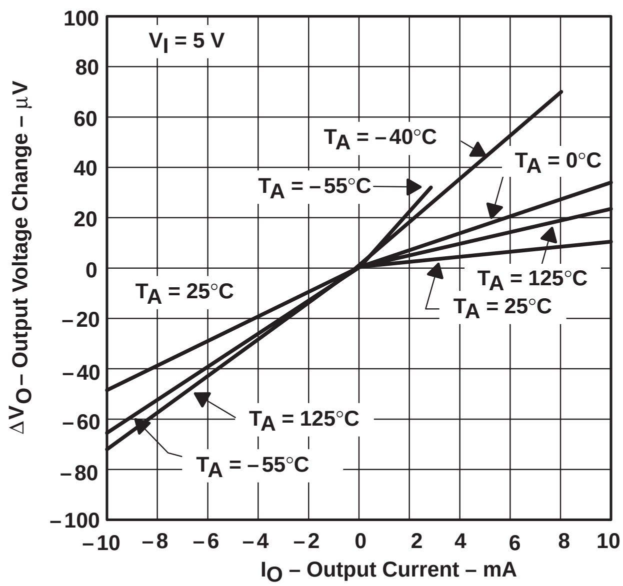
- **2.5-V Virtual Ground for 5-V/GND Analog Systems**
- **Self-Contained in Small-Outline, Dual-In-Line or 3-Terminal TO-226AA Packages**
- **High Output-Current Capability Sink or Source . . . 20 mA Typ**
- **Micropower Operation . . . 170 μA Typ**
- **Excellent Regulation Characteristics**
  - **Output 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.

OUTPUT REGULATION



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.

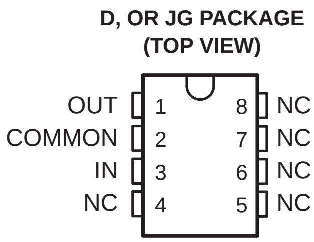
The TLE2425 improves input regulation as well as output regulation and, in addition, reduces output impedance and power dissipation in a majority of virtual-ground-generation circuits. Both input regulation and load regulation exceed 12 bits of accuracy on a single 5-V system. Signal-conditioning front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

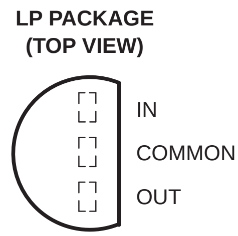
The TLE2425C is characterized for operation from 0°C to 70°C. The TLE2425I is characterized for operation from –40°C to 85°C. The TLE2425M is characterized for operation over the full military temperature range of –55°C to 125°C.

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES			CHIP FORM (Y)
	SMALL OUTLINE (D)	CERAMIC DIP (JG)	PLASTIC TO-226AA (LP)	
0°C to 70°C	TLE2425CD	—	TLE2425CD	TLE2425Y
–40°C to 85°C	TLE2425ID	—	TLE2425ID	—
–55°C to 125°C	TLE2425MD	TLE2425MD	TLE2425MD	—

† The D and LP packages are available taped and reeled in the commercial temperature range only. Add R suffix to the device type (e.g., TLE2425CDR). The chip form is tested at 25°C.



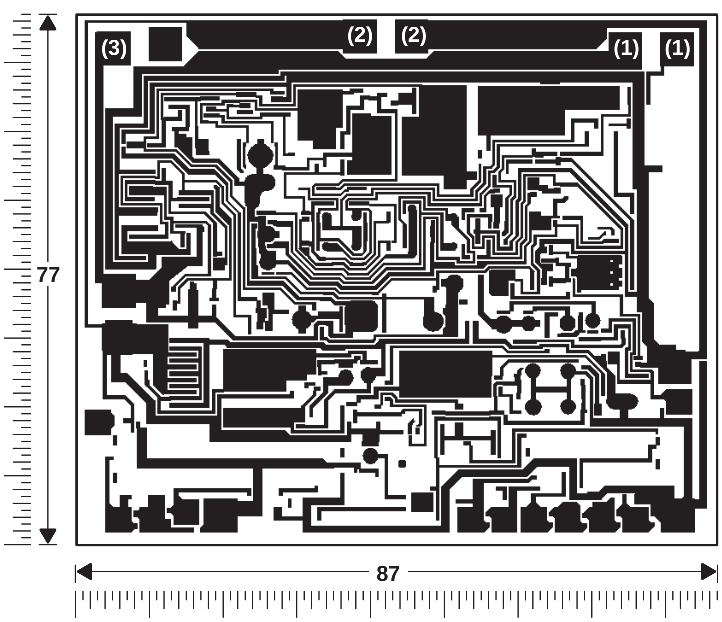


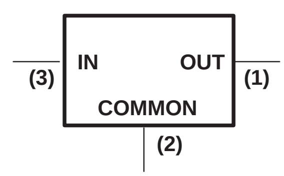
NC – No internal connection

TLE2425Y chip information

This chip, properly assembled, displays characteristics similar to the TLE2425C. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. The chip may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS





CHIP THICKNESS:
15 MILS TYPICAL

BONDING PADS:
4 × 4 MILS MINIMUM

$T_J$max = 150°C

TOLERANCES ARE ±10%.

