ULTRALOW-POWER 100-mA LOW DROPOUT LINEAR REGULATOR

Check for Samples: TPS76901-HT

FEATURES

- **100-mA Low-Dropout Regulator**
- **Available in Adjustable Versions**
- **Only 335-µA Quiescent Current With 100 mA at 210°C**
- **1-µA Quiescent Current in Standby Mode**
- **Dropout Voltage Typically 71 mV at 100 mA**
- **Over Current Limitation**

APPLICATIONS

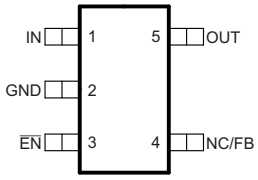
- **Down-Hole Drilling**
- **High Temperature Environments**

SUPPORTS EXTREME TEMPERATURE APPLICATIONS

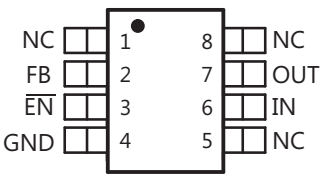
- **Controlled Baseline**
- **One Assembly/Test Site**
- **One Fabrication Site**
- **Available in Extreme (–55°C/210°C) Temperature Range** (1)
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**
- **Texas Instruments' high temperature products utilize highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.**

(1) Custom temperature ranges available

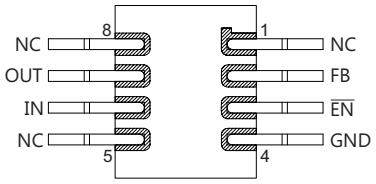
DBV PACKAGE (TOP VIEW)



HKJ PACKAGE (TOP VIEW)



HKQ PACKAGE (TOP VIEW)



HKQ as formed or HKJ mounted dead bug

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 µA 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 µA, typical at T_J = 25°C. The TPS76901 is a variable version programmable over the range of 1.2 V to 4.5 V).

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.

BARE DIE INFORMATION

DIE THICKNESS	BACKSIDE FINISH	BACKSIDE POTENTIAL	BOND PAD METALLIZATION COMPOSITION
15 mils.	Silicon with backgrind	GND	Al-Si-Cu (0.5%)

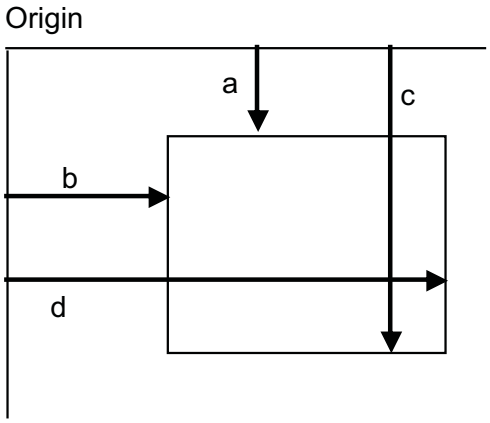
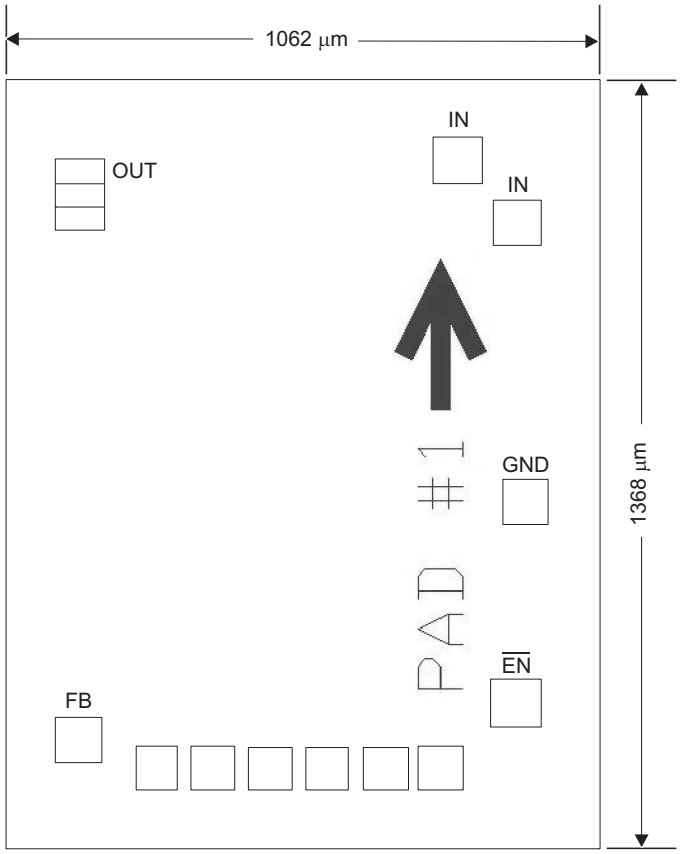


