Features

- Supply Voltage: 2.1V to 5.5V
- Low Supply Current: 70μA per channel
- Rail to Rail Input and Output
- Bandwidth: 1MHz
- Slew Rate: 0.7V/μs
- Excellent EMI Suppress Performance
- Offset Voltage: ±3 mV Maximum
- Offset Voltage Temperature Drift: 2 μV/°C
- Low Noise: 27nV/√Hz at 1 kHz
- High Output Capability: 70mA
- −40°C to 125°C Operation Temperature Range

Applications

- Active Filters, ASIC Input or Output Amplifier
- Sensor Interface
- Smoke/Gas/Environment Sensors
- Portable Instruments and Mobile Device

Description

The RS5AP600X family of single-, dual-, and quad-channel operational amplifiers is specifically designed for general-purpose applications. Featuring rail-to-rail input and output (RRIO) swings, low quiescent current (70μA, typical), wide bandwidth (1 MHz), and low noise (27nV/√Hz at 1 kHz), this family is attractive for a variety of applications that require a good balance between cost and performance, such as consumer electronics, smoke detectors, and white goods. The low-input-bias current (±1.0pA, typical) enables the RS5AP600X to be used in applications with megaohm source impedances.

The robust design of the RS5AP600X provides ease-of- use to the circuit designer: unity-gain stability with capacitive loads of up to 150pF, integrated RF/EMI rejection filter, no phase reversal in overdrive conditions, and high electrostatic discharge (ESD) protection (4-kV HBM).

The devices are optimized for operation at voltages as low as 2.1V (±1.05V) and up to 2.75V (±5.5V), and are specified over the extended temperature range of –40°C to +125°C.

The single-channel RS5AP600X is available in SOT23-5 and SC70-5 packages. The dual-channel RS5AP6002 is available in SOIC-8, MSOP-8, and DFN2X2-8 packages, and the quad-channel RS5AP6004 is offered in a TSSOP-14 and SOP-14 package.

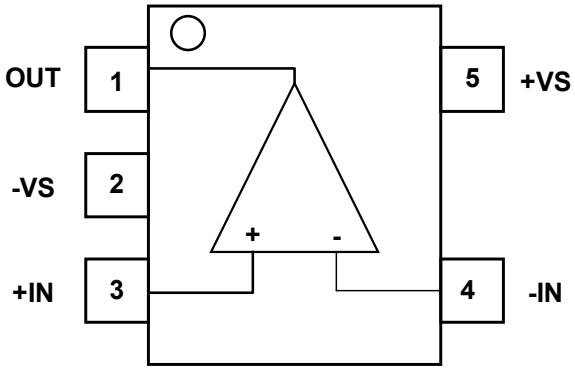
Device Information

Part Number	Package	Description
RS5AP6001TAE	SOT23-5	3mmx2.9mm
RS5AP6001UCE	SC70-5	2mmx1.25mm
RS5AP6002WE	SOP-8	6mmx4.9mm
RS5AP6002UE	MSOP-8	5.15mmx3.2mm
RS5AP6002ZAE	DFN2X2-8	2mmx2mm
RS5AP6004WE	SOP-14	8.65mmx6mm
RS5AP6004LE	TSSOP-14	6.4mmx5mm

Notes：E = Pb-free and Green

Pin Configuration and Functions

5 Pin Functions: RS5AP6001

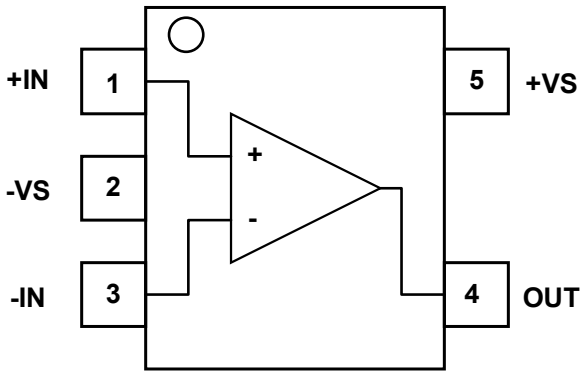


RS5AP6001
SOT-23-5, Top View

Table 1. Pin Functions: RS5AP6001

PINS		I/O	Description
NAME	No.		
OUT	1	O	Output
-VS	2	--	Negative Supply Voltage
IN+	3	I	Non-Inverting Input
IN-	4	I	Inverting Input
+VS	5	--	Positive Supply Voltage

5 Pin Functions: RS5AP6001U

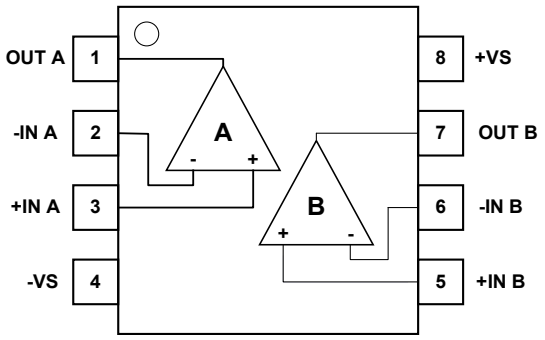


RS5AP6001U
SC70-5, Top View

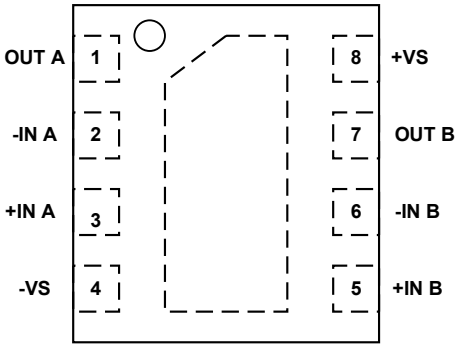
Table 2. Pin Functions: RS5AP6001U

PINS		I/O	Description
NAME	No.		
IN+	1	I	Non-Inverting Input
-VS	2	--	Negative Supply Voltage
IN-	3	I	Inverting Input
OUT	4	O	Output
+VS	5	--	Positive Supply Voltage

8 Pin Functions: RS5AP6002



RS5AP6002
SOP-8/MSOP8 Top View

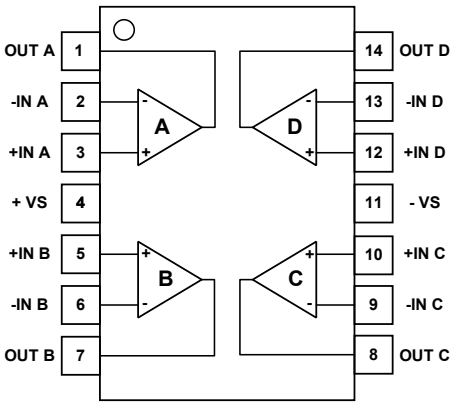


RS5AP6002
DFN2X2-8, Top View

Table 3. Pin Functions: RS5AP6002

PINS		I/O	Description
NAME	NO.		
OUTA	1	O	Output, Channel A
-IN A	2	I	Inverting Input, Channel A
+IN A	3	I	Noninverting Input, Channel A
-VS	4	--	Negative Supply Voltage
+IN B	5	I	Noninverting Input, Channel B
-IN B	6	I	Inverting Input, Channel B
OUT B	7	O	Output, channel B
+VS	8	--	Positive Supply Voltage

