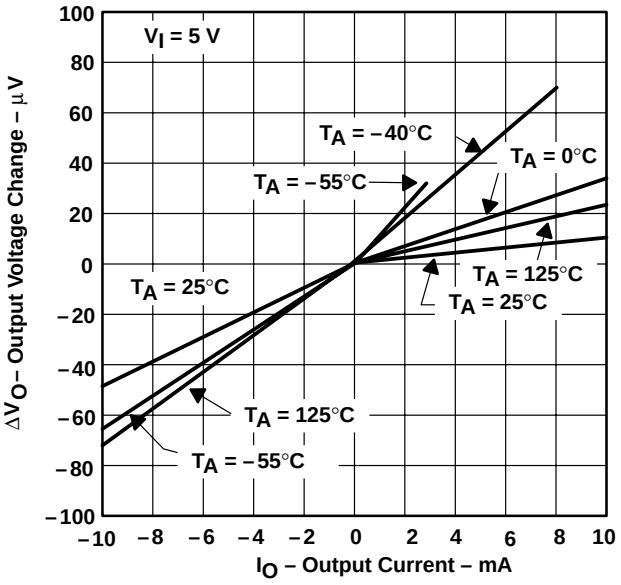
- **2.5-V Virtual Ground for 5-V/GND Analog Systems**
- **High Output-Current Capability Sink or Source . . . 20 mA Typ**
- **Micropower Operation . . . 170 μA Typ**
- **Excellent Regulation Characteristics**
  - **Output Regulation**
    - **−45 μV Typ at $I_O$ = 0 to −10 mA**
    - **+15 μV Typ at $I_O$ = 0 to +10 mA**
  - **Input Regulation = 1.5 μV/V Typ**
- **Low-Impedance Output . . . 0.0075 Ω Typ**
- **Macromodel Included**

## description

In signal-conditioning applications using a single power source, a reference voltage is required for termination of all signal grounds. To accomplish this, engineers have typically used solutions consisting of resistors, capacitors, operational amplifiers, and voltage references. Texas Instruments has eliminated all of those components with one easy-to-use 3-terminal device. That device is the TLE2425 precision virtual ground.

Use of the TLE2425 over other typical circuit solutions gives the designer increased dynamic signal range, improved signal-to-noise ratio, lower distortion, improved signal accuracy, and easier interfacing to ADCs and DACs. These benefits are the result of combining a precision micropower voltage reference and a high-performance precision operational amplifier in a single silicon chip. It is the precision and performance of these two circuit functions together that yield such dramatic system-level performance.

**OUTPUT REGULATION**




The TLE2425 improves input regulation as well as output regulation and, in addition, reduces output impedance and power dissipation in a majority of virtual-ground-generation circuits. Both input regulation and load regulation exceed 12 bits of accuracy on a single 5-V system. Signal-conditioning front ends of data acquisition systems that push 12 bits and beyond can use the TLE2425 to eliminate a major source of system error.

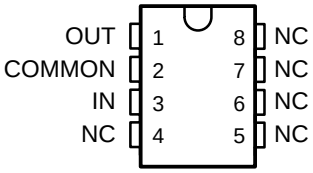
**AVAILABLE OPTIONS**

| $T_A$ | SMALL OUTLINE (D) | PLASTIC TO-226AA (LP) |
|---|---|---|
| 0°C to 70°C | TLE2425CD | TLE2425CD |
| −40°C to 85°C | TLE2425ID | TLE2425ID |
| −55°C to 125°C | TLE2425MD | — |

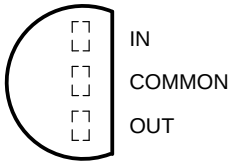
† The D package is available taped and reeled. Add R suffix to the device type (e.g., TLE2425CDR).

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

**D, OR JG PACKAGE**
**(TOP VIEW)**




**LP PACKAGE**
**(TOP VIEW)**




NC – No internal connection

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

Continuous input voltage, $V_I$ . . . . . 40 V
Output current, $I_O$ . . . . . ±80 mA
Duration of short-circuit current at (or below) 25°C (see Note 1) . . . . . unlimited
Continuous total power dissipation . . . . . See Dissipation Rating Table
Operating free-air temperature range, $T_A$: C-suffix . . . . . 0°C to 70°C
I-suffix . . . . . –40°C to 85°C
M-suffix . . . . . –55°C to 125°C
Storage temperature range, $T_{stg}$ . . . . . –65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or LP package . . . . . 300°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.

NOTE 1: The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mV | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| JG | 1050 mV | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| LP | 775 mV | 6.2 mW/°C | 496 mW | 403 mW | 155 mW |

## recommended operating conditions

| | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | MIN | MAX | |
| Input voltage, $V_I$ | 4 | 40 | 4 | 40 | 4 | 40 | V |
| Operating free-air temperature, $T_A$ | 0 | 70 | –40 | 85 | –55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_I$ = 5 V, $I_O$ = 0 (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | $T_A$† | TLE2425C | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| Output voltage | | | 25°C | 2.48 | 2.5 | 2.52 | V |
| | | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | | 25°C | | 20 | | ppm/°C |
| Bias current | $I_O$ = 0 | | 25°C | | 170 | 250 | µA |
| | | | Full range | | | 250 | |
| Input voltage regulation | $V_I$ = 4.5 V to 5.5 V | | 25°C | | 1.5 | 20 | µV |
| | | | Full range | | | 25 | |
| | $V_I$ = 4 V to 40 V | | 25°C | | 1.5 | 20 | µV/V |
| | | | Full range | | | 25 | |
| Ripple rejection | f = 120 Hz, | $\Delta V_{I(PP)}$ = 1 V | 25°C | | 80 | | dB |
| Output voltage regulation (source current)‡ | $I_O$ = 0 to –10 mA | | 25°C | –160 | –45 | 160 | µV |
| | | | Full range | –250 | | 250 | |
| | $I_O$ = 0 to –20 mA | | 25°C | –450 | –150 | 450 | |
| Output voltage regulation (sink current)‡ | $I_O$ = 0 to 10 mA | | 25°C | –160 | 15 | 160 | µV |
| | | | Full range | –250 | | 250 | |
| | $I_O$ = 0 to 20 mA | | 25°C | –235 | 65 | 235 | |
| Long-term drift of output voltage | $\Delta t$ = 1000 h, | Noncumulative | 25°C | | 15 | | ppm |
| Output impedance | | | 25°C | | 7.5 | 22.5 | mΩ |
| Short-circuit output current (sink current) | $V_O$ = 5 V | | 25°C | 30 | 55 | | mA |
| Short-circuit output current (source current) | $V_O$ = 0 | | | –30 | –50 | | |
| Output noise voltage, rms | f = 10 Hz to 10 kHz | | 25°C | | 100 | | µV |
| Output voltage response to output current step | $V_O$ to 0.1%, $I_O$ = ±10 mA | $C_L$ = 0 | 25°C | | 110 | | µs |
| | | $C_L$ = 100 pF | | | 115 | | |
| | $V_O$ to 0.01%, $I_O$ = ±10 mA | $C_L$ = 0 | | | 180 | | |
| | | $C_L$ = 100 pF | | | 180 | | |
| Output voltage response to input voltage step | $V_I$ = 4.5 to 5.5 V, | $V_O$ to 0.1% | 25°C | | 12 | | µs |
| | $V_I$ = 4.5 to 5.5 V, | $V_O$ to 0.01% | | | 30 | | |
| Output voltage turn-on response | $V_I$ = 0 to 5 V, | $V_O$ to 0.1% | 25°C | | 125 | | µs |
| | $V_I$ = 0 to 5 V, | $V_O$ to 0.01% | | | 210 | | |

