

LM333

3-Ampere Adjustable Negative Regulator

General Description

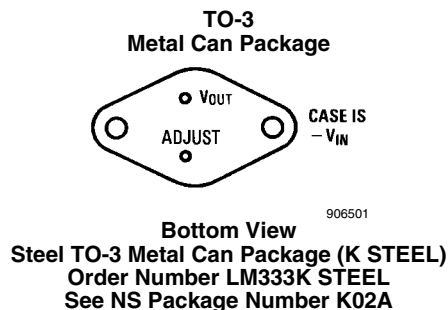
The LM333 is an adjustable 3-terminal negative voltage regulator capable of supplying in excess of $-3.0A$ over an output voltage range of $-1.2V$ to $-32V$. This regulator is exceptionally easy to apply, requiring only 2 external resistors to set the output voltage and 1 output capacitor for frequency compensation. The circuit design has been optimized for excellent regulation and low thermal transients. Further, the LM333 features internal current limiting, thermal shutdown and safe-area compensation, making them substantially immune to failure from overloads.

The LM333 serves a wide variety of applications including local on-card regulation, programmable-output voltage regulation or precision current regulation. The LM333 is an ideal complement to the LM150/LM350 adjustable positive regulators.

Features

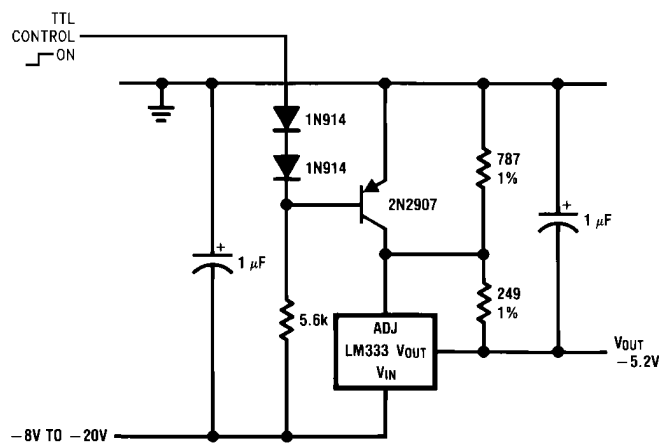
- Output voltage adjustable from $-1.2V$ to $-32V$
- $3.0A$ output current guaranteed, $-40^{\circ}C$ to $+125^{\circ}C$
- Line regulation typically $0.01\%/V$
- Load regulation typically 0.2%
- Excellent rejection of thermal transients
- $50\text{ ppm}/^{\circ}C$ temperature coefficient
- Temperature-independent current limit
- Internal thermal overload protection
- Standard 3-lead transistor package
- Output is short circuit protected

Connection Diagram



Typical Application

$-5.2V$ Regulator with Electronic Shutdown



Absolute Maximum Ratings (Note 1)

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

Power Dissipation Internally Limited
Input-Output Voltage Differential 35V

Operating Junction Temperature Range T_{MIN} to T_{MAX}
LM333 -40°C to $+125^{\circ}\text{C}$
Storage Temperature -65°C to $+150^{\circ}\text{C}$
Lead Temperature (Soldering, 10 sec.)
TO-3 Package 300°C
ESD Susceptibility TBD

Electrical Characteristics LM333

Specifications with standard typeface are for $T_J = 25^{\circ}\text{C}$, and those with **boldface type** apply over the full operating temperature range. (Note 3)

