10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Features

* High Gain Bandwidth : 10MHz
* Slew Rate: 8.5V/μs
* Input Offset Voltage: ±0.5mV(Typ.)
* Low Noise: 8.5nV/ √ Hz at 10KHz
* Rail-to-Rail Input and Output
* Supply Voltage Range: 2.1V to 5.6V
* Input Voltage Range: -0.2V to 5.7V
  with Vs = 5.5V
* Low Power:
  - HCR721: 1.2mA(Typ.)
  - HCR722/HCR724: 1.1mA/Amplifier(Typ.)
* Operating Temperature: -40'C to +125'C

Applications

* Active filter & Sensors and Audio
* A/D Converters
* Communications
* Test Equipment
* Cellular and Cordless Phones
* Laptops and PDAs
* Photodiode Amplification
* Battery-Powered Instrumentation

General Description [note a]

The HCR721 (single) /HCR722 (dual) /HCR724 (quad) are operational amplifiers, which are optimized for low voltage, low noise and low power operation. These devices can operate from 2.1V to 5.6V single supply, and consume low quiescent current.

The HCR721 /2 /4 feature a 4mV maximum input offset voltage. The minimum input common mode voltage is within 0.1V below the negative rail, and the output swing is rail-to-rail with heavy loads. They exhibit a high gain-bandwidth product of 10MHz and a slew rate of 8.5V/μs. These specifications make the operational amplifiers appropriate for various applications.

The HCR721 is available in Green SC70-5 (SOT353), and SOT-23-5 packages.

The HCR722 is available in Green SOIC-8, MSOP8, TSSOP8, and DFN3x3-8L packages.

The HCR724 is available in Green SOIC-14 and TSSOP14 packages. They are specified over the extended industrial temperature range from -40 ℃ to +125℃.
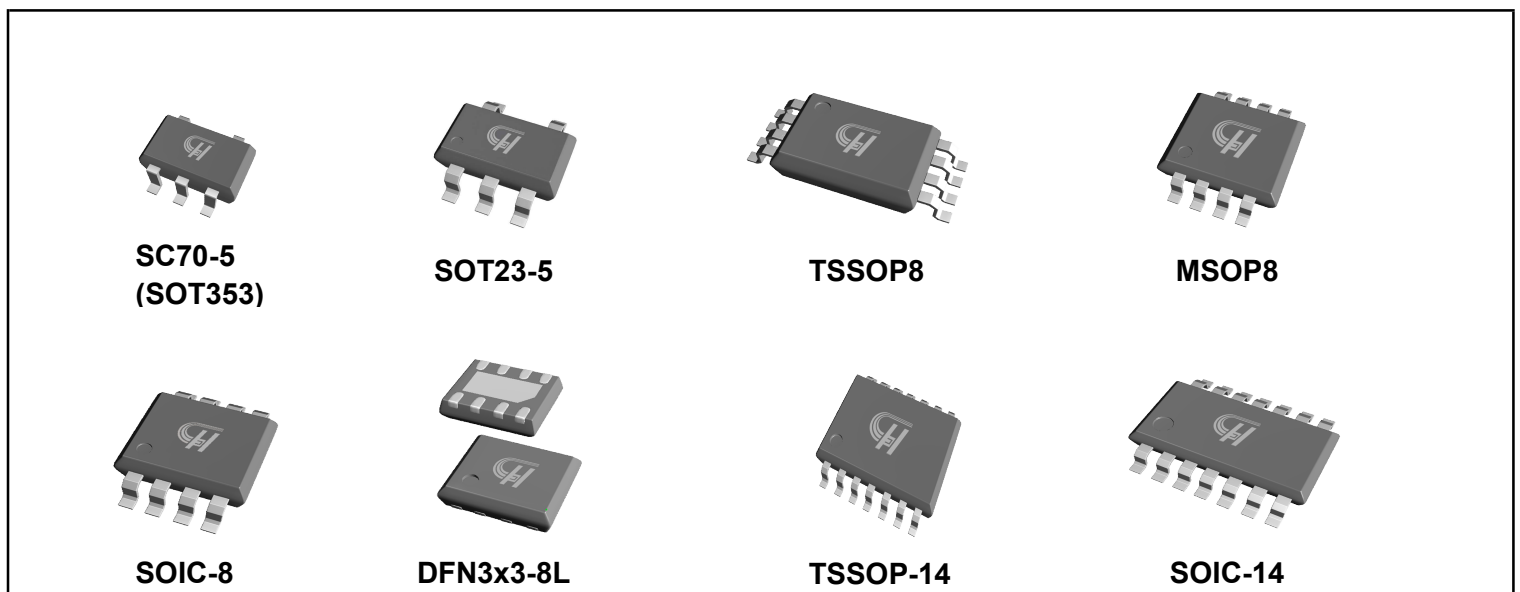

SC70-5 (SOT353)	SOT23-5	TSSOP8	MSOP8
SOIC-8	DFN3x3-8L	TSSOP-14	SOIC-14

Figure 1. Package Type of HCR721/HCR722/HCR724

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Pin Configuration

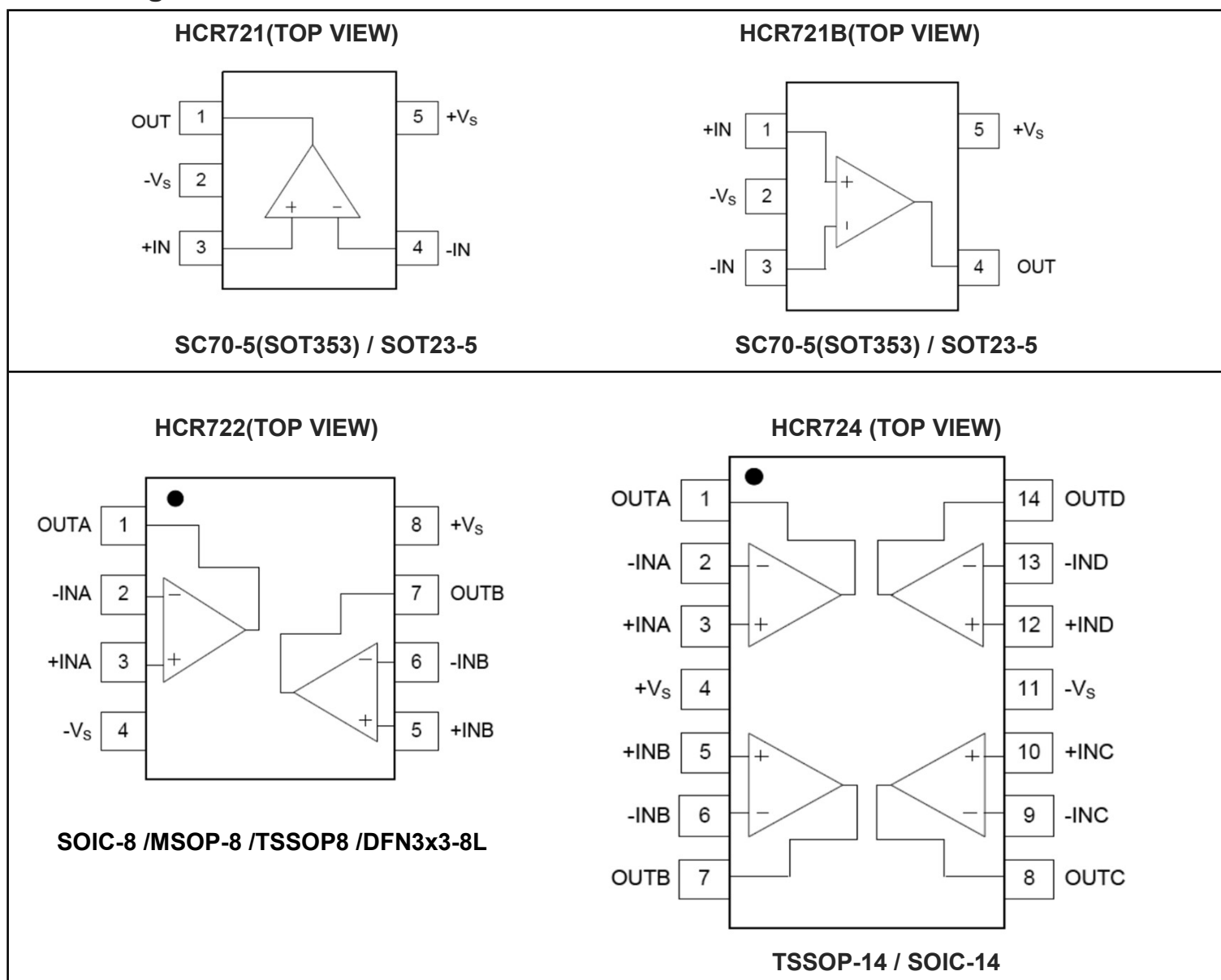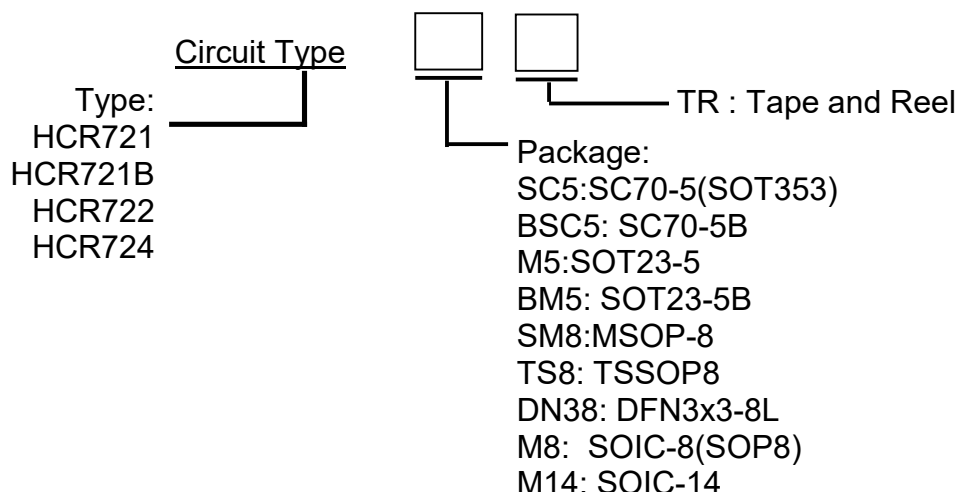HCR721(TOP VIEW)

