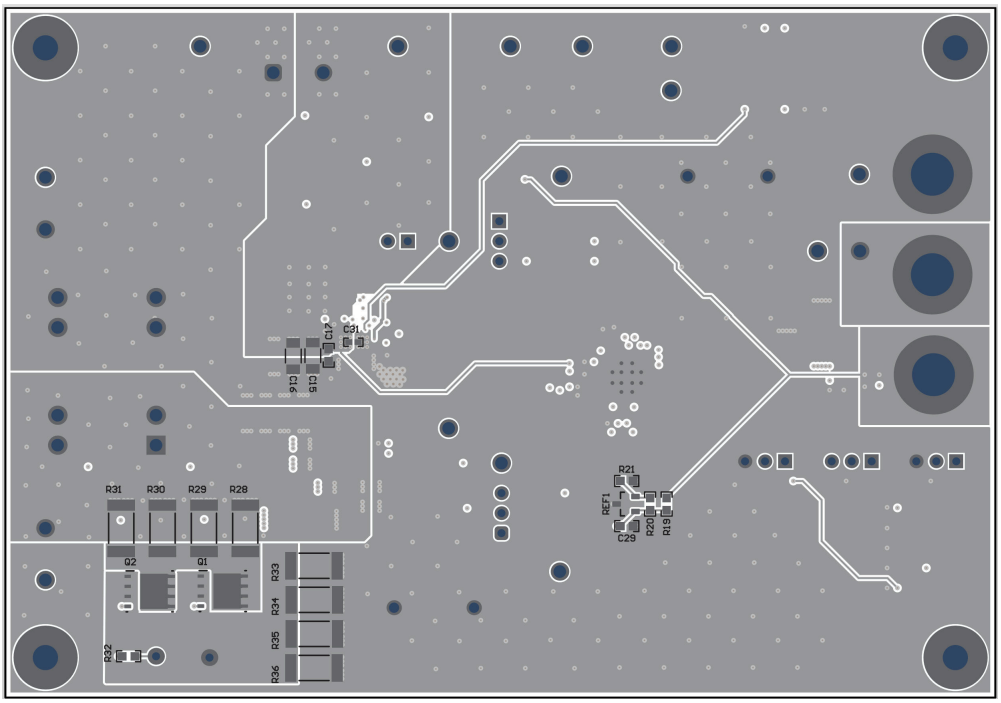


Figure 4-14. SR146A CSD967201-Q1EVM Bottom Composite (Bottom View)

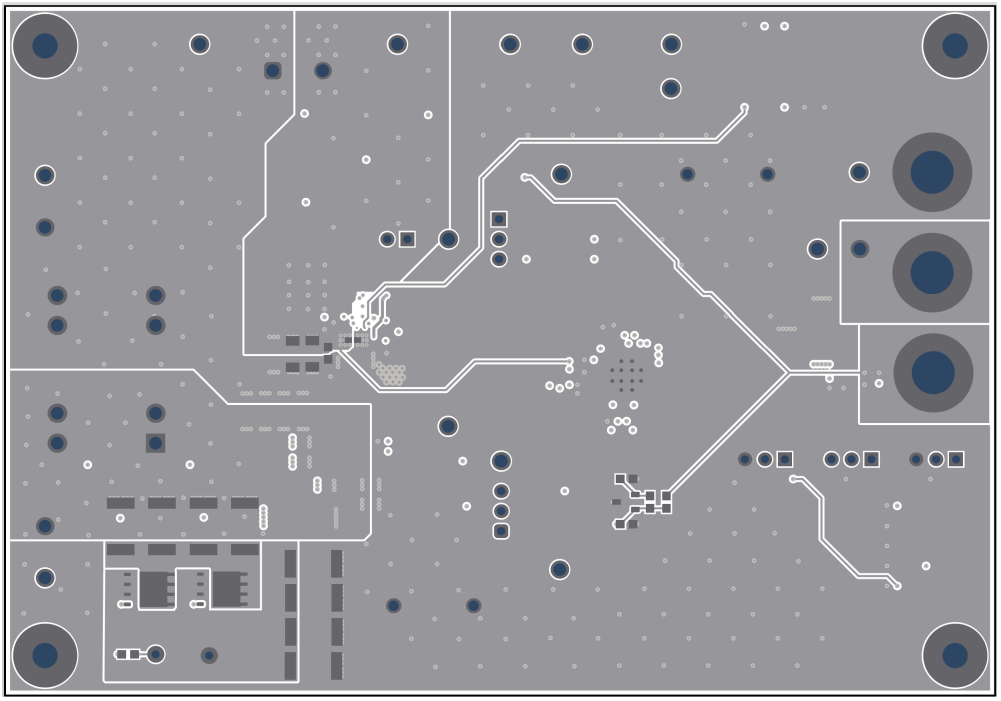


Figure 4-15. SR146A CSD967201-Q1EVM Bottom Mask View (Bottom View)

