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## LMx58-N Low-Power, Dual-Operational Amplifiers

### 1 Features

- Available in 8-Bump DSBGA Chip-Sized Package, (See AN-1112, [SNVA009](#))
- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100 dB
- Wide Bandwidth (Unity Gain): 1 MHz (Temperature Compensated)
- Wide Power Supply Range:
  - Single Supply: 3V to 32V
  - Or Dual Supplies:  $\pm 1.5\text{V}$  to  $\pm 16\text{V}$
- Very Low Supply Current Drain (500  $\mu\text{A}$ )—Essentially Independent of Supply Voltage
- Low Input Offset Voltage: 2 mV
- Input Common-Mode Voltage Range Includes Ground
- Differential Input Voltage Range Equal to the Power Supply Voltage
- Large Output Voltage Swing
- Unique Characteristics:
  - In the Linear Mode the Input Common-Mode Voltage Range Includes Ground and the Output Voltage Can Also Swing to Ground, even though Operated from Only a Single Power Supply Voltage.
  - The Unity Gain Cross Frequency is Temperature Compensated.
  - The Input Bias Current is also Temperature Compensated.
- Advantages:
  - Two Internally Compensated Op Amps
  - Eliminates Need for Dual Supplies
  - Allows Direct Sensing Near GND and  $V_{\text{OUT}}$  Also Goes to GND
  - Compatible with All Forms of Logic
  - Power Drain Suitable for Battery Operation

### 2 Applications

- Active Filters
- General Signal Conditioning and Amplification
- 4- to 20-mA Current Loop Transmitters

### 3 Description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op-amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard 3.3-V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional  $\pm 15\text{V}$  power supplies.

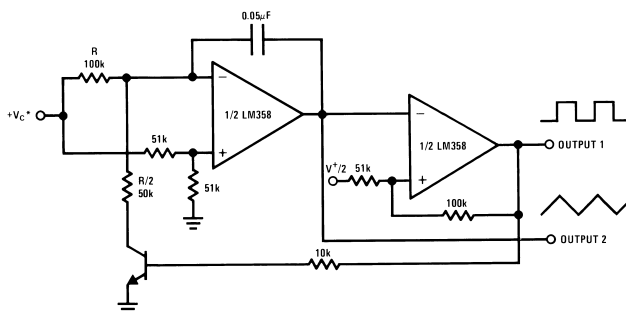
The LM358 and LM2904 are available in a chip sized package (8-Bump DSBGA) using TI's DSBGA package technology.

#### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)     |
|-------------|------------|---------------------|
| LM158-N     | TO-CAN (8) | 9.08 mm x 9.09 mm   |
|             | CDIP (8)   | 10.16 mm x 6.502 mm |
| LM258-N     | TO-CAN (8) | 9.08 mm x 9.09 mm   |
|             | DSBGA (8)  | 1.31 mm x 1.31 mm   |
| LM2904-N    | SOIC (8)   | 4.90 mm x 3.91 mm   |
|             | PDIP (8)   | 9.81 mm x 6.35 mm   |
|             | TO-CAN (8) | 9.08 mm x 9.09 mm   |
| LM358-N     | DSBGA (8)  | 1.31 mm x 1.31 mm   |
|             | SOIC (8)   | 4.90 mm x 3.91 mm   |
|             | PDIP (8)   | 9.81 mm x 6.35 mm   |
|             | TO-CAN (8) | 9.08 mm x 9.09 mm   |

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

#### Voltage Controlled Oscillator (VCO)



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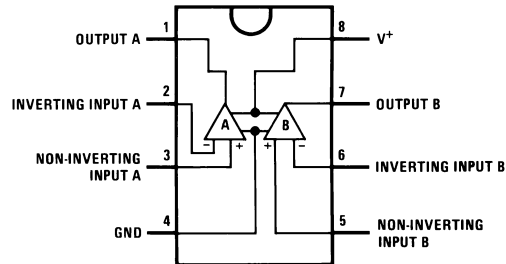
## 4 Revision History

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

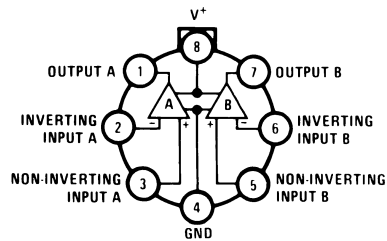
| <b>Changes from Revision H (March 2013) to Revision I</b>                                                                                                                                                                                                                                                                                                                                                                                           | <b>Page</b> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <ul style="list-style-type: none"> <li>Added <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section .....</li> </ul> | <b>1</b>    |
| <b>Changes from Revision G (March 2013) to Revision H</b>                                                                                                                                                                                                                                                                                                                                                                                           | <b>Page</b> |
| <ul style="list-style-type: none"> <li>Changed layout of National Data Sheet to TI format .....</li> </ul>                                                                                                                                                                                                                                                                                                                                          | <b>25</b>   |

## 5 Pin Configuration and Functions

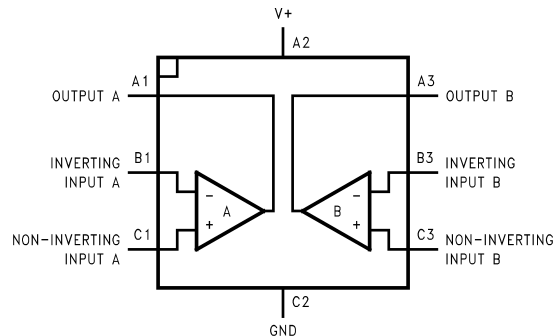
**D, P, and NAB Package  
8-Pin SOIC, PDIP, and CDIP  
Top View**



**LMC Package  
8-Pin TO-99  
Top View**



**YPB Package  
8-Pin DSBGA  
Top View**



### Pin Functions

| PIN         |           |          | TYPE | DESCRIPTION                                                                             |
|-------------|-----------|----------|------|-----------------------------------------------------------------------------------------|
| D/P/LMC NO. | DSBGA NO. | NAME     |      |                                                                                         |
| 1           | A1        | OUTA     | O    | Output , Channel A                                                                      |
| 2           | B1        | -INA     | I    | Inverting Input, Channel A                                                              |
| 3           | C1        | +INA     | I    | Non-Inverting Input, Channel A                                                          |
| 4           | C2        | GND / V- | P    | Ground for Single supply configurations. negative supply for dual supply configurations |
| 5           | C3        | +INB     | I    | Output, Channel B                                                                       |
| 6           | B3        | -INB     | I    | Inverting Input, Channel B                                                              |
| 7           | A3        | OUTB     | O    | Non-Inverting Input, Channel B                                                          |
| 8           | A2        | V+       | P    | Positive Supply                                                                         |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

 See <sup>(1)(2)(3)</sup>.

|                                                            |                                                      | LM158, LM258,<br>LM358, LM158A,<br>LM258A, LM358A |            | LM2904 |            | UNIT             |
|------------------------------------------------------------|------------------------------------------------------|---------------------------------------------------|------------|--------|------------|------------------|
|                                                            |                                                      | MIN                                               | MAX        | MIN    | MAX        |                  |
| Supply Voltage, $V^+$                                      |                                                      |                                                   | 32         |        | 26         | V                |
| Differential Input Voltage                                 |                                                      |                                                   | 32         |        | 26         | V                |
| Input Voltage                                              |                                                      | -0.3                                              | 32         | -0.3   | 26         | V                |
| Power Dissipation <sup>(4)</sup>                           | PDIP (P)                                             |                                                   | 830        |        | 830        | mW               |
|                                                            | TO-99 (LMC)                                          |                                                   | 550        |        |            | mW               |
|                                                            | SOIC (D)                                             |                                                   | 530        |        | 530        | mW               |
|                                                            | DSBGA (YPB)                                          |                                                   | 435        |        |            | mW               |
| Output Short-Circuit to GND (One Amplifier) <sup>(5)</sup> | $V^+ \leq 15 \text{ V}$ and $T_A = 25^\circ\text{C}$ |                                                   | Continuous |        | Continuous |                  |
| Input Current ( $V_{IN} < -0.3\text{V}$ ) <sup>(6)</sup>   |                                                      |                                                   | 50         |        | 50         | mA               |
| Temperature                                                |                                                      | -55                                               | 125        |        |            | $^\circ\text{C}$ |
|                                                            | PDIP Package (P): Soldering (10 seconds)             |                                                   | 260        |        | 260        | $^\circ\text{C}$ |
|                                                            | SOIC Package (D)                                     | Vapor Phase (60 seconds)                          | 215        |        | 215        | $^\circ\text{C}$ |
|                                                            |                                                      |                                                   | 220        |        | 220        | $^\circ\text{C}$ |
| Lead Temperature                                           | PDIP (P): (Soldering, 10 seconds)                    |                                                   | 260        |        | 260        | $^\circ\text{C}$ |
|                                                            | TO-99 (LMC): (Soldering, 10 seconds)                 |                                                   | 300        |        | 300        | $^\circ\text{C}$ |
| Storage temperature, $T_{stg}$                             |                                                      | -65                                               | 150        | -65    | 150        | $^\circ\text{C}$ |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Recommended Operating Conditions* indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and the test conditions, see the Electrical Characteristics.
- (2) Refer to RETS158AX for LM158A military specifications and to RETS158X for LM158 military specifications.
- (3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
- (4) For operating at high temperatures, the LM358/LM358A, LM2904 must be derated based on a  $125^\circ\text{C}$  maximum junction temperature and a thermal resistance of  $120^\circ\text{C/W}$  for PDIP,  $182^\circ\text{C/W}$  for TO-99,  $189^\circ\text{C/W}$  for SOIC package, and  $230^\circ\text{C/W}$  for DSBGA, which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM258/LM258A and LM158/LM158A can be derated based on a  $+150^\circ\text{C}$  maximum junction temperature. The dissipation is the total of both amplifiers—use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.
- (5) Short circuits from the output to  $V^+$  can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of  $V^+$ . At values of supply voltage in excess of +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.
- (6) This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the  $V^+$  voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than  $-0.3 \text{ V}$  (at  $25^\circ\text{C}$ ).

### 6.2 ESD Ratings

|             |                         |                                                                   | VALUE     | UNIT |
|-------------|-------------------------|-------------------------------------------------------------------|-----------|------|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup> | $\pm 250$ | V    |

- (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)

|                                                      | MIN             | MAX             | UNIT |
|------------------------------------------------------|-----------------|-----------------|------|
| Supply Voltage ( $V_+$ - $V_-$ ):LM158, LM258, LM358 | 3 ( $\pm 1.5$ ) | 32 ( $\pm 16$ ) | V    |
| Supply Voltage ( $V_+$ - $V_-$ ):LM2904              | 3 ( $\pm 1.5$ ) | 26 ( $\pm 13$ ) | V    |
| Operating Temperature: LM158                         | -55             | 125             | °C   |
| Operating Temperature: LM258                         | -25             | 85              | °C   |
| Operating Temperature: LM358                         | 0               | 70              | °C   |
| Operating Temperature: LM2904                        | -40             | 85              | °C   |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                        | LM158-N,<br>LM258-N,<br>LM358-N | LM158-N | LM2904-N, LM358-N |     |     | UNIT |
|-------------------------------|----------------------------------------|---------------------------------|---------|-------------------|-----|-----|------|
|                               |                                        | LMC                             | NAB     | YPB               | D   | P   |      |
|                               |                                        | 8 PINS                          |         |                   |     |     |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance | 155                             | 132     | 230               | 189 | 120 | °C/W |