SC70-5(SOT353) / SOT23-5

HCR721B(TOP VIEW)

SC70-5(SOT353) / SOT23-5

HCR722(TOP VIEW)

SOIC-8 /MSOP-8 /TSSOP8 /DFN3x3-8L

HCR724 (TOP VIEW)

TSSOP-14 / SOIC-14

Figure 2. Pin Configuration of HCR721/HCR722/HCR724(Top View)

Pin Function Table

Name	Function
+IN, +INA, +INB, +INC, +IND	Non-inverting Inputs
-IN, -INA, -INB, -INC, -IND	Inverting Inputs
+Vs	Positive Power Supply
-Vs	Negative Power Supply
OUT, OUTA, OUTB, OUTC, OUTD	Outputs

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Ordering Information

Circuit Type

Type:
HCR721
HCR721B
HCR722
HCR724

TR : Tape and Reel

Package:
SC5:SC70-5(SOT353)
BSC5: SC70-5B
M5:SOT23-5
BM5: SOT23-5B
SM8:MSOP-8
TS8: TSSOP8
DN38: DFN3x3-8L
M8: SOIC-8(SOP8)
M14: SOIC-14

Ordering Code

Part Number	Channel	Marking [1]	Op Temp('C)	MSL [2]	Package	Package Qty
HCR721/SC5TR	1	721	-40'C to +125'C	MSL3	SC70-5 (SOT353)	3000pcs/TR
HCR721/M5TR	1	721	-40'C to +125'C	MSL3	SOT23-5	3000pcs/TR
HCR721B/SC5TR	1	721B	-40'C to +125'C	MSL3	SC70-5 (SOT353)	3000pcs/TR
HCR721B/M5TR	1	721B	-40'C to +125'C	MSL3	SOT23-5	3000pcs/TR
HCR722/SM8TR	2	HCR722xx	-40'C to +125'C	MSL3	MSOP-8	4000pcs/TR
HCR722/TS8TR	2	HCR722xx	-40'C to +125'C	MSL3	TSSOP8	4000pcs/TR
HCR722/DN38TR	2	HCR722xx	-40'C to +125'C	MSL3	DFN3x3-8L	5000pcs/TR
HCR722/M8TR	2	HCR722xx	-40'C to +125'C	MSL3	SOIC-8 (SOP-8)	4000pcs/TR
HCR724/M14TR	4	HCR724xx	-40'C to +125'C	MSL3	SOIC-14	2500pcs/TR
HCR724/TSP14TR	4	HCR724xx	-40'C to +125'C	MSL3	TSSOP-14	4000pcs/TR

note 1: There may be additional marking, which relates to the lot trace code information(data code and vendor code)，the logo or the environmental category on the device.

2: HCRSEMI classify the MSL level with using the common preconditioning setting in our assembly factory conforming to the JEDEC industrial standard J-STD-20F. Please align with HCRSEMI if your end application is quite critical to the preconditioning setting or if you have special requirement.

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Absolute Maximum Ratings

Over operating free-air temperature range(unless otherwise noted) [3]

Parameter		Symbol	Value	Unit
Supply Voltage, +Vs to -Vs		V+	+7.0	V
Signal Input Voltage		V_{IN}	(V-)-0.5 to (V+)+0.5	V
Signal Output Voltage		Vout	(V-)-0.5 to (V+)+0.5	V
Signal Input Current		I_{IN}	-10 to +10	mA
Signal Output Current		Io	-150 to +150	mA
Thermal Resistance @T_A=+25'C	SC70-5 (SOT353)	$θ_{JA}$	255	'C/W
	SOT23-5	$θ_{JA}$	190	'C/W
	SOIC-8	$θ_{JA}$	110	'C/W
	MSOP-8	$θ_{JA}$	170	'C/W
	TSSOP-8	$θ_{JA}$	185	'C/W
	DFN3x3-8L	$θ_{JA}$	65	'C/W
	SOIC-14	$θ_{JA}$	90	'C/W
	TSSOP-14	$θ_{JA}$	105	'C/W
Storage Temperature Range		T_{STG}	-65 to +150	'C
Operating Temperature Range [note 2]		T_{OPR}	-40 to +125	'C
Junction Temperature		T_J	+150	'C
Lead Temperature (Soldering, 10s)		T_{LEAD}	260	'C
Human Body Model ESD Protection		ESD HBM	4	KV
Machine Model ESD Protection		ESD MM	400	V

Recommended Operating Conditions

Parameter		Symbol	Min.	Max.	Unit
Supply Voltage, +Vs to -Vs	Signal-supply	V_{IN}	2.1	5.5	V
	Dual-supply		±1.05	±2.75	V
Operating Temperature Range		Ta	-40	+125	'C

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Electrical Characteristics

(TA=25 `C, At Vs=+5V, RL=10KΩ VCM=Vs/2 .Unless Otherwise Specified.)

Parameter	Symbol	Conditions	Min	Type	Max	Unit
Input Characteristics						
Input Offset Voltage	V_{OS}	$V_{CM} = V_S/2$	-2.5	±0.5	2.5	mV
Input Bias Current:	I_B		-	±1	±10	pA
Input Offset Current:	I_{OS}		-	±1	±10	pA
Input Common Mode Voltage Range	V_{CM}	Vs=5.5V	-0.1	-	+5.6	V
Common Mode Rejection Ratio	CMRR	Vs=5.5V, V_{CM}=-0.1V to 4V	73	85	-	dB
		Vs=5.5V, V_{CM}=-0.1V to 5.6V	65	75	-	
Open-Loop Voltage Gain	A_{OL}	R_L=2KΩ, V_{out}=+0.15V to 4.85V	86	95	-	dB
		R_L=10KΩ, V_{out}=+0.05V to 4.95V	90	96	-	dB
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$		-	2.1	-	uV/'C
Output Characteristics						
Output Voltage Swing from Rail	V_{OH}	R_L=2KΩ	-	50	-	mV
	V_{OL}	R_L=10KΩ	-	10	-	mV
Output Current	I_{OUT}	R_L=10Ω to V_S/2	52	67	-	mA
Closed-Loop Output Impedance	R_i	f=1MHz, G=1	-	8.5	-	Ω
Power Supply						
Operating Voltage Range	V_S		2.1	-	5.5	V
Power Supply Rejection Ratio	PSRR	Vs=2.1V to 5.5V, V_{CM} =(-Vs)+0.5V	75	85	-	dB
Quiescent Current per Amplifier	I_Q		-	1.1	1.4	mA
Dynamic Performance						
Gain Bandwidth Product	GBP		-	10	-	MHz
Phase Margin	$\varnothing_o$	-	-	62	-	°
Full-Power Bandwith	BW_p	<1% distortion	-	400	-	KHz
Slew Rate	SR	G=+1.2V Output Step	-	8.5	-	V/uS
Settling Time to 0.1%	t_s	G=+1.2V Output Step	-	0.5	-	uS
Overload Recovery Time		V_{IN}xG=V_s	-	3.2	-	uS
Noise Performance						
Voltage Noise Density	e_n	f=1KHz	-	9.5	-	nV/√Hz
		f=10KHz	-	6.5	-	nV/√Hz

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Typical Performance Characteristics.