ALL DIMENSIONS
ARE IN MILS.

NOTE A: NOTE: Both number 1 bonding pads and both number 2 bonding pads must be bonded out to the corresponding pins.

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 MIN	TLE2425C TYP	TLE2425C MAX	UNIT
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	Δt = 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%, $I_O = \pm 10$ mA	$C_L = 0$	25°C		110		µs
		$C_L = 100$ pF			115		
	V_O to 0.01%, $I_O = \pm 10$ 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 MIN	TLE2425M TYP	TLE2425M MAX	UNIT
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	Δt = 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.

electrical characteristics V_I = 5 V, I_O = 0, T_A = 25°C (unless otherwise noted)

PARAMETER	TEST CONDITIONS		TLE2425Y MIN	TLE2425Y TYP	TLE2425Y MAX	UNIT
Output voltage				2.5		V
Temperature coefficient of output voltage				20		ppm/°C
Bias current	$I_O = 0$			170		µA
Input voltage regulation	V_I = 4.5 V to 5.5 V			1.5		µV
	V_I = 4 V to 40 V			1.5		µV/V
Ripple rejection	f = 120 Hz,	$\Delta V_{I(PP)}$ = 1 V		80		dB
Output voltage regulation (source current)†	I_O = 0 to –10 mA			–45		µV
	I_O = 0 to –20 mA			–150		
Output voltage regulation (sink current)†	I_O = 0 to 10 mA			15		µV
	I_O = 0 to 20 mA			65		
Output impedance				7.5		mΩ
Short-circuit output current (sink current)	V_O = 5 V			55		mA
Short-circuit output current (source current)	V_O = 0			–50		
Output noise voltage, rms	f = 10 Hz to 10 kHz			100		µV
Output voltage response to output current step	V_O to 0.1%, I_O = ±10 mA	C_L = 0		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%		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%		125		µs
	V_I = 0 to 5 V,	V_O to 0.01%		210		

