

### Features

- Supply Voltage: 3V to 36V
- Low Supply Current: 100 $\mu$ A per channel
- Input Common-Mode Voltage Range Includes Ground
- Can Work as Comparator
- Rail to Rail Output
- Bandwidth: 0.9 MHz
- Slew Rate: 0.5V/ $\mu$ s
- Excellent EMI Suppress Performance: 71dB at 1GHz
- Offset Voltage:  $\pm$ 3mV Maximum
- Offset Voltage Temperature Drift: 7  $\mu$ V/ $^{\circ}$ C
- $-40^{\circ}$ C to  $125^{\circ}$ C Operation Temperature Range

### Applications

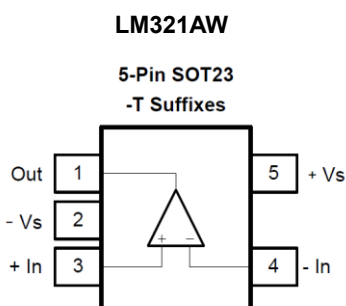
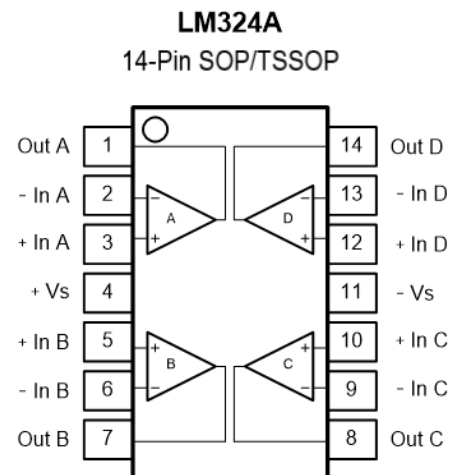
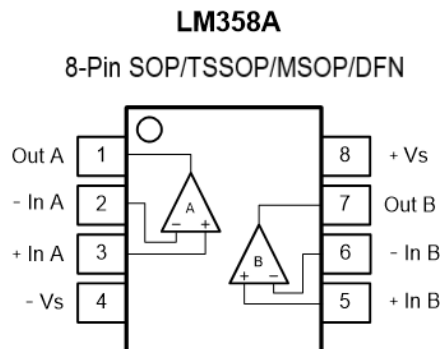
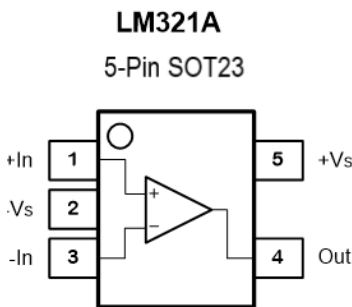
- Power Module
- Sensor Interface
- Motor Control
- Audio

### Description

The LM321A/358A/324A series amplifiers are newest high supply voltage amplifiers with low offset, low power and stable frequency response. They incorporate 3PEAK's proprietary and patented design techniques to achieve very good AC performance with 0.9MHz bandwidth, 0.5V/ $\mu$ s slew rate and maximum 3mV offset while drawing only 100 $\mu$ A of quiescent current per amplifier. The input common-mode voltage range extends to  $V_{-}$ , and the outputs swing rail-to-rail. The LM321A/358A/324A family can be used as plug-in replacements for many commercially available op-amps to reduce power and improve input/output range and performance.

The combination of features makes the LM321A/358A/324A ideal choices for power module, industrial control, motor control and audio application.

### Pin Configuration



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## Revision History

Date	Revision	Notes
2018/11/1	Rev.0	Initial Version.
2018/12/25	Rev.0.01	Updated date code information of LM358A-F1R: "AAYW" -> "YW".
2019/1/14	Rev.0.02	Updated Mark Information of LM358A-SR, LM358A-CSR: "LM358A" -> "358A"; Update Package Information: Remove "SC70", Update Package Dimensions of SOP-8.
2019/6/26	Rev.0.03	Added temperature limit of VOL, VOH, I <sub>sc</sub> . Updated Package Dimension.
2019/8/16	Rev.0.04	Updated the description of VOL, VOH in Electrical Characteristics: Remove VOL, VOH, Maximum Output Swing -> Output Voltage Swing from Positive and Negative Rail; Output Voltage Swing Low -> Output Voltage Swing from Negative Rail.
2019/12/25	Rev.0.05	Updated the mark of LM358A-F1R: "58A" -> "58".
2020/9/24	Rev.A	Updated the description of Absolute Maximum Ratings: "Maximum Junction Temperature" -> "Maximum Operating Junction Temperature".
2020/12/11	Rev.A.1	Added Maximum Value of I <sub>B</sub> , I <sub>IN</sub> in Electrical Characteristics.
2021/5/10	Rev.A.2	Updated Spec: I <sub>q</sub> of LM321A.
2022/4/29	Rev.A.3	Updated EC table: Add max of I <sub>os</sub> , Add common voltage range in 25 degree.
2022/10/10	Rev.A.4	Modified the package description: "SOIC" to "SOP". Added part number: LM321AW-S5TR.
2023/7/14	Rev.A.5	Corrected typo in order information.
2023/12/20	Rev.A.6	Added test figures.

## Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity
LM321A-TR	-40 to 125°C	SOT23-5	21A	3	Tape and Reel, 3000
LM321AW-S5TR	-40 to 125°C	SOT23-5	A28	3	Tape and Reel, 3000
LM358A-SR	-40 to 125°C	SOP8	358A	3	Tape and Reel, 4000
LM358A-CSR	-40 to 85°C	SOP8	358A	3	Tape and Reel, 4000
LM358A-F1R	-40 to 125°C	DFN8 1.5*1.5	58	1	Tape and Reel, 3000
LM358A-TSR	-40 to 125°C	TSSOP8	LM358A	3	Tape and Reel, 3000
LM358A-VR	-40 to 125°C	MSOP8	LM358A	3	Tape and Reel, 3000
LM324A-SR	-40 to 125°C	SOP14	LM324A	3	Tape and Reel, 2500
LM324A-CSR	-40 to 85°C	SOP14	LM324A	3	Tape and Reel, 2500
LM324A-TR	-40 to 125°C	TSSOP14	LM324A	3	Tape and Reel, 3000

## Absolute Maximum Ratings <sup>Note 1</sup>

Parameters	Rating
Supply Voltage, (+V <sub>S</sub> )– (–V <sub>S</sub> )	40 V
Input Voltage	(–V <sub>S</sub> ) – 0.3 to (+V <sub>S</sub> ) + 0.3
Differential Input Voltage	(+V <sub>S</sub> ) - (–V <sub>S</sub> )
Input Current: +I <sub>N</sub> , –I <sub>N</sub> <sup>Note 2</sup>	±10mA
Output Short-Circuit Duration <sup>Note 3</sup>	Infinite
Maximum Operating Junction Temperature	150°C
Operating Temperature Range	–40 to 125°C
Storage Temperature Range	–65 to 150°C
Lead Temperature (Soldering, 10 sec)	260°C

Note 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.

