



# LMX321, LMX358, LMX324

## General-purpose, low voltage rail-to-rail output operational amplifiers

Datasheet – production data

### Features

- Low power consumption: 120  $\mu$ A at 2.7 V
- Low supply voltage: 2.3 V - 5.5 V
- Rail to rail output swing
- Gain bandwidth product: 1.3 MHz
- Extended temperature range: -40°C to +125°C
- No crossover distortion
- No phase reversal
- Tiny packages

### Related products

- See TSV85x series for higher accuracy, stand-by options and smaller packages

### Applications

- Battery-powered applications
- Portable devices
- Signal conditioning
- Active filtering
- Medical instrumentation

### Description

The LMX3xx series is a set of single, dual and quad low-voltage, general-purpose operational amplifiers. These devices can operate from 2.3 V to 5.5 V with a typical current consumption of 120  $\mu$ A per channel. The LMX3xx series offers a rail-to-rail output and an input common-mode voltage that includes ground.

The LMX3xx series also exhibits a 1.3 MHz gain bandwidth and can drive capacitive loads. The devices are stable while operating at unity gain. They are offered with industry standard pinouts in tiny packages.

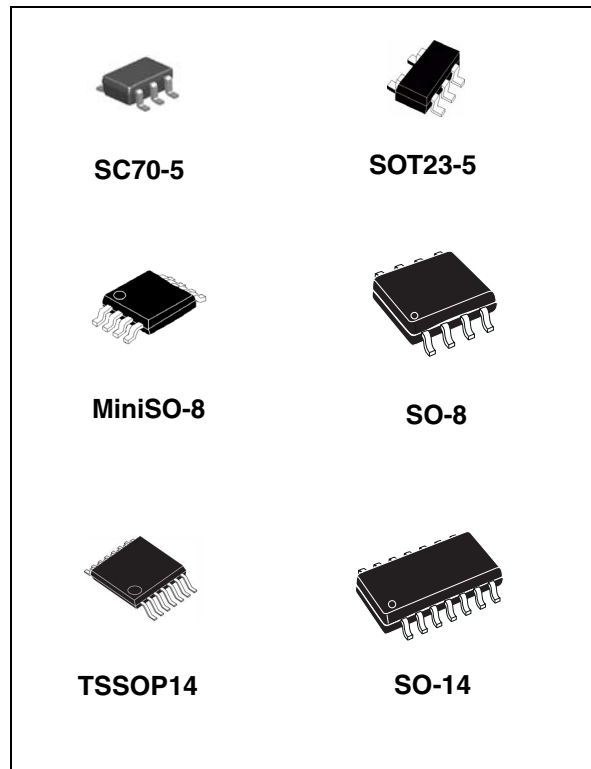
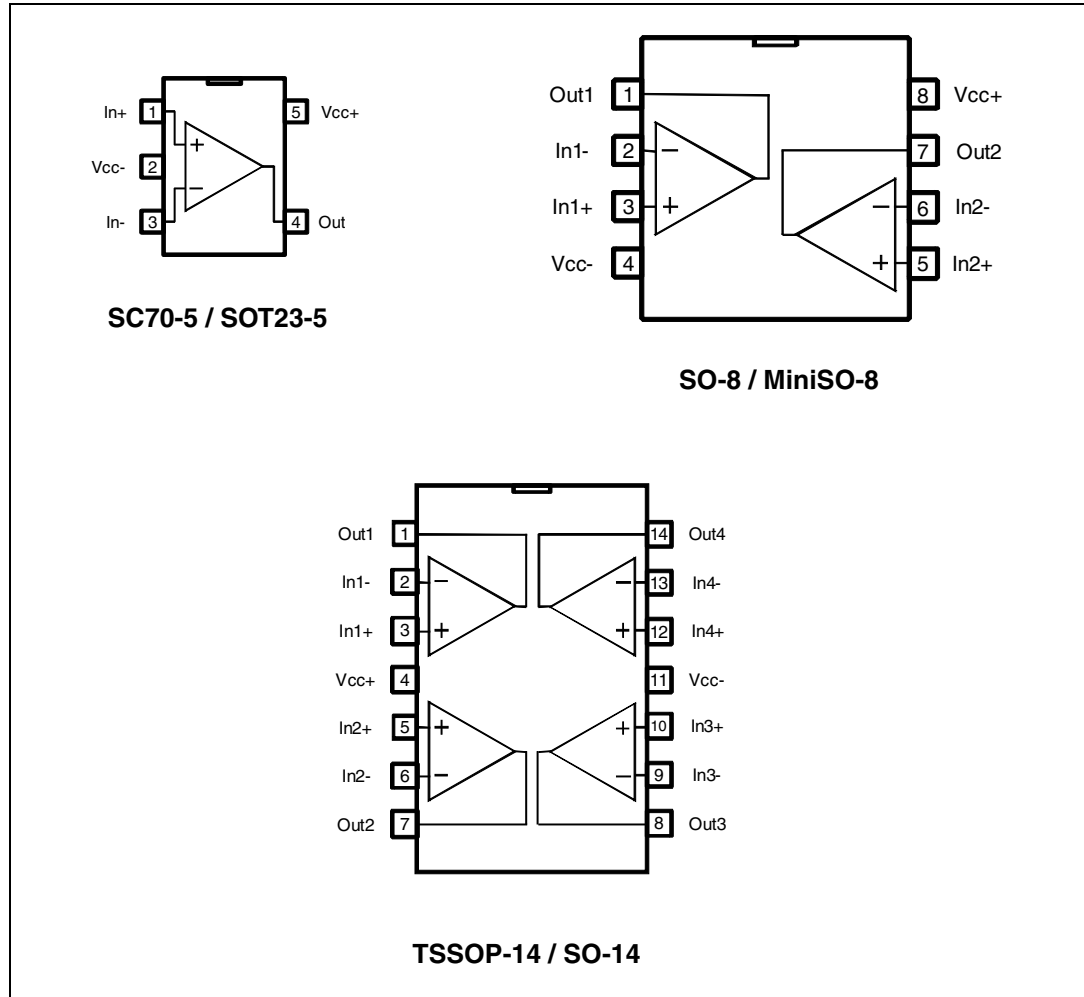


Table 1. Device summary

Reference	Single	Dual	Quad
LMX3xx	LMX321	LMX358	LMX324

# 1 Package pin connections

Figure 1. Pin connections for each package (top view)



## 2 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings (AMR)**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup>	6	V
$V_{id}$	Differential input voltage <sup>(2)</sup>	$\pm V_{CC}$	V
$V_{in}$	Input pins (IN+ and IN- pins) voltage <sup>(3)</sup>	$V_{CC-} - 0.3$ to $V_{CC+} + 0.3$	V
$I_{in}$	Input current <sup>(4)</sup>	10	mA
$T_{stg}$	Storage temperature	-65 to +150	°C
$R_{thja}$	Thermal resistance junction to ambient <sup>(5)(6)</sup>		°C/W
	SC70-5	205	
	SOT23-5	250	
	MiniSO8	190	
	SO8	125	
	TSSOP14	100	
	SO14	105	
$T_j$	Maximum junction temperature	150	°C
ESD	HBM: human body model <sup>(7)</sup>	4000	V
	MM: machine model <sup>(8)</sup>	250	
	CDM: charged device model <sup>(9)</sup>	1300	
	Latch-up immunity	200	mA