† 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

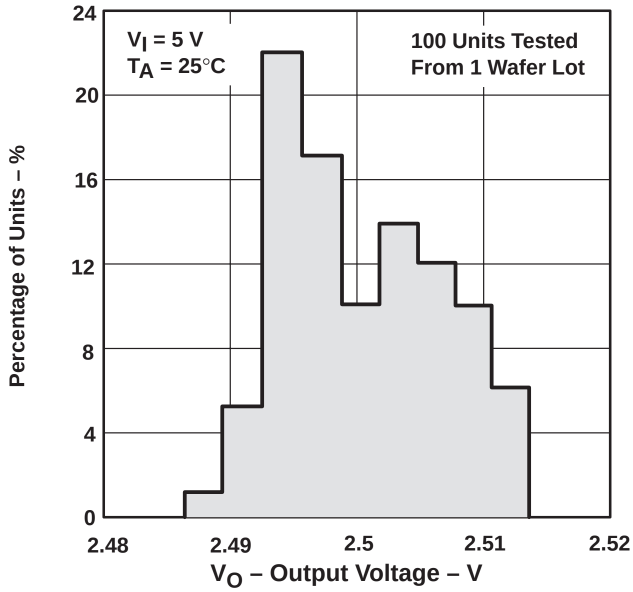


Figure 1

OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

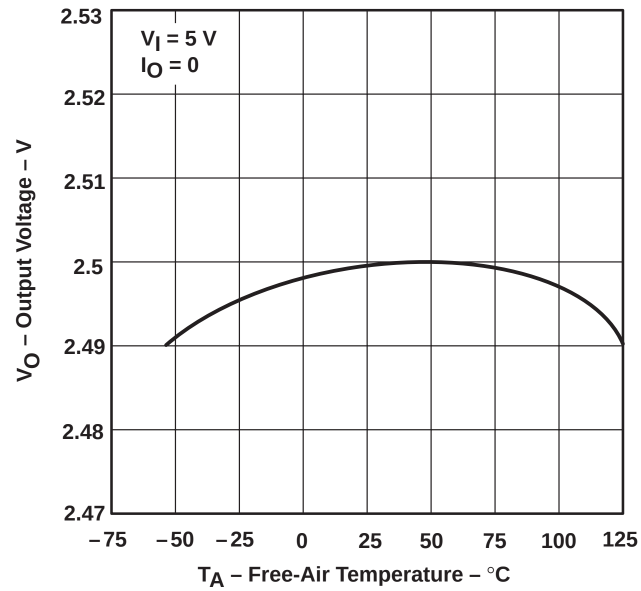


Figure 2

OUTPUT VOLTAGE HYSTERESIS
vs
FREE-AIR TEMPERATURE

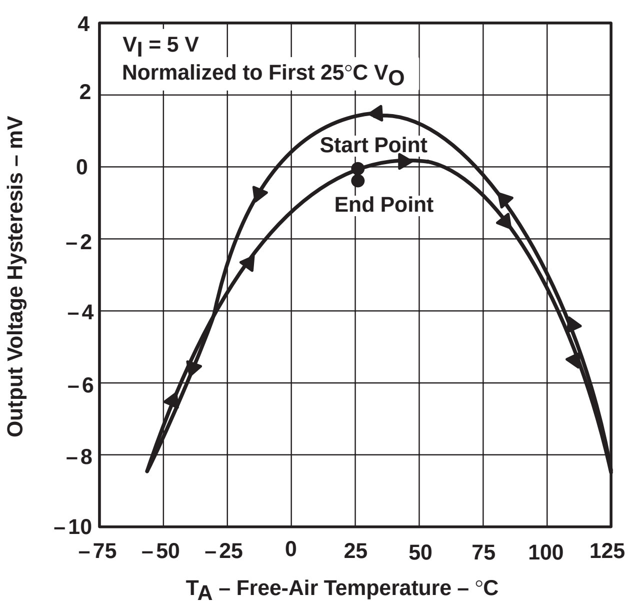


Figure 3

INPUT BIAS CURRENT
vs
INPUT VOLTAGE

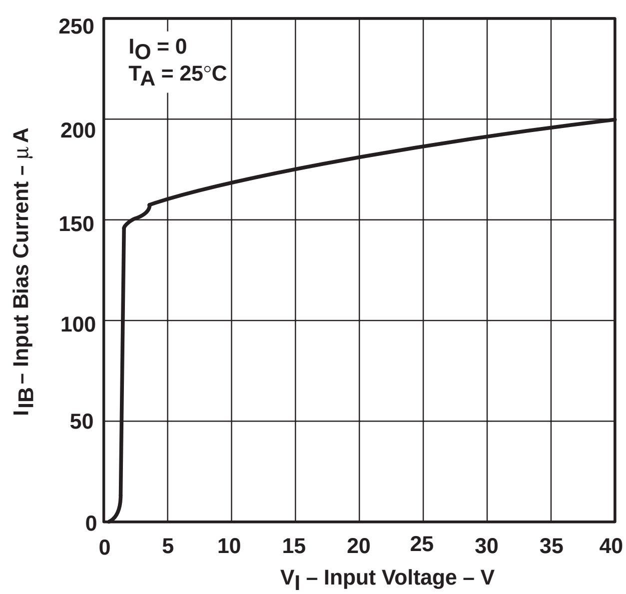


Figure 4

