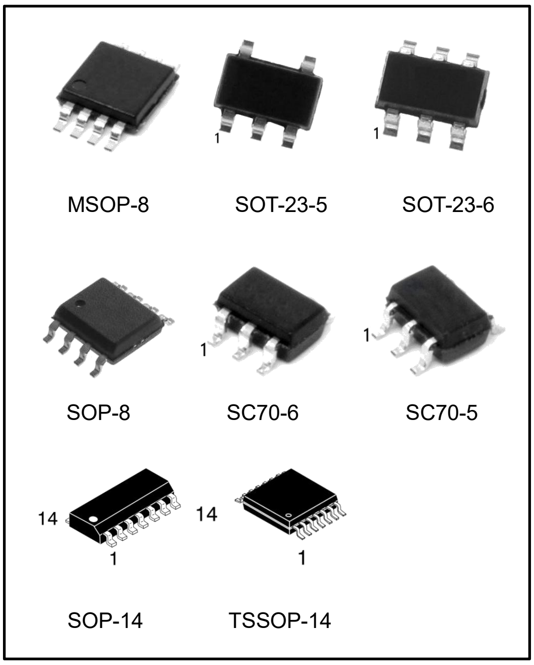
# 11MHz CMOS Rail-to-Rail IO Opamps

## 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:

LMV721 Available in SOT23-5 , SC70-5 , SOP-8 and MSOP-8 Packages
LMV722 Available in SOP-8 and MSOP-8 Packages
LMV724 Available in SOP-14 and TSSOP-14 Packages
LMV721N Available in SOT23-6 and SC70-6 Packages




## Ordering Information

| DEVICE | Package Type | MARKING | Packing | Packing Qty |
|---|---|---|---|---|
| LMV721M5/TR | SOT-23-5 | V721,LMV721,A30A | REEL | 3000pcs/reel |
| LMV721M7/TR | SC70-5 | V721 | REEL | 3000pcs/reel |
| LMV721M/TR | SOP-8 | LMV721 | REEL | 2500pcs/reel |
| LMV721MM/TR | MSOP-8 | V721 | REEL | 3000pcs/reel |
| LMV721NM6/TR | SOT-23-6 | V721N | REEL | 3000pcs/reel |
| LMV721NM7/TR | SC70-6 | V721N | REEL | 3000pcs/reel |
| LMV722M/TR | SOP-8 | LMV722 | REEL | 2500pcs/reel |
| LMV722MM/TR | MSOP-8 | LMV722,V722 | REEL | 3000pcs/reel |
| LMV724M/TR | SOP-14 | LMV724 | REEL | 2500pcs/reel |
| LMV724MT/TR | TSSOP-14 | LMV724 | REEL | 2500pcs/reel |

## General Description

The LMV72X have a high gain-bandwidth product of 11 MHz, a slew rate of 9V/μs, and a quiescent current of 1.1mA per amplifier at 5V. The LMV721N has a power-down disable feature that reduces the supply current to 90nA. The LMV72X 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 LMV72X. They are specified over the extended industrial temperature range (-40℃ to +125℃). The operating range is from 2.1V to 5.5V. The LMV721 single is available in Green SC70-5, SOT23-5, SOP-8 and MSOP-8 packages. The LMV722 dual is available in Green SOP-8 and MSOP-8 packages. The LMV724 Quad is available in Green SOP-14 and TSSOP-14 packages. The LMV721N single with shutdown is available in Green SOT23-6 and SC70-6 packages.

