1MHZ CMOS Rail-to-Rail IO Op Amp

1. Description

The MCP6001 family have a high gain-bandwidth product of 1MHz, a slew rate of 0.8V/μs, and a quiescent current of 75μ A/amplifier at 5V. The MCP6001 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 MCP6001 family. They are specified over the extended industrial temperature range (-40 ˚C to +125˚C). The operating range is from 1.8V to 6V.

2. Features

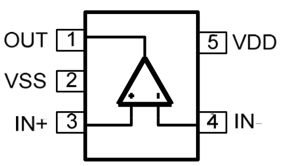
- Single-Supply Operation from +1.8V ~ +6V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 1MHz (Typ.)
- Low Input Bias Current: 1pA (Typ.)
- Low Offset Voltage: 3.5mV (Max.)
- Quiescent Current: 75μA per Amplifier (Typ.)
- Embedded RF Anti-EMI Filter
- Small Package:
  - MCP6001 Available in SOT23-5 and SC70-5 Packages
  - MCP6002 Available in SOIC-8 and MSOP-8 Packages
  - MCP6004 Available in SOIC-14 and TSSOP-14 Packages

3. Applications

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

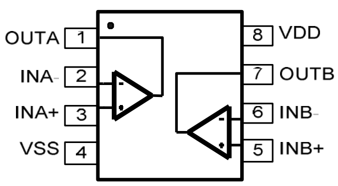
4. Pin Configuration

MCP6001



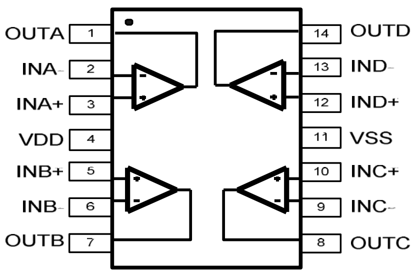
SOT-23-5/SC-70-5

MCP6002



SOIC-8/MSOP-8

MCP6004



SOIC-14/TSSOP-14

Fig. 1. Pin Assignment Diagram

5. Ordering Information

Part Number	Package Type	Packing
MCP6001T-I/OT	SOT-23-5	Tape & Reel
MCP6001T-E/OT	SOT-23-5	Tape & Reel
MCP6001T-I/LT	SC-70-5	Tape & Reel
MCP6001T-E/LT	SC-70-5	Tape & Reel
MCP6002T-I/SN	SOIC-8	Tape & Reel
MCP6002T-E/SN	SOIC-8	Tape & Reel
MCP6002T-I/MS	MSOP-8	Tape & Reel
MCP6002T-E/MS	MSOP-8	Tape & Reel
MCP6004T-I/SL	SOIC-14	Tape & Reel
MCP6004T-E/SL	SOIC-14	Tape & Reel
MCP6004T-I/ST	TSSOP-14	Tape & Reel
MCP6004T-E/ST	TSSOP-14	Tape & Reel

Note: If the physical information is inconsistent with the ordering information, please refer to the actual product.

6. 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	
Package Thermal Resistance (T_A=+25°C)		
SOP-8, θ_{JA}	125°C/W	
MSOP-8, θ_{JA}	216°C/W	
SOT23-5, θ_{JA}	190°C/W	
SC70-5, θ_{JA}	333°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.

