National Semiconductor

May 1998

LM10
Operational Amplifier and Voltage Reference

General Description

The LM10 series are monolithic linear ICs 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 270µA. A complementary output stage swings within 15 mV of the supply terminals or will deliver ±20 mA output current with ±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.

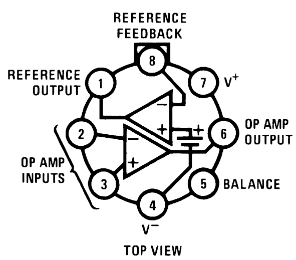
This series is available in the three standard temperature ranges, with the commercial part having relaxed limits. In addition, a low-voltage specification (suffix "L") is available in the limited temperature ranges at a cost savings.

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: 2µV/˚C
- reference drift: 0.002%/˚C

Connection and Functional Diagrams

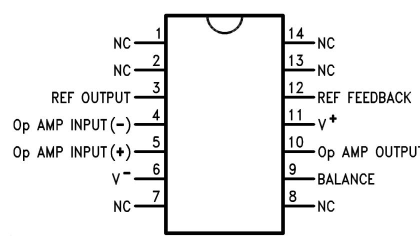
Metal Can Package (H)



DS005652-1

Order Number LM10BH, LM10CH, LM10CLH or LM10H/883 available per SMA# 5962-8760401 See NS Package Number H08A

Small Outline Package (WM)



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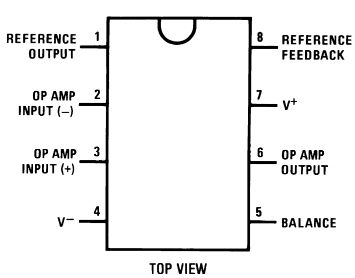
Order Number LM10CWM See NS Package Number M14B

Dual-In-Line Package (N)



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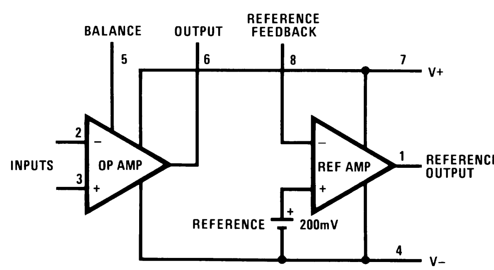
Order Number LM10CN or LM10CLN See NS Package Number N08E



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Absolute Maximum Ratings (Notes 1, 8)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

	LM10/LM10B/ LM10C	LM10BL/ LM10CL
Total Supply Voltage	45V	7V
Differential Input Voltage (Note 2)	±40V	±7V
Power Dissipation (Note 3)	internally limited	
Output Short-circuit Duration (Note 4)	continuous	
Storage-Temp. Range	−55˚C to +150˚C	
Lead Temp. (Soldering, 10 seconds)		
Metal Can	300˚C	
Lead Temp. (Soldering, 10 seconds) DIP	260˚C	
Vapor Phase (60 seconds)	215˚C	
Infrared (15 seconds)	220˚C	

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD rating is to be determined.

Maximum Junction Temperature

LM10	150˚C
LM10B	100˚C
LM10C	85˚C

Operating Ratings

Package Thermal Resistance

θ_{JA}	
H Package	150˚C/W
N Package	87˚C/W
WM Package	90˚C/W
θ_{JC}	
H Package	45˚C/W

Electrical Characteristics

T_J=25˚C, **$T_{MIN} \le T_J \le T_{MAX}$ (Boldface type refers to limits over temperature range)** (Note 5)

Parameter	Conditions	LM10/LM10B Min	LM10/LM10B Typ	LM10/LM10B Max	LM10C Min	LM10C Typ	LM10C Max	Units
Input offset voltage			0.3	2.0		0.5	4.0	mV
				3.0			**5.0**	mV
Input offset current			0.25	0.7		0.4	2.0	nA
(Note 6)				**1.5**			**3.0**	nA
Input bias current			10	20		12	30	nA
				30			**40**	nA
Input resistance		250	500		150	400		kΩ
		150			**115**			kΩ
Large signal voltage	V_S=±20V, I_{OUT}=0	120	400		80	400		V/mV
gain	V_{OUT}=±19.95V	**80**			**50**			V/mV
	V_S=±20V, V_{OUT}=±19.4V	50	130		25	130		V/mV
	I_{OUT}=±20 mA **(±15 mA)**	**20**			**15**			V/mV
	V_S=±0.6V **(0.65V)**, I_{OUT}=±2 mA	1.5	3.0		1.0	3.0		V/mV
	V_{OUT}=±0.4V **(±0.3V), V_{CM}=−0.4V**	**0.5**			**0.75**			V/mV
Shunt gain (Note 7)	1.2V **(1.3V)** ≤V_{OUT}≤40V,	14	33		10	33		V/mV
	R_L=1.1 kΩ							
	0.1 mA≤I_{OUT}≤5 mA	**6**			**6**			V/mV
	1.5V≤V^+≤40V, R_L=250Ω	8	25		6	25		V/mV
	0.1 mA≤I_{OUT}≤20 mA	**4**			**4**			V/mV
Common-mode	−20V≤V_{CM}≤19.15V **(19V)**	93	102		90	102		dB
rejection	V_S=±20V	**87**			**87**			dB
Supply-voltage	−0.2V≥V^-≥−39V	90	96		87	96		dB
rejection	V^+=1.0V **(1.1V)**	**84**			**84**			dB
	1.0V **(1.1V)** ≤V^+≤39.8V	96	106		93	106		dB
	V^-=−0.2V	**90**			**90**			dB
Offset voltage drift			2.0			5.0		µV/˚C
Offset current drift			2.0			5.0		pA/˚C
Bias current drift	T_C<100˚C		60			90		pA/˚C
Line regulation	1.2V **(1.3V)** ≤V_S≤40V		0.001	0.003		0.001	0.008	%/V
	0≤I_{REF}≤1.0 mA, V_{REF}=200 mV			**0.006**			**0.01**	%/V

Electrical Characteristics (Continued)

T_J=25˚C, **T_{MIN}≤T_J≤T_{MAX} (Boldface type refers to limits over temperature range)** (Note 5)

Parameter	Conditions	LM10/LM10B			LM10C			Units
		Min	Typ	Max	Min	Typ	Max	
Load regulation	0≤I_{REF}≤1.0 mA		0.01	0.1		0.01	0.15	%
	V^+−V_{REF}≥1.0V **(1.1V)**			**0.15**			**0.2**	%
Amplifier gain	0.2V≤V_{REF}≤35V	50	75		25	70		V/mV
		23			**15**			V/mV
Feedback sense		195	200	205	190	200	210	mV
voltage		**194**		**206**	**189**		**211**	mV
Feedback current			20	50		22	75	nA
				65			**90**	nA
Reference drift			0.002			0.003		%/˚C
Supply current			270	400		300	500	µA
				500			**570**	µA
Supply current change	1.2V **(1.3V)** ≤V_S≤40V		15	**75**		15	**75**	µA

