

## Output rail-to-rail very low noise operational amplifier

### Features

- Rail-to-rail output voltage swing  $\pm 2.4V$  @  $V_{CC} = \pm 2.5V$
- Very low noise level:  $4nV/\sqrt{Hz}$
- Ultra low distortion: 0.003%
- High dynamic features: 12MHz,  $4V/\mu s$
- Operating range: 2.7V to 10V
- ESD protection (2kV)
- Latch-up immunity (class A)

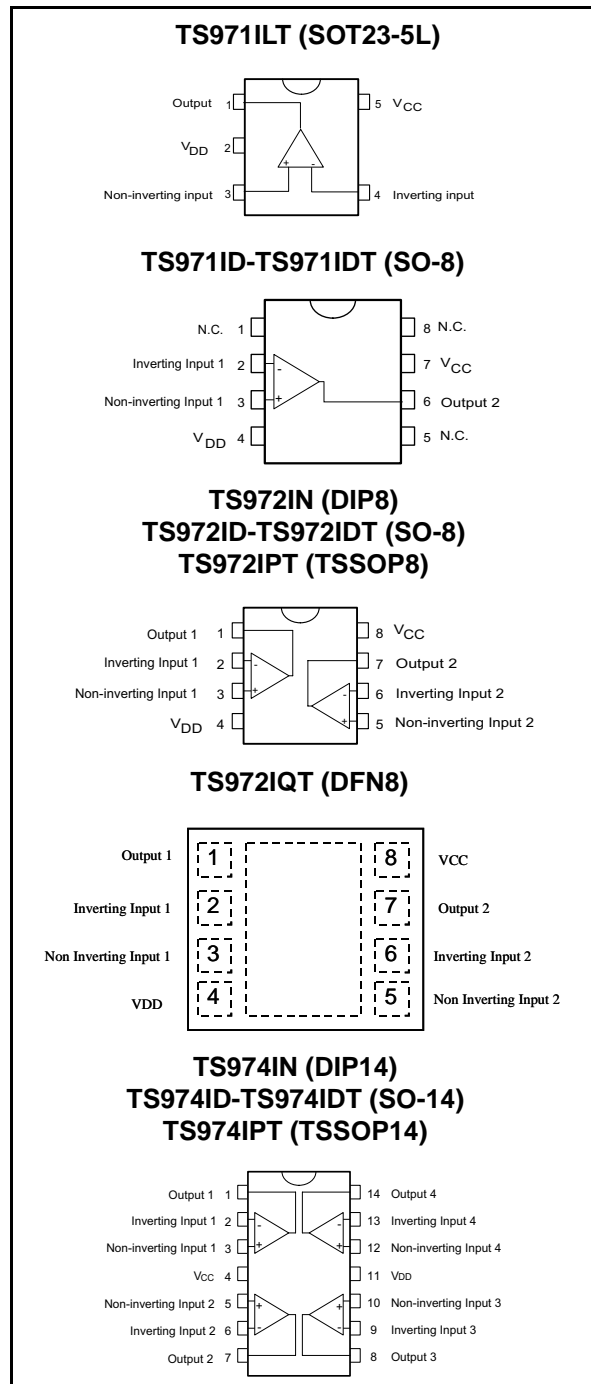
### Applications

- Portable equipment (CD players, PDA)
- Portable communications (cell phones, pagers)
- Instrumentation & sensing
- Professional audio circuits

### Description

The TS97x family of operational amplifiers operates with voltages as low as  $\pm 1.35V$  and features output rail-to-rail signal swing. The TS97x are particularly well suited for portable and battery-supplied equipment. Very low noise and low distortion characteristics make them ideal for audio pre-amplification.

The TS971 is available in a variety of packages to suit all types of applications. For applications where space-saving is critical, the SOT23 package (2.8 x 2.9mm) or the DFN package (3 x 3mm) simplify the board design because they can be placed everywhere.



# 1 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings AMR**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup>	12	V
$V_{id}$	Differential input voltage <sup>(2)</sup>	±1	V
$V_{in}$	Input voltage <sup>(3)</sup>	$V_{DD} - 0.3$ to $V_{CC} + 0.3$	V
$T_{stg}$	Storage temperature range	-65 to +150	
$T_j$	Maximum junction temperature	150	°C
$R_{thja}$	Thermal resistance junction to ambient <sup>(4)</sup>		°C/W
	SOT23-5	250	
	DFN8	40	
	SO-8	125	
	SO-14	105	
	TSSOP8	120	
	TSSOP14	100	
	DIP8 DIP14	85 80	
$R_{thjc}$	Thermal resistance junction to case <sup>(4)</sup>		°C/W
	SOT23-5	81	
	DFN8	5.2	
	SO-8	40	
	SO-14	31	
	TSSOP8	37	
	TSSOP14	32	
	DIP8 DIP14	41 33	
ESD	HBM: human body model <sup>(5)</sup>	2	kV
	MM: machine model <sup>(6)</sup>	200	V
	CDM: charged device model <sup>(7)</sup>	1.5	kV
	Lead temperature (soldering, 10sec)	260	°C

1. All voltage values, except differential voltage are with respect to network ground terminal.
  2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
  3. The magnitude of input and output voltages must never exceed  $V_{CC} + 0.3V$ .
  4. Short-circuits can cause excessive heating and destructive dissipation. Values are typical.
  5. Human body model: A 100pF capacitor is charged to the specified voltage, then discharged through a 1.5kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
  6. Machine model: A 200pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5Ω). This is done for all couples of connected pin combinations while the other pins are floating.
  7. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.
- No value specified for CDM on SOT23-5 package.

**Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.7 to 10	V
$V_{icm}$	Common mode input voltage range	$V_{DD} + 1.15$ to $V_{CC} - 1.15$	V
$T_{oper}$	Operating free air temperature range	-40 to +125	°C

## 2 Electrical characteristics

**Table 3.**  $V_{CC} = +2.5V$ ,  $V_{DD} = -2.5V$ ,  $T_{amb} = 25^{\circ}C$  (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage	$T_{min} \leq T_{amb} \leq T_{max}$		1	5 7	mV
$DV_{io}$	Input offset voltage drift	$V_{icm} = 0V$ , $V_o = 0V$		5		$\mu V/^{\circ}C$
$I_{io}$	Input offset current	$V_{icm} = 0V$ , $V_o = 0V$		10	150	nA
$I_{ib}$	Input bias current	$V_{icm} = 0V$ , $V_o = 0V$ $T_{min} \leq T_{amb} \leq T_{max}$		200 200	750 1000	nA
$V_{icm}$	Common mode input voltage range		-1.35		1.35	V
CMR	Common mode rejection ratio	$V_{icm} = \pm 1.35V$	60	85		dB
SVR	Supply voltage rejection ratio	$V_{CC} = \pm 2V$ to $\pm 3V$	60	70		dB
$A_{vd}$	Large signal voltage gain	$R_L = 2k\Omega$	70	80		dB
$V_{OH}$	High level output voltage	$R_L = 2k\Omega$	2	2.4		V
$V_{OL}$	Low level output voltage	$R_L = 2k\Omega$		-2.4	-2	V
$I_{source}$	Output source current			1.5		mA
$I_{sink}$	Output sink current			100		mA
$I_{CC}$	Supply current per amplifier	Unity gain - No load		2	2.8	mA
GBP	Gain bandwidth product	$f = 100kHz$ , $R_L = 2k\Omega$ , $C_L = 100pF$	8.5	12		MHz
SR	Slew rate	$A_V = 1$ , $V_{in} = \pm 1V$	2.8	4		V/ $\mu s$
$\phi_m$	Phase margin at unit gain	$R_L = 2k\Omega$ , $C_L = 100pF$		60		Degrees
Gm	Gain margin	$R_L = 2k\Omega$ , $C_L = 100pF$		10		dB
$e_n$	Equivalent input noise voltage	$f = 100kHz$		4		nV/ $\sqrt{Hz}$
THD	Total harmonic distortion	$f = 1kHz$ , $A_V = -1$ , $R_L = 10k\Omega$		0.003		%

