

## TLC27Lx Precision, Quad Operational Amplifiers

### 1 Features

- Input offset voltage drift: typically 0.1 $\mu$ V/month, including the first 30 days
- Wide range of supply voltages over specified temperature range:
  - 0°C to 70°C: 3V to 16V
  - -40°C to +85°C: 4V to 16V
- Single-supply operation
- Common-mode input voltage range extends below the negative rail (C-suffix, I-suffix types)
- Ultra-low power: 195 $\mu$ W at 25°C (typical),  $V_{DD} = 5$ V
- Output voltage range includes negative rail
- High input impedance: 10<sup>12</sup> $\Omega$  (typical)
- ESD-protection circuitry
- Small-outline package option also available in tape and reel
- Designed-in latch-up immunity

### 2 Applications

- [Smoke and heat detector](#)
- [Field transmitter and sensor](#)
  - [Flow transmitter](#)
  - [Pressure transmitter](#)
  - [Temperature transmitter](#)
  - [Level transmitter](#)
- [Motion detector](#)

### 3 Description

The TLC27L4x and TLC27L9 quad op amps combine a wide range of input offset-voltage grades with low offset-voltage drift, high input impedance, extremely low power, and high gain. The TLC27Lx use TI's silicon-gate LinCMOS™ technology, providing offset-voltage stability far exceeding the stability with conventional metal-gate processes.

Four offset voltage grades are available (C-suffix and I-suffix), ranging from the low-cost TLC27L4 (10mV) to the high-precision TLC27L9 (1000 $\mu$ V). The extremely high input impedance and low bias currents, along with good common-mode rejection and supply-voltage rejection, and low power consumption, make the TLC27Lx a good choice for new state-of-the-art designs and upgrading existing designs.

In general, many features associated with bipolar technology are available in LinCMOS op amps, without the power penalties of bipolar technology. General applications, such as transducer interfacing, analog calculations, amplifier blocks, active filters,

and signal buffering, are all easily designed with the TLC27Lx. The devices also exhibit low-voltage, single-supply operation, making the TLC27Lx an excellent choice for remote and inaccessible battery-powered applications. The common-mode input-voltage range includes the negative rail.

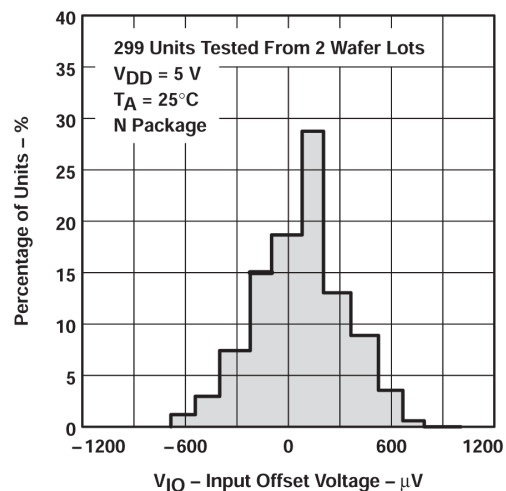
The TLC27Lx incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000V as tested under MIL-STD-883C, Method 3015.2. Exercise care when handling these devices because exposure to ESD potentially degrades device parametric performance.

C-suffix devices are characterized for operation from 0°C to 70°C. I-suffix devices are characterized for operation from -40°C to +85°C.

#### Device Information

| PART NUMBER | $V_{IOmax}$ at 25°C | PACKAGE <sup>(1)</sup>       |
|-------------|---------------------|------------------------------|
| TLC27L4     | 10mV                | D (SOIC, 14)                 |
|             |                     | N (PDIP, 14)                 |
|             |                     | NS (SOP, 14)                 |
|             |                     | PW (TSSOP, 14)               |
| TLC27L4A    | 5mV                 | D (SOIC, 14)<br>N (PDIP, 14) |
| TLC27L4B    | 2mV                 | D (SOIC, 14)                 |
| TLC27L9     | 1mV                 | D (SOIC, 14)                 |
|             |                     | N (PDIP, 14)                 |
|             |                     | NS (SOP, 14)                 |

(1) For more information, see [Section 10](#).



**Distribution of TLC27L9 Input Offset Voltage**



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## 4 Pin Configuration and Functions

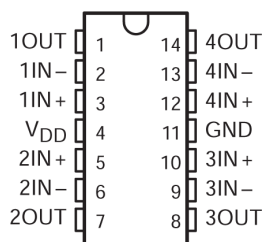


Figure 4-1. D (SOIC), N (PDIP), NS (SOP), or PW (TSSOP) 14-Pin Packages (Top View)

Table 4-1. Pin Functions

| PIN      |     | TYPE   | DESCRIPTION                              |
|----------|-----|--------|------------------------------------------|
| NAME     | NO. |        |                                          |
| 1IN+     | 3   | Input  | Noninverting input, channel 1            |
| 1IN-     | 2   | Input  | Inverting input, channel 1               |
| 1OUT     | 1   | Output | Output, channel 1                        |
| 2IN+     | 5   | Input  | Noninverting input, channel 2            |
| 2IN-     | 6   | Input  | Inverting input, channel 2               |
| 2OUT     | 7   | Output | Output, channel 2                        |
| 3IN+     | 10  | Input  | Noninverting input, channel 3            |
| 3IN-     | 9   | Input  | Inverting input, channel 3               |
| 3OUT     | 8   | Output | Output, channel 3                        |
| 4IN+     | 12  | Input  | Noninverting input, channel 4            |
| 4IN-     | 13  | Input  | Inverting input, channel 4               |
| 4OUT     | 14  | Output | Output, channel 4                        |
| GND      | 11  | Ground | Ground or negative (lowest) power supply |
| $V_{DD}$ | 4   | Power  | Positive (highest) power supply          |

## 5 Specifications

### 5.1 Absolute Maximum Ratings

Over operating free-air temperature, unless otherwise noted<sup>(1)</sup>

|                                |                                                                                          |                     | MIN                                     | MAX              | UNIT |
|--------------------------------|------------------------------------------------------------------------------------------|---------------------|-----------------------------------------|------------------|------|
| V <sub>DD</sub> <sup>(2)</sup> | Supply voltage                                                                           |                     |                                         | 18               | V    |
| V <sub>ID</sub> <sup>(3)</sup> | Differential input voltage                                                               |                     |                                         | ±V <sub>DD</sub> | V    |
| V <sub>I</sub>                 | Input voltage (any input)                                                                |                     | −0.3                                    | V <sub>DD</sub>  | V    |
| I <sub>I</sub>                 | Input current                                                                            |                     |                                         | ±5               | mA   |
| I <sub>O</sub>                 | Output current (each output)                                                             |                     |                                         | ±30              | mA   |
|                                | Total current into V <sub>DD</sub>                                                       |                     |                                         | 45               | mA   |
|                                | Total current out of GND                                                                 |                     |                                         | 45               | mA   |
|                                | Duration of short-circuit current at (or less than) T <sub>A</sub> = 25°C <sup>(4)</sup> |                     | Unlimited                               |                  |      |
|                                | Continuous total power dissipation                                                       |                     | See <a href="#">Dissipation Ratings</a> |                  |      |
| T <sub>A</sub>                 | Operating free-air temperature                                                           | C suffix            | 0                                       | 70               | °C   |
|                                |                                                                                          | I suffix            | −40                                     | 85               | °C   |
|                                |                                                                                          | M suffix            | −55                                     | 125              | °C   |
| T <sub>stg</sub>               | Storage temperature                                                                      |                     | −65                                     | 150              | °C   |
|                                | Lead temperature 1.6mm (1/16 inch) from case for 10 seconds                              | D, N, or PW package |                                         | 260              | °C   |

- (1) 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.
- (2) All voltage values, except differential voltages, are with respect to network ground.
- (3) Differential voltages are at the IN+ of a given channel, with respect to IN− for that same channel.
- (4) The output is able to be shorted to either supply. Limit temperature, supply voltages, or both to not exceed the maximum dissipation ratings (see [Section 7.1.6](#)).

### 5.2 Dissipation Ratings

| PACKAGE | T <sub>A</sub> ≤ 25°C<br>POWER RATING | T <sub>A</sub> > 25°C<br>DERATING FACTOR | T <sub>A</sub> = 70°C<br>POWER RATING | T <sub>A</sub> = 85°C<br>POWER RATING |
|---------|---------------------------------------|------------------------------------------|---------------------------------------|---------------------------------------|
| D       | 950 mW                                | 7.6 mW/°C                                | 608 mW                                | 494 mW                                |
| N       | 1575 mW                               | 12.6 mW/°C                               | 1008 mW                               | 819 mW                                |
| PW      | 700 mW                                | 5.6 mW/°C                                | 448 mW                                | —                                     |

### 5.3 Recommended Operating Conditions

|                 |                                |                       | MIN  | MAX | UNIT |
|-----------------|--------------------------------|-----------------------|------|-----|------|
| V <sub>DD</sub> | Supply voltage                 | C suffix              | 3    | 16  | V    |
|                 |                                | I suffix              | 4    | 16  |      |
| V <sub>IC</sub> | Common-mode input voltage      | V <sub>DD</sub> = 5V  | −0.2 | 3.5 | V    |
|                 |                                | V <sub>DD</sub> = 10V | −0.2 | 8.5 |      |
| T <sub>A</sub>  | Operating free-air temperature | C suffix              | 0    | 70  | °C   |
|                 |                                | I suffix              | −40  | 85  |      |

## 5.4 Electrical Characteristics, $V_{DD} = 5V$ , C Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER        |                                                                      |           | TEST CONDITIONS                                                                         | T <sub>A</sub> | TLC27L4C, TLC27L4AC,<br>TLC27L4BC, TLC27L9C |             |       | UNIT |
|------------------|----------------------------------------------------------------------|-----------|-----------------------------------------------------------------------------------------|----------------|---------------------------------------------|-------------|-------|------|
|                  |                                                                      |           |                                                                                         |                | MIN                                         | TYP         | MAX   |      |
| V <sub>IO</sub>  | Input offset voltage                                                 | TLC27L4C  | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 1.1    10                                   |             | mV    |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             | 12             |                                             |             |       |      |
|                  |                                                                      | TLC27L4AC | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 0.9    5                                    |             |       |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             | 6.5            |                                             |             |       |      |
|                  |                                                                      | TLC27L4BC | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 240                                         | 2000        | μV    |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             | 3000           |                                             |             |       |      |
|                  |                                                                      | TLC27L9C  | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 210                                         | 1000        |       |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             | 1500           |                                             |             |       |      |
| α <sub>VIO</sub> | Average temperature coefficient of input offset voltage              |           |                                                                                         | 25°C to 70°C   | 1.1                                         |             | μV/°C |      |
| I <sub>IO</sub>  | Input offset current <sup>(1) (2)</sup>                              |           | V <sub>O</sub> = 2.5V, V <sub>IC</sub> = 2.5V                                           | 25°C           | 0.5                                         |             | pA    |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 7                                           | 300         |       |      |
| I <sub>IB</sub>  | Input bias current <sup>(1) (2)</sup>                                |           | V <sub>O</sub> = 2.5V, V <sub>IC</sub> = 2.5V                                           | 25°C           | 0.6                                         |             | pA    |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 40                                          | 600         |       |      |
| V <sub>ICR</sub> | Common mode input voltage range <sup>(3)</sup>                       |           |                                                                                         | 25°C           | -0.2 to 4                                   | -0.2 to 4.2 | V     |      |
|                  |                                                                      |           |                                                                                         | 0°C to 70°C    | -0.2 to 3.5                                 |             | V     |      |
| V <sub>OH</sub>  | High-level output voltage                                            |           | V <sub>ID</sub> = 100mV, R <sub>L</sub> = 1MΩ                                           | 25°C           | 3.2                                         | 4.1         | V     |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 3                                           | 4.1         |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 3                                           | 4.2         |       |      |
| V <sub>OL</sub>  | Low-level output voltage                                             |           | V <sub>ID</sub> = -100mV, I <sub>OL</sub> = 0mA                                         | 25°C           | 1                                           | 50          | mV    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 1                                           | 50          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 1                                           | 50          |       |      |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      |           | V <sub>O</sub> = 2.5V to 2V, R <sub>L</sub> = 1MΩ                                       | 25°C           | 50                                          | 520         | V/mV  |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 50                                          | 680         |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 50                                          | 380         |       |      |
| CMRR             | Common-mode rejection ratio                                          |           | V <sub>IC</sub> = V <sub>ICR,min</sub>                                                  | 25°C           | 65                                          | 87          | dB    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 60                                          | 85          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 60                                          | 85          |       |      |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) |           | V <sub>DD</sub> = 5V to 10V, V <sub>O</sub> = 1.4V                                      | 25°C           | 70                                          | 97          | dB    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 60                                          | 97          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 60                                          | 98          |       |      |
| I <sub>DD</sub>  | Supply current (four amplifiers)                                     |           | V <sub>O</sub> = 2.5V, V <sub>IC</sub> = 2.5V, no load                                  | 25°C           | 40                                          | 68          | μA    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 48                                          | 84          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 31                                          | 56          |       |      |

(1) Typical values of input bias current and input offset current less than 5pA determined mathematically.

(2) Values specified by characterization.

(3) This range also applies to each input individually.

## 5.5 Operating Characteristics, $V_{DD} = 5V$ , C Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER       |                                | TEST CONDITIONS                                                                                                   |                         | T <sub>A</sub> | TLC27L4C, TLC27L4AC,<br>TLC27L4BC, TLC27L9C |     |        | UNIT |
|-----------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------|-------------------------|----------------|---------------------------------------------|-----|--------|------|
|                 |                                |                                                                                                                   |                         |                | MIN                                         | TYP | MAX    |      |
| SR              | Slew rate at unity gain        | R <sub>L</sub> = 1MΩ,<br>C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a>                                 | V <sub>IPP</sub> = 1V   | 25°C           | 0.03                                        |     | V/μs   |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 0.04                                        |     |        |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 0.03                                        |     |        |      |
|                 |                                |                                                                                                                   | V <sub>IPP</sub> = 2.5V | 25°C           | 0.03                                        |     |        |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 0.03                                        |     |        |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 0.02                                        |     |        |      |
| V <sub>n</sub>  | Equivalent input noise voltage | f = 1kHz, R <sub>S</sub> = 20Ω, see <a href="#">Figure 6-2</a>                                                    |                         | 25°C           | 70                                          |     | nV/√Hz |      |
| B <sub>OM</sub> | Maximum output-swing bandwidth | V <sub>O</sub> = V <sub>OH</sub> , R <sub>L</sub> = 1MΩ, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a> |                         | 25°C           | 5                                           |     | kHz    |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 6                                           |     |        |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 4.5                                         |     |        |      |
| B <sub>1</sub>  | Unity-gain bandwidth           | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-3</a>                                   |                         | 25°C           | 85                                          |     | kHz    |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 100                                         |     |        |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 65                                          |     |        |      |
| ϕ <sub>m</sub>  | Phase margin                   | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF, f = B <sub>1</sub> ,<br>see <a href="#">Figure 6-3</a>              |                         | 25°C           | 34°                                         |     | °      |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 36°                                         |     |        |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 30°                                         |     |        |      |