† Full range is 0°C to 70°C.
‡ The listed values are not production tested.

## electrical characteristics at specified free-air temperature, $V_I$ = 5 V, $I_O$ = 0 (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | $T_A$† | TLE2425I | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| Output voltage | | | 25°C | 2.48 | 2.5 | 2.52 | V |
| | | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | | 25°C | | 20 | | ppm/°C |
| Bias current | $I_O$ = 0 | | 25°C | | 170 | 250 | µA |
| | | | Full range | | | 250 | |
| Input voltage regulation | $V_I$ = 4.5 V to 5.5 V | | 25°C | | 1.5 | 20 | µV |
| | | | Full range | | | 75 | |
| | $V_I$ = 4 V to 40 V | | 25°C | | 1.5 | 20 | µV/V |
| | | | Full range | | | 75 | |
| Ripple rejection | f = 120 Hz, | $\Delta V_{I(PP)}$ = 1 V | 25°C | | 80 | | dB |
| Output voltage regulation (source current)‡ | $I_O$ = 0 to –10 mA | | 25°C | –160 | –45 | 160 | µV |
| | | | Full range | –250 | | 250 | |
| | $I_O$ = 0 to –20 mA | | 25°C | –450 | –150 | 450 | |
| Output voltage regulation (sink current)‡ | $I_O$ = 0 to 8 mA | | 25°C | –160 | 15 | 160 | µV |
| | | | Full range | –250 | | 250 | |
| | $I_O$ = 0 to 20 mA | | 25°C | –235 | 65 | 235 | |
| Long-term drift of output voltage | $\Delta t$ = 1000 h, | Noncumulative | 25°C | | 15 | | ppm |
| Output impedance | | | 25°C | | 7.5 | 22.5 | mΩ |
| Short-circuit output current (sink current) | $V_O$ = 5 V | | 25°C | 30 | 55 | | mA |
| Short-circuit output current (source current) | $V_O$ = 0 | | | –30 | –50 | | |
| Output noise voltage, rms | f = 10 Hz to 10 kHz | | 25°C | | 100 | | µV |
| Output voltage response to output current step | $V_O$ to 0.1%, $I_O$ = ±10 mA | $C_L$ = 0 | 25°C | | 110 | | µs |
| | | $C_L$ = 100 pF | | | 115 | | |
| | $V_O$ to 0.01%, $I_O$ = ±10 mA | $C_L$ = 0 | | | 180 | | |
| | | $C_L$ = 100 pF | | | 180 | | |
| Output voltage response to input voltage step | $V_I$ = 4.5 to 5.5 V, | $V_O$ to 0.1% | 25°C | | 12 | | µs |
| | $V_I$ = 4.5 to 5.5 V, | $V_O$ to 0.01% | | | 30 | | |
| Output voltage turn-on response | $V_I$ = 0 to 5 V, | $V_O$ to 0.1% | 25°C | | 125 | | µs |
| | $V_I$ = 0 to 5 V, | $V_O$ to 0.01% | | | 210 | | |

† Full range is –40°C to 85°C.
‡ The listed values are not production tested.

## electrical characteristics at specified free-air temperature, $V_I$ = 5 V, $I_O$ = 0 (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | $T_A$† | TLE2425M | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| Output voltage | | | 25°C | 2.48 | 2.5 | 2.52 | V |
| | | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | | 25°C | | 20 | | ppm/°C |
| Bias current | $I_O$ = 0 | | 25°C | | 170 | 250 | µA |
| | | | Full range | | | 250 | |
| Input voltage regulation | $V_I$ = 4.5 V to 5.5 V | | 25°C | | 1.5 | 20 | µV |
| | | | Full range | | | 100 | |
| | $V_I$ = 4.5 V to 40 V | | 25°C | | 1.5 | 20 | µV/V |
| | | | Full range | | | 100 | |
| Ripple rejection | f = 120 Hz, | $\Delta V_{I(PP)}$ = 1 V | 25°C | | 80 | | dB |
| Output voltage regulation (source current)‡ | $I_O$ = 0 to –10 mA | | 25°C | –160 | –45 | 160 | µV |
| | | | Full range | –250 | | 250 | |
| | $I_O$ = 0 to –20 mA | | 25°C | –450 | –150 | 450 | |
| Output voltage regulation (sink current)‡ | $I_O$ = 0 to 3 mA | | 25°C | –160 | 15 | 160 | µV |
| | | | Full range | –250 | | 250 | |
| | $I_O$ = 0 to 20 mA | | 25°C | –235 | 65 | 235 | |
| Long-term drift of output voltage | $\Delta t$ = 1000 h, | Noncumulative | 25°C | | 15 | | ppm |
| Output impedance | | | 25°C | | 7.5 | 22.5 | mΩ |
| Short-circuit output current (sink current) | $V_O$ = 5 V | | 25°C | 30 | 55 | | mA |
| Short-circuit output current (source current) | $V_O$ = 0 | | | –30 | –50 | | |
| Output noise voltage, rms | f = 10 Hz to 10 kHz | | 25°C | | 100 | | µV |
| Output voltage response to output current step | $V_O$ to 0.1%, $I_O$ = ±10 mA | $C_L$ = 0 | 25°C | | 110 | | µs |
| | | $C_L$ = 100 pF | | | 115 | | |
| | $V_O$ to 0.01%, $I_O$ = ±10 mA | $C_L$ = 0 | | | 180 | | |
| | | $C_L$ = 100 pF | | | 180 | | |
| Output voltage response to input voltage step | $V_I$ = 4.5 to 5.5 V, | $V_O$ to 0.1% | 25°C | | 12 | | µs |
| | $V_I$ = 4.5 to 5.5 V, | $V_O$ to 0.01% | | | 30 | | |
| Output voltage turn-on response | $V_I$ = 0 to 5 V, | $V_O$ to 0.1% | 25°C | | 125 | | µs |
| | $V_I$ = 0 to 5 V, | $V_O$ to 0.01% | | | 210 | | |

† Full range is –55°C to 125°C.
‡ The listed values are not production tested.

