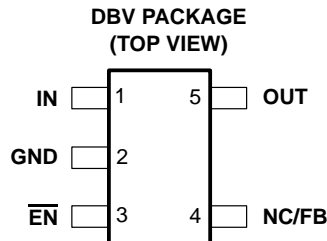# TPS77001, TPS77012, TPS77015, TPS77018, TPS77025
# TPS77027, TPS77028, TPS77030, TPS77033, TPS77050
# ULTRALOW-POWER 50-mA LOW-DROPOUT LINEAR REGULATORS

- **50-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 50 mA**
- **1 μA Quiescent Current in Standby Mode**
- **Dropout Voltage Typically 35 mV at 50 mA**
- **Over Current Limitation**
- **−40°C to 125°C Operating Junction Temperature Range**
- **5-Pin SOT-23 (DBV) Package**

**DBV PACKAGE**
**(TOP VIEW)**

| | | |
|---|---|---|
| IN | 1 | 5 OUT |
| GND | 2 | |
| $\overline{EN}$ | 3 | 4 NC/FB |

**TPS77033**
**GROUND CURRENT**
**vs**
**FREE-AIR TEMPERATURE**



## description

The TPS770xx 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 TPS770xx 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 35 mV at 50 mA of load current (TPS77050) — 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 50 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 TPS770xx 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 TPS770xx 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).
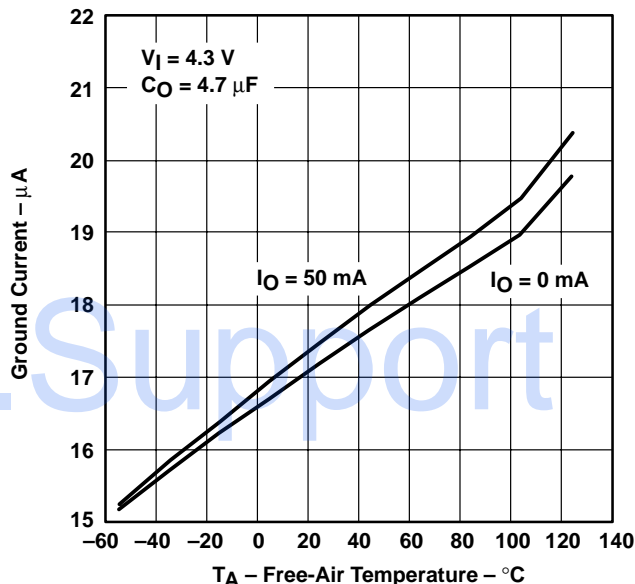
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

**TEXAS INSTRUMENTS**

**AVAILABLE OPTIONS**

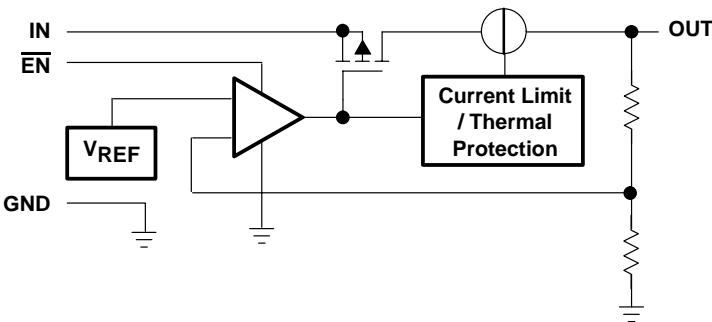| T$_J$ | VOLTAGE | PACKAGE | PART NUMBER | | SYMBOL |
|---|---|---|---|---|---|
| −40°C to 125°C | Variable 1.2V to 5.5V | SOT-23 (DBV) | TPS77001DBVT† | TPS77001DBVR‡ | PCPI |
| | 1.2 V | | TPS77012DBVT† | TPS77012DBVR‡ | PCQI |
| | 1.5 V | | TPS77015DBVT† | TPS77015DBVR‡ | PCRI |
| | 1.8 V | | TPS77018DBVT† | TPS77018DBVR‡ | PCSI |
| | 2.5 V | | TPS77025DBVT† | TPS77025DBVR‡ | PCTI |
| | 2.7 V | | TPS77027DBVT† | TPS77027DBVR‡ | PCUI |
| | 2.8 V | | TPS77028DBVT† | TPS77028DBVR‡ | PCVI |
| | 3.0 V | | TPS77030DBVT† | TPS77030DBVR‡ | PCWI |
| | 3.3 V | | TPS77033DBVT† | TPS77033DBVR‡ | PCXI |
| | 5.0 V | | TPS77050DBVT† | TPS77050DBVR‡ | PCYI |

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

## functional block diagram

**TPS77001**
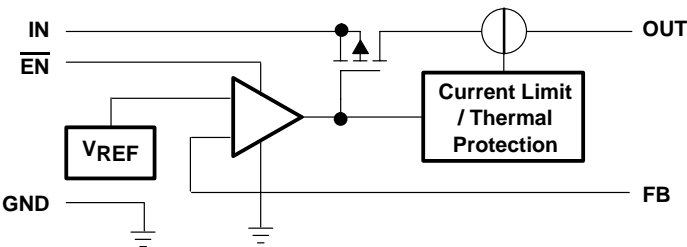


**TPS77012/15/18/25/27/28/30/33/50**

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INSTRUMENTS

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**Terminal Functions**

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| GND | 2 | | Ground |
| $\overline{EN}$ | 3 | I | Enable input |
| FB | 4 | I | Feedback voltage (TPS77001 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**

| BOARD | PACKAGE | $R_{\theta JC}$ | $R_{\theta JA}$ | DERATING FACTOR ABOVE $T_A$ = 25°C | $T_A \leq 25°C$ POWER RATING | $T_A$ = 70°C POWER RATING | $T_A$ = 85°C POWER RATING |
|---|---|---|---|---|---|---|---|
| Low K‡ | DBV | 65.8 °C/W | 259 °C/W | 3.9 mW/°C | 386 mW | 212 mW | 154 mW |
| High K§ | DBV | 65.8 °C/W | 180 °C/W | 5.6 mW/°C | 555 mW | 305 mW | 222 mW |

‡ 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.
§ 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.

