

# EVM User's Guide: LM25137F-Q1-EVM5D3

## LM25137-Q1 Evaluation Module



### Description

The LM25137-Q1-EVM5D3 evaluation module (EVM) is designed to showcase the LM(2)5137/-Q1 dual synchronous buck controller, which is intended for [functional safety](#) applications up to ASIL D or SIL 3. The EVM operates over a wide input voltage range of 6.5V to 36V to deliver 5V and 3.3V regulated outputs with better than 1% setpoint accuracy at load currents up to 20A per output.

### Get Started

1. Order the [LM25137F-Q1-EVM5D3](#).
2. Refer to the [LM5137-Q1](#) and [LM25137-Q1](#) product folders.
3. Review the Altium [PCB layout](#) source files.
4. Use the LM(2)5137-Q1 [quickstart calculator](#) to assist with component selection in your design.

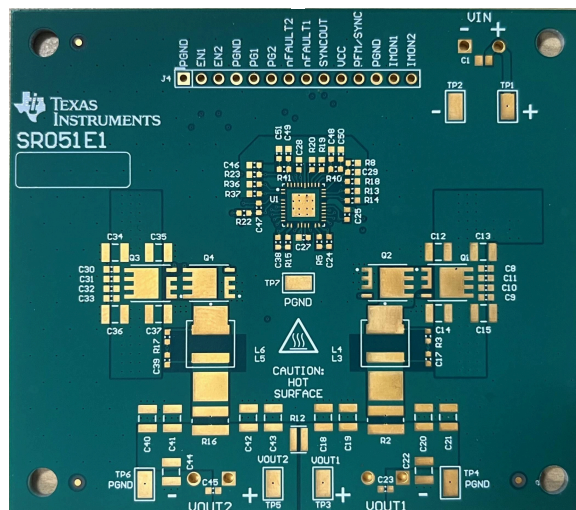
### Features

- Maximum inout voltage of 36V
  - $V_{IN}$  UVLO thresholds set at 6.5V and 4.5V
- Tightly regulated output voltages of 5V and 3.3V, each rated at 20A with 1mV load/line regulation
- High efficiency – 96% at 10A, 94% at 20A
  - VCC bias power derived from the 5V output
- Switching frequency of 440kHz synchronizable  $\pm 20\%$  with an external clock signal

- Input  $\pi$ -stage EMI filter meets CISPR 25
  - Spread spectrum (DRSS) option for lower EMI
  - Electrolytic capacitor for parallel damping
- Peak current-mode control architecture provides fast line and load transient response
  - Integrated slope compensation
  - Forced PWM (FPWM) or pulsed frequency modulation (PFM) operation
- Integrated power MOSFET gate drivers
  - 3A/2A sink/source gate drive current capability
  - Adaptive dead-time control reduces power dissipation and MOSFET temperature rise
- Integrated protection features for robust design
  - Overcurrent protection (OCP) with shunt or inductor DCR current sensing
  - Monotonic prebias output voltage startup
  - User-adjustable soft-start time set to 5ms
  - PG and  $\overline{\text{FAULT}}$  outputs for each channel
  - Dual current monitor outputs (IMON1, IMON2)
- Fully assembled, tested and proven PCB layout with 3.3"  $\times$  2.9" (84mm  $\times$  74mm) total footprint

### Applications

- High-current [automotive electronic systems](#) using 2-, 3- and 4-phase implementations
- Dual outputs for [ADAS](#) and [body](#) electronics
- [Infotainment systems](#) and [instrument clusters](#)
- [Automotive HEV/EV powertrain systems](#)



LM25137-Q1 EVM PCB, 84mm  $\times$  74mm

# 1 Evaluation Module Overview

## 1.1 Introduction

The [LM25137F-Q1-EVM5D3](#) evaluation module (EVM) is a dual-channel synchronous buck DC/DC regulator that employs synchronous rectification to achieve high conversion efficiency in a small footprint. The EVM operates over a wide input voltage range of 6.5V to 36V, providing regulated outputs of 5V and 3.3V. The output voltages have better than 1% setpoint accuracy and are adjustable by modifying the feedback resistor values, permitting the user to customize the output voltage within a range of 2.5V to 8V as needed. Alternatively, as shown in [Figure 1-2](#), the EVM is configurable as a two-phase, 40A single-output design by changing the COMP network configuration, the CNFG resistor, and connecting the outputs together.

Inherent protection features for robust design include input supply voltage, VCC and gate-drive UVLO; independent IMON, PG and FAULT indicator outputs for each channel; resistor-adjustable soft start; hiccup-mode overcurrent protection; and thermal shutdown with hysteresis. The selected power-train passive components, including 40V power MOSFETs, 1μH buck inductors, 2mΩ shunts, 10μF/50V ceramic input capacitors and 47μF/10V ceramic output capacitors – are AEC-Q200 rated and available from multiple component vendors.

The module design uses the [LM25137-Q1](#) buck controller IC, which is specifically developed for [functional safety](#) applications and incorporates the following key features:

- Wide  $V_{IN}$  range of 4V to 42V
- 100% duty cycle capability
- Ultra-low shutdown and no-load standby quiescent currents
- Multi-phase capability
- Peak current-mode control loop architecture with slope compensation
- Integrated, high-current MOSFET gate drivers with adaptive dead-time
- Optional dual-random spread spectrum (DRSS) modulation for lower EMI
- Independent current monitor (IMON), power good (PG) and FAULT indicator outputs on each channel

## 1.2 Kit Contents

- A complete filter board (EVM) rated at 20A on each output, including the LM25137-Q1 buck controller IC
- EVM Disclaimer Read Me

## 1.3 Specifications

Table 1-1 lists the EVM specifications. Unless otherwise indicated,  $V_{IN} = 13.5V$ , which is a typical automotive battery voltage.

**Table 1-1. Electrical Performance Characteristics**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>INPUT CHARACTERISTICS</b>					
Input voltage, $V_{IN}$	Operating range	6.5	13.5	36	V
Input UVLO turn-on threshold, $V_{IN-ON}$	$R_{UV1} = 200k\Omega$ , $R_{UV2} = 36.5k\Omega$		6.5		V
Input UVLO turn-off threshold, $V_{IN-OFF}$			4.5		V
Input supply current, no load, FPWM, $I_{IN-NL(FPWM)}$	$I_{OUT1} = I_{OUT2} = 0A$ , PFM tied to GND	$V_{IN} = 8V$		57	mA
		$V_{IN} = 13.5V$		70	
		$V_{IN} = 24V$		66	
		$V_{IN} = 36V$		56	
Input supply current, no load, PFM, $I_{IN-NL(PFM)}$	$I_{OUT1} = 0A$ , $V_{EN2} = 0V$ , PFM tied to VCC	$V_{IN} = 8V$		10	$\mu A$
		$V_{IN} = 13.5V$		10	
		$V_{IN} = 24V$		10	
		$V_{IN} = 36V$		10	
Input supply current in shutdown, $I_{IN-SHDN}$	$V_{EN1} = V_{EN2} = 0V$		4		$\mu A$
<b>OUTPUT CHARACTERISTICS</b>					
Output voltage, $V_{OUT1}$ <sup>(1)</sup>	FB1 tied to VDDA with 24.9k $\Omega$	4.95	5.0	5.05	V
Output voltage, $V_{OUT2}$ <sup>(1)</sup>	FB2 tied to VDDA with 7.5k $\Omega$	3.27	3.3	3.33	
Output currents, $I_{OUT1}$ , $I_{OUT2}$	$V_{IN} = 6.5V$ to 36V, airflow = 100LFM	0		20	A
Output voltage regulation in FPWM, $\Delta V_{OUT1}$ , $\Delta V_{OUT2}$	Load regulation	$I_{OUT1}$ , $I_{OUT2} = 0A$ to 20A		1	mV
	Line regulation	$V_{IN} = 6.5V$ to 36V		1	
Output voltage ripple, $V_{OUT1-AC}$ , $V_{OUT2-AC}$	$I_{OUT1} = I_{OUT2} = 20A$		10		mV <sub>RMS</sub>
Output overcurrent protection, $I_{OUT1-OC}$ , $I_{OUT2-OC}$	$R_{S1} = R_{S2} = 2m\Omega$		26		A
Soft-start time, $t_{SS}$	$R_{SS} = 20k\Omega$		5		ms
Hiccup time, $t_{RES}$	16384 clock cycles		37		ms
<b>SYSTEM CHARACTERISTICS</b>					
Switching frequency, $F_{SW}$	$R_T = 52.4k\Omega$		440		kHz
Half-load efficiency, $\eta_{HALF}$ <sup>(1)</sup>	$I_{OUT1} = I_{OUT2} = 10A$	$V_{IN} = 8V$		96.5%	
		$V_{IN} = 13.5V$		96%	
		$V_{IN} = 18V$		95.5%	
		$V_{IN} = 24V$		94.5%	
Full-load efficiency, $\eta_{FULL}$	$I_{OUT1} = I_{OUT2} = 20A$	$V_{IN} = 8V$		94%	
		$V_{IN} = 13.5V$		94%	
		$V_{IN} = 18V$		93.5%	
		$V_{IN} = 24V$		93%	
LM25137-Q1 junction temperature, $T_J$		-40		150	$^{\circ}C$

(1) The default output voltages of this EVM are 5V and 3.3V. Efficiency and other performance metrics can change based on the operating input voltage, load currents, externally-connected output capacitors and other parameters.

