



# TPS54526 4.5-V to 18-V Input, 5.5-A Synchronous Step-Down Converter with Eco-mode™

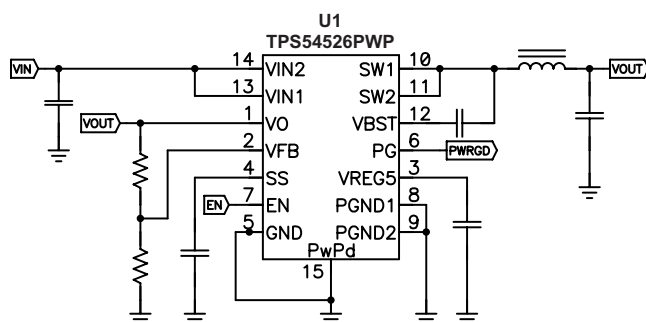
## 1 Features

- D-CAP2™ Mode Enables Fast Transient Response
- Low Output Ripple and Allows Ceramic Output Capacitor
- Wide  $V_{IN}$  Input Voltage Range: 4.5 V to 18 V
- Output Voltage Range: 0.76 V to 5.5 V
- Highly Efficient Integrated FET's Optimized for Lower Duty Cycle Applications
  - 63 m $\Omega$  (High Side) and 33 m $\Omega$  (Low Side)
- High Efficiency, less than 10  $\mu$ A at shutdown
- High Initial Bandgap Reference Accuracy
- Adjustable Soft Start
- Pre-Biased Soft Start
- 650-kHz Switching Frequency ( $f_{SW}$ )
- Cycle By Cycle Over Current Limit
- Power Good Output
- Auto-Skip Eco-mode™ for High Efficiency at Light Load

## 2 Applications

- Wide Range of Applications for Low Voltage System
  - Digital TV Power Supply
  - High Definition Blu-ray Disc™ Players
  - Networking Home Terminal
  - Digital Set Top Box (STB)

## 4 Simplified Schematic



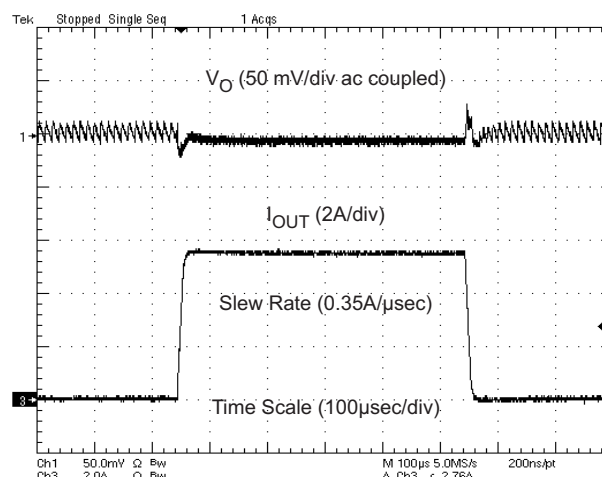
## 3 Description

The TPS54526 is an adaptive on-time D-CAP2™ mode synchronous buck converter. The TPS54526 enables system designers to complete the suite of various end equipment's power bus regulators with a cost effective, low component count, low standby current solution. The main control loop for the TPS54526 uses the D-CAP2™ mode control which provides a very fast transient response with no external compensation components. The adaptive on-time control supports seamless transition between PWM mode at higher load conditions and Eco-mode™ operation at light loads. Eco-mode™ allows the TPS54526 to maintain high efficiency during lighter load conditions. The TPS54526 also has a proprietary circuit that enables the device to adopt to both low equivalent series resistance (ESR) output capacitors, such as POSCAP, SP-CAP, and ultra-low ESR ceramic capacitors. The device operates from 4.5-V to 18-V  $V_{IN}$  input. The output voltage can be programmed between 0.76V and 5.5V. The device also features an adjustable soft start time and a power good function. The TPS54526 is available in the 14-pin HTSSOP package and the 16 pin QFN package, designed to operate from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS54526	HTSSOP (14)	5.00mm x 4.40mm
	VQFN (16)	4.00mm x 4.00mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.



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## 5 Revision History

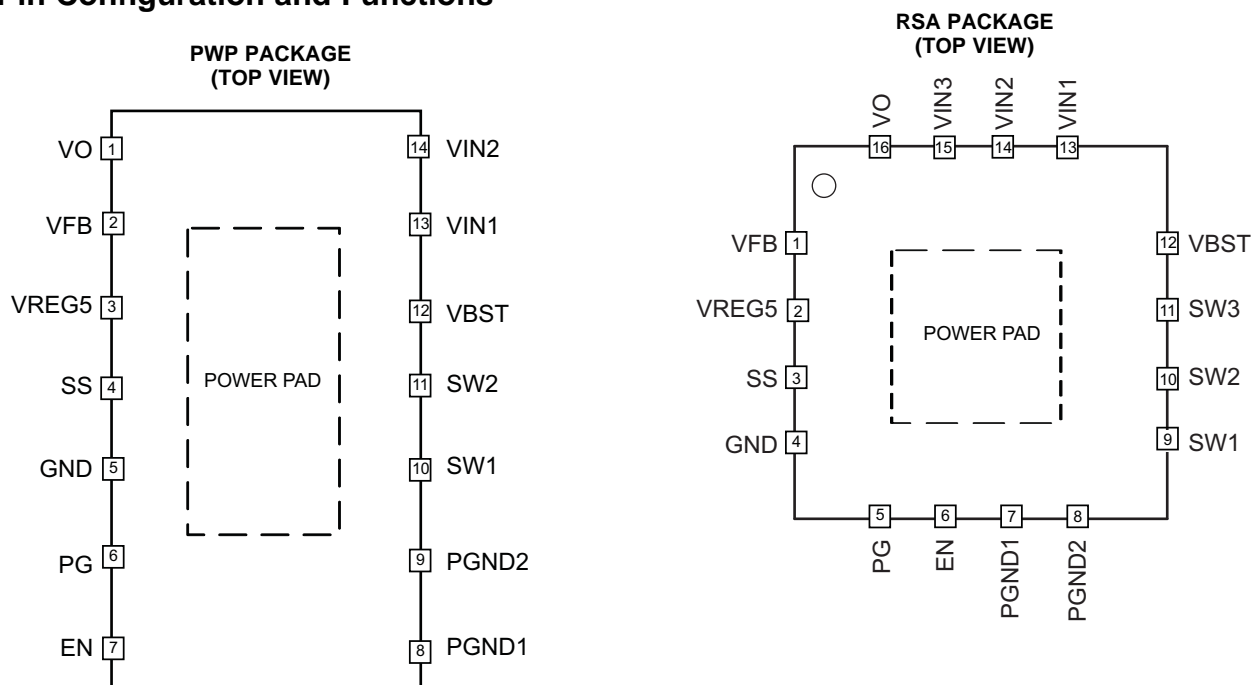
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision B (January 2014) to Revision C</b>	<b>Page</b>
• Changed the data sheet to the new TI standard format .....	<b>1</b>
• Added the Handling Ratings table .....	<b>4</b>
• Added the Timing Requirements table .....	<b>6</b>
• Added the Power Supply Recommendations section .....	<b>17</b>

<b>Changes from Revision A (July 2013) to Revision B</b>	<b>Page</b>
• Change the data sheet Title From: 4.5-V to 18-V Input, 5.5-A Synchronous Step-Down Converter with Eco-mode™ To: 4.5-V to 18-V Input, 3-A Synchronous Step-Down Converter with Eco-mode™ .....	<b>1</b>

<b>Changes from Original (May 2012) to Revision A</b>	<b>Page</b>
• Changed the Over/Under Voltage Protection section. From: "as the high-side MOSFET driver turns off and the low-side MOSFET turns on" To: "as both the high-side and low-side MOSFET drivers turn off" .....	<b>10</b>

## 6 Pin Configuration and Functions



### Pin Functions

PIN			DESCRIPTION
NAME	NUMBER		
	PWP 14	RSA 16	
VO	1	16	Connect to output of converter. This pin is used for output discharge function.
VFB	2	1	Converter feedback input. Connect to output voltage with feedback resistor divider.
VREG5	3	2	5.5 V power supply output. A capacitor (typical 1 μF) should be connected to GND. VREG5 is not active when EN is low.
SS	4	3	Soft-start control. An external capacitor should be connected to GND.
GND	5	4	Signal ground pin.
PG	6	5	Open drain power good output.
EN	7	6	Enable control input. EN is active high and must be pulled up to enable the device.
PGND1, PGND2	8, 9	7, 8	Ground returns for low-side MOSFET. Also serve as inputs of current comparators. Connect PGND and GND strongly together near the IC.
SW1, SW2, SW3 <sup>(1)</sup>	10, 11	9, 10, 11	Switch node connection between high-side NFET and low-side NFET. Also serve as inputs to current comparators.
VBST	12	12	Supply input for high-side NFET gate driver (boost terminal). Connect capacitor from this pin to respective SW1, SW2 terminals. An internal PN diode is connected between VREG5 to VBST pin.
VIN1, VIN2, VIN3 <sup>(1)</sup>	13, 14	13, 14, 15	Power input and connected to high side NFET drain. Supply input for 5-V internal linear regulator for the control circuitry.
PowerPAD™	Back side	Back side	Thermal pad of the package. Must be soldered to achieve appropriate dissipation. Should be connected to PGND.

(1) SW3, VIN3 applies to 16 pin package only.