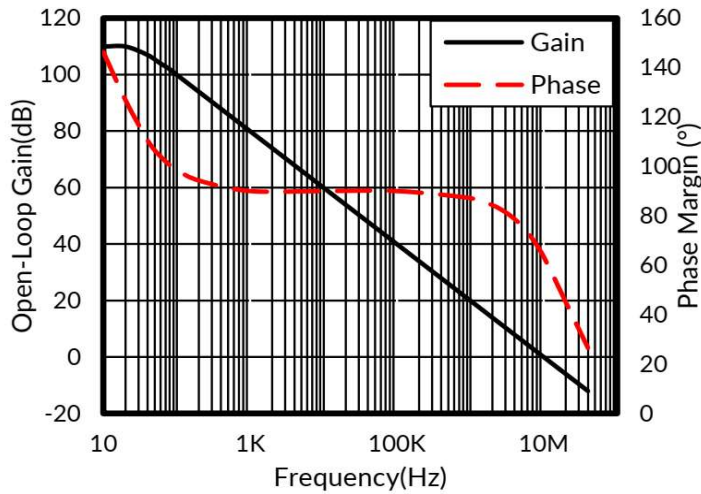**(TA=25 `C, Vs=+5V, and RL=10KΩ connected to Vs/2, VOUT=Vs/2,Unless Otherwise Noted.)**

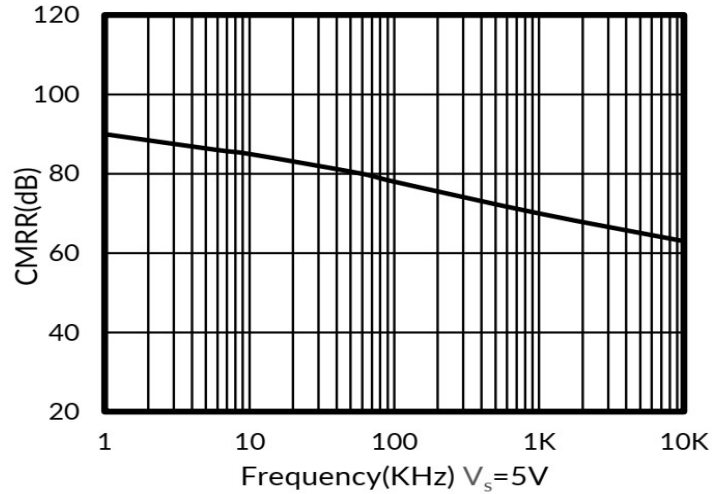Figure 3. Open-Loop Gain and
Phase vs Frequency
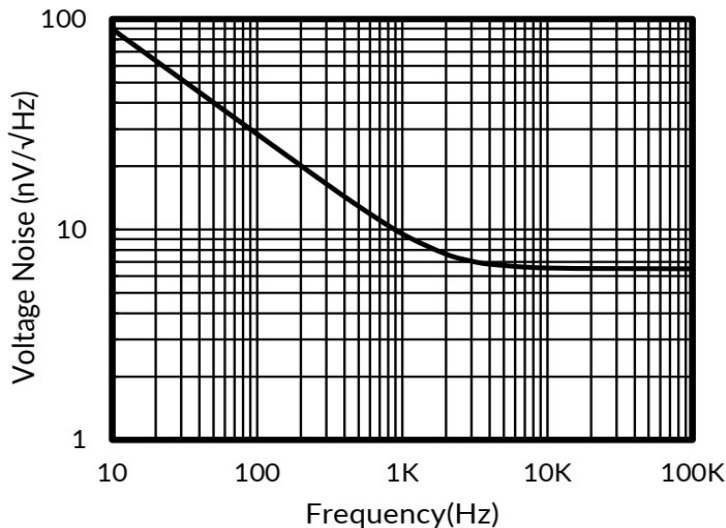
Figure 4. Common-Mode Rejection
Ratio vs Frequency

Figure 5. Input Voltage Noise Spectral
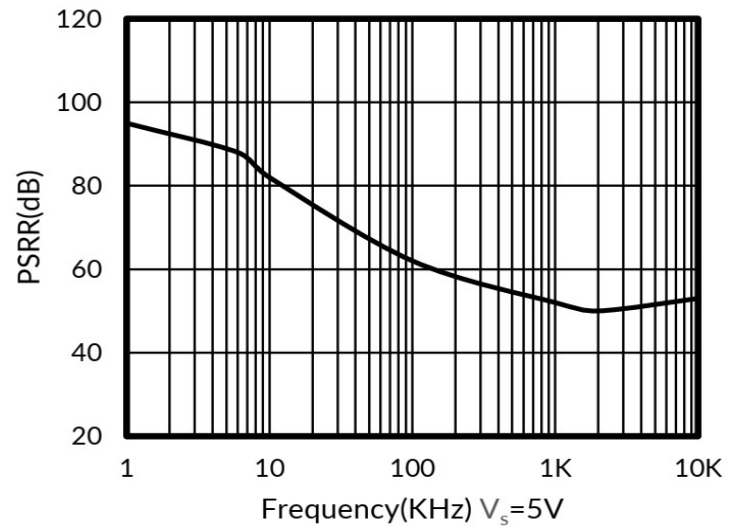Density vs Frequency
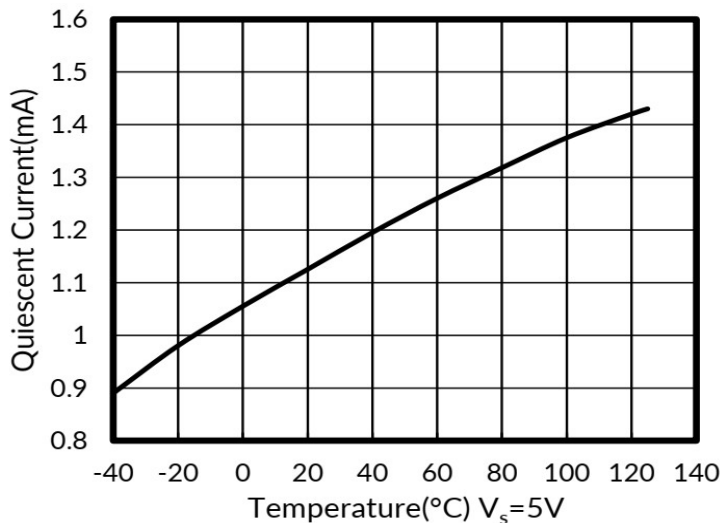
Figure 6. Power-Supply Rejection
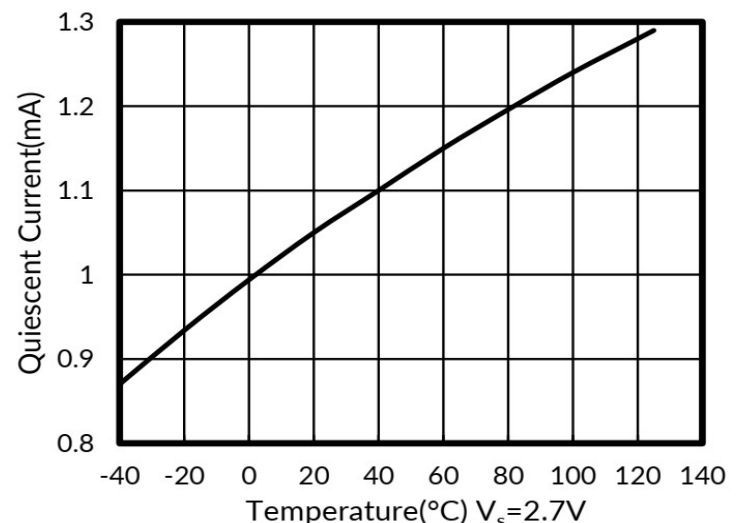Ratio vs Frequency

Figure 7. Quiescent Current vs Temperature

Figure 8. Quiescent Current vs Temperature

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Typical Performance Characteristics(con.)

(TA=25 `C, Vs=+5V, and RL=10KΩ connected to Vs/2, VOUT=Vs/2,Unless Otherwise Noted.)

