

## FEATURES

- Guaranteed Operation at +1.2V
- Op Amp and Reference on Single Chip
- Low Supply Current 400 $\mu$ A
- Capable of Floating Mode Operation
- Low Reference Drift 20ppm/ $^{\circ}$ C
- Low Offset Voltage
- Output Swings to Within 15mV of Rails

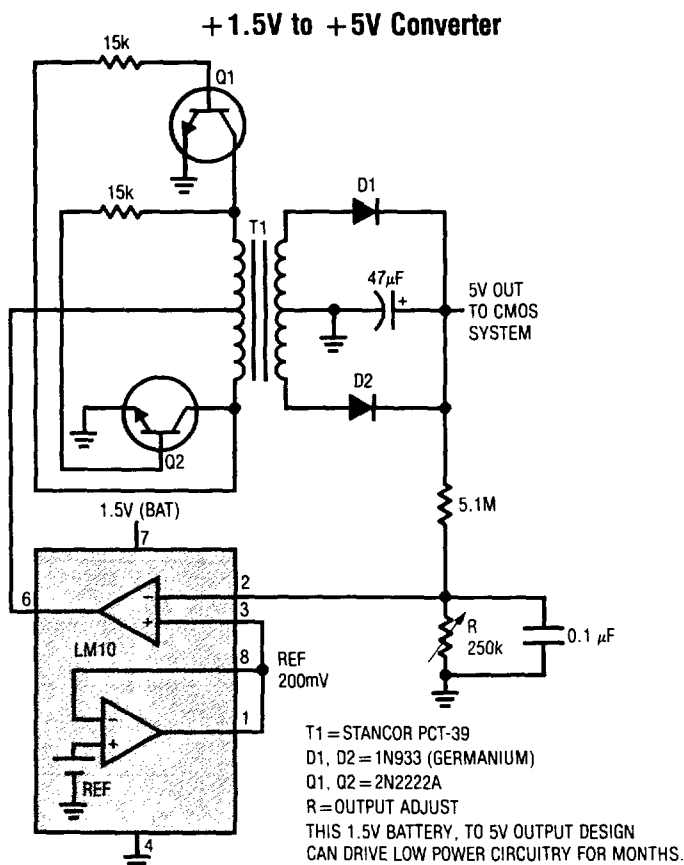
## APPLICATIONS

- Remote Signal Conditioner / Transmitter
- Battery Operated Instruments
- Precision Current Regulators
- Precision Voltage Regulators
- Thermocouple Transmitter

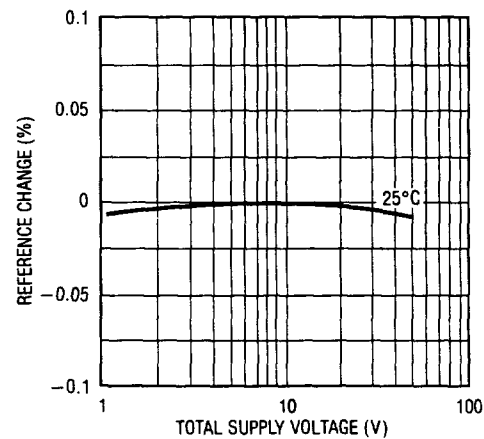
## DESCRIPTION

The LM10 combines a precision reference, a reference buffer amplifier and an independent, high quality op amp on a single chip. The device is capable of operation from a single supply as low as 1.1V, from dual supplies up to  $\pm 20$ V and typically draws 270 $\mu$ A supply current. Input voltage range for the op amp includes ground, while the unloaded output can swing to within 15mV of each rail. Further, the LM10 will deliver 20mA output current and still swing within  $\pm 400$ mV of the supply rails.

With its low operating current and floating operation capability, the LM10 is ideal for two wire analog transmitter circuits where the processed signal is carried on the same line used for power. The LM10 is suggested for portable battery powered equipment and is fully specified for operation from a single 1.2V battery. Other applications include precision current and voltage regulators, operating from very low voltages to several hundred volts.



**Line Regulation**



## ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage  
 LM10/LM10B/LM10C ..... 45V  
 LM10BL/LM10CL ..... 7V

Differential Input Voltage (Note 1)  
 LM10/LM10B/LM10C .....  $\pm 40V$   
 LM10BL/LM10CL .....  $\pm 7V$

Output Short Circuit Duration ..... Indefinite

Operating Temperature Range (Note 2)  
 LM10 .....  $-55^{\circ}C \leq T_A \leq 125^{\circ}C$   
 LM10B/LM10BL .....  $-25^{\circ}C \leq T_A \leq 85^{\circ}C$   
 LM10C/LM10CL .....  $0^{\circ}C \leq T_A \leq 70^{\circ}C$

Storage Temperature Range .....  $-65^{\circ}C \leq T_A \leq 150^{\circ}C$   
 Lead Temperature (Soldering, 10 sec.) .....  $300^{\circ}C$

## PACKAGE/ORDER INFORMATION

TOP VIEW	ORDER PART NUMBER
<p>METAL CAN H PACKAGE</p>	LM10H LM10BH LM10CH LM10BLH LM10CLH
<p>J8 HERMETIC PACKAGE                      N8 PLASTIC DIP PACKAGE</p>	LM10CN8 LM10CLN8 LM10CJ8 LM10CLJ8  LM10J8 LM10BJ8 LM10BLJ8

## OP AMP ELECTRICAL CHARACTERISTICS (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LM10/LM10B			LM10C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage			0.3	2.0		0.5	4.0	mV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Offset Voltage Drift			2.0	3.0		5.0	5.0	$\mu V/^{\circ}C$
$I_{OS}$	Input Offset Current	(Note 4)		0.25	0.7		0.4	2.0	nA
$\frac{\Delta I_{OS}}{\Delta Temp}$	Offset Current Drift			2.0	1.5		5.0	3.0	$\mu A/^{\circ}C$
$I_B$	Input Bias Current			10	20		12	30	nA
$\frac{\Delta I_B}{\Delta Temp}$	Bias Current Drift			60	30		90	40	$\mu A/^{\circ}C$
$A_{VOL}$	Large Signal Voltage Gain	$V_S = \pm 20V, I_{OUT} = 0, V_{OUT} = \pm 19.95V$		120	400		80	400	V/mV
		$V_S = \pm 20V, V_{OUT} = \pm 19.4V$		80			50		V/mV
		$I_{OUT} = \pm 20mA$		50	130		25	130	V/mV
		$I_{OUT} = \pm 15mA$		20			15		V/mV
		$V_S = \pm 0.6V, I_{OUT} = \pm 2mA$		1.5	3.0		1.0	3.0	V/mV
		$V_{OUT} = \pm 0.4V, V_{CM} = -0.4V$							
		$V_S = \pm 0.65V, I_{OUT} = \pm 2mA$		0.5			0.75		V/mV
		$V_{OUT} = \pm 0.3V, V_{CM} = -0.4V$							
	Shunt Gain (Note 5)	$0.1mA \leq I_{OUT} \leq 5mA, R_L = 1.1k\Omega$		14	33		10	33	V/mV
		$1.2V \leq V_{OUT} \leq 40V$		6			6		V/mV
		$1.3V \leq V_{OUT} \leq 40V$							
		$0.1mA \leq I_{OUT} \leq 20mA, R_L = 250\Omega$		8	25		6	25	V/mV
		$1.5V \leq V^+ \leq 40V$		4			4		V/mV

## OP AMP ELECTRICAL CHARACTERISTICS (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LM10/LM10B			LM10C			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
CMRR	Common-Mode Rejection Ratio	$V_S = \pm 20V$ $-20V \leq V_{CM} \leq 19.15V$ $-20V \leq V_{CM} \leq 19V$	93	102		90	102		dB	
			87		●	87			dB	
PSRR	Power Supply Rejection Ratio	$-0.2V \geq V^- \geq -39V$ $V^+ = 1.0V$ $V^+ = 1.1V$	90	96		87	96		dB	
			84		●	84			dB	
		$V^- = -0.2V$ $1.0V \leq V^+ \leq 39.8V$ $1.1V \leq V^+ \leq 39.8V$	96	106		93	106		dB	
			90		●	90		dB		
$R_{IN}$	Input Resistance	(Note 6)	250	500		150	400		k $\Omega$	
			150		●	115			k $\Omega$	
$I_S$	Supply Current			270	400		300	500	$\mu A$	
					●			570	$\mu A$	
$\Delta I_S$	Supply Current Change	$1.2V \leq V_S \leq 40V$ $1.3V \leq V_S \leq 40V$		15	75		15	75		$\mu A$
						●				$\mu A$

