High-Efficiency MicroSiP(TM) STEP-DOWN CONVERTER (PROFILE <1mm)

Check for Samples: TPS82692 , TPS82693, TPS82694, TPS826951, TPS82697, TPS82698, TPS82699

FEATURES

- **Total Solution Size <6.7 mm²**
- **95% Efficiency at 3MHz Operation**
- **23µA Quiescent Current**
- **High Duty-Cycle Operation**
- ***Best in Class* Load and Line Transient**
- **±2% Total DC Voltage Accuracy**
- **Automatic PFM/PWM Mode Switching**
- **Low Ripple Light-Load PFM Mode**
- **Excellent AC Load Regulation**
- **Internal Soft Start, 200-µs Start-Up Time**
- **Integrated Active Power-Down Sequencing (Optional)**
- **Current Overload and Thermal Shutdown Protection**
- **Sub 1-mm Profile Solution**

APPLICATIONS

- **LDO Replacement**
- **Cell Phones, Smart-Phones**
- **PoL Applications**

DESCRIPTION

The TPS8269xSIP device is a complete 500mA / 800mA, 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 TPS8269xSIP 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 3-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 23µA (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 TPS8269xSIP 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.

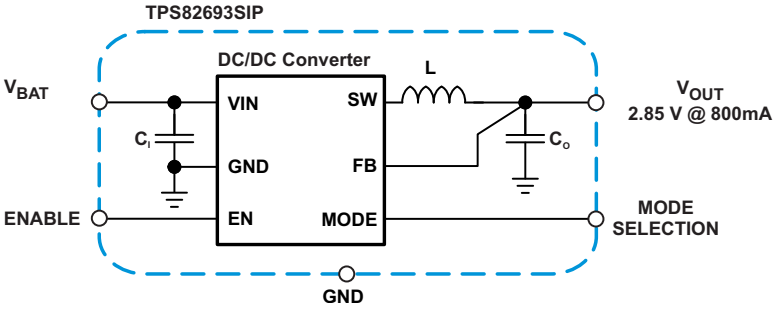


Figure 1. Typical Application

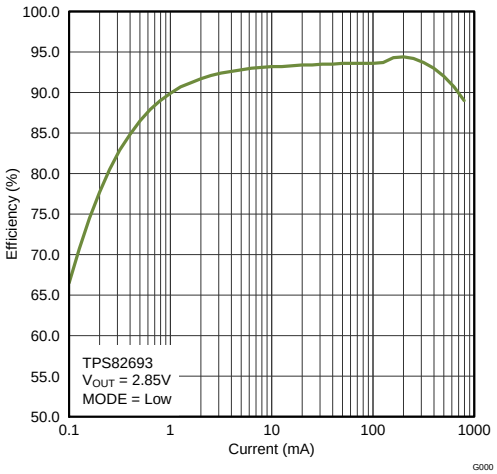


Figure 2. Efficiency vs. Load Current

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

MicroSIP, MicroSiP are trademarks of Texas Instruments.

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.

ORDERING INFORMATION(1)

T_A	PART NUMBER	OUTPUT VOLTAGE(2)	DEVICE SPECIFIC FEATURE	ORDERING(3)	PACKAGE MARKING CHIP CODE
-40°C to 85°C	TPS82692	2.2V(4)	800mA peak output current Spread Spectrum Frequency Modulation	TPS82692SIP	
	TPS82693	2.85V	800mA peak output current Spread Spectrum Frequency Modulation Output Discharge	TPS82693SIP	W3
	TPS82694	2.95V(4)	800mA peak output current Spread Spectrum Frequency Modulation	TPS82694SIP	
	TPS826951	2.5V(4)	800mA peak output current	TPS826951SIP	DO
	TPS82697	2.8V	800mA peak output current	TPS82697SIP	C2
	TPS82698	3.0V	800mA peak output current Output Discharge Spread Spectrum Frequency Modulation	TPS82698SIP	WN
	TPS82699	3.2V(4)	500mA peak output current Output Discharge	TPS82699SIP	

(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.
(2) Internal tap points are available to facilitate output voltages in 50mV increments.
(3) The SIP package is available in tape and reel. Add a R suffix (e.g. TPS82699SIPR) to order quantities of 3000 parts. Add a T suffix (e.g. TPS82699SIPT) to order quantities of 250 parts.
(4) Product preview. Contact TI factory for more information

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)(1)

			MIN	MAX	UNIT
Input Voltage	Voltage at VIN(2)(3), SW(3)		–0.3	6	V
	Voltage at VOUT(3)		–0.3	3.6	V
	Voltage at EN, MODE (3)		–0.3	V_{IN} + 0.3	V
Peak output current, I_O (4)		TPS82699		500	mA
		TPS82692, TPS82693, TPS82694, TPS826951, TPS82697, TPS62698		800(4)	mA
Power dissipation			Internally limited		
Operating temperature range, T_A (5)			–40	85	°C
Maximum internal operating temperature, $T_{INT(max)}$				125	°C
Storage temperature range, T_{stg}			–55	125	°C
ESD(6)	Human body model			2	kV
	Charge device model			1	kV

(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 is not recommended over an extended period of time.
(3) All voltage values are with respect to network ground terminal.
(4) Limit to 50% Duty Cycle over Lifetime.
(5) 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 ($T_{A(max)}$) is dependent on the maximum operating junction temperature ($T_{J(max)}$), the maximum power dissipation of the device in the application ($P_{D(max)}$), and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: $T_{A(max)} = T_{J(max)} - (\theta_{JA} \times P_{D(max)})$. To achieve optimum performance, it is recommended to operate the device with a maximum junction temperature of 105°C.
(6) The human body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin.

THERMAL INFORMATION

THERMAL METRIC(1)		TPS82693/4/51/7/8/9 SIP (8-Pins)	UNITS
θ_{JA}	Junction-to-ambient thermal resistance	83	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	53	
θ_{JB}	Junction-to-board thermal resistance	-	
ψ_{JT}	Junction-to-top characterization parameter	-	
ψ_{JB}	Junction-to-board characterization parameter	-	
θ_{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.

RECOMMENDED OPERATING CONDITIONS

			MIN	NOM	MAX	UNIT
V_{IN}	Input voltage range		2.3		4.8 (1)	V
I_O	Output current range	TPS82699	0		500	mA
		TPS82692, TPS82693 TPS82694, TPS826951 TPS82697, TPS62698			800	mA
	Additional output capacitance (PFM/PWM)			0	4	µF
	Additional output capacitance (PWM)			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 is not recommended over an extended period of time.

ELECTRICAL CHARACTERISTICS

Minimum and maximum values are at V_{IN} = 2.3V to 5.5V, V_{OUT} = 2.85V, EN = 1.8V, AUTO mode and T_A = –40°C to 85°C; Circuit of Parameter Measurement Information section (unless otherwise noted). Typical values are at V_{IN} = 3.6V, V_{OUT} = 2.85V, EN = 1.8V, AUTO mode and T_A = 25°C (unless otherwise noted).

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY CURRENT							
I_Q	Operating quiescent current	TPS8269x	I_O = 0mA. Device not switching		23	50	µA
		TPS8269x	I_O = 0mA, PWM mode		3.5		mA
$I_{(SD)}$	Shutdown current	TPS8269x	EN = GND		0.2	7	µA
UVLO	Undervoltage lockout threshold	TPS8269x			2.05	2.1	V
Protection							
	Thermal Shutdown	TPS8269x			140		°C
	Thermal Shutdown hysteresis	TPS8269x			10		°C
I_{LIM}	Peak Output Current Limit	TPS8269x			1000		mA
I_{SC}	Short Circuit Output Current Limit	TPS8269x			15		mA
ENABLE, MODE							
V_{IH}	High-level input voltage	TPS8269x		1			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

ELECTRICAL CHARACTERISTICS (continued)

Minimum and maximum values are at V_{IN} = 2.3V to 5.5V, V_{OUT} = 2.85V, EN = 1.8V, AUTO mode and T_A = –40°C to 85°C; Circuit of Parameter Measurement Information section (unless otherwise noted). Typical values are at V_{IN} = 3.6V, V_{OUT} = 2.85V, EN = 1.8V, AUTO mode and T_A = 25°C (unless otherwise noted).

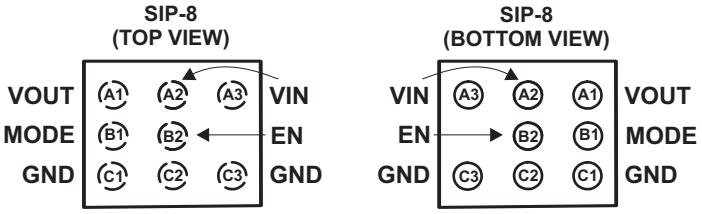
PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
OSCILLATOR							
f_{SW}	Oscillator frequency	TPS8269x	I_O = 0mA, PWM mode. T_A = 25°C	2.7	3	3.3	MHz
OUTPUT							
V_{OUT}	Regulated DC output voltage	TPS82693 TPS82697	3.15V ≤ V_{IN} ≤ 4.8V, 0mA ≤ I_O ≤ 500 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.03×V_{NOM}	V
			3.25V ≤ V_{IN} ≤ 4.8V, 500mA ≤ I_O ≤ 800 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.03×V_{NOM}	V
			3.15V ≤ V_{IN} ≤ 5.5V, 0mA ≤ I_O ≤ 500 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.04×V_{NOM}	V
			3.25V ≤ V_{IN} ≤ 5.5V, 500mA ≤ I_O ≤ 800 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.04×V_{NOM}	V
			3.15V ≤ V_{IN} ≤ 4.8V, 0mA ≤ I_O ≤ 500 mA PWM operation	0.98×V_{NOM}	V_{NOM}	1.02×V_{NOM}	V
			3.25V ≤ V_{IN} ≤ 4.8V, 500mA ≤ I_O ≤ 800 mA PWM operation	0.98×V_{NOM}	V_{NOM}	1.02×V_{NOM}	V
		TPS826951	2.9V ≤ V_{IN} ≤ 4.8V, 0mA ≤ I_O ≤ 500 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.03×V_{NOM}	V
			3.15V ≤ V_{IN} ≤ 4.8V, 500mA ≤ I_O ≤ 800 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.03×V_{NOM}	V
			2.9V ≤ V_{IN} ≤ 5.5V, 0mA ≤ I_O ≤ 500 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.04×V_{NOM}	V
			3.15V ≤ V_{IN} ≤ 5.5V, 500mA ≤ I_O ≤ 800 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.04×V_{NOM}	V
			2.9V ≤ V_{IN} ≤ 4.8V, 0mA ≤ I_O ≤ 500 mA PWM operation	0.98×V_{NOM}	V_{NOM}	1.02×V_{NOM}	V
			3.15V ≤ V_{IN} ≤ 4.8V, 500mA ≤ I_O ≤ 800 mA PWM operation	0.98×V_{NOM}	V_{NOM}	1.02×V_{NOM}	V
		TPS82698	3.3V ≤ V_{IN} ≤ 4.8V, 0mA ≤ I_O ≤ 500 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.03×V_{NOM}	V
			3.45V ≤ V_{IN} ≤ 4.8V, 500mA ≤ I_O ≤ 800 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.03×V_{NOM}	V
			3.3V ≤ V_{IN} ≤ 5.5V, 0mA ≤ I_O ≤ 500 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.04×V_{NOM}	V
			3.45V ≤ V_{IN} ≤ 5.5V, 500mA ≤ I_O ≤ 800 mA PFM/PWM operation	0.98×V_{NOM}	V_{NOM}	1.04×V_{NOM}	V
			3.3V ≤ V_{IN} ≤ 4.8V, 0mA ≤ I_O ≤ 500 mA PWM operation	0.98×V_{NOM}	V_{NOM}	1.02×V_{NOM}	V
			3.45V ≤ V_{IN} ≤ 4.8V, 500mA ≤ I_O ≤ 800 mA PWM operation	0.98×V_{NOM}	V_{NOM}	1.02×V_{NOM}	V
	Line regulation		V_{IN} = V_O + 0.5V (min 3.15V) to 5.5V I_O = 200 mA		0.18		%/V
	Load regulation		I_O = 0mA to 800 mA		–0.0002		%/mA
	Feedback input resistance	TPS8269x			480		kΩ
ΔV_O	Power-save mode ripple voltage	TPS82693 TPS826951 TPS82697	I_O = 1mA C_O = 4.7µF X5R 6.3V 0402		30		mV_{PP}
		TPS82699 TPS82698	I_O = 1mA C_O = 4.7µF X5R 6.3V 0402		65		mV_{PP}
			I_O = 1mA C_O = 10µF X5R 6.3V 0603		25		mV_{PP}
		TPS82692	I_O = 1mA C_O = 10µF X5R 6.3V 0603		22		mV_{PP}
r_{DIS}	Discharge resistor for power-down sequence				120		Ω

ELECTRICAL CHARACTERISTICS (continued)

Minimum and maximum values are at V_{IN} = 2.3V to 5.5V, V_{OUT} = 2.85V, EN = 1.8V, AUTO mode and T_A = –40°C to 85°C; Circuit of Parameter Measurement Information section (unless otherwise noted). Typical values are at V_{IN} = 3.6V, V_{OUT} = 2.85V, EN = 1.8V, AUTO mode and T_A = 25°C (unless otherwise noted).