## Applications

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

## Pin Configuration

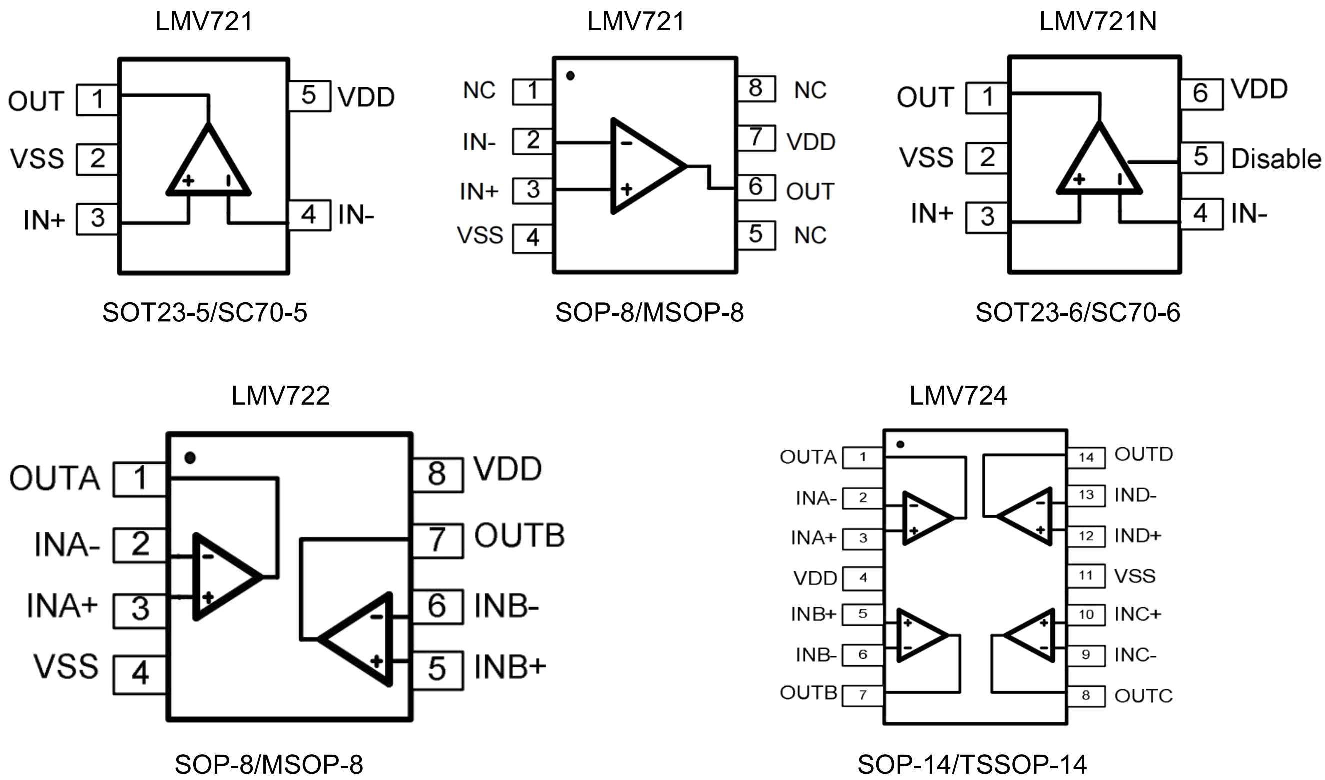



Figure 1. Pin Assignment Diagram

## Absolute Maximum Ratings

| Condition | Min | Max |
|---|---|---|
| Power Supply Voltage ($V_{DD}$ to 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 ($T_A$=+25℃)** | | |
| SOP-8, $\theta_{JA}$ | - | 125°C/W |
| MSOP-8, $\theta_{JA}$ | - | 216°C/W |
| SOT23-5, $\theta_{JA}$ | - | 190°C/W |
| SOT23-6, $\theta_{JA}$ | - | 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 | LMV721/2/4/1N | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 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 | 91 | 74 | 72 | 72 | 68 | dB | MIN |
| Quiescent Current/Amplifier ($I_Q$) | $V_{CM}$ = ($-V_S$) + 0.5V | 1.1 | 1.5 | 1.65 | 1.7 | 1.85 | Ma | MAX |
| Supply Current when Disabled (LMV721N Only) | $I_{OUT}$ = 0 | 90 | | | | | nA | MAX |

## Electrical Characteristics

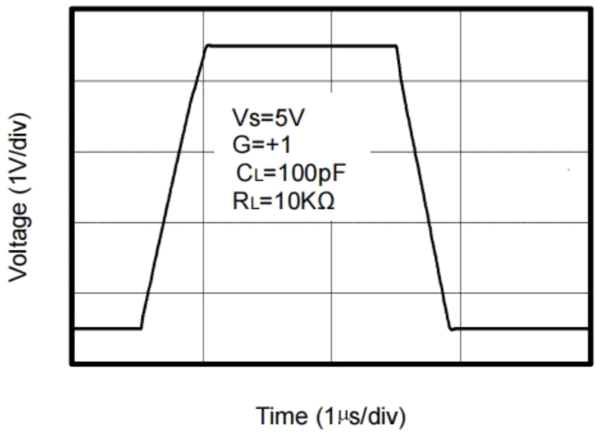
(At Vs=5V, TA = +25℃, VCM = VS/2, RL = 600Ω, unless otherwise noted.)

| PARAMETER | CONDITIONS | LMV721/2/4/1N | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 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 | 11 | | | | | MHz | TYP |
| Phase Margin ($φ_O$) | $R_L$ = 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 |