Table 1. BOND PAD COORDINATES

DESCRIPTION(1)	PAD NUMBER	a	b	c	d
IN	1	91.55	764.45	176.55	849.45
OUT	2	130.10	91.50	215.10	176.50
DNC	3	177.10	91.50	253.10	176.50
FB	4	1130.75	91.50	1215.75	176.50
DNC	5	1180.00	229.00	1256.00	305.00
DNC	6	1180.00	330.00	1256.00	406.00
DNC	7	1180.00	431.00	1256.00	507.00
DNC	8	1180.00	532.00	1256.00	608.00
DNC	9	1180.00	633.00	1256.00	709.00
DNC	10	1180.00	734.00	1256.00	810.00
$\overline{EN}$	11	1058.50	864.50	1143.50	949.50
GND	12	700.00	881.00	785.00	966.00
IN	13	202.50	864.50	287.50	949.50

(1) DNC = Do not connect

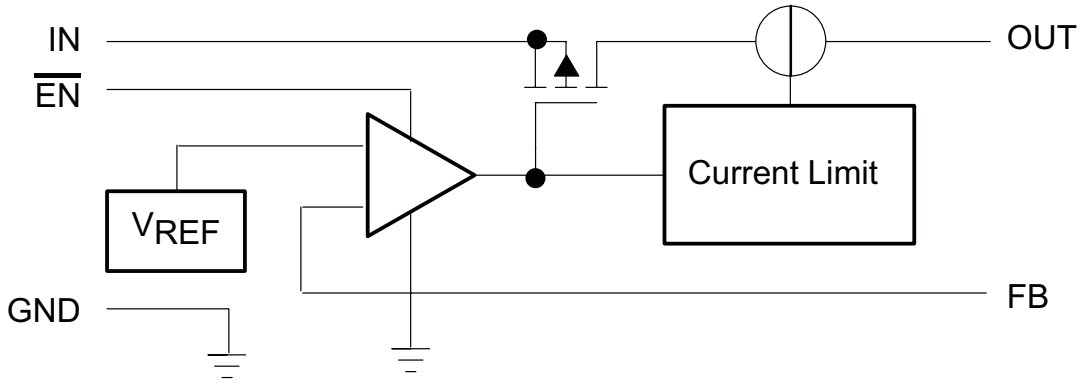

1062 µm
1368 µm
OUT
IN
IN
GND
EN
FB
PAD #1

ORDERING INFORMATION(1)

T_A	PACKAGE(2)	ORDERABLE PART NUMBER	TOP-SIDE MARKING
–55°c to 175°C	DBV	TPS76901HDBVT	PCFS
–55°c to 210°C	KGD	TPS76901SKGD1	NA
		TPS76901SKGD2	
	HKJ	TPS76901SHKJ	TPS76901SHKJ
	HKQ	TPS76901SHKQ	TPS76901SHKQ

(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.
(2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTIONAL BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS(1)

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

		VALUE	UNIT
V_{REF}	Input voltage range(2)	–0.3 to 13.5	V
	Voltage range at $\overline{EN}$	–0.3 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 Ratings Table	
T_J	Operating virtual junction temperature range	–55 to 210	°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 FOR DBV PACKAGE

BOARD	$R_{\theta JC}$	$R_{\theta JA}$	DERATING FACTOR ABOVE T_A = 25°C
Low K(1)	65.8 °C/W	259 °C/W	3.9 mW/°C
High K(2)	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.

THERMAL CHARACTERISTICS FOR HKJ OR HKQ PACKAGE

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

PARAMETER			MIN	TYP	MAX	UNIT
θ_{JC}	Junction-to-case thermal resistance	to ceramic side of case			5.7	°C/W
		to top of case lid (metal side of case)			13.7	

