National Semiconductor Corporation

LM10/LM10B(L)/LM10C(L) Op Amp 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 $\pm$20 mA output current with $\pm$0.4V saturation. Reference output can be as low as 200 mV. Some other characteristics of the LM10 are

- 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

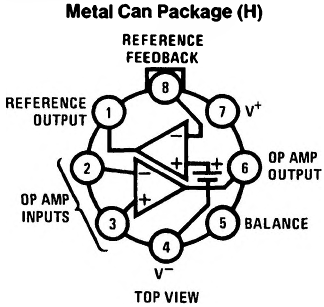
The circuit is recommended for portable equipment and is completely specified for operation from a single power cell. In contrast, high output-drive capability, both voltage and current, along with thermal overload protection, suggest it in demanding general-purpose applications.

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.

Connection and Functional Diagrams

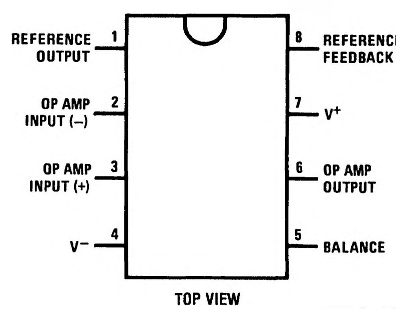
Metal Can Package (H)



TL/H/5652-1

Order Number LM10H, LM10BH, LM10CH, LM10BLH or LM10CLH
See NS Package Number H08A

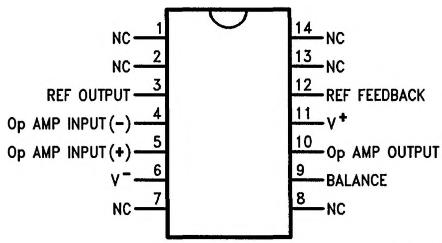
Dual-In-Line Package (N)



TL/H/5652-15

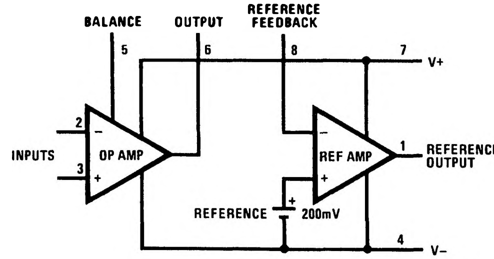
Order Number LM10CN or LM10CLN
See NS Package Number N08E

Small Outline Package (M)



TL/H/5652-17

Order Number LM10CWM or LM10CLWM
See NS Package Number M14B



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Absolute Maximum Ratings

If Military/Aerospace specified devices are required, contact the National Semiconductor Sales Office/ Distributors for availability and specifications.
(Note 7)

	LM10/LM10B/LM10C	LM10BL/LM10CL
Total Supply Voltage	45V	7V
Differential Input Voltage (note 1)	±40V	±7V
Power Dissipation (note 2)	internally limited	
Output Short-circuit Duration (note 3)	indefinite	
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" (Appendix D) for other methods of soldering surface mount devices.

ESD rating is to be determined.

Electrical Characteristics

$T_J = 25°C$, $T_{MIN} \le T_J \le T_{MAX}$ (note 4) **(Boldface type refers to limits over temperature range)**

Parameter	Conditions	LM10/LM10B			LM10C			Units
		Min	Typ	Max	Min	Typ	Max	
Input offset voltage			0.3	2.0 **3.0**		0.5	4.0 **5.0**	mV mV
Input offset current (note 5)			0.25	0.7 **1.5**		0.4	2.0 **3.0**	nA nA
Input bias current			10	20 **30**		12	30 **40**	nA nA
Input resistance		250 **150**	500		150 **115**	400		kΩ kΩ
Large signal voltage gain	$V_S = \pm 20V$, $I_{OUT} = 0$ $V_{OUT} = \pm 19.95V$ $V_S = \pm 20V$, $V_{OUT} = \pm 19.4V$ $I_{OUT} = \pm 20$ mA **(±15 mA)** $V_S = \pm 0.6V$ **(0.65V)**, $I_{OUT} = \pm 2$ mA $V_{OUT} = \pm 0.4V$ **(±0.3V), $V_{CM} = -0.4V$**	120 **80** 50 **20** 1.5 **0.5**	400 130 3.0		80 **50** 25 **15** 1.0 **0.75**	400 130 3.0		V/mV V/mV V/mV V/mV V/mV V/mV
Shunt gain (note 6)	1.2V **(1.3V)** $\le V_{OUT} \le 40V$, $R_L = 1.1$ kΩ 0.1 mA $\le I_{OUT} \le 5$ mA $1.5V \le V^+ \le 40V$, $R_L = 250\Omega$ 0.1 mA $\le I_{OUT} \le 20$ mA	14 **6** 8 **4**	33 25		10 **6** 6 **4**	33 25		V/mV V/mV V/mV V/mV
Common-mode rejection	$-20V \le V_{CM} \le 19.15V$ **(19V)** $V_S = \pm 20V$	93 **87**	102		90 **87**	102		dB dB
Supply-voltage rejection	$-0.2V \ge V^- \ge -39V$ $V^+ = 1.0V$ **(1.1V)** 1.0V **(1.1V)** $\le V^+ \le 39.8V$ $V^- = -0.2V$	90 **84** 96 **90**	96 106		87 **84** 93 **90**	96 106		dB dB dB 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

Electrical Characteristics

$T_J = 25°C$, $\mathbf{T_{MIN} \le T_J \le T_{MAX}}$, (note 4) **(Boldface type refers to limits over temperature range)** (Continued)