- All voltage values, except differential voltage, are with respect to network ground terminal.
- Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
- $V_{CC-} - V_{in}$  must not exceed 6 V,  $V_{in}$  must not exceed 6 V.
- Input current must be limited by a resistor in series with the inputs.
- Short-circuits can cause excessive heating and destructive dissipation.
- $R_{th}$  are typical values.
- Human body model: 100 pF discharged through a 1.5 k $\Omega$  resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
- Machine model: a 200 pF cap is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5  $\Omega$ ), done for all couples of pin combinations with other pins floating.
- Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

**Table 3. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.3 to 5.5	V
$V_{icm}$	Common mode input voltage range	$V_{CC-} - 0.2$ to $V_{CC+} - 1$	V
$T_{oper}$	Operating free air temperature range	-40 to +125	°C

### 3 Electrical characteristics

**Table 4. Electrical characteristics at  $V_{CC+} = 2.7$  V with  $V_{CC-} = 0$  V,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^{\circ}$  C, and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Input offset voltage				4	mV
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$			6	
$\Delta V_{io}/\Delta T$	Input offset voltage drift <sup>(1)</sup>	$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$		1		$\mu\text{V}/^{\circ}\text{C}$
$I_{io}$	Input offset current	$V_{out} = V_{CC}/2$		0.5	30	nA
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$			50	
$I_{ib}$	Input bias current	$V_{out} = V_{CC}/2$		27	60	nA
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$			110	
CMR	Common mode rejection ratio $20 \log (\Delta V_{icm}/\Delta V_{io})$	$V_{ic} = 0$ V to $V_{CC}-1$ V, $V_{out} = V_{CC}/2$	70	75		dB
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$	68			
$A_{vd}$	Large signal voltage gain	$R_L = 10$ k $\Omega$ , $V_{out} = 0.5$ V to $(V_{CC}-0.5$ V)	100	110		dB
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$	90			
		$R_L = 2$ k $\Omega$ , $V_{out} = 0.5$ V to $(V_{CC}-0.5$ V)	90	100		
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$	80			
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10$ k $\Omega$ , $-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$		10	100	mV
					200	
		$R_L = 2$ k $\Omega$ , $-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$		40	300	
					400	
$V_{OL}$	Low level output voltage	$R_L = 10$ k $\Omega$ , $-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$		65	180	mV
					280	
		$R_L = 2$ k $\Omega$ , $-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$		120	300	
					400	
$I_{out}$	$I_{sink}$	$V_{out} = V_{CC}$ , $V_{id} = -1$ V	15	26		mA
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$	15			
	$I_{source}$	$V_{out} = 0$ V, $V_{id} = 1$ V	15	21		mA
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$	12			
$I_{CC}$	Supply current (per channel)	No load, $V_{out} = V_{CC}/2$		120	180	$\mu\text{A}$
		$-40^{\circ}\text{C} < T < 125^{\circ}\text{C}$			180	

**Table 4. Electrical characteristics at  $V_{CC+} = 2.7\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified) (continued)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		1.3		MHz
$F_u$	Unity gain frequency	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		1		MHz
$\Phi_m$	Phase margin	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		60		degrees
$G_m$	Gain margin	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		10		dB
SR	Slew rate	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$ $V_{out} = 0.5\text{ V}$ to $V_{CC} - 0.5\text{ V}$		0.6		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$ $f = 10\text{ kHz}$		31 20		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
$i_n$	Equivalent input noise current	$f = 1\text{ kHz}$		0.30		$\frac{\text{pA}}{\sqrt{\text{Hz}}}$
THD+N	Total harmonic distortion + noise	$f_{in} = 1\text{ kHz}$ , $A_{CL} = 1$ , $R_L = 10\text{ k}\Omega$ , $V_{ICM} = V_{CC}/2$ , $BW = 22\text{ kHz}$ , $V_{out} = 1\text{ V}_{pp}$		0.002		%

**Table 5. Electrical characteristics at  $V_{CC+} = 5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Input offset voltage				4	mV
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			6	
$\Delta V_{io}/\Delta T$	Input offset voltage drift <sup>(1)</sup>	$-40^\circ\text{C} < T < 125^\circ\text{C}$		1		$\mu\text{V}/^\circ\text{C}$
$i_{io}$	Input offset current	$V_{out} = V_{cc}/2$		0.5	30	nA
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			50	
$i_{ib}$	Input bias current	$V_{out} = V_{cc}/2$		27	60	nA
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			110	
CMR	Common mode rejection ratio $20 \log (\Delta V_{icm}/\Delta V_{io})$	$V_{ic} = 0\text{ V}$ to $V_{cc-} - 1\text{V}$ , $V_{out} = V_{cc}/2$	72	75		dB
		$-40^\circ\text{C} < T < 125^\circ\text{C}$	70			
SVR	Supply voltage rejection ratio $20 \log (\Delta V_{cc}/\Delta V_{io})$	$V_{cc} = 2.5$ to $5\text{ V}$	72	79		dB
		$-40^\circ\text{C} < T < 125^\circ\text{C}$	70			
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{ k}\Omega$ , $V_{out} = 0.5\text{ V}$ to $(V_{CC} - 0.5\text{ V})$	100	110		dB
		$-40^\circ\text{C} < T < 125^\circ\text{C}$	90			
		$R_L = 2\text{ k}\Omega$	90	100		
		$-40^\circ\text{C} < T < 125^\circ\text{C}$	80			

**Table 5. Electrical characteristics at  $V_{CC+} = 5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified) (continued)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10\text{ k}\Omega$		10	100	mV
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			200	
		$R_L = 2\text{ k}\Omega$		40	300	
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			400	
$V_{OL}$	Low level output voltage	$R_L = 10\text{ k}\Omega$		65	180	mV
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			280	
		$R_L = 2\text{ k}\Omega$		120	300	
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			400	
$I_{out}$	$I_{sink}$	$V_{out} = V_{CC}$ , $V_{id} = -1\text{ V}$	35	43		mA
		$-40^\circ\text{C} < T < 125^\circ\text{C}$	25			
	$I_{source}$	$V_{out} = 0\text{ V}$ , $V_{id} = 1\text{ V}$	60	70		mA
		$-40^\circ\text{C} < T < 125^\circ\text{C}$	50			
$I_{CC}$	Supply current (per channel)	No load, $V_{out} = V_{CC}/2$		130	180	$\mu\text{A}$
		$-40^\circ\text{C} < T < 125^\circ\text{C}$			180	
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		1.3		MHz
$F_u$	Unity gain frequency	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		1		MHz
$\Phi_m$	Phase margin	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		60		degrees
$G_m$	Gain margin	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$		10		dB
SR	Slew rate	$R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$ $V_{out} = 0.5\text{ V to } V_{CC} - 0.5\text{ V}$		0.7		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$ $f = 10\text{ kHz}$		30 20		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
$i_n$	Equivalent input noise current	$f = 1\text{ kHz}$		0.30		$\frac{\text{pA}}{\sqrt{\text{Hz}}}$
THD+N	Total harmonic distortion + noise	$f_{in} = 1\text{ kHz}$ , $A_{CL} = 1$ , $R_L = 10\text{ k}\Omega$ , $V_{ICM} = V_{CC}/2$ , $BW = 22\text{ kHz}$ , $V_{out} = 1\text{ V}_{pp}$		0.002		%

