

## FAMILY OF MICROPOWER RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS

### FEATURES

- **BiMOS Rail-to-Rail Output**
- **Input Bias Current . . . 1 pA**
- **High Wide Bandwidth . . . 160 kHz**
- **High Slew Rate . . . 0.1 V/ $\mu$ s**
- **Supply Current . . . 7  $\mu$ A (per channel)**
- **Input Noise Voltage . . . 89 nV/ $\sqrt{\text{Hz}}$**
- **Supply Voltage Range . . . 2.7 V to 16 V**
- **Specified Temperature Range**
  - $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  . . . Industrial Grade
  - $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  . . . Commercial Grade
- **Ultra-Small Packaging**
  - 5 Pin SOT-23 (TLV27L1)

### APPLICATIONS

- **Portable Medical**
- **Power Monitoring**
- **Low Power Security Detection Systems**
- **Smoke Detectors**

### DESCRIPTION

The TLV27Lx single supply operational amplifiers provide rail-to-rail output capability. The TLV27Lx takes the minimum operating supply voltage down to 2.7 V over the extended industrial temperature range, while adding the rail-to-rail output swing feature. The TLV27Lx also provides 160-kHz bandwidth from only 7  $\mu$ A. The maximum recommended supply voltage is 16 V, which allows the devices to be operated from ( $\pm 8$ -V supplies down to  $\pm 1.35$  V) two rechargeable cells.

The rail-to-rail outputs make the TLV27Lx good upgrades for the TLC27Lx family—offering more bandwidth at a lower quiescent current. The TLV27Lx offset voltage is equal to that of the TLC27LxA variant. Their cost effectiveness makes them a good alternative to the TLC/V225x, where offset and noise are not of premium importance.

The TLV27L1/2 are available in the commercial temperature range to enable easy migration from the equivalent TLC27Lx. The TLV27L1 is not available with the power saving/performance boosting programmable pin 8.

The TLV27L1 is available in the small SOT-23 package—something the TLC27(L)1 was not—enabling performance boosting in a smaller package. The TLV27L2 is available in the 3mm x 5mm MSOP, providing PCB area savings over the 8-pin SOIC and 8-pin TSSOP.

### SELECTION GUIDE

DEVICE	$V_S$ [V]	$I_{Q/\text{ch}}$ [ $\mu$ A]	$V_{ICR}$ [V]	$V_{IO}$ [mV]	$I_{IB}$ [pA]	GBW [MHz]	SLEW RATE [V/ $\mu$ s]	$V_n$ , 1 kHz [nV/ $\sqrt{\text{Hz}}$ ]
TLV27Lx	2.7 to 16	11	$-0.2$ to $V_S+1.2$	5	60	0.18	0.06	89
TLV238x	2.7 to 16	10	$-0.2$ to $V_S-0.2$	4.5	60	0.18	0.06	90
TLC27Lx	4 to 16	17	$-0.2$ to $V_S-1.5$	10/5/2	60	0.085	0.03	68
OPAx349	1.8 to 5.5	2	$-0.2$ to $V_S+0.2$	10	10	0.070	0.02	300
OPAx347	2.3 to 5.5	34	$-0.2$ to $V_S+0.2$	6	10	0.35	0.01	60
TLC225x	2.7 to 16	62.5	0 to $V_S-1.5$	1.5/0.85	60	0.200	0.02	19

NOTE: All dc specs are maximums while ac specs are typicals.



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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.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE CODE	SYMBOL	SPECIFIED TEMPERATURE RANGE	ORDER NUMBER	TRANSPORT MEDIA
TLV27L1CD	SOIC-8	D	27V1C	0°C to 70°C	TLV27L1CD	Tube
					TLV27L1CDR	Tape and Reel
TLV27L1CDBV	SOT-23	DBV	VBIC		TLV27L1CDBVR	Tape and Reel
					TLV27L1CDBVT	
TLV27L1ID	SOIC-8	D	27V1I	–40°C to 125°C	TLV27L1ID	Tube
					TLV27L1IDR	Tape and Reel
TLV27L1IDBV	SOT-23	DBV	VBII		TLV27L1IDBVR	Tape and Reel
					TLV27L1IDBVT	
TLV27L2CD	SOIC-8	D	27V2C	0°C to 70°C	TLV27L2CD	Tube
					TLV27L2CDR	Tape and Reel
TLV27L2ID	SOIC-8	D	27V2I	–40°C to 125°C	TLV27L2ID	Tube
					TLV27L2IDR	Tape and Reel

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

Supply voltage, $V_S$	16.5 V
Input voltage, $V_I$ (see Note 1)	$V_S$
Output current, $I_O$	100 mA
Differential input voltage, $V_{ID}$	$V_S$
Continuous total power dissipation	See Dissipation Rating Table
Maximum junction temperature, $T_J$	150°C
Operating free-air temperature range, $T_A$ : C suffix	0°C to 70°C
I suffix	–40°C to 125°C
Storage temperature range, $T_{stg}$	–65°C to 125°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	300°C

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

NOTE 1: Relative to GND pin.