Parameter	Conditions	LM10/LM10B			LM10C			Units
		Min	Typ	Max	Min	Typ	Max	
Line regulation	1.2V **(1.3V)** $\le V_S \le$ 40V $0 \le I_{REF} \le$ 1.0 mA, V_{REF} = 200 mV		0.001	0.003 **0.006**		0.001	0.008 **0.01**	%/V %/V
Load regulation	$0 \le I_{REF} \le$ 1.0 mA $V^+ - V_{REF} \ge$ 1.0V **(1.1V)**		0.01	0.1 **0.15**		0.01	0.15 **0.2**	% %
Amplifier gain	0.2V $\le V_{REF} \le$ 35V	50 **23**	75		25 **15**	70		V/mV V/mV
Feedback sense voltage		195 **194**	200	205 **206**	190 **189**	200	210 **211**	mV mV
Feedback current			20	50 **65**		22	75 **90**	nA nA
Reference drift			0.002			0.003		%/°C
Supply current			270	400 **500**		300	500 **570**	μA μA
Supply current change	1.2V **(1.3V)** $\le V_S \le$ 40V		15	**75**		15	**75**	μA

Parameter	Conditions	LM10BL			LM10CL			Units
		Min	Typ	Max	Min	Typ	Max	
Input offset voltage			0.3	2.0 **3.0**		0.5	4.0 **5.0**	mV mV
Input offset current (note 5)			0.1	0.7 **1.5**		0.2	2.0 **3.0**	nA nA
Input bias current			10	20 **30**		12	30 **40**	nA nA
Input resistance		250 **150**	500		150 **115**	400		kΩ kΩ
Large signal voltage gain	$V_S = \pm$3.25V, I_{OUT} = 0 $V_{OUT} = \pm$3.2V $V_S = \pm$3.25V, I_{OUT} = 10 mA $V_{OUT} = \pm$2.75 V $V_S = \pm$0.6V **(0.65V)**, $I_{OUT} = \pm$2 mA $V_{OUT} = \pm$0.4V **(±0.3V)**, $V_{CM} = -$0.4V	60 **40** 10 **4** 1.5 **0.5**	300 25 3.0 		40 **25** 5 **3** 1.0 **0.75**	300 25 3.0 		V/mV V/mV V/mV V/mV V/mV V/mV
Shunt gain (note 6)	1.5V $\le V^+ \le$ 6.5V, R_L = 500Ω 0.1 mA $\le I_{OUT} \le$ 10 mA	8 **4**	30		6 **4**	30		V/mV V/mV
Common-mode rejection	$-$3.25V $\le V_{CM} \le$ 2.4V **(2.25V)** $V_S = \pm$3.25V	89 **83**	102		80 **74**	102		dB dB
Supply-voltage rejection	$-$0.2V $\ge V^- \ge -$5.4V V^+ = 1.0V **(1.2V)** 1.0V **(1.1V)** $\le V^+ \le$ 6.3V V^- = 0.2V	86 **80** 94 **88**	96 106 		80 **74** 80 **74**	96 106 		dB dB dB 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

Electrical Characteristics

$T_J = 25°C$, $\mathbf{T_{MIN} \le T_J \le T_{MAX}}$, (note 4) **(Boldface type refers to limits over temperature range)**

Parameter	Conditions	LM10BL			LM10CL			Units
		Min	Typ	Max	Min	Typ	Max	
Line regulation	1.2V **(1.3V)** $\le V_S \le 6.5V$ $0 \le I_{REF} \le 0.5$ mA, $V_{REF} = 200$ mV		0.001	0.01 **0.02**		0.001	0.02 **0.03**	%/V %/V
Load regulation	$0 \le I_{REF} \le 0.5$ mA $V^+ - V_{REF} \ge 1.0V$ **(1.1V)**		0.01	0.1 **0.15**		0.01	0.15 **0.2**	% %
Amplifier gain	$0.2V \le V_{REF} \le 5.5V$	30 **20**	70		20 **15**	70		V/mV V/mV
Feedback sense voltage		195 **194**	200	205 **206**	190 **189**	200	210 **211**	mV mV
Feedback current			20	50 **65**		22	75 **90**	nA nA
Reference drift			0.002			0.003		%/°C
Supply current			260	400 **500**		280	500 **570**	μA μA

Note 1: 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 2: 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 3: 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 4: These specifications apply for $V^- \le V_{CM} \le V^+ - 0.85V$ **(1.0V)**, 1.2V **(1.3V)** $< V_S \le V_{MAX}$, $V_{REF} = 0.2V$ and $0 \le I_{REF} \le 1.0$ 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 ($\tau_1 \cong 20$ ms), die heating ($\tau_2 \cong 0.2s$) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).

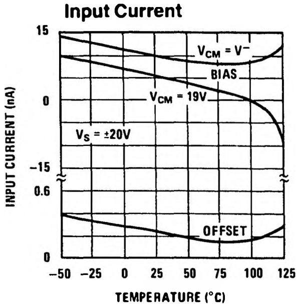
Note 5: For $T_J > 90°C$, I_{OS} may exceed 1.5 nA for $V_{CM} = V^-$. With $T_J = 125°C$ and $V^- \le V_{CM} \le V^- + 0.1V$, $I_{OS} \le 5$ nA.

Note 6: 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.

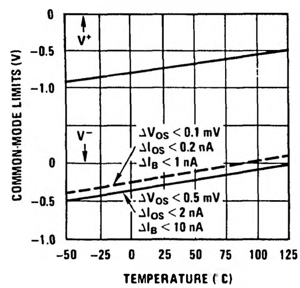
Note 7: Refer to RETS10X for LM10H military specifications.

Typical Performance Characteristics (Op Amp)

