LM10-MIL Operational Amplifier and Voltage Reference

1 Features

- Input Offset Voltage: 2 mV (Maximum)
- Input Offset Current: 0.7 nA (Maximum)
- Input Bias Current: 20 nA (Maximum)
- Reference Regulation: 0.1% (Maximum)
- Offset Voltage Drift: 2 µV/°C
- Reference Drift: 0.002%/°C

2 Applications

- Remote Amplifiers
- Battery-Level Indicators
- Thermocouple Transmitters
- Voltage and Current regulators

3 Description

The LM10-MIL is a monolithic linear IC consisting of a precision reference, an adjustable reference buffer, and an independent, high-quality operational amplifier.

The unit can operate from a total supply voltage as low as 1.1 V or as high as 40 V, drawing only 270 µA. A complementary output stage swings within 15 mV of the supply terminals or will deliver ±20-mA output current with ±0.4-V 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.

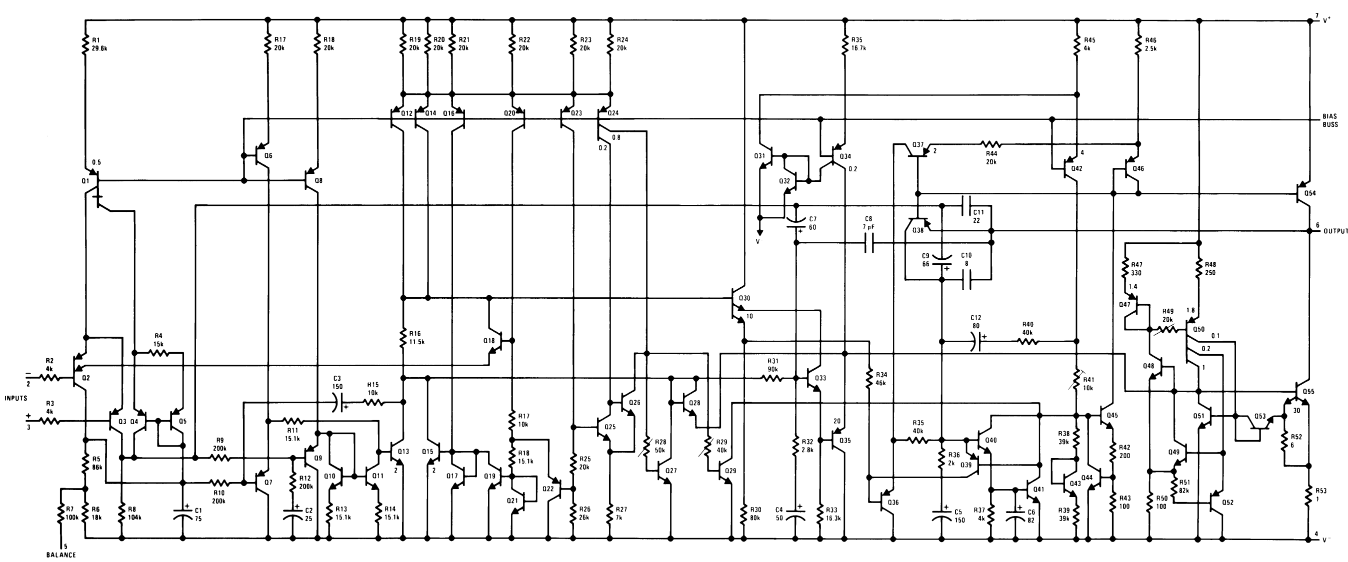
This series is available in the three standard temperature ranges, with the commercial part having relaxed limits. In addition, a low-voltage specification (suffix L) is available in the limited temperature ranges at a cost savings.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM10-MIL	SOIC (14)	8.992 mm × 7.498 mm
	SDIP (8)	8.255 mm × 8.255 mm
	PDIP (8)	9.81 mm × 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Operational Amplifier Schematic



(Pin numbers are for 8-pin packages)

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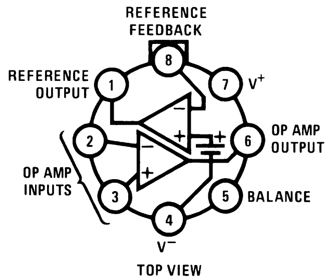
4 Revision History

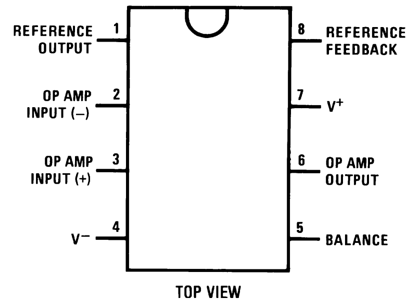
DATE	REVISION	NOTES
June 2017	*	Initial Release

5 Pin Configuration and Functions

NEV Package
8-Pin SDIP
Top View



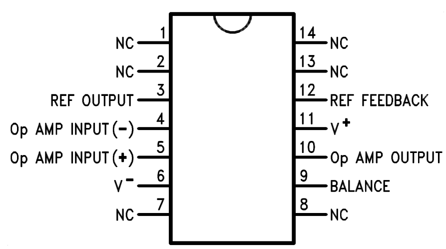
P Package
8-Pin PDIP
Top View



Pin Functions — 8-Pin SDIP or PDIP

PIN		I/O	DESCRIPTION
NAME	NO.		
Balance	5	I	Used for offset nulling
Op Amp Input (+)	3	I	Noninverting input of operational amplifier
Op Amp Input (–)	2	I	Inverting input of operational amplifier
Op Amp Output	6	O	Output terminal of operational amplifier
Reference Feedback	8	I	Feedback terminal of reference
Reference Output	1	O	Output terminal of reference
V+	7	I	Positive supply voltage
V–	4	I	Negative supply voltage

NPA Package
14-Pin SOIC
Top View



Pin Functions — 14-Pin SOIC

PIN		I/O	DESCRIPTION
NAME	NO.		
Balance	9	I	Used for offset nulling
NC	1, 2, 7, 8, 14, 13	—	No connection
Op Amp Input (–)	4	I	Inverting input of operational amplifier
Op Amp Input (+)	5	I	Noninverting input of operational amplifier
Op Amp Output	10	O	Output terminal of operational amplifier
Reference Feedback	12	I	Feedback terminal of reference
Reference Output	3	O	Output terminal of reference
V+	11	I	Positive supply voltage
V–	6	I	Negative supply voltage

6 Specifications

6.1 Absolute Maximum Ratings

See [1][2][3]

			MIN	MAX	UNIT
Total supply voltage				45	V
Differential input voltage[4]				±40	V
Power dissipation[5]			Internally limited		
Output short-circuit duration[6]			Continuous		
Lead temperature	TO	Soldering (10 seconds)		300	°C
	DIP	Soldering (10 seconds)		260	°C
		Vapor phase (60 seconds)		215	°C
		Infrared (15 seconds)		220	°C
Maximum junction temperature				150	°C
Storage temperature, T_{stg}			−55	150	°C

(1) Refer to RETS10X for LM10H military specifications.
(2) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(4) 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 $V_{IN} < V^{-}$.
(5) The maximum, operating-junction temperature is 150°C for the LM10-MIL. At elevated temperatures, devices must be derated based on package thermal resistance.
(6) 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.

6.2 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_S	Supply input voltage range (V–) – (V+)	1.2		40	V
V_{CM}	Common-mode voltage	(V–)		(V+) – 0.85	V
V_{REF}	Reference voltage		0.2		V
I_{REF}	Reference current	0		1	mA

6.3 Thermal Information

THERMAL METRIC[1]		LM10-MIL			UNIT
		NEV (SDIP)	NPA (SOIC)	P (PDIP)	
		8 PINS	14 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	150	90	87	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	45	—	—	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.4 Electrical Characteristics

T_J=25°C unless otherwise specified[(1)]

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input offset voltage	T_J=25°C		0.3	2	mV
	$T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])			3	mV
Input offset current[(2)]	T_J=25°C		0.25	0.7	nA
	$T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])			1.5	nA
Input bias current	T_J=25°C		10	20	nA
	$T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])			30	nA
Input resistance	T_J=25°C	250	500		kΩ
	$T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	150			kΩ
Large signal voltage gain	V_S = ±20 V, I_{OUT} = 0	120	400		V/mV
	V_{OUT} = ±19.95 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	80			V/mV
	V_S = ±20 V, V_{OUT} = ±19.4 V	50	130		V/mV
	I_{OUT} = ±20 mA, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	20			V/mV
	I_{OUT} = ±15 mA, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	20			V/mV
	V_S = ±0.6 V, I_{OUT} = ±2 mA	1.5	3		V/mV
	V_S = ±0.65 V, I_{OUT} = ±2 mA, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	1.5	3		V/mV
	V_{OUT} = ±0.4 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	0.5			V/mV
	V_{OUT} = ±0.3 V, V_{CM} = −0.4 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	0.5			V/mV
Shunt gain[(3)]	1.2 V ≤ V_{OUT} ≤ 40 V, R_L = 1.1 kΩ	14	33		V/mV
	1.3 V ≤ V_{OUT} ≤ 40 V, R_L = 1.1 kΩ, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	14	33		V/mV
	0.1 mA ≤ I_{OUT} ≤ 5 mA, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	6			V/mV
	1.5 V ≤ V^+ ≤ 40 V, R_L = 250 Ω	8	25		V/mV
	0.1 mA ≤ I_{OUT} ≤ 20 mA, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	4			V/mV
Common-mode rejection	−20 V ≤ V_{CM} ≤ 19.15 V	93	102		dB
	−20 V ≤ V_{CM} ≤ 19 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	93	102		dB
	V_S = ±20 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	87			dB
Supply-voltage rejection	−0.2 V ≥ V^- ≥ −39 V	90	96		dB
	V^+ = 1 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	84			dB
	V^+ = 1.1 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	84			dB
	1 V ≤ V^+ ≤ 39.8 V	96	106		dB
	1.1 V ≤ V^+ ≤ 39.8 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	96	106		dB
	V^- = −0.2 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])	90			dB
Offset voltage drift			2		μV/°C
Offset current drift			2		pA/°C
Bias current drift	T_C < 100°C		60		pA/°C
Line regulation	1.2 V ≤ V_S ≤ 40 V		0.001	0.003	%/V
	1.3 V ≤ V_S ≤ 40 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])		0.001	0.003	%/V
	0 ≤ I_{REF} ≤ 1 mA, V_{REF} = 200 mV, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])			0.006	%/V
Load regulation	0 ≤ I_{REF} ≤ 1 mA		0.01%	0.1%	
	$V^+ - V_{REF}$ ≥ 1 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])			0.15%	
	$V^+ - V_{REF}$ ≥ 1.1 V, $T_{MIN} \le T_J \le T_{MAX}$ (see [(1)])			0.15%	

