National Semiconductor

December 1994

LM199/LM299/LM399/LM3999 Precision Reference

General Description

The LM199 series are precision, temperature-stabilized monolithic zeners offering temperature coefficients a factor of ten better than high quality reference zeners. Constructed on a single monolithic chip is a temperature stabilizer circuit and an active reference zener. The active circuitry reduces the dynamic impedance of the zener to about 0.5Ω and allows the zener to operate over 0.5 mA to 10 mA current range with essentially no change in voltage or temperature coefficient. Further, a new subsurface zener structure gives low noise and excellent long term stability compared to ordinary monolithic zeners. The package is supplied with a thermal shield to minimize heater power and improve temperature regulation.

The LM199 series references are exceptionally easy to use and free of the problems that are often experienced with ordinary zeners. There is virtually no hysteresis in reference voltage with temperature cycling. Also, the LM199 is free of voltage shifts due to stress on the leads. Finally, since the unit is temperature stabilized, warm up time is fast.

The LM199 can be used in almost any application in place of ordinary zeners with improved performance. Some ideal applications are analog to digital converters, calibration standards, precision voltage or current sources or precision power supplies. Further in many cases the LM199 can replace references in existing equipment with a minimum of wiring changes.

The LM199 series devices are packaged in a standard hermetic TO-46 package inside a thermal shield. The LM199 is rated for operation from −55°C to +125°C while the LM299 is rated for operation from −25°C to +85°C and the LM399 is rated from 0°C to +70°C.

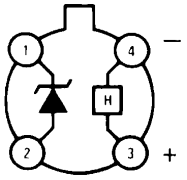
The LM3999 is packaged in a standard TO-92 package and is rated from 0°C to +70°C

Features

- Guaranteed 0.0001%/°C temperature coefficient
- Low dynamic impedance — 0.5Ω
- Initial tolerance on breakdown voltage — 2%
- Sharp breakdown at 400 μA
- Wide operating current — 500 μA to 10 mA
- Wide supply range for temperature stabilizer
- Guaranteed low noise
- Low power for stabilization — 300 mW at 25°C
- Long term stability — 20 ppm
- Proven reliability, low-stress packaging in TO-46 integrated-circuit hermetic package, for low hysteresis after thermal cycling. 33 million hours MTBF at $T_A = +25°C$ ($T_J = +86°C$)
- Certified long term stability available
- MIL-STD-883 compliant

Connection Diagrams

Metal Can Package (TO-46)



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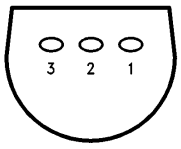
Top View

LM199/LM299/LM399 (See Table on fourth page)
NS Package Number H04D

Plastic Package TO-92



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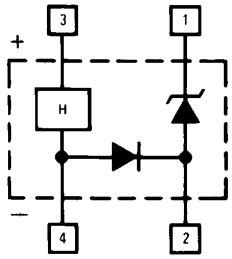
Bottom View

LM3999 (See Table on fourth page)
NS Package Number Z03A

Functional Block Diagrams

LM199/LM299/LM399



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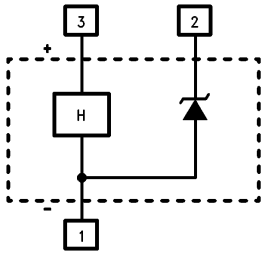
LM3999



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RRD-B30M115/Printed in U. S. A.

Absolute Maximum Ratings

Specifications for Military/Aerospace products are not contained in this datasheet. Refer to the following Reliability Electrical Test Specifications documents: RETS199X for LM199, RETS199AX for LM199A.

Temperature Stabilizer Voltage
- LM199/LM299/LM399: 40V
- LM3999: 36V

Reverse Breakdown Current: 20 mA

Forward Current
- LM199/LM299/LM399: 1 mA
- LM3999: −0.1 mA

Reference to Substrate Voltage $V_{(RS)}$ (Note 1): 40V, −0.1V

Operating Temperature Range
- LM199: −55°C to +125°C
- LM299: −25°C to +85°C
- LM399/LM3999: −0°C to +70°C

Storage Temperature Range: −55°C to +150°C

Soldering Information
- TO-92 package (10 sec.): +260°C
- TO-46 package (10 sec.): +300°C

Electrical Characteristics (Notes 2, 5)

