

### Features

- Single-Supply Operation from +2.1V ~ +5.5V
  - Rail-to-Rail Input / Output
  - Gain-Bandwidth Product: 11MHz (Typ.)
  - Low Input Bias Current: 1pA (Typ.)
  - Low Offset Voltage: 3.5mV (Max.)
  - High Slew Rate: 9V/μs
  - Settling Time to 0.1% with 2V Step: 0.3μs
  - Low Noise : 8nV/ Hz @10kHz
  - Quiescent Current: 1.1mA per Amplifier (Typ.)
  - Operating Temperature: -40°C ~ +125°C
  - Small Package:
- GS8600 Available in DFN2\*2-8 Packages**

### General Description

The GS8600 have a high gain-bandwidth product of 11MHz, a slew rate of 9V/μs, and a quiescent current of 1.1mA per amplifier at 5V. The GS8600 are designed to provide optimal performance in low voltage and low noise systems. They provide rail-to-rail output swing into heavy loads. The input common mode voltage range includes ground, and the maximum input offset voltage is 3.5mV for GS8600. They are specified over the extended industrial temperature range (-40°C to +125°C). The operating range is from 2.1V to 5.5V. The GS8600 dual is available in Green DFN2\*2-8 package.

### Applications

- Sensors
- Active Filters
- Cellular and Cordless Phones
- Laptops and PDAs
- Audio
- Handheld Test Equipment
- Battery-Powered Instrumentation
- A/D Converters

### Pin Configuration

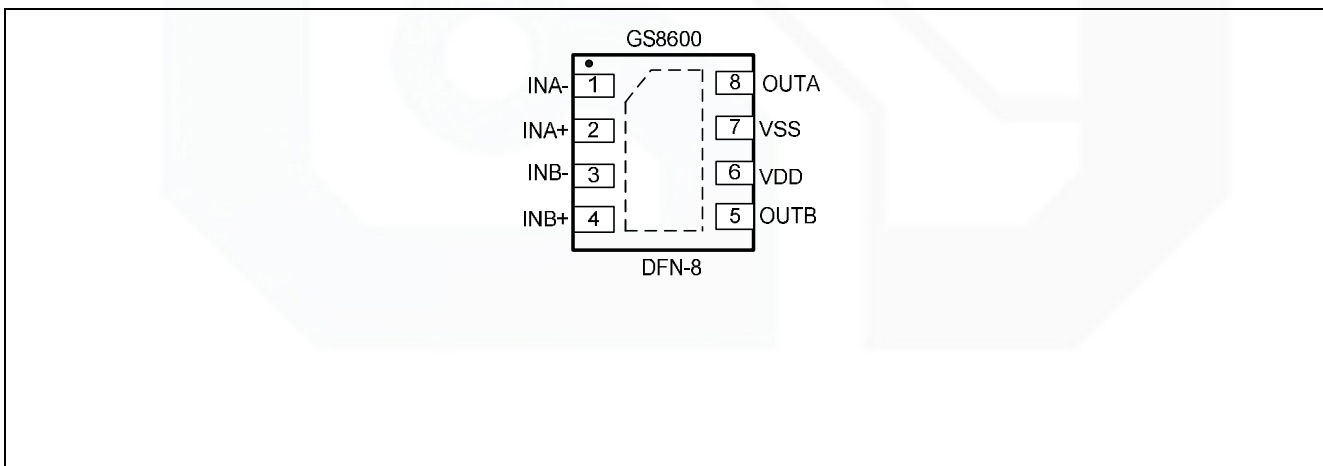


Figure 1. Pin Assignment Diagram

### Absolute Maximum Ratings

| Condition                                     | Min           | Max           |
|---|---------------|---------------|
| Power Supply Voltage ( $V_{DD}$ to $V_{SS}$ ) | -0.5V         | +7.5V         |
| Analog Input Voltage ( $IN+$ or $IN-$ )       | $V_{SS}-0.5V$ | $V_{DD}+0.5V$ |
| PDB Input Voltage                             | $V_{SS}-0.5V$ | +7V           |
| Operating Temperature Range                   | -40°C         | +125°C        |
| Junction Temperature                          | +160°C        |               |
| Storage Temperature Range                     | -55°C         | +150°C        |
| Lead Temperature (soldering, 10sec)           | +260°C        |               |
| <b>ESD Susceptibility</b>                     |               |               |
| HBM   | 8KV           |               |
| MM  | 400V          |               |

**Note:** Stress greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions outside those indicated in the operational sections of this specification are not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

