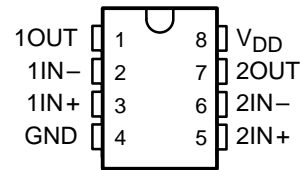
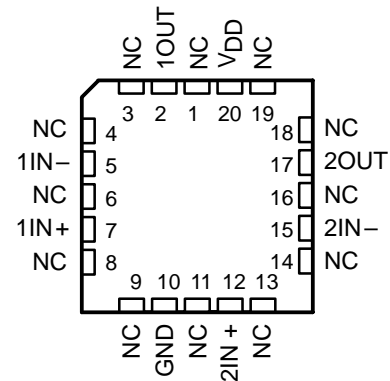


- **Trimmed Offset Voltage:**  
TLC277 . . . 500  $\mu\text{V}$  Max at 25°C,  
 $V_{\text{DD}} = 5\text{ V}$
- **Input Offset Voltage Drift . . . Typically**  
0.1  $\mu\text{V}/\text{Month}$ , Including the First 30 Days
- **Wide Range of Supply Voltages Over Specified Temperature Range:**  
0°C to 70°C . . . 3 V to 16 V  
–40°C to 85°C . . . 4 V to 16 V  
–55°C to 125°C . . . 4 V to 16 V
- **Single-Supply Operation**
- **Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix, I-Suffix types)**
- **Low Noise . . . Typically 25 nV/ $\sqrt{\text{Hz}}$  at  $f = 1\text{ kHz}$**
- **Output Voltage Range Includes Negative Rail**
- **High Input impedance . . .  $10^{12}\ \Omega$  Typ**
- **ESD-Protection Circuitry**
- **Small-Outline Package Option Also Available in Tape and Reel**
- **Designed-In Latch-Up Immunity**

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



**FK PACKAGE  
(TOP VIEW)**



NC – No internal connection

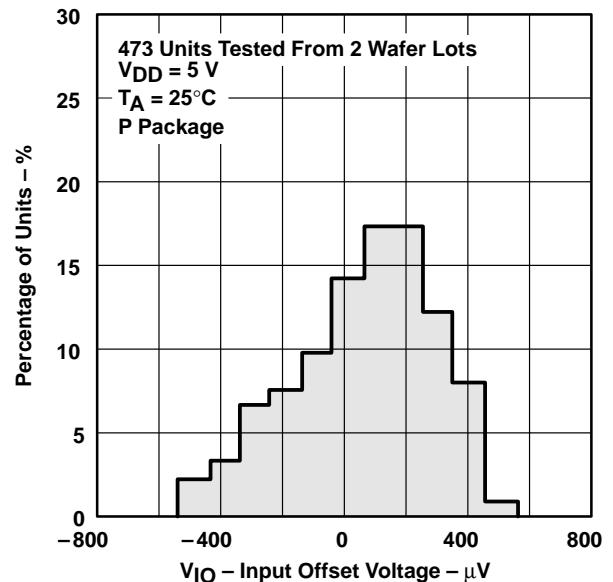
## description

The TLC272 and TLC277 precision dual operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, low noise, and speeds approaching those of general-purpose BiFET devices.

These devices use Texas Instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

The extremely high input impedance, low bias currents, and high slew rates make these cost-effective devices ideal for applications previously reserved for BiFET and NFET products. Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC272 (10 mV) to the high-precision TLC277 (500  $\mu\text{V}$ ). These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

**DISTRIBUTION OF TLC277  
INPUT OFFSET VOLTAGE**



LinCMOS is a trademark 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.



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# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

## LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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### description (continued)

AVAILABLE OPTIONS							
T <sub>A</sub>	V <sub>IO</sub> max AT 25°C	PACKAGED DEVICES					CHIP FORM (Y)
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)	
0°C to 70°C	500 µV	TLC277CD	—	—	TLC277CP	—	—
	2 mV	TLC272BCD	—	—	TLC272BCP	—	—
	5 mV	TLC272ACD	—	—	TLC272ACP	—	—
	10mV	TLC272CD	—	—	TLC272CP	TLC272CPW	TLC272Y
–40°C to 85°C	500 µV	TLC277ID	—	—	TLC277IP	—	—
	2 mV	TLC272BID	—	—	TLC272BIP	—	—
	5 mV	TLC272AID	—	—	TLC272AIP	—	—
	10 mV	TLC272ID	—	—	TLC272IP	—	—

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC277CDR).

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC272 and TLC277. The devices also exhibit low voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

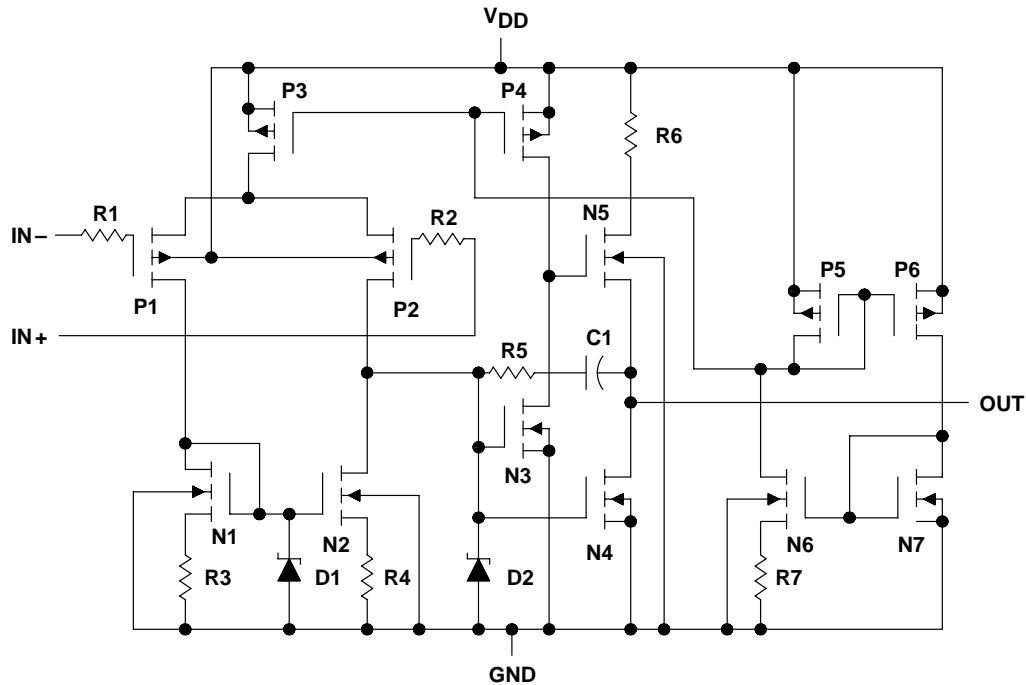
A wide range of packaging options is available, including small-outline and chip carrier versions for high-density system applications.

The device inputs and outputs are designed to withstand –100-mA surge currents without sustaining latch-up.

The TLC272 and TLC277 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

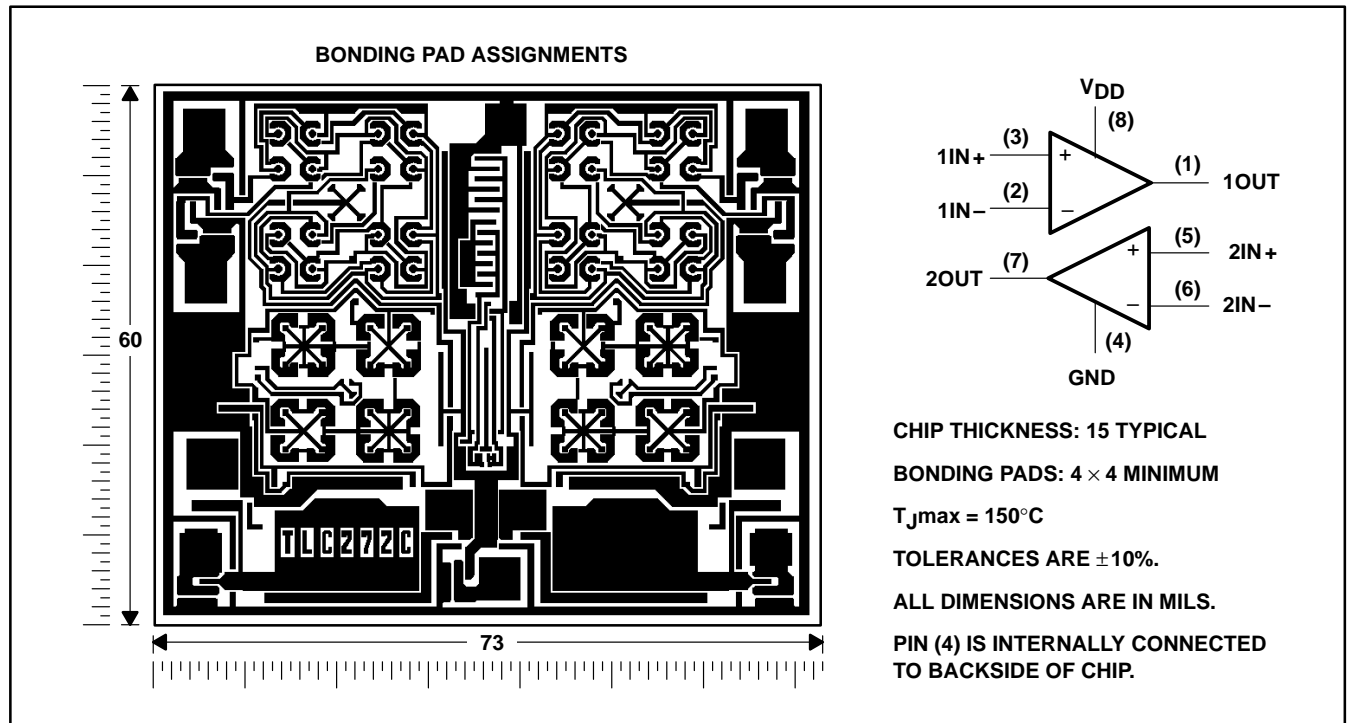
The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.

equivalent schematic (each amplifier)



### TLC272Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC272C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

## LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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

Supply voltage, $V_{DD}$ (see Note 1)	18 V
Differential input voltage, $V_{ID}$ (see Note 2)	$\pm V_{DD}$
Input voltage range, $V_I$ (any input)	-0.3 V to $V_{DD}$
Input current, $I_I$	$\pm 5$ mA
output current, $I_O$ (each output)	$\pm 30$ mA
Total current into $V_{DD}$	45 mA
Total current out of GND	45 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature, $T_A$ : C suffix	0°C to 70°C
I suffix	-40°C to 85°C
M suffix	-55°C to 125°C
Storage temperature range	-65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, P, or PW package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

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

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.  
2. Differential voltages are at  $IN+$  with respect to  $IN-$ .  
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 (see application section).

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	N/A
FK	1375 mW	11 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	N/A
PW	525 mW	4.2 mW/°C	336 mW	N/A	N/A

### recommended operating conditions

		C SUFFIX		I SUFFIX		M SUFFIX		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{DD}$		3	16	4	16	4	16	V
Common-mode input voltage, $V_{IC}$	$V_{DD} = 5$ V	-0.2	3.5	-0.2	3.5	0	3.5	V
	$V_{DD} = 10$ V	-0.2	8.5	-0.2	8.5	0	8.5	
Operating free-air temperature, $T_A$		0	70	-40	85	-55	125	°C



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# TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC272C, TLC272AC, TLC272BC, TLC277C			UNIT
					MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	TLC272C	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		1.1	10	mV
				Full range			12	
	TLC272AC	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		0.9	5	
				Full range			6.5	
	TLC272BC	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		230	2000	$\mu\text{V}$
				Full range			3000	
	TLC277C	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		200	500	
				Full range			1500	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage				25°C to 70°C		1.8		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current (see Note 4)		$V_O = 2.5\text{ V}$ , $V_{IC} = 2.5\text{ V}$		25°C		0.1	60	pA
				70°C		7	300	
$I_{IB}$ Input bias current (see Note 4)				25°C		0.6	60	pA
				70°C		40	600	
$V_{ICR}$ Common-mode input voltage range (see Note 5)				25°C	-0.2 to 4	-0.3 to 4.2		V
				Full range	-0.2 to 3.5			V
$V_{OH}$ High-level output voltage		$V_{ID} = 100\text{ mV}$ , $R_L = 10\text{ k}\Omega$		25°C	3.2	3.8		V
				0°C	3	3.8		
				70°C	3	3.8		
$V_{OL}$ Low-level output voltage		$V_{ID} = -100\text{ mV}$ , $I_{OL} = 0$		25°C		0	50	mV
				0°C		0	50	
				70°C		0	50	
$A_{VD}$ Large-signal differential voltage amplification		$V_O = 0.25\text{ V to } 2\text{ V}$ , $R_L = 10\text{ k}\Omega$		25°C		5	23	V/mV
				0°C		4	27	
				70°C		4	20	
CMRR Common-mode rejection ratio		$V_{IC} = V_{ICRmin}$		25°C		65	80	dB
				0°C		60	84	
				70°C		60	85	
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )		$V_{DD} = 5\text{ V to } 10\text{ V}$ , $V_O = 1.4\text{ V}$		25°C		65	95	dB
				0°C		60	94	
				70°C		60	96	
$I_{DD}$ Supply current (two amplifiers)		$V_O = 2.5\text{ V}$ , No load	$V_{IC} = 2.5\text{ V}$	25°C		1.4	3.2	mA
				0°C		1.6	3.6	
				70°C		1.2	2.6	

