

FEATURES

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

APPLICATIONS

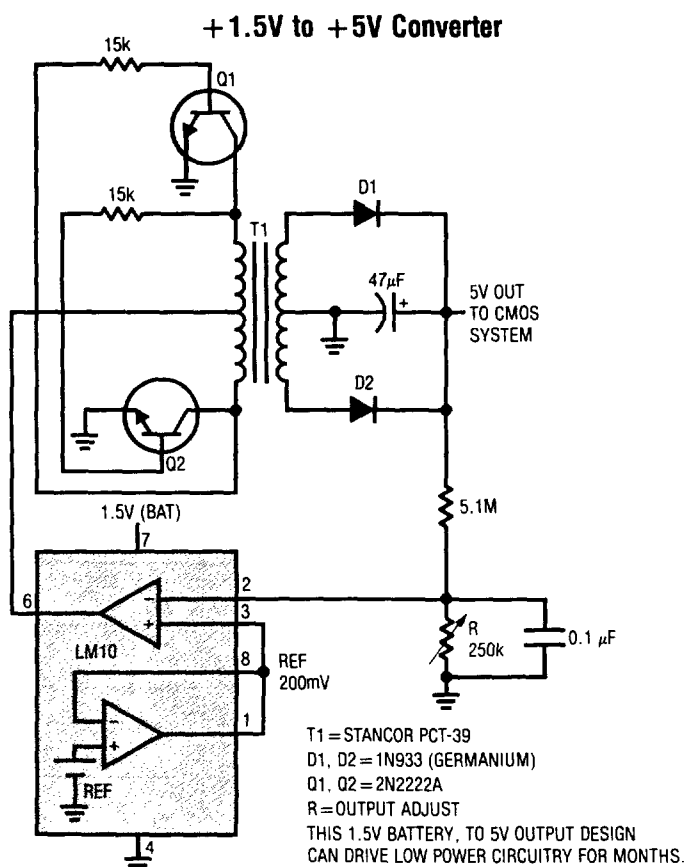
- Remote Signal Conditioner / Transmitter
- Battery Operated Instruments
- Precision Current Regulators
- Precision Voltage Regulators
- Thermocouple Transmitter

DESCRIPTION

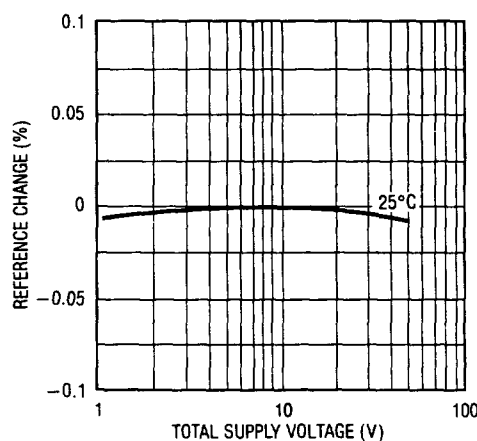
The LM10 combines a precision reference, a reference buffer amplifier and an independent, high quality op amp on a single chip. The device is capable of operation from a single supply as low as 1.1V, from dual supplies up to ± 20 V and typically draws 270 μ A supply current. Input voltage range for the 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 ± 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.

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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°C	

PACKAGE/ORDER INFORMATION

TOP VIEW REFERENCE FEEDBACK REFERENCE OUTPUT OP AMP INPUTS V ⁺ OP AMP OUTPUT BALANCE V ⁻ METAL CAN H PACKAGE	ORDER PART NUMBER
	LM10H LM10BH LM10CH LM10BLH LM10CLH
TOP VIEW REFERENCE OUTPUT OP AMP INPUT (-) OP AMP INPUT (+) V ⁻ REFERENCE FEEDBACK V ⁺ OP AMP OUTPUT BALANCE J8 HERMETIC PACKAGE N8 PLASTIC DIP PACKAGE	ORDER PART NUMBER
	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			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			5.0			$pA/^{\circ}C$
I_B	Input Bias Current		●	10	20		12	30		nA
$\frac{\Delta I_B}{\Delta Temp}$	Bias Current Drift		●	60			90			$pA/^{\circ}C$
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
		$V_S = \pm 0.6V, I_{OUT} = \pm 2mA$								
		$V_{OUT} = \pm 0.4V, V_{CM} = -0.4V$		1.5	3.0		1.0	3.0		V/mV
		$V_S = \pm 0.65V, I_{OUT} = \pm 2mA$	●	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 Ω
			●	150			115			k Ω
I_S	Supply Current				270	400		300	500	μA
			●			500			570	μA
ΔI_S	Supply Current Change	$1.2V \leq V_S \leq 40V$ $1.3V \leq V_S \leq 40V$			15	75		15	75	μA
			●			75			75	μA

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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		% / °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 3.0		0.5	4.0 5.0	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 1.5		0.2	2.0 3.0	nA nA
$\frac{\Delta I_{OS}}{\Delta Temp}$	Offset Current Drift		●		2.0			5.0		$pA/^{\circ}C$
I_B	Input Bias Current		●		10	20 30		12	30 40	nA nA
$\frac{\Delta I_B}{\Delta Temp}$	Bias Current Drift		●		60			90		$pA/^{\circ}C$
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm 3.25V, I_{OUT} = 0, V_{OUT} = \pm 3.2V$	●	60 40	300		40 25	300		V/mV V/mV
		$V_S = \pm 3.25V, V_{OUT} = \pm 2.75V$ $I_{OUT} = \pm 10mA$	●	10 4	25		5 3	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 0.5	3.0		1.0 0.75	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 4	30		6 4	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 83	102		80 74	102		dB dB
PSRR	Power Supply Rejection Ratio	$-0.2V \geq V^- \geq -5.4V$ $V^+ = 1.0V$ $V^+ = 1.2V$	●	86 80	96		80 74	96		dB dB
PSRR		$V^- = -0.2V$ $1.0V \leq V^+ \leq 6.3V$ $1.1V \leq V^+ \leq 6.3V$	●	94 88	106		80 74	106		dB dB
R_{IN}	Input Resistance	(Note 6)	●	250 150	500		150 115	400		k Ω k Ω
I_S	Supply Current		●		260	400 500		280	500 570	μA μA

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			22			nA
			●	50			75			nA
			●	65			90			nA
	Line Regulation	$0 \leq I_{REF} \leq 0.5\text{mA}$, $V_{REF} = 200\text{mV}$ $1.2\text{V} \leq V_S \leq 6.5\text{V}$ $1.3\text{V} \leq V_S \leq 6.5\text{V}$	●	0.001			0.001			%/V
			●	0.01			0.02			%/V
			●	0.001			0.03			%/V
	Load Regulation	$0 \leq I_{REF} \leq 0.5\text{mA}$ $V^+ - V_{REF} \geq 1.0\text{V}$ $V^+ - V_{REF} \geq 1.1\text{V}$	●	0.01			0.01			%
			●	0.1			0.15			%
			●	0.01			0.20			%
	Reference Amplifier Gain	$0.2\text{V} \leq V_{REF} \leq 5.5\text{V}$	●	30	70		20	70		V/mV
			●	20			15			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

over temperature

$$(a) V^- \leq V_{CM} \leq V^+ - 0.85\text{V} \quad V^- \leq V_{CM} \leq V^+ - 1.0\text{V}$$

$$(b) 1.2\text{V} \leq V_S \leq V_{MAX} \quad 1.3\text{V} \leq V_S \leq V_{MAX}$$

