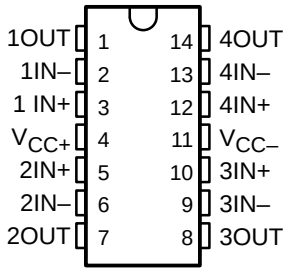
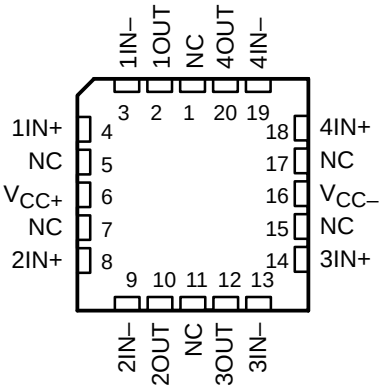
- **μA741 Operating Characteristics**
- **Low Supply-Current Drain . . . 0.6 mA Typ (per amplifier)**
- **Low Input Offset Voltage**
- **Low Input Offset Current**
- **Class AB Output Stage**
- **Input/Output Overload Protection**
- **Designed to Be Interchangeable With Industry Standard LM148, LM248, and LM348**

**LM148 . . . J PACKAGE**
**LM248 . . . D OR N PACKAGE**
**LM348 . . . D, N, OR NS PACKAGE**
**(TOP VIEW)**




**LM148 . . . FK PACKAGE**
**(TOP VIEW)**




NC – No internal connection

## description/ordering information

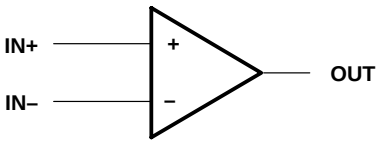
The LM148, LM248, and LM348 are quadruple, independent, high-gain, internally compensated operational amplifiers designed to have operating characteristics similar to the μA741. These amplifiers exhibit low supply-current drain and input bias and offset currents that are much less than those of the μA741.

**ORDERING INFORMATION**

| $T_A$ | $V_{IO}$max AT 25°C | PACKAGE† | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|---|---|---|---|---|
| 0°C to 70°C | 6 mV | PDIP (N) | Tube of 25 | LM348N | LM348N |
| | | SOIC (D) | Tube of 50 | LM348D | LM348 |
| | | | Reel of 2500 | LM348DR | |
| | | SOP (NS) | Reel of 2000 | LM348NSR | LM348 |
| –25°C to 85°C | 6 mV | PDIP (N) | Tube of 25 | LM248N | LM248N |
| | | SOIC (D) | Tube of 50 | LM248D | LM248 |
| | | | Reel of 2500 | LM248DR | |
| –55°C to 125°C | 5 mV | CDIP (J) | Tube of 25 | LM148J | LM148J |
| | | LCCC (FK) | Tube of 50 | LM148FK | LM148FK |

† Package drawings, standard packing quantities, thermal data, symboliztion, and PCB design guidelines are available at www.ti.com/sc/package.

## symbol (each amplifier)




## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, $V_{CC+}$ (see Note 1): LM148 . . . . . 22 V
LM248, LM348 . . . . . 18 V
Supply voltage, $V_{CC–}$ (see Note 1): LM148 . . . . . –22 V
LM248, LM348 . . . . . –18 V
Differential input voltage, $V_{ID}$ (see Note 2): LM148 . . . . . 44 V
LM248, LM348 . . . . . 36 V
Input voltage, $V_I$ (either input, see Notes 1 and 3): LM148 . . . . . –22 V
LM248, LM348 . . . . . –18 V
Duration of output short circuit (see Note 4) . . . . . Unlimited
Operating virtual junction temperature, $T_J$ . . . . . 150°C
Package thermal impedance, $\theta_{JA}$ (see Notes 5 and 6): D package . . . . . 86°C/W
N package . . . . . 80°C/W
NS package . . . . . 76°C/W
Package thermal impedance, $\theta_{JC}$ (see Notes 7 and 8): FK package . . . . . 5.61°C/W
J package . . . . . 15.05°C/W
Case temperature for 60 seconds: FK package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: J package . . . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: D, N, or NS package . . . . . 260°C
Storage temperature range, $T_{stg}$ . . . . . –65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between $V_{CC+}$ and $V_{CC–}$.
2. Differential voltages are at IN+ with respect to IN–.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or the value specified in the table, whichever is less.
4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. Maximum power dissipation is a function of $T_J(max)$, $\theta_{JA}$, and $T_A$. The maximum allowable power dissipation at any allowable ambient temperautre is $P_D = (T_J(max) – T_A)/\theta_{JA}$. Operating at the absolute maximum $T_J$ of 150°C can affect reliability.
6. The package thermal impedance is calculated in accordance with JESD 51-7.
7. Maximum power dissipation is a function of $T_J(max)$, $\theta_{JC}$, and $T_C$. The maximum allowable power dissipation at any allowable ambient temperautre is $P_D = (T_J(max) – T_C)/\theta_{JC}$. Operating at the absolute maximum $T_J$ of 150°C can affect reliability.
8. The package thermal impedance is calculated in accordance with MIL-STD-883.

