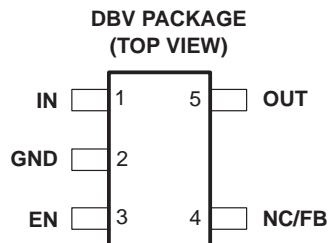


TPS76301, TPS76316, TPS76318, TPS76325, TPS76327 TPS76328, TPS76330, TPS76333, TPS76338, TPS76350 LOW-POWER 150-mA LOW-DROPOUT LINEAR REGULATORS

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- 150-mA Low-Dropout Regulator
- Output Voltage: 5 V, 3.8 V, 3.3 V, 3.0 V, 2.8 V, 2.7 V, 2.5 V, 1.8 V, 1.6 V and Variable
- Dropout Voltage, Typically 300 mV at 150 mA
- Thermal Protection
- Over Current Limitation
- Less Than 2- μ A Quiescent Current in Shutdown Mode
- -40°C to 125°C Operating Junction Temperature Range
- 5-Pin SOT-23 (DBV) Package



description

The TPS763xx family of low-dropout (LDO) voltage regulators offers the benefits of low-dropout voltage, low-power operation, and miniaturized packaging. These regulators feature low dropout voltages and quiescent currents compared to conventional LDO regulators. Offered in 5-terminal small outline integrated-circuit SOT-23 package, the TPS763xx series devices are ideal for cost-sensitive designs 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 300 mV at 150 mA of load current (TPS76333)—and is directly proportional to the load current. Since the PMOS pass element is a voltage-driven device, the quiescent current is very low (140 μ A maximum) and is stable over the entire range of output load current (0 mA to 150 mA). Intended for use in portable systems such as laptops and cellular phones, the low-dropout voltage feature and low-power operation result in a significant increase in system battery operating life.

The TPS763xx also features a logic-enabled sleep mode to shut down the regulator, reducing quiescent current to 1 μ A maximum at $T_J = 25^\circ\text{C}$. The TPS763xx is offered in 1.6-V, 1.8-V, 2.5-V, 2.7-V, 2.8-V, 3.0-V, 3.3-V, 3.8-V, and 5-V fixed-voltage versions and in a variable version (programmable over the range of 1.5 V to 6.5 V).

AVAILABLE OPTIONS

T_J	VOLTAGE	PACKAGE	PART NUMBER		SYMBOL
-40°C to 125°C	Variable	SOT-23 (DBV)	TPS76301DBVT†	TPS76301DBVR‡	PAZI
	1.6 V		TPS76316DBVT†	TPS76316DBVR‡	PBHI
	1.8 V		TPS76318DBVT†	TPS76318DBVR‡	PBAI
	2.5 V		TPS76325DBVT†	TPS76325DBVR‡	PBBI
	2.7 V		TPS76327DBVT†	TPS76327DBVR‡	PBCI
	2.8 V		TPS76328DBVT†	TPS76328DBVR‡	PBDI
	3.0 V		TPS76330DBVT†	TPS76330DBVR‡	PBII
	3.3 V		TPS76333DBVT†	TPS76333DBVR‡	PBEI
	3.8 V		TPS76338DBVT†	TPS76338DBVR‡	PBFI
	5.0 V		TPS76350DBVT†	TPS76350DBVR‡	PBGI

† The DBVT passive indicates tape and reel of 250 parts.

‡ The DBVR passive indicates tape and reel of 3000 parts.



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 **TEXAS
INSTRUMENTS**

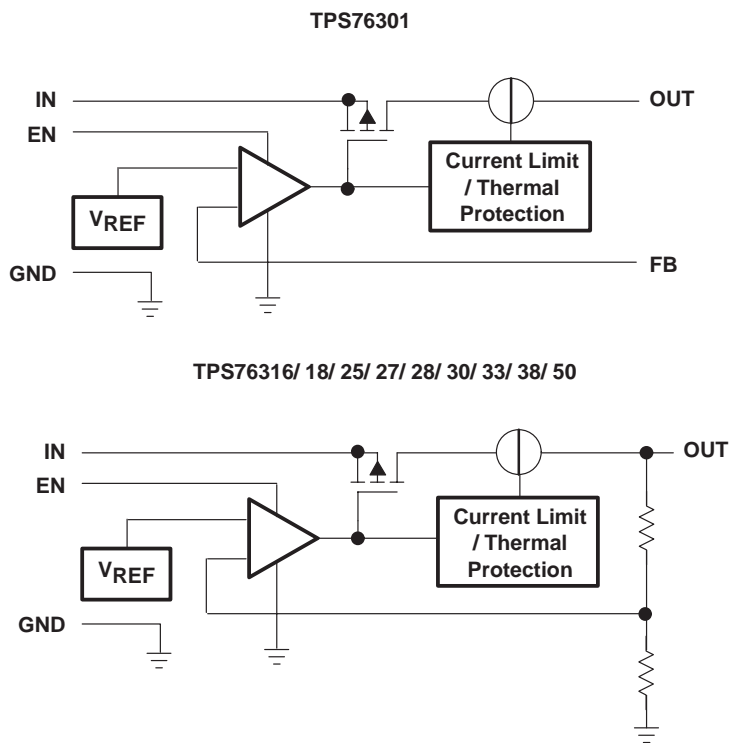
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TPS76301, TPS76316, TPS76318, TPS76325, TPS76327
 TPS76328, TPS76330, TPS76333, TPS76338, TPS76350
LOW-POWER 150-mA LOW-DROPOUT LINEAR REGULATORS

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functional block diagram



Terminal Functions

TERMINAL NAME	I/O	DESCRIPTION
GND		Ground
EN	I	Enable input
FB	I	Feedback voltage (TPS76301 only)
IN	I	Input supply voltage
NC		No connection (fixed-voltage option only)
OUT	O	Regulated output voltage

TPS76301, TPS76316, TPS76318, TPS76325, TPS76327
 TPS76328, TPS76330, TPS76333, TPS76338, TPS76350
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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Input voltage range (see Note 1)	–0.3 V to 10 V
Voltage range at 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 Tables
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 ≤ 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
Maximum	DBV	437 mW	3.5 mW/°C	280 mW	227 mW

recommended operating conditions

	MIN	NOM	MAX	UNIT
Input voltage, V_I †	2.7		10	V
Continuous output current, I_O	0		150	mA
Operating junction temperature, T_J	–40		125	°C