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## REFERENCE AMPLIFIER ELECTRICAL CHARACTERISTICS (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LM10/LM10B			LM10C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{REF}$	Feedback Sense Voltage	Voltage at Pin 1 with Pin 1 Connected to Pin 8	195	200	205	190	200	210	mV
			194	200	206	189	200	211	mV
$\frac{\Delta V_{REF}}{\Delta Temp}$	Reference Drift			0.002			0.003	% / $^{\circ}C$	
	Feedback Current	Current into Pin 8		20	50		22	75	nA
					65			90	nA
	Line Regulation	$0 \leq I_{REF} \leq 1mA$ , $V_{REF} = 200mV$ $1.2V \leq V_S \leq 40V$ $1.3V \leq V_S \leq 40V$		0.001	0.003		0.001	0.008	% / V
				0.001	0.006		0.001	0.01	% / V
	Load Regulation	$0 \leq I_{REF} \leq 1mA$ $V^+ - V_{REF} \geq 1.0V$ $V^+ - V_{REF} \geq 1.1V$		0.01	0.1		0.01	0.15	%
				0.01	0.15		0.01	0.20	%
	Reference Amplifier Gain	$0.2V \leq V_{REF} \leq 35V$	50	75		25	70		V/mV
			23		●	15			V/mV

## OP AMP ELECTRICAL CHARACTERISTICS (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LM10BL			LM10CL			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage			0.3	2.0		0.5	4.0	mV mV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Offset Voltage Drift			2.0			5.0		$\mu V/^{\circ}C$
$I_{OS}$	Input Offset Current	(Note 4)		0.1	0.7		0.2	2.0	nA nA
$\frac{\Delta I_{OS}}{\Delta Temp}$	Offset Current Drift			2.0			5.0		$\mu A/^{\circ}C$
$I_B$	Input Bias Current			10	20		12	30	nA nA
$\frac{\Delta I_B}{\Delta Temp}$	Bias Current Drift			60			90		$\mu A/^{\circ}C$
$A_{VOL}$	Large Signal Voltage Gain	$V_S = \pm 3.25V, I_{OUT} = 0, V_{OUT} = \pm 3.2V$		60	300		40	300	V/mV V/mV
		$V_S = \pm 3.25V, V_{OUT} = \pm 2.75V$ $I_{OUT} = \pm 10mA$		10	25		5	25	V/mV V/mV
		$I_{OUT} = \pm 2mA, V_{CM} = -0.4V$ $V_S = \pm 0.6V, V_{OUT} = \pm 0.4V$ $V_S = \pm 0.65V, V_{OUT} = \pm 0.3V$		1.5	3.0		1.0	3.0	V/mV V/mV
	Shunt Gain (Note 5)	$0.1mA \leq I_{OUT} \leq 10mA, R_L = 500\Omega$ $1.5V \leq V^+ \leq 6.5V$		8	30		6	30	V/mV V/mV
CMRR	Common-Mode Rejection Ratio	$V_S = \pm 3.25V$ $-3.25V \leq V_{CM} \leq 2.4V$ $-3.25V \leq V_{CM} \leq 2.25V$		89	102		80	102	dB dB
				83			74		
PSRR	Power Supply Rejection Ratio	$-0.2V \geq V^- \geq -5.4V$ $V^+ = 1.0V$ $V^+ = 1.2V$		86	96		80	96	dB dB
				80			74		
PSRR		$V^- = -0.2V$ $1.0V \leq V^+ \leq 6.3V$ $1.1V \leq V^+ \leq 6.3V$		94	106		80	106	dB dB
				88			74		
$R_{IN}$	Input Resistance	(Note 6)		250	500		150	400	k $\Omega$ k $\Omega$
					150			115	
$I_S$	Supply Current			260	400		280	500	$\mu A$ $\mu A$
					500			570	

## REFERENCE AMPLIFIER ELECTRICAL CHARACTERISTICS (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LM10BL			LM10CL			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{REF}$	Feedback Sense Voltage	Voltage at Pin 1 with Pin 1 Connected to Pin 8	●	195	200	205	190	200	210	mV
			●	194	200	206	189	200	211	mV
$\frac{\Delta V_{REF}}{\Delta Temp}$	Reference Drift		●	0.002			0.003			%/°C
	Feedback Current	Current into Pin 8	●	20	50	65	22	75	90	nA nA
	Line Regulation	$0 \leq I_{REF} \leq 0.5mA$ , $V_{REF} = 200mV$ $1.2V \leq V_S \leq 6.5V$ $1.3V \leq V_S \leq 6.5V$	●	0.001	0.01		0.001	0.02		%/V %/V
	Load Regulation	$0 \leq I_{REF} \leq 0.5mA$ $V^+ - V_{REF} \geq 1.0V$ $V^+ - V_{REF} \geq 1.1V$	●	0.01	0.1		0.01	0.15		% %
	Reference Amplifier Gain	$0.2V \leq V_{REF} \leq 5.5V$	●	30	70		20	70		V/mV V/mV

The ● denotes the specifications which apply over full operating temperature range.

**Note 1:** The input voltage can exceed the supply voltages as long as the voltage from the input to any other terminal does not exceed the maximum differential voltage, and the maximum junction temperature is not exceeded due to the excess power dissipation that occurs when the input voltage is less than the negative supply voltage.

**Note 2:** The maximum operating junction temperatures are: 150°C for the LM10; 100°C for the LM10B and LM10BL; and 85°C for the LM10C and LM10CL. Package derating factors will be found on the back page of this data sheet.

**Note 3:** These specifications apply for the following conditions unless otherwise noted:

at 25°C

$$(a) V^- \leq V_{CM} \leq V^+ - 0.85V$$

$$(b) 1.2V \leq V_S \leq V_{MAX}$$

over temperature

$$V^- \leq V_{CM} \leq V^+ - 1.0V$$

$$1.3V \leq V_S \leq V_{MAX}$$

$V_{REF} = 0.2V$  and  $0 \leq I_{REF} \leq 1.0mA$  where  $V_{MAX} = 40V$  for the LM10, LM10B and LM10C and  $V_{MAX} = 6.5V$  for the LM10BL and LM10CL. The specifications do not include errors due to thermal gradients ( $\tau_1 \approx 20ms$ ), die heating ( $\tau_2 \approx 0.2$  sec) or package heating.

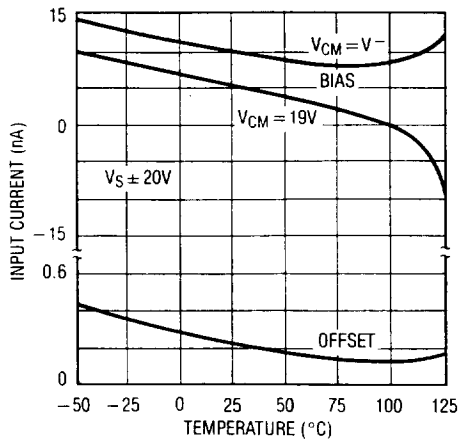
**Note 4:** For  $T_J > 90^\circ C$ ,  $I_{OS}$  may exceed 1.5nA when  $V_{CM} = V^-$ . When the common-mode input voltage is within 100mV of the negative supply and  $T_J = 125^\circ C$ , the offset current will be less than 5nA.

**Note 5:** Shunt gain defines the operation in floating applications when the output is connected to the  $V^+$  terminal and input common-mode is referred to  $V^-$  (see typical applications). The effects of larger output voltage swing with higher load resistance can be accounted for by adding the positive supply rejection error.