14 Pin Functions: RS5AP6004



RS5AP6004
SOP-14/TSSOP-14, Top View

Table 4. Pin Functions: RS5AP6004

PINS		I/O	Description
NAME	NO.		
OUTA	1	O	Output, Channel A
-IN A	2	I	Inverting Input, Channel A
+IN A	3	I	Noninverting Input, Channel A
+VS	4	--	Positive Supply Voltage
+IN B	5	I	Noninverting Input, Channel B
-IN B	6	I	Inverting Input, Channel B
OUT B	7	O	Output, channel B
OUT C	8	O	Output, channel C
–IN C	9	I	Inverting input, channel C
+IN C	10	I	Noninverting input, channel C
- VS	11	--	Negative Supply Voltage
+IN D	12	I	Noninverting input, channel D
-IN D	13	I	Inverting input, channel D
OUT D	14	O	Output, channel D

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
Supply Voltage			7	V
Input Voltage		(V^-) - 0.3	(V^+) + 0.3	V
Input Current: +IN, −IN (2)			±10	mA
Differential Input Voltage		(V^-) - (V^+)	(V^+) - (V^-)	mV
Output Short-Circuit Duration (3)			Indefinite	
T_J	Maximum Junction Temperature		150	°C
T_A	Operating Temperature Range	−40	125	°C
T_{STG}	Storage Temperature Range	−65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.
(2) The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 500 mV beyond the power supply, the input current should be limited to less than 10 mA.
(3) A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	4000	V
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	1000	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W
SOP-8	158	43	°C/W
MSOP-8	210	45	°C/W
DFN2X2-8	100	60	°C/W
SOP-14	120	36	°C/W
TSSOP-14	180	35	°C/W

Electrical Characteristics

All test conditions: V_S = 5 V, R_L = 10 K, V_{CM} = V_{DD}/2, T_A = +27°C, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range		2.1		5.5	V
I_Q	Quiescent Current per Amplifier			70		μA
PSRR	Power Supply Rejection Ratio			90		dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 3 V		0.5		mV
V_{OS} TC	Input Offset Voltage Drift	T_A = −40°C to 125°C		2		μV/°C
I_B	Input Bias Current	T_A = 25°C		1		pA
		T_A = 85°C		25		pA
I_{OS}	Input Offset Current			1		pA
C_{IN}	Input Capacitance	Differential Mode		8		pF
		Common Mode		6.5		pF
Av	Open-loop Voltage Gain	R_{LOAD} = 10 kΩ		110		dB
V_{CMR}	Common-mode Input Voltage Range		(V-) − 0.1		(V+) + 0.1	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0 V to 3 V		100		dB
Xtalk	Channel Separation	f = 1 kHz, R_L = 2 kΩ		110		dB
Output Characteristics						
V_{OH}, V_{OL}	Maximum Output Voltage Swing	R_{LOAD} = 10 kΩ		3		mV
I_{SC}	Output Short-Circuit Current			70		mA
AC Specifications						
GBW	Gain-Bandwidth Product			1		MHz
SR	Slew Rate	A_V = 1, V_{OUT} = 1.5 V to 3.5 V, C_{LOAD} = 60 pF, R_{LOAD} = 1 kΩ		0.7		V/μs
t_S	Settling Time, 0.1%	A_V = 1, 2 V Step, C_{LOAD} = 60 pF, R_{LOAD} = 1 kΩ		2.7		μs
	Settling Time, 0.01%			4.8		μs
PM	Phase Margin	R_{LOAD} = 1 kΩ, C_{LOAD} = 60 pF		60		°
GM	Gain Margin	R_{LOAD} = 1 kΩ, C_{LOAD} = 60 pF		15		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		8		μV_{PP}
e_N	Input Voltage Noise Density	f = 1 kHz		27		$nV\sqrt{HZ}$
i_N	Input Current Noise	f = 1 kHz		2		$fA\sqrt{HZ}$
THD+N	Total Harmonic Distortion and Noise	f = 1 kHz, A_V = 1, R_L = 2 kΩ, V_{OUT} = 1 Vp-p		0.003		%

Typical Performance Characteristics

V_S = 5 V, V_{CM} = 2.5 V, R_L = 10K, unless otherwise specified.