### 1.3.1 Application Circuit Diagrams

Figure 1-1 shows an LM25137-Q1 synchronous buck regulator (not including the EMI filter stage). Furthermore, as detailed in Figure 1-2, we implement a two-phase, single-output regulator by tying the outputs together, connecting COMP1 to COMP2, shorting FB2 and VSNS2 to AGND, and setting the CNFG resistor to 41.2kΩ.

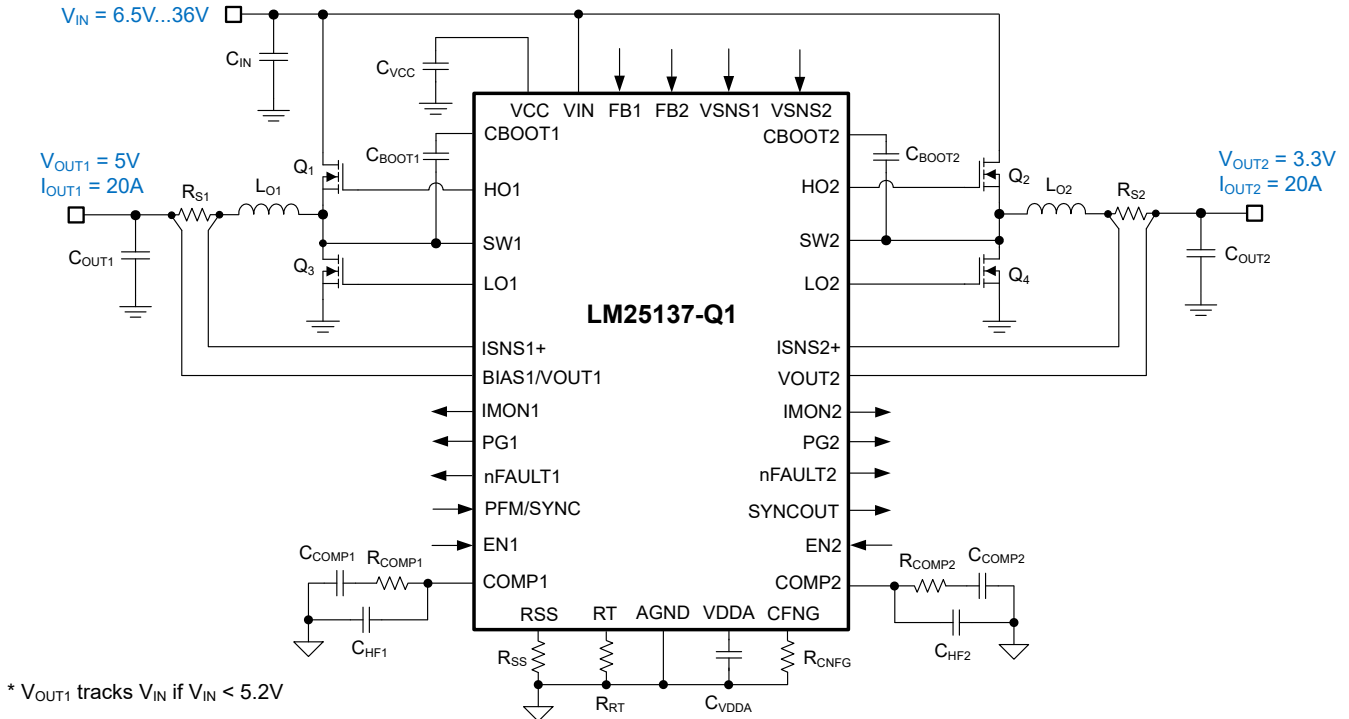


Figure 1-1. LM25137-Q1 Dual-Output Synchronous Buck Regulator Simplified Schematic

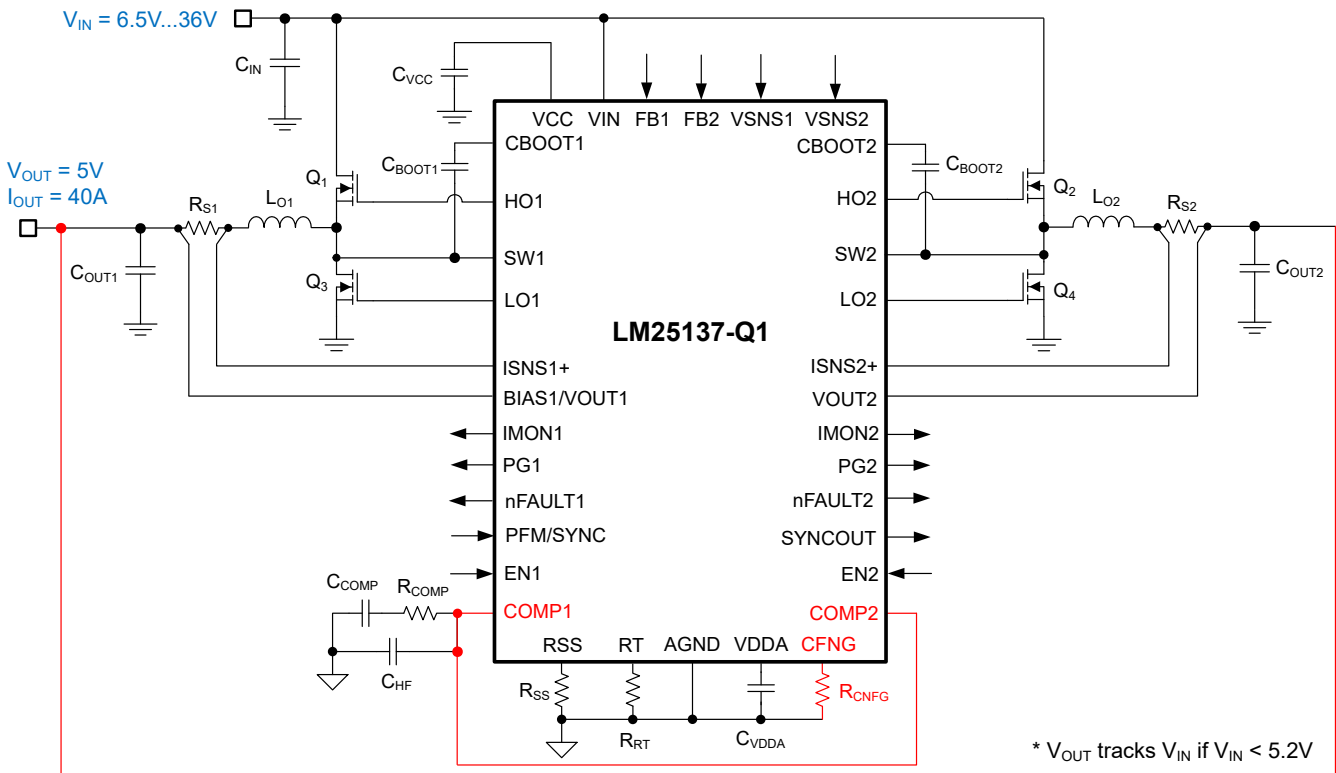


Figure 1-2. LM25137-Q1 Two-Phase Single-Output Synchronous Buck Regulator Simplified Schematic

## 1.4 Device Information

With an input operating voltage as low as 3.5V and up to 100V as specified in [Table 1-2](#), the LM(2)514x-Q1 family of automotive synchronous buck controllers from TI provides flexibility, scalability and optimized solution size for a variety of applications.

With the LM5137-Q1 and LM25137-Q1 now available to aid in functional safety system design up to ASIL D, the controller family enables DC/DC designs with high density, low EMI and increased system reliability. All controllers are rated for a maximum operating junction temperature of 150°C and have AEC-Q100 grade 1 qualification.

**Table 1-2. Automotive Synchronous Buck DC/DC Controller Family**

DC/DC Controller	Single or Dual	V <sub>IN</sub> Range	Control Method	Gate Drive Voltage	Sync Output	Programmable Spread Spectrum
<a href="#">LM5137-Q1</a>	Dual	4V to 80V	Peak current mode	5V	90° phase shift	DRSS (5% or 10%)
<a href="#">LM25137-Q1</a>	Dual	4V to 42V	Peak current mode	5V	90° phase shift	DRSS (5% or 10%)
<a href="#">LM5140-Q1</a>	Dual	3.8V to 65V	Peak current mode	5V	180° phase shift	N/A
<a href="#">LM5141-Q1</a>	Single	3.8V to 65V	Peak current mode	5V	N/A	Triangular
<a href="#">LM25141-Q1</a>	Single	3.8V to 42V	Peak current mode	5V	N/A	Triangular
<a href="#">LM5143A-Q1</a>	Dual	3.5V to 65V	Peak current mode	5V	90° phase shift	Triangular
<a href="#">LM25143-Q1</a>	Dual	3.5V to 42V	Peak current mode	5V	90° phase shift	Triangular
<a href="#">LM5145-Q1</a>	Single	5.5V to 75V	Voltage mode	7.5V	180° phase shift	N/A
<a href="#">LM5146-Q1</a>	Single	5.5V to 100V	Voltage mode	7.5V	180° phase shift	N/A
<a href="#">LM5148-Q1</a>	Single	3.5V to 80V	Peak current mode	5V	180° phase shift	DRSS
<a href="#">LM25148-Q1</a>	Single	3.5V to 42V	Peak current mode	5V	180° phase shift	DRSS
<a href="#">LM5149-Q1</a>	Single	3.5V to 80V	Peak current mode	5V	180° phase shift	DRSS
<a href="#">LM25149-Q1</a>	Single	3.5V to 42V	Peak current mode	5V	180° phase shift	DRSS

