National Semiconductor

May 1998

LM133/LM333
3-Ampere Adjustable Negative Regulators

General Description

The LM133/LM333 are adjustable 3-terminal negative voltage regulators capable of supplying in excess of −3.0A over an output voltage range of −1.2V to −32V. These regulators are 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 LM133 series features internal current limiting, thermal shutdown and safe-area compensation, making them substantially immune to failure from overloads.

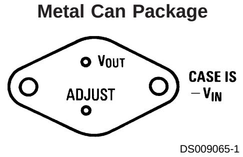
The LM133/LM333 serve a wide variety of applications including local on-card regulation, programmable-output voltage regulation or precision current regulation. The LM133/LM333 are ideal complements to the LM150/LM350 adjustable positive regulators.

Features

- Output voltage adjustable from −1.2V to −32V
- 3.0A output current guaranteed, −55˚C to +150˚C
- Line regulation typically 0.01%/V
- Load regulation typically 0.2%
- Excellent rejection of thermal transients
- 50 ppm/˚C temperature coefficient
- Temperature-independent current limit
- Internal thermal overload protection
- P+ Product Enhancement tested
- Standard 3-lead transistor package
- Output is short circuit protected

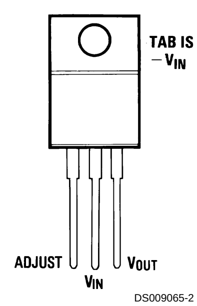
Connection Diagrams

TO-3
Metal Can Package



Bottom View
Steel TO-3 Metal Can Package (K STEEL)
Order Number LM133K STEEL or
LM333K STEEL
See NS Package Number K02A

TO-220
Plastic Package



Front View
3-Lead TO-220 Plastic Package (T)
Order Number LM333T
See NS Package Number T03B

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}
LM133	−55˚C to +150˚C
LM333	−40˚C to +125˚C
Storage Temperature	−65˚C to +150˚C
Lead Temperature (Soldering, 10 sec.)	
TO-3 Package	300˚C
TO-220 Package	260˚C
ESD Susceptibility	TBD

Electrical Characteristics LM133

Specifications with standard typeface are for T_J = 25˚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 mA	−1.250	−1.238	−1.262	V
	3V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 35V 10 mA ≤ I_L ≤ 3A, P ≤ P_{MAX}	**−1.250**	**−1.225**	**−1.275**	V
Line Regulation	3V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 35V I_{OUT} = 50 mA (Note 4)	0.01 **0.02**		0.02 **0.05**	% /V
Load Regulation	10 mA ≤ I_{OUT} ≤ 3A, P ≤ P_{MAX} (Notes 4, 5)	0.2 **0.4**		0.5 **1.0**	%
Thermal Regulation	10 ms Pulse	0.002		0.01	% /W
Temperature Stability	T_{MIN} ≤ T_J ≤ T_{MAX}	**0.4**			%
Long Term Stability	T_J = 125˚C, 1000 Hours	0.15			%
Adjust Pin Current		65 **70**		90 **100**	µA
Adjust Pin Current Change	10 mA ≤ I_L ≤ 3A 3.0V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 35V	2		**6**	µA
Minimum Load Current	$\|V_{IN} - V_{OUT}\|$ ≤ 35V	**2.5**		**5.0**	mA
	$\|V_{IN} - V_{OUT}\|$ ≤ 10V	**1.2**		**2.5**	
Current Limit (Note 5)	3V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 10V	**3.9**	**3.0**		A
	$\|V_{IN} - V_{OUT}\|$ = 20V	**2.4**	**1.25**		
	$\|V_{IN} - V_{OUT}\|$ = 30V	**0.4**	**0.3**		
Output Noise (% of V_{OUT})	10 Hz to 10 kHz	0.003			% (rms)
Ripple Rejection	V_{OUT} = 10V, f = 120 Hz C_{ADJ} = 0 µF C_{ADJ} = 10 µF	 60 77			dB
Thermal Resistance Junction-to-Case	TO-3 Package (K STEEL)	1.2		1.8	˚C/W
Thermal Shutdown Temperature		163	150	190	˚C

Electrical Characteristics LM333

Specifications with standard typeface are for T_J = 25˚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 mA	−1.250	−1.225	−1.275	V
	3V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 35V 10 mA ≤ I_L ≤ 3A, P ≤ P_{MAX}	**−1.250**	**−1.213**	**−1.287**	

Electrical Characteristics LM333 (Continued)