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

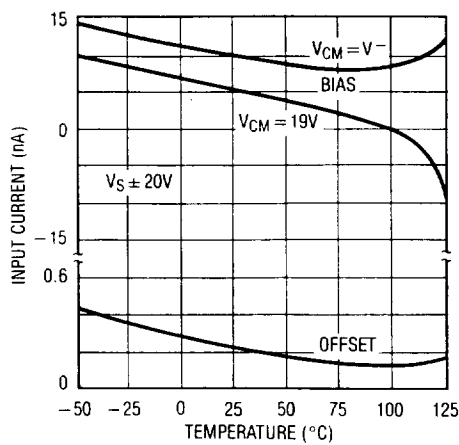
Note 4: For $T_J > 90^\circ\text{C}$, I_{OS} may exceed 1.5nA when $V_{CM} = V^-$. When the common-mode input voltage is within 100mV of the negative supply and $T_J = 125^\circ\text{C}$, the offset current will be less than 5nA.

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.

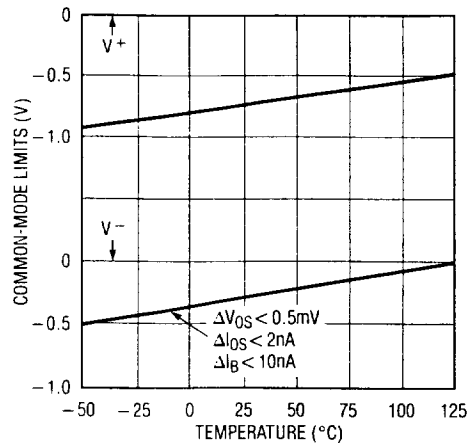
Note 6: Guaranteed by design.

TYPICAL PERFORMANCE CHARACTERISTICS (Op Amp)

