

# 600-mA, HIGH-EFFICIENCY MicroSiP™ STEP-DOWN CONVERTER (PROFILE <1.0mm)

Check for Samples: [TPS82671](#), [TPS82675](#), [TPS82676](#), [TPS82677](#)

## FEATURES

- 90% Efficiency at 5.5MHz Operation
- 17µA Quiescent Current
- Wide  $V_{IN}$  Range From 2.3V to 4.8V
- 5.5MHz Regulated Frequency Operation
- Spread Spectrum, PWM Frequency Dithering
- *Best in Class* Load and Line Transient
- ±2% Total DC Voltage Accuracy
- Automatic PFM/PWM Mode Switching
- Low Ripple Light-Load PFM Mode
- ≥35dB  $V_{IN}$  PSRR (1kHz to 10kHz)
- Internal Soft Start, 120-µs Start-Up Time
- Integrated Active Power-Down Sequencing (Optional)
- Current Overload and Thermal Shutdown Protection
- Sub 1-mm Profile Solution
- Total Solution Size <6.7 mm<sup>2</sup>

## APPLICATIONS

- Cell Phones, Smart-Phones
- Digital TV, WLAN, GPS and Bluetooth™ Applications
- POL Applications

## DESCRIPTION

The TPS8267x device is a complete 600mA, DC/DC step-down power supply intended for low-power applications. Included in the package are the switching regulator, inductor and input/output capacitors. No additional components are required to finish the design.

The TPS8267x is based on a high-frequency synchronous step-down dc-dc converter optimized for battery-powered portable applications. The MicroSiP™ DC/DC converter operates at a regulated 5.5-MHz switching frequency and enters the power-save mode operation at light load currents to maintain high efficiency over the entire load current range.

The PFM mode extends the battery life by reducing the quiescent current to 17µA (typ) during light load operation. For noise-sensitive applications, the device has PWM spread spectrum capability providing a lower noise regulated output, as well as low noise at the input. These features, combined with high PSRR and AC load regulation performance, make this device suitable to replace a linear regulator to obtain better power conversion efficiency.

The TPS8267x is packaged in a compact (2.3mm x 2.9mm) and low profile (1.0mm) BGA package suitable for automated assembly by standard surface mount equipment.

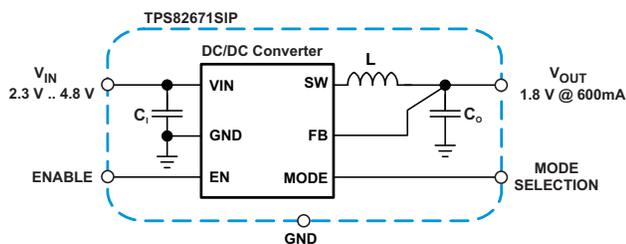


Figure 1. Typical Application

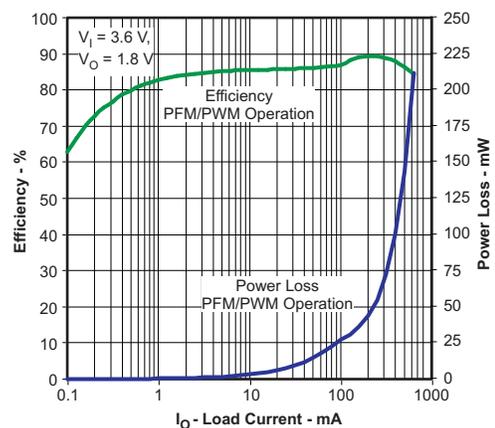


Figure 2. Efficiency vs. Load Current



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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### ORDERING INFORMATION <sup>(1)</sup>

T <sub>A</sub>	PART NUMBER	OUTPUT VOLTAGE <sup>(2)</sup>	DEVICE SPECIFIC FEATURE	ORDERING <sup>(3)</sup>	PACKAGE MARKING
-40°C to 85°C	TPS82671	1.8V	PWM Spread Spectrum Modulation Low PFM Output Ripple Voltage	TPS82671SIP	RA
	TPS82672 <sup>(4)</sup>	1.5V	PWM Spread Spectrum Modulation Low PFM Output Ripple Voltage		
	TPS82674 <sup>(4)</sup>	1.2V	PWM Spread Spectrum Modulation Low PFM Output Ripple Voltage Output Capacitor Discharge		
	TPS82675	1.2V	PWM Spread Spectrum Modulation Low PFM Output Ripple Voltage	TPS82675SIP	RB
	TPS82676	1.1V	PWM Spread Spectrum Modulation Low PFM Output Ripple Voltage Output Capacitor Discharge	TPS82676SIP	TU
	TPS82677	1.2V	Output Capacitor Discharge	TPS82677SIP	SK
	TPS82678 <sup>(4)</sup>	1.35V	PWM Spread Spectrum Modulation Output Capacitor Discharge	TPS82678SIP	TT

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).
- (2) Internal tap points are available to facilitate output voltages in 25mV increments.
- (3) The SIP package is available in tape and reel. Add a R suffix (e.g. TPS82671SIPR) to order quantities of 3000 parts. Add a T suffix (e.g. TPS82671SIPT) to order quantities of 250 parts.
- (4) Product Preview

### ABSOLUTE MAXIMUM RATINGS

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

		VALUE		UNIT
		MIN	MAX	
V <sub>I</sub>	Voltage at VIN <sup>(2)(3)</sup>	-0.3	6	V
	Voltage at VOUT <sup>(3)</sup>	-0.3	3.6	V
	Voltage at EN, MODE <sup>(3)</sup>	-0.3	V <sub>IN</sub> + 0.3	V
Power dissipation		Internally limited		
T <sub>A</sub>	Operating temperature range <sup>(4)</sup>	-40	85	°C
T <sub>INT</sub> (max)	Maximum internal operating temperature		125	°C
T <sub>stg</sub>	Storage temperature range	-55	125	°C
ESD rating <sup>(5)</sup>	Human body model		2	kV
	Charge device model		1	kV
	Machine model		200	V

- (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.
- (2) Operation above 4.8V input voltage for extended periods may affect device reliability.
- (3) All voltage values are with respect to network ground terminal.
- (4) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may have to be derated. Maximum ambient temperature (T<sub>A(max)</sub>) is dependent on the maximum operating temperature (T<sub>INT(max)</sub>), the maximum power dissipation of the device in the application (P<sub>D(max)</sub>), and the junction-to-ambient thermal resistance of the part/package in the application (θ<sub>JA</sub>), as given by the following equation: T<sub>A(max)</sub> = T<sub>J(max)</sub> - (θ<sub>JA</sub> × P<sub>D(max)</sub>). To achieve optimum performance, it is recommended to operate the device with a maximum internal temperature of 105°C.
- (5) The human body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin. The machine model is a 200-pF capacitor discharged directly into each pin.

## THERMAL INFORMATION

THERMAL METRIC <sup>(1)(2)</sup>		TPS8267xSIP		UNITS
		SIP		
		8 PINS		
$\theta_{JA}$	Junction-to-ambient (top) thermal resistance	125		°C/W
	Junction-to-ambient (bottom) thermal resistance	70		
$\theta_{JcTop}$	Junction-to-case (top) thermal resistance			
$\theta_{JB}$	Junction-to-board thermal resistance			
$\Psi_{JT}$	Junction-to-top characterization parameter			
$\Psi_{JB}$	Junction-to-board characterization parameter			
$\theta_{Jcbot}$	Junction-to-case (bottom) thermal resistance			

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

(2) Thermal data have been measured using TI's 4-layer evaluation board.

## RECOMMENDED OPERATING CONDITIONS

		MIN	NOM	MAX	UNIT	
$V_{IN}$	Input voltage range	2.3		4.8 <sup>(1)</sup>	V	
$I_O$	Output current range	0		600	mA	
Additional output capacitance (PFM/PWM operation) <sup>(2)</sup>		TPS82671 to TPS82676		0	2.5	μF
		TPS82677, TPS82678		0	4	μF
Additional output capacitance (PWM operation) <sup>(2)</sup>				0	7	μF
$T_A$	Ambient temperature	-40		+85	°C	
$T_J$	Operating junction temperature	-40		+125	°C	

(1) Operation above 4.8V input voltage for extended periods may affect device reliability.

(2) In certain applications larger capacitor values can be tolerable, see *output capacitor selection* section for more details.

## ELECTRICAL CHARACTERISTICS

Minimum and maximum values are at  $V_{IN} = 2.3V$  to  $5.5V$ ,  $V_{OUT} = 1.8V$ ,  $EN = 1.8V$ , AUTO mode and  $T_A = -40^\circ C$  to  $85^\circ C$ ; Circuit of Parameter Measurement Information section (unless otherwise noted). Typical values are at  $V_{IN} = 3.6V$ ,  $V_{OUT} = 1.8V$ ,  $EN = 1.8V$ , AUTO mode and  $T_A = 25^\circ C$  (unless otherwise noted).

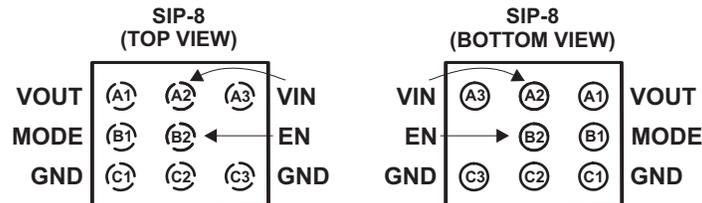
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>SUPPLY CURRENT</b>						
$I_Q$	Operating quiescent current	$I_O = 0mA$ . Device not switching		17	40	μA
		$I_O = 0mA$ . PWM operation		5.8		mA
$I_{SD}$	Shutdown current	$EN = GND$		0.5	5	μA
UVLO	Undervoltage lockout threshold			2.05	2.1	V
<b>PROTECTION</b>						
	Thermal shutdown			140		°C
	Thermal shutdown hysteresis			10		°C
$I_{LIM}$	Peak Input Current Limit			1100		mA
$I_{SC}$	Input current limit under short-circuit conditions	$V_O$ shorted to ground		13.5		mA
<b>ENABLE, MODE</b>						
$V_{IH}$	High-level input voltage		1.0			V
$V_{IL}$	Low-level input voltage				0.4	V
$I_{lkg}$	Input leakage current	Input connected to GND or VIN		0.01	1.5	μA
<b>OSCILLATOR</b>						
$f_{SW}$	Oscillator frequency	$I_O = 0mA$ . PWM operation	4.9	5.45	6.0	MHz

