National Semiconductor

MICROCIRCUIT DATA SHEET

MRLM108A-X-RH REV 1A0

Original Creation Date: 12/21/98
Last Update Date: 04/16/99
Last Major Revision Date: 04/06/99

OPERATIONAL AMPLIFIERS (SINGLE) GUARANTEED TO 100K RAD(Si) TESTED TO MIL-STD-883, METHOD 1019.5

General Description

The LM108A is a precision operational amplifier having specifications a factor of ten better than FET amplifiers over a -55 C to +125 C temperature range.

The device operates with supply voltages from ±2V to ±20V and has sufficient supply rejection to use unregulated supplies. Although the circuit is interchangeable with and uses the same compensation as the LM101A, an alternate compensation scheme can be used to make it particularly insensitive to power supply noise and to make supply bypass capacitors unnecessary.

The low current error of the LM108A makes possible many designs that are not practical with conventional amplifiers. In fact, it operates from 10M Ohms source resistances, introducing less error than devices like the 709 with 10K Ohms sources. Integrators with drifts less than 500 uV/sec and analog time delays in excess of one hour can be made using capacitors no larger than 1uF.

Industry Part Number

LM108A

Prime Die

LM108A

Controlling Document

SEE FEATURES SECTION

NS Part Numbers

LM108AHRQML
LM108AHRQMLV
LM108AJ-8RQML
LM108AJ-8RQMLV
LM108AJRQML
LM108AJRQMLV
LM108AWGRQML
LM108AWGRQMLV
LM108AWRQML
LM108AWRQMLV

Processing

MIL-STD-883, Method 5004

Quality Conformance Inspection

MIL-STD-883, Method 5005

Subgrp	Description	Temp (°C)
1	Static tests at	+25
2	Static tests at	+125
3	Static tests at	-55
4	Dynamic tests at	+25
5	Dynamic tests at	+125
6	Dynamic tests at	-55
7	Functional tests at	+25
8A	Functional tests at	+125
8B	Functional tests at	-55
9	Switching tests at	+25
10	Switching tests at	+125
11	Switching tests at	-55

Features

CONTROLLING DOCUMENT:

LM108AHRQML	5962R9863702QGA
LM108AHRQMLV	5962R9863702VGA
LM108AJ-8RQML	5962R9863702QPA
LM108AJ-8RQMLV	5962R9863702VPA
LM108AJRQML	5962R9863702QCA
LM108AJRQMLV	5962R9863702VCA
LM108AWGRQML	5962R9863702QZA
LM108AWGRQMLV	5962R9863702VZA
LM108AWRQML	5962R9863702QHA
LM108AWRQMLV	5962R9863702VHA

(Absolute Maximum Ratings)
(Note 1)

Supply Voltage			±22V
Power Dissipation (Note 2)			
METAL CAN			330mW @ +125 C
CERDIP,	14 Lead		400mW @ +125 C
CERDIP,	8 Lead		400mW @ +125 C
CERPACK,	10 Lead		330mW @ +125 C
CERAMIC SOIC			330mW @ +125 C
Differential Input Current (Note 3)			±10mA
Differential Input Voltage (Note 5)			±30V
Input Voltage (Note 4)			±20V
Output Short-Circuit Duration			Continuous
Operating Temperature Range			-55 C to +125 C
Storage Temperature Range			-65 C to +150 C
Thermal Resistance			
ThetaJA			
METAL CAN	(Still Air)		150 C/W
	(500LF/Min Air flow)		86 C/W
CERDIP, 14 Lead	(Still Air)		94 C/W
	(500LF/Min Air flow)		55 C/W
CERDIP, 8 Lead	(Still Air)		120 C/W
	(500LF/Min Air flow)		68 C/W
CERPACK, 10 Lead	(Still Air)		225 C/W
	(500LF/Min Air flow)		142 C/W
CERAMIC SOIC	(Still Air)		225 C/W
	(500LF/Min Air flow)		142 C/W
ThetaJC			
METAL CAN			38 C/W
CERDIP,	14 Lead		13 C/W
CERDIP,	8 Lead		17 C/W
CERPACK,	10 Lead		21 C/W
CERAMIC SOIC			21 C/W
Package Weight (Typical)			
METAL CAN			990mg
CERDIP,	14 Lead		2180mg
CERDIP,	8 Lead		1090mg
CERPACK,	10 Lead		225mg
CERAMIC SOIC			210mg
Maximum Junction Temperature			175 C
Soldering Information (Soldering, 10 seconds)			300 C
ESD Tolerance (Note 6)			2000V

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. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 2: The maximum power dissipation must be derated at elevated temperatures and is dictated by Tjmax (maximum junction temperature), ThetaJA (package junction to ambient thermal resistance), and TA (ambient temperature). The maximum allowable power dissipation at any temperature is Pdmax = (Tjmax - TA) /ThetaJA or the number given in the Absolute Maximum Ratings, whichever is lower.

Note 3: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 4: For supply voltages less than $\pm$20V, the absolute maximum input voltage is equal to the supply voltage.

Note 5: This rating is $\pm$1.0V unless resistances of 2K Ohms or greater are inserted in series with the inputs to limit current in the input shunt diodes to the maximum allowable value.

Note 6: Human body model, 1.5K Ohms in series with 100pF.

Electrical Characteristics

DC PARAMETERS

(The following conditions apply to all the following parameters, unless otherwise specified.)
DC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms

SYMBOL	PARAMETER	CONDITIONS	NOTES	PIN-NAME	MIN	MAX	UNIT	SUB-GROUPS
Vio	Input Offset Voltage	+Vcc = 35V, -Vcc = -5V, Vcm = -15V			-0.5	0.5	mV	1
					-1	1	mV	2, 3
		+Vcc = 5V, -Vcc = -35V, Vcm = 15V			-0.5	0.5	mV	1
					-1	1	mV	2, 3
					-0.5	0.5	mV	1
					-1	1	mV	2, 3
		+Vcc = +5V, -Vcc = -5V			-0.5	0.5	mV	1
					-1	1	mV	2, 3
Delta Vio/Delta T	Temperature Coeffient of Input Offset Voltage	25 C ≤ TA ≤ +125 C	1		-5	5	uV/C	2
		25 C ≤ TA ≤ -55 C	1		-5	5	uV/C	3
Iio	Input Offset Current	+Vcc = 35V, -Vcc = -5V, Vcm = -15V			-0.2	0.2	nA	1
					-0.4	0.4	nA	2, 3
		+Vcc = 5V, -Vcc = -35V, Vcm = 15V			-0.2	0.2	nA	1
					-0.4	0.4	nA	2, 3
					-0.2	0.2	nA	1
					-0.4	0.4	nA	2, 3
		+Vcc = +5V, -Vcc = -5V			-0.2	0.2	nA	1
					-0.4	0.4	nA	2, 3
Delta Iio/Delta T	Temperature Coeffient of Input Offset Current	25 C ≤ TA ≤ +125 C	1		-2.5	2.5	pA/C	2
		25 C ≤ TA ≤ -55 C	1		-2.5	2.5	pA/C	3