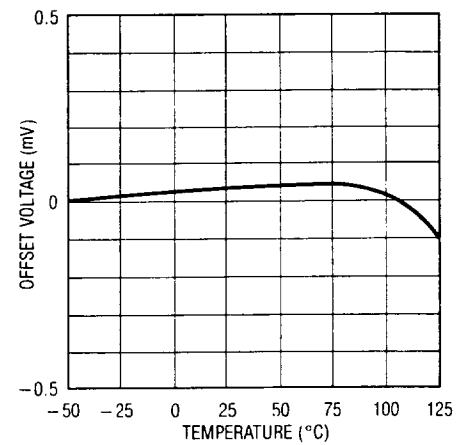
Input Current



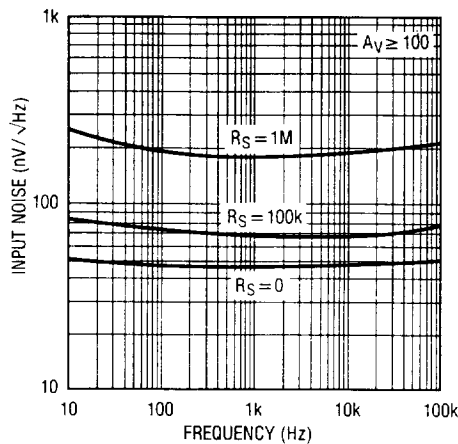
Common-Mode Limits



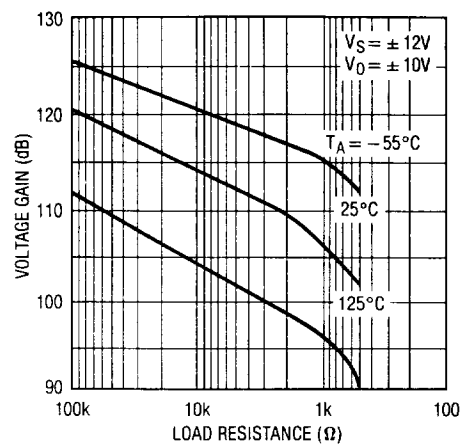
Offset Voltage Drift



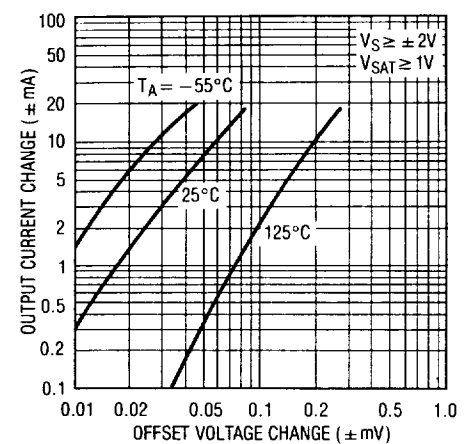
Input Noise Voltage



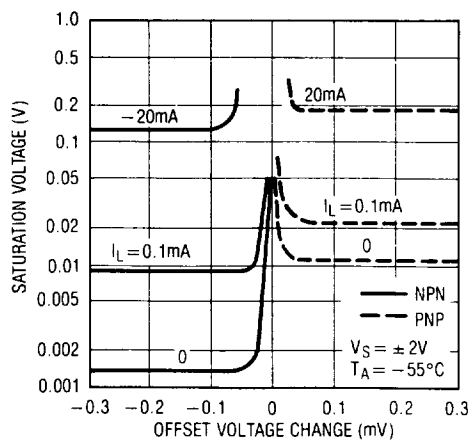
DC Voltage Gain



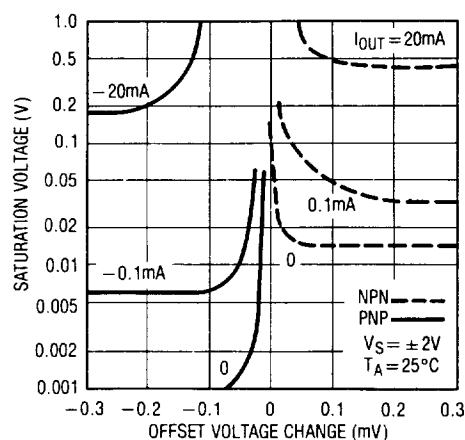
Transconductance



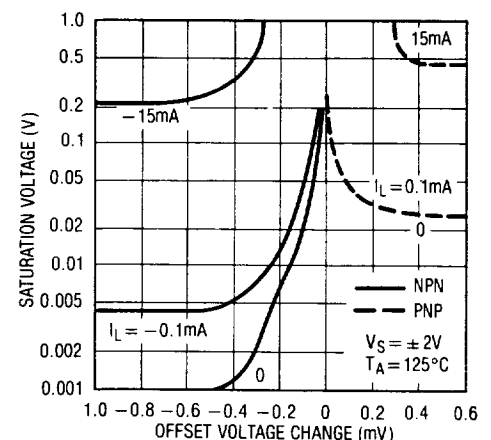
Output Saturation Characteristics



Output Saturation Characteristics

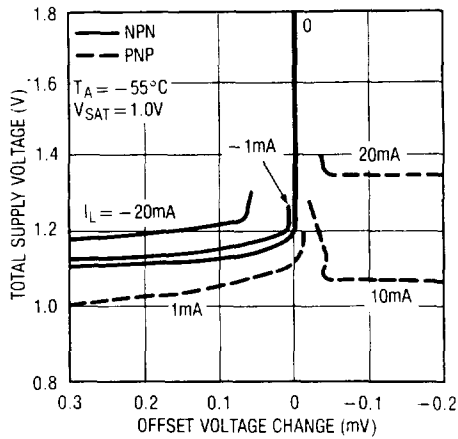


Output Saturation Characteristics

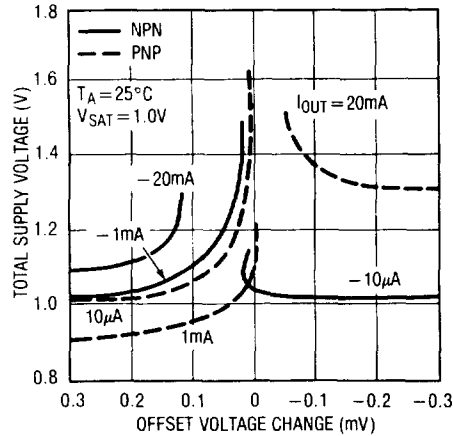


TYPICAL PERFORMANCE CHARACTERISTICS (Op Amp)

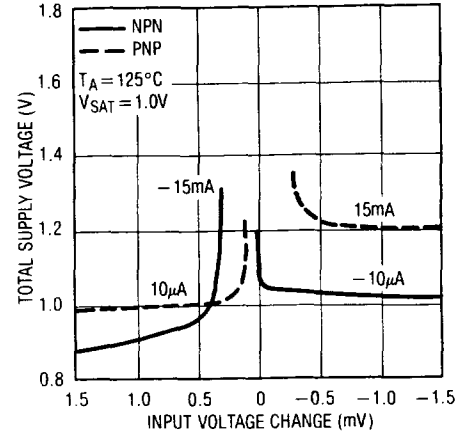
Minimum Supply Voltage



Minimum Supply Voltage

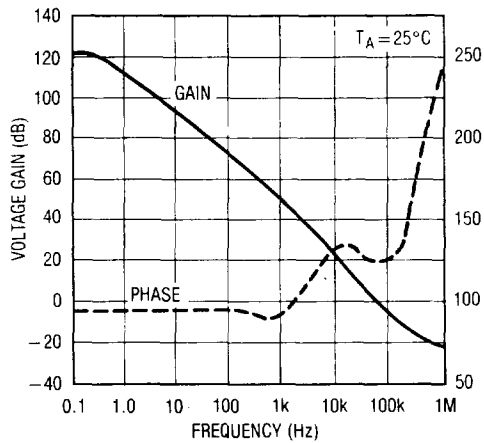


Minimum Supply Voltage

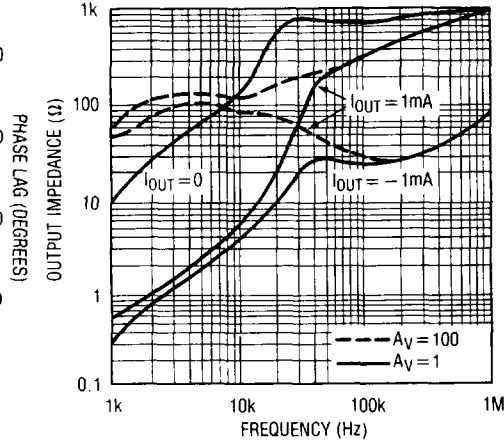


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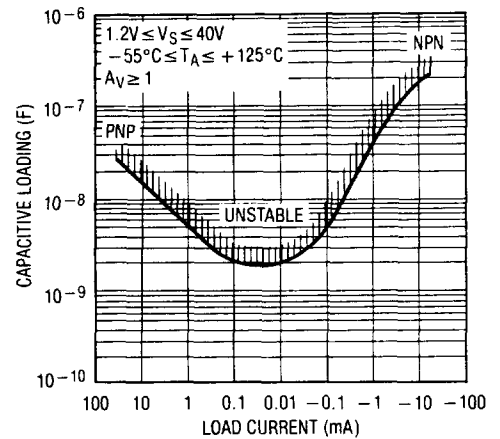
Frequency Response