## TYPICAL CHARACTERISTICS

### Table Of Graphs

| | | FIGURE |
|---|---|---|
| Output voltage | Distribution | 1 |
| | vs Free-air temperature | 2 |
| Output voltage hysteresis | vs Free-air temperature | 3 |
| Input bias current | vs Input voltage | 4 |
| | vs Free-air temperature | 5 |
| Input voltage regulation | | 6 |
| Ripple rejection | vs Frequency | 7 |
| Output voltage regulation | | 8 |
| Output impedance | vs Frequency | 9 |
| Short-circuit output current | vs Free-air temperature | 10 |
| Spectral noise voltage density | vs Frequency | 11 |
| Wide-band noise voltage | vs Frequency | 12 |
| Output voltage change with current step | vs Time | 13 |
| Output voltage change with voltage step | vs Time | 14 |
| Output voltage power-up response | vs Time | 15 |
| Output current | vs Load capacitance | 16 |

## TYPICAL CHARACTERISTICS†

**DISTRIBUTION OF OUTPUT VOLTAGE**

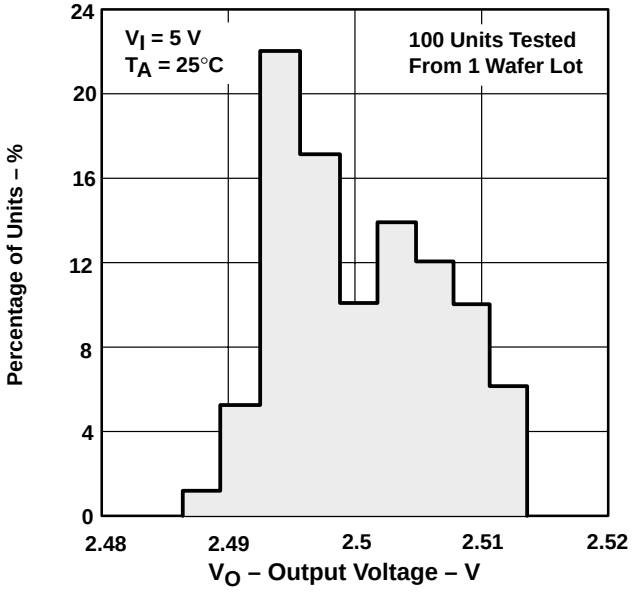



Figure 1

**OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE**

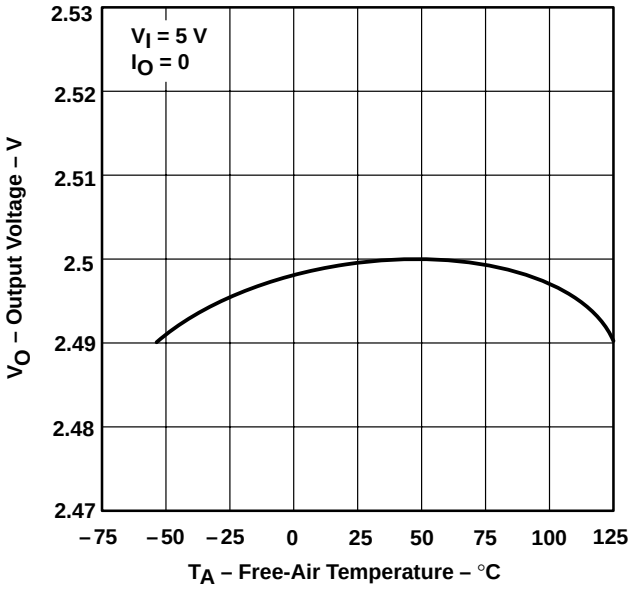



Figure 2

**OUTPUT VOLTAGE HYSTERESIS vs FREE-AIR TEMPERATURE**

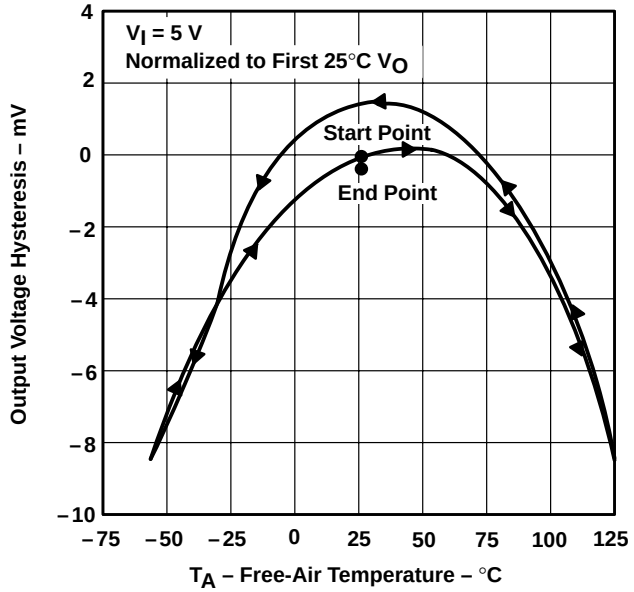



Figure 3

**INPUT BIAS CURRENT vs INPUT VOLTAGE**

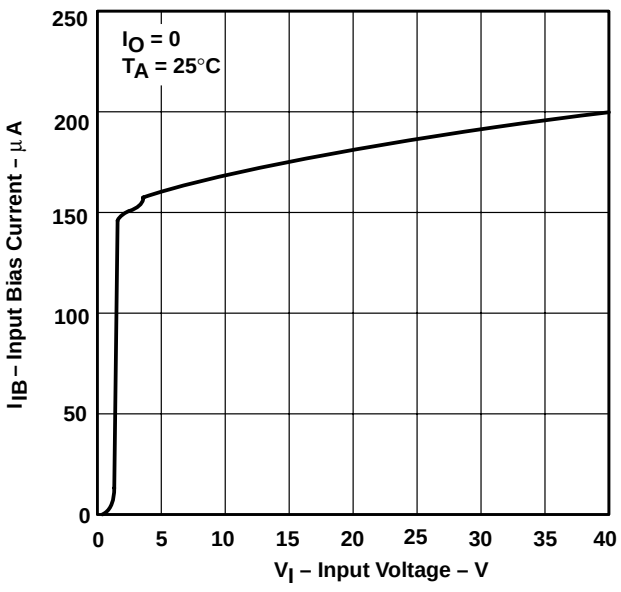



Figure 4

† Data at high and low temperatures are applicable within rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE**