Figure 9. Sink Current vs Temperature

Figure 10. Source Current vs Temperature
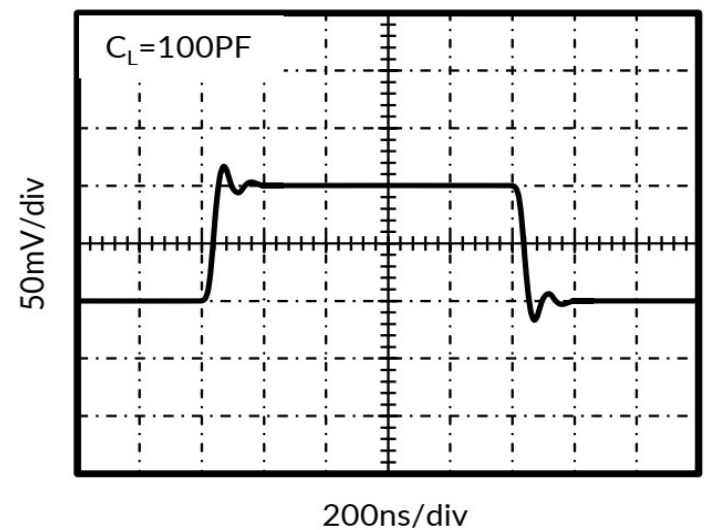
Figure 11. Input Bias Current vs Temperature

Figure 12. small-Signal Step Response

Figure 13. Large-Signal Step Response
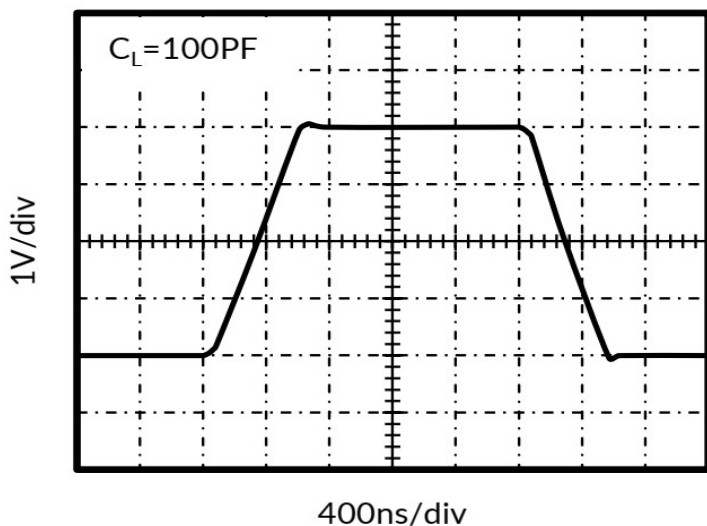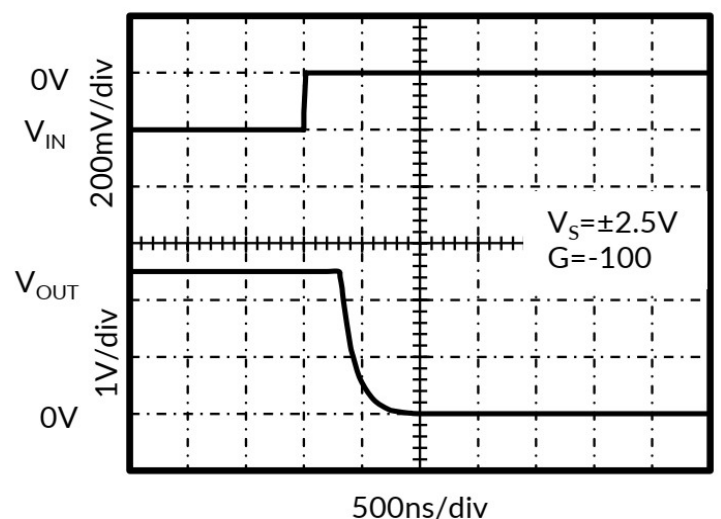
Figure 14. Positive Overload Recovery

Product Specification **www.hcrsemi.com**

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Typical Performance Characteristics(con.)

(TA=25 `C, Vs=+5V, and RL=10KΩ connected to Vs/2, VOUT=Vs/2,Unless Otherwise Noted.)
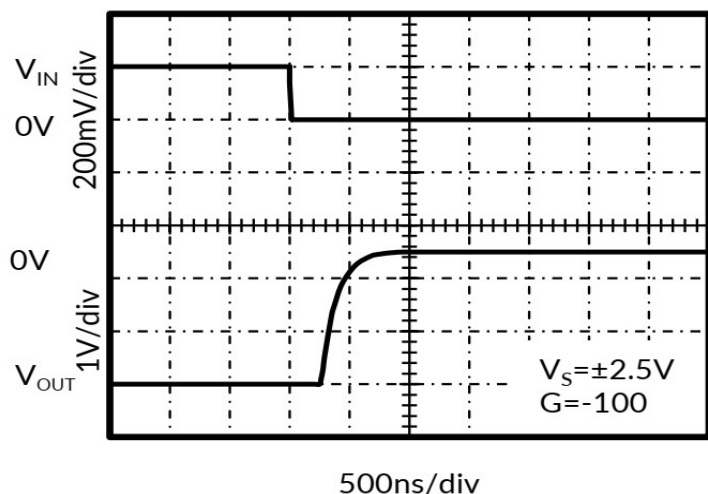

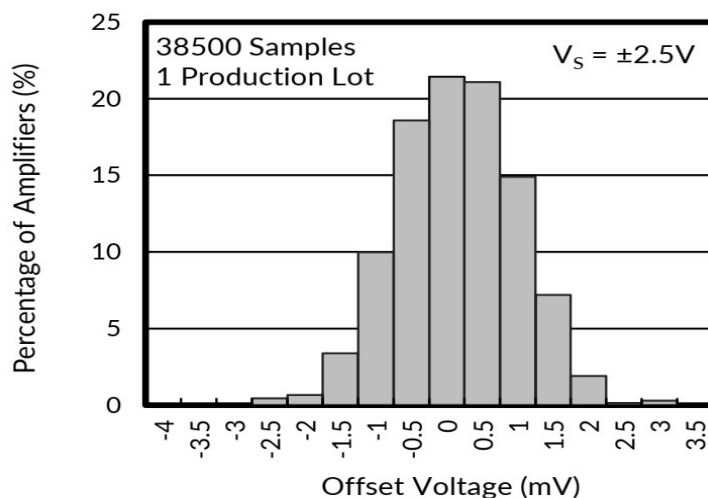Figure 15. Negative Overload Recovery

Figure 16. Offset Voltage Production Distribution

Detailed Description

Overview

The HCR721, HCR722, HCR724 are high precision, rail-to-rail operational amplifiers that can be run from a single supply voltage 2.5V to 5.5V(±1.25V to ±2.75V). Supply voltages higher than 7V(absolute maximum) can permanently damage the amplifier. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications. Good layout practice mandates use of a 0.1μF capacitor place closely across the supply pins.

Figure 17. Output Waveform Devoid of Phase Reversal During an Input Overdrive Condition

Phase Reversal Protection

The HCR721/HCR722/HCR724 family has internal phase-reversal protection. Many op amps exhibit phase reversal when the input is driven beyond the linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The input of the HCR721/HCR722/HCR724 prevents phase reversal with excessive common-mode voltage. Instead, the appropriate rail limits the output voltage. This performance is shown in figure 17.
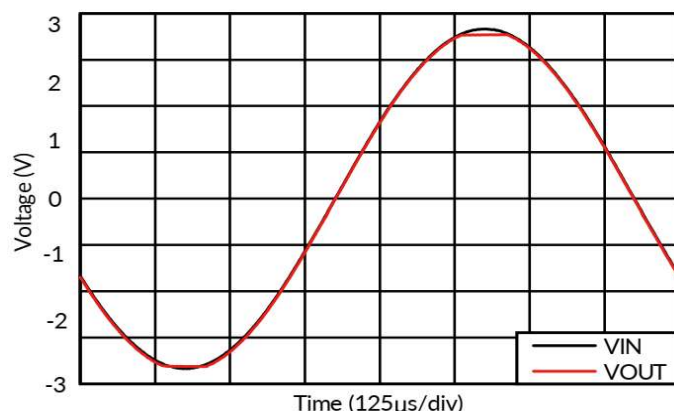
EMI Rejection Ratio (EMIRR)

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many operational amplifiers is a change in the offset voltage as a result of RF signal rectification. An operational amplifier that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this document provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the operational amplifier.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Detailed Description(con)

EMI Rejection Ratio (EMIRR)

In general, only the noninverting input is tested for EMIRR for the following three reasons:

• Operational amplifier input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.

• The noninverting and inverting operational amplifier inputs have symmetrical physical layouts and exhibit nearly matching EMIRR performance.

• EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input pin can be isolated on a printed-circuit-board (PCB). This isolation allows the RF signal to be applied directly to the noninverting input pin with no complex interactions from other components or connecting PCB traces.