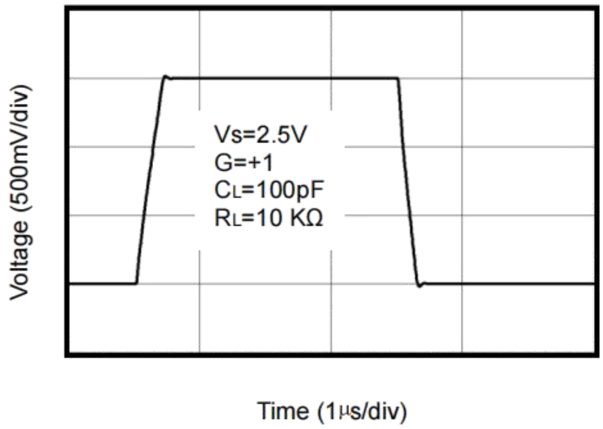
## Typical Performance characteristics

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

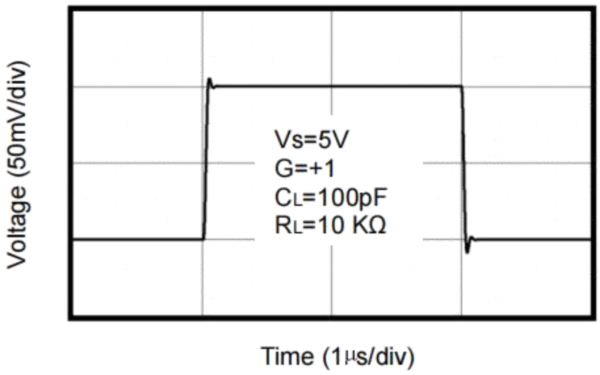
Large-Signal Step Response



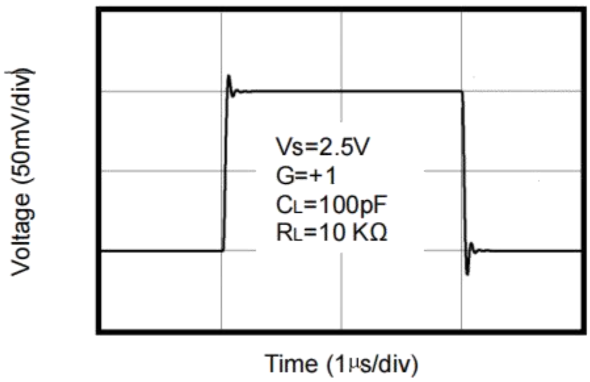

Large-Signal Step Response



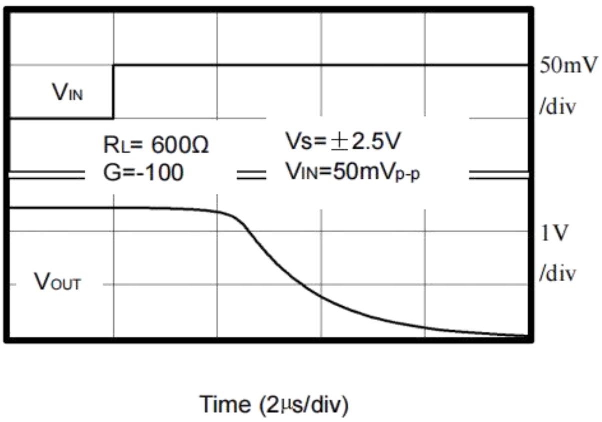

Small-Signal Step Response



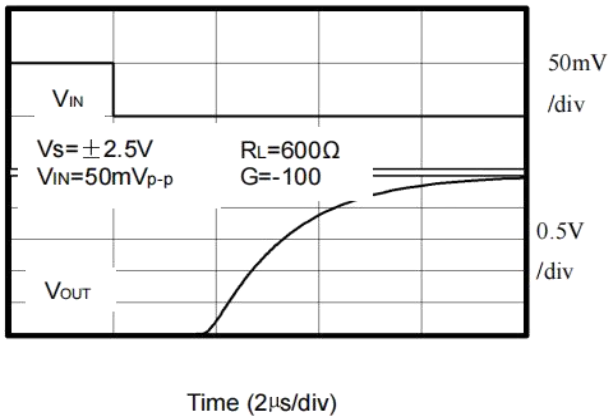

Small-Signal Step Response




Positive Overload Recovery



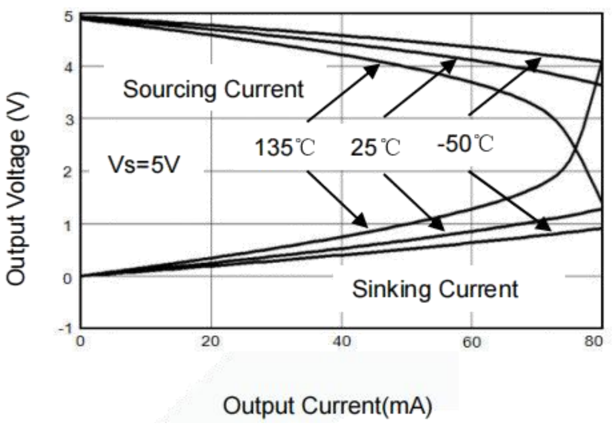

Negative Overload Recovery



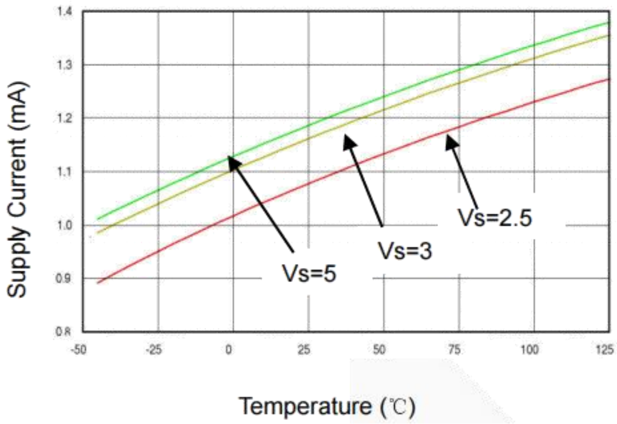
## Typical Performance characteristics

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

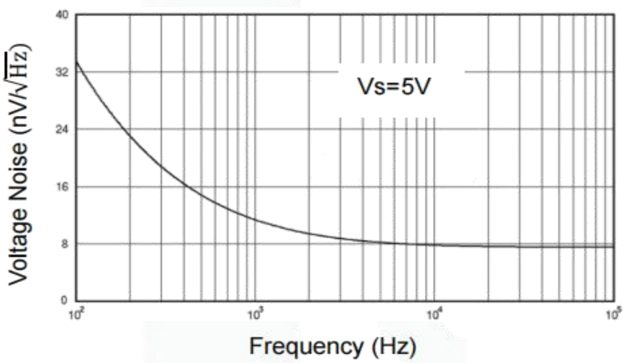
Output Voltage Swing vs.Output Current



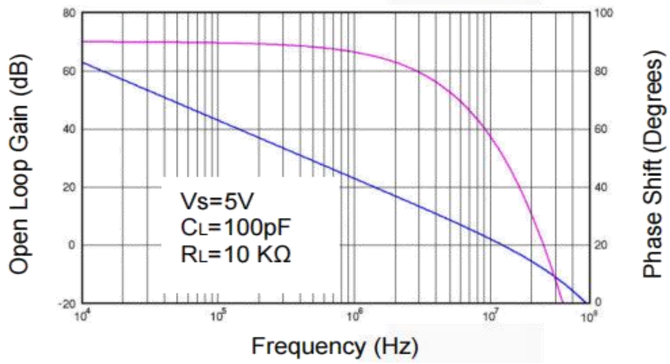

Supply Current vs. Temperature



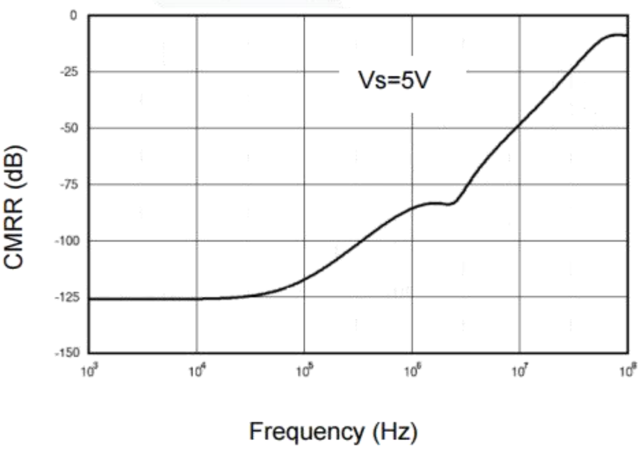

Input Voltage Noise Spectral Density vs. Frequency



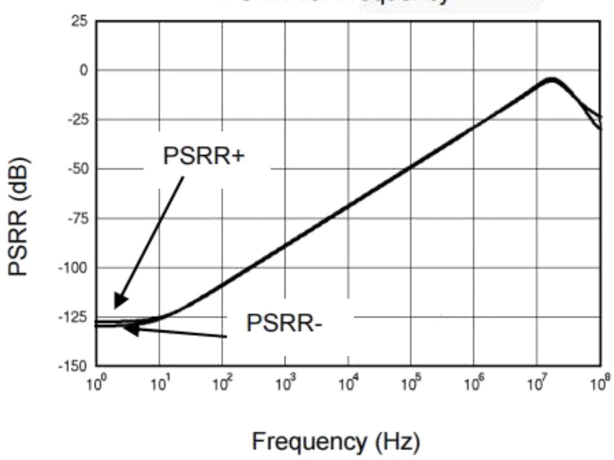

Open Loop Gain, Phase Shift vs. Frequency




CMRR vs. Frequency




PSRR vs. Frequency



# Application Note

## Size

LMV72X series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the LMV72X series packages save space on printed circuit boards and enable the design of smaller electronic products.

## Power Supply Bypassing and Board Layout

LMV72X 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 VDD pin in single supply operation. For dual supply operation, both VDD 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 LMV72X series will help to maximize battery life . They are ideal for battery powered systems

## Operating Voltage

LMV72X 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 LMV72X series extends 100mV beyond the supply rails (V SS-0.1V to VDD+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 LMV72X 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 LMV72X 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.

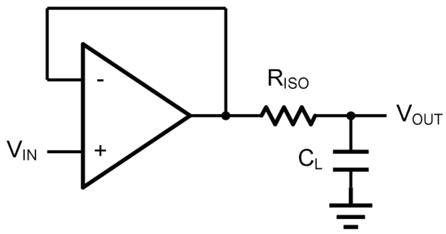



Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

The bigger the 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.