7. Electrical Characteristics

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

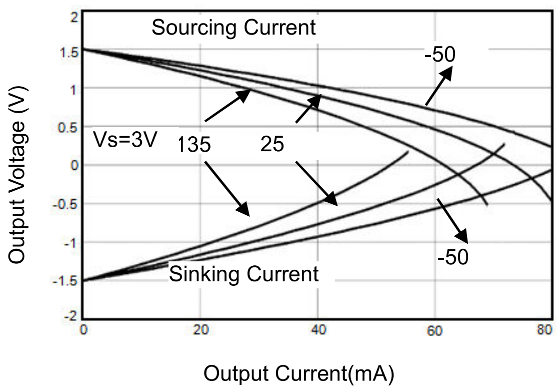
PARAMETER	SYMBOL	CONDITIONS	MCP6001/2/4				
			TYP	MIN/MAX OVER TEMPERATURE			
			+25°C	+25°C	-40°C to +85°C	UNITS	MIN/MAX
INPUT CHARACTERISTICS							
Input Offset Voltage	V_{OS}	V_{CM} = VS/2	0.8	3.5	5.6	mV	MAX
Input Bias Current	I_B		1			pA	TYP
Input Offset Current	I_{OS}		1			pA	TYP
Common-Mode Voltage Range	V_{CM}	V_S = 5.5V	-0.1 to +5.6			V	TYP
Common-Mode Rejection Ratio	CMRR	VS = 5.5V, VCM = -0.1V to 4V	70	62	62	dB	MIN
		VS = 5.5V, VCM = -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	94	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	4.980	4.970	V	MIN
	V_{OL}	R_L = 100kΩ	5	20	30	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 VS/2	84	60	45	mA	MIN
	I_{SINK}		75	60	45		
POWER SUPPLY							
Operating Voltage Range				1.8	1.8	V	MIN
				6	6	V	MAX
Power Supply Rejection Ratio	PSRR	V_S = +2.5V to +6V, V_{CM} = +0.5V	82	60	58	dB	MIN
Quiescent Current / Amplifier	I_Q		75	110	125	μA	MAX
DYNAMIC PERFORMANCE (CL = 100pF)							
Gain-Bandwidth Product	GBP		1			MHz	TYP
Slew Rate	SR	G = +1, 2V Output Step	0.8			V/μs	TYP

Settling Time to 0.1%	t_S	G = +1, 2V Output Step	5.3			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

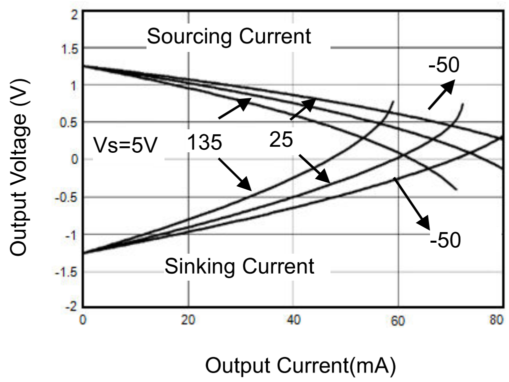
8. Typical Performance Characteristics

At T_A=+25˚C, V_s=5V, R_L=100KΩ connected to $V_S/2$ and V_{OUT}= $V_S/2$, unless otherwise noted.

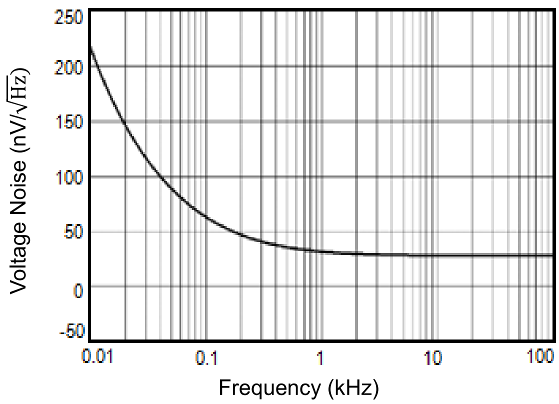
Output Voltage Swing vs.Output Current



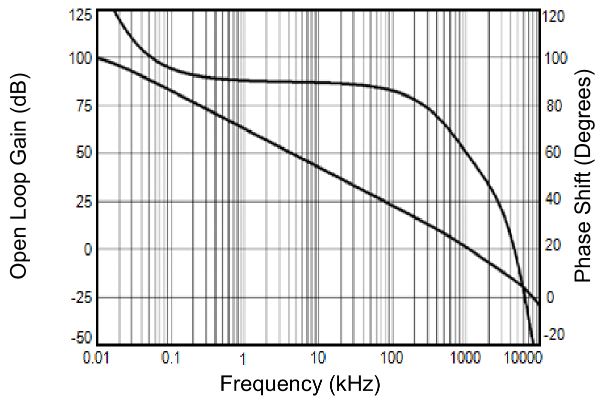
Output Voltage Swing vs.Output Current



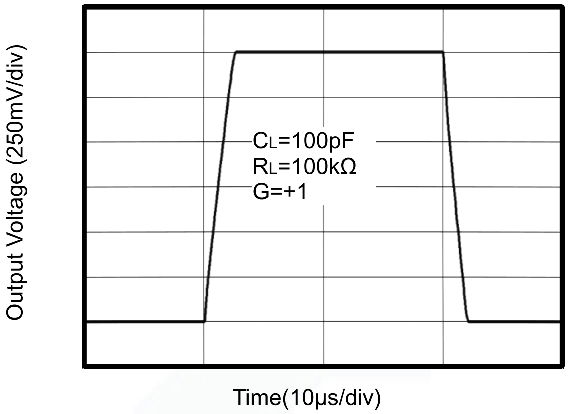
Input Voltage Noise Spectral Density vs. Frequency