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

### 6.5 Electrical Characteristics: LM158A, LM358A, LM158, LM258

$V_+ = +5.0$  V, See<sup>(1)</sup>, unless otherwise stated

| PARAMETER                 | TEST CONDITIONS                                                                                 | LM158A |     |             | LM358A |     |             | LM158, LM258 |     |             | UNIT |
|---------------------------|-------------------------------------------------------------------------------------------------|--------|-----|-------------|--------|-----|-------------|--------------|-----|-------------|------|
|                           |                                                                                                 | MIN    | TYP | MAX         | MIN    | TYP | MAX         | MIN          | TYP | MAX         |      |
| Input Offset Voltage      | See <sup>(2)</sup> , $T_A = 25^\circ\text{C}$                                                   | 1      | 2   |             | 2      | 3   |             | 2            | 5   |             | mV   |
| Input Bias Current        | $I_{IN(+)}$ or $I_{IN(-)}$ , $T_A = 25^\circ\text{C}$ ,<br>$V_{CM} = 0$ V, <sup>(3)</sup>       | 20     | 50  |             | 45     | 100 |             | 45           | 150 |             | nA   |
| Input Offset Current      | $I_{IN(+)} - I_{IN(-)}$ , $V_{CM} = 0$ V, $T_A = 25^\circ\text{C}$                              | 2      | 10  |             | 5      | 30  |             | 3            | 30  |             | nA   |
| Input Common-Mode         | $V_+ = 30$ V, <sup>(4)</sup>                                                                    |        |     |             |        |     |             |              |     |             |      |
| Voltage Range             | (LM2904, $V_+ = 26$ V), $T_A = 25^\circ\text{C}$                                                | 0      |     | $V_+ - 1.5$ | 0      |     | $V_+ - 1.5$ | 0            |     | $V_+ - 1.5$ | V    |
| Supply Current            | Over Full Temperature Range                                                                     |        |     |             |        |     |             |              |     |             |      |
|                           | $R_L = \infty$ on All Op Amps                                                                   |        |     |             |        |     |             |              |     |             |      |
|                           | $V_+ = 30$ V (LM2904 $V_+ = 26$ V)                                                              | 1      | 2   |             | 1      | 2   |             | 1            | 2   |             | mA   |
|                           | $V_+ = 5$ V                                                                                     | 0.5    | 1.2 |             | 0.5    | 1.2 |             | 0.5          | 1.2 |             | mA   |
| Large Signal Voltage Gain | $V_+ = 15$ V, $T_A = 25^\circ\text{C}$ ,<br>$R_L \geq 2$ k $\Omega$ , (For $V_O = 1$ V to 11 V) | 50     | 100 |             | 25     | 100 |             | 50           | 100 |             | V/mV |
| Common-Mode               | $T_A = 25^\circ\text{C}$ ,                                                                      | 70     | 85  |             | 65     | 85  |             | 70           | 85  |             | dB   |
| Rejection Ratio           | $V_{CM} = 0$ V to $V_+ - 1.5$ V                                                                 |        |     |             |        |     |             |              |     |             |      |
| Power Supply              | $V_+ = 5$ V to 30 V                                                                             |        |     |             |        |     |             |              |     |             |      |
| Rejection Ratio           | (LM2904, $V_+ = 5$ V to 26 V),<br>$T_A = 25^\circ\text{C}$                                      | 65     | 100 |             | 65     | 100 |             | 65           | 100 |             | dB   |

(1) These specifications are limited to  $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$  for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to  $-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ , the LM358/LM358A temperature specifications are limited to  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ , and the LM2904 specifications are limited to  $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ .

(2)  $V_O \approx 1.4$  V,  $R_S = 0$   $\Omega$  with  $V_+$  from 5 V to 30 V; and over the full input common-mode range (0 V to  $V_+ - 1.5$  V) at  $25^\circ\text{C}$ . For LM2904,  $V_+$  from 5 V to 26 V.

(3) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

(4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at  $25^\circ\text{C}$ ). The upper end of the common-mode voltage range is  $V_+ - 1.5$  V (at  $25^\circ\text{C}$ ), but either or both inputs can go to 32 V without damage (26 V for LM2904), independent of the magnitude of  $V_+$ .

**Electrical Characteristics: LM158A, LM358A, LM158, LM258 (continued)**
 $V^+ = +5.0\text{ V}$ , See<sup>(1)</sup>, unless otherwise stated

| PARAMETER                       |                 | TEST CONDITIONS                                                                 |                        | LM158A |     |     | LM358A            |     |     | LM158, LM258 |     |     | UNIT              |  |  |       |                   |    |
|---------------------------------|-----------------|---------------------------------------------------------------------------------|------------------------|--------|-----|-----|-------------------|-----|-----|--------------|-----|-----|-------------------|--|--|-------|-------------------|----|
|                                 |                 |                                                                                 |                        | MIN    | TYP | MAX | MIN               | TYP | MAX | MIN          | TYP | MAX |                   |  |  |       |                   |    |
| Power Supply                    |                 | V <sup>+</sup> = 5 V to 30 V                                                    |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
| Rejection Ratio                 |                 | (LM2904, V <sup>+</sup> = 5 V to 26 V),<br>T <sub>A</sub> = 25°C                |                        | 65     | 100 |     | 65                | 100 |     | 65           | 100 |     | dB                |  |  |       |                   |    |
| Amplifier-to-Amplifier Coupling |                 | f = 1 kHz to 20 kHz, T <sub>A</sub> = 25°C (Input Referred), See <sup>(5)</sup> |                        | -120   |     |     | -120              |     |     | -120         |     |     | dB                |  |  |       |                   |    |
| Output Current                  | Source          | V <sub>IN</sub> <sup>+</sup> = 1 V,                                             |                        | 20     |     |     | 40                |     |     | 20           |     |     | 40                |  |  | mA    |                   |    |
|                                 |                 | V <sub>IN</sub> <sup>-</sup> = 0 V,                                             |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 |                 | V <sup>+</sup> = 15 V,                                                          |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 |                 | V <sub>O</sub> = 2 V, T <sub>A</sub> = 25°C                                     |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 | Sink            | V <sub>IN</sub> <sup>-</sup> = 1 V, V <sub>IN</sub> <sup>+</sup> = 0 V          |                        | 10     |     |     | 20                |     |     | 10           |     |     | 20                |  |  | mA    |                   |    |
|                                 |                 | V <sup>+</sup> = 15 V, T <sub>A</sub> = 25°C,                                   |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 |                 | V <sub>O</sub> = 2 V                                                            |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 |                 | V <sub>IN</sub> <sup>-</sup> = 1 V,                                             |                        | 12     |     |     | 50                |     |     | 12           |     |     | 50                |  |  | μA    |                   |    |
|                                 |                 | V <sub>IN</sub> <sup>+</sup> = 0 V                                              |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 |                 | T <sub>A</sub> = 25°C, V <sub>O</sub> = 200 mV,                                 |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
| V <sup>+</sup> = 15 V           |                 |                                                                                 |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
| Short Circuit to Ground         |                 | T <sub>A</sub> = 25°C, See <sup>(6)</sup> , V <sup>+</sup> = 15 V               |                        | 40     |     |     | 60                |     |     | 40           |     |     | 60                |  |  | mA    |                   |    |
| Input Offset Voltage            |                 | See <sup>(2)</sup>                                                              |                        |        |     |     | 4                 |     |     | 5            |     |     | 7                 |  |  | mV    |                   |    |
| Input Offset Voltage Drift      |                 | R <sub>S</sub> = 0Ω                                                             |                        | 7      |     |     | 15                |     |     | 7            |     |     | 20                |  |  | μV/°C |                   |    |
| Input Offset Current            |                 | I <sub>IN(+)</sub> - I <sub>IN(-)</sub>                                         |                        |        |     |     | 30                |     |     | 75           |     |     | 100               |  |  | nA    |                   |    |
| Input Offset Current Drift      |                 | R <sub>S</sub> = 0Ω                                                             |                        | 10     |     |     | 200               |     |     | 10           |     |     | 300               |  |  | pA/°C |                   |    |
| Input Bias Current              |                 | I <sub>IN(+)</sub> or I <sub>IN(-)</sub>                                        |                        | 40     |     |     | 100               |     |     | 40           |     |     | 200               |  |  | 40    | 300               | nA |
| Input Common-Mode Voltage Range |                 | V <sup>+</sup> = 30 V, See <sup>(4)</sup> (LM2904, V <sup>+</sup> = 26 V)       |                        | 0      |     |     | V <sup>+</sup> -2 |     |     | 0            |     |     | V <sup>+</sup> -2 |  |  | 0     | V <sup>+</sup> -2 | V  |
| Large Signal Voltage Gain       |                 | V <sup>+</sup> = +15 V                                                          |                        | 25     |     |     | 15                |     |     | 25           |     |     |                   |  |  | V/mV  |                   |    |
|                                 |                 | (V <sub>O</sub> = 1 V to 11 V)                                                  |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 |                 | R <sub>L</sub> ≥ 2 kΩ                                                           |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
| Output                          | V <sub>OH</sub> | V <sup>+</sup> = +30 V                                                          | R <sub>L</sub> = 2 kΩ  | 26     |     |     | 26                |     |     | 26           |     |     |                   |  |  | V     |                   |    |
| Voltage                         |                 | (LM2904, V <sup>+</sup> = 26 V)                                                 | R <sub>L</sub> = 10 kΩ | 27     | 28  |     | 27                | 28  |     | 27           | 28  |     |                   |  |  |       |                   |    |
| Swing                           | V <sub>OL</sub> | V <sup>+</sup> = 5V, R <sub>L</sub> = 10 kΩ                                     |                        | 5      |     |     | 20                |     |     | 5            |     |     | 20                |  |  | mV    |                   |    |
| Output Current                  | Source          | V <sub>IN</sub> <sup>+</sup> = +1 V, V <sub>IN</sub> <sup>-</sup> = 0 V,        |                        | 10     |     |     | 20                |     |     | 10           |     |     | 20                |  |  | mA    |                   |    |
|                                 |                 | V <sup>+</sup> = 15 V, V <sub>O</sub> = 2 V                                     |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |
|                                 | Sink            | V <sub>IN</sub> <sup>-</sup> = +1 V, V <sub>IN</sub> <sup>+</sup> = 0 V,        |                        | 10     |     |     | 15                |     |     | 5            |     |     | 8                 |  |  | mA    |                   |    |
|                                 |                 | V <sup>+</sup> = 15 V, V <sub>O</sub> = 2 V                                     |                        |        |     |     |                   |     |     |              |     |     |                   |  |  |       |                   |    |

- (5) Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.
- (6) Short circuits from the output to  $V^+$  can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of  $V^+$ . At values of supply voltage in excess of +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