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
Input voltage range	VIN1, VIN2, EN	–0.3	20	V
	VBST	–0.3	26	V
	VBST (10 ns transient)	–0.3	28	V
	VBST (vs Sw1, SW2)	–0.3	6.5	V
	VFB, VO, SS, PG	–0.3	6.5	V
	SW1, SW2	–2	20	V
	SW1, SW2 (10 ns transient)	–3	22	V
Output voltage range	VREG5	–0.3	6.5	V
	PGND1, PGND2	–0.3	0.3	V
Voltage from GND to PowerPAD™, V <sub>diff</sub>		–0.2	0.2	V
Operating junction temperature, T <sub>J</sub>		–40	150	°C

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 7.2 Handling Ratings

			MIN	MAX	UNIT
T <sub>stg</sub>	Storage temperature range		–55	150	°C
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>	–2	2	kV
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>	–500	500	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V <sub>IN</sub>	Supply input voltage range		4.5	18	V
V <sub>I</sub>	Input voltage range	VBST	–0.3	24	V
		VBST (10 ns transient)	–0.3	27	
		VBST (vs Sw1, SW2)	–0.3	5.7	
		SS, PG	–0.3	5.7	
		EN	–0.3	18	
		VO, VFB	–0.3	5.5	
		SW1, SW2	–1.8	18	
		SW1, SW2 (10 ns transient)	–3	21	
		PGND1, PGND2	–0.3	0.1	
V <sub>O</sub>	Output voltage range	VREG5	–0.3	5.7	V
I <sub>O</sub>	Output Current range	I <sub>VREG5</sub>	0	5	mA
T <sub>A</sub>	Operating free-air temperature		–40	85	°C
T <sub>J</sub>	Operating junction temperature		–40	150	°C

## 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TPS54526		UNITS
		PWP (14) PINS	RSA (16) PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	43.7	35.2	°C/W
R <sub>θJctop</sub>	Junction-to-case (top) thermal resistance	33.1	40.6	
R <sub>θJB</sub>	Junction-to-board thermal resistance	28.4	12.3	
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	1.3	0.8	
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	28.2	12.4	
R <sub>θJcbot</sub>	Junction-to-case (bottom) thermal resistance	4.7	3.6	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## 7.5 Electrical Characteristics

over operating free-air temperature range, V<sub>IN</sub> = 12V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>SUPPLY CURRENT</b>						
I <sub>VIN</sub>	Operating - non-switching supply current	V <sub>IN</sub> current, T <sub>A</sub> = 25°C, EN = 5 V, V <sub>VFB</sub> = 0.8 V		900	1400	μA
I <sub>VINSDN</sub>	Shutdown supply current	V <sub>IN</sub> current, T <sub>A</sub> = 25°C, EN = 0 V		3.6	10	μA
<b>LOGIC THRESHOLD</b>						
V <sub>ENH</sub>	EN high-level input voltage		1.6			V
V <sub>ENL</sub>	EN low-level input voltage				0.6	V
R <sub>EN</sub>	EN pin resistance to GND	V <sub>EN</sub> = 12 V	220	440	880	kΩ
<b>VFB VOLTAGE AND DISCHARGE RESISTANCE</b>						
V <sub>FBTH</sub>	VFB threshold voltage	VFB voltage light load mode, T <sub>A</sub> = 25°C, V <sub>O</sub> = 1.05 V, I <sub>O</sub> = 10mA		771		mV
		T <sub>A</sub> = 25°C, V <sub>O</sub> = 1.05 V, continuous mode	757	765	773	
		T <sub>A</sub> = 0°C to 85°C, V <sub>O</sub> = 1.05 V, continuous mode <sup>(1)</sup>	753		777	
		T <sub>A</sub> = -40°C to 85°C, V <sub>O</sub> = 1.05 V, continuous mode <sup>(1)</sup>	751		779	
I <sub>VFB</sub>	VFB input current	V <sub>VFB</sub> = 0.8 V, T <sub>A</sub> = 25°C		0	±0.15	μA
R <sub>Dischg</sub>	V <sub>O</sub> discharge resistance	V <sub>EN</sub> = 0 V, V <sub>O</sub> = 0.5 V, T <sub>A</sub> = 25°C		50	100	Ω
<b>VREG5 OUTPUT</b>						
V <sub>VREG5</sub>	VREG5 output voltage	T <sub>A</sub> = 25°C, 6 V < V <sub>IN</sub> < 18 V, 0 < I <sub>VREG5</sub> < 5 mA	5.2	5.5	5.7	V
V <sub>VREG5</sub>	VREG5 Line regulation	6.0 V < V <sub>IN</sub> < 18 V, I <sub>VREG5</sub> = 5 mA			20	mV
V <sub>VREG5</sub>	VREG5 Load regulation	0 mA < I <sub>VREG5</sub> < 5 mA			100	mV
I <sub>VREG5</sub>	VREG5 Output current	V <sub>IN</sub> = 6 V, V <sub>VREG5</sub> = 4 V, T <sub>A</sub> = 25°C		60		mA
<b>MOSFET</b>						
R <sub>dsonh</sub>	High side switch resistance	T <sub>A</sub> = 25°C, V <sub>BST</sub> - V <sub>SW1,2</sub> = 5.5 V		63		mΩ
R <sub>dsonl</sub>	Low side switch resistance	T <sub>A</sub> = 25°C		33		mΩ

(1) Not production tested.

## Electrical Characteristics (continued)

over operating free-air temperature range,  $V_{IN} = 12V$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
CURRENT LIMIT						
I <sub>ocl</sub>	Current limit	L <sub>OUT</sub> = 1.5 μH <sup>(2)</sup> ,	6.1	6.9	8.4	A
THERMAL SHUTDOWN						
T <sub>SDN</sub>	Thermal shutdown threshold	Shutdown temperature <sup>(2)</sup>	165			°C
		Hysteresis <sup>(2)</sup>	35			
SOFT START						
I <sub>SSC</sub>	SS charge current	V <sub>SS</sub> = 1.0 V	4.2	6.0	7.8	μA
I <sub>SSD</sub>	SS discharge current	V <sub>SS</sub> = 0.5 V	0.1	0.2		mA
POWER GOOD						
V <sub>THPG</sub>	PG threshold	V <sub>VFB</sub> rising (good)	85	90	95	%
		V <sub>VFB</sub> falling (fault)	85			%
I <sub>PG</sub>	PG sink current	V <sub>PG</sub> = 0.5 V	2.5	5		mA
OUTPUT UNDERVOLTAGE AND OVERVOLTAGE PROTECTION						
V <sub>OVP</sub>	Output OVP trip threshold	OVP detect	120	125	130	%
V <sub>UVP</sub>	Output UVP trip threshold	UVP detect	60	65	70	%
		Hysteresis	10			%
UVLO						
V <sub>UVLO</sub>	UVLO threshold	Wake up VREG5 voltage	3.31	3.61	3.91	V
		Fall VREG5 voltage	2.82	3.12	3.42	
		Hysteresis VREG5 voltage	0.37	0.49	0.61	

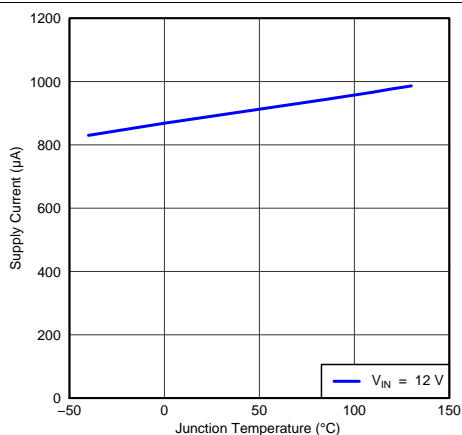
(2) Not production tested.

## 7.6 Timing Requirements

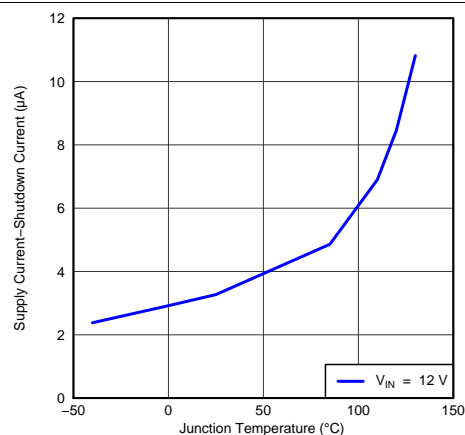
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>ON-TIME TIMER CONTROL</b>						
$t_{ON}$	On time	$V_{IN} = 12 V, V_O = 1.05 V$		155		ns
$t_{OFF(MIN)}$	Minimum off time	$T_A = 25^\circ C, V_{FB} = 0.7 V$		260	330	ns
<b>OUTPUT UNDERVOLTAGE AND OVERVOLTAGE PROTECTION</b>						
$t_{OVPDEL}$	Output OVP prop delay			10		$\mu s$
$t_{UVPDEL}$	Output UVP delay			0.25		ms
$t_{UVPEN}$	Output UVP enable delay	Relative to soft-start time		x 1.7		

## 7.7 Typical Characteristics

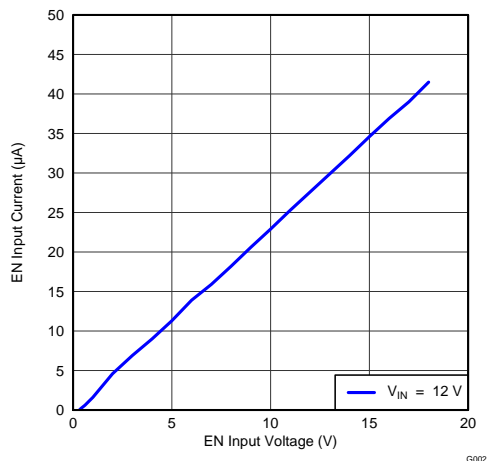
$V_{IN} = 12\text{ V}$ ,  $T_A = 25\text{ }^{\circ}\text{C}$  (unless otherwise noted)



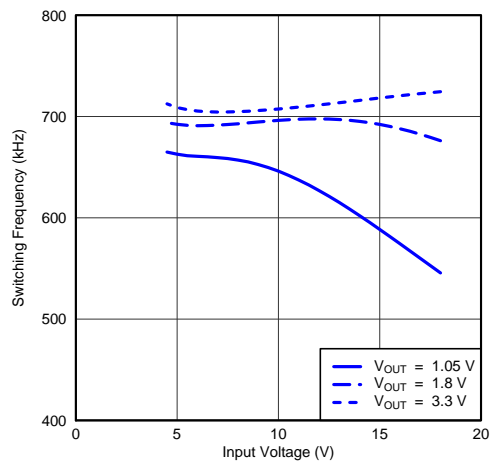
**Figure 1.  $V_{IN}$  Current vs Junction Temperature**