(1) These specifications apply for $V^- \le V_{CM} \le V^+ - 0.85$ V, 1 V ($T_{MIN} \le T_J \le T_{MAX}$), 1.2 V, 1.3 V ($T_{MIN} \le T_J \le T_{MAX}$) < $V_S \le V_{MAX}$, V_{REF} = 0.2 V and 0 ≤ I_{REF} ≤ 1 mA, unless otherwise specified: V_{MAX} = 40 V for the standard part and 6.5 V for the low voltage part. The full-temperature-range operation is −55°C to 125°C for the LM10-MIL. The specifications do not include the effects of thermal gradients ($\tau_1 \simeq$ 20 ms), die heating ($\tau_2 \simeq$ 0.2 s) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).
(2) For T_J > 90°C, I_{OS} may exceed 1.5 nA for $V_{CM} = V^-$. With T_J = 125°C and $V^- \le V_{CM} \le V^-$ + 0.1 V, I_{OS} ≤ 5 nA.
(3) This defines operation in floating applications such as the bootstrapped regulator or two-wire transmitter. Output is connected to the V^+ terminal of the IC and input common mode is referred to V^- (see *System Examples*). Effect of larger output-voltage swings with higher load resistance can be accounted for by adding the positive-supply rejection error.

Electrical Characteristics (continued)

T_J=25°C unless otherwise specified[1]

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Amplifier gain	0.2 V ≤ V_{REF} ≤ 35 V	T_J=25°C	50	75		V/mV
		T_{MIN} ≤ T_J ≤ T_{MAX} (see [1])	23			V/mV
Feedback sense voltage	T_J=25°C		195	200	205	mV
	T_{MIN} ≤ T_J ≤ T_{MAX} (see [1])		194		206	mV
Feedback current	T_J=25°C			20	50	nA
	T_{MIN} ≤ T_J ≤ T_{MAX} (see [1])				65	nA
Reference drift				0.002		%/°C
Supply current	T_J=25°C			270	400	µA
	T_{MIN} ≤ T_J ≤ T_{MAX} (see [1])				500	µA
Supply current change	1.2 V ≤ V_S ≤ 40 V	T_J=25°C		15		µA
		T_{MIN} ≤ T_J ≤ T_{MAX} (see [1])			75	
	1.3 V ≤ V_S ≤ 40 V	T_J=25°C		15		µA
		T_{MIN} ≤ T_J ≤ T_{MAX} (see [1])			75	

6.5 Typical Characteristics

6.5.1 Typical Characteristics (Op Amp)

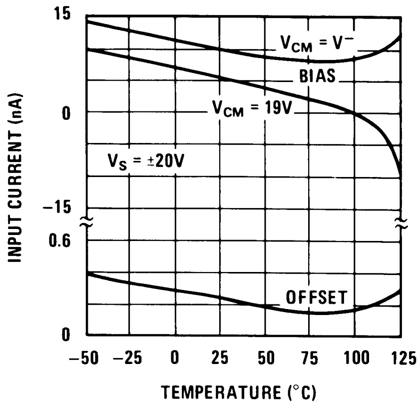


Figure 1. Input Current

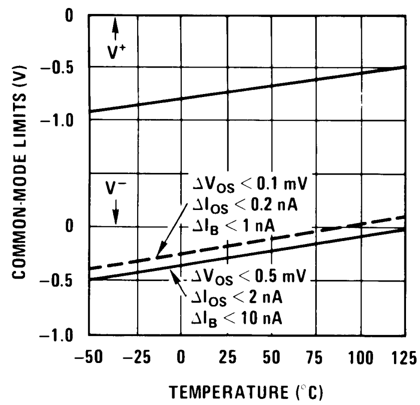


Figure 2. Common-Mode Limits

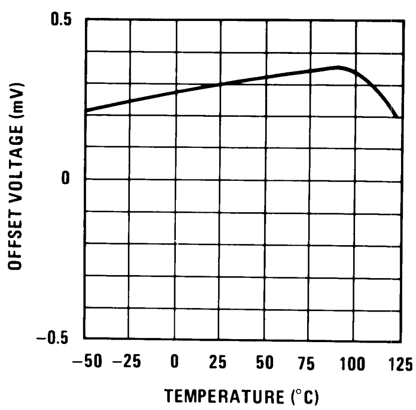


Figure 3. Output Voltage Drift

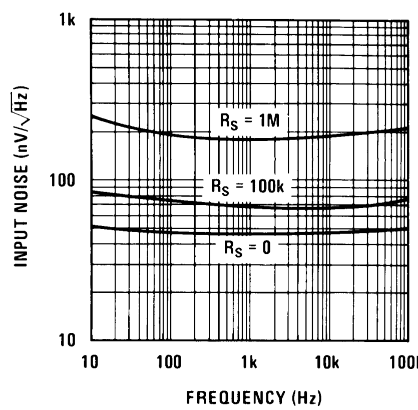


Figure 4. Input Noise Voltage

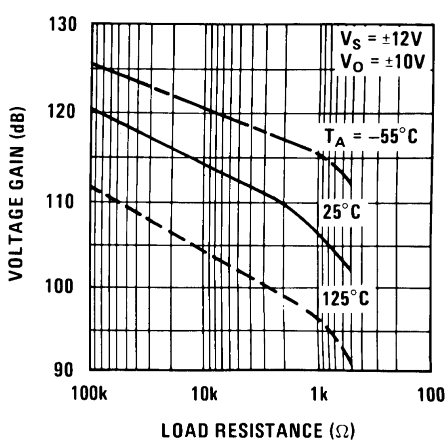


Figure 5. DC Voltage Gain

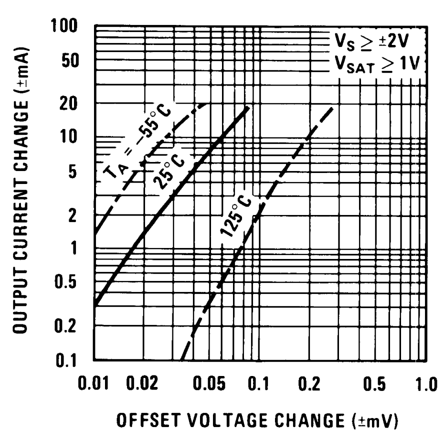


Figure 6. Transconductance

Typical Characteristics (Op Amp) (continued)

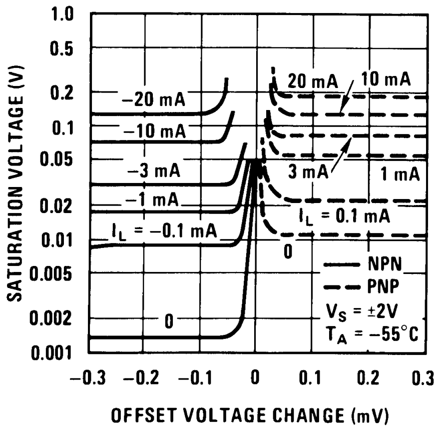


Figure 7. Output Saturation Characteristics

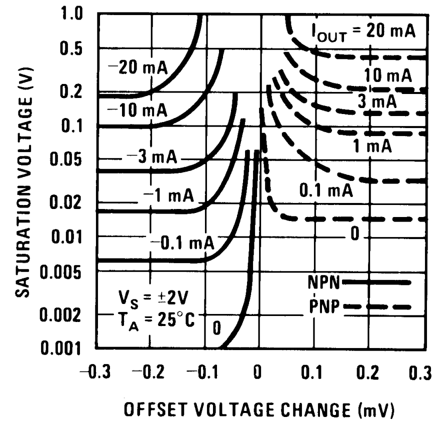


Figure 8. Output Saturation Characteristics

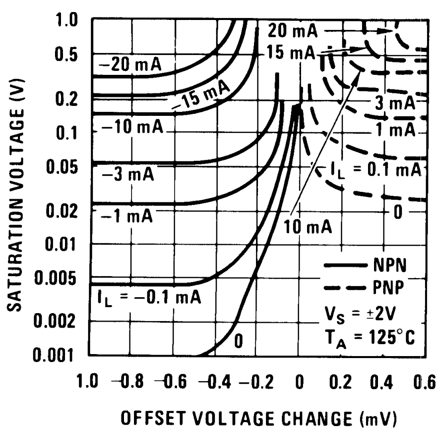


Figure 9. Output Saturation Characteristics

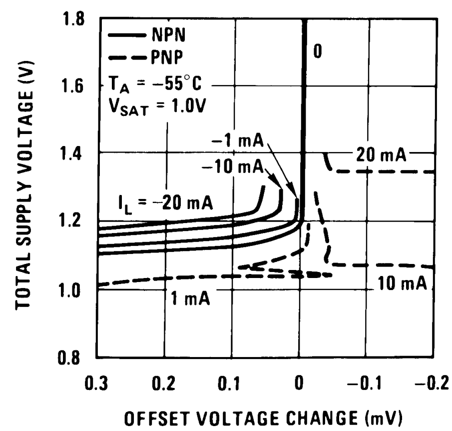


Figure 10. Minimum Supply Voltage

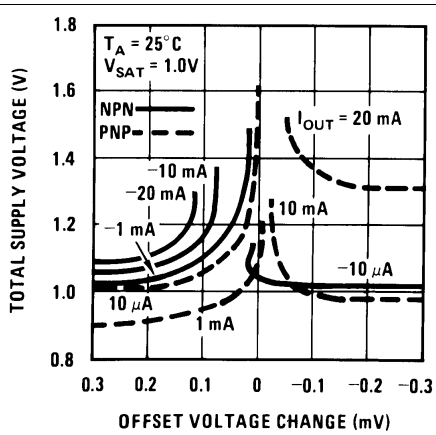


Figure 11. Minimum Supply Voltage

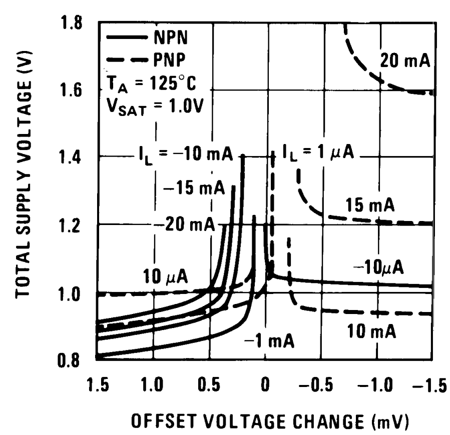


Figure 12. Minimum Supply Voltage

Typical Characteristics (Op Amp) (continued)

