

Features

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

Applications

- Power Module
- Sensor Interface
- Motor Control
- Audio

Description

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

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

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Revision History

Date	Revision	Notes
2018-11-01	Rev.Pre.0	Preliminary version.
2018-12-25	Rev.Pre.1	Updated date code information of LM358A-F1R: from "AAYW" to "YW".
2019-01-14	Rev.Pre.2	Updated Marking Information of LM358A-SR, LM358A-CSR: from "LM358A" to "358A". Updated Package Information: removed "SC70". Updated Package Outline Dimensions of SOP8.
2019-06-26	Rev.Pre.3	Added temperature limit of V_{OL} , V_{OH} , I_{SC} . Updated Package Outline Dimensions.
2019-08-16	Rev.Pre.4	Updated Electrical Characteristics: • Removed V_{OL}, V_{OH}; • Corrected "Maximum Output Swing" to "Output Voltage Swing from Positive and Negative Rail"; • Corrected "Output Voltage Swing Low" to "Output Voltage Swing from Negative Rail".
2019-12-25	Rev.Pre.5	Updated Marking Information of LM358A-F1R: from "58A" to "58".
2020-09-24	Rev.A.0	Updated Absolute Maximum Ratings: • Corrected "Maximum Junction Temperature" to "Maximum Operating Junction Temperature".
2020-12-11	Rev.A.1	Added maximum value of I_B , I_{IN} in Electrical Characteristics.
2021-05-10	Rev.A.2	Updated specification: I_Q of the LM321A.
2022-04-29	Rev.A.3	Updated Electrical Characteristics: added maximum value of I_{OS} . Added common voltage range in 25 degrees.
2022-10-10	Rev.A.4	Modified the package description: from "SOIC" to "SOP". Added a new part number: LM321AW-S5TR.
2023-07-14	Rev.A.5	Corrected typos in Order Information.
2023-12-20	Rev.A.6	Added test figures.
2025-12-01	Rev.A.7	The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged • Updated to a new datasheet format • Updated the POD format • Added the thermal pad description in the Pin Configuration and Functions

Pin Configuration and Functions

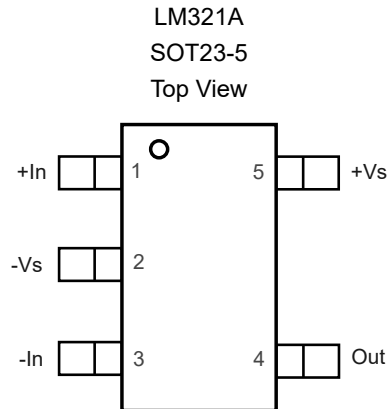


Table 1. Pin Functions: LM321A

Pin No.	Name	I/O	Description
1	+In	I	Non-inverting input
2	-Vs		Negative power supply
3	-In	I	Inverting input
4	Out	O	Output
5	+Vs		Positive power supply

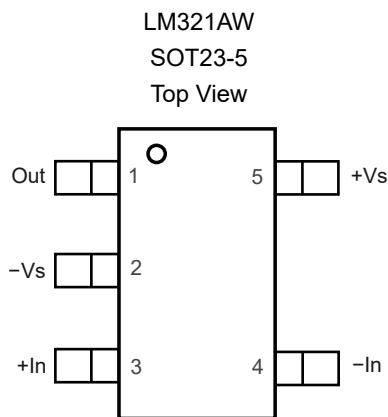
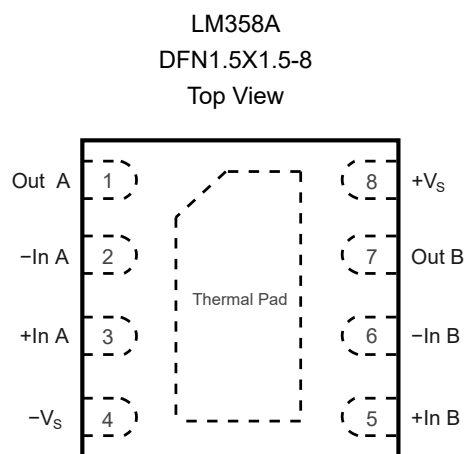
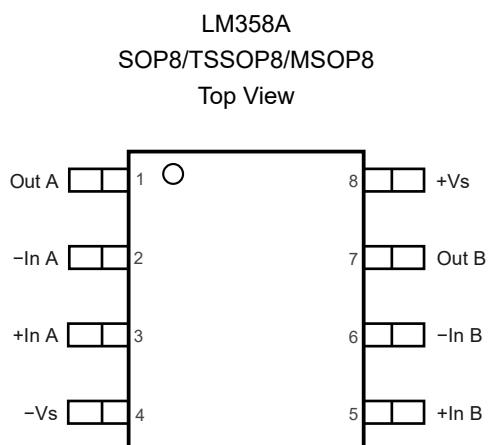
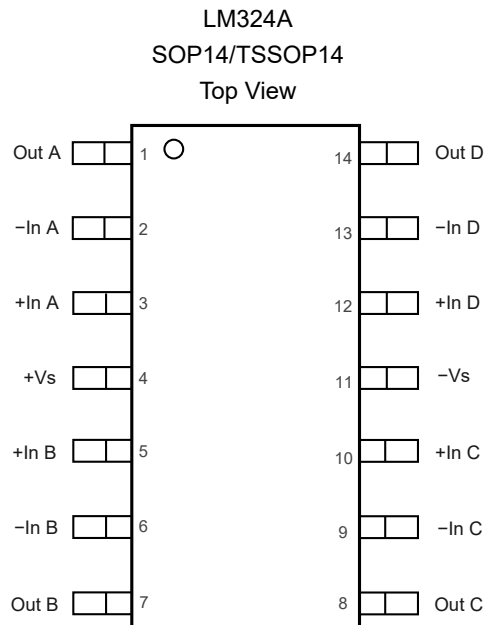


Table 2. Pin Functions: LM321AW

Pin No.	Name	I/O	Description
1	Out	O	Output
2	-Vs		Negative power supply
3	+In	I	Non-inverting input
4	-In	I	Inverting input
5	+Vs		Positive power supply

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Table 3. Pin Functions: LM358A

Pin No.	Name	I/O	Description
1	Out A	O	Output
2	-In A	I	Inverting input
3	+In A	I	Non-inverting input
4	-Vs		Negative power supply
5	+In B	I	Non-inverting input
6	-In B	I	Inverting input
7	Out B	O	Output
8	+Vs		Positive power supply
	Thermal Pad		The thermal pad of the DFN1.5X1.5-8 is recommended to be left float or connected to -Vs.