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

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

## LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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**electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		T <sub>A</sub> <sup>†</sup>	TLC272C, TLC272AC, TLC272BC, TLC277C			UNIT
					MIN	TYP	MAX	
V <sub>IO</sub>	Input offset voltage	TLC272C	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω,	V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	1.1	10	mV
					Full range		12	
		TLC272AC	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω,	V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	0.9	5	
					Full range		6.5	
		TLC272BC	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω,	V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	290	2000	μV
					Full range		3000	
		TLC277C	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω,	V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	250	800	
					Full range		1900	
α <sub>VIO</sub> Temperature coefficient of input offset voltage				25°C to 70°C	2		μV/°C	
I <sub>IO</sub> Input offset current (see Note 4)		V <sub>O</sub> = 5 V, V <sub>IC</sub> = 5 V		25°C	0.1	60	pA	
				70°C	7	300		
I <sub>IB</sub> Input bias current (see Note 4)				25°C	0.7	60	pA	
				70°C	50	600		
V <sub>ICR</sub>	Common-mode input voltage range (see Note 5)			25°C	−0.2 to 9	−0.3 to 9.2	V	
				Full range	−0.2 to 8.5		V	
V <sub>OH</sub>	High-level output voltage	V <sub>ID</sub> = 100 mV, R <sub>L</sub> = 10 kΩ		25°C	8	8.5	V	
				0°C	7.8	8.5		
				70°C	7.8	8.4		
V <sub>OL</sub>	Low-level output voltage	V <sub>ID</sub> = −100 mV, I <sub>OL</sub> = 0		25°C	0	50	mV	
				0°C	0	50		
				70°C	0	50		
A <sub>VD</sub>	Large-signal differential voltage amplification	V <sub>O</sub> = 1 V to 6 V, R <sub>L</sub> = 10 kΩ		25°C	10	36	V/mV	
				0°C	7.5	42		
				70°C	7.5	32		
CMRR	Common-mode rejection ratio	V <sub>IC</sub> = V <sub>ICRmin</sub>		25°C	65	85	dB	
				0°C	60	88		
				70°C	60	88		
k <sub>SVR</sub>	Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	V <sub>DD</sub> = 5 V to 10 V, V <sub>O</sub> = 1.4 V		25°C	65	95	dB	
				0°C	60	94		
				70°C	60	96		
I <sub>DD</sub>	Supply current (two amplifiers)	V <sub>O</sub> = 5 V, No load V <sub>IC</sub> = 5 V,		25°C	1.9	4	mA	
				0°C	2.3	4.4		
				70°C	1.6	3.4		

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

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC272I, TLC272AI, TLC272BI, TLC277I			UNIT
					MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	TLC272I	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		1.1	10	mV
				Full range			13	
	TLC272AI	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		0.9	5	
				Full range			7	
	TLC272BI	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		230	2000	$\mu\text{V}$
				Full range			3500	
	TLC277I	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ ,	$V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		200	500	
				Full range			2000	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage				25°C to 85°C		1.8		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current (see Note 4)		$V_O = 2.5\text{ V}$ ,	$V_{IC} = 2.5\text{ V}$	25°C		0.1	60	pA
				85°C		24	15	
$I_{IB}$ Input bias current (see Note 4)				25°C		0.6	60	pA
				85°C		200	35	
$V_{ICR}$ Common-mode input voltage range (see Note 5)				25°C	-0.2 to 4	-0.3 to 4.2		V
				Full range	-0.2 to 3.5			V
$V_{OH}$ High-level output voltage		$V_{ID} = 100\text{ mV}$ ,	$R_L = 10\text{ k}\Omega$	25°C		3.2	3.8	V
				-40°C		3	3.8	
				85°C		3	3.8	
$V_{OL}$ Low-level output voltage		$V_{ID} = -100\text{ mV}$ ,	$I_{OL} = 0$	25°C		0	50	mV
				-40°C		0	50	
				85°C		0	50	
$A_{VD}$ Large-signal differential voltage amplification		$V_O = 1\text{ V to }6\text{ V}$ ,	$R_L = 10\text{ k}\Omega$	25°C		5	23	V/mV
				-40°C		3.5	32	
				85°C		3.5	19	
CMRR Common-mode rejection ratio		$V_{IC} = V_{ICRmin}$		25°C		65	80	dB
				-40°C		60	81	
				85°C		60	86	
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )		$V_{DD} = 5\text{ V to }10\text{ V}$ ,	$V_O = 1.4\text{ V}$	25°C		65	95	dB
				-40°C		60	92	
				85°C		60	96	
$I_{DD}$ Supply current (two amplifiers)		$V_O = 2.5\text{ V}$ , No load	$V_{IC} = 2.5\text{ V}$	25°C		1.4	3.2	mA
				-40°C		1.9	4.4	
				85°C		1.1	2.4	

$^\dagger$  Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

## LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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**electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		T <sub>A</sub> <sup>†</sup>	TLC272I, TLC272AI, TLC272BI, TLC277I			UNIT
					MIN	TYP	MAX	
V <sub>IO</sub>	Input offset voltage	TLC272I	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω, V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	1.1	10	mV	
				Full range	13			
		TLC272AI	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω, V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	0.9	5		
				Full range	7			
		TLC272BI	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω, V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	290	2000	μV	
				Full range	3500			
		TLC277I	V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 50 Ω, V <sub>IC</sub> = 0, R <sub>L</sub> = 10 kΩ	25°C	250	800		
				Full range	2900			
α <sub>VIO</sub> Temperature coefficient of input offset voltage				25°C to 85°C	2		μV/°C	
I <sub>IO</sub>	Input offset current (see Note 4)	V <sub>O</sub> = 5 V, V <sub>IC</sub> = 5 V		25°C	0.1	60	pA	
I <sub>IB</sub>	Input bias current (see Note 4)			85°C	26	1000		
				25°C	0.7	60	pA	
				85°C	220	2000		
V <sub>ICR</sub>	Common-mode input voltage range (see Note 5)			25°C	-0.2 to 9	-0.3 to 9.2	V	
				Full range	-0.2 to 8.5		V	
V <sub>OH</sub>	High-level output voltage	V <sub>ID</sub> = 100 mV, R <sub>L</sub> = 10 kΩ		25°C	8	8.5	V	
				-40°C	7.8	8.5		
				85°C	7.8	8.5		
V <sub>OL</sub>	Low-level output voltage	V <sub>ID</sub> = -100 mV, I <sub>OL</sub> = 0		25°C	0	50	mV	
				-40°C	0	50		
				85°C	0	50		
A <sub>VD</sub>	Large-signal differential voltage amplification	V <sub>O</sub> = 1 V to 6 V, R <sub>L</sub> = 10 kΩ		25°C	10	36	V/mV	
				-40°C	7	46		
				85°C	7	31		
CMRR	Common-mode rejection ratio	V <sub>IC</sub> = V <sub>ICRmin</sub>		25°C	65	85	dB	
				-40°C	60	87		
				85°C	60	88		
k <sub>SVR</sub>	Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	V <sub>DD</sub> = 5 V to 10 V, V <sub>O</sub> = 1.4 V		25°C	65	95	dB	
				-40°C	60	92		
				85°C	60	96		
I <sub>DD</sub>	Supply current (two amplifiers)	V <sub>O</sub> = 5 V, No load V <sub>IC</sub> = 5 V,		25°C	1.4	4	mA	
				-40°C	2.8	5		
				85°C	1.5	3.2		

$^\dagger$  Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

SLOS091E – OCTOBER 1987 – REVISED FEBRUARY 2002

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

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC272M, TLC277M			UNIT
					MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	TLC272M	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ , $V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		1.1	10	mV
				Full range			12	
		TLC277M	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ , $V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		200	500	$\mu\text{V}$
				Full range			3750	
$\alpha_{VIO}$	Temperature coefficient of input offset voltage			25°C to 125°C		2.1		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current (see Note 4)	$V_O = 2.5\text{ V}$	$V_{IC} = 2.5\text{ V}$	25°C		0.1	60	pA
				125°C		1.4	15	nA
$I_{IB}$	Input bias current (see Note 4)			25°C		0.6	60	pA
				125°C		9	35	nA
$V_{ICR}$	Common-mode input voltage range (see Note 5)			25°C	0 to 4	–0.3 to 4.2		V
				Full range	0 to 3.5			V
$V_{OH}$	High-level output voltage	$V_{ID} = 100\text{ mV}$ , $R_L = 10\text{ k}\Omega$		25°C		3.2	3.8	V
				–55°C		3	3.8	
				125°C		3	3.8	
$V_{OL}$	Low-level output voltage	$V_{ID} = -100\text{ mV}$ , $I_{OL} = 0$		25°C		0	50	mV
				–55°C		0	50	
				125°C		0	50	
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 0.25\text{ V to }2\text{ V}$	$R_L = 10\text{ k}\Omega$	25°C		5	23	V/mV
				–55°C		3.5	35	
				125°C		3.5	16	
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$		25°C		65	80	dB
				–55°C		60	81	
				125°C		60	84	
$k_{SVR}$	Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ V to }10\text{ V}$ , $V_O = 1.4\text{ V}$		25°C		65	95	dB
				–55°C		60	90	
				125°C		60	97	
$I_{DD}$	Supply current (two amplifiers)	$V_O = 2.5\text{ V}$ , No load	$V_{IC} = 2.5\text{ V}$	25°C		1.4	3.2	mA
				–55°C		2	5	
				125°C		1	2.2	

$^\dagger$  Full range is –55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.  
5. This range also applies to each input individually.



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

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**electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC272M, TLC277M			UNIT
					MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	TLC272M	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ , $V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		1.1	10	mV
				Full range			12	
		TLC277M	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ , $V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$	25°C		250	800	$\mu\text{V}$
				Full range			4300	
$\alpha_{VIO}$	Temperature coefficient of input offset voltage			25°C to 125°C		2.2		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current (see Note 4)	$V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$		25°C		0.1	60	pA
				125°C		1.8	15	nA
$I_{IB}$	Input bias current (see Note 4)			25°C		0.7	60	pA
				125°C		10	35	nA
$V_{ICR}$	Common-mode input voltage range (see Note 5)			25°C	0 to 9	–0.3 to 9.2		V
				Full range	0 to 8.5			V
$V_{OH}$	High-level output voltage	$V_{ID} = 100\text{ mV}$ , $R_L = 10\text{ k}\Omega$		25°C		8	8.5	V
				–55°C		7.8	8.5	
				125°C		7.8	8.4	
$V_{OL}$	Low-level output voltage	$V_{ID} = -100\text{ mV}$ , $I_{OL} = 0$		25°C		0	50	mV
				–55°C		0	50	
				125°C		0	50	
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ V to }6\text{ V}$ , $R_L = 10\text{ k}\Omega$		25°C		10	36	V/mV
				–55°C		7	50	
				125°C		7	27	
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$		25°C		65	85	dB
				–55°C		60	87	
				125°C		60	86	
$k_{SVR}$	Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ V to }10\text{ V}$ , $V_O = 1.4\text{ V}$		25°C		65	95	dB
				–55°C		60	90	
				125°C		60	97	
$I_{DD}$	Supply current (two amplifiers)	$V_O = 5\text{ V}$ , No load $V_{IC} = 5\text{ V}$		25°C		1.9	4	mA
				–55°C		3	6	
				125°C		1.3	2.8	

$^\dagger$  Full range is –55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



**electrical characteristics,  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	TLC272Y			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ , $V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$		1.1	10	mV
$\alpha_{VIO}$ Temperature coefficient of input offset voltage			1.8		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current (see Note 4)	$V_O = 2.5\text{ V}$ , $V_{IC} = 2.5\text{ V}$	0.1			pA
$I_{IB}$ Input bias current (see Note 4)		0.6			pA
$V_{ICR}$ Common-mode input voltage range (see Note 5)		-0.2 to 4	-0.3 to 4.2		V
$V_{OH}$ High-level output voltage	$V_{ID} = 100\text{ mV}$ , $R_L = 10\text{ k}\Omega$	3.2	3.8		V
$V_{OL}$ Low-level output voltage	$V_{ID} = -100\text{ mV}$ , $I_{OL} = 0$		0	50	mV
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 0.25\text{ V to } 2\text{ V}$ , $R_L = 10\text{ k}\Omega$	5	23		V/mV
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	65	80		dB
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ V to } 10\text{ V}$ , $V_O = 1.4\text{ V}$	65	95		dB
$I_{DD}$ Supply current (two amplifiers)	$V_O = 2.5\text{ V}$ , No load $V_{IC} = 2.5\text{ V}$		1.4	3.2	mA

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.  
5. This range also applies to each input individually.

**electrical characteristics,  $V_{DD} = 10\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	TLC272Y			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$ , $V_{IC} = 0$ , $R_L = 10\text{ k}\Omega$		1.1	10	mV
$\alpha_{VIO}$ Temperature coefficient of input offset voltage			1.8		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current (see Note 4)	$V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	0.1			pA
$I_{IB}$ Input bias current (see Note 4)		0.7			pA
$V_{ICR}$ Common-mode input voltage range (see Note 5)		-0.2 to 9	-0.3 to 9.2		V
$V_{OH}$ High-level output voltage	$V_{ID} = 100\text{ mV}$ , $R_L = 10\text{ k}\Omega$	8	8.5		V
$V_{OL}$ Low-level output voltage	$V_{ID} = -100\text{ mV}$ , $I_{OL} = 0$		0	50	mV
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 1\text{ V to } 6\text{ V}$ , $R_L = 10\text{ k}\Omega$	10	36		V/mV
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	65	85		dB
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ V to } 10\text{ V}$ , $V_O = 1.4\text{ V}$	65	95		dB
$I_{DD}$ Supply current (two amplifiers)	$V_O = 5\text{ V}$ , No load $V_{IC} = 5\text{ V}$		1.9	4	mA

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.  
5. This range also applies to each input individually.

# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

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### operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS		$T_A$	TLC272C, TLC272AC, TLC272BC, TLC277C			UNIT
				MIN	TYP	MAX	
SR      Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 20\text{ pF}$ , See Figure 1	$V_{I\text{PP}} = 1\text{ V}$	25°C		3.6		V/ $\mu\text{s}$
			0°C		4		
			70°C		3		
		$V_{I\text{PP}} = 2.5\text{ V}$	25°C		2.9		
			0°C		3.1		
			70°C		2.5		
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , See Figure 2	$R_S = 20\text{ }\Omega$ ,	25°C		25		nV/ $\sqrt{\text{Hz}}$
$B_{OM}$ Maximum output-swing bandwidth	$V_O = V_{OH}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ , See Figure 1	25°C		320		kHz
			0°C		340		
			70°C		260		
$B_1$ Unity-gain bandwidth	$V_I = 10\text{ mV}$ , See Figure 3	$C_L = 20\text{ pF}$ ,	25°C		1.7		MHz
			0°C		2		
			70°C		1.3		
$\phi_m$ Phase margin	$V_I = 10\text{ mV}$ , $C_L = 20\text{ pF}$ ,	$f = B_1$ , See Figure 3	25°C		46°		
			0°C		47°		
			70°C		43°		

### operating characteristics at specified free-air temperature, $V_{DD} = 10\text{ V}$

PARAMETER	TEST CONDITIONS		$T_A$	TLC272C, TLC272AC, TLC272BC, TLC277C			UNIT
				MIN	TYP	MAX	
SR      Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 20\text{ pF}$ , See Figure 1	$V_{I\text{PP}} = 1\text{ V}$	25°C		5.3		V/ $\mu\text{s}$
			0°C		5.9		
			70°C		4.3		
		$V_{I\text{PP}} = 5.5\text{ V}$	25°C		4.6		
			0°C		5.1		
			70°C		3.8		
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , See Figure 2	$R_S = 20\text{ }\Omega$ ,	25°C		25		nV/ $\sqrt{\text{Hz}}$
$B_{OM}$ Maximum output-swing bandwidth	$V_O = V_{OH}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ , See Figure 1	25°C		200		kHz
			0°C		220		
			70°C		140		
$B_1$ Unity-gain bandwidth	$V_I = 10\text{ mV}$ , See Figure 3	$C_L = 20\text{ pF}$ ,	25°C		2.2		MHz
			0°C		2.5		
			70°C		1.8		
$\phi_m$ Phase margin	$V_I = 10\text{ mV}$ , $C_L = 20\text{ pF}$ ,	$f = B_1$ , See Figure 3	25°C		49°		
			0°C		50°		
			70°C		46°		



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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**operating characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$**

PARAMETER	TEST CONDITIONS		$T_A$	TLC272I, TLC272AI, TLC272BI, TLC277I			UNIT
				MIN	TYP	MAX	
SR      Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 20\text{ pF}$ , See Figure 1	$V_{I\text{PP}} = 1\text{ V}$	25°C		3.6		V/ $\mu\text{s}$
			–40°C		4.5		
			85°C		2.8		
		$V_{I\text{PP}} = 2.5\text{ V}$	25°C		2.9		
			–40°C		3.5		
			85°C		2.3		
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , See Figure 2	$R_S = 20\text{ }\Omega$ ,	25°C		25		nV/ $\sqrt{\text{Hz}}$
$B_{OM}$ Maximum output-swing bandwidth	$V_O = V_{OH}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ , See Figure 1	25°C		320		kHz
			–40°C		380		
			85°C		250		
$B_1$ Unity-gain bandwidth	$V_I = 10\text{ mV}$ , See Figure 3	$C_L = 20\text{ pF}$ ,	25°C		1.7		MHz
			–40°C		2.6		
			85°C		1.2		
$\phi_m$ Phase margin	$V_I = 10\text{ mV}$ , $C_L = 20\text{ pF}$ ,	$f = B_1$ , See Figure 3	25°C		46°		
			–40°C		49°		
			85°C		43°		

**operating characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$**

PARAMETER	TEST CONDITIONS		$T_A$	TLC272I, TLC272AI, TLC272BI, TLC277I			UNIT
				MIN	TYP	MAX	
SR      Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 20\text{ pF}$ , See Figure 1	$V_{I\text{PP}} = 1\text{ V}$	25°C		5.3		V/ $\mu\text{s}$
			–40°C		6.8		
			85°C		4		
		$V_{I\text{PP}} = 5.5\text{ V}$	25°C		4.6		
			–40°C		5.8		
			85°C		3.5		
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , See Figure 2	$R_S = 20\text{ }\Omega$ ,	25°C		25		nV/ $\sqrt{\text{Hz}}$
$B_{OM}$ Maximum output-swing bandwidth	$V_O = V_{OH}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ , See Figure 1	25°C		200		kHz
			–40°C		260		
			85°C		130		
$B_1$ Unity-gain bandwidth	$V_I = 10\text{ mV}$ , See Figure 3	$C_L = 20\text{ pF}$ ,	25°C		2.2		MHz
			–40°C		3.1		
			85°C		1.7		
$\phi_m$ Phase margin	$V_I = 10\text{ mV}$ , $C_L = 20\text{ pF}$ ,	$f = B_1$ , See Figure 3	25°C		49°		
			–40°C		52°		
			85°C		46°		



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

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### operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A$	TLC272M, TLC277M			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 20\text{ pF}$ , See Figure 1	$V_{I\text{PP}} = 1\text{ V}$	25°C	3.6		V/ $\mu\text{s}$
			–55°C	4.7		
			125°C	2.3		
		$V_{I\text{PP}} = 2.5\text{ V}$	25°C	2.9		
			–55°C	3.7		
			125°C	2		
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , See Figure 2	$R_S = 20\text{ }\Omega$	25°C	25		nV/ $\sqrt{\text{Hz}}$
$B_{OM}$ Maximum output-swing bandwidth	$V_O = V_{OH}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ , See Figure 1	25°C	320		kHz
			–55°C	400		
			125°C	230		
$B_1$ Unity-gain bandwidth	$V_I = 10\text{ mV}$ , See Figure 3	$C_L = 20\text{ pF}$	25°C	1.7		MHz
			–55°C	2.9		
			125°C	1.1		
$\phi_m$ Phase margin	$V_I = 10\text{ mV}$ , $C_L = 20\text{ pF}$ , See Figure 3	$f = B_1$ , See Figure 3	25°C	46°		
			–55°C	49°		
			125°C	41°		

### operating characteristics at specified free-air temperature, $V_{DD} = 10\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A$	TLC272M, TLC277M			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 20\text{ pF}$ , See Figure 1	$V_{I\text{PP}} = 1\text{ V}$	25°C	5.3		V/ $\mu\text{s}$
			–55°C	7.1		
			125°C	3.1		
		$V_{I\text{PP}} = 5.5\text{ V}$	25°C	4.6		
			–55°C	6.1		
			125°C	2.7		
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , See Figure 2	$R_S = 20\text{ }\Omega$	25°C	25		nV/ $\sqrt{\text{Hz}}$
$B_{OM}$ Maximum output-swing bandwidth	$V_O = V_{OH}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ , See Figure 1	25°C	200		kHz
			–55°C	280		
			125°C	110		
$B_1$ Unity-gain bandwidth	$V_I = 10\text{ mV}$ , See Figure 3	$C_L = 20\text{ pF}$	25°C	2.2		MHz
			–55°C	3.4		
			125°C	1.6		
$\phi_m$ Phase margin	$V_I = 10\text{ mV}$ , $C_L = 20\text{ pF}$ , See Figure 3	$f = B_1$ , See Figure 3	25°C	49°		
			–55°C	52°		
			125°C	44°		



# TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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## operating characteristics, $V_{DD} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS			TLC272Y			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ ,	$V_{I\text{PP}} = 1\text{ V}$		3.6		$\text{V}/\mu\text{s}$
				$V_{I\text{PP}} = 2.5\text{ V}$		2.9		
$V_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$ ,	$R_S = 20\text{ }\Omega$ ,	See Figure 2		25		$\text{nV}/\sqrt{\text{Hz}}$
$B_{OM}$	Maximum output-swing bandwidth	$V_O = V_{OH}$ , See Figure 1	$C_L = 20\text{ pF}$ ,	$R_L = 10\text{ k}\Omega$ ,		320		$\text{kHz}$
$B_1$	Unity-gain bandwidth	$V_I = 10\text{ mV}$ ,	$C_L = 20\text{ pF}$ ,	See Figure 3		1.7		$\text{MHz}$
$\phi_m$	Phase margin	$V_I = 10\text{ mV}$ , See Figure 3	$f = B_1$ ,	$C_L = 20\text{ pF}$ ,		46°		

## operating characteristics, $V_{DD} = 10\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS			TLC272Y			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$R_L = 10\text{ k}\Omega$ , See Figure 1	$C_L = 20\text{ pF}$ ,	$V_{I\text{PP}} = 1\text{ V}$		5.3		$\text{V}/\mu\text{s}$
				$V_{I\text{PP}} = 5.5\text{ V}$		4.6		
$V_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$ ,	$R_S = 20\text{ }\Omega$ ,	See Figure 2		25		$\text{nV}/\sqrt{\text{Hz}}$
$B_{OM}$	Maximum output-swing bandwidth	$V_O = V_{OH}$ , See Figure 1	$C_L = 20\text{ pF}$ ,	$R_L = 10\text{ k}\Omega$ ,		200		$\text{kHz}$
$B_1$	Unity-gain bandwidth	$V_I = 10\text{ mV}$ ,	$C_L = 20\text{ pF}$ ,	See Figure 3		2.2		$\text{MHz}$
$\phi_m$	Phase margin	$V_I = 10\text{ mV}$ , See Figure 3	$f = B_1$ ,	$C_L = 20\text{ pF}$ ,		49°		



## PARAMETER MEASUREMENT INFORMATION

### single-supply versus split-supply test circuits

Because the TLC272 and TLC277 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

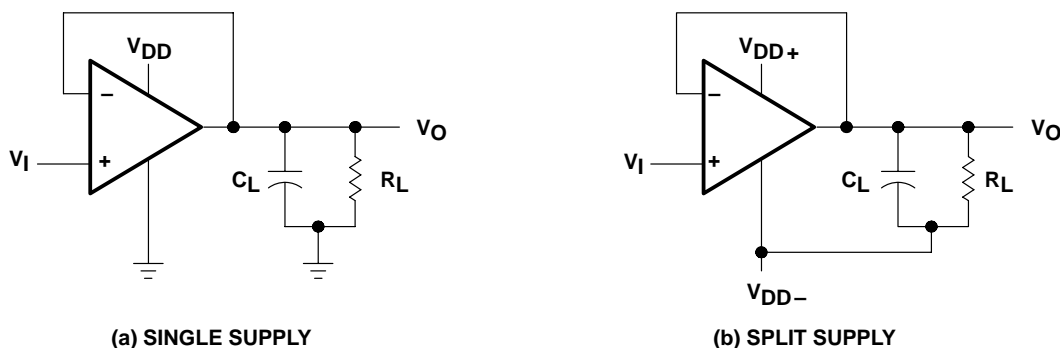


Figure 1. Unity-Gain Amplifier

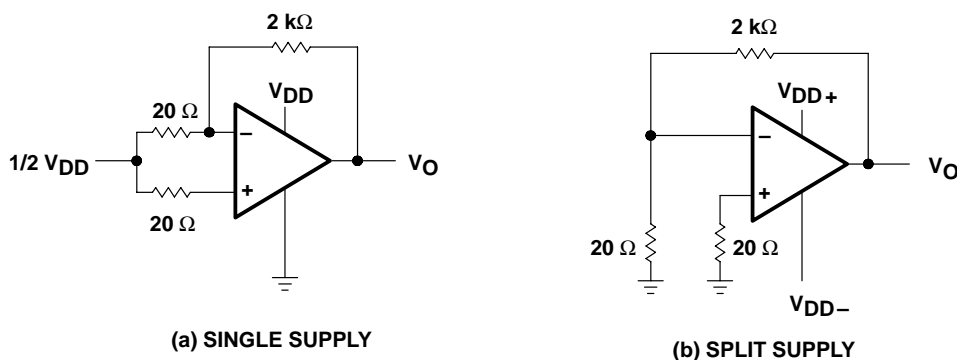


Figure 2. Noise-Test Circuit

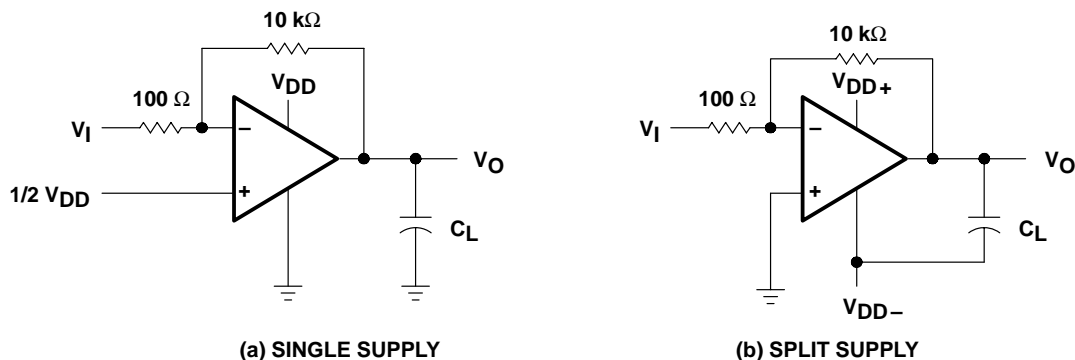


Figure 3. Gain-of-100 Inverting Amplifier

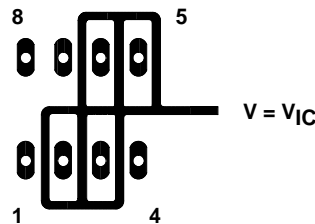
## PARAMETER MEASUREMENT INFORMATION

### input bias current

Because of the high input impedance of the TLC272 and TLC277 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
2. Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.