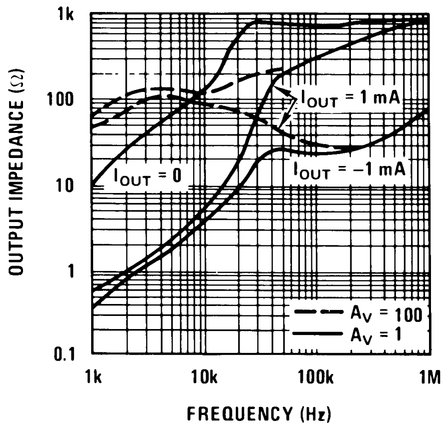


Figure 13. Output Impedance

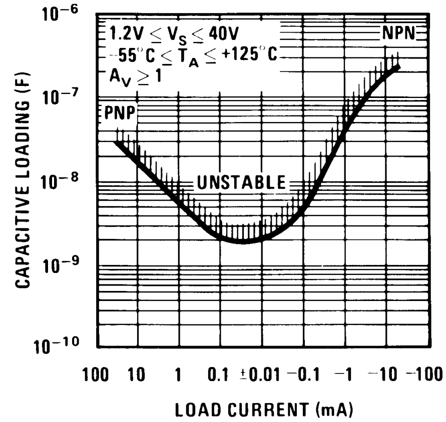


Figure 14. Typical Stability Range

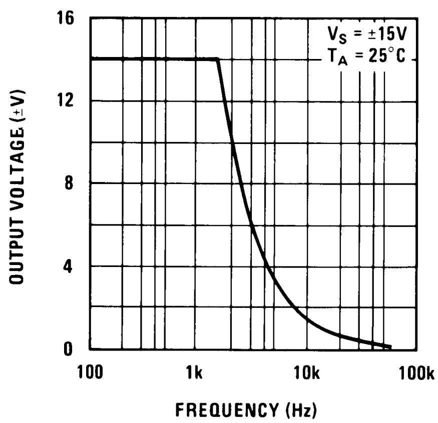


Figure 15. Large Signal Response

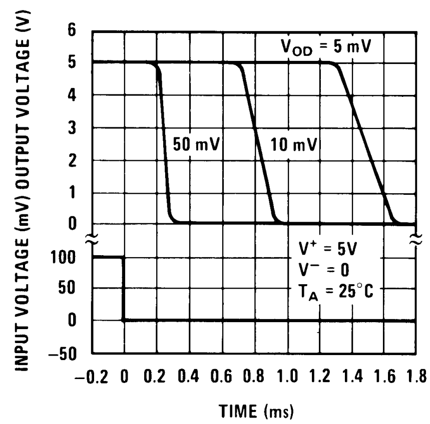


Figure 16. Comparator Response Time For Various Input Overdrives

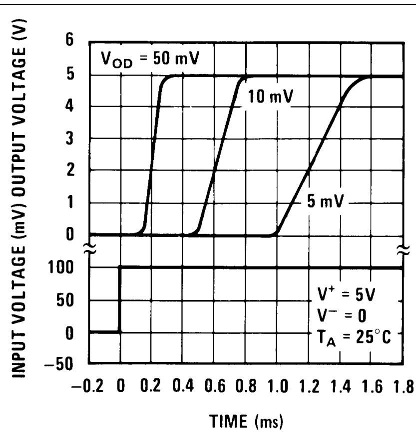


Figure 17. Comparator Response Time For Various Input Overdrives

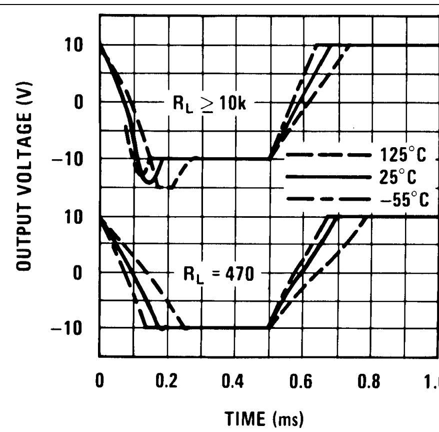


Figure 18. Follower Pulse Response

Typical Characteristics (Op Amp) (continued)

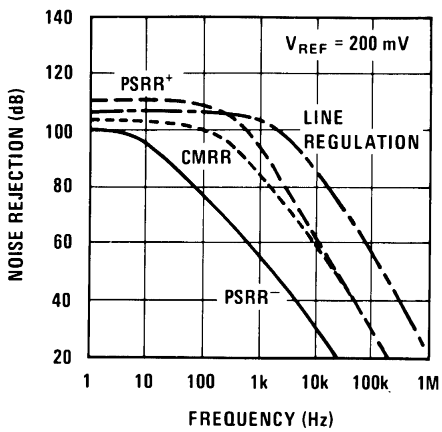


Figure 19. Noise Rejection

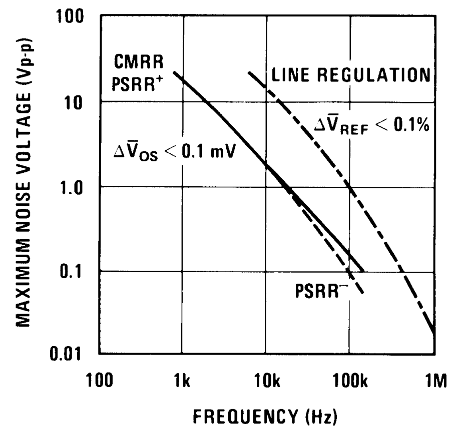


Figure 20. Rejection Slew Limiting

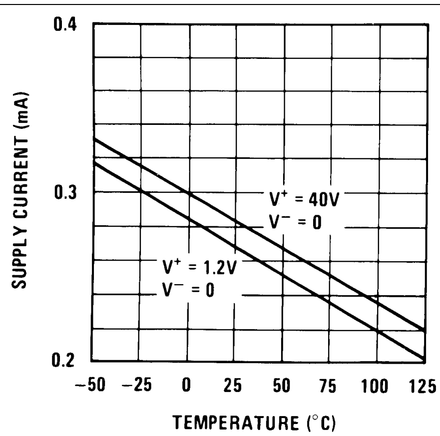


Figure 21. Supply Current

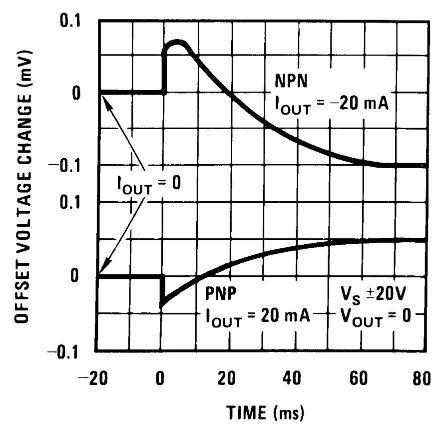


Figure 22. Thermal Gradient Feedback

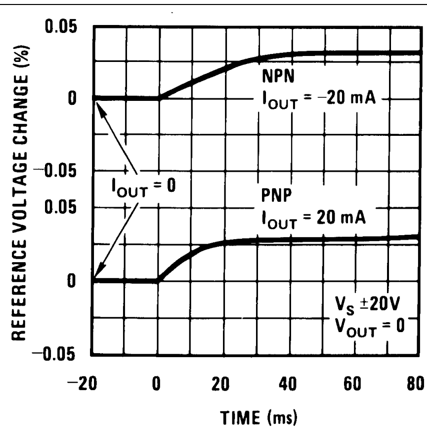


Figure 23. Thermal Gradient Cross-Coupling

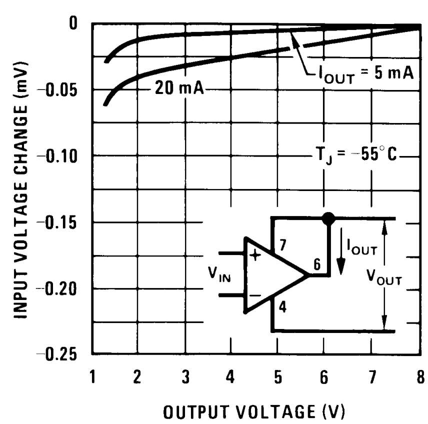


Figure 24. Shunt Gain

Typical Characteristics (Op Amp) (continued)

