LOW-NOISE, HIGH PSRR, RF 200-mA LOW-DROPOUT LINEAR REGULATORS

FEATURES

- **200-mA RF Low-Dropout Regulator With Enable**
- **Available in 1.8-V, 2.5-V, 3-V, 3.3-V, and Adjustable (1.22-V to 5.5-V)**
- **High PSRR (68dB at 1 kHz)**
- **Ultralow-Noise (23 μV_{RMS}, TPS73018)**
- **Fast Start-Up Time (50 µs)**
- **Stable With a 2.2-µF Ceramic Capacitor**
- **Excellent Load/Line Transient Response**
- **Very Low Dropout Voltage (120 mV at Full Load)**
- **5- and 6-Pin SOT23 (DBV) Package**

APPLICATIONS

- **RF: VCOs, Receivers, ADCs**
- **Audio**
- **Cellular and Cordless Telephones**
- **Bluetooth™, Wireless LAN**
- **Handheld Organizers, PDAs**

DESCRIPTION

The TPS730xx family of low-dropout (LDO) low-power linear voltage regulators features high power-supply rejection ratio (PSRR), ultralow-noise, fast start-up, and excellent line and load transient responses a small SOT23 package. Each device in the family is stable, with a small 2.2-µF ceramic capacitor on the output. The TPS730xx family uses an advanced, proprietary BiCMOS fabrication process to yield low dropout voltages (e.g., 120 mV at 200 mA, TPS73030). Each device achieves fast start-up times (approximately 50 µs with a 0.001-µF bypass capacitor) while consuming low quiescent current (170 µA typical). Moreover, when the device is placed in standby mode, the supply current is reduced to less than 1 µA. The TPS73018 exhibits approximately 23 μV_{RMS} of output voltage noise at 2.8-V output with a 0.01-µF bypass capacitor. Applications with analog components that are noise-sensitive, such as portable RF electronics, benefit from the high PSRR and low-noise features as well as the fast response time.

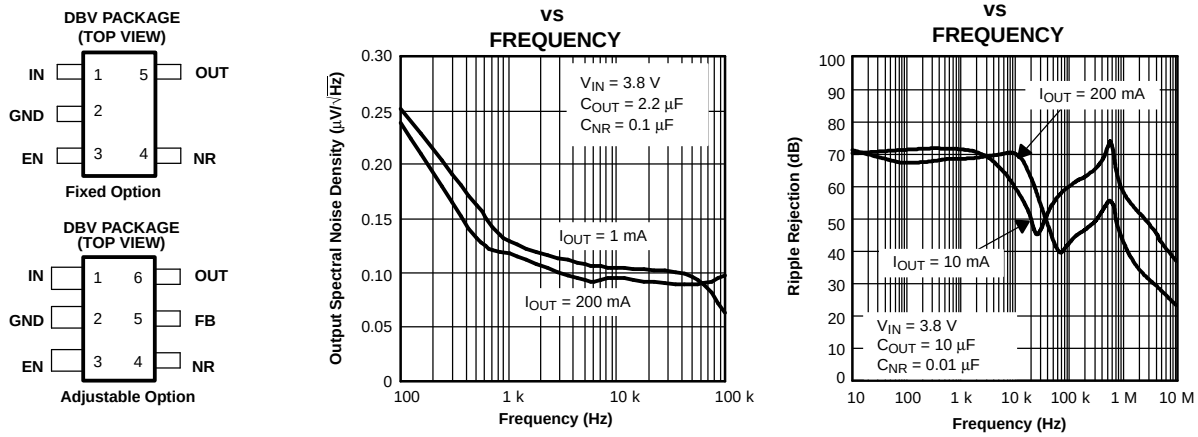


Figure 1.

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

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

AVAILABLE OPTIONS[1][2]

PRODUCT	VOLTAGE	PACKAGE	T_J	SYMBOL	PART NUMBER
TPS73001	1.22 V to 5.5 V	SOT23 (DBV)	-40°C to +125°C	PGVI	TPS73001DBVR
TPS73018	1.8 V	SOT23 (DBV)		PHHI	TPS73018DBVR
TPS73025	2.5 V	SOT23 (DBV)		PGWI	TPS73025DBVR
TPS73030	3 V	SOT23 (DBV)		PGYI	TPS73030DBVR
TPS73033	3.3 V	SOT23 (DBV)		PHUI	TPS73033DBVR

(1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.
(2) DBV**R** indicates tape and reel of 3000 parts.

