# 10MHz CMOS Rail-to-Rail IO Opamps

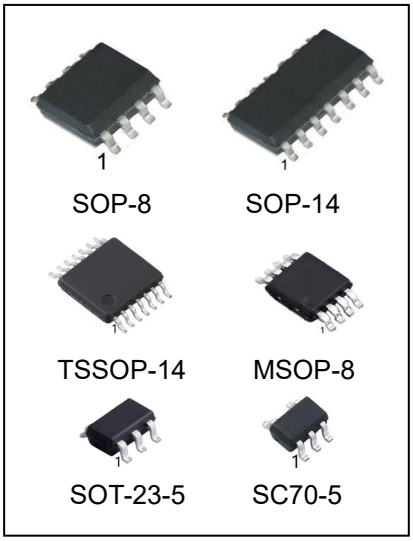
## Features

- Single-Supply Operation from +2.1V ~ +5.5V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 10MHz (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:

  AD8605 Available in SOT-23-5 and SC70-5 Packages

  AD8606 Available in SOP-8 and MSOP-8 Packages

  AD8608 Available in SOP-14 and TSSOP-14 Packages




## Ordering Information

| DEVICE | Package Type | MARKING | Packing | Packing Qty |
|---|---|---|---|---|
| AD8605M5/TR | SOT-23-5 | 8605,B3A,B3A# | REEL | 3000pcs/reel |
| AD8605M7/TR | SC70-5(SOT-353) | 8605,B3A,B3A# | REEL | 3000pcs/reel |
| AD8606M/TR | SOP-8 | AD8606,8606 | REEL | 2500pcs/reel |
| AD8606MM/TR | MSOP-8 | 8606,B6A,B6A# | REEL | 3000pcs/reel |
| AD8608M/TR | SOP-14 | AD8608,8608 | REEL | 2500pcs/reel |
| AD8608MT/TR | TSSOP-14 | AD8608,8608 | REEL | 2500pcs/reel |

Note: SOT-353 equal to SC70-5 Package Type

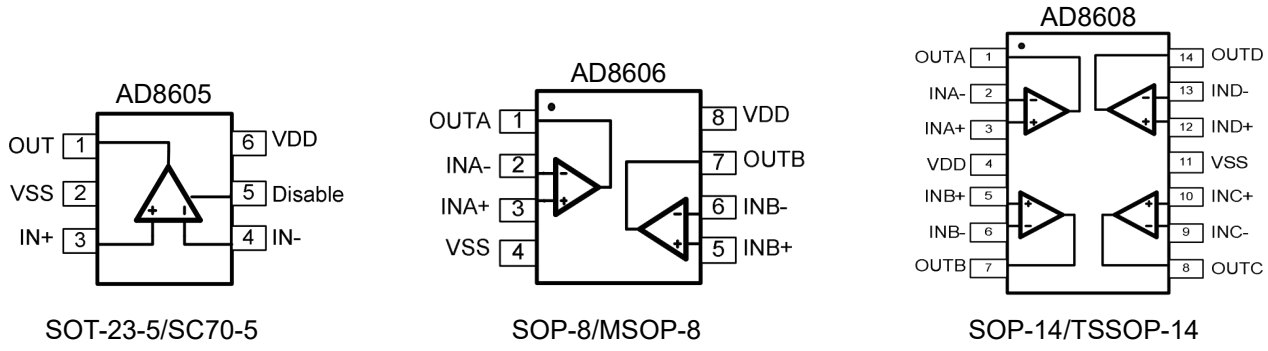
## General Description

The AD860x have a high gain-bandwidth product of 10 MHz, a slew rate of 9V/μs, and a quiescent current of 1.1mA per amplifier at 5V. The AD860x 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 AD860x. They are specified over the extended industrial temperature range (-40℃ to +125℃). The operating range is from 2.1V to 5.5V. The AD8605 single is available in Green SC70-5 and SOT-23-5 packages. The AD8606 dual is available in Green SOP-8 and MSOP-8 packages. The AD8608 Quad is available in Green SOP-14 and TSSOP-14 packages.

## Applications

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

## Pin Configuration




SOT-23-5/SC70-5 SOP-8/MSOP-8 SOP-14/TSSOP-14

Figure 1. Pin Assignment Diagram

## Absolute Maximum Ratings

| Condition | Min | Max |
|---|---|---|
| Power Supply Voltage ($V_{DD}$ to Vss) | -0.5V | +7.5V |
| Analog Input Voltage (IN+ or IN-) | Vss-0.5V | $V_{DD}$+0.5V |
| PDB Input Voltage | Vss-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) | - | +245°C |
| **Package Thermal Resistance (TA=+25℃)** | | |
| SOP-8, $\theta_{JA}$ | - | 125°C/W |
| MSOP-8, $\theta_{JA}$ | - | 216°C/W |
| SOT-23-5, $\theta_{JA}$ | - | 190°C/W |
| SC70-5, $\theta_{JA}$ | - | 333°C/W |
| **ESD Susceptibility** | | |
| 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.