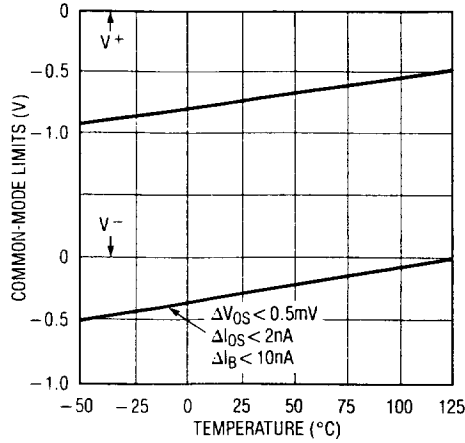
**Note 6:** Guaranteed by design.

# TYPICAL PERFORMANCE CHARACTERISTICS (Op Amp)

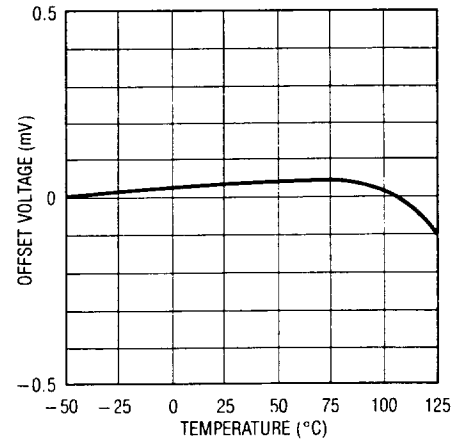
**Input Current**



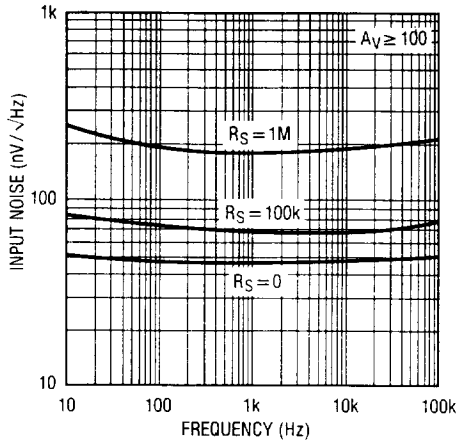
**Common-Mode Limits**



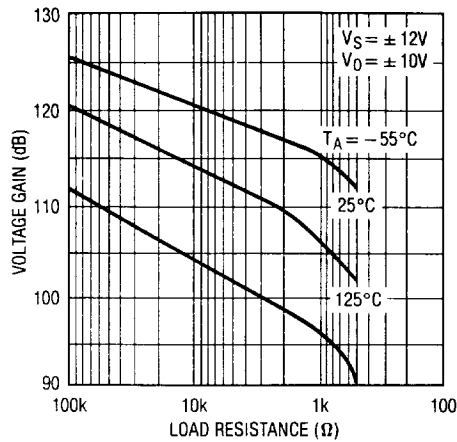
**Offset Voltage Drift**



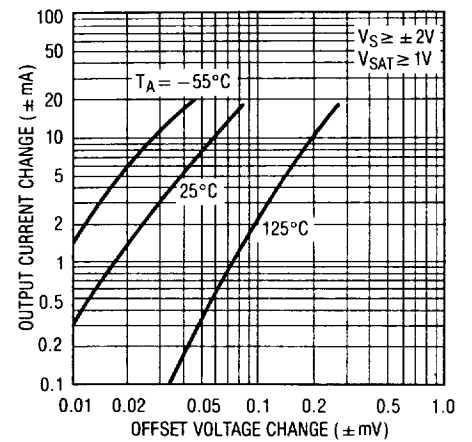
**Input Noise Voltage**



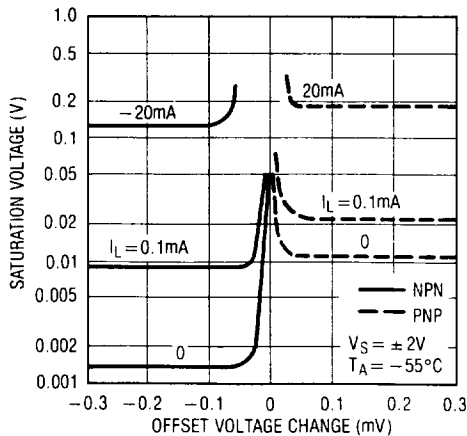
**DC Voltage Gain**



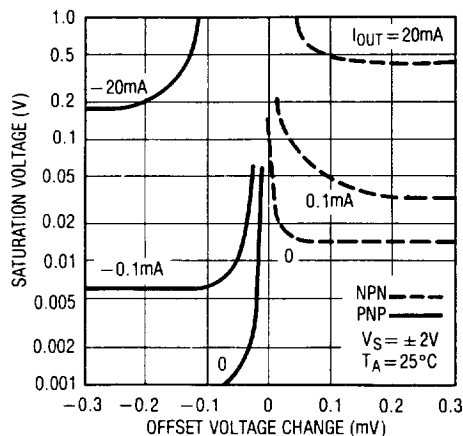
**Transconductance**



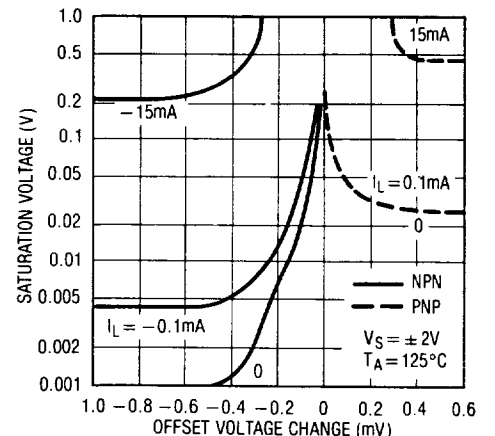
**Output Saturation Characteristics**



**Output Saturation Characteristics**

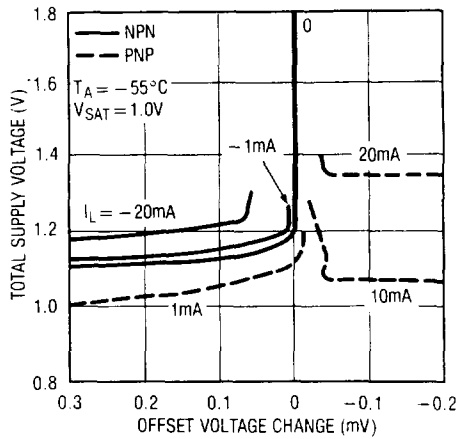


**Output Saturation Characteristics**

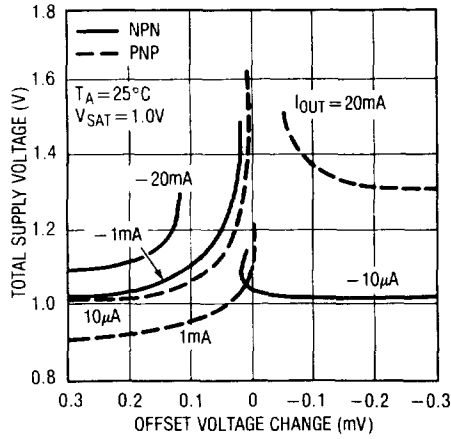


# TYPICAL PERFORMANCE CHARACTERISTICS (Op Amp)

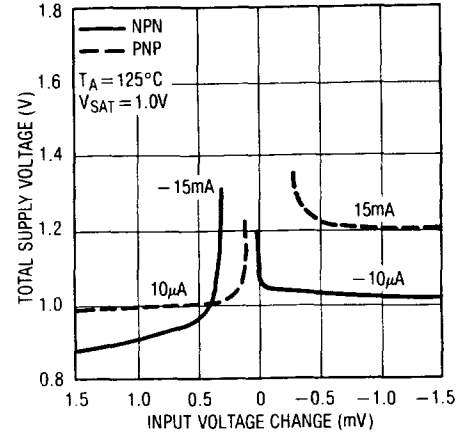
Minimum Supply Voltage



Minimum Supply Voltage

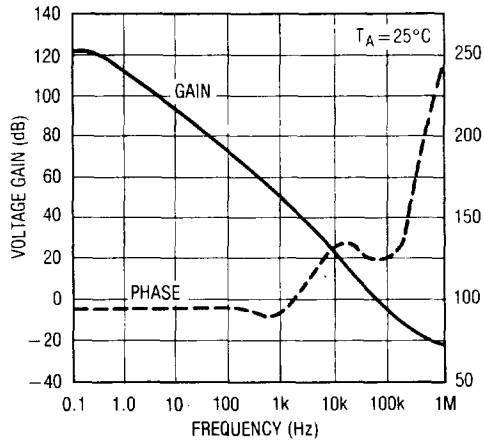


Minimum Supply Voltage

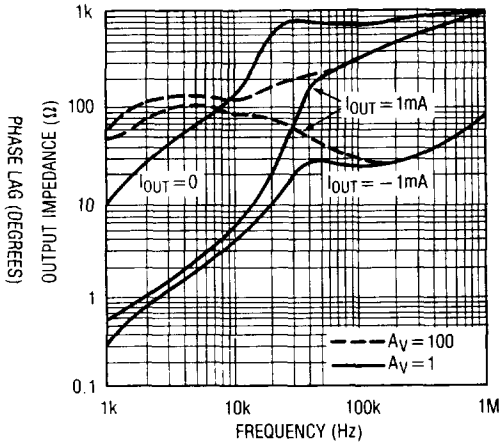


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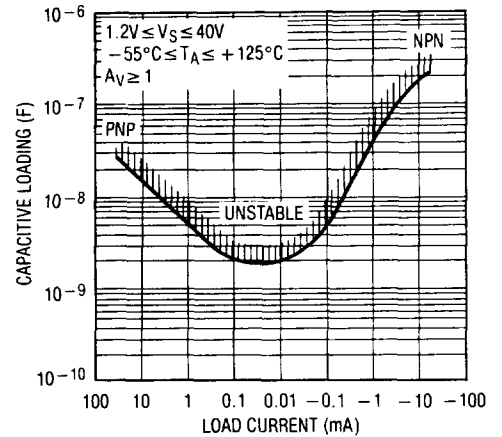
Frequency Response



