

LM10QML Operational Amplifier and Voltage Reference

Check for Samples: [LM10QML](#)

FEATURES

- Input Offset Voltage: 2.0 mV (max)
- Input Offset Current: 0.7 nA (max)
- Input Bias Current: 20 nA (max)
- Reference Regulation: 0.1% (max)
- Offset Voltage Drift: 2 μ V/°C
- Reference Drift: 0.002%/°C

DESCRIPTION

The LM10 is a monolithic linear IC consisting of a precision reference, an adjustable reference buffer and an independent, high quality op amp.

The unit can operate from a total supply voltage as low as 1.1V or as high as 40V, drawing only 270 μ A. A complementary output stage swings within 15 mV of the supply terminals or will deliver \pm 20 mA output current with \pm 0.4V saturation. Reference output can be as low as 200 mV.

The circuit is recommended for portable equipment and is completely specified for operation from a single power cell. In contrast, high output-drive capability, both voltage and current, along with thermal overload protection, suggest it in demanding general-purpose applications.

The device is capable of operating in a floating mode, independent of fixed supplies. It can function as a remote comparator, signal conditioner, SCR controller or transmitter for analog signals, delivering the processed signal on the same line used to supply power. It is also suited for operation in a wide range of voltage- and current-regulator applications, from low voltages to several hundred volts, providing greater precision than existing ICs.

Connection and Functional Diagram

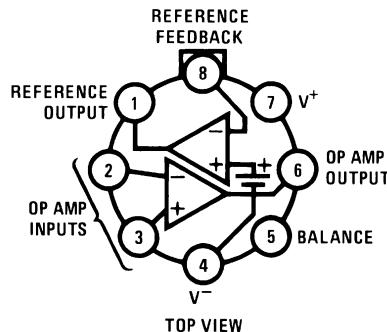
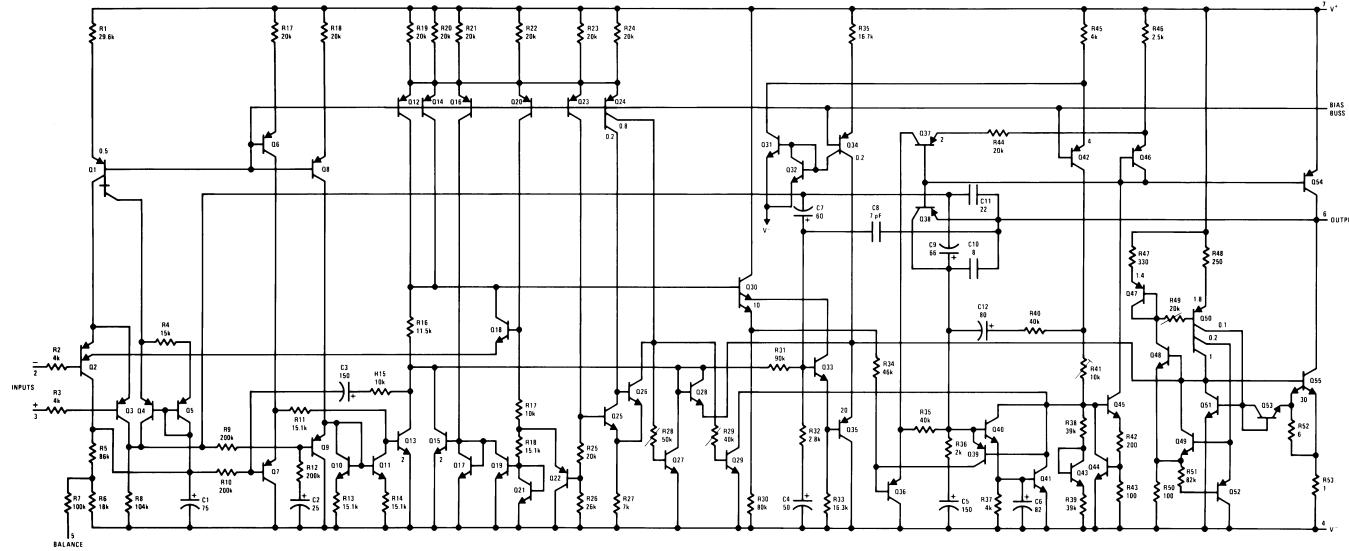
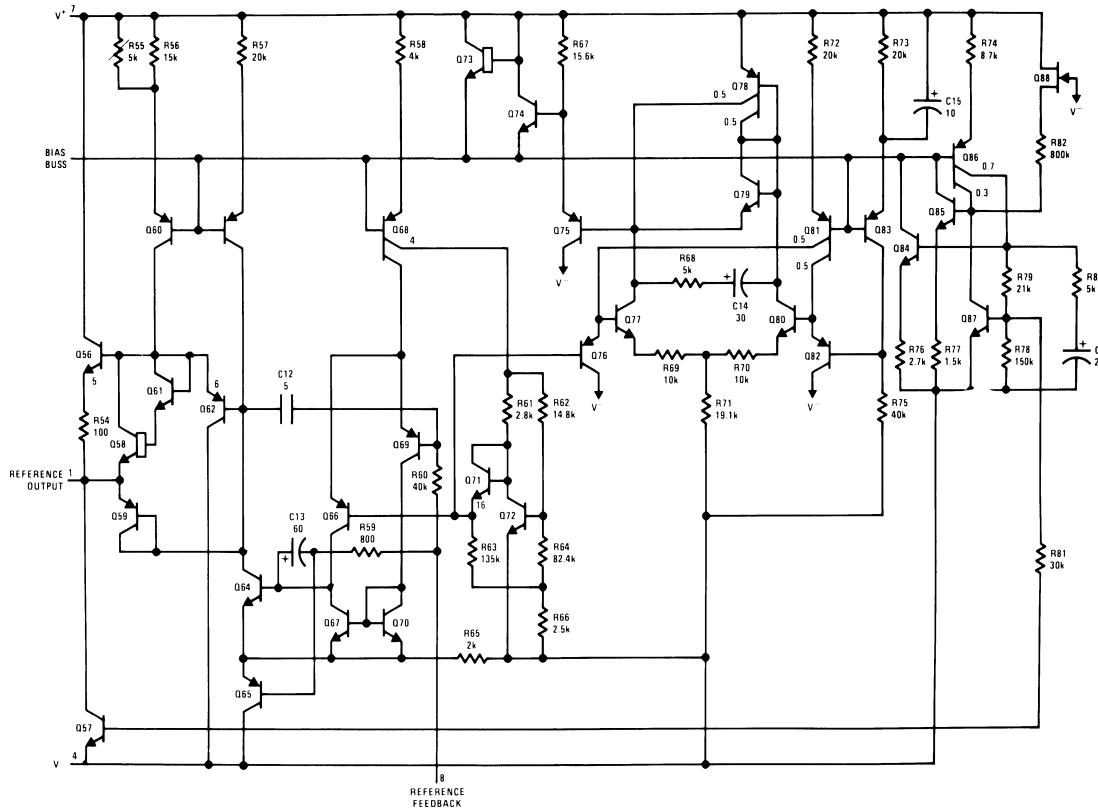


Figure 1. TO Package (NEV)
Package Number NEV0008A



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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Figure 2. Operational Amplifier Schematic — (Pin numbers are for 8-pin packages)**Figure 3. Reference and Internal Regulator Schematic — (Pin numbers are for 8-pin packages)**

Absolute Maximum Ratings⁽¹⁾

Total Supply Voltage	45V	
Differential Input Voltage ⁽²⁾	±40V	
Power Dissipation (P _{Dmax}) ⁽³⁾	Internally Limited	
Output Short-circuit Duration ⁽⁴⁾	Continuous	
Storage Temperature Range	-55°C ≤ T _A ≤ +150°C	
Maximum Junction Temperature (T _{Jmax})	150°C	
Lead Temperature (Soldering 10 seconds)	300°C	
Thermal Resistance	θ _{JA}	Still Air
		500LF/Min Air flow
	θ _{JC}	45°C
ESD	Rating to be determined	

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
- (2) The Input voltage can exceed the supply voltages provided that the voltage from the input to any other terminal does not exceed the maximum differential input voltage and excess dissipation is accounted for when V_I < V_S⁻.
- (3) The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{Jmax} (maximum junction temperature), θ_{JA} (package junction to ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is P_{Dmax} = (T_{Jmax} - T_A)/θ_{JA} or the number given in the Absolute Maximum Ratings, whichever is lower..
- (4) Internal thermal limiting prevents excessive heating that could result in sudden failure, but the IC can be subjected to accelerated stress with a shorted output and worst-case conditions.

Quality Conformance Inspection

Mil-Std-883, Method 5005 - Group A

Subgroup	Description	Temp °C
1	Static tests at	+25
2	Static tests at	+125
3	Static tests at	-55
4	Dynamic tests at	+25
5	Dynamic tests at	+125
6	Dynamic tests at	-55
7	Functional tests at	+25
8A	Functional tests at	+125
8B	Functional tests at	-55
9	Switching tests at	+25
10	Switching tests at	+125
11	Switching tests at	-55
12	Settling time at	+25
13	Settling time at	+125
14	Settling time at	-55

LM10H Electrical Characteristics DC Parameters

The following conditions apply to all the following parameters, unless otherwise specified.

DC: At room temperature $1.2V \leq V_S \leq 45V$, $V_S^- \leq V_{CM} \leq V \pm 0.85V$.

DC: At temperature extremes $1.3V \leq V_S \leq 45V$, $V_S^- \leq V_{CM} \leq V \pm 1.0V$.