Specifications with standard typeface are for T_J = 25˚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
Line Regulation	$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 35V$ I_{OUT} = 50 mA (Note 4)	0.01 **0.02**		0.04 **0.07**	% /V
Load Regulation	10 mA ≤ I_L ≤ 3A, P ≤ P_{MAX} (Notes 4, 5)	0.2 **0.4**		1.0 **1.5**	%
Thermal Regulation	10 ms Pulse	0.002		0.02	% /W
Temperature Stability	$T_{MIN} \le T_J \le T_{MAX}$	**0.5**			%
Long Term Stability	T_J = 125˚C, 1000 Hours	0.2			%
Adjust Pin Current		65 **70**		95 **100**	µA
Adjust Pin Current Change	10 mA ≤ I_L ≤ 3A $3.0V \le \lvert V_{IN} - V_{OUT} \rvert \le 35V$	2.5		**8**	µA
Minimum Load Current	$\lvert V_{IN} - V_{OUT} \rvert \le 35V$	**2.5**		**10**	mA
	$\lvert V_{IN} - V_{OUT} \rvert \le 10V$	**1.5**		**5.0**	
Current Limit (Note 5)	$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 10V$	**3.9**	3.0		A
	$\lvert V_{IN} - V_{OUT} \rvert = 20V$	**2.4**	1.0		
	$\lvert V_{IN} - V_{OUT} \rvert = 30V$	**0.4**	0.20		
Output Noise (% of V_{OUT})	10 Hz to 10 kHz	0.003			% (rms)
Ripple Rejection	V_{OUT} = 10V, f = 120 Hz C_{ADJ} = 0 µF C_{ADJ} = 10 µF	 60 77			dB
Thermal Resistance Junction to Case	TO-3 Package (K STEEL)	1.2		1.8	˚C/W
	TO-220 Package (T)	3		4	
Thermal Shutdown Temperature		163			˚C
Thermal Resistance Junction to Ambient (No Heatsink)	K Package	35			˚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.

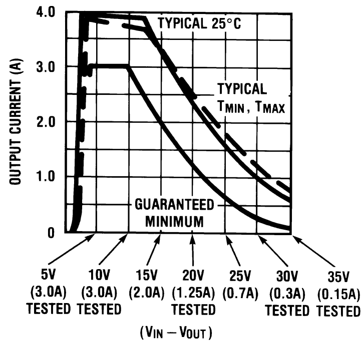
Note 3: Unless otherwise specified: $\lvert V_{IN} - V_{OUT} \rvert$ = 5V, I_{OUT} = 0.5A, P_{DISS} ≤ 30W.

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 at the output pin, ⅛" below the base of the package.

Note 5: The output current of the LM333 is guaranteed to be ≥ 3A in the range $3V \le \lvert V_{IN} - V_{OUT} \rvert \le 10V$. For the range $10V \le \lvert V_{IN} - V_{OUT} \rvert \le 15V$, 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

LM133 Guaranteed Output Current



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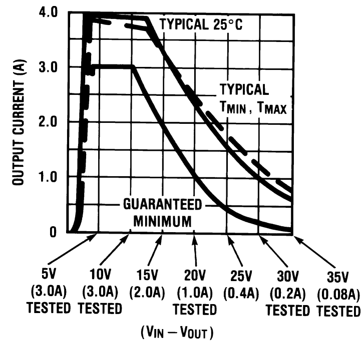
LM333 Guaranteed Output Current



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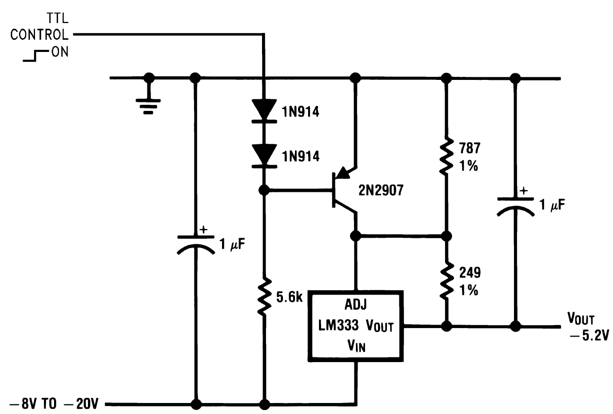
Typical Applications