## recommended operating conditions

| | MIN | MAX | UNIT |
|---|---|---|---|
| Supply voltage, $V_{CC+}$ | 4 | 18 | V |
| Supply voltage, $V_{CC–}$ | –4 | –18 | V |

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | | | LM148 | | | LM248 | | | LM348 | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 0 | | 25°C | | 1 | 5 | | 1 | 6 | | 1 | 6 | mV |
| | | | | Full range | | | 6 | | | 7.5 | | | 7.5 | |
| $I_{IO}$ | Input offset current | $V_O$ = 0 | | 25°C | | 4 | 25 | | 4 | 50 | | 4 | 50 | nA |
| | | | | Full range | | | 75 | | | 125 | | | 100 | |
| $I_{IB}$ | Input bias current | $V_O$ = 0 | | 25°C | | 30 | 100 | | 30 | 200 | | 30 | 200 | nA |
| | | | | Full range | | | 325 | | | 500 | | | 400 | |
| $V_{ICR}$ | Common-mode input voltage range | | | Full range | ±12 | | | ±12 | | | ±12 | | | V |
| $V_{OM}$ | Maximum peak output voltage swing | $R_L$ = 10 kΩ | | 25°C | ±12 | ±13 | | ±12 | ±13 | | ±12 | ±13 | | V |
| | | $R_L$ ≥ 10 kΩ | | Full range | ±12 | | | ±12 | | | ±12 | | | |
| | | $R_L$ = 2 kΩ | | 25°C | ±10 | ±12 | | ±10 | ±12 | | ±10 | ±12 | | |
| | | $R_L$ ≥ 2 kΩ | | Full range | ±10 | | | ±10 | | | ±10 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = ±10 V, $R_L$ = ≥ 2 kΩ | | 25°C | 50 | 160 | | 25 | 160 | | 25 | 160 | | V/mV |
| | | | | Full range | 25 | | | 15 | | | 15 | | | |
| $r_i$ | Input resistance‡ | | | 25°C | 0.8 | 2.5 | | 0.8 | 2.5 | | 0.8 | 2.5 | | MΩ |
| $B_1$ | Unity-gain bandwidth | $A_{VD}$ = 1 | | 25°C | | 1 | | | 1 | | | 1 | | MHz |
| $\phi_m$ | Phase margin | $A_{VD}$ = 1 | | 25°C | | 60° | | | 60° | | | 60° | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$min, $V_O$ = 0 | | 25°C | 70 | 90 | | 70 | 90 | | 70 | 90 | | dB |
| | | | | Full range | 70 | | | 70 | | | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_{CC\pm}$ = ±9 V to ±15 V, $V_O$ = 0 | | 25°C | 77 | 96 | | 77 | 96 | | 77 | 96 | | dB |
| | | | | Full range | 77 | | | 77 | | | 77 | | | |
| $I_{OS}$ | Short-circuit output current | | | 25°C | | ±25 | | | ±25 | | | ±25 | | mA |
| $I_{CC}$ | Supply current (four amplifiers) | No load | $V_O$ = 0 | 25°C | | | | | 2.4 | 4.5 | | 2.4 | 4.5 | mA |
| | | | $V_O$ = $V_{OM}$ | | | 2.4 | 3.6 | | | | | | | |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation | f = 1 Hz to 20 kHz | | 25°C | | 120 | | | 120 | | | 120 | | dB |

† All characteristics are measured under open-loop conditions with zero common-mode input voltage, unless otherwise specified. Full range for $T_A$ is –55°C to 125°C for LM148, –25°C to 85°C for LM248, and 0°C to 70°C for LM348.

‡ This parameter is not production tested.

