

# TLC4501, TLC4501A, TLC4502, TLC4502A

## FAMILY OF SELF-CALIBRATING (Self-Cal™) PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS

SLOS221B – MAY 1998 – REVISED APRIL 2001

- Self-Calibrates Input Offset Voltage to 40  $\mu\text{V}$  Max
- Low Input Offset Voltage Drift . . . 1  $\mu\text{V}/^\circ\text{C}$
- Input Bias Current . . . 1 pA
- Open Loop Gain . . . 120 dB
- Rail-To-Rail Output Voltage Swing
- Stable Driving 1000 pF Capacitive Loads
- Gain Bandwidth Product . . . 4.7 MHz
- Slew Rate . . . 2.5 V/ $\mu\text{s}$
- High Output Drive Capability . . .  $\pm 50$  mA
- Calibration Time . . . 300 ms
- Characterized From  $-55^\circ\text{C}$  to  $125^\circ\text{C}$
- Available in Q-Temp Automotive HighRel Automotive Applications Configuration Control / Print Support Qualification to Automotive Standards

### description

The TLC4501 and TLC4502 are the highest precision CMOS single supply rail-to-rail operational amplifiers available today. The input offset voltage is 10  $\mu\text{V}$  typical and 40  $\mu\text{V}$  maximum. This exceptional precision, combined with a 4.7-MHz bandwidth, 2.5-V/ $\mu\text{s}$  slew rate, and 50-mA output drive, is ideal for multiple applications including: data acquisition systems, measurement equipment, industrial control applications, and portable digital scales.

These amplifiers feature *self-calibrating* circuitry which digitally trims the input offset voltage to less than 40  $\mu\text{V}$  within the first 300 ms of operation. The offset is then digitally stored in an integrated successive approximation register (SAR). Immediately after the data is stored, the calibration circuitry effectively drops out of the signal path, shuts down, and the device functions as a standard operational amplifier.

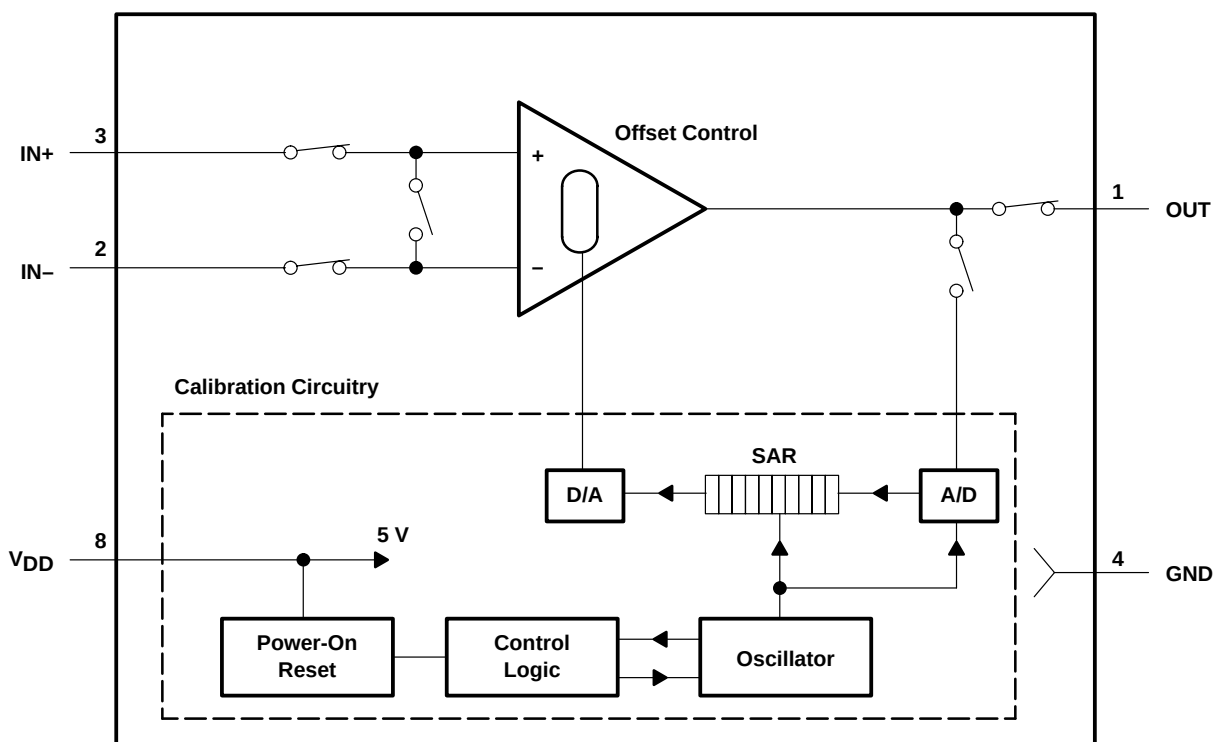


Figure 1. Channel One of the TLC4502



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.

LinEPIC and Self-Cal are trademarks of Texas Instruments.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

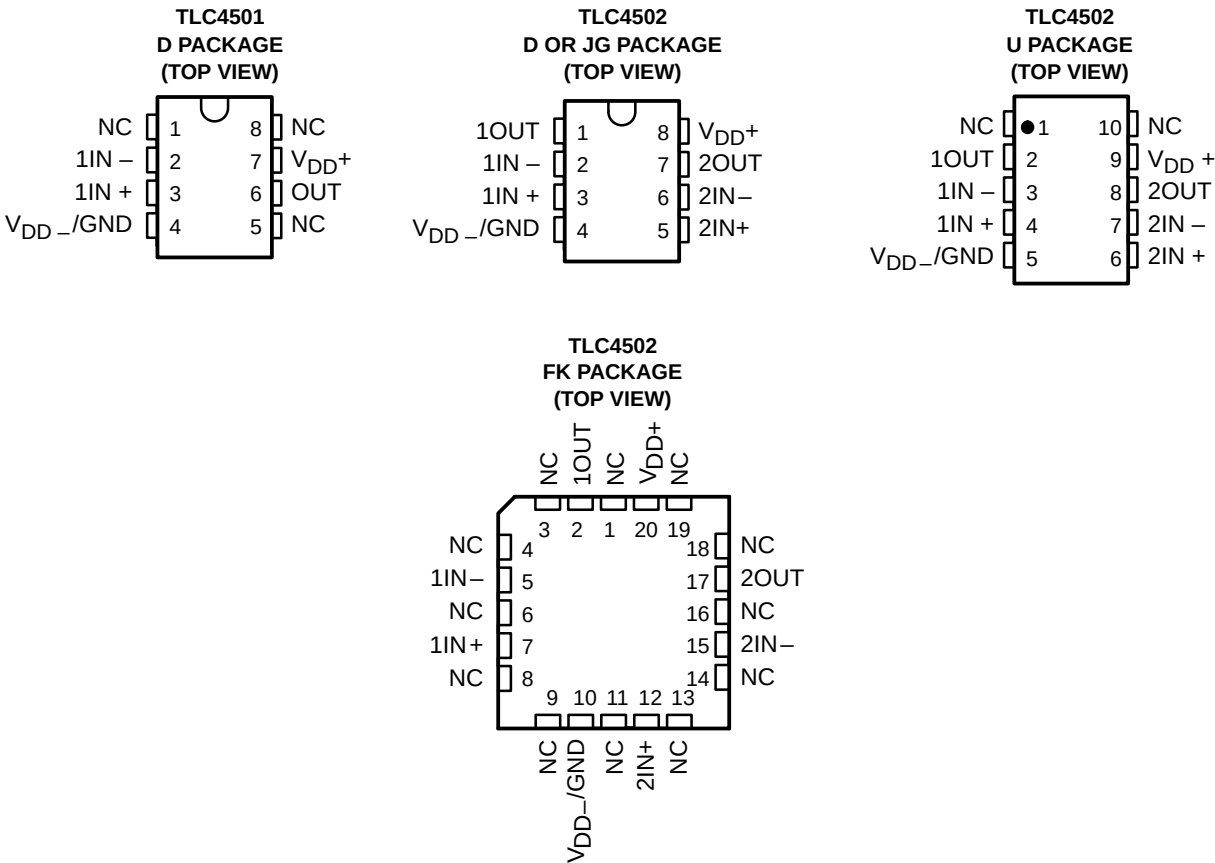
Copyright © 2001, Texas Instruments Incorporated  
On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

**description (continued)**

Using this technology eliminates the need for noisy and expensive chopper techniques, laser trimming, and power hungry, split supply bipolar operational amplifiers.



NC – No internal connection

| AVAILABLE OPTIONS |                             |                       |                      |                     |                          |
|-------------------|-----------------------------|-----------------------|----------------------|---------------------|--------------------------|
| T <sub>A</sub>    | V <sub>IO</sub> max AT 25°C | PACKAGED DEVICES      |                      |                     |                          |
|                   |                             | SMALL OUTLINE†<br>(D) | CHIP CARRIER<br>(FK) | CERAMIC DIP<br>(JG) | CERAMIC FLAT PACK<br>(U) |
| 0°C to 70°C       | 40 μV                       | TLC4501ACD            | —                    | —                   | —                        |
|                   | 50 μV                       | TLC4502ACD            | —                    | —                   | —                        |
|                   | 80 μV                       | TLC4501CD             | —                    | —                   | —                        |
|                   | 100 μV                      | TLC4502CD             | —                    | —                   | —                        |
| –40°C to 125°C    | 40 μV                       | TLC4501AID            | —                    | —                   | —                        |
|                   | 50 μV                       | TLC4502AID            | —                    | —                   | —                        |
|                   | 80 μV                       | TLC4501ID             | —                    | —                   | —                        |
|                   | 100 μV                      | TLC4502ID             | —                    | —                   | —                        |
| –40°C to 125°C    | 50 μV                       | TLC4502AQD            | —                    | —                   | —                        |
|                   | 100 μV                      | TLC4502QD             | —                    | —                   | —                        |
| –55°C to 125°C    | 50 μV                       | TLC4502AMD            | TLC4502AMFKB         | TLC4502AMJGB        | TLC4502AMUB              |
|                   | 100 μV                      | TLC4502MD             | TLC4502MFKB          | TLC4502MJGB         | TLC4502MUB               |

† The D package is also available taped and reeled.

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>**

|                                                                   |                              |
|-------------------------------------------------------------------|------------------------------|
| Supply voltage, $V_{DD+}$ (see Note 1)                            | 7 V                          |
| Differential input voltage, $V_{ID}$ (see Note 2)                 | $\pm 7$ V                    |
| Input voltage range, $V_I$ (any input, see Note 1)                | –0.3 V to 7 V                |
| Input current, $I_I$ (each input)                                 | $\pm 5$ mA                   |
| Output current, $I_O$ (each output)                               | $\pm 100$ mA                 |
| Total current into $V_{DD+}$                                      | $\pm 100$ mA                 |
| Total current out of $V_{DD-}/GND$                                | $\pm 100$ mA                 |
| Electrostatic discharge (ESD)                                     | > 2 kV                       |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited                    |
| Continuous total power dissipation                                | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$ : TLC4502C            | 0°C to 70°C                  |
| TLC4502I                                                          | –40°C to 125°C               |
| TLC4502Q                                                          | –40°C to 125°C               |
| TLC4502M                                                          | –55°C to 125°C               |
| Storage temperature range, $T_{stg}$                              | –65°C to 150°C               |
| Case temperature for 60 seconds, $T_C$ : FK package               | 260°C                        |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds      | 260°C                        |

<sup>†</sup> 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, except differential voltages, are with respect to  $V_{DD-}/GND$ .  
2. Differential voltages are at  $IN+$  with respect to  $IN-$ . Excessive current flows when an input is brought below  $V_{DD-} - 0.3$  V.  
3. 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 | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|---------|---------------------------------------------|---------------------------------------------------|------------------------------------------|------------------------------------------|-------------------------------------------|
| D       | 725 mW                                      | 5.8 mW/°C                                         | 464 mW                                   | 377 mW                                   | 145 mW                                    |
| FK      | 1375 mW                                     | 11.0 mW/°C                                        | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| JG      | 1050 mW                                     | 8.4 mW/°C                                         | 672 mW                                   | 546 mW                                   | 210 mW                                    |
| U       | 675 mW                                      | 5.4 mW/°C                                         | 432 mW                                   | 350 mW                                   | 135 mW                                    |

**recommended operating conditions**

|                                       | TLC4502C  |                 | TLC4502I  |                 | TLC4502Q  |                 | TLC4502M  |                 | UNIT |
|---------------------------------------|-----------|-----------------|-----------|-----------------|-----------|-----------------|-----------|-----------------|------|
|                                       | MIN       | MAX             | MIN       | MAX             | MIN       | MAX             | MIN       | MAX             |      |
| Supply voltage, $V_{DD}$              | 4         | 6               | 4         | 6               | 4         | 6               | 4         | 6               | V    |
| Input voltage range, $V_I$            | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | V    |
| Common-mode input voltage, $V_{IC}$   | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | V    |
| Operating free-air temperature, $T_A$ | 0         | 70              | –40       | 125             | –40       | 125             | –55       | 125             | °C   |



**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$ ,  $GND = 0$  (unless otherwise noted)

| PARAMETER            |                                                                       | TEST CONDITIONS                                                                          |             | T <sub>A</sub> <sup>†</sup> | TLC450xC         |      |       | UNIT |
|----------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------|-----------------------------|------------------|------|-------|------|
|                      |                                                                       |                                                                                          |             |                             | MIN              | TYP  | MAX   |      |
| V <sub>IO</sub>      | Input offset voltage                                                  | V <sub>DD</sub> = ±2.5 V, V <sub>O</sub> = 0, V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω | TLC4501     | Full range                  | −80              | 10   | 80    | μV   |
|                      |                                                                       |                                                                                          | TLC4501A    |                             | −40              | 10   | 40    |      |
|                      |                                                                       |                                                                                          | TLC4502     |                             | −100             | 10   | 100   |      |
|                      |                                                                       |                                                                                          | TLC4502A    |                             | −50              | 10   | 50    |      |
| α <sub>VIO</sub>     | Temperature coefficient of input offset voltage                       | V <sub>DD</sub> = ±2.5 V, V <sub>O</sub> = 0, V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω |             | Full range                  | 1                |      | μV/°C |      |
| I <sub>IO</sub>      | Input offset current                                                  |                                                                                          |             | 25°C                        | 1 60             |      | pA    |      |
|                      |                                                                       |                                                                                          |             | Full range                  | 500              |      |       |      |
| I <sub>IB</sub>      | Input bias current                                                    |                                                                                          |             | 25°C                        | 1 60             |      | pA    |      |
|                      |                                                                       | Full range                                                                               | 500         |                             |                  |      |       |      |
| V <sub>OH</sub>      | High-level output voltage                                             | I <sub>OH</sub> = − 500 μA                                                               |             | 25°C                        | 4.99             |      | V     |      |
|                      |                                                                       | I <sub>OH</sub> = − 5 mA                                                                 |             | 25°C                        | 4.9              |      |       |      |
|                      |                                                                       |                                                                                          |             | Full range                  | 4.7              |      |       |      |
| V <sub>OL</sub>      | Low-level output voltage                                              | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 500 μA                                        |             | 25°C                        | 0.01             |      | V     |      |
|                      |                                                                       | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 5 mA                                          |             | 25°C                        | 0.1              |      |       |      |
|                      |                                                                       |                                                                                          |             | Full range                  | 0.3              |      |       |      |
| A <sub>VD</sub>      | Large-signal differential voltage amplification                       | V <sub>IC</sub> = 2.5 V, R <sub>L</sub> = 1 kΩ, V <sub>O</sub> = 1 V to 4 V, See Note 4  |             | 25°C                        | 200              | 1000 | V/mV  |      |
|                      |                                                                       |                                                                                          |             | Full range                  | 200              |      |       |      |
| R <sub>I(D)</sub>    | Differential input resistance                                         |                                                                                          |             | 25°C                        | 10               |      | kΩ    |      |
| R <sub>L</sub>       | Input resistance                                                      | See Note 4                                                                               |             | 25°C                        | 10 <sup>12</sup> |      | Ω     |      |
| C <sub>L</sub>       | Common-mode input capacitance                                         | f = 10 kHz,                                                                              | P package   | 25°C                        | 8                |      | pF    |      |
| z <sub>O</sub>       | Closed-loop output impedance                                          | A <sub>V</sub> = 10,                                                                     | f = 100 kHz | 25°C                        | 1                |      | Ω     |      |
| CMRR                 | Common-mode rejection ratio                                           | V <sub>IC</sub> = 0 to 2.7 V, V <sub>O</sub> = 2.5 V, R <sub>S</sub> = 1 kΩ              |             | 25°C                        | 90               | 100  | dB    |      |
|                      |                                                                       |                                                                                          |             | Full range                  | 85               |      |       |      |
| k <sub>SVR</sub>     | Supply-voltage rejection ratio (ΔV <sub>DD</sub> ±/ΔV <sub>IO</sub> ) | V <sub>DD</sub> = 4 V to 6 V, V <sub>IC</sub> = 0, No load                               |             | 25°C                        | 90               | 100  | dB    |      |
|                      |                                                                       |                                                                                          |             | Full range                  | 90               |      |       |      |
| I <sub>DD</sub>      | Supply current                                                        | V <sub>O</sub> = 2.5 V, No load                                                          | TLC4501/A   | 25°C                        | 1                | 1.5  | mA    |      |
|                      |                                                                       |                                                                                          |             |                             | Full range       | 2    |       |      |
|                      |                                                                       |                                                                                          | TLC4502/A   | 25°C                        | 2.5              | 3.5  |       |      |
|                      |                                                                       |                                                                                          |             |                             | Full range       | 4    |       |      |
| V <sub>IT(CAL)</sub> | Calibration input threshold voltage                                   |                                                                                          |             | Full range                  | 4                |      | V     |      |

$^\dagger$  Full range is 0°C to 70°C.