−5.2V Regulator with Electronic Shutdown



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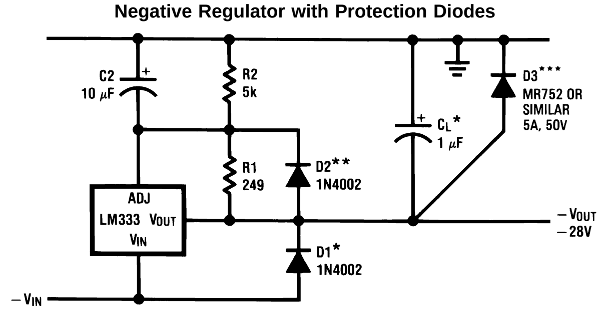
Negative Regulator with Protection Diodes



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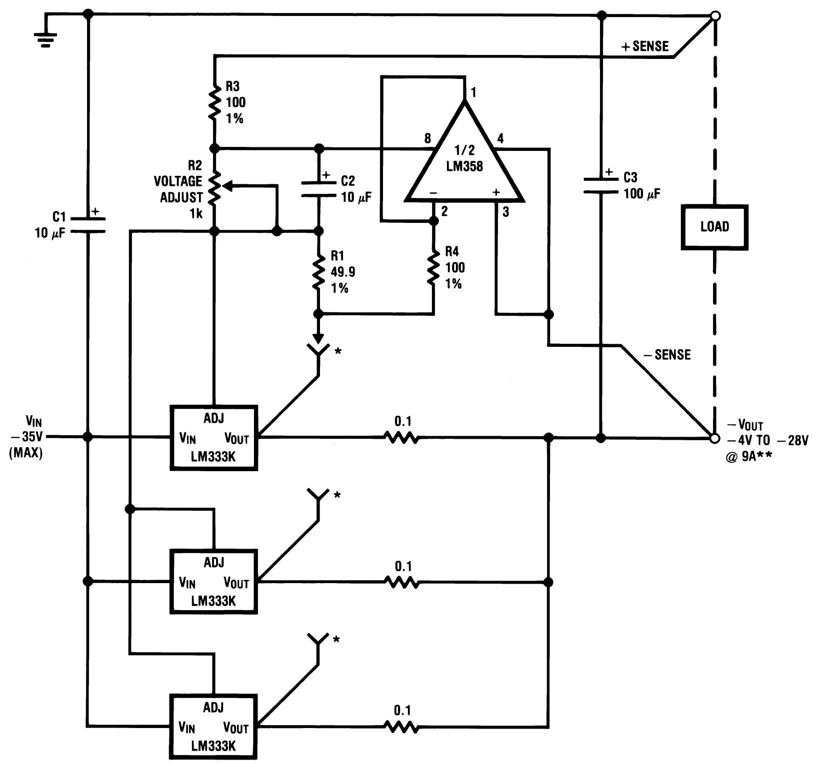
*When C_L is larger than 20 µF, D1 protects the LM133 in case the input supply is shorted.
**When C2 is larger than 10 µF and $-V_{OUT}$ is larger than −25V, D2 protects the LM133 in case the output is shorted.
***In case V_{OUT} is shorted to a positive supply, D3 protects the LM133 from overvoltage, and protects the load from reversed voltage.

Typical Applications (Continued)

High-Performance 9-Ampere Adjustable Regulator



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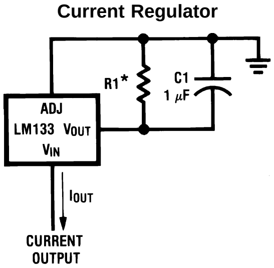
*Wire R1 and R4 to the regulator that provides the highest V_{OUT} with a 3A load.

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

Current Regulator



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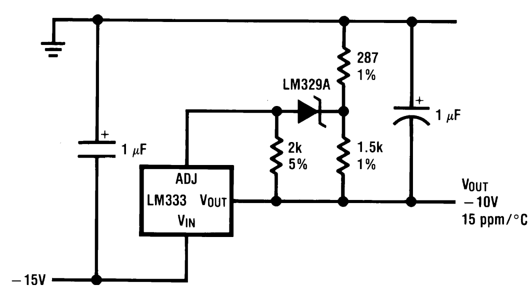
$$I_{OUT} = \frac{V_{REF}}{R1}$$