Table 4. Pin Functions: LM324A

Pin No.	Name	I/O	Description
1	Out A	O	Output
2	-In A	I	Inverting input
3	+In A	I	Non-inverting input
4	+Vs		Positive power supply
5	+In B	I	Non-inverting input
6	-In B	I	Inverting input
7	Out B	O	Output
8	Out C	O	Output power supply
9	-In C	I	Inverting input
10	+In C	I	Non-inverting input
11	-Vs		Negative power supply
12	+In D	I	Non-inverting input
13	-In D	I	Inverting input
14	Out D	O	Output

Specifications

Absolute Maximum Ratings ⁽¹⁾

Parameters		Min	Max	Unit
	Supply Voltage, (+V _S)– (–V _S)		40	V
	Input Voltage	(–V _S) – 0.3	(+V _S) + 0.3	V
	Differential Input Voltage	(+V _S)	(–V _S)	V
	Input Current: +IN, –IN ⁽²⁾	–10	10	mA
	Output Short-Circuit Duration ⁽³⁾		Infinite	
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 300 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⁾	3	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 ⁽²⁾	2	kV

(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
SOP8	158	43	°C/W
TSSOP8	191	44	°C/W
MSOP8	210	45	°C/W
DFN1.5X1.5-8	200	60	°C/W
SOP14	120	36	°C/W
TSSOP14	180	35	°C/W

Electrical Characteristics

All test conditions: $V_S = 30\text{ V}$, $T_A = 25^\circ\text{C}$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, unless otherwise noted.

Symbol	Parameter	Conditions	T _A	Min	Typ	Max	Unit
Power Supply							
V _S	Supply Voltage Range			3		36	V
I _Q	Quiescent Current per Amplifier, LM321A	V _S = 30 V			150	250	μA
			−40 to 125°C		350	μA	
		V _S = 5 V			150	200	μA
			−40 to 125°C		300	μA	
I _Q	Quiescent Current per Amplifier, LM358A, LM324A	V _S = 30 V			110	200	μA
			−40 to 125°C		250	μA	
		V _S = 5 V			100	150	μA
			−40 to 125°C		200	μA	
PSRR	Power Supply Rejection Ratio	V _S = 5 V to 36 V		85	120		dB
			−40 to 125°C	80			dB
Input Characteristics							
V _{OS}	Input Offset Voltage	V _S = 30 V, V _{CM} = 0 V to 28 V		−3	0.1	3	mV
			0 to 70°C	−4		4	mV
			−40 to 125°C	−7		7	mV
		V _S = 5 V, V _{CM} = 0 V to 3 V		−3	0.1	3	mV
			0 to 70°C	−4		4	mV
			−40 to 125°C	−7		7	mV
V _{OS} TC	Input Offset Voltage Drift		−40 to 125°C		7		μV/°C
I _B	Input Bias Current				60	500	pA
		−40 to 125°C		600	1000	pA	
I _{OS}	Input Offset Current ⁽¹⁾				60	500	pA
		−40 to 125°C		600	1000	pA	
I _{IN}	Different Input Current	V _S = 36 V, V _{ID} = 36 V			5	150	nA
		V _S = 36 V, V _{ID} = 36 V	−40 to 125°C		20	1000	nA
C _{IN}	Input Capacitance	Differential mode			5		pF
		Common mode			5		pF
A _V	Open-Loop Voltage Gain			95	110		dB
		−40 to 125°C	90			dB	
V _{CMR}	Common-Mode Input Voltage Range			(V−)		(V+) − 1.5	V
		−40 to 125°C	(V−)		(V+) − 2	V	

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Symbol	Parameter	Conditions	T _A	Min	Typ	Max	Unit
CMRR	Common-Mode Rejection Ratio	V _{CM} = 0 V to 28 V		75	120		dB
			−40 to 125°C	70	90		dB
Output Characteristics							
	Output Voltage Swing from Positive and Negative Rail	R _{LOAD} = 10 kΩ to V _S / 2			200	300	mV
			−40 to 125°C			700	mV
		R _{LOAD} = 2 kΩ to V _S / 2			1.1	1.3	V
			−40 to 125°C			2	V
	Output Voltage Swing from Negative Rail	V _S = 5 V, R _{LOAD} = 10 kΩ to 0 V			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, 2-V step			0.5		V/μs
t _s	Settling Time, 0.1%	G = 1, 2-V step			4		μs
	Settling Time, 0.01%				5		μs
PM	Phase Margin	V _S = 30 V, R _L = 1 kΩ, C _L = 100 pF			60		°
GM	Gain Margin	V _S = 30 V, R _L = 1 kΩ, C _L = 100 pF			15		dB
	Channel Separation	f = 1 kHz to 20 kHz			120		dB
Noise Performance							
E _N	Input Voltage Noise	f = 0.1 Hz to 10 Hz			3		μV _{RMS}
e _N	Input Voltage Noise Density	f = 1 kHz			70		nV/√Hz
i _N	Input Current Noise	f = 1 kHz			3		fA/√Hz
THD+N	Total Harmonic Distortion and Noise	f = 1 kHz, G =1, R _L = 10 kΩ, V _{OUT} = 6 V _{RMS}			0.001		%

(1) Provided by bench tests and design simulation.

Typical Performance Characteristics

All test conditions: $V_S = \pm 15\text{ V}$, $V_{CM} = 0\text{ V}$, $R_L = 10\text{ k}\Omega$, unless otherwise specified.