1. See [Chapter 4.4: Input offset voltage drift over temperature](#).

Figure 2. Supply current vs. supply voltage at  $V_{icm} = V_{CC}/2$

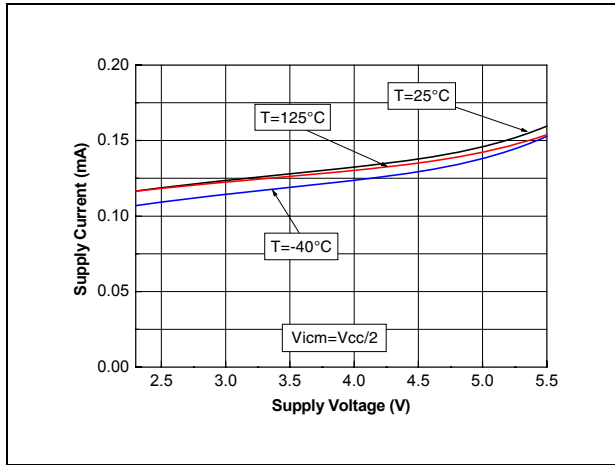


Figure 3. Vio distribution at  $V_{CC} = 5 V$

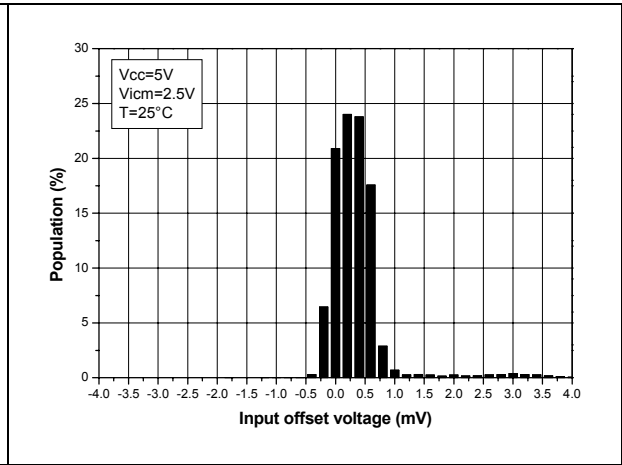


Figure 4. Input offset voltage vs. input common mode voltage at  $V_{CC} = 5 V$

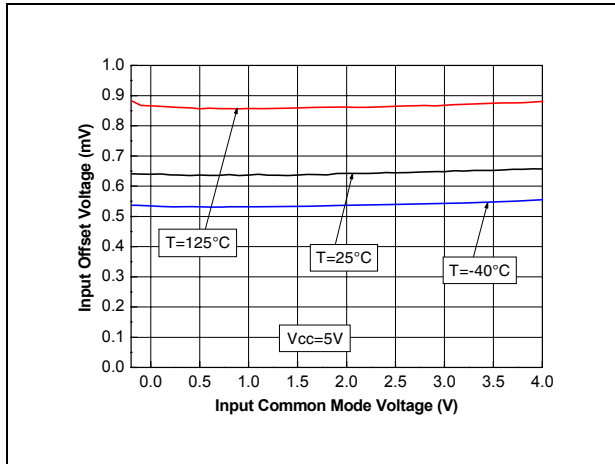


Figure 5. Output current vs. output voltage at  $V_{CC} = 2.7 V$

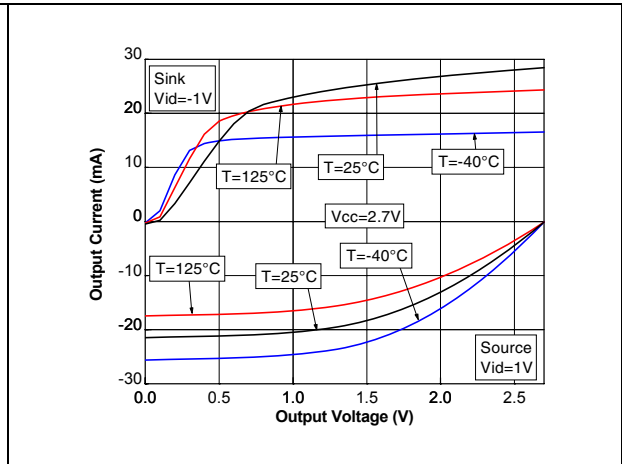


Figure 6. Output current vs. output voltage at  $V_{CC} = 5 V$

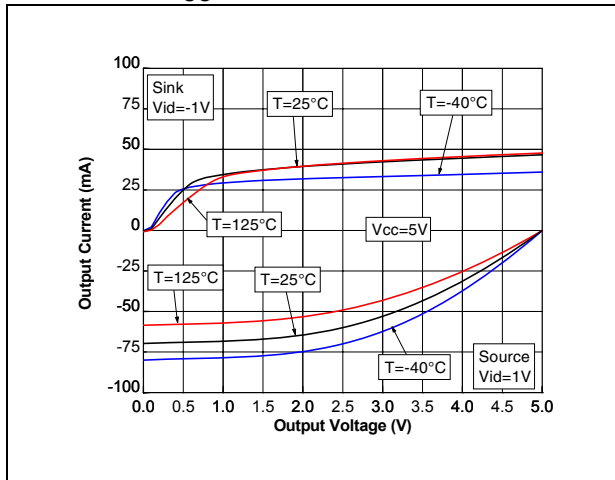


Figure 7. Output current vs. supply voltage at  $V_{icm} = V_{CC}/2$