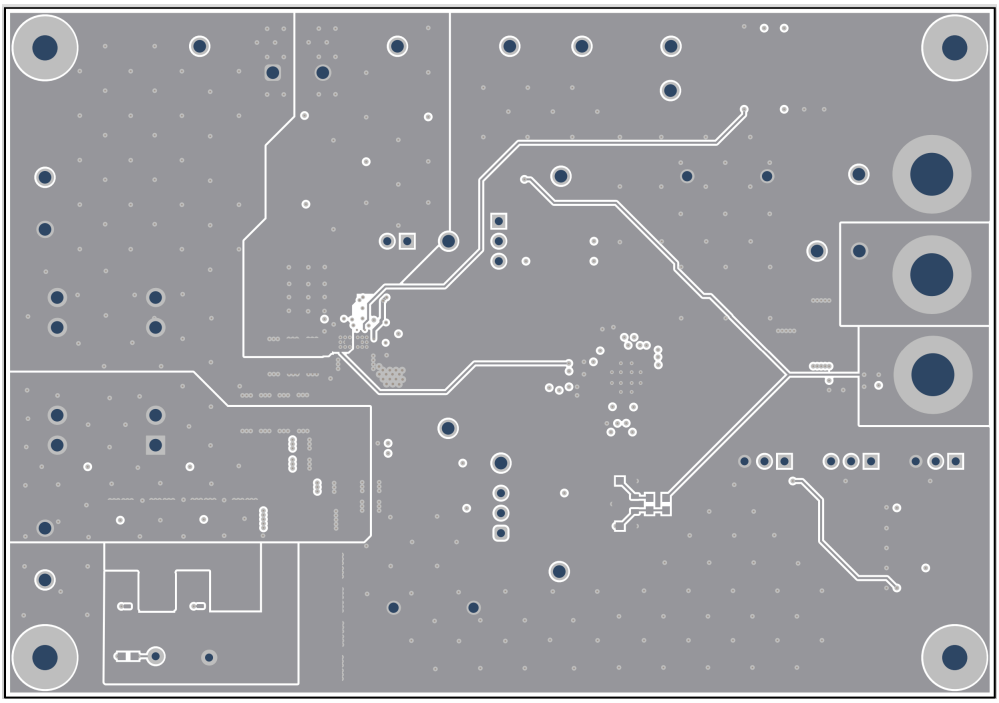


Figure 4-16. SR146A CSD967201-Q1EVM Bottom Layer (Bottom View)