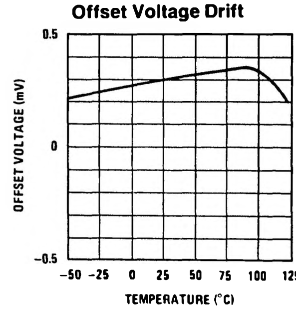
Input Current



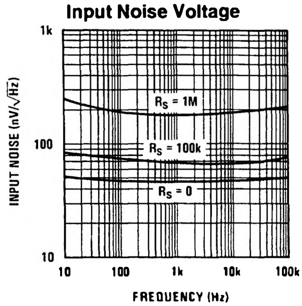
Common Mode Limits



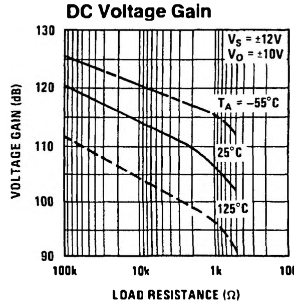
Offset Voltage Drift



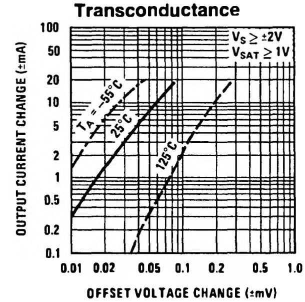
Input Noise Voltage



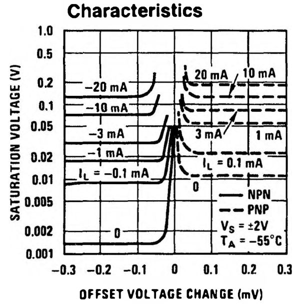
DC Voltage Gain



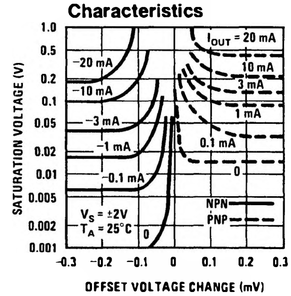
Transconductance



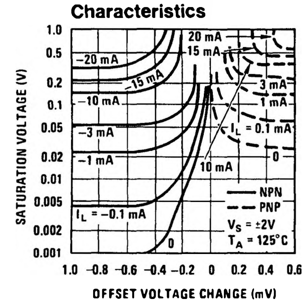
Output Saturation Characteristics



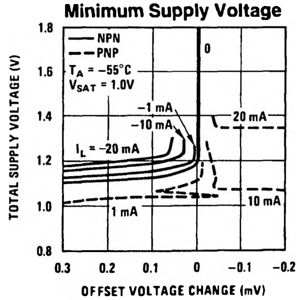
Output Saturation Characteristics



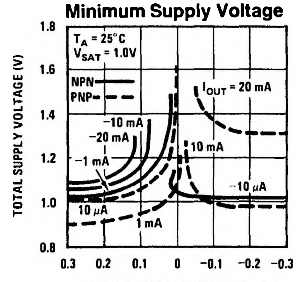
Output Saturation Characteristics



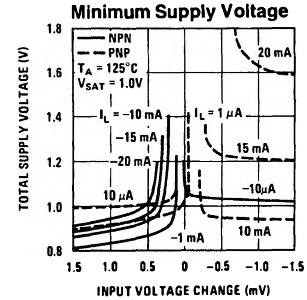
Minimum Supply Voltage



Minimum Supply Voltage



Minimum Supply Voltage



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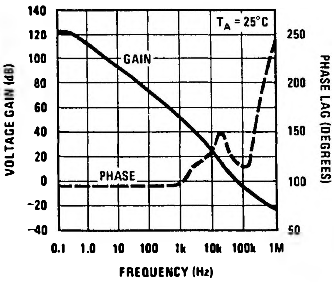
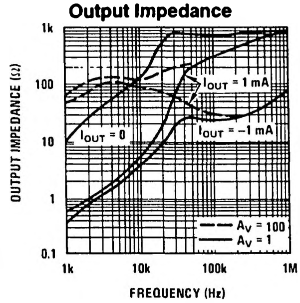
Typical Performance Characteristics (Op Amp) (Continued)

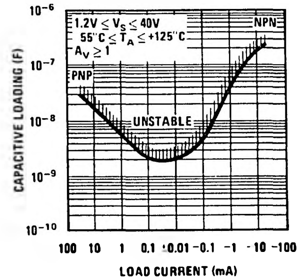
Frequency Response



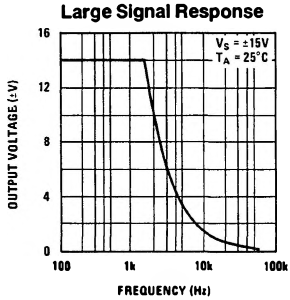
Output Impedance



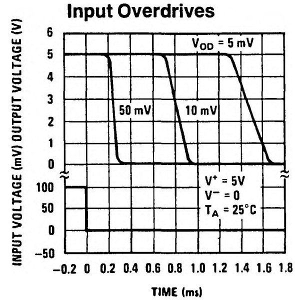
Typical Stability Range



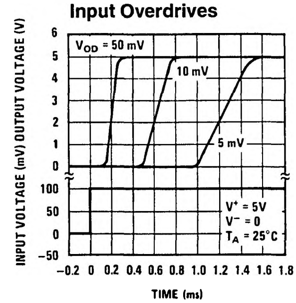
Large Signal Response



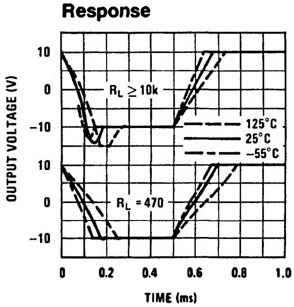
Comparator Response Time For Various Input Overdrives



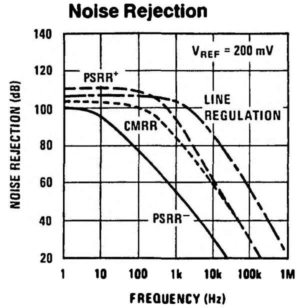
Comparator Response Time For Various Input Overdrives