## 5.6 Electrical Characteristics, $V_{DD} = 10V$ , C Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER        |                                                                      |           | TEST CONDITIONS                                                                         | T <sub>A</sub> | TLC27L4C,<br>TLC27L4AC,<br>TLC27L4BC,<br>TLC27L9C |             |       | UNIT |
|------------------|----------------------------------------------------------------------|-----------|-----------------------------------------------------------------------------------------|----------------|---------------------------------------------------|-------------|-------|------|
|                  |                                                                      |           |                                                                                         |                | MIN                                               | TYP         | MAX   |      |
| V <sub>IO</sub>  | Input offset voltage                                                 | TLC27L4C  | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 1.1                                               | 10          | mV    |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             |                | 12                                                |             |       |      |
|                  |                                                                      | TLC27L4AC | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 0.9                                               | 5           |       |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             |                | 6.5                                               |             |       |      |
|                  |                                                                      | TLC27L4BC | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 260                                               | 2000        | μV    |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             |                | 3000                                              |             |       |      |
|                  |                                                                      | TLC27L9C  | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 210                                               | 1200        |       |      |
|                  |                                                                      |           | 0°C to 70°C                                                                             |                | 1900                                              |             |       |      |
| α <sub>VIO</sub> | Average temperature coefficient of input offset voltage              |           |                                                                                         | 25°C to 70°C   | 1                                                 |             | μV/°C |      |
| I <sub>IO</sub>  | Input offset current <sup>(1) (2)</sup>                              |           | V <sub>O</sub> = 5V, V <sub>IC</sub> = 5V                                               | 25°C           | 0.5                                               |             | pA    |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 7                                                 | 300         |       |      |
| I <sub>IB</sub>  | Input bias current <sup>(1) (2)</sup>                                |           | V <sub>O</sub> = 5V, V <sub>IC</sub> = 5V                                               | 25°C           | 0.7                                               |             | pA    |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 50                                                | 600         |       |      |
| V <sub>ICR</sub> | Common-mode input voltage range <sup>(3)</sup>                       |           |                                                                                         | 25°C           | -0.2 to 9                                         | -0.2 to 9.2 | V     |      |
|                  |                                                                      |           |                                                                                         | 0°C to 70°C    | -0.2 to 8.5                                       |             | V     |      |
| V <sub>OH</sub>  | High-level output voltage                                            |           | V <sub>ID</sub> = 100mV, R <sub>L</sub> = 1MΩ                                           | 25°C           | 8                                                 | 8.9         | V     |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 7.8                                               | 8.9         |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 7.8                                               | 8.9         |       |      |
| V <sub>OL</sub>  | Low-level output voltage                                             |           | V <sub>ID</sub> = -100mV, I <sub>OL</sub> = 0mA                                         | 25°C           | 5                                                 | 50          | mV    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 5                                                 | 50          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 5                                                 | 50          |       |      |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      |           | V <sub>O</sub> = 1V to 6V, R <sub>L</sub> = 1MΩ                                         | 25°C           | 50                                                | 870         | V/mV  |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 50                                                | 1020        |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 50                                                | 660         |       |      |
| CMRR             | Common-mode rejection ratio                                          |           | V <sub>IC</sub> = V <sub>ICRmin</sub>                                                   | 25°C           | 65                                                | 94          | dB    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 60                                                | 93          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 60                                                | 93          |       |      |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) |           | V <sub>DD</sub> = 5V to 10V, V <sub>O</sub> = 1.4V                                      | 25°C           | 70                                                | 97          | dB    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 60                                                | 97          |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 60                                                | 98          |       |      |
| I <sub>DD</sub>  | Supply current (four amplifiers)                                     |           | V <sub>O</sub> = 5V, V <sub>IC</sub> = 5V, no load                                      | 25°C           | 57                                                | 92          | μA    |      |
|                  |                                                                      |           |                                                                                         | 0°C            | 72                                                | 132         |       |      |
|                  |                                                                      |           |                                                                                         | 70°C           | 44                                                | 80          |       |      |

(1) Typical values of input bias current and input offset current less than 5pA determined mathematically.

(2) Values specified by characterization.

(3) This range also applies to each input individually.

## 5.7 Operating Characteristics, $V_{DD} = 10V$ , C Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER       |                                | TEST CONDITIONS                                                                                                   |                         | T <sub>A</sub> | TLC27L4C, TLC27L4AC,<br>TLC27L4BC, TLC27L9C |        |      | UNIT |
|-----------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------|-------------------------|----------------|---------------------------------------------|--------|------|------|
|                 |                                |                                                                                                                   |                         |                | MIN                                         | TYP    | MAX  |      |
| SR              | Slew rate at unity gain        | R <sub>L</sub> = 1MΩ,<br>C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a>                                 | V <sub>IPP</sub> = 1V   | 25°C           | 0.05                                        |        | V/μs |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 0.05                                        |        |      |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 0.04                                        |        |      |      |
|                 |                                |                                                                                                                   | V <sub>IPP</sub> = 5.5V | 25°C           | 0.04                                        |        |      |      |
|                 |                                |                                                                                                                   |                         | 0°C            | 0.05                                        |        |      |      |
|                 |                                |                                                                                                                   |                         | 70°C           | 0.04                                        |        |      |      |
| V <sub>n</sub>  | Equivalent input noise voltage | f = 1kHz , R <sub>S</sub> = 20Ω,<br>see <a href="#">Figure 6-2</a>                                                | 25°C                    | 70             |                                             | nV/√Hz |      |      |
| B <sub>OM</sub> | Maximum output-swing bandwidth | V <sub>O</sub> = V <sub>OH</sub> , R <sub>L</sub> = 1MΩ, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a> | 25°C                    | 1              |                                             | kHz    |      |      |
|                 |                                |                                                                                                                   | 0°C                     | 1.3            |                                             |        |      |      |
|                 |                                |                                                                                                                   | 70°C                    | 0.9            |                                             |        |      |      |
| B <sub>1</sub>  | Unity-gain bandwidth           | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-3</a>                                   | 25°C                    | 110            |                                             | kHz    |      |      |
|                 |                                |                                                                                                                   | 0°C                     | 110            |                                             |        |      |      |
|                 |                                |                                                                                                                   | 70°C                    | 90             |                                             |        |      |      |
| ϕ <sub>m</sub>  | Phase margin                   | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF, f = B <sub>1</sub> ,<br>see <a href="#">Figure 6-3</a>              | 25°C                    | 38°            |                                             | °      |      |      |
|                 |                                |                                                                                                                   | 0°C                     | 40°            |                                             |        |      |      |
|                 |                                |                                                                                                                   | 70°C                    | 34°            |                                             |        |      |      |

## 5.8 Electrical Characteristics, $V_{DD} = 5V$ , I Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER        |                                                                      |                                                        | TEST CONDITIONS                                                                         | T <sub>A</sub> | TLC27L4I, TLC27L4AI, TLC27L4BI, TLC27L9I |      |       | UNIT |
|------------------|----------------------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------|------------------------------------------|------|-------|------|
|                  |                                                                      |                                                        |                                                                                         |                | MIN                                      | TYP  | MAX   |      |
| V <sub>IO</sub>  | Input offset voltage                                                 | TLC27L4I                                               | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 1.1                                      | 10   | mV    |      |
|                  |                                                                      |                                                        |                                                                                         | −40°C to +85°C |                                          | 13   |       |      |
|                  |                                                                      | TLC27L4AI                                              | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 0.9                                      | 5    |       |      |
|                  |                                                                      |                                                        |                                                                                         | −40°C to +85°C |                                          | 7    |       |      |
|                  |                                                                      | TLC27L4BI                                              | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 240                                      | 2000 | μV    |      |
|                  |                                                                      |                                                        |                                                                                         | −40°C to +85°C |                                          | 3500 |       |      |
|                  |                                                                      | TLC27L9I                                               | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V, R <sub>L</sub> = 1MΩ | 25°C           | 210                                      | 1000 |       |      |
|                  |                                                                      |                                                        |                                                                                         | −40°C to +85°C |                                          | 2000 |       |      |
| α <sub>VIO</sub> | Average temperature coefficient of input offset voltage              |                                                        |                                                                                         | 25°C to 85°C   | 1.1                                      |      | μV/°C |      |
| I <sub>IO</sub>  | Input offset current <sup>(1) (2)</sup>                              | V <sub>O</sub> = 2.5V, V <sub>IC</sub> = 2.5V          | 25°C                                                                                    | 0.5            |                                          | pA   |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 24             | 1000                                     |      |       |      |
| I <sub>IB</sub>  | Input bias current <sup>(1) (2)</sup>                                | V <sub>O</sub> = 2.5V, V <sub>IC</sub> = 2.5V          | 25°C                                                                                    | 0.6            |                                          | pA   |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 200            | 2000                                     |      |       |      |
| V <sub>ICR</sub> | Common-mode input voltage range <sup>(3)</sup>                       |                                                        | 25°C                                                                                    | −0.2 to 4      | −0.2 to 4.2                              | V    |       |      |
|                  |                                                                      |                                                        | −40°C to +85°C                                                                          | −0.2 to 3.5    |                                          | V    |       |      |
| V <sub>OH</sub>  | High-level output voltage                                            | V <sub>ID</sub> = 100mV, R <sub>L</sub> = 1MΩ          | 25°C                                                                                    | 3.2            | 4.1                                      | V    |       |      |
|                  |                                                                      |                                                        | −40°C                                                                                   | 3              | 4.1                                      |      |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 3              | 4.2                                      |      |       |      |
| V <sub>OL</sub>  | Low-level output voltage                                             | V <sub>ID</sub> = −100mV, I <sub>OL</sub> = 0mA        | 25°C                                                                                    | 1              | 50                                       | mV   |       |      |
|                  |                                                                      |                                                        | −40°C                                                                                   | 1              | 50                                       |      |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 1              | 50                                       |      |       |      |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      | V <sub>O</sub> = 0.25V to 2V, R <sub>L</sub> = 1MΩ     | 25°C                                                                                    | 50             | 480                                      | V/mV |       |      |
|                  |                                                                      |                                                        | −40°C                                                                                   | 50             | 900                                      |      |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 50             | 330                                      |      |       |      |
| CMRR             | Common-mode rejection ratio                                          | V <sub>IC</sub> = V <sub>ICR</sub> min                 | 25°C                                                                                    | 65             | 87                                       | dB   |       |      |
|                  |                                                                      |                                                        | −40°C                                                                                   | 60             | 85                                       |      |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 60             | 85                                       |      |       |      |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) | V <sub>DD</sub> = 5V to 10V, V <sub>O</sub> = 1.4V     | 25°C                                                                                    | 70             | 97                                       | dB   |       |      |
|                  |                                                                      |                                                        | −40°C                                                                                   | 60             | 97                                       |      |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 60             | 98                                       |      |       |      |
| I <sub>DD</sub>  | Supply current (four amplifiers)                                     | V <sub>O</sub> = 2.5V, V <sub>IC</sub> = 2.5V, no load | 25°C                                                                                    | 39             | 68                                       | μA   |       |      |
|                  |                                                                      |                                                        | −40°C                                                                                   | 62             | 108                                      |      |       |      |
|                  |                                                                      |                                                        | 85°C                                                                                    | 29             | 52                                       |      |       |      |

(1) Typical values of input bias current and input offset current less than 5pA determined mathematically.

(2) Values specified by characterization.

(3) This range also applies to each input individually.



## 5.9 Operating Characteristics, $V_{DD} = 5V$ , I Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER       |                                | TEST CONDITIONS                                                                                                   |                         | T <sub>A</sub> | TLC27L4I, TLC27L4AI,<br>TLC27L4BI, TLC27L9I |     |     | UNIT   |
|-----------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------|-------------------------|----------------|---------------------------------------------|-----|-----|--------|
|                 |                                |                                                                                                                   |                         |                | MIN                                         | TYP | MAX |        |
| SR              | Slew rate at unity gain        | R <sub>L</sub> = 1MΩ,<br>C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a>                                 | V <sub>IPP</sub> = 1V   | 25°C           | 0.03                                        |     |     | V/μs   |
|                 |                                |                                                                                                                   |                         | -40°C          | 0.04                                        |     |     |        |
|                 |                                |                                                                                                                   |                         | 85°C           | 0.03                                        |     |     |        |
|                 |                                |                                                                                                                   | V <sub>IPP</sub> = 2.5V | 25°C           | 0.03                                        |     |     |        |
|                 |                                |                                                                                                                   |                         | -40°C          | 0.04                                        |     |     |        |
|                 |                                |                                                                                                                   |                         | 85°C           | 0.02                                        |     |     |        |
| V <sub>n</sub>  | Equivalent input noise voltage | f = 1kHz, R <sub>S</sub> = 20Ω,<br>see <a href="#">Figure 6-2</a>                                                 | 25°C                    |                | 70                                          |     |     | nV/√Hz |
| B <sub>OM</sub> | Maximum output-swing bandwidth | V <sub>O</sub> = V <sub>OH</sub> , R <sub>L</sub> = 1MΩ, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a> | 25°C                    |                | 5                                           |     |     | kHz    |
|                 |                                |                                                                                                                   | -40°C                   |                | 7                                           |     |     |        |
|                 |                                |                                                                                                                   | 85°C                    |                | 4                                           |     |     |        |
| B <sub>1</sub>  | Unity-gain bandwidth           | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-3</a>                                   | 25°C                    |                | 85                                          |     |     | kHz    |
|                 |                                |                                                                                                                   | -40°C                   |                | 110                                         |     |     |        |
|                 |                                |                                                                                                                   | 85°C                    |                | 55                                          |     |     |        |
| ϕ <sub>m</sub>  | Phase margin                   | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF, f = B <sub>1</sub> ,<br>see <a href="#">Figure 6-3</a>              | 25°C                    |                | 34°                                         |     |     | °      |
|                 |                                |                                                                                                                   | -40°C                   |                | 38°                                         |     |     |        |
|                 |                                |                                                                                                                   | 85°C                    |                | 28°                                         |     |     |        |

## 5.10 Electrical Characteristics, $V_{DD} = 10V$ , I Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER        |                                                                      |           | TEST CONDITIONS                                                                            | T <sub>A</sub> | TLC27L4I, TLC27L4AI,<br>TLC27L4BI, TLC27L9I |             |       | UNIT |
|------------------|----------------------------------------------------------------------|-----------|--------------------------------------------------------------------------------------------|----------------|---------------------------------------------|-------------|-------|------|
|                  |                                                                      |           |                                                                                            |                | MIN                                         | TYP         | MAX   |      |
| V <sub>IO</sub>  | Input offset voltage                                                 | TLC27L4I  | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V,<br>R <sub>L</sub> = 1MΩ | 25°C           | 1.1                                         | 10          | mV    |      |
|                  |                                                                      |           |                                                                                            | –40°C to +85°C |                                             | 13          |       |      |
|                  |                                                                      | TLC27L4AI | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V,<br>R <sub>L</sub> = 1MΩ | 25°C           | 0.9                                         | 5           |       |      |
|                  |                                                                      |           |                                                                                            | –40°C to +85°C |                                             | 7           |       |      |
|                  |                                                                      | TLC27L4BI | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V,<br>R <sub>L</sub> = 1MΩ | 25°C           | 260                                         | 2000        | μV    |      |
|                  |                                                                      |           |                                                                                            | –40°C to +85°C |                                             | 3500        |       |      |
|                  |                                                                      | TLC27L9I  | V <sub>O</sub> = 1.4V, R <sub>S</sub> = 50Ω, V <sub>IC</sub> = 0V,<br>R <sub>L</sub> = 1MΩ | 25°C           | 210                                         | 1200        |       |      |
|                  |                                                                      |           |                                                                                            | –40°C to +85°C |                                             | 2900        |       |      |
| α <sub>VIO</sub> | Average temperature coefficient of input offset voltage              |           |                                                                                            | 25°C to 85°C   | 1                                           |             | μV/°C |      |
| I <sub>IO</sub>  | Input offset current <sup>(1) (2)</sup>                              |           | V <sub>O</sub> = 5V, V <sub>IC</sub> = 5V                                                  | 25°C           | 0.5                                         |             | pA    |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 26                                          | 1000        |       |      |
| I <sub>IB</sub>  | Input bias current <sup>(1) (2)</sup>                                |           | V <sub>O</sub> = 5V, V <sub>IC</sub> = 5V                                                  | 25°C           | 0.7                                         |             | pA    |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 220                                         | 2000        |       |      |
| V <sub>ICR</sub> | Common-mode input voltage range <sup>(3)</sup>                       |           |                                                                                            | 25°C           | –0.2 to 9                                   | –0.2 to 9.2 | V     |      |
|                  |                                                                      |           |                                                                                            | –40°C to +85°C | –0.2 to 8.5                                 |             | V     |      |
| V <sub>OH</sub>  | High-level output voltage                                            |           | V <sub>ID</sub> = 100mV, R <sub>L</sub> = 1MΩ                                              | 25°C           | 8                                           | 8.9         | V     |      |
|                  |                                                                      |           |                                                                                            | –40°C          | 7.8                                         | 8.9         |       |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 7.8                                         | 8.9         |       |      |
| V <sub>OL</sub>  | Low-level output voltage                                             |           | V <sub>ID</sub> = –100mV, I <sub>OL</sub> = 0mA                                            | 25°C           | 5                                           | 50          | mV    |      |
|                  |                                                                      |           |                                                                                            | –40°C          | 5                                           | 50          |       |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 5                                           | 50          |       |      |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      |           | V <sub>O</sub> = 1V to 6V, R <sub>L</sub> = 1MΩ                                            | 25°C           | 50                                          | 800         | V/mV  |      |
|                  |                                                                      |           |                                                                                            | –40°C          | 50                                          | 1550        |       |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 50                                          | 585         |       |      |
| CMRR             | Common-mode rejection ratio                                          |           | V <sub>IC</sub> = V <sub>ICR</sub> min                                                     | 25°C           | 65                                          | 94          | dB    |      |
|                  |                                                                      |           |                                                                                            | –40°C          | 60                                          | 93          |       |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 60                                          | 93          |       |      |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) |           | V <sub>DD</sub> = 5V to 10V, V <sub>O</sub> = 1.4V                                         | 25°C           | 70                                          | 97          | dB    |      |
|                  |                                                                      |           |                                                                                            | –40°C          | 60                                          | 97          |       |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 60                                          | 98          |       |      |
| I <sub>DD</sub>  | Supply current (four amplifiers)                                     |           | V <sub>O</sub> = 5V, V <sub>IC</sub> = 5V, no load                                         | 25°C           | 57                                          | 92          | μA    |      |
|                  |                                                                      |           |                                                                                            | –40°C          | 98                                          | 172         |       |      |
|                  |                                                                      |           |                                                                                            | 85°C           | 40                                          | 72          |       |      |

(1) Typical values of input bias current and input offset current less than 5pA determined mathematically.