## 6.6 Electrical Characteristics: LM358, LM2904

$V^+ = +5.0\text{ V}$ , See<sup>(1)</sup>, unless otherwise stated

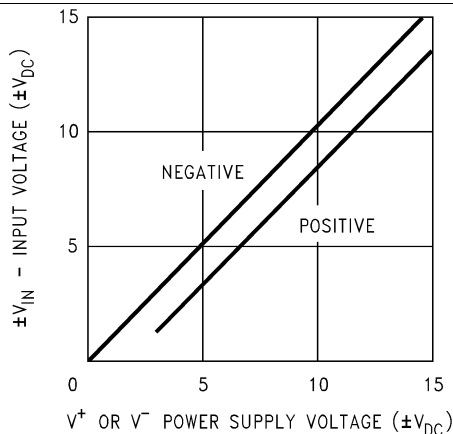
| PARAMETER                       |        | TEST CONDITIONS                                                                                                | LM358  |     |                     | LM2904 |     |                     | UNIT  |
|---------------------------------|--------|----------------------------------------------------------------------------------------------------------------|--------|-----|---------------------|--------|-----|---------------------|-------|
|                                 |        |                                                                                                                | MIN    | TYP | MAX                 | MIN    | TYP | MAX                 |       |
| Input Offset Voltage            |        | See <sup>(2)</sup> , T <sub>A</sub> = 25°C                                                                     |        | 2   | 7                   |        | 2   | 7                   | mV    |
| Input Bias Current              |        | I <sub>IN(+)</sub> or I <sub>IN(-)</sub> , T <sub>A</sub> = 25°C,<br>V <sub>CM</sub> = 0 V, See <sup>(3)</sup> |        | 45  | 250                 |        | 45  | 250                 | nA    |
| Input Offset Current            |        | I <sub>IN(+)</sub> - I <sub>IN(-)</sub> , V <sub>CM</sub> = 0 V, T <sub>A</sub> = 25°C                         |        | 5   | 50                  |        | 5   | 50                  | nA    |
| Input Common-Mode Voltage Range |        | V <sup>+</sup> = 30 V, See <sup>(4)</sup><br>(LM2904, V <sup>+</sup> = 26 V), T <sub>A</sub> = 25°C            | 0      |     | V <sup>+</sup> -1.5 | 0      |     | V <sup>+</sup> -1.5 | V     |
| Supply Current                  |        | Over Full Temperature Range                                                                                    |        |     |                     |        |     |                     |       |
|                                 |        | R <sub>L</sub> = ∞ on All Op Amps                                                                              |        |     |                     |        |     |                     |       |
|                                 |        | V <sup>+</sup> = 30 V (LM2904 V <sup>+</sup> = 26 V)                                                           |        | 1   | 2                   |        | 1   | 2                   | mA    |
|                                 |        | V <sup>+</sup> = 5 V                                                                                           |        | 0.5 | 1.2                 |        | 0.5 | 1.2                 | mA    |
| Large Signal Voltage            |        | V <sup>+</sup> = 15V, T <sub>A</sub> = 25°C,                                                                   |        |     |                     |        |     |                     |       |
| Gain                            |        | R <sub>L</sub> ≥ 2 kΩ, (For V <sub>O</sub> = 1 V to 11 V)                                                      | 25     | 100 |                     | 25     | 100 |                     | V/mV  |
| Common-Mode Rejection Ratio     |        | T <sub>A</sub> = 25°C,                                                                                         | 65     | 85  |                     | 50     | 70  |                     | dB    |
|                                 |        | V <sub>CM</sub> = 0 V to V <sup>+</sup> -1.5 V                                                                 |        |     |                     |        |     |                     |       |
| Power Supply Rejection Ratio    |        | V <sup>+</sup> = 5 V to 30 V                                                                                   | 65     | 100 |                     | 50     | 100 |                     | dB    |
|                                 |        | (LM2904, V <sup>+</sup> = 5 V to 26 V), T <sub>A</sub> = 25°C                                                  |        |     |                     |        |     |                     |       |
| Amplifier-to-Amplifier Coupling |        | f = 1 kHz to 20 kHz, T <sub>A</sub> = 25°C<br>(Input Referred), See <sup>(5)</sup>                             | -120   |     |                     | -120   |     |                     | dB    |
| Output Current                  | Source | V <sub>IN</sub> <sup>+</sup> = 1 V,                                                                            | 20     | 40  |                     | 20     | 40  |                     | mA    |
|                                 |        | V <sub>IN</sub> <sup>-</sup> = 0 V,                                                                            |        |     |                     |        |     |                     |       |
|                                 |        | V <sup>+</sup> = 15 V,                                                                                         |        |     |                     |        |     |                     |       |
|                                 |        | V <sub>O</sub> = 2 V, T <sub>A</sub> = 25°C                                                                    |        |     |                     |        |     |                     |       |
|                                 | Sink   | V <sub>IN</sub> <sup>-</sup> = 1 V, V <sub>IN</sub> <sup>+</sup> = 0 V                                         | 10     | 20  |                     | 10     | 20  |                     | mA    |
|                                 |        | V <sup>+</sup> = 15V, T <sub>A</sub> = 25°C,                                                                   |        |     |                     |        |     |                     |       |
|                                 |        | V <sub>O</sub> = 2 V                                                                                           |        |     |                     |        |     |                     |       |
|                                 |        | V <sub>IN</sub> <sup>-</sup> = 1 V,                                                                            | 12     | 50  |                     | 12     | 50  |                     | μA    |
|                                 |        | V <sub>IN</sub> <sup>+</sup> = 0 V                                                                             |        |     |                     |        |     |                     |       |
|                                 |        | T <sub>A</sub> = 25°C, V <sub>O</sub> = 200 mV,                                                                |        |     |                     |        |     |                     |       |
| V <sup>+</sup> = 15 V           |        |                                                                                                                |        |     |                     |        |     |                     |       |
| Short Circuit to Ground         |        | T <sub>A</sub> = 25°C, See <sup>(6)</sup> , V <sup>+</sup> = 15 V                                              |        | 40  | 60                  |        | 40  | 60                  | mA    |
| Input Offset Voltage            |        | See <sup>(2)</sup>                                                                                             | 9      |     |                     | 10     |     |                     | mV    |
| Input Offset Voltage Drift      |        | R <sub>S</sub> = 0 Ω                                                                                           | 7      |     |                     | 7      |     |                     | μV/°C |
| Input Offset Current            |        | I <sub>IN(+)</sub> - I <sub>IN(-)</sub>                                                                        | 150    |     |                     | 45 200 |     |                     | nA    |
| Input Offset Current Drift      |        | R <sub>S</sub> = 0 Ω                                                                                           | 10     |     |                     | 10     |     |                     | pA/°C |
| Input Bias Current              |        | I <sub>IN(+)</sub> or I <sub>IN(-)</sub>                                                                       | 40 500 |     |                     | 40 500 |     |                     | nA    |

- (1) These specifications are limited to  $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$  for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to  $-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ , the LM358/LM358A temperature specifications are limited to  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ , and the LM2904 specifications are limited to  $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ .
- (2)  $V_O \approx 1.4\text{ V}$ ,  $R_S = 0\text{ }\Omega$  with  $V^+$  from  $5\text{ V}$  to  $30\text{ V}$ ; and over the full input common-mode range ( $0\text{ V}$  to  $V^+ - 1.5\text{ V}$ ) at  $25^\circ\text{C}$ . For LM2904,  $V^+$  from  $5\text{ V}$  to  $26\text{ V}$ .
- (3) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
- (4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than  $0.3\text{ V}$  (at  $25^\circ\text{C}$ ). The upper end of the common-mode voltage range is  $V^+ - 1.5\text{ V}$  (at  $25^\circ\text{C}$ ), but either or both inputs can go to  $32\text{ V}$  without damage ( $26\text{ V}$  for LM2904), independent of the magnitude of  $V^+$ .
- (5) Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.
- (6) Short circuits from the output to  $V^+$  can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately  $40\text{ mA}$  independent of the magnitude of  $V^+$ . At values of supply voltage in excess of  $+15\text{ V}$ , continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

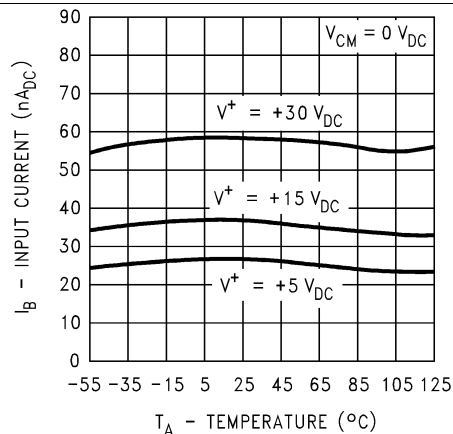
**Electrical Characteristics: LM358, LM2904 (continued)**
 $V^+ = +5.0\text{ V}$ , See<sup>(1)</sup>, unless otherwise stated

| PARAMETER                       |                 | TEST CONDITIONS                                                           |                        | LM358 |     |                   | LM2904 |     |     | UNIT              |  |    |    |  |  |    |  |
|---------------------------------|-----------------|---------------------------------------------------------------------------|------------------------|-------|-----|-------------------|--------|-----|-----|-------------------|--|----|----|--|--|----|--|
|                                 |                 |                                                                           |                        | MIN   | TYP | MAX               | MIN    | TYP | MAX |                   |  |    |    |  |  |    |  |
| Input Common-Mode Voltage Range |                 | V <sup>+</sup> = 30 V, See <sup>(4)</sup> (LM2904, V <sup>+</sup> = 26 V) |                        | 0     |     | V <sup>+</sup> -2 |        | 0   |     | V <sup>+</sup> -2 |  | V  |    |  |  |    |  |
| Large Signal Voltage Gain       |                 | V <sup>+</sup> = +15 V                                                    |                        | 15    |     |                   | 15     |     |     | V/mV              |  |    |    |  |  |    |  |
|                                 |                 | (V <sub>O</sub> = 1 V to 11 V)                                            |                        |       |     |                   |        |     |     |                   |  |    |    |  |  |    |  |
|                                 |                 | R <sub>L</sub> ≥ 2 kΩ                                                     |                        |       |     |                   |        |     |     |                   |  |    |    |  |  |    |  |
| Output                          | V <sub>OH</sub> | V <sup>+</sup> = 30 V                                                     | R <sub>L</sub> = 2 kΩ  | 26    |     |                   | 22     |     |     | V                 |  |    |    |  |  |    |  |
| Voltage                         |                 | (LM2904, V <sup>+</sup> = 26 V)                                           | R <sub>L</sub> = 10 kΩ | 27    | 28  |                   | 23     | 24  |     | V                 |  |    |    |  |  |    |  |
| Swing                           | V <sub>OL</sub> | V <sup>+</sup> = 5 V, R <sub>L</sub> = 10 kΩ                              |                        | 5     |     | 20                |        | 5   |     | 100               |  | mV |    |  |  |    |  |
| Output Current                  | Source          | V <sub>IN</sub> <sup>+</sup> = 1 V, V <sub>IN</sub> <sup>-</sup> = 0 V,   |                        | 10    |     |                   | 20     |     |     | 10                |  |    | 20 |  |  | mA |  |
|                                 |                 | V <sup>+</sup> = 15 V, V <sub>O</sub> = 2 V                               |                        |       |     |                   |        |     |     |                   |  |    |    |  |  |    |  |
|                                 | Sink            | V <sub>IN</sub> <sup>-</sup> = 1 V, V <sub>IN</sub> <sup>+</sup> = 0 V,   |                        | 5     |     |                   | 8      |     |     | 5                 |  |    | 8  |  |  | mA |  |
|                                 |                 | V <sup>+</sup> = 15 V, V <sub>O</sub> = 2 V                               |                        |       |     |                   |        |     |     |                   |  |    |    |  |  |    |  |

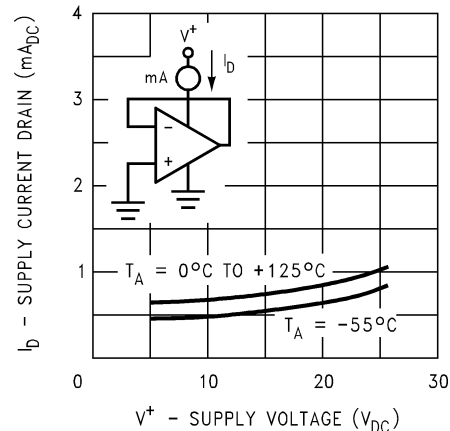
## 6.7 Typical Characteristics



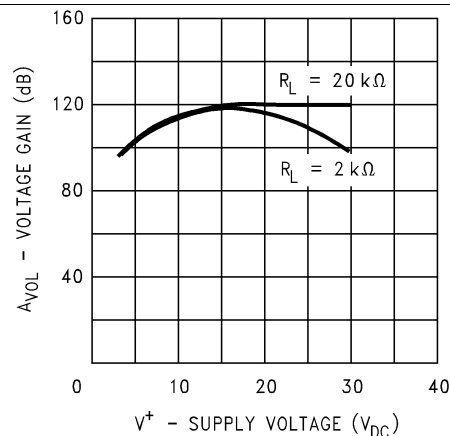
**Figure 1. Input Voltage Range**



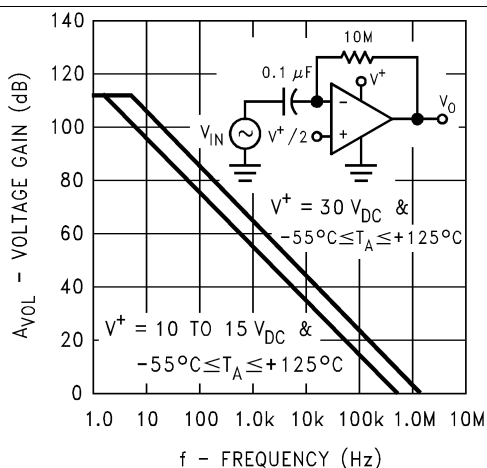
**Figure 2. Input Current**



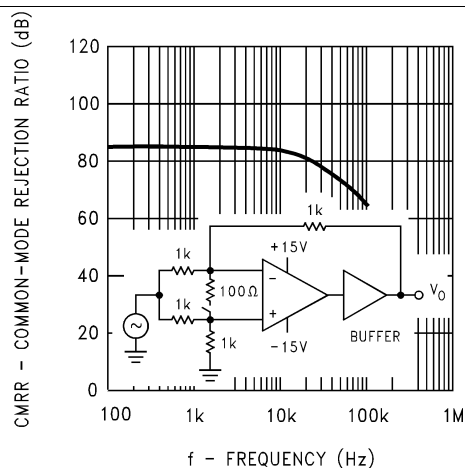
**Figure 3. Supply Current**



**Figure 4. Voltage Gain**



**Figure 5. Open Loop Frequency Response**



**Figure 6. Common-Mode Rejection Ratio**

## Typical Characteristics (continued)

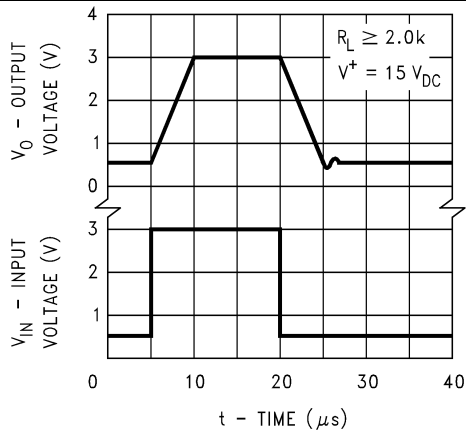


Figure 7. Voltage Follower Pulse Response

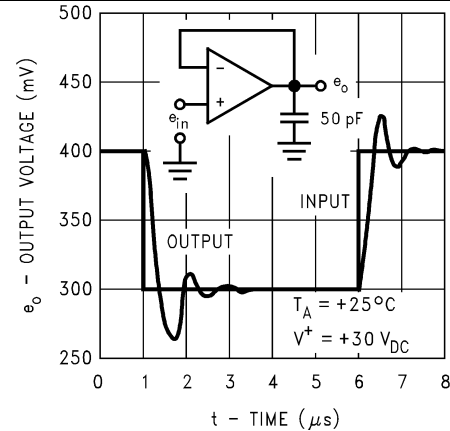


Figure 8. Voltage Follower Pulse Response (Small Signal)