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Start-up time	TPS82693 TPS82699 TPS826951 TPS82698 TPS82697	I_O = 0mA, Time from active EN to V_O		200		µs
		TPS82692	I_O = 0mA, Time from active EN to V_O		160		µs

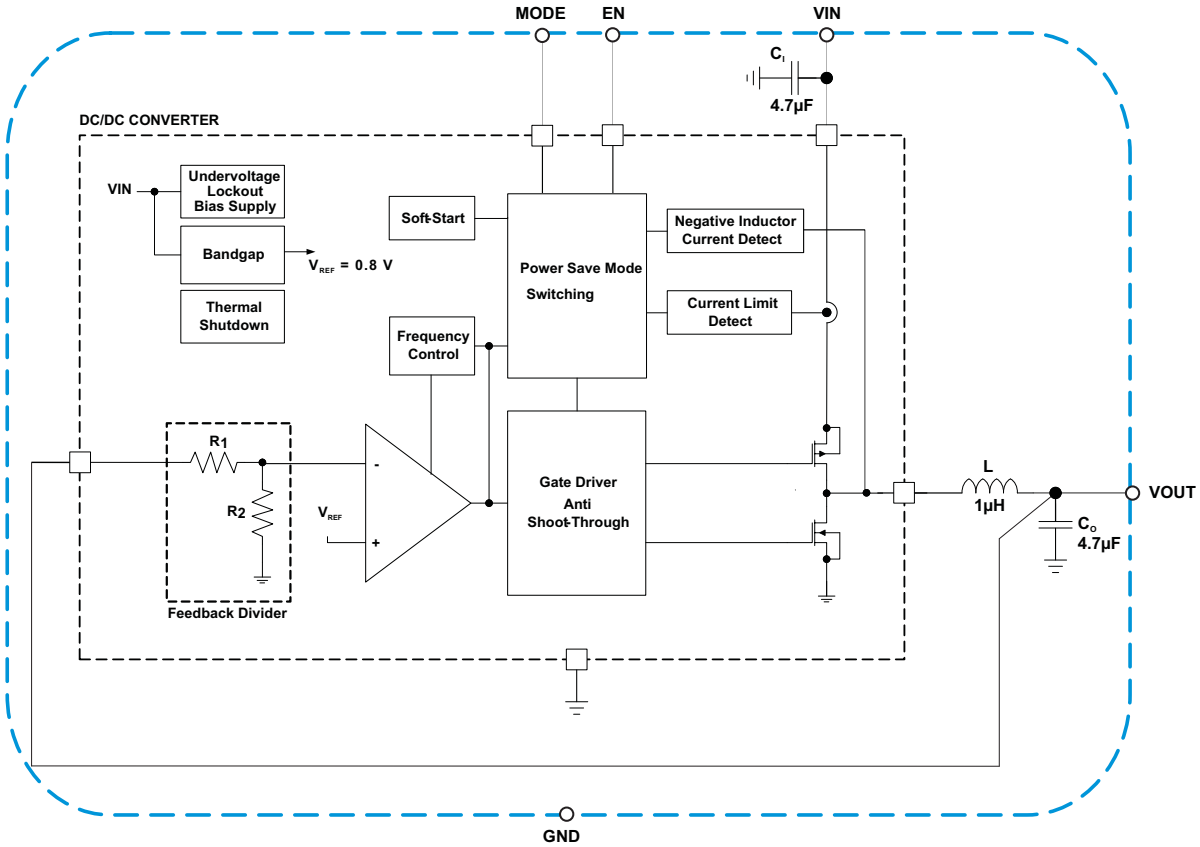
PIN ASSIGNMENTS TPS8269X



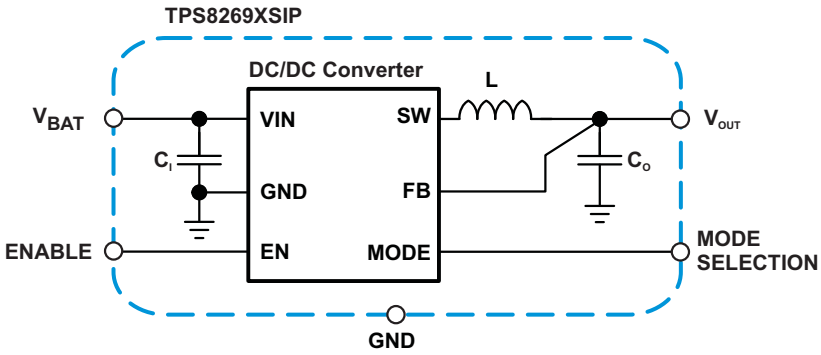
PIN FUNCTIONS

TERMINAL		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 TPS8269xSIP's internal regulator.
EN	B2	I	This is the enable pin of the device. Connecting this pin to ground forces the converter into shutdown mode. Pulling this pin to V_{IN} enables 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 enabled, regulated frequency PWM operation forced.
GND	C1, C2, C3	–	Ground pin.

FUNCTIONAL BLOCK DIAGRAM



PARAMETER MEASUREMENT INFORMATION



TYPICAL CHARACTERISTICS

Table 1. Table of Graphs

			FIGURE
η	Efficiency	vs Load current (TPS82699 V_{OUT} = 3.2V)	Figure 3, Figure 4, Figure 5
		vs Load current (TPS82693 V_{OUT} = 2.85V)	Figure 6, Figure 7, Figure 8
		vs Load current (TPS82697 V_{OUT} = 2.8V)	Figure 9, Figure 10
		vs Load current (TPS826951 V_{OUT} = 2.5V)	Figure 11, Figure 12
		vs Load current (TPS82698 V_{OUT} = 3.0V)	Figure 13, Figure 14
		vs Input Voltage (TPS82699 V_{OUT} = 3.2V)	Figure 15
	Peak-to-peak output ripple voltage	vs Load current (TPS82699 V_{OUT} = 3.2V)	Figure 16, Figure 17
V_O	DC output voltage	vs Load Current (TPS82699 V_{OUT} = 3.2V)	Figure 18
		vs Load Current (TPS82693 V_{OUT} = 2.85V)	Figure 19, Figure 20
	Load transient response	TPS82699 V_{OUT} = 3.2V	Figure 21, Figure 22, Figure 23
		TPS826951 V_{OUT} = 2.5V	Figure 24, Figure 25
	AC load transient response	TPS82699 V_{OUT} = 3.2V	Figure 26, Figure 27, Figure 28, Figure 29
		TPS826951 V_{OUT} = 2.5V	Figure 30, Figure 31, Figure 32, Figure 33
		TPS82698 V_{OUT} = 3.0V	Figure 34, Figure 35, Figure 36
	PFM/PWM boundaries	vs Input voltage (TPS82699 V_{OUT} = 3.2V)	Figure 37
I_Q	Quiescent current	vs Input voltage	Figure 38
f_s	PWM switching frequency	vs Input voltage (TPS82699 V_{OUT} = 3.2V)	Figure 39
	Start-up	(TPS82699 V_{OUT} = 3.2V)	Figure 40, Figure 41
	Shut-Down		Figure 42

TYPICAL CHARACTERISTICS (continued)

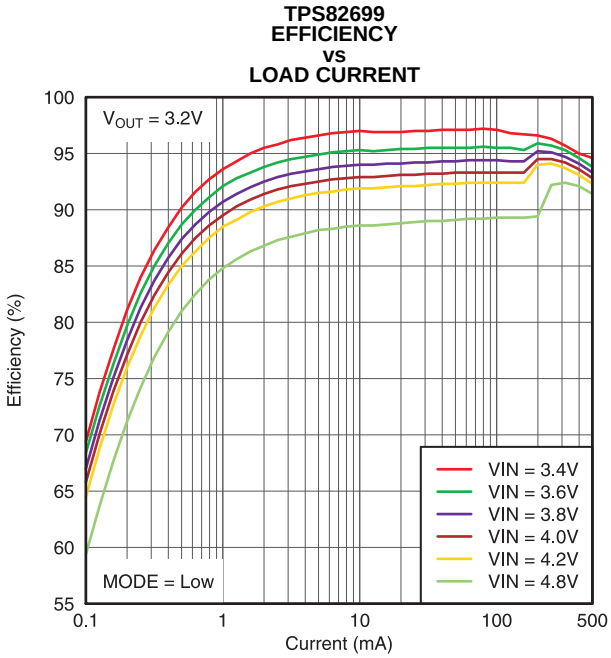


Figure 3.

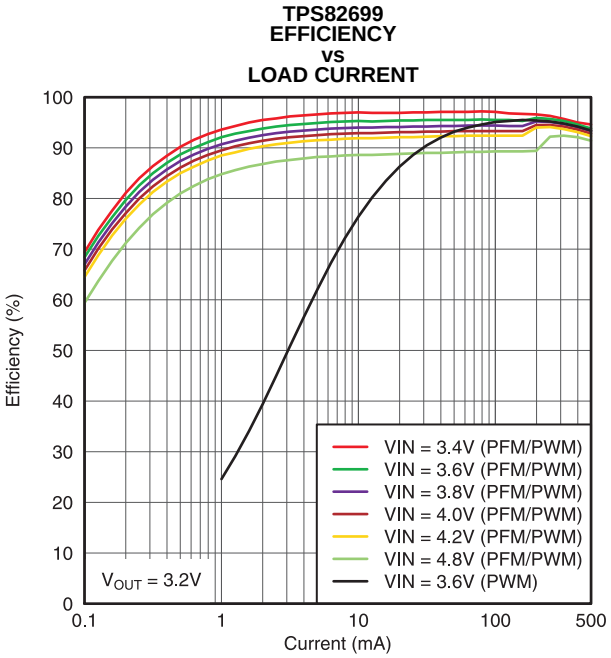


Figure 4.

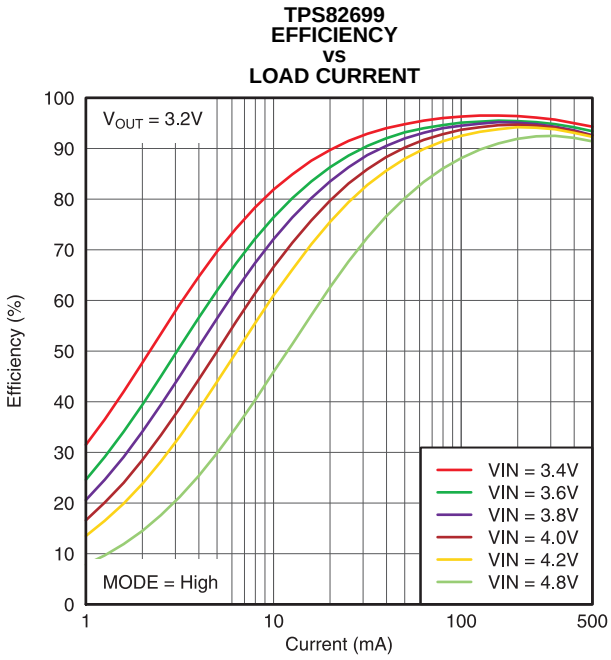


Figure 5.