DISSIPATION RATING TABLE

PACKAGE	$\theta_{JC}$ (°C/W)	$\theta_{JA}$ (°C/W)	$T_A \leq 25^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING
D (8)	38.3	176	710 mW	370 mW
DBV (5)	55	324.1	385 mW	201 mW
DBV (6)	55	294.3	425 mW	221 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, ( $V_S$ )	Dual supply	±1.35	±8	V
	Single supply	2.7	16	
Input common-mode voltage range		–0.2	$V_S - 1.2$	V
Operating free-air temperature, $T_A$	C-suffix	0	70	°C
	I-suffix	–40	125	

electrical characteristics at recommended operating conditions,  $V_S = 2.7\text{ V}$ ,  $5\text{ V}$ , and  $10\text{ V}$  (unless otherwise noted)

#### dc performance

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
$V_{IO}$ Input offset voltage	$V_{IC} = V_S/2$ , $R_L = 100\text{ k}\Omega$ , $V_O = V_S/2$ , $R_S = 50\text{ }\Omega$	25°C		0.5	5	mV
		Full range			7	
$\alpha_{VIO}$ Offset voltage drift		25°C		1.1		$\mu\text{V}/^\circ\text{C}$
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ V to }V_S - 1.2\text{ V}$ , $R_S = 50\text{ }\Omega$	25°C	71	86		dB
		Full range	70			
$A_{VD}$ Large-signal differential voltage amplification	$V_{O(PP)} = V_S/2$ , $R_L = 100\text{ k}\Omega$	$V_S = 2.7\text{ V}$ , 5 V	25°C	80	100	dB
		Full range	77			
	$V_S = \pm 5\text{ V}$	25°C	77	82		
		Full range	74			

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

#### input characteristics

PARAMETER	TEST CONDITIONS	$T_A$	MIN	TYP	MAX	UNIT
$I_{IO}$ Input offset current	$V_{IC} = V_S/2$ , $R_L = 100\text{ k}\Omega$ , $V_O = V_S/2$ , $R_S = 50\text{ }\Omega$	$\leq 25^\circ\text{C}$		1	60	pA
		$\leq 70^\circ\text{C}$			100	
		$\leq 125^\circ\text{C}$			1000	
$I_{IB}$ Input bias current		$\leq 25^\circ\text{C}$		1	60	pA
		$\leq 70^\circ\text{C}$			200	
		$\leq 125^\circ\text{C}$			1000	
$r_{i(d)}$ Differential input resistance		25°C		1000		G $\Omega$
$C_{IC}$ Common-mode input capacitance	$f = 1\text{ kHz}$	25°C		8		pF

#### power supply

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
$I_Q$ Quiescent current (per channel)	$V_O = V_S/2$	25°C		7	11	$\mu\text{A}$
		Full range			16	
PSRR Power supply rejection ratio ( $\Delta V_S/\Delta V_{IO}$ )	$V_S = 2.7\text{ V to }16\text{ V}$ , $V_{IC} = V_S/2\text{ V}$ No load,	25°C	74	82		dB
		Full range	70			

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

**electrical characteristics at recommended operating conditions,  $V_S = 2.7\text{ V}$ ,  $5\text{ V}$ , and  $\pm 5\text{ V}$  (unless otherwise noted) (continued)**

**output characteristics**

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	MIN	TYP	MAX	UNIT
$V_O$	Output voltage swing from rail	$V_{IC} = V_S/2$ , $I_{OL} = 100\text{ }\mu\text{A}$	$V_S = 2.7\text{ V}$	25°C	200	160		V
				Full range	220			
			$V_S = 5\text{ V}$	25°C	120	85		
				Full range	200			
			$V_S = \pm 5\text{ V}$	25°C	120	50		
				Full range	150			
		$V_{IC} = V_S/2$ , $I_{OL} = 500\text{ }\mu\text{A}$	$V_S = 5\text{ V}$	25°C	800	420		
				Full range	900			
			$V_S = \pm 5\text{ V}$	25°C	400	200		
				Full range	500			
$I_O$	Output current	$V_O = 0.5\text{ V}$ from rail	$V_S = 2.7\text{ V}$	25°C		400		$\mu\text{A}$

