

**XL158 SOP8 XL258 SOP8 XL358D SOP8  
 XD358 DIP8 XL2904D SOP8 XD2904 DIP8**

**1 Features**

- Wide Supply Ranges
  - Single Supply: 3 V to 32 V (26 V for XL2904)
  - Dual Supplies: ±1.5 V to ±16 V (±13 V for XL2904)
- Low Supply-Current Drain, Independent of Supply Voltage: 0.7 mA Typical
- Wide Unity Gain Bandwidth: 0.7 MHz
- Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground
- Low Input Bias and Offset Parameters
  - Input Offset Voltage: 3 mV Typical  
A Versions: 2 mV Typical
  - Input Offset Current: 2 nA Typical
  - Input Bias Current: 20 nA Typical  
A Versions: 15 nA Typical
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage: 32 V (26 V for XL2904)
- Open-Loop Differential Voltage Gain: 100 dB Typical
- Internal Frequency Compensation
- On Products Compliant to MIL-PRF-38535, All Parameters are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

**2 Applications**

- Blu-ray Players and Home Theaters
- Chemical and Gas Sensors
- DVD Recorder and Players
- Digital Multimeter: Bench and Systems
- Digital Multimeter: Handhelds
- Field Transmitter: Temperature Sensors
- Motor Control: AC Induction, Brushed DC, Brushless DC, High-Voltage, Low-Voltage, Permanent Magnet, and Stepper Motor
- Oscilloscopes
- TV: LCD and Digital
- Temperature Sensors or Controllers Using Modbus
- Weigh Scales

**3 Description**

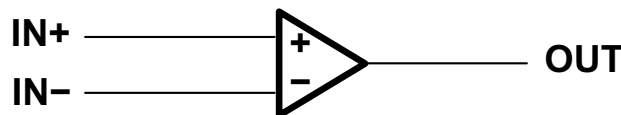
These devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply or split supply over a wide range of voltages.

**4 Device Information<sup>(1)</sup>**

| PART NUMBER      | PACKAGE   | BODY SIZE (NOM)   |
|------------------|-----------|-------------------|
| 158 258 358 2904 | VSSOP (8) | 3.00 mm × 3.00 mm |
|                  | SOIC (8)  | 4.90 mm × 3.90 mm |
|                  | SO (8)    | 5.20 mm × 5.30 mm |
|                  | TSSOP (8) | 3.00 mm × 4.40 mm |
|                  | PDIP (8)  | 9.81 mm × 6.35 mm |
| X58 2904         | CDIP (8)  | 9.60 mm × 6.67 mm |
|                  | LCCC (20) | 8.89 mm × 8.89 mm |

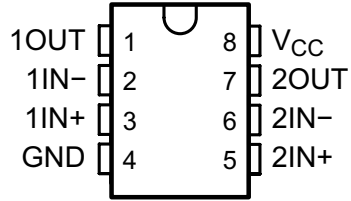
(1) For all available packages, see the orderable addendum at the end of the data sheet.

**Symbol (Each Amplifier)**

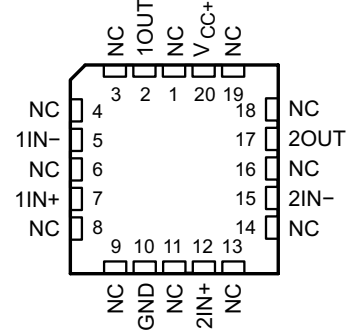


## 5 Pin Configuration and Functions

D, DGK, P, PS, PW and JG Package  
 8-Pin SOIC, VSSOP, PDIP, SO, TSSOP and CDIP  
 (Top View)



FK Package  
 20-Pin LCCC  
 (Top View)



NC - No internal connection

### Pin Functions

| PIN              |          |  | I/O | DESCRIPTION    |
|------------------|----------|--|-----|----------------|
| NAME             | LCCC NO. | SOIC, SSOP, CDIP, PDIP, SO, TSSOP, CFP NO. |     |                |
| 1IN-             | 5        | 2  | I   | Negative input |
| 1IN+             | 7        | 3  | I   | Positive input |
| 1OUT             | 2        | 1  | O   | Output         |
| 2IN-             | 15       | 6  | I   | Negative input |
| 2IN+             | 12       | 5  | I   | Positive input |
| 2OUT             | 17       | 7  | O   | Output         |
| GND              | 10       | 4  | —   | Ground         |
| NC               | 1        | —  | —   | Do not connect |
|                  | 3        |  |     |                |
|                  | 4        |  |     |                |
|                  | 6        |  |     |                |
|                  | 8        |  |     |                |
|                  | 9        |  |     |                |
|                  | 11       |  |     |                |
|                  | 13       |  |     |                |
|                  | 14       |  |     |                |
| 16               |          |  |     |                |
| 18               |          |  |     |                |
| 19               |          |  |     |                |
| V <sub>CC</sub>  | —        | 8  | —   | Power supply   |
| V <sub>CC+</sub> | 20       | —  | —   | Power supply   |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|   |  | XLx58, XLx58x,<br>XL2904 |           | XL2904    |           | UNIT |
|---|--|--------------------------|-----------|-----------|-----------|------|
|   |  | MIN                      | MAX       | MIN       | MAX       |      |
| V <sub>CC</sub>   | Supply voltage <sup>(2)</sup>                                | -0.3                     | ±16 or 32 | -0.3      | ±13 or 26 | V    |
| V <sub>ID</sub>   | Differential input voltage <sup>(3)</sup>                    | -32                      | 32        | -26       | 26        | V    |
| V <sub>I</sub>  | either input<br>Input voltage                                | -0.3                     | 32        | -0.3      | 26        | V    |
| Duration of output short circuit (one amplifier) to ground at (or below) T <sub>A</sub> = 25°C, V <sub>CC</sub> ≤ 15 V <sup>(4)</sup> |  | Unlimited                |           | Unlimited |           | s    |
| T <sub>A</sub>  | Operating free air temperature                               | XL158                    | -55       | 125       |           | °C   |
|   |  | XL258                    | -25       | 85        |           |      |
|   |  | XL358                    | 0         | 70        |           |      |
|   |  | XL2904                   | -40       | 125       | -40       |      |
| T <sub>J</sub>  | Operating virtual junction temperature                       | 150                      |           | 150       |           | °C   |
|   | Case temperature for 60 seconds                              | FK package               | 260       |           |           | °C   |
|   | Lead temperature 1.6 mm (1/16 inch) from case for 60 seconds | JG package               | 300       |           | 300       | °C   |
| T <sub>stg</sub>  | Storage temperature  | -65                      | 150       | -65       | 150       | °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 and V<sub>CC</sub> specified for the measurement of I<sub>OS</sub>) are with respect to the network GND.
- (3) Differential voltages are at IN+, with respect to IN-.
- (4) Short circuits from outputs to V<sub>CC</sub> can cause excessive heating and eventual destruction.

