

TPS55010EVM-009, Low-Power, Isolated Fly-Buck™ Converter

This user's guide contains information for the TPS55010EVM-009 evaluation module (PWR009). Included are the performance specifications, the schematic, and the bill of materials for the TPS55010EVM-009.

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1 Introduction

This user's guide contains background information for the TPS55010 as well as support documentation for the TPS55010EVM-009 evaluation module (PWR009). Included are the performance specifications, the schematic, and the bill of materials for the TPS55010EVM-009.

1.1 Background

The TPS55010 dc/dc converter is designed to provide up to a 200-mA output from an input voltage source of 4.5 V to 5.5 V. Rated input voltage and output current range for the evaluation module are given in [Table 1](#). This evaluation module is designed to demonstrate the small, printed-circuit-board areas that may be achieved when designing with the TPS55010 regulator. The switching frequency is externally set at a nominal 350 kHz. Both high-side and low-side MOSFETs are incorporated inside the TPS55010 package along with the gate drive circuitry. The low drain-to-source on-resistance of the MOSFETs allows the TPS55010 to achieve good efficiency. The compensation components are external to the integrated circuit (IC), and an external divider allows for an adjustable output voltage. Additionally, the TPS55010 provides adjustable slow-start and undervoltage lockout inputs. The absolute maximum input voltage for the TPS55010EVM-009 is 6 V.

Table 1. Input Voltage and Output Current Summary

EVM	Input Voltage Range	Output Current Range
TPS55010EVM-009	$V_{IN} = 4.5 \text{ V to } 6 \text{ V}$	0 A to 200 mA

1.2 Performance Specification Summary

A summary of the TPS55010EVM-009 performance specifications is provided in [Table 2](#). Specifications are given for an input voltage of $V_{IN} = 5 \text{ V}$ and an output voltage of 5 V, unless otherwise specified. The TPS55010EVM-009 is designed and tested for $V_{IN} = 4.5 \text{ V to } 6 \text{ V}$. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 2. TPS55010EVM-009 Electrical and Performance Specification

Parameter	Condition	MIN	TYP	MAX	UNIT
Output voltage	$4.5 \text{ V} \leq V_{IN} \leq 5.5 \text{ V}$, $I_{LOAD} \leq 200 \text{ mA}$	4.5	5	6	V
Output current	$4.5 \text{ V} \leq V_{IN} \leq 5.5 \text{ V}$			0.2	A
Output ripple voltage, peak-to-peak	$I_{LOAD} = 200 \text{ mA}$		20		mV
Switching frequency	$I_{LOAD} = 200 \text{ mA}$		350		kHz
Efficiency, end-to-end	$I_{LOAD} = 200 \text{ mA}$		85%		
Line regulation	$I_{LOAD} = 200 \text{ mA}$		± 0.06		V
Load regulation	$I_{LOAD} = 10 \text{ mA to } 200 \text{ mA}$		± 0.3		V
Control loop crossover frequency	$I_{LOAD} = 200 \text{ mA}$		25		kHz
Slow start			40		ms
Operating temperature		-25		85	°C

1.3 Modifications

These evaluation modules are designed to provide access to the features of the TPS55010. Some modifications can be made to this module.

1.3.1 Input Voltage Range

TPS55010EVM-009 can operate from an input voltage of 5 V or 3.3 V, nominally. For 3.3-V nominal input voltage, remove R3 (allows the EVM to start up from lower input voltages), and change R9 to 511 kΩ (changes switching frequency to 200 kHz).

1.3.2 Operating Frequency, Slow-Start, and UVLO

The operating frequency, slow-start time, and UVLO voltage can be adjusted. R9 sets the operating frequency, C5 sets the slow-start time, and the resistor divider of R2 and R3 sets the UVLO start and stop voltages. See the TPS55010 data sheet ([SLVSAV0](#)) for details on adjusting these parameters.

1.3.3 Zener Diode and Output Snubber

Under no-load conditions, VOUT can get as high as 15 V if output voltage limiting is not provided. TPS55010EVM-009 provides a Zener diode (5.6 V nominal) in series with a resistor to limit the output voltage at J2 to 6 V. The Zener diode presents a negligible load to the circuit with external loads above approximately 3 mA at J2.

