Dual, 200mA Output, Low Noise, High PSRR Low-Dropout Linear Regulators in 2mm x 2mm SON Package

FEATURES

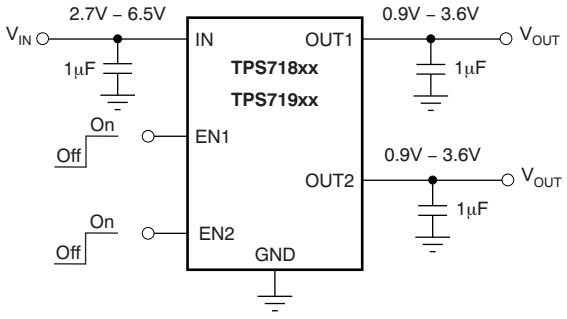
- **Dual, 200mA High-Performance LDOs**
- **Low Total Quiescent Current: 90μA with Both LDOs Enabled**
- **Low Noise: 70μV_{RMS}/V**
- **Active Output Pulldown (TPS719xx)**
- **Independent Enables for Each LDO**
- **PSRR: 65dB at 1kHz, 45dB at 1MHz**
- **Available in Multiple Fixed-Output Voltage Combinations from 0.9V to 3.6V Using Innovative Factory EEPROM Programming**
- **Fast Start-Up Time: 160μs**
- **Over-Current, Over-Temperature and Under-Voltage Protection**
- **Low Dropout: 230mV at 200mA**
- **Stable with 1μF Ceramic Output Capacitor**
- **Available in 2mm × 2mm SON-6 Package**

APPLICATIONS

- **Digital Cameras**
- **Cellular Camera Phones**
- **Wireless LAN, Bluetooth®**
- **Handheld Products**

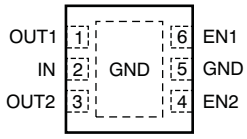
DESCRIPTION

The TPS718xx and TPS719xx families of low-dropout (LDO) regulators offer a high power-supply rejection ratio (PSRR), low noise, fast start-up, and excellent line and load transient responses while consuming a very low 90μA (typical) at no load ground current with both LDOs enabled. The TPS719xx also provides an active pulldown circuit to quickly discharge output loads. The TPS718xx and TPS719xx are stable with ceramic capacitors and use an advanced BiCMOS fabrication process to yield a typical dropout voltage of 230mV at 200mA output loads. The TPS718xx and TPS719xx also use a precision voltage reference and feedback loop to achieve 3% overall accuracy over all load, line, process, and temperature variations. Both families of devices are fully specified from T_J = –40°C to +125°C and are offered in a 2mm × 2mm SON-6 package that is ideal for applications such as mobile handsets and WLAN that require good thermal dissipation while maintaining a very small footprint.



Typical Application Circuit

TPS718xx, TPS719xx
DRV Package
2mm x 2mm SON
(TOP VIEW)



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(1)

PRODUCT	V_{OUT}(2)(3)
TPS718**xx-yywwwz** TPS719**xx-yywwwz**	**XX** is nominal output voltage for LDO1 (for example, 28 = 2.8V). **YY** nominal output voltage for LDO2. **WWW** is package designator. **Z** is Tape & Reel quantity (R = 3000, T = 250).
Examples: TPS71918–285DRVR TPS719185-33DRVR	**XX** = 18 = 1.8V, **YYY** = 285 = 2.85V **XXX** = 185 = 1.85V, **YY** = 33 = 3.3V **DRV** = 2mm x 2mm SON package **Z** = R = 3000 piece reel

(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) Both outputs are programmable from 0.9V to 3.6V in 50mV increments.
(3) Output voltages from 0.9V to 3.6V in 50mV increments are available through the use of innovative factory EEPROM programming; minimum order quantities may apply. Contact factory for details and availability.

ABSOLUTE MAXIMUM RATINGS(1)

Over operating temperature range (unless otherwise noted). All voltages are with respect to GND.

PARAMETER	TPS718xx, TPS719xx	UNIT
Input voltage range, V_{IN}	–0.3 to +7.0	V
Enable voltage range, V_{EN1} and V_{EN2}	–0.3 to V_{IN} + 0.3V	V
Output voltage range, V_{OUT}	–0.3 to +7.0	V
Peak output current	Internally limited	
Output short-circuit duration	Indefinite	
Junction temperature range, T_J	–55 to +150	°C
Storage temperature range , T_{STG}	–55 to +150	°C
Total continuous power dissipation, P_{DISS}	See Dissipation Ratings Table	
ESD rating, HBM	2	kV
ESD rating, CDM	500	V

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

DISSIPATION RATINGS

BOARD	PACKAGE	$R_{\theta JC}$	$R_{\theta JA}$	DERATING FACTOR ABOVE T_A = +25°C	T_A < +25°C	T_A = +70°C	T_A = +85°C
High-K(1)	DRV	20°C/W	95°C/W	10.53mW/°C	1053mW	579mW	421mW

(1) The JEDEC high-K (2s2p) board used to derive this data was a 3in × 3in, multilayer board with 1-ounce internal power and ground planes and 2-ounce copper traces on top and bottom of the board.

ELECTRICAL CHARACTERISTICS

Over operating temperature range (T_J = –40°C to +125°C), V_{IN} = $V_{OUT(TYP)}$ + 0.5V or 2.7V, whichever is greater; I_{OUT} = 0.5mA, V_{EN1} = V_{EN2} = V_{IN}, C_{OUT} = 1.0µF, unless otherwise noted. Typical values are at T_J = +25°C.