† To calculate the minimum input voltage for your maximum output current, use the following equation:

$$V_{I(\min)} = V_{O(\max)} + V_{DO(\max \text{ load})}$$



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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V _O	Output voltage	TPS76301	3.25 V > V _I ≥ 2.7 V, 2.5 V ≥ V _O ≥ 1.5 V, I _O = 1 mA to 75 mA, T _J = 25°C	0.98V _O	V _O	1.02V _O	V
			3.25 V > V _I ≥ 2.7 V, 2.5 V ≥ V _O ≥ 1.5 V, I _O = 1 mA to 75 mA,	0.97V _O	V _O	1.03V _O	
			V _I ≥ 3.25 V, 5 V ≥ V _O ≥ 1.5 V, I _O = 1 mA to 100 mA, T _J = 25°C	0.98V _O	V _O	1.02V _O	
			V _I ≥ 3.25 V, 5 V ≥ V _O ≥ 1.5 V, I _O = 1 mA to 100 mA,	0.97V _O	V _O	1.03V _O	
			V _I ≥ 3.25 V, 5 V ≥ V _O ≥ 1.5 V, I _O = 1 mA to 150 mA, T _J = 25°C	0.975V _O	V _O	1.025V _O	
			V _I ≥ 3.25 V, 5 V ≥ V _O ≥ 1.5 V, I _O = 1 mA to 150 mA,	0.9625V _O	V _O	1.0375V _O	
		TPS76316	V _I = 2.7 V, 1 mA < I _O < 75 mA, T _J = 25°C	1.568	1.6	1.632	V
			V _I = 2.7 V, 1 mA < I _O < 75 mA	1.552	1.6	1.648	
			V _I = 3.25 V, 1 mA < I _O < 100 mA, T _J = 25°C	1.568	1.6	1.632	
			V _I = 3.25 V, 1 mA < I _O < 100 mA	1.552	1.6	1.648	
			V _I = 3.25 V, 1 mA < I _O < 150 mA, T _J = 25°C	1.560	1.6	1.640	
			V _I = 3.25 V, 1 mA < I _O < 150 mA	1.536	1.6	1.664	
		TPS76318	V _I = 2.7 V, 1 mA < I _O < 75 mA, T _J = 25°C	1.764	1.8	1.836	V
			V _I = 2.7 V, 1 mA < I _O < 75 mA	1.746	1.8	1.854	
			V _I = 3.25 V, 1 mA < I _O < 100 mA, T _J = 25°C	1.764	1.8	1.836	
			V _I = 3.25 V, 1 mA < I _O < 100 mA	1.746	1.8	1.854	
			V _I = 3.25 V, 1 mA < I _O < 150 mA, T _J = 25°C	1.755	1.8	1.845	
			V _I = 3.25 V, 1 mA < I _O < 150 mA	1.733	1.8	1.867	
		TPS76325	I _O = 1 mA to 100 mA, T _J = 25°C	2.45	2.5	2.55	V
			I _O = 1 mA to 100 mA	2.425	2.5	2.575	
			I _O = 1 mA to 150 mA, T _J = 25°C	2.438	2.5	2.562	
			I _O = 1 mA to 150 mA	2.407	2.5	2.593	
		TPS76327	I _O = 1 mA to 100 mA, T _J = 25°C	2.646	2.7	2.754	V
			I _O = 1 mA to 100 mA	2.619	2.7	2.781	
			I _O = 1 mA to 150 mA, T _J = 25°C	2.632	2.7	2.767	
			I _O = 1 mA to 150 mA	2.599	2.7	2.801	
		TPS76328	I _O = 1 mA to 100 mA, T _J = 25°C	2.744	2.8	2.856	V
			I _O = 1 mA to 100 mA	2.716	2.8	2.884	
			I _O = 1 mA to 150 mA, T _J = 25°C	2.73	2.8	2.87	
			I _O = 1 mA to 150 mA	2.695	2.8	2.905	
TPS76330	I _O = 1 mA to 100 mA, T _J = 25°C	2.94	3.0	3.06	V		
	I _O = 1 mA to 100 mA	2.91	3.0	3.09			
	I _O = 1 mA to 150 mA, T _J = 25°C	2.925	3.0	3.075			
	I _O = 1 mA to 150 mA	2.888	3.0	3.112			



**TPS76301, TPS76316, TPS76318, TPS76325, TPS76327
TPS76328, TPS76330, TPS76333, TPS76338, TPS76350
LOW-POWER 150-mA LOW-DROUPT LINEAR REGULATORS**

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**electrical characteristics over recommended operating free-air temperature range,
 $V_I = V_O(\text{typ}) + 1 \text{ V}$, $I_O = 1 \text{ mA}$, $EN = IN$, $C_O = 4.7 \mu\text{F}$ (unless otherwise noted) (continued)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage	TPS76333	$I_O = 1 \text{ mA to } 100 \text{ mA}$, $T_J = 25^\circ\text{C}$	3.234	3.3	3.366	V
			$I_O = 1 \text{ mA to } 100 \text{ mA}$	3.201	3.3	3.399	
			$I_O = 1 \text{ mA to } 150 \text{ mA}$, $T_J = 25^\circ\text{C}$	3.218	3.3	3.382	
			$I_O = 1 \text{ mA to } 150 \text{ mA}$	3.177	3.3	3.423	
		TPS76338	$I_O = 1 \text{ mA to } 100 \text{ mA}$, $T_J = 25^\circ\text{C}$	3.724	3.8	3.876	V
			$I_O = 1 \text{ mA to } 100 \text{ mA}$	3.705	3.8	3.895	
			$I_O = 1 \text{ mA to } 150 \text{ mA}$, $T_J = 25^\circ\text{C}$	3.686	3.8	3.914	
			$I_O = 1 \text{ mA to } 150 \text{ mA}$	3.667	3.8	3.933	
		TPS76350	$I_O = 1 \text{ mA to } 100 \text{ mA}$, $T_J = 25^\circ\text{C}$	4.875	5	5.125	V
			$I_O = 1 \text{ mA to } 100 \text{ mA}$	4.825	5	5.175	
			$I_O = 1 \text{ mA to } 150 \text{ mA}$, $T_J = 25^\circ\text{C}$	4.750	5	5.15	
			$I_O = 1 \text{ mA to } 150 \text{ mA}$	4.80	5	5.20	
$I_{(Q)}$	Quiescent current (GND terminal current)	$I_O = 0 \text{ to } 150 \text{ mA}$, $T_J = 25^\circ\text{C}$, See Note 2		85	100	μA	
		$I_O = 0 \text{ to } 150 \text{ mA}$, See Note 2			140		
	Standby current	$EN < 0.5 \text{ V}$, $T_J = 25^\circ\text{C}$		0.5	1	μA	
		$EN < 0.5 \text{ V}$			2		
V_n	Output noise voltage	$BW = 300 \text{ Hz to } 50 \text{ kHz}$, $C_O = 10 \mu\text{F}$, $T_J = 25^\circ\text{C}$, See Note 2		140		μV	
PSRR	Ripple rejection	$f = 1 \text{ kHz}$, $C_O = 10 \mu\text{F}$, $T_J = 25^\circ\text{C}$, See Note 2		60		dB	
	Current limit	$T_J = 25^\circ\text{C}$, See Note 3		0.8	1.5	A	
	Output voltage line regulation ($\Delta V_O/V_O$) (see Note 4)	$V_O + 1 \text{ V} < V_I \leq 10 \text{ V}$, $V_I \geq 3.5 \text{ V}$, $T_J = 25^\circ\text{C}$		0.04	0.07	%V	
		$V_O + 1 \text{ V} < V_I \leq 10 \text{ V}$, $V_I \geq 3.5 \text{ V}$			0.1		
V_{IH}	EN high level input	See Note 2		1.4	2	V	
V_{IL}	EN low level input	See Note 2	0.5	1.2			
I_I	EN input current	$EN = 0 \text{ V}$		-0.01	-0.5	μA	
		$EN = IN$		-0.01	-0.5		