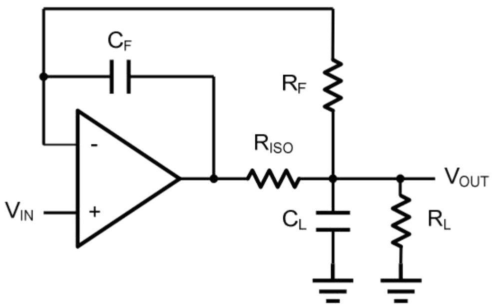



Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

# 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 LMV72X.

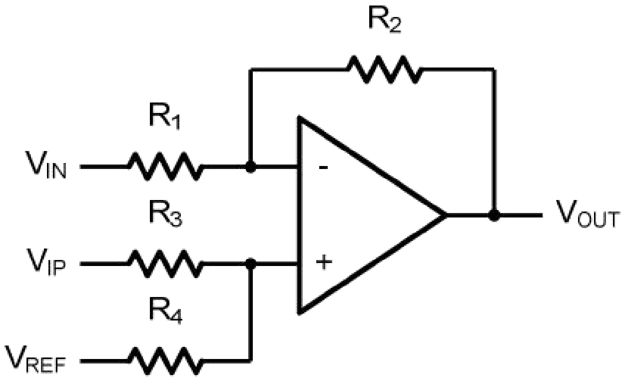



Figure 4. Differential Amplifier

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

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 ƒC=1/(2πR3C1).

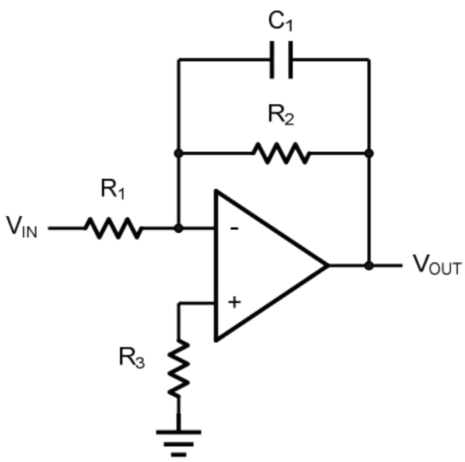



Figure 5. Low Pass Active Filter

## Instrumentation Amplifier

The triple LMV72X 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.

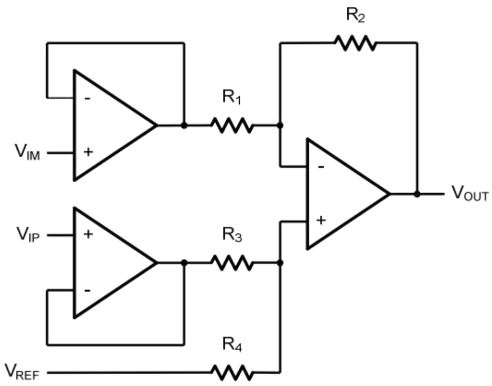
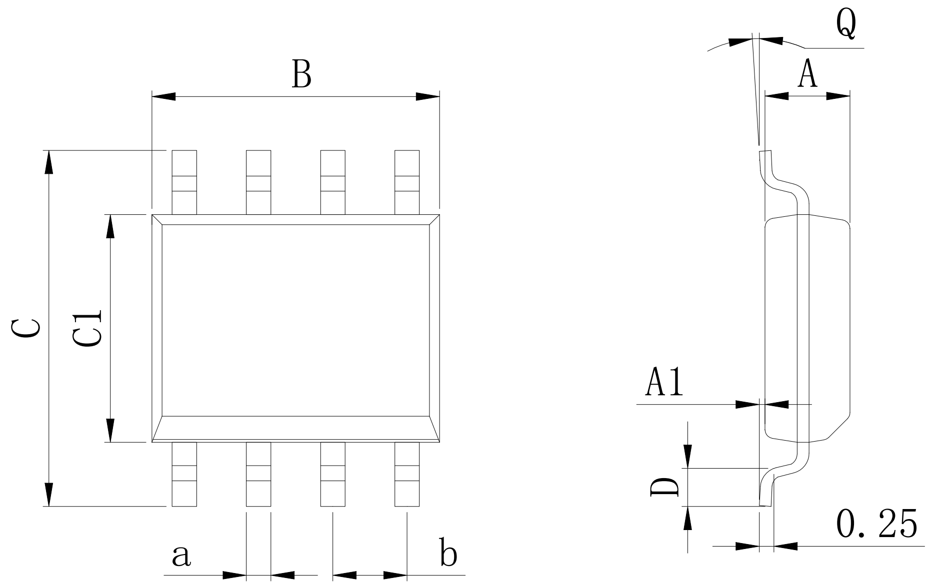