Note 2: The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 300mV beyond the power supply, the input current should be limited to less than 10mA.

Note 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 Rating

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001	3	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002	2	kV

## Thermal Information

Package Type	θ <sub>JA</sub>	θ <sub>JC</sub>	Unit
5-Pin SOT23	250	81	°C/W
8-Pin SOP	158	43	°C/W
8-Pin TSSOP	191	44	°C/W
8-Pin MSOP	210	45	°C/W
8-Pin DFN 1.5*1.5	200	60	°C/W
14-Pin SOP	120	36	°C/W
14-Pin TSSOP	180	35	°C/W

## Electrical Characteristics

All test condition is  $V_S = 30V$ ,  $T_A = 25^\circ C$ ,  $R_L = 10k\Omega$ ,  $C_L = 100pF$ , unless otherwise noted.

Symbol	Parameter	Conditions	T <sub>A</sub>	Min	Typ	Max	Unit
Power Supply							
V <sub>S</sub>	Supply Voltage Range			3		36	V
I <sub>Q</sub>	Quiescent Current per Amplifier, LM321A	V <sub>S</sub> = 30V			150	250	μA
			−40 to 125°C			350	μA
		V <sub>S</sub> = 5V			150	200	μA
			−40 to 125°C			300	μA
I <sub>Q</sub>	Quiescent Current per Amplifier, LM358A, LM324A	V <sub>S</sub> = 30V			110	200	μA
			−40 to 125°C			250	μA
		V <sub>S</sub> = 5V			100	150	μA
			−40 to 125°C			200	μA
PSRR	Power Supply Rejection Ratio	V <sub>S</sub> = 5V to 36V		85	120		dB
			−40 to 125°C	80			dB
Input Characteristics							
V <sub>OS</sub>	Input Offset Voltage	V <sub>S</sub> = 30V, V <sub>CM</sub> = 0V to 28V		−3	0.1	3	mV
			0 to 70°C	−4		4	mV
			−40 to 125°C	−7		7	mV
		V <sub>S</sub> = 5V, V <sub>CM</sub> = 0V to 3V		−3	0.1	3	mV
			0 to 70°C	−4		4	mV
			−40 to 125°C	−7		7	mV
V <sub>OS</sub> TC	Input Offset Voltage Drift		−40 to 125°C		7		μV/°C
I <sub>B</sub>	Input Bias Current				60	500	pA
		−40 to 125°C			600	1000	pA
I <sub>OS</sub>	Input Offset Current <sup>Note 1</sup>				60	500	pA
		−40 to 125°C			600	1000	pA
I <sub>IN</sub>	Different Input Current	V <sub>S</sub> = 36V, V <sub>ID</sub> = 36V			5	150	nA
		V <sub>S</sub> = 36V, V <sub>ID</sub> = 36V	−40 to 125°C		20	1000	nA
C <sub>IN</sub>	Input Capacitance	Differential Mode			5		pF
		Common Mode			5		pF
A <sub>v</sub>	Open-loop Voltage Gain			95	110		dB
		−40 to 125°C		90			dB
V <sub>CMR</sub>	Common-mode Input Voltage Range			(V <sub>−</sub> )		(V <sub>+</sub> ) − 1.5	V
		−40 to 125°C		(V <sub>−</sub> )		(V <sub>+</sub> ) − 2	V
CMRR	Common Mode Rejection Ratio	V <sub>CM</sub> = 0V to 28V		75	120		dB
			−40 to 125°C	70	90		dB
Output Characteristics							
	Output Voltage Swing from	R <sub>LOAD</sub> = 10kΩ to V <sub>S</sub> /2			200	300	mV

	Positive and Negative Rail		−40 to 125°C			700	mV
		$R_{LOAD} = 2k\Omega$ to $V_S/2$			1.1	1.3	V
			−40 to 125°C			2	V
	Output Voltage Swing from Negative Rail	$V_S = 5V$ , $R_{LOAD} = 10k\Omega$ to 0V			5	10	mV
$I_{SC}$	Output Short-Circuit Current			25	30		mA
		−40 to 125°C	15				mA
AC Specifications							
GBW	Gain-Bandwidth Product				0.9		MHz
SR	Slew Rate	$G = 1$ , 2V step			0.5		V/ $\mu$ s
$t_s$	Settling Time, 0.1%	$G = 1$ , 2V step			4		$\mu$ s
	Settling Time, 0.01%				5		$\mu$ s
PM	Phase Margin	$V_S = 30V$ , $R_L = 1K$ , $C_L = 100pF$			60		°
GM	Gain Margin	$V_S = 30V$ , $R_L = 1K$ , $C_L = 100pF$			15		dB
	Channel Separation	$f = 1\text{ kHz}$ to 20 kHz			120		dB
Noise Performance							
$E_N$	Input Voltage Noise	$f = 0.1\text{Hz}$ to 10Hz			3		$\mu V_{RMS}$
$e_N$	Input Voltage Noise Density	$f = 1\text{kHz}$			70		nV/ $\sqrt{\text{Hz}}$
$i_N$	Input Current Noise	$f = 1\text{kHz}$			3		fA/ $\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion and Noise	$f = 1\text{kHz}$ , $G = 1$ , $R_L = 10k\Omega$ , $V_{OUT} = 6V_{RMS}$			0.001		%

Note 1: Provided by bench test and design simulation

### Typical Performance Characteristics

$V_s = \pm 15V$ ,  $V_{CM} = 0V$ ,  $R_L = 10k\Omega$ , unless otherwise specified.