### 6.2 ESD Ratings

|                    |                         | VALUE   | UNIT  |
|--------------------|-------------------------|---|-------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup> | ±500  |
|                    |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101   | ±1000 |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

|                 |                                | XLx58, XLx58x,<br>XL2904 |                     | XL2904 |                     | UNIT |     |
|-----------------|--------------------------------|--------------------------|---------------------|--------|---------------------|------|-----|
|                 |                                | MIN                      | MAX                 | MIN    | MAX                 |      |     |
| V <sub>CC</sub> | Supply voltage                 | 3                        | 30                  | 3      | 26                  | V    |     |
| V <sub>CM</sub> | Common-mode voltage            | 0                        | V <sub>CC</sub> - 2 | 0      | V <sub>CC</sub> - 2 | V    |     |
| T <sub>A</sub>  | Operating free air temperature | XL158                    | -55                 | 125    |                     | °C   |     |
|                 |                                | XL2904                   | -40                 | 125    | -40                 |      | 125 |
|                 |                                | XL358                    | 0                   | 70     |                     |      |     |
|                 |                                | XL258                    | -25                 | 85     |                     |      |     |

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### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> | XLx58, XLx58x, XL2904                     |                |          |         |               |              | XLx58,<br>XLx58x,<br>XL2904<br>V | XLx58,<br>XLx58x,<br>XL2904<br>V | UNIT |
|-------------------------------|---|----------------|----------|---------|---------------|--------------|----------------------------------|----------------------------------|------|
|                               | D (SOIC)                                  | DGK<br>(VSSOP) | P (PDIP) | PS (SO) | PW<br>(TSSOP) | FK<br>(LCCC) | JG<br>(CDIP)                     |                                  |      |
|                               | 8 PINS                                    | 8 PINS         | 8 PINS   | 8 PINS  | 8 PINS        | 20 PINS      | 8 PINS                           |                                  |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance    | 97             | 172      | 85      | 95            | 149          | —                                | —                                | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance | 72.2           | —        | —       | —             | —            | 5.61                             | 14.5                             |      |

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

### 6.5 Electrical Characteristics for XLx58

at specified free-air temperature, V<sub>CC</sub> = 5 V (unless otherwise noted)

| PARAMETER                        | TEST CONDITIONS <sup>(1)</sup>                                       | T <sub>A</sub> <sup>(2)</sup>   | XL158<br>XL258 |                               |            | XL358                         |                       |       | UNIT |
|----------------------------------|--|---|----------------|-------------------------------|------------|-------------------------------|-----------------------|-------|------|
|                                  |  |   | MIN            | TYP <sup>(3)</sup>            | MAX        | MIN                           | TYP <sup>(3)</sup>    | MAX   |      |
| V <sub>IO</sub>                  | Input offset voltage   | V <sub>CC</sub> = 5 V to MAX,<br>V <sub>IC</sub> = V <sub>IC(min)</sub> ,<br>V <sub>O</sub> = 1.4 V | 25°C           | 3                             | 5          | 3                             | 7                     | mV    |      |
|                                  |  |   | Full range     |                               | 7          |                               | 9                     |       |      |
| αV <sub>IO</sub>                 | Average temperature coefficient of input offset voltage              |   | Full range     | 7                             |            | 7                             |                       | μV/°C |      |
| I <sub>IO</sub>                  | Input offset current   | V <sub>O</sub> = 1.4 V  | 25°C           | 2                             | 30         | 2                             | 50                    | nA    |      |
|                                  |  |   | Full range     |                               | 100        |                               | 150                   |       |      |
| αI <sub>IO</sub>                 | Average temperature coefficient of input offset current              |   | Full range     | 10                            |            | 10                            |                       | pA/°C |      |
| I <sub>IB</sub>                  | Input bias current   | V <sub>O</sub> = 1.4 V  | 25°C           | -20                           | -150       | -20                           | -250                  | nA    |      |
|                                  |  |   | Full range     |                               | -300       |                               | -500                  |       |      |
| V <sub>ICR</sub>                 | Common-mode input voltage range                                      | V <sub>CC</sub> = 5 V to MAX  | 25°C           | 0 to<br>V <sub>CC</sub> - 1.5 |            | 0 to<br>V <sub>CC</sub> - 1.5 |                       | V     |      |
|                                  |  |   | Full range     | 0 to<br>V <sub>CC</sub> - 2   |            | 0 to<br>V <sub>CC</sub> - 2   |                       |       |      |
| V <sub>OH</sub>                  | High-level output voltage  | R <sub>L</sub> ≥ 2 kΩ   | 25°C           | V <sub>CC</sub> - 1.5         |            |                               | V <sub>CC</sub> - 1.5 |       |      |
|                                  |  | R <sub>L</sub> ≥ 10 kΩ  | 25°C           |                               |            |                               |                       |       |      |
|                                  |  | V <sub>CC</sub> = MAX   |                | R <sub>L</sub> = 2 kΩ         | Full range | 26                            |                       | 26    | V    |
|                                  |  | R <sub>L</sub> ≥ 10 kΩ  | Full range     | 27                            | 28         | 27                            | 28                    |       |      |
| V <sub>OL</sub>                  | Low-level output voltage   | R <sub>L</sub> ≤ 10 kΩ  | Full range     | 5                             | 20         | 5                             | 20                    | mV    |      |
| A <sub>VD</sub>                  | Large-signal differential voltage amplification                      | V <sub>CC</sub> = 15 V<br>V <sub>O</sub> = 1 V to 11 V,<br>R <sub>L</sub> ≥ 2 kΩ                    | 25°C           | 50                            | 100        | 25                            | 100                   | V/mV  |      |
|                                  |  |   | Full range     | 25                            |            | 15                            |                       |       |      |
| CMRR                             | Common-mode rejection ratio  | V <sub>CC</sub> = 5 V to MAX,<br>V <sub>IC</sub> = V <sub>IC(min)</sub>                             | 25°C           | 70                            | 80         | 65                            | 80                    | dB    |      |
| k <sub>SVR</sub>                 | Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to MAX  | 25°C           | 65                            | 100        | 65                            | 100                   | dB    |      |
| V <sub>O1</sub> /V <sub>O2</sub> | Crosstalk attenuation  | f = 1 kHz to 20 kHz   | 25°C           | 120                           |            | 120                           |                       | dB    |      |
| I <sub>O</sub>                   | Output current   | V <sub>CC</sub> = 15 V,<br>V <sub>ID</sub> = 1 V,<br>V <sub>O</sub> = 0                             | Source         | 25°C                          | -20        | -30                           | -20                   | -30   | mA   |
|                                  |  |   |                | Full range                    | -10        |                               | -10                   |       |      |
|                                  |  | V <sub>CC</sub> = 15 V,<br>V <sub>ID</sub> = -1 V,<br>V <sub>O</sub> = 15 V                         | Sink           | 25°C                          | 10         | 20                            | 10                    | 20    |      |
|                                  |  |   |                | Full range                    | 5          |                               | 5                     |       |      |
|                                  |  | V <sub>ID</sub> = -1 V, V <sub>O</sub> = 200 mV   | 25°C           | 12                            | 30         | 12                            | 30                    | μA    |      |
| I <sub>OS</sub>                  | Short-circuit output current   | V <sub>CC</sub> at 5 V, GND at -5 V,<br>V <sub>O</sub> = 0  | 25°C           | ±40                           | ±60        | ±40                           | ±60                   | mA    |      |
| I <sub>CC</sub>                  | Supply current (two amplifiers)                                      | V <sub>O</sub> = 2.5 V, No load   | Full range     | 0.7                           | 1.2        | 0.7                           | 1.2                   | mA    |      |
|                                  |  | V <sub>CC</sub> = MAX, V <sub>O</sub> = 0.5 V <sub>CC</sub> ,<br>No load                            | Full range     | 1                             | 2          | 1                             | 2                     |       |      |

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V<sub>CC</sub> for testing purposes is 26 V for XL2902 and 30 V for the others.

