

# LM333

## 3-Ampere Adjustable Negative Regulator

### General Description

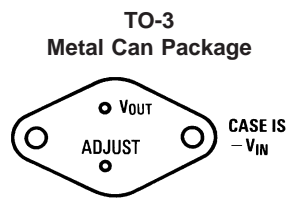
The LM333 is an adjustable 3-terminal negative voltage regulator capable of supplying in excess of  $-3.0A$  over an output voltage range of  $-1.2V$  to  $-32V$ . This regulator is exceptionally easy to apply, requiring only 2 external resistors to set the output voltage and 1 output capacitor for frequency 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,  $-55^{\circ}C$  to  $+150^{\circ}C$
- 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

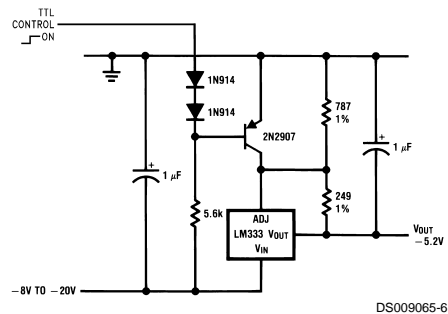
### Connection Diagram



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

### 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 LM333  $T_{MIN}$  to  $T_{MAX}$   
-40°C to +125°C  
Storage Temperature -65°C to +150°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
	$3\text{V} \leq  V_{IN} - V_{OUT}  \leq 35\text{V}$ $10\text{ mA} \leq I_L \leq 3\text{A}$ , $P \leq P_{MAX}$	<b>-1.250</b>	<b>-1.213</b>	<b>-1.287</b>	
Line Regulation	$3\text{V} \leq  V_{IN} - V_{OUT}  \leq 35\text{V}$ $I_{OUT} = 50\text{ mA}$ (Note 4)	0.01 <b>0.02</b>		0.04 <b>0.07</b>	% /V
Load Regulation	$10\text{ mA} \leq I_L \leq 3\text{A}$ , $P \leq P_{MAX}$ (Notes 4, 5)	0.2 <b>0.4</b>		1.0 <b>1.5</b>	%
Thermal Regulation	10 ms Pulse	0.002		0.02	% /W
Temperature Stability	$T_{MIN} \leq T_J \leq T_{MAX}$	<b>0.5</b>			%
Long Term Stability	$T_J = 125^\circ\text{C}$ , 1000 Hours	0.2			%
Adjust Pin Current		65 <b>70</b>		95 <b>100</b>	$\mu\text{A}$
Adjust Pin Current Change	$10\text{ mA} \leq I_L \leq 3\text{A}$ $3.0\text{V} \leq  V_{IN} - V_{OUT}  \leq 35\text{V}$	2.5		<b>8</b>	$\mu\text{A}$
Minimum Load Current	$ V_{IN} - V_{OUT}  \leq 35\text{V}$	<b>2.5</b>		<b>10</b>	mA
	$ V_{IN} - V_{OUT}  \leq 10\text{V}$	<b>1.5</b>		<b>5.0</b>	
Current Limit (Note 5)	$3\text{V} \leq  V_{IN} - V_{OUT}  \leq 10\text{V}$	<b>3.9</b>	3.0		A
	$ V_{IN} - V_{OUT}  = 20\text{V}$	<b>2.4</b>	1.0		
	$ V_{IN} - V_{OUT}  = 30\text{V}$	<b>0.4</b>	0.20		
Output Noise (% of $V_{OUT}$ )	10 Hz to 10 kHz	0.003			% (rms)
Ripple Rejection	$V_{OUT} = 10\text{V}$ , $f = 120\text{ Hz}$ $C_{ADJ} = 0\text{ }\mu\text{F}$ $C_{ADJ} = 10\text{ }\mu\text{F}$	60			dB
		77			
Thermal Resistance Junction to Case	TO-3 Package (K STEEL)	1.2		1.8	$^\circ\text{C/W}$
	TO-220 Package (T)	3		4	
Thermal Shutdown Temperature		163			$^\circ\text{C}$
Thermal Resistance Junction to Ambient (No Heatsink)	K Package	35			$^\circ\text{C/W}$
	T Package	50			