### Package/Ordering Information

| MODEL  | CHANNEL | ORDER NUMBER | PACKAGE DESCRIPTION | PACKAGE OPTION     | MARKING INFORMATION |
|--------|---------|--------------|---------------------|--------------------|---------------------|
| GS8600 | Dual    | GS8600-FR    | DFN2*2-8            | Tape and Reel,3000 | GS8600              |

## Electrical Characteristics

(At  $V_S=5V$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_S/2$ ,  $R_L = 600 \Omega$ , unless otherwise noted.)

| PARAMETER   | CONDITIONS   | GS8600       |                          |             |               |                 |                  |       |           |
|---|--|--------------|--------------------------|-------------|---------------|-----------------|------------------|-------|-----------|
|   |  | TYP          | MIN/MAX OVER TEMPERATURE |             |               |                 |                  | UNITS | MIN / MAX |
|   |  | +25°C        | +25°C                    | 0°C to 70°C | -40°C to 85°C | -40 °C to 125°C |                  |       |           |
| <b>INPUT CHARACTERISTICS</b>                            |  |              |                          |             |               |                 |                  |       |           |
| Input Offset Voltage ( $V_{OS}$ )                       |  | 0.8          | 3.5                      | 3.9         | 4.3           | 4.6             | mV               | MAX   |           |
| Input Bias Current ( $I_B$ )                            |  | 1            |                          |             |               |                 | pA               | TYP   |           |
| Input Offset Current ( $I_{OS}$ )                       |  | 1            |                          |             |               |                 | pA               | TYP   |           |
| Input Common Mode Voltage Range ( $V_{CM}$ )            | $V_S = 5.5V$                                       | -0.1 to +5.6 |                          |             |               |                 | V                | TYP   |           |
| Common Mode Rejection Ratio (CMRR)                      | $V_S = 5.5V$ , $V_{CM} = -0.1V$ to 4V              | 82           | 65                       | 64          | 64            | 63              | dB               | MIN   |           |
|   | $V_S = 5.5V$ , $V_{CM} = -0.1V$ to 5.6V            | 75           |                          |             |               |                 | dB               | MIN   |           |
| Open-Loop Voltage Gain ( $A_{OL}$ )                     | $R_L = 600\Omega$ , $V_O = 0.15V$ to 4.85V         | 90           | 80                       | 76          | 75            | 68              | dB               | MIN   |           |
|   | $R_L = 10k\Omega$ , $V_O = 0.05V$ to 4.95V         | 108          |                          |             |               |                 | dB               | MIN   |           |
| Input Offset Voltage Drift ( $\Delta V_{OS}/\Delta T$ ) |  | 2.4          |                          |             |               |                 | $\mu V/^\circ C$ | TYP   |           |
| <b>OUTPUT CHARACTERISTICS</b>                           |  |              |                          |             |               |                 |                  |       |           |
| Output Voltage Swing from Rail                          | $R_L = 600\Omega$                                  | 0.1          |                          |             |               |                 | V                | TYP   |           |
|   | $R_L = 10k\Omega$                                  | 0.015        |                          |             |               |                 | V                | TYP   |           |
| Output Current ( $I_{OUT}$ )                            |  | 70           | 55                       | 45          | 42            | 38              | mA               | MIN   |           |
| Closed-Loop Output Impedance                            | $f = 100kHz$ , $G = 1$                             | 7.5          |                          |             |               |                 | $\Omega$         | TYP   |           |
| <b>POWER SUPPLY</b>                                     |  |              |                          |             |               |                 |                  |       |           |
| Operating Voltage Range                                 |  |              | 2.1                      | 2.1         | 2.1           | 2.1             | V                | MIN   |           |
|   |  |              | 5.5                      | 5.5         | 5.5           | 5.5             | V                | MAX   |           |
| Power Supply Rejection Ratio (PSRR)                     | $V_S = +2.5V$ to +5.5V<br>$V_{CM} = (-V_S) + 0.5V$ | 91           | 74                       | 72          | 72            | 68              | dB               | MIN   |           |
| Quiescent Current/Amplifier ( $I_Q$ )                   | $I_{OUT} = 0$                                      | 1.1          | 1.5                      | 1.65        | 1.7           | 1.85            | mA               | MAX   |           |

## Electrical Characteristics

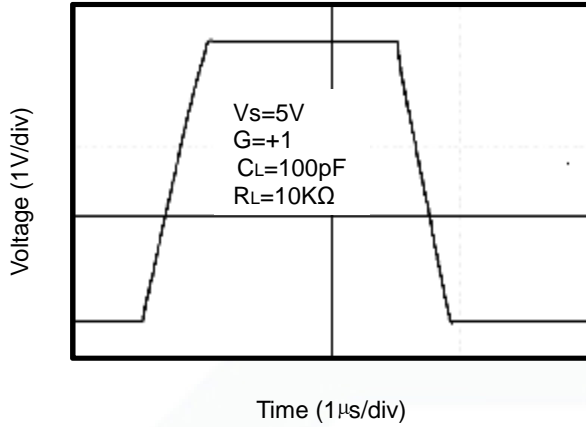
(At  $V_S=5V$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_S/2$ ,  $R_L = 600\ \Omega$ , unless otherwise noted.)