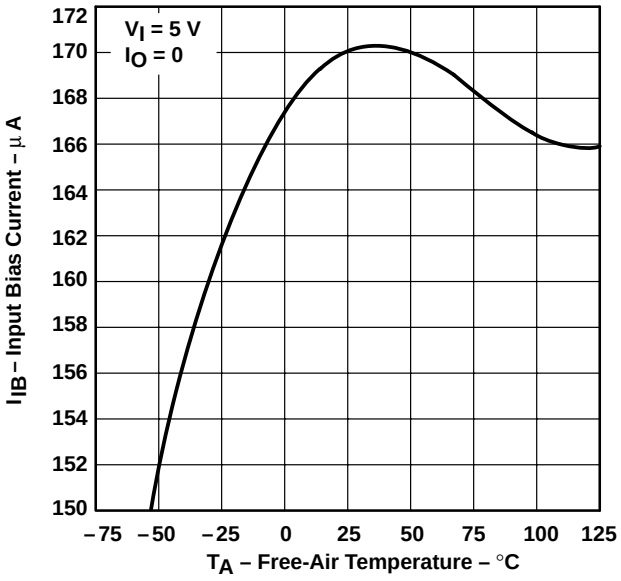



**Figure 5**

**INPUT VOLTAGE REGULATION**

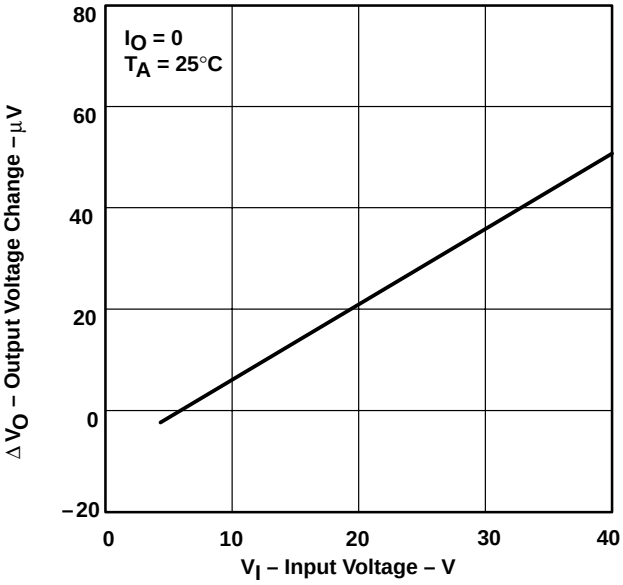



**Figure 6**

**RIPPLE REJECTION vs FREQUENCY**

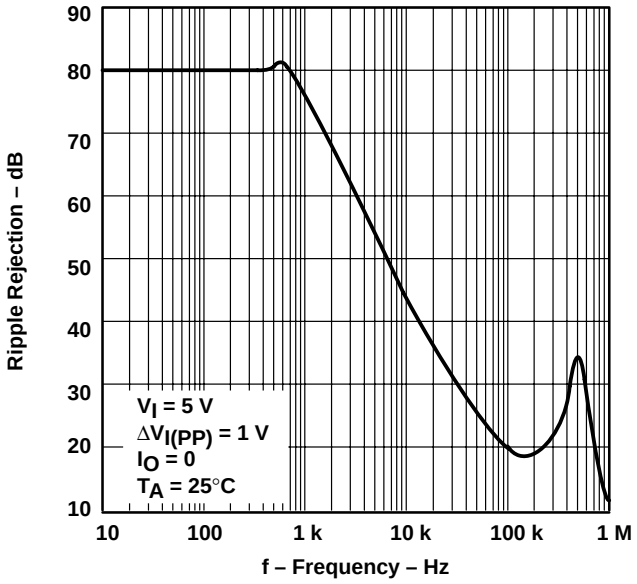



**Figure 7**

**OUTPUT VOLTAGE REGULATION**

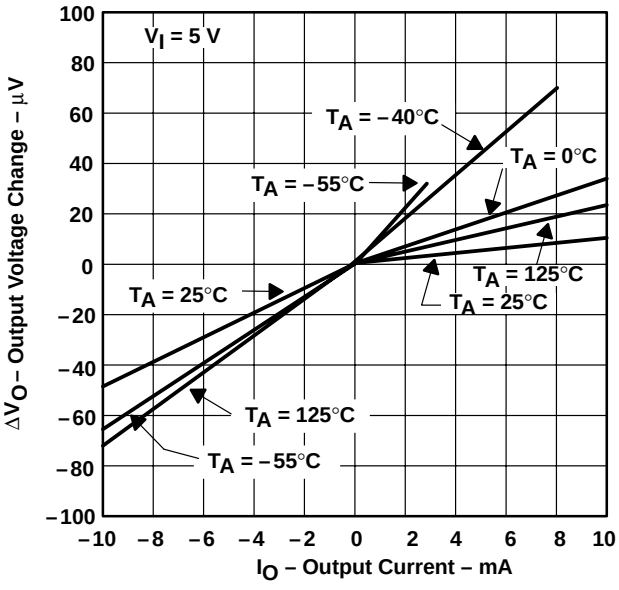



**Figure 8**

† Data at high and low temperatures are applicable within rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