RECOMMENDED OPERATING CONDITIONS

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

		MIN	NOM	MAX	UNIT
V_I	Input votlage(1)	5		10	V
V_O	Ouput voltage range	1.2		4.5	V
I_O	Continuous output current(2)	0		100	mA
T_J	Operating junction temperature	–55		210	°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 operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage (10 µA to 100 mA load)(1)	1.2 V ≤ V_O ≤ 4.5 V	T_J = 25°C		V_O		V
			T_J = –55°C to 125°C	0.95V_O		1.03V_O	
			T_J = 175°C	0.84V_O		1.03V_O	
			T_J = 210°C	0.84V_O		1.03V_O	
I_Q	Quiescent Current (GND current)(1) (2)	$\overline{EN}$ = 0 V, 0 mA < I_O < 100 mA	T_J = 25°C		17		µA
		$\overline{EN}$ = 4 V, I_O = 100 mA	T_J = –55°C to 125°C			28	
			T_J = 175°C		23	28	
			T_J = 210°C		335		
	Load regulation	$\overline{EN}$ = 0 V, I_O = 0 to 100 mA	T_J = 25°C		12		mV
			T_J = 175°C		16.5		
			T_J = 210°C		23.4		
	Output voltage line regulation ($\Delta V_O/V_O$)(2)	5 V ≤ V_I ≤ 10 V(1)	T_J = 25°C		0.04		%
			T_J = –55°C to 125°C			0.1	
			T_J = 175°C			0.275	
			T_J = 210°C			0.34	
V_N	Output noise voltage	BW = 300 Hz to 50 kHz, C_O = 10 µF	T_J = 25°C		190		µVms

(1) Minimum IN operating voltage is 5V. Maximum IN voltage 10 V, minimum output current 10 µA, maximum output current 100 mA.
(2) Line Regulation (%) = (ΔV_{OUT}) / (ΔV_{IN}) x 100

ELECTRICAL CHARACTERISTICS (continued)

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
	Output current limit	V_O = 0 V(1)	T_J = 25°C		350		mA
			T_J = –55°C to 125°C			750	
			T_J = 175°C		350	750	
			T_J = 210°C		505		
I_{STDBY}	Standby current	$\overline{EN}$ = V_I, 5 V ≤ V_I ≤ 10 V	T_J = 25°C		1		µA
			T_J = –55°C to 125°C			2	
			T_J = 175°C		8.8	11.85	
			T_J = 210°C		150		
I_{FB}	FB input current	FB = 1.224 V	T_J = –55°C to 125°C	–1		1	µA
			T_J = 175°C		0.02		
			T_J = 210°C		0.2		
V_{IH}	High level enable input voltage	5 V ≤ V_I ≤ 10 V	T_J = 25°C	1.7			V
V_{IL}	Low level enable input voltage	5 V ≤ V_I ≤ 10 V	T_J = 25°C			0.9	V
			T_J = 175°C		0.6		
			T_J = 210°C		0.4		
PSRR	Power supply ripple rejection	f = 1 kHz, CO = 10 µF(3)	T_J = 25°C		60		dB
I_{IN}	Input current	$\overline{EN}$ = 0 V	T_J = 25°C	–1	0	1	µA
			T_J = 175°C		0.14		
			T_J = 210°C		3.5		
		$\overline{EN}$ = V_I	T_J = 25°C	–1		1	
			T_J = 175°C		3.8		
			T_J = 210°C		5.5		

(3) Minimum IN operating voltage is 5V. Maximum IN voltage 10 V, minimum output current 10 µA, maximum output current 100 mA.

DEVICE INFORMATION

TERMINAL FUNCTIONS

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
NC	1, 5, 8		No connection
FB	2	I	Feedback voltage
$\overline{EN}$	3	I	Enable input
GND	4		Ground
IN	6	I	Input supply voltage
OUT	7	O	Regulated output voltage

