# 1MHZ 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: 1MHz (Typ.)**
- **Low Input Bias Current: 1pA (Typ.)**
- **Low Offset Voltage: 3.5mV (Max.)**
- **Quiescent Current: 40μA per Amplifier (Typ.)**
- **Operating Temperature: -40°C ~ +125°C**
- **Embedded RF Anti-EMI Filter**
- **Small Package:**

**LMV321 Available in SOT23-5 Packages**

**LMV358 Available in SOP-8, MSOP-8, DIP-8 Packages**

**LMV324 Available in SOP-14 and TSSOP-14 Packages**

## General Description

The LMV321 family have a high gain-bandwidth product of 1MHz, a slew rate of 0.6V/μs, and a quiescent current of 40μA/amplifier at 5V. The LMV321 family is 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 LMV321 family. They are specified over the extended industrial temperature range (-40℃ to +125℃). The operating range is from 2.1V to 5.5V.

## Applications

- ASIC Input or Output Amplifier
- Sensor Interface
- Medical Communication
- Smoke Detectors
- Audio Output
- Piezoelectric Transducer Amplifier
- Medical Instrumentation
- Portable Systems

## Ordering Information

| DEVICE | Package Type | MARKING | Packing | Packing Qty |
|---|---|---|---|---|
| LMV321CDBVRG | SOT23-5L | A13 | REEL | 3000pcs/reel |
| LMV321IDBVRG | SOT23-5L | A13 | REEL | 3000pcs/reel |
| LMV358CDRG | SOP8L | LMV358 | REEL | 2500pcs/reel |
| LMV358IDRG | SOP8L | LMV358 | REEL | 2500pcs/reel |
| LMV358CPG | DIP8L | LMV358 | TUBE | 1000pcs/box |
| LMV358IPG | DIP8L | LMV358 | TUBE | 1000pcs/box |
| LMV358CMMRG | MSOP8L | V358 | REEL | 3000pcs/reel |
| LMV358IMMRG | MSOP8L | V358 | REEL | 3000pcs/reel |
| LMV324CDRG | SOP14L | LMV324 | REEL | 2500pcs/reel |
| LMV324IDRG | SOP14L | LMV324 | REEL | 2500pcs/reel |
| LMV324CPWRG | TSSOP14L | LMV324 | REEL | 2500pcs/reel |
| LMV324IPWRG | TSSOP14L | LMV324 | REEL | 2500pcs/reel |

## Pin Configuration

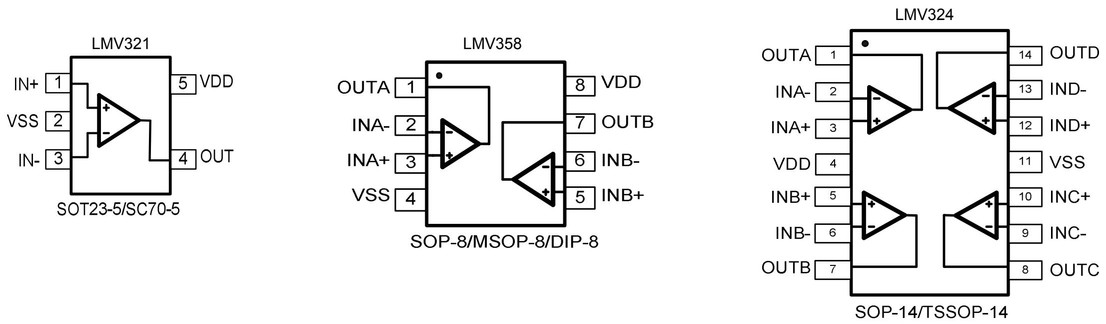



Figure 1. Pin Assignment Diagram

## 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 | LMV3xxI | -40°C | +125°C |
| | LMV3xxC | 0°C | + 70 °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 | | 300V | |

