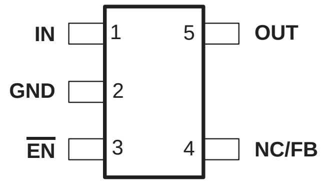
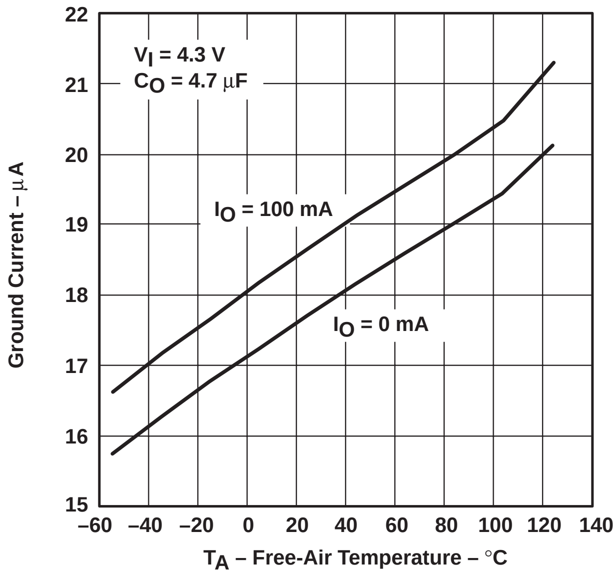
- **100-mA Low-Dropout Regulator**
- **Available in 1.2-V, 1.5-V, 1.8-V, 2.5-V, 2.7-V, 2.8-V, 3.0-V, 3.3-V, and 5-V Fixed-Output and Adjustable Versions**
- **Only 17 μA Quiescent Current at 100 mA**
- **1 μA Quiescent Current in Standby Mode**
- **Dropout Voltage Typically 71 mV at 100mA**
- **Over Current Limitation**
- **–40°C to 125°C Operating Junction Temperature Range**
- **5-Pin SOT-23 (DBV) Package**

DBV PACKAGE
(TOP VIEW)



TPS76933
GROUND CURRENT
vs
FREE-AIR TEMPERATURE



description

The TPS769xx family of low-dropout (LDO) voltage regulators offers the benefits of low dropout voltage, ultralow-power operation, and miniaturized packaging. These regulators feature low dropout voltages and ultralow quiescent current compared to conventional LDO regulators. Offered in a 5-terminal small outline integrated-circuit SOT-23 package, the TPS769xx series devices are ideal for micropower operations and where board space is at a premium.

A combination of new circuit design and process innovation has enabled the usual PNP pass transistor to be replaced by a PMOS pass element. Because the PMOS pass element behaves as a low-value resistor, the dropout voltage is very low, typically 71 mV at 100 mA of load current (TPS76950), and is directly proportional to the load current. Since the PMOS pass element is a voltage-driven device, the quiescent current is ultralow (28 μA maximum) and is stable over the entire range of output load current (0 mA to 100 mA). Intended for use in portable systems such as laptops and cellular phones, the ultralow-dropout voltage feature and ultralow-power operation result in a significant increase in system battery operating life.

The TPS769xx also features a logic-enabled sleep mode to shut down the regulator, reducing quiescent current to 1 μA typical at T_J = 25°C. The TPS769xx is offered in 1.2-V, 1.5-V, 1.8-V, 2.5-V, 2.7-V, 2.8-V, 3.0-V, 3.3-V, and 5-V fixed-voltage versions and in a variable version (programmable over the range of 1.2 V to 5.5 V).

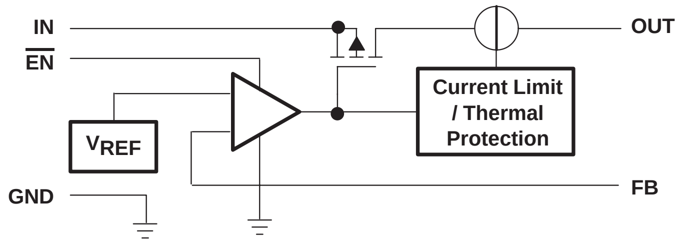
AVAILABLE OPTIONS

T_J	VOLTAGE	PACKAGE	PART NUMBER		SYMBOL
–40°C to 125°C	Variable 1.2V to 5.5V	SOT-23 (DBV)	TPS76901DBVT†	TPS76901DBVR‡	PCFI
	1.2 V		TPS76912DBVT†	TPS76912DBVR‡	PCGI
	1.5 V		TPS76915DBVT†	TPS76915DBVR‡	PCHI
	1.8 V		TPS76918DBVT†	TPS76918DBVR‡	PCII
	2.5 V		TPS76925DBVT†	TPS76925DBVR‡	PCJI
	2.7 V		TPS76927DBVT†	TPS76927DBVR‡	PCKI
	2.8 V		TPS76928DBVT†	TPS76928DBVR‡	PCLI
	3.0 V		TPS76930DBVT†	TPS76930DBVR‡	PCMI
	3.3 V		TPS76933DBVT†	TPS76933DBVR‡	PCNI
	5.0 V		TPS76950DBVT†	TPS76950DBVR‡	PCOI

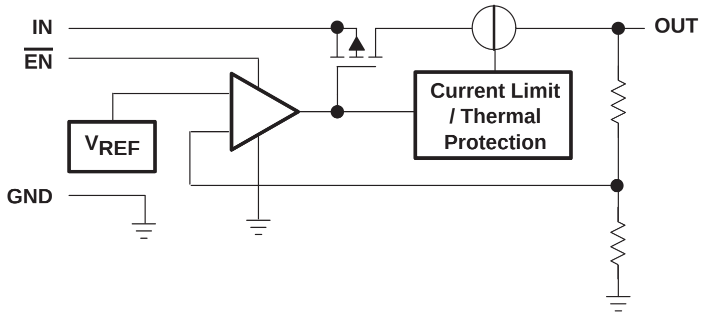
† The DBVT indicates tape and reel of 250 parts.
‡ The DBVR indicates tape and reel of 3000 parts.

functional block diagram

TPS76901



TPS76912/15/18/25/27/28/30/33/50



Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
GND	2		Ground
$\overline{EN}$	3	I	Enable input
FB	4	I	Feedback voltage (TPS76901 only)
IN	1	I	Input supply voltage
NC	4		No connection (Fixed options only)
OUT	5	O	Regulated output voltage

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Input voltage range (see Note 1) . . . . –0.3 V to 13.5 V
Voltage range at $\overline{EN}$ . . . . –0.3 V to V_I + 0.3 V
Voltage on OUT, FB . . . . 7 V
Peak output current . . . . Internally limited
ESD rating, HBM . . . . 2 kV
Continuous total power dissipation . . . . See Dissipation Rating Table
Operating virtual junction temperature range, T_J . . . . –40°C to 150°C
Storage temperature range, T_{stg} . . . . –65°C to 150°C

† 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.