Placeholders for an R-C snubber are provided across the output rectifier. Although the snubber impacts efficiency, it can be used to dampen the ringing across the rectifier.

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS55010EVM-009 evaluation module. The section also includes test results typical for the evaluation module and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

2.1 Input/Output Connections

The TPS55010EVM-009 is provided with input/output connectors and test points as shown in [Table 3](#). A power supply capable of supplying 0.5 A must be connected to J1 through a pair of 20 AWG wires. The load must be connected to J2 through a pair of 20 AWG wires. Test-point TP2 provides a place to monitor the V_{IN} input voltages with TP5 providing a convenient ground reference. TP10 is used to monitor the output voltage with TP4 as the ground reference.

Table 3. EVM Connectors and Test Points

Reference Designator	Label	Description
J1	INPUT	VIN connector
J2	OUTPUT	VOUT connector
TP2	VIN	Input VIN circuit point
TP5	GND	Input GND circuit point
TP10	VOUT	Output VOUT circuit point
TP4	AGND	Output AGND circuit point
TP1	FAULT	FAULT pin
TP3	EN	EN pin
TP6	SS	SLOW START pin
TP7	PH	PH pin
TP8	LOOP	Injection point for loop measurements
TP9	VC	Regulated voltage
TP12	GND	Input GND circuit point

2.2 Efficiency

Figure 1 shows the efficiency for the TPS55010EVM-009 at an ambient temperature of 25°C.

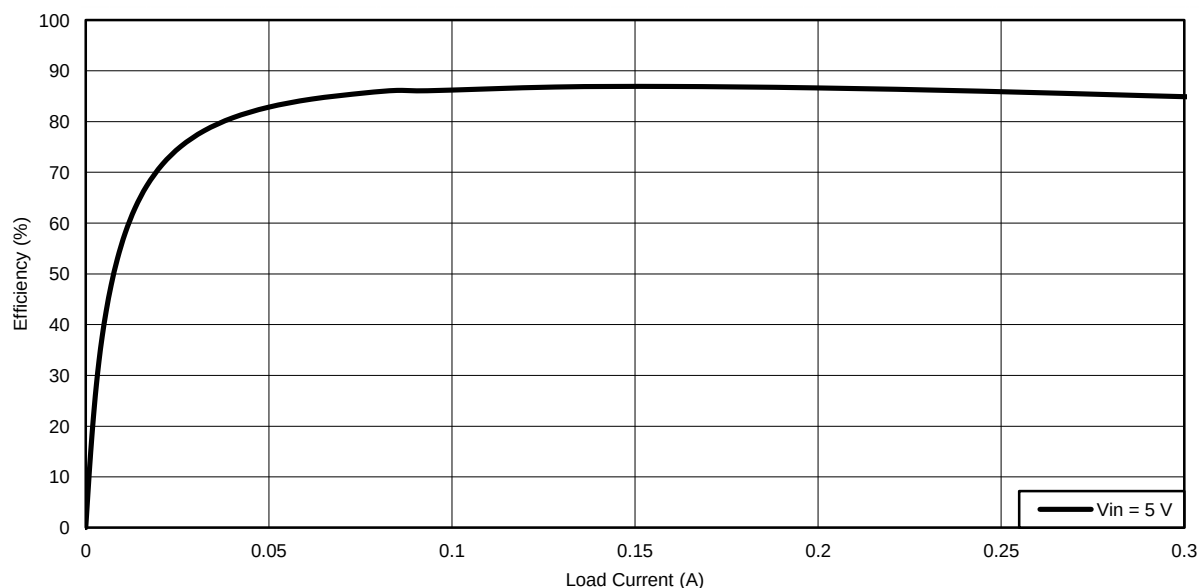


Figure 1. TPS55010EVM-009 Efficiency

The efficiency may be lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the internal MOSFET.

2.3 Load Regulation

Figure 2 shows the load regulation for the TPS55010EVM-009 at an ambient temperature of 25°C.