Parameter	Conditions	Typical	Min (Note 2)	Max (Note 2)	Units
Reference Voltage	$I_L = 10\text{ mA}$	-1.250	-1.225	-1.275	V
	$3\text{V} \leq V_{IN} - V_{OUT} \leq 35\text{V}$	-1.250	-1.213	-1.287	
	$10\text{ mA} \leq I_L \leq 3\text{A}, P \leq P_{MAX}$				
Line Regulation	$3\text{V} \leq V_{IN} - V_{OUT} \leq 35\text{V}$	0.01		0.04	% /V
	$I_{OUT} = 50\text{ mA}$ (Note 4)	0.02		0.07	
Load Regulation	$10\text{ mA} \leq I_L \leq 3\text{A}, P \leq P_{MAX}$	0.2		1.0	%
	(Notes 4, 5)	0.4		1.5	
Thermal Regulation	10 ms Pulse	0.002		0.02	% /W
Temperature Stability	$T_{MIN} \leq T_J \leq T_{MAX}$	0.5			%
Long Term Stability	$T_J = 125^{\circ}\text{C}$, 1000 Hours	0.2			%
Adjust Pin Current		65		95	μA
		70		100	
Adjust Pin Current Change	$10\text{ mA} \leq I_L \leq 3\text{A}$	2.5		8	μA
	$3.0\text{V} \leq V_{IN} - V_{OUT} \leq 35\text{V}$				
Minimum Load Current	$ V_{IN} - V_{OUT} \leq 35\text{V}$	2.5		10	mA
	$ V_{IN} - V_{OUT} \leq 10\text{V}$	1.5		5.0	
Current Limit (Note 5)	$3\text{V} \leq V_{IN} - V_{OUT} \leq 10\text{V}$	3.9	3.0		A
	$ V_{IN} - V_{OUT} = 20\text{V}$	2.4	1.0		
	$ V_{IN} - V_{OUT} = 30\text{V}$	0.4	0.20		
Output Noise (% of V_{OUT})	10 Hz to 10 kHz	0.003			% (rms)
Ripple Rejection	$V_{OUT} = 10\text{V}, f = 120\text{ Hz}$				dB
	$C_{ADJ} = 0\text{ }\mu\text{F}$	60			
	$C_{ADJ} = 10\text{ }\mu\text{F}$	77			
Thermal Shutdown Temperature		163			$^{\circ}\text{C}$
Thermal Resistance Junction to Case (θ_{JC})	TO-3 Package (K Steel)	1.2		1.8	$^{\circ}\text{C/W}$
Thermal Resistance Junction to Ambient (θ_{JA}) (No Heatsink)	TO-3 Package (K Steel)	35			$^{\circ}\text{C/W}$

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device outside of its stated operating conditions.

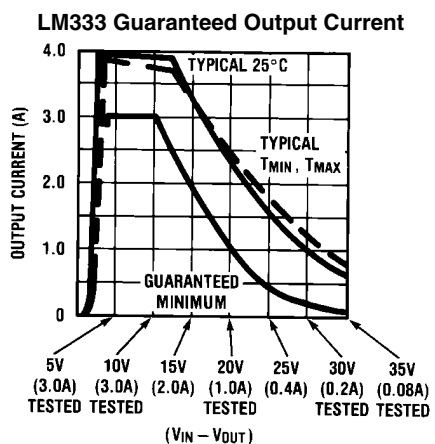
Note 2: All limits are guaranteed at either room temperature (standard type face) or at **temperature extremes (bold typeface)** by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods.

Note 3: Unless otherwise specified: $|V_{IN} - V_{OUT}| = 5\text{V}$, $I_{OUT} = 0.5\text{A}$, $P_{DISS} \leq 30\text{W}$.

Note 4: Load and line regulation are measured at constant junction temperature, using low duty cycle pulse testing (output voltage changes due to heating effects are covered by the Thermal Regulation specification). For the TO-3 package, load regulation is measured on the output pin, below the base of the package.

Note 5: The output current of the LM333 is guaranteed to be $\geq 3\text{A}$ in the range $3\text{V} \leq |V_{IN} - V_{OUT}| \leq 10\text{V}$. For the range $10\text{V} \leq |V_{IN} - V_{OUT}| \leq 15\text{V}$, the guaranteed minimum output current is equal to: $30 / (V_{IN} - V_{OUT})$. Refer to *Guaranteed Performance Characteristics* for guaranteed output currents at other voltages.