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

	PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
Recommended	DBV	350 mW	3.5 mW/°C	192 mW	140 mW
Absolute Maximum	DBV	437 mW	3.5 mW/°C	280 mW	227 mW

recommended operating conditions

	MIN	NOM	MAX	UNIT
Input voltage, V_I (see Note 2)	2.7		10	V
Output voltage range, V_O	1.2		5.5	V
Continuous output current, I_O (see Note 3)	0		100	mA
Operating junction temperature, T_J	–40		125	°C

NOTES: 2. To calculate the minimum input voltage for your maximum output current, use the following formula:
$V_I(min) = V_O(max) + V_{DO}$ (max load)
3. Continuous output current and operating junction temperature are limited by internal protection circuitry, but it is not recommended that the device operate under conditions beyond those specified in this table for extended periods of time.

electrical characteristics over recommended operating free-air temperature range, $V_I = V_{O(typ)}$ + 1 V, I_O = 100 mA, $\overline{EN}$ = 0 V, C_O = 4.7 µF (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Output voltage (10 µA to 100 mA load) (see Note 4)	TPS76901	1.2 V ≤ V_O ≤ 5.5 V,	T_J = 25°C		V_O		V
		1.2 V ≤ V_O ≤ 5.5 V,	T_J = –40°C to 125°C	0.97V_O		1.03V_O	
	TPS76912	T_J = 25°C,	2.7 V < V_{IN} < 10 V		1.224		
		T_J = –40°C to 125°C,	2.7 V < V_{IN} < 10 V	1.187		1.261	
	TPS76915	T_J = 25°C,	2.7 V < V_{IN} < 10 V		1.5		
		T_J = –40°C to 125°C,	2.7 V < V_{IN} < 10 V	1.455		1.545	
	TPS76918	T_J = 25°C,	2.8 V < V_{IN} < 10 V		1.8		
		T_J = –40°C to 125°C,	2.8 V < V_{IN} < 10 V	1.746		1.854	
	TPS76925	T_J = 25°C,	3.5 V < V_{IN} < 10 V		2.5		
		T_J = –40°C to 125°C,	3.5 V < V_{IN} < 10 V	2.425		2.575	
	TPS76927	T_J = 25°C,	3.7 V < V_{IN} < 10 V		2.7		
		T_J = –40°C to 125°C,	3.7 V < V_{IN} < 10 V	2.619		2.781	
	TPS76928	T_J = 25°C,	3.8 V < V_{IN} < 10 V		2.8		
		T_J = –40°C to 125°C,	3.8 V < V_{IN} < 10 V	2.716		2.884	
	TPS76930	T_J = 25°C,	4.0 V < V_{IN} < 10 V		3.0		
		T_J = –40°C to 125°C,	4.0 V < V_{IN} < 10 V	2.910		3.090	
	TPS76933	T_J = 25°C,	4.3 V < V_{IN} < 10 V		3.3		
		T_J = –40°C to 125°C,	4.3 V < V_{IN} < 10 V	3.201		3.399	
	TPS76950	T_J = 25°C,	6.0 V < V_{IN} < 10 V		5.0		
		T_J = –40°C to 125°C,	6.0 V < V_{IN} < 10 V	4.850		5.150	
Quiescent current (GND current) (See Note 4 and Note 5)		$\overline{EN}$ = 0V, T_J = 25°C	0 mA < I_O < 100 mA,		17		µA
		$\overline{EN}$ = 0V, T_J = –40°C to 125°C	I_O = 100 mA,			28	
Load regulation		$\overline{EN}$ = 0V, T_J = 25°C	I_O = 0 to 100 mA,		12		mV
Output voltage line regulation ($\Delta V_O/V_O$) (See Note 5)		V_O + 1 V < V_I ≤ 10 V, See Note 4	T_J = 25°C,		0.04		%/V
		V_O + 1 V < V_I ≤ 10 V, T_J = –40°C to 125°C,	See Note 4			0.1	
Output noise voltage		BW = 300 Hz to 50 kHz, C_O = 10 µF,	T_J = 25°C		190		µVrms
Output current limit		V_O = 0 V,	See Note 4		350	750	mA
Standby current		$\overline{EN}$ = V_I,	2.7 < V_I < 10 V		1		µA
		T_J = –40°C to 125°C				2	µA

NOTES: 4. Minimum IN operating voltage is 2.7 V or $V_{O(typ)}$ + 1 V, whichever is greater. Maximum IN voltage 10 V, minimum output current 10 µA, maximum output current 100 mA.

5. If V_O ≤ 1.8 V then V_{imin} = 2.7 V, V_{imax} = 10 V:

$$\text{Line Reg. (mV)} = (\%/V) \times \frac{V_O\left(V_{imax} - 2.7\ V\right)}{100} \times 1000$$

If V_O ≥ 2.5 V then V_{imin} = V_O + 1 V, V_{imax} = 10 V:

$$\text{Line Reg. (mV)} = (\%/V) \times \frac{V_O\left(V_{imax} - \left(V_O + 1\ V\right)\right)}{100} \times 1000$$

electrical characteristics over recommended operating free-air temperature range, $V_I = V_{O(typ)}$ + 1 V, I_O = 100 mA, $\overline{EN}$ = 0 V, C_O = 4.7 µF (unless otherwise noted) (continued)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
FB input current		FB = 1.224 V (TPS76901)		–1		1	µA
High level enable input voltage		2.7 V < V_I < 10 V		1.7			V
Low level enable input voltage		2.7 V < V_I < 10 V				0.9	V
Power supply ripple rejection		f = 1 kHz, T_J = 25°C,	C_O = 10 µF, See Note 4		60		dB
Input current (EN)		$\overline{EN}$ = 0 V		–1	0	1	µA
		$\overline{EN}$ = V_I		–1		1	µA
Dropout voltage (See Note 6)	TPS76928	I_O = 50 mA,	T_J = 25°C		60		mV
		I_O = 50 mA,	T_J = –40°C to 125°C			125	
		I_O = 100 mA,	T_J = 25°C		122		
		I_O = 100 mA,	T_J = –40°C to 125°C			245	
	TPS76930	I_O = 50 mA,	T_J = 25°C		57		
		I_O = 50 mA,	T_J = –40°C to 125°C			115	
		I_O = 100 mA,	T_J = 25°C		115		
		I_O = 100 mA,	T_J = –40°C to 125°C			230	
	TPS76933	I_O = 50 mA,	T_J = 25°C		48		
		I_O = 50 mA,	T_J = –40°C to 125°C			100	
		I_O = 100 mA,	T_J = 25°C		98		
		I_O = 100 mA,	T_J = –40°C to 125°C			200	
	TPS76950	I_O = 50 mA,	T_J = 25°C		35		
		I_O = 50 mA,	T_J = –40°C to 125°C			85	
		I_O = 100 mA,	T_J = 25°C		71		
		I_O = 100 mA,	T_J = –40°C to 125°C			170	

NOTES: 4. Minimum IN operating voltage is 2.7 V or $V_{O(typ)}$ + 1 V, whichever is greater. Maximum IN voltage 10 V, minimum output current 10 µA, maximum output current 100 mA.

