



# TSV321-TSV358-TSV324

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

### 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
- Operating temperature range:  $-40^\circ\text{ C, }+125^\circ\text{ C}$

### Applications

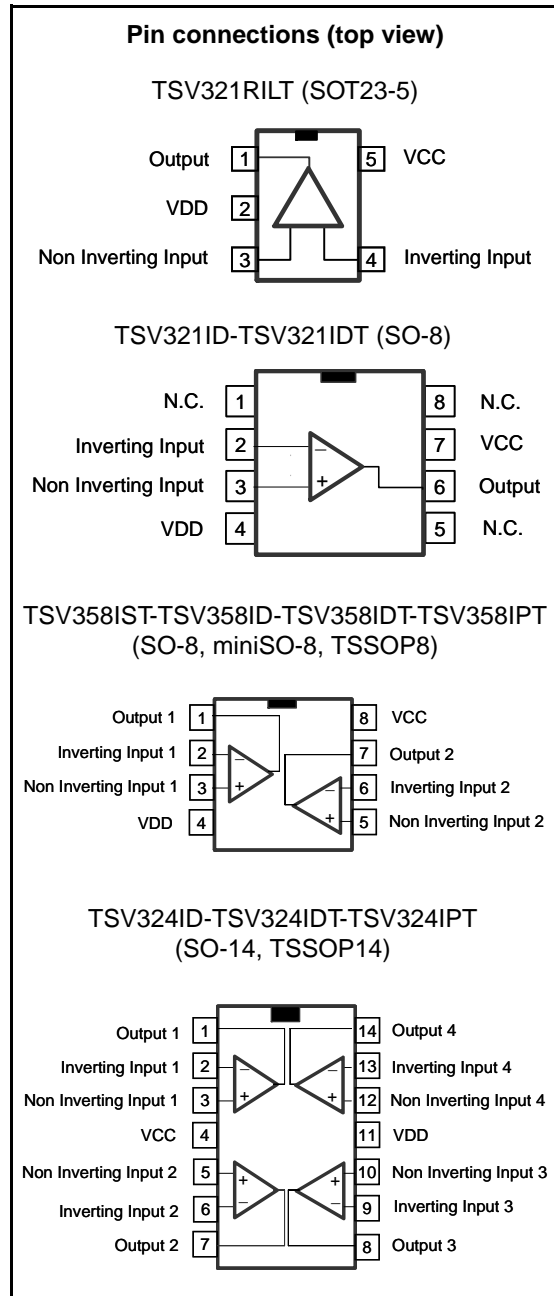
- Battery-powered applications
- Audio driver (headphone driver)
- Sensor signal conditioning
- Laptop/notebook computers

### Description

The TSV358 and TSV324 (dual and quad) are low voltage versions of the LM358 and LM324 commodity operational amplifiers. The TSV321 is the single version. The TSV321/358/324 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  $25^\circ\text{ C}$  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, 10s)	250	°C
	Output short-circuit duration	See note <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 the 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 $T_{amb} = 25^{\circ}\text{C}$ , $2.5 \leq V_{CC} \leq 6\text{V}$ $T_{min} < T_{amb} < T_{max}$ , $2.5 \leq V_{CC} \leq 5.5\text{V}$	$V_{DD} - 0.2$ 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  $V_{CC} = +3V$ ,  $V_{DD} = 0V$ ,  $R_L$ ,  $C_L$  connected to  $V_{CC}/2$ , and  $T_{amb} = 25^\circ C$  (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		$\mu V/^\circ C$
$I_{io}$	Input offset current	$V_{icm} = V_{out} = V_{CC}/2$ <sup>(1)</sup> $T_{min} \leq T_{amb} \leq T_{max}$		3	30 60	nA
$I_{ib}$	Input bias current	$V_{icm} = V_{out} = V_{CC}/2$ <sup>(1)</sup> $T_{min} \leq T_{amb} \leq T_{max}$		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	$V_{out} = 0.5V$ to $2.5V$ $R_L = 2k\Omega$ $R_L = 600\Omega$	80 74	92 95		dB
$V_{OH}$	High level output voltage	$V_{id} = 100mV$ $R_L = 2k\Omega$ $R_L = 600\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2k\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\Omega$	2.82 2.80 2.82 2.80	2.95 2.95		V
$V_{OL}$	Low level output voltage	$V_{id} = -100mV$ $R_L = 2k\Omega$ $R_L = 600\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2k\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\Omega$		88 115	120 160 120 160	mV
$I_o$	Output source current	$V_{id} = 100mV$ , $V_O = V_{DD}$	20	80		mA
	Output sink current	$V_{id} = -100mV$ , $V_O = V_{CC}$	20	80		
$I_{CC}$	Supply current (per amplifier)	$A_{VCL} = 1$ , no load $T_{min} \leq T_{amb} \leq T_{max}$		420	650 690	$\mu A$
GBP	Gain bandwidth product	$R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$	1	1.3		MHz
SR	Slew rate	$R_L = 10k\Omega$ , $C_L = 100pF$	0.42	0.6		V/ $\mu s$
$\phi_m$	Phase margin	$C_L = 100pF$		53		Degrees
en	Input voltage noise			27		nV/ $\sqrt{Hz}$
THD	Total harmonic distortion			0.01		%