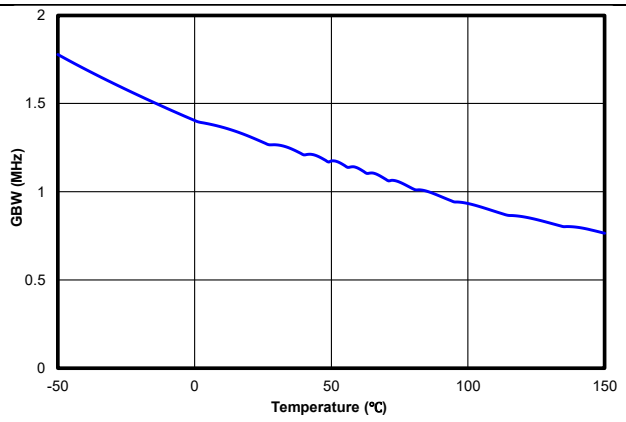


Figure 1. Unity Gain Bandwidth vs. Temperature

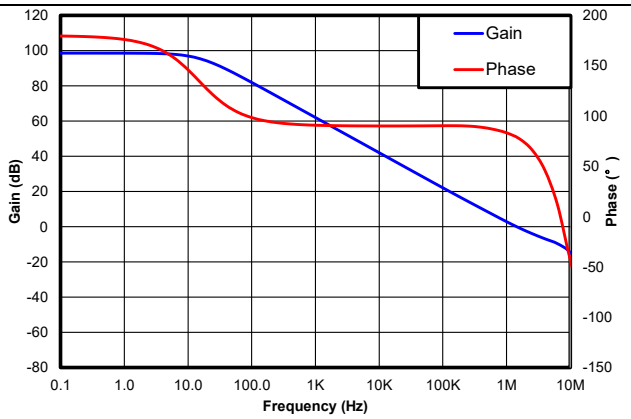


Figure 2. Open-Loop Gain and Phase

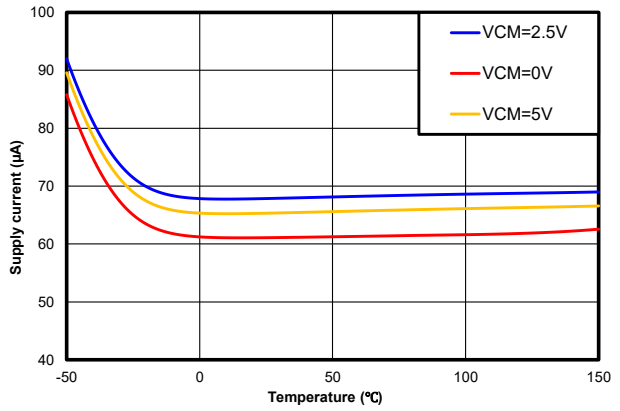


Figure 3. Supply Current vs. Temperature

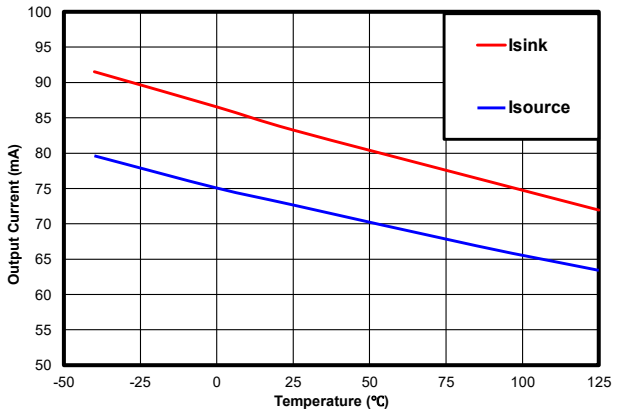


Figure 4. Short Circuit Current vs. Temperature

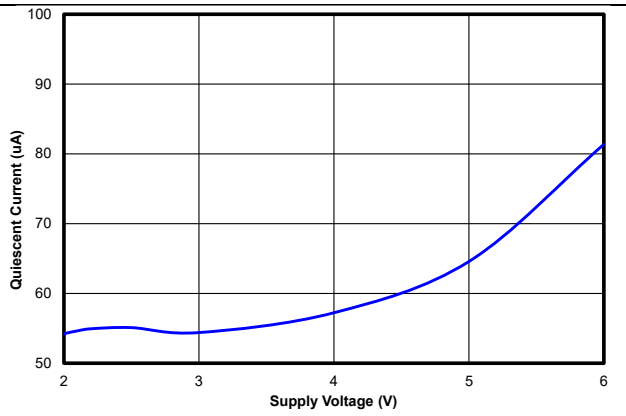


Figure5. Quiescent Current vs. Supply Voltage

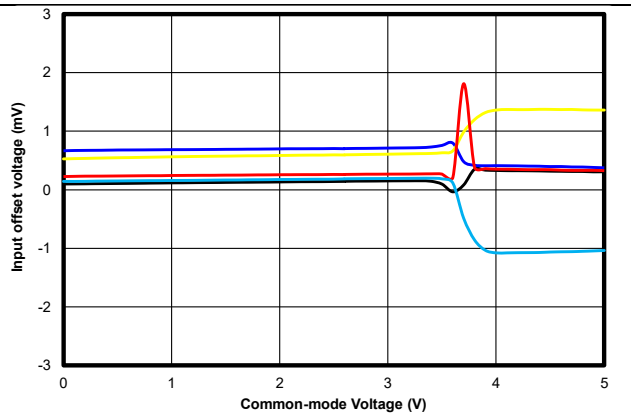


Figure6. Offset Voltage vs. Common-Mode Voltage

Typical Performance Characteristics (Continued)

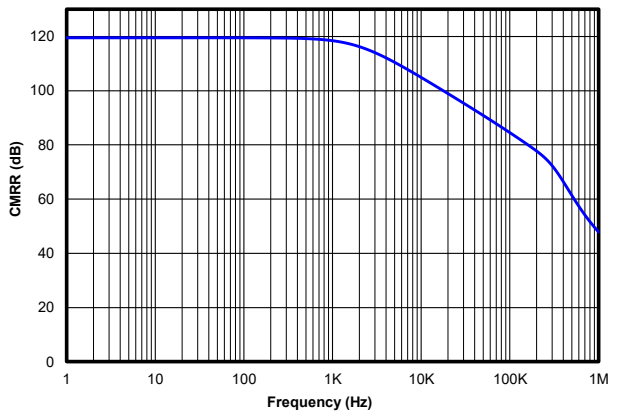


Figure 7. CMRR vs. Frequency

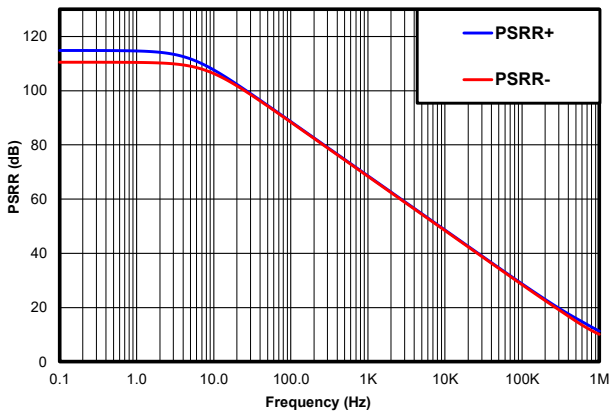


Figure 8. PSRR vs. Frequency

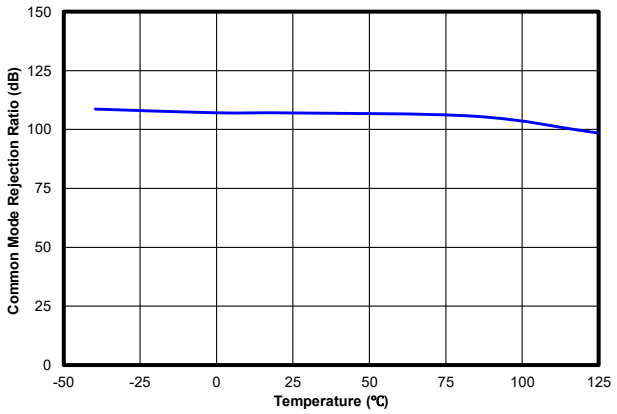


Figure 9. CMRR vs. Temperature

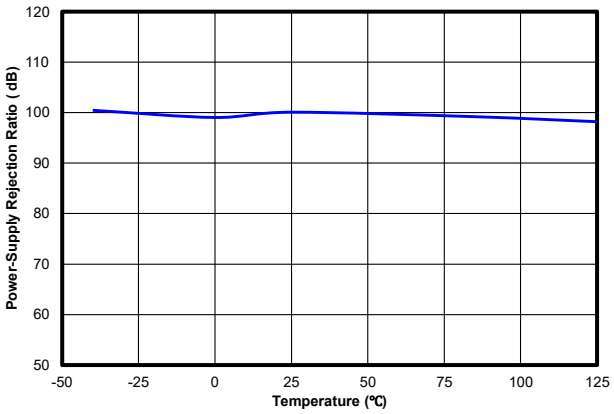


Figure 10. PSRR vs. Temperature

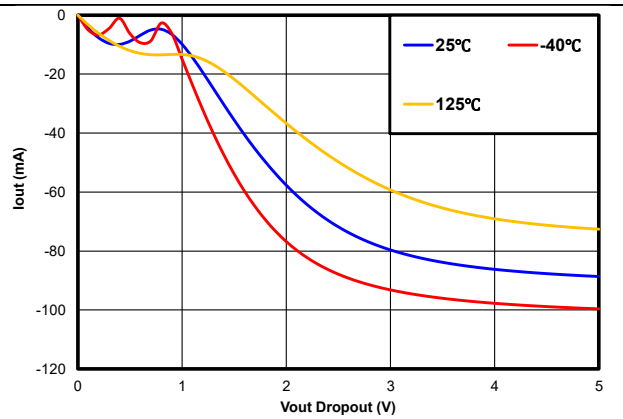


Figure 11. Negative Output Swing vs. Load Current

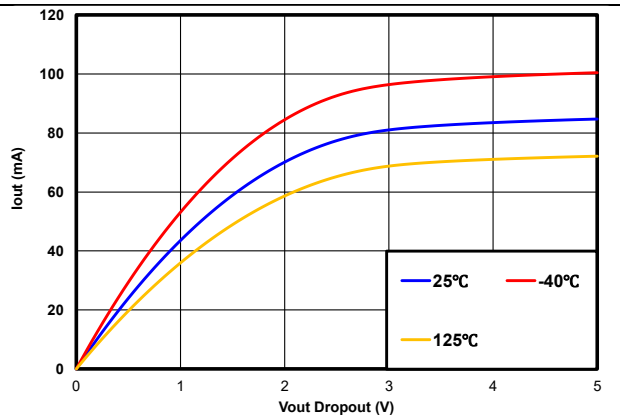


Figure 12. Positive Output Swing vs. Load Current

Typical Performance Characteristics (Continued)

