EVM User's Guide: LM5169FEVM

LM5169FNGUR Evaluation Module

Description

The LM5169FEVM is a fly-buck regulator that utilizes the LM5169FNGUR to produce a regulated 10V output capable of supplying a 300mA load on the primary side of the transformer with a switching frequency of 750kHz. A reflected output of 10V, providing up to 300mA, is available on the secondary side of the transformer. The LM5169FNGUR is a synchronous buck converter with a wide input voltage range, integrated power MOSFETs, overcurrent protection and precision enable.

Get Started

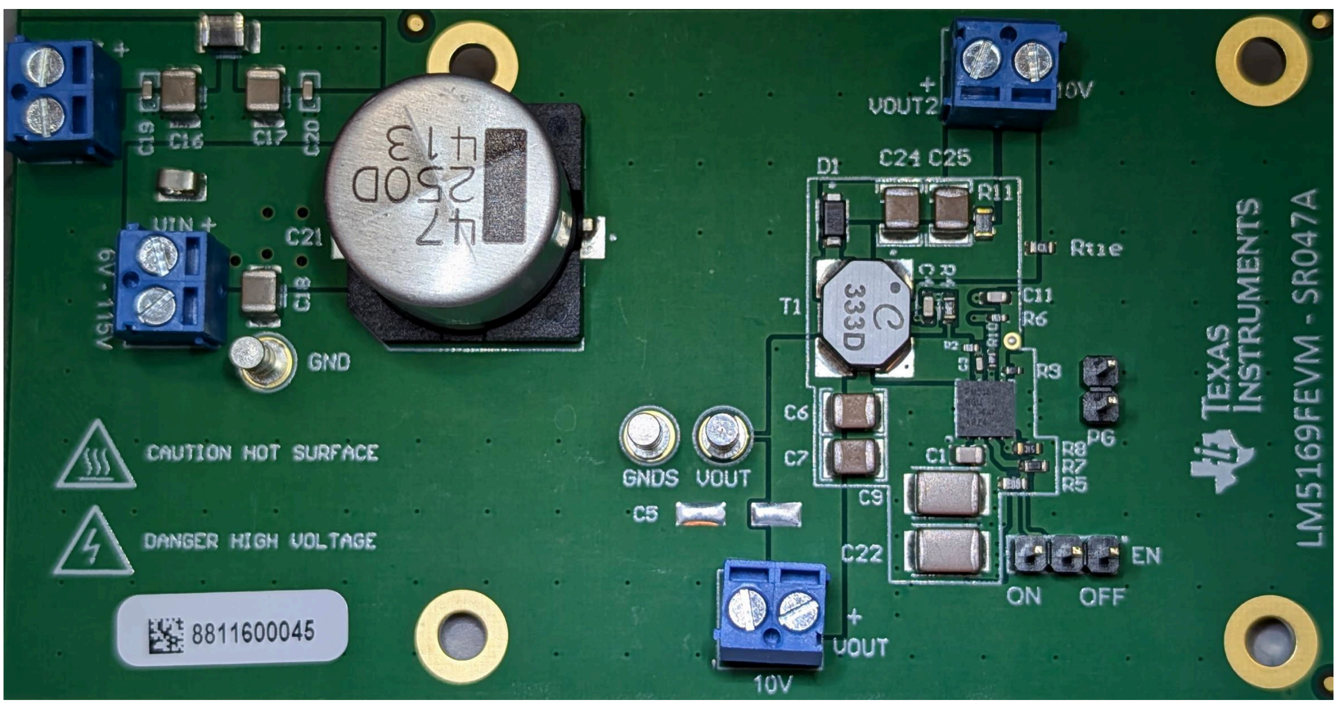
1. Order the LM5169FEVM from ti.com.
2. Carefully review the user's guide.
3. Set up the EVM as detailed in the user's guide.
4. Test and measure performance.

Features

- Wide input voltage range from 20V to 115V
- Fixed 3ms soft start
- COT mode control architecture
- Peak and valley current-limit protection
- FPWM mode for fly-buck capability
- WSON package for small solution-size

Applications

- Communications - brick power module
- Industrial battery pack (≥10 S)
- Battery pack - e-bike, e-scooter, LEV
- Factory automation - PLC
- Motor drives - BLDC
- Grid infrastructure - solar



LM5169FEVM

1 Evaluation Module Overview

1.1 Introduction

The LM5169FEVM is configured to deliver a regulated 10V output, with 0.3A at 750kHz switching frequency, and an additional 10V floating output also capable of 0.3A. The LM5169 uses a COT control architecture, with input voltage feedforward to provide a constant frequency regulator with tightly regulated output voltage. This type of control requires adequate voltage ripple at the FB input to achieve stable regulation. The LM5169FEVM is set up with type III ripple injection to minimize the output voltage ripple while making sure there is a stable regulator. The LM5169FEVM also provides the option to use type I or type II ripple injection. See the *LM516x, 0.65A/0.3A, 120V Absolute Maximum, Step-Down Converter With Fly-Buck™ Converter Capability* data sheet for more information. An overall view of the LM5169FEVM and the schematic are shown in Figure 2-1 and Figure 4-1, respectively. While the board is optimized for the LM5169FNGUR, there are component pads which can make the board compatible with the LM5017 to evaluate design changes when replacing the device with the LM5169.

1.2 Kit Contents

Table 1-1 lists the contents of the EVM kit. Contact the TI Product Information Center at (972) 644-5580 if any component is missing.

Table 1-1. EVM Contents

Item	Quantity
LM5169FEVM	1

1.3 Specification

A simplified schematic for the LM5169FEVM is shown in Figure 1-1, and the EVM specifications are listed in Table 3-1.

