

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

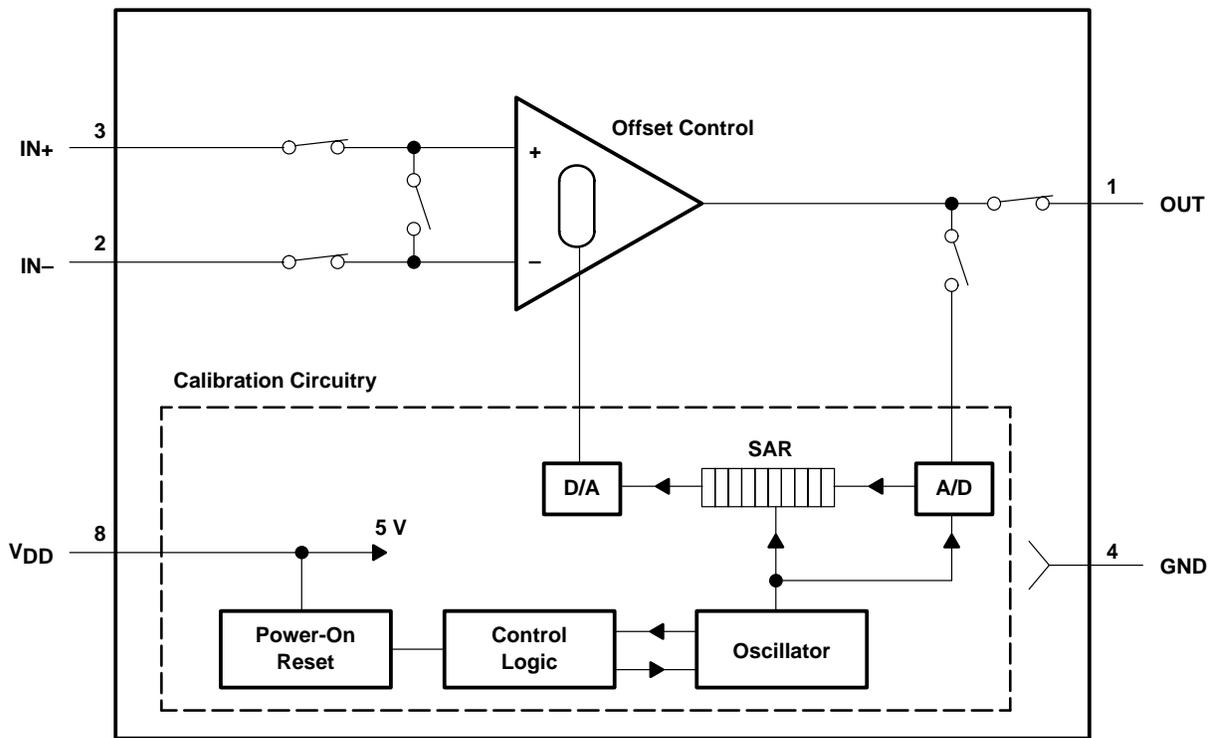
SLOS221B – MAY 1998 – REVISED APRIL 2001

- 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

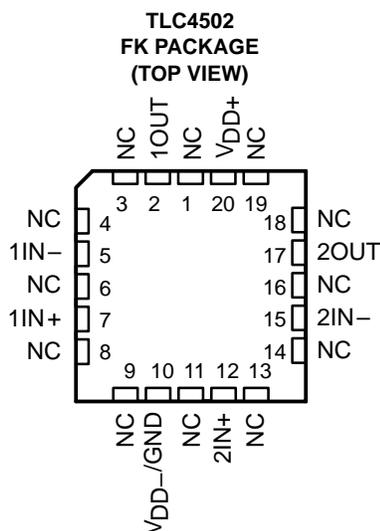
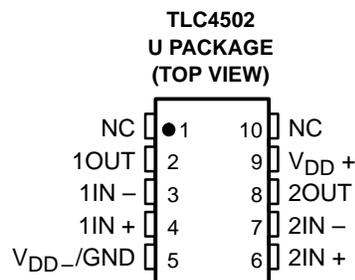
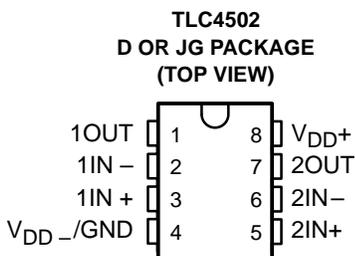
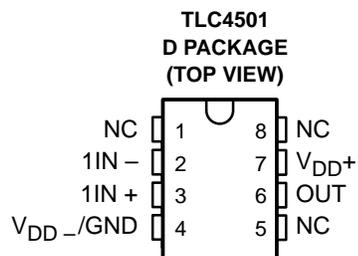
Copyright © 2001, Texas Instruments Incorporated  
 On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

# 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† (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	CERAMIC FLAT PACK (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.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

**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)†**

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

† 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	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ 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						
Common-mode input voltage, $V_{IC}$	$V_{DD-}$	$V_{DD+} - 2.3$	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	$T_A$ †	TLC450xC			UNIT	
			MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	Full range	TLC4501	-80	10	80	$\mu\text{V}$
			TLC4501A	-40	10	40	
			TLC4502	-100	10	100	
			TLC4502A	-50	10	50	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		Full range		1		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	25°C		1	60	pA	
		Full range			500		
$I_{IB}$ Input bias current		25°C		1	60	pA	
		Full range			500		
$V_{OH}$ High-level output voltage	$I_{OH} = -500\ \mu\text{A}$	25°C		4.99		V	
	$I_{OH} = -5\text{ mA}$	25°C		4.9			
		Full range		4.7			
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	25°C		0.01		V	
	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 5\text{ mA}$	25°C		0.1			
		Full range			0.3		
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$ , $R_L = 1\text{ k}\Omega$ , See Note 4	25°C	200	1000		V/mV	
		Full range	200				
$R_{I(D)}$ Differential input resistance		25°C		10		k $\Omega$	
$R_L$ Input resistance	See Note 4	25°C		$10^{12}$		$\Omega$	
$C_L$ Common-mode input capacitance	$f = 10\text{ kHz}$ , P package	25°C		8		pF	
$Z_O$ Closed-loop output impedance	$A_V = 10$ , $f = 100\text{ kHz}$	25°C		1		$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 1\text{ k}\Omega$	25°C	90	100		dB	
		Full range	85				
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD} \pm / \Delta V_{IO}$ )	$V_{DD} = 4\text{ V to }6\text{ V}$ , $V_{IC} = 0$ , No load	25°C	90	100		dB	
		Full range	90				
$I_{DD}$ Supply current	$V_O = 2.5\text{ V}$ , No load	TLC4501/A	25°C	1	1.5	mA	
			Full range		2		
		TLC4502/A	25°C	2.5	3.5		
			Full range		4		
$V_{IT(CAL)}$ Calibration input threshold voltage		Full range	4			V	

† 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		$T_A$ †	TLC450xC, TLC450xAC			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }2.5\text{ V}, C_L = 100\text{ pF}$		25°C	1.5	2.5		$\text{V}/\mu\text{s}$
				Full range	1			$\text{V}/\mu\text{s}$
$V_n$	Equivalent input noise voltage	f = 10 Hz		25°C	70			$\text{nV}/\sqrt{\text{Hz}}$
		f = 1 kHz		25°C	12			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz		25°C	1			$\mu\text{V}$
		f = 0.1 to 10 Hz		25°C	1.5			
$I_n$	Equivalent input noise current			25°C	0.6			$\text{fA}/\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V},$ f = 10 kHz, $R_L = 1\text{ k}\Omega,$ $C_L = 100\text{ pF}$		$A_V = 1$	25°C	0.02%		
				$A_V = 10$	25°C	0.08%		
				$A_V = 100$	25°C	0.55%		
Gain-bandwidth product		f = 10 kHz, $C_L = 100\text{ pF}$	$R_L = 1\text{ k}\Omega,$	25°C	4.7			MHz
$B_{OM}$	Maximum output swing bandwidth	$V_{O(PP)} = 2\text{ V},$ $R_L = 1\text{ k}\Omega,$	$A_V = 1,$ $C_L = 100\text{ pF}$	25°C	1			MHz
$t_s$	Settling time	$A_V = -1,$ Step = 0.5 V to 2.5 V, $R_L = 1\text{ k}\Omega,$ $C_L = 100\text{ pF}$		to 0.1%	25°C	1.6		$\mu\text{s}$
				to 0.01%	25°C	2.2		
$\phi_m$	Phase margin at unity gain	$R_L = 1\text{ k}\Omega,$	$C_L = 100\text{ pF}$	25°C	74			
Calibration time				25°C	300			ms

† 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	$T_A$ †	TLC450xI			UNIT	
			MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	Full range	TLC4501	-80	10	80	$\mu\text{V}$
			TLC4501A	-40	10	40	
			TLC4502	-100	10	100	
			TLC4502A	-50	10	50	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		Full range		1		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	25°C		1	60	$\text{pA}$	
		-40°C to 85°C			500	$\text{pA}$	
		Full range			5	$\text{nA}$	
$I_{IB}$ Input bias current	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	25°C		1	60	$\text{pA}$	
		-40°C to 85°C			500	$\text{pA}$	
		Full range			10	$\text{nA}$	
$V_{OH}$ High-level output voltage	$I_{OH} = -500\ \mu\text{A}$	25°C		4.99		$\text{V}$	
	$I_{OH} = -5\text{ mA}$	25°C		4.9			
		Full range		4.7			
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	25°C		0.01		$\text{V}$	
	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 5\text{ mA}$	25°C		0.1			
		Full range		0.3			
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$ , $R_L = 1\text{ k}\Omega$ , See Note 4	25°C	200	1000		$\text{V/mV}$	
		Full range	200				
$R_{I(D)}$ Differential input resistance		25°C		10		$\text{k}\Omega$	
$R_L$ Input resistance	See Note 4	25°C		$10^{12}$		$\Omega$	
$C_L$ Common-mode input capacitance	$f = 10\text{ kHz}$ , P package	25°C		8		$\text{pF}$	
$Z_O$ Closed-loop output impedance	$A_V = 10$ , $f = 100\text{ kHz}$	25°C		1		$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 1\text{ k}\Omega$	25°C	90	100		$\text{dB}$	
		Full range	85				
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD} \pm / \Delta V_{IO}$ )	$V_{DD} = 4\text{ V to }6\text{ V}$ , $V_{IC} = 0$ , No load	25°C	90	100		$\text{dB}$	
		Full range	90				
$I_{DD}$ Supply current	$V_O = 2.5\text{ V}$ , No load	TLC4501/A	25°C	1	1.5	$\text{mA}$	
			Full range		2		
		TLC4502/A	25°C	2.5	3.5		
			Full range		4		
$V_{IT(CAL)}$ Calibration input threshold voltage		Full range	4			$\text{V}$	

† 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		$T_A$ †	TLC450xI, TLC450xAI			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }2.5\text{ V}, C_L = 100\text{ pF}$		25°C	1.5	2.5		$\text{V}/\mu\text{s}$
				Full range	1			$\text{V}/\mu\text{s}$
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C	70		$\text{nV}/\sqrt{\text{Hz}}$	
		$f = 1\text{ kHz}$		25°C	12			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ to }1\text{ Hz}$		25°C	1		$\mu\text{V}$	
		$f = 0.1\text{ to }10\text{ Hz}$		25°C	1.5			
$I_n$	Equivalent input noise current			25°C	0.6		$\text{fA}/\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V},$ $f = 10\text{ kHz},$ $R_L = 1\text{ k}\Omega,$ $C_L = 100\text{ pF}$		$A_V = 1$	25°C	0.02%		
				$A_V = 10$	25°C	0.08%		
				$A_V = 100$	25°C	0.55%		
Gain-bandwidth product		$f = 10\text{ kHz},$ $C_L = 100\text{ pF}$	$R_L = 1\text{ k}\Omega,$	25°C	4.7		MHz	
$B_{OM}$	Maximum output swing bandwidth	$V_{O(PP)} = 2\text{ V},$ $R_L = 1\text{ k}\Omega,$	$A_V = 1,$ $C_L = 100\text{ pF}$	25°C	1		MHz	
$t_s$	Settling time	$A_V = -1,$ Step = $0.5\text{ V to }2.5\text{ V},$ $R_L = 1\text{ k}\Omega,$ $C_L = 100\text{ pF}$		to 0.1%	25°C	1.6		$\mu\text{s}$
				to 0.01%	25°C	2.2		
$\phi_m$	Phase margin at unity gain	$R_L = 1\text{ k}\Omega,$	$C_L = 100\text{ pF}$	25°C	74			
Calibration time				25°C	300		ms	