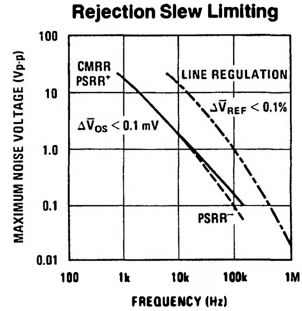
Follower Pulse Response



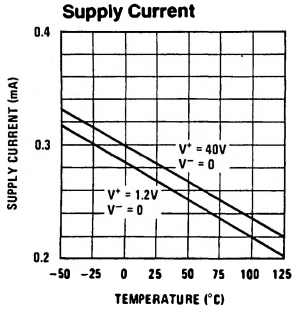
Noise Rejection



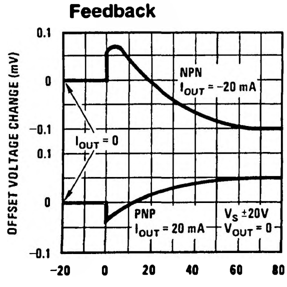
Rejection Slew Limiting



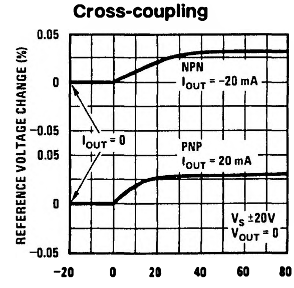
Supply Current



Thermal Gradient Feedback



Thermal Gradient Cross-coupling



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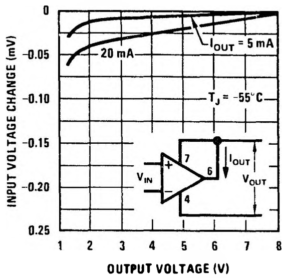
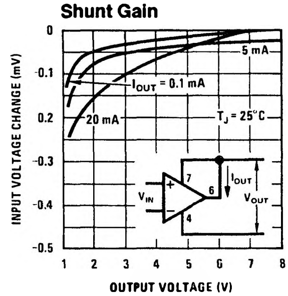
Typical Performance Characteristics (Op Amp) (Continued)

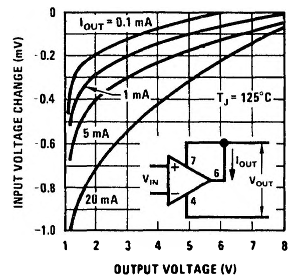
Shunt Gain



Shunt Gain



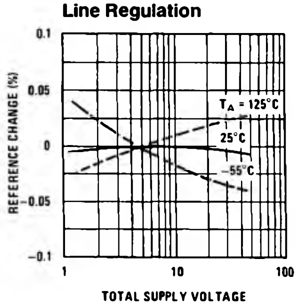
Shunt Gain



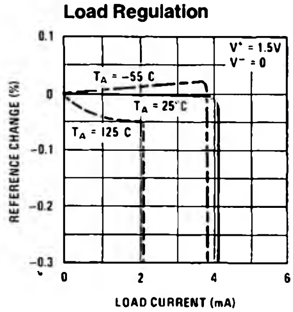
TL/H/5652–4

Typical Performance Characteristics (Reference)

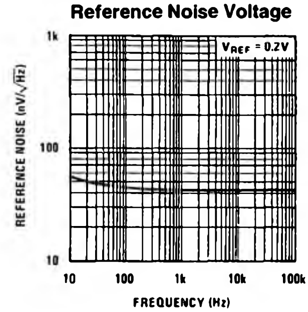
Line Regulation



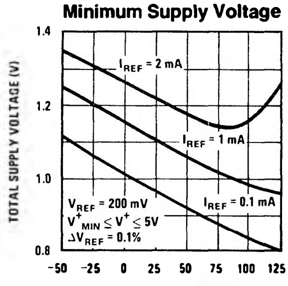
Load Regulation



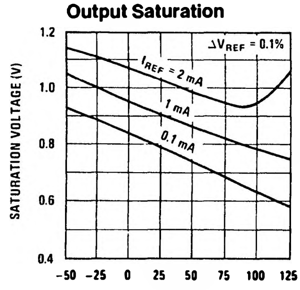
Reference Noise Voltage



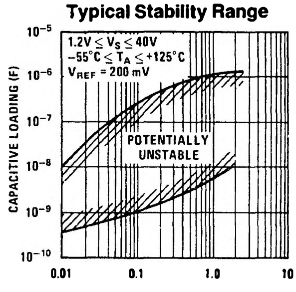
Minimum Supply Voltage



Output Saturation



Typical Stability Range

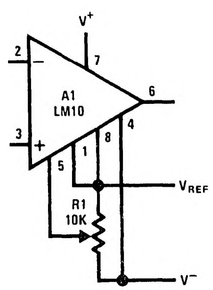


TL/H/5652–5

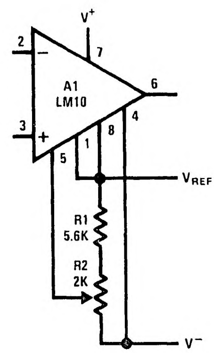
Typical Applications†† (Pin numbers are for devices in 8-pin packages)

Op Amp Offset Adjustment

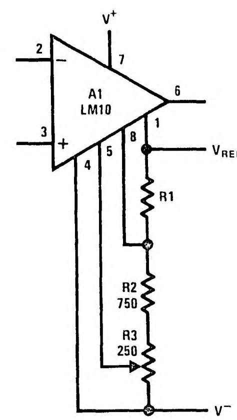
Standard



Limited Range

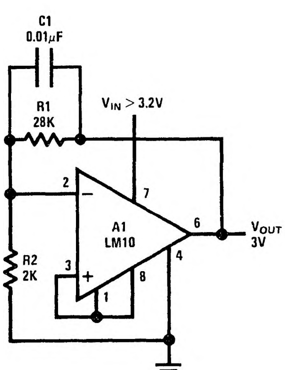


Limited Range With Boosted Reference

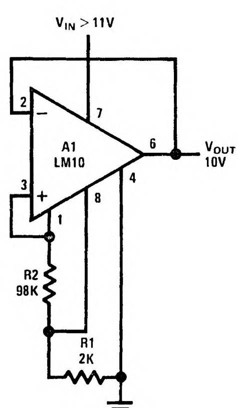


Positive Regulators†

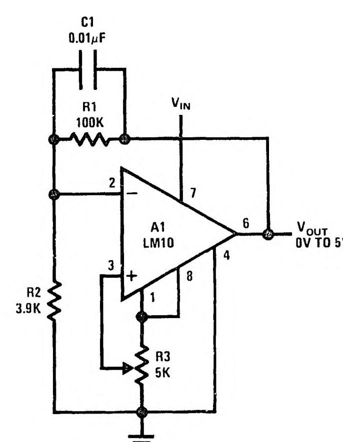
Low Voltage



Best Regulation



Zero Output



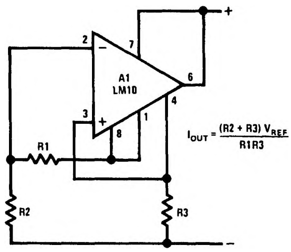
TL/H/5652-6

†Use only electrolytic output capacitors.