Figure 1. Input offset voltage distribution

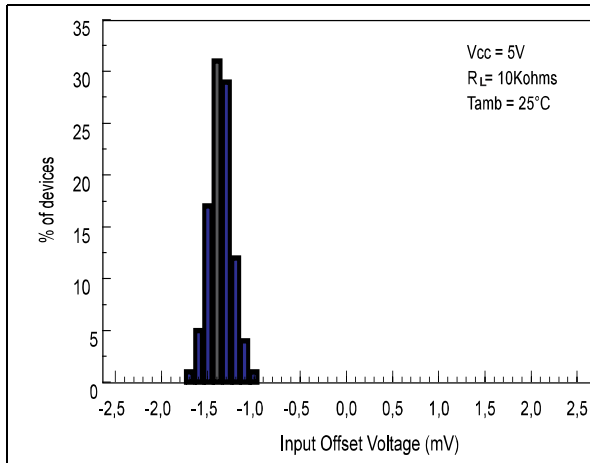


Figure 2. Voltage gain & phase vs. frequency

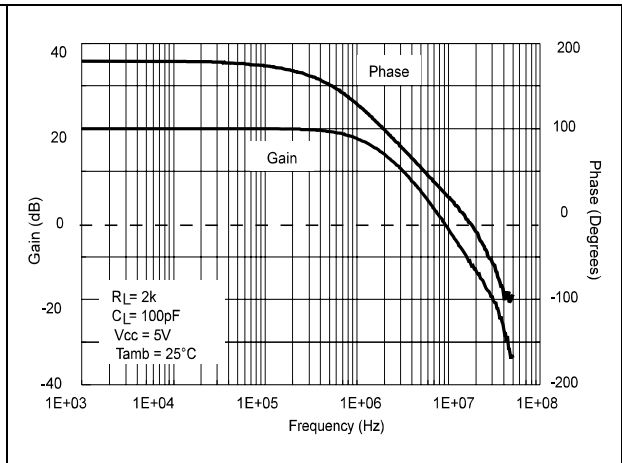


Figure 3. Voltage gain & phase vs. frequency Figure 4. THS vs.  $V_{out}$

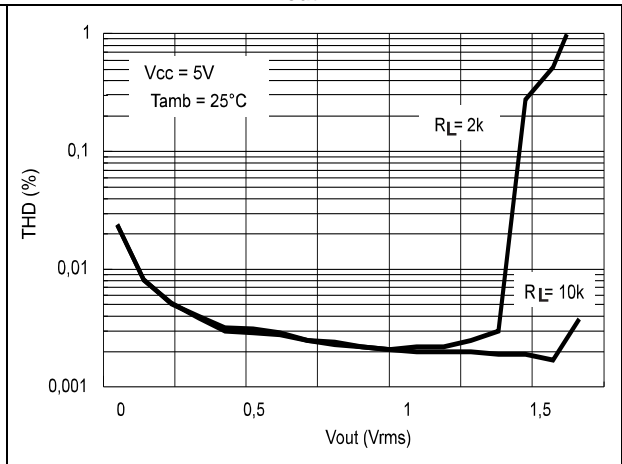
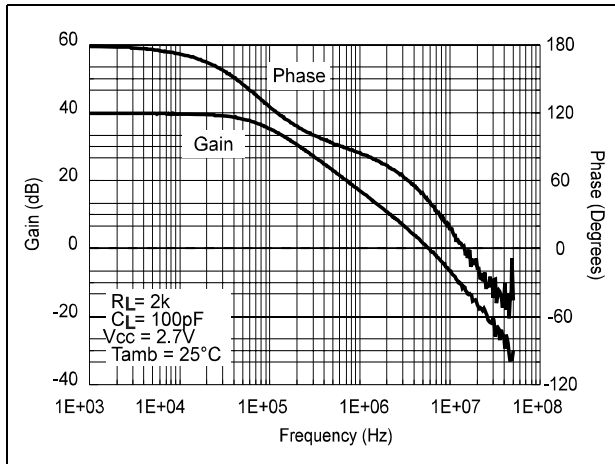