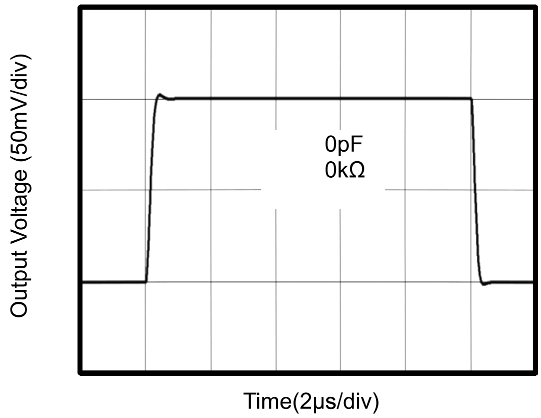
Open Loop Gain, Phase Shift vs. Frequency



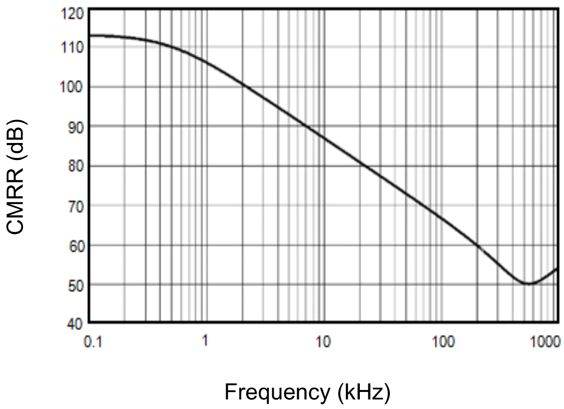
Large Signal Transient Response



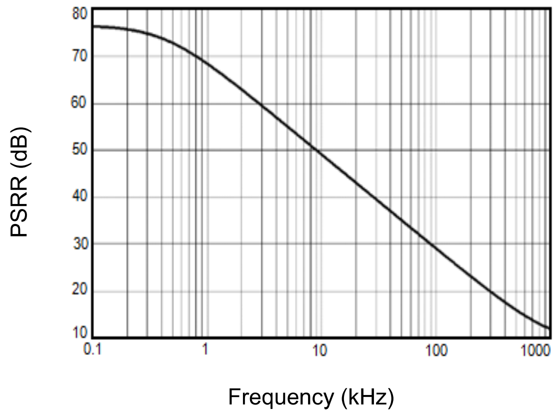
Small Signal Transient Response



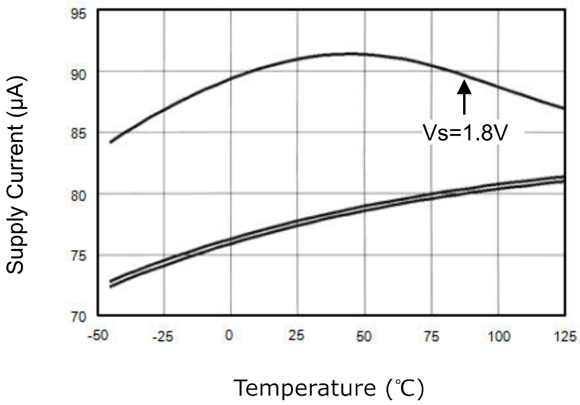
CMRR vs. Frequency



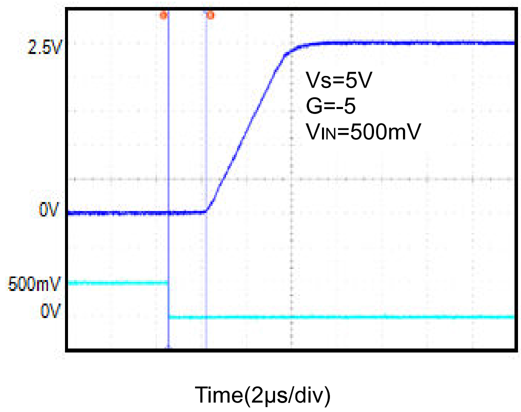
PSRR vs. Frequency



Supply Current vs. Temperature



Overload Recovery Time



9. Application Note

Size

MCP6001 family series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the MCP6001 family packages save space on printed circuit boards and enable the design of smaller electronic products.