**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

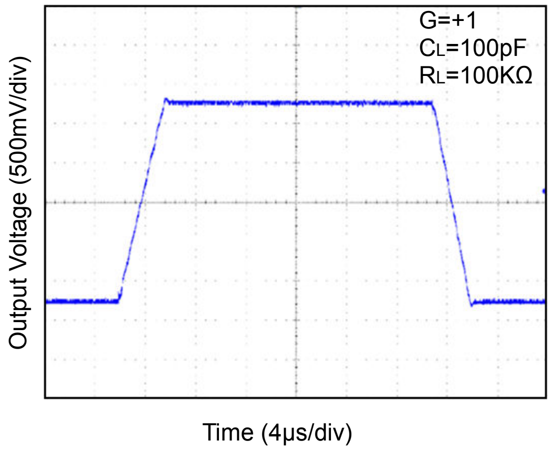
(At $V_S$ = +5V, $R_L$ = 100kΩ connected to $V_S$/2, and $V_{OUT}$ = $V_S$/2, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | LMV321/358/324 | | | | |
|---|---|---|---|---|---|---|---|
| | | | TYP | MIN/MAX OVER TEMPERATURE | | | |
| | | | +25℃ | +25℃ | -40℃ to +85℃ | UNITS | MIN/MAX |
| **INPUT CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | $V_{CM}$ = $V_S$/2 | 0.4 | 3.5 | 5.6 | mV | MAX |
| Input Bias Current | $I_B$ | | 1 | | | pA | TYP |
| Input Offset Current | $I_{OS}$ | | 1 | | | pA | TYP |
| 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 | 70 | 62 | 62 | dB | MIN |
| | | $V_S$ = 5.5V, $V_{CM}$ = -0.1V to 5.6V | 68 | 56 | 55 | | |
| Open-Loop Voltage Gain | $A_{OL}$ | $R_L$ = 5kΩ, $V_O$ = +0.1V to +4.9V | 80 | 70 | 70 | dB | MIN |
| | | $R_L$ = 10kΩ, $V_O$ = +0.1V to +4.9V | 100 | 90 | 85 | | |
| Input Offset Voltage Drift | $\Delta V_{OS}/\Delta_T$ | | 2.7 | | | μV/°C | TYP |
| **OUTPUT CHARACTERISTICS** | | | | | | | |
| Output Voltage Swing from Rail | $V_{OH}$ | $R_L$ = 100kΩ | 4.997 | 4.990 | 4.980 | V | MIN |
| | $V_{OL}$ | $R_L$ = 100kΩ | 3 | 10 | 20 | mV | MAX |
| | $V_{OH}$ | $R_L$ = 10kΩ | 4.992 | 4.970 | 4.960 | V | MIN |
| | $V_{OL}$ | $R_L$ = 10kΩ | 8 | 30 | 40 | mV | MAX |
| Output Current | $I_{SOURCE}$ | $R_L$ = 10Ω to $V_S$/2 | 84 | 60 | 45 | mA | MIN |
| | $I_{SINK}$ | | 75 | 60 | 45 | | |
| **POWER SUPPLY** | | | | | | | |
| Operating Voltage Range | | | | 2.1 | 2.5 | V | MIN |
| | | | | 5.5 | 5.5 | V | MAX |
| Power Supply Rejection Ratio | PSRR | $V_S$ = +2.5V to +5.5V, $V_{CM}$ = +0.5V | 82 | 60 | 58 | dB | MIN |
| Quiescent Current / Amplifier | $I_Q$ | | 40 | 60 | 80 | μA | MAX |
| **DYNAMIC PERFORMANCE (CL = 100pF)** | | | | | | | |
| Gain-Bandwidth Product | GBP | | 1 | | | MHz | TYP |
| Slew Rate | SR | G = +1, 2V Output Step | 0.6 | | | V/μs | TYP |
| Settling Time to 0.1% | $t_S$ | G = +1, 2V Output Step | 5 | | | μs | TYP |
| Overload Recovery Time | | $V_{IN}$ ·Gain = $V_S$ | 2.6 | | | μs | TYP |
| **NOISE PERFORMANCE** | | | | | | | |
| Voltage Noise Density | $e_n$ | f = 1kHz | 27 | | | $nV/\sqrt{Hz}$ | TYP |
| | | f = 10kHz | 20 | | | $nV/\sqrt{Hz}$ | TYP |

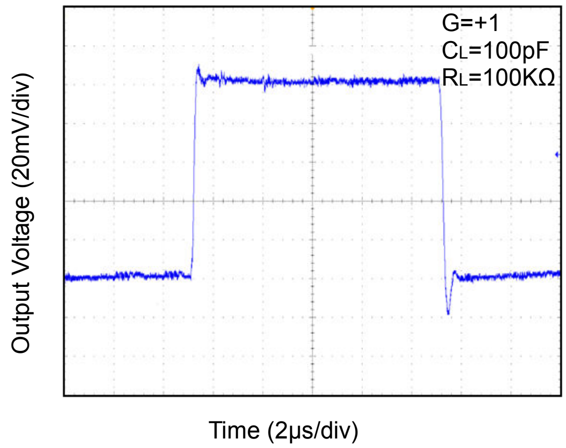
## Typical Performance characteristics

At $T_A$=+25°C, $V_S$=+5V, and $R_L$=100KΩ connected to $V_S$/2, unless otherwise noted.