## operating characteristics, $V_{CC\pm}$ = ±15 V, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain | $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figure 1 | | 0.5 | | V/μs |

## PARAMETER MEASUREMENT INFORMATION

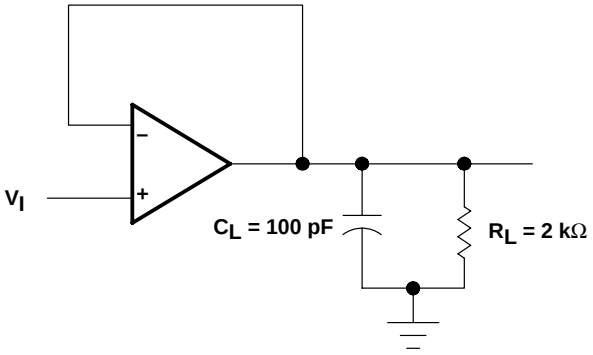



**Figure 1. Unity-Gain Amplifier**

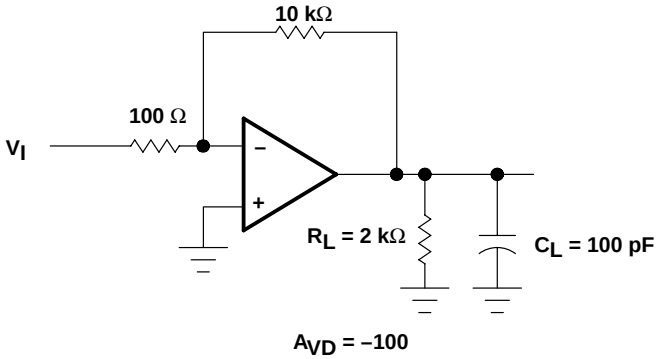



**Figure 2. Inverting Amplifier**

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| Data Converters | dataconverter.ti.com | Automotive | www.ti.com/automotive |
| DSP | dsp.ti.com | Broadband | www.ti.com/broadband |
| Interface | interface.ti.com | Digital Control | www.ti.com/digitalcontrol |
| Logic | logic.ti.com | Military | www.ti.com/military |
| Power Mgmt | power.ti.com | Optical Networking | www.ti.com/opticalnetwork |
| Microcontrollers | microcontroller.ti.com | Security | www.ti.com/security |
| Low Power Wireless | www.ti.com/lpw | Telephony | www.ti.com/telephony |
| | | Video & Imaging | www.ti.com/video |
| | | Wireless | www.ti.com/wireless |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| LM148FKB | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| LM148J | ACTIVE | CDIP | J | 14 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| LM148JB | ACTIVE | CDIP | J | 14 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| LM248D | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM248DE4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM248DG4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM248DR | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM248DRE4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM248DRG4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM248N | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| LM248NE4 | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| LM348D | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348DE4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348DG4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348DR | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348DRE4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348DRG4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348N | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| LM348NE4 | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| LM348NSR | ACTIVE | SO | NS | 14 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348NSRE4 | ACTIVE | SO | NS | 14 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| LM348NSRG4 | ACTIVE | SO | NS | 14 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |

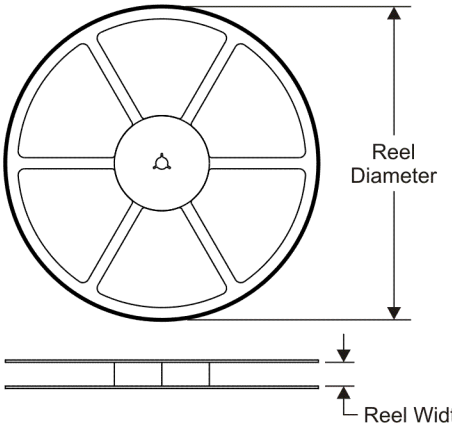
(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

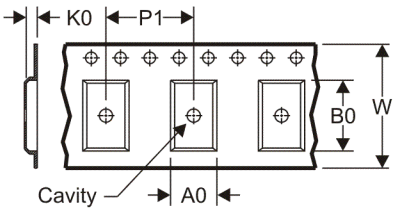
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