The EMIRR IN+ of the HCR721/HCR722/HCR724 is plotted versus frequency in Figure 18. If available, any dual and quad operational amplifier device versions have approximately identical EMIRR IN+ performance. The HCR721/HCR722/HCR724 unity-gain bandwidth is 10MHz. EMIRR performance below this frequency denotes interfering signals that fall within the operational amplifier bandwidth.
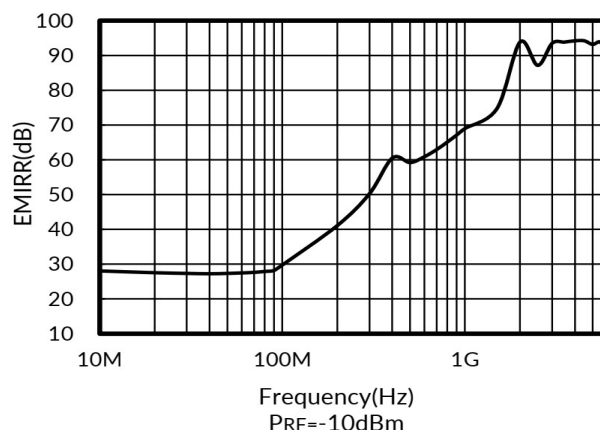

Figure 18. HCR721/HCR722/HCR724 EMIRR vs Frequency

EMIRR IN+ Test Configuration

Figure 19 shows the circuit configuration for testing the EMIRR IN+. RF source is connected to the operational amplifier noninverting input pin using a transmission line. The operational amplifier is configured in a unity-gain buffer topology with the output connected to a low-pass filter (LPF) and a digital multimeter (DMM).

A large impedance mismatch at the operational amplifier input causes a voltage reflection; however, this effect is characterized and accounted for when determining the EMIRR IN+. The resulting dc offset voltage is sampled and measured by the multimeter. The LPF isolates the multimeter from residual RF signals that can interfere with multimeter accuracy.
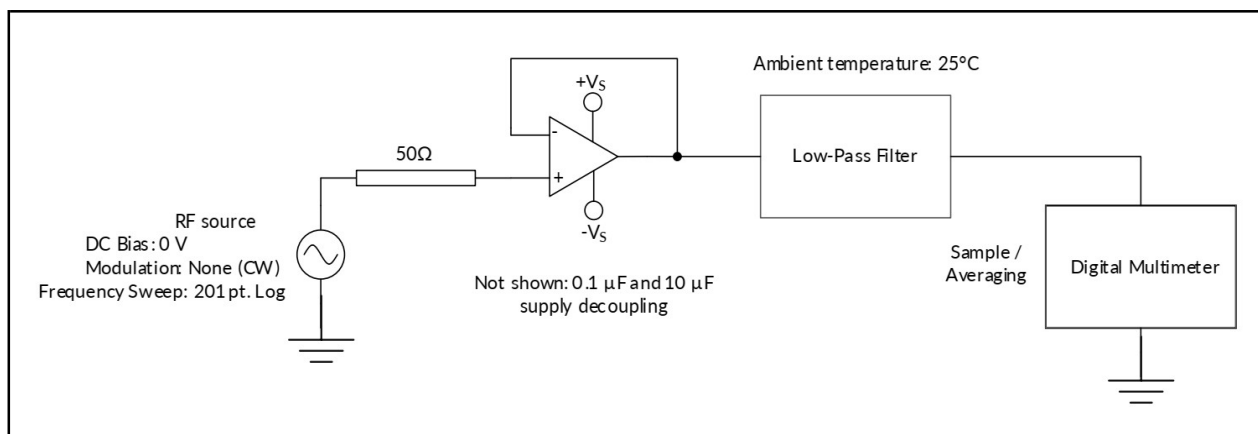

Figure 19. EMIRR IN+ Test Configuration Sche matic

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Application Note

The HCR721/HCR722/HCR724 are high precision, rail-to-rail operational amplifiers that can be run from a single-supply voltage 2.5V to 5.5V (±1.25V to ±2.75V). Supply voltages higher than 7V(absolute maximum) can permanently damage the amplifier. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications. Good layout practice mandates use of a 0.1μF capacitor place closely across the supply pins.

Typical Applications
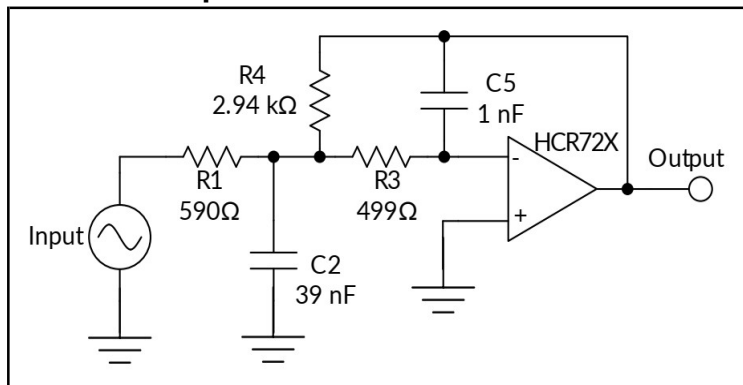
25-kHz Low-pass Filter

Figure 20. 25-kHz Low-pass Filter

Design Requirements

Low-pass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing.

The HCR721/HCR722/HCR724 devices are ideally suited to construct high-speed, high-precision active filters. Figure 20 shows a second-order, low-pass filter commonly encountered in signal processing applications. Use the following parameters for this design example:

• Gain = 5 V/V (inverting gain)

• Low-pass cutoff frequency = 25 kHz

• Second-order Chebyshev filter response with 3-dB gain peaking in the passband

Detailed Design Procedure

The infinite-gain multiple-feedback circuit for a low-pass network function is shown in Figure 20. Use Equation 1 to calculate the voltage transfer function.

$$\frac{Output}{Input}(s) = \frac{-1/R_1 R_3 C_2 C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3 R_4 C_2 C_5} \quad (1)$$

This circuit produces a signal inversion. For this circuit, the gain at dc and the low-pass cutoff frequency are calculated by Equation 2:

$$Gain = \frac{R_4}{R_1} \quad (2)$$

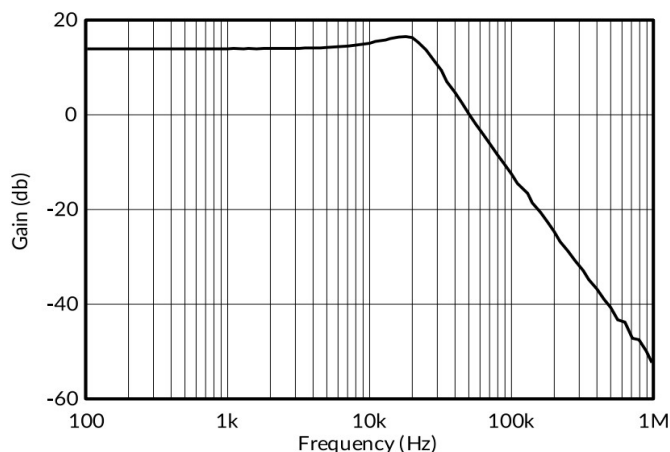$$f_C = \frac{1}{2\pi}\sqrt{(1/R_3 R_4 C_2 C_5)}$$