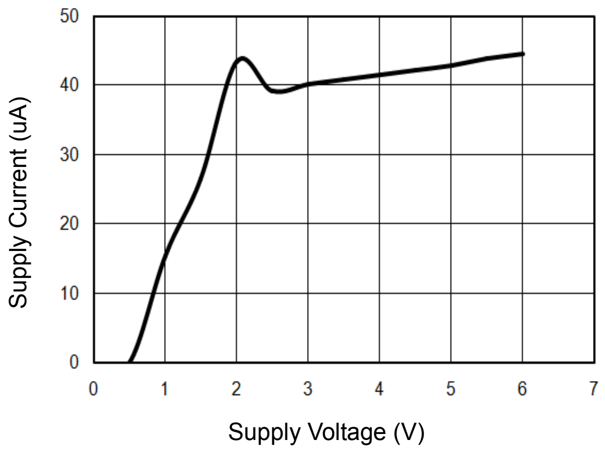
Large-Signal Step Response



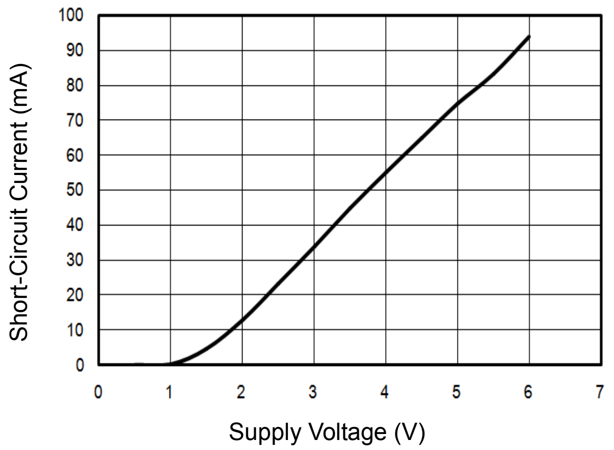

Small-Signal Step Response



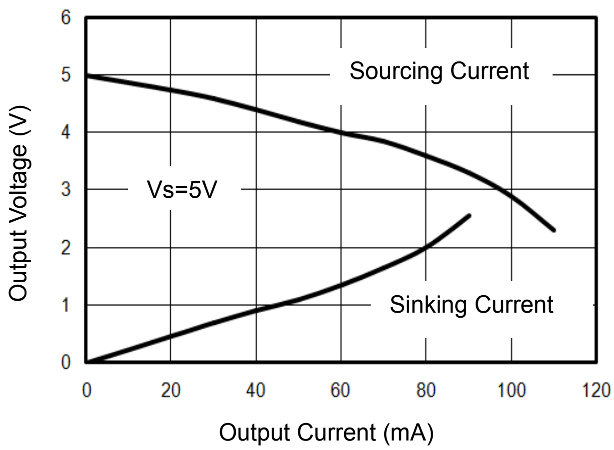

Supply Current vs. Supply Voltage



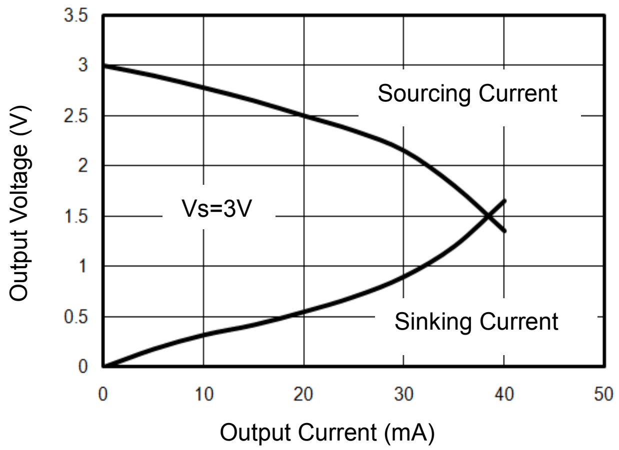

Short-Circuit Current vs. Supply Voltage




Output Voltage vs. Output Current



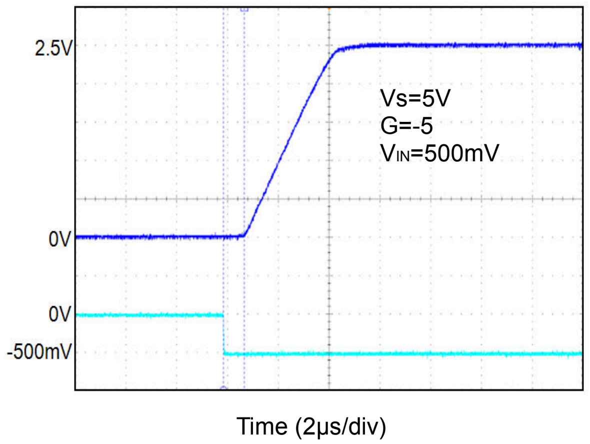

Output Voltage vs. Output Current



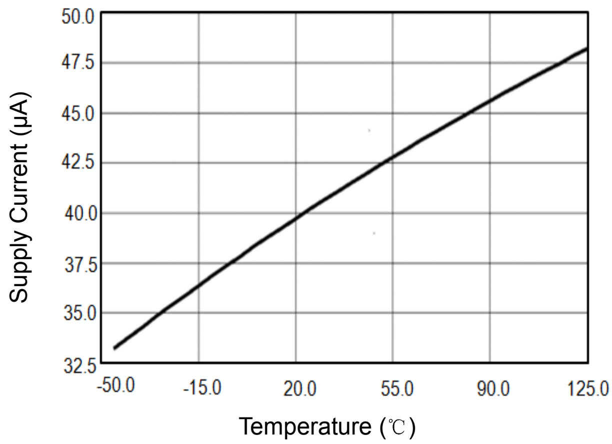
## Typical Performance characteristics

At $T_A$=+25°C, $V_S$=+5V, and $R_L$=100KΩ connected to $V_S$/2, unless otherwise noted.