## Electrical Characteristics

(At Vs=5V, $T_A$ = +25℃, $V_{CM}$ = $V_S$/2, $R_L$ = 600Ω, unless otherwise noted.)

| PARAMETER | CONDITIONS | AD8605/6/8 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | | |
| | | +25℃ | +25℃ | 0℃ to 70℃ | -40℃ to 85℃ | -40℃ to 125℃ | UNITS | MIN / MAX |
| **INPUT CHARACTERISTICS** | | | | | | | | |
| 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 ($A_{OL}$) | $R_L$ = 600Ω, $V_O$ = 0.15V to 4.85V | 90 | 80 | 76 | 75 | 68 | dB | MIN |
| | $R_L$ = 10kΩ, $V_O$ = 0.05V to 4.95V | 108 | | | | | dB | MIN |
| Input Offset Voltage Drift ($\Delta V_{OS}/\Delta T$) | | 2.4 | | | | | μV/℃ | TYP |
| **OUTPUT CHARACTERISTICS** | | | | | | | | |
| Output Voltage Swing from Rail | $R_L$ = 600Ω | 0.1 | | | | | V | TYP |
| | $R_L$ = 10kΩ | 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 | | | | | Ω | TYP |
| **POWER-DOWN DISABLE** | | | | | | | | |
| Turn-On Time | | 1.1 | | | | | μs | TYP |
| Turn-Off Time | | 0.3 | | | | | μs | TYP |
| DISABLE Voltage-Off | | | 0.8 | | | | V | MAX |
| DISABLE Voltage-On | | | 2 | | | | V | MIN |
| **POWER SUPPLY** | | | | | | | | |
| 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 |
| | $I_{OUT}$ = 0 | 1.1 | 1.5 | 1.65 | 1.7 | 1.85 | Ma | MAX |
| | | | | | | | | MAX |

## Electrical Characteristics

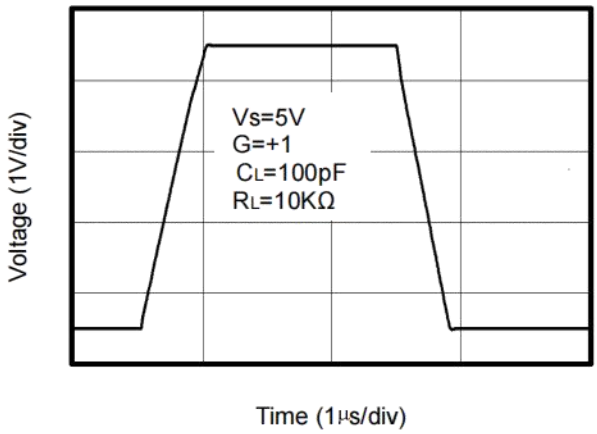
(At Vs=5V, TA = +25℃, VCM = VS/2, RL = 600Ω, unless otherwise noted.)

| PARAMETER | CONDITIONS | AD8605/6/8 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | | |
| | | +25℃ | +25℃ | 0℃ to 70℃ | -40℃ to 85℃ | -40℃to 125℃ | UNITS | MIN / MAX |
| DYNAMIC PERFORMANCE | | | | | | | | |
| Gain-Bandwidth Product (GBP) | $R_L$ = 10kΩ, $C_L$ = 100pF | 10 | | | | | MHz | TYP |
| Phase Margin (φO) | $R_L$ = 10kΩ, $C_L$ = 100pF | 51 | | | | | Degrees | TYP |
| Full Power Bandwidth (BWP) | ＜1% distortion, $R_L$ = 600Ω | 400 | | | | | kHz | TYP |
| Slew Rate (SR) | G = +1, 2V Step, $R_L$ = 10kΩ | 9 | | | | | V/μs | TYP |
| Settling Time to 0.1% ($t_S$) | G = +1, 2V Step, $R_L$ = 600Ω | 0.3 | | | | | μs | TYP |
| Overload Recovery Time | $V_{IN}$ ·Gain = VS, $R_L$ = 600Ω | 1.5 | | | | | μs | TYP |
| NOISE PERFORMANCE | | | | | | | | |
| Voltage Noise Density ($e_n$) | f = 1kHz | 11.5 | | | | | nV /Hz | TYP |
| | f = 10kHz | 8 | | | | | nV /Hz | TYP |

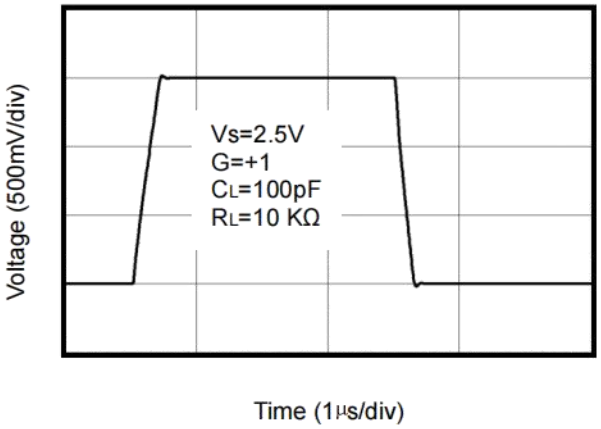
## Typical Performance characteristics

(At Vs=5V, $T_A$ = +25℃, $V_{CM}$ = Vs/2, $R_L$ = 600Ω, unless otherwise noted.)