## ELECTRICAL CHARACTERISTICS (continued)

Minimum and maximum values are at  $V_{IN} = 2.3V$  to  $5.5V$ ,  $V_{OUT} = 1.8V$ ,  $EN = 1.8V$ , AUTO mode and  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ ; Circuit of Parameter Measurement Information section (unless otherwise noted). Typical values are at  $V_{IN} = 3.6V$ ,  $V_{OUT} = 1.8V$ ,  $EN = 1.8V$ , AUTO mode and  $T_A = 25^{\circ}C$  (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
<b>OUTPUT</b>							
$V_{OUT}$	Regulated DC output voltage	TPS82671 TPS82672	$2.5V \leq V_1 \leq 4.8V$ , $0mA \leq I_O \leq 600mA$ PFM/PWM operation	$0.98 \times V_{NOM}$	$V_{NOM}$	$1.03 \times V_{NOM}$	V
		TPS82674 TPS82675	$2.5V \leq V_1 \leq 5.5V$ , $0mA \leq I_O \leq 600mA$ PFM/PWM operation	$0.98 \times V_{NOM}$	$V_{NOM}$	$1.04 \times V_{NOM}$	V
		TPS82676 TPS82678	$2.5V \leq V_1 \leq 5.5V$ , $0mA \leq I_O \leq 600mA$ PWM operation	$0.98 \times V_{NOM}$	$V_{NOM}$	$1.02 \times V_{NOM}$	V
		TPS82677 TPS82678	$2.5V \leq V_1 \leq 4.8V$ , $0mA \leq I_O \leq 600mA$ PFM/PWM operation	$0.98 \times V_{NOM}$	$V_{NOM}$	$1.04 \times V_{NOM}$	V
		TPS82677 TPS82678	$2.5V \leq V_1 \leq 5.5V$ , $0mA \leq I_O \leq 600mA$ PWM operation	$0.98 \times V_{NOM}$	$V_{NOM}$	$1.02 \times V_{NOM}$	V
		Line regulation	$V_1 = V_O + 0.5V$ (min 2.5V) to 5.5V, $I_O = 200mA$		0.23		%/V
Load regulation	$I_O = 0mA$ to 600 mA. PWM operation		-0.00085		%/mA		
Feedback input resistance					480		k $\Omega$
$\Delta V_O$	Power-save mode ripple voltage	TPS82671	$I_O = 1mA$ , $V_O = 1.8V$		19		mV <sub>PP</sub>
		TPS82675	$I_O = 1mA$ , $V_O = 1.2V$		16		mV <sub>PP</sub>
		TPS82676	$I_O = 1mA$ , $V_O = 1.1V$		16		mV <sub>PP</sub>
		TPS82677	$I_O = 1mA$ , $V_O = 1.2V$		25		mV <sub>PP</sub>
		TPS82678	$I_O = 1mA$ , $V_O = 1.35V$		TBD		mV <sub>PP</sub>
Start-up time	TPS82671	$I_O = 0mA$ , Time from active EN to $V_O$		120		$\mu s$	
$r_{DIS}$	Discharge resistor for power-down sequence	TPS82674 TPS82676 TPS82677 TPS82678	Device featuring active discharge		70	150	$\Omega$

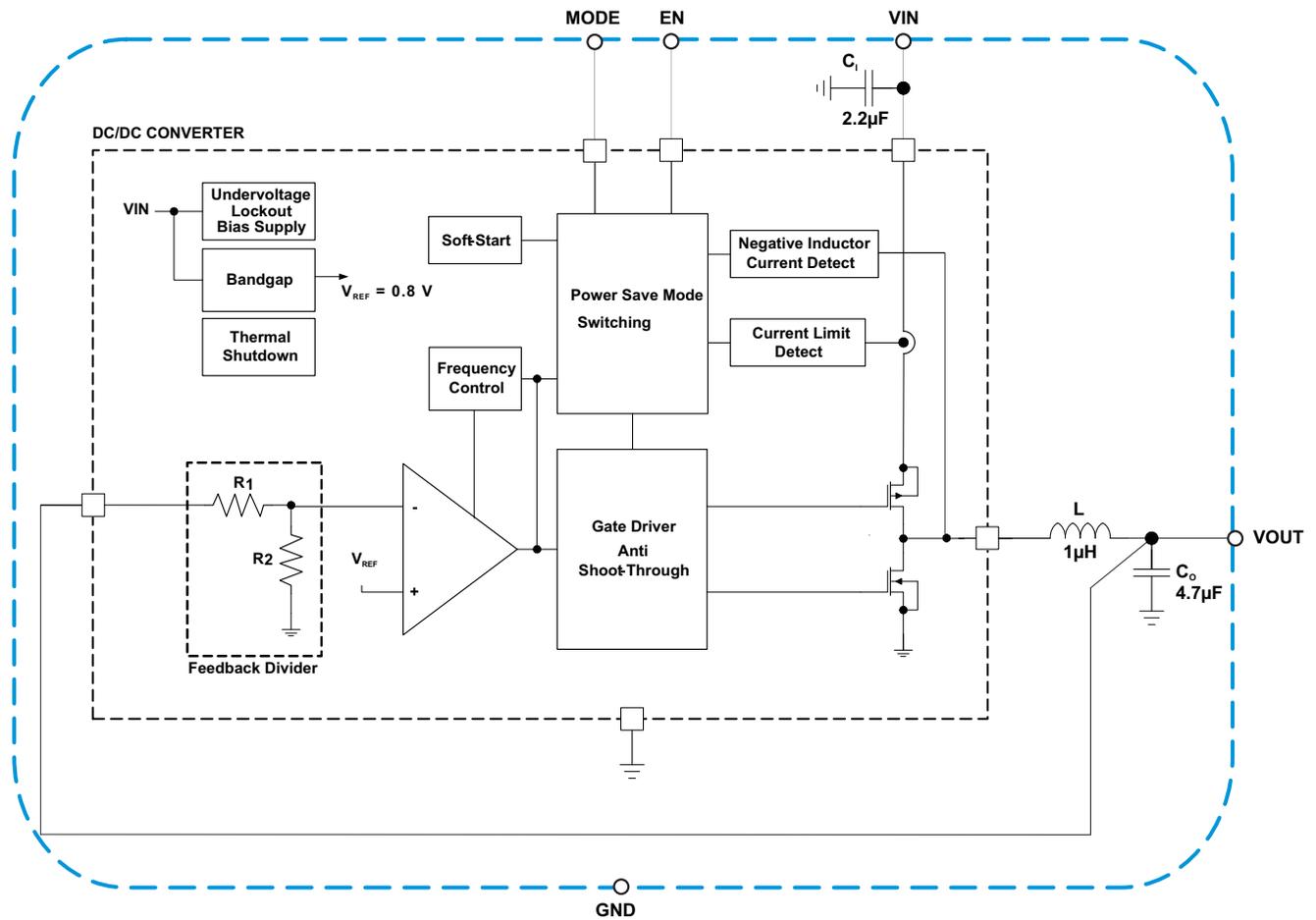
## PIN ASSIGNMENTS



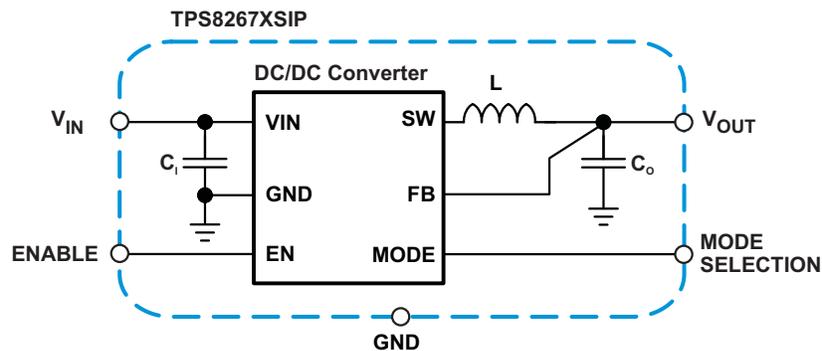
## PIN DESCRIPTIONS

PIN		I/O	DESCRIPTION
NAME	NO.		
VOUT	A1	O	Power output pin. Apply output load between this pin and GND.
VIN	A2, A3	I	The VIN pins supply current to the TPS8267x internal regulator.
EN	B2	I	This is the enable pin of the device. Connect this pin to ground to force the converter into shutdown mode. Pull this pin to $V_1$ to enable the device. This pin must not be left floating and must be terminated.
MODE	B1	I	This is the mode selection pin of the device. This pin must not be left floating and must be terminated. MODE = LOW: The device is operating in regulated frequency pulse width modulation mode (PWM) at high-load currents and in pulse frequency modulation mode (PFM) at light load currents. MODE = HIGH: Low-noise mode is enabled and regulated frequency PWM operation is forced.
GND	C1, C2, C3	–	Ground pin.

## FUNCTIONAL BLOCK DIAGRAM



## PARAMETER MEASUREMENT INFORMATION



## TYPICAL CHARACTERISTICS

### Table of Graphs

			FIGURE	
$\eta$	Efficiency	vs Load current	3, 4	
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	Peak-to-peak output ripple voltage	vs Load current	6, 7, 8	
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	Load transient response		14, 15, 16, 17 18, 19, 20	
	AC load transient response		21	
	Load transient response		22, 23, 24, 25 26, 27, 28	
	AC load transient response		29	
	PFM/PWM boundaries	vs Input voltage	30, 31	
$I_Q$	Quiescent current	vs Input voltage	32	
$f_s$	PWM switching frequency	vs Input voltage	33	
	Start-up		34, 35	
PSRR	Power supply rejection ratio	vs. Frequency	36	
		Spurious output noise (PFM mode)	vs. Frequency	37
		Spurious output noise (PWM mode)	vs. Frequency	38
		Output spectral noise density	vs. Frequency	39

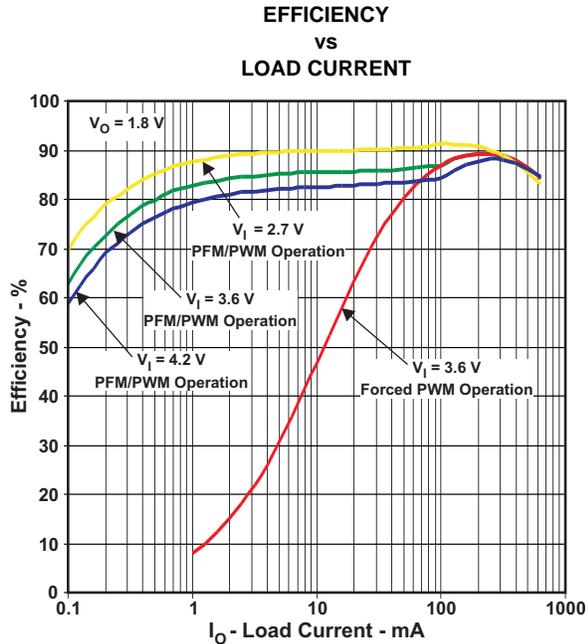


Figure 3.