† 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

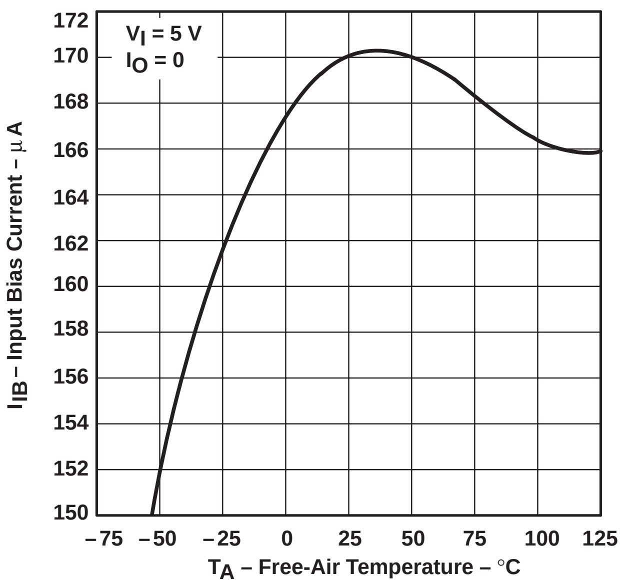


Figure 5

INPUT VOLTAGE REGULATION

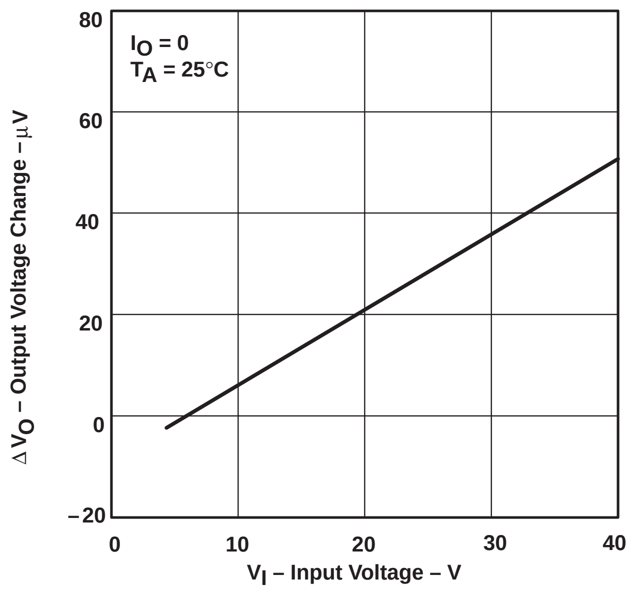


Figure 6

RIPPLE REJECTION
vs
FREQUENCY

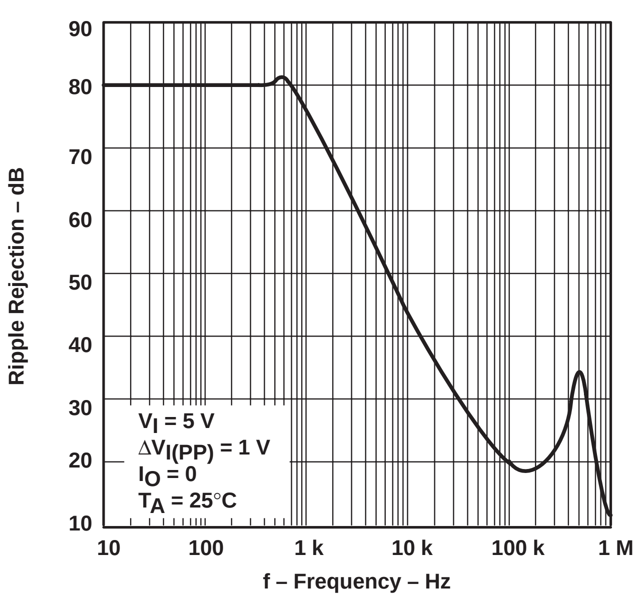


Figure 7

OUTPUT VOLTAGE REGULATION

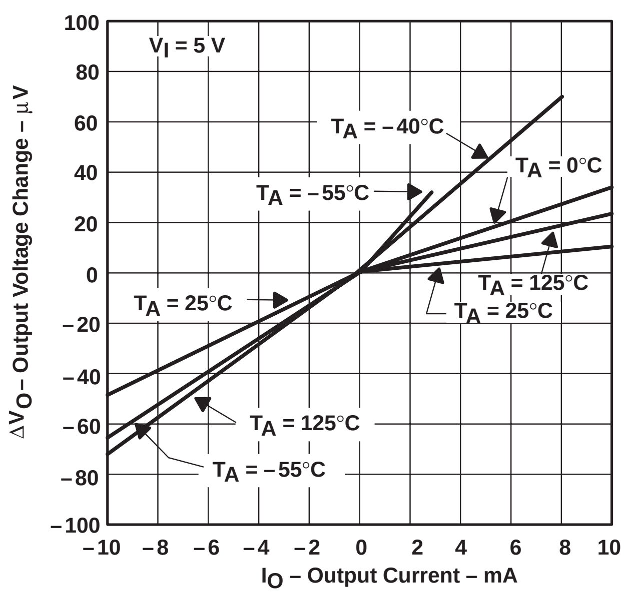


Figure 8

† 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

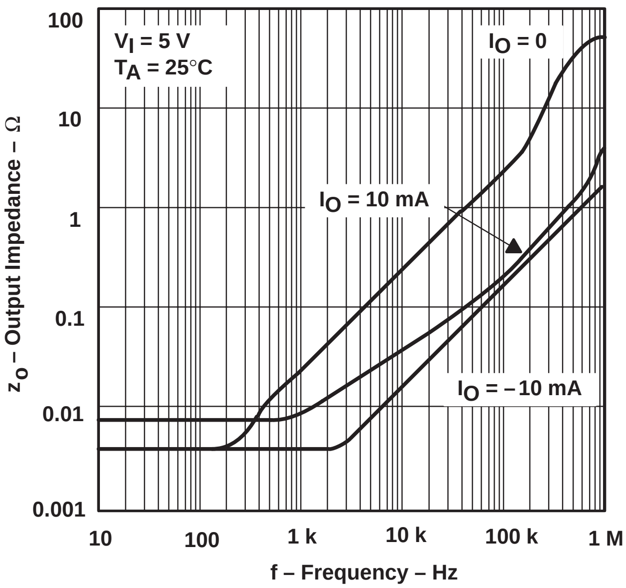