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

**dynamic performance**

PARAMETER		TEST CONDITIONS		$T_A$	MIN	TYP	MAX	UNIT
GBP	Gain bandwidth product	$R_L = 100\text{ k}\Omega$ , $C_L = 10\text{ pF}$ , $f = 1\text{ kHz}$		25°C		160		kHz
SR	Slew rate at unity gain	$V_{O(pp)} = 1\text{ V}$ , $R_L = 100\text{ k}\Omega$ , $C_L = 50\text{ pF}$		25°C		0.06		V/ $\mu\text{s}$
				$-40^\circ\text{C}$		0.05		
				125°C		0.8		
$\phi_M$	Phase margin	$R_L = 100\text{ k}\Omega$ , $C_L = 50\text{ pF}$		25°C		62		$^\circ$
$t_s$	Settling time (0.1%)	$V_{(STEP)pp} = 1\text{ V}$ , $A_V = -1$ , $C_L = 50\text{ pF}$ , $R_L = 100\text{ k}\Omega$	Rise	25°C		62		$\mu\text{s}$
			Fall			44		

**noise/distortion performance**

PARAMETER		TEST CONDITIONS		$T_A$	MIN	TYP	MAX	UNIT
$V_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$		25°C		89		$\text{nV}/\sqrt{\text{Hz}}$
$I_n$	Equivalent input noise current	$f = 1\text{ kHz}$		25°C		0.6		$\text{fA}/\sqrt{\text{Hz}}$

## TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
$V_{IO}$	Input offset voltage	vs Common-mode input voltage	1, 2, 3
$I_{IB}/I_{IO}$	Input bias and offset current	vs Free-air temperature	4
$V_{OH}$	High-level output voltage	vs High-level output current	5, 7, 9
$V_{OL}$	Low-level output voltage	vs Low-level output current	6, 8, 10
$I_Q$	Quiescent current	vs Supply voltage	11
		vs Free-air temperature	12
	Supply voltage and supply current ramp up		13
$A_{VD}$	Differential voltage gain and phase shift	vs Frequency	14
GBP	Gain-bandwidth product	vs Free-air temperature	15
$\phi_m$	Phase margin	vs Load capacitance	16
CMRR	Common-mode rejection ratio	vs Frequency	17
PSRR	Power supply rejection ratio	vs Frequency	18
	Input referred noise voltage	vs Frequency	19
SR	Slew rate	vs Free-air temperature	20
$V_{O(PP)}$	Peak-to-peak output voltage	vs Frequency	21
	Inverting small-signal response		22
	Inverting large-signal response		23
	Crosstalk	vs Frequency	24