**Figure 2.  $V_{IN}$  Shutdown Current vs Junction Temperature**

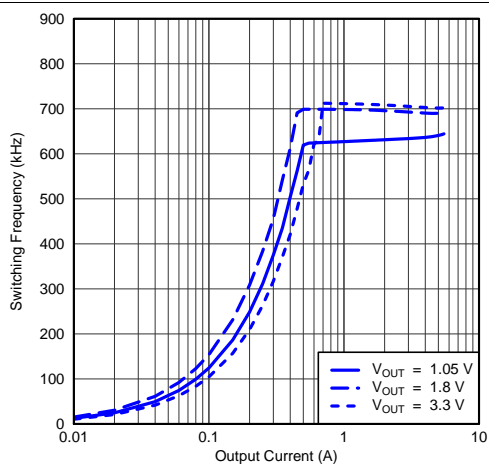


**Figure 3. EN Current vs EN Voltage**

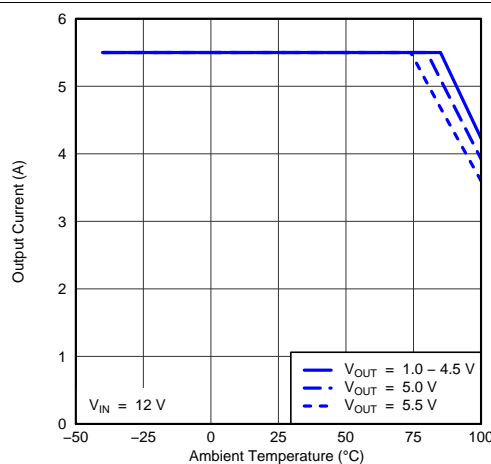


$I_O = 1\text{ A}$

**Figure 4. Switching Frequency vs Input Voltage**



**Figure 5. Switching Frequency vs Output Current**



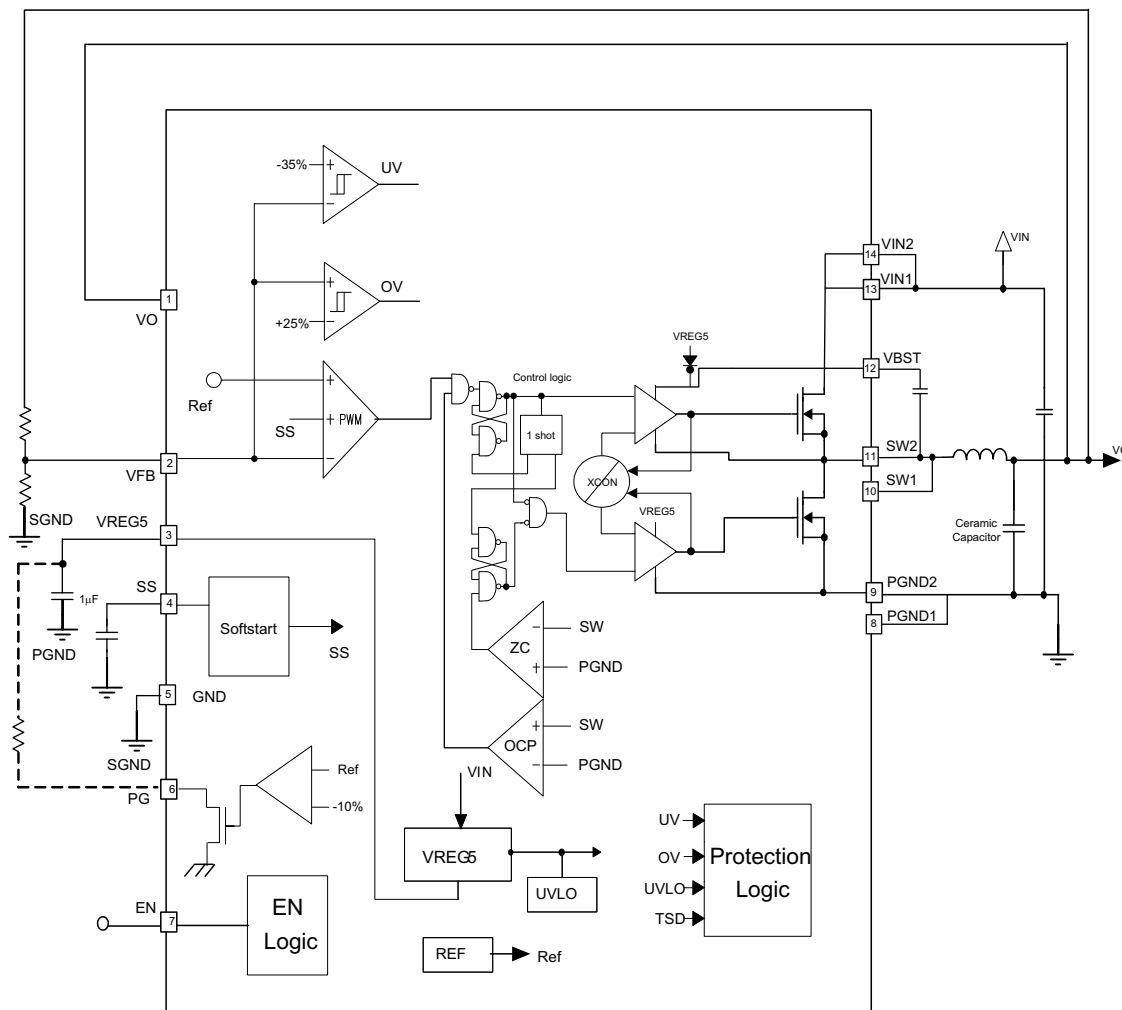
**Figure 6. Output Current vs Ambient Temperature**

## 8 Detailed Description

### 8.1 Overview

The TPS54526 is a 5.5-A synchronous step-down (buck) converter with two integrated N-channel MOSFETs and auto-skip Eco-mode™ to improve light load efficiency. It operates using D-CAP2™ mode control. The fast transient response of D-CAP2™ control reduces the output capacitance required to meet a specific level of performance. Proprietary internal circuitry allows the use of low ESR output capacitors including ceramic and special polymer types.

### 8.2 Functional Block Diagram



- A. The block diagram shown is for the PWP 14 pin package. The QFN 16 pin package block diagram is identical except for the pin out.



## 8.3 Feature Description

### 8.3.1 PWM Operation

The main control loop of the TPS54526 is an adaptive on-time pulse width modulation (PWM) controller that supports a proprietary D-CAP2™ mode control. D-CAP2™ mode control combines constant on-time control with an internal compensation circuit for pseudo-fixed frequency and low external component count configuration with both low ESR and ceramic output capacitors. It is stable with virtually no ripple at the output.

At the beginning of each cycle, the high-side MOSFET is turned on. The MOSFET is turned off after the internal one-shot timer expires. The one-shot timer is set by the converter input voltage, VIN, and the output voltage, VO, to maintain a pseudo-fixed frequency over the input voltage range, hence it is called adaptive on-time control. The one-shot timer is reset and the high-side MOSFET is turned on again when the feedback voltage falls below the reference voltage. An internal ramp is added to reference voltage to simulate output ripple, eliminating the need for ESR induced output ripple from D-CAP2™ mode control.

### 8.3.2 PWM Frequency and Adaptive On-Time Control

TPS54526 uses an adaptive on-time control scheme and does not have a dedicated on board oscillator. The TPS54526 runs with a pseudo-constant frequency of 650 kHz by using the input voltage and output voltage to set the on-time one-shot timer. The on-time is inversely proportional to the input voltage and proportional to the output voltage, therefore, when the duty ratio is VOUT/VIN, the frequency is constant.

### 8.3.3 Soft Start and Pre-Biased Soft Start

The soft start function is adjustable. When the EN pin becomes high, 6 µA current begins charging the capacitor which is connected from the SS pin to GND. Smooth control of the output voltage is maintained during start up. The equation for the slow start time is shown in Equation 1. VFB voltage is 0.765 V and SS pin source current is 6 µA.

$$t_{SS}(ms) = \frac{C_{SS}(nF) \times V_{REF} \times 1.1}{I_{SS}(\mu A)} = \frac{C_{SS}(nF) \times 0.765 \times 1.1}{6} \quad (1)$$

The TPS54526 contains a unique circuit to prevent current from being pulled from the output during startup if the output is pre-biased. When the soft-start commands a voltage higher than the pre-bias level (internal soft start becomes greater than feedback voltage VFB), the controller slowly activates synchronous rectification by starting the first low side FET gate driver pulses with a narrow on-time. It then increments that on-time on a cycle-by-cycle basis until it coincides with the time dictated by (1-D), where D is the duty cycle of the converter. This scheme prevents the initial sinking of the pre-bias output, and ensure that the out voltage (VO) starts and ramps up smoothly into regulation and the control loop is given time to transition from pre-biased start-up to normal mode operation.

### 8.3.4 Power Good

The TPS54526 has power-good open drain output. The power good function is activated after soft start has finished. The power good function becomes active after 1.7 times soft-start time. When the output voltage is within -10% of the target value, internal comparators detect power good state and the power good signal becomes high. Rpg resistor value, which is connected between PG and VREG5, is required from 25kΩ to 150kΩ. If the feedback voltage goes under 15% of the target value, the power good signal becomes low after a 5 µs internal delay.

### 8.3.5 VREG5

VREG5 is an internally generated voltage source used by the TPS54526. It is derived directly from the input voltage and is nominally regulated to 5.5 V when the input voltage is above 5.6 V. The output of the VREG5 regulator is the input to the internal UVLO function. VREG5 must be above the UVLO wake up threshold voltage (3.6 V typical) for the TPS54526 to function. Connect a 1 µF capacitor between pin 3 of the TPS54526 and power ground for proper regulation of the VREG5 output. The VREG5 output voltage is available for external use. It is recommended to use no more than 5 mA for external loads. The VREG5 output is disabled when the TPS54526 EN pin is open or pulled low.

## Feature Description (continued)

### 8.3.6 Output Discharge Control

TPS54526 discharges the output when EN is low, or the controller is turned off by the protection functions (OVP, UVP, UVLO and thermal shutdown). The output is discharged by an internal 50- $\Omega$  MOSFET which is connected from VO to PGND. The internal low-side MOSFET is not turned on during the output discharge operation to avoid the possibility of causing negative voltage at the output.

### 8.3.7 Current Protection

The output overcurrent protection (OCP) is implemented using a cycle-by-cycle valley detect control circuit. The switch current is monitored by measuring the low-side FET switch voltage between the SW pin and GND. This voltage is proportional to the switch current. To improve accuracy, the voltage sensing is temperature compensated.

During the on-time of the high-side FET switch, the switch current increases at a linear rate determined by  $V_{IN}$ ,  $V_{OUT}$ , the on-time, and the output inductor value. During the on-time of the low-side FET switch, this current decreases linearly. The average value of the switch current is the load current  $I_{OUT}$ . If the measured voltage is above the voltage proportional to the current limit. Then, the device constantly monitors the low-side FET switch voltage, which is proportional to the switch current, during the low-side on-time.

The converter maintains the low-side switch on until the measured voltage is below the voltage corresponding to the current limit at which time the switching cycle is terminated and a new switching cycle begins. In subsequent switching cycles, the on-time is set to a fixed value and the current is monitored in the same manner.

There are some important considerations for this type of overcurrent protection. The load current one half of the peak-to-peak inductor current higher than the overcurrent threshold. Also when the current is being limited, the output voltage tends to fall as the demanded load current may be higher than the current available from the converter. This may cause the output under-voltage protection circuit to be activated. When the overcurrent condition is removed, the output voltage will return to the regulated value. This protection is non-latching.

### 8.3.8 Over/Under Voltage Protection

TPS54526 monitors a resistor divided feedback voltage to detect over and under voltage. When the feedback voltage becomes higher than 125% of the target voltage, the OVP comparator output goes high and the circuit latches as both the high-side and low-side MOSFET drivers turns off. When the feedback voltage becomes lower than 65% of the target voltage, the UVP comparator output goes high and an internal UVP delay counter begins. After 250  $\mu$ s, the device latches off both internal top and bottom MOSFET. This function is enabled approximately 1.7 x softstart time.