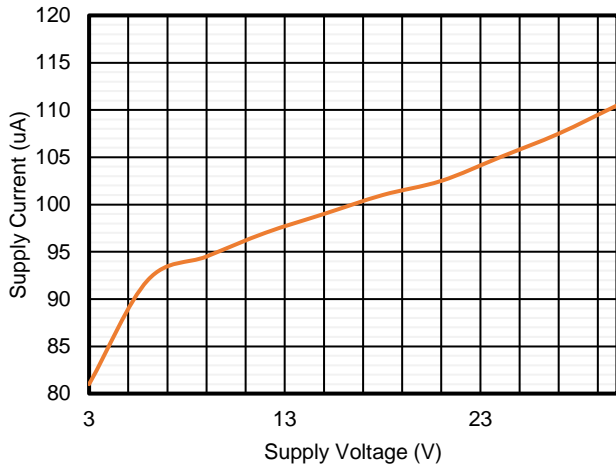


Figure 1. Quiescent Current vs. Supply Voltage

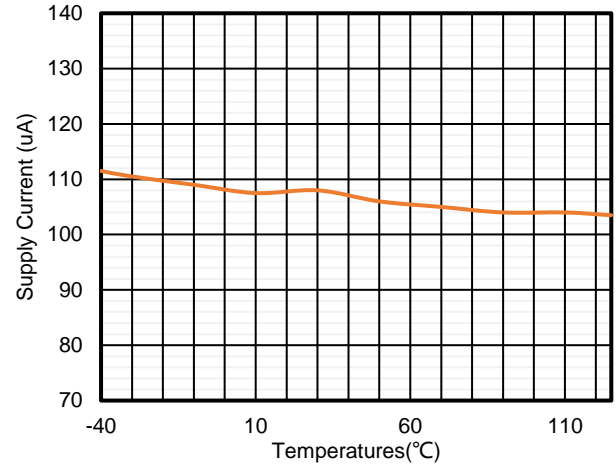


Figure 2. Quiescent Current vs. Temperature

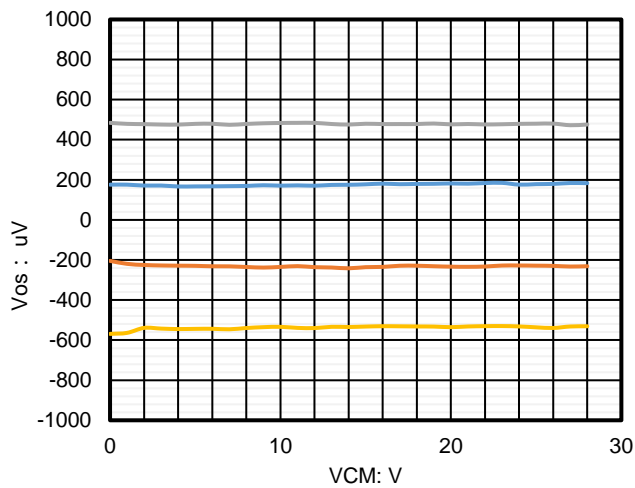


Figure 3. Offset Voltage vs. Common Mode Voltage

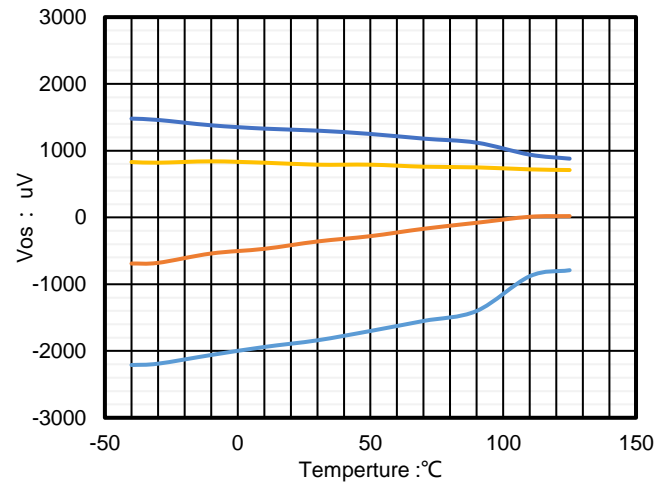


Figure 4. Offset Voltage vs. Temperature

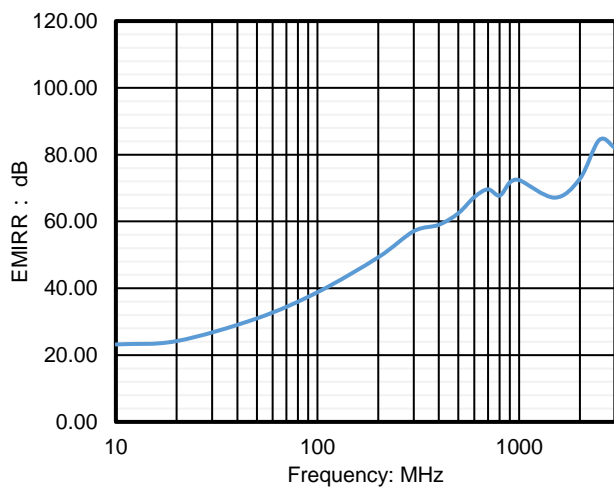


Figure 5. EMIRR+ vs. Frequency

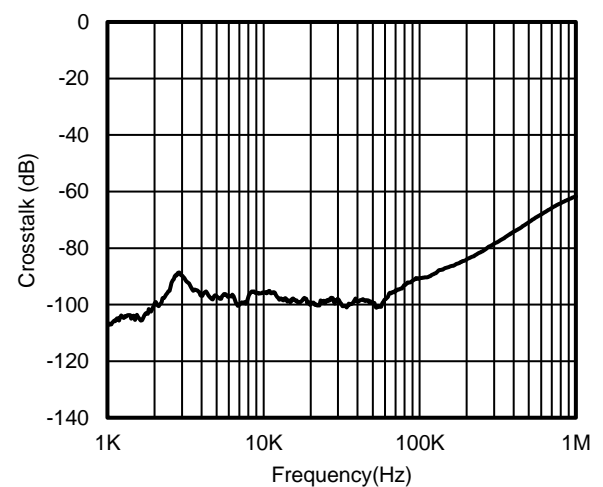


Figure 6. Crosstalk vs. Frequency



$V_s = \pm 15V$ ,  $V_{CM} = 0V$ ,  $R_L = 10k\Omega$ , unless otherwise specified.