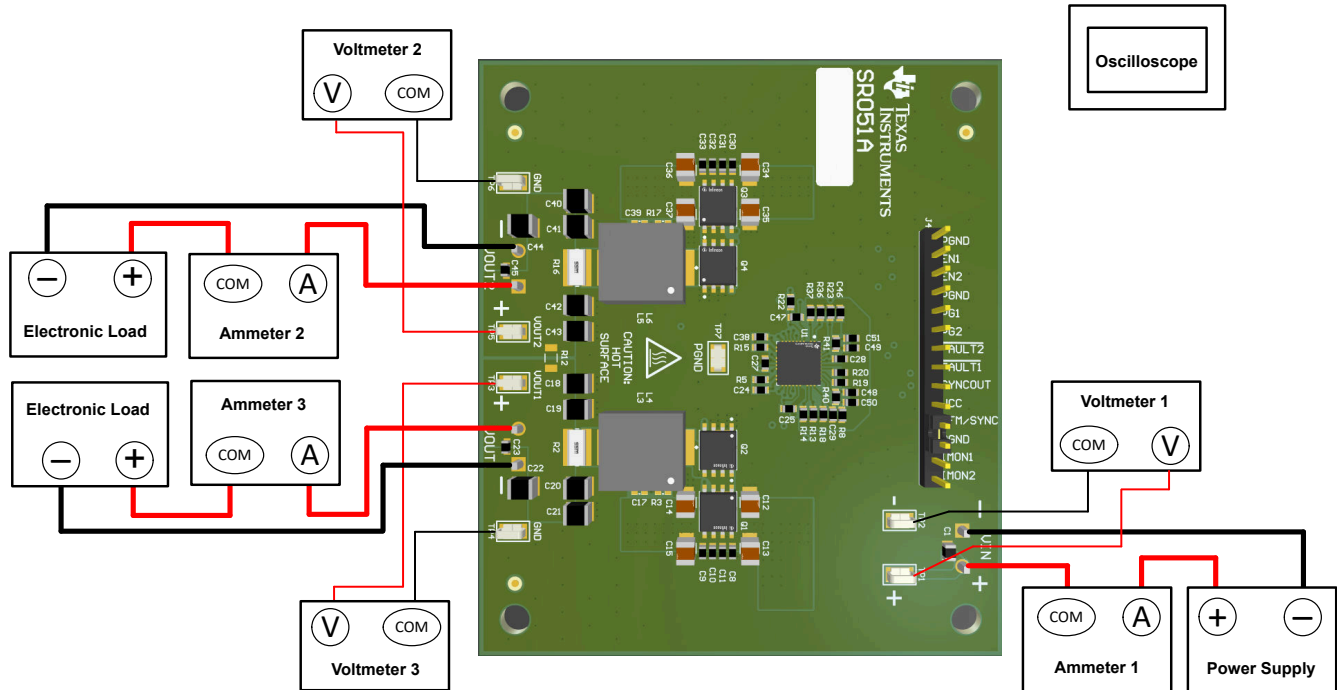
The [LM25137-Q1](#) is available in a 36-pin VQFN package with 6mm × 6mm footprint to enable DC/DC designs with high density and low component count. Use the LM25137-Q1 with [WEBENCH® Power Designer](#) to create a custom regulator design. To optimize component selection and examine predicted efficiency performance across line and load ranges, download the LM(2)5137-Q1 [quickstart calculator](#).

## 2 Hardware

### 2.1 Test Setup and Procedure

#### 2.1.1 EVM Connections

Referencing the EVM connections described in [Table 2-1](#), [Figure 2-1](#) shows the recommended test setup to evaluate the LM25137F-Q1-EVM5D3. Working at an ESD-protected workstation, verify that any wrist straps, boot straps or mats are connected and referencing the user to earth ground before handling the EVM.



**Figure 2-1. EVM Test Setup**

**Table 2-1. EVM Power Connections**

LABEL	DESCRIPTION
VIN	Positive input voltage power and sense connection
GND	Negative input voltage power and sense connection
VOUT1	Channel 1 positive output voltage power and sense connection
VOUT2	Channel 2 positive output voltage power and sense connection
GND	Negative output voltage power and sense connection

**Table 2-2. EVM Signal Connections**

LABEL	DESCRIPTION
PGND	GND connection
EN1, EN2	ENABLE inputs – tie to GND to disable the respective channel
PG1, PG2	Power Good outputs
FAULT1, FAULT2	FAULT outputs
SYNCOUT	Synchronization output
VCC	Bias rail connection
PFM/SYNCIN	Synchronization input
IMON1, IMON2	Current monitor outputs

### CAUTION

Refer to the [LM5137-Q1](#) data sheet, [quickstart calculator](#) and [WEBENCH® Power Designer](#) for additional guidance pertaining to component selection and controller operation.

## 2.1.2 Test Equipment

**Voltage Source:** Use an input voltage source capable of supplying 0V to 36V and 25A.

### Multimeters:

- **Voltmeter 1:** Input voltage at VIN to GND. Set voltmeter to an input impedance of 100M $\Omega$ .
- **Voltmeter 2:** Output voltage at VOUT1 to GND. Set voltmeter to an input impedance of 100M $\Omega$ .
- **Voltmeter 3:** Output voltage at VOUT2 to GND. Set voltmeter to an input impedance of 100M $\Omega$ .
- **Ammeter 1:** Input current. Set ammeter to 1-second aperture time.
- **Ammeter 2:** Output current for channel 1. Set ammeter to 1-second aperture time.
- **Ammeter 2:** Output current for channel 2. Set ammeter to 1-second aperture time.

**Electronic Load:** The load must be an electronic constant-resistance (CR) or constant-current (CC) mode load capable of 0A to 20A at 5V. For a no-load input current measurement, disconnect the electronic load because the load can draw a small residual current.

**Oscilloscope:** With the scope set to 20MHz bandwidth and AC coupling, measure the output voltage ripple directly across an output capacitor with a short ground lead normally provided with the scope probe. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the ground barrel of the probe through the ground lead to the negative terminal of the capacitor. TI does not recommend using a long-leaded ground connection because this can induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed.

**Safety:** Always use caution when touching any circuits that can be live or energized.

## 2.1.3 Recommended Test Setup

### 2.1.3.1 Input Connections

- Prior to connecting the DC input source, set the current limit of the input supply to 0.1A maximum. Make sure the input source is initially set to 0V and connected to the VIN+ and VIN– connection points as shown in [Figure 2-1](#). TI recommends an additional input bulk capacitor to provide damping when using long input lines.
- Connect voltmeter 1 at the VIN+ and VIN– sense points to measure the input voltage.
- Connect ammeter 1 to measure the input current and set to at least 1-second aperture time.

### 2.1.3.2 Output Connections

- Connect electronic loads to VOUT1 and VOUT2 power connections. Set the loads to constant-resistance mode or constant-current mode at 0A before applying input voltage.
- Connect voltmeter 2 at VOUT1 and GND connections to measure the output voltage of channel 1.
- Connect voltmeter 3 at VOUT2 and GND connections to measure the output voltage of channel 2.
- Connect ammeter 2 and ammeter 3 to measure the output currents.

## 2.1.4 Test Procedure

### 2.1.4.1 Line and Load Regulation, Efficiency

- Set up the EVM as described above.
- Set load to constant resistance or constant current mode and to sink 0A.
- Increase input source from 0V to 12V; use voltmeter 1 to measure the input voltage.
- Increase the current limit of the input supply to 25A.
- Using voltmeter 2 to measure the output voltage,  $V_{OUT1}$ , vary the load current from 0A to 20A;  $V_{OUT1}$  must remain within the load regulation specification.
- Using voltmeter 3 to measure the output voltage,  $V_{OUT2}$ , vary the load current from 0A to 20A;  $V_{OUT2}$  needs to remain within the load regulation specification.
- Set the load currents to 10A (50% rated load) and vary the input source voltage from 6.5V to 36V;  $V_{OUT1}$  and  $V_{OUT2}$  must remain within the line regulation specification.
- Decrease the load to 0A. Decrease the input source voltage to 0V.

### 3 Implementation Results

#### 3.1 Test Data and Performance Curves

Figure 3-1 through Figure 3-14 present typical performance curves for the LM25137F-Q1-EVM5D3. Because actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and can differ from actual field measurements.