6. IN voltage equals V_O(Typ) – 100mV; TPS76901 output voltage set to 3.3V nominal with external resistor divider. TPS76912, TPS76915, TPS76918, TPS76925, and TPS76927 dropout voltage limited by input voltage range limitations.

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_O	Output voltage	vs Output current	1, 2, 3
		vs Free-air temperature	4, 5, 6
	Ground current	vs Free-air temperature	7
	Output spectral noise density	vs Frequency	8
Z_o	Output impedance	vs Frequency	9
V_{DO}	Dropout voltage	vs Free-air temperature	10
	Ripple rejection	vs Frequency	11
	LDO startup time		12
	Line transient response		13, 15
	Load transient response		14, 16
	Equivalent series resistance (ESR)	vs Output current	17, 19
		vs Added ceramic capacitance	18, 20

TYPICAL CHARACTERISTICS

TPS76925
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

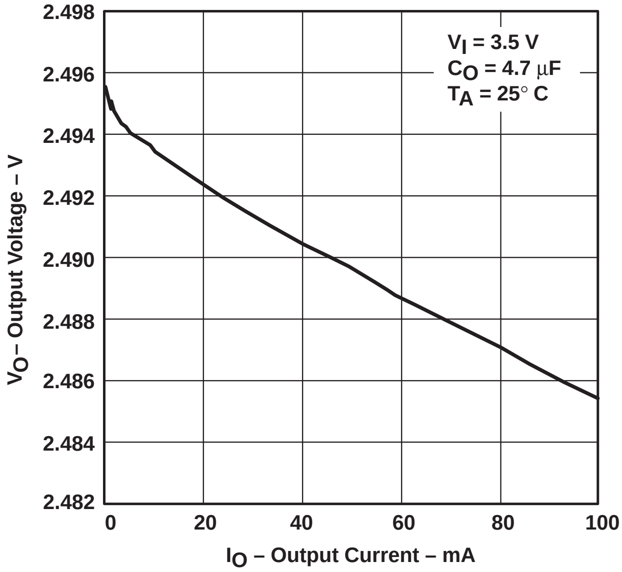


Figure 1

TPS76915
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

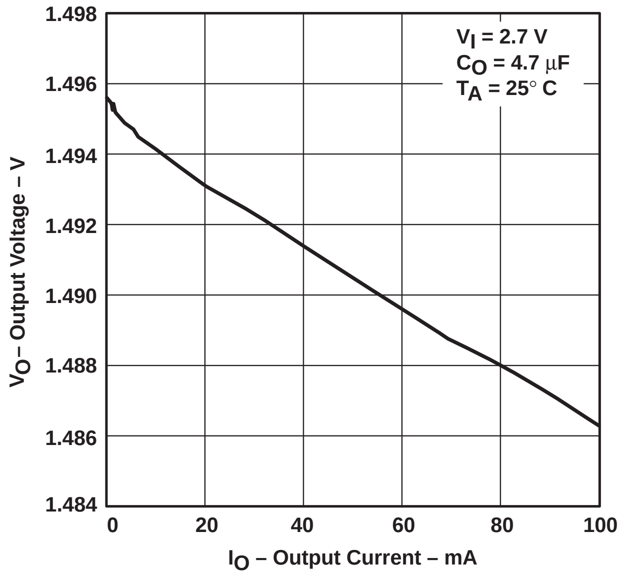


Figure 2

TPS76933
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

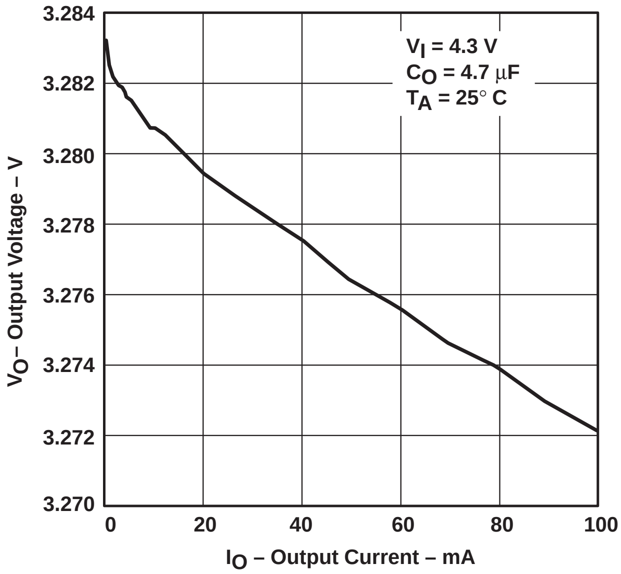


Figure 3

TPS76915
OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

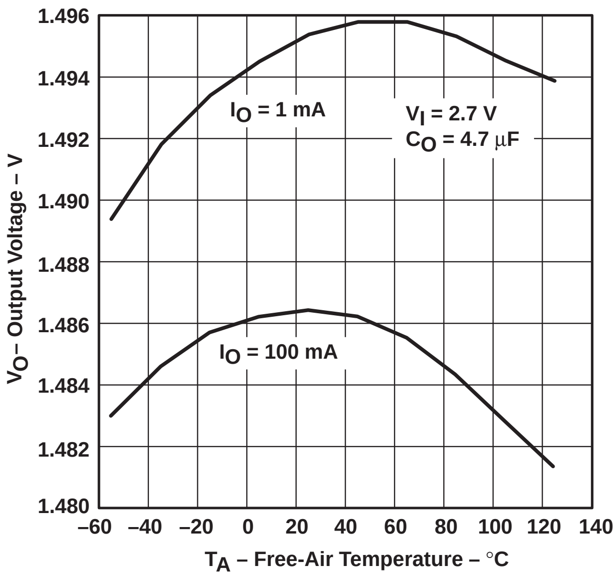


Figure 4

TYPICAL CHARACTERISTICS

TPS76925
OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

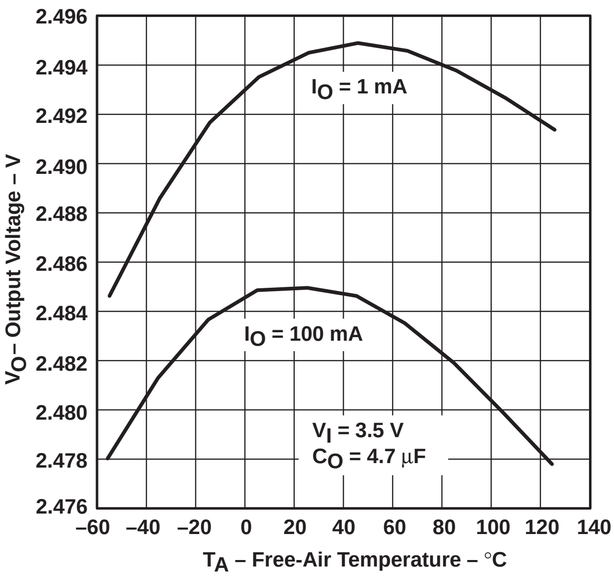


Figure 5

TPS76933
OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

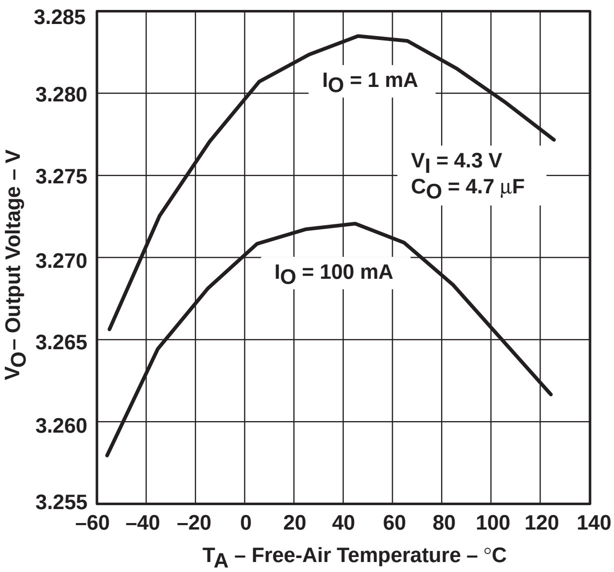


Figure 6

TPS76933
GROUND CURRENT
vs
