

# **ULTRALOW-POWER 100-mA LOW DROPOUT LINEAR REGULATORS**

Check for Samples: [TPS76901-EP](#)

## **FEATURES**

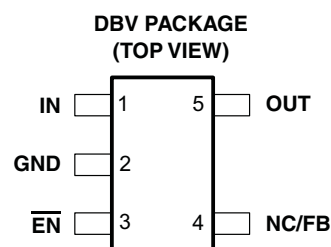
- 100-mA Low-Dropout Regulator
- Available in Adjustable Versions
- Only 335- $\mu$ A Quiescent Current With 100 mA at 150°C
- 1- $\mu$ A Quiescent Current in Standby Mode
- Dropout Voltage Typically 71 mV at 100 mA
- Over Current Limitation

## **APPLICATIONS**

- Down-Hole Drilling
- High Temperature Environments

## **SUPPORTS EXTREME TEMPERATURE APPLICATIONS**

- Controlled Baseline
- One Assembly/Test Site
- One Fabrication Site
- Available in Extreme (–55°C/150°C) Temperature Range<sup>(1)</sup>
- Extended Product Life Cycle
- Extended Product-Change Notification
- Product Traceability
- Texas Instruments' high temperature products utilize highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.



(1) Custom temperature ranges available

## **DESCRIPTION**

The TPS76901 low-dropout (LDO) voltage regulator offers the benefits of low dropout voltage, ultralow-power operation, and miniaturized packaging. This regulator features low dropout voltages and ultralow quiescent current compared to conventional LDO regulators. The TPS76901 is 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, and is directly proportional to the load current. Since the PMOS pass element is a voltage-driven device, the quiescent current is ultralow (28  $\mu$ A maximum) and is stable over the entire range of output load current (0 mA to 100 mA). Intended for use in portable systems such as laptops and cellular phones, the ultralow-dropout voltage feature and ultralow-power operation result in a significant increase in system battery operating life.

The TPS76901 also features a logic-enabled sleep mode to shut down the regulator, reducing quiescent current to 1  $\mu$ A, typical at  $T_J = 25^\circ\text{C}$ . The TPS76901 is a variable version programmable over the range of 1.2 V to 4.5 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.



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.

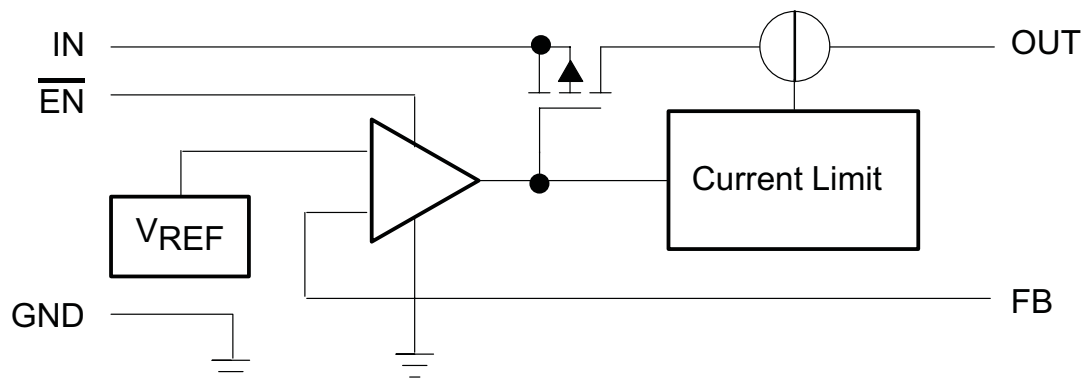
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### ORDERING INFORMATION<sup>(1)</sup>

| T <sub>A</sub> | PACKAGE <sup>(2)</sup> | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|------------------------|-----------------------|------------------|
| –55°C to 150°C | DBV                    | TPS76901SDBVTEP       | PCFS             |

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at [www.ti.com](http://www.ti.com).
- (2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).

### FUNCTIONAL BLOCK DIAGRAM



### ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

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

|   | VALUE                         | UNIT |
|---|-------------------------------|------|
| V <sub>REF</sub> Input voltage range <sup>(2)</sup>         | –0.3 to 13.5                  | V    |
| Voltage range at $\overline{\text{EN}}$                     | –0.3 to V <sub>I</sub> + 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 Ratings Table |      |
| T <sub>J</sub> Operating virtual junction temperature range | –55 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.