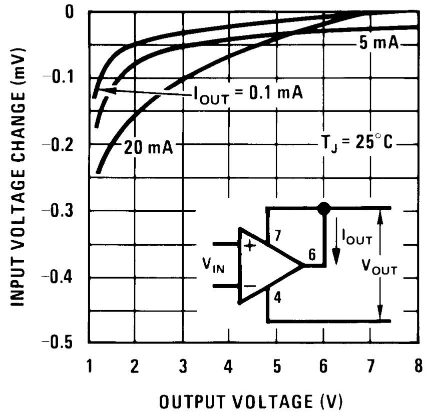


Figure 25. Shunt Gain

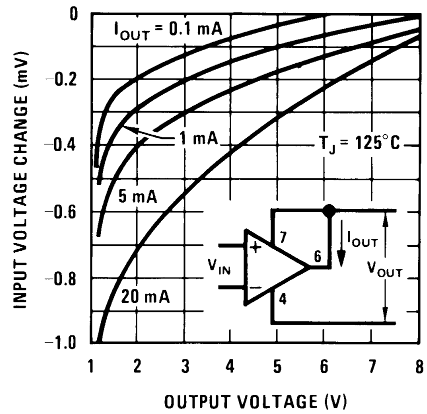


Figure 26. Shunt Gain

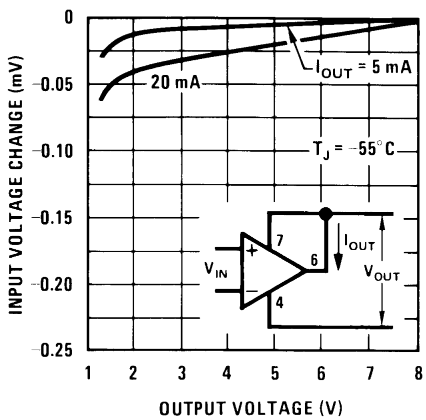


Figure 27. Shunt Gain

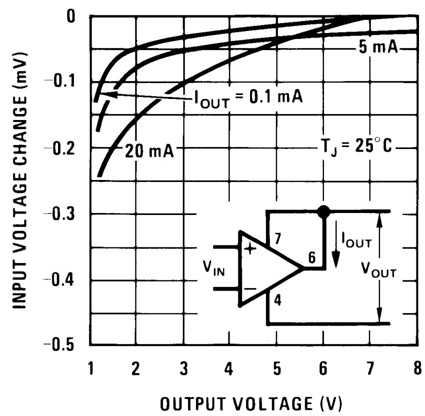


Figure 28. Shunt Gain

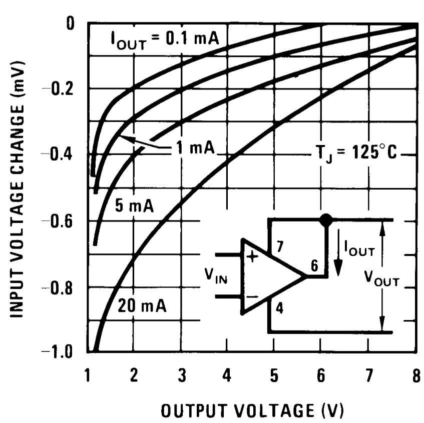


Figure 29. Shunt Gain

6.5.2 Typical Characteristics (Reference)

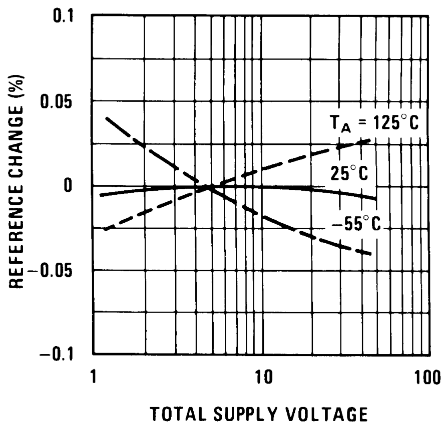


Figure 30. Line Regulation

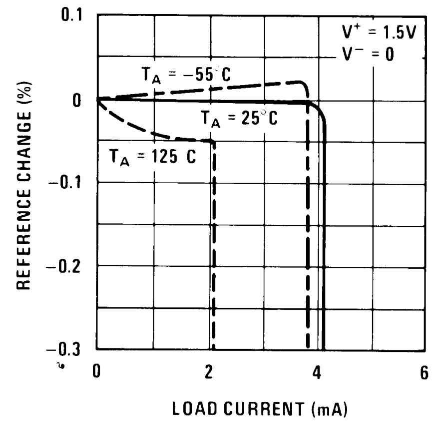


Figure 31. Load Regulation

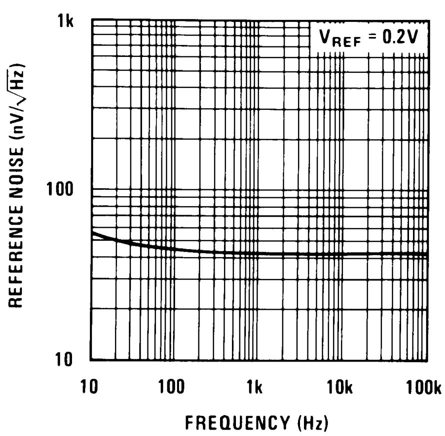


Figure 32. Reference Noise Voltage

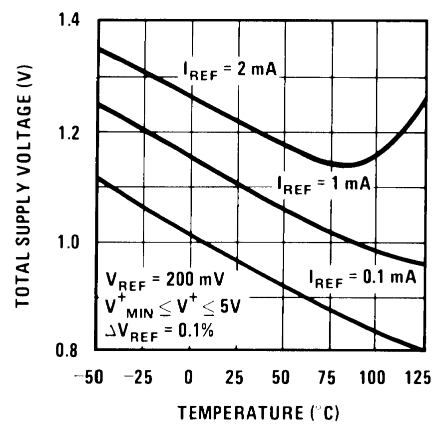


Figure 33. Minimum Supply Voltage

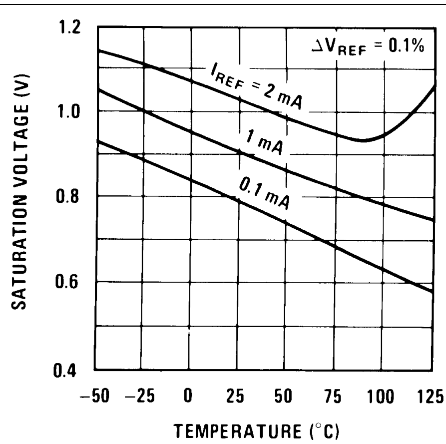


Figure 34. Output Saturation

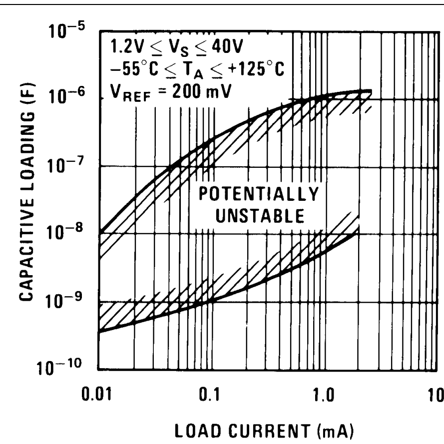


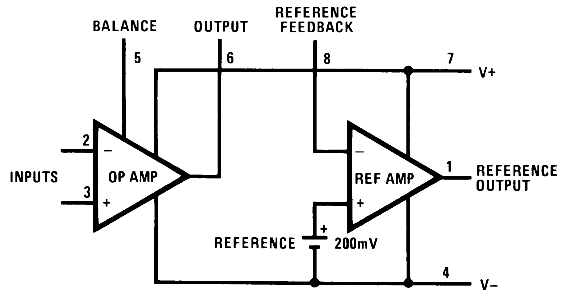
Figure 35. Typical Stability Range

7 Detailed Description

7.1 Overview

The LM10-MIL is a dual-operational amplifier combined with a voltage reference capable of a single-supply operation down to 1.1 V. It provides high overall performance, making it ideal for many general-purpose applications. The circuit can also operate in a floating mode, powered by residual voltage, independent of fixed supplies and it is well-protected from temperature drift.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Operating Characteristics

The LM10-MIL is specified for operation from 1.2 V to 40 V. Many of the specifications apply from –55ºC to 125ºC. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in electrical characteristics tables under *Specifications* and in the *Typical Characteristics* section.

7.3.2 Common-Mode Voltage Range

The input common-mode voltage range of the LM10-MIL extends from the negative rail to 0.85 V less than the positive rail.

7.3.3 Operational Amplifier

The minimum operating voltage is reduced to nearly one volt and the current gain is less affected by temperature, resulting in a fairly flat bias current over temperature.

7.3.4 Voltage Reference

Second-order nonlinearities are compensated for which eliminates the bowed characteristics of conventional designs, resulting in better temperature stability.

7.4 Device Functional Modes

7.4.1 Floating Mode

To use the device in a floating mode, the operational amplifier output is shorted to V+ which disables the PNP portion of the output stage. Thus, with a positive input signal, neither halves of the output conducts and the current between the supply terminals is equal to the quiescent supply current. With negative input signals, the NPN portion of the output begins to turn on, reaching the short circuit current for a few hundred microvolts overdrive.

7.4.2 Linear Operation

This device can also operate linearly while in the floating mode. An example of this is shown in the *Typical Application* section.

8 Application and Implementation

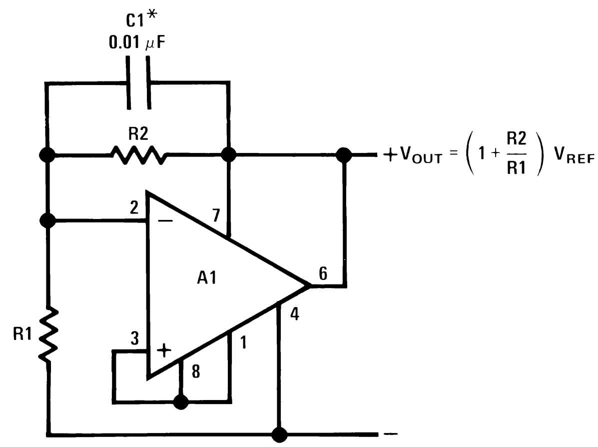
NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

With heavy amplifier loading to V⁻, resistance drops in the V⁻ lead can adversely affect reference regulation. Lead resistance can approach 1 Ω. Therefore, the common to the reference circuitry should be connected as close as possible to the package.