Figure 5. THD vs.  $V_{out}$

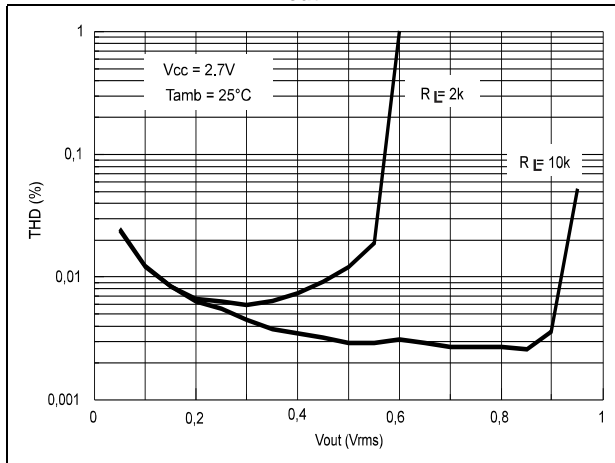


Figure 6. THD vs. frequency

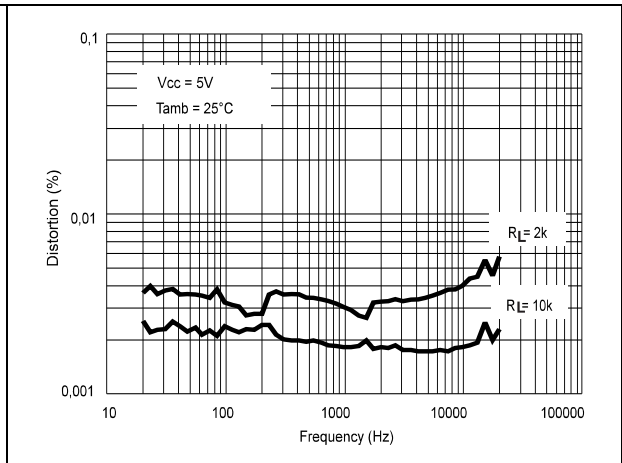


Figure 7. Noise voltage vs. frequency

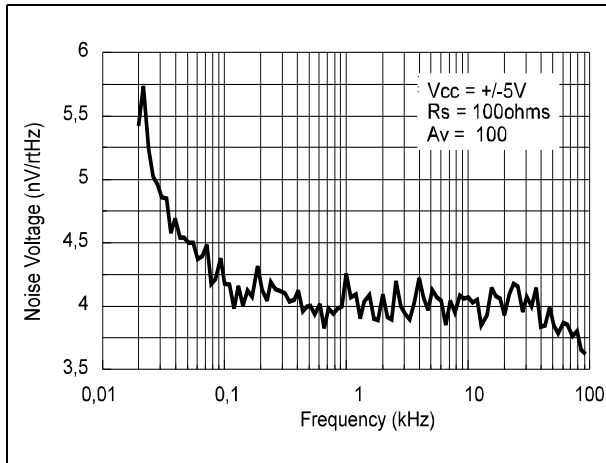


Figure 8. Gain bandwidth product vs.  $I_{out}$

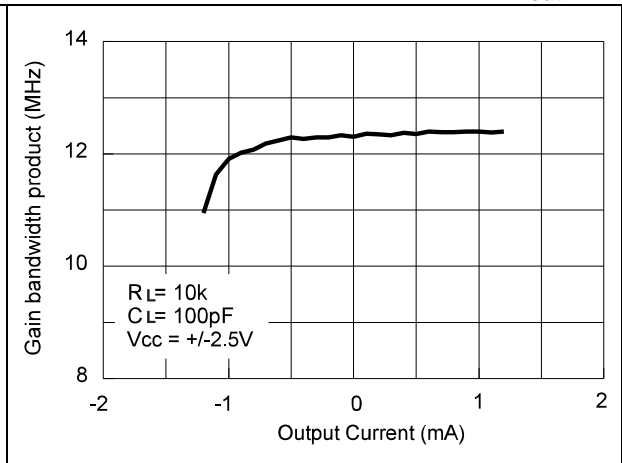


Figure 9. Phase margin vs.  $I_{out}$

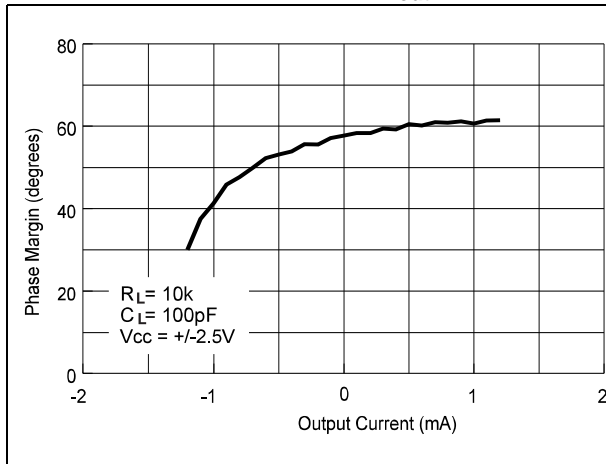


Figure 10. Phase margin vs.  $V_{CC}$

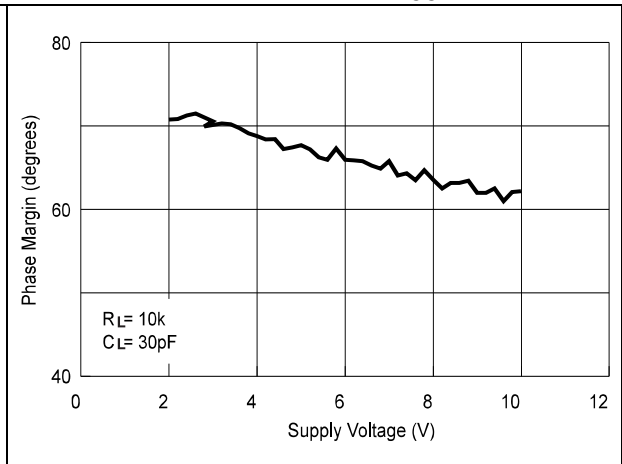


Figure 11. Phase margin vs.  $V_{CC}$

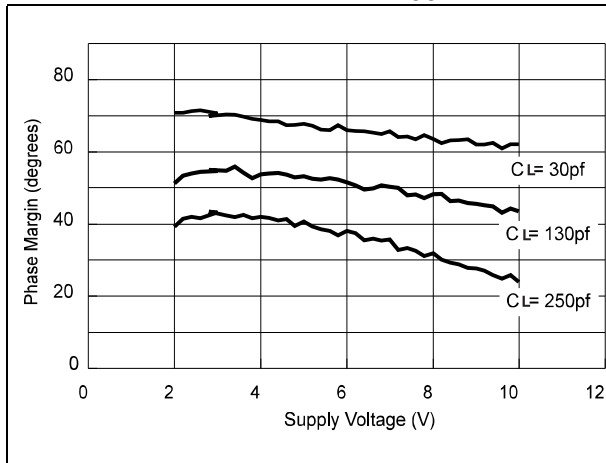
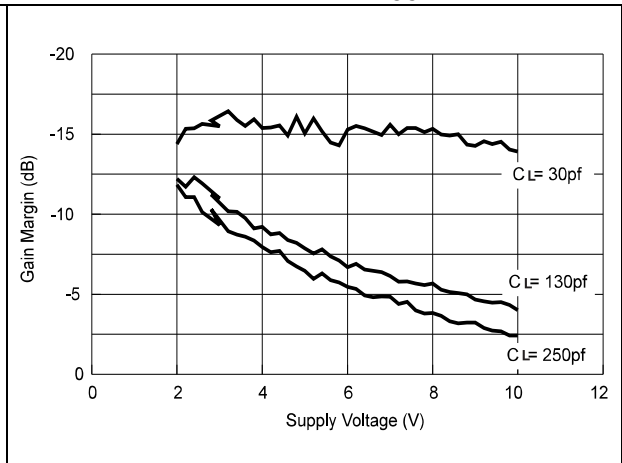


Figure 12. Gain margin vs.  $V_{CC}$



### 3 Package information

In order to meet environmental requirements, ST 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 ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

#### 3.1 SOT23-5 package information

Figure 13. SOT23-5 package mechanical drawing

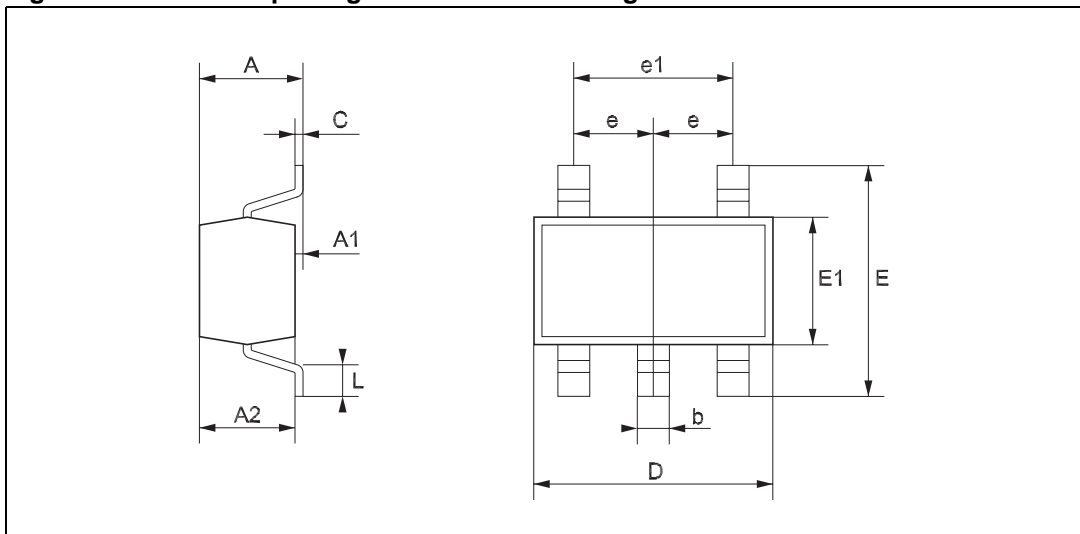


Table 4. SOT23-5 package mechanical data

Ref.	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 DIP8 package information