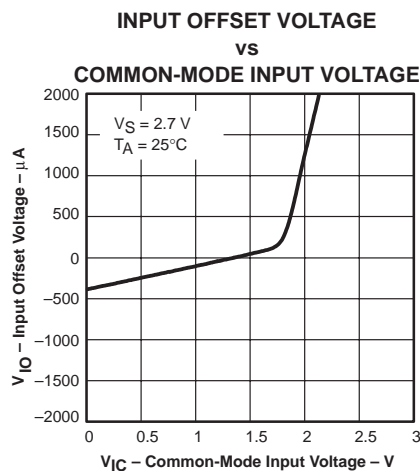


Figure 1

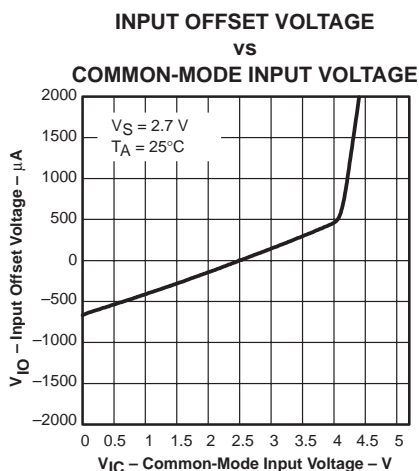


Figure 2

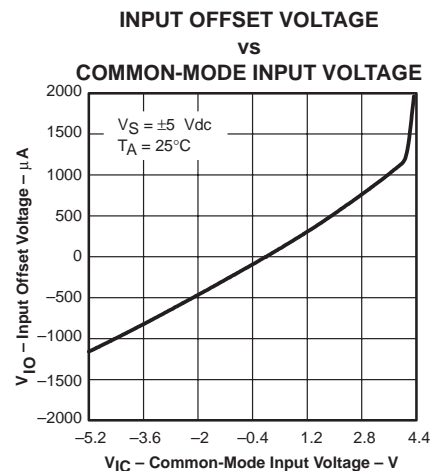


Figure 3

## TYPICAL CHARACTERISTICS

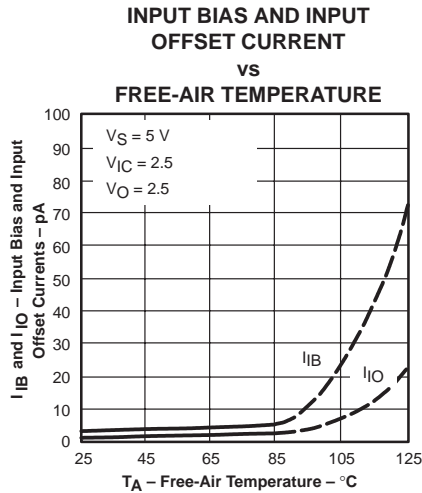


Figure 4

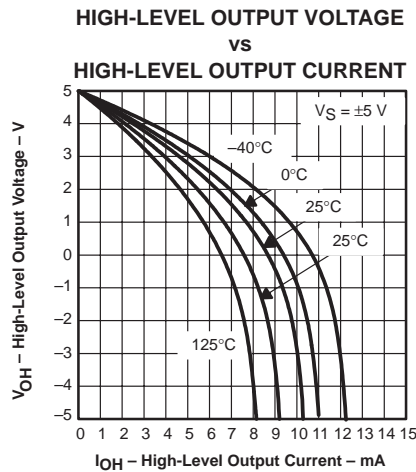


Figure 5

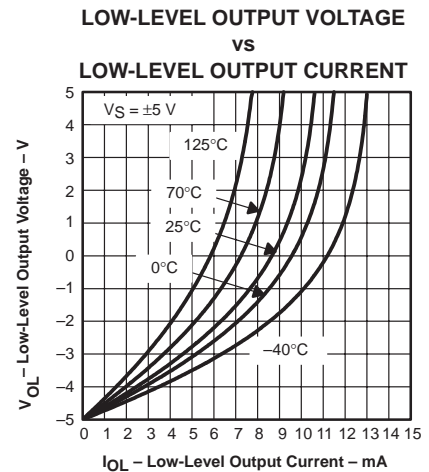


Figure 6

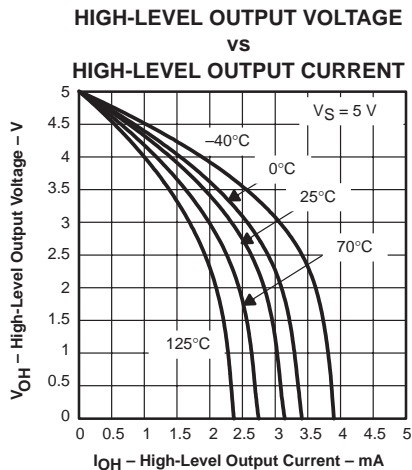


Figure 7

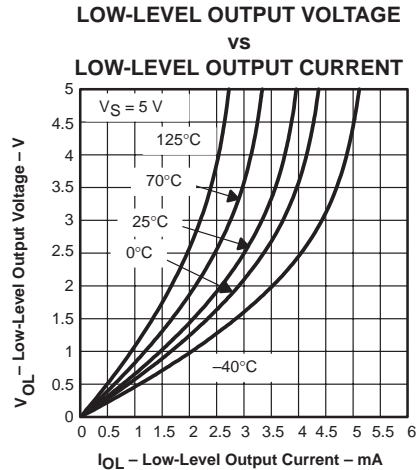