**Figure 4. Isolation Metal Around Device Inputs  
(JG and P packages)**

### low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

### input offset voltage temperature coefficient

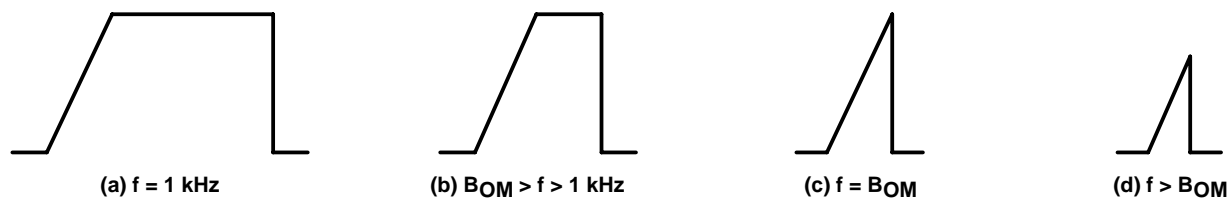
Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.

## PARAMETER MEASUREMENT INFORMATION

### full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.



**Figure 5. Full-Power-Response Output Signal**

### test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

## TYPICAL CHARACTERISTICS

**Table of Graphs**

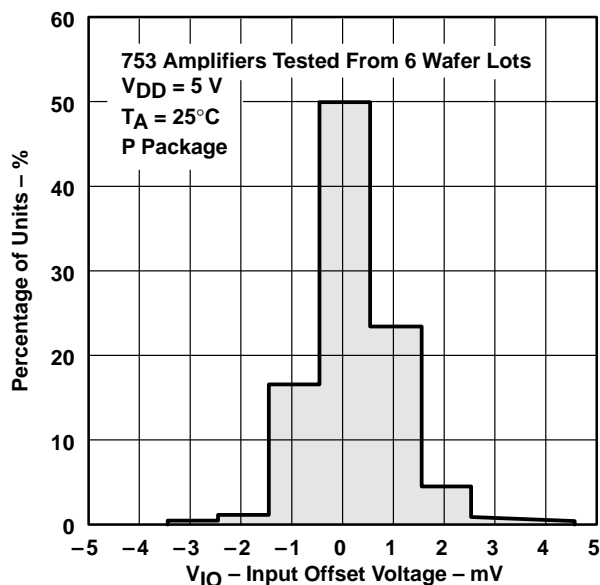
			<b>FIGURE</b>
$V_{IO}$	Input offset voltage	Distribution	6, 7
$\alpha_{VIO}$	Temperature coefficient of input offset voltage	Distribution	8, 9
$V_{OH}$	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
$V_{OL}$	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
$A_{VD}$	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 21 32, 33
$I_{IB}$	Input bias current	vs Free-air temperature	22
$I_{IO}$	Input offset current	vs Free-air temperature	22
$V_{IC}$	Common-mode input voltage	vs Supply voltage	23
$I_{DD}$	Supply current	vs Supply voltage vs Free-air temperature	24 25
$SR$	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	29
$B_1$	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
$\phi_m$	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	34 35 36
$V_n$	Equivalent input noise voltage	vs Frequency	37
	Phase shift	vs Frequency	32, 33

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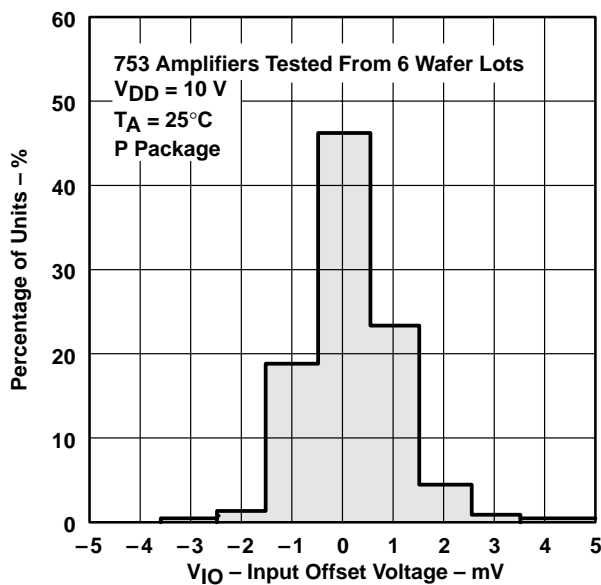
## TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLC272  
INPUT OFFSET VOLTAGE**



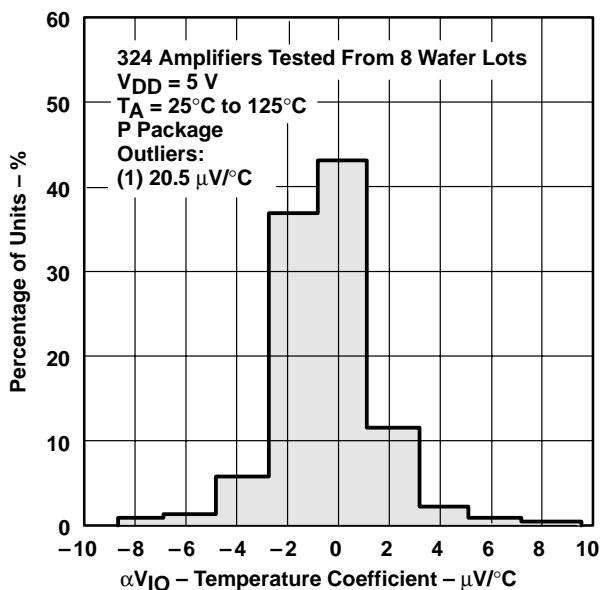
**Figure 6**

**DISTRIBUTION OF TLC272  
INPUT OFFSET VOLTAGE**



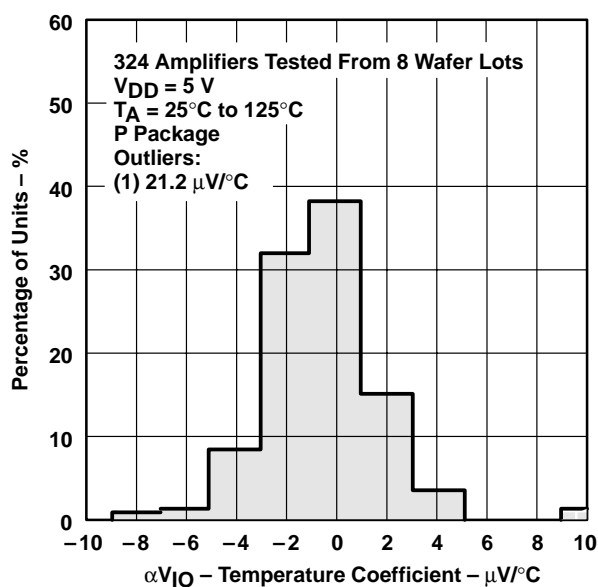
**Figure 7**

**DISTRIBUTION OF TLC272 AND TLC277  
INPUT OFFSET VOLTAGE  
TEMPERATURE COEFFICIENT**



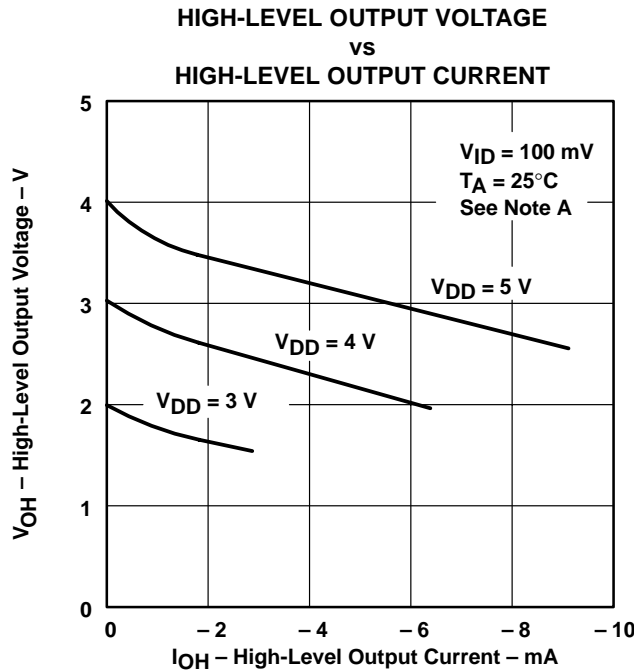
**Figure 8**

**DISTRIBUTION OF TLC272 AND TLC277  
INPUT OFFSET VOLTAGE  
TEMPERATURE COEFFICIENT**



**Figure 9**

# TYPICAL CHARACTERISTICS†



NOTE A: The 3-V curve only applies to the C version.

Figure 10

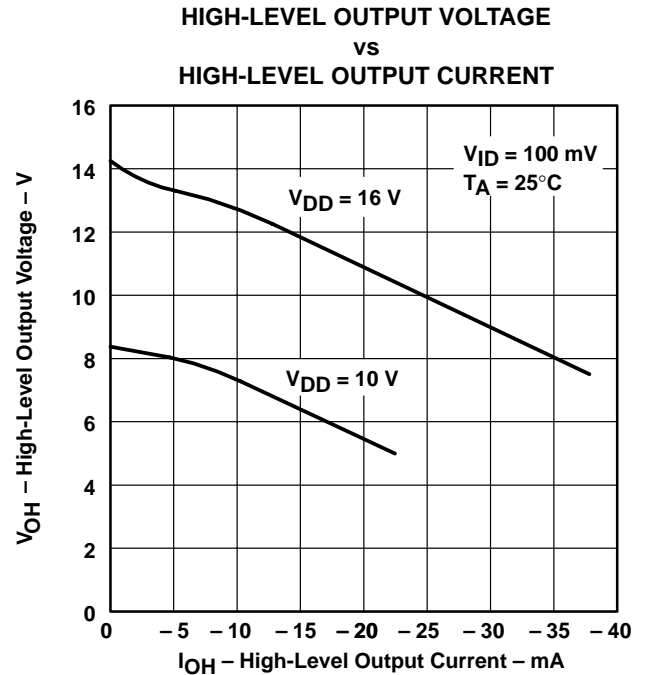


Figure 11

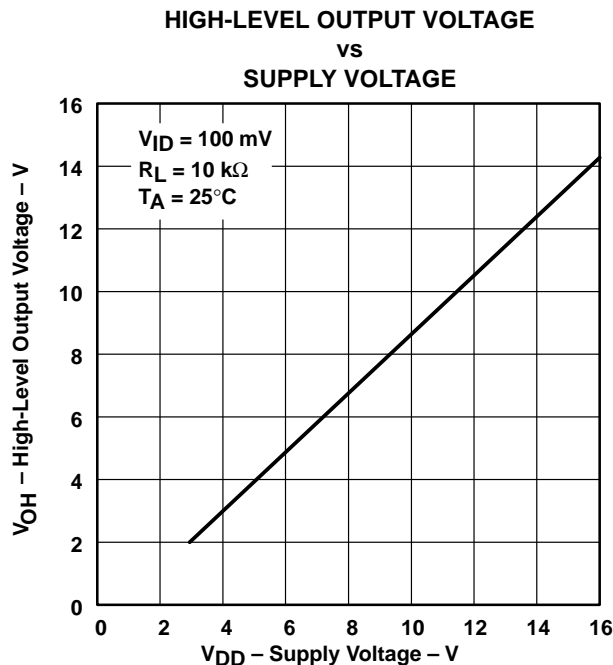


Figure 12

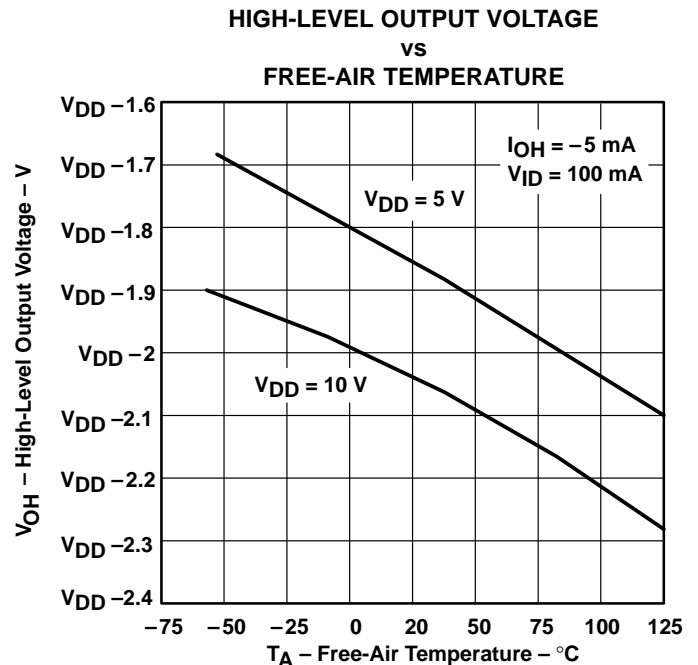


Figure 13

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

# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

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### TYPICAL CHARACTERISTICS†