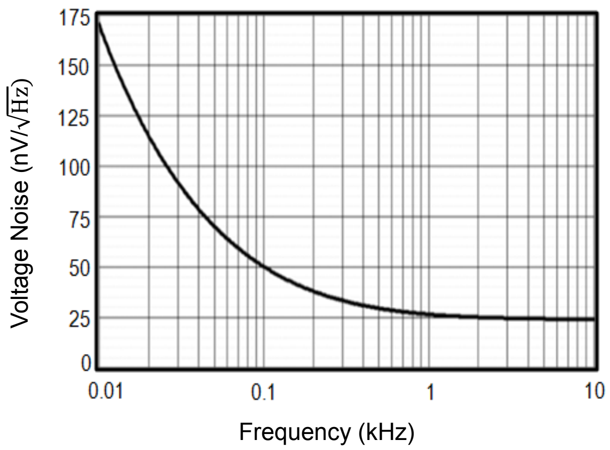
Overload Recovery Time



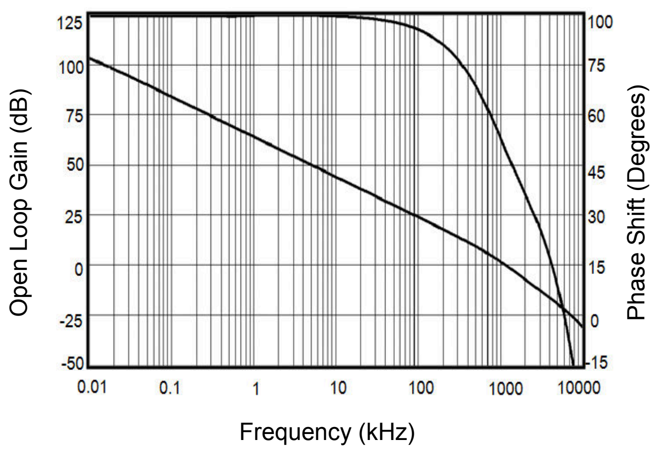

Supply Current vs. Temperature



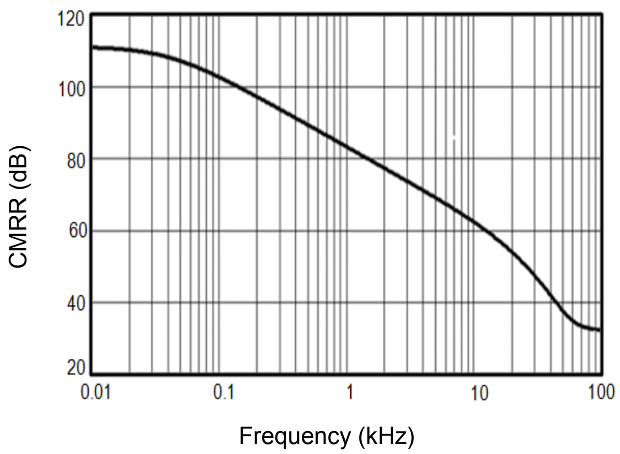

Input Voltage Noise Spectral Density vs. Frequency



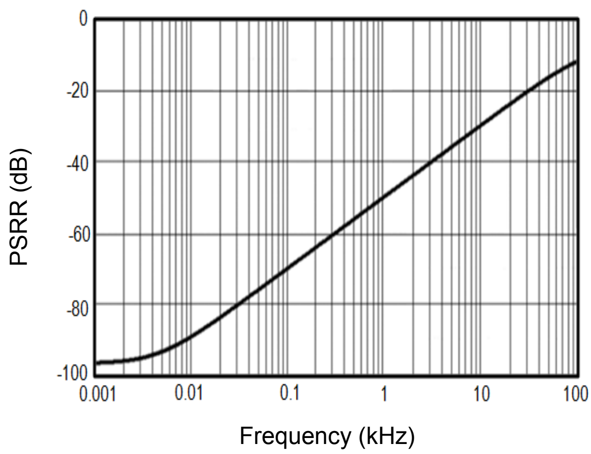

Open Loop Gain, Phase Shift vs. Frequency at +5V




CMRR vs. Frequency




PSRR vs. Frequency



## Application Note

### Size

LMV321 family series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the LMV321 family packages save space on printed circuit boards and enable the design of smaller electronic products.

### Power Supply Bypassing and Board Layout

LMV321 family 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 40uA per channel) of LMV321 family will help to maximize battery life. They are ideal for battery powered systems