Parameter	Conditions	LM199H/LM299H			LM399H			Units
		Min	Typ	Max	Min	Typ	Max	
Reverse Breakdown Voltage	0.5 mA ≤ I_R ≤ 10 mA	6.8	6.95	7.1	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change with Current	0.5 mA ≤ I_R ≤ 10 mA		6	9		6	12	mV
Reverse Dynamic Impedance	I_R = 1 mA		0.5	1		0.5	1.5	Ω
Reverse Breakdown Temperature Coefficient	−55°C ≤ T_A ≤ +85°C, LM199		0.00003	0.0001				%/°C
	+85°C ≤ T_A ≤ +125°C, LM199		0.0005	0.0015				%/°C
	−25°C ≤ T_A ≤ 85°C, LM299		0.00003	0.0001				%/°C
	0°C ≤ T_A ≤ +70°C, LM399					0.00003	0.0002	%/°C
RMS Noise	10 Hz ≤ f ≤ 10 kHz		7	20		7	50	μV
Long Term Stability	Stabilized, 22°C ≤ T_A ≤ 28°C, 1000 Hours, I_R = 1 mA ± 0.1%		20			20		ppm
Temperature Stabilizer Supply Current	T_A = 25°C, Still Air, V_S = 30V		8.5	14		8.5	15	mA
	T_A = −55°C		22	28				
Temperature Stabilizer Supply Voltage		9		40	9		40	V
Warm-Up Time to 0.05%	V_S = 30V, T_A = 25°C		3			3		sec.
Initial Turn-on Current	9 ≤ V_S ≤ 40, T_A = +25°C, (Note 3)		140	200		140	200	mA

Electrical Characteristics (Note 2)

Parameter	Conditions	LM3999Z			Units
		Min	Typ	Max	
Reverse Breakdown Voltage	0.6 mA ≤ I_R ≤ 10 mA	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change with Current	0.6 mA ≤ I_R ≤ 10 mA		6	20	mV
Reverse Dynamic Impedance	I_R = 1 mA		0.6	2.2	Ω
Reverse Breakdown Temperature Coefficient	0°C ≤ T_A ≤ 70°C		0.0002	0.0005	%/°C
RMS Noise	10 Hz ≤ f ≤ 10 kHz		7		μV
Long Term Stability	Stabilized, 22°C ≤ T_A ≤ 28°C, 1000 Hours, I_R = 1 mA ±0.1%		20		ppm
Temperature Stabilizer	T_A = 25°C, Still Air, V_S = 30V		12	18	mA
Temperature Stabilizer Supply Voltage				36	V
Warm-Up Time to 0.05%	V_S = 30V, T_A = 25°C		5		sec.
Initial Turn-On Current	9 ≤ V_S ≤ 40, T_A = 25°C		140	200	mA

Electrical Characteristics (Notes 2, 5)

Parameter	Conditions	LM199AH, LM299AH			LM399AH			Units
		Min	Typ	Max	Min	Typ	Max	
Reverse Breakdown Voltage	0.5 mA ≤ I_R ≤ 10 mA	6.8	6.95	7.1	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change with Current	0.5 mA ≤ I_R ≤ 10 mA		6	9		6	12	mV
Reverse Dynamic Impedance	I_R = 1 mA		0.5	1		0.5	1.5	Ω
Reverse Breakdown Temperature Coefficient	−55°C ≤ T_A ≤ +85°C, LM199A		0.00002	0.00005				%/°C
	+85°C ≤ T_A ≤ +125°C, LM199A		0.0005	0.0010				%/°C
	−25°C ≤ T_A ≤ 85°C, LM299A		0.00002	0.00005				%/°C
	0°C ≤ T_A ≤ +70°C, LM399A					0.00003	0.0001	%/°C
RMS Noise	10 Hz ≤ f ≤ 10 kHz		7	20		7	50	μV
Long Term Stability	Stabilized, 22°C ≤ T_A ≤ 28°C, 1000 Hours, I_R = 1 mA ± 0.1%		20			20		ppm
Temperature Stabilizer Supply Current	T_A = 25°C, Still Air, V_S = 30V		8.5	14		8.5	15	mA
	T_A = − 55°C		22	28				
Temperature Stabilizer Supply Voltage		9		40	9		40	V
Warm-Up Time to 0.05%	V_S = 30V, T_A = 25°C		3			3		sec.
Initial Turn-on Current	9 ≤ V_S ≤ 40, T_A = +25°C, (Note 3)		140	200		140	200	mA

Electrical Characteristics (Notes 2, 5)

