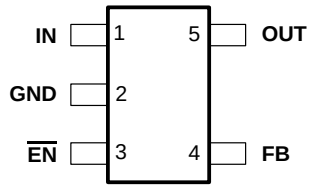
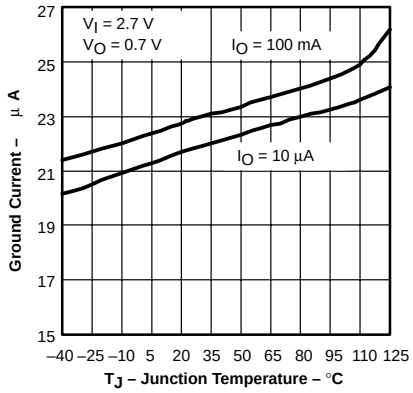
- **100-mA Low-Dropout Regulator**
- **Adjustable Output Voltage (0.7 V to 5.5 V)**
- **Only 23 μA Quiescent Current at 100 mA**
- **1 μA Quiescent Current in Standby Mode**
- **Over Current Limitation**
- **–40°C to 125°C Operating Junction Temperature Range**
- **5-Pin SOT-23 (DBV) Package**

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




**GROUND CURRENT**
**vs**
**JUNCTION TEMPERATURE**




## description

The TPS76201 low-dropout (LDO) voltage regulator features an adjustable output voltage as low as 0.7 V. It is an ideal regulator for sub 1.2-V DSP core voltage supplies and is equally suited for similar applications with other low-voltage processors and controllers. SOT-23 packaging and the high-efficiency that results from the regulator's ultralow power operation make the TPS76201 especially useful in handheld and portable battery applications. This regulator features 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 TPS76201 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. Since the PMOS pass element is a voltage-driven device, the quiescent current is ultralow (30 μA maximum) and is stable over the entire range of output load current (10 μA to 100 mA). Intended for use in portable systems such as laptops and cellular phones, the ultralow-power operation results in a significant increase in the system battery operating life.

The TPS76201 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 TPS76201 is offered in an adjustable version (programmable over the range of 0.7 V to 5.5 V).

**AVAILABLE OPTIONS†**

| $T_J$ | VOLTAGE | PACKAGE | PART NUMBER | | SYMBOL |
|---|---|---|---|---|---|
| –40°C to 125°C | Variable 0.7 V to 5.5 V | SOT-23 (DBV) | TPS76201DBVT‡ | TPS76201DBVR§ | PFUI |

† Contact the factory for availability of fixed output options.
‡ The DBVT indicates tape and reel of 250 parts.
§ The DBVR indicates tape and reel of 3000 parts.

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.

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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Input voltage range (see Note 1) . . . . . –0.3 V to 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 | $T_A \le 25°C$ 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, $V_O$ | 0.7 | | 5.5 | V |
| Continuous output current, $I_O$ (see Note 3) | 0.01 | | 100 | 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:
$V_{Imin} = V_{Omax} + V_{DO}$(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.

**electrical characteristics over recommended operating free-air temperature range, $V_I = V_{O(typ)} + 1$ V, $I_O = 100$ mA, $\overline{EN} = 0$ V, $C_o = 4.7$ μF (unless otherwise noted)**

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| Output voltage (10 μA to 100 mA load) (see Note 4) | 0.7 V ≤ $V_O$ ≤ 5.5 V, | $T_J$ = 25°C | | $V_O$ | | V |
| | 0.7 V ≤ $V_O$ ≤ 5.5 V, | $T_J$ = –40°C to 125°C | 0.97$V_O$ | | 1.03$V_O$ | |
| Quiescent current (GND current) (see Notes 4 and 5) | $\overline{EN}$ = 0V, 10 μA < $I_O$ < 100 mA | $T_J$ = 25°C | | 23 | | μA |
| | $\overline{EN}$ = 0 V, 10 μA < $I_O$ < 100 mA | $T_J$ = –40°C to 125°C, | | | 30 | |
| Load regulation | $\overline{EN}$ = 0 V, 10 μA < $I_O$ < 100 mA | $T_J$ = 25°C | | 12 | | mV |
| Output voltage line regulation ($\Delta V_O/V_O$) (see Note 5) | 2.7 V < $V_I$ ≤ 10 V, See Note 4 | $T_J$ = 25°C, | | 0.04 | | %/V |
| | 2.7 V < $V_I$ ≤ 10 V, $T_J$ = –40°C to 125°C, | See Note 4 | | | 0.1 | |
| Output noise voltage | BW = 300 Hz to 50 kHz, $V_O$ = 0.7 V, | $C_o$ = 10 μF, $T_J$ = 25°C | | 60 | | $\mu V_{RMS}$ |
| Output current limit | $V_O$ = 0 V, | 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 |
| FB input current | FB = 0.666 V | | –1 | | 1 | μA |
| 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 | | | | 0.8 | V |
| Power supply ripple rejection | f = 1 kHz, $T_J$ = 25°C, | $C_o$ = 10 μF, See Note 4 | | 60 | | dB |
| Input current (EN) | $\overline{EN}$ = 0 V | | –1 | 0 | 1 | μA |
| | $\overline{EN}$ = $V_I$ | | –1 | | 1 | 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 100 mA.