Application Curve

Figure 21. Low-Pass Filter Transfer Function

Layout Guidelines

Attention to good layout practices is always recommended. Keep traces short. When possible, use a PCB ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1μF capacitor closely across the supply pins. These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the EMI susceptibility.
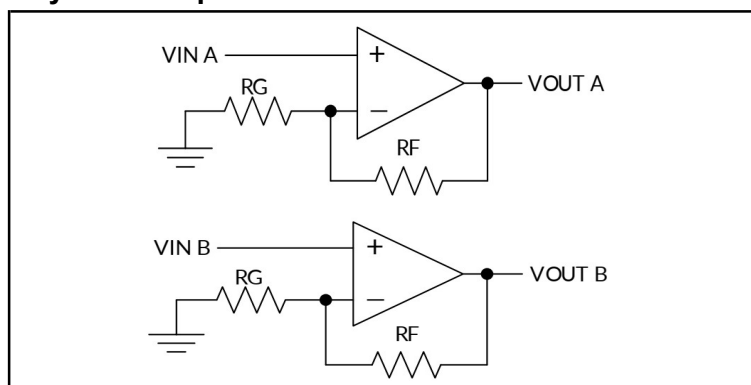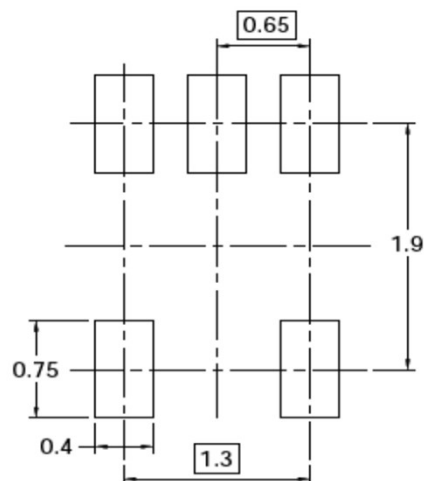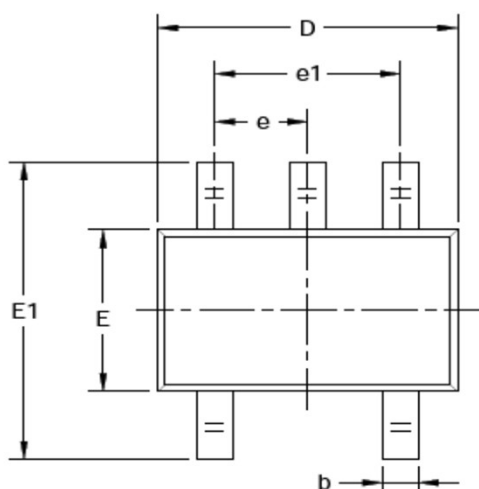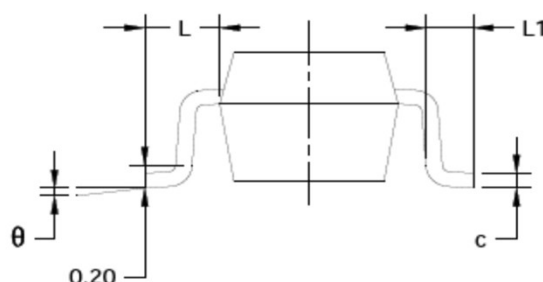
Layout Example

Figure 22. Schematic Representation

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions

SC5: SC70-5(SOT353) packages

RECOMMENDED LAND PATTERN (Unit: mm)

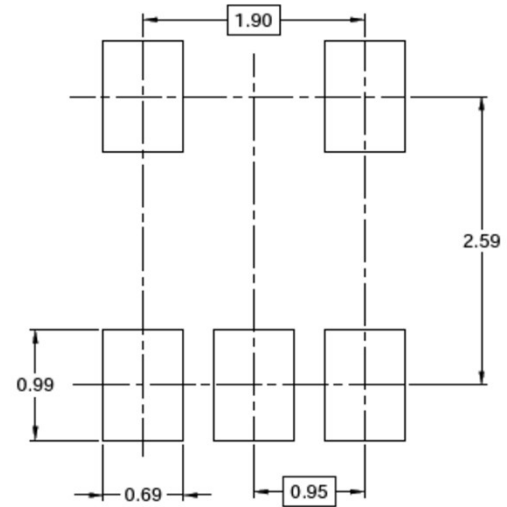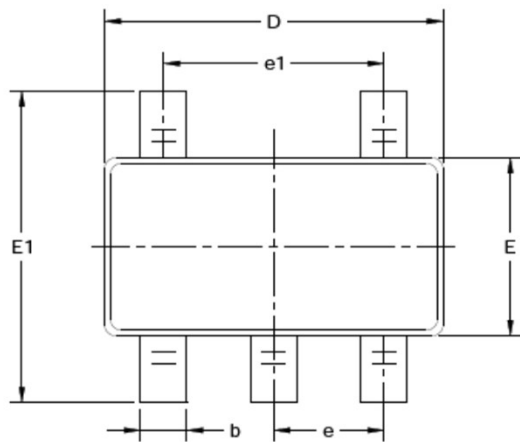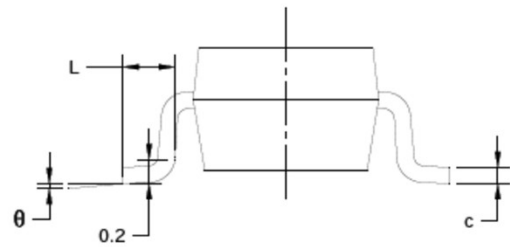| Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.080	0.150	0.003	0.006
D	2.000	2.200	0.079	0.087
E	1.150	1.350	0.045	0.053
E1	2.150	2.450	0.085	0.096
e	0.65 TYP		0.026 TYP	
e1	1.300 BSC		0.051 BSC	
L	0.525 REF		0.021 REF	
L1	0.260	0.460	0.010	0.018
θ	0°	8°	0°	8°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions(Con.)

M5: SOT23-5 package

RECOMMENDED LAND PATTERN (Unit: mm)

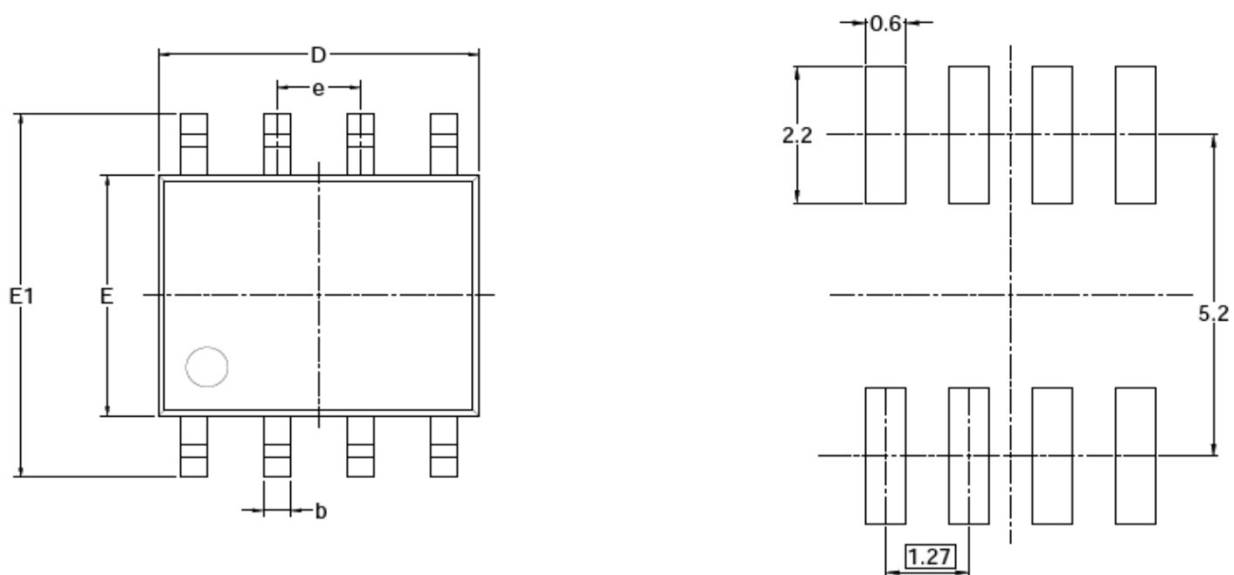| Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.900 BSC		0.075 BSC	
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions(Con.)

M8: SOIC-8(SOP-8) Package

RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions(Con.)

SM8: MSOP-8 Package

RECOMMENDED LAND PATTERN (Unit: mm)

