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National Semiconductor

May 4, 2011

LM2991

Negative Low Dropout Adjustable Regulator

General 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 $\overline{On}$ /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 a guaranteed 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 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.

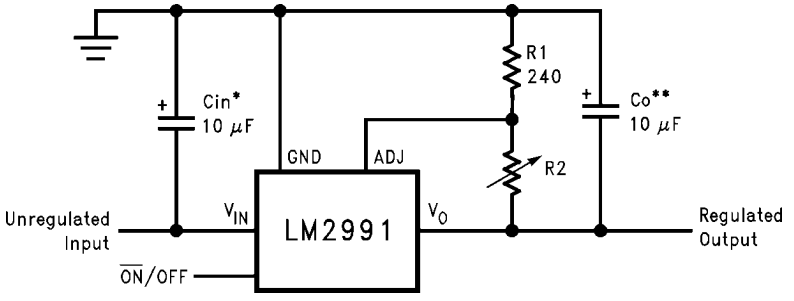
Features

- 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 $\overline{ON}$/OFF switch
- Functional complement to the LM2941 series

Applications

- Post switcher regulator
- Local, on-card, regulation
- Battery operated equipment

Typical Application



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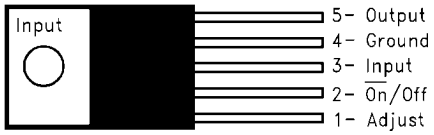
$V_{OUT} = V_{REF} (1 + R2/R1)$

*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



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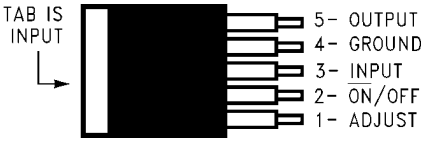
Front View
TO-220, 5-Lead, Straight
See NS Package Number T05A



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Top View
TO263, 5-Lead, Surface-Mount
See NS Package TS5B

Ordering Information

Order Number	Package Type	NSC Package	Package Marking	Supplied As
LM2991S	5-Lead TO-263	TS5B	LM2991S	Rail of 45
LM2991SX	5-Lead TO-263	TS5B	LM2991S	Reel of 500
LM2991T	5-Pin TO-220	T05A	LM2991T	Rail of 45

Absolute Maximum Ratings (*Note 1*)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Voltage	−26V to +0.3V
ESD Susceptibility (*Note 2*)	2 kV
Power Dissipation (*Note 3*)	Internally limited
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	230°C

Operating Ratings (*Note 1*)

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

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 (*Note 4*)	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 **0.3**	V
	I_O = 1A, ΔV_O ≤ 100 mV	0.6		0.8 **1**	V
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

Note 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 guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

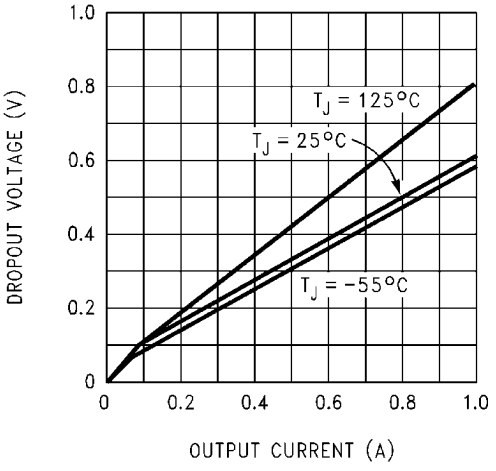
Note 2: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 3: 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 TO-263, and junction-to-case thermal resistance is 3°C/W. If the 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.

Note 4: Typicals are at T_J = 25°C and represent the most likely parametric norm.