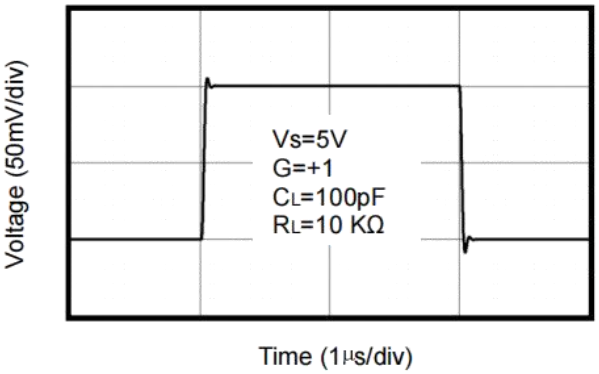
Large-Signal Step Response



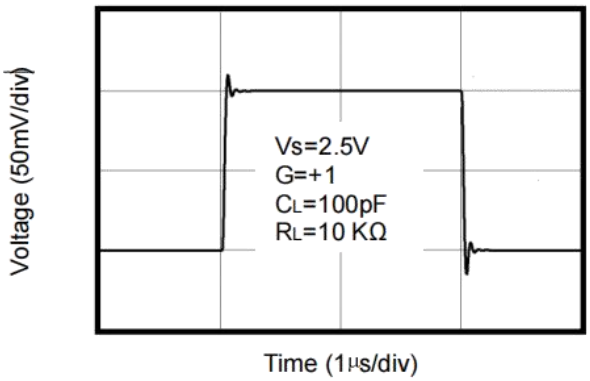

Large-Signal Step Response



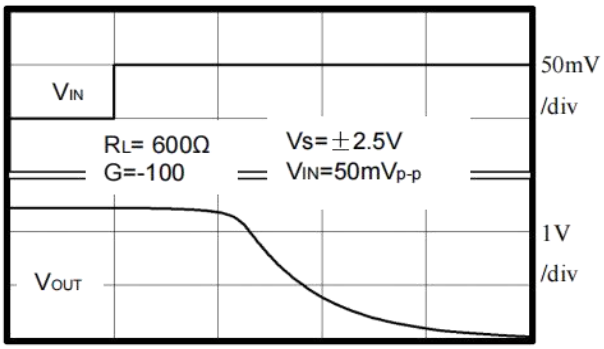

Small-Signal Step Response



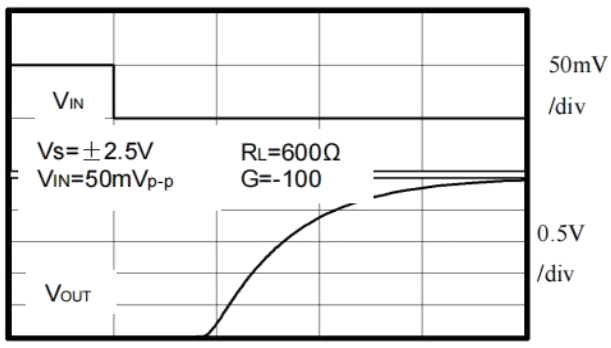

Small-Signal Step Response




Positive Overload Recovery



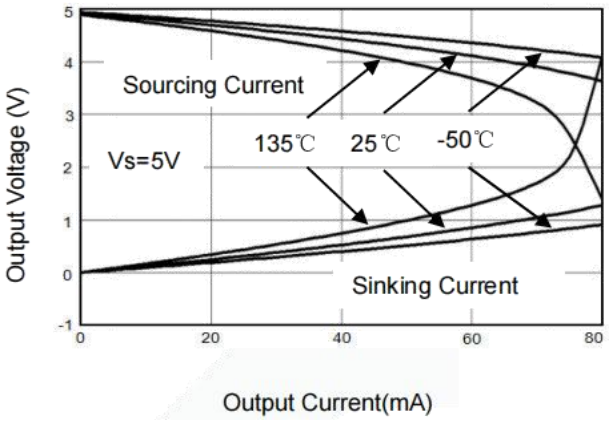

Negative Overload Recovery



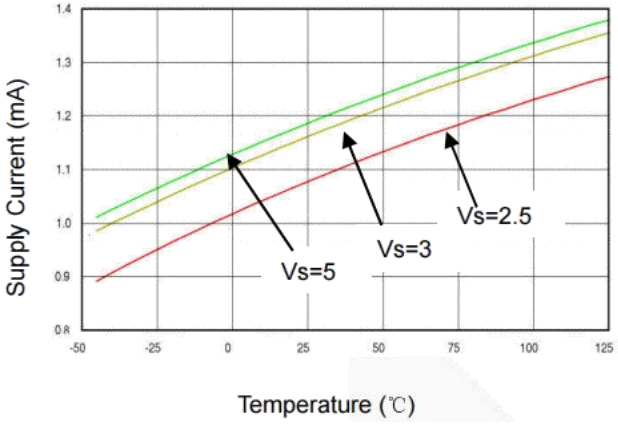
## Typical Performance characteristics

(At Vs=5V, TA = +25°C, VCM = VS/2, RL = 600Ω, unless otherwise noted.)