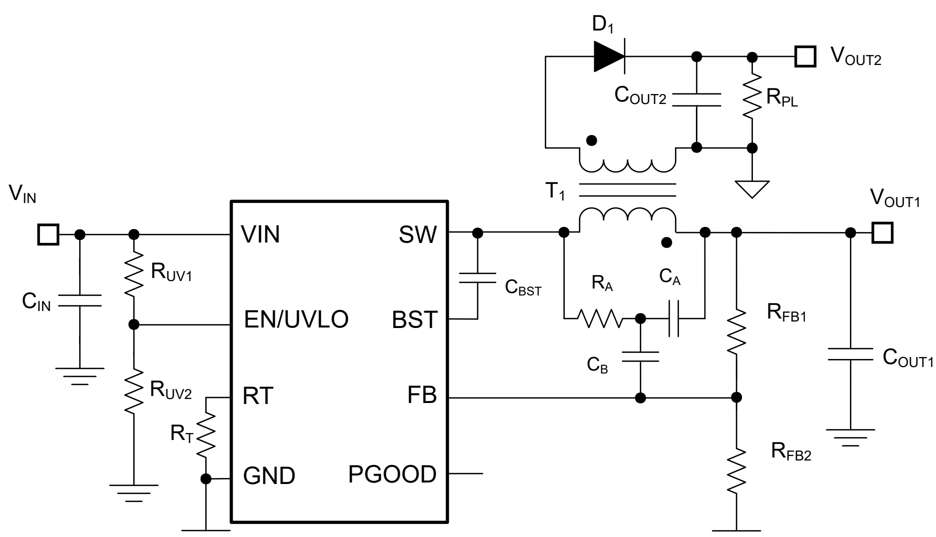


Figure 1-1. LM5169F Fly-Buck Simplified Schematic

1.4 Device Information

Table 1-2. EVM Configuration

EVM	CONVERTER IC	PACKAGE
LM5169FEVM	LM5169FNGUR	8-pin NGU package with PowerPAD (4.0mm × 4.0mm)

1.5 General TI High Voltage Evaluation User Safety Guidelines

WARNING

Always follow TI's set-up and application instructions, including use of all interface components within the recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center http://support.ti.com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions can result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open-framed, unenclosed printed-circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

- **Work Area Safety:**
  - Maintain a clean and orderly work area.
  - A qualified observer or observers must be present any time circuits are energized.
  - Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
  - All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding $50V_{RMS}$/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
  - Use a stable and non-conductive work surface.
  - Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
- **Electrical Safety:**

  As a precautionary measure, a good engineering practice to assume that the entire EVM can have fully accessible and active high voltages.

  - De-energize the TI HV EVM and all the inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
  - With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
  - When EVM readiness is complete, energize the EVM as intended.

WARNING

WARNING: While the EVM is energized, never touch the EVM or the electrical circuits as the EVM or the electrical circuits can be at high voltages capable of causing electrical shock hazard.

- **Personal Safety:**
  – Wear personal protective equipment, for example, latex gloves, safety glasses with side shields, or both, or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.
- **Limitation for Safe Use:**
  – EVMs are not to be used as all or part of a production unit.

Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training, and is designed to operate from an AC power supply or a high-voltage DC supply. Please read this user's guide and the safety-related documents that come with the EVM package before operating this EVM.

CAUTION

Do not leave the EVM powered when unattended.

WARNING

Hot surface! Contact can cause burns. Do not touch!

WARNING

High Voltage! Electric shock is possible when connecting board to live wire. Board needs to be handled with care by a professional.
For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

2 Hardware

2.1 Quick Start Procedure

1. Connect the input voltage supply to the VIN connector (+ and –).
2. Connect the load or loads to the VOUT and the VOUT2 connectors (+ and –).
3. Set the input supply voltage to an appropriate level between 20V to 115V.
4. Turn on the power supply. The EVM powers up and provides V_{OUT} = 10V, and V_{OUT2} = 10V.

See Figure 2-3 for the location of the connectors.

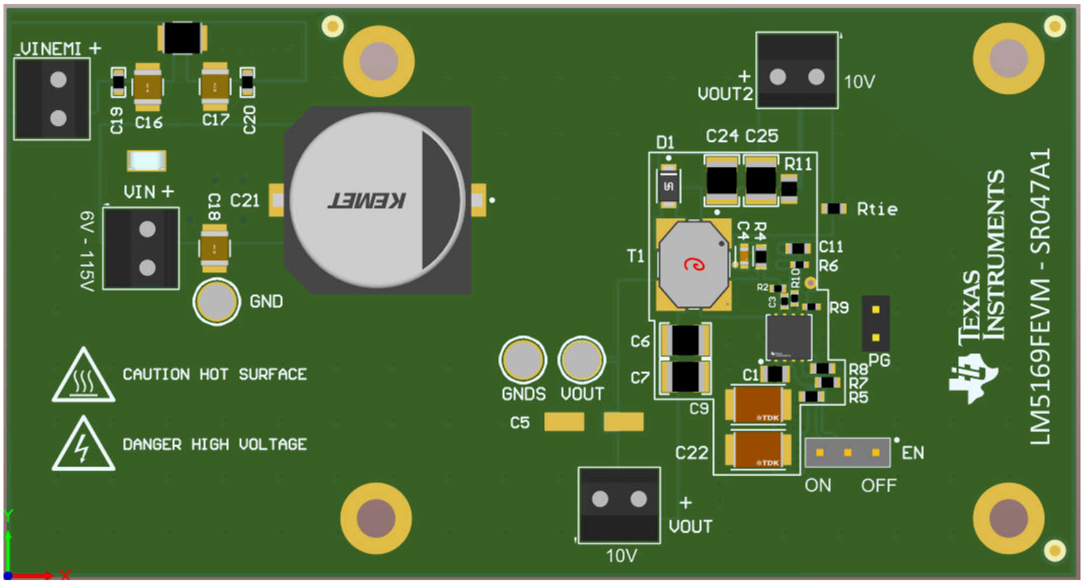


Figure 2-1. LM5169FEVM (Top View)