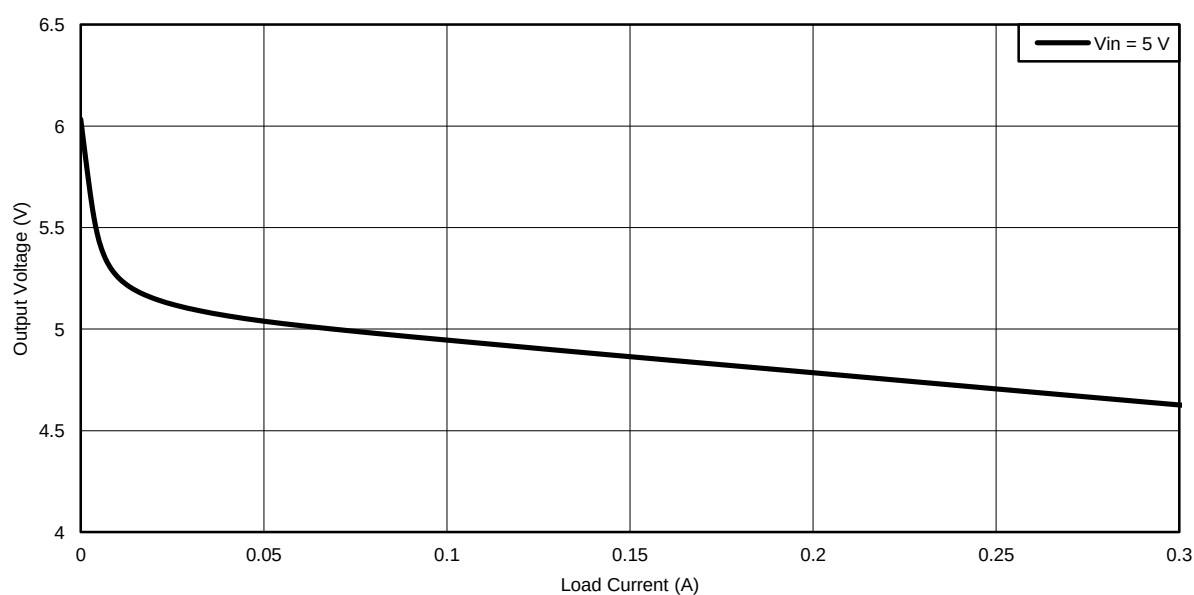


Figure 2. TPS55010EVM-009 Load Regulation

2.4 Line Regulation

Figure 3 shows the line regulation for the TPS55010EVM-009 at an ambient temperature of 25°C.