† 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	$T_A$ †	TLC4502Q, TLC4502M			UNIT	
			MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	TLC4502 TLC4502A	Full range	-100 -50	10 10	100 50	$\mu\text{V}$
$\alpha_{VIO}$ Temperature coefficient of input offset voltage			Full range		1		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current	$V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$		25°C		1	60	nA
			125°C			5	
$I_{IB}$ Input bias current			25°C		1	60	nA
			125°C			10	
$V_{OH}$ High-level output voltage	$I_{OH} = -500\ \mu\text{A}$		25°C		4.99		V
	$I_{OH} = -5\text{ mA}$		25°C		4.9		
			Full range		4.7		
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$		25°C		0.01		V
	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 5\text{ mA}$		25°C		0.1		
			Full range			0.3	
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$ , $R_L = 1\text{ k}\Omega$ , See Note 4		25°C	200	1000		V/mV
			Full range	200			
$R_{I(D)}$ Differential input resistance			25°C		10		k $\Omega$
$R_L$ Input resistance	See Note 4		25°C		10 <sup>12</sup>		$\Omega$
$C_L$ Common-mode input capacitance	$f = 10\text{ kHz}$ , P package		25°C		8		pF
$z_O$ Closed-loop output impedance	$A_V = 10$ , $f = 100\text{ kHz}$		25°C		1		$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 1\text{ k}\Omega$		25°C	90	100		dB
			Full range	85			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD} \pm / \Delta V_{IO}$ )	$V_{DD} = 4\text{ V to }6\text{ V}$ , $V_{IC} = V_{DD} / 2$ , No load		25°C	90	100		dB
			Full range	90			
$I_{DD}$ Supply current	$V_O = 2.5\text{ V}$ , No load		25°C		2.5	3.5	mA
			Full range			4	
$V_{IT(CAL)}$ Calibration input threshold voltage			Full range	4			V

† 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		$T_A$ †	TLC4502Q, TLC4502M, TLC4502AQ, TLC4502AM			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }2.5\text{ V},$ See Note 4		$C_L = 100\text{ pF}$	25°C	1.5	2.5	V/ $\mu\text{s}$
					Full range	1		V/ $\mu\text{s}$
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C	70		nV/ $\sqrt{\text{Hz}}$	
		$f = 1\text{ kHz}$		25°C	12			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ to }1\text{ Hz}$		25°C	1		$\mu\text{V}$	
		$f = 0.1\text{ to }10\text{ Hz}$		25°C	1.5			
$I_n$	Equivalent input noise current			25°C	0.6		fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V},$ $f = 10\text{ kHz},$ $R_L = 1\text{ k}\Omega,$ $C_L = 100\text{ pF}$		$A_V = 1$	25°C	0.02%		
				$A_V = 10$	25°C	0.08%		
				$A_V = 100$	25°C	0.55%		
Gain-bandwidth product		$f = 10\text{ kHz},$ $C_L = 100\text{ pF}$	$R_L = 1\text{ k}\Omega,$	25°C	4.7		MHz	
BOM	Maximum output swing bandwidth	$V_{O(PP)} = 2\text{ V},$ $R_L = 1\text{ k}\Omega,$	$A_V = 1,$ $C_L = 100\text{ pF}$	25°C	1		MHz	
$t_s$	Settling time	$A_V = -1,$ Step = 0.5 V to 2.5 V, $R_L = 1\text{ k}\Omega,$ $C_L = 100\text{ pF}$		to 0.1%	25°C	1.6		$\mu\text{s}$
				to 0.01%	25°C	2.2		
$\phi_m$	Phase margin at unity gain	$R_L = 1\text{ k}\Omega,$	$C_L = 100\text{ pF}$	25°C	74			
Calibration time				25°C	300		ms	

† 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
		Gain-bandwidth product	vs Free-air temperature
$\phi_m$	Phase margin	vs Load capacitance	28
		vs Frequency	14
		Gain margin	vs Load capacitance
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