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
V_{IO}	Input Offset Voltage	$I_O = 0mA$		-2.0	2.0	mV	1
				-3.0	3.0	mV	2, 3
		$V_S = 1.2V$, $I_O = \pm 2mA$		-3.0	3.0	mV	1
		$V_S = 1.3V$, $I_O = \pm 2mA$		-4.0	4.0	mV	2, 3
		$V_S = 4V$, $I_O = \pm 20mA$		-3.0	3.0	mV	1
I_{IO}	Input Offset Current			-0.7	0.7	nA	1
				-1.5	1.5	nA	2, 3
I_{IB}	Input Bias Current			20		nA	1
				30		nA	2, 3
CMRR	Common Mode Rejection	$V_S = 45V$, $-20V \leq V_{CM} \leq 24.2V$		93		dB	1
				87		dB	2, 3
PSRR	Supply Voltage Rejection	$V_S^+ = 0.85V$, $-0.35V \geq V_S^- \geq -44.2V$		90		dB	1
		$V_S^+ = 1V$, $-0.3V \geq V_S^- \geq -44.2V$		84		dB	2, 3
		$0.85V \leq V_S^+ \leq 44.6V$, $V_S^- = -0.35V$		96		dB	1
		$1V \leq V_S^+ \leq 44.6V$, $V_S^- = -0.3V$		90		dB	2, 3
V_{RLine}	Line Regulation	$I_{Ref} = 1mA$		91		dB	1
				85		dB	2, 3
V_{RLoad}	Load Regulation	$V_S = 1.2V$, $0 \leq I_O \leq 1mA$		60		dB	1
		$V_S = 1.3V$, $0 \leq I_O \leq 1mA$		57		dB	2, 3
I_S	Supply Current			400		μA	1
				500		μA	2, 3
Av	Large Signal Voltage Gain	$V_S = \pm 20V$, $I_O = 0A$, $V_O = \pm 19.95V$		120		K	4
				80		K	5, 6
		$V_S = \pm 2V$, $I_O = \pm 20mA$, $V_O = \pm 1.4V$		5.0		K	4
				1.5		K	5, 6
		$V_S^+ = 0.85V$, $V_{CM} = -0.25V$ $V_S^- = -0.35V$, $I_O = \pm 2mA$, $-0.15V \leq V_O \leq 0.65V$		1.5		K	4
				0.5		K	5, 6
Avsh	Shunt Gain	$1.1V \leq V_{OUT} \leq 6.1V$, $-5mA \leq I_{OUT} \leq -0.1mA$	See (1)	14		K	4
		$1.2V \leq V_{OUT} \leq 6.2V$, $-5mA \leq I_{OUT} \leq -0.1mA$	See (1)	6.0		K	5, 6
		$1.4V \leq V_{OUT} \leq 6.4V$, $-5mA \leq I_{OUT} \leq -0.1mA$	See (1)	8.0		K	4
		$1.4V \leq V_{OUT} \leq 6.4V$, $-20mA \leq I_{OUT} \leq -0.1mA$	See (1)	4.0		K	5, 6

(1) This defines operation in floating applications such as the bootstrapped regulator or two-wire transmitter. Output is connected to the V_S^+ terminal of the IC and input common mode is referred to V_S^- (see [Typical Applications](#) –). Effect of larger output-voltage swings with higher load resistance can be accounted for by adding the positive-supply rejection error.

LM10H Electrical Characteristics DC Parameters (continued)

The following conditions apply to all the following parameters, unless otherwise specified.

DC: At room temperature $1.2V \leq V_S \leq 45V$, $V_S \leq V_{CM} \leq V \pm 0.85V$.

DC: At temperature extremes $1.3V \leq V_S \leq 45V$, $V_S \leq V_{CM} \leq V \pm 1.0V$.

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
Av	Amplifier Gain	$0.2V \leq V_{Ref} \leq 35V$, $I_{Ref} = 1mA$		50		K	
				23		K	
V _{Sense}	Feedback Sense Voltage	$0.2V \leq V_{Ref} \leq 35V$, $0 \leq I_{Ref} \leq 1 mA$		195	205	mV	
				194	206	mV	
I _{Sense}	Feedback Current				50	nA	
					65	nA	
ΔI _S	Supply Current Change	0.5V ≤ V _O ≤ 25V		-75	75	μA	
		V _S = 5V, 4.5V ≤ V _O ≤ 5V		-60	60	μA	
R _I	Input Resistance		See ⁽²⁾		250	KΩ	
			See ⁽²⁾		150	KΩ	

(2) Specified parameter, not tested.

Definition of Terms

Input offset voltage: That voltage which must be applied between the input terminals to bias the unloaded output in the linear region.

Input offset current: The difference in the currents at the input terminals when the unloaded output is in the linear region.

Input bias current: The absolute value of the average of the two input currents.

Input resistance: The ratio of the change in input voltage to the change in input current on either input with the other grounded.

Large signal voltage gain: The ratio of the specified output voltage swing to the change in differential input voltage required to produce it.

Shunt gain: The ratio of the specified output voltage swing to the change in differential input voltage required to produce it with the output tied to the V_S^+ terminal of the IC. The load and power source are connected between the V_S^+ and V_S^- terminals, and input common-mode is referred to the V_S^- terminal.

Common-mode rejection: The ratio of the input voltage range to the change in offset voltage between the extremes.

Supply-voltage rejection: The ratio of the specified supply-voltage change to the change in offset voltage between the extremes.

Line regulation: The average change in reference output voltage over the specified supply voltage range.

Load regulation: The change in reference output voltage from no load to that load specified.

Feedback sense voltage: The voltage, referred to V_S^- , on the reference feedback terminal while operating in regulation.

Reference amplifier gain: The ratio of the specified reference output change to the change in feedback sense voltage required to produce it.

Feedback current: The absolute value of the current at the feedback terminal when operating in regulation.

Supply current: The current required from the power source to operate the amplifier and reference with their outputs unloaded and operating in the linear range.

Typical Performance Characteristics (Op Amp)

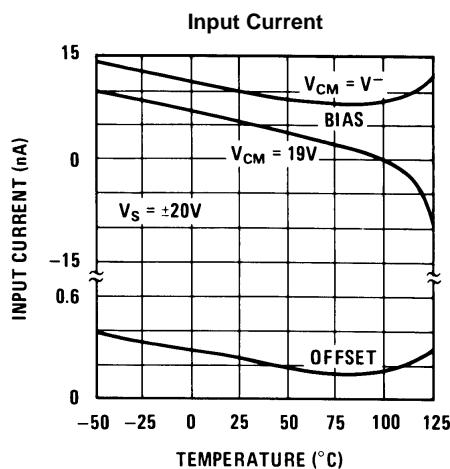


Figure 4.

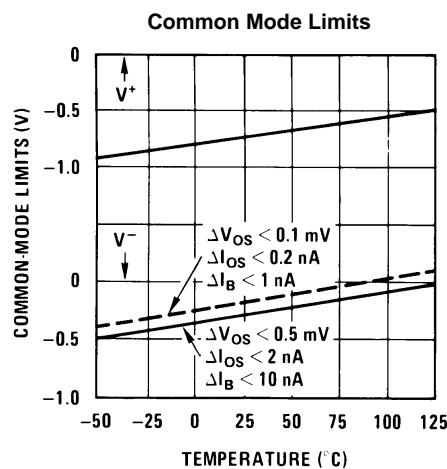


Figure 5.

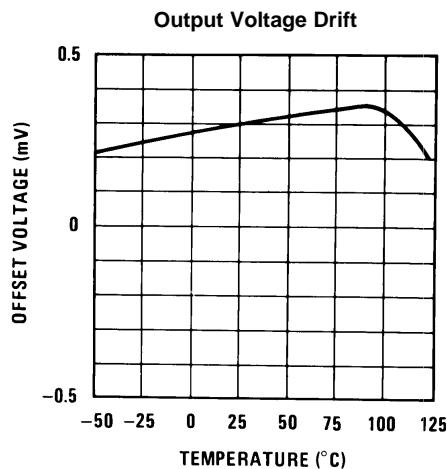


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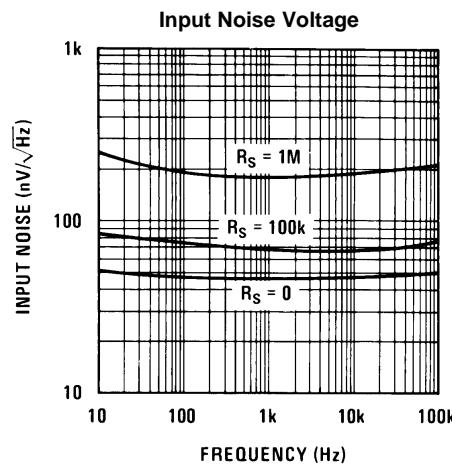


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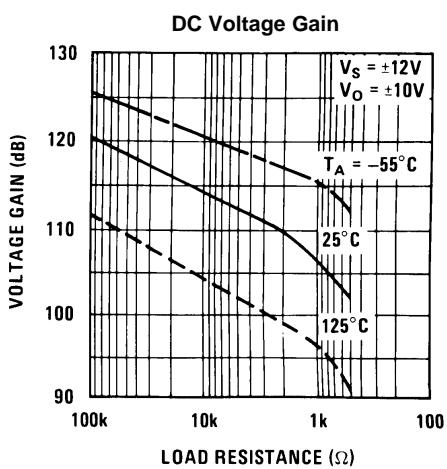


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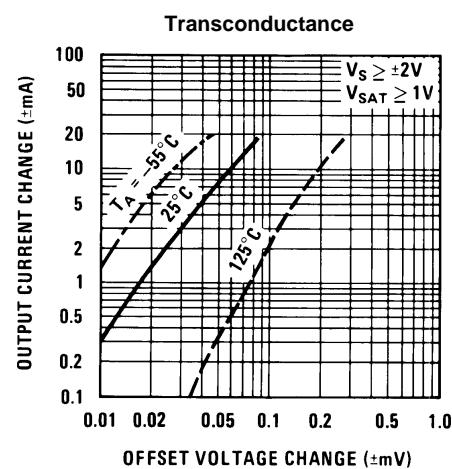


Figure 9.

