

TPS79101, TPS79118
TPS79133, TPS79147

SLVS325C – MARCH 2001 – REVISED MAY 2002

ULTRALOW NOISE, HIGH PSRR, FAST RF 100-mA LOW-DROPOUT LINEAR REGULATORS

FEATURES

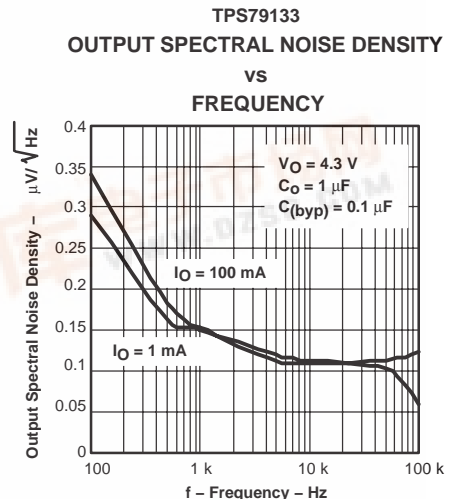
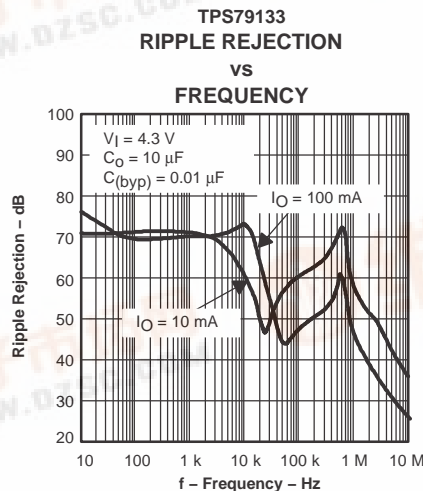
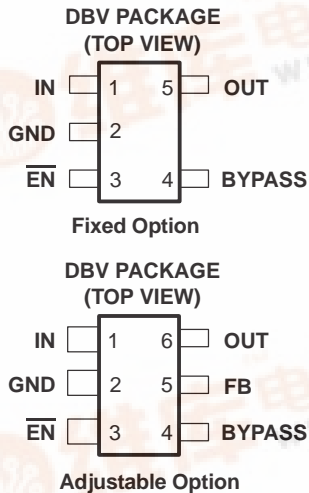
- 100-mA Low-Dropout Regulator With $\overline{\text{EN}}$
- Available in 1.8-V, 3.3-V, 4.7-V, and Adj.
- High PSRR (70 dB at 10 kHz)
- Ultralow Noise (15 μV_{RMS})
- Fast Start-Up Time (63 μs)
- Stable With Any 1- μF Ceramic Capacitor
- Excellent Load/Line Transient
- Very Low Dropout Voltage (38 mV at Full Load, TPS79147)
- 5-Pin SOT23 (DBV) Package
- TPS792xx Provides EN Options

APPLICATIONS

- Cellular and Cordless Telephones
- VCOs
- RF
- Bluetooth™, Wireless LAN
- Handheld Organizers, PDA

DESCRIPTION

The TPS791xx 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 in a small outline, SOT23, package. Each device in the family is stable, with a small 1- μF ceramic capacitor on the output. The family uses an advanced, proprietary BiCMOS fabrication process to yield extremely low dropout voltages (e.g., 38 mV at 100 mA, TPS79147). Each device achieves fast start-up times (approximately 63 μs with a 0.001 μF bypass capacitor) while consuming very 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 TPS79118 exhibits approximately 15 μV_{RMS} of output voltage noise with a 0.1 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.





These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ORDERING INFORMATION

T _J	VOLTAGE	PACKAGE	PART NUMBER		SYMBOL
-40°C to 125°C	1.2 to 5.5 V	SOT23 (DBV)	TPS79101DBVT ⁽¹⁾	TPS79101DBVR ⁽²⁾	PEUI
	1.8 V		TPS79118DBVT ⁽¹⁾	TPS79118DBVR ⁽²⁾	PERI
	3.3 V		TPS79133DBVT ⁽¹⁾	TPS79133DBVR ⁽²⁾	PESI
	4.7 V		TPS79147DBVT ⁽¹⁾	TPS79147DBVR ⁽²⁾	PETI

- (1) The DBVT indicates tape and reel of 250 parts.
(2) The DBVR indicates tape and reel of 3000 parts.

ABSOLUTE MAXIMUM RATINGS

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

	TPS79101, TPS79118 TPS79133, TPS79147
Input voltage range ⁽²⁾	-0.3 V to 6 V
Voltage range at EN	-0.3 V to V _I + 0.3 V
Voltage on OUT	-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 Rating Table
Operating virtual junction temperature range, T _J	-40°C to 150°C
Operating ambient temperature range, T _A	-40°C to 85°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.
(2) All voltage values are with respect to network ground terminal.

PACKAGE DISSIPATION RATING

BOARD	PACKAGE	R _{θJC}	R _{θJA}	DERATING FACTOR ABOVE T _A = 25°C	T _A ≤ 25°C POWER RATING	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING
Low K ⁽¹⁾	DBV	63.75°C/W	256°C/W	3.906 mW/°C	391 mW	215 mW	156 mW
High K ⁽²⁾	DBV	63.75°C/W	178.3°C/W	5.609 mW/°C	561 mW	308 mW	224 mW

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

RECOMMENDED OPERATING CONDITIONS

	MIN	NOM	MAX	UNIT
Input voltage, V _I ⁽¹⁾	2.7		5.5	V
Continuous output current, I _O ⁽²⁾	0		100	mA
Operating junction temperature, T _J	-40		125	°C