Power Supply Bypassing and Board Layout

MCP6001 family series operates from a single 1.8V to 6V supply or dual ±0.9V to ±3V 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 75μA per channel) of MCP6001 family will help to maximize battery life. They are ideal for battery powered systems.

Operating Voltage

MCP6001 family operates under wide input supply voltage (1.8V to 6V). 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 MCP6001 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 MCP6001 family can typically swing to less than10mV from supply rail in light resistive loads (>100kΩ), and 60mV of supply rail in moderate resistive loads (10kΩ).

Capacitive Load Tolerance

The MCP6001 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.

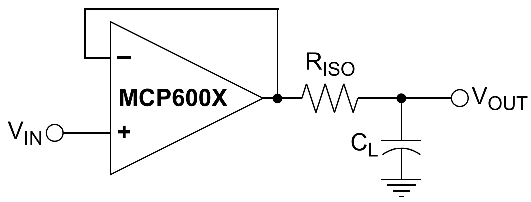


Fig. 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

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 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.

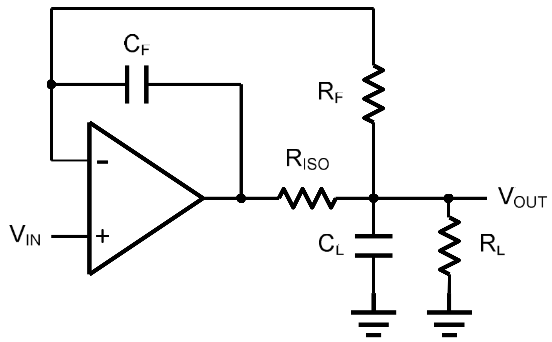


Fig. 3. Indirectly Driving a Capacitive Load with DC Accuracy

10. 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. Fig. 4. shown the differential amplifier using MCP6001 family.

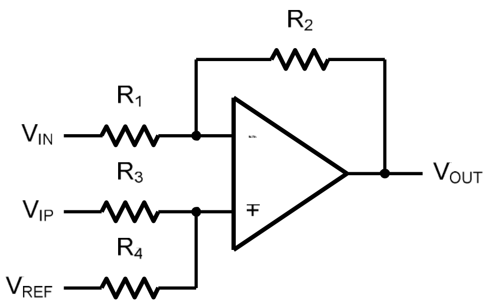


Fig. 4. Differential Amplifier

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

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 Fig. 5. The DC gain is defined by $-R_2/R_1$. The filter has a -20dB/decade roll-off after its corner frequency $f_C=1/(2\pi R_3C_1)$.

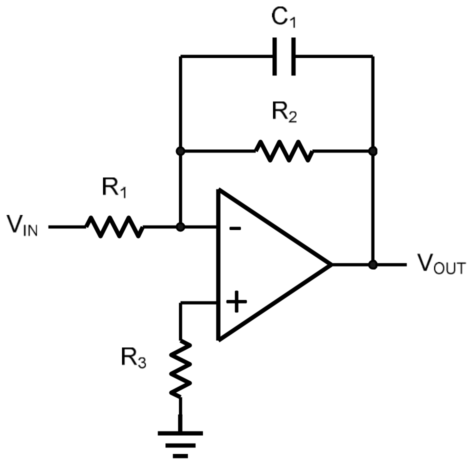


Fig. 5. . Low Pass Active Filter

Instrumentation Amplifier

The triple MCP6001 family can be used to build a three-op-amp instrumentation amplifier as shown in Fig. 6. The amplifier in Fig. 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.