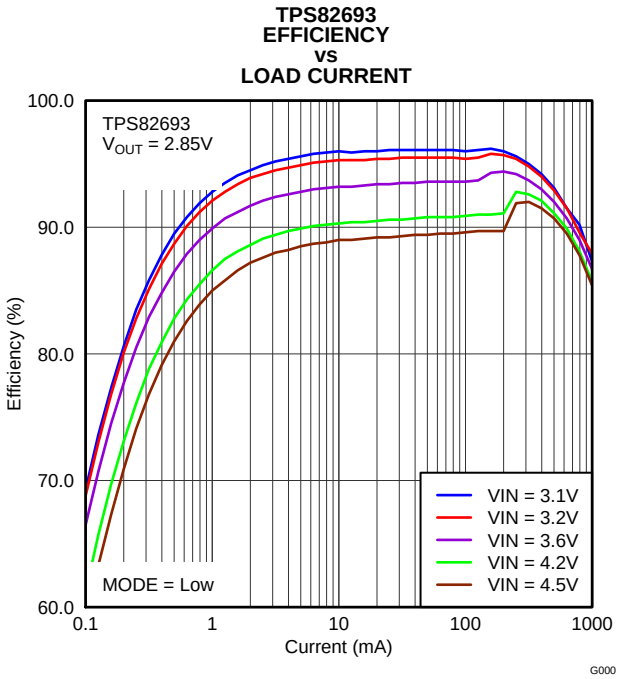


Figure 6.

TYPICAL CHARACTERISTICS (continued)

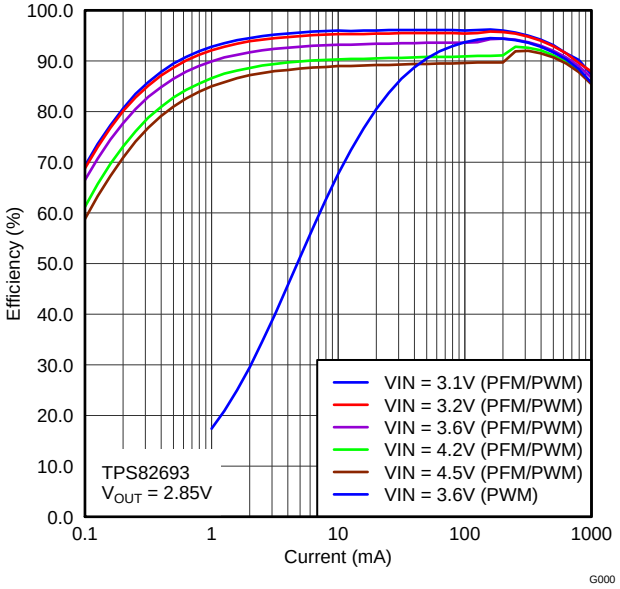


Figure 7.

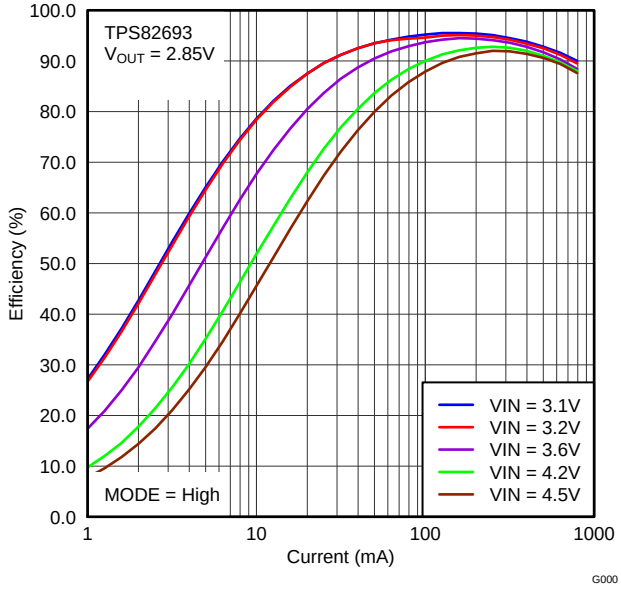


Figure 8.

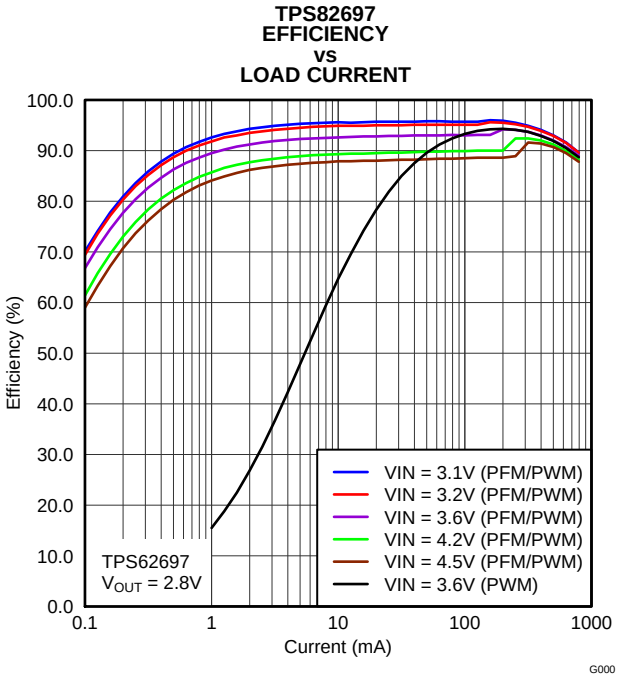


Figure 9.

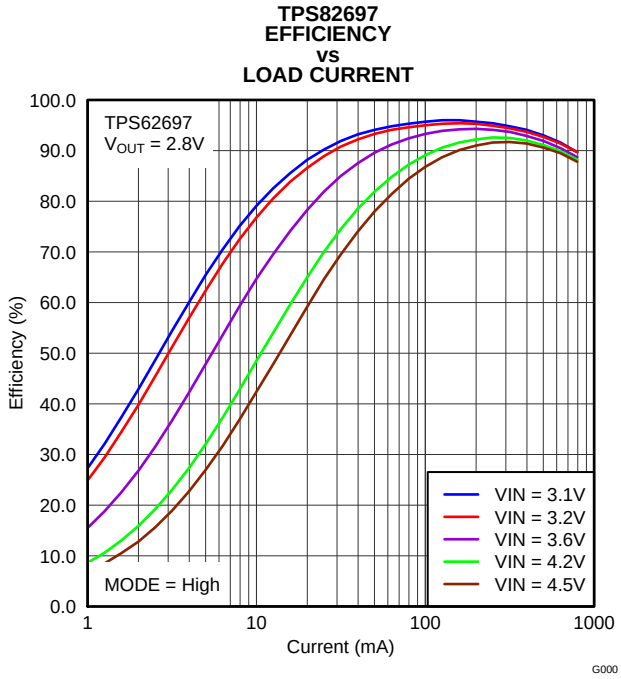


Figure 10.

TYPICAL CHARACTERISTICS (continued)

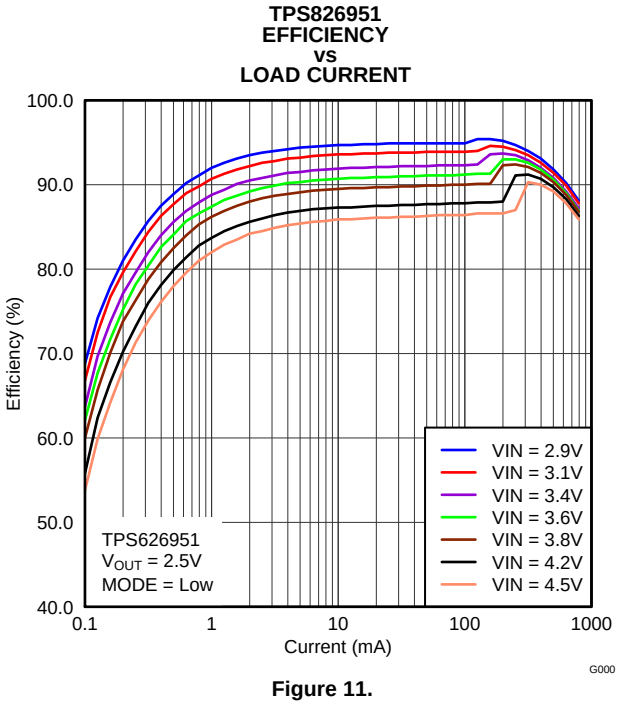


Figure 11.

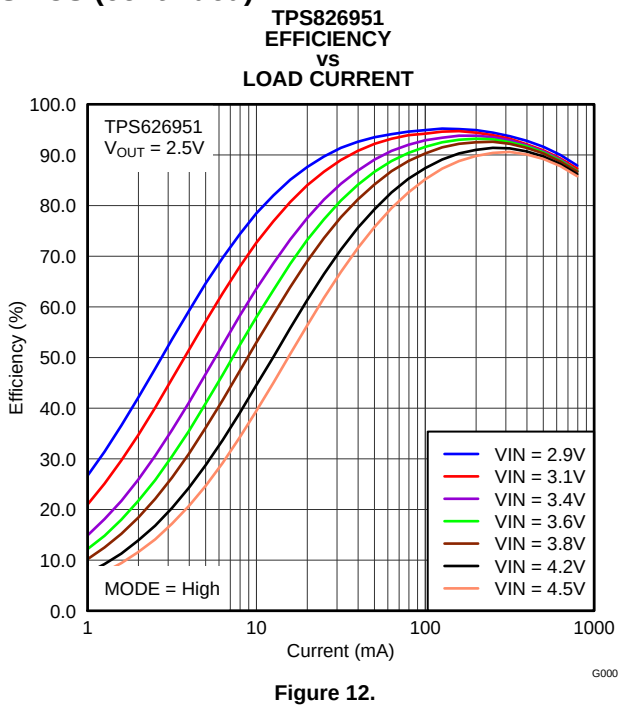


Figure 12.

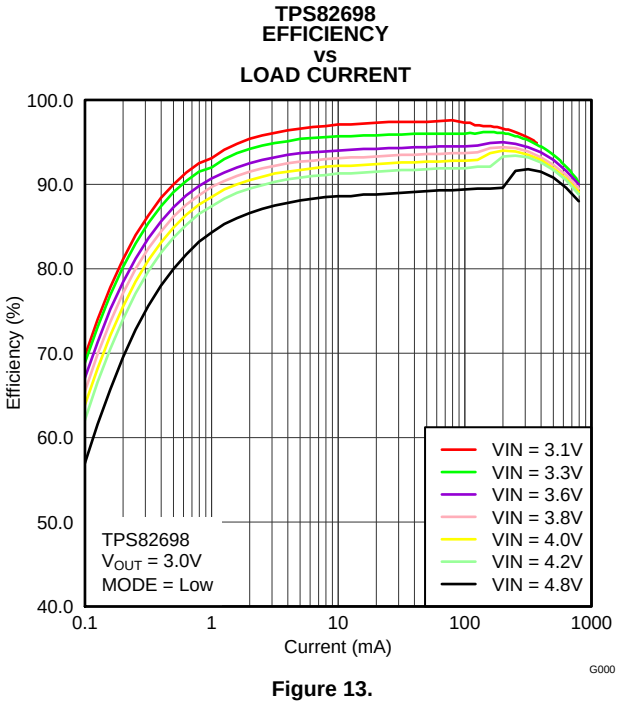


Figure 13.