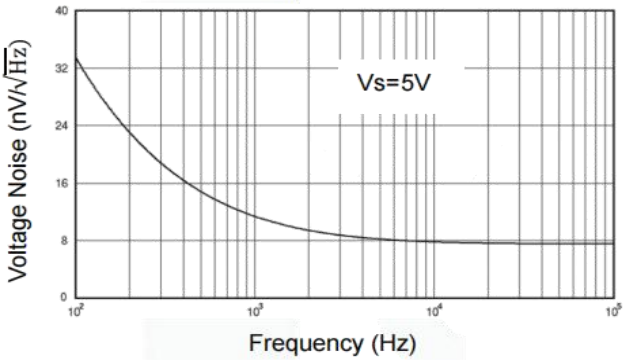
Output Voltage Swing vs.Output Current



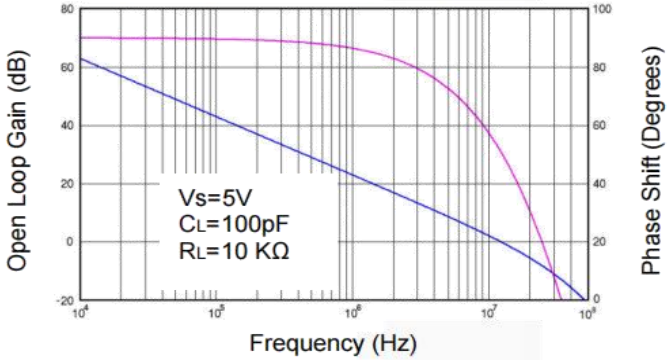

Supply Current vs. Temperature



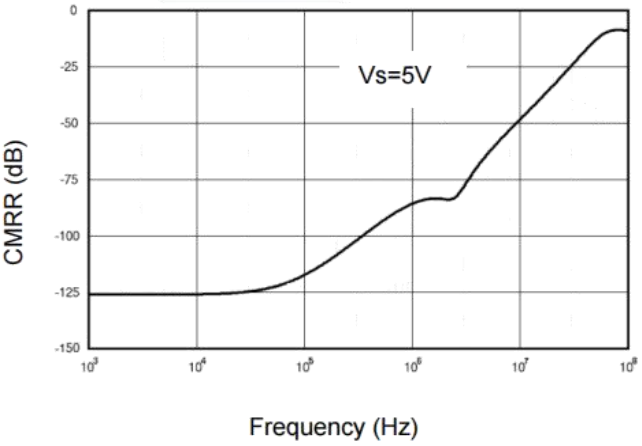

Input Voltage Noise Spectral Density vs. Frequency



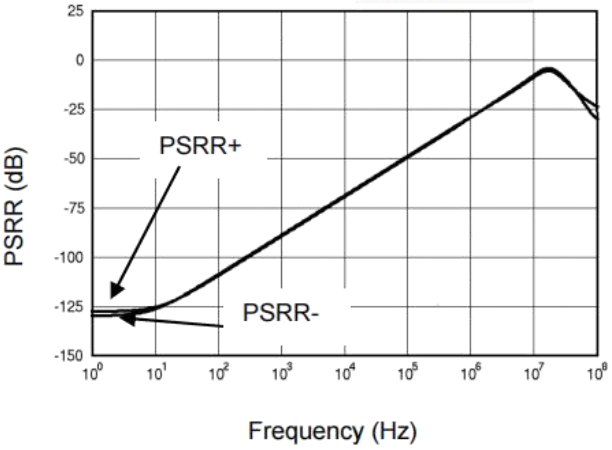

Open Loop Gain, Phase Shift vs. Frequency




CMRR vs. Frequency




PSRR vs. Frequency



# Application Note

## Size

AD860x series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the AD860x series packages save space on printed circuit boards and enable the design of smaller electronic products.

## Power Supply Bypassing and Board Layout

AD860x series operates from a single 2.1V to 5.5V supply or dual ±1.05V to ±2.75V supplies. For best performance, a 0.1μF ceramic capacitor should be placed close to the $V_{DD}$ pin in single supply operation. For dual supply operation, both $V_{DD}$ and VSS supplies should be bypassed to ground with separate 0.1μF ceramic capacitors.

## Low Supply Current

The low supply current (typical 1.1mA per channel) of AD860x series will help to maximize battery life . They are ideal for battery powered systems

## Operating Voltage

AD860x series operate under wide input supply voltage (2.1V to 5.5V). In addition, all temperature specifications apply from -40°C to +125°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 AD860x series extends 100mV beyond the supply rails (VSS-0.1V to $V_{DD}$+0.1V). 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 AD860x series can typically swing to less than 2mV from supply rail in light resistive loads (>100kΩ), and 15mV of supply rail in moderate resistive loads (10kΩ).

## Capacitive Load Tolerance

The AD860x family is optimized for bandwidth and speed, not for driving capacitive loads. Output capacitance will create apole 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.

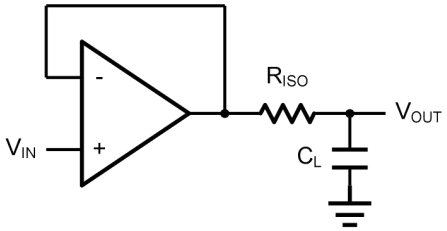



Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

The bigger the RISO resistor value, the more stable VOUT will be. However, if there is a resistive load RL in parallel with the capacitive load, a voltage divider (proportional to RISO/RL) is formed, this will result in a gain error.

