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 ON/OFF Switch**
- **Functional Complement to the LM2941 Series**

APPLICATIONS

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

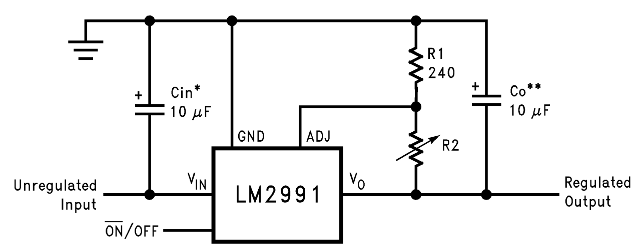
DESCRIPTION

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 ($V_{OUT} - V_{IN} \leq 3V$).

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



$V_{OUT} = V_{REF} (1 + R2/R1)$
*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.

Connection Diagrams

Front View

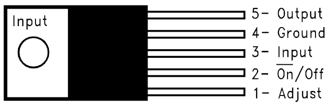


Figure 1. TO-220 Package, 5-Lead See Package Number KC and NDH

Top View

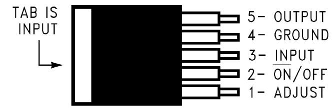


Figure 2. DDPAK, TO-263 Package, 5-Lead, Surface-Mount See Package Number KTT

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(1)(2)

Input Voltage	−26V to +0.3V
ESD Susceptibility(3)	2 kV
Power Dissipation(4)	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 (θ_{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, θ_{JA} is 50°C/W; with 1 square inch of copper area, θ_{JA} is 37°C/W; and with 1.6 or more square inches of copper area, θ_{JA} is 32°C/W.

OPERATING RATINGS(1)

Junction Temperature Range (T_J)	−40°C to +125°C
$\overline{\text{ON}}$/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 µF, R1 = 2.7 kΩ, T_J = 25°C, unless otherwise specified. **Boldface** limits apply over the entire operating junction temperature range.

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

(1) Typicals are at T_J = 25°C and represent the most likely parametric norm.

TYPICAL PERFORMANCE CHARACTERISTICS

Dropout Voltage

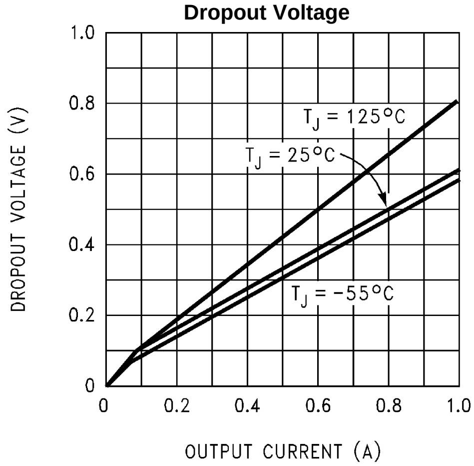


Figure 3.

Normalized Output Voltage

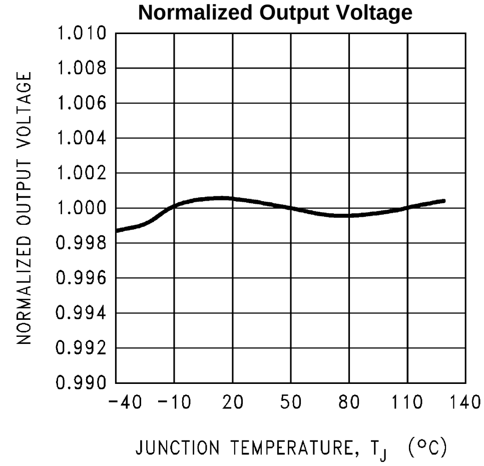


Figure 4.

Output Voltage

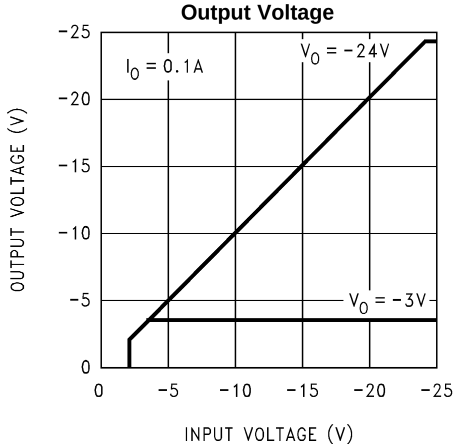


Figure 5.

