# 1.5MHZ Zero-Drift CMOS Rail-to-Rail IO Opamp with RF Filter

## Features

- **Single-Supply Operation from +2.1V ~ +5.5V**
- **Rail-to-Rail Input / Output**
- **Gain-Bandwidth Product: 1.5MHz (Typ. @25°C)**
- **Low Input Bias Current: 20pA (Typ. @25°C)**
- **Low Offset Voltage: 5uV (Max. @25°C)**
- **Quiescent Current: 320µA per Amplifier (Typ.)**
- **Operating Temperature: -40°C ~ +125°C**

- **Zero Drift: 0.05µV/$^o$C (Max.)**
- **Embedded RF Anti-EMI Filter**
- **Small Package:**
**HGA335 Available in SOT23-5 and SOP-8 Packages**
**HGA2335 Available in MSOP-8 and SOP-8 Packages**

## General Description

The HGAx335 amplifier is single/dual supply, micro-power, zero-drift CMOS operational amplifiers, the amplifiers offer bandwidth of 1.5MHz, rail-to-rail inputs and outputs, and single-supply operation from 2.1V to 5.5V. HGAx335 uses chopper stabilized technique to provide very low offset voltage (less than 5µV maximum) and near zero drift over temperature. Low quiescent supply current of 320µA per amplifier and very low input bias current of 20pA make the devices an ideal choice for low offset, low power consumption and high impedance applications. The HGAx335 offers excellent CMRR without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.

The HGA335 is available in SOT23-5 and SOP8 packages. And the HGA2335 is available in MSOP8 and SOP8 packages.The extended temperature range of -40$^o$C to +125$^o$C over all supply voltages offers additional design flexibility.

## Applications

- Transducer Application
- Temperature Measurements
- Electronics Scales

- Handheld Test Equipment
- Battery-Powered Instrumentation

## ORDERING INFORMATION

| DEVICE | Package Type | MARKING | Packing | Packing Qty |
|---|---|---|---|---|
| HGA335M5/TR | SOT23-5 | A335 | REEL | 3000pcs/reel |
| HGA335M/TR | SOP-8L | HGA335 | REEL | 2500pcs/reel |
| HGA2335M/TR | SOP-8L | HGA2335 | REEL | 2500pcs/reel |
| HGA2335MM/TR | MSOP-8L | A2335 | REEL | 3000pcs/reel |

## Pin Configuration
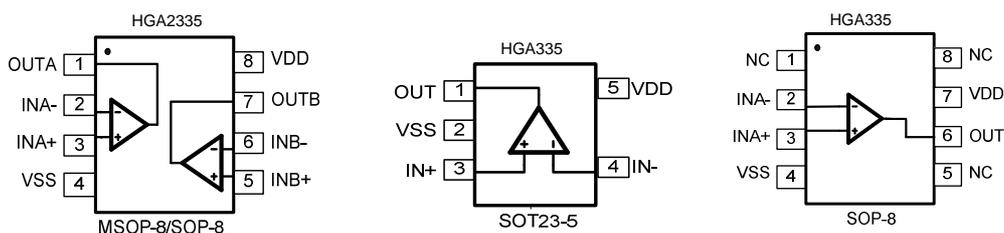


Figure 1. Pin Assignment Diagram

## 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) | +260°C | |
| **Package Thermal Resistance ($T_A$=+25℃)** | | |
| SOP-8, $\theta_{JA}$ | 125°C/W | |
| MSOP-8, $\theta_{JA}$ | 216°C/W | |
| SOT23-5, $\theta_{JA}$ | 190°C/W | |
| **ESD Susceptibility** | | |
| HBM | 6KV | |
| 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.
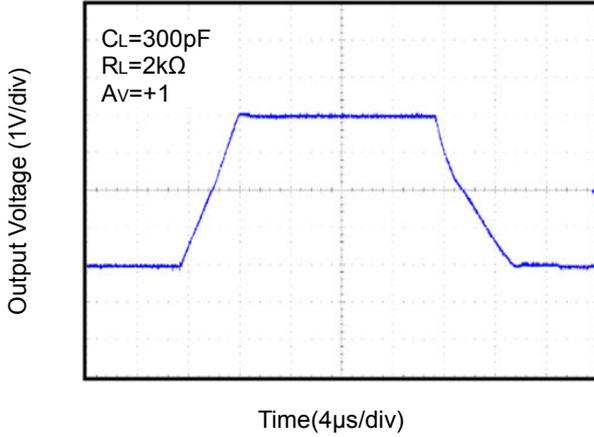
## Electrical Characteristics