(2) Full range is -55°C to 125°C for XL158, -25°C to 85°C for LM258, and 0°C to 70°C for XL358, and -40°C to 125°C for XL2904.

(3) All typical values are at T<sub>A</sub> = 25°C

## 6.6 Electrical Characteristics for XL2904

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

| PARAMETER  | TEST CONDITIONS <sup>(1)</sup>   |                              | $T_A$ <sup>(2)</sup> | XL2904              |                              |               | UNIT |
|--|--|------------------------------|----------------------|---------------------|------------------------------|---------------|------|
|  |  |                              |                      | MIN                 | TYP <sup>(3)</sup>           | MAX           |      |
| $V_{IO}$ Input offset voltage  | $V_{CC} = 5\text{ V to MAX,}$<br>$V_{IC} = V_{ICR(min)},$<br>$V_O = 1.4\text{ V}$            | Non-A-suffix devices         | 25°C                 | 3                   | 7                            | mV            |      |
|  |  |                              | Full range           | 10                  |                              |               |      |
|  |  | A-suffix devices             | 25°C                 | 1                   | 2                            |               |      |
|  |  |                              | Full range           | 4                   |                              |               |      |
| $\alpha V_{IO}$ Average temperature coefficient of input offset voltage      |  | Full range                   | 7                    |                     | $\mu\text{V}/^\circ\text{C}$ |               |      |
| $I_{IO}$ Input offset current  | $V_O = 1.4\text{ V}$   | Non-V device                 | 25°C                 | 2                   | 50                           | nA            |      |
|  |  |                              | Full range           | 300                 |                              |               |      |
|  |  | V-suffix device              | 25°C                 | 2                   | 50                           |               |      |
|  |  |                              | Full range           | 150                 |                              |               |      |
| $\alpha I_{IO}$ Average temperature coefficient of input offset current      |  | Full range                   | 10                   |                     | $\text{pA}/^\circ\text{C}$   |               |      |
| $I_{IB}$ Input bias current  | $V_O = 1.4\text{ V}$   |                              | 25°C                 | -20                 | -250                         | nA            |      |
|  |  |                              | Full range           | -500                |                              |               |      |
| $V_{ICR}$ Common-mode input voltage range                                    | $V_{CC} = 5\text{ V to MAX}$   |                              | 25°C                 | 0 to $V_{CC} - 1.5$ |                              | V             |      |
|  |  |                              | Full range           | 0 to $V_{CC} - 2$   |                              |               |      |
| $V_{OH}$ High-level output voltage   | $R_L \geq 10\text{ k}\Omega$<br>$V_{CC} = \text{MAX,}$<br>Non-V device                       | $R_L = 2\text{ k}\Omega$     | 25°C                 | $V_{CC} - 1.5$      |                              | V             |      |
|  |  |                              | Full range           | 22                  |                              |               |      |
|  |  | $R_L \geq 10\text{ k}\Omega$ | 25°C                 | 23                  | 24                           |               |      |
|  |  |                              | Full range           | 26                  |                              |               |      |
|  |  |                              | Full range           | 27                  | 28                           |               |      |
| $V_{OL}$ Low-level output voltage  | $R_L \leq 10\text{ k}\Omega$   |                              | Full range           | 5                   | 20                           | mV            |      |
|  |  |                              | 25°C                 | 25                  | 100                          | V/mV          |      |
| $A_{VD}$ Large-signal differential voltage amplification                     | $V_{CC} = 15\text{ V,}$<br>$V_O = 1\text{ V to }11\text{ V,}$<br>$R_L \geq 2\text{ k}\Omega$ |                              | Full range           | 15                  |                              |               |      |
|  |  |                              | 25°C                 | 50                  | 80                           | dB            |      |
| CMRR Common-mode rejection ratio   | $V_{CC} = 5\text{ V to MAX,}$<br>$V_{IC} = V_{ICR(min)}$                                     | Non-V device                 | 25°C                 | 65                  | 80                           |               |      |
|  |  | V-suffix device              | 25°C                 | 65                  | 80                           |               |      |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC} / \Delta V_{IO}$ ) | $V_{CC} = 5\text{ V to MAX}$   |                              | 25°C                 | 65                  | 100                          | dB            |      |
| $V_{O1} / V_{O2}$ Crosstalk attenuation                                      | $f = 1\text{ kHz to }20\text{ kHz}$  |                              | 25°C                 | 120                 |                              | dB            |      |
| $I_O$ Output current   | $V_{CC} = 15\text{ V,}$<br>$V_{ID} = 1\text{ V,}$<br>$V_O = 0$                               | Source                       | 25°C                 | -20                 | -30                          | mA            |      |
|  |  |                              | Full range           | -10                 |                              |               |      |
|  |  | Sink                         | 25°C                 | 10                  | 20                           |               |      |
|  | Full range   |                              | 5                    |                     |                              |               |      |
|  | $V_{ID} = -1\text{ V, } V_O = 200\text{ mV}$   | Non-V device                 | 25°C                 | 30                  |                              | $\mu\text{A}$ |      |
|  |  | V-suffix device              | 25°C                 | 12                  | 40                           |               |      |
| $I_{OS}$ Short-circuit output current  | $V_{CC}$ at 5 V, $V_O = 0$ , GND at -5 V   |                              | 25°C                 | $\pm 40$            | $\pm 60$                     | mA            |      |
|  |  |                              | Full range           | 0.7                 | 1.2                          | mA            |      |
| $I_{CC}$ Supply current (four amplifiers)                                    | $V_O = 2.5\text{ V, No load}$  |                              | Full range           | 1                   | 2                            |               |      |
|  | $V_{CC} = \text{MAX, } V_O = 0.5 V_{CC}, \text{ No load}$                                    |                              | Full range           | 1                   | 2                            |               |      |

- (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for XL2904 and 32 V for XD2904
- (2) Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for XL158  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for XL258,  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for XL358, and  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for XL2904.
- (3) All typical values are at  $T_A = 25^\circ\text{C}$ .