Electrical Characteristics

T_J=25˚C, **T_{MIN}≤T_J≤T_{MAX} (Boldface type refers to limits over temperature range)** (Note 5)

Parameter	Conditions	LM10BL			LM10CL			Units
		Min	Typ	Max	Min	Typ	Max	
Input offset voltage			0.3	2.0		0.5	4.0	mV
				3.0			**5.0**	mV
Input offset current			0.1	0.7		0.2	2.0	nA
(Note 6)				**1.5**			**3.0**	nA
Input bias current			10	20		12	30	nA
				30			**40**	nA
Input resistance		250	500		150	400		kΩ
		150			**115**			kΩ
Large signal voltage	V_S=±3.25V, I_{OUT}=0	60	300		40	300		V/mV
gain	V_{OUT}=±3.2V	**40**			**25**			V/mV
	V_S=±3.25V, I_{OUT}=10 mA	10	25		5	25		V/mV
	V_{OUT}=±2.75 V	**4**			**3**			V/mV
	V_S=±0.6V **(0.65V),** I_{OUT}=±2 mA	1.5	3.0		1.0	3.0		V/mV
	V_{OUT}=±0.4V **(±0.3V),** V_{CM}=−0.4V	**0.5**			**0.75**			V/mV
Shunt gain (Note 7)	1.5V≤V^+≤6.5V, R_L=500Ω	8	30		6	30		V/mV
	0.1 mA≤I_{OUT}≤10 mA	**4**			**4**			V/mV
Common-mode	−3.25V≤V_{CM}≤2.4V **(2.25V)**	89	102		80	102		dB
rejection	V_S=±3.25V	**83**			**74**			dB
Supply-voltage	−0.2V≥V^-≥−5.4V	86	96		80	96		dB
rejection	V^+=1.0V **(1.2V)**	**80**			**74**			dB
	1.0V **(1.1V)** ≤V^+≤6.3V	94	106		80	106		dB
	V^-=0.2V	**88**			**74**			dB
Offset voltage drift			2.0			5.0		µV/˚C
Offset current drift			2.0			5.0		pA/˚C
Bias current drift			60			90		pA/˚C
Line regulation	1.2V **(1.3V)** ≤V_S≤6.5V		0.001	0.01		0.001	0.02	%/V
	0≤I_{REF}≤0.5 mA, V_{REF}=200 mV			**0.02**			**0.03**	%/V
Load regulation	0≤I_{REF}≤0.5 mA		0.01	0.1		0.01	0.15	%
	V^+−V_{REF}≥1.0V **(1.1V)**			**0.15**			**0.2**	%

Electrical Characteristics (Continued)

T_J=25˚C, **T_{MIN}≤T_J≤T_{MAX} (Boldface type refers to limits over temperature range)** (Note 5)

Parameter	Conditions	LM10BL			LM10CL			Units
		Min	Typ	Max	Min	Typ	Max	
Amplifier gain	0.2V≤V_{REF}≤5.5V	30	70		20	70		V/mV
		20			**15**			V/mV
Feedback sense voltage		195	200	205	190	200	210	mV
		194		**206**	**189**		**211**	mV
Feedback current			20	50		22	75	nA
				65			**90**	nA
Reference drift			0.002			0.003		%/˚C
Supply current			260	400		280	500	µA
				500			**570**	µA

Note 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 guarantee specific performance limits.

Note 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 $V_{IN}<V^-$.

Note 3: The maximum, operating-junction temperature is 150˚C for the LM10, 100˚C for the LM10B(L) and 85˚C for the LM10C(L). At elevated temperatures, devices must be derated based on package thermal resistance.

Note 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.

Note 5: These specifications apply for V^-≤V_{CM}≤V^+−0.85V **(1.0V),** 1.2V **(1.3V)** <V_S≤V_{MAX}, V_{REF}=0.2V and 0≤I_{REF}≤1.0 mA, unless otherwise specified: V_{MAX}=40V for the standard part and 6.5V for the low voltage part. Normal typeface indicates 25˚C limits. **Boldface type indicates limits and altered test conditions for full-temperature-range operation;** this is −55˚C to 125˚C for the LM10, −25˚C to 85˚C for the LM10B(L) and 0˚C to 70˚C for the LM10C(L). The specifications do not include the effects of thermal gradients (τ_1≅20 ms), die heating (τ_2≅0.2s) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).

Note 6: For T_J>90˚C, I_{OS} may exceed 1.5 nA for V_{CM}=V^-. With T_J=125˚C and V^-≤V_{CM}≤V^-+0.1V, I_{OS}≤5 nA.

Note 7: 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 typical applications). Effect of larger output-voltage swings with higher load resistance can be accounted for by adding the positive-supply rejection error.

Note 8: Refer to RETS10X for LM10H military specifications.

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.

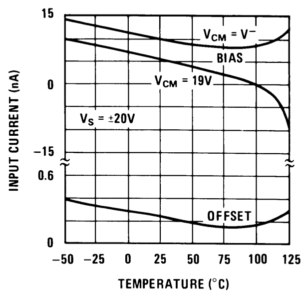
Reference amplifier gain: The ratio of the specified reference output change to the change in feedback sense voltage required to produce it.

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.

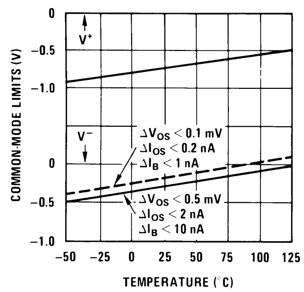
Typical Performance Characteristics (Op Amp)