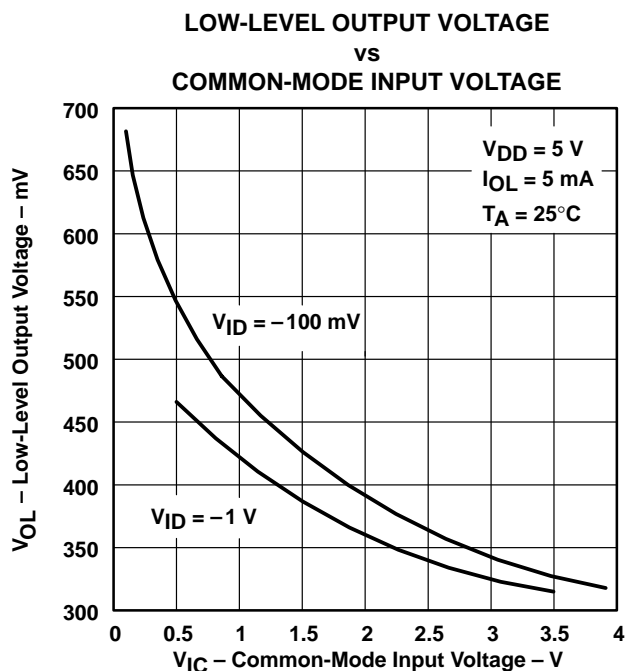


Figure 14

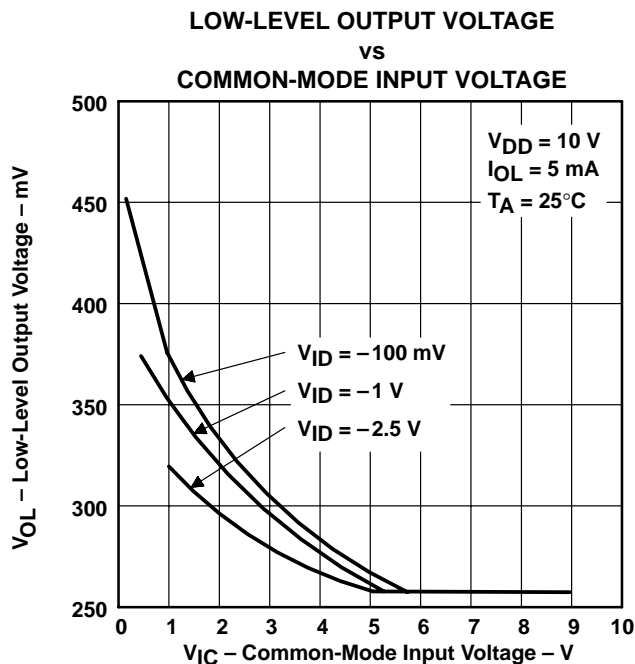


Figure 15

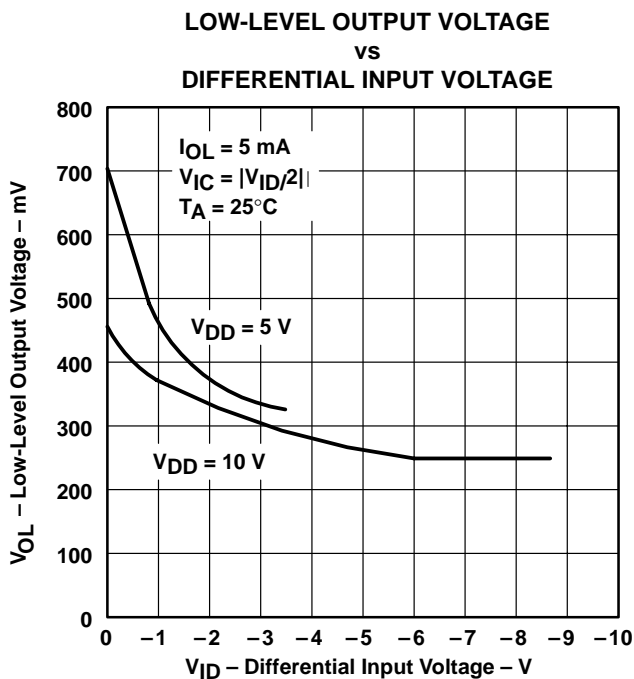


Figure 16

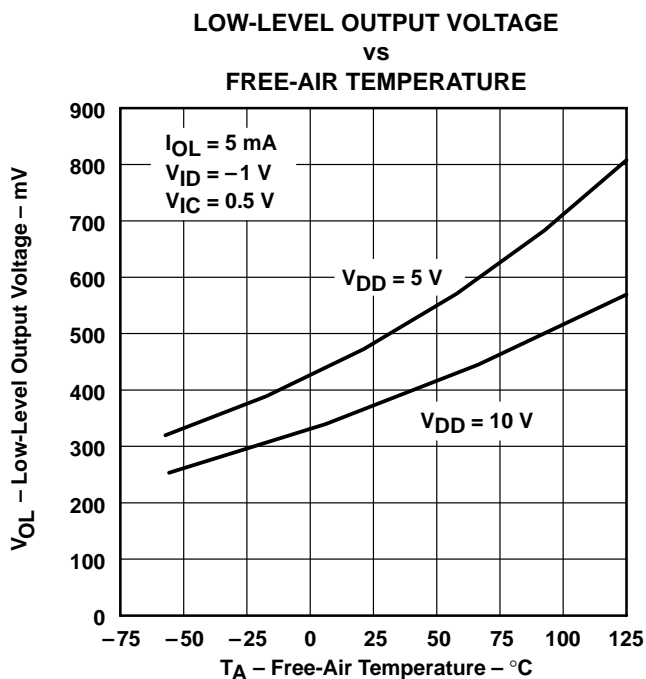


Figure 17

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

# TYPICAL CHARACTERISTICS†

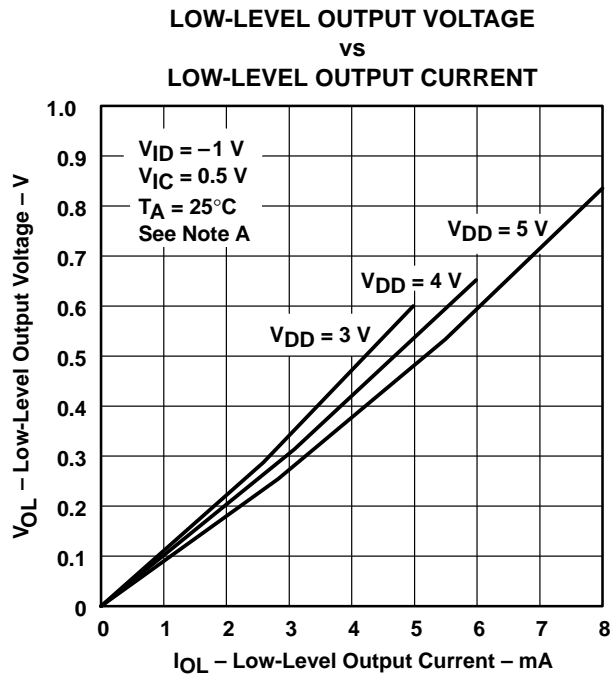


Figure 18

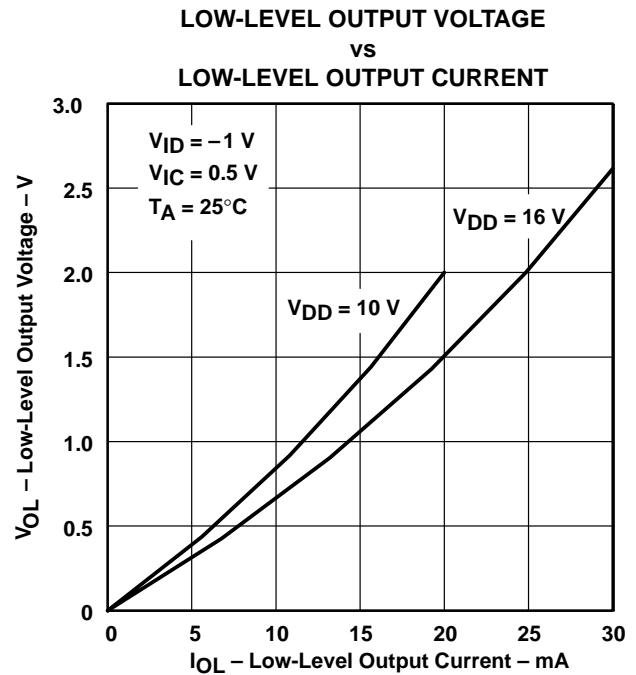


Figure 19

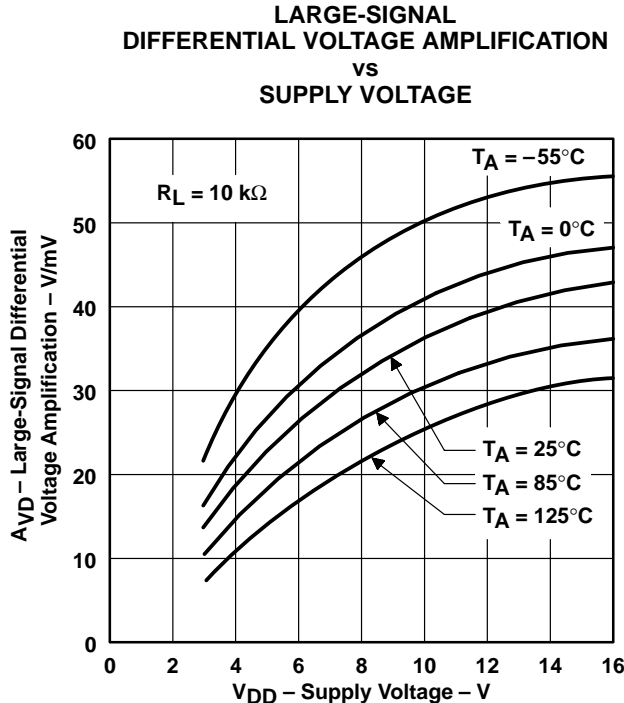


Figure 20

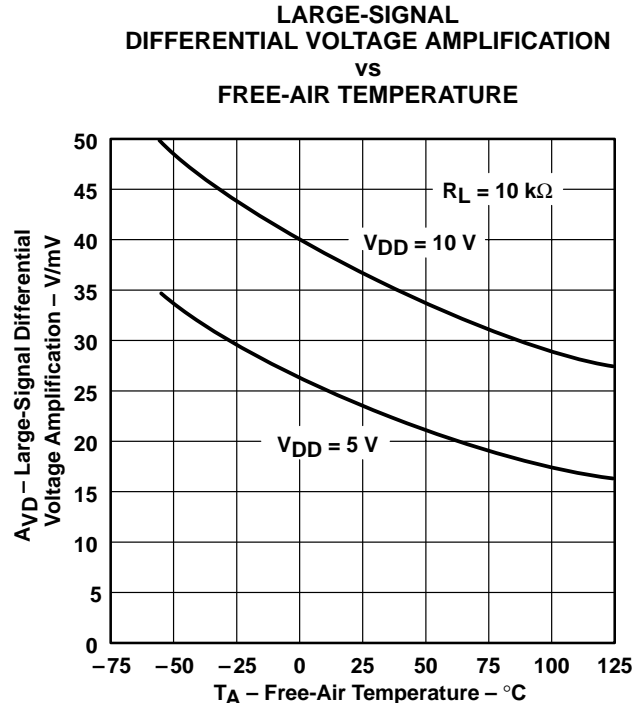


Figure 21

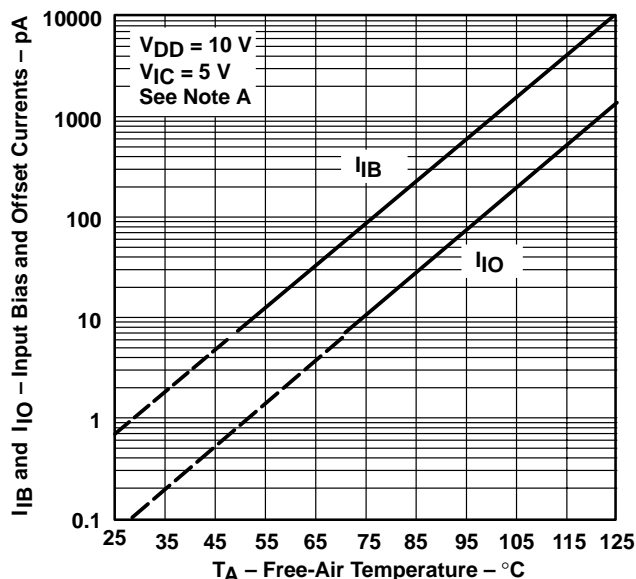
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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## TYPICAL CHARACTERISTICS†

