

TPS55010EVM-051, Low-Power, Isolated, Fly-buck™ Dual-Output Converter

This user's guide contains information for the TPS55010EVM-051 evaluation module (PWR051). Included are the performance specifications, the schematic, and the bill of materials for the TPS55010EVM-051.

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1 Introduction

This user's guide contains background information for the TPS55010 as well as support documentation for the TPS55010EVM-051 evaluation module (PWR051). Included are the performance specifications, the schematic, and the bill of materials for the TPS55010EVM-051.

1.1 Background

The TPS55010EVM-051 is designed to provide dual 40-mA outputs 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 400 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-051 is 7 V.

Table 1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS55010EVM-051	$V_{IN} = 3 \text{ V to } 6 \text{ V}$	0 A to 40 mA (dual outputs)

1.2 Performance Specification Summary

A summary of the TPS55010EVM-051 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-051 is designed and tested for $V_{IN} = 4 \text{ V to } 6 \text{ V}$. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 2. TPS55010EVM-051 Electrical and Performance Specification

Parameter	Condition				UNIT		
		MIN	TYP	MAX			
Output voltage	$4.5 \text{ V} \leq V_{IN} \leq 5.5 \text{ V}$, $I_{LOAD} = \pm 40 \text{ mA}$	5 V	± 14	± 15	± 21	V	
Output current	$4.5 \text{ V} \leq V_{IN} \leq 5.5 \text{ V}$				± 0.04	A	
Output ripple voltage, peak-to-peak	$I_{LOAD} = \pm 40 \text{ mA}$	$V_{IN} = 5 \text{ V}$			15	mV	
Switching frequency	$I_{LOAD} = \pm 40 \text{ mA}$	$V_{IN} = 5 \text{ V}$			400	kHz	
Efficiency, end-to-end	$I_{LOAD} = \pm 40 \text{ mA}$	$V_{IN} = 5 \text{ V}$			90	%	
Line regulation	$I_{LOAD} = \pm 20 \text{ mA}$, $4.5 \text{ V} \leq V_{IN} \leq 5.5 \text{ V}$	$V_{IN} = 5 \text{ V}$			± 0.25	V	
Load regulation	$I_{LOAD} = 5 \text{ mA to } 40 \text{ mA}$	$V_{IN} = 5 \text{ V}$			± 2	V	
Control loop crossover frequency	$I_{LOAD} = \pm 40 \text{ mA}$				0.6	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 Zener Diode and Output Snubber

Under no-load conditions, VOUT can get as high as ± 30 V if output voltage limiting is not provided. TPS55010EVM-051 provides two Zener diodes (18 V nominal) in series with a resistor to limit the output voltages at J2 to ± 20 V. The Zener diodes present negligible load to the circuit with external loads above approximately 1 mA.

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS55010EVM-051 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-051 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. Test-point TP2 provides a place to monitor the V_{IN} input voltages with TP5 providing a convenient ground reference. TP10 and TP13 are used to monitor and load the output voltages with TP4 and TP14 as the ground references.

Table 3. EVM Connectors and Test Points

Reference Designator	Label	Description
J1	INPUT	VIN connector
TP10	+VOUT	Positive VOUT circuit point
TP2	VIN	Input VIN circuit point
TP5	GND	Input GND circuit point
TP13	-VOUT	Negative VOUT circuit point
TP4, TP14	AGND	Output AGND circuit point
TP1	FLT	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
TP11	RTC	RTCLK pin
TP12	GND	Input GND circuit point

2.2 Efficiency

Figure 1 shows the efficiency for the TPS55010EVM-051 at an ambient temperature of 25°C.