- NOTES: 2. Minimum I_N operating voltage is 2.7 V or $V_O(\text{typ}) + 1 \text{ V}$, whichever is greater.
3. Test condition includes, output voltage $V_O = 0$ volts (for variable device FB is shorted to V_O), and pulse duration = 10 mS.
4. If $V_O < 2.5 \text{ V}$ and $V_{i\text{max}} = 10 \text{ V}$, $V_{i\text{min}} = 3.5 \text{ V}$:

$$\text{Line Reg. (mV)} = (\%/V) \times \frac{V_O(V_{i\text{max}} - 3.5 \text{ V})}{100} \times 1000$$

If $V_O > 2.5 \text{ V}$ and $V_{i\text{max}} = 10 \text{ V}$, $V_{i\text{min}} = V_O + 1 \text{ V}$:

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

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 TPS76328, TPS76330, TPS76333, TPS76338, TPS76350
 LOW-POWER 150-mA LOW-DROPOUT LINEAR REGULATORS

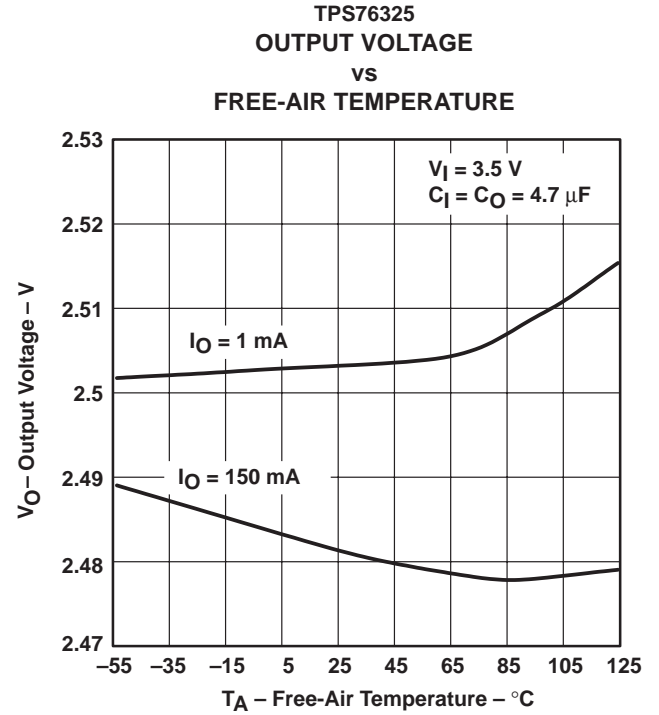
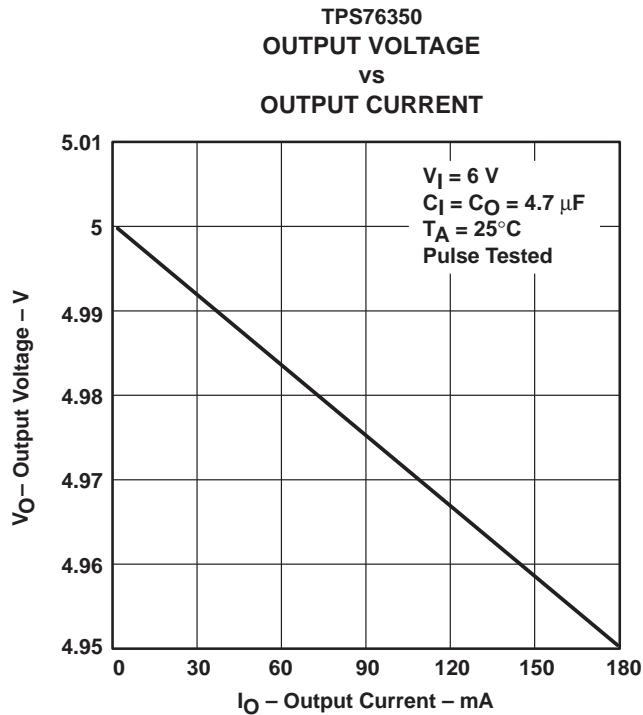
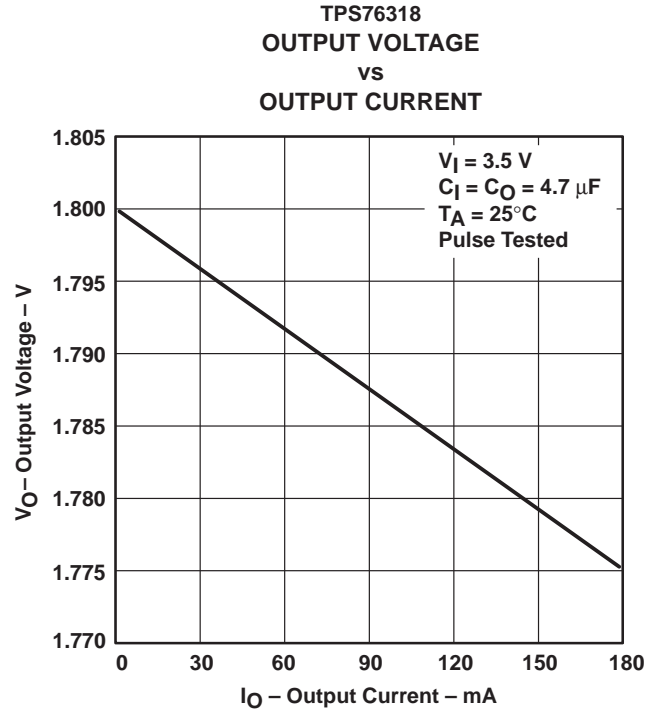
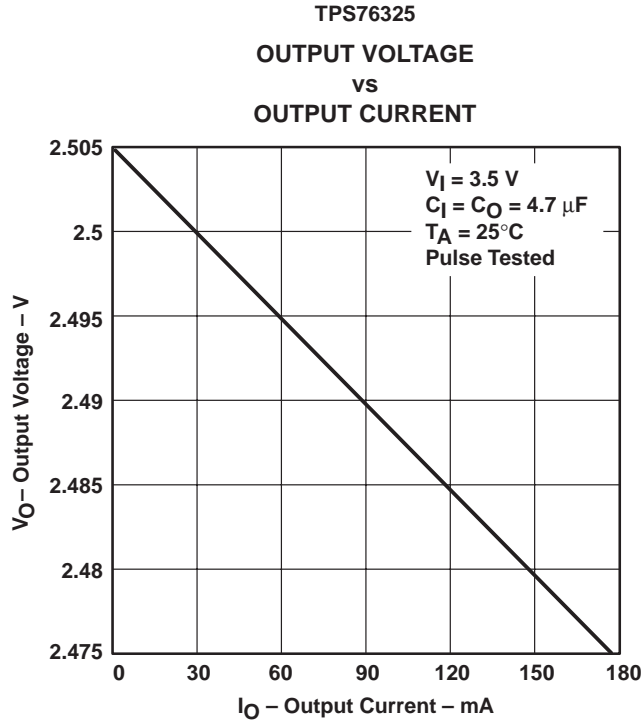
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electrical characteristics over recommended operating free-air temperature range,
 $V_I = V_O(\text{typ}) + 1 \text{ V}$, $I_O = 1 \text{ mA}$, $EN = IN$, $C_O = 4.7 \mu\text{F}$ (unless otherwise noted) (continued)