Figure 14. DIP8 package mechanical drawing

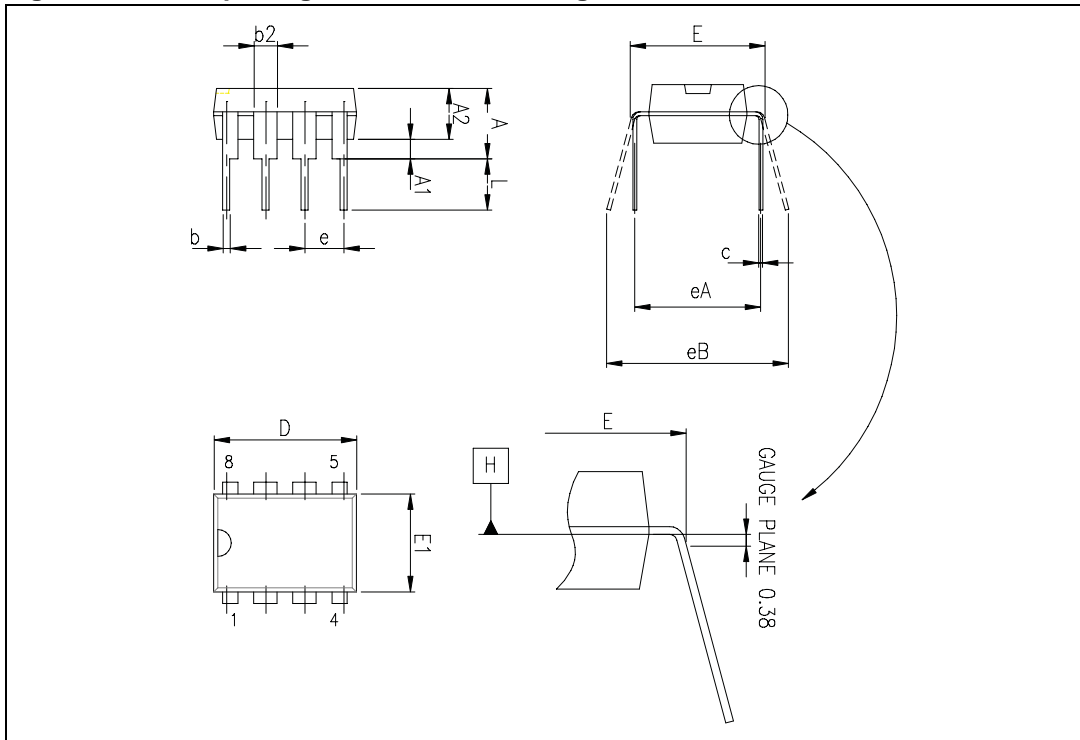


Table 5. DIP8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			5.33			0.210
A1	0.38			0.015		
A2	2.92	3.30	4.95	0.115	0.130	0.195
b	0.36	0.46	0.56	0.014	0.018	0.022
b2	1.14	1.52	1.78	0.045	0.060	0.070
c	0.20	0.25	0.36	0.008	0.010	0.014
D	9.02	9.27	10.16	0.355	0.365	0.400
E	7.62	7.87	8.26	0.300	0.310	0.325
E1	6.10	6.35	7.11	0.240	0.250	0.280
e		2.54			0.100	
eA		7.62			0.300	
eB			10.92			0.430
L	2.92	3.30	3.81	0.115	0.130	0.150



### 3.3 SO-8 package information

Figure 15. SO-8 package mechanical drawing

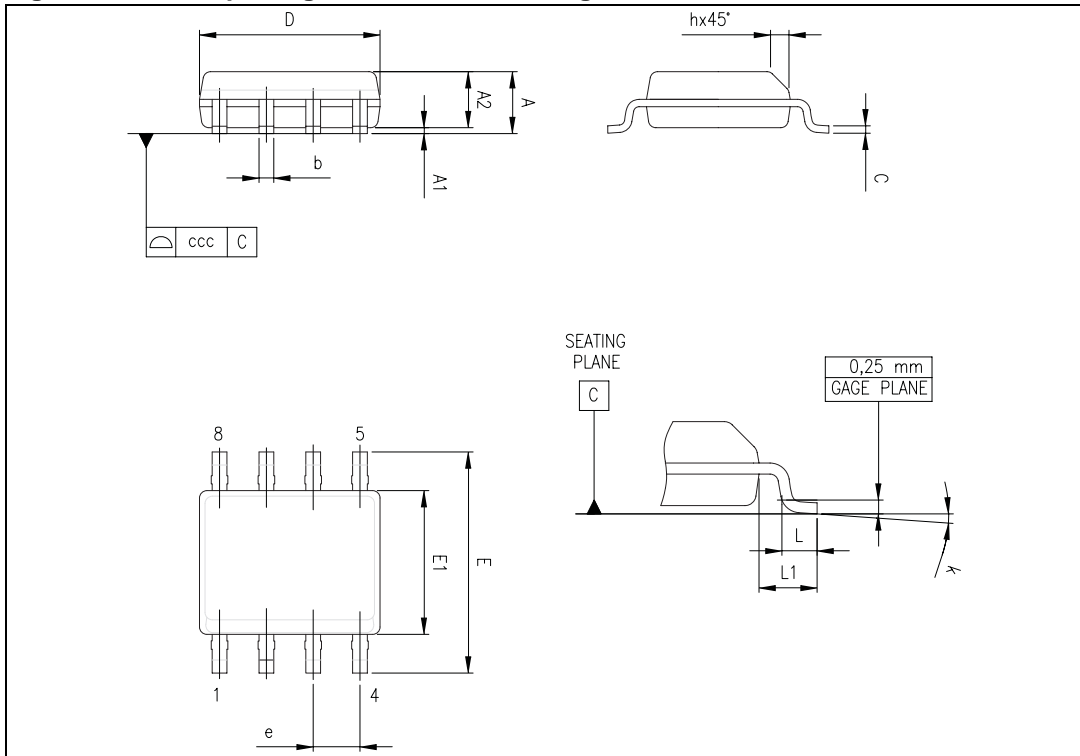


Table 6. SO-8 package mechanical data

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
H	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