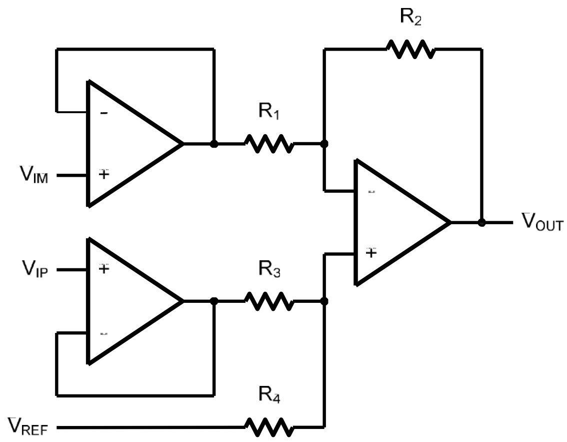
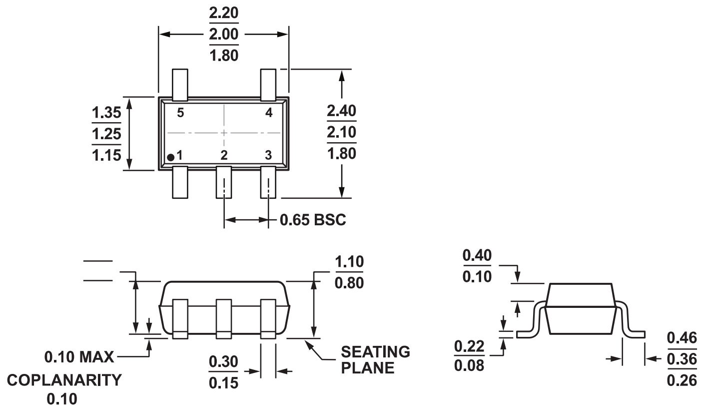


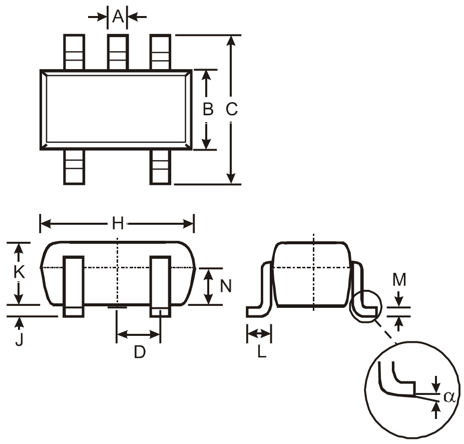
Fig. 6. Instrument Amplifier

11. Package Outlines

SC70-5

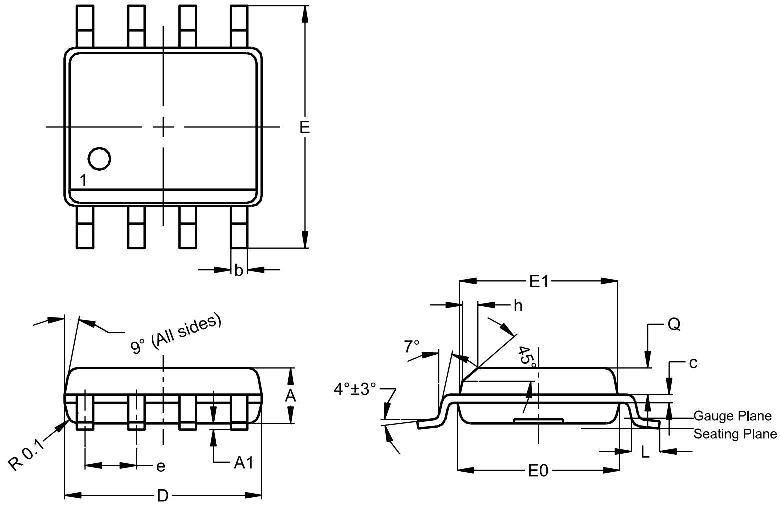


SOT-23-5



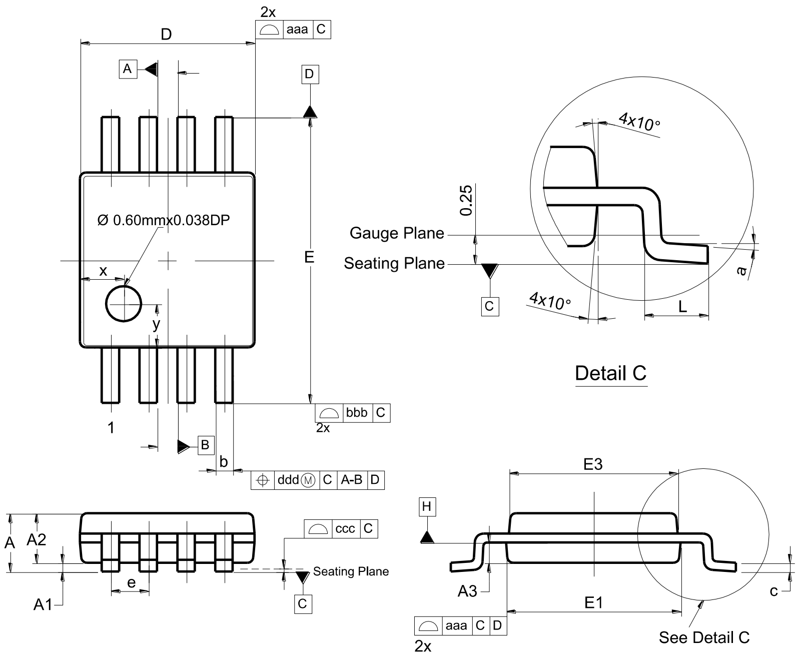
SOT-23-5			
Dim	**Min**	**Max**	**Typ**
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	-	-	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	-
All Dimensions in mm			