| PARAMETER                       | CONDITIONS                                    | GS8600 |                          |             |               |                |  |                |           |
|---------------------------------|---|--------|--------------------------|-------------|---------------|----------------|--|----------------|-----------|
|                                 |   | TYP    | MIN/MAX OVER TEMPERATURE |             |               |                |  | UNITS          | MIN / MAX |
|                                 |   | +25°C  | +25°C                    | 0°C to 70°C | -40°C to 85°C | -40°C to 125°C |  |                |           |
| <b>DYNAMIC PERFORMANCE</b>      |   |        |                          |             |               |                |  |                |           |
| Gain-Bandwidth Product (GBP)    | $R_L = 10k\Omega$ , $C_L = 100pF$             | 11     |                          |             |               |                |  | MHz            | TYP       |
| Phase Margin ( $\phi_o$ )       | $R_L = 10k\Omega$ , $C_L = 100pF$             | 51     |                          |             |               |                |  | Degrees        | TYP       |
| Full Power Bandwidth (BWP)      | < 1% distortion, $R_L = 600\Omega$            | 400    |                          |             |               |                |  | kHz            | TYP       |
| Slew Rate (SR)                  | $G = +1$ , 2V Step, $R_L = 10k\Omega$         | 9      |                          |             |               |                |  | V/ $\mu s$     | TYP       |
| Settling Time to 0.1% ( $t_s$ ) | $G = +1$ , 2V Step, $R_L = 600\Omega$         | 0.3    |                          |             |               |                |  | $\mu s$        | TYP       |
| Overload Recovery Time          | $V_{IN} \cdot Gain = V_S$ , $R_L = 600\Omega$ | 1.5    |                          |             |               |                |  | $\mu s$        | TYP       |
| <b>NOISE PERFORMANCE</b>        |   |        |                          |             |               |                |  |                |           |
| Voltage Noise Density ( $e_n$ ) | $f = 1kHz$                                    | 11.5   |                          |             |               |                |  | $nV/\sqrt{Hz}$ | TYP       |
|                                 | $f = 10kHz$                                   | 8      |                          |             |               |                |  | $nV/\sqrt{Hz}$ | TYP       |

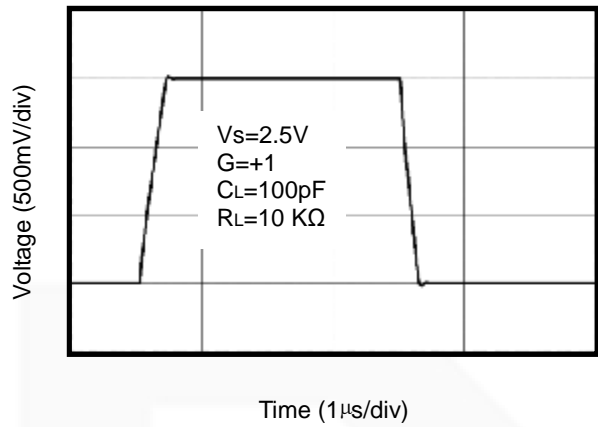
## Typical Performance characteristics

(At  $V_s=5V$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_s/2$ ,  $R_L = 600\Omega$ , unless otherwise noted.)