ABSOLUTE MAXIMUM RATINGS

over operating temperature range (unless otherwise noted)[1]

	UNIT
V_{IN} range	-0.3 V to 6 V
V_{EN} range	-0.3 V to V_{IN} + 0.3 V
V_{OUT} range	-0.3 V to 6 V
Peak output current	Internally limited
ESD rating, HBM	2 kV
ESD rating, CDM	500 V
Continuous total power dissipation	See Dissipation Ratings Table
Junction temperature range	-40°C to 150°C
Storage temperature range, T_{stg}	-65°C to 150°C

(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.

DISSIPATION RATINGS TABLE

BOARD	PACKAGE	$R_{\theta JC}$	$R_{\theta JA}$	DERATING FACTOR ABOVE T_A = 25°C	$T_A \le 25°C$ POWER RATING	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING
Low-K(1)	DBV	65°C/W	255°C/W	3.9 mW/°C	390 mW	215 mW	155 mW
High-K(2)	DBV	65°C/W	180°C/W	5.6 mW/°C	560 mW	310 mW	225 mW

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

ELECTRICAL CHARACTERISTICS

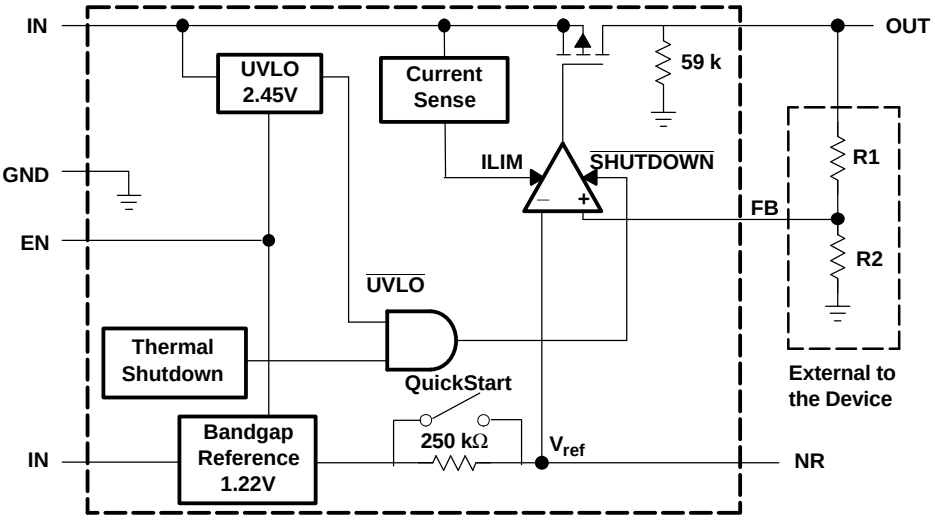
over recommended operating temperature range T_J = -40 to 125°C, $V_{EN} = V_{IN}$, $V_{IN} = V_{OUT(nom)}$ + 1 V(1), I_{OUT} = 1 mA, C_{OUT} = 10 µF, C_{NR} = 0.01 µF (unless otherwise noted). Typical values are at 25°C.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IN} Input voltage(1)				2.7		5.5	V
I_{OUT} Continuous output current				0		200	mA
V_{FB} Internal reference (TPS73001)				1.201	1.225	1.250	V
Output voltage range (TPS73001)				V_{FB}		5.5 - V_{DO}	V
Output voltage accuracy		0 µA ≤ I_{OUT} ≤ 200 mA,	2.75 V ≤ V_{IN} < 5.5 V	-2%	$V_{OUT(nom)}$	+2%	V
Line regulation ($\Delta V_{OUT}\%/\Delta V_{IN}$) (1)		V_{OUT} + 1 V ≤ V_{IN} ≤ 5.5 V			0.05		%/V
Load regulation ($\Delta V_{OUT}\%/\Delta I_{OUT}$)		0 µA ≤ I_{OUT} ≤ 200 mA,	T_J = 25°C		5		mV
Dropout voltage(2)($V_{IN} = V_{OUT(nom)}$ - 0.1V)		I_{OUT} = 200 mA			120	210	mV
Output current limit		V_{OUT} = 0 V		285		600	mA
GND pin current		0 µA ≤ I_{OUT} ≤ 200 mA			170	250	µA
Shutdown current(3)		V_{EN} = 0 V, 2.7 V ≤ V_{IN} ≤ 5.5 V			0.07	1	µA
FB pin current		V_{FB} = 1.8 V				1	µA
Power-supply ripple rejection	TPS73028	f = 1kHz, T_J = 25°C,	I_{OUT} = 200 mA		68		dB
Output noise voltage (TPS73018)		BW = 200 Hz to 100 kHz, I_{OUT} = 200 mA	C_{NR} = 0.01 µF		23		μV_{RMS}
Time, start-up (TPS73018)		R_L = 14 Ω, C_{OUT} = 1 µF	C_{NR} = 0.001 µF		50		µs
High level enable input voltage		2.7 V ≤ V_{IN} ≤ 5.5 V		1.7		V_{IN}	V
Low level enable input voltage		2.7 V ≤ V_{IN} ≤ 5.5 V		0		0.7	V
EN pin current		V_{EN} = 0		-1		1	µA
UVLO threshold		V_{CC} rising		2.25		2.65	V
UVLO hysteresis					100		mV