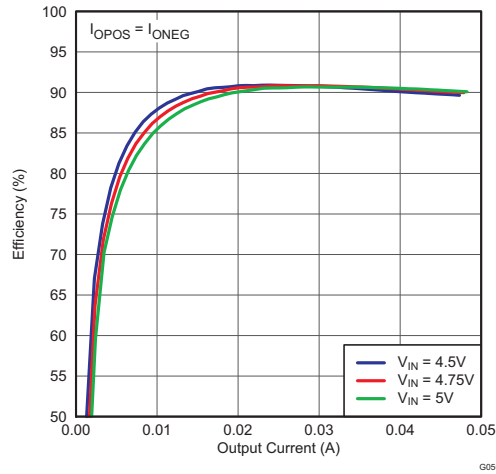


Figure 1. TPS55010EVM-051 Efficiency

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-051 at an ambient temperature of 25°C.

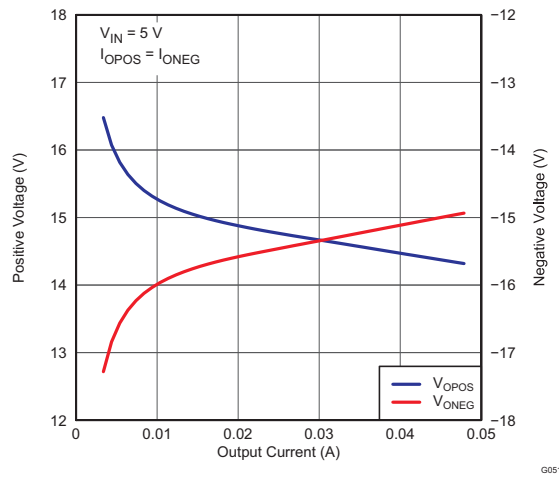


Figure 2. TPS55010EVM-051 Load Regulation

2.4 Line Regulation

Figure 3 shows the line regulation for the TPS55010EVM-051 at an ambient temperature of 25°C.

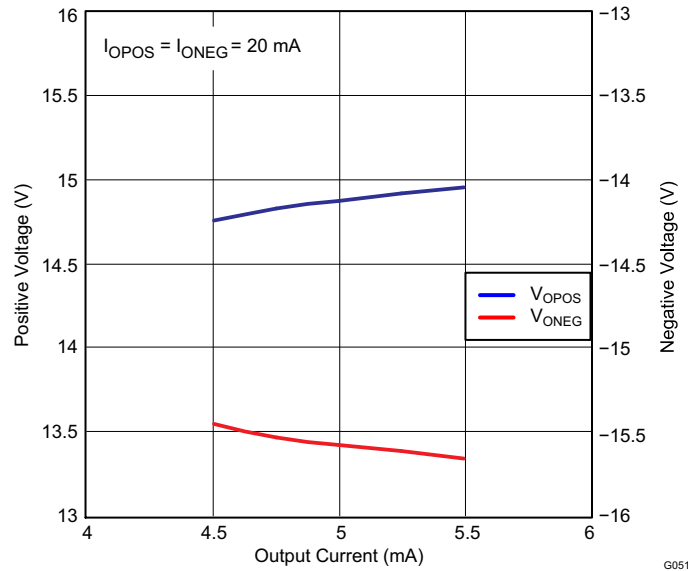


Figure 3. TPS55010EVM-051 Line Regulation, $V_{IN} = 5\text{ V}$

2.5 Loop Characteristics

The TPS55010EVM-051 loop-response characteristics are shown in Figure 4. Gain and phase plots are shown for $V_{IN} = 5\text{ V}$ and load current = $\pm 40\text{ mA}$. The unity gain bandwidth is 600 Hz and phase margin is 45 degrees.