## THERMAL CHARACTERISTICS

| BOARD                 | PACKAGE | R <sub>θJC</sub> | R <sub>θJA</sub> | DERATING FACTOR<br>ABOVE T <sub>A</sub> = 25°C |
|-----------------------|---------|------------------|------------------|--|
| Low K <sup>(1)</sup>  | DBV     | 65.8 °C/W        | 259 °C/W         | 3.9 mW/°C                                      |
| High K <sup>(2)</sup> | DBV     | 65.8 °C/W        | 180 °C/W         | 5.6 mW/°C                                      |

- (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.

## RECOMMENDED OPERATING CONDITIONS

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

|                |  | MIN | NOM | MAX | UNIT |
|----------------|--|-----|-----|-----|------|
| V <sub>I</sub> | Input voltage <sup>(1)</sup>             | 5   |     | 10  | V    |
| V <sub>O</sub> | Output voltage range                     | 1.2 |     | 4.5 | V    |
| I <sub>O</sub> | Continuous output current <sup>(2)</sup> | 0   |     | 100 | mA   |
| T <sub>J</sub> | Operating junction temperature           | –55 |     | 150 | °C   |

- (1) To calculate the minimum input voltage for your maximum output current, use the following formula:  
 $V_{I(min)} = V_O(max) + V_{DO}(max \text{ load})$ .
- (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

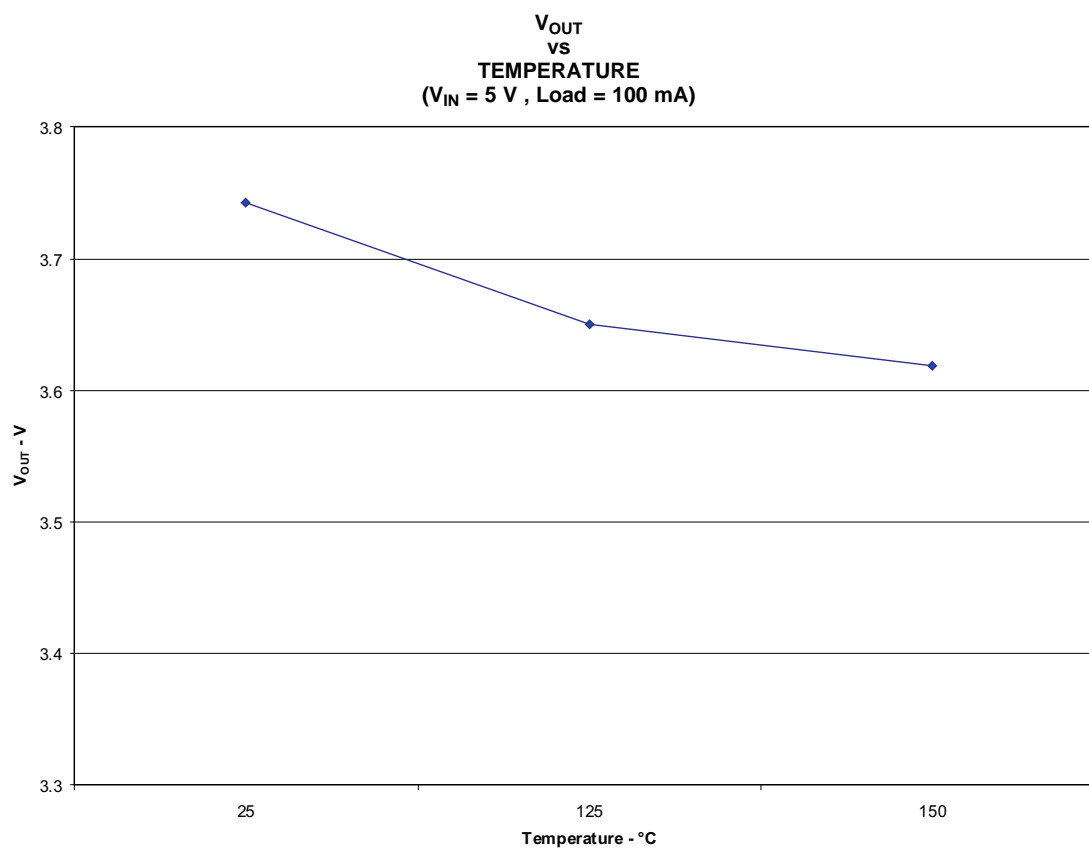
over operating free-air temperature range (unless otherwise noted)