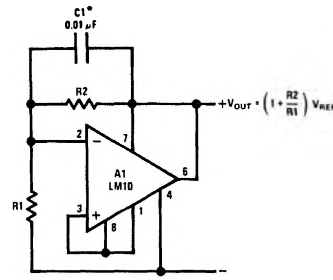
††Circuit descriptions available in application note AN-211.

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

Current Regulator

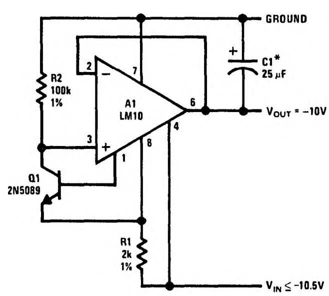


Shunt Regulator



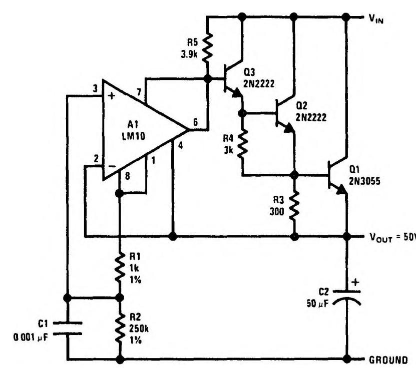
*Required For Capacitive Loading

Negative Regulator

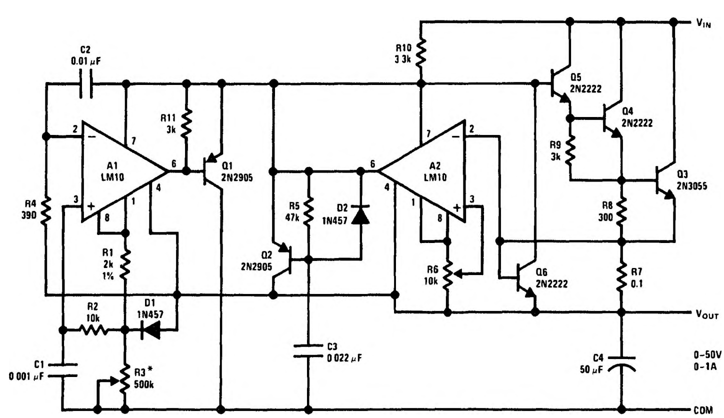


*Electrolytic

Precision Regulator



Laboratory Power Supply



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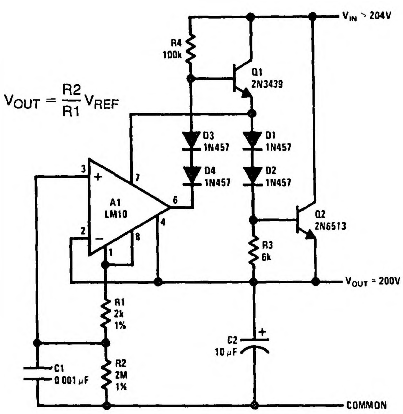
$^*V_{OUT} = 10^{-4}\ R3$

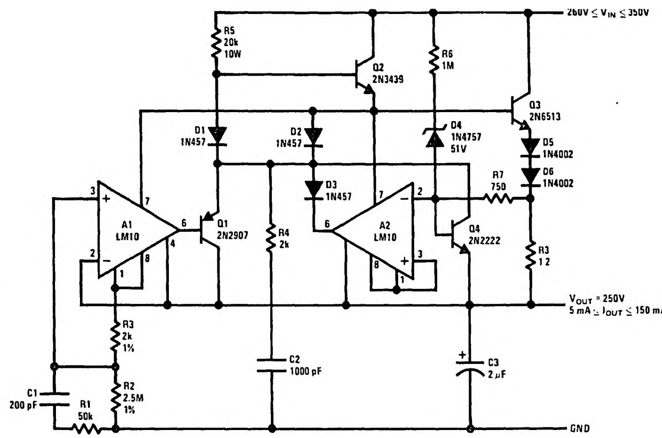
††Circuit descriptions available in application note AN-211.

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

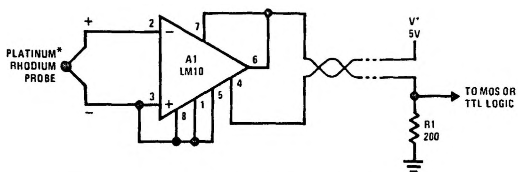
HV Regulator



Protected HV Regulator

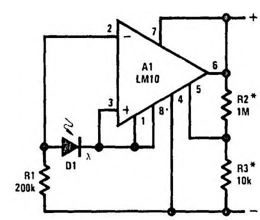


Flame Detector



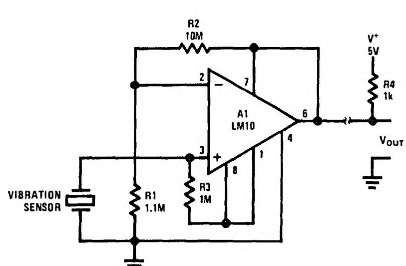
*800°C Threshold Is Established By Connecting Balance To V_{REF}.