TYPICAL CHARACTERISTICS

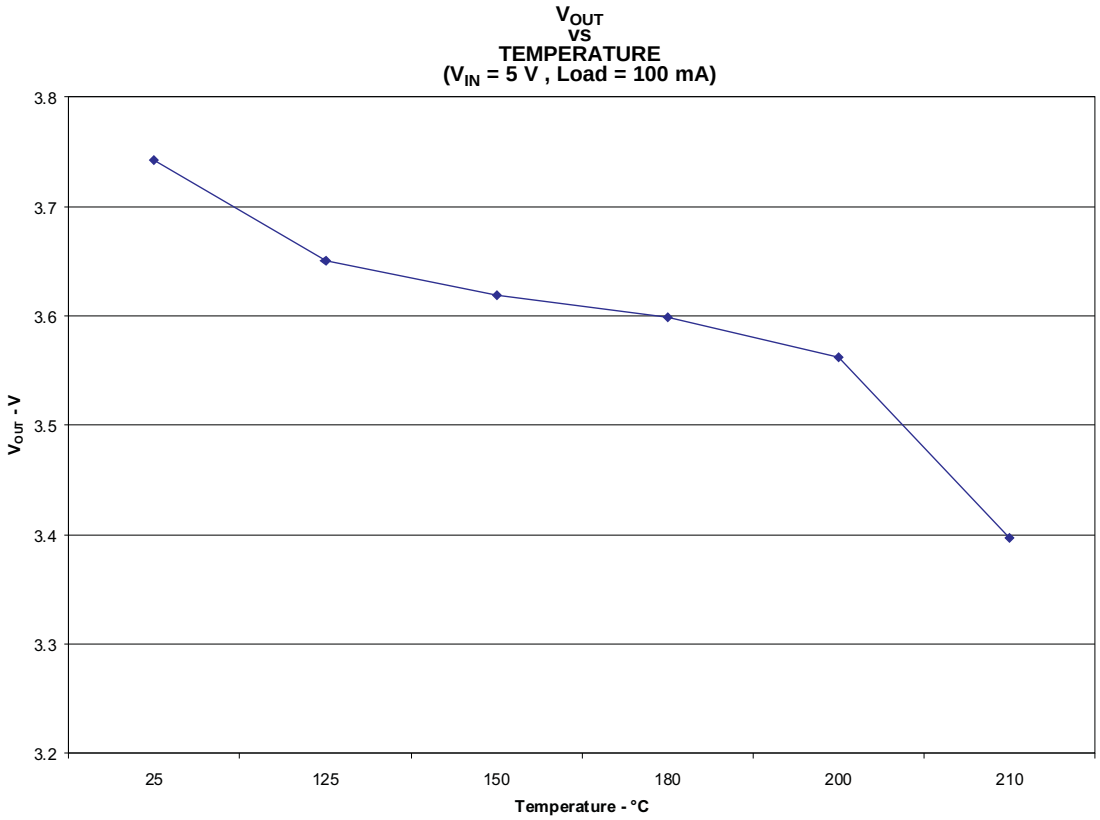


Figure 1.

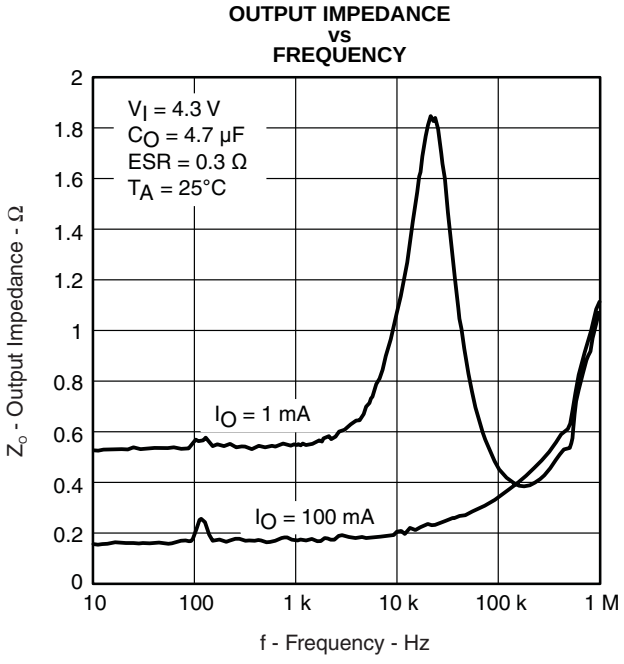


Figure 2.

TYPICAL CHARACTERISTICS (continued)