8.2 Typical Application



* required for capacitive loading

Figure 36. Shunt Voltage Regulator

8.2.1 Design Requirements

Table 1 lists the design parameters for this example.

Table 1. Design Parameters

DESIGN PARAMETERS	EXAMPLE VALUE
Ambient Temperature Range	–55°C to 125°C
Supply Voltage Range	1.2 V to 40 V
Common-Mode Input Range	(V–) to (V+) – 0.85 V

8.2.2 Detailed Design Procedure

Given that the transfer function of this circuit is:

$$V_{OUT} = (1 + \frac{R_2}{R_1})V_{REF} \quad (1)$$

the output can be set between 0.2 V and the breakdown voltage of the IC by selecting an appropriate value for R2. The circuit regulates for input voltages within a saturation drop of the output (typically 0.4 V at 20 mA and 0.15 V at 5 mA). The regulator is protected from shorts or overloads by current limiting and thermal shutdown.

Typical regulation is about 0.05% load and 0.003%/V line. A substantial improvement in regulation can be effected by connecting the operational amplifier as a follower and setting the reference to the desired output voltage. This has the disadvantage that the minimum input-output differential is increased to a little more than a diode drop. If the operational amplifier were connected for a gain of 2, the output could again saturate. But this requires an additional pair of precision resistors.

The regulator in Figure 36 could be made adjustable to zero by connecting the operational amplifier to a potentiometer on the reference output. This has the disadvantage that the regulation at the lower voltage settings is not as good as it might otherwise be.

8.2.3 Application Curve

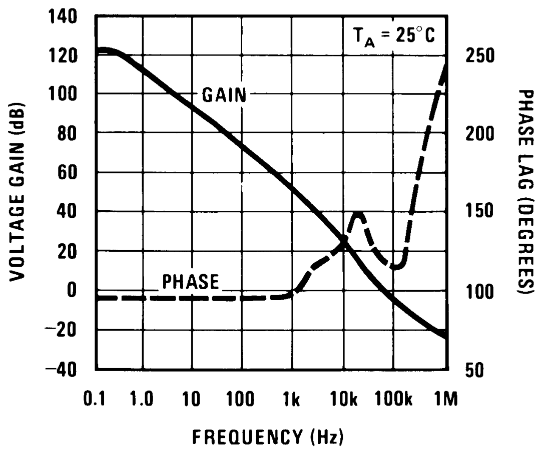


Figure 37. Frequency Response

8.3 System Examples

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

8.3.1 Operational Amplifier Offset Adjustment

(Pin numbers are for 8-pin packages)

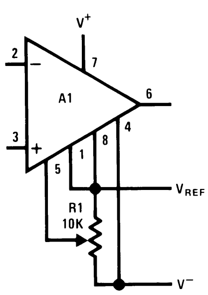


Figure 38. Standard

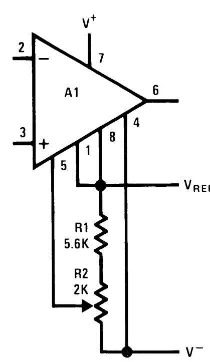


Figure 39. Limited Range

System Examples (continued)

(Pin numbers are for 8-pin packages)

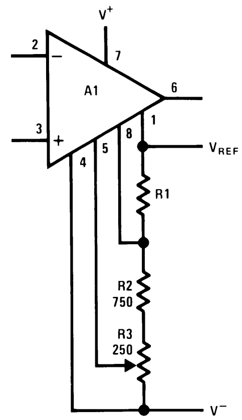


Figure 40. Limited Range With Boosted Reference

8.3.2 Positive Regulators

(Pin numbers are for 8-pin packages)

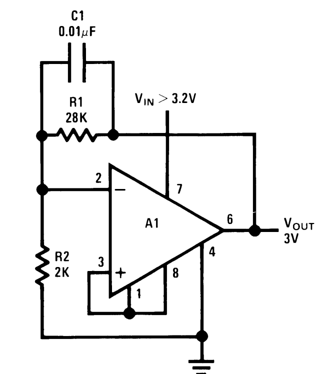


Figure 41. Low Voltage

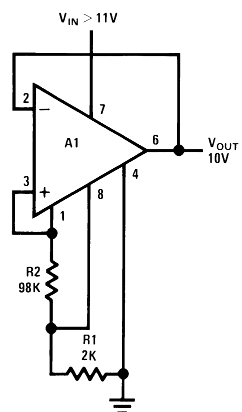
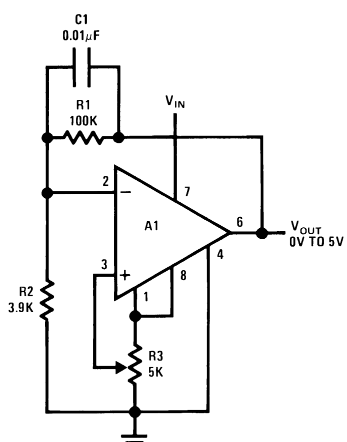


Figure 42. Best Regulation



Use only electrolytic output capacitors.

Figure 43. Zero Output

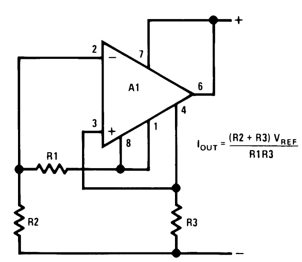
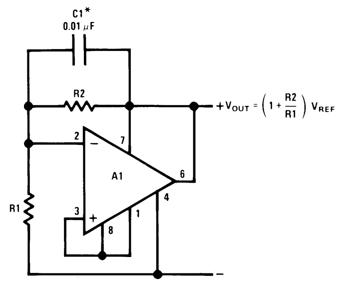


Figure 44. Current Regulator

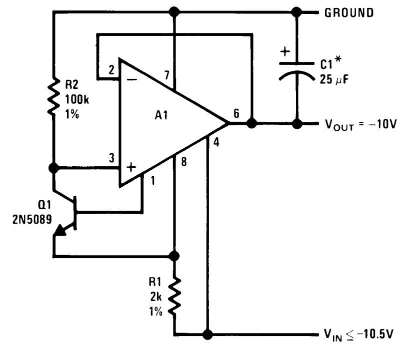
System Examples (continued)

(Pin numbers are for 8-pin packages)



Required For Capacitive Loading

Figure 45. Shunt Regulator



*Electrolytic

Figure 46. Negative Regulator

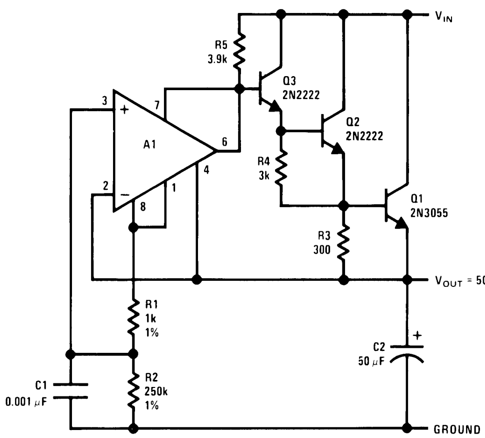
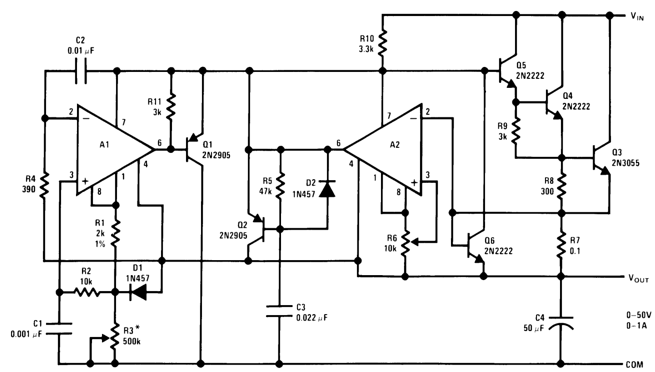
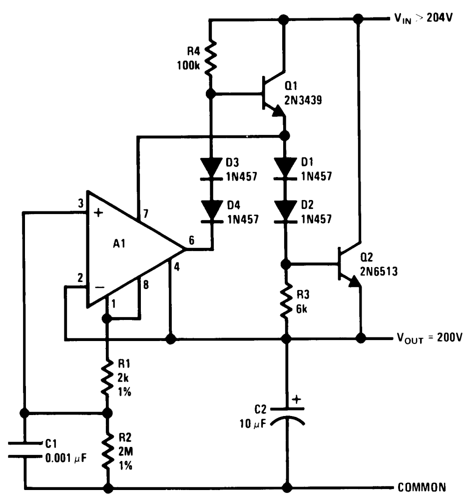


Figure 47. Precision Regulator



$^{*}V_{OUT}=10^{-4}$ R3

Figure 48. Laboratory Power Supply



$$V_{OUT} = \frac{R2}{R1} V_{REF}$$

Figure 49. HV Regulator

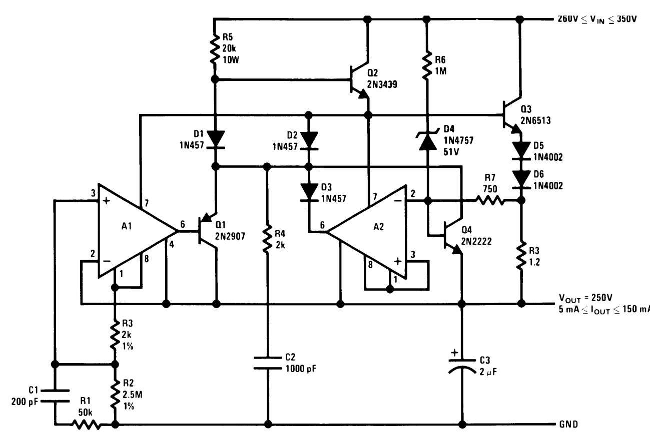
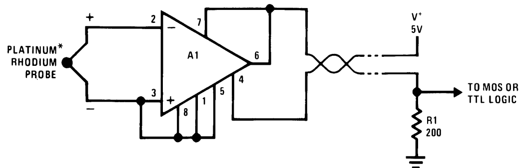