Typical Performance Characteristics

Dropout Voltage



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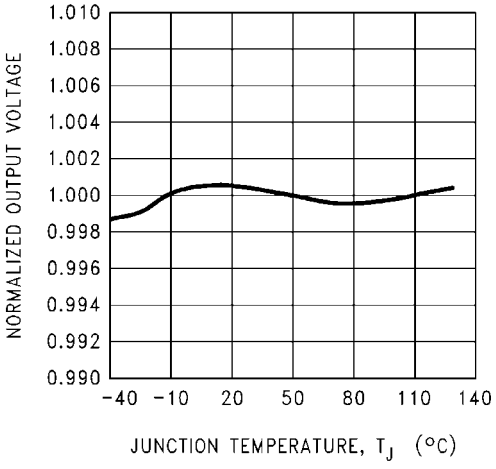
Normalized Output Voltage



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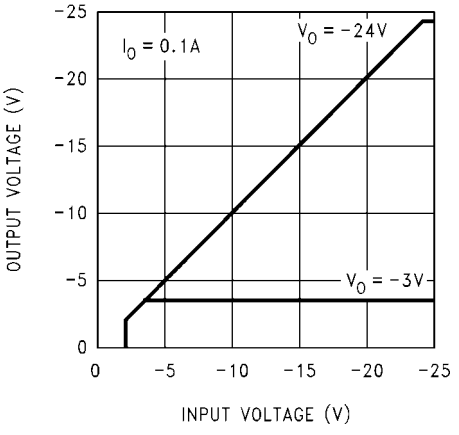
Output Voltage



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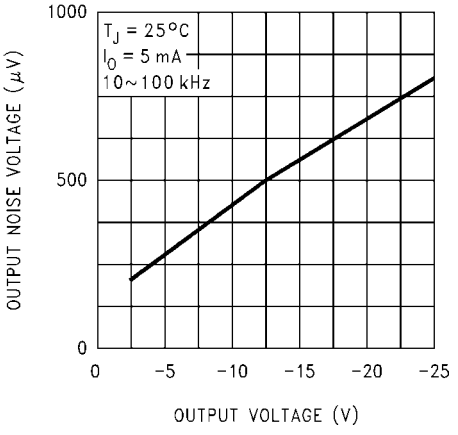
Output Noise Voltage



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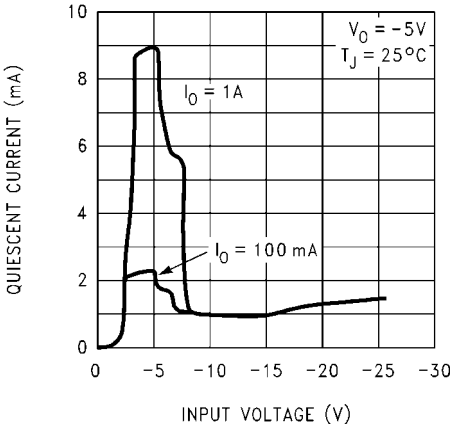
Quiescent Current



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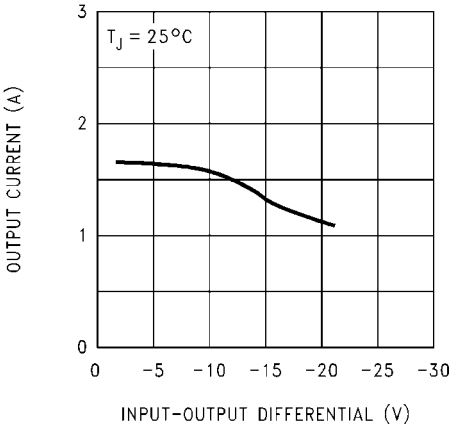
Maximum Output Current



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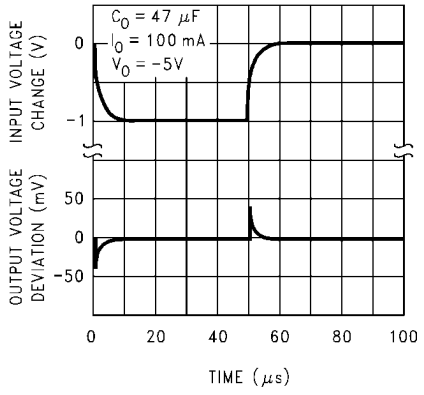
Line Transient Response