### 8.3.9 UVLO Protection

Undervoltage lock out protection (UVLO) monitors the voltage of the  $V_{REG5}$  pin. When the  $V_{REG5}$  voltage is lower than UVLO threshold voltage, the TPS54526 is shut off. This protection is non-latching.

### 8.3.10 Thermal Shutdown

TPS54526 monitors the temperature of itself. If the temperature exceeds the threshold value (typically 165°C), the device is shut off. This is non-latch protection.

## 8.4 Device Functional Modes

### 8.4.1 Auto-Skip Eco-Mode™ Control

The TPS54526 is designed with Auto-Skip Eco-mode™ to increase light load efficiency. As the output current decreases from heavy load condition, the inductor current is also reduced and eventually comes to point that its rippled valley touches zero level, which is the boundary between continuous conduction and discontinuous conduction modes. The rectifying MOSFET is turned off when its zero inductor current is detected. As the load current further decreases the converter run into discontinuous conduction mode. The on-time is kept almost the same as it was in the continuous conduction mode so that it takes longer time to discharge the output capacitor with smaller load current to the level of the reference voltage. The transition point to the light load operation  $I_{OUT(LL)}$  current can be calculated in [Equation 2](#).

$$I_{OUT(LL)} = \frac{1}{2 \times L \times f_{SW}} \times \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{V_{IN}} \quad (2)$$

## 9 Application and Implementation

### 9.1 Application Information

### 9.2 Typical Application

The TPS54526 is an adaptive on-time D-CAP2™ mode synchronous buck converter. Idea applications are: Digital TV Power Supply, High Definition Blu-ray Disc™ Player, Networking Home Terminal and Digital Set Top Box.

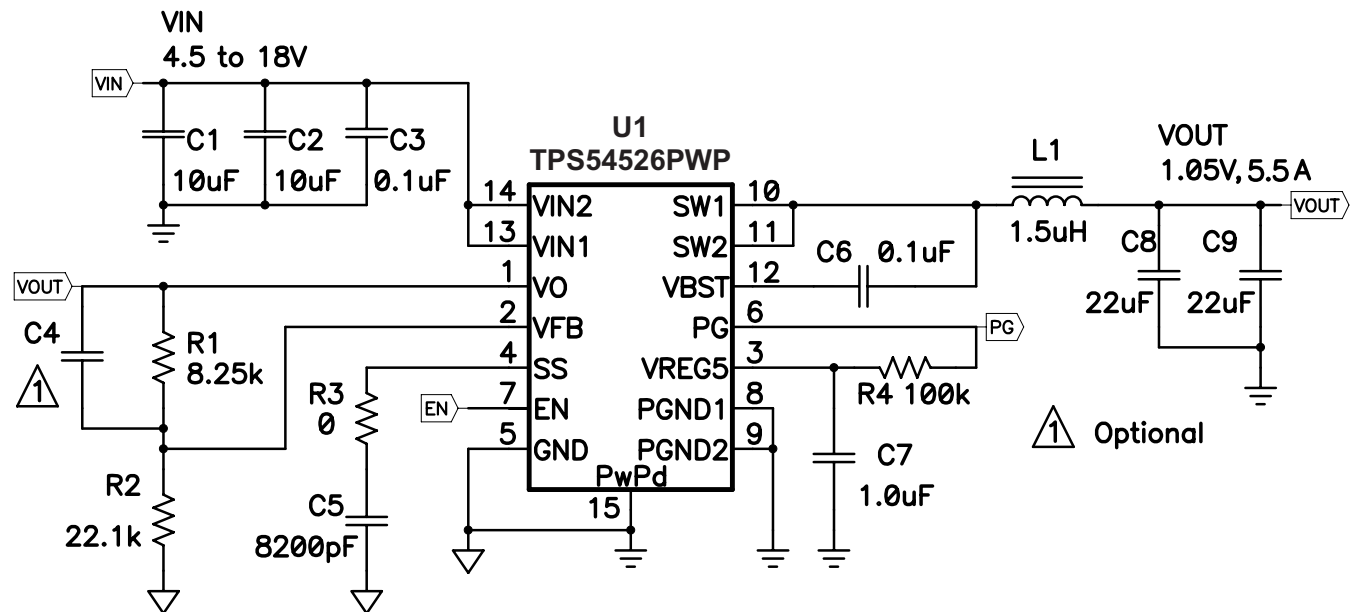


Figure 7. Schematic Diagram for This Design Example

#### 9.2.1 Design Requirements

For this design example, use the following input parameters.

Table 1. Design Parameters

DESIGN PARAMETERS	VALUES
Input voltage range	4.5V – 18 V
Output voltage	1.05 V
Output current rating	0 – 5.5 A
Output voltage ripple	7 mV <sub>PP</sub> (12 V <sub>IN</sub> / 5.5 A)

#### 9.2.2 Detailed Design Procedure

##### 9.2.2.1 Step By Step Design Procedure

To begin the design process, the designer must know a the following application parameters:

- Input voltage range
- Output voltage
- Output current
- Output voltage ripple
- Input voltage ripple

### 9.2.2.2 Output Voltage Resistors Selection

The output voltage is set with a resistor divider from the output node to the VFB pin. It is recommended to use 1% tolerance or better divider resistors. Start by using Equation 3 to calculate  $V_{OUT}$

To improve efficiency at very light loads consider using larger value resistors, too high of resistance will be more susceptible to noise and voltage errors from the VFB input current will be more noticeable

$$V_{OUT} = 0.765 \cdot \left(1 + \frac{R1}{R2}\right) \quad (3)$$

### 9.2.2.3 Output Filter Selection

The output filter used with the TPS54526 is an LC circuit. This LC filter has double pole at:

$$F_p = \frac{1}{2\pi \sqrt{L_{OUT} \times C_{OUT}}} \quad (4)$$

At low frequencies, the overall loop gain is set by the output set-point resistor divider network and the internal gain of the TPS54526. The low frequency phase is 180 degrees. At the output filter pole frequency, the gain rolls off at a -40 dB per decade rate and the phase drops rapidly. D-CAP2™ introduces a high frequency zero that reduces the gain roll off to -20 dB per decade and increases the phase to 90 degrees one decade above the zero frequency. The inductor and capacitor selected for the output filter must be selected so that the double pole of Equation 4 is located below the high frequency zero but close enough that the phase boost provided by the high frequency zero provides adequate phase margin for a stable circuit. To meet this requirement use the values recommended in Table 2

**Table 2. Recommended Component Values**

Output Voltage (V)	R1 (kΩ)	R2 (kΩ)	C4 (pF) <sup>(1)</sup>	L1 (μH)	C8 + C9 (μF)
1	6.81	22.1		1.0 - 1.5	22 - 68
1.05	8.25	22.1		1.0 - 1.5	22 - 68
1.2	12.7	22.1		1.0 - 1.5	22 - 68
1.5	21.5	22.1		1.5	22 - 68
1.8	30.1	22.1	5 - 22	1.5	22 - 68
2.5	49.9	22.1	5 - 22	2.2	22 - 68
3.3	73.2	22.1	5 - 22	2.2	22 - 68
5	124	22.1	5 - 22	3.3	22 - 68

(1) Optional

For higher output voltages at or above 1.8 V, additional phase boost can be achieved by adding a feed forward capacitor (C4) in parallel with R1.

Since the DC gain is dependent on the output voltage, the required inductor value increases as the output voltage increases. For higher output voltages above 1.8 V, additional phase boost can be achieved by adding a feed forward capacitor (C4) in parallel with R1

The inductor peak-to-peak ripple current, peak current and RMS current are calculated using Equation 5, Equation 6 and Equation 7. The inductor saturation current rating must be greater than the calculated peak current and the RMS or heating current rating must be greater than the calculated RMS current. Use 650 kHz for  $f_{SW}$ .

$$I_{lp} - p = \frac{V_{OUT}}{V_{IN(max)}} \cdot \frac{V_{IN(max)} - V_{OUT}}{L_O \cdot f_{SW}} \quad (5)$$

$$I_{lpeak} = I_O + \frac{I_{lp} - p}{2} \quad (6)$$

$$I_{Lo(RMS)} = \sqrt{I_O^2 + \frac{1}{12} I_{lp} - p^2} \quad (7)$$

For this design example, the calculated peak current is 6.01 A and the calculated RMS current is 5.5 A. The inductor used is a TDK SPM6530-1R5M100 with a peak current rating of 11.5 A and an RMS current rating of 11 A.

The capacitor value and ESR determines the amount of output voltage ripple. The TPS54526 is intended for use with ceramic or other low ESR capacitors. Recommended values range from 22uF to 68uF. Use [Equation 8](#) to determine the required RMS current rating for the output capacitor

$$I_{CO(RMS)} = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{\sqrt{12} \cdot V_{IN} \cdot L_O \cdot f_{SW}} \quad (8)$$

For this design two TDK C3216X5R0J226M 22uF output capacitors are used. The typical ESR is 2 mΩ each. The calculated RMS current is .284 A and each output capacitor is rated for 4 A.

#### 9.2.2.4 Input Capacitor Selection

The TPS54526 requires an input decoupling capacitor and a bulk capacitor is needed depending on the application. A ceramic capacitor over 10 uF. is recommended for the decoupling capacitor. An additional 0.1 μF capacitor from pin 14 to ground is recommended to improve the stability of the over-current limit function. The capacitor voltage rating needs to be greater than the maximum input voltage.

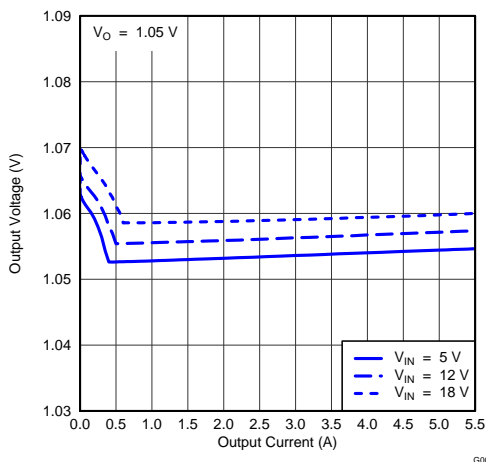
#### 9.2.2.5 Bootstrap Capacitor Selection

A 0.1 μF ceramic capacitor must be connected between the VBST to SW pin for proper operation. It is recommended to use a ceramic capacitor.

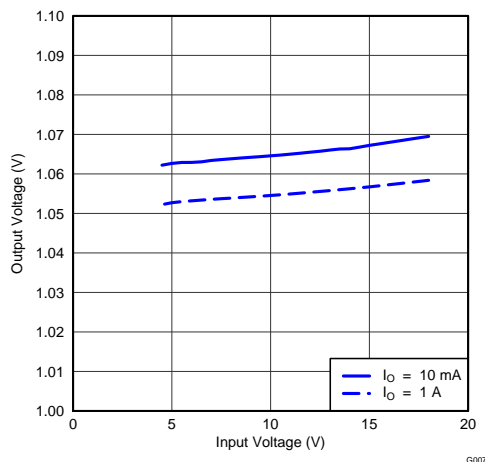
#### 9.2.2.6 VREG5 Capacitor Selection

A 1.0 μF ceramic capacitor must be connected between the VREG5 to GND pin for proper operation. It is recommended to use a ceramic capacitor.