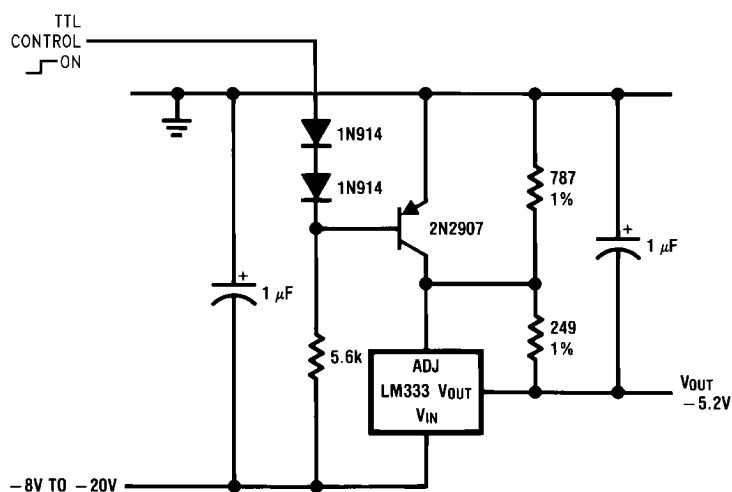
Guaranteed Performance Characteristics



906505

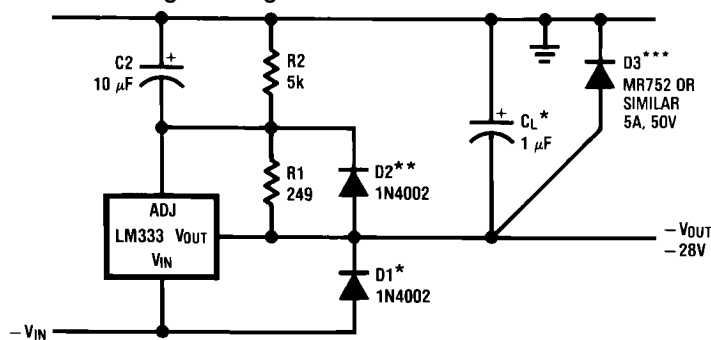
Typical Applications

-5.2V Regulator with Electronic Shutdown



906506

Negative Regulator with Protection Diodes

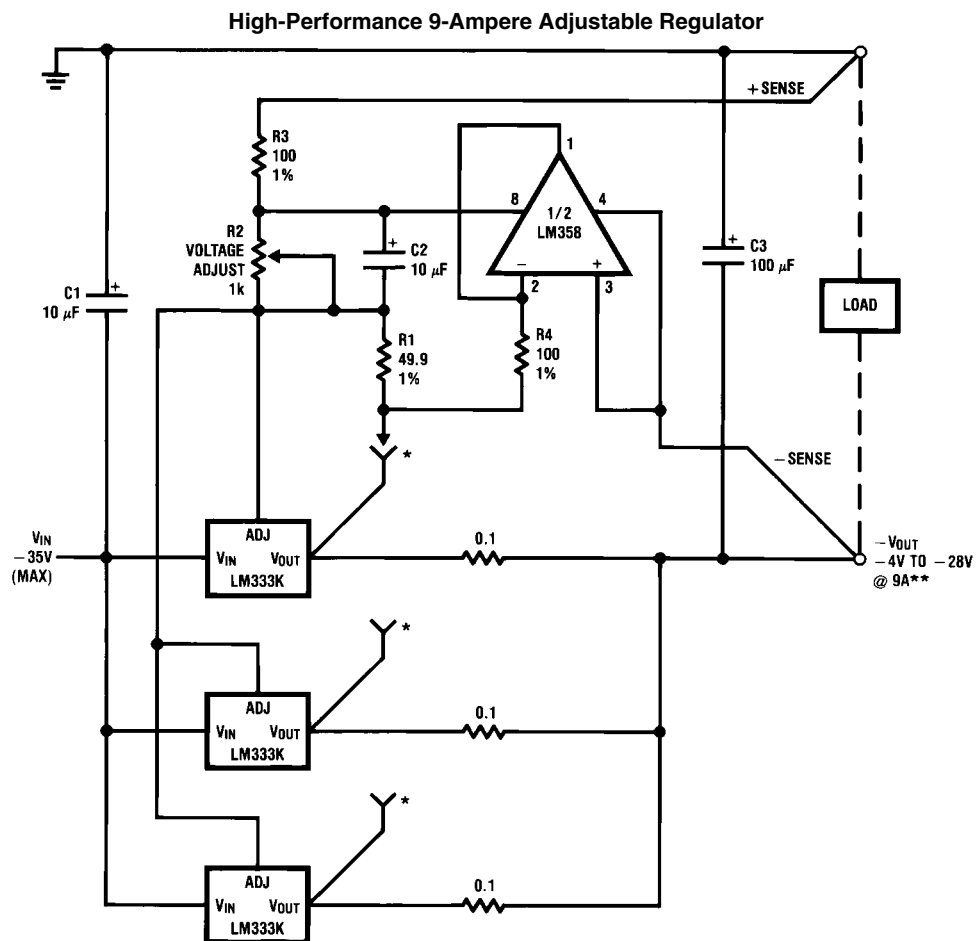


906507

