

## LM2991 Negative Low Dropout Adjustable Regulator

Check for Samples: [LM2991](#)

### FEATURES

- Output Voltage Adjustable from –3V to –24V, Typically –2V to –25V
- Output Current in Excess of 1A
- Dropout Voltage Typically 0.6V at 1A Load
- Low Quiescent Current
- Internal Short Circuit Current Limit
- Internal Thermal Shutdown with Hysteresis
- TTL, CMOS Compatible  $\overline{\text{ON/OFF}}$  Switch
- Functional Complement to the LM2941 Series

### APPLICATIONS

- Post Switcher Regulator
- Local, On-Card, Regulation
- Battery Operated Equipment

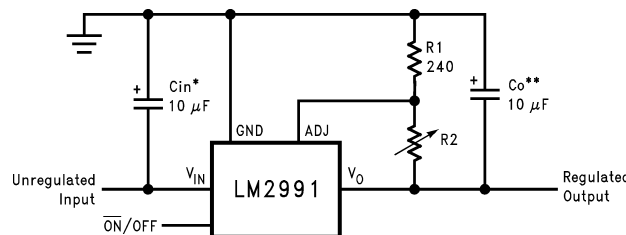
### DESCRIPTION

The LM2991 is a low dropout adjustable negative regulator with a output voltage range between –3V to –24V. The LM2991 provides up to 1A of load current and features a On /Off pin for remote shutdown capability.

The LM2991 uses new circuit design techniques to provide a low dropout voltage, low quiescent current and low temperature coefficient precision reference. The dropout voltage at 1A load current is typically 0.6V and an ensured worst-case maximum of 1V over the entire operating temperature range. The quiescent current is typically 1 mA with a 1A load current and an input-output voltage differential greater than 3V. A unique circuit design of the internal bias supply limits the quiescent current to only 9 mA (typical) when the regulator is in the dropout mode ( $V_{\text{OUT}} - V_{\text{IN}} \leq 3\text{V}$ ).

The LM2991 is short-circuit proof, and thermal shutdown includes hysteresis to enhance the reliability of the device when inadvertently overloaded for extended periods. The LM2991 is available in 5-lead TO-220 and DDPAK/TO-263 packages and is rated for operation over the automotive temperature range of –40°C to +125°C. Mil-Aero versions are also available.

### Typical Application



$$V_{\text{OUT}} = V_{\text{REF}} (1 + R2/R1)$$

\*Required if the regulator is located further than 6 inches from the power supply filter capacitors. A 1 µF solid tantalum or a 10 µF aluminum electrolytic capacitor is recommended.

\*\*Required for stability. Must be at least a 10 µF aluminum electrolytic or a 1 µF solid tantalum to maintain stability.

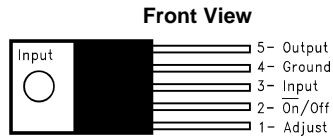
May be increased without bound to maintain regulation during transients. Locate the capacitor as close as possible to the regulator. The equivalent series resistance (ESR) is critical, and should be less than 10Ω over the same operating temperature range as the regulator.



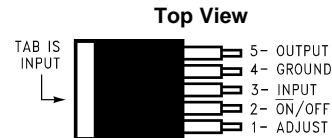
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## Connection Diagrams



**Figure 1. TO-220 Package, 5-Lead, Straight**  
See Package Number KC



**Figure 2. DPAK, TO-263 Package, 5-Lead, Surface-Mount**  
See Package Number NDH



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

## Absolute Maximum Ratings<sup>(1)(2)</sup>

Input Voltage	-26V to +0.3V
ESD Susceptibility <sup>(3)</sup>	2 kV
Power Dissipation <sup>(4)</sup>	Internally limited
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	230°C

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
- (3) Human body model, 100 pF discharged through a 1.5 kΩ resistor.
- (4) The maximum allowable power dissipation is a function of the maximum operating junction temperature ( $T_{J(MAX)}$ ), the thermal resistance of the package ( $\theta_{JA}$ ), and the ambient temperature ( $T_A$ ). The maximum allowable power dissipation is:  $P_D = (T_{J(MAX)} - T_A)/\theta_{JA}$ , where  $T_{J(MAX)}$  is 125°C, and  $T_A$  is the maximum expected ambient temperature. If this dissipation is exceeded, the die temperature will rise above 125°C. Excessive power dissipation will cause the LM2991 to go into thermal shutdown (See [THERMAL SHUTDOWN](#)). For the LM2991, the junction-to-ambient thermal resistance is 53°C/W for the TO-220, 73°C/W for the DPAK/TO-263, and junction-to-case thermal resistance is 3°C/W. If the DPAK/TO-263 package is used, the thermal resistance can be reduced by increasing the PC board copper area thermally connected to the package. Using 0.5 square inches of copper area,  $\theta_{JA}$  is 50°C/W; with 1 square inch of copper area,  $\theta_{JA}$  is 37°C/W; and with 1.6 or more square inches of copper area,  $\theta_{JA}$  is 32°C/W.

## Operating Ratings<sup>(1)</sup>

Junction Temperature Range ( $T_J$ )	-40°C to +125°C
ON/OFF Pin	0V to +5V
Maximum Input Voltage (Operational)	-26V

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics.

## Electrical Characteristics

$V_{IN} = -10V$ ,  $V_O = -3V$ ,  $I_O = 1A$ ,  $C_O = 47 \mu F$ ,  $R1 = 2.7 k\Omega$ ,  $T_J = 25^\circ C$ , unless otherwise specified. **Boldface** limits apply over the entire operating junction temperature range.