### Operating Voltage

LMV321 family operates 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 LMV321 family 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 LMV321 family can typically swing to less than 5mV from supply rail in light resistive loads (>100kΩ), and 30mV of supply rail in moderate resistive loads (10kΩ).

### Capacitive Load Tolerance

The LMV321 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.

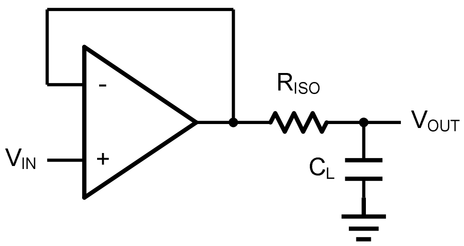



Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

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.

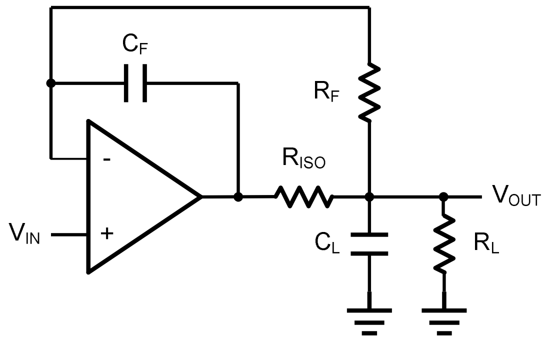



Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

## 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 LMV321 family.

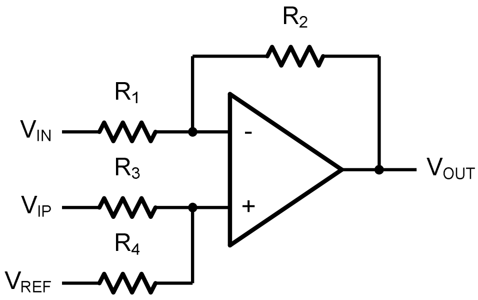



Figure 4. Differential Amplifier

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

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 $f_C=1/(2\pi R_3C_1)$.