Input Current



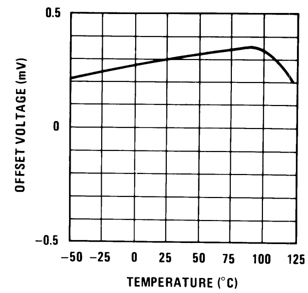
DS005652-18

Common Mode Limits



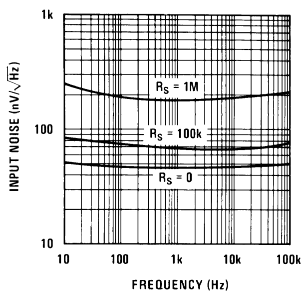
DS005652-19

Output Voltage Drift



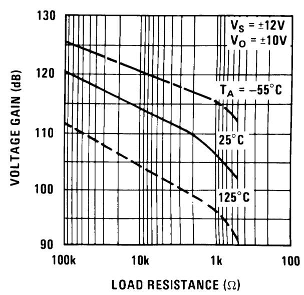
DS005652-20

Input Noise Voltage



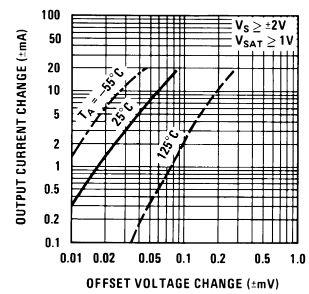
DS005652-21

DC Voltage Gain



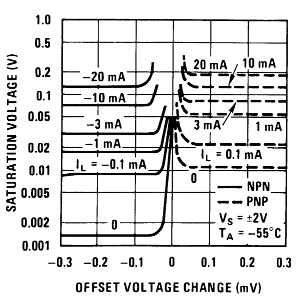
DS005652-22

Transconductance



DS005652-23

Output Saturation Characteristics



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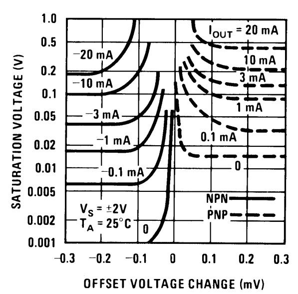
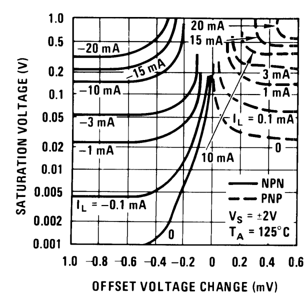
Output Saturation Characteristics



DS005652-25

Output Saturation Characteristics



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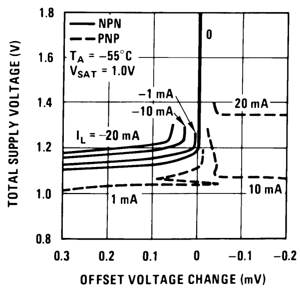
Typical Performance Characteristics (Op Amp) (Continued)

Minimum Supply Voltage



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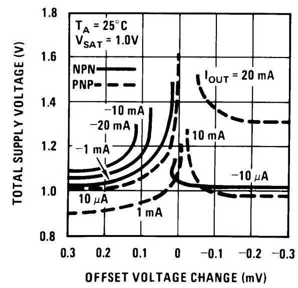
Minimum Supply Voltage



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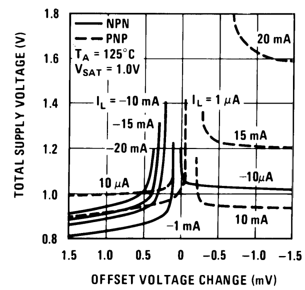
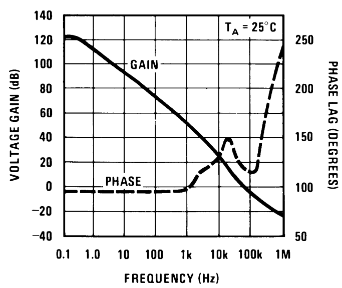
Minimum Supply Voltage



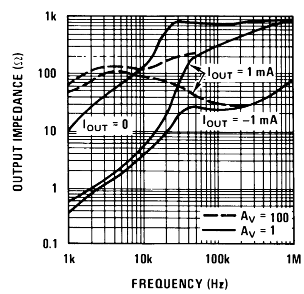
DS005652-29

Frequency Response



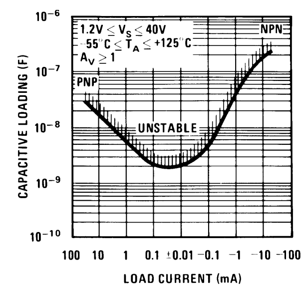
DS005652-30

Output Impedance



DS005652-31

Typical Stability Range



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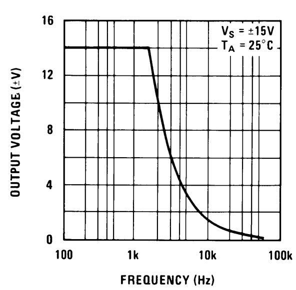
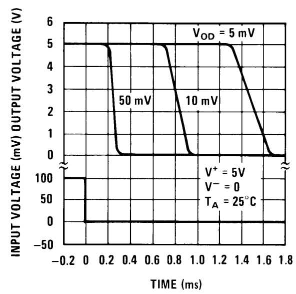
Large Signal Response



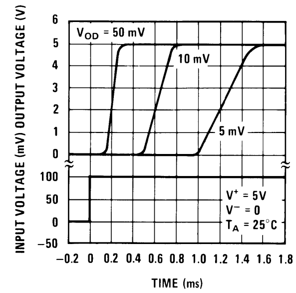
DS005652-33

Comparator Response Time For Various Input Overdrives



DS005652-34

Comparator Response Time For Various Input Overdrives



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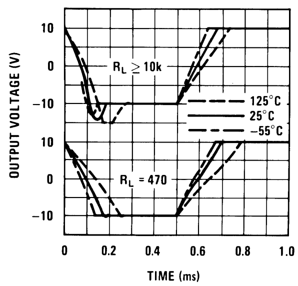
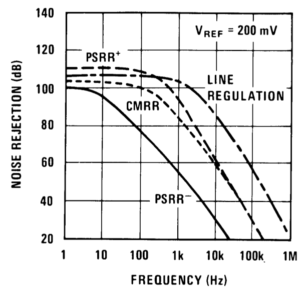
Typical Performance Characteristics (Op Amp) (Continued)

Follower Pulse Response



DS005652-36

Noise Rejection



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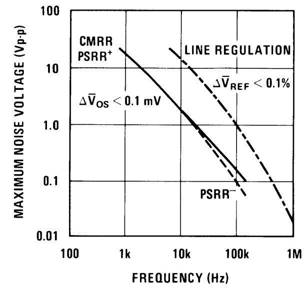
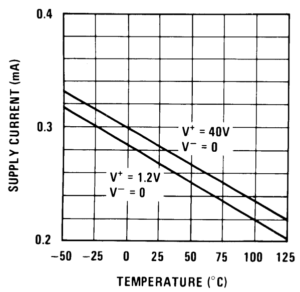
Rejection Slew Limiting



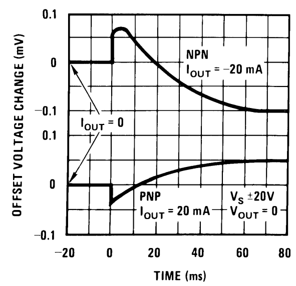
DS005652-38

Supply Current



DS005652-39

Thermal Gradient Feedback



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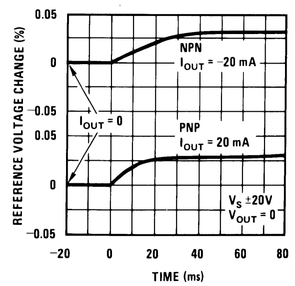
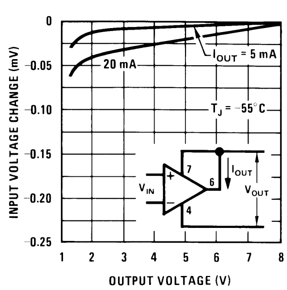
Thermal Gradient Cross-coupling