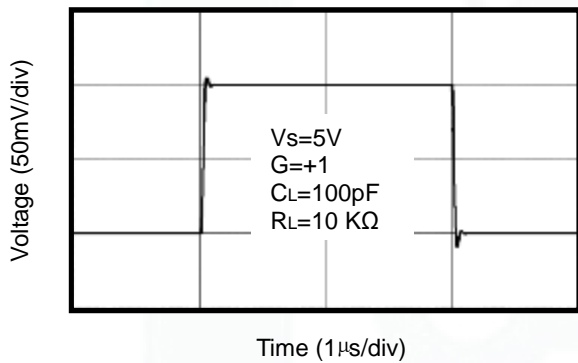
Large-Signal Step Response



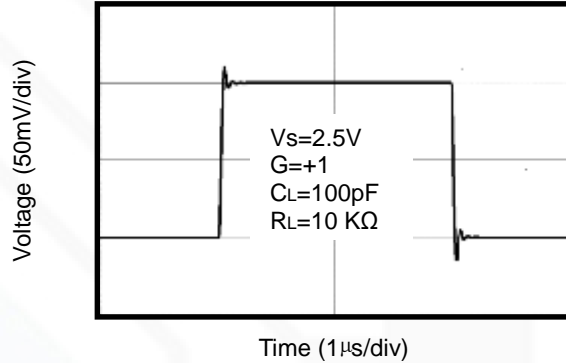
Large-Signal Step Response



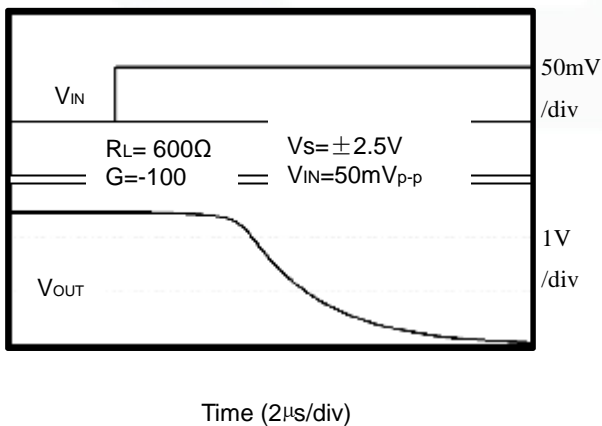
Small-Signal Step Response



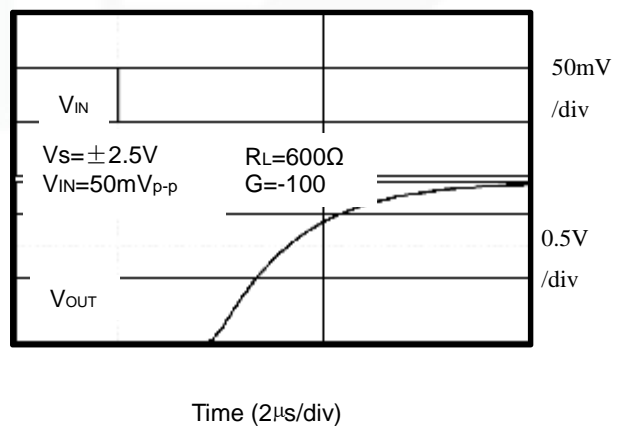
Small-Signal Step Response



Positive Overload Recovery



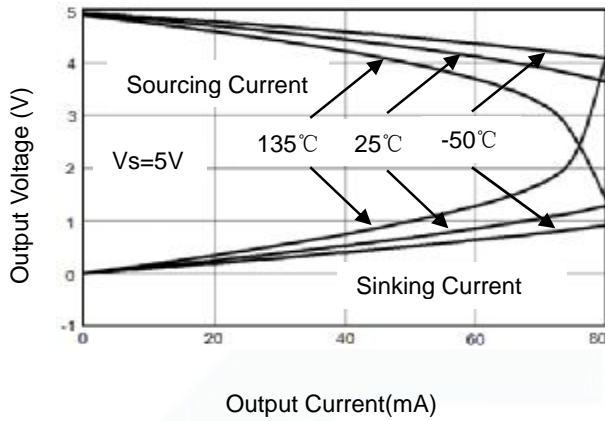
Negative Overload Recovery



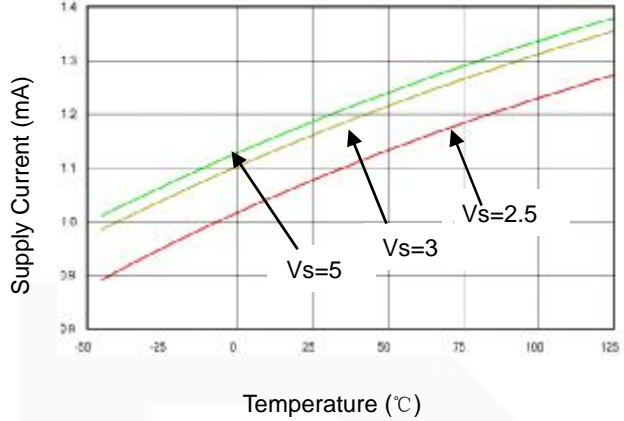
### Typical Performance characteristics

(At  $V_s=5V$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_s/2$ ,  $R_L = 600\Omega$ , unless otherwise noted.)