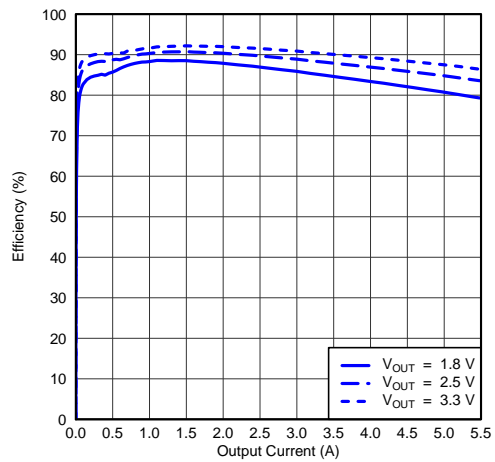
## 9.2.3 Application Curve



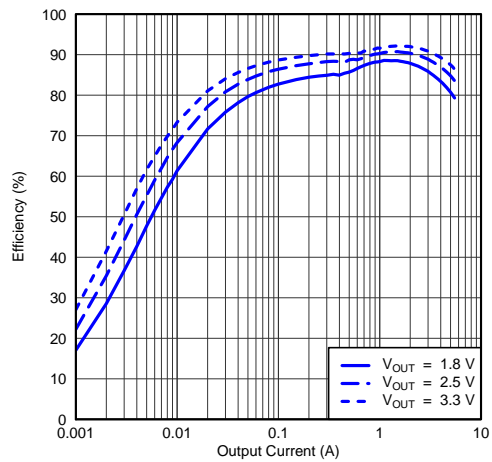
**Figure 8. 1.05V Output Voltage vs Output Current**



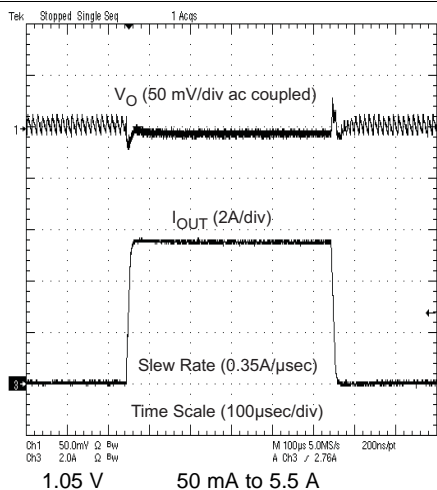
**Figure 9. 1.05V Output Voltage vs Input Voltage**



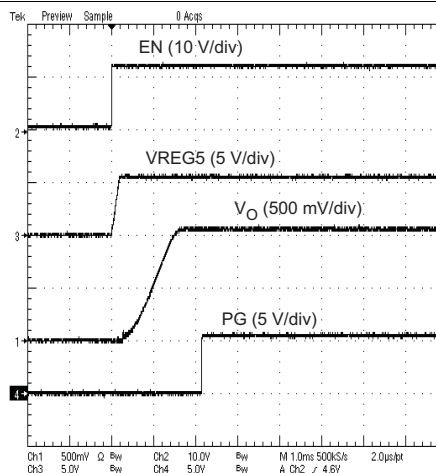
**Figure 10. Efficiency vs Output Current**



**Figure 11. Light Load Efficiency vs Output Current**



**Figure 12. Load Transient Response**

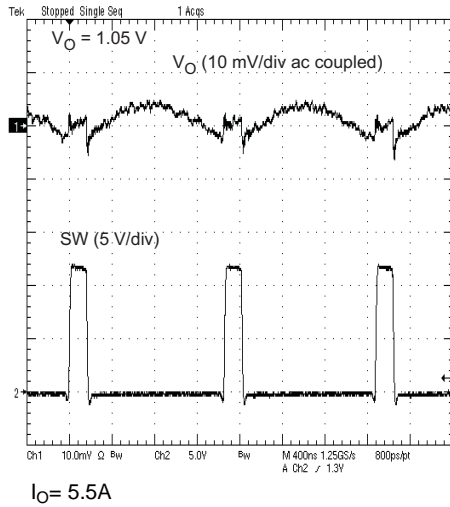


**Figure 13. Startup Waveform**

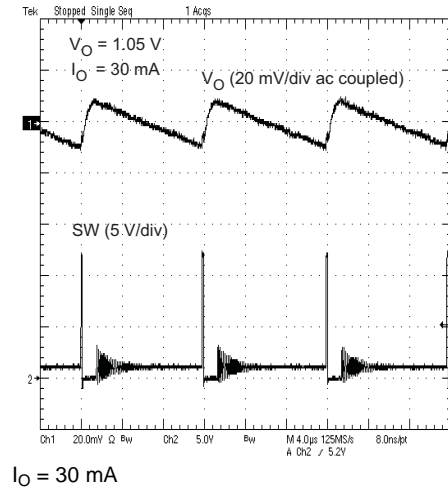
**TPS54526**

SLVSB84C –MAY 2012–REVISED JUNE 2014

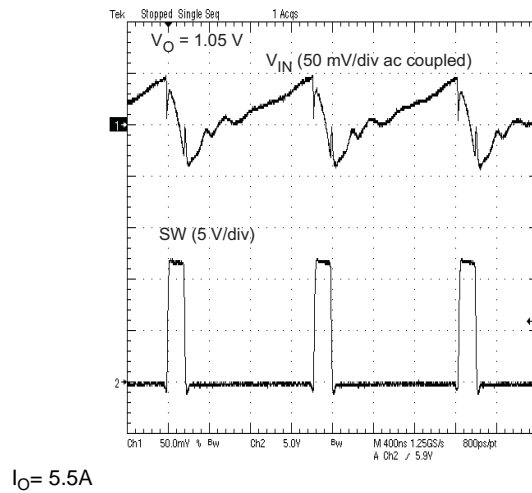
[www.ti.com](http://www.ti.com)



**Figure 14. Voltage Ripple at Output**



**Figure 15. Eco-mode Voltage Ripple at Output**



**Figure 16. Voltage Ripple at Input**



## 10 Power Supply Recommendations

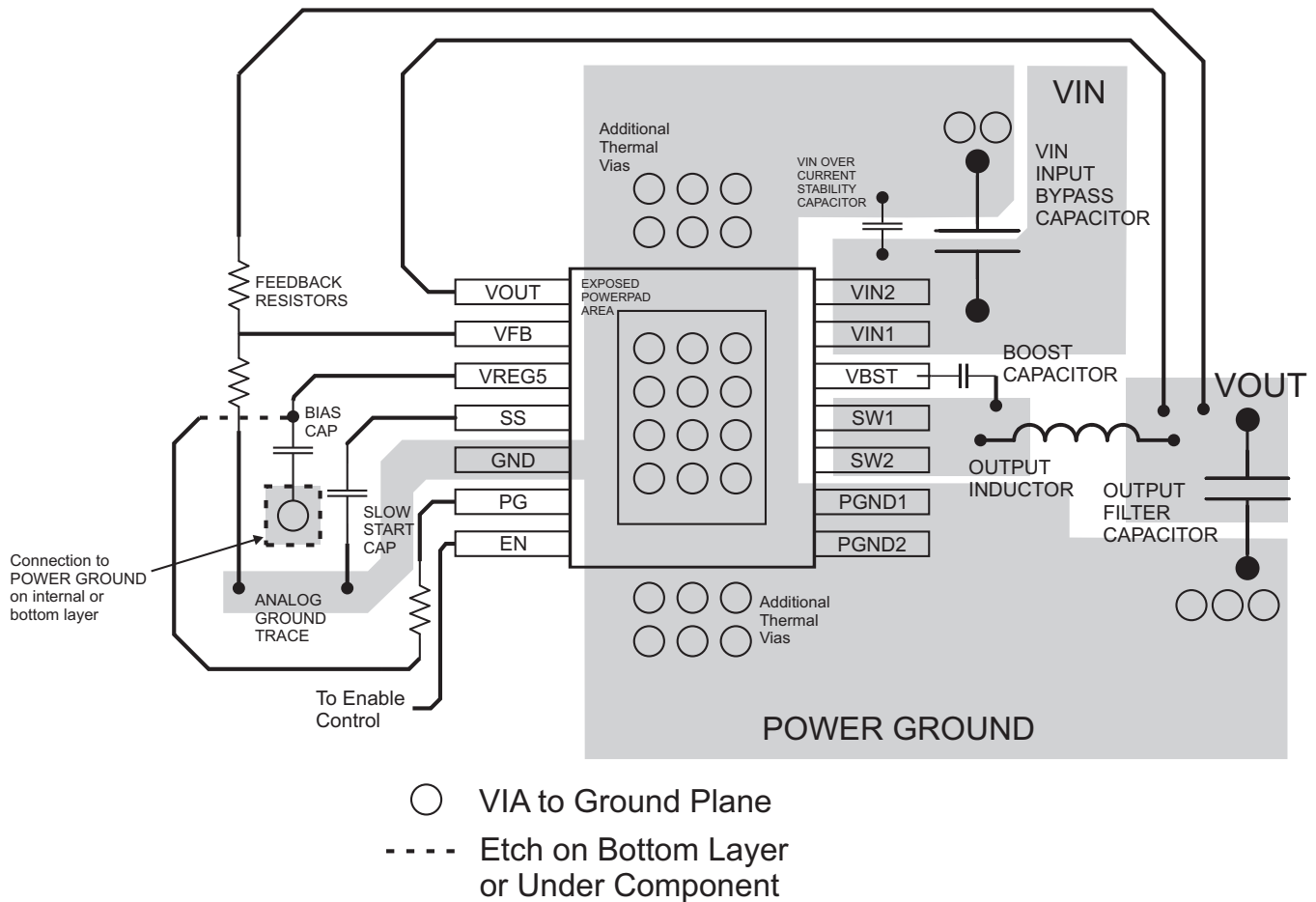
The device is designed to operate from an input voltage supply range between 4.5 V and 18 V. This input supply should be well regulated. If the input supply is located more than a few inches from the TPS54526 converter additional bulk capacitance may be required in addition to the ceramic bypass capacitors. An electrolytic capacitor with a value of 100  $\mu$ F is a typical choice.