NOTE 4:  $R_L$  and  $C_L$  values are referenced to 2.5 V.



**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

**operating characteristics,  $V_{DD} = 5\text{ V}$**

| PARAMETER              |                                             | TEST CONDITIONS                                                                             |                                             | T <sub>A</sub> <sup>†</sup> | TLC450xC, TLC450xAC |     |     | UNIT   |
|------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------|-----------------------------|---------------------|-----|-----|--------|
|                        |                                             |                                                                                             |                                             |                             | MIN                 | TYP | MAX |        |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 2.5 V, C <sub>L</sub> = 100 pF                                    |                                             | 25°C                        | 1.5                 | 2.5 |     | V/μs   |
|                        |                                             |                                                                                             |                                             | Full range                  | 1                   |     |     | V/μs   |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                                   |                                             | 25°C                        | 70                  |     |     | nV/√Hz |
|                        |                                             | f = 1 kHz                                                                                   |                                             | 25°C                        | 12                  |     |     |        |
| V <sub>N(PP)</sub>     | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz                                                                             |                                             | 25°C                        | 1                   |     |     | μV     |
|                        |                                             | f = 0.1 to 10 Hz                                                                            |                                             | 25°C                        | 1.5                 |     |     |        |
| I <sub>n</sub>         | Equivalent input noise current              |                                                                                             |                                             | 25°C                        | 0.6                 |     |     | fA/√Hz |
| THD + N                | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V, f = 10 kHz, R <sub>L</sub> = 1 kΩ, C <sub>L</sub> = 100 pF | A <sub>V</sub> = 1                          | 25°C                        | 0.02%               |     |     |        |
|                        |                                             |                                                                                             | A <sub>V</sub> = 10                         | 25°C                        | 0.08%               |     |     |        |
|                        |                                             |                                                                                             | A <sub>V</sub> = 100                        | 25°C                        | 0.55%               |     |     |        |
| Gain-bandwidth product |                                             | f = 10 kHz, C <sub>L</sub> = 100 pF                                                         | R <sub>L</sub> = 1 kΩ,                      | 25°C                        | 4.7                 |     |     | MHz    |
| B <sub>OM</sub>        | Maximum output swing bandwidth              | V <sub>O(PP)</sub> = 2 V, R <sub>L</sub> = 1 kΩ,                                            | A <sub>V</sub> = 1, C <sub>L</sub> = 100 pF | 25°C                        | 1                   |     |     | MHz    |
| t <sub>s</sub>         | Settling time                               | A <sub>V</sub> = -1, Step = 0.5 V to 2.5 V, R <sub>L</sub> = 1 kΩ, C <sub>L</sub> = 100 pF  | to 0.1%                                     | 25°C                        | 1.6                 |     |     | μs     |
|                        |                                             |                                                                                             | to 0.01%                                    | 25°C                        | 2.2                 |     |     |        |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 1 kΩ,                                                                      | C <sub>L</sub> = 100 pF                     | 25°C                        | 74                  |     |     |        |
| Calibration time       |                                             |                                                                                             |                                             | 25°C                        | 300                 |     |     | ms     |

$^\dagger$  Full range is 0°C to 70°C.

NOTE 4:  $R_L$  and  $C_L$  values are referenced to 2.5 V.

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$ ,  $GND = 0$  (unless otherwise noted)

| PARAMETER            |                                                                       | TEST CONDITIONS                                                                          |               | T <sub>A</sub> <sup>†</sup> | TLC450xI |      |       | UNIT |
|----------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------|---------------|-----------------------------|----------|------|-------|------|
|                      |                                                                       |                                                                                          |               |                             | MIN      | TYP  | MAX   |      |
| V <sub>IO</sub>      | Input offset voltage                                                  | V <sub>DD</sub> = ±2.5 V, V <sub>O</sub> = 0, V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω | TLC4501       | Full range                  | –80      | 10   | 80    | μV   |
|                      |                                                                       |                                                                                          | TLC4501A      |                             | –40      | 10   | 40    |      |
|                      |                                                                       |                                                                                          | TLC4502       |                             | –100     | 10   | 100   |      |
|                      |                                                                       |                                                                                          | TLC4502A      |                             | –50      | 10   | 50    |      |
| α <sub>VIO</sub>     | Temperature coefficient of input offset voltage                       | V <sub>DD</sub> = ±2.5 V, V <sub>O</sub> = 0, V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω |               | Full range                  | 1        |      | μV/°C |      |
| I <sub>IO</sub>      | Input offset current                                                  |                                                                                          |               | 25°C                        | 1 60     |      | pA    |      |
|                      |                                                                       |                                                                                          |               | –40°C to 85°C               | 500      |      |       |      |
|                      |                                                                       |                                                                                          |               | Full range                  | 5        |      | nA    |      |
| I <sub>IB</sub>      | Input bias current                                                    | V <sub>DD</sub> = ±2.5 V, V <sub>O</sub> = 0, V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω | 25°C          | 1 60                        |          | pA   |       |      |
|                      |                                                                       |                                                                                          | –40°C to 85°C | 500                         |          |      |       |      |
|                      |                                                                       |                                                                                          | Full range    | 10                          |          | nA   |       |      |
| V <sub>OH</sub>      | High-level output voltage                                             | I <sub>OH</sub> = – 500 μA                                                               | 25°C          | 4.99                        |          | V    |       |      |
|                      |                                                                       | I <sub>OH</sub> = – 5 mA                                                                 | 25°C          | 4.9                         |          |      |       |      |
|                      |                                                                       |                                                                                          | Full range    | 4.7                         |          |      |       |      |
| V <sub>OL</sub>      | Low-level output voltage                                              | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 500 μA                                        | 25°C          | 0.01                        |          | V    |       |      |
|                      |                                                                       | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 5 mA                                          | 25°C          | 0.1                         |          |      |       |      |
|                      |                                                                       |                                                                                          | Full range    | 0.3                         |          |      |       |      |
| A <sub>VD</sub>      | Large-signal differential voltage amplification                       | V <sub>IC</sub> = 2.5 V, R <sub>L</sub> = 1 kΩ, V <sub>O</sub> = 1 V to 4 V, See Note 4  | 25°C          | 200                         | 1000     | V/mV |       |      |
|                      |                                                                       |                                                                                          | Full range    | 200                         |          |      |       |      |
| R <sub>I(D)</sub>    | Differential input resistance                                         |                                                                                          | 25°C          | 10                          |          | kΩ   |       |      |
| R <sub>L</sub>       | Input resistance                                                      | See Note 4                                                                               | 25°C          | 10 <sup>12</sup>            |          | Ω    |       |      |
| C <sub>L</sub>       | Common-mode input capacitance                                         | f = 10 kHz, P package                                                                    | 25°C          | 8                           |          | pF   |       |      |
| z <sub>O</sub>       | Closed-loop output impedance                                          | A <sub>v</sub> = 10, f = 100 kHz                                                         | 25°C          | 1                           |          | Ω    |       |      |
| CMRR                 | Common-mode rejection ratio                                           | V <sub>IC</sub> = 0 to 2.7 V, V <sub>O</sub> = 2.5 V, R <sub>S</sub> = 1 kΩ              | 25°C          | 90                          | 100      | dB   |       |      |
|                      |                                                                       |                                                                                          | Full range    | 85                          |          |      |       |      |
| k <sub>SVR</sub>     | Supply-voltage rejection ratio (ΔV <sub>DD</sub> ±/ΔV <sub>IO</sub> ) | V <sub>DD</sub> = 4 V to 6 V, V <sub>IC</sub> = 0, No load                               | 25°C          | 90                          | 100      | dB   |       |      |
|                      |                                                                       |                                                                                          | Full range    | 90                          |          |      |       |      |
| I <sub>DD</sub>      | Supply current                                                        | V <sub>O</sub> = 2.5 V, No load                                                          | TLC4501/A     | 25°C                        | 1        | 1.5  | mA    |      |
|                      |                                                                       |                                                                                          |               | Full range                  | 2        |      |       |      |
|                      |                                                                       |                                                                                          | TLC4502/A     | 25°C                        | 2.5      | 3.5  |       |      |
|                      |                                                                       |                                                                                          |               | Full range                  | 4        |      |       |      |
| V <sub>IT(CAL)</sub> | Calibration input threshold voltage                                   |                                                                                          |               | Full range                  | 4        |      | V     |      |

$^\dagger$  Full range is –40°C to 125°C.

NOTE 4:  $R_L$  and  $C_L$  values are referenced to 2.5 V.



**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

**operating characteristics,  $V_{DD} = 5\text{ V}$**

| PARAMETER              |                                             | TEST CONDITIONS                                                                             |                      | T <sub>A</sub> <sup>†</sup>                 | TLC450xI, TLC450xAI |     |     | UNIT   |
|------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------|----------------------|---------------------------------------------|---------------------|-----|-----|--------|
|                        |                                             |                                                                                             |                      |                                             | MIN                 | TYP | MAX |        |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 2.5 V, C <sub>L</sub> = 100 pF                                    |                      | 25°C                                        | 1.5                 | 2.5 |     | V/μs   |
|                        |                                             |                                                                                             |                      | Full range                                  | 1                   |     |     | V/μs   |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                                   |                      | 25°C                                        | 70                  |     |     | nV/√Hz |
|                        |                                             | f = 1 kHz                                                                                   |                      | 25°C                                        | 12                  |     |     |        |
| V <sub>N(PP)</sub>     | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz                                                                             |                      | 25°C                                        | 1                   |     |     | μV     |
|                        |                                             | f = 0.1 to 10 Hz                                                                            |                      | 25°C                                        | 1.5                 |     |     |        |
| I <sub>n</sub>         | Equivalent input noise current              |                                                                                             |                      | 25°C                                        | 0.6                 |     |     | fA/√Hz |
| THD + N                | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V, f = 10 kHz, R <sub>L</sub> = 1 kΩ, C <sub>L</sub> = 100 pF | A <sub>V</sub> = 1   | 25°C                                        | 0.02%               |     |     |        |
|                        |                                             |                                                                                             | A <sub>V</sub> = 10  | 25°C                                        | 0.08%               |     |     |        |
|                        |                                             |                                                                                             | A <sub>V</sub> = 100 | 25°C                                        | 0.55%               |     |     |        |
| Gain-bandwidth product |                                             | f = 10 kHz, R <sub>L</sub> = 1 kΩ, C <sub>L</sub> = 100 pF                                  |                      | 25°C                                        | 4.7                 |     |     | MHz    |
| B <sub>OM</sub>        | Maximum output swing bandwidth              | V <sub>O(PP)</sub> = 2 V, R <sub>L</sub> = 1 kΩ,                                            |                      | A <sub>V</sub> = 1, C <sub>L</sub> = 100 pF | 25°C                | 1   |     | MHz    |
| t <sub>s</sub>         | Settling time                               | A <sub>V</sub> = −1, Step = 0.5 V to 2.5 V, R <sub>L</sub> = 1 kΩ, C <sub>L</sub> = 100 pF  | to 0.1%              | 25°C                                        | 1.6                 |     |     | μs     |
|                        |                                             |                                                                                             | to 0.01%             | 25°C                                        | 2.2                 |     |     |        |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 1 kΩ, C <sub>L</sub> = 100 pF                                              |                      | 25°C                                        | 74                  |     |     |        |
| Calibration time       |                                             |                                                                                             |                      | 25°C                                        | 300                 |     |     | ms     |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

NOTE 4:  $R_L$  and  $C_L$  values are referenced to 2.5 V.

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$ ,  $GND = 0$  (unless otherwise noted)

| PARAMETER            |                                                                          | TEST CONDITIONS                                                                                   |                                              | T <sub>A</sub> <sup>†</sup> | TLC4502Q,<br>TLC4502M |             |          | UNIT      |       |
|----------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------|-----------------------|-------------|----------|-----------|-------|
|                      |                                                                          |                                                                                                   |                                              |                             | MIN                   | TYP         | MAX      |           |       |
| V <sub>IO</sub>      | Input offset voltage                                                     | V <sub>DD</sub> = ±2.5 V,<br>V <sub>IC</sub> = 0,                                                 | V <sub>O</sub> = 0,<br>R <sub>S</sub> = 50 Ω | TLC4502<br>TLC4502A         | Full range            | –100<br>–50 | 10<br>10 | 100<br>50 | μV    |
| α <sub>VIO</sub>     | Temperature coefficient of input offset voltage                          | V <sub>DD</sub> = ±2.5 V,<br>V <sub>IC</sub> = 0,<br>V <sub>O</sub> = 0,<br>R <sub>S</sub> = 50 Ω |                                              |                             | Full range            | 1           |          |           | μV/°C |
| I <sub>IO</sub>      | Input offset current                                                     |                                                                                                   |                                              |                             | 25°C                  | 1           |          | 60        | nA    |
|                      |                                                                          |                                                                                                   |                                              |                             | 125°C                 |             |          | 5         |       |
| I <sub>IB</sub>      | Input bias current                                                       |                                                                                                   |                                              |                             | 25°C                  | 1           |          | 60        | nA    |
|                      |                                                                          | 125°C                                                                                             |                                              |                             | 10                    |             |          |           |       |
| V <sub>OH</sub>      | High-level output voltage                                                | I <sub>OH</sub> = – 500 μA                                                                        |                                              | 25°C                        | 4.99                  |             | V        |           |       |
|                      |                                                                          | I <sub>OH</sub> = – 5 mA                                                                          |                                              | 25°C                        | 4.9                   |             |          |           |       |
|                      |                                                                          |                                                                                                   |                                              | Full range                  | 4.7                   |             |          |           |       |
| V <sub>OL</sub>      | Low-level output voltage                                                 | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 500 μA                                                 |                                              | 25°C                        | 0.01                  |             | V        |           |       |
|                      |                                                                          | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 5 mA                                                   |                                              | 25°C                        | 0.1                   |             |          |           |       |
|                      |                                                                          |                                                                                                   |                                              | Full range                  | 0.3                   |             |          |           |       |
| A <sub>VD</sub>      | Large-signal differential voltage amplification                          | V <sub>IC</sub> = 2.5 V,<br>R <sub>L</sub> = 1 kΩ, V <sub>O</sub> = 1 V to 4 V,<br>See Note 4     |                                              | 25°C                        | 200                   | 1000        | V/mV     |           |       |
|                      |                                                                          |                                                                                                   |                                              | Full range                  | 200                   |             |          |           |       |
| R <sub>I(D)</sub>    | Differential input resistance                                            |                                                                                                   |                                              | 25°C                        | 10                    |             | kΩ       |           |       |
| R <sub>L</sub>       | Input resistance                                                         | See Note 4                                                                                        |                                              | 25°C                        | 10 <sup>12</sup>      |             | Ω        |           |       |
| C <sub>L</sub>       | Common-mode input capacitance                                            | f = 10 kHz, P package                                                                             |                                              | 25°C                        | 8                     |             | pF       |           |       |
| z <sub>O</sub>       | Closed-loop output impedance                                             | A <sub>V</sub> = 10, f = 100 kHz                                                                  |                                              | 25°C                        | 1                     |             | Ω        |           |       |
| CMRR                 | Common-mode rejection ratio                                              | V <sub>IC</sub> = 0 to 2.7 V, V <sub>O</sub> = 2.5 V,<br>R <sub>S</sub> = 1 kΩ                    |                                              | 25°C                        | 90                    | 100         | dB       |           |       |
|                      |                                                                          |                                                                                                   |                                              | Full range                  | 85                    |             |          |           |       |
| k <sub>SVR</sub>     | Supply-voltage rejection ratio<br>(ΔV <sub>DD</sub> ±/ΔV <sub>IO</sub> ) | V <sub>DD</sub> = 4 V to 6 V, V <sub>IC</sub> = V <sub>DD</sub> /2,<br>No load                    |                                              | 25°C                        | 90                    | 100         | dB       |           |       |
|                      |                                                                          |                                                                                                   |                                              | Full range                  | 90                    |             |          |           |       |
| I <sub>DD</sub>      | Supply current                                                           | V <sub>O</sub> = 2.5 V, No load                                                                   |                                              | 25°C                        | 2.5                   | 3.5         | mA       |           |       |
|                      |                                                                          |                                                                                                   |                                              | Full range                  | 4                     |             |          |           |       |
| V <sub>IT(CAL)</sub> | Calibration input threshold voltage                                      |                                                                                                   |                                              | Full range                  | 4                     |             | V        |           |       |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q suffix,  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M suffix.

NOTE 4:  $R_L$  and  $C_L$  values are referenced to 2.5 V.