Parameter	Conditions	Typical <sup>(1)</sup>	Min	Max	Units
Reference Voltage	$5 mA \leq I_O \leq 1A$	-1.210	-1.234	-1.186	V
	$5 mA \leq I_O \leq 1A$ , $V_O - 1V \geq V_{IN} \geq -26V$		<b>-1.27</b>	<b>-1.15</b>	
Output Voltage Range		-2		-3	V
	$V_{IN} = -26V$	-25	-24		
Line Regulation	$I_O = 5 mA$ , $V_O - 1V \geq V_{IN} \geq -26V$	0.004		0.04	%/V
Load Regulation	$50 mA \leq I_O \leq 1A$	0.04		0.4	%
Dropout Voltage	$I_O = 0.1A$ , $\Delta V_O \leq 100 mV$	0.1		0.2	V
				<b>0.3</b>	
	$I_O = 1A$ , $\Delta V_O \leq 100 mV$	0.6		0.8	V
				<b>1</b>	
Quiescent Current	$I_O \leq 1A$	0.7		<b>5</b>	mA
Dropout Quiescent Current	$V_{IN} = V_O$ , $I_O \leq 1A$	16		50	mA
Ripple Rejection	$V_{ripple} = 1 V_{rms}$ , $f_{ripple} = 1 kHz$ , $I_O = 5 mA$	60	50		dB
Output Noise	10 Hz – 100 kHz, $I_O = 5 mA$	200		450	$\mu V$
$\overline{ON}$ /OFF Input Voltage	( $V_{OUT}$ : ON)	1.2		<b>0.8</b>	V
	( $V_{OUT}$ : OFF)	1.3	<b>2.4</b>		
$\overline{ON}$ /OFF Input Current	$V_{\overline{ON}/OFF} = 0.8V$ ( $V_{OUT}$ : ON)	0.1		10	$\mu A$
	$V_{\overline{ON}/OFF} = 2.4V$ ( $V_{OUT}$ : OFF)	40		100	
Output Leakage Current	$V_{IN} = -26V$ , $V_{\overline{ON}/OFF} = 2.4V$ , $V_{OUT} = 0V$	60		250	$\mu A$
Current Limit	$V_{OUT} = 0V$	2	1.5		A

(1) Typicals are at  $T_J = 25^\circ C$  and represent the most likely parametric norm.

## Typical Performance Characteristics

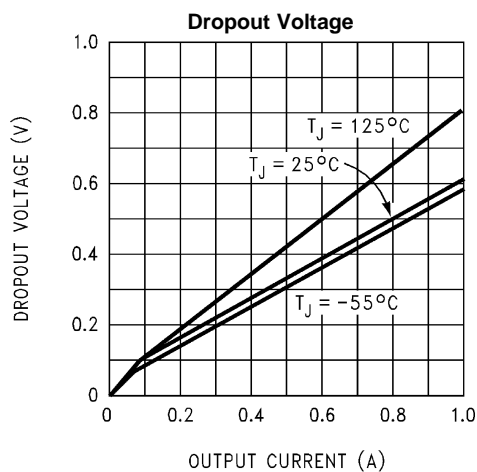


Figure 3.

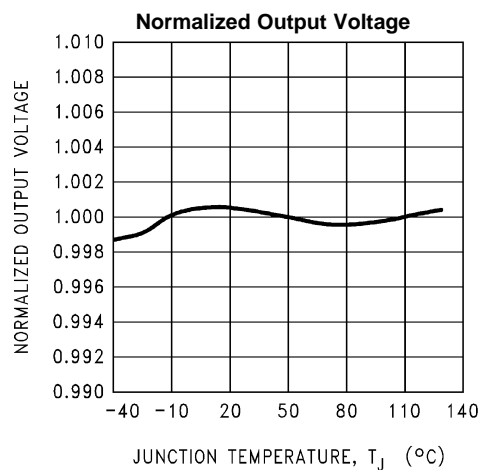


Figure 4.

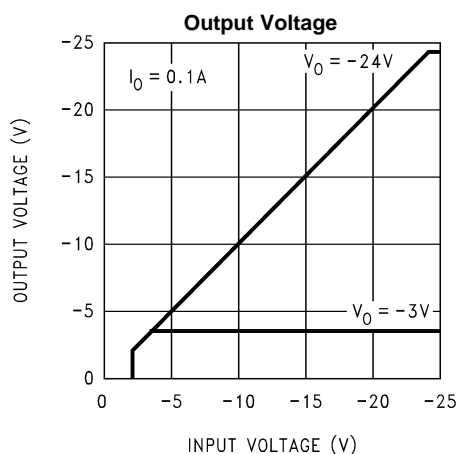


Figure 5.

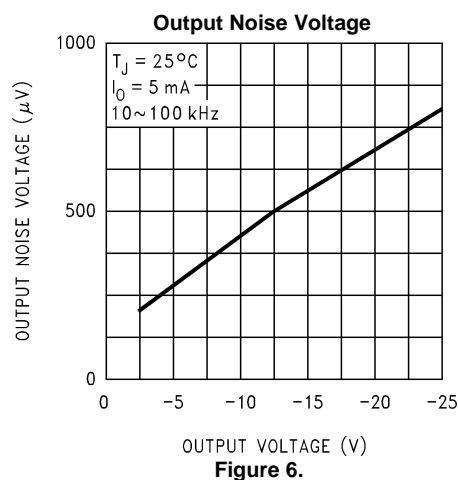


Figure 6.