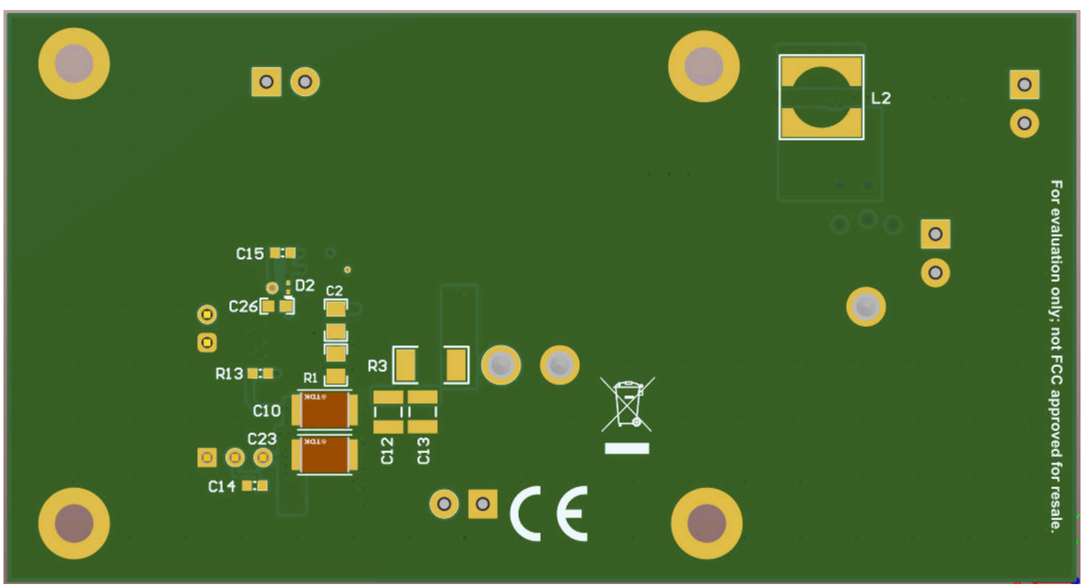


Figure 2-2. LM5169FEVM (Bottom View)

2.2 Detailed Descriptions

This section describes the connectors and the test points on the EVM and how to properly connect, set up, and use the LM5169FEVM. See Figure 2-3 for the location of connectors and jumpers.

VOUT Output voltage of the converter

VOUT screw terminal connector. Apply load to this connector (+ and –). The VOUT test point is used to monitor output voltage.

VOUT2 Secondary output voltage of the converter

VOUT2 screw terminal connector. One side of this output is connected to the primary ground (GND) through a tie resistor, R_{tie} (R12). This resistor can be removed for a true floating voltage source. Apply load to this connector (+ and –).

GND Ground of the converter

GND and GNDS test points. Used as ground test points for the EVM.

VIN Input voltage to the converter

VIN screw terminal connector. Apply input voltage to this connector (+ and –). The VIN test point is used to monitor input voltage.

VINEMI Input voltage to input filter of the converter

If this is desired to use the built-in EMI filter on the EVM, then connect the input supply to the VINEMI screw terminal connector (+ and –).

Input Filter EMI mitigation

An input EMI filter is provided on the EVM. Note L2 and C18 are not populated and must be installed for the EMI filter to operate. Also, note that the maximum input voltage to the filter is $100V_{DC}$.

EN/UVLO Jumper Set EN/UVLO pin options

Use this jumper to enable and disable the EVM. The resistors connected to this pin set the input UVLO thresholds. Input UVLO thresholds are set to approximately 6V and 5.6V. These levels can be changed by changing the values of R5 and R7. For external control of the device, these resistors must be removed and the control signal applied to the center pin of the header. Note that for accurate shutdown current measurement, these resistors must also be removed and the EN input (center pin) grounded.

1. Jumper open (default setup): Device starts up and shuts down with UVLO.
2. Center pin connected to *ON*: Device starts up and shuts down without UVLO.
3. Center pin connected to *OFF*: Device is off.

PGOOD The PGOOD header used as a test point to monitor the power-good indicator. This flag indicates whether the output voltage has reached the regulation level. PGOOD is an open-drain output that is tied to V_{OUT} through a 100kΩ, resistor R_{10}.

