

LM133/LM333 3-Ampere Adjustable Negative Regulators

General Description

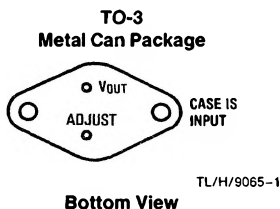
The LM133/LM333 are adjustable 3-terminal negative voltage regulators capable of supplying in excess of -3.0A over an output voltage range of -1.2V to -32V . These regulators are exceptionally easy to apply, requiring only 2 external resistors to set the output voltage and 1 output capacitor for frequency 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 virtually blowout-proof against 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 $+150^\circ\text{C}$
- Line regulation typically $0.01\%/V$
- Load regulation typically 0.1%
- Excellent rejection of thermal transients
- $50\text{ ppm}/^\circ\text{C}$ temperature coefficient
- Temperature-independent current limit
- Internal thermal overload protection
- 100% electrical burn-in
- Standard 3-lead transistor package
- Output is short circuit protected

Connection Diagrams

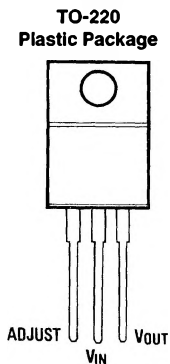
Typical Applications



**Steel TO-3 Metal Can Package (K
STEEL)**

**Order Number LM133K STEEL or
LM333K STEEL**

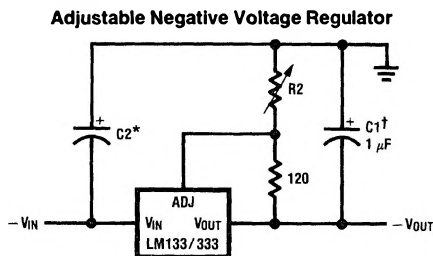
See NS Package Number K02A



3-Lead TO-220 Plastic Package (T)

Order Number LM333T

See NS Package Number T03B



Full output current not available at high input-output voltages.

$$-V_{OUT} = -1.25V \left(1 + \frac{R_2}{120\Omega} \right) + (-I_{ADJ} \times R_2)$$

$^1C_1 = 1\text{ }\mu\text{F}$ solid tantalum or $10\text{ }\mu\text{F}$ aluminum electrolytic required for stability.

$^*C_2 = 1\text{ }\mu\text{F}$ solid tantalum is required only if regulator is more than 4" from power supply filter capacitor.

Output capacitors in the range of $1\text{ }\mu\text{F}$ to $1000\text{ }\mu\text{F}$ of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, 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 $+150^{\circ}\text{C}$ 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
TO-220 Package	260°C

Preconditioning

Burn-In In Thermal Limit	100% All Devices
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Electrical Characteristics LM133 (Note 1) (Note 5)

Parameter	Conditions	Typical	Tested Limit (Note 3)	Design Limit (Note 4)	Units (Max Unless Noted)
Reference Voltage	$T_J = 25^{\circ}\text{C}$, $I_L = 10\text{ mA}$	-1.250	-1.238 -1.262		V(MIN) V(MAX)
	$T_{MIN} \leq T_J \leq T_{MAX}$, $3\text{V} \leq V_{IN} - V_{OUT} \leq 35\text{V}$, $10\text{ mA} \leq I_L \leq 3\text{A}$, $P \leq P_{MAX}$ LM133 LM333	-1.250	-1.225 -1.275		V(MIN) V(MAX)
Line Regulation	$T_J = 25^{\circ}\text{C}$, $3\text{V} \leq V_{IN} - V_{OUT} \leq 35\text{V}$, $I_{OUT} = 50\text{ mA}$ (Note 2)	0.01	0.02		% /V
	LM133	0.02	0.05		% /V
Load Regulation	$T_J = 25^{\circ}\text{C}$, $10\text{ mA} \leq I_{OUT} \leq 3\text{A}$, $P \leq P_{MAX}$ (Notes 2 and 6)	0.2	0.5		%
	LM133	0.4	1.0		%
Thermal Regulation	$T_J = 25^{\circ}\text{C}$, 10 ms Pulse	0.002	0.01		% /W
Temperature Stability	$T_{MIN} \leq T_J \leq T_{MAX}$	0.4			%
Long Term Stability	$T_J = 125^{\circ}\text{C}$, 1000 Hours	0.15		0.8	%
Adjust Pin Current	$T_J = 25^{\circ}\text{C}$				
	LM133 LM333	65 70	90 100		μA μA
Adjust Pin Current Change	$T_J = 25^{\circ}\text{C}$, $10\text{ mA} \leq I_L \leq 3\text{A}$	2	5	6	μA
	$T_J = 25^{\circ}\text{C}$, $3.0\text{V} \leq V_{IN} - V_{OUT} \leq 35\text{V}$	2	5	6	μA
Minimum Load Current	$ V_{IN} - V_{OUT} \leq 35\text{V}$, $T_J = 25^{\circ}\text{C}$				
	LM133 LM333	2.5 1.2	5.0 2.5		mA mA
Current Limit (Note 6)	$3\text{V} \leq V_{IN} - V_{OUT} \leq 10\text{V}$, $T_J = 25^{\circ}\text{C}$				
	LM133	3.9	3.0		A(MIN)
	$ V_{IN} - V_{OUT} = 20\text{V}$, $T_J = 25^{\circ}\text{C}$				
	LM133 LM333	2.4 0.4	1.25 0.3		A(MIN) A(MIN)
Output Noise (% of V_{OUT})	10 Hz to 10 kHz, $T_J = 25^{\circ}\text{C}$	0.003		0.010	% (rms)
Ripple Rejection	$V_{OUT} = 10\text{V}$, $f = 120\text{ Hz}$, $T_J = 25^{\circ}\text{C}$				
	$C_{ADJ} = 0\text{ }\mu\text{F}$	60		55	dB
	$C_{ADJ} = 10\text{ }\mu\text{F}$	77		70	dB
Thermal Resistance	TO-3 Package (K STEEL)	1.2		1.8	$^{\circ}\text{C/W}$
	TO-220 Package (T)	3		4	$^{\circ}\text{C/W}$
Thermal Shutdown Temperature	LM133	163	150		$^{\circ}\text{C(MIN)}$
	LM333			190	$^{\circ}\text{C(MAX)}$