Parameter	Conditions	LM199AH-20, LM299AH-20			LM399AH-50			Units
		Min	Typ	Max	Min	Typ	Max	
Reverse Breakdown Voltage	0.5 mA ≤ I_R ≤ 10 mA	6.8	6.95	7.1	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change With Current	0.5 mA ≤ I_R ≤ 10 mA		6	9		6	12	mV
Reverse Dynamic Impedance	I_R = 1 mA		0.5	1		0.5	1.5	Ω
Reverse Breakdown Temperature Coefficient	−55°C ≤ T_A ≤ 85°, LM199A		0.00002	0.00005				%/°C
	85°C ≤ T_A ≤ 125°C, LM199A		0.0005	0.0010				%/°C
	−25°C ≤ T_A ≤ 85°C, LM299A		0.00002	0.00005				%/°C
	0°C ≤ T_A ≤ 70°C, LM399A					0.00003	0.0001	%/°C
RMS Noise	10 Hz ≤ f ≤ 10 kHz		7	20		7	50	μV
Long Term Stability	Stabilized, 22°C ≤ T_A ≤ 28°C, 1000 Hours, I_R = 1 mA ± 0.1%		8	20		9	50	ppm
Temperature Stabilizer Supply Current	T_A = 25°C, Still Air, V_S = 30V		8.5	14		8.5	15	mA
	T_A = 55°C		22	28				
Temperature Stabilizer Supply Voltage		9		40	9		40	V
Warm-Up Time to 0.05%	V_S = 30V, T_A = 25°C		3			3		s
Initial Turn-on Current	9 ≤ V_S ≤ 40, T_A = 25°C, (Note 3)		140	200		140	200	mA

Note 1: The substrate is electrically connected to the negative terminal of the temperature stabilizer. The voltage that can be applied to either terminal of the reference is 40V more positive or 0.1V more negative than the substrate.

Note 2: These specifications apply for 30V applied to the temperature stabilizer and −55°C ≤ T_A ≤ +125°C for the LM199; −25°C ≤ T_A ≤ +85°C for the LM299 and 0°C ≤ T_A ≤ +70°C for the LM399 and LM3999.

Note 3: This initial current can be reduced by adding an appropriate resistor and capacitor to the heater circuit. See the performance characteristic graphs to determine values.

Note 4: Do not wash the LM199 with its polysulfone thermal shield in TCE.

Note 5: A military RETS electrical test specification is available for the LM199H/883, LM199AH/883, and LM199AH-20/883 on request.

Ordering Information

Initial Tolerance	0°C to +70°C	−25°C to +85°C	−55°C to +125°C	NS Package
2%		LM299AH	LM199AH, LM199AH/883	H04D
5%	LM399H LM399AH	LM299H	LM199H, LM199H/883	H04D
5%	LM3999Z			Z03A
Guaranteed Long Term Stability	LM399AH-50	LM299AH-20	LM199AH-20, LM199AH-20/883	H04D

Certified Long Term Drift

The National Semiconductor LM199AH-20, LM299AH-20, and LM399AH-50 are ultra-stable Zener references specially selected from the production runs of LM199AH, LM299AH, LM399AH and tested to confirm a long-term stability of 20, 20, or 50 ppm per 1000 hours, respectively. The devices are measured every 168 hours and the voltage of each device is logged and compared in such a way as to show the deviation from its initial value. Each measurement is taken with a probable-worst-case deviation of ±2 ppm, compared to the Reference Voltage, which is derived from several groups of NBS-traceable references such as LM199AH-20's, 1N827's, and saturated standard cells, so that the deviation of any one group will not cause false indications. Indeed, this comparison process has recently been automated using a specially prepared computer program which is custom-designed to reject noisy data (and require a repeat reading) and to record the average of the best 5 of 7 readings, just as a sagacious standards engineer will reject unbelievable readings.

The typical characteristic for the LM199AH-20 is shown below. This computerized print-out form of each reference's stability is shipped with the unit.

Typical Characteristics

National Semiconductor
Certified Long Term Drift

Hrs	Drift
168	−20
336	−24
504	−36
672	−34
840	−40
1008	−36

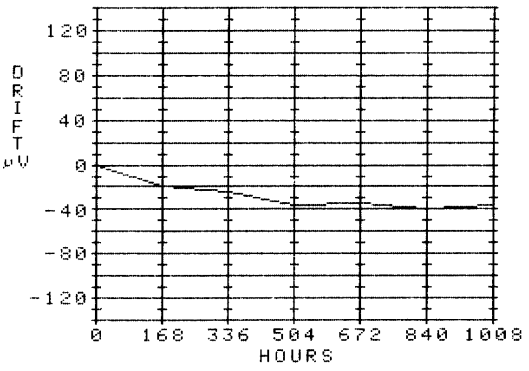
LM199AH-20
Part #6849

Limits

LM199AH-20	140 μV
LM299AH-20	140 μV
LM399AH-20	350 μV

Testing Conditions

Heater Voltage	30V
Zener Current	1 mA
Ambient Temp.	25°C



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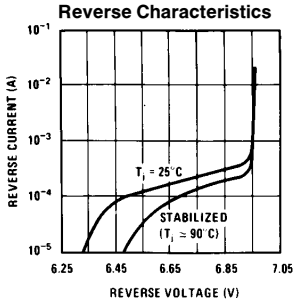
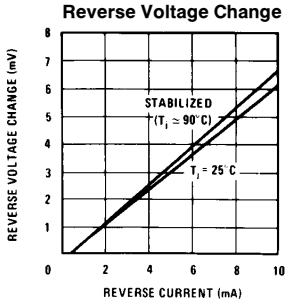
Typical Performance Characteristics