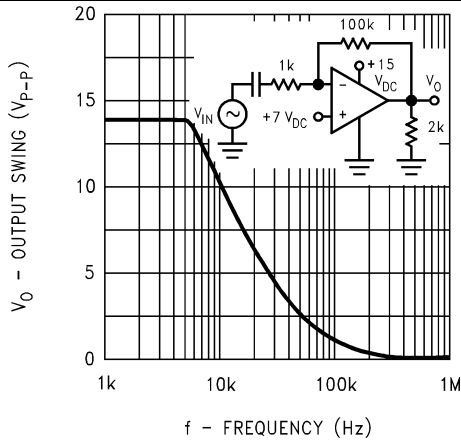


Figure 9. Large Signal Frequency Response

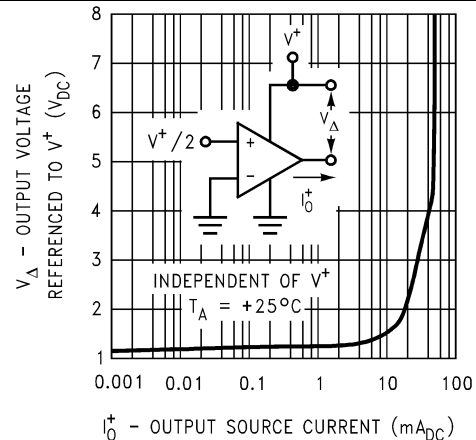


Figure 10. Output Characteristics Current Sourcing

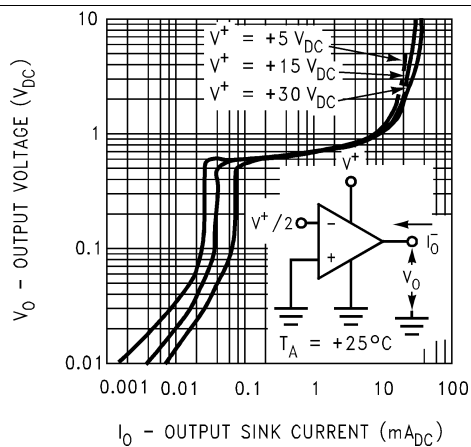


Figure 11. Output Characteristics Current Sinking

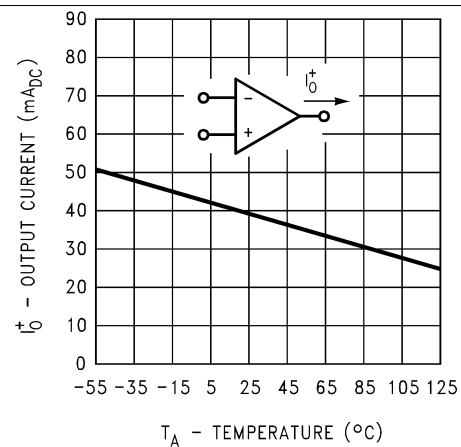


Figure 12. Current Limiting

## Typical Characteristics (continued)

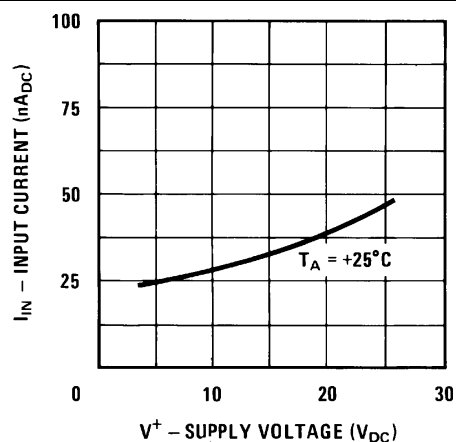


Figure 13. Input Current (LM2902 Only)

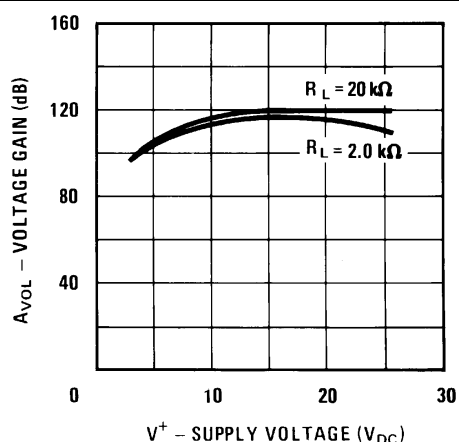


Figure 14. Voltage Gain (LM2902 Only)

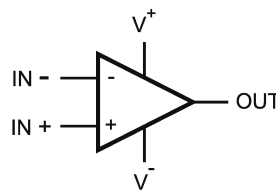
## 7 Detailed Description

### 7.1 Overview

The LM158 series are operational amplifiers which can operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0  $V_{DC}$ . These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3  $V_{DC}$ .

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than  $V^+$  without damaging the device. Protection should be provided to prevent the input voltages from going negative more than  $-0.3 V_{DC}$  (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

### 7.2 Functional Block Diagram



**Figure 15. (Each Amplifier)**

### 7.3 Feature Description

The amplifier's differential inputs consist of a non-inverting input (+IN) and an inverting input (–IN). The amplifier amplifies only the difference in voltage between the two inputs, which is called the differential input voltage. The output voltage of the op-amp  $V_{out}$  is given by Equation 1:

$$V_{OUT} = A_{OL} (IN+ - IN-)$$

where

- $A_{OL}$  is the open-loop gain of the amplifier, typically around 100dB (100,000x, or 10uV per Volt). (1)

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

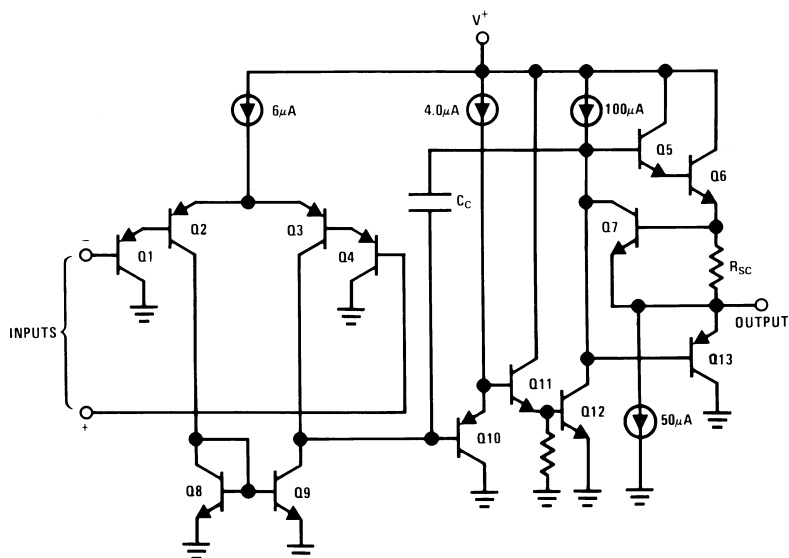
For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of 3  $V_{DC}$  to 30  $V_{DC}$ .

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip power dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see [Typical Characteristics](#)) than a standard IC op amp.

## 7.4 Device Functional Modes



**Figure 16. Schematic Diagram**

The circuits presented in the [Typical Single-Supply Applications](#) emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op-amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of  $V^+/2$ ) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

## 8 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. Customers should validate and test their design implementation to confirm system functionality.

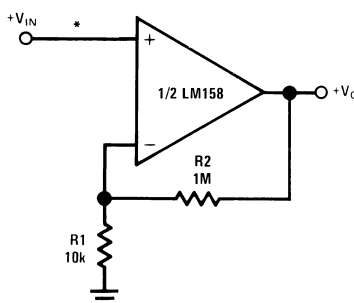
### 8.1 Application Information

The LM158 family bring performance, economy, and ease-of-use to a wide variety of op-amp applications.

### 8.2 Typical Applications

#### 8.2.1 Noninverting DC Gain

Figure 17 shows a high input impedance non-inverting circuit. This circuit gives a closed-loop gain equal to the ratio of the sum of R1 and R2 to R1 and a closed-loop 3 dB bandwidth equal to the amplifier unity-gain frequency divided by the closed-loop gain. This design has the benefit of a very high input impedance, which is equal to the differential input impedance multiplied by loop gain. (Open loop gain/Closed loop gain.) In DC coupled applications, input impedance is not as important as input current and its voltage drop across the source resistance. Note that the amplifier output will go into saturation if the input is allowed to float. This may be important if the amplifier must be switched from source to source.



\*R not needed due to temperature independent  $I_{IN}$

**Figure 17. Non-Inverting DC Gain (0-V Output)**

##### 8.2.1.1 Design Requirements

For this example application, the supply voltage is +5V, and  $100x \pm 5\%$  of noninverting gain is necessary. Signal input impedance is approx 10k $\Omega$ .

##### 8.2.1.2 Detailed Design Procedure

Using the equation for a non-inverting amplifier configuration ;  $G = 1 + R2/R1$ , set R1 to 10k $\Omega$ , and R2 to 99x the value of R1, which would be 990k $\Omega$ . Replacing the 990k $\Omega$  with a 1M $\Omega$  will result in a gain of 101, which is within the desired gain tolerance.

The gain-frequency characteristic of the amplifier and its feedback network must be such that oscillation does not occur. To meet this condition, the phase shift through amplifier and feedback network must never exceed 180° for any frequency where the gain of the amplifier and its feedback network is greater than unity. In practical applications, the phase shift should not approach 180° since this is the situation of conditional stability. Obviously the most critical case occurs when the attenuation of the feedback network is zero.

## Typical Applications (continued)

### 8.2.1.3 Application Curve

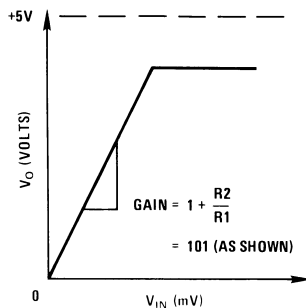
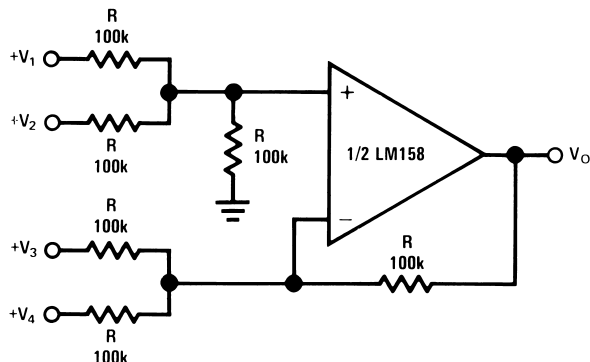


Figure 18. Transfer Curve for Non-Inverting Configuration

## 8.2.2 System Examples

### 8.2.2.1 Typical Single-Supply Applications

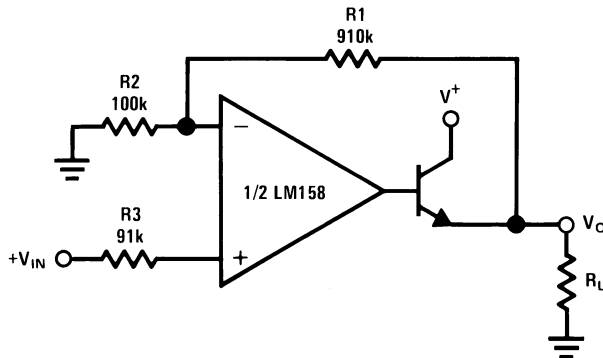
( $V^+ = 5.0 V_{DC}$ )



Where:  $V_O = V_1 + V_2 - V_3 - V_4$

( $V_1 + V_2 \geq (V_3 + V_4)$  to keep  $V_O > 0 V_{DC}$ )

Figure 19. DC Summing Amplifier  
( $V_{IN'S} \geq 0 V_{DC}$  and  $V_O \geq 0 V_{DC}$ )