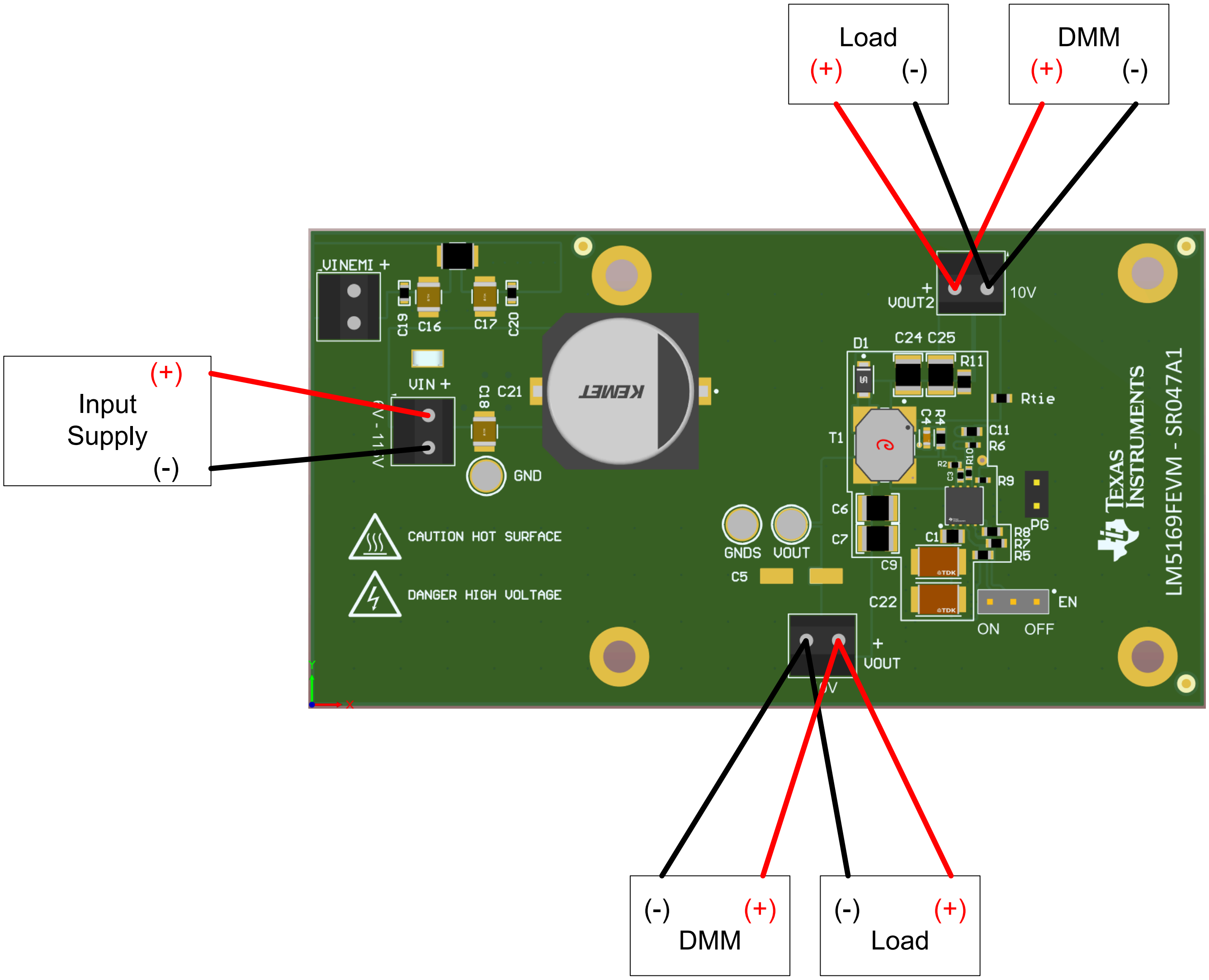


Figure 2-3. LM5169FEVM Test Setup

2.2.1 Compatibility With the LM5017

The LM5169FEVM has component pads available to make the device compatible with the LM5017 for evaluation compared to the LM5169. Configuring the EVM for the LM5017 requires the following changes:

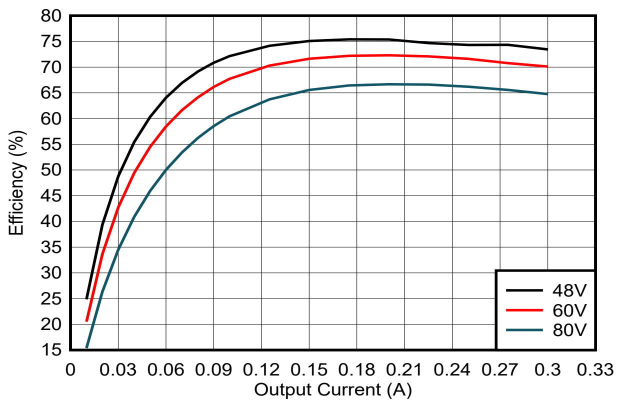
- Remove the LM5169 PG resistor, R10
- Remove the LM5169 RT resistor, R8
- Populate the LM5017 RON resistor, R13
- Populate the LM5017 VCC capacitor, C26
- Populate the LM5017 VCC diode, D2

While the EVM is compatible with the LM5017 using the above changes, the PCB design is optimized for the LM5169. Refer to the LM5017 data sheet for the relevant external component selection criteria.

3 Implementation Results

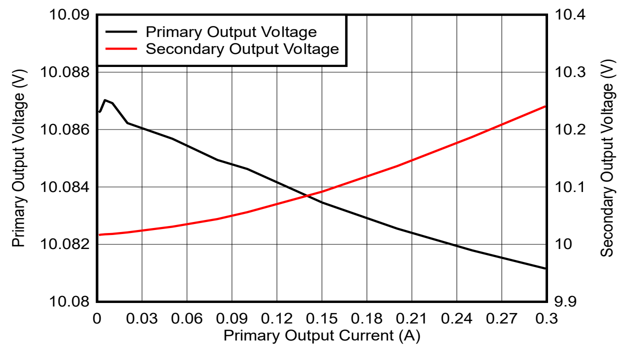
3.1 Performance Curves

Unless otherwise specified the following condition apply: T_A = 25ºC, I_{OUT1} = primary output current, I_{OUT2} = secondary output current.



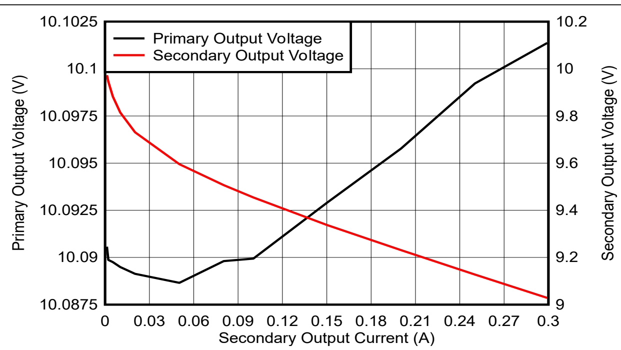
Output Current = I_{OUT1} = I_{OUT2}

Figure 3-1. Efficiency



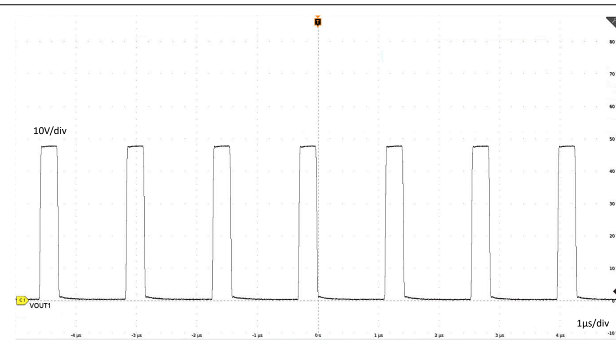
I_{OUT2} = 0A V_{IN} = 48V

Figure 3-2. Load Regulation



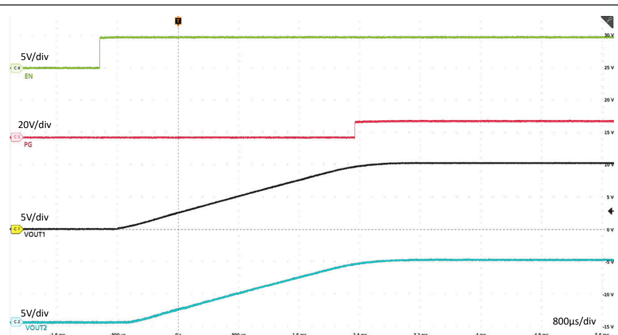
I_{OUT1} = 0A V_{IN} = 48V

Figure 3-3. Load Regulation



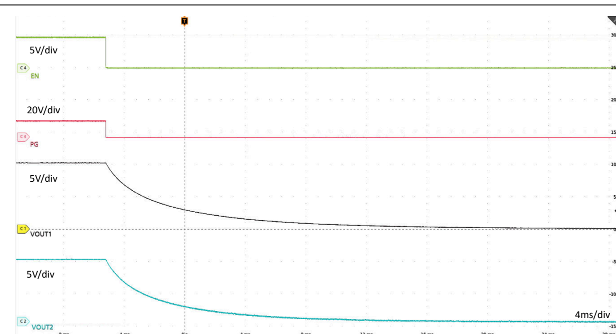
I_{OUT} = 0A V_{IN} = 48V

Figure 3-4. Typical Switching Waveform



V_{IN} = 48V I_{OUT} = I_{OUT2} = 100mA

Figure 3-5. Typical Start-Up Waveform



V_{IN} = 48V I_{OUT} = I_{OUT2} = 100mA

Figure 3-6. Typical Shutdown Waveform

3.2 EVM Characteristics

Unless otherwise specified, the following conditions apply: T_A = 25ºC, I_{OUT1} = primary output current, I_{OUT2} = secondary output current