Output Noise Voltage

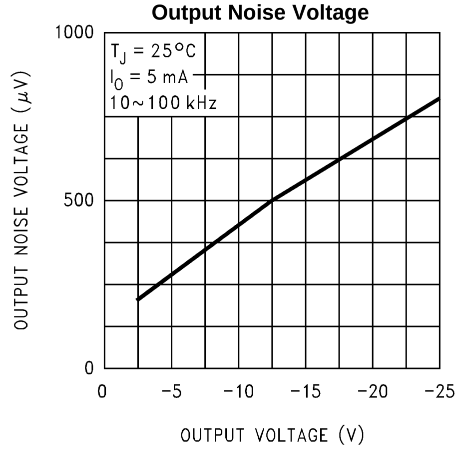


Figure 6.

Quiescent Current

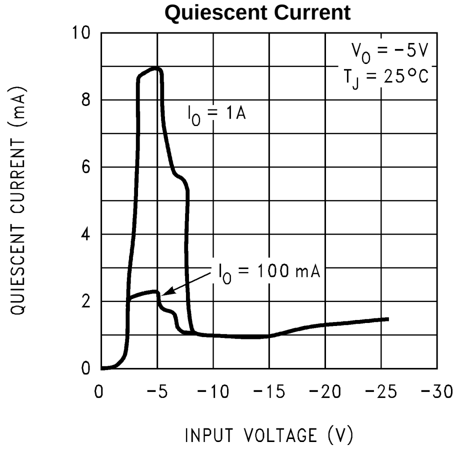


Figure 7.

Maximum Output Current

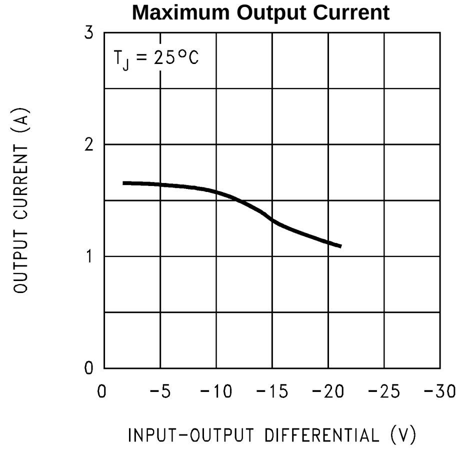


Figure 8.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Line Transient Response

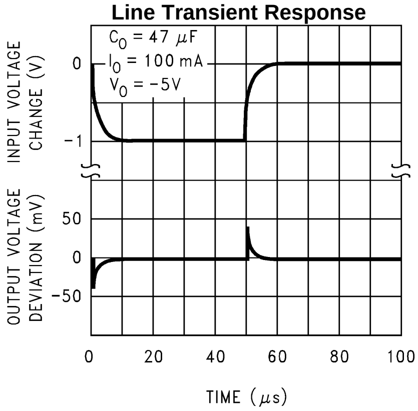


Figure 9.

Load Transient Response

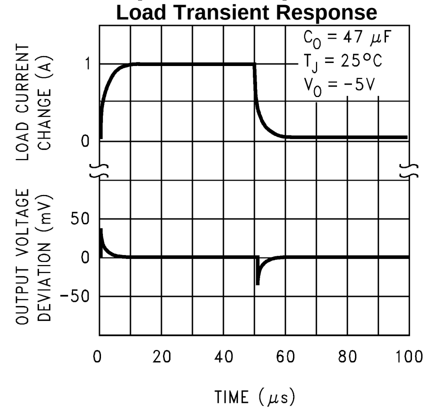


Figure 10.

Maximum Output Current

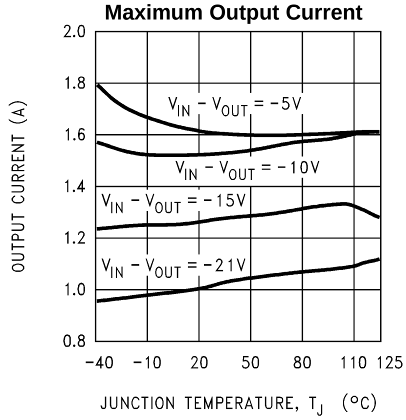


Figure 11.

Ripple Rejection

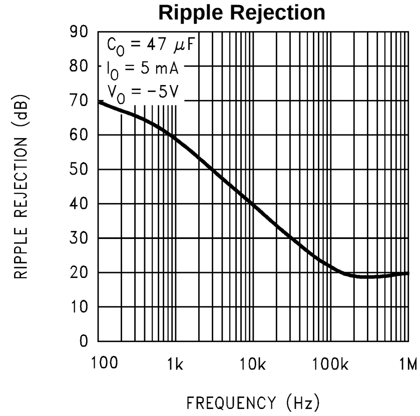


Figure 12.

Output Impedance

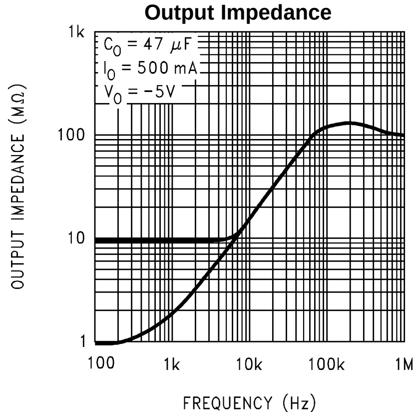


Figure 13.