Electrical Characteristics

DC PARAMETERS(Continued)

(The following conditions apply to all the following parameters, unless otherwise specified.)
DC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms

SYMBOL	PARAMETER	CONDITIONS	NOTES	PIN-NAME	MIN	MAX	UNIT	SUB-GROUPS
+Iib	Input Bias Current	+Vcc = 35V, -Vcc = -5V, Vcm = -15V			-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
		+Vcc = 5V, -Vcc = -35V, Vcm = 15V			-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
					-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
		+Vcc = +5V, -Vcc = -5V			-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
-Iib	Input Bias Current	+Vcc = 35V, -Vcc = -5V, Vcm = -15V			-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
		+Vcc = 5V, -Vcc = -35V, Vcm = 15V			-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
					-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
		+Vcc = +5V, -Vcc = -5V			-0.1	2	nA	1
					-1	2	nA	2
					-0.1	3	nA	3
+PSRR	Power Supply Rejection Ratio	+Vcc = 10V, -Vcc = -20V			-16	16	uV/V	1, 2, 3
-PSRR	Power Supply Rejection Ratio	+Vcc = 20V, -Vcc = -10V			-16	16	uV/V	1, 2, 3
CMRR	Common Mode Rejection Ratio	Vcm = ±15V			96		dB	1, 2, 3
Ios+	Short Circuit Current	+Vcc = +15V, -Vcc = -15V, t ≤ 25mS			-15		mA	1, 2, 3

Electrical Characteristics

DC PARAMETERS(Continued)

(The following conditions apply to all the following parameters, unless otherwise specified.)
DC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms

SYMBOL	PARAMETER	CONDITIONS	NOTES	PIN-NAME	MIN	MAX	UNIT	SUB-GROUPS
Ios-	Short Circuit Current	+Vcc = +15V, -Vcc = -15V, t ≤ 25mS				15	mA	1, 2, 3
Icc	Power Supply Current	+Vcc = +15V, -Vcc = -15V				0.6	mA	1, 2
						0.8	mA	3

AC/DC PARAMETERS

(The following conditions apply to all the following parameters, unless otherwise specified.)
DC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms
AC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms

+Vop	Output Voltage Swing	Rl = 10K Ohms			16		V	4, 5, 6
-Vop	Output Voltage Swing	Rl = 10K Ohms				-16	V	4, 5, 6
Avs+	Open Loop Voltage Gain	Rl = 10K Ohms, Vout = +15V	3		80		V/mV	4
			3		40		V/mV	5, 6
Avs-	Open Loop Voltage Gain	Rl = 10K Ohms, Vout = -15V	3		80		V/mV	4
			3		40		V/mV	5, 6
Avs	Open Loop Voltage Gain	±Vcc = ±5V, Rl = 10K Ohms, Vout = ±2V	3		20		V/mV	4, 5, 6
TR(tr)	Transient Response Rise Time	Rl = 10K Ohms, Cl = 100pF, f < 1KHz, Vin = +50mV	4			1000	nS	9, 10, 11
TR(os)	Transient Response Overshoot	Rl = 10K Ohms, Cl = 100pF, f < 1KHz, Vin = +50mV	4			50	%	9, 10, 11
Sr(+)	Slew Rate	Av = 1, Vin = -5V to +5V			0.05		V/uS	9, 10, 11
Sr(-)	Slew Rate	Av = 1, Vin = +5V to -5V			0.05		V/uS	9, 10, 11
NI(BB)	Noise Broadband	BW = 10Hz to 5KHz, Rs = 0 Ohms	2			15	uVrms	9
NI(PC)	Noise Popcorn	BW = 10Hz to 5KHz, Rs = 100K Ohms	2			40	uVpk	9

Electrical Characteristics

DC PARAMETERS: DRIFT VALUES

(The following conditions apply to all the following parameters, unless otherwise specified.)
DC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms. "Delta calculations performed on JAN S and QMLV devices at group B, subgroup 5 only".

SYMBOL	PARAMETER	CONDITIONS	NOTES	PIN-NAME	MIN	MAX	UNIT	SUB-GROUPS
Vio	Input Offset Voltage				-0.25	0.25	mV	1
+Iib	Input Bias Current				-0.5	0.5	nA	1
-Iib	Input Bias Current				-0.5	0.5	nA	1

DC/AC PARAMETERS: POST RADIATION LIMITS +25 C (SEE NOTE 5)

(The following conditions apply to all the following parameters, unless otherwise specified.)
DC: ±Vcc = ±20V, Vcm = 0V, Rs = 50 Ohms.

+Iib	Input Bias Current	+Vcc = 35V, -Vcc = -5V, Vcm = -15V	5			5.0	nA	1
		+Vcc = 5V, -Vcc = -35V, Vcm = -15V	5			5.0	nA	1
			5			5.0	nA	1
		+Vcc = +5V, -Vcc = -5V	5			5.0	nA	1
-Iib	Input Bias Current	+Vcc = 35V, -Vcc = -5V, Vcm = -15V	5			5.0	nA	1
		+Vcc = 5V, -Vcc = -35V, Vcm = -15V	5			5.0	nA	1
			5			5.0	nA	1
		+Vcc = +5V, -Vcc = -5V	5			5.0	nA	1
Iio	Input Offset Current	+Vcc = 35V, -Vcc = -5V, Vcm = -15V	5			0.5	nA	1
		+Vcc = 5V, -Vcc = -35V, Vcm = -15V	5			0.5	nA	1
			5			0.5	nA	1
		+Vcc = +5V, -Vcc = -5V	5			0.5	nA	1