## 6.7 Electrical Characteristics for XL158 and XL258

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

| PARAMETER                     | TEST CONDITIONS <sup>(1)</sup>  | $T_A$ <sup>(1)</sup> | XL158 |                    |     | XL258 |                    |     | UNIT |
|-------------------------------|---|----------------------|-------|--------------------|-----|-------|--------------------|-----|------|
|                               |   |                      | MIN   | TYP <sup>(2)</sup> | MAX | MIN   | TYP <sup>(2)</sup> | MAX |      |
| $V_{IO}$ Input offset voltage | $V_{CC} = 5\text{ V to }30\text{ V,}$<br>$V_{IC} = V_{ICR(min)},$<br>$V_O = 1.4\text{ V}$ | 25°C                 |       |                    | 2   |       | 2                  | 3   | mV   |
|                               |   | Full range           |       |                    | 4   |       |                    | 4   |      |

- (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for XL2904 and 30 V for others.
- (2) All typical values are at  $T_A = 25^\circ\text{C}$ .

**XL158 SOP8 XL258 SOP8 XL358D SOP8  
XD358 DIP8 XL2904D SOP8 XD2904 DIP8**

**Electrical Characteristics for XL158 and XL258 (continued)**

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

| PARAMETER         | TEST CONDITIONS <sup>(1)</sup>                                  | $T_A$ <sup>(1)</sup>   | XL158                        |                     |                   | XL258               |                    |               | UNIT                         |     |    |
|-------------------|---|--|------------------------------|---------------------|-------------------|---------------------|--------------------|---------------|------------------------------|-----|----|
|                   |   |  | MIN                          | TYP <sup>(2)</sup>  | MAX               | MIN                 | TYP <sup>(2)</sup> | MAX           |                              |     |    |
| $\alpha V_{IO}$   | Average temperature coefficient of input offset voltage         | Full range   |                              | 7                   | 15 <sup>(3)</sup> |                     | 7                  | 15            | $\mu\text{A}/^\circ\text{C}$ |     |    |
| $I_{IO}$          | Input offset current  | $V_O = 1.4\text{ V}$   | 25°C                         | 2                   | 10                | 2                   | 15                 |               | nA                           |     |    |
|                   |   | Full range   |                              |                     | 30                |                     | 30                 |               |                              |     |    |
| $\alpha I_{IO}$   | Average temperature coefficient of input offset current         | Full range   |                              | 10                  | 200               |                     | 10                 | 200           | $\text{pA}/^\circ\text{C}$   |     |    |
| $I_{IB}$          | Input bias current  | $V_O = 1.4\text{ V}$   | 25°C                         | -15                 | -50               | -15                 | -80                |               | nA                           |     |    |
|                   |   | Full range   |                              |                     | -100              |                     | -100               |               |                              |     |    |
| $V_{ICR}$         | Common-mode input voltage range                                 | $V_{CC} = 30\text{ V}$   | 25°C                         | 0 to $V_{CC} - 1.5$ |                   | 0 to $V_{CC} - 1.5$ |                    |               | V                            |     |    |
|                   |   | Full range   |                              | 0 to $V_{CC} - 2$   |                   | 0 to $V_{CC} - 2$   |                    |               |                              |     |    |
| $V_{OH}$          | High-level output voltage                                       | $R_L \geq 2\text{ k}\Omega$  | 25°C                         | $V_{CC} - 1.5$      |                   | $V_{CC} - 1.5$      |                    |               | V                            |     |    |
|                   |   | $V_{CC} = 30\text{ V}$   | $R_L = 2\text{ k}\Omega$     | Full range          | 26                |                     | 26                 |               |                              |     |    |
|                   |   |  | $R_L \geq 10\text{ k}\Omega$ | Full range          | 27                | 28                  | 27                 | 28            |                              |     |    |
| $V_{OL}$          | Low-level output voltage  | $R_L \leq 10\text{ k}\Omega$   | Full range                   | 5                   | 20                | 5                   | 20                 | mV            |                              |     |    |
| $A_{VD}$          | Large-signal differential voltage amplification                 | $V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V}$ to $11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$ | 25°C                         | 50                  | 100               | 50                  | 100                |               | V/mV                         |     |    |
|                   |   |  | Full range                   |                     | 25                |                     | 25                 |               |                              |     |    |
| CMRR              | Common-mode rejection ratio                                     |  | 25°C                         | 70                  | 80                | 70                  | 80                 | dB            |                              |     |    |
| $k_{SVR}$         | Supply-voltage rejection ratio ( $\Delta V_D / \Delta V_{IO}$ ) |  | 25°C                         | 65                  | 100               | 65                  | 100                | dB            |                              |     |    |
| $V_{O1} / V_{O2}$ | Crosstalk attenuation   | $f = 1\text{ kHz}$ to $20\text{ kHz}$  | 25°C                         |                     | 120               |                     | 120                | dB            |                              |     |    |
| $I_O$             | Output current  | $V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ , $V_O = 0$                                 | Source                       | 25°C                | -20               | -30                 | -60                | -20           | -30                          | -60 | mA |
|                   |   |  | Full range                   |                     | -10               |                     | -10                |               |                              |     |    |
|                   |   | Sink   | 25°C                         | 10                  | 20                | 10                  | 20                 |               |                              |     |    |
|                   |   |  | Full range                   |                     | 5                 |                     | 5                  |               |                              |     |    |
|                   |   | $V_{ID} = -1\text{ V}$ , $V_O = 200\text{ mV}$   | 25°C                         | 12                  | 30                | 12                  | 30                 | $\mu\text{A}$ |                              |     |    |
| $I_{OS}$          | Short-circuit output current                                    | $V_{CC}$ at $5\text{ V}$ , GND at $-5\text{ V}$ , $V_O = 0$                                | 25°C                         |                     | $\pm 40$          | $\pm 60$            |                    | $\pm 40$      | $\pm 60$                     | mA  |    |
| $I_{CC}$          | Supply current (four amplifiers)                                | $V_O = 2.5\text{ V}$ , No load   | Full range                   |                     | 0.7               | 1.2                 |                    | 0.7           | 1.2                          | mA  |    |
|                   |   | $V_{CC} = \text{MAX V}$ , $V_O = 0.5\text{ V}$ , No load                                   | Full range                   |                     | 1                 | 2                   |                    | 1             | 2                            |     |    |

(3) On products compliant to MIL-PRF-38535, this parameter is not production tested.

**6.8 Electrical Characteristics for XL358**

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

| PARAMETER       | TEST CONDITIONS <sup>(1)</sup>                          | $T_A$ <sup>(2)</sup> | XL358 |                    |     | UNIT                         |
|-----------------|---|----------------------|-------|--------------------|-----|------------------------------|
|                 |   |                      | MIN   | TYP <sup>(3)</sup> | MAX |                              |
| $V_{IO}$        | Input offset voltage                                    | 25°C                 |       | 2                  | 3   | mV                           |
|                 |   | Full range           |       |                    | 5   |                              |
| $\alpha V_{IO}$ | Average temperature coefficient of input offset voltage | Full range           |       | 7                  | 20  | $\mu\text{A}/^\circ\text{C}$ |
| $I_{IO}$        | Input offset current                                    | 25°C                 |       | 2                  | 30  | nA                           |
|                 |   | Full range           |       |                    | 75  |                              |
| $\alpha I_{IO}$ | Average temperature coefficient of input offset current | Full range           |       | 10                 | 300 | $\text{pA}/^\circ\text{C}$   |

- (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for XL2904 and 30 V for others.
- (2) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for XL2904 and 30 V for others.
- (3) All typical values are at  $T_A = 25^\circ\text{C}$ .