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 22

COMMON-MODE  
INPUT VOLTAGE POSITIVE LIMIT  
vs  
SUPPLY VOLTAGE

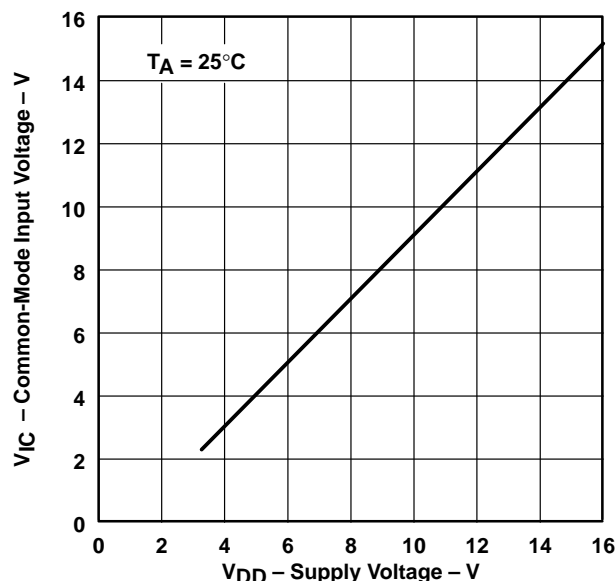


Figure 23

SUPPLY CURRENT  
vs  
SUPPLY VOLTAGE

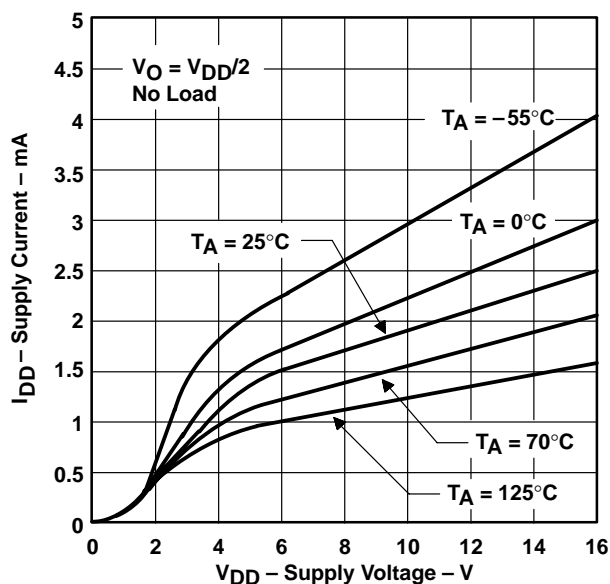


Figure 24

SUPPLY CURRENT  
vs  
FREE-AIR TEMPERATURE

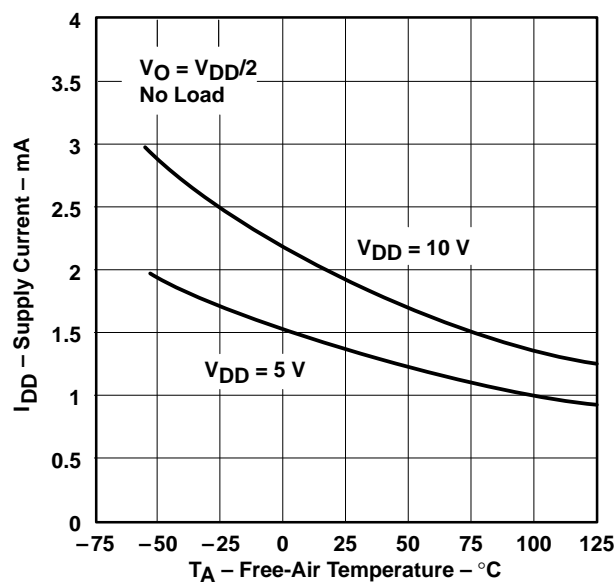


Figure 25

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

# TYPICAL CHARACTERISTICS†

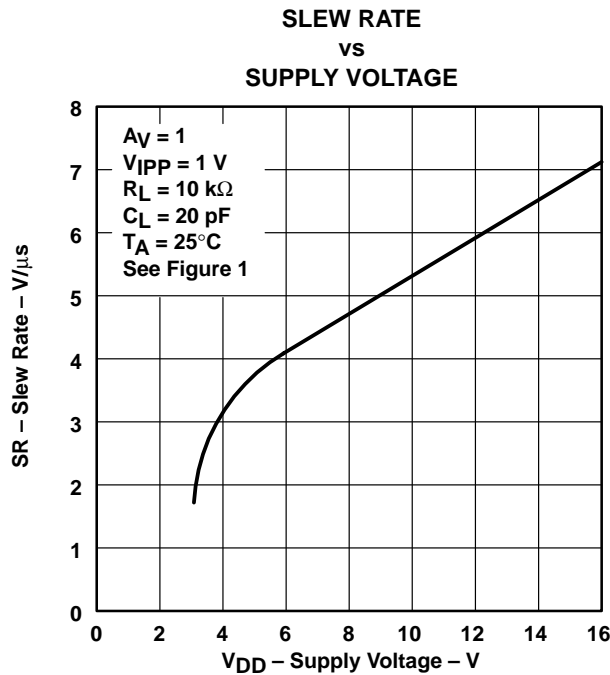


Figure 26

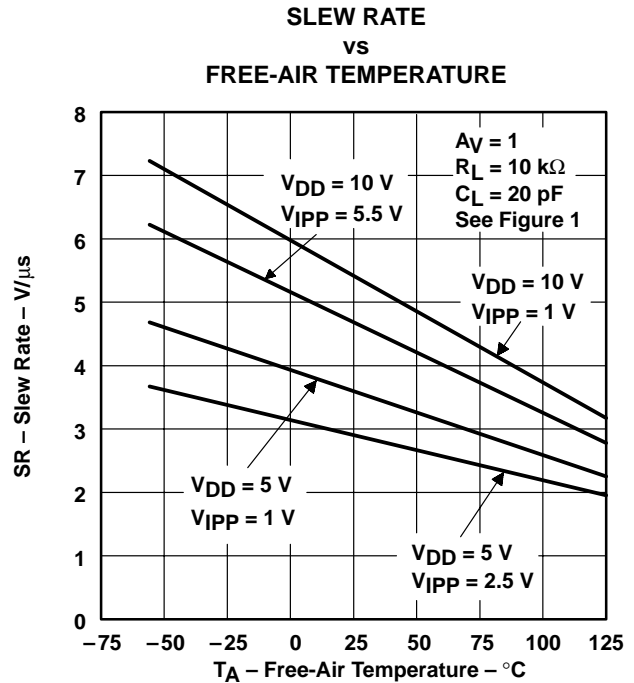


Figure 27

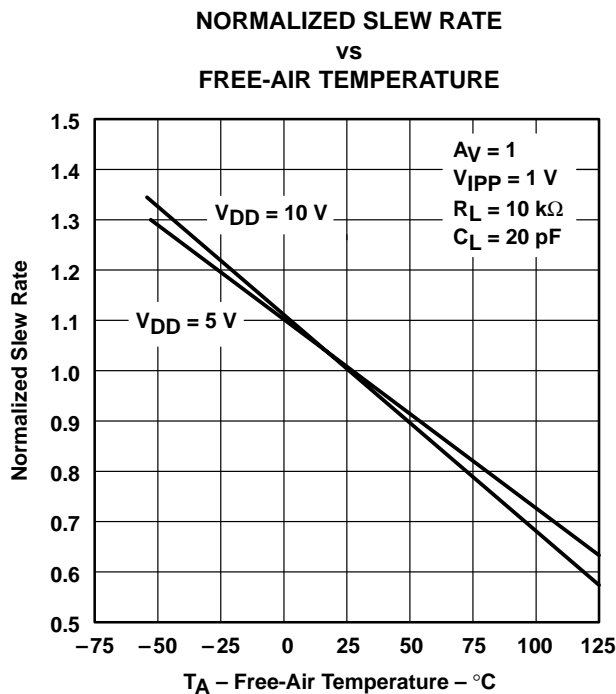


Figure 28

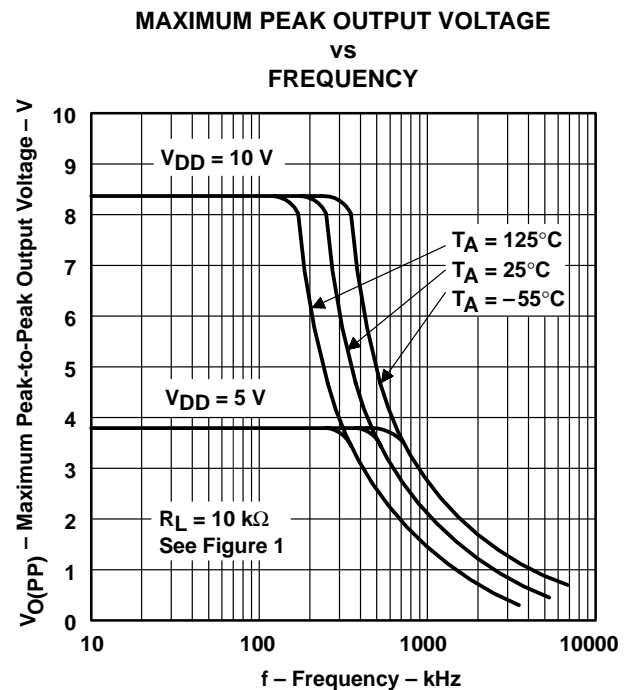


Figure 29

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

# TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS†

UNITY-GAIN BANDWIDTH  
vs  
FREE-AIR TEMPERATURE

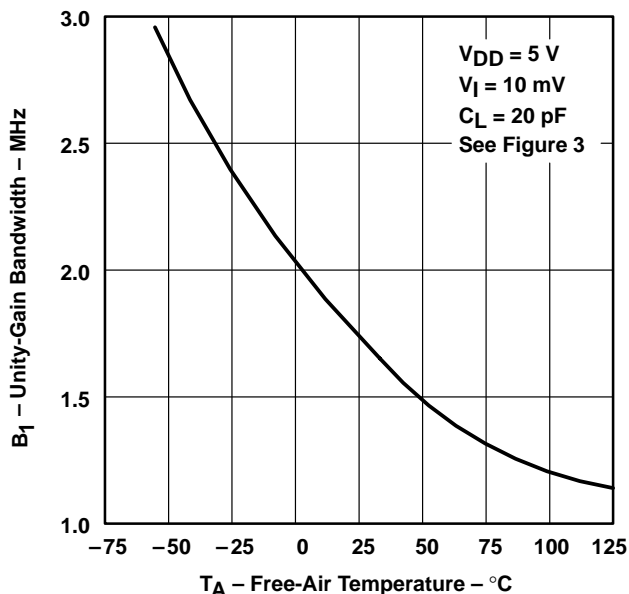


Figure 30

UNITY-GAIN BANDWIDTH  
vs  
SUPPLY VOLTAGE

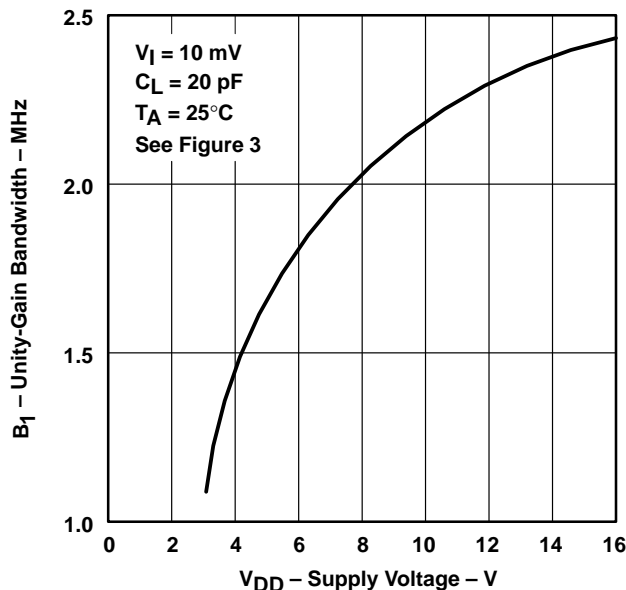


Figure 31

LARGE-SIGNAL DIFFERENTIAL VOLTAGE  
AMPLIFICATION AND PHASE SHIFT  
vs  
FREQUENCY

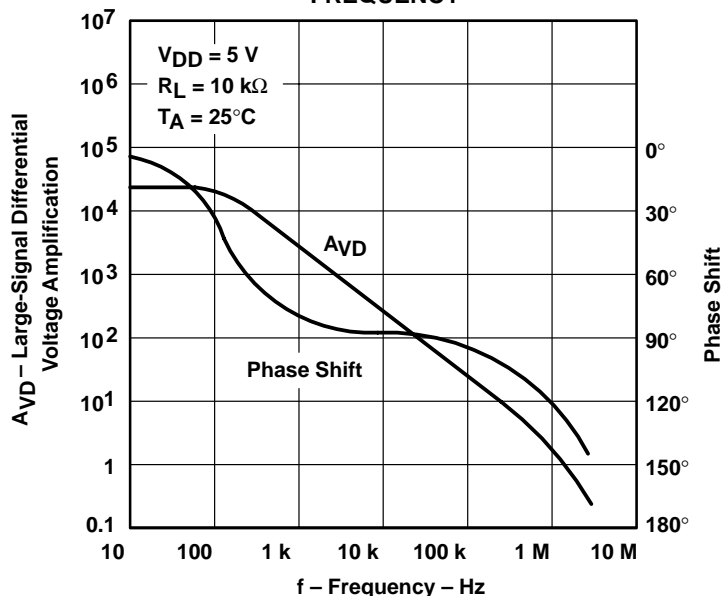


Figure 32

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

## TYPICAL CHARACTERISTICS†

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

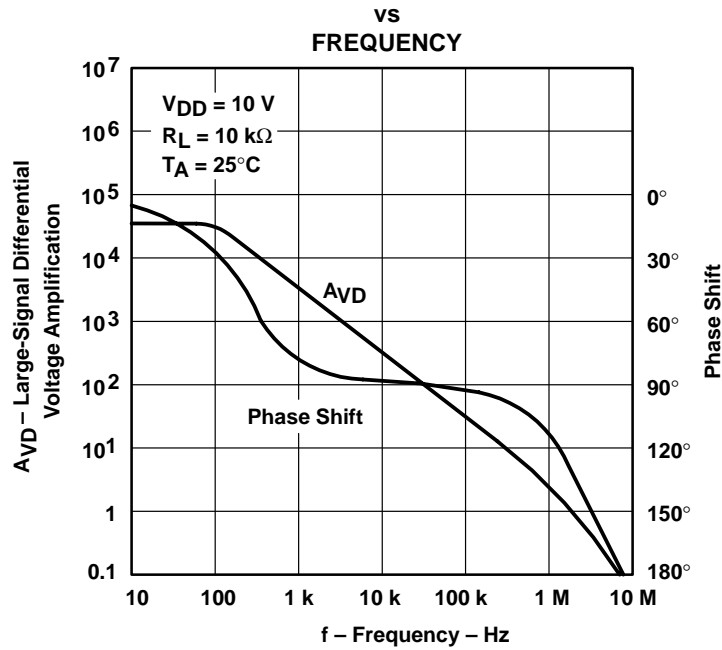


Figure 33

### PHASE MARGIN VS SUPPLY VOLTAGE

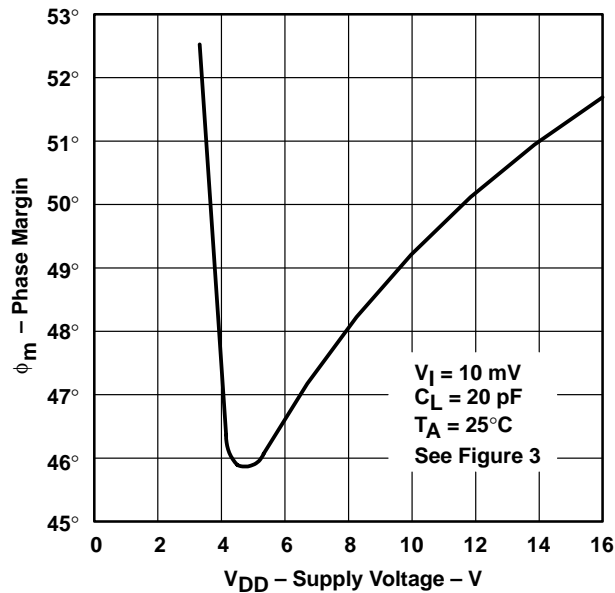


Figure 34

### PHASE MARGIN VS FREE-AIR TEMPERATURE

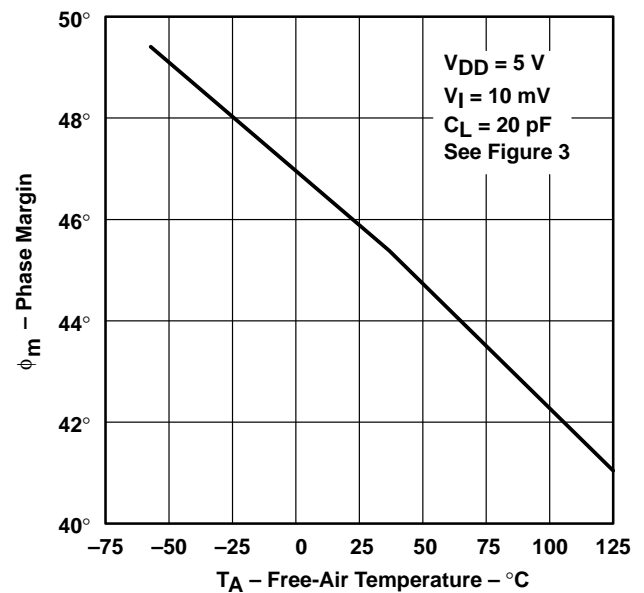


Figure 35

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

TYPICAL CHARACTERISTICS

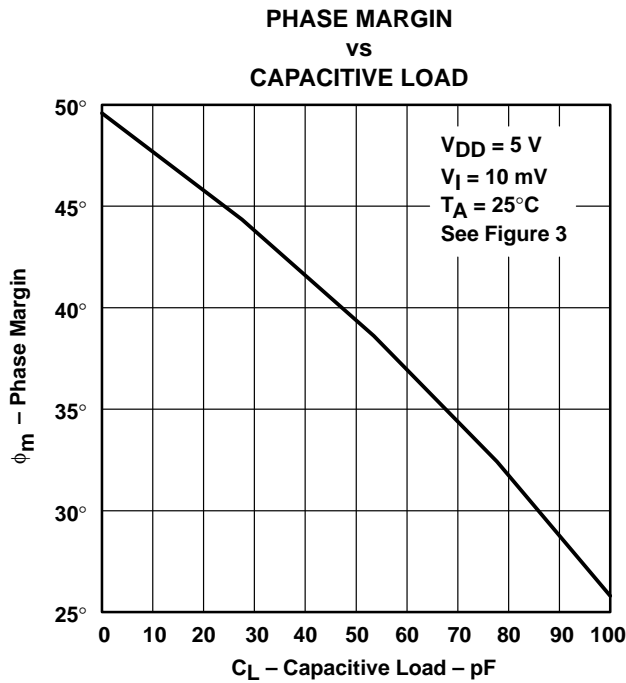


Figure 36

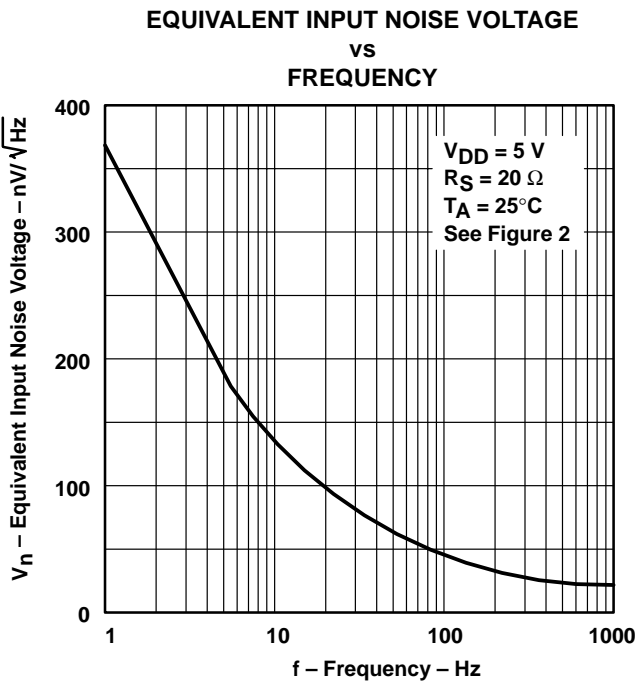


Figure 37

## APPLICATION INFORMATION

### single-supply operation

While the TLC272 and TLC277 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC272 and TLC277 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC272 and TLC277 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

1. Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require RC decoupling.

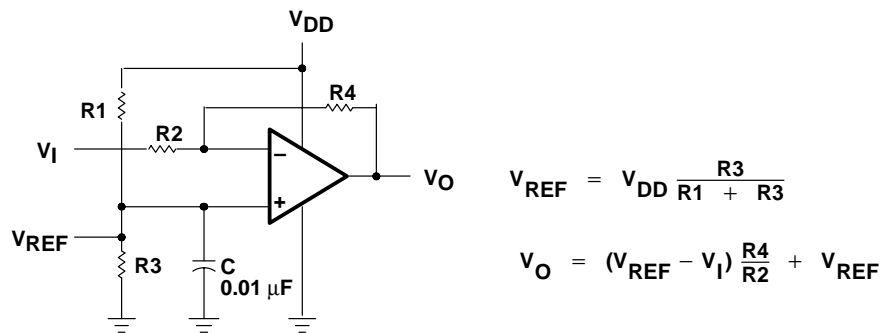


Figure 38. Inverting Amplifier With Voltage Reference

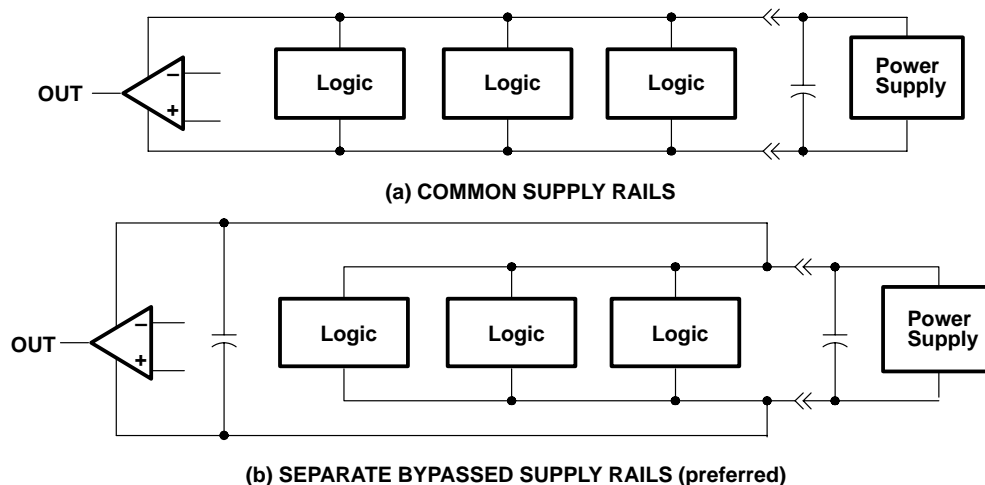


Figure 39. Common vs Separate Supply Rails