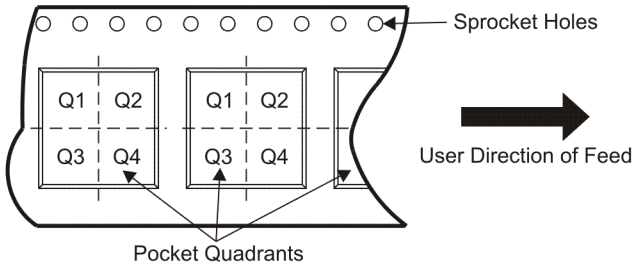



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

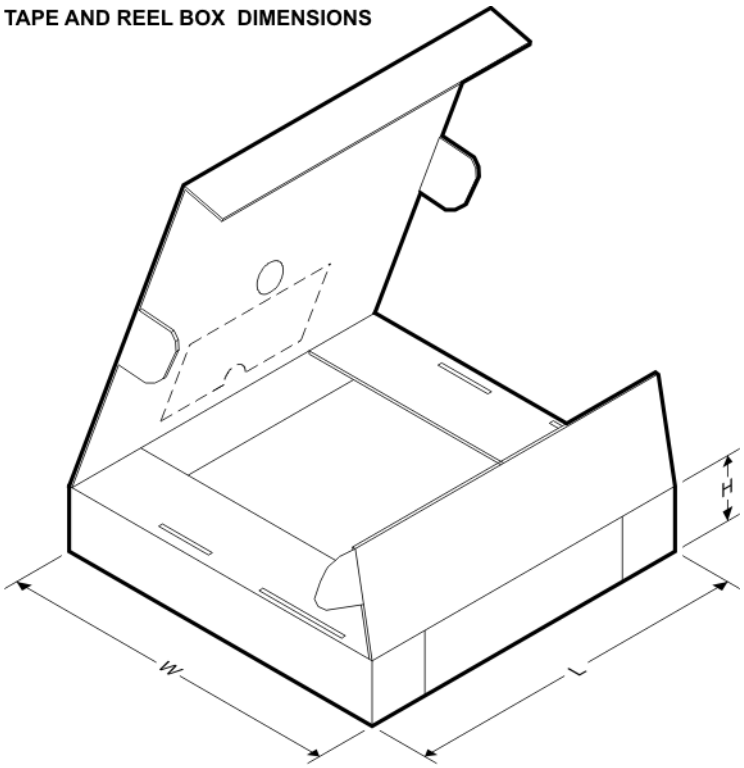
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM248DR | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.0 | 2.1 | 8.0 | 16.0 | Q1 |
| LM348DR | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.0 | 2.1 | 8.0 | 16.0 | Q1 |
| LM348DR | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.0 | 2.1 | 8.0 | 16.0 | Q1 |
| LM348NSR | SO | NS | 14 | 2000 | 330.0 | 16.4 | 8.2 | 10.5 | 2.5 | 12.0 | 16.0 | Q1 |