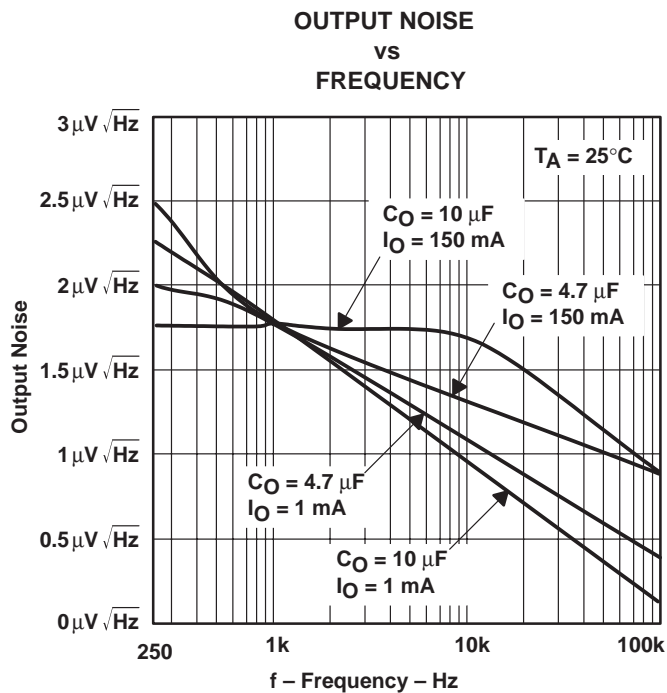
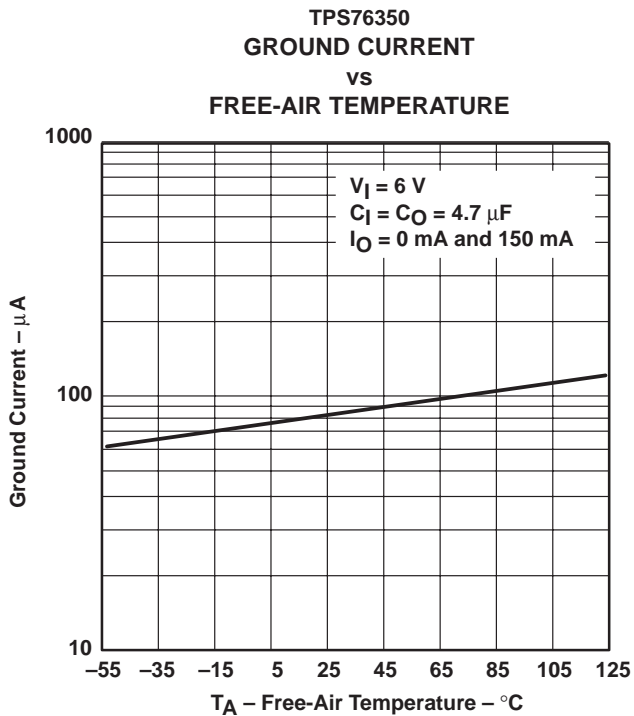
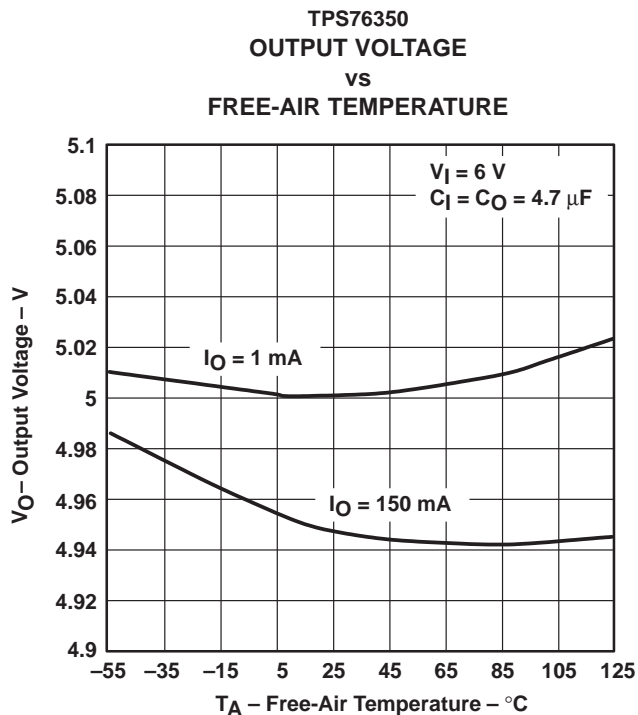
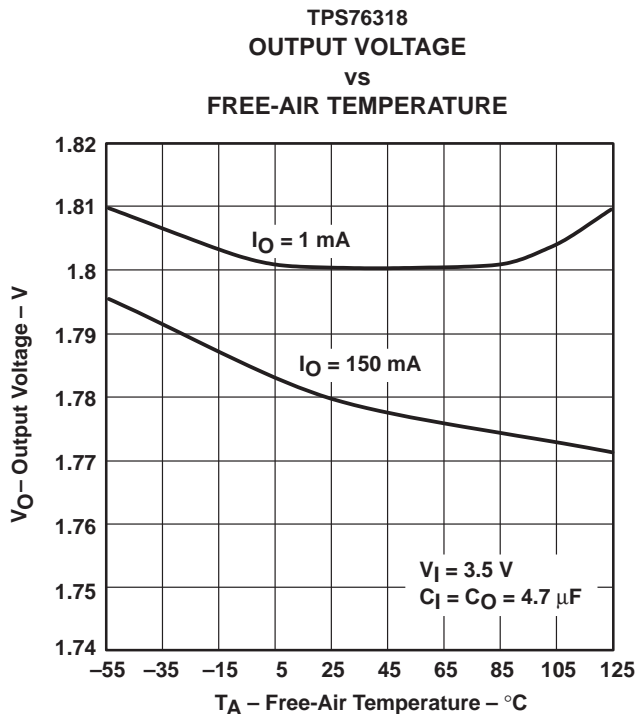
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V _{DO} Dropout voltage	TPS76325	I _O = 0 mA, T _J = 25°C		0.2		mV
		I _O = 1 mA, T _J = 25°C		3		
		I _O = 50 mA, T _J = 25°C		120	150	
		I _O = 50 mA			200	
		I _O = 75 mA, T _J = 25°C		180	225	
		I _O = 75 mA			300	
		I _O = 100 mA, T _J = 25°C		240	300	
		I _O = 100 mA			400	
		I _O = 150 mA, T _J = 25°C		360	450	
		I _O = 150 mA			600	
	TPS76333	I _O = 0 mA, T _J = 25°C		0.2		mV
		I _O = 1 mA, T _J = 25°C		3		
		I _O = 50 mA, T _J = 25°C		100	125	
		I _O = 50 mA			166	
		I _O = 75 mA, T _J = 25°C		150	188	
		I _O = 75 mA			250	
		I _O = 100 mA, T _J = 25°C		200	250	
		I _O = 100 mA			333	
		I _O = 150 mA, T _J = 25°C		300	375	
		I _O = 150 mA			500	
	TPS76350	I _O = 0 mA, T _J = 25°C		0.2		mV
		I _O = 1 mA, T _J = 25°C		2		
		I _O = 50 mA, T _J = 25°C		60	75	
		I _O = 50 mA			100	
		I _O = 75 mA, T _J = 25°C		90	113	
		I _O = 75 mA			150	
		I _O = 100 mA, T _J = 25°C		120	150	
		I _O = 100 mA			200	
		I _O = 150 mA, T _J = 25°C		180	225	
		I _O = 150 mA			300	



TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

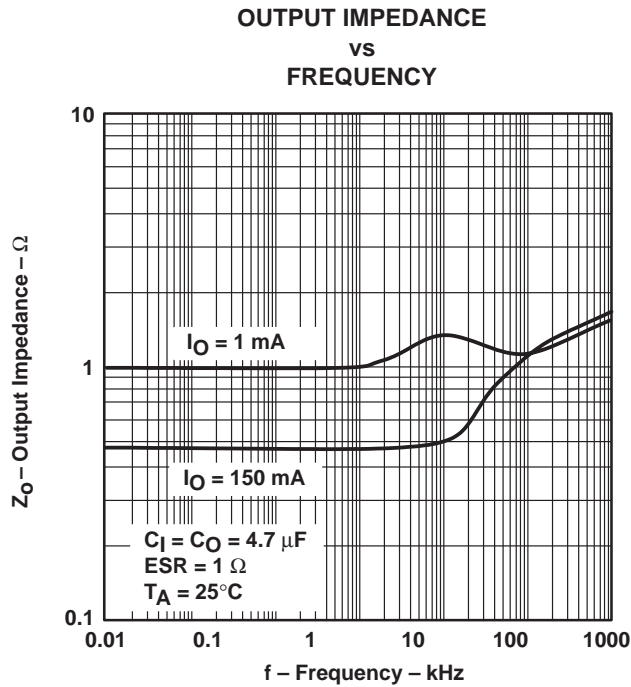


Figure 9

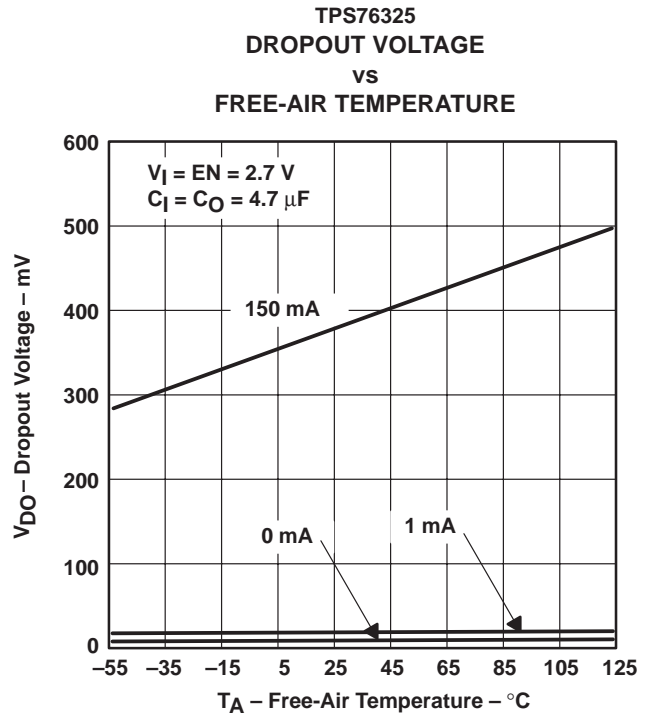


Figure 10

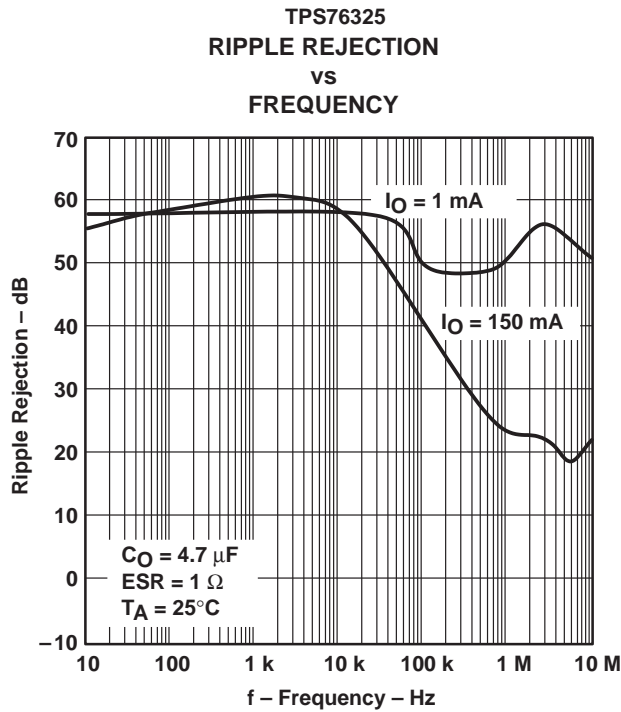


Figure 11

TYPICAL CHARACTERISTICS

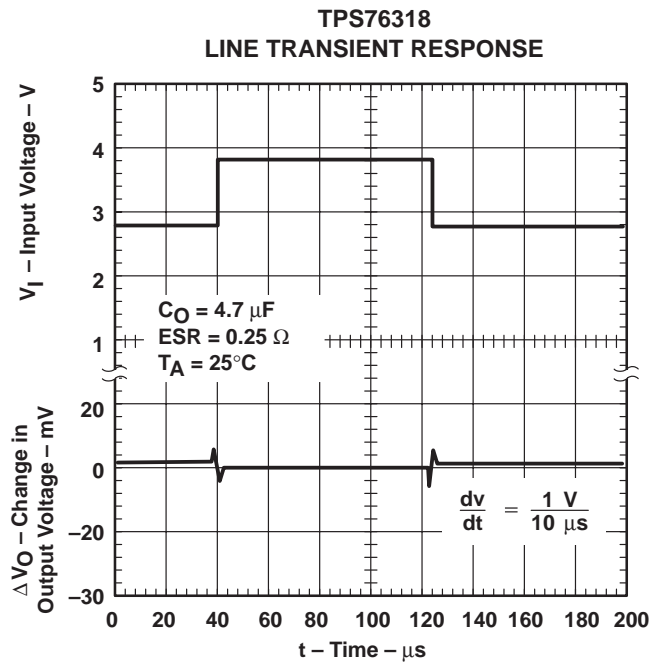


Figure 12

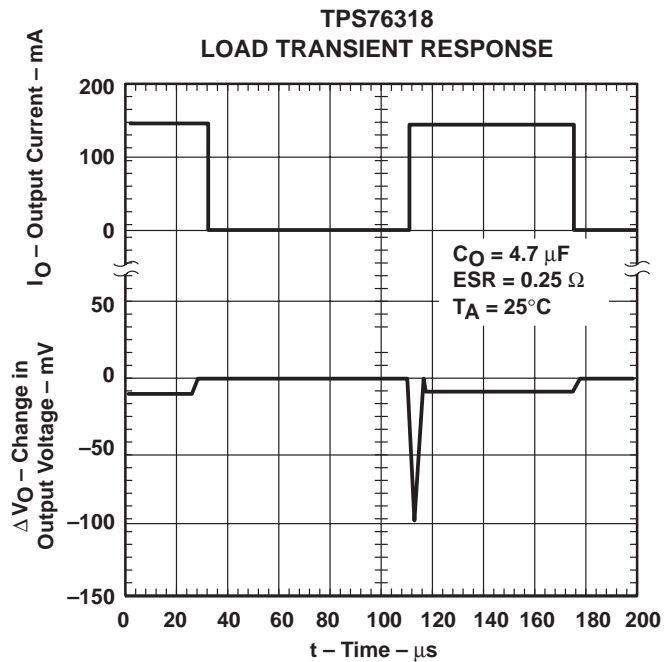


Figure 13

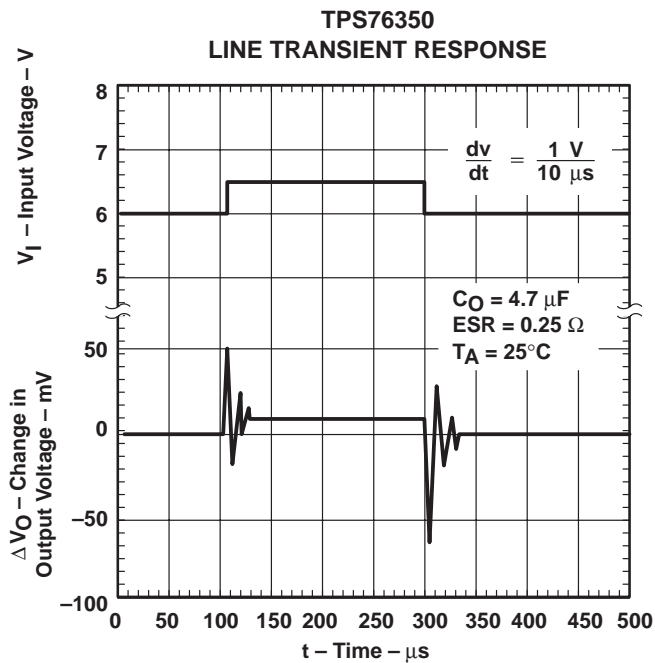


Figure 14

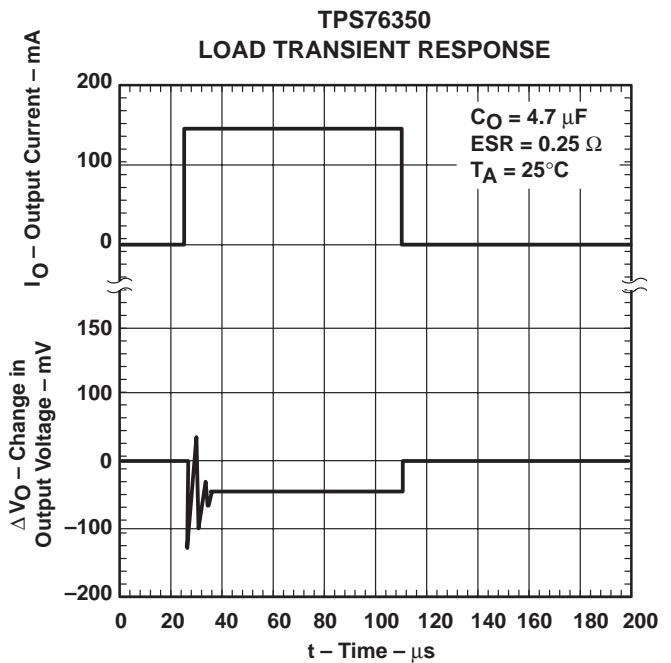


Figure 15

TYPICAL CHARACTERISTICS

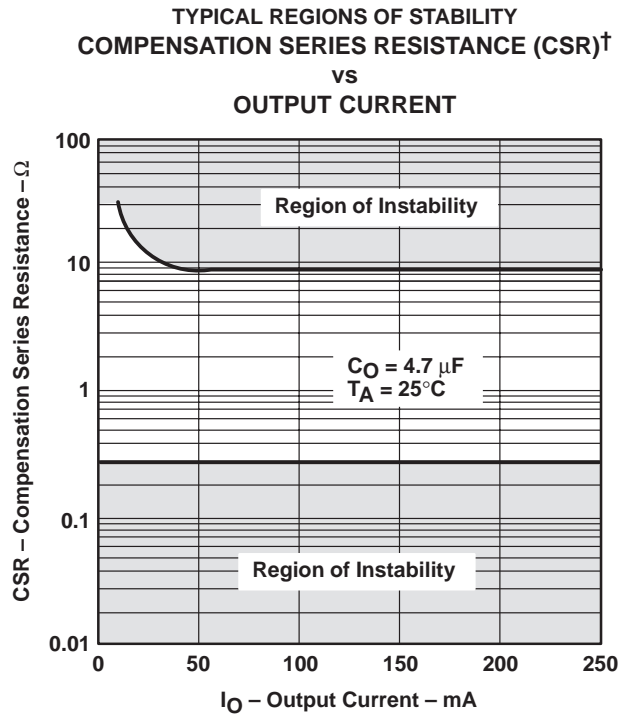


Figure 16

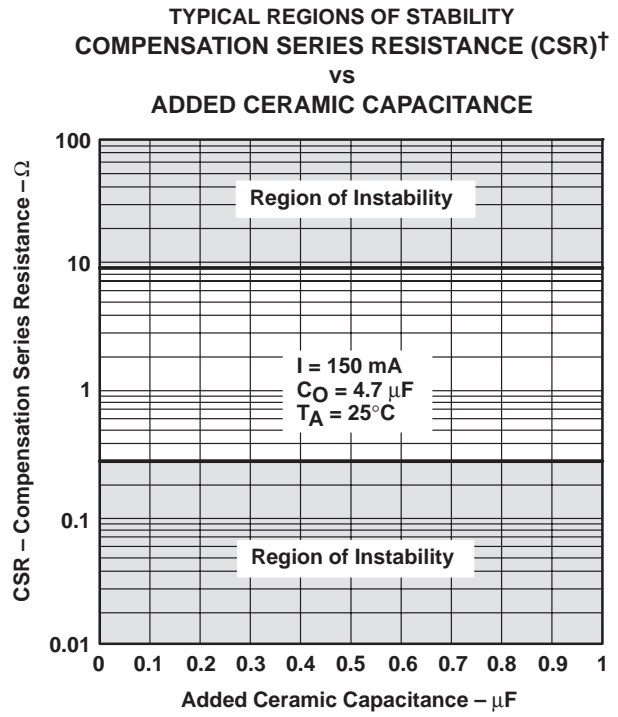


Figure 17

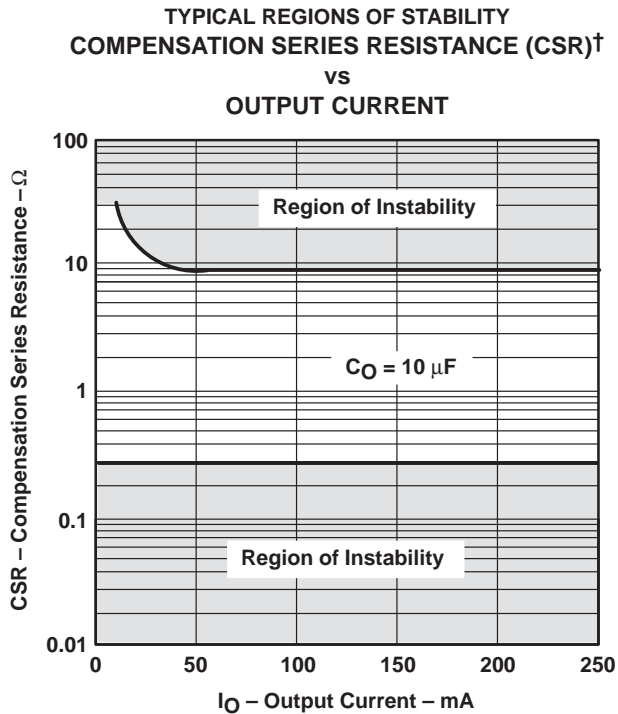


Figure 18

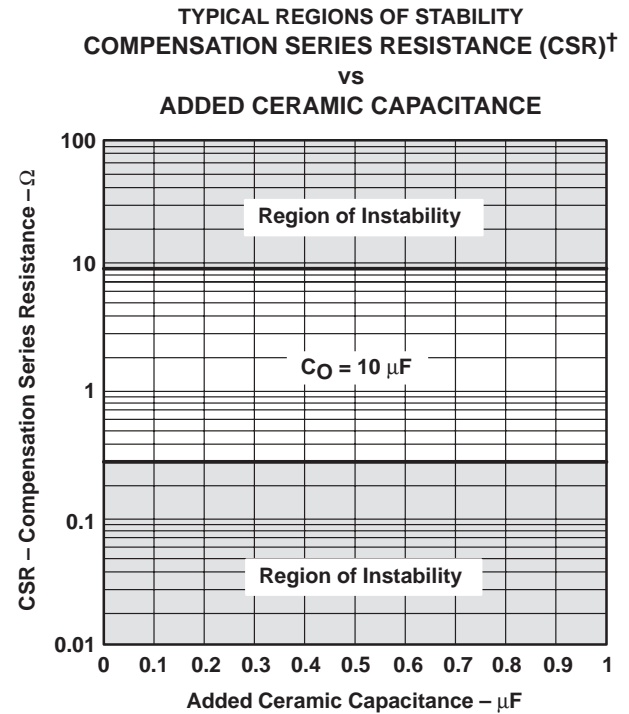


Figure 19

[†] CSR refers to the total series resistance, including the ESR of the capacitor, any series resistance added externally, and PWB trace resistance to C_O .

APPLICATION INFORMATION