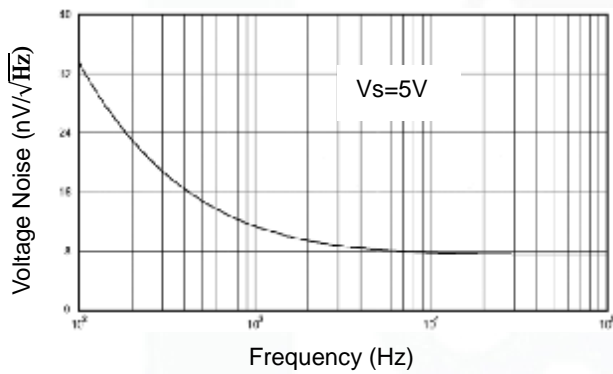
Output Voltage Swing vs. Output Current



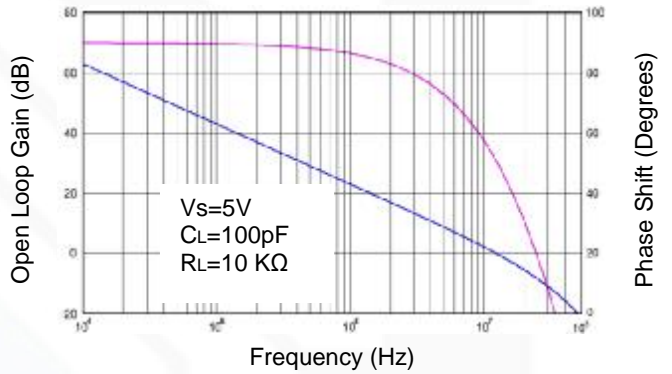
Supply Current vs. Temperature



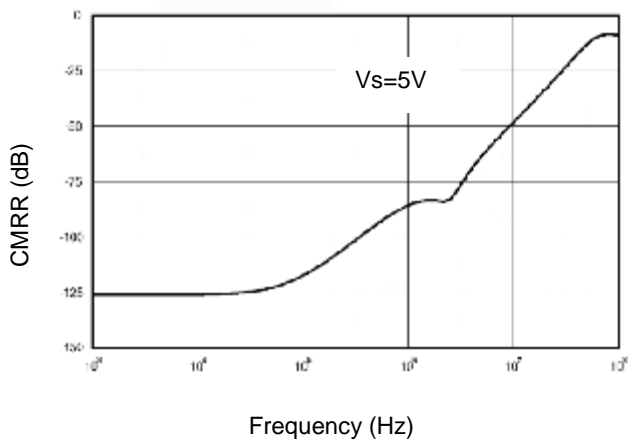
Input Voltage Noise Spectral Density vs. Frequency



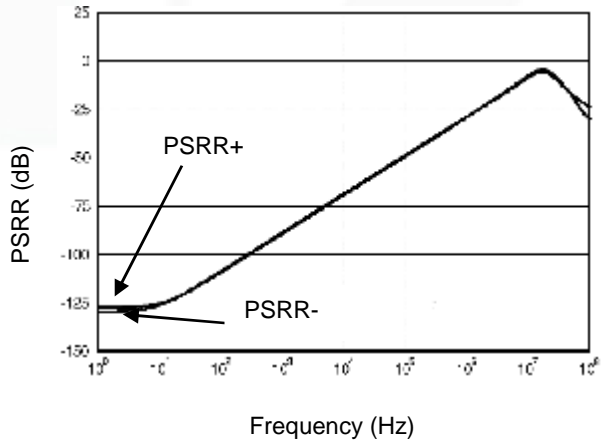
Open Loop Gain, Phase Shift vs. Frequency



CMRR vs. Frequency



PSRR vs. Frequency



## Application Note

### Size

GS8600 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the GS8600 series packages save space on printed circuit boards and enable the design of smaller electronic products.

### Power Supply Bypassing and Board Layout

GS8600 series operates from a single 2.1V to 5.5V supply or dual  $\pm 1.05\text{V}$  to  $\pm 2.75\text{V}$  supplies. For best performance, a  $0.1\mu\text{F}$  ceramic capacitor should be placed close to the  $V_{\text{DD}}$  pin in single supply operation. For dual supply operation, both  $V_{\text{DD}}$  and  $V_{\text{SS}}$  supplies should be bypassed to ground with separate  $0.1\mu\text{F}$  ceramic capacitors.

### Low Supply Current

The low supply current (typical  $1.1\text{mA}$  per channel) of GS8600 series will help to maximize battery life. They are ideal for battery powered systems

### Operating Voltage

GS8600 series operate under wide input supply voltage (2.1V to 5.5V). In addition, all temperature specifications apply from  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Most behavior remains unchanged throughout the full operating voltage range. These guarantees ensure operation throughout the single Li-Ion battery lifetime

### Rail-to-Rail Input

The input common-mode range of GS8600 series extends  $100\text{mV}$  beyond the supply rails ( $V_{\text{SS}}-0.1\text{V}$  to  $V_{\text{DD}}+0.1\text{V}$ ). This is achieved by using complementary input stage. For normal operation, inputs should be limited to this range.