$\overline{ON}$ /OFF Control Voltage

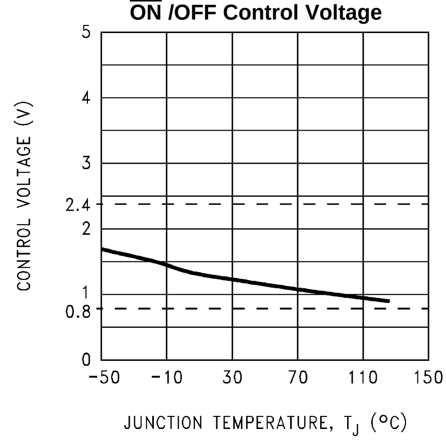


Figure 14.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Adjust Pin Current

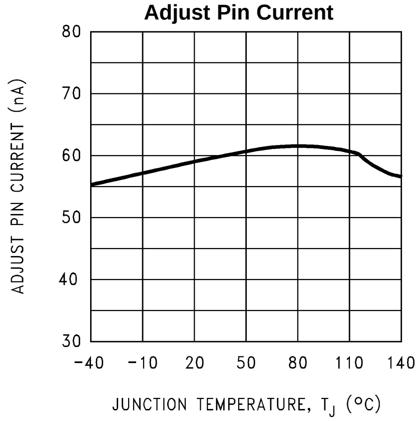


Figure 15.

Low Voltage Behavior

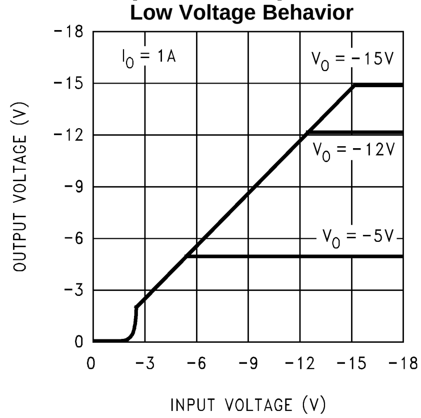


Figure 16.

Maximum Power Dissipation (TO-220)

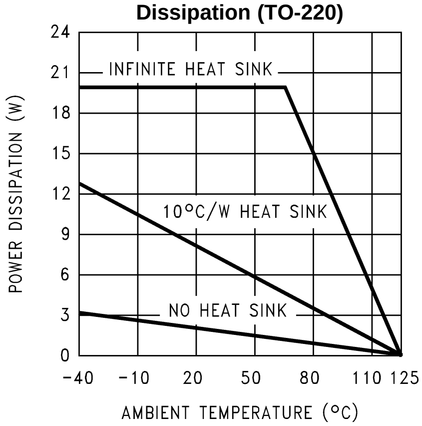


Figure 17.

Maximum Power Dissipation (DDPAK/TO-263)(1)

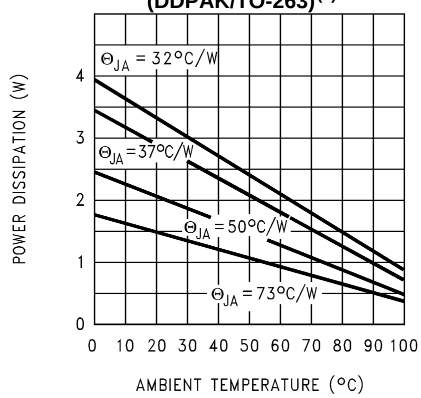


Figure 18.

(1) The maximum allowable power dissipation is a function of the maximum operating junction temperature ($T_{J(MAX)}$), the thermal resistance of the package (θ_{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, θ_{JA} is 50°C/W; with 1 square inch of copper area, θ_{JA} is 37°C/W; and with 1.6 or more square inches of copper area, θ_{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 µF is recommended, but an aluminum electrolytic (≥ 10 µF) may be used. However, aluminum electrolytic types should not be used in applications where the ambient temperature can drop below 0°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 mΩ and 10Ω.

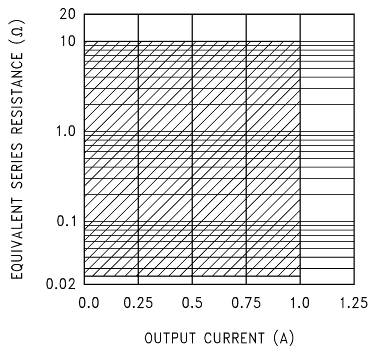


Figure 19. Output Capacitor ESR Range

A solid Tantalum (value ≥ 1 µF) is the best choice for the output capacitor. An aluminum electrolytic (≥ 10 µF) 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°C down to −40°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 mΩ means that ceramic capacitors can not be used directly on the output of an LDO. A ceramic (≥ 2.2 µF) can be used on the output if some external resistance is placed in series with it (1Ω recommended). Dielectric types X7R or X5R must be used if the temperature range of the application varies more than ± 25° 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 µF 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 µA 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 kΩ.