Electrical Characteristics LM133 (Note 1) (Note 5)

Parameter	Conditions	Typical	Tested Limit (Note 3)	Design Limit (Note 4)	Units (Max Unless Noted)	
Reference Voltage	$T_J = 25^\circ\text{C}$, $I_L = 10\text{ mA}$ $T_{\text{MIN}} \leq T_J \leq T_{\text{MAX}}$, $3\text{V} \leq V_{\text{IN}} - V_{\text{OUT}} \leq 35\text{V}$, $10\text{ mA} \leq I_L \leq 3\text{A}$, $P \leq P_{\text{MAX}}$	-1.250 -1.250	-1.225 -1.275	 -1.213 -1.287	V(MIN) V(MAX) V(MIN) V(MAX)	
Line Regulation	$T_J = 25^\circ\text{C}$, $3\text{V} \leq V_{\text{IN}} - V_{\text{OUT}} \leq 35\text{V}$, $I_{\text{OUT}} = 50\text{ mA}$ (Note 2)	0.001 0.02	0.004	0.07	% / V % / V	
Load Regulation	$T_J = 25^\circ\text{C}$, $10\text{ mA} \leq I_{\text{OUT}} \leq 3\text{A}$, $P \leq P_{\text{MAX}}$ (Notes 2 and 6)	0.2 0.4	1.0	1.5	% %	
Thermal Regulation	$T_J = 25^\circ\text{C}$, 10 ms Pulse	0.002	0.02		% / W	
Temperature Stability	$T_{\text{MIN}} \leq T_J \leq T_{\text{MAX}}$	0.5			%	
Long Term Stability	$T_J = 125^\circ\text{C}$, 1000 Hours	0.2		0.8	%	
Adjust Pin Current	$T_J = 25^\circ\text{C}$	65 70	95	100	μA μA	
Adjust Pin Current Change	$T_J = 25^\circ\text{C}$, $10\text{ mA} \leq I_L \leq 3\text{A}$ $T_J = 25^\circ\text{C}$, $3.0\text{V} \leq V_{\text{IN}} \leq 35\text{V}$	2.5 2.5	7 7	8 8	μA μA	7
Minimum Load Current	$ V_{\text{IN}} - V_{\text{OUT}} \leq 35\text{V}$, $T_J = 25^\circ\text{C}$ $ V_{\text{IN}} - V_{\text{OUT}} \leq 10\text{V}$, $T_J = 25^\circ\text{C}$	2.5 1.5	10 5.0	10 5.0	mA mA	
Current Limit (Note 6)	$3\text{V} \leq V_{\text{IN}} - V_{\text{OUT}} \leq 10\text{V}$, $T_J = 25^\circ\text{C}$ $ V_{\text{IN}} - V_{\text{OUT}} = 20\text{V}$, $T_J = 25^\circ\text{C}$ $ V_{\text{IN}} - V_{\text{OUT}} = 30\text{V}$, $T_J = 25^\circ\text{C}$	3.9 2.4 0.4	2.0 1.0 0.20	3.0 1.0 0.2	A(MIN) A(MIN) A(MIN)	
Output Noise (% of V_{OUT})	10 Hz to 10 kHz, $T_J = 25^\circ\text{C}$	0.003		0.010	% (rms)	
Ripple Rejection	$V_{\text{OUT}} = 10\text{V}$, $f = 120\text{ Hz}$, $T_J = 25^\circ\text{C}$ $C_{\text{ADJ}} = 0\text{ }\mu\text{F}$ $C_{\text{ADJ}} = 10\text{ }\mu\text{F}$	60 77		50 66	dB dB	
Thermal Resistance Junction to Case	TO-3 Package (K STEEL) TO-220 Package (T)	1.2 3		1.8 4	$^\circ\text{C/W}$ $^\circ\text{C/W}$	
Thermal Shutdown Temperature		163		150 190	$^\circ\text{C(MIN)}$ $^\circ\text{C(MAX)}$	
Thermal Resistance Junction to Ambient (No Heatsink)	K Package T Package	35 50			$^\circ\text{C/W}$ $^\circ\text{C/W}$	