### 3.4 TSSOP8 package information

Figure 16. TSSOP8 package mechanical drawing

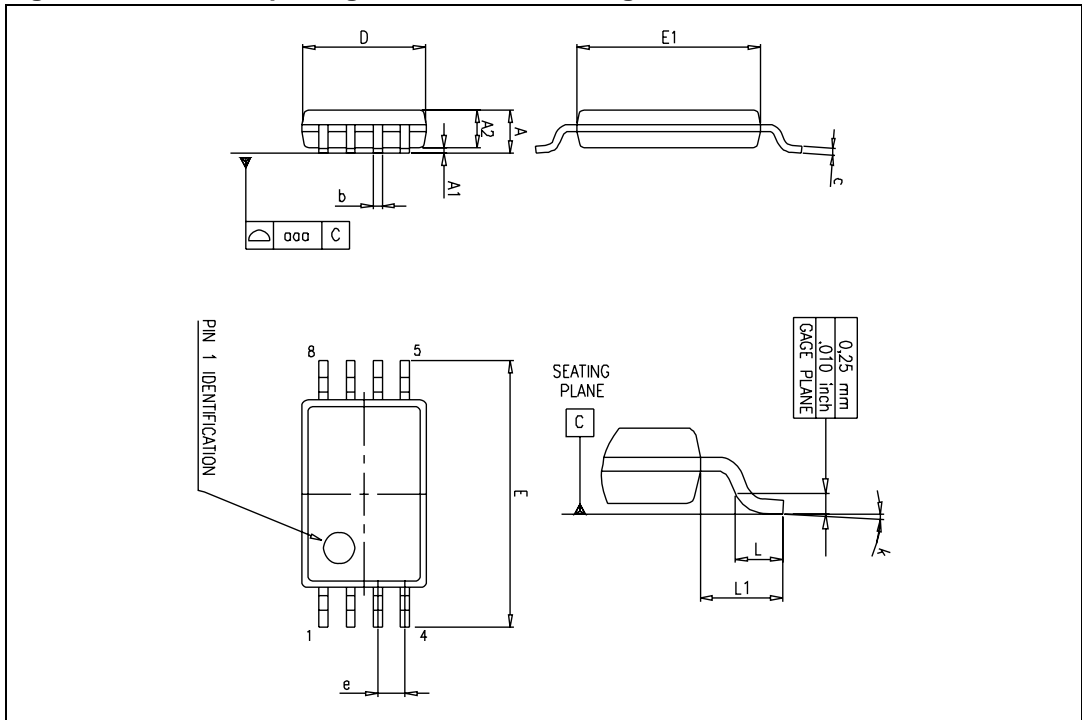


Table 7. TSSOP8 package mechanical data

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	

### 3.5 DIP14 package information

Figure 17. DIP14 package mechanical drawing

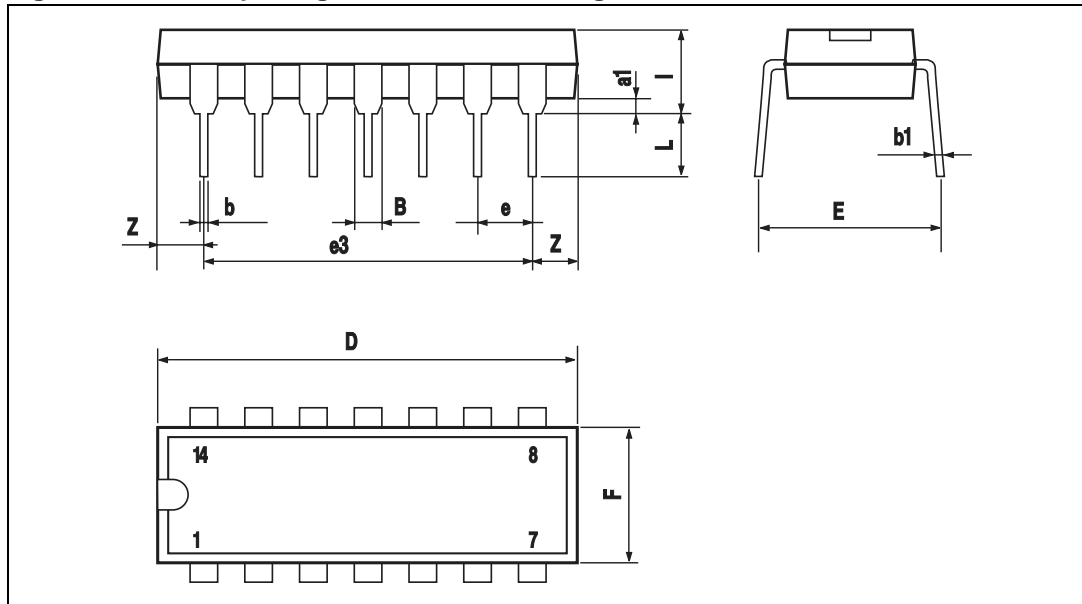


Table 8. DIP14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
l			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