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range(1)			2.7		6.5	V
V_{OUT1}, V_{OUT2}	Output voltage range			0.9		3.6	V
V_{OUT1}, V_{OUT2}	Output accuracy	Nominal	T_J = +25°C		±2.5		mV
		Over V_{IN}, I_{OUT}, Temp	V_{OUT} + 0.5V ≤ V_{IN} ≤ 6.5V 0mA ≤ I_{OUT} ≤ 200mA	–3.0		+3.0	%
$\Delta V_{OUT}/\Delta V_{IN}$	Line regulation		$V_{OUT(NOM)}$ + 0.5V ≤ V_{IN} ≤ 6.5V, I_{OUT} = 5mA		130		µV/V
$\Delta V_{OUT}/\Delta I_{OUT}$	Load regulation		0mA ≤ I_{OUT} ≤ 200mA		75		µV/mA
V_{DO}	Dropout voltage(2) (V_{IN} = $V_{OUT(NOM)}$ – 0.1V)		I_{OUT} = 200mA		230	400	mV
I_{CL}	Output current limit (per output)		V_{OUT} = 0.9 × $V_{OUT(NOM)}$	240	340	575	mA
I_{GND}	Ground pin current		I_{OUT1} = I_{OUT2} = 0.1mA		90	160	µA
			I_{OUT1} = I_{OUT2} = 200mA		250		µA
I_{SHDN}	Shutdown current (I_{GND})		$V_{EN1,2}$ ≤ 0.4V, 2.7V ≤ V_{IN} < 4.5V, T_J = –40°C to +85°C		0.3	3.0	µA
			$V_{EN1,2}$ ≤ 0.4V, 4.5V ≤ V_{IN} ≤ 6.5V, T_J = –40°C to +85°C		1.8		µA
PSRR	Power-supply rejection ratio V_{IN} = 3.8V, V_{OUT} = 2.8V, I_{OUT} = 200mA		f = 100Hz		63		dB
			f = 1kHz		63		dB
			f = 10kHz		72		dB
			f = 100kHz		58		dB
			f = 1MHz		44		dB
V_N	Output noise voltage BW = 100Hz to 100kHz				70 × V_{OUT}		μV_{RMS}
T_{STR}	Startup time(3)		R_L = 14Ω, V_{OUT} = 2.8V, C_{OUT} = 1.0µF		160		µs
T_{SHUT}	Shutdown time(4), (5) (TPS719xx only)		R_L = ∞, C_{OUT} = 1.0µF, V_{OUT} = 2.8V		180		µs
$V_{EN(HI)}$	Enable high (enabled) (EN1 and EN2)		V_{IN} ≤ 5.5V	1.2		6.5	V
			5.5V < V_{IN} ≤ 6.5V	1.25		6.5	V
$V_{EN(LO)}$	Enable low (shutdown) (EN1 and EN2)			0		0.4	V
I_{EN}	Enable pin current, enabled (EN1 and EN2)		EN1 = EN2 = 6.5V		0.04	1.0	µA
UVLO	Under-voltage lockout		V_{IN} rising	2.38	2.45	2.52	V
	Hysteresis		V_{IN} falling		150		mV
T_{SD}	Thermal shutdown temperature		Shutdown, temperature increasing		+160		°C
			Reset, temperature decreasing		+140		°C
T_J	Operating junction temperature			–40		+125	°C

(1) Minimum V_{IN} = V_{OUT} + V_{DO} or 2.7V, whichever is greater.
(2) V_{DO} is not measured for devices with $V_{OUT(NOM)}$ < 2.8V because minimum V_{IN} = 2.7V.
(3) Time from V_{EN} = 1.25V to V_{OUT} = 95% ($V_{OUT(NOM)}$).
(4) Time from V_{EN} = 0.4V to V_{OUT} = 5% ($V_{OUT(NOM)}$).
(5) See *Shutdown* section in the Applications Information for more details.

DEVICE INFORMATION

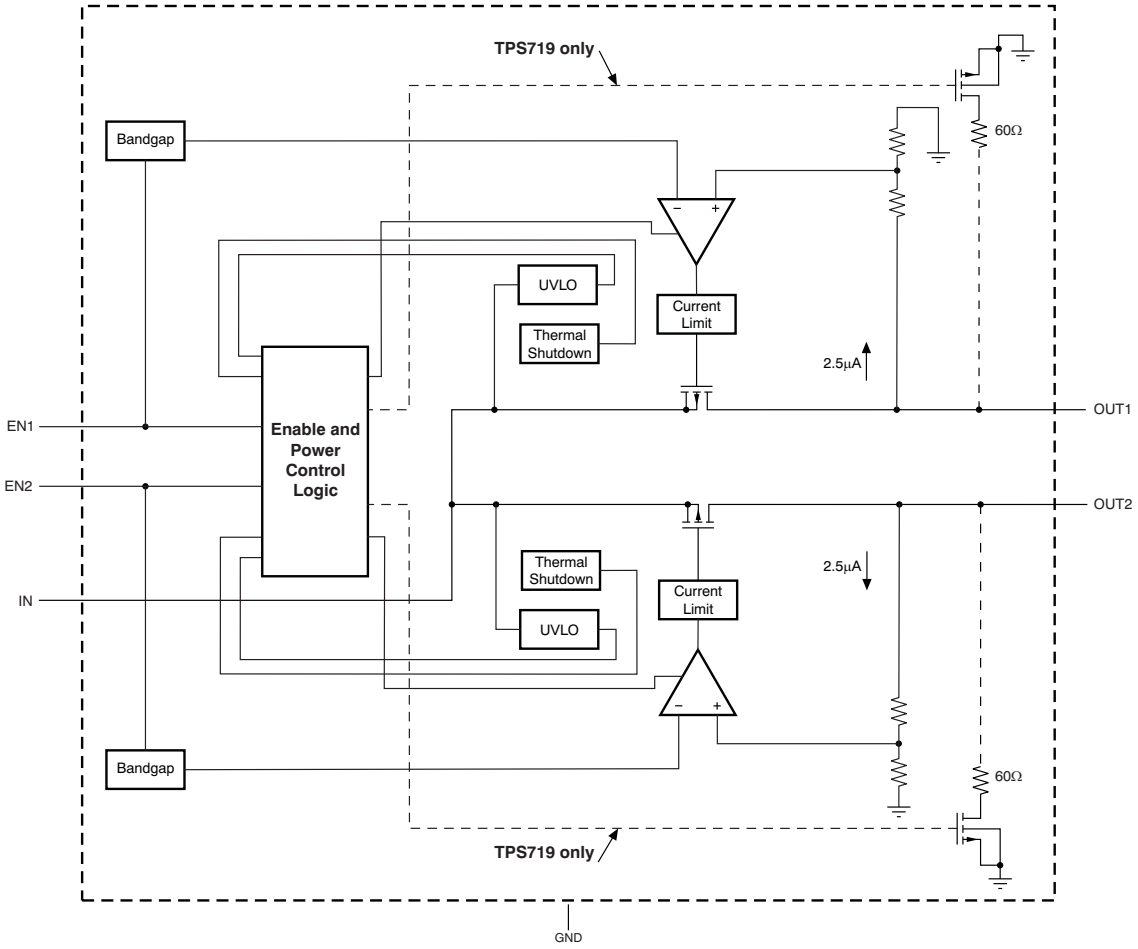


Figure 1. Functional Block Diagram

DRV PACKAGE
2mm × 2mm SON
(TOP VIEW)