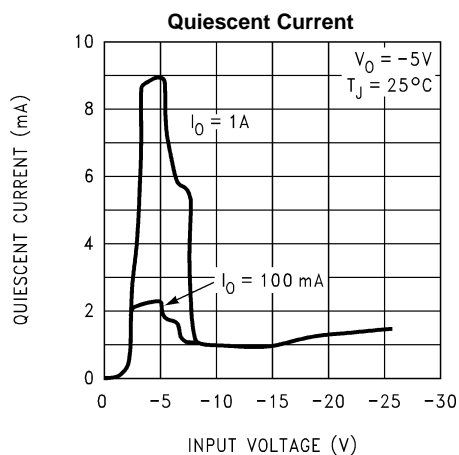


Figure 7.

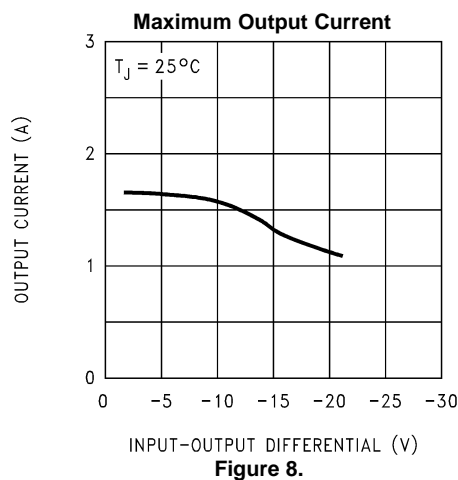
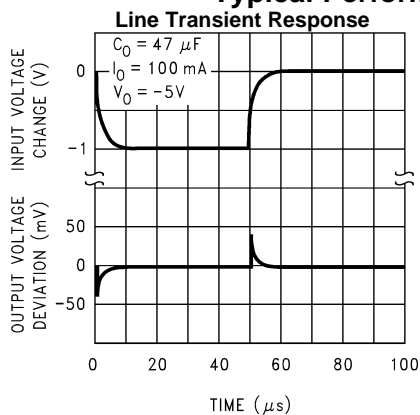
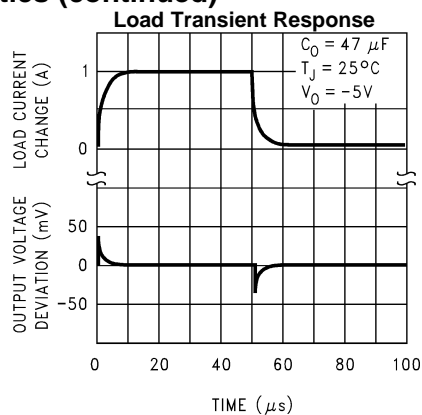


Figure 8.

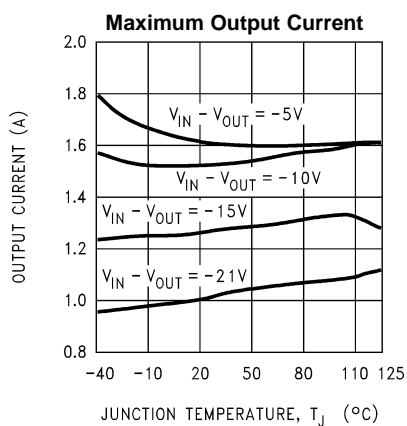
## Typical Performance Characteristics (continued)



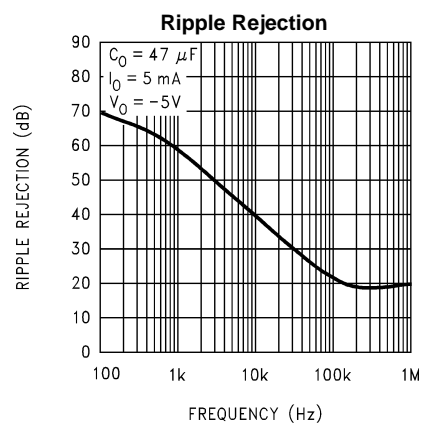
**Figure 9.**



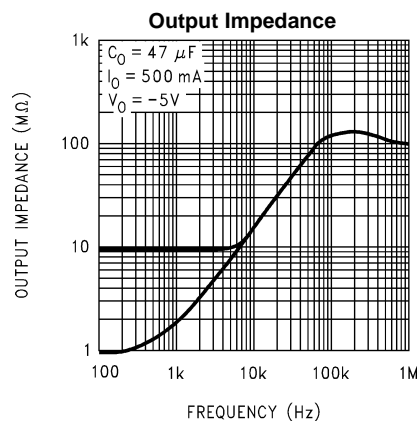
**Figure 10.**



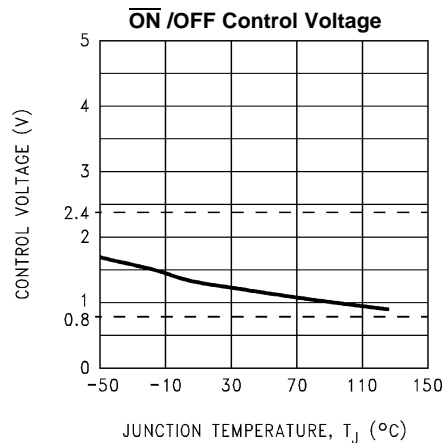
**Figure 11.**



**Figure 12.**



**Figure 13.**



**Figure 14.**

## Typical Performance Characteristics (continued)

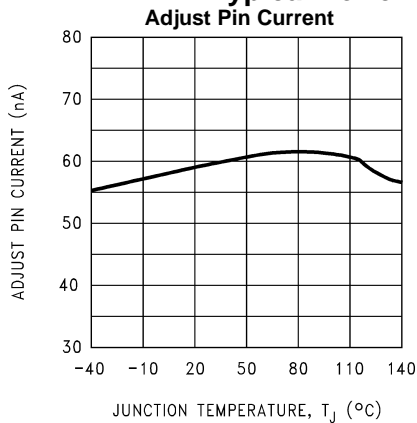


Figure 15.