**XL158 SOP8 XL258 SOP8 XL358D SOP8  
XD358 DIP8 XL2904D SOP8 XD2904 DIP8**

**Electrical Characteristics for XL358 (continued)**

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

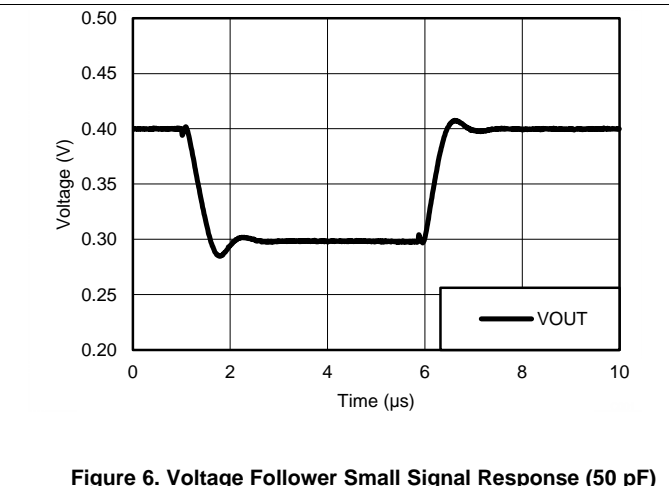
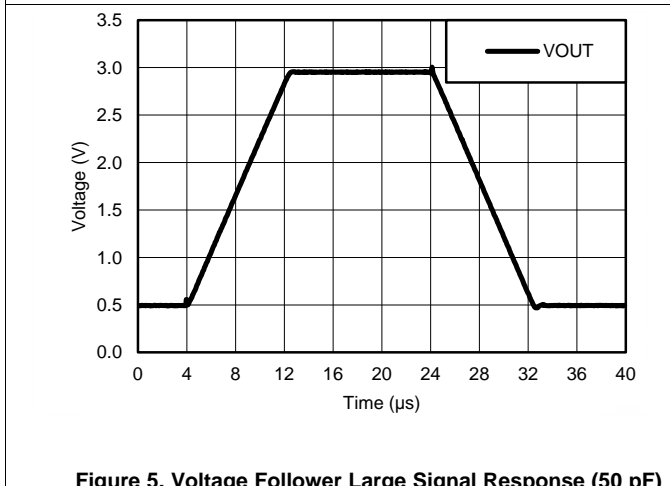
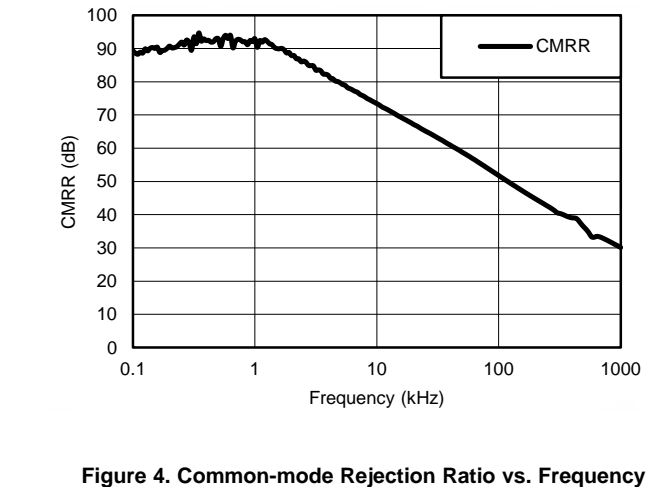
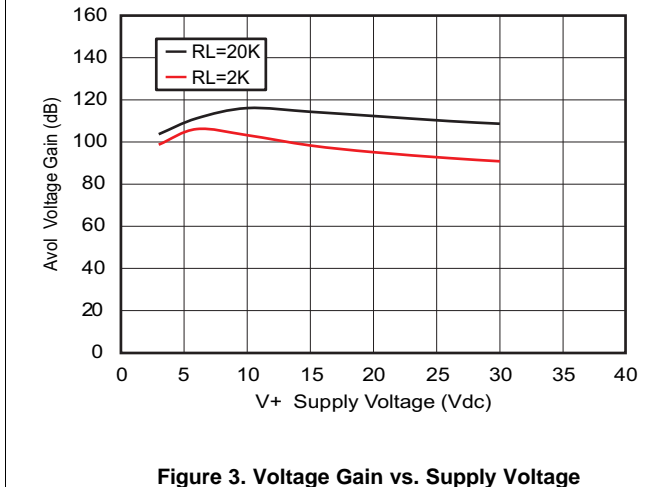
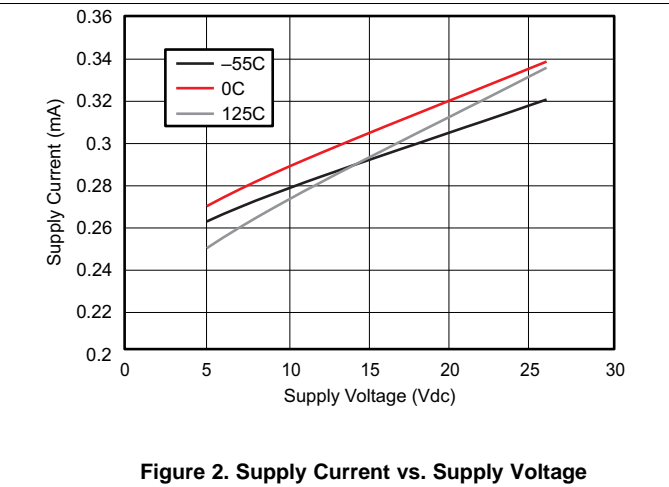
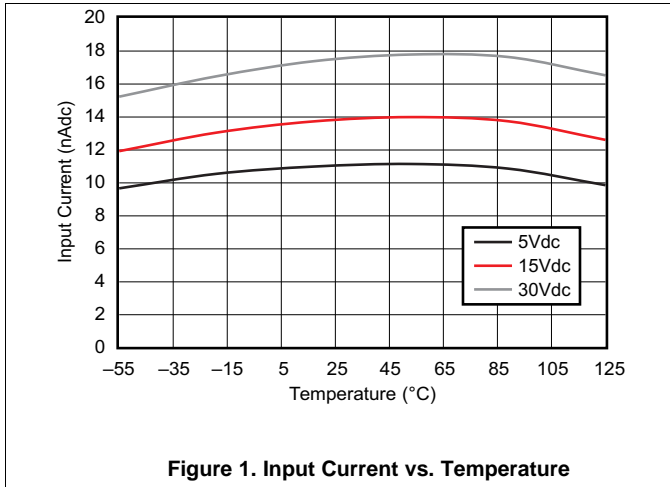
| PARAMETER  | TEST CONDITIONS <sup>(1)</sup>  | $T_A$ <sup>(2)</sup>         | XL358               |                    |          | UNIT          |    |
|--|---|------------------------------|---------------------|--------------------|----------|---------------|----|
|  |   |                              | MIN                 | TYP <sup>(3)</sup> | MAX      |               |    |
| $I_{IB}$ Input bias current  | $V_O = 1.4\text{ V}$  | 25°C                         |                     | -15                | -100     | nA            |    |
|  |   | Full range                   |                     |                    | -200     |               |    |
| $V_{ICR}$ Common-mode input voltage range                                  | $V_{CC} = 30\text{ V}$  | 25°C                         | 0 to $V_{CC} - 1.5$ |                    |          | V             |    |
|  |   | Full range                   | 0 to $V_{CC} - 2$   |                    |          |               |    |
| $V_{OH}$ High-level output voltage   | $R_L \geq 2\text{ k}\Omega$   | 25°C                         | $V_{CC} - 1.5$      |                    |          | V             |    |
|  | $V_{CC} = 30\text{ V}$  | $R_L = 2\text{ k}\Omega$     | Full range          | 26                 |          |               |    |
|  |   | $R_L \geq 10\text{ k}\Omega$ | Full range          | 27                 | 28       |               |    |
| $V_{OL}$ Low-level output voltage  | $R_L \leq 10\text{ k}\Omega$  | Full range                   |                     | 5                  | 20       | mV            |    |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to }11\text{ V}$ ,<br>$R_L \geq 2\text{ k}\Omega$ | 25°C                         | 25                  | 100                |          | V/mV          |    |
|  |   | Full range                   | 15                  |                    |          |               |    |
| CMRR Common-mode rejection ratio   |   | 25°C                         | 65                  | 80                 |          | dB            |    |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) |   | 25°C                         | 65                  | 100                |          | dB            |    |
| $V_{O1}/V_{O2}$ Crosstalk attenuation                                      | $f = 1\text{ kHz to }20\text{ kHz}$   | 25°C                         |                     | 120                |          | dB            |    |
| $I_O$ Output current   | $V_{CC} = 15\text{ V}$ ,<br>$V_{ID} = 1\text{ V}$ ,<br>$V_O = 0$                            | Source                       | 25°C                | -20                | -30      | -60           | mA |
|  |   | Full range                   |                     | -10                |          |               |    |
|  | $V_{CC} = 15\text{ V}$ ,<br>$V_{ID} = -1\text{ V}$ ,<br>$V_O = 15\text{ V}$                 | Sink                         | 25°C                | 10                 | 20       |               |    |
|  |   | Full range                   |                     | 5                  |          |               |    |
| $V_{ID} = -1\text{ V}$ , $V_O = 200\text{ mV}$                             |   | 25°C                         |                     | 30                 |          | $\mu\text{A}$ |    |
| $I_{OS}$ Short-circuit output current                                      | $V_{CC}$ at 5 V, GND at -5 V,<br>$V_O = 0$  | 25°C                         |                     | $\pm 40$           | $\pm 60$ | mA            |    |
| $I_{CC}$ Supply current (four amplifiers)                                  | $V_O = 2.5\text{ V}$ , No load  | Full range                   |                     | 0.7                | 1.2      | mA            |    |
|  | $V_{CC} = \text{MAX V}$ , $V_O = 0.5\text{ V}$ ,<br>No load                                 | Full range                   |                     | 1                  | 2        |               |    |