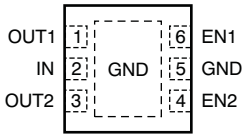


Table 1. PIN DESCRIPTIONS

TPS718xx, TPS719xx		
NAME	**NO.**	**DESCRIPTION**
OUT1	1	Output of Regulator 1. A small ceramic capacitor (typically ≥ 1μF) is needed from this pin to ground to assure stability.
IN	2	Input supply to both regulators.
OUT2	3	Output of Regulator 2. A small ceramic capacitor (typically ≥ 1μF) is needed from this pin to ground to assure stability.
EN2	4	Enable pin for Regulator 2. Driving the Enable pin (EN2) high turns on Regulator 2. Driving this pin low puts Regulator 2 into shutdown mode, reducing operating current.
GND	5	Ground. Thermal pad should also be connected to ground.
EN1	6	Enable pin for Regulator 1. Driving the Enable pin (EN1) high turns on Regulator 1. Driving this pin low puts Regulator 1 into shutdown mode, reducing operating current.

TYPICAL CHARACTERISTICS

Over operating temperature range (T_J = –40°C to +125°C), V_{IN} = $V_{OUT(TYP)}$ + 0.5V or 2.7V, whichever is greater; I_{OUT} = 0.5mA, V_{EN1} = V_{EN2} = V_{IN}, C_{OUT} = 1.0µF, unless otherwise noted. Typical values are at T_J = +25°C.

LINE REGULATION

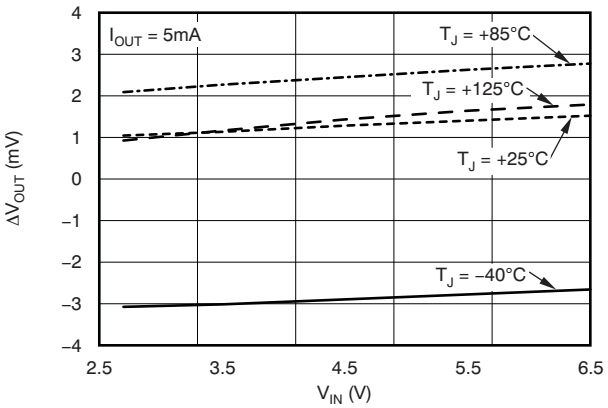


Figure 2.

LINE REGULATION

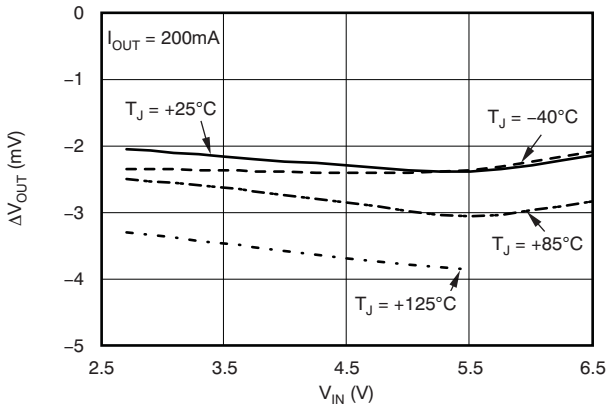


Figure 3.

LOAD REGULATION UNDER LIGHT LOADS

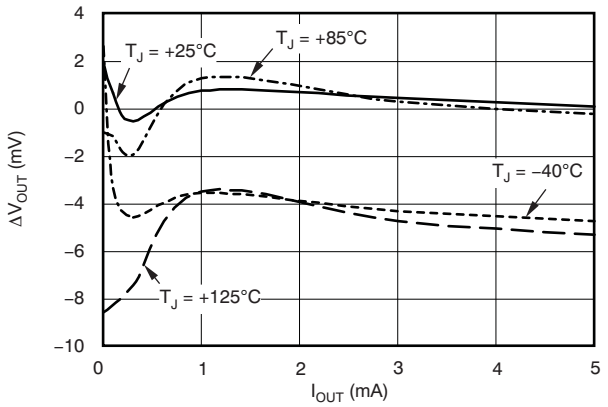


Figure 4.

LOAD REGULATION

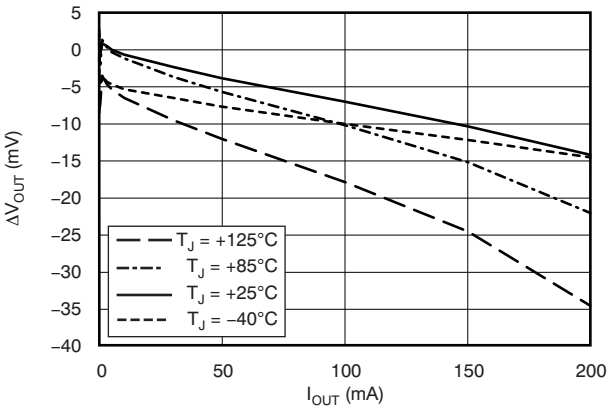


Figure 5.

OUTPUT VOLTAGE vs TEMPERATURE

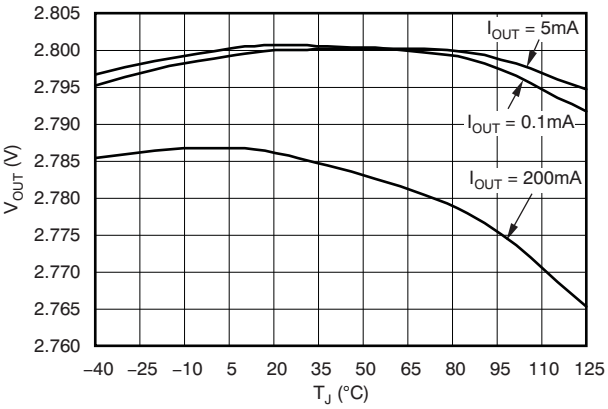


Figure 6.