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

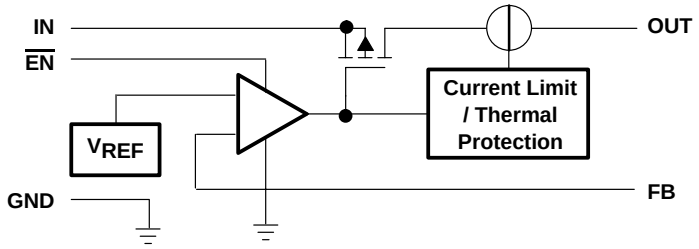
$$\text{Line Reg. (mV)} = (\%/V) \times \frac{V_O\left(V_{Imax} - 2.7\ V\right)}{100} \times 1000$$

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

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

## functional block diagram

**TPS76201**




### Terminal Functions

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

## TYPICAL CHARACTERISTICS

### Table of Graphs

| | | | FIGURE |
|---|---|---|---|
| $V_O$ | Output voltage | vs Output current | 1, 2 |
| | | vs Junction temperature | 3 |
| | Ground current | vs Junction temperature | 4 |
| | Output spectral noise density | vs Frequency | 5 |
| $z_o$ | Output impedance | vs Frequency | 6 |
| $V_{DO}$ | Dropout voltage | vs Input voltage | 7 |
| | | vs Junction temperature | 8 |
| | Power supply ripple rejection | vs Frequency | 9 |
| | Output voltage and enable voltage | vs Time (start-up) | 10 |
| | Line transient response | | 11, 13 |
| | Load transient response | | 12, 14 |
| | Equivalent series resistance (ESR) | vs Output current | 15, 16 |