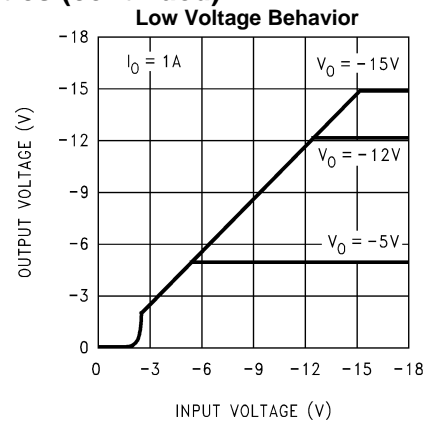


Figure 16.

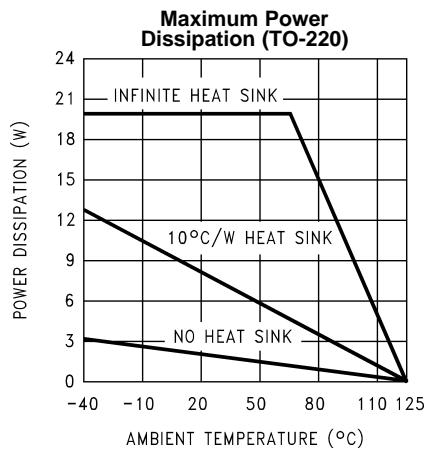


Figure 17.

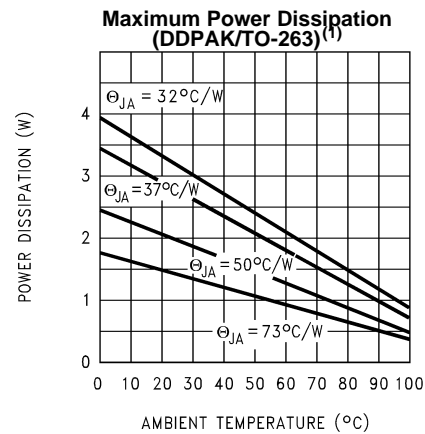


Figure 18.

- (1) The maximum allowable power dissipation is a function of the maximum operating junction temperature ( $T_{J(MAX)}$ ), the thermal resistance of the package ( $\theta_{JA}$ ), and the ambient temperature ( $T_A$ ). The maximum allowable power dissipation is:  $P_D = (T_{J(MAX)} - T_A)/\theta_{JA}$ , where  $T_{J(MAX)}$  is 125°C, and  $T_A$  is the maximum expected ambient temperature. If this dissipation is exceeded, the die temperature will rise above 125°C. Excessive power dissipation will cause the LM2991 to go into thermal shutdown (See [THERMAL SHUTDOWN](#)). For the LM2991, the junction-to-ambient thermal resistance is 53°C/W for the TO-220, 73°C/W for the DDPAK/TO-263, and junction-to-case thermal resistance is 3°C/W. If the DDPAK/TO-263 package is used, the thermal resistance can be reduced by increasing the PC board copper area thermally connected to the package. Using 0.5 square inches of copper area,  $\theta_{JA}$  is 50°C/W; with 1 square inch of copper area,  $\theta_{JA}$  is 37°C/W; and with 1.6 or more square inches of copper area,  $\theta_{JA}$  is 32°C/W.

## APPLICATION HINTS

### EXTERNAL CAPACITORS

Like any low-dropout regulator, external capacitors are required to stabilize the control loop. These capacitors must be correctly selected for proper performance.

### INPUT CAPACITOR

An input capacitor is required if the regulator is located more than 6 inches from the input power supply filter capacitor (or if no other input capacitor is present).

A solid Tantalum or ceramic capacitor whose value is at least 1  $\mu\text{F}$  is recommended, but an aluminum electrolytic ( $\geq 10 \mu\text{F}$ ) may be used. However, aluminum electrolytic types should not be used in applications where the ambient temperature can drop below  $0^{\circ}\text{C}$  because their internal impedance increases significantly at cold temperatures.

### OUTPUT CAPACITOR

The output capacitor must meet the ESR limits shown in Figure 19, which means it must have an ESR between about 25  $\text{m}\Omega$  and 10  $\Omega$ .

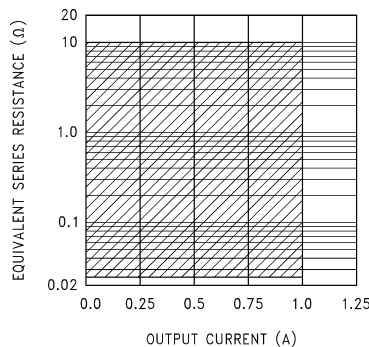


Figure 19. Output Capacitor ESR Range

A solid Tantalum (value  $\geq 1 \mu\text{F}$ ) is the best choice for the output capacitor. An aluminum electrolytic ( $\geq 10 \mu\text{F}$ ) may be used if the ESR is in the stable range.

It should be noted that the ESR of a typical aluminum electrolytic will increase by as much as 50X as the temperature is reduced from  $25^{\circ}\text{C}$  down to  $-40^{\circ}\text{C}$ , while a Tantalum will exhibit an ESR increase of about 2X over the same range. For this and other reasons, aluminum electrolytics should not be used in applications where low operating temperatures occur.