##### 3.1.1 Efficiency

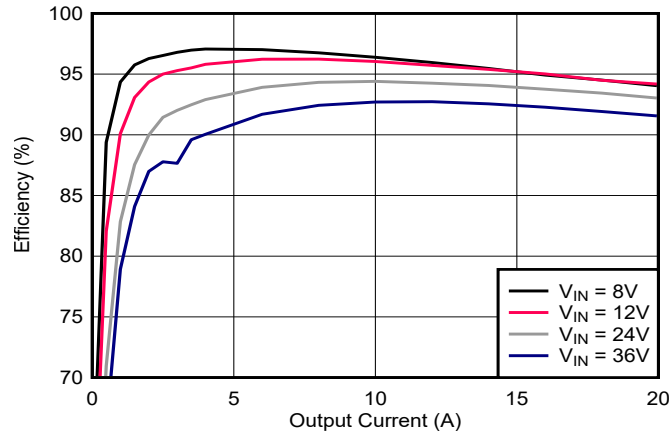


Figure 3-1. Combined Efficiency, V<sub>OUT1</sub> = 5V, V<sub>OUT2</sub> = 3.3V

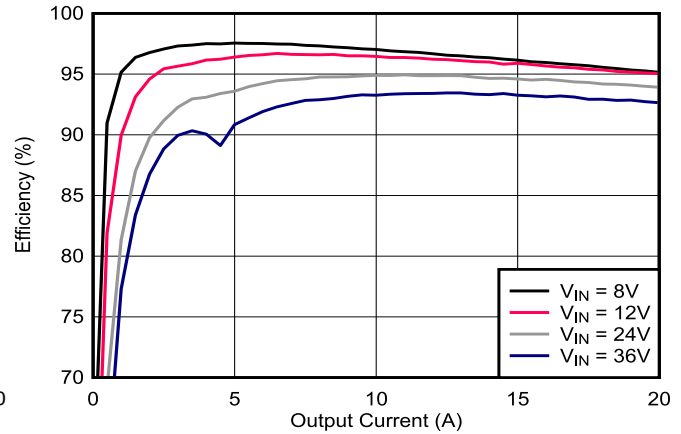


Figure 3-2. Ch1 Efficiency, V<sub>OUT1</sub> = 5V, FPWM, Channel 2 OFF

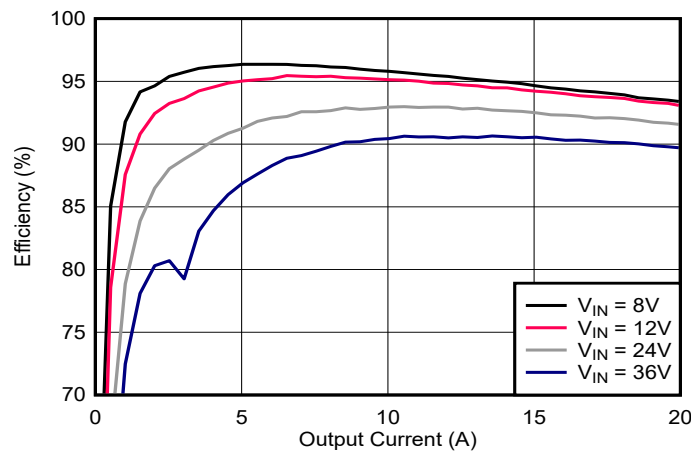


Figure 3-3. Ch2 Efficiency, V<sub>OUT2</sub> = 3.3V, FPWM, Channel 1 OFF

### 3.1.2 Operating Waveforms

#### 3.1.2.1 Load Transient Response

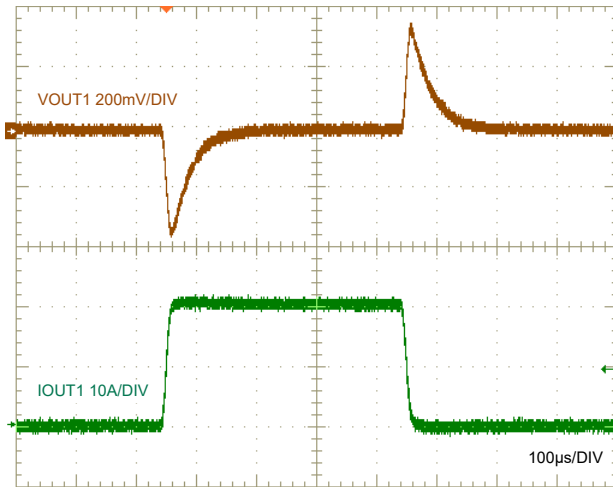


Figure 3-4. Ch1 (5V) Load Transient Response,  $V_{IN} = 12V$ , FPWM, 0A to 20A at 2A/ $\mu s$

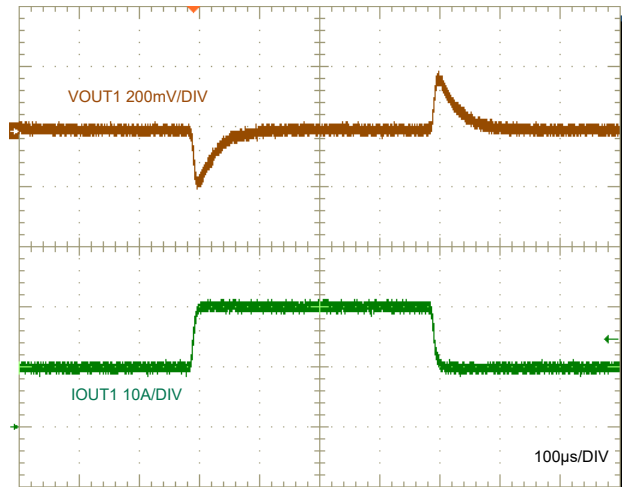


Figure 3-5. Ch1 (5V) Load Transient Response,  $V_{IN} = 12V$ , FPWM, 10A to 20A at 2A/ $\mu s$

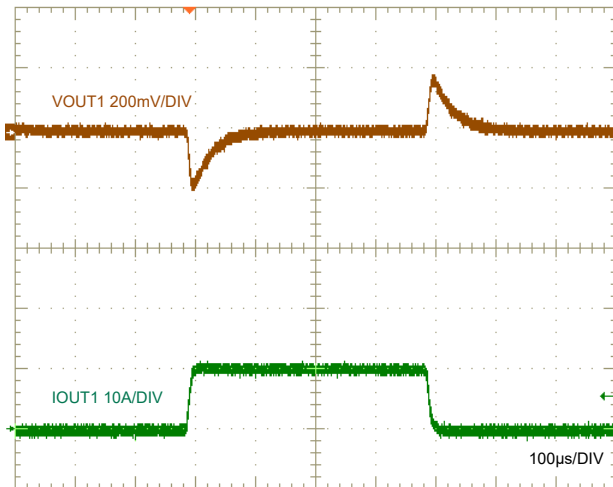


Figure 3-6. Ch1 (5V) Load Transient Response,  $V_{IN} = 12V$ , FPWM, 0A to 10A at 2A/ $\mu s$

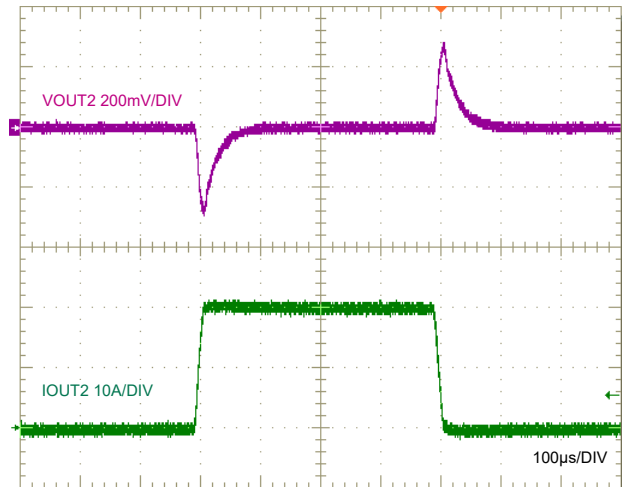


Figure 3-7. Ch2 (3.3V) Load Transient Response,  $V_{IN} = 12V$ , FPWM, 0A to 20A at 2A/ $\mu s$

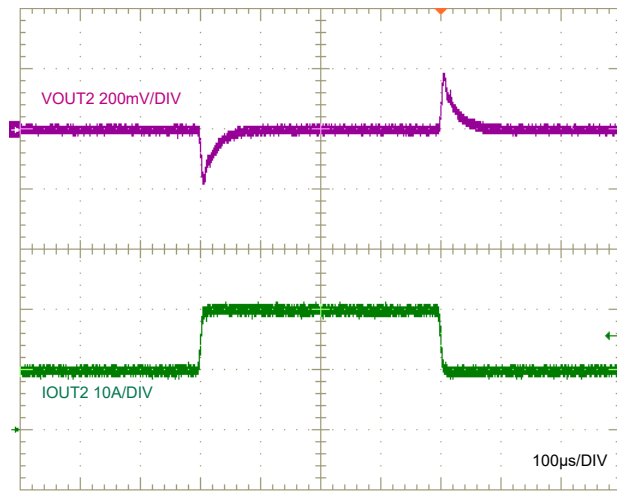


Figure 3-8. Ch2 (3.3V) Load Transient Response,  $V_{IN} = 12V$ , FPWM, 10A to 20A at 2A/ $\mu$ s

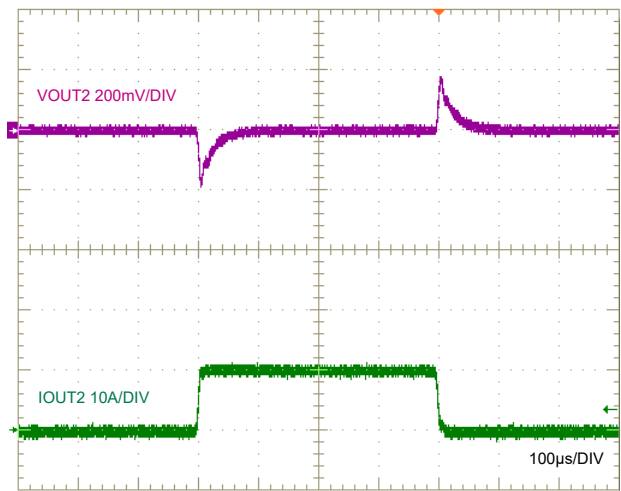


Figure 3-9. Ch2 (3.3V) Load Transient Response,  $V_{IN} = 12V$ , FPWM, 0A to 10A at 2A/ $\mu$ s