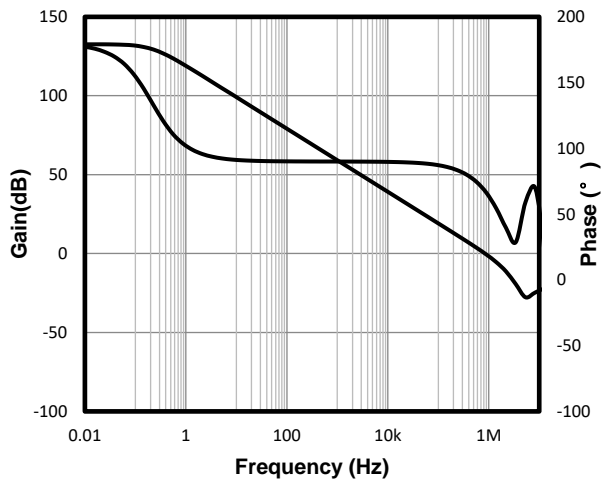


Figure 7. Open Loop Gain and Phase vs. Frequency

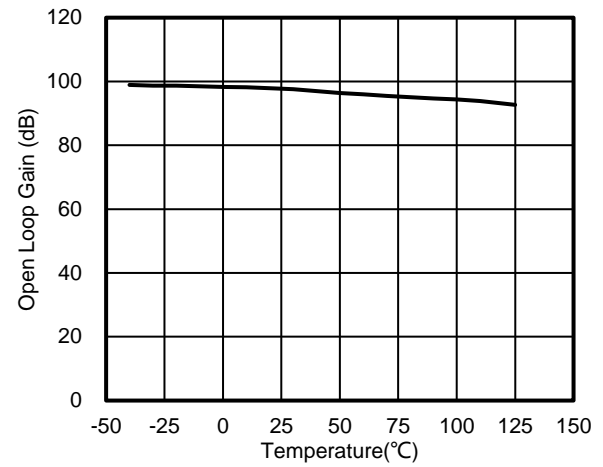


Figure 8. Open Loop Gain vs. Temperature

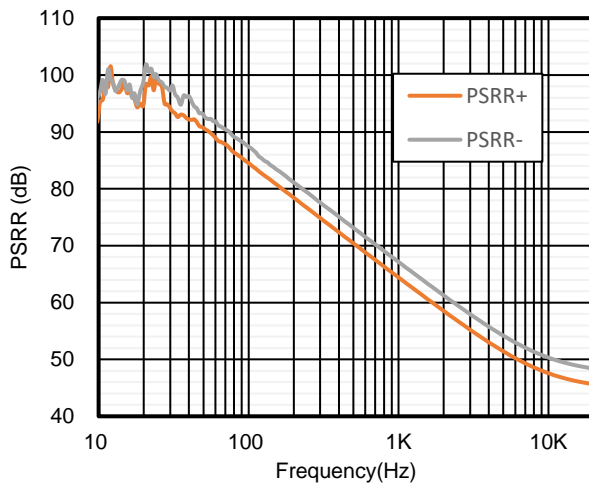


Figure 9. PSRR vs. Frequency

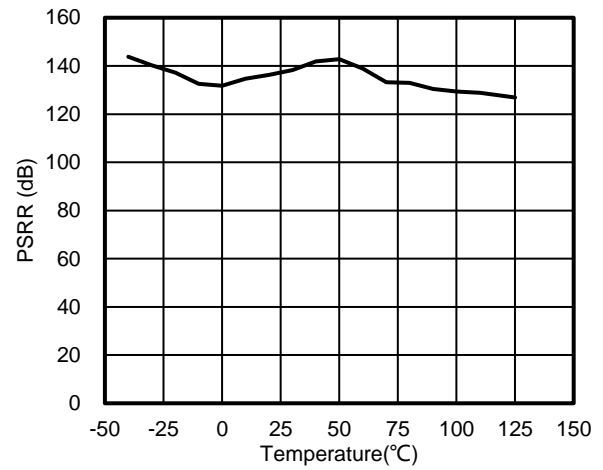


Figure 10. PSRR vs. Temperature

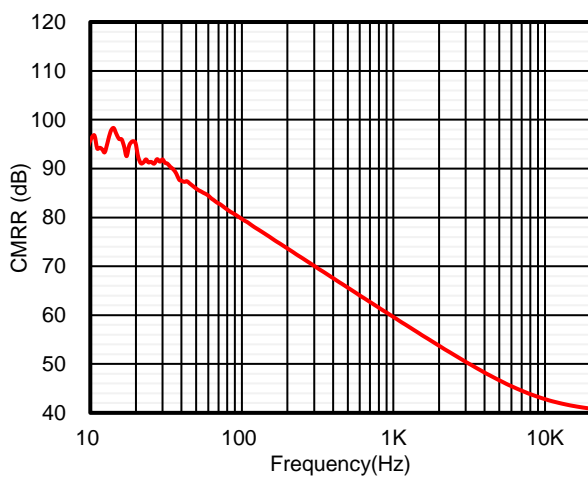


Figure 11. CMRR vs. Frequency

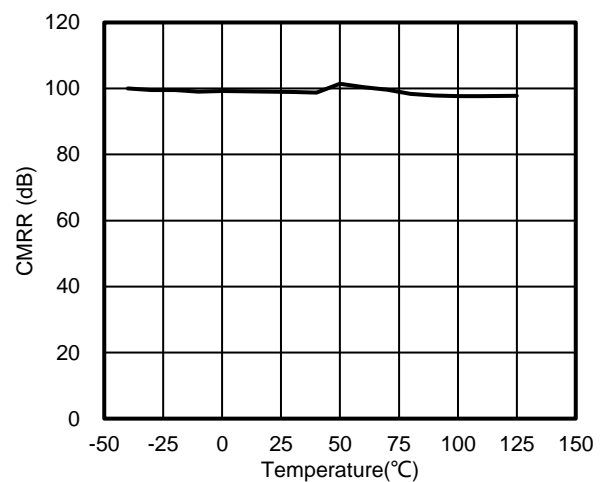


Figure 12. CMRR vs. Temperature

$V_s = \pm 15V$ ,  $V_{CM} = 0V$ ,  $R_L = 10k\Omega$ , unless otherwise specified.