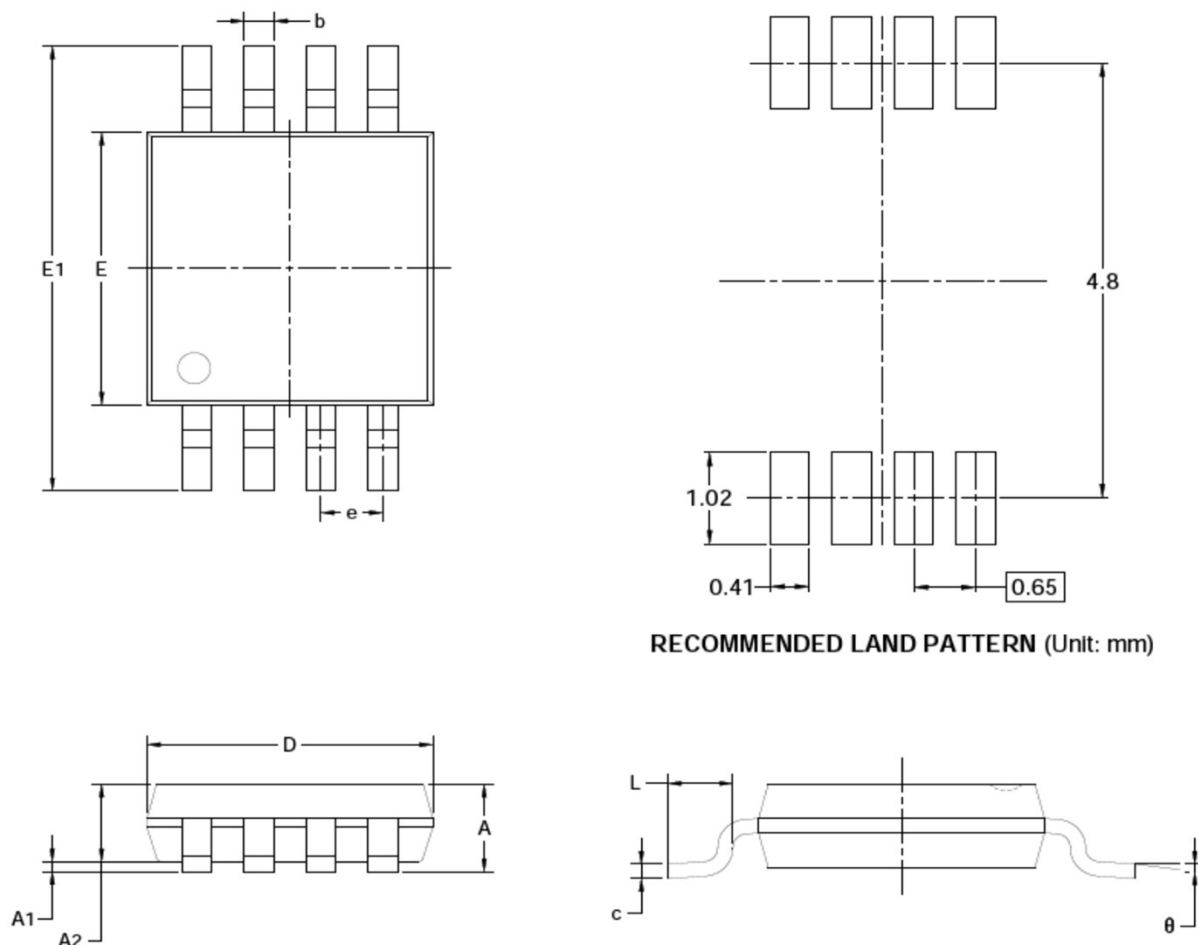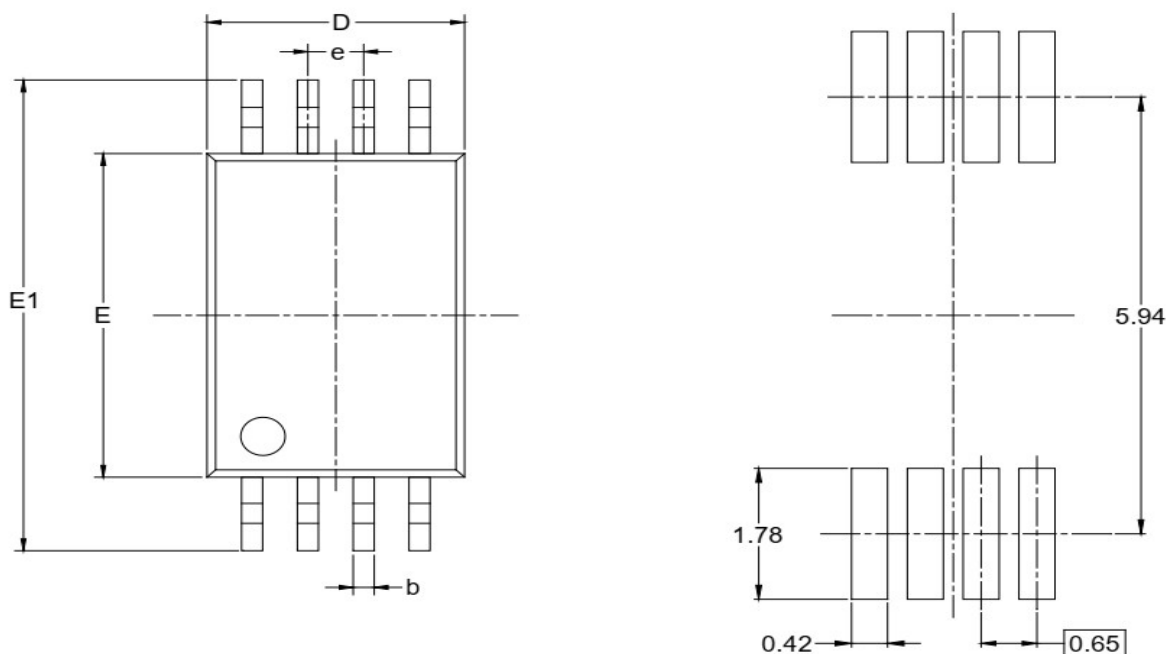| Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
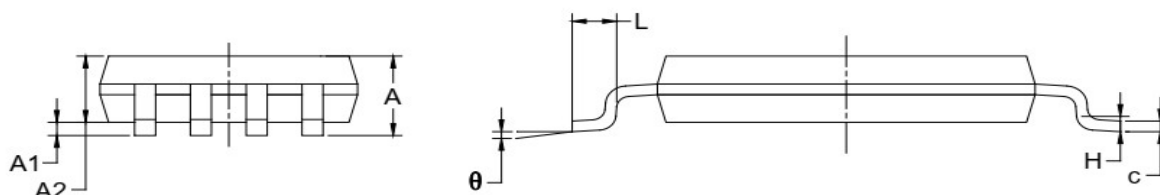2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions(Con.)

TS8: TSSOP-8 Package

RECOMMENDED LAND PATTERN (Unit: mm)

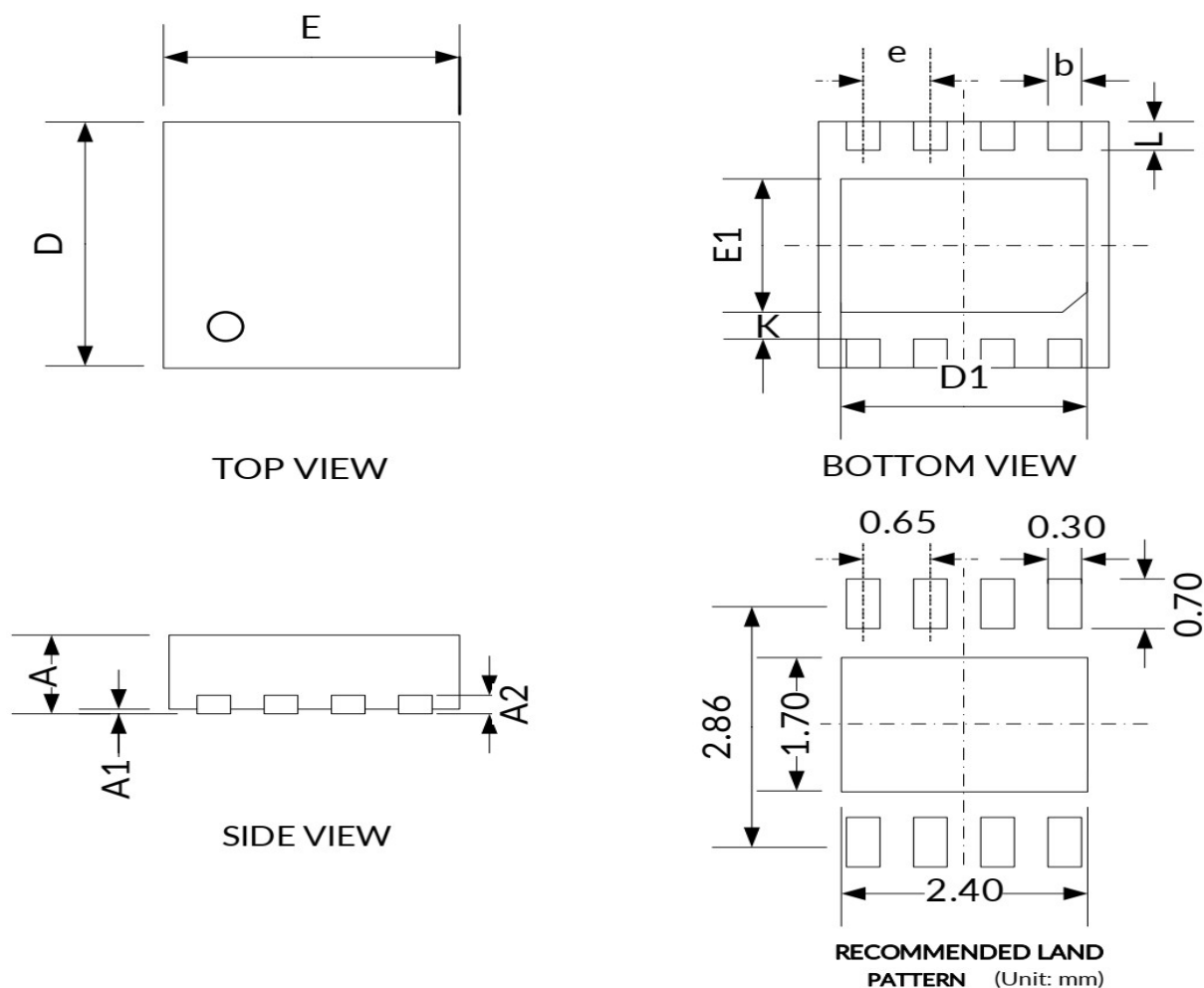| Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A		1.100		0.043
A1	0.050	0.150	0.002	0.006
A2	0.800	1.000	0.031	0.039
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	2.900	3.100	0.114	0.122
E	4.300	4.500	0.169	0.177
E1	6.250	6.550	0.246	0.258
e	0.650 BSC		0.026 BSC	
L	0.500	0.700	0.02	0.028
H	0.25 TYP		0.01 TYP	
θ	1°	7°	1°	7°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions(Con.)