Note 1: Unless otherwise specified, these specifications apply: $-55^\circ\text{C} \leq T_J \leq +150^\circ\text{C}$ for the LM133; and $-40^\circ\text{C} \leq T_J + 125^\circ\text{C}$ for the LM333; $|V_{\text{IN}} - V_{\text{OUT}}| = 5\text{V}$; and $I_{\text{OUT}} = 0.5\text{A}$. Although power dissipation is internally limited, these specifications are applicable for power dissipations up to 30W.

Note 2: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation. Load regulation is measured on the output pin at a point $1/8''$ below the base of the TO-3 package.

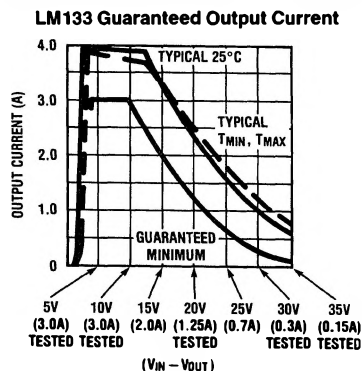
Note 3: Testing limits are guaranteed and 100% tested in production.

Note 4: Design limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

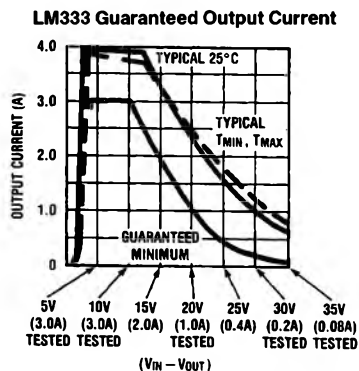
Note 5: Specifications in **boldface** apply over the full rated temperature range.

Note 6: The output capability of the LM333 is guaranteed at 3A in the range of $3\text{V} \leq |V_{\text{IN}} - V_{\text{OUT}}| \leq 10\text{V}$. At voltages above 10V, the available output current decreases, but in the range $10\text{V} \leq |V_{\text{IN}} - V_{\text{OUT}}| \leq 15\text{V}$, the available current is $30\text{W} - |V_{\text{IN}} - V_{\text{OUT}}|$. At voltages higher than 15V, refer to graphs for actual guaranteed output current available.

Guaranteed Performance Characteristics



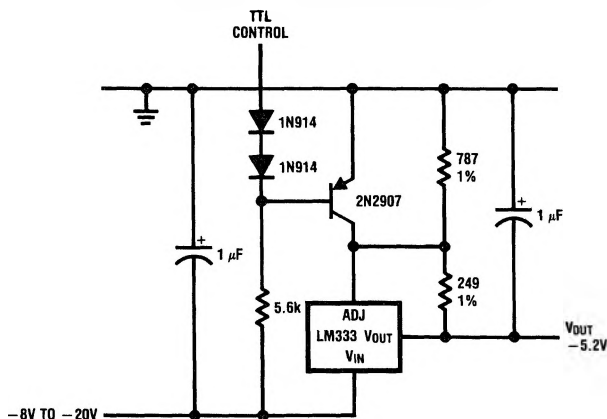
TL/H/9065-4



TL/H/9065-5

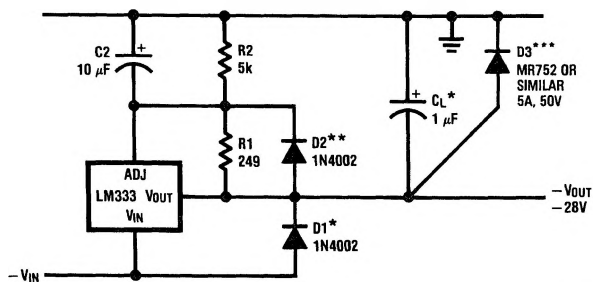
Typical Applications (Continued)

