

## General purpose input/output rail-to-rail low power operational amplifiers

Datasheet – production data

### Features

- Operating range  $V_{CC} = 2.5\text{ V to }6\text{ V}$
- Rail-to-rail input and output
- Extended  $V_{icm}$  ( $V_{DD} - 0.2\text{ V to }V_{CC} + 0.2\text{ V}$ )
- Capable of driving a  $32\ \Omega$  load resistor
- High stability:  $500\text{ pF}$
- Available in SOT23-5 micropackage, SO-8, SO-14, TSSOP8, TSSOP14, and MiniSO-8 package
- Operating temperature range:  $-40\text{ }^\circ\text{C, }+125\text{ }^\circ\text{C}$

### Applications

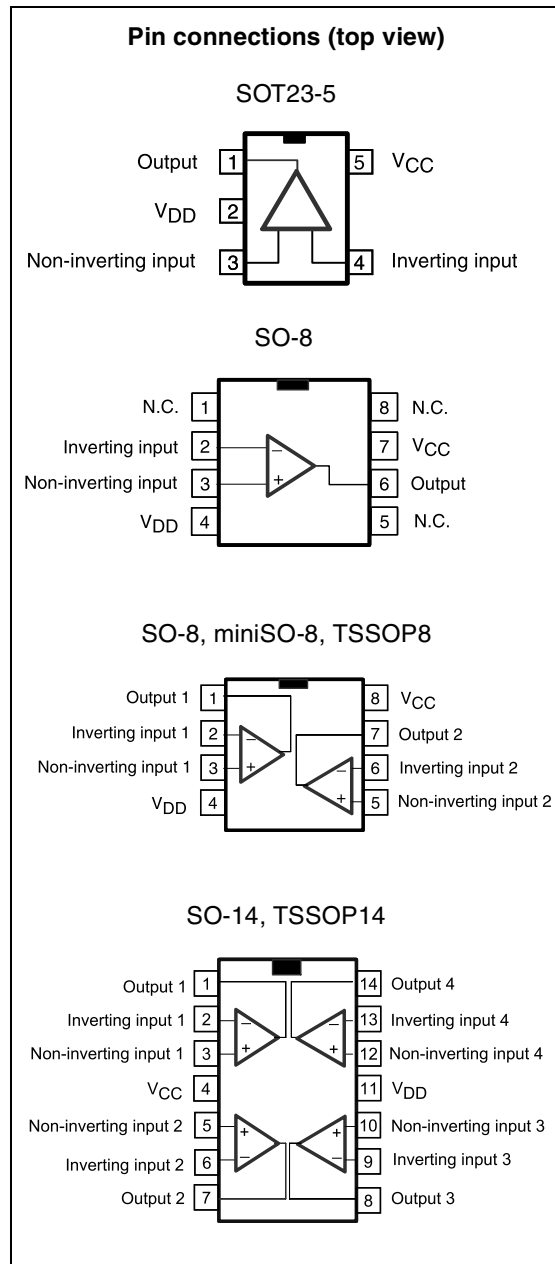
- Battery powered applications
- Audio driver (headphone driver)
- Sensor signal conditioning
- Laptop/notebook computers

### Description

The TSV358 and TSV324 (dual and quad) devices are low voltage versions of the LM358 and LM324 commodity operational amplifiers. The TSV321 device is the single version. The TSV321/358/324 devices are able to operate with voltages as low as 2.5 V and feature both I/O rail-to-rail.

The common mode input voltage extends 200 mV beyond the supply voltages at 25 °C while the output voltage swing is within 100 mV of each rail with a 600  $\Omega$  load resistor. At  $V_{CC} = 3\text{ V}$ , these devices offer 1.3 MHz of gain bandwidth product and provide high output current capability with a typical value of 80 mA.

These features make the TSV3xx family ideal for active filters, general purpose low voltage applications, and general purpose portable devices.



# 1 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup>	7	V
$V_{id}$	Differential input voltage <sup>(2)</sup>	$\pm 1$	V
$V_{in}$	Input voltage	$V_{DD} - 0.3$ to $V_{CC} + 0.3$	V
$T_{stg}$	Storage temperature	-65 to +150	°C
$T_j$	Maximum junction temperature	150	°C
$R_{thja}$	Thermal resistance junction-to-ambient <sup>(3)</sup>		°C/W
	SOT23-5	250	
	SO-8	125	
	SO-14	105	
	TSSOP8	120	
	TSSOP14	100	
$R_{thjc}$	Thermal resistance junction-to-case <sup>(3)</sup>		°C/W
	SOT23-5	81	
	SO-8	40	
	SO-14	31	
	TSSOP8	37	
	TSSOP14	32	
ESD	HBM: human body model <sup>(4)</sup>	2	kV
	MM: machine model <sup>(5)</sup>	200	V
	CDM: charged device model <sup>(6)</sup>	1.5	kV
	Latch-up immunity	200	mA
	Lead temperature (soldering, 10 s)	250	°C
	Output short-circuit duration	See <sup>(7)</sup>	

- All voltages values, except differential voltage are with respect to network terminal.
- Differential voltages are the non-inverting input terminal with respect to the inverting input terminal. If  $V_{id} > \pm 1$  V, the maximum input current must not exceed  $\pm 1$  mA. When  $V_{id} > \pm 1$  V, an input series resistor must be added to limit input current.
- 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 capacitor 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 ground.
- Short-circuits from the output to  $V_{CC}$  can cause excessive heating. The maximum output current is approximately 80 mA, independent of the magnitude of  $V_{CC}$ . Destructive dissipation can result from simultaneous short-circuits on all amplifiers.

**Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.5 to 6	V
$V_{icm}$	Common mode input voltage range $T_{amb} = 25\text{ }^{\circ}\text{C}$ , $2.5 \leq V_{CC} \leq 6\text{ V}$ $T_{min} < T_{amb} < T_{max}$ , $2.5 \leq V_{CC} \leq 5.5\text{ V}$	$V_{DD} - 0.2$ to $V_{CC} + 0.2$ $V_{DD}$ to $V_{CC}$	V
$T_{oper}$	Operating free air temperature range	-40 to +125	$^{\circ}\text{C}$

## 2 Electrical characteristics

**Table 3. Electrical characteristics at  $V_{CC} = +3\text{ V}$ ,  $V_{DD} = 0\text{ V}$ ,  $R_L$ ,  $C_L$  connected to  $V_{CC}/2$ , and  $T_{amb} = 25\text{ °C}$  (unless otherwise specified)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage	$V_{icm} = V_{out} = V_{CC}/2$ TSV321/358/324 $T_{min} \leq T_{amb} \leq T_{max}$ TSV321A/358A/324A $T_{min} \leq T_{amb} \leq T_{max}$		0.2 0.1	3 6 1 3	mV
$\Delta V_{io}$	Input offset voltage drift			2		$\mu\text{V}/\text{°C}$
$I_{io}$	Input offset current	$V_{icm} = V_{out} = V_{CC}/2^{(1)}$ $T_{min} \leq T_{amb} \leq T_{max}$		3	30 60	nA
$I_{ib}$	Input bias current	$V_{icm} = V_{out} = V_{CC}/2^{(1)}$ $T_{min} \leq T_{amb} \leq T_{max}$		40	125 150	nA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0 \leq V_{icm} \leq V_{CC}$ , $V_{out} = V_{CC}/2$	60	80		dB
$A_{vd}$	Large signal voltage gain	$V_{out} = 0.5\text{ V to } 2.5\text{ V}$ $R_L = 2\text{ k}\Omega$ $R_L = 600\ \Omega$	80 74	92 95		dB
$V_{OH}$	High level output voltage	$V_{id} = 100\text{ mV}$ $R_L = 2\text{ k}\Omega$ $R_L = 600\ \Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2\text{ k}\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\ \Omega$	2.82 2.80 2.82 2.80	2.95 2.95		V
$V_{OL}$	Low level output voltage	$V_{id} = -100\text{ mV}$ $R_L = 2\text{ k}\Omega$ $R_L = 600\ \Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2\text{ k}\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\ \Omega$		88 115	120 160 120 160	mV
$I_o$	Output source current	$V_{id} = 100\text{ mV}$ , $V_O = V_{DD}$	20	80		mA
	Output sink current	$V_{id} = -100\text{ mV}$ , $V_O = V_{CC}$	20	80		
$I_{CC}$	Supply current (per amplifier)	$A_{VCL} = 1$ , no load $T_{min} \leq T_{amb} \leq T_{max}$		420	650 690	$\mu\text{A}$
GBP	Gain bandwidth product	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $f = 100\text{ kHz}$	1	1.3		MHz
SR	Slew rate	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$	0.42	0.6		$\text{V}/\mu\text{s}$
$\phi_m$	Phase margin	$C_L = 100\text{ pF}$		53		Degrees
en	Input voltage noise			27		$\text{nV}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion			0.01		%

1. Maximum values include unavoidable inaccuracies of the industrial tests.

**Table 4. Electrical characteristics at  $V_{CC} = +5\text{ V}$ ,  $V_{DD} = 0\text{ V}$ ,  $R_L$ ,  $C_L$  connected to  $V_{CC}/2$ , and  $T_{amb} = 25\text{ }^\circ\text{C}$  (unless otherwise specified)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage	$V_{icm} = V_{out} = V_{CC}/2$ TSV321/358/324 $T_{min} \leq T_{amb} \leq T_{max}$ TSV321A/358A/324A $T_{min} \leq T_{amb} \leq T_{max}$		0.2 0.1	3 6 1 3	mV
$\Delta V_{io}$	Input offset voltage drift			2		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current	$V_{icm} = V_{out} = V_{CC}/2^{(1)}$ $T_{min} \leq T_{amb} \leq T_{max}$		3	30 60	nA
$I_{ib}$	Input bias current	$V_{icm} = V_{out} = V_{CC}/2^{(1)}$ $T_{min} \leq T_{amb} \leq T_{max}$		70	130 150	nA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0 \leq V_{icm} \leq V_{CC}$ ; $V_{out} = V_{CC}/2$	65	85		dB
SVR	Supply voltage rejection ratio $20 \log (\Delta V_{CC}/\Delta V_{io})$	$V_{CC} = 2.5\text{ V to } 5\text{ V}$	70	90		dB
$A_{vd}$	Large signal voltage gain	$V_{out} = 0.5\text{ V to } 4.5\text{ V}$ $R_L = 2\text{ k}\Omega$ $R_L = 600\ \Omega$	83 77	92 85		dB
$V_{OH}$	High level output voltage	$V_{id} = 100\text{ mV}$ $R_L = 2\text{ k}\Omega$ $R_L = 600\ \Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2\text{ k}\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\ \Omega$	4.80 4.75 4.80 4.75	4.95 4.90		V
$V_{OL}$	Low level output voltage	$V_{id} = -100\text{ mV}$ $R_L = 2\text{ k}\Omega$ $R_L = 600\ \Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2\text{ k}\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\ \Omega$		88 115	130 188 130 188	mV
$I_o$	Output source current	$V_{id} = 100\text{ mV}$ , $V_O = V_{DD}$	20	80		mA
	Output sink current	$V_{id} = -100\text{ mV}$ , $V_O = V_{CC}$	20	80		
$I_{CC}$	Supply current (per amplifier)	$A_{VCL} = 1$ , no load $T_{min} \leq T_{amb} \leq T_{max}$		500	835 875	$\mu\text{A}$
GBP	Gain bandwidth product	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $f = 100\text{ kHz}$	1	1.4		MHz
SR	Slew rate	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$	0.42	0.6		$\text{V}/\mu\text{s}$
$\phi_m$	Phase margin	$C_L = 100\text{ pF}$		55		Degrees
en	Input voltage noise			27		$\text{nV}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion			0.01		%