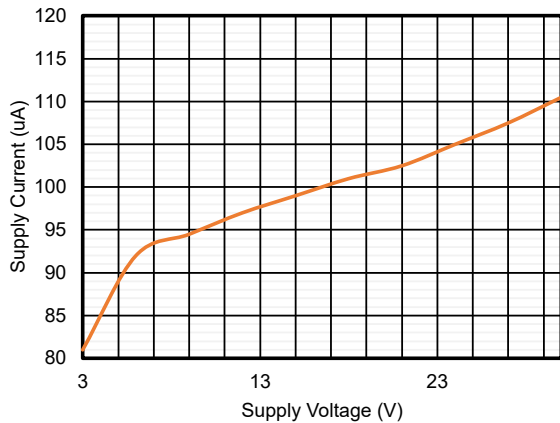


Figure 1. Quiescent Current vs. Supply Voltage

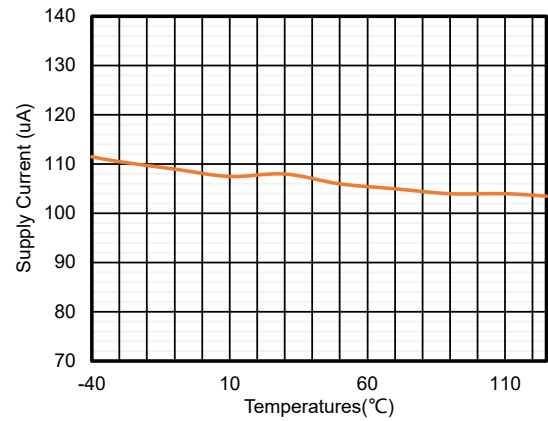


Figure 2. Quiescent Current vs. Temperature

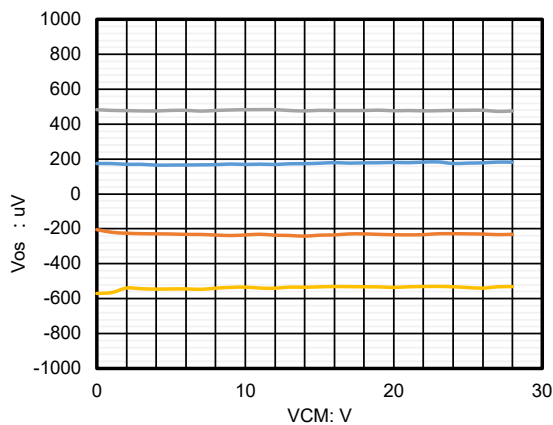


Figure 3. Offset Voltage vs. Common-Mode Voltage

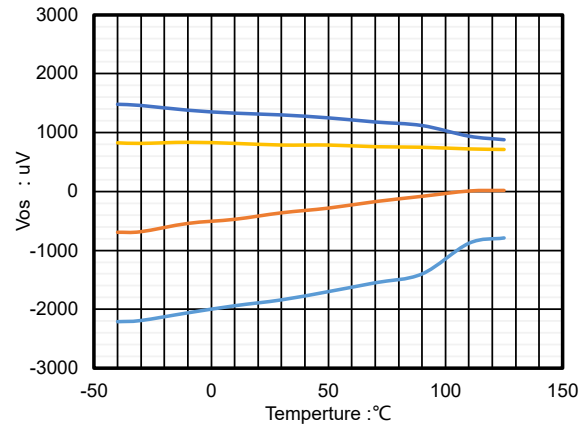