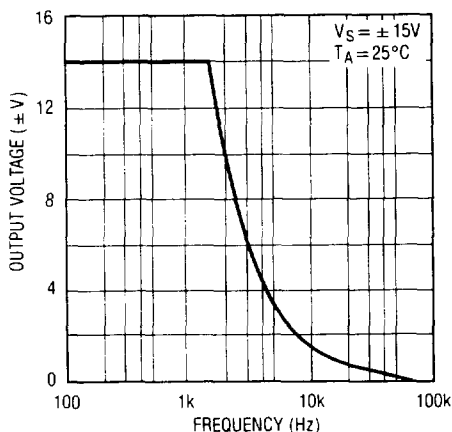
Output Impedance



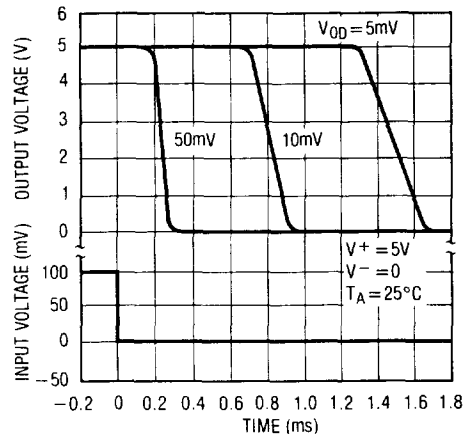
Typical Stability Range



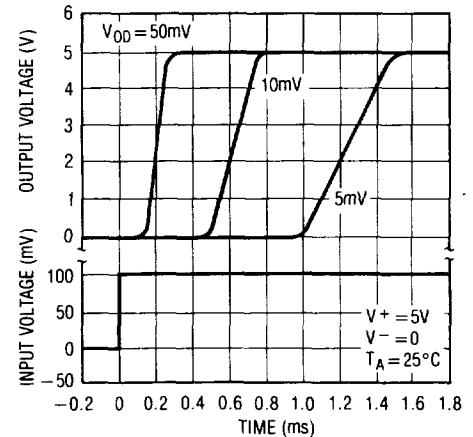
Large Signal Response



Comparator Response Time for Various Input Overdrives

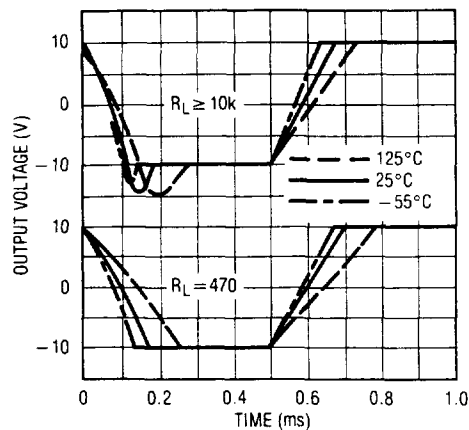


Comparator Response Time for Various Input Overdrives

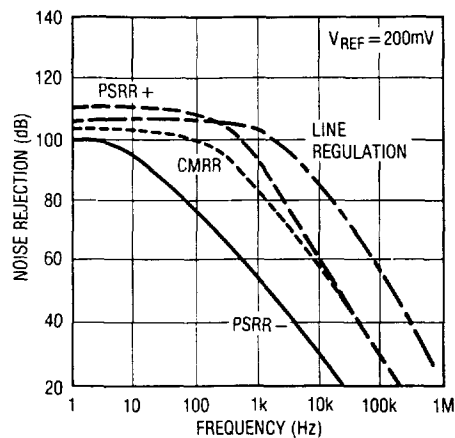


TYPICAL PERFORMANCE CHARACTERISTICS

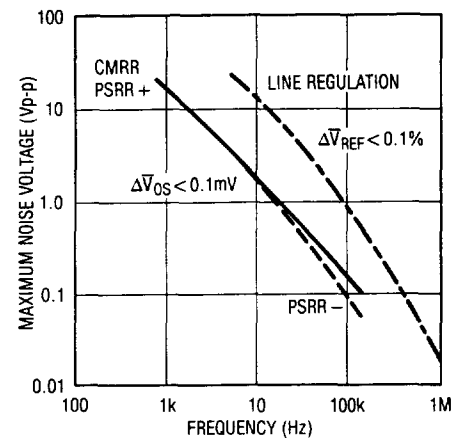
Follower Pulse Response



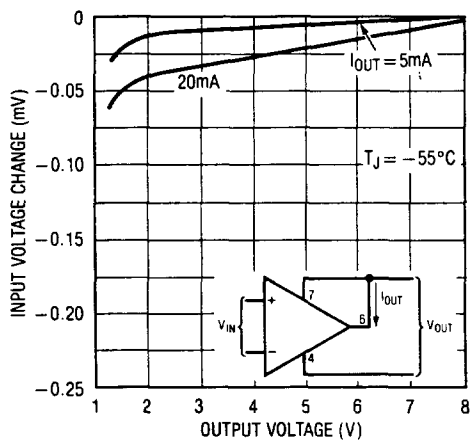
Noise Rejection



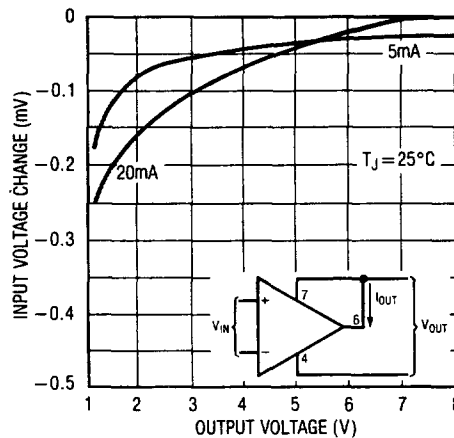
Rejection Slew Limiting



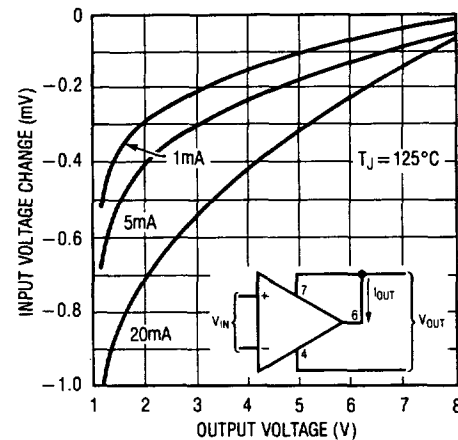
Shunt Gain



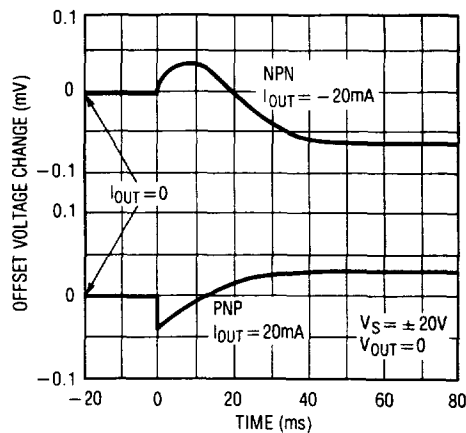
Shunt Gain



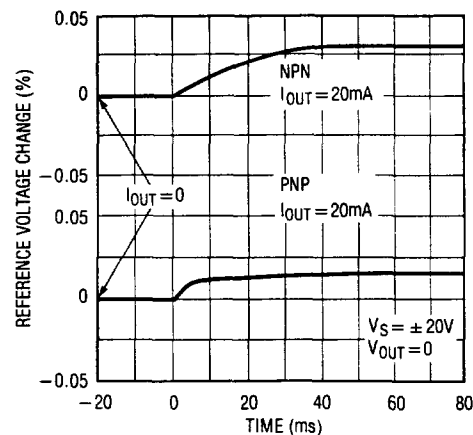
Shunt Gain



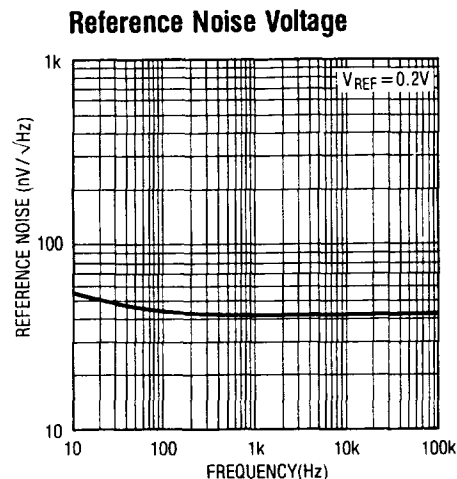
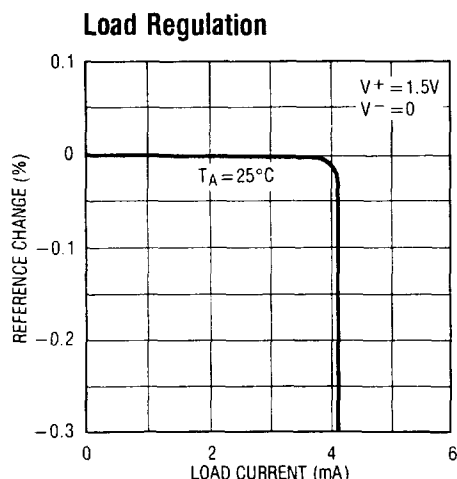
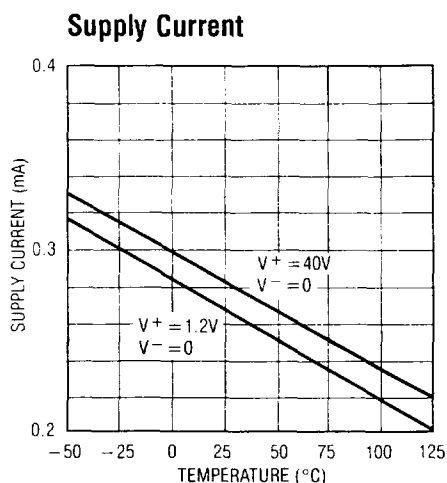
Thermal Gradient Feedback