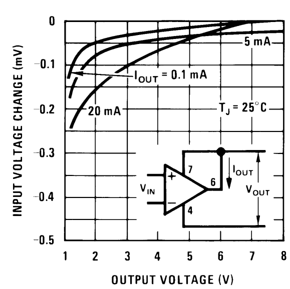
DS005652-41

Shunt Gain



DS005652-42

Shunt Gain



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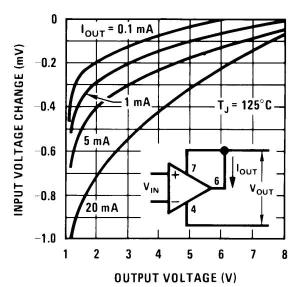
Shunt Gain



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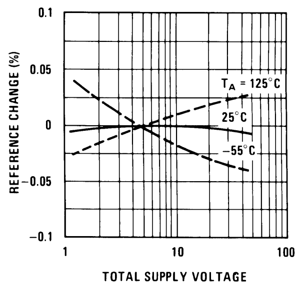
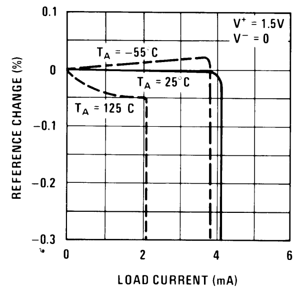
Typical Performance Characteristics (Reference)

Line Regulation



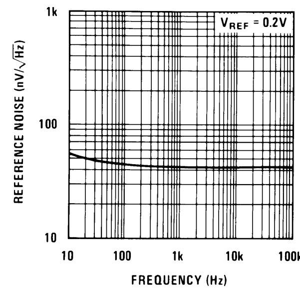
DS005652-45

Load Regulation



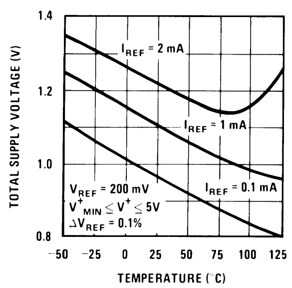
DS005652-46

Reference Noise Voltage



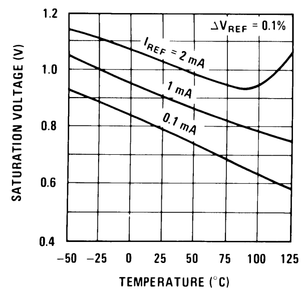
DS005652-47

Minimum Supply Voltage



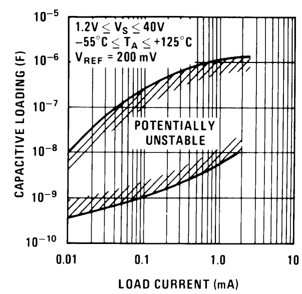
DS005652-48

Output Saturation



DS005652-49

Typical Stability Range

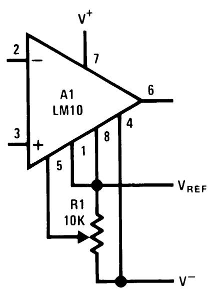


DS005652-50

Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages)

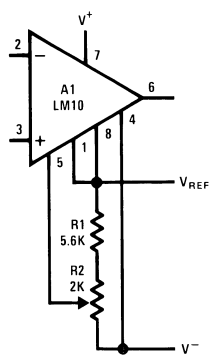
Op Amp Offset Adjustment

Standard



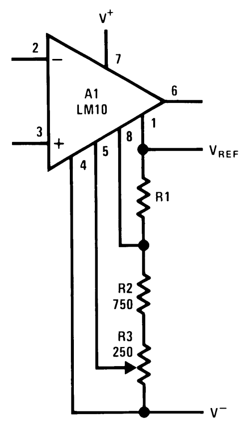
DS005652-51

Limited Range



DS005652-52

Limited Range With Boosted Reference

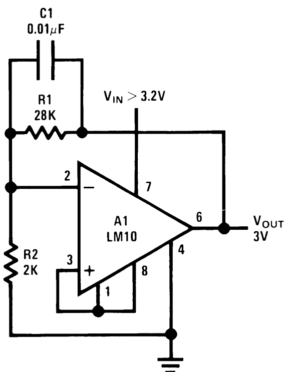


DS005652-53

Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

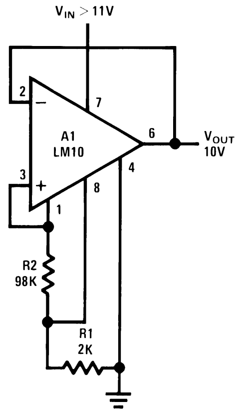
Positive Regulators (Note 9)

Low Voltage



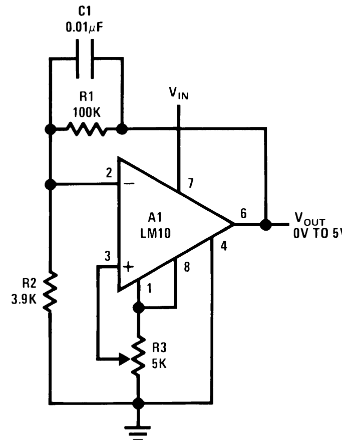
DS005652-54

Best Regulation



DS005652-55

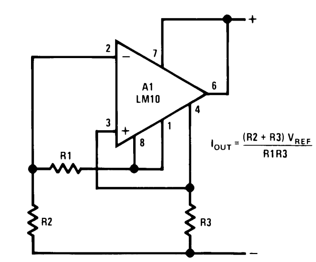
Zero Output



DS005652-56

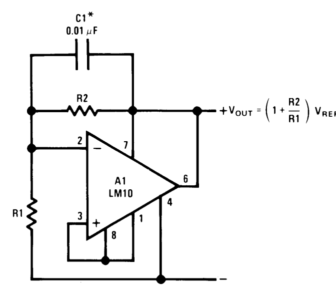
Note 9: Use only electrolytic output capacitors.