Figure 8

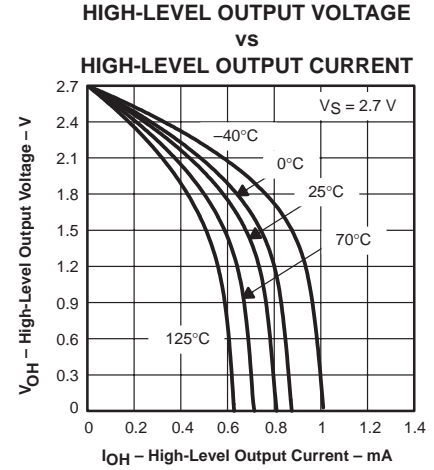


Figure 9

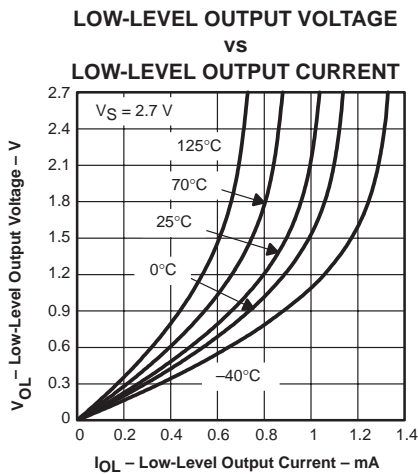


Figure 10

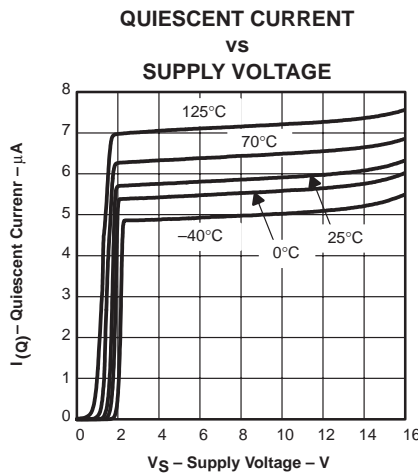


Figure 11

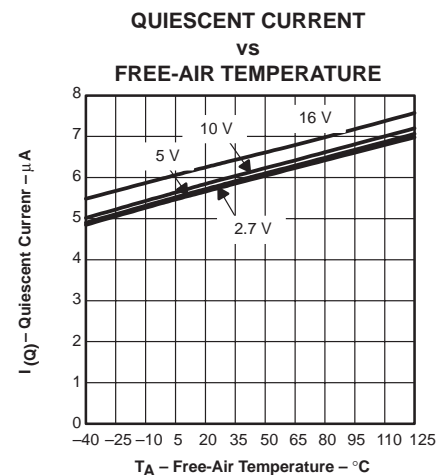


Figure 12

## TYPICAL CHARACTERISTICS

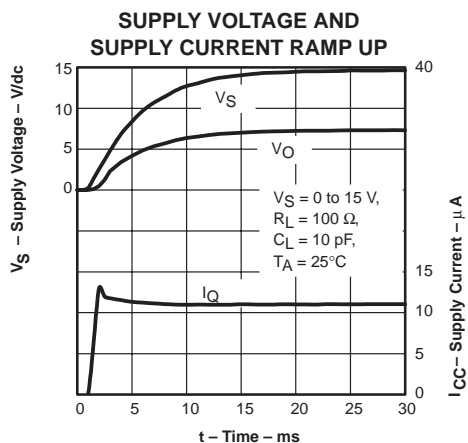


Figure 13

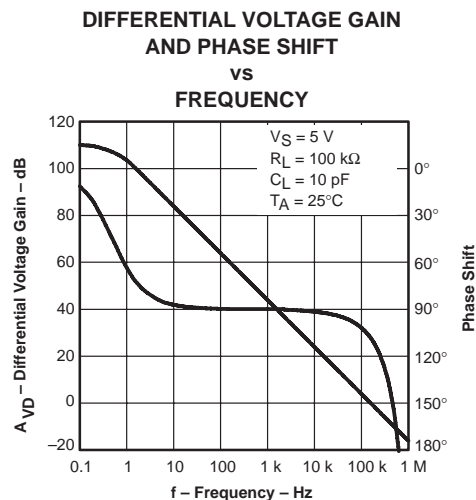


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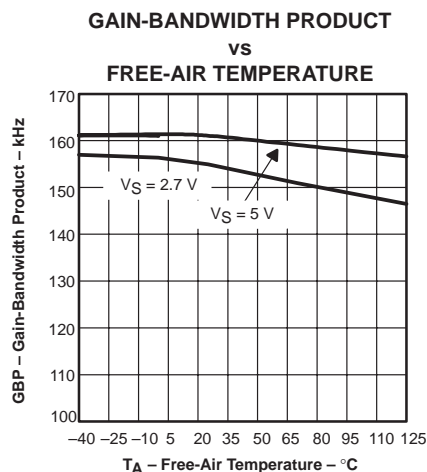