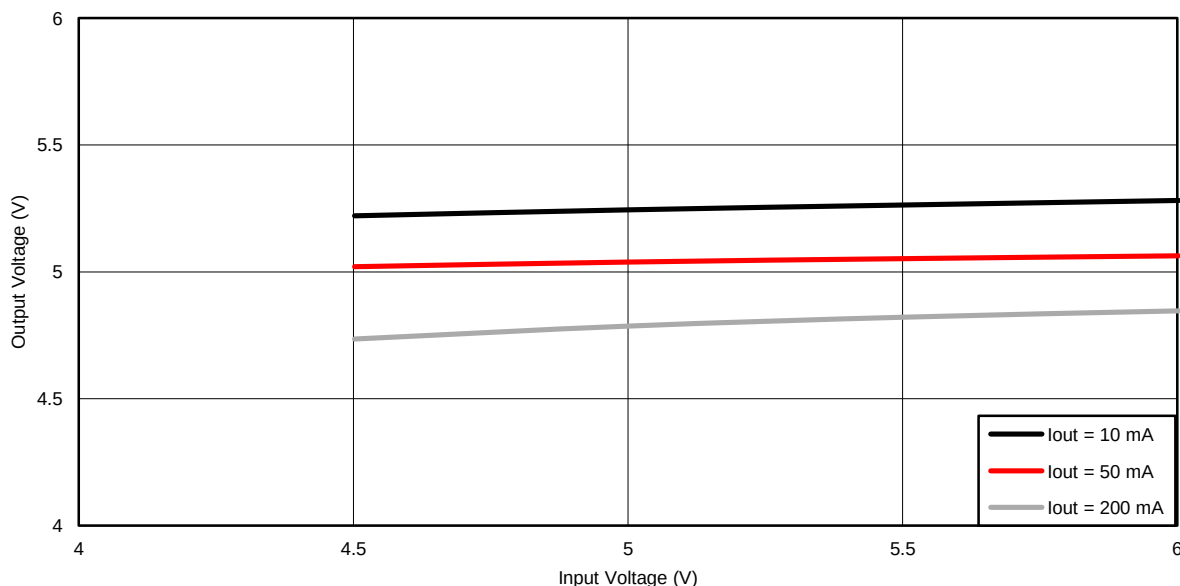


Figure 3. TPS55010EVM-009 Line Regulation, $V_{IN} = 5\text{ V}$

2.5 Loop Characteristics

The TPS55010EVM-009 loop-response characteristics are shown in Figure 4. Gain and phase plots are shown for $V_{IN} = 5\text{ V}$ and a load current of both 0 mA and 200 mA. At a 0-mA load, the unity gain bandwidth is 32.5 kHz and phase margin is 53 degrees. At a 200-mA load, the unity gain bandwidth is 25.2 kHz and the phase margin is 82 degrees.

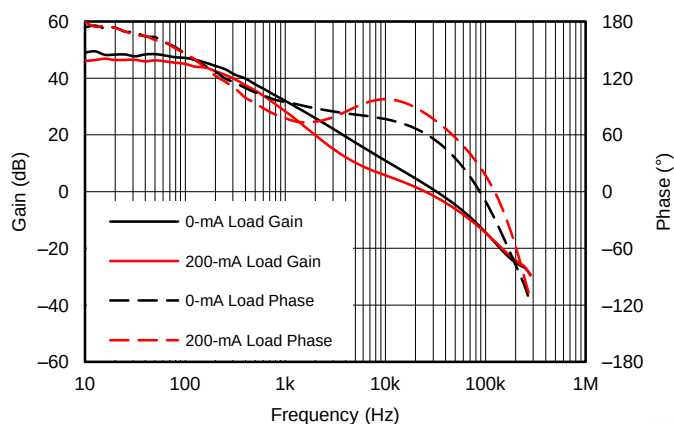


Figure 4. TPS55010EVM-009 Loop Response

2.6 Output Voltage Ripple

The TPS55010EVM-009 output voltage ripple is shown in Figure 5. The output current is the rated full load of 200 mA and $V_{IN} = 5$ V. The ripple voltage is measured directly across the output capacitors.

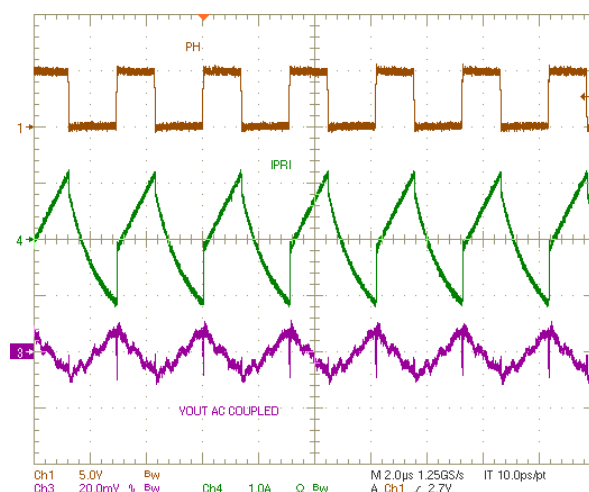


Figure 5. TPS55010EVM-009 Output Voltage Ripple

2.7 Input Voltage Ripple

The TPS55010EVM-009 input voltage ripple is shown in Figure 6. The output current is the rated full load of 200 mA and $V_{IN} = 5$ V. The ripple voltage is measured directly across the input capacitors.

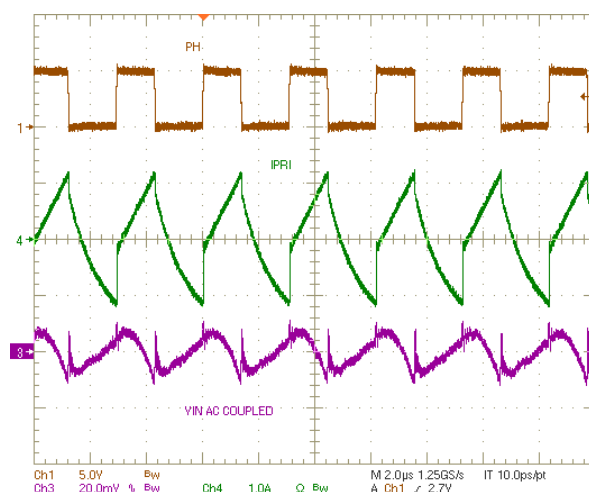


Figure 6. TPS55010EVM-009 Input Voltage Ripple

2.8 Powering Up

Figure 7 shows the start-up waveforms with rising V_{IN} and the output loaded with 22 Ω . In Figure 7, the output starts to rise when V_{IN} reaches the rising UVLO of 4.5 V.