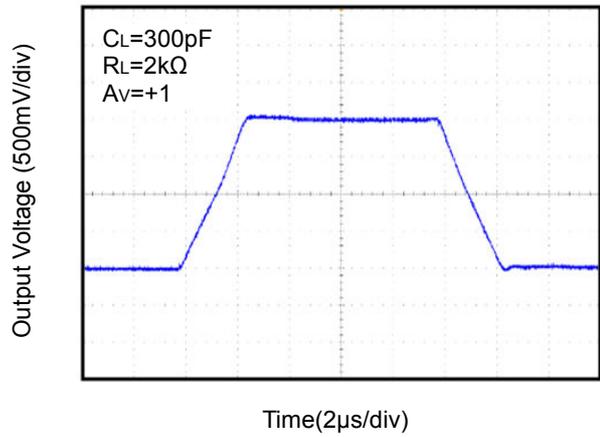($V_S$ = +5V, $V_{CM}$ = +2.5V, $V_O$ = +2.5V, $T_A$ = +25℃, unless otherwise noted.)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | |
| Input Offset Voltage ($V_{OS}$) | | | 1 | 5 | μV |
| Input Bias Current ($I_B$) | | | 20 | | pA |
| Input Offset Current ($I_{OS}$) | | | 10 | | pA |
| Common-Mode Rejection Ratio (CMRR) | $V_{CM}$ = 0V to 5V | | 110 | | dB |
| Large Signal Voltage Gain ( $A_{VO}$) | $R_L$ = 10kΩ, $V_O$ = 0.3V to 4.7V | | 145 | | dB |
| Input Offset Voltage Drift ($\Delta V_{OS}/\Delta_T$) | | | 50 | | nV/℃ |
| **OUTPUT CHARACTERISTICS** | | | | | |
| Output Voltage High ($V_{OH}$) | $R_L$ = 100kΩ to - $V_S$ | | 4.998 | | V |
| | $R_L$ = 10kΩ to - $V_S$ | | 4.994 | | V |
| Output Voltage Low ($V_{OL}$) | $R_L$ = 100kΩ to + $V_S$ | | 2 | | mV |
| | $R_L$ = 10kΩ to + $V_S$ | | 5 | | mV |
| Short Circuit Limit ($I_{SC}$) | $R_L$ =10Ω to - $V_S$ | | 43 | | mA |
| Output Current ($I_O$) | | | 30 | | mA |
| **POWER SUPPLY** | | | | | |
| Power Supply Rejection Ratio (PSRR) | $V_S$ = 2.5V to 5.5V | | 115 | | dB |
| Quiescent Current ($I_Q$) | $V_O$ = 0V, $R_L$ = 0Ω | | 320 | | μA |
| DYNAMIC PERFORMANCE | | | | | |
| Gain-Bandwidth Product (GBP) | G = +100 | | 1.5 | | MHz |
| Slew Rate (SR) | $R_L$ = 10kΩ | | 0.84 | | V/μs |
| Overload Recovery Time | | | 0.10 | | ms |
| **NOISE PERFORMANCE** | | | | | |
| Voltage Noise ($e_n$ p-p) | 0Hz to 10Hz | | 0.81 | | $\mu V_{P-P}$ |
| Voltage Noise Density ($e_n$) | f = 1kHz | | 49 | | $nV/\sqrt{Hz}$ |

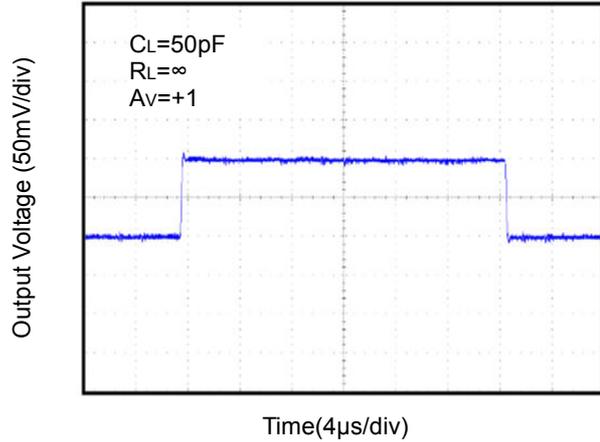## Typical Performance characteristics

Large Signal Transient Response at +5V

$C_L$=300pF
$R_L$=2kΩ
$A_V$=+1

Output Voltage (1V/div)