DISTRIBUTION OF TLC4502 INPUT  
 OFFSET VOLTAGE

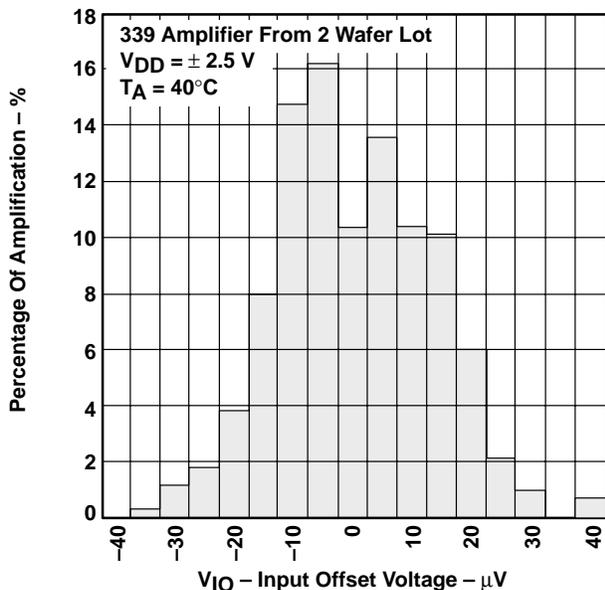


Figure 2

DISTRIBUTION OF TLC4502 INPUT  
 OFFSET VOLTAGE

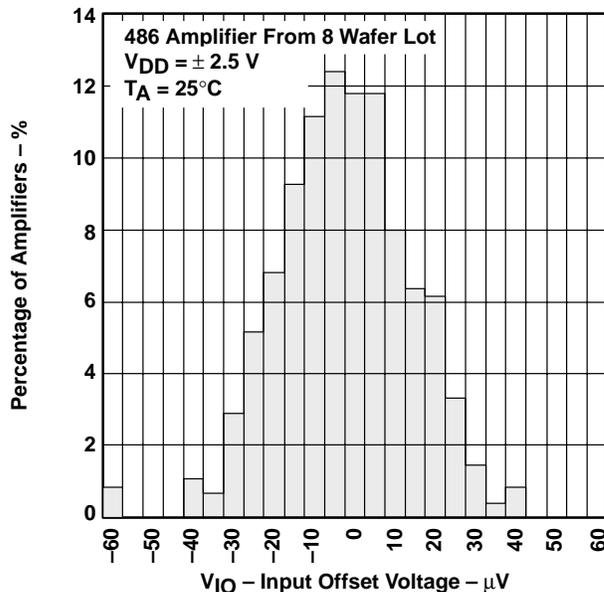


Figure 3

DISTRIBUTION OF TLC4502 INPUT  
 OFFSET VOLTAGE

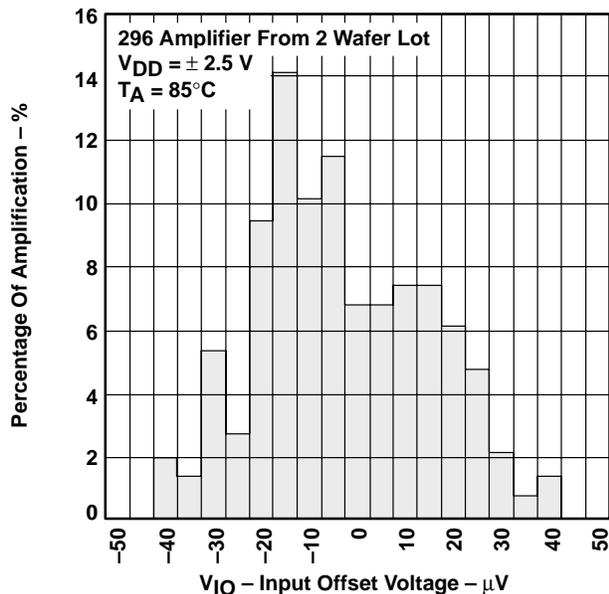


Figure 4

INPUT OFFSET VOLTAGE  
 vs  
 COMMON-MODE INPUT VOLTAGE

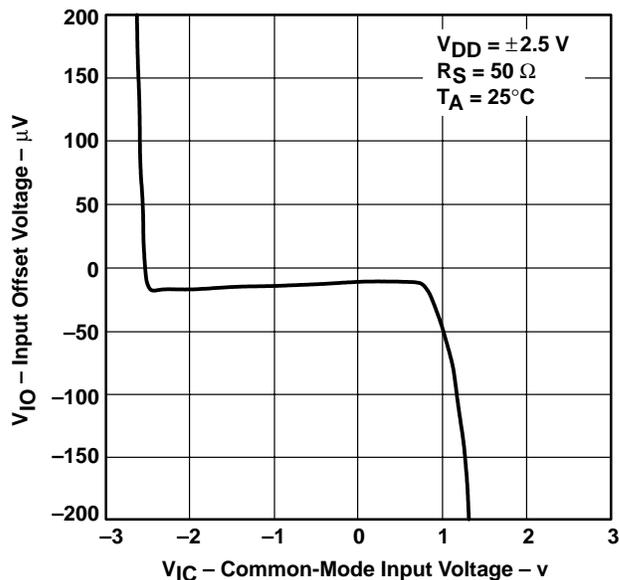


Figure 5

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

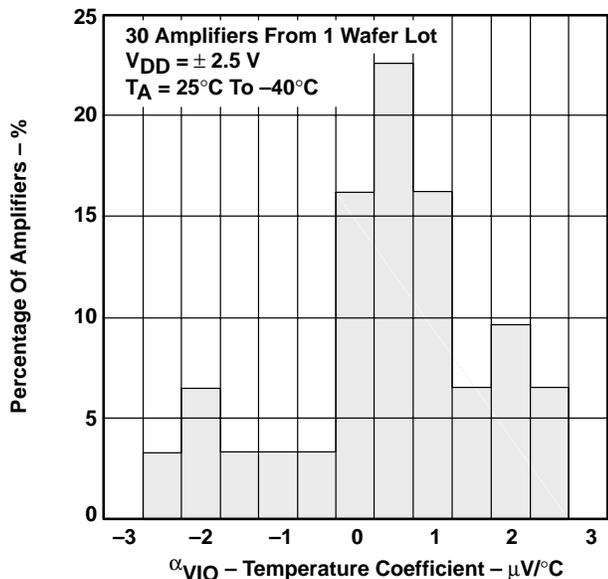


Figure 6

DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

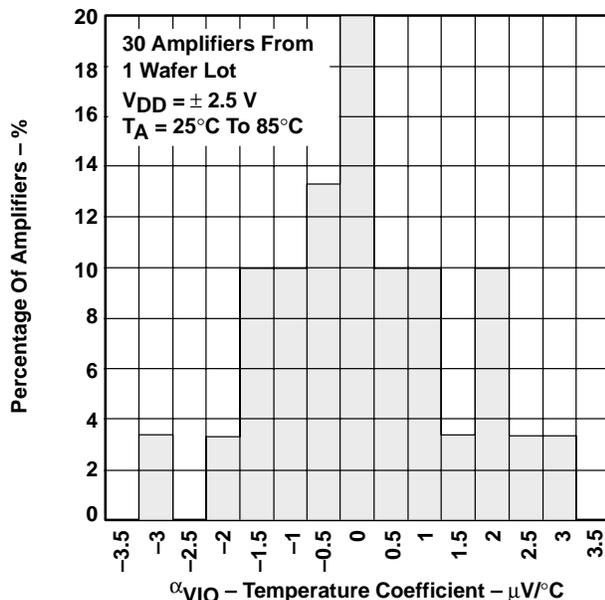


Figure 7

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

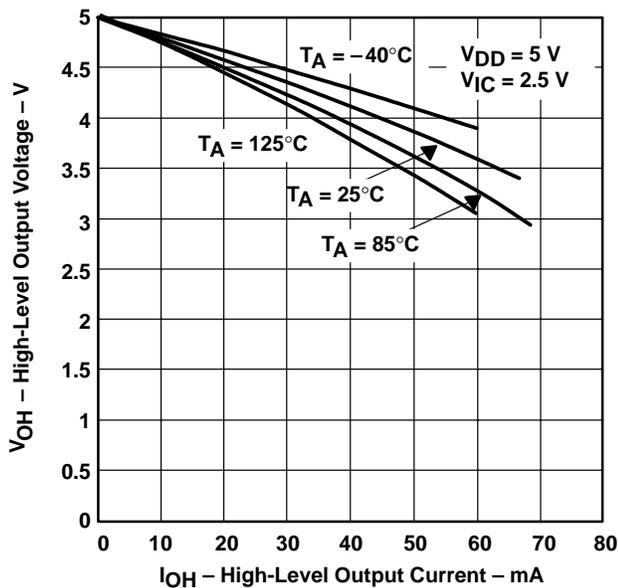


Figure 8

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

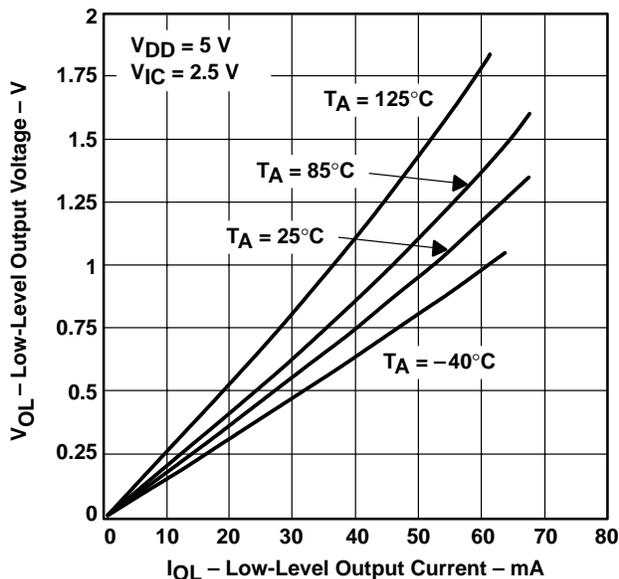


Figure 9

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

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE  
 VS  
 FREQUENCY

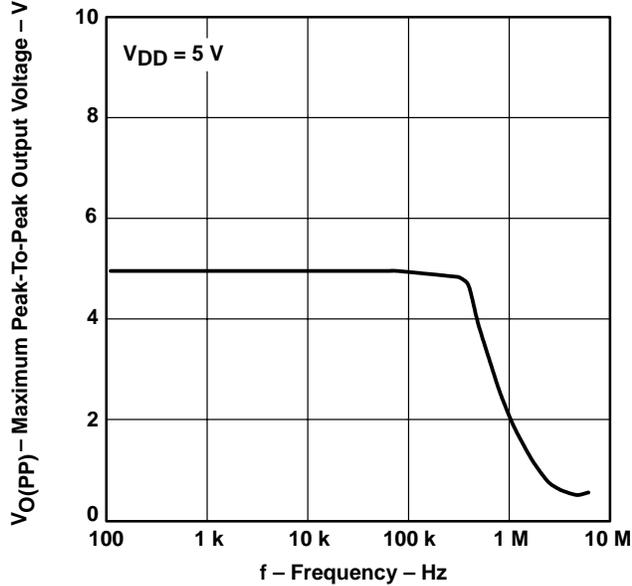


Figure 10

SHORT-CIRCUIT OUTPUT CURRENT  
 VS  
 FREE-AIR TEMPERATURE

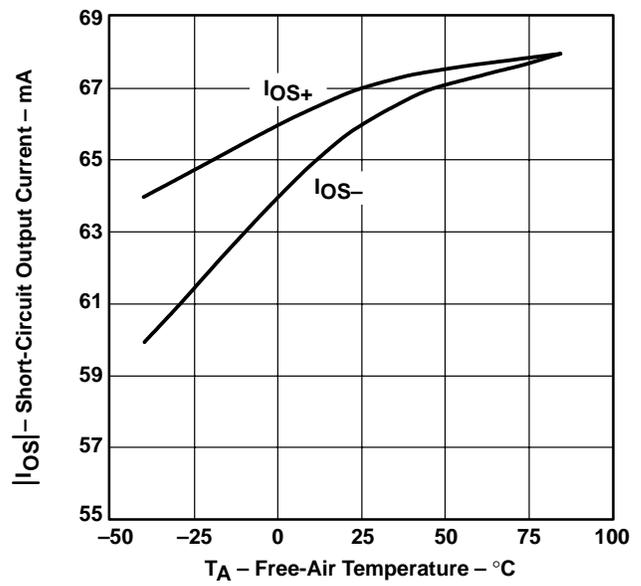


Figure 11

OUTPUT VOLTAGE  
 VS  
 DIFFERENTIAL INPUT VOLTAGE

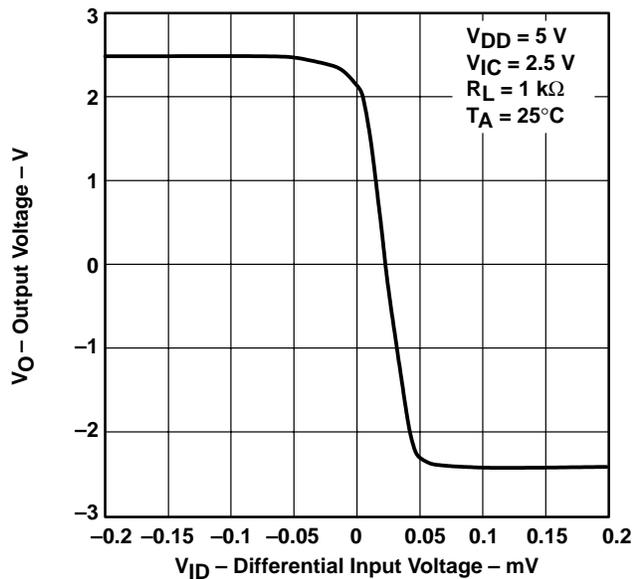


Figure 12

LARGE-SIGNAL DIFFERENTIAL  
 VOLTAGE AMPLIFICATION  
 VS  
 FREE-AIR TEMPERATURE

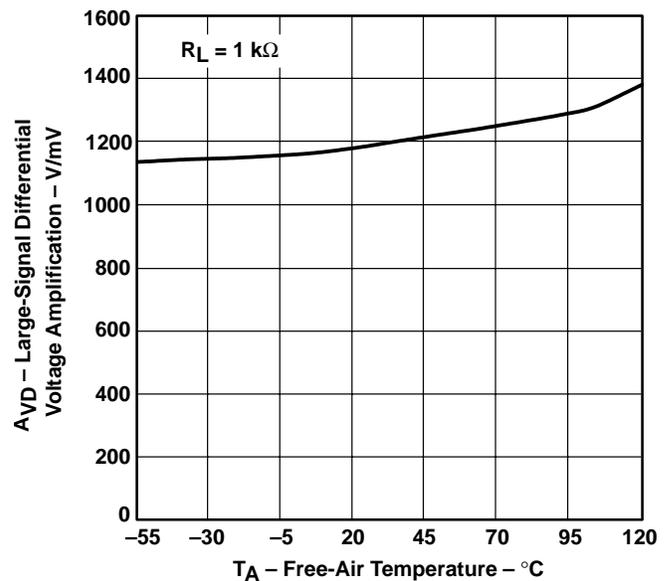


Figure 13

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE  
 AMPLIFICATION AND PHASE MARGIN  
 vs  
 FREQUENCY