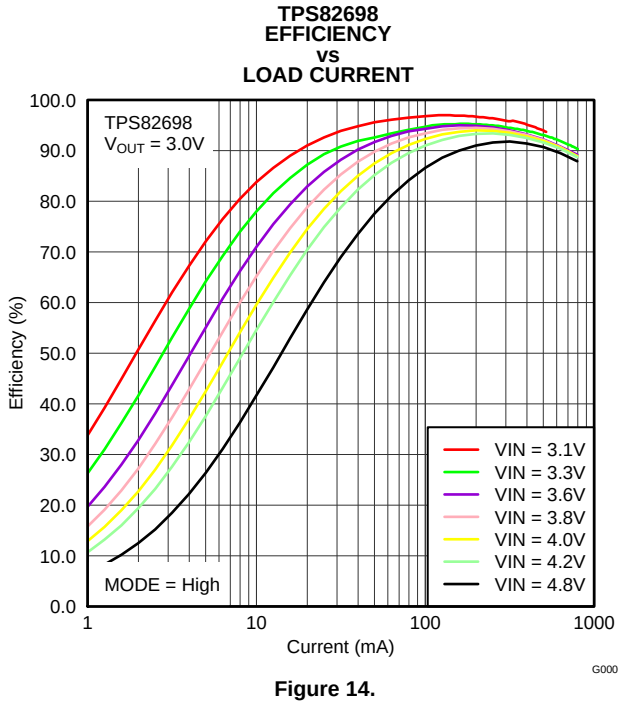


Figure 14.

TYPICAL CHARACTERISTICS (continued)

TPS82699
EFFICIENCY
vs
INPUT VOLTAGE

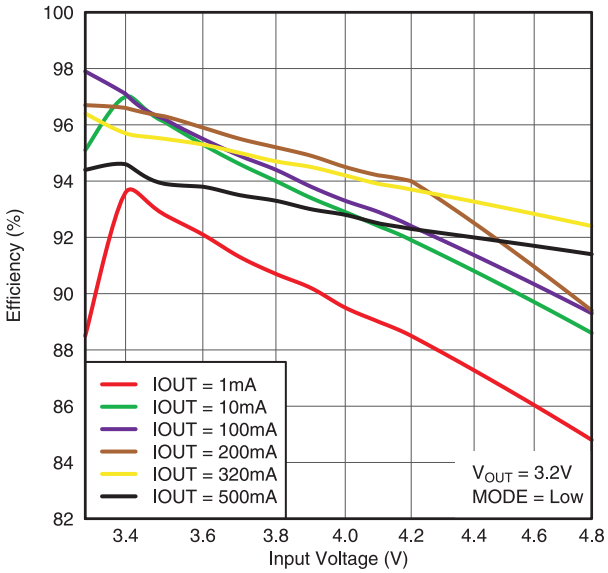


Figure 15.

TPS82699
PEAK-TO-PEAK OUTPUT RIPPLE VOLTAGE
vs
LOAD CURRENT

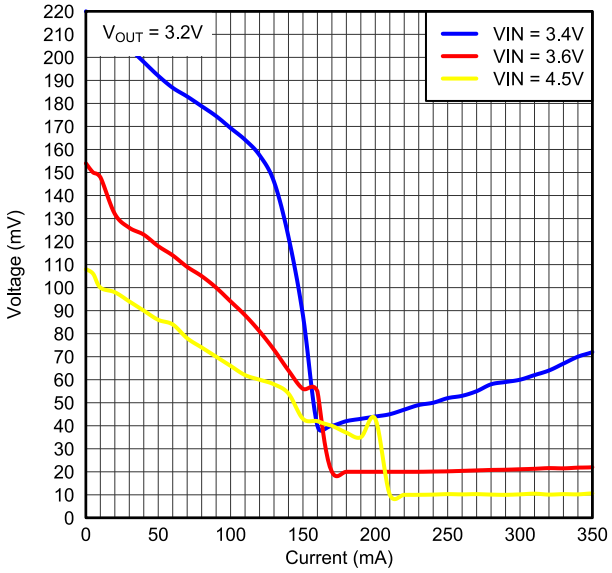


Figure 16.

TPS82699
PEAK-TO-PEAK OUTPUT RIPPLE VOLTAGE
vs
LOAD CURRENT

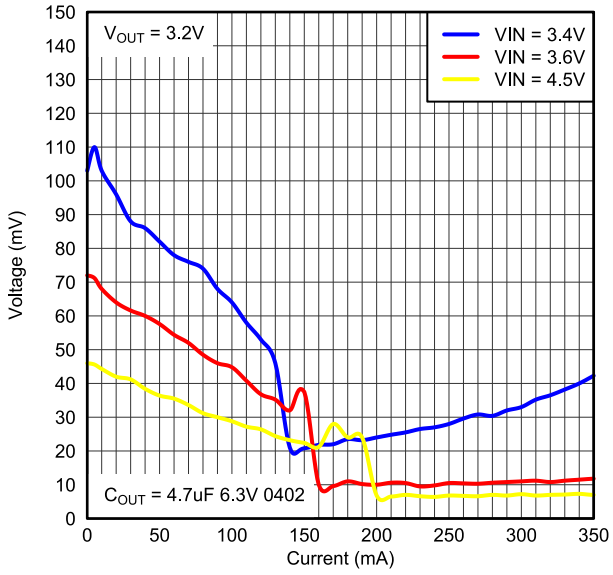


Figure 17.

TPS82699
DC OUTPUT VOLTAGE
vs
LOAD CURRENT

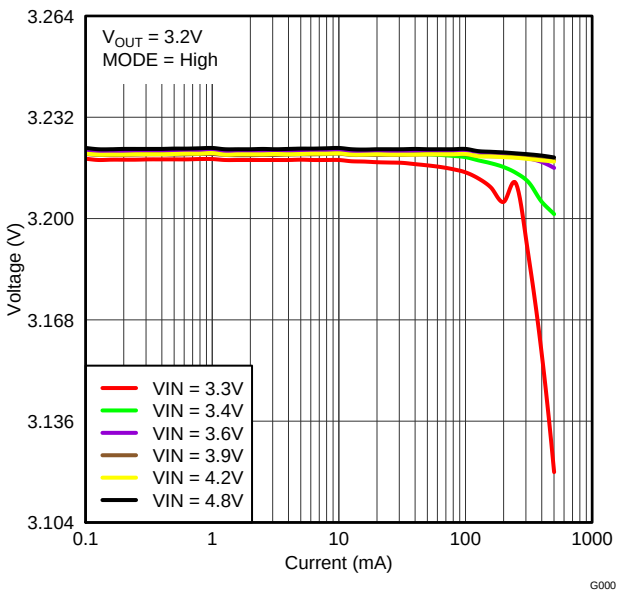


Figure 18.

TYPICAL CHARACTERISTICS (continued)

TPS82693
DC OUTPUT VOLTAGE
vs
LOAD CURRENT

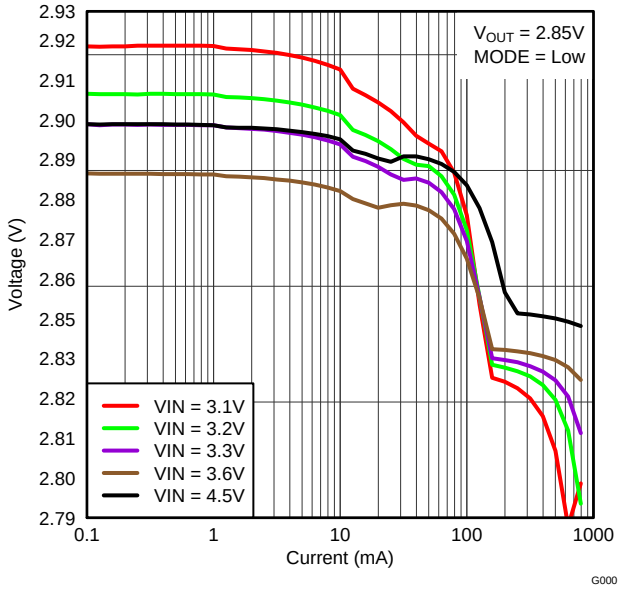


Figure 19.

TPS82693
DC OUTPUT VOLTAGE
vs
LOAD CURRENT

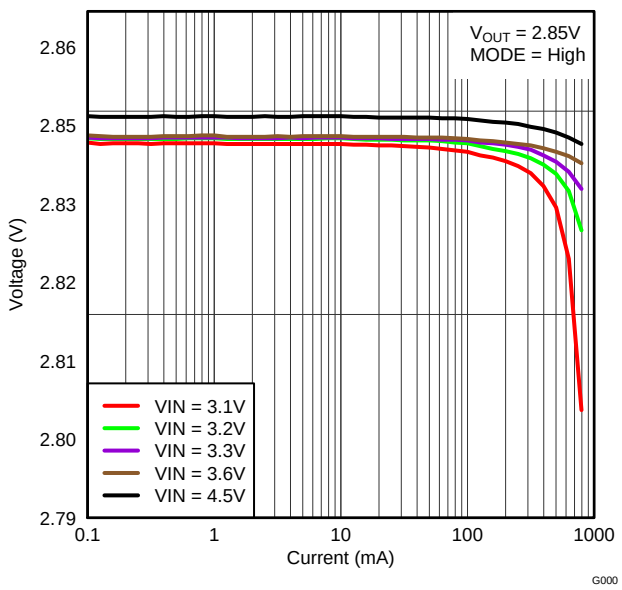


Figure 20.

TPS82699
LOAD TRANSIENT RESPONSE IN
PFM/PWM OPERATION

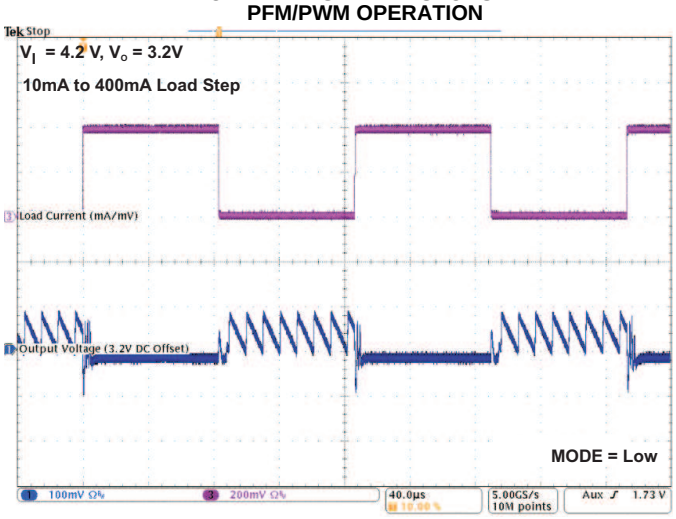


Figure 21.

TPS82699
LOAD TRANSIENT RESPONSE IN
PFM/PWM OPERATION

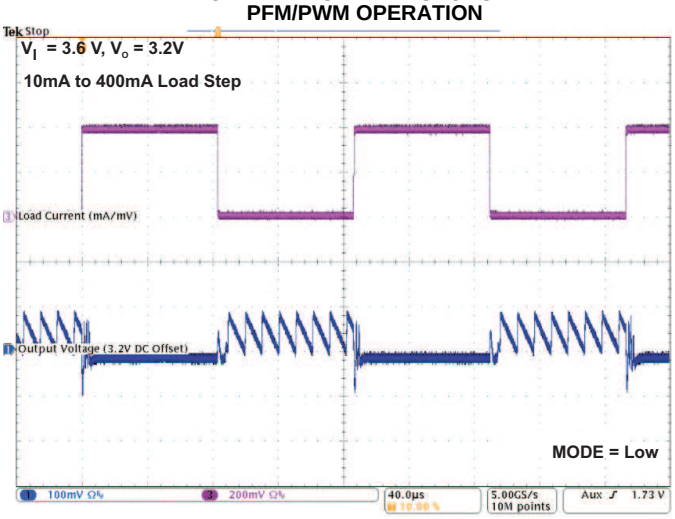


Figure 22.