**TAPE AND REEL BOX DIMENSIONS**

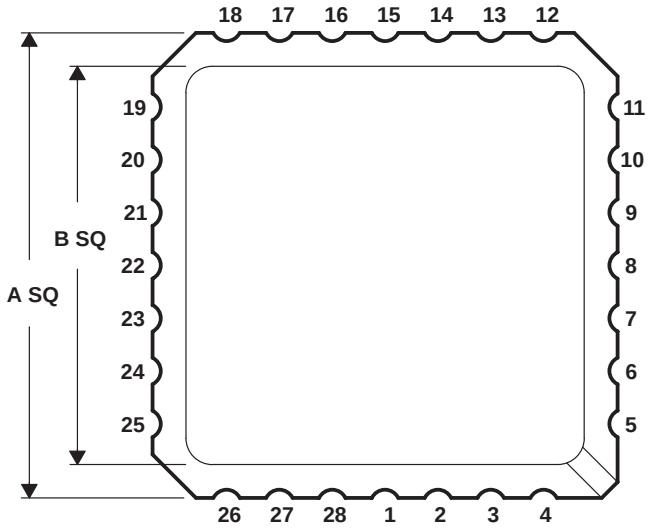



*All dimensions are nominal

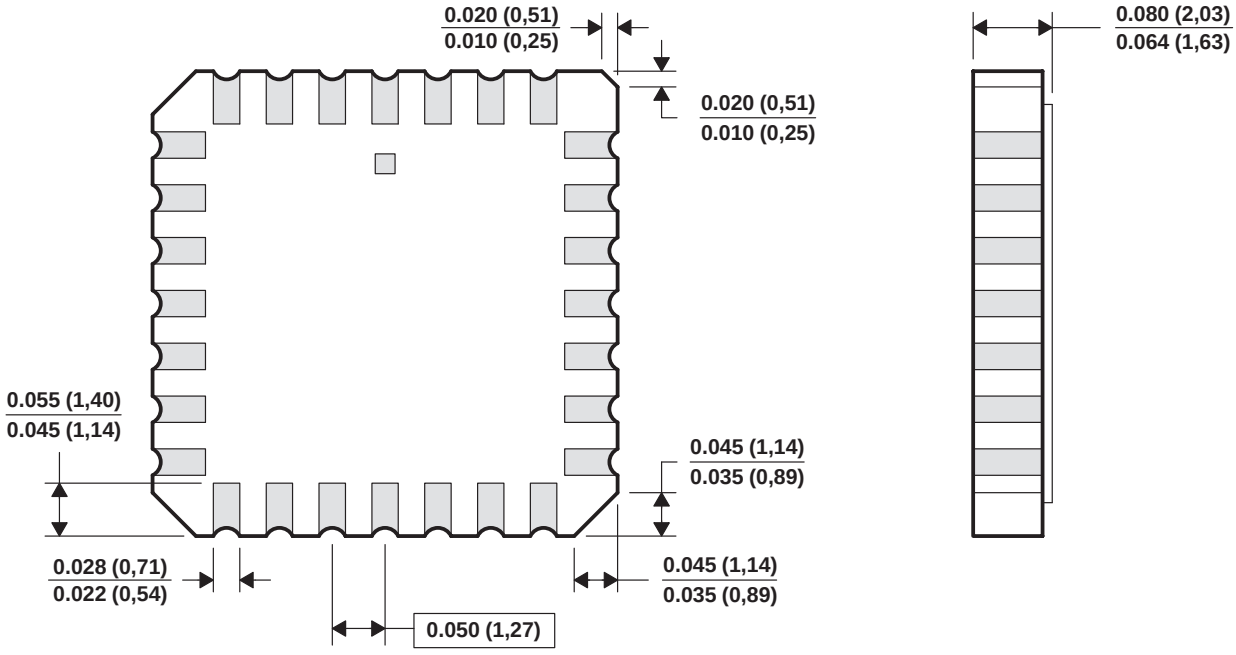
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LM248DR | SOIC | D | 14 | 2500 | 346.0 | 346.0 | 33.0 |
| LM348DR | SOIC | D | 14 | 2500 | 333.2 | 345.9 | 28.6 |
| LM348DR | SOIC | D | 14 | 2500 | 346.0 | 346.0 | 33.0 |
| LM348NSR | SO | NS | 14 | 2000 | 346.0 | 346.0 | 33.0 |

**FK (S-CQCC-N**)** **LEADLESS CERAMIC CHIP CARRIER**

**28 TERMINAL SHOWN**




| NO. OF TERMINALS ** | A | | B | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| 20 | 0.342 (8,69) | 0.358 (9,09) | 0.307 (7,80) | 0.358 (9,09) |
| 28 | 0.442 (11,23) | 0.458 (11,63) | 0.406 (10,31) | 0.458 (11,63) |
| 44 | 0.640 (16,26) | 0.660 (16,76) | 0.495 (12,58) | 0.560 (14,22) |
| 52 | 0.739 (18,78) | 0.761 (19,32) | 0.495 (12,58) | 0.560 (14,22) |
| 68 | 0.938 (23,83) | 0.962 (24,43) | 0.850 (21,6) | 0.858 (21,8) |
| 84 | 1.141 (28,99) | 1.165 (29,59) | 1.047 (26,6) | 1.063 (27,0) |