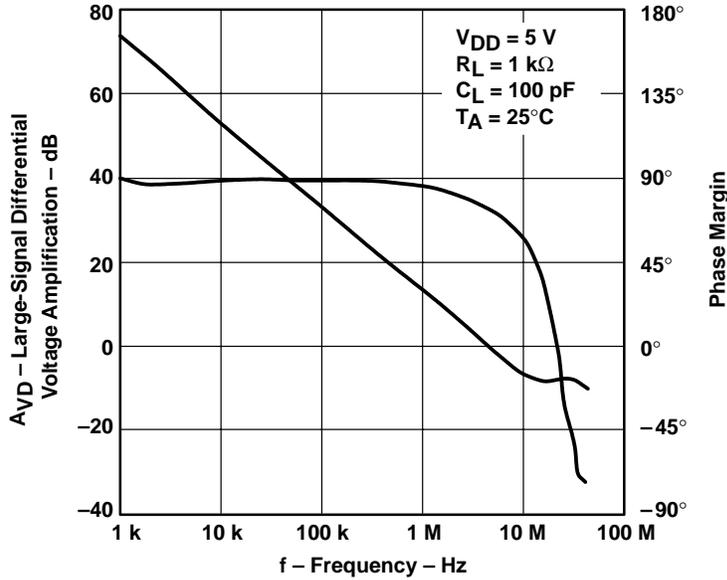


Figure 14

OUTPUT IMPEDANCE  
 vs  
 FREQUENCY

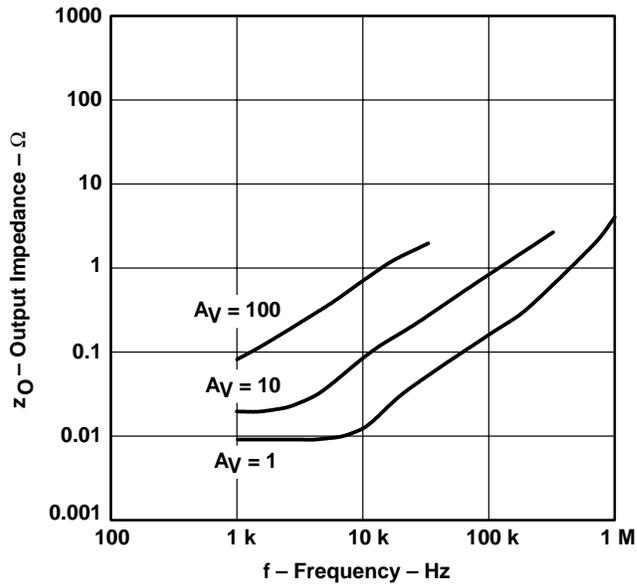


Figure 15

TYPICAL CHARACTERISTICS

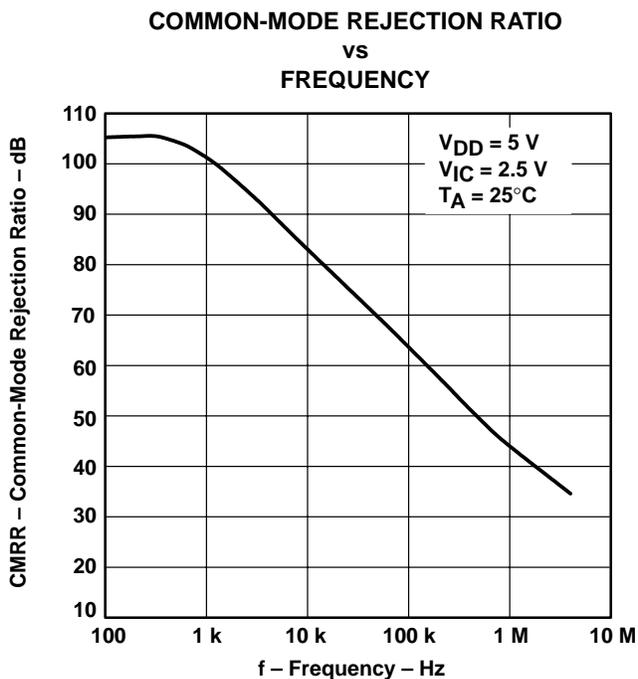


Figure 16

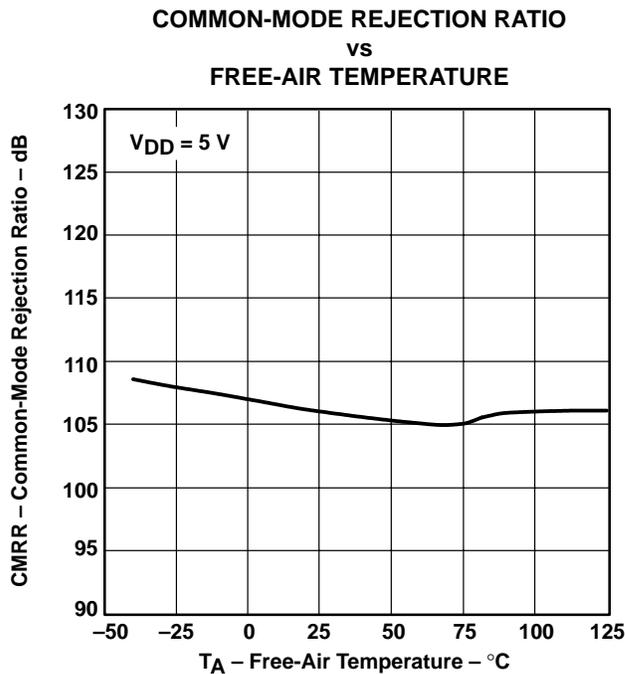


Figure 17

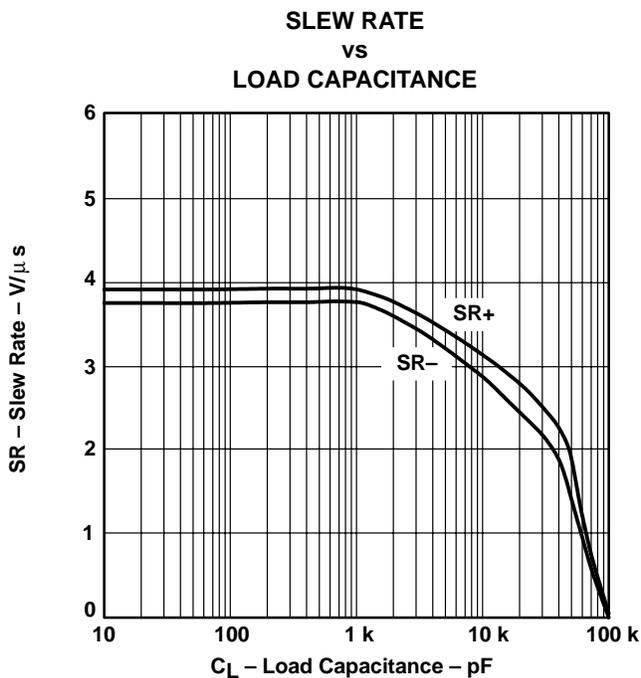


Figure 18

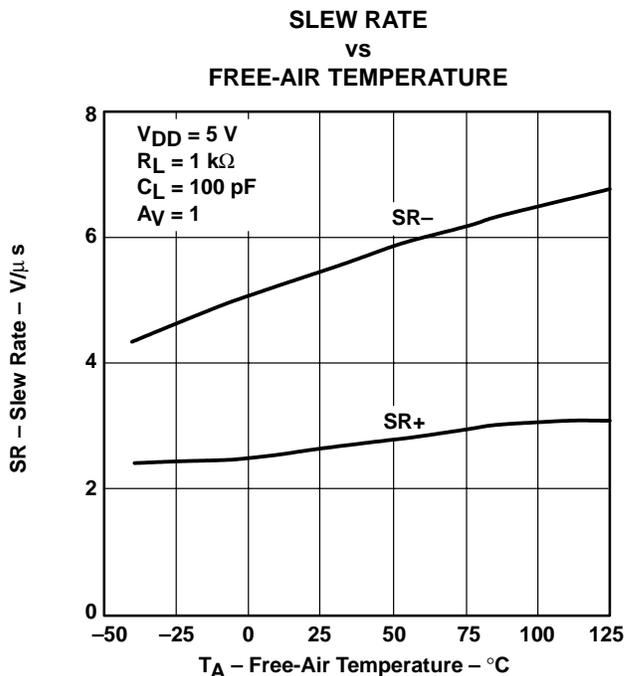


Figure 19

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL PULSE RESPONSE

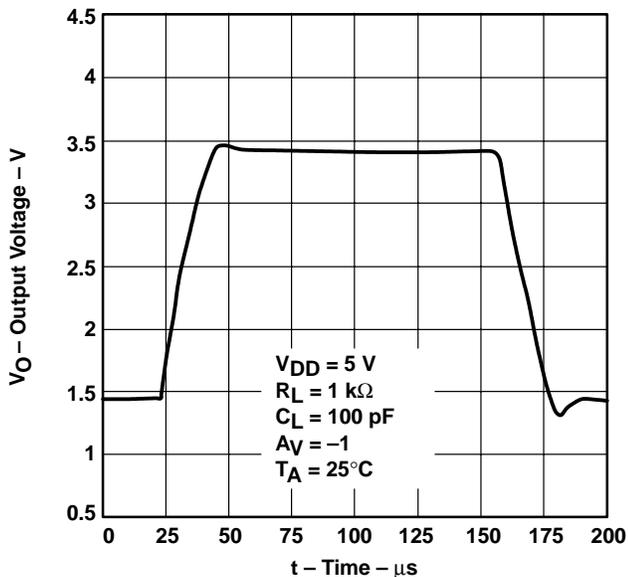


Figure 20

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

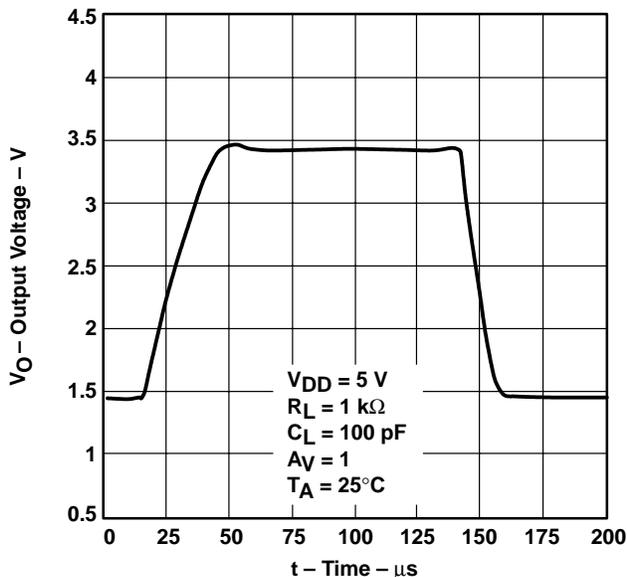


Figure 21

INVERTING SMALL-SIGNAL PULSE RESPONSE

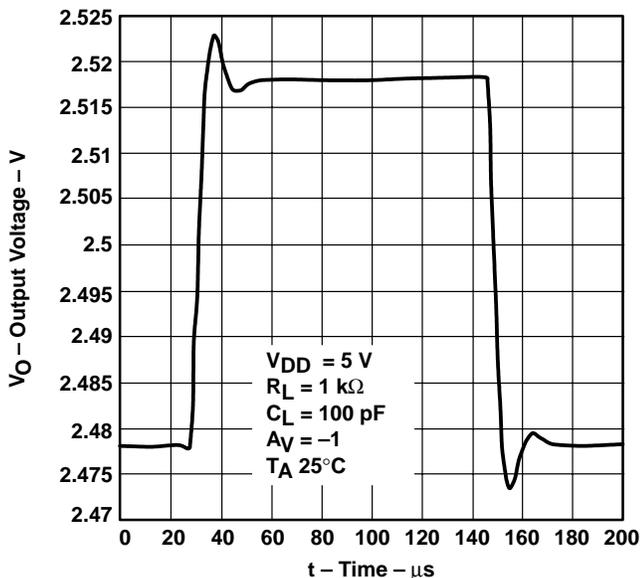


Figure 22

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

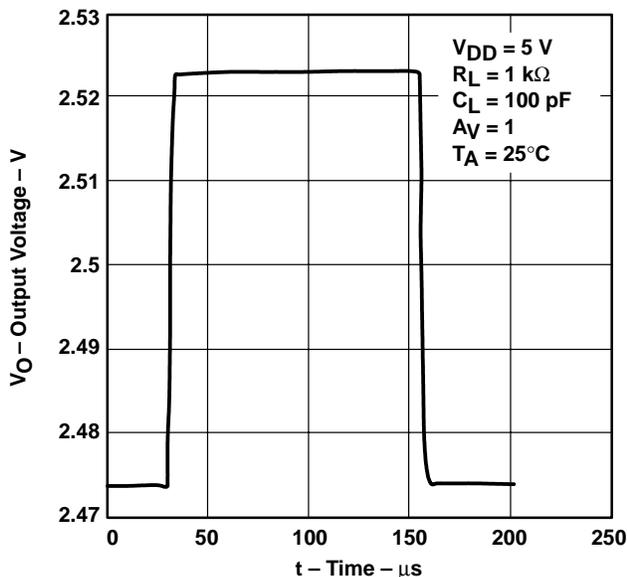


Figure 23

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

EQUIVALENT INPUT NOISE VOLTAGE  
 vs  
 FREQUENCY