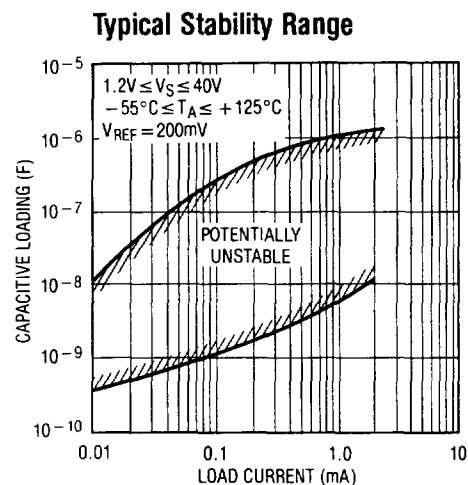
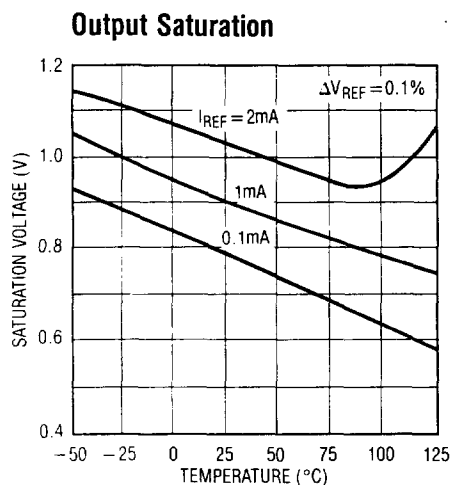
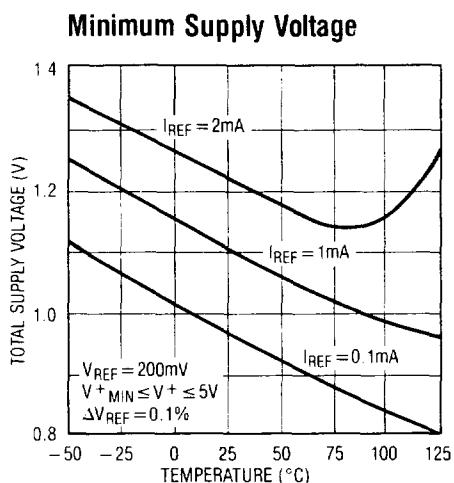
Change in Reference Op Amp Loading



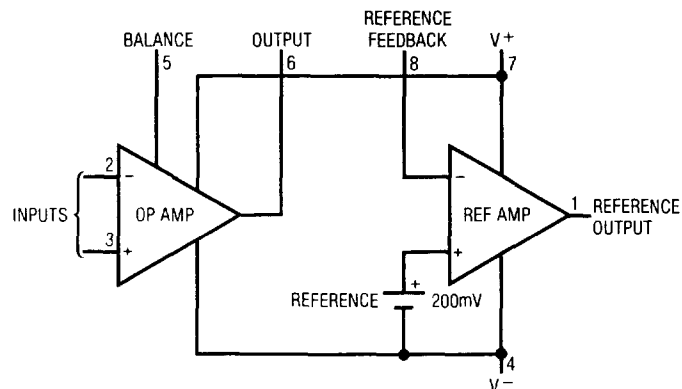
TYPICAL PERFORMANCE CHARACTERISTICS (Reference)



2



BLOCK DIAGRAM



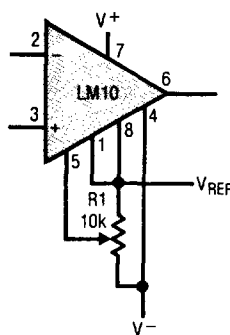
APPLICATION HINTS

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

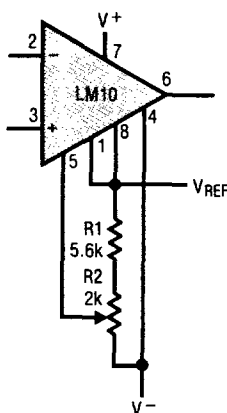
Lead resistance can approach 1Ω . Therefore, the common to the reference circuitry should be connected as close as possible to the package.