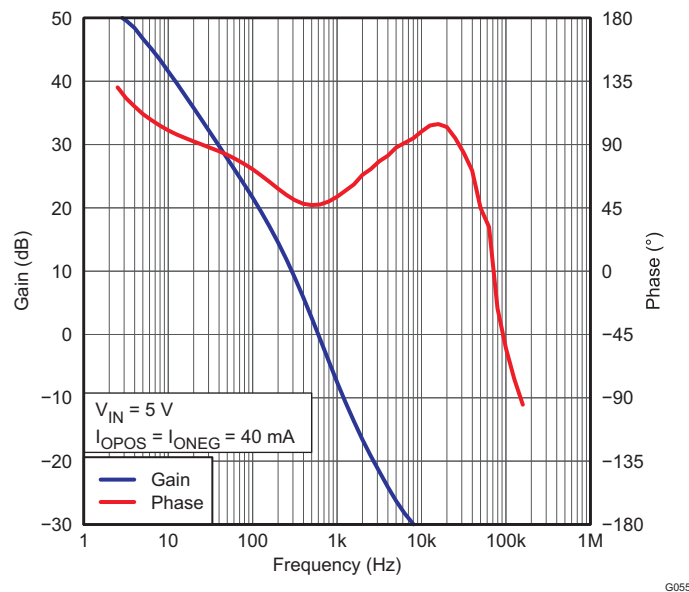


Figure 4. TPS55010EVM-051 Loop Response

2.6 Output Voltage Ripple

The TPS55010EVM-051 output voltage ripple is shown in Figure 5. The output current is the rated full load of ± 40 mA and $V_{IN} = 5$ V. The ripple voltage is measured directly across the positive output capacitor.

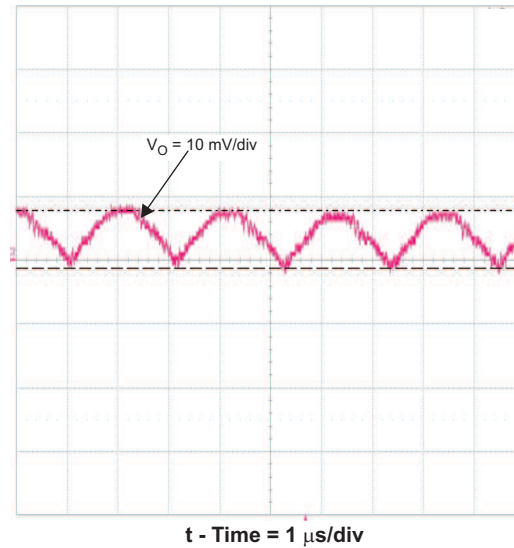


Figure 5. TPS55010EVM-051 Output Voltage Ripple

2.7 Input Voltage Ripple

The TPS55010EVM-051 input voltage ripple is shown in Figure 6. The output current is the rated full load of ± 40 mA and $V_{IN} = 5$ V. The ripple voltage is measured directly across the input capacitors.

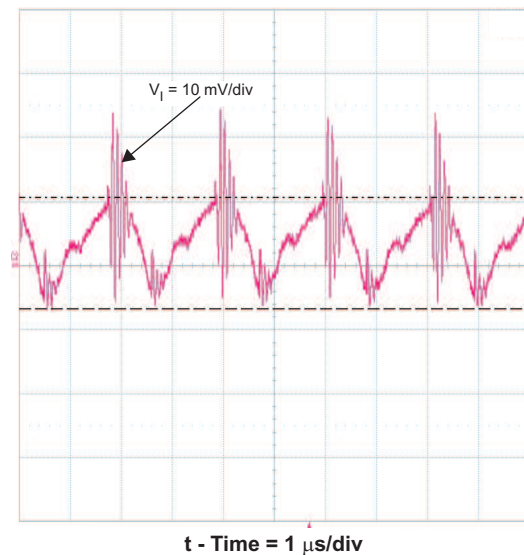


Figure 6. TPS55010EVM-051 Input Voltage Ripple

2.8 Powering Up

Figure 7 shows the start-up waveforms with rising V_{IN} and the output loaded with $360\ \Omega$. In Figure 7, the output starts to rise when V_{IN} reaches the rising UVLO of $4.5\ V$.