## 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 | | 50 | 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.

**TEXAS INSTRUMENTS**

## electrical characteristics over recommended operating free–air temperature range, $V_I = V_{O(typ)} + 1$ V, $I_O = 50$ mA, $\overline{EN} = 0V$, $C_O = 4.7\ \mu F$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| Output voltage (10 µA to 50 mA load) (see Note 4) | TPS77001 | $1.2$ V $\leq V_O \leq 5.5$ V, | $T_J = 25°C$ | | $V_O$ | | V |
| | | $1.2$ V $\leq V_O \leq 5.5$ V, | $T_J = -40°C$ to $125°C$ | $0.97V_O$ | | $1.03V_O$ | |
| | TPS77012 | $T_J = 25°C$, | $2.7$ V $< V_{IN} < 10$ V | | $1.224$ | | |
| | | $T_J = -40°C$ to $125°C$, | $2.7$ V $< V_{IN} < 10$ V | $1.187$ | | $1.261$ | |
| | TPS77015 | $T_J = 25°C$, | $2.7$ V $< V_{IN} < 10$ V | | $1.5$ | | |
| | | $T_J = -40°C$ to $125°C$, | $2.7$ V $< V_{IN} < 10$ V | $1.455$ | | $1.545$ | |
| | TPS77018 | $T_J = 25°C$, | $2.8$ V $< V_{IN} < 10$ V | | $1.8$ | | |
| | | $T_J = -40°C$ to $125°C$, | $2.8$ V $< V_{IN} < 10$ V | $1.746$ | | $1.854$ | |
| | TPS77025 | $T_J = 25°C$, | $3.5$ V $< V_{IN} < 10$ V | | $2.5$ | | |
| | | $T_J = -40°C$ to $125°C$, | $3.5$ V $< V_{IN} < 10$ V | $2.425$ | | $2.575$ | |
| | TPS77027 | $T_J = 25°C$, | $3.7$ V $< V_{IN} < 10$ V | | $2.7$ | | |
| | | $T_J = -40°C$ to $125°C$, | $3.7$ V $< V_{IN} < 10$ V | $2.619$ | | $2.781$ | |
| | TPS77028 | $T_J = 25°C$, | $3.8$ V $< V_{IN} < 10$ V | | $2.8$ | | |
| | | $T_J = -40°C$ to $125°C$, | $3.8$ V $< V_{IN} < 10$ V | $2.716$ | | $2.884$ | |
| | TPS77030 | $T_J = 25°C$, | $4.0$ V $< V_{IN} < 10$ V | | $3.0$ | | |
| | | $T_J = -40°C$ to $125°C$, | $4.0$ V $< V_{IN} < 10$ V | $2.910$ | | $3.090$ | |
| | TPS77033 | $T_J = 25°C$, | $4.3$ V $< V_{IN} < 10$ V | | $3.3$ | | |
| | | $T_J = -40°C$ to $125°C$, | $4.3$ V $< V_{IN} < 10$ V | $3.201$ | | $3.399$ | |
| | TPS77050 | $T_J = 25°C$, | $6.0$ 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) | | $\overline{EN} = 0V$, $T_J = 25°C$ | $0$ mA $< I_O < 50$mA, | | $17$ | | µA |
| | | $\overline{EN} = 0V$, $T_J = -40°C$ to $125°C$ | $I_O = 50$mA, | | | $28$ | |
| Output voltage line regulation ($\Delta V_O/V_O$) (see Notes 4 and 5) | | $V_O + 1$ V $< V_I \leq 10$ V, | $T_J = 25°C$ | | $0.04$ | | %/V |
| | | $V_O + 1$ V $< V_I \leq 10$ V, $T_J = -40°C$ to $125°C$ | | | | $0.1$ | |
| Load regulation | | $\overline{EN} = 0V$, $T_J = 25°C$ | $I_O = 0$ to $50$ mA, | | $8$ | | mV |
| Output noise voltage | | BW = 300 Hz to 50 kHz, $C_O = 10\ \mu F$, | $T_J = 25°C$ | | $190$ | | µVrms |
| Output current limit | | $V_O = 0V$, | 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 50 mA.

5. If $V_O \leq 1.8$ V then $V_{Imin} = 2.7$ V, $V_{Imax} = 10$ V:

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

If $V_O \geq 2.5$ V then $V_{Imin} = V_O + 1$ V, $V_{Imax} = 10$ V:

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

TEXAS
INSTRUMENTS

**electrical characteristics over recommended operating free–air temperature range, $V_I$ = $V_{O(typ)}$ + 1 V, $I_O$ = 50 mA, $\overline{EN}$ = 0V, $C_O$ = 4.7 $\mu$F (unless otherwise noted) (continued)**

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| FB input current | | FB = 1.224 V (TPS77001) | | −1 | | 1 | $\mu$A |
| 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 $\mu$F, See Note 4 | | 60 | | dB |
| Input current (EN) | | $\overline{EN}$ = 0 V | | −1 | 0 | 1 | $\mu$A |
| | | $\overline{EN}$ = $V_I$ | | −1 | | 1 | $\mu$A |
| Dropout voltage (see Note 6) | TPS77028 | $I_O$ = 50 mA, | $T_J$ = 25°C | | 60 | | mV |
| | | $I_O$ = 50 mA | $T_J$ = −40°C to 125°C | | | 125 | |
| | TPS77030 | $I_O$ = 50 mA, | $T_J$ = 25°C | | 57 | | |
| | | $I_O$ = 50 mA | $T_J$ = −40°C to 125°C | | | 115 | |
| | TPS77033 | $I_O$ = 50 mA, | $T_J$ = 25°C | | 48 | | |
| | | $I_O$ = 50 mA | $T_J$ = −40°C to 125°C | | | 100 | |
| | TPS77050 | $I_O$ = 50 mA, | $T_J$ = 25°C | | 35 | | |
| | | $I_O$ = 50 mA | $T_J$ = −40°C to 125°C | | | 85 | |

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 $\mu$A, maximum output current 50 mA.