DROPOUT VOLTAGE vs OUTPUT CURRENT

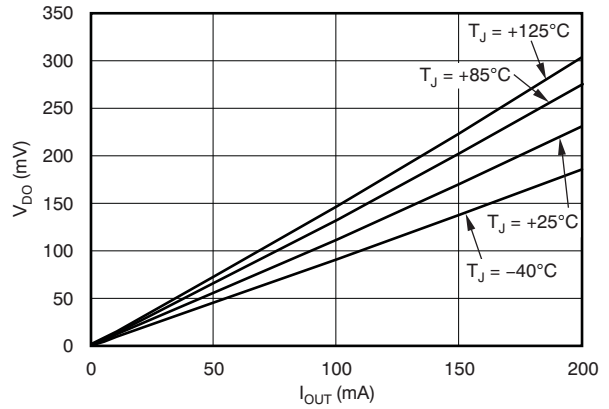


Figure 7.

TYPICAL CHARACTERISTICS (continued)

Over operating temperature range (T_J = –40°C to +125°C), V_{IN} = $V_{OUT(TYP)}$ + 0.5V or 2.7V, whichever is greater; I_{OUT} = 0.5mA, V_{EN1} = V_{EN2} = V_{IN}, C_{OUT} = 1.0µF, unless otherwise noted. Typical values are at T_J = +25°C.

GROUND PIN CURRENT vs OUTPUT CURRENT

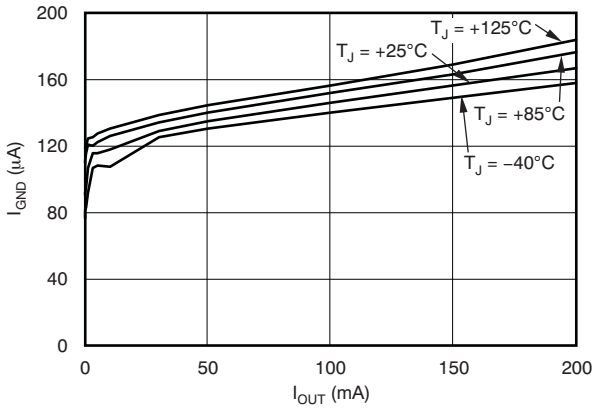


Figure 8.

GROUND PIN CURRENT vs INPUT VOLTAGE

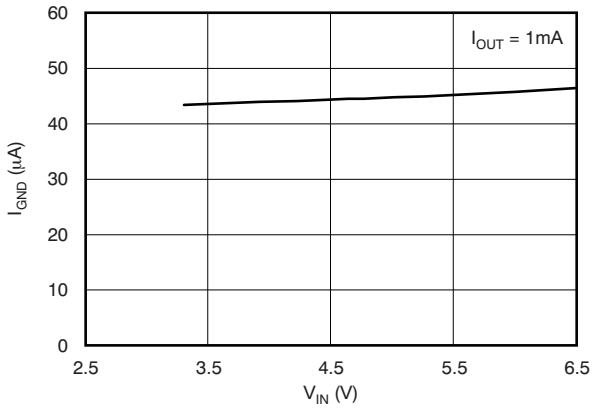


Figure 9.

GROUND PIN CURRENT vs TEMPERATURE (BOTH LDOs ENABLED)

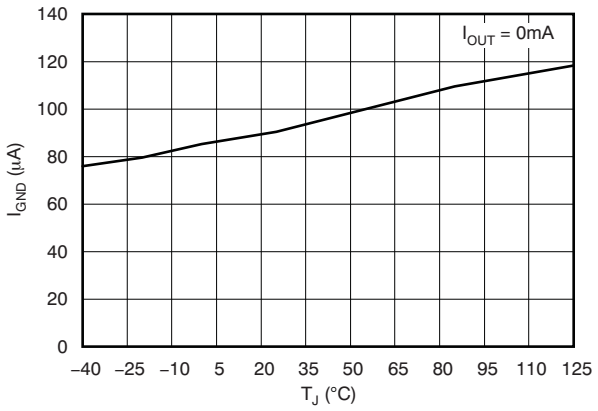


Figure 10.

SHUTDOWN CURRENT vs INPUT VOLTAGE

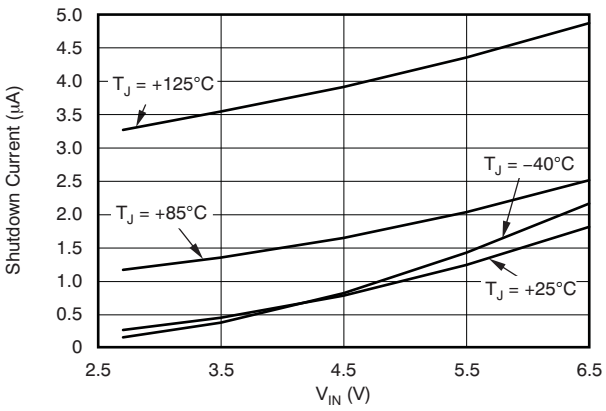


Figure 11.

CURRENT LIMIT vs INPUT VOLTAGE

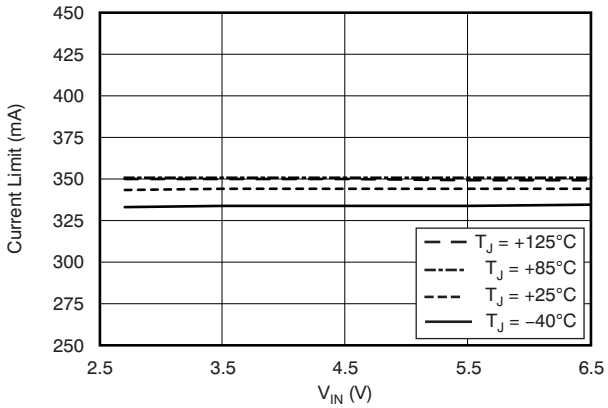


Figure 12.