- (1) 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)
(2) 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, ($T_J = -40$ to 125°C), $V_I = V_{O(\text{typ})} + 1\text{ V}$, $I_O = 1\text{ mA}$, $\overline{\text{EN}} = 0\text{ V}$, $C_O = 10\text{ }\mu\text{F}$, $C_{O(\text{byp})} = 0.01\text{ }\mu\text{F}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage	TPS79101	$T_J = 25^\circ\text{C}$, $1.22\text{ V} \leq V_O \leq 5.2\text{ V}$	V_O			V
		$0\text{ }\mu\text{A} < I_O < 100\text{ mA}^{(1)}$, $1.22\text{ V} \leq V_O \leq 5.2\text{ V}$	$0.98 V_O$	$1.02 V_O$		
	TPS79118	$T_J = 25^\circ\text{C}$	1.8			
		$0\text{ }\mu\text{A} < I_O < 100\text{ mA}$, $2.8\text{ V} < V_I < 5.5\text{ V}$	1.764	1.836		
	TPS79133	$T_J = 25^\circ\text{C}$	3.3			
		$0\text{ }\mu\text{A} < I_O < 100\text{ mA}$, $4.3\text{ V} < V_I < 5.5\text{ V}$	3.234	3.366		
TPS79147	$T_J = 25^\circ\text{C}$	4.7				
	$0\text{ }\mu\text{A} < I_O < 100\text{ mA}$, $5.2\text{ V} < V_I < 5.5\text{ V}$	4.606	4.794			
Quiescent current (GND current)		$0\text{ }\mu\text{A} < I_O < 100\text{ mA}$, $T_J = 25^\circ\text{C}$	170			μA
		$0\text{ }\mu\text{A} < I_O < 100\text{ mA}$	250			
Load regulation		$0\text{ }\mu\text{A} < I_O < 100\text{ mA}$, $T_J = 25^\circ\text{C}$	5			mV
Output voltage line regulation ($\Delta V_O/V_O$)(2)		$V_O + 1\text{ V} < V_I \leq 5.5\text{ V}$, $T_J = 25^\circ\text{C}$	0.05			%/V
		$V_O + 1\text{ V} < V_I \leq 5.5\text{ V}$	0.12			
Output noise voltage (TPS79118)		$\text{BW} = 100\text{ Hz to } 100\text{ kHz}$, $I_O = 100\text{ mA}$, $T_J = 25^\circ\text{C}$	$C_{(\text{byp})} = 0.001\text{ }\mu\text{F}$	32		μV_{RMS}
			$C_{(\text{byp})} = 0.0047\text{ }\mu\text{F}$	17		
			$C_{(\text{byp})} = 0.01\text{ }\mu\text{F}$	16		
			$C_{(\text{byp})} = 0.1\text{ }\mu\text{F}$	15		
Time, start-up (TPS79133)		$R_L = 33\text{ }\Omega$, $C_O = 1\text{ }\mu\text{F}$, $T_J = 25^\circ\text{C}$	$C_{(\text{byp})} = 0.001\text{ }\mu\text{F}$	53		μs
			$C_{(\text{byp})} = 0.0047\text{ }\mu\text{F}$	67		
			$C_{(\text{byp})} = 0.01\text{ }\mu\text{F}$	98		
Output current limit		$V_O = 0\text{ V}^{(1)}$	285	600		mA
UVLO threshold		V_{CC} rising	2.25	2.65		V
UVLO hysteresis		$T_J = 25^\circ\text{C}$, V_{CC} rising	100			mV

(1) The minimum IN operating voltage is 2.7 V or $V_{O(\text{typ})} + 1\text{ V}$, whichever is greater. The maximum IN voltage is 5.5 V. The maximum output current is 100 mA.

(2) If $V_O \leq 1.8\text{ V}$ then $V_{I\text{min}} = 2.7\text{ V}$, $V_{I\text{max}} = 5.5\text{ V}$:

$$\text{Line regulation (mV)} = (\%/V) \times \frac{V_O(V_{I\text{max}} - 2.7\text{ V})}{100} \times 1000$$

If $V_O \geq 2.5\text{ V}$ then $V_{I\text{min}} = V_O + 1\text{ V}$, $V_{I\text{max}} = 5.5\text{ V}$:

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

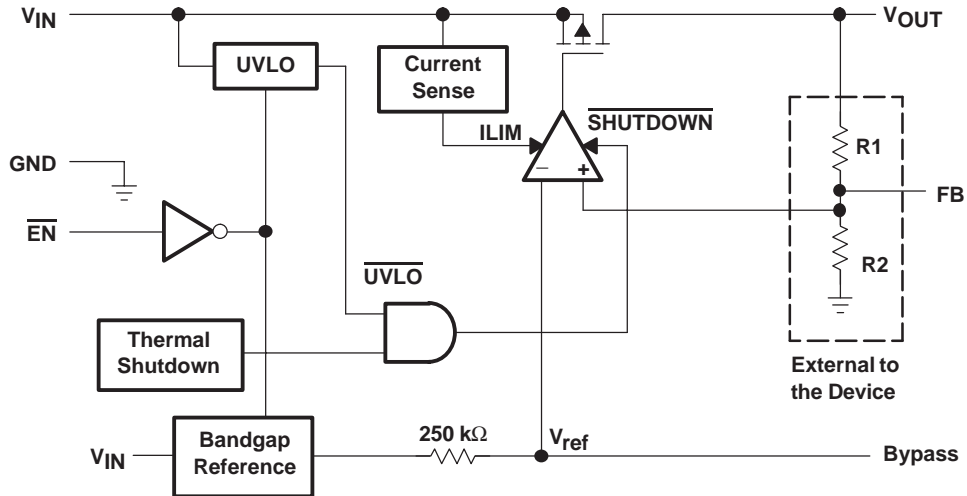
ELECTRICAL CHARACTERISTICS continued

over recommended operating free-air temperature range, ($T_J = -40$ to 125 °C), $V_I = V_{O(typ)} + 1$ V, $I_O = 1$ mA, $\overline{EN} = 0$ V, $C_O = 10$ μ F, $C_{O(byp)} = 0.01$ μ F (unless otherwise noted)