(2) Values specified by characterization.

(3) This range also applies to each input individually.

## 5.11 Operating Characteristics, $V_{DD} = 10V$ , I Suffix

at specified free-air temperature (unless otherwise noted)

| PARAMETER       |                                | TEST CONDITIONS                                                                                                   |                          | T <sub>A</sub> | TLC27L4I, TLC27L4AI,<br>TLC27L4BI, TLC27L9I |     |        | UNIT |
|-----------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------|--------------------------|----------------|---------------------------------------------|-----|--------|------|
|                 |                                |                                                                                                                   |                          |                | MIN                                         | TYP | MAX    |      |
| SR              | Slew rate at unity gain        | R <sub>L</sub> = 1MΩ,<br>C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a>                                 | V <sub>I</sub> PP = 1V   | 25°C           | 0.05                                        |     | V/μs   |      |
|                 |                                |                                                                                                                   |                          | −40°C          | 0.06                                        |     |        |      |
|                 |                                |                                                                                                                   |                          | 85°C           | 0.03                                        |     |        |      |
|                 |                                |                                                                                                                   | V <sub>I</sub> PP = 2.5V | 25°C           | 0.04                                        |     |        |      |
|                 |                                |                                                                                                                   |                          | −40°C          | 0.05                                        |     |        |      |
|                 |                                |                                                                                                                   |                          | 85°C           | 0.03                                        |     |        |      |
| V <sub>n</sub>  | Equivalent input noise voltage | f = 1kHz, R <sub>S</sub> = 20Ω,<br>see <a href="#">Figure 6-2</a>                                                 |                          | 25°C           | 70                                          |     | nV/√Hz |      |
| B <sub>OM</sub> | Maximum output-swing bandwidth | V <sub>O</sub> = V <sub>OH</sub> , R <sub>L</sub> = 1MΩ, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-1</a> |                          | 25°C           | 1                                           |     | kHz    |      |
|                 |                                |                                                                                                                   |                          | −40°C          | 1.4                                         |     |        |      |
|                 |                                |                                                                                                                   |                          | 85°C           | 0.8                                         |     |        |      |
| B <sub>1</sub>  | Unity-gain bandwidth           | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF,<br>see <a href="#">Figure 6-3</a>                                   |                          | 25°C           | 110                                         |     | kHz    |      |
|                 |                                |                                                                                                                   |                          | −40°C          | 110                                         |     |        |      |
|                 |                                |                                                                                                                   |                          | 85°C           | 80                                          |     |        |      |
| ϕ <sub>m</sub>  | Phase margin                   | V <sub>I</sub> = 10mV, C <sub>L</sub> = 20pF, f = B <sub>1</sub> ,<br>see <a href="#">Figure 6-3</a>              |                          | 25°C           | 38°                                         |     | °      |      |
|                 |                                |                                                                                                                   |                          | −40°C          | 42°                                         |     |        |      |
|                 |                                |                                                                                                                   |                          | 85°C           | 32°                                         |     |        |      |

## 5.12 Typical Characteristics

data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Table 5-1. Table of Graphs**

|                |                                     |                               | FIGURE                                                      |
|----------------|-------------------------------------|-------------------------------|-------------------------------------------------------------|
| $V_{IO}$       | Input offset voltage                | Distribution                  | <a href="#">Figure 5-1,</a><br><a href="#">Figure 5-2</a>   |
| $\alpha_{VIO}$ | Temperature coefficient             | Distribution                  | <a href="#">Figure 5-3,</a><br><a href="#">Figure 5-4</a>   |
| $V_{OH}$       | High-level output voltage           | vs High-level output current  | <a href="#">Figure 5-5,</a><br><a href="#">Figure 5-6</a>   |
|                |                                     | vs Supply voltage             | <a href="#">Figure 5-7</a>                                  |
|                |                                     | vs Free-air temperature       | <a href="#">Figure 5-8</a>                                  |
| $V_{OL}$       | Low-level output voltage            | vs Common-mode input voltage  | <a href="#">Figure 5-9,</a><br><a href="#">Figure 5-10</a>  |
|                |                                     | vs Differential input voltage | <a href="#">Figure 5-11</a>                                 |
|                |                                     | vs Free-air temperature       | <a href="#">Figure 5-12</a>                                 |
|                |                                     | vs Low-level output current   | <a href="#">Figure 5-13,</a><br><a href="#">Figure 5-14</a> |
| $A_{VD}$       | Differential voltage amplification  | vs Supply voltage             | <a href="#">Figure 5-15</a>                                 |
|                |                                     | vs Free-air temperature       | <a href="#">Figure 5-16</a>                                 |
|                |                                     | vs Frequency                  | <a href="#">Figure 5-25,</a><br><a href="#">Figure 5-26</a> |
| $I_B/I_{IO}$   | Input bias and input offset current | vs Free-air temperature       | <a href="#">Figure 5-17</a>                                 |
| $V_{IC}$       | Common-mode input voltage           | vs Supply voltage             | <a href="#">Figure 5-18</a>                                 |
| $I_{DD}$       | Supply current                      | vs Supply voltage             | <a href="#">Figure 5-19</a>                                 |
|                |                                     | vs Free-air temperature       | <a href="#">Figure 5-20</a>                                 |
| $S_R$          | Slew rate                           | vs Supply voltage             | <a href="#">Figure 5-21</a>                                 |
|                |                                     | vs Free-air temperature       | <a href="#">Figure 5-22</a>                                 |
|                | Normalized slew rate                | vs Free-air temperature       | <a href="#">Figure 5-23</a>                                 |
| $V_{O(PP)}$    | Maximum peak-to-peak output voltage | vs Frequency                  | <a href="#">Figure 5-24</a>                                 |
| $\phi_m$       | Phase margin                        | vs Supply voltage             | <a href="#">Figure 5-27</a>                                 |
|                |                                     | vs Free-air temperature       | <a href="#">Figure 5-28</a>                                 |
|                |                                     | vs Capacitive loads           | <a href="#">Figure 5-29</a>                                 |
| $V_n$          | Equivalent input noise voltage      | vs Frequency                  | <a href="#">Figure 5-30</a>                                 |
| $\phi$         | Phase shift                         | vs Frequency                  | <a href="#">Figure 5-25,</a><br><a href="#">Figure 5-26</a> |

## 5.12 Typical Characteristics (continued)

data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

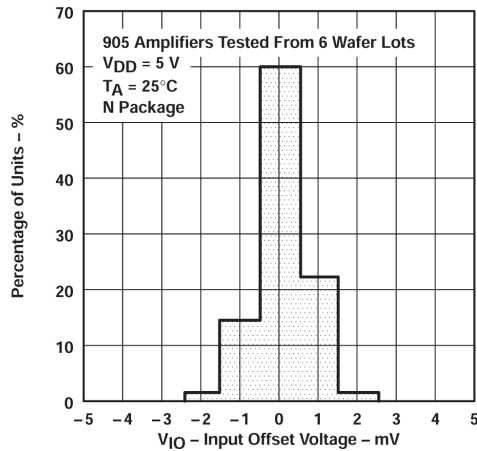


Figure 5-1. Distribution of TLC27L4 Input Offset Voltage

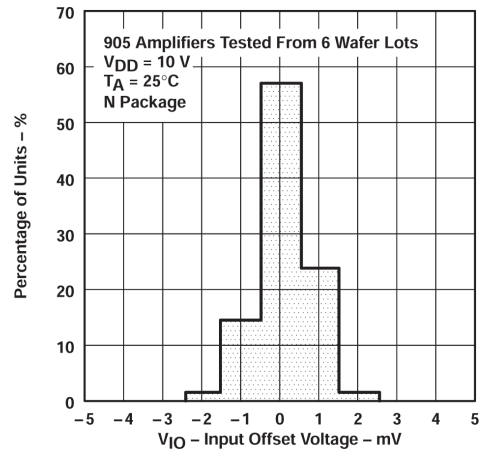


Figure 5-2. Distribution of TLC27L4 Input Offset Voltage

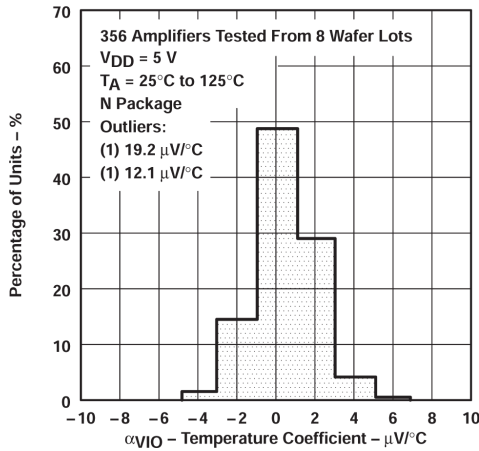


Figure 5-3. Distribution of TLC27L4 and TLC27L9 Input Offset Voltage Temperature Coefficient

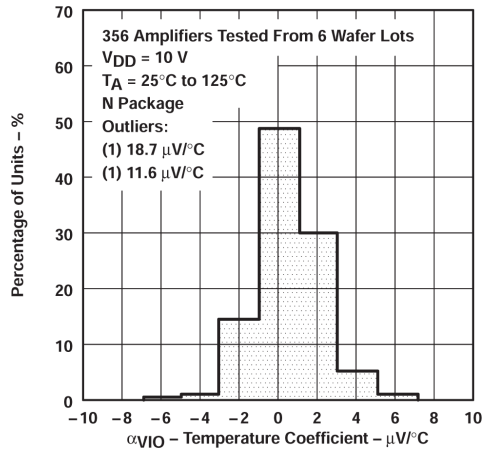


Figure 5-4. Distribution of TLC27L4 and TLC27L9 Input Offset Voltage Temperature Coefficient

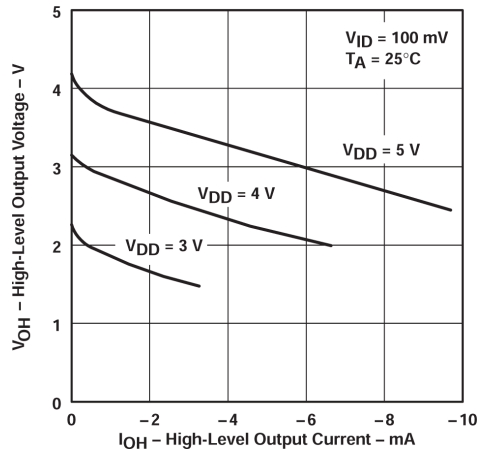


Figure 5-5. High-level Output Voltage vs High-level Output Current

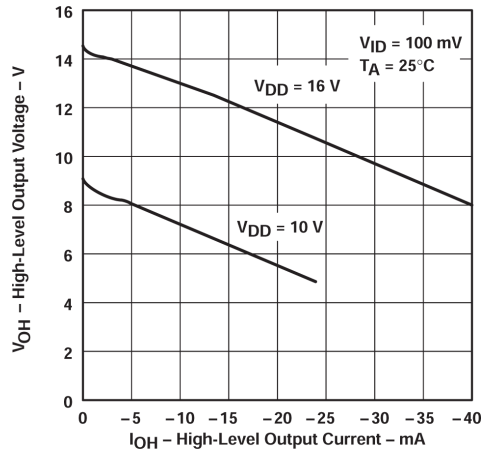


Figure 5-6. High-level Output Voltage vs High-level Output Current

## 5.12 Typical Characteristics (continued)

data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

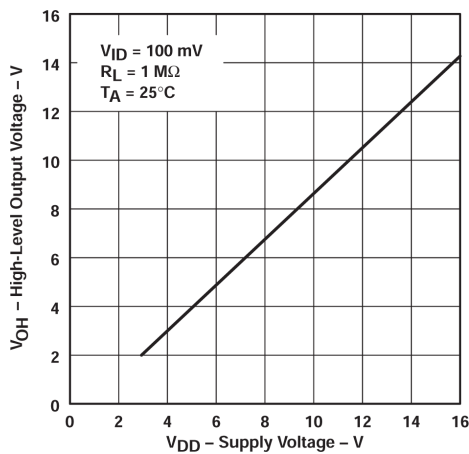


Figure 5-7. High-level Output Voltage vs Supply Voltage

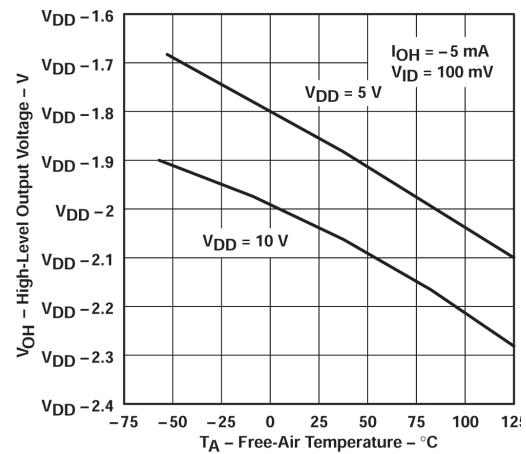


Figure 5-8. High-level Output Voltage vs Free-air Temperature

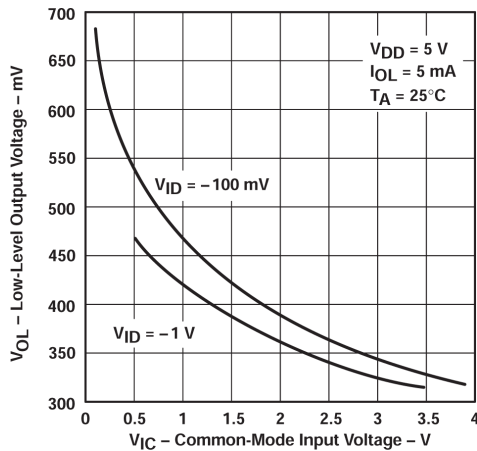


Figure 5-9. Low-level Output Voltage vs Common-mode Input Voltage

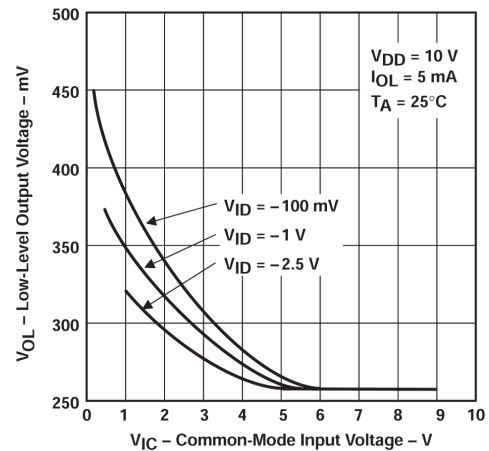


Figure 5-10. Low-level Output Voltage vs Common-mode Input Voltage

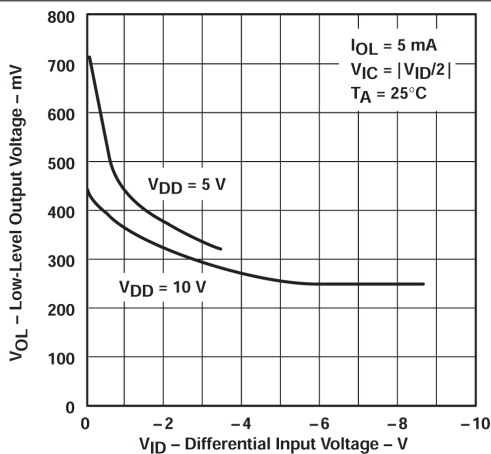


Figure 5-11. Low-level Output Voltage vs Differential Input Voltage

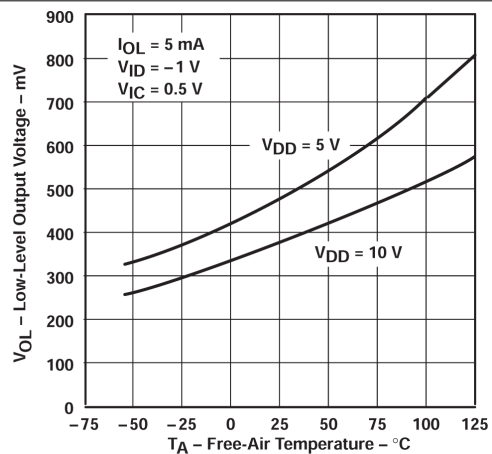
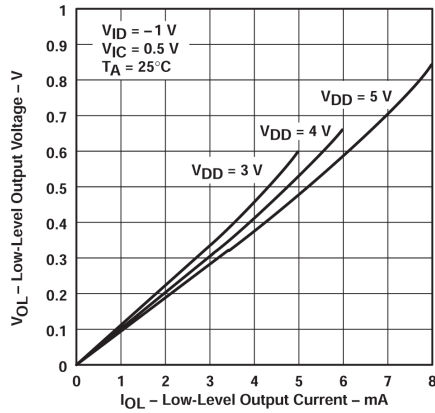