Table 3-1. LM5169FEVM Electrical Performance Characteristics

Parameter	Test Conditions		MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS						
Input voltage range, V_{VIN}	EVM input voltage operating range		20	48	115	V
Input voltage turn-on, $V_{IN(ON)}$	Adjusted by EN/UVLO resistors			6.0		V
Input voltage turn-off, $V_{IN(OFF)}$				5.6		V
Input voltage hysteresis, $V_{IN(HYS)}$				0.4		V
Input current, no load, $I_{IN(NL)}$	I_{OUT} = 0A	V_{IN} = 48V		11.7		mA
Input current, disabled, $I_{IN(OFF)}$	$V_{EN/UVLO}$ = 0V, no EN divider	V_{IN} = 36V		5.4		µA
OUTPUT CHARACTERISTICS						
Output voltage, V_{OUT1}	V_{IN} = 48V, I_{OUT1} = I_{OUT2} = 0A			10.09		V
Output voltage, V_{OUT2}	V_{IN} = 48V, I_{OUT1} = I_{OUT2} = 0A			10.02		
Output current, I_{OUT1}	V_{IN} = 48V, I_{OUT2} = 0A			0.3		A
Output current, I_{OUT2}	V_{IN} = 48V, I_{OUT1} = 0A			0.3		A
Output voltage regulation, ΔV_{OUT1}	Load regulation, V_{IN} = 48V	I_{OUT1} = 0A to 0.3A, I_{OUT2} = 0A		5.45		mV
Output voltage regulation, ΔV_{OUT2}	Load regulation, V_{IN} = 48V	I_{OUT1} = 0A to 0.3A, I_{OUT2} = 0A		225		
Output voltage regulation, ΔV_{OUT1}	Load regulation, V_{IN} = 48V	I_{OUT2} = 0A to 0.3A, I_{OUT1} = 0A		10.84		
Output voltage regulation, ΔV_{OUT2}	Load regulation, V_{IN} = 48V	I_{OUT2} = 0A to 0.3A, I_{OUT1} = 0A		946		
Output voltage regulation, ΔV_{OUT1}	Line regulation, I_{OUT1} = I_{OUT2} = 0A	V_{IN} = 24V to 115V		53		
Output voltage regulation, ΔV_{OUT2}	Line regulation, I_{OUT1} = I_{OUT2} = 0A	V_{IN} = 24V to 115V		912		
Maximum output current from primary output	V_{IN} = 48V, I_{OUT2} = 0A			0.69		A
Soft-start time, t_{SS}				3.5		ms
SYSTEM CHARACTERISTICS						
Switching frequency	V_{IN} = 36V, I_{OUT1} = 0A , I_{OUT2} = 0A			714		kHz
Half-load efficiency	I_{OUT1} = I_{OUT2} = 0.15A	V_{IN} = 48V		75%		
Full load efficiency	I_{OUT1} = I_{OUT2} = 0.3A	V_{IN} = 48V		73%		
		V_{IN} = 60V		70%		

4 Hardware Design Files

4.1 Schematic

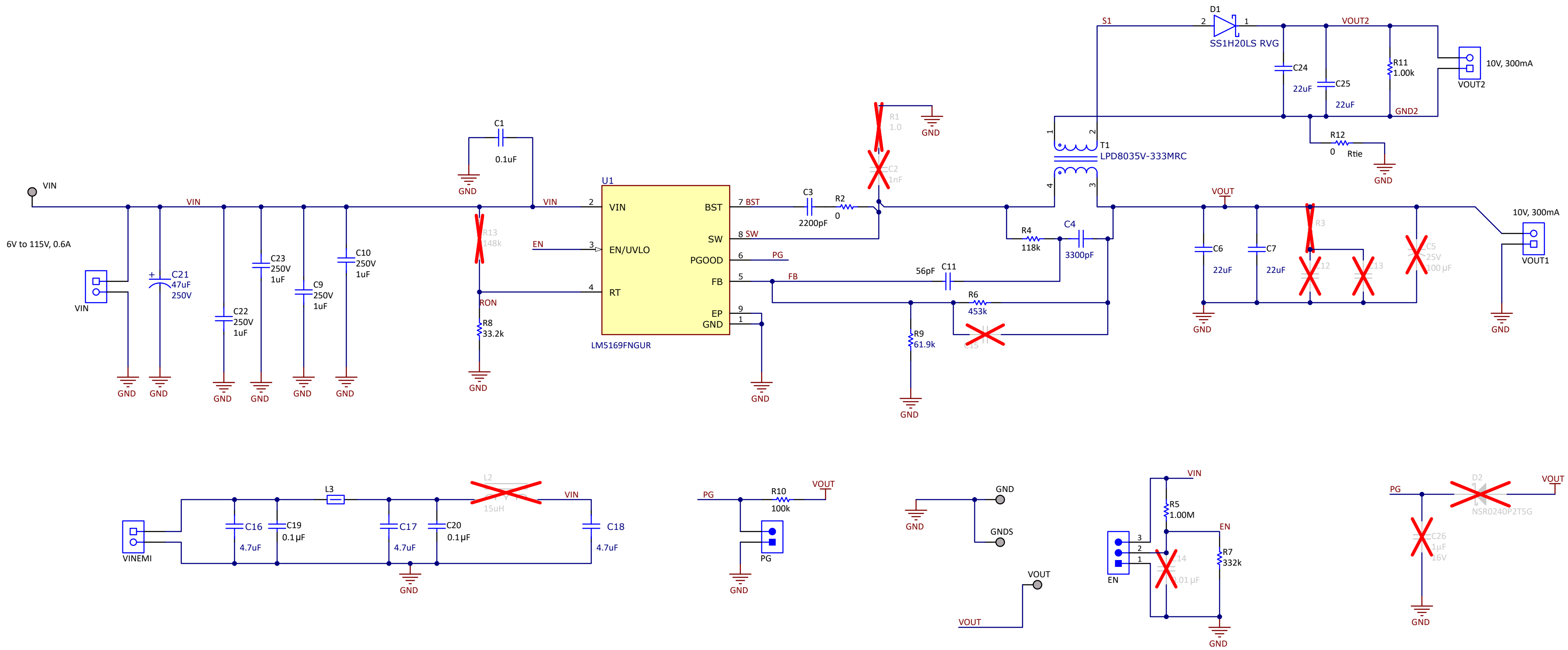


Figure 4-1. LM5169FEVM Schematic

4.2 PCB Layout

Figure 4-2 through Figure 4-5 show the board layout for the LM5169FEVM.