Time(4μs/div)

Large Signal Transient Response at +2.5V

$C_L$=300pF
$R_L$=2kΩ
$A_V$=+1

Output Voltage (500mV/div)

Time(2μs/div)

Small Signal Transient Response at +5V

$C_L$=50pF
$R_L$=∞
$A_V$=+1

Output Voltage (50mV/div)

Time(4μs/div)

Small Signal Transient Response at +2.5V

$C_L$=50pF
$R_L$=∞
$A_V$=+1

Output Voltage (50mV/div)
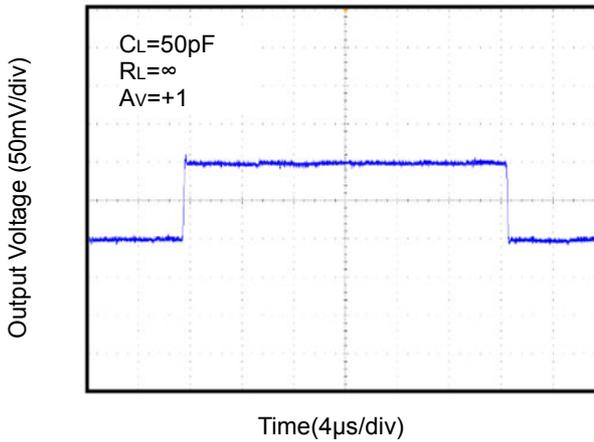
Time(4μs/div)

Closed Loop Gain vs. Frequency at +5V

Closed Loop Gain (dB)

G=-100
G=-10
G=+1

Frequency (kHz)

Closed Loop Gain vs. Frequency at +2.5V

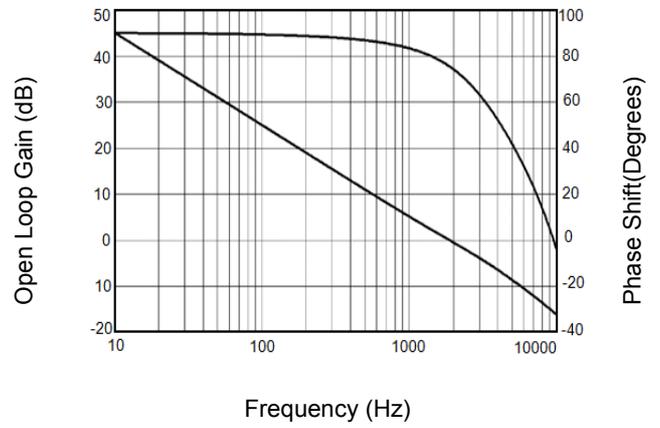Closed Loop Gain (dB)

G=-100
G=-10
G=+1
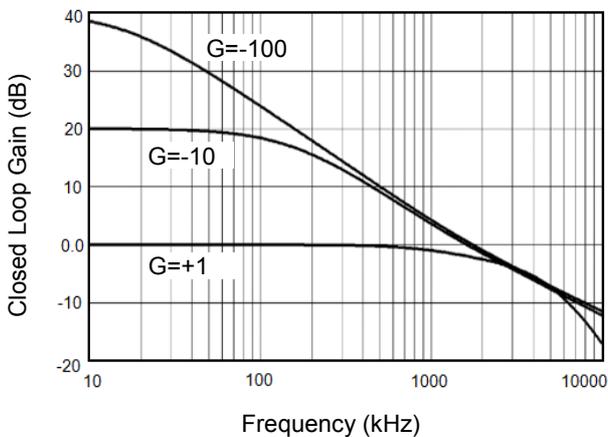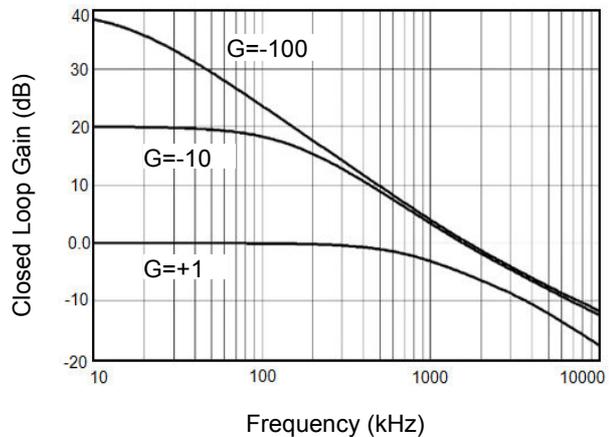
Frequency (kHz)