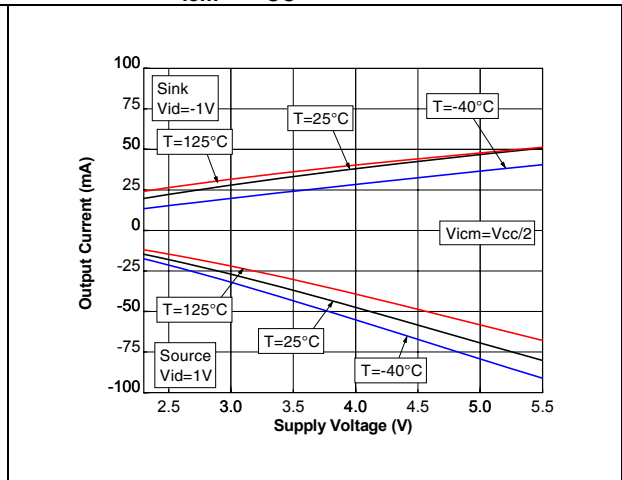


Figure 8. Voltage gain and phase with  $C_l = 100 \text{ pF}$

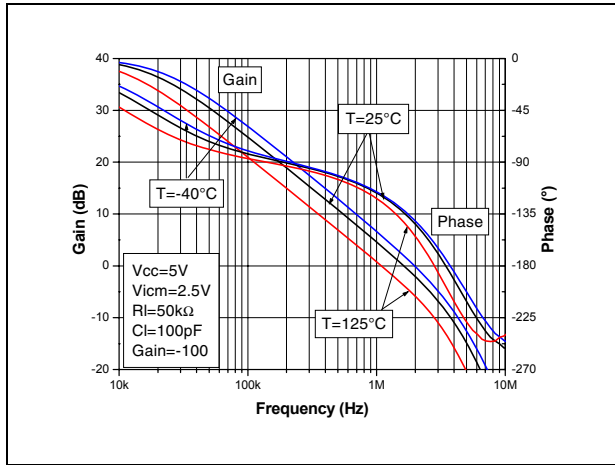


Figure 9. Voltage gain and phase with  $C_l = 200 \text{ pF}$

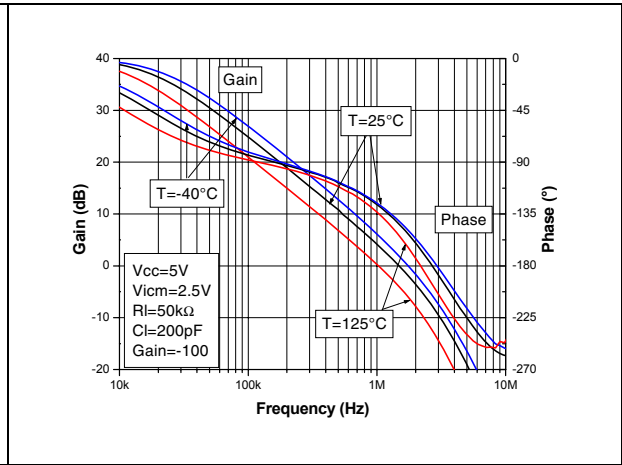


Figure 10. Gain margin vs. load capacitor at  $V_{CC} = 5 \text{ V}$

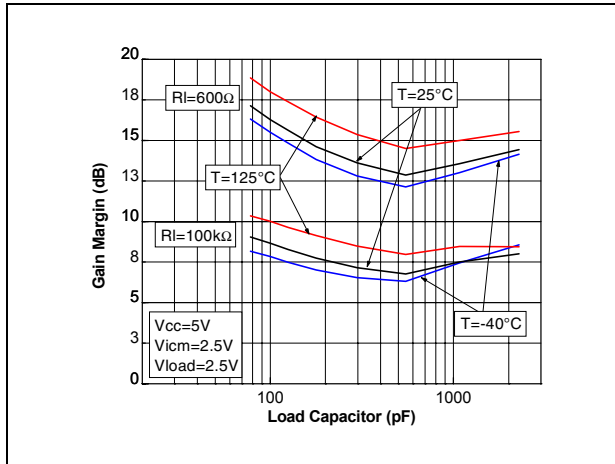
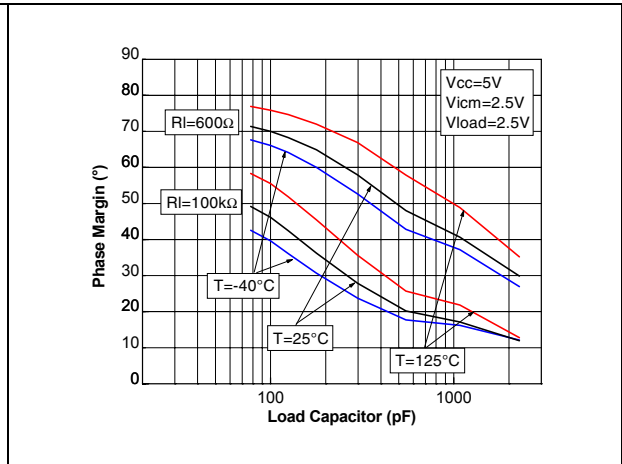
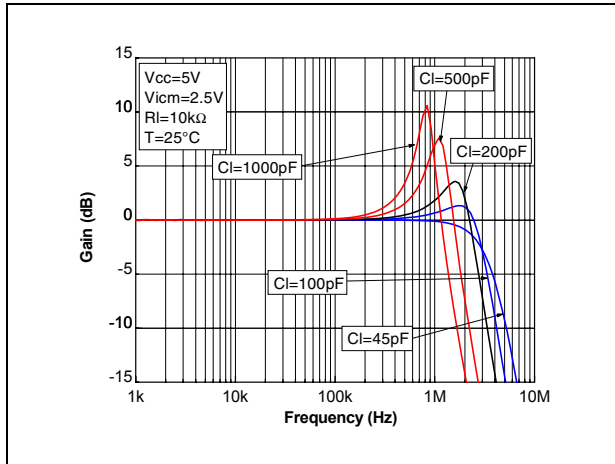


Figure 11. Phase margin vs. load capacitor at  $V_{CC} = 5 \text{ V}$

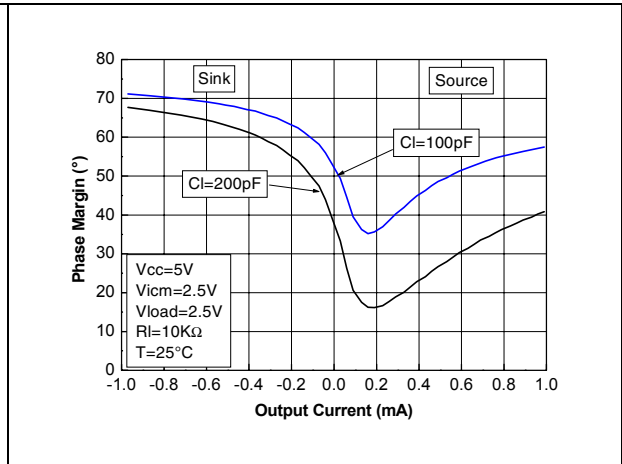




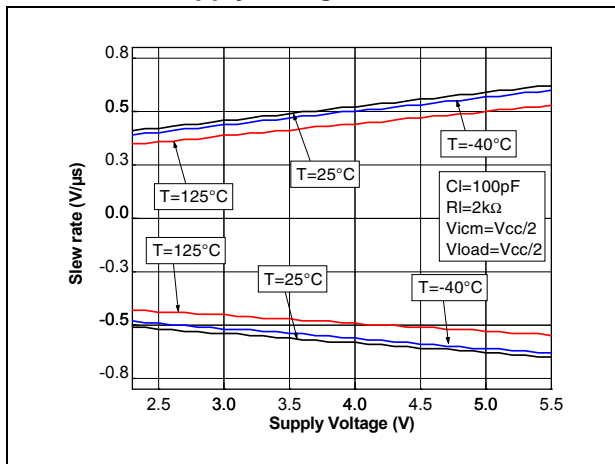
**Figure 12. Closed-loop gain in voltage follower configuration for different capacitive loads**