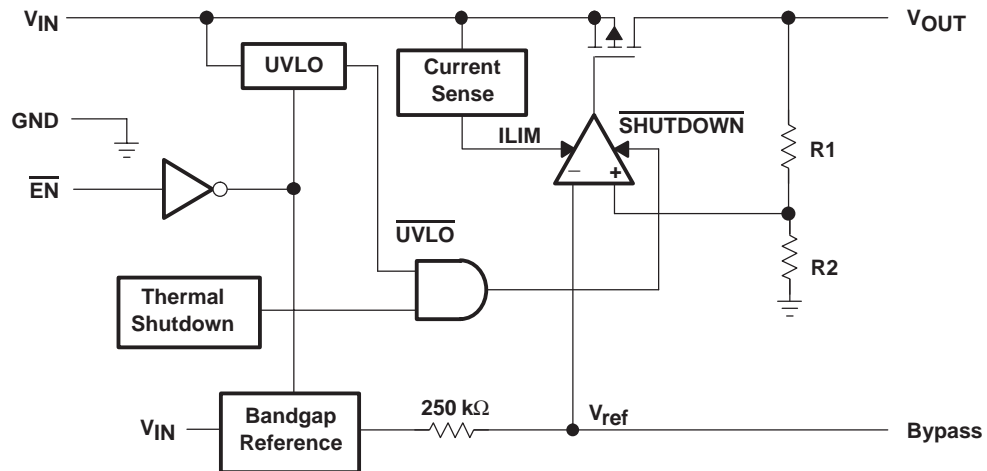
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Standby current		$\overline{EN} = V_I$, 2.7 V < V_I < 5.5 V		0.07	1	μ A
High level enable input voltage		2.7 V < V_I < 5.5 V	2			V
Low level enable input voltage		2.7 V < V_I < 5.5 V			0.7	V
Input current (\overline{EN})		$\overline{EN} = V_I$	-1		1	μ A
Power supply ripple rejection	TPS79118	$f = 100$ Hz, $T_J = 25$ °C, $I_O = 10$ mA		80		dB
		$f = 100$ Hz, $T_J = 25$ °C, $I_O = 100$ mA		75		
		$f = 10$ kHz, $T_J = 25$ °C, $I_O = 100$ mA		72		
		$f = 100$ kHz, $T_J = 25$ °C, $I_O = 100$ mA		45		
	TPS79133	$f = 100$ Hz, $T_J = 25$ °C, $I_O = 10$ mA		70		
		$f = 100$ Hz, $T_J = 25$ °C, $I_O = 100$ mA		75		
		$f = 10$ kHz, $T_J = 25$ °C, $I_O = 100$ mA		73		
		$f = 100$ kHz, $T_J = 25$ °C, $I_O = 100$ mA		37		
Dropout voltage ⁽¹⁾	TPS79133	$I_O = 100$ mA, $T_J = 25$ °C		50		mV
		$I_O = 100$ mA			90	
	TPS79147	$I_O = 100$ mA, $T_J = 25$ °C		38		
		$I_O = 100$ mA			70	

(1) I_N voltage equals $V_{O(typ)} - 100$ mV; The TPS79118 dropout voltage is limited by the input voltage range limitations.

FUNCTIONAL BLOCK DIAGRAM—ADJUSTABLE VERSION



FUNCTIONAL BLOCK DIAGRAM—FIXED VERSION



Terminal Functions

TERMINAL			I/O	DESCRIPTION
NAME	ADJ	FIXED		
BYPASS	4	4		An external bypass capacitor, connected to this terminal, in conjunction with an internal resistor, creates a low-pass filter to further reduce regulator noise.
$\overline{\text{EN}}$	3	3	I	The $\overline{\text{EN}}$ terminal is an input which enables or shuts down the device. When $\overline{\text{EN}}$ is a logic high, the device will be in shutdown mode. When $\overline{\text{EN}}$ is a logic low, the device will be enabled.
FB	5	N/A	I	This terminal is the feedback input voltage for the adjustable device.
GND	2	2		Regulator ground
IN	1	1	I	The IN terminal is the input to the device.
OUT	6	5	O	The OUT terminal is the regulated output of the device.