**OUTPUT IMPEDANCE vs FREQUENCY**

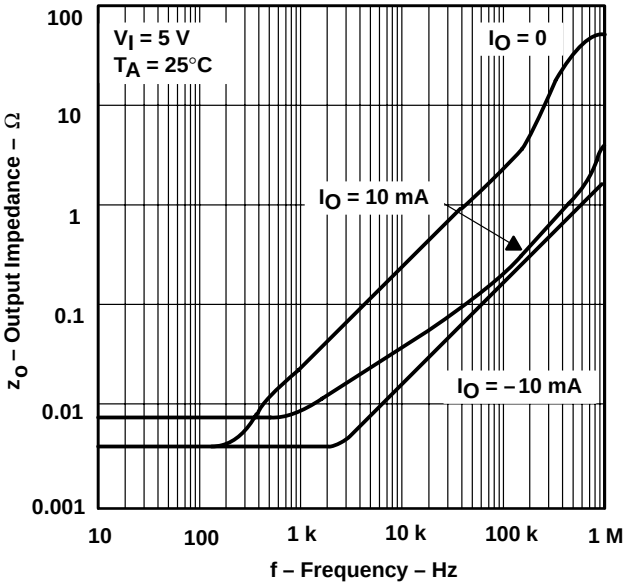



Figure 9

**SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE**

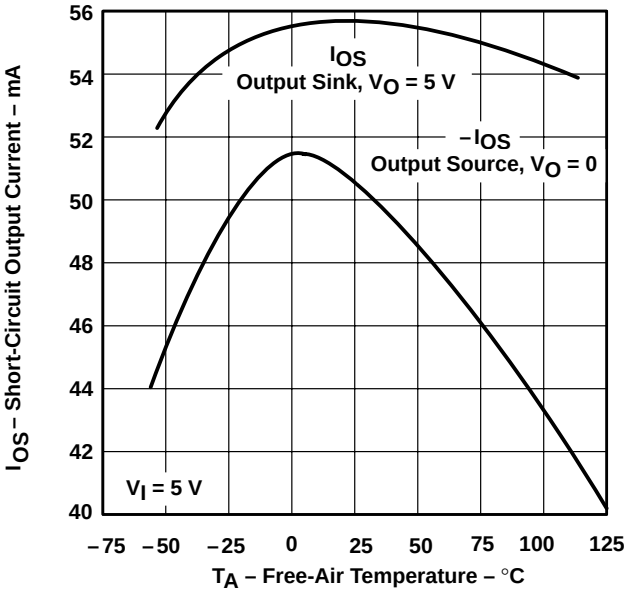



Figure 10

**SPECTRAL NOISE VOLTAGE DENSITY vs FREQUENCY**

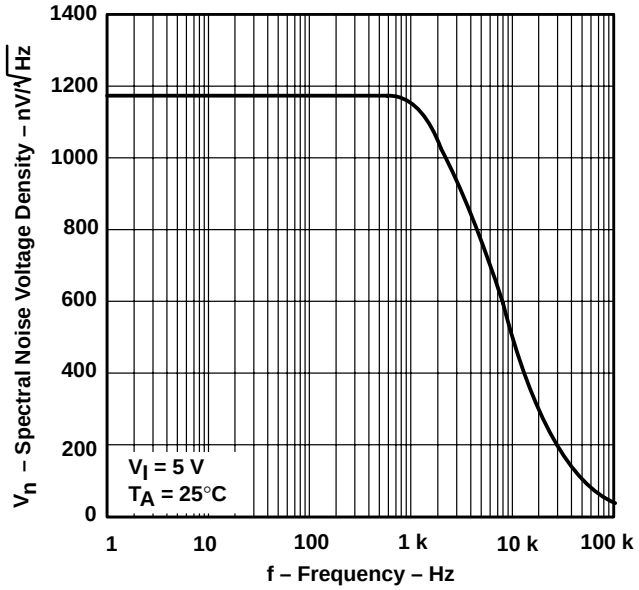



Figure 11

**WIDE-BAND NOISE VOLTAGE vs FREQUENCY**

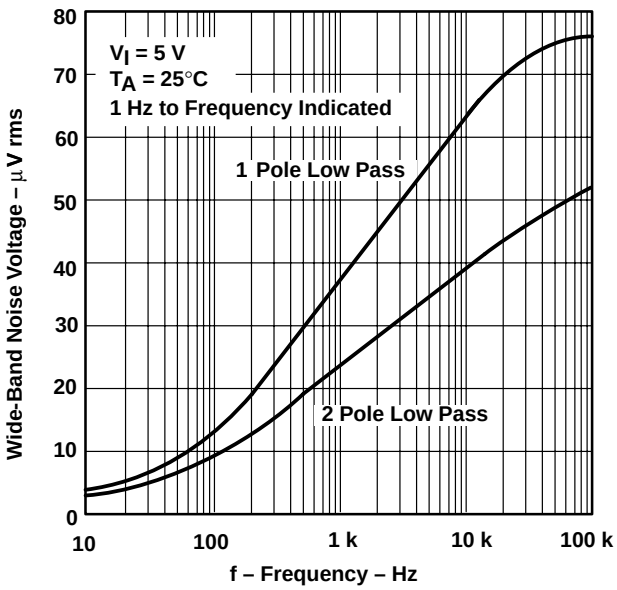



Figure 12

## TYPICAL CHARACTERISTICS

**OUTPUT VOLTAGE RESPONSE TO OUTPUT CURRENT STEP vs TIME**

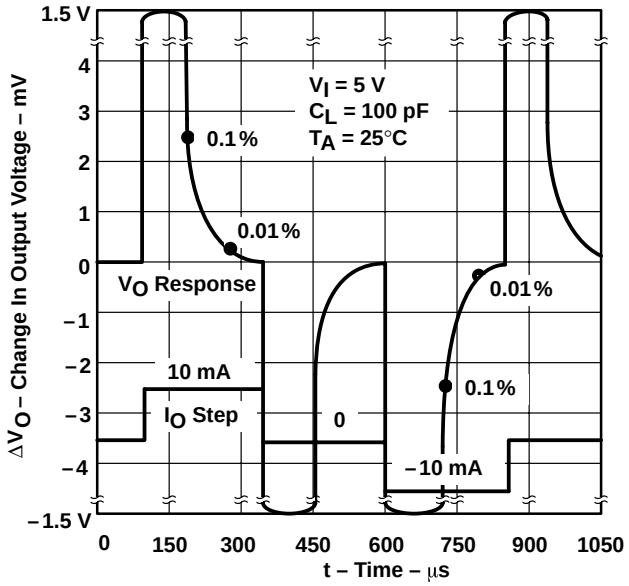



Figure 13

**OUTPUT VOLTAGE RESPONSE TO INPUT VOLTAGE STEP vs TIME**

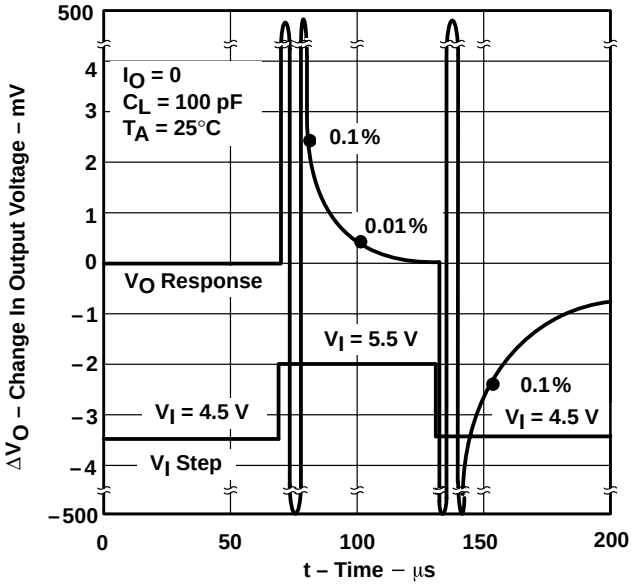



Figure 14

**OUTPUT VOLTAGE POWER-UP RESPONSE vs TIME**

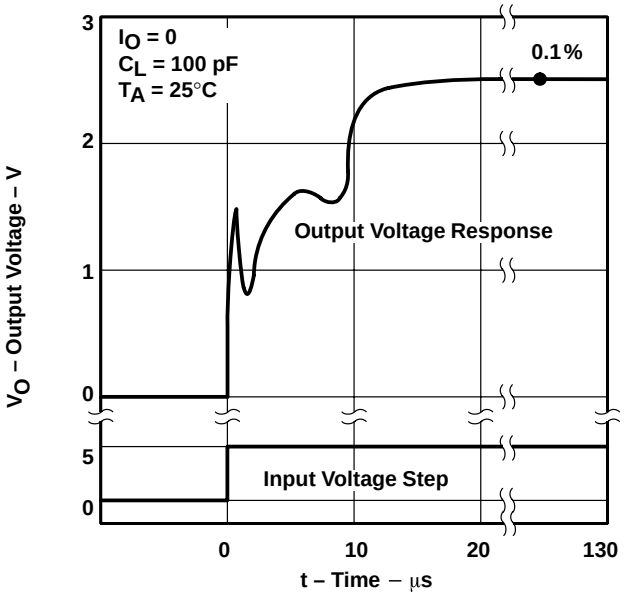



Figure 15

**STABILITY RANGE OUTPUT CURRENT vs LOAD CAPACITANCE**

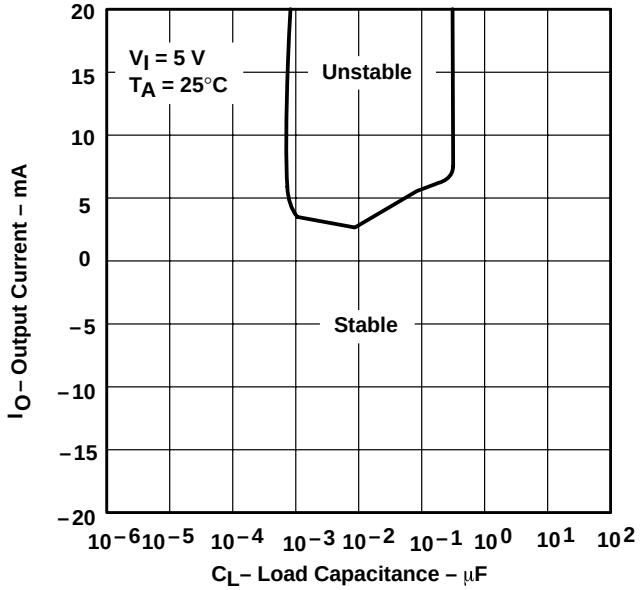



Figure 16

## macromodel information

```
*   TLE2425 OPERATIONAL AMPLIFIER “MACROMODEL” SUBCIRCUIT
*   CREATED USING PARTS RELEASE 4.03 ON 08/21/90 AT 13:51
*   REV (N/A)     SUPPLY VOLTAGE: 5 V
*   CONNECTIONS:  INPUT
*                 |   COMMON
*                 |   |   OUTPUT
*                 |   |   |
.SUBCKT TLE2425   3   4   5
*
```