6. IN voltage equals $V_O$(Typ) −100mV; TPS77001 output voltage set to 3.3 V nominal with external resistor divider. TPS77012, TPS77015, TPS77018, TPS77025, and TPS77027 dropout voltage limited by input voltage range limitations.
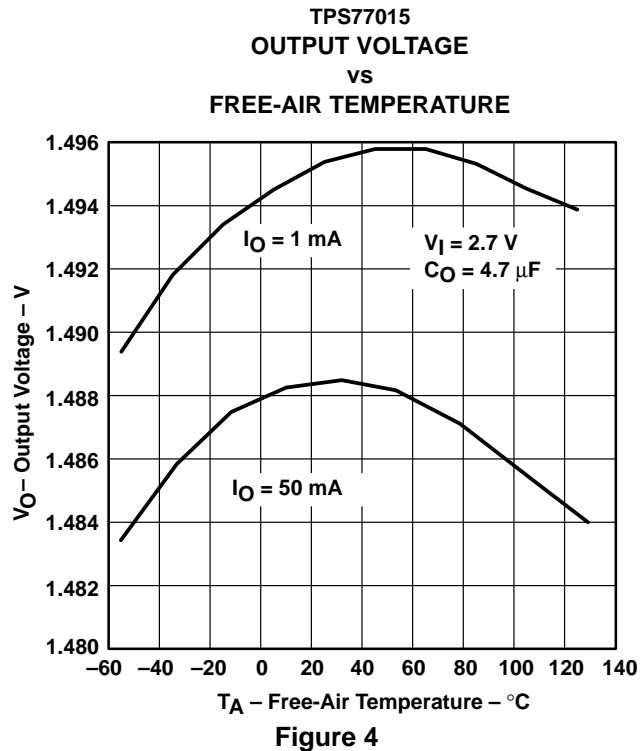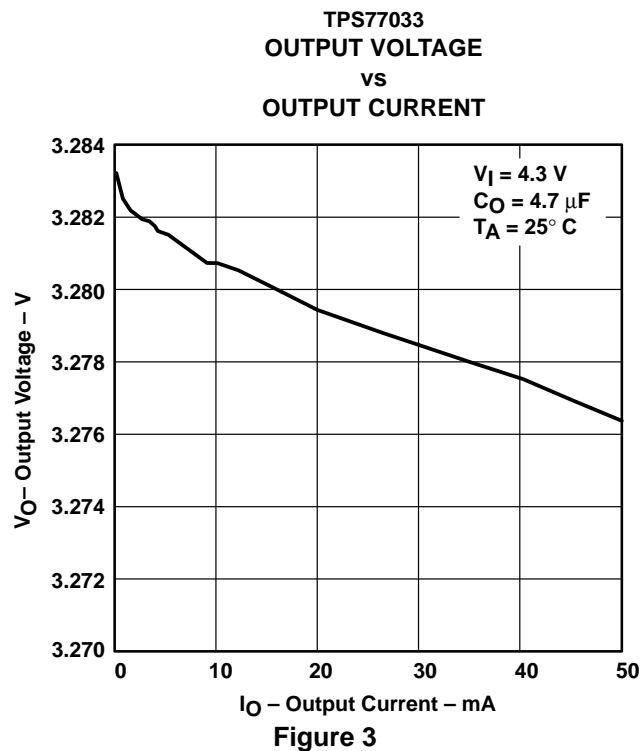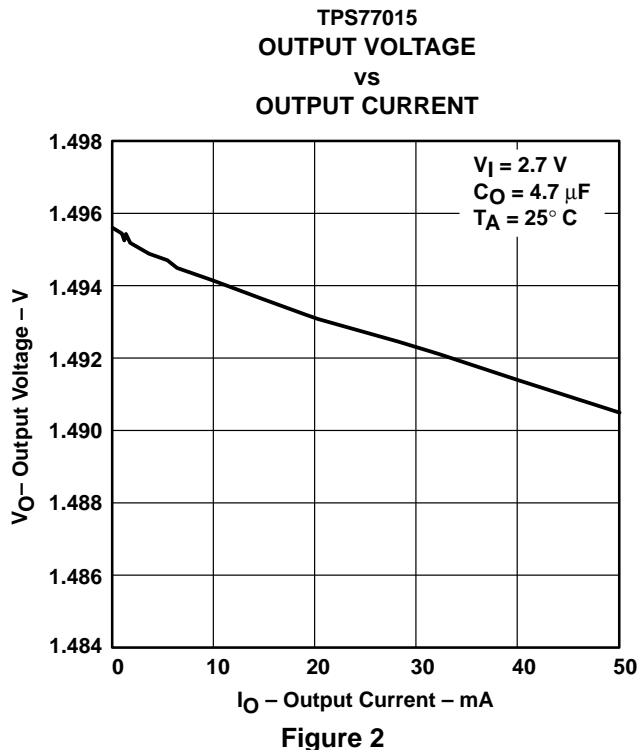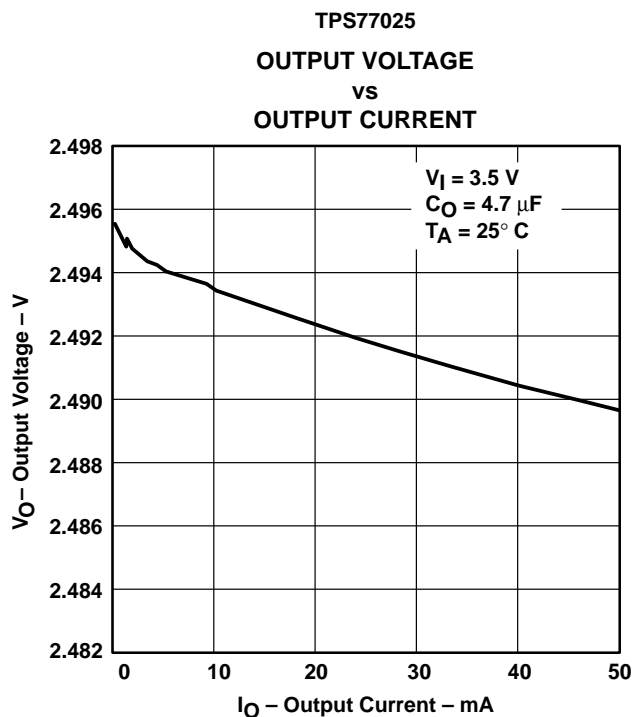
# TYPICAL CHARACTERISTICS

## 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 |

**TEXAS INSTRUMENTS**

## TYPICAL CHARACTERISTICS

TPS77025

**OUTPUT VOLTAGE**
**vs**
**OUTPUT CURRENT**

$V_I = 3.5$ V
$C_O = 4.7$ μF
$T_A = 25°$ C

**Figure 1**

TPS77015

**OUTPUT VOLTAGE**
**vs**
**OUTPUT CURRENT**

$V_I = 2.7$ V
$C_O = 4.7$ μF
$T_A = 25°$ C

**Figure 2**

TPS77033

**OUTPUT VOLTAGE**
**vs**
**OUTPUT CURRENT**

$V_I = 4.3$ V
$C_O = 4.7$ μF
$T_A = 25°$ C

**Figure 3**

TPS77015

**OUTPUT VOLTAGE**
**vs**
**FREE-AIR TEMPERATURE**

$I_O = 1$ mA
$I_O = 50$ mA
$V_I = 2.7$ V
$C_O = 4.7$ μF

**Figure 4**

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**TPS77001, TPS77012, TPS77015, TPS77018, TPS77025**
**TPS77027, TPS77028, TPS77030, TPS77033, TPS77050**
**ULTRALOW-POWER 50-mA LOW-DROPOUT LINEAR REGULATORS**

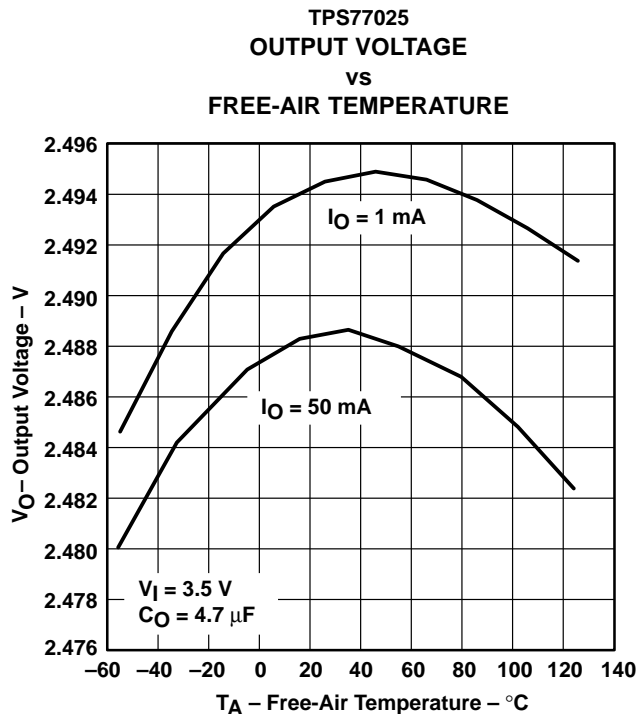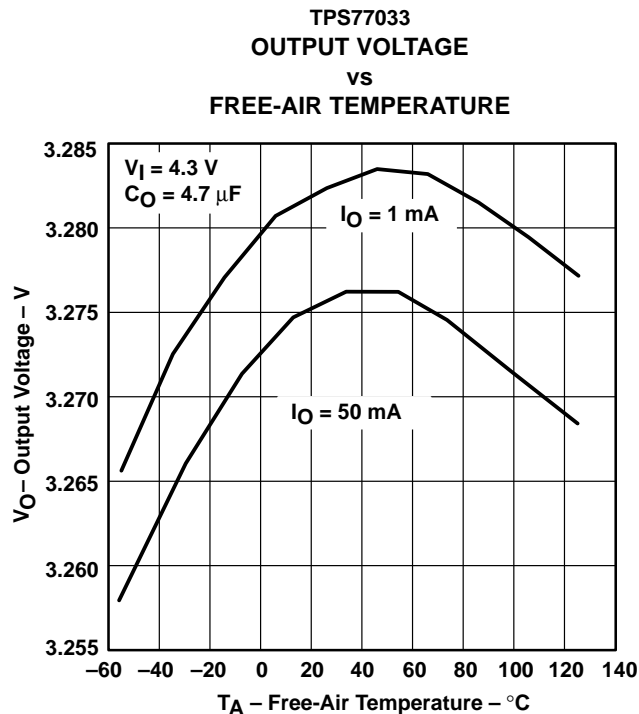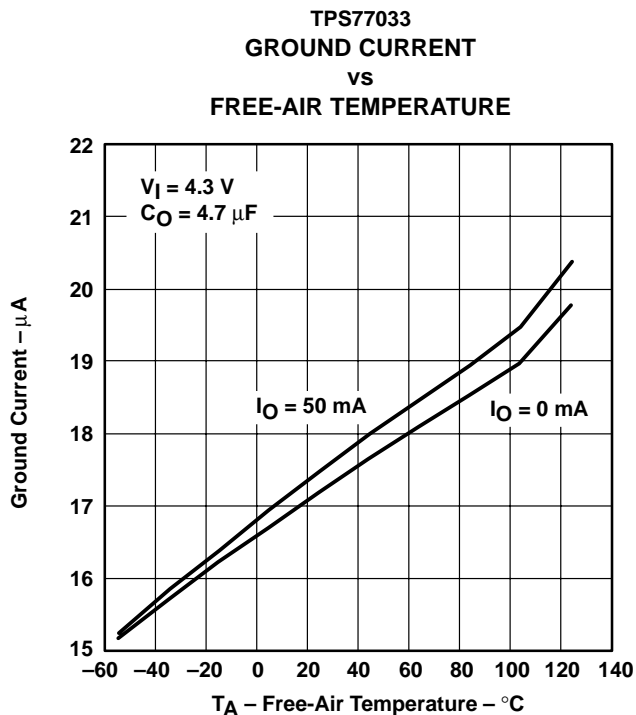SLVS210D – JUNE 1999 – REVISED MAY 2001