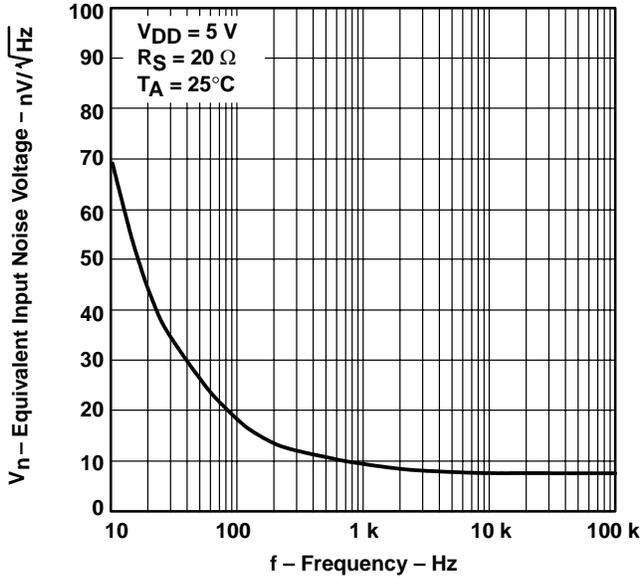


Figure 24

INPUT NOISE VOLTAGE OVER  
 A 10-SECOND PERIOD

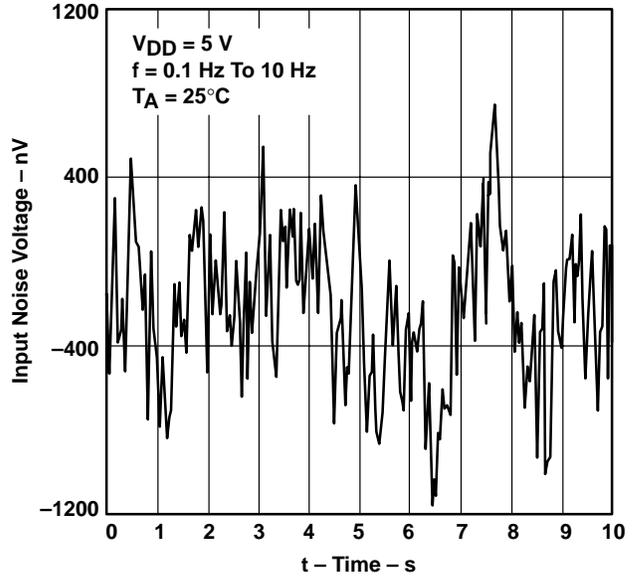


Figure 25

TOTAL HARMONIC DISTORTION PLUS NOISE  
 vs  
 FREQUENCY

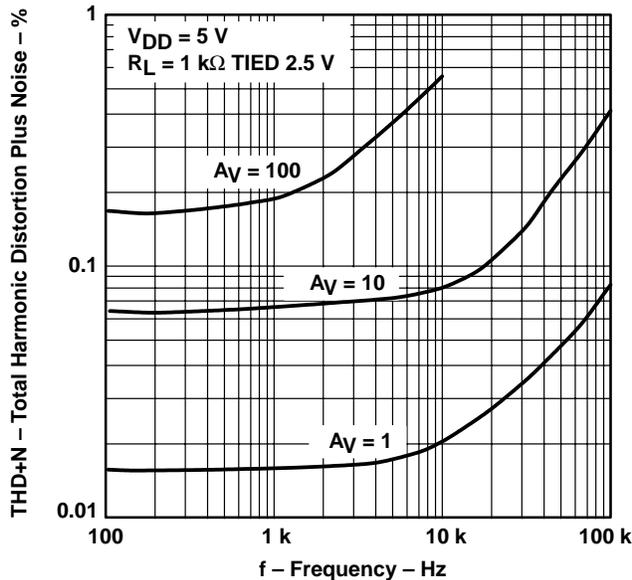


Figure 26

GAIN-BANDWIDTH PRODUCT  
 vs  
 FREE-AIR TEMPERATURE

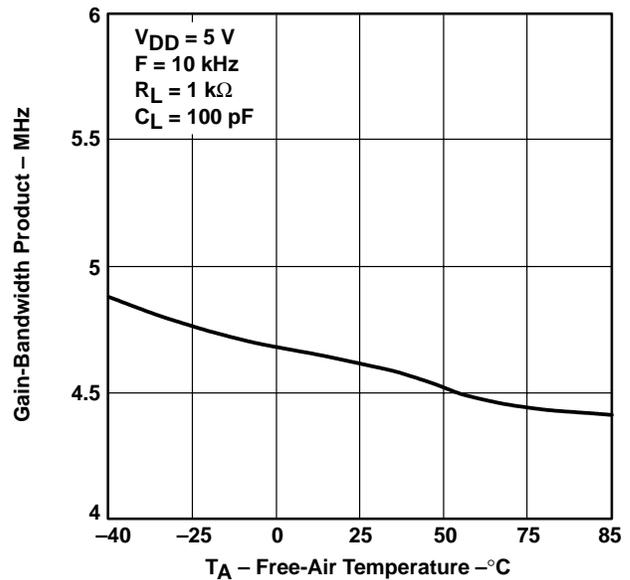


Figure 27



TYPICAL CHARACTERISTICS

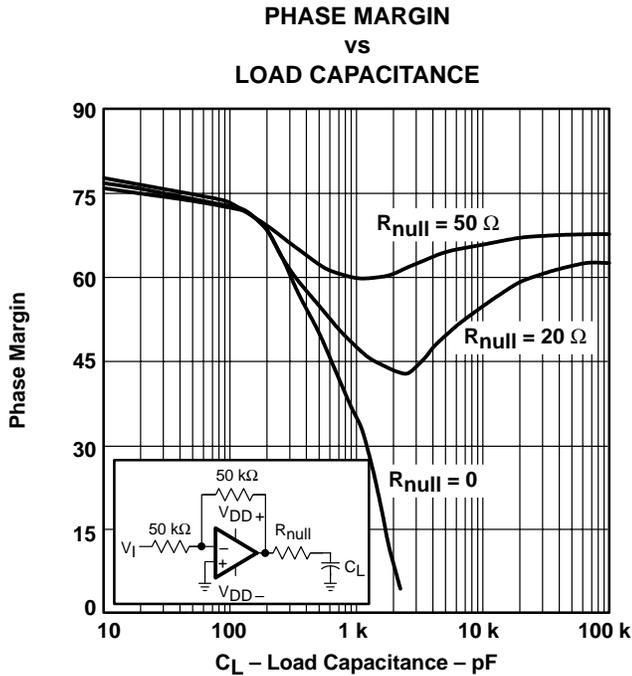


Figure 28

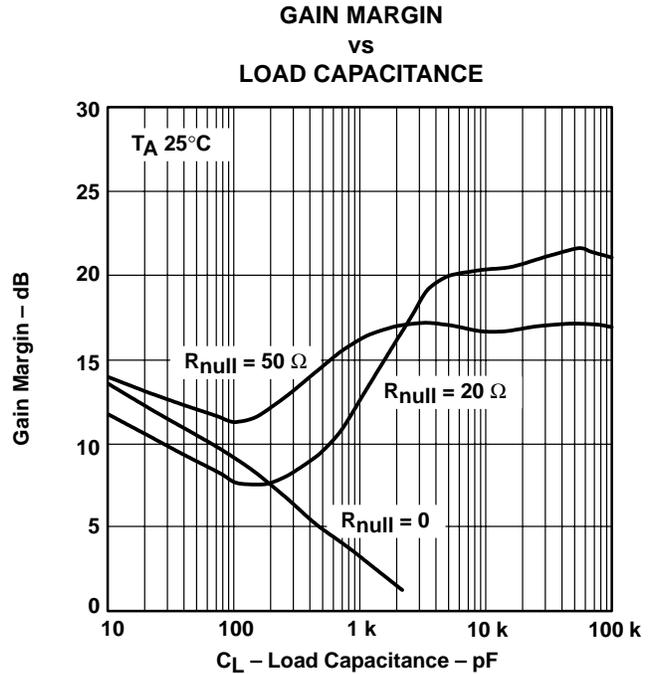


Figure 29

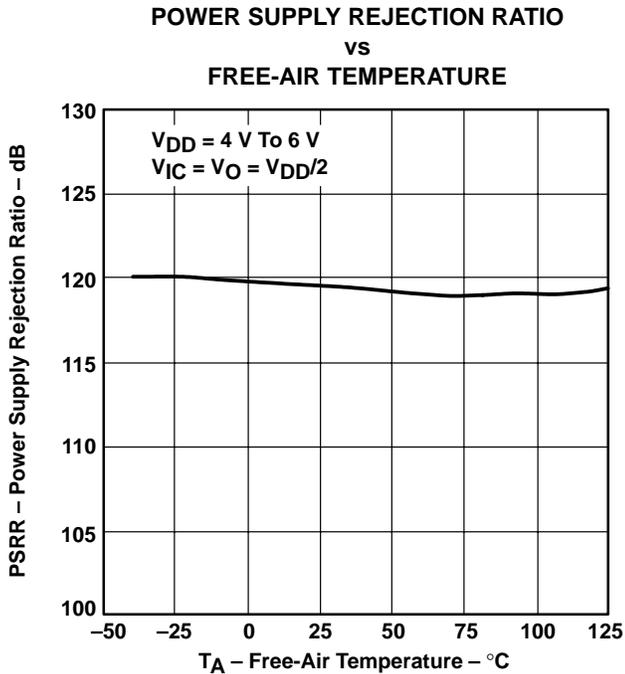


Figure 30

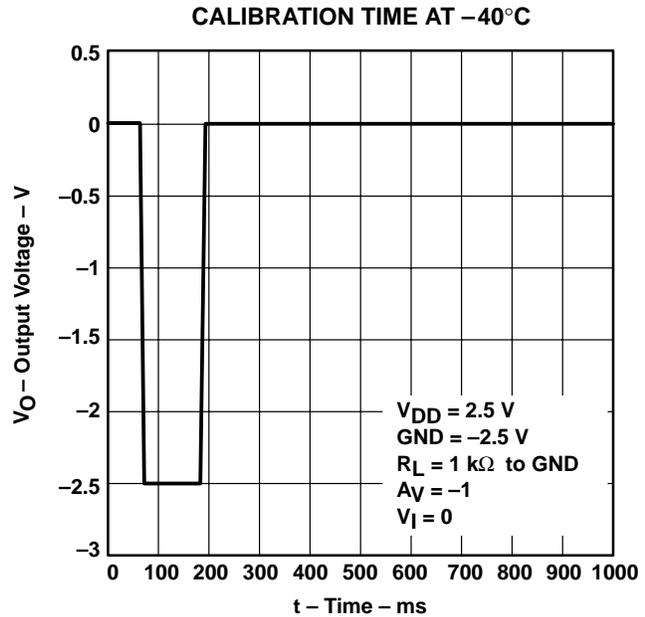


Figure 31

TYPICAL CHARACTERISTICS

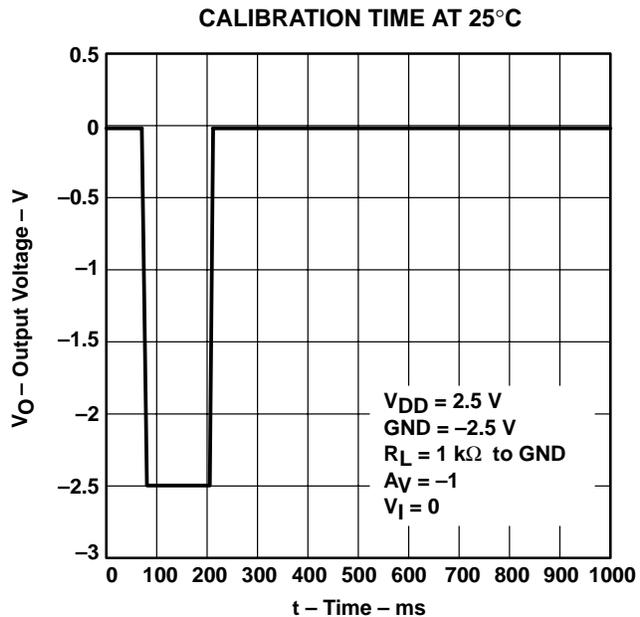


Figure 32

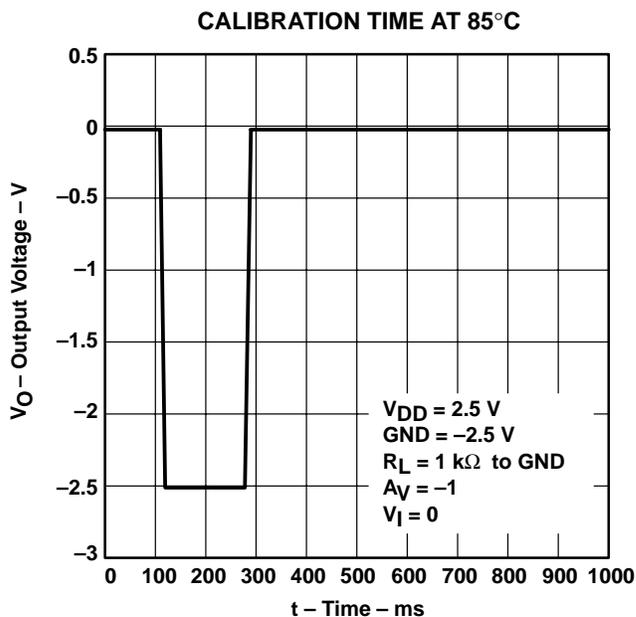


Figure 33

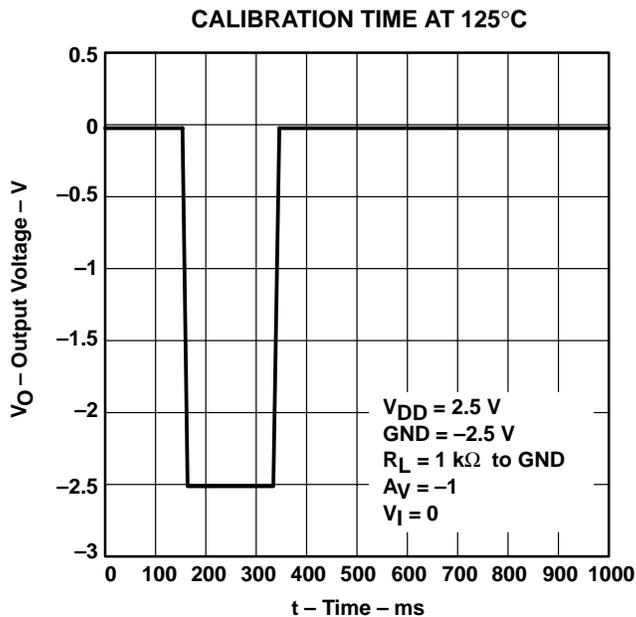


Figure 34

**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  $500\text{ pF}$  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.