---

```
*   OPAMP SECTION
    C1     11  12  21.66E-12
    C2      6  7   30.00E-12
    C3     87  0   10.64E-9
    CPSR   85  86  15.9E-9
    DCM+   81  82  DX
    DCM-   83  81  DX
    DC      5  53  DX
    DE     54  5   DX
    DLN    92  90  DX
    DLP    90  91  DX
    DP      4  3   DX
    ECMR   84  99  (2,99) 1
    EGND   99  0   POLY(2)   (3,0)  (4,0)  0   .5  .5
    EPSR   85  0   POLY(1)   (3,4)  -16.22E-6 3.24E-6
    ENSE   89  2   POLY(1)   (88,0) 120E-6 1
    FB      7  99  POLY(6)   VB  VC  VE  VLP VLN VPSR   0   74.8E6 -10E6  10E6   10E6
+   -10E6  74E6
    GA      6  0   11  12  320.4E-6
    GCM     0  6   10  99  1.013E-9
    GPSR   85  86  (85,86)   100E-6
    GRC1   4   11  (4,11) 3.204E-4
    GRC2   4   12  (4,12) 3.204E-4
    GRE1   13  10  (13,10)   1.038E-3
    GRE2   14  10  (14,10)   1.038E-3
    HLIM   90  0   VLIM   1K
    HCMR   80  1   POLY(2)   VCM+   VCM-   0   1E2 1E2
    IRP     3  4   146E-6
    IEE     3  10  DC  24.05E-6
    IIO     2  0   .2E-9
    I1     88  0   1E-21
    Q1     11  89  13  QX
    Q2     12  80  14  QX
    R2      6  9   100.0E3
    RCM    84  81  1K
    REE    10  99  8.316E6
    RN1    87  0   2.55E8
    RN2    87  88  11.67E3
```