POWER-SUPPLY RIPPLE REJECTION vs FREQUENCY (V_{IN} – V_{OUT} = 0.5V)

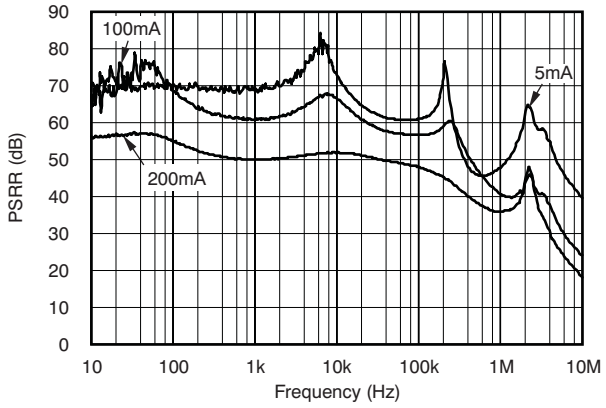


Figure 13.

TYPICAL CHARACTERISTICS (continued)

Over operating temperature range (T_J = –40°C to +125°C), V_{IN} = $V_{OUT(TYP)}$ + 0.5V or 2.7V, whichever is greater; I_{OUT} = 0.5mA, V_{EN1} = V_{EN2} = V_{IN}, C_{OUT} = 1.0µF, unless otherwise noted. Typical values are at T_J = +25°C.

POWER-SUPPLY RIPPLE REJECTION vs FREQUENCY (V_{IN}– V_{OUT} = 1V)

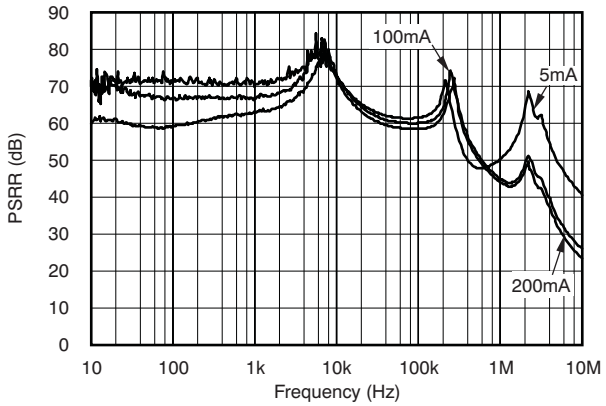


Figure 14.

POWER-SUPPLY RIPPLE REJECTION vs INPUT VOLTAGE

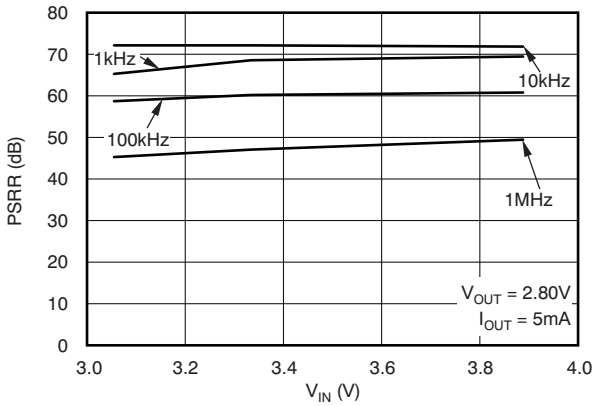


Figure 15.

POWER-SUPPLY RIPPLE REJECTION vs INPUT VOLTAGE

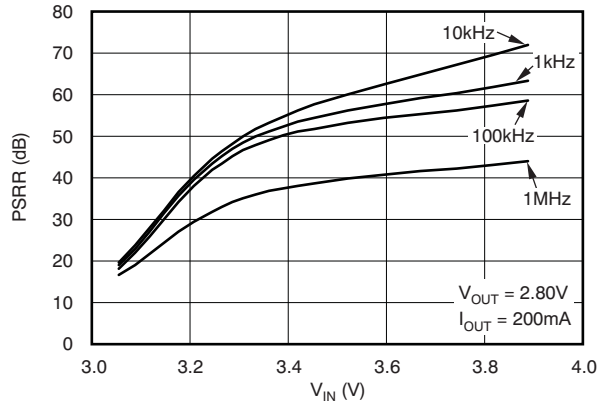


Figure 16.

OUTPUT SPECTRAL NOISE DENSITY vs FREQUENCY

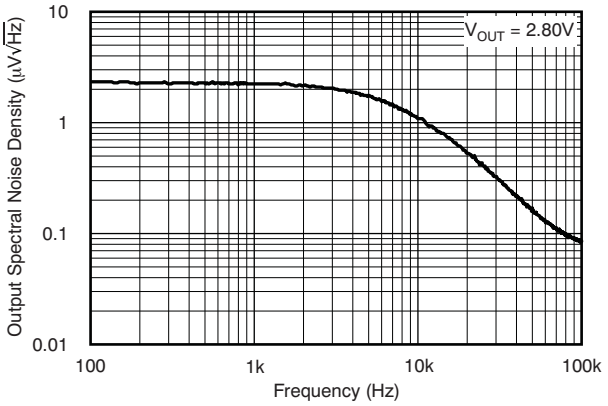


Figure 17.

LINE TRANSIENT RESPONSE

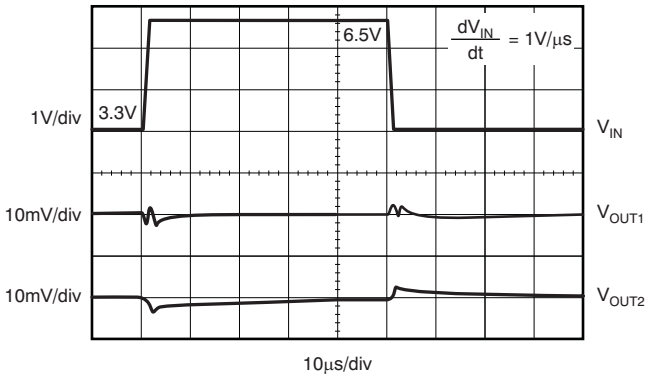


Figure 18.

LOAD TRANSIENT RESPONSE

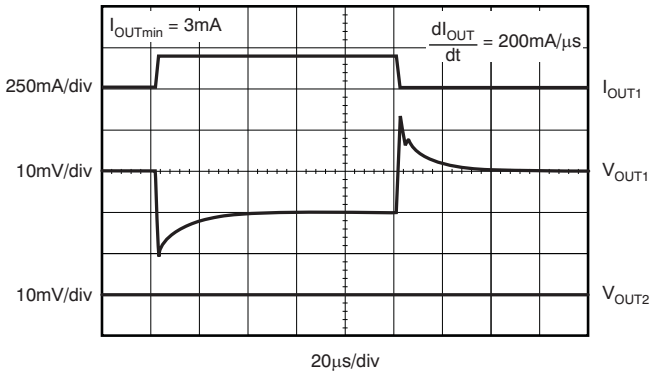


Figure 19.