LDO STARTUP TIME

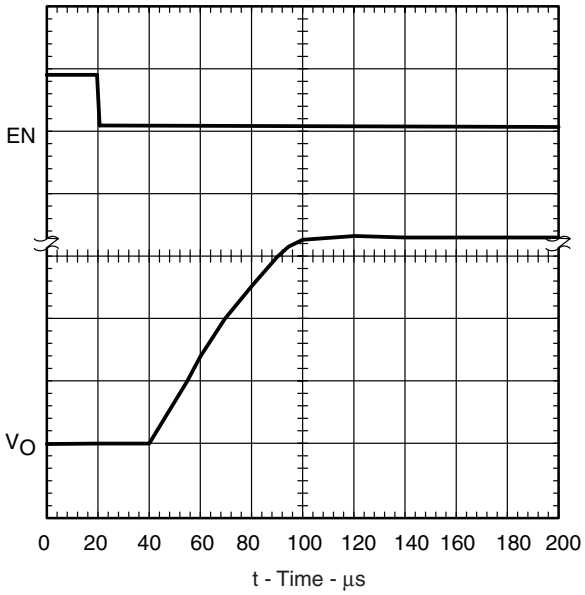
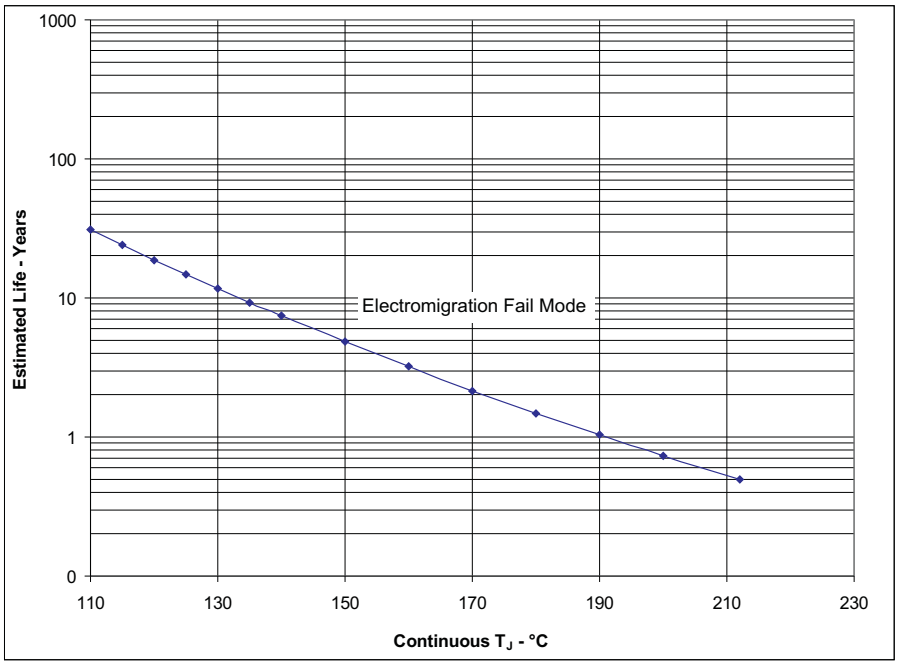


Figure 3.

TYPICAL CHARACTERISTICS (continued)

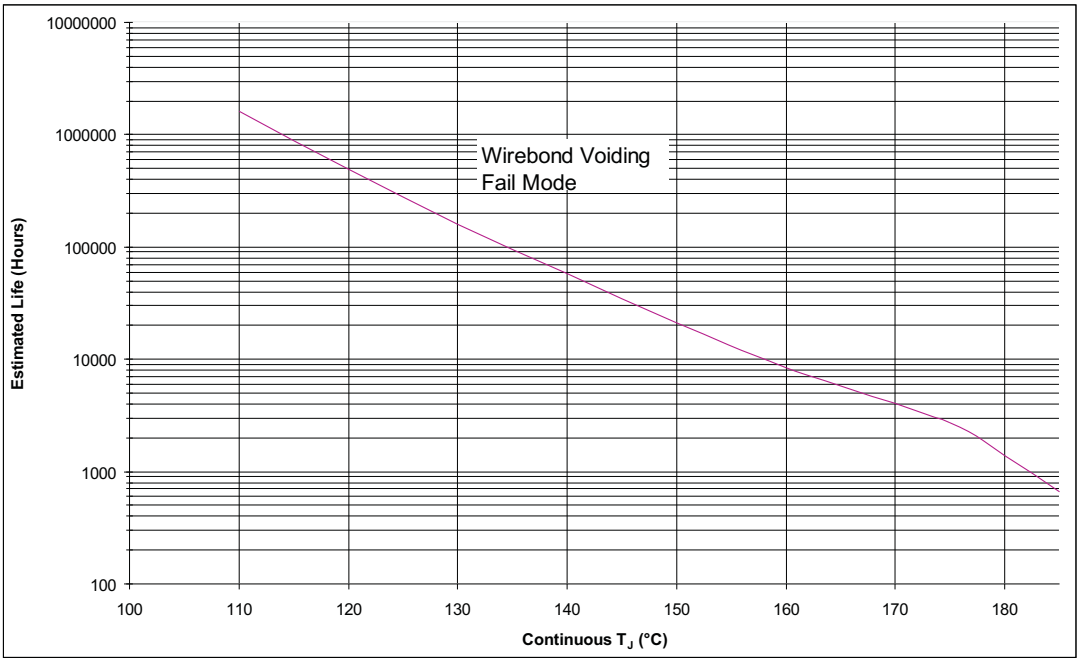


Note:

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).

Figure 4. TPS76901HDBVT / TPS76901SKGD1 / TPS76901SKGD2 / TPS76901SHKJ / TPS76901SHKQ Operating Life Derating Chart

TYPICAL CHARACTERISTICS (continued)



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).