The lower stable ESR limit of 25  $\text{m}\Omega$  means that ceramic capacitors can not be used directly on the output of an LDO. A ceramic ( $\geq 2.2 \mu\text{F}$ ) can be used on the output if some external resistance is placed in series with it (1  $\Omega$  recommended). Dielectric types X7R or X5R must be used if the temperature range of the application varies more than  $\pm 25^{\circ}$  from ambient to assure the amount of capacitance is sufficient.

### CERAMIC BYPASS CAPACITORS

Many designers place distributed ceramic capacitors whose value is in the range of 1000 pF to 0.1  $\mu\text{F}$  at the power input pins of the IC's across a circuit board. These can cause reduced phase margin or oscillations in LDO regulators.

The advent of multi-layer boards with dedicated power and ground planes has removed the trace inductance that (previously) provided the necessary "de-coupling" to shield the output of the LDO from the effects of bypass capacitors.

These capacitors should be avoided if possible, and kept as far away from the LDO output as is practical.

## MINIMUM LOAD

A minimum load current of 500  $\mu$ A is required for proper operation. The external resistor divider can provide the minimum load, with the resistor from the adjust pin to ground set to 2.4 k $\Omega$ .

## SETTING THE OUTPUT VOLTAGE

The output voltage of the LM2991 is set externally by a resistor divider using the following equation:

$$V_{OUT} = V_{REF} \times (1 + R_2/R_1) - (I_{ADJ} \times R_2)$$

where

- $V_{REF} = -1.21V$  (1)

The output voltage can be programmed within the range of -3V to -24V, typically an even greater range of -2V to -25V. The adjust pin current is about 60 nA, causing a slight error in the output voltage. However, using resistors lower than 100 k $\Omega$  makes the error due to the adjust pin current negligible. For example, neglecting the adjust pin current, and setting R2 to 100 k $\Omega$  and  $V_{OUT}$  to -5V, results in an output voltage error of only 0.16%.

## ON/OFF PIN

The LM2991 regulator can be turned off by applying a TTL or CMOS level high signal to the  $\overline{ON/OFF}$  pin. The impedance of the voltage source driving the  $\overline{ON/OFF}$  pin should be low enough to source the  $\overline{ON/OFF}$  pin input current to meet the OFF threshold voltage level, 100  $\mu$ A maximum at 2.4V.

If the  $\overline{ON/OFF}$  function is not needed, the pin should be connected to Ground. The  $\overline{ON/OFF}$  pin should not be left floating, as this is not an ensured operating condition.

See the Adjustable Current Sink Application, [Figure 21](#).

## FORCING THE OUTPUT POSITIVE

Due to an internal clamp circuit, the LM2991 can withstand positive voltages on its output. If the voltage source pulling the output positive is DC, the current must be limited to 1.5A. A current over 1.5A fed back into the LM2991 could damage the device. The LM2991 output can also withstand fast positive voltage transients up to 26V, without any current limiting of the source. However, if the transients have a duration of over 1 ms, the output should be clamped with a Schottky diode to ground.

## THERMAL SHUTDOWN

The LM2991 has an internally set thermal shutdown point of typically 160°C, with approximately 10°C of hysteresis. This thermal shutdown temperature point is outside the specified [Operating Rating](#) range, above the [Absolute Maximum Ratings](#), and is intended as a safety feature for momentary fault conditions only. Continuous operation near the thermal shutdown temperature should be avoided as it may have a negative affect on the life of the device.