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

**Table 4. Electrical characteristics at  $V_{CC} = +5V$ ,  $V_{DD} = 0V$ ,  $R_L$ ,  $C_L$  connected to  $V_{CC}/2$ , and  $T_{amb} = 25^\circ C$  (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		$\mu V/^\circ C$
$I_{io}$	Input offset current	$V_{icm} = V_{out} = V_{CC}/2$ <sup>(1)</sup> $T_{min} \leq T_{amb} \leq T_{max}$		3	30 60	nA
$I_{ib}$	Input bias current	$V_{icm} = V_{out} = V_{CC}/2$ <sup>(1)</sup> $T_{min} \leq T_{amb} \leq T_{max}$		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 $20 \log (\Delta V_{CC}/\Delta V_{io})$	$V_{CC} = 2.5$ to $5V$	70	90		dB
$A_{vd}$	Large signal voltage gain	$V_{out} = 0.5V$ to $4.5V$ $R_L = 2k\Omega$ $R_L = 600\Omega$	83 77	92 85		dB
$V_{OH}$	High level output voltage	$V_{id} = 100mV$ $R_L = 2k\Omega$ $R_L = 600\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2k\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\Omega$	4.80 4.75 4.80 4.75	4.95 4.90		V
$V_{OL}$	Low level output voltage	$V_{id} = -100mV$ $R_L = 2k\Omega$ $R_L = 600\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 2k\Omega$ $T_{min} \leq T_{amb} \leq T_{max}$ , $R_L = 600\Omega$		88 115	130 188 130 188	mV
$I_o$	Output source current	$V_{id} = 100mV$ , $V_O = V_{DD}$	20	80		mA
	Output sink current	$V_{id} = -100mV$ , $V_O = V_{CC}$	20	80		
$I_{CC}$	Supply current (per amplifier)	$A_{VCL} = 1$ , no load $T_{min} \leq T_{amb} \leq T_{max}$		500	835 875	$\mu A$
GBP	Gain bandwidth product	$R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$	1	1.4		MHz
SR	Slew rate	$R_L = 10k\Omega$ , $C_L = 100pF$	0.42	0.6		V/ $\mu s$
$\phi_m$	Phase margin	$C_L = 100pF$		55		Degrees
en	Input voltage noise			27		nV/ $\sqrt{Hz}$
THD	Total harmonic distortion			0.01		%