1. Maximum values include unavoidable inaccuracies of the industrial tests.

Figure 1. Supply current/amplifier vs. supply voltage

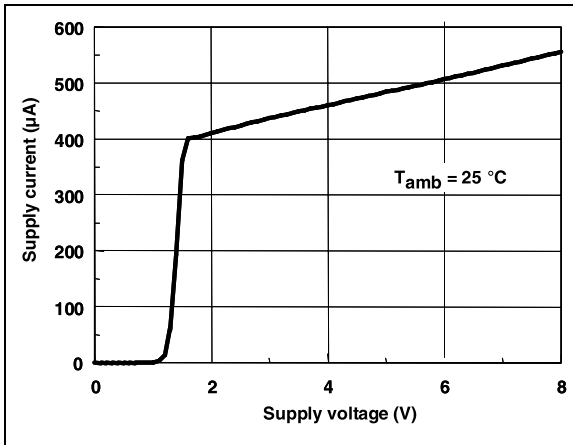


Figure 2. Supply current/amplifier vs. temperature

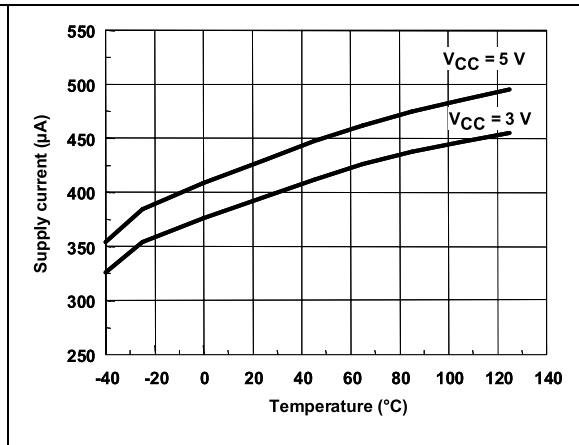


Figure 3. Output power vs. supply voltage

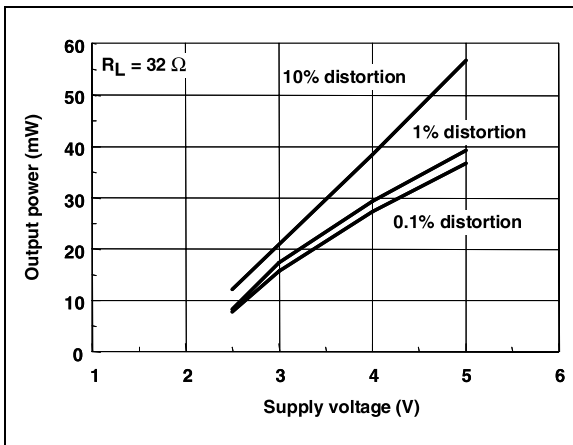


Figure 4. Input offset voltage drift vs. temperature

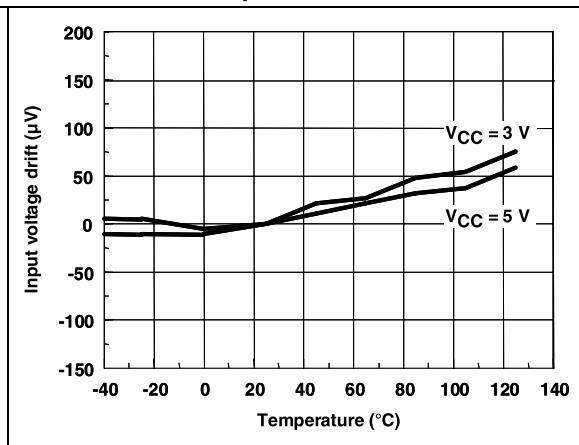


Figure 5. Input bias current vs. temperature

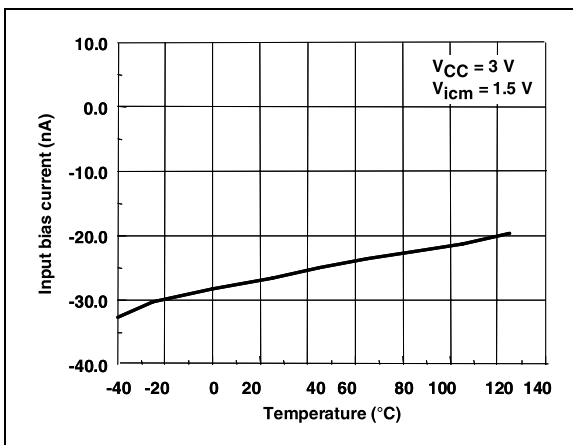


Figure 6. Open loop gain vs. temperature at VCC = 5 V

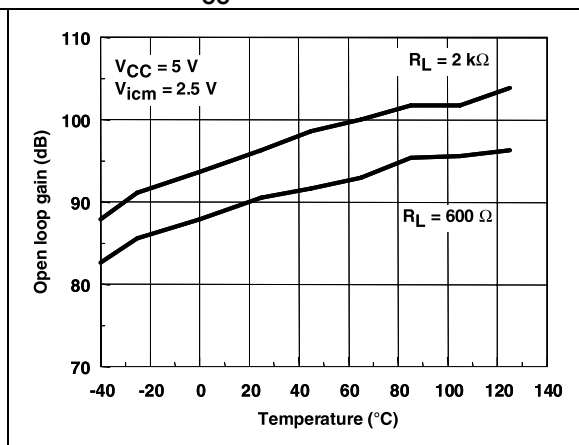


Figure 7. Open loop gain vs. temperature at  $V_{CC} = 3\text{ V}$