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 kΩ makes the error due to the adjust pin current negligible. For example, neglecting the adjust pin current, and setting R2 to 100 kΩ and V_{OUT} to −5V, results in an output voltage error of only 0.16%.

$\overline{\text{ON}}$/OFF Pin

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

If the $\overline{\text{ON}}$/OFF function is not needed, the pin should be connected to Ground. The $\overline{\text{ON}}$/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

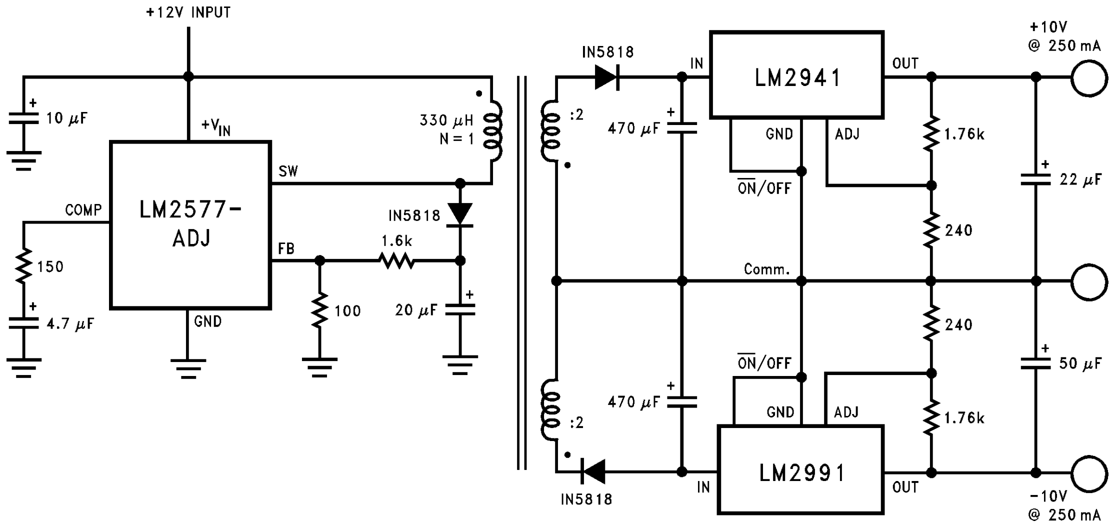


Figure 20. Fully Isolated Post-Switcher Regulator

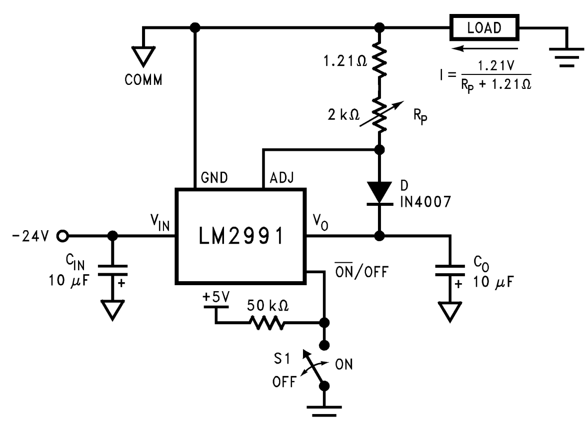
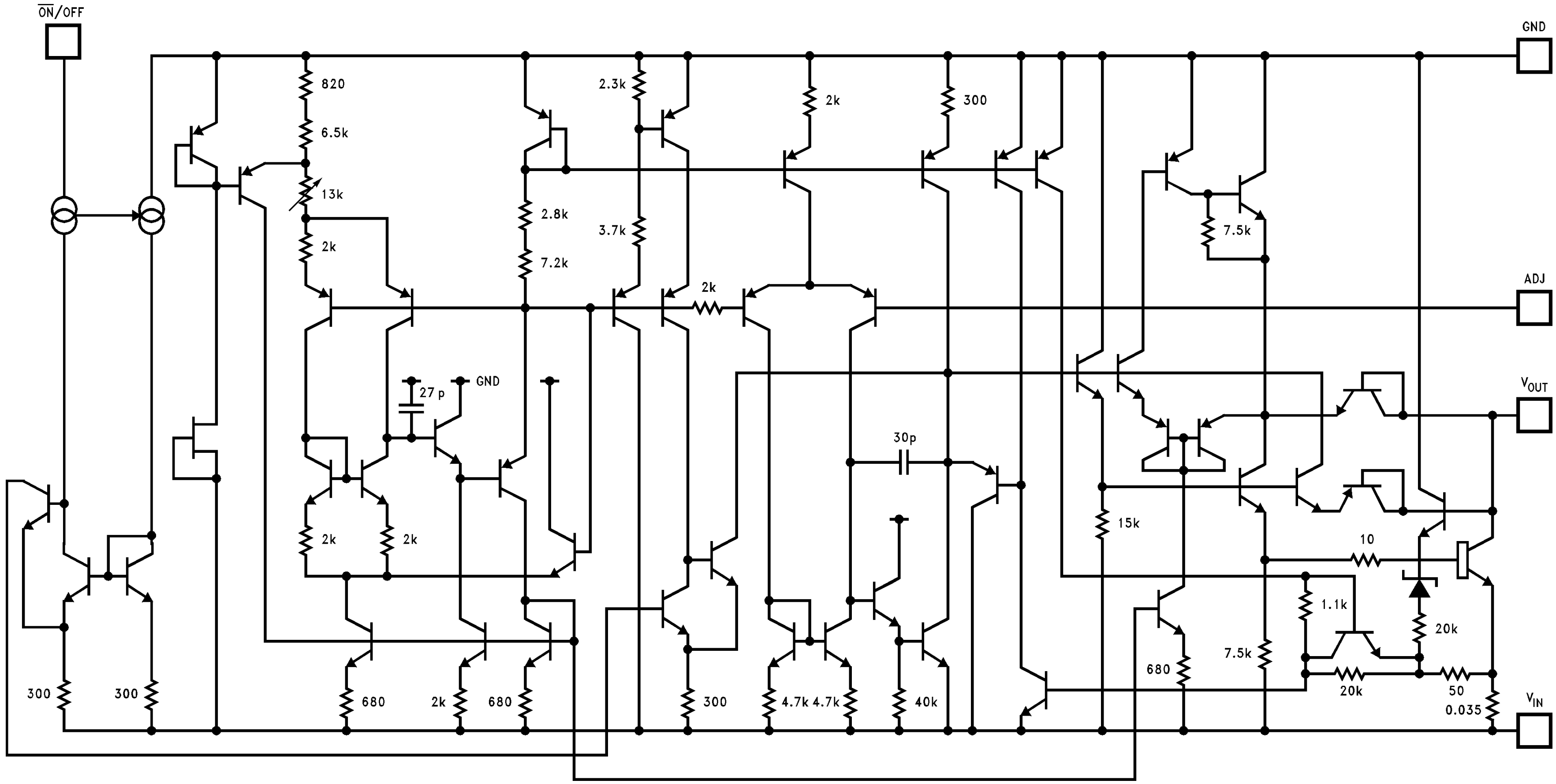


Figure 21. Adjustable Current Sink

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 (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM2991S	NRND	DDPAK/ TO-263	KTT	5	45	TBD	Call TI	Call TI	-40 to 125	LM2991S P+	