**Figure 13. Phase margin vs. output current at  $V_{CC} = 5 V$**



**Figure 14. Positive and negative slew rate vs. supply voltage**



**Figure 15. Positive slew rate at  $V_{CC} = 5 V$  with  $C_l = 100 pF$**

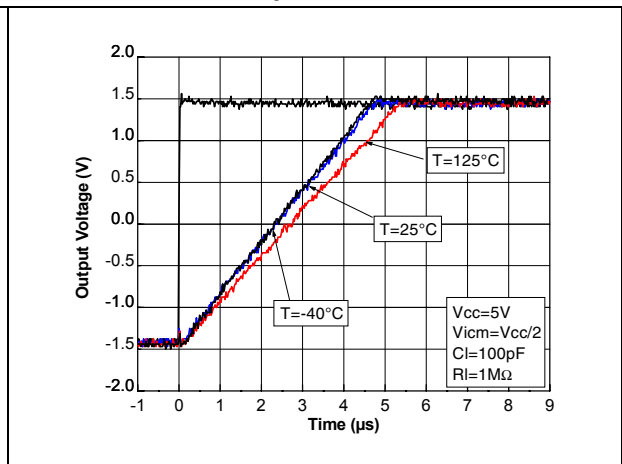


Figure 16. Negative slew rate at  $V_{CC} = 5\text{ V}$  with  $C_I = 100\text{ pF}$       Figure 17. Noise vs. frequency

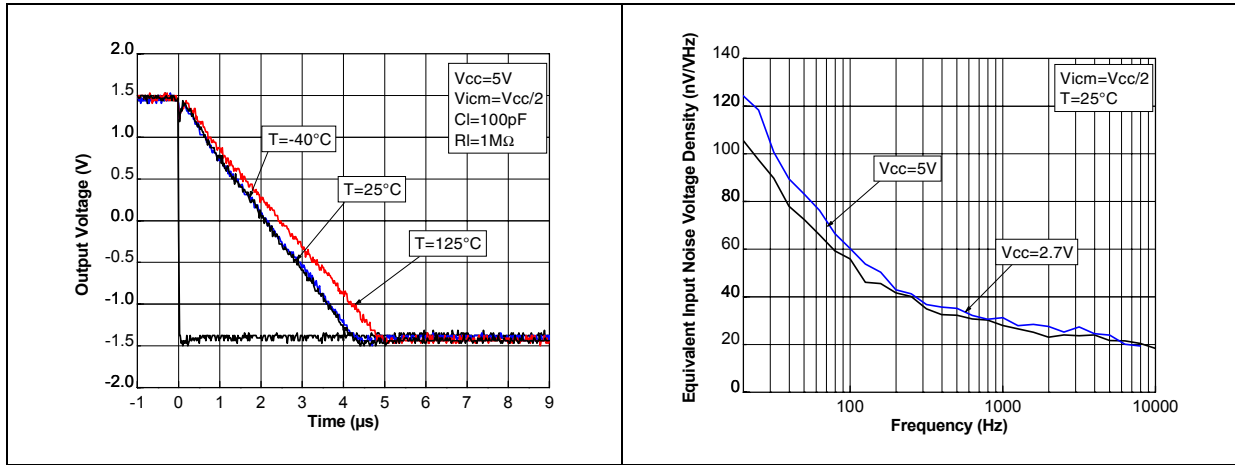


Figure 18. 0.1 Hz to 10 Hz noise at  $V_{CC} = 5\text{ V}$       Figure 19. Distortion + noise vs. frequency

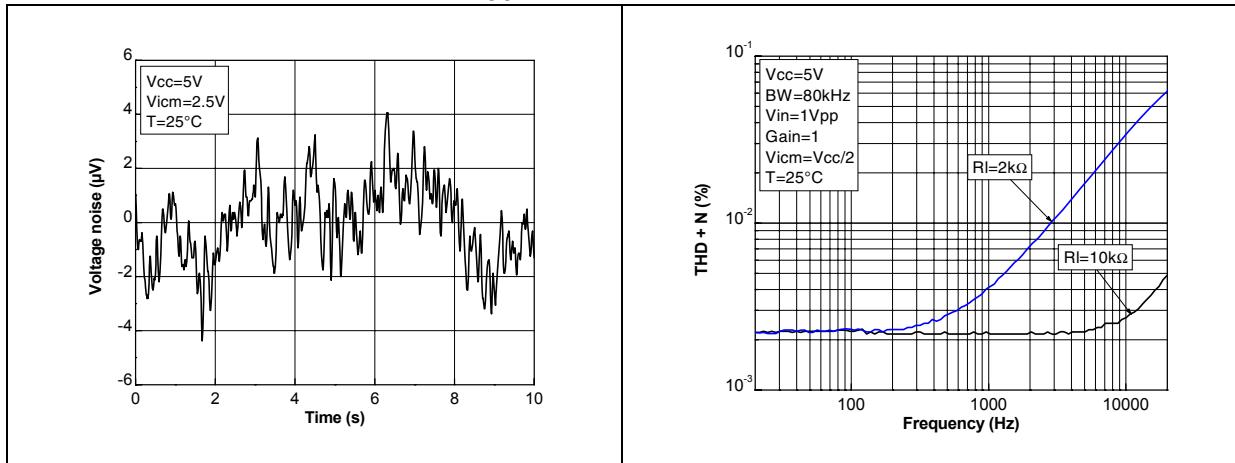
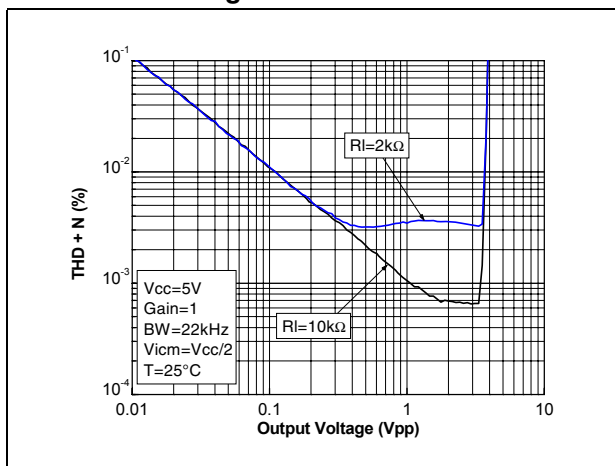


Figure 20. Distortion + noise vs. output voltage



## 4 Application information

### 4.1 Operating voltages

The LMX321, LMX358 and LMX324 can operate from 2.3 to 5.5 V. The devices' parameters are fully specified for 2.7 and 5 V power supplies. Additionally, the main specifications are guaranteed in extended temperature ranges from -40° C to +125° C.