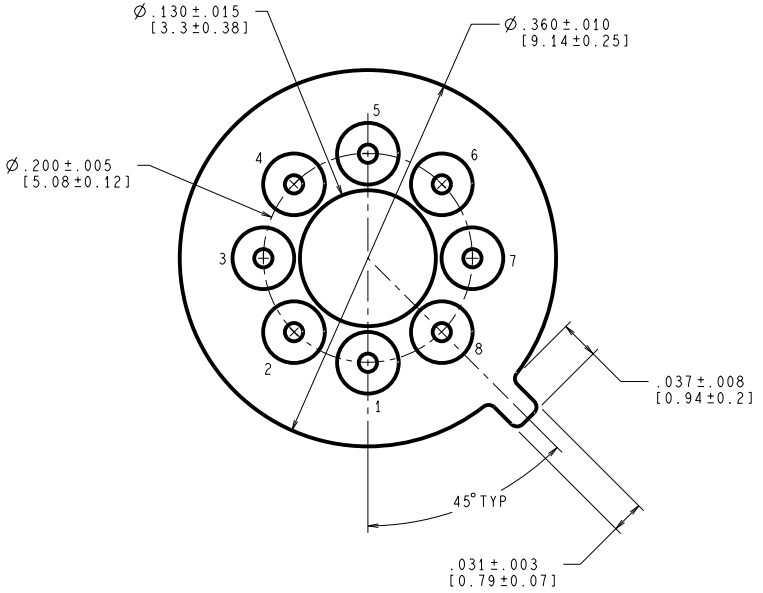
Note 1: Calculated parameter.
Note 2: Test on either A360, J273 AC or bench test.
Note 3: Datalog reading in K = V/mV.
Note 4: Bench test.
Note 5: Pre and post irradiation limits are identical to those listed under AC and DC electrical characteristics except as listed in the Post Radiation Limits Table. These parts may be dose rate sensitive in a space environment and demonstrate enhanced low dose rate effect. Radiation end point limits for the noted parameters are guaranteed only for the conditions as specified in MIL-STD-883, Method 1019.5.

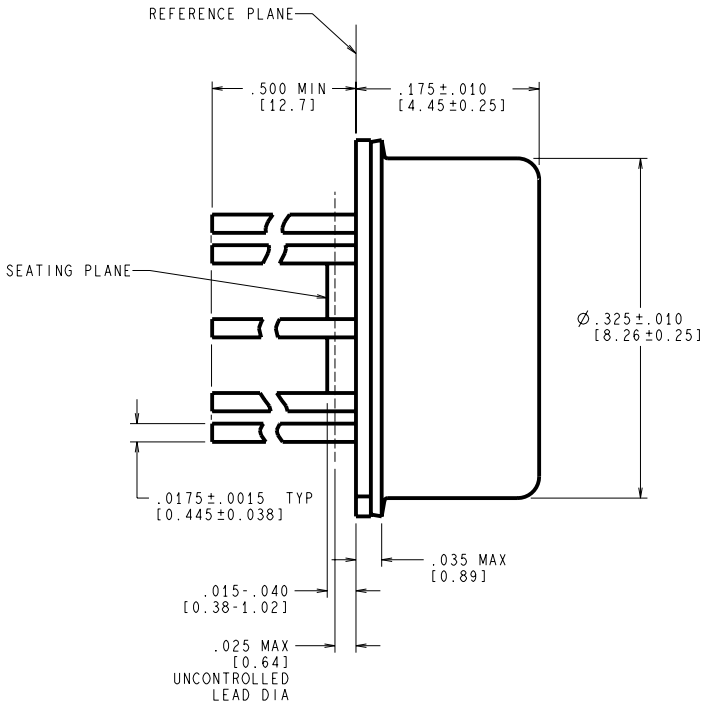
Graphics and Diagrams

GRAPHICS#	DESCRIPTION
H08CRF	METAL CAN (H), TO-99, 8LD, .200 DIA P.C. (P/P DWG)
J08ARL	CERDIP (J), 8 LEAD (P/P DWG)
J14ARH	CERDIP (J), 14 LEAD (P/P DWG)
P000253A	CERAMIC SOIC (WG), 10 LEAD (PINOUT)
P000310A	METAL CAN (H), TO-99, 8LD, .200 DIA P.C. (PINOUT)
P000311A	CERDIP (J), 14 LEAD (PINOUT)
P000312A	CERDIP (J), 8 LEAD (PINOUT)
P000431A	CERPACK (W), 10 LEAD (PINOUT)
W10ARG	CERPACK (W), 10 LEAD (P/P DWG)
WG10ARC	CERAMIC SOIC (WG), 10 LEAD (P/P DWG)

See attached graphics following this page.

REVISIONS				
LTR	DESCRIPTION	E.C.N.	DATE	BY/APP'D
F	REVISE & REDRAW PER CURRENT STANDARD; UPDATE MIL/AERO STAMP & TITLE.	11002	06/22/95	MS/





CONTROLLING DIMENSION IS INCH
VALUES IN [] ARE MILLIMETERS

MIL-I-38535
CONFIGURATION CONTROL

NOTES: UNLESS OTHERWISE SPECIFIED

1. LEADS TO BE LOCATED WITHIN .007 IN/ 0.18 mm OF THEIR TRUE POSITIONS RELATIVE TO A MAXIMUM WIDTH TAB.
2. STANDARD METAL CAN TYPE: SOLID BASE WITH CERAMIC STANDOFF.
3. APPLIES TO MIL-AERO AND LINEAR PRODUCTS.
4. REFERENCE JEDEC REGISTRATION TO-99, JEDEC PUBLICATION No.95.

APPROVALS	DATE
DRAWN: MARTA SUCHY	06/22/95
DFTG. CHK.	
ENGR. CHK.	

National Semiconductor
2900 Semiconductor dr, Santa Clara, CA 95052-8090

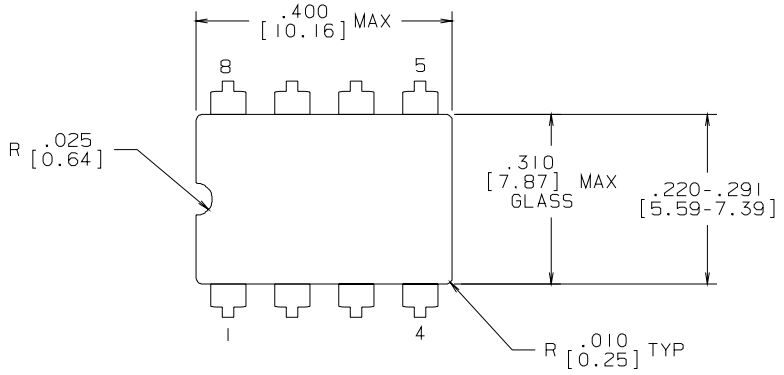
METAL CAN, TO-99, 8 LEAD, .200 DIA P.C.