**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

operating characteristics,  $V_{DD} = 5\text{ V}$

| PARAMETER              |                                             | TEST CONDITIONS                                                                                      |                                                | T <sub>A</sub> <sup>†</sup>    | TLC4502Q, TLC4502M,<br>TLC4502AQ,<br>TLC4502AM |     |        | UNIT |
|------------------------|---------------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------|--------------------------------|------------------------------------------------|-----|--------|------|
|                        |                                             |                                                                                                      |                                                |                                | MIN                                            | TYP | MAX    |      |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 2.5 V,<br>See Note 4                                                       |                                                | C <sub>L</sub> = 100 pF        | 25°C                                           | 1.5 | 2.5    | V/μs |
|                        |                                             |                                                                                                      |                                                |                                | Full range                                     | 1   |        | V/μs |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                                            |                                                | 25°C                           | 70                                             |     | nV/√Hz |      |
|                        |                                             | f = 1 kHz                                                                                            |                                                | 25°C                           | 12                                             |     |        |      |
| V <sub>N(PP)</sub>     | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz                                                                                      |                                                | 25°C                           | 1                                              |     | μV     |      |
|                        |                                             | f = 0.1 to 10 Hz                                                                                     |                                                | 25°C                           | 1.5                                            |     |        |      |
| I <sub>n</sub>         | Equivalent input noise current              |                                                                                                      |                                                | 25°C                           | 0.6                                            |     | fA/√Hz |      |
| THD + N                | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V,<br>f = 10 kHz,<br>R <sub>L</sub> = 1 kΩ,<br>C <sub>L</sub> = 100 pF | A <sub>V</sub> = 1                             | 25°C                           | 0.02%                                          |     |        |      |
|                        |                                             |                                                                                                      | A <sub>V</sub> = 10                            | 25°C                           | 0.08%                                          |     |        |      |
|                        |                                             |                                                                                                      | A <sub>V</sub> = 100                           | 25°C                           | 0.55%                                          |     |        |      |
| Gain-bandwidth product |                                             | f = 10 kHz,<br>C <sub>L</sub> = 100 pF                                                               |                                                | R <sub>L</sub> = 1 kΩ,<br>25°C | 4.7                                            |     | MHz    |      |
| B <sub>OM</sub>        | Maximum output swing bandwidth              | V <sub>O(PP)</sub> = 2 V,<br>R <sub>L</sub> = 1 kΩ,                                                  | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF | 25°C                           | 1                                              |     | MHz    |      |
| t <sub>s</sub>         | Settling time                               | A <sub>V</sub> = −1,<br>Step = 0.5 V to 2.5 V,<br>R <sub>L</sub> = 1 kΩ,<br>C <sub>L</sub> = 100 pF  | to 0.1%                                        | 25°C                           | 1.6                                            |     | μs     |      |
|                        |                                             |                                                                                                      | to 0.01%                                       | 25°C                           | 2.2                                            |     |        |      |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 1 kΩ,<br>C <sub>L</sub> = 100 pF                                                    |                                                | 25°C                           | 74                                             |     |        |      |
| Calibration time       |                                             |                                                                                                      |                                                | 25°C                           | 300                                            |     | ms     |      |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q suffix,  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M suffix.

NOTE 4:  $R_L$  and  $C_L$  values are referenced to 2.5 V.

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

**TYPICAL CHARACTERISTICS**

**Table of Graphs**

|                 |                                                 |                               | <b>FIGURE</b> |
|-----------------|-------------------------------------------------|-------------------------------|---------------|
| $V_{IO}$        | Input offset voltage                            | Distribution                  | 2, 3, 4       |
|                 |                                                 | vs Common-mode input voltage  | 5             |
| $\alpha V_{IO}$ | Input offset voltage temperature coefficient    | Distribution                  | 6, 7          |
| $V_{OH}$        | High-level output voltage                       | vs High-level output current  | 8             |
| $V_{OL}$        | Low-level output voltage                        | vs Low-level output current   | 9             |
| $V_{O(PP)}$     | Maximum peak-to-peak output voltage             | vs Frequency                  | 10            |
| $I_{OS}$        | Short-circuit output current                    | vs Free-air temperature       | 11            |
| $V_O$           | Output voltage                                  | vs Differential input voltage | 12            |
| $A_{VD}$        | Large-signal differential voltage amplification | vs Free-air temperature       | 13            |
|                 |                                                 | vs Frequency                  | 14            |
| $z_o$           | Output impedance                                | vs Frequency                  | 15            |
| CMRR            | Common-mode rejection ratio                     | vs Frequency                  | 16            |
|                 |                                                 | vs Free-air temperature       | 17            |
| SR              | Slew rate                                       | vs Load capacitance           | 18            |
|                 |                                                 | vs Free-air temperature       | 19            |
|                 | Inverting large-signal pulse response           |                               | 20            |
|                 | Voltage-follower large-signal pulse response    |                               | 21            |
|                 | Inverting small-signal pulse response           |                               | 22            |
|                 | Voltage-follower small-signal pulse response    |                               | 23            |
| $V_n$           | Equivalent input noise voltage                  | vs Frequency                  | 24            |
|                 |                                                 | Over a 10-second period       | 25            |
| THD + N         | Total harmonic distortion plus noise            | vs Frequency                  | 26            |
|                 |                                                 | vs Free-air temperature       | 27            |
| $\phi_m$        | Phase margin                                    | vs Load capacitance           | 28            |
|                 |                                                 | vs Frequency                  | 14            |
|                 | Gain margin                                     | vs Load capacitance           | 29            |
|                 |                                                 | vs Frequency                  | 30            |
| PSRR            | Power-supply rejection ratio                    | vs Free-air temperature       | 30            |
|                 | Calibration time at $-40^{\circ}\text{C}$       |                               | 31            |
|                 | Calibration time at $25^{\circ}\text{C}$        |                               | 32            |
|                 | Calibration time at $85^{\circ}\text{C}$        |                               | 33            |
|                 | Calibration time at $125^{\circ}\text{C}$       |                               | 34            |