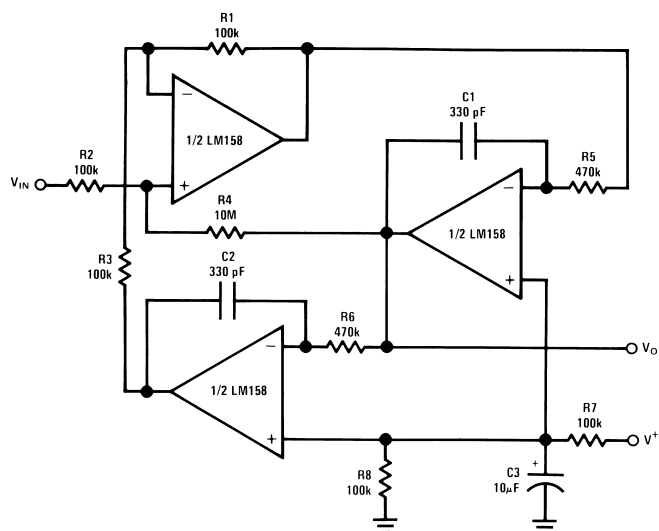
$V_O = 0 V_{DC}$  for  $V_{IN} = 0 V_{DC}$

$A_V = 10$

Figure 20. Power Amplifier

## Typical Applications (continued)

( $V^+ = 5.0\text{ V}_{\text{DC}}$ )

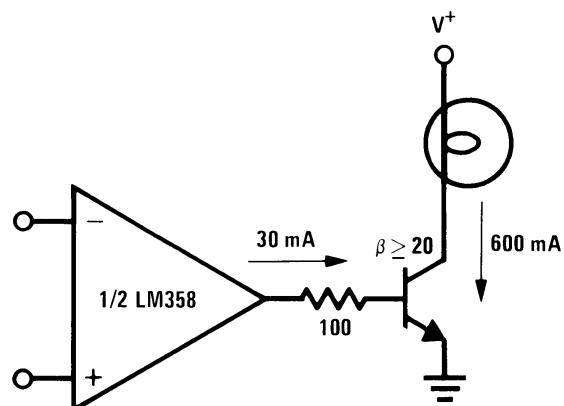


$f_o = 1\text{ kHz}$

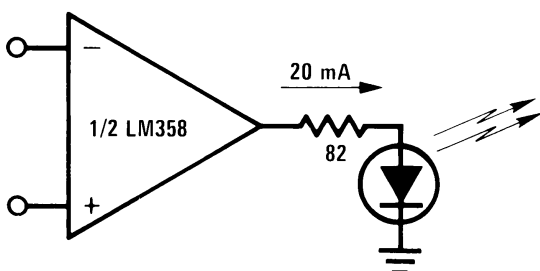
$Q = 50$

$A_v = 100\text{ (40 dB)}$

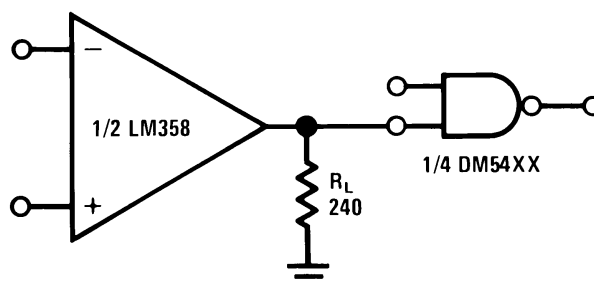
**Figure 21. "BI-QUAD" RC Active Bandpass Filter**



**Figure 22. Lamp Driver**



**Figure 23. LED Driver**



**Figure 24. Driving TTL**

## Typical Applications (continued)

( $V^+ = 5.0\text{ V}_{\text{DC}}$ )

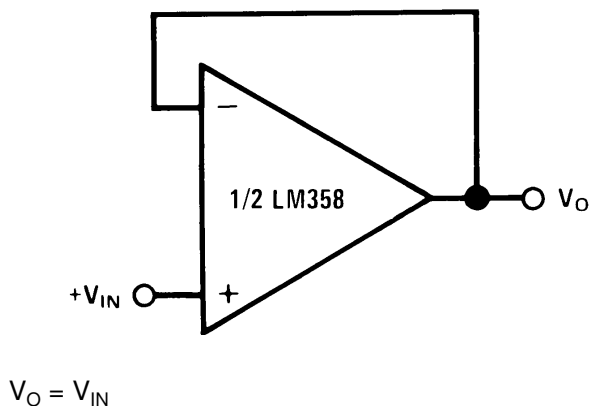


Figure 25. Voltage Follower

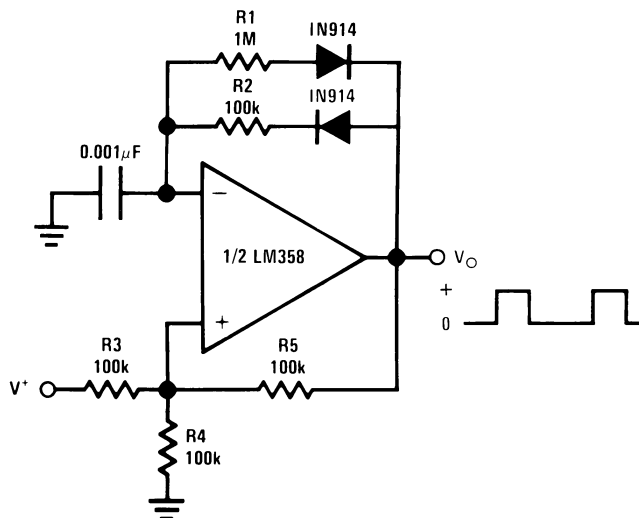


Figure 26. Pulse Generator

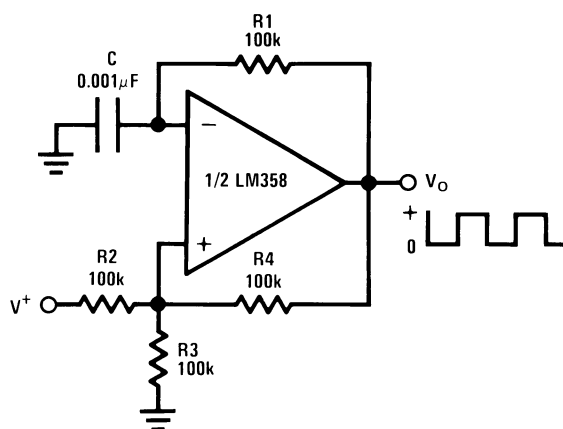


Figure 27. Squarewave Oscillator

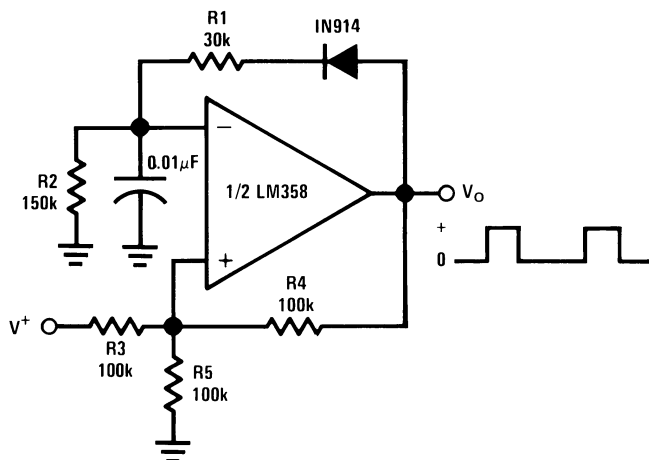
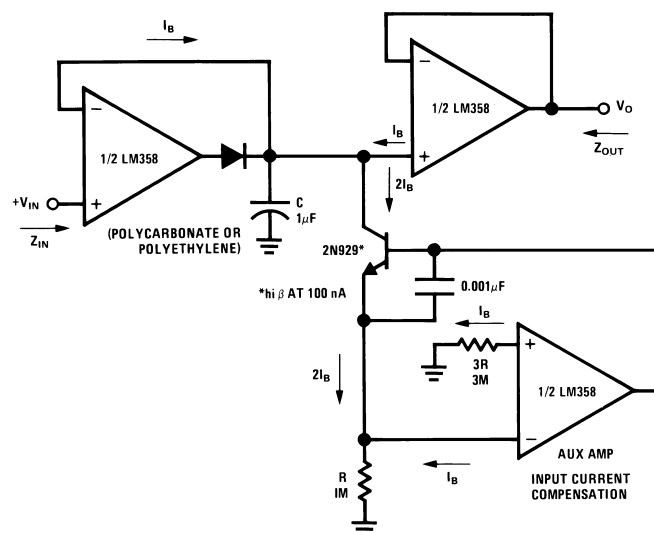


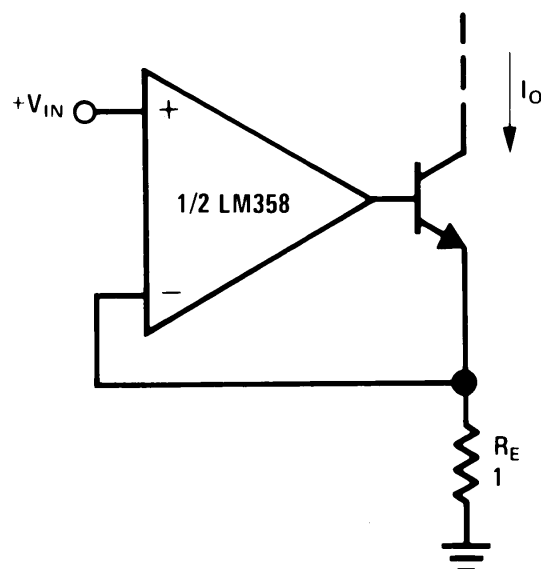
Figure 28. Pulse Generator

## Typical Applications (continued)

 $(V^+ = 5.0\text{ V}_{DC})$ 


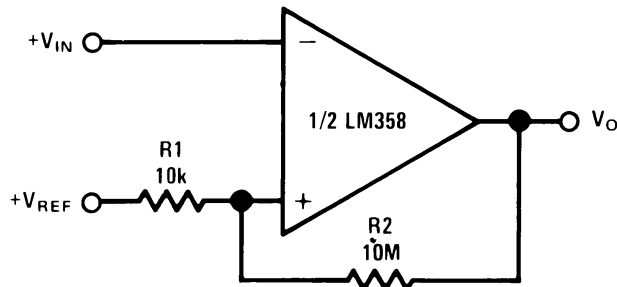
HIGH  $Z_{IN}$   
LOW  $Z_{OUT}$

**Figure 29. Low Drift Peak Detector**

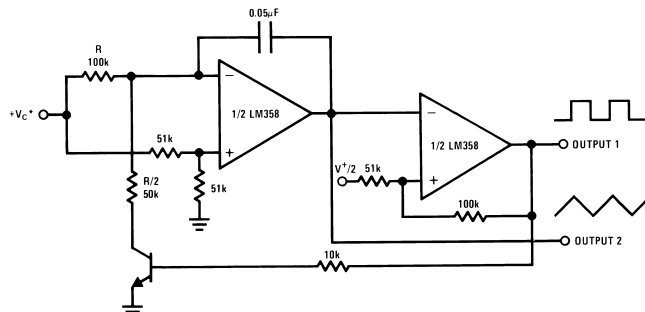


$I_O = 1\text{ amp/volt } V_{IN}$   
(Increase  $R_E$  for  $I_O$  small)

**Figure 30. High Compliance Current Sink**



**Figure 31. Comparator with Hysteresis**

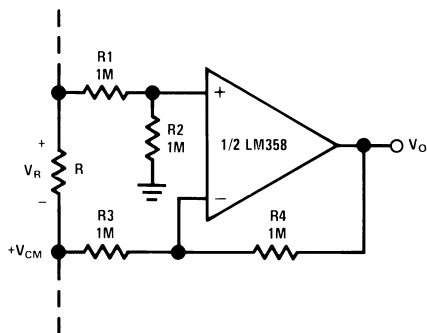


\*WIDE CONTROL VOLTAGE RANGE:  $0\text{ V}_{DC} \leq V_C \leq 2(V^+ - 1.5\text{ V}_{DC})$