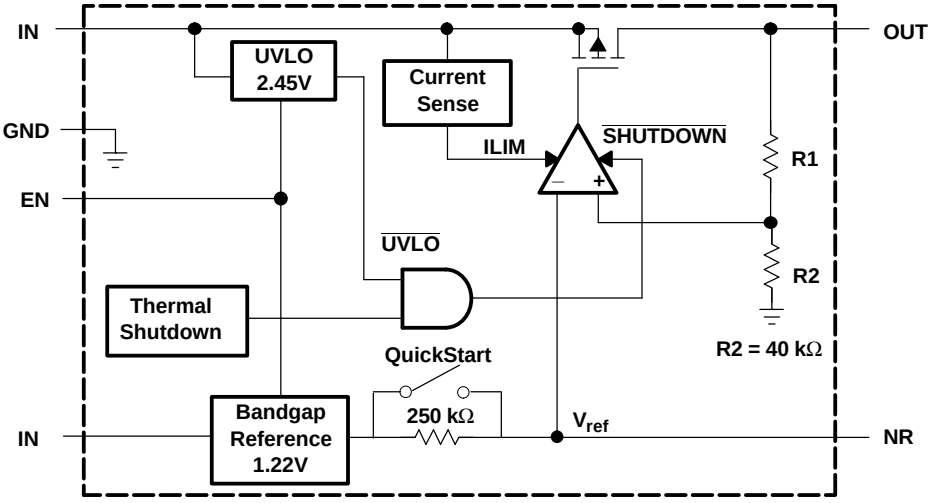
(1) Minimum V_{IN} is 2.7 V or V_{OUT} + V_{DO}, whichever is greater.
(2) Dropout is not measured for the TPS73018 and TPS73025 since minimum V_{IN} = 2.7 V.
(3) For adjustable versions, this applies only after V_{IN} is applied; then V_{EN} transitions high to low.

FUNCTIONAL BLOCK DIAGRAMS

ADJUSTABLE VERSION



FIXED VERSION



Terminal Functions

TERMINAL			DESCRIPTION
NAME	SOT23 ADJ	SOT23 FIXED	
NR	4	4	Connecting an external capacitor to this pin bypasses noise generated by the internal bandgap. This improves power-supply rejection and reduces output noise.
EN	3	3	Driving the enable pin (EN) high turns on the regulator. Driving this pin low puts the regulator into shutdown mode. EN can be connected to IN if not used.
FB	5	N/A	This terminal is the feedback input voltage for the adjustable device.
GND	2	2	Regulator ground
IN	1	1	Unregulated input to the device.
OUT	6	5	Output of the regulator.

TYPICAL CHARACTERISTICS (SOT23 PACKAGE)

**TPS73028
OUTPUT VOLTAGE
vs
OUTPUT CURRENT**

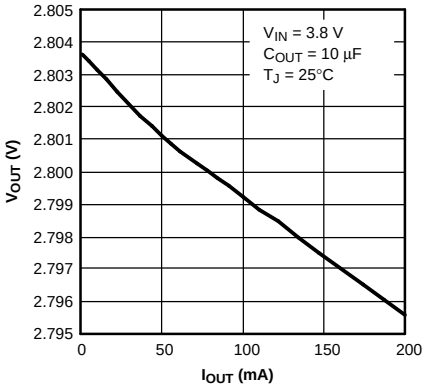


Figure 2.