The 8-pin NGU PowerPAD™ package offers an exposed thermal pad, which must be soldered to the copper landing on the PCB for excellent thermal performance. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to dissipate heat with an array of thermal vias under the thermal pad to connect to all four layers.

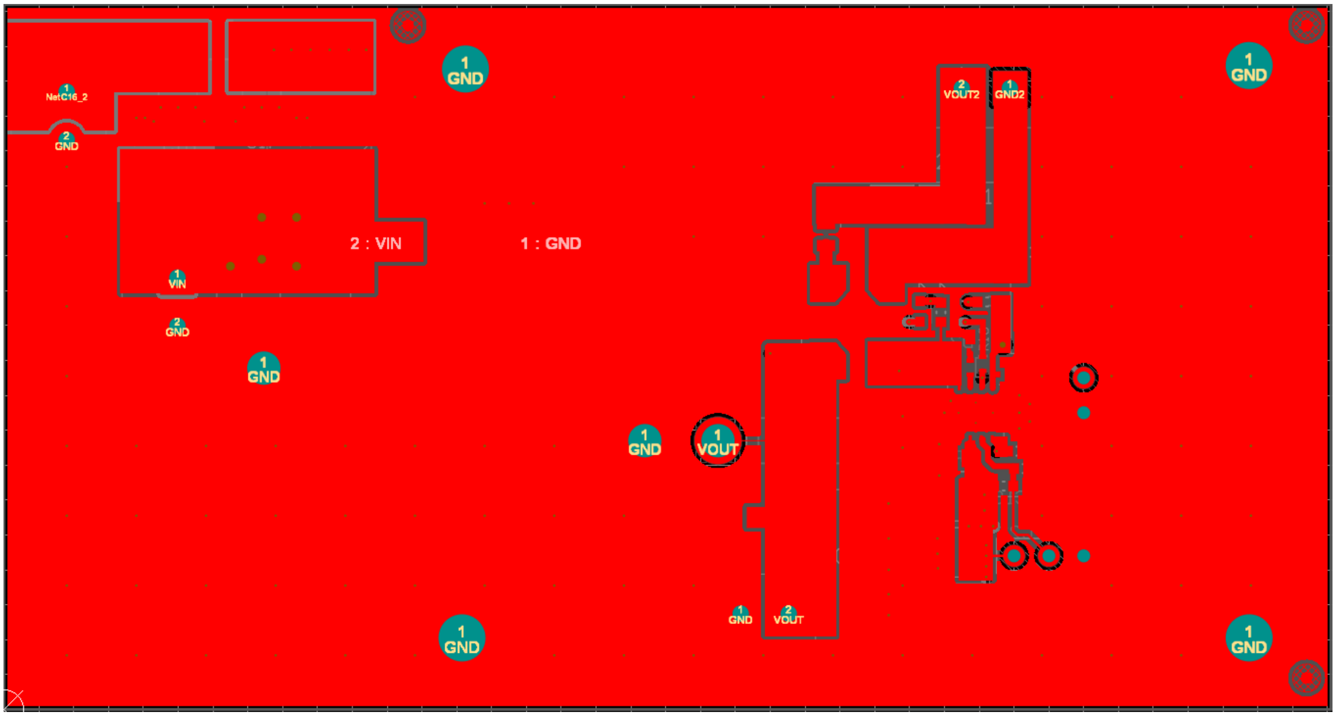


Figure 4-2. Top Layer

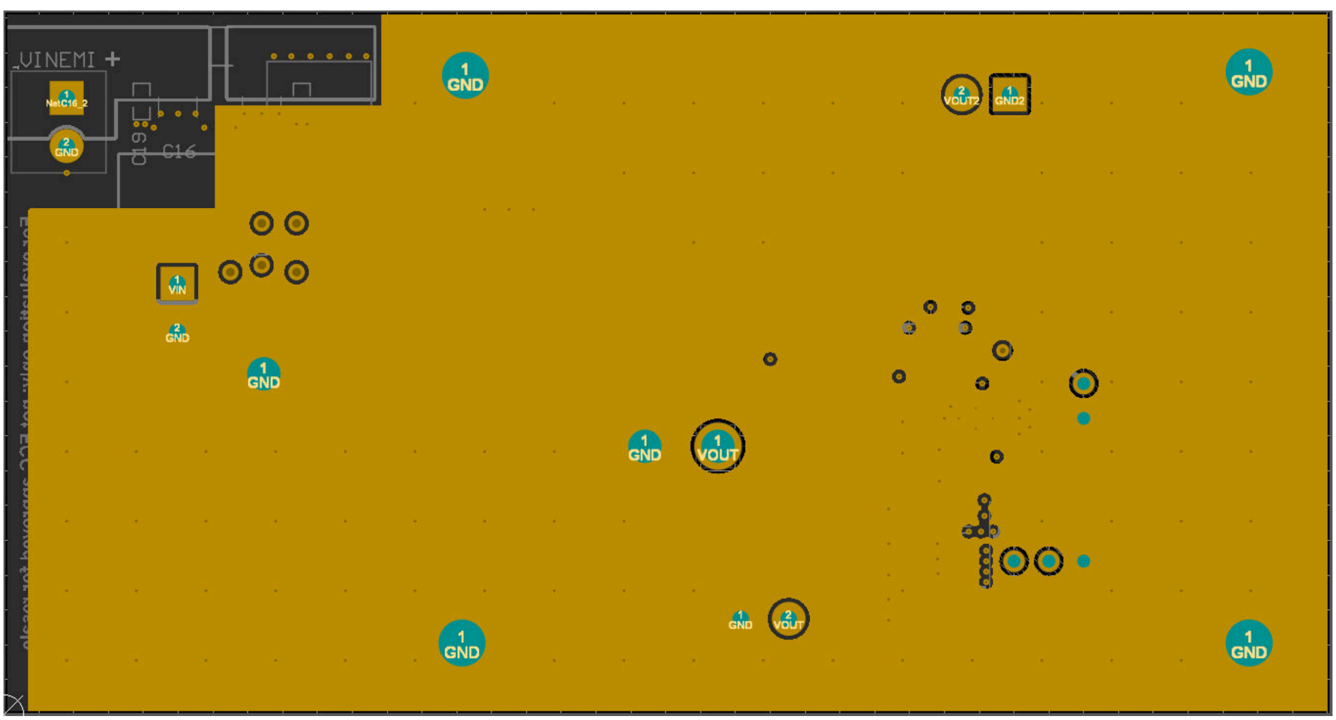


Figure 4-3. Mid-Layer 1 Ground Plane

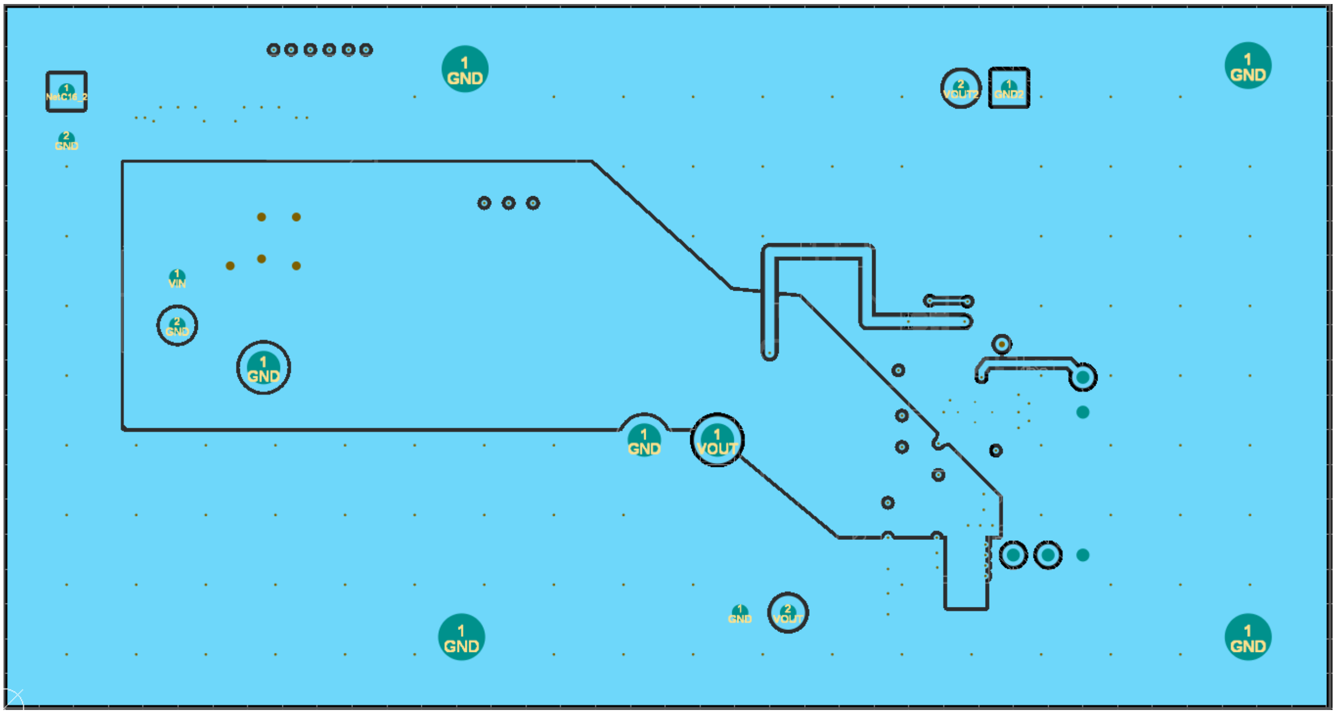


Figure 4-4. Mid-Layer 2 Routing

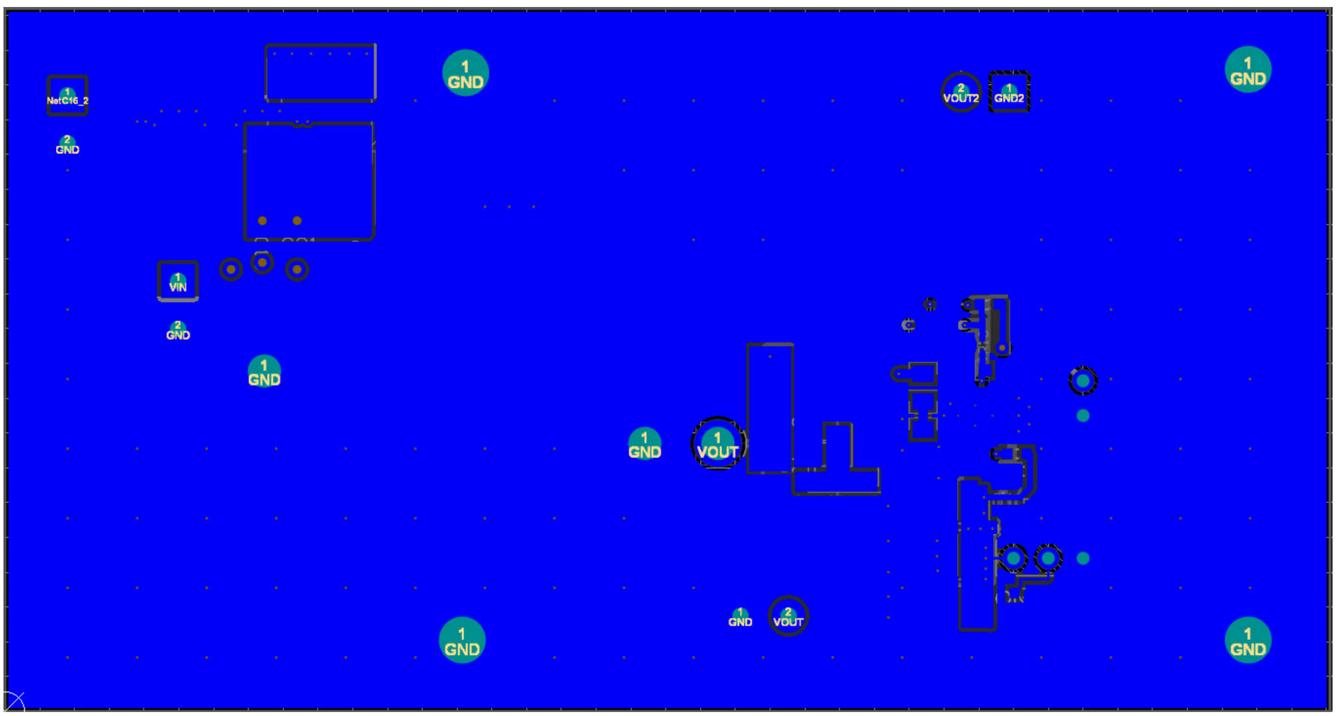


Figure 4-5. Bottom Layer

4.3 Bill of Materials

Table 4-1. LM5169FEVM Bill of Materials

DESIGNATOR	QUANTITY	DESCRIPTION	PART NUMBER	MANUFACTURER
C1	1	CAP, CERM, 0.1uF, 250V, +/- 10%, X7T, 0805	C2012X7T2E104K125AA	TDK
C3	1	CAP, CERM, 2200pF, 50V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	GCM155R71H222KA37D	MuRata
C4	1	3300pF ±5% 100V Ceramic Capacitor X7R 0603 (1608 Metric)	06031C332J4Z2A	AVX Corporation
C6, C7, C24, C25	4	CAP, CERM, 22uF, 25V, +/- 10%, X5R, 1210	CL32A226KAJNNNE	Samsung Electro-Mechanics
C9, C10, C22, C23	4	Cap Ceramic 1uF 250V X7T 10% Pad SMD 1812 +125°C Automotive T/R	CGA8P3X7T2E105K250KE	TDK
C11	1	CAP, CERM, 56pF, 50V, +/- 5%, C0G/NP0, 0603	C0603C560J5GACTU	Kemet
C16, C17, C18	3	4.7µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric)	CNC6P1X7R2A475K250AE	TDK