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+	Samples
LM2991SX	NRND	DDPAK/ TO-263	KTT	5	500	TBD	Call TI	Call TI	-40 to 125	LM2991S P+	
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+	Samples
LM2991T	NRND	TO-220	KC	5	45	TBD	Call TI	Call TI	-40 to 125	LM2991T P+	
LM2991T/LB03	NRND	TO-220	NDH	5	45	TBD	Call TI	Call TI		LM2991T P+	
LM2991T/LF03	ACTIVE	TO-220	NDH	5	45	Pb-Free (RoHS Exempt)	CU SN	Level-1-NA-UNLIM		LM2991T P+	Samples
LM2991T/NOPB	ACTIVE	TO-220	KC	5	45	Pb-Free (RoHS Exempt)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM2991T P+	Samples

(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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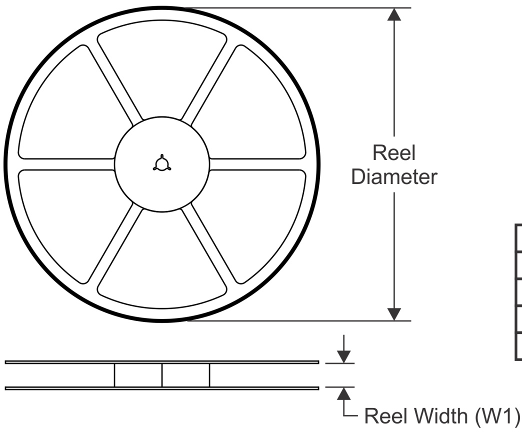
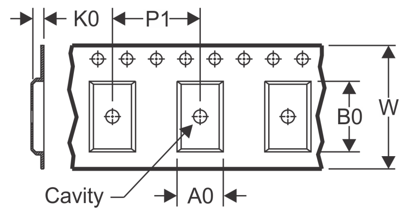
TAPE AND REEL INFORMATION