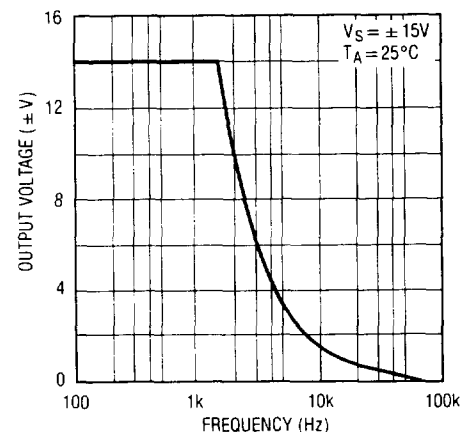
Output Impedance



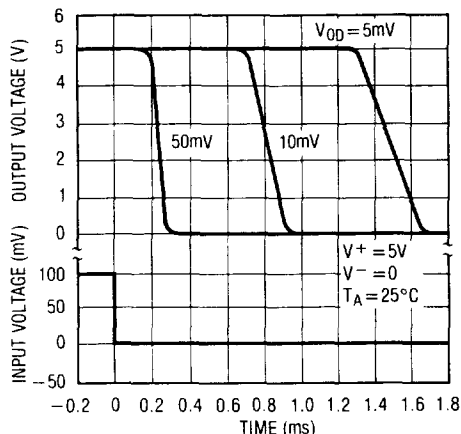
Typical Stability Range



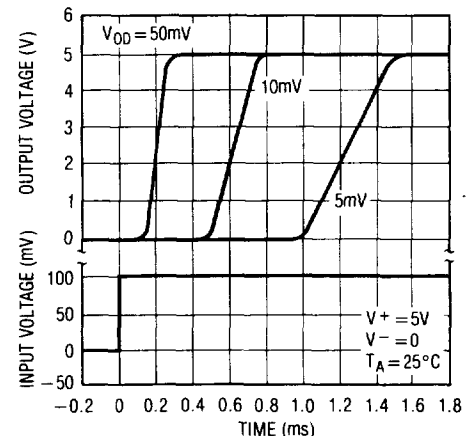
Large Signal Response



Comparator Response Time for Various Input Overdrives

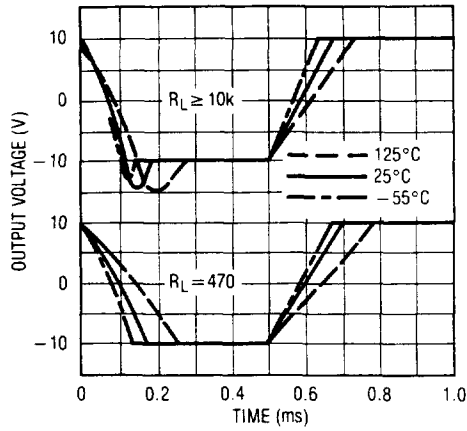


Comparator Response Time for Various Input Overdrives

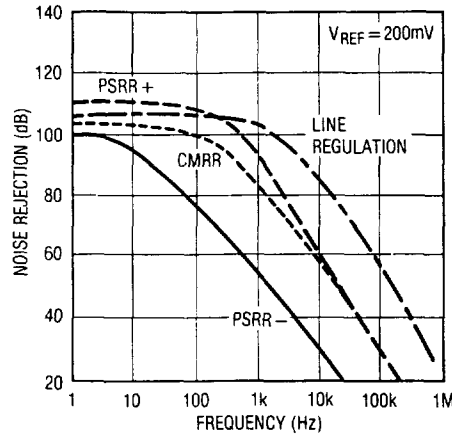


# TYPICAL PERFORMANCE CHARACTERISTICS

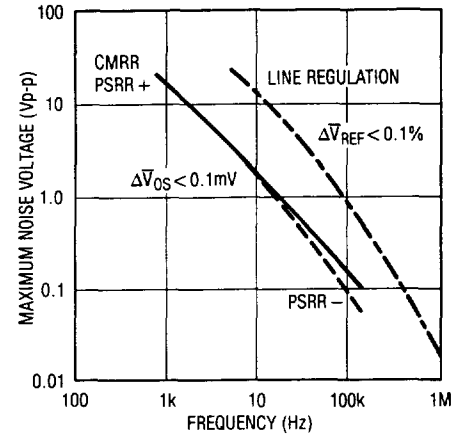
**Follower Pulse Response**



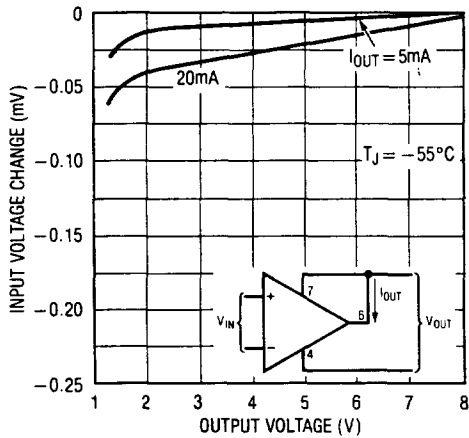
**Noise Rejection**



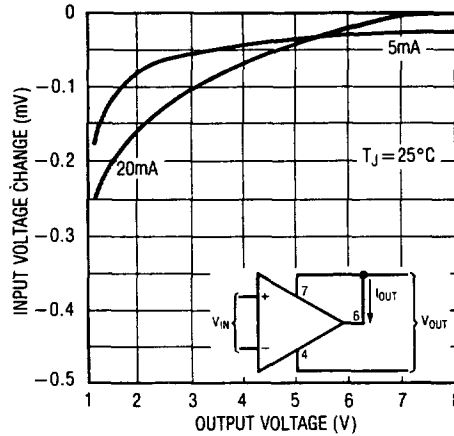
**Rejection Slew Limiting**



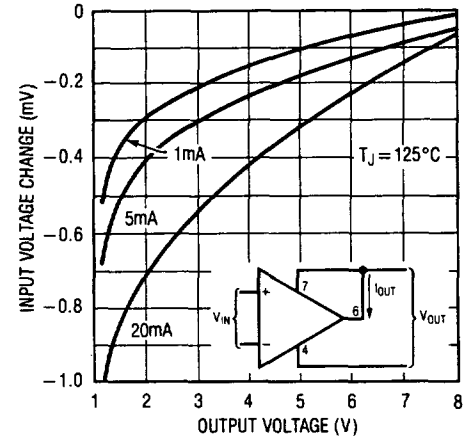
**Shunt Gain**



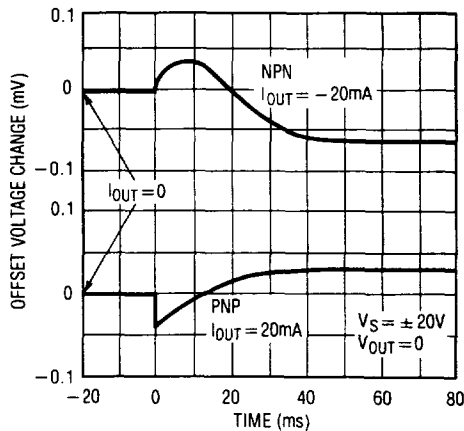
**Shunt Gain**



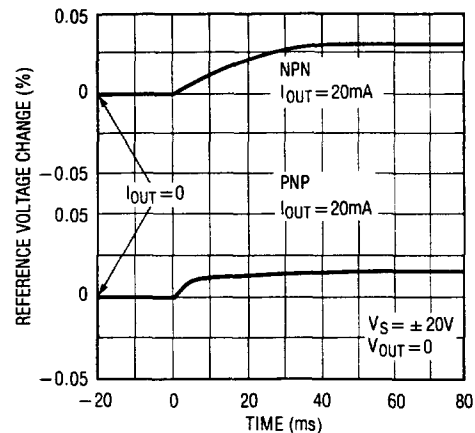
**Shunt Gain**



**Thermal Gradient Feedback**



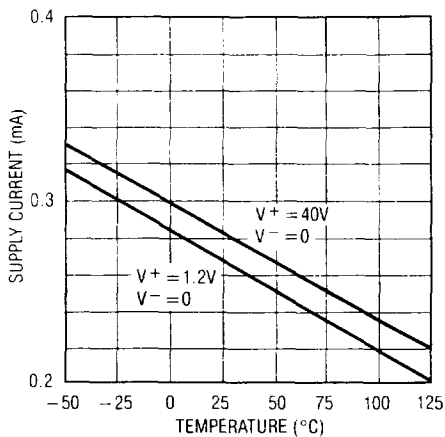