* When C_L is larger than 20 μ F, D1 protects the LM333 in case the input supply is shorted.

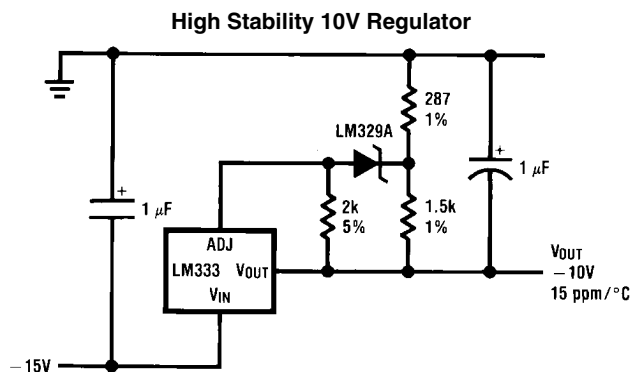
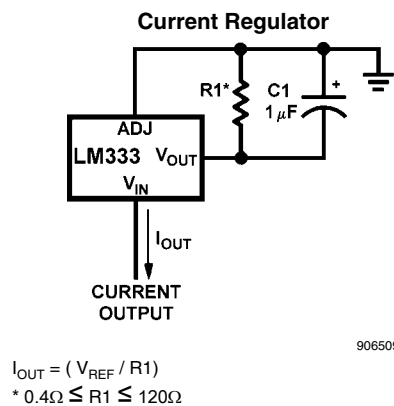
** When C_2 is larger than 10 μ F and $-V_{OUT}$ is larger than -25V, D2 protects the LM333 in case the output is shorted.