TYPICAL CHARACTERISTICS

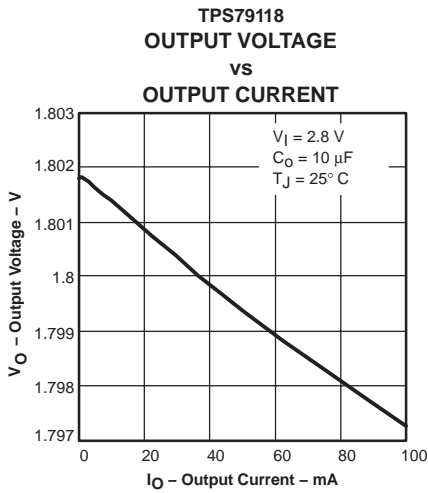


Figure 1

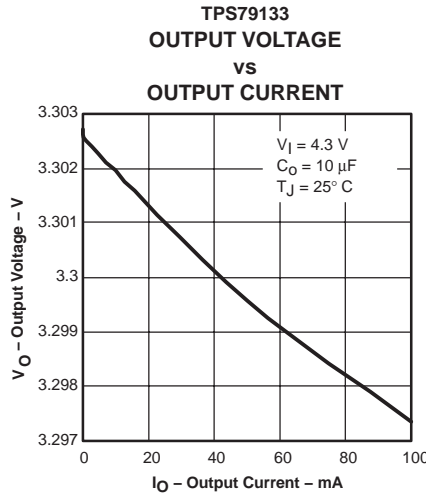


Figure 2

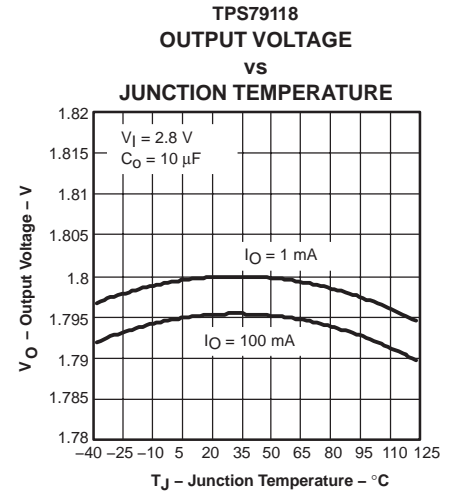


Figure 3

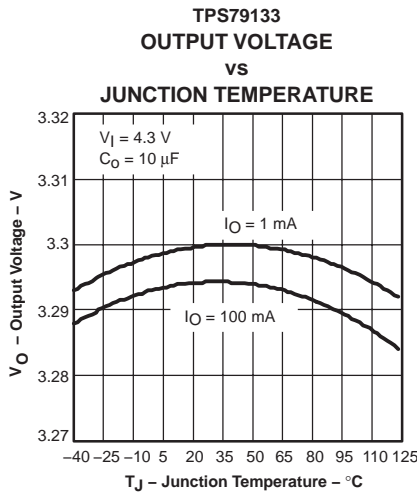


Figure 4

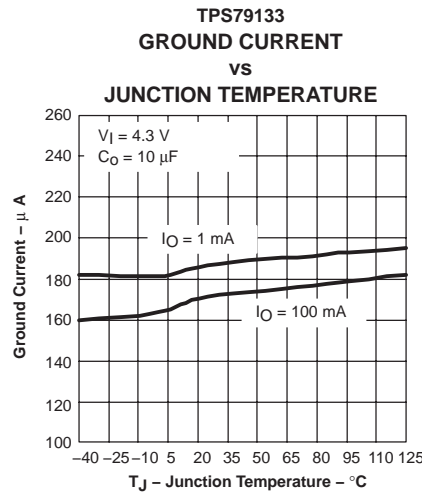


Figure 5

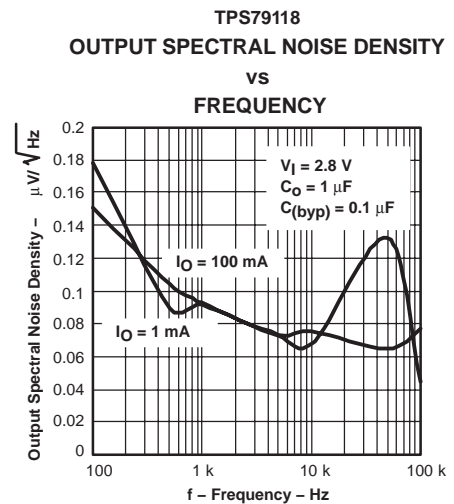


Figure 6

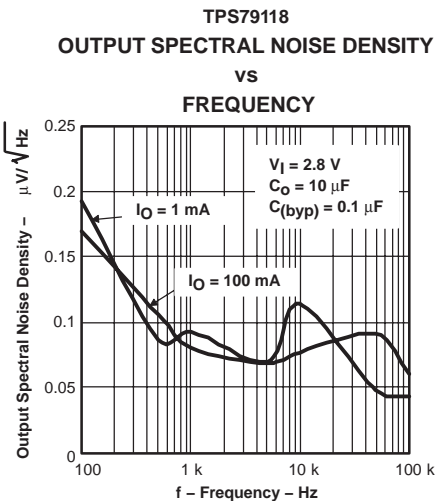


Figure 7

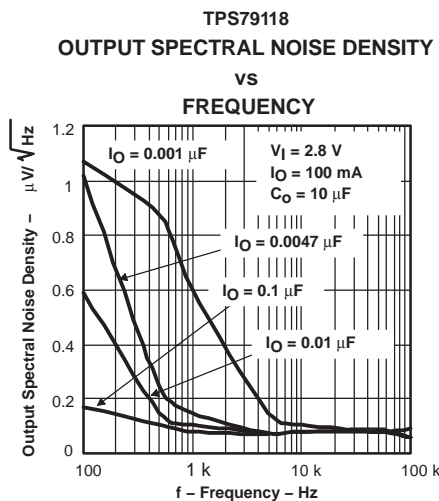


Figure 8

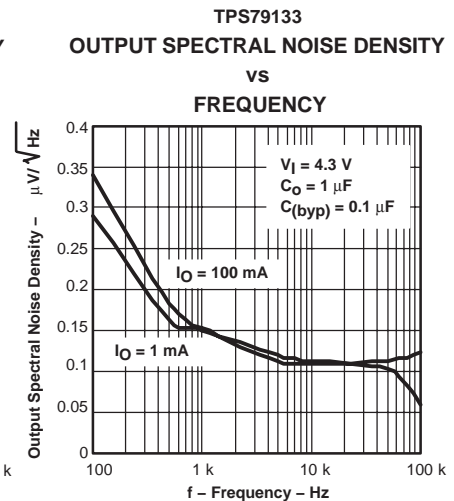


Figure 9

TYPICAL CHARACTERISTICS

**TPS79133
OUTPUT SPECTRAL NOISE DENSITY
VS
FREQUENCY**

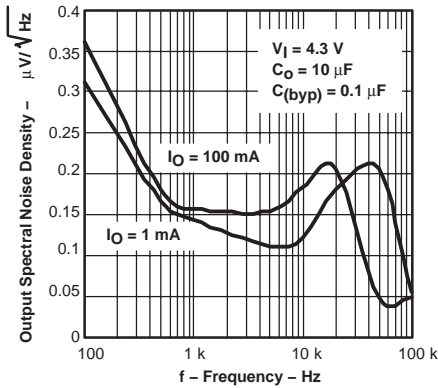


Figure 10

**TPS79133
OUTPUT SPECTRAL NOISE DENSITY
VS
FREQUENCY**

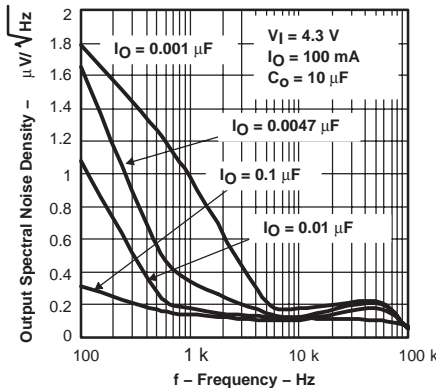