FREE-AIR TEMPERATURE

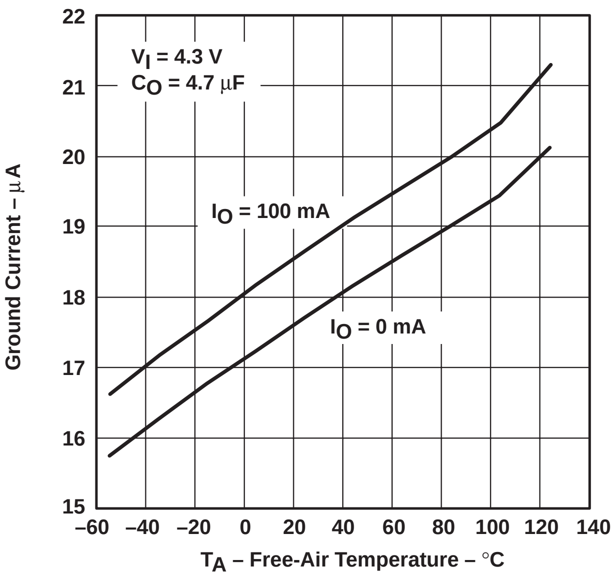


Figure 7

TPS76933
OUTPUT SPECTRAL NOISE DENSITY
vs
FREQUENCY

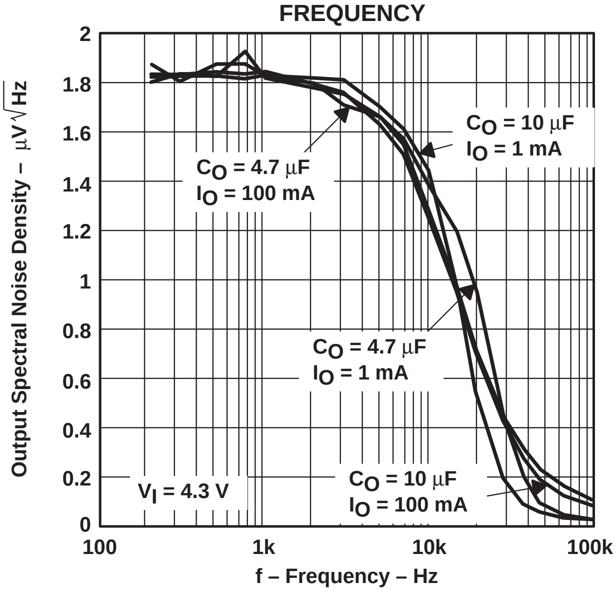


Figure 8

TYPICAL CHARACTERISTICS

**OUTPUT IMPEDANCE
vs
FREQUENCY**

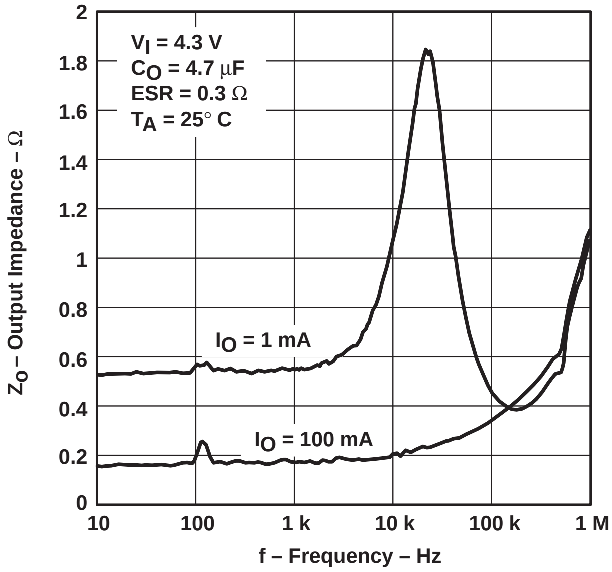


Figure 9

**TPS76933
DROPOUT VOLTAGE
vs
FREE-AIR TEMPERATURE**

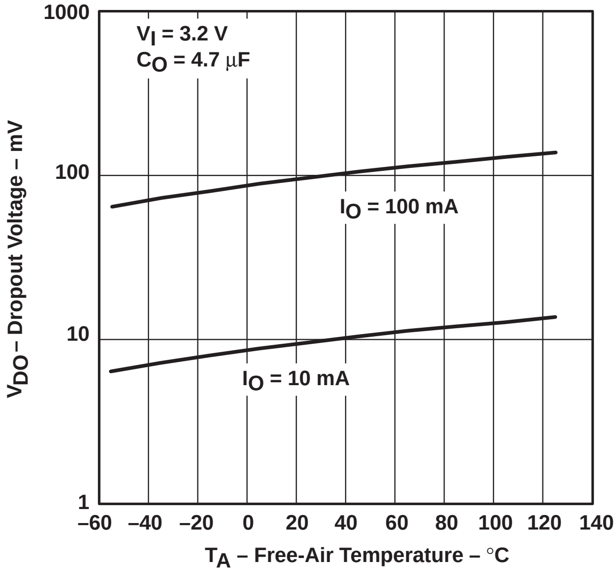


Figure 10

**TPS76933
RIPPLE REJECTION
vs
FREQUENCY**

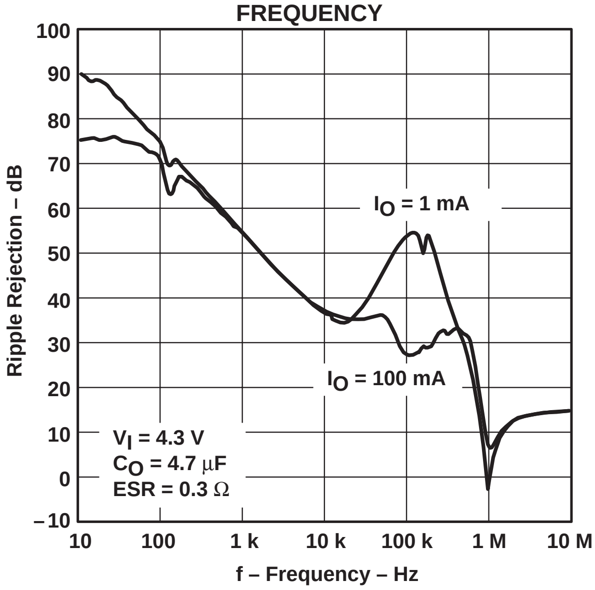


Figure 11

LDO STARTUP TIME

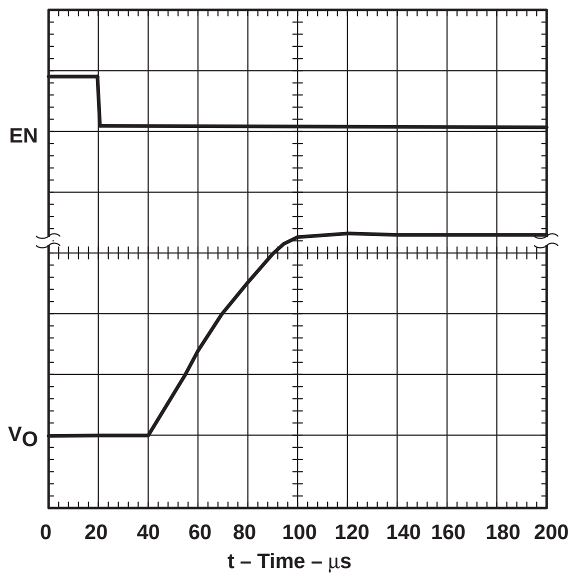


Figure 12

TYPICAL CHARACTERISTICS

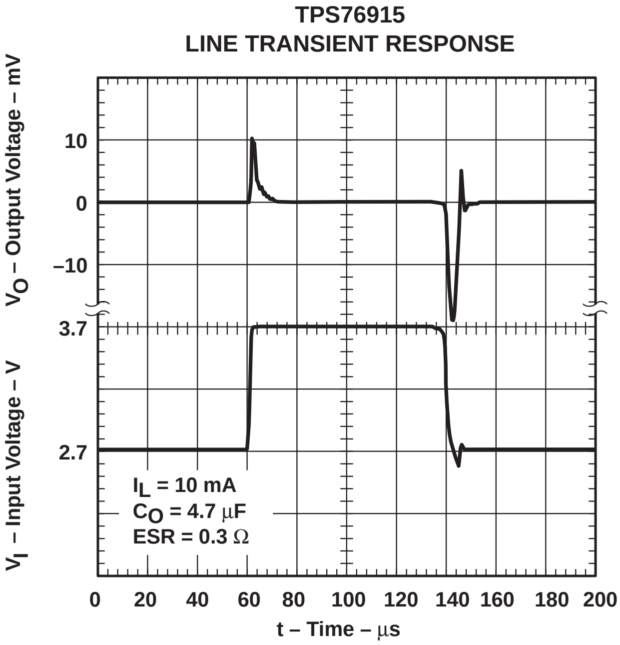


Figure 13

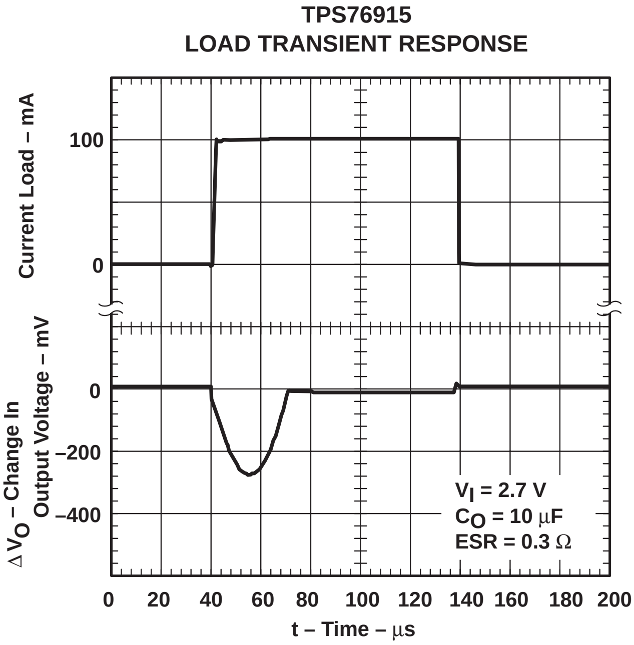


Figure 14

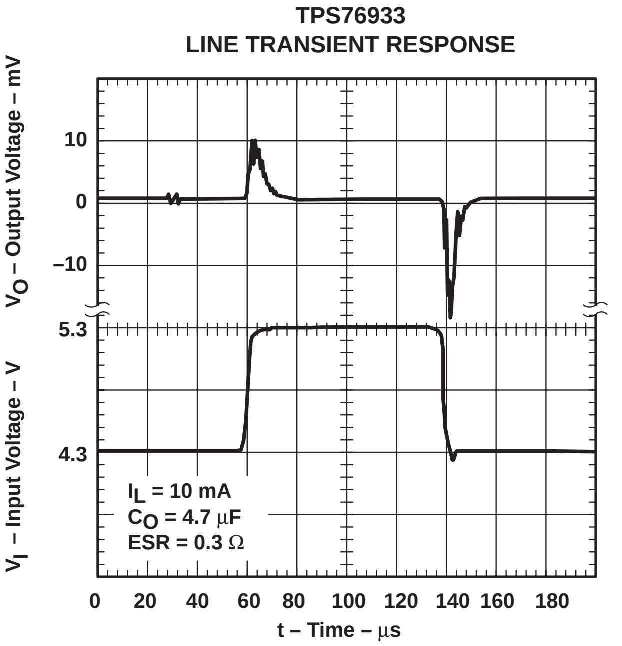


Figure 15

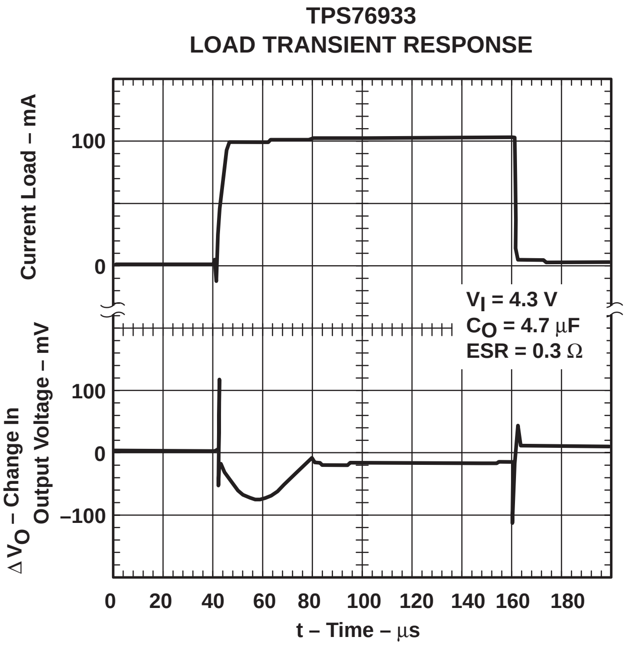


Figure 16

TYPICAL CHARACTERISTICS

TPS76933
TYPICAL REGIONS OF STABILITY
EQUIVALENT SERIES RESISTANCE (ESR)†
vs
OUTPUT CURRENT

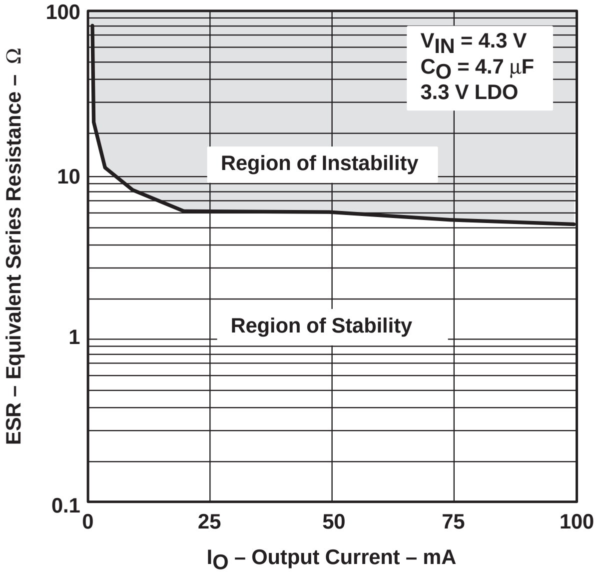


Figure 17

TPS76933
TYPICAL REGIONS OF STABILITY
EQUIVALENT SERIES RESISTANCE (ESR)
vs
ADDED CERAMIC CAPACITANCE

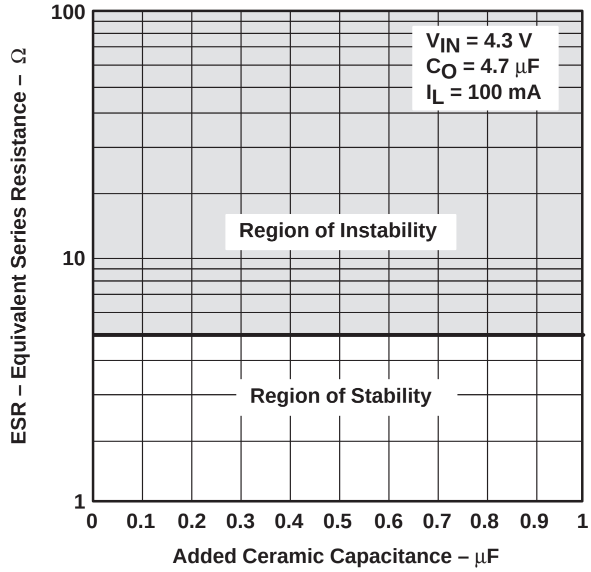


Figure 18

TPS76933
TYPICAL REGIONS OF STABILITY
EQUIVALENT SERIES RESISTANCE (ESR)†
vs
OUTPUT CURRENT

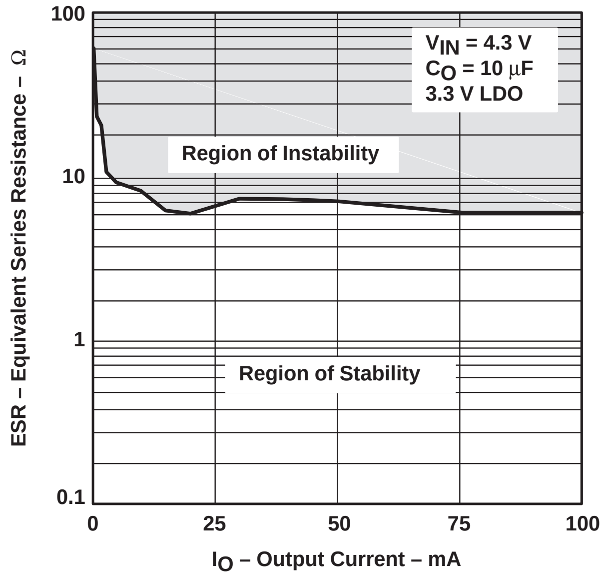


Figure 19

TPS76933
TYPICAL REGIONS OF STABILITY
EQUIVALENT SERIES RESISTANCE (ESR)
vs
ADDED CERAMIC CAPACITANCE

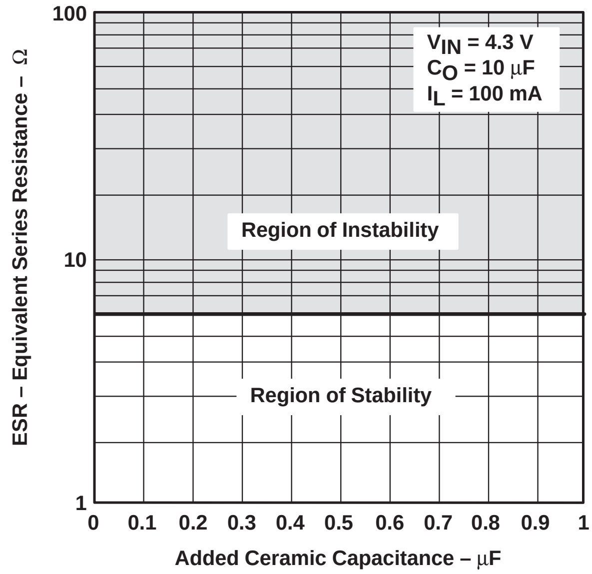


Figure 20

APPLICATION INFORMATION