**Change in Reference Op Amp Loading**



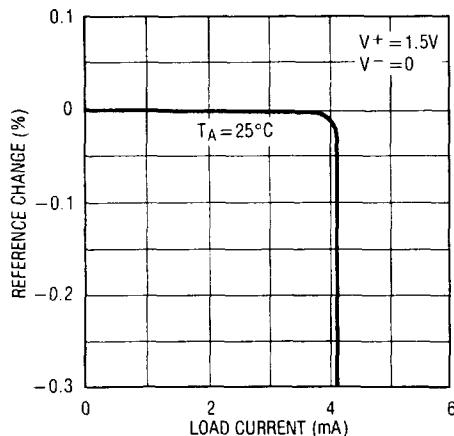


# TYPICAL PERFORMANCE CHARACTERISTICS (Reference)

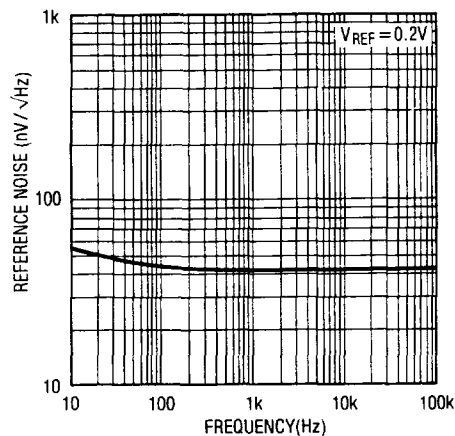
Supply Current



Load Regulation

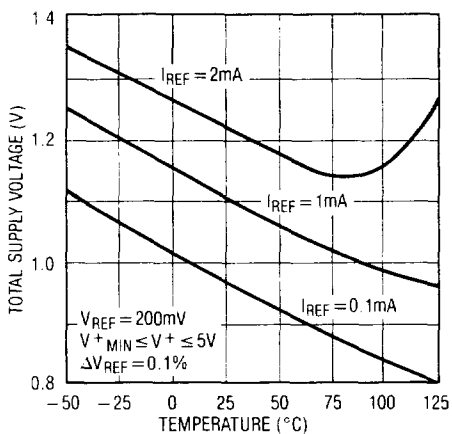


Reference Noise Voltage

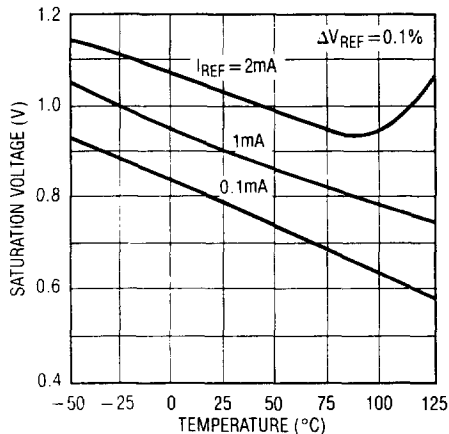


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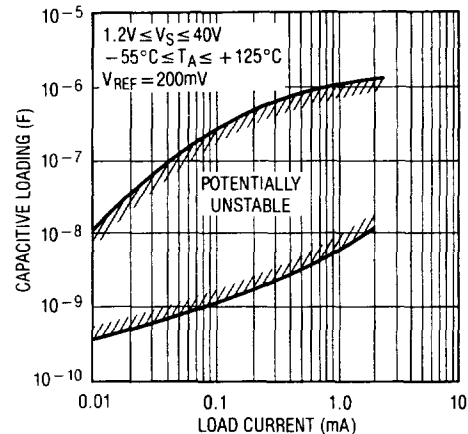
Minimum Supply Voltage



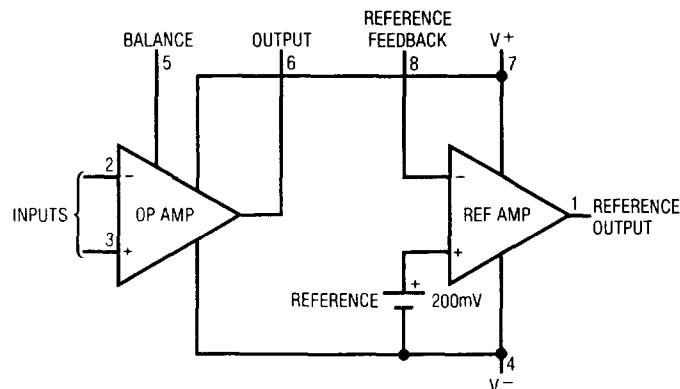
Output Saturation



Typical Stability Range



## BLOCK DIAGRAM



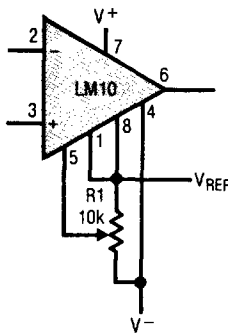
## APPLICATION HINTS

With heavy amplifier loading to  $V^-$ , resistance drops in the  $V^-$  lead can adversely affect reference regulation.

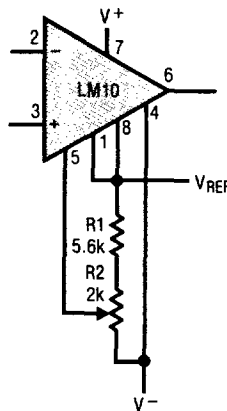
Lead resistance can approach  $1\Omega$ . Therefore, the common to the reference circuitry should be connected as close as possible to the package.