Light Level Sensor

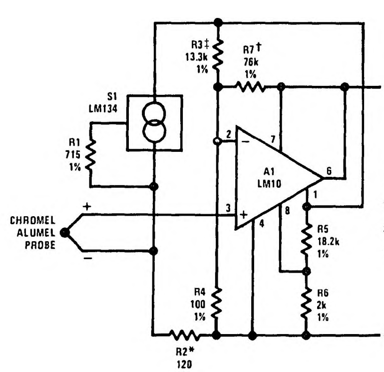


*Provides Hysteresis

Remote Amplifier



Remote Thermocouple Amplifier



$4V \leq V_{OUT} \leq 20V$

$200°C \leq T_P \leq 700°C$

†Span Trim

‡Level-shift Trim

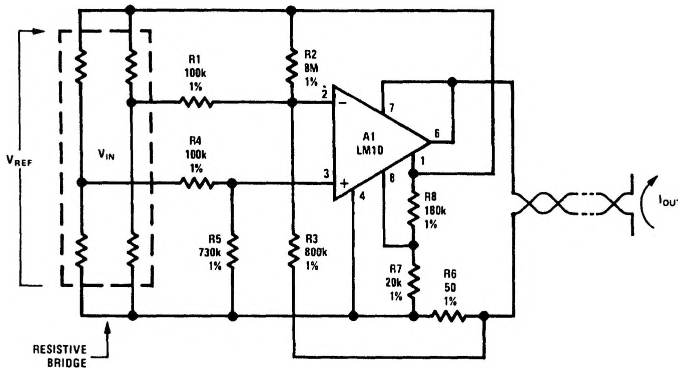
*Cold-junction Trim

TL/H/5652–8

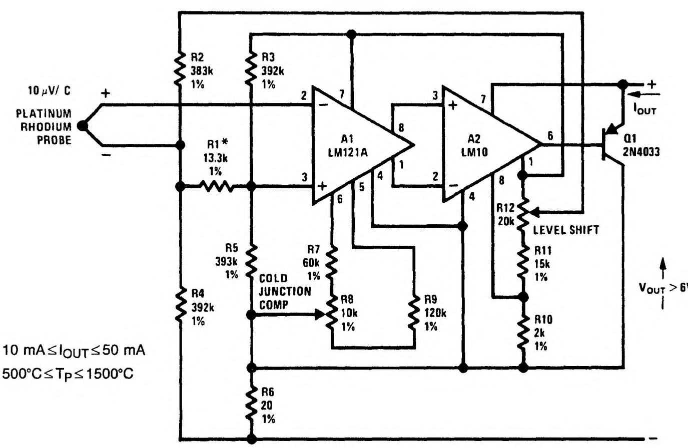
††Circuit descriptions available in application note AN-211.

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

Transmitter for Bridge Sensor



Precision Thermocouple Transmitter

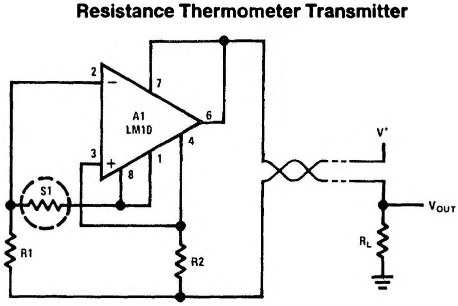


$10\ mA \leq I_{OUT} \leq 50\ mA$

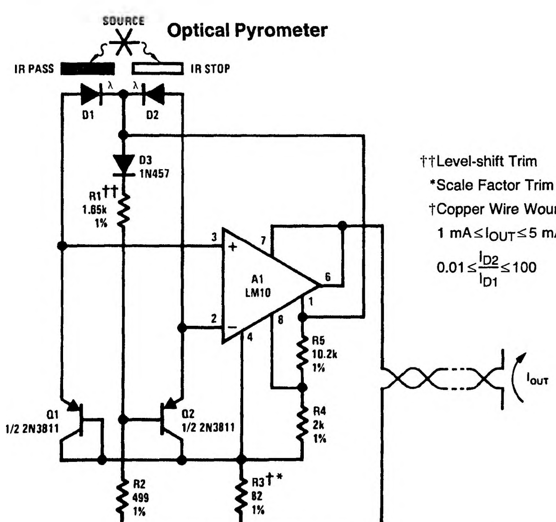
$500°C \leq T_P \leq 1500°C$

*Gain Trim

Resistance Thermometer Transmitter



Optical Pyrometer



††Level-shift Trim

*Scale Factor Trim

†Copper Wire Wound

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

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

††Circuit descriptions available in application note AN-211.

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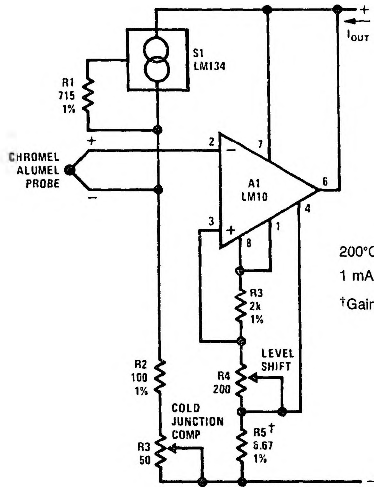
Typical Applications †† (Pin numbers are for devices in 8-pin packages) (Continued)