The TPS769xx family of low-dropout (LDO) regulators have been optimized for use in battery-operated equipment. They feature extremely low dropout voltages, low quiescent current (17 µA nominally), and enable inputs to reduce supply currents to 1 µA when the regulators are turned off.

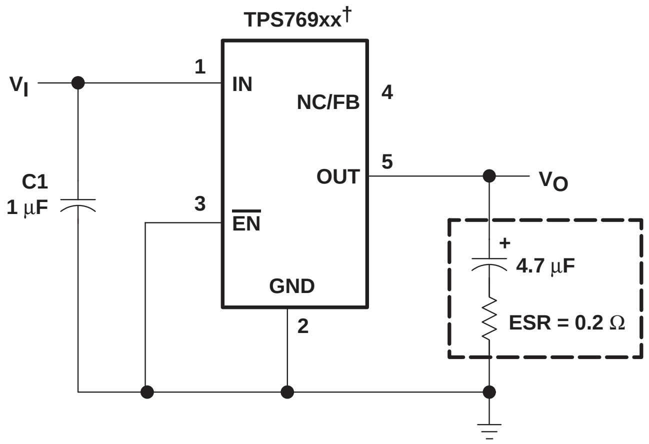
device operation

The TPS769xx uses a PMOS pass element to dramatically reduce both dropout voltage and supply current over more conventional PNP-pass-element LDO designs. The PMOS pass element is a voltage-controlled device and, unlike a PNP transistor, it does not require increased drive current as output current increases. Supply current in the TPS769xx is essentially constant from no load to maximum load.

Current limiting and thermal protection prevent damage by excessive output current and/or power dissipation. The device switches into a constant-current mode at approximately 350 mA; further load reduces the output voltage instead of increasing the output current. The thermal protection shuts the regulator off if the junction temperature rises above approximately 165°C. Recovery is automatic when the junction temperature drops approximately 25°C below the high temperature trip point. The PMOS pass element includes a back gate diode that conducts reverse current when the input voltage level drops below the output voltage level.

A voltage of 1.7 V or greater on the $\overline{EN}$ input will disable the TPS769xx internal circuitry, reducing the supply current to 1µA. A voltage of less than 0.9 V on the $\overline{EN}$ input will enable the TPS769xx and will enable normal operation to resume. The $\overline{EN}$ input does not include any deliberate hysteresis, and it exhibits an actual switching threshold of approximately 1.5 V.