Figure 4. Offset Voltage vs. Temperature

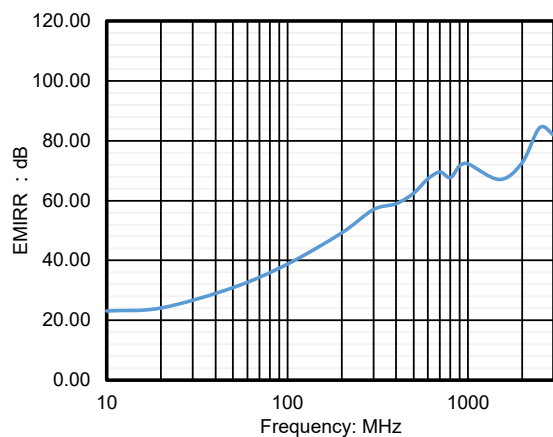


Figure 5. EMIRR+ vs. Frequency

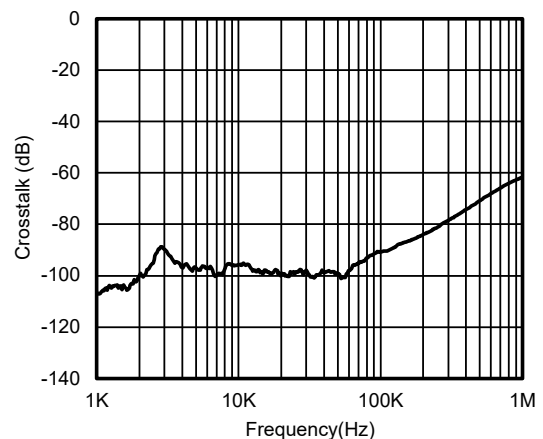
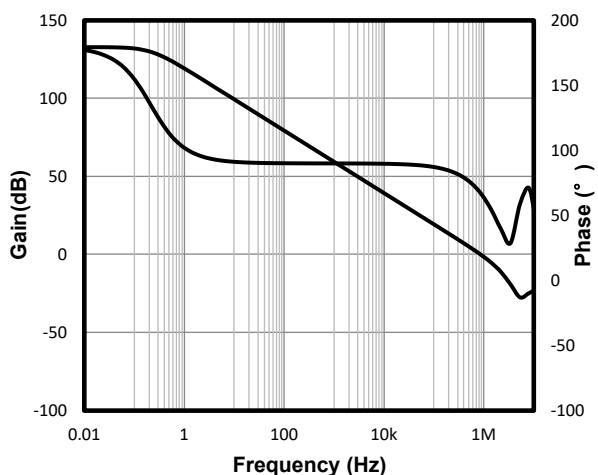
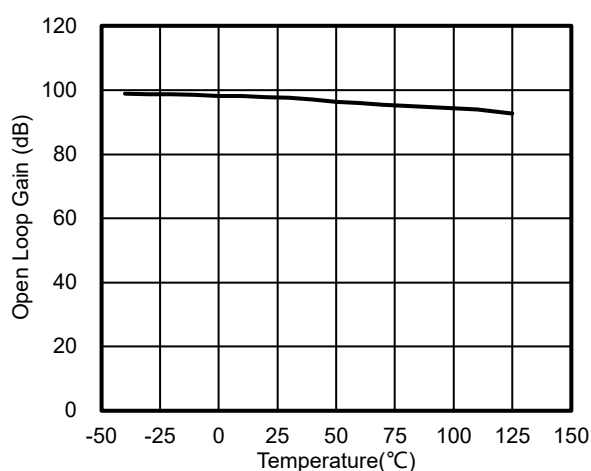
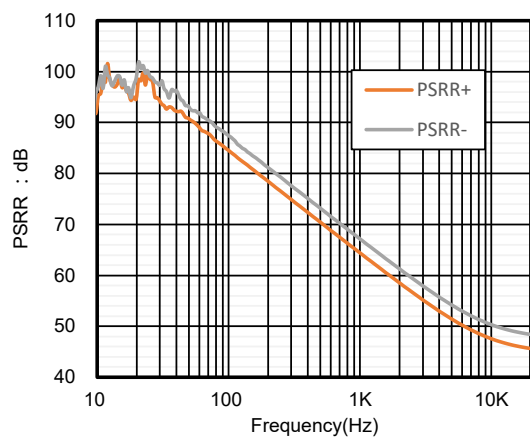