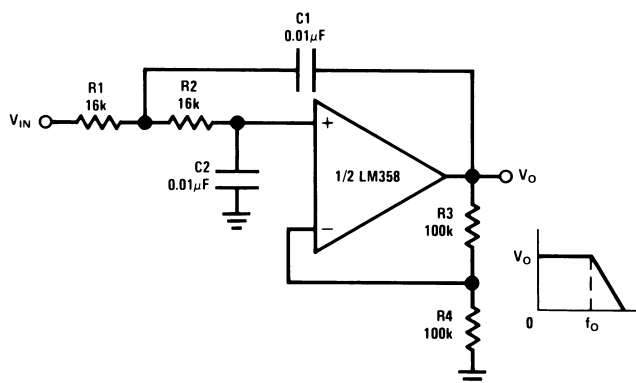
**Figure 32. Voltage Controlled Oscillator (VCO)**

## Typical Applications (continued)

( $V^+ = 5.0\text{ V}_{\text{DC}}$ )



**Figure 33. Ground Referencing a Differential Input Signal**

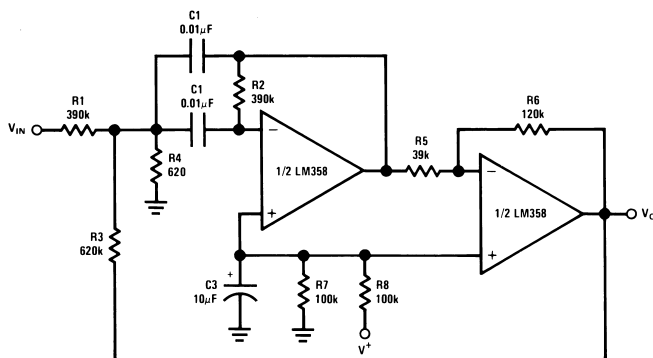


$f_o = 1\text{ kHz}$

$Q = 1$

$A_V = 2$

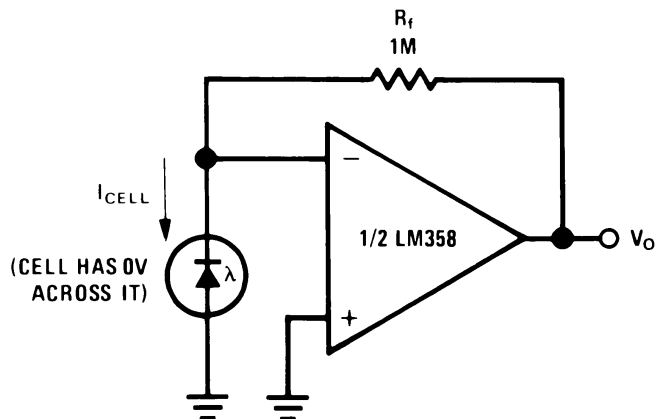
**Figure 34. DC Coupled Low-Pass RC Active Filter**



$f_o = 1\text{ kHz}$

$Q = 25$

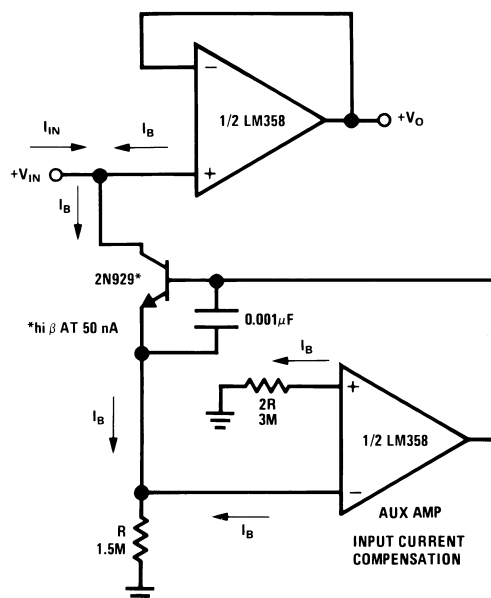
**Figure 35. Bandpass Active Filter**



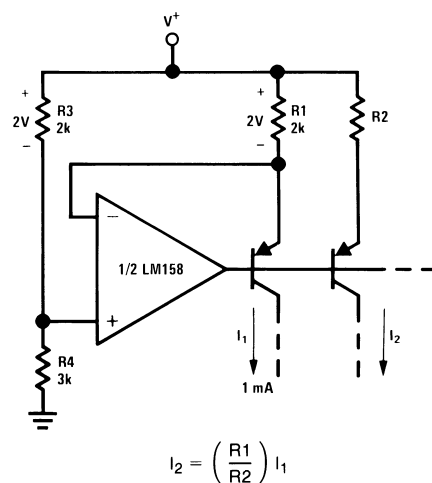
**Figure 36. Photo Voltaic-Cell Amplifier**

## Typical Applications (continued)

( $V^+ = 5.0 V_{DC}$ )



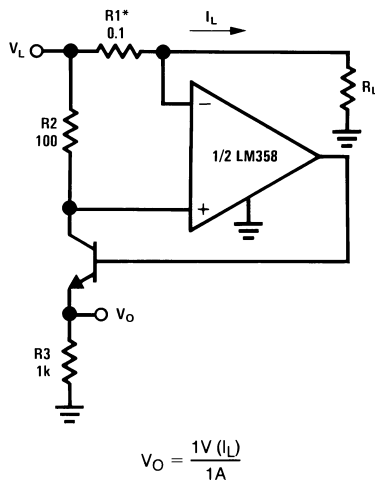
**Figure 37. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)**



**Figure 38. Fixed Current Sources**

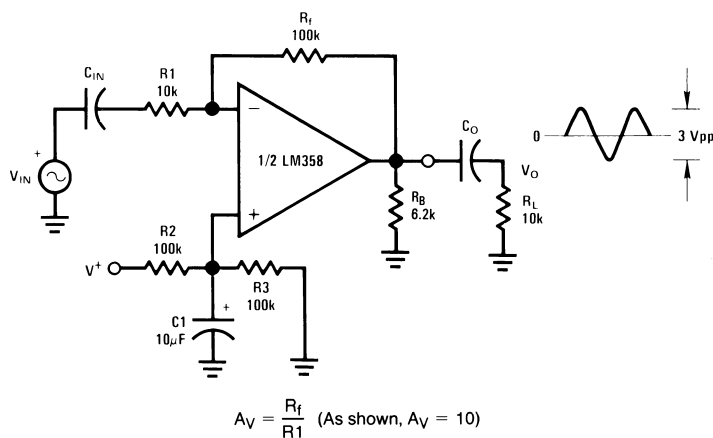
## Typical Applications (continued)

( $V^+ = 5.0\text{ V}_{DC}$ )



\*(Increase R1 for  $I_L$  small)  
 $V_L \leq V^+ - 2V$

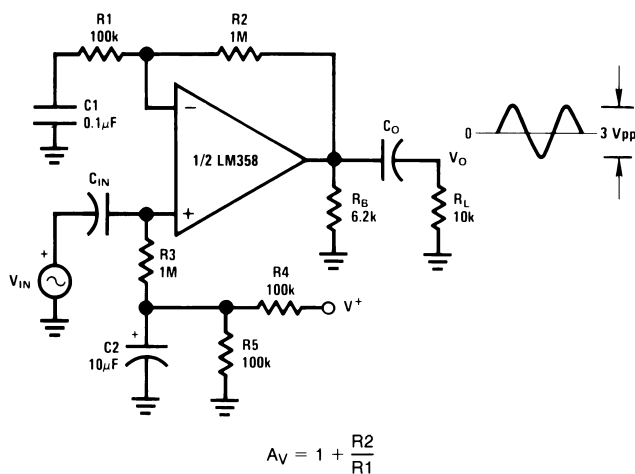
**Figure 39. Current Monitor**



**Figure 40. AC Coupled Inverting Amplifier**

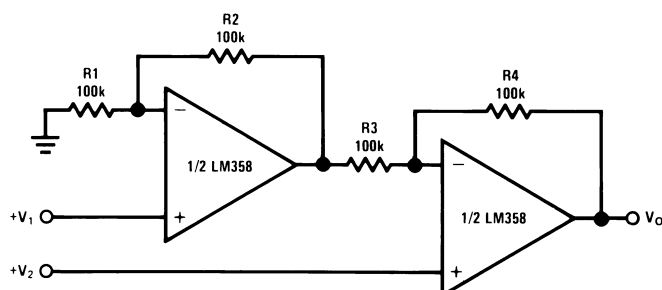
## Typical Applications (continued)

( $V^+ = 5.0\text{ V}_{\text{DC}}$ )



$A_V = 11$  (As Shown)

**Figure 41. AC Coupled Non-Inverting Amplifier**

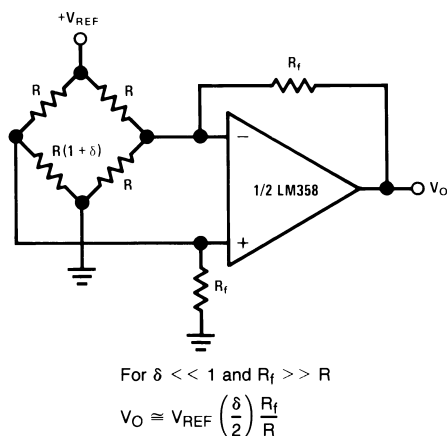


For  $\frac{R_1}{R_2} = \frac{R_4}{R_3}$  (CMRR depends on this resistor ratio match)

$$V_O = 1 + \frac{R_4}{R_3} (V_2 - V_1)$$

As Shown:  $V_O = 2 (V_2 - V_1)$

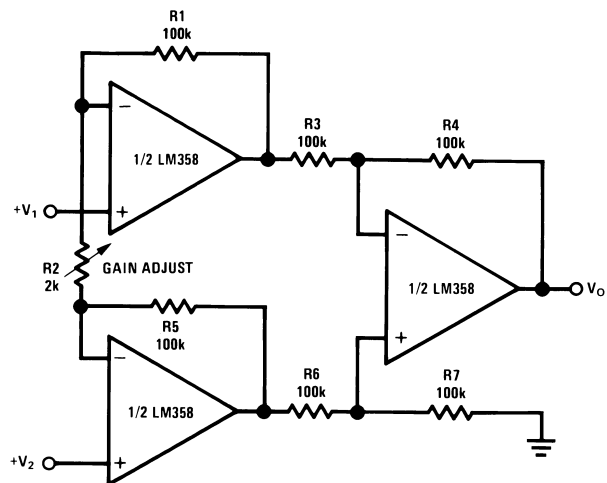
**Figure 42. High Input Z, DC Differential Amplifier**



**Figure 43. Bridge Current Amplifier**

## Typical Applications (continued)

( $V^+ = 5.0 V_{DC}$ )



If  $R1 = R5$  &  $R3 = R4 = R6 = R7$  (CMRR depends on match)

$$V_O = 1 + \frac{2R1}{R2} (V_2 - V_1)$$

As shown  $V_O = 101 (V_2 - V_1)$

**Figure 44. High Input Z Adjustable-Gain DC Instrumentation Amplifier**

## 9 Power Supply Recommendations

For proper operation, the power supplies must be properly decoupled. For decoupling the supply pins it is suggested that 10 nF capacitors be placed as close as possible to the op-amp power supply pins. For single supply, place a capacitor between V+ and V– supply leads. For dual supplies, place one capacitor between V+ and ground, and one capacitor between V– and ground.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

## 10 Layout

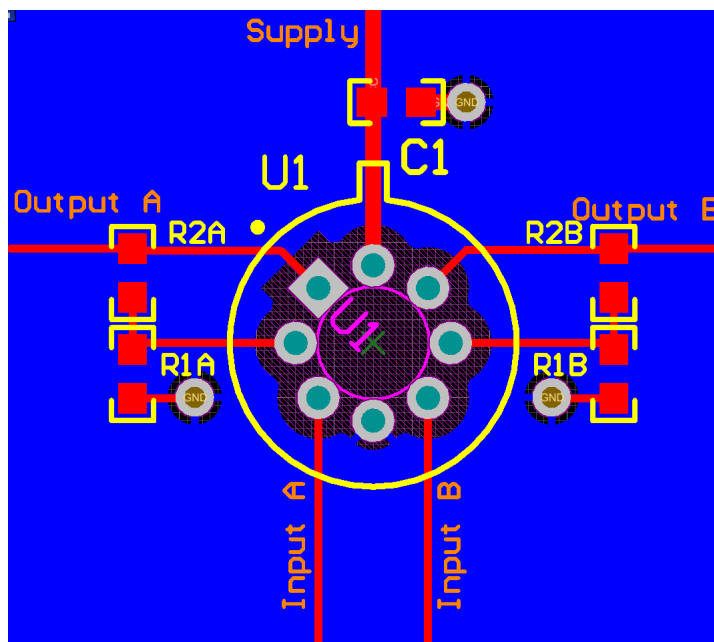
### 10.1 Layout Guidelines

For single-ended supply configurations, the V+ pin should be bypassed to ground with a low ESR capacitor. The optimum placement is closest to the V+ pin. Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ and ground. The ground pin should be connected to the PCB ground plane at the pin of the device. The feedback components should be placed as close to the device as possible to minimize stray parasitics.