### 3.1.2.2 Startup/Shutdown With $V_{IN}$

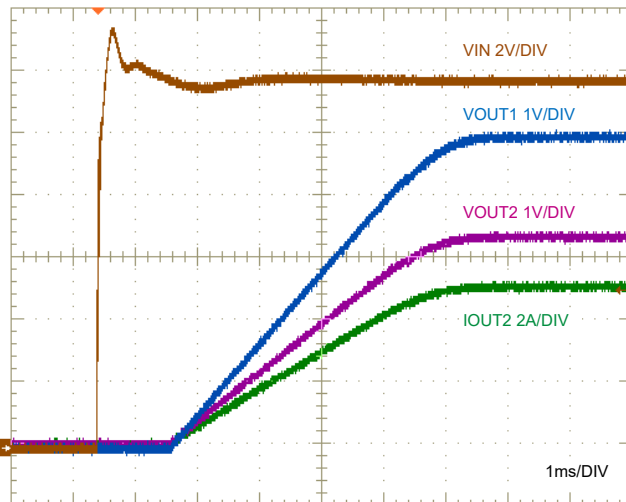


Figure 3-10. Startup Characteristic,  $V_{IN}$  Stepped to 12V,  $I_{OUT1} = I_{OUT2} = 5A$  Resistive,  $R_{SS} = 20k\Omega$

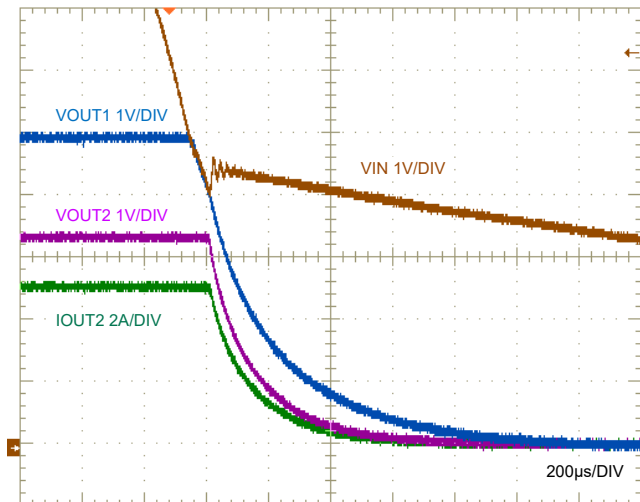


Figure 3-11. Shutdown Characteristic,  $V_{IN} = 12V$ ,  $I_{OUT1} = I_{OUT2} = 5A$  Resistive

### 3.1.2.3 Startup/Shutdown With ENABLE ON and OFF

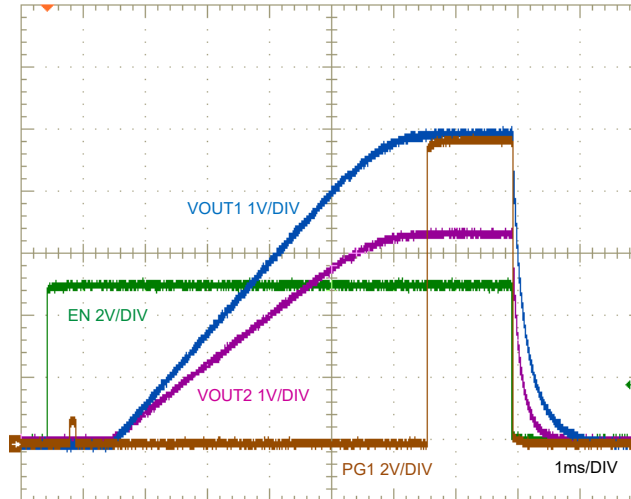


Figure 3-12. ENABLE ON and OFF,  $V_{IN} = 12V$ ,  $I_{OUT1} = I_{OUT2} = 5A$  Resistive,  $R_{SS} = 20k\Omega$

### 3.1.2.4 Switching

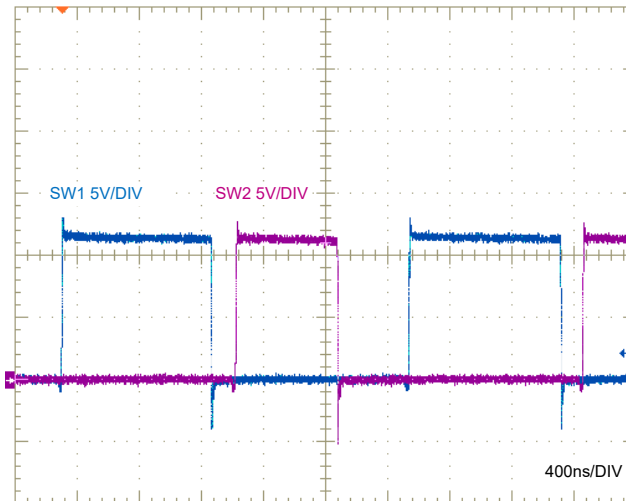


Figure 3-13. Switch-node Voltages,  $V_{IN} = 12V$ ,  $I_{OUT1} = I_{OUT2} = 10A$

### 3.1.3 Thermal Performance

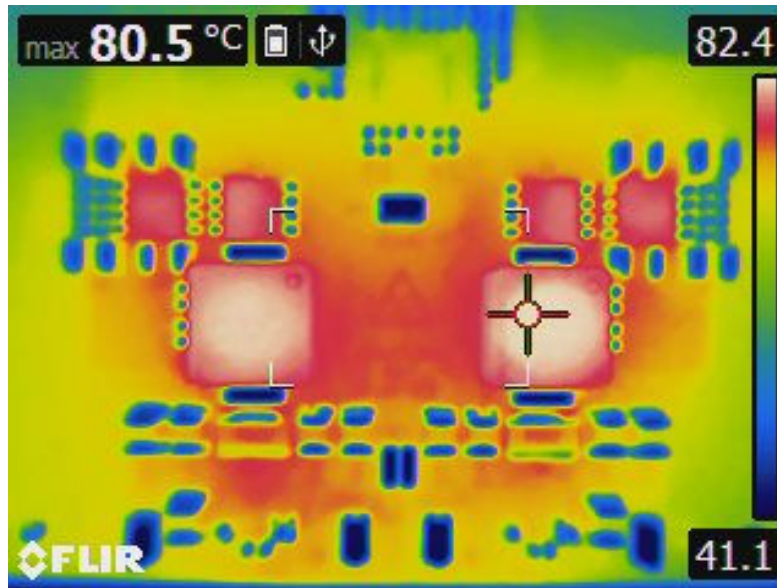


Figure 3-14. Thermal Performance,  $V_{IN} = 12V$ ,  $I_{OUT1} = I_{OUT2} = 15A$ , Free Convection Airflow

## 4 Hardware Design Files

For development support see the following:

- LM(2)5137-Q1 [quickstart calculator](#)
- LM25137F-Q1-EVM5D3 [Altium layout source files](#)
- LM5137-Q1 PSPICE for TI and SIMPLIS [simulation models](#)
- For TI's reference design library, visit [TI Reference Design library](#)
- To design a low-EMI power supply, review TI's comprehensive [EMI Training Series](#)
- Application Note:
  - [Improve High-current DC/DC Regulator EMI Performance for Free With Optimized Power Stage Layout](#)

## 4.1 Schematic

Figure 4-1 provides the EVM schematic.

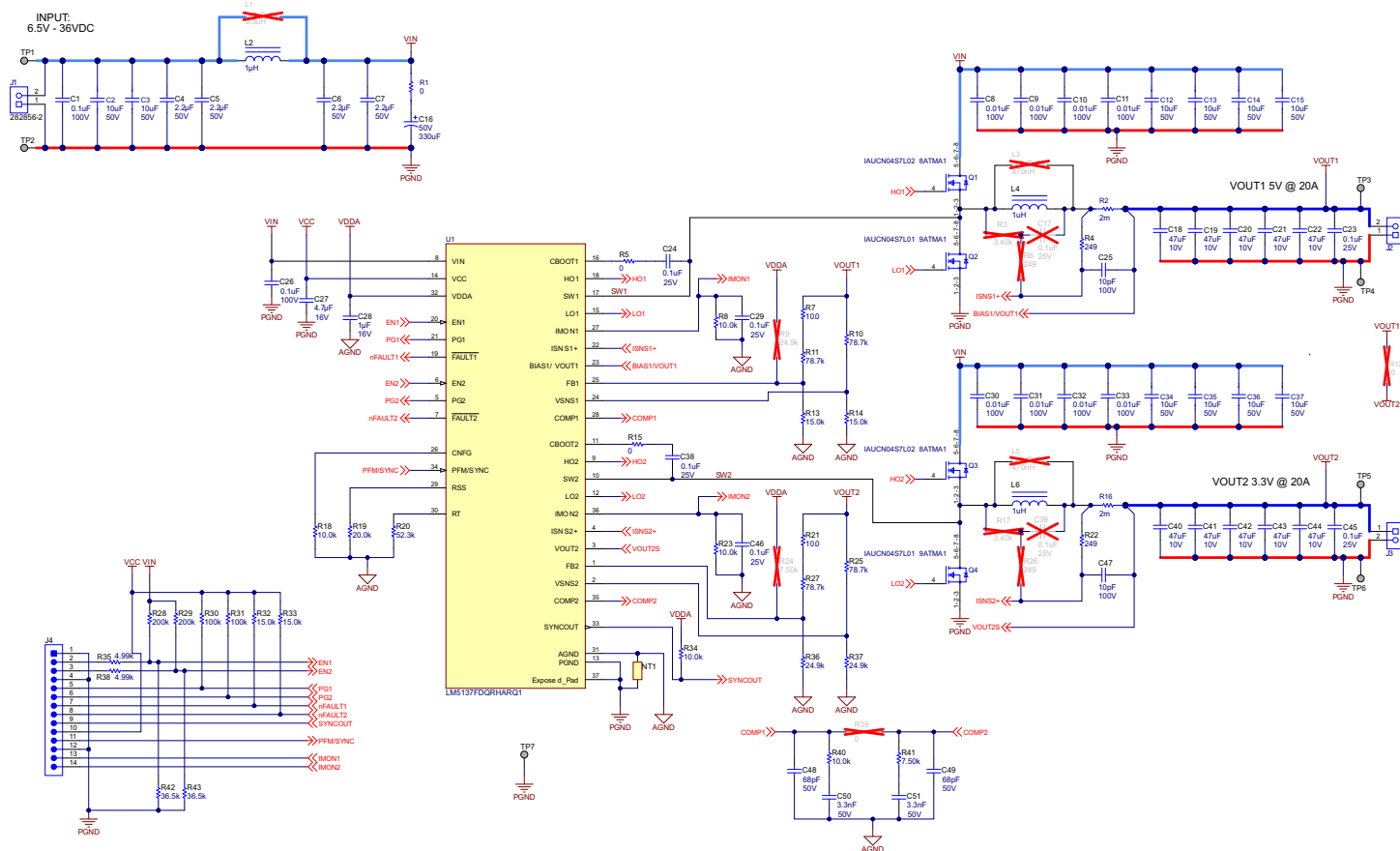


Figure 4-1. EVM Schematic

## 4.2 PCB Layout

Figure 4-2 through Figure 4-9 show the design of the EVM using a 6-layer PCB with 2-oz copper thickness. The EVM is essentially a single-sided design except for certain input filtering and small-signal components located on the bottom side.