### Rail-to-Rail Output

Rail-to-Rail output swing provides maximum possible dynamic range at the output. This is particularly important when operating in low supply voltages. The output voltage of GS8600 series can typically swing to less than  $2\text{mV}$  from supply rail in light resistive loads ( $>100\text{k}\Omega$ ), and  $15\text{mV}$  of supply rail in moderate resistive loads ( $10\text{k}\Omega$ ).

### Capacitive Load Tolerance

The GS8600 family is optimized for bandwidth and speed, not for driving capacitive loads. Output capacitance will create a pole in the amplifier's feedback path, leading to excessive peaking and potential oscillation. If dealing with load capacitance is a requirement of the application, the two strategies to consider are (1) using a small resistor in series with the amplifier's output and the load capacitance and (2) reducing the bandwidth of the amplifier's feedback loop by increasing the overall noise gain. Figure 2. shows a unity gain follower using the series resistor strategy. The resistor isolates the output from the capacitance and, more importantly, creates a zero in the feedback path that compensates for the pole created by the output capacitance.

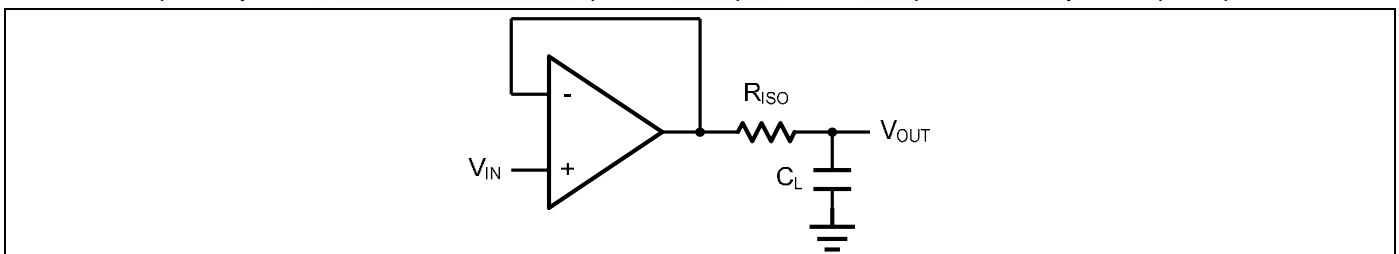


Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

The bigger the  $R_{\text{ISO}}$  resistor value, the more stable  $V_{\text{OUT}}$  will be. However, if there is a resistive load  $R_{\text{L}}$  in parallel with the capacitive load, a voltage divider (proportional to  $R_{\text{ISO}}/R_{\text{L}}$ ) is formed, this will result in a gain error.

The circuit in Figure 3 is an improvement to the one in Figure 2.  $R_{\text{F}}$  provides the DC accuracy by feed-forward the  $V_{\text{IN}}$  to  $R_{\text{L}}$ .  $C_{\text{F}}$

and  $R_{ISO}$  serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving the phase margin in the overall feedback loop. Capacitive drive can be increased by increasing the value of  $C_F$ . This in turn will slow down the pulse response.

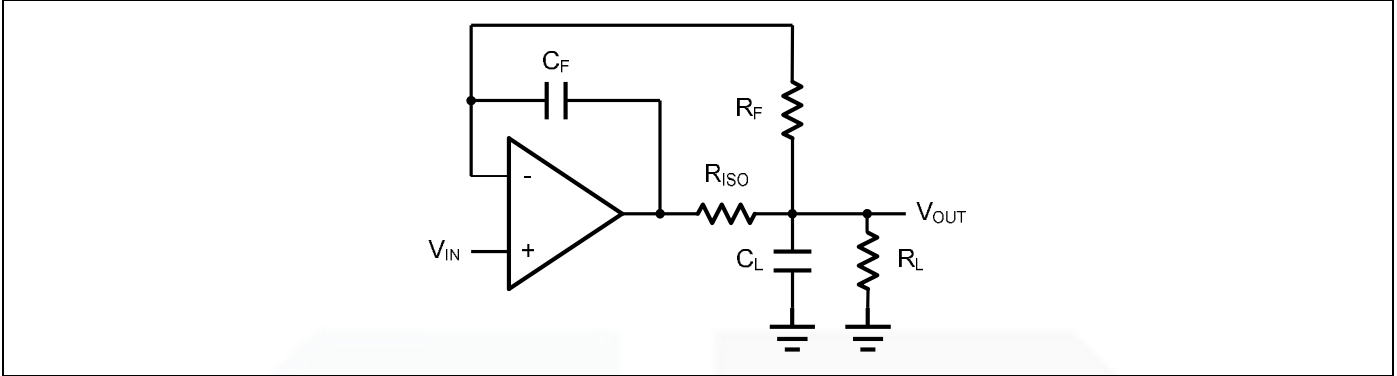


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy



## Typical Application Circuits

### Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common to the two inputs. It is useful as a computational amplifier in making a differential to single-end conversion or in rejecting a common mode signal. Figure 4. shows the differential amplifier using GS8600.