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

Figure 1. Supply current/amplifier vs. supply voltage

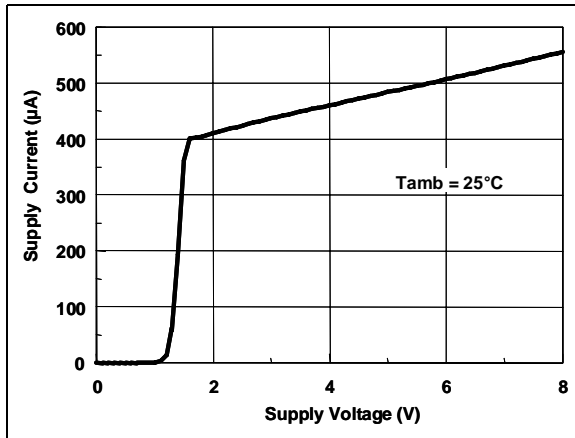


Figure 2. Supply current/amplifier vs. temperature

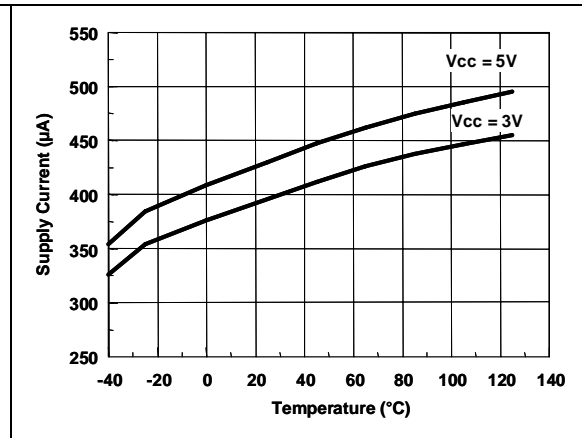


Figure 3. Output power vs. supply voltage

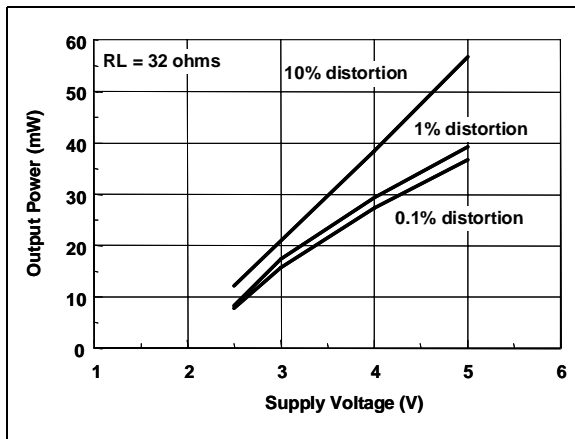


Figure 4. Input offset voltage drift vs. temperature

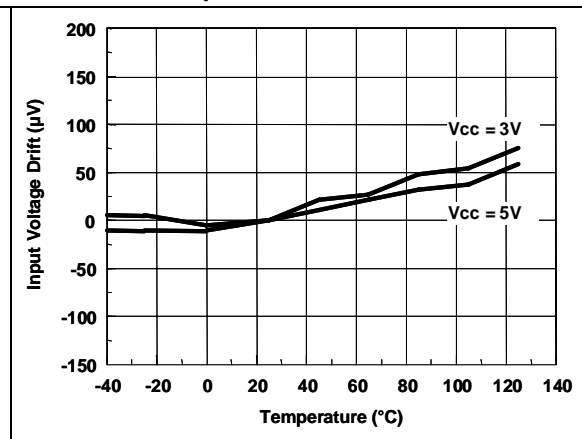


Figure 5. Input bias current vs. temperature

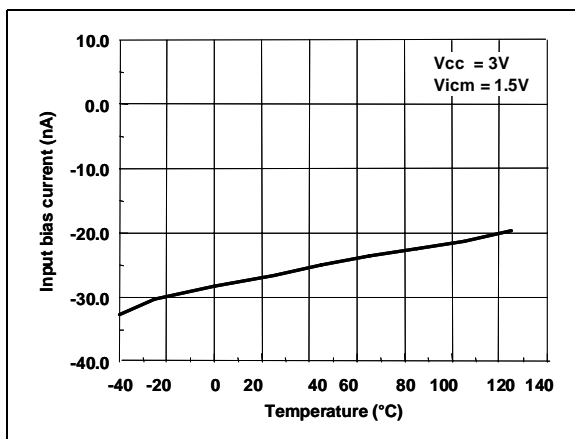


Figure 6. Open loop gain vs. temperature at Vcc = 5 V

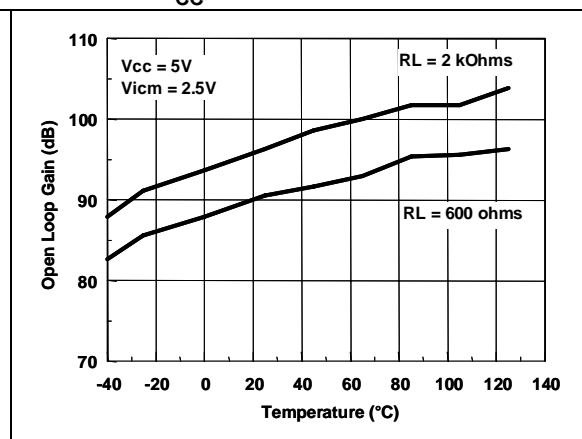


Figure 7. Open loop gain vs. temperature at  $V_{CC} = 3\text{ V}$