C19, C20	2	CAP, CERM, 0.1µF, 100V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	HMK107B7104KAHT	Taiyo Yuden
C21	1	47µF 250V Aluminum Electrolytic Capacitors Radial, Can - SMD 2000 Hrs at 105°C	EDH476M250A9TAA	KEMET
D1	1	Rectifier Diode Schottky 200V 1A 2-Pin SOD-123HE T/R	SS1H20LS RVG	Taiwan Semiconductor
J2, J3, J7, J8	4	Terminal Block, 3.5mm Pitch, 2x1, TH	ED555/2DS	On-Shore Technology
J4	1	Header, 100mil, 3x1, Gold, TH	HTSW-103-07-G-S	Samtec
J6	1	Header, 100mil, 2x1, Gold, TH	TSW-102-07-G-S	Samtec
L3	1	Ferrite Bead, 2000 ohm at 100MHz, 1.2A, 1210	FBMH3225HM202NT	Taiyo Yuden
R2	1	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale
R4	1	RES, 118 k, 1%, 0.1 W, 0603	RC0603FR-07118KL	Yageo
R5	1	RES, 1.00M, 1%, 0.1W, 0603	RC0603FR-071ML	Yageo
R6	1	RES, 453 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402453KFKED	Vishay-Dale
R7	1	RES, 332 k, 1%, 0.1 W, 0603	RC0603FR-07332KL	Yageo
R8	1	RES, 33.2 k, 1%, 0.1 W, 0603	RC0603FR-0733K2L	Yageo
R9	1	RES, 61.9 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040261K9FKED	Vishay-Dale
R10	1	RES, 100 k, 1%, 0.1 W, 0402	ERJ-2RKF1003X	Panasonic
R11	1	RES, 1.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	CRCW08051K00FKEA	Vishay-Dale
R12	1	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale
T1	1	Power inductor, coupled, shielded, 20% tol, RoHS, halogen-free	LPD8035V-333MRC	Coilcraft
TP1	1	Test Lead clips and hooks, SMT	S1751-46	Harwin
TP2, TP3, TP4	3	Terminal, Turret, TH, Triple	1598-2	Keystone