*0.4Ω ≤ R1 ≤ 120Ω

High Stability 10V Regulator



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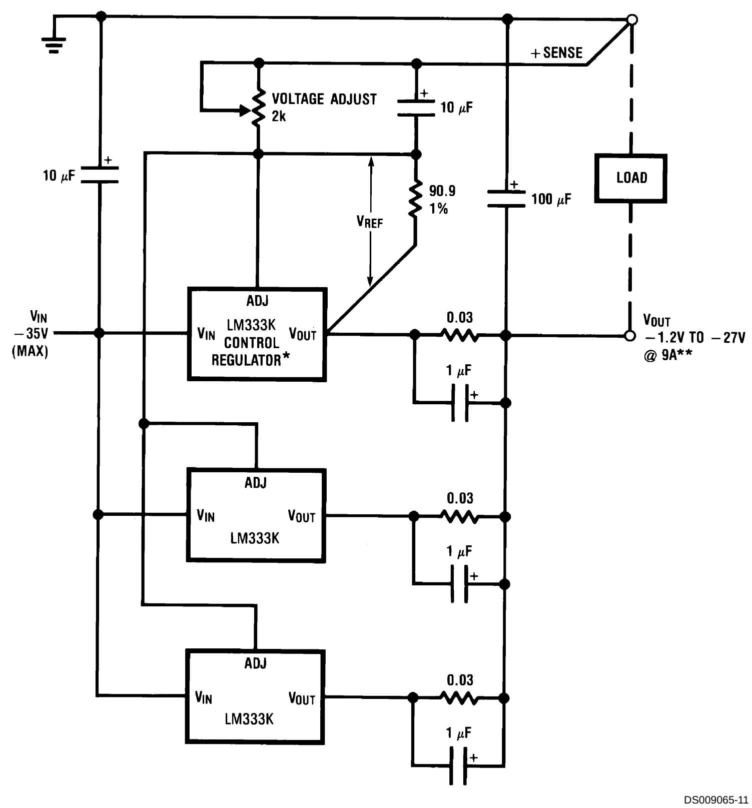
Typical Applications (Continued)

High-Current Adjustable Regulator

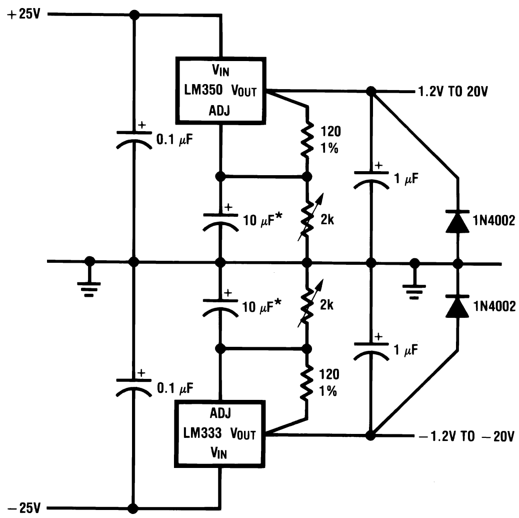


*Control regulator must have the largest V_{REF}

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

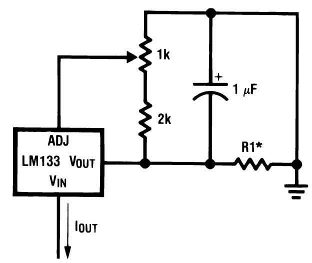
Typical Applications (Continued)

Adjustable Lab Voltage Regulator



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

Adjustable Current Regulator



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

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

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 50 ms 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 LM133's specification is 0.01%/W, max.

In *Figure 1*, a typical LM133's output drifts only 2 mV (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%/Wx20W = 0.2% max. When the 20W pulse is ended, the thermal regulation again shows a 2 mV step as the LM133 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 10 ms, and the thermal error stays well within 0.1% (10 mV).

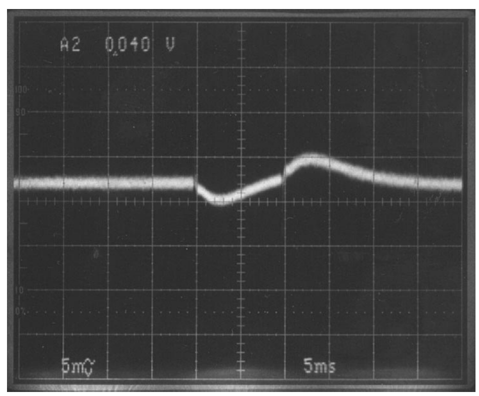


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FIGURE 1.