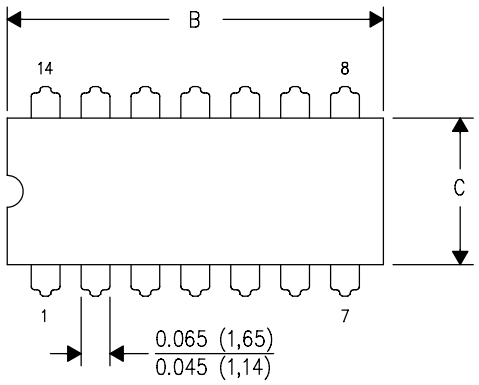

**4040140/D 10/96**

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

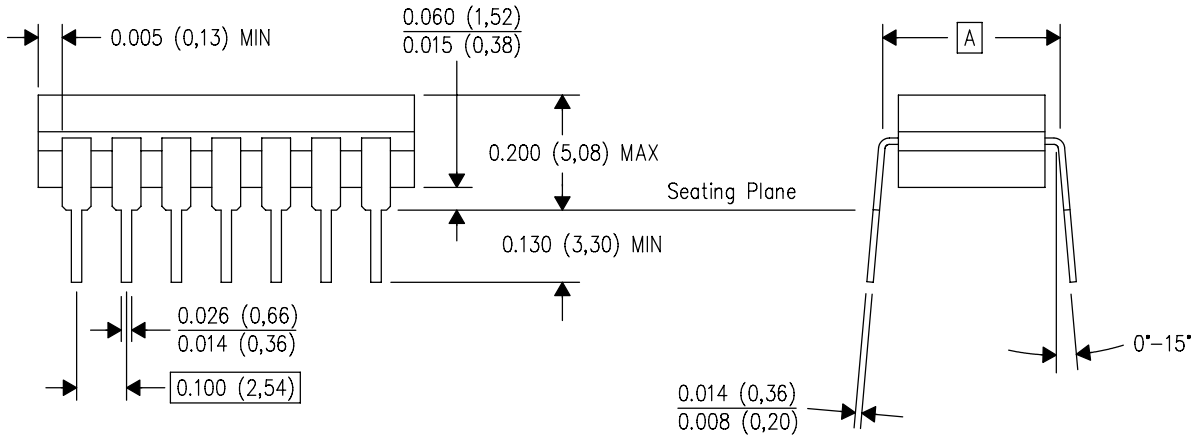
J (R–GDIP–T**)

14 LEADS SHOWN

# CERAMIC DUAL IN–LINE PACKAGE




| DIM \ PINS ** | 14 | 16 | 18 | 20 |
|---|---|---|---|---|
| A | 0.300 (7,62) BSC | 0.300 (7,62) BSC | 0.300 (7,62) BSC | 0.300 (7,62) BSC |
| B MAX | 0.785 (19,94) | .840 (21,34) | 0.960 (24,38) | 1.060 (26,92) |
| B MIN | — | — | — | — |
| C MAX | 0.300 (7,62) | 0.300 (7,62) | 0.310 (7,87) | 0.300 (7,62) |
| C MIN | 0.245 (6,22) | 0.245 (6,22) | 0.220 (5,59) | 0.245 (6,22) |