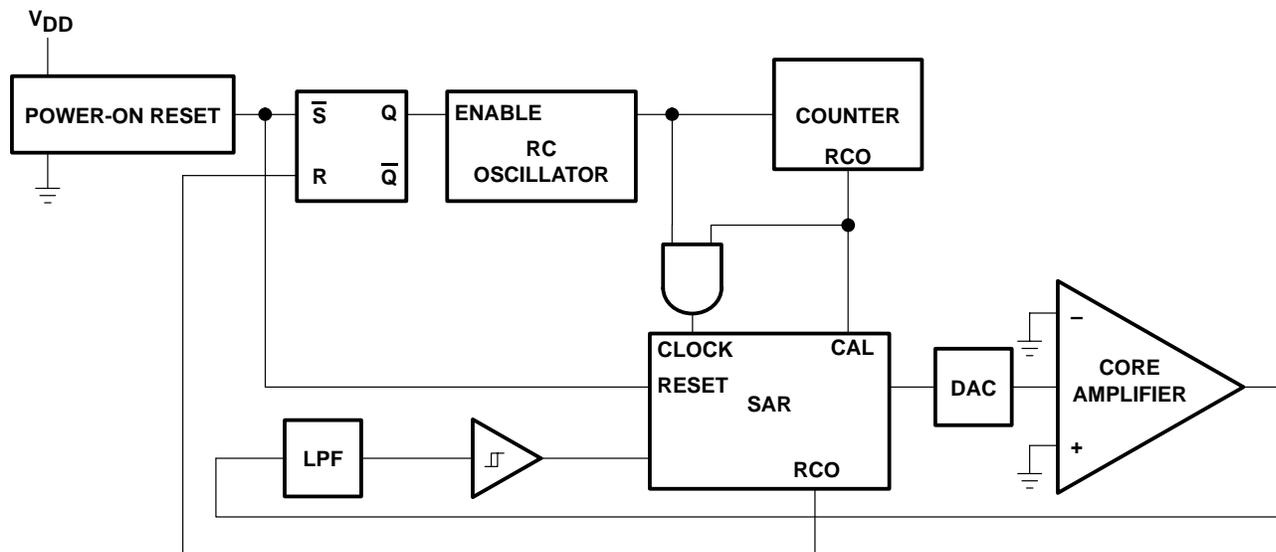
During the calibration procedure, the operational amplifier is removed from the signal path and both inputs are tied to GND. Figure 35 shows a block diagram of the amplifier during calibration mode.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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

SLOS221B – MAY 1998 – REVISED APRIL 2001



**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

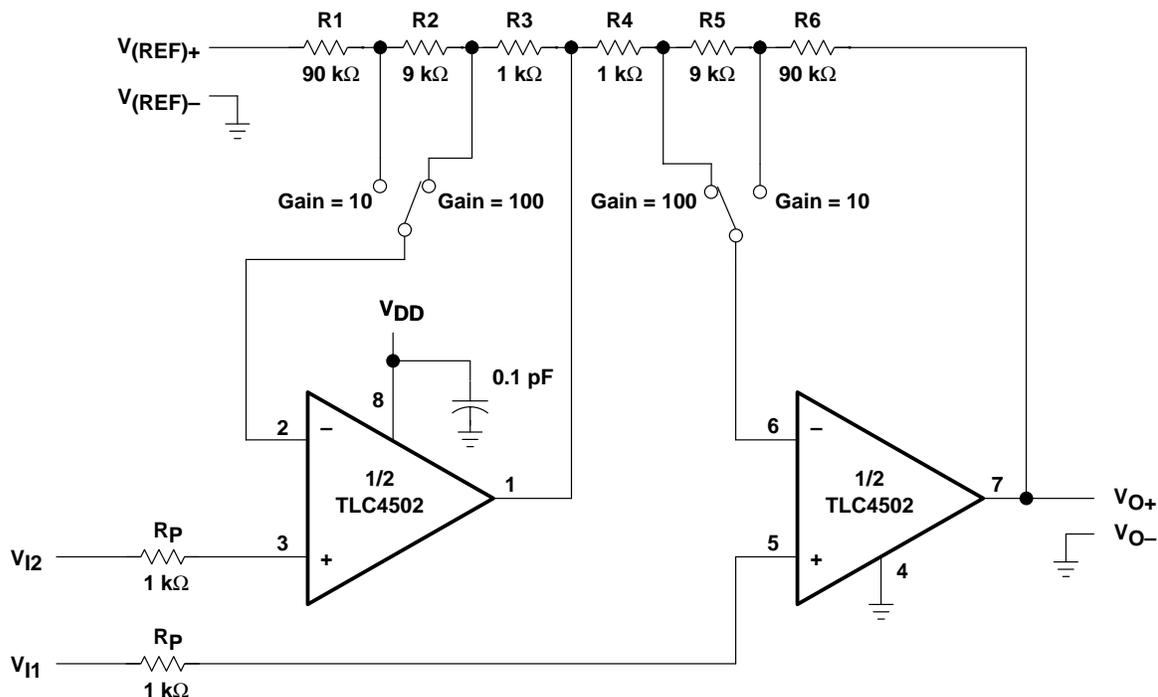
It is also ideal in circuits like:

- 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.



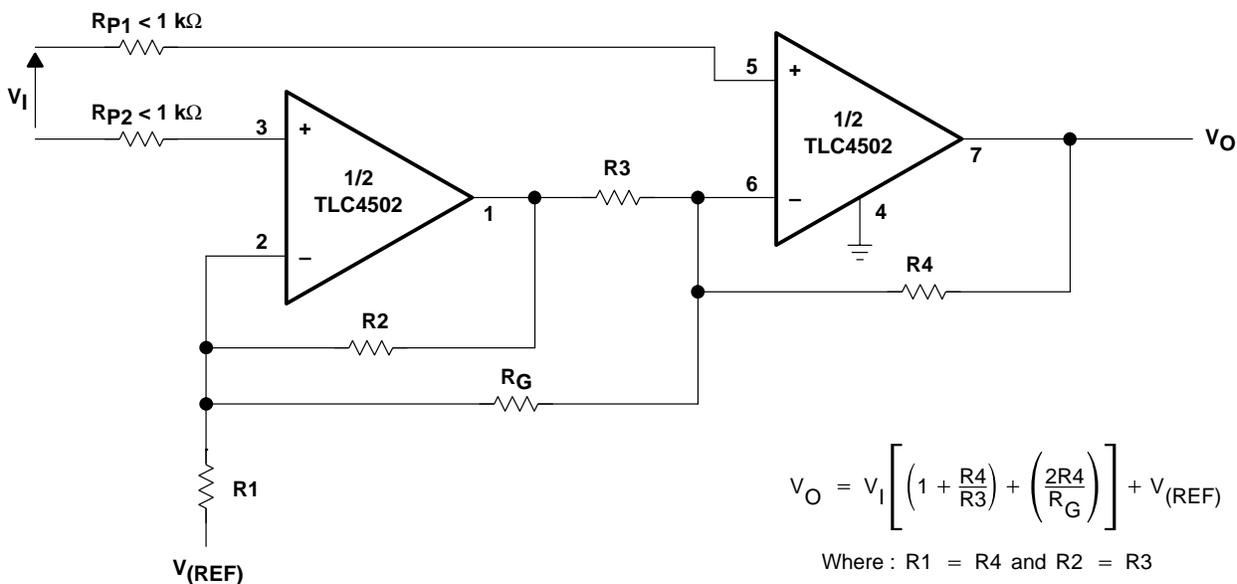
APPLICATION INFORMATION



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

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

Figure 36. Single-Supply Programmable Instrumentation Amplifier Circuit

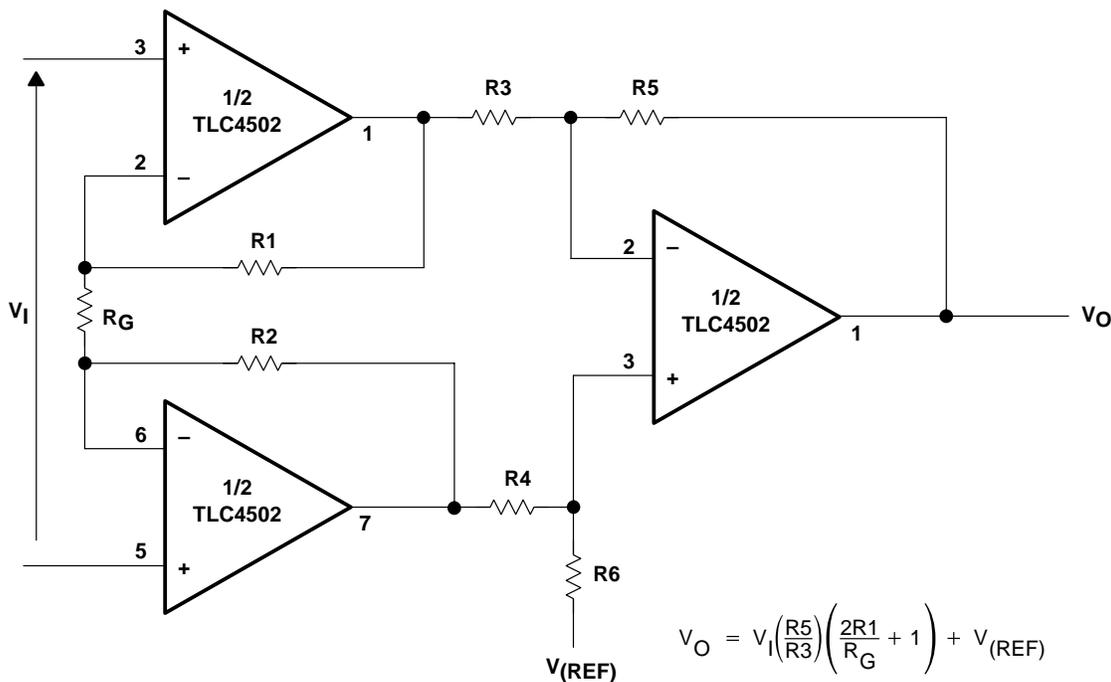


$$V_O = V_I \left[ \left( 1 + \frac{R_4}{R_3} \right) + \left( \frac{2R_4}{R_G} \right) \right] + V_{(REF)}$$