| PARAMETER          |   | TEST CONDITIONS   |                                 | MIN                | TYP            | MAX                | UNIT |
|--------------------|---|---|---------------------------------|--------------------|----------------|--------------------|------|
| V <sub>O</sub>     | Output voltage<br>(10 µA to 100 mA load) <sup>(1)</sup>                             | 12. V ≤ V <sub>O</sub> ≤ 4.5 V                                    | T <sub>J</sub> = 25°C           |                    | V <sub>O</sub> |                    | V    |
|                    |   |   | T <sub>J</sub> = –55°C to 150°C | 0.97V <sub>O</sub> |                | 1.03V <sub>O</sub> |      |
| I <sub>Q</sub>     | Quiescent Current<br>(GND current) <sup>(1) (2)</sup>                               | $\overline{EN} = 0 \text{ V}$ ,<br>0 mA < I <sub>O</sub> < 100 mA | T <sub>J</sub> = 25°C           |                    | 17             |                    | µA   |
|                    |   |   | T <sub>J</sub> = –55°C to 150°C |                    |                | 28                 |      |
|                    | Load regulation   | $\overline{EN} = 0 \text{ V}$ ,<br>I <sub>O</sub> = 0 to 100 mA   | T <sub>J</sub> = 25°C           |                    | 12             |                    | mV   |
|                    |   |   | T <sub>J</sub> = 150°C          |                    | 13.5           |                    |      |
|                    | Output voltage line regulation<br>(ΔV <sub>O</sub> /V <sub>O</sub> ) <sup>(2)</sup> | 5 V ≤ V <sub>I</sub> ≤ 10 V <sup>(1)</sup>                        | T <sub>J</sub> = 25°C           |                    | 0.04           |                    | %    |
|                    |   |   | T <sub>J</sub> = –55°C to 150°C |                    |                | 0.1                |      |
| V <sub>N</sub>     | Output noise voltage  | BW = 300 Hz to 50 kHz,<br>C <sub>O</sub> = 10 µF                  | T <sub>J</sub> = 25°C           |                    | 190            |                    | µVms |
|                    | Output current limit  | V <sub>O</sub> = 0 V <sup>(1)</sup>                               | T <sub>J</sub> = 25°C           |                    | 350            |                    | mA   |
|                    |   |   | T <sub>J</sub> = –55°C to 150°C |                    |                | 750                |      |
| I <sub>STDBY</sub> | Standby current   | $\overline{EN} = V_I$ , 5 V ≤ V <sub>I</sub> ≤ 10 V               | T <sub>J</sub> = 25°C           |                    | 1              |                    | µA   |
|                    |   |   | T <sub>J</sub> = –55°C to 150°C |                    |                | 2.4                |      |
| I <sub>FB</sub>    | FB input current  | FB = 1.18 V   | T <sub>J</sub> = –55°C to 150°C | –1                 |                | 1                  | µA   |
| V <sub>IH</sub>    | High level enable input voltage   | 5 V ≤ V <sub>I</sub> ≤ 10 V                                       | T <sub>J</sub> = 25°C           | 1.7                |                |                    | V    |
| V <sub>IL</sub>    | Low level enable input voltage  | 5 V ≤ V <sub>I</sub> ≤ 10 V                                       | T <sub>J</sub> = 25°C           |                    |                | 0.9                | V    |
|                    |   |   | T <sub>J</sub> = 150°C          |                    | 0.75           |                    |      |
| PSRR               | Power supply ripple rejection   | f = 1 kHz,<br>C <sub>O</sub> = 10 µF <sup>(1)</sup>               | T <sub>J</sub> = 25°C           |                    | 60             |                    | dB   |
| I <sub>IN</sub>    | Input current   | $\overline{EN} = 0 \text{ V}$                                     | T <sub>J</sub> = –55°C to 150°C | –1                 | 0              | 1                  | µA   |
|                    |   | $\overline{EN} = V_I$   |                                 | –1                 |                | 1                  |      |