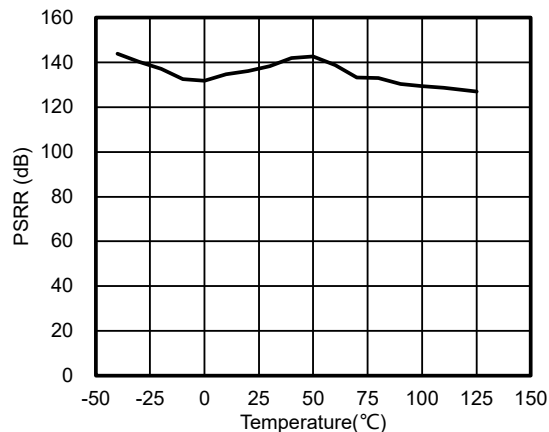
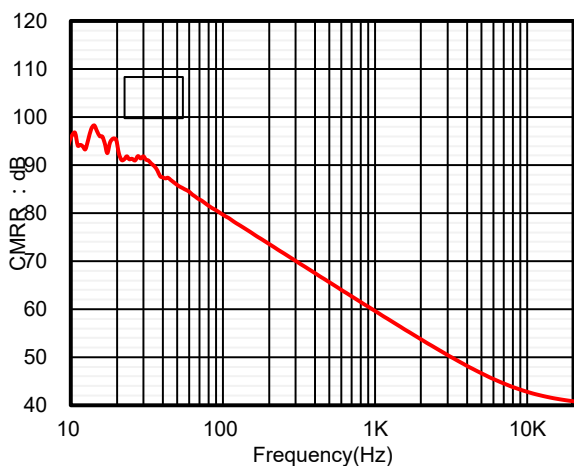
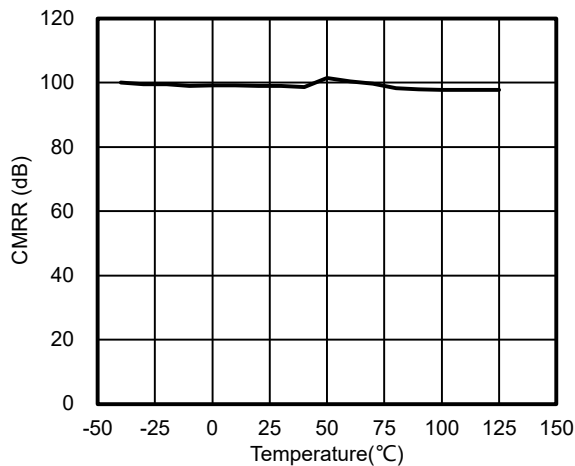
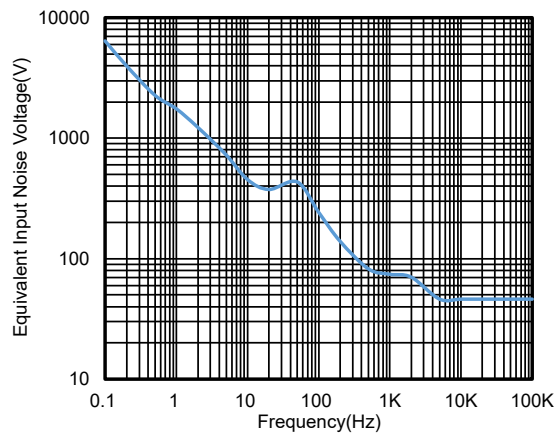
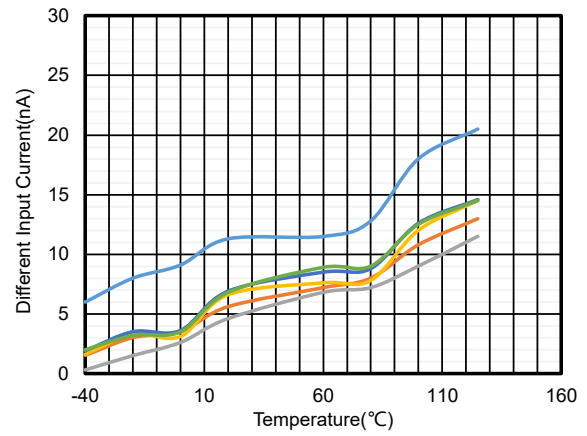
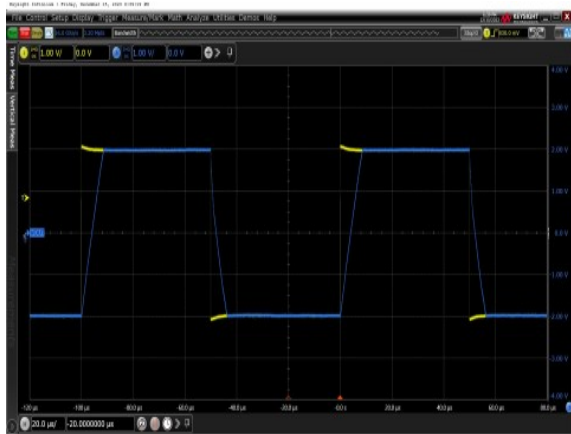
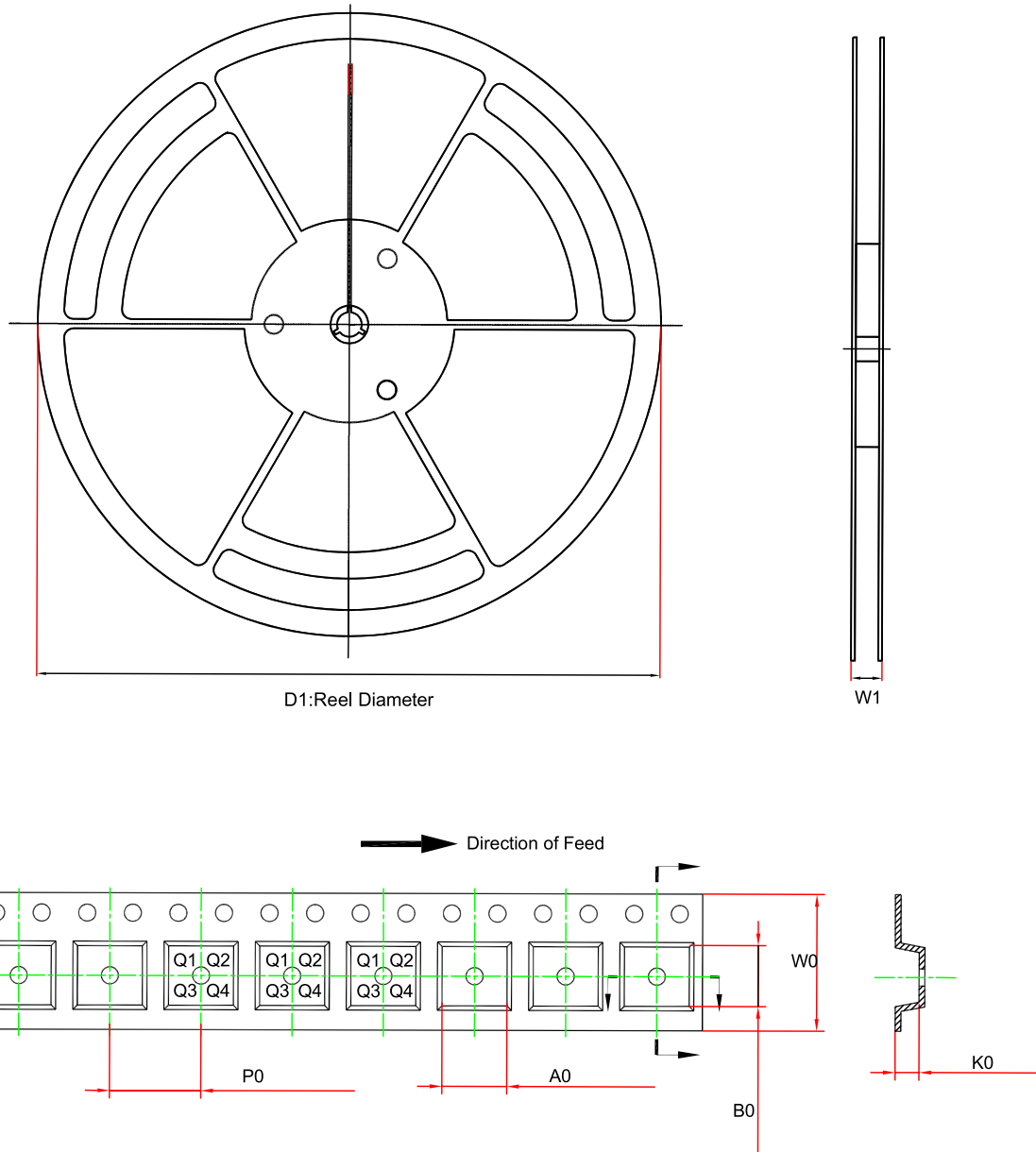