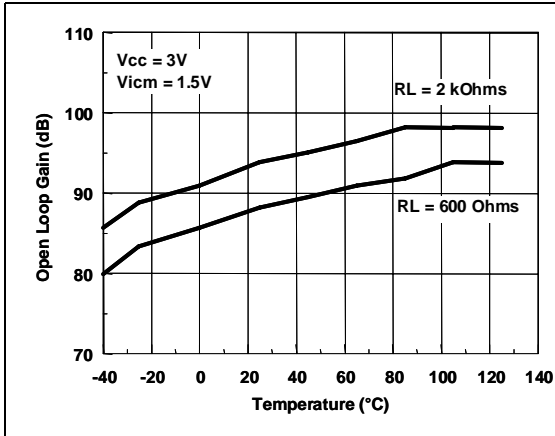


Figure 8. High level output voltage vs. temperature

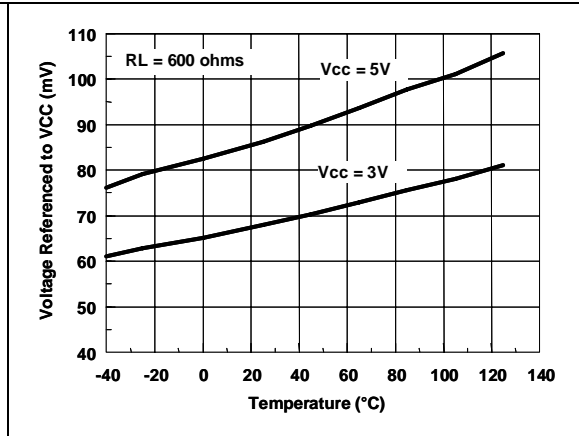


Figure 9. Low level output voltage vs. temperature

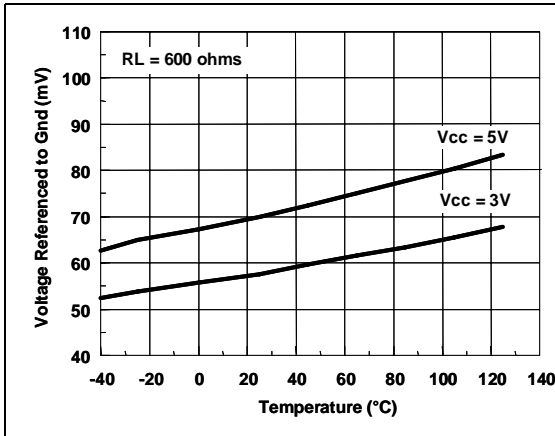


Figure 10. Output current vs. temperature at  $V_{CC} = 5\text{ V}$

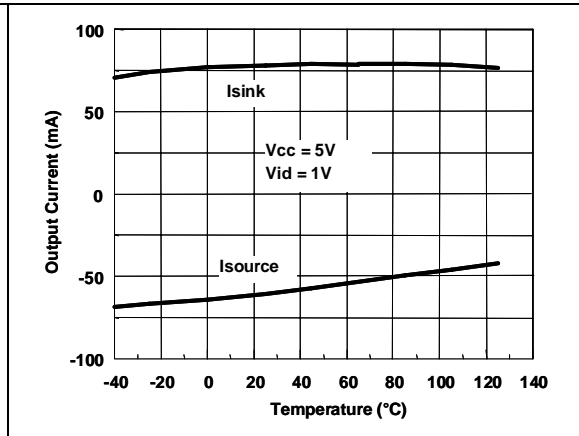


Figure 11. Output current vs. temperature at  $V_{CC} = 3\text{ V}$

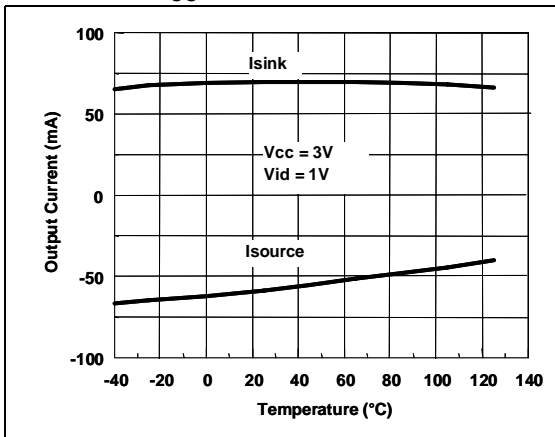


Figure 12. Output current vs. output voltage at  $V_{CC} = 5\text{ V}$

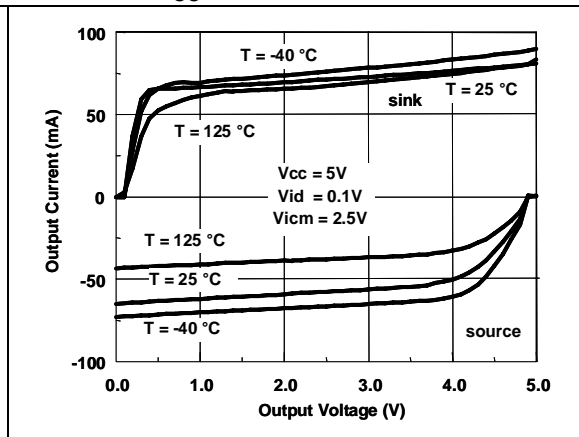


Figure 13. Output current vs. output voltage at  $V_{CC} = 3\text{ V}$

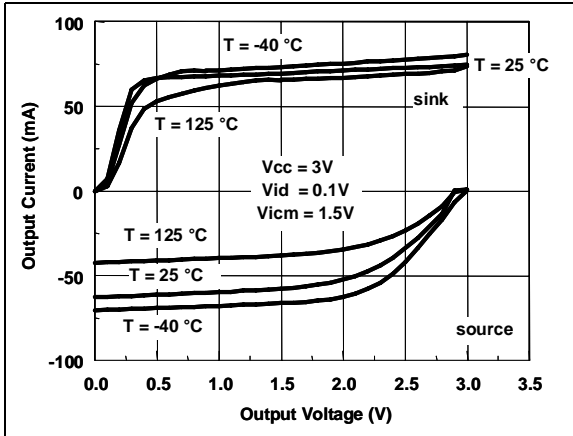


Figure 14. Gain and phase vs. frequency at  $V_{CC} = 5\text{ V}$