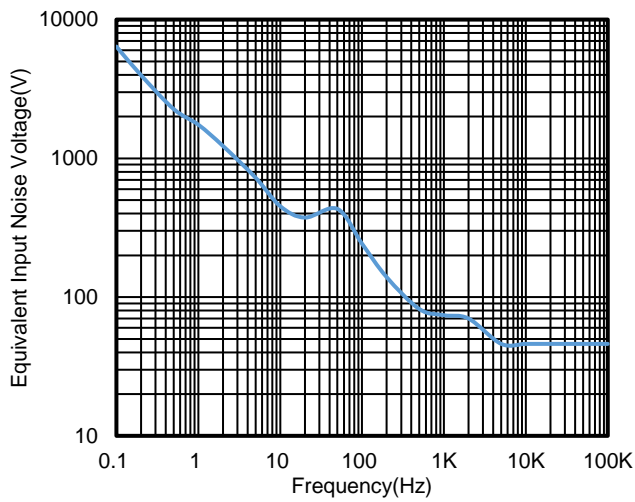


Figure 13. Voltage Noise Spectral Density vs. Frequency

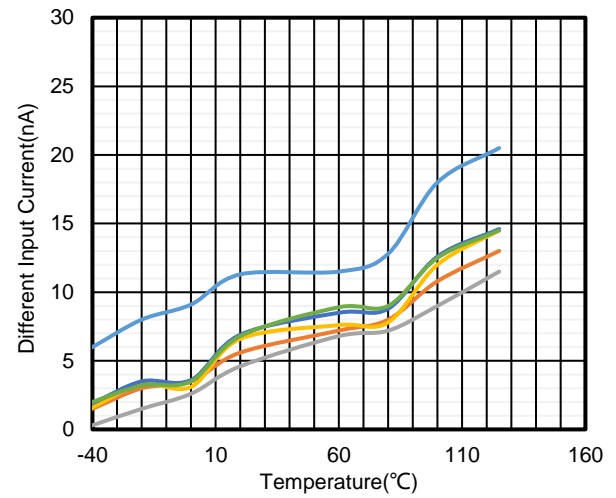


Figure 14. Different Input Current vs. Temperature

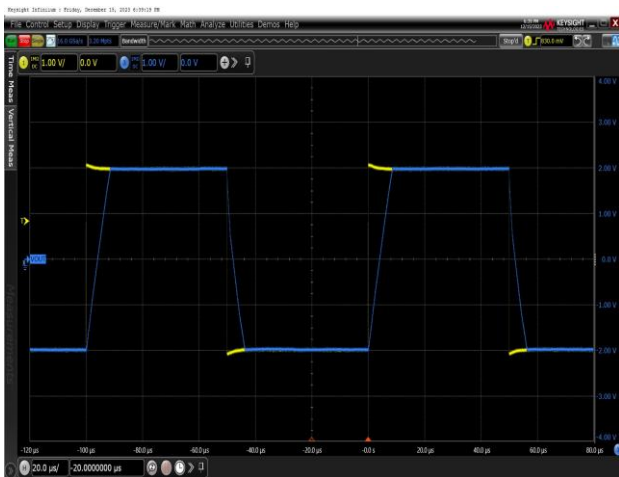
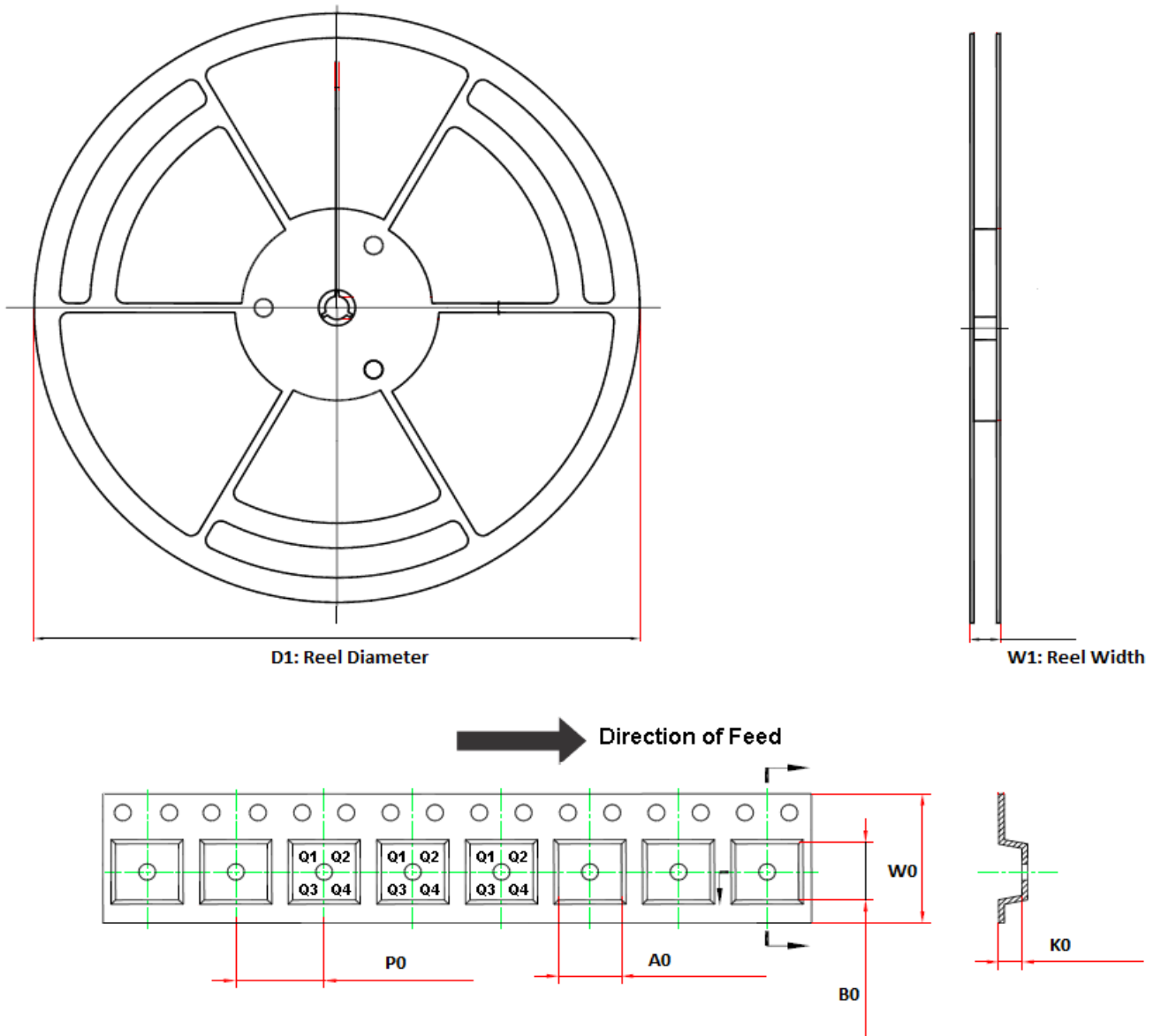