Figure 50. Protected HV Regulator

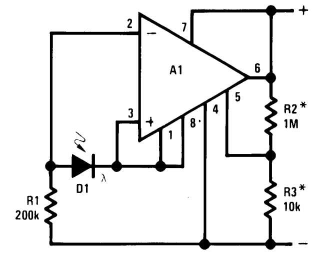
System Examples (continued)

(Pin numbers are for 8-pin packages)



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

Figure 51. Flame Detector



*Provides Hysteresis

Figure 52. Light Level Sensor

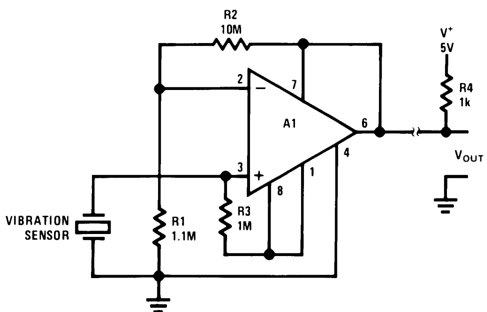


Figure 53. Remote Amplifier

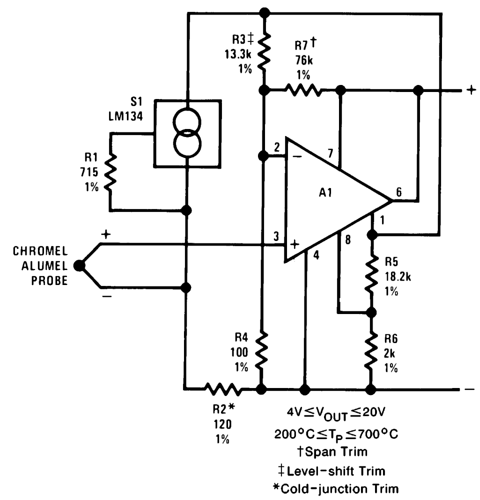


Figure 54. Remote Thermocouple Amplifier

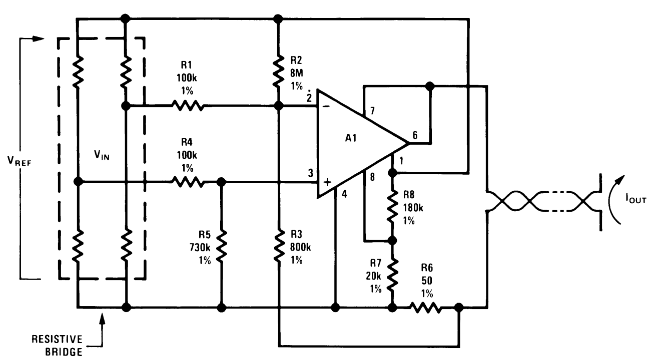
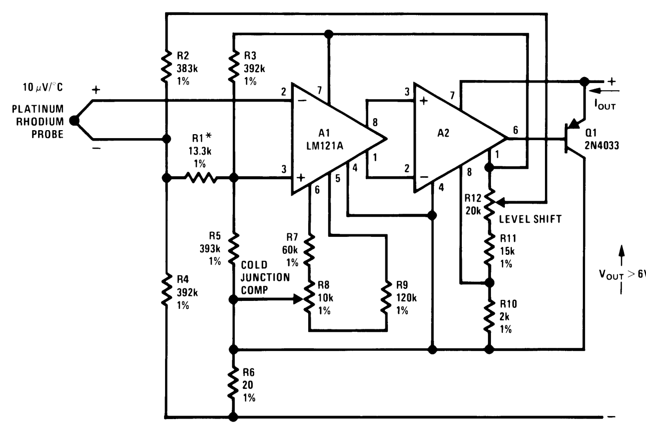


Figure 55. Transmitter for Bridge Sensor



10 mA≤I_{OUT}≤50 mA
500°C≤T_P≤1500°C
*Gain Trim

Figure 56. Precision Thermocouple Transmitter

System Examples (continued)

(Pin numbers are for 8-pin packages)

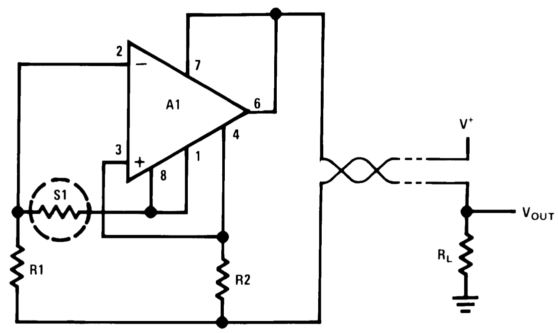
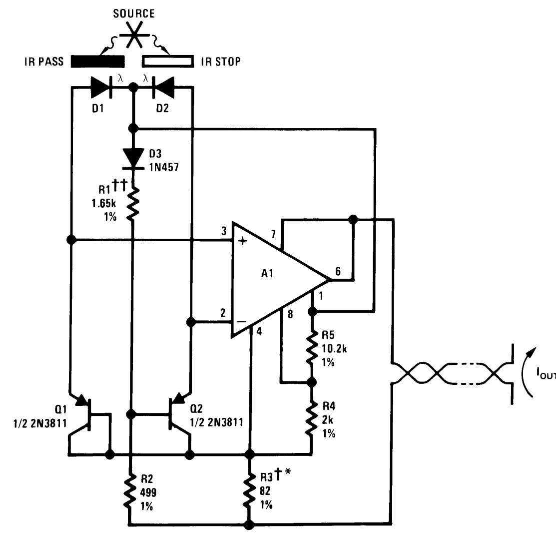


Figure 57. Resistance Thermometer Transmitter



††Level-shift Trim

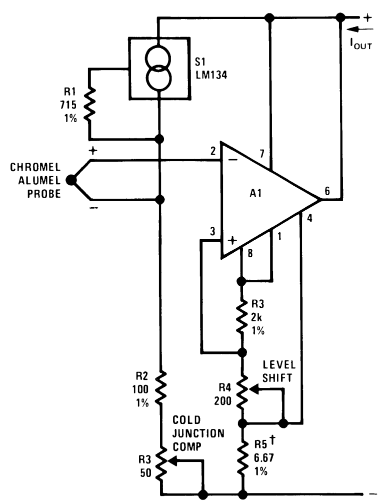
*Scale Factor Trim

†Copper Wire Wound

$1\ mA \le I_{OUT} \le 5\ mA$

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

Figure 58. Optical Pyrometer

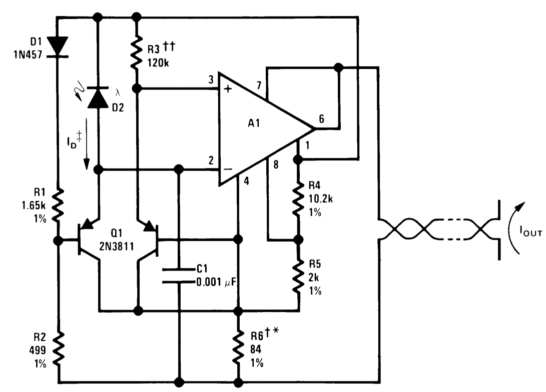


200°C≤T_p≤700°C

1 mA≤I_{OUT}≤5 mA

†Gain Trim

Figure 59. Thermocouple Transmitter



1 mA≤I_{OUT}≤5 mA

‡50 µA≤I_D≤500 µA

††Center Scale Trim

†Scale Factor Trim

*Copper Wire Wound

Figure 60. Logarithmic Light Sensor

System Examples (continued)

(Pin numbers are for 8-pin packages)

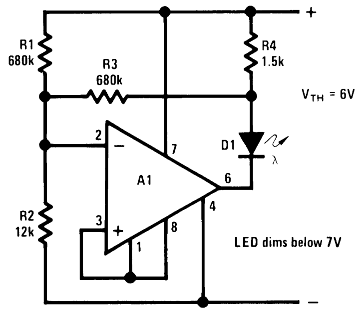


Figure 61. Battery-level Indicator

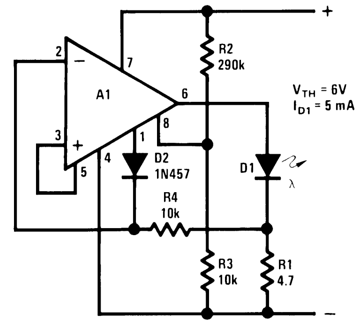
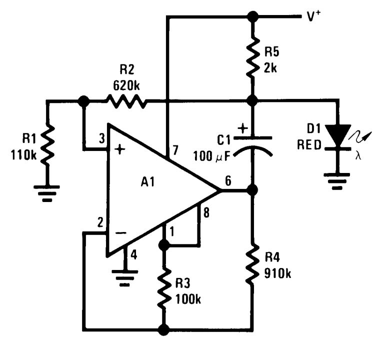
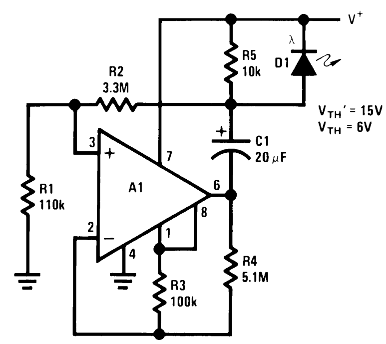