A typical application circuit is shown in Figure 21.



† TPS76912, TPS76915, TPS76918, TPS76925, TPS76927, TPS76928, TPS76930, TPS76933, TPS76950 (fixed-voltage options).

Figure 21. Typical Application Circuit

APPLICATION INFORMATION

external capacitor requirements

Although not required, a 0.047-µF or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS769xx, is recommended to improve transient response and noise rejection. A higher-value electrolytic input capacitor may be necessary if large, fast-rise-time load transients are anticipated and the device is located several inches from the power source.

Like all low dropout regulators, the TPS769xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 4.7 µF. The ESR (equivalent series resistance) of the capacitor should be between 0.2 Ω and 10 Ω. to ensure stability. Capacitor values larger than 4.7 µF are acceptable, and allow the use of smaller ESR values. Capacitances less than 4.7 µF are not recommended because they require careful selection of ESR to ensure stability. Solid tantalum electrolytic, aluminum electrolytic, and multilayer ceramic capacitors are all suitable, provided they meet the requirements described above. Most of the commercially available 4.7 µF surface-mount solid tantalum capacitors, including devices from Sprague, Kemet, and Nichico, meet the ESR requirements stated above. Multilayer ceramic capacitors may have very small equivalent series resistances and may thus require the addition of a low value series resistor to ensure stability.