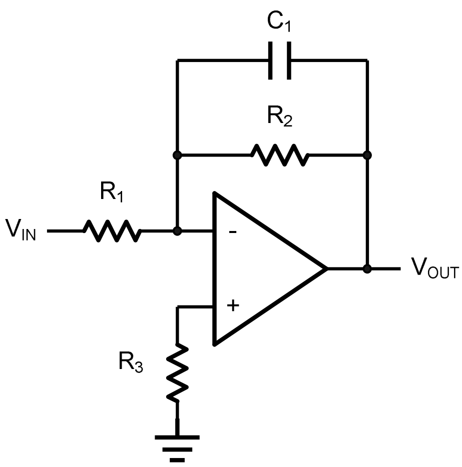



Figure 5. Low Pass Active Filter

## Instrumentation Amplifier

The triple LMV321 family 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.

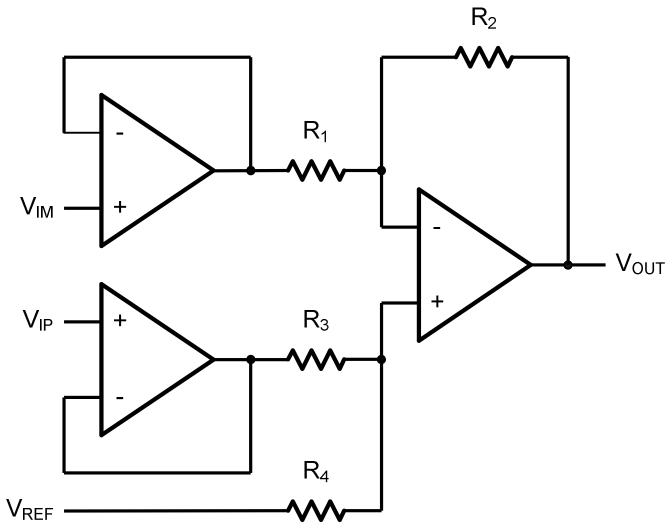
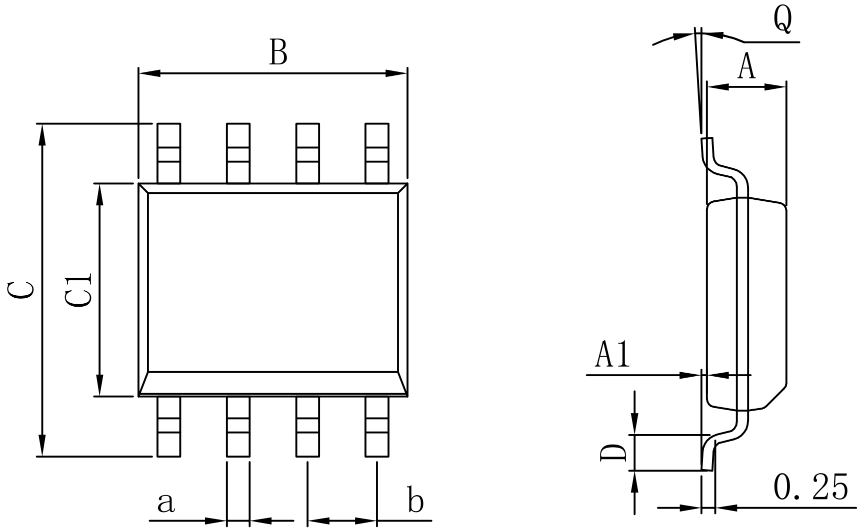