C2	0	CAP, CERM, 1000pF, 250V, +/- 10%, X7R, 0805	QMK212B7102KD-T	Taiyo Yuden
C5	0	CAP, AL, 100µF, 25V, +/- 20%, SMD	UWT1E101MCL1GS	Nichicon
C12, C13	0	CAP, CERM, 22uF, 25V, +/- 10%, X7R, AEC-Q200 Grade 1, 1210	TMK325B7226KMHT	Taiyo Yuden
C14	0	CAP, CERM, 0.01µF, 100V,+/- 10%, X8R, AEC-Q200 Grade 0, 0603	CGA3E2X8R2A103K080AD	TDK
C15	0	CAP, CERM, 1000pF, 50V, +/- 5%, X7R, AEC-Q200 Grade 1, 0603	C0603C102J5RACAUTO	Kemet
C26	0	CAP, CERM, 1µF, 16V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	GCM188R71C105KA64J	MuRata
D2	0	Diode, Schottky, 40V, 0.2A, SOD-923	NSR0240P2T5G	ON Semiconductor
FID1, FID2, FID3	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A

Table 4-1. LM5169FEVM Bill of Materials (continued)

DESIGNATOR	QUANTITY	DESCRIPTION	PART NUMBER	MANUFACTURER
L2	0	Inductor, Shielded Drum Core, Ferrite, 15uH, 1.8A, 0.05 ohm, AEC-Q200 Grade 1, SMD	MSS7341T-153MLB	Coilcraft
R1	0	RES, 1.0, 5%, 0.4 W, AEC-Q200 Grade 0, 0805	ESR10EZPJ1R0	Rohm
R3	0	RES, 0.2, 1%, 1 W, 2010	CSRN2010FKR200	Stackpole Electronics Inc
R13	0	RES, 33.2 k, 1%, 0.1 W, 0603	RC0603FR-0733K2L	Yageo
U1	1	0.65A, 120V absolute maximum, Step-Down Converter with Fly-Buck Converter Capability	LM5169FNGUR	Texas Instruments

5 Additional Information

5.1 Trademarks

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

IMPORTANT NOTICE AND DISCLAIMER

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265