TYPICAL APPLICATIONS

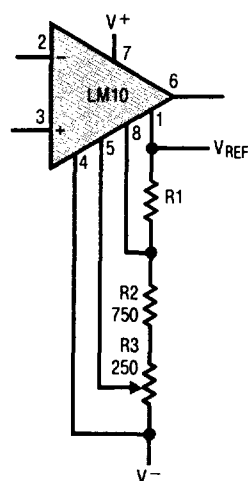
**Standard
Offset Adjustment**



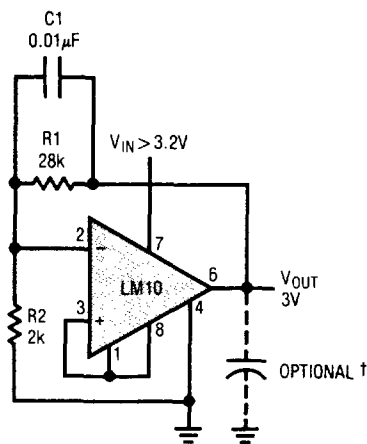
**Limited Range
Offset Adjustment**



**Limited Range Offset Adjustment
with Boosted Reference**

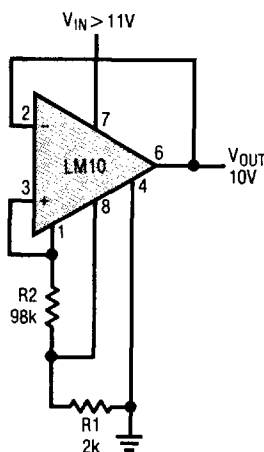


Low Voltage Regulator

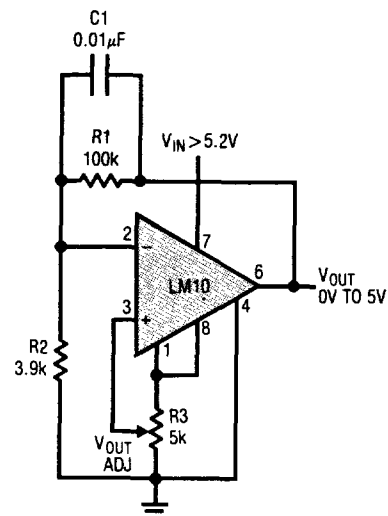


† USE ELECTROLYTIC OUTPUT CAPACITORS

Best Regulation

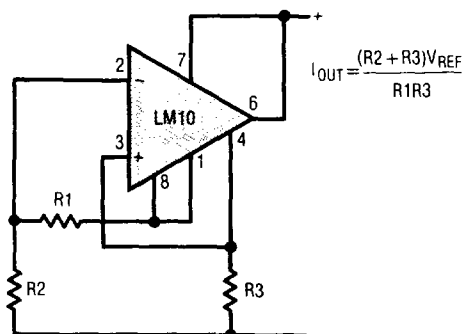


0V to 5V Regulator

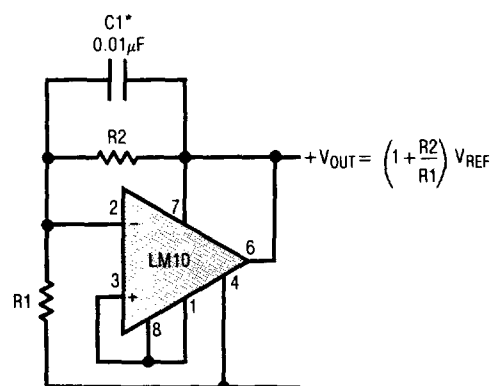


TYPICAL APPLICATIONS

Two-Terminal Current Regulator



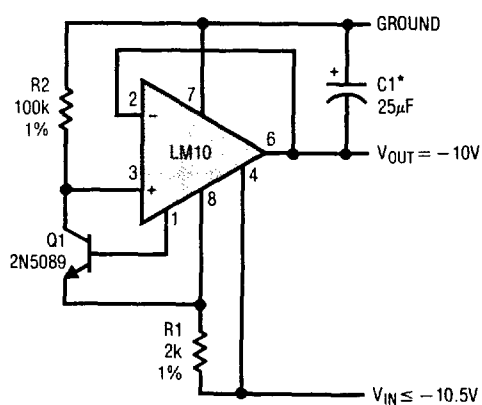
Shunt Regulator



*REQUIRED FOR CAPACITIVE LOADING

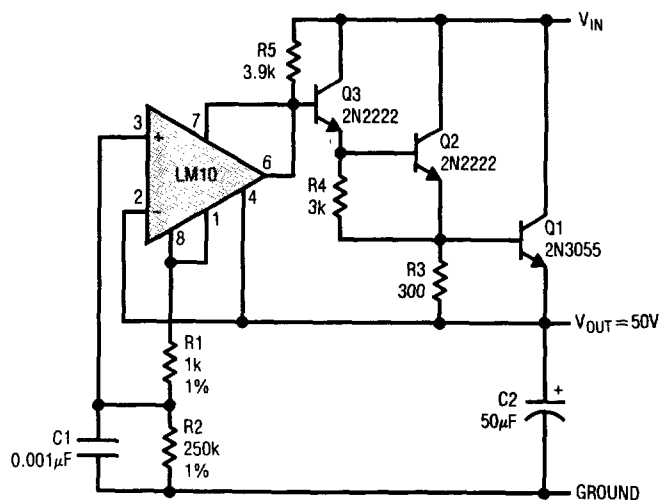
2

Negative Regulator

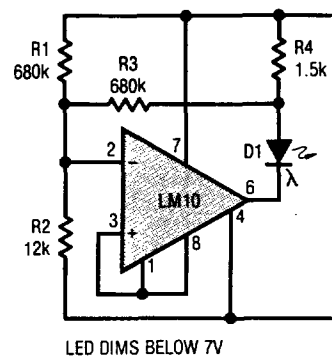


*ELECTROLYTIC

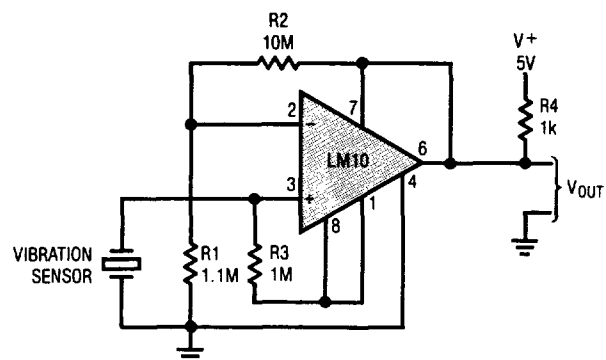
Floating Regulator



6V Battery-Level Indicator

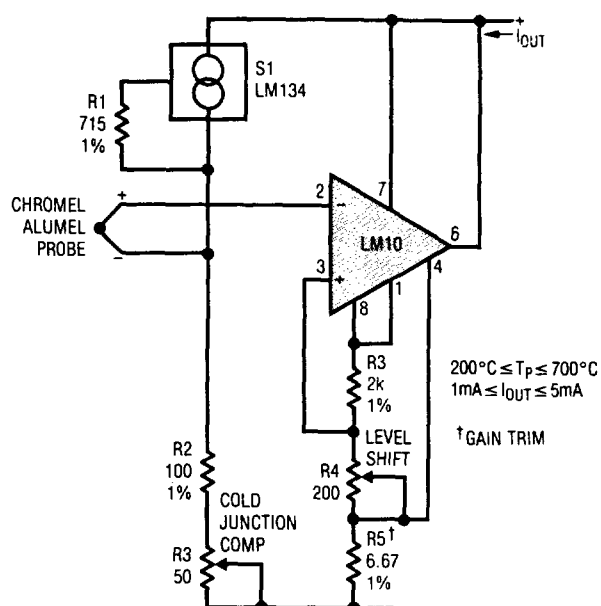


Transducer Amplifier

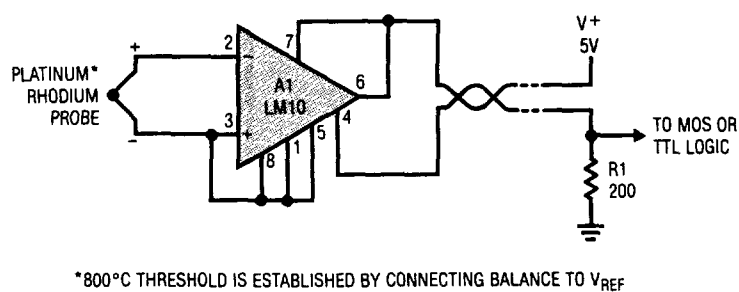


TYPICAL APPLICATIONS

Thermocouple Transmitter

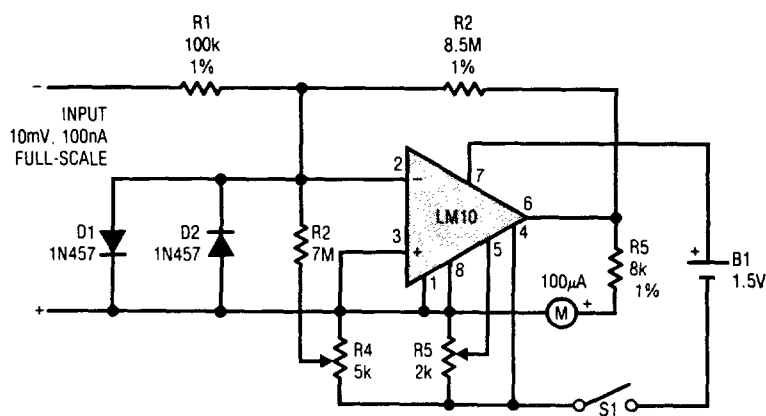


Flame Detector