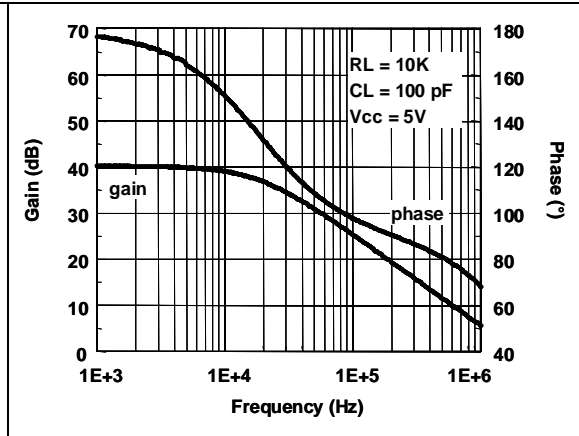


Figure 15. Gain and phase vs. frequency at  $V_{CC} = 3\text{ V}$

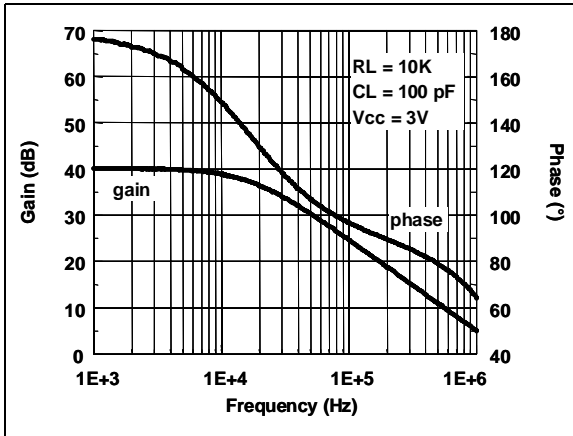


Figure 16. Slew rate vs. temperature at  $V_{CC} = 5\text{ V}$

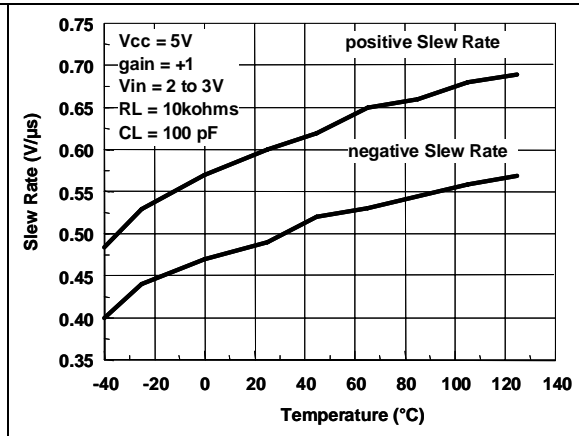


Figure 17. Slew rate vs. temperature at  $V_{CC} = 3\text{ V}$

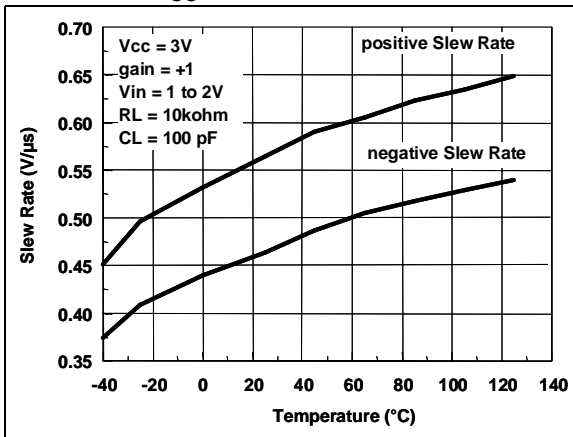
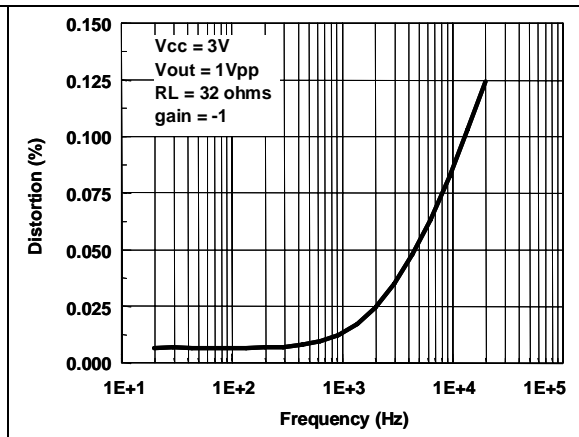


Figure 18. Distortion vs. frequency





### 3 Package information

In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK<sup>®</sup> packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an STMicroelectronics trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