4.3 Bill of Materials (BOM)

Table 4-1. CSD967201-Q1EVM Bill of Materials

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
!PCB	1	–	Printed Circuit Board	–	SR146A	Any
1V8/PSIA/GND, 3V3/EN PS/DRONA, 3V3/ENA/GND, PWM_BUF/PWM/ PWM_SRC	4	–	Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
BOOT/PHASE	1	–	Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
BP33, EN_PS, PWM, PWM_EXT, SCL, SDA, SWS, TMON, VREFIN	9	–	Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone Electronics, Keystone
C1	1	0.01µF	CAP, CERM, 0.01µF, 25V, ±10%, X7R, 0402	0402	GCM155R71E103KA37D	MuRata
C3, C28, CA1, CA2, CA3	5	2.2µF	Multi-Layer Ceramic Capacitor 2.2µF 10V X7S ±10% 0402 Paper T/R	0402	GRT155C71A225KE13D	Murata
C4, C5	2	4.7µF	4.7µF ±20% 6.3V Ceramic Capacitor X7T 0402 (1005 Metric)	0402	GRT155D70J475ME13J	Murata
C6	1	1nF	Ceramic Capacitor for Automotive 1nF ±2% 50VDC C0G 0402 Paper T/R	0402	GCM1555C1H102GA16J	Murata
C7, C25, C29	3	1uF	CAP, CERM, 1µF, 10V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	LMK107B7105KAHT	Taiyo Yuden
C8	1	0.1µF	CAP, CERM, 0.1µF, 50V, ±10%, X6S, 0402	0402	C1005X6S1H104K050BB	TDK
C9	1	470µF	470µF 25V Aluminum Electrolytic Capacitors Radial, Can – SMD 2000 Hrs at 105°C	SMD2	EEEFK1E471AP	Panasonic
C13, C14, C15, C16	4	10µF	CAP, CERM, 10µF, 25V, ±10%, X7S, AEC-Q200 Grade 1, 1206_190	1206_190	GCM31CC71E106KA03L	MuRata
C17	1	1µF	CAP, CERM, 1µF, 25V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71E105KA64D	MuRata
C18, C19, C31	3	0.1µF	CAP, CERM, 0.1µF, 25V, ±10%, X7R, 0402	0402	GRM155R71E104KE14D	MuRata
C20, C21, C22, C23	4	220µF	CAP, CERM, 220µF, 4V, ±20%, X5R, 1206_190	1206_190	GRM31CR60G227ME11L	MuRata
C24	1	1000pF	CAP, CERM, 1000pF, 50V, ±5%, X7R, 0603	0603	CL10C102JB8NNNC	Samsung Electro-Mechanics
C26	1	0.01µF	CAP, CERM, 0.01µF, 50V, ±10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B3X7R1H103K050BB	TDK
C27	1	100nF	Automotive CAP, 100 nF, 25V, ±10%, X7R, 0603, 5mm Bending	0603	CL10B104KA8VPJC	Samsung
C30	1	0.047µF	CAP, CERM, 0.047µF, 10V, ±5%, X8L, AEC-Q200 Grade 0, 0402	0402	C0402C473J8NACTU	Kemet
CA4	1	47µF	CAP, CERM, 47µF, 10V, ±20%, X7R, 1210	1210	GRM32ER71A476ME15L	MuRata
CA5	1	220µF	CAP, TA, 220µF, 10V, ±10%, 0.5Ω, SMD	7343-43	T491X227K010AT	Kemet
CO1, CO2, CO3, CO4, CO5	5	10µF	CL21 Series 0805 10uF 6.3V ±10% Tolerance X7R Multilayer Ceramic Chip Capacitor	0805	CL21B106KQQNNNE	Samsung
CO6	1	470µF	CAP, Aluminum Polymer, 470µF, 2.5V, ±20%, 0.003Ω, SMD_7.3x1.9x4.3mm SMD	SMD_7.3x1.9x4.3mm	EEF-GX0E471R	Panasonic
CSBIASA/IMON/CSBIAS1K	1	–	Header, 100mil, 3x1, Gold, TH	3x1 Header	TSW-103-07-G-S	Samtec

Table 4-1. CSD967201-Q1EVM Bill of Materials (continued)

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
FBA1	1	–	4.7kΩ at 100MHz 1 Signal Line Ferrite Bead 0805 (2012 Metric) 850mA 400mΩ	0805	BLM21HE472SH1K	Murata
FGEN, ISNS	2	–	Test Point, Miniature, Yellow, TH	Yellow Miniature Testpoint	5004	Keystone
GND, GND_IC, GNDS_VIN, GNDS_VOUT	4	–	Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone Electronics
GND, P5V (5.5V / 1A MAX), VDRV (5.5V / 1A MAX)	3	–	Standard Banana Jack, Uninsulated, 8.9mm	Keystone575-8	575-8	Keystone
GND_JW1, GND_JW2	2	–	1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
H1, H2, H3, H4	4	–	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4	–	Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1	1	–	Connector Header Surface Mount 10 position 0.100" (2.54mm)	CONN_HDR10	61231020621	Wurth Electroincs
L1	1	0.085µH	Automotive Power Inductor, 0.085µH 20% 1MHz, 0.36mΩ, 53A, 5.8x5.8x3.8mm SMT	SMT_IND_5MM8_5MM8	IHLL242NDZEZ85NMAZ	Vishay
LBL1	1	–	Thermal Transfer Printable Labels, 0.650" W x 0.200" H – 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1, Q2	2	30V	MOSFET, N-CH, 30V, 25A, DQJ0008A (VSONP-8)	DQJ0008A	CSD17579Q5A	Texas Instruments
R1, R3, R4, R25	4	0	RES, 0, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R5, R6, R13	3	100k	RES, 100k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW0402100KFKED	Vishay-Dale
R7	1	20k	RES, 20k, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW040220K0JNED	Vishay-Dale
R8, R9, R11	3	10.0k	RES, 10.0k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R10	1	154k	RES, 154k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW0402154KFKED	Vishay-Dale
R12	1	36.5k	RES, 36.5k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW040236K5FKED	Vishay-Dale
R14	1	6.04k	RES, 6.04k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04026K04FKED	Vishay-Dale
R16	1	1k	1kΩ ±0.01% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thin Film	0603	RNCF0603TKW1K00	Stackpole Electronics
R17	1	27.0k	RES, 27.0k, 1%, 0.1W, AEC-Q200 Grade 0, 0402	0402	ERJ2RKF2702X	Panasonic
R18	1	8.06k	RES, 8.06k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04028K06FKED	Vishay-Dale
R19, R24	2	1.00k	RES, 1.00k, 1%, 0.1W, 0603	0603	RC0603FR-071KL	Yageo
R20	1	1.65k	RES, 1.65k, 0.1%, 0.1W, 0603	0603	RG1608P-1651-B-T5	Susumu Co Ltd
R21	1	7.68k	RES, 7.68k, 1%, 0.1W, AEC-Q200 Grade 0, 0603	0603	CRCW06037K68FKEA	Vishay-Dale
R26	1	2.2	RES, 2.20, 1%, 0.2W, 0402	0402	RCS04022R20FKED	Vishay-Dale
R27	1	1	RES, 1.00, 1%, 0.125W, AEC-Q200 Grade 0, 0805	0805	ERJ-6RQF1R0V	Panasonic
R28, R29, R30, R31	4	0	RES, 0, 5%, 1W, AEC-Q200 Grade 0, 2512	2512	CRCW25120000Z0EG	Vishay-Dale
R32	1	10.0k	RES, 10.0k, 1%, 0.1W, 0603	0603	ERJ-3EKF1002V	Panasonic
R33, R34, R35, R36	4	0.05	RES, 0.05, 1%, 3W, 2512	2512	CRA2512-FZ-R050ELF	Bourns
REF1	1	–	Low-Voltage Adjustable Precision Shunt Regulator, 129ppm/°C, 80mA, 0 to 70°C, 3-pin SOT-23 (DBZ), Green (RoHS & no Sb/Br)	DBZ0003A	TLVH432BCDBZR	Texas Instruments