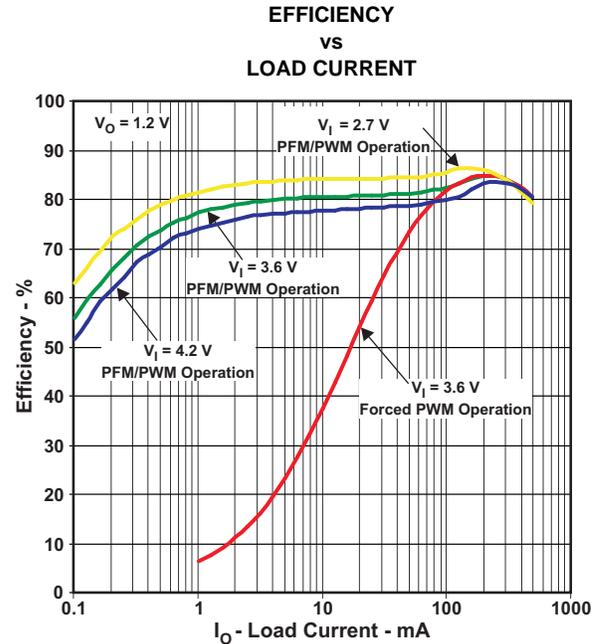
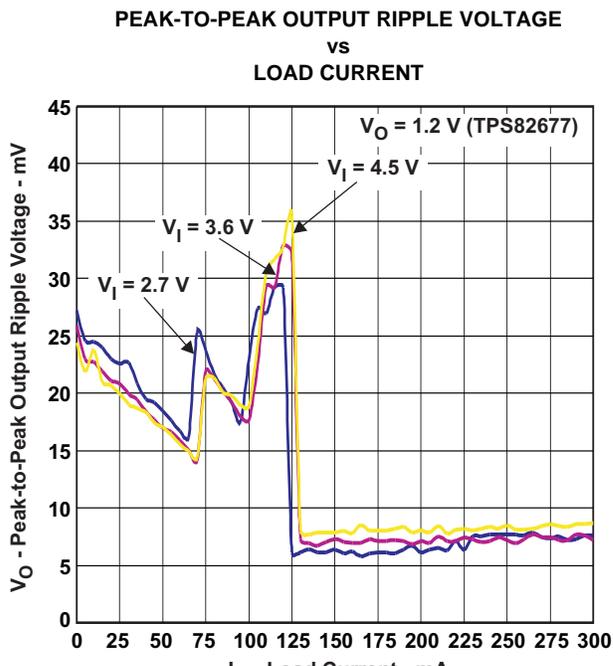
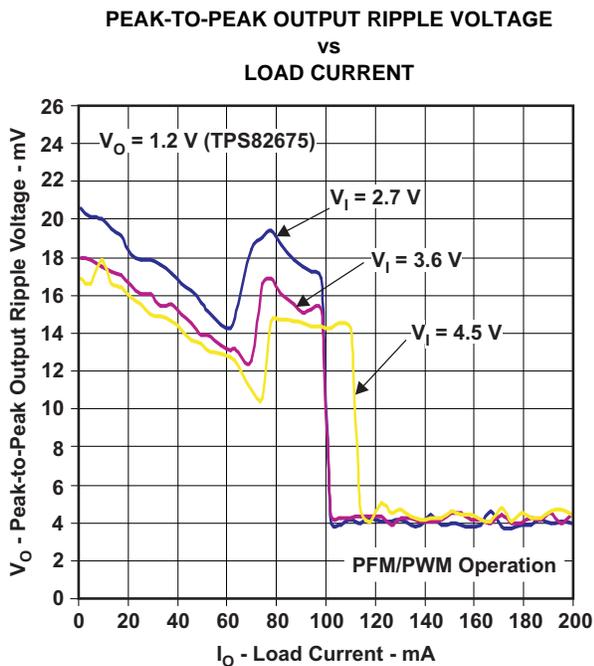
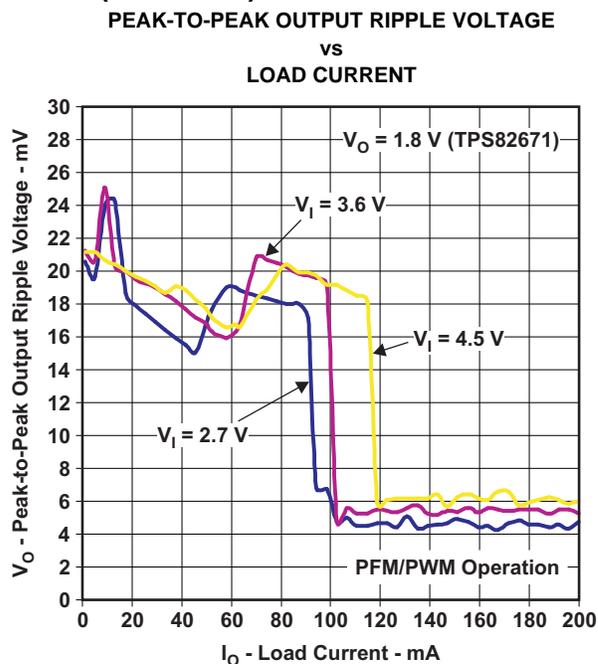
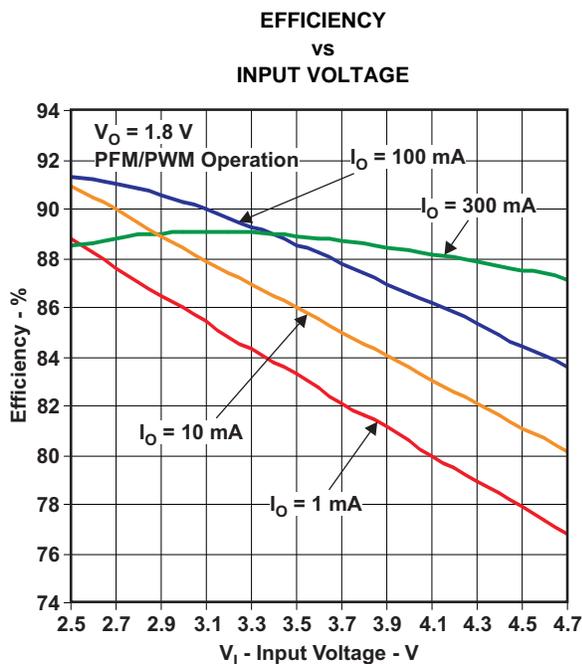


Figure 4.

TYPICAL CHARACTERISTICS (continued)



TYPICAL CHARACTERISTICS (continued)

DC OUTPUT VOLTAGE  
 vs  
 LOAD CURRENT

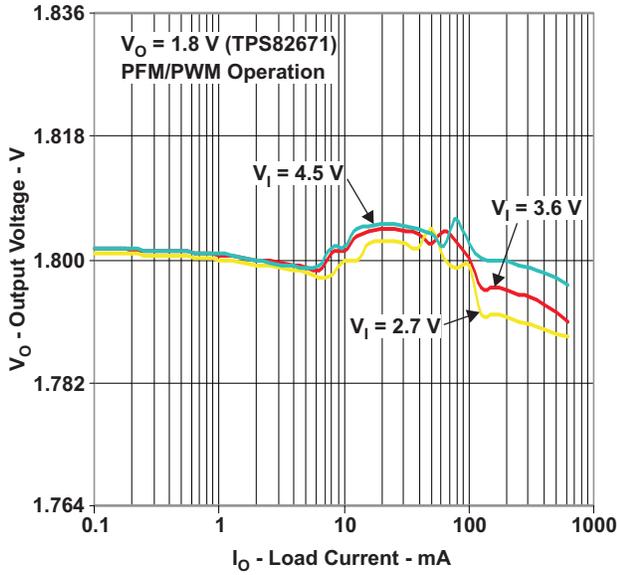


Figure 9.

DC OUTPUT VOLTAGE  
 vs  
 LOAD CURRENT

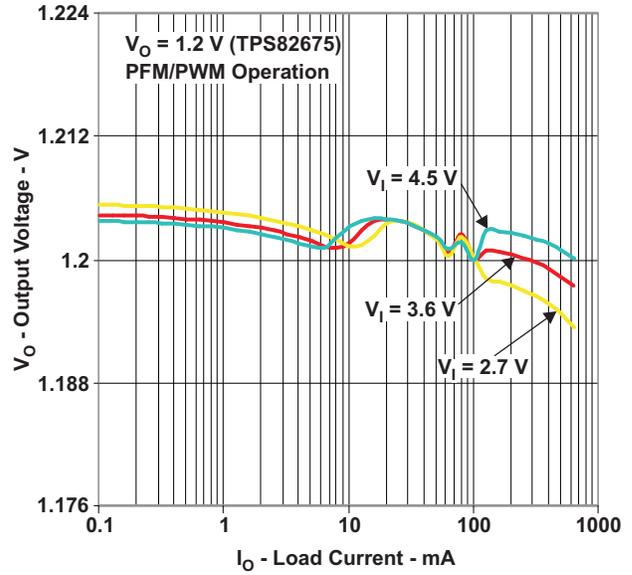


Figure 10.

DC OUTPUT VOLTAGE  
 vs  
 LOAD CURRENT

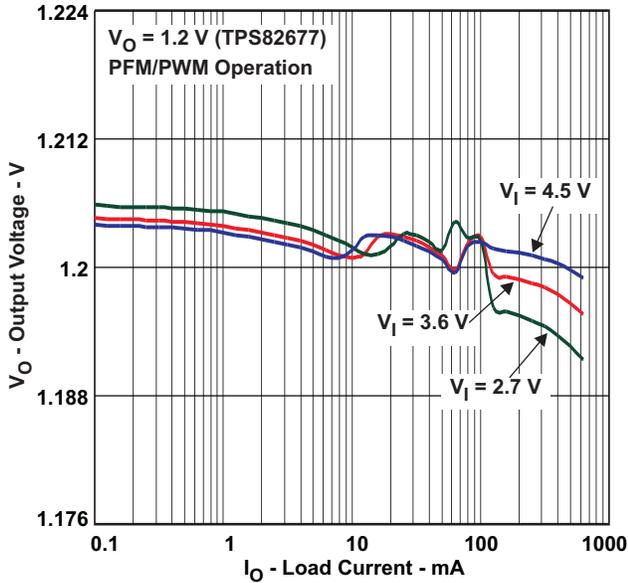


Figure 11.

COMBINED LINE/LOAD TRANSIENT RESPONSE

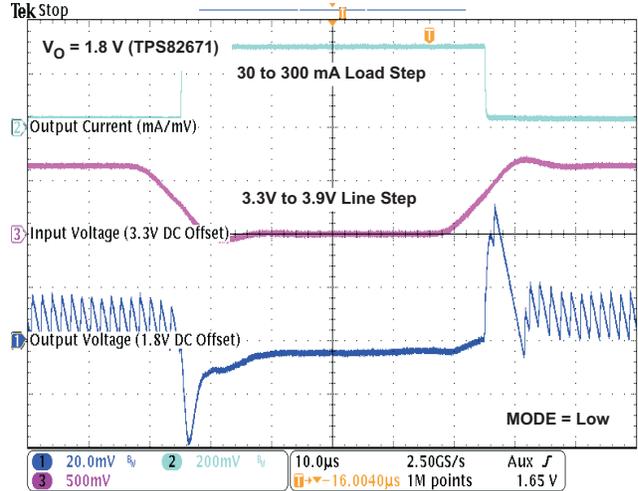


Figure 12.

TYPICAL CHARACTERISTICS (continued)

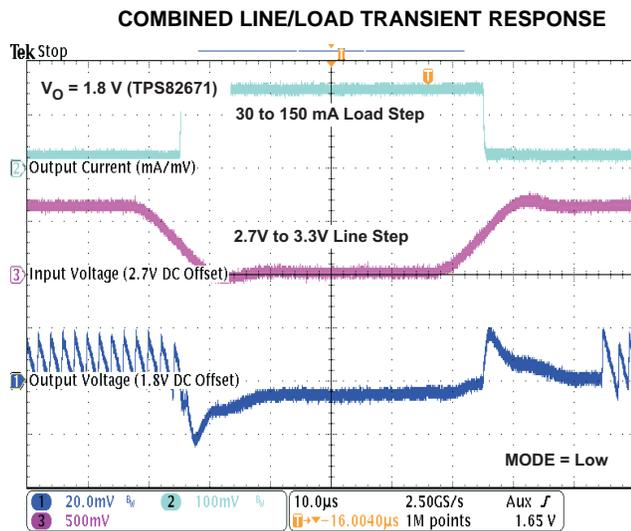


Figure 13.

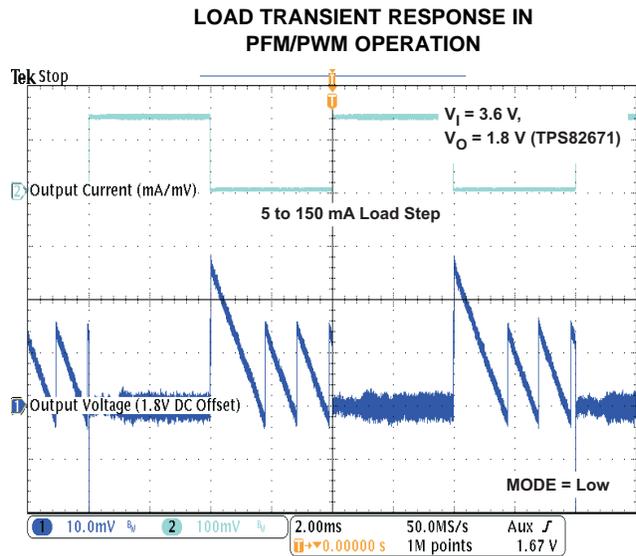


Figure 14.