**6.9 Operating Conditions**

$V_{CC} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

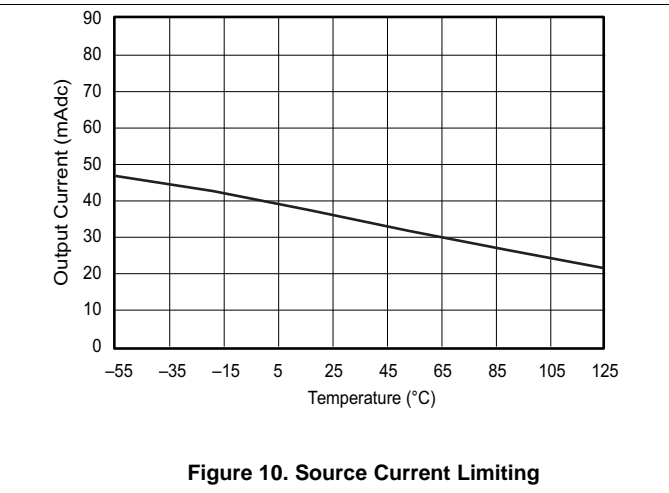
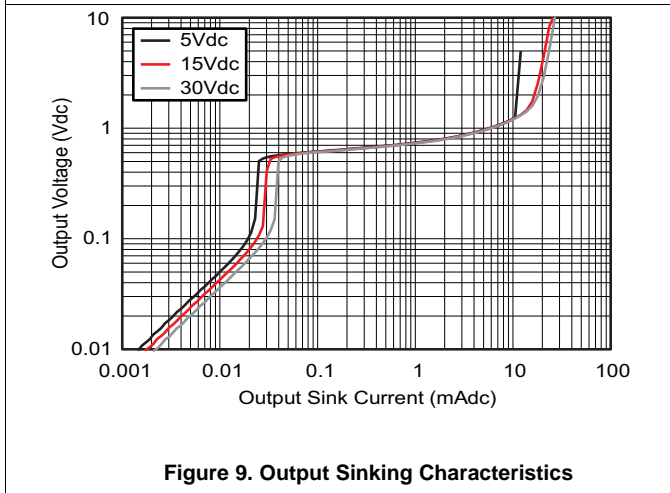
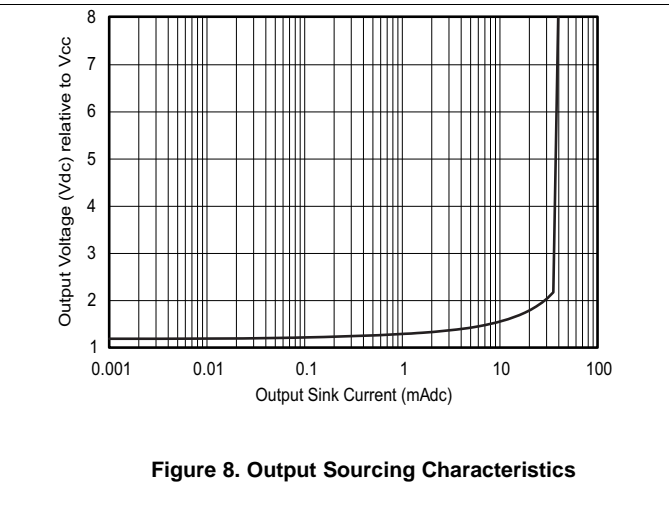
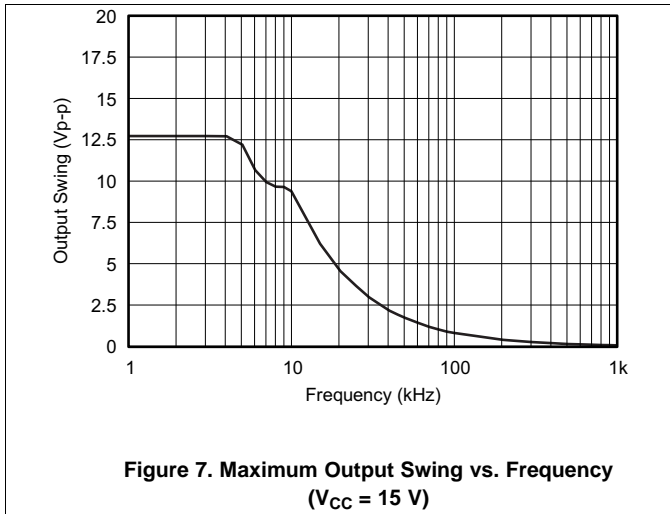
| PARAMETER                            | TEST CONDITIONS   | TYP | UNIT                   |
|--------------------------------------|---|-----|------------------------|
| SR Slew rate at unity gain           | $R_L = 1\text{ M}\Omega$ , $C_L = 30\text{ pF}$ , $V_I = \pm 10\text{ V}$ (see Figure 11) | 0.3 | V/ $\mu\text{s}$       |
| $B_1$ Unity-gain bandwidth           | $R_L = 1\text{ M}\Omega$ , $C_L = 20\text{ pF}$ (see Figure 11)                           | 0.7 | MHz                    |
| $V_n$ Equivalent input noise voltage | $R_S = 100\ \Omega$ , $V_I = 0\text{ V}$ , $f = 1\text{ kHz}$ (see Figure 12)             | 40  | nV/ $\sqrt{\text{Hz}}$ |