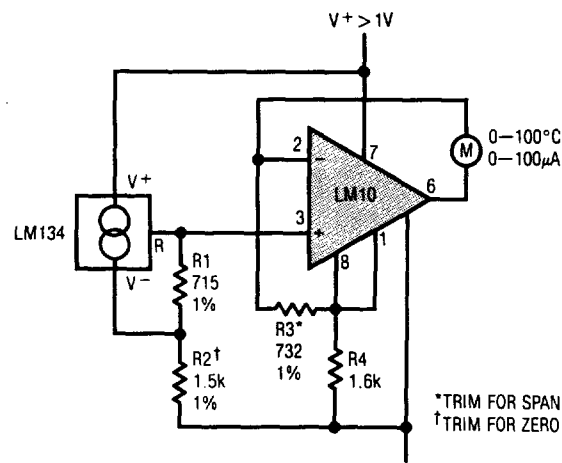


2

Meter Amplifier



Thermometer

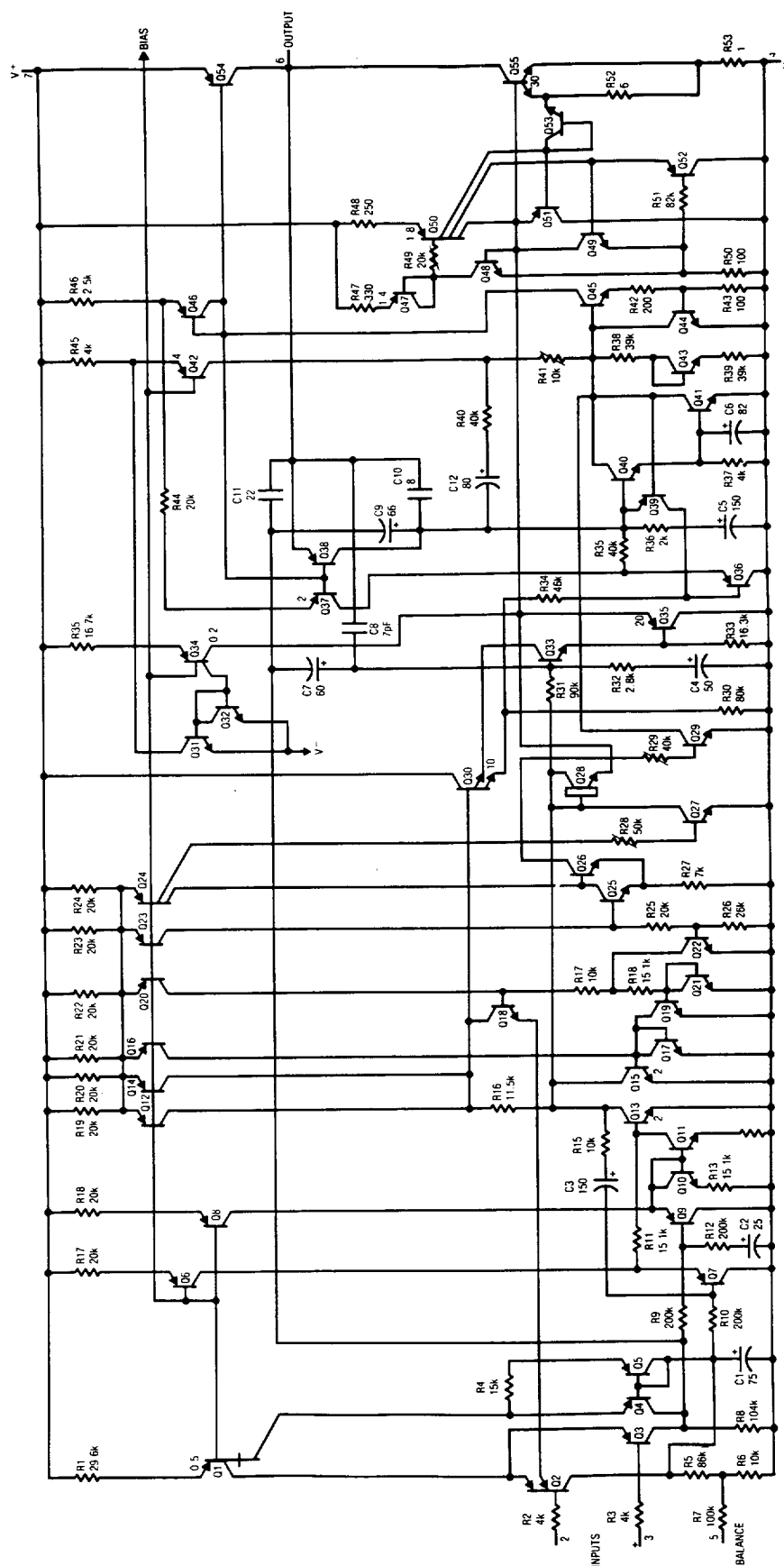


The circuit diagram shows an LM10 operational amplifier configured as a variable gain amplifier. The non-inverting input (pin 3) is connected to a voltage divider consisting of resistors R1 (6.2M) and R2 (1M) connected to a 1.5V supply (VS), and resistor R3 (300k) connected to ground. A capacitor C1 (0.02μF) is connected between the non-inverting input and ground. The inverting input (pin 2) is connected to the output (pin 6) via resistor R8 (3M) and to a potentiometer R4 (100k) via resistor R5 (1M). The wiper of the potentiometer R4 is connected to ground through resistor R6 (2.2M). A capacitor C2 (0.05μF) is connected between the inverting input and the wiper of R4. The output (pin 6) is also connected to a capacitor C4 (4.7μF) and a microphone (MIC). A feedback capacitor C3 (0.47μF) is connected between the output and the inverting input. The op-amp is powered by a 1.5V supply (VS) at pin 7 and ground at pin 4. Pin 1 is connected to ground through resistor R7 (10k).