Figure 11

**ROOT MEAN SQUARED OUTPUT NOISE
VS
BYPASS CAPACITANCE**

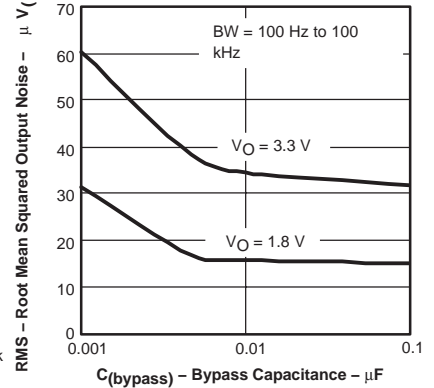


Figure 12

**TPS79133
OUTPUT IMPEDANCE
VS
FREQUENCY**

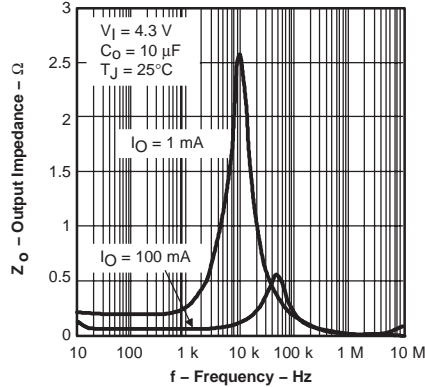


Figure 13

**TPS79133
DROPOUT VOLTAGE
VS
JUNCTION TEMPERATURE**

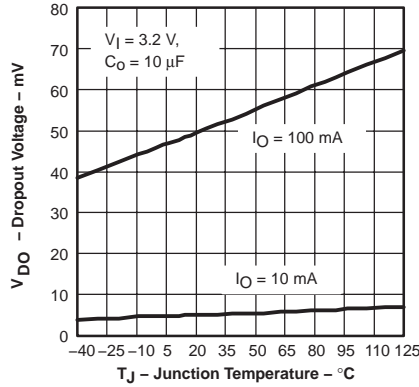


Figure 14

**TPS792133
DROPOUT VOLTAGE
VS
OUTPUT CURRENT**

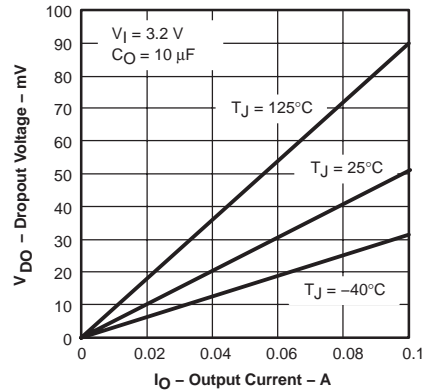


Figure 15

**TPS79101
DROPOUT VOLTAGE
VS
INPUT VOLTAGE**

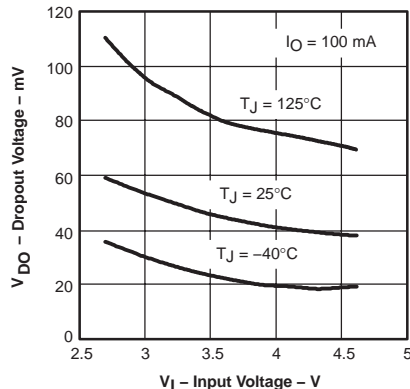


Figure 16

**MINIMUM REQUIRED INPUT VOLTAGE
VS
OUTPUT VOLTAGE**

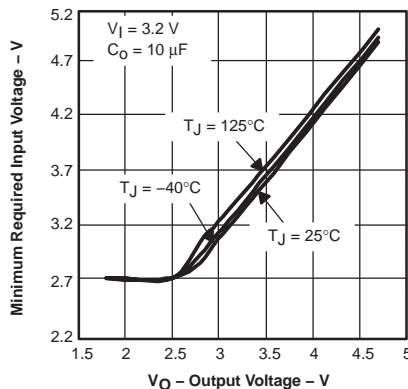


Figure 17

**TPS79118
RIPPLE REJECTION
VS
FREQUENCY**

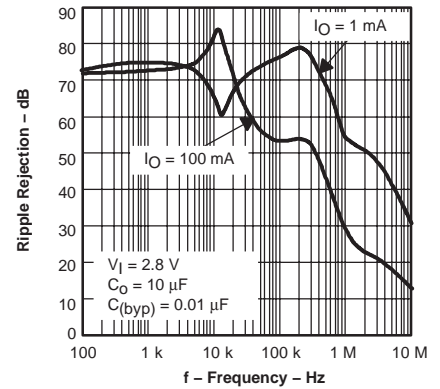