**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.

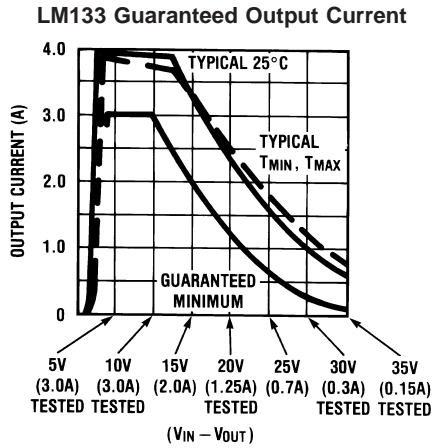
**Note 2:** All limits are guaranteed at either room temperature (standard type face) or at **temperature extremes (bold typeface)** by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods.

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

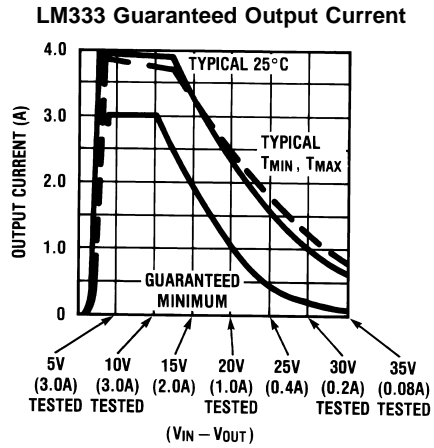
**Note 4:** Load and line regulation are measured at constant junction temperature, using low duty cycle pulse testing (output voltage changes due to heating effects are covered by the Thermal Regulation specification). For the TO-3 package, load regulation is measured on the output pin,  $1/8$ " below 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 graphs for guaranteed output currents at other voltages.

# Guaranteed Performance Characteristics



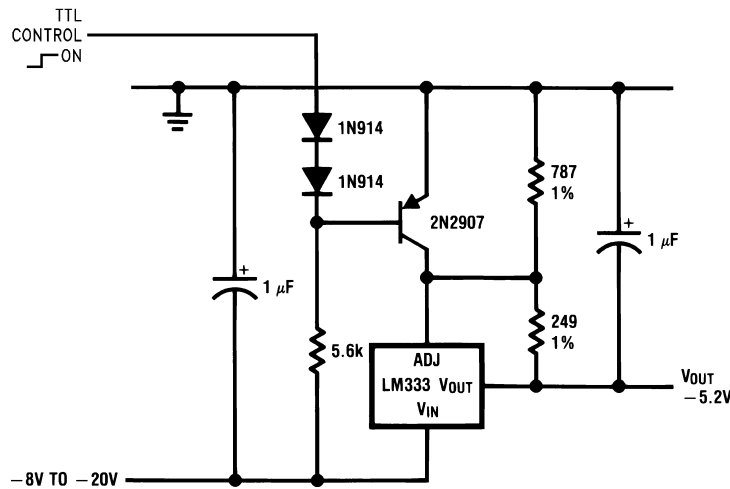
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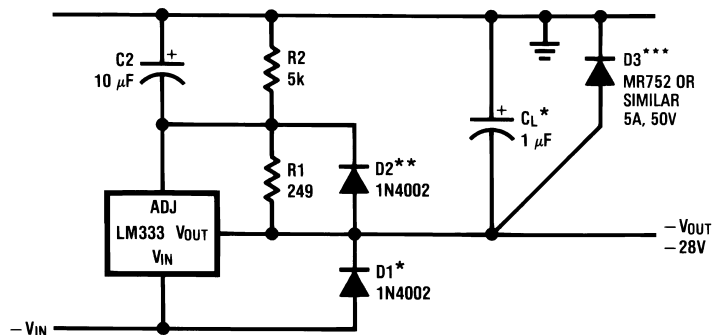
## Typical Applications

### -5.2V Regulator with Electronic Shutdown



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### Negative Regulator with Protection Diodes