Where : R1 = R4 and R2 = R3

Figure 37. Two Operational-Amplifier Instrumentation Amplifier Circuit

APPLICATION INFORMATION



Where: R1 = R2, R3 = R4, and R5 = R6

Figure 38. Three Operational-Amplifier Instrumentation Amplifier Circuit

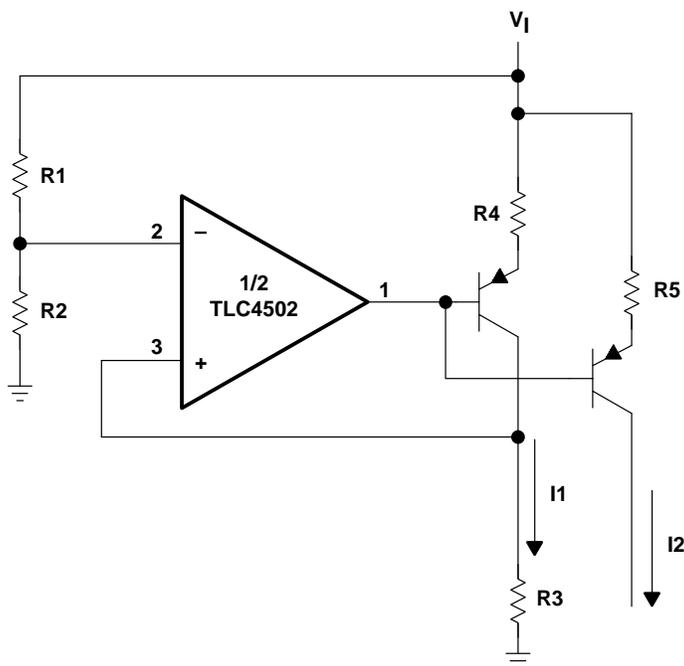


Figure 39. Fixed Current-Source Circuit

APPLICATION INFORMATION

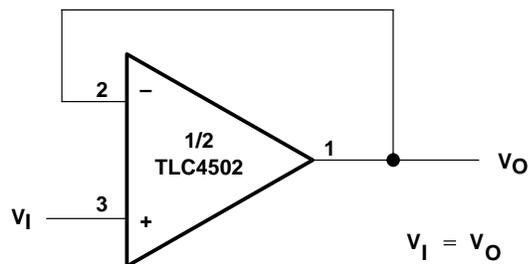


Figure 40. Voltage-Follower Circuit

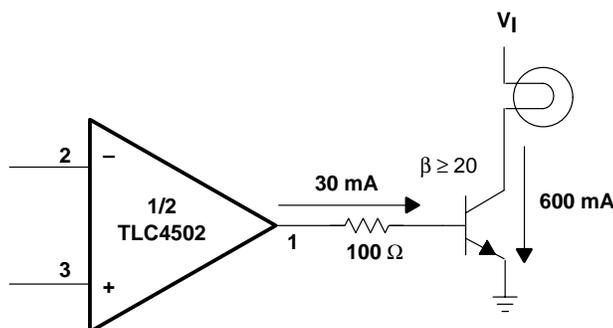


Figure 41. Lamp-Driver Circuit

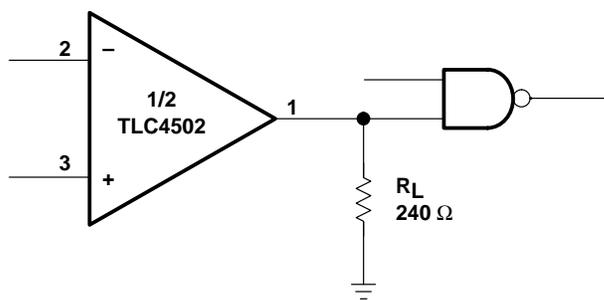


Figure 42. TTL-Driver Circuit

APPLICATION INFORMATION

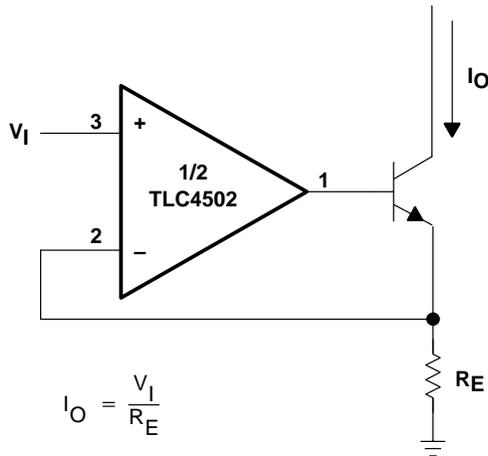


Figure 43. High-Compliance Current-Sink Circuit

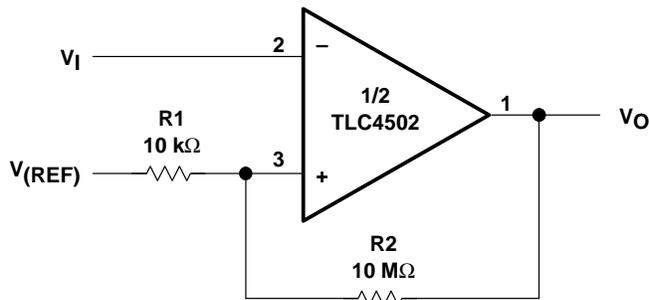


Figure 44. Comparator With Hysteresis Circuit

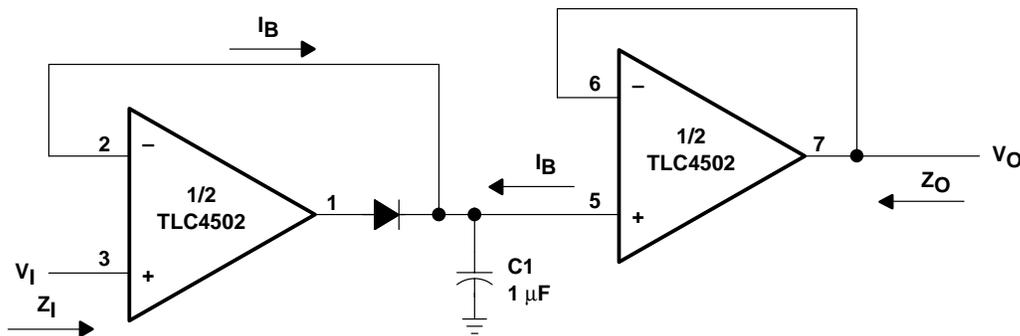


Figure 45. Low-Drift Detector Circuit



**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-9753701Q2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962-9753701Q2A TLC4502 MFKB	<a href="#">Samples</a>
5962-9753701QHA	ACTIVE	CFP	U	10	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753701QHA TLC4502M	<a href="#">Samples</a>
5962-9753701QPA	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753701QPA TLC4502M	<a href="#">Samples</a>
5962-9753702Q2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962-9753702Q2A TLC4502 AMFKB	<a href="#">Samples</a>
5962-9753702QHA	ACTIVE	CFP	U	10	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753702QHA TLC4502AM	<a href="#">Samples</a>
5962-9753702QPA	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753702QPA TLC4502AM	<a href="#">Samples</a>
TLC4501ACD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501AC	<a href="#">Samples</a>
TLC4501AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501AI	<a href="#">Samples</a>
TLC4501AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501AI	<a href="#">Samples</a>
TLC4501AQD	PREVIEW	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125		
TLC4501AQDR	PREVIEW	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125		
TLC4501CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501C	<a href="#">Samples</a>
TLC4501CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501C	<a href="#">Samples</a>
TLC4501ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501I	<a href="#">Samples</a>
TLC4501IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501I	<a href="#">Samples</a>
TLC4501IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501I	<a href="#">Samples</a>

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TLC4501IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4501I	<a href="#">Samples</a>
TLC4501QD	PREVIEW	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125		
TLC4501QDR	PREVIEW	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125		
TLC4502ACD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AC	<a href="#">Samples</a>
TLC4502ACDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AC	<a href="#">Samples</a>
TLC4502ACDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AC	<a href="#">Samples</a>
TLC4502ACDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AC	<a href="#">Samples</a>
TLC4502AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AI	<a href="#">Samples</a>
TLC4502AIDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AI	<a href="#">Samples</a>
TLC4502AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AI	<a href="#">Samples</a>
TLC4502AMD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-55 to 125	4502AM	<a href="#">Samples</a>
TLC4502AMDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502AM	<a href="#">Samples</a>
TLC4502AMFKB	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962-9753702Q2A TLC4502 AMFKB	<a href="#">Samples</a>
TLC4502AMJGB	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753702QPA TLC4502AM	<a href="#">Samples</a>
TLC4502AMUB	ACTIVE	CFP	U	10	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753702QHA TLC4502AM	<a href="#">Samples</a>
TLC4502AQD	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125	C4502A	
TLC4502AQDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		C4502A	<a href="#">Samples</a>
TLC4502AQDR	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125	C4502A	
TLC4502AQDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		C4502A	<a href="#">Samples</a>

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TLC4502CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502C	<a href="#">Samples</a>
TLC4502CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502C	<a href="#">Samples</a>
TLC4502CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502C	<a href="#">Samples</a>
TLC4502CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502C	<a href="#">Samples</a>
TLC4502ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502I	<a href="#">Samples</a>
TLC4502IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502I	<a href="#">Samples</a>
TLC4502IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502I	<a href="#">Samples</a>
TLC4502IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502I	<a href="#">Samples</a>
TLC4502MD	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI	-55 to 125	4502M	
TLC4502MDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		4502M	<a href="#">Samples</a>
TLC4502MFKB	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962- 9753701Q2A TLC4502 MFKB	<a href="#">Samples</a>
TLC4502MJG	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	TLC4502MJG	<a href="#">Samples</a>
TLC4502MJGB	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753701QPA TLC4502M	<a href="#">Samples</a>
TLC4502MUB	ACTIVE	CFP	U	10	1	TBD	A42	N / A for Pkg Type	-55 to 125	9753701QHA TLC4502M	<a href="#">Samples</a>
TLC4502QD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	C4502Q	<a href="#">Samples</a>
TLC4502QDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		C4502Q	<a href="#">Samples</a>
TLC4502QDR	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI	-40 to 125	C4502Q	
TLC4502QDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		C4502Q	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

**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](#)

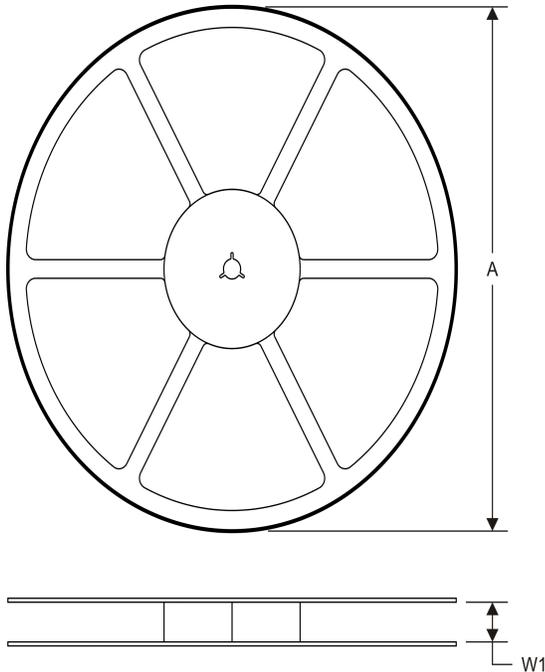
● Military: [TLC4502M](#), [TLC4502AM](#)

NOTE: Qualified Version Definitions:

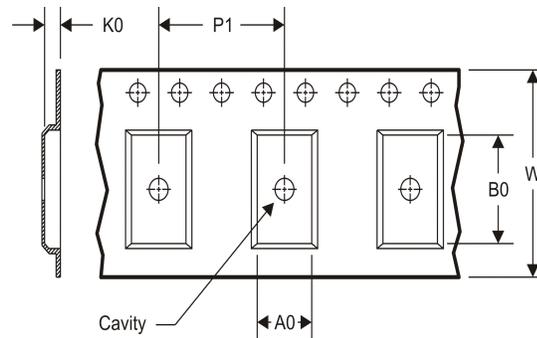
- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications

## TAPE AND REEL INFORMATION

### REEL DIMENSIONS



### TAPE DIMENSIONS

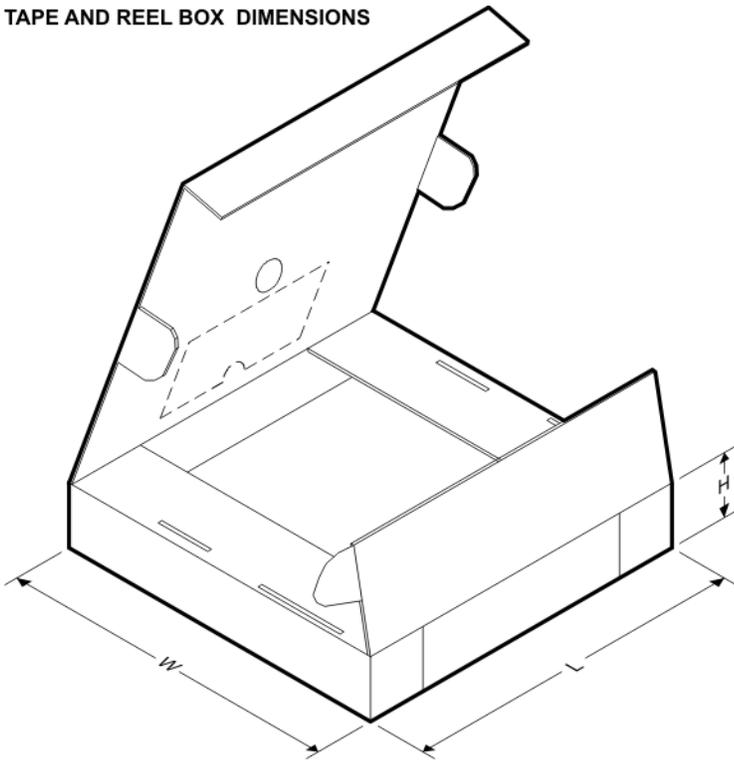


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

### 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

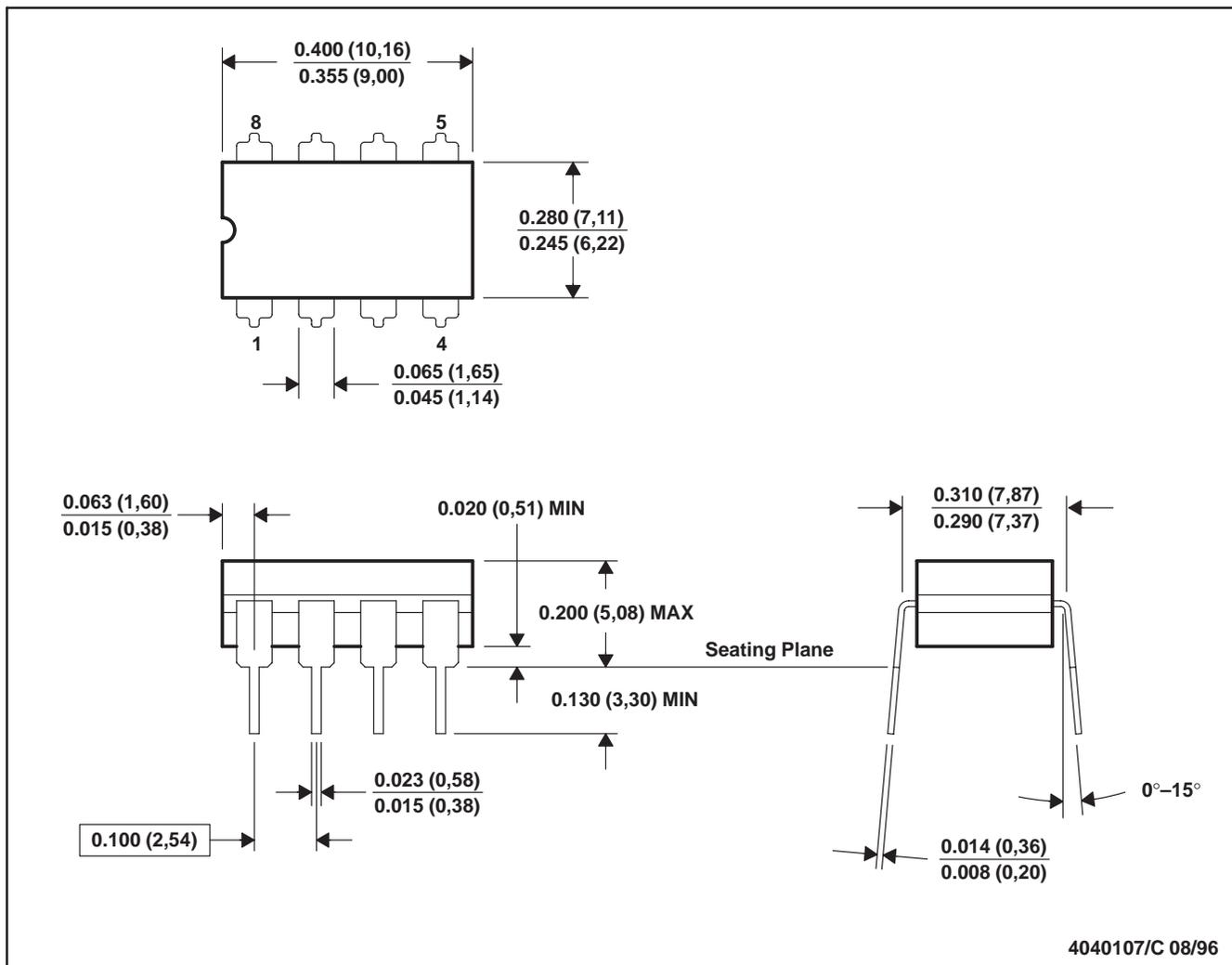
**TAPE AND REEL BOX DIMENSIONS**


\*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



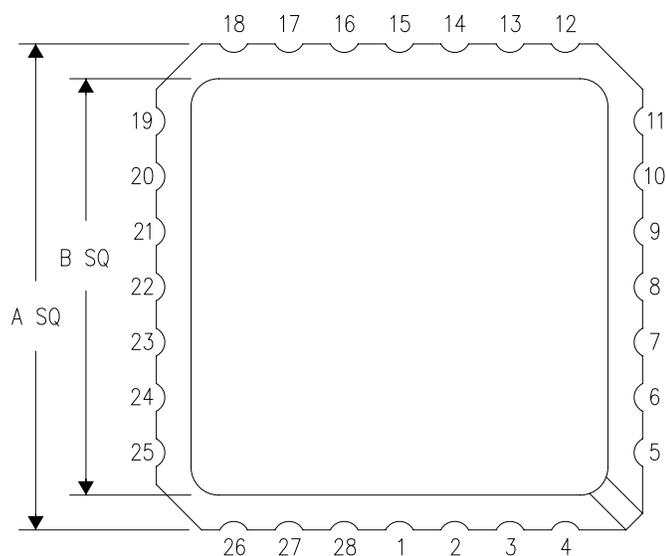
- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. This package can be hermetically sealed with a ceramic lid using glass frit.  
 D. Index point is provided on cap for terminal identification.  
 E. Falls within MIL STD 1835 GDIP1-T8



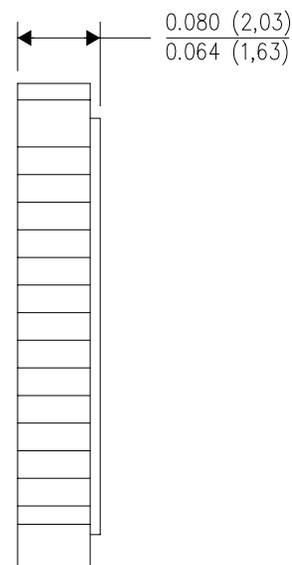
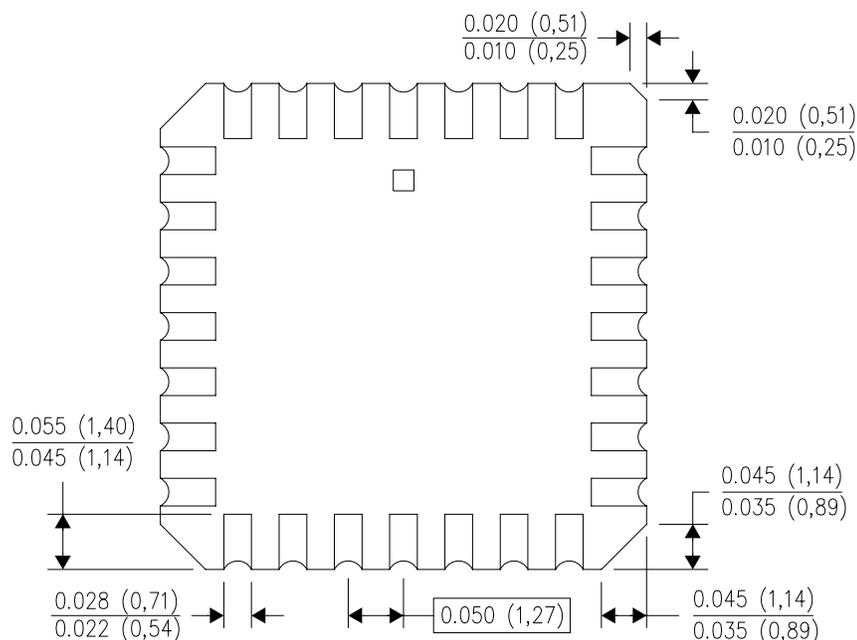
FK (S-CQCC-N\*\*)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



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



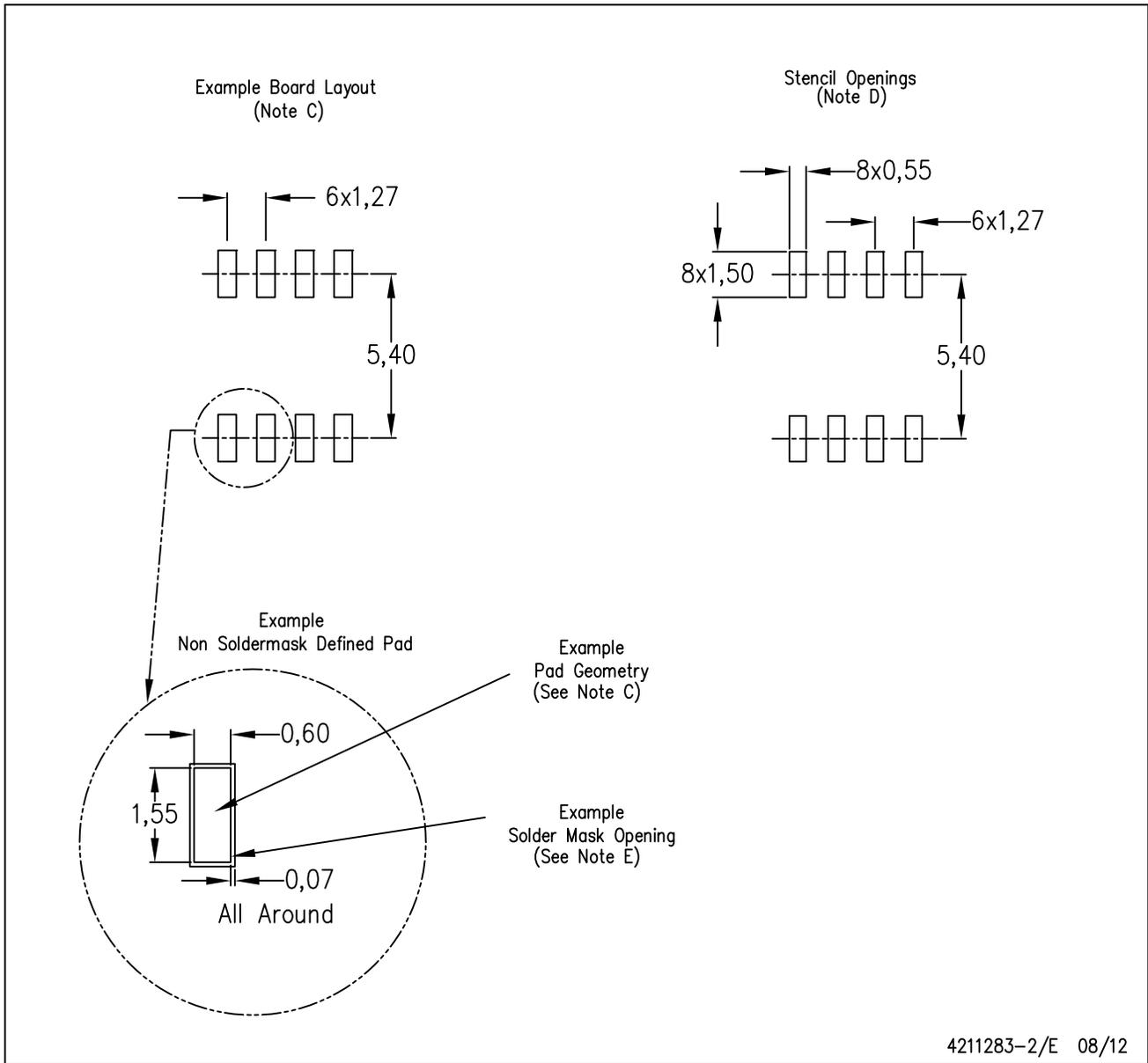
4040140/D 01/11

- 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 millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

## 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)