Figure 62. Battery-threshold Indicator



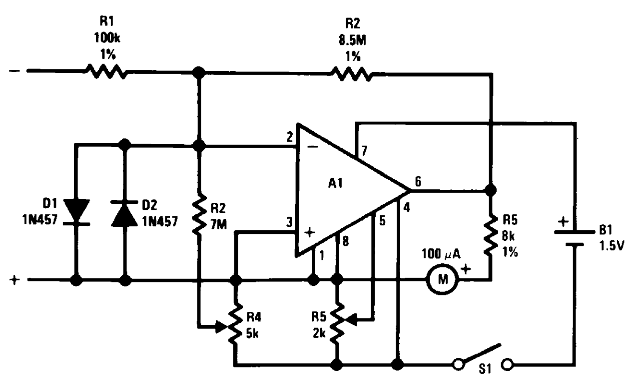
Flashes Above 1.2V
Rate Increases With
Voltage

Figure 63. Single-cell Voltage Monitor



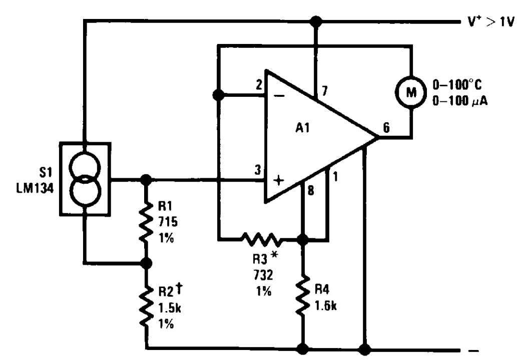
Flash Rate Increases
Above 6V and Below 15V

Figure 64. Double-ended Voltage Monitor



INPUT
10 mV, 100nA
FULL-SCALE

Figure 65. Meter Amplifier

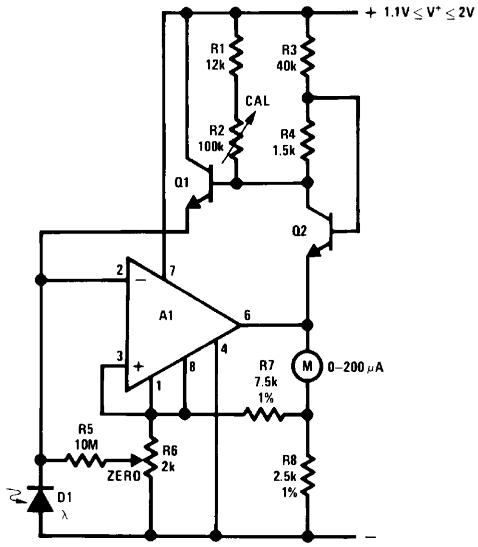


*Trim For Span
†Trim For Zero

Figure 66. Thermometer

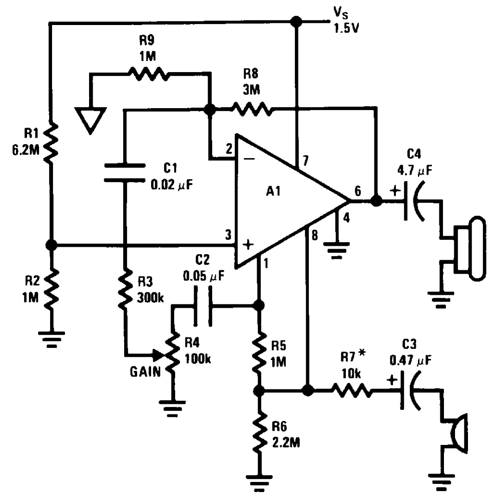
System Examples (continued)

(Pin numbers are for 8-pin packages)



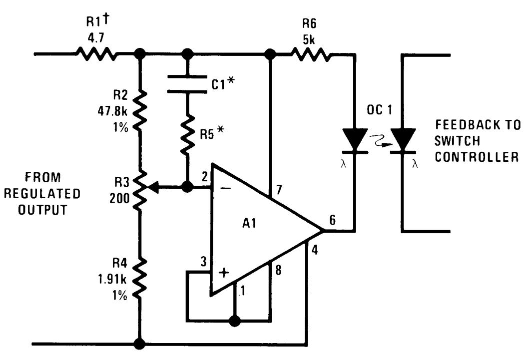
$1 \leq \lambda / \lambda_0 \leq 10^5$

Figure 67. Light Meter



Z_{OUT}~680Ω @ 5 kHz
A_V≤1k
f_1~100 Hz
f_2~5 kHz
R_L~500
*Max Gain Trim

Figure 68. Microphone Amplifier



†Controls “Loop Gain”
*Optional Frequency Shaping

Figure 69. Isolated Voltage Sensor

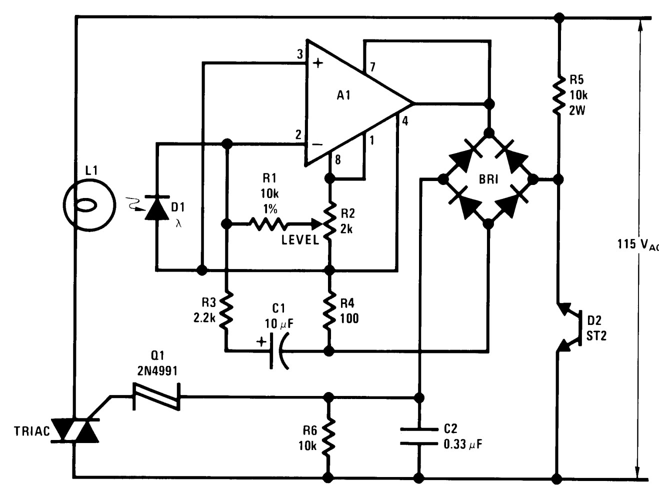


Figure 70. Light-Level Controller

System Examples (continued)

(Pin numbers are for 8-pin packages)

8.3.3 Reference and Internal Regulator

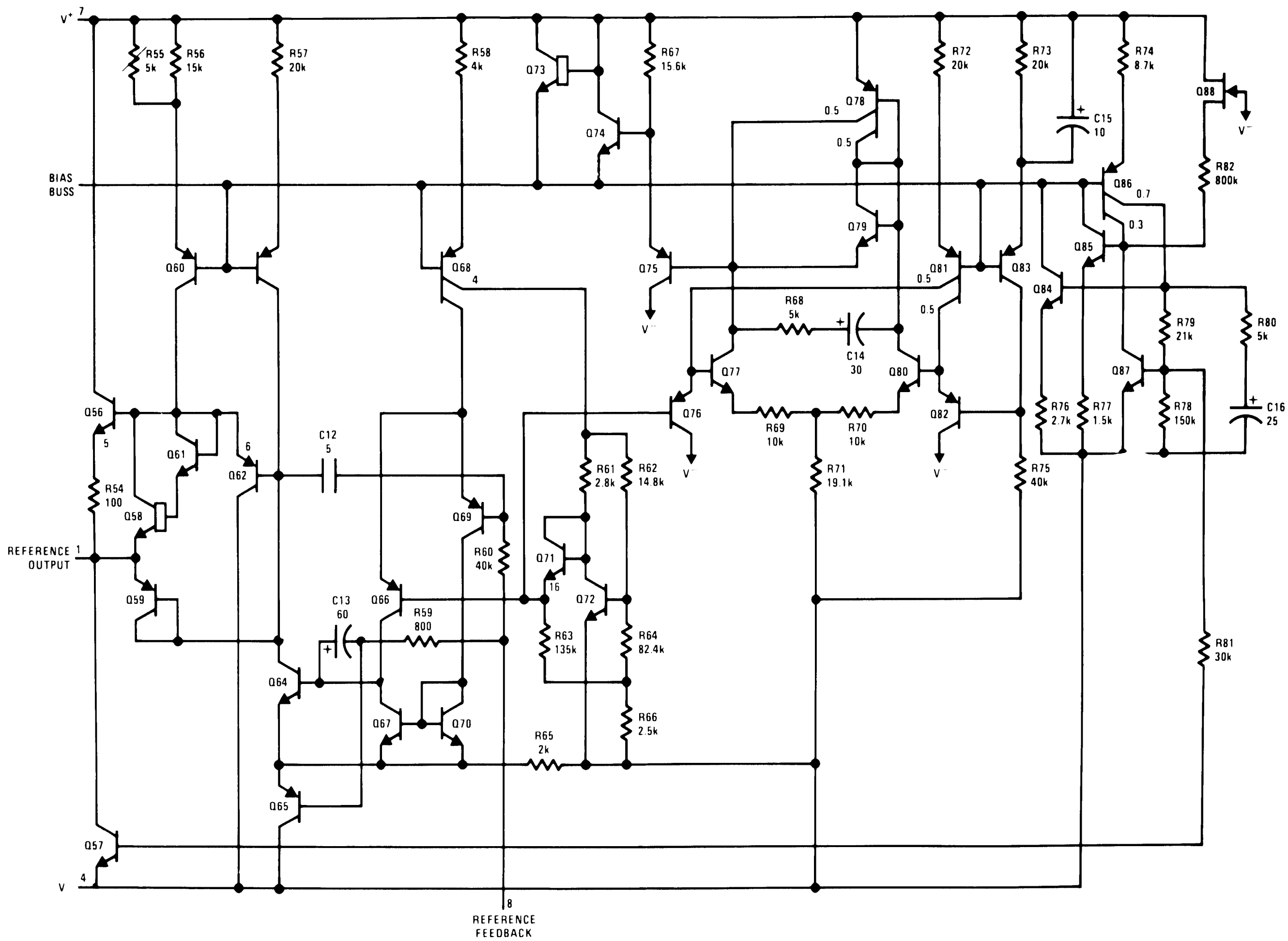


Figure 71. Reference and Internal Regulator

9 Power Supply Recommendations

The LM10-MIL is specified for operation from 1.2 V to 40 V unless otherwise stated. Many specifications apply from –55ºC to 125ºC. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the *Specifications* section.

> **CAUTION**
>
> Supply voltages larger than 40 V can permanently damage the device; see the *Absolute Maximum Ratings* table.

10 Layout

10.1 Layout Guidelines

For best operational performance of the device, good printed-circuit board (PCB) layout practices are recommended. Low-loss, 0.1-uF bypass capacitors should be connected between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable to single-supply applications.