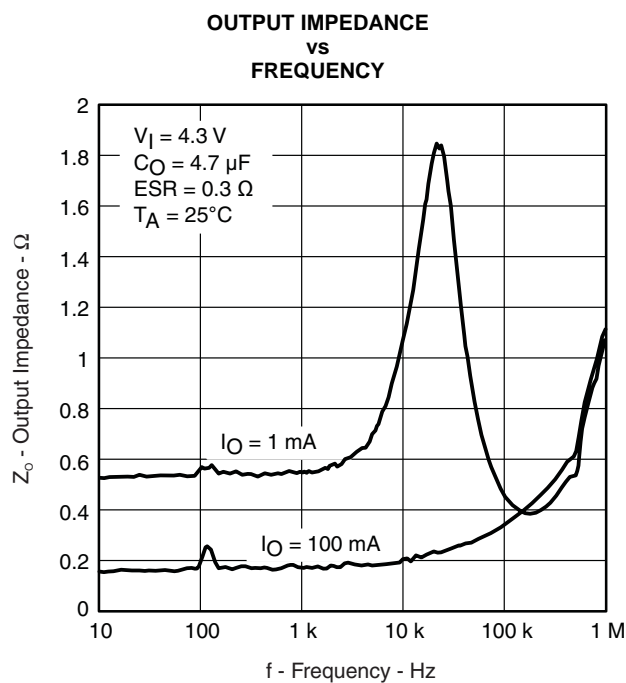
- (1) Minimum I<sub>N</sub> operating voltage is 5V. Maximum I<sub>N</sub> voltage 10 V, minimum output current 10 µA, maximum output current 100 mA.
- (2) Line Regulation (%) = (ΔV<sub>OUT</sub>) / (ΔV<sub>IN</sub>) x 100

**DEVICE INFORMATION****TERMINAL FUNCTIONS**

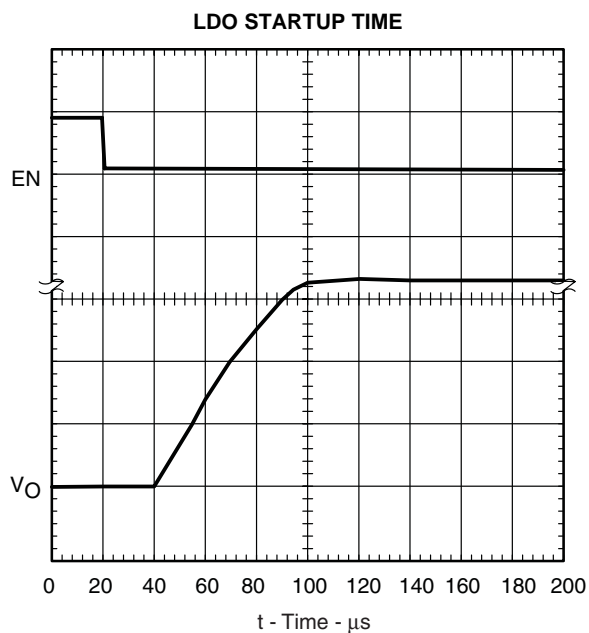
| TERMINAL               |     | I/O | DESCRIPTION |
|------------------------|-----|-----|-------------|
| NAME                   | NO. |     |             |
| IN                     | 1   | I   | Input       |
| GND                    | 2   | -   | Ground      |
| $\overline{\text{EN}}$ | 3   | I   | Enable      |
| FB                     | 4   | I   | Feedback    |
| OUT                    | 5   | O   | Output      |