Figure 6. Crosstalk vs. Frequency

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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


Figure 13. Voltage Noise Spectral Density vs. Frequency

Figure 14. Different Input Current vs. Temperature

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

Tape and Reel Information



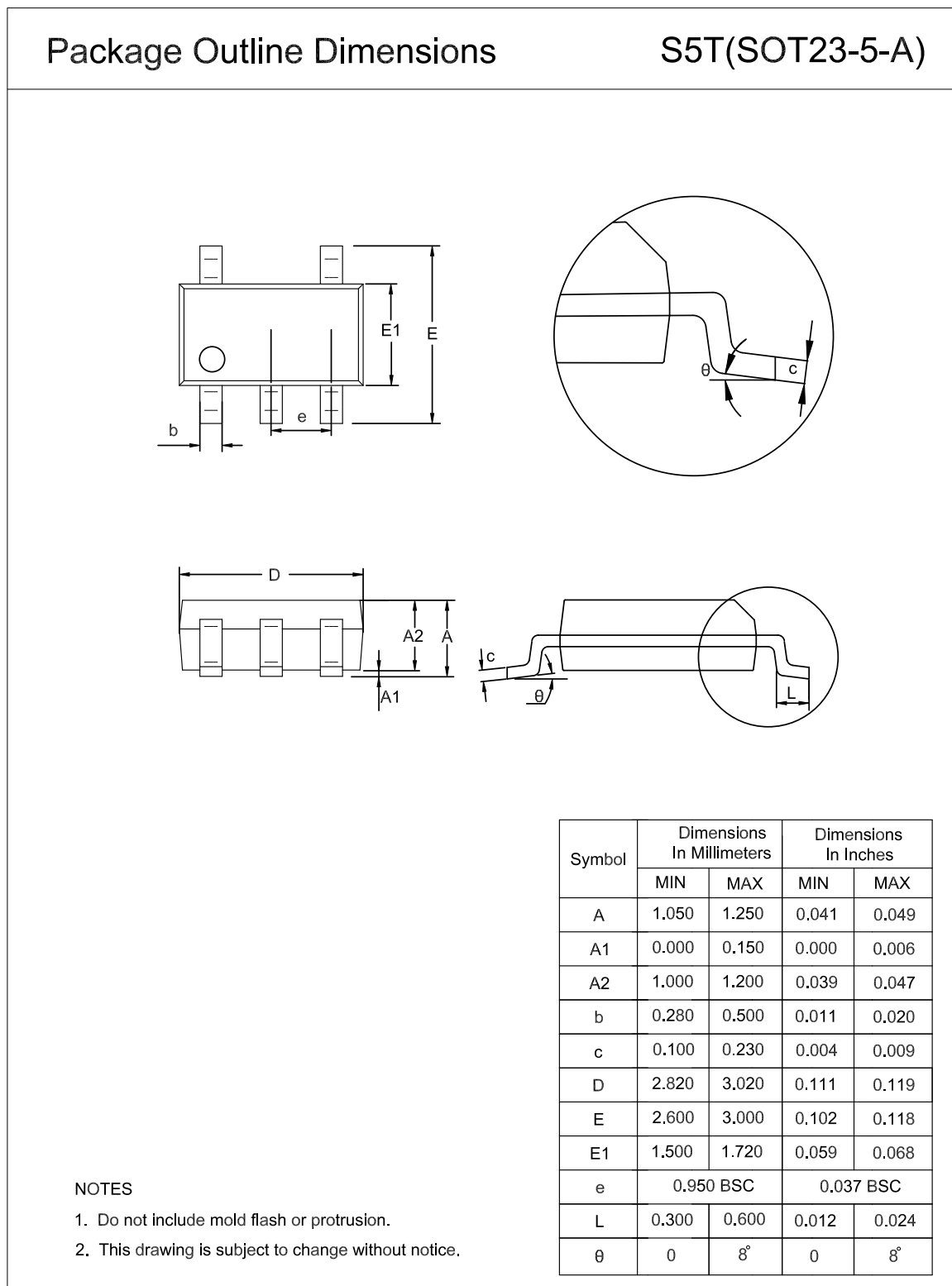
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
LM321A-TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
LM321AW-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
LM358A-SR	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
LM358A-CSR	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
LM358A-VR	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	DFN1.5X1.5-8	180.0	13.1	1.7	1.7	0.75	4.0	8.0	Q1

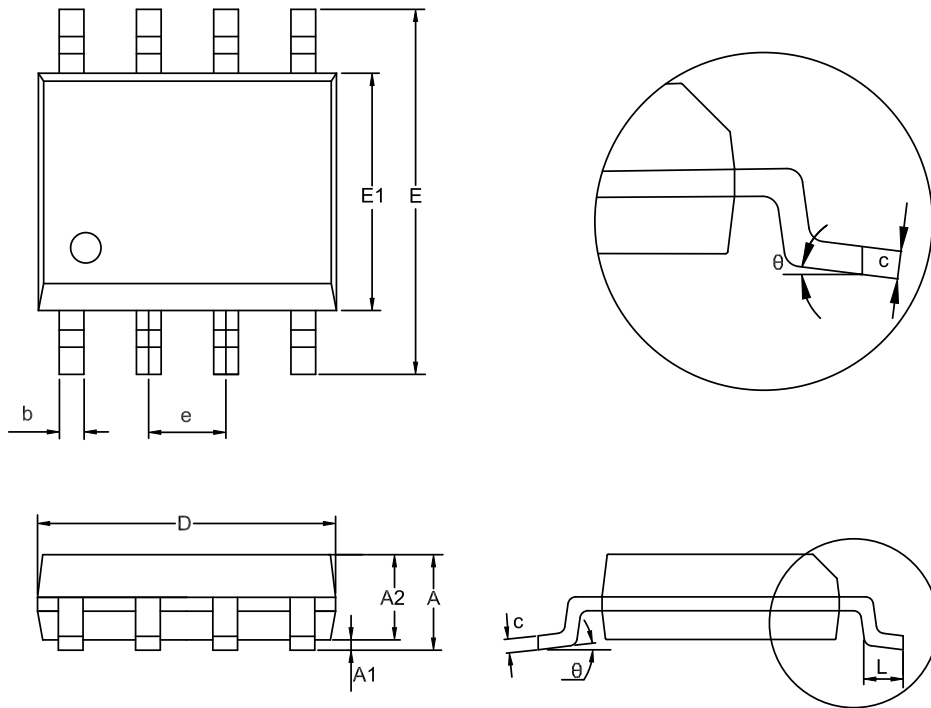
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Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
LM324A-SR	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
LM324A-CSR	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
LM324A-TR	TSSOP14	330.0	17.6	6.8	5.4	1.2	8.0	12.0	Q1