**TPS73028
OUTPUT VOLTAGE
vs
JUNCTION TEMPERATURE**

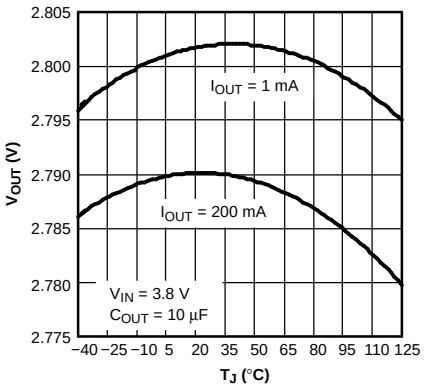


Figure 3.

**TPS73028
GROUND CURRENT
vs
JUNCTION TEMPERATURE**

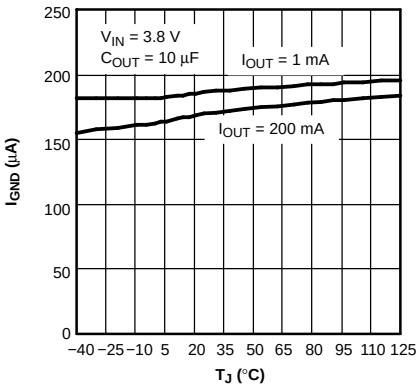


Figure 4.

**TPS73028 OUTPUT SPECTRAL
NOISE DENSITY
vs
FREQUENCY**

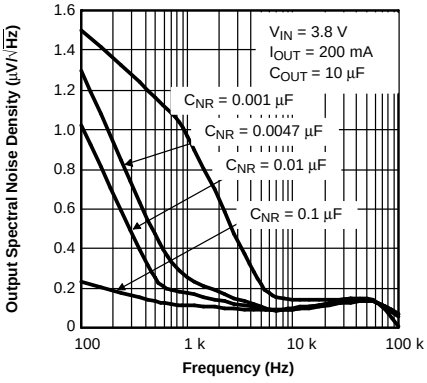


Figure 5.

**ROOT MEAN SQUARE OUTPUT
NOISE
vs
C_{NR}**

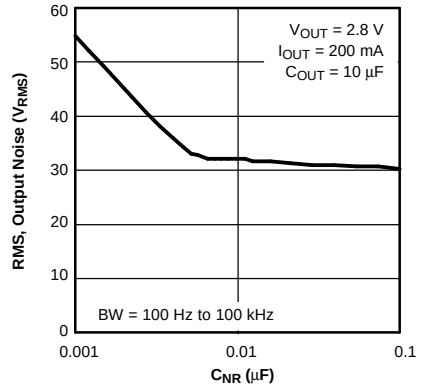


Figure 6.

**TPS73028
DROPOUT VOLTAGE
vs
JUNCTION TEMPERATURE**

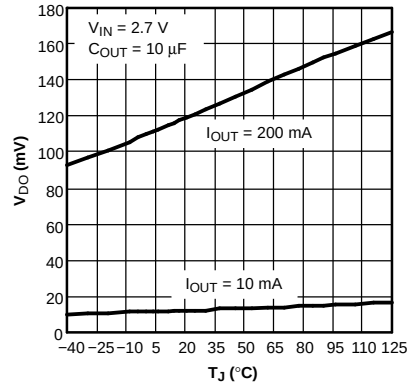


Figure 7.

TYPICAL CHARACTERISTICS (SOT23 PACKAGE) (continued)

TPS73028
RIPPLE REJECTION
vs
FREQUENCY

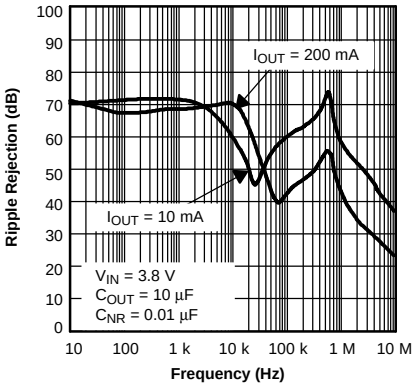


Figure 8.

TPS73028 OUTPUT VOLTAGE,
ENABLE VOLTAGE
vs
TIME (START-UP)

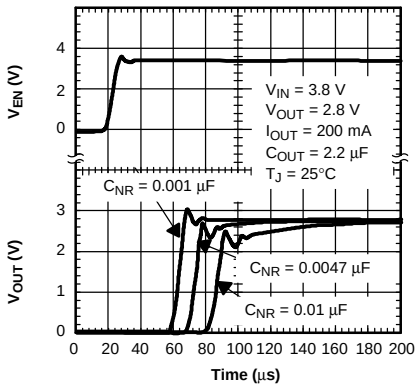


Figure 9.