Figure 15. Large Signal Response, 4V Step,  $G = 1$

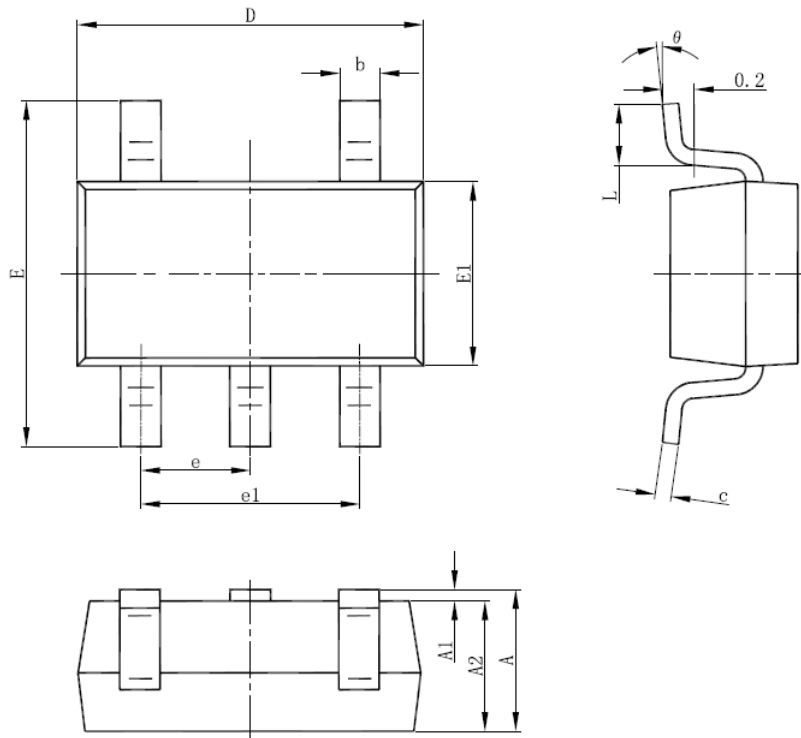
## Tape and Reel Information



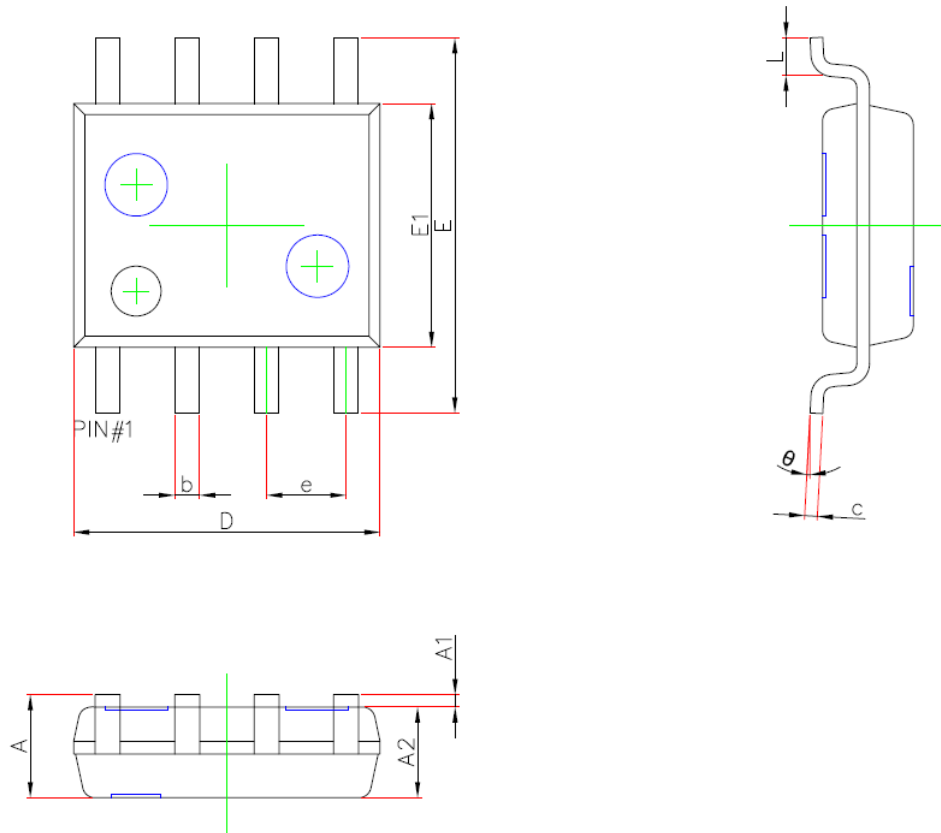
Order Number	Package	D1	W1	A0	B0	K0	P0	W0	Pin1 Quadrant
LM321A-TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
LM321AW-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
LM358A-SR	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
LM358A-CSR	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
LM358A-VR	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
LM358A-TSR	TSSOP8	330.0	17.6	6.8	3.3	1.2	8.0	12.0	Q1
LM358A-F1R	DFN8 1.5*1.5	178.0	12.3	1.7	1.7	0.75	4.0	8.0	Q1
LM324A-SR	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
LM324A-CSR	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
LM324A-TR	TSSOP14	330.0	17.6	6.8	5.4	1.2	8.0	12.0	Q1