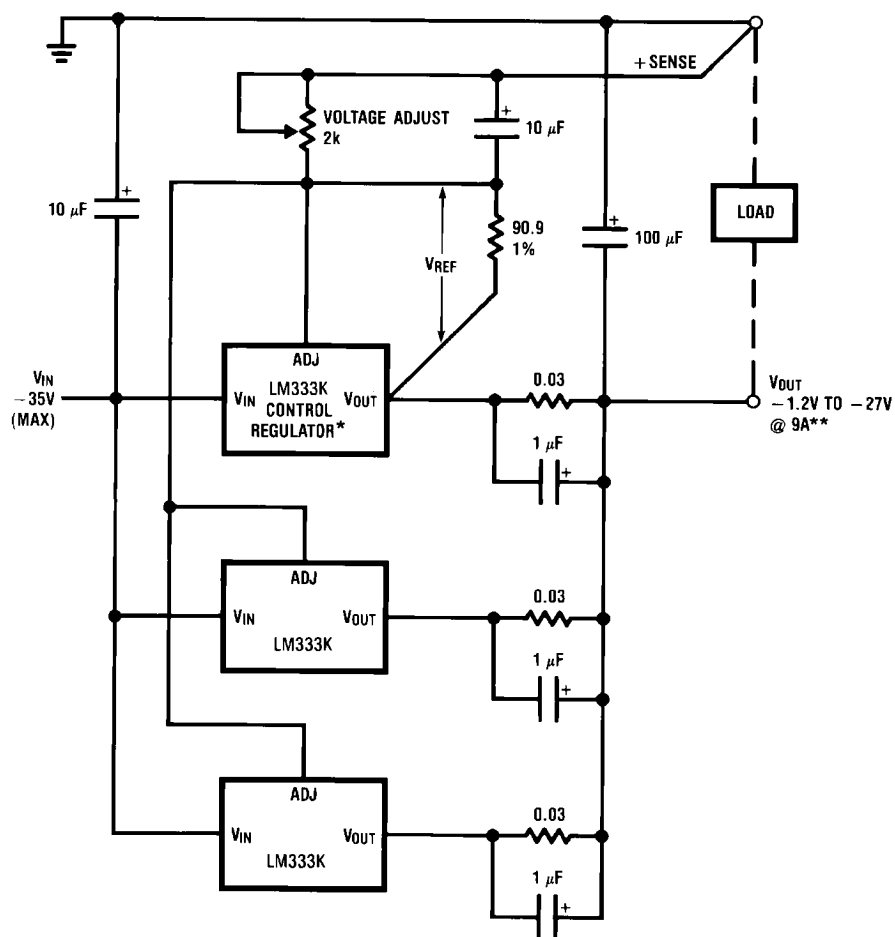
*** In case V_{OUT} is shorted to a positive supply, D3 protects the LM333 from over-voltage, and protects the load from reversed voltage.



* Wire R1 and R4 to the regulator that provides the highest V_{OUT} with a 3A load.

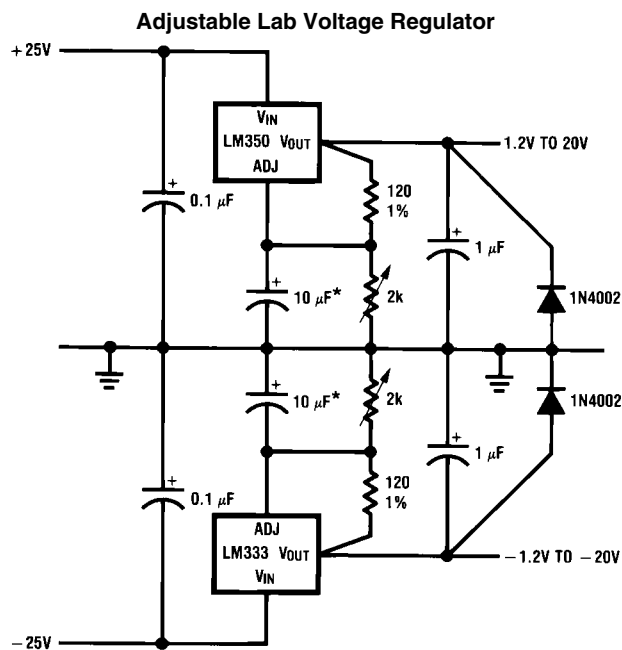
** Full output current requires $5V \leq |V_{IN} - V_{OUT}| \leq 10V$. At higher input-output voltages, load current will be less (see *Guaranteed Performance Characteristics*)





906511

** Full output current requires $5V \leq |V_{IN} - V_{OUT}| \leq 10V$. At higher input-output voltages, load current will be less (see *Guaranteed Performance Characteristics*)



* The 10 μF capacitors are optional to improve ripple rejection.