- 5.2V Regulator with Electronic Shutdown*



TL/H/9065-6

Negative Regulator with Protection Diodes



TL/H/9065-7

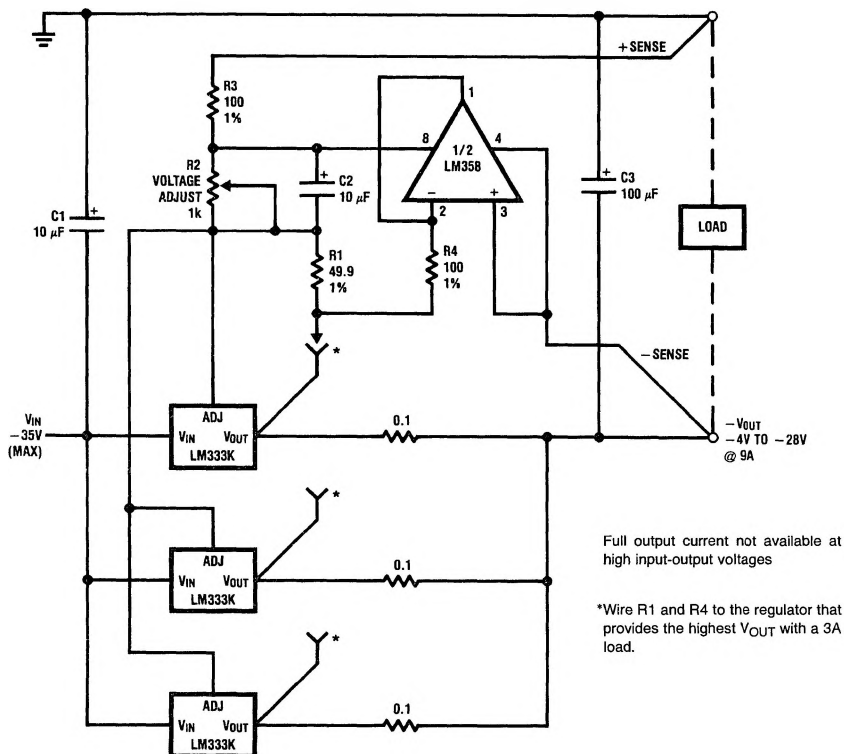
*When C_L is larger than 20 µF, D1 protects the LM133 in case the input supply is shorted.

**When C_2 is larger than 10 µF and $-V_{OUT}$ is larger than -25V, D2 protect 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