Current Regulator



DS005652-57

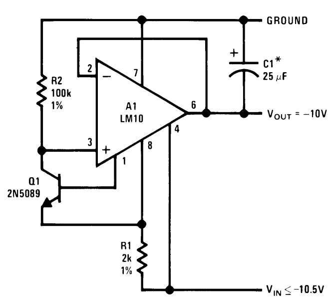
Shunt Regulator



DS005652-58

Required For Capacitive Loading

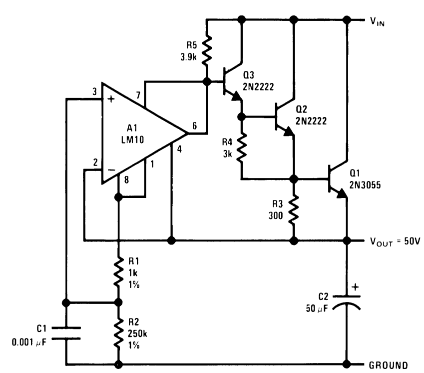
Negative Regulator



DS005652-59

*Electrolytic

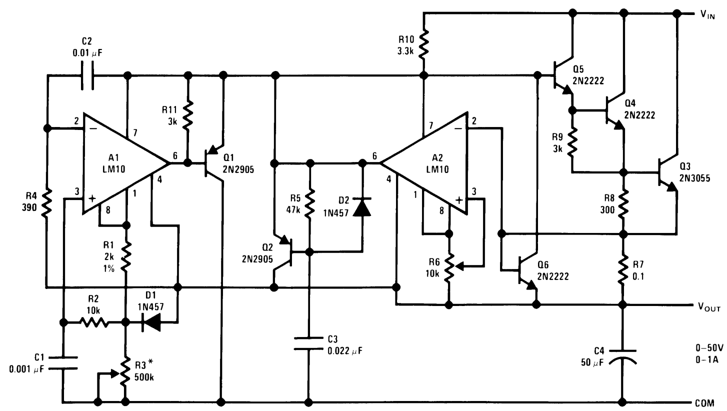
Precision Regulator



DS005652-60

Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

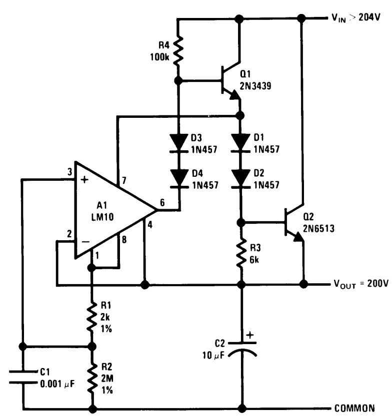
Laboratory Power Supply



DS005652-61

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

HV Regulator



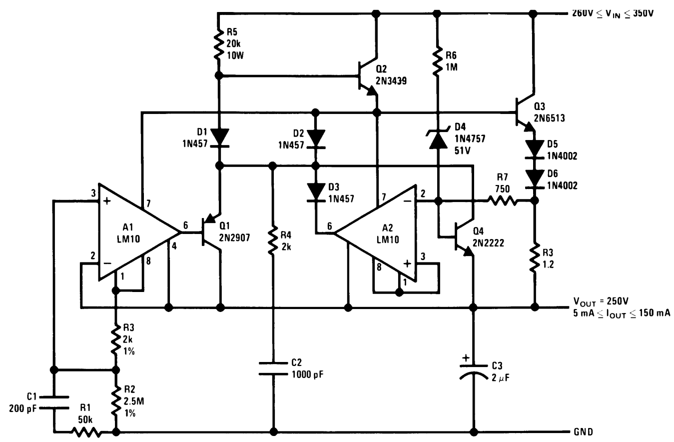
DS005652-62

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

DS005652-84

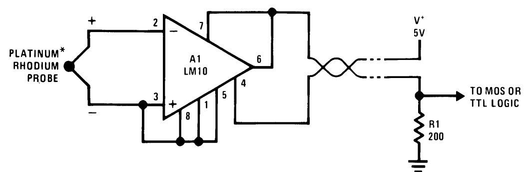
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Protected HV Regulator



DS005652-63

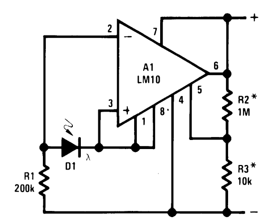
Flame Detector



DS005652-64

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

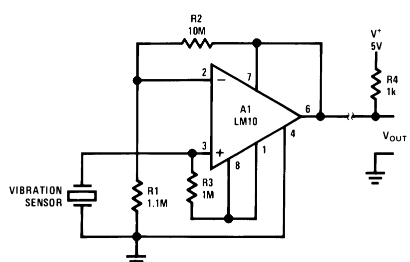
Light Level Sensor



DS005652-65

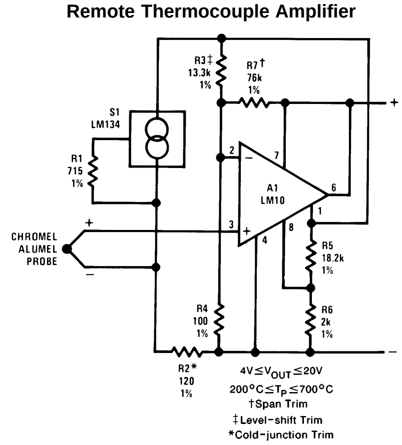
*Provides Hysteresis

Remote Amplifier



DS005652-66

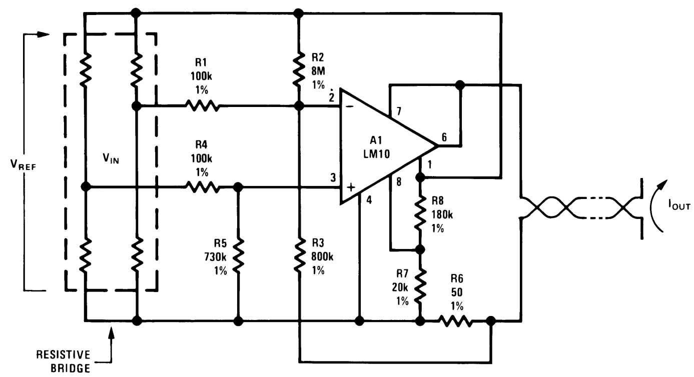
Remote Thermocouple Amplifier



DS005652-67

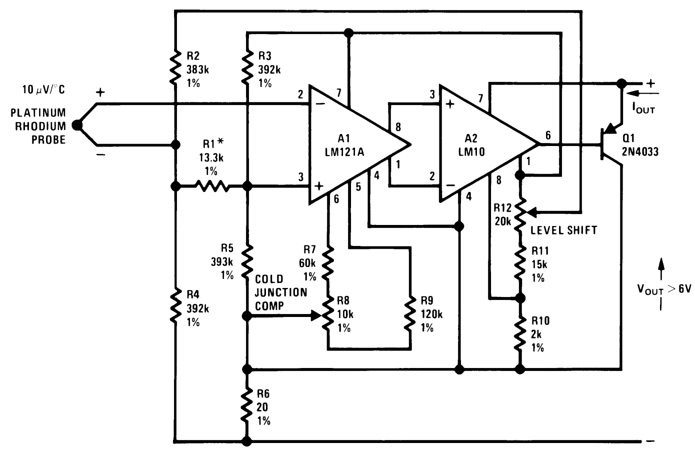
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Transmitter for Bridge Sensor