REEL DIMENSIONS

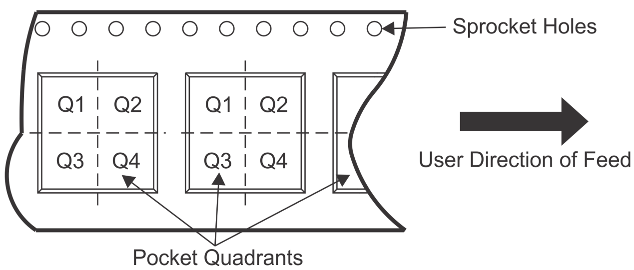


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

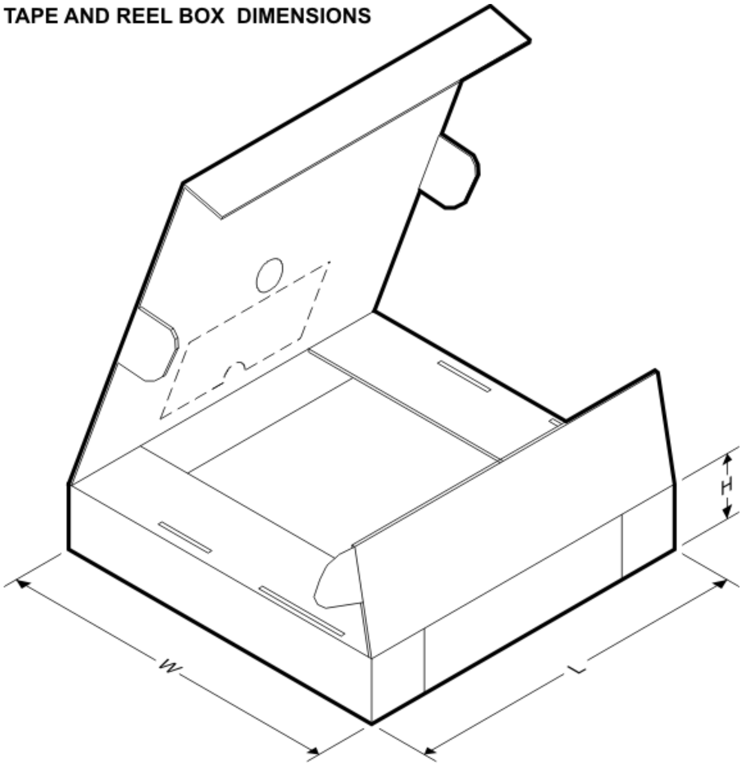
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2991SX	DDPAK/ TO-263	KTT	5	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2991SX/NOPB	DDPAK/ TO-263	KTT	5	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