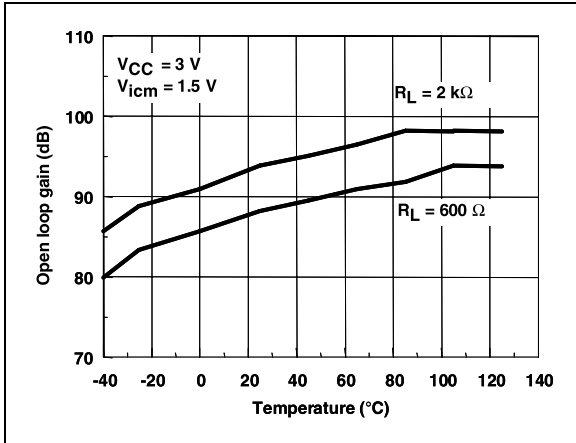


Figure 8. High level output voltage vs. temperature

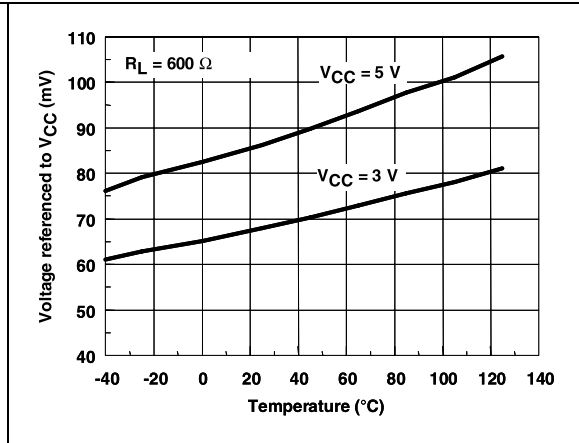


Figure 9. Low level output voltage vs. temperature

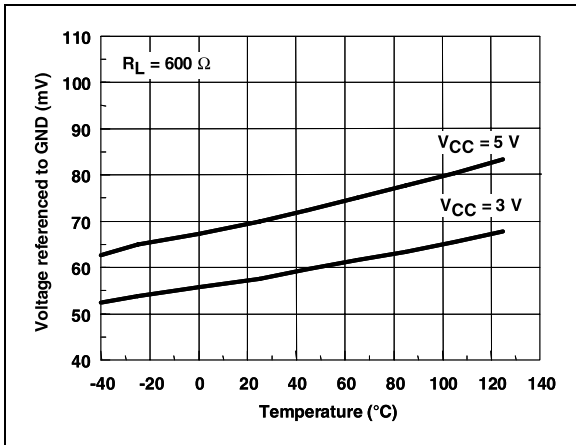


Figure 10. Output current vs. temperature at  $V_{CC} = 5\text{ V}$

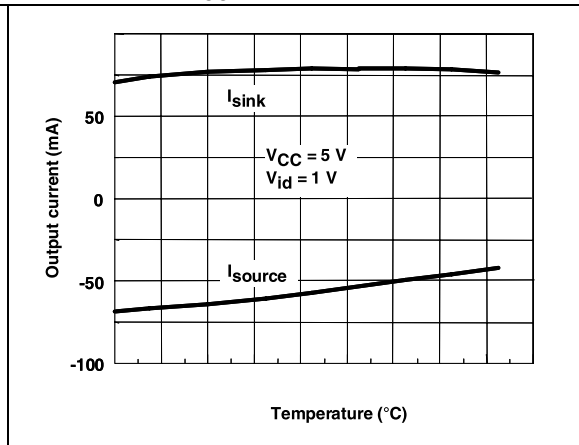


Figure 11. Output current vs. temperature at  $V_{CC} = 3\text{ V}$

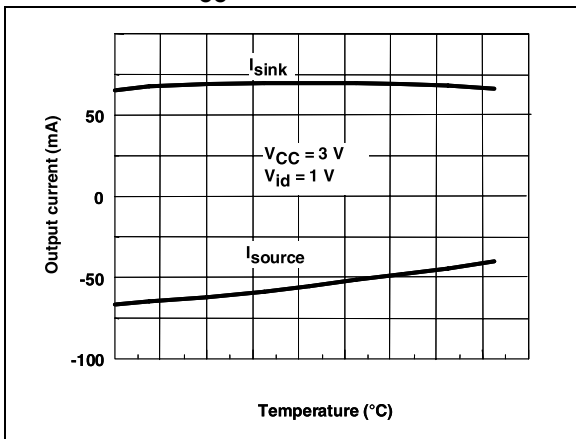


Figure 12. Output current vs. output voltage at  $V_{CC} = 5\text{ V}$

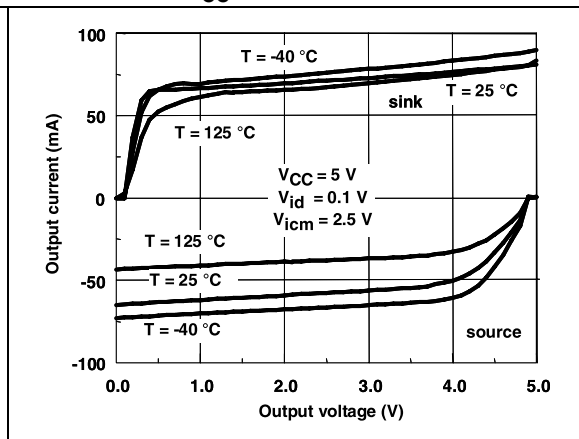


Figure 13. Output current vs. output voltage at  $V_{CC} = 3\text{ V}$