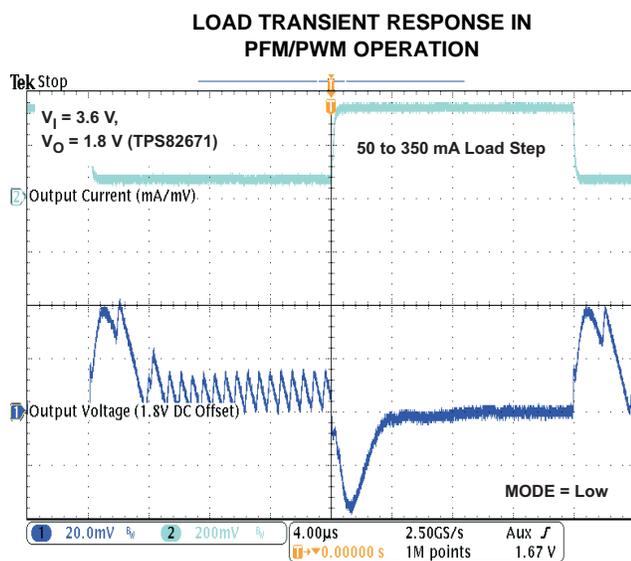


Figure 15.

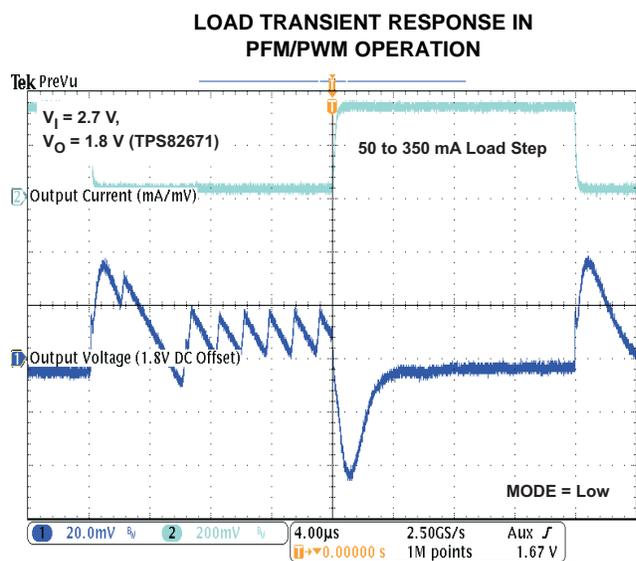


Figure 16.

TYPICAL CHARACTERISTICS (continued)

LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

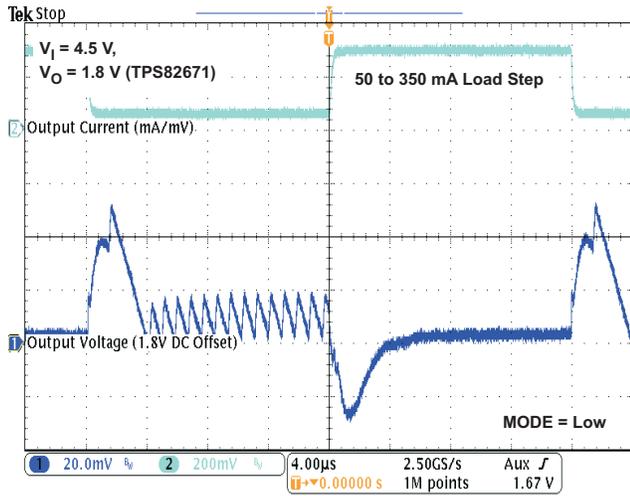


Figure 17.

LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

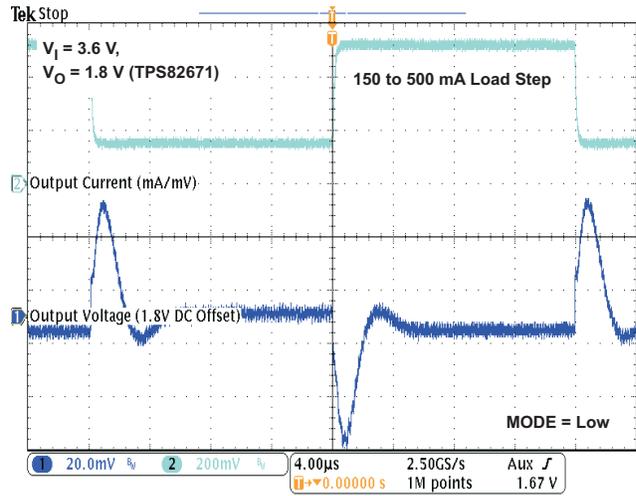


Figure 18.

LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

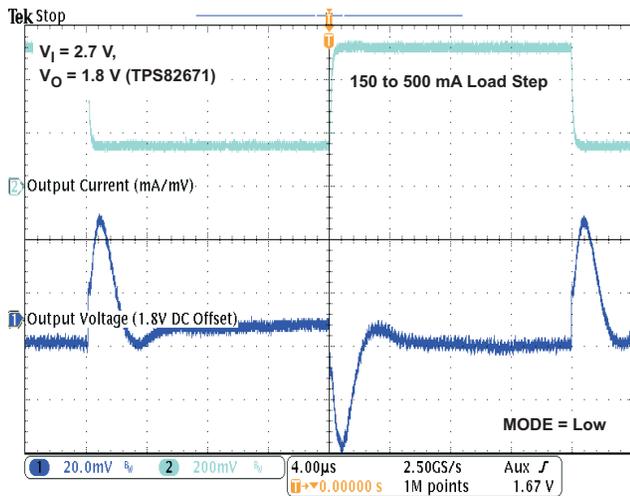


Figure 19.

LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

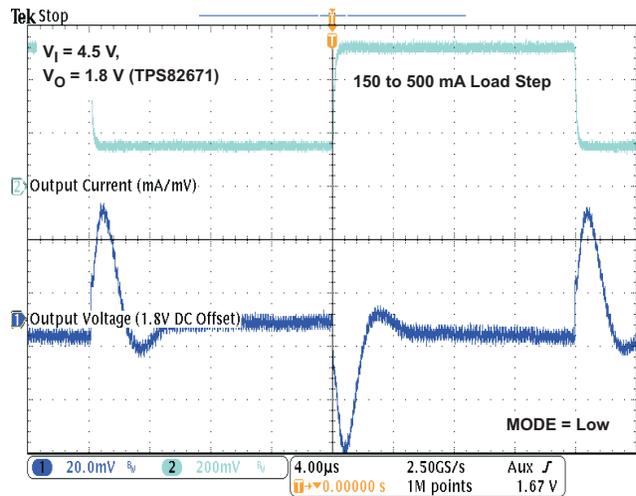


Figure 20.

TYPICAL CHARACTERISTICS (continued)

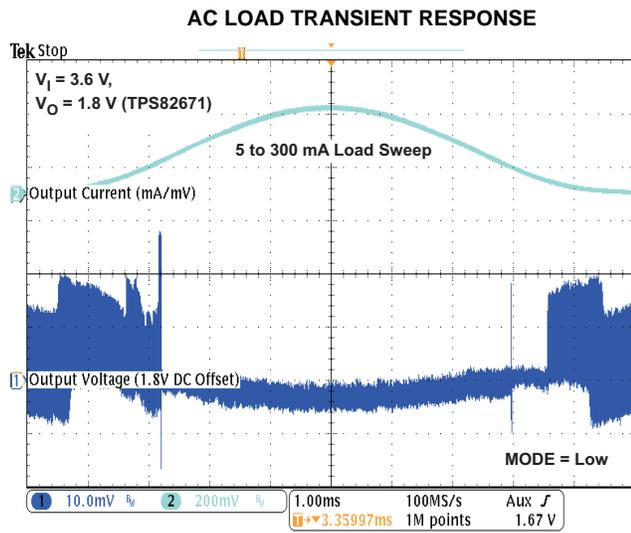


Figure 21.

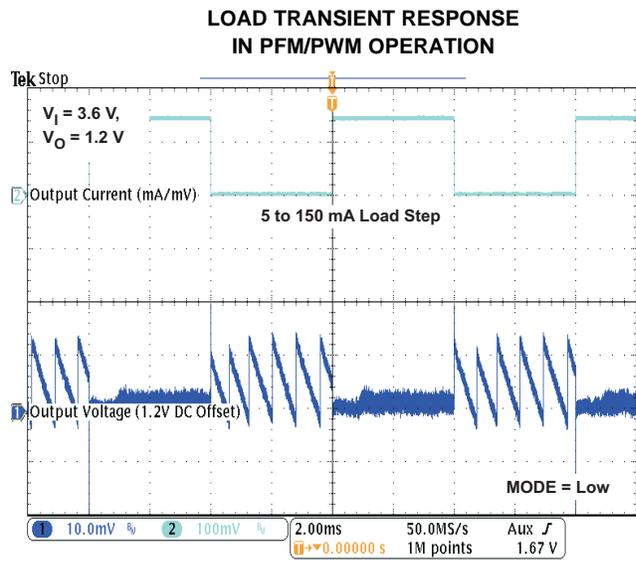


Figure 22.

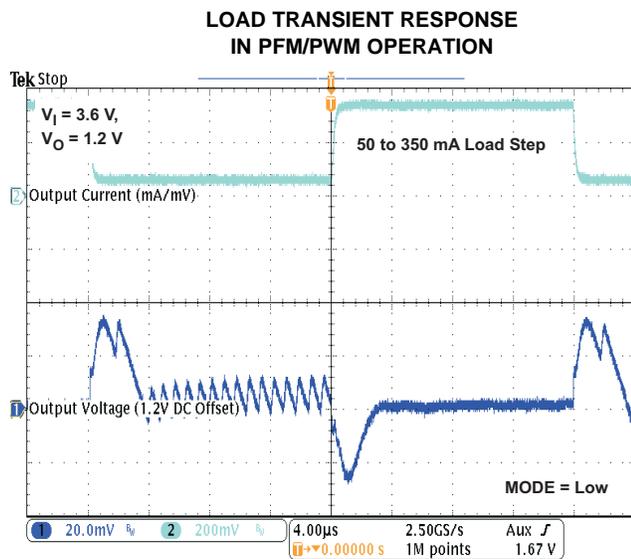


Figure 23.

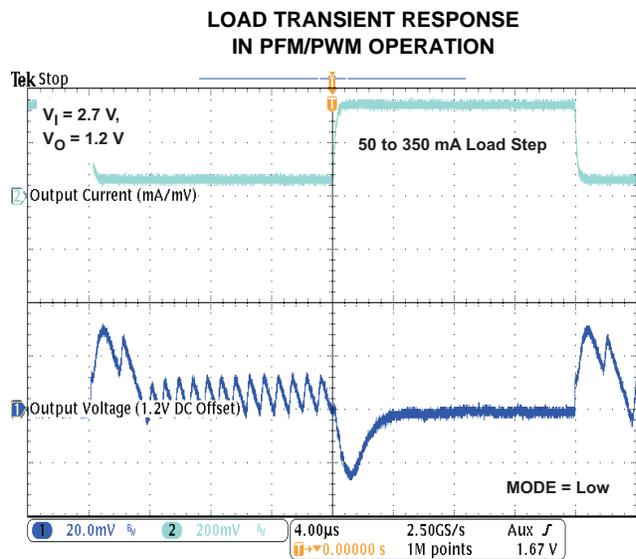


Figure 24.