Figure 6. Instrument Amplifier

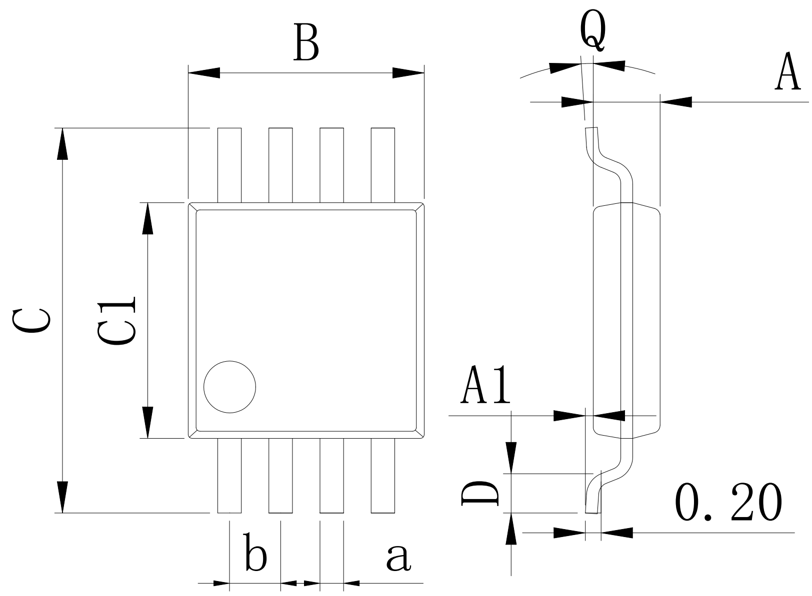
## Physical Dimensions

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 | |

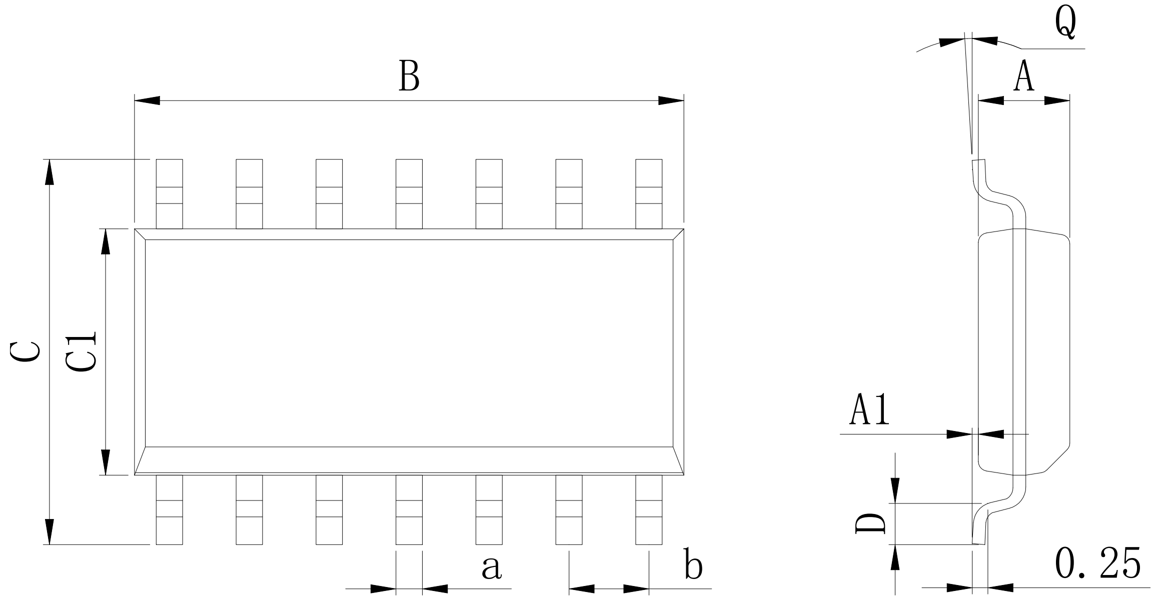
MSOP-8




| 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 | |

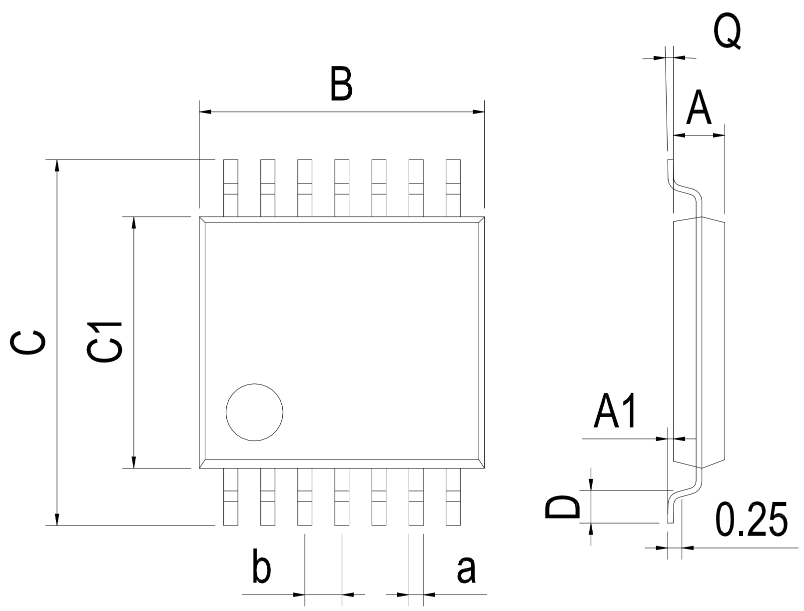
## Physical Dimensions

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 | |

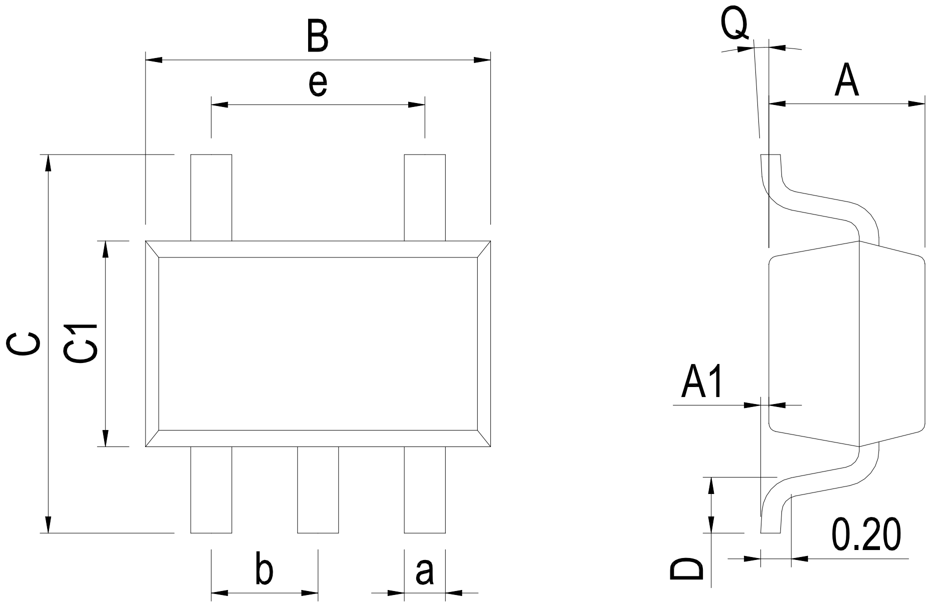
TSSOP-14




| 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 | |

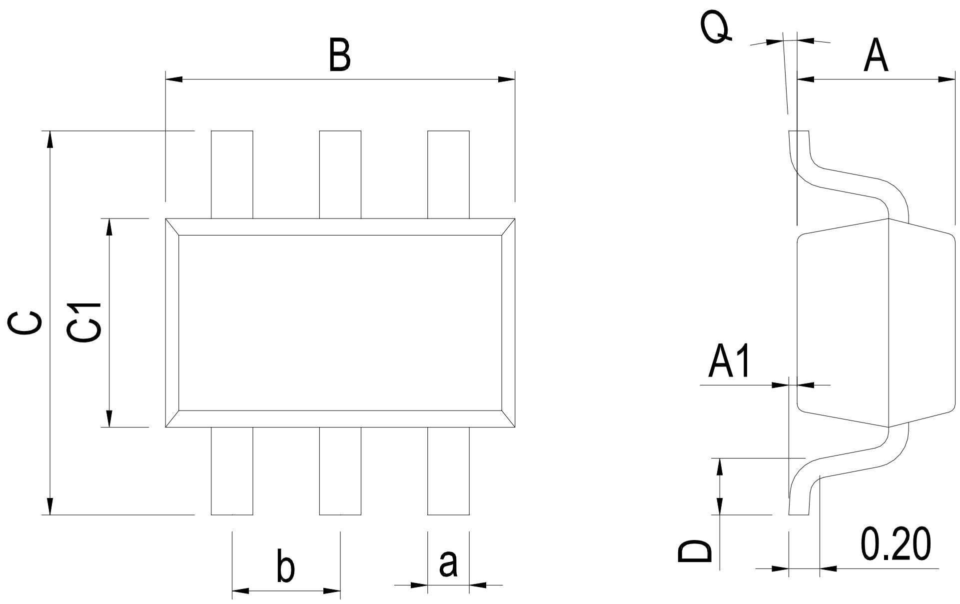