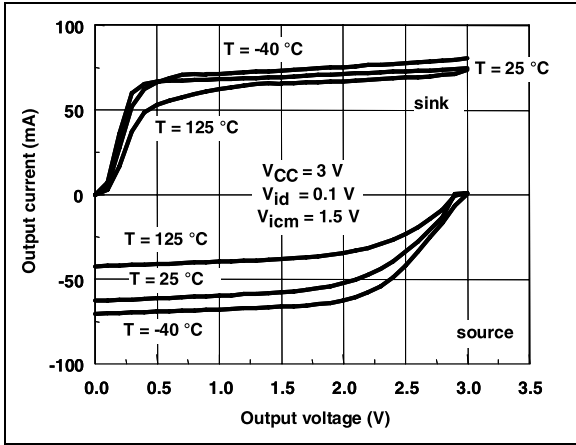


Figure 14. Gain and phase vs. frequency at  $V_{CC} = 5\text{ V}$

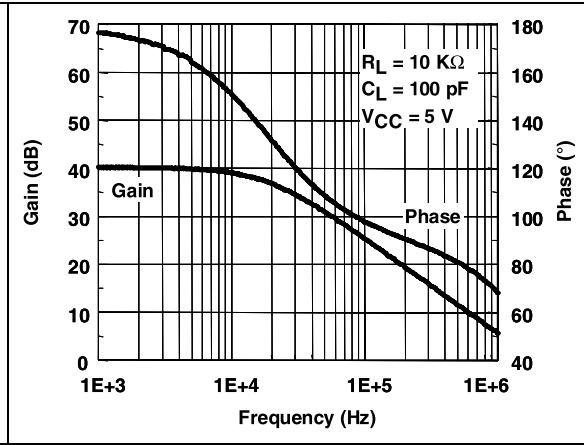


Figure 15. Gain and phase vs. frequency at  $V_{CC} = 3\text{ V}$

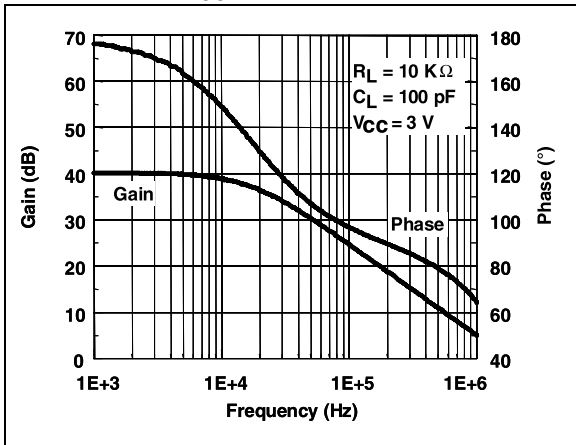


Figure 16. Slew rate vs. temperature at  $V_{CC} = 5\text{ V}$

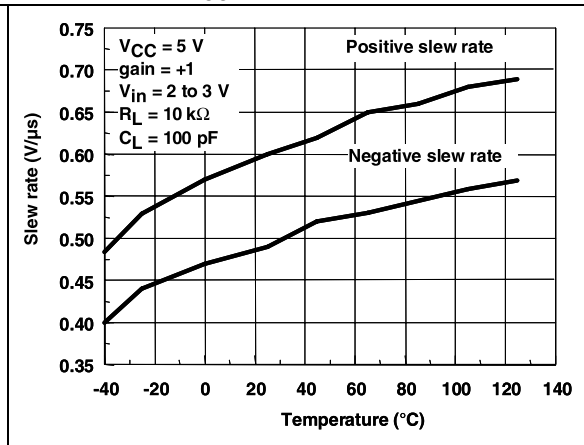


Figure 17. Slew rate vs. temperature at  $V_{CC} = 3\text{ V}$

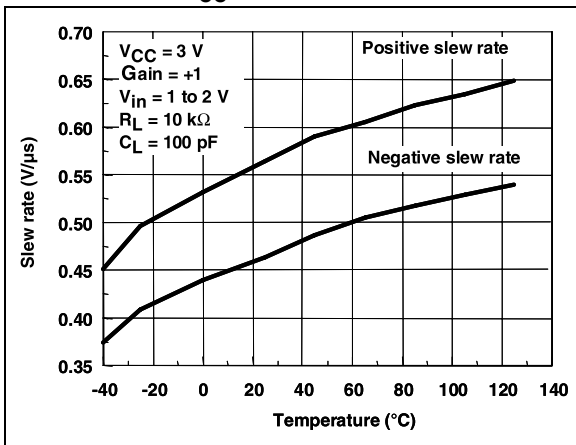
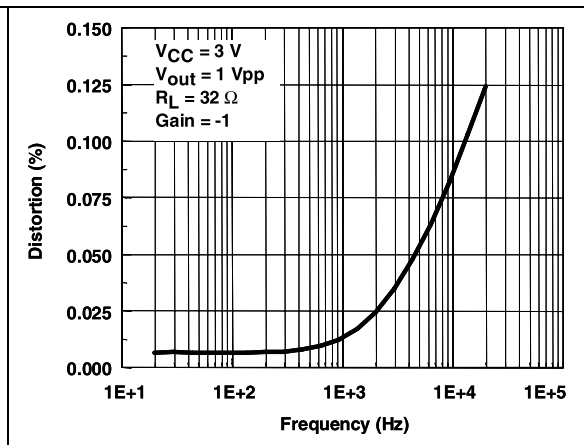


Figure 18. Distortion vs. frequency





### 3 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 specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK is an ST trademark.