## TYPICAL APPLICATIONS

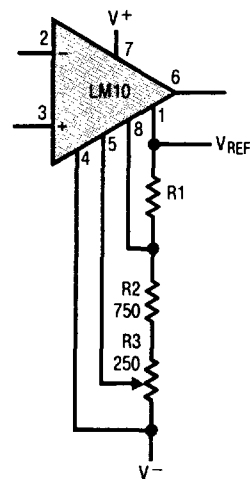
**Standard Offset Adjustment**



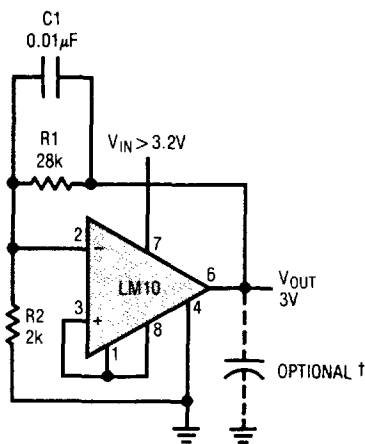
**Limited Range Offset Adjustment**



**Limited Range Offset Adjustment with Boosted Reference**

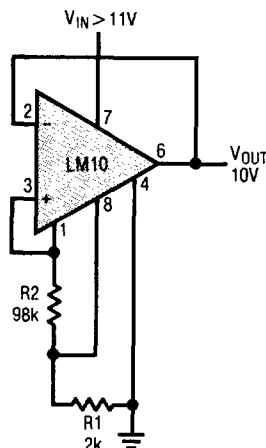


**Low Voltage Regulator**

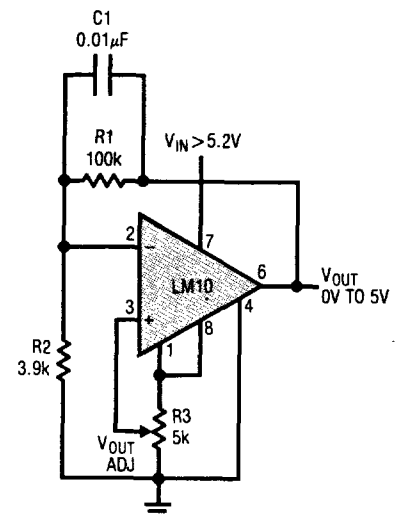


† USE ELECTROLYTIC OUTPUT CAPACITORS

**Best Regulation**

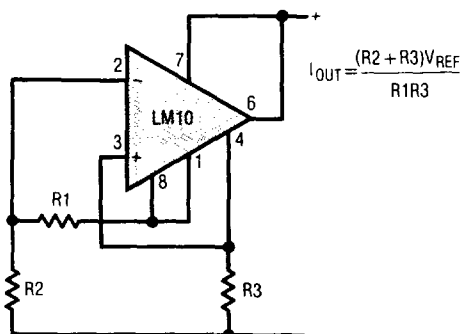


**0V to 5V Regulator**

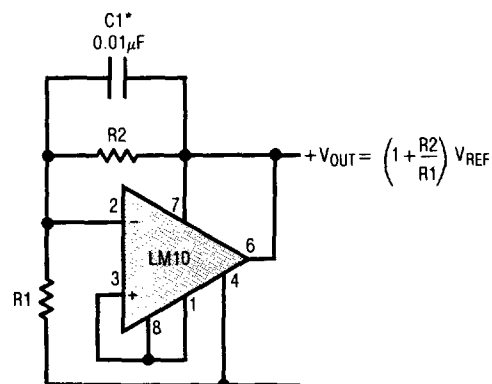


# TYPICAL APPLICATIONS

Two-Terminal Current Regulator



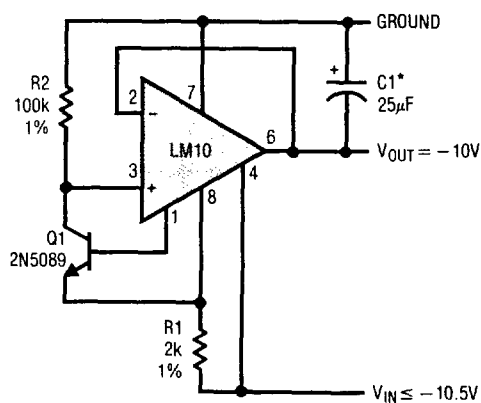
Shunt Regulator



\*REQUIRED FOR CAPACITIVE LOADING

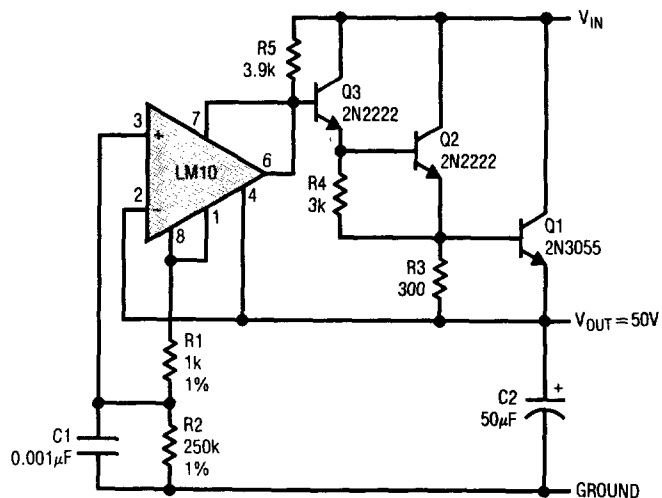
2

Negative Regulator



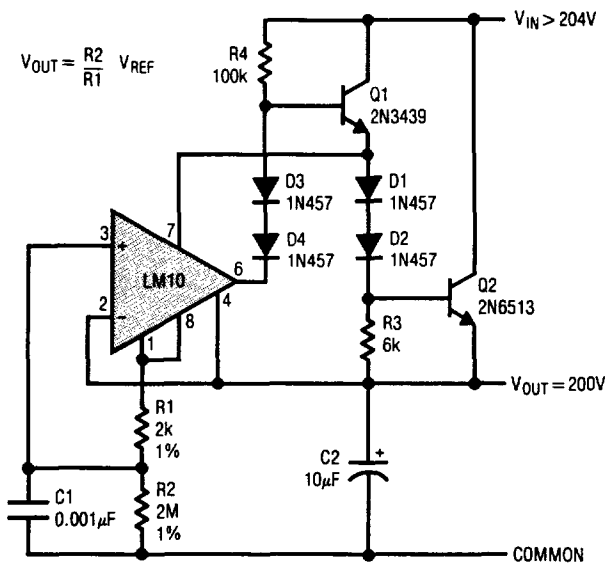