DS005652-68

Precision Thermocouple Transmitter

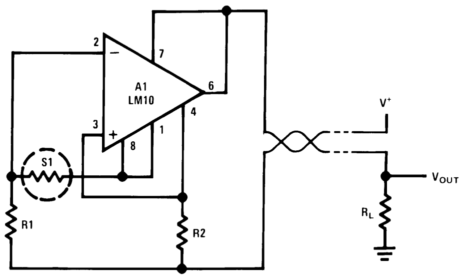


DS005652-69

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

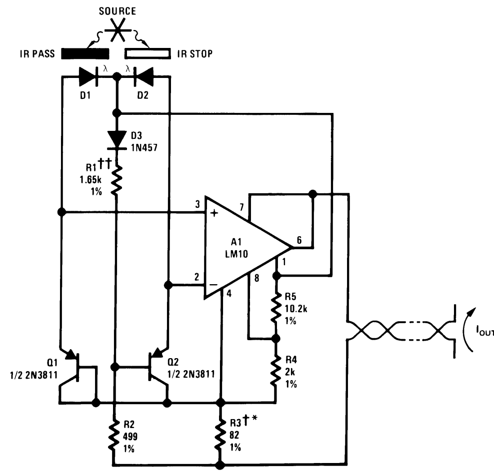
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Resistance Thermometer Transmitter



DS005652-70

Optical Pyrometer



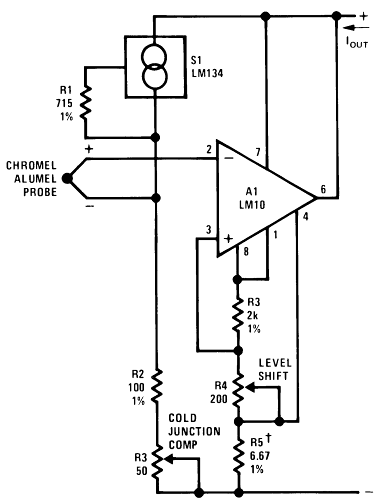
DS005652-71

††Level-shift Trim
*Scale Factor Trim
†Copper Wire Wound

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

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

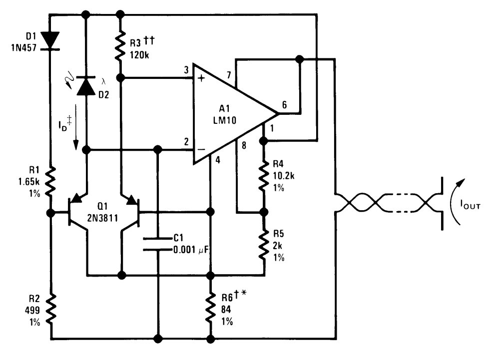
Thermocouple Transmitter



DS005652-72

$200^\circ C \leq T_p \leq 700^\circ C$
$1\ mA \leq I_{OUT} \leq 5\ mA$
†Gain Trim

Logarithmic Light Sensor

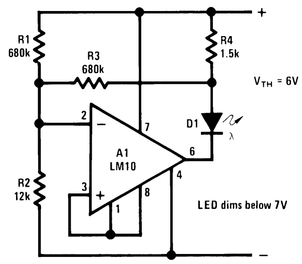


DS005652-73

$1\ mA \leq I_{OUT} \leq 5\ mA$
‡$50\ \mu A \leq I_D \leq 500\ \mu A$
††Center Scale Trim
†Scale Factor Trim
*Copper Wire Wound

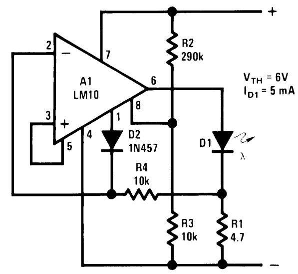
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Battery-level Indicator