#### 3.1 SOT23-5 package information

Figure 19. SOT23-5 package outline

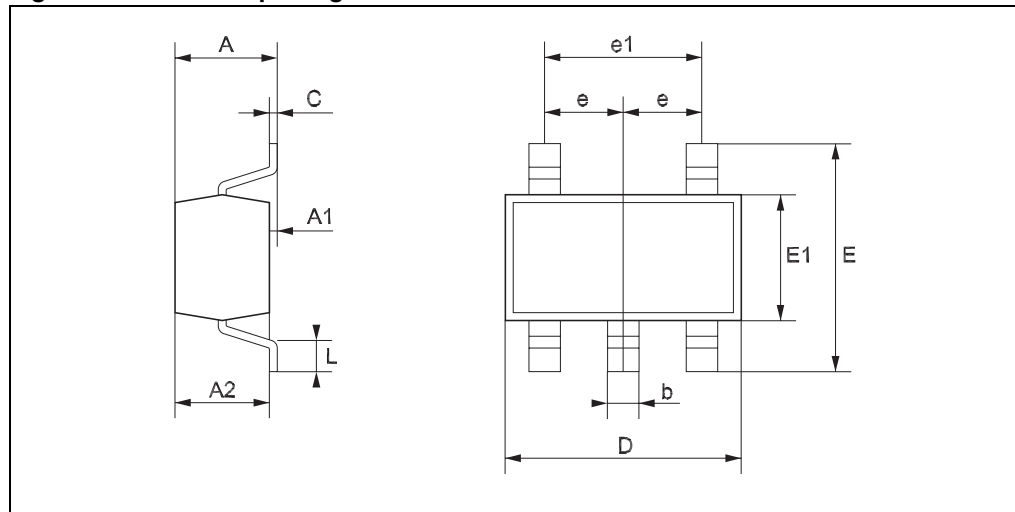


Table 5. SOT23-5 package mechanical data

Symbol	Dimensions					
	Millimeters			Mils		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90		1.45	35.4		57.1
A1	0.00		0.15	0.00		5.9
A2	0.90		1.30	35.4		51.2
b	0.35		0.50	13.7		19.7
C	0.09		0.20	3.5		7.8
D	2.80		3.00	110.2		118.1
E	2.60		3.00	102.3		118.1
E1	1.50		1.75	59.0		68.8
e		0.95			37.4	
e1		1.9			74.8	
L	0.35		0.55	13.7		21.6

### 3.2 SO-8 package information

Figure 20. SO-8 package outline

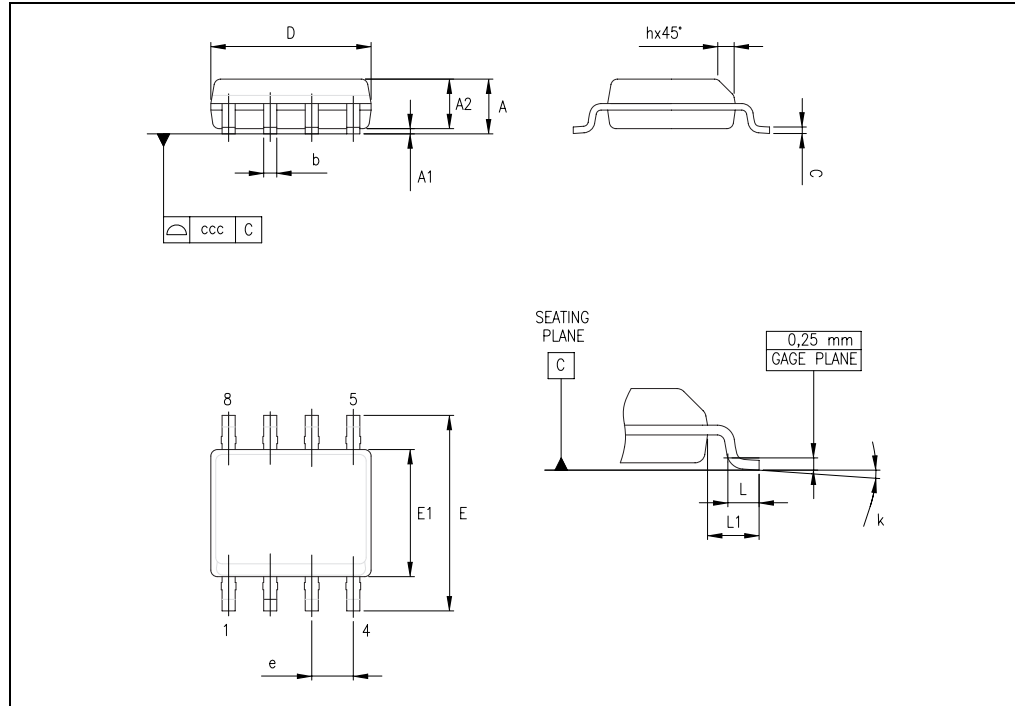


Table 6. SO-8 package mechanical data

Symbol	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
k	1°		8°	1°		8°
ccc			0.10			0.004