Package Outline Dimensions

SOT23-5

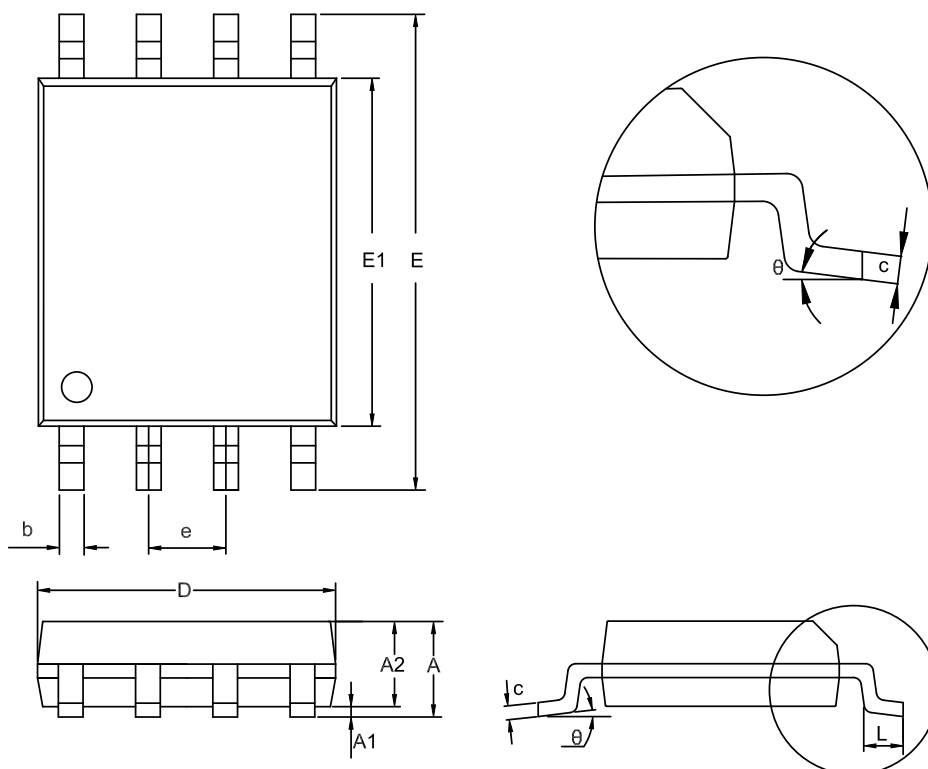


SOP8
Package Outline Dimensions
SO1(SOP-8-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	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	1.000	0.016	0.039
θ	0	8°	0	8°

NOTES

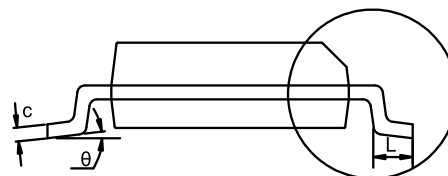
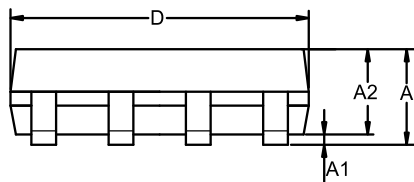
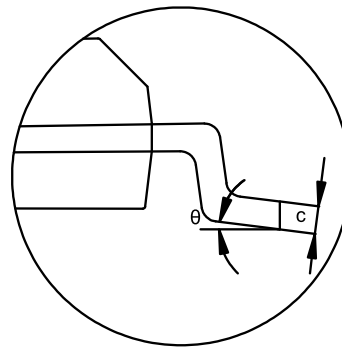
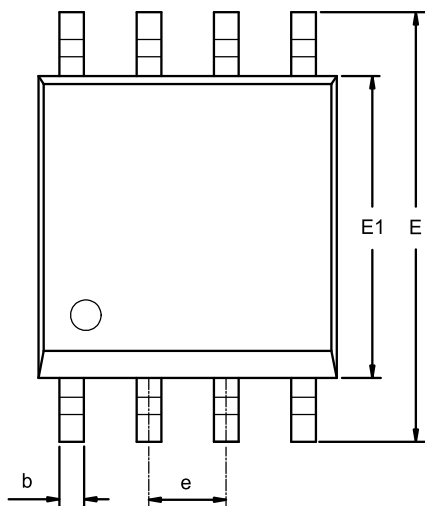
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

TSSOP8
Package Outline Dimensions
TS1(TSSOP-8-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	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	2.900	3.100	0.114	0.122
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

NOTES

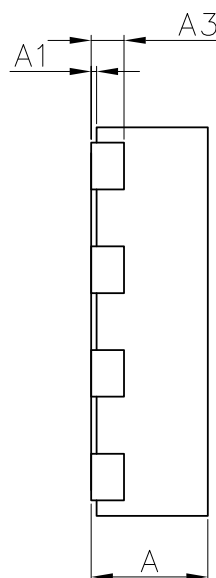
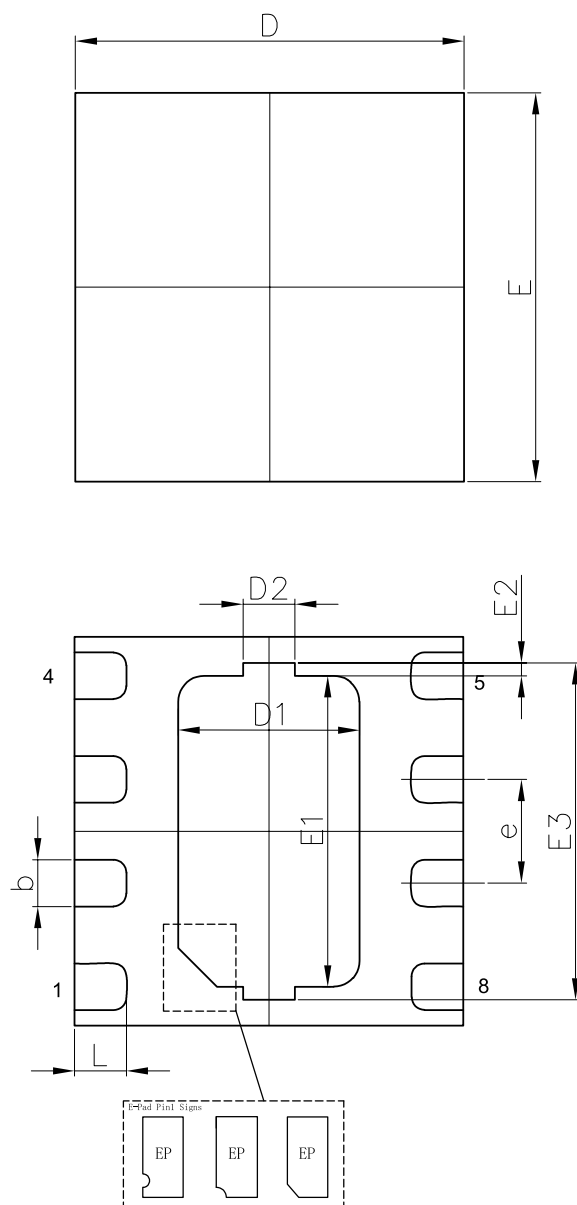
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

MSOP8
Package Outline Dimensions
VS1(MSOP-8-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	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	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