TYPICAL CHARACTERISTICS (continued)

TPS82699
LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

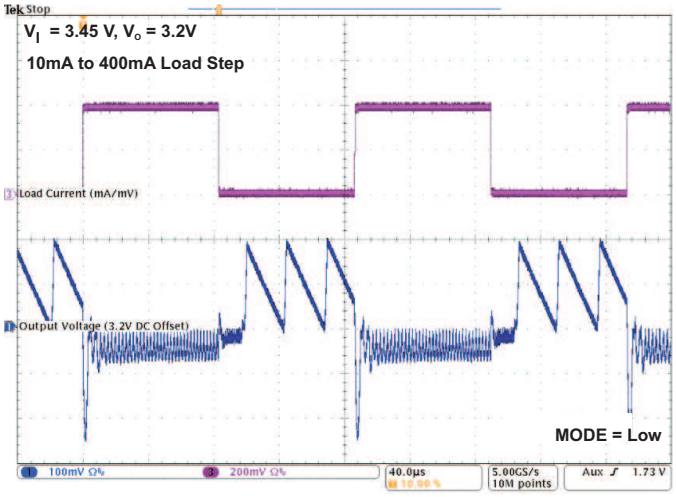


Figure 23.

TPS826951
LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

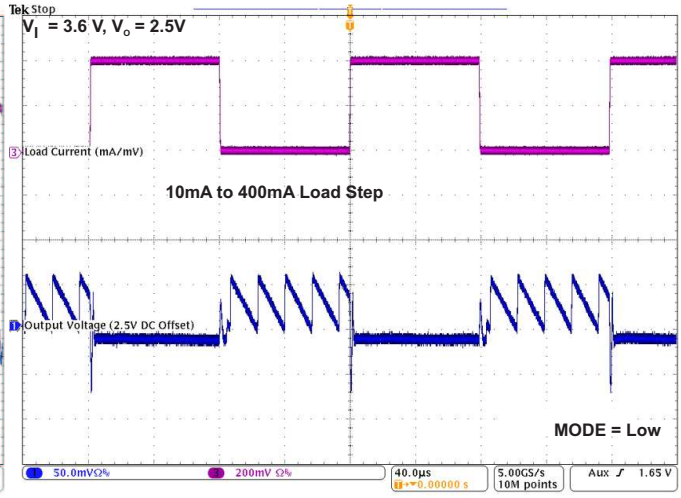


Figure 24.

TPS826951
LOAD TRANSIENT RESPONSE IN PFM/PWM OPERATION

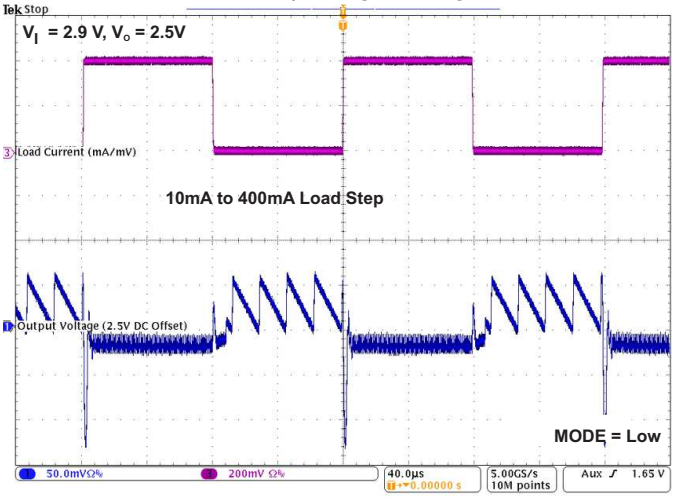


Figure 25.

TPS82699
AC LOAD TRANSIENT RESPONSE

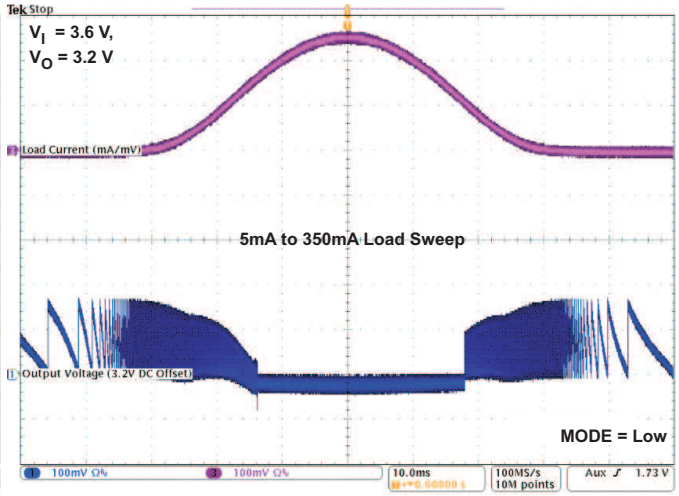


Figure 26.

TYPICAL CHARACTERISTICS (continued)

TPS82699
AC LOAD TRANSIENT RESPONSE

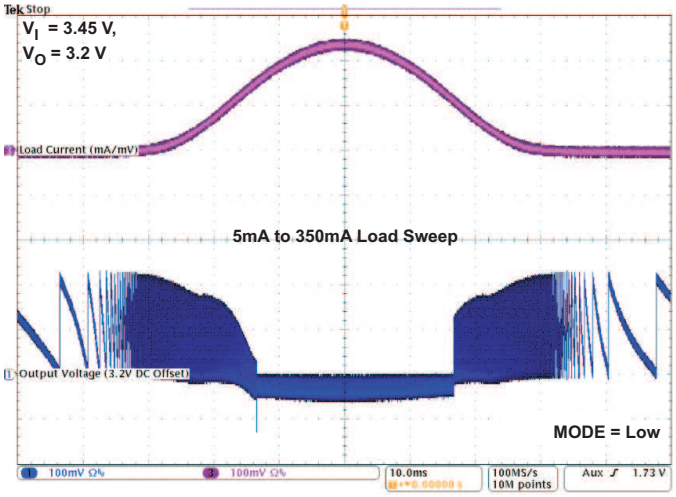


Figure 27.

TPS82699
AC LOAD TRANSIENT RESPONSE

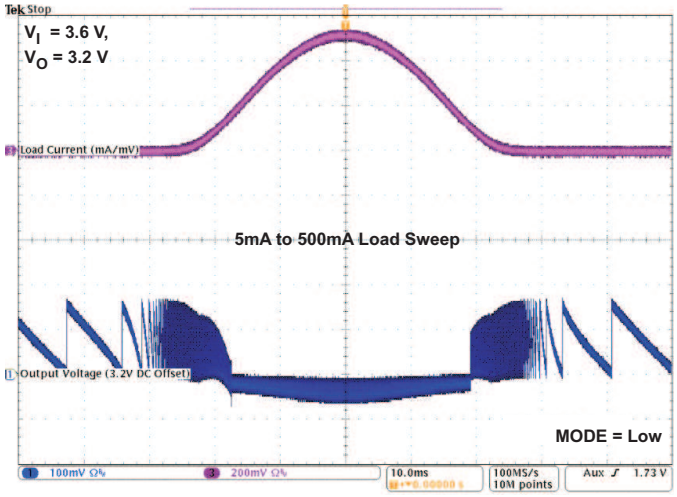


Figure 28.

TPS82699
AC LOAD TRANSIENT RESPONSE

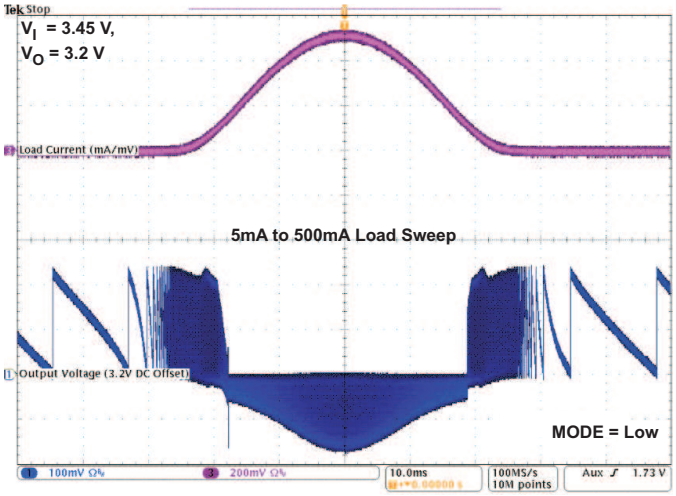


Figure 29.

TPS826951
AC LOAD TRANSIENT RESPONSE

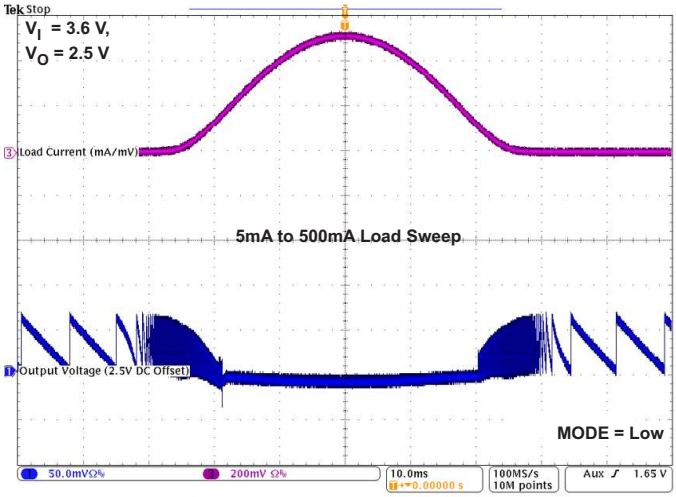


Figure 30.

TYPICAL CHARACTERISTICS (continued)

TPS826951
AC LOAD TRANSIENT RESPONSE

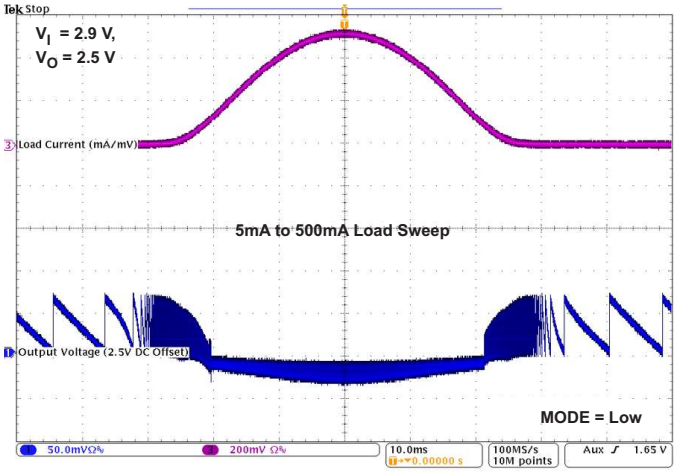


Figure 31.

TPS826951
AC LOAD TRANSIENT RESPONSE

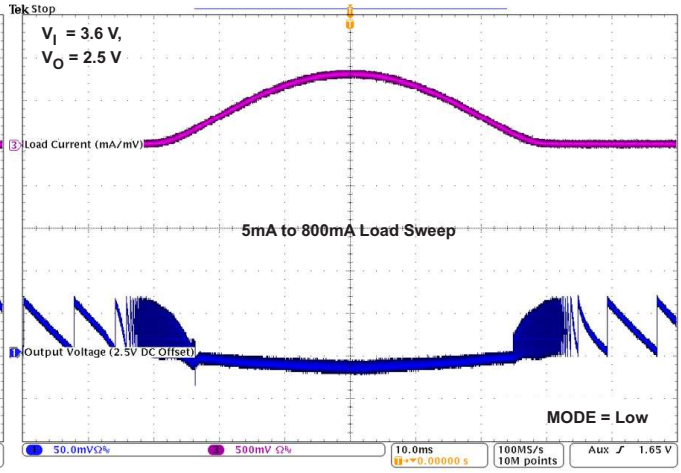


Figure 32.

TPS826951
AC LOAD TRANSIENT RESPONSE

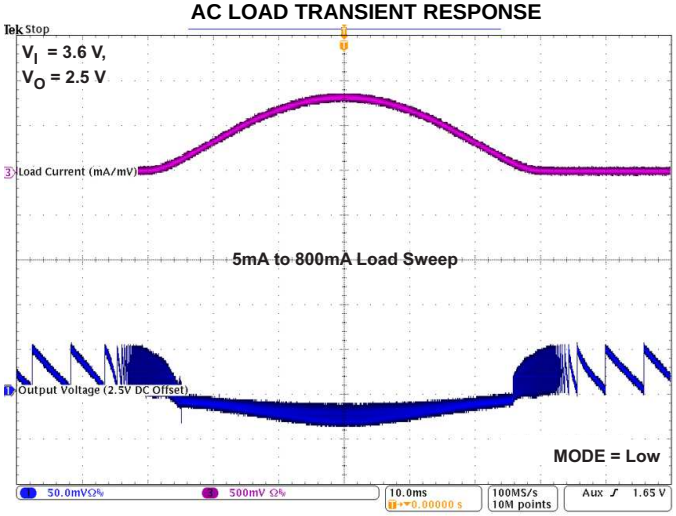


Figure 33.