6.10 Typical Characteristics





Typical Characteristics (continued)



7 Parameter Measurement Information

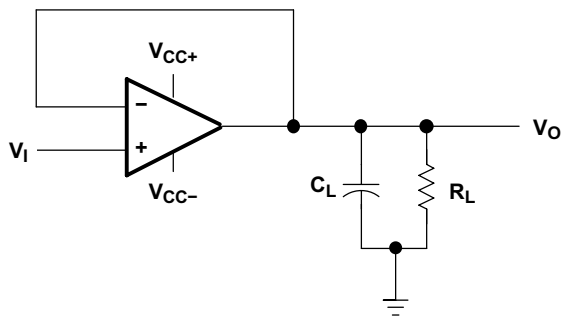


Figure 11. Unity-Gain Amplifier

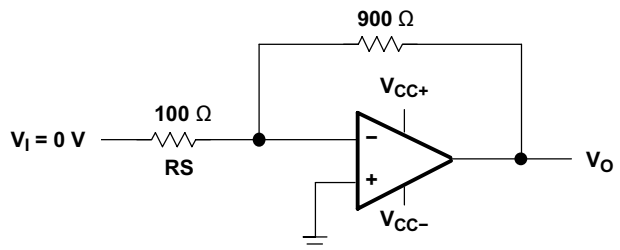


Figure 12. Noise-Test Circuit

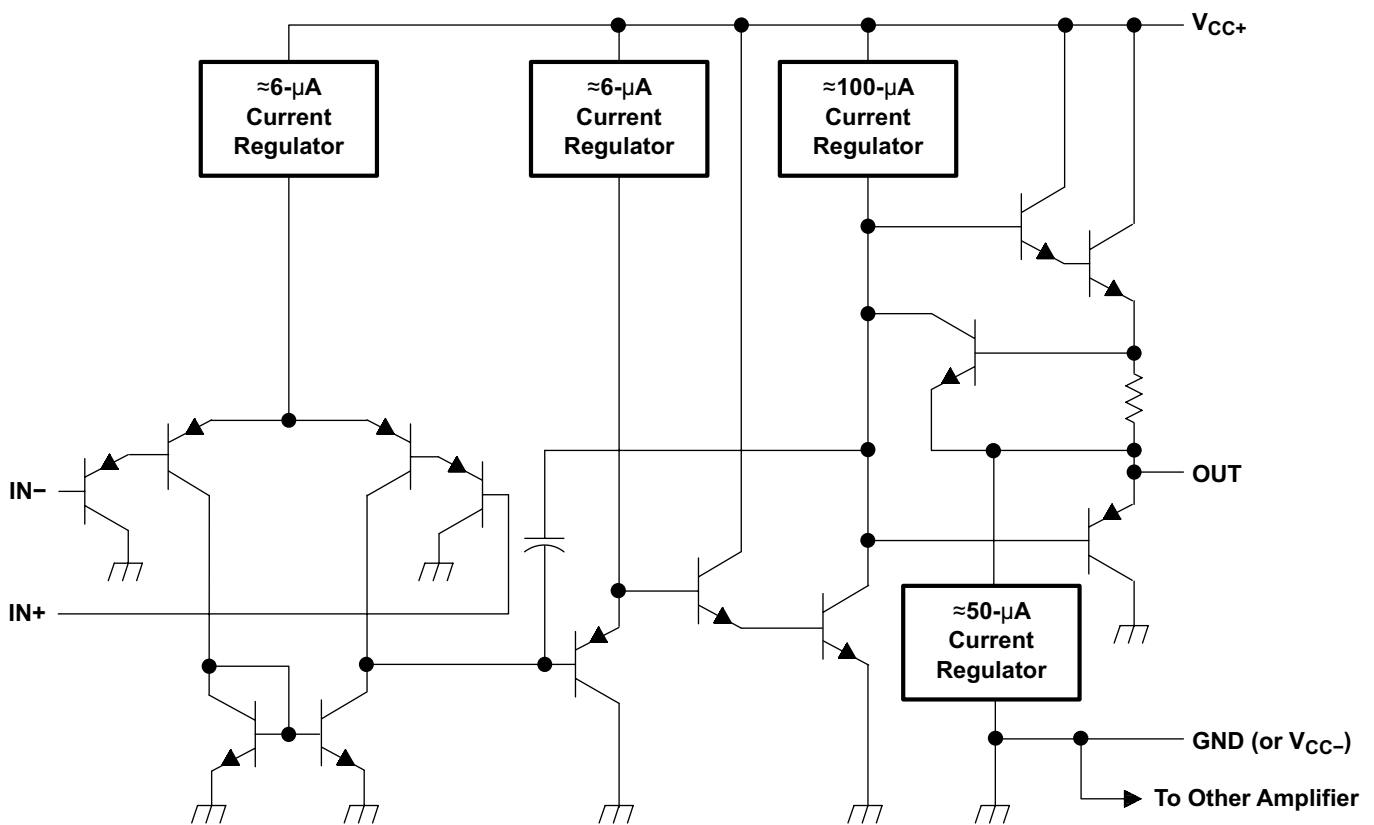
## 8 Detailed Description

### 8.1 Overview

These devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the XL2904 device), and  $V_{CC}$  is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, DC amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5-V supply used in digital systems and easily can provide the required interface electronics without additional  $\pm 5$ -V supplies.

### 8.2 Functional Block Diagram



| COMPONENT COUNT |    |
|-----------------|----|
| Epi-FET         | 1  |
| Diodes          | 2  |
| Resistors       | 7  |
| Transistors     | 51 |
| Capacitors      | 2  |

### 8.3 Feature Description

#### 8.3.1 Unity-Gain Bandwidth

The unity-gain bandwidth is the frequency up to which an amplifier with a unity gain may be operated without greatly distorting the signal. These devices have a 0.7-MHz unity-gain bandwidth.