## 11 Layout

### 11.1 Layout Guidelines

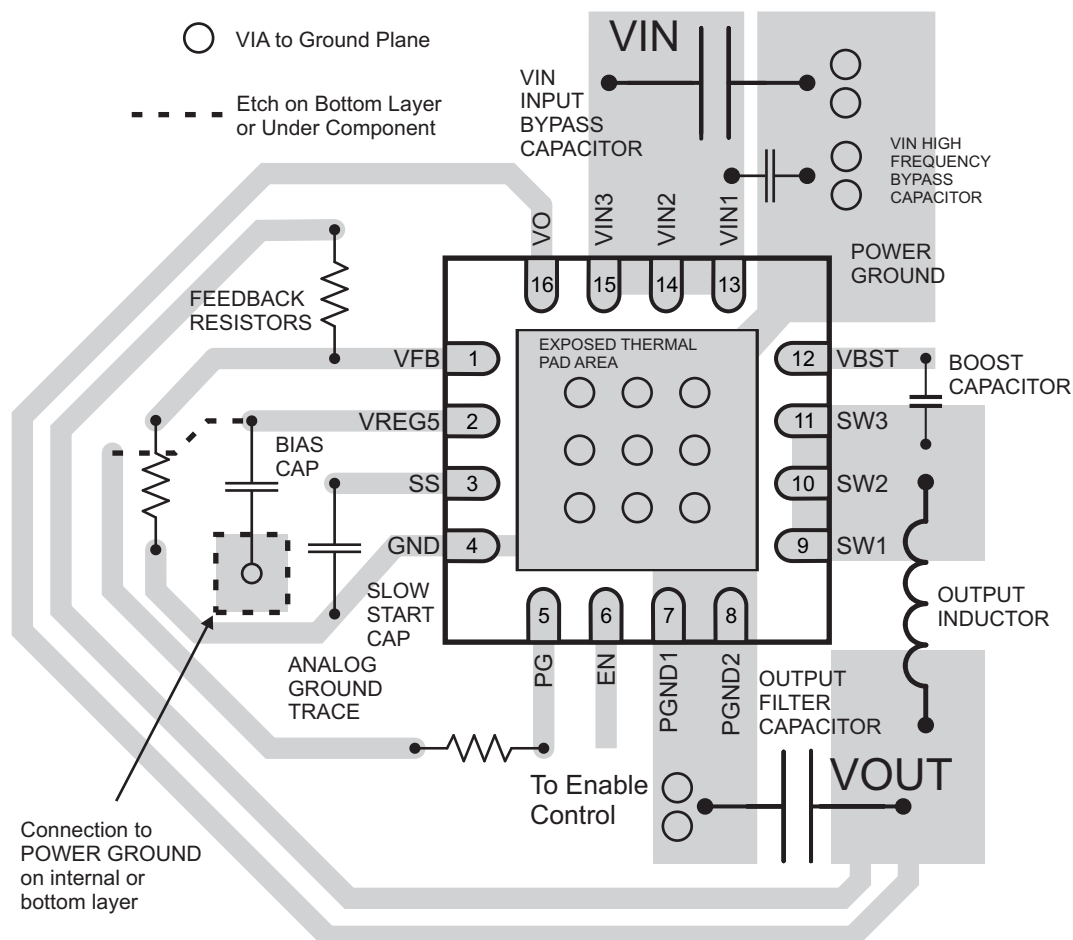
- Keep the input switching current loop as small as possible.
- Keep the SW node as physically small and short as possible to minimize parasitic capacitance and inductance and to minimize radiated emissions. Kelvin connections should be brought from the output to the feedback pin of the device.
- Keep analog and non-switching components away from switching components.
- Make a single point connection from the signal ground to power ground.
- Do not allow switching current to flow under the device.
- VREG5 capacitor should be placed near the device, and connected PGND.
- Output capacitor should be connected to a broad pattern of the PGND.
- Voltage feedback loop should be as short as possible, and preferably with ground shield.
- Lower resistor of the voltage divider which is connected to the VFB pin should be tied to AGND.
- Providing sufficient via is preferable for VIN, SW and PGND connection.
- PCB pattern for VIN and SW should be as broad as possible.
- VIN Capacitor should be placed as near as possible to the device.
- The top side power ground (PGND) copper fill area near the IC should be as large as possible. This will aid in thermal dissipation as well lower conduction losses in the ground return
- Exposed pad of device must be connected to PGND with solder. The PGND area under the IC should be as large as possible and completely cover the exposed thermal pad. The bottom side of the board should contain a large copper area under the device that is directly connected to the exposed area with small diameter vias. Small diameter vias will prevent solder from being drawn away from the exposed thermal pad. Any additional internal layers should also contain copper ground areas under the device and be connected to the thermal vias.

## 11.2 Layout Example



**Figure 17. PCB Layout for PWP Package**

## Layout Example (continued)



**Figure 18. PCB Layout for RSA Package**

## 12 Device and Documentation Support

### 12.1 Trademarks

D-CAP2, Eco-mode are trademarks of Texas Instruments.

Blu-ray Disc is a trademark of Blu-ray Disc Association.

### 12.2 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 12.3 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 13 Mechanical, Packaging, and Orderable Information

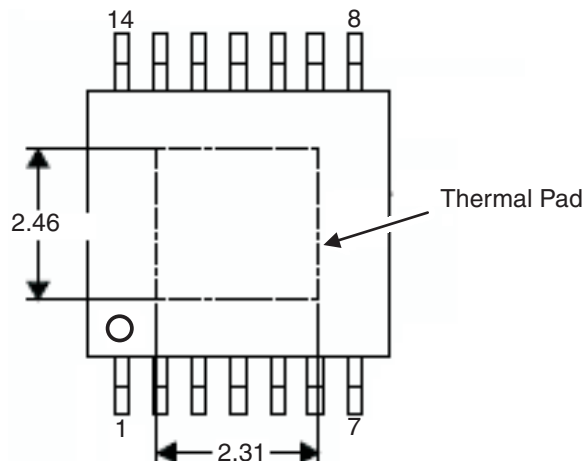
The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

### 13.1 Thermal Information

This PowerPad™ package incorporates an exposed thermal pad that is designed to be directly to an external heatsink. The thermal pad must be soldered directly to the printed board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD™ package and how to use the advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD™ Thermally Enhanced Package, Texas Instruments Literature No. [SLMA002](#) and Application Brief, PowerPAD™ Made Easy, Texas Instruments Literature No. [SLMA004](#).

The exposed thermal pad dimensions for this package are shown in the following illustration.



**Figure 19. Thermal Pad Dimensions**

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS54526PWP	ACTIVE	HTSSOP	PWP	14	90	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PS54526	<a href="#">Samples</a>
TPS54526PWPR	ACTIVE	HTSSOP	PWP	14	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PS54526	<a href="#">Samples</a>
TPS54526RSAR	ACTIVE	QFN	RSA	16	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	TPS 54526	<a href="#">Samples</a>
TPS54526RSAT	ACTIVE	QFN	RSA	16	250	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	TPS 54526	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and

continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS54526PWPR	HTSSOP	PWP	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TPS54526RSAR	QFN	RSA	16	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
TPS54526RSAT	QFN	RSA	16	250	180.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2

## TAPE AND REEL BOX DIMENSIONS



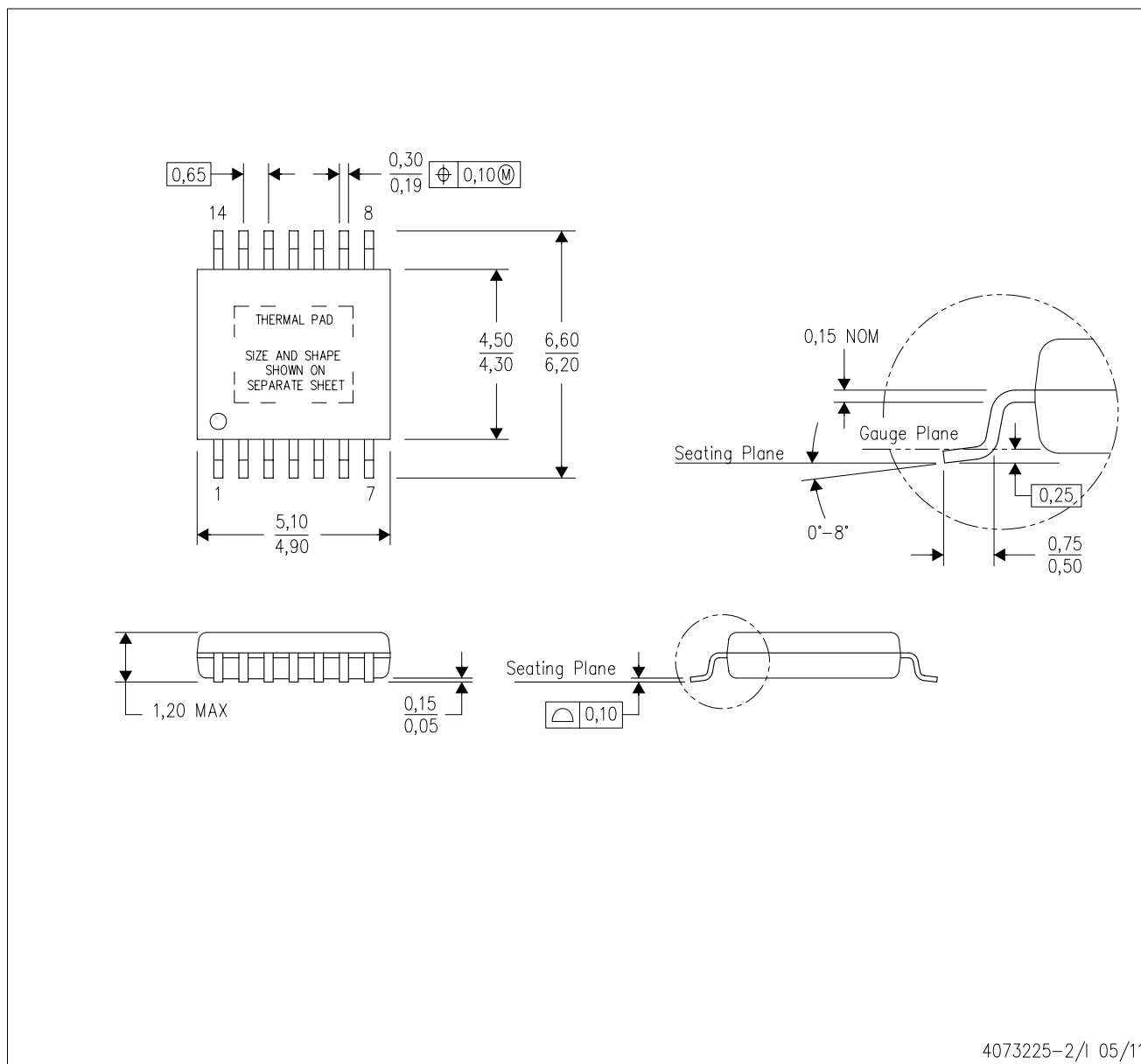
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS54526PWPR	HTSSOP	PWP	14	2000	350.0	350.0	43.0
TPS54526RSAR	QFN	RSA	16	3000	367.0	367.0	35.0
TPS54526RSAT	QFN	RSA	16	250	210.0	185.0	35.0



PWP (R-PDSO-G14)

PowerPAD™ PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusions. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - E. Falls within JEDEC MO-153

PowerPAD is a trademark of Texas Instruments.