SOIC-8



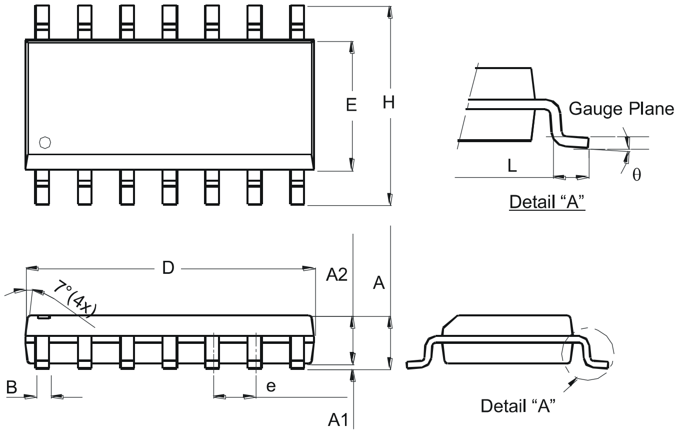
SOIC-8			
Dim	**Min**	**Max**	**Typ**
A	1.40	1.50	1.45
A1	0.10	0.20	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E0	3.85	3.95	3.90
e	--	--	1.27
h	-	--	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

MSOP-8



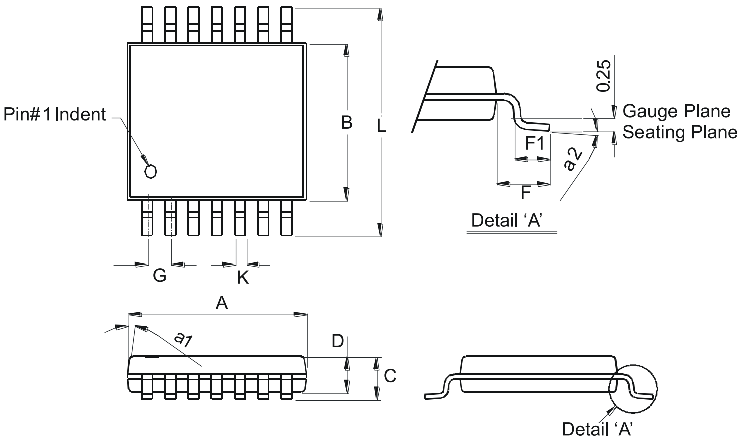
MSOP-8			
Dim	**Min**	**Max**	**Typ**
A	--	1.10	--
A1	0.05	0.15	0.10
A2	0.75	0.95	0.86
A3	0.29	0.49	0.39
b	0.22	0.38	0.30
c	0.08	0.23	0.15
D	2.90	3.10	3.00
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
E3	2.85	3.05	2.95
e	--	--	0.65
L	0.40	0.80	0.60
a	0°	8°	4°
x	--	--	0.750
y	--	--	0.750
aaa	0.20		
bbb	0.25		
ccc	0.10		
ddd	0.13		
All Dimensions in mm			

SOIC-14



SOIC-14		
Dim	**Min**	**Max**
A	1.47	1.73
A1	0.10	0.25
A2	1.45 Typ	
B	0.33	0.51
D	8.53	8.74
E	3.80	3.99
e	1.27 Typ	
H	5.80	6.20
L	0.38	1.27
θ	0°	8°
All Dimensions in mm		

TSSOP-14



TSSOP-14		
Dim	**Min**	**Max**
a1	7° (4X)	
a2	0°	8°
A	4.9	5.10
B	4.30	4.50
C	-	1.2
D	0.8	1.05
F	1.00 Typ	
F1	0.45	0.75
G	0.65 Typ	
K	0.19	0.30
L	6.40 Typ	
All Dimensions in mm		

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