Thermocouple Transmitter

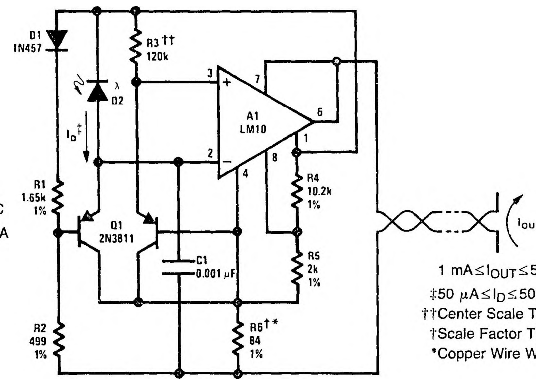


200°C ≤ T_p ≤ 700°C

1 mA ≤ I_{OUT} ≤ 5 mA

†Gain Trim

Logarithmic Light Sensor



1 mA ≤ I_{OUT} ≤ 5 mA

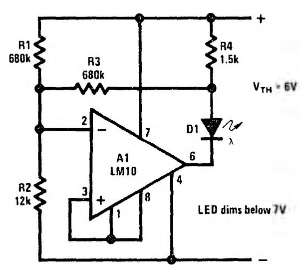
‡50 μA ≤ I_D ≤ 500 μA

††Center Scale Trim

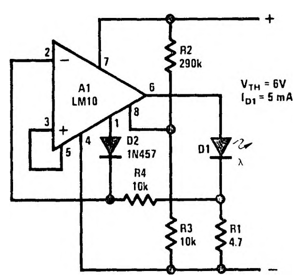
†Scale Factor Trim

*Copper Wire Wound

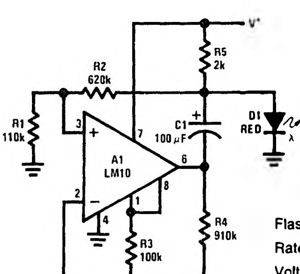
Battery-level Indicator



Battery-threshold Indicator

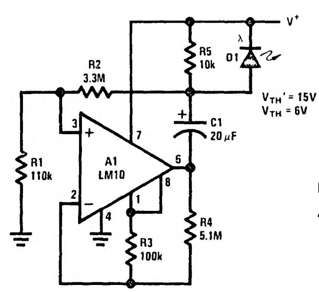


Single-cell Voltage Monitor



Flashes Above 1.2V Rate Increases With Voltage

Double-ended Voltage Monitor



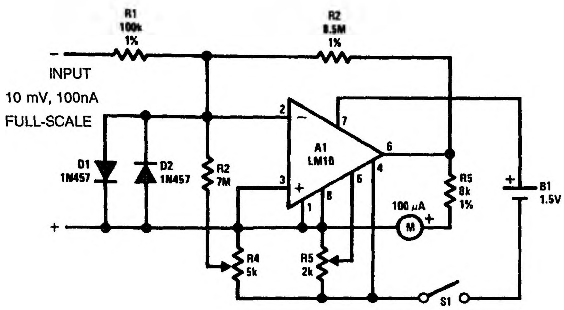
Flash Rate Increases Above 6V and Below 15V

TL/H/5652-10

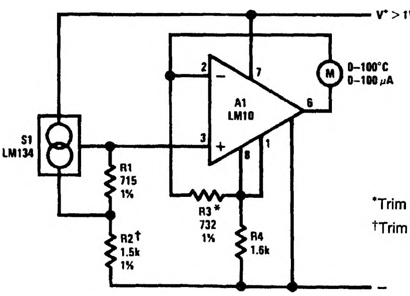
††Circuit descriptions available in application note AN-211.

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

Meter Amplifier



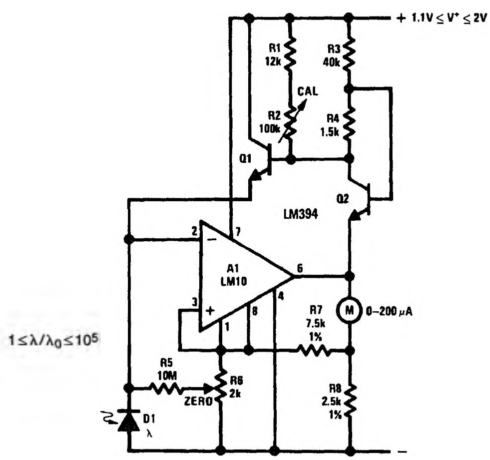
Thermometer



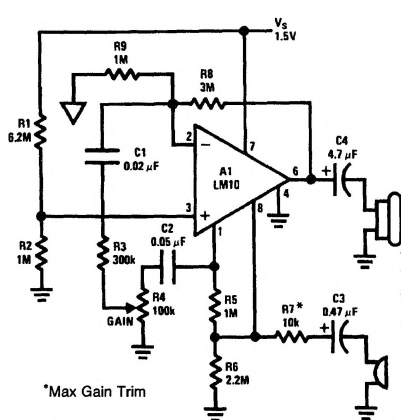
*Trim For Span

†Trim For Zero

Light Meter



Microphone Amplifier



$Z_{OUT} \sim 680\Omega$
@ 5 kHz

$A_V \le 1k$
$f_1 \sim 100$ Hz
$f_2 \sim 5$ kHz
$R_L \sim 500$

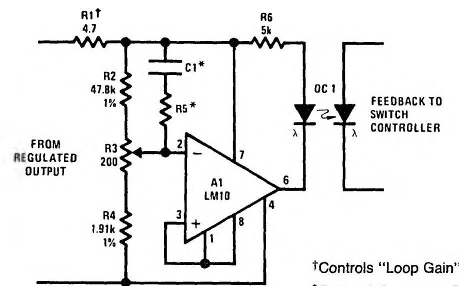
*Max Gain Trim

TL/H/5652–11

††Circuit descriptions available in application note AN-211.

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

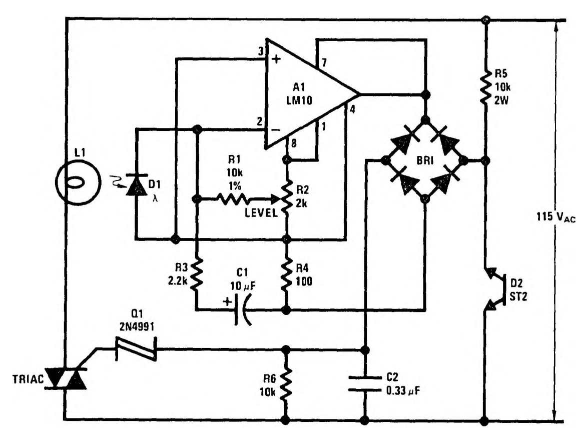
Isolated Voltage Sensor



†Controls "Loop Gain"