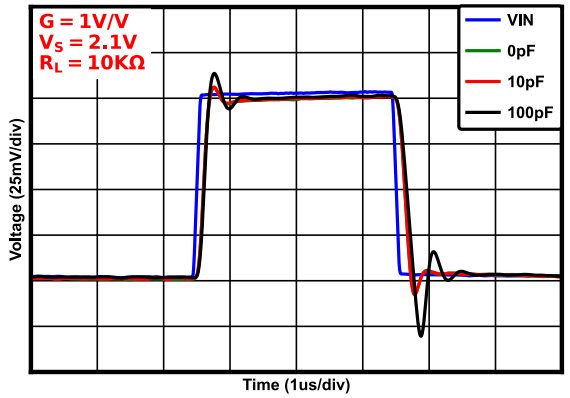


Figure 13. Small Signal Impulse Response (Minimum supply voltage)

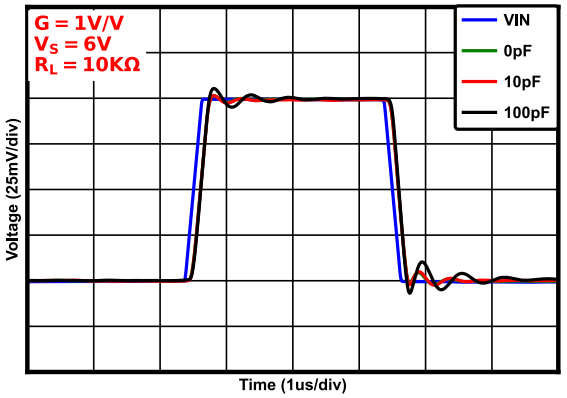


Figure 14. Small Signal Impulse Response (Maximum supply voltage)

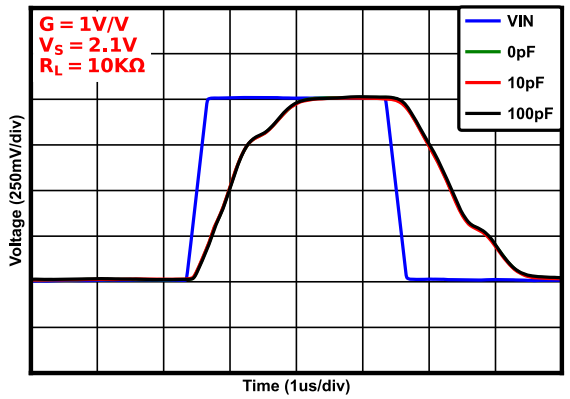


Figure 15. Large Signal Impulse Response (Minimum supply voltage)

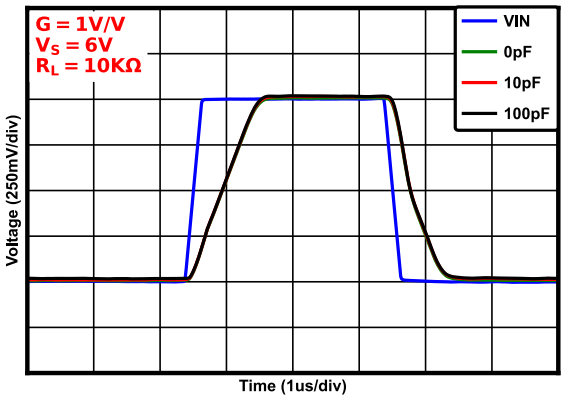


Figure 16. Large Signal Impulse Response (Maximum supply voltage)

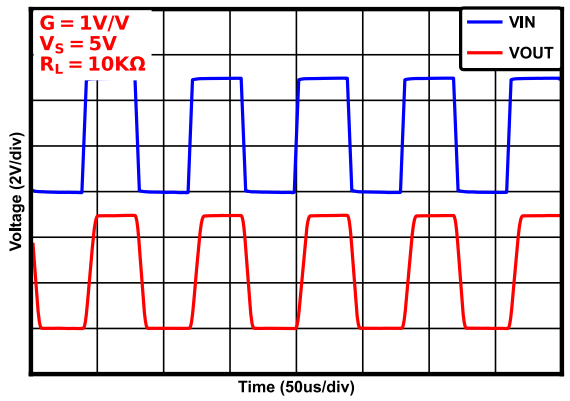


Figure 17. Large-Scale Step Response

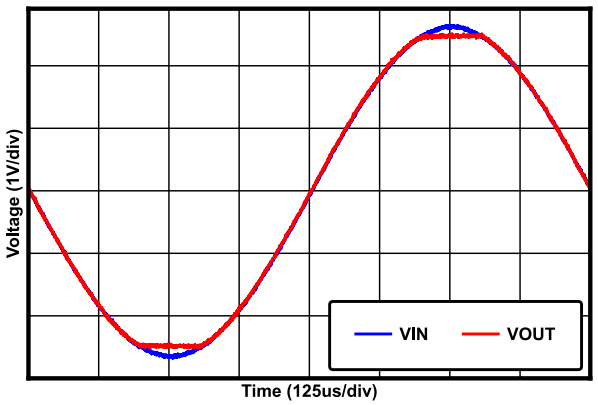


Figure 18. No Phase Reversal

Typical Performance Characteristics (Continued)