## TYPICAL CHARACTERISTICS

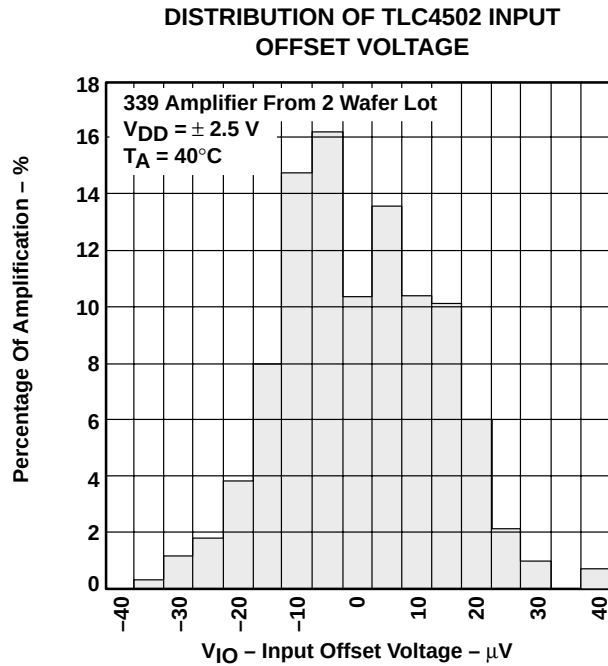


Figure 2

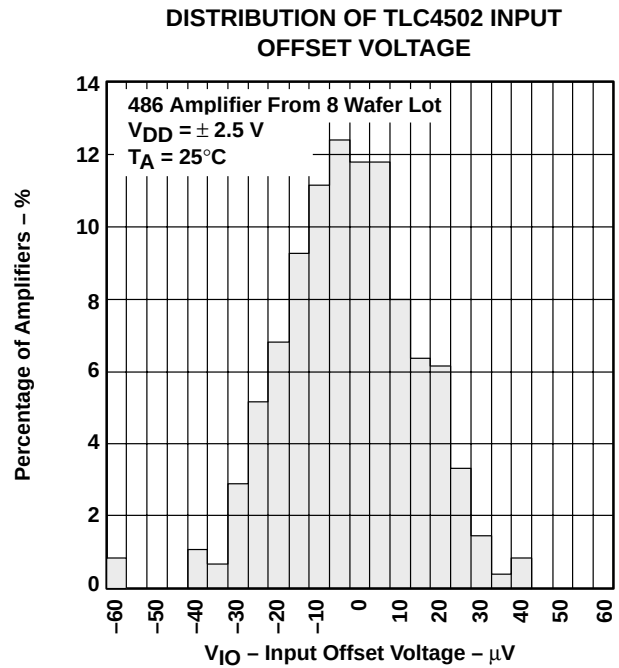


Figure 3

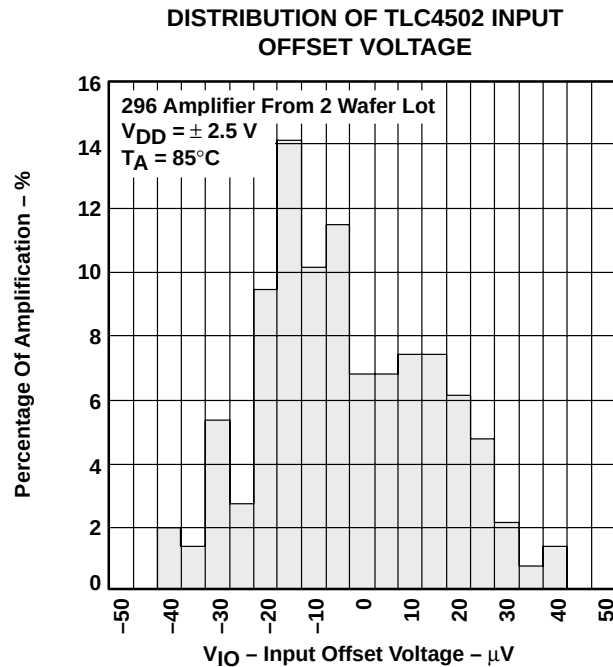


Figure 4

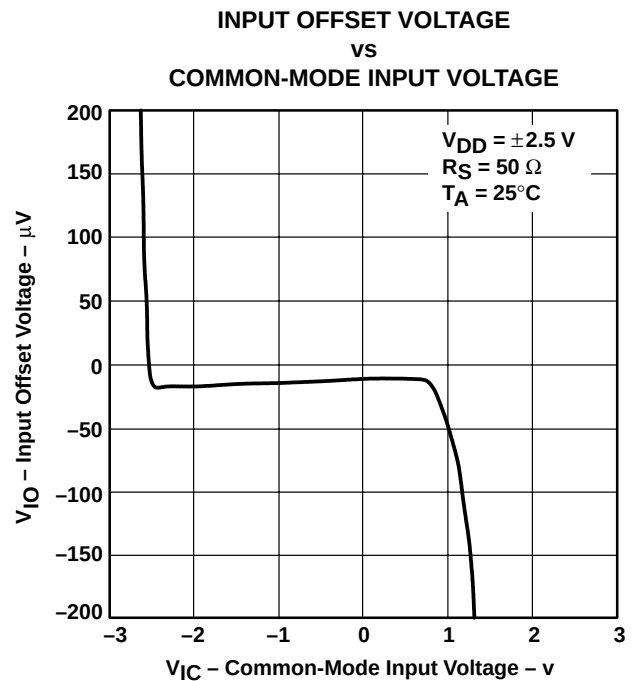


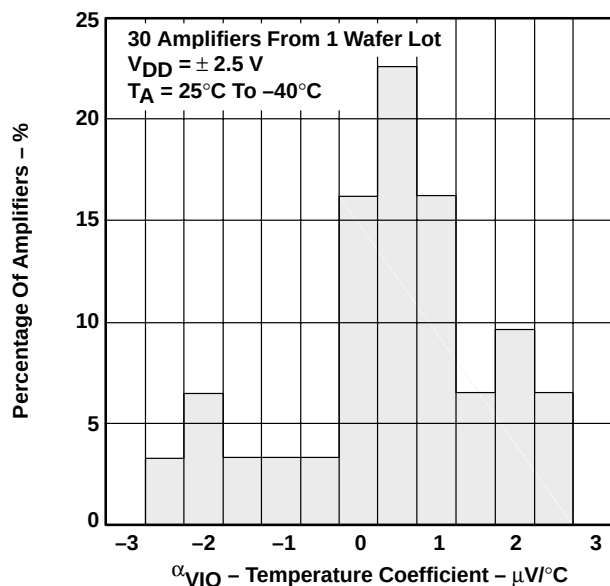
Figure 5

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

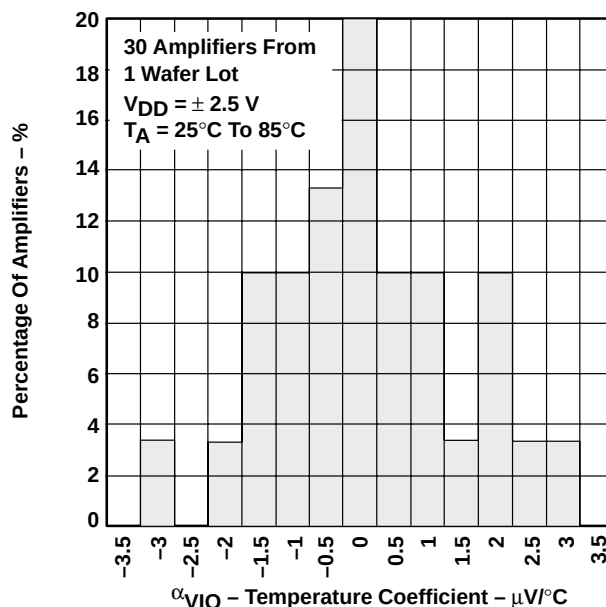
**TYPICAL CHARACTERISTICS**

**DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT**



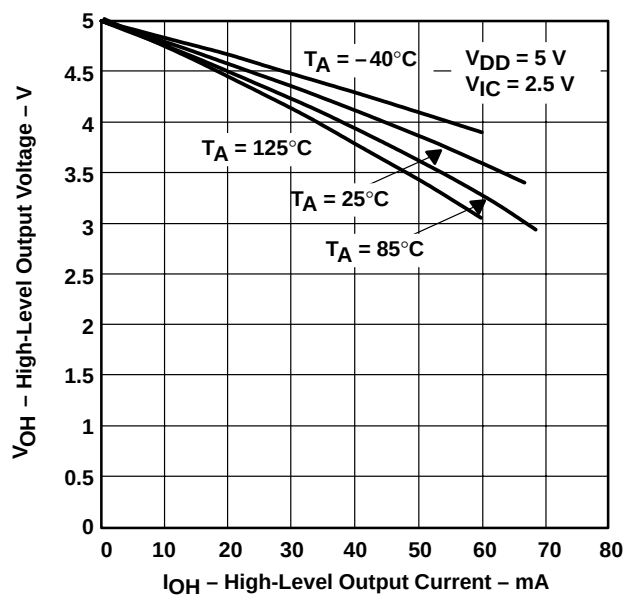
**Figure 6**

**DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT**



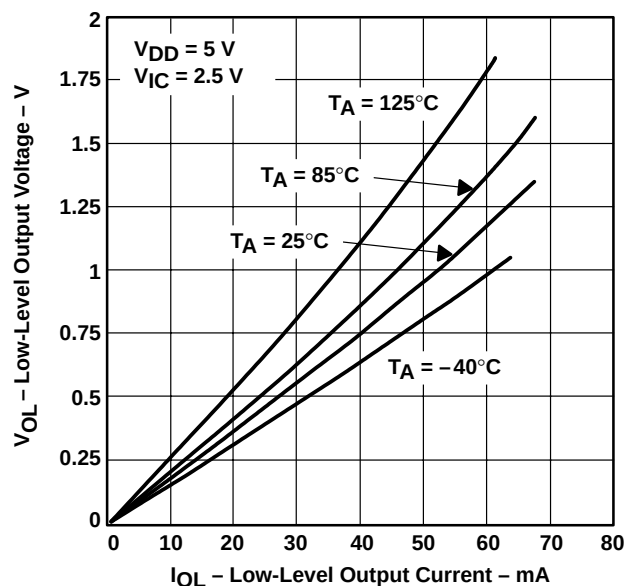
**Figure 7**

**HIGH-LEVEL OUTPUT VOLTAGE VS HIGH-LEVEL OUTPUT CURRENT**



**Figure 8**

**LOW-LEVEL OUTPUT VOLTAGE VS LOW-LEVEL OUTPUT CURRENT**



**Figure 9**

## TYPICAL CHARACTERISTICS

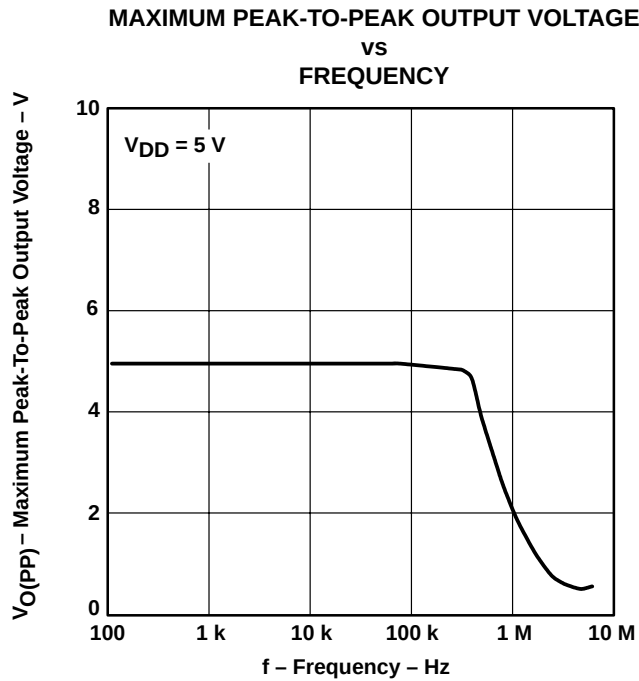


Figure 10

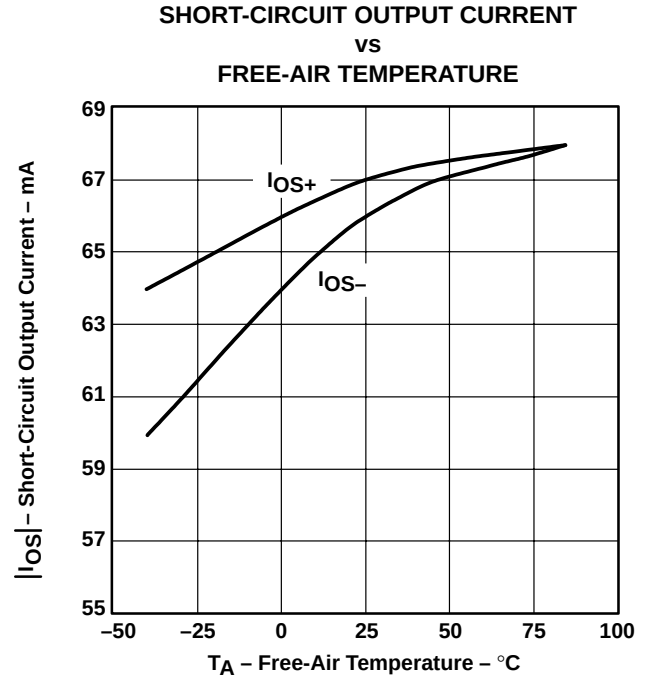


Figure 11

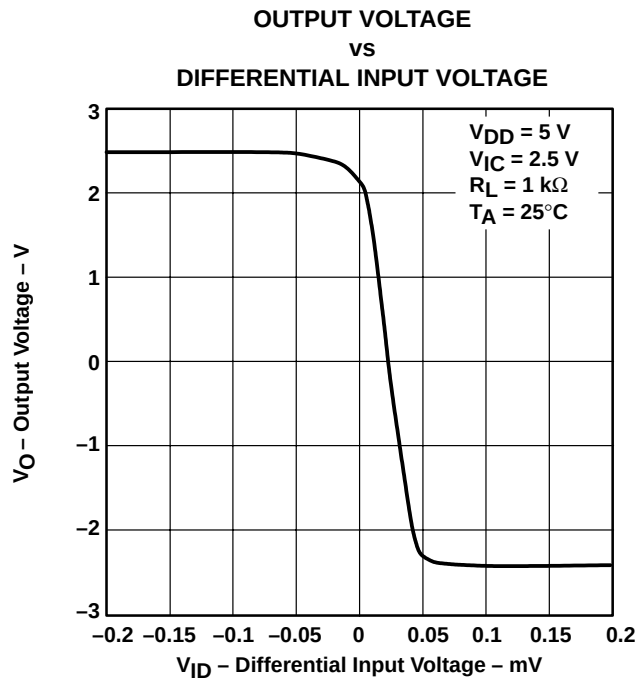


Figure 12

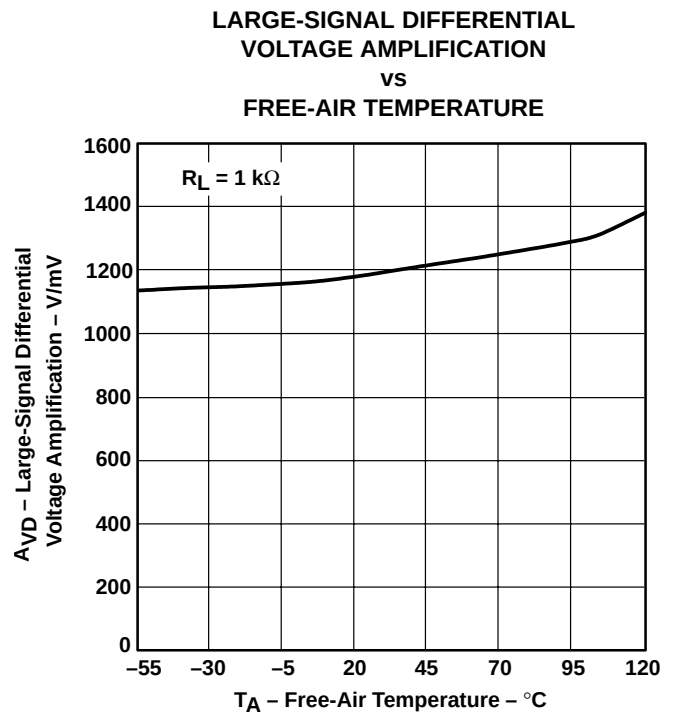


Figure 13

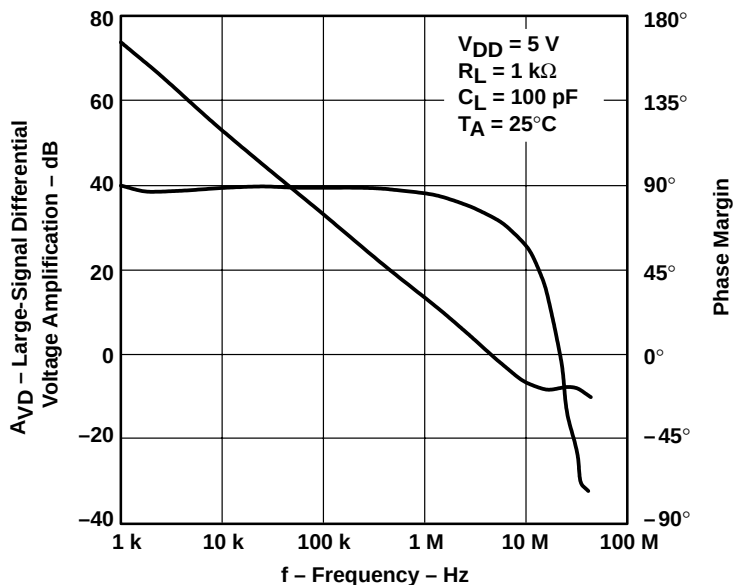
**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

**TYPICAL CHARACTERISTICS**

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE  
AMPLIFICATION AND PHASE MARGIN**