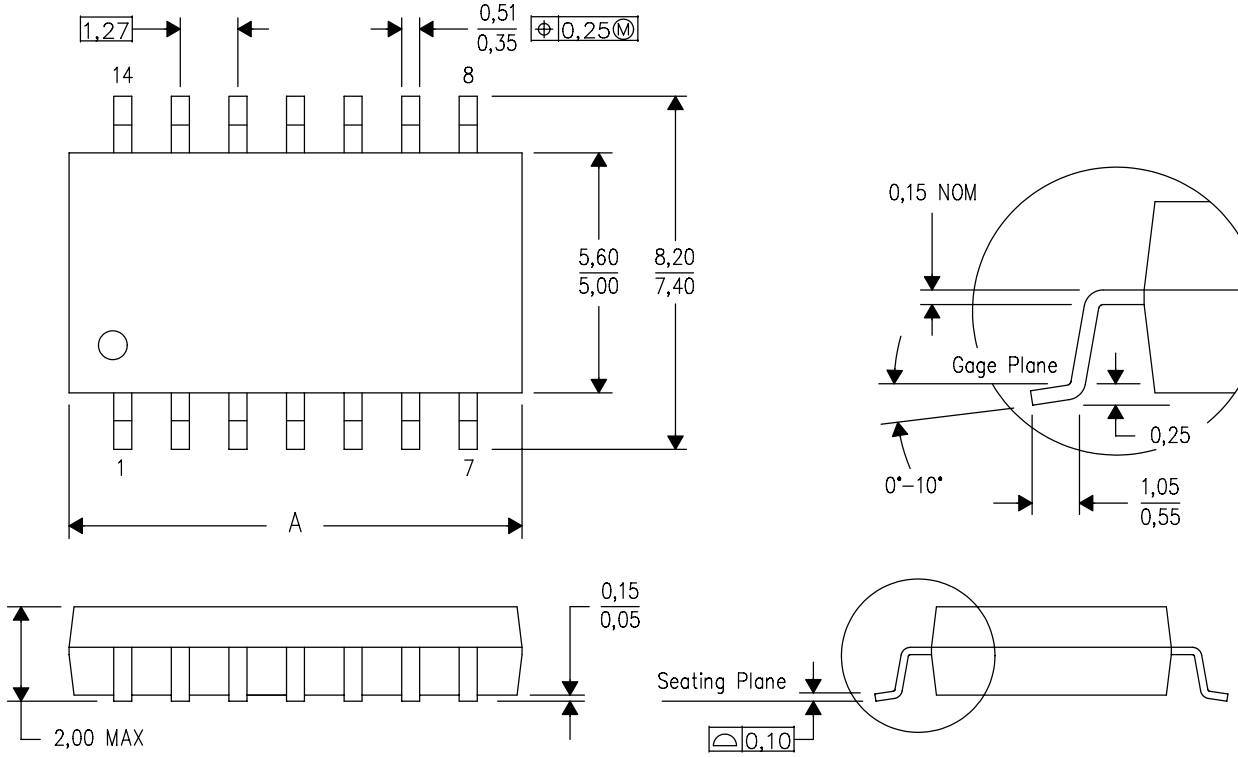

4040083/F 03/03

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package is hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
E. Falls within MIL STD 1835 GDIP1–T14, GDIP1–T16, GDIP1–T18 and GDIP1–T20.