Figure 9

SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE

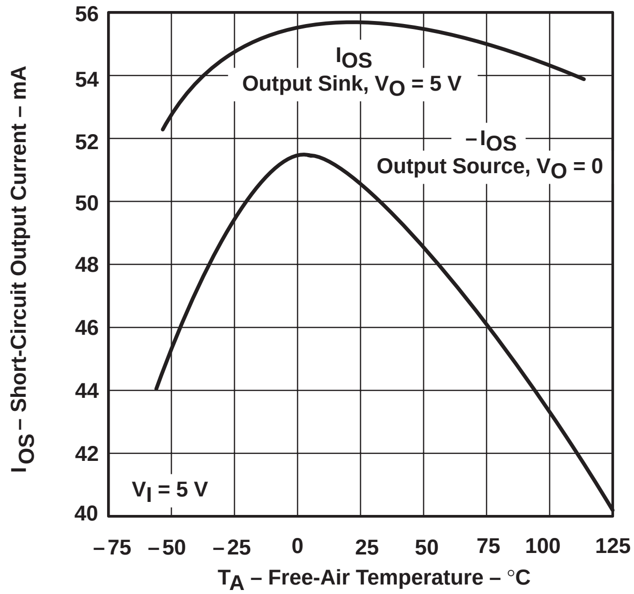


Figure 10

SPECTRAL NOISE VOLTAGE DENSITY vs FREQUENCY

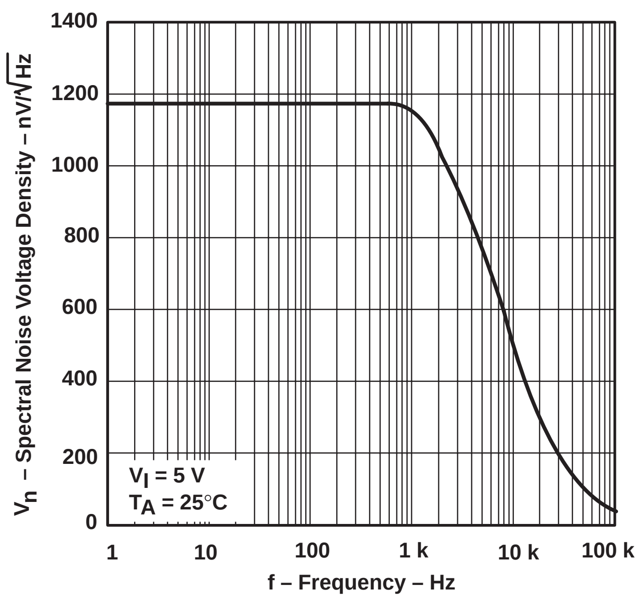


Figure 11

WIDE-BAND NOISE VOLTAGE vs FREQUENCY

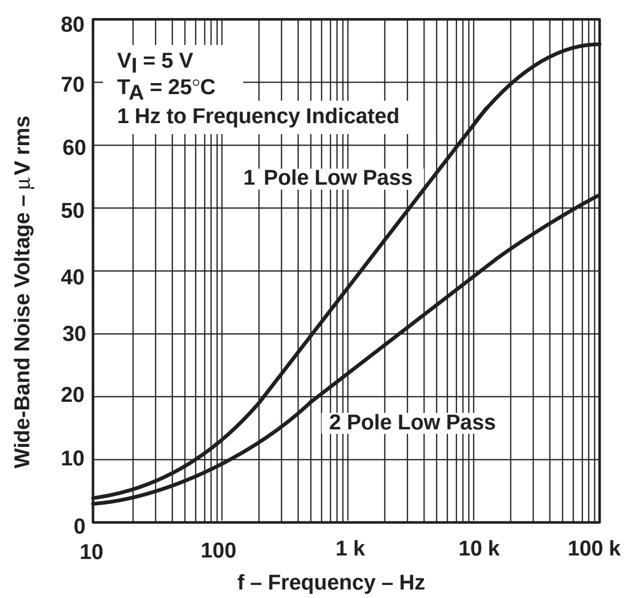


Figure 12

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE RESPONSE
TO OUTPUT CURRENT STEP
vs
TIME