## TYPICAL CHARACTERISTICS

**TPS77025**
**OUTPUT VOLTAGE**
**vs**
**FREE-AIR TEMPERATURE**



**Figure 5**

**TPS77033**
**OUTPUT VOLTAGE**
**vs**
**FREE-AIR TEMPERATURE**



**Figure 6**

**TPS77033**
**GROUND CURRENT**
**vs**
**FREE-AIR TEMPERATURE**



**Figure 7**

**TPS77033**
**OUTPUT SPECTRAL NOISE DENSITY**
**vs**
**FREQUENCY**



**Figure 8**

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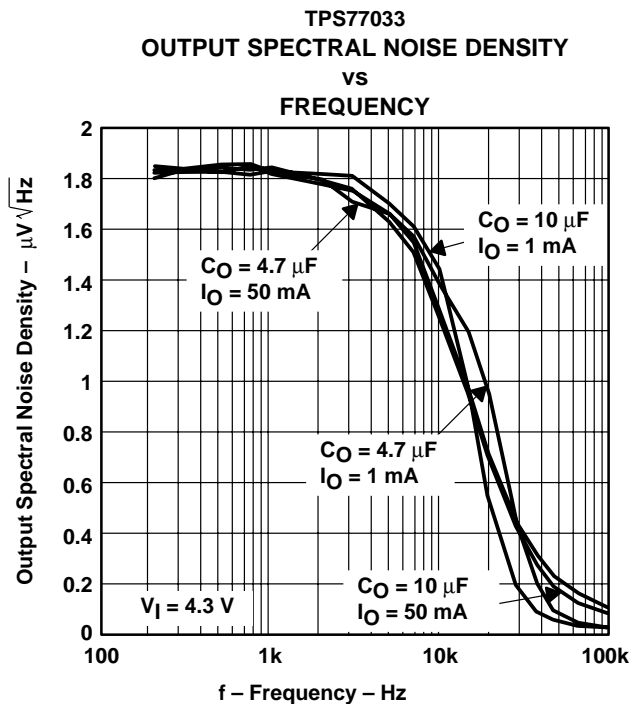INSTRUMENTS

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7

# TPS77001, TPS77012, TPS77015, TPS77018, TPS77025
# TPS77027, TPS77028, TPS77030, TPS77033, TPS77050
# ULTRALOW-POWER 50-mA LOW-DROPOUT LINEAR REGULATORS

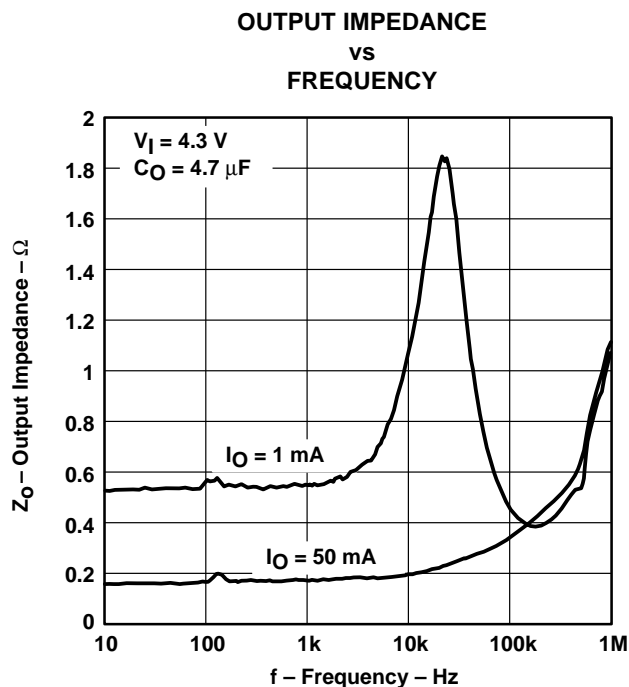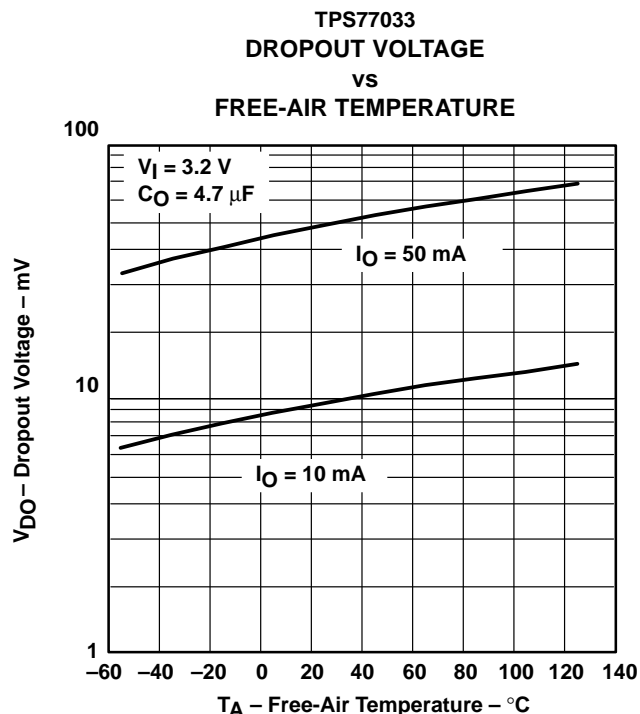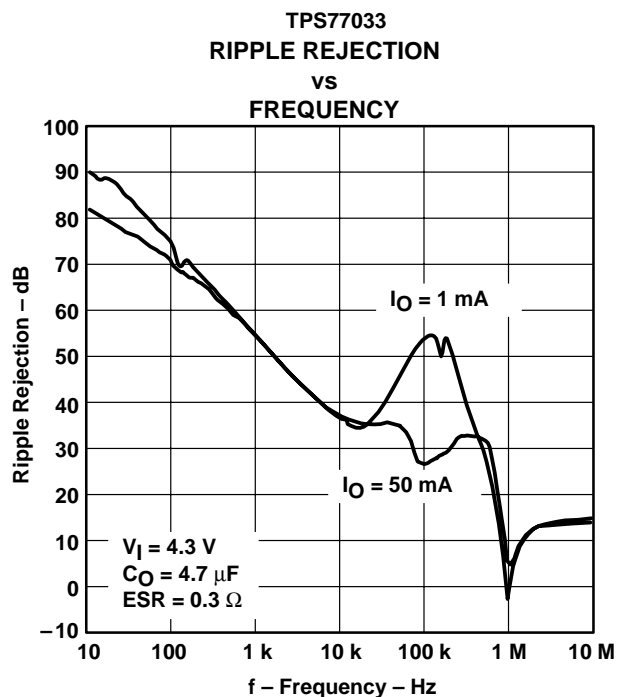SLVS210D – JUNE 1999 – REVISED MAY 2001