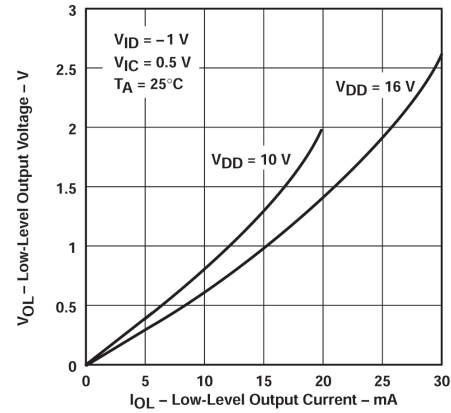
Figure 5-12. Low-level Output Voltage vs Free-air Temperature

## 5.12 Typical Characteristics (continued)

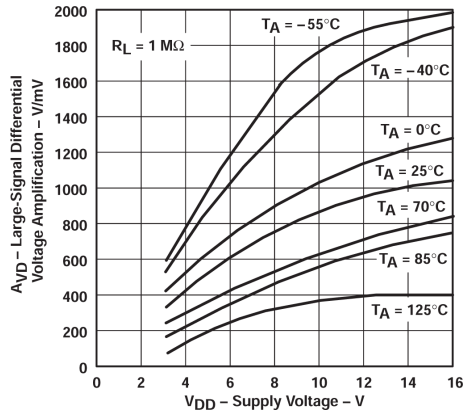
data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices



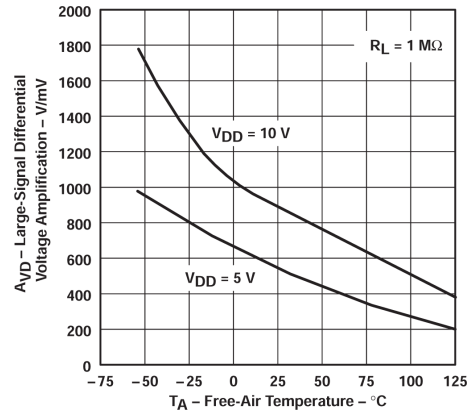
**Figure 5-13. Low-level Output Voltage vs Low-level Output Current**



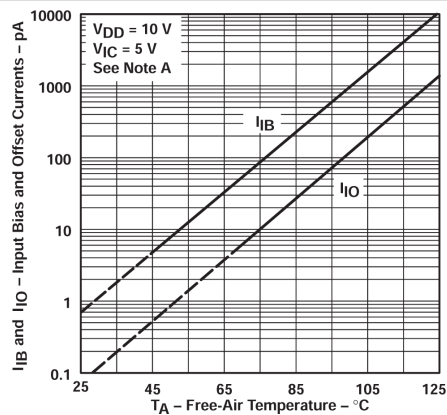
**Figure 5-14. Low-level Output Voltage vs Low-level Output Current**



**Figure 5-15. Large-signal Differential Voltage Amplification vs Supply Voltage**

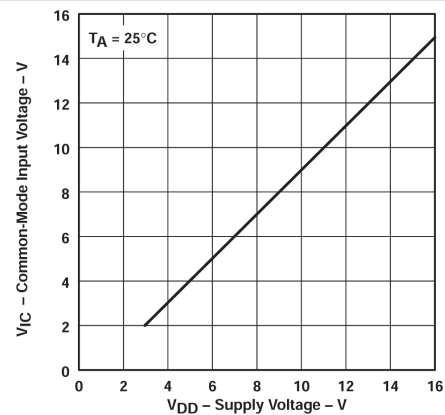


**Figure 5-16. Large-signal Differential Voltage Amplification vs Free-air Temperature**



Typical values of input bias current and input offset current less than 5pA determined mathematically.

**Figure 5-17. Input Bias Current and Input Offset Current vs Free-air Temperature**



**Figure 5-18. Common-mode Input Voltage Positive Limit vs Supply Voltage**

## 5.12 Typical Characteristics (continued)

data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

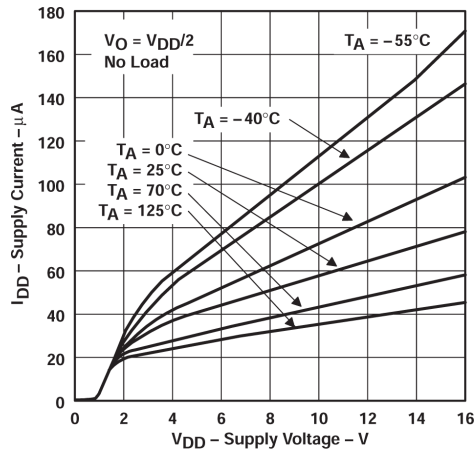


Figure 5-19. Supply Current vs Supply Voltage

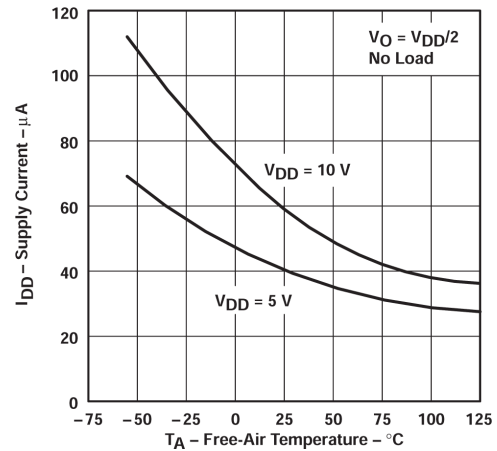


Figure 5-20. Supply Current vs Free-air Temperature

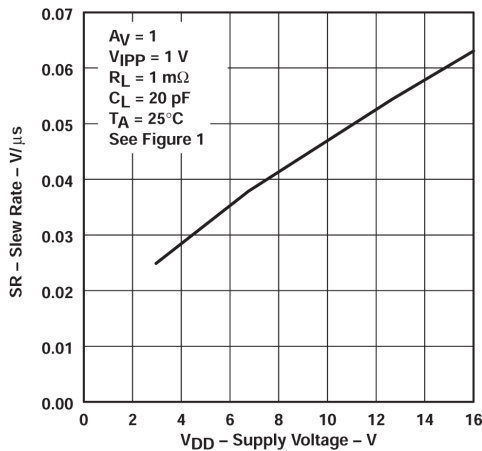


Figure 5-21. Slew Rate vs Supply Voltage

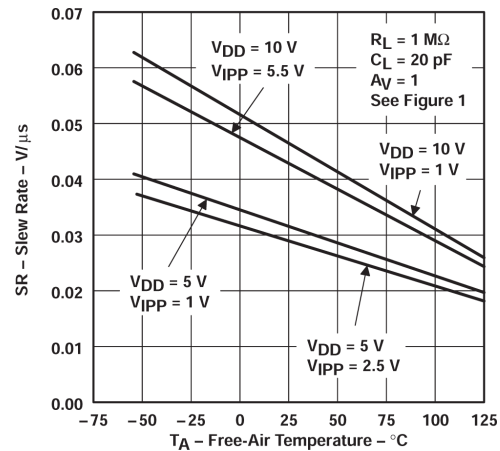


Figure 5-22. Slew Rate vs Free-air Temperature

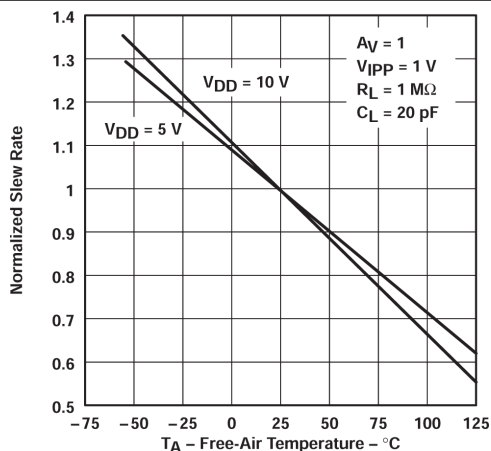


Figure 5-23. Normalized Slew Rate vs Free-air Temperature

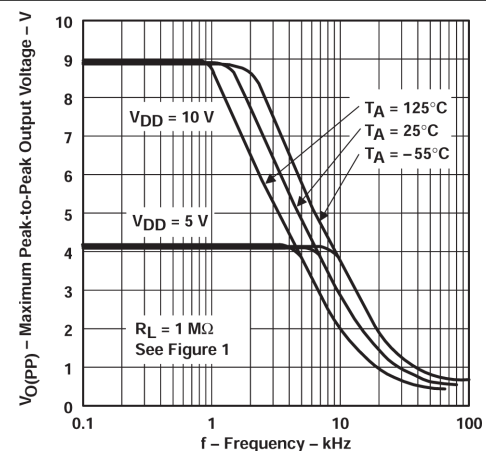
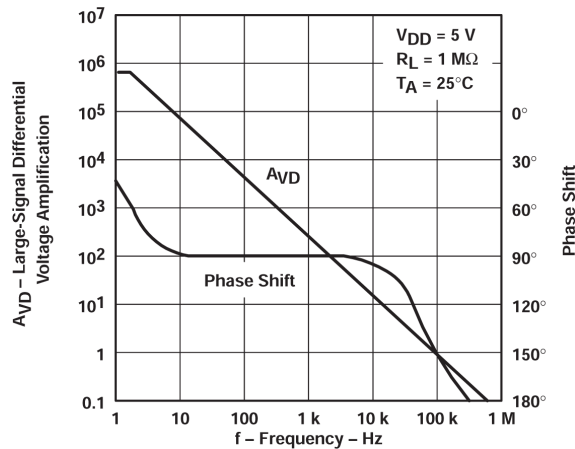


Figure 5-24. Maximum Peak-to-peak Output Voltage vs Frequency

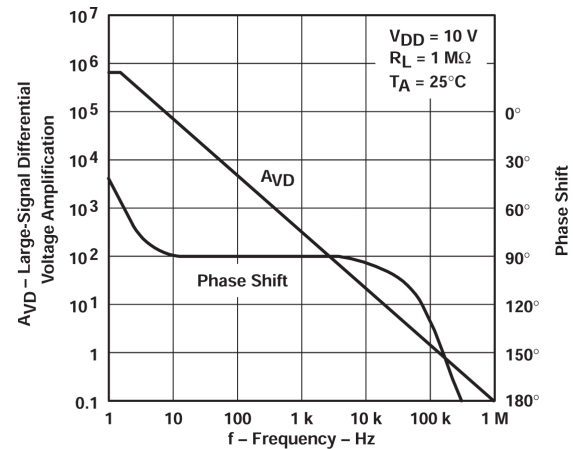


## 5.12 Typical Characteristics (continued)

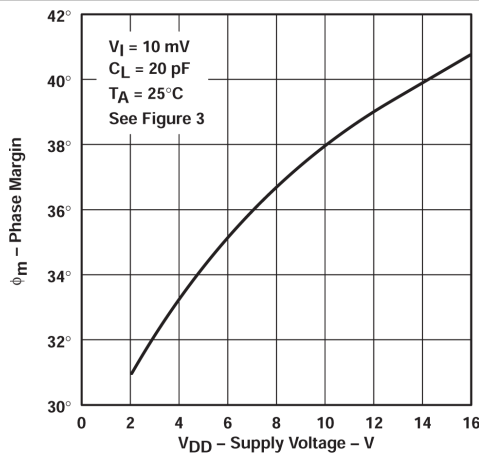
data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices



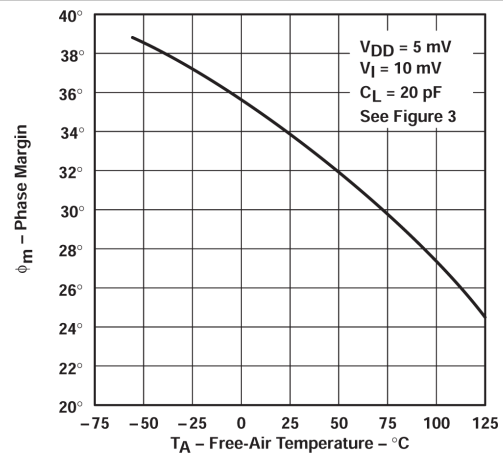
**Figure 5-25. Large-signal Differential Voltage Amplification and Phase Shift vs Frequency**



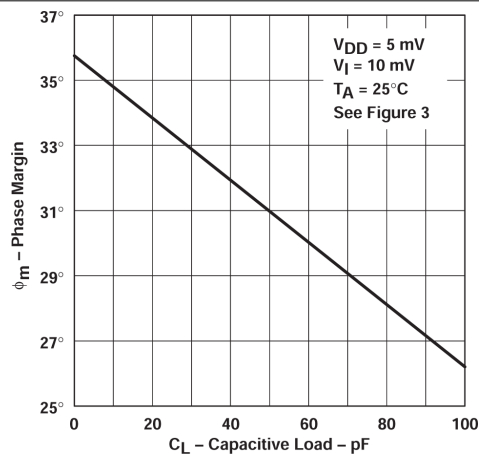
**Figure 5-26. Large-signal Differential Voltage Amplification and Phase Shift vs Frequency**



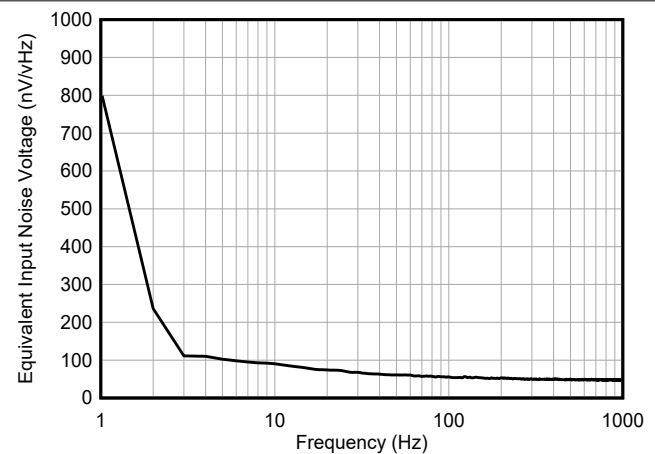
**Figure 5-27. Phase Margin vs Supply Voltage**



**Figure 5-28. Phase Margin vs Free-air Temperature**



**Figure 5-29. Phase Margin vs Capacitive Load**



**Figure 5-30. Equivalent Input Noise Voltage vs Frequency**

## 6 Parameter Measurement Information

### 6.1 Single-Supply Versus Split-Supply Test Circuits

The TLC27Lx are optimized for single-supply operation. Circuit configurations used for the various tests often present some inconvenience because in many cases, the input signal is offset from ground. Avoid this inconvenience by testing the device with split supplies and the output load tied to the negative rail. The following figures show a comparison of single-supply versus split-supply test circuits. The use of either circuit gives the same result.