Figure 6. Instrument Amplifier

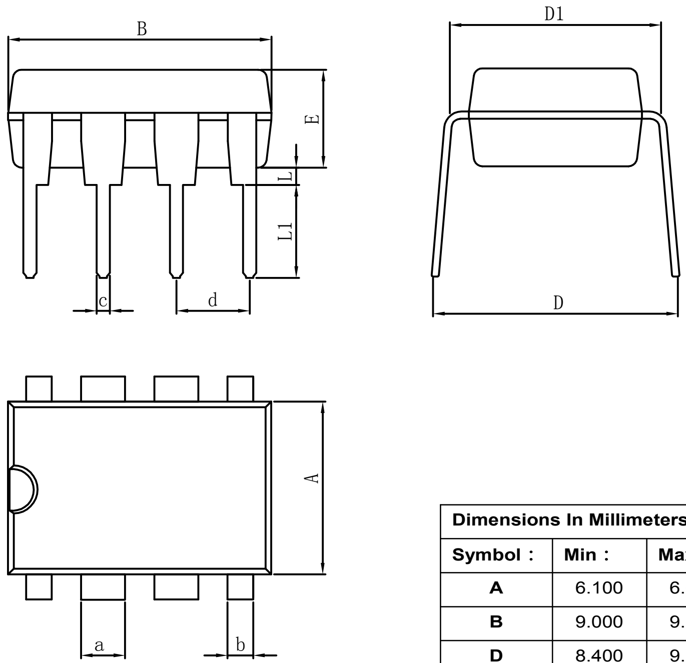
## PACKAGE

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 | | | |

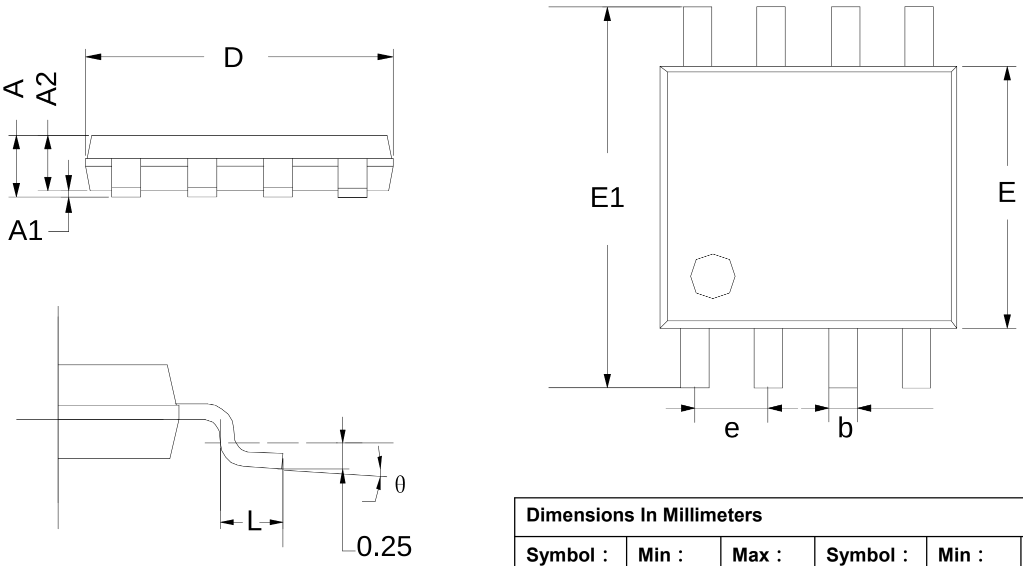
DIP8




| Dimensions In Millimeters | | | | | |
|---|---|---|---|---|---|
| Symbol : | Min : | Max : | Symbol : | Min : | Max : |
| A | 6.100 | 6.680 | L1 | 3.000 | 3.600 |
| B | 9.000 | 9.500 | a | 1.524 TYP | |
| D | 8.400 | 9.000 | b | 0.889 TYP | |
| D1 | 7.420 | 7.820 | c | 0.457 TYP | |
| E | 3.100 | 3.550 | d | 2.540 TYP | |
| L | 0.500 | 0.700 | | | |