### 3.6 SO-14 package information

Figure 18. SO-14 package mechanical drawing

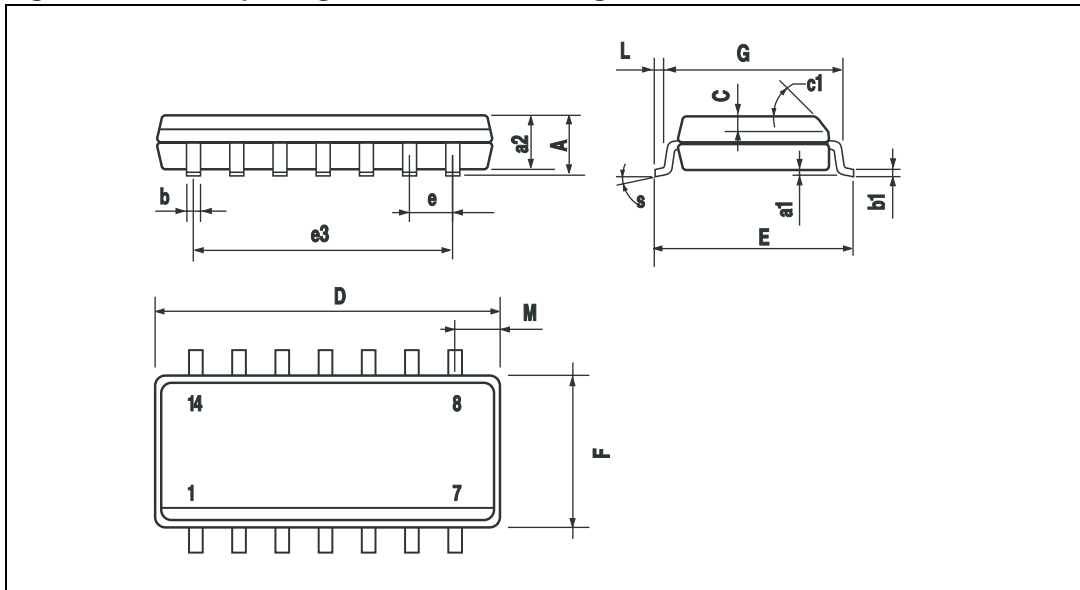


Table 9. SO-14 package mechanical data

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.)					

### 3.7 TSSOP14 package information

Figure 19. TSSOP14 package mechanical drawing

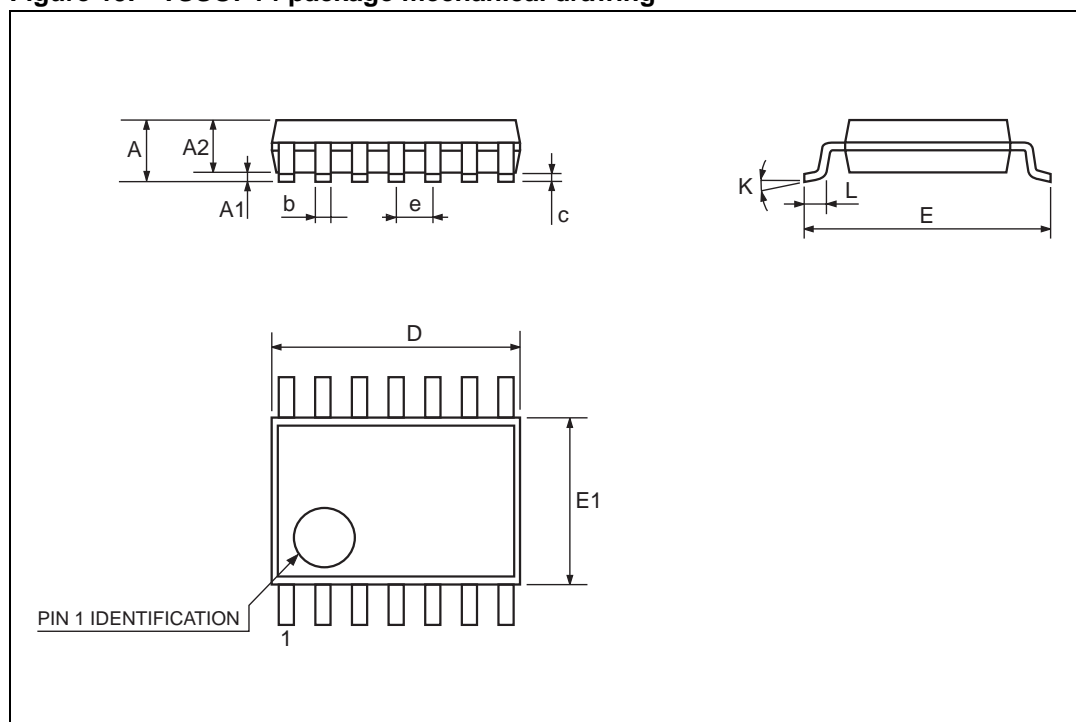


Table 10. TSSOP14 package mechanical data

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°
L	0.45	0.60	0.75	0.018	0.024	0.030