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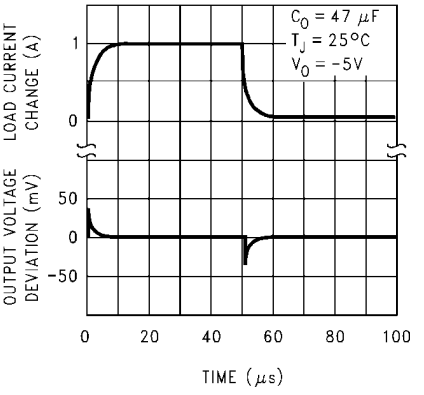
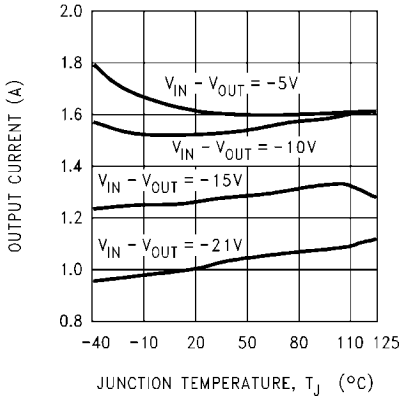
Load Transient Response



1126020

Maximum Output Current



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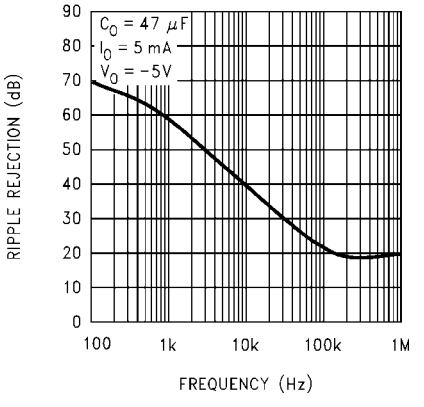
Ripple Rejection



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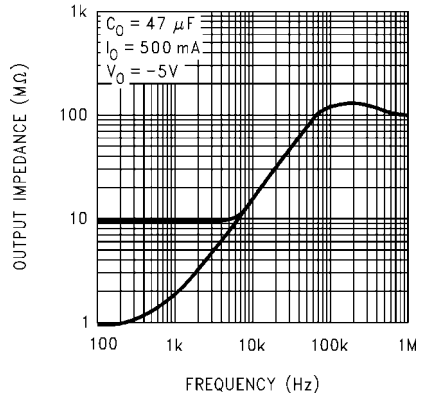
Output Impedance



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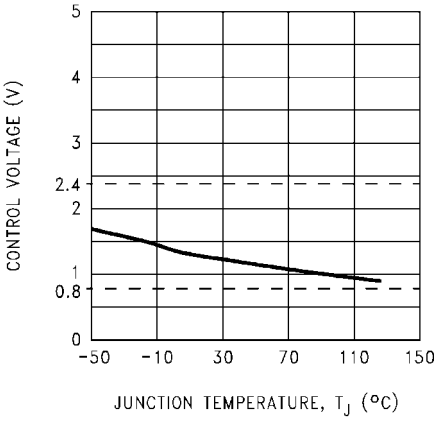
$\overline{ON}$ /OFF Control Voltage



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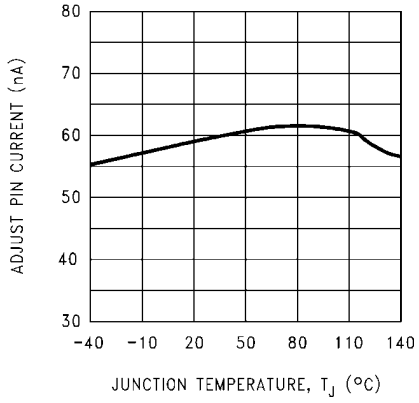
Adjust Pin Current



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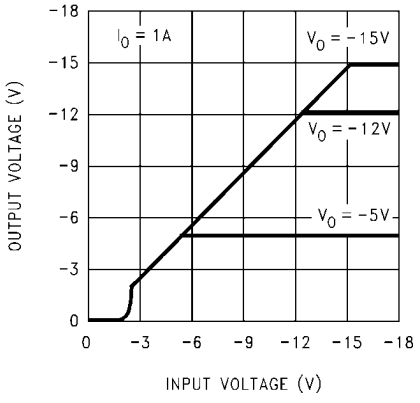
Low Voltage Behavior