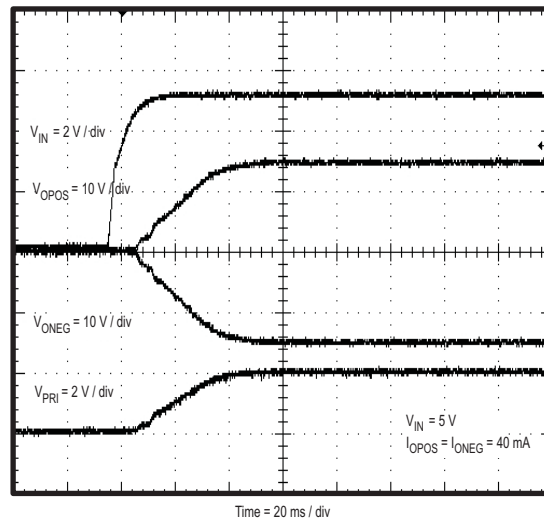


Figure 7. TPS55010EVM-051 Start-Up With Rising V_{IN}

3 Board Layout

This section provides a description of the TPS55010EVM-051, board layout, and layer illustrations.

3.1 Layout

The board layout for the TPS55010EVM-051 is shown in [Figure 8](#) through [Figure 11](#). 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](#).

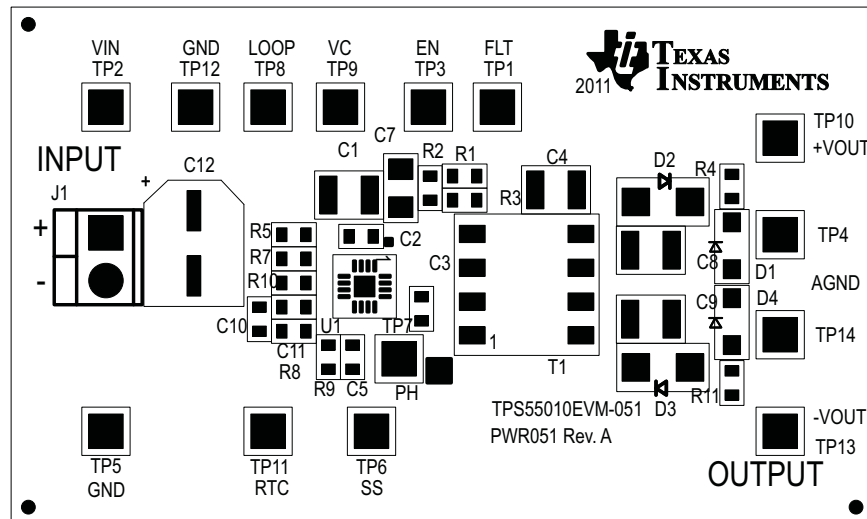


Figure 8. TPS55010EVM-051 Top Assembly