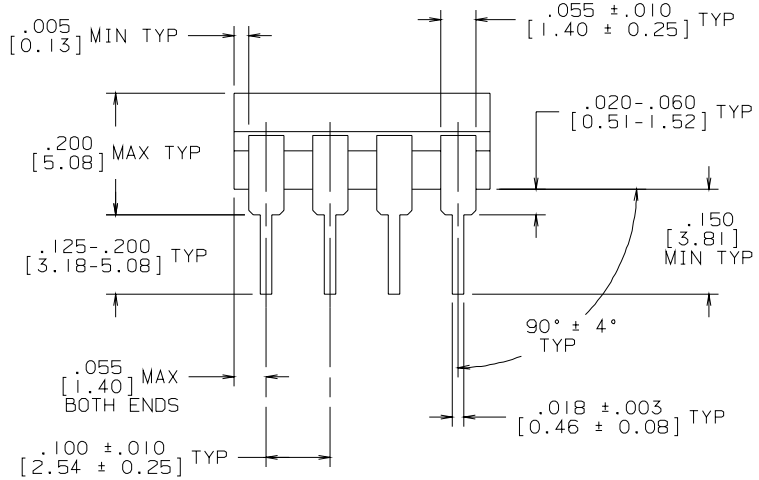
PROJECTION — INCH [MM]

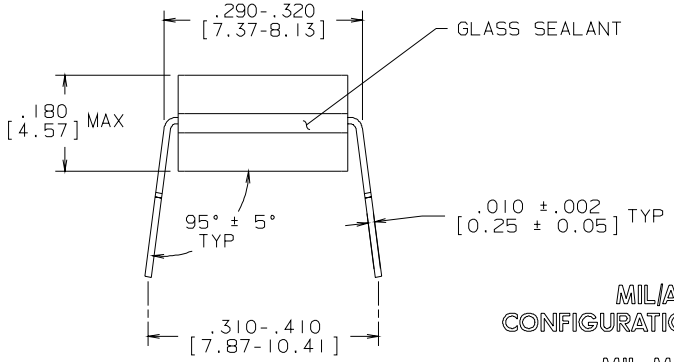
SCALE	SIZE	DRAWING NUMBER	REV
N/A	C	MKT-H08C	F

DO NOT SCALE DRAWING — SHEET 1 of 1

REVISIONS				
LTR	DESCRIPTION	E.C.N.	DATE	BY/APP'D
L	REVISE PER CURRENT STD; REDRAW	10002	09/21/93	TL/







MIL/AERO
CONFIGURATION CONTROL

MIL-M-38510
CONFIGURATION CONTROL

NOTES: UNLESS OTHERWISE SPECIFIED

1. LEAD FINISH TO BE 200 MICROINCHES / 5.08 MICROMETERS MINIMUM SOLDER MEASURED AT THE CREST OF THE MAJOR FLATS.
2. JEDEC REGISTRATION MO-036, VARIATION AA, DATED 04/1981.

CONTROLLING DIMENSION: INCH

APPROVALS	DATE
DRAWN T. LEQUANG	09/21/93
DFTG. CHK.	
ENGR. CHK.	
APPROVAL	

PROJECTION

INCH
[MM]

NATIONAL SEMICONDUCTOR CORPORATION
2900 Semiconductor Drive, Santa Clara, CA 95052-8090

CERDIP (J), 8 LEAD

SCALE	SIZE	DRAWING NUMBER	REV
N/A	B	MKT-J08A	L

DO NOT SCALE DRAWING | SHEET 1 OF 1

REVISIONS				
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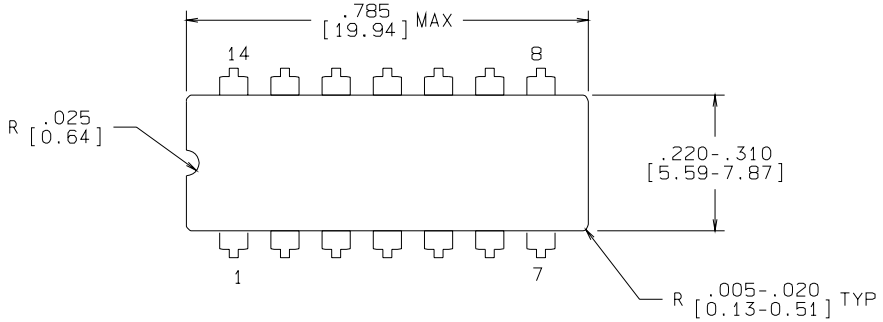
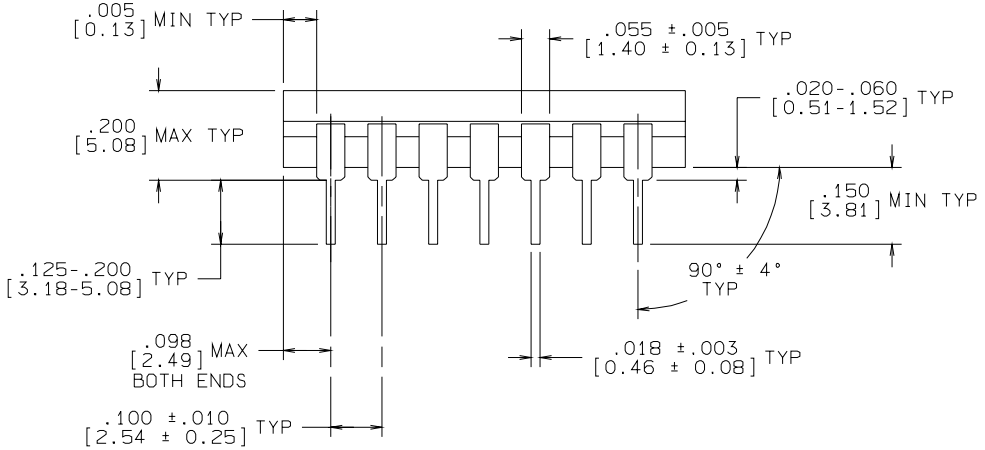
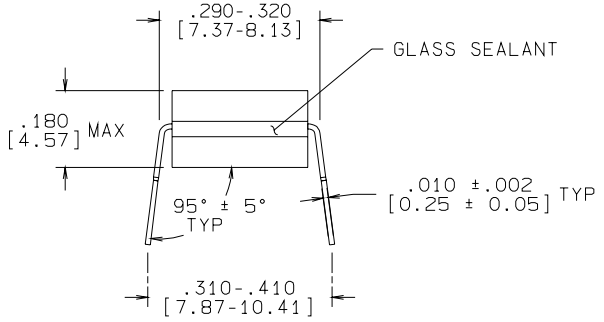