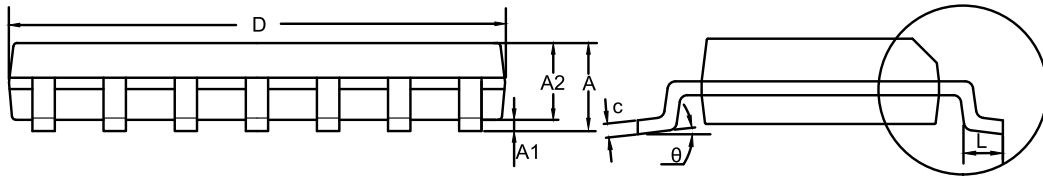
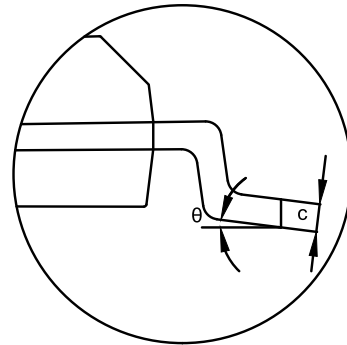
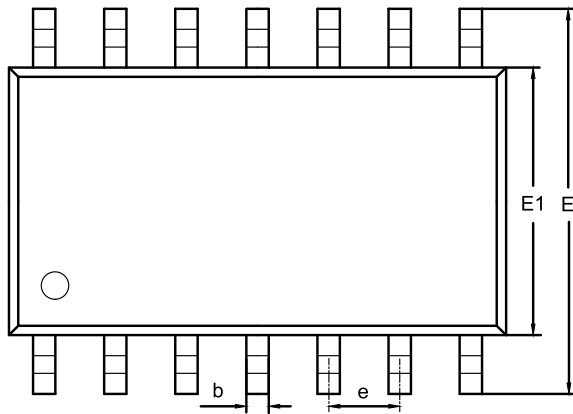
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

DFN1.5X1.5-8
Package Outline Dimensions
DFS(DFN1.5X1.5-8-A)


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
b	0.150	0.250	0.006	0.010
A3	0.127 REF		0.005 REF	
D	1.450	1.550	0.057	0.061
D1	0.600	0.800	0.024	0.031
D2	0.200 REF		0.008 REF	
E	1.450	1.550	0.057	0.061
E1	1.100	1.300	0.043	0.051
E2	0.050 REF		0.002 REF	
E3	1.200	1.400	0.047	0.055
e	0.400 BSC		0.016 BSC	
L	0.150	0.250	0.006	0.010

NOTES

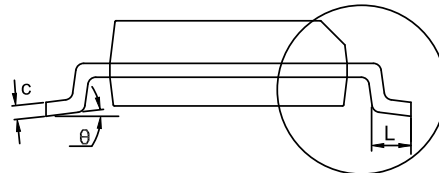
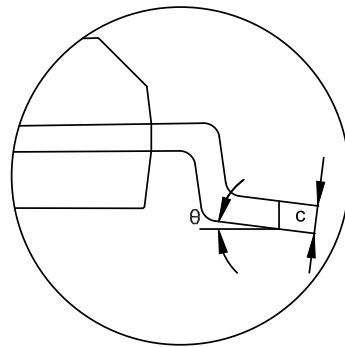
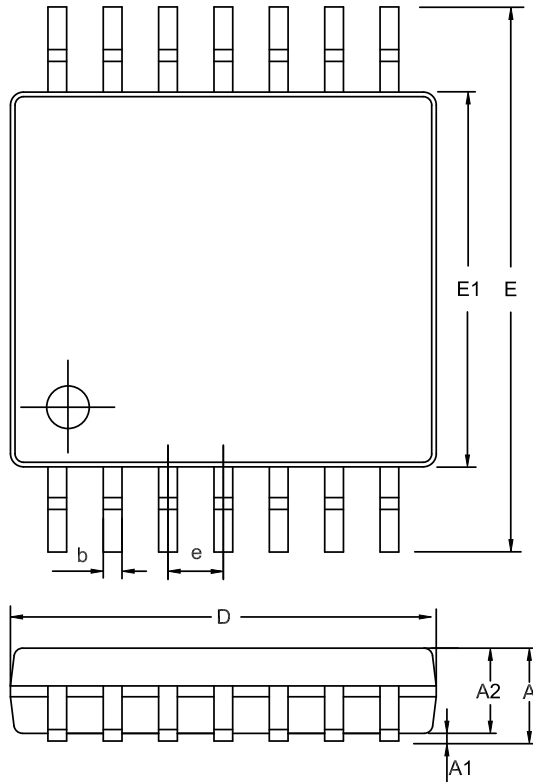
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.
3. The many types of E-pad Pin1 signs may appear in the product.

SOP14
Package Outline Dimensions
SO2(SOP-14-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
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	1.270	0.016	0.050
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

TSSOP14
Package Outline Dimensions
TS2(TSSOP-14-A)

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	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	4.900	5.100	0.193	0.201
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
LM321A-TR	-40 to 125°C	SOT23-5	21A	3	Tape and Reel, 3000	Green
LM321AW-S5TR	-40 to 125°C	SOT23-5	A28	3	Tape and Reel, 3000	Green
LM358A-SR	-40 to 125°C	SOP8	358A	3	Tape and Reel, 4000	Green
LM358A-CSR	-40 to 85°C	SOP8	358A	3	Tape and Reel, 4000	Green
LM358A-F1R	-40 to 125°C	DFN1.5X1.5-8	58	1	Tape and Reel, 3000	Green
LM358A-TSR	-40 to 125°C	TSSOP8	LM358A	3	Tape and Reel, 3000	Green
LM358A-VR	-40 to 125°C	MSOP8	LM358A	3	Tape and Reel, 3000	Green
LM324A-SR	-40 to 125°C	SOP14	LM324A	3	Tape and Reel, 2500	Green
LM324A-CSR	-40 to 85°C	SOP14	LM324A	3	Tape and Reel, 2500	Green
LM324A-TR	-40 to 125°C	TSSOP14	LM324A	3	Tape and Reel, 3000	Green

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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