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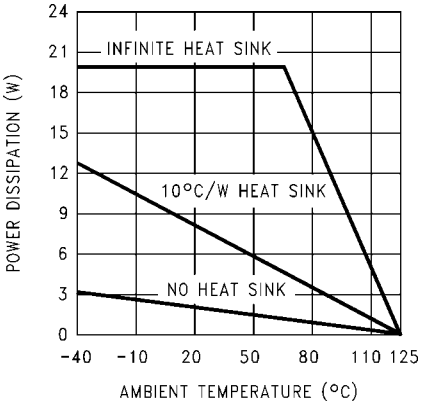
Maximum Power Dissipation (TO-220)



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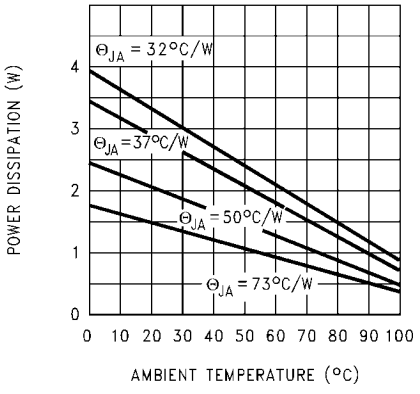
Maximum Power Dissipation (TO-263) (See Note 3)



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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 1*, which means it must have an ESR between about 25 mΩ and 10Ω.

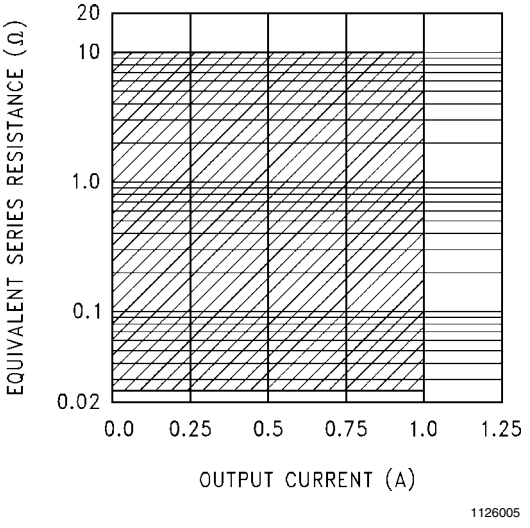


FIGURE 1. Output Capacitor ESR Range

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 $V_{REF} = -1.21V$. 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%.

$\overline{ON}$/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 µA 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 a guaranteed operating condition.

See the Adjustable Current Sink Application, *Figure 3*.

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 guaranteed Operating Rating range, above the Absolute Maximum Rating, 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