## TYPICAL CHARACTERISTICS

**OUTPUT VOLTAGE vs OUTPUT CURRENT**

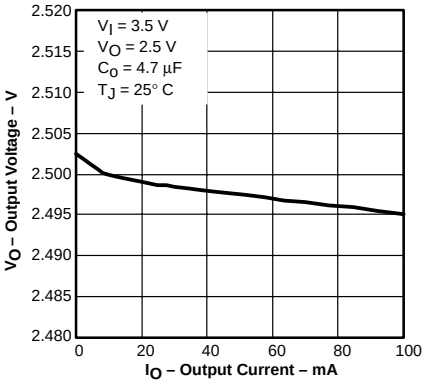



Figure 1

**OUTPUT VOLTAGE vs OUTPUT CURRENT**

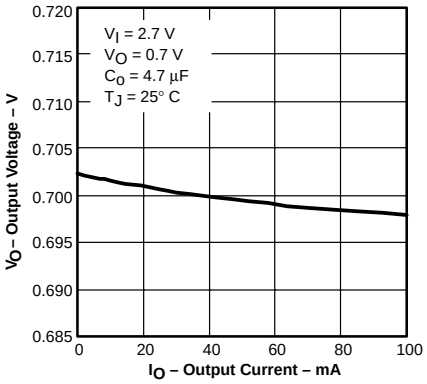



Figure 2

**OUTPUT VOLTAGE vs JUNCTION TEMPERATURE**

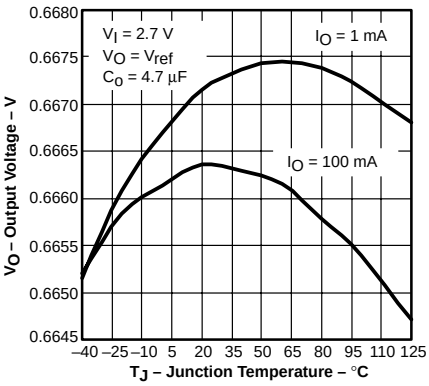



Figure 3

**GROUND CURRENT vs JUNCTION TEMPERATURE**

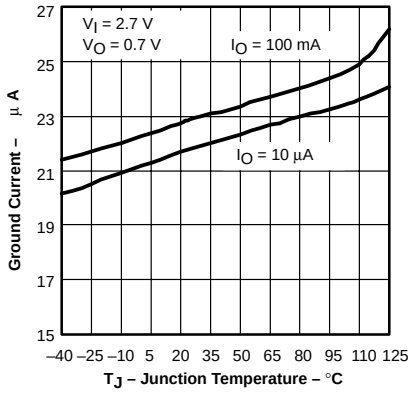



Figure 4

**OUTPUT SPECTRAL NOISE DENSITY vs FREQUENCY**

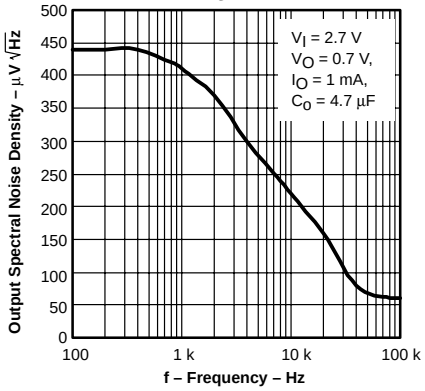



Figure 5

**OUTPUT IMPEDANCE vs FREQUENCY**

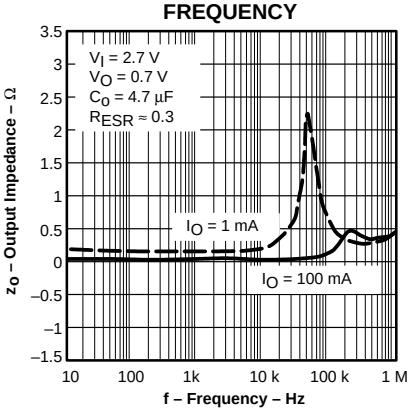



Figure 6

**DROPOUT VOLTAGE vs INPUT VOLTAGE**

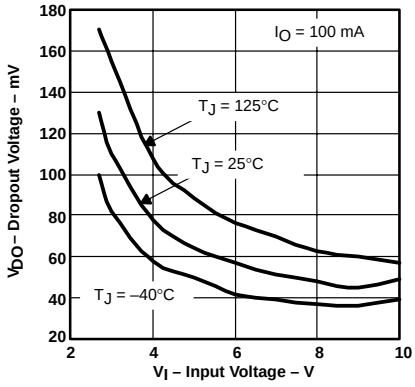



Figure 7

**DROPOUT VOLTAGE vs JUNCTION TEMPERATURE**

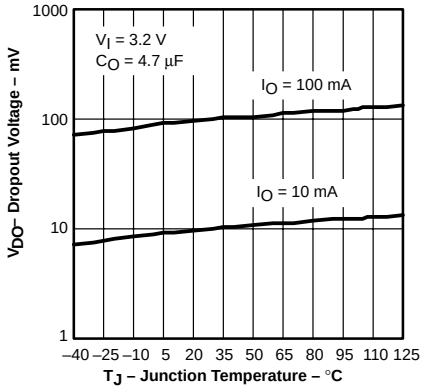



Figure 8

**POWER SUPPLY RIPPLE REJECTION vs FREQUENCY**

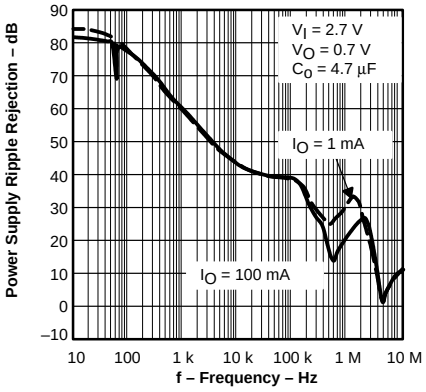



Figure 9

## TYPICAL CHARACTERISTICS

**OUTPUT VOLTAGE AND ENABLE VOLTAGE vs TIME (START-UP)**

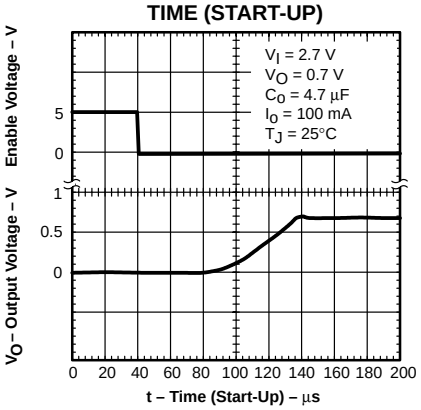



Figure 10

**LINE TRANSIENT RESPONSE**

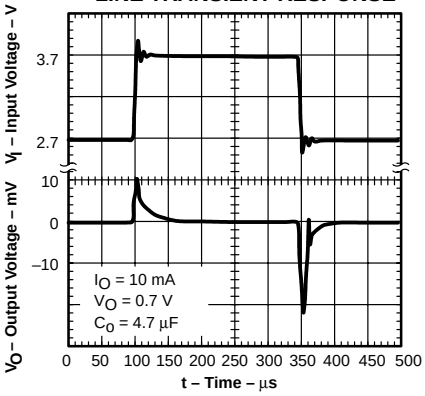



Figure 11

**LOAD TRANSIENT RESPONSE**

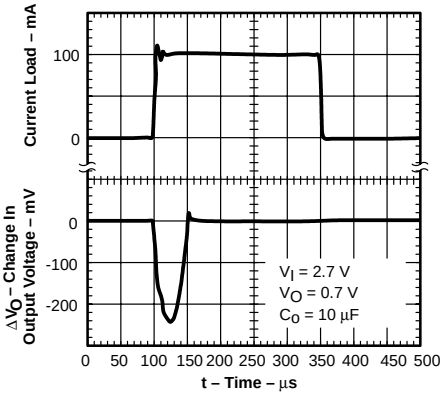



Figure 12

**LINE TRANSIENT RESPONSE**

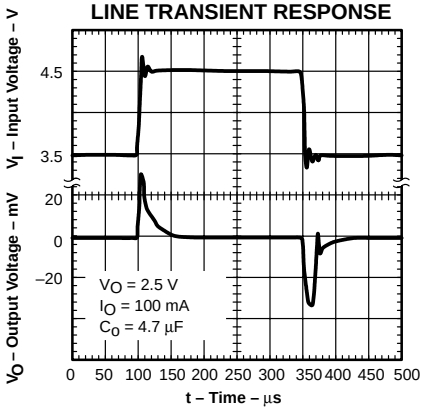



Figure 13

**LOAD TRANSIENT RESPONSE**

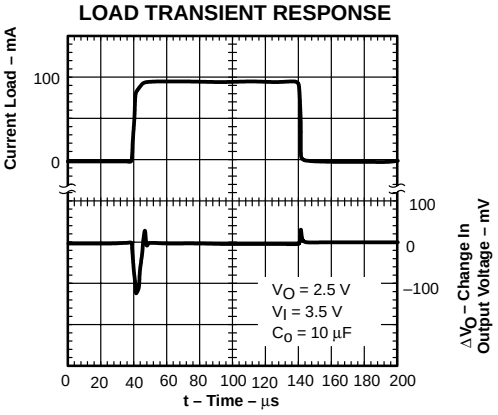