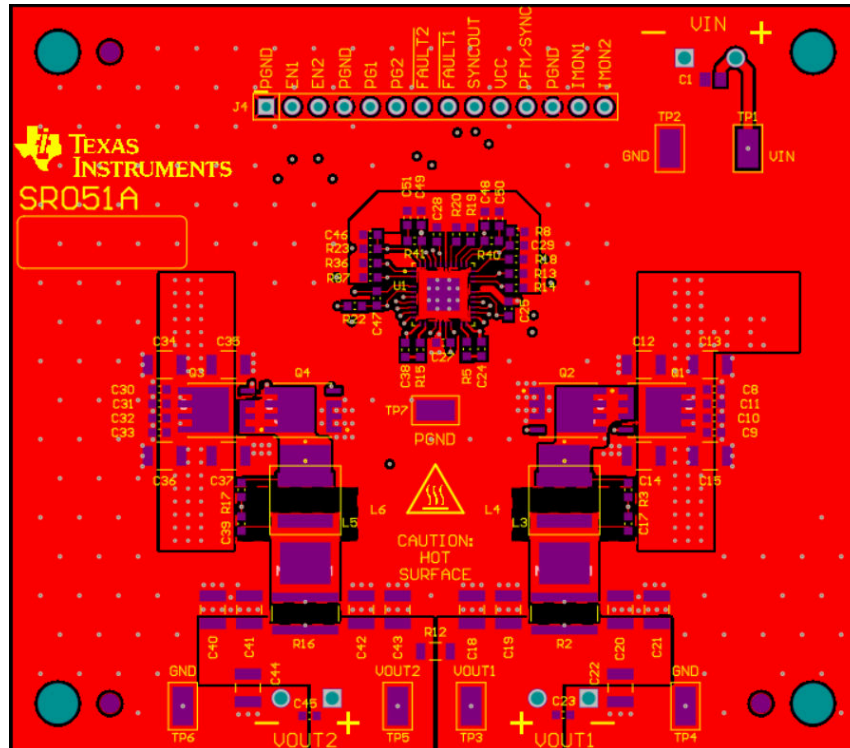


Figure 4-2. Top Copper (Top View)

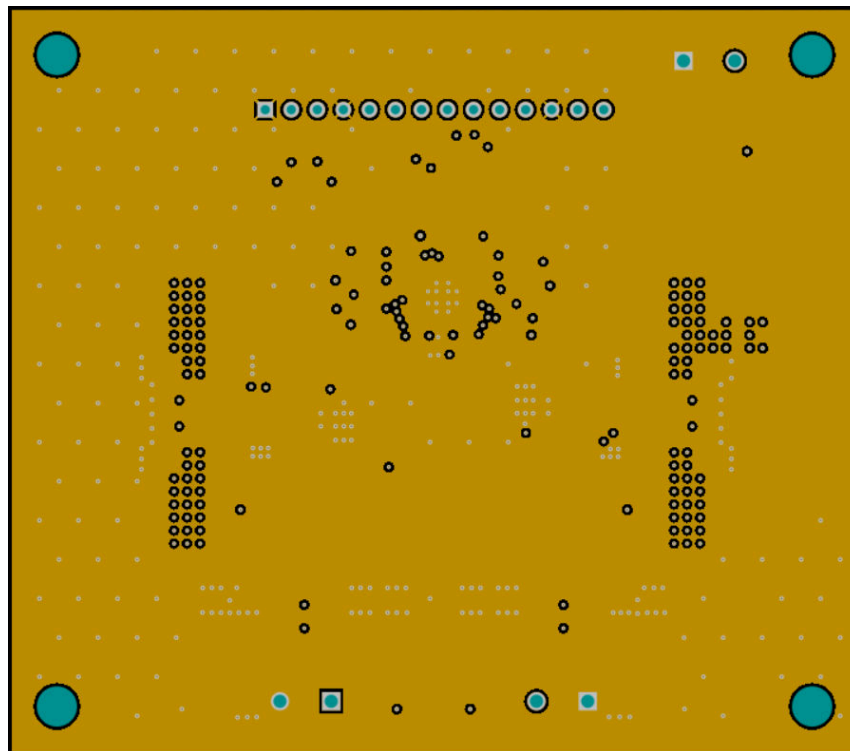


Figure 4-3. Layer 2 Copper (Top View)

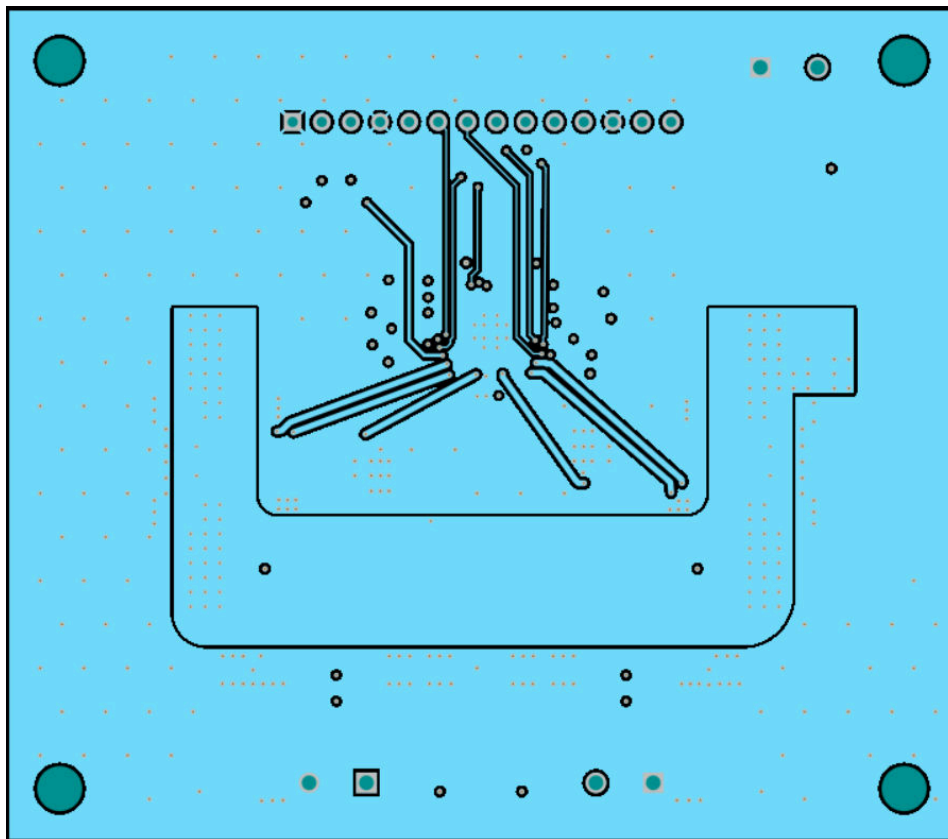


Figure 4-4. Layer 3 Copper (Top View)

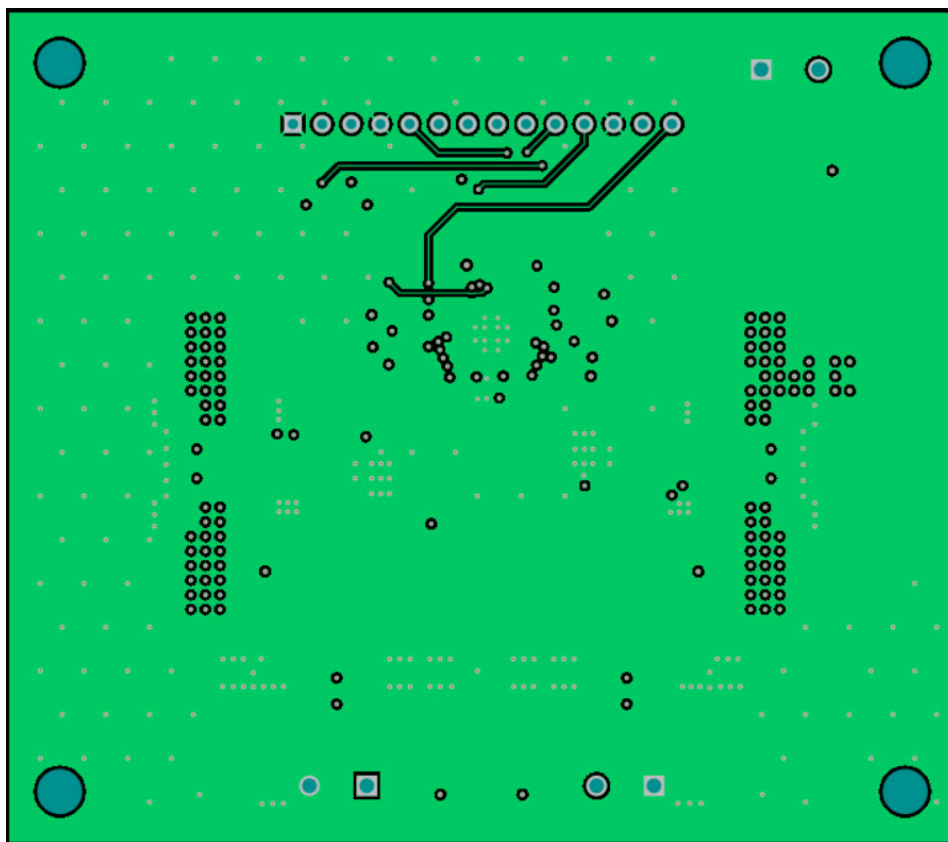


Figure 4-5. Layer 4 Copper (Top View)