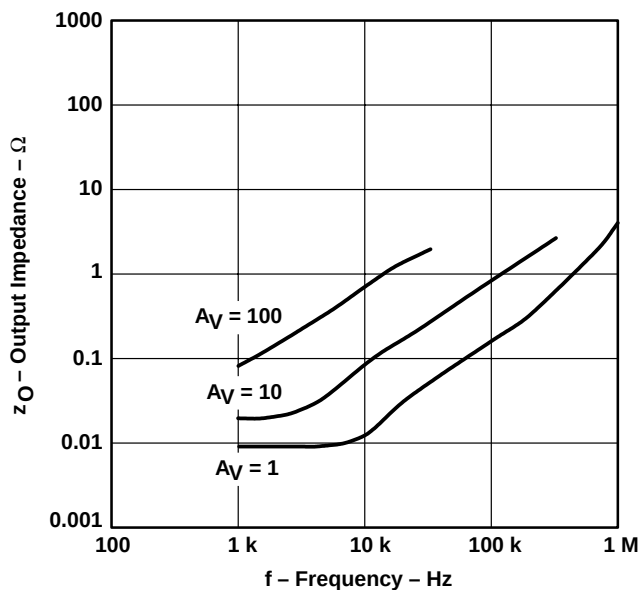
**VS  
FREQUENCY**



**Figure 14**

**OUTPUT IMPEDANCE**

**VS  
FREQUENCY**



**Figure 15**

## TYPICAL CHARACTERISTICS

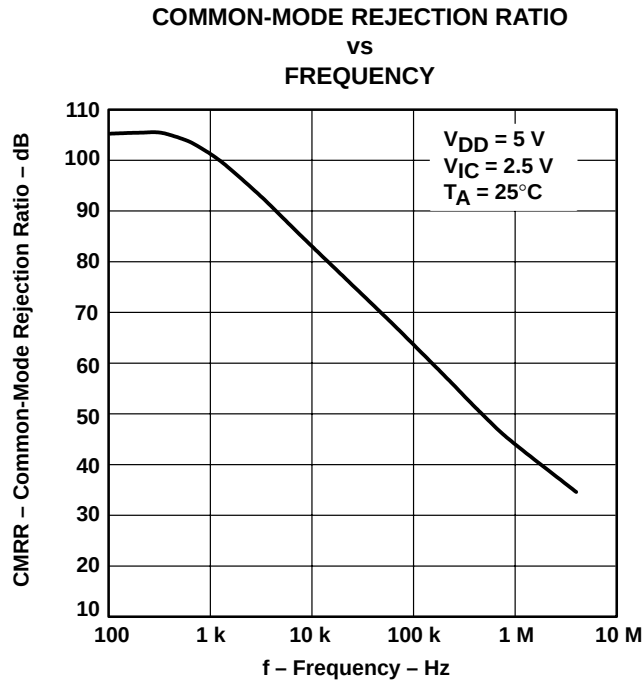


Figure 16

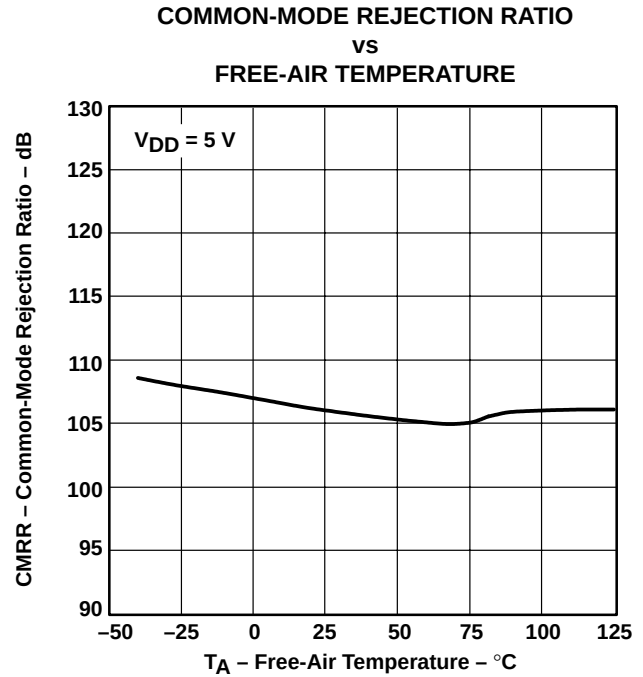


Figure 17

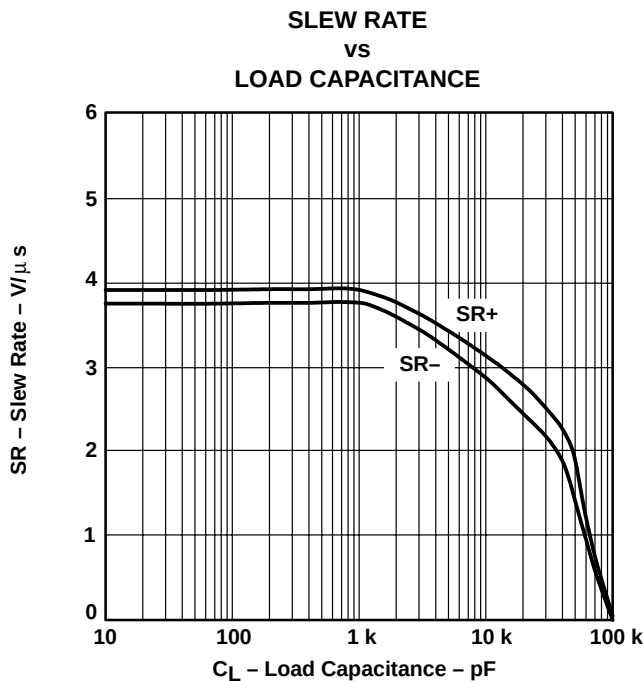


Figure 18

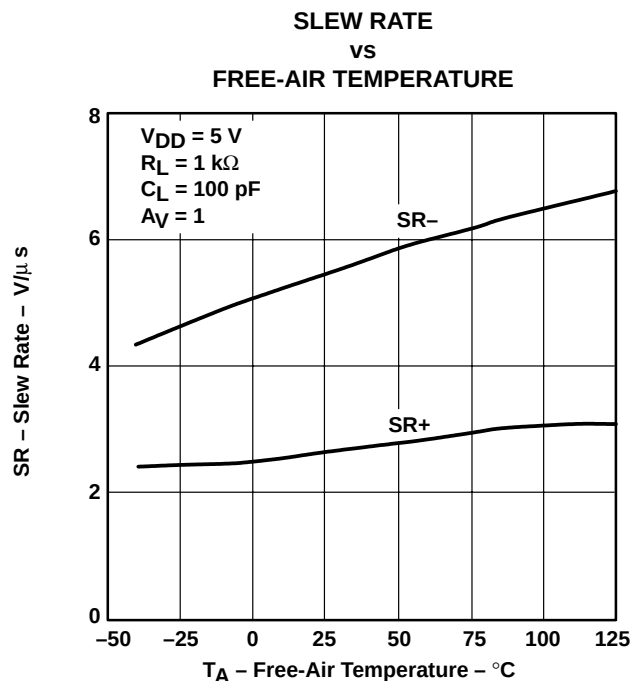


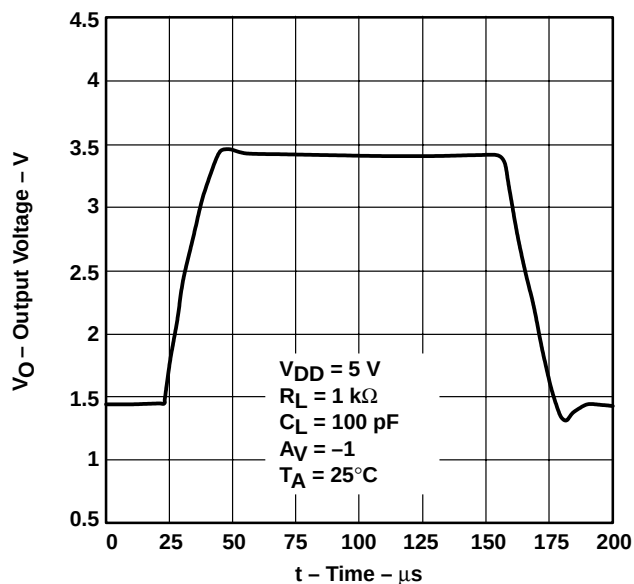
Figure 19

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

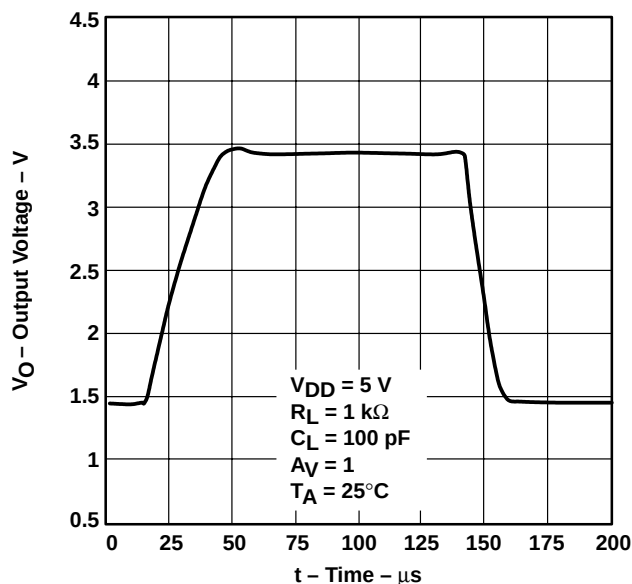
**TYPICAL CHARACTERISTICS**

**INVERTING LARGE-SIGNAL PULSE RESPONSE**



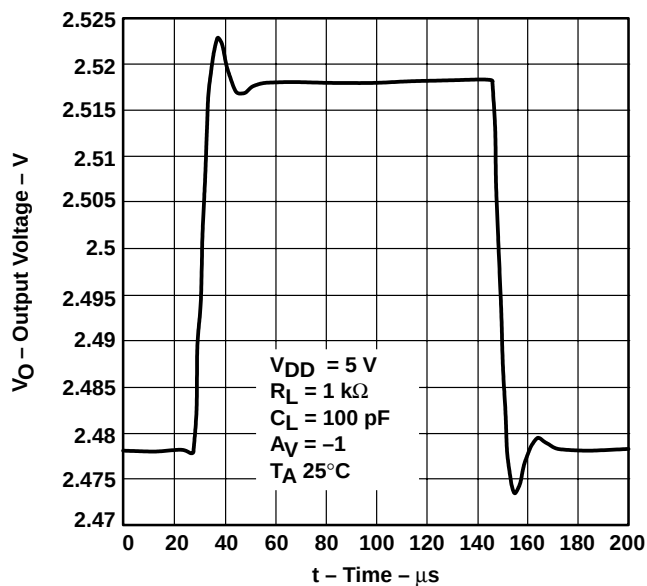
**Figure 20**

**VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE**



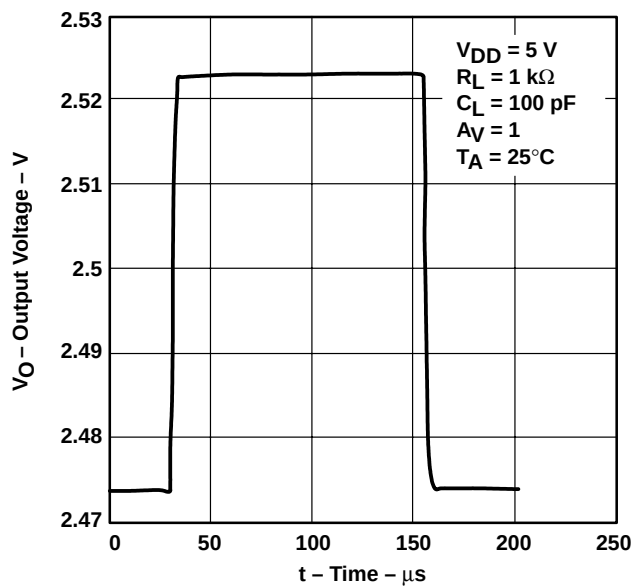
**Figure 21**

**INVERTING SMALL-SIGNAL PULSE RESPONSE**



**Figure 22**

**VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE**



**Figure 23**



## TYPICAL CHARACTERISTICS

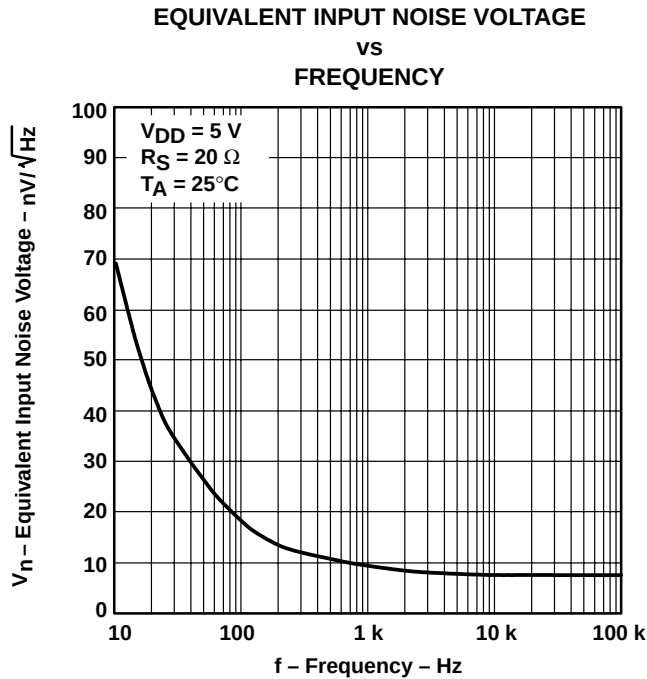


Figure 24

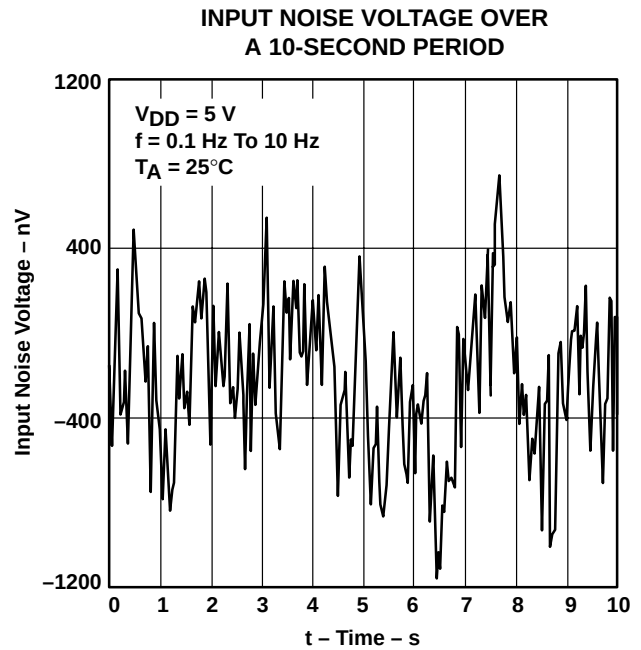


Figure 25

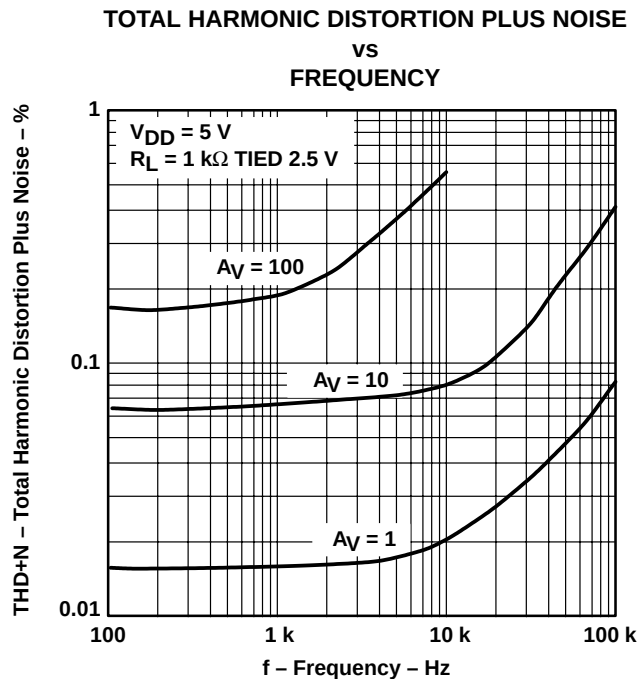


Figure 26

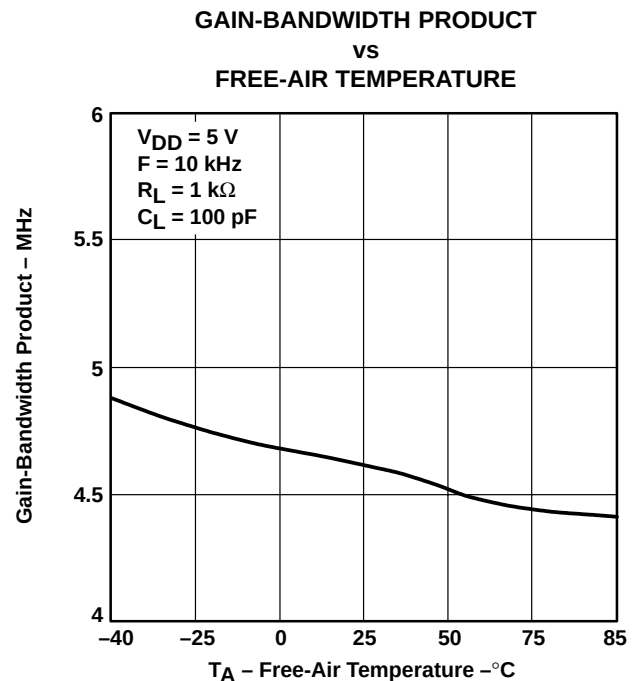
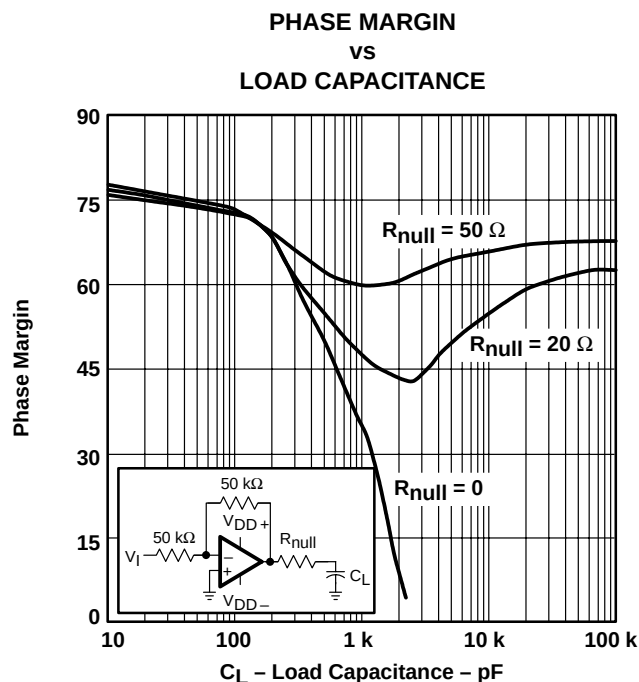


Figure 27

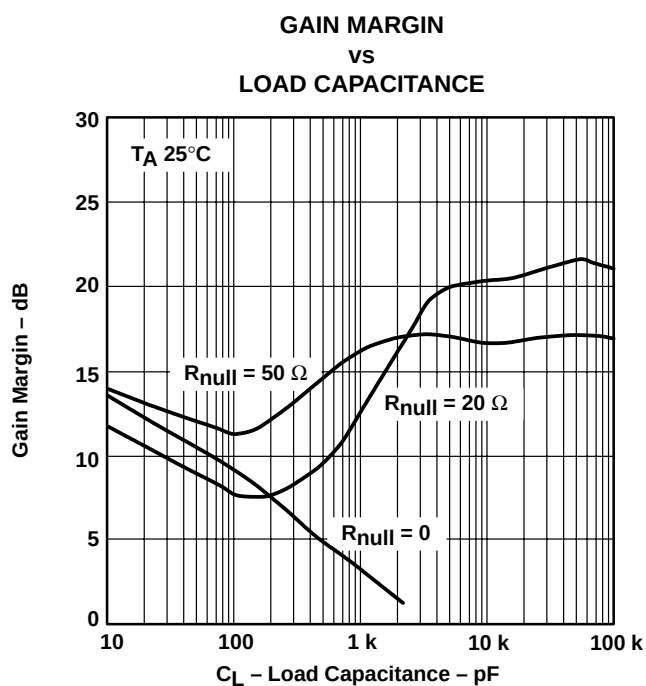
**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

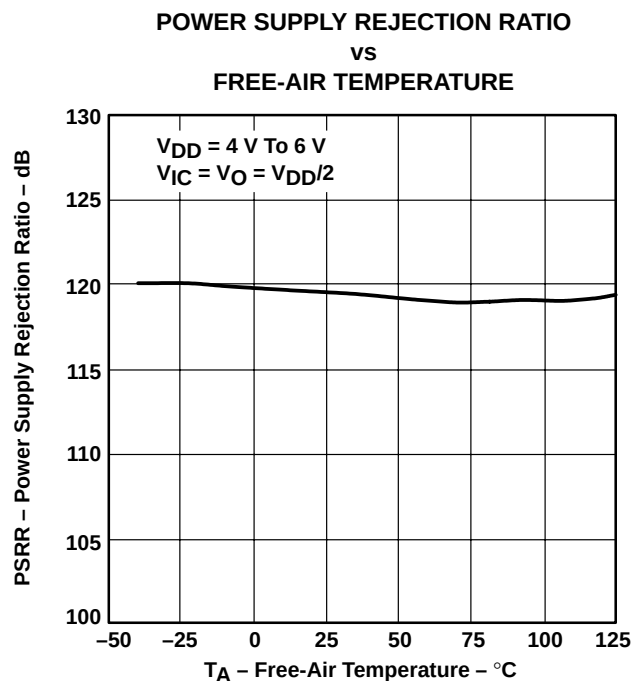
**TYPICAL CHARACTERISTICS**



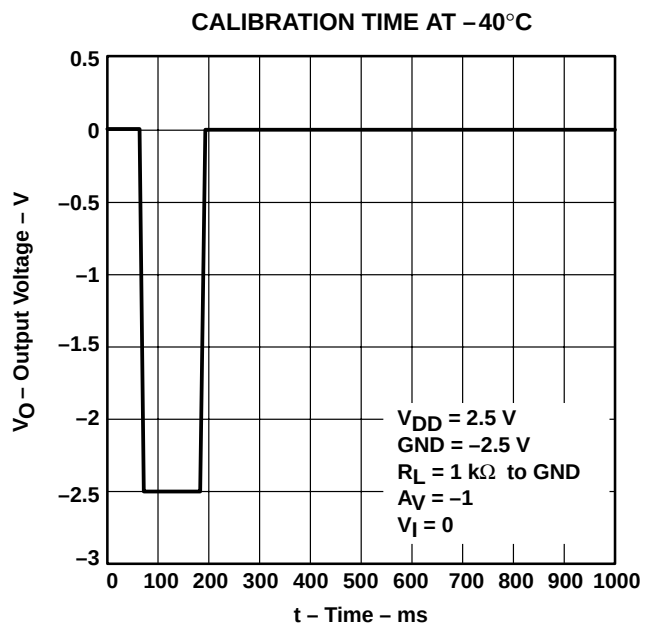
**Figure 28**



**Figure 29**



**Figure 30**



**Figure 31**

## TYPICAL CHARACTERISTICS

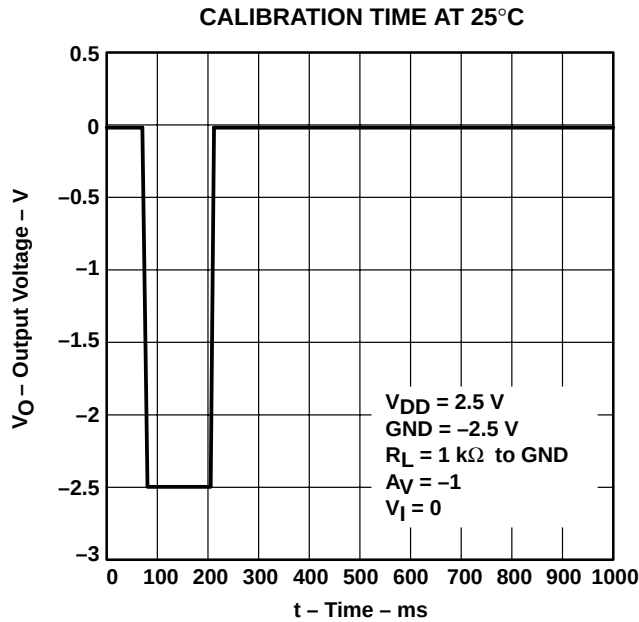


Figure 32

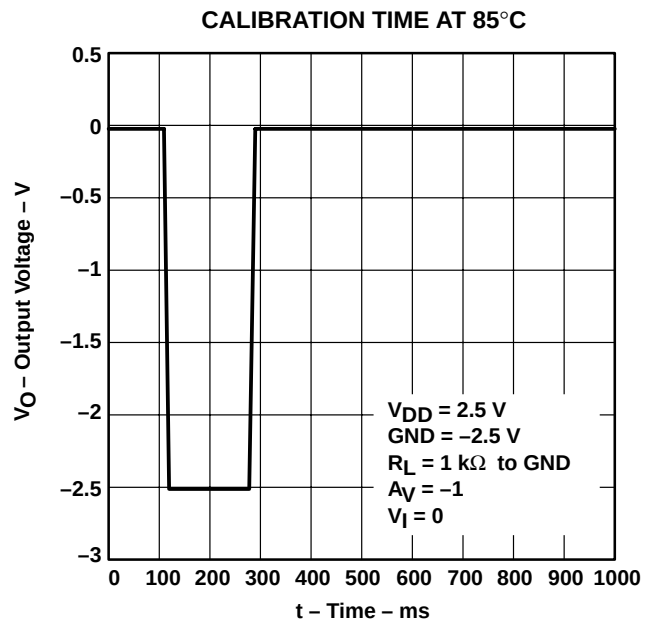


Figure 33

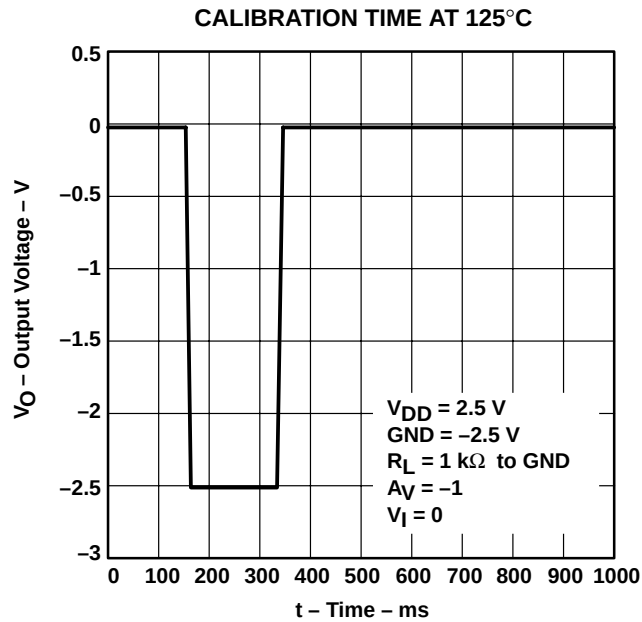


Figure 34

# TLC4501, TLC4501A, TLC4502, TLC4502A

## FAMILY OF SELF-CALIBRATING (Self-Cal™)

### PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS

SLOS221B – MAY 1998 – REVISED APRIL 2001

---

#### APPLICATION INFORMATION

- The TLC4502 is designed to operate with only a single 5-V power supply, have true differential inputs, and remain in the linear mode with an input common-mode voltage of 0.
- The TLC4502 has a standard dual-amplifier pinout, allowing for easy design upgrades.
- Large differential input voltages can be easily accommodated and, as input differential-voltage protection diodes are not needed, no large input currents result from large differential input voltage. Protection should be provided to prevent the input voltages from going negative more than  $-0.3\text{ V}$  at  $25^{\circ}\text{C}$ . An input clamp diode with a resistor to the device input terminal can be used for this purpose.
- For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor can be used from the output of the amplifier to ground. This increases the class-A bias current and prevents crossover distortion. Where the load is directly coupled, for example in dc applications, there is no crossover distortion.
- Capacitive loads, which are applied directly to the output of the amplifier, reduce the loop stability margin. Values of 500 pF can be accommodated using the worst-case noninverting unity-gain connection. Resistive isolation should be considered when larger load capacitance must be driven by the amplifier.