CONTROLLING DIMENSION: INCH

MIL/AERO CONFIGURATION CONTROL

MIL-M-38510 CONFIGURATION CONTROL

NOTES: UNLESS OTHERWISE SPECIFIED

1. LEAD FINISH TO BE 200 MICROINCHES / 5.08 MICROMETERS MINIMUM SOLDER MEASURED AT THE CREST OF THE MAJOR FLATS.
2. JEDEC REGISTRATION MO-036, VARIATION AB, DATED 04/1981.

APPROVALS	DATE
DRAWN T. LEQUANG	09/15/93
DFTG. CHK.	
ENGR. CHK.	
APPROVAL	

PROJECTION

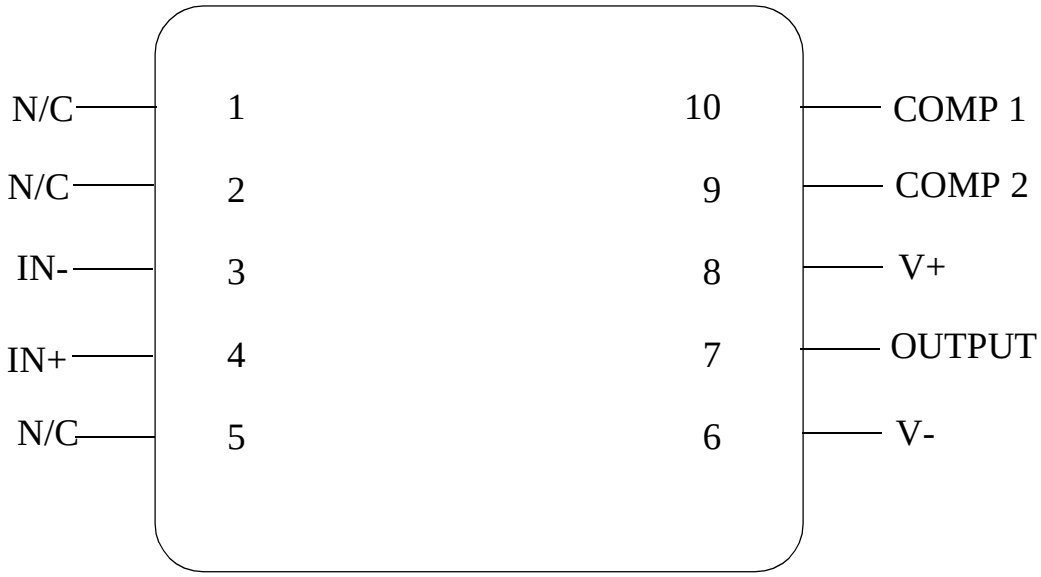
INCH
[MM]

NATIONAL SEMICONDUCTOR CORPORATION
2900 Semiconductor Drive, Santa Clara, CA 95052-8090