## APPLICATION INFORMATION

### input characteristics

The TLC272 and TLC277 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at  $V_{DD} - 1\text{ V}$  at  $T_A = 25^\circ\text{C}$  and at  $V_{DD} - 1.5\text{ V}$  at all other temperatures.

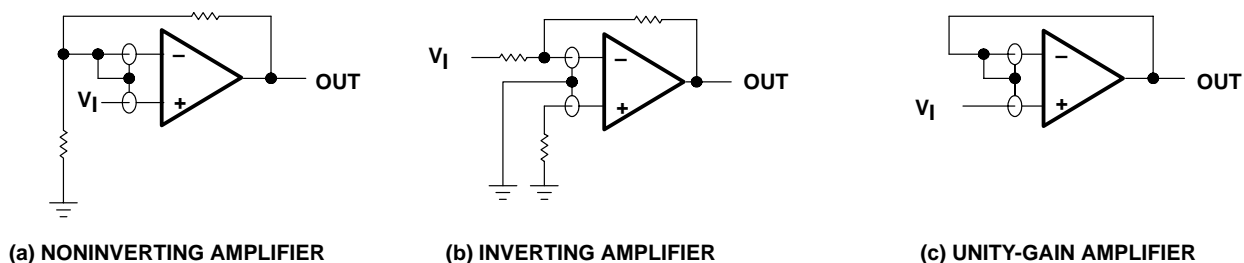
The use of the polysilicon-gate process and the careful input circuit design gives the TLC272 and TLC277 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically  $0.1\text{ }\mu\text{V/month}$ , including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC272 and TLC277 are well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

### noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC272 and TLC277 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than  $50\text{ k}\Omega$ , since bipolar devices exhibit greater noise currents.



**Figure 40. Guard-Ring Schemes**

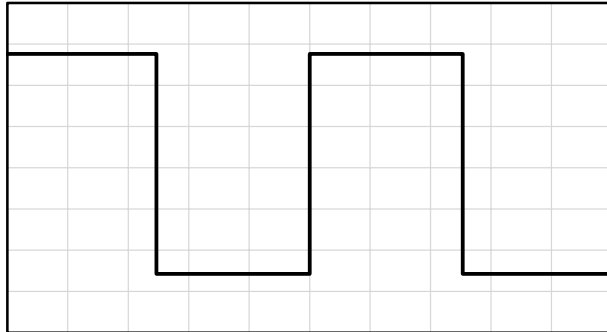
### output characteristics

The output stage of the TLC272 and TLC277 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

All operating characteristics of the TLC272 and TLC277 are measured using a  $20\text{-pF}$  load. The devices can drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.

## APPLICATION INFORMATION

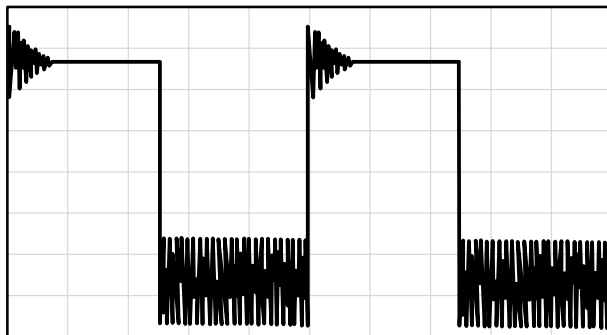
### output characteristics (continued)



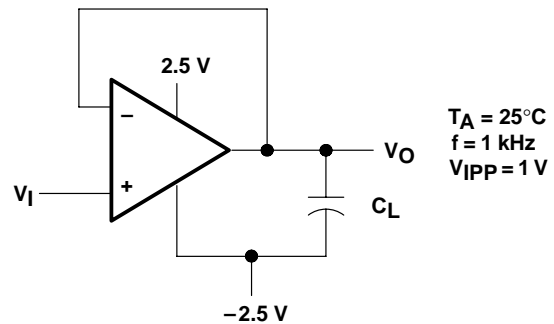
(a)  $C_L = 20 \text{ pF}$ ,  $R_L = \text{NO LOAD}$



(b)  $C_L = 130 \text{ pF}$ ,  $R_L = \text{NO LOAD}$



(c)  $C_L = 150 \text{ pF}$ ,  $R_L = \text{NO LOAD}$



(d) TEST CIRCUIT

**Figure 41. Effect of Capacitive Loads and Test Circuit**

Although the TLC272 and TLC277 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor ( $R_P$ ) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on resistance between approximately  $60 \Omega$  and  $180 \Omega$ , depending on how hard the operational amplifier input is driven. With very low values of  $R_P$ , a voltage offset from 0 V at the output occurs. Second, pullup resistor  $R_P$  acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

## APPLICATION INFORMATION

### output characteristics (continued)

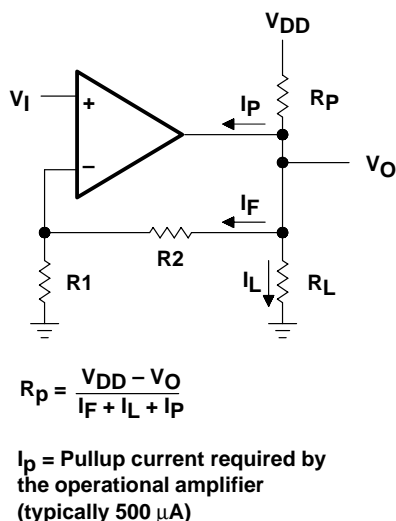


Figure 42. Resistive Pullup to Increase  $V_{OH}$

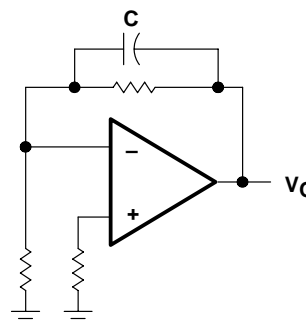


Figure 43. Compensation for Input Capacitance

### feedback

Operational amplifier circuits almost always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