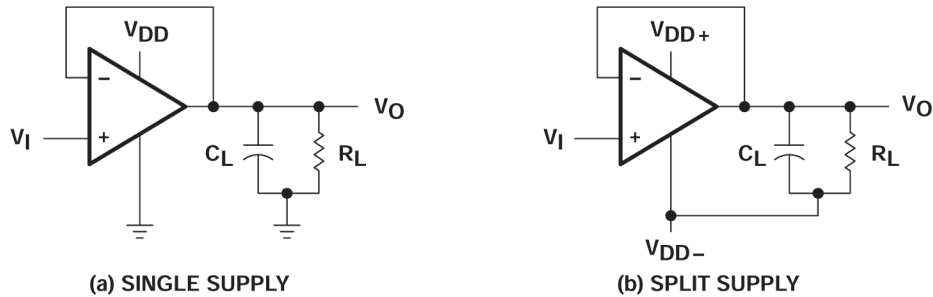


Figure 6-1. Unity-Gain Amplifier

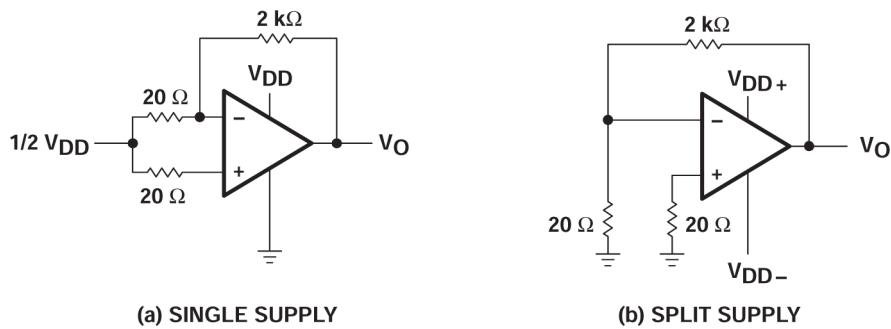


Figure 6-2. Noise-Test Circuit

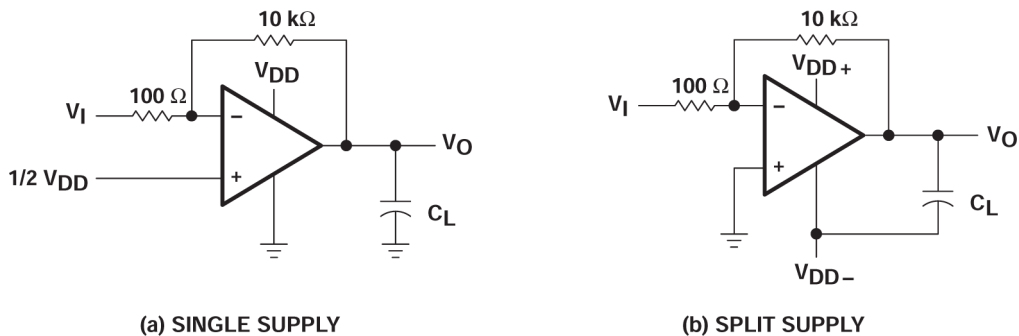


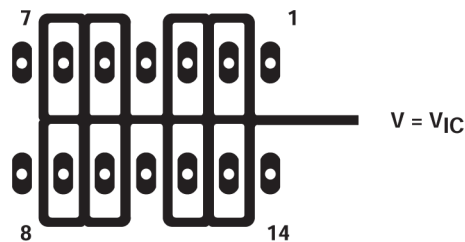
Figure 6-3. Gain-of-100 Inverting Amplifier

## 6.2 Input Bias Current

Because of the high input impedance of the TLC27Lx operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal ambient temperature is typically less than 1pA, 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 6-4](#)). Leakages that can 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.

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 6-4. Isolation Metal around Device Inputs (N Package)**

## 6.3 Low-Level Output Voltage

To obtain low-level supply-voltage operation, some compromise is necessary in the input stage. This compromise results in the device low-level output voltage being dependent on both 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, observe these two conditions. If conditions other than these are to be used, see the *Typical Characteristics* in [Section 5.12](#).

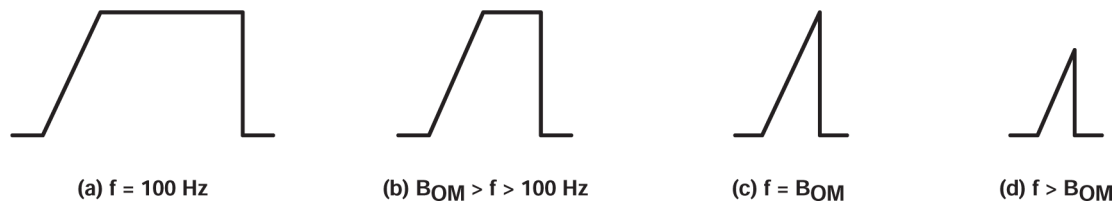
## 6.4 Input Offset Voltage Temperature Coefficient

Erroneous readings often result from attempts to measure the 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 less than freezing, moisture is able to collect on both the device and the test socket. This moisture results in leakage and contact resistance that potentially causes erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage because the moisture also covers the isolation metal, thereby rendering the techniques useless. Perform these measurements at temperatures greater than freezing to minimize error.

## 6.5 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 typically measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal. When the output shows significant distortion, the input frequency is noted as the full-linear bandwidth. The full-peak response is defined as the maximum output frequency, without regard to distortion, at which the full peak-to-peak output swing is maintained. When the output frequency is greater than the full-peak response bandwidth, or maximum output-swing bandwidth, the 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 in [Figure 6-1](#). 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 6-5](#)). A square wave allows a more accurate determination of the point at which the maximum peak-to-peak output is reached.



**Figure 6-5. Full-Power-Response Output Signal**

## 6.6 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 bipolar and BiFET devices. The problem becomes more pronounced with reduced supply levels and lower temperatures.

## 7 Application and Implementation

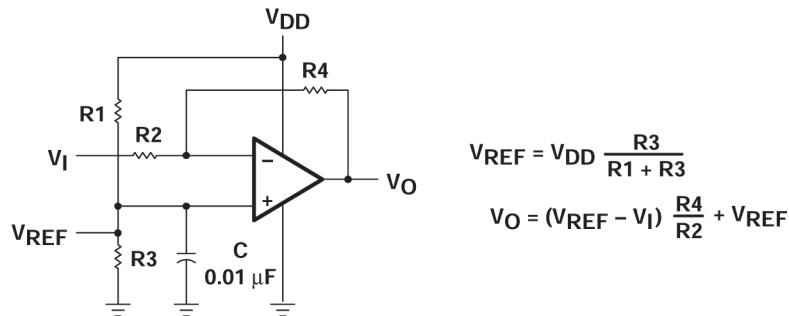
### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 7.1 Application Information

#### 7.1.1 Single-Supply Operation

While the TLC27Lx perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This optimization 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 3V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS. For maximum dynamic range, 16V single-supply operation is recommended.



**Figure 7-1. Inverting Amplifier with Voltage Reference**

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 typically sufficient to establish this reference level (see [Figure 7-1](#)). The low-input bias-current consumption of the TLC27Lx permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC27Lx work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, take the following recommended precautions:

1. Power linear devices from separate bypassed supply lines (see [Figure 7-2](#)); otherwise, linear device supply rails potentially fluctuate as a result of 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, RC decoupling is probably necessary in high-frequency applications.

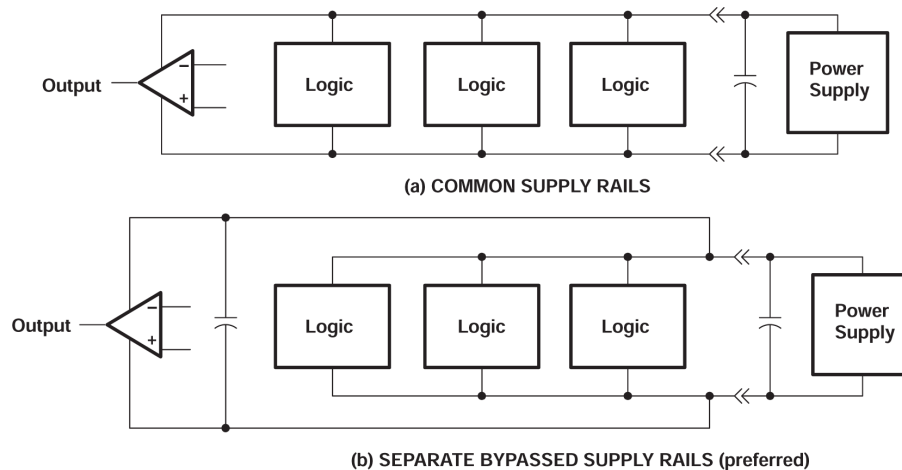


Figure 7-2. Common Versus Separate Supply Rails

### 7.1.2 Input Characteristics

The TLC27Lx are specified with a minimum and a maximum input voltage that, if exceeded at either input, possibly causes the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. The lower range limit includes the negative rail, while the upper range limit is specified at  $V_{DD} - 1V$  at  $T_A = 25^\circ C$  and at  $V_{DD} - 1.5V$  at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the legacy TLC27Lx 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 is calculated to be typically  $0.1\mu V/\text{month}$ , including the first month of operation.

Migration from the legacy 150mm LinCMOS process to a 300mm diameter wafer process has brought associated improvements to input offset voltage precision. The new silicon also features improved slew rate, supply-voltage rejection ratio, and voltage noise. However, this change does introduce a new crossover region, where shifts in input offset (typically  $300\mu V$ – $400\mu V$ ) occur as the input common-mode voltage approaches the  $V_{DD}$  rail. Figure 7-3 and Figure 7-4 plot the mean and standard deviation of this characteristic at various temperatures for a 10V supply.

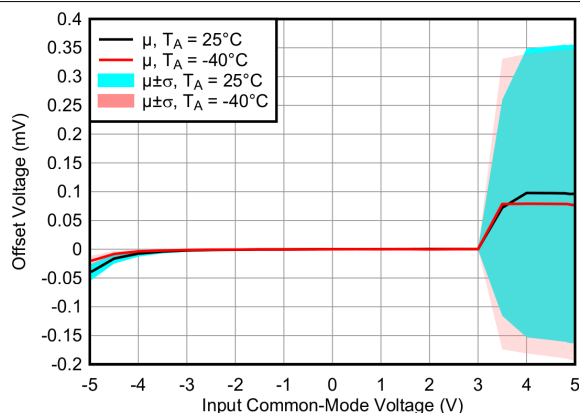


Figure 7-3. Offset Voltage vs Input Common-Mode Voltage

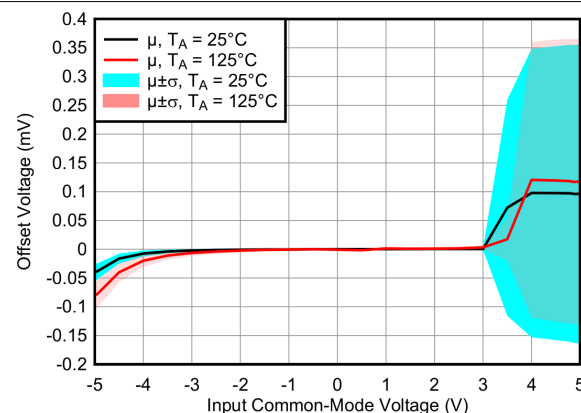


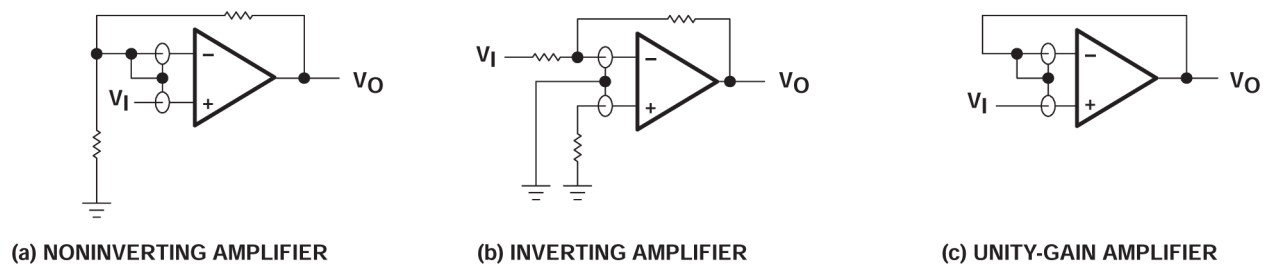
Figure 7-4. Offset Voltage vs Input Common-Mode Voltage

Because of the extremely high input impedance and resulting low bias-current requirements, the TLC27Lx are an excellent choice for low-level signal processing. However, leakage currents on printed-circuit boards and sockets sometimes easily exceed bias-current requirements and cause a degradation in device performance. As best practice, include guard rings around inputs (similar to those of [Figure 6-4](#) in the *Parameter Measurement Information* section). Drive these guards from a low-impedance source at the same voltage level as the common-mode input (see [Figure 7-5](#)).

Tie the inputs of any unused amplifiers to ground to avoid possible oscillation.

### 7.1.3 Noise Performance

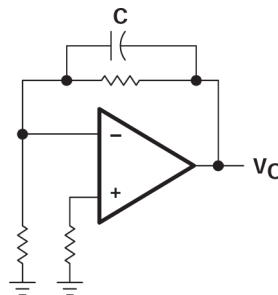
The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias-current requirements of the TLC27Lx result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50kΩ because bipolar devices exhibit greater noise currents.



**Figure 7-5. Guard-Ring Schemes**

### 7.1.4 Feedback

Operational amplifier circuits almost always employ feedback, and because feedback is the first prerequisite for oscillation, caution is appropriate. Most oscillation problems result from driving capacitive loads and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see [Figure 7-6](#)). The value of this capacitor is optimized empirically.



**Figure 7-6. Compensation for Input Capacitance**

### 7.1.5 Electrostatic Discharge Protection

The TLC27Lx incorporate an internal electrostatic-discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000V as tested under MIL-STD-883C, Method 3015.2. However, exercise care when handling these devices as exposure to ESD potentially results 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.

### 7.1.6 Latch-Up

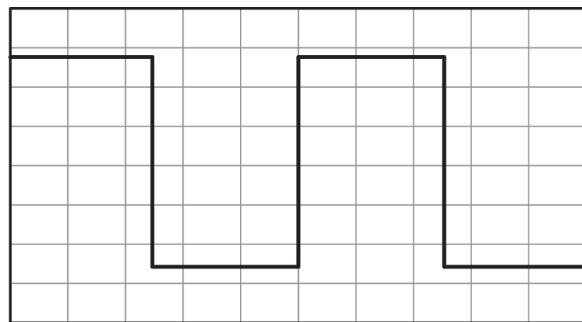
CMOS devices are susceptible to latch-up due to inherent parasitic thyristors. With this in mind, the TLC27Lx inputs and output are designed to withstand  $-100\text{mA}$  surge currents without sustaining latch-up. However, use best practices to reduce the chance of latch-up whenever possible. Do not forward bias internal-protection diodes. Do not exceed the supply voltage by more than  $300\text{mV}$  for applied input and output voltages. Exercise care when using capacitive coupling on pulse generators. Shunt supply transients by using decoupling capacitors ( $0.1\mu\text{F}$  typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is typically between the positive supply rail and ground, and is triggered by surges on the supply lines, voltages on either the output or inputs that exceed the supply voltage, or both. After 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 typically results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

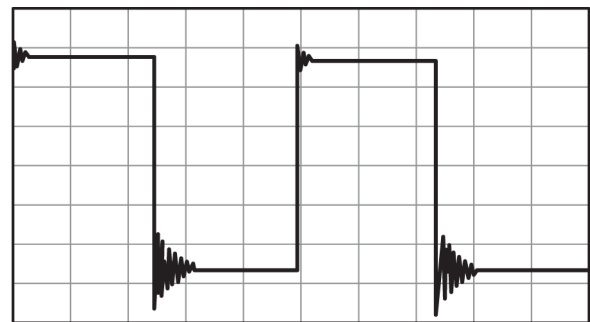
### 7.1.7 Output Characteristics

The output stage of the TLC27Lx is designed to sink and source relatively high amounts of current (see also [Typical Characteristics](#)). If the output is subjected to a short-circuit condition, the high-current capability is able to cause device damage under certain conditions. Output current capability increases with supply voltage.