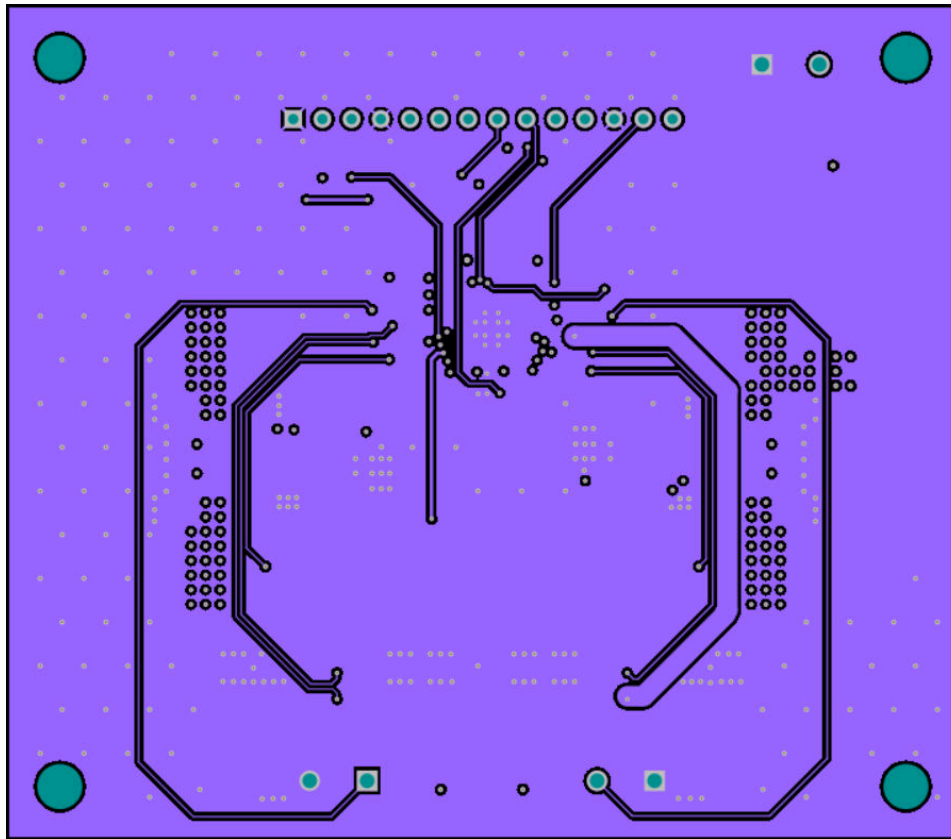


Figure 4-6. Layer 5 Copper (Top View)

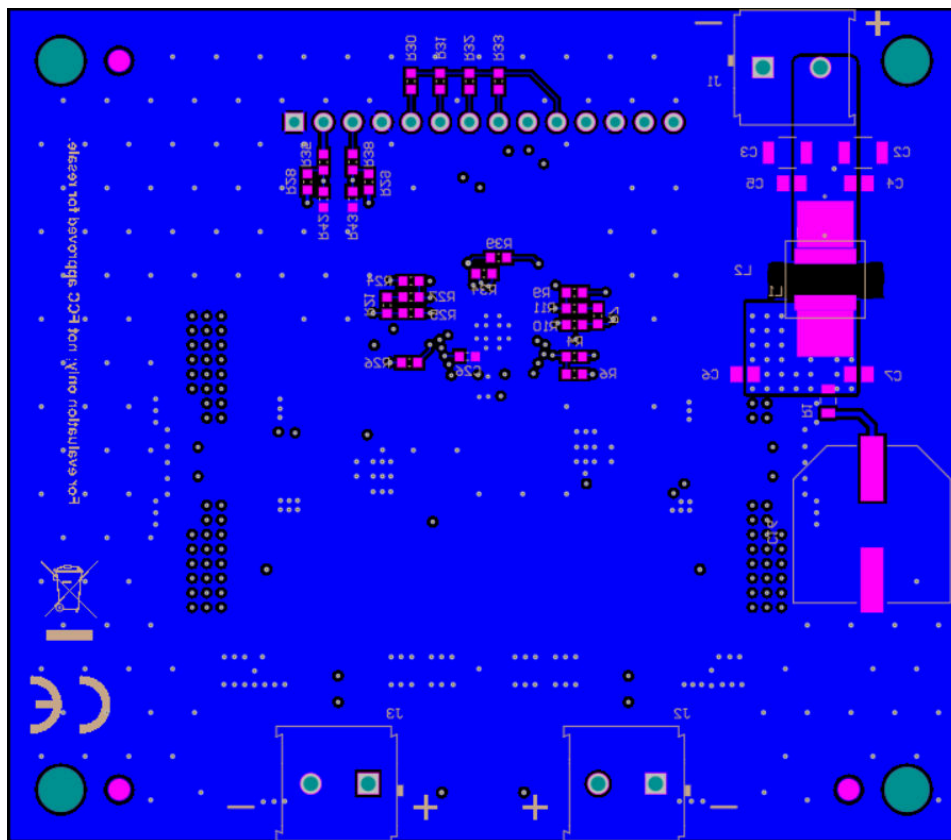


Figure 4-7. Bottom Copper (Top View)