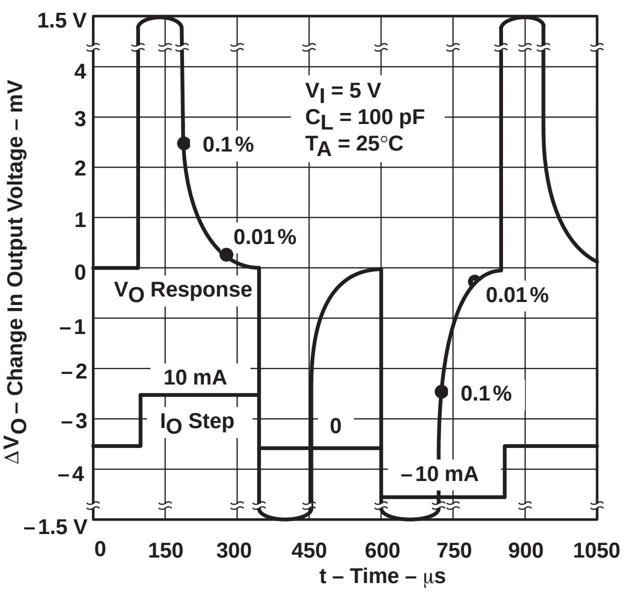


Figure 13

OUTPUT VOLTAGE RESPONSE
TO INPUT VOLTAGE STEP
vs
TIME

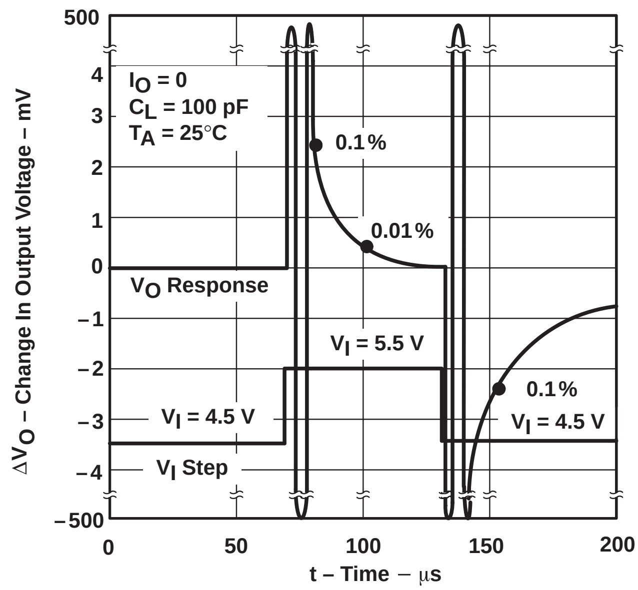


Figure 14

OUTPUT VOLTAGE POWER-UP RESPONSE
vs
TIME

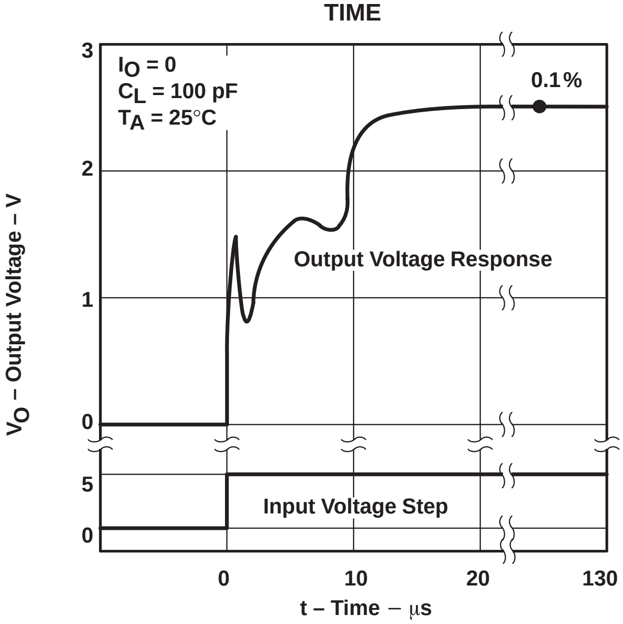


Figure 15

STABILITY RANGE
OUTPUT CURRENT
vs
LOAD CAPACITANCE

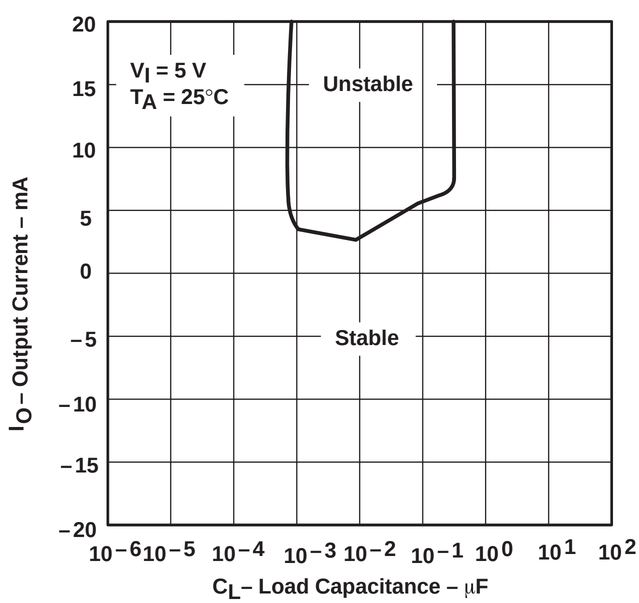


Figure 16