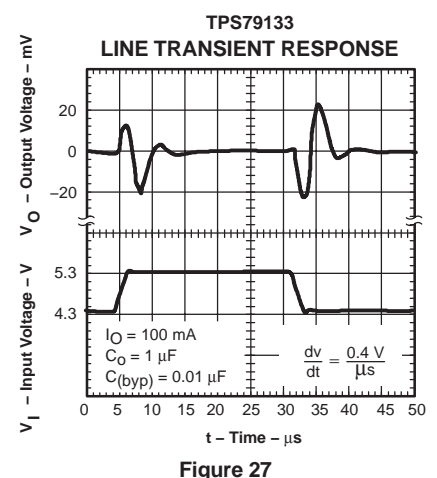
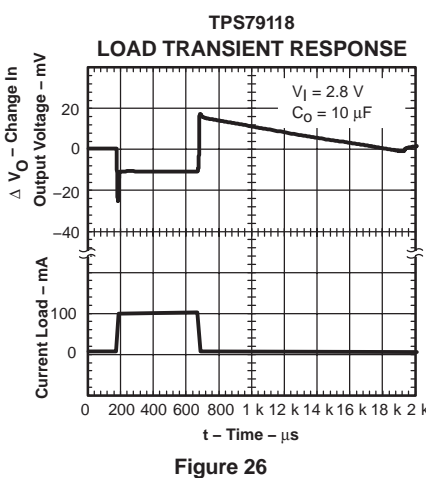
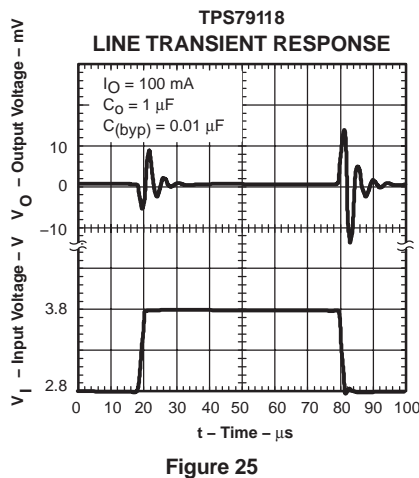
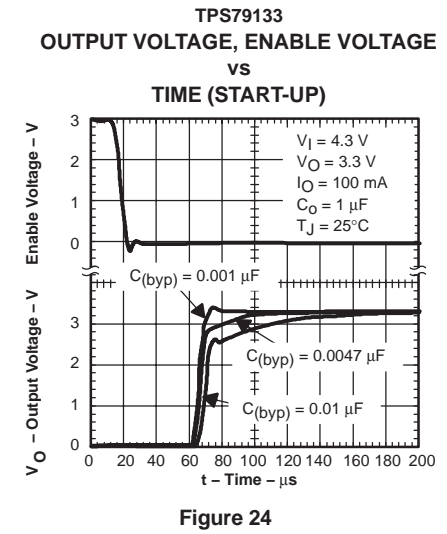
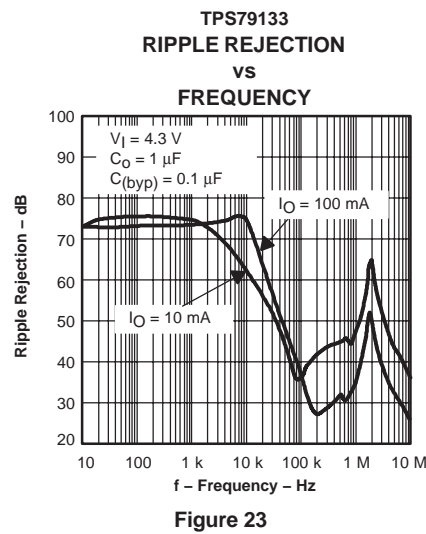
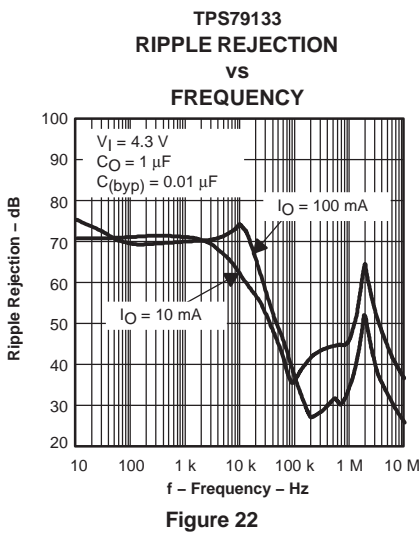
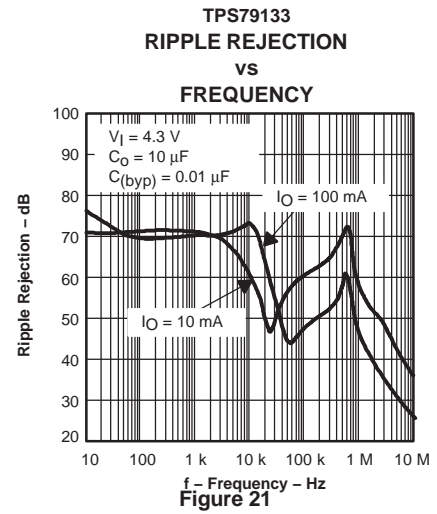
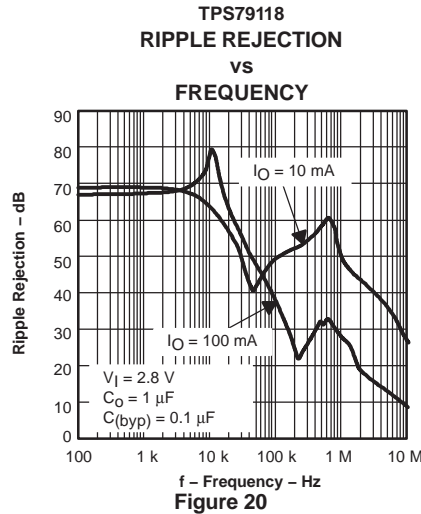
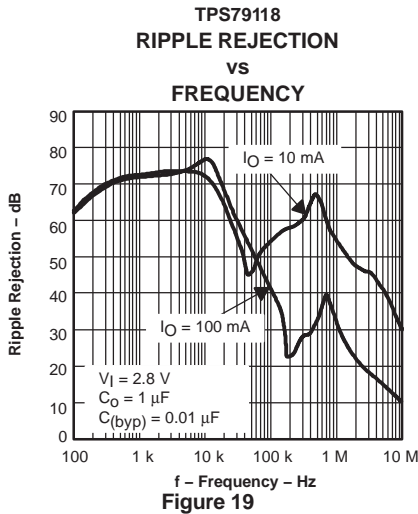
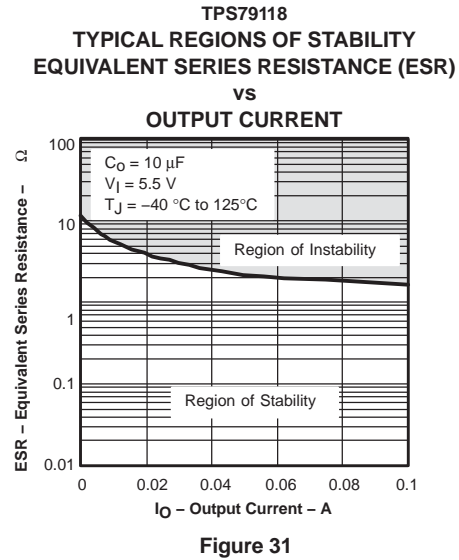
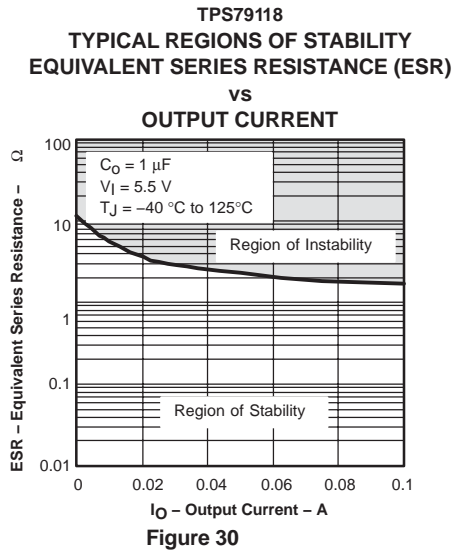
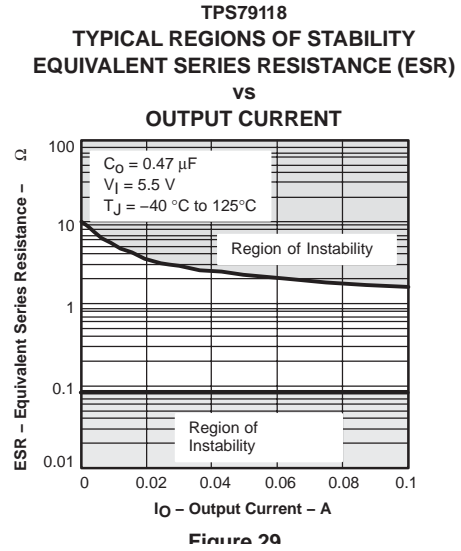
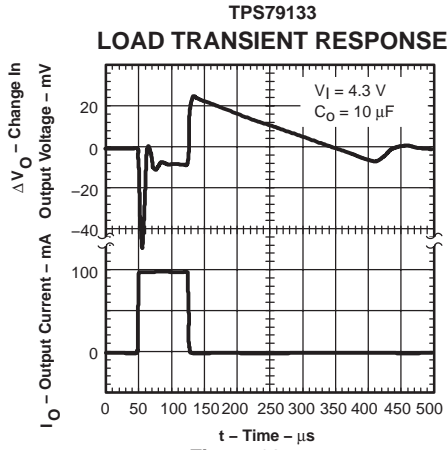


Figure 18

TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS



APPLICATION INFORMATION

The TPS791xx family of low-dropout (LDO) regulators have 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 32.