CERDIP (J), 14 LEAD,

SCALE	SIZE	DRAWING NUMBER	REV
N/A	B	MKT-J14A	H

DO NOT SCALE DRAWING | SHEET 1 OF 1



LM108AWG

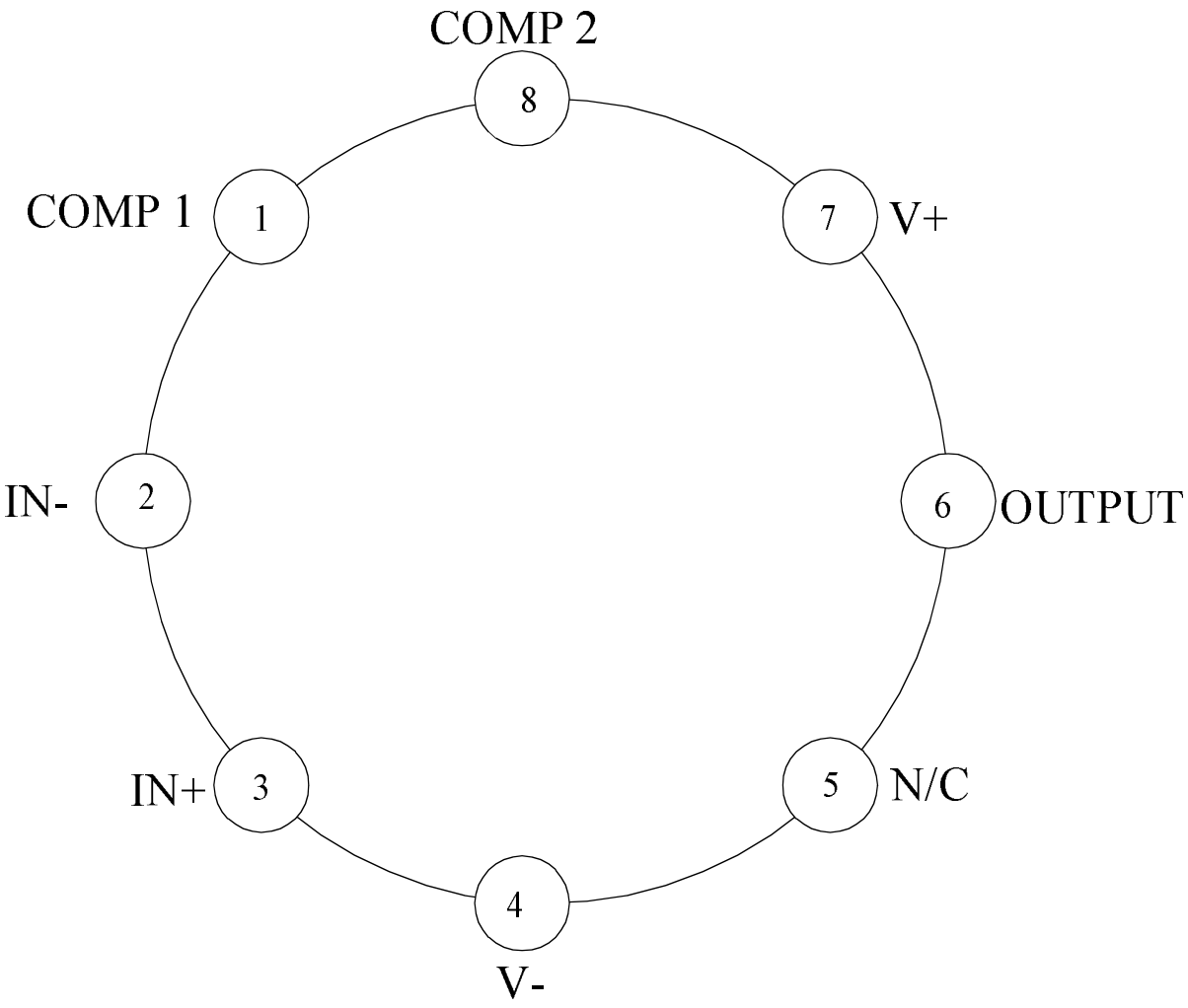
10 - LEAD CERAMIC SOIC

CONNECTION DIAGRAM

TOP VIEW

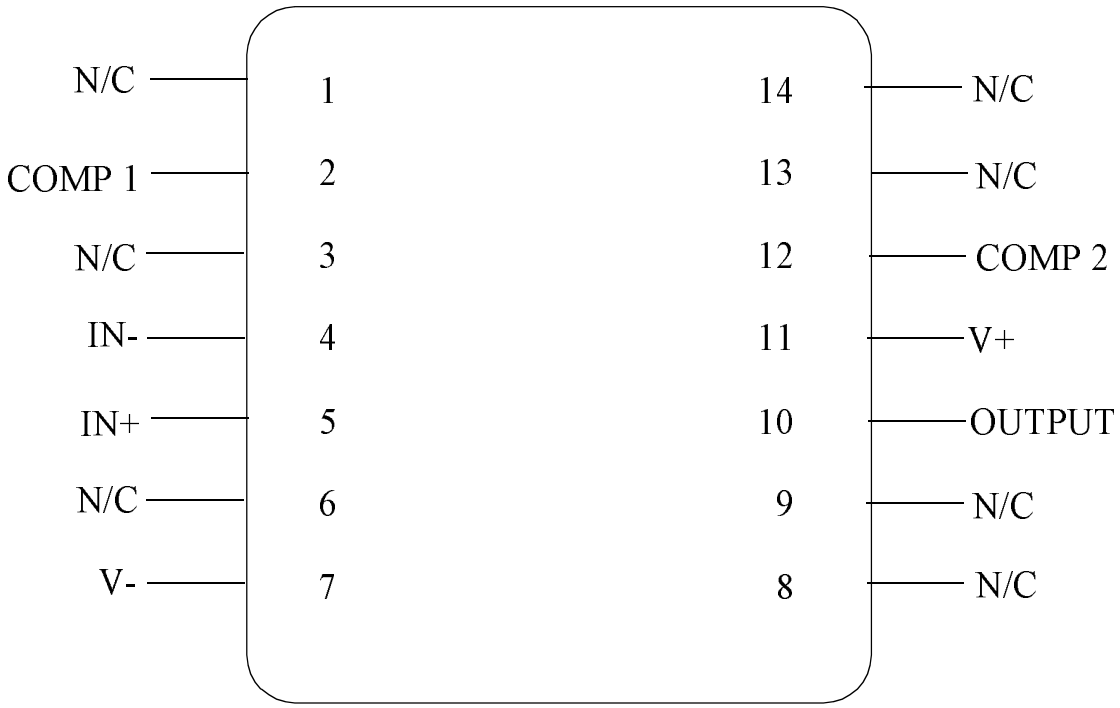
P000253A

National Semiconductor™
MIL/AEROSPACE OPERATIONS
2900 SEMICONDUCTOR DRIVE
SANTA CLARA, CA 95050



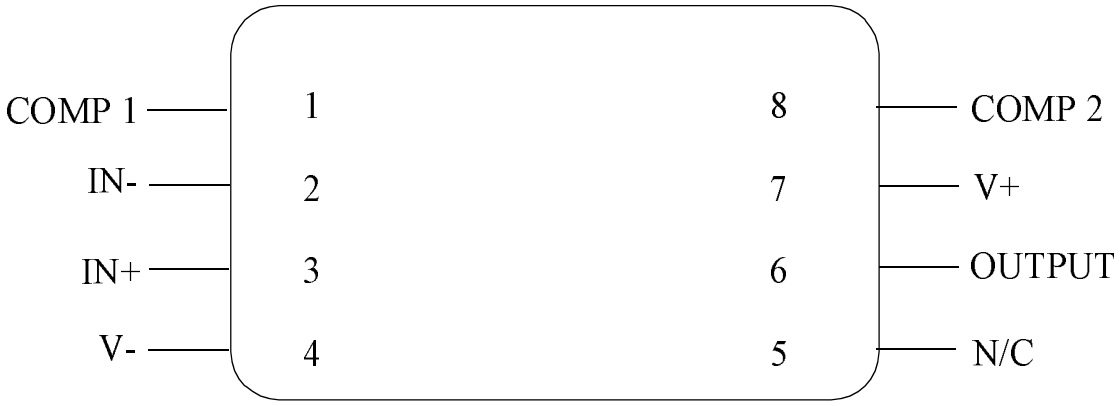
LM108AH, LM108H
8 - PIN METAL CAN
CONNECTION DIAGRAM
TOP VIEW
P000310A

National Semiconductor™
MIL/AEROSPACE OPERATIONS
2900 SEMICONDUCTOR DRIVE
SANTA CLARA, CA 95050



LM108AJ, LM108J
14 - LEAD DIP
CONNECTION DIAGRAM
TOP VIEW
P000311A

National Semiconductor™
MIL/AEROSPACE OPERATIONS
2900 SEMICONDUCTOR DRIVE
SANTA CLARA, CA 95050