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   O   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
```

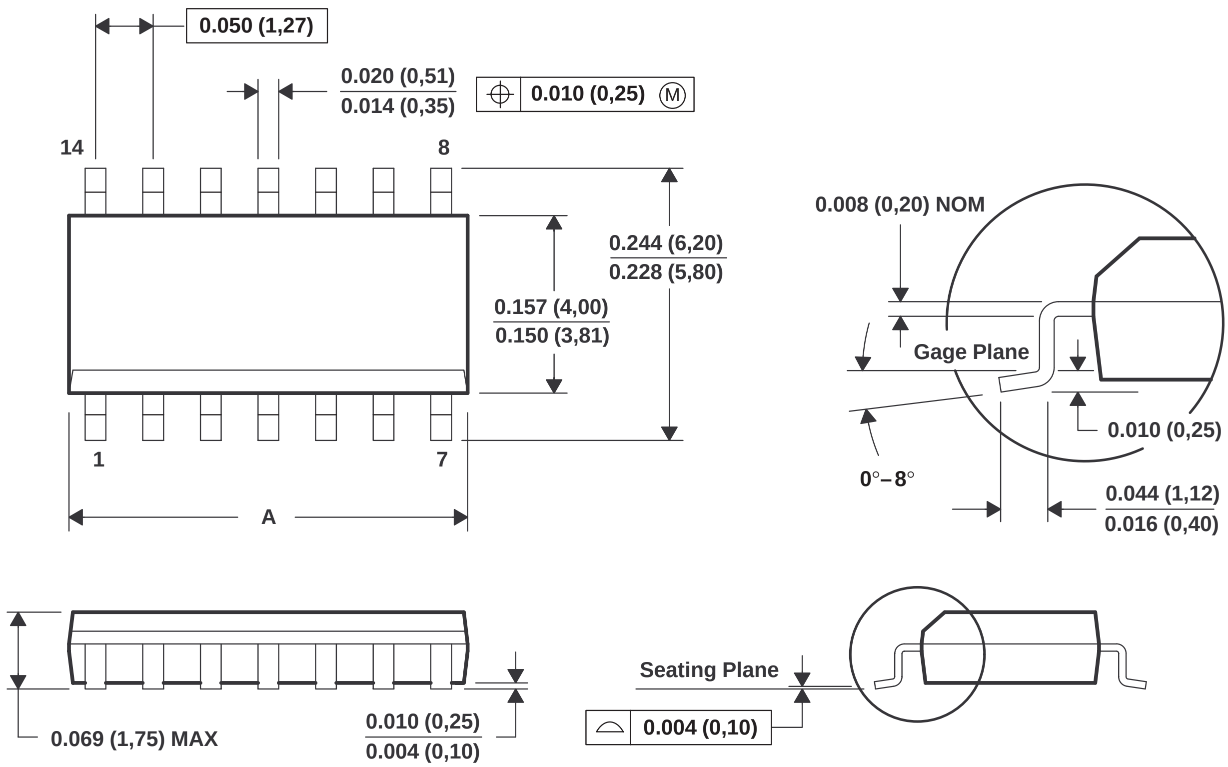
macromodel information (continued)

```
    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



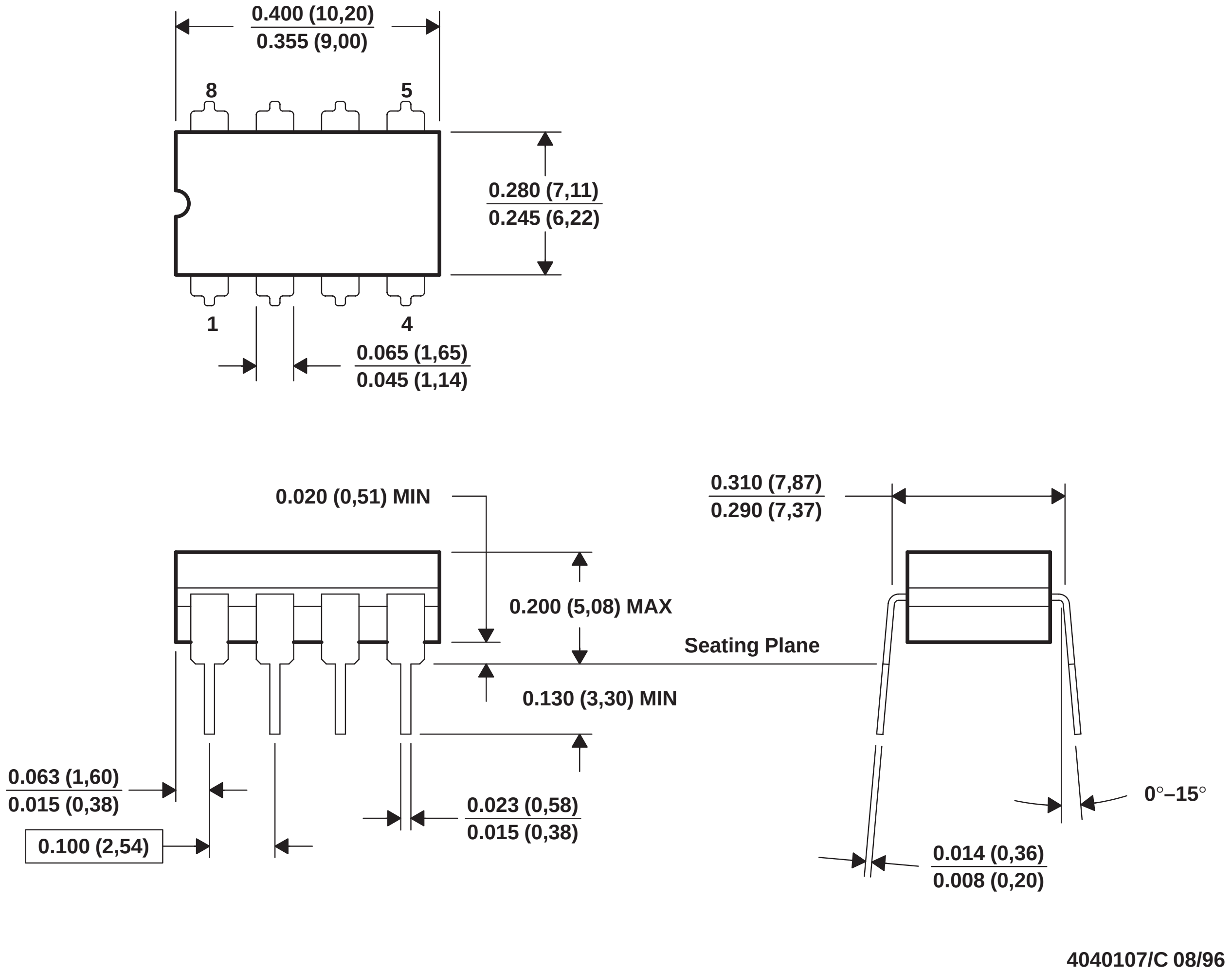
DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