TPS73028
LINE TRANSIENT RESPONSE

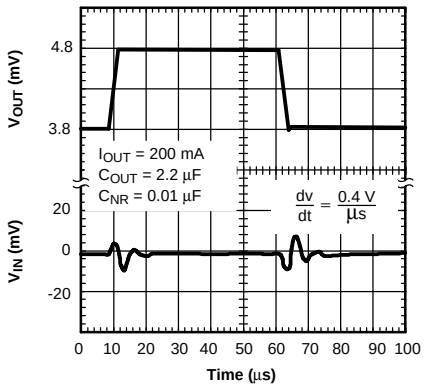


Figure 10.

TPS73028
LOAD TRANSIENT RESPONSE

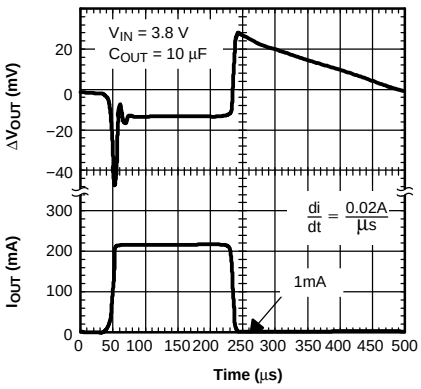


Figure 11.

POWER-UP / POWER-DOWN

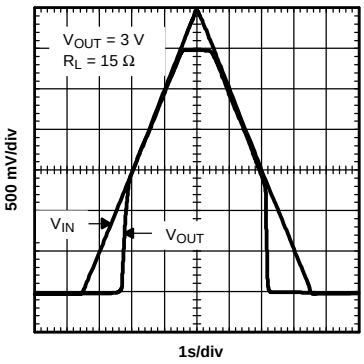


Figure 12.

DROPOUT VOLTAGE
vs
OUTPUT CURRENT

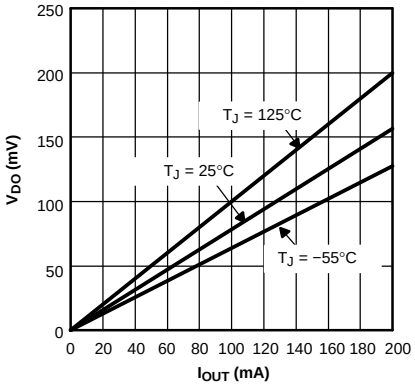


Figure 13.

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

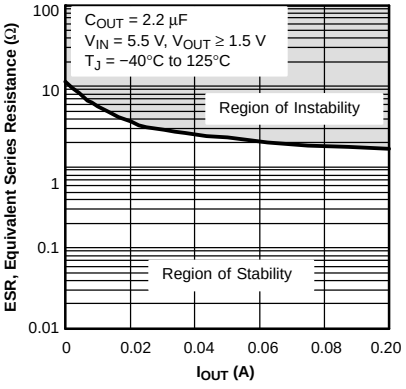


Figure 14.

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

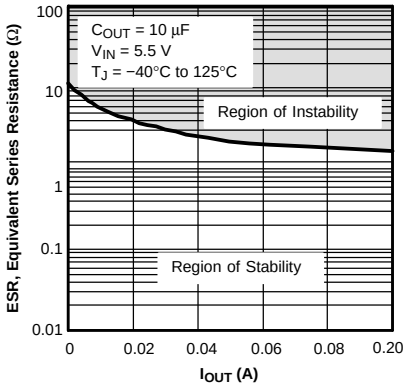


Figure 15.

APPLICATION INFORMATION

The TPS730xx family of low-dropout (LDO) regulators has been optimized for use in noise-sensitive battery-operated equipment. The device features extremely low dropout voltages, high PSRR, ultralow output noise, low quiescent current (170 µA typically), and enable-input to reduce supply currents to less than 1 µA when the regulator is turned off.

A typical application circuit is shown in Figure 16.