10.2 Layout Example

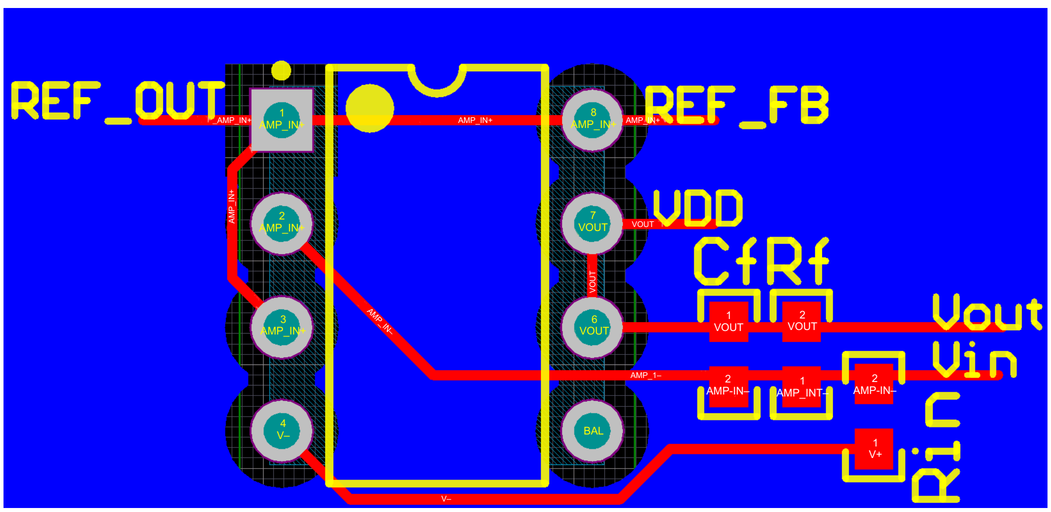


Figure 72. Layout Example

11 Device and Documentation Support

11.1 Device Support

11.1.1 Device Nomenclature

11.1.1.1 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^+ terminal of the IC. The load and power source are connected between the V^+ and V^- terminals, and input common-mode is referred to the V^- 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^-, 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.

11.2 Documentation Support

11.2.1 Related Documentation

For related documentation, see the following:

AN-211 New Op Amp Ideas, SNOA638

11.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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)
LM10BH	Active	Production	TO-CAN (LMG) | 8	500 | TRAY NON-STD	No	Call TI	Level-1-NA-UNLIM	-40 to 85	(LM10BH, LM10BH)
LM10BH/NOPB	Active	Production	TO-CAN (LMG) | 8	500 | TRAY NON-STD	Yes	Call TI	Level-1-NA-UNLIM	-40 to 85	(LM10BH, LM10BH)
LM10CH	Active	Production	TO-CAN (LMG) | 8	500 | TRAY NON-STD	No	Call TI	Level-1-NA-UNLIM	0 to 70	(LM10CH, LM10CH)
LM10CH/NOPB	Active	Production	TO-CAN (LMG) | 8	500 | OTHER	Yes	Call TI	Level-1-NA-UNLIM	0 to 70	(LM10CH, LM10CH)

(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.

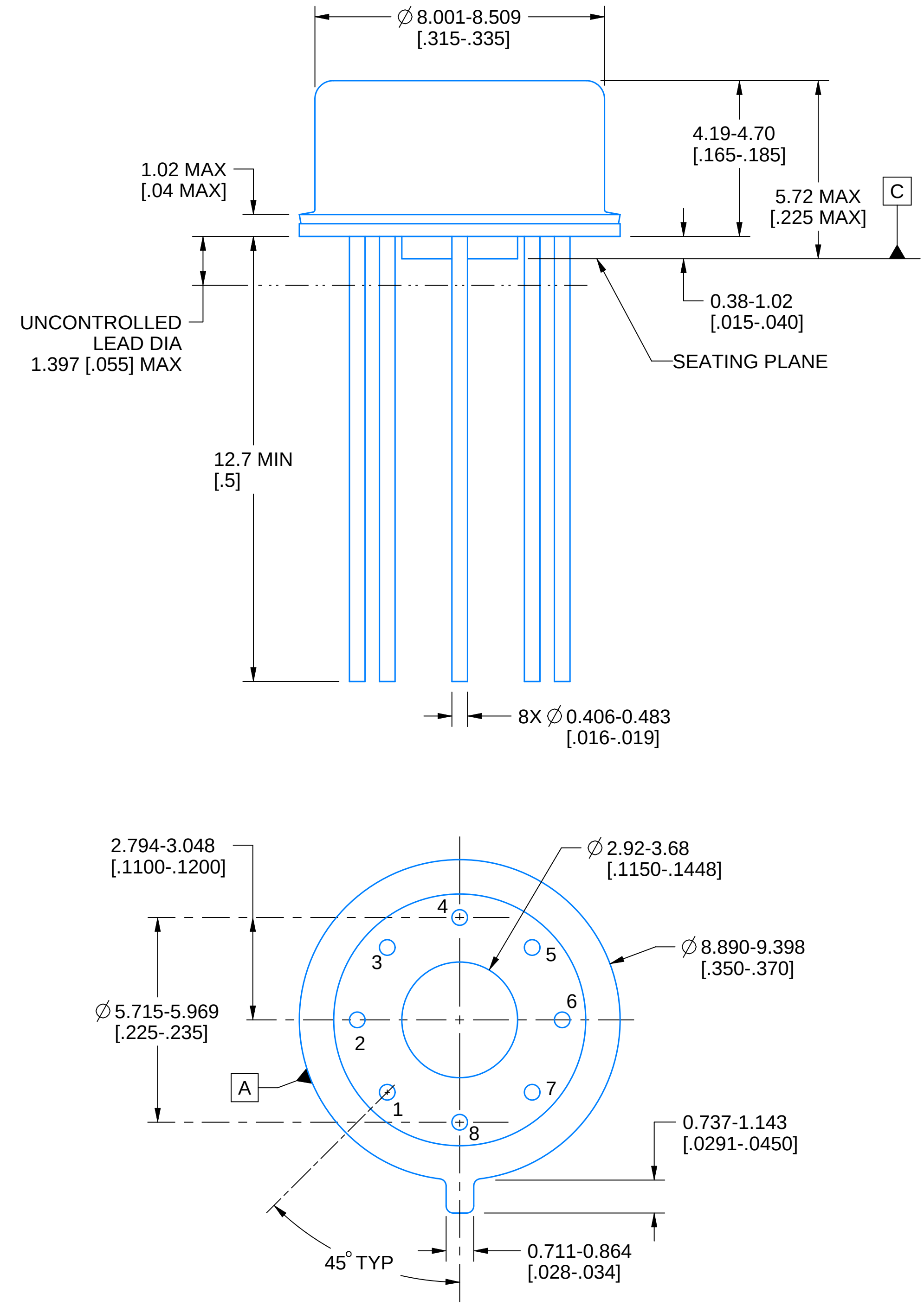
Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

LMG0008A

TO-CAN - 5.72 mm max height

TRANSISTOR OUTLINE



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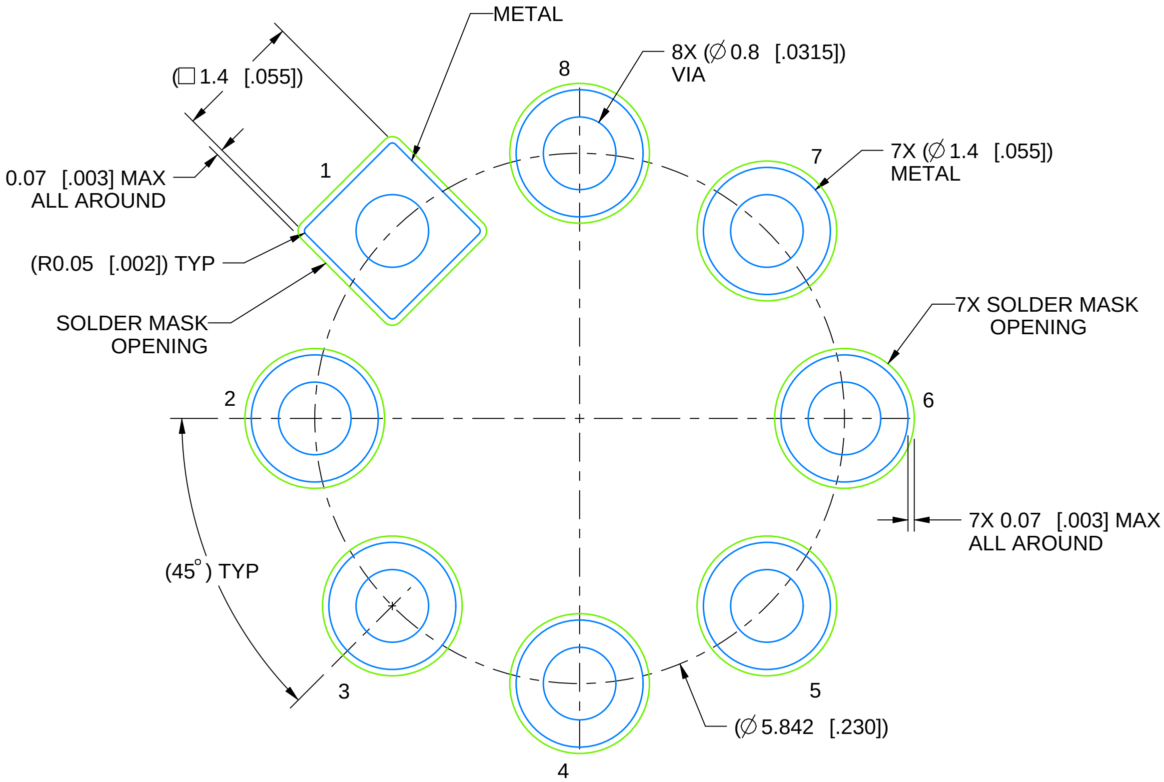
NOTES:

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.



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

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