CAPACITOR SELECTION

PART NO.	MFR.	VALUE	MAX ESR†	SIZE (H × L × W)†
T494B475K016AS	KEMET	4.7 µF	1.5 Ω	1.9 × 3.5 × 2.8
195D106x0016x2T	SPRAGUE	10 µF	1.5 Ω	1.3 × 7.0 × 2.7
695D106x003562T	SPRAGUE	10 µF	1.3 Ω	2.5 × 7.6 × 2.5
TPSC475K035R0600	AVX	4.7 µF	0.6 Ω	2.6 × 6.0 × 3.2

† Size is in mm. ESR is maximum resistance in Ohms at 100 kHz and T_A = 25°C. Contact manufacturer for minimum ESR values.

APPLICATION INFORMATION

output voltage programming

The output voltage of the TPS76901 adjustable regulator is programmed using an external resistor divider as shown in Figure 22. The output voltage is calculated using:

$$V_O = V_{ref} \times \left(1 + \frac{R1}{R2}\right) \tag{1}$$

Where:

V_{ref} = 1.224 V typ (the internal reference voltage)

Resistors R1 and R2 should be chosen for approximately 7-µA divider current. Lower value resistors can be used but offer no inherent advantage and waste more power. Higher values should be avoided as leakage currents at FB increase the output voltage error. The recommended design procedure is to choose R2 = 169 kΩ to set the divider current at 7 µA and then calculate R1 using:

$$R1 = \left(\frac{V_O}{V_{ref}} - 1\right) \times R2 \tag{2}$$

OUTPUT VOLTAGE PROGRAMMING GUIDE

OUTPUT VOLTAGE (V)	DIVIDER RESISTANCE (kΩ)‡	
	R1	R2
2.5	174	169
3.3	287	169
3.6	324	169
4.0	383	169
5.0	523	169

‡ 1% values shown.