**TYPICAL CHARACTERISTICS (continued)**

**LOAD TRANSIENT RESPONSE  
 IN PFM/PWM OPERATION**

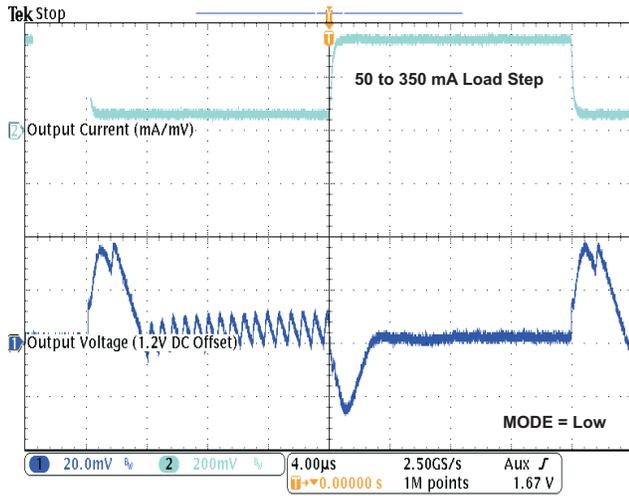


Figure 25.

**LOAD TRANSIENT RESPONSE  
 IN PFM/PWM OPERATION**

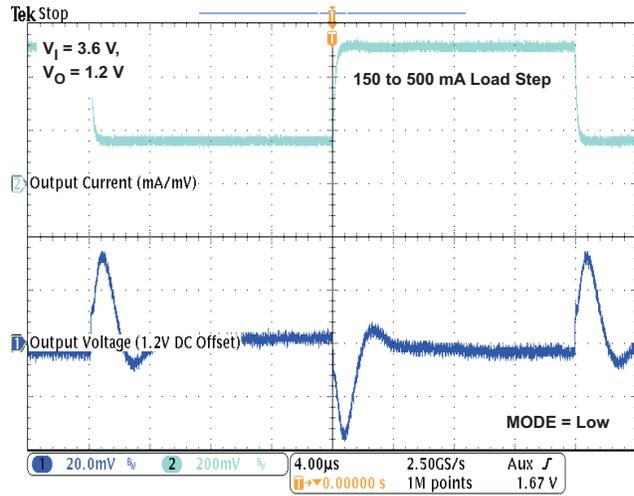


Figure 26.

**LOAD TRANSIENT RESPONSE  
 IN PFM/PWM OPERATION**

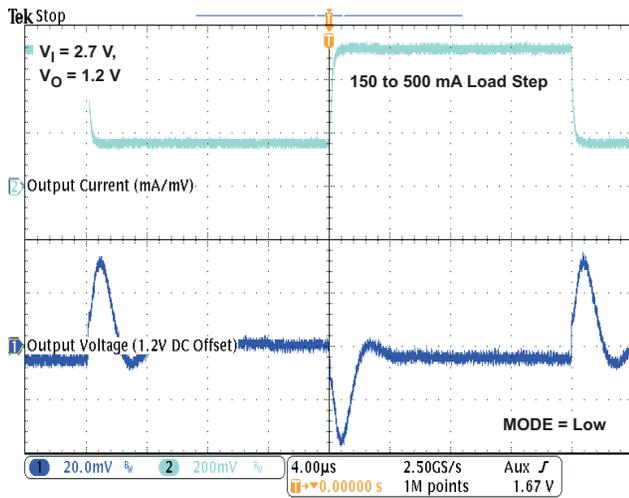


Figure 27.

**LOAD TRANSIENT RESPONSE  
 IN PFM/PWM OPERATION**

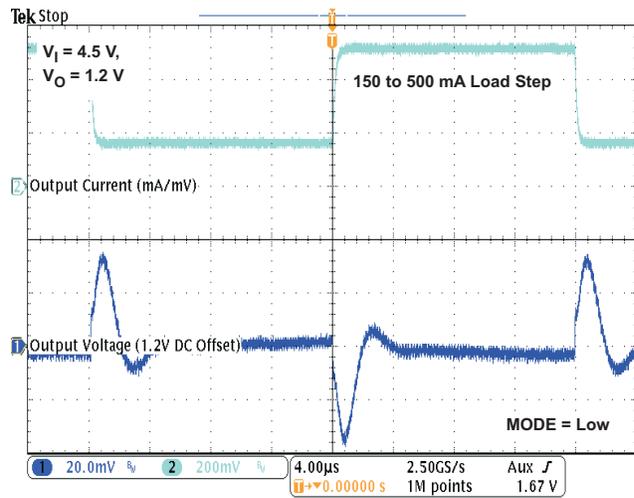


Figure 28.

TYPICAL CHARACTERISTICS (continued)

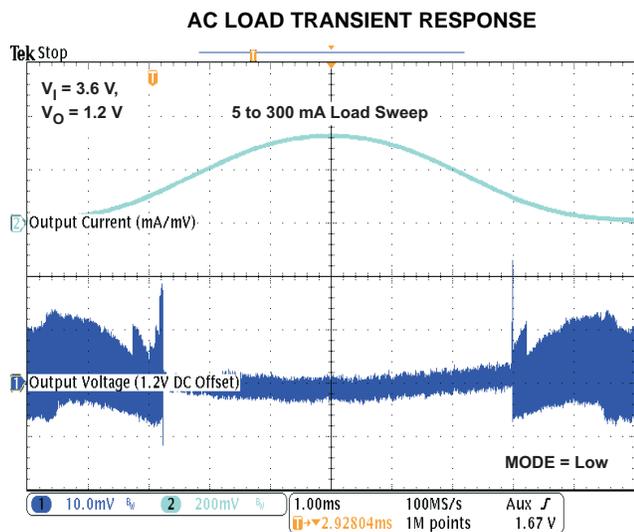


Figure 29.

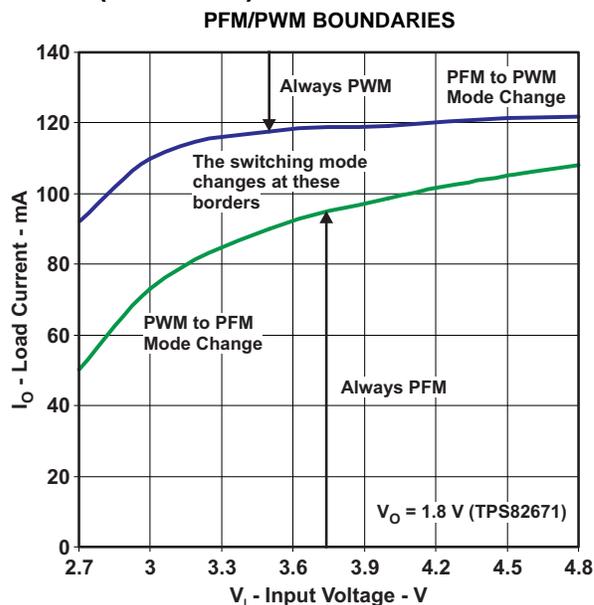


Figure 30.

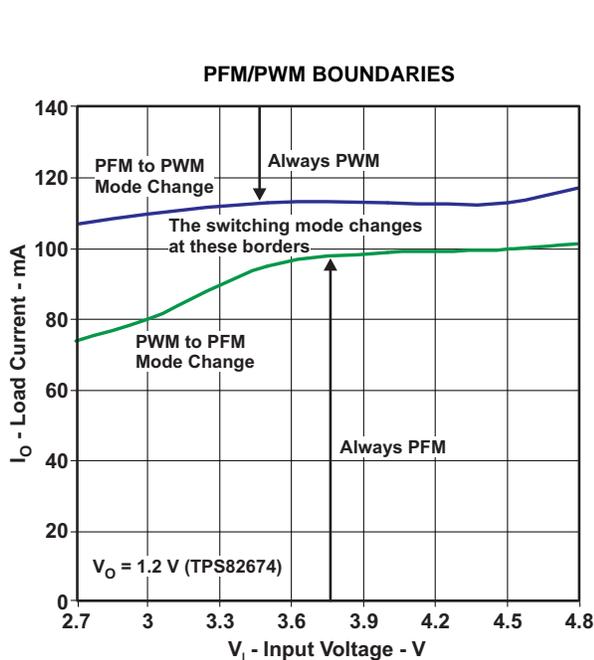


Figure 31.

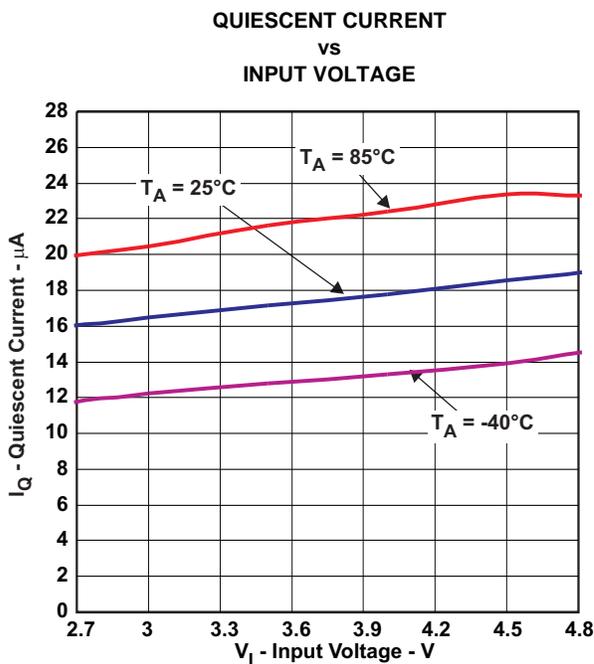


Figure 32.

TYPICAL CHARACTERISTICS (continued)

PWM SWITCHING FREQUENCY  
 vs  
 INPUT VOLTAGE

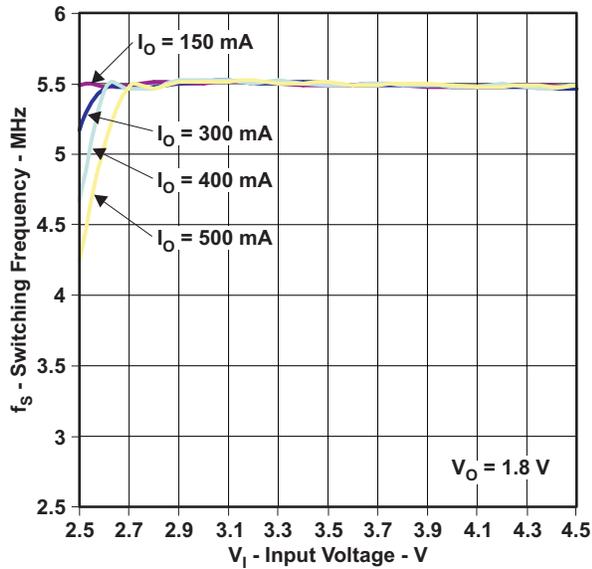


Figure 33.

START-UP

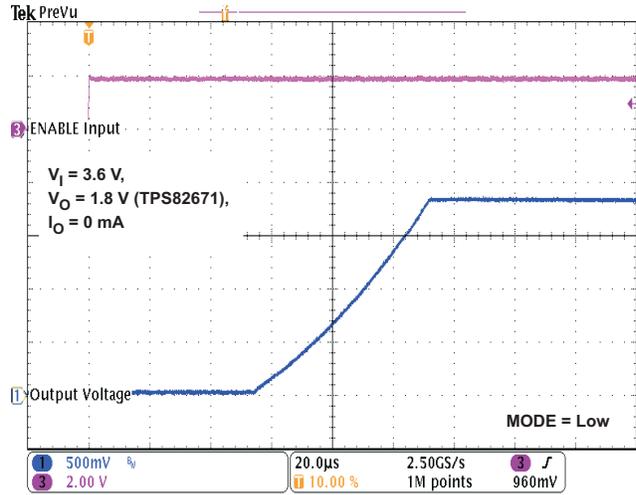


Figure 34.