### 4.2.1 Component Drawings

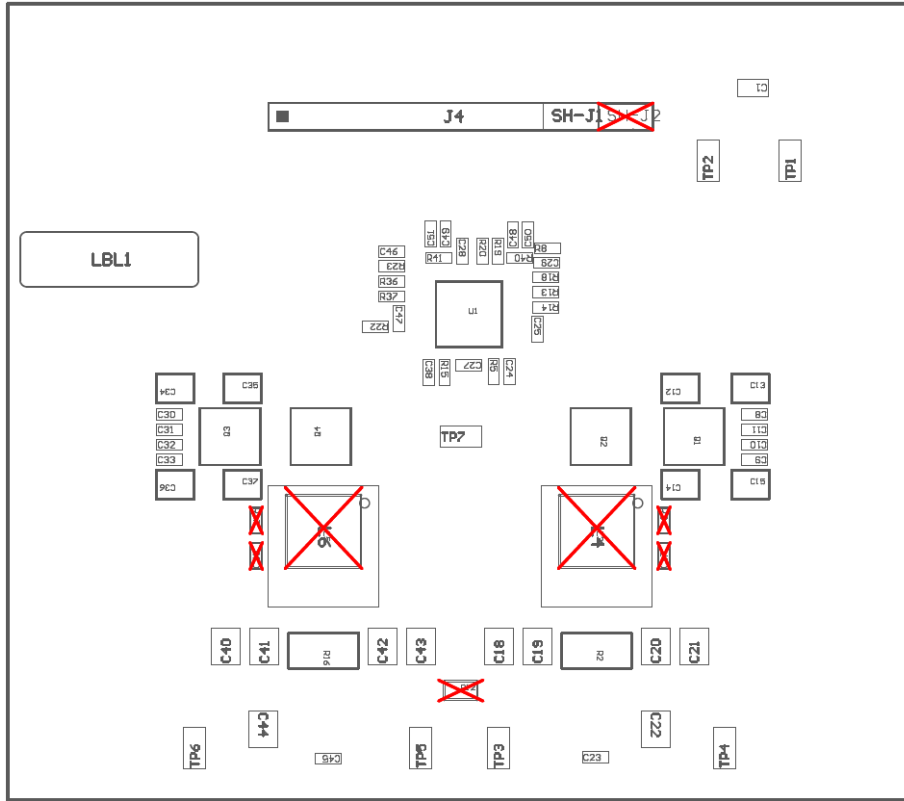


Figure 4-8. Top Component Drawing

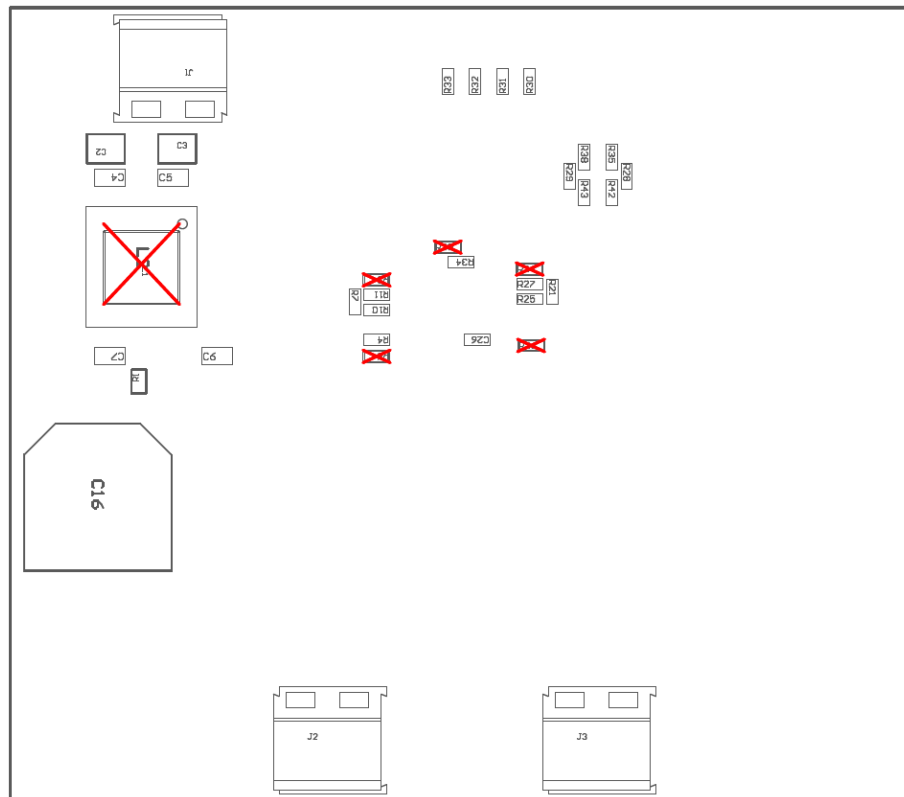


Figure 4-9. Bottom Component Drawing

### 4.3 Bill of Materials

**Table 4-1. Bill of Materials**

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	C1	Capacitor, ceramic, 0.1μF, 100V, X7R, 0805	Std	Std
10	C2, C3, C12, C13, C14, C15, C34, C35, C36, C37	Capacitor, ceramic, 10μF, 50V, X7S, 1210, AEC-Q200	GCM32EC71H106KA03L	Murata
		Capacitor, ceramic, 10μF, 50V, X7R, 1210, AEC-Q200	CNA6P1X7R1H106K250AE	TDK
4	C4, C5, C6, C7	Capacitor, ceramic, 2.2μF, 50V, X7R, 0805, AEC-Q200	CGA4J3X7R1H225K125AE	TDK
8	C8, C9, C10, C11, C30, C31, C32, C33	Capacitor, ceramic, 10nF, 100V, X7R, 0603	GRM188R72A103KA01D	Murata
1	C16	Capacitor, electrolytic, 330μF, 50V, AEC-Q200	EEV-FK1H331Q	Panasonic
10	C18, C19, C20, C21, C22, C40, C41, C42, C43, C44	Capacitor, ceramic, 47μF, 10V, X7R, 1210, AEC-Q200	GRM32ER71A476KE15L	Murata
6	C23, C24, C29, C38, C45, C46	Capacitor, ceramic, 0.1μF, 25V, X7R, 0603	Std	Std
1	C26	Capacitor, ceramic, 0.1μF, 100V, X7R, 0603	Std	Std
1	C27	Capacitor, ceramic, 4.7μF, 16V, X7R, 0603	Std	Std
1	C28	Capacitor, ceramic, 1μF, 16V, X7R, 0603	Std	Std
2	C48, C49	Capacitor, ceramic, 68pF, 50V, C0G, 5%, 0603	Std	Std
2	C50, C51	Capacitor, ceramic, 3.3nF, 50V, X7R, 10%, 0603	Std	Std
4	H1, H2, H3, H4	Hex standoff threaded #4-40 nylon 0.750", 3/4" natural	1902D	Keystone
4	H5, H6, H7, H8	#4-40 pan head machine screw Phillips drive nylon	NY PMS 440 0038 PH	Building Fasteners
3	J1, J2, J3	Terminal block, 5mm, 2-pole, tin, TH	282856-2	TE Connectivity
1	J4	Header, 100mil, 14 × 1, Gold, TH	TSW-114-07-G-S	Samtec
3	L2, L4, L6	Inductor, 1μH, 37A, 2.3mΩ, AEC-Q200	VCHA105D-1R0MS6	Cyntec
		Inductor, 1μH, 33.8A, 2.7mΩ, AEC-Q200	784373680010	Würth Elektronik
2	Q1, Q3	MOSFET, N-channel, 40V, 2.8mΩ, AEC-Q101	IAUCN04S7L028ATMA1	Infineon
2	Q2, Q4	MOSFET, N-channel, 40V, 1.9mΩ, AEC-Q101	IAUCN04S7L019ATMA1	Infineon
1	R1	Resistor, 0Ω, 0805	Std	Std
1	R2, R16	Resistor, 2mΩ, 3W, 2%, 1225, AEC-Q200	KRL6432E-M-R002-G-T1	Susumu
2	R4, R22	Resistor, 249Ω, 1/10W, 1%, 0603	Std	Std
2	R5, R15	Resistor, 0Ω, 1/10W, 1%, 0603	Std	Std
2	R7, R21	Resistor, 10Ω, 1/10W, 1%, 0603	Std	Std
5	R8, R18, R23, R30, R40	Resistor, 10kΩ, 1/10W, 1%, 0603	Std	Std
4	R10, R11, R25, R27	Resistor, 78.7kΩ, 1/10W, 1%, 0603	Std	Std
4	R13, R14, R32, R33	Resistor, 15kΩ, 1/10W, 1%, 0603	Std	Std
1	R19	Resistor, 20kΩ, 1/10W, 1%, 0603	Std	Std
1	R20	Resistor, 52.3kΩ, 1/10W, 1%, 0603	Std	Std
2	R28, R29	Resistor, 200kΩ, 1/10W, 1%, 0603	Std	Std
2	R30, R31	Resistor, 100kΩ, 1/10W, 1%, 0603	Std	Std
2	R12, R15	Resistor, 49.9Ω, 1/10W, 1%, 0603	Std	Std
2	R35, R38	Resistor, 4.99kΩ, 1/10W, 1%, 0603	Std	Std
2	R36, R37	Resistor, 24.9kΩ, 1/10W, 1%, 0603	Std	Std
1	R41	Resistor, 7.5kΩ, 1/10W, 1%, 0603	Std	Std
2	R42, R43	Resistor, 36.5kΩ, 1/10W, 1%, 0603	Std	Std
7	TP1, TP2, TP3, TP4, TP5, TP6, TP7	Test point, miniature, SMT	5019	Keystone
1	U1	IC, LM5137-Q1, 80V dual synchronous buck controller, VQFN-36	LM5137FDQRHARQ1	TI
1	PCB1	PCB, FR4, 6 layer, 2oz, 84mm × 74mm	PCB	–

## 5 Additional Information

### 5.1 Trademarks

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## 6 Device and Documentation Support

### 6.1 Device Support

#### 6.1.1 Development Support

For development support see the following:

- For TI's reference design library, visit [TI Designs](#)
- For TI's WEBENCH design environments, visit the [WEBENCH® Design Center](#)
- LM(2)5137-Q1 DC/DC controller [quickstart calculator](#) and [PSPICE](#) simulation models

### 6.2 Documentation Support

#### 6.2.1 Related Documentation

For related documentation see the following:

- [LM5137-Q1 Data Sheet](#) (SNVSC69)
- [LM5143-Q1 4-Phase Buck Regulator Design](#) (SNVA870)
- [Improve High-current DC/DC Regulator Performance for Free with Optimized Power Stage Layout](#) (SNVA803)
- [Reduce Buck Converter EMI and Voltage Stress by Minimizing Inductive Parasitics](#) (SLYT682)
- [AN-2162 Simple Success with Conducted EMI from DC-DC Converters](#) (SNVA489)
- White Papers:
  - [Valuing Wide  \$V\_{IN}\$ , Low EMI Synchronous Buck Circuits for Cost-driven, Demanding Applications](#) (SLYY104)
  - [An Overview of Conducted EMI Specifications for Power Supplies](#) (SLYY136)
  - [An Overview of Radiated EMI Specifications for Power Supplies](#) (SLYY142)

#### 6.2.1.1 PCB Layout Resources

- [Improve High-Current DC/DC Regulator EMI Performance for Free With Optimized Power Stage Layout](#) (SNVA803)
- [AN-1149 Layout Guidelines for Switching Power Supplies](#) (SNVA021)
- [AN-1229 Simple Switcher PCB Layout Guidelines](#) (SNVA054)
- [Constructing Your Power Supply – Layout Considerations](#) (SLUP230)
- [Low Radiated EMI Layout Made SIMPLE with LM4360x and LM4600x](#) (SNVA721)

#### 6.2.1.2 Thermal Design Resources

- [AN-2020 Thermal Design by Insight, Not Hindsight](#) (SNVA419)
- [AN-1520 A Guide to Board Layout for Best Thermal Resistance for Exposed Pad Packages](#) (SNVA183)
- [Semiconductor and IC Package Thermal Metrics](#) (SPRA953)
- [Thermal Design Made Simple with LM43603 and LM43602](#) (SNVA719)
- [PowerPAD Thermally Enhanced Package](#) (SLMA002)
- [PowerPAD Made Easy](#) (SLMA004)
- [Using New Thermal Metrics](#) (SBVA025)

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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.
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  - 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 DEGRADATION 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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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.

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2. 実験局の免許を取得後ご使用いただく。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see [http://www.tij.co.jp/lstds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page)

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#### 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.
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8. *Limitations on Damages and Liability:*

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8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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