TPS82698
AC LOAD TRANSIENT RESPONSE

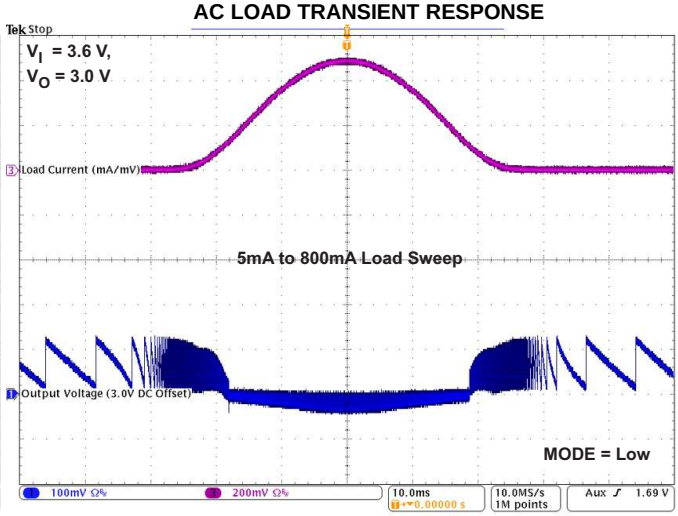


Figure 34.

TYPICAL CHARACTERISTICS (continued)

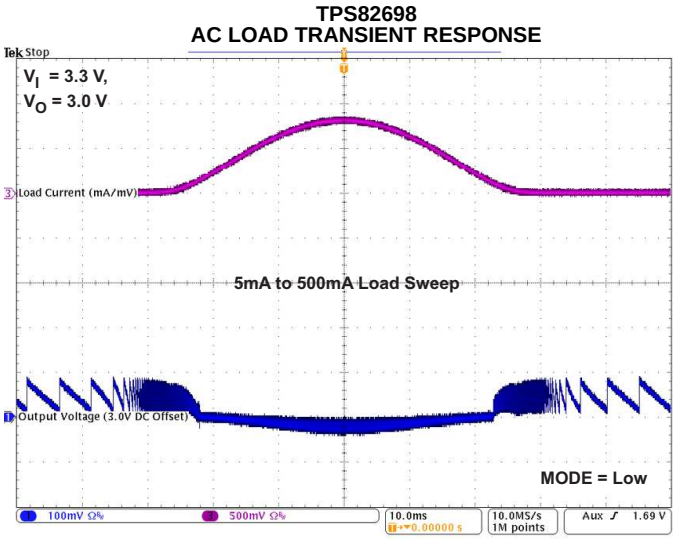


Figure 35.

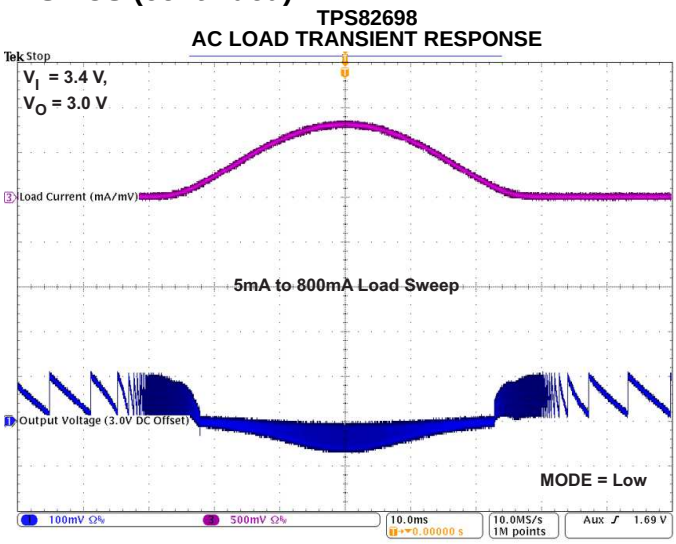


Figure 36.

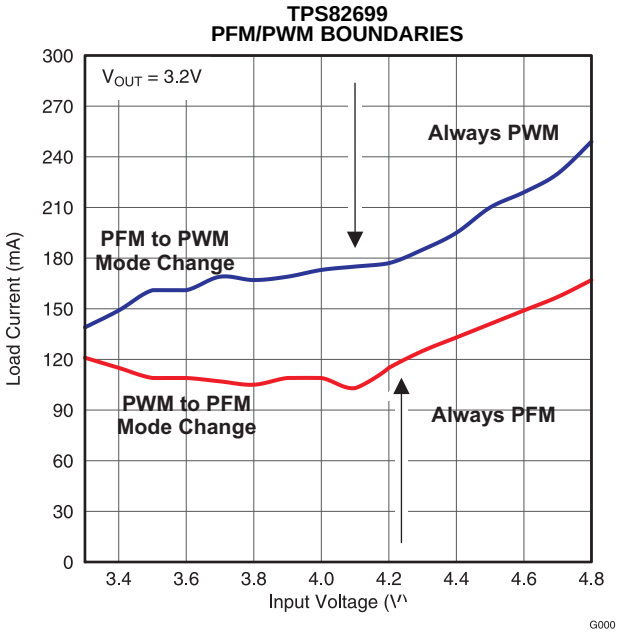


Figure 37.

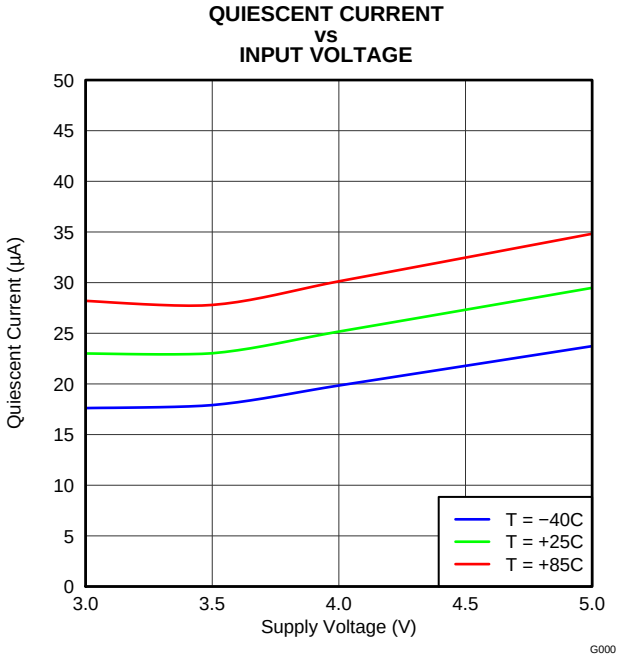


Figure 38.

TYPICAL CHARACTERISTICS (continued)

TPS82699
PWM SWITCHING FREQUENCY
vs
INPUT VOLTAGE

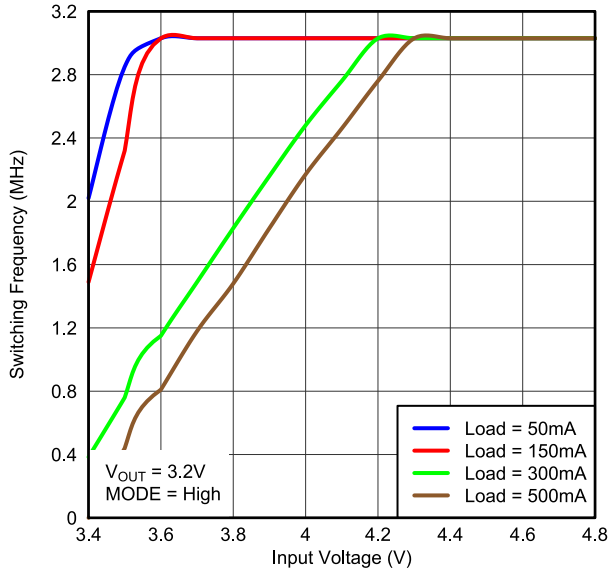


Figure 39.

TPS82699
START-UP

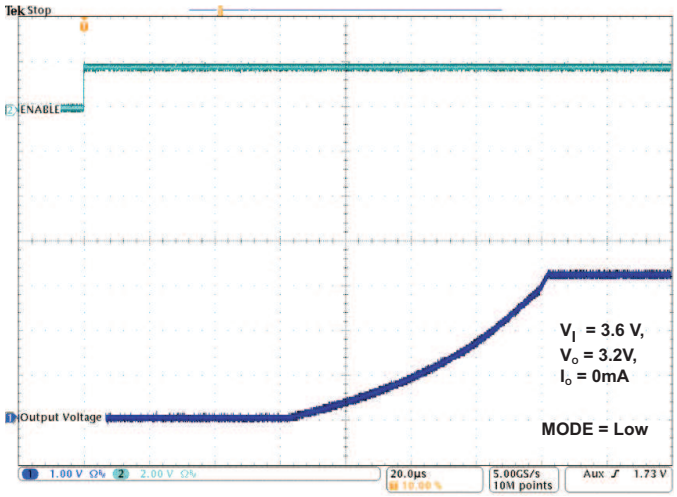


Figure 40.

TPS82699
START-UP

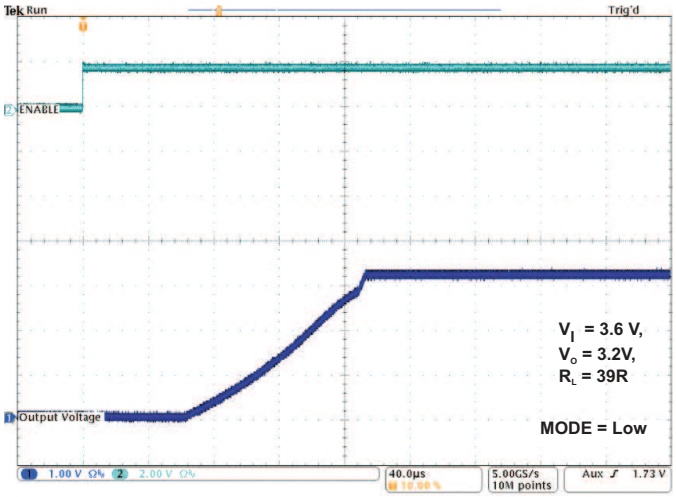


Figure 41.

TPS82699
Shut-Down

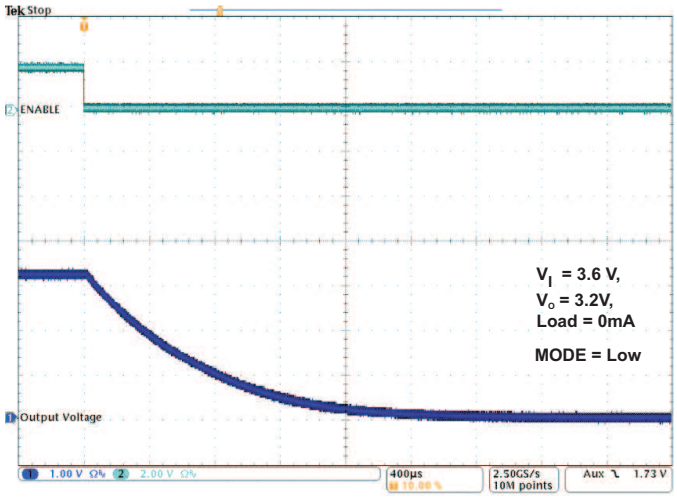


Figure 42.

DETAILED DESCRIPTION

OPERATION

The TPS8269xSIP is a standalone synchronous step-down converter operating at a regulated 3-MHz frequency pulse width modulation (PWM) at moderate to heavy load currents (up to 500mA / 800mA output current). At light load currents, the TPS8269xSIP's 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 (ca. 23µA) allows to maintain high efficiency at light load, while preserving fast transient response for applications requiring tight output regulation.