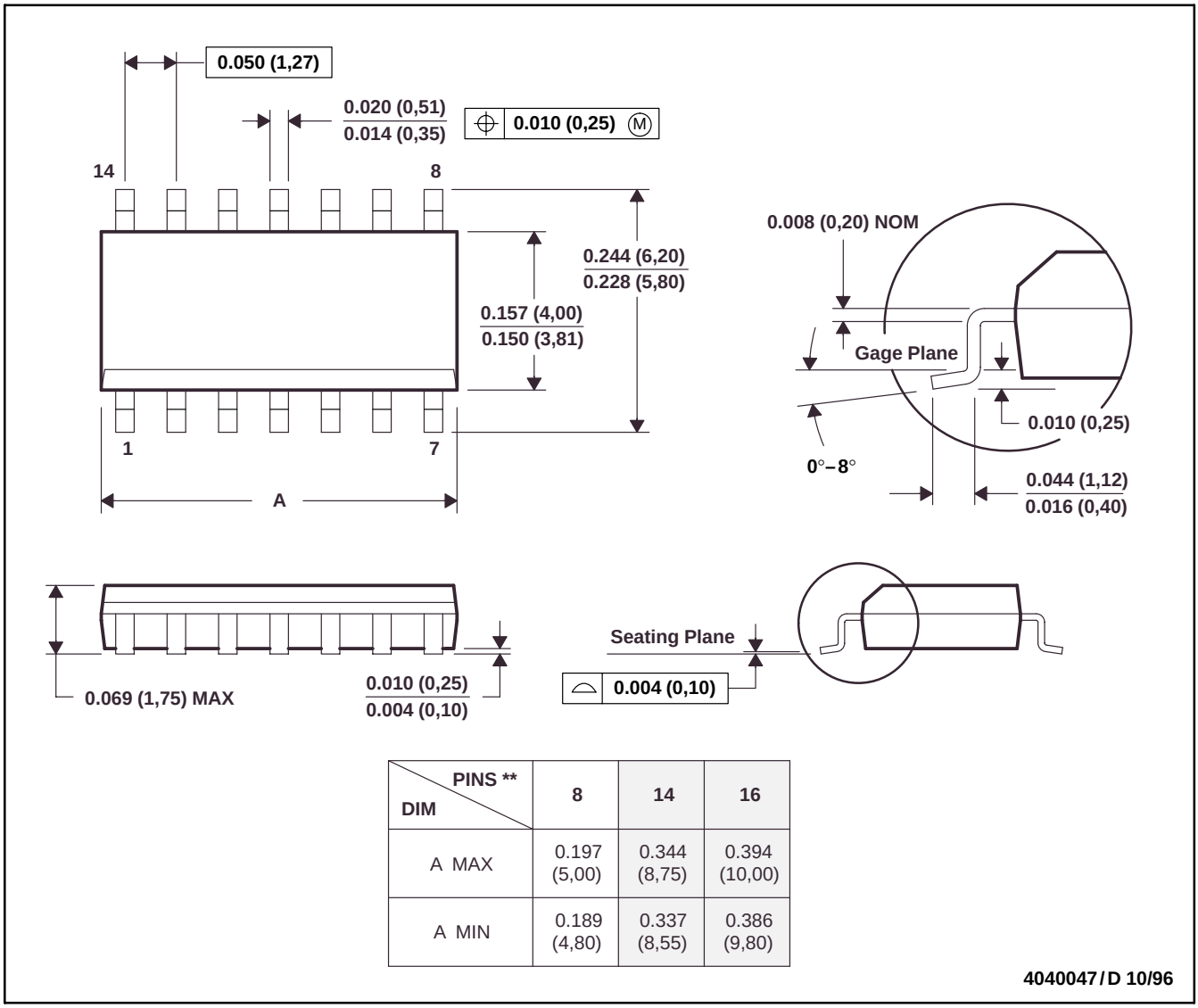
## macromodel information (continued)

```
        RO1     8  5   63
        RO2     7  99  62
        VCM+   82  99  1.0
        VCM–   83  99  –2.3
        VB      9  0   DC  0
        VC      3  53  DC  1.400
        VE     54  4   DC  1.400
        VLIM    7  8   DC  0
        VLP    91  0   DC  30
        VLN     0  92  DC  30
        VPSR    0  86  DC  0
        RFB     5  2   1K
        RIN    30  1   1K
        RCOM   34  4   .1
    *REGULATOR SECTION
        RG1    30  0   20MEG
        RG2    30  31  .2
        RG3    31  35  400K
        RG4    35  34  411K
        RG5    31  36  25MEG
        HREG   31  32  POLY(2)   VPSET  VNSET  0   1E2 1E2
        VREG   32  33  DC  0V
        EREG   33  34  POLY(1)   (36,34)   1.23 1
        VADJ   36  34  1.27V
        HPSET  37  0   VREG   1.030E3
        VPSET  38  0   DC  20V
        HNSET  39  0   VREG   6.11E5
        VNSET  40  0   DC  –20V
        DSUB    4  34  DX
        DPOS   37  38  DX
        DNNEG  40  39  DX
    .MODEL DX  D(IS=800.0E–18)
    .MODEL QX  PNP(IS=800.0E–18 BF=480)
    .ENDS
```