Figure 14

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

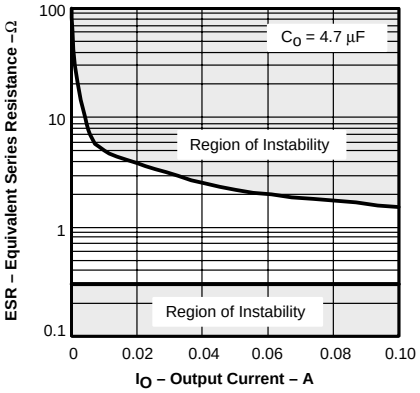



Figure 15

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

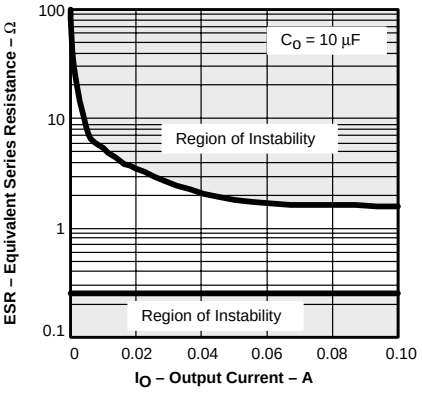



Figure 16

## APPLICATION INFORMATION

The TPS76201 low-dropout (LDO) regulator has been optimized for use in battery-operated equipment including, but not limited to, the sub 1.2-V DSP core voltage supplies. It features low quiescent current (23 μA nominally) and enable inputs to reduce supply currents to 1 μA when the regulators are turned off.

A typical application circuit is shown in Figure 17.

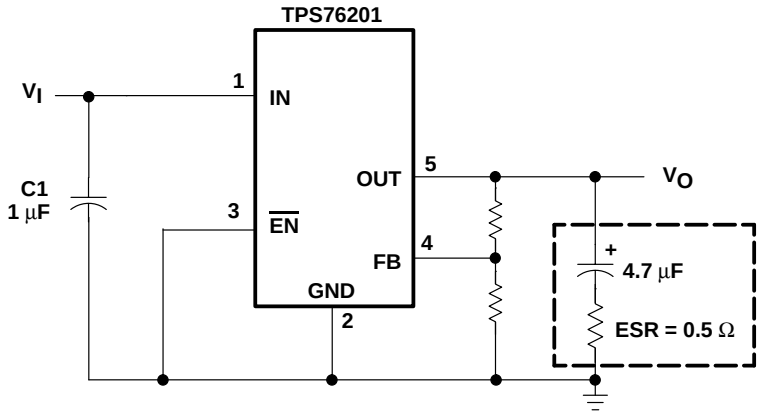



**Figure 17. Typical Application Circuit**

### external capacitor requirements

Although not required, a 0.047-μF or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS76201, 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 TPS76201 requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 4.7 μF. The ESR (equivalent series resistance) of the capacitor should be between 0.3 Ω and 1.5 Ω. to ensure stability. Capacitor values larger than 4.7 μF are acceptable, and allow the use of smaller ESR values. Capacitances less than 4.7 μF 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 μF 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 × L × W)‡ |