The TPS8269xSIP 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.

POWER-SAVE MODE

If the load current decreases, the converter will enter Power Save Mode operation automatically. During power-save mode the converter operates in discontinuous current (DCM) with a minimum of one pulse, which produces low output ripple compared with other PFM architectures.

When in power-save mode, the converter resumes its operation when the output voltage trips below the nominal voltage. It 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 again.

PFM mode is left and PWM operation is entered as the output current can no longer be supported in PFM mode. As a consequence, the DC output voltage is typically positioned ca. 1.5% above the nominal output voltage and the transition between PFM and PWM is seamless.

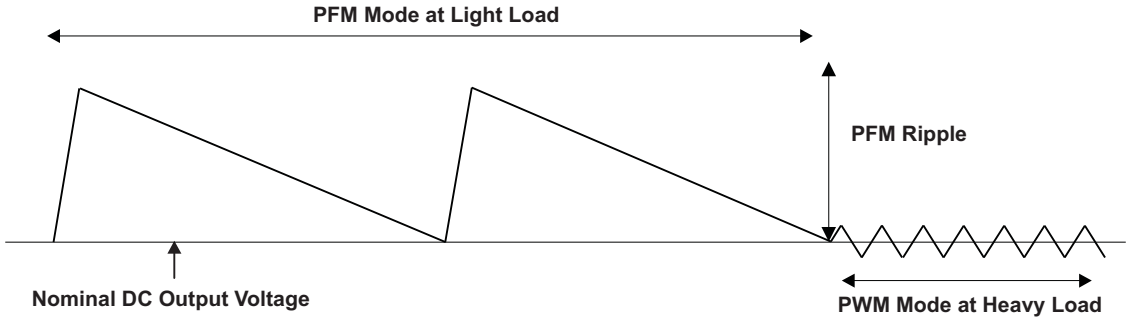


Figure 43. Operation in PFM Mode and Transfer to PWM Mode

MODE SELECTION

The MODE pin allows to select the operating mode of the device. Connecting this 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 in the PFM mode during light loads, which maintains high efficiency over a wide load current range.

Pulling the MODE pin high forces the converter to operate in the PWM mode even at light load currents. The advantage is that the converter operates with a fixed frequency that allows simple filtering of the switching frequency for noise-sensitive applications. In this mode, the efficiency is lower 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 allows efficient power management by adjusting the operation of the converter to the specific system requirements.

LOW DROPOUT, 100% DUTY CYCLE OPERATION

The device starts to enter 100% duty cycle mode once input and output voltage come close together. In order to maintain the output voltage, the DC/DC converter's high-side MOSFET is turned on 100% for one or more cycles.

With further decreasing V_{IN} the high-side switch is constantly turned on, thereby providing a low input-to-output voltage difference. This is particularly useful in battery-powered applications to achieve longest operation time by taking full advantage of the whole battery voltage range.

SOFT START

The TPS8269xSIP has an internal soft-start circuit that limits the inrush current during start-up. This limits input voltage drops when a battery or a high-impedance power source is connected to the input of the MicroSiP™ 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 enable. Should the output voltage not have reached its target value by that time, such as in the case of heavy load, the soft-start transitions to a second mode of operation.

If the output voltage has raised above 0.5V (approximately), the converter increases the input current limit thereby enabling the power supply to come-up properly. The start-up time mainly depends on the capacitance present at the output node and load current.

ENABLE

The TPS8269xSIP 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 V_{IN} current reduces to the device leakage current, typically a few hundred nano amps.

The TPS8269xSIP device can actively discharge the output capacitor when it turns off (refer to Ordering Information Table). 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 TPS8269x should be sufficient. If the application exhibits a noisy or erratic switching frequency, experiment with additional input ceramic capacitance to find a remedy.

The TPS8269x 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 TPS8269x allows the use of a tiny ceramic output capacitor (C_O). For most applications, the output capacitor integrated in the TPS8269x 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 TPS8269x is designed as a Point-Of-Load (POL) regulator, to operate stand-alone without requiring any additional capacitance. Adding a 4.7µF ceramic output capacitor (X7R or X5R dielectric) generally works from a converter stability point of view, helps to minimize the output ripple voltage in PFM mode and improves the converter's transient response under when input and output voltage are close together.

For best operation (i.e. optimum efficiency over the entire load current range, proper PFM/PWM auto transition), the TPS8269xSIP 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 100mΩ) 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 44 shows the appropriate diameters for a MicroSiP™ layout.

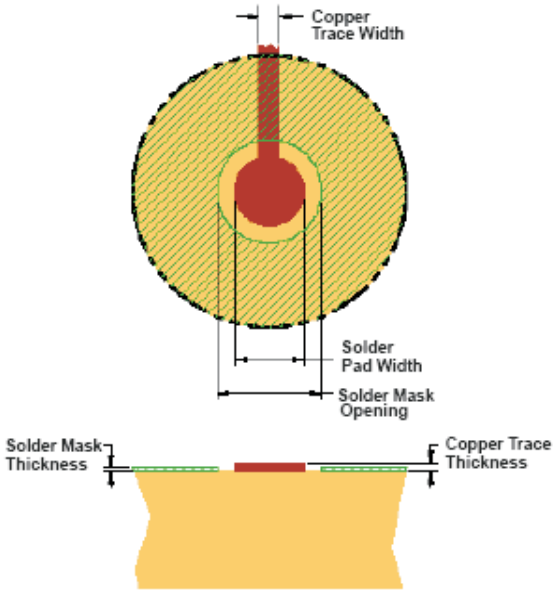


Figure 44. Recommended Land Pattern Image and Dimensions

SOLDER PAD DEFINITIONS (1)(2)(3)(4)	COPPER PAD	SOLDER MASK (5) OPENING	COPPER THICKNESS	STENCIL (6) 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 0.5mm 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 TPS8269x 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 AND RELIABILITY INFORMATION

The TPS8269x output current may need to be de-rated if it is required to operate in a high ambient temperature or deliver a large amount of continuous power. The amount of current de-rating is dependent upon the input voltage, output power and environmental thermal conditions. Care should especially be taken in applications where the localized PWB temperature exceeds 65°C.

The TPS8269x die and inductor temperature should be kept lower than the maximum rating of 125°C, so care should be taken in the circuit layout to ensure good heat sinking. Sufficient cooling should be provided to ensure reliable operation.

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.

To estimate the junction temperature, approximate the power dissipation within the TPS8269x 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 TPS8269x device or a TPS8269x evaluation module. Then calculate the internal temperature rise of the TPS8269x above the surface of the printed circuit board by multiplying the TPS8269x power dissipation by the thermal resistance.

The thermal resistance numbers listed in the Thermal Information table are based on modeling the MicroSiP™ package mounted on a high-K test board specified per JEDEC standard. For increased accuracy and fidelity to the actual application, it is recommended to run a thermal image analysis of the actual system. Figure 45 and Figure 46 are thermal images of TI's evaluation board with readings of the temperatures at specific locations on the device.

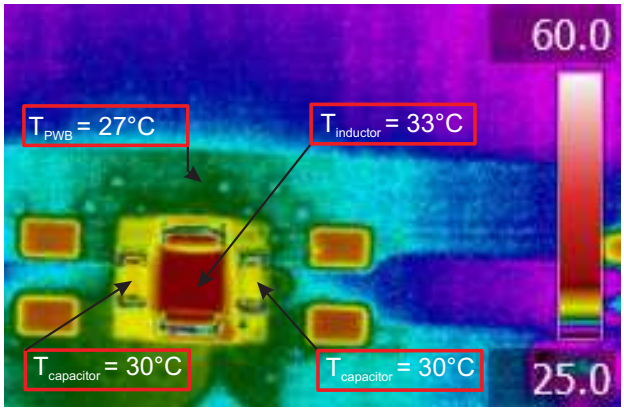


Figure 45. V_{IN}=3.6V, V_{OUT}=2.85V, I_{OUT}=400mA 80mW Power Dissipation at Room Temp.

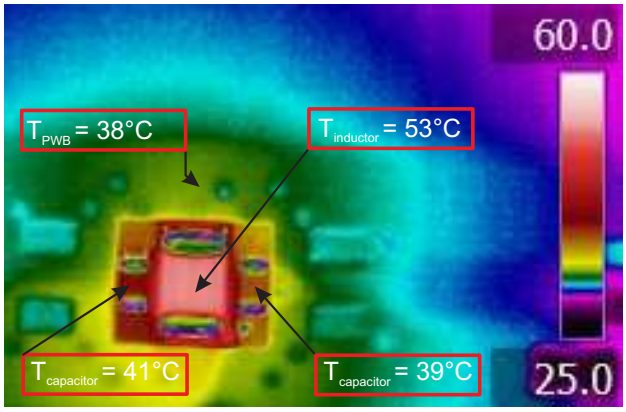


Figure 46. V_{IN}=3.6V, V_{OUT}=2.85V, I_{OUT}=800mA 330mW Power Dissipation at Room Temp.

The TPS8269x is equipped with a thermal shutdown that will inhibit power switching at high junction temperatures. The activation threshold of this function, however, is above 125°C to avoid interfering with normal operation. Thus, it follows that prolonged or repetitive operation under a condition in which the thermal shutdown activates necessarily means that the components internal to the MicroSiP™ package are subjected to high temperatures for prolonged or repetitive intervals, which may damage or impair the reliability of the device.

MLCC capacitor reliability/lifetime is depending on temperature and applied voltage conditions. At higher temperatures, MLCC capacitors are subject to stronger stress. On the basis of frequently evaluated failure rates determined at standardized test conditions, the reliability of all MLCC capacitors can be calculated for their actual operating temperature and voltage.

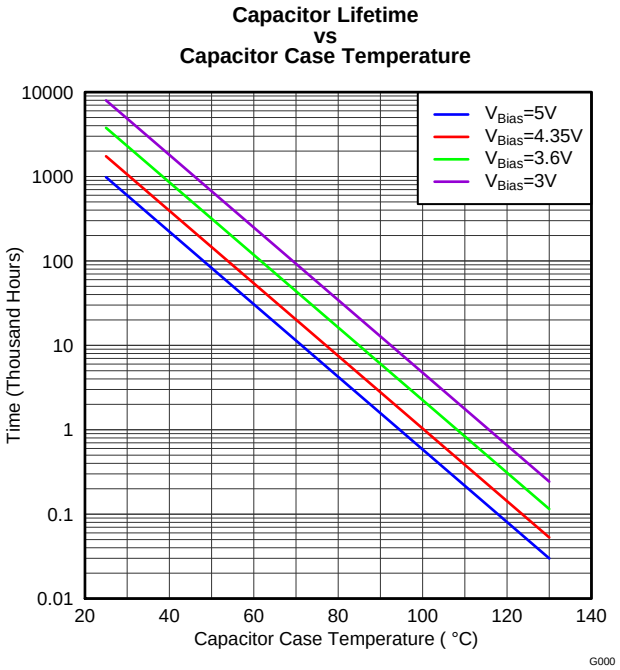


Figure 47.

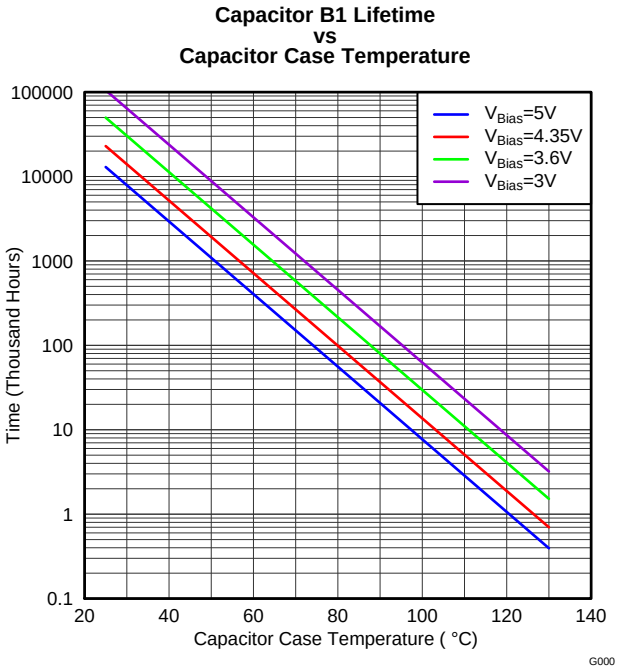
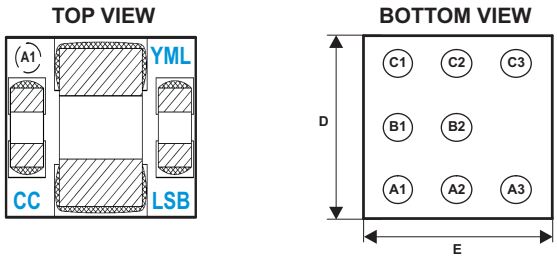


Figure 48.