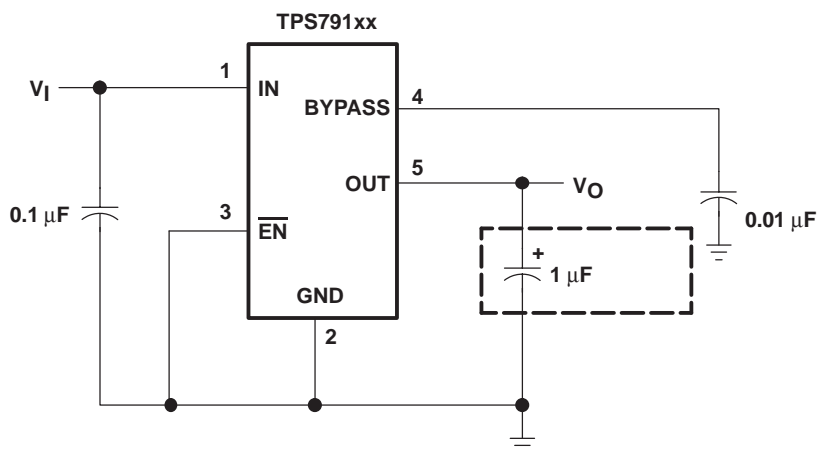


Figure 32. Typical Application Circuit

EXTERNAL CAPACITOR REQUIREMENTS

A 0.1- μF or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS791xx, is required for stability and to improve transient response, noise rejection, and ripple 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 TPS791xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 1 μF . Any 1 μF or larger ceramic capacitor is suitable. The device is also stable with a 0.47 μF ceramic capacitor with at least 75 m Ω of ESR.

The internal voltage reference is a key source of noise in an LDO regulator. The TPS791xx has a BYPASS pin which is connected to the voltage reference through a 250-k Ω internal resistor. The 250-k Ω internal resistor, in conjunction with an external bypass capacitor connected to the BYPASS 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 BYPASS 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.

For example, the TPS79118 exhibits approximately 15 μV_{RMS} of output voltage noise using a 0.1 μF ceramic bypass capacitor and a 1 μF ceramic output capacitor. Note that the output starts up slower as the bypass capacitance increases due to the RC time constant at the bypass pin that is created by the internal 250 k Ω 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 ground pin of the device. In addition, the ground connection for the bypass capacitor should connect directly to the ground pin of the device.

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:

$$P_{D(max)} = \frac{T_{Jmax} - T_A}{R_{\theta JA}} \quad (1)$$

Where:

T_{Jmax} is the maximum allowable junction temperature.

$R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package, see the dissipation rating table.

T_A is the ambient temperature.

The regulator dissipation is calculated using:

$$P_D = (V_I - V_O) \times I_O \quad (2)$$

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

PROGRAMMING THE TPS79101 ADJUSTABLE LDO REGULATOR

The output voltage of the TPS79101 adjustable regulator is programmed using an external resistor divider as shown in Figure 33. The output voltage is calculated using:

$$V_O = V_{ref} \times \left(1 + \frac{R1}{R2}\right) \quad (3)$$

Where:

$V_{ref} = 1.2246$ V typ (the internal reference voltage)

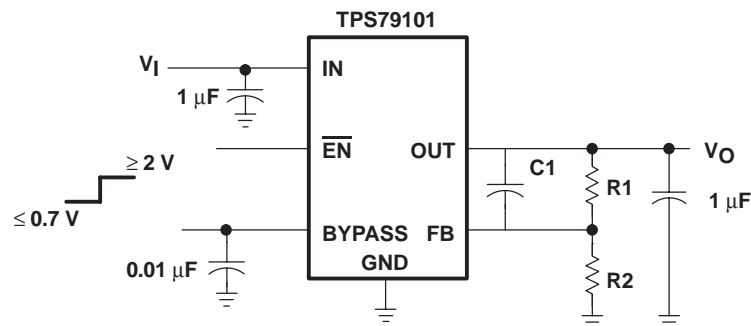
Resistors R1 and R2 should be chosen for approximately 50- μ A divider current. Lower value resistors can be used for improved noise performance, but the solution consumes more power. Higher resistor values should be avoided as leakage current into/out of FB across R1/R2 creates an offset voltage that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

$$R1 = \left(\frac{V_O}{V_{ref}} - 1\right) \times R2 \quad (4)$$

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:

$$C1 = \frac{(3 \times 10^{-7}) \times (R1 + R2)}{(R1 \times R2)} \quad (5)$$

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 2.2 μ F instead of 1 μ F.



**OUTPUT VOLTAGE
PROGRAMMING GUIDE**

OUTPUT VOLTAGE	R1	R2	C1
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 33. TPS79101 Adjustable LDO Regulator Programming