The circuit in Figure 3 is an improvement to the one in Figure 2. RF provides the DC accuracy by feed-forward the VIN to RL. CF and RISO 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 CF. This in turn will slow down the pulse response.

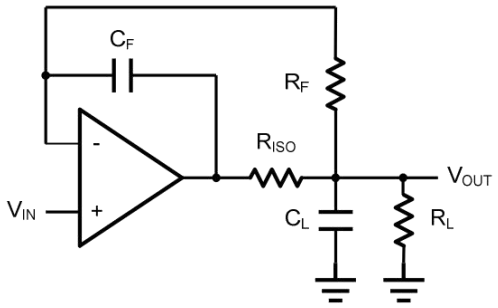



Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

# Typical Application Circuits

## Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common 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. shown the differential amplifier using AD860x.

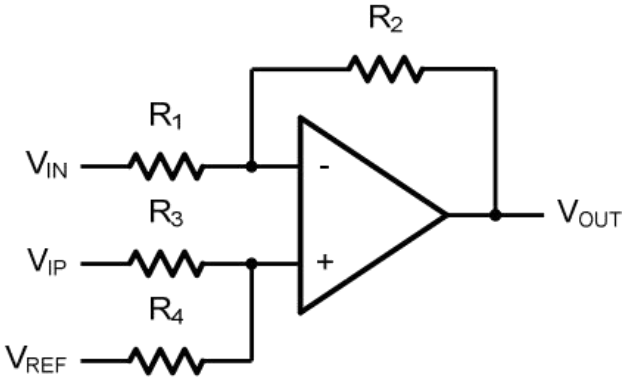



Figure 4. Differential Amplifier

$$V_{OUT} = (\frac{R_1 + R_2}{R_3 + R_4})\frac{R_4}{R_1}V_{IN} - \frac{R2}{R1}V_{IP} + (\frac{R_1 + R_2}{R_3 + R_4})\frac{R_3}{R_1}V_{REF}$$

If the resistor ratios are equal (i.e. R1=R3 and R2=R4), 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 –R2/R1. The filter has a -20dB/decade roll-off after its corner frequency $f$C=1/(2πR3C1).

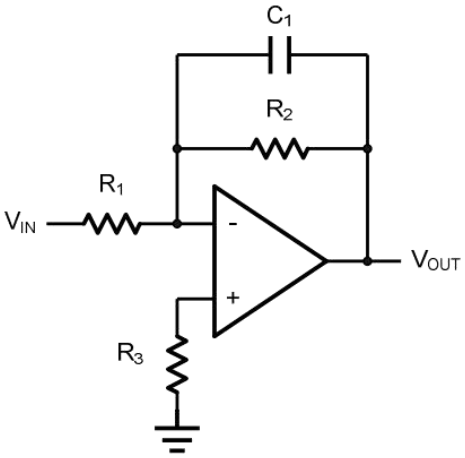



Figure 5. Low Pass Active Filter

## Instrumentation Amplifier

The triple AD860x 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 R2/R1. The two differential voltage followers assure the high input impedance of the amplifier.

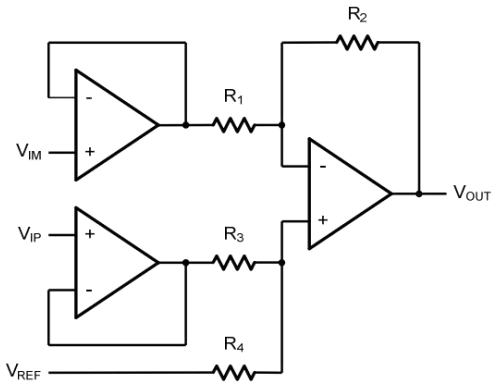
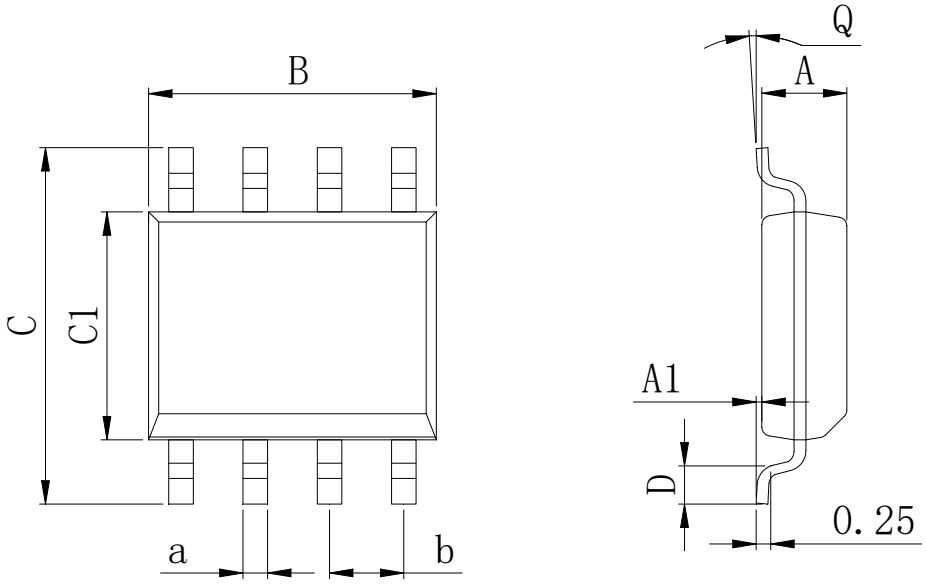