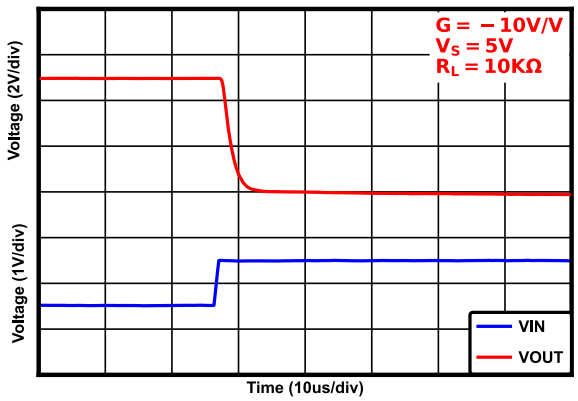


Figure 19. Positive Over-Voltage Recovery

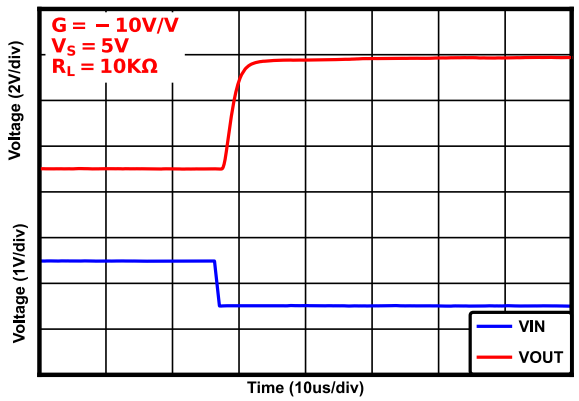


Figure 20. Negative Over-Voltage Recovery

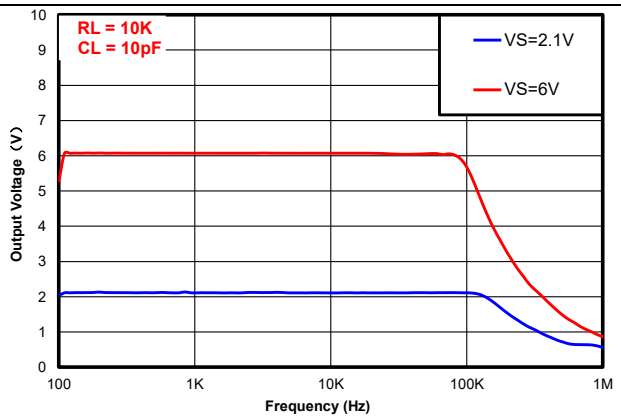


Figure 21. Maximum Output Voltage vs Frequency and Supply Voltage

Application Information

Low Supply Voltage and Low Power Consumption

The RS5AP600X family of operational amplifiers can operate with power supply voltages from 2.1V to 5.5V. Each amplifier draws only 70μA quiescent current. The low supply voltage capability and low supply current are ideal for portable applications demanding high capacitive load driving capability and stable wide bandwidth. The RS5AP600X family is optimized for wide bandwidth low power applications. They have an industry-leading high GBWP to power ratio and are unity gain stable for any capacitive load. When the load capacitance increases, the increased capacitance at the output pushed the non-dominant pole to lower frequency in the open loop frequency response, lowering the phase and gain margin. Higher gain configurations tend to have better capacitive drive capability than lower gain configurations due to lower closed loop bandwidth and hence higher phase margin.

Ground Sensing and Rail to Rail Output

The RS5AP600X family has excellent output drive capability, delivering over 70mA of output drive current. The output stage is a rail-to-rail topology that is capable of swinging to within 10mV of either rail. Since the inputs can go 200mV beyond either rail, the op-amp can easily perform 'true ground' sensing.

The maximum output current is a function of the total supply voltage. As the supply voltage to the amplifier increases, the output current capability also increases. Attention must be paid to keep the junction temperature of the IC below 150°C when the output is in continuous short-circuit. The output of the amplifier has reverse-biased ESD diodes connected to each supply. The output should not be forced more than 0.5V beyond either supply, otherwise current will flow through these diodes.

Driving Large Capacitive Load

Larger load capacitance decreases the overall phase margin in a feedback system where internal frequency compensation is utilized. As the load capacitance increases, the feedback loop's phase margin decreases, and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response with overshoot and ringing in output step response. The unity-gain buffer (G = +1 V/V) is the most sensitive to large capacitive loads.

When driving large capacitive loads with the RS5AP600X OPA family (e.g., > 200pF when G = +1V/V), a small series resistor at the output (R_{ISO} in Figure 22) improves the feedback loop's phase margin and stability by making the output load resistive at higher frequencies.

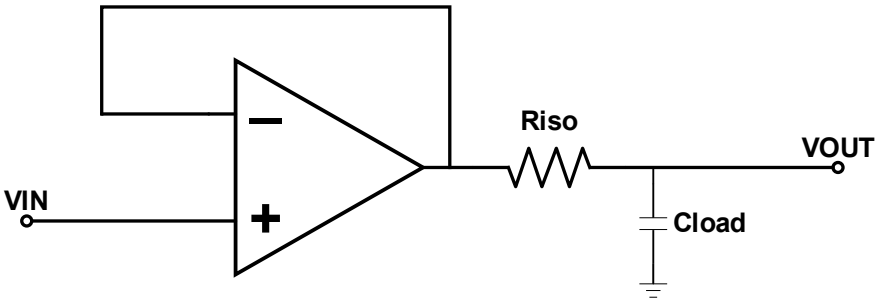
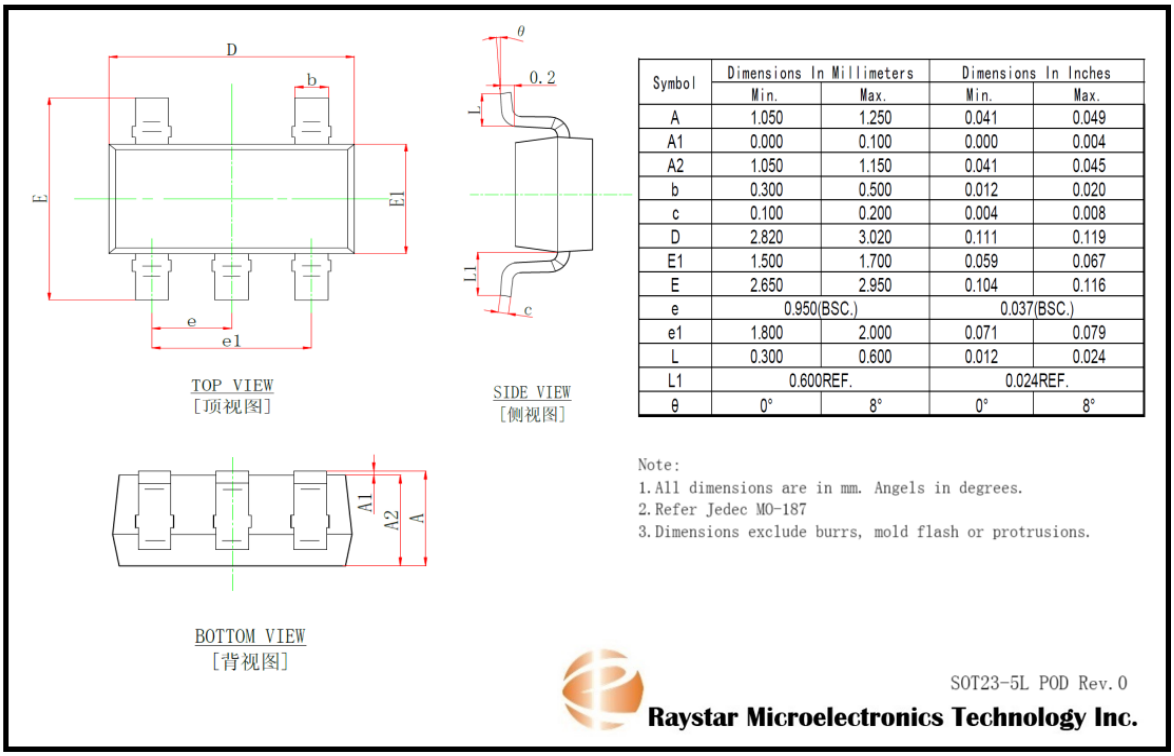