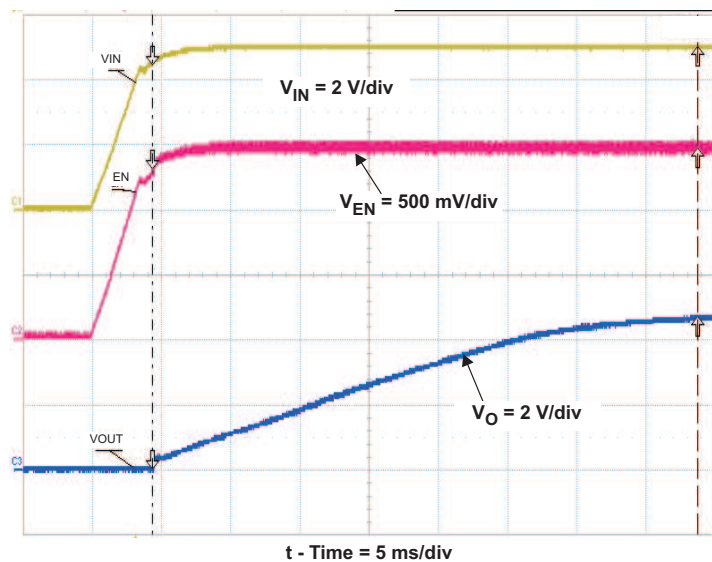


Figure 7. TPS55010EVM-009 Start-Up With Rising V_{IN}

3 Board Layout

This section provides a description of the TPS55010EVM-009, board layout, and layer illustrations.

3.1 Layout

The board layout for the TPS55010EVM-009 is shown in Figure 8 through Figure 10. The top-side layer of the EVM is laid out in a manner typical of a user application. The top and bottom layers are 2-oz copper. A basic set of layout guidelines include:

- Place the input capacitors close to the TPS55010 VIN and GND terminals.
- Arrange the transformer, input capacitors, and the regulated voltage capacitor in a manner to minimize loop area.
- Connect the GND end of the analog control circuitry (COMP, VSENSE, RT/CLK, and SS pins) together apart from the main power GND. Reference this analog GND trace/shape to the power GND (PowerPAD™ IC package of TPS55010) at a single point.
- The PowerPAD™ package of the TPS55010 provides a means to remove heat from the device and must be connected to the GND plane with multiple vias as shown in the TPS55010 data sheet, [SLVSAV0](#).