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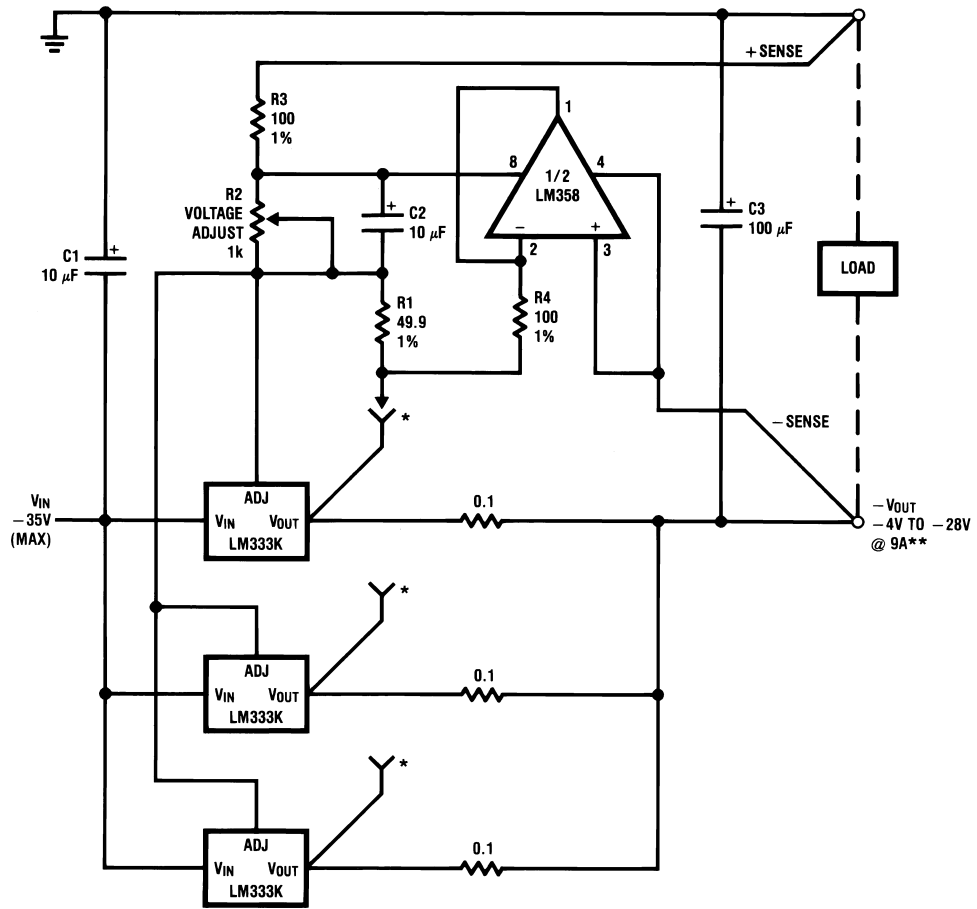
\*When  $C_L$  is larger than 20  $\mu F$ , D1 protects the LM333 in case the input supply is shorted.

\*\*When C2 is larger than 10  $\mu F$  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 overvoltage, and protects the load from reversed voltage.

Typical Applications (Continued)

High-Performance 9-Ampere Adjustable Regulator

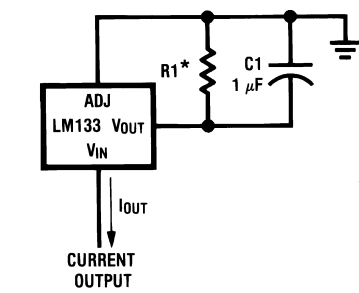


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\*Wire R1 and R4 to the regulator that provides the highest  $V_{OUT}$  with a 3A load.