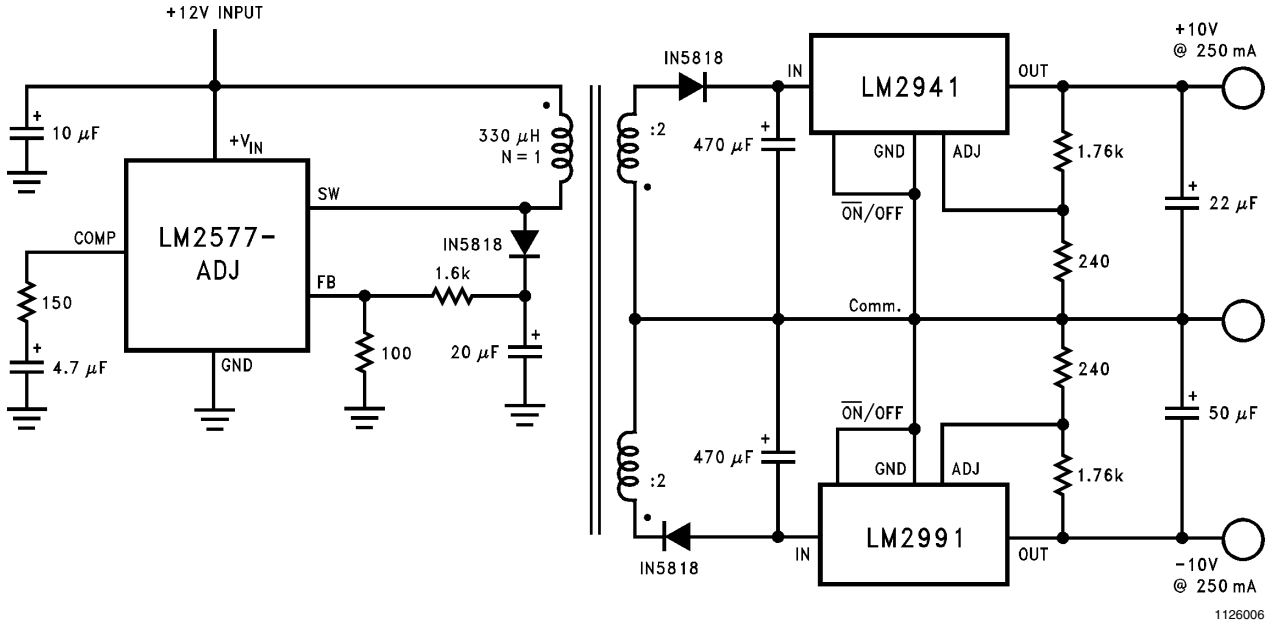


FIGURE 2. Fully Isolated Post-Switcher Regulator