Figure 22. Drive Large Capacitive Load

Package Information

SOT23-5



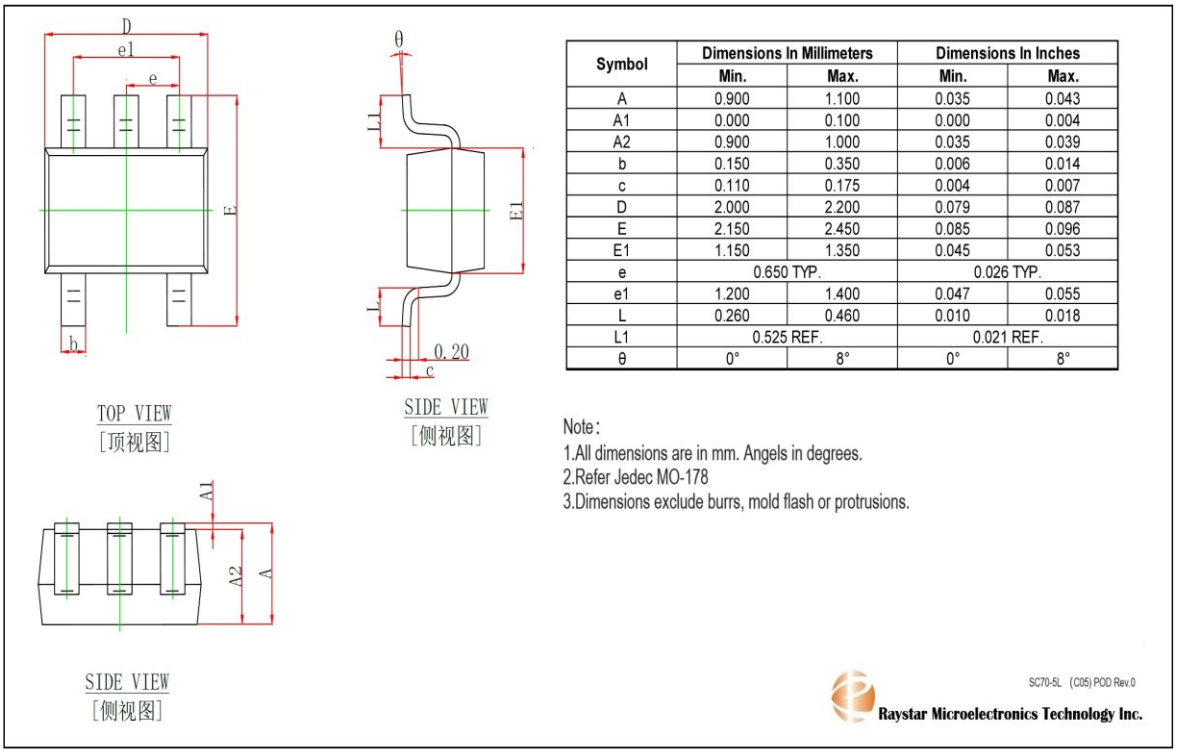
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E1	1.500	1.700	0.059	0.067
E	2.650	2.950	0.104	0.116
e	0.950(BSC.)		0.037(BSC.)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
L1	0.600REF.		0.024REF.	
θ	0°	8°	0°	8°

Note:
1. All dimensions are in mm. Angels in degrees.
2. Refer Jedec MO-187
3. Dimensions exclude burrs, mold flash or protrusions.

SOT23-5L POD Rev.0

Raystar Microelectronics Technology Inc.

SC70-5

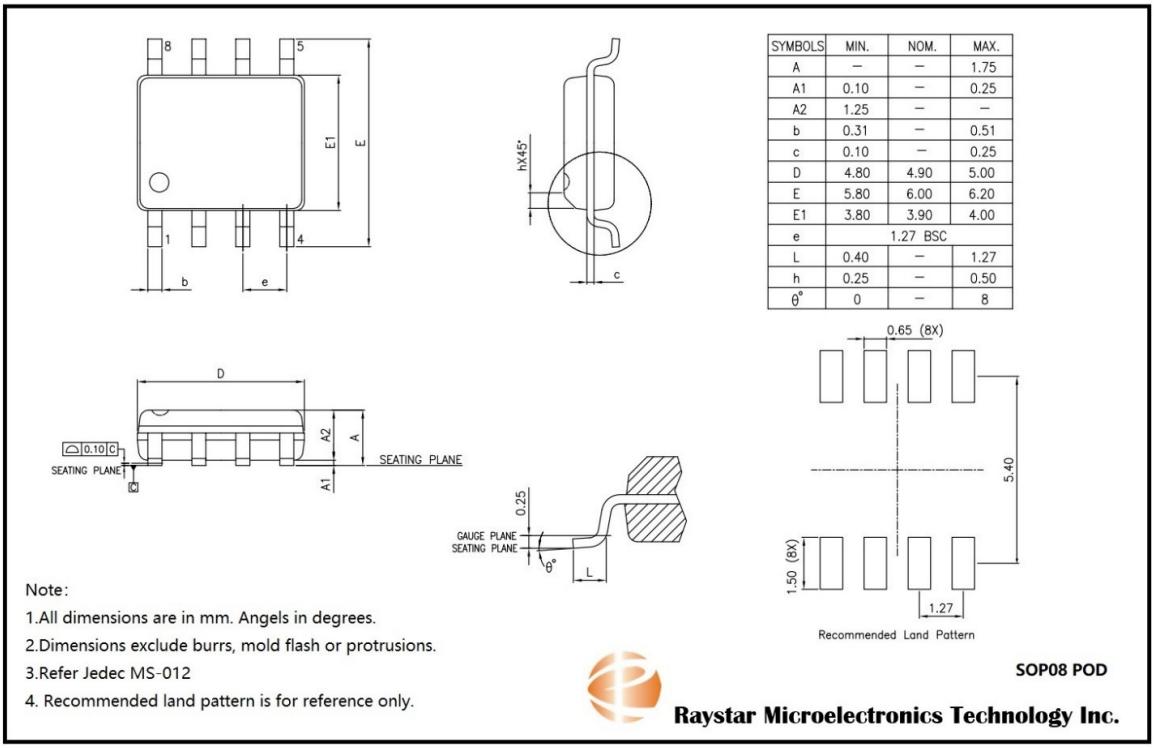


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.110	0.175	0.004	0.007
D	2.000	2.200	0.079	0.087
E	2.150	2.450	0.085	0.096
E1	1.150	1.350	0.045	0.053
e	0.650 TYP.		0.026 TYP.	
e1	1.200	1.400	0.047	0.055
L	0.260	0.460	0.010	0.018
L1	0.525 REF.		0.021 REF.	
θ	0°	8°	0°	8°

Note:
1.All dimensions are in mm. Angels in degrees.
2.Refer Jedec MO-178
3.Dimensions exclude burrs, mold flash or protrusions.

SC70-5L (C05) POD Rev.0
Raystar Microelectronics Technology Inc.