Failures caused by systematic degradation can be described by the Arrhenius model. The most critical parameter (IR) is the Insulation Resistance (i.e. leakage current). The drop of IR below a lower limit (e.g. 1 MΩ) is used as the failure criterion, see Figure 47. Figure 48 (B1 life) defines the capacitor lifetime based on a failure rate reaching 1%. It should be noted that the wear-out mechanisms occurring in the MLCC capacitors are not reversible but cumulative over time.

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 TPS8269x 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

REVISION HISTORY

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

Changes from Original (March 2013) to Revision A	Page
• Added package marking for TPS826951	2
• Added package marking for TPS82697	2
• Added Spread Spectrum Frequency Modulation for TPS82698	2
• Added Regulated DC Output Voltage parameters to electrical characteristics table for device TPS82697	5
• Added Regulated DC Output Voltage parameters to electrical characteristics table for device TPS826951	5
• Added Regulated DC Output Voltage parameters to electrical characteristics table for device TPS82698	5
• Added Power-save mode ripple voltage to electrical characteristics table for device TPS826951	5
• Added Power-save mode ripple voltage to electrical characteristics table for device TPS82697	5
• Added Power-save mode ripple voltage to electrical characteristics table for device TPS82698	5
• Added Start-up time to electrical characteristics table for device TPS826951	6
• Added Start-up time to electrical characteristics table for device TPS82698	6
• Added Start-up time to electrical characteristics table for device TPS82697	6
• Added Efficiency vs Load Current Graph figure references to Table of Graphs.	8
• Added Efficiency vs Load Current forced PWM operation for device TPS82697	10
• Added Efficiency vs Load Current forced PWM operation for device TPS82697	10
• Added Efficiency vs Load Current PFM/PWM operation for device TPS826951	11
• Added Efficiency vs Load Current forced PWM operation for device TPS826951	11
• Added Efficiency vs Load Current PFM/PWM operation for device TPS82698	11
• Added Efficiency vs Load Current forced PWM operation for device TPS82698	11
• Added Transient Response Plot for device TPS826951	13
• Added Transient Response Plot for device TPS826951	14
• Added AC Load Transient Response Plot for device TPS826951	15
• Added Added AC Load Transient Response Plot for device TPS826951	15
• Added AC Load Transient Response Plot for device TPS826951	15
• Added AC Load Transient Response Plot for device TPS826951	16
• Added AC Load Transient Response Plot for device TPS82698	16
• Added AC Load Transient Response Plot for device TPS82698	16
• Added AC Load Transient Response Plot for device TPS82698	16

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS82693SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 85	W3 TXI693	Samples
TPS82693SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 85	W3 TXI693	Samples
TPS826970SIPR	PREVIEW	uSiP	SIP	8	3000	TBD	Call TI	Call TI	-40 to 85		
TPS826970SIPT	PREVIEW	uSiP	SIP	8	250	TBD	Call TI	Call TI	-40 to 85		
TPS82697SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 85	C2 TXI697	Samples
TPS82697SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 85	C2 TXI697	Samples
TPS82698SIPR	ACTIVE	uSiP	SIP	8	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 85	WN TXI698	Samples
TPS82698SIPT	ACTIVE	uSiP	SIP	8	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 85	WN TXI698	Samples

(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) 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)

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

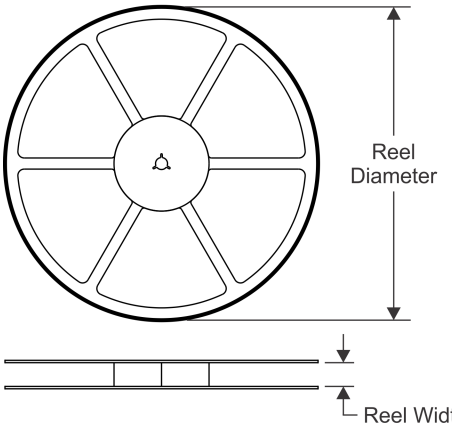
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

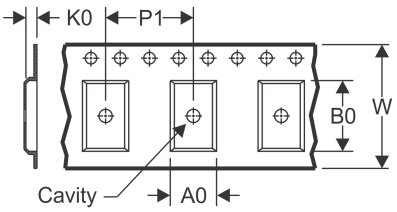
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

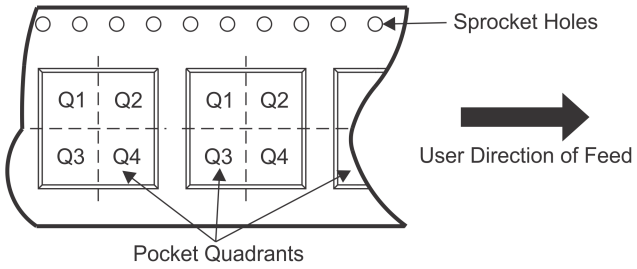


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

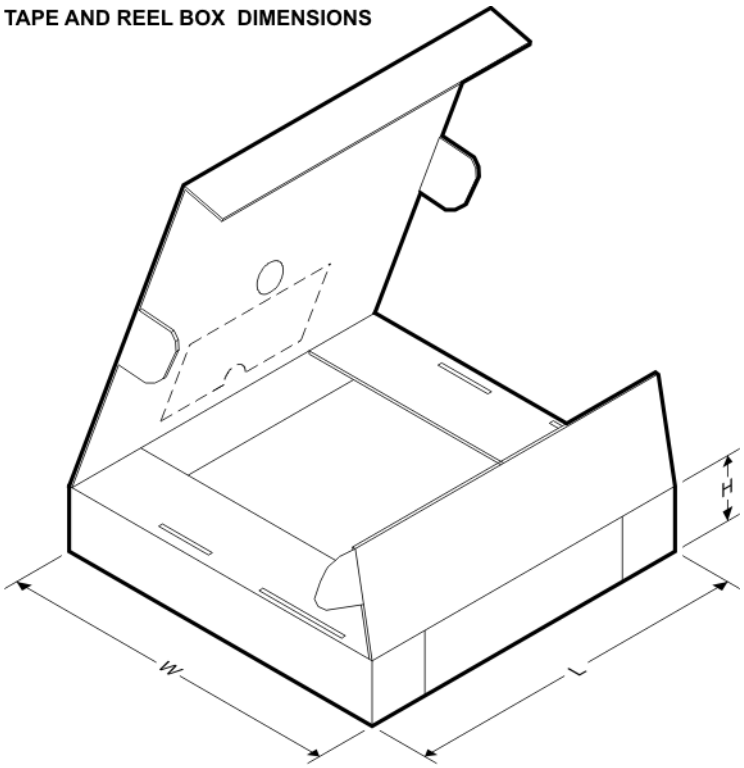
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TPS82693SIPR	uSiP	SIP	8	3000	178.0	9.0	2.45	3.05	1.1	4.0	8.0	Q2
TPS82697SIPR	uSiP	SIP	8	3000	178.0	9.0	2.45	3.05	1.1	4.0	8.0	Q2
TPS82698SIPR	uSiP	SIP	8	3000	178.0	9.0	2.45	3.05	1.1	4.0	8.0	Q2

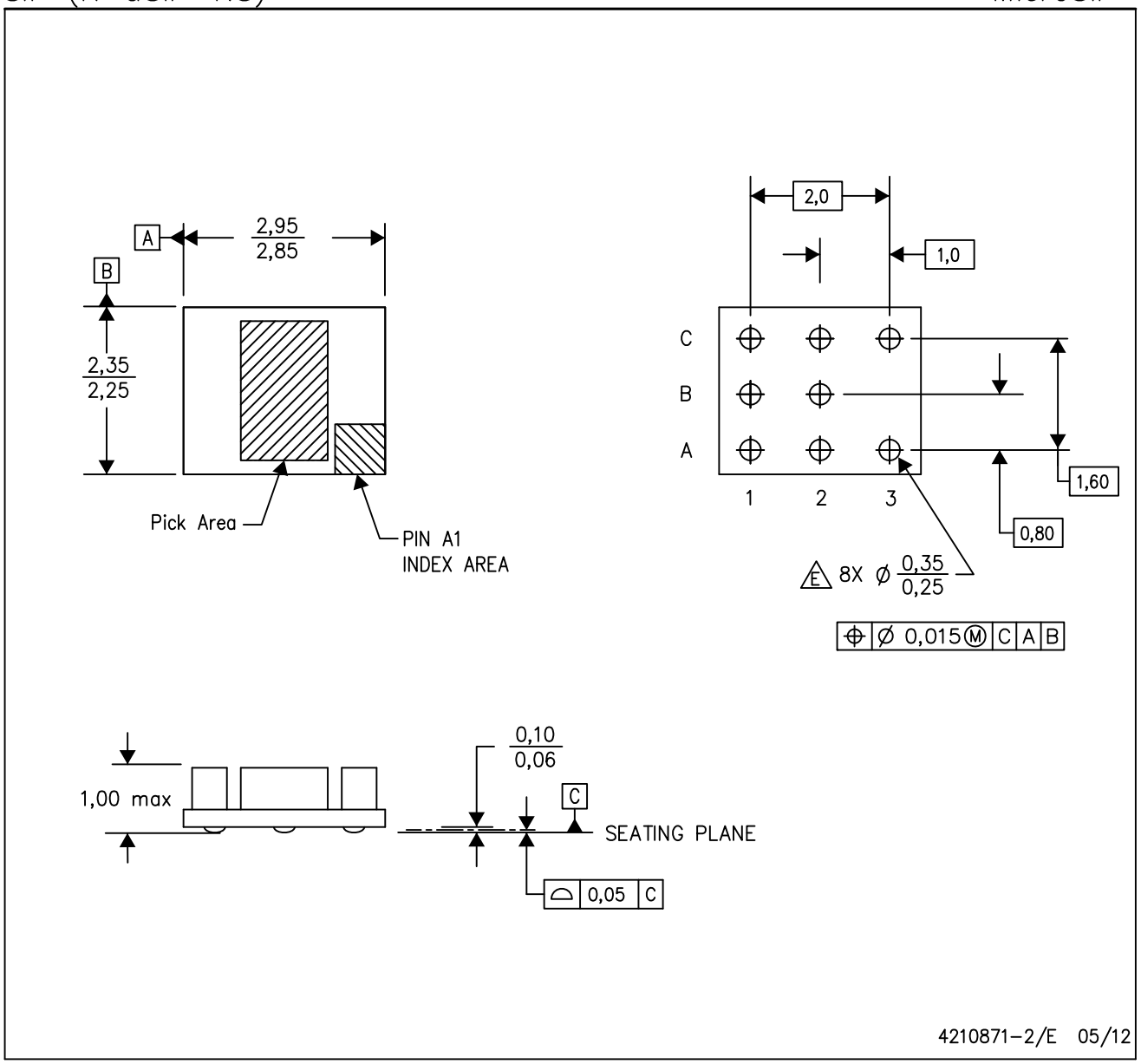
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS82693SIPR	uSiP	SIP	8	3000	223.0	194.0	35.0
TPS82697SIPR	uSiP	SIP	8	3000	223.0	194.0	35.0
TPS82698SIPR	uSiP	SIP	8	3000	223.0	194.0	35.0

SIP (R–uSiP–N8) MicroSiP™



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

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