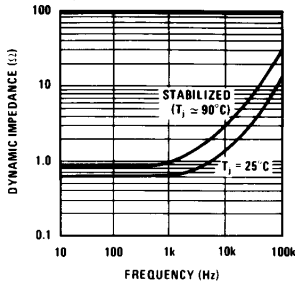
Reverse Characteristics



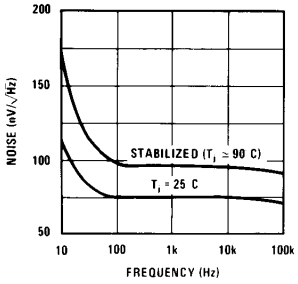
Reverse Voltage Change



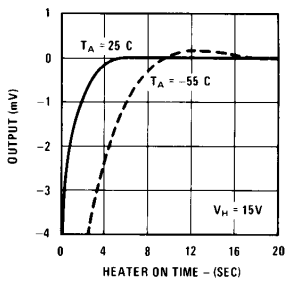
Dynamic Impedance



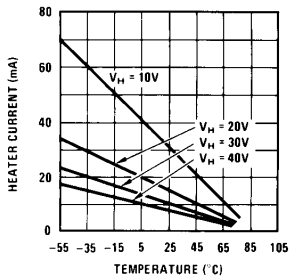
Zener Noise Voltage



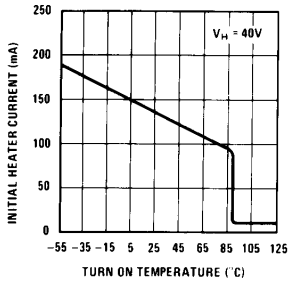
Stabilization Time



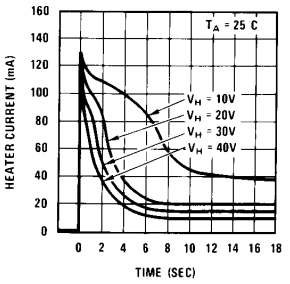
Heater Current



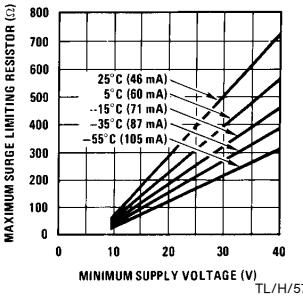
Initial Heater Current



Heater Current (To Limit This Surge, See Next Graph)



Heater Surge Limit Resistor vs Minimum Supply Voltage at Various Minimum Temperatures



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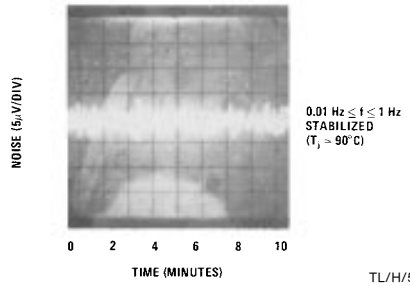
*Heater must be bypassed with a 2 μF or larger tantalum capacitor if resistors are used.

Low Frequency Noise Voltage



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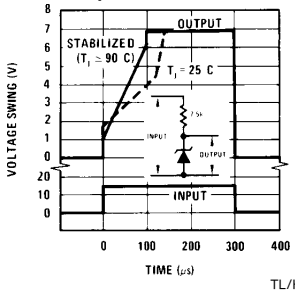
Response Time



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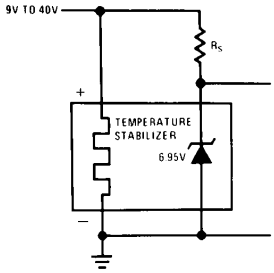
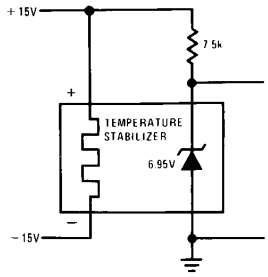
Typical Applications