Figure 6. Instrument Amplifier

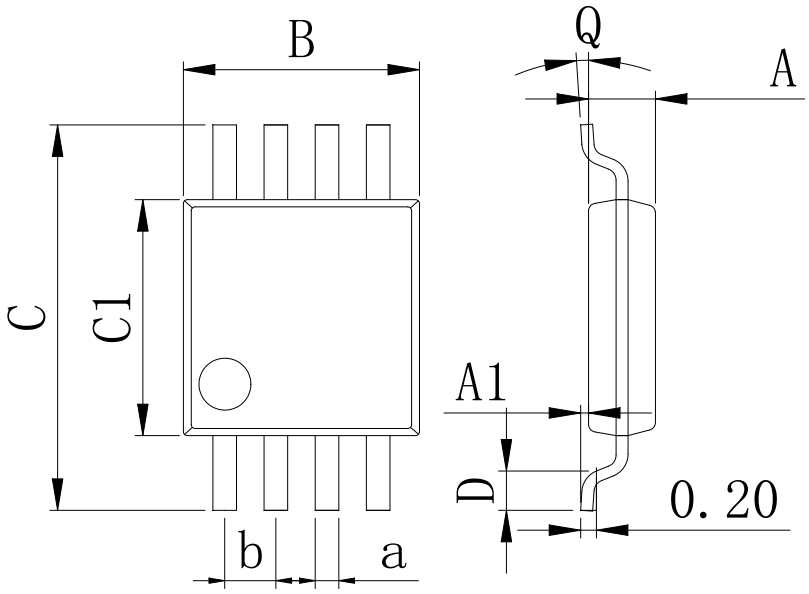
## Physical Dimensions

SOP-8




| Dimensions In Millimeters(SOP-8) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b |
| **Min:** | 1.35 | 0.05 | 4.90 | 5.80 | 3.80 | 0.40 | 0° | 0.35 | 1.27 BSC |
| **Max:** | 1.55 | 0.20 | 5.10 | 6.20 | 4.00 | 0.80 | 8° | 0.45 | |

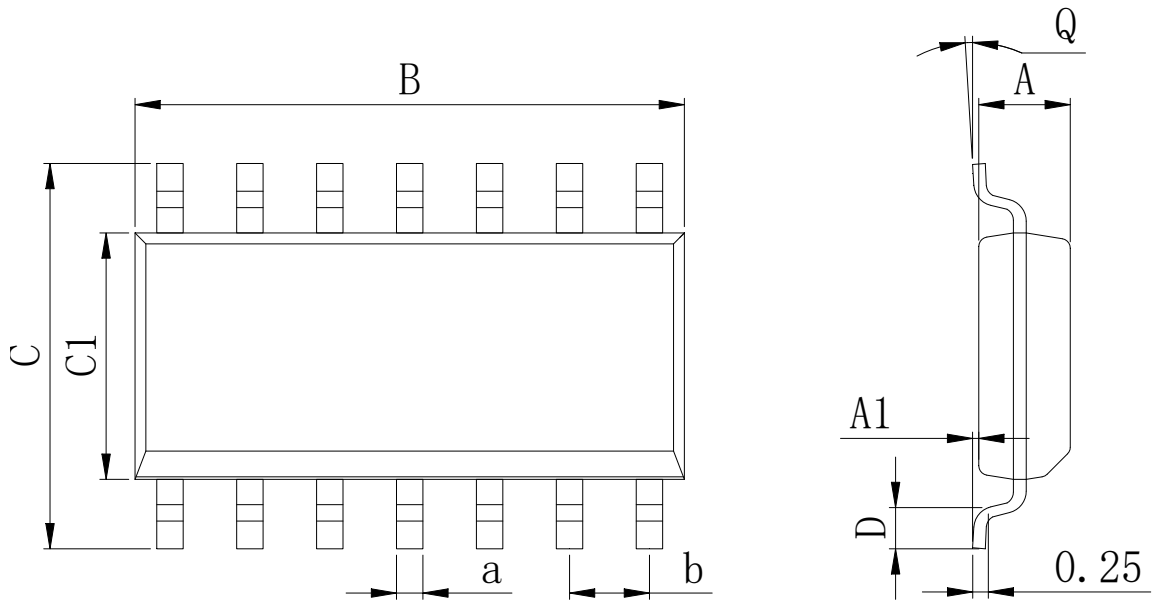
MSOP-8




| Dimensions In Millimeters(MSOP-8) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b |
| **Min:** | 0.80 | 0.05 | 2.90 | 4.75 | 2.90 | 0.35 | 0° | 0.25 | 0.65 BSC |
| **Max:** | 0.90 | 0.20 | 3.10 | 5.05 | 3.10 | 0.75 | 8° | 0.35 | |