#### 3.1 SOT23-5 package information

Figure 19. SOT23-5 package mechanical drawing

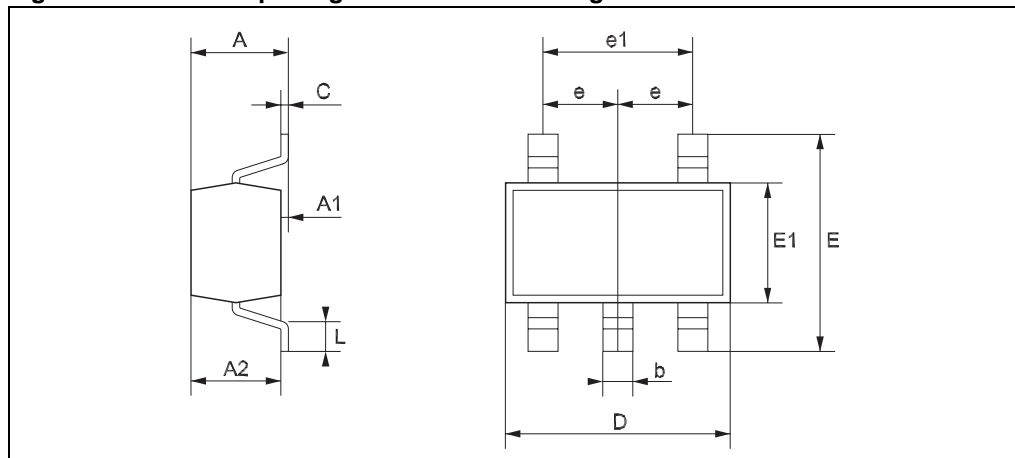


Table 5. SOT23-5 package mechanical data

Ref.	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 mechanical drawing

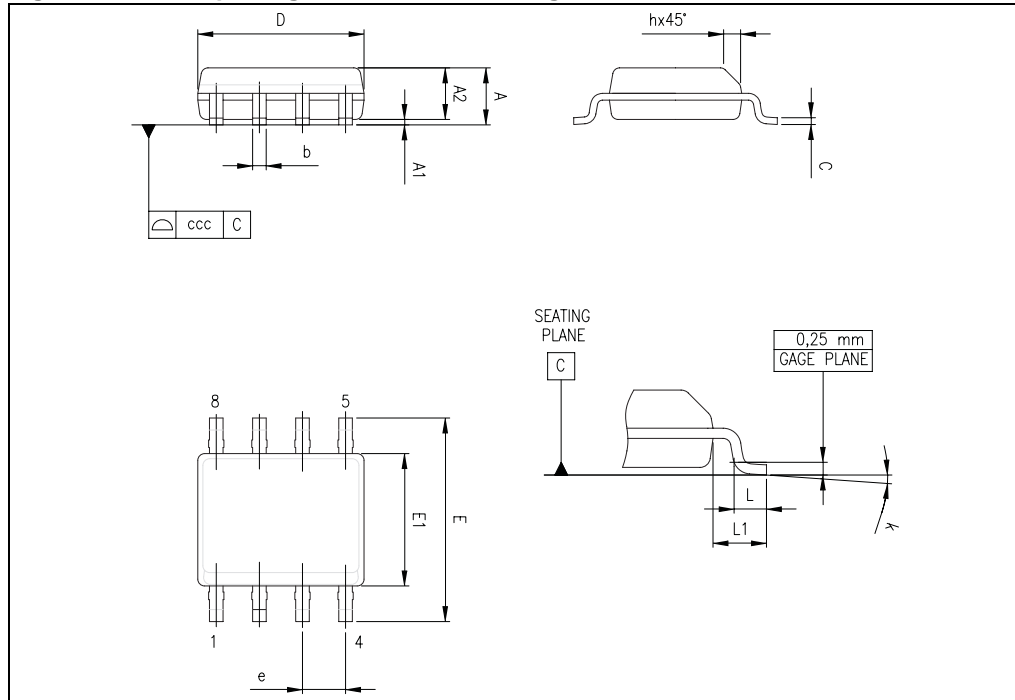


Table 6. SO-8 package mechanical data

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
k	1°		8°	1°		8°
ccc			0.10			0.004