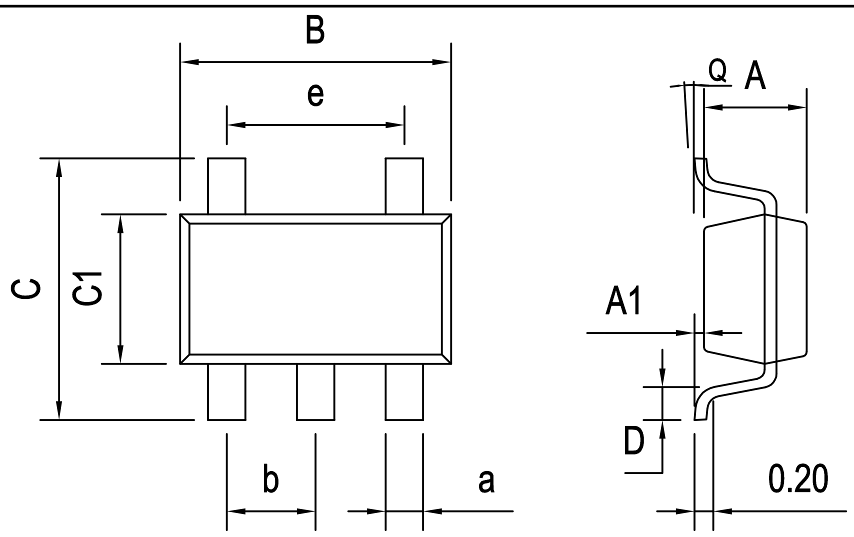
## PACKAGE

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 | |

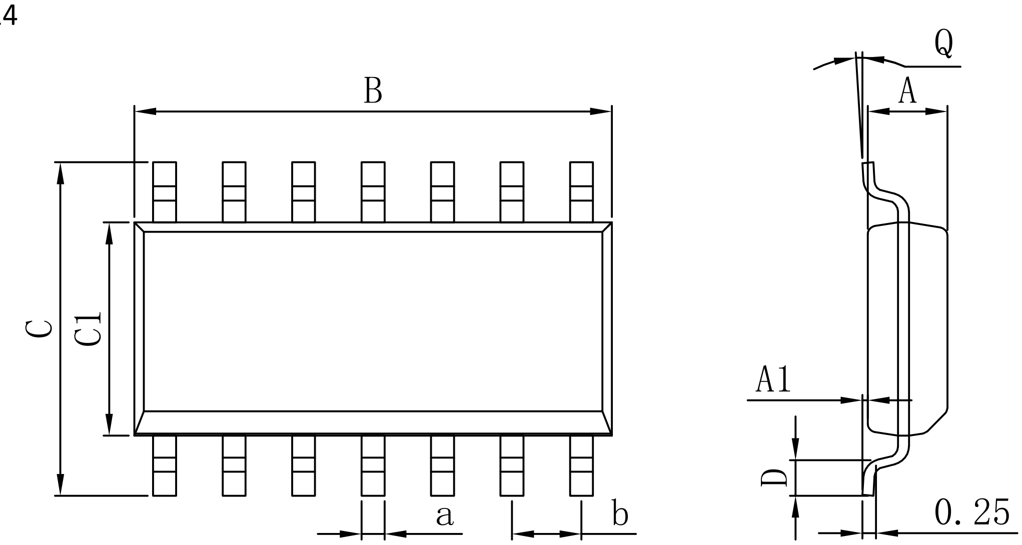
SOT23-5




| 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 | |

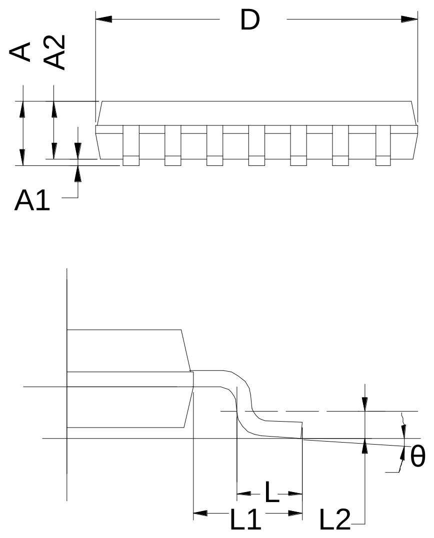
## PACKAGE

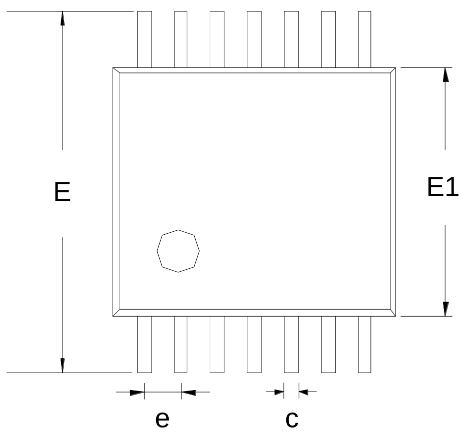
SOP14




| 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** | 8.500 | 9.000 | **a** | 0.420 TYP | |
| **C** | 5.800 | 6.250 | **b** | 1.270 TYP | |
| **C1** | 3.800 | 4.000 | | | |

TSSOP14




| Dimensions In Millimeters | | | | | |
|---|---|---|---|---|---|
| **Symbol :** | **Min :** | **Max :** | **Symbol :** | **Min :** | **Max :** |
| **A** | 0.950 | 1.200 | **E1** | 4.300 | 4.500 |
| **A1** | 0.050 | 0.150 | **L** | 0.450 | 0.750 |
| **A2** | 0.800 | 1.000 | **θ** | 0° | 8° |
| **B** | 0.200 | 0.280 | **e** | 0.650 BSC | |
| **C** | 0.100 | 0.190 | **L1** | 1.000 REF | |
| **D** | 4.860 | 5.060 | **L2** | 1.250 BSC | |
| **E** | 6.200 | 6.600 | | | |

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