The TPS763xx low-dropout (LDO) regulators are new families of regulators which have been optimized for use in battery-operated equipment and feature extremely low dropout voltages, low quiescent current (140 μ A), and an enable input to reduce supply currents to less than 2 μ A when the regulator is turned off.

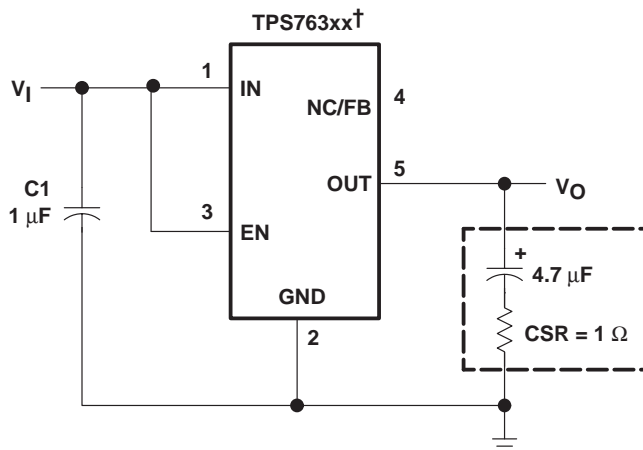
device operation

The TPS763xx 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 that, unlike a PNP transistor, does not require increased drive current as output current increases. Supply current in the TPS763xx 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 1 A; 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 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 diode that safely conducts reverse current when the input voltage level drops below the output voltage level.

A logic low on the enable input, EN shuts off the output and reduces the supply current to less than 2 μ A. EN should be tied high in applications where the shutdown feature is not used.

A typical application circuit is shown in Figure 20.



† TPS76316, TPS76318, TPS76325, TPS76327, TPS76328, TPS76330, TPS76333, TPS76338, TPS76350 (fixed-voltage options).

Figure 20. Typical Application Circuit

APPLICATION INFORMATION

external capacitor requirements

Although not required, a 0.047- μF or larger ceramic bypass input capacitor, connected between IN and GND and located close to the TPS763xx, 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 TPS763xx requires an output capacitor connected between OUT and GND to stabilize the internal loop control. The minimum recommended capacitance value is 4.7 μF and the ESR (equivalent series resistance) must be between 0.2 Ω and 10 Ω . Capacitor values 4.7 μF or larger are acceptable, provided the ESR is less than 10 Ω . 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 should have minimum values of 1 μF over the full operating temperature range of the equipment.