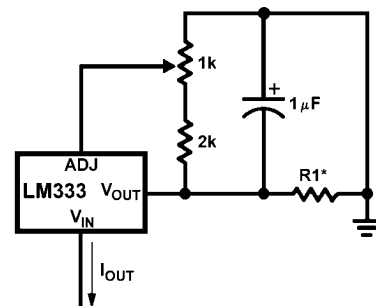
906512

THERMAL REGULATION

When power is dissipated in an IC, a temperature gradient occurs across the IC chip affecting the individual IC circuit components. With an IC regulator, this gradient can be especially severe since the power dissipation is large. Thermal regulation is the effect of these temperature gradients on output voltage (in percentage output change) per watt of power change in a specified time. Thermal regulation error is independent of electrical regulation or temperature coefficient, and occurs within 5 ms to 50ms after a change in power dissipation. Thermal regulation depends on IC layout as well as electrical design. The thermal regulation of a voltage regulator is defined as the percentage change of V_{OUT} , per watt, within the first 10 ms after a step of power is applied. The LM333's specification is 0.01%/W, max.

In Figure 1, a typical LM333's output drifts only 2mV (or 0.02% of $V_{\text{OUT}} = -10\text{V}$) when a 20W pulse is applied for 10 ms. This performance is thus well inside the specification limit of $0.01\%/W \times 20\text{W} = 0.2\%$ max. When the 20W pulse is ended, the thermal regulation again shows a 2 mV step as the LM333 chip cools off. Note that the load regulation error of about 1 mV (0.01%) is additional to the thermal regulation error. In Figure 2, when the 20W pulse is applied for 100 ms, the output

Adjustable Current Regulator

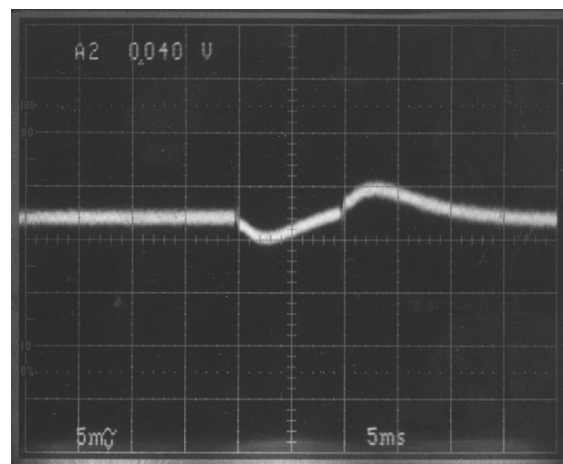


$$I_{\text{OUT}} = (1.5\text{V} / R1) \pm 15\% \text{ adjustable}$$

$$* 0.5\Omega \leq R1 \leq 24\Omega$$

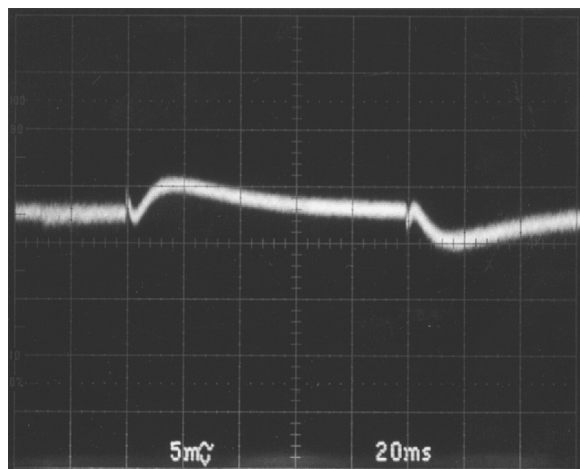
906513

drifts only slightly beyond the drift in the first 10ms, and the thermal error stays well within 0.1% (10mV).



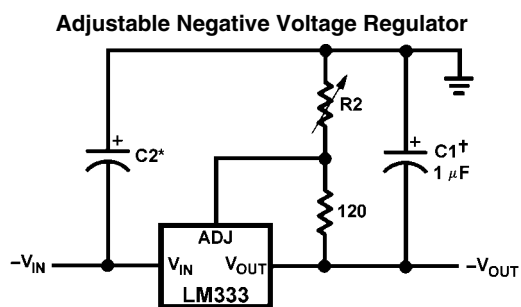
906514

FIGURE 1.