## TYPICAL CHARACTERISTICS

**OUTPUT IMPEDANCE
vs
FREQUENCY**



$V_I$ = 4.3 V
$C_O$ = 4.7 μF

$I_O$ = 1 mA

$I_O$ = 50 mA

$Z_O$ – Output Impedance – Ω

f – Frequency – Hz

**Figure 9**

**TPS77033
DROPOUT VOLTAGE
vs
FREE-AIR TEMPERATURE**



$V_I$ = 3.2 V
$C_O$ = 4.7 μF

$I_O$ = 50 mA

$I_O$ = 10 mA

$V_{DO}$ – Dropout Voltage – mV

$T_A$ – Free-Air Temperature – °C

**Figure 10**

**TPS77033
RIPPLE REJECTION
vs
FREQUENCY**



$I_O$ = 1 mA

$I_O$ = 50 mA

$V_I$ = 4.3 V
$C_O$ = 4.7 μF
ESR = 0.3 Ω

Ripple Rejection – dB

f – Frequency – Hz

**Figure 11**

**LDO STARTUP TIME**



EN

$V_O$

t – Time – μs

**Figure 12**

TEXAS
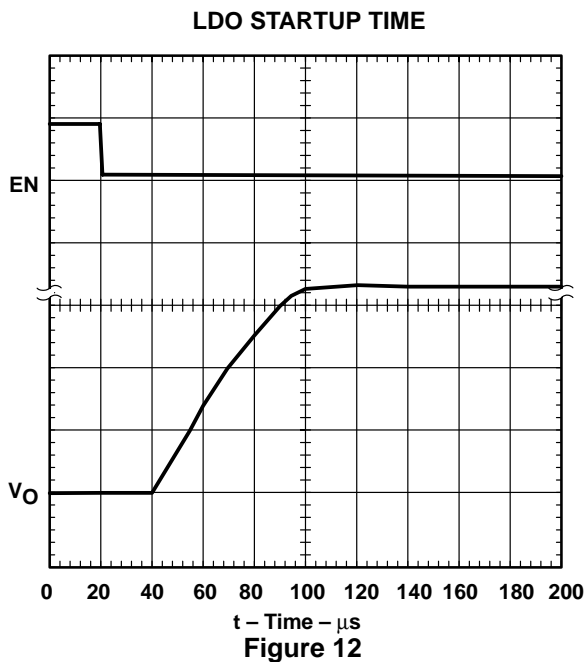INSTRUMENTS

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**TPS77001, TPS77012, TPS77015, TPS77018, TPS77025**
**TPS77027, TPS77028, TPS77030, TPS77033, TPS77050**
**ULTRALOW-POWER 50-mA LOW-DROPOUT LINEAR REGULATORS**

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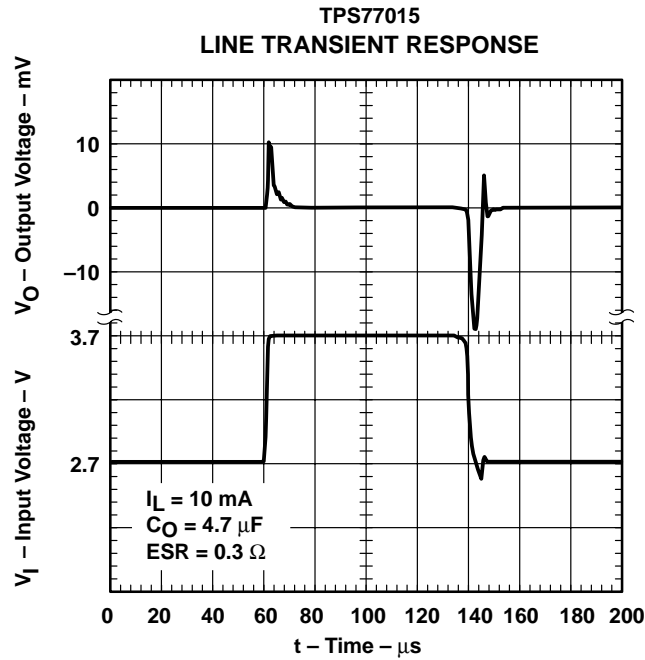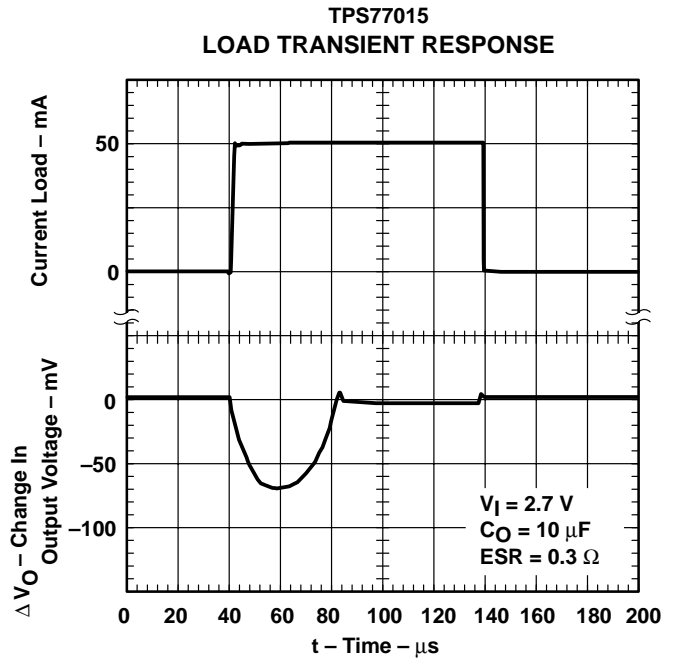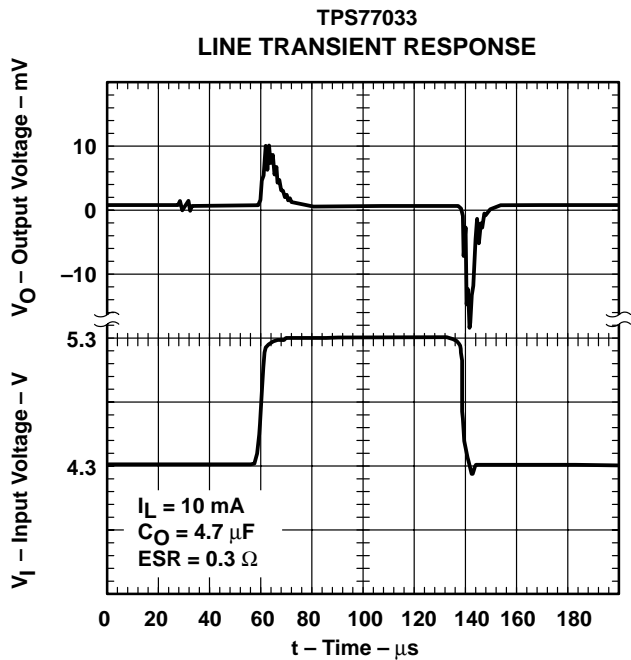
## TYPICAL CHARACTERISTICS