## Typical Performance characteristics

Open Loop Gain, Phase Shift
vs. Frequency at +5V
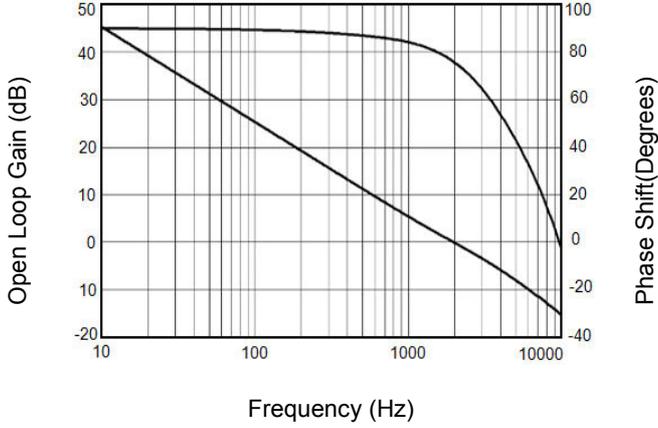


Open Loop Gain (dB)
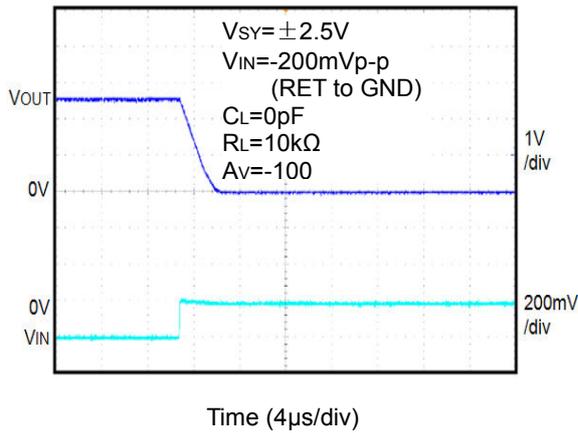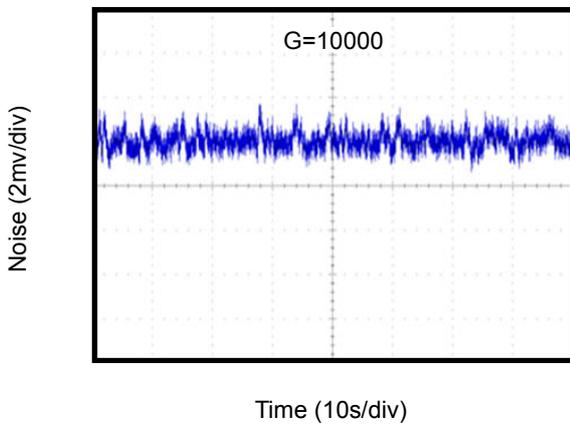Phase Shift(Degrees)
Frequency (Hz)

Open Loop Gain, Phase Shift
vs. Frequency at +2.5V



Open Loop Gain (dB)
Phase Shift(Degrees)
Frequency (Hz)

Positive Overvoltage Recovery



$V_{SY}=\pm 2.5V$
$V_{IN}=-200mVp\text{-}p$
(RET to GND)
$C_L=0pF$
$R_L=10k\Omega$
$A_V=-100$

VOUT
0V
0V
VIN
1V/div
200mV/div
Time (4µs/div)

Negative Overvoltage Recovery



Open Loop Gain (dB)

$V_{SY}=\pm 2.5V$
$V_{IN}=-200mVp\text{-}p$
(RET to GND)
$C_L=0pF$
$R_L=10k\Omega$
$A_V=-100$

VOUT
0V
0V
VIN
1V/div
200mV/div
Time (40µs/div)