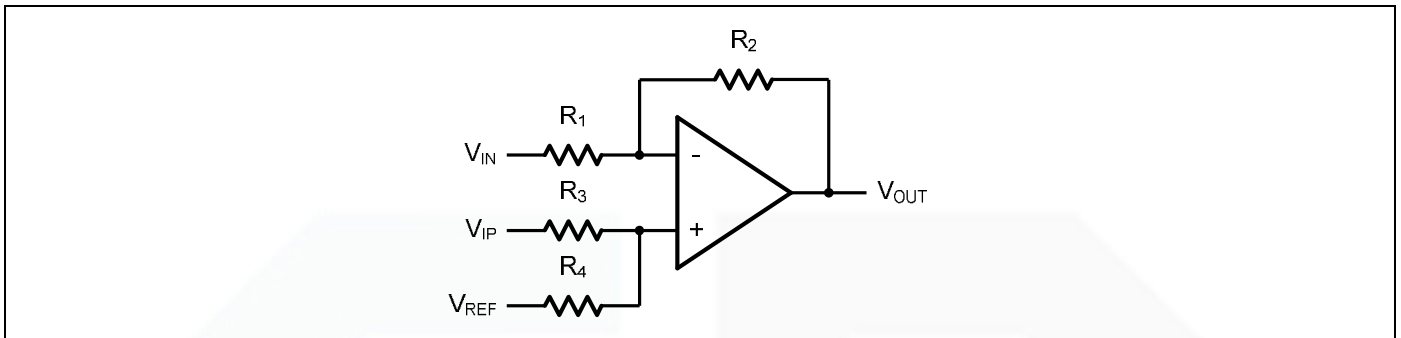


Figure 4. Differential Amplifier

$$V_{OUT} = \left(\frac{R_1+R_2}{R_3+R_4}\right) \frac{R_4}{R_1} V_{IN} - \frac{R_2}{R_1} V_{IP} + \left(\frac{R_1+R_2}{R_3+R_4}\right) \frac{R_3}{R_1} V_{REF}$$

If the resistor ratios are equal (i.e.  $R_1=R_3$  and  $R_2=R_4$ ), then

$$V_{OUT} = \frac{R_2}{R_1} (V_{IP} - V_{IN}) + V_{REF}$$

### Low Pass Active Filter

The low pass active filter is shown in Figure 5. The DC gain is defined by  $-R_2/R_1$ . The filter has a -20dB/decade roll-off after its corner frequency  $f_c=1/(2\pi R_3 C_1)$ .