DN38: DFN3x3-8L Package

TOP VIEW

BOTTOM VIEW

SIDE VIEW

RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A [1]	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF [2]		0.008 REF [2]	
b	0.200	0.300	0.008	0.012
D [1]	2.900	3.100	0.114	0.122
D1	2.250	2.350	0.089	0.093
E [1]	2.900	3.100	0.114	0.122
E1	1.450	1.550	0.057	0.061
e	0.650 TYP		0.026 TYP	
L	0.425	0.525	0.017	0.021
K	0.200 REF [2]		0.008 REF [2]	

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier
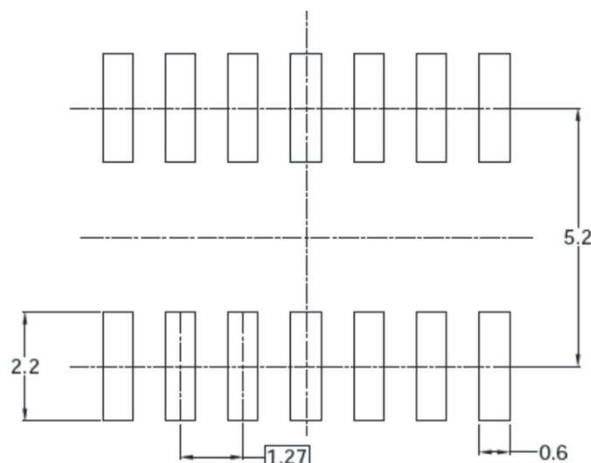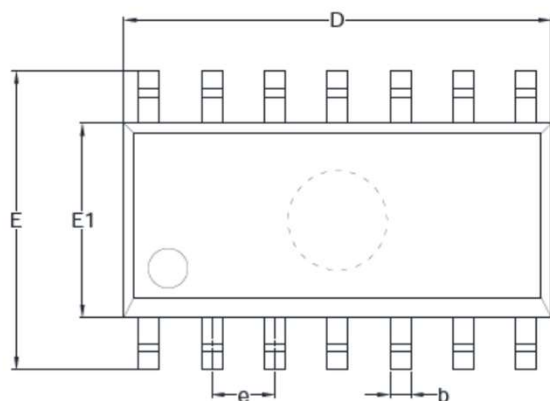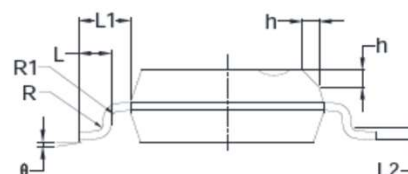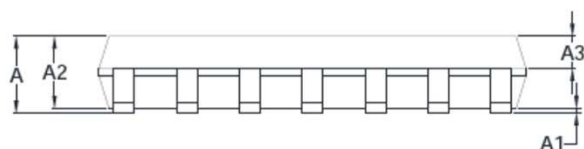
Mechanical Dimensions(Con.)

M14: SOIC-14 Package

RECOMMENDED LAND PATTERN (Unit: mm)

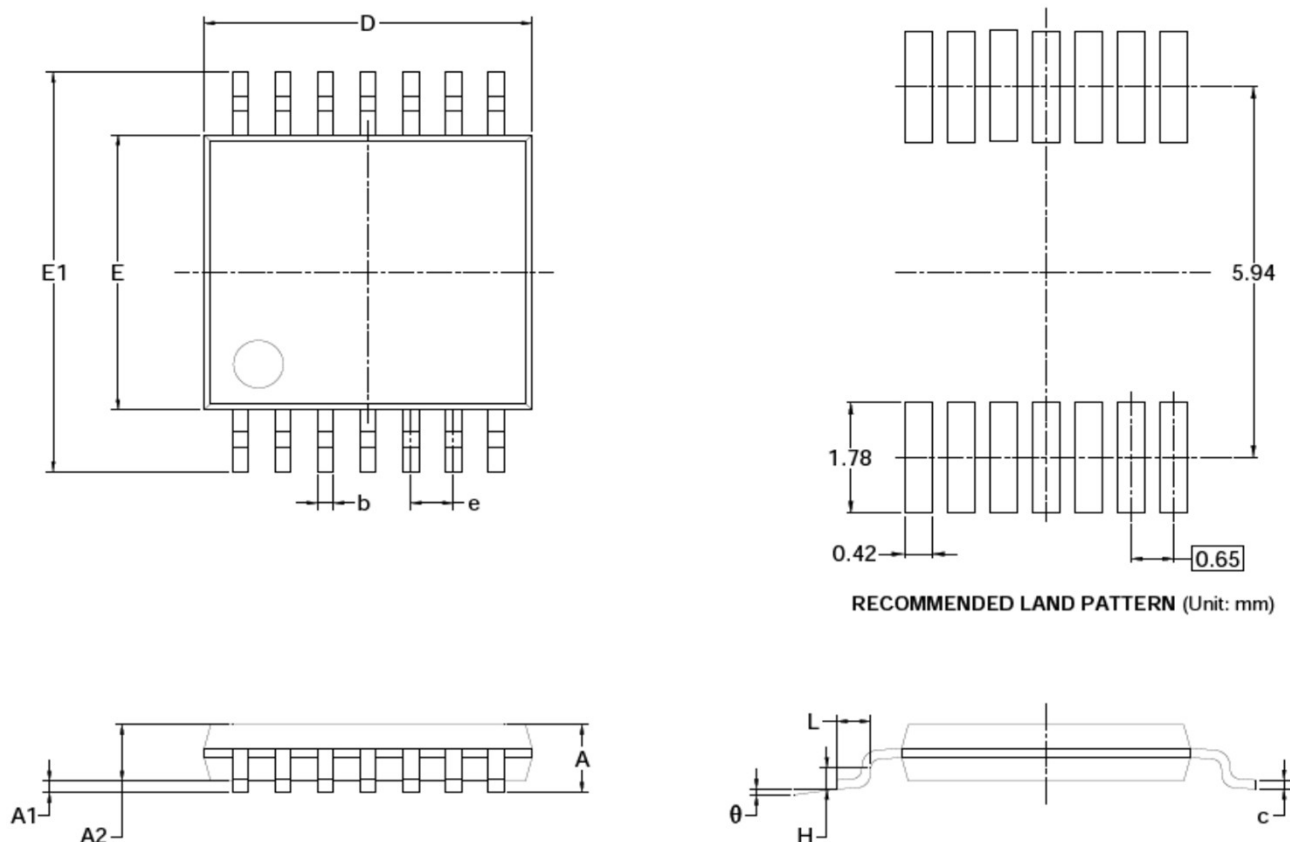| Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2	1.25	1.65	0.049	0.065
A3	0.55	0.75	0.022	0.030
b	0.36	0.49	0.014	0.019
D	8.53	8.73	0.336	0.344
E	5.80	6.20	0.228	0.244
E1	3.80	4.00	0.150	0.157
e	1.27 BSC		0.050 BSC	
L	0.45	0.80	0.018	0.032
L1	1.04 REF		0.040 REF	
L2	0.25 BSC		0.01 BSC	
R	0.07		0.003	
R1	0.07		0.003	
h	0.30	0.50	0.012	0.020
θ	0°	8°	0°	8°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

10MHz, Low Noise Rail-to-Rail I/O CMOS Operational Amplifier

Mechanical Dimensions(Con.)

TSP14: TSSOP-14 Package

RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A		1.200		0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.860	5.100	0.191	0.201
E	4.300	4.500	0.169	0.177
E1	6.250	6.550	0.246	0.258
e	0.650 BSC		0.026 BSC	
L	0.500	0.700	0.02	0.028
H	0.25 TYP		0.01 TYP	
θ	1°	7°	1°	7°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.