**TPS77015**
**LINE TRANSIENT RESPONSE**

$I_L$ = 10 mA
$C_O$ = 4.7 $\mu$F
ESR = 0.3 $\Omega$

**Figure 13**

**TPS77015**
**LOAD TRANSIENT RESPONSE**

$V_I$ = 2.7 V
$C_O$ = 10 $\mu$F
ESR = 0.3 $\Omega$

**Figure 14**

**TPS77033**
**LINE TRANSIENT RESPONSE**

$I_L$ = 10 mA
$C_O$ = 4.7 $\mu$F
ESR = 0.3 $\Omega$

**Figure 15**

**TPS77033**
**LOAD TRANSIENT RESPONSE**

$V_I$ = 4.3 V
$C_O$ = 4.7 $\mu$F
ESR = 0.3 $\Omega$

**Figure 16**

TEXAS
INSTRUMENTS

## TYPICAL CHARACTERISTICS

**TPS77033**
**TYPICAL REGIONS OF STABILITY**
**EQUIVALENT SERIES RESISTANCE (ESR)[†]**
**vs**
**OUTPUT CURRENT**



$V_{IN} = 4.3$ V
$C_O = 4.7$ µF
ESR = 0.3 Ω
3.3 V LDO

Region of Instability

Region of Stability

**I$_O$ – Output Current – mA**

**Figure 17**

**TPS77033**
**TYPICAL REGIONS OF STABILITY**
**EQUIVALENT SERIES RESISTANCE (ESR)**
**vs**
**ADDED CERAMIC CAPACITANCE**



$V_{IN} = 4.3$ V
$C_O = 4.7$ µF
$I_L = 50$ mA

Region of Instability

Region of Stability

**Added Ceramic Capacitance – µF**

**Figure 18**

**TPS77033**
**TYPICAL REGIONS OF STABILITY**
**EQUIVALENT SERIES RESISTANCE (ESR)[†]**
**vs**
**OUTPUT CURRENT**



$V_{IN} = 4.3$ V
$C_O = 10$ µF
ESR = 0.3 Ω
3.3 V LDO

Region of Instability

Region of Stability

**I$_O$ – Output Current – mA**

**Figure 19**

**TPS77033**
**TYPICAL REGIONS OF STABILITY**
**EQUIVALENT SERIES RESISTANCE (ESR)**
**vs**
**ADDED CERAMIC CAPACITANCE**



$V_{IN} = 4.3$ V
$C_O = 10$ µF
$I_L = 50$ mA

Region of Instability

Region of Stability

**Added Ceramic Capacitance – µF**

**Figure 20**

![Texas Instruments logo] **TEXAS INSTRUMENTS**

**TPS77001, TPS77012, TPS77015, TPS77018, TPS77025**
**TPS77027, TPS77028, TPS77030, TPS77033, TPS77050**
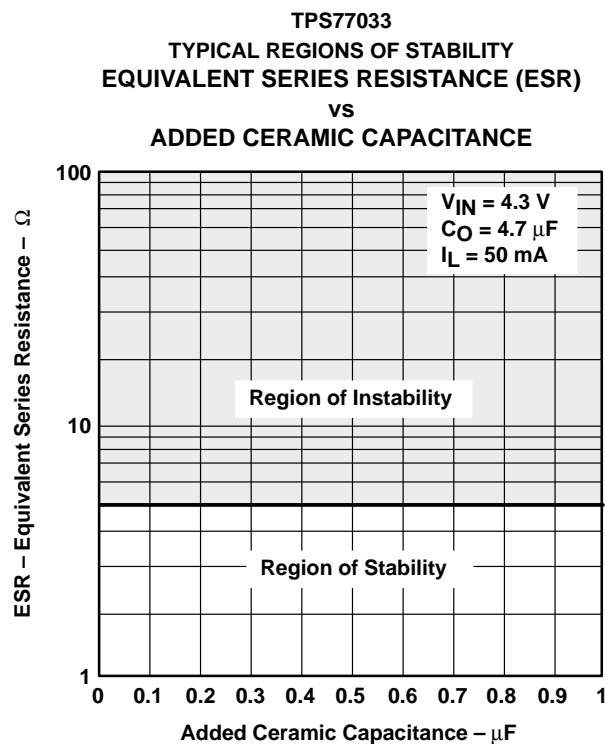**ULTRALOW-POWER 50-mA LOW-DROPOUT LINEAR REGULATORS**

SLVS210D – JUNE 1999 – REVISED MAY 2001
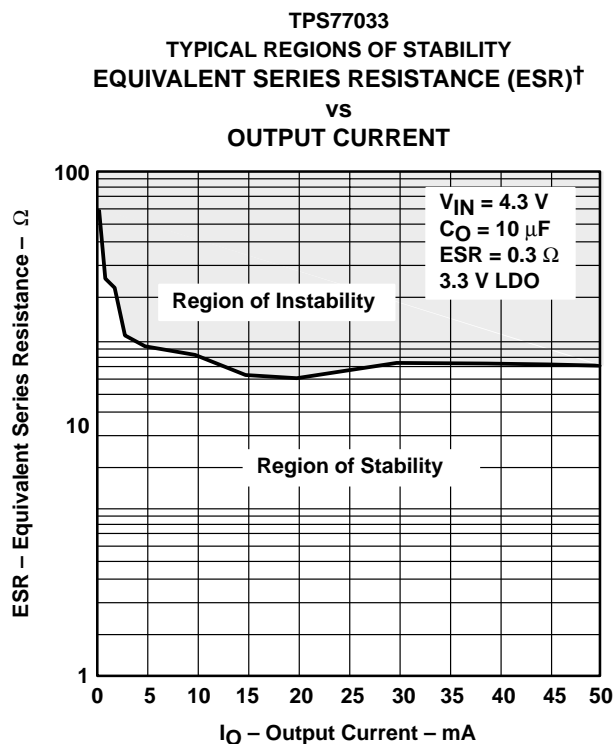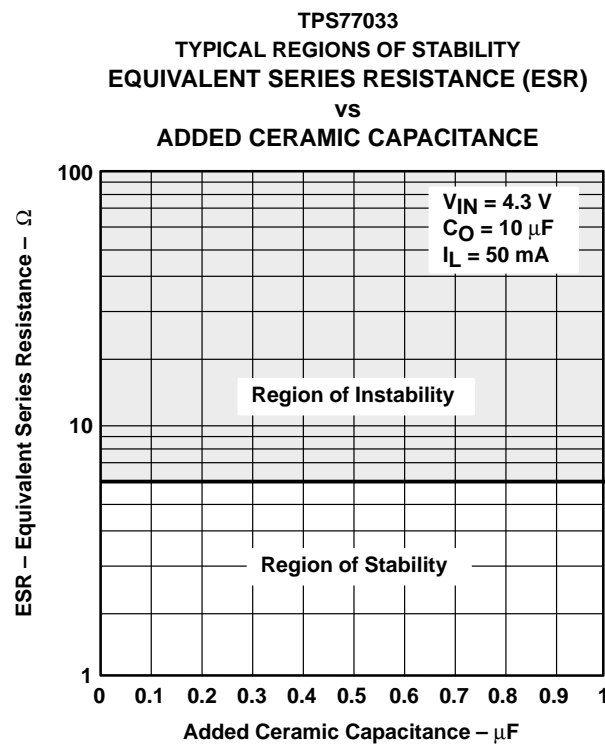
## APPLICATION INFORMATION

The TPS770xx 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 less than 1 µA when the regulators are turned off.