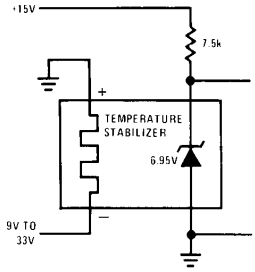
Single Supply Operation



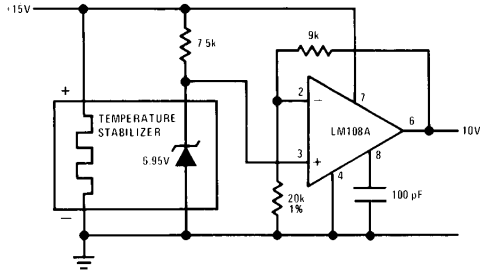
Split Supply Operation



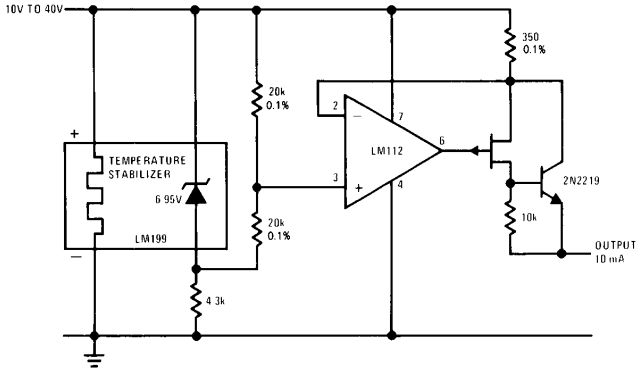
Negative Heater Supply with Positive Reference



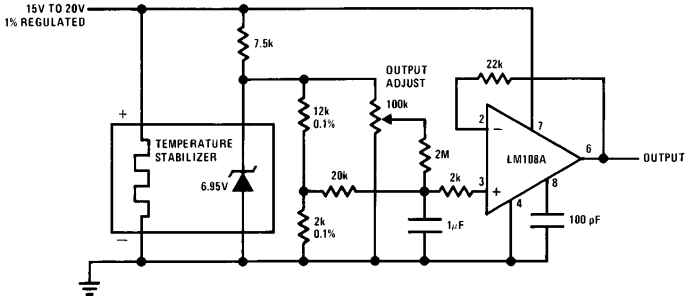
Buffered Reference With Single Supply



Positive Current Source



Standard Cell Replacement



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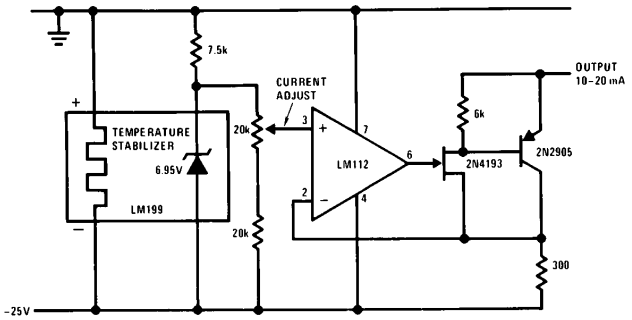
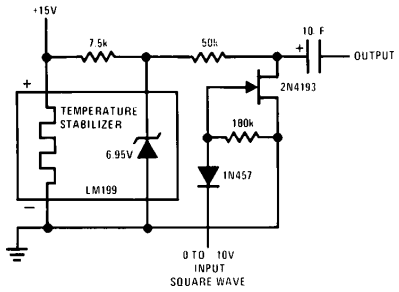
Typical Applications (Continued)

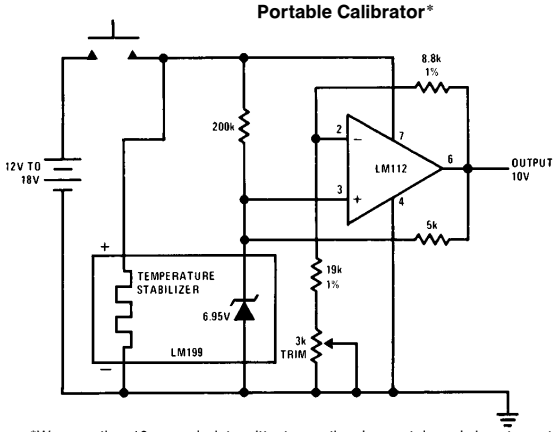
Negative Current Source



Square Wave Voltage Reference

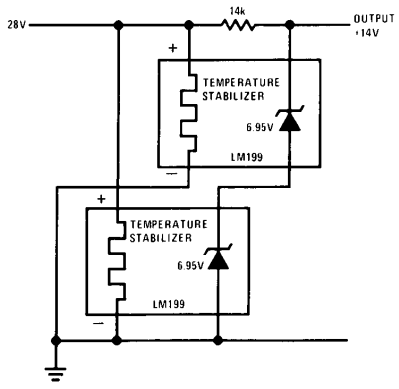


Portable Calibrator*

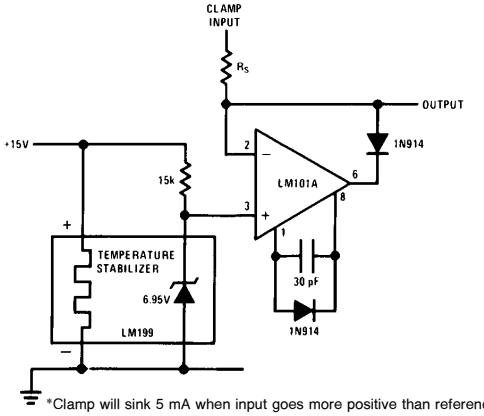


*Warm-up time 10 seconds; intermittent operation does not degrade long term stability.