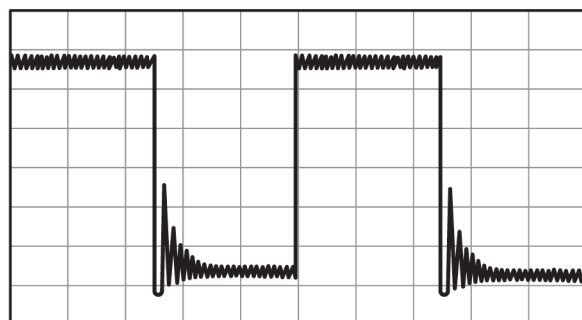
All operating characteristics of the TLC27Lx were measured using a  $20\text{pF}$  load. The devices drive higher capacitive loads. However, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see [Figure 7-7](#)). In many cases, adding some compensation in the form of a series resistor in the feedback loop alleviates the problem.



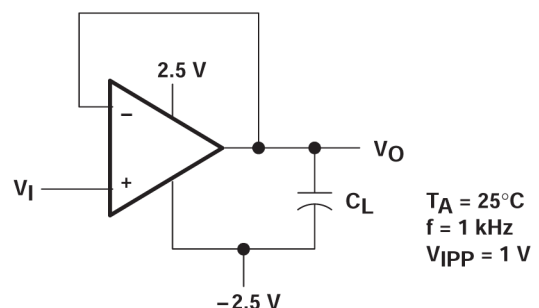
(a)  $C_L = 20\text{ pF}$ ,  $R_L = \text{NO LOAD}$



(b)  $C_L = 260\text{ pF}$ ,  $R_L = \text{NO LOAD}$



(c)  $C_L = 310\text{ pF}$ ,  $R_L = \text{NO LOAD}$



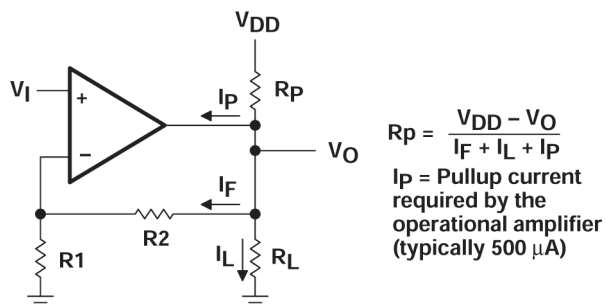
(d) TEST CIRCUIT

**Figure 7-7. Effect of Capacitive Loads and Test Circuit**

Although the TLC27Lx possess excellent high-level output voltage and current capability, methods are available for boosting this capability, 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 7-8](#)). There are two disadvantages to using this circuit.

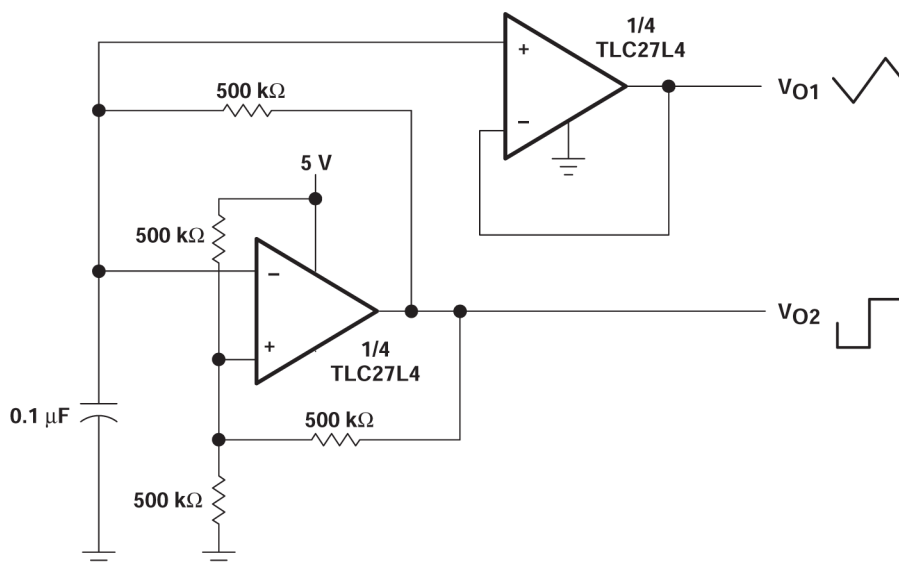


First, the NMOS pulldown transistor must sink a comparatively large amount of current. In this circuit, the pulldown transistor behaves like a linear resistor with an on-resistance between approximately 60Ω and 180Ω, depending on how hard the operational amplifier input is driven. With very low values of  $R_P$ , a voltage offset from 0V at the output occurs. Secondly, pullup resistor  $R_P$  acts as a drain load to the pulldown resistor, and the gain of the operational amplifier is reduced at output voltage levels where the corresponding pullup resistor is not supplying the output current.



**Figure 7-8. Resistive Pullup to Increase  $V_{OH}$**

### 7.1.8 Typical Applications



**Figure 7-9. Multivibrator**

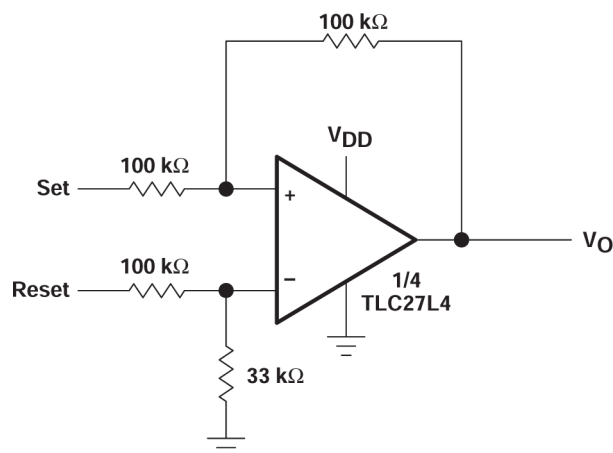


Figure 7-10. Set/Reset Flip-Flop,  $V_{DD} = 5V$  to  $16V$

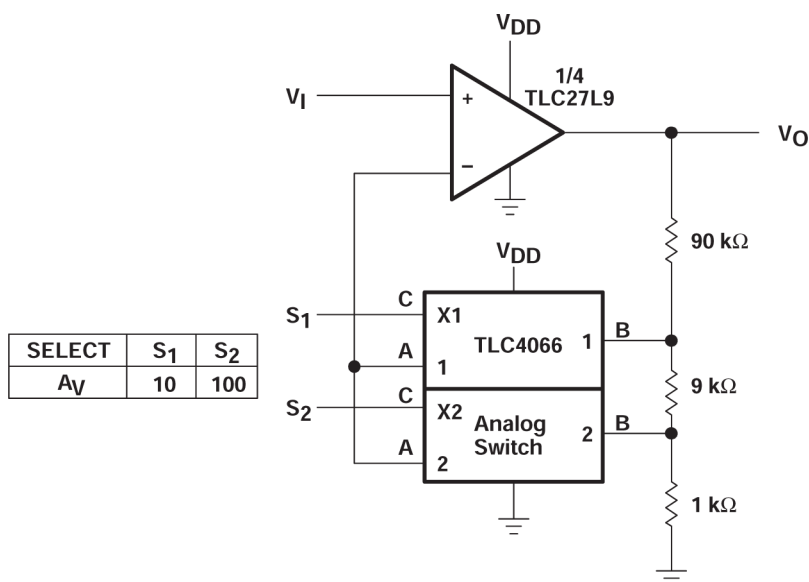


Figure 7-11. Amplifier with Digital Gain Selection,  $V_{DD} = 5V$  to  $12V$

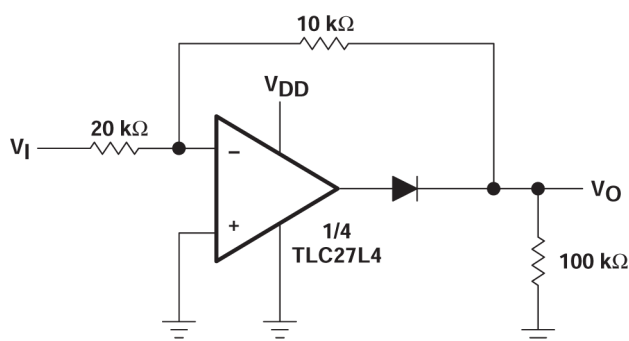
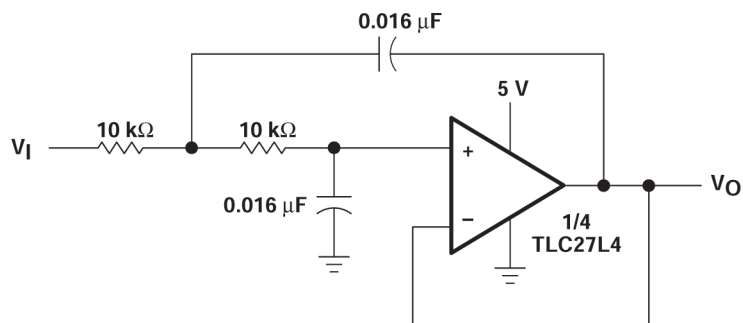
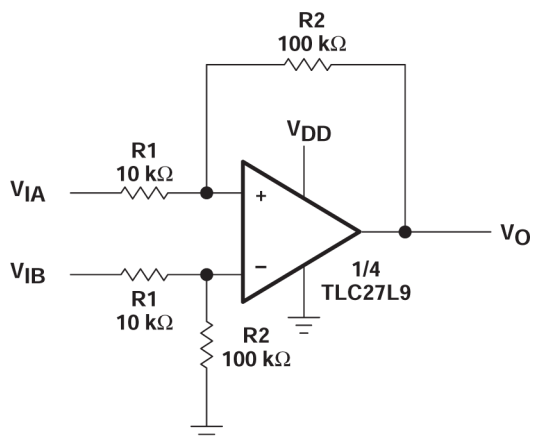


Figure 7-12. Full-Wave Rectifier,  $V_{DD} = 5V$  to  $16V$



**Figure 7-13. Two-Pole Low-Pass Butterworth Filter, Normalized to  $F_C = 1\text{ kHz}$  and  $R_L = 10\text{ k}\Omega$**



**Figure 7-14. Difference Amplifier,  $V_{DD} = 5\text{ V}$  to  $16\text{ V}$ ,  $V_O = R_2 / R_1 (V_{IB} - V_{IA})$**

## 8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

### 8.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 8.2 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 8.3 Trademarks

LinCMOS™ and TI E2E™ are trademarks of Texas Instruments.  
All trademarks are the property of their respective owners.

### 8.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 8.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision D (March 2001) to Revision E (July 2025)                                                                                                                                     | Page |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| • Deleted obsolete TLC27L4M, TLC27L9M, and TLC27L4Y devices and associated content from document....                                                                                               | 1    |
| • Updated the numbering format for tables, figures, and cross-references throughout the document.....                                                                                              | 1    |
| • Added <i>Applications, Pin Configuration and Functions, Application and Implementation, Device and Documentation Support, and Mechanical, Packaging, and Orderable Information</i> sections..... | 1    |
| • Deleted <i>Equivalent Schematic</i> section.....                                                                                                                                                 | 2    |
| • Added <i>Pin Configuration and Functions</i> section with pin descriptions.....                                                                                                                  | 2    |
| • Changed typical offset voltage from 200μV to 210μV and maximum offset voltage from 900μV to 1000μV for TLC27L9C at T <sub>A</sub> = 25°C.....                                                    | 4    |
| • Deleted maximum input bias current and input offset of 60pA at T <sub>A</sub> = 25°C from all <i>Electrical Characteristics</i>                                                                  | 4    |
| • Added table note that input bias current and input offset current are specified by characterization.....                                                                                         | 4    |
| • Changed typical input offset current from 0.1pA to 0.5pA.....                                                                                                                                    | 4    |
| • Changed typical minimum input common-mode voltage for T <sub>A</sub> = 25°C from –0.3V to –0.2V.....                                                                                             | 4    |
| • Changed typical low-level output voltage from 0mV to 1mV.....                                                                                                                                    | 4    |
| • Changed typical CMRR at T <sub>A</sub> = 25°C from 94dB to 87dB.....                                                                                                                             | 4    |
| • Changed typical CMRR at T <sub>A</sub> = 0°C and T <sub>A</sub> = 70°C from 95dB to 85dB.....                                                                                                    | 4    |
| • Added table note that input bias current and input offset current are specified by characterization.....                                                                                         | 6    |
| • Changed typical input offset current from 0.1pA to 0.5pA.....                                                                                                                                    | 6    |
| • Changed typical minimum input common-mode voltage for T <sub>A</sub> = 25°C from –0.3V to –0.2V.....                                                                                             | 6    |
| • Changed typical low-level output voltage from 0mV to 5mV.....                                                                                                                                    | 6    |

|                                                                                                                                                                                                     |    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| • Changed typical CMRR at $T_A = 25^\circ\text{C}$ from 97dB to 94dB.....                                                                                                                           | 6  |
| • Changed typical CMRR at $T_A = 0^\circ\text{C}$ and $T_A = 70^\circ\text{C}$ from 97dB to 93dB.....                                                                                               | 6  |
| • Changed typical unity-gain bandwidth at $T_A = 0^\circ\text{C}$ from 125kHz to 110kHz.....                                                                                                        | 7  |
| • Changed typical offset voltage from 200 $\mu\text{V}$ to 210 $\mu\text{V}$ and maximum offset voltage from 900 $\mu\text{V}$ to 1000 $\mu\text{V}$ for TLC27L9I at $T_A = 25^\circ\text{C}$ ..... | 8  |
| • Added table note that input bias current and input offset current are specified by characterization.....                                                                                          | 8  |
| • Changed typical input offset current from 0.1pA to 0.5pA.....                                                                                                                                     | 8  |
| • Changed typical minimum input common-mode voltage for $T_A = 25^\circ\text{C}$ from $-0.3\text{V}$ to $-0.2\text{V}$ .....                                                                        | 8  |
| • Changed typical low-level output voltage from 0mV to 1mV.....                                                                                                                                     | 8  |
| • Changed typical CMRR at $T_A = 25^\circ\text{C}$ from 94dB to 87dB.....                                                                                                                           | 8  |
| • Changed typical CMRR at $T_A = -40^\circ\text{C}$ and $T_A = 85^\circ\text{C}$ from 95dB to 85dB.....                                                                                             | 8  |
| • Changed typical unity-gain bandwidth at $T_A = -40^\circ\text{C}$ from 130kHz to 110kHz.....                                                                                                      | 9  |
| • Added table note that input bias current and input offset current are specified by characterization.....                                                                                          | 10 |
| • Changed typical input offset current from 0.1pA to 0.5pA.....                                                                                                                                     | 10 |
| • Changed typical minimum input common-mode voltage for $T_A = 25^\circ\text{C}$ from $-0.3\text{V}$ to $-0.2\text{V}$ .....                                                                        | 10 |
| • Changed typical low-level output voltage from 0mV to 5mV.....                                                                                                                                     | 10 |
| • Changed typical CMRR at $T_A = 25^\circ\text{C}$ from 97dB to 94dB.....                                                                                                                           | 10 |
| • Changed typical CMRR at $T_A = 85^\circ\text{C}$ from 97dB to 93dB.....                                                                                                                           | 10 |
| • Changed typical CMRR at $T_A = -40^\circ\text{C}$ from 98dB to 93dB.....                                                                                                                          | 10 |
| • Changed typical unity-gain bandwidth at $T_A = -40^\circ\text{C}$ from 155kHz to 110kHz.....                                                                                                      | 11 |
| • Deleted Figures 30 and 31.....                                                                                                                                                                    | 12 |
| • Updated Figure 5-30.....                                                                                                                                                                          | 12 |
| • Updated description of full-linear and full-peak responses in <i>Full-Power Response</i> .....                                                                                                    | 20 |
| • Added guidance concerning changes to input crossover region to <i>Input Characteristics</i> .....                                                                                                 | 22 |

| <b>Changes from Revision C (August 1994) to Revision D (March 2001)</b>                                                                | <b>Page</b> |
|----------------------------------------------------------------------------------------------------------------------------------------|-------------|
| • Added maximum input bias current and input offset of 60pA at $T_A = 25^\circ\text{C}$ to all <i>Electrical Characteristics</i> ..... | 4           |