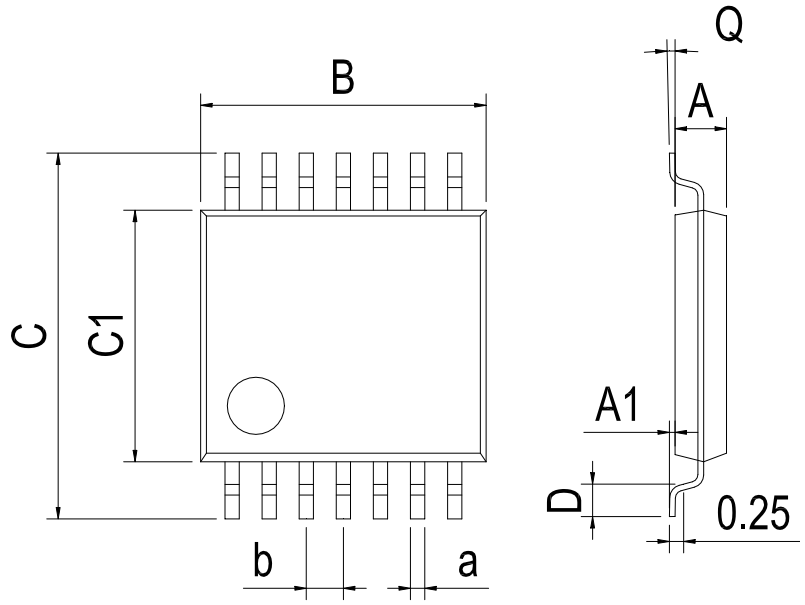
## Physical Dimensions

SOP-14




| Dimensions In Millimeters(SOP-14) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b |
| **Min:** | 1.35 | 0.05 | 8.55 | 5.80 | 3.80 | 0.40 | 0° | 0.35 | 1.27 BSC |
| **Max:** | 1.55 | 0.20 | 8.75 | 6.20 | 4.00 | 0.80 | 8° | 0.45 | |

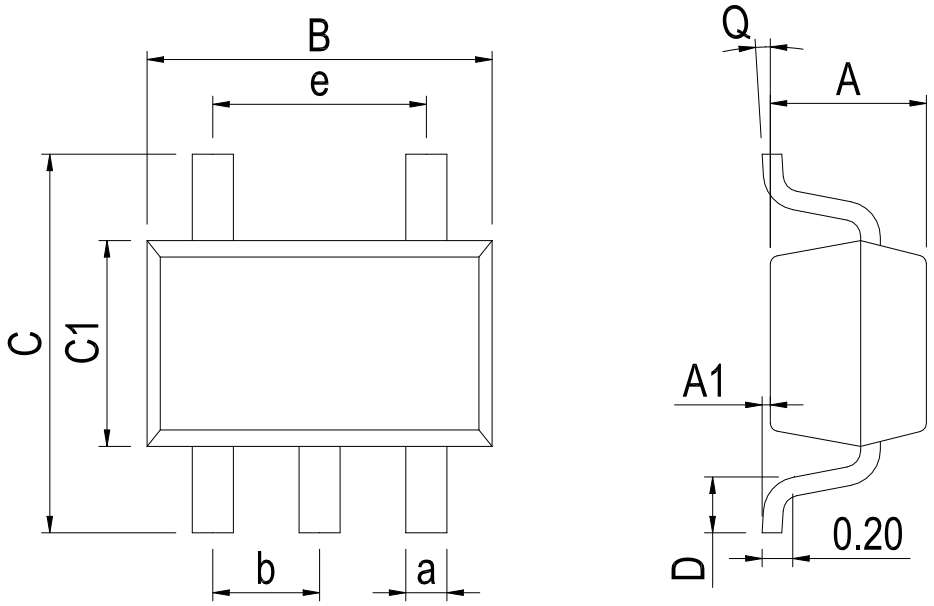
TSSOP-14




| Dimensions In Millimeters(TSSOP-14) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b |
| **Min:** | 0.85 | 0.05 | 4.90 | 6.20 | 4.30 | 0.40 | 0° | 0.20 | 0.65 BSC |
| **Max:** | 0.95 | 0.20 | 5.10 | 6.60 | 4.50 | 0.80 | 8° | 0.25 | |