### 3.3 TSSOP8 package information

Figure 21. TSSOP8 package outline

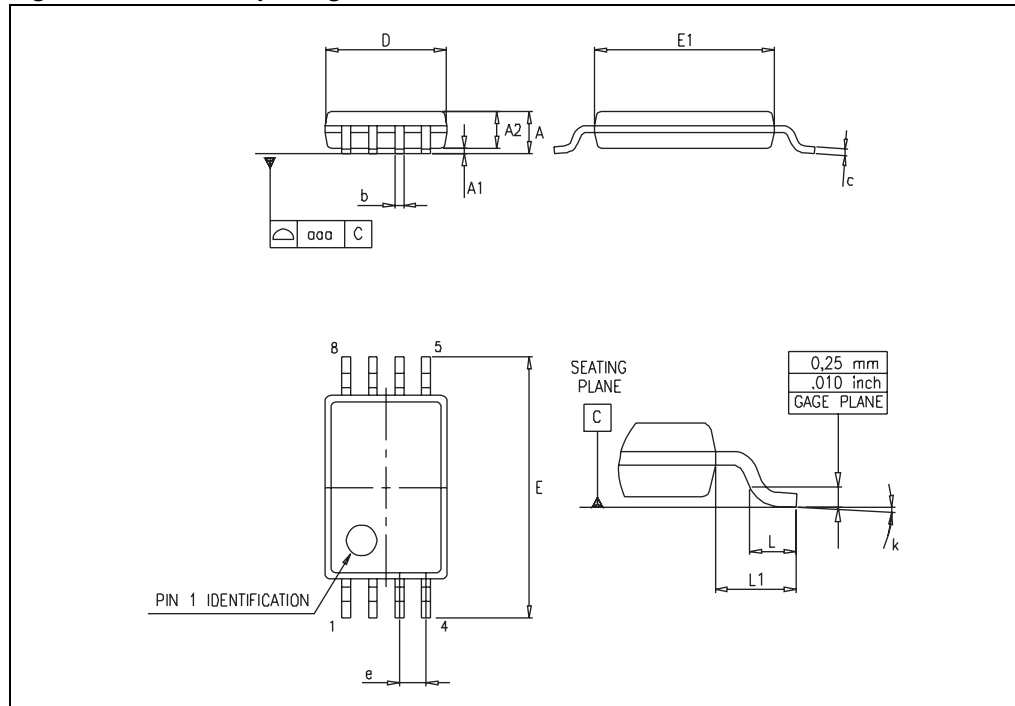


Table 7. TSSOP8 package mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.2			0.047
A1	0.05		0.15	0.002		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		0.008
D	2.90	3.00	3.10	0.114	0.118	0.122
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.0256	
k	0°		8°	0°		8°
L	0.45	0.60	0.75	0.018	0.024	0.030
L1		1			0.039	
aaa		0.1			0.004	

### 3.4 MiniSO-8 package information

Figure 22. MiniSO-8 package outline

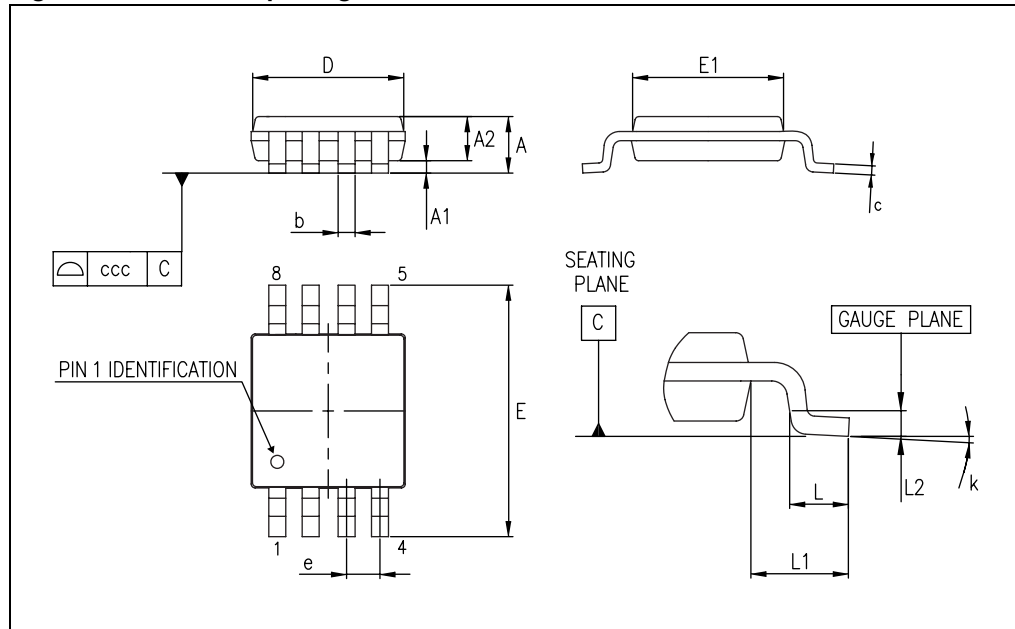


Table 8. MiniSO-8 package mechanical data

Symbol	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

### 3.5 SO-14 package information

Figure 23. SO-14 package outline

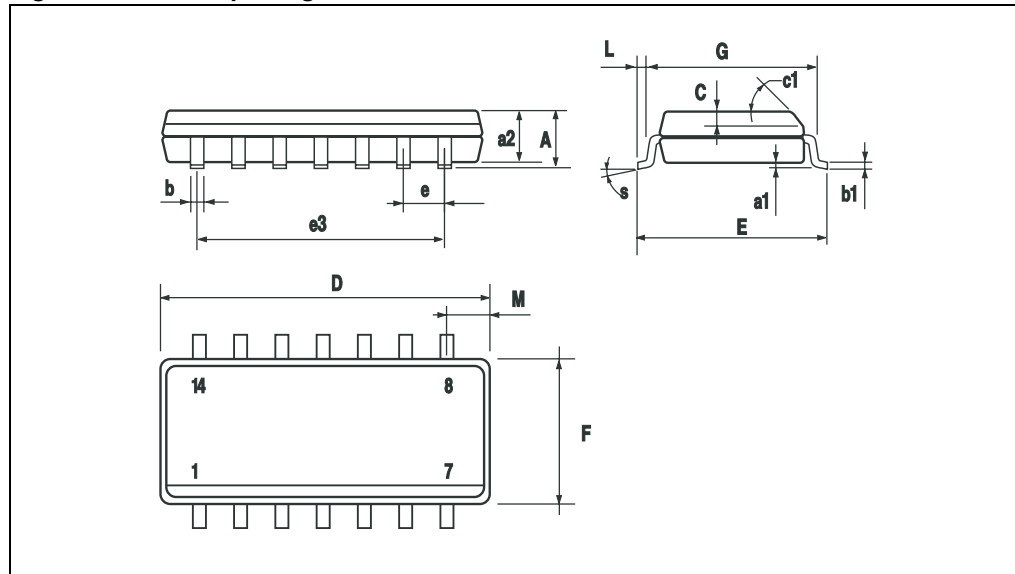


Table 9. SO-14 package mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.068
a1	0.1		0.2	0.003		0.007
a2			1.65			0.064
b	0.35		0.46	0.013		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.019	
c1	45° (typ.)					
D	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F	3.8		4.0	0.149		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.019		0.050
M			0.68			0.026
S	8° (max.)					