#### 8.3.2 Slew Rate

The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. These devices have a 0.3-V/ $\mu$ s slew rate.

#### 8.3.3 Input Common Mode Range

The valid common mode range is from device ground to  $V_{CC} - 1.5$  V ( $V_{CC} - 2$  V across temperature). Inputs may exceed  $V_{CC}$  up to the maximum  $V_{CC}$  without device damage. At least one input must be in the valid input common mode range for output to be correct phase. If both inputs exceed valid range then output phase is undefined. If either input is less than -0.3 V then input current should be limited to 1mA and output phase is undefined.

### 8.4 Device Functional Modes

These devices are powered on when the supply is connected. This device can be operated as a single supply operational amplifier or dual supply amplifier depending on the application.

## 9 Application and Implementation

### 9.1 Application Information

The XLx58 and XL2904 operational amplifiers are useful in a wide range of signal conditioning applications. Inputs can be powered before  $V_{CC}$  for flexibility in multiple supply circuits.

### 9.2 Typical Application

A typical application for an operational amplifier in an inverting amplifier. This amplifier takes a positive voltage on the input, and makes it a negative voltage of the same magnitude. In the same manner, it also makes negative voltages positive.

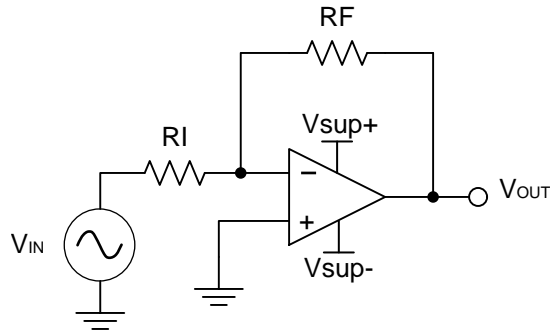


Figure 13. Application Schematic

#### 9.2.1 Design Requirements

The supply voltage must be chosen such that it is larger than the input voltage range and output range. For instance, this application will scale a signal of  $\pm 0.5$  V to  $\pm 1.8$  V. Setting the supply at  $\pm 12$  V is sufficient to accommodate this application.

#### 9.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using [Equation 1](#) and [Equation 2](#):

$$A_v = \frac{V_{OUT}}{V_{IN}} \quad (1)$$

$$A_v = \frac{1.8}{-0.5} = -3.6 \quad (2)$$

Once the desired gain is determined, choose a value for  $R_I$  or  $R_F$ . Choosing a value in the kilohm range is desirable because the amplifier circuit will use currents in the milliamp range. This ensures the part will not draw too much current. This example will choose 10 k $\Omega$  for  $R_I$  which means 36 k $\Omega$  will be used for  $R_F$ . This was determined by [Equation 3](#).

$$A_v = -\frac{R_F}{R_I} \quad (3)$$

## Typical Application (continued)

### 9.2.3 Application Curve

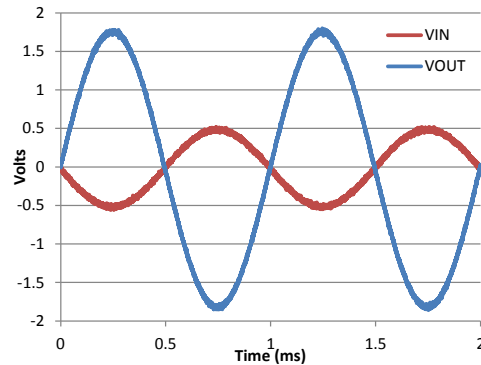


Figure 14. Input and Output Voltages of the Inverting Amplifier

## 10 Power Supply Recommendations

### CAUTION

Supply voltages larger than 32 V for a single supply (26 V for the XL2904), or outside the range of  $\pm 16$  V for a dual supply ( $\pm 13$  V for the LM2904) can permanently damage the device (see the [Absolute Maximum Ratings](#)).

Place 0.1- $\mu$ F bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high impedance power supplies. For more detailed information on bypass capacitor placement, refer to the [Layout](#).

## 11 Layout

### 11.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole, as well as the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1- $\mu$ F ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds, paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping RF and RG close to the inverting input minimizes parasitic capacitance, as shown in [Layout Examples](#).
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

## 11.2 Layout Examples

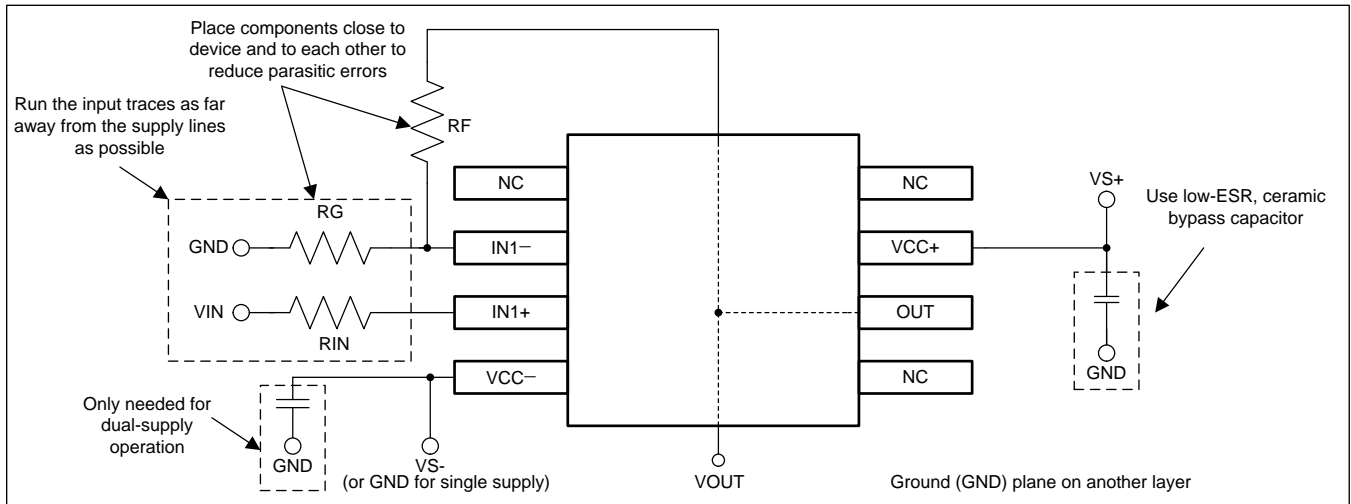


Figure 15. Operational Amplifier Board Layout for Noninverting Configuration

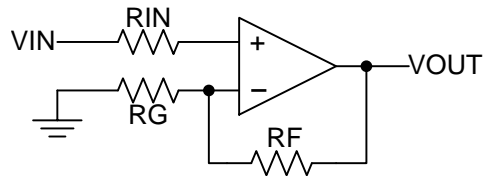


Figure 16. Operational Amplifier Schematic for Noninverting Configuration

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