## Typical Applications

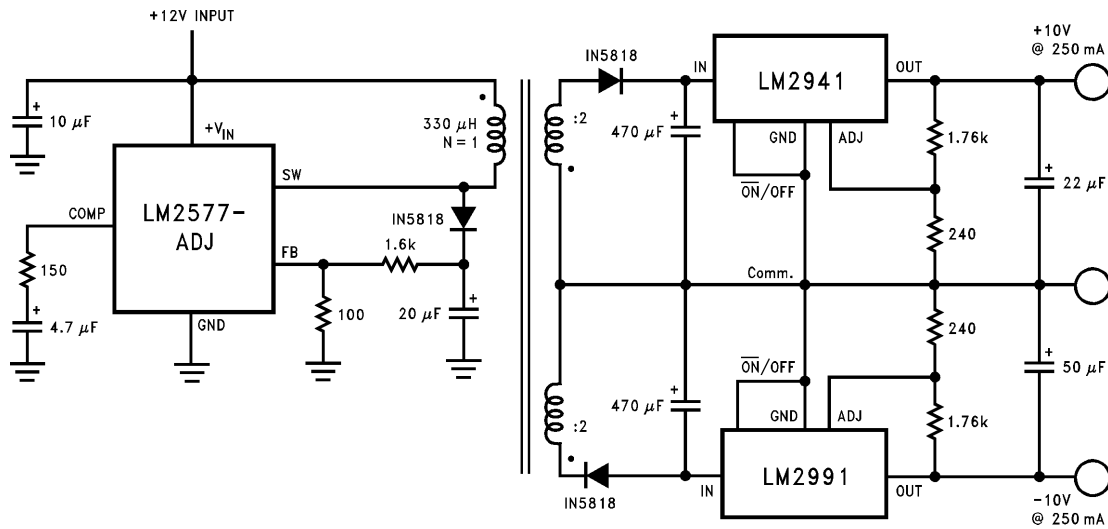


Figure 20. Fully Isolated Post-Switcher Regulator

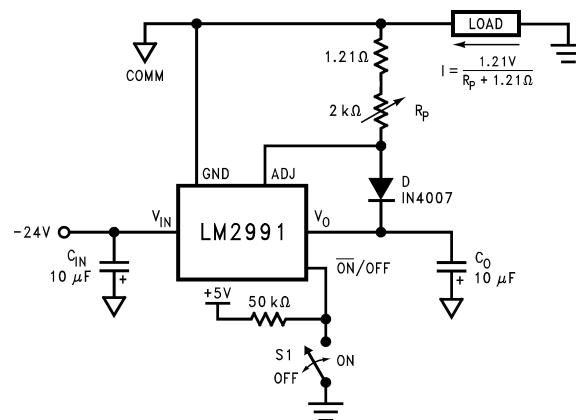
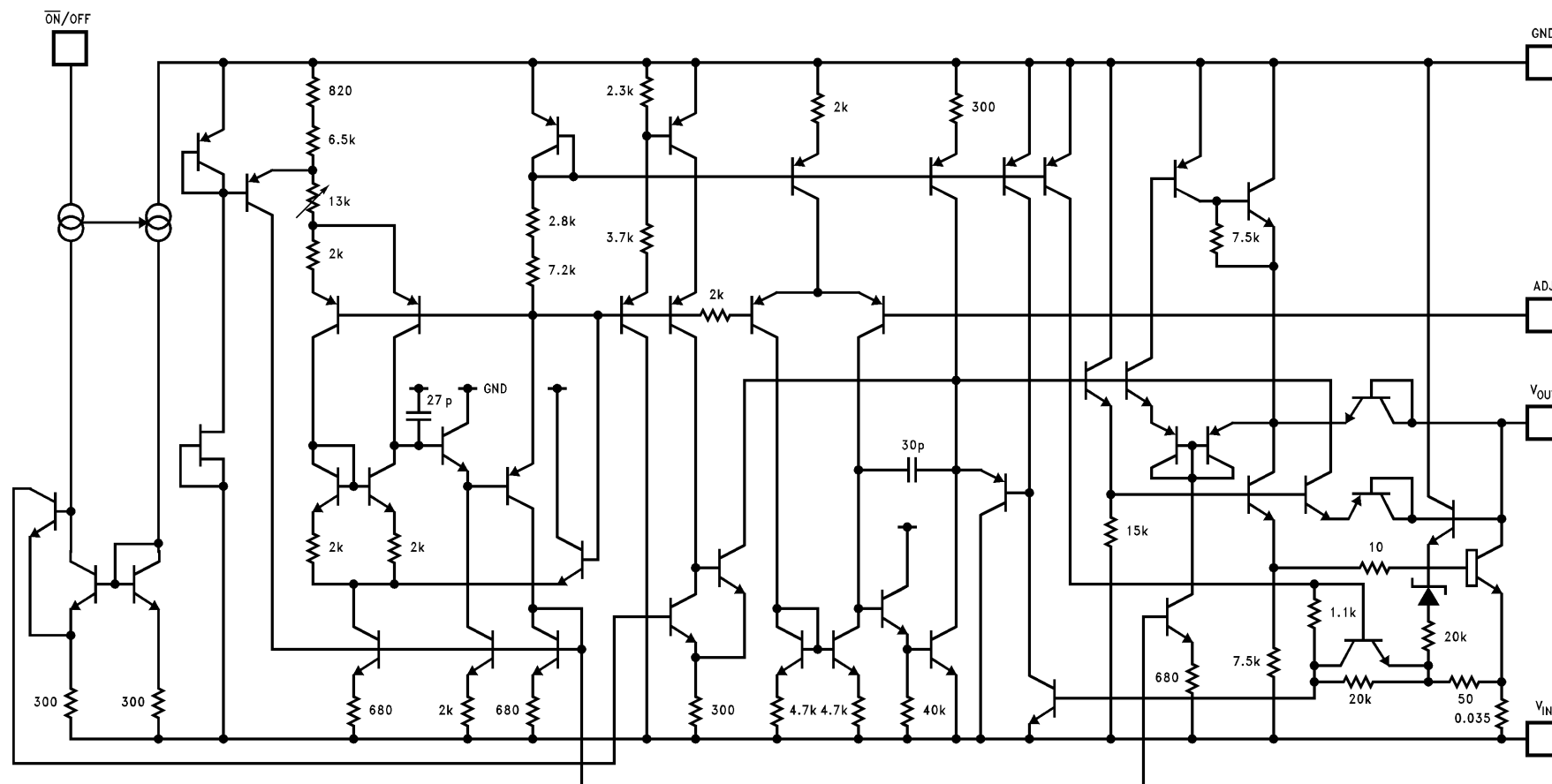


Figure 21. Adjustable Current Sink

## Equivalent Schematic



## REVISION HISTORY

### Changes from Revision G (April 2013) to Revision H

### Page

- Changed layout of National Data Sheet to TI format ..... [10](#)

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
LM2991S	ACTIVE	DDPAK/ TO-263	KTT	5	45	TBD	Call TI	Call TI	-40 to 125	LM2991S P+	<a href="#">Samples</a>
LM2991S/NOPB	ACTIVE	DDPAK/ TO-263	KTT	5	45	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2991S P+	<a href="#">Samples</a>
LM2991SX	ACTIVE	DDPAK/ TO-263	KTT	5	500	TBD	Call TI	Call TI	-40 to 125	LM2991S P+	<a href="#">Samples</a>
LM2991SX/NOPB	ACTIVE	DDPAK/ TO-263	KTT	5	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2991S P+	<a href="#">Samples</a>
LM2991T	ACTIVE	TO-220	KC	5	45	TBD	Call TI	Call TI	-40 to 125	LM2991T P+	<a href="#">Samples</a>
LM2991T/LB03	ACTIVE	TO-220	NDH	5	45	TBD	Call TI	Call TI		LM2991T P+	<a href="#">Samples</a>
LM2991T/LF03	ACTIVE	TO-220	NDH	5	45	Pb-Free (RoHS Exempt)	CU SN	Level-1-NA-UNLIM		LM2991T P+	<a href="#">Samples</a>
LM2991T/NOPB	ACTIVE	TO-220	KC	5	45	Pb-Free (RoHS Exempt)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM2991T P+	<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)