*Optional Frequency Shaping

Light-level Controller



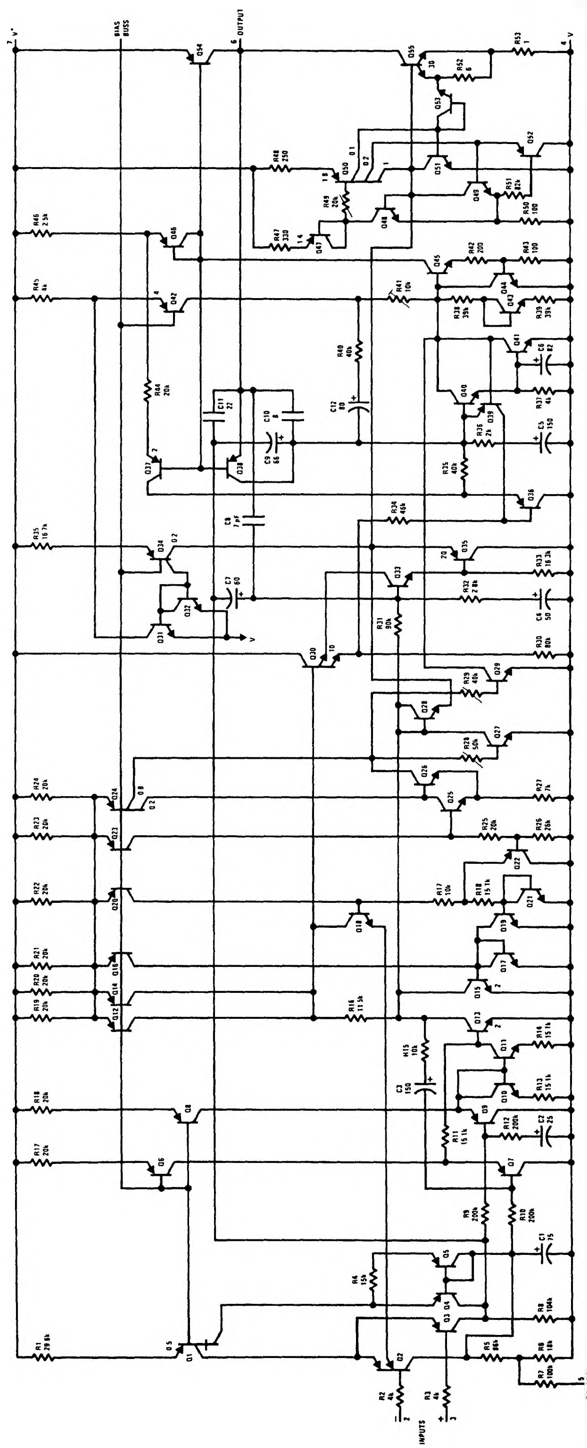
TL/H/5652–12

††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)



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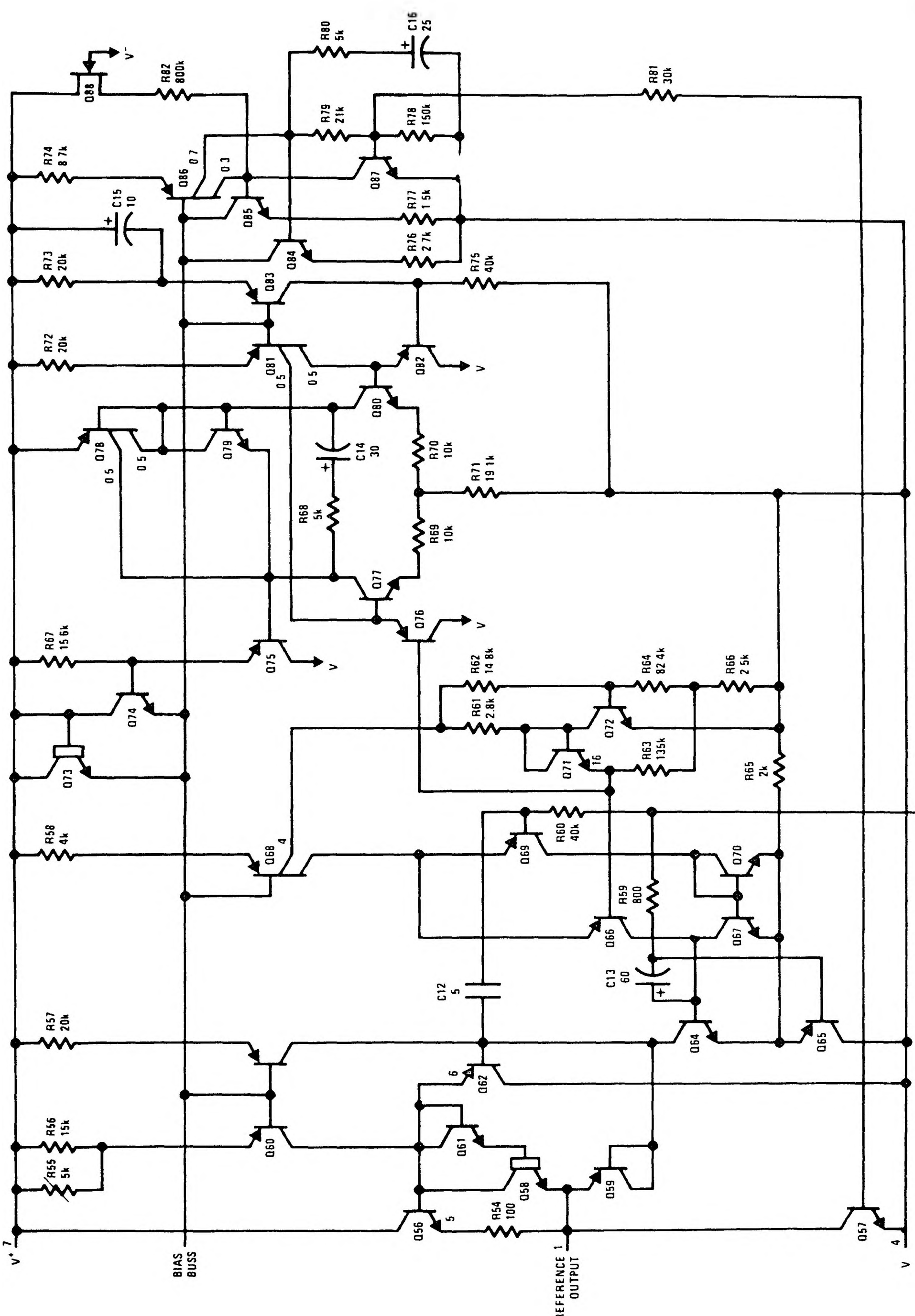
Reference and Internal Regulator (Pin numbers are for 8-pin packages)



TL/H/5652-14

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.