Typical Performance Characteristics (Op Amp) (continued)

Output Saturation Characteristics

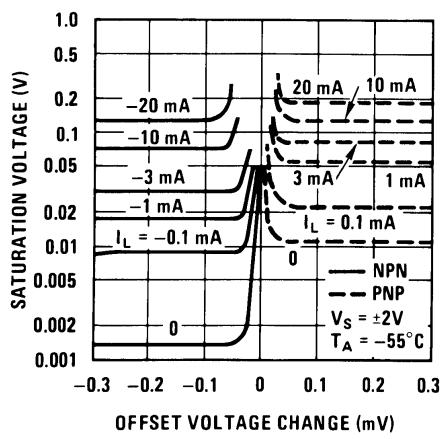


Figure 10.

Output Saturation Characteristics

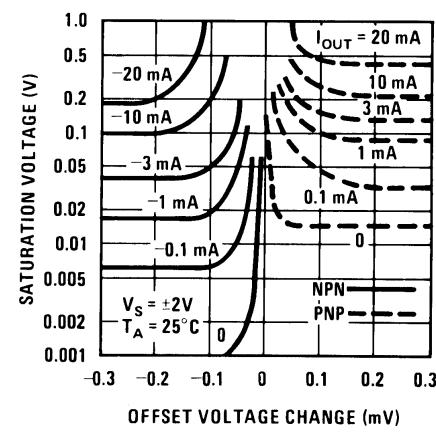


Figure 11.

Output Saturation Characteristics

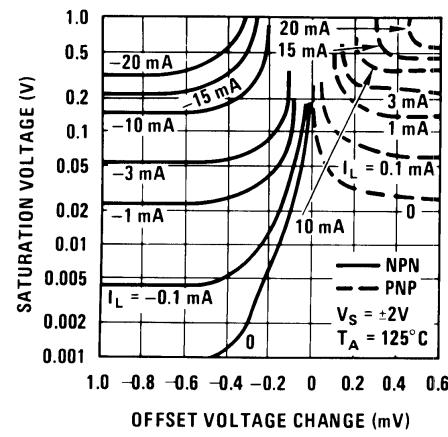


Figure 12.

Minimum Supply Voltage

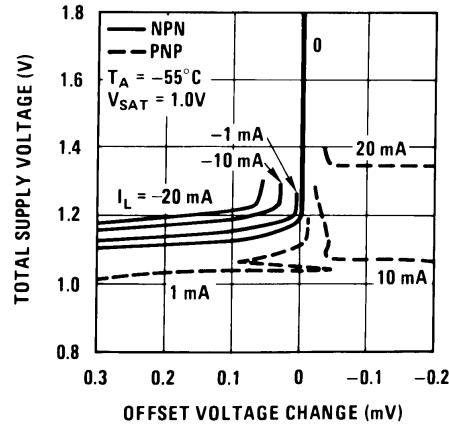


Figure 13.

Minimum Supply Voltage

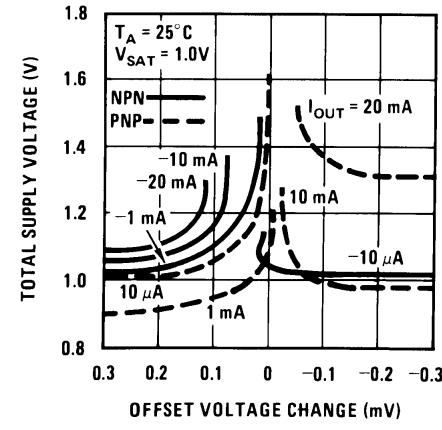


Figure 14.

Minimum Supply Voltage

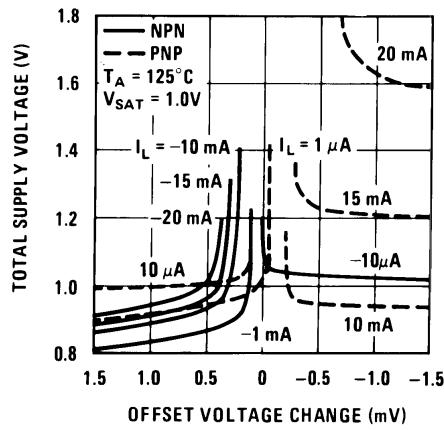
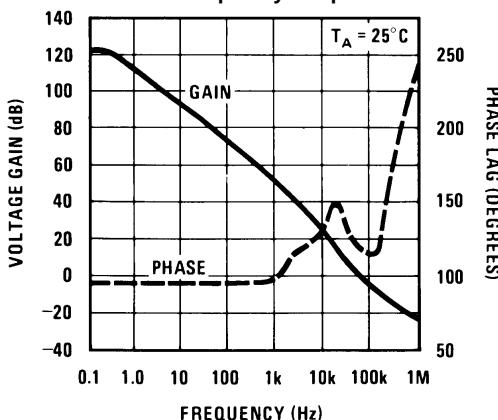


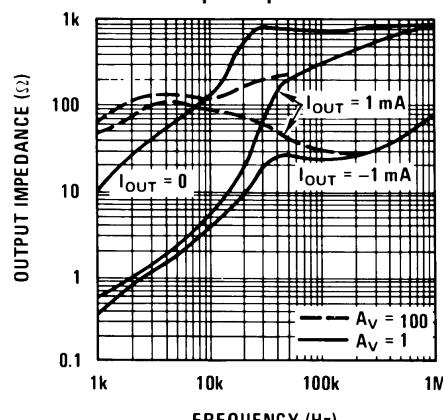
Figure 15.

Typical Performance Characteristics (Op Amp) (continued)

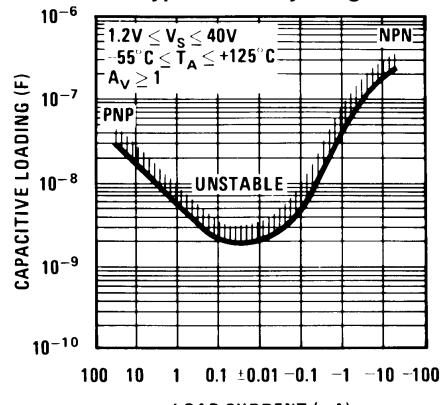
Frequency Response


Figure 16.

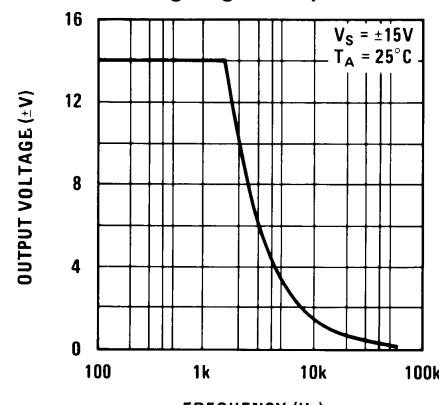
Output Impedance


Figure 17.

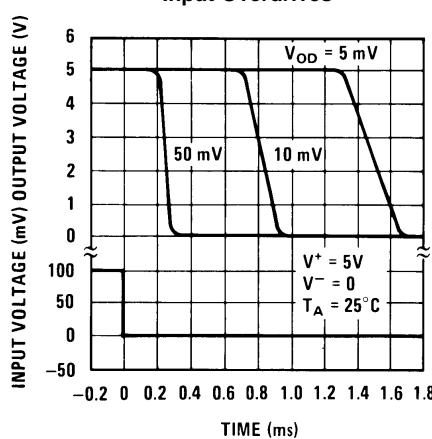
Typical Stability Range


Figure 18.

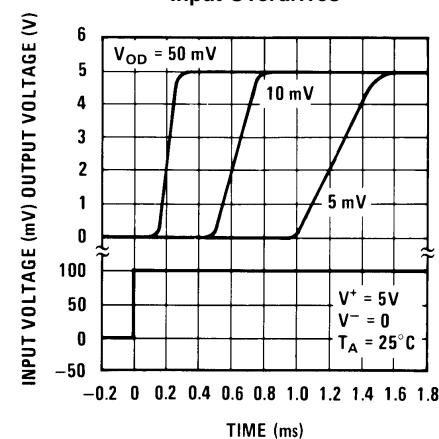
Large Signal Response


Figure 19.

Comparator Response Time For Various Input Overdrives


Figure 20.

Comparator Response Time For Various Input Overdrives


Figure 21.