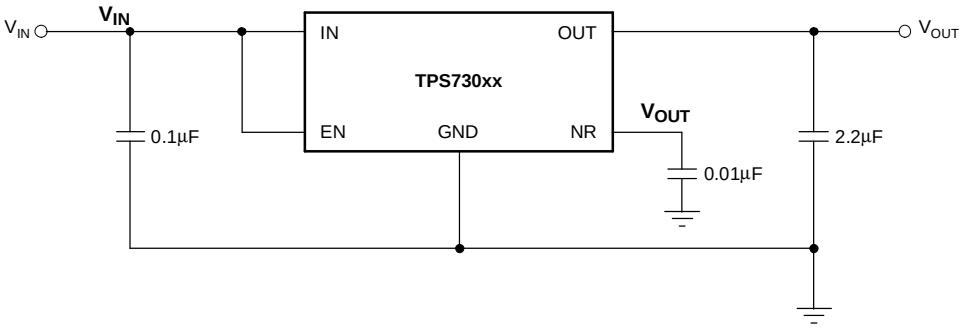


Figure 16. Typical Application Circuit

External Capacitor Requirements

A 0.1-µF or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS730xx, is required for stability and improves transient response, noise rejection, and ripple rejection. A higher-value input capacitor may be necessary if large, fast-rise-time load transients are anticipated or the device is located several inches from the power source.

Like most low dropout regulators, the TPS730xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 2.2 µF. Any 2.2-µF or larger ceramic capacitor is suitable, provided the capacitance does not vary significantly over temperature. If load current is not expected to exceed 100 mA, a 1.0-µF ceramic capacitor can be used.

The internal voltage reference is a key source of noise in an LDO regulator. The TPS730xx has an NR pin which is connected to the voltage reference through a 250-kΩ internal resistor. The 250-kΩ internal resistor, in conjunction with an external bypass capacitor connected to the NR pin, creates a low pass filter to reduce the voltage reference noise and, therefore, the noise at the regulator output. In order for the regulator to operate properly, the current flow out of the NR pin must be at a minimum, because any leakage current creates an IR drop across the internal resistor thus creating an output error. Therefore, the bypass capacitor must have minimal leakage current. The bypass capacitor should be no more than 0.1-µF to ensure that it is fully charged during the quickstart time provided by the internal switch shown in the Functional Block Diagrams

As an example, the TPS73018 exhibits only 23 μV_{RMS} of output voltage noise using a 0.01-µF ceramic bypass capacitor and a 2.2-µF ceramic output capacitor. Note that the output starts up slower as the bypass capacitance increases due to the RC time constant at the NR pin that is created by the internal 250-kΩ resistor and external capacitor.

Board Layout Recommendation to Improve PSRR and Noise Performance

To improve ac measurements like 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 bypass capacitor should connect directly to the GND pin of the device.

APPLICATION INFORMATION (continued)

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 Equation 1:

$$P_{D(max)} = \frac{T_J max - T_A}{R_{\Theta JA}} \quad (1)$$

Where:

- $T_J$max is the maximum allowable junction temperature.
- $R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package (see the Dissipation Ratings Table).
- T_A is the ambient temperature.

The regulator dissipation is calculated using Equation 2:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (2)$$

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

Programming the TPS73001 Adjustable LDO Regulator

The output voltage of the TPS73001 adjustable regulator is programmed using an external resistor divider as shown in Figure 17. The output voltage is calculated using Equation 3:

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R_1}{R_2}\right) \quad (3)$$

Where:

- V_{REF} = 1.225 V typ (the internal reference voltage)

Resistors R1 and R2 should be chosen for approximately 50-µA divider current. Lower value resistors can be used for improved noise performance, but the solution consumes more power. Higher resistor values should be avoided as leakage current into/out of FB across R1/R2 creates an offset voltage that artificially increases/decreases the feedback voltage and thus erroneously decreases/increases V_{OUT}. The recommended design procedure is to choose R2 = 30.1 kΩ to set the divider current at 50 µA, C1 = 15 pF for stability, and then calculate R1 using Equation 4:

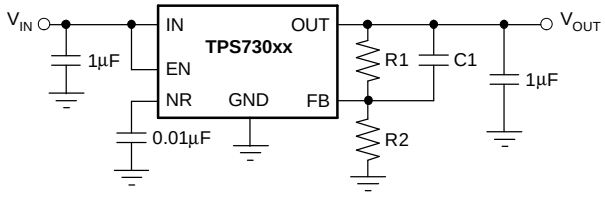
$$R_1 = \left(\frac{V_{OUT}}{V_{ref} - 1}\right) \times R_2 \quad (4)$$