### 3.3 TSSOP8 package information

Figure 21. TSSOP8 package mechanical drawing

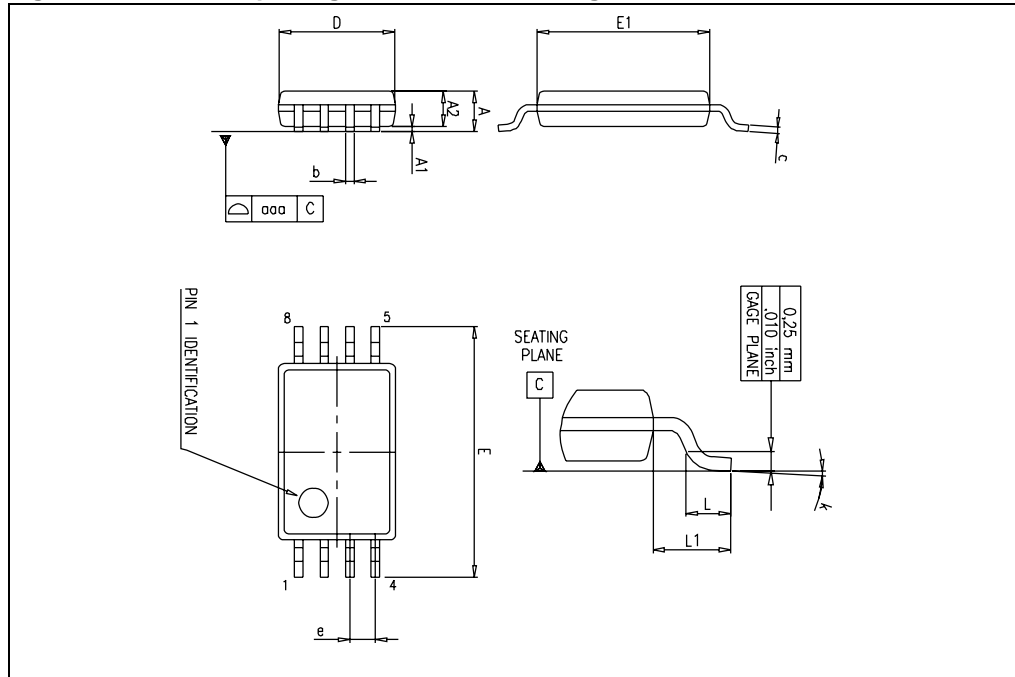


Table 7. TSSOP8 package mechanical data

Ref.	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 mechanical drawing

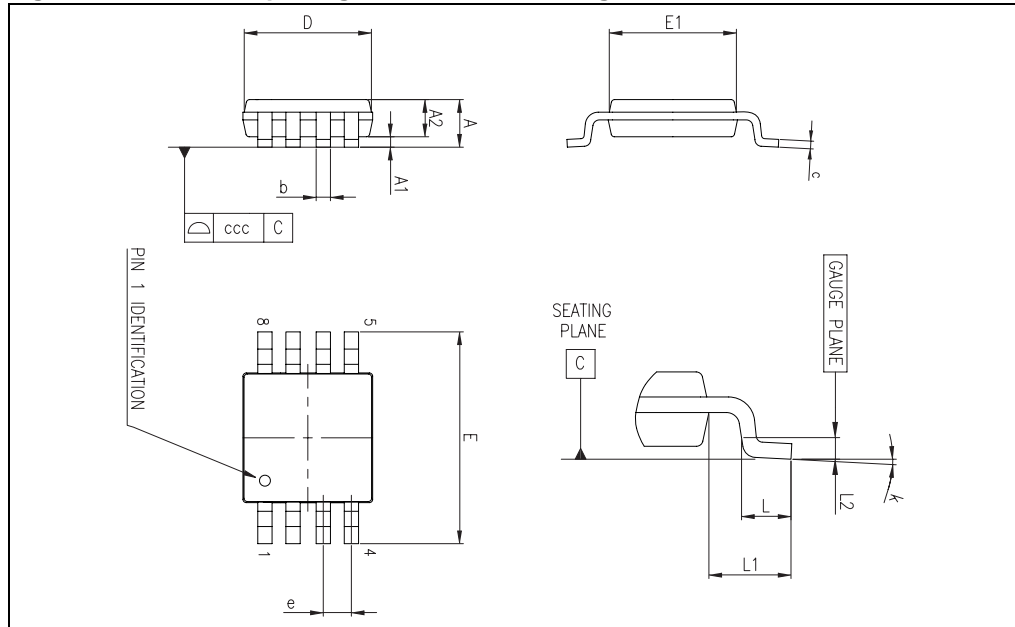


Table 8. MiniSO-8 package mechanical data

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

### 3.5 SO-14 package information

Figure 23. SO-14 package mechanical drawing

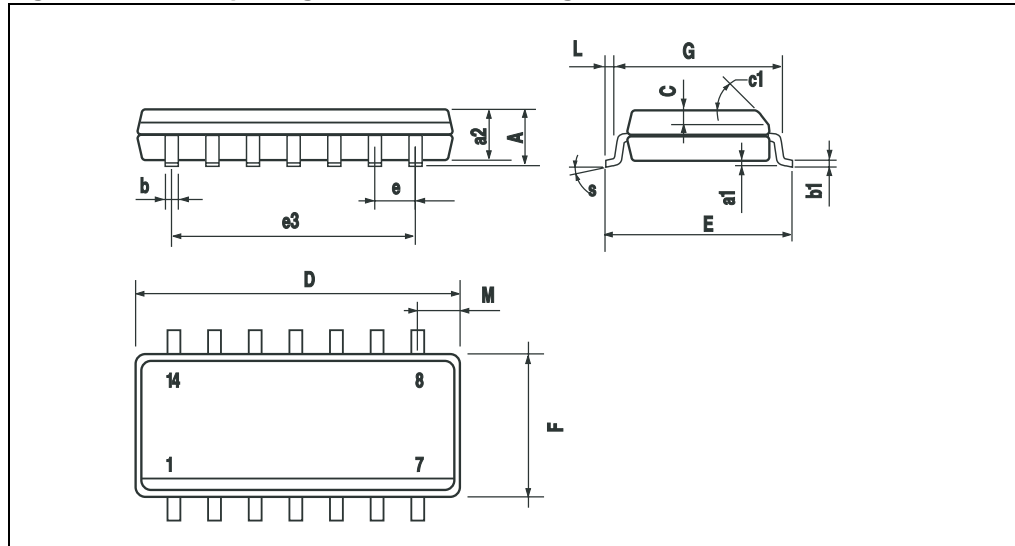


Table 9. SO-14 package mechanical data

Ref.	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 mechanical drawing

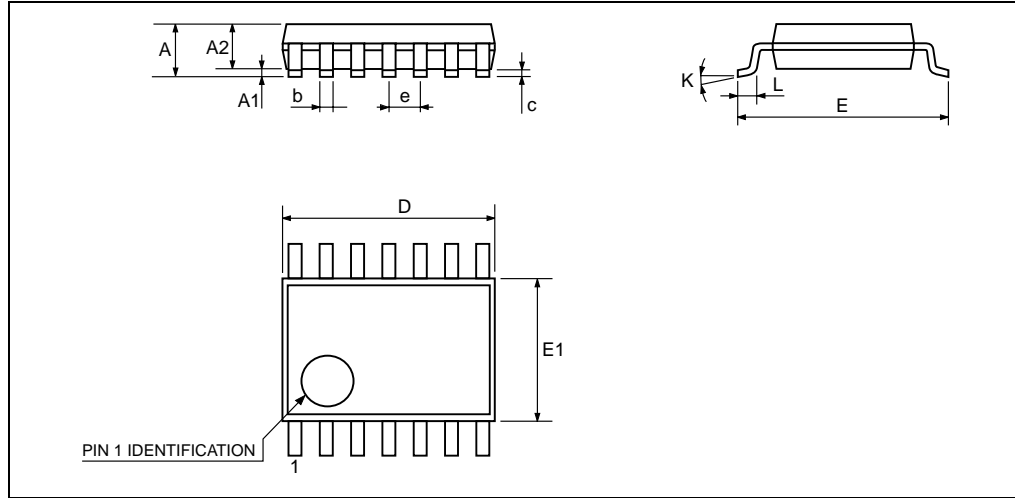


Figure 25. TSSOP14 package mechanical data

Ref.	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 & reel	K174
TSV321RAILT				K178
TSV321RIYLT <sup>(1)</sup>		SOT23-5 (Automotive grade level)	Tape & reel	K179
TSV321RAIYLT <sup>(1)</sup>				K187
TSV321ID/IDT		SO-8	Tube or tape & reel	V321ID
TSV321IYD/IYDT <sup>(1)</sup>		SO-8 (Automotive grade level)	Tube or tape & reel	V321Y
TSV321AID/IDT		SO-8	Tube or tape & reel	V321AI