Typical Performance Characteristics (Op Amp) (continued)

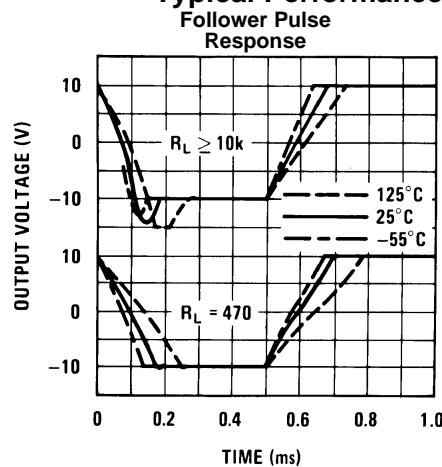


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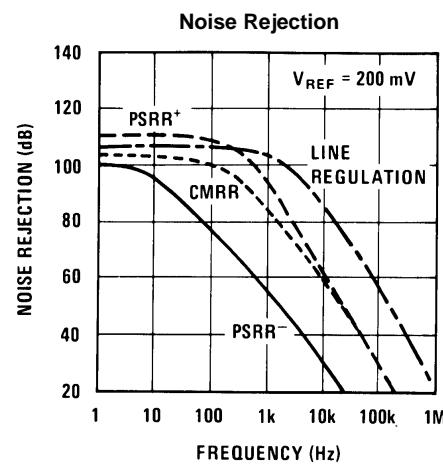


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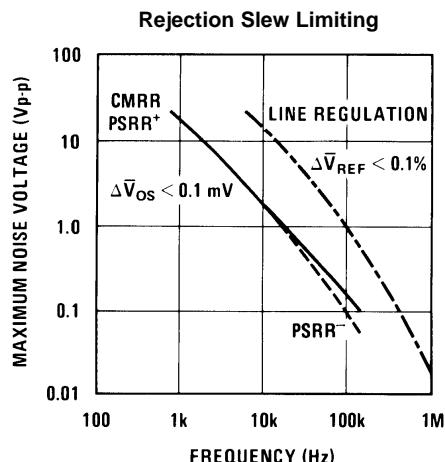


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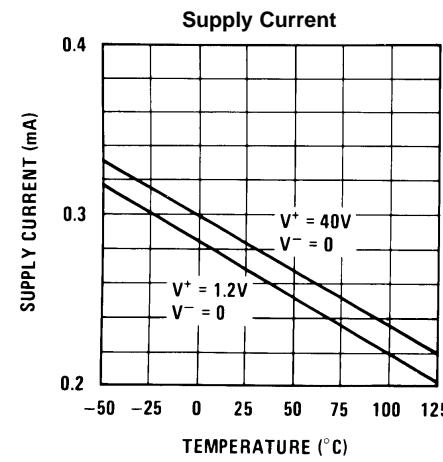


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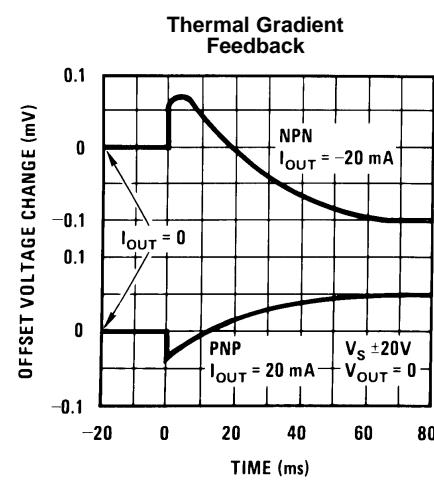


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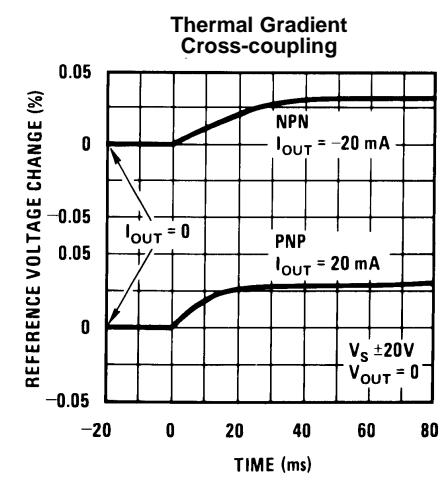


Figure 27.

Typical Performance Characteristics (Op Amp) (continued)

Shunt Gain

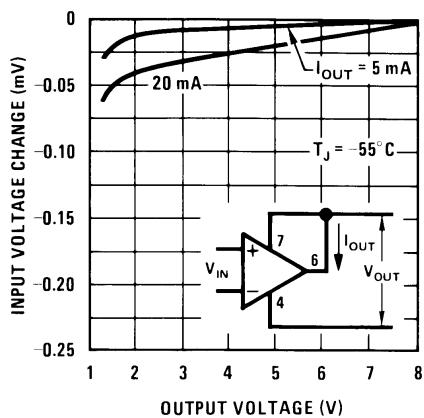


Figure 28.

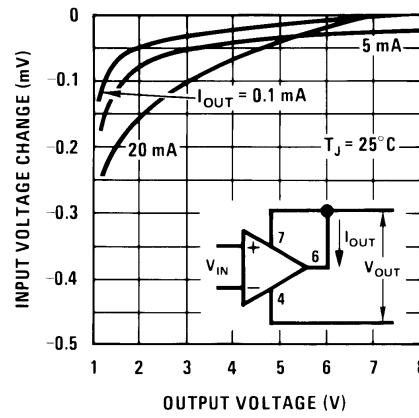


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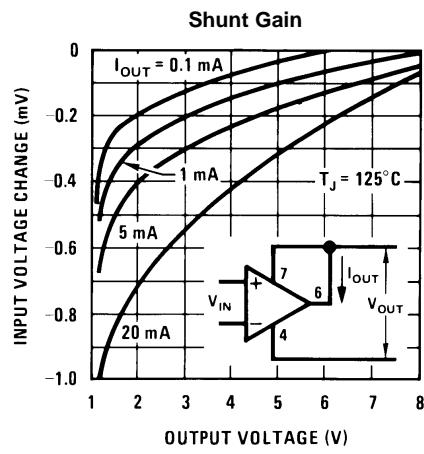


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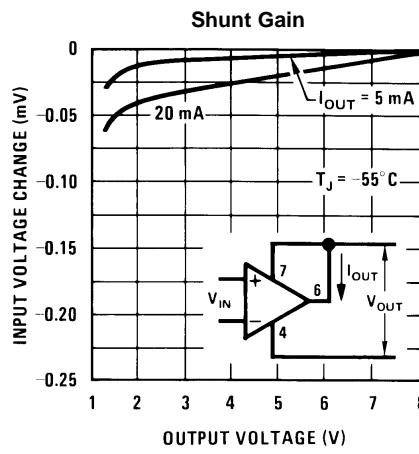


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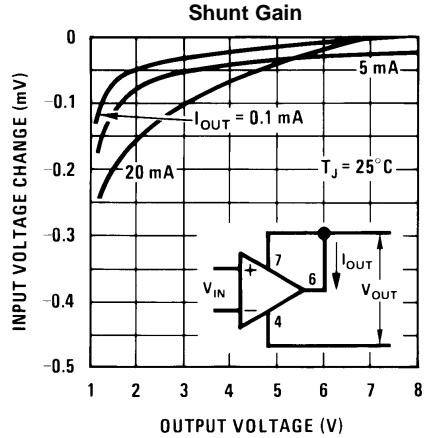


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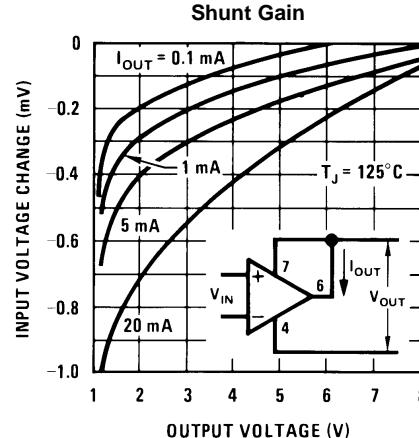


Figure 33.

Typical Performance Characteristics (Reference)

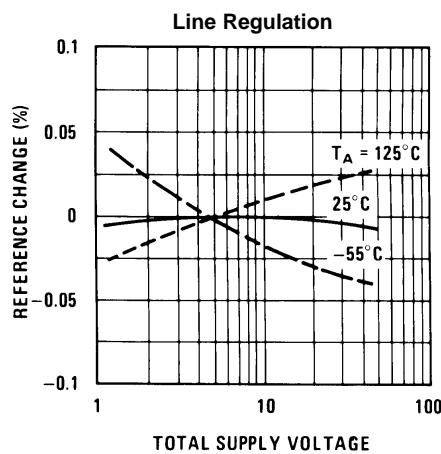


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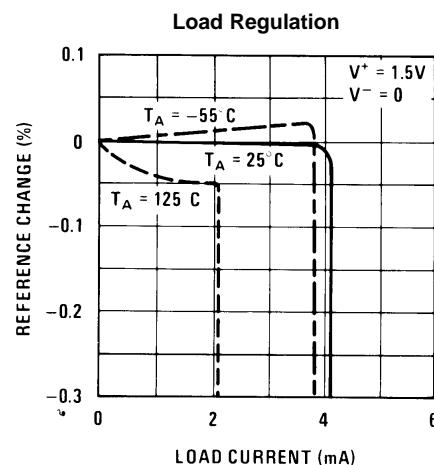


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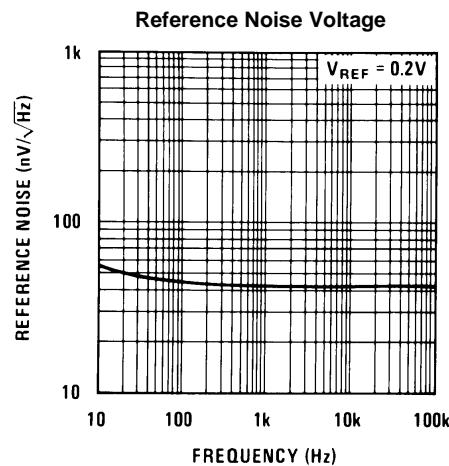


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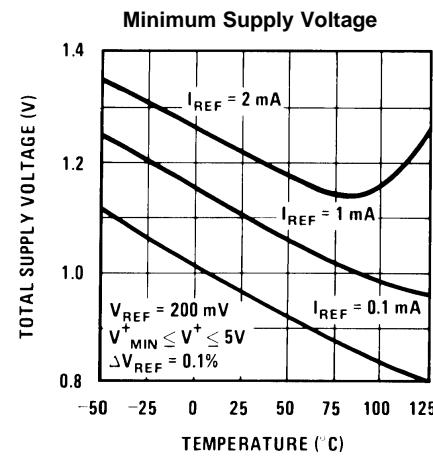