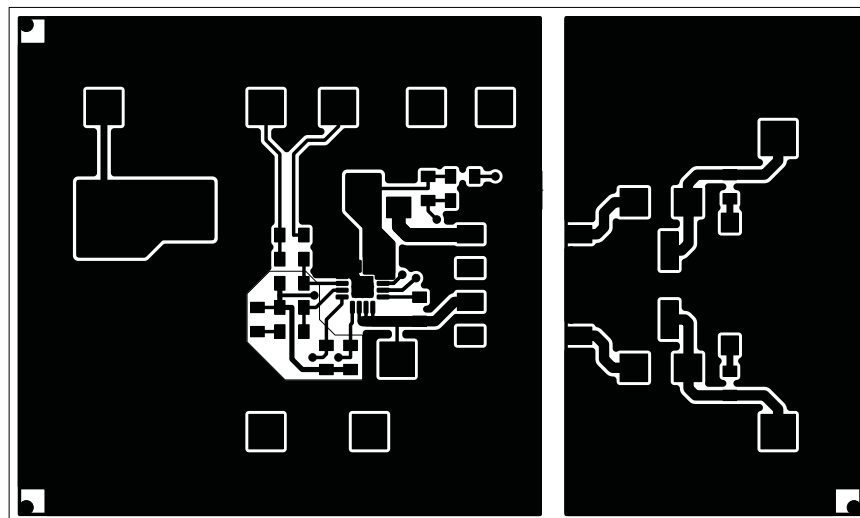


Figure 9. TPS55010EVM-051 Top Copper

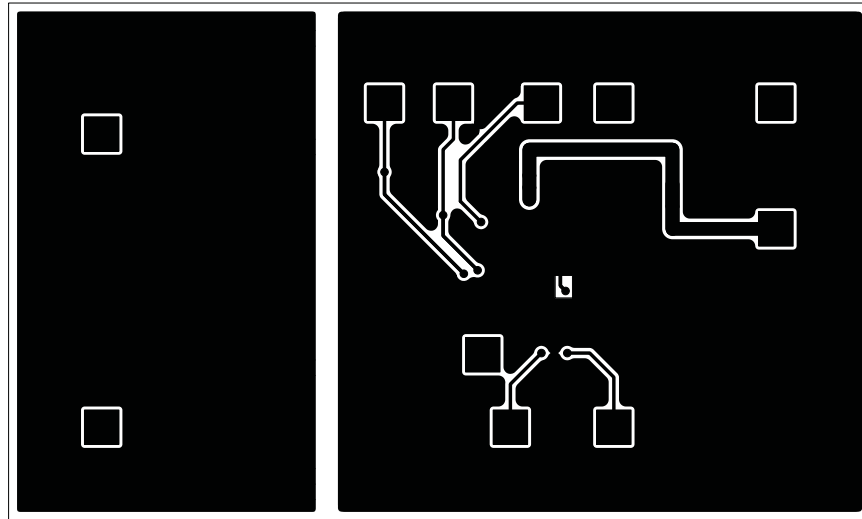


Figure 10. TPS55010EVM-051 Bottom Copper

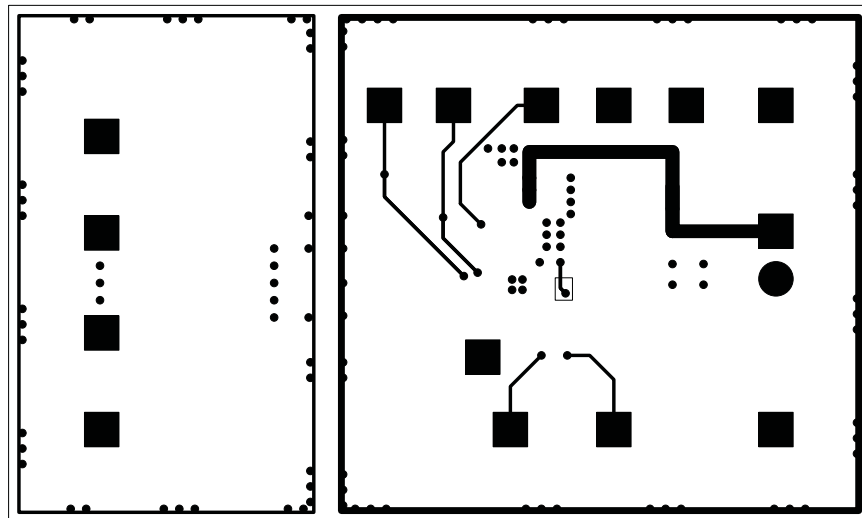


Figure 11. TPS55010EVM-051 Bottom Assembly

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.

4 Schematic and Bill of Materials

This section presents the TPS55010EVM-051 schematic and bill of materials.

4.1 Schematic

Figure 12 is the schematic for the TPS55010EVM-051.