LM108AJ-8, LM108J-8

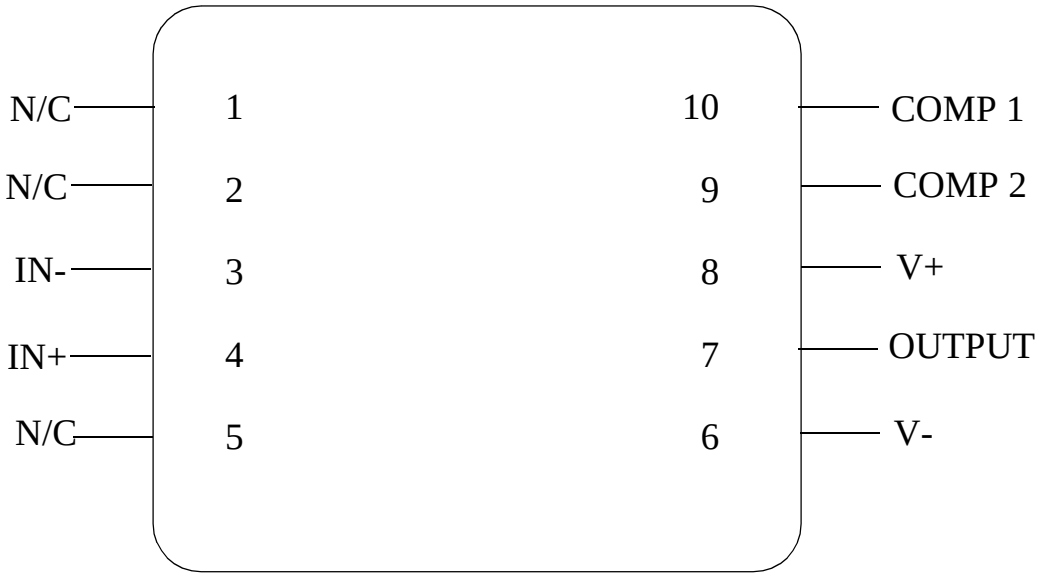
8 - LEAD DIP

CONNECTION DIAGRAM

TOP VIEW

P000312A

National Semiconductor™
MIL/AEROSPACE OPERATIONS
2900 SEMICONDUCTOR DRIVE
SANTA CLARA, CA 95050



LM108AW

10 - LEAD CERPACK

CONNECTION DIAGRAM
TOP VIEW

P000431A

National Semiconductor™
MIL/AEROSPACE OPERATIONS
2900 SEMICONDUCTOR DRIVE
SANTA CLARA, CA 95050

REVISIONS				
LTR	DESCRIPTION	E.C.N.	DATE	BY/APP'D
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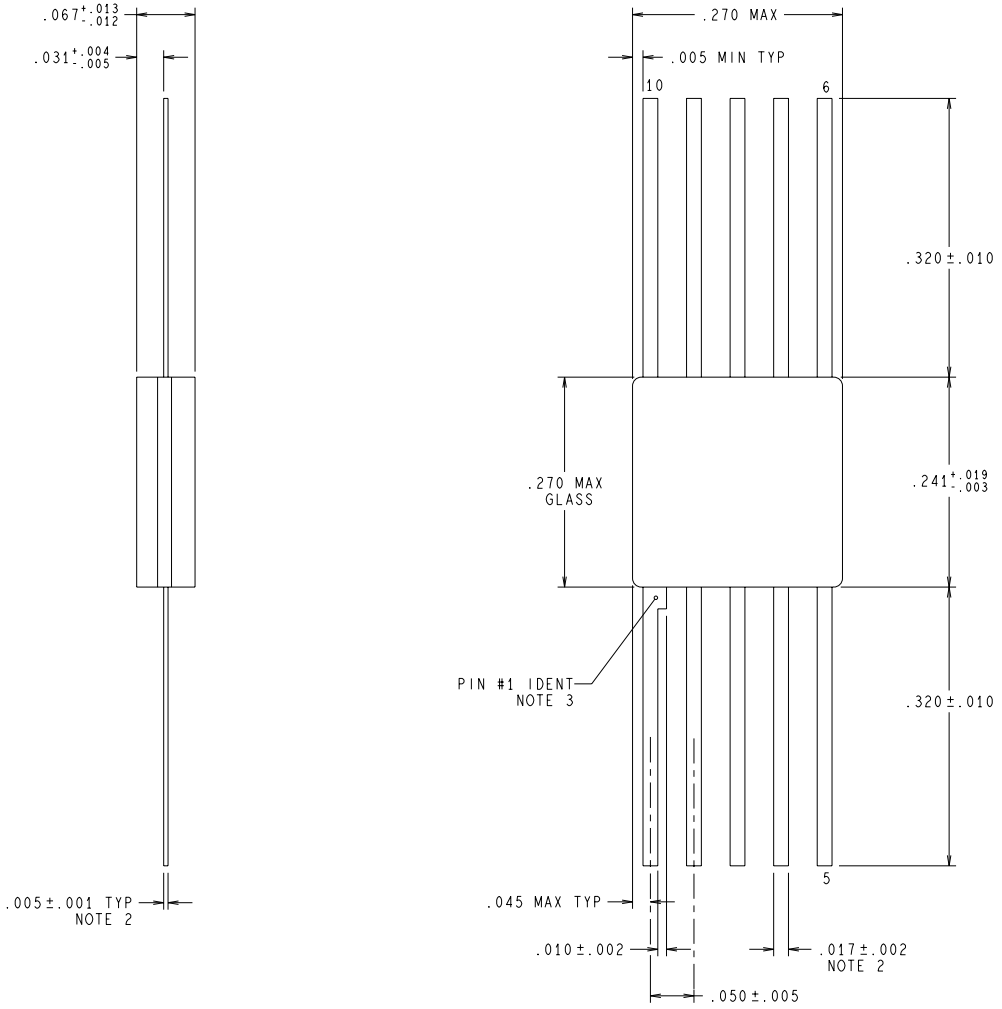


NOTES: UNLESS OTHERWISE SPECIFIED.

1. LEAD FINISH: SOLDER DIPPED WITH Sn60 OR Sn63 SOLDER CONFORMING TO MIL-M-38510 TO A MINIMUM THICKNESS OF 200 MICROINCHES. SOLDER MAY BE APPLIED OVER LEAD BASIS METAL OR Sn PLATE.
2. MAXIMUM LIMIT MAY BE INCREASED BY .003 INCHES AFTER LEAD FINISH APPLIED.
3. LEAD 1 IDENTIFICATION SHALL BE:
   a) A NOTCH OR OTHER MARK WITHIN THIS AREA
   b) A TAB ON LEAD 1, EITHER SIDE
4. REFERENCE JEDEC REGISTRATION MO-003, VARIATION AG, DATED 06/01/76.