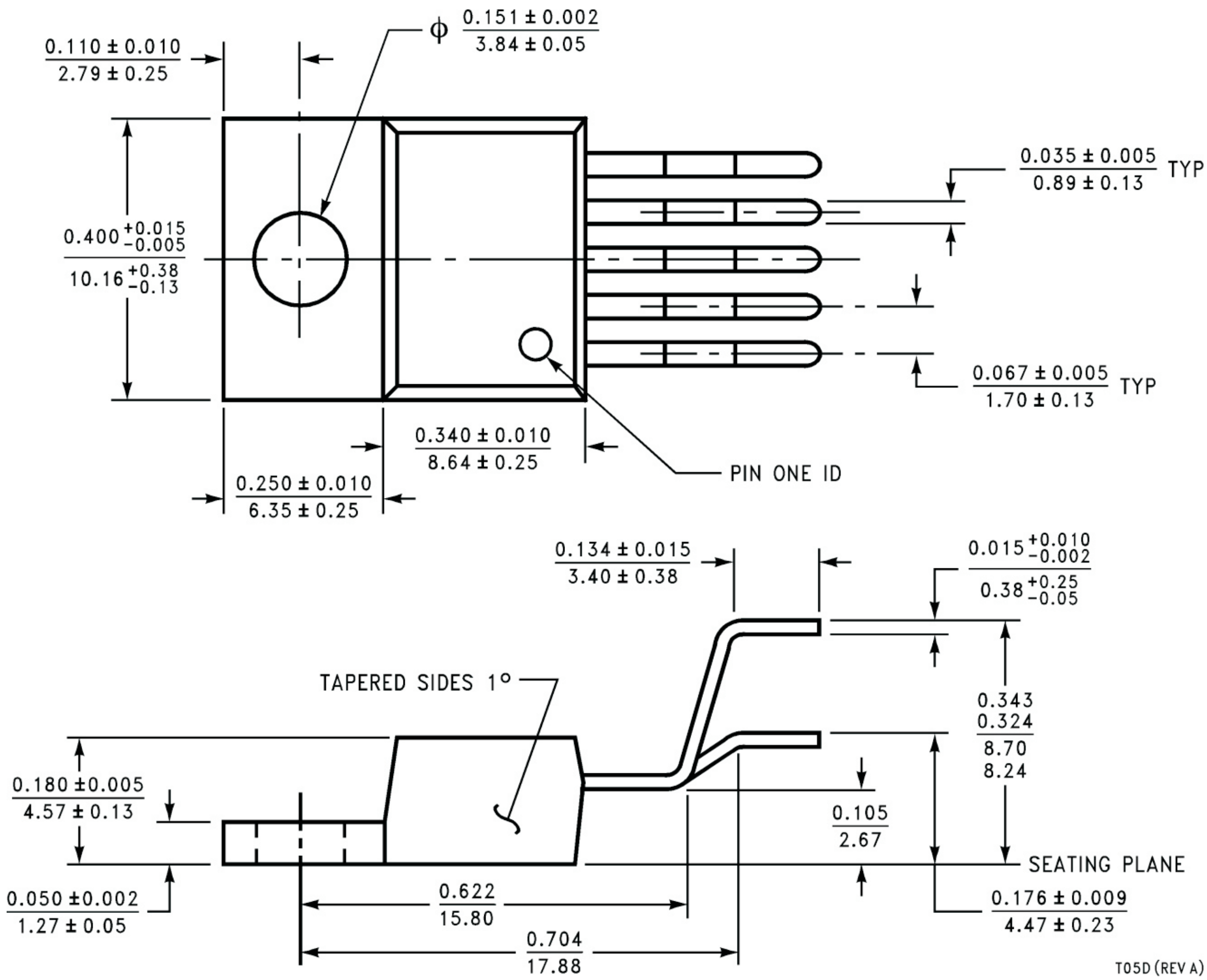
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

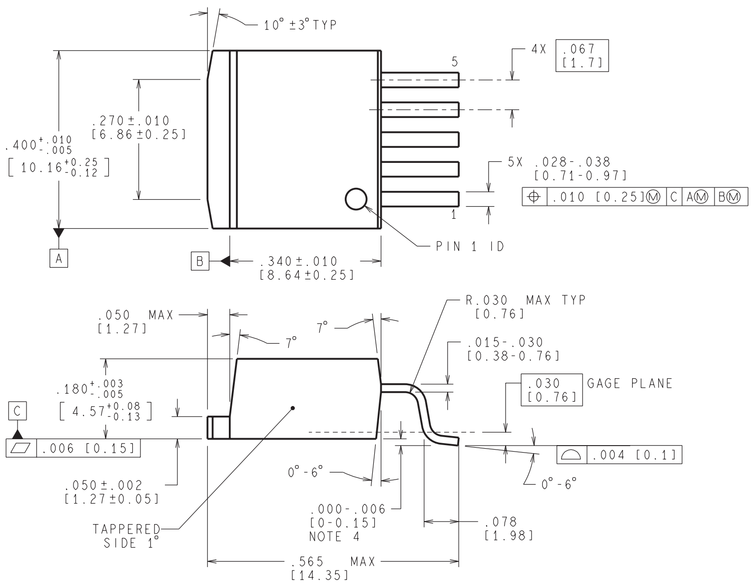
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2991SX	DDPAK/TO-263	KTT	5	500	367.0	367.0	45.0
LM2991SX/NOPB	DDPAK/TO-263	KTT	5	500	367.0	367.0	45.0