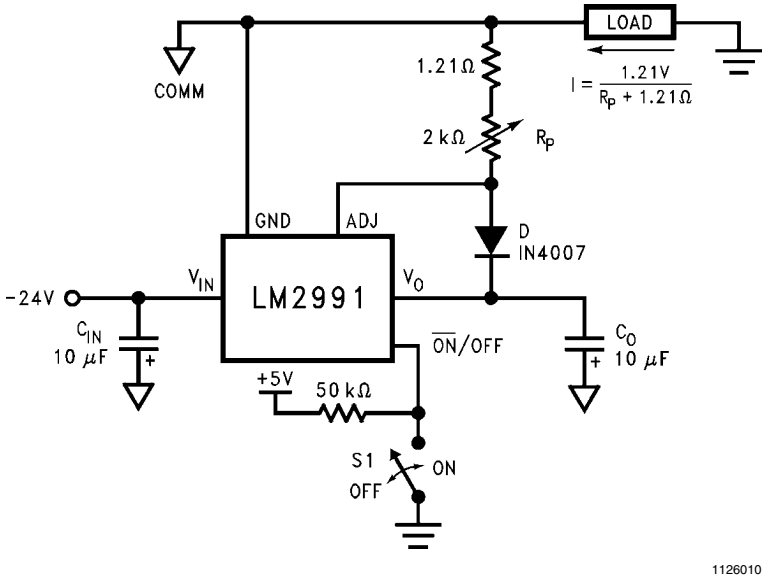
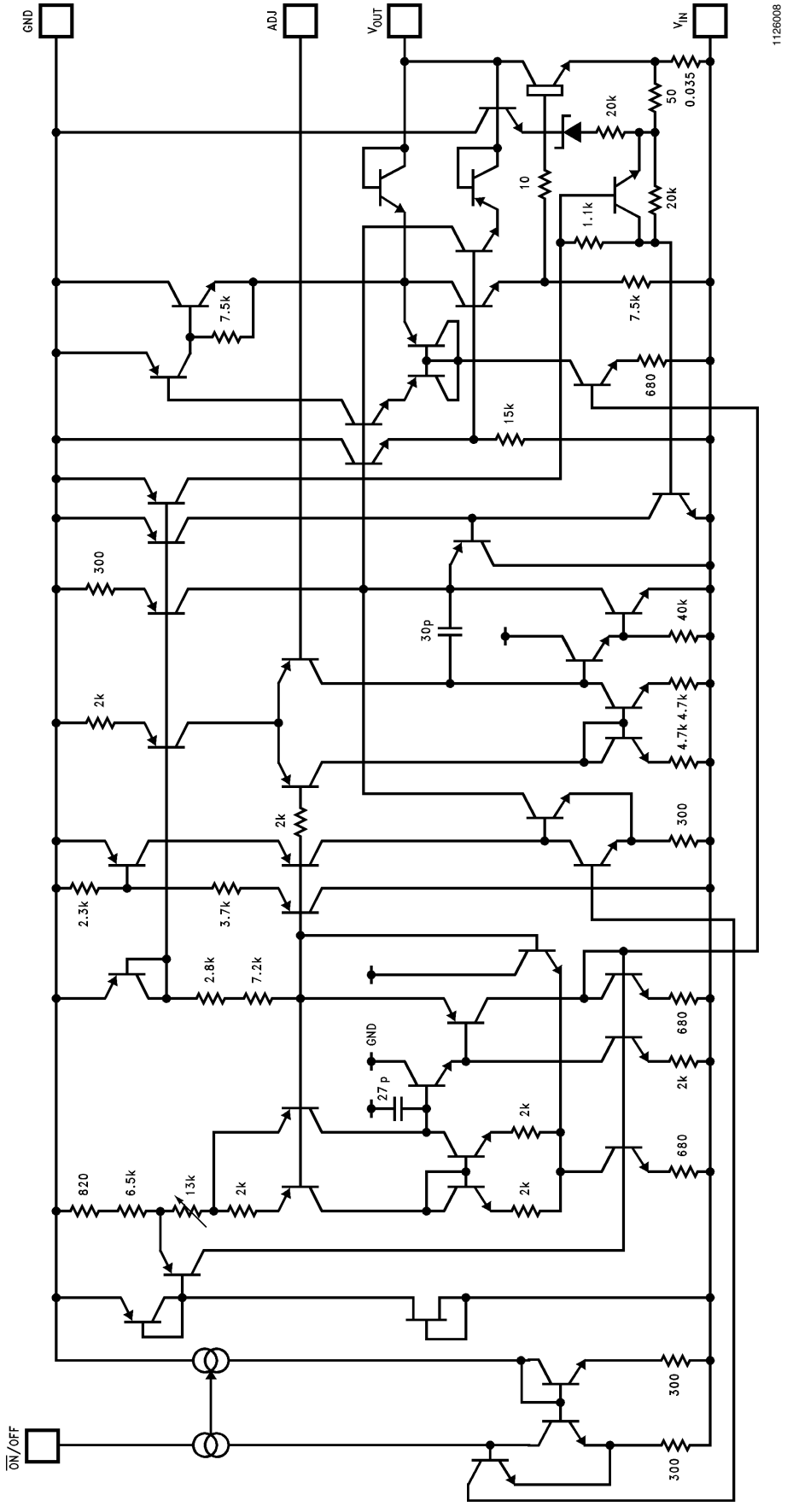
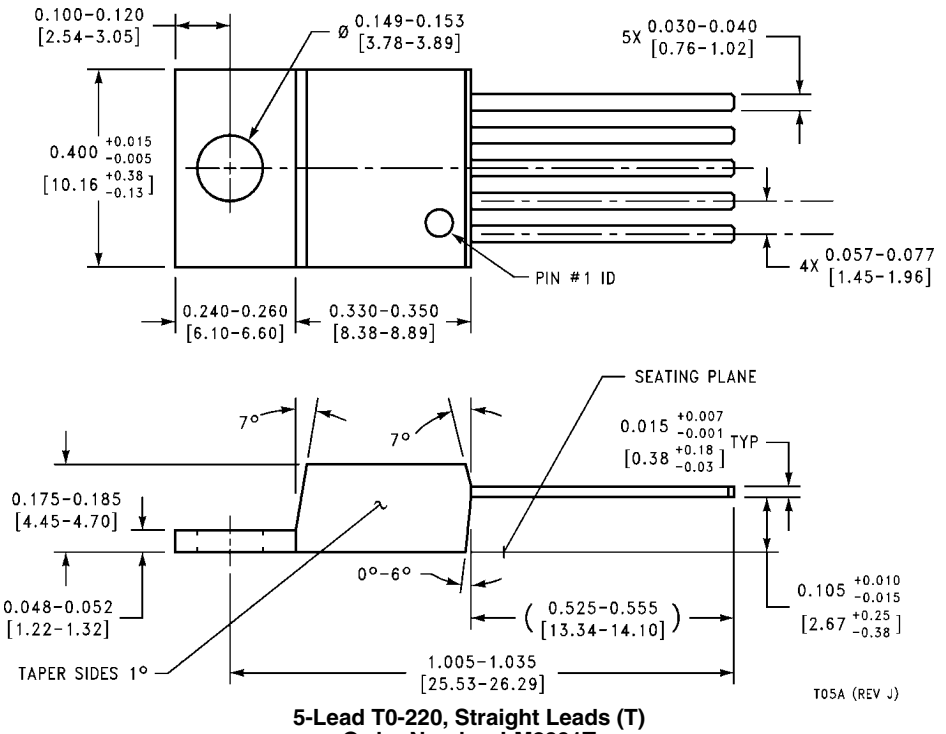