### 4.2 Input common-mode range

The LMX321, LMX358 and LMX324 have an input common-mode range that includes ground. The input common-mode range is extended from  $V_{CC-} - 0.2$  V to  $V_{CC+} - 1$  V, with no output phase reversal.

### 4.3 Rail-to-rail output

The operational amplifiers' output levels can go close to the rails: 180 mV maximum above and below the rail when connected to a 10 k $\Omega$  resistive load to  $V_{CC}/2$ .

### 4.4 Input offset voltage drift over temperature

The maximum input voltage drift over the temperature variation is defined as follows:

$$\frac{\Delta V_{io}}{\Delta T} = \max \left| \frac{V_{io}(T) - V_{io}(25^\circ \text{C})}{T - 25^\circ \text{C}} \right|$$

for  $T_{\min} < T < T_{\max}$ .

### 4.5 PCB layouts

For correct operation, it is advised to add 10 nF decoupling capacitors as close as possible to the power supply pins.

### 4.6 Macromodel

Accurate macromodels of the LMX321, LMX358 and LMX324 are available on STMicroelectronics' web site at [www.st.com](http://www.st.com). This model is a trade-off between accuracy and complexity (that is, time simulation) of the LMX321, LMX358 and LMX324 operational amplifiers. It emulates the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. It also helps to validate a design approach and to select the right operational amplifier, *but it does not replace on-board measurements*.

## 5 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> packages, depending on their level of environmental compliance. ECOPACK<sup>®</sup> specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK<sup>®</sup> is an ST trademark.

### 5.1 SO-8 package information

Figure 21. SO-8 package mechanical drawing

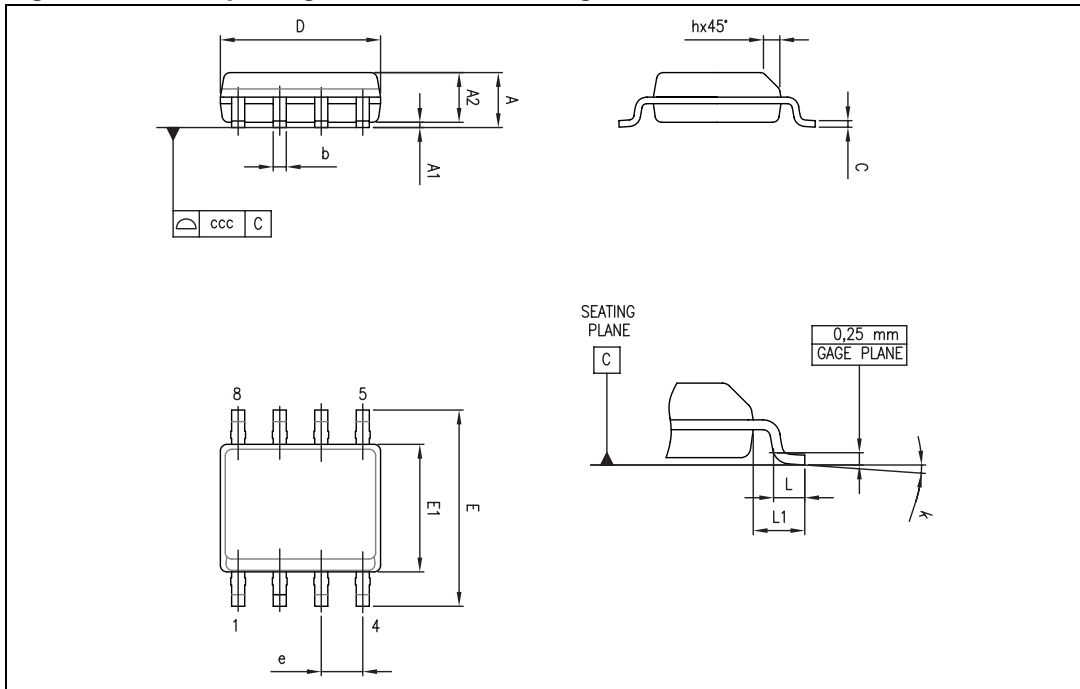


Table 6. SO-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
A1	0.10		0.25	0.004		0.010
A2	1.25			0.049		
b	0.28		0.48	0.011		0.019
c	0.17		0.23	0.007		0.010
D	4.80	4.90	5.00	0.189	0.193	0.197
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e		1.27			0.050	
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
L1		1.04			0.040	
k	1°		8°	1°		8°
ccc			0.10			0.004

## 5.2 SO-14 package information

Figure 22. SO-14 package mechanical drawing

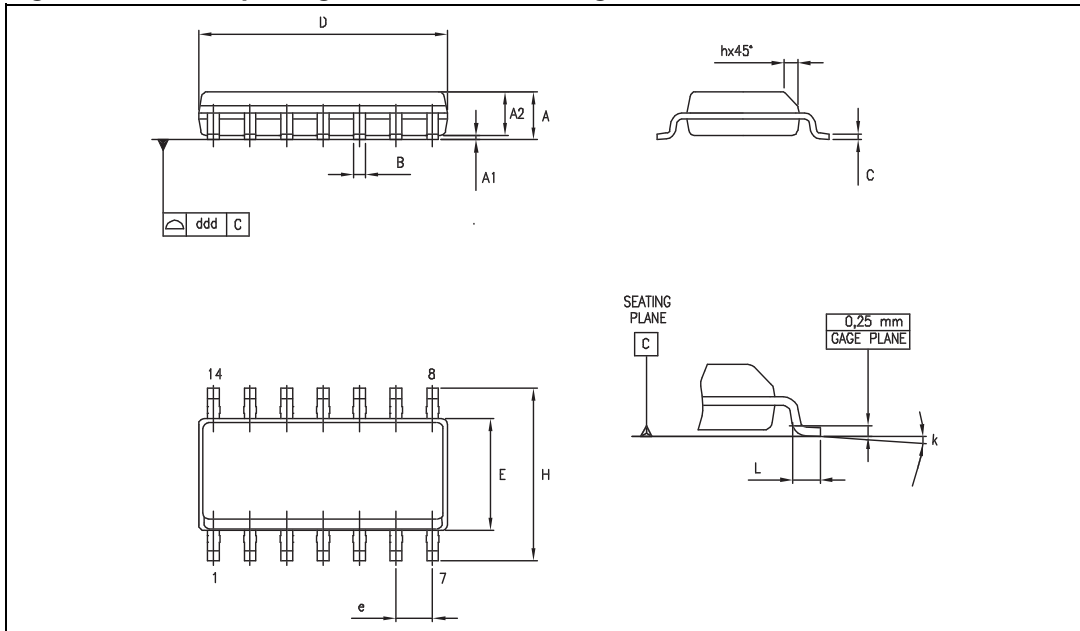


Table 7. SO-14 package mechanical data

Dimensions						
Ref.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	1.35		1.75	0.05		0.068
A1	0.10		0.25	0.004		0.009
A2	1.10		1.65	0.04		0.06
B	0.33		0.51	0.01		0.02
C	0.19		0.25	0.007		0.009
D	8.55		8.75	0.33		0.34
E	3.80		4.0	0.15		0.15
e		1.27			0.05	
H	5.80		6.20	0.22		0.24
h	0.25		0.50	0.009		0.02
L	0.40		1.27	0.015		0.05
k	8° (max.)					
ddd			0.10			0.004