|---|---|---|---|---|
| T494B475K016AS | KEMET | 4.7 μF | 1.5 Ω | 1.9 × 3.5 × 2.8 |
| 195D106x0016x2T | SPRAGUE | 10 μF | 1.5 Ω | 1.3 × 7.0 × 2.7 |
| 695D106x003562T | SPRAGUE | 10 μF | 1.3 Ω | 2.5 × 7.6 × 2.5 |
| TPSC475K035R0600 | AVX | 4.7 μF | 0.6 Ω | 2.6 × 6.0 × 3.2 |

† ESR is maximum resistance in Ohms at 100 kHz and $T_A$ = 25°C. Contact manufacturer for minimum ESR values.
‡ Size is in mm.

## APPLICATION INFORMATION

### output voltage programming

The output voltage of the TPS76201 adjustable regulator is programmed using an external resistor divider as shown in Figure 18. The output voltage is calculated using:

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

Where:

$V_{ref}$ = 0.6663 V typ (the internal reference voltage)

Resistors R1 and R2 should be chosen for approximately 10-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 = 66.5 kΩ to set the divider current at 10 μA and then calculate R1 using:

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

**OUTPUT VOLTAGE PROGRAMMING GUIDE**

| OUTPUT VOLTAGE (V) | DIVIDER RESISTANCE (kΩ)‡ | |
|---|---|---|
| | R1 | R2 |
| 0.7 | 3.36 | 66.5 |
| 0.9 | 23.2 | 66.5 |
| 1.2 | 53.6 | 66.5 |
| 1.5 | 83.5 | 66.5 |
| 1.8 | 113 | 66.5 |
| 2.5 | 182 | 66.5 |
| 3.3 | 246 | 66.5 |
| 3.6 | 294 | 66.5 |
| 4 | 332 | 66.5 |
| 5 | 432 | 66.5 |

‡ 1% values shown.