FIGURE 3. Adjustable Current Sink

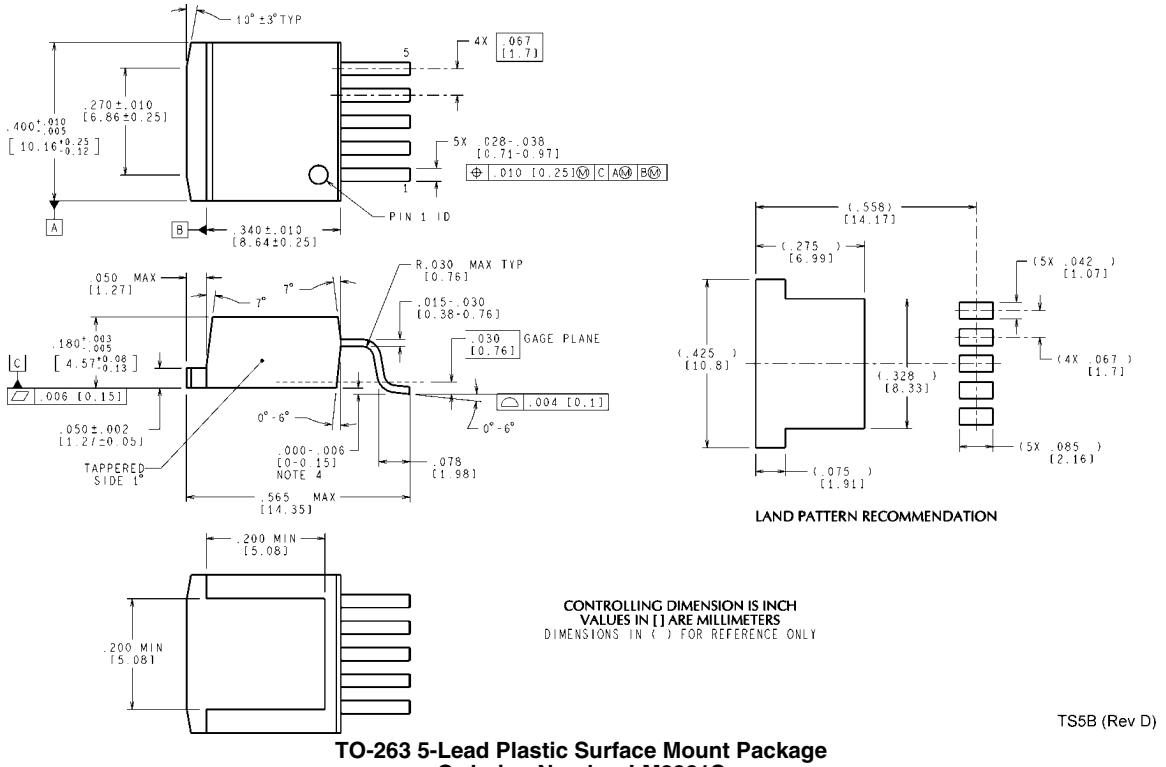
Equivalent Schematic



Physical Dimensions inches (millimeters) unless otherwise noted



5-Lead T0-220, Straight Leads (T)
Order Number LM2991T
NS Package Number T05A



TO-263 5-Lead Plastic Surface Mount Package
Ordering Number LM2991S
NS Package Number TS5B

Notes

Notes

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