TYPICAL CHARACTERISTICS (continued)

Over operating temperature range (T_J = –40°C to +125°C), V_{IN} = $V_{OUT(TYP)}$ + 0.5V or 2.7V, whichever is greater; I_{OUT} = 0.5mA, V_{EN1} = V_{EN2} = V_{IN}, C_{OUT} = 1.0µF, unless otherwise noted. Typical values are at T_J = +25°C.

TPS719 ENABLE RESPONSE

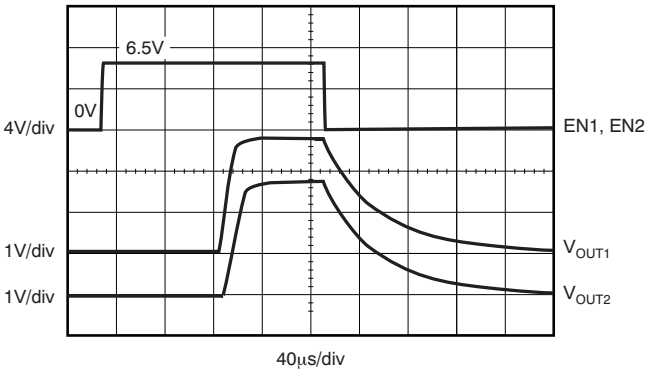


Figure 20.

POWER-UP/POWER-DOWN

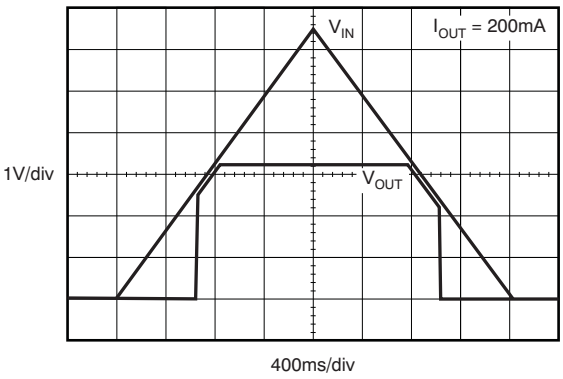


Figure 21.

APPLICATION INFORMATION

The TPS718xx/TPS719xx belong to a family of new generation LDO regulators that use innovative circuitry to achieve ultra-wide bandwidth and high loop gain, resulting in extremely high PSRR (up to 1MHz) at very low headroom (V_{IN} – V_{OUT}). These features, combined with low noise, two independent enables, low ground pin current and ultra-small packaging, make this part ideal for portable applications. This family of regulators offer sub-bandgap output voltages, current limit and thermal protection, and is fully specified from –40°C to +125°C.

Figure 22 shows the basic circuit connections.

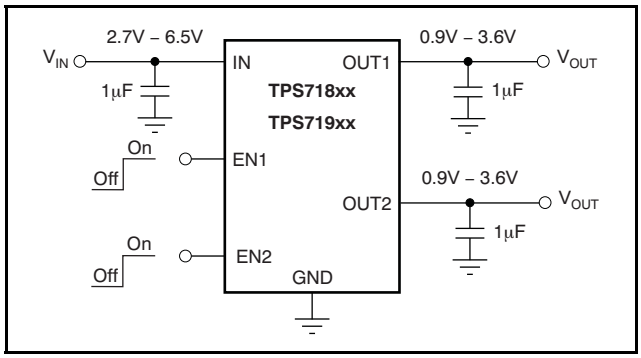


Figure 22. Typical Application Circuit

Input and Output Capacitor Requirements

Although an input capacitor is not required for stability, it is good analog design practice to connect a 0.1µF to 1.0µF low equivalent series resistance (ESR) capacitor across the input supply near the regulator. This capacitor counteracts reactive input sources and improves transient response, noise rejection, and ripple rejection. A higher-value capacitor may be necessary if large, fast rise-time load transients are anticipated or if the device is located close to the power source. If source impedance is not sufficiently low, a 0.1µF input capacitor may be necessary to ensure stability.

The TPS718xx/TPS719xx are designed to be stable with standard ceramic capacitors of values 1.0µF or larger at the output. X5R- and X7R-type capacitors are best because they have minimal variation in value and ESR over temperature. Maximum ESR should be <1.0Ω.

Board Layout Recommendations to Improve PSRR and Noise Performance

To improve ac performance such as PSRR, output noise, and transient response, it is recommended that the board be designed with separate ground planes for V_{IN} and V_{OUT}, with each ground plane connected only at the GND pin of the device. In addition, the ground connection for the output capacitor should connect directly to the GND pin of the device. High ESR capacitors may degrade PSRR.

Internal Current Limit

The TPS718xx/TPS719xx internal current limits help protect the regulator during fault conditions. During current limit, the output sources a fixed amount of current that is largely independent of output voltage. For reliable operation, the device should not be operated in a current limit state for extended periods of time.

The PMOS pass element in the TPS718xx/TPS719xx has a built-in body diode that conducts current when the voltage at OUT exceeds the voltage at IN. This current is not limited, so if extended reverse voltage operation is anticipated, external limiting to 5% of rated output current may be appropriate.

Shutdown

The enable pin (EN) is active high and is compatible with standard and low voltage, TTL-CMOS levels. When shutdown capability is not required, EN can be connected to IN. The TPS719 with internal active output pulldown circuitry discharges the output with a time constant (*t*) of:

$$t = 3\left(\frac{60 \times R_L}{60 + R_L}\right) \times C_{OUT}$$

with:

- R_L = output load resistance
- C_{OUT} = Output capacitance

Dropout Voltage

The TPS718xx/TPS719xx use a PMOS pass transistor to achieve low dropout. When (V_{IN} – V_{OUT}) is less than the dropout voltage (V_{DO}), the PMOS pass device is in its linear region of operation and the input-to-output resistance is the $R_{DS(ON)}$ of the PMOS pass element. V_{DO} approximately scales with output current because the PMOS device behaves like a resistor in dropout.