## MECHANICAL DATA

**NS (R-PDSO-G**)** **PLASTIC SMALL-OUTLINE PACKAGE**

**14-PINS SHOWN**

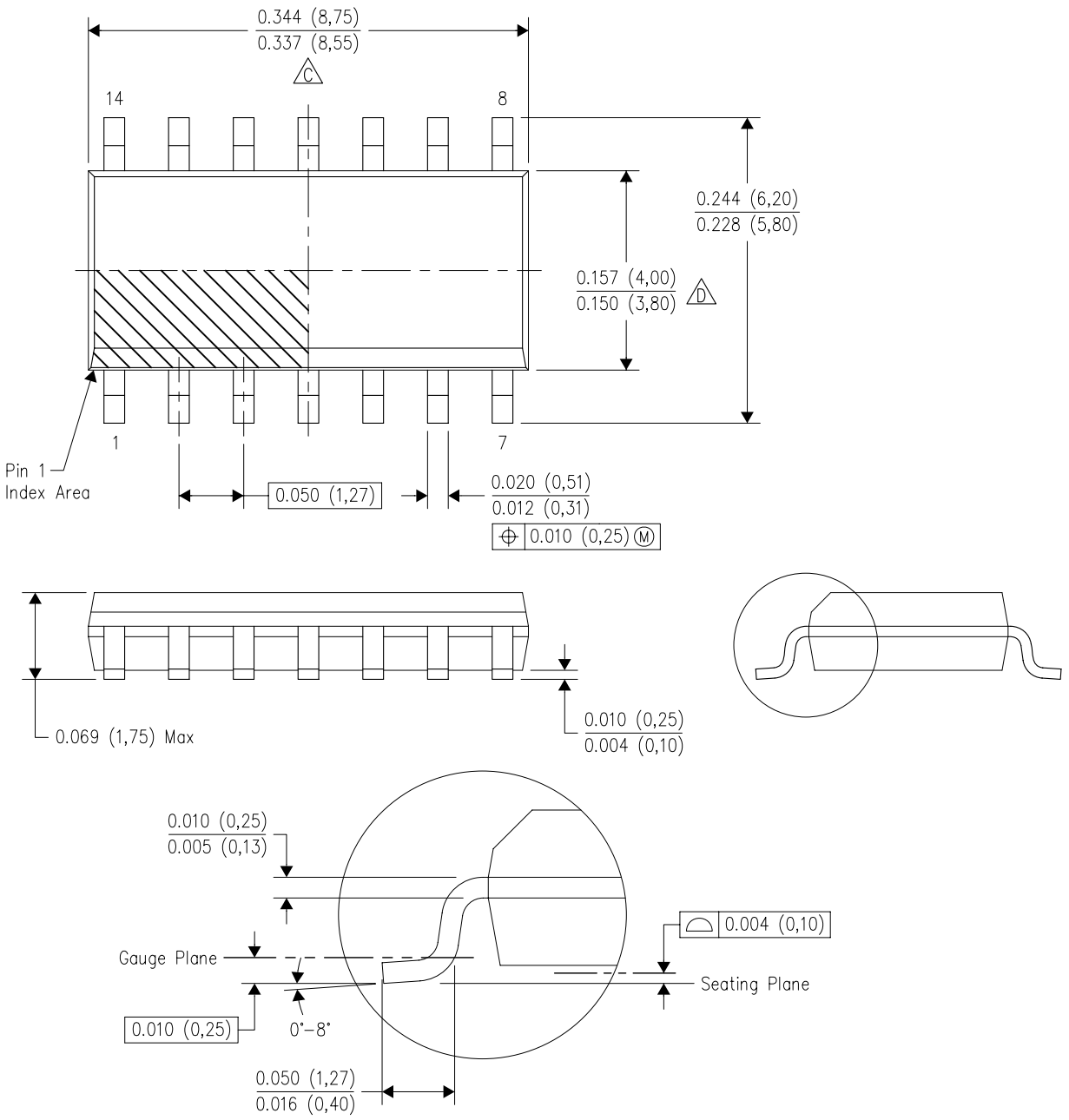



| DIM \ PINS ** | 14 | 16 | 20 | 24 |
|---|---|---|---|---|
| A MAX | 10,50 | 10,50 | 12,90 | 15,30 |
| A MIN | 9,90 | 9,90 | 12,30 | 14,70 |

4040062/C 03/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

D (R–PDSO–G14) PLASTIC SMALL–OUTLINE PACKAGE

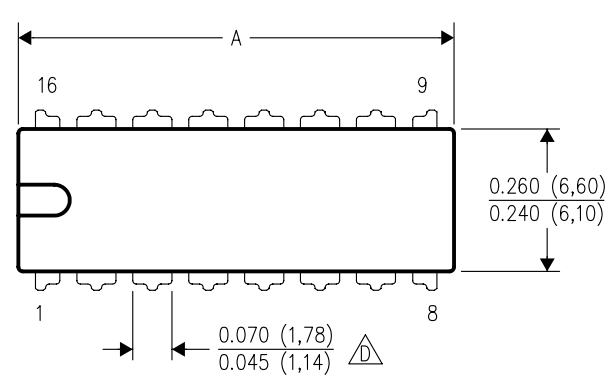



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS–012 variation AB.

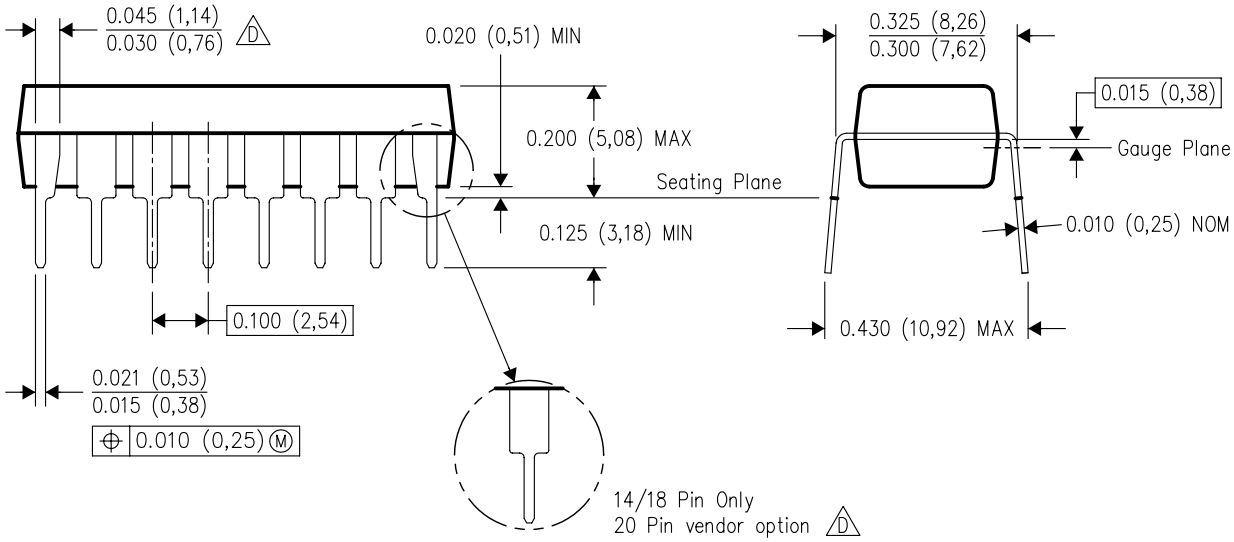
## N (R–PDIP–T**)

## PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN




| DIM \ PINS ** | 14 | 16 | 18 | 20 |
|---|---|---|---|---|
| A MAX | 0.775 (19,69) | 0.775 (19,69) | 0.920 (23,37) | 1.060 (26,92) |
| A MIN | 0.745 (18,92) | 0.745 (18,92) | 0.850 (21,59) | 0.940 (23,88) |
| MS–001 VARIATION (C) | AA | BB | AC | AD |




4040049/E 12/2002

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.