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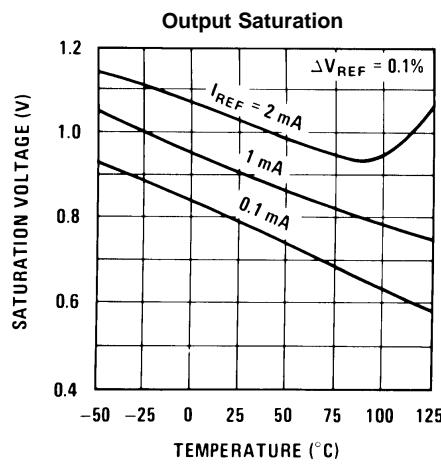


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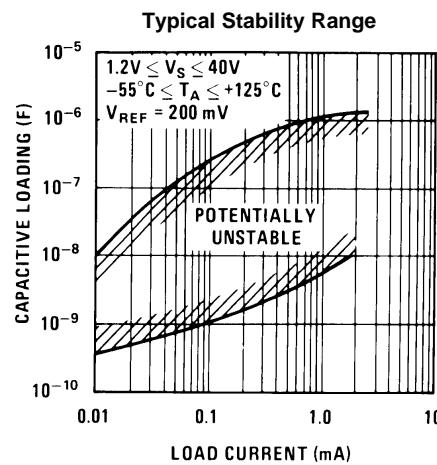


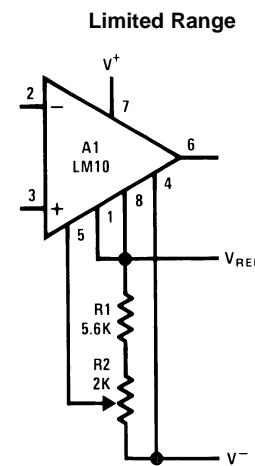
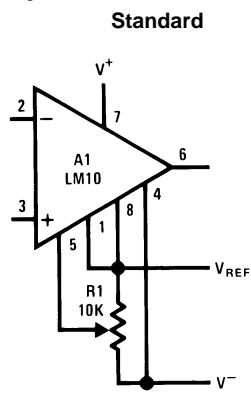
Figure 39.

Typical Applications

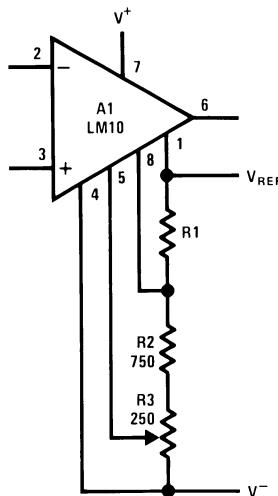
Circuit descriptions available in application note AN-211 ([SNOA638](#)).

(Pin numbers are for devices in 8-pin packages)

Op Amp Offset Adjustment



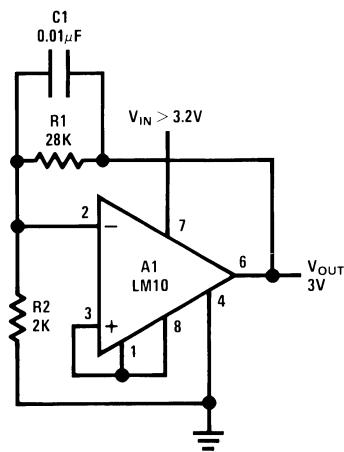
Limited Range With Boosted Reference



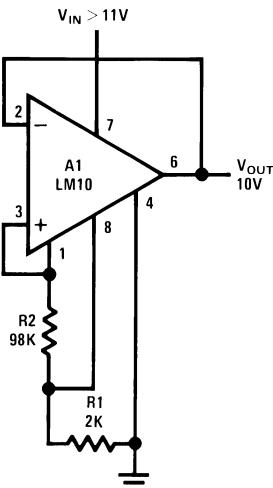
Positive Regulators

Use only electrolytic output capacitors.

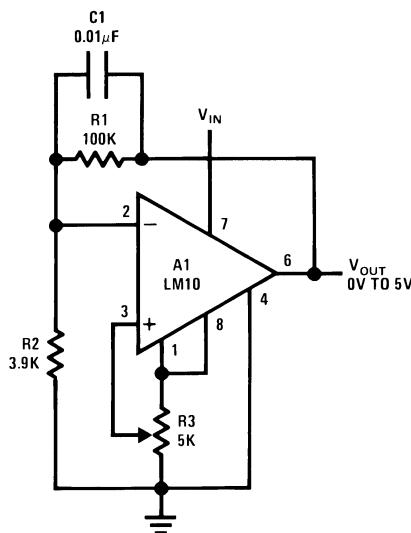
Low Voltage



Best Regulation

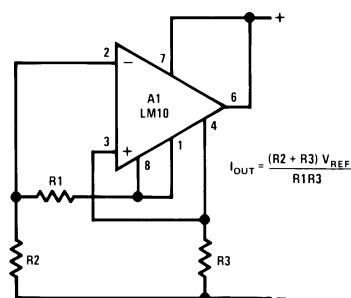


Zero Output

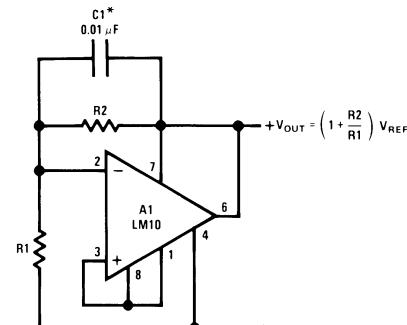


Use only electrolytic output capacitors.

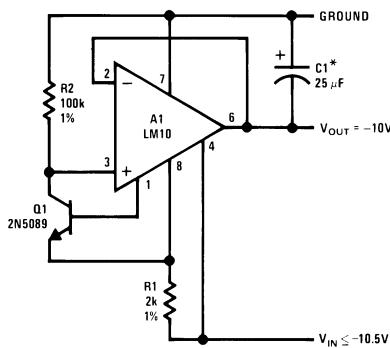
Current Regulator



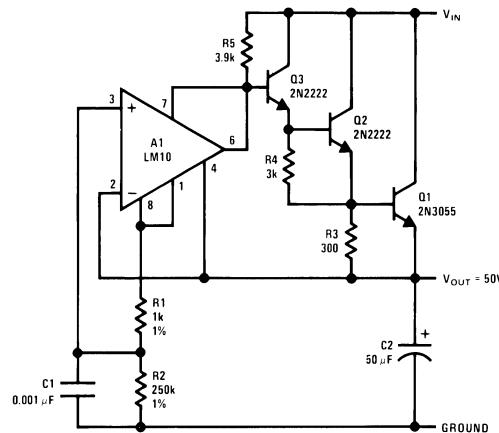
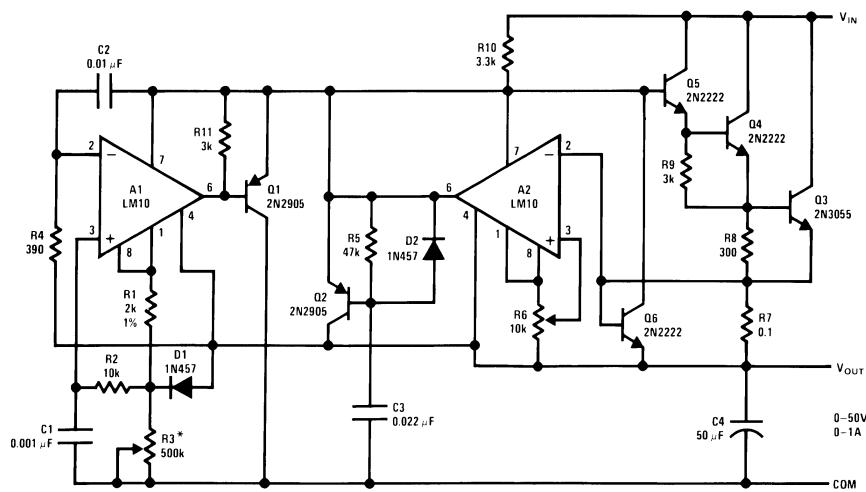
Shunt Regulator



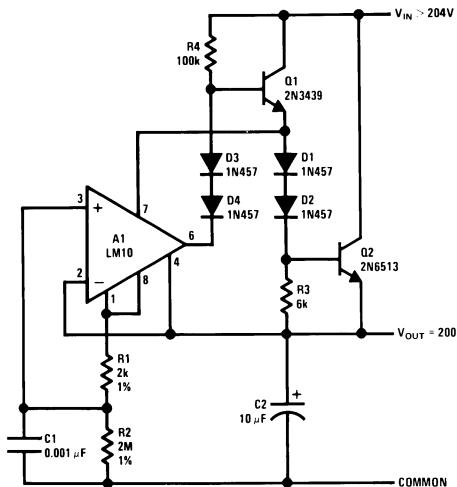
Required For Capacitive Loading

Negative Regulator


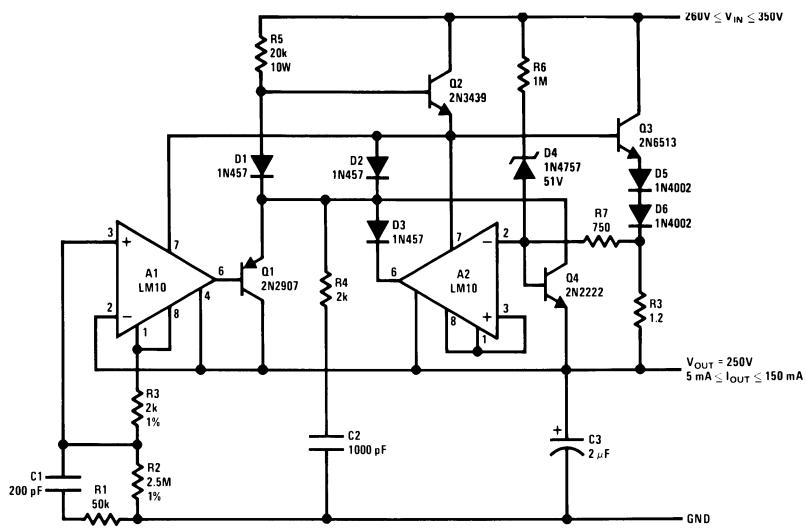
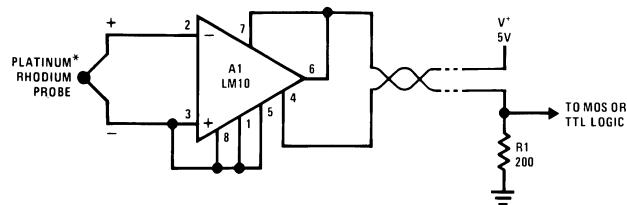
*Electrolytic