SOP-8



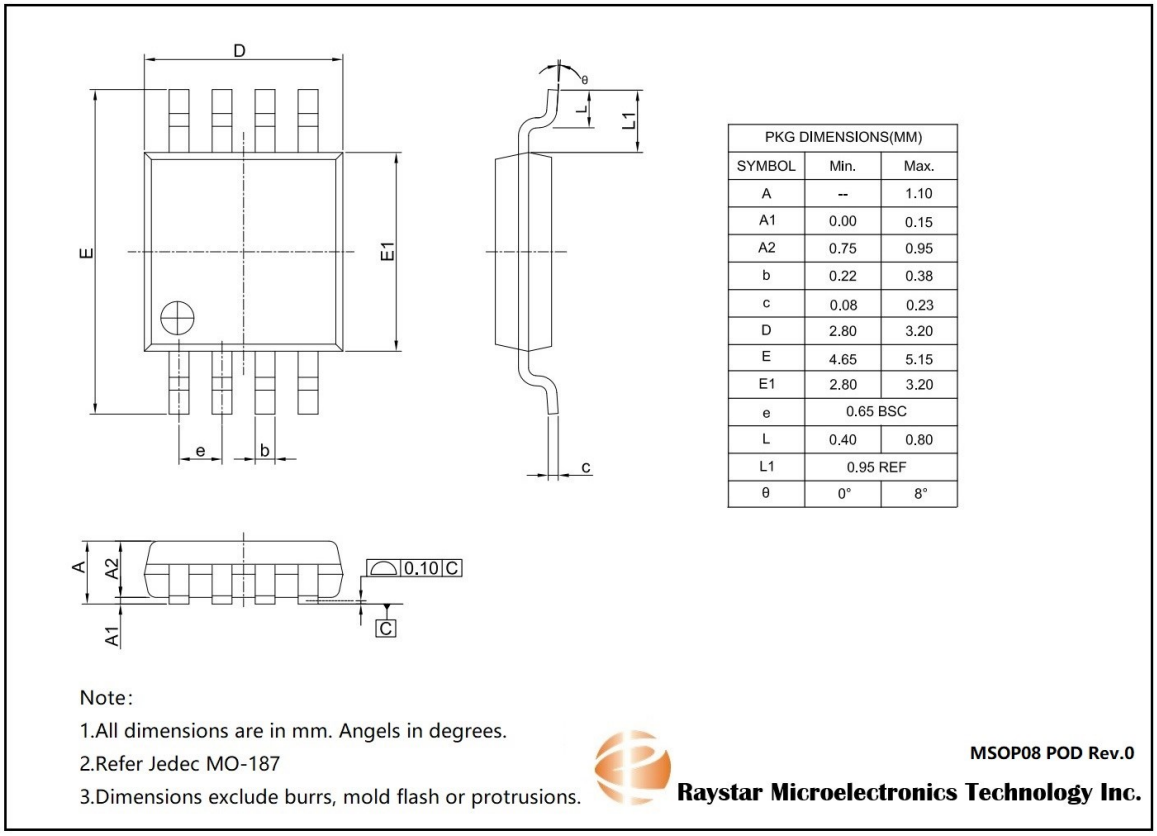
SYMBOLS	MIN.	NOM.	MAX.
A	–	–	1.75
A1	0.10	–	0.25
A2	1.25	–	–
b	0.31	–	0.51
c	0.10	–	0.25
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27 BSC		
L	0.40	–	1.27
h	0.25	–	0.50
θ°	0	–	8

Note:
1.All dimensions are in mm. Angels in degrees.
2.Dimensions exclude burrs, mold flash or protrusions.
3.Refer Jedec MS-012
4. Recommended land pattern is for reference only.

SOP08 POD

Raystar Microelectronics Technology Inc.

MSOP-8

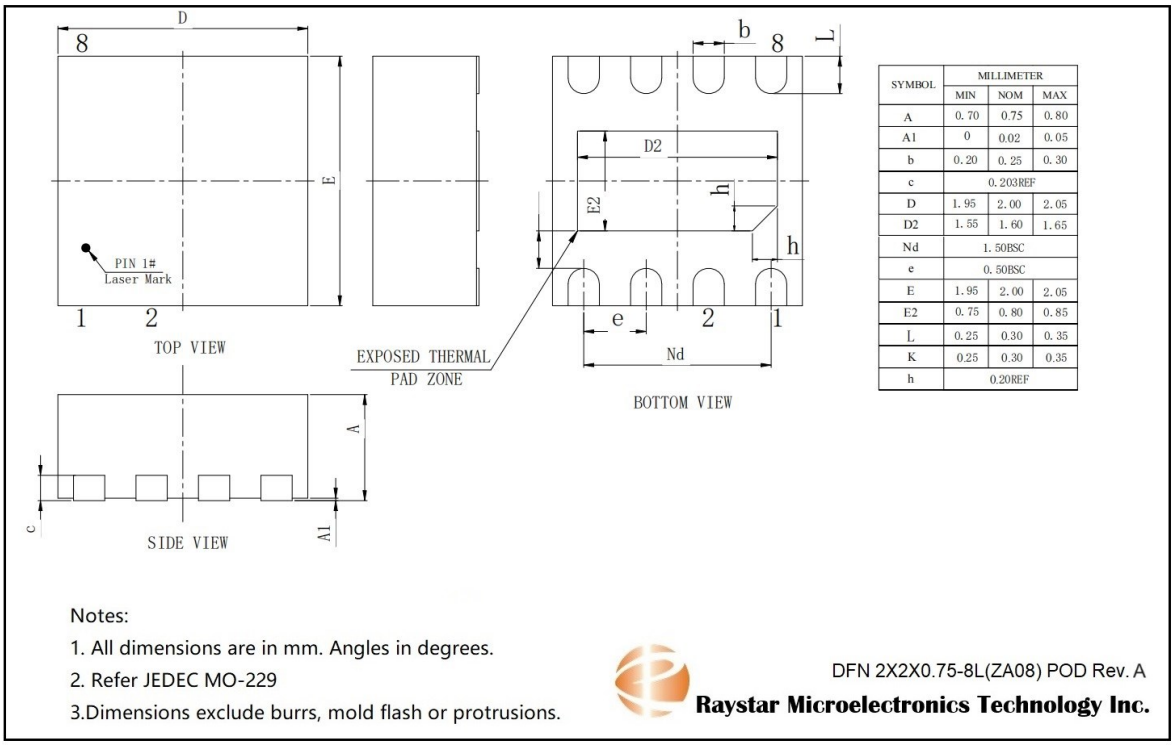


PKG DIMENSIONS(MM)		
SYMBOL	Min.	Max.
A	--	1.10
A1	0.00	0.15
A2	0.75	0.95
b	0.22	0.38
c	0.08	0.23
D	2.80	3.20
E	4.65	5.15
E1	2.80	3.20
e	0.65 BSC	
L	0.40	0.80
L1	0.95 REF	
θ	0°	8°

Note:
1.All dimensions are in mm. Angels in degrees.
2.Refer Jedec MO-187
3.Dimensions exclude burrs, mold flash or protrusions.

MSOP08 POD Rev.0
Raystar Microelectronics Technology Inc.