### 3.8 DFN8 exposed pad package information

Figure 20. DFN8 3x3 exposed pad package mechanical drawing

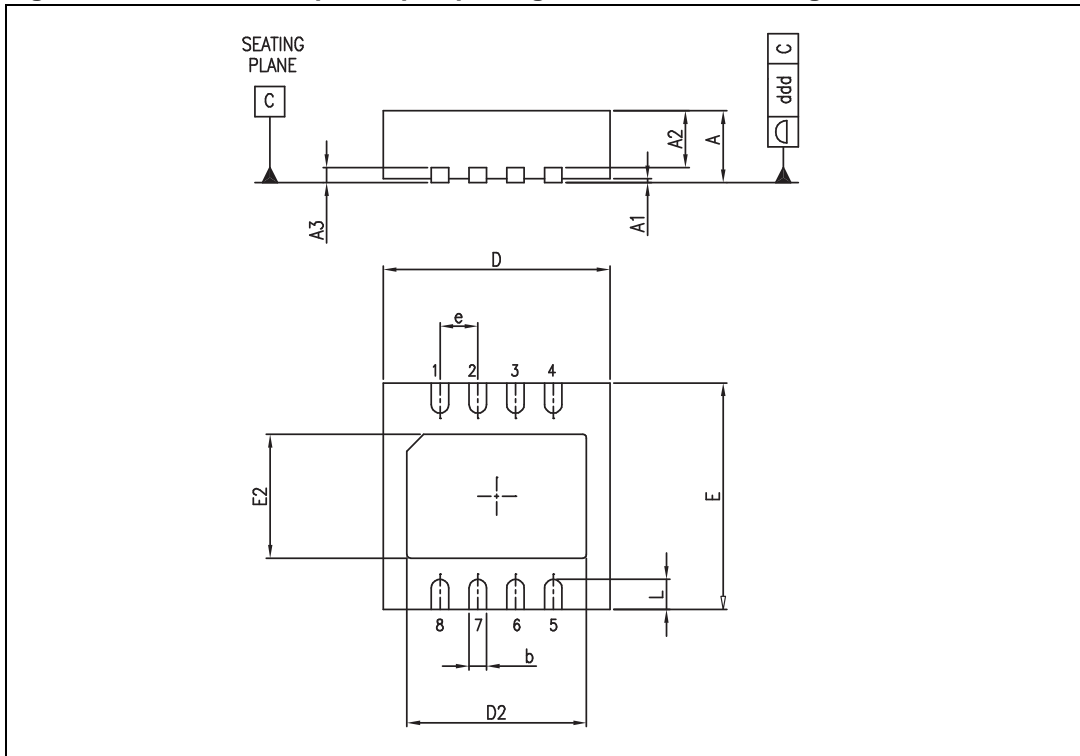


Table 11. DFN8 3x3 exposed pad package mechanical data

Ref.	Dimensions					
	Millimeters			Mils		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.80	0.90	1.00	31.5	35.4	39.4
A1		0.02	0.05		0.8	2.0
A2		0.70			25.6	
A3		0.20			7.9	
b	0.18	0.23	0.30	7.1	9.1	11.8
D	2.875	3.00	3.125		118.1	
D2	2.23	2.	2.48	87.8	90.7	97.7
E	2.875	3.00	3.125		118.1	
E2	1.49	1.64	1.74	58.7	64.6	68.5
e		0.65			25.6	
L	0.30	0.40	0.50	11.8	15.7	19.7

## 4 Ordering information

Table 12. Order codes

Order code	Temperature range	Package	Packing	Marking
TS971ID TS971IDT	-40°C, +125°C	SO-8	Tube or Tape & reel	971I
TS971ILT		SOT23-5L	Tape & reel	K120
TS971IYD <sup>(1)</sup> TS971IYDT <sup>(1)</sup>		SO-8 (Automotive grade level)		971IY
TS971IYLT <sup>(2)</sup>		SOT23-5L (Automotive grade level)		K121
TS972IN		DIP8	Tube	TS972IN
TS972ID TS972IDT		SO-8	Tube or Tape & reel	972I
TS972IPT		TSSOP8 (Thin shrink outline package)	Tape & Reel	
TS972IQT		DFN8 (Dual micro lead frame package)		
TS972IYD <sup>(1)</sup> TS972IYDT <sup>(1)</sup>		SO-8 (Automotive grade level)	Tube or Tape & reel	972IY
TS972IYPT <sup>(2)</sup>		TSSOP8 (Automotive grade level)	Tape & reel	972IY
TS974IN		DIP14	Tube	TS974IN
TS974ID TS974IDT		SO-14	Tube or Tape & reel	974I
TS974IPT		TSSOP14 (Thin shrink outline package)	Tape & reel	
TS974IYD <sup>(1)</sup> TS974IYDT <sup>(1)</sup>		SO-14 (Automotive grade level)		
TS974IYPT <sup>(2)</sup>		TSSOP14 (Automotive grade level)		974IY

1. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent.
2. 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 13. Document revision history**

Date	Revision	Changes
15-Nov- 2002	1	First release.
9-May- 2005	2	Modifications on AMR table (explanation of $V_{id}$ and $V_i$ limits)
31-Aug-2005	3	PPAP references inserted in the datasheet, see Table 1 on page 2.
9-Dec-2005	4	Thermal resistance junction to case data added in <a href="#">Table 1. on page 2</a> Missing PPAP references inserted in the datasheet, see <a href="#">Table 12: Order codes</a> .
3-Oct-2007	5	Added $R_{thja}$ and $R_{thjc}$ values for DIP8 and DIP14 packages in <a href="#">Table 1</a> . ESD footnotes updated in <a href="#">Table 1: Absolute maximum ratings AMR</a> . Description section updated on cover page. Markings for automotive grade parts corrected in <a href="#">Table 12: Order codes</a> .
20-Dec-2007	6	Reformatted package information in <a href="#">Section 3: Package information</a> . Footnotes for automotive grade parts corrected in <a href="#">Table 12: Order codes</a> .



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