### 5.3 TSSOP14 package information

Figure 23. TSSOP14 package mechanical drawing

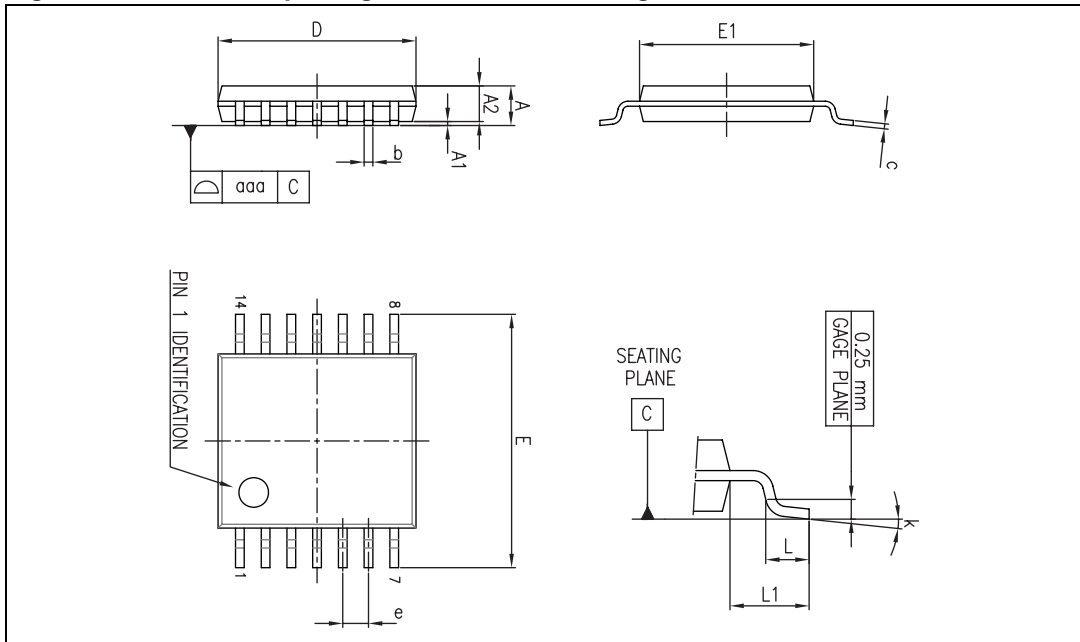


Table 8. TSSOP14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.012
c	0.09		0.20	0.004		0.0089
D	4.90	5.00	5.10	0.193	0.197	0.201
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.176
e		0.65			0.0256	
L	0.45	0.60	0.75	0.018	0.024	0.030
L1		1.00			0.039	
k	0°		8°	0°		8°
aaa			0.10			0.004

### 5.4 MiniSO-8 package information

Figure 24. MiniSO-8 package mechanical drawing

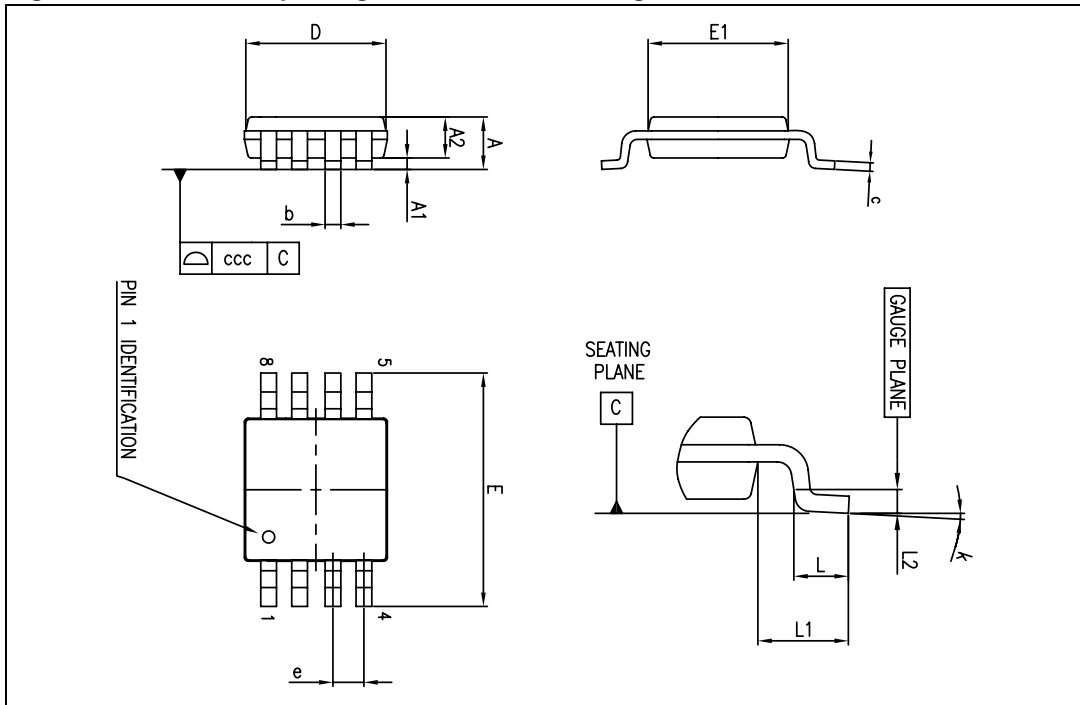


Table 9. MiniSO-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.1			0.043
A1	0		0.15	0		0.006
A2	0.75	0.85	0.95	0.030	0.033	0.037
b	0.22		0.40	0.009		0.016
c	0.08		0.23	0.003		0.009
D	2.80	3.00	3.20	0.11	0.118	0.126
E	4.65	4.90	5.15	0.183	0.193	0.203
E1	2.80	3.00	3.10	0.11	0.118	0.122
e		0.65			0.026	
L	0.40	0.60	0.80	0.016	0.024	0.031
L1		0.95			0.037	
L2		0.25			0.010	
k	0°		8°	0°		8°
ccc			0.10			0.004