## Package Outline Dimensions

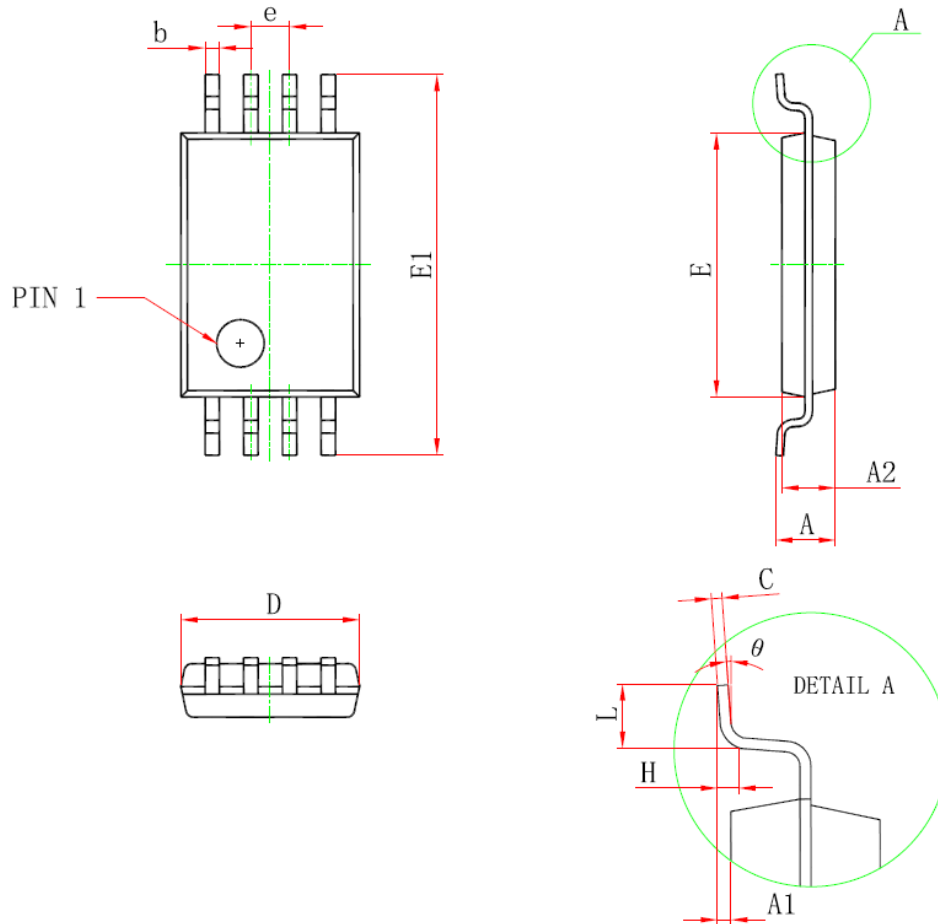
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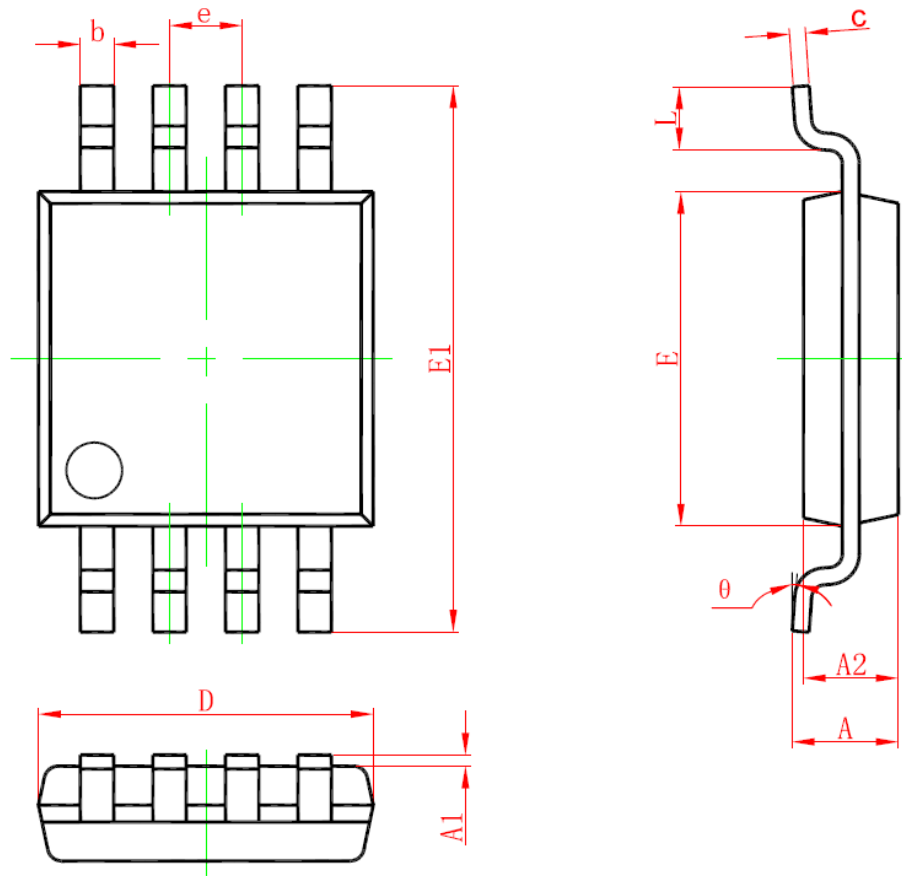
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E1	1.500	1.700	0.059	0.067
E	2.650	2.950	0.104	0.116
e	0.950(BSC)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

**SOP8**


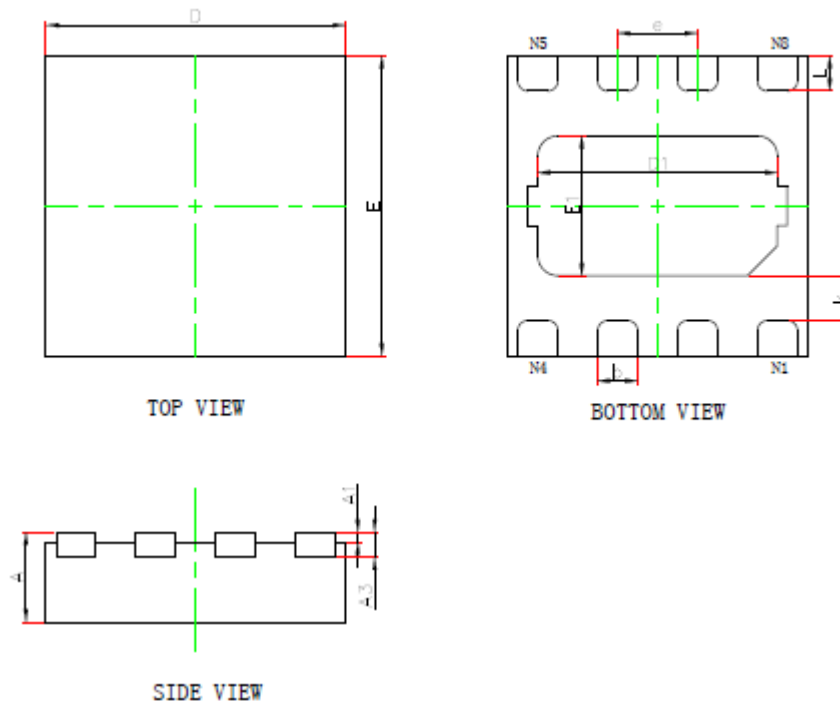
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270(BSC)		0.050(BSC)	
L	0.400	0.800	0.016	0.031
$\theta$	0°	8°	0°	8°