PWP (R-PDSO-G14)

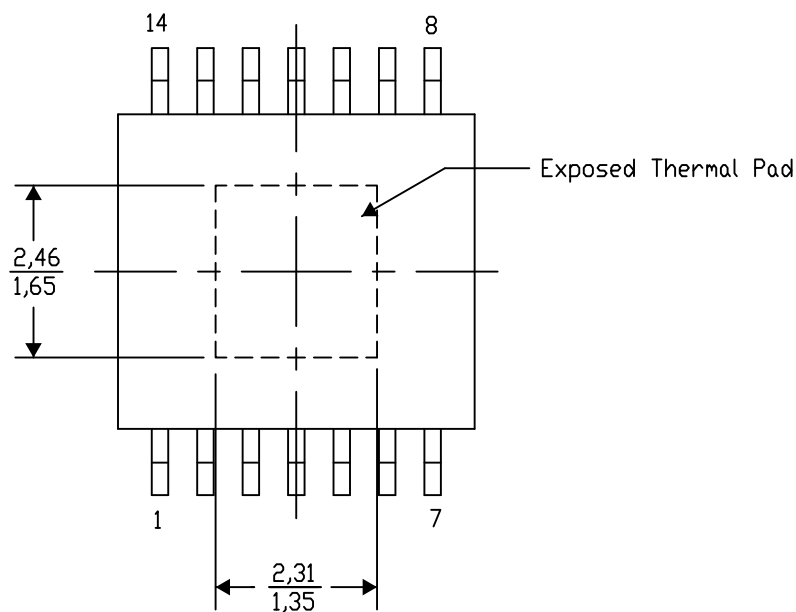
PowerPAD™ SMALL PLASTIC OUTLINE

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Top View

Exposed Thermal Pad Dimensions

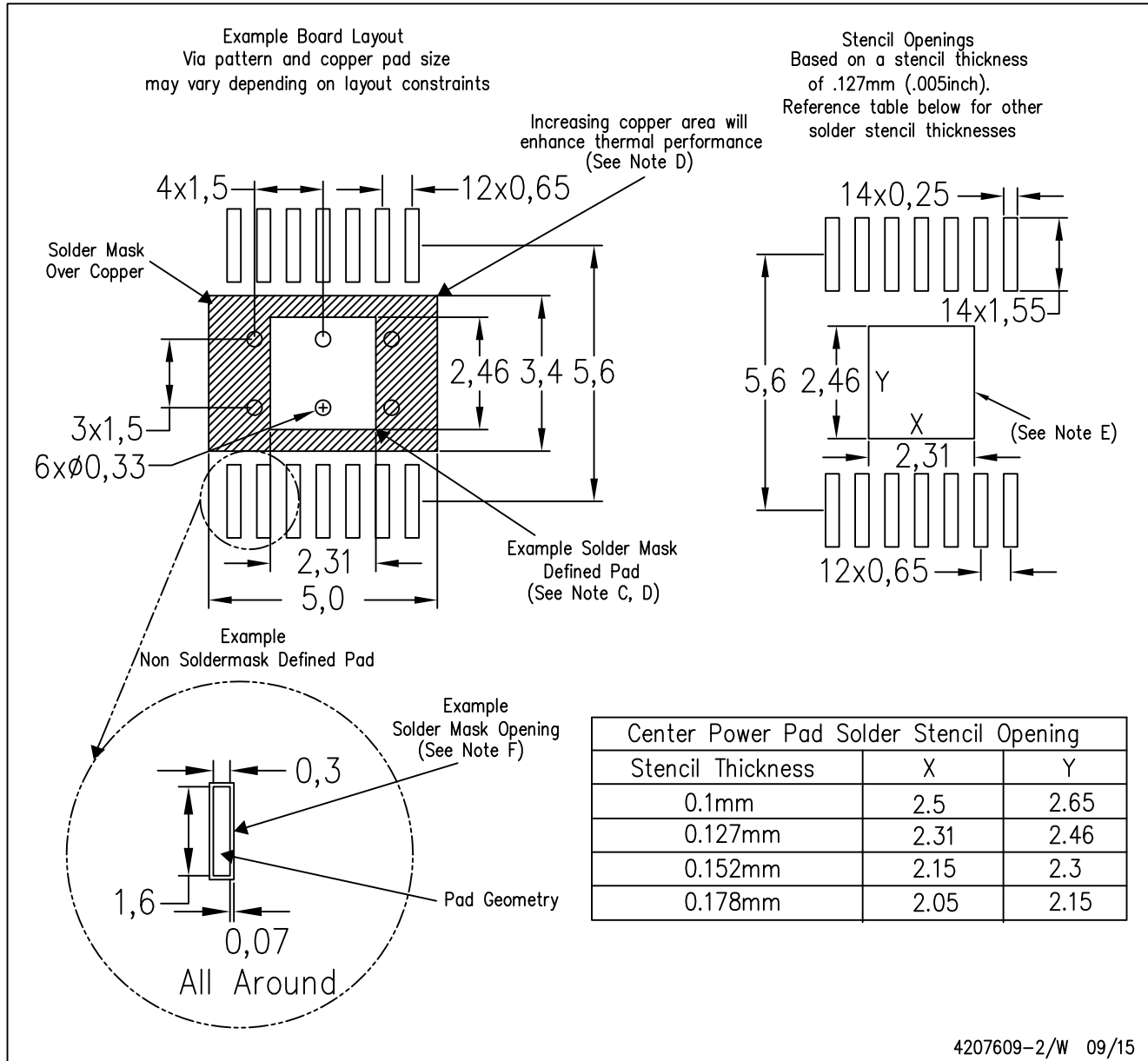
4206332-2/AO 01/16

NOTE: A. All linear dimensions are in millimeters

PowerPAD is a trademark of Texas Instruments

## PWP (R-PDSO-G14)

## PowerPAD™ PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>. Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PWP (R-PDSO-G14)

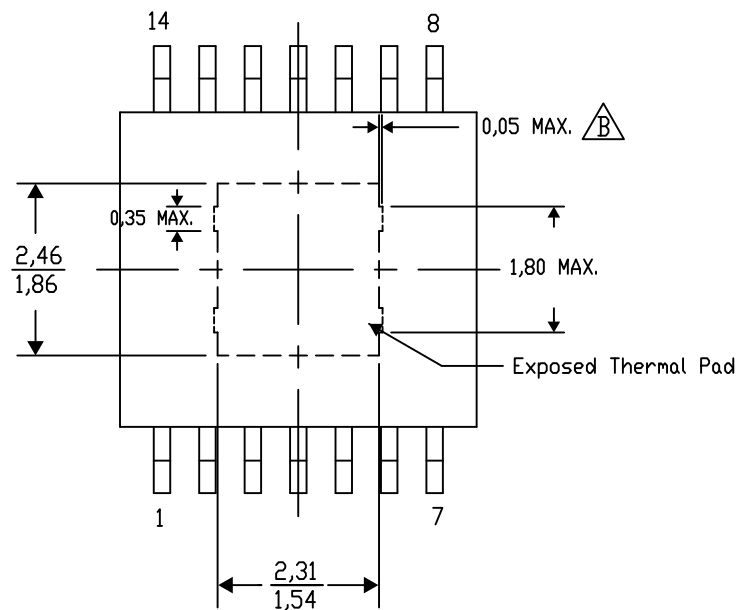
PowerPAD™ SMALL PLASTIC OUTLINE

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).


For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



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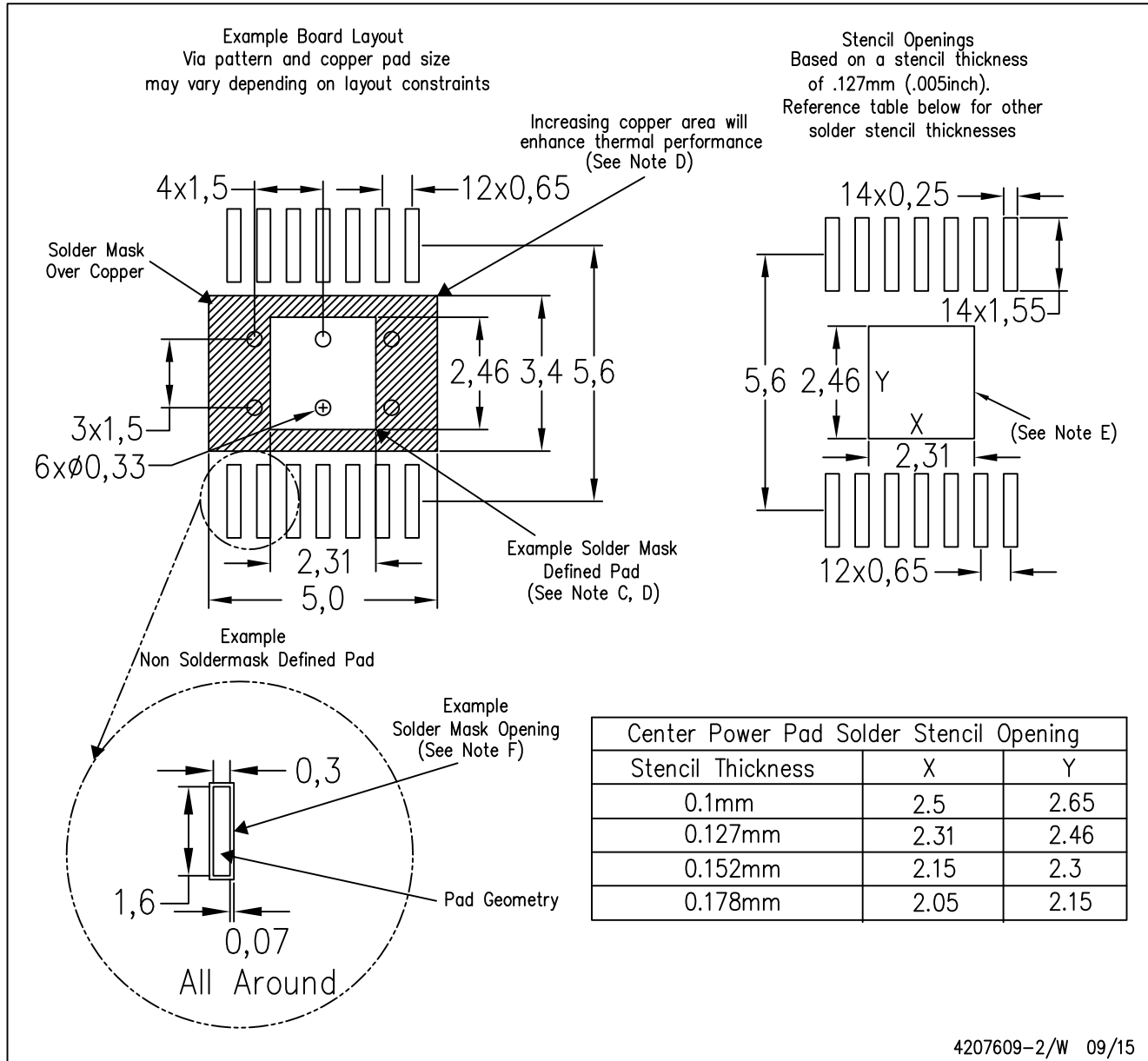
NOTE: A. All linear dimensions are in millimeters

 Exposed tie strap features may not be present.