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

Current Regulator

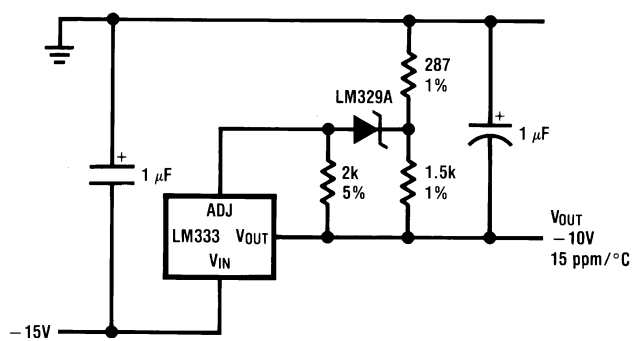


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$$I_{OUT} = \frac{V_{REF}}{R1}$$

\* $0.4\Omega \leq R1 \leq 120\Omega$

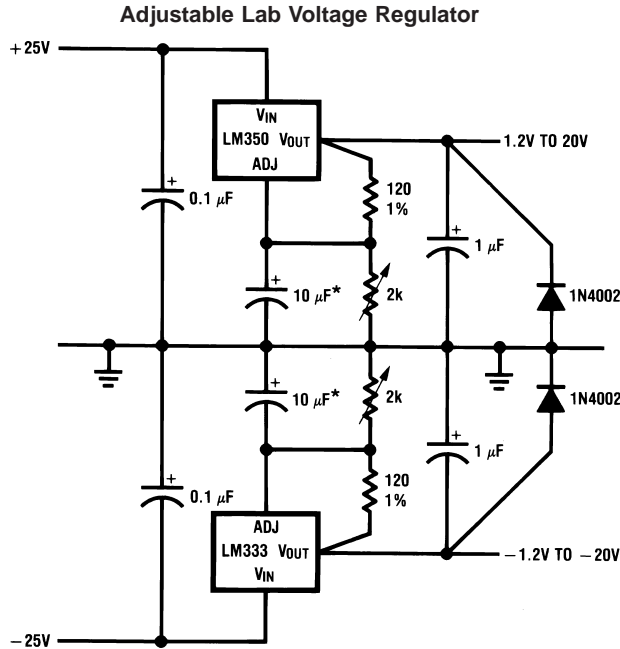
High Stability 10V Regulator



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## Typical Applications (Continued)



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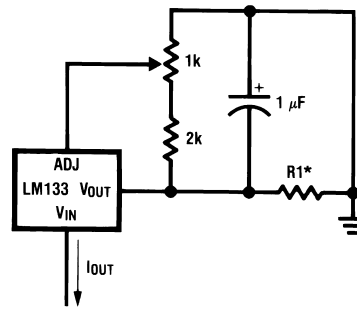
\*The 10 μF capacitors are optional to improve ripple rejection.

### 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  $V_{OUT} = -10V$ ) when a 20W pulse is applied for 10 ms. This performance is thus well inside the specification limit of  $0.01\%/W \times 20W = 0.2\%$  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 drifts only slightly beyond the drift in the first 10ms, and the thermal error stays well within 0.1% (10mV).