Figure 15

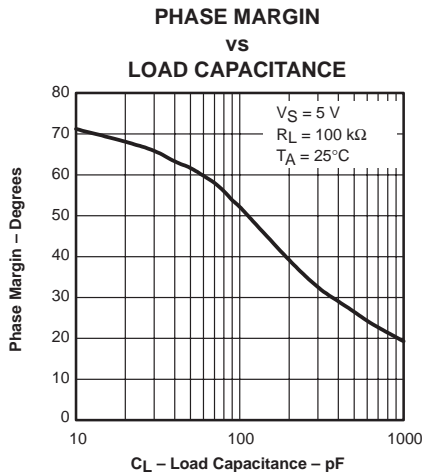


Figure 16

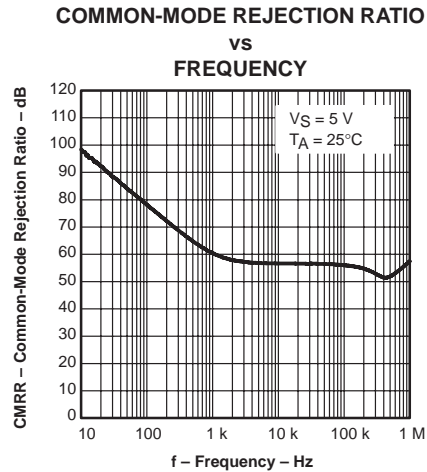


Figure 17

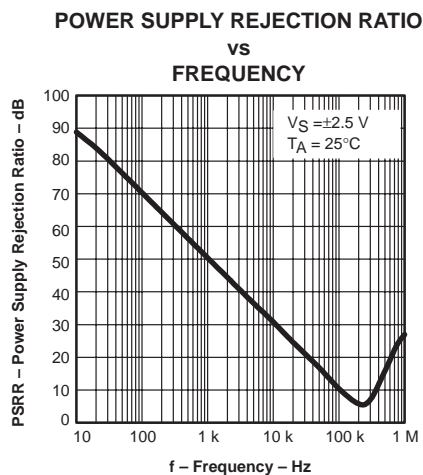


Figure 18

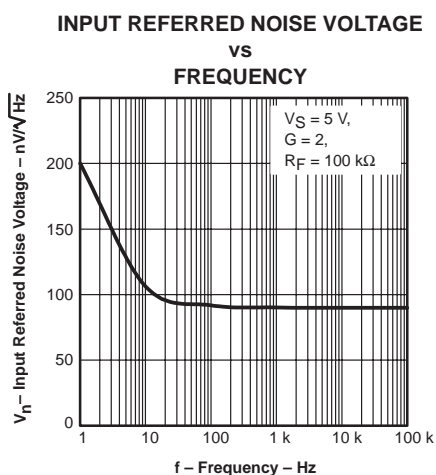


Figure 19

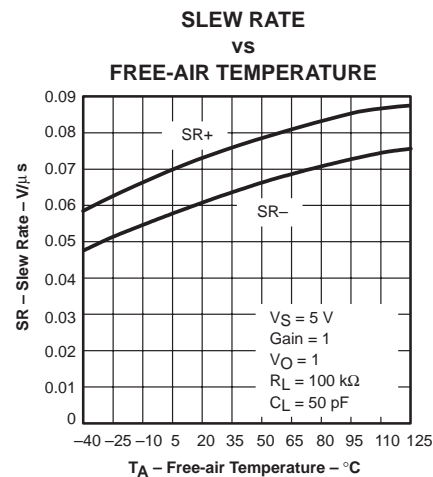


Figure 20

## TYPICAL CHARACTERISTICS

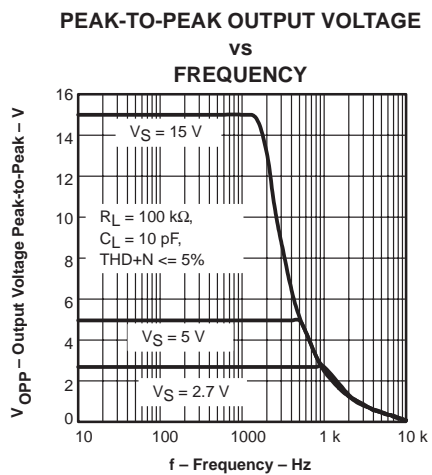


Figure 21

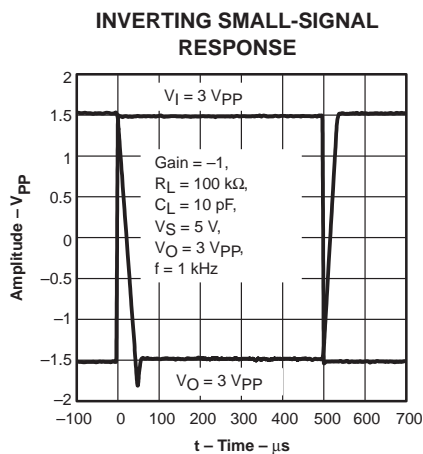


Figure 22

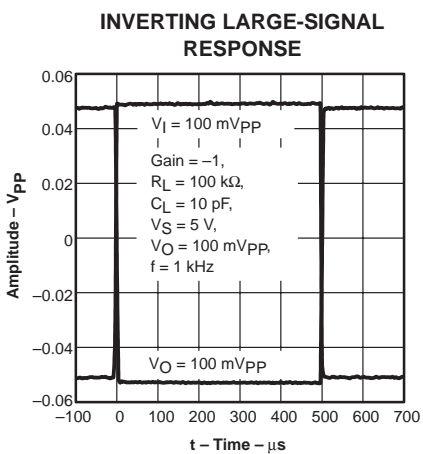


Figure 23

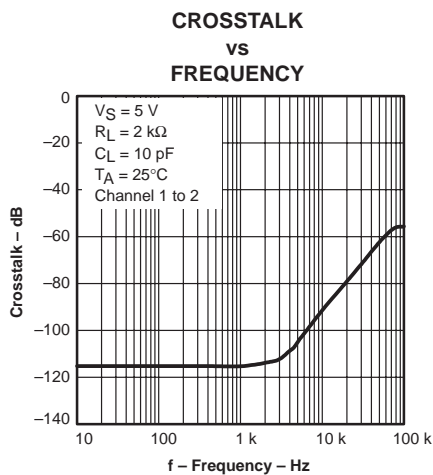


Figure 24



## APPLICATION INFORMATION

### offset voltage

The output offset voltage ( $V_{OO}$ ) is the sum of the input offset voltage ( $V_{IO}$ ) and both input bias currents ( $I_{IB}$ ) times the corresponding gains. The following schematic and formula can be used to calculate the output offset voltage:

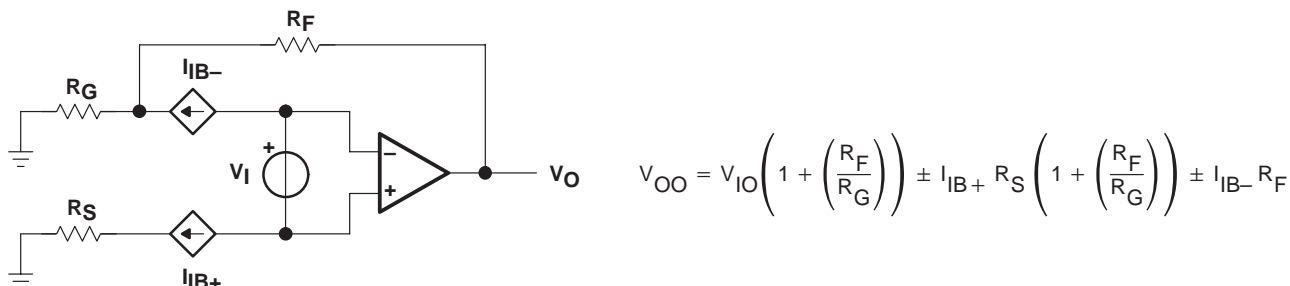


Figure 25. Output Offset Voltage Model

### general configurations

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. The simplest way to accomplish this is to place an RC filter at the noninverting terminal of the amplifier (see Figure 26).

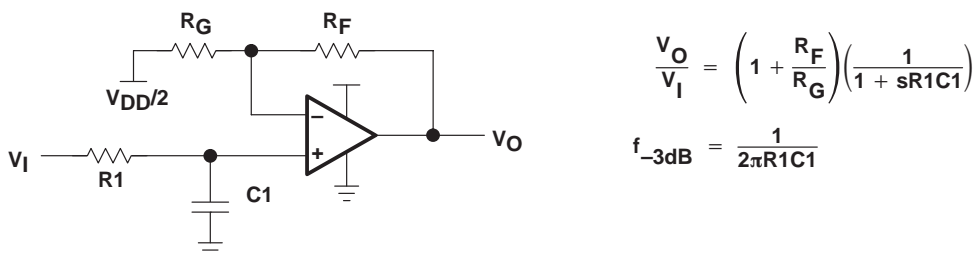


Figure 26. Single-Pole Low-Pass Filter

If even more attenuation is needed, a multiple pole filter is required. The Sallen-Key filter can be used for this task. For best results, the amplifier should have a bandwidth that is 8 to 10 times the filter frequency bandwidth. Failure to do this can result in phase shift of the amplifier.

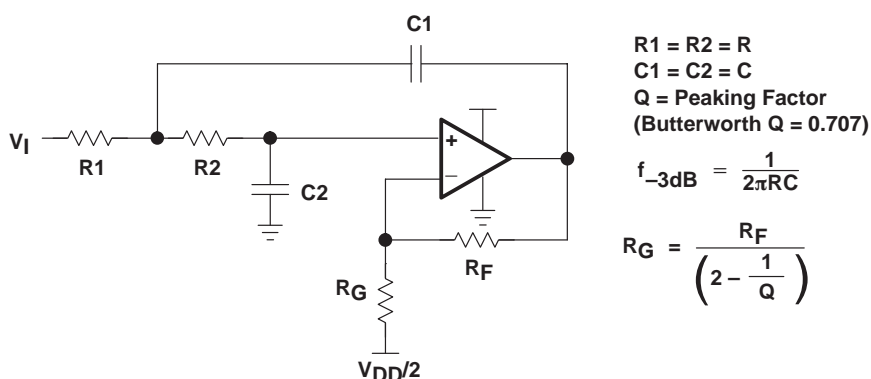


Figure 27. 2-Pole Low-Pass Sallen-Key Filter

## APPLICATION INFORMATION

### circuit layout considerations

To achieve the levels of high performance of the TLV27Lx, follow proper printed-circuit board design techniques. A general set of guidelines is given in the following.