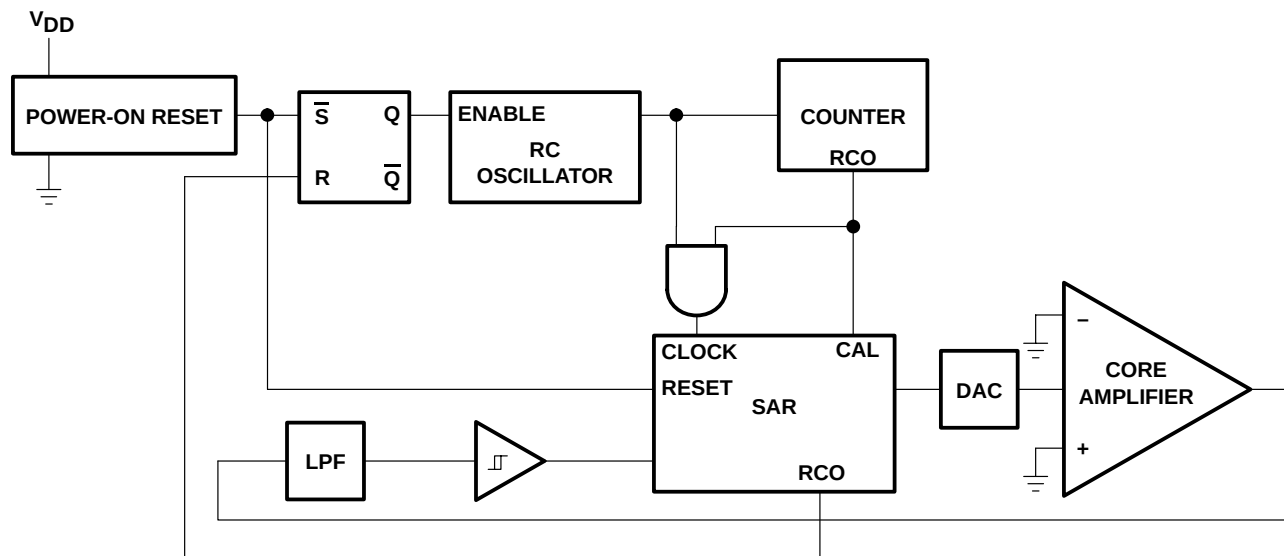
The following typical application circuits emphasize operation on only a single power supply. When complementary power supplies are available, the TLC4502 can be used in all of the standard operational amplifier circuits. In general, introducing a pseudo-ground (a bias voltage of  $V_I/2$  like that generated by the TLE2426) allows operation above and below this value in a single-supply system. Many application circuits shown take advantage of the wide common-mode input-voltage range of the TLC4502, which includes ground. In most cases, input biasing is not required and input voltages that range to ground can easily be accommodated.

#### description of calibration procedure

To achieve high dc gain, large bandwidth, high CMRR and PSRR, as well as good output drive capability, the TLC4502 is built around a 3-stage topology: two gain stages, one rail-to-rail, and a class-AB output stage. A nested Miller topology is used for frequency compensation.

During the calibration procedure, the operational amplifier is removed from the signal path and both inputs are tied to GND. Figure 35 shows a block diagram of the amplifier during calibration mode.





**Figure 35. Block Diagram During Calibration Mode**

The class AB output stage features rail-to-rail voltage swing and incorporates additional switches to put the output node into a high-impedance mode during the calibration cycle. Small-replica output transistors (matched to the main output transistors) provide the amplifier output signal for the calibration circuit. The TLC4502 also features built-in output short-circuit protection. The output current flowing through the main output transistors is continuously being sensed. If the current through either of these transistors exceeds the preset limit (60 mA – 70 mA) for more than about 1  $\mu$ s, the output transistors are shut down to approximately their quiescent operating point for approximately 5 ms. The device is then returned to normal operation. If the short circuit is still in place, it is detected in less than 1  $\mu$ s and the device is shut down for another 5 ms.

The offset cancellation uses a current-mode digital-to-analog converter (DAC), whose full-scale current allows for an adjustment of approximately  $\pm 5$  mV to the input offset voltage. The digital code producing the cancellation current is stored in the successive-approximation register (SAR).

During power up, when the offset cancellation procedure is initiated, an on-chip RC oscillator is activated to provide the timing of the successive-approximation algorithm. To prevent wide-band noise from interfering with the calibration procedure, an analog low-pass filter followed by a Schmitt trigger is used in the decision chain to implement an averaging process. Once the calibration procedure is complete, the RC oscillator is deactivated to reduce supply current and the associated noise.

**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

---

**APPLICATION INFORMATION**

The key operational-amplifier parameters CMRR, PSRR, and offset drift were optimized to achieve superior offset performance. The TLC4502 calibration DAC is implemented by a binary-weighted current array using a pseudo-R-2R MOSFET ladder architecture, which minimizes the silicon area required for the calibration circuitry, and thereby reduces the cost of the TLC4502.

Due to the performance (precision, PSRR, CMRR, gain, output drive, and ac performance) of the TLC4502, it is ideal for applications like:

- Data acquisition systems
- Medical equipment
- Portable digital scales
- Strain gauges
- Automotive sensors
- Digital audio circuits
- Industrial control applications

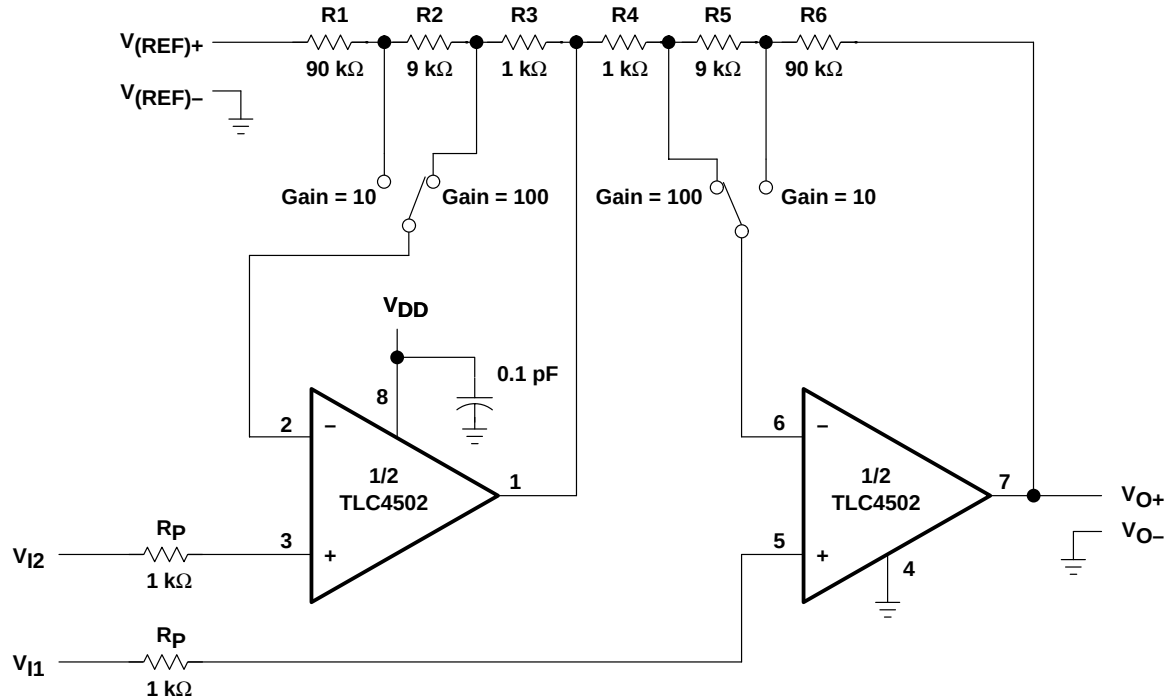
It is also ideal in circuits like:

- A precision buffer for current-to-voltage converters, a/d buffers, or bridge applications
- High-impedance buffers or preamplifiers
- Long term integration
- Sample-and-hold circuits
- Peak detectors

The TLC4502 self-calibrating operational amplifier is manufactured using Texas instruments LinEPIC process technology and is available in an 8-pin SOIC (D) Package. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 125°C. The M-suffix devices are characterized for operation from –55°C to 125°C.



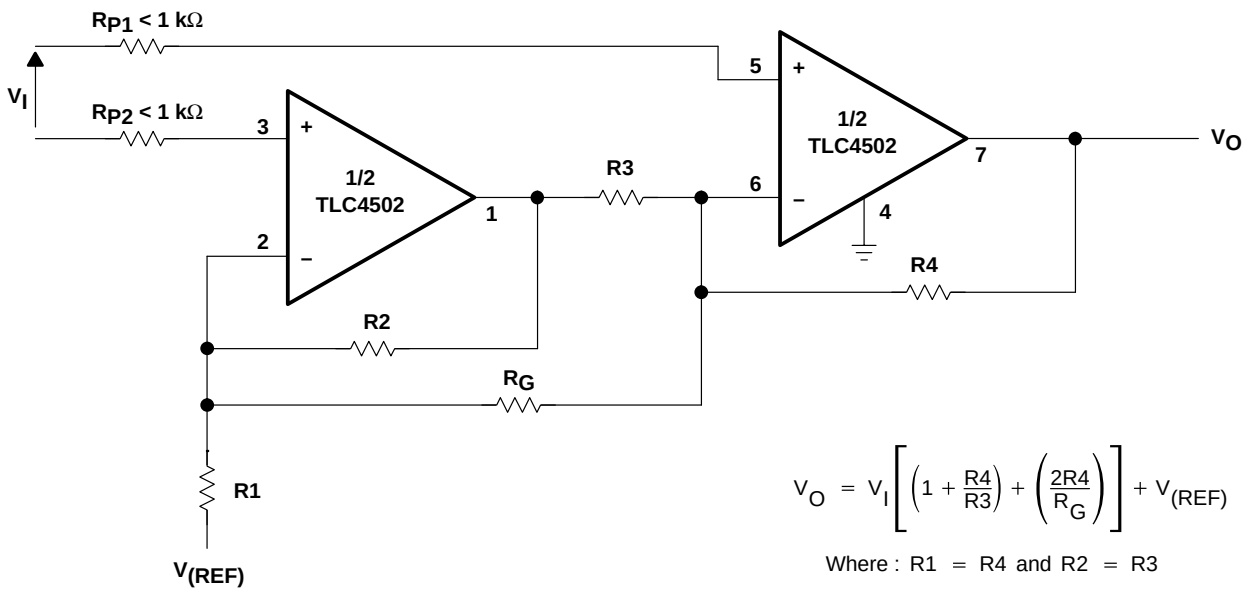
### APPLICATION INFORMATION



$$(\text{Gain} = 10) \quad V_O = (V_{I1} - V_{I2}) \left( 1 + \frac{R_6}{R_4 + R_5} \right) + V_{(REF)} \quad \text{Where } R_1 = R_6, R_2 = R_5, \text{ and } R_3 = R_4$$

$$(\text{Gain} = 100) \quad V_O = (V_{I1} - V_{I2}) \left( 1 + \frac{R_5 + R_6}{R_4} \right) + V_{(REF)} \quad \text{Where } R_1 = R_6, R_2 = R_5, \text{ and } R_3 = R_4$$

**Figure 36. Single-Supply Programmable Instrumentation Amplifier Circuit**

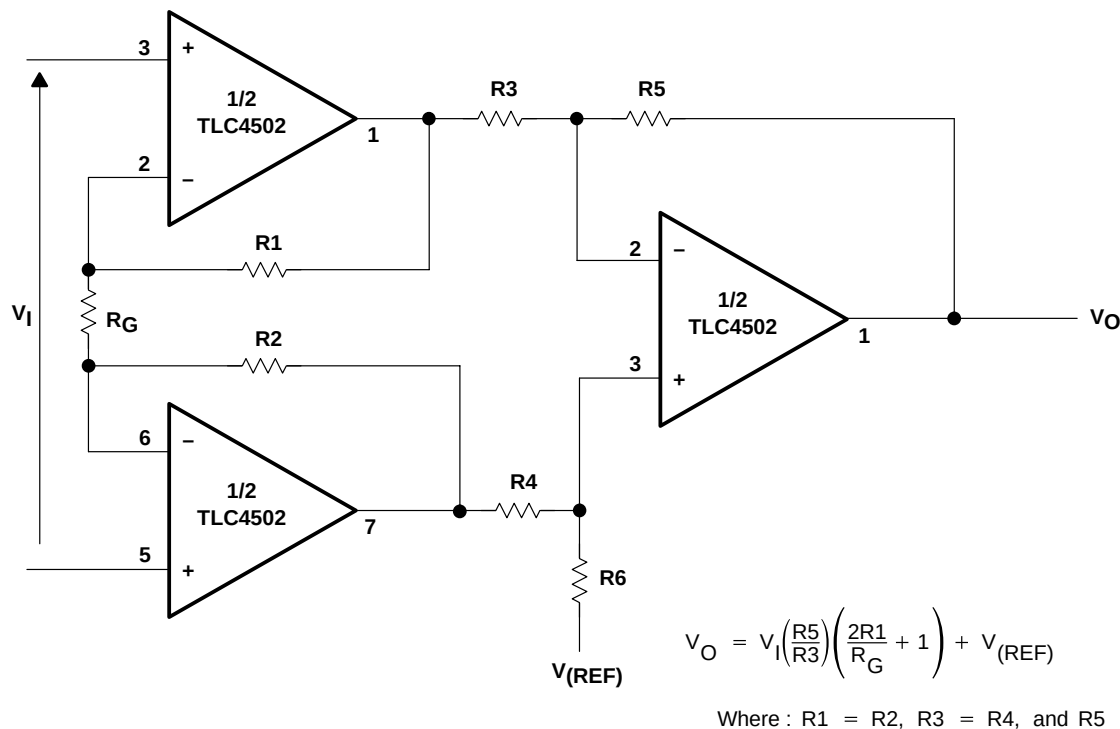


$$V_O = V_I \left[ \left( 1 + \frac{R_4}{R_3} \right) + \left( \frac{2R_4}{R_G} \right) \right] + V_{(REF)}$$

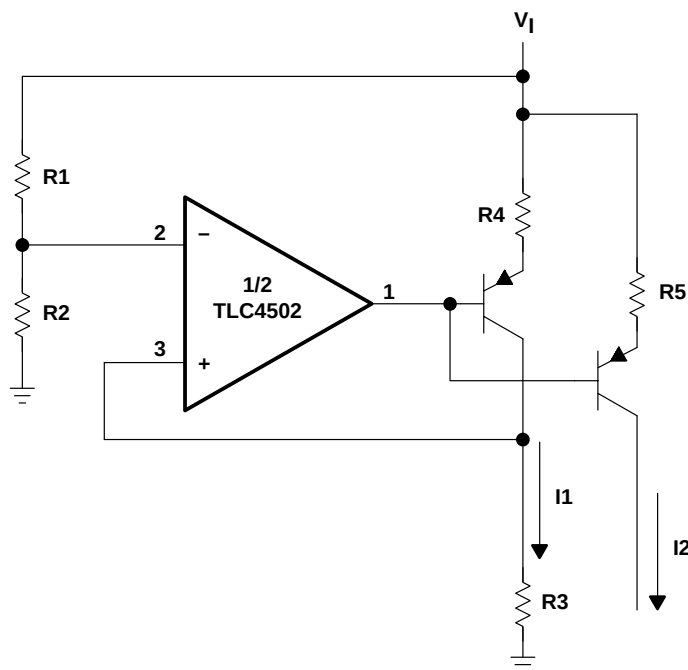
Where :  $R_1 = R_4$  and  $R_2 = R_3$

**Figure 37. Two Operational-Amplifier Instrumentation Amplifier Circuit**

## APPLICATION INFORMATION



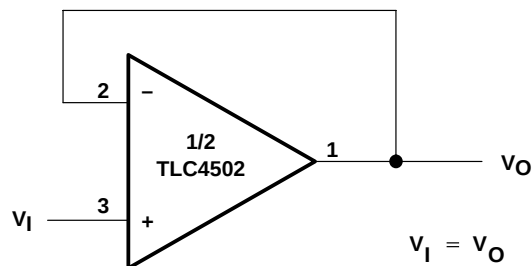
**Figure 38. Three Operational-Amplifier Instrumentation Amplifier Circuit**



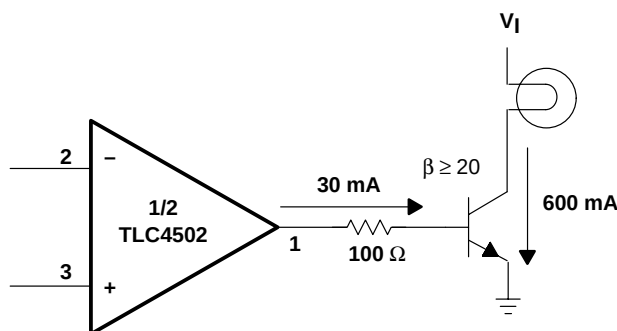
**Figure 39. Fixed Current-Source Circuit**