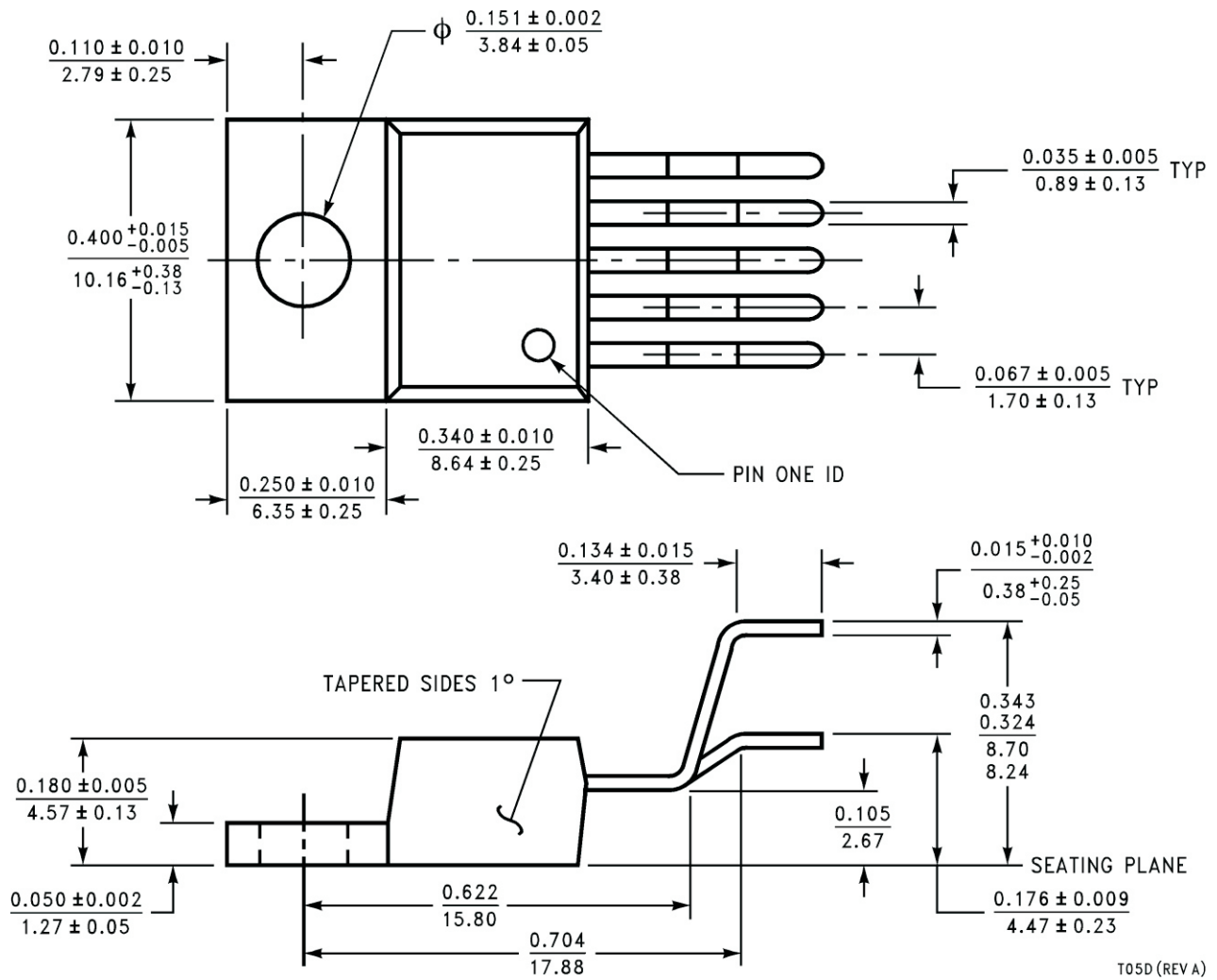
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