**TYPICAL CHARACTERISTICS****Figure 1.**

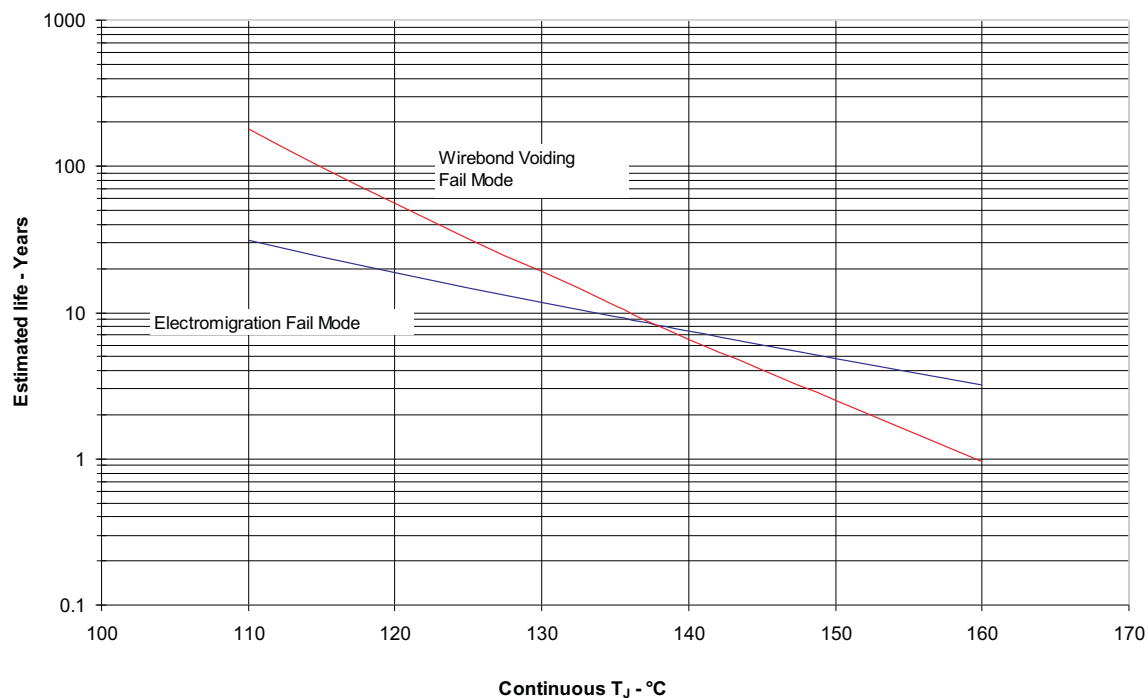
## TYPICAL CHARACTERISTICS (continued)



**Figure 2.**



**Figure 3.**

**TYPICAL CHARACTERISTICS (continued)****Figure 4. TPS76901SDBVTEP Operating Life Derating Chart**

Note:

1. See datasheet for absolute maximum and minimum recommended operating conditions.
2. Silicon operating life design goal is 10 years at 105°C junction temperature (does not include package interconnect life).

## APPLICATION INFORMATION<sup>(1)</sup>

The TPS76901 low-dropout (LDO) regulator has been optimized for use in battery-operated equipment. It features extremely low dropout voltages, low quiescent current (17  $\mu\text{A}$  nominally), and enables inputs to reduce supply currents to 1  $\mu\text{A}$  when the regulators are turned off.

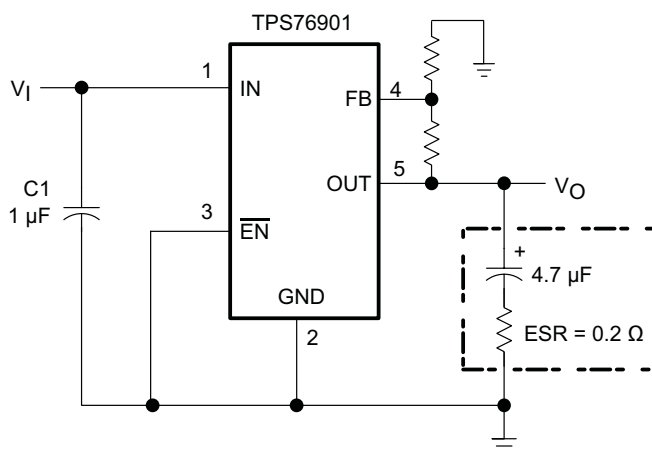
### DEVICE OPERATION

The TPS76901 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 TPS76901 is essentially constant from no load to maximum load.

Current limiting prevents damage by excessive output current. 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 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 TPS76901 internal circuitry, reducing the supply current to 1  $\mu\text{A}$ . A voltage of less than 0.9 V on the EN input will enable the TPS76901 and will enable normal operation to resume. The 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 5](#).