### device operation

The TPS770xx 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 TPS770xx 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 EN input will disable the TPS770xx internal circuitry, reducing the supply current to 1µA. A voltage of less than 0.9 V on the $\overline{EN}$ input will enable the TPS770xx 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.
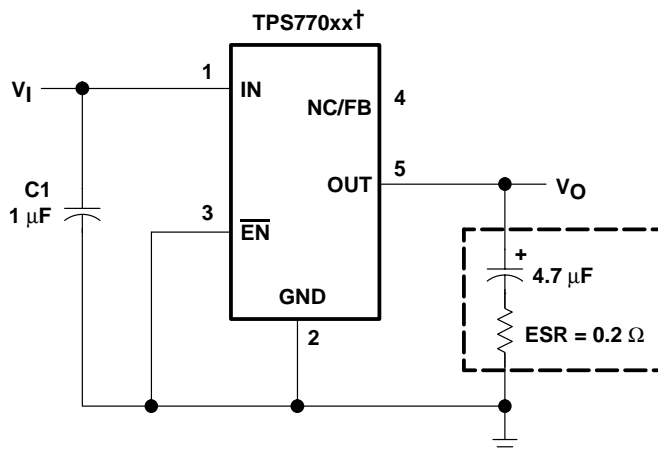


† TPS77012, TPS77015, TPS77018, TPS77025, TPS77027, TPS77028, TPS77030, TPS77033, TPS77050 (fixed-voltage options).

**Figure 21. Typical Application Circuit**

## APPLICATION INFORMATION

### external capacitor requirements

Although not required, a 0.047-$\mu$F or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS770xx, 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 TPS770xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 4.7 $\mu$F. The ESR (equivalent series resistance) of the capacitor should be between 0.2 $\Omega$ and 10 $\Omega$. to ensure stability. Capacitor values larger than 4.7 $\mu$F are acceptable, and allow the use of smaller ESR values. Capacitances less than 4.7 $\mu$F 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 $\mu$F 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 $\times$ L $\times$ W)[†] |
|---|---|---|---|---|
| T494B475K016AS | KEMET | 4.7 $\mu$F | 1.5 $\Omega$ | 1.9 $\times$ 3.5 $\times$ 2.8 |
| 195D106x0016x2T | SPRAGUE | 10 $\mu$F | 1.5 $\Omega$ | 1.3 $\times$ 7.0 $\times$ 2.7 |
| 695D106x003562T | SPRAGUE | 10 $\mu$F | 1.3 $\Omega$ | 2.5 $\times$ 7.6 $\times$ 2.5 |
| TPSC475K035R0600 | AVX | 4.7 $\mu$F | 0.6 $\Omega$ | 2.6 $\times$ 6.0 $\times$ 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.

TEXAS
INSTRUMENTS
POST OFFICE BOX 655303 ● DALLAS, TEXAS 75265

## APPLICATION INFORMATION

### output voltage programming

The output voltage of the TPS77001 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.
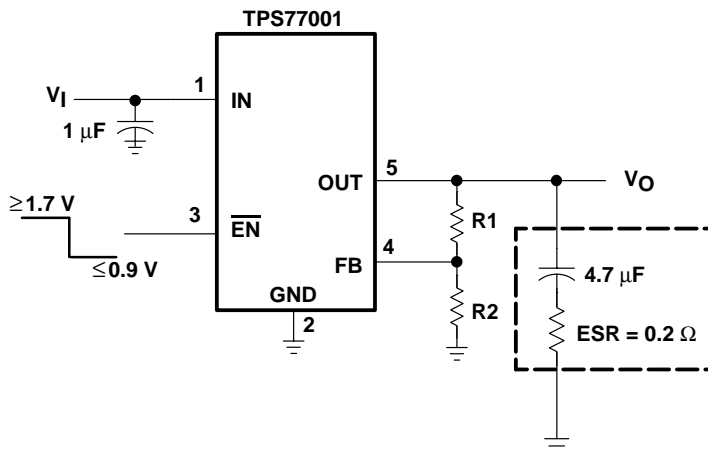


**Figure 22. TPS77001 Adjustable LDO Regulator Programming**

## 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, see the dissipation rating table.

$T_A$ 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 TPS770xx 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 TPS770xx features internal current limiting and thermal protection. During normal operation, the TPS770xx 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.
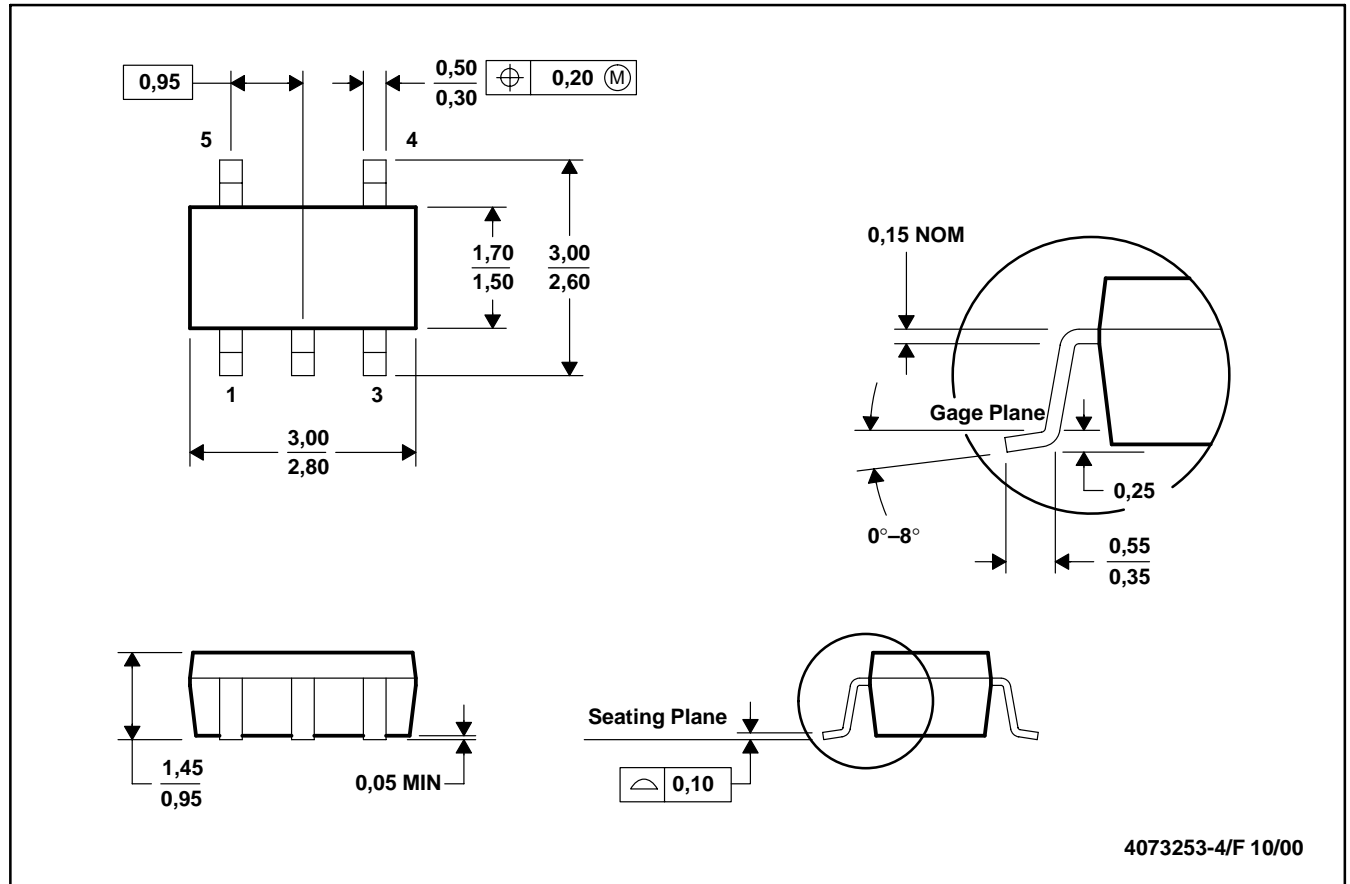
**TEXAS**
**INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