DFN2X2-8

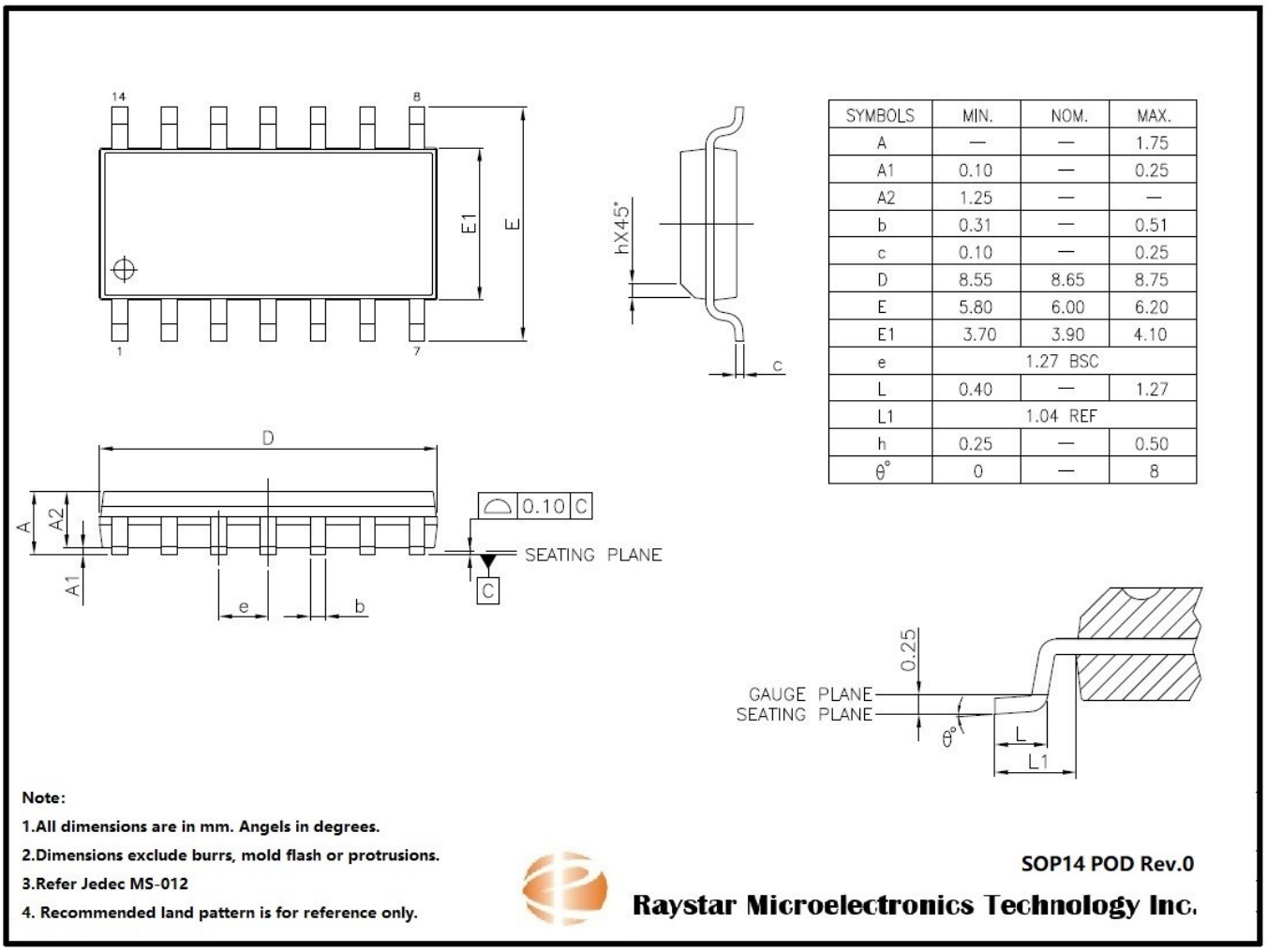


SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0	0.02	0.05
b	0.20	0.25	0.30
c	0.203REF		
D	1.95	2.00	2.05
D2	1.55	1.60	1.65
Nd	1.50BSC		
e	0.50BSC		
E	1.95	2.00	2.05
E2	0.75	0.80	0.85
L	0.25	0.30	0.35
K	0.25	0.30	0.35
h	0.20REF		

Notes:
1. All dimensions are in mm. Angles in degrees.
2. Refer JEDEC MO-229
3.Dimensions exclude burrs, mold flash or protrusions.

DFN 2X2X0.75-8L(ZA08) POD Rev. A
Raystar Microelectronics Technology Inc.

SOP-14



SYMBOLS	MIN.	NOM.	MAX.
A	—	—	1.75
A1	0.10	—	0.25
A2	1.25	—	—
b	0.31	—	0.51
c	0.10	—	0.25
D	8.55	8.65	8.75
E	5.80	6.00	6.20
E1	3.70	3.90	4.10
e		1.27 BSC	
L	0.40	—	1.27
L1		1.04 REF	
h	0.25	—	0.50
θ°	0	—	8

Note:

1.All dimensions are in mm. Angels in degrees.

2.Dimensions exclude burrs, mold flash or protrusions.

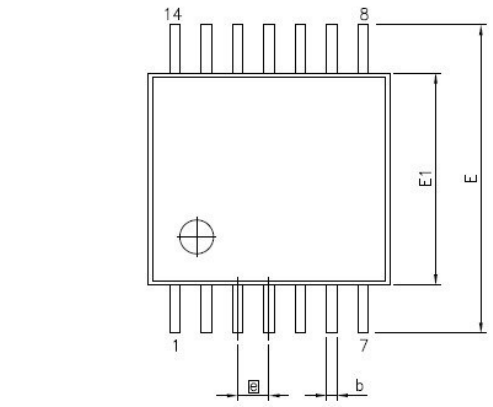
3.Refer Jedec MS-012

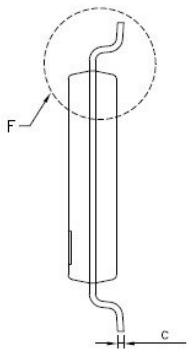
4. Recommended land pattern is for reference only.

SOP14 POD Rev.0

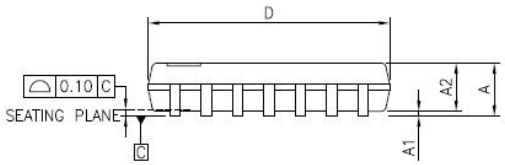
Raystar Microelectronics Technology Inc.

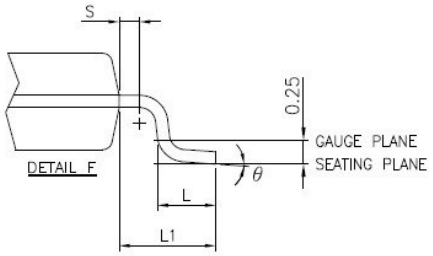
TSSOP-14





SYMBOLS	MIN.	NOM.	MAX.
A	–	–	1.20
A1	0.05	–	0.15
A2	0.80	1.00	1.05
b	0.19	–	0.30
c	0.09	–	0.20
D	4.90	5.00	5.10
E1	4.30	4.40	4.50
E	6.20	6.40	6.60
e	0.65 BSC		
L1	1.00 REF		
L	0.45	0.60	0.75
S	0.20	–	–
θ	0°	–	8°





Note:

1.All dimensions are in mm. Angels in degrees.

2.Dimensions exclude burrs, mold flash or protrusions.

3.Refer Jedec MO-153F

4. Recommended land pattern is for reference only.

TSSOP14 POD Rev.0

Raystar Microelectronics Technology Inc.

Revision History

Revision	Description	Date
V0.9	Preliminary release	2024/06/07
V1.0	Initial Release	2024/07/28
V1.1	1. Added 4-channel version operational amplifier 2. Added CMRR & PSRR vs. temperature relationship chart 3. Updated short-circuit output current vs. temperature relationship chart 4. Added step response charts for small and large signals 5. Added input-output phase chart 6. Added overload recovery chart	2024/09/12
V1.2	1. Updated recommended operating voltage range to 2.1~5.5V 2. Added SC70-5 package	2024/10/30