As with any linear regulator, PSRR and transient response are degraded as (V_{IN} – V_{OUT}) approaches dropout. This effect is shown in Figure 13 and Figure 14 in the Typical Characteristics section.

Transient Response

As with any regulator, increasing the size of the output capacitor will reduce over/undershoot magnitude but increase duration of the transient response.

Under-Voltage Lock-Out (UVLO)

The TPS718xx/TPS719xx utilize an under-voltage lock-out circuit to keep the output shut off until internal circuitry is operating properly. The UVLO circuit has a de-glitch feature so that it typically ignores undershoot transients on the input if they are less than 50µs duration. On the TPS719xx, the active pulldown discharges V_{OUT} when the device is in UVLO off condition. However, the input voltage needs to be greater than 0.8V for active pulldown to work.

Minimum Load

The TPS718xx/TPS719xx are stable with no output load. Traditional PMOS LDO regulators suffer from lower loop gain at very light output loads. The TPS718xx/TPS719xx employ an innovative, low-current mode circuit under very light or no-load conditions, resulting in improved output voltage regulation performance down to zero output current.

THERMAL INFORMATION

Thermal Protection

Thermal protection disables the output when the junction temperature rises to approximately +160°C, allowing the device to cool. When the junction temperature cools to approximately +140°C the output circuitry is again enabled. Depending on power dissipation, thermal resistance, and ambient temperature, the thermal protection circuit may cycle on and off. This cycling limits the dissipation of the regulator, protecting it from damage due to overheating.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heatsink. For reliable operation, junction temperature should be limited to +125°C maximum. To estimate the margin of safety in a complete design (including heatsink), increase the ambient temperature until the thermal protection is triggered; use worst-case loads and signal conditions. For good reliability, thermal protection should trigger at least +35°C above the maximum expected ambient condition of your particular application. This configuration produces a worst-case junction temperature of +125°C at the highest expected ambient temperature and worst-case load.

The internal protection circuitry of the TPS718xx/TPS719xx has been designed to protect against overload conditions. It was not intended to replace proper heatsinking. Continuously running the TPS718xx/TPS719xx into thermal shutdown degrades device reliability.

Power Dissipation

The ability to remove heat from the die is different for each package type, presenting different considerations in the printed circuit board (PCB) layout. The PCB area around the device that is free of other components moves the heat from the device to the ambient air. Performance data for JEDEC low- and high-K boards are given in the *Dissipation Ratings* table. Using heavier copper increases the effectiveness in removing heat from the device. The addition of plated through-holes to heat-dissipating layers also improves the heatsink effectiveness.

Power dissipation depends on input voltage and load conditions. Power dissipation (P_D) is equal to the product of the output current times the voltage drop across the output pass element (V_{IN} to V_{OUT}), as shown in Equation 1:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (1)$$

Package Mounting

Solder pad footprint recommendations for the TPS718xx/TPS719xxx are available from the Texas Instruments web site at www.ti.com.

PACKAGING INFORMATION

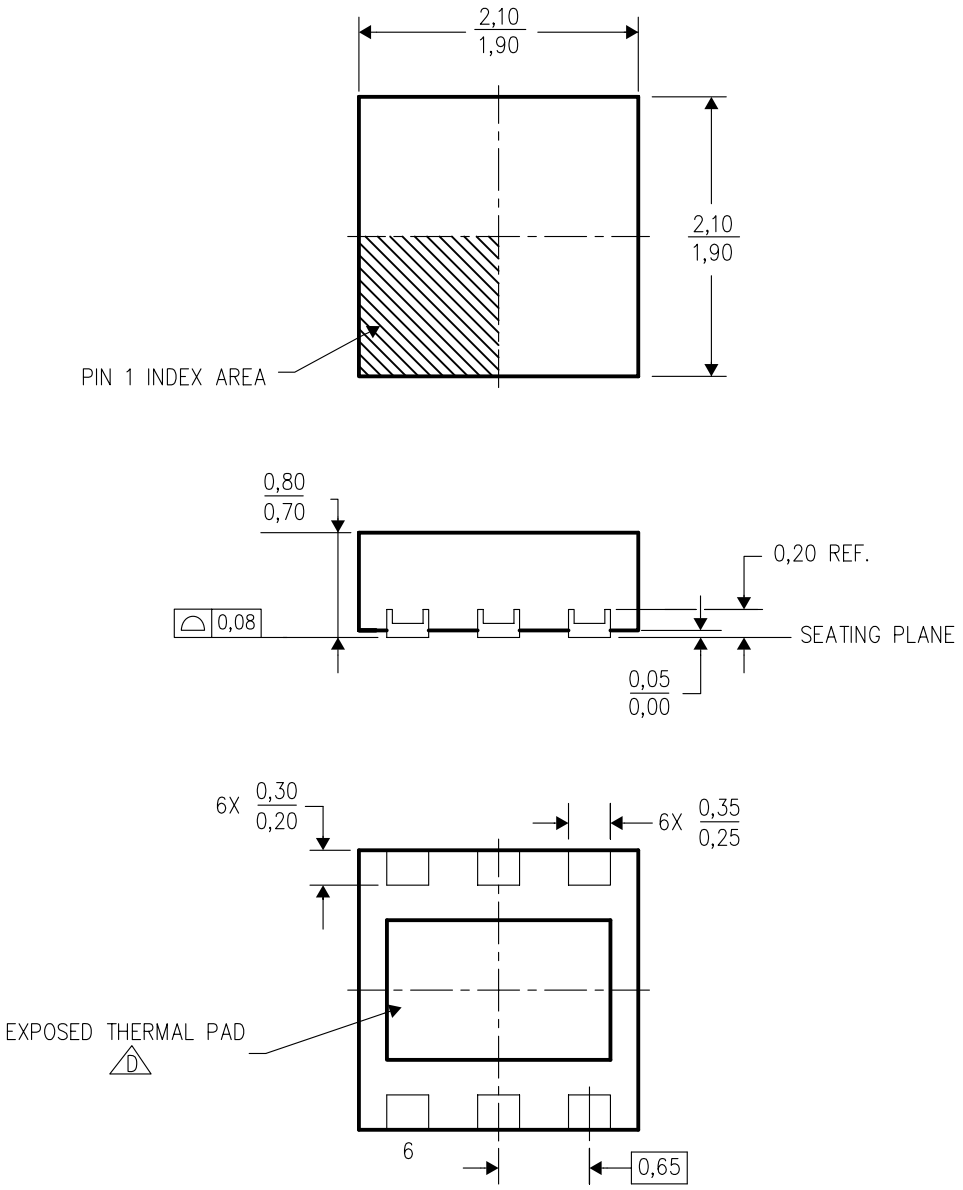
Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
TPS71926-15DRVR	PREVIEW	SON	DRV	6	3000	TBD	Call TI	Call TI
TPS71926-15DRVT	PREVIEW	SON	DRV	6	250	TBD	Call TI	Call TI
TPS71928-28DRVR	PREVIEW	SON	DRV	6	3000	TBD	Call TI	Call TI
TPS71928-28DRVT	PREVIEW	SON	DRV	6	250	TBD	Call TI	Call TI
TPS71933-33DRVR	PREVIEW	SON	DRV	6	3000	TBD	Call TI	Call TI
TPS71933-33DRVT	PREVIEW	SON	DRV	6	250	TBD	Call TI	Call TI