## Physical Dimensions

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 | | |

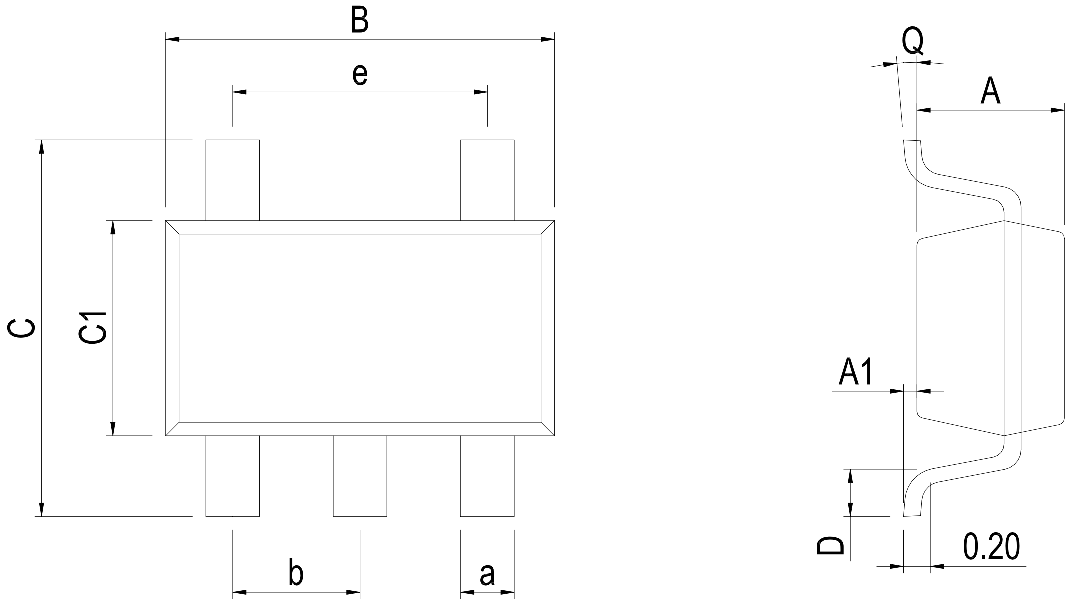
SOT-23-6




| Dimensions In Millimeters(SOT-23-6) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b |
| **Min:** | 1.05 | 0.00 | 2.82 | 2.65 | 1.50 | 0.30 | 0° | 0.30 | 0.95 BSC |
| **Max:** | 1.15 | 0.15 | 3.02 | 2.95 | 1.70 | 0.60 | 8° | 0.40 | |

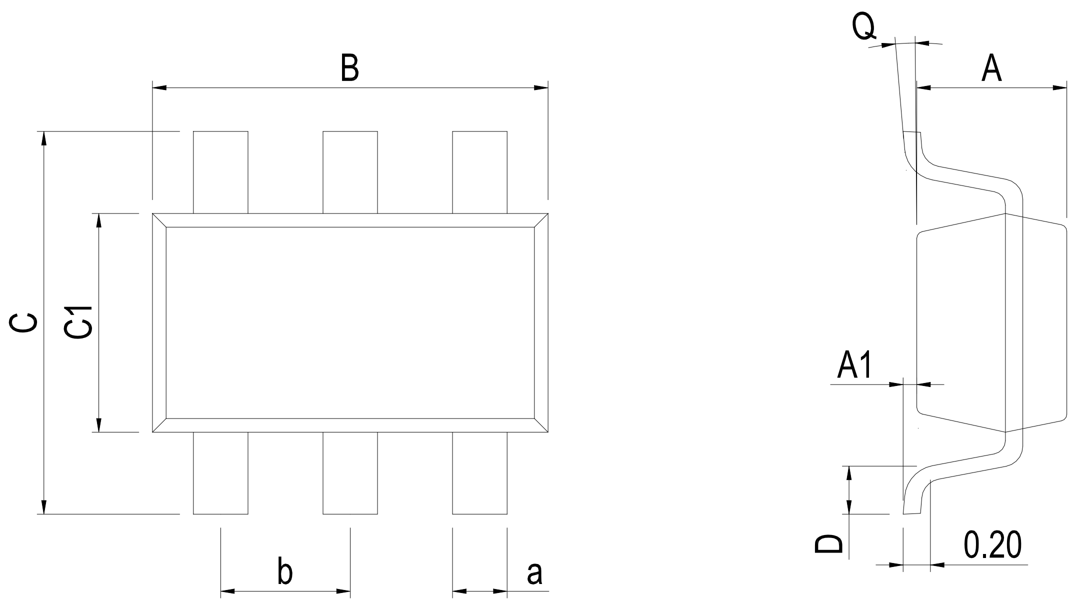
## Physical Dimensions

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° | 0.30 | 0.65 BSC | 1.30 BSC |
| **Max:** | 1.00 | 0.15 | 2.20 | 2.45 | 1.35 | 0.46 | 8° | 0.40 | | |

SC70-6




| Dimensions In Millimeters(SC70-6) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Symbol:** | A | A1 | B | C | C1 | D | Q | a | b |
| **Min:** | 0.90 | 0.00 | 2.00 | 2.15 | 1.15 | 0.26 | 0° | 0.30 | 0.65 BSC |
| **Max:** | 1.00 | 0.15 | 2.20 | 2.45 | 1.35 | 0.46 | 8° | 0.40 | |

## Revision History

| DATE | REVISION | PAGE |
|---|---|---|
| 2016-7-5 | New | 1-17 |
| 2023-7-20 | Update encapsulation type、Update Lead Temperature | 1、3 |

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