Precision Regulator

Laboratory Power Supply


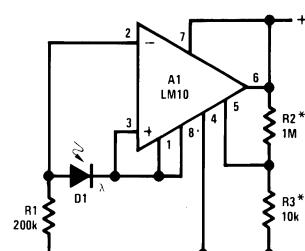
$*V_O = 10^{-4} R_3$

HV Regulator


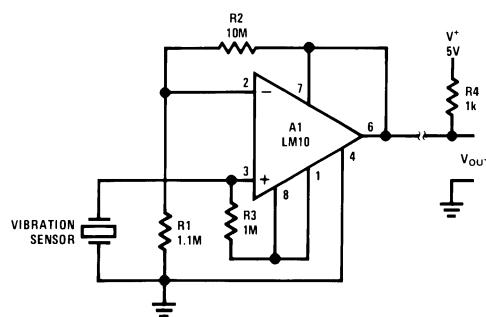
$$V_{OUT} = \frac{R_2}{R_1} V_{REF}$$

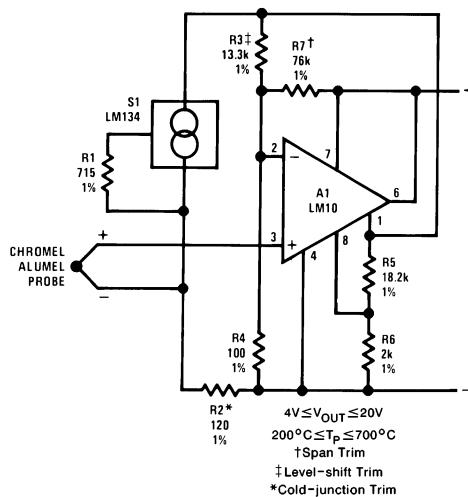
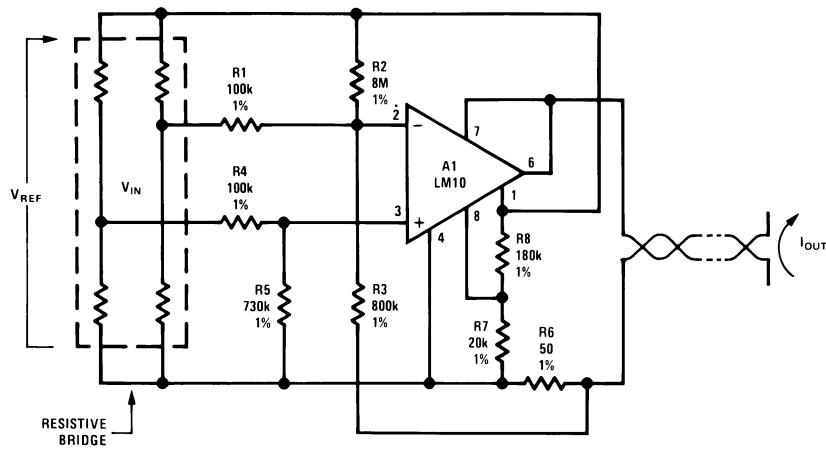
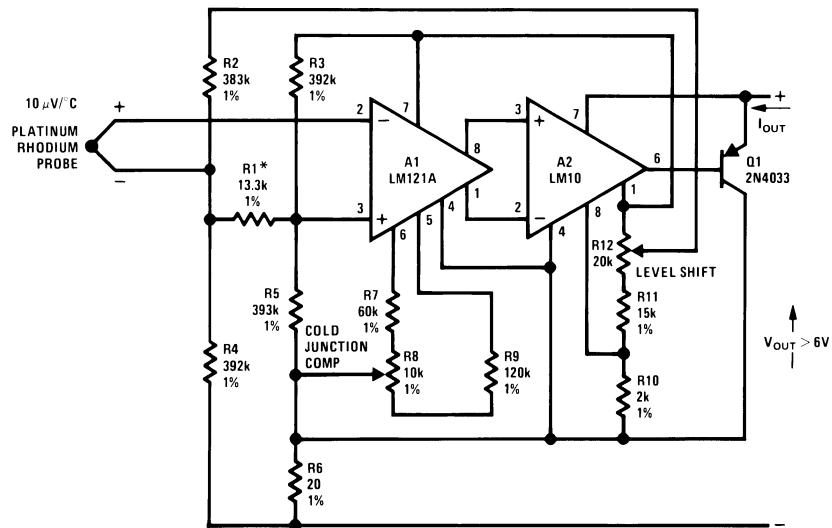
Protected HV Regulator

Flame Detector


*800°C Threshold Is Established By Connecting Balance To V_{Ref} .

Light Level Sensor


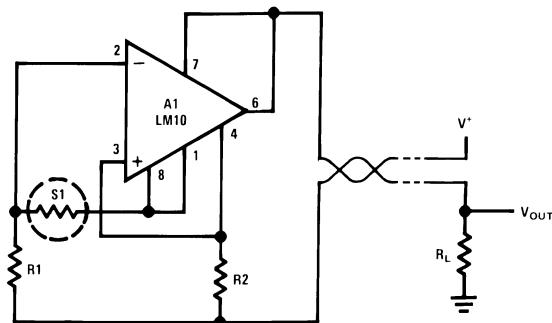
*Provides Hysteresis

Remote Amplifier


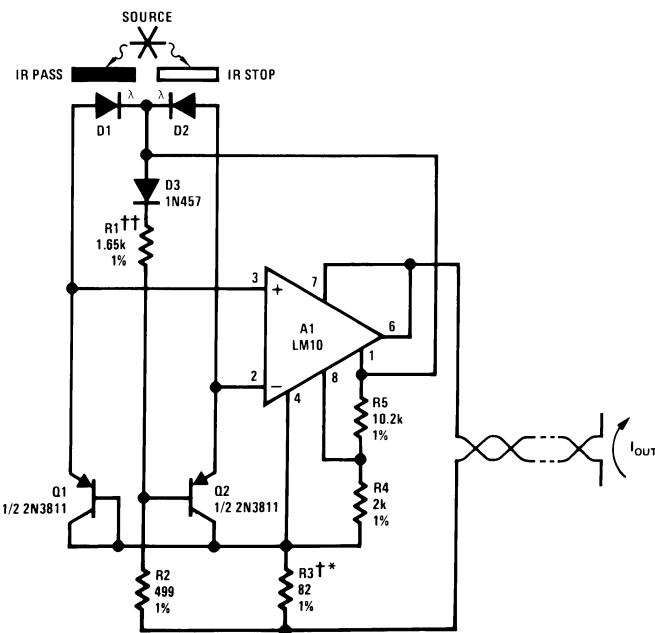
Remote Thermocouple Amplifier

Transmitter for Bridge Sensor

Precision Thermocouple Transmitter

 $10 \text{ mA} \leq I_{\text{OUT}} \leq 50 \text{ mA}$
 $500^\circ\text{C} \leq T_P \leq 1500^\circ\text{C}$