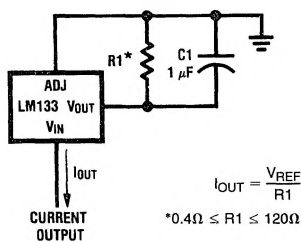


Full output current not available at high input-output voltages

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

TL/H/9065-8

Current Regulator

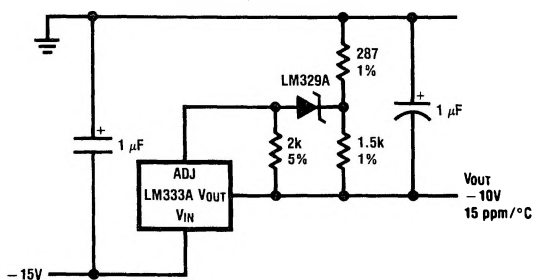


$$I_{OUT} = \frac{V_{REF}}{R1}$$

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

TL/H/9065-9

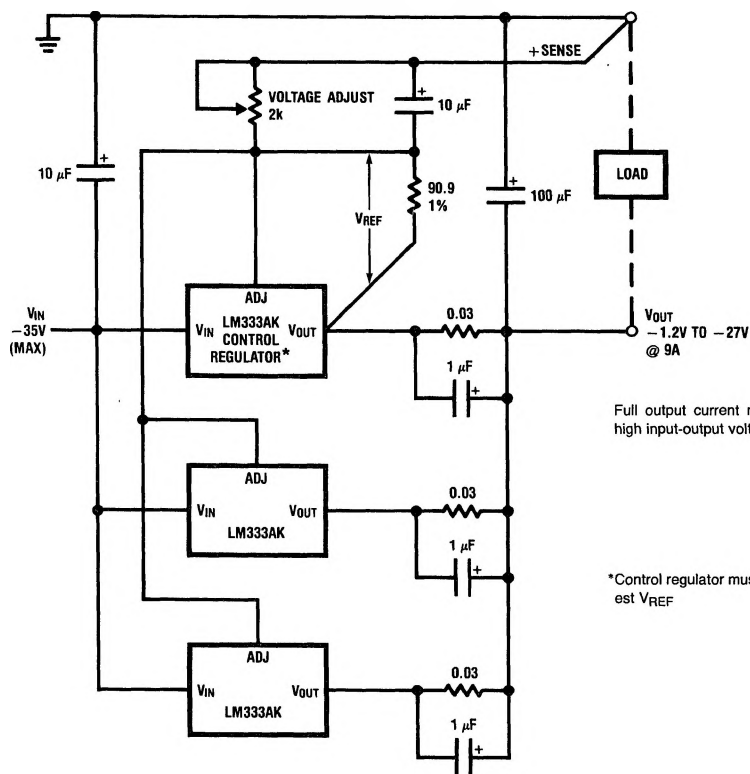
High Stability—10V Regulator



TL/H/9065-10

Typical Applications (Continued)

High-Current Adjustable Regulator

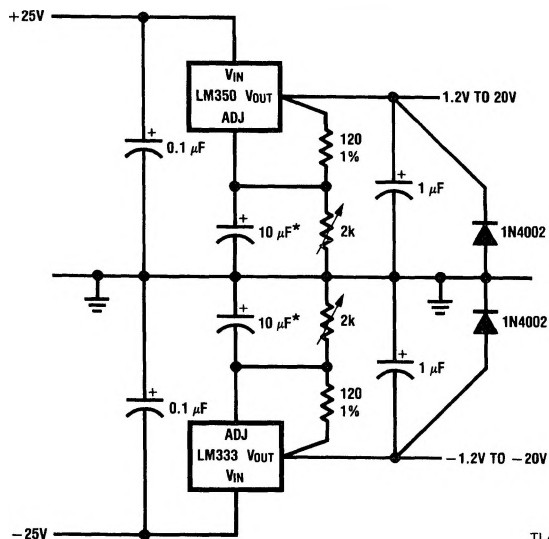


Full output current not available at high input-output voltages

*Control regulator must have the largest V_{REF}

TL/H/9065-11

Adjustable Lab Voltage Regulator

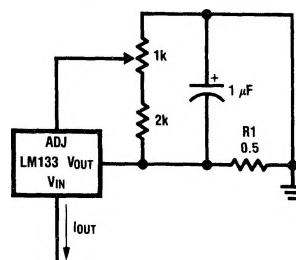


Full output current not available at high input-output voltages.

*The 10 μ F capacitors are optional to improve ripple rejection.

TL/H/9065-12

Adjustable Current Regulator



TL/H/9065-13

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

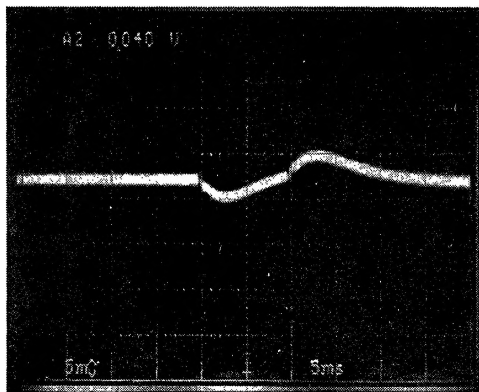
Typical Applications (Continued)

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} ,

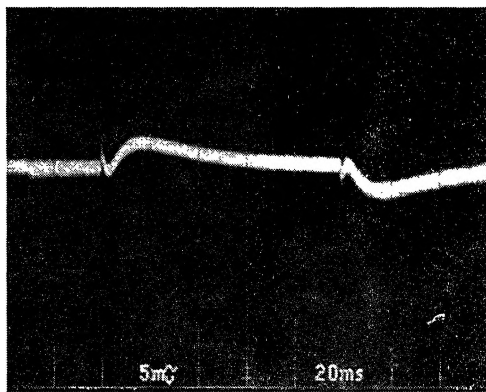
per watt, within the first 10 ms after a step of power is applied. The LM133's specification is 0.01%/W, max.

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 $0.01\%/W \times 20W = 0.2\%$ 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).



TL/H/9065-14

FIGURE 1



TL/H/9065-15

FIGURE 2