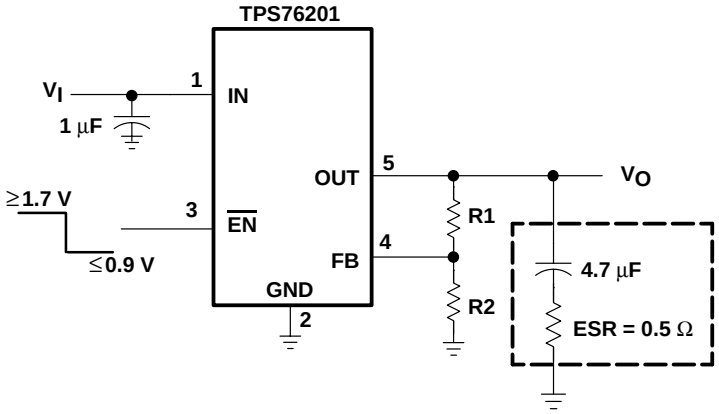



**Figure 18. TPS76201 Adjustable LDO Regulator Programming**

## 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.

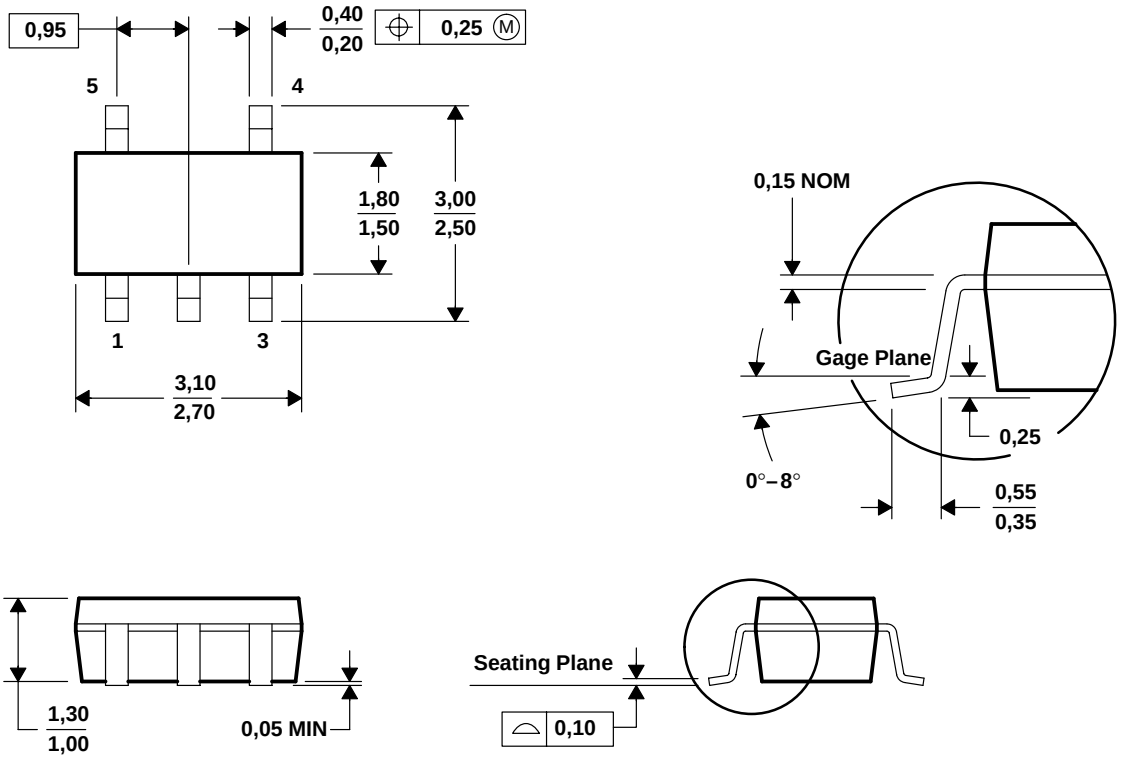
### regulator protection

The TPS76201 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 TPS76201 features internal current limiting and thermal protection. During normal operation, the TPS76201 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.

## MECHANICAL DATA

**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 include mold flash or protrusion.

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