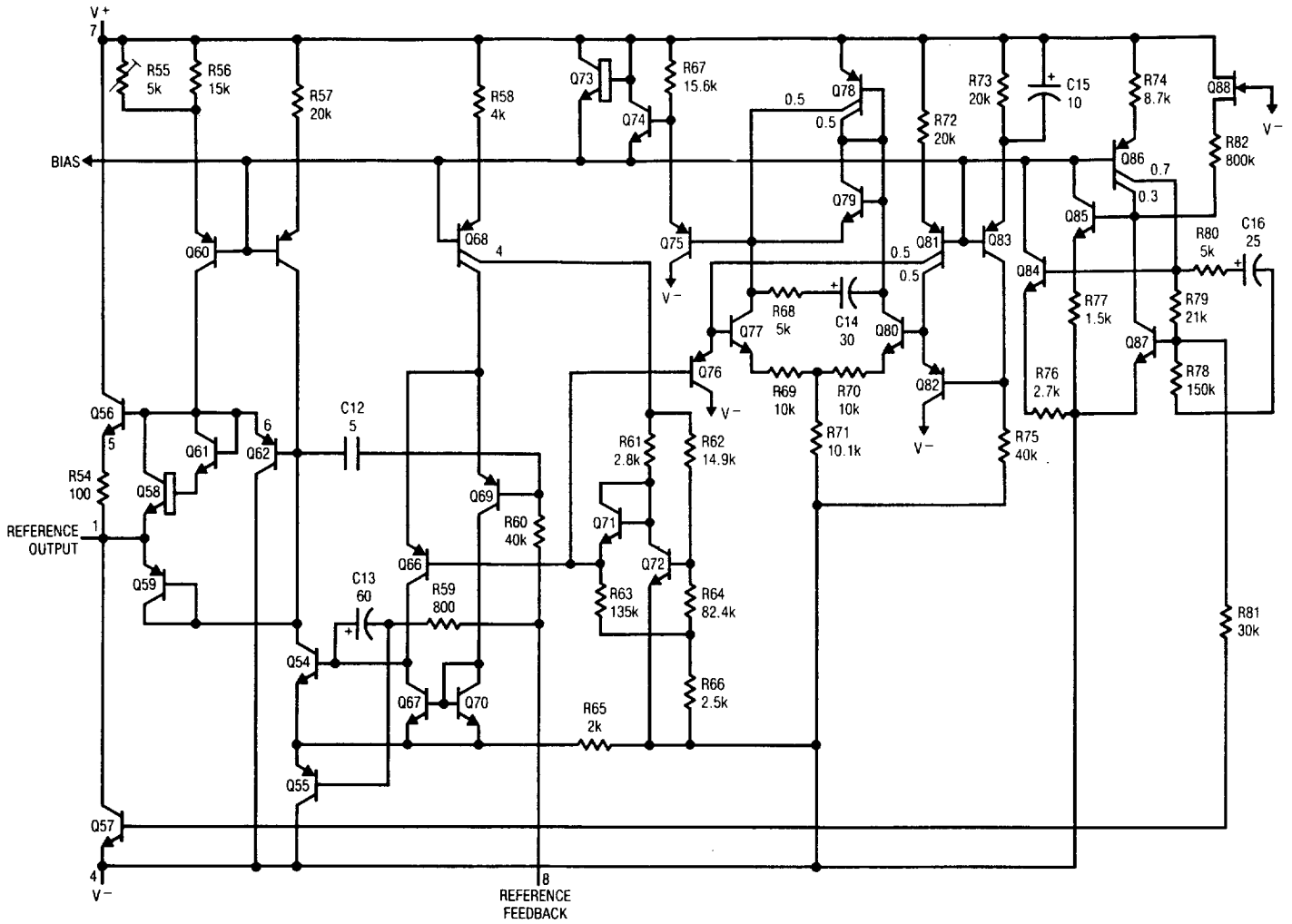
The diagram shows an LM10 op-amp configured as a voltage follower. The non-inverting input (pin 3) is connected to a voltage divider consisting of resistors R2 (47.8k, 1%) and R3 (200). The inverting input (pin 2) is connected to the output (pin 6) through a feedback network consisting of resistors R4 (1.91k, 1%), R5 (4.7k), and R6 (5k), and a capacitor C1. The output (pin 6) is connected to a switch controller through a feedback loop consisting of two 4N28 diodes. The LM10 is powered by a regulated output (pin 1) and ground (pin 8). The feedback loop is labeled "FEEDBACK TO SWITCH CONTROLLER".

† CONTROLS "LOOP GAIN" FOR ENTIRE LOOP

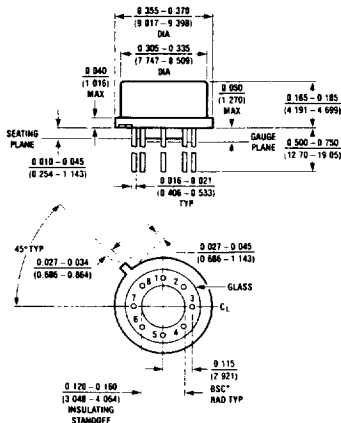
OP AMP SCHEMATIC DIAGRAM



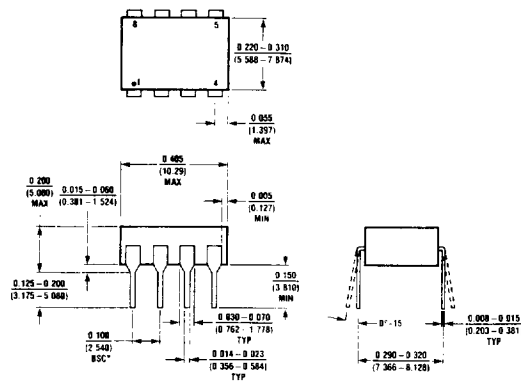
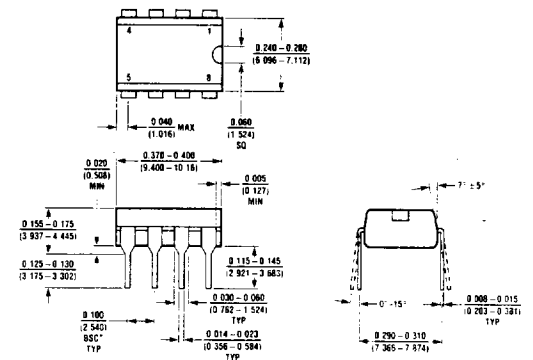
REFERENCE AND INTERNAL REGULATOR SCHEMATIC DIAGRAM



PACKAGE DESCRIPTION

H Package
Metal Can

NOTE: DIMENSIONS IN INCHES

J8 Package
8 Lead Hermetic DipNOTE: DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED
*LEADS WITHIN 0.007 OF TRUE POSITION (TYP) AT GAUGE PLANEN8 Package
8 Lead PlasticNOTE: DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED
*LEADS WITHIN 0.007 OF TRUE POSITION (TYP) AT GAUGE PLANE

T_{jmax}	θ_{ja}	θ_{jc}
150°C	150°C/W	45°C/W

T_{jmax}	θ_{ja}
150°C	100°C/W

T_{jmax}	θ_{ja}
100°C	130°C/W