[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.

DRV (S–PDSO–N6) PLASTIC SMALL OUTLINE



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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. Small Outline No–Lead (SON) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.

THERMAL PAD MECHANICAL DATA

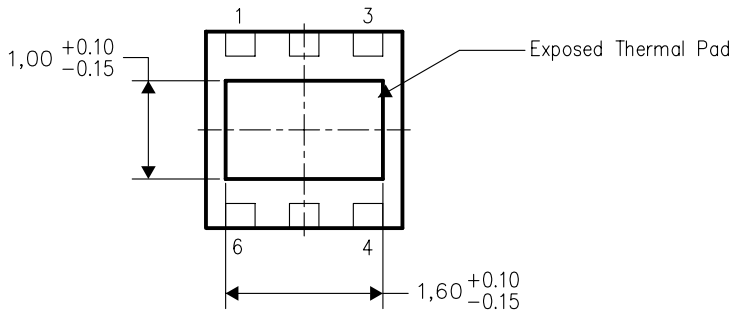
DRV (S–PDSO–N6)

THERMAL INFORMATION

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

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, Quad Flatpack No–Lead Logic Packages, Texas Instruments Literature No. SCBA017. This document is available at www.ti.com.

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

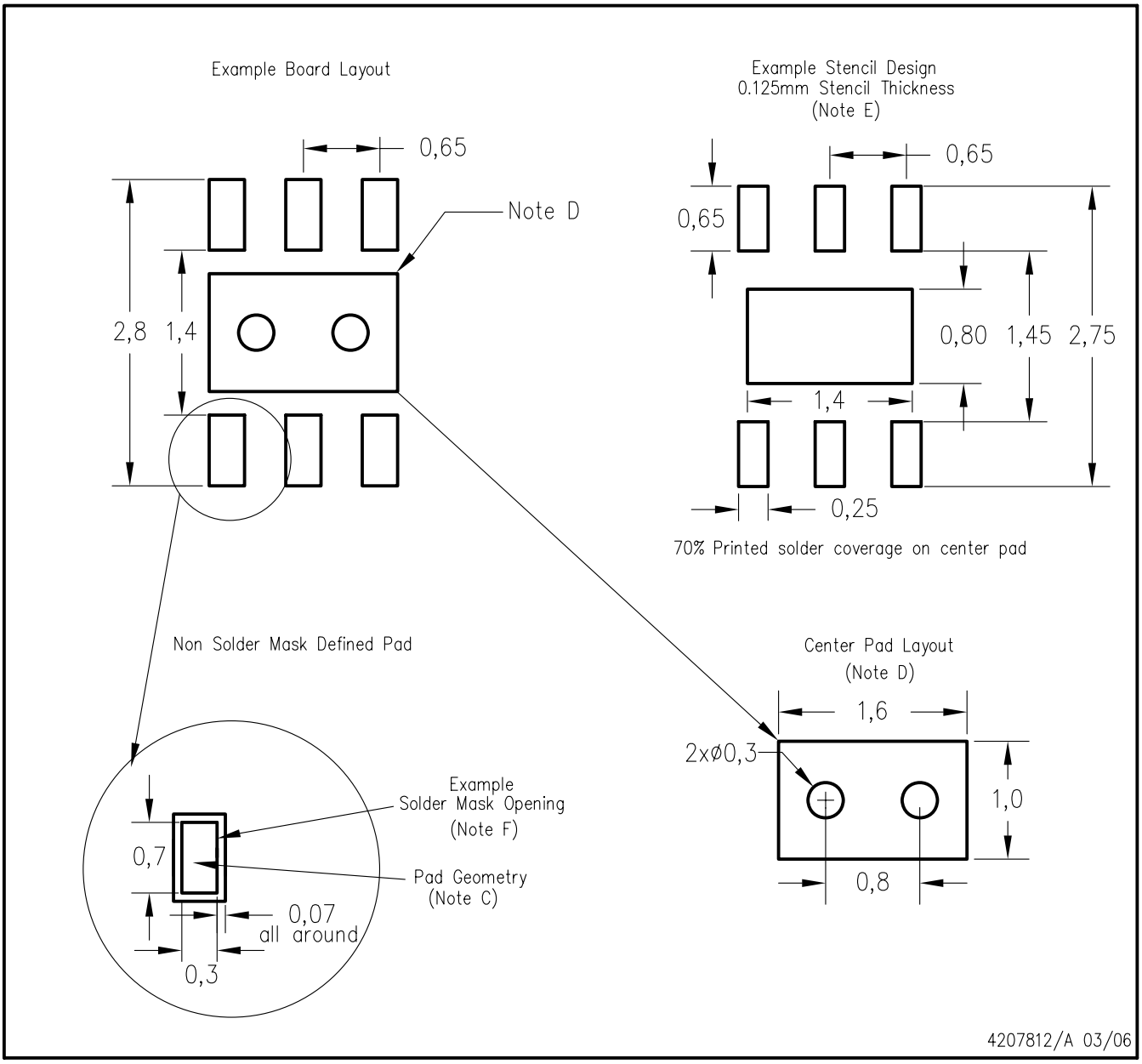


Bottom View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

DRV (S–PDSO–N6)



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, QFN Packages, Texas Instruments Literature No. SCBA017, SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for solder mask tolerances.

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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265