Figure 5. TPS76901HDBVT Operating Life Derating Chart

APPLICATION INFORMATION (1)

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 µA nominally), and enables inputs to reduce supply currents to 1 µA 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 µA. 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 6.

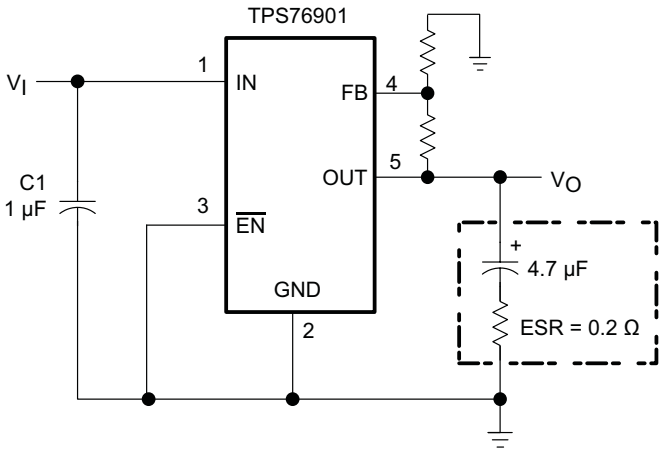


Figure 6. Typical Application Circuit

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 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 µF. The ESR (equivalent series resistance) of the capacitor should be between 0.2 Ω and 10 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.

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

Table 2. CAPACITOR SELECTION

PART NO.	MANUFACTURER	VALUE	MAX ESR(1)	SIZE (H x L x W)(1)
T494B475K016AS	KEMET	4.7 µF	1.5 Ω	1.9 x 3.5 x 2.8
195D106x0016x2T	SPRAGUE	10 µF	1.5 Ω	1.3 x 7.0 x 2.7
695D106x003562T	SPRAGUE	10 µF	1.3 Ω	2.5 x 7.6 x 2.5
TPSC475K035R0600	AVX	4.7 µF	0.6 Ω	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°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 7. The output voltage is calculated using:

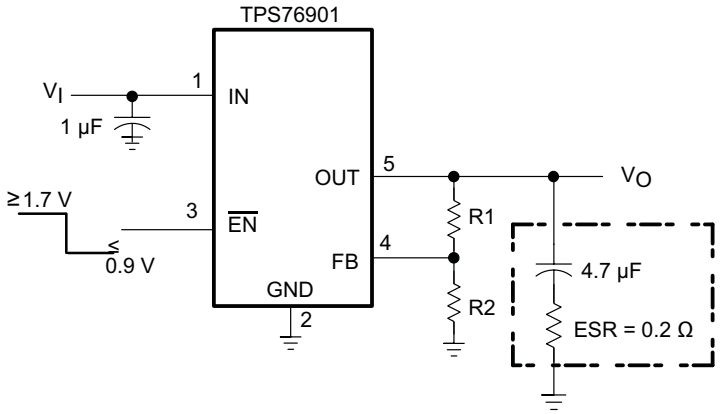
$$V_O = V_{REF} \bullet \left(1 + \frac{R1}{R2}\right) \quad (1)$$

Where:

V_{REF} = 1.16 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:

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



Note:

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

Figure 7. Adjustable LDO Reulator 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.

REVISION HISTORY

Changes from Revision E (April 2012) to Revision D	Page
• Added KGD2 package option	4

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPS76901SHKJ	Active	Production	CFP (HKJ) | 8	25 | TUBE	Yes	Call TI	N/A for Pkg Type	-55 to 210	TPS76901S HKJ
TPS76901SHKJ.A	Active	Production	CFP (HKJ) | 8	25 | TUBE	Yes	Call TI	N/A for Pkg Type	-55 to 210	TPS76901S HKJ
TPS76901SHKQ	Active	Production	CFP (HKQ) | 8	25 | TUBE	Yes	AU	N/A for Pkg Type	-55 to 210	TPS76901S HKQ TPS76901
TPS76901SHKQ.A	Active	Production	CFP (HKQ) | 8	25 | TUBE	Yes	AU	N/A for Pkg Type	-55 to 210	TPS76901S HKQ TPS76901
TPS76901SKGD1	Active	Production	XCEPT (KGD) | 0	400 | NOT REQUIRED	Yes	Call TI	N/A for Pkg Type	-55 to 210	
TPS76901SKGD1.A	Active	Production	XCEPT (KGD) | 0	400 | NOT REQUIRED	Yes	Call TI	N/A for Pkg Type	-55 to 210	
TPS76901SKGD2	Active	Production	XCEPT (KGD) | 0	10 | NOT REQUIRED	No	Call TI	N/A for Pkg Type	-55 to 210	
TPS76901SKGD2.A	Active	Production	XCEPT (KGD) | 0	10 | NOT REQUIRED	No	Call TI	N/A for Pkg Type	-55 to 210	