START-UP

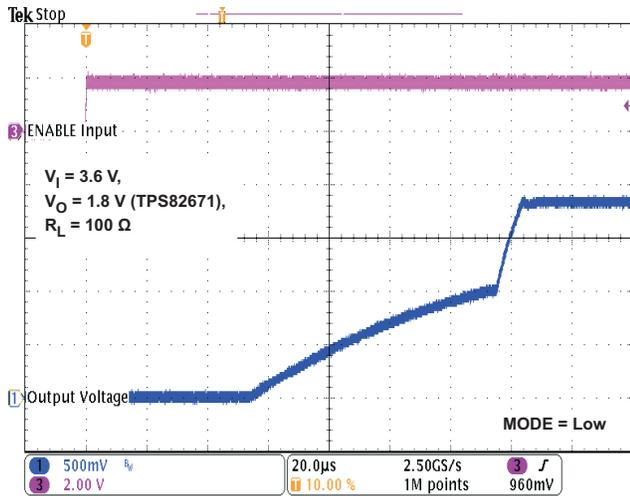


Figure 35.

POWER SUPPLY REJECTION RATIO  
 vs  
 FREQUENCY

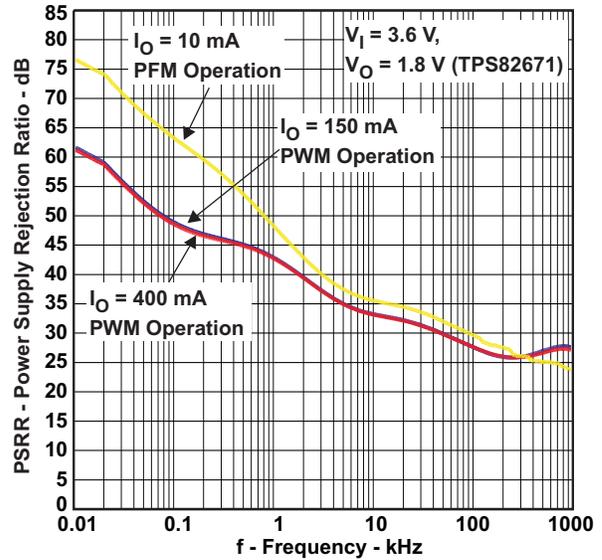


Figure 36.

TYPICAL CHARACTERISTICS (continued)

SPURIOUS OUTPUT NOISE (PFM MODE)

vs  
FREQUENCY

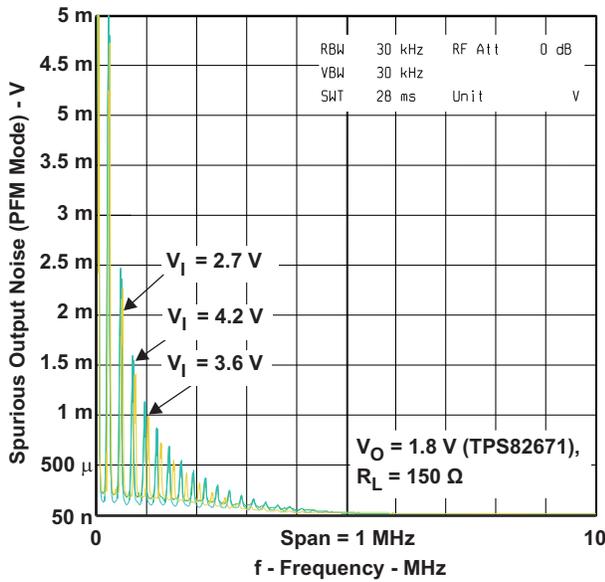


Figure 37.

SPURIOUS OUTPUT NOISE (PWM MODE)

vs  
FREQUENCY

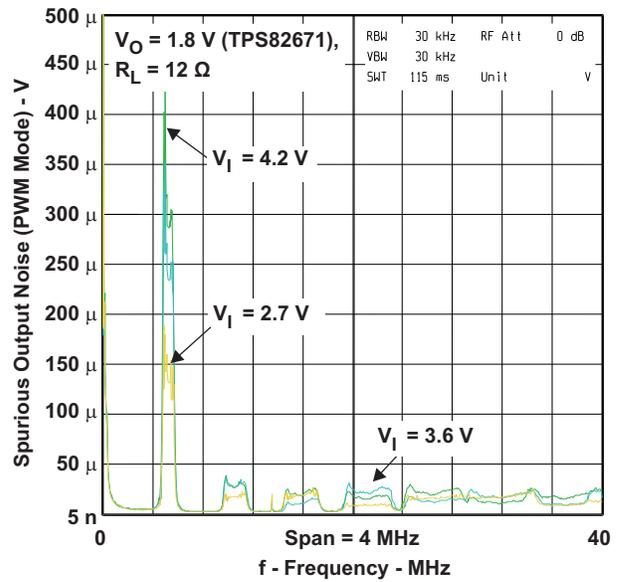


Figure 38.

OUTPUT SPECTRAL NOISE DENSITY

vs  
FREQUENCY

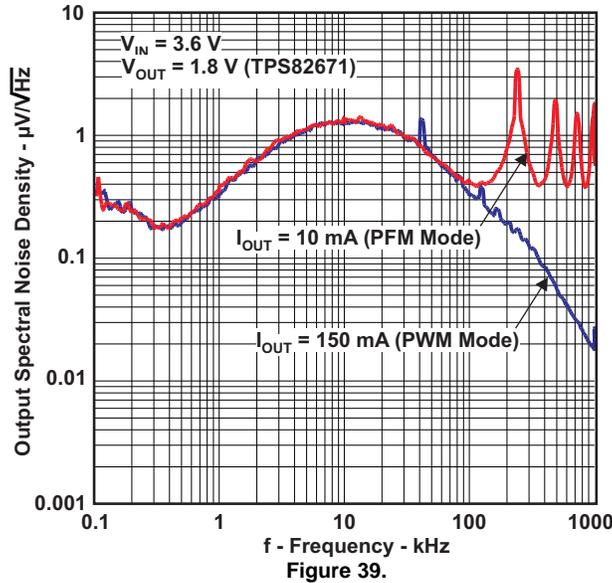


Figure 39.

## DETAILED DESCRIPTION

### OPERATION

The TPS8267x is a stand-alone, synchronous, step-down converter. The converter operates at a regulated 5.5-MHz frequency pulse width modulation (PWM) at moderate to heavy load currents (up to 600mA output current). At light load currents, the TPS8267x converter operates in power-save mode with pulse frequency modulation (PFM).

The converter uses a unique frequency-locked ring-oscillating modulator to achieve *best-in-class* load and line response. One key advantage of the non-linear architecture is that there is no traditional feed-back loop. The loop response to change in  $V_O$  is essentially instantaneous, which explains the transient response. Although this type of operation normally results in a switching frequency that varies with input voltage and load current, an internal frequency lock loop (FLL) holds the switching frequency constant over a large range of operating conditions.

Combined with *best-in-class* load and line-transient response characteristics, the low quiescent current of the device (approximately 17 $\mu$ A) helps to maintain high efficiency at light load while that current preserves a fast transient response for applications that require tight output regulation.

The TPS8267x integrates an input current limit to protect the device against heavy load or short circuits and features an undervoltage lockout circuit to prevent the device from misoperation at low input voltages. Fully functional operation is permitted down to 2.1V input voltage.

### POWER-SAVE MODE

If the load current decreases, the converter enters power-save mode automatically. During power-save mode, the converter operates in discontinuous current, (DCM) single-pulse PFM mode, which produces a low output ripple compared with other PFM architectures.

When in power-save mode, the converter resumes its operation when the output voltage falls below the nominal voltage. The converter ramps up the output voltage with a minimum of one pulse and goes into power-save mode when the output voltage is within its regulation limits.

The IC exits PFM mode and enters PWM mode when the output current can no longer be supported in PFM mode. As a consequence, the DC output voltage is typically positioned approximately 0.5% above the nominal output voltage. The transition between PFM and PWM is seamless.

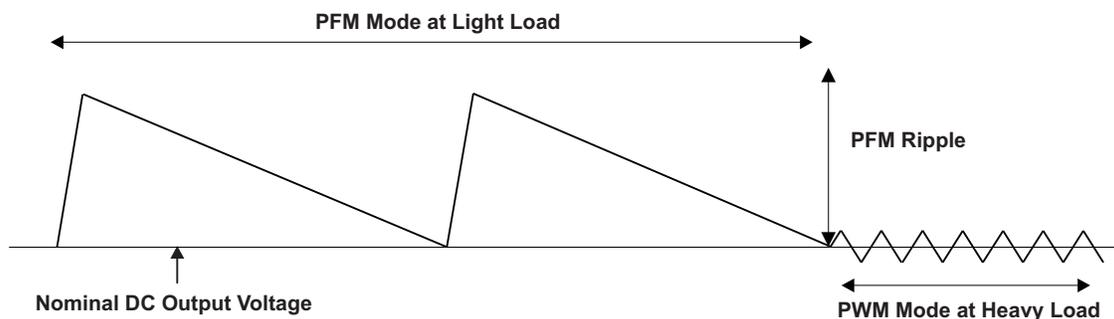


Figure 40. Operation in PFM Mode and Transfer to PWM Mode

### MODE SELECTION

The MODE pin selects the operating mode of the device. Connecting the MODE pin to GND enables the automatic PWM and power-save mode operation. The converter operates in regulated frequency PWM mode at moderate to heavy loads, and operates in PFM mode during light loads. This type of operation maintains high efficiency over a wide load current range.

Pulling the MODE pin high forces the converter to operate in PWM mode even at light-load currents. The advantage is that the converter modulates its switching frequency according to a spread spectrum PWM modulation technique that allows simple filtering of the switching harmonics in noise-sensitive applications. In this mode, the efficiency is lower when compared to the power-save mode during light loads.

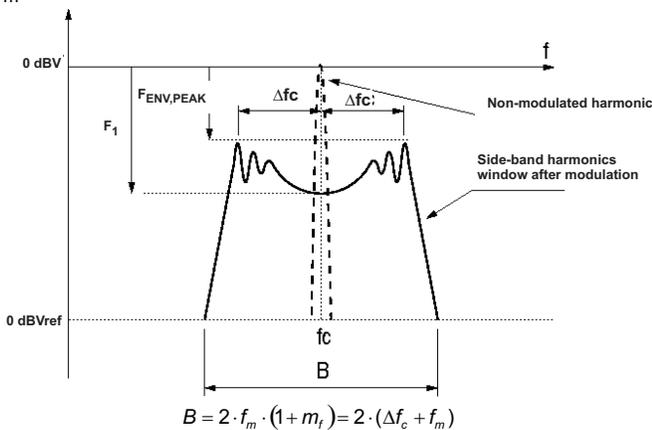
For additional flexibility, it is possible to switch from power-save mode to PWM mode during operation. This type of operation allows efficient power management by adjusting the operation of the converter to the specific system requirements.

## SPREAD SPECTRUM, PWM FREQUENCY DITHERING

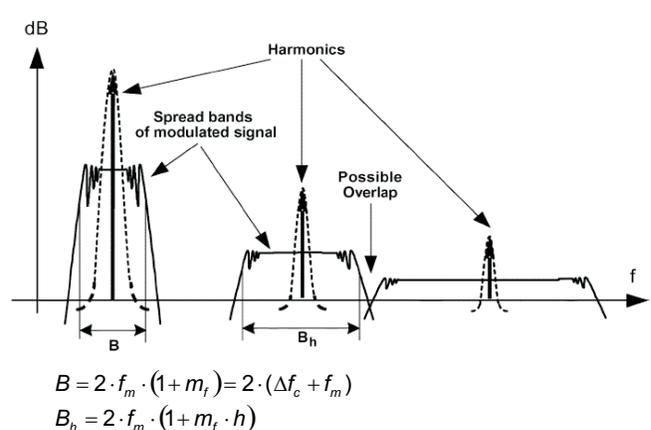
The goal of spread spectrum architecture is to spread out the emitted RF energy over a larger frequency range so that any resulting electromagnetic interference (EMI) is similar to white noise. The end result is a spectrum that is continuous and lower in peak amplitude. Spread spectrum makes it easier to comply with EMI standards. It also makes it easier to comply with the power supply ripple requirements in cellular and non-cellular wireless applications. Radio receivers are typically susceptible to narrowband noise that is focused on specific frequencies.