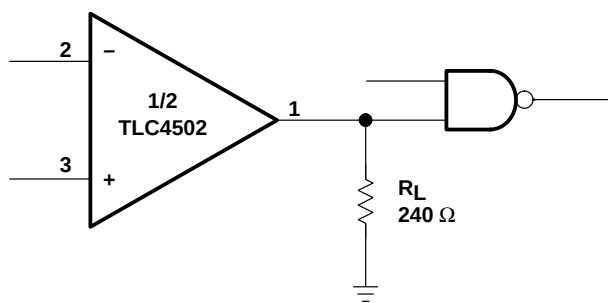
### APPLICATION INFORMATION



**Figure 40. Voltage-Follower Circuit**



**Figure 41. Lamp-Driver Circuit**

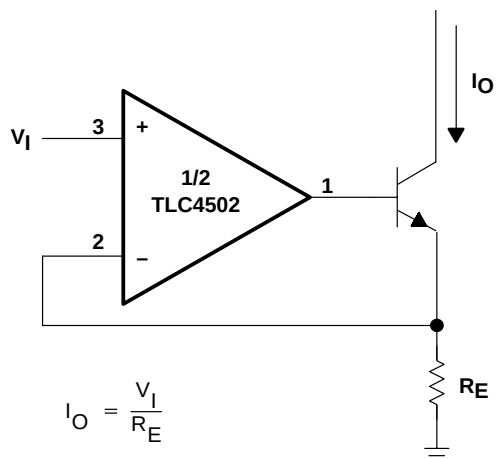


**Figure 42. TTL-Driver Circuit**

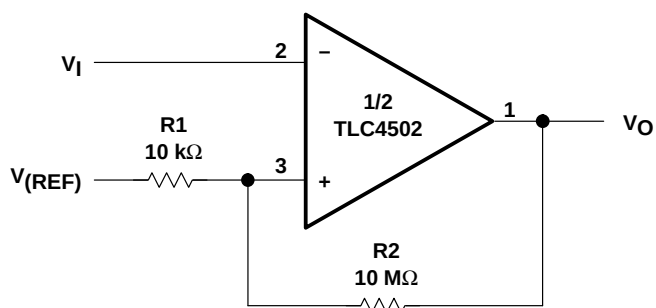
**TLC4501, TLC4501A, TLC4502, TLC4502A**  
**FAMILY OF SELF-CALIBRATING (Self-Cal™)**  
**PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS**

SLOS221B – MAY 1998 – REVISED APRIL 2001

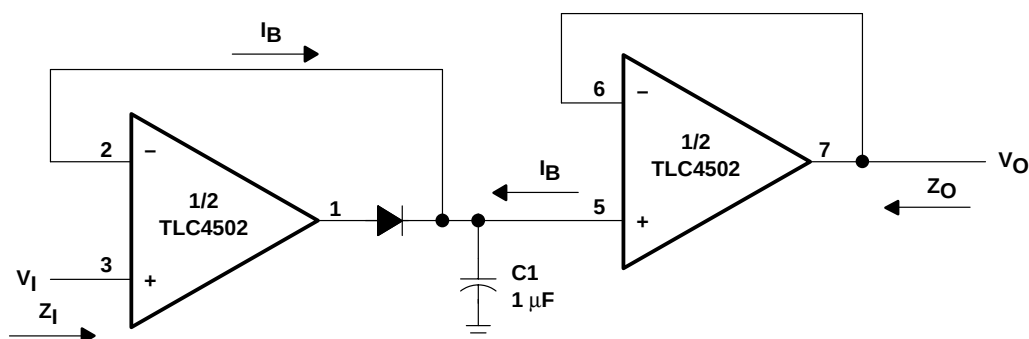
**APPLICATION INFORMATION**



**Figure 43. High-Compliance Current-Sink Circuit**



**Figure 44. Comparator With Hysteresis Circuit**



**Figure 45. Low-Drift Detector Circuit**

# TLC4501, TLC4501A, TLC4502, TLC4502A FAMILY OF SELF-CALIBRATING (Self-Cal™) PRECISION CMOS RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS

SLOS221B – MAY 1998 – REVISED APRIL 2001

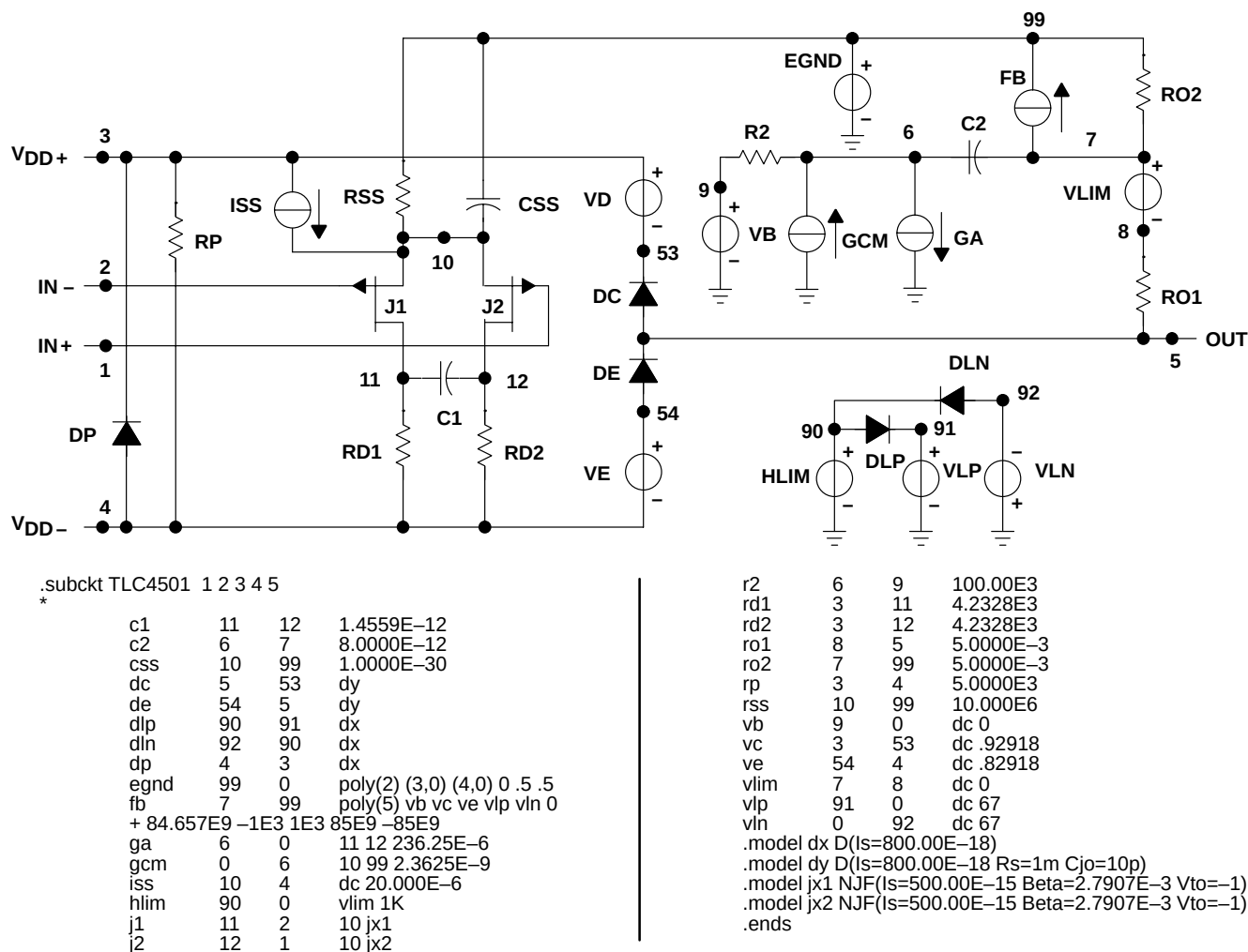
## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*™ Release 8, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 4) and subcircuit in Figure 46 are generated using the TLC4501 typical electrical and operating characteristics at  $T_A = 25^\circ\text{C}$ . Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 4: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).



**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Samples<br>(Requires Login) |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|-----------------------------|
| 5962-9753701Q2A  | ACTIVE        | LCCC         | FK                 | 20   | 1           | TBD                        | Call TI          | Call TI              |                             |
| 5962-9753701QHA  | ACTIVE        | CFP          | U                  | 10   | 1           | TBD                        | Call TI          | Call TI              |                             |
| 5962-9753701QPA  | ACTIVE        | CDIP         | JG                 | 8    | 1           | TBD                        | Call TI          | Call TI              |                             |
| 5962-9753702Q2A  | ACTIVE        | LCCC         | FK                 | 20   | 1           | TBD                        | Call TI          | Call TI              |                             |
| 5962-9753702QHA  | ACTIVE        | CFP          | U                  | 10   | 1           | TBD                        | Call TI          | Call TI              |                             |
| 5962-9753702QPA  | ACTIVE        | CDIP         | JG                 | 8    | 1           | TBD                        | Call TI          | Call TI              |                             |
| TLC4501ACD       | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501ACDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501AID       | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501AIDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501AIDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501AQD       | PREVIEW       | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4501AQDR      | PREVIEW       | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4501CD        | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501CDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501ID        | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501IDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501IDR       | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501IDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4501QD        | PREVIEW       | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Samples<br>(Requires Login) |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|-----------------------------|
| TLC4501QDR       | PREVIEW       | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4502ACD       | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502ACDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502ACDR      | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502ACDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AID       | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AIDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AIDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AMD       | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AMDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AMFKB     | ACTIVE        | LCCC         | FK                 | 20   | 1           | TBD                        | POST-PLATE       | N / A for Pkg Type   |                             |
| TLC4502AMJGB     | ACTIVE        | CDIP         | JG                 | 8    | 1           | TBD                        | A42              | N / A for Pkg Type   |                             |
| TLC4502AMUB      | ACTIVE        | CFP          | U                  | 10   | 1           | TBD                        | A42              | N / A for Pkg Type   |                             |
| TLC4502AQD       | OBSOLETE      | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4502AQDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502AQDR      | OBSOLETE      | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4502AQDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502CD        | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502CDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Samples<br>(Requires Login) |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|-----------------------------|
| TLC4502CDR       | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502CDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502ID        | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502IDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502IDR       | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502IDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502MD        | OBSOLETE      | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4502MDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502MFKB      | ACTIVE        | LCCC         | FK                 | 20   | 1           | TBD                        | POST-PLATE       | N / A for Pkg Type   |                             |
| TLC4502MJG       | ACTIVE        | CDIP         | JG                 | 8    | 1           | TBD                        | A42              | N / A for Pkg Type   |                             |
| TLC4502MJGB      | ACTIVE        | CDIP         | JG                 | 8    | 1           | TBD                        | A42              | N / A for Pkg Type   |                             |
| TLC4502MUB       | ACTIVE        | CFP          | U                  | 10   | 1           | TBD                        | A42              | N / A for Pkg Type   |                             |
| TLC4502QD        | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502QDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   |                             |
| TLC4502QDR       | OBSOLETE      | SOIC         | D                  | 8    |             | TBD                        | Call TI          | Call TI              |                             |
| TLC4502QDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& 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)

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

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

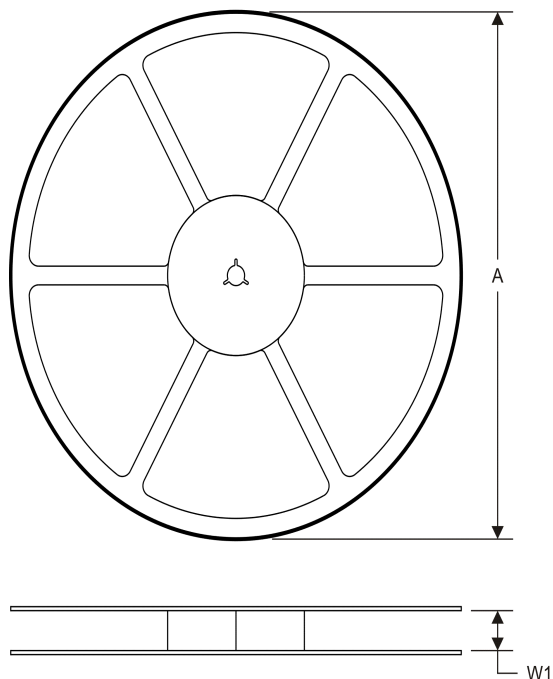
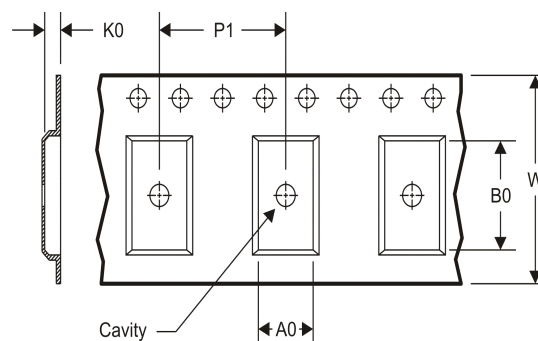
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF TLC4502, TLC4502A, TLC4502AM, TLC4502M :**

- Catalog: [TLC4502A](#), [TLC4502](#)
- Military: [TLC4502M](#), [TLC4502AM](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications

**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                   |

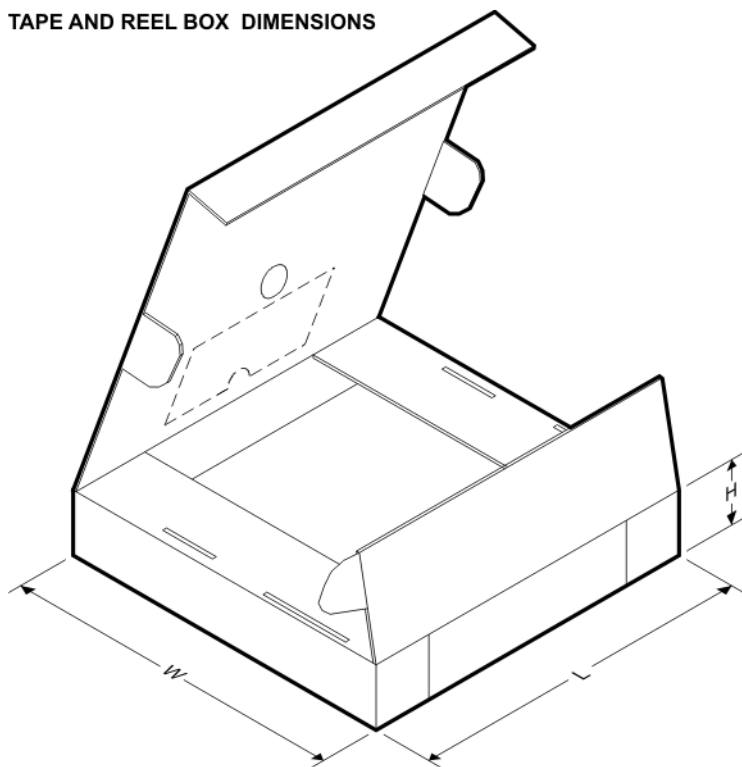
**TAPE AND REEL INFORMATION**

\*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 |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLC4501AIDR | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLC4501IDR  | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLC4502ACDR | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLC4502AIDR | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLC4502CDR  | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLC4502IDR  | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |



## TAPE AND REEL BOX DIMENSIONS

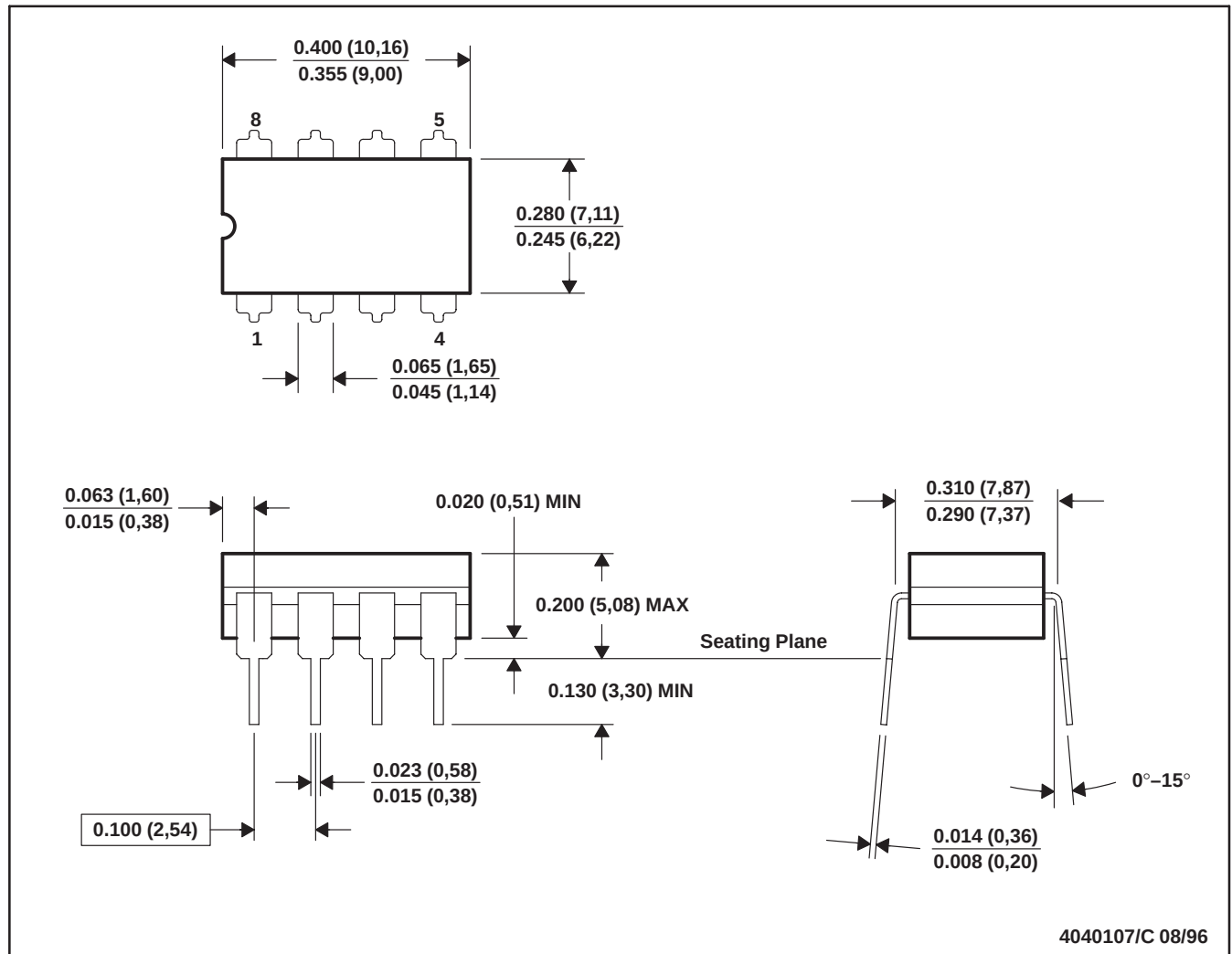


\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLC4501AIDR | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| TLC4501IDR  | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| TLC4502ACDR | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| TLC4502AIDR | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| TLC4502CDR  | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| TLC4502IDR  | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |

## JG (R-GDIP-T8)

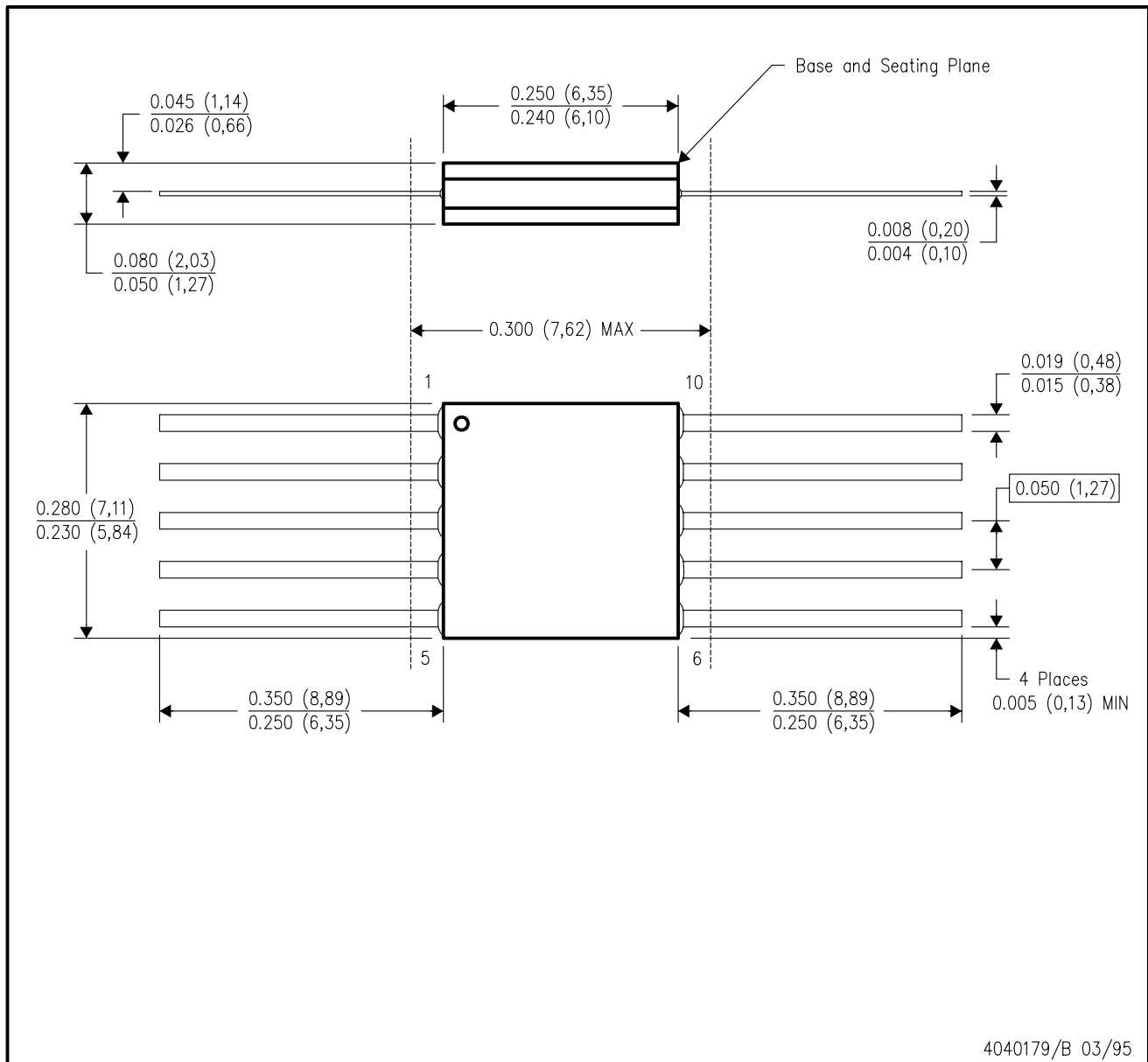
## CERAMIC DUAL-IN-LINE



- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - This package can be hermetically sealed with a ceramic lid using glass frit.
  - Index point is provided on cap for terminal identification.
  - Falls within MIL STD 1835 GDIP1-T8

U (S-GDFP-F10)

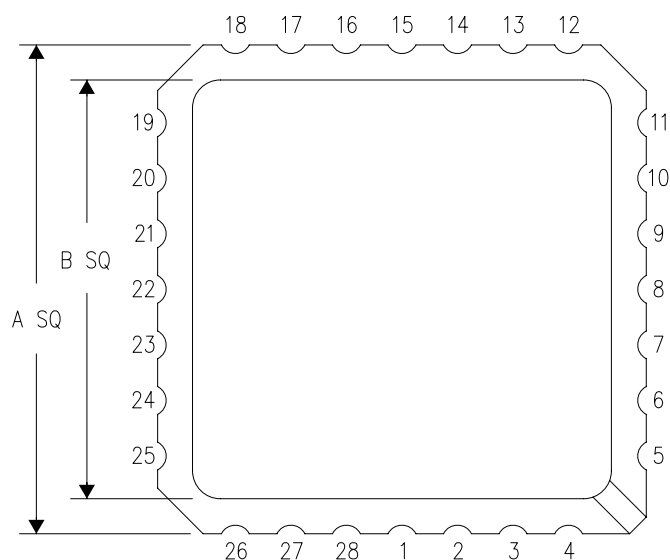
CERAMIC DUAL FLATPACK



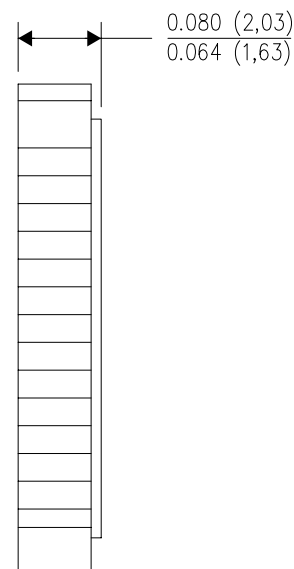
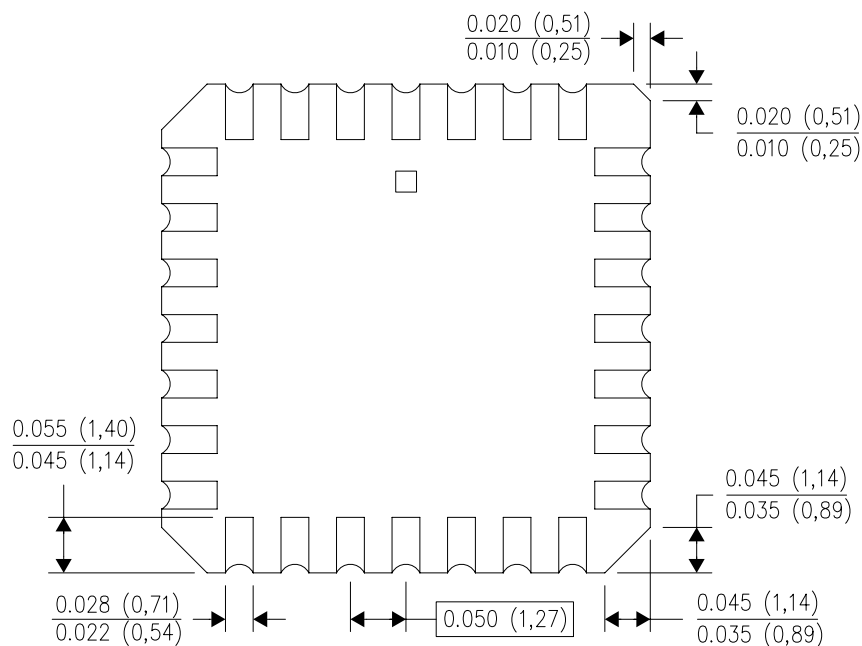
FK (S-CQCC-N\*\*)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



| NO. OF<br>TERMINALS<br>** | A                |                  | B                |                  |
|---------------------------|------------------|------------------|------------------|------------------|
|                           | MIN              | MAX              | MIN              | MAX              |
| 20                        | 0.342<br>(8,69)  | 0.358<br>(9,09)  | 0.307<br>(7,80)  | 0.358<br>(9,09)  |
| 28                        | 0.442<br>(11,23) | 0.458<br>(11,63) | 0.406<br>(10,31) | 0.458<br>(11,63) |
| 44                        | 0.640<br>(16,26) | 0.660<br>(16,76) | 0.495<br>(12,58) | 0.560<br>(14,22) |
| 52                        | 0.740<br>(18,78) | 0.761<br>(19,32) | 0.495<br>(12,58) | 0.560<br>(14,22) |
| 68                        | 0.938<br>(23,83) | 0.962<br>(24,43) | 0.850<br>(21,6)  | 0.858<br>(21,8)  |
| 84                        | 1.141<br>(28,99) | 1.165<br>(29,59) | 1.047<br>(26,6)  | 1.063<br>(27,0)  |

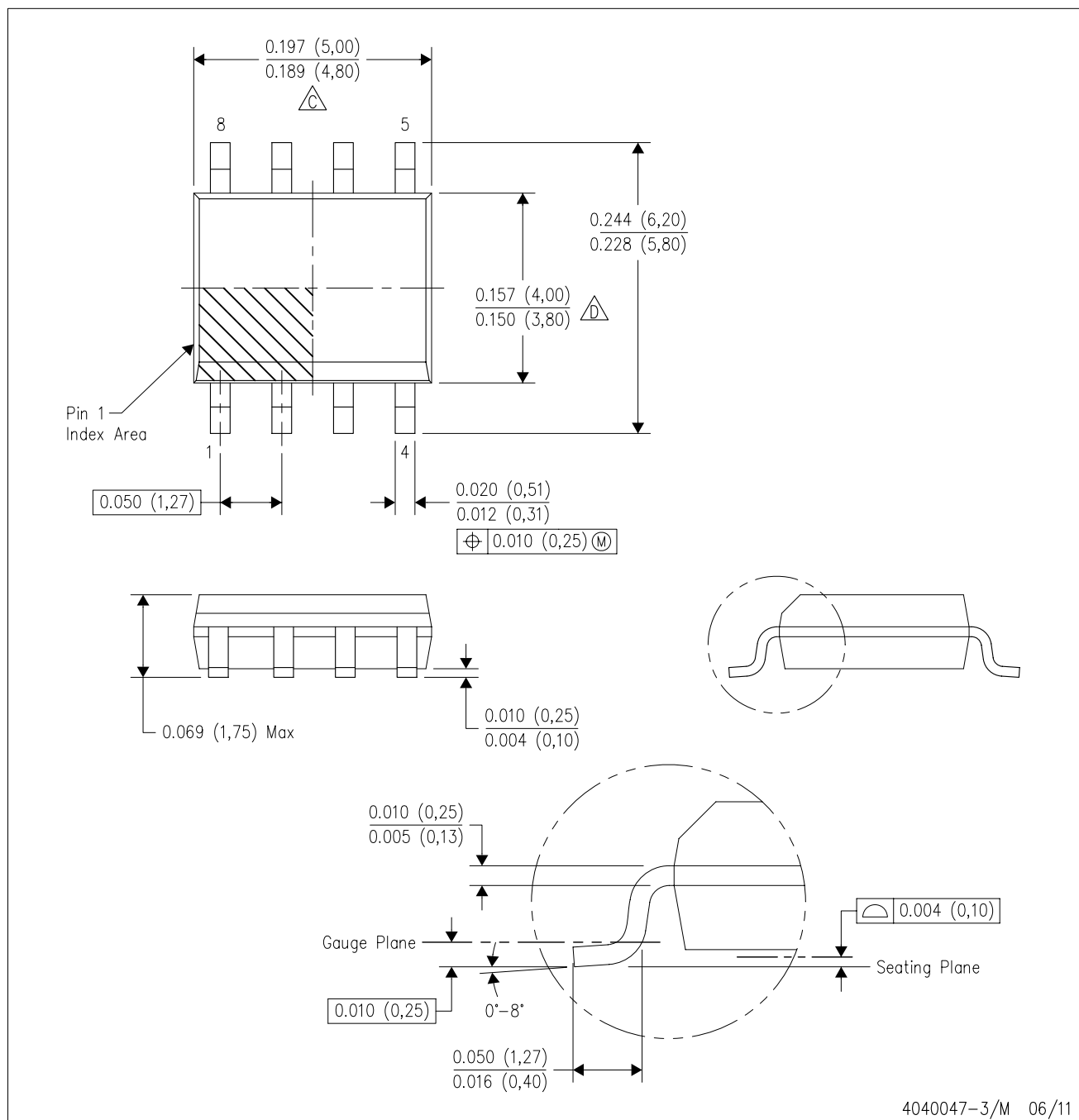


4040140/D 01/11

- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - This package can be hermetically sealed with a metal lid.
  - Falls within JEDEC MS-004

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

|                              |                                                                                      |
|------------------------------|--------------------------------------------------------------------------------------|
| Audio                        | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                               |
| Amplifiers                   | <a href="http://amplifier.ti.com">amplifier.ti.com</a>                               |
| Data Converters              | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>                       |
| DLP® Products                | <a href="http://www.dlp.com">www.dlp.com</a>                                         |
| DSP                          | <a href="http://dsp.ti.com">dsp.ti.com</a>                                           |
| Clocks and Timers            | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
| Interface                    | <a href="http://interface.ti.com">interface.ti.com</a>                               |
| Logic                        | <a href="http://logic.ti.com">logic.ti.com</a>                                       |
| Power Mgmt                   | <a href="http://power.ti.com">power.ti.com</a>                                       |
| Microcontrollers             | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                         | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Applications Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
| Wireless Connectivity        | <a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a> |

### Applications

|                               |                                                                                          |
|-------------------------------|------------------------------------------------------------------------------------------|
| Automotive and Transportation | <a href="http://www.ti.com/automotive">www.ti.com/automotive</a>                         |
| Communications and Telecom    | <a href="http://www.ti.com/communications">www.ti.com/communications</a>                 |
| Computers and Peripherals     | <a href="http://www.ti.com/computers">www.ti.com/computers</a>                           |
| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
| Energy and Lighting           | <a href="http://www.ti.com/energy">www.ti.com/energy</a>                                 |
| Industrial                    | <a href="http://www.ti.com/industrial">www.ti.com/industrial</a>                         |
| Medical                       | <a href="http://www.ti.com/medical">www.ti.com/medical</a>                               |
| Security                      | <a href="http://www.ti.com/security">www.ti.com/security</a>                             |
| Space, Avionics and Defense   | <a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a> |
| Video and Imaging             | <a href="http://www.ti.com/video">www.ti.com/video</a>                                   |

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)



Компания «ЭлектроПласт» предлагает заключение долгосрочных отношений при поставках импортных электронных компонентов на взаимовыгодных условиях!

Наши преимущества:

- Оперативные поставки широкого спектра электронных компонентов отечественного и импортного производства напрямую от производителей и с крупнейших мировых складов;
- Поставка более 17-ти миллионов наименований электронных компонентов;
- Поставка сложных, дефицитных, либо снятых с производства позиций;
- Оперативные сроки поставки под заказ (от 5 рабочих дней);
- Экспресс доставка в любую точку России;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- Лицензия ФСБ на осуществление работ с использованием сведений, составляющих государственную тайну;
- Поставка специализированных компонентов (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Aeroflex, Peregrine, Syfer, Eurofarad, Texas Instrument, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

Помимо этого, одним из направлений компании «ЭлектроПласт» является направление «Источники питания». Мы предлагаем Вам помощь Конструкторского отдела:

- Подбор оптимального решения, техническое обоснование при выборе компонента;
- Подбор аналогов;
- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.



#### Как с нами связаться

**Телефон:** 8 (812) 309 58 32 (многоканальный)

**Факс:** 8 (812) 320-02-42

**Электронная почта:** [org@eplast1.ru](mailto:org@eplast1.ru)

**Адрес:** 198099, г. Санкт-Петербург, ул. Калинина, дом 2, корпус 4, литера А.