0.1Hz to 10Hz Noise at +5V



G=10000
Noise (2mv/div)
Time (10s/div)
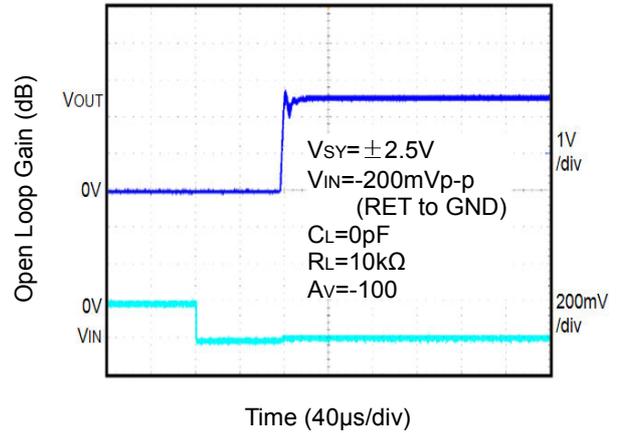
0.1Hz to 10Hz Noise at +2.5V



G=10000
Noise (2mv/div)
Time (10s/div)
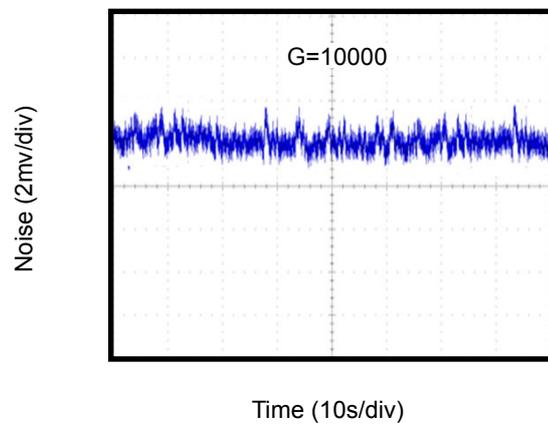
## Application Note

### Size

HGAx335 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the HGAx335 series packages save space on printed circuit boards and enable the design of smaller electronic products.

### Power Supply Bypassing and Board Layout

HGAx335 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 $V_{SS}$ supplies should be bypassed to ground with separate 0.1µF ceramic capacitors.

### Low Supply Current

The low supply current (typical 320uA per channel) of HGAx335 series will help to maximize battery life. They are ideal for battery powered systems

### Operating Voltage

HGAx335 series operate under wide input supply voltage (2.1V to 5.5V). In addition, all temperature specifications apply from -40 $^{o}$C to +125 $^{o}$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 HGAx335 series extends 100mV beyond the supply rails ($V_{SS}$-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 HGAx335 series can typically swing to less than 5mV from supply rail in light resistive loads (>100kΩ), and 60mV of supply rail in moderate resistive loads (10kΩ).

### Capacitive Load Tolerance

The HGAx335 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.
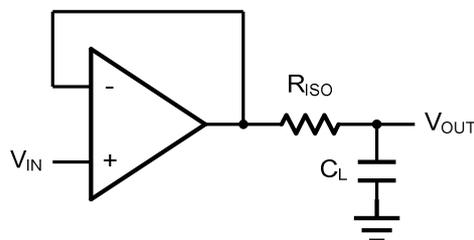


Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

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

The circuit in Figure 3 is an improvement to the one in Figure 2. $R_F$ provides the DC accuracy by feed-forward the $V_{IN}$ to $R_L$. $C_F$

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.
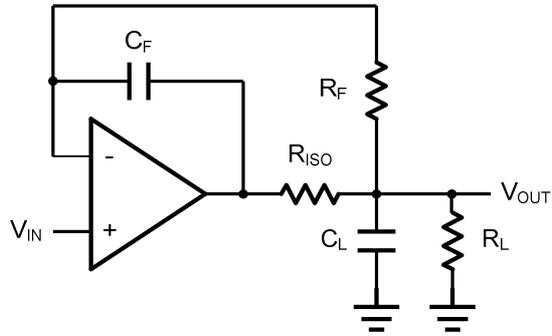


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

## Typical Application Circuits

### Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common 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 HGAx335.
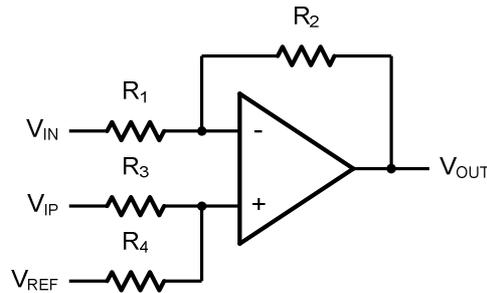