For dual supply configurations, both the V+ pin and V– pin should be bypassed to ground with a low ESR capacitor. The optimum placement is closest to the corresponding supply pin. Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ or V– and ground. The feedback components should be placed as close to the device as possible to minimize stray parasitics.

For both configurations, as ground plane underneath the device is recommended.

### 10.2 Layout Example



**Figure 45. Layout Example**

## 11 Device and Documentation Support

### 11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 1. Related Links**

| PARTS    | PRODUCT FOLDER             | SAMPLE & BUY               | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|----------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| LM158-N  | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| LM258-N  | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| LM2904-N | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| LM358-N  | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

### 11.2 Trademarks

All trademarks are the property of their respective owners.

### 11.3 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 11.4 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 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 Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM158AH          | ACTIVE        | TO-99        | LMC                | 8    | 500            | TBD                        | Call TI                 | Call TI              | -55 to 125   | ( LM158AH ~ LM158AH)    | <a href="#">Samples</a> |
| LM158AH/NOPB     | ACTIVE        | TO-99        | LMC                | 8    | 500            | Green (RoHS<br>& no Sb/Br) | Call TI                 | Level-1-NA-UNLIM     | -55 to 125   | ( LM158AH ~ LM158AH)    | <a href="#">Samples</a> |
| LM158H           | ACTIVE        | TO-99        | LMC                | 8    | 500            | TBD                        | Call TI                 | Call TI              | -55 to 125   | ( LM158H ~ LM158H)      | <a href="#">Samples</a> |
| LM158H/NOPB      | ACTIVE        | TO-99        | LMC                | 8    | 500            | Green (RoHS<br>& no Sb/Br) | Call TI                 | Level-1-NA-UNLIM     | -55 to 125   | ( LM158H ~ LM158H)      | <a href="#">Samples</a> |
| LM158J           | ACTIVE        | CDIP         | NAB                | 8    | 40             | TBD                        | Call TI                 | Call TI              | -55 to 125   | LM158J                  | <a href="#">Samples</a> |
| LM258H           | ACTIVE        | TO-99        | LMC                | 8    | 500            | TBD                        | Call TI                 | Call TI              | -25 to 85    | ( LM258H ~ LM258H)      | <a href="#">Samples</a> |
| LM258H/NOPB      | ACTIVE        | TO-99        | LMC                | 8    | 500            | Green (RoHS<br>& no Sb/Br) | Call TI                 | Level-1-NA-UNLIM     | -25 to 85    | ( LM258H ~ LM258H)      | <a href="#">Samples</a> |
| LM2904ITP/NOPB   | ACTIVE        | DSBGA        | YPB                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | A<br>09                 | <a href="#">Samples</a> |
| LM2904ITPX/NOPB  | ACTIVE        | DSBGA        | YPB                | 8    | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | A<br>09                 | <a href="#">Samples</a> |
| LM2904M          | NRND          | SOIC         | D                  | 8    | 95             | TBD                        | Call TI                 | Call TI              | -40 to 85    | LM<br>2904M             |                         |
| LM2904M/NOPB     | ACTIVE        | SOIC         | D                  | 8    | 95             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | -40 to 85    | LM<br>2904M             | <a href="#">Samples</a> |
| LM2904MX         | NRND          | SOIC         | D                  | 8    | 2500           | TBD                        | Call TI                 | Call TI              | -40 to 85    | LM<br>2904M             |                         |
| LM2904MX/NOPB    | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | -40 to 85    | LM<br>2904M             | <a href="#">Samples</a> |
| LM2904N/NOPB     | ACTIVE        | PDIP         | P                  | 8    | 40             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-NA-UNLIM     | -40 to 85    | LM<br>2904N             | <a href="#">Samples</a> |
| LM358AM          | NRND          | SOIC         | D                  | 8    | 95             | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM<br>358AM             |                         |
| LM358AM/NOPB     | ACTIVE        | SOIC         | D                  | 8    | 95             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | 0 to 70      | LM<br>358AM             | <a href="#">Samples</a> |
| LM358AMX         | NRND          | SOIC         | D                  | 8    | 2500           | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM<br>358AM             |                         |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM358AMX/NOPB    | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | 0 to 70      | LM<br>358AM             | <a href="#">Samples</a> |
| LM358AN/NOPB     | ACTIVE        | PDIP         | P                  | 8    | 40             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-NA-UNLIM     | 0 to 70      | LM<br>358AN             | <a href="#">Samples</a> |
| LM358H/NOPB      | ACTIVE        | TO-99        | LMC                | 8    | 500            | Green (RoHS<br>& no Sb/Br) | Call TI                 | Level-1-NA-UNLIM     | 0 to 70      | ( LM358H ~ LM358H)      | <a href="#">Samples</a> |
| LM358M           | NRND          | SOIC         | D                  | 8    | 95             | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM<br>358M              |                         |
| LM358M/NOPB      | ACTIVE        | SOIC         | D                  | 8    | 95             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | 0 to 70      | LM<br>358M              | <a href="#">Samples</a> |
| LM358MX          | NRND          | SOIC         | D                  | 8    | 2500           | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM<br>358M              |                         |
| LM358MX/NOPB     | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | 0 to 70      | LM<br>358M              | <a href="#">Samples</a> |
| LM358N/NOPB      | ACTIVE        | PDIP         | P                  | 8    | 40             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-NA-UNLIM     | 0 to 70      | LM<br>358N              | <a href="#">Samples</a> |
| LM358TP/NOPB     | ACTIVE        | DSBGA        | YPB                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | 0 to 70      | A<br>07                 | <a href="#">Samples</a> |
| LM358TPX/NOPB    | ACTIVE        | DSBGA        | YPB                | 8    | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | 0 to 70      | A<br>07                 | <a href="#">Samples</a> |

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

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

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

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

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

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

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

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

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

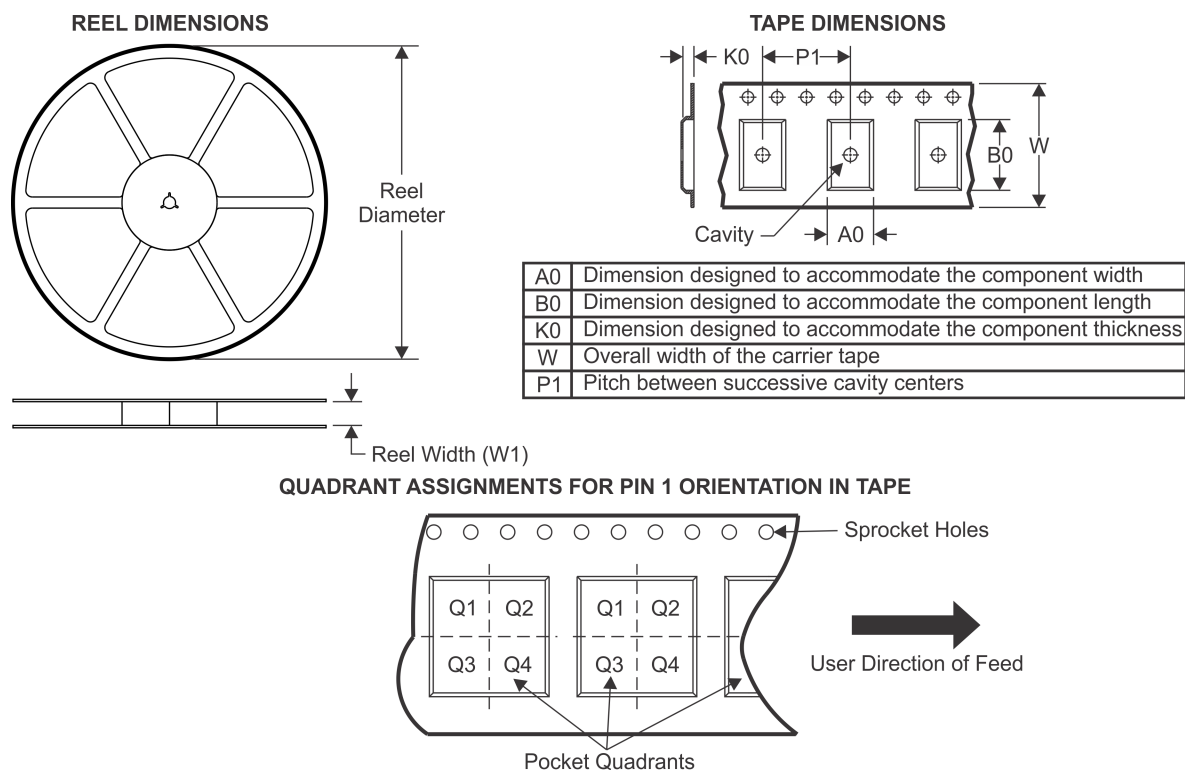
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

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

- <sup>(3)</sup> MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.
- <sup>(4)</sup> There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.
- <sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.
- <sup>(6)</sup> Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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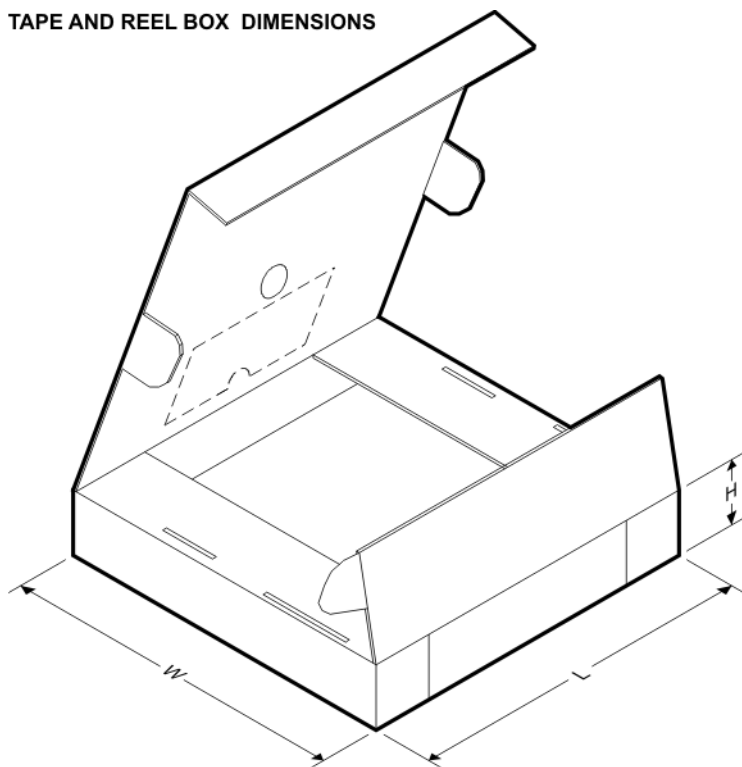
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**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 |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM2904ITP/NOPB  | DSBGA        | YPB             | 8    | 250  | 178.0              | 8.4                | 1.5     | 1.5     | 0.66    | 4.0     | 8.0    | Q1            |
| LM2904ITPX/NOPB | DSBGA        | YPB             | 8    | 3000 | 178.0              | 8.4                | 1.5     | 1.5     | 0.66    | 4.0     | 8.0    | Q1            |
| LM2904MX        | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM2904MX/NOPB   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM358AMX        | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM358AMX/NOPB   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM358MX         | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM358MX/NOPB    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM358TP/NOPB    | DSBGA        | YPB             | 8    | 250  | 178.0              | 8.4                | 1.5     | 1.5     | 0.66    | 4.0     | 8.0    | Q1            |
| LM358TPX/NOPB   | DSBGA        | YPB             | 8    | 3000 | 178.0              | 8.4                | 1.5     | 1.5     | 0.66    | 4.0     | 8.0    | Q1            |