TSV358ID/IDT		SO-8	Tube or tape & reel	V358ID
TSV358AID/IDT				V358AID
TSV358IYD/IYDT <sup>(1)</sup>		SO-8 (Automotive grade level)	Tube or tape & reel	V358YD
TSV358AIYD/AIYDT <sup>(1)</sup>				V358AY
TSV358IPT		TSSOP8 (Thin shrink outline package)	Tape & reel	V358I
TSV358AIPT				V358A
TSV358IYPT <sup>(1)</sup>		TSSOP8 (Automotive grade level)	Tape & reel	V358Y
TSV358AIYPT <sup>(1)</sup>				V58AY
TSV358IST		MiniSO-8	Tape & reel	K175
TSV358AIST				K184
TSV324ID/IDT		SO-14	Tube or tape & reel	V324ID
TSV324AID/AIDT				V324AI
TSV324IYD/IYDT <sup>(1)</sup>		SO-14 (Automotive grade level)	Tube or tape & reel	V324YD
TSV324AIYD/AIYDT <sup>(1)</sup>				V324AY
TSV324IPT		TSSOP14 (Thin shrink outline package)	Tape & reel	V324IP
TSV324AIPT				V324A
TSV324AIYPT <sup>(1)</sup>		TSSOP14 (Automotive grade level)	Tape & reel	V324AY
TSV324IYPT <sup>(1)</sup>				V324Y

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent are on-going.

## 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 TS321A/TS324A/TS358A 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.



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