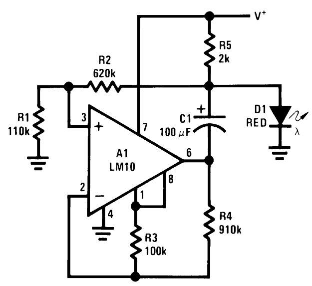
DS005652-74

Battery-threshold Indicator



DS005652-75

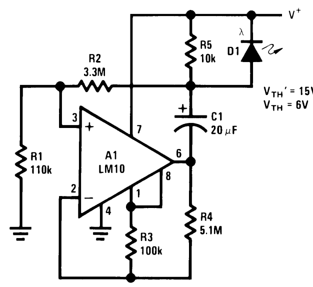
Single-cell Voltage Monitor



DS005652-76

Flashes Above 1.2V
Rate Increases With
Voltage

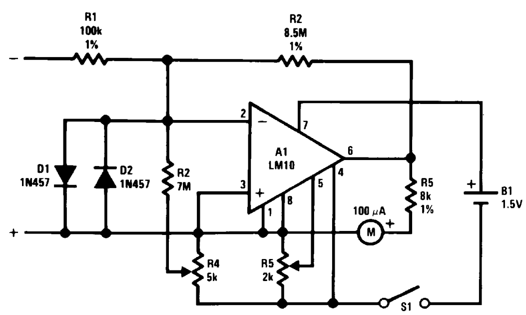
Double-ended Voltage Monitor



DS005652-77

Flash Rate Increases
Above 6V and Below 15V

Meter Amplifier

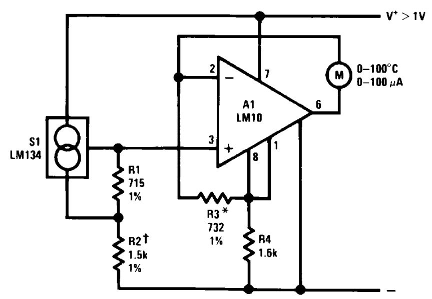


DS005652-78

INPUT
10 mV, 100nA
FULL-SCALE

Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

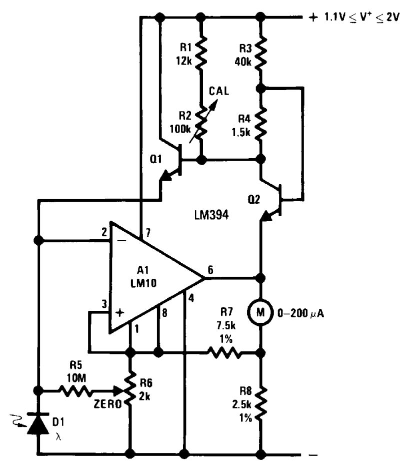
Thermometer



DS005652-79

*Trim For Span
†Trim For Zero

Light Meter

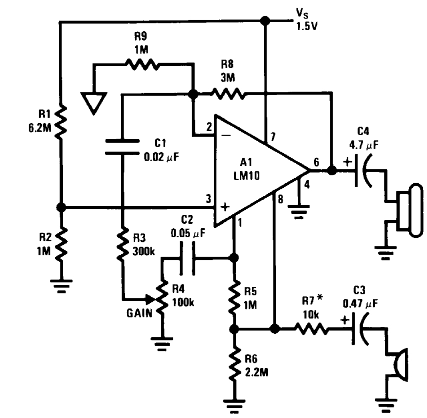


DS005652-80

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

Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

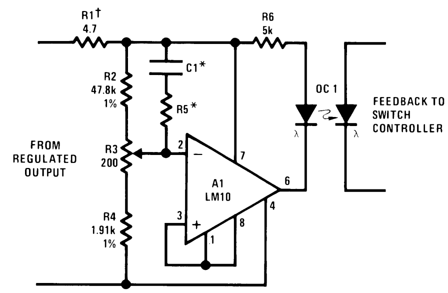
Microphone Amplifier



DS005652-81

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

Isolated Voltage Sensor

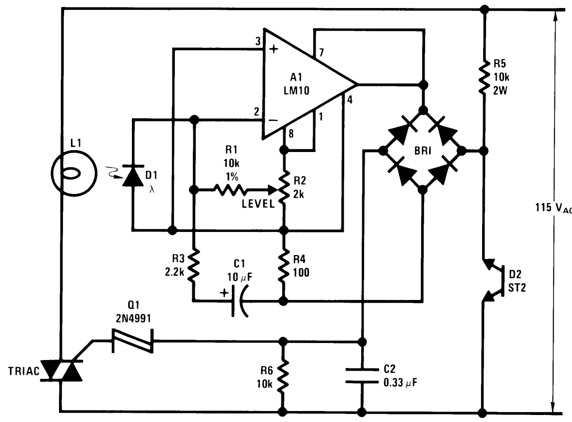


DS005652-82

†Controls "Loop Gain"
*Optional Frequency Shaping

Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Light-level Controller



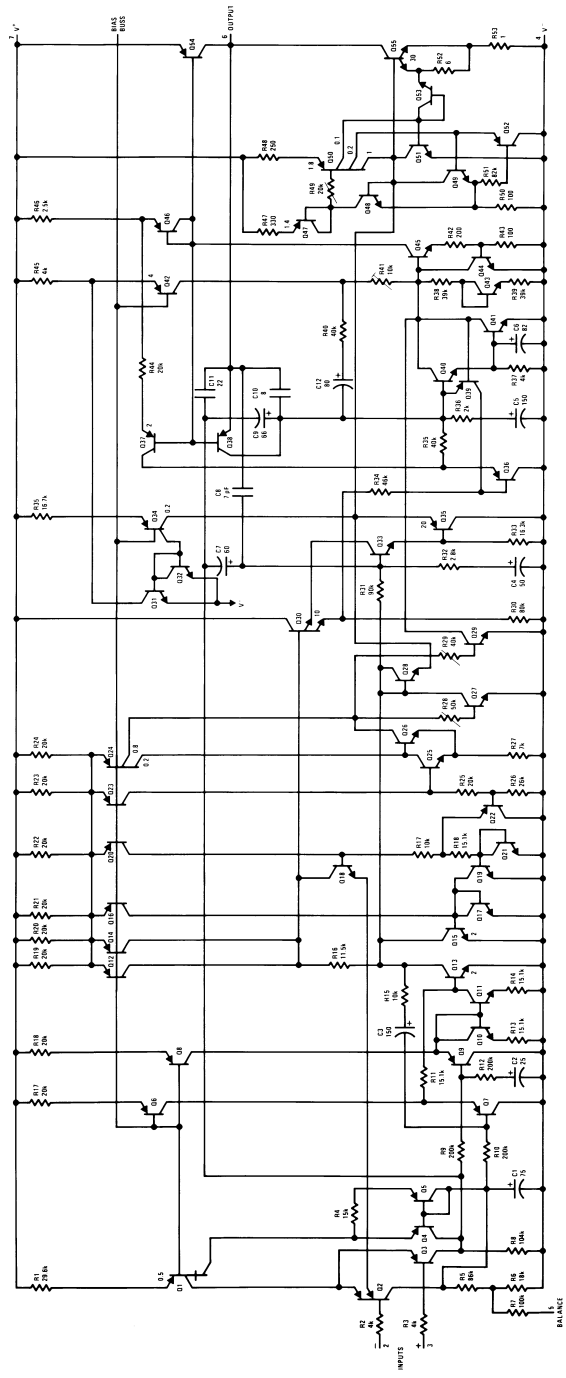
DS005652-83

Note 10: Circuit descriptions available in application note AN-211.

Application Hints

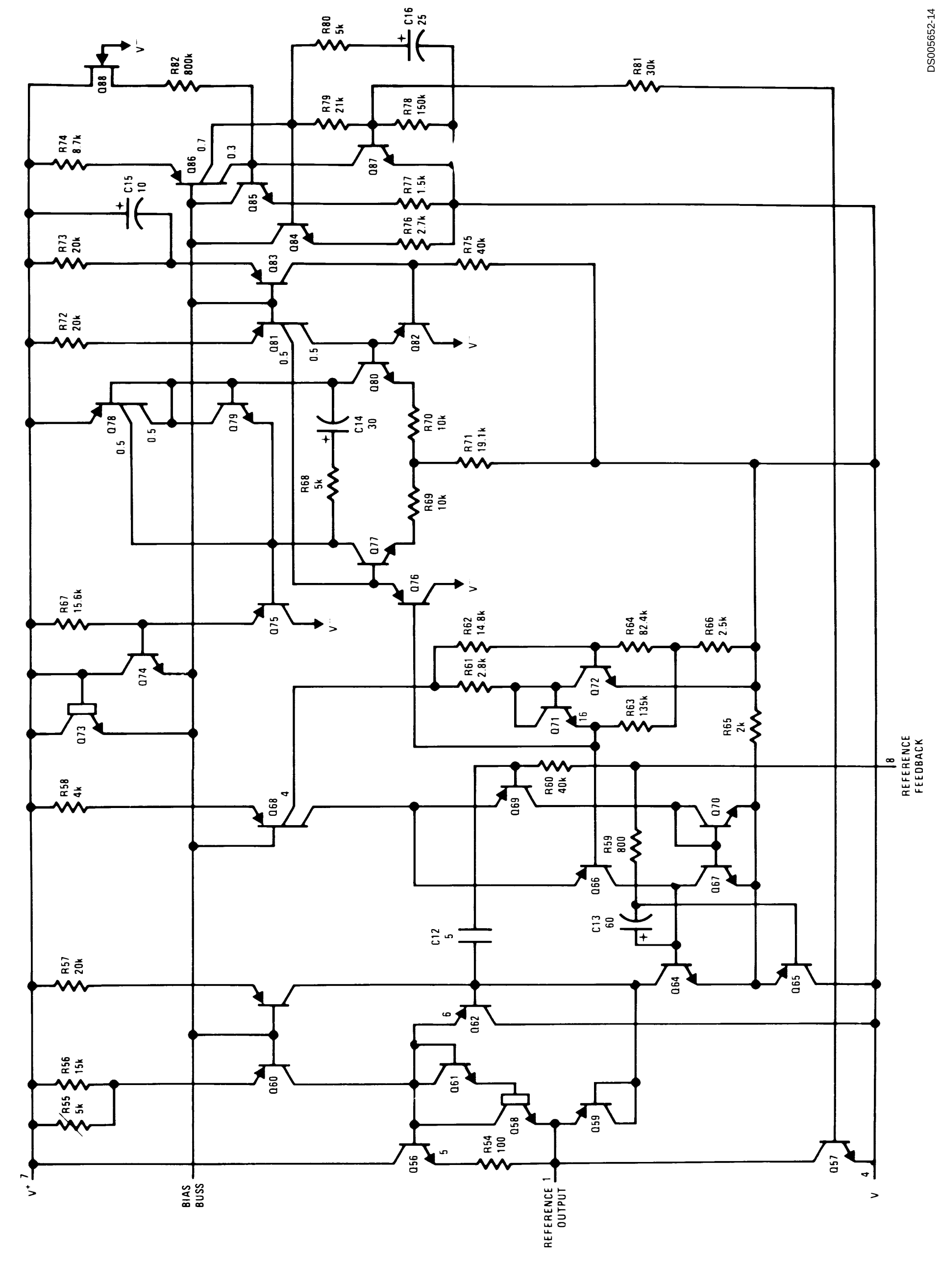
With heavy amplifier loading to V^-, resistance drops in the V^- lead can adversely affect reference regulation. Lead resistance can approach 1Ω. Therefore, the common to the reference circuitry should be connected as close as possible to the package.