## MECHANICAL DATA

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



4073253-4/F 10/00

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

## PACKAGING INFORMATION

| Orderable Device | Status [1] | Package Type | Package Drawing | Pins | Package Qty | Eco Plan [2] | Lead/Ball Finish | MSL Peak Temp [3] |
|---|---|---|---|---|---|---|---|---|
| TPS77001DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77001DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77001DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77001DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77012DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77012DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77012DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77012DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77015DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77015DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77015DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77015DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77018DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77018DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77018DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77018DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77025DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77025DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77025DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77025DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77027DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77027DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77027DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77027DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77028DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |

| Orderable Device | Status [1] | Package Type | Package Drawing | Pins | Package Qty | Eco Plan [2] | Lead/Ball Finish | MSL Peak Temp [3] |
|---|---|---|---|---|---|---|---|---|
| TPS77028DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77028DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77028DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77030DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77030DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77030DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77030DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77033DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77033DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77033DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77033DBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77050DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77050DBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77050DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS77050DBVTG4 | 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), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[3] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**OTHER QUALIFIED VERSIONS OF TPS77001, TPS77012, TPS77015, TPS77033 :**
- Automotive: TPS77001-Q1, TPS77012-Q1, TPS77015-Q1, TPS77033-Q1

NOTE: Qualified Version Definitions:
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

![Texas Instruments logo]

# PACKAGE MATERIALS INFORMATION

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**



**TAPE DIMENSIONS**



| A0 | Dimension designed to accommodate the component width |
|----|-------------------------------------------------------|
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W  | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |
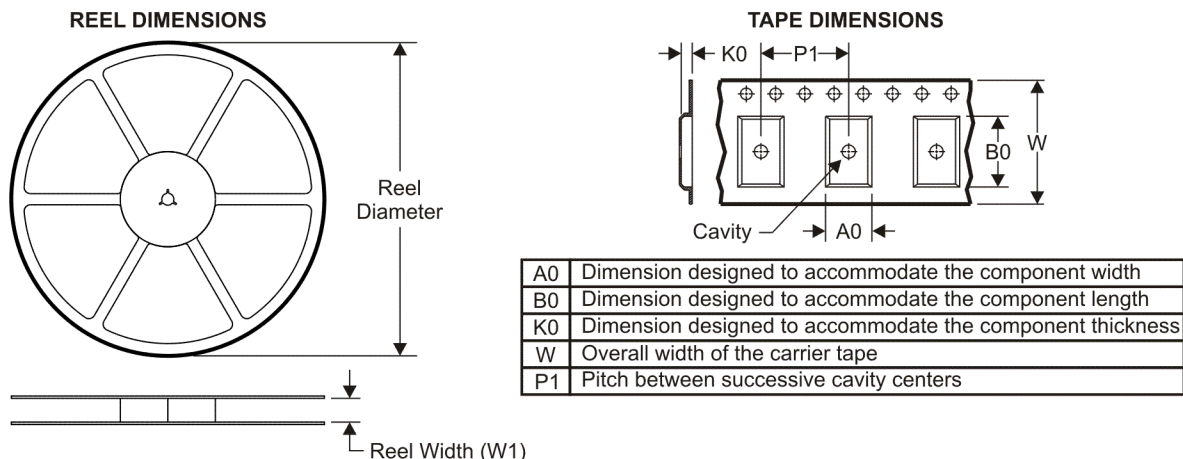
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**
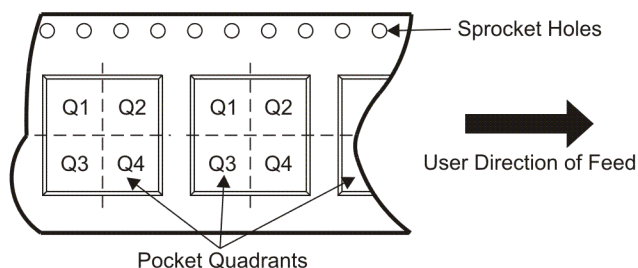


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------|--------------|-----------------|------|-----|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS77001DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77001DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 9.0 | 3.15 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77001DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77012DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77012DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77015DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77015DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77018DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77018DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77025DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77025DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77027DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77027DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77028DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77028DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77030DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77030DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77033DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |

# PACKAGE MATERIALS INFORMATION

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------|--------------|-----------------|------|-----|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS77033DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77050DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS77050DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |

**TAPE AND REEL BOX DIMENSIONS**
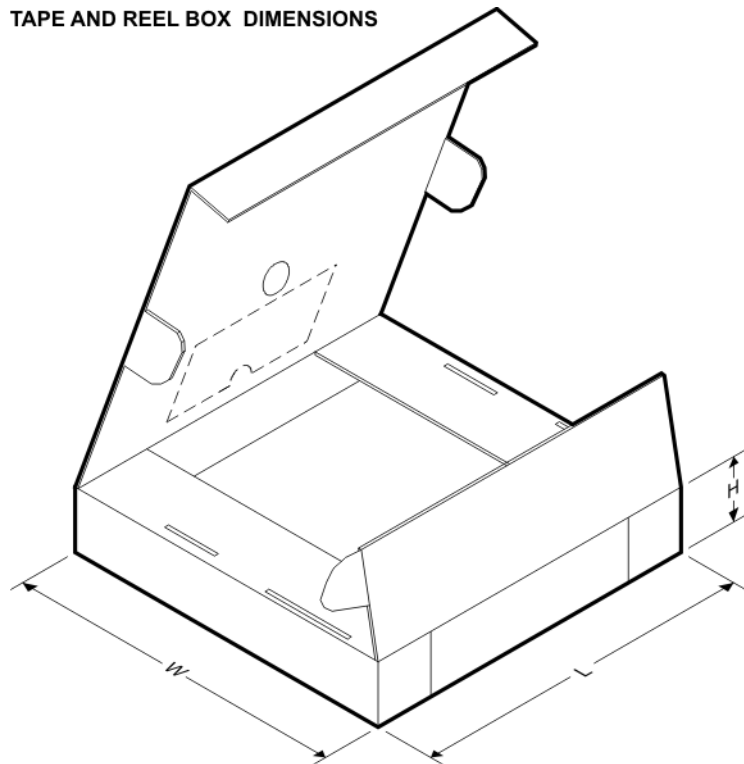


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------|--------------|-----------------|------|-----|-------------|------------|-------------|
| TPS77001DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77001DBVT | SOT-23 | DBV | 5 | 250 | 182.0 | 182.0 | 20.0 |
| TPS77001DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77012DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77012DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77015DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77015DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77018DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77018DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77025DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77025DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77027DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77027DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77028DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TPS77028DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77030DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77030DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77033DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77033DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |
| TPS77050DBVR | SOT-23 | DBV | 5 | 3000 | 195.0 | 200.0 | 45.0 |
| TPS77050DBVT | SOT-23 | DBV | 5 | 250 | 195.0 | 200.0 | 45.0 |