In order to improve the stability of the adjustable version, it is suggested that a small compensation capacitor be placed between OUT and FB. For voltages < 1.8 V, the value of this capacitor should be 100 pF. For voltages > 1.8 V, the approximate value of this capacitor can be calculated as shown in Equation 5:

$$C_1 = \frac{(3 \times 10^{-7}) \times (R_1 + R_2)}{(R_1 \times R_2)} \quad (5)$$

The suggested value of this capacitor for several resistor ratios is shown in the table below. If this capacitor is not used (such as in a unity-gain configuration) or if an output voltage < 1.8 V is chosen, then the minimum recommended output capacitor is 4.7 µF instead of 2.2 µF.

APPLICATION INFORMATION (continued)



OUTPUT VOLTAGE PROGRAMMING GUIDE

OUTPUT VOLTAGE	R1	R2	C1
1.22 V	short	open	0 pF
2.5 V	31.6 kΩ	30.1 kΩ	22 pF
3.3 V	51 kΩ	30.1 kΩ	15 pF
3.6 V	59 kΩ	30.1 kΩ	15 pF

Figure 17. TPS73001 Adjustable LDO Regulator Programming

Regulator Protection

The TPS730xx 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 TPS730xx features internal current limiting and thermal protection. During normal operation, the TPS730xx limits output current to approximately 400 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 or the absolute maximum voltage ratings of the device. 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.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TPS73001DBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73001DBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73001DBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73001DBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73018DBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73018DBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73018DBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73018DBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73025DBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73025DBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73025DBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73025DBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73030DBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73030DBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73030DBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73030DBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73033DBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73033DBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73033DBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TPS73033DBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

(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) or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

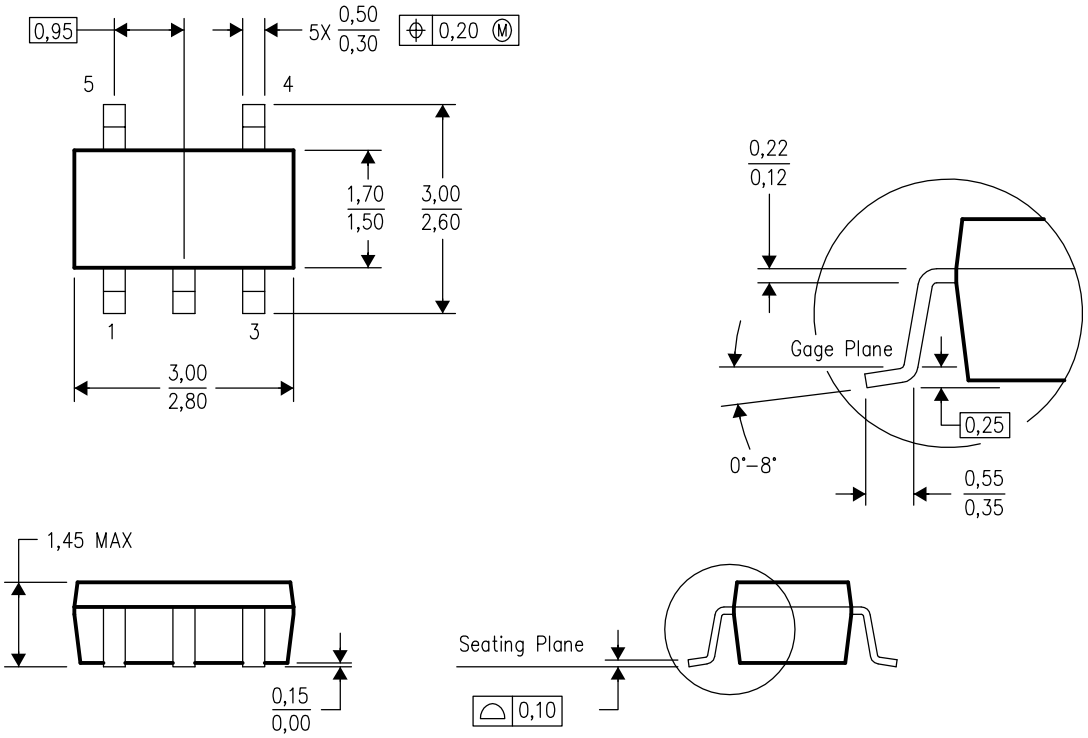
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials.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

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DBV (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4073253–4/H 10/2003

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO–178 Variation AA.

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

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