\*ELECTROLYTIC

Floating Regulator

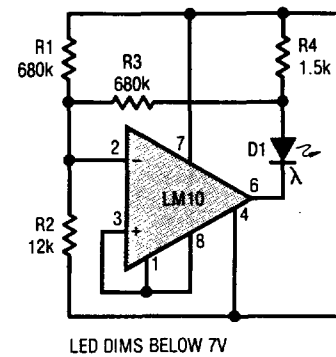


## TYPICAL APPLICATIONS

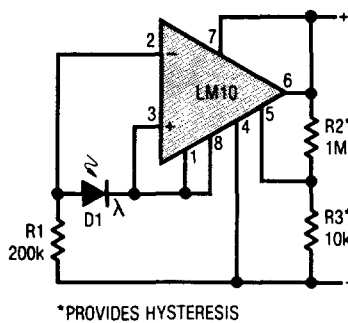
### High Voltage Regulator



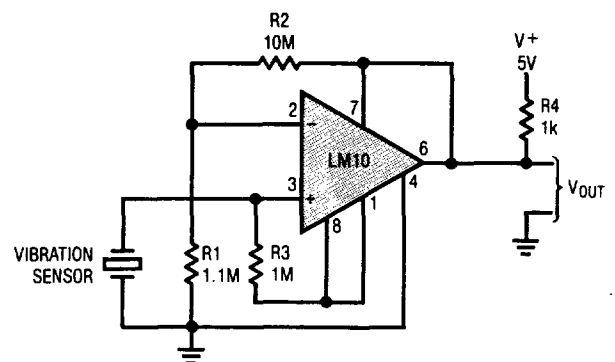
### 6V Battery-Level Indicator



### Light Level Sensor

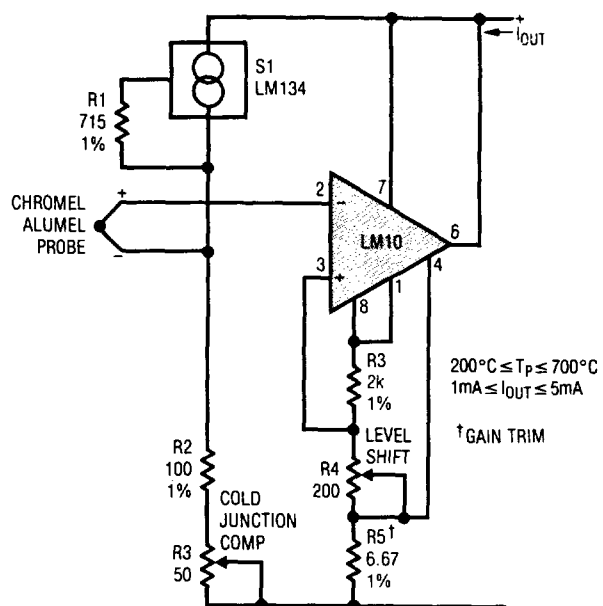


### Transducer Amplifier

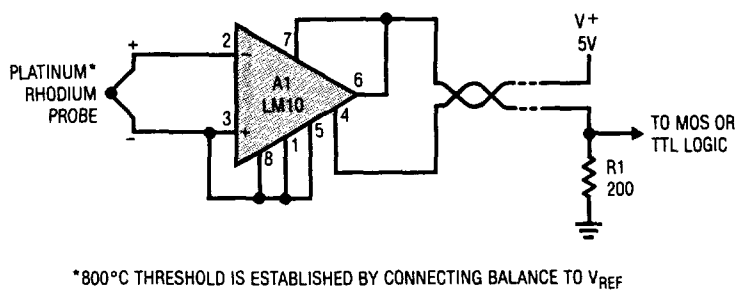


# TYPICAL APPLICATIONS

**Thermocouple Transmitter**

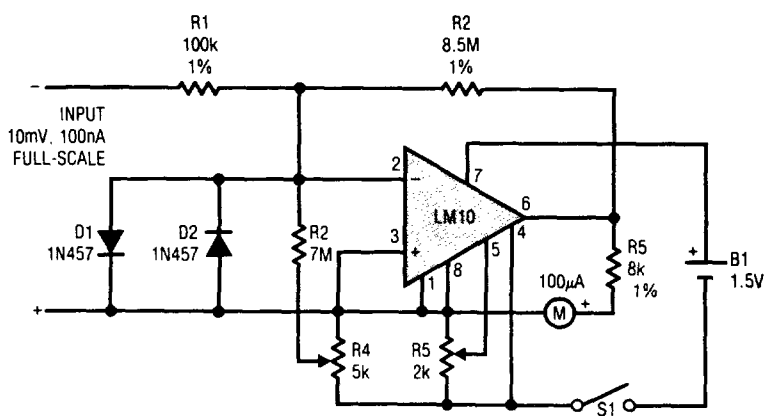


**Flame Detector**

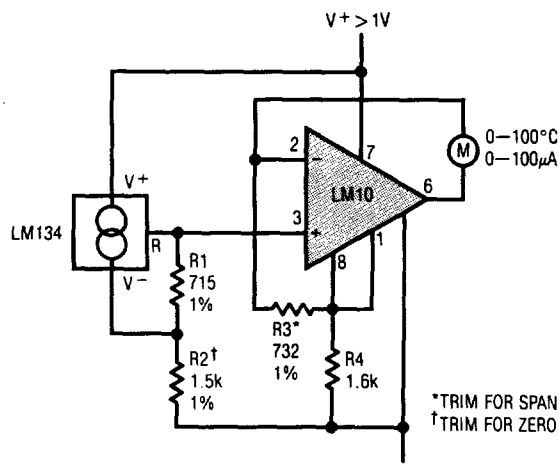


**2**

**Meter Amplifier**

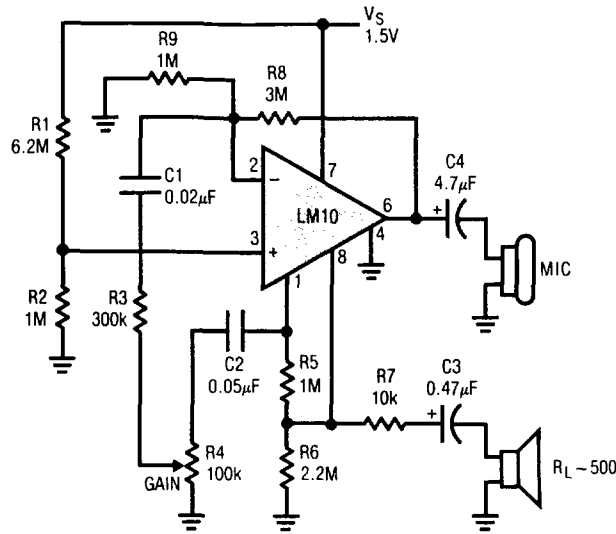


**Thermometer**

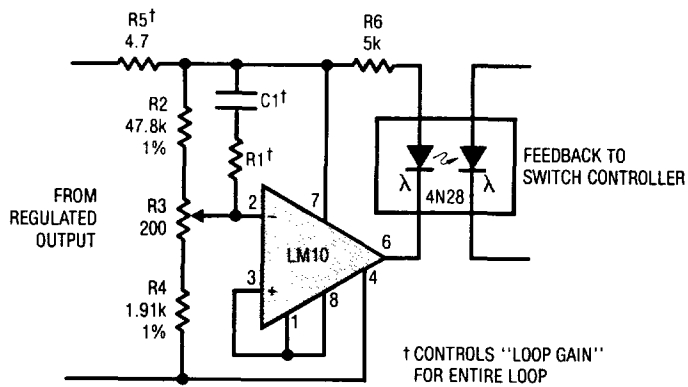


**TYPICAL APPLICATIONS**

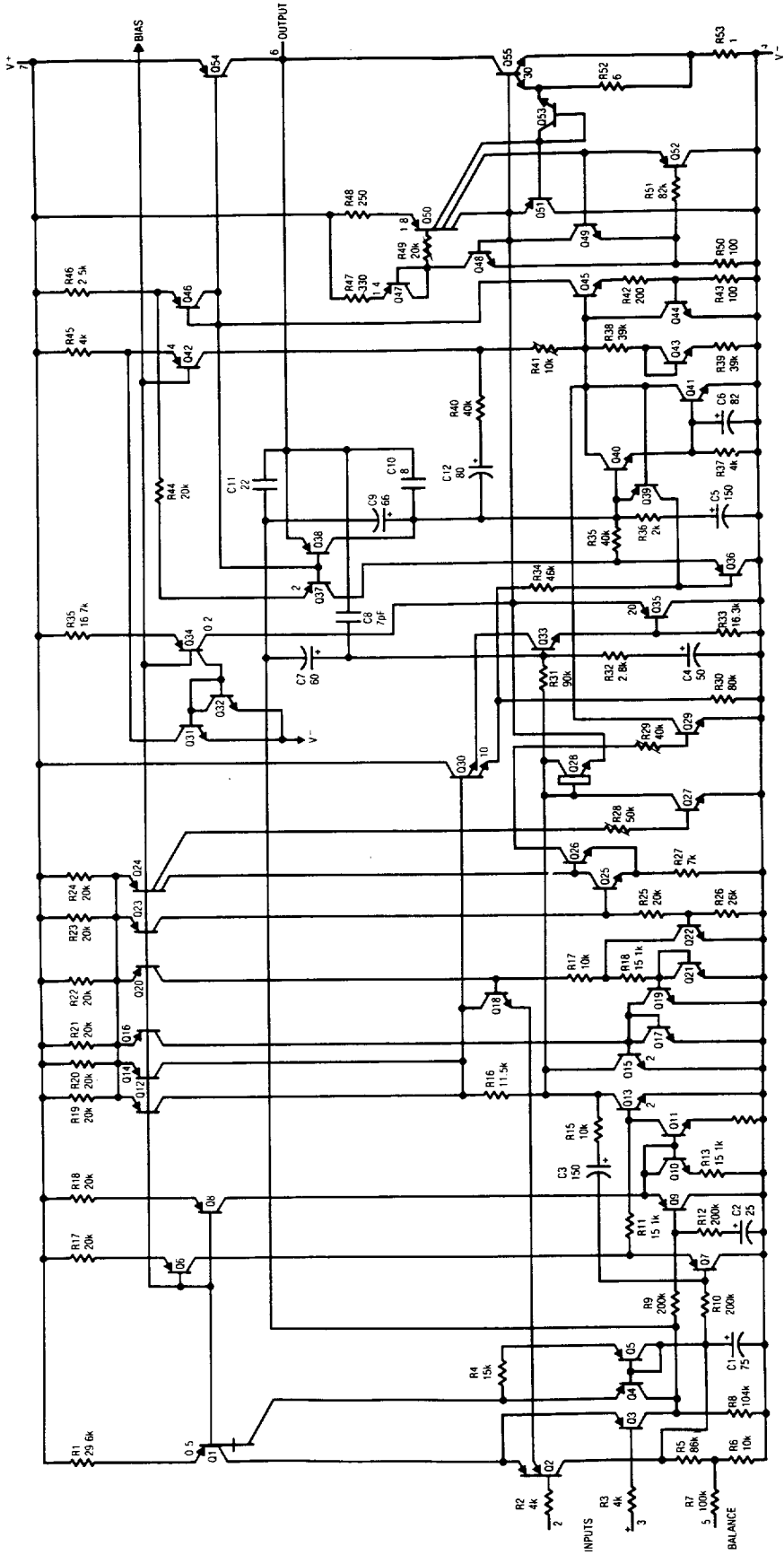
**Microphone Amplifier**  
 $A_v \approx 1k$