Switching regulators can be particularly troublesome in applications where electromagnetic interference (EMI) is a concern. Switching regulators operate on a cycle-by-cycle basis to transfer power to an output. In most cases, the frequency of operation is either fixed or regulated, based on the output load. This method of conversion creates large components of noise at the frequency of operation (fundamental) and multiples of the operating frequency (harmonics).

The spread spectrum architecture varies the switching frequency by approximately  $\pm 10\%$  of the nominal switching frequency, thereby significantly reduces the peak radiated and conducting noise on both the input and output supplies. The frequency dithering scheme is modulated with a triangle profile and a modulation frequency  $f_m$ .



**Figure 41. Spectrum of a Frequency Modulated Sin. Wave with Sinusoidal Variation in Time**



**Figure 42. Spread Bands of Harmonics in Modulated Square Signals <sup>(1)</sup>**

Figure 41 and Figure 42 show that after modulation the sideband harmonic is attenuated when compared to the non-modulated harmonic, and when the harmonic energy is spread into a certain frequency band. The higher the modulation index ( $m_f$ ) the larger the attenuation.

$$m_f = \frac{\delta \times f_c}{f_m} \quad (1)$$

With:

$f_c$  is the carrier frequency (i.e. nominal switching frequency)

$f_m$  is the modulating frequency (approx.  $0.016 \cdot f_c$ )

$\delta$  is the modulation ratio (approx 0.1)

$$\delta = \frac{\Delta f_c}{f_c} \quad (2)$$

(1) Spectrum illustrations and formulae (Figure 41 and Figure 42) copyright IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY, VOL. 47, NO.3, AUGUST 2005. See REFERENCES Section for full citation.

The maximum switching frequency is limited by the process and by the parameter modulation ratio ( $\delta$ ), together with  $f_m$ , which is the bandwidth of the side-band harmonics around the carrier frequency  $f_c$ . The bandwidth of a frequency modulated waveform is approximately given by the Carson's rule and can be summarized as:

$$B = 2 \times f_m \times (1 + m_f) = 2 \times (\Delta f_c + f_m) \quad (3)$$

$f_m < \text{RBW}$ : The receiver is not able to distinguish individual side-band harmonics; so, several harmonics are added in the input filter and the measured value is higher than expected in theoretical calculations.

$f_m > \text{RBW}$ : The receiver is able to properly measure each individual side-band harmonic separately, so that the measurements match the theoretical calculations.

## SOFT START

The TPS8267x has an internal soft-start circuit that limits the in-rush current during start-up. This circuit limits input voltage drop when a battery or a high-impedance power source is connected to the input of the MicroSiP™ DC/DC converter.

The soft-start system progressively increases the switching on-time from a minimum pulse-width of 35ns as a function of the output voltage. This mode of operation continues for approximately 100µs after the enable. If the output voltage does not reach its target value within the soft-start time, the soft-start transitions to a second mode of operation.

If the output voltage rises above approximately 0.5V, the converter increases the input current limit and thus enables the power supply to come up properly. The start-up time mainly depends on the capacitance present at the output node and the load current.

## ENABLE

The TPS8267x device starts operation when EN is set high and starts up with the soft start as previously described. For proper operation, the EN pin must be terminated and must not be left floating.

Pulling the EN pin low forces the device into shutdown. In this mode, all internal circuits are turned off and the  $V_{IN}$  current reduces to the device leakage current, which is typically a few hundred nanoamps.

The TPS8267x device can actively discharge the output capacitor when it turns off. The integrated discharge resistor has a typical resistance of 100 Ω. The required time to ramp down the output voltage depends on the load current and the capacitance present at the output node.

## APPLICATION INFORMATION

### INPUT CAPACITOR SELECTION

Because of the pulsating input current nature of the buck converter, a low ESR input capacitor is required to prevent large voltage transients that can cause misbehavior of the device or interference in other circuits in the system.

For most applications, the input capacitor that is integrated into the TPS8267x should be sufficient. If the application exhibits a noisy or erratic switching frequency, experiment with additional input ceramic capacitance to find a remedy.

The TPS8267x uses a tiny ceramic input capacitor. When a ceramic capacitor is combined with trace or cable inductance, such as from a wall adapter, a load step at the output can induce ringing at the VIN pin. This ringing can couple to the output and be mistaken as loop instability or can even damage the part. In this circumstance, additional "bulk" capacitance, such as electrolytic or tantalum, should be placed between the input of the converter and the power source lead to reduce ringing that can occur between the inductance of the power source leads and  $C_I$ .

### OUTPUT CAPACITOR SELECTION

The advanced, fast-response, voltage mode, control scheme of the TPS8267x allows the use of a tiny ceramic output capacitor ( $C_O$ ). For most applications, the output capacitor integrated in the TPS8267x is sufficient.

At nominal load current, the device operates in PWM mode; the overall output voltage ripple is the sum of the voltage step that is caused by the output capacitor ESL and the ripple current that flows through the output capacitor impedance. At light loads, the output capacitor limits the output ripple voltage and provides holdup during large load transitions.

The TPS8267x is designed as a Point-Of-Load (POL) regulator, to operate stand-alone without requiring any additional capacitance. Adding a 2.2 $\mu$ F ceramic output capacitor (X7R or X5R dielectric) generally works from a converter stability point of view, but does not necessarily help to minimize the output ripple voltage.

For best operation (i.e. optimum efficiency over the entire load current range, proper PFM/PWM auto transition), the TPS8267xSIP requires a minimum output ripple voltage in PFM mode. The typical output voltage ripple is ca. 1% of the nominal output voltage  $V_O$ . The PFM pulses are time controlled resulting in a PFM output voltage ripple and PFM frequency that depends (first order) on the capacitance seen at the MicroSiP™ DC/DC converter's output.

In applications requiring additional output bypass capacitors located close to the load, care should be taken to ensure proper operation. If the converter exhibits marginal stability or erratic switching frequency, experiment with additional low value series resistance (e.g. 50 to 100m $\Omega$ ) in the output path to find a remedy.

Because the damping factor in the output path is directly related to several resistive parameters (e.g. inductor DCR, power-stage  $r_{DS(on)}$ , PWB DC resistance, load switches  $r_{DS(on)}$  ...) that are temperature dependant, the converter small and large signal behavior must be checked over the input voltage range, load current range and temperature range.

The easiest sanity test is to evaluate, directly at the converter's output, the following aspects:

- PFM/PWM efficiency
- PFM/PWM and forced PWM load transient response

During the recovery time from a load transient, the output voltage can be monitored for settling time, overshoot or ringing that helps judge the converter's stability. Without any ringing, the loop has usually more than 45° of phase margin.

## LAYOUT CONSIDERATION

In making the pad size for the SiP LGA balls, it is recommended that the layout use non-solder-mask defined (NSMD) land. With this method, the solder mask opening is made larger than the desired land area, and the opening size is defined by the copper pad width. Figure 43 shows the appropriate diameters for a MicroSiP™ layout.

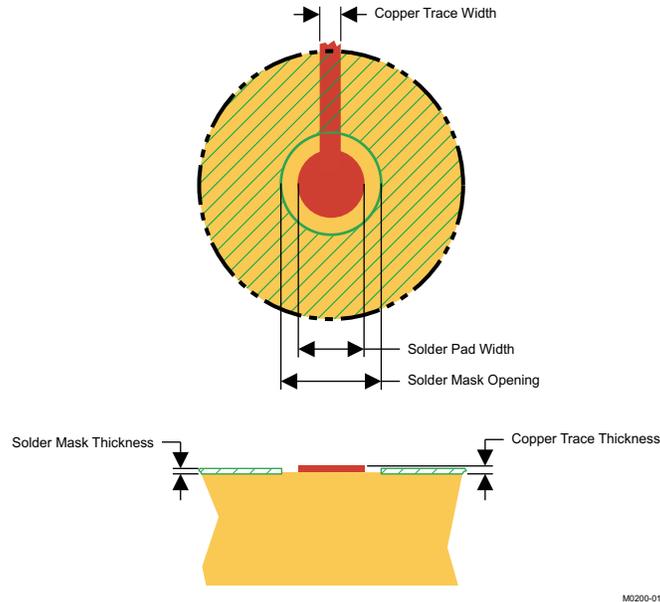


Figure 43. Recommended Land Pattern Image and Dimensions

SOLDER PAD DEFINITIONS <sup>(1)(2)(3)(4)</sup>	COPPER PAD	SOLDER MASK <sup>(5)</sup> OPENING	COPPER THICKNESS	STENCIL <sup>(6)</sup> OPENING	STENCIL THICKNESS
Non-solder-mask defined (NSMD)	0.30mm	0.360mm	1oz max (0.032mm)	0.34mm diameter	0.1mm thick

- (1) Circuit traces from non-solder-mask defined PWB lands should be 75µm to 100µm wide in the exposed area inside the solder mask opening. Wider trace widths reduce device stand off and affect reliability.
- (2) Best reliability results are achieved when the PWB laminate glass transition temperature is above the operating the range of the intended application.
- (3) Recommend solder paste is Type 3 or Type 4.
- (4) For a PWB using a Ni/Au surface finish, the gold thickness should be less than 0.5µm to avoid a reduction in thermal fatigue performance.
- (5) Solder mask thickness should be less than 20 µm on top of the copper circuit pattern.
- (6) For best solder stencil performance use laser cut stencils with electro polishing. Chemically etched stencils give inferior solder paste volume control.

## SURFACE MOUNT INFORMATION

The TPS8267x MicroSiP™ DC/DC converter uses an open frame construction that is designed for a fully automated assembly process and that features a large surface area for pick and place operations. See the "Pick Area" in the package drawings.

Package height and weight have been kept to a minimum thereby to allow the MicroSiP™ device to be handled similarly to a 0805 component.

See JEDEC/IPC standard J-STD-20b for reflow recommendations.

## THERMAL INFORMATION

The die temperature of the TPS8267x must be lower than the maximum rating of 125°C, so care should be taken in the layout of the circuit to ensure good heat sinking of the TPS8267x.

To estimate the junction temperature, approximate the power dissipation within the TPS8267x by applying the typical efficiency stated in this datasheet to the desired output power; or, by taking a power measurement if you have an actual TPS8267x device and TPS82671EVM evaluation module. Then calculate the internal temperature rise of the TPS8267x above the surface of the printed circuit board by multiplying the TPS8267x power dissipation by the thermal resistance.

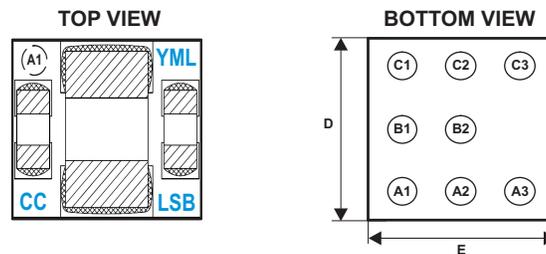
The actual thermal resistance of the TPS8267x to the printed circuit board depends on the layout of the circuit board, but the thermal resistance given in the Thermal Information Table can be used as a guide.