## 5.5 SOT23-5 package information

Figure 25. SOT23-5L package mechanical drawing

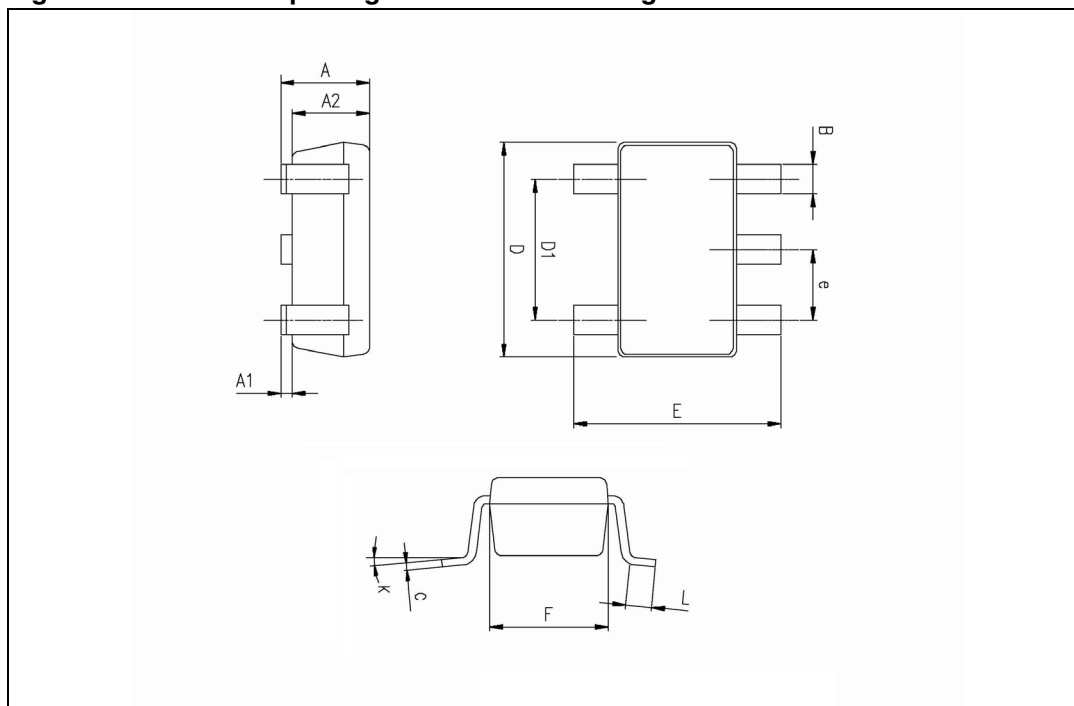


Table 10. SOT23-5L package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90	1.20	1.45	0.035	0.047	0.057
A1			0.15			0.006
A2	0.90	1.05	1.30	0.035	0.041	0.051
B	0.35	0.40	0.50	0.013	0.015	0.019
C	0.09	0.15	0.20	0.003	0.006	0.008
D	2.80	2.90	3.00	0.110	0.114	0.118
D1		1.90			0.075	
e		0.95			0.037	
E	2.60	2.80	3.00	0.102	0.110	0.118
F	1.50	1.60	1.75	0.059	0.063	0.069
L	0.10	0.35	0.60	0.004	0.013	0.023
K	0 degrees		10 degrees			

### 5.6 SC70-5 (or SOT323-5) package information

Figure 26. SC70-5 (or SOT323-5) package mechanical drawing

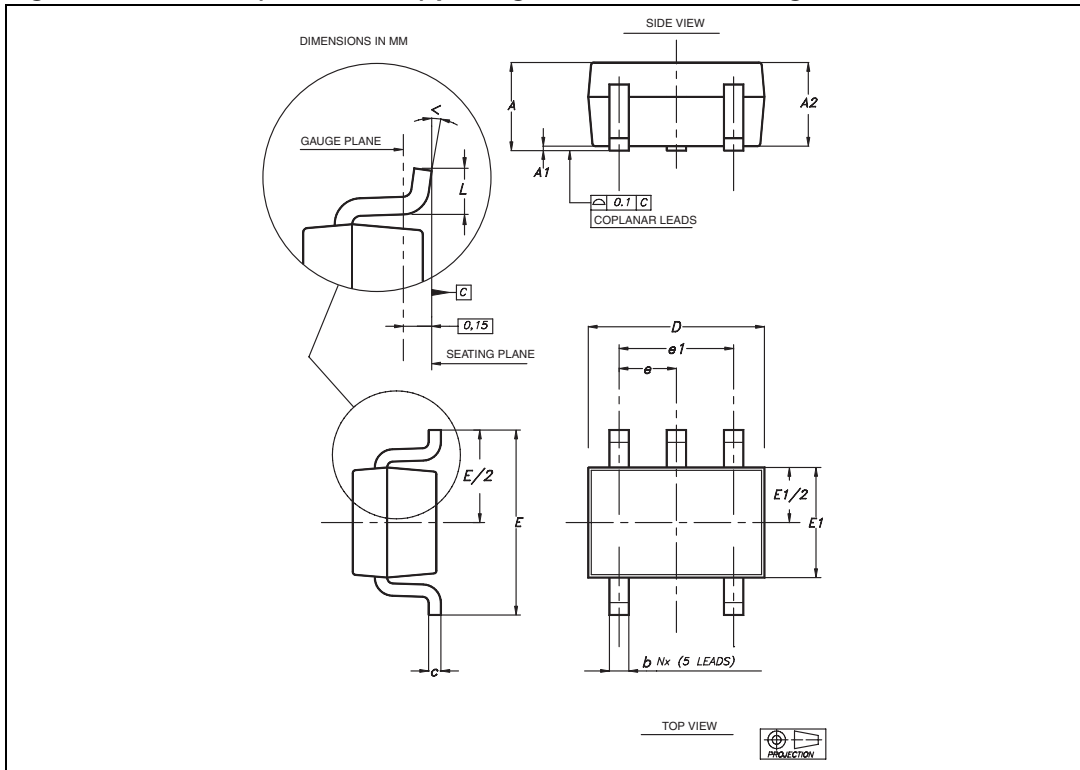


Table 11. SC70-5 (or SOT323-5) package mechanical data

Ref	Dimensions					
	Millimeters			Inches		
	Min	Typ	Max	Min	Typ	Max
A	0.80		1.10	0.032		0.043
A1			0.10			0.004
A2	0.80	0.90	1.00	0.032	0.035	0.039
b	0.15		0.30	0.006		0.012
c	0.10		0.22	0.004		0.009
D	1.80	2.00	2.20	0.071	0.079	0.087
E	1.80	2.10	2.40	0.071	0.083	0.094
E1	1.15	1.25	1.35	0.045	0.049	0.053
e		0.65			0.025	
e1		1.30			0.051	
L	0.26	0.36	0.46	0.010	0.014	0.018
$\angle$	0°		8°			

## 6 Ordering information

**Table 12. Order codes for devices without shutdown feature**

Order code	Temperature range	Package	Packing	Marking
LMX321ICT	-40° C to +125° C	SC70-5	Tape and reel	K21
LMX321ILT		SOT23-5		K430
LMX358IST		MiniSO8		K430
LMX358IDT		SO8		LMX358I
LMX324IPT		TSSOP14		LMX324I
LMX324IDT		SO14		LMX324I

## 7 Revision history

**Table 13. Document revision history**

Date	Revision	Changes
19-Mar-2012	1	Initial release.
06-Apr-2012	2	Document status promoted from Target Specification to Production Data.

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