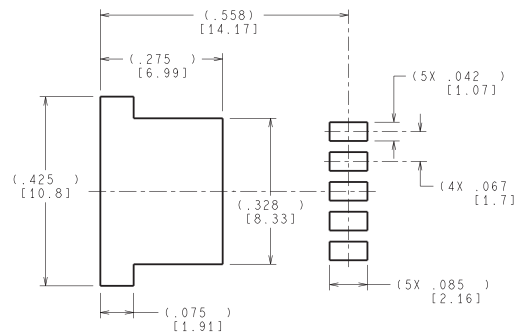
NDH0005D



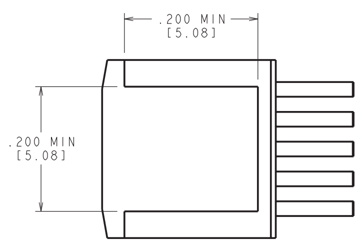
0.110 ± 0.010
2.79 ± 0.25
φ 0.151 ± 0.002
3.84 ± 0.05
0.035 ± 0.005 TYP
0.89 ± 0.13
0.400 +0.015 −0.005
10.16 +0.38 −0.13
0.067 ± 0.005 TYP
1.70 ± 0.13
0.340 ± 0.010
8.64 ± 0.25
PIN ONE ID
0.250 ± 0.010
6.35 ± 0.25
0.134 ± 0.015
3.40 ± 0.38
0.015 +0.010 −0.002
0.38 +0.25 −0.05
TAPERED SIDES 1°
0.343
0.324
8.70
8.24
0.180 ±0.005
4.57 ± 0.13
0.105
2.67
SEATING PLANE
0.050 ±0.002
1.27 ± 0.05
0.622
15.80
0.176 ± 0.009
4.47 ± 0.23
0.704
17.88
T05D (REV A)

KTT0005B





LAND PATTERN RECOMMENDATION

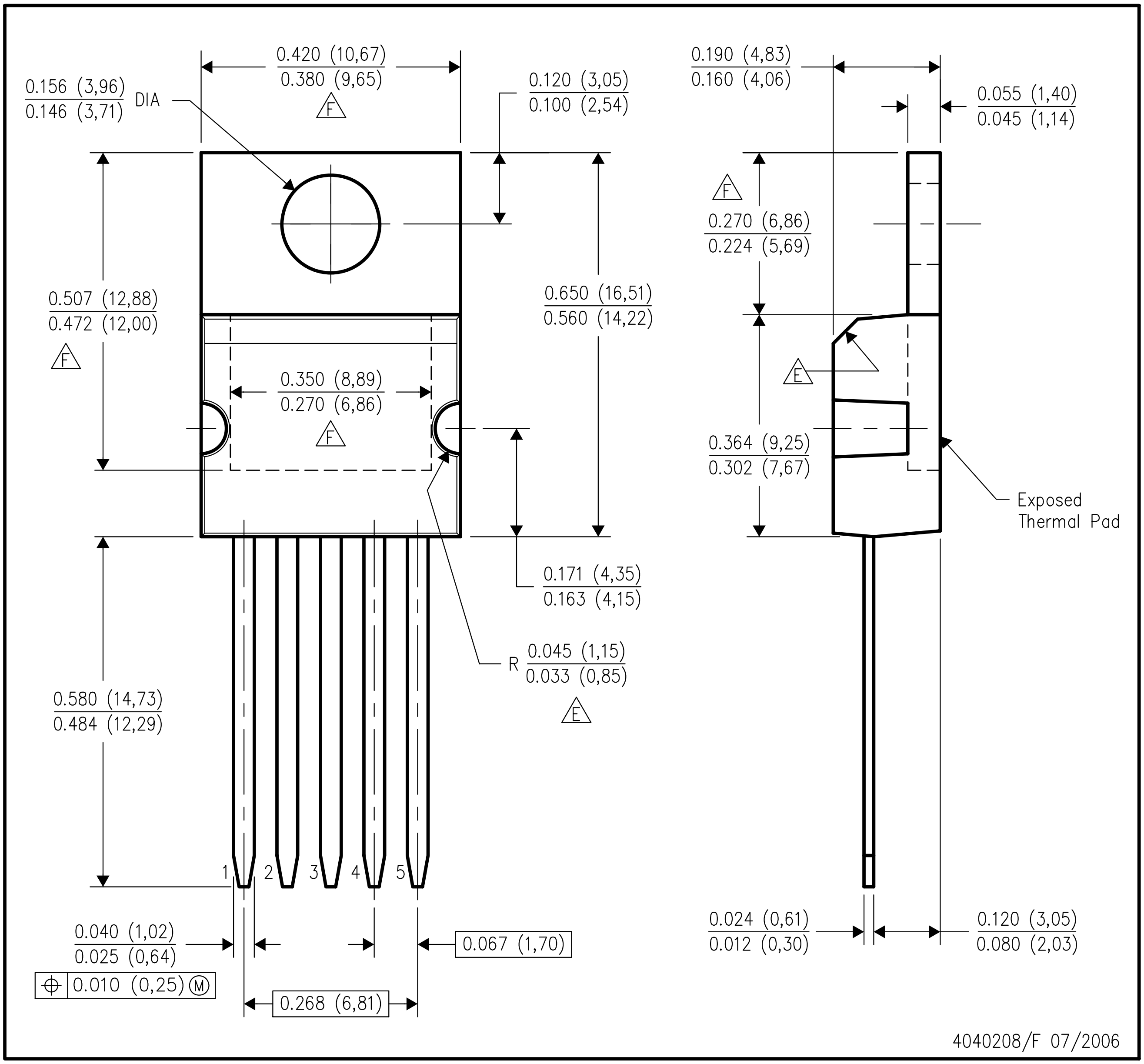


BOTTOM SIDE OF PACKAGE

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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