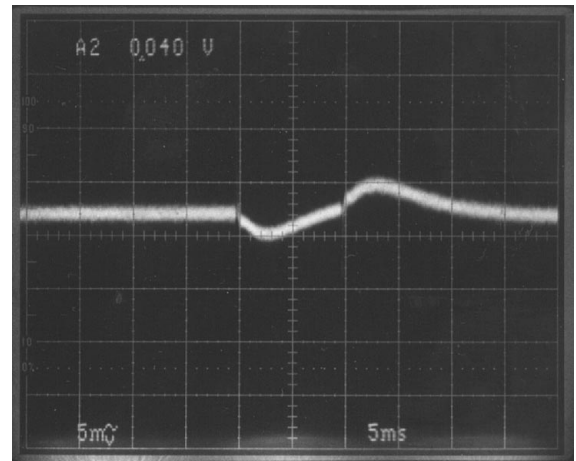
### Adjustable Current Regulator



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

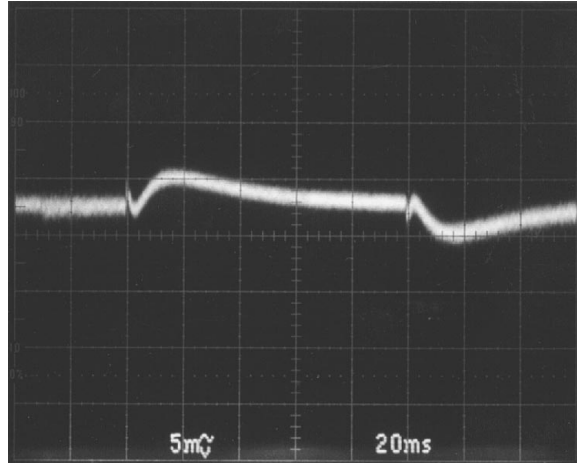
\* $0.5\Omega \leq R1 \leq 24\Omega$



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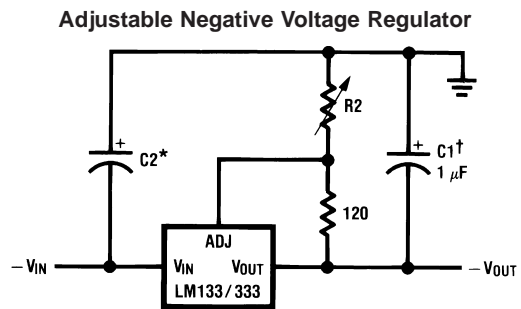
FIGURE 1.

## Typical Applications (Continued)



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FIGURE 2.



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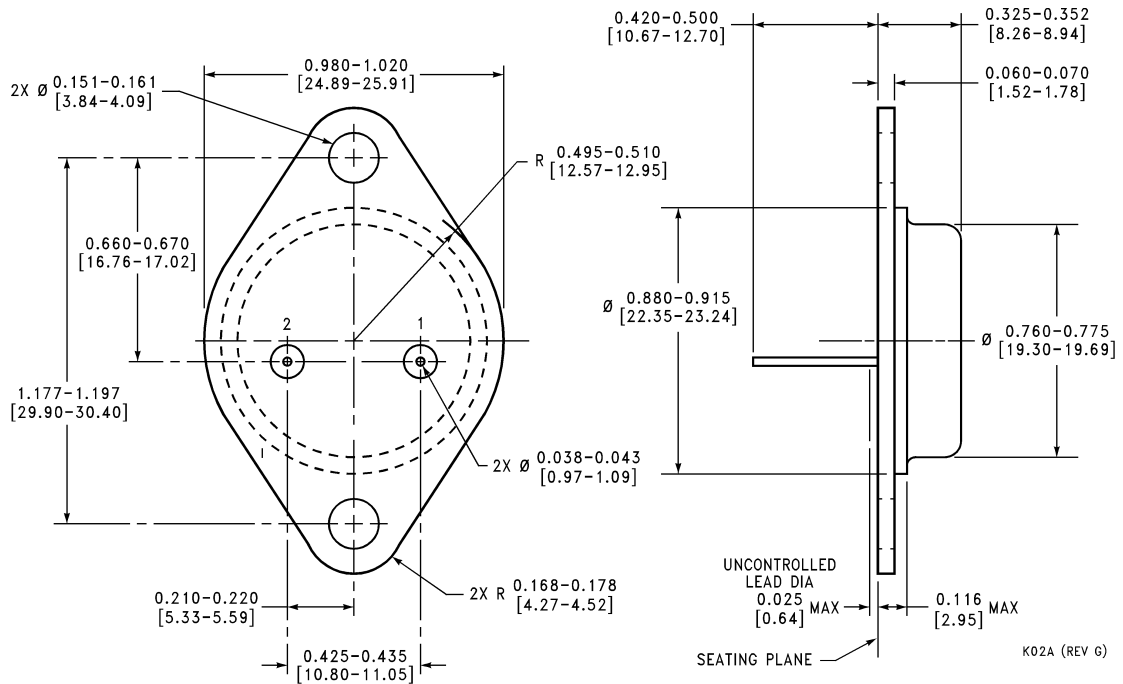
$$-V_{OUT} = -1.25V \left( 1 + \frac{R2}{120\Omega} \right) + (-I_{ADJ} \times R2)$$

†C1 = 1  $\mu$ F solid tantalum or 10  $\mu$ F aluminum electrolytic required for stability.

\*C2 = 1  $\mu$ F solid tantalum is required only if regulator is more than 4" from power supply filter capacitor.

Output capacitors in the range of 1  $\mu$ F to 1000  $\mu$ F 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**

KO2A (REV G)

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