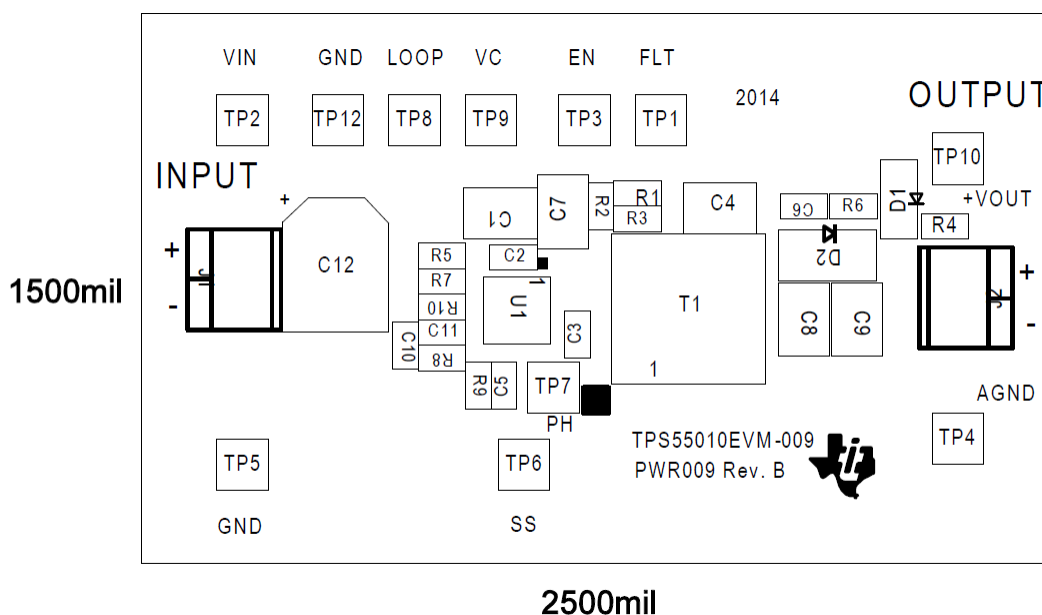


Figure 8. TPS55010EVM-009 Top Assembly

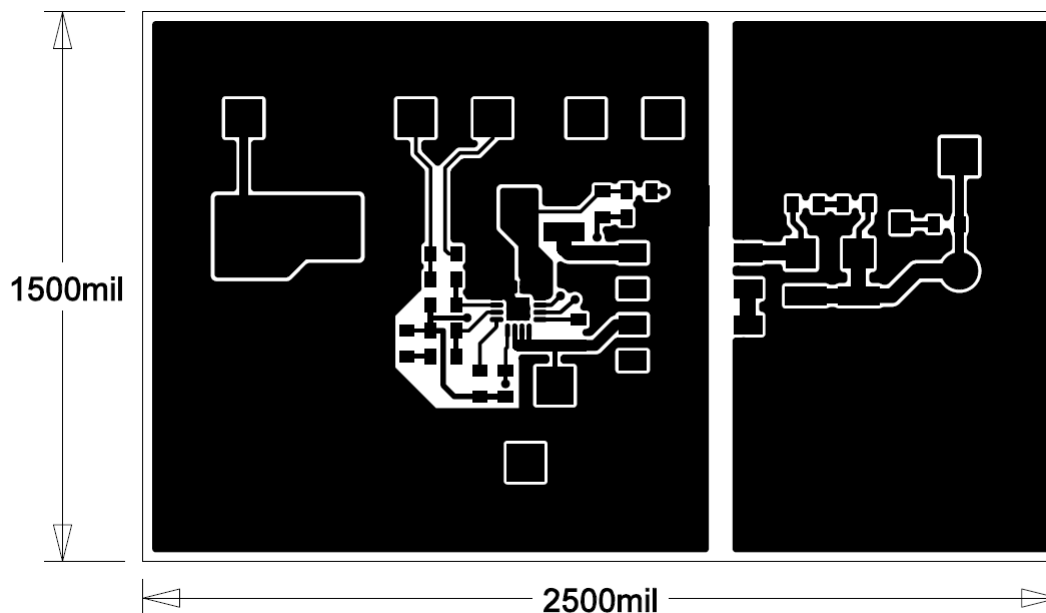


Figure 9. TPS55010EVM-009 Top Copper

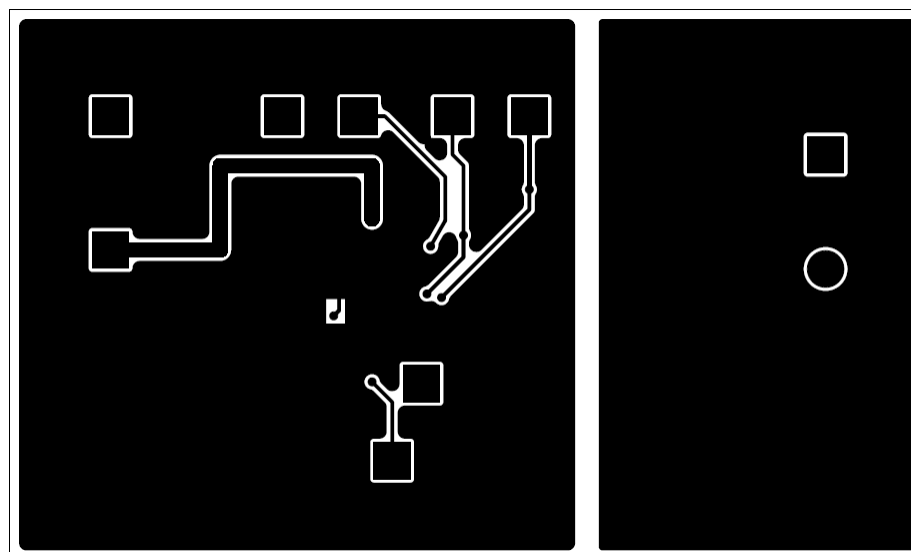


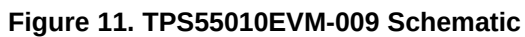
Figure 10. TPS55010EVM-009 Bottom Copper