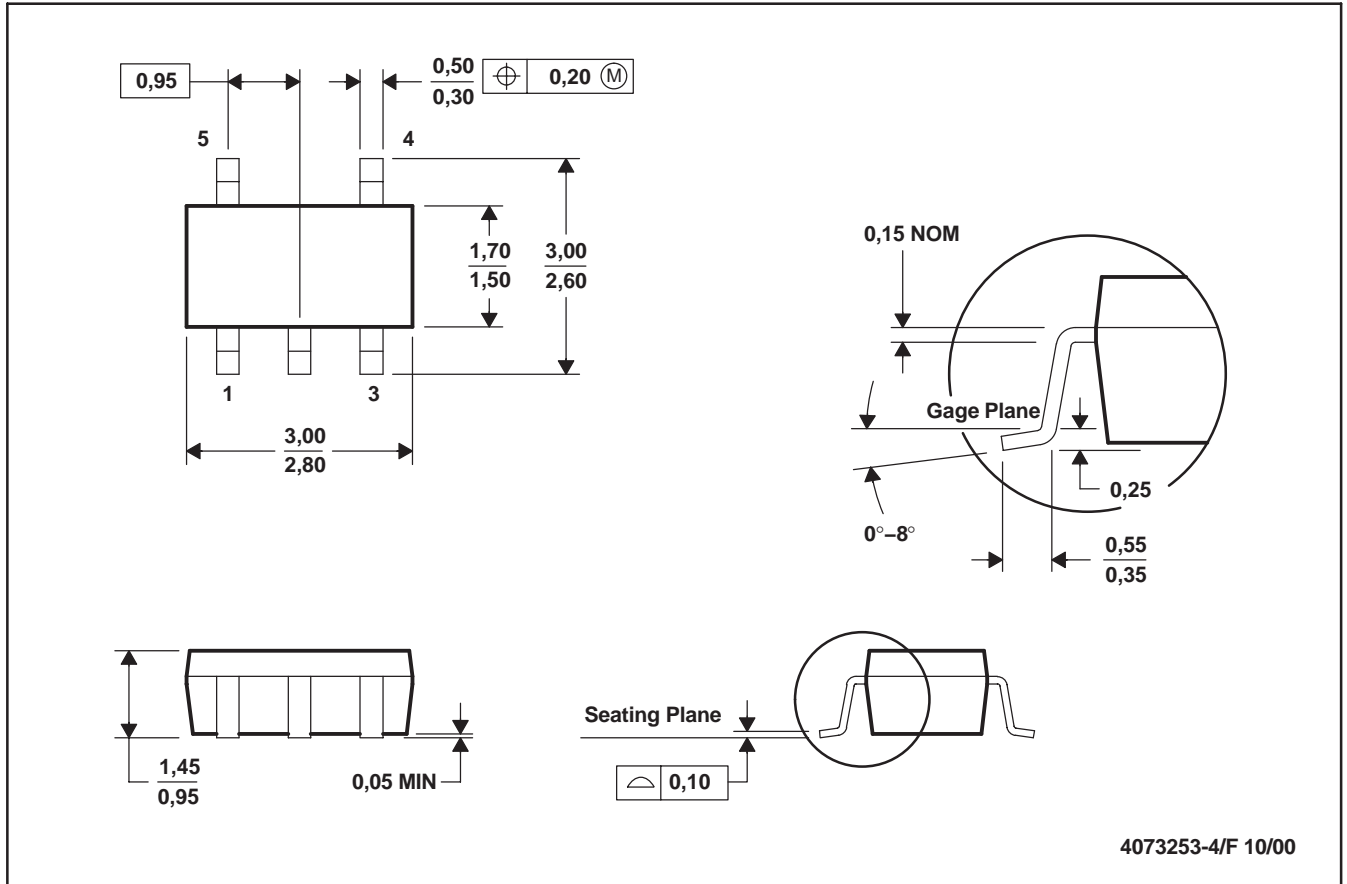
REGULATOR PROTECTION

The TPS791xx 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 TPS791xx features internal current limiting and thermal protection. During normal operation, the TPS791xx 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.

MECHANICAL DATA

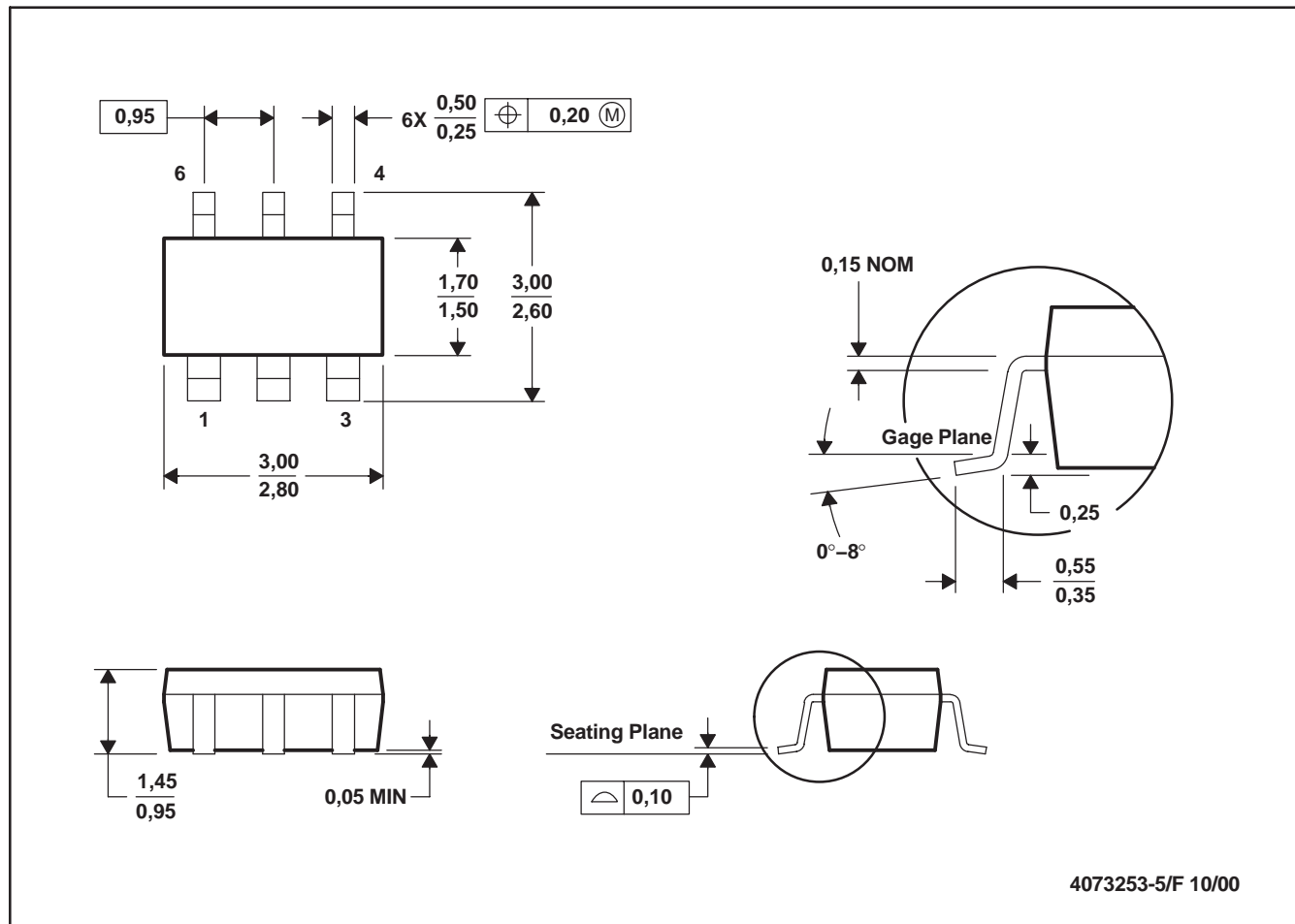
DBV (R-PDSO-G5) PLASTIC SMALL-OUTLINE



- 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

MECHANICAL DATA

DBV (R-PDSO-G6) PLASTIC SMALL-OUTLINE



- 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. Leads 1, 2, 3 are wider than leads 4, 5, 6 for package orientation.
 E. Pin 1 is located below the first letter of the top side symbolization.

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