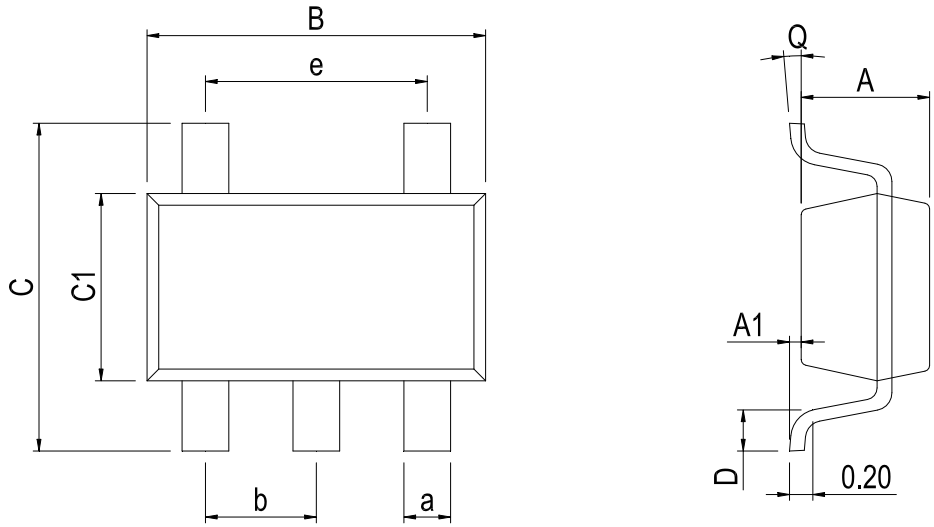
## Physical Dimensions

SOT-23-5




| Dimensions In Millimeters(SOT-23-5) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b | e |
| **Min:** | 1.05 | 0.00 | 2.82 | 2.65 | 1.50 | 0.30 | 0° | 0.30 | 0.95 BSC | 1.90 BSC |
| **Max:** | 1.15 | 0.15 | 3.02 | 2.95 | 1.70 | 0.60 | 8° | 0.40 | | |

SC70-5




| Dimensions In Millimeters(SC70-5) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b | e |
| **Min:** | 0.90 | 0.00 | 2.00 | 2.15 | 1.15 | 0.26 | 0° | 0.15 | 0.65 BSC | 1.30 BSC |
| **Max:** | 1.00 | 0.15 | 2.20 | 2.45 | 1.35 | 0.46 | 8° | 0.35 | | |

## Revision History

| DATE | REVISION | PAGE |
|---|---|---|
| 2016-7-8 | New | 1-16 |
| 2023-10-31 | Update encapsulation type，Update Lead Temperature、Update SC70-5 Physical Dimensions | 1、3、14 |
| 2024-8-22 | Add a model marking name | 1 |

**IMPORTANT STATEMENT:**

Huaguan Semiconductor reserves the right to change its products and services without notice. Before ordering, the customer shall obtain the latest relevant information and verify whether the information is up to date and complete. Huaguan Semiconductor does not assume any responsibility or obligation for the altered documents.

Customers are responsible for complying with safety standards and taking safety measures when using Huaguan Semiconductor products for system design and machine manufacturing. You will bear all the following responsibilities: Select the appropriate Huaguan Semiconductor products for your application; Design, validate and test your application; Ensure that your application meets the appropriate standards and any other safety,security or other requirements. To avoid the occurrence of potential risks that may lead to personal injury or property loss.

Huaguan Semiconductor products have not been approved for applications in life support, military, aerospace and other fields, and Huaguan Semiconductor will not bear the consequences caused by the application of products in these fields. All problems, responsibilities and losses arising from the user's use beyond the applicable area of the product shall be borne by the user and have nothing to do with Huaguan Semiconductor, and the user shall not claim any compensation liability against Huaguan Semiconductor by the terms of this Agreement.

The technical and reliability data (including data sheets), design resources (including reference designs), application or other design suggestions, network tools, safety information and other resources provided for the performance of semiconductor products produced by Huaguan Semiconductor are not guaranteed to be free from defects and no warranty, express or implied, is made. The use of testing and other quality control technologies is limited to the quality assurance scope of Huaguan Semiconductor. Not all parameters of each device need to be tested.

The documentation of Huaguan Semiconductor authorizes you to use these resources only for developing the application of the product described in this document. You have no right to use any other Huaguan Semiconductor intellectual property rights or any third party intellectual property rights. It is strictly forbidden to make other copies or displays of these resources. You should fully compensate Huaguan Semiconductor and its agents for any claims, damages, costs, losses and debts caused by the use of these resources. Huaguan Semiconductor accepts no liability for any loss or damage caused by infringement.

# X-ON Electronics

Largest Supplier of Electrical and Electronic Components

***Click to view similar products for*** Operational Amplifiers - Op Amps ***category:***

***Click to view products by*** HGSEMI ***manufacturer:***

Other Similar products are found below :

HA17358AFEL-E SC2902DTBR2G SC239DR2G UPC258G2-A NCV33202DMR2G NJM324E NTE925 AZV358MTR-G1 AP4310AUMTR-AG1 SCY33178DR2G NCV5652MUTWG NCV20034DR2G NTE778S NTE871 NTE937 LM258WPT NJU7057RB1-TE2 SCY6358ADR2G NJM2904CRB1-TE1 NJM8532RB1-TE1 NJM2100M-TE1 TP2584-SR LM324A-SR TPMCP6004T-I/SL TP1562AL1-VR HT324ARQZ IL324DT RS724XP-Q1 CLM2543IDWR RS8424XP TSV6291AICT(UMW) TLV521DCKR(UMW) LM2904BAQPWRQ1 TLV9041IDPWR AD844SQ/883B LM833N LM358P RS6334PXP RS8704XP RS8414PXP RS724PXP MCP6486T-E/LT MCP6486UT-E/LT LMV324DR2G(MS) LMV324IDR(MS) MCP6004T-I/SL(MS) MCP6L04T-E/SL(MS) FMLN16G FMLN16T LMV321AQDCKRQ1