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 $T_A = 25^\circ\text{C}$. Listings are sorted by height.

output voltage programming

The output voltage of the TPS76301 adjustable regulator is programmed using an external resistor divider as shown in Figure 21. The output voltage is calculated using:

$$V_O = 0.995 \times V_{\text{ref}} \times \left(1 + \frac{R1}{R2}\right) \quad (1)$$

Where:

$V_{\text{ref}} = 1.192 \text{ V}$ typ (the internal reference voltage)

0.995 is a constant used to center the load regulator (1%)

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 $R2 = 169 \text{ k}\Omega$ to set the divider current at 7 μA and then calculate R1 using:

$$R1 = \left(\frac{V_O}{0.995 \times V_{\text{ref}}} - 1 \right) \times R2 \quad (2)$$

APPLICATION INFORMATION

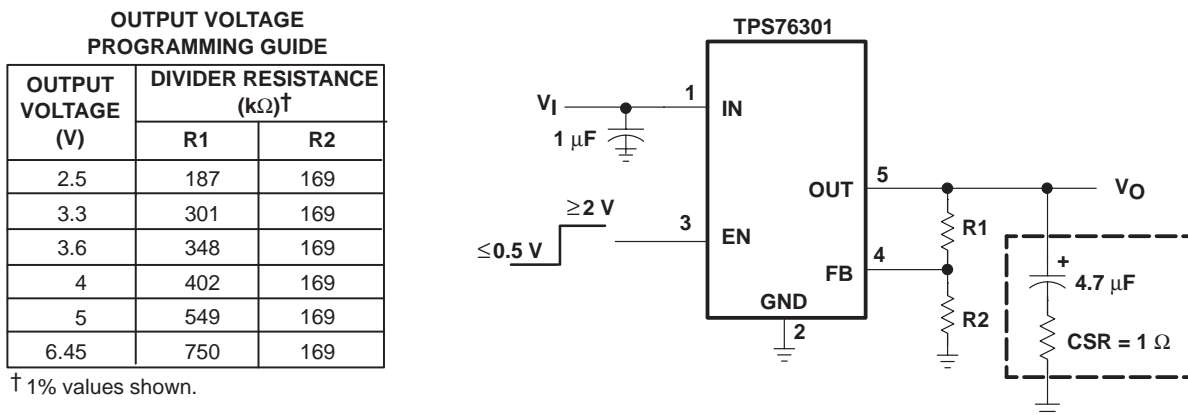


Figure 21. TPS76301 Adjustable LDO Regulator Programming

power dissipation and junction temperature

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature allowable to avoid damaging the device is 150°C. 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:

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

Where:

T_{Jmax} is the maximum allowable junction temperature

R_{θJA} 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:

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

Power dissipation resulting from quiescent current is negligible.

APPLICATION INFORMATION

regulator protection

The TPS763xx pass element has a built-in back diode that safely conducts reverse currents 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 is anticipated, external limiting might be appropriate.

The TPS763xx also features internal current limiting and thermal protection. During normal operation, the TPS763xx limits output current to approximately 800 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 165°C, thermal-protection circuitry shuts it down. Once the device has cooled down to below 140°C, regulator operation resumes.

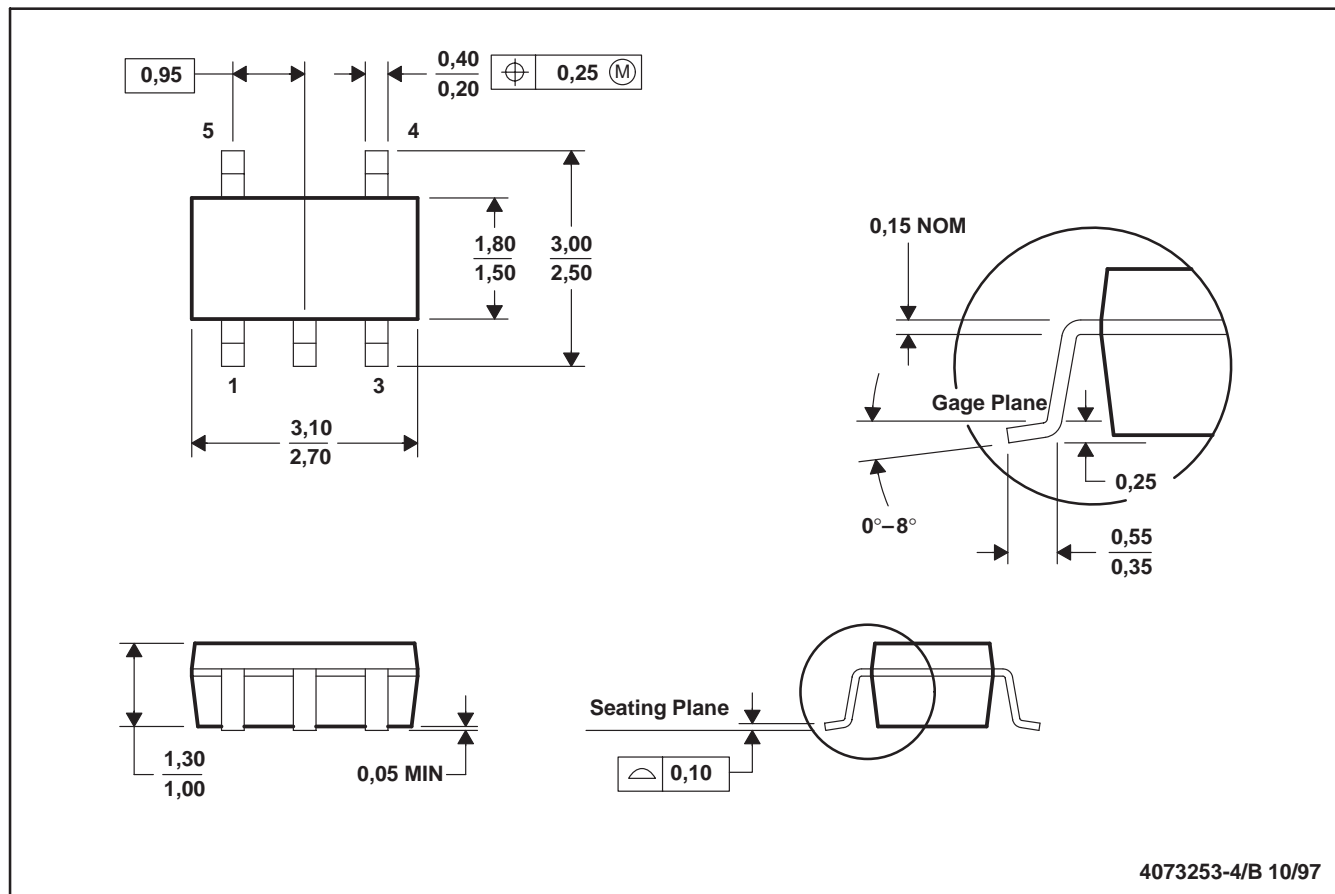
TPS76301, TPS76316, TPS76318, TPS76325, TPS76327
 TPS76328, TPS76330, TPS76333, TPS76338, TPS76350
 LOW-POWER 150-mA LOW-DROPOUT LINEAR REGULATORS

SLVS181E – DECEMBER 1998 – REVISED APRIL 2000

MECHANICAL DATA

DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE



4073253-4/B 10/97

- 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.

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