## 10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number       | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TLC27L4ACD</a>  | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | 27L4AC              |
| <a href="#">TLC27L4ACDR</a> | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAU                      | Level-1-260C-UNLIM                | 0 to 70      | 27L4AC              |
| TLC27L4ACDR.A               | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | 27L4AC              |
| <a href="#">TLC27L4ACN</a>  | Obsolete      | Production           | PDIP (N)   14   | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | TLC27L4ACN          |
| <a href="#">TLC27L4AID</a>  | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | 27L4AI              |
| <a href="#">TLC27L4AIDR</a> | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAU                      | Level-1-260C-UNLIM                | -40 to 85    | 27L4AI              |
| TLC27L4AIDR.A               | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | 27L4AI              |
| <a href="#">TLC27L4AIN</a>  | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 85    | TLC27L4AIN          |
| TLC27L4AIN.A                | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 85    | TLC27L4AIN          |
| <a href="#">TLC27L4BCD</a>  | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | 27L4BC              |
| <a href="#">TLC27L4BCDR</a> | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAU                      | Level-1-260C-UNLIM                | 0 to 70      | 27L4BC              |
| TLC27L4BCDR.A               | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | 27L4BC              |
| <a href="#">TLC27L4BCN</a>  | Obsolete      | Production           | PDIP (N)   14   | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | TLC27L4BCN          |
| <a href="#">TLC27L4BID</a>  | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | 27L4BI              |
| <a href="#">TLC27L4BIDR</a> | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAU                      | Level-1-260C-UNLIM                | -40 to 85    | 27L4BI              |
| TLC27L4BIDR.A               | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | 27L4BI              |
| TLC27L4BIDRG4               | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 85    |                     |
| <a href="#">TLC27L4BIN</a>  | Obsolete      | Production           | PDIP (N)   14   | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | TLC27L4BIN          |
| <a href="#">TLC27L4CD</a>   | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | TLC27L4C            |
| <a href="#">TLC27L4CDR</a>  | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAU                      | Level-1-260C-UNLIM                | 0 to 70      | TLC27L4C            |
| TLC27L4CDR.A                | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L4C            |
| <a href="#">TLC27L4CN</a>   | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | 0 to 70      | TLC27L4CN           |
| TLC27L4CN.A                 | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | 0 to 70      | TLC27L4CN           |
| <a href="#">TLC27L4CNS</a>  | Active        | Production           | SOP (NS)   14   | 50   TUBE             | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L4             |
| TLC27L4CNS.A                | Active        | Production           | SOP (NS)   14   | 50   TUBE             | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L4             |
| <a href="#">TLC27L4CNSR</a> | Active        | Production           | SOP (NS)   14   | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L4             |
| TLC27L4CNSR.A               | Active        | Production           | SOP (NS)   14   | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L4             |
| <a href="#">TLC27L4CPW</a>  | Obsolete      | Production           | TSSOP (PW)   14 | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | P27L4C              |
| <a href="#">TLC27L4CPWR</a> | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | P27L4C              |

| Orderable part number       | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| TLC27L4CPWR.A               | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | P27L4C              |
| <a href="#">TLC27L4ID</a>   | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | TLC27L4I            |
| <a href="#">TLC27L4IDR</a>  | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAU                      | Level-1-260C-UNLIM                | -40 to 85    | TLC27L4I            |
| TLC27L4IDR.A                | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | TLC27L4I            |
| <a href="#">TLC27L4IN</a>   | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 85    | TLC27L4IN           |
| TLC27L4IN.A                 | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 85    | TLC27L4IN           |
| TLC27L4INE4                 | Active        | Production           | PDIP (N)   14   | 25   TUBE             | -           | Call TI                              | Call TI                           | -40 to 85    |                     |
| <a href="#">TLC27L4IPW</a>  | Obsolete      | Production           | TSSOP (PW)   14 | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | P27L4I              |
| <a href="#">TLC27L4IPWR</a> | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | P27L4I              |
| TLC27L4IPWR.A               | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | P27L4I              |
| <a href="#">TLC27L9CD</a>   | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | 0 to 70      | TLC27L9C            |
| <a href="#">TLC27L9CDR</a>  | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L9C            |
| TLC27L9CDR.A                | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L9C            |
| <a href="#">TLC27L9CN</a>   | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | 0 to 70      | TLC27L9CN           |
| TLC27L9CN.A                 | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | 0 to 70      | TLC27L9CN           |
| <a href="#">TLC27L9CNSR</a> | Active        | Production           | SOP (NS)   14   | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L9             |
| TLC27L9CNSR.A               | Active        | Production           | SOP (NS)   14   | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | 0 to 70      | TLC27L9             |
| <a href="#">TLC27L9ID</a>   | Obsolete      | Production           | SOIC (D)   14   | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | TLC27L9I            |
| <a href="#">TLC27L9IDR</a>  | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | TLC27L9I            |
| TLC27L9IDR.A                | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 85    | TLC27L9I            |
| <a href="#">TLC27L9IN</a>   | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 85    | TLC27L9IN           |
| TLC27L9IN.A                 | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 85    | TLC27L9IN           |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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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.



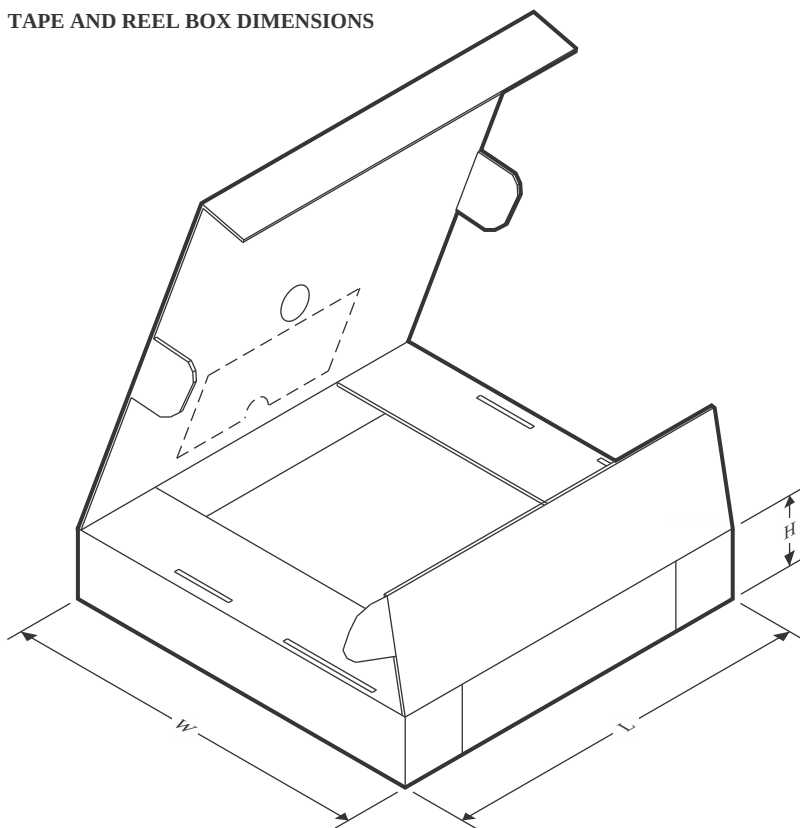
## TAPE AND REEL INFORMATION



\*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 |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLC27L4ACDR | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4AIDR | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4BCDR | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4BIDR | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4CDR  | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4CDDR | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4CNSR | SOP          | NS              | 14   | 2000 | 330.0              | 16.4               | 8.1     | 10.4    | 2.5     | 12.0    | 16.0   | Q1            |
| TLC27L4CPWR | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TLC27L4IDR  | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L4IPWR | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TLC27L9CDR  | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TLC27L9CNSR | SOP          | NS              | 14   | 2000 | 330.0              | 16.4               | 8.1     | 10.4    | 2.5     | 12.0    | 16.0   | Q1            |
| TLC27L9IDR  | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLC27L4ACDR | SOIC         | D               | 14   | 2500 | 340.5       | 336.1      | 32.0        |
| TLC27L4AIDR | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TLC27L4BCDR | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TLC27L4BIDR | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TLC27L4CDR  | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TLC27L4CDR  | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TLC27L4CNSR | SOP          | NS              | 14   | 2000 | 353.0       | 353.0      | 32.0        |
| TLC27L4CPWR | TSSOP        | PW              | 14   | 2000 | 353.0       | 353.0      | 32.0        |
| TLC27L4IDR  | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TLC27L4IPWR | TSSOP        | PW              | 14   | 2000 | 353.0       | 353.0      | 32.0        |
| TLC27L9CDR  | SOIC         | D               | 14   | 2500 | 350.0       | 350.0      | 43.0        |
| TLC27L9CNSR | SOP          | NS              | 14   | 2000 | 353.0       | 353.0      | 32.0        |
| TLC27L9IDR  | SOIC         | D               | 14   | 2500 | 350.0       | 350.0      | 43.0        |

**TUBE**

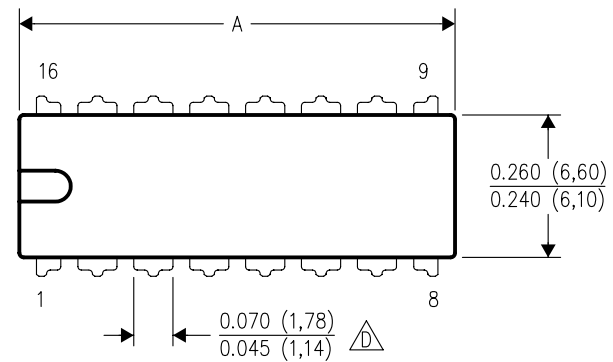

\*All dimensions are nominal

| Device       | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|--------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| TLC27L4AIN   | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L4AIN.A | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L4CN    | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L4CN.A  | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L4CNS   | NS           | SOP          | 14   | 50  | 530    | 10.5   | 4000   | 4.1    |
| TLC27L4CNS.A | NS           | SOP          | 14   | 50  | 530    | 10.5   | 4000   | 4.1    |
| TLC27L4IN    | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L4IN.A  | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L9CN    | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L9CN.A  | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L9IN    | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLC27L9IN.A  | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |

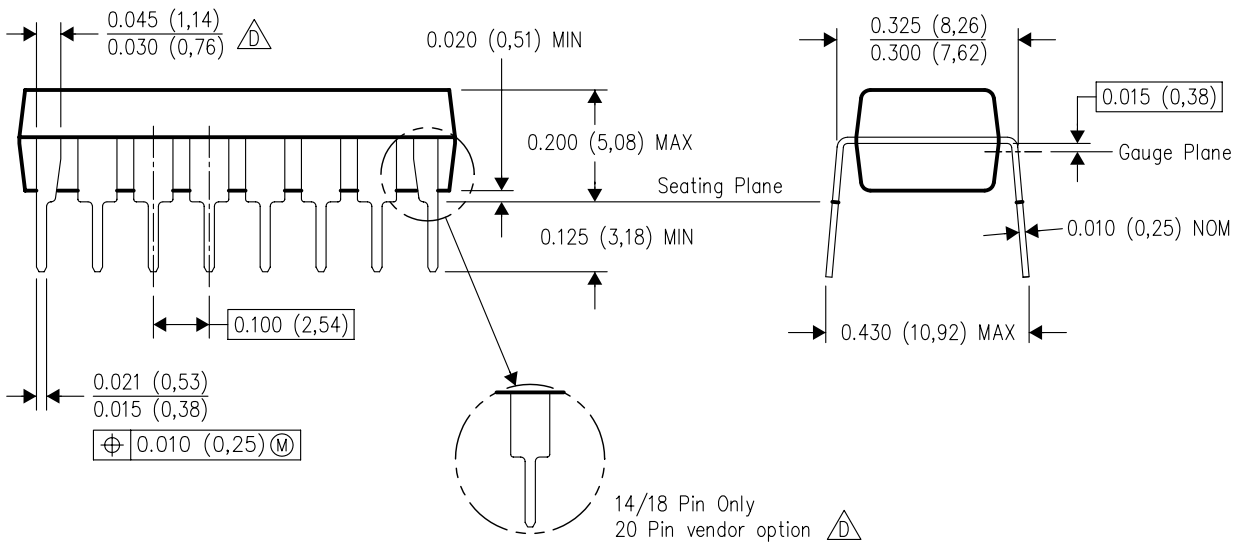
## N (R-PDIP-T\*\*)

16 PINS SHOWN

## PLASTIC DUAL-IN-LINE PACKAGE



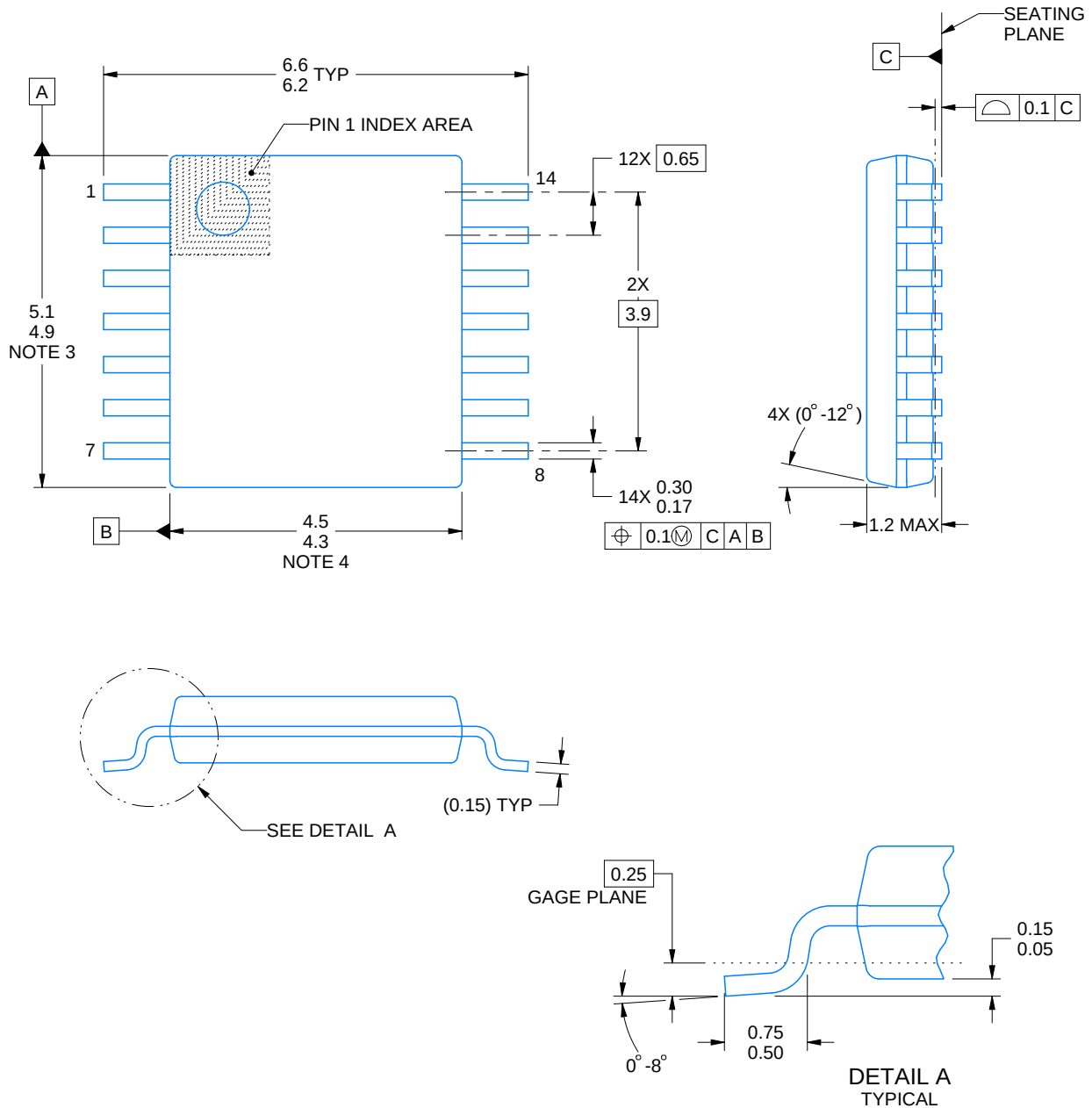
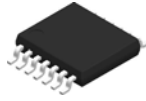
| PINS **             | 14               | 16               | 18               | 20               |
|---------------------|------------------|------------------|------------------|------------------|
| DIM                 |                  |                  |                  |                  |
| A MAX               | 0.775<br>(19,69) | 0.775<br>(19,69) | 0.920<br>(23,37) | 1.060<br>(26,92) |
| A MIN               | 0.745<br>(18,92) | 0.745<br>(18,92) | 0.850<br>(21,59) | 0.940<br>(23,88) |
| MS-001<br>VARIATION | AA               | BB               | AC               | AD               |



14/18 Pin Only  
20 Pin vendor option

4040049/E 12/2002

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
  - The 20 pin end lead shoulder width is a vendor option, either half or full width.