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

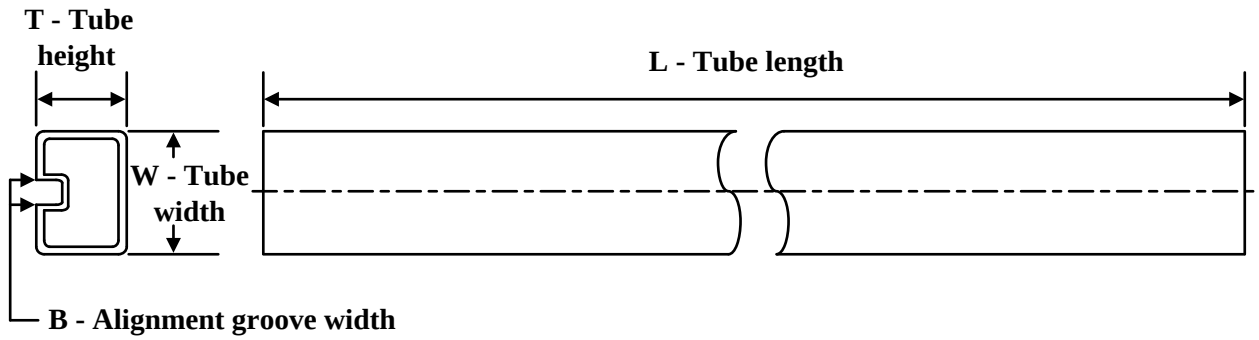
OTHER QUALIFIED VERSIONS OF TPS76901-HT :

- Enhanced Product : TPS76901-EP

NOTE: Qualified Version Definitions:

- Enhanced Product - Supports Defense, Aerospace and Medical Applications

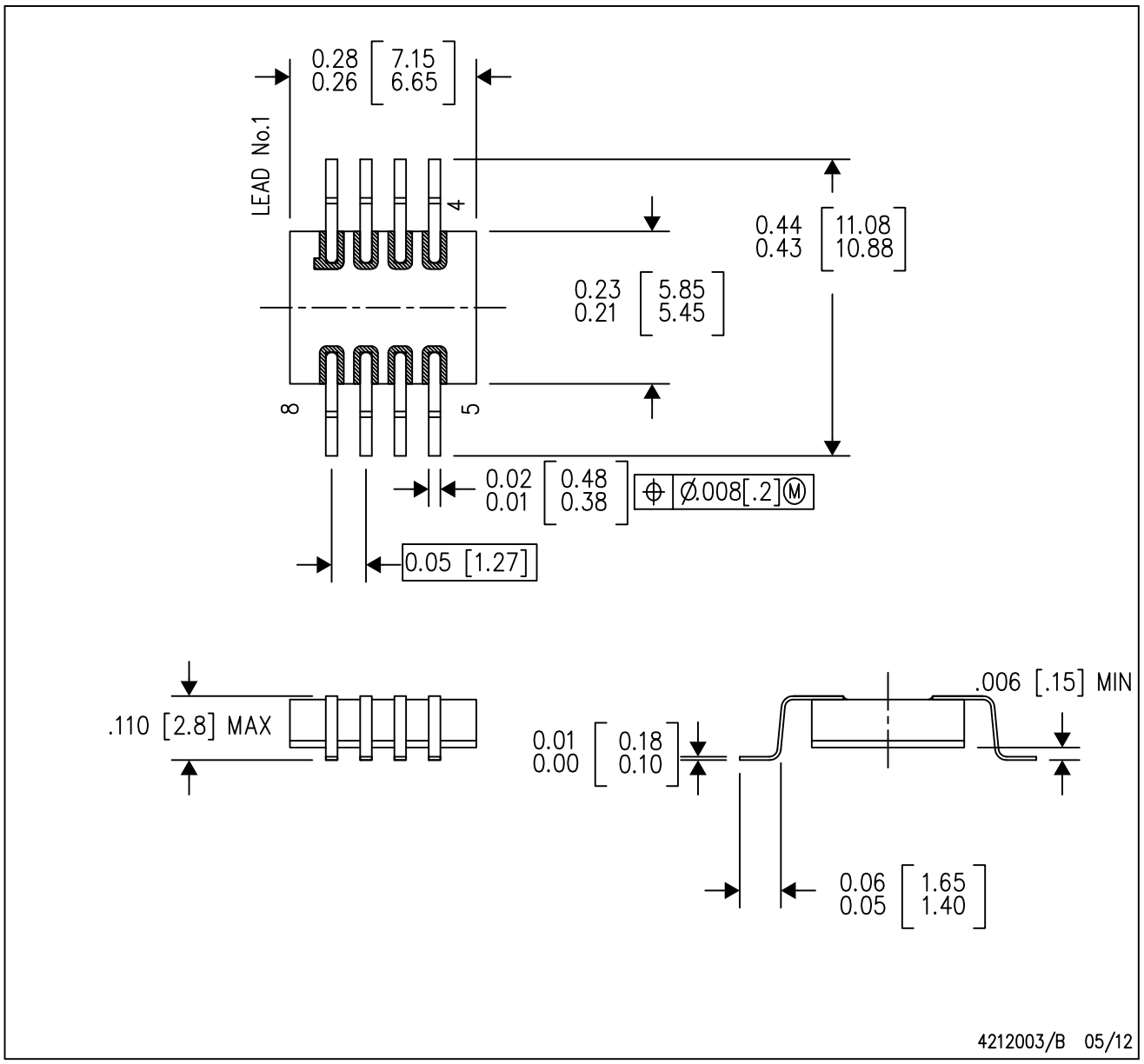
TUBE



*All dimensions are nominal

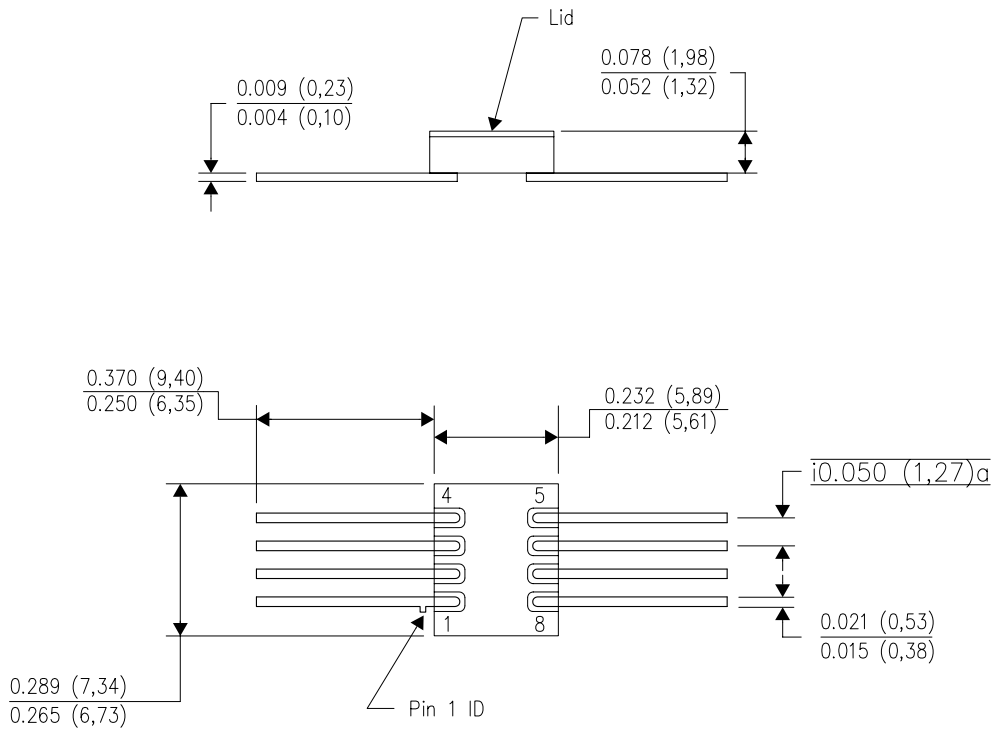
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
TPS76901SHKJ	HKJ	CFP	8	25	506.98	26.16	6220	NA
TPS76901SHKJ.A	HKJ	CFP	8	25	506.98	26.16	6220	NA
TPS76901SHKQ	HKQ	CFP	8	25	506.98	26.16	6220	NA
TPS76901SHKQ.A	HKQ	CFP	8	25	506.98	26.16	6220	NA

HKQ (R–CDFP–G8) CERAMIC GULL WING



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals will be gold plated.
E. Lid is not connected to any lead.

HKJ (R–CDFP–F8) CERAMIC DUAL FLATPACK



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NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals will be gold plated.

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