**Figure 5. Typical Application Circuit**

### EXTERNAL CAPACITOR REQUIREMENTS

Although not required, a 0.047- $\mu\text{F}$  or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS76901, 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 TPS76901 requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 4.7  $\mu\text{F}$ . 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  $\mu\text{F}$  are acceptable, and allow the use of smaller ESR values. Capacitances less than 4.7  $\mu\text{F}$  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- $\mu\text{F}$  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.

<sup>(1)</sup> Application information is provided for commercial temperature as a reference and not for high temperature.

**Table 1. CAPACITOR SELECTION**

| PART NO.         | MANUFACTURER | VALUE       | MAX ESR <sup>(1)</sup> | SIZE (H x L x W) <sup>(1)</sup> |
|------------------|--------------|-------------|------------------------|---------------------------------|
| T494B475K016AS   | KEMET        | 4.7 $\mu$ F | 1.5 $\Omega$           | 1.9 x 3.5 x 2.8                 |
| 195D106x0016x2T  | SPRAGUE      | 10 $\mu$ F  | 1.5 $\Omega$           | 1.3 x 7.0 x 2.7                 |
| 695D106x003562T  | SPRAGUE      | 10 $\mu$ F  | 1.3 $\Omega$           | 2.5 x 7.6 x 2.5                 |
| TPSC475K035R0600 | AVX          | 4.7 $\mu$ F | 0.6 $\Omega$           | 2.6 x 6.0 x 3.2                 |

(1) Size is in mm. ESR is maximum resistance in Ohms at 100 kHz and  $T_A = 25^\circ\text{C}$ . Contact manufacturer for minimum ESR values.

## OUTPUT VOLTAGE PROGRAMMING

The output voltage of the TPS76901 adjustable regulator is programmed using an external resistor divider as shown in Figure 6. The output voltage is calculated using:

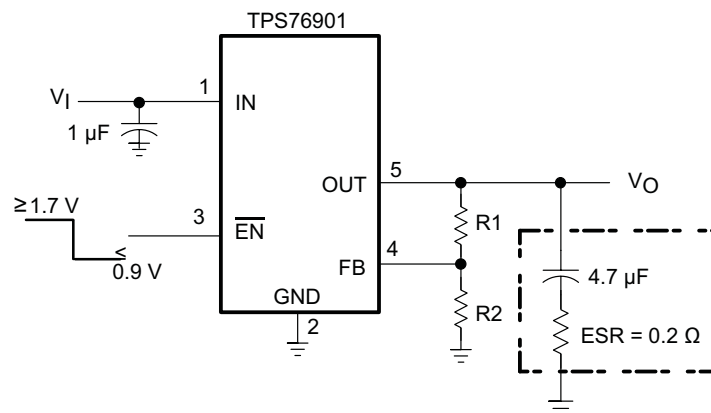
$$V_O = V_{REF} \cdot \left(1 + \frac{R1}{R2}\right) \quad (1)$$

Where:

$V_{REF} = 1.127\text{ V typ}$  (the internal reference voltage)

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

$$R1 = \left(\frac{V_O}{V_{REF}} - 1\right) \cdot R2 \quad (2)$$



Note:

1. The above calculations hold good for room temperature values only.

**Figure 6. Adjustable LDO Regulator Programming**

## REGULATOR PROTECTION

The TPS76901 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 TPS76901 features internal current limiting protection. During normal operation, the TPS76901 limits output current to approximately 350 mA. When current limiting engages, the output voltage scales back linearly until the over current condition ends.



## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPS76901SDBVTEP  | ACTIVE        | SOT-23       | DBV                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -55 to 150   | PCFS                    | <a href="#">Samples</a> |
| V62/10607-01XE   | ACTIVE        | SOT-23       | DBV                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -55 to 150   | PCFS                    | <a href="#">Samples</a> |

(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.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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**OTHER QUALIFIED VERSIONS OF TPS76901-EP :**

- Catalog: [TPS76901](#)
- Automotive: [TPS76901-Q1](#)

**NOTE:** Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

**TAPE AND REEL INFORMATION**


\*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 |
|-----------------|--------------|-----------------|------|-----|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS76901SDBVTEP | SOT-23       | DBV             | 5    | 250 | 180.0              | 9.0                | 3.15    | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |

## TAPE AND REEL BOX DIMENSIONS

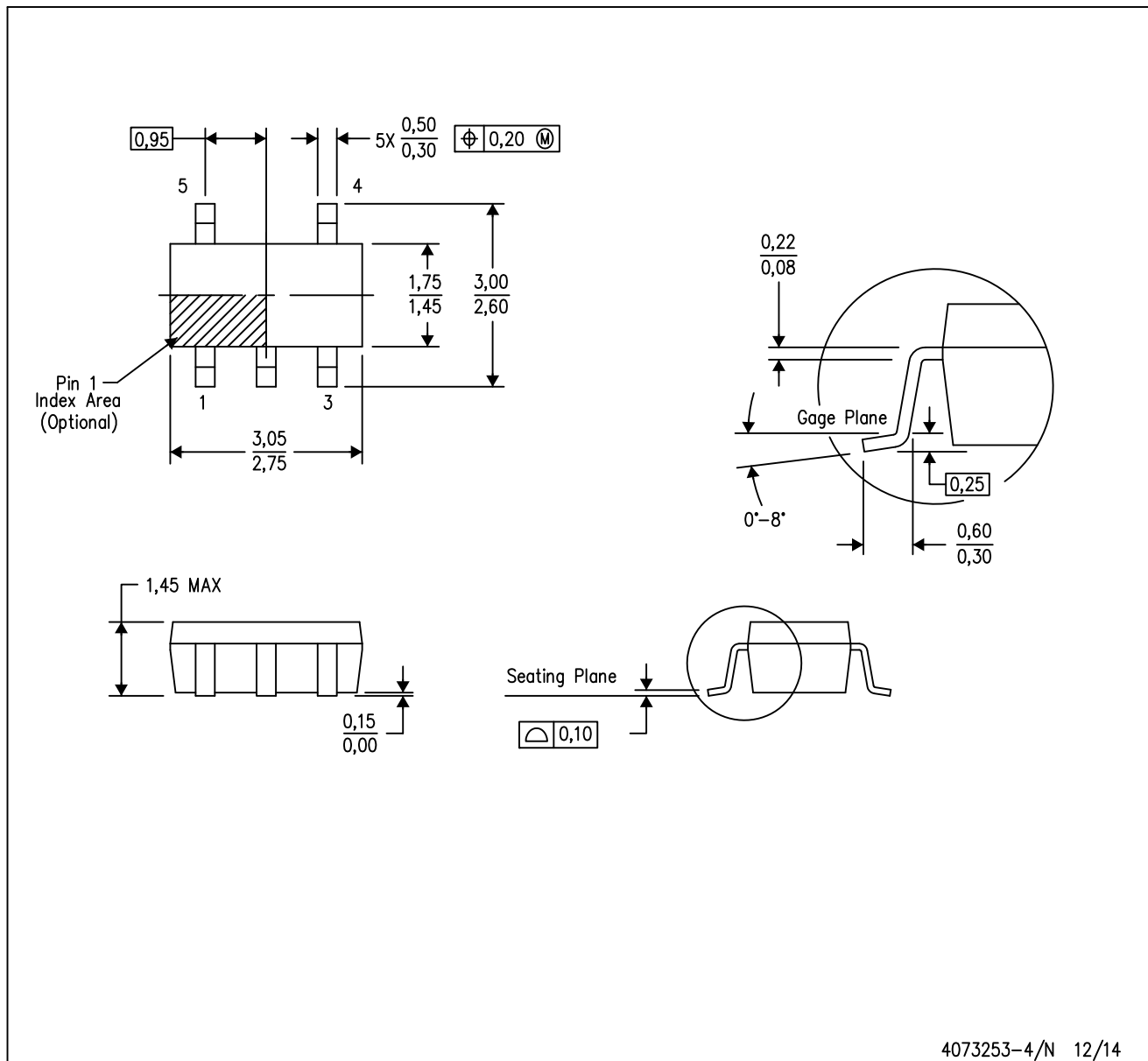


\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|-----|-------------|------------|-------------|
| TPS76901SDBVTEP | SOT-23       | DBV             | 5    | 250 | 203.0       | 203.0      | 32.0        |

DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-178 Variation AA.

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. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

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### Products

|                              |  |
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