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

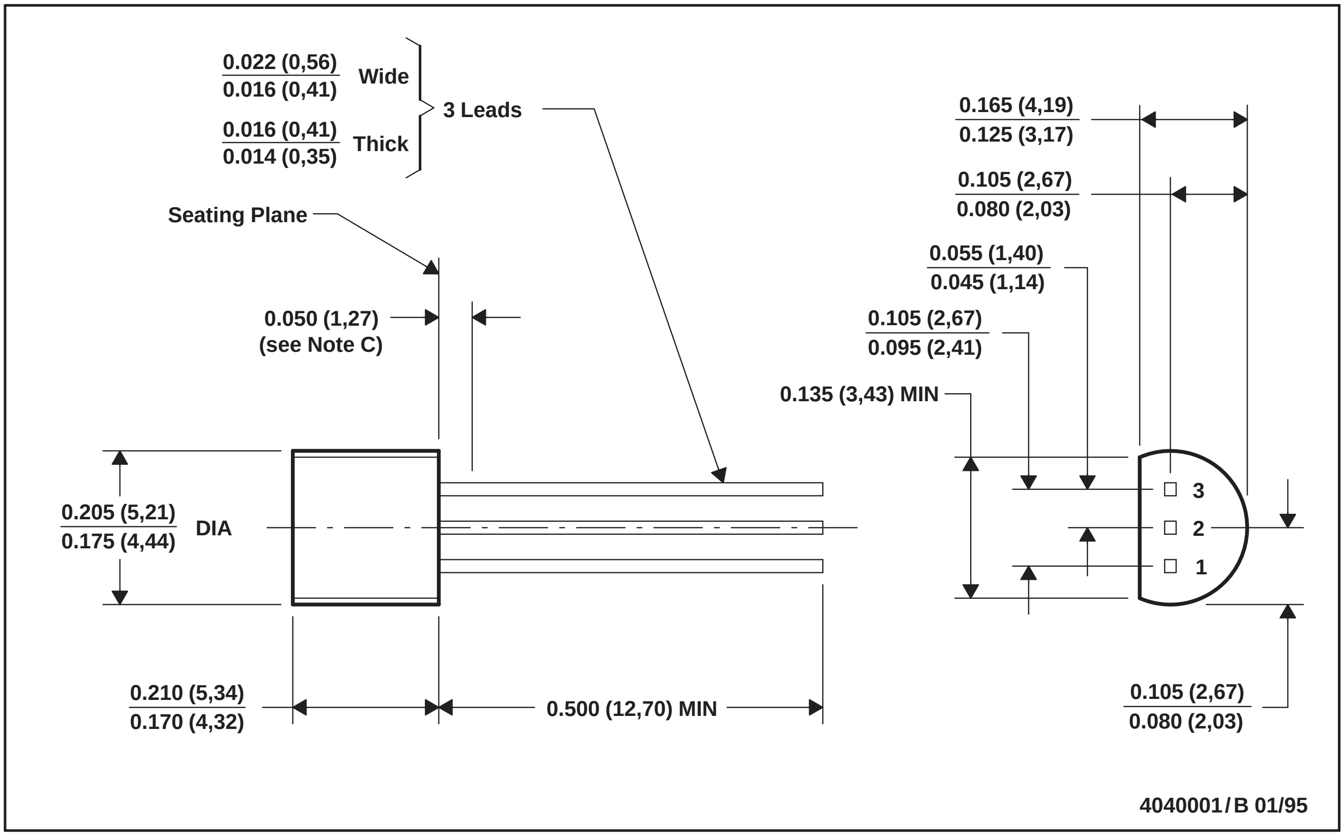
JG (R-GDIP-T8) **CERAMIC DUAL-IN-LINE PACKAGE**



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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