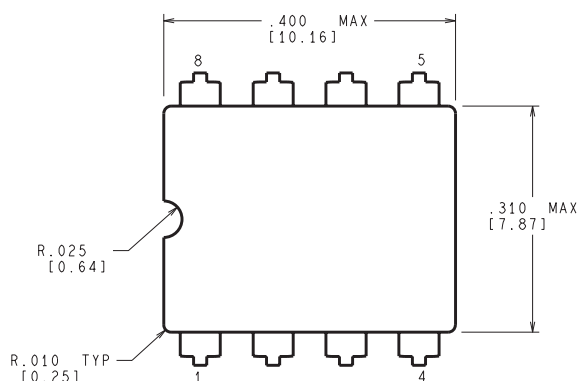
## TAPE AND REEL BOX DIMENSIONS



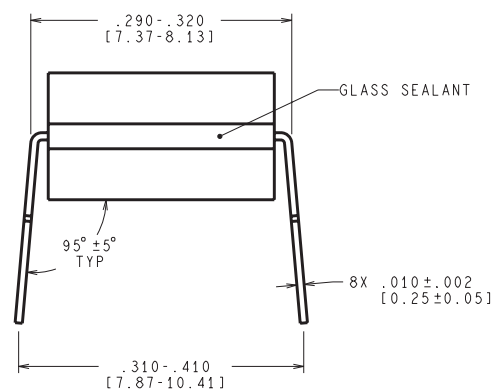
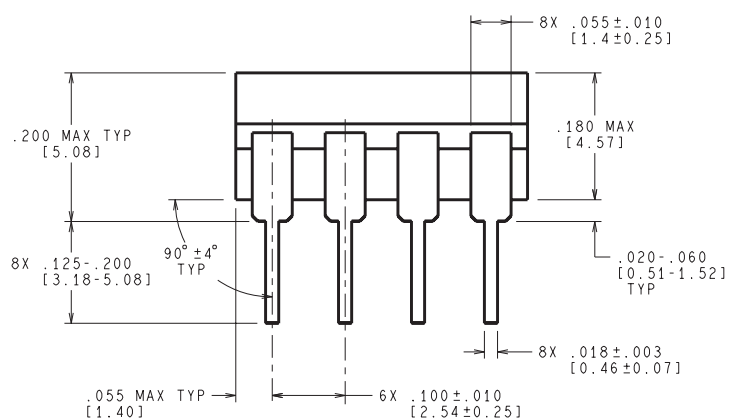
\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM2904ITP/NOPB  | DSBGA        | YPB             | 8    | 250  | 210.0       | 185.0      | 35.0        |
| LM2904ITPX/NOPB | DSBGA        | YPB             | 8    | 3000 | 210.0       | 185.0      | 35.0        |
| LM2904MX        | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM2904MX/NOPB   | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM358AMX        | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM358AMX/NOPB   | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM358MX         | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM358MX/NOPB    | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM358TP/NOPB    | DSBGA        | YPB             | 8    | 250  | 210.0       | 185.0      | 35.0        |
| LM358TPX/NOPB   | DSBGA        | YPB             | 8    | 3000 | 210.0       | 185.0      | 35.0        |

NAB0008A



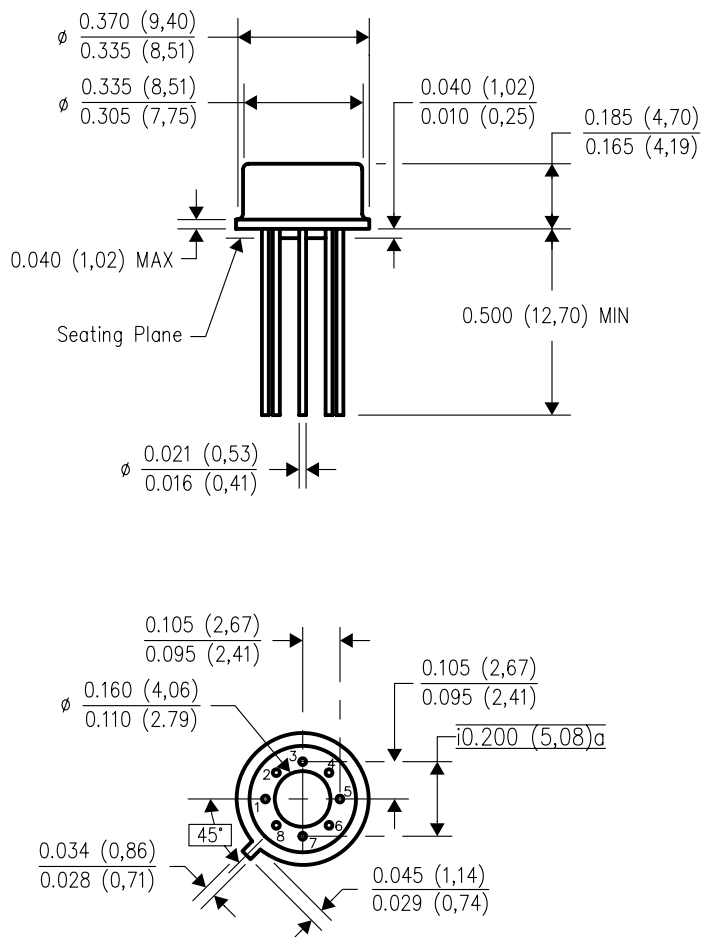
CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS



J08A (Rev M)

## LMC (O-MBCY-W8)

## METAL CYLINDRICAL PACKAGE

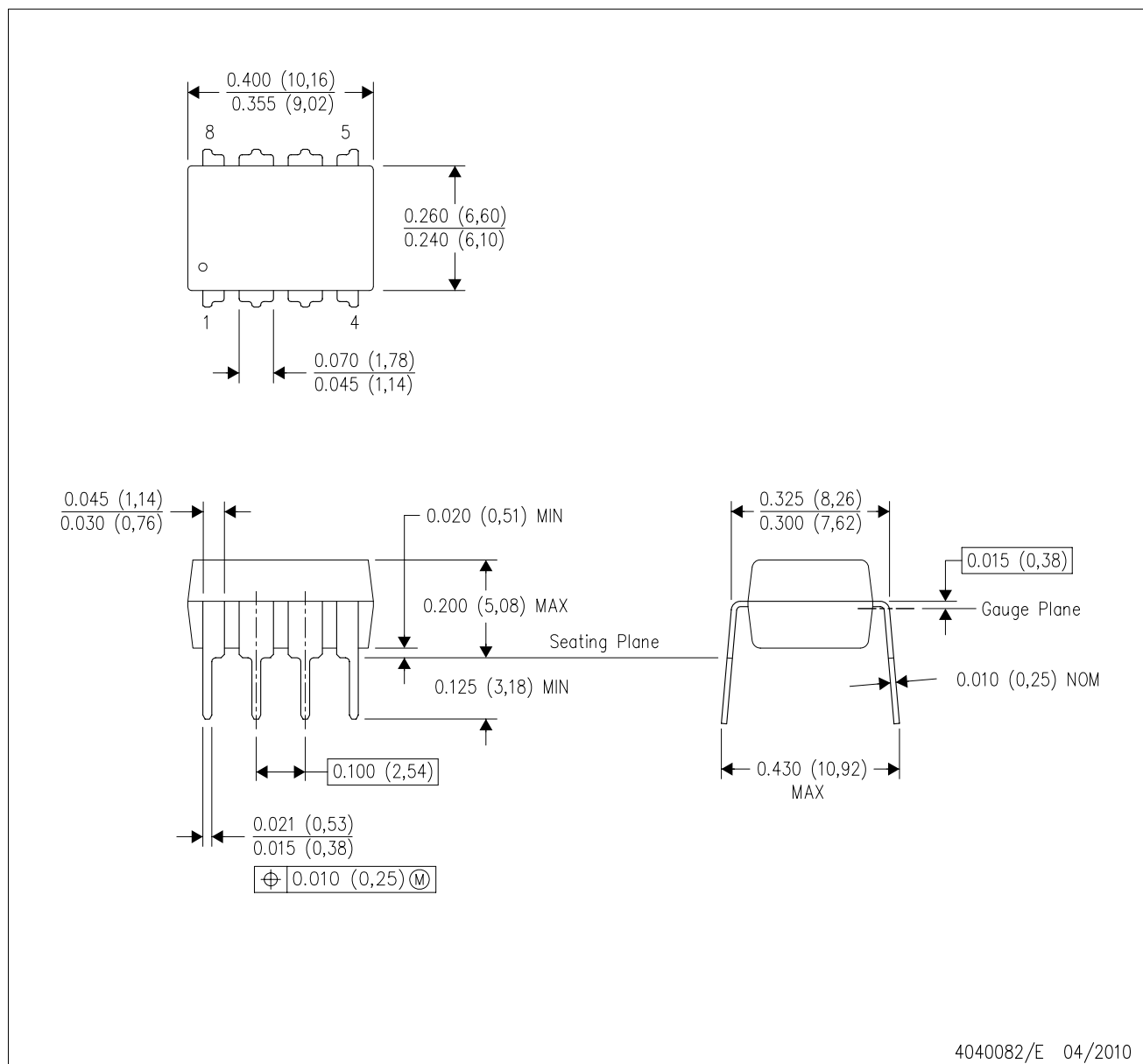


4202483/B 09/07

- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
  - Pin numbers shown for reference only. Numbers may not be marked on package.
  - Falls within JEDEC MO-002/TO-99.

P (R-PDIP-T8)

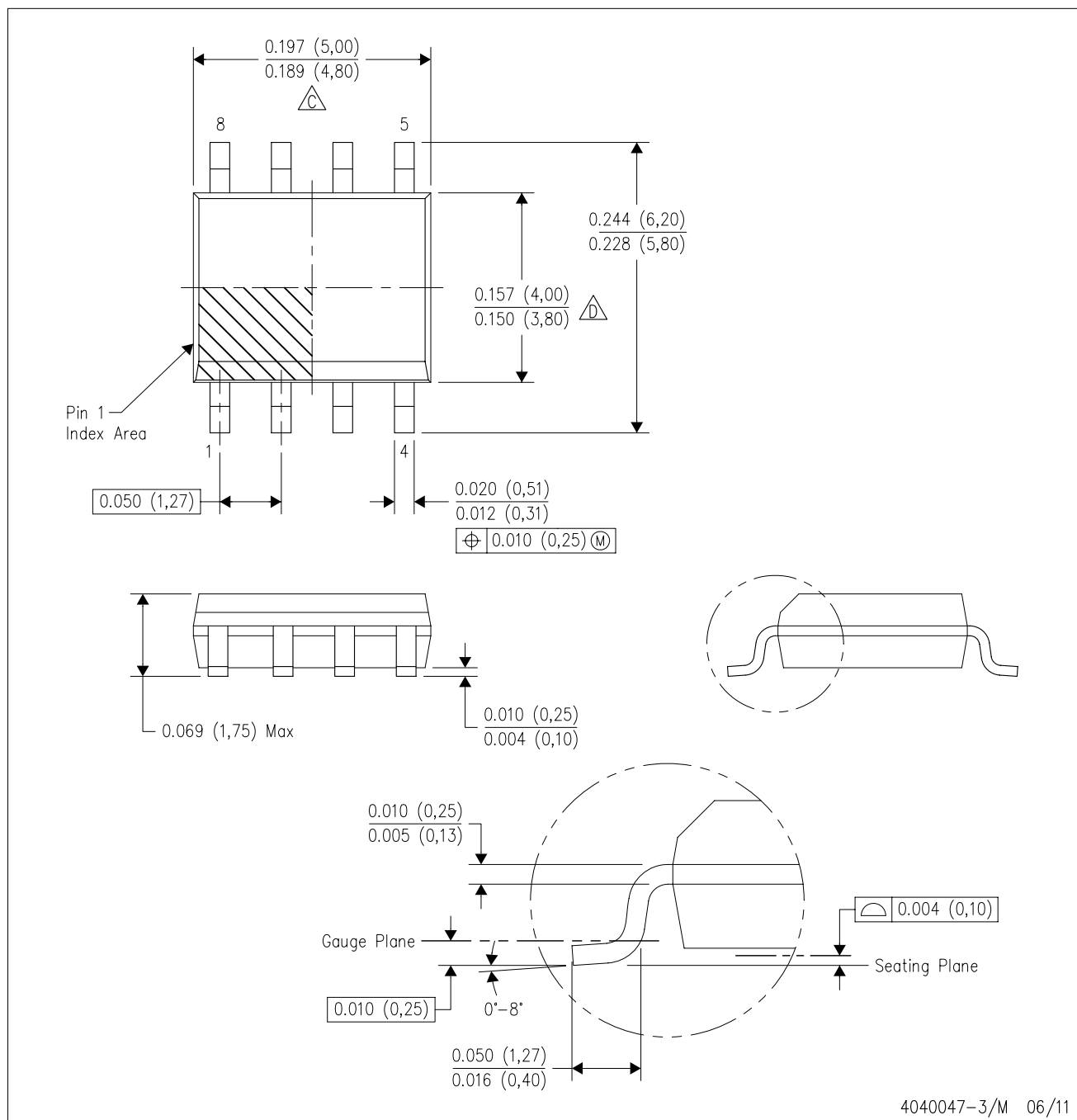
PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.



E: Max = 1.337 mm, Min =1.276 mm



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