Table 4-1. CSD967201-Q1EVM Bill of Materials (continued)

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
SH-JP1, SH-JP2, SH-JP3, SH-JP4, SH-JP5	5	–	Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
SW_SMB1	1	–	Connector, Receptacle, 50Ω, TH	SMB Connector	SMBR004D00	JAE Electronics
TP1	1	–	Header, 2.54mm, 5x2, Gold, SMT	Header, 2.54mm, 5x2, SMT	TSM-105-01-L-DV-P	Samtec
TP2	1	–	Header, 2.54mm, 2x2, Gold, SMT	Header, 2.54mm, 2x2, SMT	TSM-102-01-L-DV	Samtec
TP3	1	–	Header, 2.54mm, 3x2, Gold, SMT	Header, 2.54mm, 3x2, SMT	TSM-103-01-L-DV	Samtec
U1	1	–	Synchronous Buck Smart Power Stage	WQFN-FCRLF38	CSD967201Q1	Texas Instruments
U3	1	–	Automotive Catalog, Dual, 200mA, Low-IQ Low-Dropout Regulator for Portable Devices, DSE0006A (WSON-6)	DSE0006A	TLV7103318QDSERQ1	Texas Instruments
U4	1	–	IC Buffer Non-Invert 5.5V SOT5	–	–	–
VDRV, VDRVS, VINS, VOUT, VOUTS	5	–	Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics
VIN (20V / 30A DC)	1	–	Terminal Block, 6.35mm, 2x1, TH	On-Shore_OSTT7020150	OSTT7020150	On-Shore Technology
VOUT (2.5V / 60A DC)	1	–	2 Position Wire to Board Terminal Block Horizontal with Board 0.591" (15.00mm) Through Hole	CONN_TERM_BLOCK	–	Phoenix Contact
C2	0	1000pF	CAP, CERM, 1000pF, 50V, ±5%, X7R, 0603	0603	CL10C102JB8NNNC	Samsung Electro-Mechanics
C10, C11	0	22µF	CAP, CERM, 22uF, 16V, ±20%, X6S, 0805	0805	GRM21BC81C226ME44L	MuRata
C12	0	10µF	CAP, CERM, 10uF, 25V, ±10%, X7S, AEC-Q200 Grade 1, 1206_190	1206_190	GCM31CC71E106KA03L	MuRata
FID1, FID2, FID3	0	–	Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
L2	0	0.22µH	Inductor 0.22µH 20% 100kHz 0.75mΩ 50A 10.3x10.0x4.0mm SMT AEC-Q200	SMT_IND_10MM3_10MM0	MMD110DZIR22M	MAG LAYERS
R2, R15, R22	0	0	RES, 0, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R23	0	2.2	RES, 2.20, 1%, 0.2W, 0402	0402	RCS04022R20FKED	Vishay-Dale
U2	0	–	Dual channel, (N+M) ≤ 4 phase, step-down automotive multiphase controller with I2C interface	VQFN40	Any	Any

5 Additional Information

5.1 Known Hardware or Software Issues

No changes to the published schematic, BOM, or layout.

5.2 Trademarks

E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

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