<sup>(4)</sup> Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

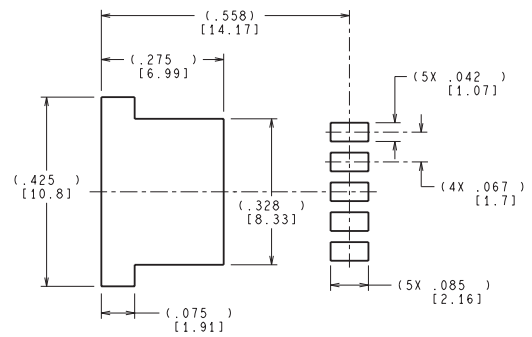
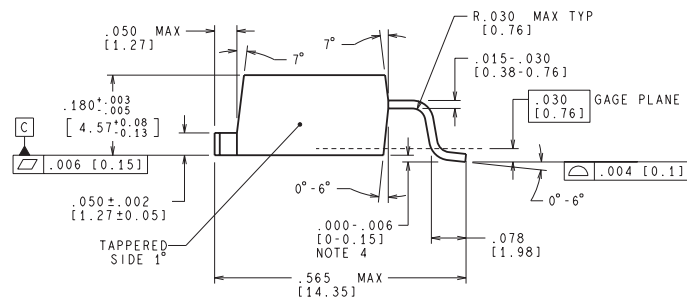
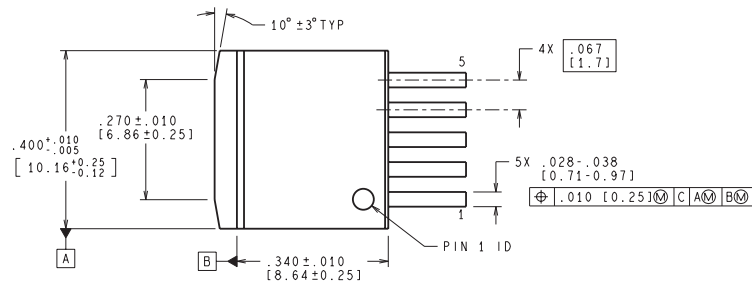
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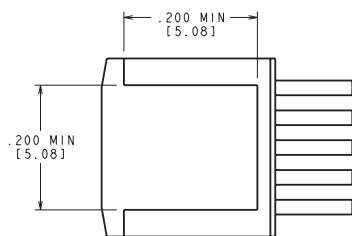
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LAND PATTERN RECOMMENDATION



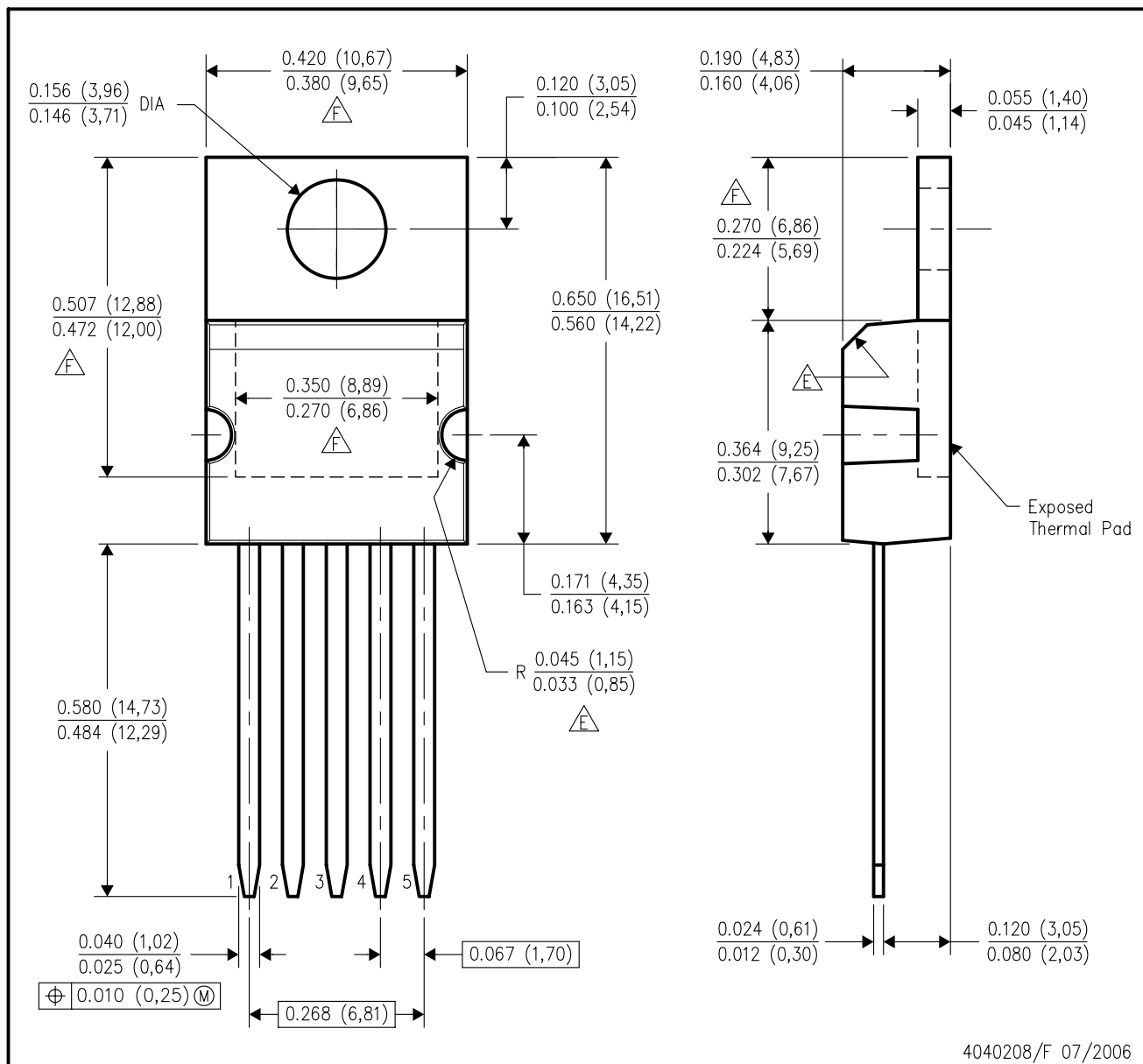
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CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

TS5B (Rev D)

## KC (R-PSFM-T5)

## PLASTIC FLANGE-MOUNT PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. All lead dimensions apply before solder dip.
  - D. The center lead is in electrical contact with the mounting tab.
  - E These features are optional.
  - F Thermal pad contour optional within these dimensions.



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