*Gain Trim

Resistance Thermometer Transmitter



Optical Pyrometer



††Level-shift Trim

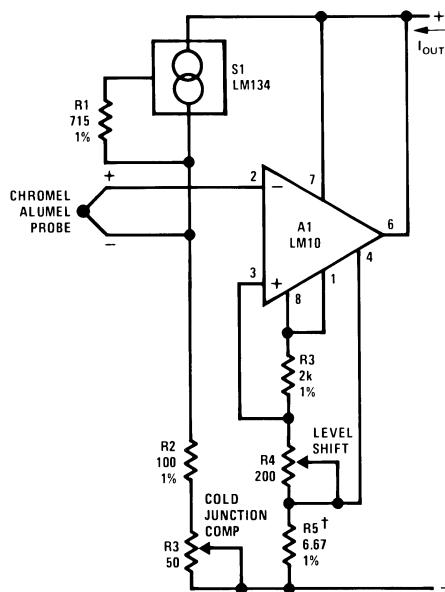
*Scale Factor Trim

†Copper Wire Wound

$$1 \text{ mA} \leq I_{\text{OUT}} \leq 5 \text{ mA}$$

$$0.01 \leq \frac{I_{D2}}{I_{D1}} \leq 100$$

Thermocouple Transmitter

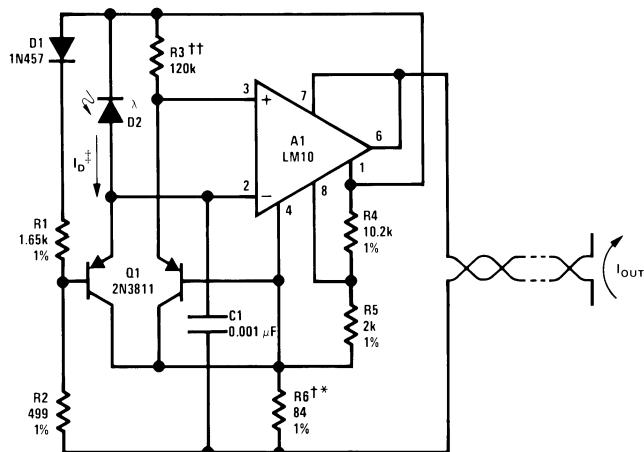


$$200^\circ\text{C} \leq T_p \leq 700^\circ\text{C}$$

1 mA \leq I_{OUT} \leq 5 mA

†Gain Trim

Logarithmic Light Sensor



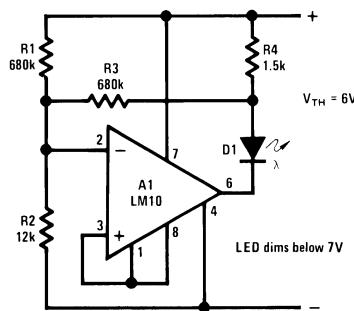
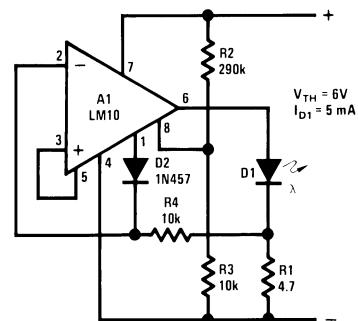
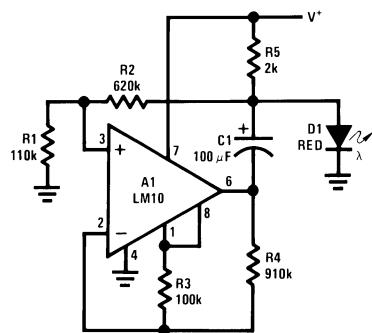
1 mA \leq I_{OUT} \leq 5 mA

$\pm 50 \mu\text{A} \leq I_D \leq 500 \mu\text{A}$

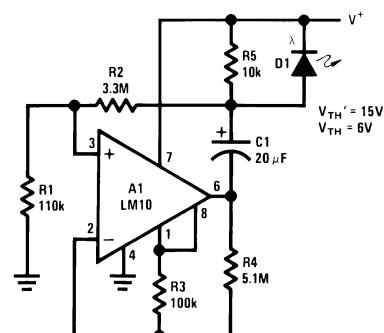
++Center Scale Trim

†Scale Factor Trim

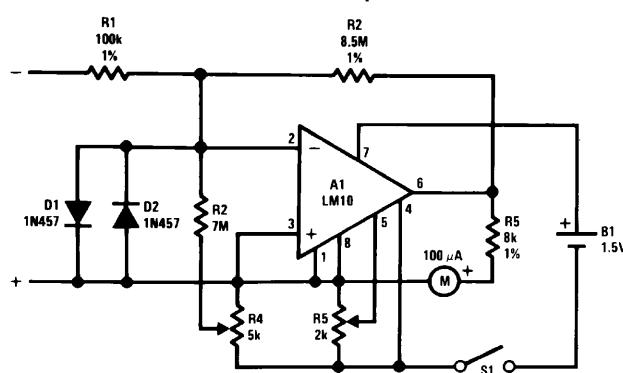
*Copper Wire Wound

Battery-level Indicator**Battery-threshold Indicator****Single-cell Voltage Monitor**

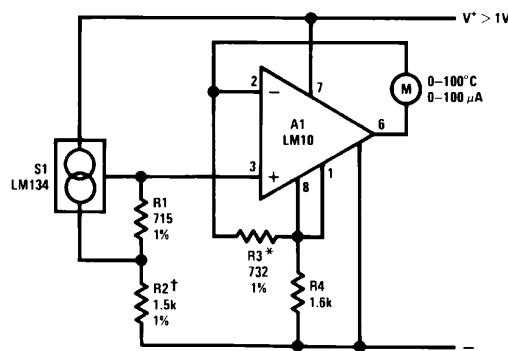
Flashes Above 1.2V
Rate Increases With
Voltage

Double-ended Voltage Monitor

Flash Rate Increases
Above 6V and Below 15V

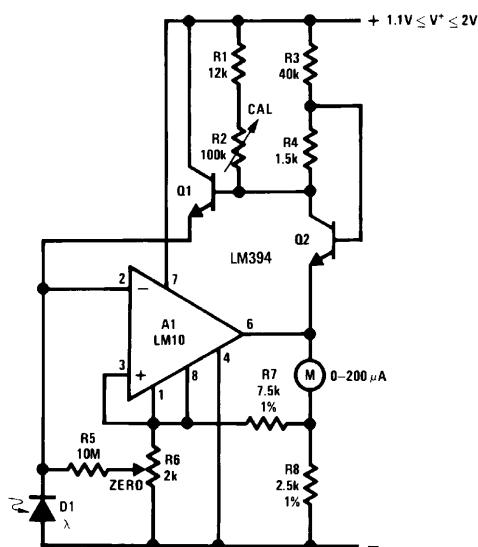
Meter Amplifier

Input
10 mV, 100nA
Full-Scale

Thermometer


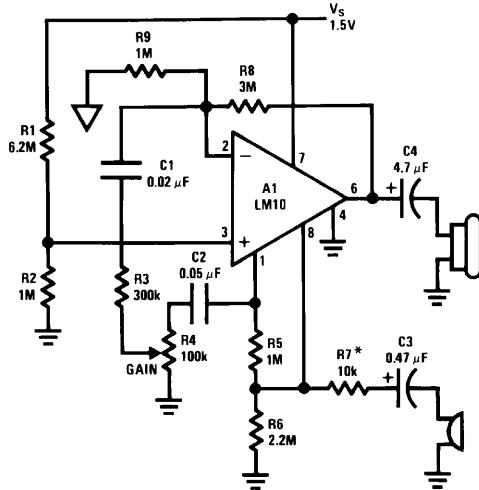
*Trim For Span

†Trim For Zero

Light Meter


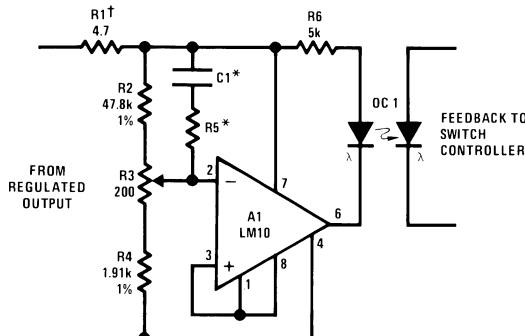
$1 \leq \lambda/\lambda_0 \leq 10^5$

Microphone Amplifier

 $Z_{OUT} \sim 680\Omega$ @ 5 kHz $A_V \leq 1k$ $f_1 \sim 100$ Hz $f_2 \sim 5$ kHz $R_L \sim 500$

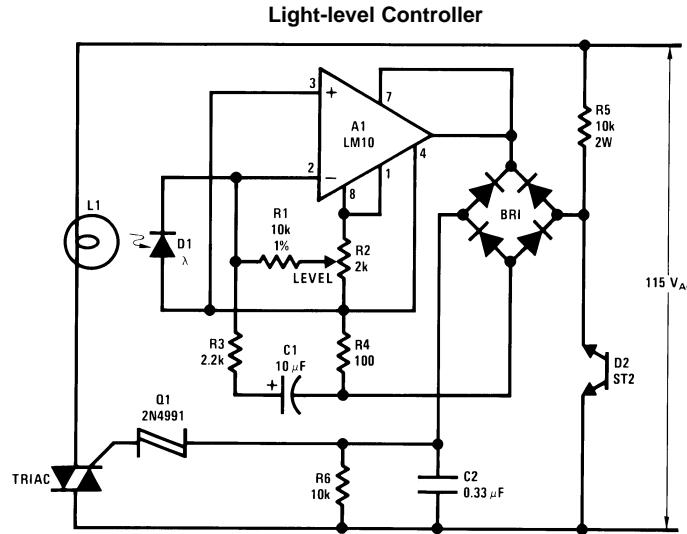
*Max Gain Trim

Isolated Voltage Sensor



†Controls "Loop Gain"

*Optional Frequency Shaping



Circuit descriptions available in application note AN-211 ([SNOA638](#)).

APPLICATION HINTS

With heavy amplifier loading to V_S^- , resistance drops in the V_S^- 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.