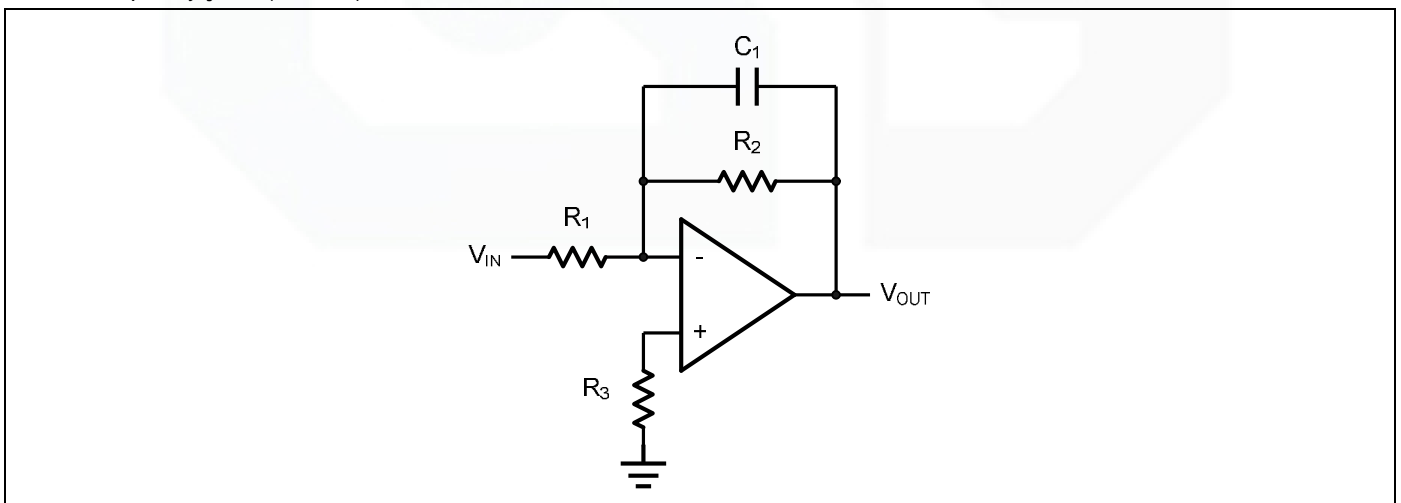


Figure 5. Low Pass Active Filter

**Instrumentation Amplifier**

The triple GS8600 can be used to build a three-op-amp instrumentation amplifier as shown in Figure 6. The amplifier in Figure 6 is a high input impedance differential amplifier with gain of  $R_2/R_1$ . The two differential voltage followers assure the high input impedance of the amplifier.

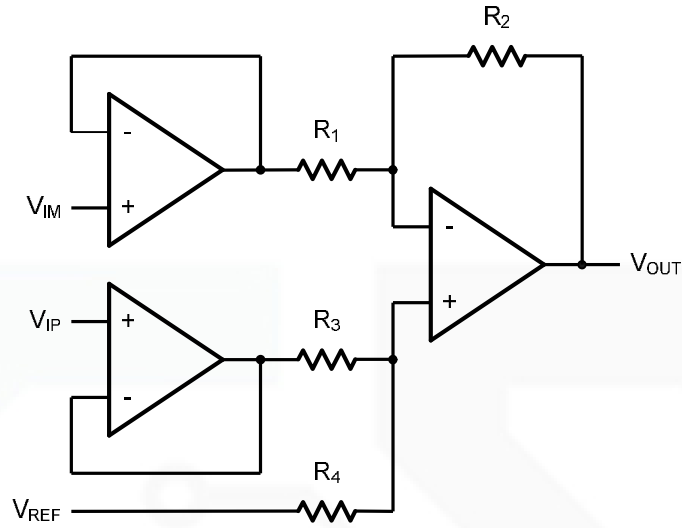
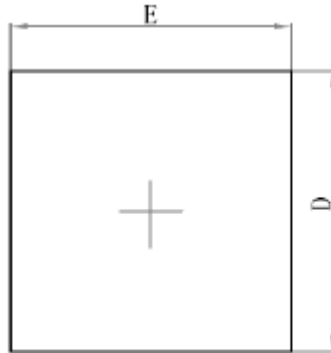
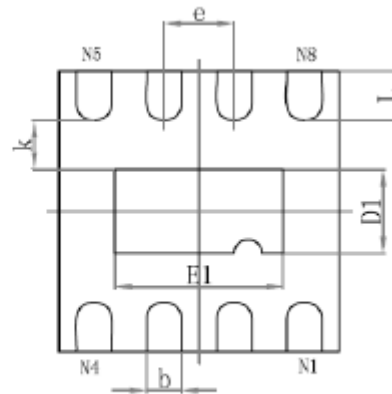
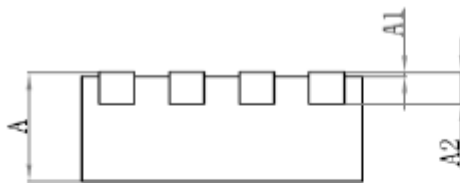


Figure 6. Instrument Amplifier

**Package Information**
**DFN-8**

**Top View**

**Bottom View**

**Side View**

| Symbol | Dimensions<br>In Millimeters |       |       | Dimensions In Inches |       |       |
|--------|------------------------------|-------|-------|----------------------|-------|-------|
|        | Min                          | Nom   | Max   | Min                  | Nom   | Max   |
| A      | 0.80                         | 0.85  | 0.9   | 0.031                | 0.033 | 0.035 |
| A1     | 0.00                         | 0.02  | 0.05  | 0.000                | 0.001 | 0.002 |
| A2     | 0.153                        | 0.203 | 0.253 | 0.006                | 0.008 | 0.010 |
| b      | 0.18                         | 0.24  | 0.30  | 0.007                | 0.009 | 0.012 |
| D      | 1.9                          | 2.0   | 2.1   | 0.075                | 0.079 | 0.083 |
| E      | 1.9                          | 2.0   | 2.1   | 0.075                | 0.079 | 0.083 |
| D1     | 0.5                          | 0.6   | 0.7   | 0.020                | 0.024 | 0.028 |
| E1     | 1.1                          | 1.2   | 1.3   | 0.043                | 0.047 | 0.051 |
| e      |                              | 0.50  |       |                      | 0.20  |       |
| k      | 0.2                          |       |       | 0.008                |       |       |
| L      | 0.25                         | 0.35  | 0.45  | 0.010                | 0.014 | 0.018 |

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