14V Reference



Precision Clamp*



*Clamp will sink 5 mA when input goes more positive than reference

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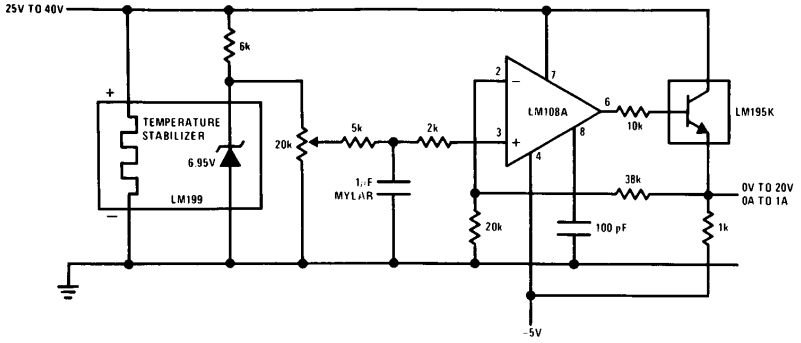
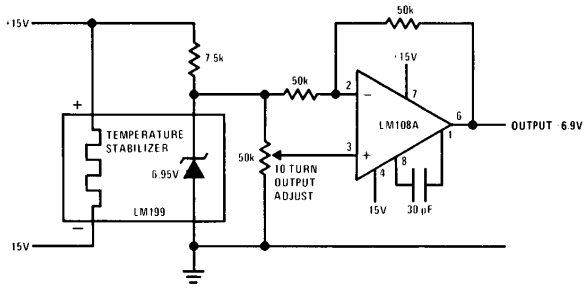
Typical Applications (Continued)

0V to 20V Power Reference



Bipolar Output Reference



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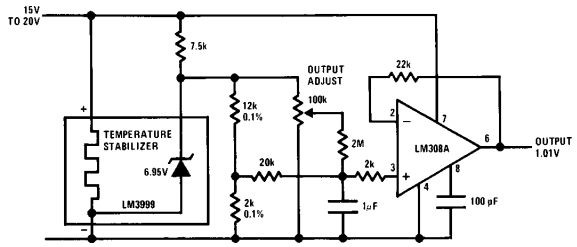
Voltage Reference



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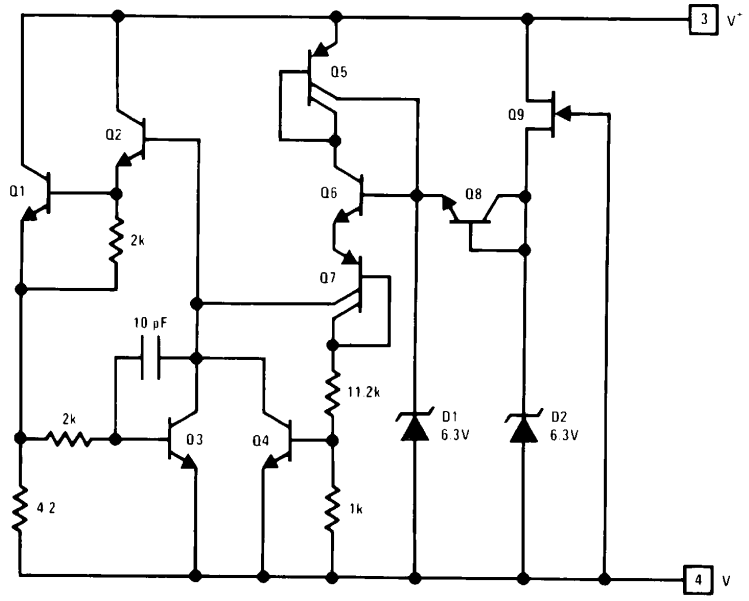
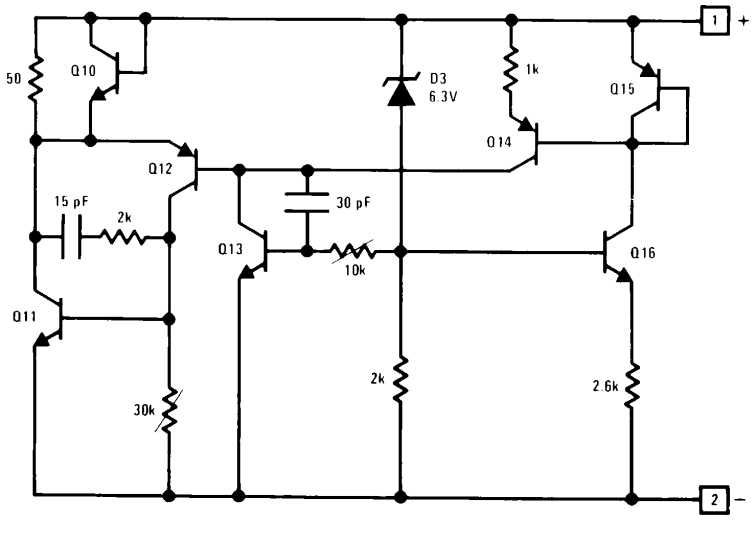
Schematic Diagrams