MIL/AERO CONFIGURATION CONTROL

MIL-M-38510 CONFIGURATION CONTROL

APPROVALS	DATE
DRAWN: D.E.Grady	07/28/94
DFTG. CHK.	
ENGR. CHK.	

PROJECTION — INCH [MM]

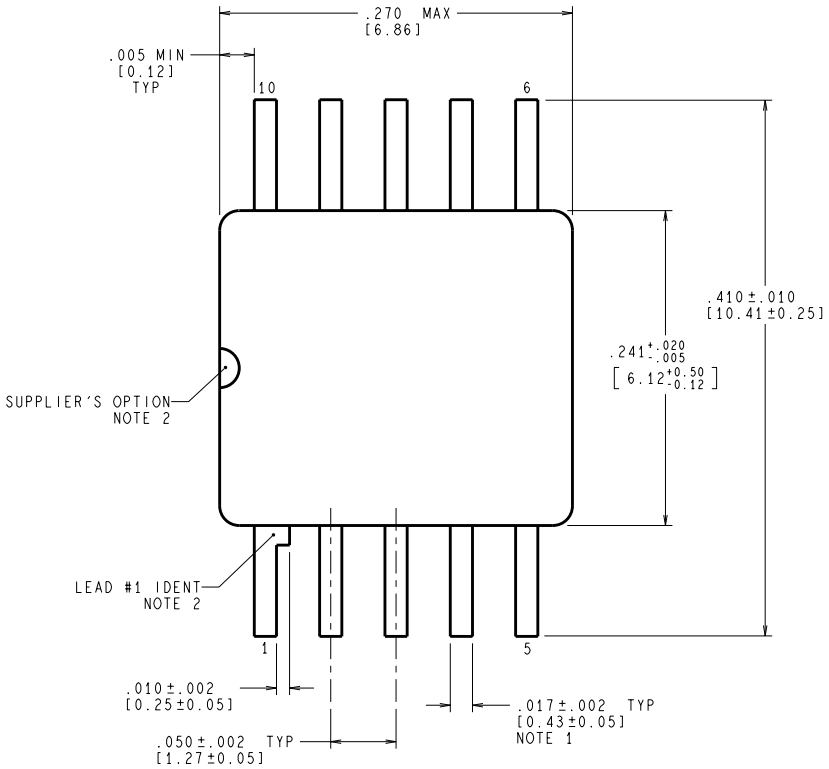
National Semiconductor
2900 Semiconductor dr, Santa Clara, CA 95052-8090

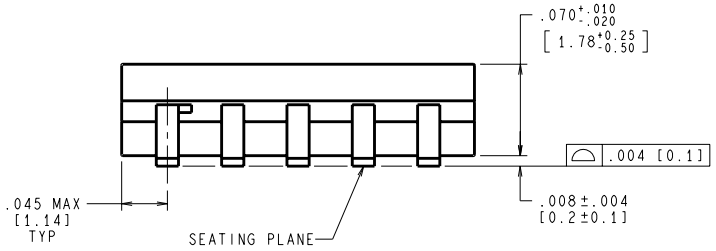
CERPACK, 10 LEAD

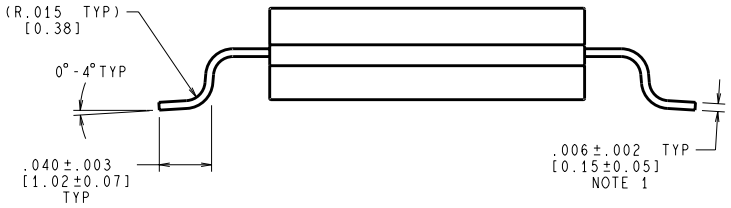
SCALE	SIZE	DRAWING NUMBER	REV
N/A	C	MKT-W10A	G

DO NOT SCALE DRAWING — SHEET 1 of 1

REVISIONS				
LTR	DESCRIPTION	E.C.N.	DATE	BY/APP'D
A	RELEASE TO DOCUMENT CONTROL	11374	02/29/1996	MS/KH
B	LD PITCH TOL WAS ±.005; CHANGE LD RADIUS TO REF DIM; REMOVE THE OTHER R.006±.002 DIM .040±.003 WAS .037±.003	11441	04/19/1996	MS/KH
C	R .015[0.38] WAS R .006[0.15]	11838	10/08/1997	TL/







NOTES: UNLESS OTHERWISE SPECIFIED

1. LEAD FINISH: SOLDER DIPPED WITH Sn60 OR Sn63 SOLDER CONFORMING TO MIL-PRF-38535 TO A MINIMUM THICKNESS OF 200 MICROINCHES/ 5.08 MICROMETERS. SOLDER MAY BE APPLIED OVER LEAD BASIS METAL OR Sn PLATE. MAXIMUM LIMIT MAY BE INCREASED BY .003 IN/ 0.08mm AFTER LEAD FINISH APPLIED.
2. LEAD 1 IDENTIFICATION SHALL BE:
   a) A NOTCH OR OTHER MARK WITHIN THIS AREA
   b) A TAB ON LEAD 1, EITHER SIDE
3. NO JEDEC REGISTRATION AS OF FEBRUARY 1996.

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MIL-PRF-38535
CONFIGURATION CONTROL

APPROVALS	DATE
DRAWN: MARTA SUCHY	02/29/96
DFTG. CHK.	
ENGR. CHK.	

National Semiconductor
2900 Semiconductor dr, Santa Clara, CA 95052-8090

CERPACK, 10 LEAD, GULL WING

PROJECTION
INCH [MM]

SCALE	SIZE	DRAWING NUMBER	REV
N/A	C	(SC)MKT-WG10A	C

DO NOT SCALE DRAWING | SHEET 1 of 1

Revision History

Rev	ECN #	Rel Date	Originator	Changes
0A0	M0003181	04/16/99	Rose Malone	Initial MDS Release: MRLM108A-X-RH, Rev. 0A0 - Rad Hard Data Sheet.
1A0	M0003364	04/16/99	Rose Malone	Update MDS: MRLM108A-X-RH, Rev. 0A0 to MRLM108A-X-RH, Rev. 1A0. Update Thermal Resistance - Cerpack (Still Air) from 150 C/W to 225 C/W, Electricals: DC and Drift Values and Post Radiation Section - Removed reference to Rs=5 Mohms from Iio, +Iib, -Iib. Correction made to correlate with test program.