4220202/B 12/2023

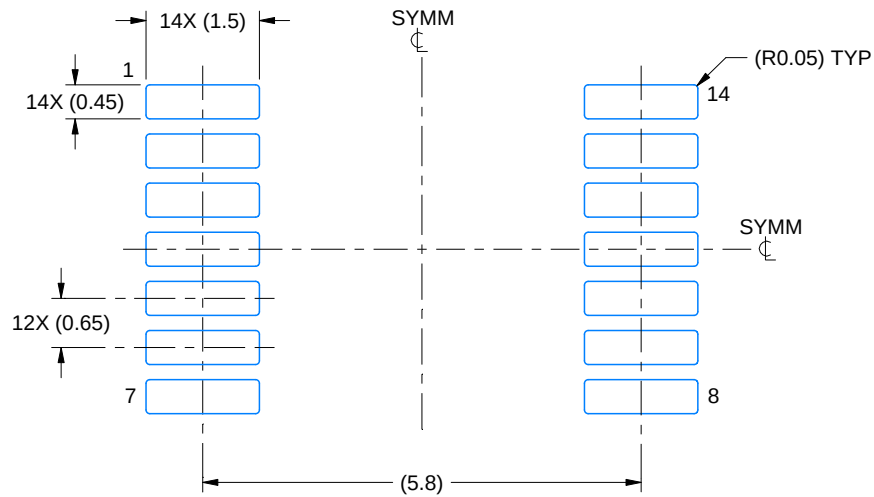
## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

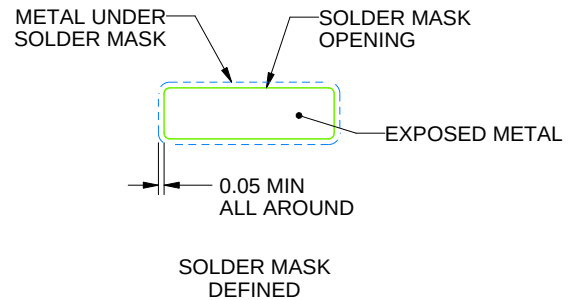
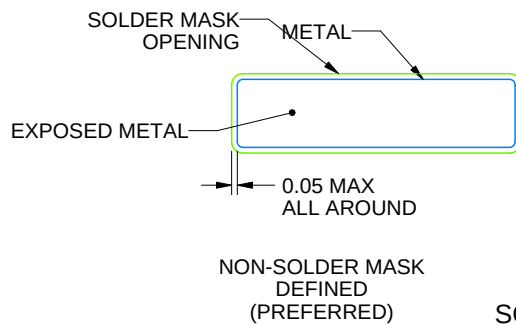
**PW0014A**

**TSSOP - 1.2 mm max height**

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



## SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

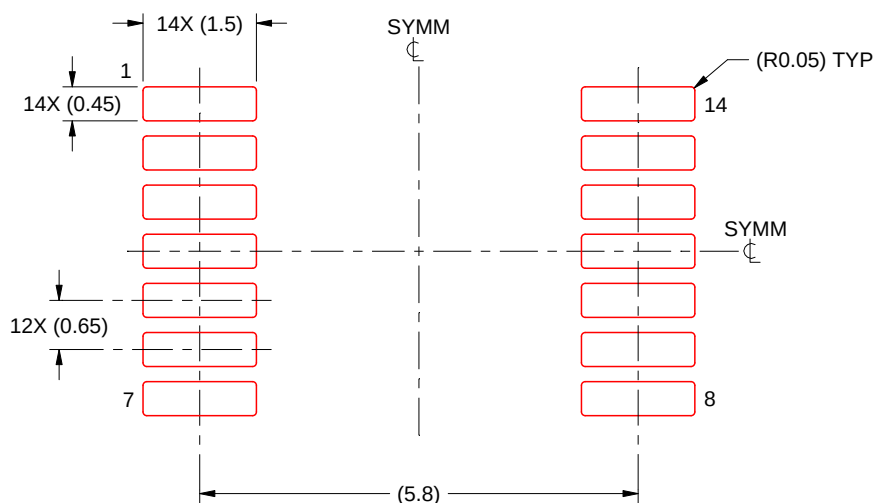
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

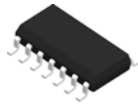


SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

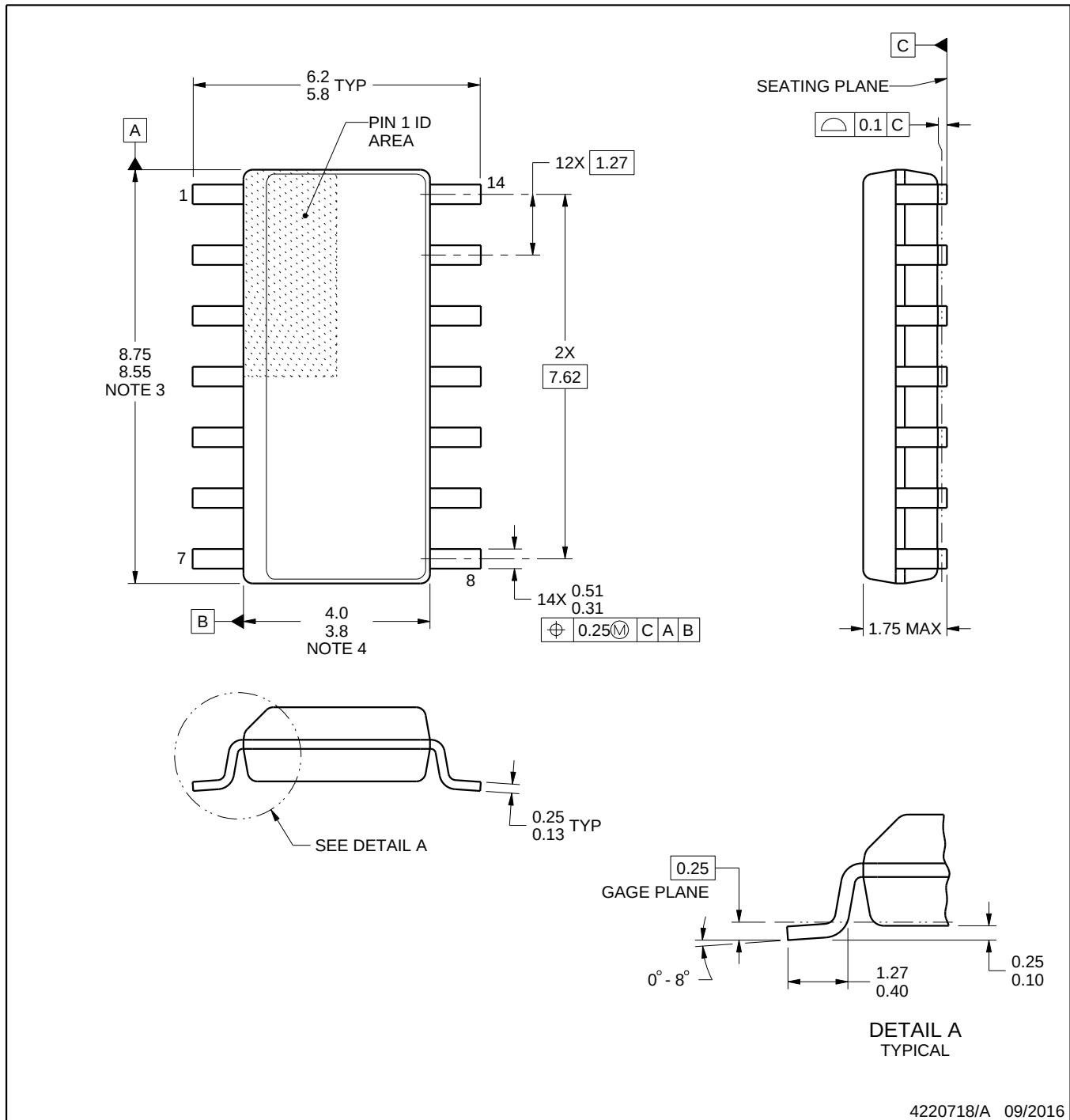
4220202/B 12/2023

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

**D0014A****PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



4220718/A 09/2016

**NOTES:**

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.

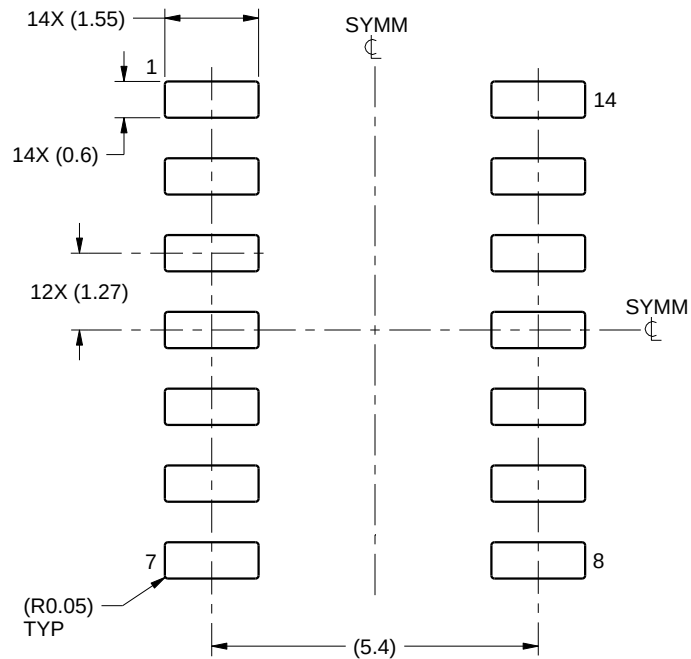


# EXAMPLE BOARD LAYOUT

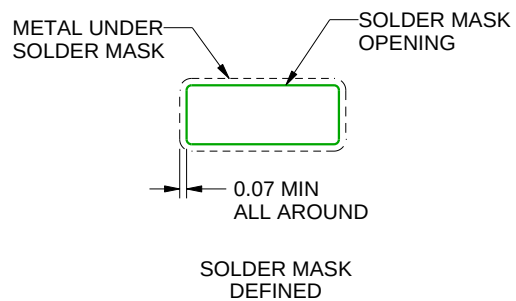
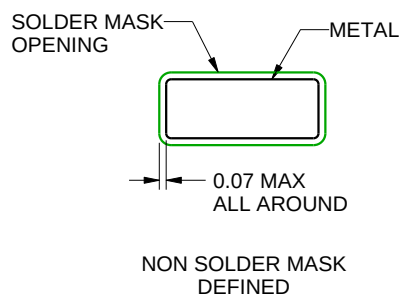
D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
SCALE:8X



SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

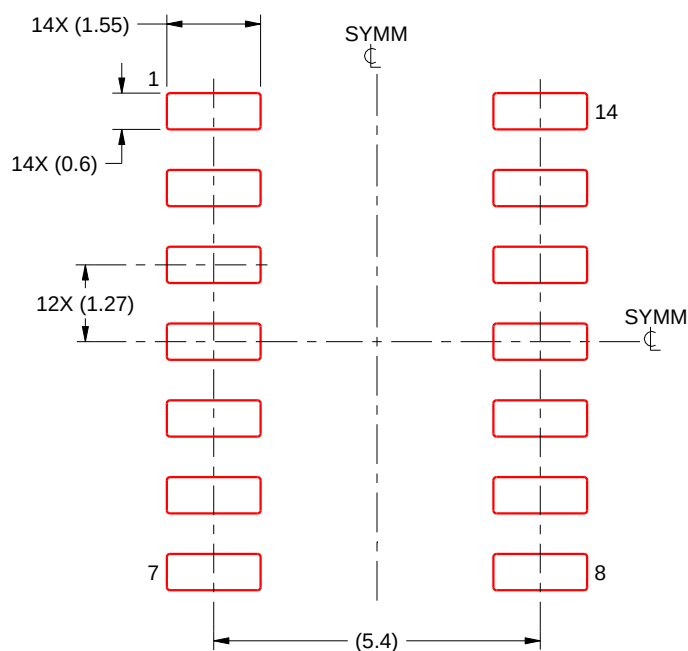
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:8X

4220718/A 09/2016

NOTES: (continued)

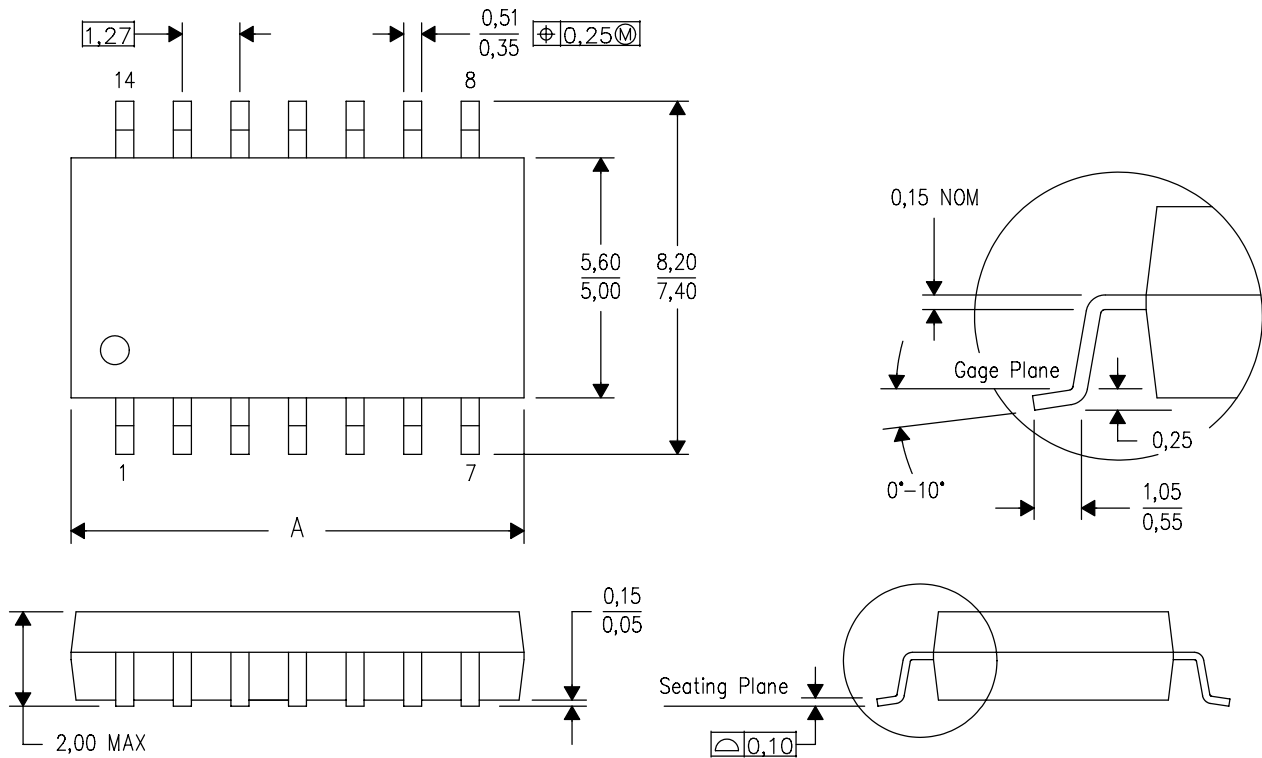
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# MECHANICAL DATA

NS (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14-PINS SHOWN



| DIM \ PINS ** | 14    | 16    | 20    | 24    |
|---------------|-------|-------|-------|-------|
| A MAX         | 10,50 | 10,50 | 12,90 | 15,30 |
| A MIN         | 9,90  | 9,90  | 12,30 | 14,70 |

4040062/C 03/03

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

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