### 3.6 TSSOP14 package information

Figure 24. TSSOP14 package outline

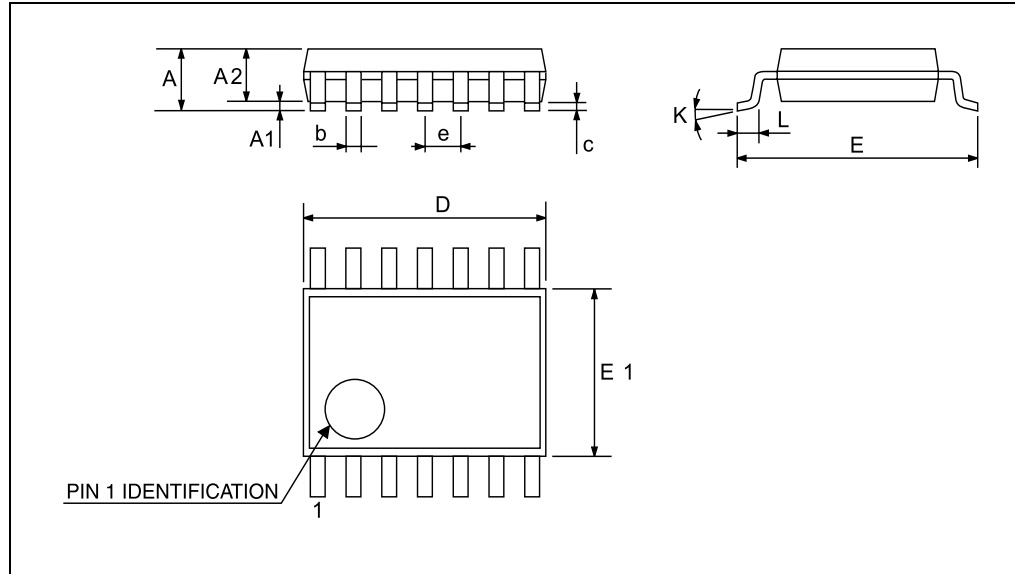


Figure 25. TSSOP14 package mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.2			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.8	1	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	4.9	5	5.1	0.193	0.197	0.201
E	6.2	6.4	6.6	0.244	0.252	0.260
E1	4.3	4.4	4.48	0.169	0.173	0.176
e		0.65 BSC			0.0256 BSC	
K	0°		8°	0°		8°
L1	0.45	0.60	0.75	0.018	0.024	0.030

## 4 Ordering information

Table 10. Order codes

Order code	Temperature range	Package	Packaging	Marking
TSV321RILT	-40 °C to +125 °C	SOT23-5	Tape and reel	K174
TSV321RAILT				K178
TSV321RIYLT <sup>(1)</sup>		SOT23-5 (automotive grade level)	Tape and reel	K179
TSV321RAIYLT <sup>(1)</sup>				K187
TSV321IDT		SO-8	Tube or tape and reel	V321ID
TSV321IDT		SO-8	Tube or tape and reel	V321AI
TSV358IDT		SO-8	Tube or tape and reel	V358ID
				V358AID
TSV358IYDT <sup>(1)</sup>		SO-8 (automotive grade level)	Tube or tape and reel	V358YD
TSV358AIYDT <sup>(1)</sup>				V358AY
TSV358IPT		TSSOP8 (thin shrink outline package)	Tape and reel	V358I
TSV358AIPT				V358A
TSV358IYPT <sup>(2)</sup>		TSSOP8 (automotive grade level)	Tape and reel	V358Y
TSV358AIYPT <sup>(2)</sup>				V58AY
TSV358IST		MiniSO-8	Tape and reel	K175
TSV358AIST				K184
TSV324IDT		SO-14	Tube or tape and reel	V324ID
TSV324AIDT				V324AI
TSV324IYDT <sup>(1)</sup>		SO-14 (automotive grade level)	Tube or tape and reel	V324YD
TSV324AIYDT <sup>(1)</sup>				V324AY
TSV324IPT	TSSOP14 (thin shrink outline package)	Tape and reel	V324IP	
TSV324AIPT			V324A	
TSV324AIYPT <sup>(1)</sup>	TSSOP14 (automotive grade level)	Tape and reel	V324AY	
TSV324IYPT <sup>(1)</sup>			V324Y	

1. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent.
2. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent are ongoing.

## 5 Revision history

Table 11. Document revision history

Date	Revision	Changes
2-Aug-2005	1	First release - Products in full production.
20-Sep-2005	2	Addition of TSV321A/TSV324A/TSV358A data in tables in <a href="#">Section 2: Electrical characteristics on page 4</a> . Minor formatting and grammatical changes.
7-Dec-2005	3	Missing PPAP references inserted see <a href="#">Section 4: Ordering information on page 15</a> .
28-Jun-2007	4	Correction made on output drive capability, 80mA in description on cover page. SVR measurement conditions inserted in electrical characteristics tables. Offset voltage limit in temperature added in <a href="#">Section 2: Electrical characteristics on page 4</a> . Correction made on Input Bias Current typical value in <a href="#">Section 2: Electrical characteristics on page 4</a> . Captions of electrical characteristics figures updated. Automotive grade order codes added to <a href="#">Section 4: Ordering information on page 15</a> .
21-Feb-2008	5	Corrected SO-14 $R_{thja}$ value to 105 °C/W. Updated presentation of package information. Corrected footnote for automotive grade order codes in order code table.
13-Sep-2012	6	Updated <a href="#">Features</a> (added SO-8, SO-14, TSSOP8, TSSOP14, and MiniSO-8 package). Updated "Pin connection" figure on page 1 (removed part numbers). Removed TSV321ID, TSV321AID, TSV321IYDT, TSV358ID, TSV358AID, TSV324ID, TSV324AID, TSV321IYD, TSV358IYD, TSV358AIYD, TSV321IYD, TSV324IYD, and TSV324AIYD order code from <a href="#">Table 10</a> . Qualified status of TSV324AIYPT, TSV324IYPT, TSV324IYDT, TSV324AIYDT, TSV358IYDT, TSV321RIYLT, TSV321RAIYLT, and TSV358AIYDT order code in <a href="#">Table 10</a> . Updated ECOPACK text in <a href="#">Section 3</a> . Minor corrections throughout document.



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