**TSSOP8**


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
D	2.900	3.100	0.114	0.122
E	4.300	4.500	0.169	0.177
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
E1	6.250	6.550	0.246	0.258
A		1.200		0.047
A2	0.800	1.000	0.031	0.039
A1	0.050	0.150	0.002	0.006
e	0.65 (BSC)		0.026 (BSC)	
L	0.500	0.700	0.020	0.028
H	0.25(TYP)		0.01(TYP)	
θ	1°	7°	1°	7°

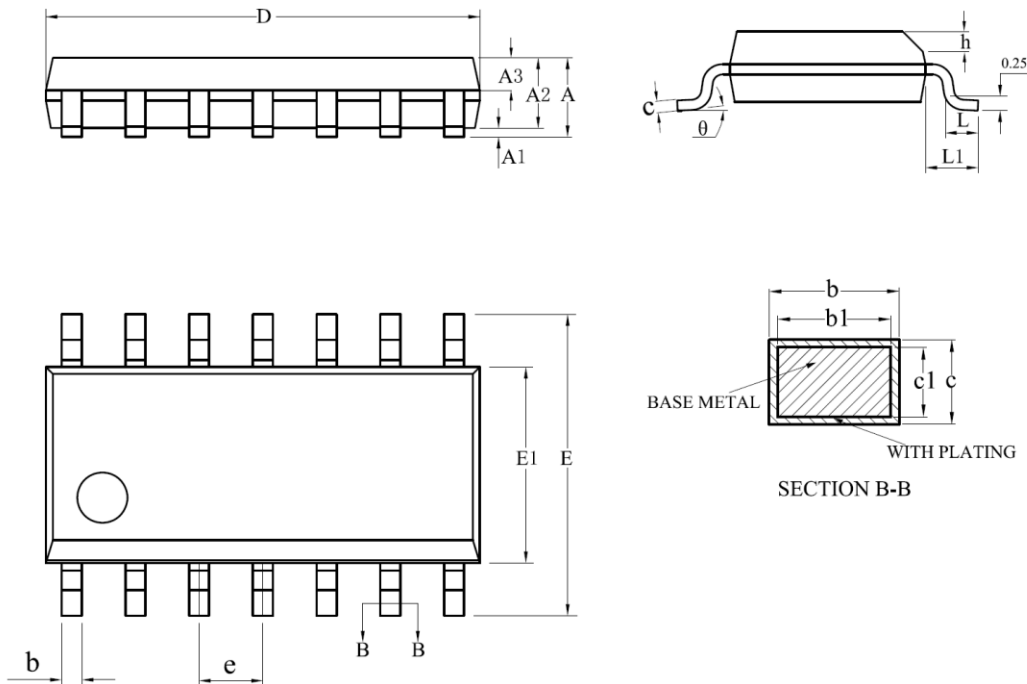
**MSOP8**


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	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

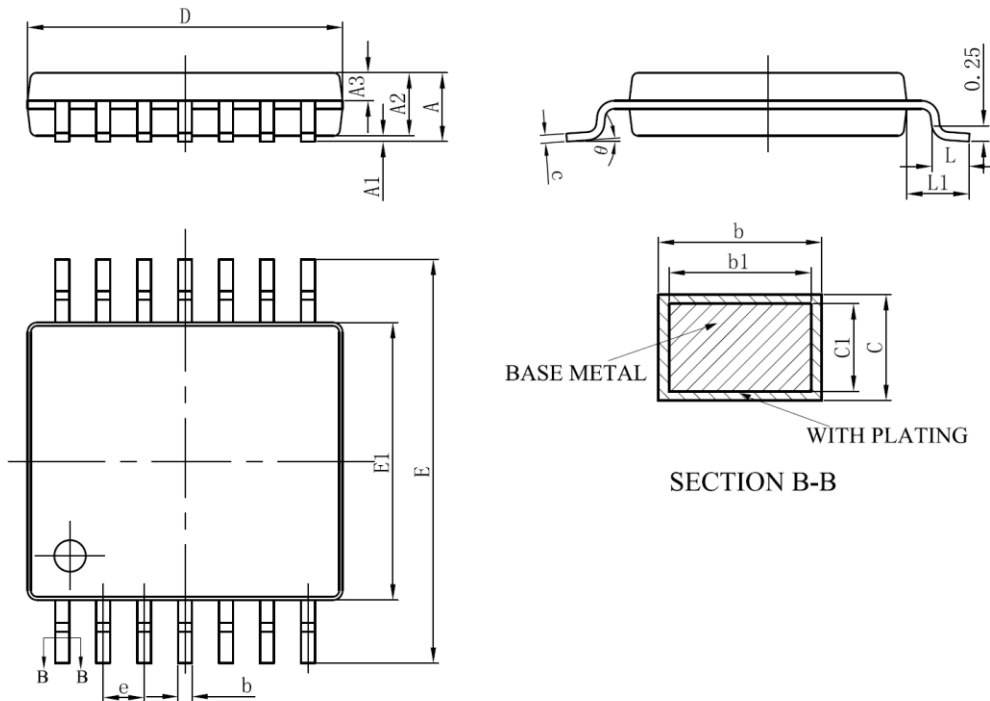
**DFN-8 1.5\*1.5**


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.400	0.500	0.016	0.020
A1	0.000	0.050	0.000	0.002
A3	0.700	0.800		
A3	0.127REF.		0.005REF.	
D	1.450	1.550	0.057	0.061
E	1.450	1.550	0.057	0.061
D1	1.100	1.300	0.043	0.051
E1	0.600	0.800	0.024	0.031
k	0.200MIN.		0.008REF.	
b	0.150	0.250	0.006	0.010
e	0.400TYP.		0.016TYP.	
L	0.099	0.251	0.004	0.010



**SOP14**


SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.05	—	0.225
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	—	0.47
b1	0.38	0.41	0.44
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	8.55	8.65	8.75
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27BSC		
h	0.25	—	0.50
L	0.50	—	0.80
L1	1.05REF		
$\theta$	0	—	8°

**TSSOP14**


SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.20
A1	0.05	—	0.15
A2	0.90	1.00	1.05
A3	0.39	0.44	0.49
b	0.20	—	0.28
b1	0.19	0.22	0.25
c	0.13	—	0.17
c1	0.12	0.13	0.14
D	4.90	5.00	5.10
E1	4.30	4.40	4.50
E	6.20	6.40	6.60
e	0.65BSC		
L	0.45	0.60	0.75
L1	1.00BSC		
$\theta$	0	—	8°

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