Temperature Stabilizer

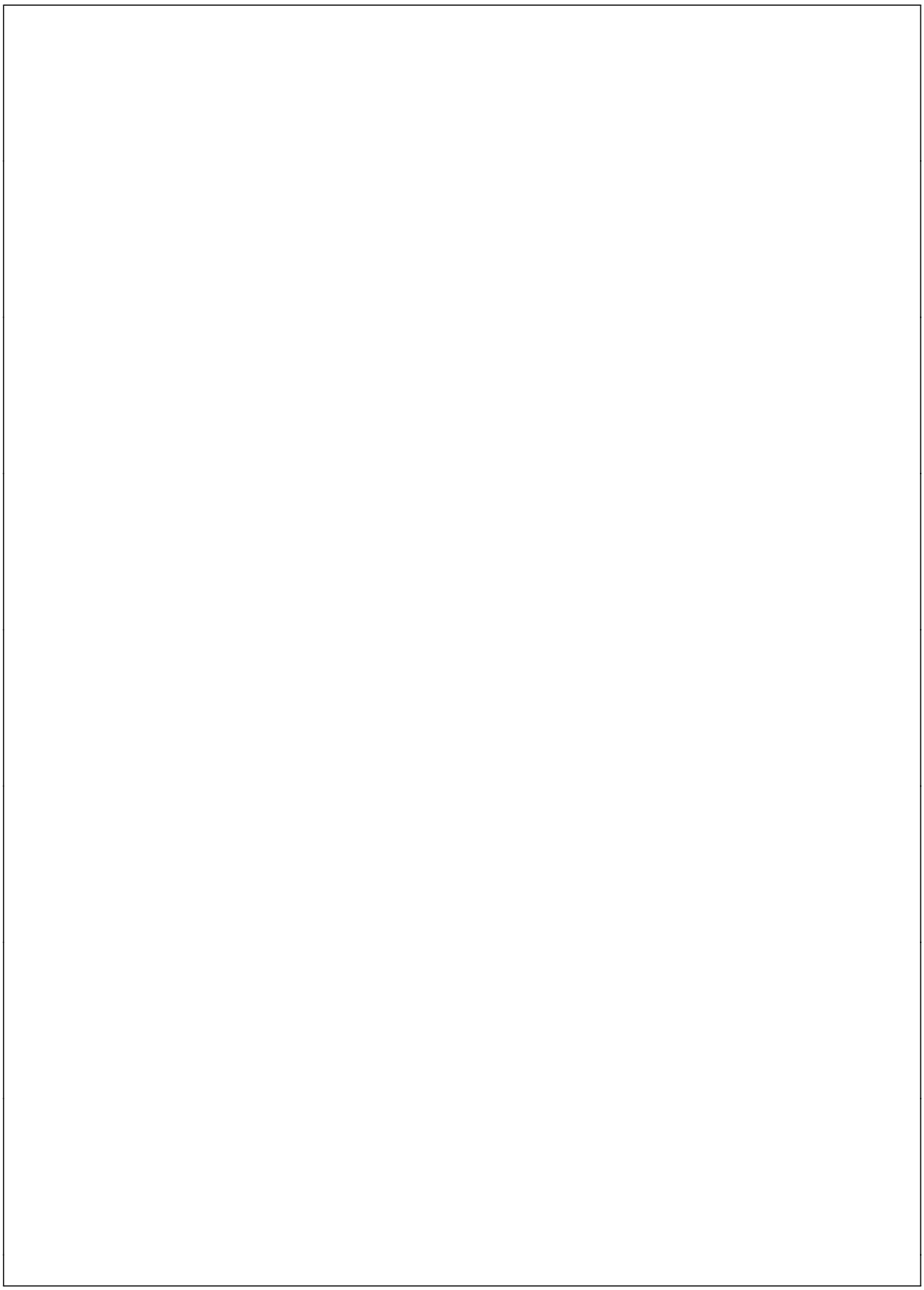


TL/H/5717–01

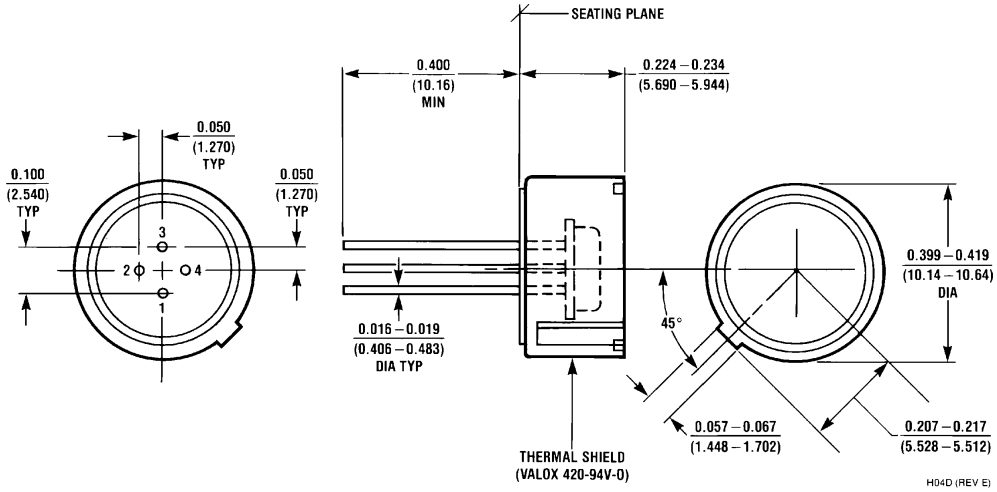
Reference



TL/H/5717–13

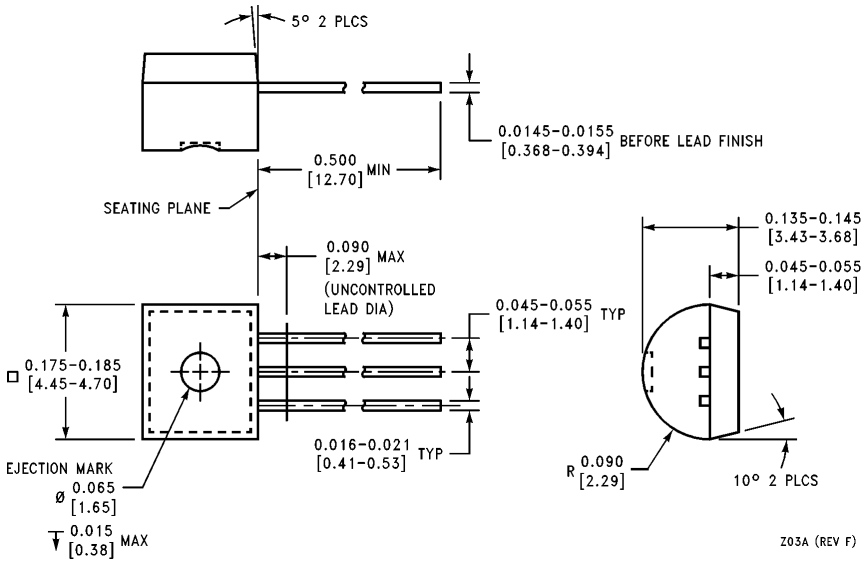


Physical Dimensions inches (millimeters)



Order Number LM199H, LM199H/883, LM299H, LM399H, LM199AH, LM199AH/883, LM199AH-20, LM199AH-20/883, LM299AH, LM299AH-20, LM399AH or LM399AH-50
NS Package H04D

Physical Dimensions inches (millimeters) (Continued)



Plastic Package
Order Number LM3999Z
NS Package Z03A

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National Semiconductor Corporation
1111 West Bardin Road
Arlington, TX 76017
Tel: 1(800) 272-9959
Fax: 1(800) 737-7018

National Semiconductor Europe
Fax: (+49) 0-180-530 85 86
Email: cnjwge@tevm2.nsc.com
Deutsch Tel: (+49) 0-180-530 85 85
English Tel: (+49) 0-180-532 78 32
Français Tel: (+49) 0-180-532 93 58
Italiano Tel: (+49) 0-180-534 16 80

National Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
Tel: 81-043-299-2309
Fax: 81-043-299-2408