Figure 4. Differential Amplifier

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

If the resistor ratios are equal (i.e. $R_1=R_3$ 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 $f_C=1/(2\pi R_3 C_1)$.
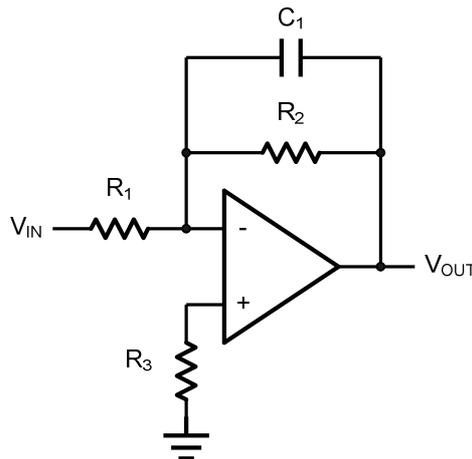


Figure 5. Low Pass Active Filter

## Instrumentation Amplifier

The triple HGAx335 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.
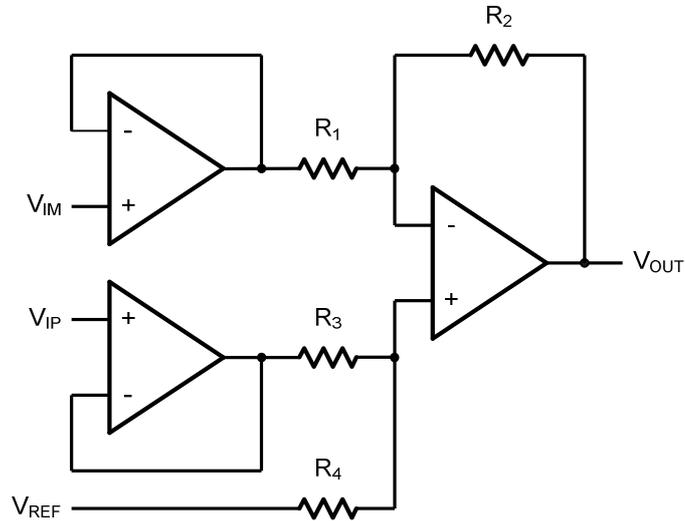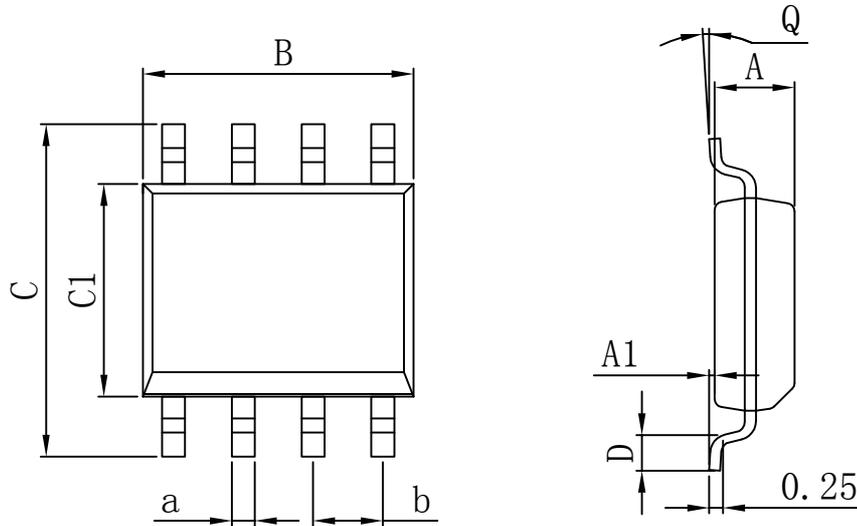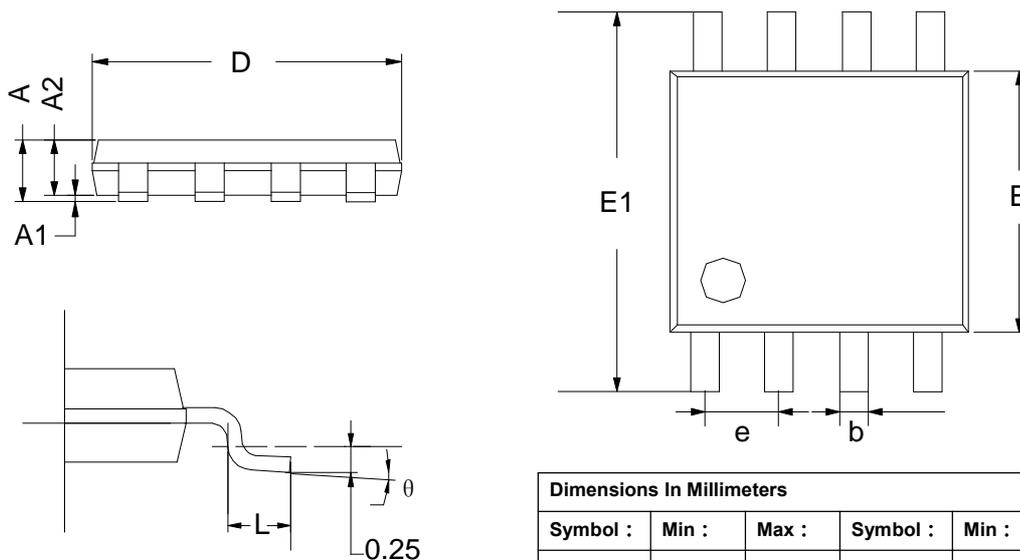
Figure 6. Instrument Amplifier