- Ground planes—It is highly recommended that a ground plane be used on the board to provide all components with a low inductive ground connection. However, in the areas of the amplifier inputs and output, the ground plane can be removed to minimize the stray capacitance.
- Proper power supply decoupling—Use a 6.8- $\mu$ F tantalum capacitor in parallel with a 0.1- $\mu$ F ceramic capacitor on each supply terminal. It may be possible to share the tantalum among several amplifiers depending on the application, but a 0.1- $\mu$ F ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1- $\mu$ F capacitor should be placed as close as possible to the supply terminal. As this distance increases, the inductance in the connecting trace makes the capacitor less effective. The designer should strive for distances of less than 0.1 inches between the device power terminals and the ceramic capacitors.
- Sockets—Sockets can be used but are not recommended. The additional lead inductance in the socket pins will often lead to stability problems. Surface-mount packages soldered directly to the printed-circuit board is the best implementation.
- Short trace runs/compact part placements—Optimum high performance is achieved when stray series inductance has been minimized. To realize this, the circuit layout should be made as compact as possible, thereby minimizing the length of all trace runs. Particular attention should be paid to the inverting input of the amplifier. Its length should be kept as short as possible. This will help to minimize stray capacitance at the input of the amplifier.
- Surface-mount passive components—Using surface-mount passive components is recommended for high performance amplifier circuits for several reasons. First, because of the extremely low lead inductance of surface-mount components, the problem with stray series inductance is greatly reduced. Second, the small size of surface-mount components naturally leads to a more compact layout thereby minimizing both stray inductance and capacitance. If leaded components are used, it is recommended that the lead lengths be kept as short as possible.

## APPLICATION INFORMATION

### general power dissipation considerations

For a given  $\theta_{JA}$ , the maximum power dissipation is shown in Figure 28 and is calculated by the following formula:

$$P_D = \left( \frac{T_{MAX} - T_A}{\theta_{JA}} \right)$$

Where:

$P_D$  = Maximum power dissipation of TLV27Lx IC (watts)

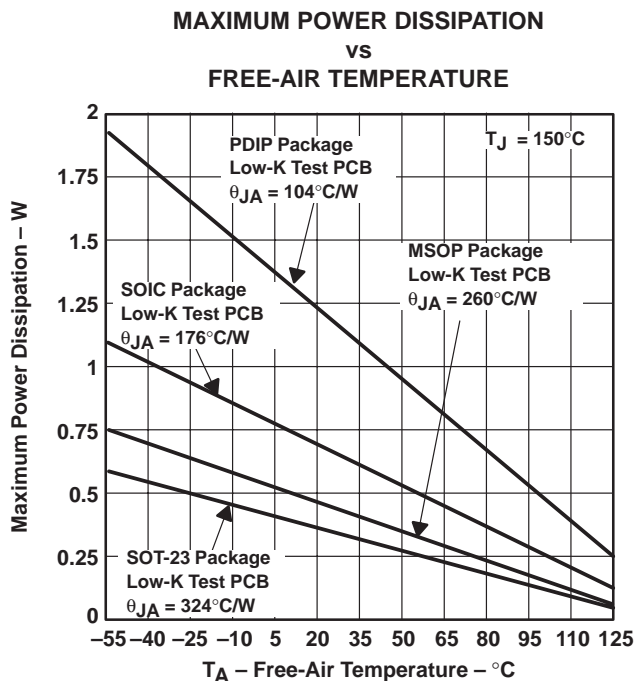
$T_{MAX}$  = Absolute maximum junction temperature (150°C)

$T_A$  = Free-ambient air temperature (°C)

$\theta_{JA} = \theta_{JC} + \theta_{CA}$

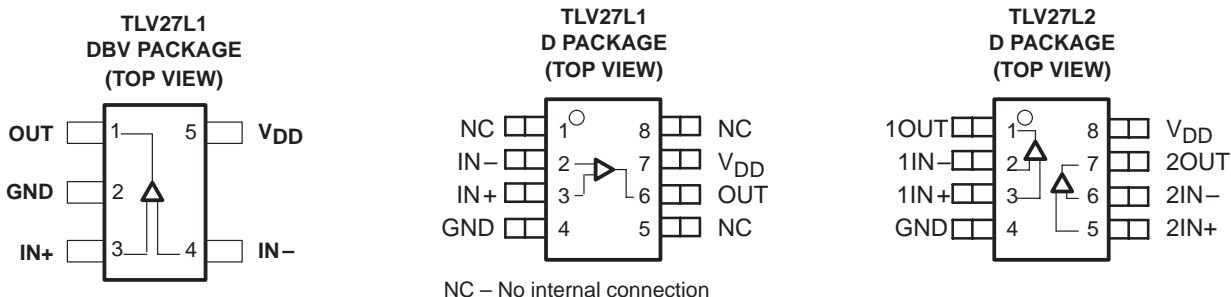
$\theta_{JC}$  = Thermal coefficient from junction to case

$\theta_{CA}$  = Thermal coefficient from case to ambient air (°C/W)



NOTE A: Results are with no air flow and using JEDEC Standard Low-K test PCB.

**Figure 28. Maximum Power Dissipation vs Free-Air Temperature**



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