906515

FIGURE 2.



906503

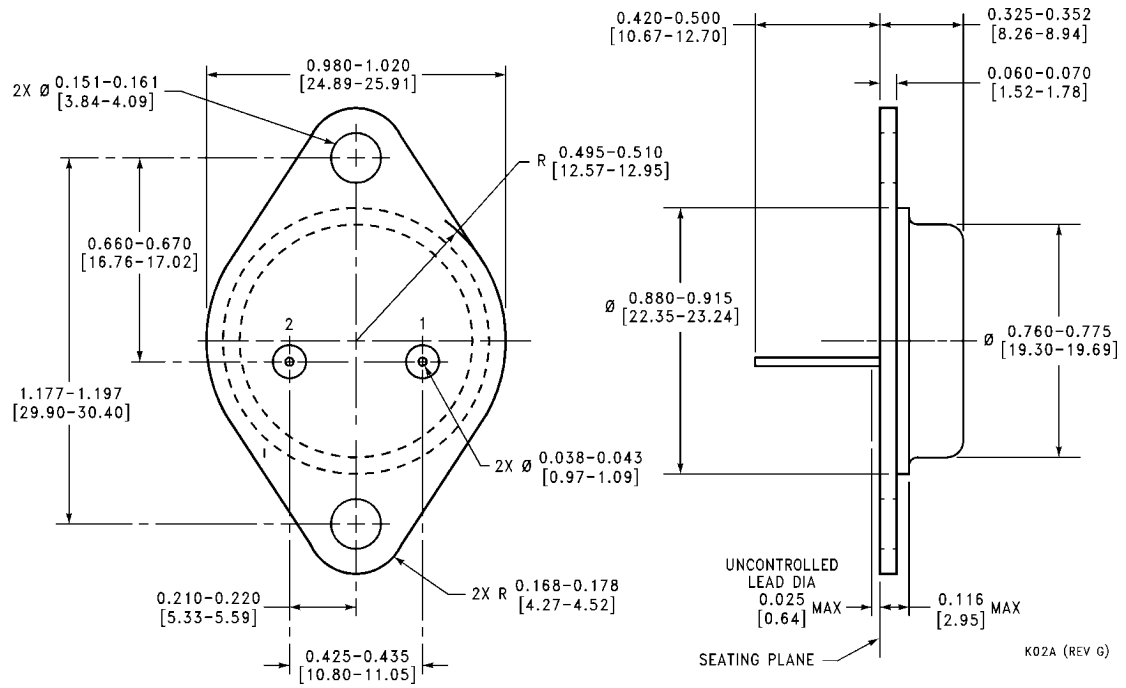
$$-V_{OUT} = -1.25V \left(1 + \frac{R2}{120\Omega} \right) + \left(-I_{ADJ} \times R2 \right)$$

† C1 = 1 μF solid tantalum or 10 μF aluminum electrolytic required for stability.

* C2 = 1 μF solid tantalum is required only if regulator is more than 4 ft from power supply filter capacitor.

Output capacitors in the range of 1 μF to 1000 μF of aluminum or tantalum electrolytic are commonly used to provide lower output impedance and improved transient response.

Physical Dimensions inches (millimeters) unless otherwise noted



Steel TO-3 Metal Can Package (K STEEL)
Order Number LM333K STEEL
NS Package Number K02A

K02A (REV G)

Notes

Notes

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2007 National Semiconductor Corporation

For the most current product information visit us at www.national.com



**National Semiconductor
Americas Customer
Support Center**
Email:
new.feedback@nsc.com
Tel: 1-800-272-9959

**National Semiconductor Europe
Customer Support Center**
Fax: +49 (0) 180-530-85-86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +49 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor Asia
Pacific Customer Support Center**
Email: ap.support@nsc.com

**National Semiconductor Japan
Customer Support Center**
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560