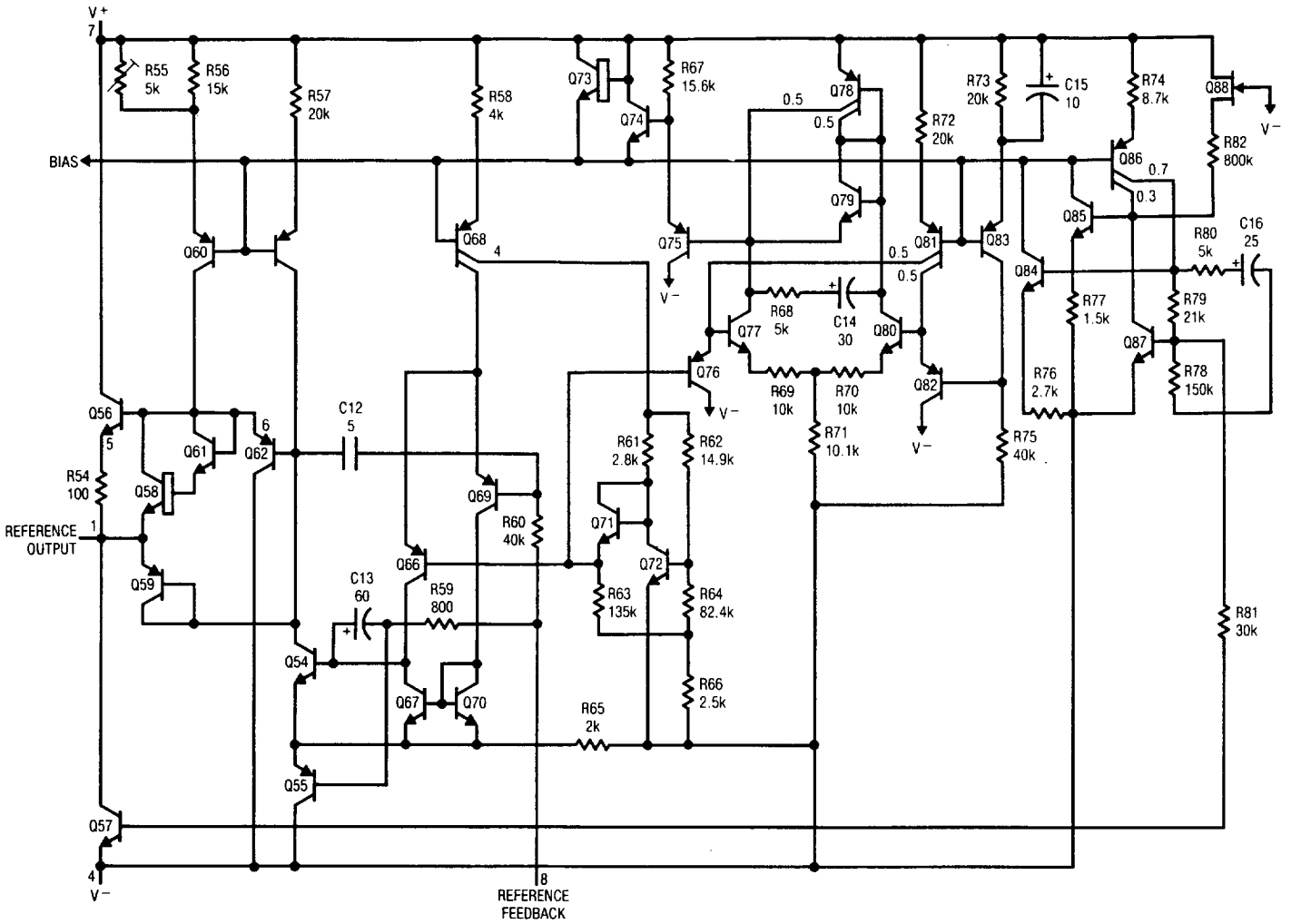
**Isolated Voltage Sensor**  
**for Switching Regulators**



# OP AMP SCHEMATIC DIAGRAM

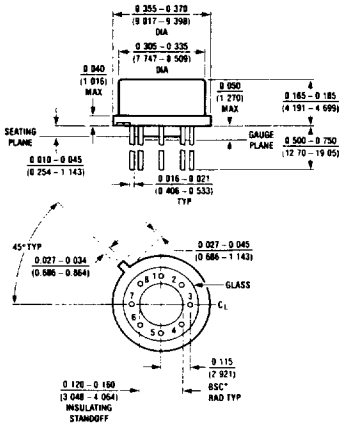


# REFERENCE AND INTERNAL REGULATOR SCHEMATIC DIAGRAM



## PACKAGE DESCRIPTION

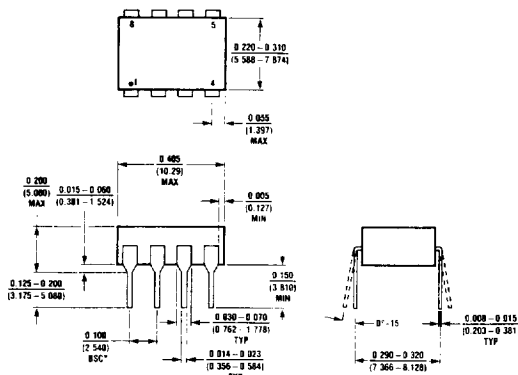
**H Package**  
Metal Can



NOTE DIMENSIONS IN INCHES

$T_{jmax}$	$\theta_{ja}$	$\theta_{jc}$
150°C	150°C/W	45°C/W

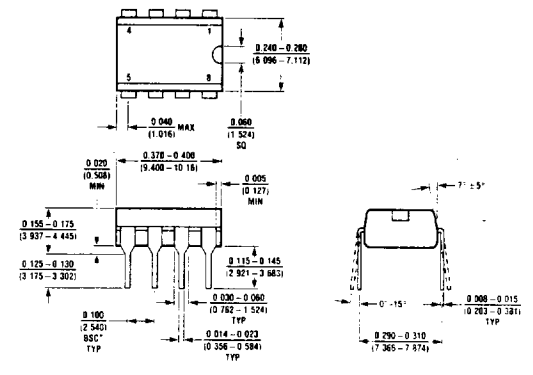
**J8 Package**  
8 Lead Hermetic Dip



NOTE DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED  
\*LEADS WITHIN 0.007 OF TRUE POSITION (TP) AT GAUGE PLANE

$T_{jmax}$	$\theta_{ja}$
150°C	100°C/W

**N8 Package**  
8 Lead Plastic



NOTE DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED  
\*LEADS WITHIN 0.007 OF TRUE POSITION (TP) AT GAUGE PLANE

$T_{jmax}$	$\theta_{ja}$
100°C	130°C/W