### electrostatic discharge protection

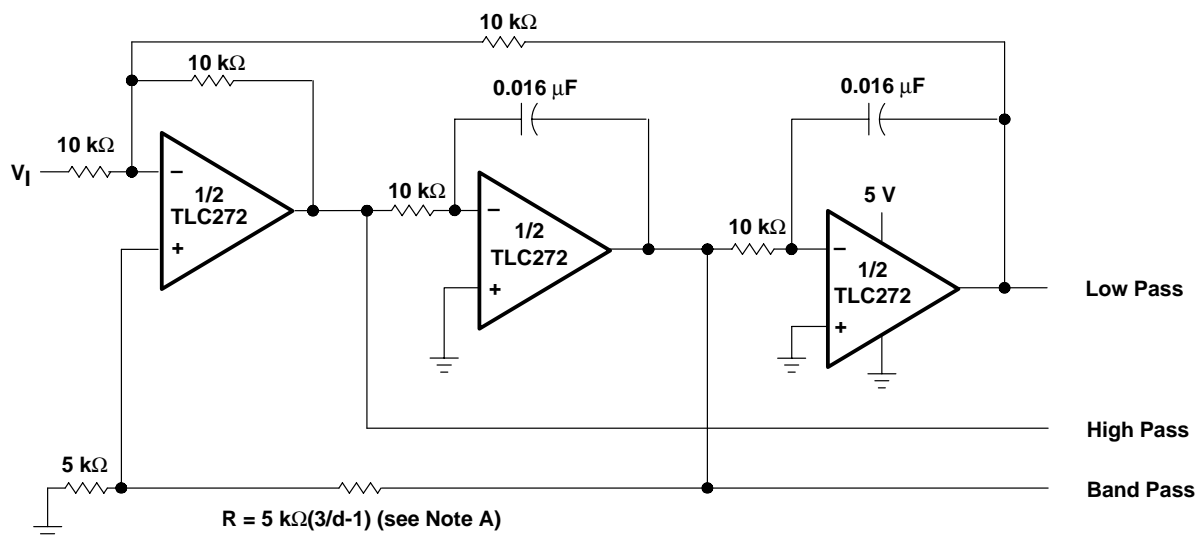
The TLC272 and TLC277 incorporate an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

### latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC272 and TLC277 inputs and outputs were designed to withstand –100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1  $\mu$ F typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

## APPLICATION INFORMATION



NOTE A:  $d$  = damping factor,  $1/Q$

Figure 44. State-Variable Filter

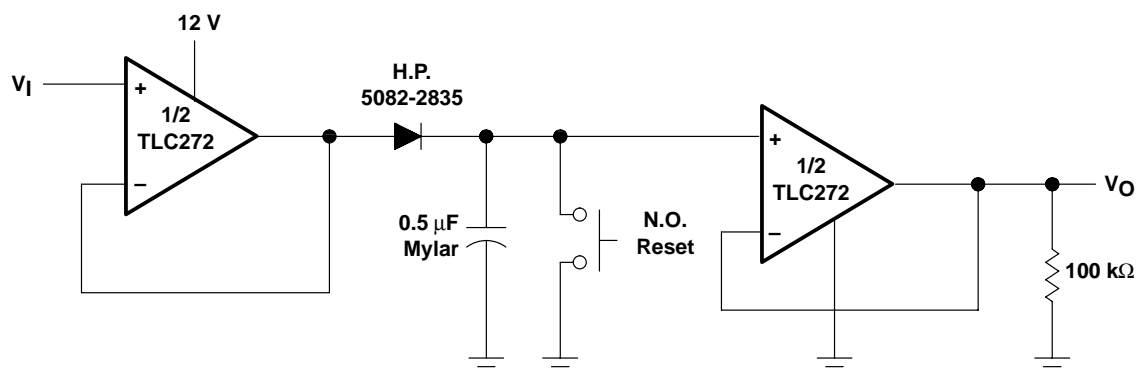


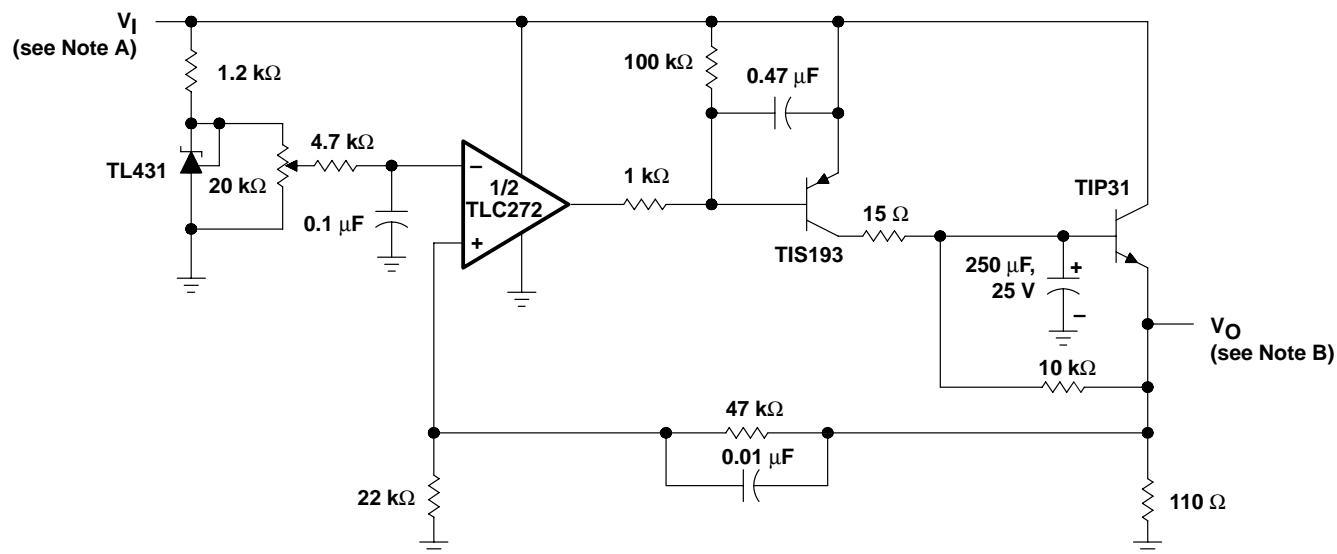
Figure 45. Positive-Peak Detector

# TLC272, TLC272A, TLC272B, TLC272Y, TLC277

## LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

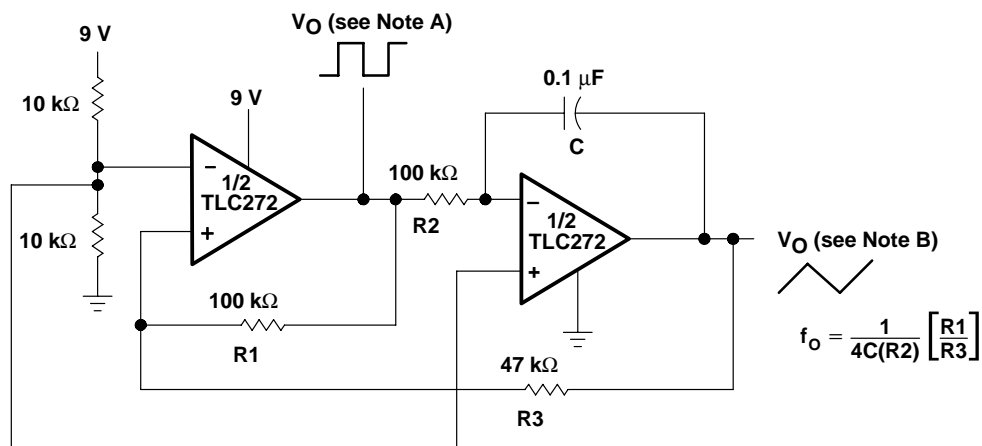
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### APPLICATION INFORMATION



NOTES: A.  $V_I = 3.5$  to  $15$  V  
B.  $V_O = 2$  V, 0 to 1 A

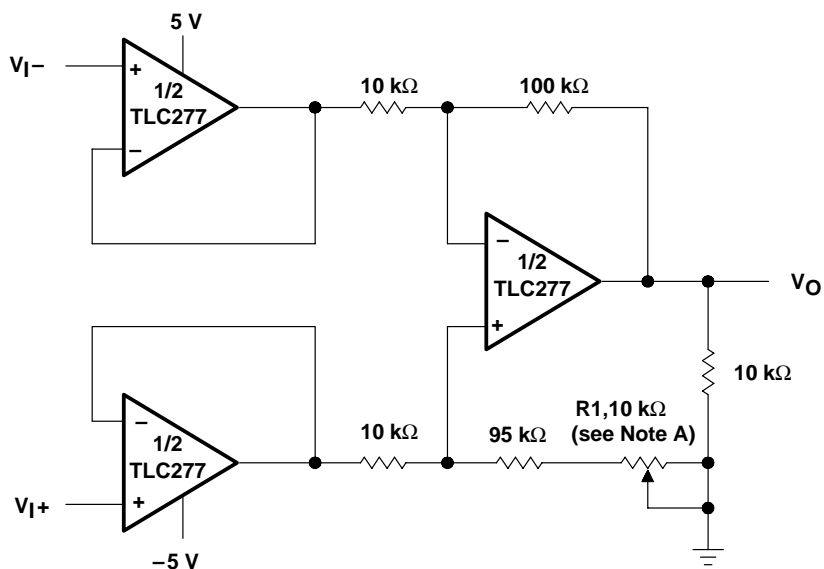
Figure 46. Logic-Array Power Supply



NOTES: A.  $V_{O(PP)} = 8$  V  
B.  $V_{O(PP)} = 4$  V

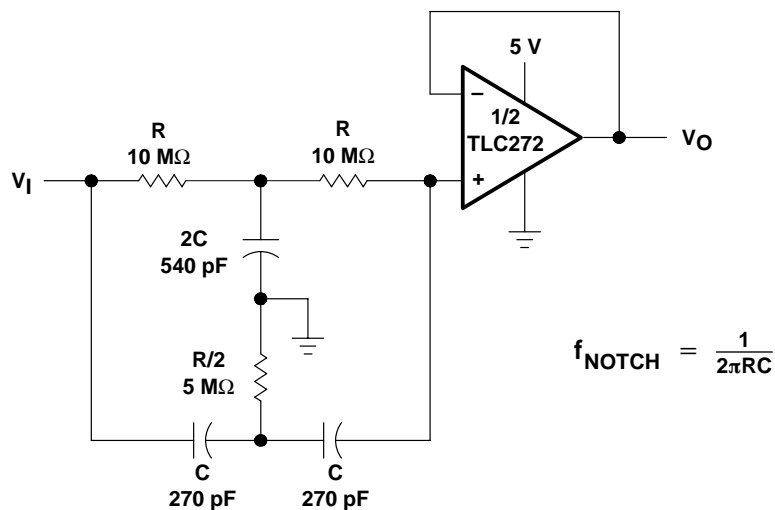
Figure 47. Single-Supply Function Generator

## APPLICATION INFORMATION



NOTE B: CMRR adjustment must be noninductive.

**Figure 48. Low-Power Instrumentation Amplifier**



**Figure 49. Single-Supply Twin-T Notch Filter**

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
5962-89494022A	OBSOLETE	LCCC	FK	20		TBD	Call TI	Call TI
TLC272ACD	ACTIVE	SOIC	D	8	75	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272ACDR	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272ACP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272ACPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272ACPSR	ACTIVE	SO	PS	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
TLC272AID	ACTIVE	SOIC	D	8	75	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272AIDR	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272AIP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272AIPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272BCD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272BCDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272BCDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272BCP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272BCPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272BCPSR	ACTIVE	SO	PS	8	2000	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272BID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272BIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272BIP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272BIPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272CD	ACTIVE	SOIC	D	8	75	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272CP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272CPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272CPSR	ACTIVE	SO	PS	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
TLC272CPSRG4	ACTIVE	SO	PS	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
TLC272CPW	ACTIVE	TSSOP	PW	8	150	TBD	CU NIPDAU	Level-1-220C-UNLIM

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TLC272CPWLE	OBSOLETE	TSSOP	PW	8		TBD	Call TI	Call TI
TLC272CPWR	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
TLC272CPWRG4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC272ID	ACTIVE	SOIC	D	8	75	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272IDR	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC272IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC272IPW	ACTIVE	TSSOP	PW	8	150	TBD	CU NIPDAU	Level-1-220C-UNLIM
TLC272MFKB	OBSOLETE	LCCC	FK	20		TBD	Call TI	Call TI
TLC272MJG	OBSOLETE	CDIP	JG	8		TBD	Call TI	Call TI
TLC272MJGB	OBSOLETE	CDIP	JG	8		TBD	Call TI	Call TI
TLC272P-M	PREVIEW	PDIP	P	8		Pb-Free (RoHS)	CU NIPDAU	Level-NA-NA-NA
TLC277CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC277CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC277CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC277CP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC277CPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC277CPSR	ACTIVE	SO	PS	8	2000	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1YEAR/ Level-1-220C-UNLIM
TLC277ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC277IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC277IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC277IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC277IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TLC277MFKB	OBSOLETE	LCCC	FK	20		TBD	Call TI	Call TI
TLC277MJG	OBSOLETE	CDIP	JG	8		TBD	Call TI	Call TI
TLC277MJGB	OBSOLETE	CDIP	JG	8		TBD	Call TI	Call TI

<sup>(1)</sup> 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) 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.

**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.

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