3.2 Estimated Circuit Area

The estimated printed-circuit board area for the components used in this design is 0.70 in². This area does not include test points or connectors.

This section presents the TPS55010EVM-009 schematic and bill of materials.

Figure 11 is the schematic for the TPS55010EVM-009.



4.2 Bill of Materials

Table 4 presents the bill of materials for the TPS55010EVM-009.

Table 4. Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
2	C1, C7	47µF	Capacitor, Ceramic, 10V, X5R, 10%	1210	Std	Std
3	C2, C3, C5	0.1µF	Capacitor, Ceramic, Low Inductance, 16V, X7R, 10%	0603	Std	Std
1	C4	1000pF	Capacitor, Ceramic, 2kV, X7R, 10%	1210	Std	Std
1	C6	1000pF	Capacitor, Ceramic, Low Inductance, 16V, X7R, 10%	0603	Std	Std
2	C8, C9	10µF	Capacitor, Ceramic, 10V, X5R, 10%	1210	Std	Std
1	C10	3900pF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
1	C11	100pF	Capacitor, Ceramic, 50V, NP0, 5%	0603	Std	Std
1	C12	220µF	Capacitor, Aluminum, 6.3V, ±20%	0.260 x 0.276 inch	EEE-FK0J221P	Panasonic
1	D1	BZT52C5V6	Diode, Zener, Planar Power, 500mW, 5.6V	SOD-123	BZT52C5V6-7-F	Diodes, Inc
1	D2	B120-13-F	Diode, Schottky, 1000-mA, 20-V	SMA	B120-13-F	Diodes, Inc
2	J1, J2	ED555/2DS	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25 inch	ED555/2DS	OST
2	R1, R7	100k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	71.5k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	26.7k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R4	200	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	49.9	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R6	200	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R8	DNP	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R9	280k	Resistor, Chip, 1/16W, 1	0603	Std	Std
1	R10	61.9k	Resistor, Chip, 1/16W, 1	0603	Std	Std
4	TP1, TP3, TP6	5012	Test Point, White, Thru Hole	0.125 x 0.125 inch	5010	Keystone
3	TP2, TP9, TP10	5010	Test Point, Black, Thru Hole	0.125 x 0.125 inch	5010	Keystone
3	TP4, TP5, TP12	5011	Test Point, Black, Thru Hole	0.125 x 0.125 inch	5011	Keystone
2	TP7, TP8	5013	Test Point, Orange, Thru Hole	0.125 x 0.125 inch	5013	Keystone
1	T1	2.5µH	Transformer, ±10%	0.410 x 0.510 inch	750311880	Würth
1	U1	TPS55010RTE	IC, DC-DC Converter	QFN-16	TPS55010RTE	TI
1	--		PCB, 2.5 In x 1.5 In x 0.062 In	2.5" x 2.5" x 0.062"	PWR009	Any

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from A Revision (June 2014) to B Revision	Page
Changed schematic values of R7 from 16.5k to 100k and R10 from 10.0 k to 61.9k.	10

Changes from Original (May 2011) to A Revision	Page
• Changed 7 V to 6 V in background section.	2
• Changed 3 V to 4.5 V in the input voltage and output current summary table and in the first paragraph of the performance specification summary section.	2
• Changed content of the electrical and performance specification table.....	2
• Changed efficiency graph.	4
• Changed load regulation graph.	4
• Deleted line regulation, VIN = 3.3 V graph.....	5
• Changed line regulation graph.....	5
• Changed PCB layout images.	8
• Changed schematic diagram.	10
• Changed BOM: moved C7, changed content of C10 and C11 rows.	11

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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 instructions, 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.

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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.

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

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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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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/sds/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.

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Last updated 10/2025