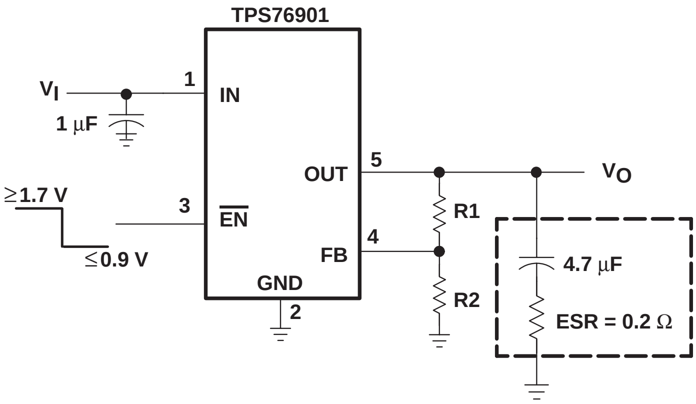


Figure 22. TPS76901 Adjustable LDO Regulator Programming

APPLICATION INFORMATION

power dissipation and junction temperature

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature should be restricted to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure the junction temperature is within acceptable limits, calculate the maximum allowable dissipation, $P_{D(max)}$, and the actual dissipation, P_D, which must be less than or equal to $P_{D(max)}$.

The maximum-power-dissipation limit is determined using the following equation:

$$P_{D(max)} = \frac{T_J max - T_A}{R_{\theta JA}}$$

Where:

$T_J max$ is the maximum allowable junction temperature

$R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package, i.e., 285°C/W for the 5-terminal SOT23.

T_A is the ambient temperature.

The regulator dissipation is calculated using:

$$P_D = \left(V_I - V_O\right) \times I_O$$

Power dissipation resulting from quiescent current is negligible. Excessive power dissipation will trigger the thermal protection circuit.

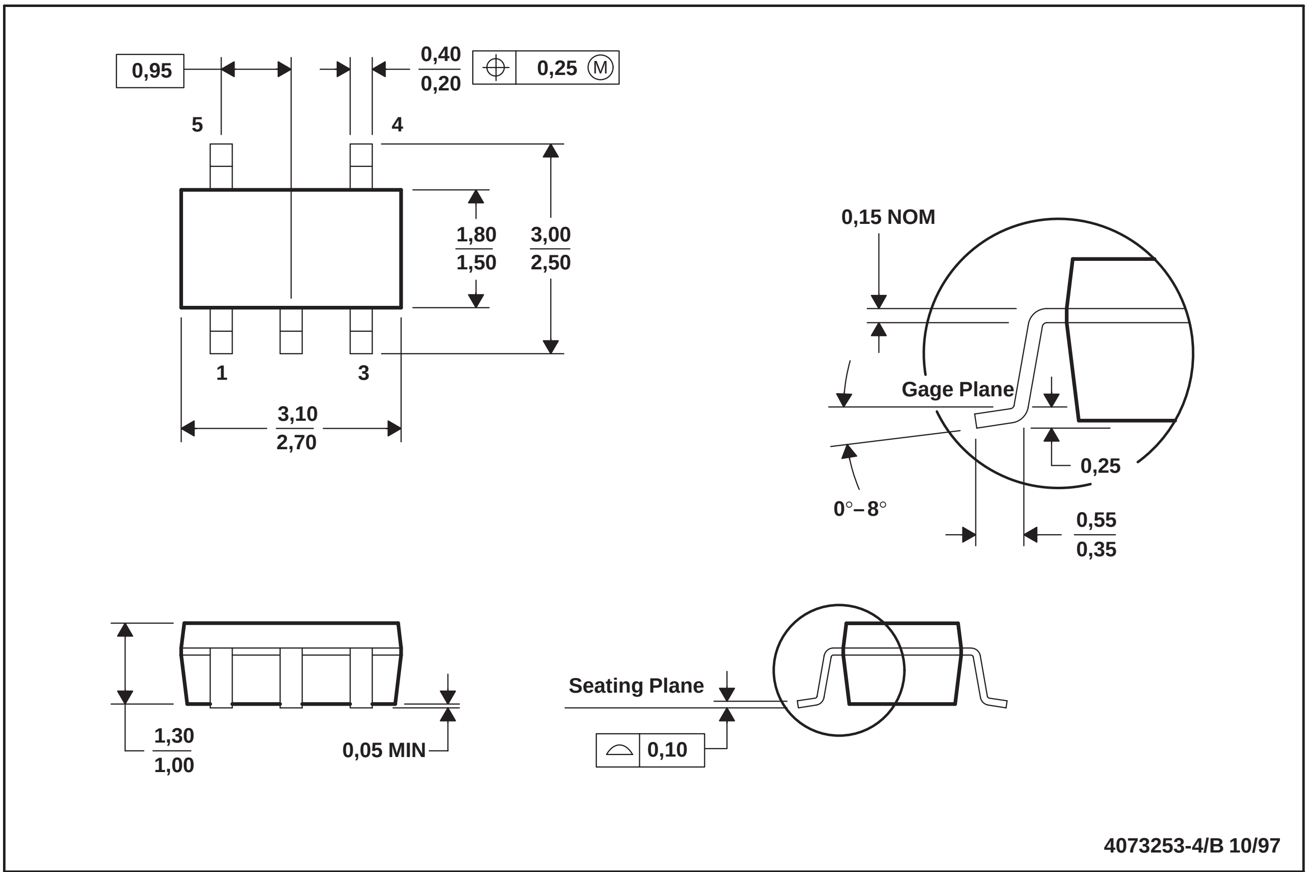
regulator protection

The TPS769xx PMOS-pass transistor has a built-in back diode that conducts reverse current when the input voltage drops below the output voltage (e.g., during power down). Current is conducted from the output to the input and is not internally limited. If extended reverse voltage operation is anticipated, external limiting might be appropriate.

The TPS769xx features internal current limiting and thermal protection. During normal operation, the TPS769xx limits output current to approximately 350 mA. When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. While current limiting is designed to prevent gross device failure, care should be taken not to exceed the power dissipation ratings of the package. If the temperature of the device exceeds approximately 165°C, thermal-protection circuitry shuts it down. Once the device has cooled down to below approximately 140°C, regulator operation resumes.

MECHANICAL DATA

DBV (R-PDSO-G5) **PLASTIC SMALL-OUTLINE PACKAGE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions include mold flash or protrusion.

IMPORTANT NOTICE