PowerPAD is a trademark of Texas Instruments

## PWP (R-PDSO-G14)

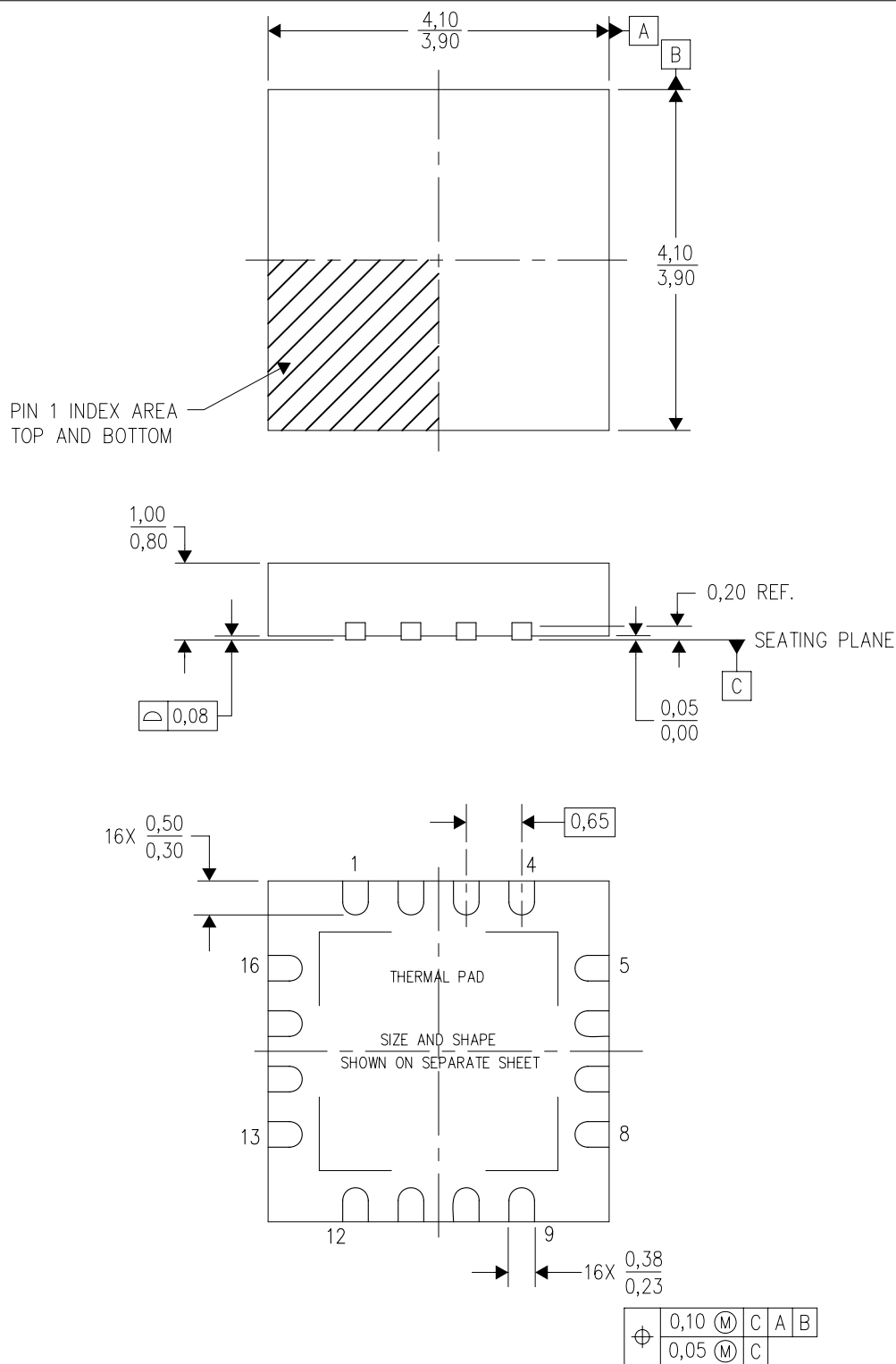
## PowerPAD™ PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>. Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

RSA (S-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



4205141/D 06/11

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - Quad Flatpack, No-leads (QFN) package configuration.
  - The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - Falls within JEDEC MO-220.

RSA (S-PVQFN-N16)

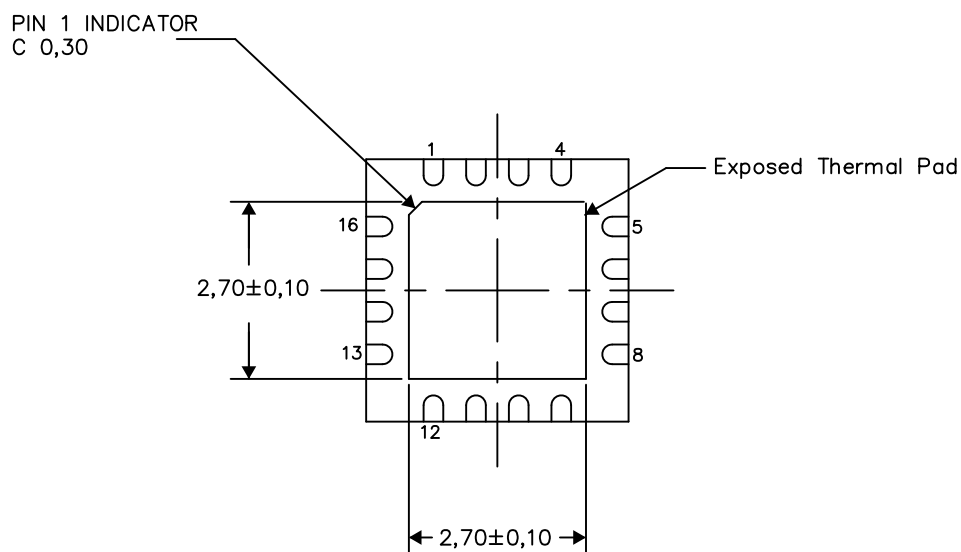
PLASTIC QUAD FLATPACK NO-LEAD

## THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

Exposed Thermal Pad Dimensions

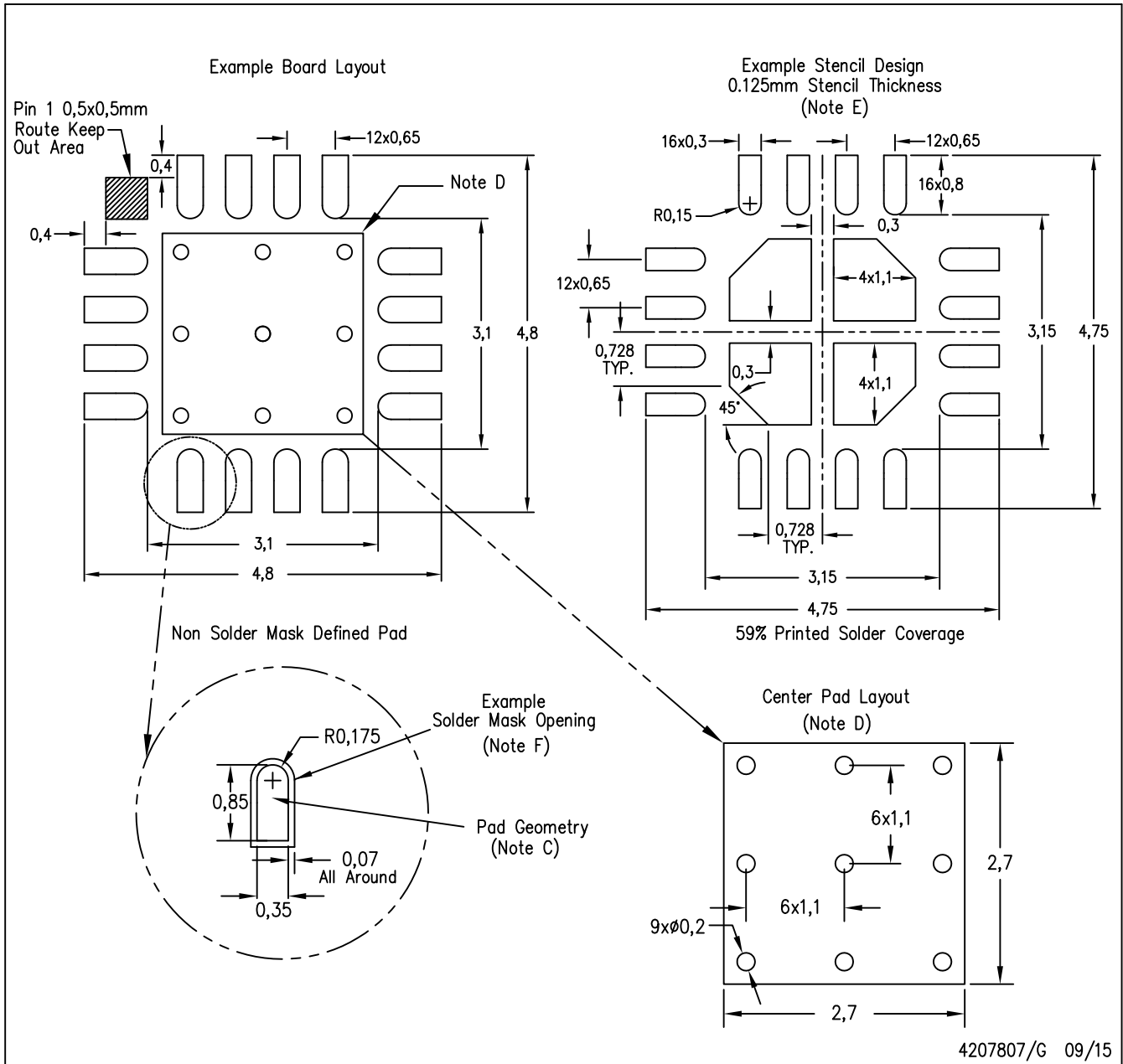
4206364-2/0 09/15

## NOTES:

A. All linear dimensions are in millimeters

RSA (S-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



4207807/G 09/15

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, QFN Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - F. Customers should contact their board fabrication site for solder mask tolerances.



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