## MECHANICAL INFORMATION

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

**14 PIN SHOWN**



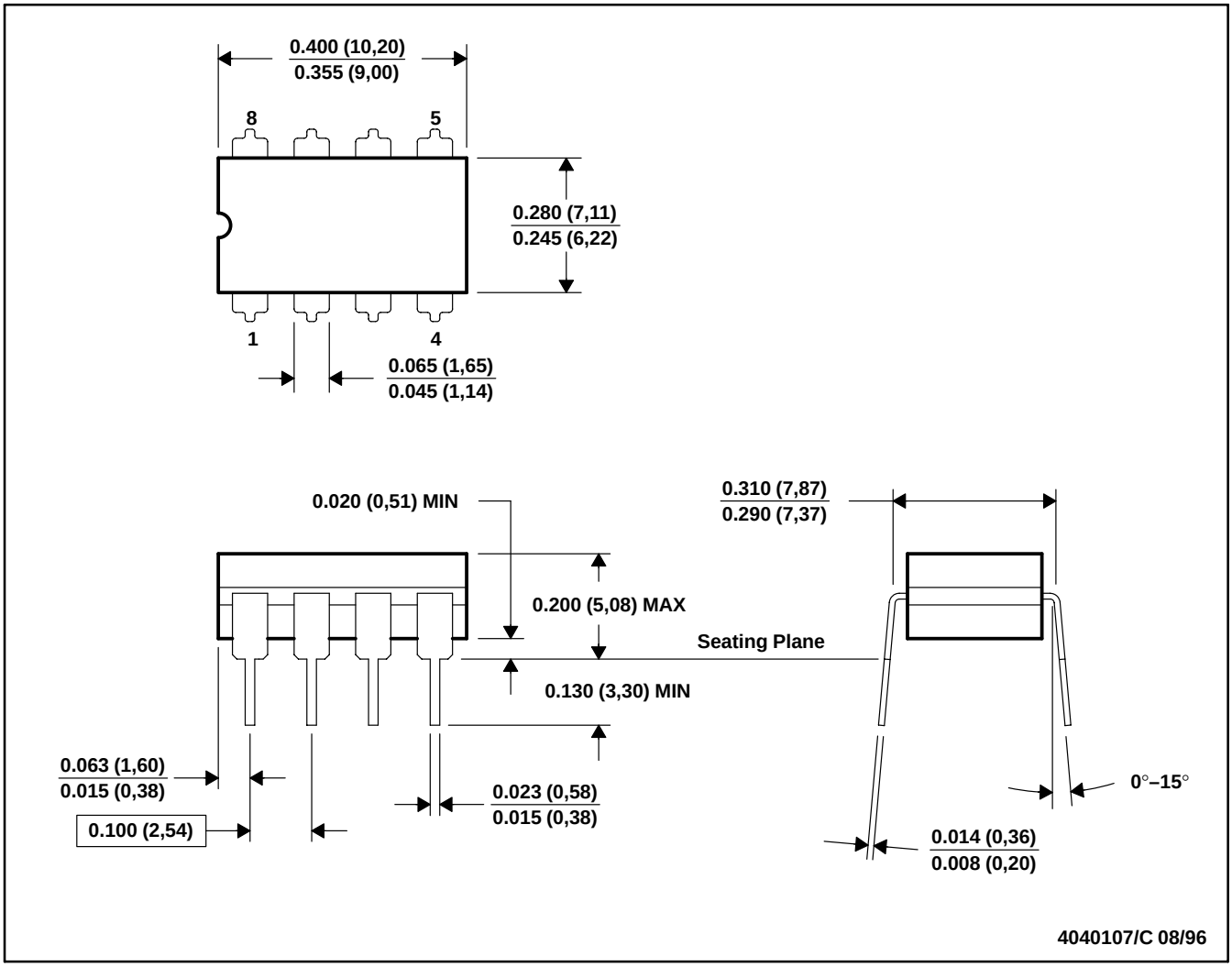

| DIM \ PINS ** | 8 | 14 | 16 |
|---|---|---|---|
| A MAX | 0.197 (5,00) | 0.344 (8,75) | 0.394 (10,00) |
| A MIN | 0.189 (4,80) | 0.337 (8,55) | 0.386 (9,80) |

**4040047/D 10/96**

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

## MECHANICAL INFORMATION

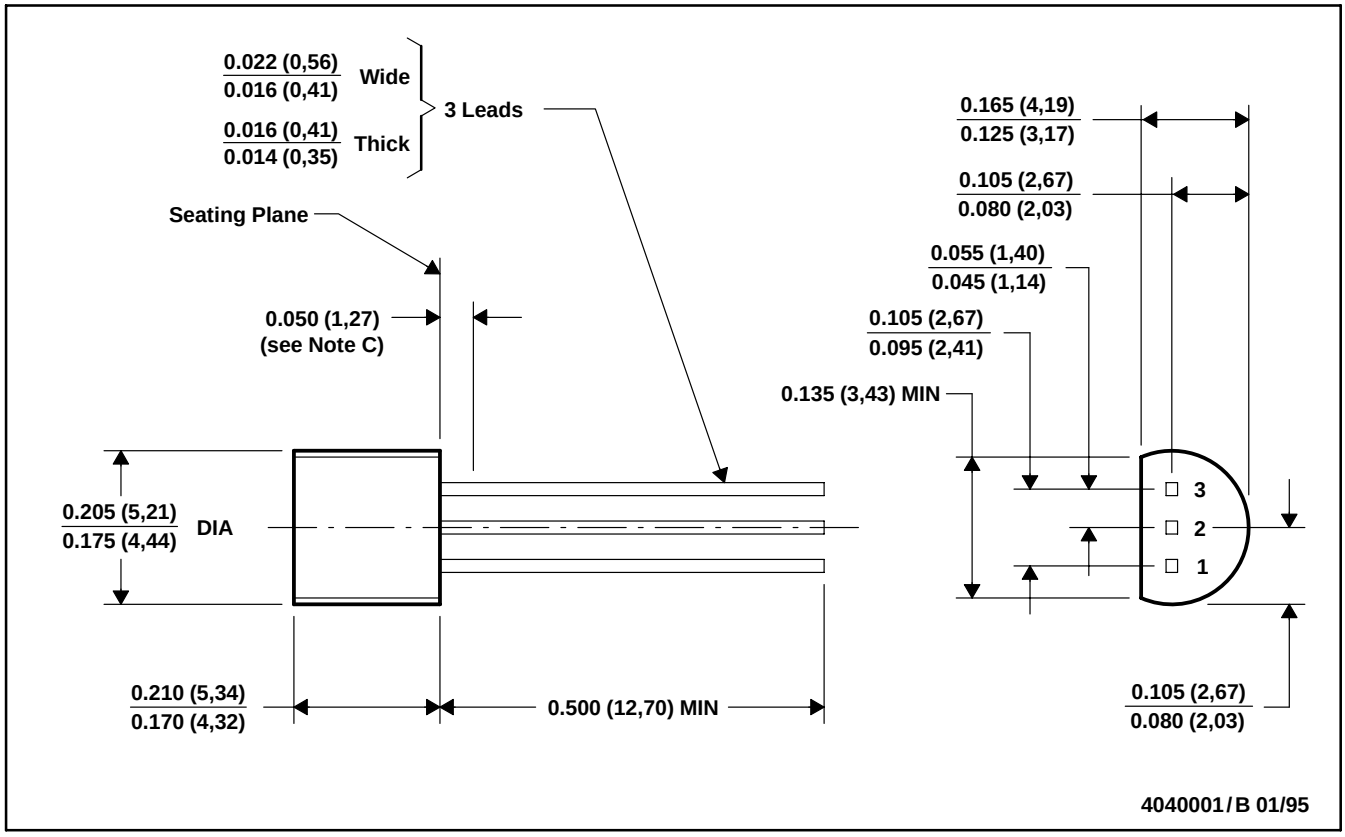
**JG (R-GDIP-T8)** **CERAMIC DUAL-IN-LINE PACKAGE**




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 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-T8

## MECHANICAL INFORMATION

**LP (O-PBCY-W3)** **PLASTIC CYLINDRICAL PACKAGE**




NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Lead dimensions are not controlled within this area.
D. Falls within JEDEC TO-226AA (TO-226AA replaces TO-92)

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