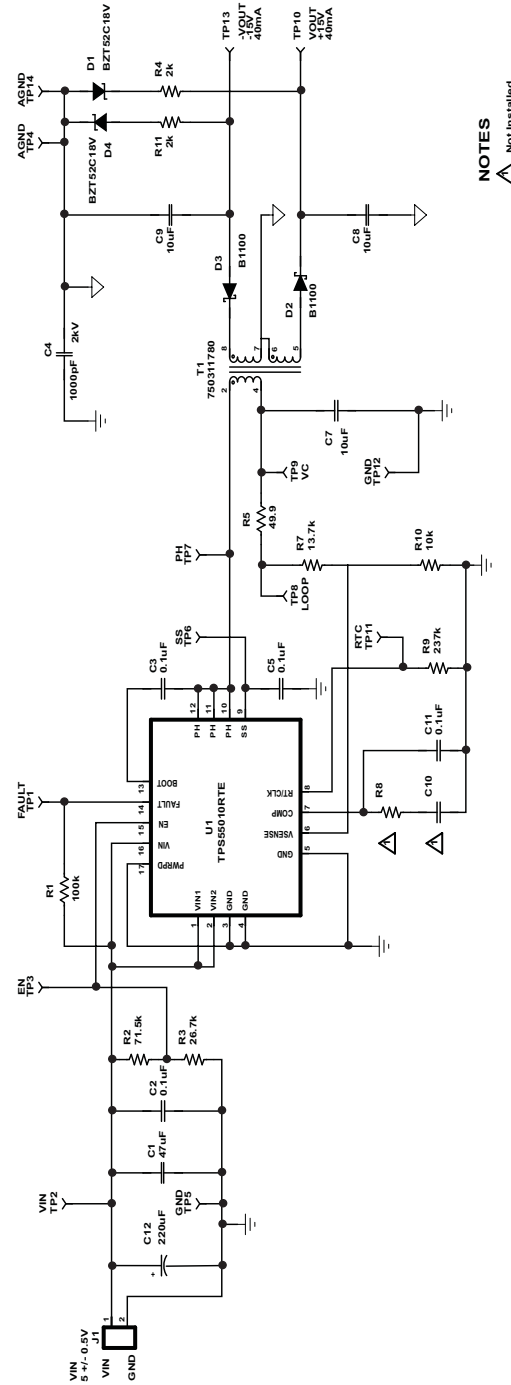


Figure 12. TPS55010EVM-051 Schematic

4.2 Bill of Materials

Table 4 presents the bill of materials for the TPS55010EVM-051.

Table 4. Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C1	47 μ F	Capacitor, Ceramic, 10V, X5R, 10%	1210	Std	Std
4	C2, C3, C5, C11	0.1 μ F	Capacitor, Ceramic, 16V, X7R, 10%	0603	Std	Std
1	C4	1000pF	Capacitor, Ceramic, 2kV, X7R, 10%	1210	Std	Std
1	C7	10 μ F	Capacitor, Ceramic, 10V, X5R, 10%	1206	Std	Std
2	C8, C9	10 μ F	Capacitor, Ceramic, 25V, X5R, 10%	1210	Std	Std
0	C10	DNP	Capacitor, Ceramic, 16V, X7R, 10%	0603	Std	Std
1	C12	220 μ F	Capacitor, Aluminum, 6.3V, \pm 20%	0.260 x 0.276 inch	EEE-FK0J221P	Panasonic
2	D1, D4	BZT52C18V	Diode, Zener, Planar Power, 500mW, 18V	SOD-123	BZT52C18-7-F	Diodes, Inc
2	D2, D3	B1100	Diode, Schottky, 1000-mA, 100-V	SMA	B1100-13-F	Diodes, Inc
1	J1	ED555/2DS	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25 inch	ED555/2DS	OST
1	R1	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
2	R4, R11	2k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	49.9	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R7	13.7k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R8	DNP	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R9	237k	Resistor, Chip, 1/16W, 1	0603	Std	Std
1	R10	61.9k	Resistor, Chip, 1/16W, 1	0603	Std	Std
4	TP1, TP3, TP6, TP11	5012	Test Point, White, Thru Hole	0.125 x 0.125 inch	5012	Keystone
4	TP2, TP9, TP10, TP13	5010	Test Point, Red, Thru Hole	0.125 x 0.125 inch	5010	Keystone
4	TP4, TP5, TP12, TP14	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 μ H	Transformer, \pm 10%	0.410 x 0.510 inch	750311780	Wurth
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"	PWR051	Any

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 4 V to 6 V and the output voltage range of -22 V to +22 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 55°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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