Typical Applications (Continued)

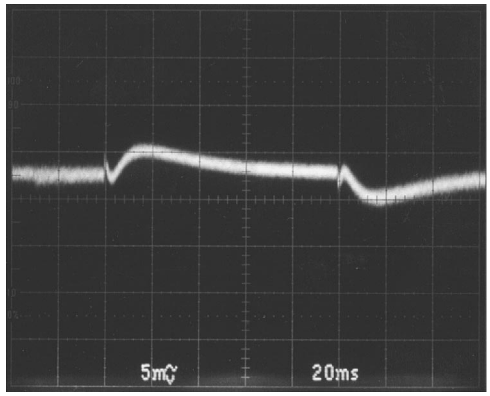

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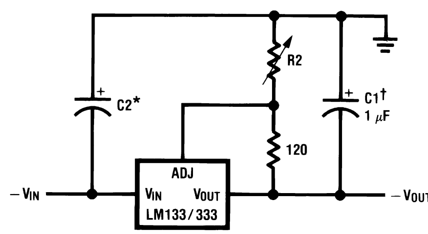
FIGURE 2.

Adjustable Negative Voltage Regulator



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

†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" 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.

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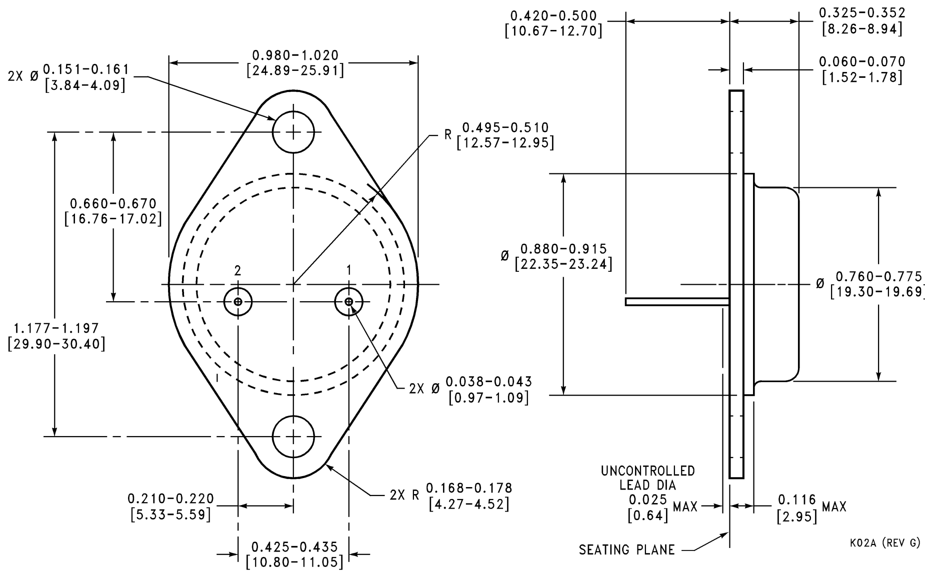
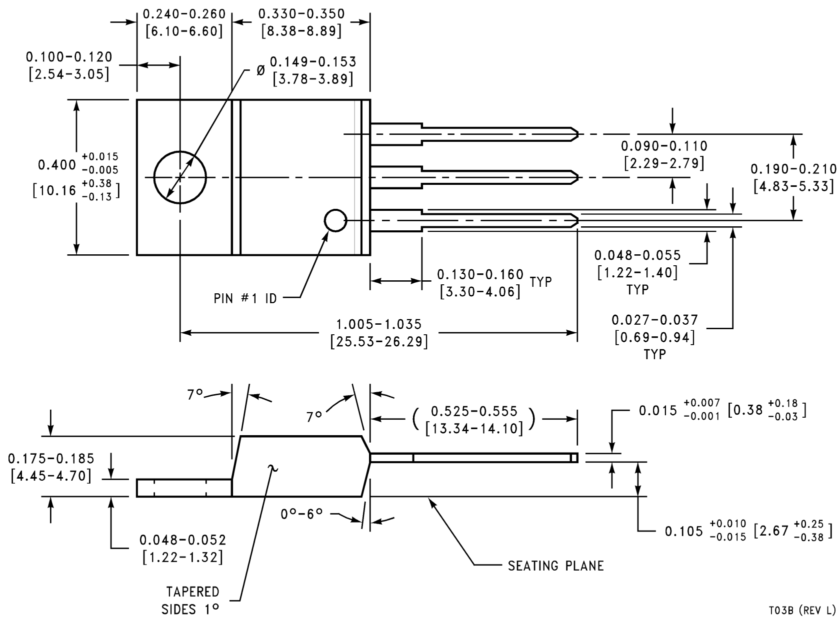
Physical Dimensions inches (millimeters) unless otherwise noted



Steel TO-3 Metal Can Package (K STEEL)
Order Number LM133K STEEL or LM333K STEEL
NS Package Number K02A



3-Lead TO-220 Plastic Package (T)
Order Number LM333T
NS Package Number T03B

Notes

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