Three basic approaches for enhancing thermal performance are listed below:

- Improve the power dissipation capability of the PCB design.
- Improve the thermal coupling of the component to the PCB.
- Introduce airflow into the system.

## PACKAGE SUMMARY

### SIP PACKAGE



Code:

- CC — Customer Code (device/voltage specific)
- YML — Y: Year, M: Month, L: Lot trace code
- LSB — L: Lot trace code, S: Site code, B: Board locator

## MicroSiP™ DC/DC MODULE PACKAGE DIMENSIONS

The TPS8267x device is available in an 8-bump ball grid array (BGA) package. The package dimensions are:

- D = 2.30 ±0.05 mm
- E = 2.90 ±0.05 mm

## REFERENCES

"EMI Reduction in Switched Power Converters Using Frequency Modulation Techniques", in *IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY*, VOL. 4, NO. 3, AUGUST 2005, pp 569-576 by Josep Balcells, Alfonso Santolaria, Antonio Orlandi, David González, Javier Gago.

## REVISION HISTORY

Note: Page numbers of current version may differ from previous versions.

Changes from Original (October 2010) to Revision A	Page
• Added devices TPS82677 and TPS82678 to Header info .....	1
• Added TPS82678 to Ordering Info table and removed "Product Preview" attribute from TPS82677 .....	2
• Changed graph for <a href="#">Figure 8</a> .....	7
• Changed graph for <a href="#">Figure 11</a> .....	8
• Added copyright attribution for spectrum illustrations .....	17

Changes from Revision A (April 2011) to Revision B	Page
• Added TPS82676 part number to the data sheet header .....	1
• Deleted product preview attribute from TPS82676 device in the Ordering Information table. ....	2

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
TPS82671SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82671SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82675SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82675SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82676SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82676SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82677SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	
TPS82677SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	

<sup>(1)</sup> 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.

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

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

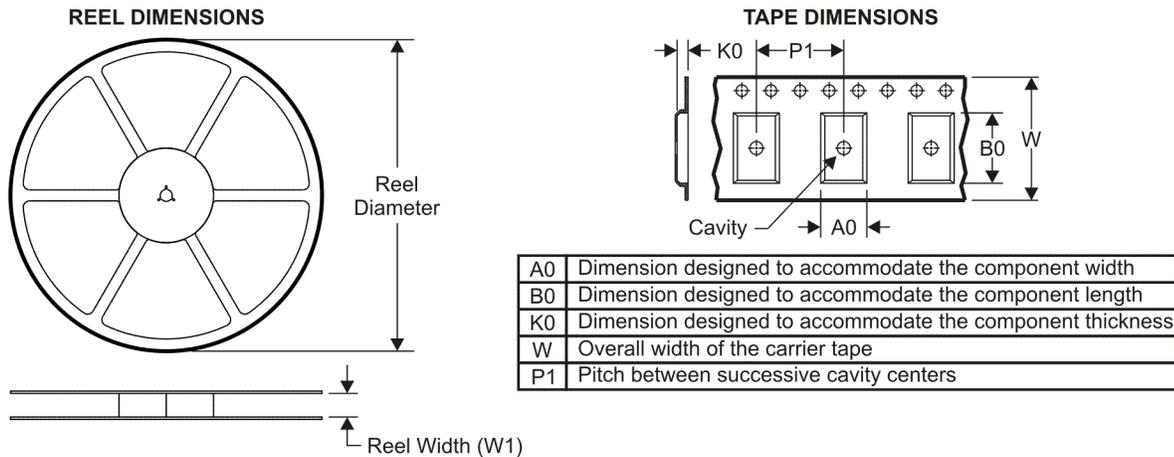
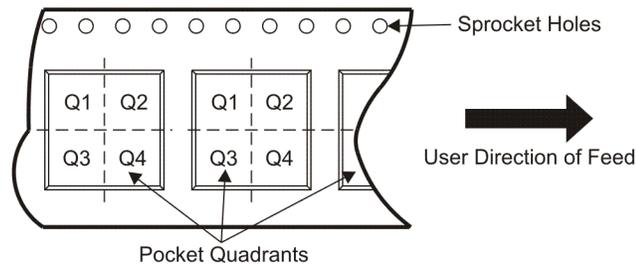
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

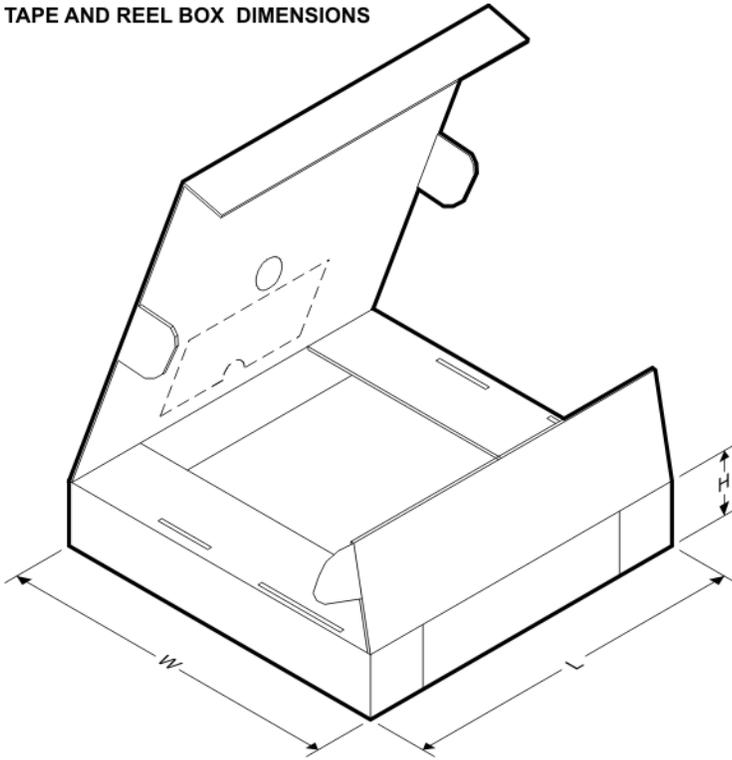
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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*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
TPS82671SIPR	uSiP	SIP	8	3000	180.0	8.4	2.45	3.05	1.1	4.0	8.0	Q2
TPS82675SIPR	uSiP	SIP	8	3000	180.0	8.4	2.45	3.05	1.1	4.0	8.0	Q2
TPS82676SIPR	uSiP	SIP	8	3000	180.0	8.4	2.45	3.05	1.1	4.0	8.0	Q2
TPS82676SIPT	uSiP	SIP	8	250	180.0	8.4	2.45	3.05	1.1	4.0	8.0	Q2
TPS82677SIPR	uSiP	SIP	8	3000	180.0	8.4	2.45	3.05	1.1	4.0	8.0	Q2
TPS82677SIPT	uSiP	SIP	8	250	180.0	8.4	2.45	3.05	1.1	4.0	8.0	Q2

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

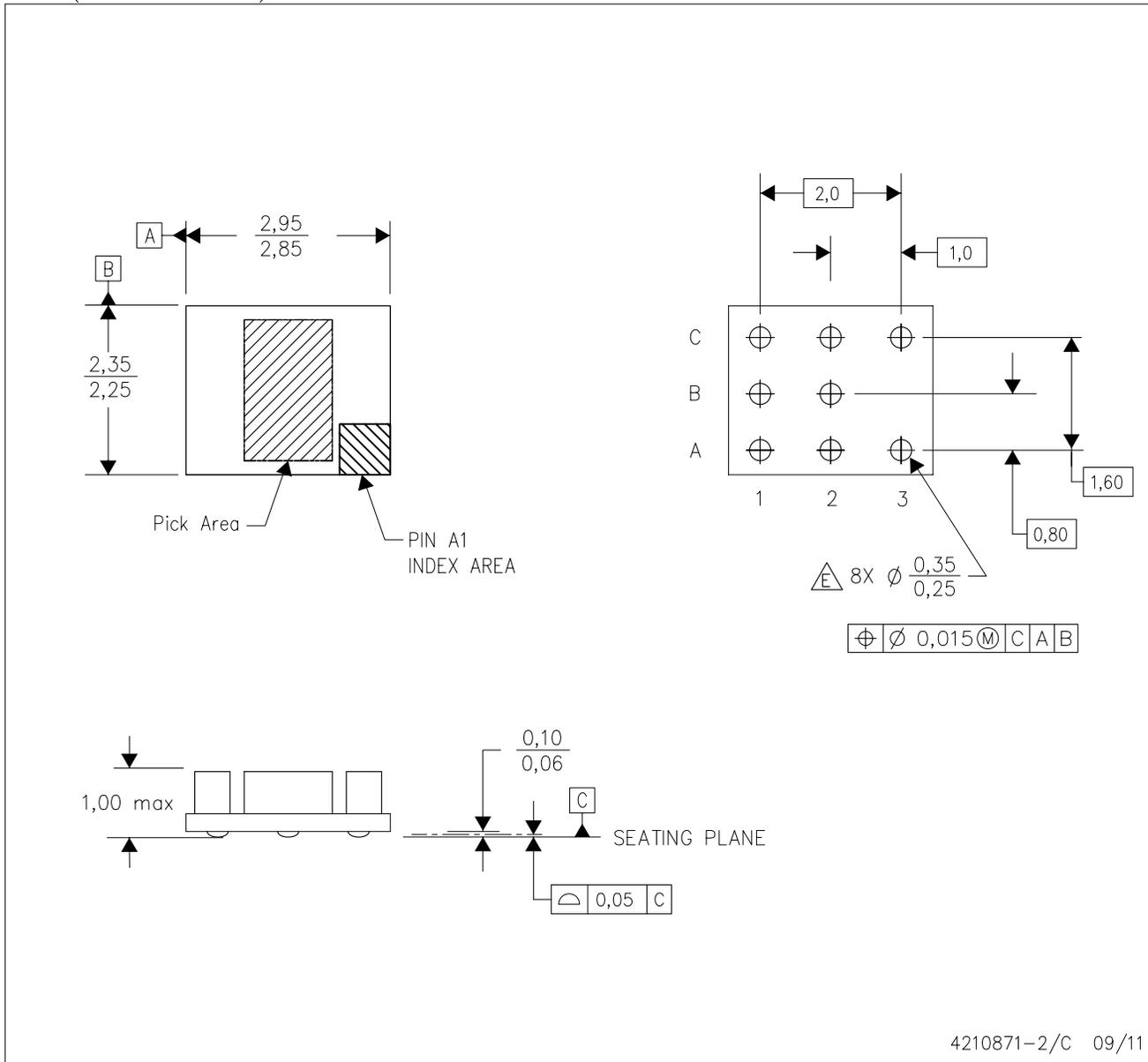
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS82671SIPR	uSiP	SIP	8	3000	202.0	201.0	28.0
TPS82675SIPR	uSiP	SIP	8	3000	202.0	201.0	28.0
TPS82676SIPR	uSiP	SIP	8	3000	202.0	201.0	28.0
TPS82676SIPT	uSiP	SIP	8	250	202.0	201.0	28.0
TPS82677SIPR	uSiP	SIP	8	3000	202.0	201.0	28.0
TPS82677SIPT	uSiP	SIP	8	250	202.0	201.0	28.0

# MECHANICAL DATA

TPS62670SiP, TPS62690SiP, TPS82671SiP, TPS82675SiP

SIP (R-uSiP-N8)

MicroSiP™



4210871-2/C 09/11

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - MicroSiP™ package configuration – Micro System in Package.
  - Reference Product Data Sheet for array population.  
3 x 3 matrix pattern is shown for illustration only.
- $\triangle E$  This package contains Pb-free balls.

MicroSiP is a trademark of Texas Instruments

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