Operational Amplifier Schematic (Pin numbers are for 8-pin packages)

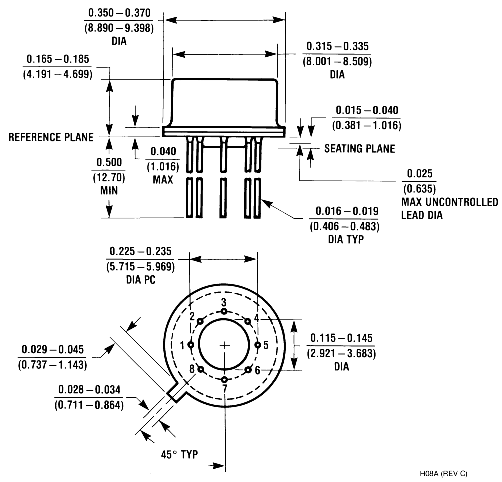


DS005652-13

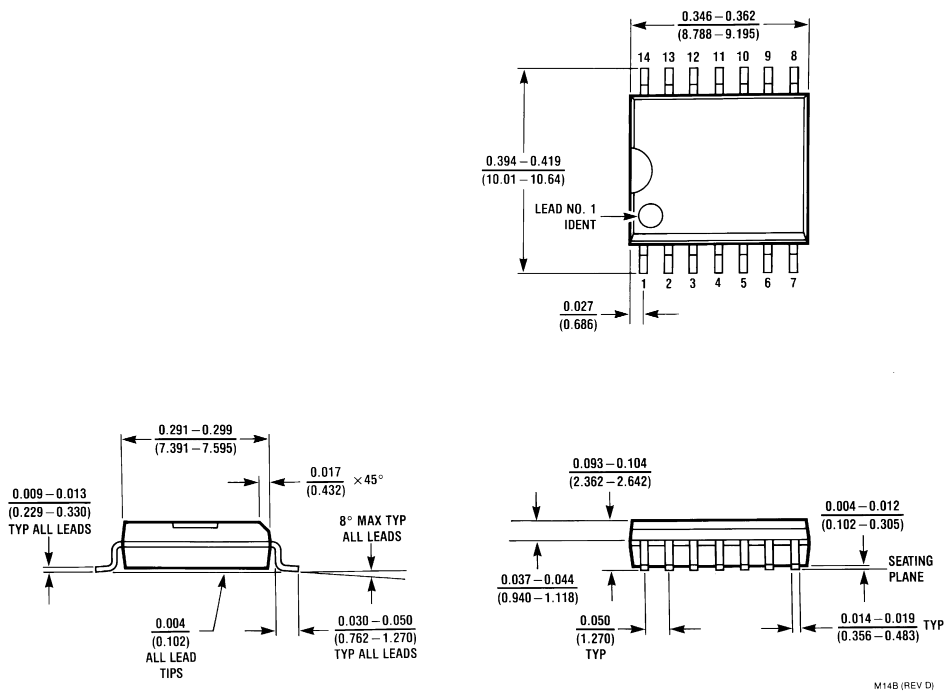
Reference and Internal Regulator (Pin numbers are for 8-pin packages)



Physical Dimensions inches (millimeters) unless otherwise noted

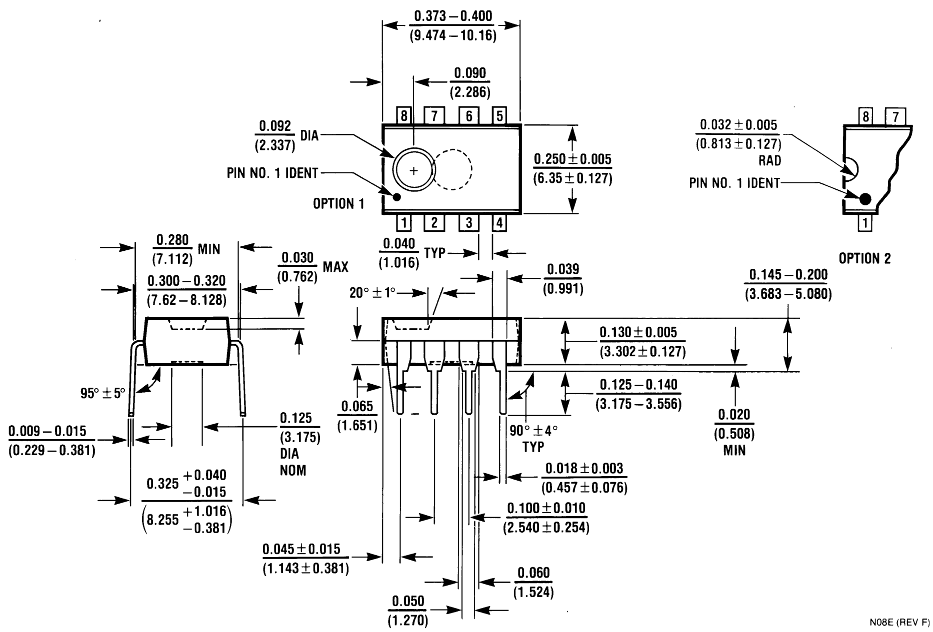


Metal Can Package (H)
Order Number LM10BH, LM10CH, LM10CLH or LM10H/883
NS Package Number H08A



S.O. Package (WM)
Order Number LM10CWM
NS Package Number M14B

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Dual-In-Line Package (N)
Order Number LM10CN or LM10CLN
NS Package Number N08E

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