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**PACKAGE**

SOP8



| Dimensions In Millimeters | | | | | |
|---|---|---|---|---|---|
| **Symbol :** | **Min :** | **Max :** | **Symbol :** | **Min :** | **Max :** |
| **A** | 1.225 | 1.570 | **D** | 0.400 | 0.950 |
| **A1** | 0.100 | 0.250 | **Q** | 0° | 8° |
| **B** | 4.800 | 5.100 | **a** | 0.420 TYP | |
| **C** | 5.800 | 6.250 | **b** | 1.270 TYP | |
| **C1** | 3.800 | 4.000 | | | |

MSOP8



| Dimensions In Millimeters | | | | | |
|---|---|---|---|---|---|
| **Symbol :** | **Min :** | **Max :** | **Symbol :** | **Min :** | **Max :** |
| **A** | 0.800 | 1.200 | **E1** | 4.700 | 5.100 |
| **A1** | 0 | 0.200 | **L** | 0.410 | 0.650 |
| **A2** | 0.760 | 0.970 | **θ** | 0° | 6° |
| **D** | 2.900 | 3.100 | **b** | 0.300 TYP | |
| **E** | 2.900 | 3.100 | **e** | 0.650 TYP | |

**PACKAGE**

SOT23-5
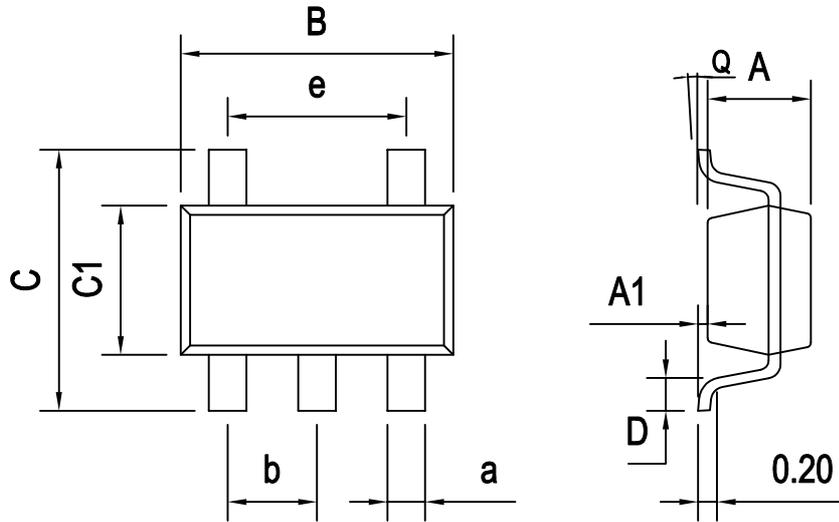


| Dimensions In Millimeters | | | | | |
|---|---|---|---|---|---|
| Symbol : | Min : | Max : | Symbol : | Min : | Max : |
| A | 1.050 | 1.150 | D | 0.300 | 0.600 |
| A1 | 0.000 | 0.100 | Q | 0° | 8° |
| B | 2.820 | 3.020 | a | 0.400 TYP | |
| C | 2.650 | 2.950 | b | 0.950 TYP | |
| C1 | 1.500 | 1.700 | e | 1.900 TYP | |

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