Table 1. Revision History

Date Released	Revision	Section	Changes
10/26/2010	A	New release to corporate format	1 MDS converted to standard corporate format. MNLM10-X Rev 0AL will be archived
03/26/2013	A	All sections	Changed layout of National Data Sheet to TI format

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
5962-8760401GA	Active	Production	TO-CAN (LMG) 8	20 JEDEC TRAY (5+1)	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	(LM10H/883, LM158H) 5962-8760401GA Q A CO 5962-8760401GA Q > T
LM10H/883	Active	Production	TO-CAN (LMG) 8	20 JEDEC TRAY (5+1)	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	(LM10H/883, LM158H) 5962-8760401GA Q A CO 5962-8760401GA Q > T

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

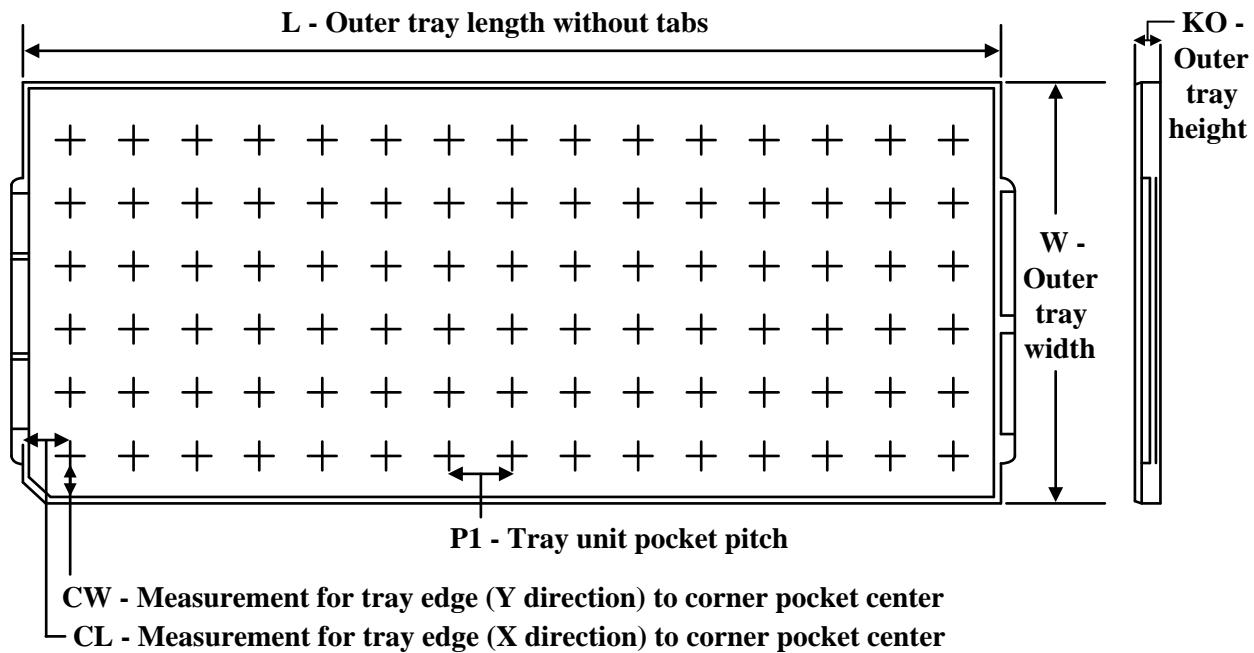
⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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TRAY


Chamfer on Tray corner indicates Pin 1 orientation of packed units.

*All dimensions are nominal

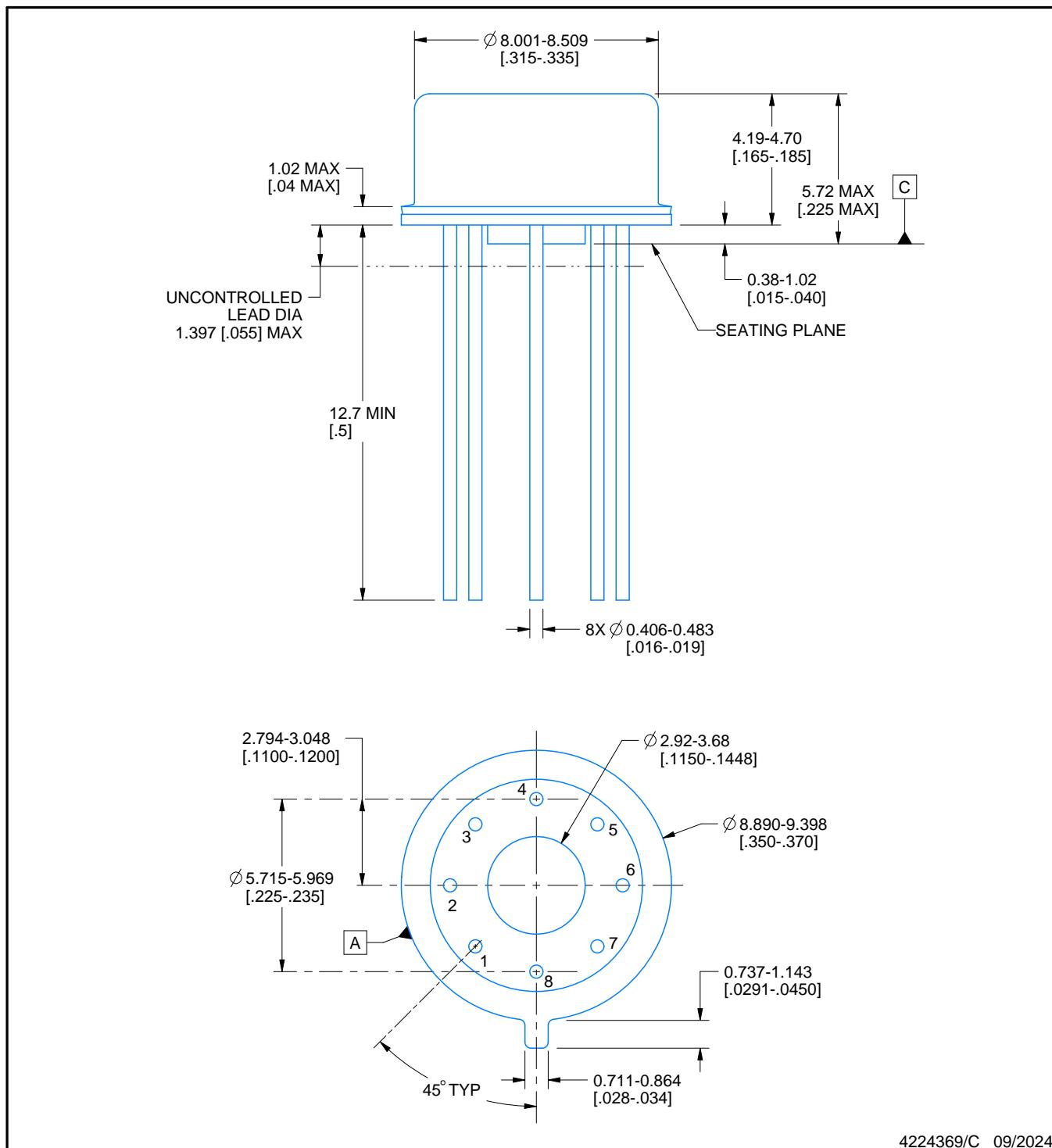
Device	Package Name	Package Type	Pins	SPQ	Unit array matrix	Max temperature (°C)	L (mm)	W (mm)	KO (µm)	P1 (mm)	CL (mm)	CW (mm)
5962-8760401GA	LMG	TO-CAN	8	20	2 X 10	150	126.49	61.98	8890	11.18	12.95	18.54
LM10H/883	LMG	TO-CAN	8	20	2 X 10	150	126.49	61.98	8890	11.18	12.95	18.54

PACKAGE OUTLINE

LMG0008A

TO-CAN - 5.72 mm max height

TRANSISTOR OUTLINE



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NOTES:

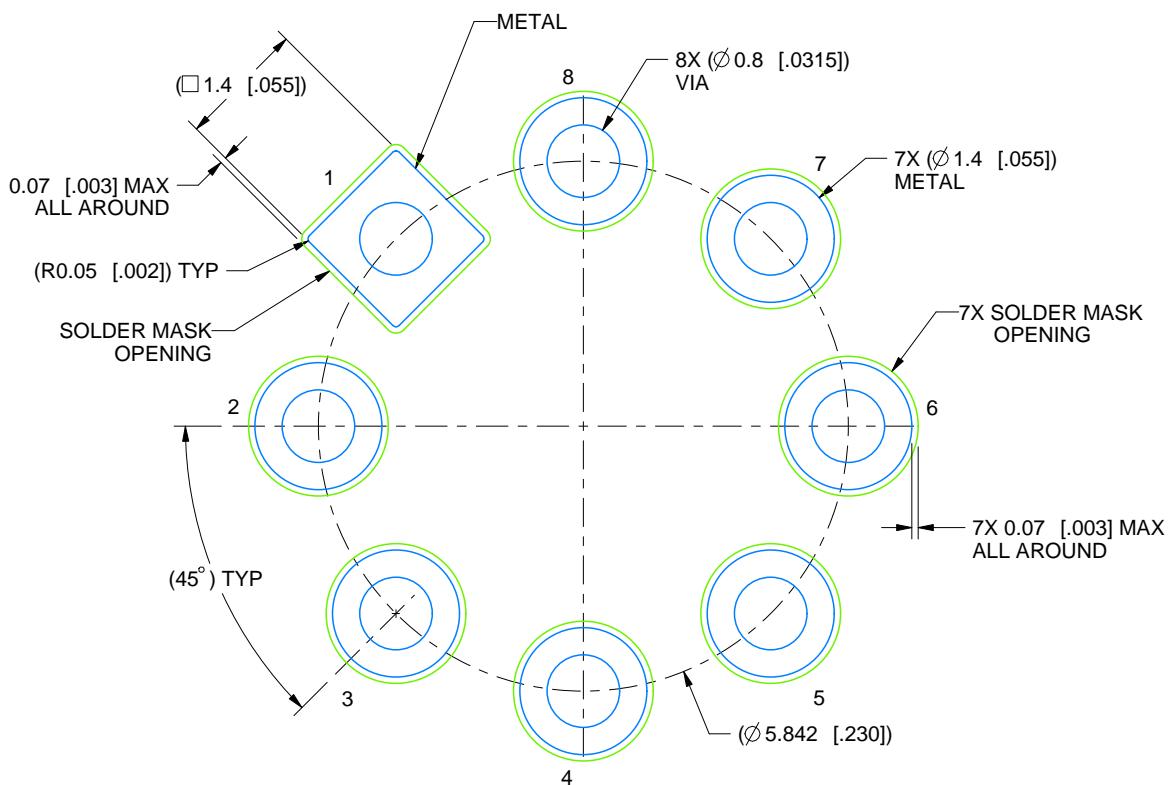
1. All linear dimensions are in millimeters [inches]. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

EXAMPLE BOARD LAYOUT

LMG0008A

TO-CAN - 5.72 mm max height

TRANSISTOR OUTLINE



LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE: 12X

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